Nos. 13-1527, 14-1121, 14-1526, and 14-1528 (consolidated)

United States Court of Appeals for the Federal Circuit

WESTERNGECO LLC,
Plaintiff-Cross-Appellant,

v.

ION GEOPHYSICAL CORPORATION,
Defendant-Appellant.

Appeals from the United States District Court for the Southern District of Texas in Case No. 09-CV-01827, Judge Keith P. Ellison

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October 21, 2014

CERTIFICATE OF INTEREST

Counsel for Cross-Appellant WesternGeco LLC certifies the following:

1. The full name of every party represented by me is:

WESTERNGECO LLC

2. The name of the real party in interest (if the party named in the caption is not the real party interest) represented by me is: N/A.

3. All parent corporations and any publicly held companies that own 10 percent or more of the stock of the party or amicus curiae represented by me are: WesternGeco LLC is an indirectly, wholly owned subsidiary of Schlumberger Limited, a publicly traded company.

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or agency or are expected to appear in this court are:

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TABLE OF CONTENTS

STATEMENT OF RELATED CASES 1
STATEMENT OF JURISDICTION 1
PRELIMINARY STATEMENT 1
STATEMENT OF THE ISSUES 5
STATEMENT OF THE CASE 6
I. Background 7
A. WesternGeco's Patents and Q-Marine System 7
B. ION's Infringing DigiFIN 12
II. District Court Proceedings 16
A. Pretrial Rulings 17
1. Summary Judgment of Infringement of Claim 18 of the '520 Patent Under §271(f)(1) 17
2. Exclusion of WesternGeco's Reasonable Royalty Theory 20
B. Trial 21
1. Infringement and Defenses 21
2. Subjective Prong of Willful Infringement 24
C. Post-Trial 24
1. ION's Post-Trial Challenge to WesternGeco's Ownership of the Bittleston Patents 24
2. Objective Prong of Willful Infringement 26
3. Injunction, Supplemental Damages, and Final Judgment 26
SUMMARY OF THE ARGUMENT 27
ARGUMENT 30
I. WesternGeco Has Standing to Enforce the Bittleston Patents, and The District Court Correctly So Held for Three Independently Sufficient Reasons 30

A. WesternGeco Holds Legal Title to the Bittleston Patents Because the Patent Office Issued Them to WesternGeco 31

B. The Inventors Assigned the Bittleston Patents to WesternGeco 35

C. ION Admitted Facts Establishing WesternGeco's Ownership of the Bittleston Patents 41

II. ION's Infringement Under §271(f)(1) and §271(f)(2) Should be Affirmed 46

A. The District Court Correctly Construed §271(f)(1) 48

1. The Plain Language Of §271(f)(1) Requires Intent That Components Be Combined 48

2. The Drafting History of §271(f)(1) Confirms the Plain Language 51

B. Regardless of the District Court's Interpretation §271(f)(1), No Basis Exists for Overturning the Jury Verdict of Infringement Under §271(f)(2) 54

1. ION Did Not Object to the Statements it Now Complains About 55

2. The Jury Was Given the Instructions ION Requested, and WesternGeco Did Not Misstate the Court's Summary Judgment Order 56

3. The Trial Record Independently Established ION's Infringement Under §271(f)(2) 62

C. *Commil* Does Not Require A New Trial 64

1. *Commil* Is Inapplicable To §271(f)(2) 65

2. *Commil* Does Not Require Proof of No Good Faith Belief In Invalidity, Nor Would a *Commil*-Based Instruction Have Affected the Outcome 66

III. The Jury's Lost Profits Award Should Be Affirmed 68

A. ION's DigiFIN Competes With WesternGeco's Q-Marine 69

B. Neither *Power Integrations* Nor §271(f) Forecloses Lost Profits in this Context 73

CONDITIONAL CROSS-APPEAL 78

IV. WesternGeco's Original Reasonable Royalty Calculation Was Improperly Excluded 78

A. ION's Profits Are Not A Cap On WesternGeco's Entitlement to Reasonable Royalty Damages 79

B. WesternGeco Reasonably Used Survey Revenues As a Royalty Base 81

V. ION's Infringement Was Objectively Willful 84

A. The District Court Applied Wrong Standard In Finding No Objective Willfulness 84

B. ION's Infringement of WesternGeco's Patents Was Objectively Willful 87

CONCLUSION 89

TABLE OF AUTHORITIES

Cases

Ajinomoto Co. v. Archer-Daniels-Midland Co.,
228 F.3d 1338 (Fed. Cir. 2000) 40

Alexsam, Inc. v. IDT Corp.,
715 F.3d 1336 (Fed. Cir. 2013) 45

Arachnid, Inc. v. Merit Indus., Inc.,
939 F.2d 1574 (Fed. Cir. 1991) 31, 32, 36

Bard Peripheral Vascular, Inc. v. W.L. Gore & Assoc., Inc.,
682 F.3d 1005 (Fed. Cir. 2012) 84, 85

Barnhart v. Thomas,
540 U.S. 20 (2003) 48

Bd. of Trustees of Leland Stanford Junior Univ. v. Roche Molecular Sys., Inc.,
487 F. Supp. 2d 1099 (N.D. Cal. 2007) 33

Bd. of Trustees of Leland Stanford Junior Univ. v. Roche Molecular Sys., Inc.,
131 S. Ct. 2188 (2011) 33

Bd. of Trustees of Leland Stanford Junior Univ. v. Roche Molecular Sys., Inc.,
583 F.3d 832 (Fed. Cir. 2009) 33

Bettcher Indus., Inc. v. Bunzl USA, Inc.,
661 F.3d 629 (Fed. Cir. 2011) 54

Bluebonnet Sav. Bank, F.S.B. v. United States,
466 F.3d 1349 (Fed. Cir. 2006) 78

Bocanegra v. Vicmar Servs., Inc.,
320 F.3d 581 (5th Cir. 2003) 79

Cardiac Pacemakers, Inc. v. St. Jude Med., Inc.,
576 F.3d 1348 (Fed. Cir. 2009) 51, 76

Christian Legal Soc'y v. Martinez,
561 U.S. 661 (2010) 42, 45, 46

TABLE OF AUTHORITIES (CONT'D)

Coker v. Coker,
650 S.W.2d 391 (Tex. 1983) 41

Comair Rotron, Inc. v. Nippon Densan Corp.,
49 F.3d 1535 (Fed. Cir. 1995) 72

Commil USA, LLC v. Cisco Sys., Inc.,
720 F.3d 1361 (Fed. Cir. 2013) ..... passim

Conn. Nat'l Bank v. Germain,
503 U.S. 249 (1992) 48

Deepsouth Packaging Co. v. Laitram Corp.,
406 U.S. 518 (1972) ..... passim

eBay Inc. v. MercExchange, L.L.C.,
547 U.S. 388 (2006) 27

Elec. Auto-Lite Co. v. P. & D. Mfg. Co.,
78 F.2d 700 (2d Cir. 1935)
revised, 109 F.2d 566 (2d Cir. 1940) 33

Enovsys LLC v. Nextel Commc'ns, Inc.,
614 F.3d 1333 (Fed. Cir. 2010) 30

Ferguson v. Neighborhood Hous. Servs. of Cleveland, Inc.,
780 F.2d 549 (6th Cir. 1986) 43, 63

Gasoline Prods. Co. v. Champlin Refining Co.,
283 U.S. 494 (1931) 63, 64

Gen. Elec. Co. v. Joiner,
522 U.S. 136 (1997) 78

Gen. Motors Corp. v. Devex Corp.,
461 U.S. 648 (1983) 73, 74

Genzyme Corp. v. Transkaryotic Therapies, Inc.,
346 F.3d 1094 (Fed. Cir. 2003) 35

Glenayre Elec., Inc. v. Jackson,
443 F.3d 851 (Fed. Cir. 2006) 82, 83

Global-Tech Appliances, Inc. v. SEB S.A.,
131 S. Ct. 2060 (2011) 49, 50

Golight, Inc. v. Wal-Mart Stores, Inc.,
355 F.3d 1327 (Fed. Cir. 2004) 82

TABLE OF AUTHORITIES (CONT'D)

Gooding v. United States,
416 U.S. 430 (1974) 49

Grain Processing Corp. v. Am. Maize-Prods. Co.,
185 F.3d 1341 (Fed. Cir. 1999) 73, 75

In re Sanders,
551 F.3d 397 (6th Cir. 2008) 48

In re Seagate Tech., LLC,
497 F.3d 1360 (Fed. Cir. 2007) (*en banc*) 84

InTouch Techs. Inc. v. VGO Commc'ns, Inc.,
751 F.3d 1327 (Fed. Cir. 2014) 61

Isquith v. Middle S. Utils., Inc.,
847 F.2d 186 (5th Cir. 1988) 44

Jimenez v. Wood Cnty.,
660 F.3d 841 (5th Cir. 2011) 65

Johnson v. Michelin Tire Corp.,
812 F.2d 200 (5th Cir. 1987) 55

Jurgens v. McKasy,
927 F.2d 1552 (Fed. Cir. 1991) 88

King Instruments Corp. v. Perego,
65 F.3d 941 (Fed. Cir. 1995) 72

Limelight Networks, Inc. v. Akamai Techs., Inc.,
134 S. Ct. 2111 (2014) 50, 51

Lipton Indus., Inc. v. Ralston Purina Co.,
670 F.2d 1024 (CCPA 1982) 44

Liquid Dynamics Corp. v. Vaughn Co.,
449 F.3d 1209 (Fed. Cir. 2006) 50

Lucent Techs., Inc. v. Gateway, Inc.,
580 F.3d 1301 (Fed. Cir. 2009) 56

Mahurkar v. C.R. Bard, Inc.,
79 F.3d 1572 (Fed. Cir. 1996) 73

Mars, Inc. v. Coin Acceptors, Inc.,
527 F.3d 1359 (Fed. Cir. 2008)
modified, 577 F.3d 1377 (Fed. Cir. 2009) 80

TABLE OF AUTHORITIES (CONT'D)

Merial Ltd. v. Cipla Ltd.,
681 F.3d 1283 (Fed. Cir. 2012) 75

Meyer v. Berkshire Life Ins. Co.,
372 F.3d 261 (4th Cir. 2004) 42

Microsoft Corp. v. AT&T,
550 U.S. 437 (2007) 51, 76

Monsanto Co. v. Ralph,
382 F.3d 1374 (Fed. Cir. 2004) 69, 80, 81

Morales v. Dep't of Army,
947 F.2d 766 (5th Cir. 1991) 43

Nat'l Cable Television Ass'n v. Am. Cinema Editors, Inc.,
937 F.2d 1572 (Fed. Cir. 1991) 50

Octane Fitness LLC v. ICON Health & Fitness, Inc.,
134 S. Ct. 1749 (2014) 85, 86

Owen Equip. & Erection Co. v. Kroger,
437 U.S. 365 (1978) 44, 45

Pandrol USA, LP v. Airboss Ry. Prods., Inc.,
320 F.3d 1354 (Fed. Cir. 2003) 30

Panduit Corp. v. Stahlin Bros. Fibre Works, Inc.,
575 F.2d 1152 (6th Cir. 1978) 71, 72, 82

Positive 66

Positive Black Talk Inc. v. Cash Money Records, Inc.,
394 F.3d 357 (5th Cir. 2004) 65

Power Integrations, Inc. v. Fairchild Semiconductor Intern., Inc.,
589 F. Supp. 2d 505 (D. Del. 2008) 74

Power Integrations, Inc. v. Fairchild Semiconductors Int'l, Inc.,
711 F.3d 1348 (Fed. Cir. 2013) 69, 75, 76

Presidio Components, Inc. v. Am. Tech. Ceramics Corp.,
702 F.3d 1351 (Fed. Cir. 2012) 72

Prof'l Real Estate Inv., Inc. v. Columbia Pictures Indus., Inc.,
508 U.S. 49 (1993) 85, 86

TABLE OF AUTHORITIES (CONT'D)

Radio Steel & Mfg. Co. v. MTD Prods., Inc.,
788 F.2d 1554 (Fed. Cir. 1986) 80

Reed Elsevier, Inc. v. Muchnick,
559 U.S. 154 (2010) 65

Rite-Hite Corp. v. Kelley Co., Inc.,
56 F.3d 1538 (Fed. Cir. 1995) 73, 75

Ry. Co. v. Ramsey,
89 U.S. (22 Wall.) 322 (1874) 42, 43, 45

Sanofi-Aventis Deutschland GmbH v. Glenmark Pharms.,
748 F.3d 1354 (Fed. Cir. 2014) 30

Shockley v. Arcan, Inc.,
248 F.3d 1349 (Fed. Cir. 2001) 83

Shum v. Intel Corp.,
633 F.3d 1067 (Fed. Cir. 2010) 78

Siemens Med. Solutions USA, Inc. v. Saint-Gobain Ceramics & Plastics, Inc., 637 F.3d 1269 (Fed. Cir. 2011) 83

SiRF Tech., Inc. v. ITC,
601 F.3d 1319 (Fed. Cir. 2010) 34, 37

Snellman v. Ricoh Co.,
862 F.2d 283 (Fed. Cir. 1988) 80

Speedplay, Inc. v. Bebop, Inc.,
211 F.3d 1245 (Fed. Cir. 2000) 36

SRI Int'l Inc. v. Adv. Tech. Labs., Inc.,
127 F.3d 1462 (Fed. Cir. 1997) 88

St. Mary's Honor Ctr. v. Hicks,
509 U.S. 502 (1993) 50

State Indus., Inc. v. Mor–Flo Indus., Inc.,
883 F.2d 1573 (Fed. Cir. 1989) 80

Steel Co. v. Citizens for a Better Env't,
523 U.S. 83 (1998) 50

Swift & Co. v. Hocking Valley Ry. Co.,
243 U.S. 281 (1917) 44, 45

TABLE OF AUTHORITIES (CONT'D)

SynQor, Inc. v. Artesyn Techs., Inc.,
709 F.3d 1365 (Fed. Cir. 2013) 63, 88

T.D. Williamson, Inc. v. Laymon,
723 F. Supp. 587 (N.D. Okla. 1989),
aff'd 923 F.2d 871 (Fed. Cir. 1990) 77

Texas v. Am. Tobacco Co.,
463 F.3d 399 (5th Cir. 2006) 41

U.S. Phillips Corp. v. Iwasaki Elec. Co.,
505 F.3d 1371 (Fed. Cir. 2007) 34

United States v. DeGarmo,
450 F.3d 360 (8th Cir. 2006) 59

United States v. Maynard,
236 F.3d 601 (10th Cir. 2000) 59

United States v. Rice,
607 F.3d 133 (5th Cir. 2010) 55

United States v. Smith,
726 F.2d 183 (5th Cir. 1984) 57

Verzosa v. Merrill Lynch,
589 F.2d 974 (9th Cir. 1978) 43

Vidrine v. Kan. City S. Ry. Co.,
466 F.2d 1217 (5th Cir. 1972) 63, 64

Vita-Mix Corp. v. Basic Holding, Inc.,
581 F.3d 1317 (Fed. Cir. 2009) 78

Wallace v. Methodist Hosp. Sys.,
271 F.3d 212 (5th Cir. 2001) 70

Weeks v. Angelone,
528 U.S. 225 (2000) 58

Whitcomb v. Spring Valley Coal Co.,
47 F. 652 (C.C.N.D. Ill. 1891) 33

Yale Lock Mfg. Co. v. Sargent,
117 U.S. 536 (1886) 72

TABLE OF AUTHORITIES (CONT'D)

Statutes

28 U.S.C. §1295(a)(1) 1
28 U.S.C. §1331 1
28 U.S.C. §1338(a) 1
28 U.S.C. §2107(a) 1
28 U.S.C. §2201 1
35 U.S.C. §100(d) 32
35 U.S.C. §152 ..... 33, 34
35 U.S.C. §261 39
35 U.S.C. §271(a) ..... passim
35 U.S.C. §271(b) ..... passim
35 U.S.C. §271(f) ..... passim
35 U.S.C. §271(f)(1) ..... passim
35 U.S.C. §271(f)(2) ..... passim
35 U.S.C. §281 ..... 31, 32
35 U.S.C. §284 ..... 29, 68
35 U.S.C. §285 86
35 U.S.C. §287(a) 34
35 U.S.C. §363 37

Rules

Fed. R. App. P. 4(a) 1

Regulations

37 C.F.R. §3.73(c)(1) (2012) (formerly §3.73(b)(1) (2005)) 33, 34

Secondary Sources

2 McCormick, *Evidence* §233 (4th ed. 1992) 39
31 Wright & Miller, *Federal Practice & Procedure* §7182 (1st ed.) 39
A Bill to Amend Title 35, United States Code, to Increase the Effectiveness of the Patent Laws and for Other Purposes: Hearing on S.

TABLE OF AUTHORITIES (CONT'D)

1535 and S. 1841 Before the Subcomm. on Patents, Copyrights and Trademarks, 98th Cong., 26 (1984).....53

H.R. 4526, 98th Cong. (1st Sess. 1984).....52, 53

S. Rep. 98-663 (Oct. 5, 1984).....53

STATEMENT OF RELATED CASES

No other appeal in or from the same civil action has been previously before this or any other appellate court. The Court's decision may affect *WesternGeco LLC v. Petroleum Geo-Services, Inc.*, No. 13-cv-2725 (S.D. Tex., compl. filed Sept. 16, 2013), a pending matter that involves the patents at issue here.

STATEMENT OF JURISDICTION

The district court had jurisdiction under 28 U.S.C. §§1331, 1338(a), 2201, and entered final judgment May 7, 2014. JA97-98. WesternGeco's May 21, 2014 cross-appeal was timely. *See* 28 U.S.C. §2107(a); Fed. R. App. P. 4(a); JA13543. This Court has jurisdiction under 28 U.S.C. §1295(a)(1).

PRELIMINARY STATEMENT

Following a four-week trial, the jury found that ION infringed the asserted claims of WesternGeco's patents, rejected ION's invalidity defenses, and found ION's infringement was willful. The evidence overwhelmingly showed that ION infringed, and that ION knew it infringed. ION specifically developed its DigiFIN system as an "answer to" WesternGeco's patented system to "compete in the market space that WesternGeco … created." JA7000; JA7006; JA8052. ION's own

customers recognized that ION infringed and told ION so. *See, e.g.*, JA7338. And ION's Executive Chairman lied under oath to hide the extent of ION's infringement. JA46; JA21031:2-21032:3.

On appeal, ION accepts that WesternGeco's patents are valid and that ION's products practice the claimed inventions when combined. Instead, ION tries to escape liability for three of the four patents with eleventh-hour arguments about standing. It seeks a new trial on all claims based on a clear misreading of 35 U.S.C. §271(f)(1), which ION tries to bootstrap into an argument for overturning the jury's separate infringement verdict under §271(f)(2). And it tries to eliminate most of the jury's award by arguing, in effect, that a patentee can never recover lost profits under §271(f). ION's arguments are meritless and highlight the lengths to which ION is willing to go to avoid responsibility for its actions.

First, ION's standing argument—raised for the first time months after trial—consists largely of speculation and innuendo, and ignores that *the patents themselves say they were were issued to WesternGeco*. Along the way, ION attempts to repudiate its previous, binding factual admissions that WesternGeco owns the patents. In any event, there is

nothing clearly erroneous about the district court's factual findings that WesternGeco is the owner.

Second, ION's argument that §271(f)(1) requires an intent to induce *infringement*, as opposed to the combination of components, cannot be squared with the plain language of the statute. Were there any doubt, the history surrounding adoption of §271(f) makes it clear. But even if ION were somehow correct in its reading of §271(f)(1), that would have no effect on the jury's separate verdict of infringement under §271(f)(2). ION has no basis for connecting its §271(f)(1) arguments to the jury's verdict under §271(f)(2).

Third, ION argues WesternGeco cannot recover lost profits because the *parties* were not direct competitors. But there can be no dispute that their *products* compete. That is all that matters. ION also argues that lost profits are not available for infringement under §271(f) because they were lost due to overseas combination of ION's products. Yet, the inducement of that overseas combination is precisely the conduct §271(f) defines as an act of infringement. ION's rationale would thwart Congress' objectives in adopting §271(f) by denying patentees

the right to fully recover for the harm infringers cause. The district court's judgment should be affirmed.

WesternGeco's cross-appeal is conditional. This case has been pending for over five years and WesternGeco seeks finality. However, if the Court reverses in part or orders a remand on the basis of ION's appeal arguments (none of which are case-dispositive), WesternGeco respectfully appeals two rulings that affect WesternGeco's remedies. *First*, the district court excluded WesternGeco's damages expert's initial reasonable royalty theory from trial on the ground that the amount exceeded ION's profits and was therefore impermissible "as a matter of law." JA62. As a result, WesternGeco was required to request a lower royalty award from the jury and to accept a lower supplemental damage award from the court, neither of which fully accounted for the economic reality of ION's infringement.

Second, the court applied an unduly stringent standard akin to Rule 11 to find that ION's infringement was not objectively willful, JA24, resulting in a judgment that ION was not a willful infringer and precluding WesternGeco from seeking enhanced damages.

The judgment should be affirmed in full; if it is not, the Court should reverse the district court's rulings excluding WesternGeco's original reasonable royalty analysis and finding ION's infringement not objectively willful.

STATEMENT OF THE ISSUES

1. Whether the district court correctly held that WesternGeco owns the Bittleston patents based on the trial court record, the PTO's issuance of the patents to WesternGeco, and ION's factual admissions that WesternGeco owns the patents.

2. Whether: (a) the district court correctly construed §271(f)(1) based on its plain language and as confirmed by the drafting history to require intent to combine components, (b) the jury's separate finding of infringement under §271(f)(2) based on unobjected-to instructions should stand in any event, and (c) ION's request for a new trial should be denied as it relies on objections ION never made and a jury instruction ION never requested.

3. Whether WesternGeco is entitled to lost profits for infringing components supplied from the United States where ION knew and in-

tended those components would be combined and used in direct competition with WesternGeco's patented products.

Conditional Cross-Appeal:

4. Whether the district court erred by excluding WesternGeco's initial reasonable royalty analysis on the ground that royalties cannot exceed the infringer's profits "as a matter of law".

5. Whether the district court erred by determining, on a standard akin to Rule 11, that ION's infringement was not objectively willful.

STATEMENT OF THE CASE

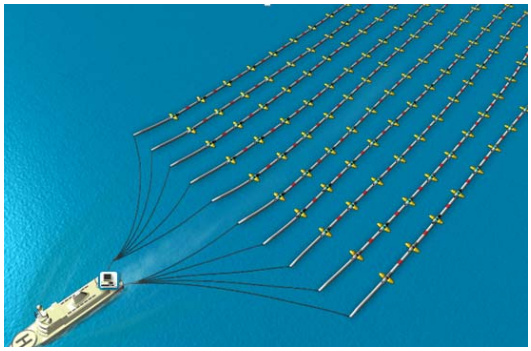
In June 2009, WesternGeco sued ION for infringement of three "Bittleston patents" (Nos. 7,080,607, 7,162,967, and 7,293,520) and the "Zajac patent" (No. 6,691,038). Before trial, the district court granted summary judgment that ION infringed claim 18 of the '520 patent under 35 U.S.C. §271(f)(1). After a four-week trial in 2012, the jury found that ION also infringed claim 18 of the '520 patent under §271(f)(2), and infringed the remaining claims asserted at trial under §271(f)(1) and §271(f)(2). The jury found the patents were not invalid, and that ION's infringement was subjectively willful, and awarded WesternGeco $105,900,000 in damages.

The district court denied ION's post-trial motions for a new trial and JMOL, granted an injunction, found ION's pre-verdict infringement was not objectively willful, awarded supplemental damages, and entered final judgment. ION now appeals and no longer disputes that WesternGeco's patents are valid or that systems using ION's components literally practice all elements of the asserted claims.

I. Background

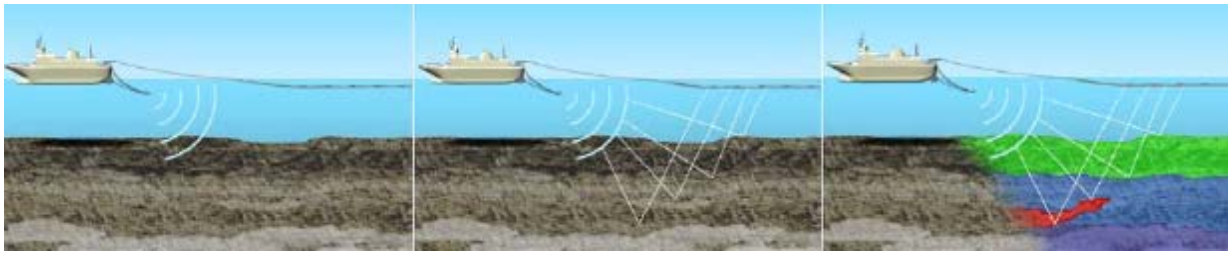
A. WesternGeco's Patents and Q-Marine System

The patents relate to marine seismic surveys—technology for exploring for oil and gas beneath the ocean floor. A vessel tows an array of "marine seismic streamers," which are cables four to six miles-long and filled with sensors, over the area to be scanned. JA1498:8-13.



An airgun sends sound waves toward the ocean floor, and the sensors detect the reflected signal to map the subsurface geology, similar to the

way sonograms use sound waves to image a patient's internal organs. JA1250:13-1251:3; JA1500:15-24.

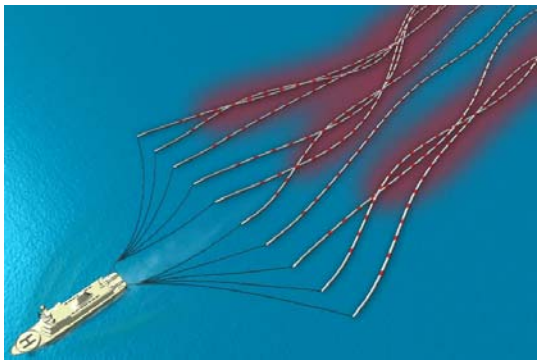


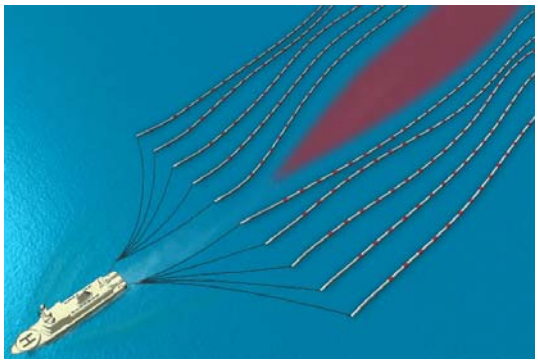
The resulting data can identify and characterize reservoirs for exploration and development. JA1251:4-12.

Surveys using towed streamer arrays are expensive and time-consuming, costing anywhere from $5 million to hundreds of millions of dollars. JA3071:11-25. The data, however, is highly valuable to oil companies because the fixed cost of drilling a well is hundreds of millions of dollars, and a single oil field costs approximately $1 billion to develop, JA3072:1-18, all of which is wasted if a company drills and finds no oil.

WesternGeco is the worldwide leader in geophysical services and based in Houston, Texas. WesternGeco invented, patented, and commercialized the first seismic surveying system with "lateral steering," i.e., the ability to place miles-long streamers precisely where desired in open deep-water environments. JA1499:8-1500:14. Prior art devices

controlled depth but not lateral position. JA531. Without lateral steering, currents, towing vessel movements, wakes from other vessels, weather, obstructions, and other conditions on the high seas risked catastrophic tangles and caused uneven geometries, increasing the costs and dangers of conducting surveys and degrading the survey data quality. JA1281:16-1282:6; JA1283:10-1288:2; JA1293:3-9; JA1294:8-1298:3; 1512:4-1514:10.





WesternGeco's inventions solved those problems. Working for Geco-Prakla, a WesternGeco predecessor, Simon Bittleston and Øyvind Hillesund invented control systems for steering these many miles of streamers by coordinating the hundreds of winged positioning devices deployed across the miles-long array of streamers—JA1509:11-1512:3; JA1514:11-1517:7; JA1532:19-1534:3; JA1536:5-1539:23; JA7276-91—a task akin to steering 200 separate airplanes on auto-pilot simultaneously, while dealing with spotty location information and unpredictable

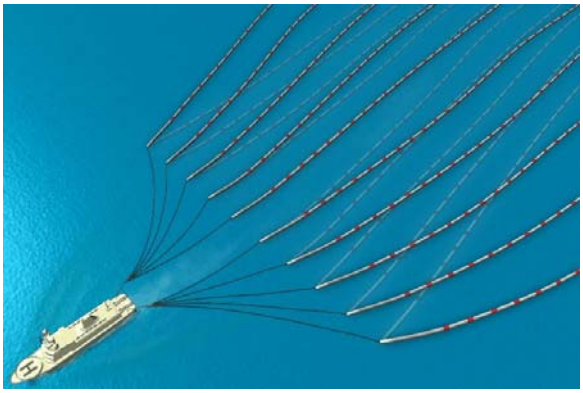
forces of currents and waves. JA1499:8-1500:1. Those inventions resulted in the "Bittleston patents" in this case. *See* JA526-36; JA515-25; JA503-14.

WesternGeco's fourth patent, the Zajac patent, filed June 15, 2001, JA478-92, built on the Bittleston patents to improve "4D surveys"—surveying the same area at different times with sufficient precision to compare results and observe changes in the seabed and subsoil over time. *See, e.g.*, JA485:1:45-49; JA490:12:14-39.

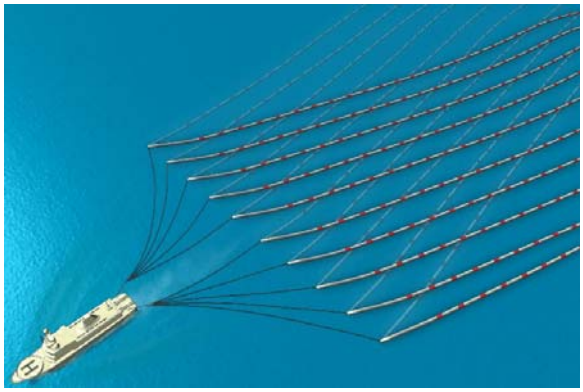
After nearly a decade of research and tens of millions of dollars' investment, WesternGeco commercialized the Bittleston and Zajac inventions in its "Q-Marine" streamer system. JA1776:9-22; JA2612:18-2613:7 (describing Q technology as "hundred million dollar gamble"); JA2622:9-19. Q-Marine and its Q-Fin steering devices were the industry's first laterally steerable streamer array. JA2622:20-22.

This was undisputedly a significant breakthrough that facilitated safer and more efficient surveys, and higher-quality data collection. JA1293:3-18; JA1294:8-19; JA1297:12-1298:3; JA1299:22-1300:21; JA1301:10-1302:14; JA5115:19-5116:7. In addition to surmounting problems in the prior art, lateral steering allowed for advanced features

such as "fan" or "feather angle" modes—where streamers spread to cover a larger area, or move at an angle to avoid obstacles, counteract currents, or repeat a previous survey. JA1324:7-14; JA1323:13-23; *see* JA536 (asserted claims 18, 19, and 23 reciting features).



fan



feather angle

WesternGeco's Q-Marine, with lateral steering capabilities, was well-received in the industry and immensely profitable. WesternGeco protected its investment by integrating vertically and adopting a policy of not licensing or supplying competitors. JA2638:25-2639:23; JA5101:9-22. Rather, WesternGeco made the equipment and performed the surveys itself. As the only company to offer lateral steering, WesternGeco filled a void. JA1290:7-19; JA1293:10-18; JA4631:22-24; JA5109:24-5110:14. WesternGeco was able to negotiate directly with customers who wanted lateral steering, and to obtain contract awards directly, rather than through bidding processes. JA2624:25-2625:20.

WesternGeco won direct survey contracts from Statoil (ca. 2001), Shell, Chevron, ONGC (India's national oil company), Petrobras (Brazil's), PEMEX (Mexico's), and others. JA2622:9-15; JA2624:25-2625:20. As customers understood the technology's value, they began specifying lateral steering as a requirement for their surveys—which only WesternGeco could provide. JA2625:18-2626:6. Further, WesternGeco could command a price premium over conventional surveys because its lateral steering surveys yielded higher-quality data. JA2626:7-16. WesternGeco's technology also reduced the time to complete a survey, thus increasing the number of surveys WesternGeco's fleet could perform each year. JA2626:17-2630:4. From 2001 to 2007, WesternGeco owned 100% of the lateral steering market, and earned billions of dollars with its proprietary technology, JA2695:8-12, including more than $500 million from Q-Marine surveys the year just before ION began infringing. JA3302:11-23.

B. ION's Infringing DigiFIN

Based in Houston, ION manufactures marine seismic equipment and supplies it to survey companies. After witnessing WesternGeco's success with Q-Marine, ION made a competing DigiFIN Advanced

Streamer Command and Control System, which launched in 2007. ION developed the DigiFIN system as an "[a]nswer to" WesternGeco's Q-Marine, JA8052, and targeted the "proprietary 'Q' marine systems market space… that WesternGeco has created" as reflected in ION's business plans:

> The compelling reason for IO[N] to enter into this market segment is the value that this device will bring to the existing marine seismic fleet …
>
> * * *
>
> Today the oil companies have no alternative to [WesternGeco's] 'Q' vessels. The DigiFIN opens the door to all 3D vessels … to compete in the market space that WesternGeco has created.

JA7000, JA7006; *see* JA4474:4-8.

Like WesternGeco's Q-Marine, ION's DigiFIN system provides lateral steering capabilities using streamer positioning devices ("DigiFINs") and a shipboard Lateral Controller to provide commands to the DigiFINs. *See, e.g.*, JA7032-34; JA7343-44. ION does not dispute that its DigiFIN system practices the inventions claimed in the patents-in-suit.

In 2007, ION began supplying the components of its system—the DigiFINs and the Lateral Controller—to surveyor customers. ION

shipped components from its Louisiana warehouse, JA3789:4-3790:10; JA4026:10-4028:10, and ION's customers would use ION's system to compete directly with WesternGeco for surveys. JA1312:3-1313:9; JA1491:9-1492:18.

After ION launched its DigiFIN system, WesternGeco "lost jobs specifically where lateral[ly] steer[ing] stream[ers wa]s required. And in the jobs where [WesternGeco] d[id] compete, [its] margin has suffered." JA1328:11-16. ION's customers acknowledged that they "would not have won" surveys "without steering capabilities" that ION's DigiFIN system provided. JA7340. To compete, WesternGeco was forced to accept lower prices for performing surveys with its patented technology. JA1314:22-1315:17; JA2695:13-16; JA7340 (2008 internal ION email: "welcome to the world of commodity towed streamer services").

ION was aware of three of the patents before its first DigiFIN sale in 2007, JA3790:11-16, and aware of the '520 patent no later than February 2009. JA3996:20-3997:13. ION's customers were aware of WesternGeco's patents and raised concerns about infringement.

For example, attorneys for ION customer Statoil concluded in February 2009 that ION's DigiFIN would infringe claim 18 of the '520 patent and claim 15 of the '967 patent:

> [The '967 patent's claims] "clearly envisage[] a system working along broadly the same lines as described above in relation to Ion," concluding that the "use of the Ion devices to steer streamers would infringe claim 1 [and] … [c]laim 15 …."
>
> * * *
>
> [C]laim 1 of the ['520] patent … would be infringed by using the Ion system. There is also a corresponding independent apparatus claim 18 which would also be infringed for the same reasons.

JA8070-71, JA8073-74.

In April 2009, ION's customer Fugro raised similar concerns that DigiFIN "can potentially be infringing [WesternGeco's] patents on every single survey we [Fugro] do," JA7072-73, and that Fugro was "still not at ease with Geco patent issues." JA7338; *see* JA2990:18-2991:10; JA2104:4-2106:2; JA8078; JA7070. Fugro demanded indemnity from ION, JA2099:16-2100:9; JA7091-99, and other ION customers followed suit. *See* JA5163:17-25, JA5247:4-5250:22, JA8062-68 (Polarcus); JA5243:6-5246:16, JA8069 (Bergen); JA5553:17-5554:13 (Dolphin).

ION first responded with a "Product Assurance Pledge," providing some remedies to customers, JA7100; JA2992:21-2993:9; JA3032:6-15; JA3972:12-3975:6; JA3976:16-3978:6, and later provided at least Fugro a more specific "indemnity" agreement. JA7074-90; JA2988:19-2991:10.

In 2011, while this litigation and ION's indemnity discussions were ongoing, ION changed its accounting to invoice DigiFIN sales through a Dubai subsidiary, JA4038:9-4039:18; JA7342, to assuage Fugro's concerns about U.S.-supplied DigiFINs because of this litigation. JA5277:19-5280:2; JA7101-03. The change, however, was only on paper—every DigiFIN was still manufactured in and supplied from the same factory in Harahan, Louisiana. JA3039:13-3041:11; JA5276:2-8.

II. District Court Proceedings

In June 2009, WesternGeco sued ION in the Southern District of Texas, alleging willful infringement of the Bittleston and Zajac patents. ION customer Fugro was joined in 2010. Fugro settled with WesternGeco mid-trial in 2012, at the end of ION's presentation, and after ION made clear it did not intend to indemnify Fugro. JA2942:9-14; JA3971:19-23; JA4050:8-21.

A. Pretrial Rulings

1. Summary Judgment of Infringement of Claim 18 of the '520 Patent Under §271(f)(1)

In June 2012, the district court granted summary judgment to WesternGeco that ION infringed claim 18 of the '520 patent under 35 U.S.C. §271(f)(1). JA53-54; *see* JA357-67.

Claim 18 recites the following:

> An apparatus comprising: (a) an array of streamers each having *a plurality of streamer positioning devices* there along; (b) *a control system configured to use a control mode* selected from a feather angle mode, a turn control mode, a streamer separation mode, and two or more of these modes.

JA536.[1]

Both subsections of §271(f) require supplying "component[s]" "from the United States," with the intent that they be combined "outside of the United States," and that the combination "would infringe the patent if such combination occurred within the United States." The district court found no genuine dispute on those points—ION supplied DigiFINs (the claimed "streamer positioning devices") and the lateral controller (the claimed "control system") from the United States, JA358-

[1] Unless otherwise noted, all emphases are added.

59, for its customers to combine outside of the United States, in a manner that met all elements of claim 18.

As to §271(f)(1), ION's employees' testimony confirmed that the DigiFIN and lateral controller were "a substantial portion of the components of a patented invention." JA359-60. After requesting briefing on §271(f)(1)'s intent requirement, JA370-72, the district court examined the language and drafting history, and concluded that the "plain language … is unambiguous and can be read only one way." JA50. The unlawful conduct is "the exportation and the *encouragement of assembly*, which assembly would be an infringement if it were done in the United States." JA51. Section 271(f)(1) "does not require that the infringer … intend the infringement of[] the patent," only the intent to combine the components." *Id.* Thus, the district court concluded that §271(f)(1) requires that the infringer actively induce the combination of components, and that that combination would constitute patent infringement if done in the United States. JA50-54. The undisputed evidence proved ION had that intent. JA53-54 (ION's "intent to induce combination is shown throughout instruction manuals that ION … issued and distributed, which instruct end users to use the steering

modes of the '520 patent."); JA3790:7-10. The district court thus granted summary judgment that ION infringed claim 18 of the '520 patent under §271(f)(1).

The court similarly analyzed §271(f)(2), which it read to require that the infringer "(1) intended the combination of components; (2) knew that the combination he intended was patented; and (3) knew that the combination he intended would be infringing if it occurred in the United States." JA55. The court determined that DigiFIN and the Lateral Controller were especially adapted for use in the invention and had no substantial non-infringing uses because ION's and Fugro's "documents make clear that DigiFIN and the lateral controllers are designed and used with steering modes, including the infringing even separation mode." JA367-70. The court found a genuine factual dispute, however, as to whether ION knew that the combination was infringing. JA56-57.

After the district court's summary judgment order, ION moved its entire inventory of DigiFINs from its Louisiana warehouse to Norway, and then to a warehouse in Dubai, ostensibly to remove them from the Court's jurisdiction. JA392-96. Although ION's Executive Chairman testified that ION stopped selling DigiFIN after summary judgment,

the post-trial accounting showed that testimony to be false—some of these DigiFINs were already under contract and ION certainly "hope[d]" to sell the remainder. JA393-94.

2. Exclusion of WesternGeco's Reasonable Royalty Theory

WesternGeco sought reasonable royalty and lost profits damages for ION's infringement. Before trial, the district court excluded WesternGeco's reasonable royalty damages theory and required WesternGeco to present a reduced alternative theory to the jury. JA63

WesternGeco's damages expert, Sims, originally opined that WesternGeco was due (a) lost profits for twenty-five surveys that WesternGeco would have performed (instead of a competitor) absent ION's infringement, and (b) a 10-11.5% royalty for the remaining infringing surveys based on the significant value WesternGeco's patented technology contributed. JA10256-58. Sims applied a 10% royalty to the revenue ION's customers earned from performing surveys with DigiFIN, resulting in a $300.8 million total royalty—reflecting the economic reality that DigiFIN gave ION's customers the ability to compete with WesternGeco's proprietary technology and contributed to over 20% of the survey's value. JA10257-58.

ION objected. JA10147-50. The district court allowed the lost-profits analysis to proceed but excluded the royalty theory on the ground that the number exceeded ION's profits from DigiFIN sales, and that "[a]s a matter of law, no such risk can be taken in a hypothetical negotiation…." JA62. WesternGeco proffered Sims' original analysis to preserve its rights for appeal, JA2981:10-20, and proceeded to trial with an alternative analysis under which WesternGeco was due $14.9 million in royalties based on ION's $42.3 million in component revenues. JA3432:5-19; JA3439:18-3440:3.

B. Trial

WesternGeco's claims and ION's defenses were tried to the jury over four weeks in 2012.

1. Infringement and Defenses

WesternGeco asserted infringement of claim 18 of the '520 patent under 35 U.S.C. § 271(f)(2)—as the district court had granted summary judgment of infringement under §271(f)(1)—and the following under both §271(f)(1) and §271(f)(2): claims 19 and 23 of the '520 patent, claim 15 of the '967 patent, claim 15 of the '607 patent, and claim 14 of the '038 patent. JA71-72. The jury was instructed separately on infringement under §271(f)(1) and §271(f)(2), JA11087-88, and was asked to

render separate verdicts on each claim and as to each theory of infringement. JA71-72; *see* JA11087 ("You must determine infringement under 35 U.S.C. §271(f)(1) on a claim-by-claim basis."); JA11088 (same for §271(f)(2)).

In claim construction, partial summary judgment orders, and trial rulings that ION does not appeal, the court rejected ION's principal defenses. *See, e.g.*, JA385 (rejecting non-infringement argument regarding '038 patent); JA174-76; JA191-97 (granting summary judgment to WesternGeco's as to ION's §116 and unenforceability defenses); JA537-39 (dismissing ION's §101 and three §112 defenses).

At trial, the evidence established ION's liability beyond doubt. As to infringement, in many instances, ION's own documents closely matched the court's claim construction. Claims 19 and 23 of the '520 patent illustrate the point:

	Claim Construction	**ION's Manual**
Claim 19: Feather Angle Mode	"a control mode that attempts to set and maintain each streamer in a straight line offset from the towing direction by a certain feather angle" JA133.	In "Ghost Mode," the lateral controller "positions the streamers at an even separation along their length from the reference streamer and each other while simultaneously driving the reference streamer to the desired

		feather value." JA7305.
Claim 23: Turn Control Mode	the "mode wherein streamer positioning device(s) generate a force in the opposite direction of a turn and then directing each streamer positioning device to the position defined in the feather angle mode." JA134-35.	"The DigiFIN system … increases turn efficiency by steering streamers outward and straightening them more quickly." JA7105; *see also* JA7308

ION's remaining invalidity defenses were shown to be meritless at trial. For example, ION's enablement expert (Edgar) admitted that ION's defense was based on unclaimed elements or claim construction at odds with the court's construction. JA4148:17-4149:19; 4153:6-4156:8; JA4158:13-16; JA4162:12-4164:10; JA4166:20-4167:23. ION's other technical expert (Brune), contradicted Edgar and admitted that the Bittleston patents *were* enabled. JA4938:13-4939:16.

The jury ultimately found infringement of all asserted claims, JA71-72, and rejected ION's invalidity defenses. JA73-76. ION no longer disputes validity.

2. Subjective Prong of Willful Infringement

The jury found, under a clear-and-convincing-evidence standard, that ION's infringement was subjectively willful. JA77 (verdict); JA11096 (instructions). As noted, ION was aware of WesternGeco's patents before the litigation, and multiple ION customers had raised concerns about infringing WesternGeco's patents—including identifying specific infringed claims and demanding indemnity. *Statement of Case §I.B, supra.* Further, ION was reluctant to provide indemnity, and changed its accounting practices to obscure that it was continuing to make and sell DigiFINs from the United States. *See id.*

C. Post-Trial

On June 19, 2013, the district court resolved fourteen post-trial motions. JA1-48. Those relevant to this appeal, and subsequent damages proceedings, are described below.

1. ION's Post-Trial Challenge to WesternGeco's Ownership of the Bittleston Patents

After trial, new counsel entered appearances for ION and began requesting discovery regarding WesternGeco's ownership of its patents. After WesternGeco responded, and approximately a month after ION filed its post-trial JMOL and new trial motions, ION pronounced itself

unsatisfied with WesternGeco's response to its post-trial discovery inquiries, and filed a partial motion to dismiss for lack of subject matter jurisdiction. That motion asserted that WesternGeco did not own the Bittleston patents. JA5-6. In the three-and-a-half preceding years of litigation, WesternGeco's ownership of the Bittleston patents had been unquestioned. On its face, each patent lists "WesternGeco, L.L.C." as the "Assignee," and ION's earlier pleadings had acknowledged the fact of WesternGeco's ownership. WesternGeco responded to ION's arguments and documented its ownership of the Bittleston patents.

The district court denied ION's motion for three independent reasons. First, ION had previously pled the *fact* of WesternGeco's ownership of the Bittleston patents. JA6-7. Although parties cannot confer jurisdiction by consent, they may admit facts that show jurisdiction, and can be held to those admissions. *Id.* Second, the PTO issued the patents directly to WesternGeco, and ION did not rebut the presumptive correctness of the PTO's action. JA7. Finally, WesternGeco's evidence documented the chain of title leading to its ownership of the patents. JA7-8.

2. Objective Prong of Willful Infringement

Although denying the rest of ION's motions, the court granted ION's motion for judgment of a matter of law of no willfulness. The court did not address the jury's finding of subjective willfulness, JA28, but applied a "no reasonable litigant" standard, JA24, to hold that ION's defenses were not objectively baseless. JA24-28.

3. Injunction, Supplemental Damages, and Final Judgment

The court entered a permanent injunction barring ION from supplying or causing DigiFIN to be supplied from the United States. JA45-46, JA89. The court found it "deeply troubling" that ION's Executive Chairman Robert Peebler had testified falsely at trial that ION had stopped selling DigiFINs following the court's pretrial summary judgment ruling. JA46 (referencing JA5491:12-5492:1). ION's post-trial accounting submissions "reveal[ed] that [Peebler's] assertion was false and ION did sell more DigiFIN after the Court's ruling and even after trial." *Id.* The court assessed supplemental damages for DigiFIN units that ION sold and delivered that were not included in the verdict, JA82-86; JA93-97. After initially extrapolating from the jury's full damage award (lost profits and reasonable royalty), JA86-87, the court ultimate-

ly based supplemental damages on only the royalty award. JA93-97. The court determined that all four factors of *eBay Inc. v. MercExchange, L.L.C.*, 547 U.S. 388 (2006), favored a permanent injunction. JA46.

SUMMARY OF THE ARGUMENT

ION's Appeal. ION's post-trial attempt to dispute WesternGeco's ownership of three of the patents-in-suit is unsound. First, on the basis of submissions indicating WesternGeco's ownership, the Patent Office issued the patents to WesternGeco—noting WesternGeco's "assignee" status on the face of each patent—and that WesternGeco has not since transferred them. Second, WesternGeco's evidence showed the transfer of title from the inventors to it, and the district court did not clearly err in crediting that evidence. Finally, ION affirmatively pled the fact of the inventors having assigned their inventions to WesternGeco, and cannot retract its factual stipulations after trial.

The district court correctly held that §271(f)(1) requires intent to induce the combination of components, as opposed to intent to induce infringement. The statute's plain language compels that reading, and drafting history confirms it. And regardless of ION's arguments regarding §271(f)(1), there is no basis to overturn the jury's separate infringe-

ment verdict under §271(f)(2). §271(f)(1) and §271(f)(2) recite different types of infringement, with different proofs. WesternGeco separately proved both types of infringement. The jury was separately instructed on each and rendered separate verdicts on each, and those verdicts are supported by substantial evidence. ION's arguments regarding this Court's recent *Commil* decision are likewise without merit. ION grossly misreads *Commil*. The evidentiary and jury-instructions errors *Commil* addressed were not present here. Moreover, *Commil* concerned §271(b), not §271(f). Even accepting some conceptual overlap between §271(b) and §271(f)(1), nothing in the logic or holdings of *Commil* has any bearing on the judgment that ION infringes under §271(f)(2).

ION's challenge to the lost profits award is directly contrary to precedent and the language of §271(f). ION's and WesternGeco's *products* undisputedly competed, and WesternGeco proved that ION's infringement caused WesternGeco to lose profits. It does not matter whether the *parties* are also direct competitors. ION's "extraterritoriality" arguments rely heavily on the aspects of *Deepsouth* that Congress overruled by enacting §271(f). WesternGeco proved patent infringement, as Congress defined it, and is therefore entitled to "damages ade-

quate to compensate for the infringement" under §284. WesternGeco proved lost profits caused by ION's infringement, and the jury's award properly included those damages.

Conditional Cross-Appeal. If the judgment is not affirmed, the Court should reverse the exclusion of WesternGeco's initial royalty analysis. The district court erred in ruling that a patentee cannot, "as a matter of law," seek royalties that exceed an infringer's profits. Precedent uniformly rejects such a rule. WesternGeco's initial analysis was consistent with the record and captured the economic reality of the injuries that ION's infringement caused WesternGeco.

The Court should also reverse the district court's ruling that ION's infringement was not objectively willful. The legal test is whether the infringer's defenses were reasonable. The district court applied a heightened "no reasonable litigant" standard, based on a misreading of this Court's cases that is no longer plausible after the Supreme Court's *Octane* decision. On this record, under any standard, ION's infringement was objectively willful—ION's now-abandoned defenses to infringement failed, mostly on summary judgment; ION's own customer

informed ION, in detail, of the objectively high risk of infringement liability; and ION was reluctant to offer indemnity.

ARGUMENT

I. WesternGeco Has Standing to Enforce the Bittleston Patents, and The District Court Correctly So Held for Three Independently Sufficient Reasons

A party holding legal title to a patent has standing to sue for patent infringement. *See generally Pandrol USA, LP v. Airboss Ry. Prods., Inc.*, 320 F.3d 1354, 1368 (Fed. Cir. 2003). "Whether a party has standing to bring and maintain suit is a question of law reviewed de novo. … [R]elated factual findings will be disturbed only if they are clearly erroneous." *Enovsys LLC v. Nextel Commc'ns, Inc.*, 614 F.3d 1333, 1340-41 (Fed. Cir. 2010); *see Sanofi-Aventis Deutschland GmbH v. Glenmark Pharms.*, 748 F.3d 1354, 1364 (Fed. Cir. 2014) (reviewing factual findings underlying standing only for clear error).

WesternGeco's legal title to the Bittleston patents is a question of fact, *Sanofi-Aventis*, 748 F.3d at 1364, and was already established: (1) the Patent Office issued the Bittleston patents *to WesternGeco*, and WesternGeco never transferred them; (2) WesternGeco independently established, with evidence, that it is the assignee, and the district court's assessment of that evidence was not clearly erroneous; and (3)

ION admitted the fact of WesternGeco's ownership of the Bittleston patents multiple times and cannot retract its factual admissions now.

Any and all of those reasons are sufficient to support the district court's factual determination of WesternGeco's ownership and affirm WesternGeco's standing. ION mischaracterizes the record and relies on misstatements of law and unfounded insinuations about the district judge's motivations. *See, e.g.*, ION-Br. 21 ("[T]he court … was adamant that standing should not undo the jury trial. … This is understandable at a personal level but legally irrelevant.").

A. WesternGeco Holds Legal Title to the Bittleston Patents Because the Patent Office Issued Them to WesternGeco

By statute, the "patentee" has the right to sue for infringement. 35 U.S.C. §281. The "patentee" is "*to whom the patent was issued*," and "also the successors in title to the patentee." *Id.* §100(d); *see Arachnid, Inc. v. Merit Indus., Inc.*, 939 F.2d 1574, 1578 n.2 (Fed. Cir. 1991) ("The entity to whom the grant of a patent is made by the PTO [or that entity's successor in title] *holds the 'legal title' to the patent*.").

WesternGeco is undisputedly "to whom the patent was issued" and therefore "the patentee." ION does not dispute that the Patent Of-

fice issued the Bittleston patents *to WesternGeco*. The file histories confirm that fact, JA13524-33 ('520 patent); JA13437-44 ('967); JA13351-56 ('607), as does the face of each patent:

(12) **United States Patent**
Hillesund et al.

(10) **Patent No.: US 7,293,520 B2**
(45) **Date of Patent: *Nov. 13, 2007**

(54) **CONTROL SYSTEM FOR POSITIONING OF A MARINE SEISMIC STREAMERS**

(75) Inventors: **Oyvind Hillesund**, Histon (GB); **Simon Hastings Bittleston**, Bury St Edmunds (GB)

(73) Assignee: **WesternGeco, L.L.C.**, Houston, TX (US)

3,774,570	A	11/1973	Pearson	114/235 B
3,896,756	A	7/1975	Pearson et al.	114/235 B
3,931,608	A	1/1976	Cole	367/17
3,943,483	A	3/1976	Strange	340/7 PC
3,961,303	A	6/1976	Paitson	367/17
4,033,278	A	7/1977	Waters	114/245
4,063,213	A	12/1977	Itria et al.	367/17
4,087,780	A	5/1978	Itria et al.	367/17
4,222,340	A	9/1980	Cole	114/245
4,227,479	A	10/1980	Gertler et al.	114/312

JA526 ('520 patent, highlighting added); *see* JA515 ('967 patent); JA503 ('607 patent). WesternGeco thus owns the Bittleston patents, and ION does not contend that WesternGeco transferred them. That alone is sufficient to reject ION's standing argument.

ION contends that the Patent Office erred in issuing the Bittleston patents to WesternGeco. ION-Br. 25-27. But even if the Patent Office somehow erred—which it did not—the issuance of the patents to WesternGeco conferred legal title on WesternGeco. 35 U.S.C. §§100(d), 281; *Arachnid,* 939 F.2d at 1578 n.2. At most, ION contends that WesternGeco *should* not own the patents, not that WesternGeco *does* not own them. ION's standing challenge thus stumbles out of the gate, and

ION cites no case where a court ever looked behind the Patent Office's actions in issuing a patent to the plaintiff to find that the plaintiff lacked standing.

Rather, it is long-settled that the entity to whom the Patent Office issues a patent is the presumptive owner. *Elec. Auto-Lite Co. v. P. & D. Mfg. Co.*, 78 F.2d 700, 704 (2d Cir. 1935), *revised on other grounds*, 109 F.2d 566 (2d Cir. 1940); *Whitcomb v. Spring Valley Coal Co.*, 47 F. 652, 655-56 (C.C.N.D. Ill. 1891); *see Bd. of Trustees of Leland Stanford Junior Univ. v. Roche Molecular Sys., Inc.*, 487 F. Supp. 2d 1099, 1111 n.4 (N.D. Cal. 2007), *aff'd*, 583 F.3d 832 (Fed. Cir. 2009), *aff'd*, 131 S. Ct. 2188 (2011). By statute and its own regulations, the Patent Office only issues patents to assignees who "establish ... ownership … to the satisfaction of the Director." *See* 37 C.F.R. §3.73(c)(1) (2012) (formerly §3.73(b)(1) (2005)); 35 U.S.C. §152. And the Patent Office's action is agency action entitled to deference and the traditional presumption of regularity. *Elec. Auto-Lite*, 78 F.2d at 704; *Whitcomb*, 47 F. at 655-56.

ION's contrary arguments are unsound. ION asserts that no presumption arises from the Patent Office's issuance of the patents to WesternGeco. ION-Br. 25. The cases ION cites do not support it. *SiRF*

Tech., Inc. v. ITC, 601 F.3d 1319 (Fed. Cir. 2010), states that "[t]he recording of an assignment with the [PTO] … creates a presumption of validity as to the assignment …." *Id.* at 1327-28. *SiRF* does not overrule longstanding precedent that the party to whom the patent is issued is presumed to be the assignee, nor does it cast doubt on the proposition that the party *to whom the Patent Office issues a patent* is the "patentee." *U.S. Phillips Corp. v. Iwasaki Elec. Co.*, 505 F.3d 1371 (Fed. Cir. 2007), is also inapposite. *Iwasaki* concerned the marking statute, 35 U.S.C. §287(a), and held that, because patentees are not required to record assignments, and the listed owner may transfer a patent after receiving it from the Patent Office, "the assignation printed on the face of a patent is not a conclusive indication of the patent's *current* ownership." 505 F.3d at 1375. Marking is not at issue here, and WesternGeco did not subsequently transfer any rights to the Bittleston Patents.

ION argues that the Patent Office's issuance of the patents to WesternGeco is meaningless because "there [wa]s no 'examination' [of the assignment] on the merits …." ION-Br. 26. But ownership must be established before the Patent Office issues a patent to an assignee. *See* 35 U.S.C. §152; 37 C.F.R. §3.73(c)(1) (2012). The Patent Office is pre-

sumed to comply with its own rules, *Genzyme Corp. v. Transkaryotic Therapies, Inc.*, 346 F.3d 1094, 1103 n.3 (Fed. Cir. 2003), and the record reflects that it did so here.

For each application, both inventors (Hillesund and Bittleston) signed powers of attorney allowing WesternGeco's counsel to prosecute the applications. JA12665-66; JA12673-74; JA12678-79. The applications were filed listing WesternGeco as the assignee. JA12664; JA12671. The Patent Office's records include assignments to WesternGeco, JA12203-10, fee transmittal forms identifying WesternGeco as the assignee, JA12668; JA12675; JA12682, sworn statements that WesternGeco owns the patents, JA12681; JA12667, and a "Statement under 37 C.F.R. 3.73(b)" confirming that WesternGeco is the "Applicant/Owner" and "Assignee" of the Bittleston patents. JA12213-15. The District Court's factual finding of ownership is thus well-supported and not clearly erroneous.

B. The Inventors Assigned the Bittleston Patents to WesternGeco

The Patent Office's issuance of the patents to WesternGeco is sufficient to prove WesternGeco's ownership. ION argues that some further "chain of title" evidence is required. ION-Br. 31 (citing *Speedplay,*

Inc. v. Bebop, Inc., 211 F.3d 1245 (Fed. Cir. 2000)). It is not. In *Speedplay*, the plaintiff was a third party "asserting that it obtained all substantial rights" from the party to whom the Patent Office issued the patents. *Id.* at 1249. Here, WesternGeco *is* the party to whom the Patent Office issued the patents, and "holds the legal title." *Arachnid,* 939 F.2d at 1578 n.2.

In any event, WesternGeco *did* document the transfer of patent rights from the inventors to WesternGeco. The District Court reviewed that evidence and found WesternGeco "prove[d] its ownership of the patents" by assignment from the inventors, and that ION's contrary contentions were "unconvincing." JA7-8. ION fails to demonstrate clear error in those findings.

Schlumberger Technology Corporation ("Schlumberger") is the parent and owner of WesternGeco. WesternGeco was formed in 2000 from the merger between Western Geophysical and Schlumberger subsidiary Geco-Prakla. WesternGeco acquired the patents through four events:

1. Inventors assigned inventions to Geco-Prakla. In 1993 and 1997, inventors Bittleston and Hillesund executed assignments of

their inventions to Geco-Prakla when they joined the company. JA1504:5-13; JA4539:25-4340:5; JA12805(424:24-425:9). Though ION has argued otherwise, it is black-letter law that assignments can pre-date patent applications. *SiRF*, 601 F.3d at 1326.

2. 1998 Cost-Sharing Agreement transferred U.S. patent rights from Geco-Prakla to Schlumberger. In 1998, Geco-Prakla transferred its U.S. patent rights from Geco-Prakla to Schlumberger, JA12820(§1.02); JA12824(§1.10); JA12828-29(§3.01); *see* JA12818, including "patent applications … based upon inventions relating to seismic oil field services or equipment[,] … obtained by or for the Geco Prakla Companies." JA12824(§1.10). That included U.S. rights to the PCT application to which the Bittleston patents all claim priority. *See* 35 U.S.C. §363; JA503; JA515; JA526; JA12195-96; JA12205-06.

3. Schlumberger transferred PCT application and U.S. Intellectual Property Rights to WesternGeco in merger. In the 2000 merger creating WesternGeco, two agreements transferred patent rights to WesternGeco. First, the merger agreement explicitly transferred the PCT application. JA12850; JA12741(§4.18); JA12780(§9.1). Second, a technology transfer agreement provided that Schlumberger

"agrees to and hereby does grant, transfer, and assign to GHLLC [WesternGeco] with regard to the [United States] all of STC's [Schlumberger's] rights, title and interest in and to the Intellectual Property[2] in existence on the effective date of this Agreement, to use or dispose of pursuant to [the merger agreement]." JA12854(§2.01).

4. 2000 Cost-Sharing Agreement confirmed WesternGeco's Ownership. A December 2000 Cost-Sharing Agreement among the "Western GECO Companies" provided that WesternGeco (then still named "GHLLC")[3] would own all seismic patent rights for the United States going forward, JA12857(§1.03); JA12858(§1.12); JA12860(§3.01); JA12868, including the right to "enforce the same and to retain any royalties or other recovery therefrom." JA12861(§4.02).

The District Court reviewed the foregoing evidence and correctly concluded that WesternGeco owned the Bittleston patents. JA8. ION

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[2] The technology transfer agreement defined "Intellectual Property" to include "Patent Rights" developed under the 1998 Cost Sharing Agreement. JA12854(§1.02).

[3] The merged company was originally named Geco Holdings LLC (also referred to as "GHLLC"), then WesternGeco Holdings LLC, then WesternGeco LLC. JA12799-802.

fails to demonstrate clear error in that ruling, and most of its arguments are little more than simple denials of WesternGeco's evidence.

ION disputes that Bittleston and Hillesund assigned their inventions to Geco-Prakla in writing. ION-Br. 32-33 (citing 35 U.S.C. §261). Both inventors unequivocally testified, however, that the assignments *were written* and executed, JA1504:5-13; JA4539:25-4540:5; JA12805(424:24-425:9), and those assignments were confirmed by subsequent, pre-litigation written instruments, JA12195-96; JA12205-06, and corroborated by a wealth of other evidence ION fails to discuss. *Supra* at 35-38.

Similarly unavailing is ION's reference to the "best evidence rule." ION-Br. 32-33. ION made no such argument below, and concedes the Rules of Evidence "do not control" this question. *Id.* Even if the "best evidence rule" was relevant, a document's existence may be proved by testimony. 31 Wright & Miller, *Federal Practice & Procedure* §7182 (1st ed.) ("[E]vidence that a document was written or that a photograph was taken raises no issue."); 2 McCormick, *Evidence* §233 (4th ed. 1992) ("[E]vidence that a certain document is in existence … is not within the rule and may be given without producing the document."). More gener-

ally, having challenged standing for the first time after trial, ION is in no position to challenge the quality of the trial evidence bearing on standing. *See Ajinomoto Co. v. Archer-Daniels-Midland Co.*, 228 F.3d 1338, 1343 (Fed. Cir. 2000). The district court did not clearly err in crediting WesternGeco's evidence that the inventors assigned their rights to Geco-Prakla.

ION's other arguments principally flow from ION's denial of the inventors' assignments to Geco-Prakla. ION's discussion of the merger documents, ION-Br. 34-35, and contention that 2001-dated documents did not confirm earlier assignments but were assignments for the first time to Schlumberger, *id.* at 33, both turn on that erroneous premise. And on their face, the documents ION cites actually acknowledge the prior assignments. JA12843; JA12846 (inventors "acknowledge [that they] *have sold*, assigned, transferred and conveyed" their U.S. patent rights to Schlumberger). In an apparent belt-and-suspenders approach, those documents add that the inventors "by this assignment, *do* sell, transfer, and convey." JA12846; JA12843. But the contrasting verb tenses do not compel a finding that those documents were new assign-

ments, as ION contends. ION-Br. 33. The district court's contrary finding was not clearly erroneous.[4]

Even if ION were correct that Schlumberger did not acquire rights in the Bittleston patents until 2001—and ION is not correct—WesternGeco still owns the Bittleston patents by operation of the 2000 technology transfer agreement. That agreement applied to all "Intellectual Property in existence on the effective date of this Agreement" regardless of whether Schlumberger owned it at the time. JA12854 (§2.01). The 1999 PCT Application was "in existence on the effective date," and thus transferred to WesternGeco automatically whenever Schlumberger acquired it—whether in 2000 or 2001.

C. ION Admitted Facts Establishing WesternGeco's Ownership of the Bittleston Patents

The district court also correctly held that ION's binding acknowledgements of the fact of WesternGeco's ownership of the Bittleston patents served to establish WesternGeco's standing.

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[4] At best, ION identifies an ambiguity that parol evidence would resolve. *See, e.g. Texas v. Am. Tobacco Co.*, 463 F.3d 399, 409 (5th Cir. 2006); *Coker v. Coker*, 650 S.W.2d 391, 394 (Tex. 1983). Patent Office filings and sworn testimony corroborate that the 2001 documents merely confirmed prior assignments.

At this case's inception in 2009, ION pled in its counterclaim that "the Bittleston Patents *were assigned to WesternGeco*." JA12912(¶107). And at the start of the trial in 2012, in a joint filing, ION and WesternGeco agreed to instruct the jury that "[t]he case involves patents obtained by Simon Bittleston … and *transferred by the inventors to WesternGeco*." JA10839 (filing); *see* JA1144 (instructions given). It was not until after the jury's verdict in WesternGeco's favor—years into this litigation—that ION purported to question WesternGeco's ownership. "[F]actual stipulations," however, "are formal concessions that have the effect of withdrawing a fact from issue and dispensing wholly with the need for proof of the fact." *Christian Legal Soc'y v. Martinez*, 561 U.S. 661, 677-78 (2010). ION's pleadings provided a sufficient independent basis to deny ION's standing motion.

While parties cannot confer jurisdiction by consent, it is long settled that "parties may admit the existence of *facts* which show jurisdiction, and the courts may act judicially upon such … admission[s]." *Ry. Co. v. Ramsey*, 89 U.S. (22 Wall.) 322, 327 (1874); *see Meyer v. Berkshire Life Ins. Co.*, 372 F.3d 261, 265 (4th Cir. 2004) (similar); *Ferguson v. Neighborhood Hous. Servs. of Cleveland, Inc.*, 780 F.2d 549, 550-51 (6th

Cir. 1986) (same); *Verzosa v. Merrill Lynch*, 589 F.2d 974, 977 (9th Cir. 1978). Factual assertions in pleadings are binding admissions. *Morales v. Dep't of Army*, 947 F.2d 766, 769 (5th Cir. 1991). It matters not that admitted facts may have jurisdictional significance. *Ramsey*, 89 U.S. at 327. ION admitted not the legal conclusion of "standing," but the underlying *fact* that the inventors transferred ownership to WesternGeco. JA12912(¶107); JA10839. *Ramsey* and its progeny reject ION's argument that its admissions are "tantamount to stipulation to jurisdiction." ION-Br. 28. In *Ferguson*, the Sixth Circuit rejected a similar argument as "overlook[ing] the distinction between an admission that federal subject matter jurisdiction exists, and an admission of facts serving in part to establish federal subject matter jurisdiction." 780 F.2d at 551.

ION argues that the jury charge simply summarized WesternGeco's allegations, and notes that its counterclaim was made with an "on information and belief" qualifier. ION-Br. 28-29. Neither point has merit. The relevant agreed-upon portion of jury instructions concerns undisputed background facts as context preceding the parties' respective allegations. JA1144:11-12 (transcript: "This case involves patents

obtained by [the inventors] and transferred by the inventors to WesternGeco." preceding WesternGeco's allegations); JA10839 (filing, same)

And this Court and others have specifically rejected the argument that the incantation "on information and belief" can negate the binding effect of what follows. *Lipton Indus., Inc. v. Ralston Purina Co.*, 670 F.2d 1024, 1030 (CCPA 1982); *Isquith v. Middle S. Utils., Inc.*, 847 F.2d 186, 194-95 (5th Cir. 1988). ION's answer is nearly identical to the answer in *Pandrol* that this Court found supported standing. *Compare* Answer and Counterclaims, *Pandrol USA, LP v. Airboss Ry. Prods., Inc.*, No. 99-1802, 1999 WL 33933998 (W.D. Mo. May 17, 1999) (denying in ¶1 that Pandrol was the assignee and admitting in ¶66 "on information and belief, [Pandrol] is in fact the owner thereof and/or has the right to control enforcement of the … patents"), *with* JA12898-99, 12912 (denying in ¶¶7-11 that WesternGeco was the assignee and admitting in ¶107 that "[o]n information and belief, the Bittleston Patents were assigned to WesternGeco").

Swift & Co. v. Hocking Valley Ry. Co., 243 U.S. 281 (1917), and *Owen Equip. & Erection Co. v. Kroger*, 437 U.S. 365 (1978), which ION cites, ION-Br. 28-30, are not to the contrary. Even as ION describes

Swift, the parties purported to stipulate *on appeal* to "*the legal effect* of admitted facts"—i.e., "on a subsidiary question of law." *Swift*, 243 U.S. at 289-90 (quoted ION's Br. 28). "Courts are 'not bound to accept, as controlling, stipulations as to questions of law.'" *Alexsam, Inc. v. IDT Corp.*, 715 F.3d 1336, 1346 n.9 (Fed. Cir. 2013). Here, however, ION stipulated to the *fact* of the inventors having assigned the patents to WesternGeco, which is binding, even if the admitted facts have jurisdictional significance. *Ramsey*, 89 U.S. at 327.

Owen did not even involve stipulated facts. Kroger's complaint alleged that Owen was "a Nebraska corporation with its principal place of business in Nebraska," and "Owen's answer admitted that it was 'a corporation organized and existing under the laws of the State of Nebraska,' *and denied every other allegation of the complaint*." 437 U.S. at 368-69. At trial, it was revealed that Owen's principal place of business was Iowa, which affected diversity jurisdiction because the plaintiff (Kroger) was an Iowa citizen. 437 U.S. at 369. Owen had never stipulated otherwise, however, and even if Owen had, *Owen* is inapposite because nothing at the trial here contradicted ION's admission that WesternGeco owned the Bittleston Patents. *Christian Legal Society*

makes clear that parties cannot escape prior factual stipulations on appeal. 561 U.S. at 667.

The district court's refusal to let ION retract its factual admissions after trial was thus not "an inference against ION," ION-Br. 30, but a recognition of the binding effect of factual stipulations. ION accepted and reaffirmed WesternGeco's ownership of the Bittleston patents for more than three years. It was not until after ION had a jury verdict against it that it tried to reverse its admissions in hopes of raising a new defense. ION's assertions that its delay has anything to do with purported "misinformation" by WesternGeco, ION-Br. at 30, is utterly baseless. ION's standing argument relies on the Bittleston patents' file histories, which are publicly available and which ION cited throughout this litigation for other purposes. The district court's factual findings were not clearly erroneous, and WesternGeco has standing.

II. ION's Infringement Under §271(f)(1) and §271(f)(2) Should be Affirmed

The district court properly construed §271(f)(1) to require intent to combine the supplied components, rather than intent to infringe.

If the Court affirms that interpretation of §271(f)(1), ION's remaining new-trial arguments necessarily fail. Other than its *Commil-*

based arguments, ION does not contend that it is entitled to a new trial if the district court correctly construed §271(f)(1). But even if this Court agrees with ION's interpretation of §271(f)*(1)*, there is no need for a new trial on §271(f)*(2)*. The jury was separately instructed on §271(f)(1) and §271(f)(2), rendered separate verdicts on each, and ION does not dispute that the jury was properly instructed on §271(f)(2). Indeed, the jury was instructed not to consider the court's finding of infringement of claim 18 under §271(f)(1) when assessing the infringement of other claims. JA11077n.1; JA6112:1-6; *see* JA11087-88 ("determine infringement … on a claim-by-claim basis"); *infra* §II.B.2.

ION's *Commil*-based argument fares no better. Unlike the defendant in *Commil*, ION was not prohibited from presenting evidence of its purported good-faith belief of invalidity of WesternGeco's patents. And in any event, the jury rejected ION's invalidity defense and found that ION's infringement was subjectively willful. ION makes no meaningful attempt to meet its burden to show that a *Commil*-based instruction would have changed the result of the trial. The district court's summary judgment ruling and the jury's verdict should be affirmed.

A. The District Court Correctly Construed §271(f)(1)

1. The Plain Language Of §271(f)(1) Requires Intent That Components Be Combined

The full text of 35 U.S.C. § 271 is in the addendum to this brief. Section 271(f)(1) provides as follows.

> **(f)(1)** Whoever without authority supplies or causes to be supplied in or from the United States all or a substantial portion of the components of a patented invention, where such components are uncombined in whole or in part, in such manner as to *actively induce the combination of such components* outside of the United States in a manner that would infringe the patent if such combination occurred within the United States, shall be liable as an infringer.

Statutory construction begins with the text of the statute, and if the words are unambiguous, "judicial inquiry is complete." *Conn. Nat'l Bank v. Germain*, 503 U.S. 249, 254 (1992).

Section 271(f)(1) recites a single mental state: the accused infringer must "actively induce *the combination* of such components." By the statute's plain terms, "the combination of such components" is what must be "actively induced" to incur liability. *See, e.g.*, *In re Sanders*, 551 F.3d 397, 399 (6th Cir. 2008) ("When a word … points back to an antecedent or some other referent, the true referent should generally be the closest appropriate word ...."); *Barnhart v. Thomas*, 540 U.S. 20, 26 (2003). The "combination of such components" immediately follows "to

actively induce," and it is thus the "combination of such components" that must be induced to incur liability. That the components must be assembled "outside of the United States in a manner that would infringe the patent if such combination occurred in the United States" does not require that the infringer be aware of the patent. Rather, that language ensures that the punishable conduct is limited to what would constitute infringement if done in the United States. ION's arguments would improperly import additional language into §271(f)(1)—*i.e.*, "in a manner that *it knows* would infringe the patent." But "the statute does not include [these] words," and they should therefore not be inserted. *Gooding v. United States*, 416 U.S. 430, 455 (1974).

ION argues that §271(b) and §271(f)(1) have the same intent requirement because "both recite the same inducement language." ION-Br. 38. Although both subsections recite the words "actively induce," they differ critically as to *what* must be actively induced. In contrast to §271(f)(1), §271(b) provides in full that "[w]hoever actively induces *infringement of a patent* shall be liable as an infringer." In *Global-Tech Appliances, Inc. v. SEB S.A.*, 131 S. Ct. 2060 (2011), the Supreme Court thus held that "actively induces *infringement of a patent*"—not "actively

induces"—"requires knowledge that the induced acts constitute patent infringement." *Id.* at 2065, 2068. *Global-Tech* thus does not support ION because §271(f)(1), as just explained, requires active inducement of "*the combination* of such components," not "infringement of a patent."

Nor do *Liquid Dynamics Corp. v. Vaughn Co.*, 449 F.3d 1209 (Fed. Cir. 2006), or *Limelight Networks, Inc. v. Akamai Techs., Inc.*, 134 S. Ct. 2111 (2014), support ION. In *Liquid Dynamics*, the parties did not dispute the meaning of §271(f)(1). This Court affirmed on the sufficiency of the evidence showing intent to cause infringement, and assumed, without deciding, that §271(f)(1) required such intent. 449 F.3d at 1222-23. Judicial opinions are not to be read like statutes, *St. Mary's Honor Ctr. v. Hicks*, 509 U.S. 502, 515 (1993), and precedent does not arise from unlitigated assumptions about facts or law. *Nat'l Cable Television Ass'n v. Am. Cinema Editors, Inc.*, 937 F.2d 1572, 1581 (Fed. Cir. 1991); *see Steel Co. v. Citizens for a Better Env't*, 523 U.S. 83, 91 (1998). *Limelight* is likewise unhelpful to ION and, if anything, supports the district court's ruling. *Limelight* remarked that §271(f)(1) "illustrates [that] when Congress wishes to impose liability for inducing activity *that does not itself constitute direct infringement*, it knows pre-

cisely how to do so." 134 S. Ct. at 2118. Here, Congress imposed liability for actively inducing "*the combination of such components*"—which, all agree, is not itself direct infringement. The district court correctly so held and correctly concluded that the "plain language … is unambiguous and can only be read one way." JA50.

2. The Drafting History of §271(f)(1) Confirms the Plain Language

This Court and the Supreme Court acknowledge that Congress enacted §271(f) in response to *Deepsouth Packaging Co. v. Laitram Corp.*, 406 U.S. 518 (1972). *See Microsoft Corp. v. AT&T*, 550 U.S. 437, 444 (2007) ("Congress specifically intended §271(f) as a response to the Supreme Court's decision in *Deepsouth*."); *Cardiac Pacemakers, Inc. v. St. Jude Med., Inc.*, 576 F.3d 1348, 1364 (Fed. Cir. 2009) (en banc in relevant part). In *Deepsouth*, Deepsouth conceded that Laitram's patents barred it from making and selling its shrimp deveining machine in the United States, but argued that it was not prohibited from making *parts* in the United States, and selling those parts to foreign buyers for assembly and use abroad. 406 U.S. at 522-24. The Supreme Court agreed and held that those acts were not infringement under 35 U.S.C. §271(a), as it was "not an infringement to make or use a patented prod-

uct outside of the United States," *id.* at 527, and "a patent on a combination is a patent on the assembled or functioning whole, not on the separate parts." *Id.* at 528. Reading the Patent Act to reach Deepsouth's conduct, the Court reasoned, would require "a clear congressional indication of intent." *Id.* at 532.

That clear indication came in 1984, when Congress amended 35 U.S.C. §271 to add section (f). As originally proposed, section (f) was a unitary section, and included the knowledge requirement that ION argues for here:

> Whoever without authority supplies or causes to be supplied in the United States the material components of a patented invention, where such components are uncombined in whole or in part, intending that such components will be combined outside of the United States, and *knowing that if such components were combined within the United States the combination would be an infringement of the patent*, shall be liable as an infringer.

H.R. 4526, 98th Cong. (1st Sess. 1983). That knowledge requirement, however, was ultimately deleted and not enacted. At a hearing, U.S. Patent Commissioner Gerald Mossinghoff "suggest[ed] deletion of" that knowledge requirement as unfair to patentees and inconsistent with general patent law principles:

> Under the patent laws today, a patent may be infringed without the infringer's knowing that he is doing so. It is *inconsistent and unfair*, therefore, to provide a remedy for overseas assembly of a patented device only if the exporter knows that such assembly will infringe the patent. *It is enough that the infringer intends for the components of the invention to be combined outside of the United States.*

A Bill to Amend Title 35, United States Code, to Increase the Effectiveness of the Patent Laws and for Other Purposes: Hearing on S. 1535 and S. 1841 Before the Subcomm. on Patents, Copyrights and Trademarks, 98th Cong., 26 (1984); *see id.* at 55–56, 151–52.

After Mossinghoff's testimony, proposed §271(f) was split into subsections (f)(1) and (f)(2), with the earlier draft's "knowledge" language deleted and with commentary endorsing Mossinghoff's views. S. Rep. 98-663, at 20, 30 (Oct. 5, 1984) ("The Administration is supportive of [the amendment], as evidenced by the testimony of … Mossinghoff … and the PTO's "participat[ion] in discussions with the Subcommittee following the hearing on S. 1535 that led to the new draft approved by the Subcommittee in July, 1984."). Section 271(f)(1) was ultimately enacted without the "knowledge" language, and thus struck a balance by stopping short of imposing strict liability on commercial shippers, but nonetheless closing the *Deepsouth* loophole that allowed U.S. com-

panies like Deepsouth and ION to avoid liability by shipping patented inventions abroad in unassembled pieces. The history of §271(f)'s enactment in response to *Deepsouth* confirms that the district court's plain reading of the text of §271(f)(1) is both correct and affirmatively intended by the Congress that enacted it.

B. Regardless of the District Court's Interpretation §271(f)(1), No Basis Exists for Overturning the Jury Verdict of Infringement Under §271(f)(2)

The jury was separately instructed on infringement under §271(f)(1) and §271(f)(2) and rendered separate verdicts on each. Even if this Court disagrees with the district court's reading of §271(f)(1)'s intent requirement, that is no basis for overturning the separate infringement verdict under §271(f)(2). ION's contrary arguments depend on revisionist history about the trial and on statements ION never objected to. ION can only seek a new trial based on jury instructions if "(1) it made a proper and timely objection to the jury instructions, (2) those instructions were legally erroneous, … (3) the errors had prejudicial effect, … and (4) it requested alternative instructions that would have remedied the error." *Bettcher Indus., Inc. v. Bunzl USA, Inc.*, 661 F.3d 629, 638-39 (Fed. Cir. 2011). ION cannot meet that burden.

1. ION Did Not Object to the Statements it Now Complains About

ION notes seven instances where WesternGeco truthfully informed the jury of the district court's summary judgment ruling. ION claims those statements were made "over ION's objections …." ION-Br. 41. The record, however, reflects that ION did not object to any of those statements. JA1072; JA1182; JA1211; JA2244; JA3962; JA4660; JA5491. Indeed, not only did ION not object, but it elicited testimony from its own witnesses that it had been found to infringe claim 18 under 35 U.S.C. §271(f)(1). JA4778-79; JA4806-07. ION cannot now complain on appeal about WesternGeco's statements. *See Johnson v. Michelin Tire Corp.*, 812 F.2d 200, 210 n.8 (5th Cir. 1987) (defendant waived objection by "asking [its own witness], on direct examination" about objected-to subject). More generally, even if there were any inaccuracy in the instances ION objects to, isolated statements during a four-week, 5000-transcript-page trial, do not rise to the level of having "continually referred to ION as an adjudged infringer." ION-Br. 44; *see United States v. Rice*, 607 F.3d 133, 140 (5th Cir. 2010) (improper comments "were minimal and harmless in the context of the entire trial. The

statements occupy only a few lines in a record that spans several thousand pages").

Further, while ION initially moved *in limine* to exclude "[a]ny mention of or reference to th[e] Court's Orders denying or granting motions for summary judgment," JA10653, ION changed course at the pretrial hearing, contending that "the [jury] *should* find out" about the summary judgment ruling "in an instruction from the Court and also that finding is limited to an (f)(1) finding." JA10791. The district court declined to give such an instruction before *voir dire*, as it does not "normally give a substantive opening instructions about patent law or anything else." JA10793-94. ION never voiced disagreement with that ruling and thus cannot challenge it now. *Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1325 (Fed. Cir. 2009).

2. The Jury Was Given the Instructions ION Requested, and WesternGeco Did Not Misstate the Court's Summary Judgment Order

ION misstates the district court's instructions and WesternGeco's statements at trial. ION argues that it requested an instruction that the jury "should not consider this [summary judgment] finding in deciding the question of infringement as to any other claim or when deciding

infringement under §271(f)(2)." ION-Br. 43. The jury was, in fact, so instructed: "though [the court has] already found that ION infringes Claim 18 of the '520 Patent under 35 U.S.C. §271(f)(1), you still must decide whether Claim 18 is infringed under 35 U.S.C. §271(f)(2)." JA11077n.1; JA6112:1-6.

Further ensuring that the jury considered each claim and each theory of infringement separately, the jury was separately instructed on infringement under §271(f)(1) and §271(f)(2), and instructed in each instance to "determine infringement … on a claim-by-claim basis." JA11087-88. The verdict form placed §271(f)(1) and §271(f)(2) on separate pages and had separate lines for each claim. JA71-72. And claim 18 was only in the instructions and verdict form for §271(f)(2). *Compare* JA11087 and JA71 *with* JA11088 and JA72. As the jury was given the substance of the instructions ION requested, ION cannot allege error on appeal. *See United States v. Smith*, 726 F.2d 183, 186 (5th Cir. 1984). ION baldly asserts that a "lay jury" would be confused about §§271(f)(1) and (f)(2) being different types of infringement. ION-Br. 42. But juries are presumed to follow their instructions, the instructions just described were particularly careful to separate the different claims and

theories, and ION does not point to anything to overcome that presumption here. *See Weeks v. Angelone,* 528 U.S. 225, 234 (2000).

To the extent ION suggests that the jury should not have been told about the court's summary judgment order at all, that argument is not available. ION and Fugro *agreed* that the jury should be informed about the court's summary judgment order, JA10791 (ION); JA3975:11-16 (Fugro), and the jury instructions and WesternGeco's counsel were both careful to describe that order's scope accurately. ION's repeated suggestion that the court's summary judgment order on §271(f)(1) somehow "infected" the jury's consideration of §271(f)(2), *e.g.*, ION-Br. 41, is inconsistent with the record and provides no basis for overturning the jury's verdict.

Contrary to ION's suggestion, Fugro—not ION—requested a curative instruction, JA3975:11-14, *which the court gave*:

> ***THE COURT:*** There has been a finding before trial started of infringement on one claim of one patent. … So I don't want any misapprehension as to the fact there are many claims that have not been found to have been infringed. And as to the claims, there will be an opportunity for you to decide whether they are valid or not. [WesternGeco's counsel] *hasn't said anything to the contrary*.

JA3976:3-12; *see* JA3982:1-7. Although the court agreed WesternGeco had properly informed the jury of ION's infringement, giving the very curative instruction requested negates any possible prejudice. *See United States v. DeGarmo*, 450 F.3d 360, 366 (8th Cir. 2006); *United States v. Maynard*, 236 F.3d 601, 607 (10th Cir. 2000).

Refusing to accept that the jury was given every instruction requested, ION misrepresents the record in *voir dire*, opening jury instructions, WesternGeco's closing, and the content of the jury instructions. ION points to a juror's question in *voir dire* asking "[i]f one of the patents has already been found to be infringed on, is this case about infringing a patent or is it about damages?", ION-Br. 41, and claims that that WesternGeco "answered the jury's question, arguing the case was really only about damages." *Id.* Rather than citing WesternGeco's answer to the juror's question, however, ION cites WesternGeco's opening statement (to which ION did not object, and which the jury was instructed was not evidence). ION's Br. 41 (citing JA1182); JA1147:1-4. WesternGeco's actual response to the juror's question was "It will be about all of those things because, first of all, we have other claims that we say have been infringed and multiple claims[;] … the de-

fendants say our patents aren't valid, … [a]nd then there is the damages issue." JA1080.

In addition, ION's suggestion that the court referred to ION as an infringer without qualification in the opening instructions, ION-Br. 43, is simply wrong. The court specifically stated that it had "already made a finding of infringement *as to Claim 18 of the '520 patent.*" JA1145:6-8.

Next, ION claims WesternGeco told the jury "that the mental state required for 271(f)(2) had already been found by the court," relying on two portions of WesternGeco's closing arguments. ION-Br. 42. The record shows, however, that WesternGeco's statements were accurate. In the first portion of closing argument ION relies on, WesternGeco accurately informed the jury that §271(f)(2) requires greater proof of intent than (f)(1). JA6196 ("The last prong of (f)(2) is another difference. 271(f)(1) does not require you to intend to infringe."); JA6197 ("With (f)(1), you just have to send a substantial portion of the components … (f)(2) has intent."). The other portion relates to WesternGeco's *willfulness* claim, not infringement under §271(f)(2), and accurately reflected the fact that ION was, in fact, found to infringe before trial. JA6201 ("Did ION have some reasonable basis—this is another fact for willful-

ness—to believe it didn't infringe? No. The Court has already found before we even got here that they infringed *one claim* of the patent."). Moreover, ION did not object to either statement, and the jury was instructed that those statements were not evidence. JA1148:23-1149:3; *see InTouch Techs. Inc. v. VGO Commc'ns, Inc.*, 751 F.3d 1327, 1355 n.9 (Fed. Cir. 2014).

As to the jury instructions, ION crop-quotes the instruction under §271(f)(1) to suggest the finding of infringement under 35 U.S.C. §271(f)(1) necessarily affected infringement under §271(f)(2). ION-Br. 43. The full instruction does not bear that reading. The court accurately informed the jury of the limited aspect of its summary judgment ruling that bore on infringement of other claims under 35 U.S.C. §271(f)(1):

> You must accept my finding on infringement *as it relates to Claim 18 of the '520 Patent* under 35 U.S.C. §271(f)(1). Specifically, I have already determined that ION has supplied or caused to be supplied from the United States a substantial portion of the components—which I found to be the DigiFIN and the Lateral Controller—of the patented invention of *Claim 18 of the '520 Patent*. I also have already found that ION intended those components to be combined outside of the United States in a manner that would infringe the patent if the combining had been done in the United States.
>
> In evaluating whether ION infringes the other asserted claims, you must accept my finding that ION intended the

> DigiFIN and the Lateral Controller to be combined outside of the United States.

JA11087. The reference to "whether ION infringes the other asserted claims" plainly to refers to infringement of claims other than claim 18 under §271(f)(1). And even if that reference were ambiguous, ION does not dispute that it intended the DigiFIN and the Lateral Controller to be combined. Regardless of whether ION is right about the intent requirement of §271(f)(1), the district court was correct to hold on summary judgment that ION intended for the components to be combined, and ION has no evidence or basis for suggesting otherwise.

3. The Trial Record Independently Established ION's Infringement Under §271(f)(2)

In addition to ION's failure to demonstrate error, ION fails to demonstrate prejudice. The record amply supports the jury's verdict that ION infringes under 35 U.S.C. §271(f)(2). ION does not dispute that the jury was properly instructed on infringement under §271(f)(2), nor that ION intended DigiFIN and the Lateral Controller to be combined. And the record was replete with evidence that ION was well-aware DigiFIN infringed. For example, as noted, *Statement of Case* §I.B, *supra*, ION knew about the patents, and ION's customers told ION, in detail, how and why that they believed using DigiFIN infringed

WesternGeco's patents. JA7072-73; JA7338; JA2099:16-2100:9. ION provided watered-down indemnity to many of its customers for the use of DigiFIN. JA7100; JA2992:21-2993:9; JA3032:6-15; JA3972:12-3975:6; JA3976:16-3978:6. When ION finally did provide Fugro with indemnity, ION walked back on its promise mid-trial and said it was not providing indemnity to Fugro for its use of DigiFIN. JA7082-83; JA2942:9-15; JA3971:19-23; JA4050:14-21. Based on that evidence, any "error" in the district court's determination of infringement of claim 18 of the '520 patent under §271(f)(1) was necessarily harmless to the jury's determination of infringement under 35 U.S.C. §271(f)(2). *See SynQor, Inc. v. Artesyn Techs., Inc.*, 709 F.3d 1365, 1379-80 (Fed. Cir. 2013).

ION relies on *Vidrine v. Kan. City S. Ry. Co.*, 466 F.2d 1217 (5th Cir. 1972), and *Gasoline Prods. Co. v. Champlin Refining Co.*, 283 U.S. 494 (1931), to argue that the jury viewed §271(f)(1) and §271(f)(2) as inseparable. ION-Br. 42. Both cases are inapposite. In each, liability and damages were remanded because additional findings on liability were needed to determine damages. *Gasoline Prods.*, 283 U.S. at 499-500; *Vidrine*, 466 F.3d at 1226. Infringement under one section is not

necessary to the other in the same way that damages cannot issue without a predicate finding of liability. The jury was instructed separately on §271(f)(1) and §271(f)(2), and asked to issue separate answers on the verdict form. Although there was some overlap in the evidence supporting the two infringement theories, the jury was properly permitted to find infringement of each claim under each theory, both, or neither, and there is thus no Seventh Amendment issue of the type noted in *Gasoline Products* and *Vidrine*. *See Commil USA, LLC v. Cisco Sys., Inc.*, 720 F.3d 1361, 1371 (Fed. Cir. 2013).

C. *Commil* Does Not Require A New Trial

In *Commil*, this Court reviewed a judgment of induced infringement under §271(b), and concluded: (1) that the jury instructions erroneously allowed a verdict based on negligence rather than knowledge, *id.* at 1366-67, and (2) that the district court erroneously granted a motion *in limine* to prevent Cisco from presenting evidence of its good-faith belief in the invalidity of the patent-in-suit. *Id.* at 1367-69.

Neither error occurred here. *Commil* has no bearing on this case and ION misstates its holding. More generally, the Court need not reach ION's *Commil* argument because ION did not present it to the

district court, though *Commil* issued eleven months before entry of final judgment. The Court has discretion to address unpreserved arguments only where the proponent demonstrates "error [that] is plain, affects substantial rights, and seriously affects the fairness, integrity, or public reputation of judicial proceedings." *Jimenez v. Wood Cnty.*, 660 F.3d 841, 845 (5th Cir. 2011). The party seeking reversal must show "that the instructions made an obviously incorrect statement of law that was probably responsible for an incorrect verdict, leading to substantial injustice." *Positive Black Talk Inc. v. Cash Money Records, Inc.*, 394 F.3d 357, 369 (5th Cir. 2004), *abrogated on other grounds*, *Reed Elsevier, Inc. v. Muchnick*, 559 U.S. 154 (2010). There is no error in any event, and ION certainly cannot meet that "demanding standard." *Jimenez*, 660 F.3d at 845.

1. *Commil* Is Inapplicable To §271(f)(2)

As noted, the jury's instructions and verdict separated infringement under 35 U.S.C. §271(f)(1) and (f)(2). *Commil* concerned induced infringement under §271(b). *Commil* did not address §271(f) at all, but even assuming ION's incorrect analogy between §271(b) and §271(f)(1)—which both refer to "active induce[ment]," though of differ-

ent acts—*Commil* has no bearing on §271(f)(2). Subsection (f)(2) is more analogous to contributory infringement under §271(c), which was not before the court in *Commil*. Even the jury instructions ION cites that include *Commil*-based language for induced infringement do not include any similar language for contributory infringement. JA12505-06; JA13593-95. Thus, even accepting ION's arguments that *Commil* changed the law (and it did not), it certainly did not change the law with respect to §271(f)(2). *Commil* has no bearing at all on that aspect of the jury's verdict, and certainly does not render that aspect of the instructions an "obviously incorrect statement of law that was probably responsible for an incorrect verdict, leading to substantial injustice." *Positive*, 394 F.3d at 369.

2. *Commil* Does Not Require Proof of No Good Faith Belief In Invalidity, Nor Would a *Commil*-Based Instruction Have Affected the Outcome

ION asserts that *Commil* "necessitates proof that ION had no good faith belief in the invalidity of the asserted patents." ION-Br. 45. That is not *Commil*'s holding—*Commil* itself expressly disavowed that reading. 720 F.3d at 1368 n.1 ("*[W]e certainly do not hold* that if the inducer of infringement believes in good faith that the patent is invalid,

there can be no liability for induced infringement … [n]or do we include a belief in patent validity as a criterion of infringement.").

Rather, *Commil* held that the district court erred in categorically excluding Cisco's evidence of good-faith belief in invalidity, *id.* at 1367-69, as such evidence "may negate the requisite intent for induced infringement." *Id.* at 1368. ION points to no similar order here, nor does ION contend that it was prevented from presenting any evidence or arguments that *Commil* allows. ION was permitted to—and did—present whatever evidence of good faith and invalidity it had, and the jury rejected it. The jury found ION subjectively willful, found ION's invalidity defenses lacking in merit, and found that WesternGeco met its burden of proof of infringement. JA71-77.

ION claims that the absence of a *Commil*-based instruction was "plain error that affected ION's substantial rights, and seriously affected the trial's fairness." ION-Br. 47. ION never explains how the presence of such an instruction would have changed the outcome. Even accepting ION's representation that it "presented reasonable, objectively supported invalidity defenses," ION-Br. 46, the jury assessed that evidence and did not credit it. Moreover, ION presented no evidence that

any of its officers or employees subjectively believed in 2007-2012 in any of ION's later trial defenses. Here, the jury found that ION's infringement was subjectively willful and thus necessarily rejected ION's contention that it had a good faith belief in invalidity. JA77; *see* JA11096 (instructing jury to consider "[w]hether or not … the infringer … had a reasonable defense to infringement"). Indeed, the jury found by *clear and convincing evidence*—a higher burden than is required for infringement—that ION did *not* have a good-faith basis for believing it was not liable for infringement. Two ION witnesses testified that they did not believe ION was "infringing any valid claims," but did not state any basis for their beliefs, JA3954:21-3955:2; JA5164:17-25, and the jury was not required to credit their testimony. ION cannot seriously contend that a *Commil*-based instruction would have changed the outcome of the trial.

III. The Jury's Lost Profits Award Should Be Affirmed

ION infringed WesternGeco's patents under §§271(f)(1) and (f)(2). WesternGeco is thus entitled to damages "adequate to compensate for the infringement." 35 U.S.C. §284. ION argues that lost profits were improper because of (1) the difference between its and WesternGeco's

business models, and (2) this Court's decision in *Power Integrations, Inc. v. Fairchild Semiconductors Int'l, Inc.*, 711 F.3d 1348 (Fed. Cir. 2013). Both arguments are unsound. The evidence established that WesternGeco's Q-Marine and ION's DigiFIN compete directly and that the introduction of ION's DigiFIN caused WesternGeco to lose profits. *Power Integrations* merely holds—in an essentially straightforward application of *Deepsouth*—that §§271(a) and (b) do not reach wholly foreign conduct, regardless of whether that conduct is "foreseeable." *Power Integrations* does not address §271(f) at all and certainly does not "directly refute the ***same*** … causation theory [WesternGeco] relied upon." ION-Br. 47 (original emphasis). Every DigiFIN that caused lost profits in this case was manufactured in and supplied from the United States.

A. ION's DigiFIN Competes With WesternGeco's Q-Marine

On appeal, "[a] jury's damages award … must be upheld unless the amount is grossly excessive or monstrous, clearly not supported by the evidence, or based only on speculation or guesswork." *Monsanto Co. v. Ralph*, 382 F.3d 1374, 1383 (Fed. Cir. 2004). The Court should affirm the jury's decision unless "the facts and inferences point so strongly and overwhelmingly in favor of one party that the Court believes that rea-

sonable [jurors] could not arrive at a contrary verdict." *Wallace v. Methodist Hosp. Sys.*, 271 F.3d 212, 218-19 (5th Cir. 2001).

The jury instructions on lost profits stated that "[t]he burden is on WesternGeco to show that *its product competed in the same market with ION's product* and that it would have made the alleged lost sales if the infringement had not occurred." JA6139. ION agrees that the jury was properly instructed, ION-Br. 57 n.18, which should end the inquiry. It was undisputed at trial that ION's infringing DigiFIN system competed with WesternGeco's Q-Marine in the same market. ION developed DigiFIN with that specific intention. JA4474:4-8; JA7006 ("The DigiFIN opens the door … to compete in the market space that WesternGeco has created."); JA8052 ("[a]nswer to" Q-Marine). The evidence further established that the launch of DigiFIN caused WesternGeco to lose survey jobs where lateral steering was required. JA1328:11-19; JA1314:22-1315:17; JA2695:17-19; JA3302:11-23; JA7339; JA7322.

ION used "competition" as a theme of its opening statement, and its witnesses admitted that its customers use DigiFIN to compete with Q-Marine for jobs that required lateral steering. JA3228:11-3229:8.

> Q And in your business plan, you indicated that by introducing DigiFIN, your customers -- that's the Fugros of the

> world, right -- would be able to compete in that proprietary Q-Marine systems market space, correct?
> A Yes. We were trying to create competition.
> Q In the proprietary market space WesternGeco had developed?
> A In the market space.

JA4015:11-4016:5; *see* JA3791:11-23 ("There is a market for marine seismic surveys using laterally steerable streamers in the U.S. because …WesternGeco, ION Geophysical … sell products or services to supply that market. In addition, there is a submarket for 4D surveys … ION Geophysical sells devices that and services that compete in these markets."). Indeed, ION told the SEC that "Q-Technology ... *competes directly* with ION's technology for marine streamer, seabed, and land acquisition." JA7135.

Despite the absence of any dispute that the products compete directly, ION asserts that "[n]o reasonable jury could have found that *Panduit* was satisfied, since *the parties* were not competing in the marketplace." ION-Br. 57-58. Essentially, ION argues, because WesternGeco is vertically integrated and performs surveys on its own, while ION sells its system to survey companies to compete with WesternGeco, lost profits are categorically unavailable to WesternGeco. ION misstates the law. The fundamental inquiry for lost profits—and damages

generally—is causation, not the patentee's and infringer's respective business models. *Panduit Corp. v. Stahlin Bros. Fibre Works, Inc.*, 575 F.2d 1152, 1156 (6th Cir. 1978) (Markey, C.J., by designation) (quoting *Yale Lock Mfg. Co. v. Sargent*, 117 U.S. 536, 552 (1886)) (in determining damages one asks "how much had the Patent Holder and Licensee suffered by the infringement. And that question (is) primarily: had the Infringer not infringed, what would Patent Holder-Licensee have made?"); *id.* (compensation determined "*without regard* to the question whether the defendant has gained or lost by his unlawful acts"); *King Instruments Corp. v. Perego*, 65 F.3d 941, 948 (Fed. Cir. 1995) (same).

Thus, this Court has affirmed awards of lost profits where the infringer's *product* competes with the patentee's, *see, e.g.*, *Presidio Components, Inc. v. Am. Tech. Ceramics Corp.*, 702 F.3d 1351, 1360 (Fed. Cir. 2012) ("the two *products* compete[d] 'head-to-head' in the … market for the same customers and for the same applications."), and conversely has found error where such a comparison was not made. *See, e.g.*, *Comair Rotron, Inc. v. Nippon Densan Corp.*, 49 F.3d 1535, 1540 (Fed. Cir. 1995) ("[B]efore applying the *Panduit* test, a court must determine whether the *accused device* competes with the patentee's *product* in the

marketplace."); *Mahurkar v. C.R. Bard, Inc.*, 79 F.3d 1572, 1581 (Fed. Cir. 1996) ("To apply the *Panduit* test, the trial court would have needed to ascertain whether [the patentee's] and [infringer's] *products* competed for the same customers …."). The question is whether the *products*, not the *parties*, compete. ION cites no case supporting its contrary argument. There is no dispute that WesternGeco's Q-Marine competes with ION's infringing DigiFIN, and the jury's lost profits award was amply supported.

B. Neither *Power Integrations* Nor §271(f) Forecloses Lost Profits in this Context

35 U.S.C. §284 entitles a prevailing claimant to "damages adequate to compensate for the infringement, but in no event less than a reasonable royalty for the use made of the invention by the infringer." Section 284 ensures that a "patent owner would in fact receive full compensation for 'any damages' he suffered as a result of the infringement." *Gen. Motors Corp. v. Devex Corp.*, 461 U.S. 648, 654-55 (1983). "Full compensation *includes any foreseeable lost profits the patent owner can prove*." *Grain Processing Corp. v. Am. Maize-Prods. Co.*, 185 F.3d 1341, 1349 (Fed. Cir. 1999); *Rite-Hite Corp. v. Kelley Co., Inc.*, 56 F.3d 1538, 1546-47 (Fed. Cir. 1995) (en banc).

Nothing in the Patent Act indicates that the foregoing principles apply with any reduced force to infringement under §271(f). Section 284 refers to "the infringement," without regard for which subsection of §271 the infringement arises under. If more clarity is needed, both sub-sections of §271(f) conclude with the provision that "whoever" performs the enumerated acts "shall be liable as an infringer." "When Congress wished to limit an element of recovery in a patent infringement action, it said so explicitly." *Gen. Motors*, 461 U.S. at 653.

Nor did the Court retreat from the foregoing principles in *Power Integrations*. There, the plaintiff asserted infringement under 35 U.S.C. §§271(a)-(b). *See* 589 F. Supp. 2d 505, 511-12 (D. Del. 2008); 585 F. Supp. 2d 562, 564 (D. Del. 2008. The district court remitted a portion of the jury's damages award because that portion was not "rooted" in *any* actual infringing activity:

> the amount of damages … adopted by the jury is not actually rooted in Fairchild's infringing activity in the United States …. [and] was *not* related to parts that were manufactured, used, or sold in the United States by Fairchild, and was *not* based on parts that were imported into the United States by Fairchild or anyone else."

Power, 589 F. Supp. 2d at 511. On appeal, Power Integration argued that "principles of 'full compensation' extend to cover [defendant's]

worldwide sales" that had no ties to the United States. *Power Integrations*, 711 F.3d at 1371. This Court affirmed, explaining that Power Integrations was not "entitled to compensatory damages caused by infringing activity that occurred outside … the United States," and that "[t]he entirely extraterritorial production, use, or sale of an invention patented in the United States is an independent intervening act that, under almost all circumstances, cuts off the chain of causation initiated by an act of domestic infringement." *Id.* at 1372. *Power Integrations* did not and could not overrule the principle that "[f]ull compensation includes any foreseeable lost profits the patent owner can prove." *Grain Processing*, 185 F.3d at 1349; *see Rite-Hite*, 56 F.3d at 1546-47. *Power Integrations* merely affirmed the denial of damages for activity that was not rooted in actual infringing conduct under §§271(a)-(b), the only provisions at issue in that case. *Cf. Merial Ltd. v. Cipla Ltd.*, 681 F.3d 1283, 1302-03 (Fed. Cir. 2012) (rejecting the "overbroad contention that acts outside of the United States cannot violate any provision of §271.").

Here, however, the jury's lost profits award is plainly rooted in ION's infringing activity under §271(f). There is no dispute that *every* DigiFIN supplied by ION was supplied from the United States.

JA3789:6-25. Unlike Power Integrations' claims of infringement under 35 U.S.C. §§271(a)-(b), there is no "cut off" in the causal chain. Not only were WesternGeco's lost profits foreseeable as a result of ION's infringement, they were the precise result ION intended when it developed and launched DigiFIN. JA7000, JA7006. WesternGeco's lost profits claim is tied directly to ION's infringement under §271(f)—which, the evidence showed and the jury found, directly caused WesternGeco to lose profits.

ION's resort to the presumption against extraterritoriality and citation of *Deepsouth* are puzzling given that §271(f) was enacted to overrule *Deepsouth*. To be sure, this Court and the Supreme Court have carefully enforced limits on the scope of §271(f). *See Microsoft*, 550 U.S. at 457 ("inapplicable to the export of design tools"); *Cardiac Pacemakers*, 576 F.3d at 1359 ("does not cover method claims"). But neither *Power Integrations* nor any other case grafts on the additional limits on damages that ION seeks here. ION argues that "[i]f purely extraterritorial acts gave rise to U.S. liability, U.S. patents would effectively become worldwide patents." ION-Br. 50. But ION's acts were *not* purely extraterritorial—every DigiFIN was manufactured in and supplied from

the United States—and that is why it was found liable under §271(f). ION raises the specter of liability for every "exporter of a non-infringing component with no intent to induce infringement or circumvent a patent." *Id.* Not so. FedEx, UPS, or the USPS would not have the intent to combine components that §§271(f)(1) and (f)(2) require. ION, however, *did* have that intent, as the jury found. The judgment properly holds ION accountable under generally applicable principles of patent damages.

Also unavailing is ION's attempt to explain away cases where this Court and others have affirmed awards of lost profits under §271(f). ION attempts to distinguish *Williamson, Inc. v. Laymon*, 723 F. Supp. 587 (N.D. Okla. 1989), *aff'd* 923 F.2d 871 (Fed. Cir. 1990), on the ground that "defendants would ship the components to the foreign jobsite for their own use." ION-Br. 54. That is what the defendant argued in *Williamson* to avoid liability under §271(f). The district court rejected that argument, *id.* at 592, and determined that "the denial of lost profits to TDW from defendants' 1986 Venezuelan job [wa]s clearly erroneous" for the simple fact that defendants infringed under §271(f). *Id.* at 593. Here, the jury was properly instructed, and substantial evidence sup-

ports its award of lost profits. No principle of law requires a different result.

CONDITIONAL CROSS-APPEAL

As shown above, the judgment should be affirmed in full. If, however, the Court reverses in part, or orders a remand on the basis of any of ION's arguments, WesternGeco conditionally cross-appeals the district court's exclusion of WesternGeco's initial royalty calculation and its ruling that ION's infringement was not objectively willful. *See, e.g.*, *Bluebonnet Sav. Bank, F.S.B. v. United States*, 466 F.3d 1349, 1365 (Fed. Cir. 2006) ("Because the plaintiffs' cross-appeal is conditional on our rejection of the trial court's damages award, we do not address the cross-appeal. AFFIRMED."); *Shum v. Intel Corp.*, 633 F.3d 1067, 1071 n.2 (Fed. Cir. 2010) (similar); *Vita-Mix Corp. v. Basic Holding, Inc.*, 581 F.3d 1317, 1331 (Fed. Cir. 2009) ("Because the issue of direct infringement … is remanded…, we reach the conditional cross-appeal.").

IV. WesternGeco's Original Reasonable Royalty Calculation Was Improperly Excluded

Exclusion of expert evidence is reviewed for an abuse of discretion. *Gen. Elec. Co. v. Joiner*, 522 U.S. 136, 143 (1997). However, an error of law is by definition an abuse of discretion. *Bocanegra v. Vicmar Servs.,*

Inc., 320 F.3d 581, 584 (5th Cir. 2003). If there is an abuse of discretion, the Court must determine whether the error "affected substantial rights of the complaining party." *Id.*

The district court excluded WesternGeco's expert Sims' initial royalty calculation on the ground that it exceeded ION's profits from its DigiFIN sales and was thus unreasonable "*as a matter of law*":

> the Court cannot assume … that ION, in a hypothetical negotiation with WG, would have taken a risk on the infringement question and agreed to a huge, profit-eliminating (and even revenue eliminating) royalty obligation for itself. *As a matter of law*, no such risk can be taken in a hypothetical negotiation in which infringement is deemed known.

JA62. That ruling was erroneous. There is no *per se* rule that a patentee's entitlement to a reasonable royalty measure of damages is capped at the amount of the infringer's profits. As a result of the district court's ruling, WesternGeco was unable to request adequate compensation for ION's infringement from the jury or from the court after trial.

A. ION's Profits Are Not A Cap On WesternGeco's Entitlement to Reasonable Royalty Damages

This Court's precedent has consistently rejected the notion that the royalty measure of damages must be less than, or even based on, an infringer's profit. Such an artificial cap on damages, imposed "as a

matter of law," and divorced from the facts of the case, is legal error, and this Court has repeatedly so held. *See Snellman v. Ricoh Co.*, 862 F.2d 283, 289-90 (Fed. Cir. 1988) (vacating district court's order that reduced jury verdict for exceeding infringer's sales); *Mars, Inc. v. Coin Acceptors, Inc.*, 527 F.3d 1359, 1374 (Fed. Cir. 2008) ("[W]e reject [defendant's] argument that a reasonable royalty can never result in an infringer operating at a loss."), *modified on other grounds*, 577 F.3d 1377 (Fed. Cir. 2009); *State Indus., Inc. v. Mor–Flo Indus., Inc.,* 883 F.2d 1573, 1580 (Fed. Cir. 1989) ("There is no rule that a royalty be no higher than the infringer's net profit margin."). Indeed, the Court has explained that the reasonable royalty determination "is based not on the infringer's profit, but on the royalty to which a willing licensor and a willing licensee would have agreed at the time the infringement began." *Radio Steel & Mfg. Co. v. MTD Prods., Inc.*, 788 F.2d 1554, 1557 (Fed. Cir. 1986). Although an infringer's potential profit from the patented invention is "[a]mong the factors to be considered," "*the law does not require that an infringer be permitted to make a profit*." *Monsanto*, 382 F.3d at 1384.

In *Monsanto* in particular, the Court rejected the argument that "no sane farmer would ever negotiate a royalty in excess of his anticipated profits." *Id.* While the farmer's profit was relevant, also relevant was the fact that the "patentee [wa]s unwilling to grant an unlimited license [and] the hypothetical negotiation process has its limits." *Id.* Likewise here, WesternGeco exercised its right to exclude and never licensed its technology. JA2739:6-19. WesternGeco earned revenues from its patented technology based on marine seismic surveys it conducted with that technology. For the right to practice its proprietary technology, WesternGeco would have to be compensated for the revenues it lost as a result of that license, which reflects the harm from ION's infringement. To disregard those facts in favor of a rule that caps WesternGeco's damages at ION's profits is legal error.

B. WesternGeco Reasonably Used Survey Revenues As a Royalty Base

WesternGeco's royalty analysis was rooted in the facts of the case, and WesternGeco should have been permitted to present that analysis to the jury. ION presented no evidence that Sims' proposed royalty was not reasonable, other than its conclusory assertion that it would not have agreed ex ante to a profit-eliminating royalty. What ION "might

have preferred to pay," however, "is not the test for damages." *Golight, Inc. v. Wal-Mart Stores, Inc.*, 355 F.3d 1327, 1338 (Fed. Cir. 2004). Nor is it any answer to say that ION's profit from its infringement was less than the revenue WesternGeco lost by that infringement. The damages inquiry is "how much had the Patent Holder … suffered by the infringement," determined "*without regard* to the question whether the defendant has gained or lost by his unlawful acts." *Panduit*, 575 F.2d at 1156.

Nor is it any answer to say that ION's customers, rather than ION, capture much of the profits from ION's infringement. This Court has explained that it is typically sufficient to sue the manufacturing infringer, and patentees are not required to sue every downstream entity:

> A patentee who suffers lost profits or loss of royalty income ordinarily can be compensated and made whole ***by the manufacturing infringer.*** … [T]he length of the accused manufacturer's distribution chain should have no impact on the patentee's ability to be made whole by the manufacturer.

Glenayre Elec., Inc. v. Jackson, 443 F.3d 851, 859, 872 (Fed. Cir. 2006) (a patentee may "receive[] full compensation from a manufacturer for the infringing activities of the manufacturer and its customers."). "[P]arties that make and sell an infringing device are joint tort-

feasors with parties that purchase an infringing device for use or resale. Each joint tort-feasor is liable for the full amount of damages (up to a full single recovery) suffered by the patentee." *Shockley v. Arcan, Inc.*, 248 F.3d 1349, 1364 (Fed. Cir. 2001). That principle applies equally here—just as ION infringes under §271(f) by supplying components, its customers infringe under §271(f) by *causing* components to be supplied by ION.

Accordingly, WesternGeco may recover damages against a manufacturer (ION) for its customers' (seismic surveyors) unlicensed use of the invention. *See Siemens Med. Solutions USA, Inc. v. Saint-Gobain Ceramics & Plastics, Inc.*, 637 F.3d 1269, 1277, 1291 (Fed. Cir. 2011) (affirming award of $45 million in lost profits based on customer's sales against defendant component manufacturer who sold less than $10 million in components); *Glenayre*, 443 F.3d at 858-859 ("[D]amages assessed for indirect infringement normally will be the same as damages that would be assessed had the patentee sued and obtained a judgment against the customers.").

WesternGeco's initial royalty analysis was reasonable under the facts of this case, and it was legal error to keep that analysis from the

jury simply because it produced a number higher than ION's profits. In the event the Court reverses the award of lost profits, or otherwise remands this case, the district court's pretrial order excluding WesternGeco's initial analysis should be reversed, and WesternGeco should be permitted to seek damages consistent with that analysis. The district court's post-trial order setting WesternGeco's supplemental damages, in turn, should also be vacated, as the court based that order on a desire for consistency with its pretrial ruling, "with the damages methodology presented at trial," and with the jury's reasonable royalty determination, which followed from that pretrial ruling. JA94.

V. ION's Infringement Was Objectively Willful

A. The District Court Applied Wrong Standard In Finding No Objective Willfulness

35 U.S.C. §284 permits courts to "increase the damages up to three times the amount found or assessed." An award of enhanced damages under that statute "requires a showing of willful infringement." *In re Seagate Tech., LLC*, 497 F.3d 1360, 1368 (Fed. Cir. 2007) (en banc). Willful infringement has objective and subjective prongs. *Bard Peripheral Vascular, Inc. v. W.L. Gore & Assoc., Inc.*, 682 F.3d 1005, 1007 (Fed. Cir. 2012).

The objective prong is a question of law, reviewed *de novo* on appeal. *Id.* at 1007-08. Instead of assessing whether ION's defenses were or were not "reasonable," *id.,* the district court applied a stricter "no reasonable litigant" standard, reasoning that "WesternGeco has the burden to show that *no reasonable litigant* could realistically expect success on the merits" to succeed on the objective prong. *See* JA24-25.

That was incorrect. The district court's heightened standard appears to come from a misreading of this Court's cases that is no longer plausible after *Octane Fitness LLC v. ICON Health & Fitness, Inc.*, 134 S. Ct. 1749 (2014).

Bard, which the district court cited, drew a comparison with *Professional Real Estate Investors, Inc. v. Columbia Pictures Industries, Inc.*, 508 U.S. 49 (1993) ("*PRE*"), which holds that the sham exception to *Noerr-Pennington* immunity from antitrust liability (the "no reasonable litigant" standard) is a question of law. But *Bard* did not take the further step of holding that the "no reasonable litigant" standard from a narrow issue of antitrust law *is* the standard for objective willfulness under patent law.

Octane rejects that leap of logic in the context of 35 U.S.C. §285, explaining that the "[no reasonable litigant] formulation is overly rigid" and "so demanding that it would appear to render §285 largely superfluous." 134 S. Ct. at 1756, 1758 (rejecting *PRE*-based argument). Further, applying the *PRE* standard to §285 would make "little sense" because (a) that standard found "no roots in the text of §285" and (b) "[i]n the *Noerr–Pennington* context"—the context of *PRE*—"defendants seek immunity from a judicial declaration that their filing of a lawsuit was actually unlawful; [whereas in patent cases], they seek immunity from a far less onerous declaration that they should bear the costs of that lawsuit in exceptional cases." *Id.* at 1757-58. For those same reasons, *PRE*'s "no reasonable litigant" also makes "little sense" in the context of §284. *Compare* 35 U.S.C. §284 ("the court *may* increase the damages"), *with* §285 ("The court … *may* award reasonable attorney fees"). It was therefore error for the district court to apply the *PRE* standard in assessing the objective willfulness of ION's infringement.

B. ION's Infringement of WesternGeco's Patents Was Objectively Willful

Under any standard, the evidence of ION's willfulness was overwhelming. ION was fully aware of WesternGeco's patents and faced an objectively high risk of infringement liability.

First, all of ION's defenses failed, and ION does not appeal any of them. As described above, most of ION's defenses failed *as a matter of law* such that the district court rejected them either before trial or before the case was submitted to the jury. *See Statement of Case* §II.B.1-2, *supra*. The few defenses ION took to trial were objectively unreasonable and properly rejected by the jury. ION's enablement defense, for example, improperly focused on unclaimed features, was directly contradicted by ION's technical expert who testified that the claims *were* enabled, JA4938:13-4939:16, and was unsupported by ION's actual enablement expert, who applied the wrong claim construction and ignored the patents-in-suit's specifications. *See supra* at 23. ION's anticipation and obviousness arguments relied on art already considered by the Patent Office. JA4945:21-25; JA4973:23-4975:16; JA478.

Second, ION's own customers thought DigiFIN infringed, to the point of identifying specific patent claims and repeatedly demanding

indemnities or similar assurances. *See Statement of Case*, §I.B, *supra*. These independent conclusions that ION likely infringed reflect the unreasonableness of ION's defenses. *See SRI Int'l Inc. v. Adv. Tech. Labs., Inc.*, 127 F.3d 1462, 1465 (Fed. Cir. 1997) (affirming willful infringement where "two in-house engineers expressed their concerns … stating, … "I believe that we probably are infringing on [the plaintiff's] Patent …."); *Jurgens v. McKasy*, 927 F.2d 1552, 1562 (Fed. Cir. 1991) (affirming increased damages where the infringer continued to sell accused products after obtaining an indemnity agreement); *SynQor*, 709 F.3d at 1385 (same).

Third, ION was reluctant to give indemnity precisely because its defenses were so weak. ION's "Product Assurance Pledge" provided flimsy protection, and even though ION later provided Fugro with an "indemnity" agreement, ION "contest[ed] the agreement … is in any way valid or binding." JA2942:9-14; *see* JA3971:19-23; JA4050:8-21.

The trial evidence conclusively refutes any contention that ION's defenses were "reasonable." Based on the record, ION's conduct was objectively willful.

CONCLUSION

The district court's judgment should be affirmed in full. However, if the Court reverses or remands any part of the judgment, it should also reverse the district court's rulings excluding WesternGeco's original reasonable damages calculation and concluding that ION's infringement was not objectively willful, and should remand for further proceedings regarding ION's willfulness and WesternGeco's entitlement to damages.

October 21, 2014

Respectfully submitted,

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ADDENDUM

Memorandum and Order (Dkt. No. 634, June 19, 2013) JA1-48

Memorandum and Order (Dkt. No. 402, July 15, 2012) JA59-70

U.S. Patent No. 6,691,038 B2 (Zajac) JA478-92

U.S. Patent No. 7,080,607 B2 (Hillesund and Bittleston) JA503-14

U.S. Patent No. 7,162,967 B2 (Hillesund and Bittleston) JA515-25

U.S. Patent No. 7,293,520 B2 (Hillesund and Bittleston) JA526-36

35 U.S.C. §271 (2012) ..... A-1 to A-6

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

WESTERNGECO L.L.C.,	§	
	§	
Plaintiff,	§	
	§	
v.	§	**Case No. 4:09-cv-1827**
	§	
ION GEOPHYSICAL CORPORATION, et al.	§	
	§	
	§	
Defendants.	§	

MEMORANDUM AND ORDER

Pending before the Court are the following motions:

1. ION's Partial Motion to Dismiss for Lack of Subject Matter Jurisdiction (Doc. No. 565);

2. ION's Rule 59 Motion for New Trial on Invalidity Under 35 U.S.C. §§ 102 and 103 (Doc. No. 550);

3. ION's Request for Findings and Conclusions on Enablement and, Alternatively, Motion for New Trial (Doc. No. 552);

4. ION's Renewed Motion for Judgment as a Matter of Law and Alternative Motion for New Trial Regarding Non-Infringement (Doc. No. 556);

5. ION's Motion for New Trial on Infringement Under 35 U.S.C. § 271(f)(2) (Doc. No. 557);

6. ION's Motion for JMOL and New Trial Due to Incorrect Claim Construction (Doc. No. 561);

7. ION's Motion for Entry of Findings and Conclusions of No Willful Infringement, Renewed Motion for Judgment as a Matter of Law of No Willful Infringement, and Alternative Motion for New Trial (Doc. No. 559);

8. WesternGeco's Motion for Willfulness and Enhanced Damages (Doc. No. 560);

9. WesternGeco's Motion to Find this Case Exceptional Under Section 285 and for Attorneys' Fees (Doc. No. 554);

10. ION's Motion for JMOL, Motion for New Trial on Damages alternatively Motion for Remittitur (Doc. No. 562);

11. WesternGeco's Motion for Prejudgment Interest and Post-Discovery Damages (Doc. No. 553);

12. WesternGeco's Motion for Costs (Doc. No. 555);

13. ION's Motion to Compel Production of Documents From WesternGeco (Doc. No. 609); and

14. WesternGeco's Motion for a Permanent Injunction or, in the Alternative, an Ongoing Royalty (Doc. No. 558).

Upon considering the Motions, all responses thereto, the applicable law, and oral arguments, the Court finds that:

1. ION's Partial Motion to Dismiss for Lack of Subject Matter Jurisdiction (Doc. No. 565) must be **DENIED;**

2. ION's Rule 59 Motion for New Trial on Invalidity Under 35 U.S.C. §§ 102 and 103 (Doc. No. 550) must be **DENIED;**

3. ION's Request for Findings and Conclusions on Enablement and, Alternatively, Motion for New Trial (Doc. No. 552) must be **DENIED;**

4. ION's Renewed Motion for Judgment as a Matter of Law and Alternative Motion for New Trial Regarding Non-Infringement (Doc. No. 556) must be **DENIED;**

5. ION's Motion for New Trial on Infringement Under 35 U.S.C. § 271(f)(2) (Doc. No. 557) must be **DENIED;**

6. ION's Motion for JMOL and New Trial Due to Incorrect Claim Construction (Doc. No. 561) must be **DENIED;**

7. ION's Motion for Entry of Findings and Conclusions of No Willful Infringement, Renewed Motion for Judgment as a Matter of Law of No Willful Infringement, and Alternative Motion for New Trial (Doc. No. 559) must be **GRANTED;**

8. WesternGeco's Motion for Willfulness and Enhanced Damages (Doc. No. 560) must be **DENIED;**

9. WesternGeco's Motion to Find this Case Exceptional Under Section 285 and for Attorneys' Fees (Doc. No. 554) must be **DENIED;**

10. ION's Motion for JMOL, Motion for New Trial on Damages alternatively Motion for Remittitur (Doc. No. 562) must be **DENIED;**

11. WesternGeco's Motion for Prejudgment Interest and Post-Discovery Damages (Doc. No. 553) must be **GRANTED;**

12. WesternGeco's Motion for Costs (Doc. No. 555) must be **GRANTED in part and DENIED in part;**

13. ION's Motion to Compel Production of Documents From WesternGeco (Doc. No. 609) must be **DENIED;**

14. WesternGeco's Motion for a Permanent Injunction or, in the Alternative, an Ongoing Royalty (Doc. No. 558) must be **GRANTED**.

I. BACKGROUND

This is a patent infringement case originally brought by WesternGeco L.L.C. ("Plaintiff" or "WesternGeco") against ION Geophysical Corporation ("ION"). At issue in this case is marine seismic streamer technology that is deployed behind ships. These streamers, essentially long cables, use acoustic signals and sensors to create three-dimensional maps of the subsurface of the ocean floor in order to facilitate natural resource exploration and management. For many seismic studies, greater control over the depth and lateral position of streamers is important in order to achieve optimal imagery from the signals and to maneuver around impediments such as rocks and oil rigs. WesternGeco's patents all pertain to streamer positioning devices, or devices that are used to control the position of a streamer as it is towed. At trial, WesternGeco argued that ION had infringed on four of its U.S. patents—U.S. Patent No. 7,293,520 (the "'520 Patent"); 7,162,967 (the "'967 Patent"), 7,080,607 (the "'607 Patent") ("Bittleston Patents" collectively); and U.S. Patent. No. 6,691,038 (the "'038 Patent" or "Zajac Patent").

After a three and a half week trial, the jury returned a verdict in favor of WesternGeco. (Doc. No. 536.) The jury found that ION infringed the '520 Patent, the '967 Patent, the '607 Patent, and the '038 Patent pursuant to Section 271(f)(1) & (2). The jury did not find anticipation

or non-enablement of the '520 Patent or the '967 Patent. The jury did not find anticipation, obviousness or non-enablement of the '607 Patent or the '038 Patent. The jury did find that ION willfully infringed. The jury awarded $93.4 million in lost profits and a reasonable royalty of $12.5 million. Both parties have now filed numerous post-trial motions. The Court will address each of the motions in turn.

II. LEGAL STANDARDS

A. Judgment as a Matter of Law ("JMOL")

The Fifth Circuit reviews a district court's ruling on a motion for judgment as a matter of law *de novo*. *See Cambridge Toxicology Grp., Inc. v. Exnicios*, 495 F.3d 169, 179 (5th Cir. 2007). Judgment as a matter of law is appropriate "[i]f a party has been fully heard on an issue during a jury trial and the court finds that a reasonable jury would not have a legally sufficient evidentiary basis to find for the party on that issue." *See* Fed. R. Civ. P. 50(a)(1); *Gomez v. St. Jude Med. Daig Div. Inc.*, 442 F.3d 919, 927 (5th Cir. 2006). "The decision to grant a directed verdict . . . is not a matter of discretion, but a conclusion of law based upon a finding that there is insufficient evidence to create a fact question for the jury." *Omnitech Int'l v. Clorox Co.*, 11 F.3d 1316, 1323 (5th Cir. 1994) (citations omitted) (internal quotation marks omitted). A legally sufficient evidentiary basis requires more than a mere scintilla of evidence. *Hollywood Fantasy Corp. v. Gabor*, 151 F.3d 203, 211 (5th Cir. 1998).

The trial court is required to consider the entire record when considering a renewed judgment as a matter of law motion. *Reeves v. Sanderson Plumbing Prod., Inc.*, 530 U.S. 133, 149–50 (2000). Therefore, a court "should consider all of the evidence—not just that evidence which supports the non-mover's case—but in the light and with all reasonable inferences most

favorable to the party opposed to the motion." *Goodner v. Hyundai Motor Co., Ltd.*, 650 F.3d 1034, 1040 (5th Cir. 2011).

B. Rule 59 Motion for New Trial

The district court's ruling on a Rule 59 motion for new trial is reviewed for an abuse of discretion. *Beckham v. Louisiana Dock Co., L.L.C.*, 124 Fed.App'x. 268, 270 (5th Cir. 2005). A district court can grant a new trial under FRCP 59(a) "for any reason for which a new trial has heretofore been granted in an action at law in federal court." A new trial should not be granted "unless, at a minimum, the verdict is against the great weight of the evidence." *Dawson v. Wal-Mart Stores, Inc.*, 978 F.2d 205, 208 (5th Cir. 1992). The Court must again view the evidence "in a light most favorable to the jury's verdict, and the verdict must be affirmed unless the evidence points so strongly and overwhelmingly in favor of one party that the court believes that reasonable [jurors] could not arrive at a contrary conclusion." *Id*. "Where the jury could have reached a number of different conclusions, all of which would have sufficient support based on the evidence, the jury's findings will be upheld." *Id.*. If an issue is raised for the first time on a motion for a new trial, the issue is waived. *Auster Oil & Gas, Inc. v. Stream*, 835 F.2d 597, 601 (5th Cir. 1988).

III. PARTIAL MOTION TO DISMISS

ION has filed a Partial Motion to Dismiss for Lack of Subject Matter Jurisdiction. (Doc. No. 565.) ION moves to dismiss for lack of subject matter jurisdiction with respect to WesternGeco's claims that ION infringed the Bittleston Patents. ION claims that WesternGeco does not own the Bittleston Patents and therefore lacks standing to sue for infringement.

A. Legal Standard

"Standing is a constitutional requirement pursuant to Article III and it is a threshold jurisdictional issue" that may be decided on a Rule 12(b)(1) motion. *Abraxis Bioscience, Inc. v. Novainta LLC*, 625 F.3d 1359, 1363 (Fed. Cir. 2010). WesternGeco bears the burden of proving standing by a preponderance of the evidence. A case can be dismissed for lack of subject matter jurisdiction at any time. A court may consider evidence outside the pleadings when resolving a motion to dismiss for lack of subject matter jurisdiction under Rule 12(b)(1). *See Ramming v. U.S.*, 281 F.3d 158, 161 (5th Cir. 2001). Only a patent owner may have a remedy by civil action for infringement. *Paradise Creations, Inc. v. UV Sales, Inc.*, 315 F.3d 1304, 1308 (Fed. Cir. 2003). The Patent Act defines a patentee as the person to whom the patent as issued and any successors in title to the patentee. 35 U.S.C. § 100(d). Patent rights can only be assigned in writing. 35 U.S.C. § 261.

B. Chain of Title

ION argues that WesternGeco has not proved it has ownership of the Bittleston patents, and therefore, its standing to sue. WesternGeco has provided ION two types of documents, a Merger Agreement between Schlumberger Technology Corporation ("STC") and WesternGeco and assignments from the inventors to STC, but not from the inventors to WesternGeco. ION argues that WesternGeco must possess a written chain of title from the inventors. ION further argues that the USPTO assignment records do not contain any executed assignment document from the inventors to WesternGeco. Based on these facts, ION argues that WesternGeco has not proved it is the owner of the patents.

ION has never raised this issue in a motion before and had stipulated earlier in the suit that WesternGeco did own the patents. While "[c]onsent of parties cannot give the courts of the

U.S. jurisdiction . . . the parties may admit the existence of facts which show jurisdiction, and the courts may act judicially upon such admission." *Ry. Co. v. Ramsey*, 89 U.S. (22 Wall.) 322, 327 (1875). First, ION had stated in its Answer and Counterclaims that "[o]n information and belief, the Bittleston Patents were assigned to WesternGeco." (Doc. No. 6 ¶ 106.) In the same Answer, ION also stated it did not know for certain whether WesternGeco owned the patents, but proceeded for three years as if WesternGeco did own them. Second, ION agreed the jury should be instructed that WesternGeco owns the patents and is entitled to collect damages. ION now attempts to assert a position that is wholly different from its position regarding patent ownership throughout this litigation.

Additionally, the Patent Office issued each of the Bittleston patents to WesternGeco as the "Assignee." The entity to whom the Patent Office issues a patent is the presumptive owner. ION has the burden to rebut that presumption, which it has not done. Conversely, WesternGeco has presented sufficient evidence to prove its ownership of the patents. WesternGeco presented evidence at the trial that the inventors assigned their patent to STC. Then in the November 30, 2000 Technology Transfer Agreement, STC transferred and assigned the patents to WesternGeco. That agreement stated:

> STC agrees to and hereby does grant, transfer and assign to [WesternGeco] with regard to the Territory all of STC's rights, title and interest in and to the Intellectual Property in existence."

"Intellectual Property" was defined in the agreement to include any patent rights. ION argues that an "agreement" to assign is not the same as assigning. However, the language of the agreement states clearly that STC "agrees to and hereby does grant, transfer, and assign." The Court is satisfied that WesternGeco was assigned the rights.

ION further argues that the assignment to STC occurred in 2001. Since STC and WesternGeco merged in 2000, STC did not have the patent rights to assign and therefore the patents still belonged to STC. The Court finds this argument unconvincing. The 2001 assignments state that the inventors "acknowledge [they] have sold, assigned, transferred and conveyed" the U.S. patent rights to STC. (Doc. No. 606, Ex. 11 at WG 955146; Ex. 12 at WG 955144.) This is a confirmation of the inventors' assignments to STC that dates back to the 1998 Cost Sharing Agreement, which states:

> Ownership of the Patent Rights . . . shall be vested in the Participants in their Respective Areas. (Doc. No. 606, Ex. 10 at WG 955272.)

STC was designated the "Participant" for the "Respective Area". Therefore, STC owned the patents when it assigned the patents to WesternGeco in 2000.

ION has proceeded throughout the years as if WesternGeco owned the patents and the record reflects that WesternGeco does own the patents by written assignment. Therefore, the Court must deny ION's Motion to Dismiss.

IV. INVALIDITY

ION has filed a Rule 59 Motion for New Trial on Invalidity Under 35 U.S.C. §§ 102 and 103. (Doc. No. 550.) ION moves for a new trial on the basis that all the asserted patent claims but two are invalid as anticipated or obvious under 35 U.S.C. §§ 102 and 103. Specifically, ION contends that Claim 18 of the '520 Patent and Claim 15 of the '607 Patent were anticipated by U.S. Patent No. 5,790,472 ("Workman Patent"). Claim 14 of the '038 Patent was anticipated by International Application Publication WO 2000/20895 (the "'895 Publication"). Also, ION asserts that Claim 15 of the '967 Patent and Claim 15 of the '607 Patent were obvious based on the combination of the Workman Patent; and the International Application Publication WO 98/28636 (the "'636 Patent") and Claim 14 of the '038 Patent were made obvious by the '895

Patent. After considering the arguments, the Court finds that the jury's verdict was reasonable and there was no indication of unfairness to warrant a new trial. This motion must be denied.

A. Anticipation

A patent is invalid as anticipated under 35 U.S.C. § 102 when "every element and limitation of the claim was previously described in a single prior art reference, either expressly or inherently, so as to place a person of ordinary skill in possession of the invention." *Sanofi-Synthelabo v. Apotex, Inc.*, 550 F.3d 1075, 1082 (Fed. Cir. 2008). The standard for proving anticipation is clear and convincing evidence. *Id.* The prior art that ION asserts anticipates WesternGeco's patents were all considered by the United States Patent and Trademark Office ("PTO") during prosecution, yet the PTO still granted WesternGeco the patents at issue. While not dispositive, this is further evidence the jury could have relied upon when reaching its verdict. At trial, the jury decided that WesternGeco's patents were not anticipated and ION has not met the clear and convincing evidence standard to prove otherwise.

1. Claim 18 of the '520 Patent

ION claims that the Workman Patent anticipated Claim 18 of the '520 Patent. However, the jury could reasonably find from evidence and testimony presented at trial that the Workman Patent does not teach or enable lateral steering or the "streamer positioning devices" claimed in the Bittleston Patents. The streamer positioning devices mentioned in the Workman Patent refers to depth control devices, not lateral positioning devices as used in the Bittleston patents. (Doc. No. 574 p. 7.)

Likewise, ION claims that the Workman Patent anticipates this claim because it discloses the "streamer separate mode." The Court construed "streamer separation mode" to mean "a control mode that attempts to set and maintain the spacing between adjacent streamers" (Doc.

No. 120 p. 45.) The Workman Patent states only that a "threshold parameter" of "at least 100 meters" be maintained. (Doc. No. 583 p. 5.) This threshold parameter does not specify that a precise spacing be set and maintained between adjacent streamers. WesternGeco aptly points out that, without maintaining any space, the streamers could range from 100 meters apart to 100 miles. (Doc. No. 602 p. 3.) With this, and other evidence and testimony, the jury could reasonably find that Claim 18 of the '520 Patent was not anticipated.

2. Claim 15 of the '607 Patent

ION argues that the Workman Patent anticipates Claim 15 of the '607 Patent by disclosing limitation (a), (b), and (c) of the Claim. Claim 15 states:

(a) a plurality of streamer positioning devices on or inline with each streamer,
(b) a prediction unit adapted to predict positions of at least some of the streamer positioning devices,
(c) a control unit adapted to use the predicted positions to calculate desired changes in positions of one or more of the streamer positioning devices.

However, at trial, ION's expert witness, Robert Brune admitted that Claim 15 of the '607 patent requires lateral steering and Workman does not enable lateral steering. To anticipate, a patent must teach and enable all claim limitations. Since lateral steering is a limitation of Claim 15, it is reasonable that the jury would conclude that Claim 15 of the '607 Patent was not anticipated.

3. Claim 14 of the '038 Patent

ION argues that Claim 14 of the '038 Patent is anticipated based on the '895 Publication, which discloses all of the limitations of Claim 14. However, Mr. Brune admitted at trial that the '895 Publication does not disclose the 4D surveys claimed in the '038 Patent. The jury could weigh this evidence and testimony and conclude that Claim 14 was not anticipated.

B. Obviousness

A patent is invalid for obviousness "if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains." 35 U.S.C. § 103(A). "Obviousness is a legal determination that may be submitted to a jury with proper instruction." *In re Hayes Microcomputer Products, Inc. Patent Litigation*, 982 F.2d 1527, 1539 (Fed. Cir. 1992). ION expressly agreed to submit the question of obviousness to the jury in the form of the special verdict form. (Doc. No. 536.) ION has not met its burden to overturn the jury's finding of nonobviousness.

1. Claim 15 of the '967 Patent

ION argues that Claim 15 of the '967 Patent is obvious based on the combination of the Workman Patent and the '636 Publication, which are prior art. Claim 15 reads:

> An array of seismic streamers towed by a towing vessel comprising:
>
> (a) a plurality of streamer positioning devices on or inline with each streamer, at least one of the streamer positioning devices having a wing;
> (b) global control system transmitting location information to at least one local control system on the [*sic*] at least one streamer positioning device having a wing, the local control system adjusting the wing.

However, ION has failed to show that any person of ordinary skill in the art would have selected and combined these prior art elements in the normal course of research and development to yield the claimed invention. *Unigene Labs., Inc. v. Apotex, Inc.*, 655 F.3d 1352, 1360 (Fed. Cir. 2011). ION has not met its burden to overturn the jury's finding of nonobviousness.

2. Claim 15 of the '607 Patent

ION argues that Claim 15 of the '607 Patent is obvious based on the combination of the Workman Patent and the '636 Publication, which are prior art. At trial, Mr. Brune explained that

the Workman Patent, '636 Publication and '607 Patent are in the same field. Therefore, ION argues, a person of ordinary skill in the art would be motivated to combine the Workman Patent and the '636 Publication. However, ION fails to explain how the combination could disclose and enable all of these limitations and harmonize the differences in the two patents. *In re Kumar*, 418 F.3d 1361, 1369 (Fed. Cir. 2005) ("To render a later invention unpatentable for obviousness, the prior art must enable a person of ordinary skill in the field to make and use the later invention."). ION has not met its burden to overturn the jury's finding of nonobviousness.

3. Claim 14 of the '038 Patent

ION argues that Claim 14 is obvious based on the '895 Publication. Mr. Brune testified that, even assuming that the tracking systems are not expressly or inherently disclosed in the '895 Publication, they would have been obvious to a person having ordinary skill in the art. Mr. Brune further testified that, at least since the late 1980s, compass navigation, acoustic navigation, and satellite navigation have existed. However, Mr. Brune also remarked during cross examination that using laterally steerable streamers in order to match a later survey to a reference position from a prior survey or reference file "is definitely a notable improvement." (Trial Tr. At 3988:20-25.) The jury could weigh this admission and reasonably conclude that Claim 14 was not obvious.

ION has not demonstrated that the jury's verdict on anticipation or obviousness was against the great weight of the evidence. *See Dresser–Rand Co. v. Virtual Automation, Inc.*, 361 F.3d 831, 838-39 (5th Cir. 2004). Therefore, ION's Rule 59 Motion for New Trial on Invalidity Under 35 U.S.C. §§ 102 and 103 must be denied.

V. ENABLEMENT

ION has filed a Request for Findings and Conclusions on Enablement and, Alternatively, Motion for New Trial. (Doc. No. 552.) The Patent Act states:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor or joint inventor of carrying out the invention.

35 U.S.C.A. § 112.

To be enabled, a patent specification must provide sufficient information to enable a person skilled in the relevant art to make and use the claimed invention without undue experimentation. The Federal Circuit has set forth the following factors that courts may weigh in deciding whether a disclosure would require undue experimentation:

1. the quantity of experimentation necessary;
2. the amount of direction or guidance presented;
3. the presence or absence of working examples;
4. the nature of the invention;
5. the state of the prior art;
6. the relative skill of those in the art;
7. the predictability or unpredictability of the art; and
8. the breadth of the claims.

Martek Bioscience Corp. v. Nutrinova, Inc., 579 F.3d 1363, 1378 (Fed. Cir. 2009). ION must "prove invalidity based on nonenablement by clear and convincing evidence." *MagSil Corp. v. Hitachi Global Storage Technologies, Inc.*, 687 F.3d 1377, 1380 (Fed. Cir. 2012). After considering the motion, all responses, oral argument, and the applicable law, the Court must deny this motion**.**

A. Findings and Conclusions

ION claims that the Court must state its findings of facts and conclusions of law because the enablement question was sent to the jury as an "advisory determination." Rule 52(a)(1).

However, both parties agreed to submit the question of enablement to the jury and neither party indicated this was merely an advisory verdict. The Federal Circuit has held that "it is not error to submit legal questions to the jury as part of a Rule 49(a) special verdict form, since the answer to the legal question necessarily resolves any disputed underlying factual issues, the court must accept implicit factual findings upon which the legal conclusion is based when they are supported by substantial evidence." *Kinetic Concepts, Inc. v. Smith & Nephew, Inc.*, 688 F.3d 1342, 1359 (Fed. Cir. 2012). The Federal Circuit has held that enablement is a question of law, but "is amenable to resolution by the jury where the issues are factual in nature." *BJ Services Co. v. Halliburton Energy Services, Inc.*, 338 F.3d 1368, 1372 (Fed. Cir. 2003). Therefore, the Court need not enter findings and conclusions of law since the question was properly submitted to the jury.

B. New Trial

In the alternative, ION moves for a new trial on enablement on the Bittleston Patents (composed of Claims 18, 19, 23 of '520 Patent; Claim 15 of '967 Patent; and Claim 15 of the '607 Patent), and Claim 14 of the Zajac Patent ('038 Patent).

1. Bittleston Patents

The Bittleston Patent claims in suit require a control system and ION argues that there is not sufficient information to enable a deterministic control system. ION relies on the trial testimony of two witnesses for this assertion. Dr. Thomas Edgar stated that "[i]t would require an extreme amount of experimentation" to execute the control system. (Trial Tr. 3146:14-18.) A former WesternGeco employee, James Martin, said that crucial information was not disclosed so as to maintain a trade secret. (Trial Tr. 3671:5-3674:10.)

However, ION's expert, Dr. Edgar, admitted in cross-examination that there is no mention of deterministic calculations, and since this is not a claimed invention, it need not be enabled. Dr. Edgar also testified that a person of ordinary skill in the art could use a "simple feedback control loop" with the patent's disclosure to make and use the claimed control modes. (Trial Tr. 3148:11-3150:19.) Furthermore, Mr. Martin stated that he did not know whether the withheld information had to do with the control mode. This testimony, from witnesses not under WesternGeco's control, are sufficient to support a jury verdict that the Bittleston Patents were enabled, and ION has not met the standard of clear and convincing evidence to warrant a new trial.

2. Zajac Patent

ION claims that Claim 14 of the Zajac Patent is not enabled because it fails to teach one skilled in the art how to make or use the invention in order to determine what positioning commands to issue to active streamer positioning devices. ION cites various parts of Mr. Zajac's testimony in which Mr. Zajac admits that the device is very complex and the patent does not enable one to implement the claimed invention. However, WesternGeco presented testimony that the Zajac Patent is an improvement of the Bittleston Patents and it explicitly builds on and cites to those patents. Mr. Brune also testified that the Zajac Patent, read in conjunction with the Bittleston Patents, enabled the claimed invention. Furthermore, other portions of Mr. Zajac's testimony reveal that Mr. Zajac did not include some specifications because those practices were already known to and available to one of ordinary skill in the art. *Koito Mfg. Co. v. Turn-Key-Tech., LLC*, 381 F.3d 1142, 1156 (Fed. Cir. 2004) (a patentee does not "need to include in the specification that which is already known to and available to one of ordinary skill in the art."). Furthermore, ION's expert, Dr. Edgar, also conceded on cross-examination that the active

streamer positioning device was enabled. (Trial Tr. at 3167:19-23.) The jury had the opportunity to weigh this evidence and the verdict is not against the great weight of evidence. Therefore, ION has not shown that a new trial is warranted on enablement and its motion should be denied.

VI. Non-Infringement

ION's has filed a Renewed Motion for Judgment as a Matter of Law and Alternative Motion for New Trial Regarding Non-Infringement (Doc. No. 556) on all claims because it asserts that no claims have been infringed. WesternGeco asserted that the following claims were literally infringed: Claims 18, 19 and 23 of the '520 Patent; Claim 15 of the '967 Patent; Claim 15 of the '607 Patent; and Claim 14 of the '038 Patent. To literally infringe, the accused system must embody every claim limitation as construed by the court. *Gen. Elec. Co. v. Nintendo Co.*, 179 F.3d 1350, 1357-58 (Fed. Cir. 1999). WesternGeco also asserted that the following claims were infringed under the doctrine of equivalents ("DOE") if they were not literally infringed: Claims 18, 19 and 23 of the '520 Patent; and Claim 15 of the '967 Patent. DOE requires that the accused system contain each limitation of the claim or its equivalent. *Warner-Jenkinson Co. v. Hilton Davis Chem. Co.*, 520 U.S. 17, 40 (1997). A claim limitation is "equivalently present in an accused device if only 'insubstantial differences' distinguish the missing claim element from the corresponding aspects of the accused device." *Riles v. Shell Exploration & Prod. Co.*, 298 F.3d 1302, 1309-10 (Fed. Cir. 2002). Each of the claims are discussed below, but ultimately, the Court must deny ION's motion.

A. Claims 19 and 23 of the '520 Patent

ION argues that Claims 19 and 23 of the '520 Patent do not infringe literally or under the Doctrine of Equivalents. ION argues that Claim 19 does not infringe literally because ION's system does not include a "feather angle mode." The Court construed "feather angle mode" to

mean "a control mode that attempts to set and maintain each streamer in a straight line offset from the towing direction by a certain feather angle." (Doc. No. 530, "Jury Instructions", No. 6.) ION argues that only the ghost streamer, and not "each streamer," is set to the feather angle. However, sufficient evidence supports the jury's verdict that Claim 19 of the '520 Patent was literally infringed. The remaining streamers align themselves with the reference streamer at that same feather angle. A number of Fugro's and ION's employees and customers testified at trial that ION's system operates in feather mode. (Trial Tr. 3468:25–3469:8, 3474:19–25 (Daniel Seale, ION's senior systems engineer); *id*. at 2055:12–15, 2062:7–9, 3340:17–3342:1, 3353:2–11, 3362:14–23, 3433:15–24, 3435:3–3436:6 (Crawford Macnab, ION's Orca software project manager); *id*. at 1008:5–7, 1009:4–8, 1013:22–1014:19, 1024:21–1025:10, 1028:18–22, 1030:1–3 (Leif Morten By, Fugro's former Navigation Manager); *id*. at 3025:8–13 (David Moffat, ION's Senior Vice President)). The jury could reasonably determine that there was literal infringement.

ION argues that Claim 23 of the '520 Patent does not infringe literally because it does not have the "feather angle mode" or a "turn control mode." ION argues that, because there is no feather angle mode and the "turn control mode" depends on it, there is no literal infringement. However, the preceding paragraph demonstrates that there is not enough evidence to overturn the jury's verdict on "feather angle mode." As for the "turn control mode," the Court construed it to mean a "mode wherein streamer positioning device(s) generate a force in the opposite direction of a turn and then directing each streamer positioning device to the position defined in the feather angle mode." (Jury Instruction, No. 6.) ION argues that both DigiBIRD and DigiFIN products would have to "generate a force in the opposite direction", but the DigiBIRD is undisputedly a depth-control device only that cannot generate forces in the opposite direction of a turn. Evidence and testimony at trial showed that DigiFIN products did generate a force in the

opposite direction of the turn. Literal infringement does not depend on DigiBIRD products also generating a force in the opposite direction. The Court's construction did not require all of the streamer positioning devices to participate in the turn control mode, only one or more devices. Therefore, the jury could have found that DigiFIN's turn control mode was sufficient to literally infringe Claim 23 of the '520 Patent. ION has not shown that the weight of the evidence was against the jury's verdict on Claims 19 and 23 of the '520 Patent.

B. Claim 15 of the '607 Patent

Claim 15 of the '607 Patent reads:

> An array of seismic streamers towed by a towing vessel comprising:
> . . .
> (b) a prediction unit adapted to predict positions of at least some of the streamer positioning devices . . .

ION argues that Claim 15 of the '607 Patent cannot be infringed because of how the word "predict" is defined. ION argues that the jury instructions obligate the jury to apply the ordinary meaning of the term "predict" because the Court did not construe the term. ION claims that the plain and ordinary meaning of the term "predict" requires a future element, and ION's devices do not tell the future positions of the streamer position devices. ION made this argument before this Court previously and this Court held that "predict" is not limited to future "wall-clock" times. The Court held that the future sense of "predict" is not the plain and ordinary meaning of "predict" to a person of ordinary skill in the art. Predict could mean using a past position to "predict" position at a later time, such as the present position. At an earlier time, this Court rejected ION's construction of "predict" and finds no reason to overturn its decision now. Therefore, ION's Motion for JMOL or New Trial on claim 15 of '607 Patent must be denied.

C. Claim 15 of the '967 Patent

Claim 15 of the '967 Patent reads:

> An array of seismic streamers towed by a towing vessel comprising:
> . . .
> (b) a global control system transmitting location information to at least one local control system . . .

The Court construed "location information" to mean "information regarding location." (Jury Instruction, No. 6.) ION argues that its system does not transmit location information from the Lateral Controller to DigiFINs as required by Claim 15. However, WesternGeco presented testimony at trial by expert, Dr. Michael Triantafyllou, stating that the DigiFIN did receive the fin angle, which is "an equivalent concept, whether you send location or a fin calculated on location." (Trial Tr. 1463:9–22.) Other evidence was also presented at trial to show that this fin angle was location information. Crawford Macnab, ION's software project manager, confirmed that ORCA sends location information to the lateral controller and that the lateral controller manipulates and sends this location information to the DigiFIN. (Trial Tr. 2053:24–2054:4; *see also id*. at 3431:24–3432:4, 3433:7–10.) Sufficient evidence supports the jury's finding on Claim 15 of the '967 Patent.

D. Claim 14 of the '038 Patent

Relevant to ION's argument, Claim 14 of the '038 Patent reads:

> A seismic streamer array tracking and positioning system comprising:
> . . .
> A master controller for issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry;
> . . .
> Compares the vertical and horizontal positions of the streamers versus time and the array geometry versus time to desired streamer positions and array geometry versus time . . .

ION argues that it could not infringe literally since the Lateral Controller does not send "target depth" to the DigiFIN and it does not perform a comparison function as required by Claim 14. However, neither Claim 14 nor the Court's construction require "target depth" to be

sent, merely "positioning commands" that are "signals or instructions to control positioning." (Doc. No. 120 p. 46.) WesternGeco presented evidence at trial that DigiFIN did just this. Additionally, evidence and testimony was presented to support a finding that DigiFIN compares desired streamer positions versus time. Dr. Triantafillou explained that ION's system "compares the vertical and horizontal positions of the streamers versus time and the array geometry versus time to desired streamer positions and array geometry versus time." (Trial Tr. 1355:22-1370:24, 1443:4-14.) The jury could have reasonably relied on this information to reach its verdict.

ION also argues that its system does not include the "active streamer positioning device" ("ASPD") recited in Claim 24. An ASPD was construed by the Court as "a device capable of controlling the vertical and horizontal position of the seismic streamer". (Jury Instructions, No. 6.) Before trial, the Court decided that ION's DigiFIN device could control the vertical and horizontal position of the streamer, thereby preventing ION from arguing that DigiFIN was not an ASPD. (Doc. No. 402 p. 9.) ION argues that the Court decided wrongly because DigiFIN cannot control depth. ION does not present any new evidence and the Court need not overrule its previous decision that DigiFIN is an ASPD. Accordingly, ION's Motion regarding for Claim 14 of the '038 Patent must be denied.

VII. INFRINGEMENT UNDER 35 U.S.C. § 271(f)(2)

ION has filed a Motion for New Trial on Infringement Under 35 U.S.C. § 271(f)(2) (Doc. No. 557), claiming the evidence cannot support a finding that ION possessed the requisite knowledge to infringe 35 U.S.C. § 271(f)(2). Section 271(f) was enacted in response to the Supreme Court's decision in *Deepsouth Packaging Co. v. Laitram Corp*., 406 U.S. 518 (1972). The loophole presented in *Deepsouth* was that shipping an unassembled patented product abroad for later assembly avoids patent infringement. This Court interpreted § 271(f)(2) to have the

same intent requirement as contributory infringement under § 276(c). (Doc. No. 372 p. 7.) Specifically, this Court held that the intent requirement of §271(f)(2) "requires a plaintiff to prove that the defendant (1) intended the combination of components; (2) knew that the combination he intended was patented; and (3) knew that the combination he intended would be infringing if it occurred in the United States." (*Id*.) Neither party disputes this statutory construction.

ION denies intent to infringe on all claims because it contends it did not know it was infringing. First, ION argues that it could not have intended to infringe Claim 19 of the '520 Patent because it reasonably understood that its system did not comprise the required feather angle mode. Second, ION argues it could not have intended to infringe Claim 23 of the '520 Patent because it required ION's system to have a feather angle mode and the turn control mode and ION claims it did not think its system had either of these modes. Third, ION argues it could not have intended to infringe Claim 15 of the '967 Patent because it did not think its system had location information. Fourth, ION argues it could not have intended to infringe Claim 15 of the '607 Patent because it did not think its system had a prediction unit. Lastly, ION argues it could not have intended to infringe Claim 14 of the '038 Patent because it asserts its system did not have a master controller or an ASPD.

However, ION does not dispute the jury's determination that neither the DigiFIN nor the Lateral Controller has any substantial non-infringing uses. Nor does ION dispute that it knew that the DigiFIN and the Lateral Controller were especially made or adapted for use in the patented invention. The Supreme Court has held, "One who makes and sells articles which are only adapted to be used in a patented combination will be presumed to intend the natural consequences of his acts; he will be presumed to intend that they shall be used in the

combination of the patent." *Metro-Goldwyn-Mayer Studios Inc. v. Grokster, Ltd*., 545 U.S. 913, 932 (2005). ION responds that the inquiry is not about intent, but knowledge, so *Grokster*, which concerns § 272(c), does not apply. However, in a previous Order, this Court noted that § 272(c) has the same intent requirement as § 272(f)(2). (Doc. No. 372 p. 7.) In *Spansion, Inc. v. Int'l Trade Comm'n*, 629 F.3d 1331 (Fed. Cir. 2010), the Federal Circuit held that because "appellants were aware of the . . .patent, and [patentee] successfully showed that the accused devices did not have any substantial noninfringing uses", then "presum[ing] the requisite knowledge for contributory infringement . . .was not erroneous." *Id*. at 1355. ION has not shown that the weight of the evidence is contrary to the jury's verdict to warrant a new trial. Therefore, this motion should be denied.

VIII. CLAIM CONSTRUCTION

ION has filed a Motion for JMOL and New Trial Due to Incorrect Claim Construction. (Doc. No. 561.) ION moves for JMOL or new trial for non-infringement of Claims 18, 19, and 23 of the '520 Patent, Claim 15 of the '967 Patent, and Claim 15 of the '607 Patent, claiming there was not sufficient evidence to sustain the verdict of infringement under 35 U.S.C. § 271(f) when the correct construction of "streamer positioning device" is applied. ION similarly argues there is not sufficient evidence to sustain the verdict if the correct construction of "active streamer positioning device" is used with respect to Claim 14 of the '038 Patent. The Court already decided these claim constructions in 2010. (Doc. No. 120.)

It appears that ION's motion is procedurally improper since it failed to move under Rule 50(a) on the basis of an "incorrect claim construction." ION contends that it argued JMOL for non-infringement on each of the patents, but JMOL for non-infringement is not a motion for incorrect claim construction, which ION now argues. Second, ION failed to object to the jury

instructions, which construed the terms at issue. Third, ION's motion could be understood as a motion for reconsideration of this Court's claim construction order (Doc. No. 120), in which case the motion is untimely since it comes two years after the order. It appears to the Court that ION is merely rehashing its prior claim construction arguments and has not presented any change in law or fact that would cause the Court to overturn its previous ruling. Therefore, ION's motion regarding incorrect claim construction must be denied.

IX. WILLFUL INFRINGEMENT

Both parties have filed motions on the issue of willful infringement. ION has filed a Motion for Entry of Findings and Conclusions of No Willful Infringement, Renewed Motion for Judgment as a Matter of Law of No Willful Infringement, and Alternative Motion for New Trial. (Doc. No. 559.) WesternGeco has filed a Motion for Willfulness and Enhanced Damages. (Doc. No. 560.) In 2007, the Federal Circuit altered the willful infringement inquiry to one of recklessness. *In re Seagate Tech., LLC*, 497 F.3d 1360, 1371 (Fed. Cir. 2007). The Federal Circuit requires a two-prong showing of recklessness by clear and convincing evidence. *Id*. The first prong requires a showing of objective recklessness and the second a showing of subjective recklessness. *Bard Peripheral Vascular, Inc. v. W.L. Gore & Associates, Inc.*, 682 F.3d 1003, 1005 (Fed. Cir. 2012) cert. denied, 12-458, 2013 WL 141409 (U.S. Jan. 14, 2013). To establish objective recklessness, WesternGeco would have to prove that the "infringer acted despite an objectively high likelihood that its actions constituted infringement of a valid patent. Once the threshold objective standard is satisfied, the patentee must also demonstrate that this objectively-defined risk . . . was either known or so obvious that it should have been known to the accused infringer." *Bard Peripheral Vascular, Inc. v. W.L. Gore & Associates, Inc.*, 682 F.3d at 1005. The objective prong is a question of law to be decided by the Court; the subjective prong is a

question of fact that was decided by the jury. *Id.* at 1005-06. The Court had not yet decided the objective prong before the subjective prong was submitted to the jury, which found willful infringement. After considering the arguments made by each party, the Court finds no objective recklessness, and therefore, no willfulness.

A. Objective Recklessness

The Federal Circuit has recognized that "in ordinary circumstances, willfulness will depend on an infringer's prelitigation conduct." *Seagate*, 497 F.3d at 1374. The Court must base its determination of objective recklessness "on the record ultimately made in the infringement proceedings". *Bard*, 682 F.3d at 1008. WesternGeco argues that objective recklessness is proven because the jury found subjective recklessness and the Court ruled in favor of WesternGeco as a matter of law regarding ION's infringement of the '520 Patent, ION's defenses of laches, equitable estoppel, waiver, and unclean hands, and ION's § 101, written description, best mode and indefiniteness invalidity defenses. However, WesternGeco's assertion that the Court's grant of summary judgment and the jury's infringement findings are dispositive of the objective recklessness inquiry is incorrect. The Federal Circuit is clear that "[d]efeat of a litigation position, even on summary judgment, does not warrant an automatic finding that the suit was objectively baseless; all of the circumstances must be considered." *Aspex Eyewear Inc. v. Clariti Eyewear, Inc.*, 605 F.3d 1305, 1315 (Fed. Cir. 2010). Instead, to prove the objective prong, WesternGeco must show by clear and convincing evidence that "[ION] acted despite an objectively high likelihood that its actions constituted infringement of a valid patent." *Bard*, 682 F.3d at 1005. Thus, WesternGeco has the burden to show that "no reasonable litigant could realistically expect success on the merits." *Id.* at 1006, 1008; *iLOR, LLC v. Google, Inc.*, 631

F.3d 1372, 1378 (Fed. Cir. 2011); *Old Reliable Wholesale, Inc. v. Cornell Corp.*, 635 F.3d 539, 544 (Fed. Cir. 2011).

ION claims that it was not unreasonable for it to rely on its belief that there was no infringement because it reasonably believed:

- Claim 19 of the '520 did not have a feather angle mode;
- Claim 23 of the '520 Patent did not have a feather angle mode or turn control mode;
- Claims of the '520 Patent did not have control systems;
- Claim 15 of the'967 Patent did not have location information;
- Claim 15 of the '607 Patent did not have a prediction unit;
- Claim 14 of the '038 Patent did not have a master controller or an ASPD.

1. Claims 18, 19, and 23 of the '520 Patent

At issue are the "feather angle mode" and the "turn control mode" limitations of these claims. The Court construed these modes as:

> Feather angle mode: a control mode that attempts to set and maintain each streamer in a straight line offset from the towing direction by a certain feather angle.
>
> Turn control mode: mode wherein streamer positioning device(s) generate a force in the opposite direction of a turn and then directing each streamer positioning device to the position defined in the feather angle mode.

(Doc. No. 120, 24-27, 45.) At trial, it was uncontroverted that ION's system does not set and maintain each streamer at a certain feather angle. Instead, ION's system only sets the "ghost streamer" at a specific feather angle. (Trial Tr. 3781:3-3784:9.) The Court finds that ION's defense against infringement is not objectively baseless in that no reasonable litigant could realistically expect to succeed. Likewise, the uncontroverted evidence at trial was that the streamer positioning devices in ION's system could not all generate a force in the opposite direction of a turn and then be directed to the position defined in the feather angle mode. (Trial Tr. 3786:7-23.) Specifically, the DigiBIRDs could not "generate a force in the opposite direction

of the turn." Though the jury found in favor of WesternGeco, ION's defense for turn control mode was not unreasonable.

2. The '607 Patent

Claim 15 of the '607 Patent requires "a prediction unit adapted to predict positions of at least some of the [SPDs]." ION claims that the use of the word "predict" led it to believe the claim required a forecasting of future positions rather than an estimation of current positions. Though the Court ultimately construed the term "predict" to mean the ability to not be bound by wall-clock times and could mean present time, ION's argument is not unreasonable by clear and convincing evidence.

3. The '967 Patent

WesternGeco contends that ION's user manual and DigiFIN's product specification both describe transmission of location information from a global control system to a local control system as in Claim 15 of the '967 patent. Claim 15 of the '967 Patent requires "a global control system transmitting location information to at least one local control system on the at least one [SPD]." ION construed an SPD to have the capacity to steer both laterally and vertically. (Doc. No. 73 p. 6.) Therefore, because the DigiFINs only receive a fin angle command from the alleged global control system, it did not transmit "information regarding location." (Trial Tr. 2767:9-25.) It was ION's position that the fin angle does not represent the location, latitude, longitude, depth, or lateral position to which the DigiFIN is to be moved. (Trial Tr. 3451:22-25, 3462:16-3463:24.)

WesternGeco argues that infringement of this claim was objectively reckless because a third party, StatoilHydro, conducted an infringement investigation and concluded that the '967 Patent "clearly envisages a system working along broadly the same lines as described above in

relation to ION." (Doc. No. 560 p. 8.) The parties argue about the admissibility of the investigation for the truth of the matter asserted. However, the Court need not reach that point in the objective recklessness inquiry. The Federal Circuit has delineated the purposes of each of the prongs:

> *Seagate* established a two-pronged test for establishing the requisite recklessness. Thus, to establish willful infringement, "a patentee must show by clear and convincing evidence that the infringer acted despite an objectively high likelihood that its actions constituted infringement of a valid patent." Once the "threshold objective standard is satisfied, the patentee must also demonstrate that this objectively-defined risk . . .was either known or so obvious that it should have been known to the accused infringer."

Bard, 682 F.3d at 1005 (citations omitted). Therefore a third party's opinion regarding ION's possible infringement is more appropriate for the subjective recklessness inquiry rather than for objective recklessness. Focusing only on ION's asserted defenses, the Court does not find them objectively baseless.

4. The '038 Patent

The Court construed an ASPD as a device capable of controlling the vertical and horizontal position of the seismic streamer. (Doc. No. 120 p. 46.) ION's litigation defense for the '038 Patent was that DigiFIN was not an ASPD because the DigiFIN could not be commanded to steer a streamer to a particular depth and lateral position so as to maintain a specified array shape. (Trial Tr. 3499:15-3500:2.) ION further argued that it believed its system did not consist of a master controller for issuing vertical and horizontal positioning commands to **each** ASPD for maintaining a specified array geometry. The Court finds and holds that this was a reasonable defense.

5. ION's Invalidity Defenses

ION's defenses at trial were lack of enablement, anticipation and obviousness. The Court considered ION's defenses above in ION's Rule 59 Motion for New Trial on Invalidity Under 35

U.S.C. §§ 102 and 103. (Doc. No. 550.) Though the Court does not find for ION on invalidity, its arguments are not objectively baseless. Therefore, the Court finds no objective recklessness.

B. Subjective Prong

Because the Court finds no objective recklessness, the threshold standard, it need not evaluate the jury's finding of subjective recklessness for reasonableness. WesternGeco must prove both subjective and objective recklessness by clear and convincing evidence. Since WesternGeco has not proven objective recklessness by clear and convincing evidence, the Court finds no willful infringement.

X. EXCEPTIONAL

WesternGeco has filed a Motion to Find this Case Exceptional Under Section 285 and for Attorneys' Fees. (Doc. No. 554.) "The court in exceptional cases may award reasonable attorney fees to the prevailing party." 35 U.S.C. § 285. The award of attorneys' fees serves as a "deterrent[] to blatant, blind, willful infringement of valid patents." *Mathis v.* Spears, 857 F.2d 749, 754 (Fed. Cir. 1988). The first step is to decide whether the case is exceptional by clear and convincing evidence within the meaning of § 285. *Beckman Instruments, Inc. v. LKB Produkter AB*, 892 F.2d 1547, 1551 (Fed. Cir. 1989). Second, if the case is deemed exceptional, the Court must determine whether an award of fees is appropriate and, if so, in what amount. *Highmark, Inc. v. Allcare Health Mgmt. Sys., Inc.*, 687 F.3d 1300, 1308 (Fed. Cir. 2012).

To find a case exceptional, there must be some "material inappropriate conduct related to the matter in litigation, such as willful infringement, fraud or inequitable conduct in procuring the patent, misconduct during litigation, vexatious or unjustified litigation, conduct that violates Fed. R. Civ. P. 11, or like infractions." *Brooks Furniture Mfg., Inc. v. Dutailier Int'l, Inc.*, 393 F.3d 1378, 1381 (Fed. Cir. 2005). "Litigation misconduct generally involves unethical or

unprofessional conduct by a party or his attorneys during the course of adjudicative proceedings." *Highmark*, 687 F.3d. at 1315-16. Further, a lawyer's conduct cannot be evaluated with the benefit of hindsight. *Christiansburg Garment Co. v. EEOC*, 434 U.S. 412, 421-22 (1978). If the court finds the case to be exceptional, then it can determine whether attorneys' fees are appropriate. *Beckman Instruments, Inc*., 892 F.2d at 1551. "[B]efore imposing sanctions under its inherent power, a court must make a specific finding that the sanctioned party acted in "bad faith."" *Maguire Oil Co. v. City of Houston*, 143 F.3d 205, 209 (5th Cir. 1998).

WesternGeco makes a number of arguments as to why the Court should find this case exceptional. Each will be discussed in turn, and ultimately, the Court finds that this case is not exceptional.

A. Willfulness

A finding of willfulness does not require a finding that a case is exceptional under § 285. *Brooktree Corp. v. Advanced Micro Devices, Inc*., 977 F.2d 1555, 1582 (Fed. Cir. 1992) (affirming district court decision declining to find a case exceptional despite a jury finding of willfulness due, in part, to the closeness of the willfulness question); *Laitram Corp. v. NEC Corp.*, 115 F.3d 947, 955 (Fed. Cir. 1997) (affirming district court's finding case not exceptional and denial of attorneys' fees despite jury's willfulness finding given infringer's presentation of a good faith defense against willfulness and substantial challenge to infringement). However, as discussed above, the Court found no willful infringement so this cannot be a factor in favor of finding the case exceptional.

B. Vexatious Litigation and Other Litigation Misconduct

Another criteria for declaring a case exceptional includes vexatious litigation and litigation misconduct. "Any attorney . . . who so multiplies the proceedings in any case

unreasonably and vexatiously may be required by the court to satisfy personally the excess costs, expenses, and attorneys' fees reasonably incurred because of such conduct." 28 U.S.C. § 1927. An exceptional case based on litigation misconduct is reserved for extreme cases. Such sanctions are an extraordinary remedy that should be "sparingly applied." *FDIC v. Calhoun*, 34 F.3d 1291, 1297 (5th Cir. 1994). A court "may not shift the entire financial burden of an action" under § 1927 "except when the entire course of proceedings were unwarranted and should neither have been commenced nor persisted in." *Calhoun*, 34 F.3d at 1297.

WesternGeco claims ION was a vexatious litigant because it asserted meritless defenses and counterclaims; used unnecessary tactics such as Hague requests during discovery; and filed repeated motions for reconsideration. According to WesternGeco, vexatious litigation tactics during trial included attempting to re-litigate infringement and inventorship and argue an irrelevant "own patent" defense. Further, vexatious tactics post-trial included new meritless defenses. However, the Court is not convinced that this conduct rises to the level of vexatious litigation or misconduct pursuant to § 1927. This was a complicated case that spanned many years and nearly a month of trial. ION initially had to defend itself against 163 claims of infringement, which would require a defense strategy that includes many filings, defenses, and arguments. The Court noted multiple times that the issues were close questions of law and fact. Furthermore, ION's defenses and counterclaims were hotly contested as evidenced by the long Memoranda and Orders issued by this Court. The Court has seen this case from its inception and does not find that ION's litigation conduct rises to the high level necessary to find this case exceptional.

XI. DAMAGES

ION moves for JMOL, new trial, or remittitur on damages. (Doc. No. 562.) ION claims that the $105.9 million award decided by the jury was based on two defective and overlapping damage models: lost profits and reasonable royalty. The jury awarded WesternGeco 100% of the lost profits it sought and 84% of the reasonable royalty it sought. This amounted to $93.4 million for lost profits and $12.5 million in reasonable royalty. "[A] decision on remittitur . . . is within the sound discretion of the trial court . . . and damages are set aside 'only upon a clear showing of excessiveness.' An excessive award exceeds the 'maximum amount calculable from the evidence.'" *Fractus, S.A. v. Samsung Elecs. Co.*, No. 6:09-cv-203, 2012 WL 2505741, at *22 (E.D. Tex. June 28, 2012).

A. Lost Profits

1. Foreign Infringement

ION argues that the lost profits award must be vacated because it is not based on the domestic acts of infringement in this case but on the revenues that WesternGeco estimated its overseas competitors received for their non-infringing uses of ION's equipment in ten seismic surveys performed in foreign waters. ION says to do so is not permitted by § 271(f) and would give improper extraterritorial effect to U.S. law. ION insists that it can only be liable for "supplying" the component and cannot extend to subsequent "making" or "using" of a device abroad. However, Section 271(f)(1) in whole states:

> Whoever without authority supplies or causes to be supplied in or from the United States all or a substantial portion of the components of a patented invention, where such components are uncombined in whole or in part, in such manner as to actively induce the combination of such components outside of the United States in a manner that would infringe the patent if such combination occurred within the United States, shall be liable as an infringer.

If ION were strictly held liable for supplying, then §271(f) would lose all its weight, allowing a loophole for manufacturers to export components for infringing uses abroad. The legislative history noted that § 271(f) was intended to prevent copiers from avoiding U.S. patents by supplying components of a patented product in this country so that the assembly of the components may be completed abroad. Patent Law Amendments, Pub.L. No. 98-622, 1984 U.S. Code Cong. & Admin. News (98 Stat.) at 5828. This section of the patent law amendment was proposed in response to the U.S. Supreme Court's decision in *Deepsouth Packing Co. v. Laitram Corp*., 406 U.S. 518 (1972), which created a loophole in prior patent law, allowing copiers to avoid liability for products patented in the United States, by shipping the patented components for combination in foreign countries. The Federal Circuit and district courts have repeatedly awarded lost profits under § 271(f) based on lost foreign sales. *See, e.g., Union Carbide Chems. & Plastics Tech. Corp. v. Shell Oil Co.,* 425 F.3d 1366, 1378 (Fed. Cir. 2005), *overruled on other grounds* (approving reliance on "foreign sales for the purpose of recovering additional damages under 35 U.S.C. § 271(f)(2)."); *W.R. Grace & Co.--Conn. v. Intercat, Inc.*, 60 F. Supp. 2d 316, 321 (D. Del. 1999) (holding "plaintiff is entitled to damages based on Intercat's international sales.").

Furthermore, while 35 U.S.C.A. § 271(a) limits infringing sales to those sales made within the United States, lost profits based on an accused infringer's sales of a patented product in a foreign country may be properly recoverable as an item of lost profits if the patentee can show "a reasonable probability that but for the infringement," it would have made the foreign sales that were made by the accused infringer. Such foreign sales are only proper to include in the damage calculus when there is an act of infringement occurring in the United States directly associated with the foreign sale, such as the making of the product in the United States, if the

predicates of § 271(f) can be met. 4 Annotated Patent Digest § 30:44. It was undisputed at trial that every DigiFIN that ION sold was made in and supplied from the United States. (*See, e.g.*, Trail Transcript 2788:22-2790:10.) Therefore, lost profits can appropriately be recovered from these infringing sales.

2. *Panduit* Test

Although not separately required, the *Panduit* factors support the jury's lost profits award. The *Panduit* test provides that to obtain profits on sales the patentee would have made but for the infringement, the patent owner must prove: (1) demand for the patented product; (2) absence of acceptable non-infringing substitutes, (3) his manufacturing and marketing capability to exploit the demand, and (4) the amount of the profit he would have made. *Panduit Corp. v. Stahlin Bros. Fibre Works, Inc.*, 575 F.2d 1152, 1156 (6th Cir. 1978).

The record evidence satisfies the *Panduit* test, which creates a presumption of "but for" causation when met. But before the *Panduit* factors are analyzed, the Court must address ION's argument that the *Panduit* test does not apply. ION proceeded before trial and during trial as if the *Panduit* test applied. Before trial, both parties agreed that the *Panduit* factors were appropriate. (Doc. No. 402 p. 6 ("Mr. Sims applied the methodological approach that all parties agree is appropriate by utilizing the *Panduit* factors.")) During trial, ION's damages expert, Mr. Gunderson, spent over an hour and a half explaining to the jury his analysis of the *Panduit* factors in this case. (*See, e.g.*, Trial Tr. 4665:16-4698:9, 4701:23-4742:5.) Even ION's actions aside, applying the *Panduit* factors was one appropriate means by which the jury could find lost profits. (Jury Instruction No. 19 ("it would have made the sales it says it lost but for the infringement.")

ION argues that even if the *Panduit* test is applicable, the factors are not met with sufficient evidence. The Court finds that WesternGeco presented sufficient evidence to prove each of the four prongs. First, ION conceded at trial that there was demand for the patented product. (Doc. No. 562 pp. 15-24; Trial Tr. 4669:9-4670:3.) Second, WesternGeco presented evidence regarding the Nautilus and eBird, which the jury could reasonably conclude were not acceptable, non-infringing alternatives available during the relevant time period. Third, WesternGeco presented evidence through Mr. Sims, who concluded that WesternGeco would have had 59 months of available capacity to perform the lost jobs, more than double the capacity required. (Trial Tr. 2266:5-2267:25, 2297:6-18, 2445:5-16.) Therefore, WesternGeco presented sufficient evidence for the jury reasonably to find that it had the capability to exploit the demand. Fourth, WesternGeco presented its lost profit calculation through the Customer Relationship Management ("CRM") database, which WesternGeco's damages expert, Raymond Sims, relied on in his calculations. ION argues the CRM was not reliable. However, the Court allowed the CRM into evidence and the jury had the opportunity to weigh the evidence. The *Panduit* factors were one way for the jury to find lost profits. Based on the evidence presented at trial, the jury could reasonably have found lost profits.

B. Reasonable Royalty

1. Double Counting

ION claims there was improper recovery of both measures of damages because a patentee may recover either lost profits or a reasonable royalty for each infringing act, but not both. *Lucent Technologies, Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1324 (Fed. Cir. 2009) ("Two alternative categories of infringement compensation are the patentee's lost profits and the reasonable royalty he would have received through arms-length bargaining."). ION claims the

jury was instructed in such a way that they could award both a reasonable royalty and lost profits for the same acts of infringement. However, the jury instructions were clearly worded to avoid double counting:

> If you find that WesternGeco has established infringement, WesternGeco is entitled to at least a reasonable royalty to compensate it for that infringement. If you find that WesternGeco has not proved its claim for lost profits, or has proved its claim for lost profits for only a portion of the infringing sales, then you must award WesternGeco a reasonable royalty for all infringing sales for which it has not been awarded lost profits damages.

(Jury Instruction No. 20.) The jury instruction is the exact wording of the Model Patent Jury Instructions provided by the Federal Circuit Bar Association:

> If you find that [patent holder] has established infringement, [patent holder] is entitled to at least a reasonable royalty to compensate it for that infringement. If you find that [patent holder] has not proved its claim for lost profits, or has proved its claim for lost profits for only a portion of the infringing sales, then you must award [patent holder] a reasonable royalty for all infringing sales for which it has not been awarded lost profits damages.

(Model Patent Jury Instruction p. 88.) ION did not object to this jury instruction at trial and even if it had, the instructions are worded clearly to avoid double counting.

2. Apportionment

ION argues that the reasonable royalty found by the jury fails to apportion the damages to account for the value of WesternGeco's patented improvement. ION argues that a reasonable royalty may be calculated on the sale of a product provided that the royalty reflects only the contribution of the patented technology, not the entire value of the product. ION claims WesternGeco's patents offer an improvement to existing technology rather than a revolutionary invention. At trial, on behalf of WesternGeco, Mr. Sims applied an analytical approach to quantifying the value of the patented technology. ION had the opportunity thoroughly to cross examine Mr. Sims at trial and the jury could make its own determinations of his credibility.

3. Marking

ION also argues it was erroneous for the Court to deny ION's requested marking instruction, allowing the jury to award excessive damages. When a patentee fails to show either that it marked or was not required to mark, the patentee is precluded from recovering damages for any infringement that occurred prior to the date the alleged infringer was notified of the infringement. ION claims that, because Mr. Sims's testimony on the reasonable royalty included damages for infringement prior to the date of actual notice, the Court's failure to instruct on marking resulted in an improper award of damages. This Court has already considered and rejected ION's arguments regarding a marking instruction. (Doc. No. 562 p. 32; Doc. No. 508 p. 5; Doc. No. 530 p. 24.) ION has not presented new evidence that would require the Court to overturn its previous decisions.

XII. PREJUDGMENT INTEREST AND POST-DISCOVERY DAMAGES

A. Prejudgment Interest

WesternGeco has filed a Motion for Prejudgment Interest and Post-Discovery Damages. (Doc. No. 553.) ION does not dispute that prejudgment interest is appropriate, and both parties agree that the prejudgment interest should be compounded annually. The Supreme Court has interpreted 35 U.S.C. § 284[1] to mean that "prejudgment interest should ordinarily be awarded" in patent infringement cases. *Gen. Motors Corp. v. Devex Corp.*, 461 U.S. 648, 655 (1983). The only dispute is at what rate the interest is calculated. WesternGeco claims that the prejudgment interest should be awarded at the Texas Statutory Rate.[2] ION argues that the prime rate should be

[1] "Upon finding for the claimant the court shall award the claimant damages adequate to compensate for the infringement . . . together with interest and costs as fixed by the court." 35 U.S.C. § 284.

[2] The Texas Statutory Rate is: (1) the prime rate as published by the Board of Governors of the Federal Reserve System on the date of computation; (2) five percent a year if the prime rate as published by the Board of Governors of the Federal Reserve System described by Subdivision (1) is less than five percent; or (3) 15 percent a year if the prime rate as published by the Board of Governors of the Federal Reserve System described by Subdivision (1) is more than 15 percent." Tex. Fin. Code Ann. § 304.003 (West).

used. The Federal Circuit has held that "[a] trial court is afforded wide latitude in the selection of interest rates, and may award interest at or above the prime rate." *Uniroyal, Inc. v. Rudkin-Wiley Corp.*, 939 F.2d 1540, 1545 (Fed. Cir. 1991) (affirming an award of prejudgment interest at the prime rate). *See also Bio-Rad Laboratories, Inc. v. Nicolet Instrument Corp.*, 807 F.2d 964, 969 (Fed. Cir. 1986) ("The rate of prejudgment interest and whether it should be compounded or uncompounded are matters left largely to the discretion of the district court."); *Paper Converting Mach. Co. v. Magna-Graphics Corp.*, 745 F.2d 11, 24, 223 USPQ 591, 600 (Fed. Cir. 1984); *Gyromat Corp. v. Champion Spark Plug Co.*, 735 F.2d 549, 557, 222 USPQ 4, 9–10 (Fed. Cir. 1984); *Railroad Dynamics, Inc. v. A. Stucki Co.*, 727 F.2d 1506, 1520, 220 USPQ 929, 942 (Fed. Cir. 1984); *Lam, Inc. v. Johns-Manville Corp.*, 718 F.2d 1056, 1066, 219 USPQ 670, 676 (Fed. Cir. 1983). In exercising that discretion, however, the district court must be guided by the purpose of prejudgment interest, which is "to ensure that the patent owner is placed in as good a position as he would have been had the infringer entered into a reasonable royalty agreement" and permits the patentee to recover "the forgone use of the money between the time of infringement and the date of the judgment." *Devex*, 461 U.S. at 655-56.

"Courts have recognized that the prime rate best compensates a patentee for lost revenues during the period of infringement because the prime rate represents the cost of borrowing money, which is "a better measure of the harm suffered as a result of the loss of the use of money over time."" *IMX, Inc. v. LendingTree, LLC*, 469 F. Supp. 2d 203, 227-28 (D. Del. 2007) (*citing Mars, Inc. v. Conlux USA Corp.*, 818 F.Supp. 707, 720-21 (D.Del.1993), aff'd, 16 F.3d 421, 1993 WL 516659 (Fed. Cir. 1993). Other courts have found that "[t]he prime rate, compounded quarterly, is a conservative, middle-of-the road approach that takes into account normal market fluctuations." *NTP Inc. v. Research in Motion, Ltd.*, 270 F. Supp. 2d 751, 763 (E.D. Va. 2003)

amended, CIV.A. 3:01CV767, 2003 WL 22746080 (E.D. Va. Aug. 5, 2003). Therefore, the Court finds that the prime rate is the appropriate rate to be used in prejudgment interest. Since the parties have reached agreement, the interest will be compounded annually. Prejudgment interest should be awarded on both the lost profits and the royalty portions of the damages awarded for patent infringement. The interest should be awarded from the date of infringement to the date of judgment. ION is instructed to submit appropriate calculations to the Court within ten days.

B. Accounting

At the hearing on February 21, 2013, the Court ordered ION to submit its post-trial accounting because of a concern that ION's executive chairman and former CEO, Robert Peebler, was not truthful during his trial testimony. On August 13, 2012, Mr. Peebler testified under oath to the jury that ION had stopped selling DigiFIN after the Court's June 29, 2012 entry of summary judgment regarding Claim 18 of the '520 Patent. At the hearing, the Court asked ION if Mr. Peebler's testimony was truthful. ION's response was that ION Geophysical Inc. had not, but that ION Dubai, a foreign subsidiary of the Defendant, had.

ION filed its post-trial accounting which described two "sales" that occurred in September 2012. (Doc. No. 620.) ION argues that one of the "sales" was a delivery required under a March 2012 contract with Shanghai Offshore Petroleum Geophysical Corporation ("SOPGC"). ION argues that since the contract was signed in March 2012, before the Court's ruling, the sale also occurred in March 2012. The other sale was a sale and supply that occurred outside of the United States. The transaction was between ION S.a.r.l., a Luxemburg company, and a foreign buyer, where DigiFINs were shipped from Dubai to places outside of the United States. This is very troubling to the Court despite ION's argument that such "sales" were not

sales in violation of the Court's order. At trial, WesternGeco had records of sales up until May 2011. These new records show that 1,353 more units were sold by ION than were disclosed at the time of trial. It also appears that ION relocated all of its U.S. manufactured DigiFIN units to Norway the week after the Court's summary judgment decision.

The Court finds that WesternGeco is entitled to supplemental damages for ION's sales since May 2011. *See Stryker Corp. v. Davol, Inc.*, 234 F.3d 1252 (Fed. Cir. 2000) (affirming district court's decision that a court may award a successful patent plaintiff supplemental damages to compensate the plaintiff for any infringement occurring between the date of the jury's verdict and the date of the judgment.). Because the Court has only recently learned of the need for supplemental damages. WesternGeco is ordered to submit a motion regarding supplemental damages within 15 days.

XIII. COSTS

WesternGeco has filed a Motion for Costs in the amount of $535,542.03. (Doc. No. 555.) Local Rule 54.2, FRCP 54(d)(1), 35 U.S.C. § 284 and 28 U.S.C. § 1920[3] allows the prevailing party, to claim certain costs. The costs are "limited to relatively minor, incidental expenses." *Taniguchi v. Kan Pacific Saipan, Ltd.*, 132 S. Ct. 1997, 2006 (2012). A district court may decline to award costs enumerated in § 1920, but may not award costs not listed in the

[3] A judge or clerk of any court of the United States may tax as costs the following:
(1) Fees of the clerk and marshal;
(2) Fees for printed or electronically recorded transcripts necessarily obtained for use in the case;
(3) Fees and disbursements for printing and witnesses;
(4) Fees for exemplification and the costs of making copies of any materials where the copies are necessarily obtained for use in the case;
(5) Docket fees under section 1923 of this title;
(6) Compensation of court appointed experts, compensation of interpreters, and salaries, fees, expenses, and costs of special interpretation services under section 1828 of this title.
28 U.S.C.A. § 1920 (West)

statute. *Crawford Fitting Co. v. J. T. Gibbons, Inc.*, 482 U.S. 437, 441 (1987). The specific costs are discussed below.

A. Costs Relating to Fees of the Clerk and Docket Fees

Costs relating to fees of the clerk and docket fees may be recovered as authorized by 28 U.S.C. § 1920(1) & (5). (Doc. No. 555, Ex. 2.) WesternGeco claims it incurred $350.00 in these fees and ION does not dispute this amount.

B. Costs Relating to Fees for Service of Summons and Subpoenas

WesternGeco has withdrawn its request for subpoena costs.

C. Costs Relating to Depositions and Transcripts

Video and written transcripts are recoverable under 28 U.S.C. §1920(2). WesternGeco claims it incurred $399,052.36 in costs relating to depositions and transcripts. (Doc. No. 555, Ex. 4.) ION argues that a substantial part of that requested cost is not recoverable. ION claims that the costs are bloated with incidentals, which are generally not recoverable.

1. Incidental Fees

First, ION argues that costs for synchronizing videotaped depositions ($25,340) are not recoverable. The Court agrees. Other courts have found that video synchronization is not a necessity but for the convenience of counsel. *See, e.g., U.S. ex rel. Gonzalez v. Fresenius Med. Care N. Am.*, 761 F. Supp. 2d 442, 450 (W.D. Tex. 2010) aff'd sub nom. *Gonzalez v. Fresenius Med. Care N. Am.*, 689 F.3d 470 (5th Cir. 2012) ("The Court finds, however, that video synchronization was a convenience to the parties and not a necessity."). The Fifth Circuit has held that "charges incurred merely for the convenience of one party's counsel should not be taxed to the other." *Fogleman v. ARAMCO (Arabian Am. Oil Co.)*, 920 F.2d 278, 286 (5th Cir. 1991). WesternGeco should not be able to recover for costs of video synchronizing.

Second, ION contests expenses for RealTime transcription of depositions ($11,911). Courts may award RealTime costs when it is found to be a necessary cost. *Kinzenbaw v. Case LLC*, 05-1483, 2006 WL 1096683 (Fed. Cir. Apr. 26, 2006). This was a complex and lengthy trial. ION filed more than twenty briefs during trial which required responses from WesternGeco. The Court finds that RealTime was a necessary cost. Therefore, WesternGeco can recover the costs of RealTime.

Third, ION disputes fees charged by court reporters for the original and **one copy** of deposition transcripts ($56,653.85). ION argues that, without a showing of necessity, extra copies of deposition transcripts are not recoverable. However, other courts in this district have held that an original and one copy are a "basic cost" and a necessity. *Krohn v. David Powers Homes, Inc.*, CIV. A. H-07-3885, 2009 WL 2605284 (S.D. Tex. Aug. 21, 2009). "Whether a deposition or copy was necessarily obtained for use in the case is a factual determination to be made by the district court." *Fogleman v. ARAMCO (Arabian Am. Oil Co.)*, 920 F.2d 278, 285 (5th Cir. 1991). The Court finds that this cost is recoverable.

Fourth, ION contests deposition costs in fees for original and one copy of depositions provided on an expedited basis ($88,394.36). Expedited costs are not taxable unless prior court approval is obtained or the special character of the litigation necessitates expedited receipt of the transcript. Expedited costs seem minimal based on third party invoices (Doc. No. 579 p. 7 n. 5 ("Two expedition charges (totaling $2996.78) are itemized.")), and the complicated nature of this case necessitated expediting depositions. WesternGeco may recover for these costs.

Lastly, ION contests fees for rough draft charges ($1,968). WesternGeco has made no argument that it should recover for rough draft charges, so the requested amount should also be

reduced by that amount ($1,968). Therefore, the costs of video synchronizing ($25,340) and rough drafts of depositions ($1,968), which totals $27,308, are unrecoverable as incidental costs.

2. Video Files of Depositions

WesternGeco requests costs for obtaining video files of depositions ($51,361.07). Video depositions are generally recoverable under § 1920(2) and the Court will allow it here.

3. Deposition Transcription Costs Related to Fugro

ION contests the costs that relate to WesternGeco's claims related to Fugro. WesternGeco took 51 depositions in this case and of those, 18 related directly to Fugro. WesternGeco claims it only seeks its own costs from ION, not Fugro's costs, (Doc. No 585 p. 9) so the Court will allow this recovery.

4. Trial Transcripts Related to Fugro

ION also contests trial transcription costs related to Fugro. ION estimates that Fugro's witness examinations account for about 15% of the transcript. WesternGeco claims that it has already removed Fugro time. The Court finds that WesternGeco may recover this cost since it does not include Fugro time.

D. Costs Relating to Witnesses

WesternGeco originally sought $9,864.49 in witness fees. After objections from ION, WesternGeco reduces the amount sought to $7,147.97, which ION does not dispute.

E. Costs Relating to Exemplification, Copies, and Printing

WesternGeco seeks $109,036.93 in costs relating to exemplification, copying and printing. ION disputes a portion of these charges. First, ION disputes $26,010.94 in costs for processing documents produced to ION, including charges for litigation support, creating databases, and creating TIFF images. WesternGeco does not make an argument for costs

associated with litigation support or creating databases and has not met its burden to demonstrate these costs are necessary. WesternGeco may not recover the $26,010.94.

Second WesternGeco seeks to recover $28,002.54 in costs processing documents produced by ION, namely converting ION's documents into another format to make them searchable. ION did produce a large number of documents, but this cost was for the convenience of attorneys rather than a necessity. Therefore, WesternGeco may not recover the $28,002.54.

Third, WesternGeco requests $32,522 in costs of up to six copies of a variety of documents used for trial. WesternGeco does not segregate the costs nor make an argument for why it should recover these costs. ION estimates that the costs of copies for trial should be reduced by 15%, or $4,878.30, which the Court accepts.

Fourth, WesternGeco seeks $5,099 in costs for office supplies. These are incidentals not enumerated in the statute and therefore not recoverable.

F. Costs Relating to Court-Appointed Experts

WesternGeco requests $14,100 for the costs of the Court's appointed expert. ION argues that a portion of this cost should be attributable to Fugro, but WesternGeco states that this is the cost to WesternGeco, not Fugro's cost. Therefore, the Court finds this is an appropriate amount for WesternGeco to recover.

G. Conclusion

In conclusion, from WesternGeco's requested amount of $535,542.03, the following amounts should be subtracted because they are not recoverable costs:

- Less $3,138.25 for WesternGeco's withdrawn subpoena costs;
- Less $25,340 for video synchronization;
- Less $1,968 for rough drafts of transcripts;
- Less $2,716.52 for WesternGeco's reduction of costs related to witnesses;
- Less $26,010.94 in costs for processing documents produced to ION, including charges for litigation support, creating databases, and creating TIFF images;

- Less $28,002.54 in costs processing documents produced by ION, namely converting ION's documents into another format to make them searchable;
- Less $4,878.30 for multiple copies;
- Less $5,099 in costs for office supplies.

WesternGeco can recover costs in the amount of $438,388.48.

XIV. PERMANENT INJUNCTION; ONGOING ROYALTY

WesternGeco has filed a Motion for a Permanent Injunction or, in the Alternative, an Ongoing Royalty. (Doc. No. 558.) Related to this motion, ION has filed a Motion to Compel Production of Documents From WesternGeco. (Doc. No. 609.)

A. Motion to Compel

ION asks the Court to compel production of the Fugro license agreement ("Fugro license"), letters to ION's customers and potential customers seeking to begin negotiations to enter into additional licensing agreements, and all related documentation ("Licensing Documents"). ION claims this information is directly relevant to WesternGeco's request for a permanent injunction, the scope of any such injunction, and the terms and rate for any post-judgment royalty in lieu of an injunction. ION argues that WesternGeco's permanent injunction is premised on exclusivity, which may be undermined by its license to Fugro and offer to license the patents to ION's other customers.

WesternGeco has worked with Fugro to provide a redacted version of the agreement to ION. (Doc. No. 611, Ex. 14.) The Court finds that this is sufficient. Discovery after trial is the exception and not the rule. ION has not shown the need for an exception. The Motion to Compel is denied.

B. Motion for a Permanent Injunction or, in the Alternative, an Ongoing Royalty (Doc. No. 558)

After the jury issued its verdict, ION's CEO announced ION's intention to "challenge the verdict," and stated that ION "ha[s] sufficient inventory of DigiFIN available to satisfy customer need." (Doc. No. 558, Ex. 1.) Media reports confirmed that, notwithstanding the verdict, "DigiFIN [] will remain available for sale." (Doc. No. 558, Ex. 3.) WesternGeco moves the Court to enter a permanent injunction or, in the alternative, award an ongoing royalty for the sales of ION's infringing products. (Doc. No. 558.) The Court finds that a permanent injunction is proper in this case.

1. Legal Standard

Courts have discretion to grant injunctive relief "in accordance with the principles of equity to prevent the violation of any right secured by patent, on such terms as the court deems reasonable." 35 U.S.C. § 283. By virtue of the Supreme Court's decision in *eBay*, a patentee must satisfy the well-established four-factor test for injunctive relief before a court may grant a permanent injunction:

> (1) that it has suffered an irreparable injury; (2) that remedies available at law, such as monetary damages, are inadequate to compensate for that injury; (3) that, considering the balance of hardships between the plaintiff and defendant, a remedy in equity is warranted; and (4) that the public interest would not be disserved by a permanent injunction.

eBay Inc. v. MercExchange, L.L.C., 547 U.S. 388, 391 (2006).

2. Permanent Injunction

The Court finds that a permanent injunction is proper. ION stated multiple times to the Court that "[f]ollowing the Court's finding of infringement, ION immediately ceased selling DigiFIN." (Doc. No. 577 p. 22; Doc. No. 559 p. 24.) ION represented the same to the jury:

> Q. Sir, after you were found to infringe . . . You didn't stop offering those products for sale, did you?
> A. In fact, we have no sold that product since then.
> ***
> Q. So when did you stop selling DigiFIN, sir?
> A. Well, I said stop selling – yea, we – when that happened, when the – when the Court made that ruling.
> Q. So you made a business decision that at that point, you would no longer sell DigiFIN?
> A. Yea. Until the case is solved – resolved. We are not done yet.

(Trial Tr. 4491:15-4492:1.) However, ION's post trial accounting reveals that this assertion was false and ION did sell more DigiFIN after the Court's ruling and even after trial. The Court finds these misstatements deeply troubling.

ION claims that a September 2012 sale was not a sale because the contract for the infringing product occurred in March 2012. The Court cannot accept this thinly veiled excuse. It also appears that ION shipped DigiFIN abroad from the United States to ION Dubai, which continues to make sales. The Court need not delve into whether this conduct infringed § 271(f) at this time because the misleading statements and the September 2012 sale are enough for the Court to find that all four factors of *MercExchange, L.L.C.* weigh in favor of a permanent injunction. First, WesternGeco has suffered injury and may continue to suffer injury since ION has shown that it will continue to infringe. Second, since ION has not followed the Court's order, no remedy at law can fully compensate WesternGeco besides an injunction. Third, the Court does not find particular hardships to ION. Fourth, there is no evidence that an injunction will disserve the public. In fact, ION's disregard for the Court's order warrants a permanent injunction to support the public's interest in maintaining a strong patent system.

XV. CONCLUSION

For the reasons discussed above, the Court finds that:

1. ION's Partial Motion to Dismiss for Lack of Subject Matter Jurisdiction (Doc. No. 565) is **DENIED;**

2. ION's Rule 59 Motion for New Trial on Invalidity Under 35 U.S.C. §§ 102 and 103 (Doc. No. 550) is **DENIED;**

3. ION's Request for Findings and Conclusions on Enablement and, Alternatively, Motion for New Trial (Doc. No. 552) is **DENIED;**

4. ION's Renewed Motion for Judgment as a Matter of Law and Alternative Motion for New Trial Regarding Non-Infringement (Doc. No. 556) is **DENIED;**

5. ION's Motion for New Trial on Infringement Under 35 U.S.C. § 271(f)(2) (Doc. No. 557) is **DENIED;**

6. ION's Motion for JMOL and New Trial Due to Incorrect Claim Construction (Doc. No. 561) is **DENIED;**

7. ION's Motion for Entry of Findings and Conclusions of No Willful Infringement, Renewed Motion for Judgment as a Matter of Law of No Willful Infringement, and Alternative Motion for New Trial (Doc. No. 559) is **GRANTED;**

8. WesternGeco's Motion for Willfulness and Enhanced Damages (Doc. No. 560) is **DENIED;**

9. WesternGeco's Motion to Find this Case Exceptional Under Section 285 and for Attorneys' Fees (Doc. No. 554) is **DENIED;**

10. ION's Motion for JMOL, Motion for New Trial on Damages alternatively Motion for Remittitur (Doc. No. 562) is **DENIED;**

11. WesternGeco's Motion for Prejudgment Interest and Post-Discovery Damages (Doc. No. 553) is **GRANTED;**
    a. Prejudgment interest will be calculated at the prime rate, compounded annually. ION is ordered submit calculations on the jury award within ten days.
    b. Supplemental damages are proper for ION's sales after May 2011. WesternGeco is ordered to submit a motion regarding supplemental damages within 15 days.

12. WesternGeco's Motion for Costs (Doc. No. 555) is **GRANTED in part and DENIED in part;**
    a. WesternGeco may recover costs in the amount of $438,388.48

13. ION's Motion to Compel Production of Documents From WesternGeco (Doc. No. 609) is **DENIED;**

14. WesternGeco's Motion for a Permanent Injunction or, in the Alternative, an Ongoing Royalty (Doc. No. 558) is **GRANTED.**

IT IS SO ORDERED.

SIGNED this 19th day of June, 2013.



KEITH P. ELLISON
UNITED STATES DISTRICT JUDGE

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF TEXAS
HOUSTON DIVISION

WESTERNGECO L.L.C.,	§	
	§	
Plaintiff,	§	
	§	
v.	§	**CASE NO. 4:09-CV-1827**
	§	
ION GEOPHYSICAL CORPORATION, et al.,	§	
	§	
	§	
Defendants.	§	

MEMORANDUM AND ORDER

In a pretrial conference held on Friday, July 13, 2012, the Court addressed a number of motions to exclude and motions in limine, resolving some and holding others over for trial. The Court now writes to resolve Defendants' Motions to Exclude the Expert Testimony of Raymond Sims (Doc. Nos. 250, 256), as well as certain Motions in Limine filed by the parties. (Doc. Nos. 384, 385, 386.)

I. MOTIONS TO EXCLUDE RAYMOND SIMS

Defendants ION Geophysical Corporation ("ION") and Fugro-Geoteam, Inc.; Fugro Geoteam AS; Fugro Norway Marine Services AS; Fugro, Inc.; Fugro (USA), Inc.; and Fugro Geoservices, Inc. (collectively, "Fugro") have filed motions seeking to exclude the expert testimony of Raymond Sims. (Doc. Nos. 350, 356.) Mr. Sims is the damages expert for Plaintiff WesternGeco L.L.C. ("WesternGeco" or "WG"). Defendants challenge Mr. Sims's damages analysis as to reasonable royalty damages and as to lost profits. After considering Defendants' motions, all responses thereto, oral arguments, and

the applicable law, the Court concludes that Defendants' motions must be granted in part and denied in part.

Federal Rule of Evidence 702 provides that a qualified witness may offer opinion testimony if it will help the trier of fact to understand the evidence or determine a fact in issue. Fed. R. Evid. 702. Courts are charged with the "gatekeeping function" of ensuring that expert testimony is both reliable and relevant. *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579, 589, 592-93, 597 (1993). Rule 702 requires that (1) expert testimony be based on sufficient facts or data, (2) it be the product of reliable principles and methods, and (3) those principles and methods be applied reliably to the facts of the case. Fed. R. Evid. 702.

In *Daubert*, the Supreme Court provided several nonexclusive factors to guide courts in evaluating the reliability of a methodology. Those factors include whether the theory can be and has been tested; whether the theory has been subjected to peer review and publication; the theory's known or potential rate of error; the existence and maintenance of standards and controls; and whether the theory is generally accepted. 509 U.S. at 593-94. Otherwise admissible expert testimony may be excluded under Rule 403. *Daubert*, 509 U.S. at 595; *see also* Fed. R. Evid. 403. The proponent of the expert testimony bears the burden of proving, by a preponderance of the evidence, "that the expert's findings and conclusions are based on the scientific method, and, therefore, are reliable." *Moore v. Ashland Chem. Inc.*, 151 F.3d 269, 276 (5th Cir. 1998) (en banc).

A. Reasonable Royalty

After considering Mr. Sims's reasonable royalty analysis, the Court is troubled by his application of the hypothetical license negotiation. Originally listed as one of many

reasonable royalty factors in *Georgia-Pacific Corp. v. U.S. Plywood Corp.*, 318 F. Supp. 1116, 1120 (S.D.N.Y. 1970), the hypothetical negotiation has evolved into an umbrella over all the other factors. *Powell v. Home Depot U.S.A.*, 663 F.3d 1221, 1239 (Fed. Cir. 2012) (amount of the reasonable royalty that should be awarded upon a "reasoned hypothetical negotiation analysis"); *State Indus., Inc. v. Mor-Flo Indus., Inc.*, 883 F.2d 1573, 1580 (Fed. Cir. 1989) ("The determination of a reasonable royalty, however, is based not on the infringer's profit margin, but on what a willing licensor and licensee would bargain for at hypothetical negotiations on the date infringement started."). The Federal Circuit has indicated, at times, that the hypothetical negotiation approach is not strictly mandatory. *See Wordtech Sys. v. Integrated Network Solutions, Inc.*, 609 F.3d 1308, 1319 (Fed. Cir. 2010) ("A reasonable royalty can be calculated from an established royalty, the infringer's profit projections for infringing sales, or a hypothetical negotiation between the patentee and infringer based on the factors in *Georgia-Pacific*."). However, other Federal Circuit cases, including one *en banc* decision, have indicated that it is a mandatory approach. *See Fujifilm Corp. v. Benum*, 605 F.3d 1366, 1372 (Fed. Cir. 2011) ("To determine a reasonable royalty, a jury must find the royalty that would have been agreed to in a hypothetical negotiation between a willing licensee and willing licensors at the time infringement began."); *Rite-Hite Corp. v. Kelley Co.*, 56 F.3d 1538, 1554 (Fed. Cir. 1995) (en banc) ("The royalty may be based upon an established royalty, if there is one, or if not, upon the supposed result of hypothetical negotiations between the plaintiff and defendant.") (citation omitted). In the present case, neither party appears to challenge the appropriateness or applicability of the hypothetical negotiation approach generally.

Turning to the law governing the principles of a hypothetical negotiation, the Federal Circuit has characterized the approach thus:

> The methodology encompasses fantasy and flexibility; fantasy because it requires a court to imagine what warring parties would have agreed to as willing negotiators; flexibility because it speaks of negotiations as of the time infringement began, yet permits and often requires a court to look to events and facts that occurred thereafter and that could not have been known to or predicted by the hypothesized negotiators.

Fromson v. Western Litho-Plate & Supply Co., 853 F.2d 1568, 1575 (Fed. Cir. 1988). In a hypothetical negotiation—as opposed to real-life license negotiations—a number of facts are deemed to be irrebuttably known. One is that the patent is valid, another is that the patent is infringed. *See, e.g.*, *Lucent Techs., Inc. v. Gateway, Inc.*, 580 F.3d 1301, 1325 (Fed. Cir. 2009), *cert. denied*, 130 S. Ct. 1334 (2010) ("The hypothetical negotiation also assumes that the asserted patent claims are valid and infringed."); *Studiengesellschaft Kohle m.b.H. v. Dart Indus., Inc.*, 862 F.2d 1564, 1570 (Fed. Cir. 1988) (citing trial court's recognition that, in hypothetical negotiations, there is a presumption of "an unquestionably valid patent").

Given that backdrop, the Court cannot assume, as WG's counsel has urged, that ION, in a hypothetical negotiation with WG, would have taken a risk on the infringement question and agreed to a huge, profit-eliminating (and even revenue eliminating) royalty obligation for itself. As a matter of law, no such risk can be taken in a hypothetical negotiation in which infringement is deemed known. With knowledge of validity and infringement, such a financially catastrophic agreement would have been totally unreasonable. The court in *Georgia-Pacific* acknowledged the proposition that negotiators in hypothetical negotiations must be deemed to act reasonably: "The primary inquiry, often complicated by secondary ones, is what the parties would have agreed

upon, if both were reasonably trying to reach an agreement." *Georgia-Pacific*, 318 F. Supp. at 1121 (quoting *Faulkner v. Gibbs*, 199 F.2d 635, 639 (9th Cir. 1952) (internal quotation marks omitted). Even putting case law aside, any unreasonable negotiating approach must be rejected, since the ultimate goal is to arrive at what the statute terms a "reasonable royalty." Mr. Sims's methodology inherently arrives at an unreasonable result, and one to which no reasonable negotiator for ION could possibly have agreed. The Court therefore grants ION's motion to exclude Mr. Sims's testimony on reasonable royalty.

B. Lost Profits

The Court separately considers Mr. Sims's analysis as to lost profits. To recover lost profits, a patentee must "show a reasonable probability that 'but for' the infringing activity, the patentee would have made the infringer's sales." *Crystal Semiconductor Corp. v. TriTech Microelectronics Int'l, Inc.*, 246 F.3d 1336, 1353 (Fed. Cir. 2001) (emphasis added). Considering whether such "but-for" causation exists "requires a reconstruction of the market, as it would have developed absent the infringing product, to determine what the patentee 'would . . . have made.'" *Grain Processing Corp. v. Am. Maize-Prods. Co.*, 185 F.3d 1342, 1350 (Fed. Cir. 1999) (quoting *Grain Processing Corp. v. Am. Maize-Prods. Co.*, 979 F. Supp. 1233, 1236 (N.D. Ind. 1997)). In *Panduit Corp. v. Stahlin Bros. Fibre Works, Inc.*, the Sixth Circuit developed a four-factor test for determining causation. 575 F.2d 1152 (6th Cir. 1978). The test provides that a patentee seeking to recover lost profits on sales that the patentee would have made absent infringement most show: (1) demand for the patented product; (2) absence of acceptable noninfringing alternatives; (3) the patentee's manufacturing and marketing capability to

exploit the demand; and (4) the amount of profit that the patentee would have made. *Id. at* 1156.

In considering WG's lost profits, Mr. Sims evaluated a number of surveys that ION's customers conducted using ION's DigiFIN product. He then reconstructed the market to determine whether WesternGeco would have gotten bids to perform those surveys absent ION's alleged infringement. Out of all surveys performed using DigiFIN, Mr. Sims identified a small subset which he believes WG would have been awarded in his reconstructed market. Mr. Sims then proceeded to consider each of the four *Panduit* factors, ultimately concluding that there was a high demand for steerable streamers, that noninfringing alternatives would not have been acceptable as to this subset of surveys, and that WG had the manufacturing and marketing capability to exploit the demand for steerable streamers.

The Court has considered Defendants' objections to this methodology. Those include their contentions that Mr. Sims's focus on ION's customers' surveys was improper, that he failed adequately to reconstruct the market, that his analysis utilized unreliable data, and that some of the particular surveys included in his analysis could not have been won by WesternGeco, and therefore may not be included as lost profits.

After considering these arguments, the Court is persuaded that the issues raised by Defendants are properly addressed on cross-examination and through Defendants' own presentation of evidence. Mr. Sims applied the methodological approach that all parties agree is appropriate by utilizing the *Panduit* factors. In applying that approach, he went through each of the four factors with a detailed explanation of why he reached his particular conclusions. Although there are undoubtedly other approaches that Mr. Sims

could have taken, Defendants have failed to persuade the Court that his methodology or approach was improper under the *Daubert* standard.

Notwithstanding the general admissibility of Mr. Sims's analysis, there is one survey that concerns the Court from a *Daubert* standpoint. This survey, referred to by Fugro as the Lukoil/Vanco Ghana survey, was one of the surveys that Mr. Sims opined would have been won by WG in the reconstructed market. However, the manager of WesternGeco's CRM database has agreed that WG did not submit a tender for this survey. (Deposition of Samantha Graycon, Doc. No. 356-E at 103:15-104:17.) Without having submitted a tender on this survey, WG cannot legitimately argue—and it would be confusing and unhelpful to the jury to allow Mr. Sims to contend—that this survey would have been won by WG in a reconstructed market. Thus, while the Court finds that Defendants' other challenges are properly addressed at trial, it cannot allow Mr. Sims to testify that the Lukoil/Vanco Ghana survey should be considered a lost profit survey. As such, this survey may not be included in Mr. Sims's analysis at trial.

II. MOTIONS IN LIMINE

The Court addressed a handful of the parties' Motions in Limine during the pretrial conference held on Friday, July 13. The Court now considers those unresolved motions that the parties have indicated may present issues during voir dire or opening statements.

A. ION's Second Motion in Limine

In its second Motion in Limine, ION asks the Court to exclude "[a]ny reference to a presumption of validity of any patent-in-suit." (Doc. No. 384 at 4.) ION contends that "reference to any presumption is not evidence but instead a procedural device without

any independent evidentiary value to be weighed against ION's evidence of invalidity." (*Id.*) The Court disagrees. It is beyond dispute that patents-in-suit must be presumed valid. 35 U.S.C. § 282(a). This presumption is inextricably linked to Defendants' burden to prove invalidity by clear and convincing evidence. The Court finds that the presumption of validity is not only appropriate information for the jury, but that it is helpful. ION's second Motion in Limine therefore is denied.

B. ION's Third Motion in Limine

In its third Motion in Limine, ION seeks to exclude "[a]ny mention of or reference to any indemnity obligation between ION and the Fugro Defendants." (Doc. No. 384 at 5.) ION bases this on the fact that WesternGeco has no standing to assert any right to indemnity on the part of the Fugro Defendants. WG has indicated that it does not intend to assert any rights on behalf of Fugro, but instead that it seeks to introduce the indemnity relationship as it is related to willfulness. Reference to the indemnity agreement for this purpose is not per se improper, and the Court will not exclude it in advance of trial. If it becomes clear during the course of trial that WesternGeco seeks to introduce this evidence for an improper purpose, the Court will consider excluding it at that time.

C. WesternGeco's First Motion in Limine

In its first Motion in Limine, WesternGeco seeks to preclude Defendants from disputing a number of facts that WG contends were resolved on summary judgment. (Doc. No. 386 at 1.) The Court ruled on a portion of this motion during the pre-trial conference, and will hold other portions over until trial. However, the Court wishes to clarify certain issues prior to trial.

WesternGeco moves to preclude Defendants from disputing that the DigiFIN includes an active streamer positioning device ("ASPD") capable of controlling the vertical and horizontal position of a seismic streamer. Defendants respond that, because the Court's finding on this matter was made in the context of denying Defendants' motions for summary judgment, and not in the context of granting a motion in favor of WG, this issue remains a factual question for trial. The Court does not agree. When the Court considered this issue at the summary judgment phase, it was in the context of a two-fold inquiry. The first question was whether the DigiFIN includes an ASPD. (Doc. No. 365 at 91.) The second was whether the DigiFIN includes an array geometry tracking system. (*Id.*) In order to infringe the claim at issue, the Court explained, the DigiFIN had to have both of these components. (*Id.*)

The Court held that the DigiFIN *did* have the first component, an ASPD: "The Court is persuaded, in light of the foregoing evidence, that the DigiFIN includes an ASPD capable of controlling the vertical and horizontal position of a seismic streamer." (*Id.* at 92.) As to whether DigiFIN included the second component, an array geometry tracking system, the Court found that a genuine issue of material fact existed. (*Id.* at 93.). Thus, the Court has held, conclusively, that the DigiFIN includes an ASPD, and this issue may not be relitigated. This portion of WesternGeco's first motion in limine is granted.

WesternGeco also moves for a ruling in limine that the term "predicting position" in claim 16 of the '017 patent does not "require something occurring at a future time." (Doc. No. 386 at 2.) As Defendants point out, the Court refused to construe this term and instead held that it has its ordinary meaning. (Transcript of December 15, 2011 Hearing,

Doc. No. 395-B at 55:17-20.) This portion of WesternGeco's first Motion in Limine is denied.

D. WesternGeco's Fourth Motion in Limine

WesternGeco's fourth Motion in Limine seeks to exclude "prior art not relied upon as a basis for invalidity by Defendants' experts." (Doc. No. 386 at 5.) At the pretrial conference on July 13, the Court held portions of this motion over for trial. However, as to the "Workman Reference," the Court writes to clarify that testimony about this patent will not be excluded. The Court considered the Workman Reference as a potential source of prior art in its most recent Memorandum and Order (Doc. No. 365 at 25-28), concluding that a factual issue remains with respect to the Workman reference as prior at. Allowing Defendants' experts to opine about the Workman Patent as it relates to the '520 Patent would not prejudice WesternGeco and would be helpful to the jury. WesternGeco's fourth Motion in Limine therefore is denied in part.

The remainder of WesternGeco's Motions in Limine need not be resolved prior to trial.

E. Fugro's First Motion in Limine

In its First Motion in Limine, Fugro asks the Court to preclude WG from eliciting fact or expert testimony, attempting to admit documentary evidence, or otherwise arguing before the jury that bodies of water that lie more than 12 miles outward from the U.S. coastline, the high seas (including the Chukchi Sea), or the United States' Exclusive Economic Zone (including the EEZ in the Gulf of Mexico) are U.S. territories or possessions. (Doc. No. 385 at 1-3.) Fugro also asks the Court to preclude WG from

stating, implying, or attempting to admit evidence to prove the presence of a Fugro ship within 12 miles of the U.S. coastline constitutes infringement. (*Id.*)

WG has indicated that it agrees to this motion, in part. WG avers that it will not argue before the jury that bodies of water more than 12 miles outward of the coastline are U.S. territories. WG disagrees with the latter half of the motion in which Fugro seeks to preclude WG from stating or implying that certain activities constitute infringement. WG contends that these requests are premature and inappropriate, and that certain Fugro activities, including coming to port in the United States, are circumstantial evidence of infringement.

In ruling in favor of Defendants on a portion of their motion for summary judgment of non-infringement of WG's "Zajac" patent's system claims, the Court explained that WG's evidence of Defendants' surveys outside of the United States, evidence of their use of U.S. ports, and unsupported inferences that Defendants may have conducted tests in the United States while they were in transit to the survey locations, did not give rise to a genuine issue of material fact. (Doc. No. 365 at 87.) On that basis, the Court concluded that neither Fugro nor ION made or used the patented system in the United States.

In light of the Court's rulings on summary judgment, WG may not state or imply to the jury that activities described in the Court's opinion—such as coming to port in the United States or conducting surveys outside of the United States—constitute infringement as to WG's method claims or the Zajac patent's "systems" claims. WG may discuss these activities to offer context as to how Fugro and ION operated, but testimony implying that these activities are themselves infringing is impermissible.

III. CONCLUSION

In light of the foregoing, the Court concludes that Defendants' Motions to Exclude the Expert Testimony of Raymond Sims must be **GRANTED IN PART** and **DENIED IN PART**. The parties' Motion in Limine must be **GRANTED IN PART** and **DENIED IN PART**.

IT IS SO ORDERED

SIGNED at Houston, Texas, on this the 16th day of July, 2012.



KEITH P. ELLISON
UNITED STATES DISTRICT JUDGE

US006691038B2

(12) **United States Patent**
Zajac

(10) **Patent No.: US 6,691,038 B2**
(45) **Date of Patent: Feb. 10, 2004**

(54) **ACTIVE SEPARATION TRACKING AND POSITIONING SYSTEM FOR TOWED SEISMIC ARRAYS**

(75) Inventor: **Mark Zajac**, Katy, TX (US)

(73) Assignee: **WesternGeco L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 174 days.

(21) Appl. No.: **09/882,952**

(22) Filed: **Jun. 15, 2001**

(65) **Prior Publication Data**

US 2003/0208320 A1 Nov. 6, 2003

(51) **Int. Cl.**[7] **G01V 1/38**
(52) **U.S. Cl.** **702/14**; 367/20
(58) **Field of Search** 702/14, 16; 367/16, 367/72, 20, 19, 17; 114/244, 245, 246

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,676,183	A	*	6/1987	Conboy	114/245
4,729,333	A	*	3/1988	Kirby et al.	114/244
4,890,568	A	*	1/1990	Dolengowski	114/246
5,771,202	A		6/1998	Bale et al.	367/20
5,784,335	A	*	7/1998	Deplante et al.	367/72
5,790,472	A		8/1998	Workman et al.	367/19
5,920,828	A	*	7/1999	Norris et al.	702/14
6,011,752	A		1/2000	Ambs et al.	367/17
6,028,817	A		2/2000	Ambs	367/16
6,418,378	B1	*	7/2002	Nyland	702/14

FOREIGN PATENT DOCUMENTS

EP	0613025 A1	*	8/1994	G01V/1/38
EP	0909701 A2		4/1999	G01V/1/38
GB	2122562 A	*	1/1984	B63B/21/66
GB	WO 98/28636		7/1998	G01V/1/38
WO	WO 00/20895		4/2000	G01V/1/38
WO	WO 01/16623		3/2001	G01V/1/38

OTHER PUBLICATIONS

Morice et al., SPE 63136: 4D–Ready Towed–Streamer Data and the Foinaven Benchmark, Oct. 2000, pp. 1–7.

Marine Lateral Steering Advance Unveiled, Petroleum Engineer International, Hart Publications, US, vol. 73, No. 8, Aug. 2000, p. 113.

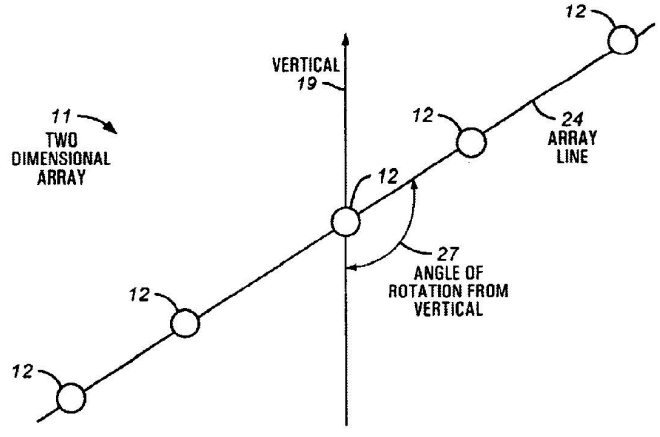
* cited by examiner

Primary Examiner—John Barlow
Assistant Examiner—Victor J. Taylor
(74) *Attorney, Agent, or Firm*—Madan, Mossman & Sriram, P.C.

(57) **ABSTRACT**

A method and apparatus comprising an active control system for a towed seismic streamer array that enables any relative positional control of any number of towed seismic streamers. The streamer positions are controlled horizontally and vertically using active control units positioned within the seismic array. The three component (x, y, z) position of each streamer element, relative to the vessel and relative to each other is controlled, tracked and stored during a seismic data acquisition run. The present invention enables a seismic array to be maneuvered as the towing vessel maintains course, enables maintenance of specific array position and geometry in the presence of variable environmental factors and facilitates four-dimensional seismic data acquisition by sensing and storing the position of the array and each array element with respect to time.

50 Claims, 6 Drawing Sheets



WESTERNGECO
09-CV-01827
PTX005

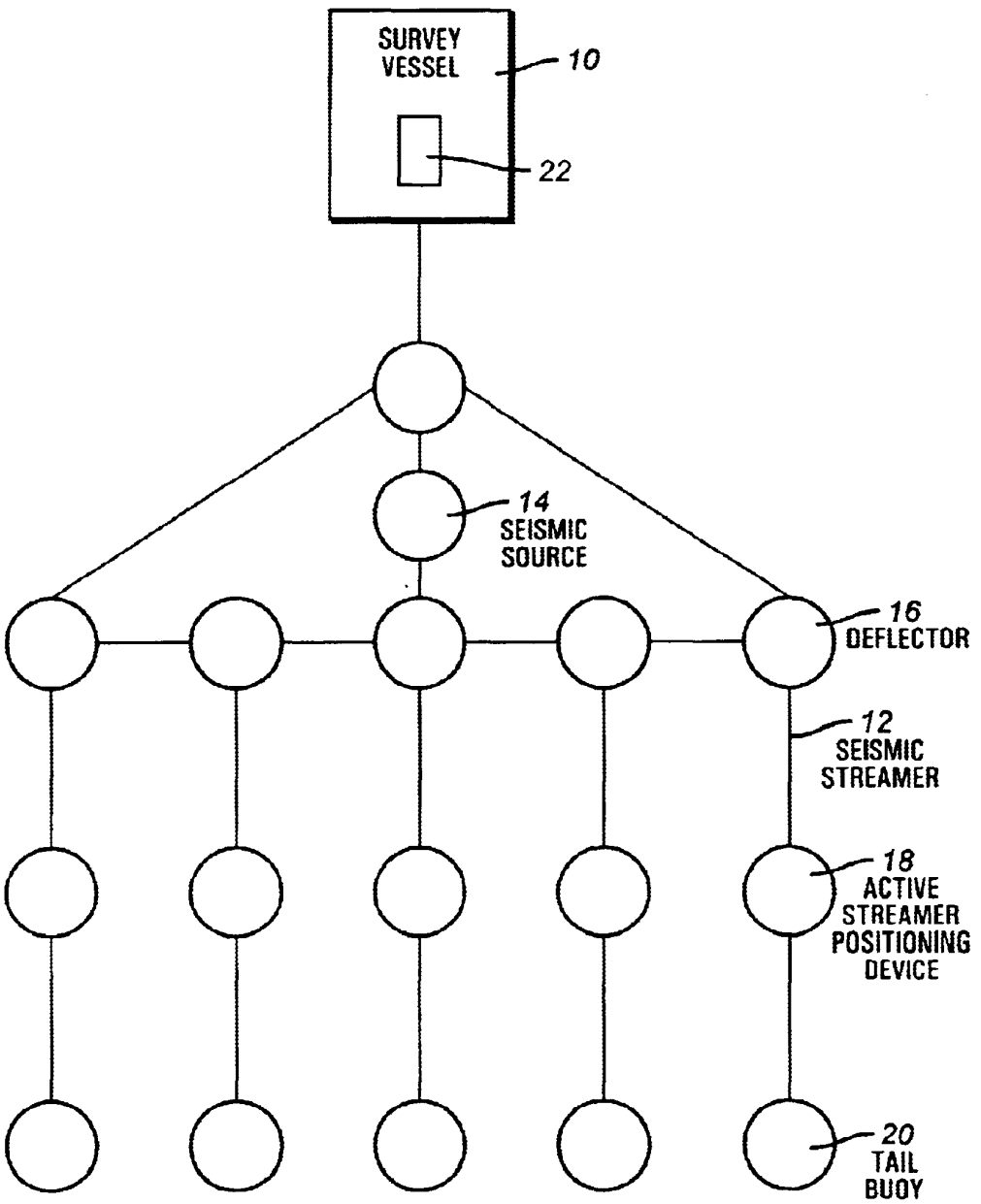

SURVEY VESSEL
10
22
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SEISMIC SOURCE
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DEFLECTOR
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SEISMIC STREAMER
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ACTIVE STREAMER POSITIONING DEVICE
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TAIL BUOY

FIG. 1

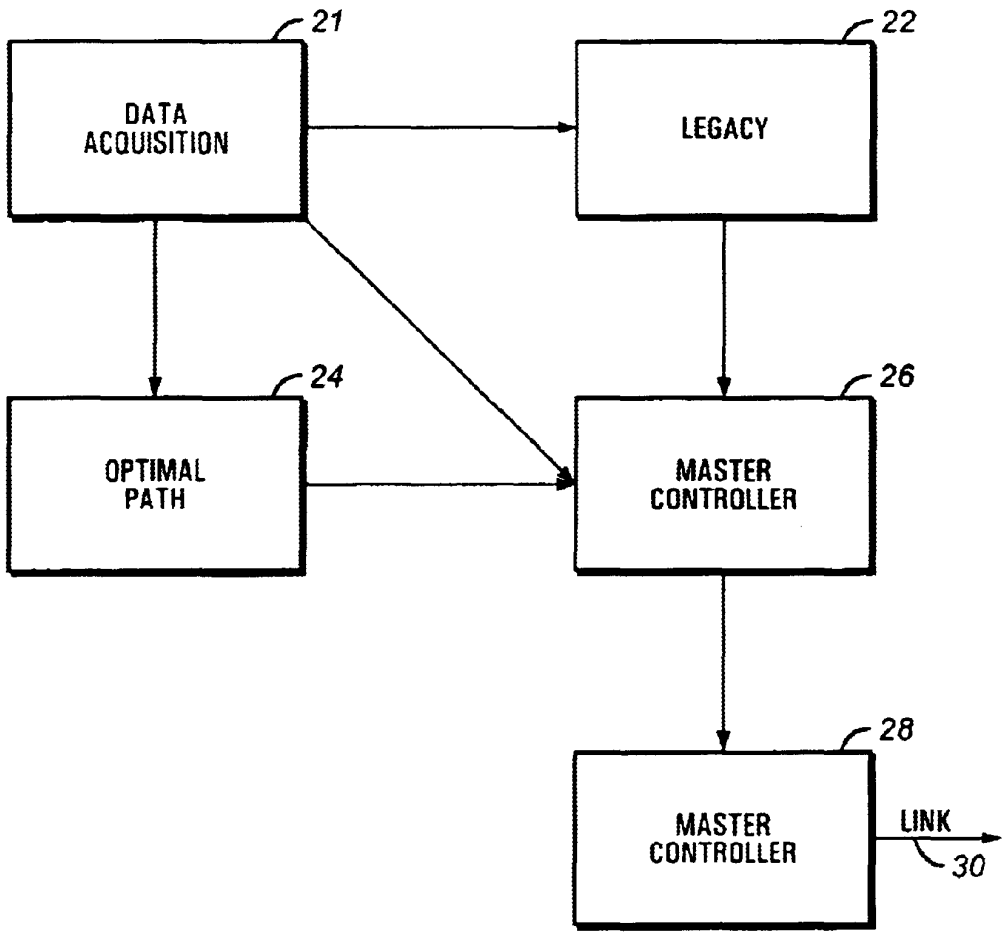

21
DATA ACQUISITION
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LEGACY
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OPTIMAL PATH
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MASTER CONTROLLER
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MASTER CONTROLLER
LINK
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FIG. 2

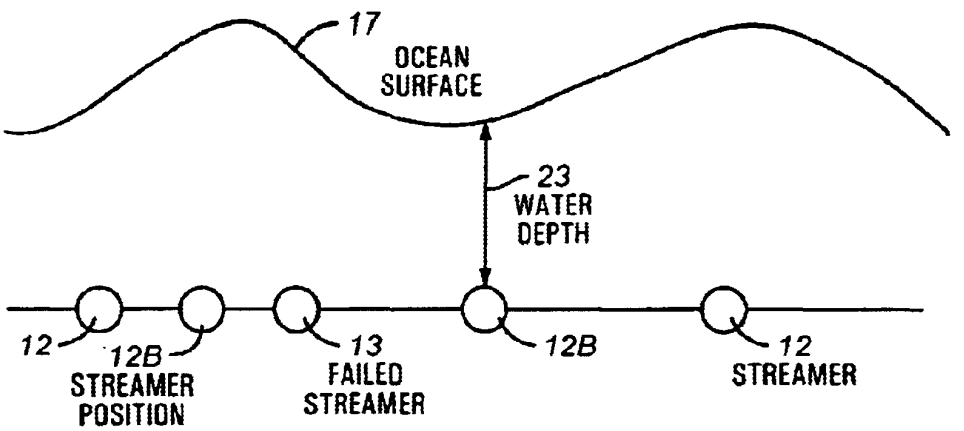

17
OCEAN
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DEPTH
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12B
STREAMER
POSITION
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FAILED
STREAMER
12B
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STREAMER

FIG. 3A

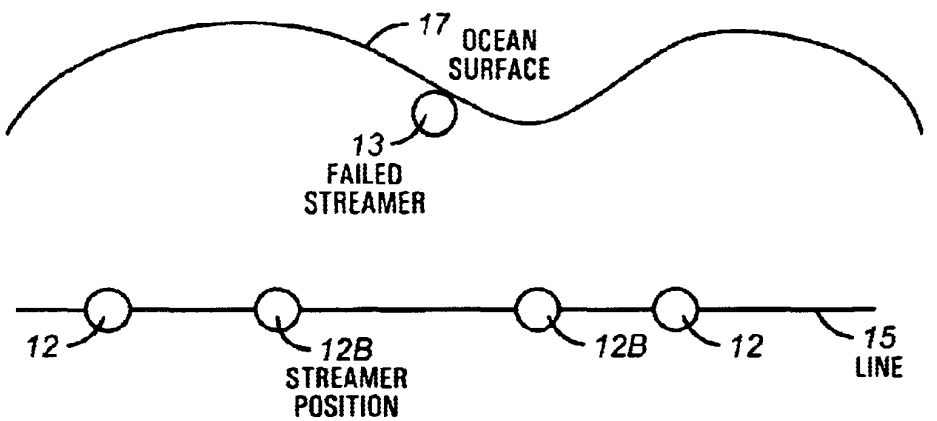

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13
FAILED
STREAMER
12
12B
STREAMER
POSITION
12B
12
15
LINE

FIG. 3B

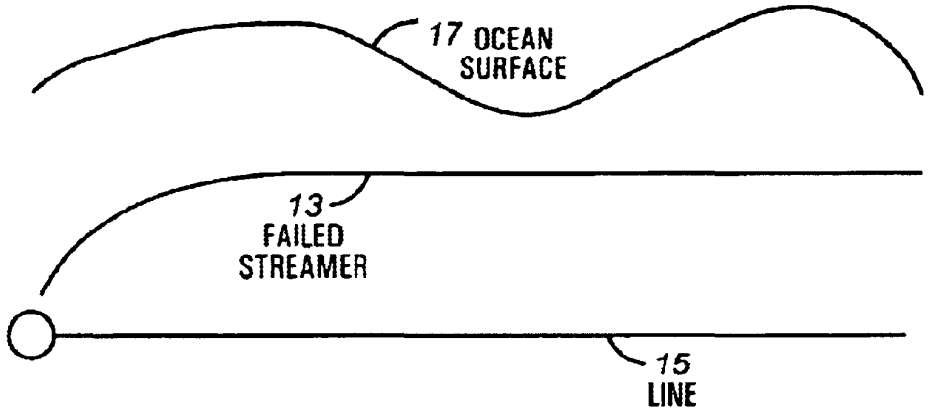

17 OCEAN SURFACE
13 FAILED STREAMER
15 LINE

FIG. 3C

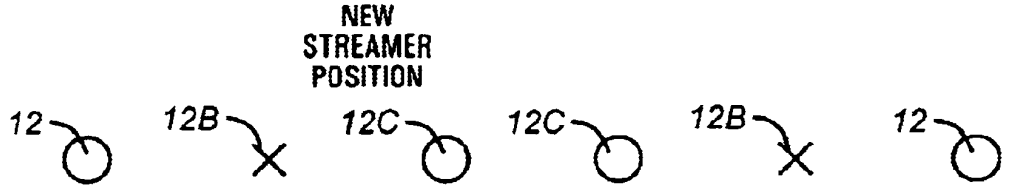

NEW STREAMER POSITION
12
12B
12C
12C
12B
12

FIG. 3D

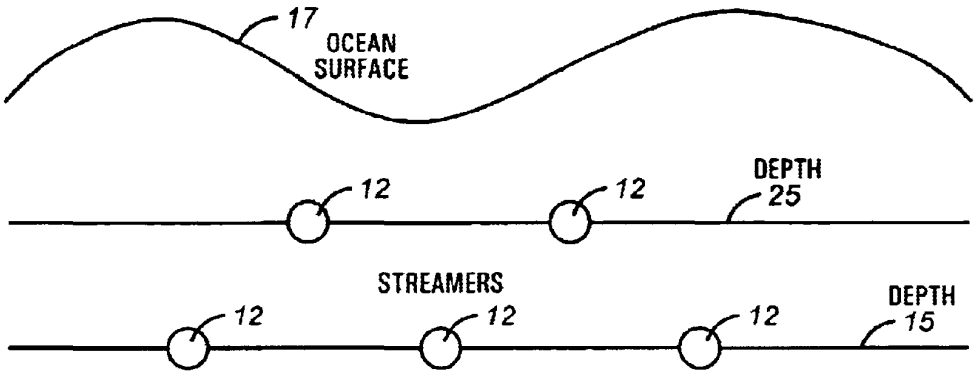

17
OCEAN
SURFACE
12
12
DEPTH
25
STREAMERS
12
12
12
DEPTH
15

FIG. 4

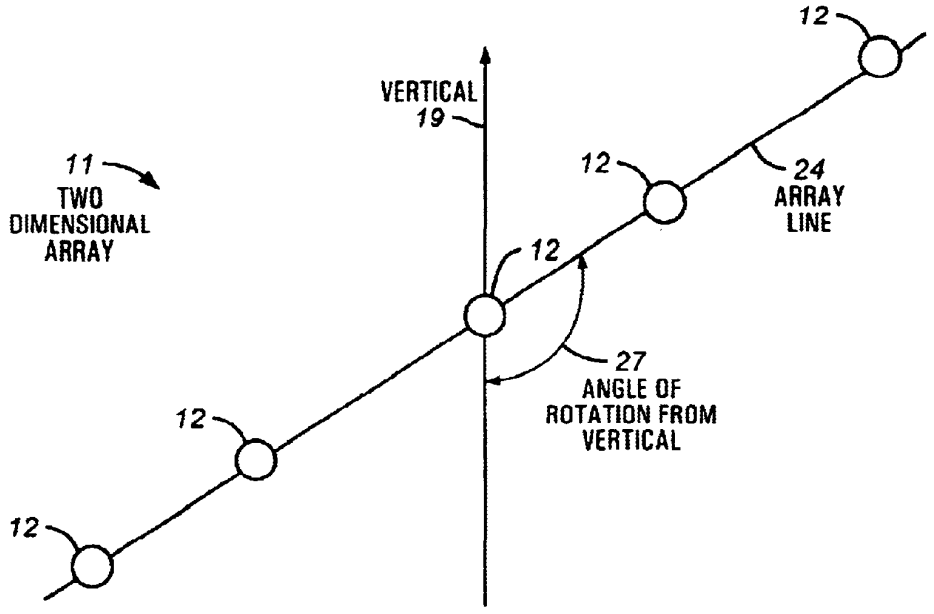

12
VERTICAL
19
11
TWO
DIMENSIONAL
ARRAY
12
24
ARRAY
LINE
12
27
ANGLE OF
ROTATION FROM
VERTICAL
12
12

FIG. 5

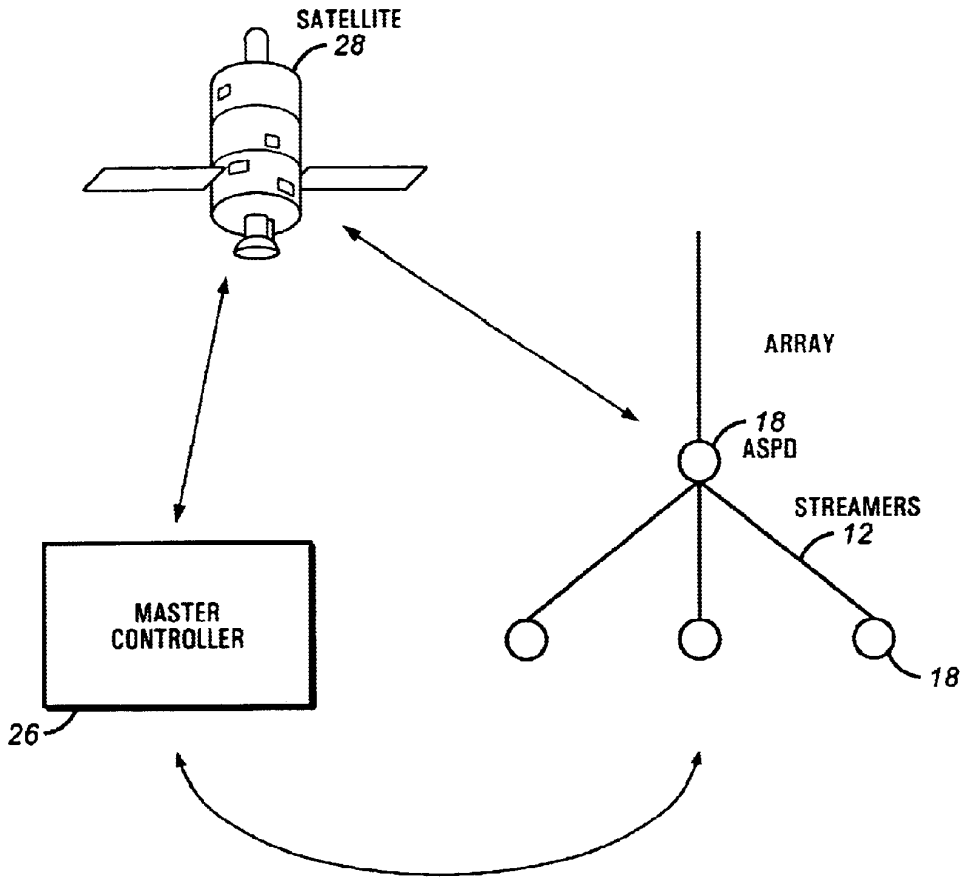

SATELLITE
28
ARRAY
18
ASPD
STREAMERS
12
18
MASTER
CONTROLLER
26

FIG. 6

ACTIVE SEPARATION TRACKING AND POSITIONING SYSTEM FOR TOWED SEISMIC ARRAYS

CROSS REFERENCE TO RELATED APPLICATIONS

This is related to U.S. patent application Ser. No. 09/603,068, filed on Jun. 26, 2000 entitled "Optimal Paths for Marine Data Collection" which is hereby incorporated herein by reference. This is related to U.S. patent application Ser. No. 09/658,846, filed on Nov. 11, 2000 entitled "Neural Network Prediction of Seismic Streamer Shape" which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to a method and apparatus for controlling sea borne seismic data acquisition systems comprising an array of streamers, and in particular to the relative vertical and horizontal positioning of seismic streamers forming a seismic array towed behind a sea borne towing vessel.

DESCRIPTION OF THE RELATED ART

The related art discloses a wide variety of towed marine seismic tracking and positioning systems and methods typically comprising one or more seismic streamers and/or one or more seismic sources. Some these seismic tracking and positioning systems and methods utilize a main or host vessel and/or other-associated unmanned vessels or vehicles to tow the seismic array. Typically towing is controlled or guided by a central control system. The known marine seismic tow tracking and positioning systems and methods are comprised of apparatuses such as seismic hydrophone streamers and attached floats, paravanes, and/or buoyant members. Typically each streamer and control apparatus is connected to the host vessel by a line, cable or tether. Considerable towing power is required of a host vessel to tow existing seismic streamer systems, cables and interconnecting sensing devices. A typical host vessel is capable of towing a plurality of tow vessels and/or carrying a plurality of seismic streamers or arrays and associated support apparatus on the vessel's deck awaiting deployment.

One such tracking and positioning system for positioning and control of marine seismic streamers is taught in the international application published under the Patent Cooperation Treaty (PCT), International Publication Number WO 00/20895, international publication date Apr. 13, 2000. A marine seismic system with independently power tow vehicles is taught by U.S. Pat. No. 6,028,817. A control device for controlling the position of a marine seismic streamer is taught in the international application published under the Patent Cooperation Treaty (PCT), International Publication Number WO 98/28636, international publication date Jul. 2, 1998.

With known seismic cable tracking and positioning systems, the location and spacing of system components is limited by the type, size, and length of cables used and by the characteristics of the towing vehicles and other control devices utilized by the known seismic tracking and positioning systems. Typically, the plurality of towed seismic streamers form an array which is towed behind the host vessel. Typically, changing the configuration of such a towed streamer array, comprised of known components is a complex, cumbersome, time-consuming operation and can often become somewhat unwieldy. Moreover, the spatial and temporal positioning capability of known towing and tracking and positioning systems is limited.

There is no known seismic tracking and positioning system that enables independent and relative positioning of individual seismic streamer array elements, for example "birds", seismic streamers, comprising sensors, sources and depth and position controls, for example to configure, manipulate and/or maintain a desired geometry of and within a towed seismic streamer array. There is also no known seismic tracking and positioning system that enables relative positioning and manipulation of an entire seismic streamer array. There is also no known tracking and positioning system that enables specification of a plurality of diverse acquisition and ancillary non-acquisition array geometries that facilitates run-time maintenance, retrieval and deployment of a towed seismic array. Moreover, there is no known seismic tracking and positioning system that tracks the geometry of the seismic streamer array and the relative positions of the individual streamers comprising array elements with respect to time and with respect to the earth's latitude and longitude so that towed seismic array data acquisition runs are repeatable, thereby enabling acquisition of four-dimensional geophysical data (x, y, z, time).

Thus, there is a need for a seismic acquisition tracking and positioning system that overcomes the above-mentioned shortcomings of known seismic data acquisition tracking and positioning systems. There has been a long-felt need for an efficient and effective towed marine seismic tracking and positioning system having system components that are easily and reliably tracked, controlled and positioned. There has also been a long-felt need for seismic data acquisition towing, tracking and positioning systems to provide sufficient positioning flexibility to enable efficient, accurate, and repeatable control of the relative and absolute horizontal and vertical positions of towed arrays and the streamers, sensors and sources within a towed array during seismic data acquisition.

SUMMARY OF THE INVENTION

The present position invention provides a method and apparatus for an active tracking and positioning system for a towed seismic streamer array. The present invention recognizes and addresses the previously mentioned shortcomings, problems and long-felt needs associated with known towed seismic tracking and positioning systems. The present invention provides a solution to the aforementioned problems and provides satisfactory meeting of those needs in its various embodiments and equivalents thereof.

The active tracking and positioning system of the present invention provides a method and apparatus that enables relative positional control of any number of towed seismic streamers. The present invention controls streamer positions horizontally and vertically using active control units positioned on each streamer within the seismic array. The three component (x, y, z) position of each streamer element, relative to the vessel, relative to each other and relative Earth coordinate latitude and longitude is controlled, tracked and stored with respect to time during each seismic data acquisition run. This stored data is referred to as legacy data. Environmental factors (wind speed, currents, temperature, salinity, etc), and maneuverability data for the streamers and geometry of the towed array (cable diameter, array type, deployed configuration, vessel type, device type, etc.) for the seismic data acquisition run are also sensed with respect to time and stored as legacy data. The acquisition of legacy data enables repetition of seismic data acquisition runs.

The present invention provides active streamer positioning devices (ASPDs) as control elements, which are installed on individual streamers comprising an array, alternatively at the diverter position, streamer head, along the length of the streamer or at the tail of the streamer. One or more ASPD is employed on each seismic array. The active control elements are also installed at the head tow point of an array, at the head or tail of one or more streamers comprising an array, and/or along any streamer comprising an element of an array. The control elements attached at the streamer head are alternatively detachably connected to the front of the array to facilitate detachment and removal of a single streamer element from the array during a data acquisition run.

The apparatus and method of the present invention enables a seismic array to be maneuvered as the towing vessel maintains it desired course or as the towing vessel maneuvers to assist in the repositioning of the array during a seismic data acquisition run. The present invention may alternatively employ methods such as force vectoring, active wings, or other known means of changing the spatial or temporal, that is the vertical or z-depth position of the streamer elements comprising the array. In addition to enabling change in the spatial and temporal positions of individual array elements, the tracking and positioning system enables maintenance of specific array position and geometry in the presence of variable environmental factors. In this mode, the control system of the present invention adjusts the lifting force of the streamer to accommodate variations in the tide, real-time current velocity and direction, water depth, towed speed, cable maneuverability, towed direction and water salinity, and salinity variations, all of which may affect the buoyancy and position of the towed seismic array. The salinity of the water in which the array is towed may vary abruptly when a salt water towing operation passes by the mouth of a fresh water supply such as a river. The salinity may diminish considerably in the fresh water region near the mouth of a river, thereby requiring adjustment of the array towing forces to maintain desired array geometry and depth.

The present invention enables repeatable, four-dimensional seismic data acquisition by sensing and storing environmental data, temperature sensitive array maneuverability data and positional tracking data for a towed array and each individual element of the towed array with respect to time. The relative horizontal and vertical positioning of each seismic cable and energy source independent of the streamer attached to the array or streamer is controlled, monitored and stored, along with real-time environmental data during a seismic data acquisition operation. The composite stored data comprises legacy data for the data acquisition run. Thus, a seismic data acquisition run can be duplicated at a later date to reproduce the same array geometry and path during subsequent data acquisition runs, in the presence of varying environmental and maneuverability conditions. That is, a particular seismic data acquisition operation is repeatable based on the legacy data, thereby enabling repeatable four-dimensional data (x, y, z, time) gathering for multiple runs over a seismic target area. The present invention also enables implementation of non-acquisition ancillary array configurations such as augmented array geometry for collapsing or expanding an array during deployment or retrieval. The present invention also enables raising a single array element for retrieval from a deployed array during acquisition.

One array section or one streamer of an array section can be deflected out of the array geometry during a data acquisition run and vertically to the surface for detachment, retrieval and/or maintenance. The present invention also enables compensation for a failed or missing streamer. Streamers adjacent a failed or missing/removed streamer can be moved closer together to compensate for the failed or missing streamer array element with or without removal of the element. This enables repair and/or removal and replacement of such a failed array element during a seismic data acquisition run without interruption of the data acquisition run to repair and or replace the disabled streamer. Runtime removal of streamers and compensation for failed streamers enables continuation of data acquisition without causing the vessel and/or array to deviate from its planned data acquisition path.

It is time consuming, difficult and expensive to interrupt the towing vessel during a data acquisition run. Interruption for replacement or repair a streamer element in a data acquisition array and a subsequent attempt to duplicate array geometry and reposition the array and necessitates starting the vessel and array again at the exact location and array geometry where the run data acquisition run was interrupted. This process is difficult and time consuming, if not impossible. The present invention enables compensation for an array element and continuation of a data acquisition run during repair and replacement of the array streamer element.

The instant invention also enables configuring the towed array geometry to compensate for changing environmental and operational conditions that affect maneuverability. The array geometry can also be configured to increase or decrease the temporal resolution and spacing of the array to avoid ghost notching. Deployment and ancillary configurations are also provided wherein, for example, the width of an array may be increased to reduce chances of streamer tangling during deployment. The present invention also enhances in fill shooting where an optimal path has been selected. The present invention enables movement of the array in conjunction with movement of the vessel along an optimal in fill shooting path. The present invention individually controls positioning of the vessel and positioning of the array. Thus, the present invention also enables the towing vessel to account for a portion of the positioning along the selected optimal in fill path or data acquisition path and positioning of the array to account for the remainder of the positioning along the path. This division of positioning movements between the vessel and the array provides a more flexible and efficient positioning system for use during in fill shooting and/or other data acquisition positioning maneuvers.

In one aspect of the invention a seismic streamer array tracking and positioning system is presented comprising a towing vessel for towing a seismic array; an array comprising a plurality of seismic streamers; an active streamer positioning device (ASPD) attached to at least one seismic streamer for positioning the seismic streamer relative to other seismic streamers within the array; and a master controller for issuing positioning commands to each ASPD for maintaining a specified array geometry. In another aspect of the invention the apparatus further comprises an environmental sensor for sensing environmental factors which influence the path of the towed array. In another aspect of the invention the apparatus further comprises a tracking system for tracking the streamer positions versus time during a seismic data acquisition run and storing the positions versus time in a legacy database for repeating the positions versus time in a subsequent data acquisition; and an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run and storing the array

geometry versus time in a legacy database for repeating the array geometry versus time in a subsequent data acquisition run.

In another aspect of the invention the apparatus further comprises a master controller which compares the positions of the streamers versus time and the array geometry versus time to a desired streamer position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer position and array geometry versus time. In another aspect of the invention the apparatus further comprises a master controller that factors in environmental factors into the positioning commands to compensate for environmental influences on the positioning of the streamers and the array geometry.

In another aspect of the invention the apparatus further comprises a master controller which compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry. In another aspect of the invention the apparatus further comprises a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer. In another aspect of the invention the apparatus further comprises a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move a failed streamer out of the array. In another aspect of the invention the apparatus further comprises a monitor for determining the status of each streamer, wherein the master controller detaches a failed streamer from the array. In another aspect of the invention the apparatus further comprises an array geometry which comprises a plurality of streamers positioned at a uniform depth. In another aspect of the invention the apparatus further comprises array geometry comprising a plurality of streamers positioned at a plurality of depths for varying temporal resolution of the array.

In another aspect of the invention the apparatus further comprises an array geometry comprising a plurality of streamers positioned along a plane, wherein the plane is rotated at an angel theta with respect to the longitudinal axis of the array. In another aspect of the invention the apparatus further comprises an apparatus wherein the array geometry is tracked via satellite and communicated to the master controller.

In another aspect of the invention a method is provided for tracking and positioning a seismic streamer array comprising a towing vessel for towing a seismic array; providing a seismic streamer array comprising a plurality of seismic streamers; providing an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer; providing a master controller for issuing positioning commands to each ASPD and to the towing vessel for maintaining an optimal path, wherein the master controller further comprises a processor for calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field, and a streamer behavior prediction processor which predicts array behavior, wherein the master controller compensates for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path, wherein the master controller compensates for environmental and maneuverability factors in the positioning commands.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the accompanying drawings in which:

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition tracking and positioning system;

FIG. **2** is a schematic diagram for the preferred array geometry tracking and positioning system showing real-time and legacy data storage and acquisition;

FIGS. **3**A, **3**B, **3**C and **3**D illustrate a schematic diagram of a towed seismic streamer array showing deflection of a failed streamer to the surface and compensation for the failed streamer by adjacent streamers;

FIG. **4** is a schematic diagram of a towed seismic streamer array showing a alternative array geometry for increasing temporal resolution of the towed array;

FIG. **5** is a schematic diagram of a towed seismic streamer array showing rotation of the array about the longitudinal axis of the array; and

FIG. **6** is a schematic diagram showing the tracking and positioning communication path provided by the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

To one skilled in this art who has the benefit of this invention's realizations, teachings, disclosures, and suggestions, other purposes and advantages will be appreciated from the following description of preferred embodiments, given for the purpose of disclosure, when taken in conjunction with the accompanying drawings. The detail in these descriptions is not intended to thwart this patent's object to claim this invention no matter how others may later disguise it by variations in form or additions of further improvements.

Turning now to FIG. **1**, a seismic survey vessel **10** is shown towing a plurality of marine seismic streamers **12** that may, for instance be 3000 meters in length. The outermost streamers **12** in the array can be as much as 400 meters apart, resulting in a horizontal displacement between each streamer of 100 meters, in an equally-spaced array configuration. A seismic source **14**, typically an airgun or one or more array of airguns, is also shown towed behind the seismic survey vessel **10**.

As shown in FIG. **1**, at the front of each streamer **12** is shown a detachable deflector **16** and at the rear of every streamer is shown a detachable tail buoy **20**. In a preferred embodiment, a detachable, active streamer positioning device **18** (ASPD) can be supplemented or substituted for the deflector **16** and/or tail buoy **20**. The detachable deflector **16** is used to horizontally position the front end of the streamer nearest to the seismic survey vessel **10**. The tail buoy **20** creates drag at the backend of the streamer farthest away from the seismic vessel **10** and provides a platform for absolute positioning or relative positioning at the tail of the streamer. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly rectilinear shape of the seismic streamer **12** shown in FIG. **1**.

The rectilinear shape of the streamer can be maintained by the present invention to overcome side currents and tides which may affect the shape of the towed cable and cause it to deviate from a preferred rectilinear shape. A rectilinear shape is preferred to maintain array geometry for accurate and repeatable seismic data acquisition runs. Deviation from a rectilinear cable shape can cause undesirable variations in the data gathered from the array. The present invention enables sensing and correction of deviations is the preferred shape of a towed streamer array.

Located between the deflector **16** and the tail buoy **20** are a plurality of ASPDs **18**. Preferably the ASPDs **18** are both vertically and horizontally steerable. These ASPDs **18** may, for instance, be located at regular intervals along the individual streamers, such as every 200 to 400 meters. The vertically and horizontally steerable ASPDs **18** can be used to constrain and configure the shape of the seismic streamer **12** between deflector **16** and the tail buoy **20** in the vertical (z or depth) and horizontal (x, y) directions. The ASPDs **18** can be placed at the head end of a streamer, at the tail end of the streamer or at any place along the streamer in between the streamer head end and streamer tail end.

Turning now to FIG. **2**, in a preferred embodiment of the present invention, the control system for the ASPD **18** may be distributed between a master controller **26** located remotely on the towing vessel (or at any other location on land, sea or satellite) and a group of one or more separate controllers **18** built into one or more ASPDs **18**, which is positioned on streamer **12** within the seismic array. The master controller **26** may be located remotely and communicate via satellite or other communication means as shown in FIG. **6**. The master controller receives data representing individual position of at least one point on the array, but preferably one or more points on each streamer element. These streamer positions from individual ASPDs **18**, are processed, compared to the desired positions and commands are transmitted to the individual ASPD **18**. The link between the active controllers on ASPD **18** and the main controller **26** can be accomplished by any suitable electronic cable, such as coaxial or fiber-optic cable attached to the towed array, via point to point communications or RF communications facilitated by a transceiver attached to the towed array. As shown in FIG. **6**, the tracking information from a plurality of points on individual streamers comprising the seismic array can be obtained and transmitted to the master controller **26** via satellite or radio frequency or any other means of communication.

The master controller may be connected via an electronic data bus, via any other suitable physical data interface, or via a wireless communication data interface to collect inputs from environmental sensors associated with vessel **10**. Sensed environmental data comprises wind speed and direction; tidal currents velocity and direction; ocean bottom depth/angle; local current velocity and direction; wave height and direction; ocean bottom depth/angle; and water temperature and salinity.

Turning now to FIG. **2**, the master controller **26** of the present invention receives the three component position of each active controller in the array, as shown in FIG. **6**. Thus, the present invention enables tracking with respect to time, of each individual ASPD and the streamer cable with which the ASPD is associated. Each active controller element is also equipped with a receiver for receipt of commands generated and formatted by the master control **26** and transmitted by active position commander **28**. The commands are sent to the ASPDs **18**, to instruct each of the ASPDs regarding commands for changing the position of each individual streamer to maintain desired array geometry and overall position. The positioning commands can be absolute commands or represent changes in position from the last command to the particular ASPD. The flexibility of the individual ASPD **18** enables precise positioning of each individual ASPD and associated streamer within the towed streamer array. The present invention enables control of the horizontal, vertical and depth position of the entire array geometry comprising the individual streamers, individual streamers and attached ASPDs, with respect to time.

The array, streamer and individual ASPD three-component (x, y, z) position data with respect to time is stored along with real time environmental data. Environmental data is received via cable or radio from sensors deployed from the vessel or the array. The stored position and environmental data is stored as legacy data in the legacy data storage **22**. Optimal path data, is generated by Optimal path processor **24**, which may be generated by a neural network or some other methodology such as human input or mathematical formulae, is input to master controller **26**. Optimal path data may be provided as a desired seismic acquisition path during primary seismic data acquisition or during in fill shooting. Optimal path data steering is preferably divided between an optimal path for the tow vessel **10** and an optimal path for the towed array. During seismic data acquisition utilizing an optimal path **24**, vessel, array, array element and ASPD positions are sensed along with environmental data are transmitted to and received by the data acquisition unit **21**. The data acquisition unit **21** stores these inputs with respect to time as legacy data in the legacy data storage **22**. The data acquisition unit **21** also passes the array and environmental tracking data to the master controller **26**. The maneuverability of the particular cable, ASPD and vessel under the particular sensed environmental conditions are also factored into the active positioning commands. For example, a cable that becomes stiffer in colder water or more buoyant in higher salinity receives an augmented steering command depending on the sensed environmental data. Master controller **26** compares the current vessel and array position data with the desired position or optimal vessel and array path position. The master controller **26** then determines, in light of the current environmental conditions and the maneuverability of the vessel, ASPDs and towed streamers comprising the array, the timing and magnitude of positioning commands to be sent to the ASPDs on the array. The positioning commands are formatted and transmitted by active position commander **28** over link **30**. Link **30** may be hardwired or wireless via satellite, laser or radio link.

In a preferred embodiment optimal path processor **24** collects real-time positioning data for the seismic array and for the towing vessel along with environmental data and maneuverability data for the array and towing vessel. The optimal path processor **24** computes predictions for the array behavior and computes the optimal path through the seismic survey area during a data acquisition run. The master control receives the predicted array behavior and takes it into account in generating and issuing positioning commands to the array ASPDs and the towing vessel. The division of the steering commands between the towing vessel and the ASPDs provides additional flexibility and control over the array along the optimal path. The additional flexibility and control of the array long the optimal path reduces the amount of in fill shooting required after a primary data acquisition run and reduces the amount of decision making required of a navigator striving to properly steer the towing vessel during a data acquisition run.

In a preferred embodiment of the present invention, the master controller monitors the actual position of each ASPD to determine the position of the streamers and the composite array geometry comprising the streamers and control elements are tracked and stored as legacy data. The actual positions of vessel, streamers, ASPDs and array geometry are compared to the desired vessel/streamers/ASPD positions and array geometry and corrective position commands are sent to the control elements to move the vessel/streamers/ASPDs to the desired position and array geometry. Tracking data and positioning commands are transmit-

ted between the master controller and active positioners via a cable connecting the master controller and the active positioners or via wireless communications.

The horizontal positions of the ASPDs **18** and/or active controllers can be derived using acoustic position systems as described in U.S. Pat. No. 4,992,990. In the alternative, satellite-based global positioning systems may be utilized separately or in conjunction to determine the positions of the array and the active controllers and streamers comprising the array. The depth of the arrays, and of the individual streamers and individual streamer elements can be determined using pressure sensors.

In calculating desired or necessary movements by vessel, streamers/array and individual ASPDs, to maintain the desired array geometry and position and the relative position of the array elements as well as the desired array position and geometry during four-dimensional data acquisition, the master controller **26** takes into account environmental factors including but not limited to water salinity, current velocity and direction as well as legacy tracking data to adjust the positioning commands provided to the active controller. The master controller also factors in the maneuverability of the streamer cable and streamer array based on the cable diameter and cable type. The master controller sends position correction commands to the active controller either as a desired position or as a force vector comprising the vertical deflection, horizontal deflection, towing velocity and cross current velocity.

The vessel towing velocity and cross current velocity may be calculated from the vessel speed and heading values and the current speed and heading values to determine the relative velocities of the streamers, active controllers and the array. In an alternative embodiment, the towing velocity and/or cross current velocity can be determined using flow meters or other commercially available water velocity meters. Thus, the present invention enables dynamic adaptive geometric configuration, tracking and control to compensate for changes in local currents, tides and salinity of the water during seismic data acquisition.

In an alternative embodiment, a neural network is provided to model and predict cable and array behavior in the presence of changing currents, tides and salinity, or other environmental factors such as wave height, wind, water temperature, etc. The present invention may also factor in compensation for streamer buoyancy, streamer diameter, maneuverability of the cable with respect to the current temperature, streamer and vessel maneuverability and combined streamer/ASPD positioning maneuverability as well as particular array geometry and spacing. The neural network is preferably trained to compensate for changes in such environmental factors in combination with the vessel and streamer/ASPD positioning maneuverability. The present invention thereby enables repeatable and consistent array geometry and positioning for collection of four-dimensional data on separate seismic data acquisition runs using different streamers having different streamer/ASPD maneuverability and under different environmental conditions.

For example, a first data acquisition run may occur during the summer when the water temperature, salinity, tides, winds and currents comprise a first set of data for a first streamer system having a first maneuverability. A second data acquisition run may occur during the winter, years later, when the water temperature, salinity, tides, winds and currents comprise a second set of data for a second streamer/ASPD system possessing a second maneuverability. In order to replicate the first data acquisition run and obtain four-dimensional data during the second data acquisition run; the present invention compensates for the differences between the environmental factors and the differences in vessel/streamers/ASPD maneuverability of the first and second run to accurately repeat the array positioning and geometry during the second run, thereby enabling repeatable seismic acquisition runs and the acquisition of four-dimensional data. The difference maneuverability of the first and second vessels is also considered by the master controller in selecting ASPD positioning commands.

The present invention enable precise maneuvering the individual streamers, the array position and the array geometry, thereby reducing in fill shooting caused by array geometry that is either too broad, too narrow or simply out of position. The present invention also determines and corrects for inappropriately shaped arrays, for example, elements in the array which become non symmetric are adjusted and moved into position so that array geometry errors in x, y, and z space are corrected and compensated by the present invention. The present invention also enables placement of streamers in close proximity without entanglement.

Turning now to FIG. **3A**, a cross section is illustrated, taken perpendicular to the longitudinal axis of the towed array of streamers **12** shown in FIG. **1**. In FIG. **3A**, the array of streamers **12** is positioned at the same water depth **23**, along line **15** at depth **23**, and beneath the ocean surface **17**. A failed streamer **13** originally positioned along line **15** is detected as failed by the master controller. The master controller issues a positioning command to the ASPD on the failed streamer **13**. As shown FIG. **3B**, the failed streamer cable **13** is maneuvered and lifted above line **15** to the surface of the water and out of the array geometry for replacement and or repair during a data acquisition run. A side view of failed streamer **13**, is shown in the raised position in FIG. **3C**. As shown in FIG. **3D**, array geometry can also be altered by the present invention to alter the beam pattern and/or coverage of the array by moving the streamers adjacent the failed streamer to replace and compensate for failed streamer cable **13**. As shown in FIG. **3D**, the streamers in position **12B** adjacent streamer **13** are moved closer together, from position **12B** to position **12C**, to compensate for streamer **13** which has been removed from the array. In a preferred embodiment, all streamers including streamer **13** are detachably connected to the streamer array so that each streamer can be easily removed during seismic data acquisition operations. The master controller **26** detects the failed streamer **13**, commands the ASPD attached to failed streamer **13** to raise streamer **13** to the surface **17**. Once on or near the surface, or simply physically displaced from the array, a manned or unmanned support vehicle can retrieve and or remove and replace streamer **13**. The master controller issues positioning commands to adjust the position of streamers adjacent streamer **13** without interrupting the seismic data acquisition run.

Thus, the present invention senses a failed streamer cable in an array geometry and adjusts the position of adjacent streamer cables so that the beam pattern of the sensing array covers the area covered by the failed streamer. The compensation for a failed array streamer and associated compensation array geometry are noted and stored by the present invention so that post processing analysis compensates for variations in the data caused by the compensation array geometry.

Turning now to FIG. **4**, a three-dimensional array of streamers **12** is shown. The three-dimensional array of FIG. **4** positions the streamers **12** at varying depths **15** and **25**,

rather than along a single line at a uniform depth. The varying depths of the streamers increases the temporal resolution of the streamer and substantially eliminates ghost notching. The depths can vary between two or more depths.

Turning now to FIG. **5**, a two-dimensional array **11**, positioned along line **24**, is shown rotated at an angel theta **27** rotated theta degrees from vertical **19**. The ability to rotate the array enables maneuvering the array in shallow water near a steep ocean bottom **14** inclined at angle theta.

The foregoing description is for purposes of example only and not intended to limit the scope of the present invention which is defined by the following claims.

What is claimed is:

1. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

an array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to at least one seismic streamer for positioning the seismic streamer relative to other seismic streamers within the array; and

a master controller for issuing positioning commands to each ASPD to adjust a vertical and horizontal position of a first streamer relative to a second streamer within the array for maintaining a specified array geometry.

2. The apparatus of claim **1** further comprising:

an environmental sensor for sensing environmental factors which influence the path of the towed array.

3. The apparatus of claim **1** further comprising:

a tracking system for tracking the streamer positions versus time during a seismic data acquisition run and storing the positions versus time in a legacy database for repeating the positions versus time in a subsequent data acquisition; and

an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run and storing the array geometry versus time in a legacy database for repeating the array geometry versus time in a subsequent data acquisition run.

4. The apparatus of claim **3** wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired streamer position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer position and array geometry versus time.

5. The apparatus of claim **4** wherein the master controller factors in environmental factors into the positioning commands to compensate for environmental influences on the positioning of the streamers and the array geometry.

6. The apparatus of claim **4** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

7. The apparatus of claim **1** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

8. The apparatus of claim **1** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move a failed streamer out of the array.

9. The apparatus of claim **1** further comprising:

a monitor for determining the status of each streamer, wherein the master controller detaches a failed streamer from the array.

10. The apparatus of claim **1** wherein the array geometry comprises a plurality of streamers positioned at a uniform depth.

11. The apparatus of claim **1** wherein the array geometry comprises a plurality of streamers positioned at a plurality of depths for varying temporal resolution of the array.

12. The apparatus of claim **1** wherein the array geometry comprises a plurality of streamers positioned along a plane, wherein the plane is rotated at an angel theta with respect to the longitudinal axis of the array.

13. The apparatus of claim **4** wherein the array geometry is tracked via satellite and communicated to the master controller.

14. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer;

a master controller for issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry;

an environmental sensor for sensing environmental factors which influence the towed path of the towed array;

a tracking system for tracking the streamer horizontal and vertical positions versus time during a seismic data acquisition run;

an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the vertical and horizontal positions of the streamers versus time and the array geometry versus time to desired streamer positions and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer positions and array geometry versus time.

15. The apparatus of claim **14** wherein the master controller factors in environmental measurements into the positioning commands to compensate for environmental influences on the positions of the streamers and the array geometry.

16. The apparatus of claim **14** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

17. The apparatus of claim **14** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

18. The apparatus of claim **14** further comprising:

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move the failed streamer out of the array.

19. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for vertically and horizontally positioning each seismic streamer relative to the array;

a master controller for issuing positioning commands to each ASPD for maintaining a specified array geometry;

an environmental sensor for sensing environmental factors which influence the path of the towed array;

a tracking system for tracking the streamer positions versus time during a seismic data acquisition run;

an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired position and array geometry versus time, wherein the master controller factors in environmental and maneuverability factors into the positioning commands to compensate for environmental and maneuverability influences on the position of the streamers and the array geometry; and

a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer and removes the failed streamer from the array.

20. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for vertically and horizontally positioning each seismic streamer relative to the array; and

a master controller for issuing positioning commands to each ASPD for maintaining a specified array path.

21. The apparatus of claim **20** wherein the master controller issues positioning commands to the towing vessel for maintaining a specified array path.

22. The apparatus of claim **20** further comprising:

a processor for calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field;

a streamer behavior prediction processor which predicts array behavior; and

wherein the master controller compensates for predicted streamer behavior in issuing vertical and horizontal positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path.

23. The apparatus of claim **22** wherein the master controller compensates for environmental factors in the positioning commands.

24. The apparatus of claim **23** wherein the master controller compensates for maneuverability factors in the positioning commands.

25. A seismic streamer array tracking and positioning system comprising:

a towing vessel for towing a seismic array;

a seismic streamer array comprising a plurality of seismic streamers;

an active streamer positioning device (ASPD) attached to each seismic streamer for vertically and horizontally positioning each seismic streamer relative to the array;

a master controller for issuing positioning commands to each ASPD and to the towing vessel for maintaining an optimal path, wherein the master controller further comprises a processor for calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field, and a streamer behavior prediction processor which predicts array behavior, wherein the master controller compensates for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path, wherein the master controller compensates for environmental and maneuverability factors in the positioning commands.

26. A method for tracking and positioning a seismic streamer array comprising:

for towing a seismic array comprising a plurality of seismic streamers;

attaching an active streamer positioning device (ASPD) each seismic streamer for positioning the seismic streamer relative to other seismic streamers within the array; and

issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry.

27. The method of claim **26** further comprising:

providing an environmental sensor for sensing environmental factors which influence the path of the towed array.

28. The method of claim **26** further comprising:

providing a tracking system for tracking the streamer positions versus time during a seismic data acquisition run and storing the positions versus time in a legacy database for repeating the positions versus time in a subsequent data acquisition; and

providing an array geometry tracking system for tracking the array geometry versus time during a seismic data acquisition run and storing the array geometry versus time in a legacy database for repeating the array geometry versus time in a subsequent data acquisition run.

29. The method of claim **28** wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired streamer position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer position and array geometry versus time.

30. The method of claim **29** wherein the master controller factors in environmental factors into the positioning commands to compensate for environmental influences on the positioning of the streamers and the array geometry.

31. The method of claim **30** wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

32. The method of claim **26** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

33. The method of claim **26** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move a failed streamer out of the array.

34. The method of claim **26** further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller detaches a failed streamer from the array.

35. The method of claim **26** wherein the array geometry comprises a plurality of streamers positioned at a uniform depth.

36. The method of claim **26** wherein the array geometry comprises a plurality of streamers positioned at a plurality of depths for varying temporal resolution of the array.

37. The method of claim 26 wherein the array geometry comprises a plurality of streamers positioned along a plane, wherein the plane is rotated at an angel theta with respect to the longitudinal axis of the array.

38. The method of claim 29 wherein the array geometry is tracked via satellite and communicated to the master controller.

39. A method for tracking and positioning a seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers from a towing vessel;

attaching an active streamer positioning device (ASPD) to each seismic streamer for positioning each seismic streamer;

issuing positioning commands from a master controller to each ASPD to adjust vertical and horizontal position of a first streamer relative to a second streamer in the array for maintaining a specified array geometry;

sensing environmental factors which influence the towed path of the towed array;

tracking the streamer positions versus time during a seismic data acquisition run;

tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to desired streamer positions and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired streamer positions and array geometry versus time.

40. The method of claim 39 wherein the master controller factors in environmental measurements into the positioning commands to compensate for environmental influences on the positions of the streamers and the array geometry.

41. The method of claim 39 wherein the master controller compensates for maneuverability in the positioning commands to compensate for maneuverability influences on the positioning of the streamers and the array geometry.

42. The method of claim 39 further comprising:

determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer.

43. The method of claim 39 further comprising:

providing a monitor for determining the status of each streamer, wherein the master controller adjusts the array geometry to move the failed streamer out of the array.

44. A method for tracking and positioning a seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers from a towing vessel;

issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array geometry;

sensing environmental factors which influence the path of the towed array;

tracking the streamer positions versus time during a seismic data acquisition run;

tracking the array geometry versus time during a seismic data acquisition run, wherein the master controller compares the positions of the streamers versus time and the array geometry versus time to a desired position and array geometry versus time and issues positioning commands to the ASPDs to maintain the desired position and array geometry versus time, wherein the master controller factors in environmental and maneuverability factors into the positioning commands to compensate for environmental and maneuverability influences on the position of the streamers and the array geometry; and

determining the status of each streamer, wherein the master controller adjusts the array geometry to compensate for a failed streamer and removes the failed streamer from the array.

45. A method for tracking and positioning seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers;

attaching an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer; and

issuing vertical and horizontal positioning commands to each ASPD for maintaining a specified array path.

46. The method of claim 45 wherein a master controller issues positioning commands to the towing vessel for maintaining a specified array path.

47. The method of claim 45 further comprising:

calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field;

predicting array behavior; and

compensating for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path.

48. The method of claim 47 wherein the master controller compensates for environmental factors in the positioning commands.

49. The method of claim 48 wherein the master controller compensates for maneuverability factors in the positioning commands.

50. A method for tracking and positioning a seismic streamer array comprising:

towing a seismic array comprising a plurality of seismic streamers;

attaching an active streamer positioning device (ASPD) attached to each seismic streamer for positioning each seismic streamer;

issuing horizontal and vertical positioning commands to each ASPD and to the towing vessel for maintaining an optimal path, calculating an optimal path for the seismic array for optimal coverage during seismic data acquisition over a seismic field, and a behavior prediction processor which predicting array behavior, wherein the master controller compensates for predicted streamer behavior in issuing positioning commands to the towing vessel and the ASPDs for positioning the array along the optimal path, wherein the master controller compensates for environmental and maneuverability factors in the positioning commands.

* * * * *

US007080607B2

(12) **United States Patent**
Hillesund et al.

(10) **Patent No.: US 7,080,607 B2**
(45) **Date of Patent: *Jul. 25, 2006**

(54) **SEISMIC DATA ACQUISITON EQUIPMENT CONTROL SYSTEM**

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(73) Assignee: **WesternGeco, L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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Related U.S. Application Data

(63) Continuation of application No. 09/787,723, filed as application No. PCT/IB99/01590 on Sep. 28, 1999, now Pat. No. 6,932,017.

(30) **Foreign Application Priority Data**

Oct. 1, 1998 (GB) 9821277.3

(51) **Int. Cl.**
B63B 21/66 (2006.01)
B63B 21/56 (2006.01)

(52) **U.S. Cl.** **114/244**

(58) **Field of Classification Search** 114/162, 114/163, 242–246, 253
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,375,800	A	4/1968	Cole et al.	114/235
3,412,705	A	11/1968	Nesson	115/12
3,434,446	A	3/1969	Cole	114/235
3,440,992	A	4/1969	Chance	114/235
3,560,912	A	2/1971	Spink et al.	340/3
3,605,674	A	9/1971	Weese	114/235 B
3,648,642	A	3/1972	Fetrow et al.	114/235
3,774,570	A	11/1973	Pearson	114/235 B

(Continued)

FOREIGN PATENT DOCUMENTS

AU 199853305 12/1997

(Continued)

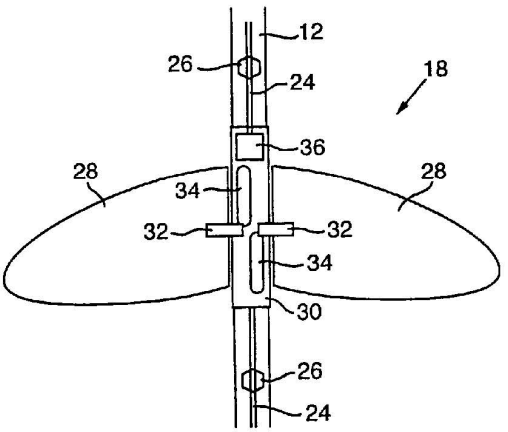
Primary Examiner—Jesus D. Sotelo

(74) *Attorney, Agent, or Firm*—WesternGeco, L.L.C.

(57) **ABSTRACT**

A method of controlling a streamer positioning device configured to be attached to a marine seismic streamer and towed by a seismic survey vessel and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The invention also involves an apparatus for controlling a streamer positioning device including means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to produce the desired change in the orientation of the wing.

25 Claims, 3 Drawing Sheets



WESTERNGECO
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PTX003

U.S. PATENT DOCUMENTS

3,896,756	A		7/1975	Pearson et al. ..... 114/235 B
3,931,608	A		1/1976	Cole 367/17
3,943,483	A		3/1976	Strange ..... 340/7 PC
3,961,303	A		6/1976	Paitson 367/17
4,033,278	A		7/1977	Waters 114/245
4,063,213	A		12/1977	Itria et al. 367/17
4,087,780	A		5/1978	Itria et al. 367/17
4,222,340	A		9/1980	Cole 114/245
4,227,479	A		10/1980	Gertler et al. 114/312
4,290,124	A		9/1981	Cole 367/18
4,313,392	A		2/1982	Guenther et al. 114/244
4,323,989	A		4/1982	Huckabee et al. 367/17
4,404,664	A		9/1983	Zachariadis 367/19
4,463,701	A		8/1984	Pickett et al. 114/245
4,484,534	A		11/1984	Thillaye du Boullay 114/244
4,676,183	A	*	6/1987	Conboy 114/245
4,694,435	A		9/1987	Magneville 367/17
4,709,355	A		11/1987	Woods et al. 367/16
4,711,194	A		12/1987	Fowler 114/245
4,723,501	A		2/1988	Hovden et al. ..... 114/144 B
4,729,333	A		3/1988	Kirby et al. 114/244
4,745,583	A		5/1988	Motal 367/18
4,766,441	A		8/1988	Phillips 343/709
4,767,183	A		8/1988	Martin 350/96.23
4,843,996	A		7/1989	Darche 114/245
4,890,568	A	*	1/1990	Dolengowski 114/246
4,890,569	A		1/1990	Givens 114/349
4,912,684	A		3/1990	Fowler 367/76
4,992,990	A		2/1991	Langeland et al. 367/19
5,042,413	A		8/1991	Benoit 114/244
5,052,814	A		10/1991	Stubblefield 367/15
5,402,745	A		4/1995	Wood 114/244
5,443,027	A		8/1995	Owsley et al. 114/244
5,507,243	A		4/1996	Williams et al. 114/245
5,517,202	A		5/1996	Patel 343/709
5,517,463	A		5/1996	Hornbostel et al. 367/13
5,529,011	A		6/1996	Williams, Jr. 114/245
5,532,975	A		7/1996	Elholm 367/16
5,619,474	A		4/1997	Kuche 367/17
5,642,330	A		6/1997	Santopietro 367/131
5,790,472	A		8/1998	Workman et al. 367/19
6,011,752	A		1/2000	Ambs et al. 367/17
6,011,753	A		1/2000	Chien 367/21
6,016,286	A		1/2000	Olivier et al. 367/17
6,144,342	A		11/2000	Bertheas et al. 343/709
6,459,653	B1		10/2002	Kuche 367/17
6,525,992	B1		2/2003	Olivier et al. 367/17
6,549,653	B1		4/2003	Osawa et al. 382/162
6,879,542	B1		4/2005	Soreau et al. 367/17

FOREIGN PATENT DOCUMENTS

AU	734810	B	6/2001
CA	2270719		12/1997
DE	69702673	T	4/2001
EP	0193215		1/1986
EP	0319716		6/1989
EP	0321705		6/1989
EP	0525391		2/1993
EP	0390987		12/1993
EP	613025	A1 *	8/1994
EP	0581441		8/1997
EP	0909701		1/2003
GB	2093610		9/1982
GB	2122562		1/1984
GB	2331971		6/1999
GB	2342081		4/2000
NO	992701		6/1999
WO	WO95/31735		11/1995
WO	WO96/21163		7/1996
WO	WO97/11395		3/1997
WO	WO97/30361		8/1997
WO	WO97/45006		12/1997
WO	WO98/28636		7/1998
WO	WO99/04293		1/1999

* cited by examiner

Fig.1.

Prior Art

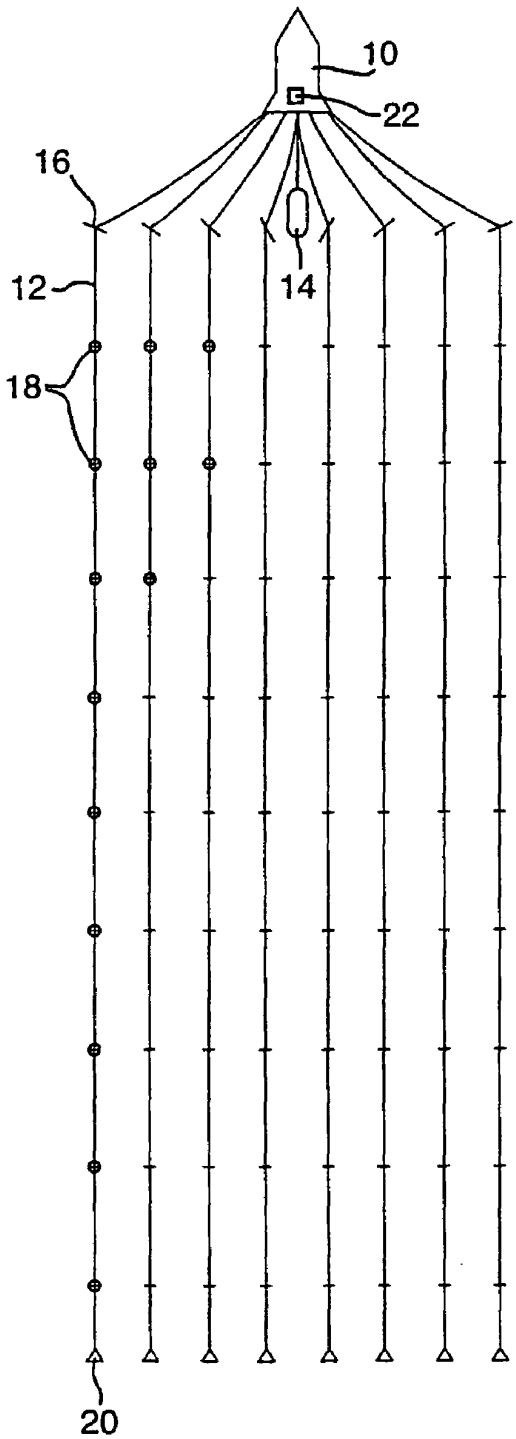


Fig.2.

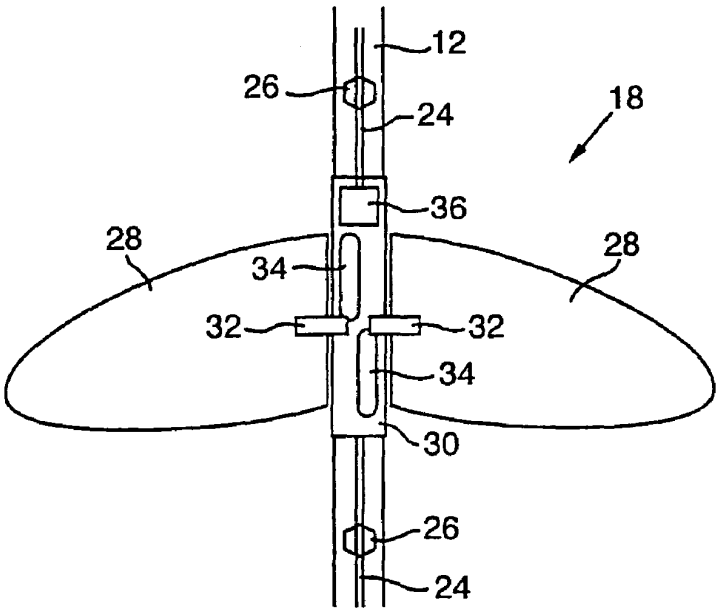

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Fig.3.

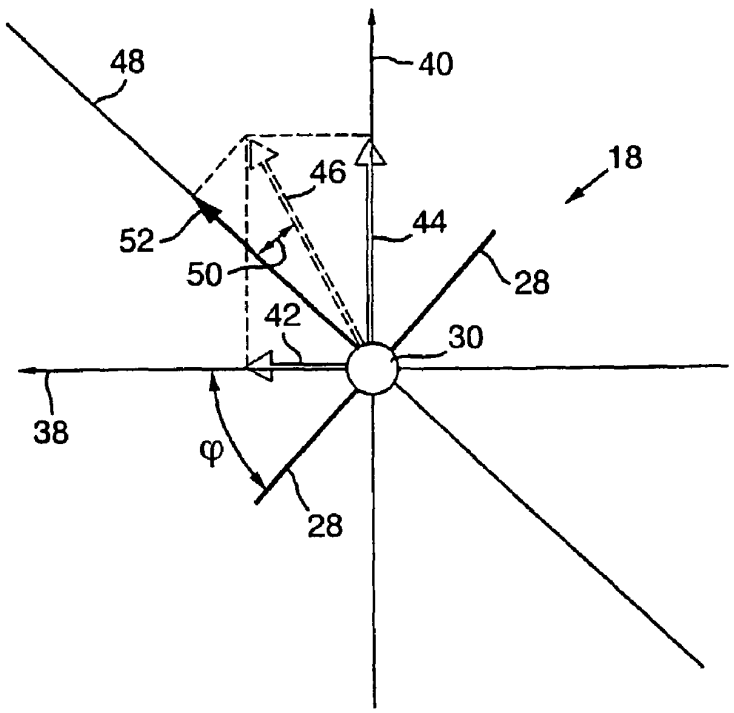
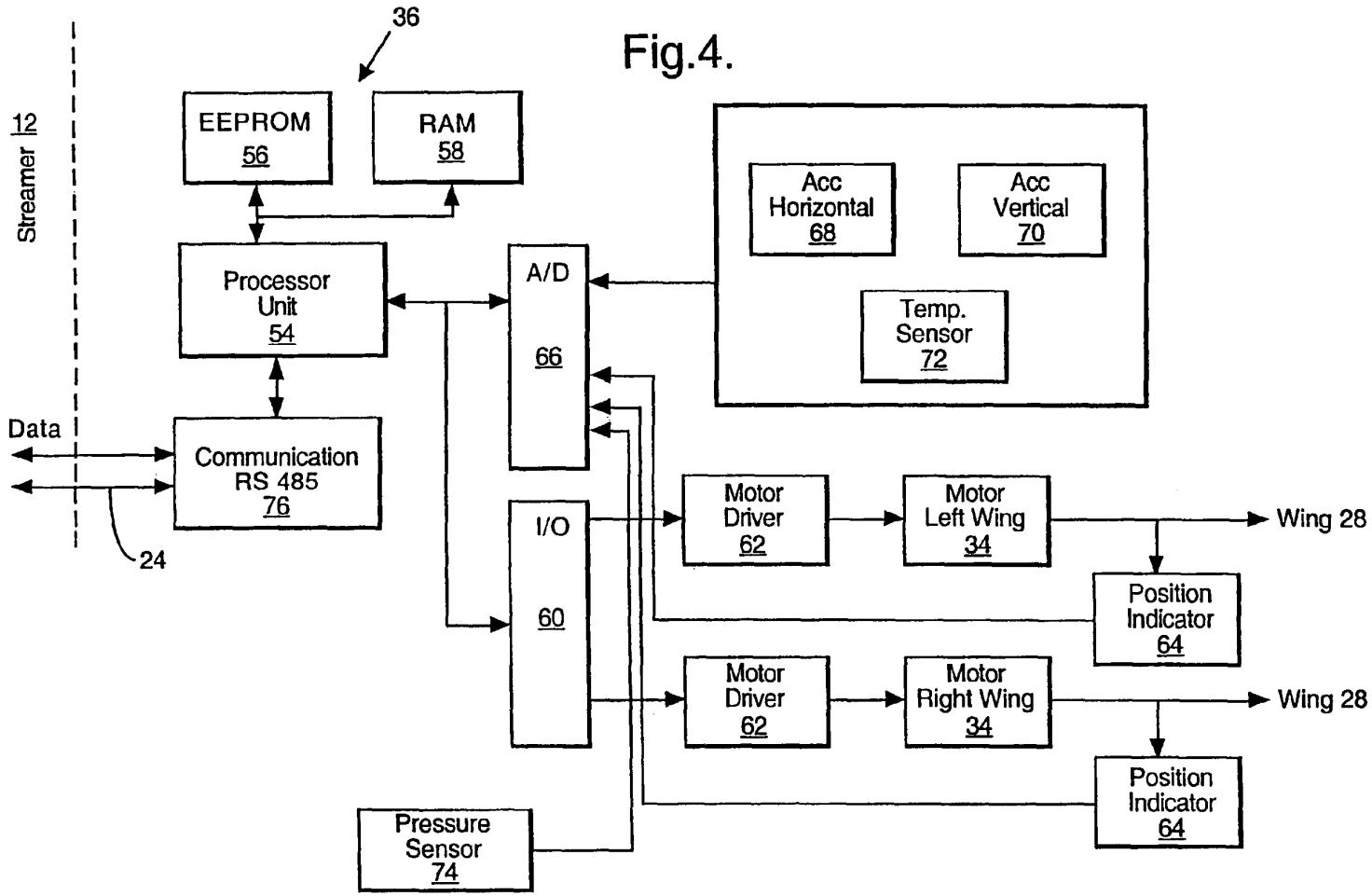

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Fig.4.


36
12
Streamer
EEPROM
56
RAM
58
Processor
Unit
54
A/D
66
Acc
Horizontal
68
Acc
Vertical
70
Temp.
Sensor
72
Data
Communication
RS 485
76
24
I/O
60
Motor
Driver
62
Motor
Left Wing
34
Wing 28
Position
Indicator
64
Motor
Driver
62
Motor
Right Wing
34
Wing 28
Position
Indicator
64
Pressure
Sensor
74

SEISMIC DATA ACQUISITON EQUIPMENT CONTROL SYSTEM

Applicant claims priority and continuation under 35 U.S.C. § 120 from parent application Ser. No. 09/787,723, filed Jul. 2, 2001, now U.S. Pat. No. 6,932,017, which was a 35 U.S.C. § 371 national stage filing from Patent Cooperation Treaty application number PCT/IB99/01590, filed Sep. 28, 1999, which in turn claimed priority from Great Britain patent application number 9821277.3, filed Oct. 1, 1998, from which Applicant has claimed foreign priority under 35 U.S.C. § 119.

BACKGROUND OF THE INVENTION

This invention relates generally to systems for controlling seismic data acquisition equipment and particularly to a system for controlling a marine seismic streamer positioning device.

A marine seismic streamer is an elongate cable-like structure, typically up to several thousand meters long, which contains arrays of seismic sensors, known as hydrophones, and associated electronic equipment along its length, and which is used in marine seismic surveying. In order to perform a 3D marine seismic survey, a plurality of such streamers are towed at about 5 knots behind a seismic survey vessel, which also tows one or more seismic sources, typically air guns. Acoustic signals produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various strata. The reflected signals are received by the hydrophones, and then digitized and processed to build up a representation of the subsurface geology.

The horizontal positions of the streamers are typically controlled by a deflector, located at the front end or "head" of the streamer, and a tail buoy, located at the back end or "tail" of the streamer. These devices create tension forces on the streamer which constrain the movement of the streamer and cause it to assume a roughly linear shape. Cross currents and transient forces cause the streamer to bow and undulate, thereby introducing deviations into this desired linear shape.

The streamers are typically towed at a constant depth of approximately ten meters, in order to facilitate the removal of undesired "ghost" reflections from the surface of the water. To keep the streamers at this constant depth, control devices known as "birds", are typically attached at various points along each streamer between the deflector and the tail buoy, with the spacing between the birds generally varying between 200 and 400 meters. The birds have hydrodynamic deflecting surfaces, referred to as wings, that allow the position of the streamer to be controlled as it is towed through the water. When a bird is used for depth control purposes only, it is possible for the bird to regularly sense its depth using an integrated pressure sensor and for a local controller within the bird to adjust the wing angles to maintain the streamer near the desired depth using only a desired depth value received from a central control system.

While the majority of birds used thus far have only controlled the depth of the streamers, additional benefits can be obtained by using properly controlled horizontally steerable birds, particularly by using the types of horizontally and vertically steerable birds disclosed in our published PCT International Application No. WO 98/28636. The benefits that can be obtained by using properly controlled horizontally steerable birds can include reducing horizontal out-of-position conditions that necessitate reacquiring seismic data in a particular area (i.e. in-fill shooting), reducing the chance of tangling adjacent streamers, and reducing the time required to turn the seismic acquisition vessel when ending one pass and beginning another pass during a 3D seismic survey.

It is estimated that horizontal out-of-position conditions reduce the efficiency of current 3D seismic survey operations by between 5 and 10%, depending on weather and current conditions. While incidents of tangling adjacent streamers are relatively rare, when they do occur they invariably result in prolonged vessel downtime. The loss of efficiency associated with turning the seismic survey vessel will depend in large part on the seismic survey layout, but typical estimates range from 5 to 10%. Simulations have concluded that properly controlled horizontally steerable birds can be expected to reduce these types of costs by approximately 30%.

One system for controlling a horizontally steerable bird, as disclosed in UK Patent GB 2093610 B, is to utilize a manually-operated central control system to transmit the magnitudes and directions of any required wing angle changes to the birds. While this method greatly simplifies the circuitry needed within the bird itself, it is virtually impossible for this type of system to closely regulate the horizontal positions of the birds because it requires manual input and supervision. This becomes a particularly significant issue when a substantial number of streamers are deployed simultaneously and the number of birds that must be controlled goes up accordingly.

Another system for controlling a horizontally steerable bird is disclosed in our published PCT International Application No. WO 98/28636. Using this type of control system, the desired horizontal positions and the actual horizontal positions are received from a remote control system and are then used by a local control system within the birds to adjust the wing angles. The actual horizontal positions of the birds may be determined every 5 to 10 seconds and there may be a 5 second delay between the taking of measurements and the determination of actual streamer positions. While this type of system allows for more automatic adjustment of the bird wing angles, the delay period and the relatively long cycle time between position measurements prevents this type of control system from rapidly and efficiently controlling the horizontal position of the bird. A more deterministic system for controlling this type of streamer positioning device is therefore desired.

It is therefore an object of the present invention to provide for an improved method and apparatus for controlling a streamer positioning device.

An advantage of the present invention is that the position of the streamer may be better controlled, thereby reducing the need for in-fill shooting, reducing the chance of streamer tangling, and reducing the time needed to turn the seismic survey vessel.

Another advantage of the present invention is that noise in marine seismic data associated with streamer position overcorrection and streamer positioning errors can be significantly reduced.

SUMMARY OF THE INVENTION

The present invention involves a method of controlling a streamer positioning device configured to be attached to a marine seismic streamer and towed by a seismic survey vessel and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the

wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The present invention also involves an apparatus for controlling a streamer positioning device. The apparatus includes means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to effectuate the desired change in the orientation of the wing. The invention and its benefits will be better understood with reference to the detailed description below and the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition equipment,

FIG. **2** is a schematic horizontal cross-sectional view through a marine seismic streamer and an attached streamer positioning device;

FIG. **3** is a schematic vertical cross-sectional view through the streamer positioning device from FIG. **2**; and

FIG. **4** is a schematic diagram of the local control system architecture of the streamer positioning device from FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, a seismic survey vessel **10** is shown towing eight marine seismic streamers **12** that may, for instance, each be 3000 meters in length. The outermost streamers **12** in the array could be 700 meters apart, resulting in a horizontal separation between the streamers of 100 meters in the regular horizontal spacing configuration shown. A seismic source **14**, typically an airgun or an array of airguns, is also shown being towed by the seismic survey vessel **10**. At the front of each streamer **12** is shown a deflector **16** and at the rear of every streamer is shown a tail buoy **20**. The deflector **16** is used to horizontally position the end of the streamer nearest the seismic survey vessel **10** and the tail buoy **20** creates drag at the end of the streamer farthest from the seismic survey vessel **10**. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly linear shape of the seismic streamer **12** shown in FIG. **1**.

Located between the deflector **16** and the tail buoy **20** are a plurality of streamer positioning devices known as birds **18**. Preferably the birds **18** are both vertically and horizontally steerable. These birds **18** may, for instance, be located at regular intervals along the steamer, such as every 200 to 400 meters. The vertically and horizontally steerable birds **18** can be used to constrain the shape of the seismic streamer **12** between the deflector **16** and the tail buoy **20** in both the vertical (depth) and horizontal directions.

In the preferred embodiment of the present invention, the control system for the birds **18** is distributed between a global control system **22** located on or near the seismic survey vessel **10** and a local control system located within or near the birds **18**. The global control system **22** is typically connected to the seismic survey vessel's navigation system and obtains estimates of system wide parameters, such as the vessel's towing direction and velocity and current direction and velocity, from the vessel's navigation system.

The most important requirement for the control system is to prevent the streamers **12** from tangling. This requirement becomes more and more important as the complexity and the total value of the towed equipment increases. The trend in the industry is to put more streamers **12** on each seismic survey vessel **10** and to decrease the horizontal separation between them. To get better control of the streamers **12**, horizontal steering becomes necessary. If the birds **18** are not properly controlled, horizontal steering can increase, rather than decrease, the likelihood of tangling adjacent streamers. Localized current fluctuations can dramatically influence the magnitude of the side control required to properly position the streamers. To compensate for these localized current fluctuations, the inventive control system utilizes a distributed processing control architecture and behavior-predictive model-based control logic to properly control the streamer positioning devices.

In the preferred embodiment of the present invention, the global control system **22** monitors the actual positions of each of the birds **18** and is programmed with the desired positions of or the desired minimum separations between the seismic steamers **12**. The horizontal positions of the birds **18** can be derived, for instance, using the types of acoustic positioning systems described in our U.S. Pat. No. 4,992,990 or in our PCT International Patent Application No. WO 98/21163. Alternatively, or additionally, satellite-based global positioning system equipment can be used to determine the positions of the equipment. The vertical positions of the birds **18** are typically monitored using pressure sensors attached to the birds, as discussed below.

The global control system **22** preferably maintains a dynamic model of each of the seismic streamers **12** and utilizes the desired and actual positions of the birds **18** to regularly calculate updated desired vertical and horizontal forces the birds should impart on the seismic streamers **12** to move them from their actual positions to their desired positions. Because the movement of the seismic streamer **12** causes acoustic noise (both from seawater flow past the bird wing structures as well as cross current flow across the streamer skin itself), it is important that the streamer movements be restrained and kept to the minimum correction required to properly position the streamers. Any streamer positioning device control system that consistently overestimates the type of correction required and causes the bird to overshoot its intended position introduces undesirable noise into the seismic data being acquired by the streamer. In current systems, this type of over-correction noise is often balanced against the "noise" or "smearing" caused when the seismic sensors in the streamers **12** are displaced from their desired positions.

The global control system **22** preferably calculates the desired vertical and horizontal forces based on the behavior of each streamer and also takes into account the behavior of the complete streamer array. Due to the relatively low sample rate and time delay associated with the horizontal position determination system, the global control system **22** runs position predictor software to estimate the actual locations of each of the birds **18**. The global control system **22** also checks the data received from the vessel's navigation system and the data will be filled in if it is missing. The interface between the global control system **22** and the local control system will typically operate with a sampling frequency of at least 0.1 Hz. The global control system **22** will typically acquire the following parameters from the vessel's navigation system: vessel speed (m/s), vessel heading (degrees), current speed (m/s), current heading (degrees), and the location of each of the birds in the horizontal plane in a vessel fixed coordinate system. Current speed and heading can also be estimated based on the average forces acting on the streamers **12** by the birds **18**. The global control system

22 will preferably send the following values to the local bird controller: demanded vertical force, demanded horizontal force, towing velocity, and crosscurrent velocity.

The towing velocity and crosscurrent velocity are preferably "water-referenced" values that are calculated from the vessel speed and heading values and the current speed and heading values, as well as any relative movement between the seismic survey vessel **10** and the bird **18** (such as while the vessel is turning), to produce relative velocities of the bird **18** with respect to the water in both the "in-line" and the "cross-line" directions. Alternatively, the global control system **22** could provide the local control system with the horizontal velocity and water in-flow angle. The force and velocity values are delivered by the global control system **22** as separate values for each bird **18** on each streamer **12** continuously during operation of the control system.

The "water-referenced" towing velocity and crosscurrent velocity could alternatively be determined using flowmeters or other types of water velocity sensors attached directly to the birds **18**. Although these types of sensors are typically quite expensive, one advantage of this type of velocity determination system is that the sensed in-line and cross-line velocities will be inherently compensated for the speed and heading of marine currents acting on said streamer positioning device and for relative movements between vessel **10** and the bird **18**.

FIG. **2** shows a type of bird **18** that is capable of controlling the position of seismic streamers **12** in both the vertical and horizontal directions. A bird **18** of this type is also disclosed in our PCT International Application No. WO 98/28636. While a number of alternative designs for the vertically and horizontally steerable birds **18** are possible, including those utilizing one full-moving wing with ailerons, three full-moving wings, and four full-moving wings, the independent two-wing principal is, conceptually, the simplest and most robust design.

In FIG. **2**, a portion of the seismic streamer **12** is shown with an attached bird **18**. A communication line **24**, which may consist of a bundle of fiber optic data transmission cables and power transmission wires, passes along the length of the seismic streamer **12** and is connected to the seismic sensors, hydrophones **26**, that are distributed along the length of the streamer, and to the bird **18**. The bird **18** preferably has a pair of independently moveable wings **28** that are connected to rotatable shafts **32** that are rotated by wing motors **34** and that allow the orientation of the wings **28** with respect to the bird body **30** to be changed. When the shafts **32** of the bird **18** are not horizontal, this rotation causes the horizontal orientation of the wings **28** to change and thereby changes the horizontal forces that are applied to the streamer **12** by the bird.

The motors **34** can consist of any type of device that is capable of changing the orientation of the wings **28**, and they are preferably either electric motors or hydraulic actuators. The local control system **36** controls the movement of the wings **28** by calculating a desired change in the angle of the wings and then selectively driving the motors **34** to effectuate this change. While the preferred embodiment depicted utilizes a separate motor **34** for each wing **28**, it would be also be possible to independently move the wings **28** using a single motor **34** and a selectively actuatable transmission mechanism.

When the bird **18** uses two wings **28** to produce the horizontal and vertical forces on the streamer **12**, the required outputs of the local control system **36** are relatively simple, the directions and magnitudes of the wing movements required for each of the wings **28**, or equivalently the magnitude and direction the motors **34** need to be driven to produce this wing movement. While the required outputs of the local control system **36** for such a two full moving wing design is quite simple, the structure and operation of the overall system required to coordinate control of the device is relatively complicated.

FIG. **3** shows a schematic vertical cross-sectional view through the streamer positioning device shown in FIG. **2** that will allow the operation of the inventive control system to be described in more detail. The components of the bird **18** shown in FIG. **3** include the wings **28** and the body **30**. Also shown in FIG. **3** are a horizontal coordinate axis **38** and a vertical coordinate axis **40**. During operation of the streamer positioning control system, the global control system **22** preferably transmits, at regular intervals (such as every five seconds) a desired horizontal force **42** and a desired vertical force **44** to the local control system **36**.

The desired horizontal force **42** and the desired vertical force **44** are combined within the local control system **36** to calculate the magnitude and direction of the desired total force **46** that the global control system **22** has instructed the local control system to apply to the streamer **12**. The global control system **22** could alternatively provide the magnitude and direction of the desired total force **46** to the local control system **36** instead of the desired horizontal force **42** and the desired vertical force **44**.

While the desired horizontal force **42** and the desired vertical force **44** are preferably calculated by the global control system **22**, it is also possible for the local control system **36** in the inventive control system to calculate one or both of these forces using a localized displacement/force conversion program. This type of localized conversion program may, for instance, use a look-up table or conversion routine that associates certain magnitudes and directions of vertical or horizontal displacements with certain magnitudes and directions of changes in the vertical or horizontal forces required. Using this type of embodiment, the global control system **22** can transmit location information to the local control system **36** instead of force information. Instead of the desired vertical force **44**, the global control system **22** can transmit a desired vertical depth and the local control system **36** can calculate the magnitude and direction of the deviation between the desired depth and the actual depth. Similarly, instead of transmitting a desired horizontal force **42**, the global control system **22** can transmit the magnitude and direction of the displacement between the actual horizontal position and the desired horizontal position of the bird **18**. One advantage to this alternative type of system is that the required vertical force can be rapidly updated as the local control system receives updated depth information from the integrated pressure sensor. Other advantages of this type of alternative system include reducing communication traffic on the communication line **24** and simplifying the programming needed to convert the measured vertical and/or horizontal displacements into corresponding forces to be applied by the birds **18**.

When the local control system **36** has a new desired horizontal force **42** and desired vertical force **44** to be applied, the wings **28** will typically not be in the proper orientation to provide the direction of the desired total force **46** required. As can be seen in FIG. **3**, the wings **28** introduce a force into the streamer **12** along an axis perpendicular to the rotational axis of the wings **28** and perpendicular to the streamer. This force axis **48** is typically not properly aligned with the desired total force **46** when new desired horizontal and vertical force values are received from the global control system **22** or determined by the local control system **36** and

some rotation of the bird **18** is required before the bird can produce this desired total force **46**. As can be seen, the force axis **48** is directly related to the bird roll angle, designated in FIG. **3** as ϕ.

The local control system **36** optimizes the control process by projecting the desired total force **46** onto the force axis **48** (i.e. multiplying the magnitude of the desired total force by the cosine of the deviation angle **50**) to produce an intermediate desired force **52** and then adjusting the wing common angle α (the angle of the wings with respect to the bird body **30**, or the average angle if there is a non-zero splay angle) to produce this magnitude of force along the force axis. The calculated desired common wing angle is compared to the current common wing angle to calculate a desired change in the common wing angle and the wing motors **34** are actuated to produce this desired change in the orientation of the wings.

A splay angle is then introduced into the wings **28** to produce a rotational movement in the bird body **30** (i.e. to rotate the force axis **48** to be aligned with the desired total force **46**). The splay angle is the difference between the angles of the wings **28** with respect to the bird body **30**. As the bird body **30** rotates and the force axis **48** becomes more closely aligned with the desired total force **46**, the bird roll angle and the bird roll angular velocity are monitored, the splay angle is incrementally reduced, and the common angle is incrementally increased until the intermediate desired force **52** is in the same direction and of the same magnitude as the desired total force. The local control system **36** carefully regulates the splay angle to ensure that the streamer is stable in roll degree of freedom. The calculated common wing angle and the splay angle are also regulated by the local control system **36** to prevent the wings **28** from stalling and to ensure that the splay angle is prioritized.

When using the type of birds described in our published PCT International Application No. WO 98/28636, where the bird **18** is rigidly attached, and cannot rotate with respect, to the streamer **12**, it is important for the control system to take the streamer twist into account. If this is not taken into account, the bird **18** can use all of its available splay angle to counter the twist in the streamer **12**. The bird **18** will then be unable to reach the demanded roll angle and the generated force will decrease. The inventive control system incorporates two functions for addressing this situation; the anti-twist function and the untwist function.

In the anti-twist function, the streamer twist is estimated by weightfunction filtering the splay angle measurements instead of simply averaging the splay angle measurements to improve the bandwidth of the estimation. The anti-twist function engages when the estimated twist has reached a critical value and it then overrides the normal shortest path control of the calculated roll angle. The anti-twist function forces the bird **18** to rotate in the opposite direction of the twist by adding +/−180 degrees to the demanded roll angle. Once the twist has been reduced to an acceptable value, the anti-twist function disengages and the normal shortest path calculation is continued.

The untwist function is implemented by the global control system **22** which monitors the splay angle for all of the birds **18** in each streamer **12**. At regular intervals or when the splay angle has reached a critical value, the global control system **22** instructs each local control system **36** to rotate each bird **18** in the opposite direction of the twist. The number of revolutions done by each bird **18** is monitored and the untwist function is disengaged once the twist has reached an acceptable level.

FIG. **4** is a schematic diagram of the architecture of the local control system **36** for the bird **18**. The local control system **36** consists of a central processor unit **54**, having EEPROM **56** and RAM **58** memory, an input/output subsystem **60** that is connected to a pair of motor drivers **62**, and an analog to digital conversion unit **66**. The motor drivers **62** are connected to and actuate the wing motors **34** to produce the desired change the orientation of the wings **28** with respect to the bird body **30**.

The wing motor **34**/wing **28** units are also connected to wing position indicators **64** that sense the relative positions of the wings and provide measurements to the analog to digital conversion unit **66** which converts the analog wing position indicator **64** measurements into digital format and conveys these digital values to the central processor unit **54**. Various types of wing position indicators **64** can be used, including resistive angle or displacement sensors, inductive sensors, capacitive sensors, hall sensors, or magneto-restrictive sensors.

A horizontal accelerometer **68** and a vertical accelerometer **70**, placed at right angles with respect to one another, are also connected to the analog to digital conversion unit **66** and these accelerometers convey measurements that allow the central processor unit **54** to determine the roll angle and roll rate of the bird **18**. An angular velocity vibrating rate gyro (rategyro) can also be used to measure the roll rate of the bird **18**. A temperature sensor **72** is connected to the analog to digital conversion unit **66** to provide temperature measurements that allow the horizontal accelerometer **68** and the vertical accelerometer **70** to be calibrated.

A pressure sensor **74** is also connected to the analog to digital conversion unit **66** to provide the central processor unit **54** with measurements of the water pressure at the bird **18**. To calculate an appropriate depth value, the measured pressure values must be filtered to limit the disturbance from waves. This is done in the inventive control system with a weightfunction filter that avoids the large phase displacements caused by mean value filters. Instead of using an instantaneous depth value or simply calculating an average depth value over a given period of time (and thereby incorporating a large phase displacement into the depth value), the inventive control system uses a differentially weighted pressure filtering scheme. First the pressure values are transformed into depth values by dividing the pressure sensor reading by the seawater density and gravitational acceleration. These depth values are then filtered using a weight function filter. Typical incremental weighting functions values range from 0.96 to 0.90 (sample weights of 1.0, 0.9, 0.81, 0.729, etc.) and the filter will typically process depth values received over a period of at least 100 seconds.

The central processor unit **54** is also connected to a RS485 communications unit **76** that allows information to be exchanged between the local control system **36** and the global control system **22** over the communication line **24** that passes through the streamer **12**. The RS485 bus may, for instance, utilize Neuron chips that communicate using a Local Operating Network protocol to control the data transfer.

Preferably, the central processor unit **54** and associated components comprise a MicroChip 17C756 processor. This type of microprocessor has very low power requirements, a dual UART on-chip, 12-channel, 10 bit ADC on-chip, 908×8 RAM, 16k×16 ROM, and 50 digital I/O channels. The software running on the central processor unit **54** will typically consist of two units, the local control unit and the hardware control unit. It is typically not possible to pre-load both of these program units into the EEPROM **56** and it is

possible to update these program units without having to open the bird **18**. The on-chip memory may thus only initially contain a boot-routine that enables the loading of software units into the external memory via the RS485 communication unit **76**. The external program memory (EEPROM **56**) will typically be a non-volatile memory so that these program units do not have to be re-loaded after every power down.

The central processor unit **54** must be able to run the local control system software fast enough to secure the sampling frequency needed for effective local bird control. This may mean, for instance, a sample rate of 10 Hz, which may be 10 to 100 times faster than the sample rate of the communications between the global control system **22** and the local control system **36**. As discussed above, the central processor unit **54** will also receive data from sensors attached to the bird **18**. The sensed values include bird roll angle, bird roll angular velocity (roll rate), the wing angles, and the static pressure of the water. These values are typically delivered to the central processor unit **54** at a sample rate of at least 10 Hz. The following values may be transmitted from the local control system **36** to the global control system **22** using the RS485 communication unit **76**: the measured roll angle, the measured roll rate, the measured wing angles, the measured water pressure, the calculated depth, and the calculated wing forces.

The system has been designed with a redundant communication system to increase its overall reliability. The bird **18** will typically have a backup communications channel, such as by overlaying a backup control signal on top of the power line current. This backup communications channel is particularly important because in the event of loss of communications to the bird **18** there would otherwise be no method for instructing the bird **18** to bring the streamer **12** to surface so the defective communications equipment can be repaired or replaced.

In contrast to previous streamer position device control systems, the present control system converts the desired horizontal force **42** and the desired vertical force **44** into a desired roll angle ϕ and a desired common wing angle α by deterministic calculations, rather than using an "incremental change/measured response/further incremental change based on measured response" type of feedback control circuit. The desired roll angle ϕ can be calculated in the manner discussed in the text describing FIG. **3** above. The magnitude of the force F imparted by the wings **28** along the force axis **48** can, for instance, be deterministically calculated using the following formula:

$$F = \frac{1}{2}\rho * A * C_L(v_{tow}\cos(\alpha) - v_{current}\sin(\alpha))^2$$

where:

ρ=water density

A=wing area

C_L=wing lift coefficient

α=common wing angle

V_{tow}=towing velocity

$V_{current}$=crosscurrent velocity

A similar deterministic calculation could be made using a calculated coefficient that incorporates the towing velocity of the bird **18**. A gain factor GF, for instance, could be calculated as follows:

$$GF = \frac{1}{2}\rho * A * C_L(v_{tow})^2$$

which could be simply multiplied by $\cos(\alpha)^2$ to estimate the force that would be applied for a given common angle.

One of the beneficial elements of the inventive control system is that the desired change in the orientation of the wing **28** is calculated using an estimate of the velocity of the bird **18** rather than simply relying on a feedback-loop type of control system that operates in the same manner regardless of the vessel speed. Because the force produced by wing **28** is proportional to the velocity of the device squared, a much mere precise calculation of the desired change in the wing orientation can be made by using an estimate of the device velocity.

The inventive control system is based on shared responsibilities between the global control system **22** located on the seismic survey vessel **10** and the local control system **36** located on the bird **18**. The global control system **22** is tasked with monitoring the positions of the streamers **12** and providing desired forces or desired position information to the local control system **36**. The local control system **36** within each bird **18** is responsible for adjusting the wing splay angle to rotate the bird to the proper position and for adjusting the wing common angle to produce the magnitude of total desired force required.

The inventive control system will primarily operate in two different control modes: a feather angle control mode and a turn control mode. In the feather angle control mode, the global control system **22** attempts to keep each streamer in a straight line offset from the towing direction by a certain feather angle. The feather angle could be input either manually, through use of a current meter, or through use of an estimated value based on the average horizontal bird forces. Only when the crosscurrent velocity is very small will the feather angle be set to zero and the desired streamer positions be in precise alignment with the towing direction.

The turn control mode is used when ending one pass and beginning another pass during a 3D seismic survey, sometimes referred to as a "line change". The turn control mode consists of two phases. In the first part of the turn, every bird **18** tries to "throw out" the streamer **12** by generating a force in the opposite direction of the turn. In the last part of the turn, the birds **18** are directed to go to the position defined by the feather angle control mode. By doing this, a tighter turn can be achieved and the turn time of the vessel and equipment reduced. Typically during the turn mode adjacent streamers will be depth separated to avoid possible entanglement during the turn and will be returned to a common depth as soon as possible after the completion of the turn. The vessel navigation system will typically notify the global control system **22** when to start throwing the streamers **12** out, and when to start straightening the streamers.

In extreme weather conditions, the inventive control system may also operate in a streamer separation control mode that attempts to minimize the risk of entanglement of the streamers. In this control mode, the global control system **22** attempts to maximize the distance between adjacent streamers. The streamers **12** will typically be separated in depth and the outermost streamers will be positioned as far away from each other as possible. The inner streamers will then be regularly spaced between these outermost streamers, i.e. each bird **18** will receive desired horizontal forces **42** or

desired horizontal position information that will direct the bird **18** to the midpoint position between its adjacent streamers.

While the embodiment of the inventive control system described above is shown in connection with a "bird" type of streamer positioning device, it will be readily understood that the control system method and apparatus may also be used in connection with streamer positioning devices that are characterized as "deflectors" or steerable "tail buoys" because they are attached to either the front end or the back end of the streamer **12**.

The present invention includes any novel feature or novel combination of features disclosed herein, either explicitly or implicitly.

The invention claimed is:

1. A method comprising:

(a) towing an a array of streamers each having a plurality of streamer positioning devices there along;

(b) predicting positions of at least some of the streamer positioning devices;

(c) using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices; and

(d) implementing at least some of the desired changes.

2. A method as claimed in claim **1**, comprising estimating velocity of at least some of the streamer positioning devices, wherein said estimated velocity is calculated using a vessel speed received from a navigation system on said seismic survey vessel.

3. A method as claimed in claim **2**, in which said estimated velocity is a water referenced towing velocity that compensates for the speed and heading of marine currents acting on said streamer positioning devices.

4. A method as claimed in claim **3**, in which said estimated velocity is compensated for relative movement between said seismic survey vessel and said streamer positioning devices.

5. A method as claimed in claim **2**, in which said step of using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices further uses an estimate of the crosscurrent velocity at the respective streamer positioning device.

6. A method as claimed in claim **5**, in which said step of using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices is regulated to prevent the positioning device from stalling.

7. A method as claimed in claim **6**, in which said step of using the predicted positions to calculate desired changes in position of one or more of the streamer positioning devices is regulated by a global control system located on or near a seismic survey vessel that is configured into a feather angle mode, wherein said global control system attempts to direct the streamer positioning devices to maintain each of said streamers in a straight line offset from the towing direction of said marine seismic vessel by a certain feather angle, and into a turn control mode, wherein said global control system directs said streamer positioning devices to generate a force in the opposite direction of a turn at the beginning of the turn.

8. A method as claimed in claim **7**, in which said global control system is further configured into a streamer separation mode, wherein said global control system attempts to direct said streamer positioning device to maintain a minimum separation distance between adjacent streamers.

9. A method as claimed in claim **8**, further including the step of displaying the position of said streamer positioning devices on said seismic survey vessel.

10. A method as claimed in claim **9**, in which each streamer positioning device is attached to and unable rotate with respect to its streamer and further comprising the step of monitoring twist in said marine seismic streamers and calculating a desired change in the orientation of hydrodynamic deflecting surfaces of the streamer positioning devices to reduce said twist.

11. A method as claimed in claim **10**, further including the step of obtaining the desired positions of at least some of the streamer positioning devices.

12. A method as claimed in claim **11**, wherein the prediction of position of a streamer positioning device and the desired position of that same streamer positioning device are used to produce a desired force to be applied to its streamer by that streamer positioning device.

13. A method as claimed in claim **12**, in which said desired force is projected onto a current force axis and orientation of hydrodynamic deflecting surfaces of the streamer positioning device is calculated that will produce said projected force at said estimated velocity.

14. A method as claimed in claim **13**, in which the streamer positioning device is rotated to align the current force axis with said desired force and its hydrodynamic deflecting surface orientation is changed as the current force axis becomes more closely aligned with said desired force.

15. An array of seismic streamers towed by a towing vessel comprising:

(a) a plurality of streamer positioning devices on or inline with each streamer;

(b) a prediction unit adapted to predict positions of at least some of the streamer positioning devices; and

(c) a control unit adapted to use the predicted positions to calculate desired changes in positions of one or more of the streamer positioning devices.

16. Apparatus as claimed in claim **15**, in which each streamer positioning device has a first hydrodynamic deflecting surface and a second hydrodynamic deflecting surface, said first deflecting surface and said second deflecting surface being independently moveable to steer the streamer positioning device laterally and vertically.

17. Apparatus as claimed in claim **16**, wherein each streamer positioning device is rigidly attached to and unable to rotate with respect to its streamer.

18. Apparatus as claimed in claim **17**, further including means for determining the angular velocity of each streamer positioning device.

19. Apparatus as claimed in claim **18**, wherein a global control system is located on or near said seismic vessel and a respective local control system is located within or near each streamer positioning device and said global control system and said local control systems communicate using a respective communication line passing through each streamer.

20. Apparatus as claimed in claim **19**, in which input values for said local control systems are downloaded over said communication lines.

21. Apparatus as claimed in claim **20**, further including a respective backup communications channel in each streamer between the global control system and the local control systems of the streamer positioning devices of the streamer.

22. Apparatus as claimed in claim **21**, in which each local control system has a cycle rate that is at least 10 times greater than the data transfer rate of said communication line.

23. Apparatus as claimed in claim **22**, in which each local control system comprises a microprocessor programmed to monitor the current orientation of the wing of its streamer

positioning device and to calculate desired changes to the orientation of said wing based on inputs from said global control system.

24. Apparatus as claimed in claim **23**, further including means for producing a weight function filtered depth value.

25. A method of controlling position of a seismic streamer comprising:

(a) calculating magnitude and direction of a desired total force or displacement to apply to the seismic streamer;

(b) adjusting, based on forces exerted on the streamer by hydrodynamic deflecting surfaces in a force axis, the calculated magnitude of total force or displacement to form an intermediate desired total force;

(c) adjusting a common angle between hydrodynamic deflecting surfaces to produce the intermediate desired total force along the force axis; and

(d) introducing a splay angle in to the hydrodynamic deflecting surfaces to produce a rotational movement in a body of the streamer positioning device to align the force axis with the direction of the desired total force.

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(54) **CONTROL SYSTEM FOR POSITIONING OF MARINE SEISMIC STREAMERS**

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(58) **Field of Classification Search** 114/162, 114/163, 242, 244–246, 253
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,404,664 A * 9/1983 Zachariadis 367/19
4,709,355 A * 11/1987 Woods et al. 367/16
5,790,472 A * 8/1998 Workman et al. 367/19

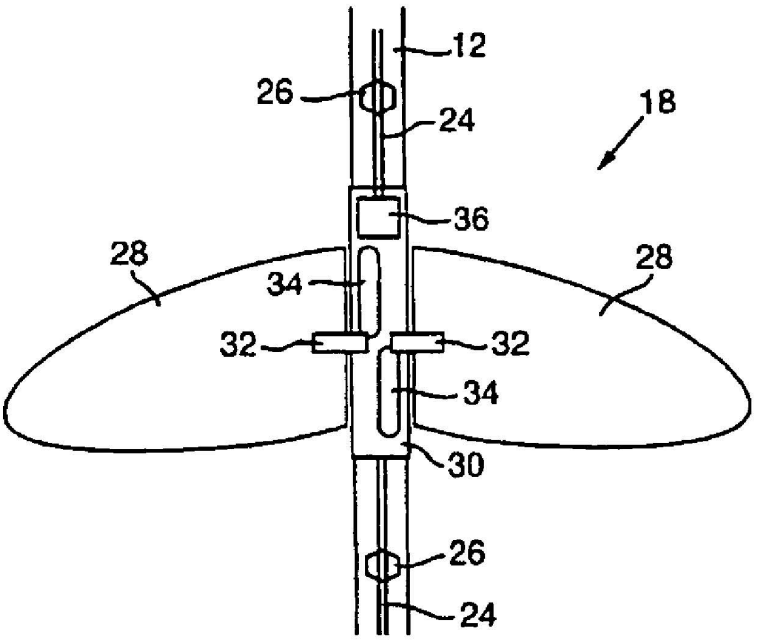
* cited by examiner

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(57) **ABSTRACT**

A method of controlling a streamer positioning device (**18**) configured to be attached to a marine seismic streamer (**12**) and towed by seismic survey vessel (**10**) and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The invention also involves an apparatus for controlling a streamer positioning device including means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to produce the desired change in the orientation of the wing.

28 Claims, 3 Drawing Sheets



WESTERNGECO
09-CV-01827
PTX002

Fig.1.

Prior Art

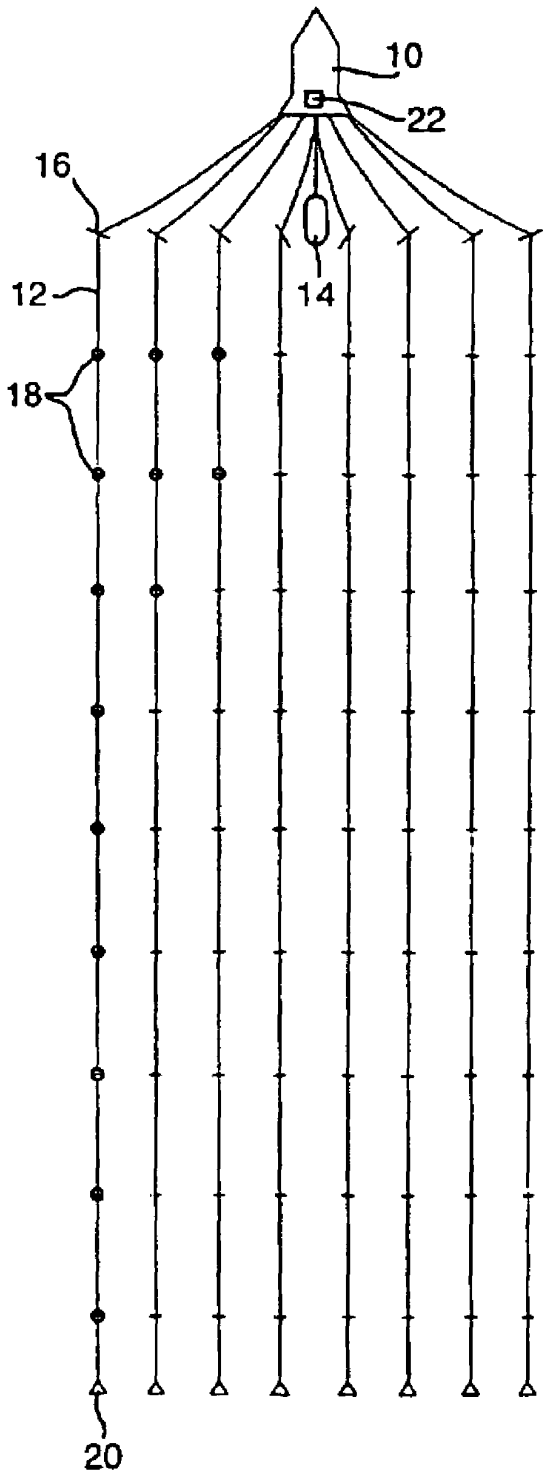


Fig.2.

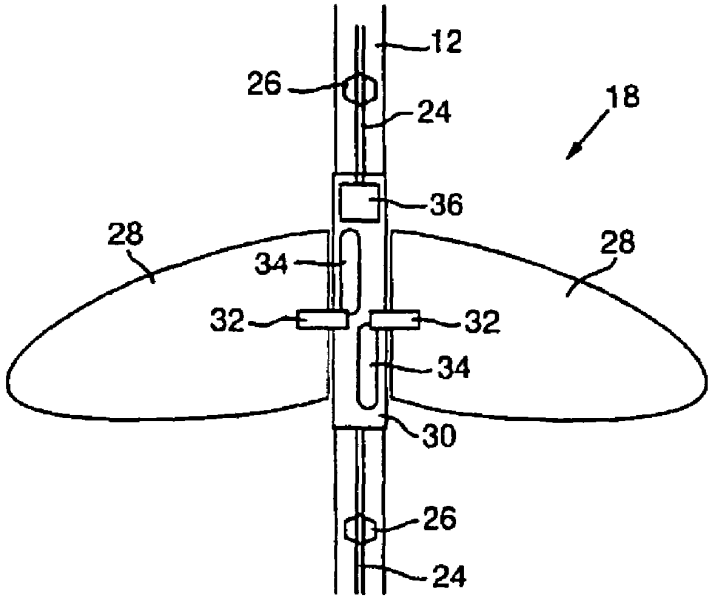

12
26
24
18
36
28
28
34
32
32
34
30
26
24

Fig.3.

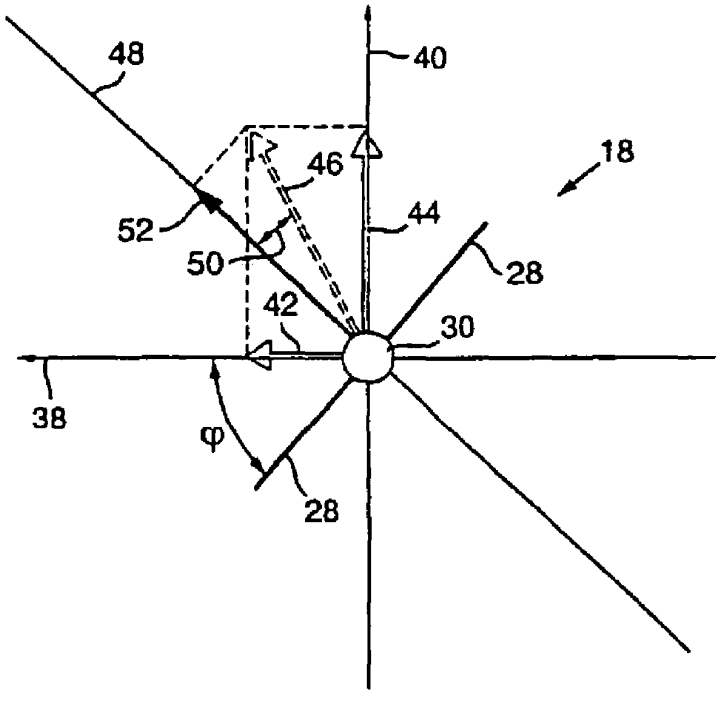
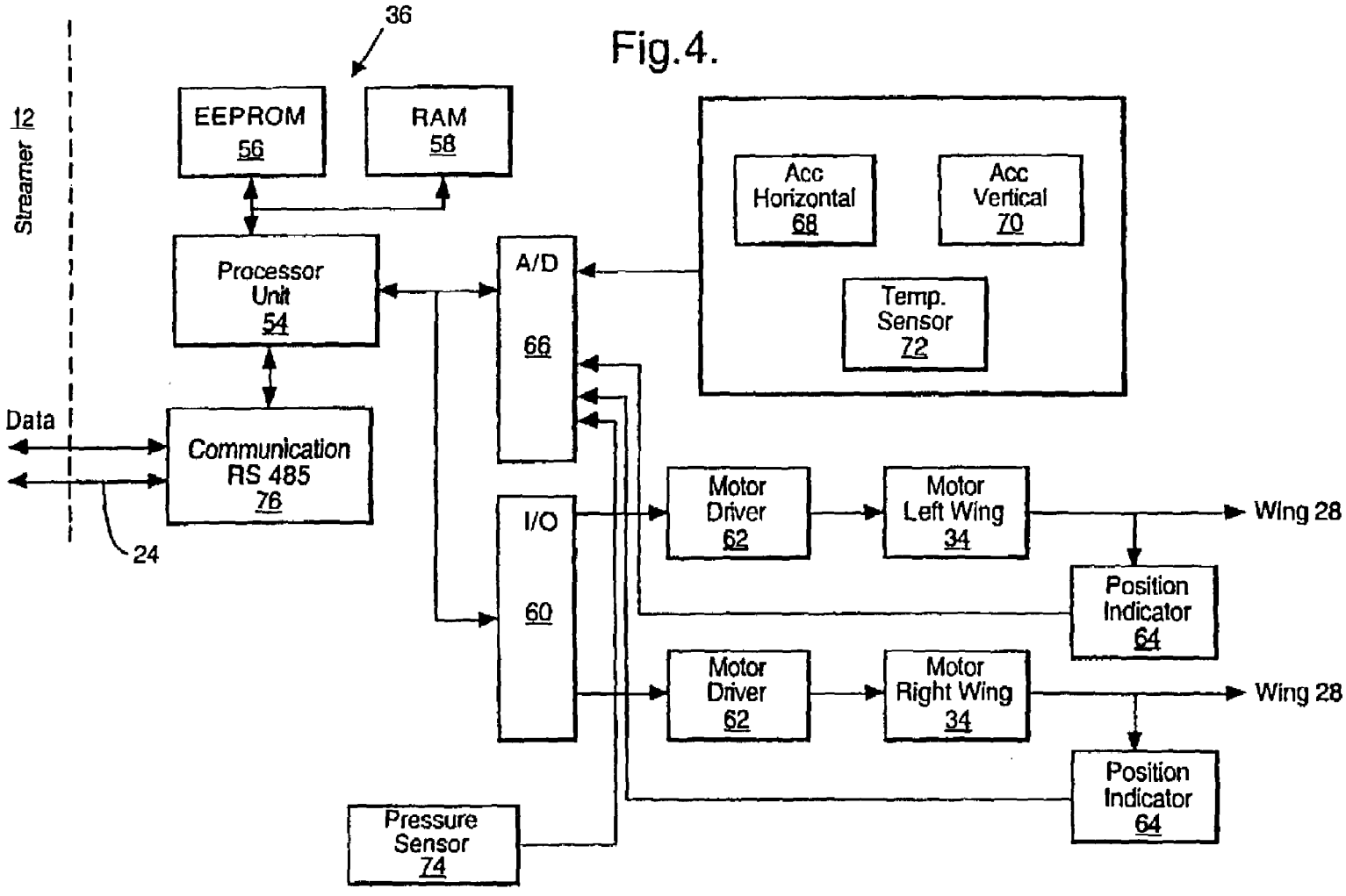

48
40
46
18
52
44
50
28
42
30
38
φ
28

Fig.4.


36
12
Streamer
EEPROM
56
RAM
58
Processor
Unit
54
A/D
66
Acc
Horizontal
68
Acc
Vertical
70
Temp.
Sensor
72
Data
Communication
RS 485
76
24
I/O
60
Motor
Driver
62
Motor
Left Wing
34
Wing 28
Position
Indicator
64
Motor
Driver
62
Motor
Right Wing
34
Wing 28
Position
Indicator
64
Pressure
Sensor
74

CONTROL SYSTEM FOR POSITIONING OF MARINE SEISMIC STREAMERS

CROSS-REFERENCE TO RELATED APPLICATIONS

Applicant claims priority under 35 U.S.C. § 120 from Ser. No. 11/070,614, filed Mar. 2, 2005, now U.S. Pat. No. 7,080,607, which was a continuation of parent application Ser. No. 09/787,723, filed Jul. 2, 2001, now U.S. Pat. No. 6,932,017, which was a 35 U.S.C. § 371 national stage filing from Patent Cooperation Treaty application number PCT/IB99/01590, filed Sep. 28, 1999, which in turn claimed priority from Great Britain patent application number 9821277.3, filed Oct. 1, 1998, from which Applicant claims foreign priority under 35 U.S.C. § 119, all of which are incorporated herein by reference. This application is also related to application Ser. Nos. 11/454,349 and 11/455,042, both filed simultaneously herewith, which also are both incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates generally to systems for controlling seismic data acquisition equipment and particularly to a system for controlling a marine seismic streamer positioning device.

A marine seismic streamer is an elongate cable-like structure, typically up to several thousand meters long, which contains arrays of seismic sensors, known as hydrophones, and associated electronic equipment along its length, and which is used in marine seismic surveying. In order to perform a 3D marine seismic survey, a plurality of such streamers are towed at about 5 knots behind a seismic survey vessel, which also tows one or more seismic sources, typically air guns. Acoustic signals produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various strata. The reflected signals are received by the hydrophones, and then digitized and processed to build up a representation of the subsurface geology.

The horizontal positions of the streamers are typically controlled by a deflector, located at the front end or "head" of the streamer, and a tail buoy, located at the back end or "tail" of the streamer. These devices create tension forces on the streamer which constrain the movement of the streamer and cause it to assume a roughly linear shape. Cross currents and transient forces cause the streamer to bow and undulate, thereby introducing deviations into this desired linear shape.

The streamers are typically towed at a constant depth of approximately ten meters, in order to facilitate the removal of undesired "ghost" reflections from the surface of the water. To keep the streamers at this constant depth, control devices known as "birds", are typically attached at various points along each streamer between the deflector and the tail buoy, with the spacing between the birds generally varying between 200 and 400 meters. The birds have hydrodynamic deflecting surfaces, referred to as wings, that allow the position of the streamer to be controlled as it is towed through the water. When a bird is used for depth control purposes only, it is possible for the bird to regularly sense its depth using an integrated pressure sensor and for a local controller within the bird to adjust the wing angles to maintain the streamer near the desired depth using only a desired depth value received from a central control system.

While the majority of birds used thus far have only controlled the depth of the streamers, additional benefits can

be obtained by using properly controlled horizontally steerable birds, particularly by using the types of horizontally and vertically steerable birds disclosed in our published PCT International Application No. WO 98/28636. The benefits that can be obtained by using properly controlled horizontally steerable birds can include reducing horizontal out-of-position conditions that necessitate reacquiring seismic data in a particular area (i.e. in-fill shooting), reducing the chance of tangling adjacent streamers, and reducing the time required to turn the seismic acquisition vessel when ending one pass and beginning another pass during a 3D seismic survey.

It is estimated that horizontal out-of-position conditions reduce the efficiency of current 3D seismic survey operations by between 5 and 10%, depending on weather and current conditions. While incidents of tangling adjacent streamers are relatively rare, when they do occur they invariably result in prolonged vessel downtime. The loss of efficiency associated with turning the seismic survey vessel will depend in large part on the seismic survey layout, but typical estimates range from 5 to 10%. Simulations have concluded that properly controlled horizontally steerable birds can be expected to reduce these types of costs by approximately 30%.

One system for controlling a horizontally steerable bird, as disclosed in UK Patent GB 2093610 B, is to utilize a manually-operated central control system to transmit the magnitudes and directions of any required wing angle changes to the birds. While this method greatly simplifies the circuitry needed within the bird itself, it is virtually impossible for this type of system to closely regulate the horizontal positions of the birds because it requires manual input and supervision. This becomes a particularly significant issue when a substantial number of streamers are deployed simultaneously and the number of birds that must be controlled goes up accordingly.

Another system for controlling a horizontally steerable bird is disclosed in our published PCT International Application No. WO 98/28636. Using this type of control system, the desired horizontal positions and the actual horizontal positions are received from a remote control system and are then used by a local control system within the birds to adjust the wing angles. The actual horizontal positions of the birds may be determined every 5 to 10 seconds and there may be a 5 second delay between the taking of measurements and the determination of actual streamer positions. While this type of system allows for more automatic adjustment of the bird wing angles, the delay period and the relatively long cycle time between position measurements prevents this type of control system from rapidly and efficiently controlling the horizontal position of the bird. A more deterministic system for controlling this type of streamer positioning device is therefore desired.

It is therefore an object of the present invention to provide for an improved method and apparatus for controlling a streamer positioning device.

An advantage of the present invention is that the position of the streamer may be better controlled, thereby reducing the need for in-fill shooting, reducing the chance of streamer tangling, and reducing the time needed to turn the seismic survey vessel.

Another advantage of the present invention is that noise in marine seismic data associated with streamer position overcorrection and streamer positioning errors can be significantly reduced.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for controlling the positions of marine seismic streamers in an array of such streamers being towed by a seismic survey vessel, the streamers having respective streamer positioning devices disposed therealong and each streamer positioning device having a wing and a wing motor for changing the orientation of the wing so as to steer the streamer positioning device laterally, said methods and apparatus involving (a) obtaining an estimated velocity of the streamer positioning devices, (b) for at least some of the streamer positioning devices, calculating desired changes in the orientation of their wings using said estimated velocity, and (c) actuating the wing motors to produce said desired changes in wing orientation.

The invention and its benefits will be better understood with reference to the detailed description below and the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition equipment;

FIG. **2** is a schematic horizontal cross-sectional view through a marine seismic streamer and an attached streamer positioning device;

FIG. **3** is a schematic vertical cross-sectional view through the streamer positioning device from FIG. **2**; and

FIG. **4** is a schematic diagram of the local control system architecture of the streamer positioning device from FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, a seismic survey vessel **10** is shown towing eight marine seismic streamers **12** that may, for instance, each be 3000 meters in length. The outermost streamers **12** in the array could be 700 meters apart, resulting in a horizontal separation between the streamers of 100 meters in the regular horizontal spacing configuration shown. A seismic source **14**, typically an airgun or an array of airguns, is also shown being towed by the seismic survey vessel **10**. At the front of each streamer **12** is shown a deflector **16** and at the rear of every streamer is shown a tail buoy **20**. The deflector **16** is used to horizontally position the end of the streamer nearest the seismic survey vessel **10** and the tail buoy **20** creates drag at the end of the streamer farthest from the seismic survey vessel **10**. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly linear shape of the seismic streamer **12** shown in FIG. **1**.

Located between the deflector **16** and the tail buoy **20** are a plurality of streamer positioning devices known as birds **18**. Preferably the birds **18** are both vertically and horizontally steerable. These birds **18** may, for instance, be located at regular intervals along the streamer, such as every 200 to 400 meters. The vertically and horizontally steerable birds **18** can be used to constrain the shape of the seismic streamer **12** between the deflector **16** and the tail buoy **20** in both the vertical (depth) and horizontal directions.

In the preferred embodiment of the present invention, the control system for the birds **18** is distributed between a global control system **22** located on or near the seismic survey vessel **10** and a local control system located within or near the birds **18**. The global control system **22** is typically connected to the seismic survey vessel's navigation system and obtains estimates of system wide parameters, such as the vessel's towing direction and velocity and current direction and velocity, from the vessel's navigation system.

The most important requirement for the control system is to prevent the streamers **12** from tangling. This requirement becomes more and more important as the complexity and the total value of the towed equipment increases. The trend in the industry is to put more streamers **12** on each seismic survey vessel **10** and to decrease the horizontal separation between them. To get better control of the streamers **12**, horizontal steering becomes necessary. If the birds **18** are not properly controlled, horizontal steering can increase, rather than decrease, the likelihood of tangling adjacent streamers. Localized current fluctuations can dramatically influence the magnitude of the side control required to properly position the streamers. To compensate for these localized current fluctuations, the inventive control system utilizes a distributed processing control architecture and behavior-predictive model-based control logic to properly control the streamer positioning devices.

In the preferred embodiment of the present invention, the global control system **22** monitors the actual positions of each of the birds **18** and is programmed with the desired positions of or the desired minimum separations between the seismic streamers **12**. The horizontal positions of the birds **18** can be derived, for instance, using the types of acoustic positioning systems described in our U.S. Pat. No. 4,992,990 or in our PCT International Patent Application No. WO 98/21163. Alternatively, or additionally, satellite-based global positioning system equipment can be used to determine the positions of the equipment. The vertical positions of the birds **18** are typically monitored using pressure sensors attached to the birds, as discussed below.

The global control system **22** preferably maintains a dynamic model of each of the seismic streamers **12** and utilizes the desired and actual positions of the birds **18** to regularly calculate updated desired vertical and horizontal forces the birds should impart on the seismic streamers **12** to move them from their actual positions to their desired positions. Because the movement of the seismic streamer **12** causes acoustic noise (both from seawater flow past the bird wing structures as well as cross current flow across the streamer skin itself), it is important that the streamer movements be restrained and kept to the minimum correction required to properly position the streamers. Any streamer positioning device control system that consistently overestimates the type of correction required and causes the bird to overshoot its intended position introduces undesirable noise into the seismic data being acquired by the streamer. In current systems, this type of over-correction noise is often balanced against the "noise" or "smearing" caused when the seismic sensors in the streamers **12** are displaced from their desired positions.

The global control system **22** preferably calculates the desired vertical and horizontal forces based on the behavior of each streamer and also takes into account the behavior of the complete streamer array. Due to the relatively low sample rate and time delay associated with the horizontal position determination system, the global control system **22** runs position predictor software to estimate the actual locations of each of the birds **18**. The global control system **22** also checks the data received from the vessel's navigation system and the data will be filled in if it is missing. The interface between the global control system **22** and the local control system will typically operate with a sampling frequency of at least 0.1 Hz. The global control system **22** will typically acquire the following parameters from the vessel's

navigation system: vessel speed (m/s), vessel heading (degrees), current speed (m/s), current heading (degrees), and the location of each of the birds in the horizontal plane in a vessel fixed coordinate system. Current speed and heading can also be estimated based on the average forces acting on the streamers **12** by the birds **18**. The global control system **22** will preferably send the following values to the local bird controller: demanded vertical force, demanded horizontal force, towing velocity, and crosscurrent velocity.

The towing velocity and crosscurrent velocity are preferably "water-referenced" values that are calculated from the vessel speed and heading values and the current speed and heading values, as well as any relative movement between the seismic survey vessel **10** and the bird **18** (such as while the vessel is turning), to produce relative velocities of the bird **18** with respect to the water in both the "in-line" and the "cross-line" directions. Alternatively, the global control system **22** could provide the local control system with the horizontal velocity and water in-flow angle. The force and velocity values are delivered by the global control system **22** as separate values for each bird **18** on each streamer **12** continuously during operation of the control system.

The "water-referenced" towing velocity and crosscurrent velocity could alternatively be determined using flowmeters or other types of water velocity sensors attached directly to the birds **18**. Although these types of sensors are typically quite expensive, one advantage of this type of velocity determination system is that the sensed in-line and cross-line velocities will be inherently compensated for the speed and heading of marine currents acting on said streamer positioning device and for relative movements between the vessel **10** and the bird **18**.

FIG. **2** shows a type of bird **18** that is capable of controlling the position of seismic streamers **12** in both the vertical and horizontal directions. A bird **18** of this type is also disclosed in our PCT International Application No. WO 98/28636. While a number of alternative designs for the vertically and horizontally steerable birds **18** are possible, including those utilizing one full-moving wing with ailerons, three full-moving wings, and four full-moving wings, the independent two-wing principal is, conceptually, the simplest and most robust design.

In FIG. **2**, a portion of the seismic streamer **12** is shown with an attached bird **18**. A communication line **24**, which may consist of a bundle of fiber optic data transmission cables and power transmission wires, passes along the length of the seismic streamer **12** and is connected to the seismic sensors, hydrophones **26**, that are distributed along the length of the streamer, and to the bird **18**. The bird **18** preferably has a pair of independently moveable wings **28** that are connected to rotatable shafts **32** that are rotated by wing motors **34** and that allow the orientation of the wings **28** with respect to the bird body **30** to be changed. When the shafts **32** of the bird **18** are not horizontal, this rotation causes the horizontal orientation of the wings **28** to change and thereby changes the horizontal forces that are applied to the streamer **12** by the bird.

The motors **34** can consist of any type of device that is capable of changing the orientation of the wings **28**, and they are preferably either electric motors or hydraulic actuators. The local control system **36** controls the movement of the wings **28** by calculating a desired change in the angle of the wings and then selectively driving the motors **34** to effectuate this change. While the preferred embodiment depicted utilizes a separate motor **34** for each wing **28**, it would be also be possible to independently move the wings **28** using a single motor **34** and a selectively actuatable transmission mechanism.

When the bird **18** uses two wings **28** to produce the horizontal and vertical forces on the streamer **12**, the required outputs of the local control system **36** are relatively simple, the directions and magnitudes of the wing movements required for each of the wings **28**, or equivalently the magnitude and direction the motors **34** need to be driven to produce this wing movement. While the required outputs of the local control system **36** for such a two full moving wing design is quite simple, the structure and operation of the overall system required to coordinate control of the device is relatively complicated.

FIG. **3** shows a schematic vertical cross-sectional view through the streamer positioning device shown in FIG. **2** that will allow the operation of the inventive control system to be described in more detail. The components of the bird **18** shown in FIG. **3** include the wings **28** and the body **30**. Also shown in FIG. **3** are a horizontal coordinate axis **38** and a vertical coordinate axis **40**. During operation of the streamer positioning control system, the global control system **22** preferably transmits, at regular intervals (such as every five seconds) a desired horizontal force **42** and a desired vertical force **44** to the local control system **36**.

The desired horizontal force **42** and the desired vertical force **44** are combined within the local control system **36** to calculate the magnitude and direction of the desired total force **46** that the global control system **22** has instructed the local control system to apply to the streamer **12**. The global control system **22** could alternatively provide the magnitude and direction of the desired total force **46** to the local control system **36** instead of the desired horizontal force **42** and the desired vertical force **44**.

While the desired horizontal force **42** and the desired vertical force **44** are preferably calculated by the global control system **22**, it is also possible for the local control system **36** in the inventive control system to calculate one or both of these forces using a localized displacement/force conversion program. This type of localized conversion program may, for instance, use a look-up table or conversion routine that associates certain magnitudes and directions of vertical or horizontal displacements with certain magnitudes and directions of changes in the vertical or horizontal forces required. Using this type of embodiment, the global control system **22** can transmit location information to the local control system **36** instead of force information. Instead of the desired vertical force **44**, the global control system **22** can transmit a desired vertical depth and the local control system **36** can calculate the magnitude and direction of the deviation between the desired depth and the actual depth. Similarly, instead of transmitting a desired horizontal force **42**, the global control system **22** can transmit the magnitude and direction of the displacement between the actual horizontal position and the desired horizontal position of the bird **18**. One advantage to this alternative type of system is that the required vertical force can be rapidly updated as the local control system receives updated depth information from the integrated pressure sensor. Other advantages of this type of alternative system include reducing communication traffic on the communication line **24** and simplifying the programming needed to convert the measured vertical and/or horizontal displacements into corresponding forces to be applied by the birds **18**.

When the local control system **36** has a new desired horizontal force **42** and desired vertical force **44** to be applied, the wings **28** will typically not be in the proper

orientation to provide the direction of the desired total force **46** required. As can be seen in FIG. **3**, the wings **28** introduce a force into the streamer **12** along an axis perpendicular to the rotational axis of the wings **28** and perpendicular to the streamer. This force axis **48** is typically not properly aligned with the desired total force **46** when new desired horizontal and vertical force values are received from the global control system **22** or determined by the local control system **36** and some rotation of the bird **18** is required before the bird can produce this desired total force **46**. As can be seen, the force axis **48** is directly related to the bird roll angle, designated in FIG. **3** as ϕ.

The local control system **36** optimizes the control process by projecting the desired total force **46** onto the force axis **48** (i.e. multiplying the magnitude of the desired total force by the cosine of the deviation angle **50**) to produce an intermediate desired force **52** and then adjusting the wing common angle α (the angle of the wings with respect to the bird body **30**, or the average angle if there is a non-zero splay angle) to produce this magnitude of force along the force axis. The calculated desired common wing angle is compared to the current common wing angle to calculate a desired change in the common wing angle and the wing motors **34** are actuated to produce this desired change in the orientation of the wings.

A splay angle is then introduced into the wings **28** to produce a rotational movement in the bird body **30** (i.e. to rotate the force axis **48** to be aligned with the desired total force **46**). The splay angle is the difference between the angles of the wings **28** with respect to the bird body **30**. As the bird body **30** rotates and the force axis **48** becomes more closely aligned with the desired total force **46**, the bird roll angle and the bird roll angular velocity are monitored, the splay angle is incrementally reduced, and the common angle is incrementally increased until the intermediate desired force **52** is in the same direction and of the same magnitude as the desired total force. The local control system **36** carefully regulates the splay angle to ensure that the streamer is stable in roll degree of freedom. The calculated common wing angle and the splay angle are also regulated by the local control system **36** to prevent the wings **28** from stalling and to ensure that the splay angle is prioritized.

When using the type of birds described in our published PCT International Application No. WO 98/28636, where the bird **18** is rigidly attached, and cannot rotate with respect, to the streamer **12**, it is important for the control system to take the streamer twist into account. If this is not taken into account, the bird **18** can use all of its available splay angle to counter the twist in the streamer **12**. The bird **18** will then be unable to reach the demanded roll angle and the generated force will decrease. The inventive control system incorporates two functions for addressing this situation; the anti-twist function and the untwist function.

In the anti-twist function, the streamer twist is estimated by weightfunction filtering the splay angle measurements instead of simply averaging the splay angle measurements to improve the bandwidth of the estimation. The anti-twist function engages when the estimated twist has reached a critical value and it then overrides the normal shortest path control of the calculated roll angle. The anti-twist function forces the bird **18** to rotate in the opposite direction of the twist by adding +/−180 degrees to the demanded roll angle. Once the twist has been reduced to an acceptable value, the anti-twist function disengages and the normal shortest path calculation is continued.

The untwist function is implemented by the global control system **22** which monitors the splay angle for all of the birds **18** in each streamer **12**. At regular intervals or when the splay angle has reached a critical value, the global control system **22** instructs each local control system **36** to rotate each bird **18** in the opposite direction of the twist. The number of revolutions done by each bird **18** is monitored and the untwist function is disengaged once the twist has reached an acceptable level. FIG. **4** is a schematic diagram of the architecture of the local control system **36** for the bird **18**. The local control system **36** consists of a central processor unit **54**, having EEPROM 56 and RAM **58** memory, an input/output subsystem **60** that is connected to a pair of motor drivers **62**, and an analog to digital conversion unit **66**. The motor drivers **62** are connected to and actuate the wing motors **34** to produce the desired change the orientation of the wings **28** with respect to the bird body **30**.

The wing motor **34**/wing **28** units are also connected to wing position indicators **64** that sense the relative positions of the wings and provide measurements to the analog to digital conversion unit **66** which converts the analog wing position indicator **64** measurements into digital format and conveys these digital values to the central processor unit **54**. Various types of wing position indicators **64** can be used, including resistive angle or displacement sensors inductive sensors, capacitive sensors, hall sensors, or magneto-restrictive sensors.

A horizontal accelerometer **68** and a vertical accelerometer **70**, placed at right angles with respect to one another, are also connected to the analog to digital conversion unit **66** and these accelerometers convey measurements that allow the central processor unit **54** to determine the roll angle and roll rate of the bird **18**. An angular velocity vibrating rate gyro (rategyro) can also be used to measure the roll rate of the bird **18**. A temperature sensor **72** is connected to the analog to digital conversion unit **66** to provide temperature measurements that allow the horizontal accelerometer **68** and the vertical accelerometer **70** to be calibrated.

A pressure sensor **74** is also connected to the analog to digital conversion unit **66** to provide the central processor unit **54** with measurements of the water pressure at the bird **18**. To calculate an appropriate depth value, the measured pressure values must be filtered to limit the disturbance from waves. This is done in the inventive control system with a weightfunction filter that avoids the large phase displacements caused by mean value filters. Instead of using an instantaneous depth value or simply calculating an average depth value over a given period of time (and thereby incorporating a large phase displacement into the depth value), the inventive control system uses a differentially weighted pressure filtering scheme. First the pressure values are transformed into depth values by dividing the pressure sensor reading by the seawater density and gravitational acceleration. These depth values are then filtered using a weight function filter. Typical incremental weighting functions values range from 0.96 to 0.90 (sample weights of 1.0, 0.9, 0.81, 0.729, etc.) and the filter will typically process depth values received over a period of at least 100 seconds.

The central processor unit **54** is also connected to a RS485 communications unit **76** that allows information to be exchanged between the local control system **36** and the global control system **22** over the communication line **24** that passes through the streamer **12**. The RS485 bus may, for instance, utilize Neuron chips that communicate using a Local Operating Network protocol to control the data transfer.

Preferably, the central processor unit **54** and associated components comprise a MicroChip 17C756 processor. This type of microprocessor has very low power requirements, a

dual UART on-chip, 12-channel, 10 bit ADC on-chip, 908×8 RAM, 16 k×16 ROM, and 50 digital I/O channels. The software running on the central processor unit **54** will typically consist of two units, the local control unit and the hardware control unit. It is typically not possible to pre-load both of these program units into the EEPROM 56 and it is possible to update these program units without having to open the bird **18**. The on-chip memory may thus only initially contain a boot-routine that enables the loading of software units into the external memory via the RS485 communication unit **76**. The external program memory (EEPROM 56) will typically be a non-volatile memory so that these program units do not have to be re-loaded after every power down.

The central processor unit **54** must be able to run the local control system software fast enough to secure the sampling frequency needed for effective local bird control. This may mean, for instance, a sample rate of 10 Hz, which may be 10 to 100 times faster than the sample rate of the communications between the global control system **22** and the local control system **36**. As discussed above, the central processor unit **54** will also receive data from sensors attached to the bird **18**. The sensed values include bird roll angle, bird roll angular velocity (roll rate), the wing angles, and the static pressure of the water. These values are typically delivered to the central processor unit **54** at a sample rate of at least 10 Hz. The following values may be transmitted from the local control system **36** to the global control system **22** using the RS485 communication unit **76**: the measured roll angle, the measured roll rate, the measured wing angles, the measured water pressure, the calculated depth, and the calculated wing forces.

The system has been designed with a redundant communication system to increase its overall reliability. The bird **18** will typically have a backup communications channel, such as by overlaying a backup control signal on top of the power line current. This backup communications channel is particularly important because in the event of loss of communications to the bird **18** there would otherwise be no method for instructing the bird **18** to bring the streamer **12** to surface so the defective communications equipment can be repaired or replaced.

In contrast to previous streamer position device control systems, the present control system converts the desired horizontal force **42** and the desired vertical force **44** into a desired roll angle ϕ and a desired common wing angle α by deterministic calculations, rather than using an "incremental change/measured response/further incremental change based on measured response" type of feedback control circuit. The desired roll angle ϕ can be calculated in the manner discussed in the text describing FIG. **3** above. The magnitude of the force F imparted by the wings **28** along the force axis **48** can, for instance, be deterministically calculated using the following formula:

$$F=0.5\rho AC_L(V_{tow}\cos(\alpha)-V_{current}\sin(\alpha))^2$$

where: ρ=water density;

A=wing area;

C_L=wing lift coefficient;

α=common wing angle;

V_{tow}=towing velocity; and

$V_{current}$=crosscurrent velocity.

A similar deterministic calculation could be made using a calculated coefficient that incorporates the towing velocity of the bird **18**. A gain factor GF, for instance, could be calculated as follows:

$$GF=0.5\rho AC_L(V_{tow})^2$$

which could be simply multiplied by $\cos(\alpha)^2$ to estimate the force that would be applied for a given common angle.

One of the beneficial elements of the inventive control system is that the desired change in the orientation of the wing **28** is calculated using an estimate of the velocity of the bird **18** rather than simply relying on a feedback-loop type of control system that operates in the same manner regardless of the vessel speed. Because the force produced by wing **28** is proportional to the velocity of the device squared, a much more precise calculation of the desired change in the wing orientation can be made by using an estimate of the device velocity.

The inventive control system is based on shared responsibilities between the global control system **22** located on the seismic survey vessel **10** and the local control system **36** located on the bird **18**. The global control system **22** is tasked with monitoring the positions of the streamers **12** and providing desired forces or desired position information to the local control system **36**. The local control system **36** within each bird **18** is responsible for adjusting the wing splay angle to rotate the bird to the proper position and for adjusting the wing common angle to produce the magnitude of total desired force required.

The inventive control system will primarily operate in two different control modes: a feather angle control mode and a turn control mode. In the feather angle control mode, the global control system **22** attempts to keep each streamer in a straight line offset from the towing direction by a certain feather angle. The feather angle could be input either manually, through use of a current meter, or through use of an estimated value based on the average horizontal bird forces. Only when the crosscurrent velocity is very small will the feather angle be set to zero and the desired streamer positions be in precise alignment with the towing direction.

The turn control mode is used when ending one pass and beginning another pass during a 3D seismic survey, sometimes referred to as a "line change". The turn control mode consists of two phases. In the first part of the turn, every bird **18** tries to "throw out" the streamer **12** by generating a force in the opposite direction of the turn. In the last part of the turn, the birds **18** are directed to go to the position defined by the feather angle control mode. By doing this, a tighter turn can be achieved and the turn time of the vessel and equipment can be substantially reduced. Typically during the turn mode adjacent streamers will be depth separated to avoid possible entanglement during the turn and will be returned to a common depth as soon as possible after the completion of the turn. The vessel navigation system will typically notify the global control system **22** when to start throwing the streamers **12** out, and when to start straightening the streamers.

In extreme weather conditions, the inventive control system may also operate in a streamer separation control mode that attempts to minimize the risk of entanglement of the streamers. In this control mode, the global control system **22** attempts to maximize the distance between adjacent streamers. The streamers **12** will typically be separated in depth and the outermost streamers will be positioned as far away from each other as possible. The inner streamers will then be regularly spaced between these outermost streamers, i.e. each bird **18** will receive desired horizontal forces **42** or

desired horizontal position information that will direct the bird **18** to the midpoint position between its adjacent streamers.

While the embodiment of the inventive control system described above is shown in connection with a "bird" type of streamer positioning device, it will be readily understood that the control system method and apparatus may also be used in connection with streamer positioning devices that are characterized as "deflectors" or steerable "tail buoys" because they are attached to either the front end or the back end of the streamer **12**.

The present invention includes any novel feature or novel combination of features disclosed herein, either explicitly or implicitly.

What is claimed is:

1. A method comprising:

(a) towing an array of streamers each having a plurality of streamer positioning devices there along, at least one of the streamer positioning devices having a wing;

(b) transmitting from a global control system location information to at least one local control system on the at least one streamer positioning devices having a wing; and

(c) adjusting the wing using the local control system.

2. The method of claim **1** wherein the adjusting comprises calculating, with the at least one local control system, a desired force on the at least one streamer positioning device using the location information, the desired force selected from a desired horizontal force, a desired vertical force, and both.

3. The method as claimed in claim **2** wherein the calculating comprises a localized conversion program that associates magnitude and direction of vertical displacement, horizontal displacement, or both displacements with magnitude and direction of the desired vertical force, the desired horizontal force, or both forces.

4. The method as claimed in claim **1**, wherein the global control system transmits a desired vertical depth for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired vertical depth and actual depth.

5. The method as claimed in claim **1**, wherein the global control system transmits a desired horizontal displacement for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired horizontal displacement and actual horizontal displacement.

6. The method as claimed in claim **1**, comprising calculating velocity of at least one of the streamer positioning devices, wherein the calculating velocity comprises at least one of a) using a vessel speed received from a navigation system on a seismic survey vessel; b) compensating for the speed and heading of marine currents acting on the at least one streamer positioning device; and c) compensating for relative movement between the seismic survey vessel and the at least one streamer positioning device.

7. The method as claimed in claim **6**, in which said step of adjusting the wing using the local control system is regulated to prevent the positioning device from stalling.

8. The method as claimed in claim **7**, in which said step of using the location information to calculate desired forces on the at least one streamer positioning device is regulated by the global control system located on or near a seismic survey vessel that is configured into a feather angle mode, wherein the global control system attempts to direct the streamer positioning devices to maintain each of the streamers in a straight line offset from the towing direction of the marine seismic vessel by a certain feather angle, and into a turn control mode, wherein the global control system directs the streamer positioning devices to generate a force in the opposite direction of a turn at the beginning of the turn.

9. The method as claimed in claim **8**, which said global control system is further configured into a streamer separation mode, wherein said global control system attempts to direct said streamer positioning device to maintain a minimum separation distance between adjacent streamers.

10. The method as claimed in claim **9**, further including the step of displaying the position of said streamer positioning devices on said seismic survey vessel.

11. The method as claimed in claim **10**, in which each streamer positioning device is attached to and unable rotate with respect to its streamer and further comprising the step of monitoring twist in said marine seismic streamers and calculating a desired change in the orientation of hydrodynamic deflecting surfaces of the streamer positioning devices to reduce said twist.

12. The method as claimed in claim **11**, further including the step of obtaining the desired positions of at least some of the streamer positioning devices.

13. The method as claimed in claim **12**, in which said desired force is projected onto a current force axis and orientation of hydrodynamic deflecting surfaces of the streamer positioning device is calculated that will produce said projected force at said calculated velocity.

14. The method as claimed in claim **13**, in which the streamer positioning device is rotated to align the current force axis with said desired force and its hydrodynamic deflecting surface orientation is changed as the current force axis becomes more closely aligned with said desired force.

15. An array of seismic streamers towed by a towing vessel comprising:

(a) a plurality of streamer positioning devices on or inline with each streamer, at least one of the streamer positioning devices having a wing;

(b) a global control system transmitting location information to at least one local control system on the at least one streamer positioning device having a wing, the local control system adjusting the wing.

16. The apparatus of claim **15** wherein the local control system calculates forces selected from a desired horizontal force, a desired vertical force, and both, on the at least one streamer positioning device using the location information.

17. The apparatus of claim **16** wherein local control system comprises a localized conversion program that associates magnitude and direction of vertical displacement, horizontal displacement, or both displacements with magnitude and direction of the desired vertical force, the desired horizontal force, or both forces.

18. The apparatus as claimed in claim **16**, wherein the global control system transmits a desired vertical depth for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired vertical depth and actual depth.

19. The apparatus as claimed in claim **16**, wherein the global control system transmits a desired horizontal displacement for the at least one streamer positioning device and the local control system calculates magnitude and direction of the deviation between the desired horizontal displacement and actual horizontal displacement.

20. The apparatus as claimed in claim **16**, comprising means for calculating velocity of at least one of the streamer positioning devices, wherein the means for calculating velocity comprises means selected from at least one of a) a

navigation system on a seismic survey vessel calculating vessel speed; b) a current meter compensating for the speed and heading of marine currents acting on the at least one streamer positioning device; and c) a unit measuring relative movement between the seismic survey vessel and the at least one streamer positioning device.

21. The apparatus as claimed in claim **20**, wherein the local control system adjusting the wing includes a regulator to prevent the positioning device from stalling.

22. The apparatus as claimed in claim **21**, wherein use of the location information to calculate desired forces on the at least one streamer positioning device is regulated by the global control system located on or near a seismic survey vessel that is configured into a feather angle mode, wherein the global control system attempts to direct the streamer positioning devices to maintain each of the streamers in a straight line offset from the towing direction of the marine seismic vessel by a certain feather angle, and into a turn control mode, wherein the global control system directs the streamer positioning devices to generate a force in the opposite direction of a turn at the beginning of the turn.

23. The apparatus as claimed in claim **22**, in which the global control system is further configured into a streamer separation mode, wherein said global control system attempts to direct said streamer positioning device to maintain a minimum separation distance between adjacent streamers.

24. The apparatus as claimed in claim **23**, comprising a display of the position of said streamer positioning devices on said seismic survey vessel.

25. The apparatus as claimed in claim **24**, in which each streamer positioning device is attached to and unable rotate with respect to its streamer, and further comprising a monitoring component to monitor twist in said marine seismic streamers and a calculating unit for calculating a desired change in the orientation of hydrodynamic deflecting surfaces of the streamer positioning devices to reduce said twist.

26. The apparatus as claimed in claim **25**, further including the step of obtaining the desired positions of at least some of the streamer positioning devices.

27. The apparatus as claimed in claim **26**, in which said desired force is projected onto a current force axis and orientation of hydrodynamic deflecting surfaces of the streamer positioning device is calculated that will produce said projected force at said calculated velocity.

28. The apparatus as claimed in claim **27**, in which the streamer positioning device is rotated to align the current force axis with said desired force and its hydrodynamic deflecting surface orientation is changed as the current force axis becomes more closely aligned with said desired force.

* * * * *

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(12) United States Patent
Hillesund et al.

(10) Patent No.: US 7,293,520 B2
(45) Date of Patent: *Nov. 13, 2007

(54) **CONTROL SYSTEM FOR POSITIONING OF A MARINE SEISMIC STREAMERS**

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(73) Assignee: **WesternGeco, L.L.C.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 102 days.

This patent is subject to a terminal disclaimer.

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G01V 1/38 (2006.01)

(52) **U.S. Cl.** **114/244**; 367/19

(58) **Field of Classification Search** 114/162, 114/163, 242, 244, 246, 253
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,375,800	A	4/1968	Cole et al.	114/235
3,412,705	A	11/1968	Nesson	115/12
3,434,446	A	3/1969	Cole	114/235
3,440,992	A	4/1969	Chance	114/235
3,560,912	A	2/1971	Spink et al.	340/3
3,605,674	A	9/1971	Weese	114/235 B
3,648,642	A	3/1972	Fetrow et al.	114/235
3,774,570	A	11/1973	Pearson	114/235 B
3,896,756	A	7/1975	Pearson et al.	114/235 B
3,931,608	A	1/1976	Cole	367/17
3,943,483	A	3/1976	Strange	340/7 PC
3,961,303	A	6/1976	Paitson	367/17
4,033,278	A	7/1977	Waters	114/245
4,063,213	A	12/1977	Itria et al.	367/17
4,087,780	A	5/1978	Itria et al.	367/17
4,222,340	A	9/1980	Cole	114/245
4,227,479	A	10/1980	Gertler et al.	114/312
4,290,124	A	9/1981	Cole	367/18

(Continued)

FOREIGN PATENT DOCUMENTS

AU	199853305	12/1997

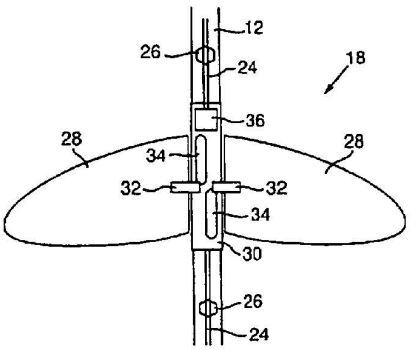
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Primary Examiner—Jesús D Sotelo
(74) *Attorney, Agent, or Firm*—Liangang (Mark) Ye; Jeffrey E. Griffin

(57) **ABSTRACT**

A method of controlling a streamer positioning device (**18**) configured to be attached to a marine seismic streamer (**12**) and towed by seismic survey vessel (**10**) and having a wing and a wing motor for changing the orientation of the wing. The method includes the steps of: obtaining an estimated velocity of the streamer positioning device, calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and actuating the wing motor to produce the desired change in the orientation of the wing. The invention also involves an apparatus for controlling a streamer positioning device including means for obtaining an estimated velocity of the streamer positioning device, means for calculating a desired change in the orientation of the wing using the estimated velocity of the streamer positioning device, and means for actuating the wing motor to produce the desired change in the orientation of the wing.

34 Claims, 3 Drawing Sheets



WESTERNGECO
09-CV-01827
PTX001

U.S. PATENT DOCUMENTS

4,313,392	A		2/1982	Guenther et al. 114/244
4,323,989	A		4/1982	Huckabee et al. 367/17
4,404,664	A		9/1983	Zachariadis 367/19
4,463,701	A		8/1984	Pickett et al. 114/245
4,484,534	A		11/1984	Thillaye du Boullay 114/244
4,694,435	A		9/1987	Magneville 367/17
4,709,355	A		11/1987	Woods et al. 367/16
4,711,194	A		12/1987	Fowler 114/245
4,723,501	A		2/1988	Hovden et al. ..... 114/144 B
4,729,333	A		3/1988	Kirby et al. 114/244
4,745,583	A		5/1988	Motal 367/18
4,766,441	A		8/1988	Phillips 343/709
4,767,183	A		8/1988	Martin 350/96.23
4,843,996	A		7/1989	Darche 114/245
4,890,568	A	*	1/1990	Dolengowski 114/246
4,890,569	A		1/1990	Givens 114/349
4,912,684	A		3/1990	Fowler 367/76
4,992,990	A		2/1991	Langeland 367/19
5,042,413	A		8/1991	Benoit 114/244
5,052,814	A		10/1991	Stubblefield 367/15
5,402,745	A		4/1995	Wood 114/244
5,443,027	A		8/1995	Owsley et al. 114/244
5,507,243	A		4/1996	Williams et al. 114/245
5,517,202	A		5/1996	Patel 343/709
5,517,463	A		5/1996	Hornbostel et al. 367/13
5,529,011	A		6/1996	Williams, Jr. 114/245
5,532,975	A		7/1996	Elholm 367/16
5,619,474	A		4/1997	Kuche 367/17
5,642,330	A		6/1997	Santopietro 367/131
5,790,472	A		8/1998	Workman et al. 367/19
5,913,280	A	*	6/1999	Nielsen et al. 114/242
5,973,995	A	*	10/1999	Walker et al. 367/20
6,011,752	A		1/2000	Ambs et al. 367/17
6,011,753	A		1/2000	Chien 367/21
6,016,286	A		1/2000	Olivier et al. 367/17
6,144,342	A		11/2000	Bertheas et al. 343/709
6,459,653	B1		10/2002	Kuche 367/17
6,525,992	B1		2/2003	Olivier et al. 367/17
6,549,653	B1		4/2003	Osawa et al. 382/162
6,879,542	B2		4/2005	Soreau et al. 367/17
6,932,017	B1	*	8/2005	Hillesund et al. 114/244

FOREIGN PATENT DOCUMENTS

AU	734810 B	6/2001
CA	2270719	12/1997
DE	69702673 T	4/2001
EP	0193215	1/1986
EP	0319716	6/1989
EP	0321705	6/1989
EP	0525391	2/1993
EP	0390987	12/1993
EP	0613025	8/1994
EP	0581441	8/1997
EP	0909701	1/2003
GB	2093610	9/1982
GB	2122562	1/1984
GB	2320706	7/1998
GB	2331971	6/1999
GB	2342081	4/2000
NO	992701	6/1999
WO	WO95/31735	11/1995
WO	WO96/21163	7/1996
WO	WO97/11395	3/1997
WO	WO97/30361	8/1997
WO	WO97/45006	12/1997
WO	WO98/28636	7/1998
WO	WO99/04293	1/1999

* cited by examiner

Fig.1.

Prior Art

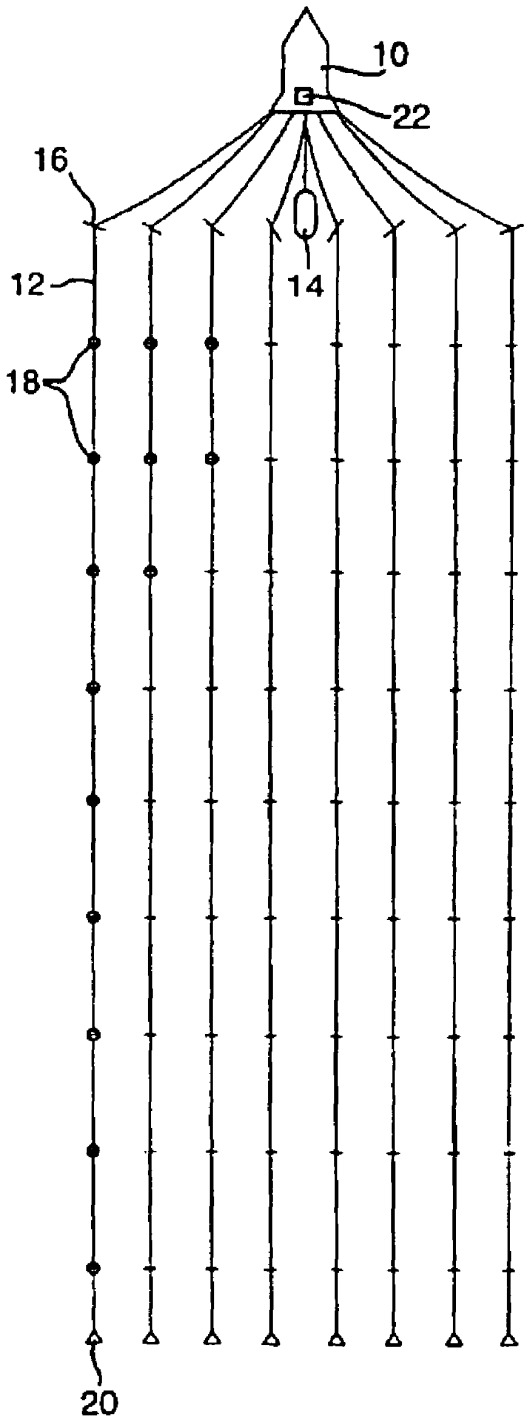


Fig.2.

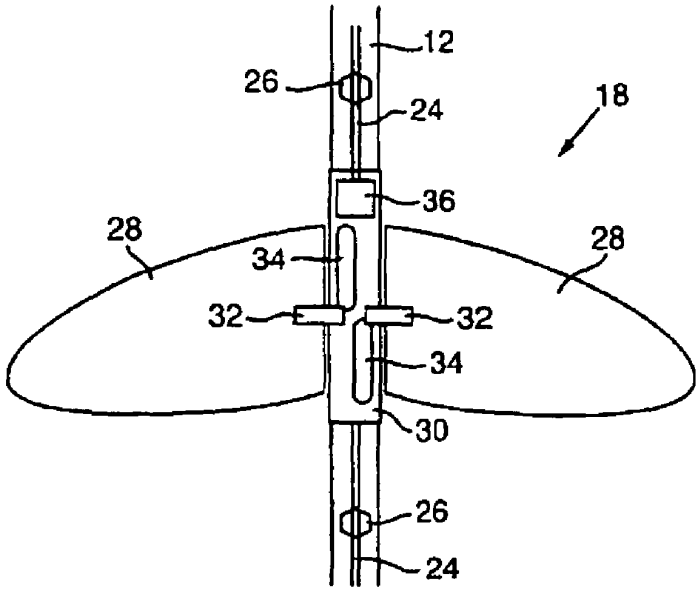

12
26
24
18
36
28
28
34
32
32
34
30
26
24

Fig.3.

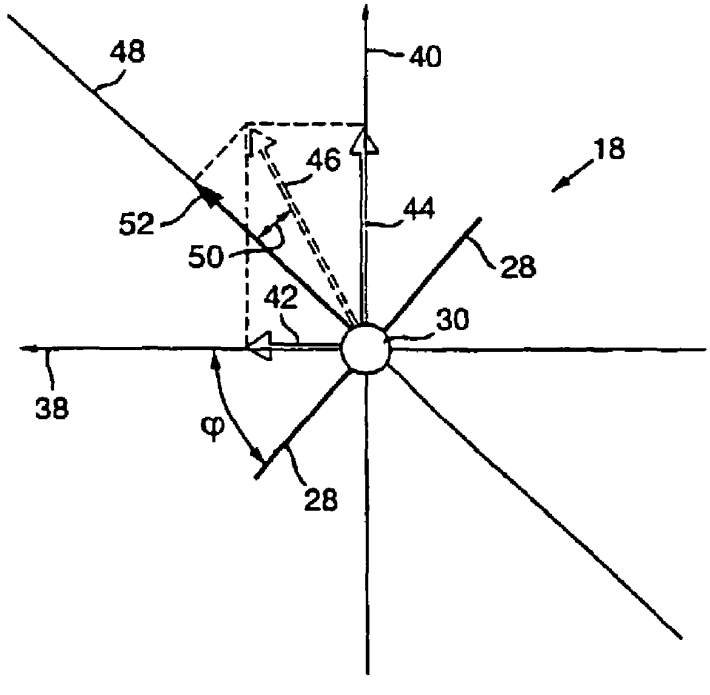
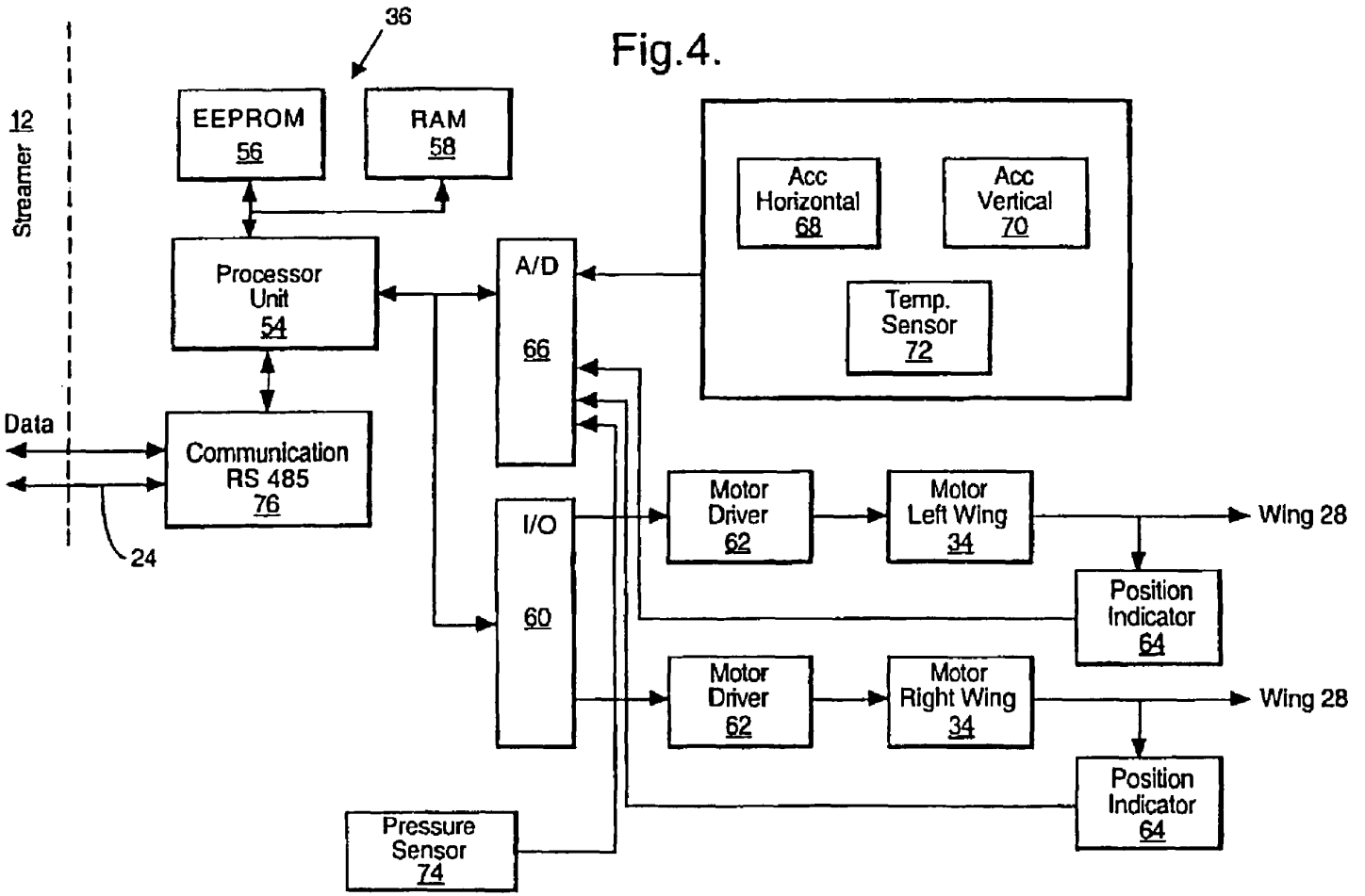

48
40
46
18
52
44
50
28
42
30
38
φ
28

Fig.4.


36
12
Streamer
EEPROM
56
RAM
58
Processor
Unit
54
A/D
66
Acc
Horizontal
68
Acc
Vertical
70
Temp.
Sensor
72
Data
Communication
RS 485
76
24
I/O
60
Motor
Driver
62
Motor
Left Wing
34
Wing 28
Position
Indicator
64
Motor
Driver
62
Motor
Right Wing
34
Wing 28
Position
Indicator
64
Pressure
Sensor
74

CONTROL SYSTEM FOR POSITIONING OF A MARINE SEISMIC STREAMERS

CROSS-REFERENCE TO RELATED APPLICATIONS

Applicant claims priority under 35 U.S.C. § 120 from Ser. No. 11/070,614, filed Mar. 2, 2005, now U.S. Pat. No. 7,080,607, which was a continuation of parent application Ser. No. 09/787,723, filed Jul. 2, 2001, now U.S. Pat. No. 6,932,017, which was a 35 U.S.C. § 371 national stage filing from Patent Cooperation Treaty application number PCT/IB99/01590, filed Sep. 28, 1999, which in turn claimed priority from Great Britain patent application number 9821277.3, filed Oct. 1, 1998, from which Applicant claims foreign priority under 35 U.S.C. § 119, all of which are incorporated herein by reference. This application is also related to co-pending application Ser. Nos. 11/454,352 and 11/454,349, filed simultaneously herewith, which also are both incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates generally to systems for controlling seismic data acquisition equipment and particularly to a system for controlling a marine seismic streamer positioning device.

A marine seismic streamer is an elongate cable-like structure, typically up to several thousand meters long, which contains arrays of seismic sensors, known as hydrophones, and associated electronic equipment along its length, and which is used in marine seismic surveying. In order to perform a 3D marine seismic survey, a plurality of such streamers are towed at about 5 knots behind a seismic survey vessel, which also tows one or more seismic sources, typically air guns. Acoustic signals produced by the seismic sources are directed down through the water into the earth beneath, where they are reflected from the various strata. The reflected signals are received by the hydrophones, and then digitized and processed to build up a representation of the subsurface geology.

The horizontal positions of the streamers are typically controlled by a deflector, located at the front end or "head" of the streamer, and a tail buoy, located at the back end or "tail" of the streamer. These devices create tension forces on the streamer which constrain the movement of the streamer and cause it to assume a roughly linear shape. Cross currents and transient forces cause the streamer to bow and undulate, thereby introducing deviations into this desired linear shape.

The streamers are typically towed at a constant depth of approximately ten meters, in order to facilitate the removal of undesired "ghost" reflections from the surface of the water. To keep the streamers at this constant depth, control devices known as "birds", are typically attached at various points along each streamer between the deflector and the tail buoy, with the spacing between the birds generally varying between 200 and 400 meters. The birds have hydrodynamic deflecting surfaces, referred to as wings, that allow the position of the streamer to be controlled as it is towed through the water. When a bird is used for depth control purposes only, it is possible for the bird to regularly sense its depth using an integrated pressure sensor and for a local controller within the bird to adjust the wing angles to maintain the streamer near the desired depth using only a desired depth value received from a central control system.

While the majority of birds used thus far have only controlled the depth of the streamers, additional benefits can

be obtained by using properly controlled horizontally steerable birds, particularly by using the types of horizontally and vertically steerable birds disclosed in our published PCT International Application No. WO 98/28636. The benefits that can be obtained by using properly controlled horizontally steerable birds can include reducing horizontal out-of-position conditions that necessitate reacquiring seismic data in a particular area (i.e. in-fill shooting), reducing the chance of tangling adjacent streamers, and reducing the time required to turn the seismic acquisition vessel when ending one pass and beginning another pass during a 3D seismic survey.

It is estimated that horizontal out-of-position conditions reduce the efficiency of current 3D seismic survey operations by between 5 and 10%, depending on weather and current conditions. While incidents of tangling adjacent streamers are relatively rare, when they do occur they invariably result in prolonged vessel downtime. The loss of efficiency associated with turning the seismic survey vessel will depend in large part on the seismic survey layout, but typical estimates range from 5 to 10%. Simulations have concluded that properly controlled horizontally steerable birds can be expected to reduce these types of costs by approximately 30%.

One system for controlling a horizontally steerable bird, as disclosed in UK Patent GB 2093610 B, is to utilize a manually-operated central control system to transmit the magnitudes and directions of any required wing angle changes to the birds. While this method greatly simplifies the circuitry needed within the bird itself, it is virtually impossible for this type of system to closely regulate the horizontal positions of the birds because it requires manual input and supervision. This becomes a particularly significant issue when a substantial number of streamers are deployed simultaneously and the number of birds that must be controlled goes up accordingly.

Another system for controlling a horizontally steerable bird is disclosed in our published PCT International Application No. WO 98/28636. Using this type of control system, the desired horizontal positions and the actual horizontal positions are received from a remote control system and are then used by a local control system within the birds to adjust the wing angles. The actual horizontal positions of the birds may be determined every 5 to 10 seconds and there may be a 5 second delay between the taking of measurements and the determination of actual streamer positions. While this type of system allows for more automatic adjustment of the bird wing angles, the delay period and the relatively long cycle time between position measurements prevents this type of control system from rapidly and efficiently controlling the horizontal position of the bird. A more deterministic system for controlling this type of streamer positioning device is therefore desired.

It is therefore an object of the present invention to provide for an improved method and apparatus for controlling a streamer positioning device.

An advantage of the present invention is that the position of the streamer may be better controlled, thereby reducing the need for in-fill shooting, reducing the chance of streamer tangling, and reducing the time needed to turn the seismic survey vessel.

Another advantage of the present invention is that noise in marine seismic data associated with streamer position over-correction and streamer positioning errors can be significantly reduced.

SUMMARY OF THE INVENTION

The present invention provides methods and apparatus for controlling the positions of marine seismic streamers in an array of such streamers being towed by a seismic survey vessel, the streamers having respective streamer positioning devices disposed therealong and each streamer positioning device having a wing and a wing motor for changing the orientation of the wing so as to steer the streamer positioning device laterally, said methods and apparatus involving (a) obtaining an estimated velocity of the streamer positioning devices, (b) for at least some of the streamer positioning devices, calculating desired changes in the orientation of their wings using said estimated velocity, and (c) actuating the wing motors to produce said desired changes in wing orientation.

The invention and its benefits will be better understood with reference to the detailed description below and the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a seismic survey vessel and associated seismic data acquisition equipment;

FIG. **2** is a schematic horizontal cross-sectional view through a marine seismic streamer and an attached streamer positioning device;

FIG. **3** is a schematic vertical cross-sectional view through the streamer positioning device from FIG. **2**; and

FIG. **4** is a schematic diagram of the local control system architecture of the streamer positioning device from FIG. **2**.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, a seismic survey vessel **10** is shown towing eight marine seismic streamers **12** that may, for instance, each be 3000 meters in length. The outermost streamers **12** in the array could be 700 meters apart, resulting in a horizontal separation between the streamers of 100 meters in the regular horizontal spacing configuration shown. A seismic source **14**, typically an airgun or an array of airguns, is also shown being towed by the seismic survey vessel **10**. At the front of each streamer **12** is shown a deflector **16** and at the rear of every streamer is shown a tail buoy **20**. The deflector **16** is used to horizontally position the end of the streamer nearest the seismic survey vessel **10** and the tail buoy **20** creates drag at the end of the streamer farthest from the seismic survey vessel **10**. The tension created on the seismic streamer by the deflector **16** and the tail buoy **20** results in the roughly linear shape of the seismic streamer **12** shown in FIG. **1**.

Located between the deflector **16** and the tail buoy **20** are a plurality of streamer positioning devices known as birds **18**. Preferably the birds **18** are both vertically and horizontally steerable. These birds **18** may, for instance, be located at regular intervals along the streamer, such as every 200 to 400 meters. The vertically and horizontally steerable birds **18** can be used to constrain the shape of the seismic streamer **12** between the deflector **16** and the tail buoy **20** in both the vertical (depth) and horizontal directions.

In the preferred embodiment of the present invention, the control system for the birds **18** is distributed between a global control system **22** located on or near the seismic survey vessel **10** and a local control system located within or near the birds **18**. The global control system **22** is typically connected to the seismic survey vessel's navigation system and obtains estimates of system wide parameters, such as the vessel's towing direction and velocity and current direction and velocity, from the vessel's navigation system.

The most important requirement for the control system is to prevent the streamers **12** from tangling. This requirement becomes more and more important as the complexity and the total value of the towed equipment increases. The trend in the industry is to put more streamers **12** on each seismic survey vessel **10** and to decrease the horizontal separation between them. To get better control of the streamers **12**, horizontal steering becomes necessary. If the birds **18** are not properly controlled, horizontal steering can increase, rather than decrease, the likelihood of tangling adjacent streamers. Localized current fluctuations can dramatically influence the magnitude of the side control required to properly position the streamers. To compensate for these localized current fluctuations, the inventive control system utilizes a distributed processing control architecture and behavior-predictive model-based control logic to properly control the streamer positioning devices.

In the preferred embodiment of the present invention, the global control system **22** monitors the actual positions of each of the birds **18** and is programmed with the desired positions of or the desired minimum separations between the seismic streamers **12**. The horizontal positions of the birds **18** can be derived, for instance, using the types of acoustic positioning systems described in our U.S. Pat. No. 4,992,990 or in our PCT International Patent Application No. WO 98/21163. Alternatively, or additionally, satellite-based global positioning system equipment can be used to determine the positions of the equipment. The vertical positions of the birds **18** are typically monitored using pressure sensors attached to the birds, as discussed below.

The global control system **22** preferably maintains a dynamic model of each of the seismic streamers **12** and utilizes the desired and actual positions of the birds **18** to regularly calculate updated desired vertical and horizontal forces the birds should impart on the seismic streamers **12** to move them from their actual positions to their desired positions. Because the movement of the seismic streamer **12** causes acoustic noise (both from seawater flow past the bird wing structures as well as cross current flow across the streamer skin itself), it is important that the streamer movements be restrained and kept to the minimum correction required to properly position the streamers. Any streamer positioning device control system that consistently overestimates the type of correction required and causes the bird to overshoot its intended position introduces undesirable noise into the seismic data being acquired by the streamer. In current systems, this type of over-correction noise is often balanced against the "noise" or "smearing" caused when the seismic sensors in the streamers **12** are displaced from their desired positions.

The global control system **22** preferably calculates the desired vertical and horizontal forces based on the behavior of each streamer and also takes into account the behavior of the complete streamer array. Due to the relatively low sample rate and time delay associated with the horizontal position determination system, the global control system **22** runs position predictor software to estimate the actual locations of each of the birds **18**. The global control system **22** also checks the data received from the vessel's navigation system and the data will be filled in if it is missing. The interface between the global control system **22** and the local control system will typically operate with a sampling frequency of at least 0.1 Hz. The global control system **22** will typically acquire the following parameters from the vessel's

navigation system: vessel speed (m/s), vessel heading (degrees), current speed (m/s), current heading (degrees), and the location of each of the birds in the horizontal plane in a vessel fixed coordinate system. Current speed and heading can also be estimated based on the average forces acting on the streamers **12** by the birds **18**. The global control system **22** will preferably send the following values to the local bird controller: demanded vertical force, demanded horizontal force, towing velocity, and crosscurrent velocity.

The towing velocity and crosscurrent velocity are preferably "water-referenced" values that are calculated from the vessel speed and heading values and the current speed and heading values, as well as any relative movement between the seismic survey vessel **10** and the bird **18** (such as while the vessel is turning), to produce relative velocities of the bird **18** with respect to the water in both the "in-line" and the "cross-line" directions. Alternatively, the global control system **22** could provide the local control system with the horizontal velocity and water in-flow angle. The force and velocity values are delivered by the global control system **22** as separate values for each bird **18** on each streamer **12** continuously during operation of the control system.

The "water-referenced" towing velocity and crosscurrent velocity could alternatively be determined using flowmeters or other types of water velocity sensors attached directly to the birds **18**. Although these types of sensors are typically quite expensive, one advantage of this type of velocity determination system is that the sensed in-line and cross-line velocities will be inherently compensated for the speed and heading of marine currents acting on said streamer positioning device and for relative movements between the vessel **10** and the bird **18**.

FIG. **2** shows a type of bird **18** that is capable of controlling the position of seismic streamers **12** in both the vertical and horizontal directions. A bird **18** of this type is also disclosed in our PCT International Application No. WO 98/28636. While a number of alternative designs for the vertically and horizontally steerable birds **18** are possible, including those utilizing one full-moving wing with ailerons, three full-moving wings, and four full-moving wings, the independent two-wing principal is, conceptually, the simplest and most robust design.

In FIG. **2**, a portion of the seismic streamer **12** is shown with an attached bird **18**. A communication line **24**, which may consist of a bundle of fiber optic data transmission cables and power transmission wires, passes along the length of the seismic streamer **12** and is connected to the seismic sensors, hydrophones **26**, that are distributed along the length of the streamer, and to the bird **18**. The bird **18** preferably has a pair of independently moveable wings **28** that are connected to rotatable shafts **32** that are rotated by wing motors **34** and that allow the orientation of the wings **28** with respect to the bird body **30** to be changed. When the shafts **32** of the bird **18** are not horizontal, this rotation causes the horizontal orientation of the wings **28** to change and thereby changes the horizontal forces that are applied to the streamer **12** by the bird.

The motors **34** can consist of any type of device that is capable of changing the orientation of the wings **28**, and they are preferably either electric motors or hydraulic actuators. The local control system **36** controls the movement of the wings **28** by calculating a desired change in the angle of the wings and then selectively driving the motors **34** to effectuate this change. While the preferred embodiment depicted utilizes a separate motor **34** for each wing **28**, it would be also be possible to independently move the wings **28** using a single motor **34** and a selectively actuatable transmission mechanism.

When the bird **18** uses two wings **28** to produce the horizontal and vertical forces on the streamer **12**, the required outputs of the local control system **36** are relatively simple, the directions and magnitudes of the wing movements required for each of the wings **28**, or equivalently the magnitude and direction the motors **34** need to be driven to produce this wing movement. While the required outputs of the local control system **36** for such a two full moving wing design is quite simple, the structure and operation of the overall system required to coordinate control of the device is relatively complicated.

FIG. **3** shows a schematic vertical cross-sectional view through the streamer positioning device shown in FIG. **2** that will allow the operation of the inventive control system to be described in more detail. The components of the bird **18** shown in FIG. **3** include the wings **28** and the body **30**. Also shown in FIG. **3** are a horizontal coordinate axis **38** and a vertical coordinate axis **40**. During operation of the streamer positioning control system, the global control system **22** preferably transmits, at regular intervals (such as every five seconds) a desired horizontal force **42** and a desired vertical force **44** to the local control system **36**.

The desired horizontal force **42** and the desired vertical force **44** are combined within the local control system **36** to calculate the magnitude and direction of the desired total force **46** that the global control system **22** has instructed the local control system to apply to the streamer **12**. The global control system **22** could alternatively provide the magnitude and direction of the desired total force **46** to the local control system **36** instead of the desired horizontal force **42** and the desired vertical force **44**.

While the desired horizontal force **42** and the desired vertical force **44** are preferably calculated by the global control system **22**, it is also possible for the local control system **36** in the inventive control system to calculate one or both of these forces using a localized displacement/force conversion program. This type of localized conversion program may, for instance, use a look-up table or conversion routine that associates certain magnitudes and directions of vertical or horizontal displacements with certain magnitudes and directions of changes in the vertical or horizontal forces required. Using this type of embodiment, the global control system **22** can transmit location information to the local control system **36** instead of force information. Instead of the desired vertical force **44**, the global control system **22** can transmit a desired vertical depth and the local control system **36** can calculate the magnitude and direction of the deviation between the desired depth and the actual depth. Similarly, instead of transmitting a desired horizontal force **42**, the global control system **22** can transmit the magnitude and direction of the displacement between the actual horizontal position and the desired horizontal position of the bird **18**. One advantage to this alternative type of system is that the required vertical force can be rapidly updated as the local control system receives updated depth information from the integrated pressure sensor. Other advantages of this type of alternative system include reducing communication traffic on the communication line **24** and simplifying the programming needed to convert the measured vertical and/or horizontal displacements into corresponding forces to be applied by the birds **18**.

When the local control system **36** has a new desired horizontal force **42** and desired vertical force **44** to be applied, the wings **28** will typically not be in the proper

orientation to provide the direction of the desired total force **46** required. As can be seen in FIG. **3**, the wings **28** introduce a force into the streamer **12** along an axis perpendicular to the rotational axis of the wings **28** and perpendicular to the streamer. This force axis **48** is typically not properly aligned with the desired total force **46** when new desired horizontal and vertical force values are received from the global control system **22** or determined by the local control system **36** and some rotation of the bird **18** is required before the bird can produce this desired total force **46**. As can be seen, the force axis **48** is directly related to the bird roll angle, designated in FIG. **3** as ϕ.

The local control system **36** optimizes the control process by projecting the desired total force **46** onto the force axis **48** (i.e. multiplying the magnitude of the desired total force by the cosine of the deviation angle **50**) to produce an intermediate desired force **52** and then adjusting the wing common angle α (the angle of the wings with respect to the bird body **30**, or the average angle if there is a non-zero splay angle) to produce this magnitude of force along the force axis. The calculated desired common wing angle is compared to the current common wing angle to calculate a desired change in the common wing angle and the wing motors **34** are actuated to produce this desired change in the orientation of the wings.

A splay angle is then introduced into the wings **28** to produce a rotational movement in the bird body **30** (i.e. to rotate the force axis **48** to be aligned with the desired total force **46**). The splay angle is the difference between the angles of the wings **28** with respect to the bird body **30**. As the bird body **30** rotates and the force axis **48** becomes more closely aligned with the desired total force **46**, the bird roll angle and the bird roll angular velocity are monitored, the splay angle is incrementally reduced, and the common angle is incrementally increased until the intermediate desired force **52** is in the same direction and of the same magnitude as the desired total force. The local control system **36** carefully regulates the splay angle to ensure that the streamer is stable in roll degree of freedom. The calculated common wing angle and the splay angle are also regulated by the local control system **36** to prevent the wings **28** from stalling and to ensure that the splay angle is prioritized.

When using the type of birds described in our published PCT International Application No. WO 98/28636, where the bird **18** is rigidly attached, and cannot rotate with respect, to the streamer **12**, it is important for the control system to take the streamer twist into account. If this is not taken into account, the bird **18** can use all of its available splay angle to counter the twist in the streamer **12**. The bird **18** will then be unable to reach the demanded roll angle and the generated force will decrease. The inventive control system incorporates two functions for addressing this situation; the anti-twist function and the untwist function.

In the anti-twist function, the streamer twist is estimated by weightfunction filtering the splay angle measurements instead of simply averaging the splay angle measurements to improve the bandwidth of the estimation. The anti-twist function engages when the estimated twist has reached a critical value and it then overrides the normal shortest path control of the calculated roll angle. The anti-twist function forces the bird **18** to rotate in the opposite direction of the twist by adding +/−180 degrees to the demanded roll angle. Once the twist has been reduced to an acceptable value, the anti-twist function disengages and the normal shortest path calculation is continued.

The untwist function is implemented by the global control system **22** which monitors the splay angle for all of the birds **18** in each streamer **12**. At regular intervals or when the splay angle has reached a critical value, the global control system **22** instructs each local control system **36** to rotate each bird **18** in the opposite direction of the twist. The number of revolutions done by each bird **18** is monitored and the untwist function is disengaged once the twist has reached an acceptable level. FIG. **4** is a schematic diagram of the architecture of the local control system **36** for the bird **18**. The local control system **36** consists of a central processor unit **54**, having EEPROM **56** and RAM **58** memory, an input/output subsystem **60** that is connected to a pair of motor drivers **62**, and an analog to digital conversion unit **66**. The motor drivers **62** are connected to and actuate the wing motors **34** to produce the desired change the orientation of the wings **28** with respect to the bird body **30**.

The wing motor **34**/wing **28** units are also connected to wing position indicators **64** that sense the relative positions of the wings and provide measurements to the analog to digital conversion unit **66** which converts the analog wing position indicator **64** measurements into digital format and conveys these digital values to the central processor unit **54**. Various types of wing position indicators **64** can be used, including resistive angle or displacement sensors inductive sensors, capacitive sensors, hall sensors, or magneto-restrictive sensors.

A horizontal accelerometer **68** and a vertical accelerometer **70**, placed at right angles with respect to one another, are also connected to the analog to digital conversion unit **66** and these accelerometers convey measurements that allow the central processor unit **54** to determine the roll angle and roll rate of the bird **18**. An angular velocity vibrating rate gyro (rategyro) can also be used to measure the roll rate of the bird **18**. A temperature sensor **72** is connected to the analog to digital conversion unit **66** to provide temperature measurements that allow the horizontal accelerometer **68** and the vertical accelerometer **70** to be calibrated.

A pressure sensor **74** is also connected to the analog to digital conversion unit **66** to provide the central processor unit **54** with measurements of the water pressure at the bird **18**. To calculate an appropriate depth value, the measured pressure values must be filtered to limit the disturbance from waves. This is done in the inventive control system with a weightfunction filter that avoids the large phase displacements caused by mean value filters. Instead of using an instantaneous depth value or simply calculating an average depth value over a given period of time (and thereby incorporating a large phase displacement into the depth value), the inventive control system uses a differentially weighted pressure filtering scheme. First the pressure values are transformed into depth values by dividing the pressure sensor reading by the seawater density and gravitational acceleration. These depth values are then filtered using a weight function filter. Typical incremental weighting functions values range from 0.96 to 0.90 (sample weights of 1.0, 0.9, 0.81, 0.729, etc.) and the filter will typically process depth values received over a period of at least 100 seconds.

The central processor unit **54** is also connected to a RS485 communications unit **76** that allows information to be exchanged between the local control system **36** and the global control system **22** over the communication line **24** that passes through the streamer **12**. The RS485 bus may, for instance, utilize Neuron chips that communicate using a Local Operating Network protocol to control the data transfer.

Preferably, the central processor unit **54** and associated components comprise a MicroChip 17C756 processor. This type of microprocessor has very low power requirements, a

dual UART on-chip, 12-channel, 10 bit ADC on-chip, 908×8 RAM, 16 k×16 ROM, and 50 digital I/O channels. The software running on the central processor unit **54** will typically consist of two units, the local control unit and the hardware control unit. It is typically not possible to pre-load both of these program units into the EEPROM **56** and it is possible to update these program units without having to open the bird **18**. The on-chip memory may thus only initially contain a boot-routine that enables the loading of software units into the external memory via the RS485 communication unit **76**. The external program memory (EEPROM **56**) will typically be a non-volatile memory so that these program units do not have to be re-loaded after every power down.

The central processor unit **54** must be able to run the local control system software fast enough to secure the sampling frequency needed for effective local bird control. This may mean, for instance, a sample rate of 10 Hz, which may be 10 to 100 times faster than the sample rate of the communications between the global control system **22** and the local control system **36**. As discussed above, the central processor unit **54** will also receive data from sensors attached to the bird **18**. The sensed values include bird roll angle, bird roll angular velocity (roll rate), the wing angles, and the static pressure of the water. These values are typically delivered to the central processor unit **54** at a sample rate of at least 10 Hz. The following values may be transmitted from the local control system **36** to the global control system **22** using the RS485 communication unit **76**: the measured roll angle, the measured roll rate, the measured wing angles, the measured water pressure, the calculated depth, and the calculated wing forces.

The system has been designed with a redundant communication system to increase its overall reliability. The bird **18** will typically have a backup communications channel, such as by overlaying a backup control signal on top of the power line current. This backup communications channel is particularly important because in the event of loss of communications to the bird **18** there would otherwise be no method for instructing the bird **18** to bring the streamer **12** to surface so the defective communications equipment can be repaired or replaced.

In contrast to previous streamer position device control systems, the present control system converts the desired horizontal force **42** and the desired vertical force **44** into a desired roll angle ϕ and a desired common wing angle α by deterministic calculations, rather than using an "incremental change/measured response/further incremental change based on measured response" type of feedback control circuit. The desired roll angle ϕ can be calculated in the manner discussed in the text describing FIG. **3** above. The magnitude of the force F imparted by the wings **28** along the force axis **48** can, for instance, be deterministically calculated using the following formula:

$$F=0.5\rho A C_L(V_{tow}\cos(\alpha)-V_{current}\sin(\alpha))^2$$

where: ρ=water density;

A=wing area;

C_L=wing lift coefficient;

α=common wing angle;

V_{tow}=towing velocity; and

$V_{current}$=crosscurrent velocity.

A similar deterministic calculation could be made using a calculated coefficient that incorporates the towing velocity of the bird **18**. A gain factor GF, for instance, could be calculated as follows:

$$GF=0.5\rho A C_L(V_{tow})^2$$

which could be simply multiplied by $\cos(\alpha)^2$ to estimate the force that would be applied for a given common angle.

One of the beneficial elements of the inventive control system is that the desired change in the orientation of the wing **28** is calculated using an estimate of the velocity of the bird **18** rather than simply relying on a feedback-loop type of control system that operates in the same manner regardless of the vessel speed. Because the force produced by wing **28** is proportional to the velocity of the device squared, a much more precise calculation of the desired change in the wing orientation can be made by using an estimate of the device velocity.

The inventive control system is based on shared responsibilities between the global control system **22** located on the seismic survey vessel **10** and the local control system **36** located on the bird **18**. The global control system **22** is tasked with monitoring the positions of the streamers **12** and providing desired forces or desired position information to the local control system **36**. The local control system **36** within each bird **18** is responsible for adjusting the wing splay angle to rotate the bird to the proper position and for adjusting the wing common angle to produce the magnitude of total desired force required.

The inventive control system will primarily operate in two different control modes: a feather angle control mode and a turn control mode. In the feather angle control mode, the global control system **22** attempts to keep each streamer in a straight line offset from the towing direction by a certain feather angle. The feather angle could be input either manually, through use of a current meter, or through use of an estimated value based on the average horizontal bird forces. Only when the crosscurrent velocity is very small will the feather angle be set to zero and the desired streamer positions be in precise alignment with the towing direction.

The turn control mode is used when ending one pass and beginning another pass during a 3D seismic survey, sometimes referred to as a "line change". The turn control mode consists of two phases. In the first part of the turn, every bird **18** tries to "throw out" the streamer **12** by generating a force in the opposite direction of the turn. In the last part of the turn, the birds **18** are directed to go to the position defined by the feather angle control mode. By doing this, a tighter turn can be achieved and the turn time of the vessel and equipment can be substantially reduced. Typically during the turn mode adjacent streamers will be depth separated to avoid possible entanglement during the turn and will be returned to a common depth as soon as possible after the completion of the turn. The vessel navigation system will typically notify the global control system **22** when to start throwing the streamers **12** out, and when to start straightening the streamers.

In extreme weather conditions, the inventive control system may also operate in a streamer separation control mode that attempts to minimize the risk of entanglement of the streamers. In this control mode, the global control system **22** attempts to maximize the distance between adjacent streamers. The streamers **12** will typically be separated in depth and the outermost streamers will be positioned as far away from each other as possible. The inner streamers will then be regularly spaced between these outermost streamers, i.e. each bird **18** will receive desired horizontal forces **42** or desired horizontal position information that will direct the bird **18** to the midpoint position between its adjacent streamers.

While the embodiment of the inventive control system described above is shown in connection with a "bird" type

of streamer positioning device, it will be readily understood that the control system method and apparatus may also be used in connection with streamer positioning devices that are characterized as "deflectors" or steerable "tail buoys" because they are attached to either the front end or the back end of the streamer **12**.

The present invention includes any novel feature or novel combination of features disclosed herein, either explicitly or implicitly.

What is claimed is:

1. A method comprising:

(a) towing an array of streamers each having a plurality of streamer positioning devices there along contributing to steering the streamers;

(b) controlling the streamer positioning devices with a control system configured to operate in one or more control modes selected from a feather angle mode, a turn control mode, and a streamer separation mode.

2. The method of claim **1** wherein the control mode is the feather angle mode, and the controlling comprises the control system attempting to keep each streamer in a straight line offset from a towing direction by a feather angle.

3. The method of claim **2** comprising inputting the feather angle manually.

4. The method of claim **2** comprising inputting the feather angle using an estimated value based on an average of horizontal forces on the streamer positioning devices.

5. The method of claim **2** comprising setting the feather angle to zero when crosscurrent velocity is very small and desired streamer positions are in alignment with the towing direction.

6. The method of claim **1** wherein the towing comprises ending one pass, turning a towing vessel having the streamers attached thereto while throwing out the streamers before beginning another pass, with the control mode in the turn control mode during the turning and throwing out.

7. The method of claim **6** comprising turning during a 3D seismic survey.

8. The method of claim **6** comprising turning during a line change.

9. The method of claim **6** comprising commanding each streamer positioning device to generate a force in an opposite direction of the turning, and then commanding each streamer positioning device to go to a position defined by the feather angle control mode.

10. The method of claim **6** comprising separating adjacent streamers by depth during the turning mode to avoid possible entanglement during the turning.

11. The method of claim **10** comprising returning adjacent streamers to a common depth after the completion of the turning.

12. The method of claim **6** comprising notifying the control system, via a vessel navigation system, when to start throwing the streamers out, and when to start straightening the streamers.

13. The method of claim **1** wherein the control mode is the streamer separation mode, the control system attempting to minimize the risk of entanglement of the streamers.

14. The method of claim **13** comprising the control system attempting to maximize distance between adjacent streamers.

15. The method of claim **13** comprising separating the streamers in depth.

16. The method of claim **15** wherein the array of streamers comprises two streamers, and comprising positioning the two streamers as far away from each other as possible.

17. The method of claim **15** wherein the array of streamers comprises three or more streamers, the array comprising one port-most streamer, one starboard-most streamer and at least one inner streamer and comprising positioning the port-most and starboard-most streamers as far away form each other as possible.

18. An apparatus comprising:

(a) an array of streamers each having a plurality of streamer positioning devices there along;

(b) a control system configured to use a control mode selected from a feather angle mode, a turn control mode, a streamer separation mode, and two or more of these modes.

19. The apparatus of claim **18** wherein the control mode is the feather angle mode, and the controlling comprises the control system attempting to keep each streamer in a straight line offset from a towing direction by a feather angle.

20. The apparatus of claim **19** comprising inputting the feather angle manually.

21. The apparatus of claim **19** comprising inputting the feather angle using an estimated value based on an average of horizontal forces on the streamer positioning devices.

22. The apparatus of claim **19** comprising setting the feather angle to zero when crosscurrent velocity is very small and desired streamer positions are in alignment with the towing direction.

23. The apparatus of claim **18** wherein the towing comprises ending one pass, turning a towing vessel having the streamers attached thereto while throwing out the streamers before beginning another pass, with the control mode in the turn control mode during the turning and throwing out.

24. The apparatus of claim **23** comprising turning during a 3D seismic survey.

25. The apparatus of claim **23** comprising turning during a line change.

26. The apparatus of claim **23** comprising commanding each streamer positioning device to generate a force in an opposite direction of the turning, and then commanding each streamer positioning device to go to a position defined by the feather angle control mode.

27. The apparatus of claim **23** comprising separating adjacent streamers by depth during the turning mode to avoid possible entanglement during the turning.

28. The apparatus of claim **27** comprising returning adjacent streamers to a common depth after the completion of the turning.

29. The apparatus of claim **23** comprising notifying the control system, via a vessel navigation system, when to start throwing the streamers out, and when to start straightening the streamers.

30. The apparatus of claim **18** wherein the control mode is the streamer separation mode, the control system attempting to minimize the risk of entanglement of the streamers.

31. The apparatus of claim **30** comprising the control system attempting to maximize distance between adjacent streamers.

32. The apparatus of claim **30** comprising separating the streamers in depth.

33. The apparatus of claim **32** wherein the array of streamers comprises two streamers, and comprising positioning the two streamers as far away from each other as possible.

34. The apparatus of claim **32** wherein the array of streamers comprises three or more streamers, the array comprising one port-most streamer, one starboard-most streamer and at least one inner streamer and comprising positioning the port-most and starboard-most streamers as far away from each other as possible.

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TO

TITLE 35—PATENTS

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stituted "An interest that constitutes an assignment" for "An assignment" in fourth par.

1982—Pub. L. 97–247 inserted ", or apostille of an official designated by a foreign country which, by treaty or convention, accords like effect to apostilles of designated officials in the United States".

1975—Pub. L. 93–596 substituted "Patent and Trademark Office" for "Patent Office".

EFFECTIVE DATE OF 2012 AMENDMENT

Amendment by Pub. L. 112–211 effective on the date that is 1 year after Dec. 18, 2012, applicable to patents issued before, on, or after that effective date and patent applications pending on or filed after that effective date, and not effective with respect to patents in litigation commenced before that effective date, see section 203 of Pub. L. 112–211, set out as an Effective Date note under section 27 of this title.

EFFECTIVE DATE OF 1982 AMENDMENT

Amendment by Pub. L. 97–247 effective Aug. 27, 1982, see section 17(a) of Pub. L. 97–247, set out as a note under section 41 of this title.

EFFECTIVE DATE OF 1975 AMENDMENT

Amendment by Pub. L. 93–596 effective Jan. 2, 1975, see section 4 of Pub. L. 93–596, set out as a note under section 1111 of Title 15, Commerce and Trade.

§ 262. Joint owners

In the absence of any agreement to the contrary, each of the joint owners of a patent may make, use, offer to sell, or sell the patented invention within the United States, or import the patented invention into the United States, without the consent of and without accounting to the other owners.

(July 19, 1952, ch. 950, 66 Stat. 810; Pub. L. 103–465, title V, § 533(b)(3), Dec. 8, 1994, 108 Stat. 4989.)

HISTORICAL AND REVISION NOTES

This section states a condition in existing law not expressed in the existing statutes.

AMENDMENTS

1994—Pub. L. 103–465 substituted "use, offer to sell, or sell" for "use or sell" and inserted "within the United States, or import the patented invention into the United States," after "invention".

EFFECTIVE DATE OF 1994 AMENDMENT

Amendment by Pub. L. 103–465 effective on date that is one year after date on which the WTO Agreement enters into force with respect to the United States [Jan. 1, 1995], with provisions relating to earliest filed patent application, see section 534(a), (b)(3) of Pub. L. 103–465, set out as a note under section 154 of this title.

CHAPTER 27—GOVERNMENT INTERESTS IN PATENTS

Sec.
[266. Repealed.]
267. Time for taking action in Government applications.

AMENDMENTS

1965—Pub. L. 89–83, § 8, July 24, 1965, 79 Stat. 261, struck out item 266 "Issue of patents without fees to Government employees".

[§ 266. Repealed. Pub. L. 89–83, § 8, July 24, 1965, 79 Stat. 261]

Section, act July 19, 1952, ch. 950, § 1, 66 Stat. 811, provided for issuance of patents to government employees without fees.

EFFECTIVE DATE OF REPEAL

Repeal effective three months after July 24, 1965, see section 7(a) of Pub. L. 89–83, set out as an Effective Date of 1965 Amendment note under section 41 of this title.

§ 267. Time for taking action in Government applications

Notwithstanding the provisions of sections 133 and 151, the Director may extend the time for taking any action to three years, when an application has become the property of the United States and the head of the appropriate department or agency of the Government has certified to the Director that the invention disclosed therein is important to the armament or defense of the United States.

(July 19, 1952, ch. 950, 66 Stat. 811; Pub. L. 106–113, div. B, § 1000(a)(9) [title IV, § 4732(a)(10)(A)], Nov. 29, 1999, 113 Stat. 1536, 1501A–582; Pub. L. 107–273, div. C, title III, § 13206(b)(1)(B), Nov. 2, 2002, 116 Stat. 1906; Pub. L. 112–29, § 20(j), Sept. 16, 2011, 125 Stat. 335.)

HISTORICAL AND REVISION NOTES

Based on Title 35, U.S.C., 1946 ed., § 37 (R.S. 4894, amended (1) Mar. 3, 1897, ch. 391, § 4, 29 Stat. 692, 693, (2) July 6, 1916, ch. 225, § 1, 39 Stat. 345, 347–8, (3) Mar. 2, 1927, ch. 273, § 1, 44 Stat. 1335, (4) Aug. 7, 1939, ch. 568, 53 Stat. 1264).

This provision, which appears as the last two sentences of the corresponding section of the present statute (see note to section 133) is made a separate section and rewritten in simpler form.

AMENDMENTS

2011—Pub. L. 112–29 struck out "of this title" after "151".

2002—Pub. L. 107–273 made technical correction to directory language of Pub. L. 106–113. See 1999 Amendment note below.

1999—Pub. L. 106–113, as amended by Pub. L. 107–273, substituted "Director" for "Commissioner" in two places.

EFFECTIVE DATE OF 2011 AMENDMENT

Amendment by section 20(j) of Pub. L. 112–29 effective upon the expiration of the 1-year period beginning on Sept. 16, 2011, and applicable to proceedings commenced on or after that effective date, see section 20(*l*) of Pub. L. 112–29, set out as a note under section 2 of this title.

EFFECTIVE DATE OF 1999 AMENDMENT

Amendment by Pub. L. 106–113 effective 4 months after Nov. 29, 1999, see section 1000(a)(9) [title IV, § 4731] of Pub. L. 106–113, set out as a note under section 1 of this title.

CHAPTER 28—INFRINGEMENT OF PATENTS

Sec.
271. Infringement of patent.
272. Temporary presence in the United States.
273. Defense to infringement based on prior commercial use.

AMENDMENTS

2011—Pub. L. 112–29, § 5(b), Sept. 16, 2011, 125 Stat. 299, amended item 273 generally, substituting "Defense to infringement based on prior commercial use" for "Defense to infringement based on earlier inventor".

1999—Pub. L. 106–113, div. B, § 1000(a)(9) [title IV, § 4302(b)], Nov. 29, 1999, 113 Stat. 1536, 1501A–557, added item 273.

§ 271. Infringement of patent

(a) Except as otherwise provided in this title, whoever without authority makes, uses, offers

to sell, or sells any patented invention, within the United States or imports into the United States any patented invention during the term of the patent therefor, infringes the patent.

(b) Whoever actively induces infringement of a patent shall be liable as an infringer.

(c) Whoever offers to sell or sells within the United States or imports into the United States a component of a patented machine, manufacture, combination or composition, or a material or apparatus for use in practicing a patented process, constituting a material part of the invention, knowing the same to be especially made or especially adapted for use in an infringement of such patent, and not a staple article or commodity of commerce suitable for substantial noninfringing use, shall be liable as a contributory infringer.

(d) No patent owner otherwise entitled to relief for infringement or contributory infringement of a patent shall be denied relief or deemed guilty of misuse or illegal extension of the patent right by reason of his having done one or more of the following: (1) derived revenue from acts which if performed by another without his consent would constitute contributory infringement of the patent; (2) licensed or authorized another to perform acts which if performed without his consent would constitute contributory infringement of the patent; (3) sought to enforce his patent rights against infringement or contributory infringement; (4) refused to license or use any rights to the patent; or (5) conditioned the license of any rights to the patent or the sale of the patented product on the acquisition of a license to rights in another patent or purchase of a separate product, unless, in view of the circumstances, the patent owner has market power in the relevant market for the patent or patented product on which the license or sale is conditioned.

(e)(1) It shall not be an act of infringement to make, use, offer to sell, or sell within the United States or import into the United States a patented invention (other than a new animal drug or veterinary biological product (as those terms are used in the Federal Food, Drug, and Cosmetic Act and the Act of March 4, 1913) which is primarily manufactured using recombinant DNA, recombinant RNA, hybridoma technology, or other processes involving site specific genetic manipulation techniques) solely for uses reasonably related to the development and submission of information under a Federal law which regulates the manufacture, use, or sale of drugs or veterinary biological products.

(2) It shall be an act of infringement to submit—

(A) an application under section 505(j) of the Federal Food, Drug, and Cosmetic Act or described in section 505(b)(2) of such Act for a drug claimed in a patent or the use of which is claimed in a patent,

(B) an application under section 512 of such Act or under the Act of March 4, 1913 (21 U.S.C. 151–158) for a drug or veterinary biological product which is not primarily manufactured using recombinant DNA, recombinant RNA, hybridoma technology, or other processes involving site specific genetic manipulation techniques and which is claimed in a patent or the use of which is claimed in a patent, or

(C)(i) with respect to a patent that is identified in the list of patents described in section 351(*l*)(3) of the Public Health Service Act (including as provided under section 351(*l*)(7) of such Act), an application seeking approval of a biological product, or

(ii) if the applicant for the application fails to provide the application and information required under section 351(*l*)(2)(A) of such Act, an application seeking approval of a biological product for a patent that could be identified pursuant to section 351(*l*)(3)(A)(i) of such Act,

if the purpose of such submission is to obtain approval under such Act to engage in the commercial manufacture, use, or sale of a drug, veterinary biological product, or biological product claimed in a patent or the use of which is claimed in a patent before the expiration of such patent.

(3) In any action for patent infringement brought under this section, no injunctive or other relief may be granted which would prohibit the making, using, offering to sell, or selling within the United States or importing into the United States of a patented invention under paragraph (1).

(4) For an act of infringement described in paragraph (2)—

(A) the court shall order the effective date of any approval of the drug or veterinary biological product involved in the infringement to be a date which is not earlier than the date of the expiration of the patent which has been infringed,

(B) injunctive relief may be granted against an infringer to prevent the commercial manufacture, use, offer to sell, or sale within the United States or importation into the United States of an approved drug, veterinary biological product, or biological product,

(C) damages or other monetary relief may be awarded against an infringer only if there has been commercial manufacture, use, offer to sell, or sale within the United States or importation into the United States of an approved drug, veterinary biological product, or biological product, and

(D) the court shall order a permanent injunction prohibiting any infringement of the patent by the biological product involved in the infringement until a date which is not earlier than the date of the expiration of the patent that has been infringed under paragraph (2)(C), provided the patent is the subject of a final court decision, as defined in section 351(k)(6) of the Public Health Service Act, in an action for infringement of the patent under section 351(*l*)(6) of such Act, and the biological product has not yet been approved because of section 351(k)(7) of such Act.

The remedies prescribed by subparagraphs (A), (B), (C), and (D) are the only remedies which may be granted by a court for an act of infringement described in paragraph (2), except that a court may award attorney fees under section 285.

(5) Where a person has filed an application described in paragraph (2) that includes a certification under subsection (b)(2)(A)(iv) or (j)(2)(A)(vii)(IV) of section 505 of the Federal

Food, Drug, and Cosmetic Act (21 U.S.C. 355), and neither the owner of the patent that is the subject of the certification nor the holder of the approved application under subsection (b) of such section for the drug that is claimed by the patent or a use of which is claimed by the patent brought an action for infringement of such patent before the expiration of 45 days after the date on which the notice given under subsection (b)(3) or (j)(2)(B) of such section was received, the courts of the United States shall, to the extent consistent with the Constitution, have subject matter jurisdiction in any action brought by such person under section 2201 of title 28 for a declaratory judgment that such patent is invalid or not infringed.

(6)(A) Subparagraph (B) applies, in lieu of paragraph (4), in the case of a patent—

(i) that is identified, as applicable, in the list of patents described in section 351(*l*)(4) of the Public Health Service Act or the lists of patents described in section 351(*l*)(5)(B) of such Act with respect to a biological product; and

(ii) for which an action for infringement of the patent with respect to the biological product—

(I) was brought after the expiration of the 30-day period described in subparagraph (A) or (B), as applicable, of section 351(*l*)(6) of such Act; or

(II) was brought before the expiration of the 30-day period described in subclause (I), but which was dismissed without prejudice or was not prosecuted to judgment in good faith.

(B) In an action for infringement of a patent described in subparagraph (A), the sole and exclusive remedy that may be granted by a court, upon a finding that the making, using, offering to sell, selling, or importation into the United States of the biological product that is the subject of the action infringed the patent, shall be a reasonable royalty.

(C) The owner of a patent that should have been included in the list described in section 351(*l*)(3)(A) of the Public Health Service Act, including as provided under section 351(*l*)(7) of such Act for a biological product, but was not timely included in such list, may not bring an action under this section for infringement of the patent with respect to the biological product.

(f)(1) Whoever without authority supplies or causes to be supplied in or from the United States all or a substantial portion of the components of a patented invention, where such components are uncombined in whole or in part, in such manner as to actively induce the combination of such components outside of the United States in a manner that would infringe the patent if such combination occurred within the United States, shall be liable as an infringer.

(2) Whoever without authority supplies or causes to be supplied in or from the United States any component of a patented invention that is especially made or especially adapted for use in the invention and not a staple article or commodity of commerce suitable for substantial noninfringing use, where such component is uncombined in whole or in part, knowing that such component is so made or adapted and intending that such component will be combined outside of the United States in a manner that would infringe the patent if such combination occurred within the United States, shall be liable as an infringer.

(g) Whoever without authority imports into the United States or offers to sell, sells, or uses within the United States a product which is made by a process patented in the United States shall be liable as an infringer, if the importation, offer to sell, sale, or use of the product occurs during the term of such process patent. In an action for infringement of a process patent, no remedy may be granted for infringement on account of the noncommercial use or retail sale of a product unless there is no adequate remedy under this title for infringement on account of the importation or other use, offer to sell, or sale of that product. A product which is made by a patented process will, for purposes of this title, not be considered to be so made after—

(1) it is materially changed by subsequent processes; or

(2) it becomes a trivial and nonessential component of another product.

(h) As used in this section, the term "whoever" includes any State, any instrumentality of a State, and any officer or employee of a State or instrumentality of a State acting in his official capacity. Any State, and any such instrumentality, officer, or employee, shall be subject to the provisions of this title in the same manner and to the same extent as any nongovernmental entity.

(i) As used in this section, an "offer for sale" or an "offer to sell" by a person other than the patentee, or any designee of the patentee, is that in which the sale will occur before the expiration of the term of the patent.

(July 19, 1952, ch. 950, 66 Stat. 811; Pub. L. 98–417, title II, § 202, Sept. 24, 1984, 98 Stat. 1603; Pub. L. 98–622, title I, § 101(a), Nov. 8, 1984, 98 Stat. 3383; Pub. L. 100–418, title IX, § 9003, Aug. 23, 1988, 102 Stat. 1563; Pub. L. 100–670, title II, § 201(i), Nov. 16, 1988, 102 Stat. 3988; Pub. L. 100–703, title II, § 201, Nov. 19, 1988, 102 Stat. 4676; Pub. L. 102–560, § 2(a)(1), Oct. 28, 1992, 106 Stat. 4230; Pub. L. 103–465, title V, § 533(a), Dec. 8, 1994, 108 Stat. 4988; Pub. L. 108–173, title XI, § 1101(d), Dec. 8, 2003, 117 Stat. 2457; Pub. L. 111–148, title VII, § 7002(c)(1), Mar. 23, 2010, 124 Stat. 815.)

HISTORICAL AND REVISION NOTES

The first paragraph of this section is declaratory only, defining infringement.

Paragraphs (b) and (c) define and limit contributory infringement of a patent and paragraph (d) is ancillary to these paragraphs, see preliminary general description of bill. One who actively induces infringement as by aiding and abetting the same is liable as an infringer, and so is one who sells a component part of a patented invention or material or apparatus for use therein knowing the same to be especially made or especially adapted for use in the infringement of the patent except in the case of a staple article or commodity of commerce having other uses. A patentee is not deemed to have misused his patent solely by reason of doing anything authorized by the section.

REFERENCES IN TEXT

The Federal Food, Drug, and Cosmetic Act, referred to in subsec. (e)(1), (2), is act June 25, 1938, ch. 675, 52 Stat. 1040, which is classified generally to chapter 9

(§ 301 et seq.) of Title 21, Food and Drugs. Sections 505 and 512 of the Act are classified to sections 355 and 360b, respectively, of Title 21. For complete classification of this Act to the Code, see section 301 of Title 21 and Tables.

Act of March 4, 1913, referred to in subsec. (e)(1), (2), is act Mar. 4, 1913, ch. 145, 37 Stat. 828. The provisions of such act relating to viruses, etc., applicable to domestic animals, popularly known as the Virus-Serum-Toxin Act, are contained in the eighth paragraph under the heading "Bureau of Animal Industry" of act Mar. 4, 1913, at 37 Stat. 832, and are classified generally to chapter 5 (§ 151 et seq.) of Title 21, Food and Drugs. For complete classification of this Act to the Code, see Short Title note set out under section 151 of Title 21 and Tables.

Section 351 of the Public Health Service Act, referred to in subsec. (e)(2)(C), (4)(D), (6)(A), (C), is classified to section 262 of Title 42, The Public Health and Welfare.

AMENDMENTS

2010—Subsec. (e)(2). Pub. L. 111–148, § 7002(c)(1)(A)(iv), substituted ", veterinary biological product, or biological product" for "or veterinary biological product" in concluding provisions.

Subsec. (e)(2)(C). Pub. L. 111–148, § 7002(c)(1)(A)(i)–(iii), added subpar. (C).

Subsec. (e)(4). Pub. L. 111–148, § 7002(c)(1)(B)(iv), substituted "(C), and (D)" for "and (C)" in concluding provisions.

Subsec. (e)(4)(B). Pub. L. 111–148, § 7002(c)(1)(B)(i), substituted ", veterinary biological product, or biological product" for "or veterinary biological product" and struck out "and" at end.

Subsec. (e)(4)(C). Pub. L. 111–148, § 7002(c)(1)(B)(ii), substituted ", veterinary biological product, or biological product" for "or veterinary biological product" and ", and" for period at end.

Subsec. (e)(4)(D). Pub. L. 111–148, § 7002(c)(1)(B)(iii), added subpar. (D).

Subsec. (e)(6). Pub. L. 111–148, § 7002(c)(1)(C), added par. (6).

2003—Subsec. (e)(5). Pub. L. 108–173 added par. (5).

1994—Subsec. (a). Pub. L. 103–465, § 533(a)(1), inserted ", offers to sell," after "uses" and "or imports into the United States any patented invention" after "the United States".

Subsec. (c). Pub. L. 103–465, § 533(a)(2), substituted "offers to sell or sells within the United States or imports into the United States" for "sells".

Subsec. (e)(1). Pub. L. 103–465, § 533(a)(3)(A), substituted "offer to sell, or sell within the United States or import into the United States" for "or sell".

Subsec. (e)(3). Pub. L. 103–465, § 533(a)(3)(B), substituted "offering to sell, or selling within the United States or importing into the United States" for "or selling".

Subsec. (e)(4)(B), (C). Pub. L. 103–465, § 533(a)(3)(C), (D), substituted "offer to sell, or sale within the United States or importation into the United States" for "or sale".

Subsec. (g). Pub. L. 103–465, § 533(a)(4), substituted "offers to sell, sells," for "sells", "importation, offer to sell, sale," for "importation, sale,", and "other use, offer to sell, or" for "other use or".

Subsec. (i). Pub. L. 103–465, § 533(a)(5), added subsec. (i).

1992—Subsec. (h). Pub. L. 102–560 added subsec. (h).

1988—Subsec. (d). Pub. L. 100–703 added cls. (4) and (5).

Subsec. (e)(1). Pub. L. 100–670, § 201(i)(1), inserted "which is primarily manufactured using recombinant DNA, recombinant RNA, hybridoma technology, or other processes involving site specific genetic manipulation techniques" after "March 4, 1913)" and "or veterinary biological products" after "sale of drugs".

Subsec. (e)(2). Pub. L. 100–670, § 201(i)(2), amended par. (2) generally. Prior to amendment, par. (2) read as follows: "It shall be an act of infringement to submit an application under section 505(j) of the Federal Food, Drug, and Cosmetic Act or described in section 505(b)(2) of such Act for a drug claimed in a patent or the use of which is claimed in a patent, if the purpose of such submission is to obtain approval under such Act to engage in the commercial manufacture, use, or sale of a drug claimed in a patent or the use of which is claimed in a patent before the expiration of such patent."

Subsec. (e)(4). Pub. L. 100–670, § 201(i)(3), inserted "or veterinary biological product" after "drug" in subpars. (A) to (C).

Subsec. (g). Pub. L. 100–418 added subsec. (g).

1984—Subsec. (e). Pub. L. 98–417 added subsec. (e).

Subsec. (f). Pub. L. 98–622 added subsec. (f).

EFFECTIVE DATE OF 1994 AMENDMENT

Amendment by Pub. L. 103–465 effective on date that is one year after date on which the WTO Agreement enters into force with respect to the United States [Jan. 1, 1995], with provisions relating to earliest filed patent application, see section 534(a), (b)(3) of Pub. L. 103–465, set out as a note under section 154 of this title.

EFFECTIVE DATE OF 1992 AMENDMENT

Amendment by Pub. L. 102–560 effective with respect to violations that occur on or after Oct. 28, 1992, see section 4 of Pub. L. 102–560, set out as a note under section 2541 of Title 7, Agriculture.

EFFECTIVE DATE OF 1988 AMENDMENT

Pub. L. 100–703, title II, § 202, Nov. 19, 1988, 102 Stat. 4676, provided that: "The amendment made by this title [amending this section] shall apply only to cases filed on or after the date of the enactment of this Act [Nov. 19, 1988]."

Pub. L. 100–418, title IX, § 9006, Aug. 23, 1988, 102 Stat. 1566, provided that:

"(a) IN GENERAL.—The amendments made by this subtitle [subtitle A (§§ 9001–9007) of title IX of Pub. L. 100–418, enacting section 295 of this title and amending this section and sections 154 and 287 of this title] take effect 6 months after the date of enactment of this Act [Aug. 23, 1988] and, subject to subsections (b) and (c), shall apply only with respect to products made or imported after the effective date of the amendments made by this subtitle.

"(b) EXCEPTIONS.—The amendments made by this subtitle shall not abridge or affect the right of any person or any successor in business of such person to continue to use, sell, or import any specific product already in substantial and continuous sale or use by such person in the United States on January 1, 1988, or for which substantial preparation by such person for such sale or use was made before such date, to the extent equitable for the protection of commercial investments made or business commenced in the United States before such date. This subsection shall not apply to any person or any successor in business of such person using, selling, or importing a product produced by a patented process that is the subject of a process patent enforcement action commenced before January 1, 1987, before the International Trade Commission, that is pending or in which an order has been entered.

"(c) RETENTION OF OTHER REMEDIES.—The amendments made by this subtitle shall not deprive a patent owner of any remedies available under subsections (a) through (f) of section 271 of title 35, United States Code, under section 337 of the Tariff Act of 1930 [19 U.S.C. 1337], or under any other provision of law."

EFFECTIVE DATE OF 1984 AMENDMENT

Amendment by Pub. L. 98–622 applicable only to the supplying, or causing to be supplied, of any component or components of a patented invention after Nov. 8, 1984, see section 106(c) of Pub. L. 98–622, set out as a note under section 103 of this title.

REPORTS TO CONGRESS; EFFECT ON DOMESTIC INDUSTRIES OF PROCESS PATENT AMENDMENTS ACT OF 1988

Pub. L. 100–418, title IX, § 9007, Aug. 23, 1988, 102 Stat. 1567, provided that the Secretary of Commerce was to

make annual reports to Congress covering each of the successive five 1-year periods beginning 6 months after Aug. 23, 1988, on the effect of the amendments made by subtitle A (§§ 9001–9007) of title IX of Pub. L. 100–418, enacting section 295 of this title and amending sections 154, 271, and 287 of this title, on those domestic industries that submit complaints to the Department of Commerce alleging that their legitimate sources of supply have been adversely affected by the amendments.

§ 272. Temporary presence in the United States

The use of any invention in any vessel, aircraft or vehicle of any country which affords similar privileges to vessels, aircraft or vehicles of the United States, entering the United States temporarily or accidentally, shall not constitute infringement of any patent, if the invention is used exclusively for the needs of the vessel, aircraft or vehicle and is not offered for sale or sold in or used for the manufacture of anything to be sold in or exported from the United States.

(July 19, 1952, ch. 950, 66 Stat. 812; Pub. L. 103–465, title V, § 533(b)(4), Dec. 8, 1994, 108 Stat. 4989.)

HISTORICAL AND REVISION NOTES

This section follows the requirement of the International Convention for the Protection of Industrial Property, to which the United States is a party, and also codifies the holding of the Supreme Court that use of a patented invention on board a foreign ship does not infringe a patent.

AMENDMENTS

1994—Pub. L. 103–465 substituted "not offered for sale or sold" for "not sold".

EFFECTIVE DATE OF 1994 AMENDMENT

Amendment by Pub. L. 103–465 effective on date that is one year after date on which the WTO Agreement enters into force with respect to the United States [Jan. 1, 1995], with provisions relating to earliest filed patent application, see section 534(a), (b)(3) of Pub. L. 103–465, set out as a note under section 154 of this title.

§ 273. Defense to infringement based on prior commercial use

(a) IN GENERAL.—A person shall be entitled to a defense under section 282(b) with respect to subject matter consisting of a process, or consisting of a machine, manufacture, or composition of matter used in a manufacturing or other commercial process, that would otherwise infringe a claimed invention being asserted against the person if—

(1) such person, acting in good faith, commercially used the subject matter in the United States, either in connection with an internal commercial use or an actual arm's length sale or other arm's length commercial transfer of a useful end result of such commercial use; and

(2) such commercial use occurred at least 1 year before the earlier of either—

(A) the effective filing date of the claimed invention; or

(B) the date on which the claimed invention was disclosed to the public in a manner that qualified for the exception from prior art under section 102(b).

(b) BURDEN OF PROOF.—A person asserting a defense under this section shall have the burden of establishing the defense by clear and convincing evidence.

(c) ADDITIONAL COMMERCIAL USES.—

(1) PREMARKETING REGULATORY REVIEW.—Subject matter for which commercial marketing or use is subject to a premarketing regulatory review period during which the safety or efficacy of the subject matter is established, including any period specified in section 156(g), shall be deemed to be commercially used for purposes of subsection (a)(1) during such regulatory review period.

(2) NONPROFIT LABORATORY USE.—A use of subject matter by a nonprofit research laboratory or other nonprofit entity, such as a university or hospital, for which the public is the intended beneficiary, shall be deemed to be a commercial use for purposes of subsection (a)(1), except that a defense under this section may be asserted pursuant to this paragraph only for continued and noncommercial use by and in the laboratory or other nonprofit entity.

(d) EXHAUSTION OF RIGHTS.—Notwithstanding subsection (e)(1), the sale or other disposition of a useful end result by a person entitled to assert a defense under this section in connection with a patent with respect to that useful end result shall exhaust the patent owner's rights under the patent to the extent that such rights would have been exhausted had such sale or other disposition been made by the patent owner.

(e) LIMITATIONS AND EXCEPTIONS.—

(1) PERSONAL DEFENSE.—

(A) IN GENERAL.—A defense under this section may be asserted only by the person who performed or directed the performance of the commercial use described in subsection (a), or by an entity that controls, is controlled by, or is under common control with such person.

(B) TRANSFER OF RIGHT.—Except for any transfer to the patent owner, the right to assert a defense under this section shall not be licensed or assigned or transferred to another person except as an ancillary and subordinate part of a good-faith assignment or transfer for other reasons of the entire enterprise or line of business to which the defense relates.

(C) RESTRICTION ON SITES.—A defense under this section, when acquired by a person as part of an assignment or transfer described in subparagraph (B), may only be asserted for uses at sites where the subject matter that would otherwise infringe a claimed invention is in use before the later of the effective filing date of the claimed invention or the date of the assignment or transfer of such enterprise or line of business.

(2) DERIVATION.—A person may not assert a defense under this section if the subject matter on which the defense is based was derived from the patentee or persons in privity with the patentee.

(3) NOT A GENERAL LICENSE.—The defense asserted by a person under this section is not a general license under all claims of the patent at issue, but extends only to the specific subject matter for which it has been established

CERTIFICATE OF SERVICE

On October 21, 2014, the foregoing brief was submitted to the Court through the CM/ECF system. All parties are represented by CM/ECF users and will be served by the CM/ECF system.

/s/ Gregg F. LoCascio, P.C.

CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATION

This brief complies with the type-volume limitations of Federal Rule of Appellate Procedure 28.1(e)(2). According to the word processing system used to prepare it, the brief contains 16,446 words.

/s/ Gregg F. LoCascio, P.C.