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Majzlik et al.

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(54) **COMPUTER INSTRUCTIONS FOR POSITIONING A WIRE USING SENSOR INFORMATION**

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(73) Assignee: **NCS Subsea, Inc.**, Stafford, TX (US)

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(51) **Int. Cl.**
G01C 17/38 (2006.01)

(52) **U.S. Cl.** **702/95**; 702/94; 702/150; 702/151

(58) **Field of Classification Search** 702/94, 702/95, 150, 151
See application file for complete search history.

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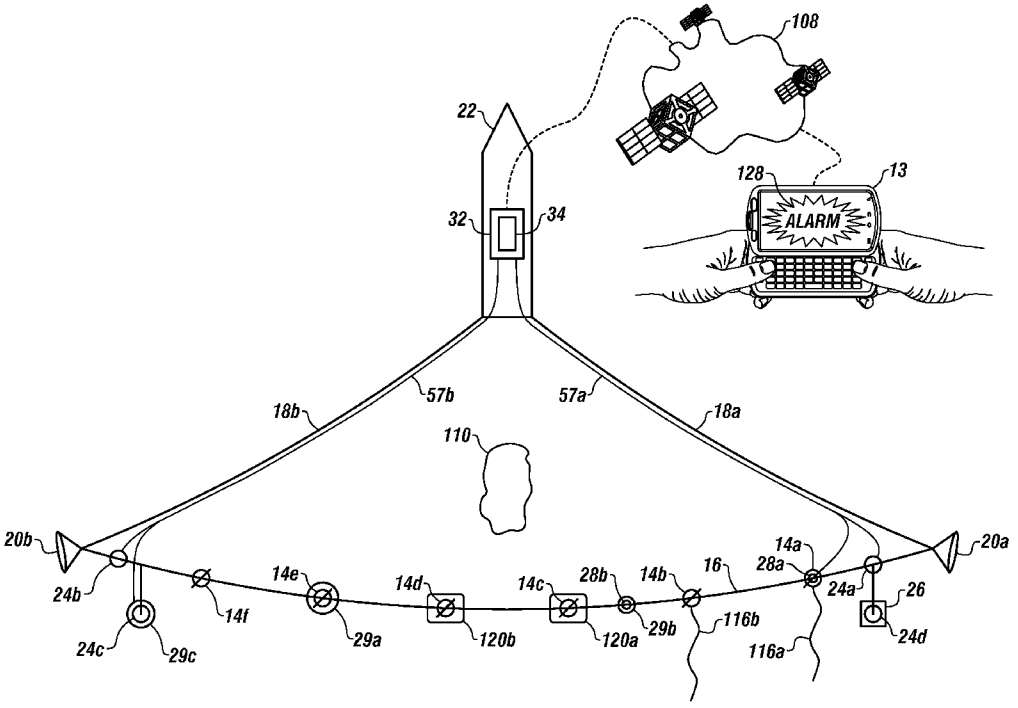
(74) *Attorney, Agent, or Firm* — Buskop Law Group, PC; Wendy Buskop

(57) **ABSTRACT**

Computer instructions for determining coordinates for nodes on a wire secured to tow lines of a floating vessel for analyzing geological formations is provided. The computer instructions can use sensors in communication with a processor to determine the coordinates of nodes and provide azimuths tangential to the wire. A library of nominal values for polynomial coefficients, a library of known distances along the wire, and a library of preset limits can be stored in a data storage. The computer instructions can: receive sensor information, compute bearing, reorient the coordinates, rotate the azimuth, construct a polynomial algorithm, compute the azimuth, form a residual, compute updated differences until the residual is within preset limits, calculate local coordinates for nodes, and rotate the local coordinates from the local coordinate system to the projected coordinate system.

19 Claims, 10 Drawing Sheets



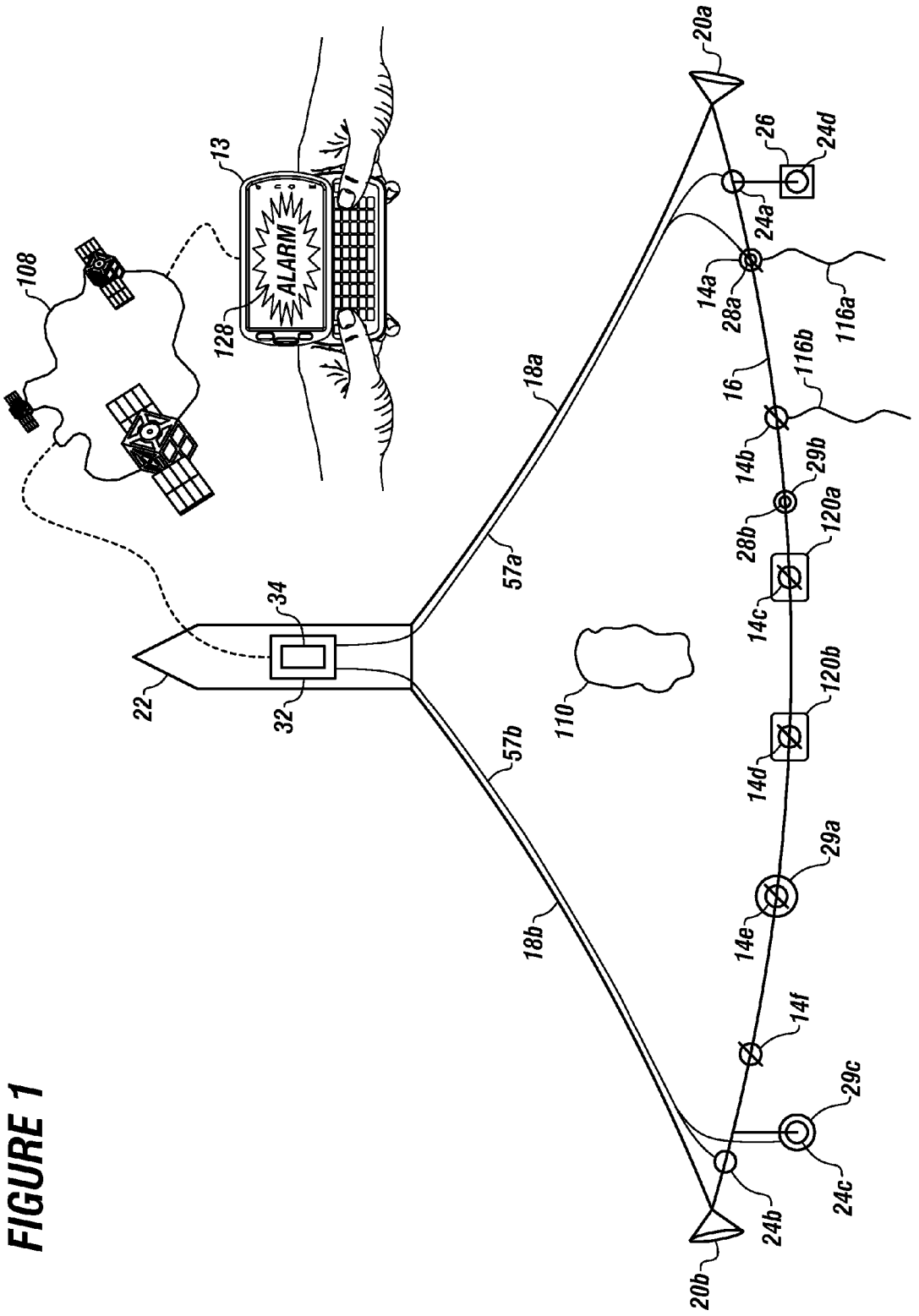

ALARM
13
128
108
34
22
32
57a
57b
18a
18b
110
20a
20b
26
24d
24a
24b
24c
14a
28a
16
116a
116b
14b
29b
28b
120a
14c
120b
14d
29a
14e
14f
29c

FIGURE 1

FIGURE 2A

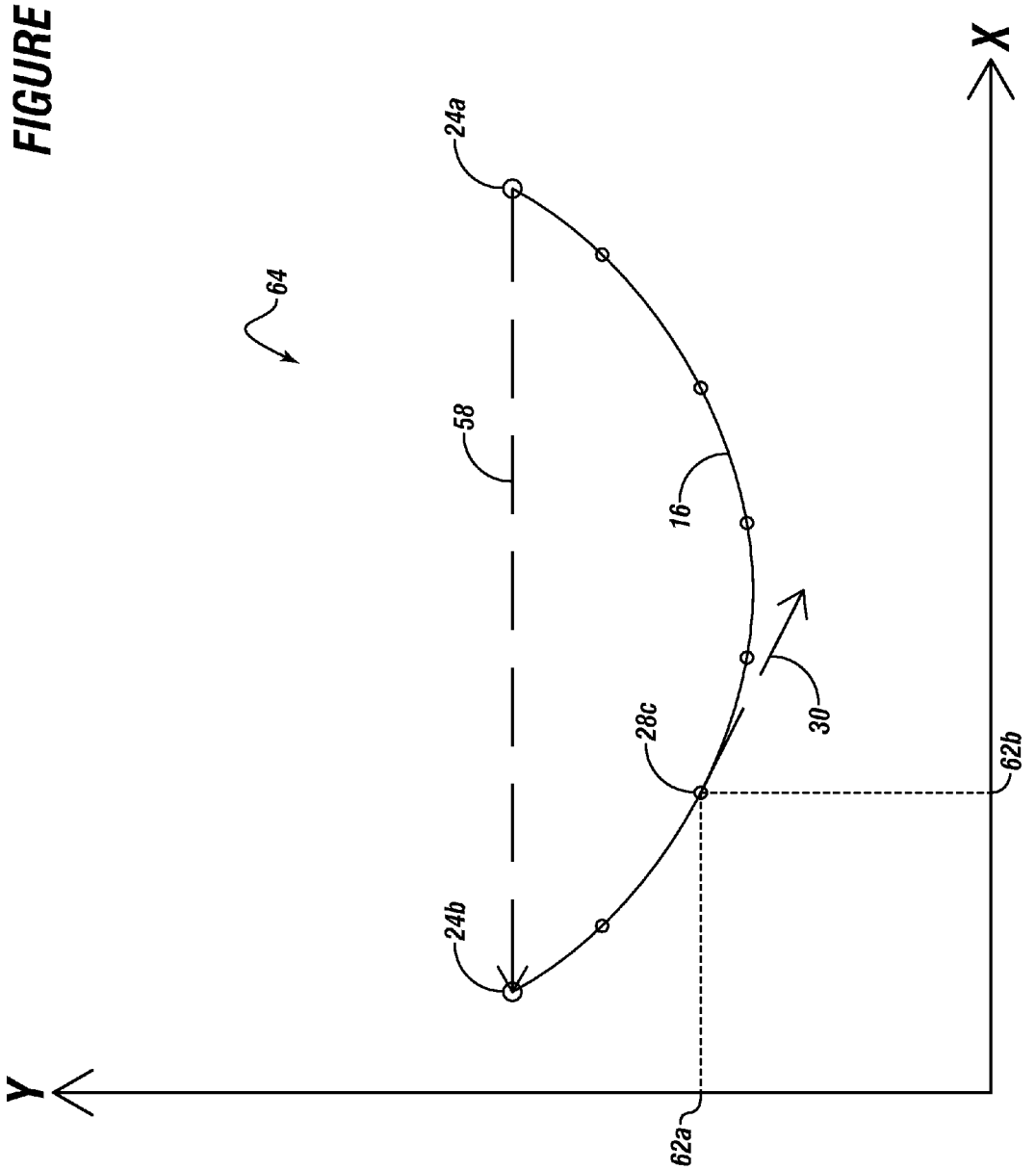


FIGURE 2B

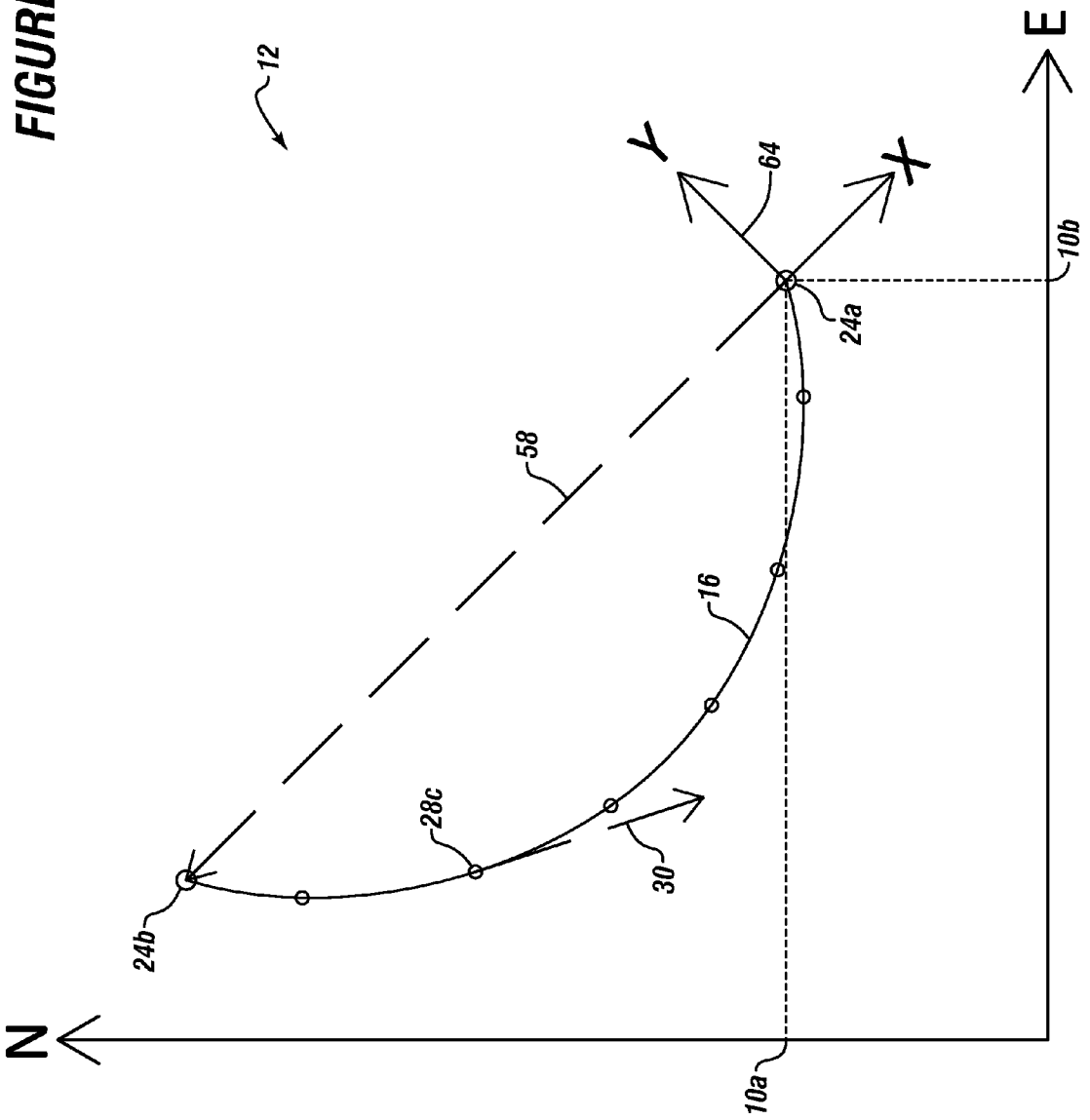


FIGURE 3A

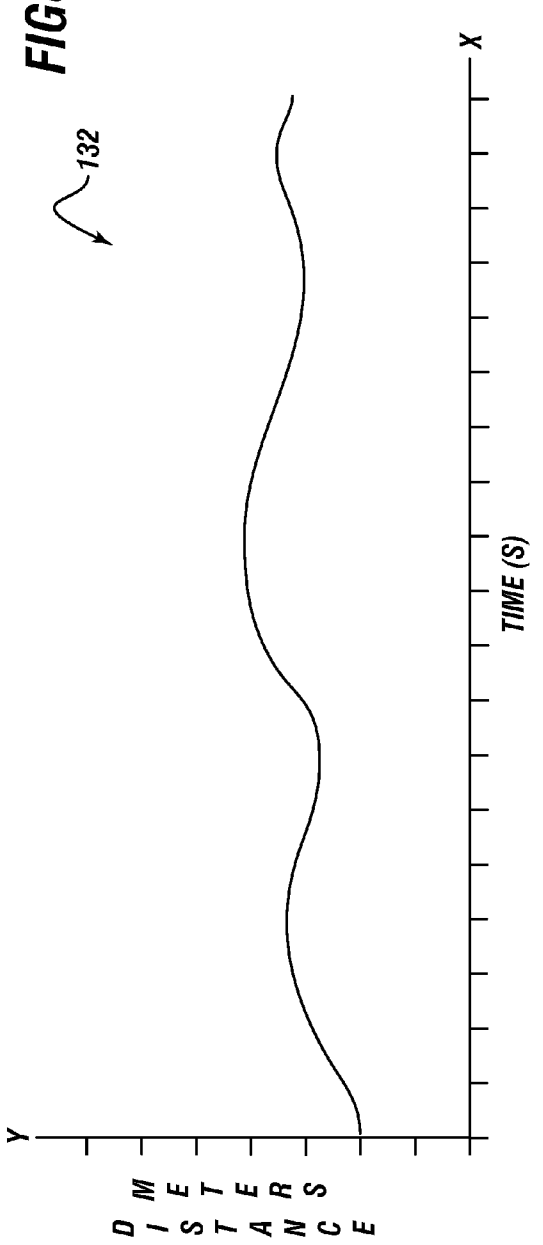


FIGURE 3B

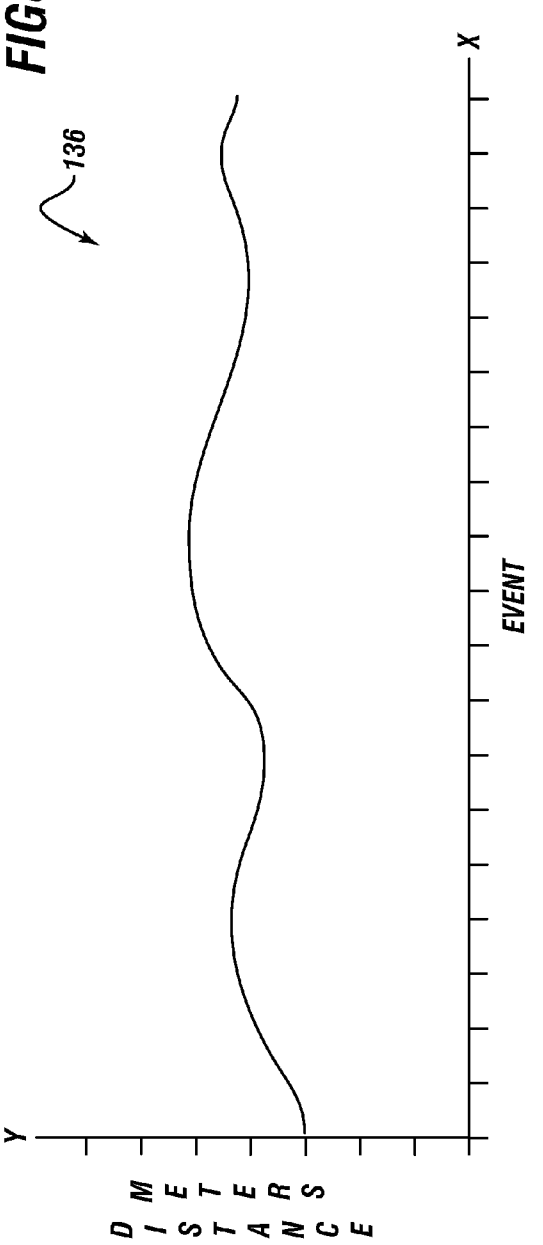


FIGURE 4

140

143a NODE	143b LOCAL X-COORDINATE	143c LOCAL Y-COORDINATE	143d PROJECTED X-COORDINATE	143e PROJECTED Y-COORDINATE	143f EVENT	143g TIME STEP
14a	62a	62b	10a	10b	119a	142a
14b	62c	62d	10c	10d	119b	142b
14c	62e	62f	10e	10f	119c	142c

FIGURE 5

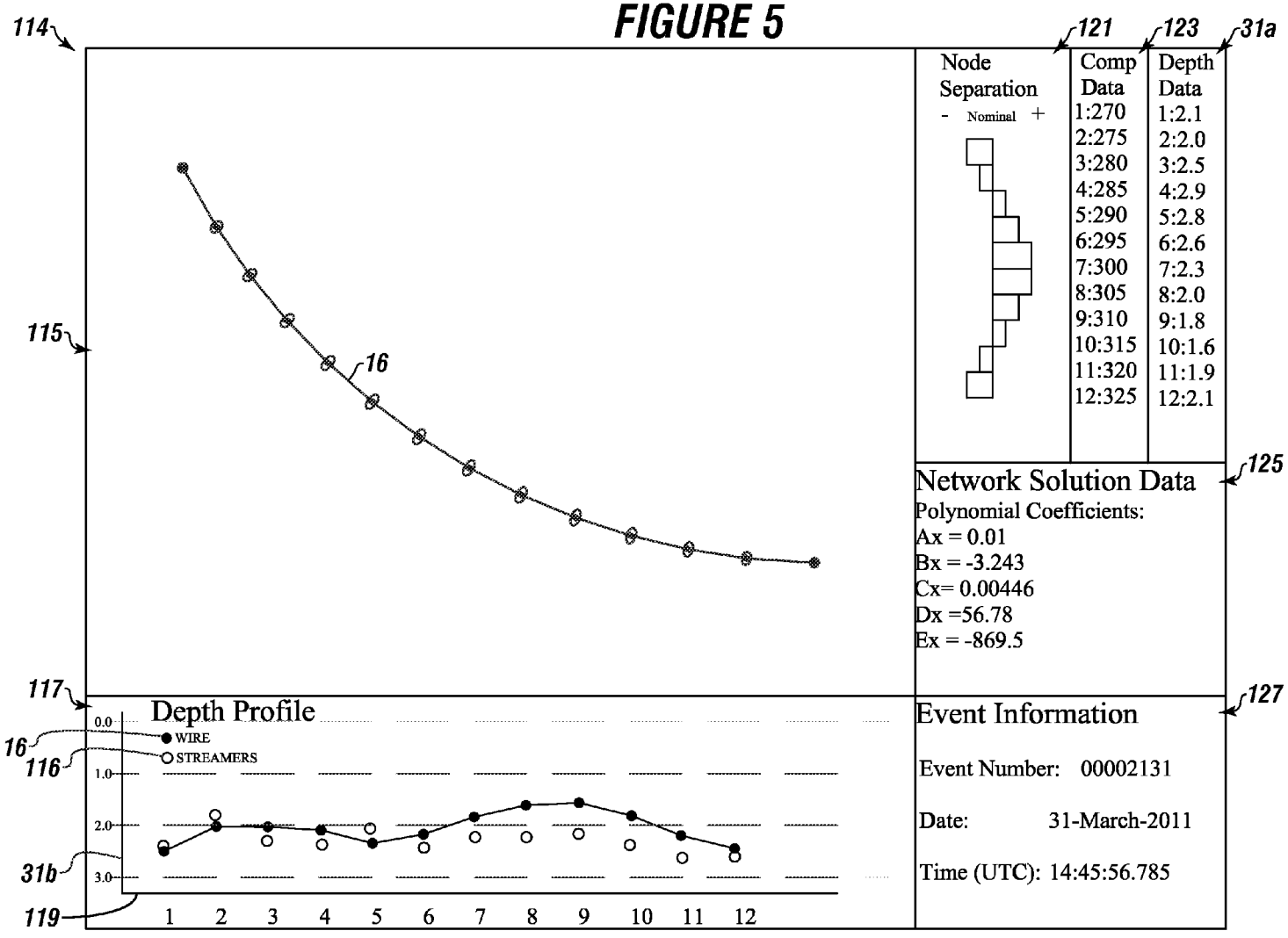
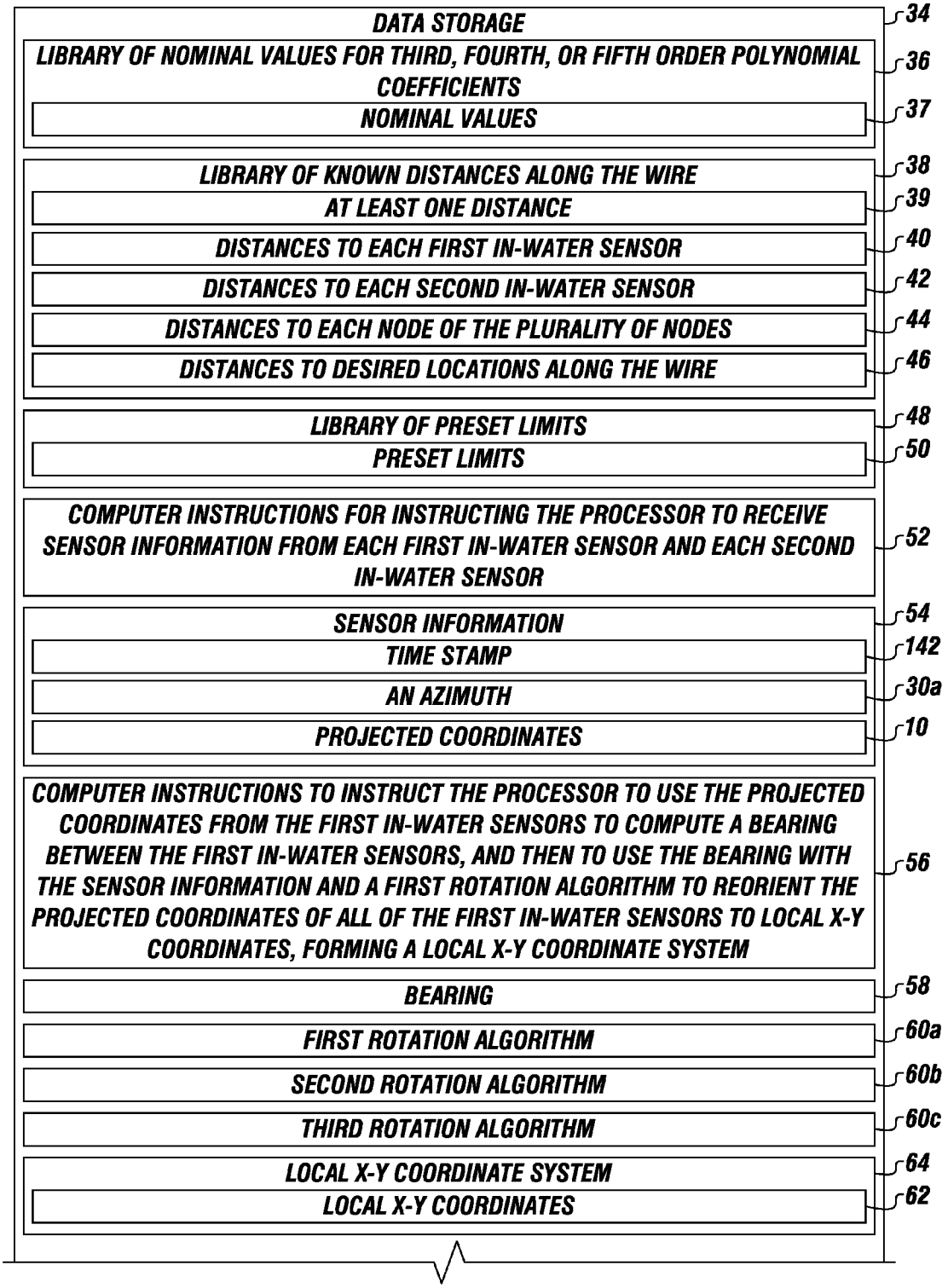

114
115
16
117
16
116
31b
119
121
123
31a
Node Separation
- Nominal +
Comp Data
Depth Data
1:270 1:2.1
2:275 2:2.0
3:280 3:2.5
4:285 4:2.9
5:290 5:2.8
6:295 6:2.6
7:300 7:2.3
8:305 8:2.0
9:310 9:1.8
10:315 10:1.6
11:320 11:1.9
12:325 12:2.1
125
Network Solution Data
Polynomial Coefficients:
Ax = 0.01
Bx = -3.243
Cx= 0.00446
Dx =56.78
Ex = -869.5
127
Event Information
Event Number: 00002131
Date: 31-March-2011
Time (UTC): 14:45:56.785
Depth Profile
WIRE
STREAMERS
0.0
1.0
2.0
3.0
1 2 3 4 5 6 7 8 9 10 11 12

FIGURE 6A


DATA STORAGE
34
LIBRARY OF NOMINAL VALUES FOR THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL COEFFICIENTS
36
NOMINAL VALUES
37
LIBRARY OF KNOWN DISTANCES ALONG THE WIRE
38
AT LEAST ONE DISTANCE
39
DISTANCES TO EACH FIRST IN-WATER SENSOR
40
DISTANCES TO EACH SECOND IN-WATER SENSOR
42
DISTANCES TO EACH NODE OF THE PLURALITY OF NODES
44
DISTANCES TO DESIRED LOCATIONS ALONG THE WIRE
46
LIBRARY OF PRESET LIMITS
48
PRESET LIMITS
50
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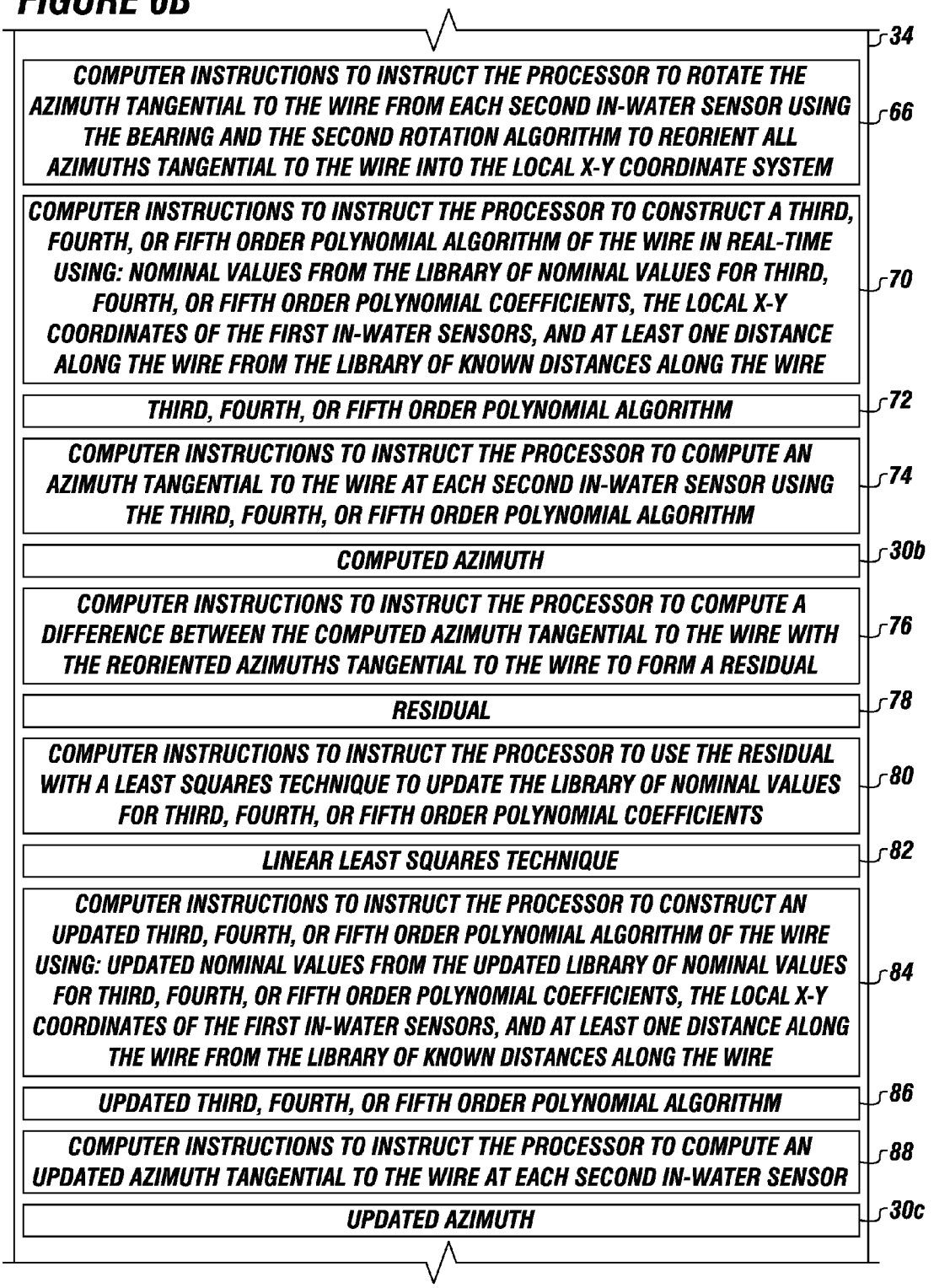
52
SENSOR INFORMATION
54
TIME STAMP
142
AN AZIMUTH
30a
PROJECTED COORDINATES
10
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO USE THE PROJECTED COORDINATES FROM THE FIRST IN-WATER SENSORS TO COMPUTE A BEARING BETWEEN THE FIRST IN-WATER SENSORS, AND THEN TO USE THE BEARING WITH THE SENSOR INFORMATION AND A FIRST ROTATION ALGORITHM TO REORIENT THE PROJECTED COORDINATES OF ALL OF THE FIRST IN-WATER SENSORS TO LOCAL X-Y COORDINATES, FORMING A LOCAL X-Y COORDINATE SYSTEM
56
BEARING
58
FIRST ROTATION ALGORITHM
60a
SECOND ROTATION ALGORITHM
60b
THIRD ROTATION ALGORITHM
60c
LOCAL X-Y COORDINATE SYSTEM
64
LOCAL X-Y COORDINATES
62

FIGURE 6B


34
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO ROTATE THE AZIMUTH TANGENTIAL TO THE WIRE FROM EACH SECOND IN-WATER SENSOR USING THE BEARING AND THE SECOND ROTATION ALGORITHM TO REORIENT ALL AZIMUTHS TANGENTIAL TO THE WIRE INTO THE LOCAL X-Y COORDINATE SYSTEM
66
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO CONSTRUCT A THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL ALGORITHM OF THE WIRE IN REAL-TIME USING: NOMINAL VALUES FROM THE LIBRARY OF NOMINAL VALUES FOR THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL COEFFICIENTS, THE LOCAL X-Y COORDINATES OF THE FIRST IN-WATER SENSORS, AND AT LEAST ONE DISTANCE ALONG THE WIRE FROM THE LIBRARY OF KNOWN DISTANCES ALONG THE WIRE
70
THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL ALGORITHM
72
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO COMPUTE AN AZIMUTH TANGENTIAL TO THE WIRE AT EACH SECOND IN-WATER SENSOR USING THE THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL ALGORITHM
74
COMPUTED AZIMUTH
30b
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO COMPUTE A DIFFERENCE BETWEEN THE COMPUTED AZIMUTH TANGENTIAL TO THE WIRE WITH THE REORIENTED AZIMUTHS TANGENTIAL TO THE WIRE TO FORM A RESIDUAL
76
RESIDUAL
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80
LINEAR LEAST SQUARES TECHNIQUE
82
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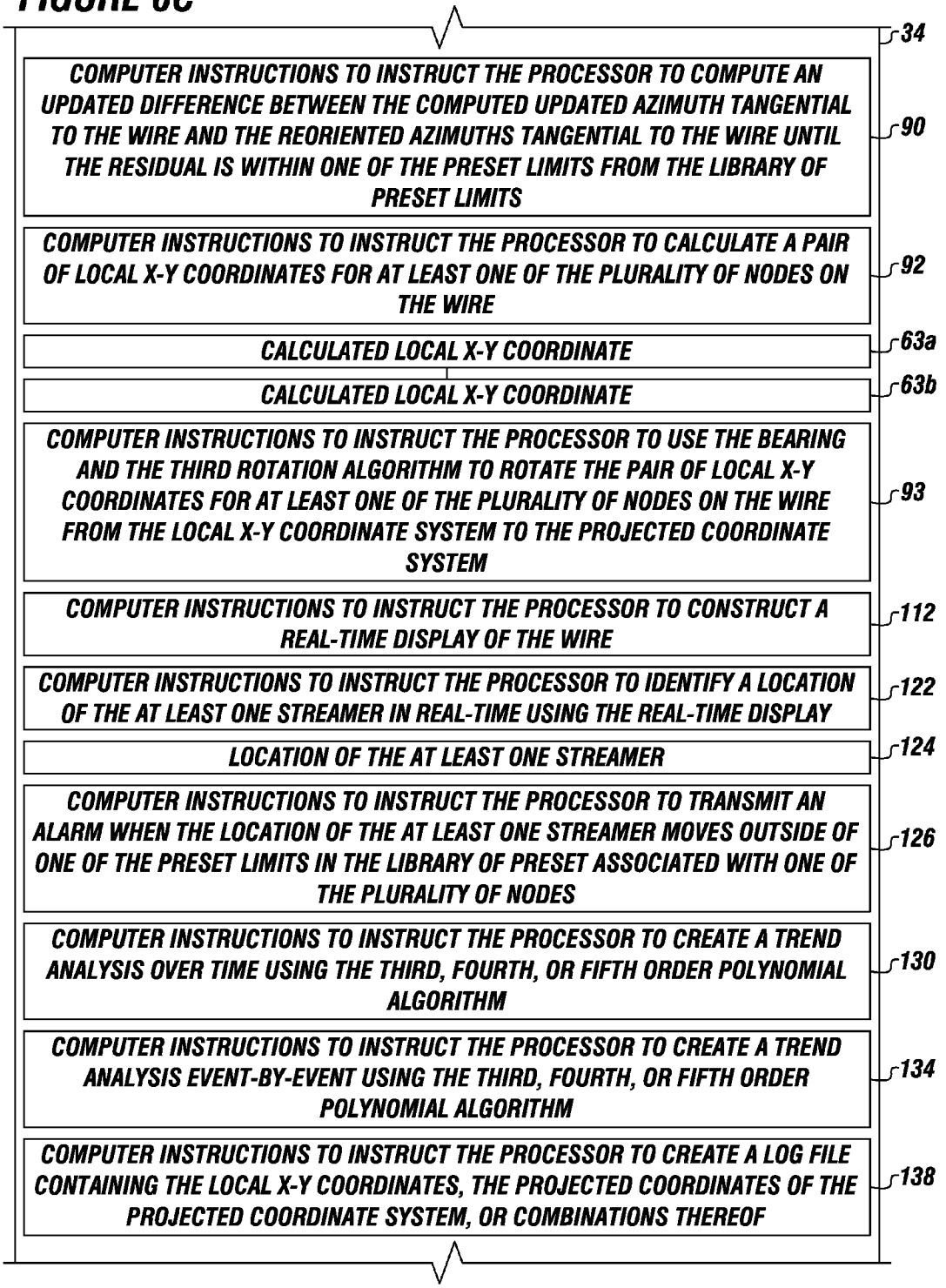
UPDATED THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL ALGORITHM
86
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO COMPUTE AN UPDATED AZIMUTH TANGENTIAL TO THE WIRE AT EACH SECOND IN-WATER SENSOR
88
UPDATED AZIMUTH
30c

FIGURE 6C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COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO COMPUTE AN UPDATED DIFFERENCE BETWEEN THE COMPUTED UPDATED AZIMUTH TANGENTIAL TO THE WIRE AND THE REORIENTED AZIMUTHS TANGENTIAL TO THE WIRE UNTIL THE RESIDUAL IS WITHIN ONE OF THE PRESET LIMITS FROM THE LIBRARY OF PRESET LIMITS
90
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92
CALCULATED LOCAL X-Y COORDINATE
63a
CALCULATED LOCAL X-Y COORDINATE
63b
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COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO CONSTRUCT A REAL-TIME DISPLAY OF THE WIRE
112
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122
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124
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO TRANSMIT AN ALARM WHEN THE LOCATION OF THE AT LEAST ONE STREAMER MOVES OUTSIDE OF ONE OF THE PRESET LIMITS IN THE LIBRARY OF PRESET ASSOCIATED WITH ONE OF THE PLURALITY OF NODES
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COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO CREATE A TREND ANALYSIS OVER TIME USING THE THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL ALGORITHM
130
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134
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO CREATE A LOG FILE CONTAINING THE LOCAL X-Y COORDINATES, THE PROJECTED COORDINATES OF THE PROJECTED COORDINATE SYSTEM, OR COMBINATIONS THEREOF
138

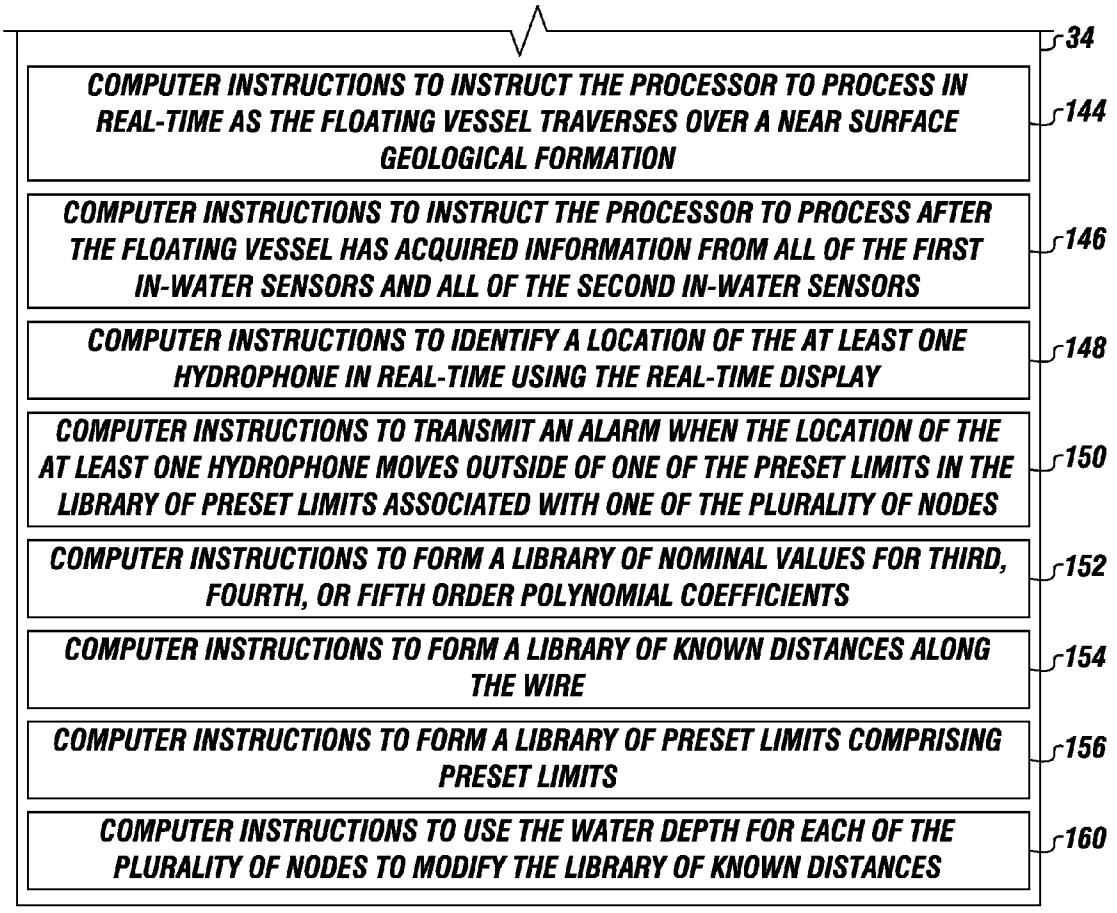
34
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO PROCESS IN REAL-TIME AS THE FLOATING VESSEL TRAVERSES OVER A NEAR SURFACE GEOLOGICAL FORMATION
144
COMPUTER INSTRUCTIONS TO INSTRUCT THE PROCESSOR TO PROCESS AFTER THE FLOATING VESSEL HAS ACQUIRED INFORMATION FROM ALL OF THE FIRST IN-WATER SENSORS AND ALL OF THE SECOND IN-WATER SENSORS
146
COMPUTER INSTRUCTIONS TO IDENTIFY A LOCATION OF THE AT LEAST ONE HYDROPHONE IN REAL-TIME USING THE REAL-TIME DISPLAY
148
COMPUTER INSTRUCTIONS TO TRANSMIT AN ALARM WHEN THE LOCATION OF THE AT LEAST ONE HYDROPHONE MOVES OUTSIDE OF ONE OF THE PRESET LIMITS IN THE LIBRARY OF PRESET LIMITS ASSOCIATED WITH ONE OF THE PLURALITY OF NODES
150
COMPUTER INSTRUCTIONS TO FORM A LIBRARY OF NOMINAL VALUES FOR THIRD, FOURTH, OR FIFTH ORDER POLYNOMIAL COEFFICIENTS
152
COMPUTER INSTRUCTIONS TO FORM A LIBRARY OF KNOWN DISTANCES ALONG THE WIRE
154
COMPUTER INSTRUCTIONS TO FORM A LIBRARY OF PRESET LIMITS COMPRISING PRESET LIMITS
156
COMPUTER INSTRUCTIONS TO USE THE WATER DEPTH FOR EACH OF THE PLURALITY OF NODES TO MODIFY THE LIBRARY OF KNOWN DISTANCES
160

FIGURE 6D

COMPUTER INSTRUCTIONS FOR POSITIONING A WIRE USING SENSOR INFORMATION

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims priority to and the benefit of U.S. Provisional Patent Application Ser. No. 61/489,199 filed on May 23, 2011, entitled "COMPUTER INSTRUCTIONS FOR POSITIONING A WIRE USING SENSOR INFORMATION." This reference is incorporated in its entirety herein.

FIELD

The present embodiments generally relate to computer instructions for determining projected coordinates in a projected coordinate system for at least one node on a wire.

BACKGROUND

A need exists for an improved seismic positioning using computer instructions for positioning wires pulled from a floating vessel over a near surface geological formation.

The present embodiments meet these needs.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description will be better understood in conjunction with the accompanying drawings as follows:

FIG. **1** depicts a wire being towed from a floating vessel.

FIGS. **2**A-**2**B depict local coordinates on a local coordinate system and projected coordinates on a projected coordinate system.

FIGS. **3**A-**3**B depict embodiments of a trend analysis over time and a trend analysis event-by-event.

FIG. **4** depicts an embodiment of a log file.

FIG. **5** depicts an embodiment of a portion of a real-time display.

FIGS. **6**A-**6**D depict an embodiment of a data storage.

The present embodiments are detailed below with reference to the listed Figures.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Before explaining the present computer instructions in detail, it is to be understood that the computer instructions are not limited to the particular embodiments and that they can be practiced or carried out in various ways.

The present embodiments relate to computer instructions for determining projected coordinates in a projected coordinate system for at least one node on a wire towed by a floating vessel. The computer instructions can be used in conjunction with a computer implemented system.

The computer instructions can be used to position equipment used to detect near surface geology formations during high resolution marine geophysical surveying.

The wire can be secured to two separated tow lines that are both secured to a floating vessel. For example, each tow line can have a diverter attached thereto opposite the floating vessel, and the wire can be secured to the diverters. The wire can form a curve. The floating vessel can be a geophysical survey vessel.

The tow lines can be wire rope, electrical wire, cable, polymer rope, hemp rope, or combinations thereof. The tow lines can be attached to the floating vessel by any suitable connector, such as cleats.

The diverters can be those made by The Baro Companies, of Stafford, Tex.

The wire can be wire made by Geometrics, and can have a plurality of nodes disposed along a length of the wire.

Each node can be a determined point along the length of the wire. For example, the node can be at a tow point for a streamer, a location of an in-water sensor, a tow point for a hydrophone, or any other location along the wire.

The projected coordinates that are determined using the computer instructions can be coordinates, such as x-y coordinates on the projected coordinate system. The projected coordinate system can be a Cartesian coordinate system projected over a body of water, such as a Universal Transverse Mercator Grid in the Gulf of Mexico.

The computer instructions can be used to determine a projected coordinate for each of the plurality of nodes on the wire.

A system usable with the computer instructions can include at least a pair of first in-water sensors. Each first in-water sensor can be positioned proximate to an end of the wire. An example of a first in-water sensor is a sensor available from PBX Systems, which provides GPS sensor data.

Each first in-water sensor can be embedded in the wire, positioned adjacent one of the plurality of nodes on the wire, proximate to the wire, on a buoy towed from the wire, or combinations thereof. The buoy can be a floating piece of foam or the like.

Each first in-water sensor can be deployed to determine the projected coordinates for a position on the wire.

In one or more embodiments each first in-water sensor can be a global positioning system sensor; a laser sensor, such as an MDL Fanbeam type sensor; an acoustic sensor, such as a Sonardyne type sensor; or combinations thereof.

In one or more embodiments the computer instructions can account for changes in the shape of the wire to provide accurate node locations using the global positioning system sensor, compass headings, and other information. For example, the compass headings can be detected by a 3004 digital compass made by Spartan Electronics.

The system usable with the computer instructions can include at least a pair of second in-water sensors. Each second in-water sensor can be embedded in the wire, attached to the wire, or combinations thereof.

The second in-water sensors can be deployed to provide azimuths tangential to the wire. The term "azimuths tangential to the wire" refers to the bearing of the wire at the node where the second in-water sensor for determining compass headings is attached.

The system usable with the computer instructions can include a processor in communication with a data storage, each first in-water sensor, and each second in-water sensor.

The computer instructions can configure the processor to process in real-time as the floating vessel traverses over a near surface geological formation.

Real-time processing can include collecting and processing data from about every 1 second to about every 20 seconds.

A near surface geological formation can be an oil reservoir, a gas reservoir, a salt dome, or other geological formations.

In one or more embodiments, instead of or in addition to processing in real-time, the processor can perform processing after the floating vessel has acquired information from all of the first in-water sensors and all of the second in-water sen-

sors. For example, the processing can be performed immediately after all of the sensor information is collected or any time thereafter.

The data storage can be a hard drive, a jump drive, or any computer readable medium.

One or more embodiments of the data storage can include a dynamic information database, such as a structured query language (SQL) server database, for storing data within, such as the sensor information.

A library of nominal values for third, fourth, and/or fifth order polynomial coefficients can be stored in the data storage.

The library of nominal values for third, fourth, and/or fifth order polynomial coefficients can include nominal values. The nominal values can be any number.

A library of known distances along the wire can be stored in the data storage.

The library of known distances along the wire can include distances from the connection of the wire to the first tow line to each of the first in-water sensors.

The library of known distances along the wire can include distances from each first in-water sensor to each second in-water sensor.

The library of known distances along the wire can include distances from each node to each other node, or from each in-water sensor to each node.

The library of known distances along the wire can include any other known distance along or relative to the wire.

A library of preset limits can be stored in the data storage comprising preset limits. For example, the preset limits can include a measurement between two nodes, a water depth, a compass heading, a rate of change in compass heading, or another measurement.

The data storage can have computer instructions for instructing the processor to receive sensor information from each first in-water sensor and each second in-water sensor. For example, each first in-water sensor and each second in-water sensor can collect sensor information and can transmit that sensor information to the processor for storage on the data storage.

The sensor information can include an azimuth tangential to the wire, the projected coordinates for a position on the wire, a water depth of a node, a compass heading of a node, a global positioning system location of a node, or combinations thereof.

Each portion of sensor information can include a time stamp associated with a specific sensor measurement. The time stamps can identify the time that the sensor measurement was taken and validated.

The data storage can have computer instructions to instruct the processor to use the projected coordinates from the first in-water sensors to compute a bearing between the first in-water sensors.

For example, the bearing can be computed by the following equation: $\theta=\arctan((y1-y2)/(x1-x2))$, with x1 and y1 being the projected coordinates of one first in-water sensor, and x2 and t2 being the projected coordinates of another first in-water sensor.

The data storage can have computer instructions to instruct the processor to use the bearing with the sensor information and a first rotation algorithm to reorient the projected coordinates of all of the first in-water sensors to local x-y coordinates, forming a local x-y coordinate system.

In one or more embodiments the first rotation algorithm can be used to rotate the projected coordinates to the local coordinates by a rotation angle θ. For example, the x coordinate of the projected coordinates can be rotated by the following equation: $x=E*\cos\theta+N*\sin\theta$. The y coordinate of the projected coordinates can be rotated by the following equation: $y=-E*\sin\theta+N*\cos\theta$. In the first rotation algorithm equations above, x is the local x coordinate, y is the local y coordinate, E is the projected easting coordinate, N is the projected northing coordinate, and θ is the rotation angle.

The data storage can have computer instructions to instruct the processor to rotate the azimuth tangential to the wire from the second in-water sensors using the bearing and a second rotation algorithm to reorient all azimuths tangential to the wire of all the second in-water sensors into the local x-y coordinate system.

In one or more embodiments the second rotation algorithm can be used to rotate the azimuth tangential to the wire into the local x-y coordinate system by a rotation angle θ. For example, a rotated azimuth tangential to the wire can be determined by: $A'=A+\theta$. In the second rotation algorithm A' is the rotated azimuth, A is the measured azimuth, and θ is the rotation angle.

The data storage can have computer instructions to instruct the processor to construct a third, fourth, and/or fifth order polynomial algorithm of the wire in real-time.

For example, a third order polynomial algorithm of the wire can be: $y=ax^3+bx^2+cx+d$. A fourth order polynomial algorithm of the wire can be: $y=ax^4+bx^3+cx^2+dx+e$. A fifth order polynomial algorithm of the wire can be: $y=ax^5+bx^4+cx^3+dx^2+ex+f$.

Within the third, fourth, and/or fifth order polynomial algorithm, x and y can both be coordinates along the wire, and a, b, c, d, e, and f can each be coefficients to be solved by a least squares technique.

For example, survey observations obtained can be the y coordinate at the head of the wire derived from the global positioning system sensors and tangential azimuths along the wire derived from compass headings of the wire.

The third, fourth, and/or fifth order polynomial algorithm can provide accurate modeling within about a decimeter in extreme cross currents.

In benign conditions, the third, fourth, and/or fifth order polynomial algorithm can provide even more accurate modeling.

The third, fourth, and/or fifth order polynomial algorithm of the wire can be constructed using the nominal values from the library of nominal values for third, fourth, and/or fifth order polynomial coefficients, the local x-y coordinates of the first in-water sensors, and at least one distance along the wire from the library of known distances along the wire.

The data storage can have computer instructions to instruct the processor to compute an azimuth tangential to the wire at each second in-water sensor using the third, fourth, and/or fifth order polynomial algorithm.

As an example of computing an azimuth tangential using the third order polynomial algorithm, the equation, $y=ax^3+bx^2+cx+d$, can be used as a third order polynomial definition of a curve.

The equation, $y=ax^3+bx^2+cx+d$, can be differentiated by x, with a solution of: $dy/dx=3ax^2+2bx+c$, as the slope of the tangent at x. The slope of the tangent at x can be converted to an azimuth using the following equation: $3\pi/2-\arctan(dy/dx)$.

The data storage can have computer instructions to instruct the processor to compute a difference between the computed azimuths tangential to the wire with the reoriented azimuths tangential to the wire from all of the second in-water sensors, thereby forming a residual.

For example, the difference between the computed azimuths tangential and the reoriented azimuths tangential can be computed by subtracting one from the other.

The data storage can have computer instructions to instruct the processor to use the residual with a linear least squares technique to update the library of nominal values for third, fourth, and/or fifth order polynomial coefficients.

In the linear least squares technique, the overall solution can minimize the sum of the squares of the residuals computed in solving every single equation using the third, fourth, and/or fifth order polynomial.

A regression model is a linear one when the model comprises a linear combination of the parameters. The generalization of the n-dimensional Pythagorean Theorem to infinite-dimensional real inner product spaces is known as Parseval's identity or Parseval's equation. Particular examples of such a representation of a function are the Fourier series and the generalized Fourier series.

The data storage can have computer instructions to instruct the processor to construct an updated third, fourth, and/or fifth order polynomial algorithm of the wire using updated nominal values from the updated library of nominal values for third, fourth, and/or fifth order polynomial coefficients, the local x-y coordinates of the first in-water sensors, and at least one distance along the wire from the library of known distances along the wire.

The data storage can have computer instructions to instruct the processor to compute an updated azimuth tangential to the wire at each second in-water sensor.

The data storage can have computer instructions to instruct the processor to compute an updated difference between the computed updated azimuths tangential to the wire with the reoriented azimuths tangential to the wire from all of the second in-water sensors until the residual is determined to be within one of the preset limits from the library of preset limits.

The data storage can have computer instructions to instruct the processor to calculate a pair of local x-y coordinates for at least one of the plurality of nodes on the wire. For example, each pair of local x-y coordinates can be calculated using the third, fourth, and/or fifth order polynomial algorithms.

The data storage can have computer instructions to instruct the processor to use the bearing and a third rotation algorithm to rotate the pair of local x-y coordinates coordinates for at least one of the plurality of nodes on the wire from the local x-y coordinate system to the projected coordinate system.

In one or more embodiments the third rotation algorithm can be used to rotate from the local coordinates to the projected coordinates by a rotation angle θ. For example, third rotation algorithm can include: $E=x*\cos(\theta)-y*\sin(\theta)$, and $N=x*\sin(\theta)+y*\cos(\theta)$. Within the third rotation algorithm x is the local x coordinate, y is the local y coordinate, E is the projected easting coordinate, N is the projected northing coordinate, and θ is the rotation angle which is the computed bearing.

One or more embodiments of the computer implemented system usable with the computer instructions can include a third in-water sensor on each of the plurality of nodes, each of the first in-water sensors, and each of the second in-water sensors. Each third in-water sensor can be in communication with the processor. The third in-water sensors can be depth sensors that can measure water depths for each of the plurality of nodes, each of the first in-water sensors, and each of the second in-water sensors, and can transmit the measured water depths to the processor.

In one or more embodiments, a network can be in communication with the processor. The network can be satellite network, a cellular network, the internet, or Ethernet cables connected between the processor and the in-water sensors, the nodes, or both.

The data storage can include computer instructions to instruct the processor to construct a real-time display of the wire. The real-time display can be a graphical user interface.

In one or more embodiments, the wire can have at least one streamer. Each streamer can be connected to at least one of the plurality nodes. Each streamer can be configured to collect seismic data, such as a size, depth, or location of a near surface geological formation. The computer instructions can allow for accurate positioning of at least one streamer.

The computer instructions can include computer instructions in the data storage to instruct the processor to identify a location of the at least one streamer in real-time using the real-time display.

The computer instructions can include computer instructions in the data storage to instruct the processor to transmit an alarm when the location of the at least one streamer moves outside of one of the preset limits in the library of preset limits associated with one of the plurality of nodes.

The alarm can be a text message, an email, an audible alarm, or a flashing light, and can be transmitted to a client device, another computer on the network, or presented in the real-time display. The alarm can be provided both onboard the floating vessel and remote to the floating vessel. The client device can be a mobile phone, a computer, a laptop, a tablet computer, or a similar device.

For example, the library of preset limits can include preset limits associated with each of the plurality of nodes. When the location a streamer moves outside of a preset limit for the node that streamer is attached to, the alarm can be transmitted.

Each streamer can be or include a hydrophone. Each hydrophone can be connected to at least one of the plurality of nodes for collecting seismic data of a near surface geological formation.

The computer instructions can include computer instructions in the data storage to instruct the processor to create a trend analysis over time using the third, fourth, and/or fifth order polynomial algorithm.

The computer instructions can include computer instructions in the data storage to instruct the processor to create a trend analysis event-by-event using the third, fourth, and/or fifth order polynomial algorithm.

The computer instructions can include computer instructions in the data storage to instruct the processor to create a log file.

The log file can contain the local x-y coordinates, the projected coordinates of the projected coordinate system, or combinations thereof.

Turning now to the Figures, FIG. **1** depicts an embodiment of a computer system usable with the computer instructions for positioning a wire **16**. The wire **16** can be connected to, and stretched between, two separated tow lines, including a first tow line **18***a* and a second tow line **18***b*.

The tow lines **18***a* and **18***b* can be secured to a floating vessel **22**. Two diverters can be secured to the tow lines **18***a* and **18***b*, including a first diverter **20***a* and a second diverter **20***b*.

The tow lines **18***a* and **18***b* can each have a length ranging from about 50 feet to about 500 feet and a diameter ranging from about ¼ of an inch to about 2 inches. The tow lines **18***a* and **18***b* can extend from the floating vessel **22** at an angle from a centerline of the floating vessel **22**, which can range from about 90 degrees to about 180 degrees.

The wire **16** can have a plurality of nodes, such as a first node **14***a*, a second node **14***b*, a third node **14***c*, a fourth node

14*d*, a fifth node **14***e*, and a sixth node **14***f*. The wire **16** can have from about 2 nodes to about 100 nodes.

The wire **16** can have a length ranging from about 50 feet to about 500 feet and a diameter ranging from about ¼ of an inch to about 2 inches.

One or more streamers can be attached to one or more of the plurality of nodes **14***a*-**14***f*. For example a first streamer **116***a* can be attached to the first node **14***a* and a second streamer **116***b* can be attached to the second node **14***b*.

The streamers **116***a* and **116***b* can have a length ranging from about 1 foot to about 500 feet.

The streamers **116***a* and **116***b* can collect seismic data of a near surface geological formation **110**, such as a fault.

One or more hydrophones can be attached to one or more of the plurality of nodes **14***a*-**14***f*. For example, a first hydrophone **120***a* can be attached to the third node **14***c* and a second hydrophone **120***b* can be attached to the fourth node **14***d*.

The hydrophones **120***a* and **120***b* can be those made by Teledyne Instruments, such as a T-2BX hydrophone with an encapsulated hydrophone sensor element or the like.

The hydrophones **120***a* and **120***b* can collect seismic data of the near surface geological formation **110**, such as a depth of the fault, size of the fault, or the like.

The computer system can include one or more first in-water sensors **24***a*, **24***b*, **24***c*, and **24***d* deployed on or proximate the wire **16**.

For example, the first in-water sensor **24***a* can be deployed near the first tow line **18***a*, and can be embedded in the wire **16**. The first in-water sensor **24***b* can be positioned proximate to the second tow line **18***b*. The first in-water sensor **24***c* can be towed near the wire **16**. The first in-water sensor **24***d* can be supported by a buoy **26** towed from the wire **16** and can be positioned proximate to the wire **16**.

The computer system can include one or more second in-water sensors **28***a* and **28***b* deployed on the wire **16**. The second in-water sensors **28***a* and **28***b* can be deployed to provide azimuths tangential to the wire **16**.

The second in-water sensor **28***a* can be embedded in the wire **16** at the first node **14***a*, and the second in-water sensor **28***b* can be attached to the wire **16** between the second node **14***b* and the third node **14***c*.

The computer system can include a processor **32** in communication with a data storage **34**, which can be disposed on the floating vessel **22**.

The processor **32** can be in communication with the first in-water sensors **24***a*-**24***d* and the second in-water sensors **28***a* and **28***b*, such as through cables **57***a* and **57***b*, which can be Ethernet cables.

The computer system can also include third in-water sensors, such as third in-water sensors **29***a*, **29***b*, and **29***c*, which can be in communication with the processor **32** through the cables **57***a* and **57***b*.

The third in-water sensor **29***a* is shown on the fifth node **14***e*, the third in-water sensor **29***b* is shown on the second in-water sensor **28***b*, and the third in-water sensor **29***c* is shown on the first in-water sensor **24***c*. The computer system can include any number of first in-water sensors, second in-water sensors, and third in-water sensors disposed at various positions along the wire **16**.

The third in-water sensors **29***a*, **29***b* and **29***c* can be depth sensors that transmit water depths for each of the plurality of nodes **14***a*-**14***f*, each of the first in-water sensors **24***a*-**24***d*, and each of the second in-water sensors **28***a* and **28***b*.

A client device **13** can be in communication with the processor **32**, such as through a network **108**, for remote monitoring. For example, the client device **13** can receive one or more alarms **128**. The alarms **128** can be flashing lights, an audible signal, or the like.

In operation, the floating vessel **22** can move along a surface of the water pulling the tow lines **18***a* and **18***b*, the wire **16**, the streamers **116***a* and **116***b*, and the hydrophones **120***a* and **120***b*.

The first in-water sensors **24***a*-**24***d*, the second in-water sensors **28***a* and **28***b*, and the third in-water sensors **29***a*, **29***b* and **29***c* can be disposed above or below the surface of the water, and can collect sensor information for transmission to the processor **32** via the cables **57***a* and **57***b*.

The processor **32** can receive the sensor information, store the sensor information in the data storage **34**, and utilize various computer instructions in the data storage **34** to perform calculations on the sensor information for positioning the plurality of nodes **14***a*-**14***f* of the wire **16**.

The processor **32** can utilize the computer instructions and data stored in the data storage **34** to perform various calculations, as described herein, to determine a position of the wire **16**, a direction of the wire **16**, and a velocity of the wire **16**.

FIG. **2**A depicts an embodiment of a local x-y coordinate system **64** with a position of the wire **16** plotted thereon.

The local x-y coordinate system **64** can be presented, such as on a display device or monitor in communication with the processor, as a portion of the real-time display.

The y-axis and x-axis both represent spatial measurements, such as in meters, of positions within the local x-y coordinate system **64**.

On the plot of the wire **16**, the position of the first in-water sensors **24***a* and **24***b* and the position of the second in-water sensor **28***c* are shown. For example, the local x-y coordinates **62***a* and **62***b* associated with the second in-water sensor **28***c* are shown plotted in the local x-y coordinate system **64**.

A computed bearing **58** between the first in-water sensor **24***a* and the first in-water sensor **24***b* can be depicted on the local x-y coordinate system **64**.

An azimuth **30** tangential to the wire **16** can also be depicted on the local x-y coordinate system **64**.

FIG. **2**B depicts an embodiment of a projected coordinate system **12** with a position of the wire **16** plotted thereon.

The projected coordinate system **12** can be presented, such as on the display device or monitor in communication with the processor, as a portion of the real-time display.

In the depicted projected coordinate system **12**, the y-axis represents spatial measurements in a northing coordinate of the projected coordinate system **12**, and the x-axis represents spatial measurements in an easting coordinate of the projected coordinate system **12**.

The origin of the projected coordinate system **12** can be determined using the projected coordinates from at least one of the first in-water sensors **24***a* and **24***b*. For example, the first in-water sensor **24***a* can have projected coordinates **10***a* and **10***b* associated therewith and plotted within the projected coordinate system **12**.

The computed bearing **58** between the first in-water sensor **24***a* and the first in-water sensor **24***b* can be depicted within the projected coordinate system **12**.

The azimuth **30** tangential to the wire **16** from the second in-water sensor **28***c* can also be depicted within the projected coordinate system **12**.

A representation of the local x-y coordinate system **64** can be depicted within the projected coordinate system **12** to show the relationship between the local x-y coordinate system **64** and the projected coordinate system **12**.

FIG. **3**A depicts an embodiment of the trend analysis over time **132** and FIG. **3**B depicts an embodiment of a trend analysis event-by-event **136**.

For example, a distance between two nodes of the plurality of nodes on the wire can be plotted with respect to time, such as in seconds, to form the trend analysis over time **132**.

A distance between two nodes of the plurality of nodes on the wire can be plotted with respect to events to form the trend analysis event-by-event **136**. For example, an event can be the release of seismic energy. The events can be sequential.

FIG. **4** depicts an embodiment of the log file **140**. The log file **140** can be created by tabulating various portions of data and sensor information within the data storage.

For example, the log file **140** can include a first column **143***a* showing various nodes of the plurality of nodes, such as the first node **14***a* in a first row of the log file **140**, the second node **14***b* in a second row of the log file **140**, and the third node **14***c* in a third row of the log file **140**.

The log file **140** can include a second column **143***b* showing the local x-coordinate of the local x-y coordinates that are associated with the node in that particular row of the log file **140**. For example, the local x-coordinate **62***a* can be 3 for the first node **14***a*, the local x-coordinate **62***c* can be 4 for the second node **14***b*, and the local x-coordinate **62***e* can be 5 for the third node **14***c*.

The log file **140** can include a third column **143***c* showing the local y-coordinate of the local x-y coordinates that are associated with the node in that particular row of the log file **140**. For example, the local y-coordinate **62***b* can be 7 for the first node **14***a*, the local y-coordinate **62***d* can be 8 for the second node **14***b*, and the local y-coordinate **62***f* can be 9 for the third node **14***c*.

The log file **140** can include a fourth column **143***d* showing the projected x-coordinate of the projected coordinates that are associated with the node in that particular row of the log file **140**. For example, the projected x-coordinate **10***a* can be 10000 for the first node **14***a*, the projected x-coordinate **10***c* can be 10001 for the second node **14***b*, and the projected x-coordinate **10***e* can be 10002 for the third node **14***c*.

The log file **140** can include a fifth column **143***e* showing the projected y-coordinate of the projected coordinates that are associated with the node in that particular row of the log file **140**. For example, the projected local y-coordinate **10***b* can be 11001 for the first node **14***a*, the projected local y-coordinate **10***d* can be 11002 for the second node **14***b*, and the projected local y-coordinate **10***f* can be 11003 for the third node **14***c*.

The log file **140** can include a sixth column **143***f* showing events associated with the nodes in the first column **143***a*. For example, a first event **119***a* can be associated with the first node **14***a*, a second event **119***b* can be associated with the second node **14***b*, and a third event **119***c* can be associated with the third node **14***c*.

The log file **140** can include a seventh column **143***g* showing a time stamp associated with each event. For example, a time stamp **142***a*, which can be 1:01 pm for example, can be associated with the first event **119***a*. A time stamp **142***b*, which can be 1:02 pm for example, can be associated with the second event **119***b*. A time stamp **142***c*, which can be 1:03 pm for example, can be associated with third event **119***c*.

FIG. **5** depicts an embodiment of a portion of the real-time display **114**.

The real-time display **114** can present a plot **115** of the wire **16**. The real-time display **114** can present a depth profile **117** for the wire **16** and the streamers **116**.

The depth profile **117** can be a plot of the water depths **31***b* of the wire **16** and the streamers **116** with respect to events **119**.

The real-time display **114** can present a depiction of node separations **121** showing the distance between nodes along the wire **16**.

The real-time display **114** can present compass data **123**, such as compass headings of the second in-water sensors.

The real-time display **114** can present water depth data, such as water depths **31***a* of the first in-water sensors, the second in-water sensors, the streamers **116**, the plurality of nodes, and/or the wire **16**.

The real-time display **114** can present network solution data **125**, such as polynomial coefficients. For example, the polynomial coefficient Ax, which is equal to 0.01, is shown along with other polynomial coefficients.

The real-time display **114** can present event information **127**, such as an event number, here shown as 00002131, a date, and a time.

FIGS. **6**A-**6**D depict an embodiment of the data storage **34**.

The data storage **34** can include the library of nominal values for third, fourth, or fifth order polynomial coefficients **36** with nominal values **37** stored therein.

The data storage **34** can include the library of known distances along the wire **38** having at least one distance **39** along the wire, distances to each first in-water sensor **40**, distances to each second in-water sensor **42**, distances to each node of the plurality of nodes **44**, and distances to desired locations along the wire **46**.

The data storage **34** can include the library of preset limits **48** with preset limits **50**.

The data storage **34** can include computer instructions for instructing the processor to receive sensor information from each first in-water sensor and each second in-water sensor **52**.

The sensor information **54** can be stored in the data storage **34** with a time stamp **142**, and can include an azimuth **30***a* tangential to the wire, and the projected coordinates **10** for a position on the wire.

The data storage **34** can include computer instructions to instruct the processor to use the projected coordinates from the first in-water sensors to compute a bearing between the first in-water sensors, and then to use the bearing with the sensor information and a first rotation algorithm to reorient the projected coordinates of all of the first in-water sensors to local x-y coordinates, forming a local x-y coordinate system **56**.

The bearing **58** can be stored in the data storage **34**.

Also the first rotation algorithm **60***a*, a second rotation algorithm **60***b*, and a third rotation algorithm **60***c* can be stored in the data storage **34**.

The data storage **34** can include the local x-y coordinates **62** in the local x-y coordinate system **64** stored therein.

The data storage **34** can include computer instructions to instruct the processor to rotate the azimuth tangential to the wire from each second in-water sensor using the bearing and the second rotation algorithm to reorient all azimuths tangential to the wire into the local x-y coordinate system **66**.

The data storage **34** can include computer instructions to instruct the processor to construct a third, fourth, or fifth order polynomial algorithm of the wire in real-time using: nominal values from the library of nominal values for third, fourth, or fifth order polynomial coefficients, the local x-y coordinates of the first in-water sensors, and at least one distance along the wire from the library of known distances along the wire **70**.

The third, fourth, or fifth order polynomial algorithm **72** can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to compute an azimuth tangential to the wire at each second in-water sensor using the third, fourth, or fifth order polynomial algorithm **74**.

The computed azimuth **30***b* can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to compute a difference between the computed azimuth tangential to the wire with the reoriented azimuths tangential to the wire to form a residual **76**.

The residual **78** can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to use the residual with a least squares technique to update the library of nominal values for third, fourth, or fifth order polynomial coefficients **80**.

The linear least squares technique **82** can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to construct an updated third, fourth, or fifth order polynomial algorithm of the wire using: updated nominal values from the updated library of nominal values for third, fourth, or fifth order polynomial coefficients, the local x-y coordinates of the first in-water sensors, and at least one distance along the wire from the library of known distances along the wire **84**.

The updated third, fourth, or fifth order polynomial algorithm **86** can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to compute an updated azimuth tangential to the wire at each second in-water sensor **88**.

The updated azimuth **30***c* can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to compute an updated difference between the computed updated azimuth tangential to the wire and the reoriented azimuth tangential to the wire until the residual is within one of the preset limits from the library of preset limits **90**.

The data storage **34** can include computer instructions to instruct the processor to calculate a pair of local x-y coordinates for at least one of the plurality of nodes on the wire **92**.

The calculated pair of local x-y coordinates **63***a* and **63***b* can be stored in the data storage **34**.

The data storage **34** can include computer instructions to instruct the processor to use the bearing and the third rotation algorithm to rotate the pair of local x-y coordinates for at least one of the plurality of nodes on the wire from the local x-y coordinate system to the projected coordinate system **93**.

The data storage **34** can have computer instructions to instruct the processor to construct a real-time display of the wire **112**.

The data storage **34** can have computer instructions to instruct the processor to identify a location of the at least one streamer in real-time using the real-time display **122**.

The location of the at least one streamer **124** can be stored in the data storage **34**.

The data storage **34** can have computer instructions to instruct the processor to transmit an alarm when the location of the at least one streamer moves outside of one of the preset limits in the library of preset associated with one of the plurality of nodes **126**.

The data storage **34** can have computer instructions to instruct the processor to create a trend analysis over time using the third, fourth, or fifth order polynomial algorithm **130**.

The data storage **34** can have computer instructions to instruct the processor to create a trend analysis event-by-event using the third, fourth, or fifth order polynomial algorithm **134**.

The data storage **34** can have computer instructions to instruct the processor to create a log file containing the local x-y coordinates, the projected coordinates of the projected coordinate system, or combinations thereof **138**.

The data storage **34** can have computer instructions to instruct the processor to process in real-time as the floating vessel traverses over a near surface geological formation **144**, and computer instructions to instruct the processor to process after the floating vessel has acquired information from all of the first in-water sensors and all of the second in-water sensors **146**.

The data storage **34** can have computer instructions to identify a location of the at least one hydrophone in real-time using the real-time display **148**, and computer instructions to transmit an alarm when the location of the at least one hydrophone moves outside of one of the preset limits in the library of preset limits associated with one of the plurality of nodes **150**.

The data storage **34** can have computer instructions to form a library of nominal values for third, fourth, or fifth order polynomial coefficients **152**, computer instructions to form a library of known distances along the wire **154**, and computer instructions to form a library of preset limits comprising preset limits **156**.

The data storage **34** can have computer instructions to use the water depth for each of the plurality of nodes to modify the library of known distances **160**.

While these embodiments have been described with emphasis on the embodiments, it should be understood that within the scope of the appended claims, the embodiments might be practiced other than as specifically described herein.

What is claimed is:

1. Computer instructions on a non-transitory computer readable medium for determining projected coordinates in a projected coordinate system for at least one node on a wire having a plurality of nodes, wherein the wire is secured to two separated tow lines, wherein each tow line has a diverter, and wherein the two separated tow lines are secured to a floating vessel, the computer instructions comprising:

a. computer instructions to form a library of nominal values for third, fourth, or fifth order polynomial coefficients;

b. computer instructions to form a library of known distances along the wire comprising:
   (i) distances to first in-water sensors;
   (ii) distances to second in-water sensors;
   (iii) distances to each node of the plurality of nodes;
   (iv) distances to locations along the wire; or
   (v) combinations thereof;

c. computer instructions to form a library of preset limits comprising preset limits;

d. computer instructions to receive sensor information from the first in-water sensors and the second in-water sensors;

e. computer instructions to:
   (i) use projected coordinates from the first in-water sensors to compute a bearing between the first in-water sensors; and
   (ii) use the bearing with the sensor information and a first rotation algorithm to reorient the projected coordinates of all of the first in-water sensors to local x-y coordinates, forming a local x-y coordinate system;

f. computer instructions to rotate azimuths tangential to the wire from the second in-water sensors using the bearing

and a second rotation algorithm, thereby reorienting all azimuths tangential to the wire into the local x-y coordinate system;

g. computer instructions to construct a third, fourth, or fifth order polynomial algorithm of the wire in using:
   (i) nominal values from the library of nominal values for third order polynomial coefficients;
   (ii) the local x-y coordinates of the first in-water sensors; and
   (iii) at least one distance along the wire from the library of known distances along the wire;

h. computer instructions to compute an azimuth tangential to the wire at each second in-water sensor using the third, fourth, or fifth order polynomial algorithm;

i. computer instructions to compute a difference between the computed azimuth tangential to the wire and the reoriented azimuths tangential to the wire to form a residual;

j. computer instructions to use the residual with a least squares technique to update the library of nominal values for third, fourth, or fifth order polynomial coefficients;

k. computer instructions to construct an updated third, fourth, or fifth order polynomial algorithm of the wire using:
   (i) updated nominal values from the updated library of nominal values for third, fourth, or fifth order polynomial coefficients;
   (ii) the local x-y coordinates of the first in-water sensors; and
   (iii) at least one distance along the wire from the library of known distances along the wire;

l. computer instructions to compute an updated azimuth tangential to the wire at each second in-water sensor;

m. computer instructions to compute an updated difference between the computed updated azimuth tangential to the wire with the reoriented azimuths tangential to the wire until the residual is within one of the preset limits from the library of preset limits;

n. computer instructions to calculate a pair of local x-y coordinates for at least one of the plurality of nodes on the wire; and

o. computer instructions to use the bearing and a third rotation algorithm to rotate the pair of local x-y coordinates for at least one of the plurality of nodes on the wire from the local x-y coordinate system to the projected coordinate system.

2. The computer instructions of claim **1**, wherein the non-transitory computer readable medium is a data storage in communication with a processor, wherein each computer instruction is configured to instruct the processor, and wherein the processor is configured to execute each computer instruction.

3. The computer instructions of claim **2**, wherein the data storage is configured to receive the sensor information from:

a. at least a pair of first in-water sensors are deployed to determine the projected coordinates for a position on the wire, wherein each first in-water sensor is:
   (i) embedded in the wire;
   (ii) positioned adjacent one of the plurality of nodes on the wire;
   (iii) proximate to the wire;
   (iv) on a buoy towed from the wire; or
   (v) combinations thereof; and

b. at least a pair of second in-water sensors are deployed to provide azimuths tangential to the wire, wherein each second in-water sensor is:
   (i) embedded in the wire;
   (ii) attached to the wire; or
   (iii) combinations thereof.

4. The computer instructions of claim **3**, wherein the data storage is further configured to receive the sensor information from a third in-water sensor on: each of the plurality of nodes, each of the first in-water sensors, and each of the second in-water sensors, wherein:

a. each third in-water sensor is in communication with the processor; and

b. each third in-water sensor is a depth sensor that transmits a water depth for each of the plurality of nodes, each of the first in-water sensors, and each of the second in-water sensors.

5. The computer instructions of claim **4**, further comprising computer instructions to use the water depths for each of the plurality of nodes to modify the library of known distances along the wire.

6. The computer instructions of claim **3**, wherein the computer instructions use the pair of first in-water sensors to determine the position on the wire, and wherein each first in-water sensor is:

a. a global positioning system sensor;

b. a laser sensor;

c. an acoustic sensor; or

d. combinations thereof.

7. The computer instructions of claim **2**, wherein a network is in communication with the processor.

8. The computer instructions of claim **2**, further comprising:

a. computer instructions to instruct the processor to process in real-time as the floating vessel traverses over a near surface geological formation;

b. computer instructions to instruct the processor to process after the floating vessel has acquired all of the sensor information from all of the first in-water sensors and all of the second in-water sensors; or

c. combinations thereof.

9. The computer instructions of claim **1**, wherein the two separated tow lines are wire rope, electrical wire, cable, polymer rope, hemp rope, or combinations thereof.

10. The computer instructions of claim **1**, further comprising computer instructions to construct a real-time display of the wire.

11. The computer instructions of claim **10**, wherein the real-time display further comprises: a depth profile of the wire and streamers on the wire, separations between nodes of the plurality of nodes, compass data, depth data, the polynomial coefficients, event information, or combinations thereof.

12. The computer instructions of claim **10**, wherein:

a. at least one streamer is attached to the wire, and wherein each streamer is connected to at least one of the plurality of nodes for collecting seismic data of a near surface geological formation; or

b. at least one hydrophone is attached to the wire, and wherein each hydrophone is connected to at least one of the plurality of nodes for collecting seismic data of the near surface geological formation.

13. The computer instructions of claim **12**, further comprising computer instructions to identify a location of the at least one streamer or the at least one hydrophone in real-time using the real-time display.

14. The computer instructions of claim **13**, further comprising computer instructions to transmit an alarm to the real-time display or over the network when the location of any of the streamers or the hydrophones moves outside of one of the preset limits in the library of preset limits.

15. The computer instructions of claim 1, further comprising computer instructions to create a trend analysis over time using the third, fourth, or fifth order polynomial algorithm, wherein the trend analysis over time is a plot of distances between nodes of the plurality of nodes versus time.

16. The computer instructions of claim 1, further comprising computer instructions to create a trend analysis event-by-event using the third, fourth, or fifth order polynomial algorithm, wherein the trend analysis event-by-event is a plot of distances between nodes of the plurality of nodes versus events.

17. The computer instructions of claim 1, further comprising computer instructions to create a log file containing the local x-y coordinates, the projected coordinates of the projected coordinate system, events, time stamps, or combinations thereof.

18. The computer instructions of claim 1, wherein the sensor information comprises a time stamp.

19. The computer instructions of claim 1, wherein the sensor information comprises:

a. azimuths tangential to the wire;

b. the projected coordinates for the position on the wire; or

c. combinations thereof.

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