AO 440 (Rev. 06/12) Summons in a Civil Action

UNITED STATES DISTRICT COURT

for the

Eastern District of Texas

Fairfield Industries Incorporated d/b/a FairfieldNodal
Plaintiff(s)
v.
Wireless Seismic, Inc.
Defendant(s)

Civil Action No. 2:13-cv-00903

SUMMONS IN A CIVIL ACTION

To: *(Defendant's name and address)*

Wireless Seismic, Inc.
c/o CT Corporation System
350 N. St. Paul Street
Suite 2900
Dallas, Texas 75201

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it) — or 60 days if you are the United States or a United States agency, or an officer or employee of the United States described in Fed. R. Civ. P. 12 (a)(2) or (3) — you must serve on the plaintiff an answer to the attached complaint or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff or plaintiff's attorney, whose name and address are:

Allen A. Arntsen
Foley & Lardner LLP
P.O. Box 1497
Madison, Wisconsin 53701-1497

If you fail to respond, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

UNITED STATES DISTRICT COURT · EASTERN DISTRICT OF TEXAS

CLERK OF COURT

David Maland

Date: **11/4/13**

Signature of Clerk or Deputy Clerk

Civil Action No. 2:13-cv-00903

PROOF OF SERVICE

(This section should not be filed with the court unless required by Fed. R. Civ. P. 4 (l))

This summons for *(name of individual and title, if any)* ______________________
was received by me on *(date)* ______________ .

❒ I personally served the summons on the individual at *(place)* ______________________
______________________ on *(date)* ______________ ; or

❒ I left the summons at the individual's residence or usual place of abode with *(name)* ______________
______________________ , a person of suitable age and discretion who resides there,
on *(date)* ______________ , and mailed a copy to the individual's last known address; or

❒ I served the summons on *(name of individual)* ______________________ , who is
designated by law to accept service of process on behalf of *(name of organization)* ______________
______________________ on *(date)* ______________ ; or

❒ I returned the summons unexecuted because ______________________ ; or

❒ Other *(specify)*:

My fees are $ __________ for travel and $ __________ for services, for a total of $ 0.00 .

I declare under penalty of perjury that this information is true.

Date: ______________

____
Server's signature

____
Printed name and title

____
Server's address

Additional information regarding attempted service, etc:

UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF TEXAS
MARSHALL DIVISION

Fairfield Industries Incorporated d/b/a FairfieldNodal, Plaintiff, vs. Wireless Seismic, Inc., Defendant.	)	Case No. 2:13-cv-903 **JURY TRIAL DEMANDED**

COMPLAINT

1. This is an action for patent infringement by Fairfield Industries Incorporated d/b/a FairfieldNodal ("Fairfield") against Wireless Seismic, Inc. ("Wireless Seismic") for infringement of United States Patent No. 7,124,028 ("the '028 patent"), United States Patent No. 7,983,847 ("the '847 patent"), and United States Patent No. 8,296,068 ("the '068 patent") under 35 U.S.C. § 271.

2. Plaintiff Fairfield Industries Incorporated is a Delaware corporation with its principal place of business at 1111 Gillingham Lane, Sugar Land, Texas 77478.

3. On information and belief, defendant Wireless Seismic, Inc. is a Delaware corporation with its principal place of business at 13100 Southwest Freeway, Suite 150, Sugar Land, Texas 77478.

4. On information and belief, Wireless Seismic's registered agent for service in Texas is CT Corporation System, 350 N. St. Paul Street, Suite 2900, Dallas, Texas 75201.

5. This action arises under the patent laws of the United States, Title 35 of the United States Code. This Court has subject matter jurisdiction over this matter pursuant to 28 U.S.C. §§ 1331 and 1338.

6. This Court has personal jurisdiction over Wireless Seismic, as Wireless Seismic does business and has committed infringing acts in this district.

7. Venue in this district is appropriate under 28 U.S.C. §§ 1391 and 1400(b).

COUNT I

8. On October 17, 2006, United States Patent No. 7,124,028 ("the '028 patent") entitled "Method and System for Transmission of Seismic Data" was duly and legally issued to Fairfield Industries, Inc., with Clifford H. Ray and Glenn D. Fisseler as inventors. Fairfield is the owner of all right, title and interest in and to the '028 patent. A copy of the '028 patent is attached as **Exhibit A**.

9. Wireless Seismic's actions in making, using, selling and offering to sell the products known as the RT 1000 and/or the RT System 2 infringe at least claims 1-22, 24-31, 34-39, 41, 42 and 46-49 of the '028 patent, both literally and under the doctrine of equivalents.

10. Wireless Seismic's actions in making, using, selling and offering to sell the RT 1000 and/or the RT System 2 and in actively inducing others to use or sell the RT 1000 and/or RT System 2 in the United States constitutes active inducement of at least claims 1-22, 24-31, 34-39, 41, 42 and 46-49 of the '028 patent in violation of 35 U.S.C. § 271(b), both literally and under the doctrine of equivalents.

11. Wireless Seismic has offered to sell and sold, and continues to offer and sell, the RT 1000 and/or the RT System 2 in the United States for use in practicing at least claims 1-22, 24-31, 34-39, 41, 42 and 46-49 of the '028 patent. Wireless Seismic did so knowing that

RT 1000 and/or RT System 2 are especially made and especially adapted for use in infringing at least claims 1-22, 24-31, 34-39, 41, 42 and 46-49 of the ’028 patent and are not staple articles or commodities of commerce suitable for any substantial noninfringing use. Accordingly, Wireless Seismic is liable to Fairfield as a contributory infringer of the ’028 patent under 35 U.S.C. § 271(c), both literally and under the doctrine of equivalents.

12. Wireless Seismic’s infringing acts are willful in that Wireless Seismic had and has knowledge of Fairfield’s rights under the ’028 patent since at least June 15, 2012, but Wireless Seismic nonetheless infringes, and actively induces and contributes to infringement by others of, at least claims 1-22, 24-31, 34-39, 41, 42 and 46-49 of the ’028 patent.

13. Wireless Seismic’s infringement of the ’028 patent has caused and will continue to cause Fairfield substantial damages and irreparable harm for which there is no adequate remedy at law.

COUNT II

14. On July 19, 2011, United States Patent No. 7,983,847 (“the ’847 patent”) entitled “Method and System for the Transmission of Seismic Data” was duly and legally issued to Fairfield Industries, Incorporated, with Clifford H. Ray and Glenn D. Fisseler as inventors. Fairfield is the owner of all right, title and interest in and to the ’847 patent. A copy of the ’847 patent is attached as **Exhibit B**.

15. Wireless Seismic’s actions in making, using, selling and offering to sell the RT 1000 and/or the RT System 2 infringe at least claims 1-5 and 7-18 of the ’847 patent, both literally and under the doctrine of equivalents.

16. Wireless Seismic’s actions in making, using, selling and offering to sell the RT 1000 and/or the RT System 2 and in actively inducing others to use or sell the RT 1000

and/or the RT System 2 in the United States constitutes active inducement of at least claims 1-5 and 7-18 of the ’847 patent in violation of 35 U.S.C. § 271(b), both literally and under the doctrine of equivalents.

17. Wireless Seismic has offered to sell and sold, and continues to offer and sell, the RT 1000 and/or the RT System 2 in the United States for use in practicing at least claims 1-5 and 7-18 of the ’847 patent. Wireless Seismic did so knowing that the RT 1000 and/or the RT System 2 are especially made and especially adapted for use in infringing at least claims 1-5 and 7-18 of the ’847 patent and are not staple articles or commodities of commerce suitable for any substantial noninfringing use. Accordingly, Wireless Seismic is liable to Fairfield as a contributory infringer of the ’847 patent under 35 U.S.C. § 271(c), both literally and under the doctrine of equivalents.

18. Wireless Seismic’s infringing acts are willful in that Wireless Seismic had and has knowledge of Fairfield’s rights under the ’847 patent since at least June 15, 2012, but Wireless Seismic nonetheless infringes, and actively induces and contributes to infringement by others of, at least claims 1-5 and 7-18 of the ’847 patent.

19. Wireless Seismic’s infringement of the ’847 patent has caused and will continue to cause Fairfield substantial damages and irreparable harm for which there is no adequate remedy at law.

COUNT III

20. On October 23, 2012, United States Patent No. 8,296,068 (“the ’068 patent”) entitled “Method for Transmission of Seismic Data” was duly and legally issued to Fairfield Industries Incorporated, with Clifford H. Ray and Glenn D. Fisseler as inventors.

Fairfield is the owner of all right, title and interest in and to the ’068 patent. A copy of the ’068 patent is attached as **Exhibit C**.

21. Wireless Seismic’s actions in making, using, selling and offering to sell the RT 1000 and/or the RT System 2 infringe claims 1-16 of the ’068 patent, both literally and under the doctrine of equivalents.

22. Wireless Seismic’s actions in making, using, selling and offering to sell the RT 1000 and/or the RT System 2 and in actively inducing others to use or sell the RT 1000 and/or the RT System 2 in the United States constitutes active inducement of claims 1-16 of the ’068 patent in violation of 35 U.S.C. § 271(b), both literally and under the doctrine of equivalents.

23. Wireless Seismic has offered to sell and sold, and continues to offer and sell, the RT 1000 and/or the RT System 2 in the United States for use in practicing claims 1-16 of the ’068 patent. Wireless Seismic did so knowing that the RT 1000 and/or the RT System 2 are especially made and especially adapted for use in infringing claims 1-16 of the ’068 patent and are not staple articles or commodities of commerce suitable for any substantial noninfringing use. Accordingly, Wireless Seismic is liable to Fairfield as a contributory infringer of the ’068 patent under 35 U.S.C. § 271(c), both literally and under the doctrine of equivalents.

24. Wireless Seismic’s infringing acts are willful in that Wireless Seismic had and has knowledge of Fairfield’s rights under the ’068 patent since at least October 23, 2012, but Wireless Seismic nonetheless infringes, and actively induces and contributes to infringement by others of, claims 1-16 of the ’068 patent.

25. Wireless Seismic's infringement of the '068 patent has caused and will continue to cause Fairfield substantial damages and irreparable harm for which there is no adequate remedy at law.

DEMAND FOR JURY TRIAL

26. Fairfield hereby demands a jury trial on all issues properly tried to a jury.

PRAYER FOR RELIEF

WHEREFORE, Fairfield respectfully requests that this Court enter judgment in its favor and grant the following relief:

A. A judgment that Wireless Seismic infringes the '028 patent under 35 U.S.C. §§ 271(a), (b) and (c), both literally and under the doctrine of equivalents.

B. A judgment that Wireless Seismic infringes the '847 patent under 35 U.S.C. §§ 271(a), (b) and (c), both literally and under the doctrine of equivalents.

C. A judgment that Wireless Seismic infringes the '068 patent under 35 U.S.C. §§ 271(a), (b) and (c), both literally and under the doctrine of equivalents.

D. A permanent injunction enjoining Wireless Seismic and its affiliates, subsidiaries, officers, directors, employees, agents, representatives, licensees, successors, assigns, and all those acting for any of them or on their behalf, or acting in concert with them, from further infringement of the '028 patent, the '847 patent and the '068 patent.

E. A judgment that Wireless Seismic's infringement has been willful.

F. An award of attorneys' fees incurred in prosecuting this action, on the basis that this is an exceptional case.

G. A judgment and order requiring Wireless Seismic to pay Fairfield damages under 35 U.S.C. § 284, including supplemental damages for any continuing post-verdict infringement up until entry of the final judgment, with an accounting, as needed, and treble damages for willful infringement as provided by 35 U.S.C. § 284.

H. A judgment and order requiring Wireless Seismic to pay Fairfield the cost of this action (including all disbursements).

I. A judgment and order requiring Wireless Seismic to pay Fairfield pre-judgment and post-judgment interest on the damages awarded.

J. Further relief as the Court may deem just and proper.

Dated: November 1, 2013

Respectfully submitted,

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US007124028B2

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

(10) **Patent No.: US 7,124,028 B2**
(45) **Date of Patent: Oct. 17, 2006**

(54) **METHOD AND SYSTEM FOR TRANSMISSION OF SEISMIC DATA**

(75) Inventors: **Clifford H. Ray**, Fulshear, TX (US); **Glenn D. Fisseler**, Houston, TX (US)

(73) Assignee: **Fairfield Industries, Inc.**, Sugar Land, 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.

(21) Appl. No.: **10/719,800**

(22) Filed: **Nov. 21, 2003**

(65) **Prior Publication Data**

US 2005/0114033 A1 May 26, 2005

(51) **Int. Cl.**
G01V 1/28 (2006.01)

(52) **U.S. Cl.** **702/1**; 367/77

(58) **Field of Classification Search** 702/14, 702/15, 18; 367/73, 76, 77, 6, 20, 21, 56
See application file for complete search history.

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2004/0252585	A1 *	12/2004	Smith et al.	367/66

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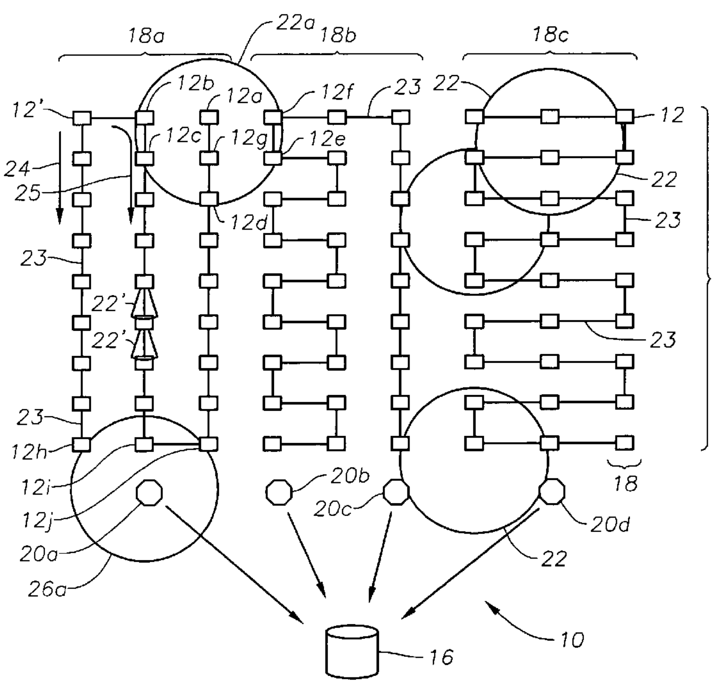
Primary Examiner—Donald McElheny, Jr.
(74) *Attorney, Agent, or Firm*—Jackson Walker L.L.P.; Mark A. Tidwell, Esq.

(57) **ABSTRACT**

The transmission method utilizes multiple seismic acquisition units within an array as intermediate short range radio receivers/transmitters to pass collected seismic data in relay fashion back to a control station. Any one seismic unit in the array is capable of transmitting radio signals to several other seismic units positioned within radio range of the transmitting unit, thus allowing the system to select an optimal transmission path. Utilizing an array of seismic units permits transmission routes back to a control station to be varied as needed. In transmissions from the most remote seismic unit to the control station, each unit within a string receives seismic data from other units and transmits the received seismic data along with the receiving unit's locally stored seismic data. Preferably, as a transmission is passed along a chain, it is bounced between seismic units so as to be relayed by each unit in the array.

49 Claims, 2 Drawing Sheets



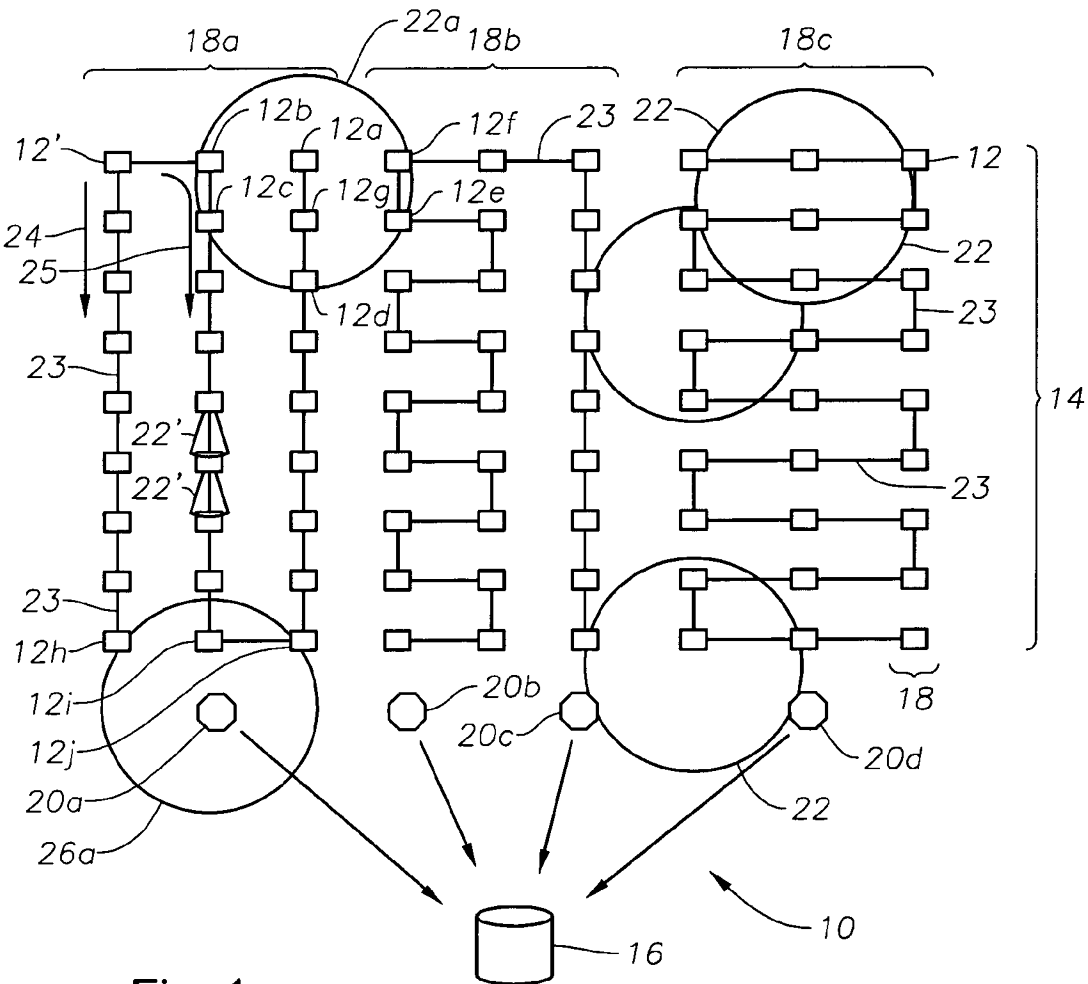

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Fig. 1

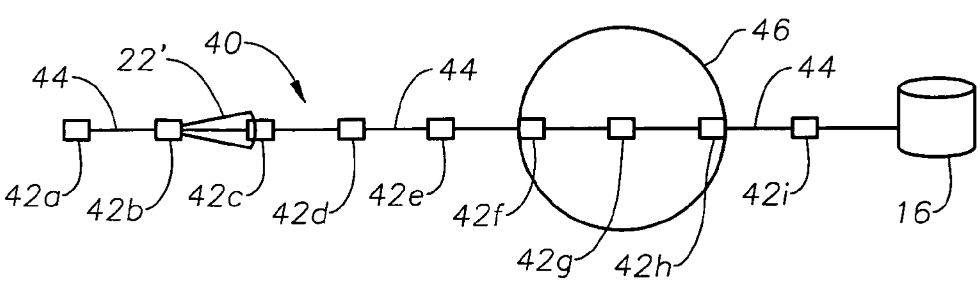
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Fig. 2

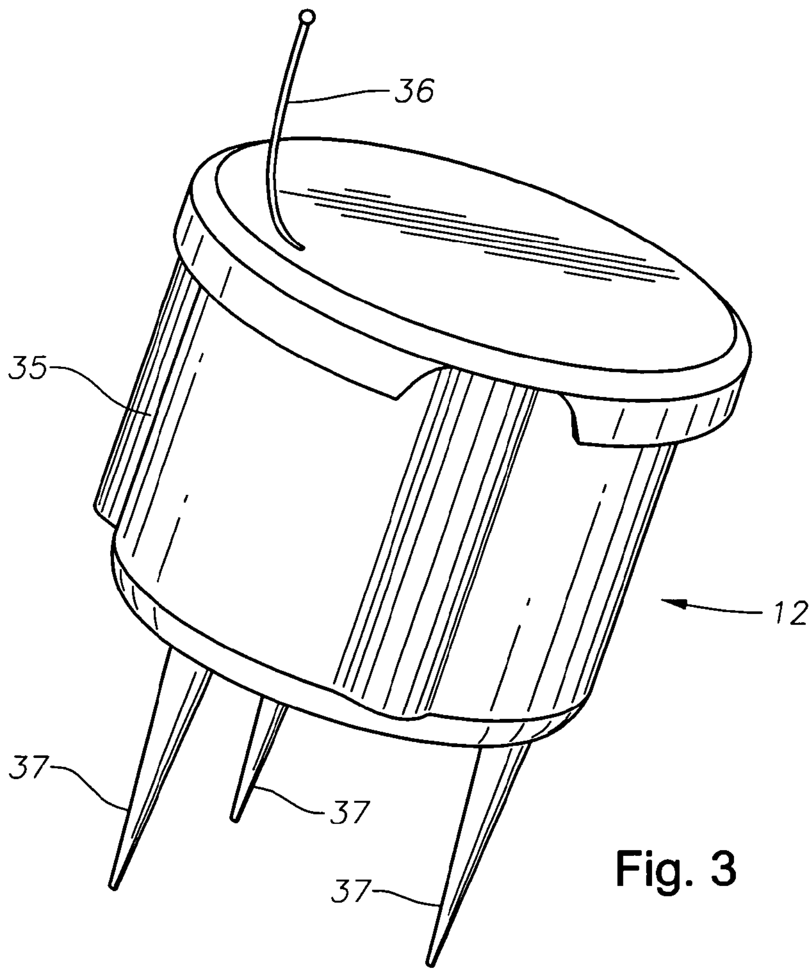

Fig. 3

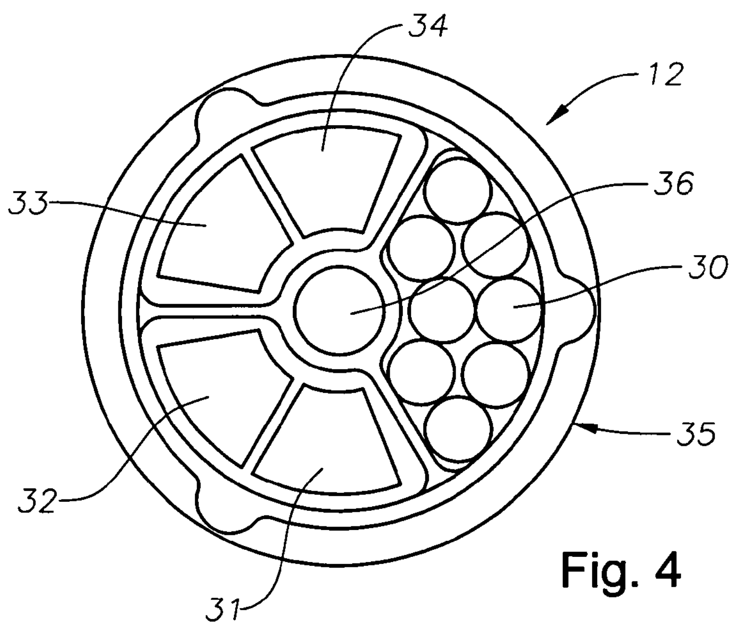

Fig. 4

METHOD AND SYSTEM FOR TRANSMISSION OF SEISMIC DATA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to seismic data acquisition, and more particularly to a method and system for transmitting data between multiple remote stations in an array and a data collection station utilizing a linked relay system to communicate therebetween permitting transmission paths to be altered.

2. Description of the Prior Art

Seismic exploration generally utilizes a seismic energy source to generate an acoustic signal that propagates into the earth and is partially reflected by subsurface seismic reflectors (i.e., interfaces between subsurface lithologic or fluid layers characterized by different elastic properties). The reflected signals are detected and recorded by seismic units having receivers or geophones located at or near the surface of the earth, thereby generating a seismic survey of the subsurface. The recorded signals, or seismic energy data, can then be processed to yield information relating to the lithologic subsurface formations, identifying such features, as, for example, lithologic subsurface formation boundaries.

Typically, the seismic units or stations are laid out in an array, wherein the array consists of a line of stations each having at least one geophone attached thereto in order to record data from the seismic cross-section below the array. For data over a larger area and for three-dimensional representations of a formation, multiple lines of stations may be set out side-by-side, such that a grid of receivers is formed. Often, the stations and their geophones are remotely located or spread apart. In land seismic surveys for example, hundreds to thousands of geophones may be deployed in a spatially diverse manner, such as a typical grid configuration where each line of stations extends for 5000 meters with stations spaced every 25 meters and the successive station lines are spaced 200 meters apart.

Various seismic data transmission systems are used to connect remote seismic acquisition units to a control station. Generally, the seismic stations are controlled from a central location that transmits control signals to the stations and collects seismic and other data back from the stations. Alternatively, the seismic stations may transmit data back to an intermediate data collection station such as a concentrator, where the data is recorded and stored until retrieved. Whichever the case, the various stations are most commonly hard wired to one another utilizing data telemetry cable. Other systems use wireless methods for control and data transmission so that the individual stations are not connected to each other. Still other systems temporarily store the data at each station until the data is extracted.

In the case of wired stations, typically several geophones are connected in a parallel-series combination on a single twisted pair of wires to form a single receiver group or channel for a station. During the data collection process, the output from each channel is digitized and recorded by the station for subsequent analysis. In turn, stations are usually connected to cables used to communicate with and transport the collected data to recorders located at either a control station or a concentrator station.

In the case of wireless seismic units, each unit communicates with either a central control station or concentrator via radio transmissions. Transmissions are made either directly between each seismic unit and the control station or directly between each seismic unit and the concentrator. To

the extent the transmissions are high power, long-range signals, such as between a seismic acquisition unit and a central control station, the transmissions generally require a license from the local governing authority. Units capable of such transmissions also have higher power requirements and thus require larger battery packages. To the extent the seismic acquisition units transmit to a concentrator station utilizing a low power, short-range signal, the transmitting and receiving units must typically have a line of site therebetween.

Illustrative of the prior art is U.S. Pat. No. 6,070,129 which teaches a method and apparatus for transmitting seismic data to a remote collection station. Specifically, an acquisition unit having a geophone attached thereto communicates with a central station either directly by radio channels, or optionally, by means of an intermediate station. To the extent a large number of acquisition units are utilized, the patent teaches that each a plurality of intermediate stations may also be utilized, wherein each intermediate station directly communicates with a portion of the acquisition units. Intermediate stations may function as data concentrators and may also be utilized to control various tasks executed by their respective groups of acquisition units. Whether data is transmitted directly between an acquisition unit and the central station or directly between an acquisition unit and an intermediate station, the transmitting system accumulates seismic data, distributes the data over successive transmission windows and discontinuously transmits the data during successive transmissions in order to lessen variation in seismic data flow.

Similarly, U.S. Pat. No. 6,219,620 teaches a seismic data acquisition system using wireless telemetry, in which a large number of remote seismic acquisition units are grouped together into a plurality of cells and each acquisition unit within a cell communicates directly with a cell access node, i.e., a concentrator, which in turn communicates with a central control unit. This patent teaches that in order to avoid overlap between transmitting seismic units within adjacent cells, adjacent cells utilize different frequencies for communication between units and their respective cell access nodes. In otherwords, adjacent cells operate at different frequencies so that a particular acquisition unit is only capable of transmitting to the cell access node assigned to its cell.

One drawback to the aforementioned seismic transmission systems of the prior art is that the failure of any one intermediate transmission station or cell access node will prevent communication with a plurality of seismic acquisition units. Furthermore, to the extent an individual unit is prevented from transmitting back to its respective cell access node due to factors external to the unit, the participation and operation of that unit within the array is lost. For example, a unit may lose radio contact with an access point due to a weak signal, weather conditions, topography, interference from other electrical devices operating in the vicinity of the unit, disturbance of the unit's deployment position or the presence of a physical structure in the line of site between the unit and the access point.

Thus, it would be desirable to provide a communication system for a seismic survey array that has flexibility in transmitting signals and data to and from remote seismic units and a control and/or data collection station. The system should be capable of communication between functional seismic units even if one or more intermediate stations fail to operate properly. In addition, the system should be capable of communication between functional seismic units even if a change in environmental or physical conditions inhibits or prevents a direct transmission between a remote unit and its control station.

SUMMARY OF THE INVENTION

The method according to the invention transmits radio signals between individual seismic acquisition units in an array, such that the transmissions can be passed in a relay chain through the array of seismic units. Multiple seismic acquisition units within the array are capable of passing transmissions to multiple other seismic units. More specifically, any one seismic acquisition unit in the array is capable of transmitting radio signals to several other seismic acquisition units positioned within radio range of the transmitting seismic acquisition unit. A network of radio-linked seismic acquisition units such as this permits seismic data transmission routes back to a control station to be varied as desired or needed. In other words, the transmission path utilized to transmit data from the individual seismic acquisition units in an array back to a control station may be altered. In transmissions up the chain, i.e., from the most remote seismic acquisition unit to the control station, each unit receives seismic data from a seismic unit "down" the chain and transmits the received seismic data up the chain along with receiving unit's locally stored seismic data. Preferably, as a transmission moves up the chain, it is bounced between seismic acquisition units so as to be relayed by each unit in the array. The specific transmission path, i.e., the chain of units, for any given transmission may vary between transmissions depending on overall system requirements. Control signals and the like can be passed back down the chain along the same or a different transmission path.

The transmitted signal strength can be altered to adjust the transmission range for a transmitting seismic unit, such that number of potential receiving seismic acquisition units can be controlled. In one embodiment, each seismic acquisition unit is omni-directional in its transmission and is capable of linking to all units within a 360° range around the transmitting unit. Alternatively, a transmitting seismic unit may utilize a directional antenna such that transmissions are made only to one or more seismic acquisition units in a limited or single direction or more limited range of transmission.

Preferably the individual seismic acquisition units are wireless and require no external cabling for data transmission or unit control. Such units may contain a battery, a short-range radio transmitter/receiver, a local clock, limited local memory, a processor and a geophone package. In one embodiment, each unit may include a short-range radio transmission antenna molded or otherwise integrated into the casing of the unit. In another embodiment, each unit may include external spikes that are used not only to couple the unit to the earth, but also as a conductive conduit through which the unit's batteries can be recharged.

At least one and preferably a plurality of seismic acquisition units in the network are located in the proximity of the control station so that the network can utilize short-range radio frequency to transmit seismic data all the way back to the control station. In another embodiment of the invention, the control station is remotely located from the seismic units and one or more concentrators are located in the proximity of the seismic acquisition units of the network so that the network can utilize short-range radio frequency to transmit seismic data to the concentrators. The concentrators, in-turn, can store the seismic data and/or transmit it back as desired to a control station.

Such a concentrator may include a long range transmitter/receiver for communicating with a control station, a short range transmitter/receiver for communicating with the seismic acquisition unit network, mass memory for long-term storage of the collected seismic data from the network, a power source, a local clock and a processor. In one embodiment, the concentrators may communicate with the control station via telemetry cable, while communicating with the seismic acquisition network via short range transmission.

Within the transmission network, there are multiple transmission paths from the most remote unit to the control station/concentrator. The particular transmission path to be used for any given transmission will be determined based on the strength of the signal between communicating units, the operational status of a unit and path efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top view of a seismic acquisition array illustrating possible transmission paths between seismic acquisition unit strings in the array.

FIG. **2** is a top view of a seismic data transmission path utilizing seismic acquisition units.

FIG. **3** is an elevation view of a seismic acquisition unit of the invention.

FIG. **4** is a cut-away top view of the unit of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the detailed description of the invention, like numerals are employed to designate like parts throughout. Various items of equipment, such as fasteners, fittings, etc., may be omitted to simplify the description. However, those skilled in the art will realize that such conventional equipment can be employed as desired.

With reference to FIG. **1**, there is shown a seismic data transmission network **10** of the invention. Transmission network **10** is comprised of a plurality of seismic acquisition units **12** spread out in a seismic array **14** and controlled by control station **16**. Array **14** is formed of multiple lines **18** of acquisition units **12**. Radio transmissions, and in particular, seismic data, are passed from seismic unit **12** to seismic unit **12** as the transmission is bounced through the network **10** to control station **16**. In one embodiment of network **10**, concentrators **20** are disposed between array **14** and control station **16**. While the invention will be described in more detail with references to transmission of seismic data, those skilled in the art will understand that the invention encompasses any type of transmissions from a seismic unit, including, without limitation, quality control data.

Each acquisition unit **12** has an omnidirectional transmission range **22** and can form a wireless link **23** with multiple acquisition units **12**. As shown, within the transmission range **22** of a unit **12**, there are multiple other units **12** capable of receiving the transmission, in essence forming a local area network comprised of acquisition units **12**. For example, unit **12*a*** has an omnidirectional transmission range **22*a***. Falling within the transmission range **22*a*** of unit **12*a*** are seismic acquisition units **12*b*–12*g***. With the flexibility to transmit to multiple acquisition units **12** each having the ability to receive and transmit seismic data to multiple other units **12** within the array **14**, each unit **12** within array **14** is presented with multiple paths for communicating seismic data back to control station **16**. For example, unit **12'** can transmit data back to control station **16** by sending it along path **24**, along path **25** or along some other path as determined by the requirements of network **10**.

In another embodiment, a transmitting seismic unit **12** may utilize directional radio antenna or antenna array such that transmissions are substantially unidirectional and made only to one or more seismic acquisition units **12** in a limited direction. It is common in the art to utilize phased antenna arrays-an array consisting of two or more antenna's-to achieve transmission directionality and gain improvement. In these types of antenna arrangement, various adjustable antenna parameters, such as phase, can be altered to control directionality and gain, and hence, transmission range. Thus, for purposes of this description, "unidirectional" means a transmission with a higher gain along one axis or in a limited direction, whereas "omni-directional" means a transmission with generally the same gain in substantially 360°. This will maintain the flexibility to transmit to multiple units in the direction the transmitting antenna is pointed, while reducing the number of path options that need to be processed by the overall system, thereby multiple paths to be transmitted on the same frequency at the same time without interfering with one another. In addition, a higher gain in a single or limited direction can be achieved without the need for additional power, or alternatively, power requirements can be decreased, and thus battery life extended, while maintaining the same gain as an omnidirectional signal.

In the illustration of FIG. **1**, array **14** is shown as being comprised of three seismic acquisition unit strings **18***a*, **18***b*, and **18***c*. Each string **18***a*, **18***b*, and **18***c* illustrates a different potential transmission path defined by wireless links **23** between the units **12** within a string. Those skilled in the art will understand that the indicated wireless links **23** are for illustrative purposes only and, for purposes of the invention, a "string" **18** of seismic units **12** for a particular transmission path is defined by the selected transmission path by which data is communicated from one unit **12** to another. Thus, for any given array **14**, a "string" of units may be constantly changing between transmissions. Such an arrangement permits transmissions to be re-routed in the event of some failure of a unit **12** within the string. Likewise, transmissions can be re-routed in the event of a weak signal between units **12** or to overcome topographic or other obstacles that could interfere with short range, line of site transmissions. Furthermore, in addition some failure of a unit, it may be desirable to reroute a transmission simply because of the operational status of a unit. For example, a unit with lower battery power may be utilized downstream at the end of a string and avoided as a transmission relay further upstream in order to conserve the unit's batteries, i.e., upstream relay units require more power to relay the transmission because of the cumulative size of the transmissions.

In the event multiple adjacent strings are desired, radio transmission parameter assignments may be made to minimize interference with other transmissions and permit reuse of the same transmission parameters. For example, string **18***a* may transmit data at a first set of radio transmission parameters while string **18***b* may transmit data at a second set of parameters. Since the transmissions from a sting **18** are short range, it may only be necessary for adjacent strings to utilize different transmission parameters. In this regard, the physical seismic unit layout of a portion of array **14** defined as a string **18** maybe dependent on the short range transmission capabilities of the seismic units **12** in the adjacent string. Non-adjacent strings utilizing the same string are sufficiently spaced apart so as not to interfered with one another. In other words, string **18***b* is defined such that its width is sufficient to ensure that any transmission from a seismic unit **12** from string **18***a* transmitting with a certain set of radio transmission parameters will not be received by any seismic unit **12** from string **18***c* set to receive transmissions using the same set of radio transmission parameters. Those skilled in the art will understand that there are many transmission parameters that can be adjusted in this regard, including the non limiting examples of frequencies, time slots, power, methods of modulation, directional antenna gain, physical spacing of units and strings, etc. Of course, interference between adjacent strings, as well as individual units, may also be minimized by making transmissions in discreet data packages sent in short transmission bursts.

Furthermore, while three strings **18** are depicted to indicate possible transmission paths, system **10** can comprise any number of strings. The number of strings for any given group of transmissions is dependent on the system requirements. For example, rather than multiple strings, each acquisition unit **12** in an array **14** may be utilized in a single transmission path such that the entire array **14** might be considered a "sting" for purposes of the description. Those skilled in the art will understand that the number of transmission paths and the number of acquisition units utilized for any given transmission may constantly be in flux to maximize the operation requirements for a particular transmission or group of transmissions.

In each case, the transmitted signal strength of a seismic unit **12** can be altered to adjust the transmission range for a transmitting seismic unit such that number of potential receiving seismic acquisition units **12** can be controlled.

At least one and preferably a plurality of seismic acquisition units **12** in network **10** are proximately located to control station **16** so that network **10** can utilize short-range radio frequency to transmit seismic data to control station **16** from the seismic units **12**. However, large amounts of data transmitted to a control station may be difficult to manage and typically requires high power, long range transmitters. Thus, in one embodiment of the invention, data is accumulated and stored at multiple, dispersed concentrators **20** remote from control station **16**. By accumulating seismic data at concentrators **20**, the need for radio licenses and other requirements associated with long range transmissions may be avoided. Concentrators **20** are located in the proximity of the seismic acquisition units **12** of the network **10** so that the network **10** can utilize low power, short-range radio transmission to transmit seismic data to the concentrators **20**. The concentrators **20**, in-turn, can store the seismic data or transmit it back as desired to control station **16**. In one embodiment, concentrators locally store seismic data but transmit quality control data received from the acquisition units back to control station **16**.

Much like the individual acquisition units **12**, each concentrator **20** preferably also has a transmission range **26** that encompasses several seismic acquisition units **12**. As within the array **14**, transmission of data from a string **18** to the accumulator **20** may be made from a plurality of units **12**. For example, accumulator **20***a* has an omnidirectional transmission range **26***a*. Falling within the transmission range **26***a* of accumulator **20***a* are seismic acquisition units **12***h*–**12***j*. As such, any of acquisition units **12***h*–**12***j* may transmit seismic data from string **18***a* to accumulator **20***a*. Thus, a failure of one of the acquisition units, such as **12***h*, would not prevent seismic data from string **18***a* from being passed up the line. Rather, the transmission path from string **18***a* to concentrator **20***a* would simply be rerouted through an operative acquisition unit, such as units **12**i or **12**j.

Concentrators **20** may also be positioned so as to be within the short range transmission distance of adjacent concentrators.

As described above, network **10** can function as either a one-way network, i.e., concentrators **20** are utilized only to receive seismic data transmitted from array **14**, or a two-way network, i.e., concentrators **20** transmit command signals out to array **14** in addition to receiving seismic data transmitted from array **14**.

In another configuration, seismic data is transmitted back from array **14** utilizing the network of linked seismic acquisition units **12**, but control signals are transmitted directly to each acquisition unit **12** from either the control station **16** or an associated concentrator **20**.

In such case, an acquisition unit **12** may be capable of receiving long range transmissions directly from a distant source with sufficient transmission power for such communications, i.e., control station **16**, an associated concentrator **20** or radio repeater stations utilized to extend range, even though the acquisition unit **12** itself is only capable of short range hopped transmissions for sending seismic data back to the control station or concentrator. [**30**] Transmissions to control station **16** from accumulators **20** or acquisition units **12** may also include global positioning system ("GPS") or other survey information to establish the location of a particular unit **12** for purposes of the shot and for purposes of retrieval. This is particularly desirable for wireless units as described herein since it may be difficult to locate such units upon retrieval. GPS survey information may also be useful in selection of a transmission path within an array as described above.

In operation, a preferred transmission path may be preset in units **12** or predetermined. Likewise, alternate transmission paths may be preset in units **12** or predetermined. These preset paths, as well as the number of paths required for a particular array **14**, are determined based on the volume of the data to be transmitted, the data transmission rates, signal strength and the number of "real time" radio channels having different transmission parameters such that the radio transmission channels are non-interfering, battery power, location of the unit, etc.

Prior to a transmission or a set of transmissions along a string, a beacon signal may be utilized to verify the preferred transmission path in much the same way as an ad hoc network or peer to peer network identifies systems within the network. Alternatively, rather than transmitting data utilizing a preset or predetermined path, the beacon signal may be used to establish a transmission path utilizing the above described parameters. If a beacon signal is transmitted and the preferred transmission path is not available, system **10** will search for another transmission path through the seismic units. In one embodiment, the beacon signal is transmitted and the local units within range send a return signal acknowledging their receipt of the beacon signal. Once a path is verified or established, as the case may be, the path may be "locked in" for purposes of the particular transmission so that system **10** will not continue searching for another path. The beacon signal may be generated from within the array **14** by the seismic units themselves or initiated by the control station or concentrator.

A synchronization signal may also be used to synchronize the recording time for the units of system **10** by establishing a future time t(**0**) at which trace recording by seismic units **12** is to begin. In contrast, the prior art typically sends out a pulse signal that immediately triggers recording by each seismic unit at the time it receives the signal such that prior art seismic units located closer to the signal source begin recording earlier than seismic units more remote from the signal source. In a preferred embodiment of the invention, all seismic units **12** may be set to start recording at a specific clock time, such that data transmitted back through network **10** is time stamped based on the synchronization shot time. In this regard, all data is time synchronized regardless of the transmission path utilized by the network or the period of time the network takes to transmit the data through the network.

In this same vein, it is also desirable to ascertain the data delay along the path based on master clock time so that data that is not time stamped can be synchronized with the data from other seismic units. The described network **10** permits data to be retrieved via radio transmission in real time or near real time.

While the invention has been described in its broadest sense as possessing the flexability to alter data tranmission paths, i.e., each unit has wireless links with multiple other units, in order to convey acquired seismic data from an array of acquisition units back to a control station or concentrator, it is also true that none of the prior art transmission systems utilize seismic data acquisition units as intermediate transmission devices. Thus, one aspect of the invention as illustrated in FIG. **2** is the use of seismic data acquisition units **12** themselves, configured in a predetermined string, as intermediate devices for passing transmissions from a seismic unit in the string to a control station. In this regard, a string **40** of seismic units **42** is predetermined and defined by an outermost unit **42***a* and a plurality of intermediate units **42***b* through **42***i*. Each unit **42** in string **40** has a wireless link **44** within its transmission range **46** only with the units directly up and directly down the string. For example, sesimic unit **42***g* is only capable of communication with sesimic units **42***f* and **42***h* via their respective wireless links **44** because only units **42***f* and **42***h* are within the transmission range **46** of unit **42***g*. Upon acquisition of data, unit **42***g* will transmit the acquired data up the string to **42***h*, along with any data received by wireless transmission from **42***f*. All sesmic data from the units **12** comprising string **40** will be conveyed up the string to control station **16**. Control station **16** can likewise utilize the seismic units **12** to pass control and command signals back down the string.

As mentioned above, one benefit of the invention is the ability to utilize flexible transmission paths that can be readily changed based on various internal and external parameters effecting the network. This flexability also renders the network itself much more reliable. Preferably, transmission paths can be established and/or rerouted on-the-fly based on these parameters. Another advantage of the system is that it utilizes less power in transmitting a signal over a given distance via multiple short transmissions than would be required of a single tranmission over the same distance. In other words, because the power required to transmit a signal decreases as one over the square of the tranmission distance, it is much more optimal to transmit a signal in several short hops than it would be to transmit the same signal over the same distance in a single hop. This is true even of low power, short range transmissions. Of course an additional advantage of the system of the invention is that it avoids the need to acquire long range radio tranmission licenses. Finally, unlike the prior art, the system of the invention eliminates the need to physically locate a concentrator or similar device in the middle of a seismic array, nor utilize the concentrator to sort and organize multiple seismic data transmissions incoming directly from individual seismic acquisition units.

Turning to the individual seismic acquisition units as illustrated in FIGS. **3** and **4**, each unit **12** is preferably wireless and requires no external cabling for data transmission or unit control. Each unit **12** may contain a battery **30**, a short-range radio transmitter/receiver **31**, a local clock **32**, limited local memory **33**, and a processor **34** housed within a casing **35**. A geophone package **36** may be housed within the casing **35** or externally attached thereto. Any standard short range radio transmission equipment may be utilized. One non-limiting example being wireless fidelity ("Wi-Fi") equipment, where transmission parameters maybe selected to provide signal carrier modulation schemes such as complementary code keying (CCK)/packet binary convolution (PBCC) or direct sequence spread-spectrum (DSSS) or multi-carrier schemes such as orthogonal frequency division multiplexing (OFDM) and code division multiple access (CDMA). Local memory capacity is preferably limited since local seismic data is only retained for a short period of time. Further, because the unit **12** need only transmit a short range signal, power requirements for the unit are minimized in contrast to the increased power requirements necessary to transmit a stronger signal to a more distant receiving device. By reducing the memory requirements, the transmission requirements and the battery requirements, the overall cost, as well as the physical size and weight, of each unit is minimized.

While each unit may include an antenna, attached via an external connector, in one embodiment of the invention, each unit **12** may include a short-range radio transmission antenna **36** molded or otherwise integrated into the casing **35** of the unit. This eliminates the need for an external connector. Each unit **12** may also include radio frequency identification or similar identification indicia, such as a bar code. Finally, each unit **12** may include a receiver for receiving long range radio transmissions directly from a control station or concentrator as described above.

In another embodiment, each unit **12** may include external projections or spikes **37** that are used not only to couple the unit to the earth, but also as an electrically conductive conduit through which the unit's internal batteries **30** can be recharged. Such a configuration minimizes the need for external connectors which are known in the industry as a source of various problems such as corrosion, leakage, etc. or alternatively, the need to otherwise open the sealed unit. While any shape, length or number of projections or spikes may be utilized, one preferred configuration utilizes three spikes that can also be utilized to couple the unit to the earth. In a three spike configuration, two of the spikes are connected to the battery through a relay or similar mechanism. The third spike would be used to control the relay. During charging, the relay would be closed; after charging, the relay would be open to prevent battery discharge.

Concentrator **20** (not shown) may include a long range radio transmitter/receiver for communicating with a control station **16**, a short range radio transmitter/receiver for communicating with the network of seismic acquisition units **12**, a power source, a local clock and a processor. In one embodiment, concentrator **20** functions simply as an intermediate long range receiver/transmitter to relay short range transmissions from the network of seismic units **12** to the control station **16**. In another embodiment, concentrator **20** is provided with mass memory for storage of seismic data transmitted from the network of seismic units **12**. In either embodiment, concentrator **20** may relay control signals and other transmission from the control station **16** back to the network of seismic units **12**. In this same vein, concentrator

20 may be disposed to function as a local control station for a network of seismic units **12**. While the preferred embodiment utilizes radio frequency for transmissions between concentrator **20** and control station **16**, transmissions therebetween may also occur through various other transmission vehicles, such as telemetry cable or optic cable.

While certain features and embodiments of the invention have been described in detail herein, it will be readily understood that the invention encompasses all modifications and enhancements within the scope and spirit of the following claims.

What is claimed is:

1. A method for seismic data transmission comprising the steps of:

A. providing a plurality of seismic acquisition units, wherein each of said seismic acquisition units is capable of acquiring seismic data, receiving a short range radio transmission and transmitting a short range radio transmission;

B. utilizing a at least two of said seismic acquisition units to transmit seismic data via short range radio transmission to another seismic acquisition unit in the array;

C. utilizing a at least two of said seismic acquisition units to receive seismic data via short range radio transmission from another seismic acquisition unit in the array;

D. partitioning said plurality of seismic acquisition units into at least two sub-sets of seismic acquisition units; and

E. using a short range radio transmission technique having parameters set so that non-interfering radio transmission may be effected in each sub-set.

2. The method of claim **1**, further comprising the steps of partitioning said plurality of seismic acquisition units into a third sub-set, wherein the first and third sub-set of seismic acquisition units are spaced apart from one another by said second sub-set of seismic acquisition units.

3. The method of claim **2**, further comprising the step of assigning transmission parameters so the third sub-set of seismic acquisition units have the same short range radio transmission parameters as that assigned to the first sub-set.

4. The method of claim **1**, further comprising the step of utilizing a plurality of said seismic acquisition units within said first subset to transmit seismic data via short range radio transmission to other seismic acquisition units in the first subset while simultaneously utilizing a plurality of said seismic acquisition units within said second subset to transmit seismic data via short range radio transmission to other seismic acquisition units in the second subset, wherein each transmission is made utilizing the short range radio transmission parameters assigned to the respective subset.

5. The method of claim **1**, further comprising the step of utilizing a plurality of said seismic acquisition units within said first subset to transmit seismic data via short range radio transmission to other seismic acquisition units in the first subset while simultaneously utilizing a plurality of said seismic acquisition units within said second subset to transmit seismic data via short range radio transmission to other seismic acquisition units in the second subset while simultaneously utilizing a plurality of said seismic acquisition units within said third subset to transmit seismic data via short range radio transmission to other seismic acquisition units in the third subset, wherein each transmission is made utilizing the short range radio transmission parameters assigned to the respective subset.

6. The method of **3**, wherein each seismic acquisition unit has a radio transmission range and the seismic acquisition units within the first and third subsets are sufficiently spaced apart so as to fall outside the transmission range of any seismic acquisition unit within the respective subsets.

7. The method of **3**, wherein each seismic acquisition unit has a radio transmission range that can be adjusted by adjusting the transmission parameters so that the first and third sub-sets have transmission ranges that do not interfere with one another.

8. The method of claim **1** wherein each acquisition unit has a set of transmission parameters associated therewith and an adjustable transmission range, the method further comprising the step of adjusting the transmission range by adjusting the transmission parameters.

9. The method of claim **8**, wherein the transmission range is adjusted by adjusting the transmission power.

10. The method of claim **1**, wherein at least one seismic acquisition unit is capable of receiving short range radio transmissions from at least two other seismic acquisition units.

11. The method of claim **10**, wherein each seismic acquisition unit is capable of receiving short range radio transmissions from at least two other seismic acquisition units.

12. The method of claim **10**, wherein each seismic acquisition unit is capable of receiving short range radio transmissions from at least three other seismic acquisition units.

13. A method for seismic data transmission comprising the steps of:

A. providing at least three spaced apart seismic acquisition units deployed in an array, wherein each of said seismic acquisition units is capable of receiving a short range radio transmission and transmitting a short range radio transmission;

B. providing a receiving station for receiving a short range radio transmission from at least one seismic acquisition unit within said array;

C. subsequent to deployment, identifying at least two separate transmission paths from a seismic acquisition unit to the receiving station, wherein a transmission path is defined as a chain of at least two seismic acquisition units and the receiving station, each capable of communicating in series via short range radio transmission;

D. selecting a transmission path from the identified transmission paths based on a set of transmission path criteria; and

E. transmitting a signal along said selected transmission path.

14. The method of claim **13**, further comprising the step of transmitting a first signal along one transmission path and transmitting a second signal along the other transmission path.

15. The method of claim **13**, wherein each of said seismic acquisition units is capable of acquiring seismic data.

16. The method of claim **15**, further comprising the step of acquiring seismic data utilizing said seismic acquisition units.

17. The method of claim **16**, wherein the transmitted signal received by the receiving station includes seismic data acquired by at least one of said seismic acquisition units.

18. The method of claim **17**, wherein the transmitted signal received by the receiving station includes seismic data acquired by a plurality of said seismic acquisition units.

19. The method of claim **1**, wherein each seismic acquisition unit has a radio transmission range.

20. The method of claim **19**, wherein at least two seismic acquisition units fall within the radio transmission range of another seismic acquisition unit.

21. The method of claim **19**, wherein the radio transmission range of each seismic acquisition unit is omnidirectional.

22. The method of claim **19**, wherein the radio transmission range of at least one of the seismic acquisition units is omnidirectional.

23. The method of claim **19**, wherein the radio transmission range of at least one of the seismic acquisition units is unidirectional.

24. The method of claim **13**, wherein the transmission chain is comprised of a plurality of seismic acquisition units.

25. The method of claim **24**, wherein said transmission chain includes each seismic acquisition unit in the array.

26. The method of claim **19**, further comprising the step of adjusting the transmission range of a seismic acquisition unit so as to alter the number of other seismic acquisition units within radio transmission range of the adjusted seismic acquisition unit.

27. The method of claim **13**, wherein said receiving station is within short range radio range of at least two seismic acquisition units.

28. The method of claim **13**, wherein said receiving station is within short range radio range of at least three seismic acquisition units.

29. The method of claim **18**, wherein said receiving station transmits control signals to said seismic acquisition units and said control signal is transmitted over the same transmission chain utilized to transmit seismic data from seismic acquisition units to the receiving station.

30. The method of claim **18**, wherein said receiving station transmits control signals to said seismic acquisition units and said control signal is transmitted over a different transmission chain than that utilized to transmit seismic data from seismic acquisition units to the receiving station.

31. The method of claim **13**, wherein the transmissions from said seismic acquisition units to the receiving station are made utilizing different transmission chains.

32. The method of claim **13**, further comprising the step of utilizing a long range transmission to transmit control signals from said receiving station to said seismic acquisition units.

33. The method of claim **1**, further comprising the step of utilizing a long range transmission to transmit control signals from said control station to said seismic acquisition units.

34. The method of claim **1**, wherein a transmission from a seismic acquisition unit includes information identifying the position of the seismic acquisition unit.

35. The method of claim **1**,wherein a transmission from a seismic acquisition unit includes information identifying the identity of the seismic acquisition unit.

36. The method of claim **13**, wherein said transmission path is preset among the seismic acquisition units.

37. The method of claim **36**, wherein a second alternate transmission path is preset among the seismic acquisition units.

38. The method of claim **13**, wherein multiple transmission paths are identified.

39. The method of claim **38**, further comprising the step of selecting a transmission path among the multiple transmission paths prior to transmitting.

40. The method of claim **1**, further comprising the step of generating a beacon signal from at least one of said seismic acquisition units.

41. The method of claim **13**, further comprising the step of determining the number of other seismic acquisition units within transmission range of a seismic acquisition unit.

42. The method of claim **13**, further comprising the step of determining the signal strength for other seismic acquisition units within transmission range of seismic acquisition unit.

43. The method of claim **13**, further comprising the step of generating a beacon signal and transmitting the beacon signal along the transmission path.

44. The method of claim **43**, further comprising the step of verifying the transmission path by generating a beacon signal.

45. The method of claim **43**, further comprising the step of utilizing said beacon signal to establish a synchronized recording time among the seismic acquisition units.

46. The method of claim **43**, further comprising the step of simultaneously initiating recording of seismic data by said seismic acquisition units.

47. The method of claim **43**, wherein seismic data transmitted from a seismic acquisition unit is time stamped.

48. The method of claim **1**, wherein each acquisition unit has a set of antenna parameters associated therewith and an adjustable transmission range, the method further comprising the step of adjusting the transmission range by adjusting the transmission parameters.

49. The method of claim **1**, wherein each acquisition unit has a set of antenna parameters associated therewith and an adjustable transmission direction, the method further comprising the step of adjusting the transmission direction by adjusting the transmission parameters.

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US007983847B2

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

(10) **Patent No.: US 7,983,847 B2**
(45) **Date of Patent: *Jul. 19, 2011**

(54) **METHOD AND SYSTEM FOR THE TRANSMISSION OF SEISMIC DATA**

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(*) 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.

(21) Appl. No.: **11/438,168**

(22) Filed: **May 22, 2006**

(65) **Prior Publication Data**

US 2006/0212226 A1 Sep. 21, 2006

Related U.S. Application Data

(62) Division of application No. 10/719,800, filed on Nov. 21, 2003, now Pat. No. 7,124,028.

(51) **Int. Cl.**
G01V 1/00 (2006.01)

(52) **U.S. Cl.** **702/14**; 367/77

(58) **Field of Classification Search** 702/14, 702/15, 18, 1, 2, 5; 367/73, 76–77, 6, 21, 367/56, 58, 117; 324/323, 347–350; 455/437–438, 455/443, 445–448, 456.1–456.6

See application file for complete search history.

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Assistant Examiner — Toan M Le
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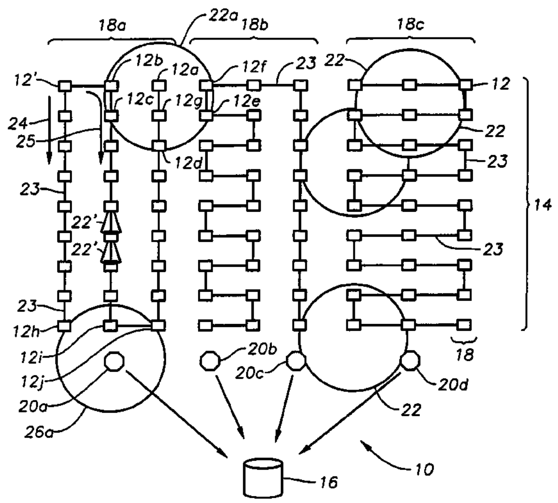
(57) **ABSTRACT**

The transmission method utilizes multiple seismic acquisition units within an array as intermediate short range radio receivers/transmitters to pass collected seismic data in relay fashion back to a control station. Any one seismic unit in the array is capable of transmitting radio signals to several other seismic units positioned within radio range of the transmitting unit, thus allowing the system to select an optimal transmission path. Utilizing an array of seismic units permits transmission routes back to a control station to be varied as needed. In transmissions from the most remote seismic unit to the control station, each unit within a string receives seismic data from other units and transmits the received seismic data along with the receiving unit's locally stored seismic data. Preferably, as a transmission is passed along a chain, it is bounced between seismic units so as to be relayed by each unit in the array.

18 Claims, 2 Drawing Sheets



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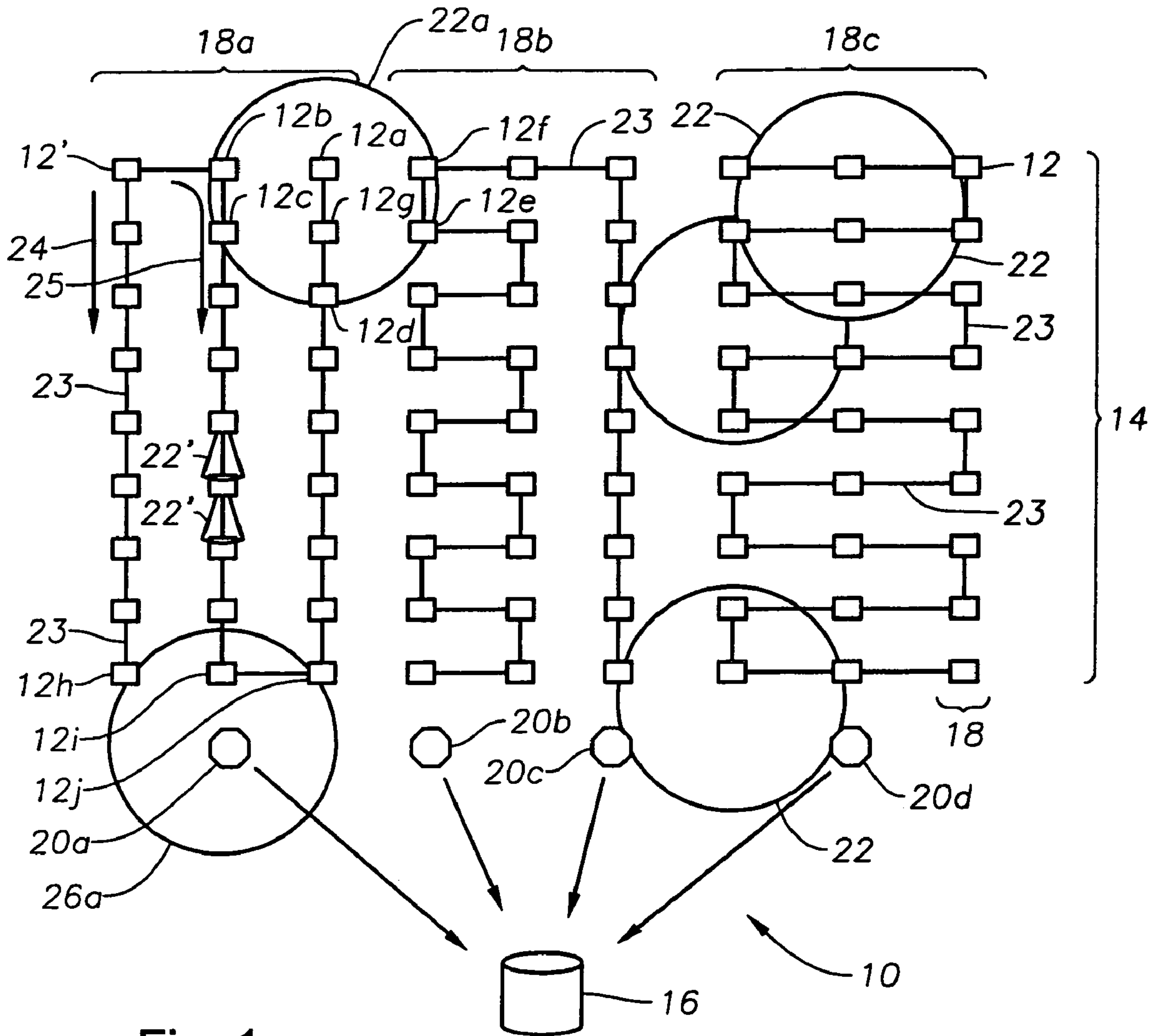
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18
12i
20b
12j
20c
20d
20a
22
26a
10
16

Fig. 1

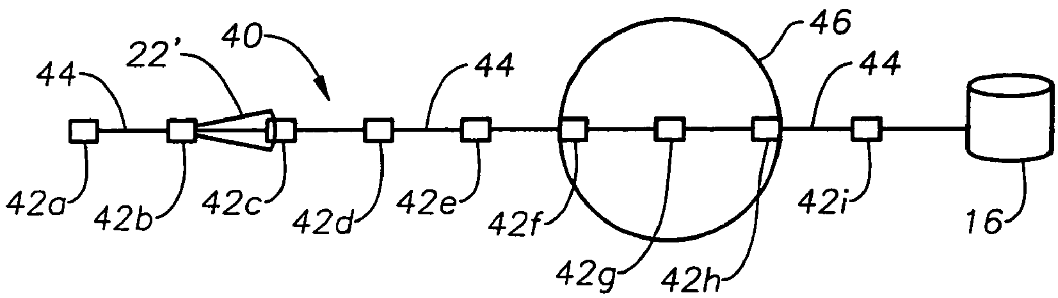
46
22'
40
44
44
44
44
42a
42b
42c
42d
42e
42f
42g
42h
42i
16

Fig. 2

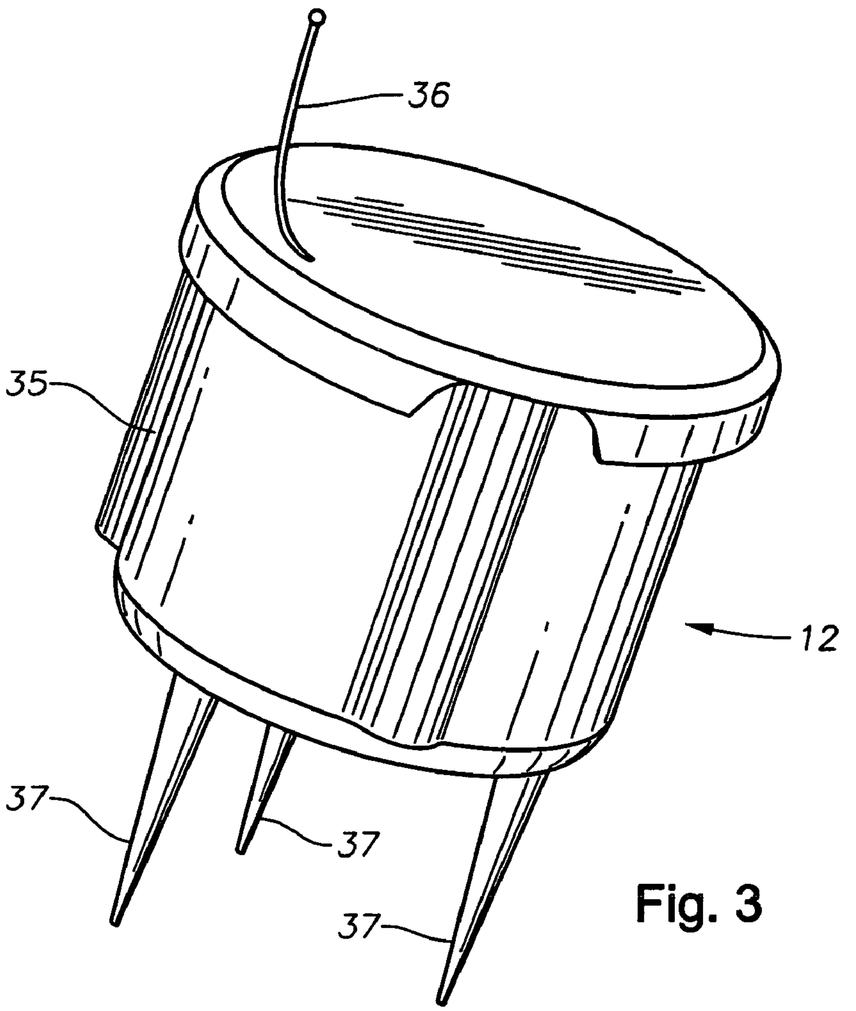

Fig. 3

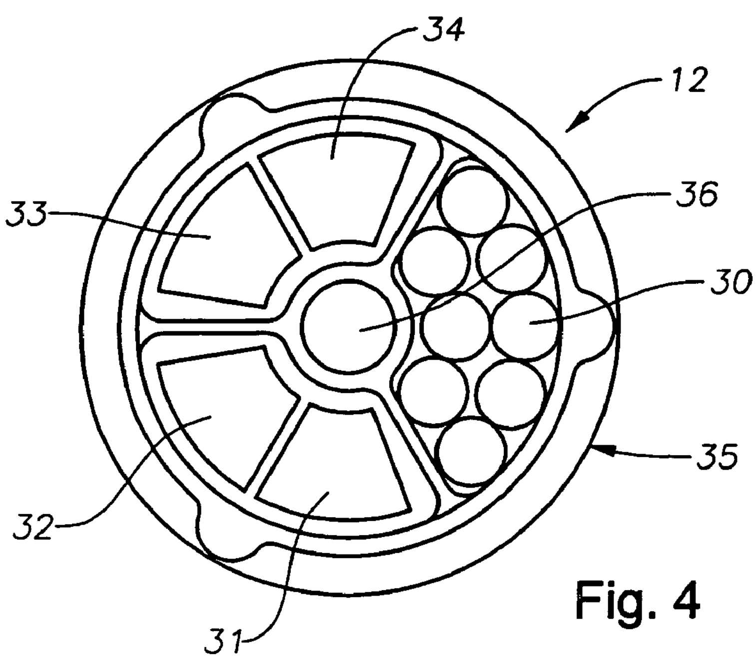

Fig. 4

METHOD AND SYSTEM FOR THE TRANSMISSION OF SEISMIC DATA

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of U.S. application Ser. No. 10/719,800 filed on Nov. 21, 2003, now U.S. Pat. No. 7,124,028 issued Oct. 17, 2006.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to seismic data acquisition, and more particularly to a method and system for transmitting data between multiple remote stations in an array and a data collection station utilizing a linked relay system to communicate therebetween permitting transmission paths to be altered.

2. Description of the Prior Art

Seismic exploration generally utilizes a seismic energy source to generate an acoustic signal that propagates into the earth and is partially reflected by subsurface seismic reflectors (i.e., interfaces between subsurface lithologic or fluid layers characterized by different elastic properties). The reflected signals are detected and recorded by seismic units having receivers or geophones located at or near the surface of the earth, thereby generating a seismic survey of the subsurface. The recorded signals, or seismic energy data, can then be processed to yield information relating to the lithologic subsurface formations, identifying such features, as, for example, lithologic subsurface formation boundaries.

Typically, the seismic units or stations are laid out in an array, wherein the array consists of a line of stations each having at least one geophone attached thereto in order to record data from the seismic cross-section below the array. For data over a larger area and for three-dimensional representations of a formation, multiple lines of stations may be set out side-by-side, such that a grid of receivers is formed. Often, the stations and their geophones are remotely located or spread apart. In land seismic surveys for example, hundreds to thousands of geophones may be deployed in a spatially diverse manner, such as a typical grid configuration where each line of stations extends for 5000 meters with stations spaced every 25 meters and the successive station lines are spaced 200 meters apart.

Various seismic data transmission systems are used to connect remote seismic acquisition units to a control station. Generally, the seismic stations are controlled from a central location that transmits control signals to the stations and collects seismic and other data back from the stations. Alternatively, the seismic stations may transmit data back to an intermediate data collection station such as a concentrator, where the data is recorded and stored until retrieved. Whichever the case, the various stations are most commonly hard wired to one another utilizing data telemetry cable. Other systems use wireless methods for control and data transmission so that the individual stations are not connected to each other. Still other systems temporarily store the data at each station until the data is extracted.

In the case of wired stations, typically several geophones are connected in a parallel-series combination on a single twisted pair of wires to form a single receiver group or channel for a station. During the data collection process, the output from each channel is digitized and recorded by the station for subsequent analysis. In turn, stations are usually connected to cables used to communicate with and transport the collected data to recorders located at either a control station or a concentrator station.

In the case of wireless seismic units, each unit communicates with either a central control station or concentrator via radio transmissions. Transmissions are made either directly between each seismic unit and the control station or directly between each seismic unit and the concentrator. To the extent the transmissions are high power, long-range signals, such as between a seismic acquisition unit and a central control station, the transmissions generally require a license from the local governing authority. Units capable of such transmissions also have higher power requirements and thus require larger battery packages. To the extent the seismic acquisition units transmit to a concentrator station utilizing a low power, short-range signal, the transmitting and receiving units must typically have a line of site therebetween.

Illustrative of the prior art is U.S. Pat. No. 6,070,129 which teaches a method and apparatus for transmitting seismic data to a remote collection station. Specifically, an acquisition unit having a geophone attached thereto communicates with a central station either directly by radio channels, or optionally, by means of an intermediate station. To the extent a large number of acquisition units are utilized, the patent teaches that each a plurality of intermediate stations may also be utilized, wherein each intermediate station directly communicates with a portion of the acquisition units. Intermediate stations may function as data concentrators and may also be utilized to control various tasks executed by their respective groups of acquisition units. Whether data is transmitted directly between an acquisition unit and the central station or directly between an acquisition unit and an intermediate station, the transmitting system accumulates seismic data, distributes the data over successive transmission windows and discontinuously transmits the data during successive transmissions in order to lessen variation in seismic data flow.

Similarly, U.S. Pat. No. 6,219,620 teaches a seismic data acquisition system using wireless telemetry, in which a large number of remote seismic acquisition units are grouped together into a plurality of cells and each acquisition unit within a cell communicates directly with a cell access node, i.e., a concentrator, which in turn communicates with a central control unit. This patent teaches that in order to avoid overlap between transmitting seismic units within adjacent cells, adjacent cells utilize different frequencies for communication between units and their respective cell access nodes. In other words, adjacent cells operate at different frequencies so that a particular acquisition unit is only capable of transmitting to the cell access node assigned to its cell.

One drawback to the aforementioned seismic transmission systems of the prior art is that the failure of any one intermediate transmission station or cell access node will prevent communication with a plurality of seismic acquisition units. Furthermore, to the extent an individual unit is prevented from transmitting back to its respective cell access node due to factors external to the unit, the participation and operation of that unit within the array is lost. For example, a unit may lose radio contact with an access point due to a weak signal, weather conditions, topography, interference from other electrical devices operating in the vicinity of the unit, disturbance of the unit's deployment position or the presence of a physical structure in the line of site between the unit and the access point.

Thus, it would be desirable to provide a communication system for a seismic survey array that has flexibility in transmitting signals and data to and from remote seismic units and a control and/or data collection station. The system should be capable of communication between functional seismic units even if one or more intermediate stations fail to operate properly. In addition, the system should be capable of communication between functional seismic units even if a change in environmental or physical conditions inhibits or prevents a direct transmission between a remote unit and its control station.

SUMMARY OF THE INVENTION

The method according to the invention transmits radio signals between individual seismic acquisition units in an array, such that the transmissions can be passed in a relay chain through the array of seismic units. Multiple seismic acquisition units within the array are capable of passing transmissions to multiple other seismic units. More specifically, any one seismic acquisition unit in the array is capable of transmitting radio signals to several other seismic acquisition units positioned within radio range of the transmitting seismic acquisition unit. A network of radio-linked seismic acquisition units such as this permits seismic data transmission routes back to a control station to be varied as desired or needed. In other words, the transmission path utilized to transmit data from the individual seismic acquisition units in an array back to a control station may be altered. In transmissions up the chain, i.e., from the most remote seismic acquisition unit to the control station, each unit receives seismic data from a seismic unit "down" the chain and transmits the received seismic data up the chain along with receiving unit's locally stored seismic data. Preferably, as a transmission moves up the chain, it is bounced between seismic acquisition units so as to be relayed by each unit in the array. The specific transmission path, i.e., the chain of units, for any given transmission may vary between transmissions depending on overall system requirements. Control signals and the like can be passed back down the chain along the same or a different transmission path.

The transmitted signal strength can be altered to adjust the transmission range for a transmitting seismic unit, such that number of potential receiving seismic acquisition units can be controlled. In one embodiment, each seismic acquisition unit is omni-directional in its transmission and is capable of linking to all units within a 360° range around the transmitting unit. Alternatively, a transmitting seismic unit may utilize a directional antenna such that transmissions are made only to one or more seismic acquisition units in a limited or single direction or more limited range of transmission.

Preferably the individual seismic acquisition units are wireless and require no external cabling for data transmission or unit control. Such units may contain a battery, a short-range radio transmitter/receiver, a local clock, limited local memory, a processor and a geophone package. In one embodiment, each unit may include a short-range radio transmission antenna molded or otherwise integrated into the casing of the unit. In another embodiment, each unit may include external spikes that are used not only to couple the unit to the earth, but also as a conductive conduit through which the unit's batteries can be recharged.

At least one and preferably a plurality of seismic acquisition units in the network are located in the proximity of the control station so that the network can utilize short-range radio frequency to transmit seismic data all the way back to the control station. In another embodiment of the invention, the control station is remotely located from the seismic units and one or more concentrators are located in the proximity of the seismic acquisition units of the network so that the network can utilize short-range radio frequency to transmit seismic data to the concentrators. The concentrators, in-turn, can store the seismic data and/or transmit it back as desired to a control station.

Such a concentrator may include a long range transmitter/receiver for communicating with a control station, a short range transmitter/receiver for communicating with the seismic acquisition unit network, mass memory for long-term storage of the collected seismic data from the network, a power source, a local clock and a processor. In one embodiment, the concentrators may communicate with the control station via telemetry cable, while communicating with the seismic acquisition network via short range transmission.

Within the transmission network, there are multiple transmission paths from the most remote unit to the control station/concentrator. The particular transmission path to be used for any given transmission will be determined based on the strength of the signal between communicating units, the operational status of a unit and path efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top view of a seismic acquisition array illustrating possible transmission paths between seismic acquisition unit strings in the array.

FIG. **2** is a top view of a seismic data transmission path utilizing seismic acquisition units.

FIG. **3** is an elevation view of a seismic acquisition unit of the invention.

FIG. **4** is a cut-away top view of the unit of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the detailed description of the invention, like numerals are employed to designate like parts throughout. Various items of equipment, such as fasteners, fittings, etc., may be omitted to simplify the description. However, those skilled in the art will realize that such conventional equipment can be employed as desired.

With reference to FIG. **1**, there is shown a seismic data transmission network **10** of the invention. Transmission network **10** is comprised of a plurality of seismic acquisition units **12** spread out in a seismic array **14** and controlled by control station **16**. Array **14** is formed of multiple lines **18** of acquisition units **12**. Radio transmissions, and in particular, seismic data, are passed from seismic unit **12** to seismic unit **12** as the transmission is bounced through the network **10** to control station **16**. In one embodiment of network **10**, concentrators **20** are disposed between array **14** and control station **16**. While the invention will be described in more detail with references to transmission of seismic data, those skilled in the art will understand that the invention encompasses any type of transmissions from a seismic unit, including, without limitation, quality control data.

Each acquisition unit **12** has an omnidirectional transmission range **22** and can form a wireless link **23** with multiple acquisition units **12**. As shown, within the transmission range **22** of a unit **12**, there are multiple other units **12** capable of receiving the transmission, in essence forming a local area network comprised of acquisition units **12**. For example, unit **12***a* has an omnidirectional transmission range **22***a*. Falling within the transmission range **22***a* of unit **12***a* are seismic acquisition units **12***b*-**12***g*. With the flexibility to transmit to multiple acquisition units **12** each having the ability to receive and transmit seismic data to multiple other units **12** within the array **14**, each unit **12** within array **14** is presented with multiple paths for communicating seismic data back to control station **16**. For example, unit **12'** can transmit data back to control station **16** by sending it along path **24**, along path **25** or along some other path as determined by the requirements of network **10**.

In another embodiment, a transmitting seismic unit **12** may utilize directional radio antenna or antenna array such that transmissions are substantially unidirectional and made only to one or more seismic acquisition units **12** in a limited direction. It is common in the art to utilize phased antenna arrays—an array consisting of two or more antenna's—to achieve transmission directionality and gain improvement. In these types of antenna arrangement, various adjustable antenna parameters, such as phase, can be altered to control directionality and gain, and hence, transmission range. Thus, for purposes of this description, "unidirectional" means a transmission with a higher gain along one axis or in a limited direction, whereas "omni-directional" means a transmission with generally the same gain in substantially 360°. This will maintain the flexibility to transmit to multiple units in the direction the transmitting antenna is pointed, while reducing the number of path options that need to be processed by the overall system, thereby multiple paths to be transmitted on the same frequency at the same time without interfering with one another. In addition, a higher gain in a single or limited direction can be achieved without the need for additional power, or alternatively, power requirements can be decreased, and thus battery life extended, while maintaining the same gain as an omnidirectional signal.

In the illustration of FIG. **1**, array **14** is shown as being comprised of three seismic acquisition unit strings **18***a*, **18***b*, and **18***c*. Each string **18***a*, **18***b*, and **18***c* illustrates a different potential transmission path defined by wireless links **23** between the units **12** within a string. Those skilled in the art will understand that the indicated wireless links **23** are for illustrative purposes only and, for purposes of the invention, a "string" **18** of seismic units **12** for a particular transmission path is defined by the selected transmission path by which data is communicated from one unit **12** to another. Thus, for any given array **14**, a "string" of units may be constantly changing between transmissions. Such an arrangement permits transmissions to be re-routed in the event of some failure of a unit **12** within the string. Likewise, transmissions can be re-routed in the event of a weak signal between units **12** or to overcome topographic or other obstacles that could interfere with short range, line of site transmissions. Furthermore, in addition some failure of a unit, it may be desirable to reroute a transmission simply because of the operational status of a unit. For example, a unit with lower battery power may be utilized downstream at the end of a string and avoided as a transmission relay further upstream in order to conserve the unit's batteries, i.e., upstream relay units require more power to relay the transmission because of the cumulative size of the transmissions.

In the event multiple adjacent strings are desired, radio transmission parameter assignments may be made to minimize interference with other transmissions and permit reuse of the same transmission parameters. For example, string **18***a* may transmit data at a first set of radio transmission parameters while string **18***b* may transmit data at a second set of parameters. Since the transmissions from a sting **18** are short range, it may only be necessary for adjacent strings to utilize different transmission parameters. In this regard, the physical seismic unit layout of a portion of array **14** defined as a string **18** may be dependent on the short range transmission capabilities of the seismic units **12** in the adjacent string. Non-adjacent strings utilizing the same string are sufficiently spaced apart so as not to interfered with one another. In other

words, string **18***b* is defined such that its width is sufficient to ensure that any transmission from a seismic unit **12** from string **18***a* transmitting with a certain set of radio transmission parameters will not be received by any seismic unit **12** from string **18***c* set to receive transmissions using the same set of radio transmission parameters. Those skilled in the art will understand that there are many transmission parameters that can be adjusted in this regard, including the non limiting examples of frequencies, time slots, power, methods of modulation, directional antenna gain, physical spacing of units and strings, etc. Of course, interference between adjacent strings, as well as individual units, may also be minimized by making transmissions in discreet data packages sent in short transmission bursts.

Furthermore, while three strings **18** are depicted to indicate possible transmission paths, system **10** can comprise any number of strings. The number of strings for any given group of transmissions is dependent on the system requirements. For example, rather than multiple strings, each acquisition unit **12** in an array **14** may be utilized in a single transmission path such that the entire array **14** might be considered a "sting" for purposes of the description. Those skilled in the art will understand that the number of transmission paths and the number of acquisition units utilized for any given transmission may constantly be in flux to maximize the operation requirements for a particular transmission or group of transmissions.

In each case, the transmitted signal strength of a seismic unit **12** can be altered to adjust the transmission range for a transmitting seismic unit such that number of potential receiving seismic acquisition units **12** can be controlled.

At least one and preferably a plurality of seismic acquisition units **12** in network **10** are proximately located to control station **16** so that network **10** can utilize short-range radio frequency to transmit seismic data to control station **16** from the seismic units **12**. However, large amounts of data transmitted to a control station may be difficult to manage and typically requires high power, long range transmitters. Thus, in one embodiment of the invention, data is accumulated and stored at multiple, dispersed concentrators **20** remote from control station **16**. By accumulating seismic data at concentrators **20**, the need for radio licenses and other requirements associated with long range transmissions may be avoided. Concentrators **20** are located in the proximity of the seismic acquisition units **12** of the network **10** so that the network **10** can utilize low power, short-range radio transmission to transmit seismic data to the concentrators **20**. The concentrators **20**, in-turn, can store the seismic data or transmit it back as desired to control station **16**. In one embodiment, concentrators locally store seismic data but transmit quality control data received from the acquisition units back to control station **16**.

Much like the individual acquisition units **12**, each concentrator **20** preferably also has a transmission range **26** that encompasses several seismic acquisition units **12**. As within the array **14**, transmission of data from a string **18** to the accumulator **20** may be made from a plurality of units **12**. For example, accumulator **20***a* has an omnidirectional transmission range **26***a*. Falling within the transmission range **26***a* of accumulator **20***a* are seismic acquisition units **12***h*-**12***j*. As such, any of acquisition units **12***h*-**12***j* may transmit seismic data from string **18***a* to accumulator **20***a*. Thus, a failure of one of the acquisition units, such as **12***h*, would not prevent seismic data from string **18***a* from being passed up the line. Rather, the transmission path from string **18***a* to concentrator **20***a* would simply be rerouted through an operative acquisition unit, such as units **12***i* or **12***j*. Concentrators **20** may also be positioned so as to be within the short range transmission distance of adjacent concentrators.

As described above, network **10** can function as either a one-way network, i.e., concentrators **20** are utilized only to receive seismic data transmitted from array **14**, or a two-way network, i.e., concentrators **20** transmit command signals out to array **14** in addition to receiving seismic data transmitted from array **14**.

In another configuration, seismic data is transmitted back from array **14** utilizing the network of linked seismic acquisition units **12**, but control signals are transmitted directly to each acquisition unit **12** from either the control station **16** or an associated concentrator **20**. In such case, an acquisition unit **12** may be capable of receiving long range transmissions directly from a distant source with sufficient transmission power for such communications, i.e., control station **16**, an associated concentrator **20** or radio repeater stations utilized to extend range, even though the acquisition unit **12** itself is only capable of short range hopped transmissions for sending seismic data back to the control station or concentrator.

Transmissions to control station **16** from accumulators **20** or acquisition units **12** may also include global positioning system ("GPS") or other survey information to establish the location of a particular unit **12** for purposes of the shot and for purposes of retrieval. This is particularly desirable for wireless units as described herein since it may be difficult to locate such units upon retrieval. GPS survey information may also be useful in selection of a transmission path within an array as described above.

In operation, a preferred transmission path may be preset in units **12** or predetermined. Likewise, alternate transmission paths may be preset in units **12** or predetermined. These preset paths, as well as the number of paths required for a particular array **14**, are determined based on the volume of the data to be transmitted, the data transmission rates, signal strength and the number of "real time" radio channels having different transmission parameters such that the radio transmission channels are non-interfering, battery power, location of the unit, etc.

Prior to a transmission or a set of transmissions along a string, a beacon signal may be utilized to verify the preferred transmission path in much the same way as an ad hoc network or peer to peer network identifies systems within the network. Alternatively, rather than transmitting data utilizing a preset or predetermined path, the beacon signal may be used to establish a transmission path utilizing the above described parameters. If a beacon signal is transmitted and the preferred transmission path is not available, system **10** will search for another transmission path through the seismic units. In one embodiment, the beacon signal is transmitted and the local units within range send a return signal acknowledging their receipt of the beacon signal. Once a path is verified or established, as the case may be, the path may be "locked in" for purposes of the particular transmission so that system **10** will not continue searching for another path. The beacon signal may be generated from within the array **14** by the seismic units themselves or initiated by the control station or concentrator.

A synchronization signal may also be used to synchronize the recording time for the units of system **10** by establishing a future time t(**0**) at which trace recording by seismic units **12** is to begin. In contrast, the prior art typically sends out a pulse signal that immediately triggers recording by each seismic unit at the time it receives the signal such that prior art seismic units located closer to the signal source begin recording earlier than seismic units more remote from the signal source. In a preferred embodiment of the invention, all seismic units **12** may be set to start recording at a specific clock time, such that data transmitted back through network **10** is time stamped based on the synchronization shot time. In this regard, all data is time synchronized regardless of the transmission path utilized by the network or the period of time the network takes to transmit the data through the network.

In this same vein, it is also desirable to ascertain the data delay along the path based on master clock time so that data that is not time stamped can be synchronized with the data from other seismic units. The described network **10** permits data to be retrieved via radio transmission in real time or near real time.

While the invention has been described in its broadest sense as possessing the flexability to alter data tranmission paths, i.e., each unit has wireless links with multiple other units, in order to convey acquired seismic data from an array of acquisition units back to a control station or concentrator, it is also true that none of the prior art transmission systems utilize seismic data acquisition units as intermediate transmission devices. Thus, one aspect of the invention as illustrated in FIG. **2** is the use of seismic data acquisition units **12** themselves, configured in a predetermined string, as intermediate devices for passing transmissions from a seismic unit in the string to a control station. In this regard, a string **40** of seismic units **42** is predetermined and defined by an outermost unit **42*a*** and a plurality of intermediate units **42*b*** through **42*i***. Each unit **42** in string **40** has a wireless link **44** within its transmission range **46** only with the units directly up and directly down the string. For example, sesimic unit **42*g*** is only capable of communication with sesimic units **42*f*** and **42*h*** via their respective wireless links **44** because only units **42*f*** and **42*h*** are within the transmission range **46** of unit **42*g***. Upon acquisition of data, unit **42*g*** will transmit the acquired data up the string to **42*h***, along with any data received by wireless transmission from **42*f***. All sesmic data from the units **12** comprising string **40** will be conveyed up the string to control station **16**. Control station **16** can likewise utilize the seismic units **12** to pass control and command signals back down the string.

As mentioned above, one benefit of the invention is the ability to utilize flexible transmission paths that can be readily changed based on various internal and external parameters effecting the network. This flexability also renders the network itself much more reliable. Preferably, transmission paths can be established and/or rerouted on-the-fly based on these parameters. Another advantage of the system is that it utilizes less power in tranmitting a signal over a given distance via multiple short transmissions than would be required of a single tranmission over the same distance. In other words, because the power required to transmitt a signal decreases as one over the square of the tranmission distance, it is much more optimal to tranmit a signal in several short hops than it would be to tranmit the same signal over the same distance in a single hop. This is true even of low power, short range transmissions. Of course an additional avantage of the system of the invention is that it avoids the need to acquire long range radio tranmission licenses. Finally, unlike the prior art, the system of the invention eliminates the need to physically locate a concentrator or similar device in the middle of a seismic array, nor utilize the concentrator to sort and organize multiple seismic data transmissions incoming directly from individual seismic acquisition units.

Turning to the individual seismic acquisition units as illustrated in FIGS. **3** and **4**, each unit **12** is preferably wireless and requires no external cabling for data transmission or unit control. Each unit **12** may contain a battery **30**, a short-range radio transmitter/receiver **31**, a local clock **32**, limited local memory **33**, and a processor **34** housed within a casing **35**. A geophone package **36** may be housed within the casing **35** or externally attached thereto. Any standard short range radio transmission equipment may be utilized. One non-limiting example being wireless fidelity ("Wi-Fi") equipment, where transmission parameters may be selected to provide signal carrier modulation schemes such as complementary code keying (CCK)/packet binary convolution (PBCC) or direct sequence spread-spectrum (DSSS) or multi-carrier schemes such as orthogonal frequency division multiplexing (OFDM) and code division multiple access (CDMA). Local memory capacity is preferably limited since local seismic data is only retained for a short period of time. Further, because the unit **12** need only transmit a short range signal, power requirements for the unit are minimized in contrast to the increased power requirements necessary to transmit a stronger signal to a more distant receiving device. By reducing the memory requirements, the transmission requirements and the battery requirements, the overall cost, as well as the physical size and weight, of each unit is minimized.

While each unit may include an antenna, attached via an external connector, in one embodiment of the invention, each unit **12** may include a short-range radio transmission antenna **36** molded or otherwise integrated into the casing **35** of the unit. This eliminates the need for an external connector. Each unit **12** may also include radio frequency identification or similar identification indicia, such as a bar code. Finally, each unit **12** may include a receiver for receiving long range radio transmissions directly from a control station or concentrator as described above.

In another embodiment, each unit **12** may include external projections or spikes **37** that are used not only to couple the unit to the earth, but also as an electrically conductive conduit through which the unit's internal batteries **30** can be recharged. Such a configuration minimizes the need for external connectors which are known in the industry as a source of various problems such as corrosion, leakage, etc. or alternatively, the need to otherwise open the sealed unit. While any shape, length or number of projections or spikes may be utilized, one preferred configuration utilizes three spikes that can also be utilized to couple the unit to the earth. In a three spike configuration, two of the spikes are connected to the battery through a relay or similar mechanism. The third spike would be used to control the relay. During charging, the relay would be closed; after charging, the relay would be open to prevent battery discharge.

Concentrator **20** (not shown) may include a long range radio transmitter/receiver for communicating with a control station **16**, a short range radio transmitter/receiver for communicating with the network of seismic acquisition units **12**, a power source, a local clock and a processor. In one embodiment, concentrator **20** functions simply as an intermediate long range receiver/transmitter to relay short range transmissions from the network of seismic units **12** to the control station **16**. In another embodiment, concentrator **20** is provided with mass memory for storage of seismic data transmitted from the network of seismic units **12**. In either embodiment, concentrator **20** may relay control signals and other transmission from the control station **16** back to the network of seismic units **12**. In this same vein, concentrator **20** may be disposed to function as a local control station for a network of seismic units **12**. While the preferred embodiment utilizes radio frequency for transmissions between concentrator **20** and control station **16**, transmissions therebetween may also occur through various other transmission vehicles, such as telemetry cable or optic cable.

While certain features and embodiments of the invention have been described in detail herein, it will be readily understood that the invention encompasses all modifications and enhancements within the scope and spirit of the following claims.

The invention claimed is:

1. A seismic data transmission system comprising:

A. at least three wireless seismic data acquisition units, each unit comprising:
(1) a casing;
(2) a battery;
(3) a short-range radio transmitter disposed within said casing;
(4) a short-range radio receiver disposed within said casing;
(5) a local clock disposed within said casing;
(6) local memory disposed within said casing;
(7) a processor disposed within said casing; and
(8) a geophone;
wherein the elements A(2)-A(8) cooperate to collect seismic data and transmit seismic data; and

B. a receiving unit comprising:
(1) a power source; and
(2) a short-range radio receiver;

C. wherein the short-range radio transmitter and receiver of each wireless seismic data acquisition unit are configured for short-range radio transmission and reception communication with at least two other wireless seismic data acquisition units;

D. wherein said seismic data acquisition units are physically arranged in an array so that each seismic data acquisition unit is adjacent to at least two other seismic data acquisition units and is capable of short-range radio transmission and reception communication with the at least two other seismic data acquisition units; and

E. wherein said receiving unit is disposed adjacent said array so that the receiving unit is adjacent to at least another seismic data acquisition unit and the short-range radio receiver of the receiving unit is configured for short-range radio reception communication with said another seismic data acquisition unit.

2. The system of claim **1**, wherein said receiving unit further comprises mass memory media.

3. The system of claim **1**, wherein said receiving unit further comprises a long-range radio transmitter.

4. The transmission system of claim **1** wherein each seismic acquisition unit further comprises an antenna.

5. The transmission system of claim **1**, wherein said antenna is molded into the casing.

6. The transmission system of claim **1** wherein each seismic acquisition unit further comprises a long range radio receiver.

7. A seismic data transmission system comprising:

A. at least three wireless seismic data acquisition units, each unit comprising:
(1) a casing;
(2) a battery;
(3) a wireless fidelity transmitter disposed within said casing;
(4) a wireless fidelity receiver disposed within said casing;
(5) a local clock disposed within said casing;
(6) local memory disposed within said casing;
(7) a processor disposed within said casing; and
(8) a geophone;
wherein the elements A(2)-A(8) cooperate to collect seismic data and transmit seismic data; and

B. a receiving unit comprising:
(1) a power source; and
(2) a wireless fidelity receiver;
C. wherein said wireless seismic data acquisition units are disposed in an array and the wireless fidelity receiver and transmitter of each seismic data acquisition unit is configured for short-range radio transmission and reception communication with at least two other adjacent seismic data acquisition units in the array; and
D. wherein said receiving unit is disposed adjacent the array and the wireless fidelity receiver of the receiving unit is configured for short-range radio reception communication with another adjacent seismic data acquisition unit.

8. A seismic data transmission system comprising:
A. at least ten wireless seismic data acquisition units, each unit comprising:
(1) a short-range radio transmitter;
(2) a short-range radio receiver; and
(3) a geophone;
wherein the elements A(1)-A(3) cooperate to collect seismic data and transmit seismic data; and
B. a receiving unit comprising:
(1) a short-range radio receiver;
C. wherein said wireless seismic data acquisition units are disposed in an array and the short-range radio transmitter and receiver of each wireless seismic data acquisition unit are configured so that a plurality of individual seismic data acquisition units are in short-range radio transmission and reception communication with at least two other individual seismic data acquisition units adjacent thereto so as to form at least two short-range radio transmission paths between adjacent seismic data acquisition units emanating from a plurality of individual units; and
D. wherein said short-range radio receiver of said receiving unit is configured to be capable of short-range radio transmission contact with at least two seismic data acquisition units; and
E. wherein said receiving unit is disposed adjacent said array so that said receiving unit is capable of short-range radio reception communication with said two seismic data acquisition units.

9. The seismic data transmission system of claim **8**, wherein said receiving unit further comprises a long-range radio transmitter.

10. The seismic data transmission system of claim **8**, wherein said receiving unit is within short-range radio transmission contact with at least three seismic data acquisition units.

11. The seismic data transmission system of claim **8**, wherein a plurality of seismic data acquisition units are within short-range radio transmission contact with at least three seismic data acquisition units.

12. The seismic data transmission system of claim **8**, further comprising at least two different array transmission paths through said array, wherein each array transmission path is comprised of a plurality of short range radio transmission paths.

13. A seismic data transmission system comprising:
A. at least four wireless seismic data acquisition units disposed in an array, each unit comprising:
(1) a short-range radio transmitter;
(2) a short-range radio receiver; and
(3) a geophone;
wherein the elements A(1)-A(3) cooperate to collect seismic data and transmit seismic data; and
B. a receiving unit comprising:
(1) a power source; and
(2) a short-range radio receiver;
C. wherein the short-range radio transmitter and receiver of at least two wireless seismic data acquisition units are configured to have a first set of transmission path parameters;
D. wherein the short-range radio transmitter and receiver of at least two wireless seismic data acquisition units are configured to have a second set of transmission path parameters, wherein said first and second sets of transmission path parameters are different; and
E. wherein said wireless seismic data acquisition units are disposed in an array so that each of said wireless seismic data acquisition units configured to have a first set of transmission path parameters is capable of short-range radio transmission and reception communication with at least two other adjacent seismic data acquisition units configured to have a first set of transmission path parameters; and
F. wherein said receiving unit is disposed adjacent said array and the short-range radio receiver thereof is configured to have at least one set of transmission path parameters so that said receiving unit is capable of short-range radio reception communication with at least two adjacent seismic data acquisition units in the array.

14. The seismic data transmission system of claim **13**, wherein said first set of transmission path parameters is a first frequency and said second set of transmission path parameters is a second frequency.

15. The seismic data transmission system of claim **13**, wherein said first set of transmission path parameters is a first channel and said second set of transmission path parameters is a second channel.

16. The seismic data transmission system of claim **13**, further comprising a control station in communication with said receiving unit.

17. The seismic data transmission system of claim **16**, wherein said control station and said receiving unit are interconnected utilizing a cable.

18. The seismic data transmission system of claim **16**, wherein said receiving unit further comprises a long range transmitter capable of communicating with the control station.

* * * * *

US008296068B2

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

(10) **Patent No.: US 8,296,068 B2**
(45) **Date of Patent: *Oct. 23, 2012**

(54) **METHOD FOR TRANSMISSION OF SEISMIC DATA**

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(*) 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.

(21) Appl. No.: **13/035,665**

(22) Filed: **Feb. 25, 2011**

(65) **Prior Publication Data**

US 2011/0149686 A1 Jun. 23, 2011

Related U.S. Application Data

(60) Continuation of application No. 11/438,168, filed on May 22, 2006, now Pat. No. 7,983,847, which is a division of application No. 10/719,800, filed on Nov. 21, 2003, now Pat. No. 7,124,028.

(51) **Int. Cl.**
G01V 1/00 (2006.01)

(52) **U.S. Cl.** **702/14**; 367/77

(58) **Field of Classification Search** 702/14, 702/1–2, 5, 15–16, 75, 81, 84, 103, 106, 702/127, 188–189; 367/6, 14, 21, 37, 49, 367/56, 58, 73, 76–77, 80, 117; 324/323, 324/347–350; 455/437–438, 443, 445–448, 455/456.1–456.6

See application file for complete search history.

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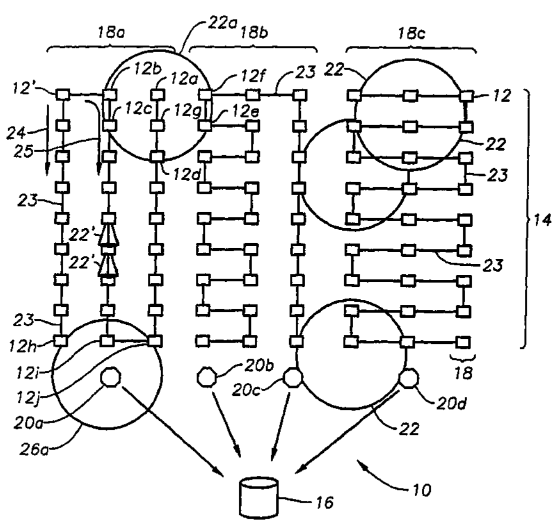
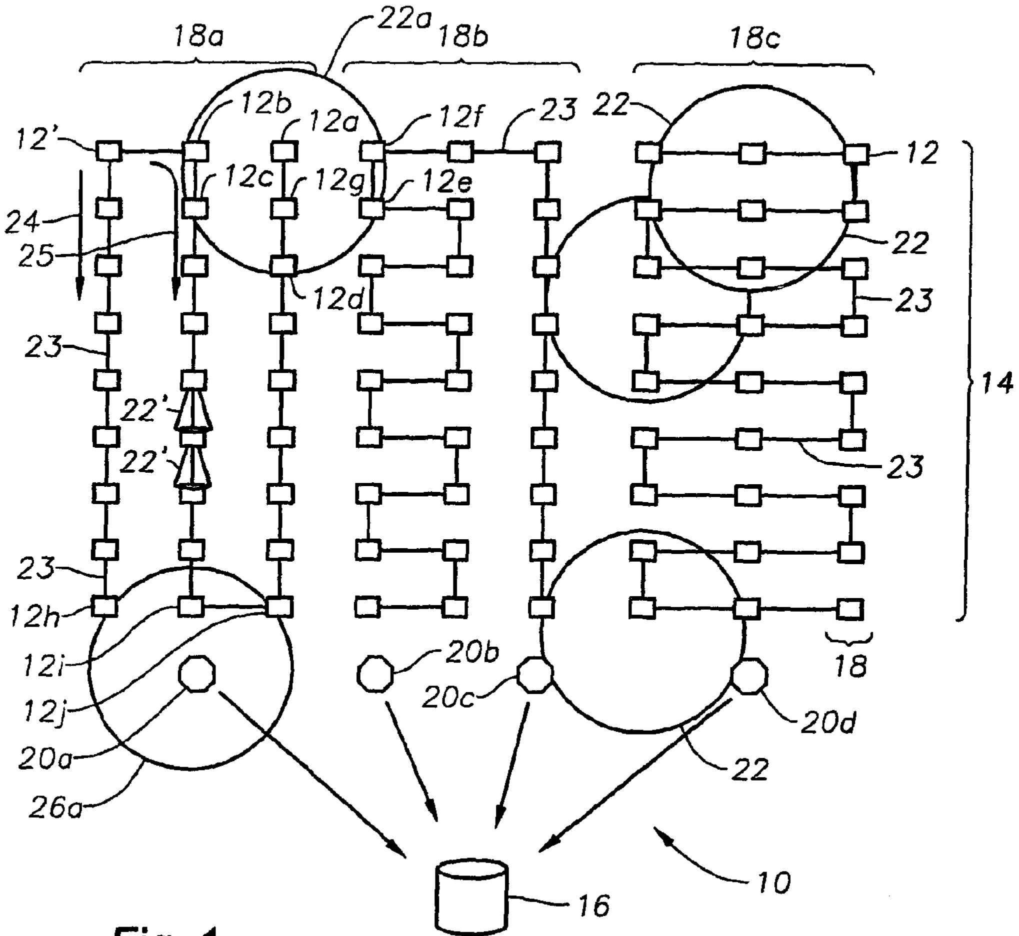
(57) **ABSTRACT**

The transmission method utilizes multiple seismic acquisition units within an array as intermediate short range radio receivers/transmitters to pass collected seismic data in relay fashion back to a control station. Any one seismic unit in the array is capable of transmitting radio signals to several other seismic units positioned within radio range of the transmitting unit, thus allowing the system to select an optimal transmission path. Utilizing an array of seismic units permits transmission routes back to a control station to be varied as needed. In transmissions from the most remote seismic unit to the control station, each unit within a string receives seismic data from other units and transmits the received seismic data along with the receiving unit's locally stored seismic data. Preferably, as a transmission is passed along a chain, it is bounced between seismic units so as to be relayed by each unit in the array.

16 Claims, 2 Drawing Sheets

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18b
18c
12'
12b
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12f
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12d
23
23
14
22'
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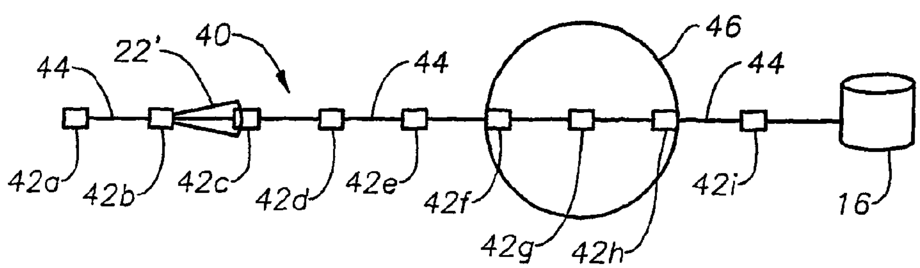
22
10
16

Fig. 1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22'
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42d
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42g
42h
42i
16

Fig. 2

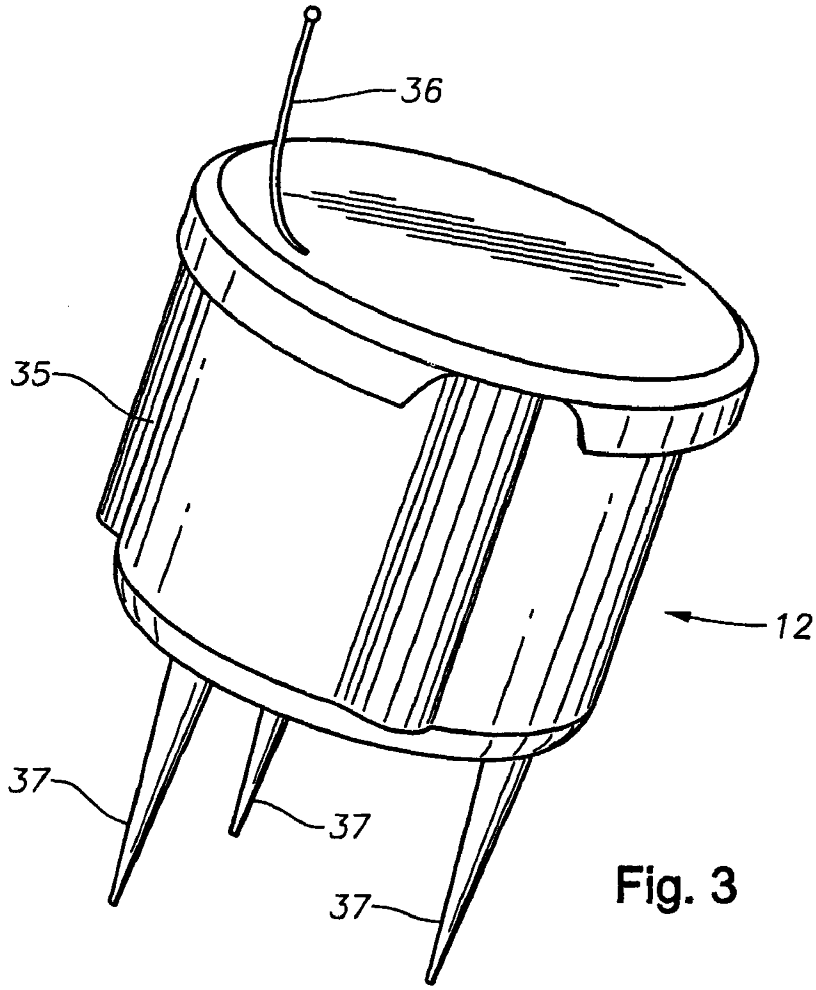

Fig. 3

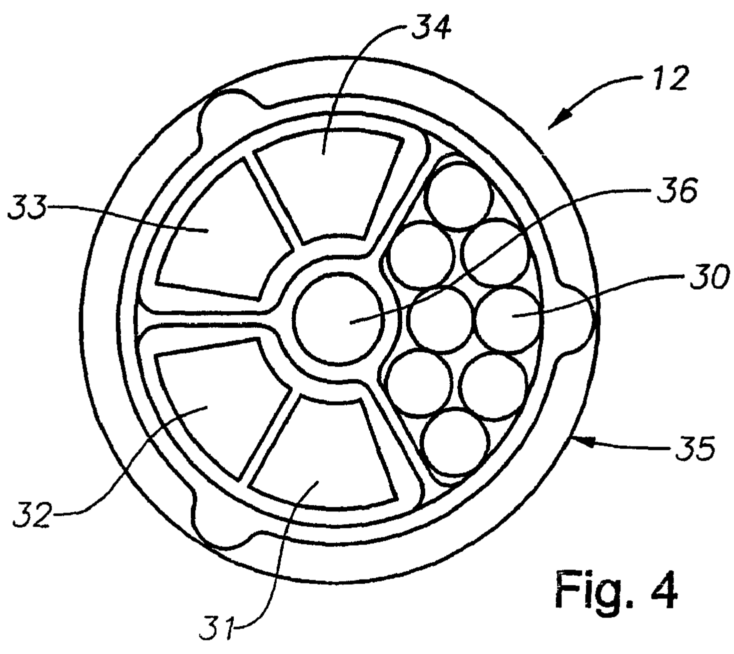

Fig. 4

METHOD FOR TRANSMISSION OF SEISMIC DATA

The present application is a continuation of patent application Ser. No. 11/438,168 filed on May 22, 2006, now U.S. Pat. No. 7,983,847, which is divisional application of, and claims priority to, U.S. patent application Ser. No. 10/719,800, filed on Nov. 21, 2003, now issued as U.S. Pat. No. 7,124,028.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to seismic data acquisition, and more particularly to a method and system for transmitting data between multiple remote stations in an array and a data collection station utilizing a linked relay system to communicate therebetween permitting transmission paths to be altered.

2. Description of the Prior Art

Seismic exploration generally utilizes a seismic energy source to generate an acoustic signal that propagates into the earth and is partially reflected by subsurface seismic reflectors (i.e., interfaces between subsurface lithologic or fluid layers characterized by different elastic properties). The reflected signals are detected and recorded by seismic units having receivers or geophones located at or near the surface of the earth, thereby generating a seismic survey of the subsurface. The recorded signals, or seismic energy data, can then be processed to yield information relating to the lithologic subsurface formations, identifying such features, as, for example, lithologic subsurface formation boundaries.

Typically, the seismic units or stations are laid out in an array, wherein the array consists of a line of stations each having at least one geophone attached thereto in order to record data from the seismic cross-section below the array. For data over a larger area and for three-dimensional representations of a formation, multiple lines of stations may be set out side-by-side, such that a grid of receivers is formed. Often, the stations and their geophones are remotely located or spread apart. In land seismic surveys for example, hundreds to thousands of geophones may be deployed in a spatially diverse manner, such as a typical grid configuration where each line of stations extends for 5000 meters with stations spaced every 25 meters and the successive station lines are spaced 200 meters apart.

Various seismic data transmission systems are used to connect remote seismic acquisition units to a control station. Generally, the seismic stations are controlled from a central location that transmits control signals to the stations and collects seismic and other data back from the stations. Alternatively, the seismic stations may transmit data back to an intermediate data collection station such as a concentrator, where the data is recorded and stored until retrieved. Whichever the case, the various stations are most commonly hard wired to one another utilizing data telemetry cable. Other systems use wireless methods for control and data transmission so that the individual stations are not connected to each other. Still other systems temporarily store the data at each station until the data is extracted.

In the case of wired stations, typically several geophones are connected in a parallel-series combination on a single twisted pair of wires to form a single receiver group or channel for a station. During the data collection process, the output from each channel is digitized and recorded by the station for subsequent analysis. In turn, stations are usually connected to

cables used to communicate with and transport the collected data to recorders located at either a control station or a concentrator station.

In the case of wireless seismic units, each unit communicates with either a central control station or concentrator via radio transmissions. Transmissions are made either directly between each seismic unit and the control station or directly between each seismic unit and the concentrator. To the extent the transmissions are high power, long-range signals, such as between a seismic acquisition unit and a central control station, the transmissions generally require a license from the local governing authority. Units capable of such transmissions also have higher power requirements and thus require larger battery packages. To the extent the seismic acquisition units transmit to a concentrator station utilizing a low power, short-range signal, the transmitting and receiving units must typically have a line of site therebetween.

Illustrative of the prior art is U.S. Pat. No. 6,070,129 which teaches a method and apparatus for transmitting seismic data to a remote collection station. Specifically, an acquisition unit having a geophone attached thereto communicates with a central station either directly by radio channels, or optionally, by means of an intermediate station. To the extent a large number of acquisition units are utilized, the patent teaches that each a plurality of intermediate stations may also be utilized, wherein each intermediate station directly communicates with a portion of the acquisition units. Intermediate stations may function as data concentrators and may also be utilized to control various tasks executed by their respective groups of acquisition units. Whether data is transmitted directly between an acquisition unit and the central station or directly between an acquisition unit and an intermediate station, the transmitting system accumulates seismic data, distributes the data over successive transmission windows and discontinuously transmits the data during successive transmissions in order to lessen variation in seismic data flow.

Similarly, U.S. Pat. No. 6,219,620 teaches a seismic data acquisition system using wireless telemetry, in which a large number of remote seismic acquisition units are grouped together into a plurality of cells and each acquisition unit within a cell communicates directly with a cell access node, i.e., a concentrator, which in turn communicates with a central control unit. This patent teaches that in order to avoid overlap between transmitting seismic units within adjacent cells, adjacent cells utilize different frequencies for communication between units and their respective cell access nodes. In other words, adjacent cells operate at different frequencies so that a particular acquisition unit is only capable of transmitting to the cell access node assigned to its cell.

One drawback to the aforementioned seismic transmission systems of the prior art is that the failure of any one intermediate transmission station or cell access node will prevent communication with a plurality of seismic acquisition units. Furthermore, to the extent an individual unit is prevented from transmitting back to its respective cell access node due to factors external to the unit, the participation and operation of that unit within the array is lost. For example, a unit may lose radio contact with an access point due to a weak signal, weather conditions, topography, interference from other electrical devices operating in the vicinity of the unit, disturbance of the unit's deployment position or the presence of a physical structure in the line of site between the unit and the access point.

Thus, it would be desirable to provide a communication system for a seismic survey array that has flexibility in transmitting signals and data to and from remote seismic units and a control and/or data collection station. The system should be capable of communication between functional seismic units even if one or more intermediate stations fail to operate properly. In addition, the system should be capable of communication between functional seismic units even if a change in environmental or physical conditions inhibits or prevents a direct transmission between a remote unit and its control station.

SUMMARY OF THE INVENTION

The method according to the invention transmits radio signals between individual seismic acquisition units in an array, such that the transmissions can be passed in a relay chain through the array of seismic units. Multiple seismic acquisition units within the array are capable of passing transmissions to multiple other seismic units. More specifically, any one seismic acquisition unit in the array is capable of transmitting radio signals to several other seismic acquisition units positioned within radio range of the transmitting seismic acquisition unit. A network of radio-linked seismic acquisition units such as this permits seismic data transmission routes back to a control station to be varied as desired or needed. In other words, the transmission path utilized to transmit data from the individual seismic acquisition units in an array back to a control station may be altered. In transmissions up the chain, i.e., from the most remote seismic acquisition unit to the control station, each unit receives seismic data from a seismic unit "down" the chain and transmits the received seismic data up the chain along with receiving unit's locally stored seismic data. Preferably, as a transmission moves up the chain, it is bounced between seismic acquisition units so as to be relayed by each unit in the array. The specific transmission path, i.e., the chain of units, for any given transmission may vary between transmissions depending on overall system requirements. Control signals and the like can be passed back down the chain along the same or a different transmission path.

The transmitted signal strength can be altered to adjust the transmission range for a transmitting seismic unit, such that number of potential receiving seismic acquisition units can be controlled. In one embodiment, each seismic acquisition unit is omni-directional in its transmission and is capable of linking to all units within a 360° range around the transmitting unit. Alternatively, a transmitting seismic unit may utilize a directional antenna such that transmissions are made only to one or more seismic acquisition units in a limited or single direction or more limited range of transmission.

Preferably the individual seismic acquisition units are wireless and require no external cabling for data transmission or unit control. Such units may contain a battery, a short-range radio transmitter/receiver, a local clock, limited local memory, a processor and a geophone package. In one embodiment, each unit may include a short-range radio transmission antenna molded or otherwise integrated into the casing of the unit. In another embodiment, each unit may include external spikes that are used not only to couple the unit to the earth, but also as a conductive conduit through which the unit's batteries can be recharged.

At least one and preferably a plurality of seismic acquisition units in the network are located in the proximity of the control station so that the network can utilize short-range radio frequency to transmit seismic data all the way back to the control station. In another embodiment of the invention, the control station is remotely located from the seismic units and one or more concentrators are located in the proximity of the seismic acquisition units of the network so that the network can utilize short-range radio frequency to transmit seismic data to the concentrators. The concentrators, in-turn, can store the seismic data and/or transmit it back as desired to a control station.

Such a concentrator may include a long range transmitter/receiver for communicating with a control station, a short range transmitter/receiver for communicating with the seismic acquisition unit network, mass memory for long-term storage of the collected seismic data from the network, a power source, a local clock and a processor. In one embodiment, the concentrators may communicate with the control station via telemetry cable, while communicating with the seismic acquisition network via short range transmission.

Within the transmission network, there are multiple transmission paths from the most remote unit to the control station/concentrator. The particular transmission path to be used for any given transmission will be determined based on the strength of the signal between communicating units, the operational status of a unit and path efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a top view of a seismic acquisition array illustrating possible transmission paths between seismic acquisition unit strings in the array.

FIG. **2** is a top view of a seismic data transmission path utilizing seismic acquisition units.

FIG. **3** is an elevation view of a seismic acquisition unit of the invention.

FIG. **4** is a cut-away top view of the unit of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the detailed description of the invention, like numerals are employed to designate like parts throughout. Various items of equipment, such as fasteners, fittings, etc., may be omitted to simplify the description. However, those skilled in the art will realize that such conventional equipment can be employed as desired.

With reference to FIG. **1**, there is shown a seismic data transmission network **10** of the invention. Transmission network **10** is comprised of a plurality of seismic acquisition units **12** spread out in a seismic array **14** and controlled by control station **16**. Array **14** is formed of multiple lines **18** of acquisition units **12**. Radio transmissions, and in particular, seismic data, are passed from seismic unit **12** to seismic unit **12** as the transmission is bounced through the network **10** to control station **16**. In one embodiment of network **10**, concentrators **20** are disposed between array **14** and control station **16**. While the invention will be described in more detail with references to transmission of seismic data, those skilled in the art will understand that the invention encompasses any type of transmissions from a seismic unit, including, without limitation, quality control data.

Each acquisition unit **12** has an omnidirectional transmission range **22** and can form a wireless link **23** with multiple acquisition units **12**. As shown, within the transmission range **22** of a unit **12**, there are multiple other units **12** capable of receiving the transmission, in essence forming a local area network comprised of acquisition units **12**. For example, unit **12***a* has an omnidirectional transmission range **22***a*. Falling within the transmission range **22***a* of unit **12***a* are seismic acquisition units **12***b*-**12***g*. With the flexibility to transmit to multiple acquisition units **12** each having the ability to receive and transmit seismic data to multiple other units **12** within the array **14**, each unit **12** within array **14** is presented with multiple paths for communicating seismic data back to control station **16**. For example, unit **12'** can transmit data back to control station **16** by sending it along path **24**, along path **25** or along some other path as determined by the requirements of network **10**.

In another embodiment, a transmitting seismic unit **12** may utilize directional radio antenna or antenna array such that transmissions are substantially unidirectional and made only to one or more seismic acquisition units **12** in a limited direction. It is common in the art to utilize phased antenna arrays-an array consisting of two or more antenna's-to achieve transmission directionality and gain improvement. In these types of antenna arrangement, various adjustable antenna parameters, such as phase, can be altered to control directionality and gain, and hence, transmission range. Thus, for purposes of this description, "unidirectional" means a transmission with a higher gain along one axis or in a limited direction, whereas "omni-directional" means a transmission with generally the same gain in substantially 360°. This will maintain the flexibility to transmit to multiple units in the direction the transmitting antenna is pointed, while reducing the number of path options that need to be processed by the overall system, thereby multiple paths to be transmitted on the same frequency at the same time without interfering with one another. In addition, a higher gain in a single or limited direction can be achieved without the need for additional power, or alternatively, power requirements can be decreased, and thus battery life extended, while maintaining the same gain as an omnidirectional signal.

In the illustration of FIG. **1**, array **14** is shown as being comprised of three seismic acquisition unit strings **18*a***, **18*b***, and **18*c***. Each string **18*a***, **18*b***, and **18*c*** illustrates a different potential transmission path defined by wireless links **23** between the units **12** within a string. Those skilled in the art will understand that the indicated wireless links **23** are for illustrative purposes only and, for purposes of the invention, a "string" **18** of seismic units **12** for a particular transmission path is defined by the selected transmission path by which data is communicated from one unit **12** to another. Thus, for any given array **14**, a "string" of units may be constantly changing between transmissions. Such an arrangement permits transmissions to be re-routed in the event of some failure of a unit **12** within the string. Likewise, transmissions can be re-routed in the event of a weak signal between units **12** or to overcome topographic or other obstacles that could interfere with short range, line of site transmissions. Furthermore, in addition some failure of a unit, it may be desirable to reroute a transmission simply because of the operational status of a unit. For example, a unit with lower battery power may be utilized downstream at the end of a string and avoided as a transmission relay further upstream in order to conserve the unit's batteries, i.e., upstream relay units require more power to relay the transmission because of the cumulative size of the transmissions.

In the event multiple adjacent strings are desired, radio transmission parameter assignments may be made to minimize interference with other transmissions and permit reuse of the same transmission parameters. For example, string **18*a*** may transmit data at a first set of radio transmission parameters while string **18*b*** may transmit data at a second set of parameters. Since the transmissions from a sting **18** are short range, it may only be necessary for adjacent strings to utilize different transmission parameters. In this regard, the physical seismic unit layout of a portion of array **14** defined as a string **18** may be dependent on the short range transmission capabilities of the seismic units **12** in the adjacent string. Non-adjacent strings utilizing the same string are sufficiently spaced apart so as not to interfered with one another. In other words, string **18*b*** is defined such that its width is sufficient to ensure that any transmission from a seismic unit **12** from string **18*a*** transmitting with a certain set of radio transmission parameters will not be received by any seismic unit **12** from string **18*c*** set to receive transmissions using the same set of radio transmission parameters. Those skilled in the art will understand that there are many transmission parameters that can be adjusted in this regard, including the non limiting examples of frequencies, time slots, power, methods of modulation, directional antenna gain, physical spacing of units and strings, etc. Of course, interference between adjacent strings, as well as individual units, may also be minimized by making transmissions in discreet data packages sent in short transmission bursts.

Furthermore, while three strings **18** are depicted to indicate possible transmission paths, system **10** can comprise any number of strings. The number of strings for any given group of transmissions is dependent on the system requirements. For example, rather than multiple strings, each acquisition unit **12** in an array **14** may be utilized in a single transmission path such that the entire array **14** might be considered a "sting" for purposes of the description. Those skilled in the art will understand that the number of transmission paths and the number of acquisition units utilized for any given transmission may constantly be in flux to maximize the operation requirements for a particular transmission or group of transmissions.

In each case, the transmitted signal strength of a seismic unit **12** can be altered to adjust the transmission range for a transmitting seismic unit such that number of potential receiving seismic acquisition units **12** can be controlled.

At least one and preferably a plurality of seismic acquisition units **12** in network **10** are proximately located to control station **16** so that network **10** can utilize short-range radio frequency to transmit seismic data to control station **16** from the seismic units **12**. However, large amounts of data transmitted to a control station may be difficult to manage and typically requires high power, long range transmitters. Thus, in one embodiment of the invention, data is accumulated and stored at multiple, dispersed concentrators **20** remote from control station **16**. By accumulating seismic data at concentrators **20**, the need for radio licenses and other requirements associated with long range transmissions may be avoided. Concentrators **20** are located in the proximity of the seismic acquisition units **12** of the network **10** so that the network **10** can utilize low power, short-range radio transmission to transmit seismic data to the concentrators **20**. The concentrators **20**, in-turn, can store the seismic data or transmit it back as desired to control station **16**. In one embodiment, concentrators locally store seismic data but transmit quality control data received from the acquisition units back to control station **16**.

Much like the individual acquisition units **12**, each concentrator **20** preferably also has a transmission range **26** that encompasses several seismic acquisition units **12**. As within the array **14**, transmission of data from a string **18** to the accumulator **20** may be made from a plurality of units **12**. For example, accumulator **20*a*** has an omnidirectional transmission range **26*a***. Falling within the transmission range **26*a*** of accumulator **20*a*** are seismic acquisition units **12*h*-12*j***. As such, any of acquisition units **12*h*-12*j*** may transmit seismic data from string **18*a*** to accumulator **20*a***. Thus, a failure of one of the acquisition units, such as **12*h***, would not prevent seismic data from string **18*a*** from being passed up the line. Rather, the transmission path from string **18*a*** to concentrator **20*a*** would simply be rerouted through an operative acquisition unit, such as units **12*i*** or **12*j***. Concentrators **20** may also be positioned so as to be within the short range transmission distance of adjacent concentrators.

As described above, network **10** can function as either a one-way network, i.e., concentrators **20** are utilized only to receive seismic data transmitted from array **14**, or a two-way network, i.e., concentrators **20** transmit command signals out to array **14** in addition to receiving seismic data transmitted from array **14**.

In another configuration, seismic data is transmitted back from array **14** utilizing the network of linked seismic acquisition units **12**, but control signals are transmitted directly to each acquisition unit **12** from either the control station **16** or an associated concentrator **20**. In such case, an acquisition unit **12** may be capable of receiving long range transmissions directly from a distant source with sufficient transmission power for such communications, i.e., control station **16**, an associated concentrator **20** or radio repeater stations utilized to extend range, even though the acquisition unit **12** itself is only capable of short range hopped transmissions for sending seismic data back to the control station or concentrator.

Transmissions to control station **16** from accumulators **20** or acquisition units **12** may also include global positioning system ("GPS") or other survey information to establish the location of a particular unit **12** for purposes of the shot and for purposes of retrieval. This is particularly desirable for wireless units as described herein since it may be difficult to locate such units upon retrieval. GPS survey information may also be useful in selection of a transmission path within an array as described above.

In operation, a preferred transmission path may be preset in units **12** or predetermined. Likewise, alternate transmission paths may be preset in units **12** or predetermined. These preset paths, as well as the number of paths required for a particular array **14**, are determined based on the volume of the data to be transmitted, the data transmission rates, signal strength and the number of "real time" radio channels having different transmission parameters such that the radio transmission channels are non-interfering, battery power, location of the unit, etc.

Prior to a transmission or a set of transmissions along a string, a beacon signal may be utilized to verify the preferred transmission path in much the same way as an ad hoc network or peer to peer network identifies systems within the network. Alternatively, rather than transmitting data utilizing a preset or predetermined path, the beacon signal may be used to establish a transmission path utilizing the above described parameters. If a beacon signal is transmitted and the preferred transmission path is not available, system **10** will search for another transmission path through the seismic units. In one embodiment, the beacon signal is transmitted and the local units within range send a return signal acknowledging their receipt of the beacon signal. Once a path is verified or established, as the case may be, the path may be "locked in" for purposes of the particular transmission so that system **10** will not continue searching for another path. The beacon signal may be generated from within the array **14** by the seismic units themselves or initiated by the control station or concentrator.

A synchronization signal may also be used to synchronize the recording time for the units of system **10** by establishing a future time t(0) at which trace recording by seismic units **12** is to begin. In contrast, the prior art typically sends out a pulse signal that immediately triggers recording by each seismic unit at the time it receives the signal such that prior art seismic units located closer to the signal source begin recording earlier than seismic units more remote from the signal source. In a preferred embodiment of the invention, all seismic units **12** may be set to start recording at a specific clock time, such that data transmitted back through network **10** is time stamped based on the synchronization shot time. In this regard, all data is time synchronized regardless of the transmission path utilized by the network or the period of time the network takes to transmit the data through the network.

In this same vein, it is also desirable to ascertain the data delay along the path based on master clock time so that data that is not time stamped can be synchronized with the data from other seismic units. The described network **10** permits data to be retrieved via radio transmission in real time or near real time.

While the invention has been described in its broadest sense as possessing the flexability to alter data transmission paths, i.e., each unit has wireless links with multiple other units, in order to convey acquired seismic data from an array of acquisition units back to a control station or concentrator, it is also true that none of the prior art transmission systems utilize seismic data acquisition units as intermediate transmission devices. Thus, one aspect of the invention as illustrated in FIG. **2** is the use of seismic data acquisition units **12** themselves, configured in a predetermined string, as intermediate devices for passing transmissions from a seismic unit in the string to a control station. In this regard, a string **40** of seismic units **42** is predetermined and defined by an outermost unit **42*a*** and a plurality of intermediate units **42*b*** through **42*i***. Each unit **42** in string **40** has a wireless link **44** within its transmission range **46** only with the units directly up and directly down the string. For example, sesimic unit **42*g*** is only capable of communication with sesimic units **42*f*** and **42*h*** via their respective wireless links **44** because only units **42*f*** and **42*h*** are within the transmission range **46** of unit **42*g***. Upon acquisition of data, unit **42*g*** will transmit the acquired data up the string to **42*h***, along with any data received by wireless transmission from **42*f***. All seismic data from the units **12** comprising string **40** will be conveyed up the string to control station **16**. Control station **16** can likewise utilize the seismic units **12** to pass control and command signals back down the string. As mentioned above, one benefit of the invention is the ability to utilize flexible transmission paths that can be readily changed based on various internal and external parameters effecting the network. This flexability also renders the network itself much more reliable. Preferably, transmission paths can be established and/or rerouted on-the-fly based on these parameters. Another advantage of the system is that it utilizes less power in transmitting a signal over a given distance via multiple short transmissions than would be required of a single transmission over the same distance. In other words, because the power required to transmit a signal decreases as one over the square of the transmission distance, it is much more optimal to transmit a signal in several short hops than it would be to transmit the same signal over the same distance in a single hop. This is true even of low power, short range transmissions. Of course an additional advantage of the system of the invention is that it avoids the need to acquire long range radio transmission licenses. Finally, unlike the prior art, the system of the invention eliminates the need to physically locate a concentrator or similar device in the middle of a seismic array, nor utilize the concentrator to sort and organize multiple seismic data transmissions incoming directly from individual seismic acquisition units.

Turning to the individual seismic acquisition units as illustrated in FIGS. **3** and **4**, each unit **12** is preferably wireless and requires no external cabling for data transmission or unit control. Each unit **12** may contain a battery **30**, a short-range radio transmitter/receiver **31**, a local clock **32**, limited local memory **33**, and a processor **34** housed within a casing **35**. A geophone package **36** may be housed within the casing **35** or externally attached thereto. Any standard short range radio transmission equipment may be utilized. One non-limiting example being wireless fidelity ("Wi-Fi") equipment, where transmission parameters may be selected to provide signal carrier modulation schemes such as complementary code keying (CCK)/packet binary convolution (PBCC) or direct sequence spread-spectrum (DSSS) or multi-carrier schemes such as orthogonal frequency division multiplexing (OFDM) and code division multiple access (CDMA). Local memory capacity is preferably limited since local seismic data is only retained for a short period of time. Further, because the unit **12** need only transmit a short range signal, power requirements for the unit are minimized in contrast to the increased power requirements necessary to transmit a stronger signal to a more distant receiving device. By reducing the memory requirements, the transmission requirements and the battery requirements, the overall cost, as well as the physical size and weight, of each unit is minimized.

While each unit may include an antenna, attached via an external connector, in one embodiment of the invention, each unit **12** may include a short-range radio transmission antenna **36** molded or otherwise integrated into the casing **35** of the unit. This eliminates the need for an external connector. Each unit **12** may also include radio frequency identification or similar identification indicia, such as a bar code. Finally, each unit **12** may include a receiver for receiving long range radio transmissions directly from a control station or concentrator as described above.

In another embodiment, each unit **12** may include external projections or spikes **37** that are used not only to couple the unit to the earth, but also as an electrically conductive conduit through which the unit's internal batteries **30** can be recharged. Such a configuration minimizes the need for external connectors which are known in the industry as a source of various problems such as corrosion, leakage, etc. or alternatively, the need to otherwise open the sealed unit. While any shape, length or number of projections or spikes may be utilized, one preferred configuration utilizes three spikes that can also be utilized to couple the unit to the earth. In a three spike configuration, two of the spikes are connected to the battery through a relay or similar mechanism. The third spike would be used to control the relay. During charging, the relay would be closed; after charging, the relay would be open to prevent battery discharge.

Concentrator **20** (not shown) may include a long range radio transmitter/receiver for communicating with a control station **16**, a short range radio transmitter/receiver for communicating with the network of seismic acquisition units **12**, a power source, a local clock and a processor. In one embodiment, concentrator **20** functions simply as an intermediate long range receiver/transmitter to relay short range transmissions from the network of seismic units **12** to the control station **16**. In another embodiment, concentrator **20** is provided with mass memory for storage of seismic data transmitted from the network of seismic units **12**. In either embodiment, concentrator **20** may relay control signals and other transmission from the control station **16** back to the network of seismic units **12**. In this same vein, concentrator **20** may be disposed to function as a local control station for a network of seismic units **12**. While the preferred embodiment utilizes radio frequency for transmissions between concentrator **20** and control station **16**, transmissions therebetween may also occur through various other transmission vehicles, such as telemetry cable or optic cable.

While certain features and embodiments of the invention have been described in detail herein, it will be readily understood that the invention encompasses all modifications and enhancements within the scope and spirit of the following claims.

The invention claimed is:

1. A method for seismic data transmission comprising the steps of:

A. providing a plurality of seismic acquisition units, wherein each of the seismic acquisition units is capable of acquiring seismic data, receiving a short range radio transmission and transmitting a short range radio transmission;

B. utilizing a first seismic acquisition unit to acquire seismic data and transmit seismic data along first transmission path using a first set of transmission parameters, wherein the first transmission path comprises a first subset of at least two of the plurality of seismic data acquisition units;

C. utilizing a second seismic acquisition unit to acquire seismic data and transmit seismic data along a second transmission path using a second set of transmission parameters, wherein the second transmission path comprises a second subset of at least two of the plurality of seismic data acquisition units, wherein the second set of transmission parameters are different from the first set of transmission parameters;

D. wherein the first set of transmission parameters and the second set of transmission parameters are selected to be non-interfering with one another.

2. The method of claim **1**, wherein the first set of transmission parameters includes a transmission frequency, f1, and the second set of transmission parameters includes a transmission frequency, f2, such that f1 and f2 are different and non-interfering.

3. The method of claim **1**, further comprising the step of utilizing a first plurality of the seismic acquisition units along the first transmission path to transmit seismic data via short range radio transmission while simultaneously utilizing a second plurality of the seismic acquisition units along the second transmission path to transmit seismic data via short range radio transmission.

4. The method of claim **3**, wherein the first set of transmission parameters includes a transmission frequency, f1, and the second set of transmission parameters includes a transmission frequency, f2, such that f1 and f2 are different and non-interfering.

5. The method of claim **1**, wherein at least one seismic acquisition unit is capable of receiving short range radio transmissions from at least two other seismic acquisition units.

6. The method of claim **1**, wherein each seismic acquisition unit is capable of receiving short range radio transmissions from at least two other seismic acquisition units.

7. The method of claim **1**, wherein each seismic acquisition unit is capable of receiving short range radio transmissions from at least three other seismic acquisition units.

8. The method of claim **1**, wherein the first transmission path and the second transmission path are different.

9. A method for seismic data transmission comprising the steps of:

A. utilizing at least two seismic acquisition units having a first set of short range radio transmission parameters to transmit and receive seismic data along a first transmission path;

B. utilizing at least two seismic acquisition units having a second set of short range radio transmission parameters to transmit and receive seismic data along a second transmission path;

C. wherein the first set of transmission parameters and the second set of transmission parameters are non-interfering with one another.

10. The method of claim **9**, wherein the first set of transmission parameters includes a transmission frequency, f1, and the second set of transmission parameters includes a transmission frequency, f2, such that f1 and f2 are different and non-interfering.

11. The method of claim **9**, wherein transmission using the first set of transmission parameters is simultaneous with transmission using the second set of transmission parameters.

12. The method of claim **11**, wherein the first set of transmission parameters includes a transmission frequency, f1, and the second set of transmission parameters includes a transmission frequency, f2, such that f1 and f2 are different and non-interfering.

13. The method of claim **9**, wherein at least one seismic acquisition unit is capable of receiving short range radio transmissions from at least two other seismic acquisition units.

14. The method of claim **9**, wherein each seismic acquisition unit is capable of receiving short range radio transmissions from at least two other seismic acquisition units.

15. The method of claim **9**, wherein each seismic acquisition unit is capable of receiving short range radio transmissions from at least three other seismic acquisition units.

16. The method of claim **9**, wherein the first transmission path and the second transmission path are different.

* * * * *

JS 44 (Rev. 12/12)

CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. *(SEE INSTRUCTIONS ON NEXT PAGE OF THIS FORM.)*

I. (a) PLAINTIFFS

Fairfield Industries Incorporated d/b/a FairfieldNodal

(b) County of Residence of First Listed Plaintiff: Fort Bend
(EXCEPT IN U.S. PLAINTIFF CASES)

(c) Attorneys *(Firm Name, Address, and Telephone Number)*

Foley & Lardner LLP, 150 E. Gilman Street, P.O. Box 1497,
Madison, Wisconsin 53701-1497 (608) 257-5035

DEFENDANTS

Wireless Seismic, Inc.

County of Residence of First Listed Defendant: ____
(IN U.S. PLAINTIFF CASES ONLY)

NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE TRACT OF LAND INVOLVED.

Attorneys *(If Known)*

II. BASIS OF JURISDICTION *(Place an "X" in One Box Only)*

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question *(U.S. Government Not a Party)*
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity *(Indicate Citizenship of Parties in Item III)*

III. CITIZENSHIP OF PRINCIPAL PARTIES *(Place an "X" in One Box for Plaintiff and One Box for Defendant)*

(For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	☐ 1	☐ 1	Incorporated *or* Principal Place of Business In This State	☐ 4	☐ 4
Citizen of Another State	☐ 2	☐ 2	Incorporated *and* Principal Place of Business In Another State	☐ 5	☐ 5
Citizen or Subject of a Foreign Country	☐ 3	☐ 3	Foreign Nation	☐ 6	☐ 6

IV. NATURE OF SUIT *(Place an "X" in One Box Only)*

CONTRACT
- ☐ 110 Insurance
- ☐ 120 Marine
- ☐ 130 Miller Act
- ☐ 140 Negotiable Instrument
- ☐ 150 Recovery of Overpayment & Enforcement of Judgment
- ☐ 151 Medicare Act
- ☐ 152 Recovery of Defaulted Student Loans (Excludes Veterans)
- ☐ 153 Recovery of Overpayment of Veteran's Benefits
- ☐ 160 Stockholders' Suits
- ☐ 190 Other Contract
- ☐ 195 Contract Product Liability
- ☐ 196 Franchise

REAL PROPERTY
- ☐ 210 Land Condemnation
- ☐ 220 Foreclosure
- ☐ 230 Rent Lease & Ejectment
- ☐ 240 Torts to Land
- ☐ 245 Tort Product Liability
- ☐ 290 All Other Real Property

TORTS

PERSONAL INJURY
- ☐ 310 Airplane
- ☐ 315 Airplane Product Liability
- ☐ 320 Assault, Libel & Slander
- ☐ 330 Federal Employers' Liability
- ☐ 340 Marine
- ☐ 345 Marine Product Liability
- ☐ 350 Motor Vehicle
- ☐ 355 Motor Vehicle Product Liability
- ☐ 360 Other Personal Injury
- ☐ 362 Personal Injury - Medical Malpractice

PERSONAL INJURY
- ☐ 365 Personal Injury - Product Liability
- ☐ 367 Health Care/ Pharmaceutical Personal Injury Product Liability
- ☐ 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
- ☐ 370 Other Fraud
- ☐ 371 Truth in Lending
- ☐ 380 Other Personal Property Damage
- ☐ 385 Property Damage Product Liability

CIVIL RIGHTS
- ☐ 440 Other Civil Rights
- ☐ 441 Voting
- ☐ 442 Employment
- ☐ 443 Housing/ Accommodations
- ☐ 445 Amer. w/Disabilities - Employment
- ☐ 446 Amer. w/Disabilities - Other
- ☐ 448 Education

PRISONER PETITIONS

Habeas Corpus:
- ☐ 463 Alien Detainee
- ☐ 510 Motions to Vacate Sentence
- ☐ 530 General
- ☐ 535 Death Penalty

Other:
- ☐ 540 Mandamus & Other
- ☐ 550 Civil Rights
- ☐ 555 Prison Condition
- ☐ 560 Civil Detainee - Conditions of Confinement

FORFEITURE/PENALTY
- ☐ 625 Drug Related Seizure of Property 21 USC 881
- ☐ 690 Other

LABOR
- ☐ 710 Fair Labor Standards Act
- ☐ 720 Labor/Management Relations
- ☐ 740 Railway Labor Act
- ☐ 751 Family and Medical Leave Act
- ☐ 790 Other Labor Litigation
- ☐ 791 Employee Retirement Income Security Act

IMMIGRATION
- ☐ 462 Naturalization Application
- ☐ 465 Other Immigration Actions

BANKRUPTCY
- ☐ 422 Appeal 28 USC 158
- ☐ 423 Withdrawal 28 USC 157

PROPERTY RIGHTS
- ☐ 820 Copyrights
- ☒ 830 Patent
- ☐ 840 Trademark

SOCIAL SECURITY
- ☐ 861 HIA (1395ff)
- ☐ 862 Black Lung (923)
- ☐ 863 DIWC/DIWW (405(g))
- ☐ 864 SSID Title XVI
- ☐ 865 RSI (405(g))

FEDERAL TAX SUITS
- ☐ 870 Taxes (U.S. Plaintiff or Defendant)
- ☐ 871 IRS—Third Party 26 USC 7609

OTHER STATUTES
- ☐ 375 False Claims Act
- ☐ 400 State Reapportionment
- ☐ 410 Antitrust
- ☐ 430 Banks and Banking
- ☐ 450 Commerce
- ☐ 460 Deportation
- ☐ 470 Racketeer Influenced and Corrupt Organizations
- ☐ 480 Consumer Credit
- ☐ 490 Cable/Sat TV
- ☐ 850 Securities/Commodities/ Exchange
- ☐ 890 Other Statutory Actions
- ☐ 891 Agricultural Acts
- ☐ 893 Environmental Matters
- ☐ 895 Freedom of Information Act
- ☐ 896 Arbitration
- ☐ 899 Administrative Procedure Act/Review or Appeal of Agency Decision
- ☐ 950 Constitutionality of State Statutes

V. ORIGIN *(Place an "X" in One Box Only)*

- ☒ 1 Original Proceeding
- ☐ 2 Removed from State Court
- ☐ 3 Remanded from Appellate Court
- ☐ 4 Reinstated or Reopened
- ☐ 5 Transferred from Another District *(specify)*
- ☐ 6 Multidistrict Litigation

VI. CAUSE OF ACTION

Cite the U.S. Civil Statute under which you are filing **(*Do not cite jurisdictional statutes unless diversity*)**:
35 U.S.C. § 271

Brief description of cause:
Defendant is infringing plaintiff's U.S. patents

VII. REQUESTED IN COMPLAINT:

☐ CHECK IF THIS IS A **CLASS ACTION** UNDER RULE 23, F.R.Cv.P.

DEMAND $

CHECK YES only if demanded in complaint:
JURY DEMAND: ☒ Yes ☐ No

VIII. RELATED CASE(S) IF ANY

(See instructions): JUDGE ____ DOCKET NUMBER ____

DATE: 11/01/2013

SIGNATURE OF ATTORNEY OF RECORD: s/Allen A. Arntsen

FOR OFFICE USE ONLY

RECEIPT # ____ AMOUNT ____ APPLYING IFP ____ JUDGE ____ MAG. JUDGE ____

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INSTRUCTIONS FOR ATTORNEYS COMPLETING CIVIL COVER SHEET FORM JS 44

Authority For Civil Cover Sheet

The JS 44 civil cover sheet and the information contained herein neither replaces nor supplements the filings and service of pleading or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. Consequently, a civil cover sheet is submitted to the Clerk of Court for each civil complaint filed. The attorney filing a case should complete the form as follows:

I.(a) **Plaintiffs-Defendants.** Enter names (last, first, middle initial) of plaintiff and defendant. If the plaintiff or defendant is a government agency, use only the full name or standard abbreviations. If the plaintiff or defendant is an official within a government agency, identify first the agency and then the official, giving both name and title.

(b) **County of Residence.** For each civil case filed, except U.S. plaintiff cases, enter the name of the county where the first listed plaintiff resides at the time of filing. In U.S. plaintiff cases, enter the name of the county in which the first listed defendant resides at the time of filing. (NOTE: In land condemnation cases, the county of residence of the "defendant" is the location of the tract of land involved.)

(c) **Attorneys.** Enter the firm name, address, telephone number, and attorney of record. If there are several attorneys, list them on an attachment, noting in this section "(see attachment)".

II. **Jurisdiction.** The basis of jurisdiction is set forth under Rule 8(a), F.R.Cv.P., which requires that jurisdictions be shown in pleadings. Place an "X" in one of the boxes. If there is more than one basis of jurisdiction, precedence is given in the order shown below.
United States plaintiff. (1) Jurisdiction based on 28 U.S.C. 1345 and 1348. Suits by agencies and officers of the United States are included here.
United States defendant. (2) When the plaintiff is suing the United States, its officers or agencies, place an "X" in this box.
Federal question. (3) This refers to suits under 28 U.S.C. 1331, where jurisdiction arises under the Constitution of the United States, an amendment to the Constitution, an act of Congress or a treaty of the United States. In cases where the U.S. is a party, the U.S. plaintiff or defendant code takes precedence, and box 1 or 2 should be marked.
Diversity of citizenship. (4) This refers to suits under 28 U.S.C. 1332, where parties are citizens of different states. When Box 4 is checked, the citizenship of the different parties must be checked**.** (See Section III below**; NOTE: federal question actions take precedence over diversity cases.**)

III. **Residence (citizenship) of Principal Parties.** This section of the JS 44 is to be completed if diversity of citizenship was indicated above. Mark this section for each principal party.

IV. **Nature of Suit.** Place an "X" in the appropriate box. If the nature of suit cannot be determined, be sure the cause of action, in Section VI below, is sufficient to enable the deputy clerk or the statistical clerk(s) in the Administrative Office to determine the nature of suit. If the cause fits more than one nature of suit, select the most definitive.

V. **Origin.** Place an "X" in one of the six boxes.
Original Proceedings. (1) Cases which originate in the United States district courts.
Removed from State Court. (2) Proceedings initiated in state courts may be removed to the district courts under Title 28 U.S.C., Section 1441. When the petition for removal is granted, check this box.
Remanded from Appellate Court. (3) Check this box for cases remanded to the district court for further action. Use the date of remand as the filing date.
Reinstated or Reopened. (4) Check this box for cases reinstated or reopened in the district court. Use the reopening date as the filing date.
Transferred from Another District. (5) For cases transferred under Title 28 U.S.C. Section 1404(a). Do not use this for within district transfers or multidistrict litigation transfers.
Multidistrict Litigation. (6) Check this box when a multidistrict case is transferred into the district under authority of Title 28 U.S.C. Section 1407. When this box is checked, do not check (5) above.

VI. **Cause of Action.** Report the civil statute directly related to the cause of action and give a brief description of the cause. **Do not cite jurisdictional statutes unless diversity.** Example: U.S. Civil Statute: 47 USC 553 Brief Description: Unauthorized reception of cable service

VII. **Requested in Complaint.** Class Action. Place an "X" in this box if you are filing a class action under Rule 23, F.R.Cv.P.
Demand. In this space enter the actual dollar amount being demanded or indicate other demand, such as a preliminary injunction.
Jury Demand. Check the appropriate box to indicate whether or not a jury is being demanded.

VIII. **Related Cases.** This section of the JS 44 is used to reference related pending cases, if any. If there are related pending cases, insert the docket numbers and the corresponding judge names for such cases.

Date and Attorney Signature. Date and sign the civil cover sheet.

AO 440 (Rev. 06/12) Summons in a Civil Action

UNITED STATES DISTRICT COURT

for the

Eastern District of Texas

Fairfield Industries Incorporated d/b/a FairfieldNodal *Plaintiff(s)* v. Wireless Seismic, Inc. *Defendant(s)*	)	Civil Action No. 2:13-cv-00903

SUMMONS IN A CIVIL ACTION

To: *(Defendant's name and address)*

Wireless Seismic, Inc.
c/o CT Corporation System
350 N. St. Paul Street
Suite 2900
Dallas, Texas 75201

A lawsuit has been filed against you.

Within 21 days after service of this summons on you (not counting the day you received it) — or 60 days if you are the United States or a United States agency, or an officer or employee of the United States described in Fed. R. Civ. P. 12 (a)(2) or (3) — you must serve on the plaintiff an answer to the attached complaint or a motion under Rule 12 of the Federal Rules of Civil Procedure. The answer or motion must be served on the plaintiff or plaintiff's attorney, whose name and address are:

Allen A. Arntsen
Foley & Lardner LLP
P.O. Box 1497
Madison, Wisconsin 53701-1497

If you fail to respond, judgment by default will be entered against you for the relief demanded in the complaint. You also must file your answer or motion with the court.

CLERK OF COURT

Date: ____________________

____
Signature of Clerk or Deputy Clerk

Civil Action No. 2:13-cv-00903

PROOF OF SERVICE

(This section should not be filed with the court unless required by Fed. R. Civ. P. 4 (l))

This summons for *(name of individual and title, if any)* ______________________

was received by me on *(date)* ______________ .

❐ I personally served the summons on the individual at *(place)* ______________________

______________________ on *(date)* ______________ ; or

❐ I left the summons at the individual's residence or usual place of abode with *(name)* ______________

______________________ , a person of suitable age and discretion who resides there,

on *(date)* ______________ , and mailed a copy to the individual's last known address; or

❐ I served the summons on *(name of individual)* ______________________ , who is

designated by law to accept service of process on behalf of *(name of organization)* ______________

______________________ on *(date)* ______________ ; or

❐ I returned the summons unexecuted because ______________________ ; or

❐ Other *(specify)*:

My fees are $ ________ for travel and $ ________ for services, for a total of $ 0.00 .

I declare under penalty of perjury that this information is true.

Date: ______________

____

Server's signature

____

Printed name and title

____

Server's address

Additional information regarding attempted service, etc:

Print | Save As... | Reset