

Description

This invention relates to a simultaneous digitizing apparatus and method for an acoustic borehole tool.

Acoustic logging tools utilize an acoustically coupled piezoelectric transducer to convert acoustic waves into output electrical signals. A typical acoustic logging tool incorporates an acoustic transmitter which propagates a pulse into the adjacent formations. A return pulse is received at the device. An input pulse is observed at each acoustic receiver. Better data interpretation can be obtained if there are multiple acoustic receivers. In a typical device there are N acoustic receivers, and they output data collectively indicating more subtle relationships. One subtle relationship in the relative phase between the various receivers. The delay time of the propagated wave front in arriving at the different receivers is also important. A multitude of data is made available by such a device.

The data burst occurs in about 500 to 1,500 microseconds after the pulse is transmitted. Simultaneous data reception and telemetry is especially difficult over a monocab. A monocab is a cable for supporting a downhole logging tool in a sonde wherein two conductors are included in the cable. While one functions as ground, power is delivered on the other conductor to be transmitted from the surface to the sonde. Additionally, this pair of conductors is used to transmit data from the tool to the surface. This two conductor system provides a somewhat limited band width for data transmission, and it is not possible to crowd full data through the monocab in real time from N acoustic receivers.

One data transfer procedure which has accommodated this limited data band width in the past is use of multiple firing of the transmitter, each firing dedicated to a single acoustic receiver. Thus, four separately created acoustic pulses could be propagated into the adjacent formations, and each of the four acoustic receivers would be sequentially operated to provide an output signal. This typically occurs as the tool is in transit up the borehole. There is an inevitable shift in position of the sonde between pulses. This movement makes it somewhat difficult to implement various data reduction procedures using N acoustic receivers where there has been a shift in the position of the acoustic transmitter and the respective receivers because each is working with different transmitted pulses. This has created difficulties in data reduction; the data reduction requires shifting to obtain time coincidence of the transmitted pulses. Since the shifted data is not what really happened, such data reduction techniques add to the complexity of interpretation. One important data reduction technique is cross correlation of the transmitted pulse and the one received pulse. The present invention enhances cross correlation.

The present apparatus and method enables use of multiple simultaneously operative acoustic

receivers supported in acoustic well logging tools.

According to the present invention, there is provided for use in a well borehole to obtain multiple simultaneous data signals from N acoustic receivers carried by an elongated acoustic logging sonde sized and adapted for passage in the well borehole and suspended by a well logging cable having a single acoustic data conductor, the multiple simultaneous signals formed in response to a single acoustic energy pulse from an acoustic transmitter carried by the sonde, a data collection system comprising:

(a) N acoustic receivers supported by, and longitudinally spaced along, an acoustic logging sonde forming N time overlapping acoustic logging output signals from the receivers where N is an integer;

(b) first multiplexing means having N inputs connected to the outputs of said N acoustic receivers;

(c) second multiplexing means connected to said first multiplexing means;

(d) digital converter means operating at a first rate and connected to said second multiplexing means for forming a time based series of digital words representative of the output signals of said N receivers;

(e) digital data buffer means in said sonde and connected to said digital converter means for recording in a formatted order a series of digital words from said converter means;

(f) means for directing digital words from said digital converter means into specified addresses in said digital data buffer means;

(g) an acoustic transmitter monitor means comprising an acoustic monitor located in the sonde connected to an acoustic transmitter located near one end of the sonde, to detect and form a signal representative of an acoustic pulse formed by the acoustic transmitter and transmitted by said acoustic transmitter, said monitor forming a signal input to said second multiplexing means;

(h) control means connected to said first and second multiplexing means for controlling operation of said first and second multiplexing means to form a series of digital words representative of the monitored transmitter pulses from said acoustic transmitter monitor, and

(2) the N acoustic logging output signals;

(i) timing means incorporated with said control means to time digitizing by said digital converter means to operate both said first and second multiplexing means to form;

(1) a first series of digital words representing the monitored transmitter pulses; and

(2) a second and later series of digital words representing the N acoustic logging output signals; and

(j) telemetry transmitting means for telemetering the first and second series of digital words from said buffer means along the single acoustic data conductor in the cable at a second rate which rate is less than the first rate such that a single acoustic energy pulse from said acoustic trans-

mitter generates N digital representations of the acoustic energy received at said N acoustic receivers corresponding to the arrival at each receiver of a single acoustic energy pulse.

The invention also includes a method of acoustic logging in a well borehole below a surface with an acoustic pulse transmitter on a sonde supported by a cable wherein the cable has a single acoustic data signal conductor and N multiple acoustic receivers on the sonde to observe overlapping received acoustic signals, the method comprising the steps of:

(a) transmitting an acoustic pulse by a transmitter;

(b) forming a signal by monitoring the acoustic pulse transmitter during operation thereof;

(c) multiplexing and digitizing the formed signal for a first time interval beginning at time equals zero to form a series of digital words representing the acoustic pulse;

(d) storing the digital words in a memory in the sonde;

(e) listening for overlapping acoustic signals resulting from the transmitted acoustic pulse at N acoustic receivers along the wall borehole and forming an analog signal from each of the N receivers;

(f) multiplexing the overlapping N received analog signals at first and second rates;

(g) digitizing the multiplexed N analog signals into a series of digital words encoding the N analog signals;

(h) storing the digital words encoding the N analog signals in a specified sequence in the memory; and

(i) telemetering from the sonde along the single acoustic data signal conductor along the cable supporting the sonde to the surface digital words in the memory representing the monitored acoustic transmitter pulse and the N received signals, wherein the telemetering rate is slower than the first rate.

In accordance with the present invention, the logging tool is lowered in a borehole. At a desired depth the acoustic transmitter is operated to form a pulse. The pulse is transmitted into the adjacent formations and various acoustic signals are observed at N acoustic receivers on the tool. The various received signals are time multiplexed and stored in memory after conversion into a set of digital words. For each of the N acoustic receivers, the received signal can be reconstructed at the time of data reduction and interpretation. Moreover, the data is stored so that it can be subsequently transferred to the surface on a monocable by means of a suitable telemetry transmitter. With the data from N acoustic receiver signals in memory, the data can be removed from memory at a rate which permits it to be transmitted in the narrow width band available in a monocable. As will be understood, broad band transmission to enable high speed transmission of N simultaneously received acoustic signals is obtained only at the price of a more expensive apparatus capable of broad band trans-

mission. The present apparatus enables the time log between acoustic events to be used for data transmission of N acoustic received events.

Many additional objects and advantages of the present apparatus will be more readily apparent on consideration of the device after its detailed description below. Such device and a method of obtaining data are set forth in detail below.

So that the manner in which the above recited features, advantages and objects of the present invention are attained and can be understood in detail, more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

Fig. 1 shows the acoustic logging system constructed in accordance with this disclosure particularly featuring a multiplexed input to a digital data converter for temporarily buffering digitized data for subsequent transfer to the surface; and

Fig. 2 is a timing chart showing the timed sequence of various signals in a system having four acoustic receivers.

Attention is first directed to Fig. 1 of the drawings where an acoustic logging device is indicated generally by the numeral 10. It is supported on a monocable 12 in a borehole 14 to thereby obtain acoustic logging data. The monocable 12 extends upwardly to the surface to pass over a sheave 16. The sheave 16 directs the cable to a reel 18 which spools and stores several thousand feet (1 foot=0.3 m) of the cable 12. The cable 12 is connected to a receiver 20. The receiver receives the acoustic logging data and transfers it to a recorder 22. The recorder 22 stores the logging data in a suitable medium such as on magnetic tape. The recorder 22 is connected by a mechanical or electronic means 24 to the sheave for the purpose of determining the depth of the sonde 10 in the borehole 14. This enables the data to be correlated to the depth in the well. In typical operations, the sonde 10 is lowered to the bottom of the well and then is retrieved from the well by spooling the cable onto the reel 18. As the sonde is raised in the well, acoustic pulses are transmitted in a controlled sequence. Data is obtained and recorded by the recorder 22 as a function of depth of the sonde 10 in the borehole.

The acoustic logging device incorporates an acoustic transmitter which is typically a piezoelectric crystal. The transmitter is identified by the numeral 26. The transmitter is immediately adjacent to an acoustic receiver 28. It functions as a transmitter monitor. It obtains a signal dependent on transmission; the acoustic receiver 28 provides an output signal indicative of transmission. It will be used in a fashion to be described. The acoustic logging tool 10 additionally supports several piezoelectric receivers. Moving from the bottom to the top of the tool, the numeral 30

identifies one receiver. A similar receiver is incorporated at 32. Additional receivers are shown at 34 and 36. They are preferably identical in operation and construction. They differ primarily in their location in the sonde. In particular they are spaced at known distances from the transmitter.

If a pulse is transmitted into the formation, a received signal is observed at all four of the receivers. The several signals from the several receivers may differ in phase and amplitude. Valuable data is found in these differences.

The four receivers are input to a multiplexer 38. The multiplexer 38 is provided with N inputs. In this instance, N is four. As will be understood, the number of acoustic receivers can be varied. This number depends on the construction of the sonde 10 and the desired data from its operation. The output signals from the four receivers are analog signals.

The analog multiplexed signal is input to a next multiplexer 40. This multiplexer does not have to be a high speed multiplexer in the same fashion as the multiplexer 38. Preferably, the multiplexer 38 is able to settle in less than one microsecond so that microsecond scanning speeds for the N inputs can be accomplished. The multiplexer 40 is provided with two inputs. One is on the conductor 42 from the acoustic receiver 28. That signal is provided for the first designated interval (typically up to about two hundred microseconds) after the transmitted pulse has been formed. In other words, transmitter monitoring occurs for the first few hundred microseconds of a pulse transmission and reception sequence. During the first microseconds of operation, there is no signal at any of the acoustic receivers. It is therefore preferable to record the acoustic transmitter monitor signal to be able to determine timing and shape of the transmitted pulse. Later on, this data will be less important and more important data furnished from the high speed multiplexer 38 is then fed through the multiplexer 40. Multiplexer 40 therefore is initially operated to transfer only the transmitter pulse signal; that is ended after an interval, and thereafter the only signals for the multiplexer 40 are from the acoustic receivers. The multiplexer 40 is input to a high speed analog to digital converter 44. It converts the variable signals into an output digital signal having a specified word length and sign bit. Typically, eight bits in the data words are formed. Greater precision can be obtained at some sacrifice in complexity or speed.

This apparatus includes a control system 46. The control system 46 times operation of all the equipment. The control system is connected to a digital data buffer 48 which is a memory device for storing the data. The data is stored in a rank and file organization to be described. The data in the buffer 48 is periodically removed for a telemetry transmitter 50 to be transferred to the surface through the monocable 12.

The control system 46 forms a fire signal for a transmitter fire controller 52 connected to the transmitter. This enables the correct timing of the transmitted pulse.

The control system 46 is additionally connected to the multiplexer 38 by means of a conductor 54. This gates the multiplexer 38 at a speed to be determined by the control system. Likewise, a control signal is provided on the conductor 56. The signal on the conductor 56 is input to the multiplexer switch 40. This instructs the circuit 40 to transfer either the transmitter signal or the multiplexed receiver signals. Additionally, the control system provides a write signal on a conductor 58. Data is written through several conductors at 60.

Data is written in an organized fashion in the digital data buffer 48. One organization for the digital data buffer is shown in Fig. 2 of the drawings. There, the four receivers are labelled on the ordinate. In addition, the transmitter monitor is also included. The abscissa is measured in microseconds. For the first few microseconds the only signal potentially available is the transmitter pulse. The transmitter monitor 28 provides a signal which is suitably digitized. Thus, the first few words into memory come from the transmitter pulse. All of these words are serially output from the high speed converter 44 into memory. Fig. 2 thus represents the first several words derived from the transmitter monitor and input into memory. It will be observed that the abscissa has a break to indicate that the number of words so stored can be varied. This is achieved by the control system 46 switching the multiplexer 40.

Fig. 2 thus shows that, after an interval, the last word is obtained from the transmitter monitor 28. The next digital word is from the receiver 30. In Fig. 2, scanning of the four receivers is shown. In the scale of Fig. 2, a digitized data word is obtained from each of the four input signals at a time spacing of approximately four microseconds per input. The data rate for the system as a whole is much faster to enable scanning of four acoustic receivers. This data rate thus enables the words to be interlaced as they are placed in memory in a specified sequence. As data words are placed in memory, they are aligned in memory in the same sequence. Thus, Fig. 2 shows the interlacing of words sequentially obtained from the several receivers and stored in memory in the interlaced fashion.

This system should be considered for operation over an interval in which several acoustic pulses are transmitted. Assume as an example that an acoustic pulse is transmitted, and that the acoustic receiver 28 is operated for 128 microseconds. The first 128 words into memory are all obtained from the transmitter. The next step (under the control system 46) involves multiplexer 38 to multiplex the N inputs. The N inputs are individually input and digitized as the scanning is repeated. The pattern of input words for the digital data buffer 48 is preserved in the buffer.

Assume that the total time frame of collecting data is 1,000 microseconds or one millisecond. In that instance, 1,000 data words are obtained. Fortunately, the spacing of the data samples from the four acoustic channels afford sufficient data

points to enable reconstruction of the analog signals at the time of data conversion. In any event, the buffer 48 stores 1,000 words. Assume further that the acoustic pulses will occur 500 milliseconds apart. If the logging tool is being raised in the borehole at a rate of 120 feet (36 m) per minute or 2 feet (0.6 m) per second, then spacing of 500 milliseconds enables data to be safely obtained approximately every foot (0.3 m). Recall that the data in the buffer was obtained over 1,000 microseconds or one millisecond. This data can then be transferred over a time interval less than about 490 milliseconds, a markedly slower rate of transfer. This slow rate enables the telemetry transmitter to obtain and transmit the data (1,000 data words) from the buffer to the surface. This data transfer occurs at such a slow rate that the pass band of the monocable imposes no particular limitation on the operation of the system. In fact, this slow rate of transfer of data is advantageous because it then enables the use of a monocable. The monocable is able to transmit this data through the telemetry transmitter in the sonde to the receiver at the surface without data degradation. The clarity and quality of data transfer is thus enhanced by the slow speed of transfer. While high speed transfer potentially could be had, the slow transfer is desirable to enable the use of the monocable.

Scale factors have been used above. Needless to say, they can be varied. For instance, the time duration of data capture can be shortened or lengthened. The sampling rate can also be shortened or lengthened. The number of data words can be varied so long as it does not exceed the capacity of the buffer 48. A typical buffer might hold perhaps 4K data words typically having an eight bit length. If needed, the memory can hold 16K or 32K data words. This is an adjustable factor which can be changed merely by placing a larger memory in the device. All of the data from logging thousands of feet (1 foot=0.3 m) of borehole, however, cannot simply be stored in memory. Rather, this apparatus enables the data to be stored momentarily in memory and transmitted by the transmitter 50 to the surface on the monocable at a time rate which is acceptable in light of the band pass of the monocable and the velocity of movement of the sonde 10 up the borehole.

Claims

1. For use in a well borehole to obtain multiple simultaneous data signals from N acoustic receivers carried by an elongated acoustic logging sonde sized and adapted for passage in the well borehole and suspended by a well logging cable having a single acoustic data conductor, the multiple simultaneous signals formed in response to a single acoustic energy pulse from an acoustic transmitter carried by the sonde, a data collection apparatus comprising:

(a) N acoustic receivers (30, 32, 34, 36) supported by, and longitudinally spaced along an

acoustic logging sonde (10) forming N time overlapping acoustic logging output signals from the receivers where N is an integer;

(b) first multiplexing means (38) having N inputs connected to the outputs of said N acoustic receivers;

(c) second multiplexing means (40) connected to said first multiplexing means;

(d) digital converter means (44) operating at a first rate and connected to said second multiplexing means for forming a time based series of digital words representative of the output signals of said N receivers;

(e) digital data buffer means (48) in said sonde and connected to said digital converter means for recording in a formatted order a series of digital words from said converter means;

(f) means for directing digital words from said digital converter means into specified addresses in said digital data buffer means;

(g) an acoustic transmitter monitor means (28) comprising an acoustic monitor located in the sonde connected to an acoustic transmitter located near one end of the sonde, to detect and form a signal representative of an acoustic pulse formed by the acoustic transmitter and transmitted by said acoustic transmitter, said monitor forming a signal input to said second multiplexing means;

(h) control means (46) connected to said first and second multiplexing means for controlling operation of said first and second multiplexing means to form a series of digital words representative of:

(1) the monitored transmitter pulses from said acoustic transmitter monitor, and

(2) the N acoustic logging output signals;

(i) timing means incorporated with said control means to time digitizing by said digital converter means to operate both said first and second multiplexing means to form:

(1) a first series of digital words representing the monitored transmitter pulses; and

(2) a second and later series of digital words representing the N acoustic logging output signals; and

(j) telemetry transmitting means (50) for telemetering the first and second series of digital words from said buffer means along the single acoustic data conductor in the cable at a second rate which rate is less than the first rate such that a single acoustic energy pulse from said acoustic transmitter generates N digital representations of the acoustic energy received at said N acoustic receivers corresponding to the arrival at each receiver of a single acoustic energy pulse.

2. A method of acoustic logging in a well borehole below a surface with an acoustic pulse transmitter on a sonde (10) supported by a cable wherein the cable has a single acoustic data signal conductor and N multiple acoustic receivers (30, 32, 34, 36) on the sonde to observe overlapping received acoustic signals, the method comprising the steps of:

(a) transmitting an acoustic pulse by a transmit-

points to enable reconstruction of the analog signals at the time of data conversion. In any event, the buffer 48 stores 1,000 words. Assume further that the acoustic pulses will occur 500 milliseconds apart. If the logging tool is being raised in the borehole at a rate of 120 feet (36 m) per minute or 2 feet (0.6 m) per second, then spacing of 500 milliseconds enables data to be safely obtained approximately every foot (0.3 m). Recall that the data in the buffer was obtained over 1,000 microseconds or one millisecond. This data can then be transferred over a time interval less than about 490 milliseconds, a markedly slower rate of transfer. This slow rate enables the telemetry transmitter to obtain and transmit the data (1,000 data words) from the buffer to the surface. This data transfer occurs at such a slow rate that the pass band of the monocable imposes no particular limitation on the operation of the system. In fact, this slow rate of transfer of data is advantageous because it then enables the use of a monocable. The monocable is able to transmit this data through the telemetry transmitter in the sonde to the receiver at the surface without data degradation. The clarity and quality of data transfer is thus enhanced by the slow speed of transfer. While high speed transfer potentially could be had, the slow transfer is desirable to enable the use of the monocable.

Scale factors have been used above. Needless to say, they can be varied. For instance, the time duration of data capture can be shortened or lengthened. The sampling rate can also be shortened or lengthened. The number of data words can be varied so long as it does not exceed the capacity of the buffer 48. A typical buffer might hold perhaps 4K data words typically having an eight bit length. If needed, the memory can hold 16K or 32K data words. This is an adjustable factor which can be changed merely by placing a larger memory in the device. All of the data from logging thousands of feet (1 foot=0.3 m) of borehole, however, cannot simply be stored in memory. Rather, this apparatus enables the data to be stored momentarily in memory and transmitted by the transmitter 50 to the surface on the monocable at a time rate which is acceptable in light of the band pass of the monocable and the velocity of movement of the sonde 10 up the borehole.

Claims

1. For use in a well borehole to obtain multiple simultaneous data signals from N acoustic receivers carried by an elongated acoustic logging sonde sized and adapted for passage in the well borehole and suspended by a well logging cable having a single acoustic data conductor, the multiple simultaneous signals formed in response to a single acoustic energy pulse from an acoustic transmitter carried by the sonde, a data collection apparatus comprising:

(a) N acoustic receivers (30, 32, 34, 36) supported by, and longitudinally spaced along an

acoustic logging sonde (10) forming N time overlapping acoustic logging output signals from the receivers where N is an integer;

(b) first multiplexing means (38) having N inputs connected to the outputs of said N acoustic receivers;

(c) second multiplexing means (40) connected to said first multiplexing means;

(d) digital converter means (44) operating at a first rate and connected to said second multiplexing means for forming a time based series of digital words representative of the output signals of said N receivers;

(e) digital data buffer means (48) in said sonde and connected to said digital converter means for recording in a formatted order a series of digital words from said converter means;

(f) means for directing digital words from said digital converter means into specified addresses in said digital data buffer means;

(g) an acoustic transmitter monitor means (28) comprising an acoustic monitor located in the sonde connected to an acoustic transmitter located near one end of the sonde, to detect and form a signal representative of an acoustic pulse formed by the acoustic transmitter and transmitted by said acoustic transmitter, said monitor forming a signal input to said second multiplexing means;

(h) control means (46) connected to said first and second multiplexing means for controlling operation of said first and second multiplexing means to form a series of digital words representative of:

(1) the monitored transmitter pulses from said acoustic transmitter monitor, and

(2) the N acoustic logging output signals;

(i) timing means incorporated with said control means to time digitizing by said digital converter means to operate both said first and second multiplexing means to form:

(1) a first series of digital words representing the monitored transmitter pulses; and

(2) a second and later series of digital words representing the N acoustic logging output signals; and

(j) telemetry transmitting means (50) for telemetering the first and second series of digital words from said buffer means along the single acoustic data conductor in the cable at a second rate which rate is less than the first rate such that a single acoustic energy pulse from said acoustic transmitter generates N digital representations of the acoustic energy received at said N acoustic receivers corresponding to the arrival at each receiver of a single acoustic energy pulse.

2. A method of acoustic logging in a well borehole below a surface with an acoustic pulse transmitter on a sonde (10) supported by a cable wherein the cable has a single acoustic data signal conductor and N multiple acoustic receivers (30, 32, 34, 36) on the sonde to observe overlapping received acoustic signals, the method comprising the steps of:

(a) transmitting an acoustic pulse by a transmit-



ter (26);

(b) forming a signal by monitoring the acoustic pulse transmitter during operation thereof;

(c) multiplexing and digitizing the formed signal for a first time interval beginning at time equals zero to form a series of digital words representing the acoustic pulse;

(d) storing the digital words in a memory in the sonde;

(e) listening for overlapping acoustic signals resulting from the transmitted acoustic pulse at N acoustic receivers along the well borehole and forming an analog signal from each of the N receivers;

(f) multiplexing the overlapping N received analog signals at first and second rates;

(g) digitizing the multiplexed N analog signals into a series of digital words encoding the N analog signals;

(h) storing the digital words encoding the N analog signals in a specified sequence in the memory; and

(i) telemetering from the sonde along the single acoustic data signal conductor along the cable supporting the sonde to the surface digital words in the memory representing the monitored acoustic transmitter pulse and the N received signals, wherein the telemetering rate is slower than the first rate.

3. A method according to claim 2, wherein the monitored signal from the acoustic transmitter is converted into digital words for a first time interval from time equals zero and thereafter digitizing only the N acoustic receiver signals for a second time interval.

4. A method according to claim 2, wherein digital words after the first interval are digital words from only the N acoustic receivers.

5. A method according to claim 2, wherein the digitizing forms of the digital words occurring during the first interval indicative of only the monitored acoustic transmitter signal.

6. A method according to claim 5, wherein digital words during the second interval are representative of only the received acoustic analog signal.

7. A method according to claim 2, wherein N is four; and the monitored acoustic transmitter signal is defined in the digital words telemetered from memory in the sonde to enable cross correlation of the data from the N_a acoustic receivers.

8. A method according to claim 7, wherein the step of multiplexing includes sequential scanning of N acoustic analog signals at a multiplexing scanning rate.

Patentansprüche

1. Vorrichtung zur Datenerfassung und zur Verwendung in einem Bohrloch, die vielfache Gleichzeitdatensignale von N Schallempfängern an einer langgestreckten Vermessungssonde erhält, welche zum Durchgang durch das Bohrloch bemessen und eingerichtet ist und an einem Bohrlochvermessungskabel mit einem einzigen

Leiter für akustische Daten hängt, und welche vielfachen Gleichzeitdatensignale infolge eines einzigen Schallenergiepulses von einem Schallsender an der Vermessungssonde gebildet werden, gekennzeichnet durch:

(a) N Schallempfänger (30, 32, 34, 36), die von einer akustischen Vermessungssonde (10) getragen und in Längsabständen daran angeordnet sind, welche Vermessungssonde N zeitlich überlappende akustische Vermessungs-Ausgangssignale an den Empfängern erzeugt, wobei N eine ganze Zahl ist;

(b) erste Multiplexermittel (38) mit N Eingängen, die an die Ausgänge der N Schallempfänger angeschlossen sind;

(c) zweite, mit den ersten verbundene Multiplexermittel (40);

(d) Digitalwandlermittel (44), die mit einer ersten Geschwindigkeit arbeiten und an die zweiten Multiplexermittel angeschlossen sind und die auf Zeitbasis eine Reihe von Digitalworten erzeugen, die den Ausgangssignalen der N Schallempfänger entsprechen;

(e) digitale Datenpuffermittel (48) in der Vermessungssonde, die an die Digitalwandlermittel angeschlossen sind und in formatierter Reihenfolge eine Reihe von Digitalworten aus den Digitalwandlermitteln aufzeichnen;

(f) Mittel, durch die Digitalworte aus den Digitalwandlermitteln bestimmten Adressen in den digitalen Datenpuffermitteln zugeführt werden;

(g) Überwachungsmittel (28) für den Schallsender, enthaltend einen Schallmonitor, der in der Vermessungssonde angeordnet und an einen Schallsender nahe einem Ende der Vermessungssonde angeschlossen ist, und welche Überwachungsmittel ein Signal, das dem von dem Schallsender gebildeten und ausgesendeten Schallenergiepuls entspricht, erfassen und erzeugen, wobei der Schallmonitor ein Signal erzeugt, das in die zweiten Multiplexermittel eingegeben wird;

(h) an die ersten und zweiten Multiplexermittel angeschlossene Steuermittel (46) zur Steuerung des Betriebs der ersten und zweiten Multiplexermittel für die Bildung einer Reihe von Digitalworten entsprechend

(1) den überwachten Senderpulsen aus den Überwachungsmitteln für den Schallsender und

(2) den N akustischen Vermessungs-Ausgangssignalen;

(i) Zeitgebermittel in den Steuermitteln für die Zeitsteuerung der Digitalisierung durch die Digitalwandlermittel zum Betrieb der ersten und zweiten Multiplexermittel für die Bildung von

(1) einer ersten Reihe von Digitalworten entsprechend den überwachten Senderpulsen und

(2) einer zweiten und späteren Reihe von Digitalworten entsprechend den N akustischen Vermessungs-Ausgangssignalen; und

(j) Fernübertragungsmittel (50) zur Fernübertragung der ersten und zweiten Reihen von Digitalworten aus den digitalen Datenpuffermitteln über den einzigen Leiter für akustische Daten in den Bohrlochvermessungskabel mit einer zweiten Geschwindigkeit, die geringer ist als die



erste Geschwindigkeit derart, daß ein einziger Schallenergiepuls des Schallsenders N digitale Darstellungen der Schallenergie erzeugt, die von den N Schallempfängern empfangen werden und der Ankunft eines einzigen Schallenergiepulses an jedem Schallempfänger entsprechen.

2. Verfahren zur akustischen Vermessung eines Bohrlochs unterhalb einer Fläche mit einem Schallpulssender an einer Sonde (10) an einem Kabel, das einen einzigen Leiter für akustische Datensignale enthält, und mit einer Vielzahl von N Schallempfängern (30, 32, 34, 36) in der Sonde zur Beobachtung überlappender, empfangener akustischer Signale, gekennzeichnet durch die Schritte:

(a) Aussenden eines Schallpulses durch einen Sender (26);

(b) Bilden eines Signals durch Überwachen des Schallpulssenders während dessen Betrieb;

(c) Multiplexen und Digitalisieren des gebildeten Signals während eines ersten Zeitintervalls, das zum Zeitpunkt $t=0$ beginnt, zur Bildung einer Reihe von Digitalworten, die den Schallpuls darstellen;

(d) Speichern der Digitalworte in einem Speicher in der Sonde;

(e) Abhören überlappender akustischer Signale, die sich aus dem ausgesandten Schallpuls an N Schallempfängern entlang dem Bohrloch ergeben, und Bilden eines Analogsignals durch jeden der N Schallempfänger;

(f) Multiplexen der überlappenden und empfangenen N Analogsignale mit ersten und zweiten Geschwindigkeiten;

(g) Digitalisieren der multiplexierten N Analogsignale zu einer Reihe von die N Analogsignale kodierenden Digitalworten;

(h) Abspeichern der die N Analogsignale kodierenden Digitalworte in einer bestimmten Sequenz in dem Speicher; und

(i) Fernübertragungen der Digitalworte, die in dem Speicher den überwachten Schallsenderpuls und die N empfangenen Signale darstellen, aus der Sonde zu der Oberfläche entlang dem einzigen Leiter für akustische Datensignale entlang dem die Sonde tragenden Kabel, wobei der Fernübertragungsgeschwindigkeit geringer als die erste Geschwindigkeit ist.

3. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß das überwachte Signal des Schallsenders während eines ersten Zeitintervalls vom Zeitpunkt $t=0$ in Digitalworte gewandelt wird und danach während eines zweiten Zeitintervalls nur die N Schallempfängersignale digitalisiert werden.

4. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Digitalworte nach dem erste Zeitintervall Digitalworte allein von den N Schallempfängern sind.

5. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß die Digitalisierung während des ersten Zeitintervalls nur Digitalworte entsprechend dem überwachten Schallsendersignal erzeugt.

6. Verfahren nach Anspruch 5, dadurch gekennzeichnet,

daß die Digitalworte während des zweiten Zeitintervalls nur den empfangenen akustischen Analogsignalen entsprechen.

7. Verfahren nach Anspruch 2, dadurch gekennzeichnet, daß N gleich 4 ist und daß das überwachte Schallsendersignal in den Digitalworten definiert ist, die vom Speicher in der Sonde fernübertragen werden und eine Kreuzkorrelation mit den Daten von den N Schallempfängern ermöglichen.

8. Verfahren nach Anspruch 7, dadurch gekennzeichnet, daß während des Multiplexens N akustische Analogsignale nacheinander mit einer Multiplex-Abtastrate abgetastet werden.

Revendications

1. Appareil de collecte de données destiné à être utilisé dans un puits de forage pour obtenir des signaux multiples de données simultanés provenant de N récepteurs acoustiques supportés par une sonde d'exploitation acoustique allongée, dimensionnée et agencée pour passer dans le puits de forage et suspendue par un câble d'exploitation de puits contenant un seul conducteur de données acoustiques, les signaux simultanés multiples formés en réponse à une seule impulsion d'énergie acoustique provenant d'un émetteur acoustique supporté par la sonde, appareil de collectage de données comportant:

(a) N récepteurs acoustiques (30, 32, 34, 36) supportés par une sonde acoustique d'exploitation (10) et espacés dans sa direction longitudinale, formant N signaux de sortie d'exploitation acoustique se chevauchant dans le temps provenant des récepteurs, où N est un nombre entier;

(b) des premiers moyens de multiplexage (38) comprenant N entrées connectées aux sorties des N récepteurs acoustiques;

(c) des seconds moyens de multiplexage (40) connectés auxdits premiers moyens de multiplexage;

(d) des moyens de conversion numérique (44) fonctionnant à une première vitesse et connectés auxdits seconds moyens de multiplexage pour former une série liée à une base de temps de mots numériques représentant les signaux de sortie desdits N récepteurs;

(e) des moyens de tampon de données numériques (48) dans ladite sonde et connectés auxdits moyens de conversion numérique pour enregistrer dans un ordre mis en format une série de mots numériques provenant desdits moyens de conversion;

(f) des moyens pour diriger des mots numériques provenant desdits moyens de conversion numérique dans des adresses spécifiées desdits moyens de tampon de données numériques;

(g) des moyens de contrôle d'émission acoustique (28) comprenant un contrôleur acoustique situé dans la sonde, connecté à un émetteur acoustique situé près d'une extrémité de la sonde pour détecter et pour former un signal représentant une impulsion acoustique formée par l'émetteur acoustique et émise par ledit émetteur acous-



tique, ledit contrôleur formant un signal appliqué auxdits seconds moyens de multiplexage;

(h) des moyens de commande (46) connectés auxdits premiers et seconds moyens de multiplexage pour commander le fonctionnement desdits premiers et seconds moyens de multiplexage de manière à former une série de mots numériques représentant:

(1) les impulsions d'émetteur contrôlées provenant dudit contrôleur d'émission acoustique, et

(2) les N signaux de sortie acoustique d'exploitation;

(i) des moyens de temporisation incorporés dans lesdits moyens de commande pour temporiser la numérisation par lesdits moyens de conversion numérique de manière à faire fonctionner lesdits premiers et lesdits seconds moyens de multiplexage pour former:

(1) une première série de mots numériques représentant les impulsions de contrôle d'émission; et

(2) une seconde série qui suit de mots numériques représentant les N signaux acoustiques de signaux d'exploitation; et

(j) des moyens d'émission de télémétrie (50) destinés à la télémétrie de la première et de la seconde séries de mots numériques provenant desdits moyens de tampon pour le seul conducteur de données acoustiques dans le câble à une seconde vitesse, cette vitesse étant inférieure à la première vitesse de manière qu'une seule impulsion d'énergie acoustique provenant dudit émetteur acoustique produise N représentations numériques de l'énergie acoustique reçue aux N récepteurs acoustiques correspondant à l'arrivée à chaque récepteur d'une seule impulsion d'énergie acoustique.

2. Procédé d'exploitation acoustique dans un puits de forage au-dessous d'une surface avec un émetteur d'impulsions acoustiques sur une sonde (10) supportée par un câble, dans lequel le câble comporte un seul conducteur de signaux de données acoustiques et N récepteurs acoustiques multiples (30, 32, 34, 36) sur la sonde pour observer des signaux acoustiques reçus se chevauchant, le procédé consistant:

(a) à émettre une impulsion acoustique par un émetteur (26);

(b) à former un signal en contrôlant l'émetteur d'impulsions acoustiques pendant son fonctionnement;

(c) à multiplexer et à numériser le signal mis en format pendant un intervalle de temps qui commence à un instant égal à zéro pour former une série de mots numériques représentant l'impulsion acoustique;

(d) à mémoriser les mots numériques dans une mémoire dans la sonde;

(e) à établir une liste des signaux acoustiques se chevauchant résultant de l'impulsion acoustique émise à N récepteurs acoustiques le long du puits de forage et à former un signal analogique à partir de chacun des N récepteurs;

(f) à multiplexer les N signaux analogiques reçus se chevauchant à une première et une seconde vitesses;

(g) à numériser les N signaux analogiques multiplexés en une série de mots numériques codant les N signaux analogiques;

(h) à mémoriser les mots numériques codant les N signaux analogiques dans une séquence spécifiée, dans la mémoire; et

(i) à effectuer une télémétrie à partir de la sonde le long du seul conducteur de signaux de données acoustiques le long du câble supportant la sonde des mots numériques en surface dans la mémoire représentant l'impulsion de contrôle d'émission acoustique et les N signaux reçus, dans lequel la vitesse de télémétrie est inférieure à la première vitesse.

3. Procédé selon la revendication 2, dans lequel le signal contrôle provenant de l'émetteur acoustique est converti en des mots numériques pendant un premier intervalle de temps à partir d'un temps égal à zéro et à numériser ensuite seulement les N signaux de récepteurs acoustiques pendant un second intervalle de temps.

4. Procédé selon la revendication 2, dans lequel des mots numériques après le premier intervalle sont des mots numériques provenant seulement des N récepteurs acoustiques.

5. Procédé selon la revendication 2, dans lequel les formes numérisées des mots numériques apparaissant pendant le premier intervalle indiquant seulement le signal d'émetteur acoustique contrôlé.

6. Procédé selon la revendication 5, dans lequel les mots numériques pendant le second intervalle ne représentent que le signal analogique acoustique reçu.

7. Procédé selon la revendication 2, dans lequel N est égal à quatre; et le signal d'émetteur acoustique contrôle est défini dans les mots numériques télémétrés provenant de la mémoire de la sonde pour permettre une corrélation croisée des données provenant des N récepteurs acoustiques.

8. Procédé selon la revendication 7, dans lequel l'opération de multiplexage consiste à explorer séquentiellement N signaux analogiques acoustiques à une fréquence d'exploration de multiplexage.

