United States Patent [19]

Foster et al.

[11] **3,742,443**

[45] **June 26, 1973**

[54] **APPARATUS FOR IMPROVING SIGNAL-TO-NOISE RATIO IN LOGGING-WHILE-DRILLING SYSTEM**

[75] Inventors: **Manus R. Foster**, Irving; **Bobbie J. Patton**, Dallas, both of Tex.

[73] Assignee: **Mobil Oil Corporation**, New York, N.Y.

[22] Filed: **July 27, 1970**

[21] Appl. No.: **58,378**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 884,441, Dec. 12, 1969, abandoned.

[52] **U.S. Cl.**..... **340/18 LD**, 181/0.5 AP, 181/0.5 F, 340/18 NC

[51] **Int. Cl.**..... **G01v 1/00**

[58] **Field of Search**..... 340/18 LD, 18 P, 340/18 NC; 181/0.5 F, 0.5 R, 0.5 AP

[56] **References Cited**

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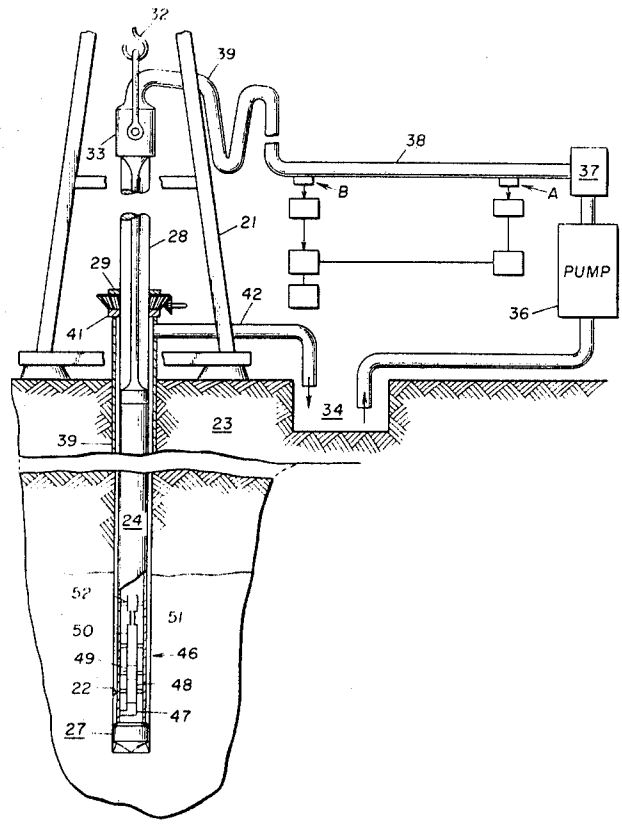
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Primary Examiner—Benjamin A. Borchelt
Assistant Examiner—H. A. Birmiel
Attorney—William J. Scherback, Frederick E. Dumoulin, Drude Faulconer, Andrew L. Gaboriault and Sidney A. Johnson

[57] **ABSTRACT**

The specification discloses a method and apparatus for substantially reducing the uphole noise in a logging-while-drilling system wherein a signal representative of a downhole parameter is generated down a well and is transmitted to the surface in the form of an acoustical wave in the drilling fluid, e.g., mud. Two spaced transducers measure the acoustical pressure at two points in the mudline between the pumps and the well and convert these pressures to corresponding signals. One of these signals is time shifted an amount equal to the travel time of sound in the mud between the two transducers and, after one of these signals has had its polarity reversed, the two signals are added to reduce the uphole noise substantially. By filtering one of the pressure measurement signals with a filter having characteristics related to the distortion of the flow path between the two spaced transducers, noise is further reduced. The combined signals are further filtered with a Wiener type filter which best recovers the signal.

12 Claims, 5 Drawing Figures



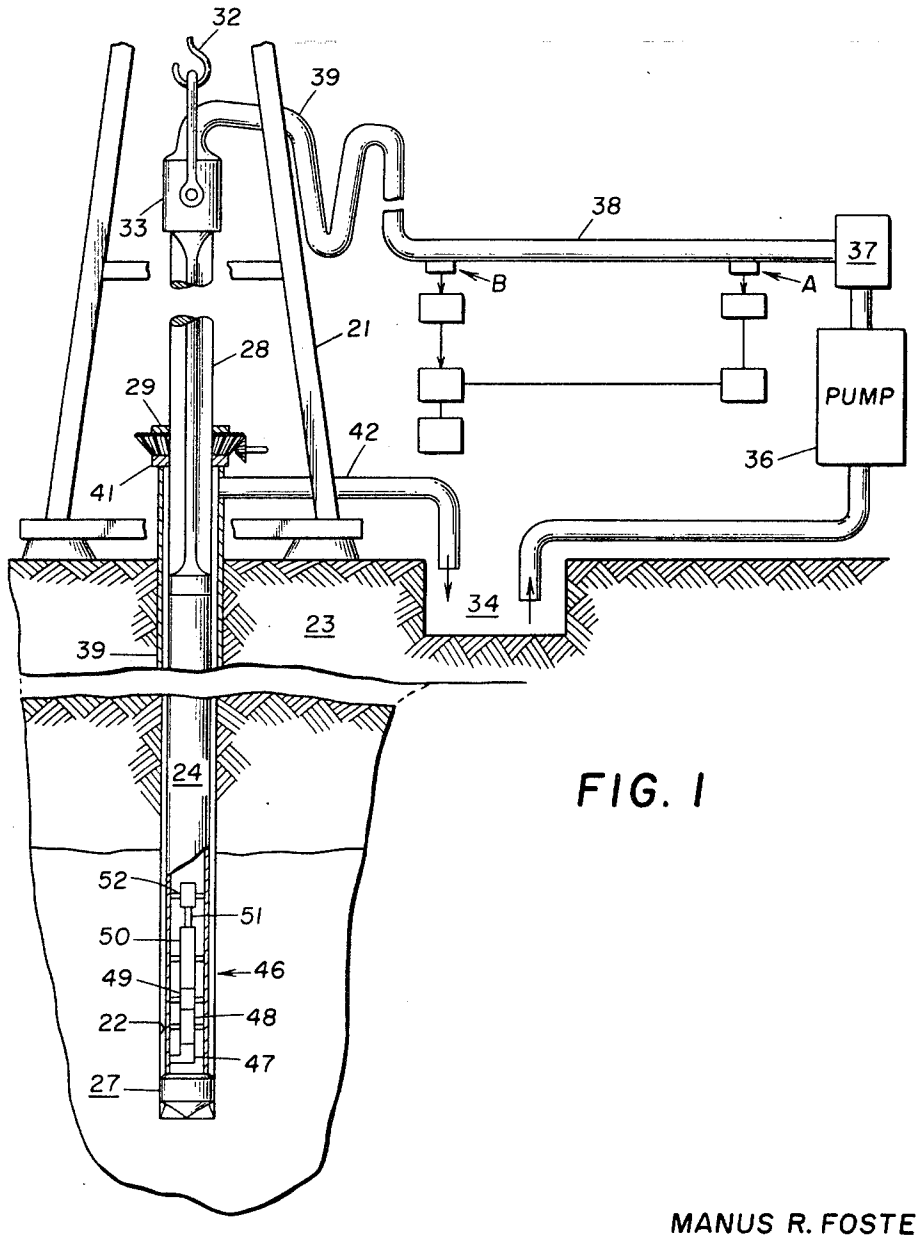


FIG. 1

MANUS R. FOSTER
BOBBIE J. PATTON
INVENTORS

BY Drude Faulconer
ATTORNEY

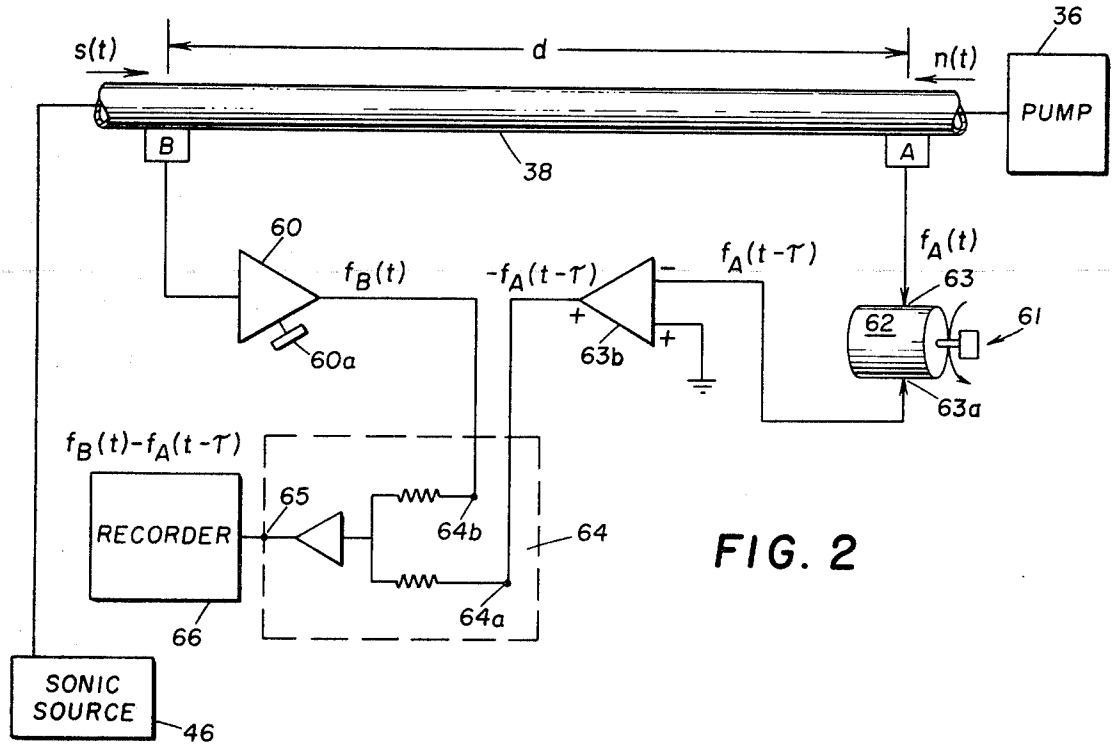


FIG. 2

FIG. 3

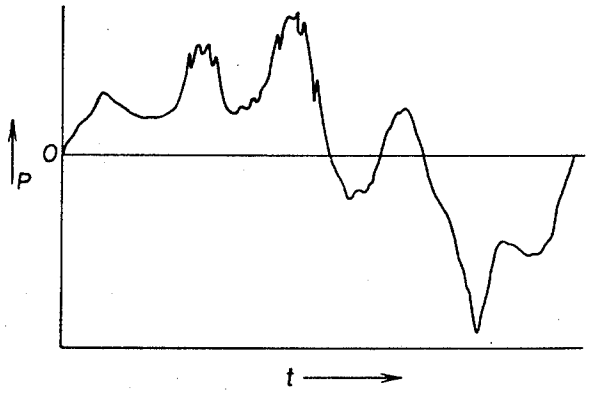
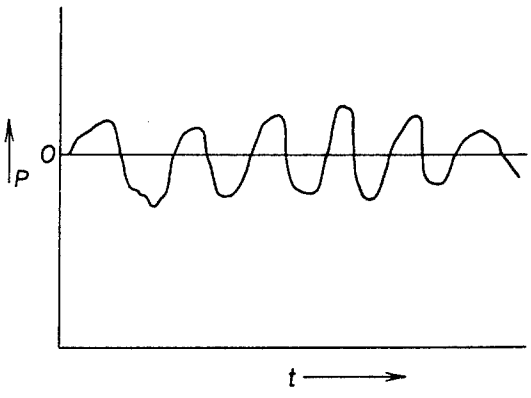


FIG. 4



MANUS R. FOSTER
BOBBIE J. PATTON
INVENTORS

BY Drude Faulconer
ATTORNEY

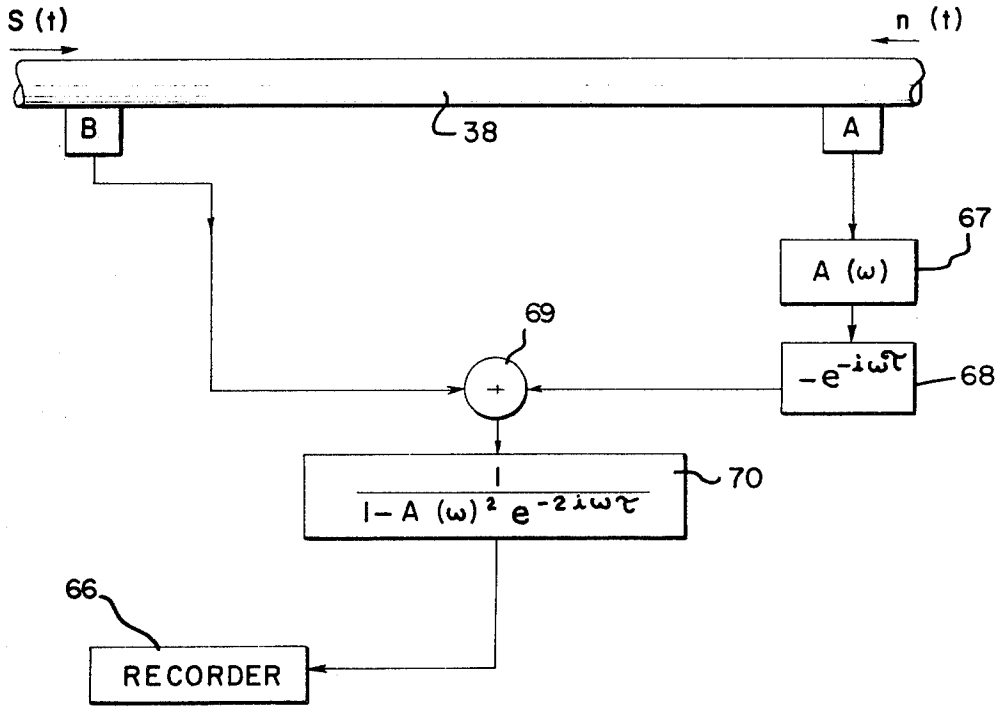


Fig. 5

MANUS R. FOSTER
BOBBIE J. PATTON
INVENTORS

APPARATUS FOR IMPROVING SIGNAL-TO-NOISE RATIO IN LOGGING-WHILE-DRILLING SYSTEM

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation in part of application Ser. No. 884,441, filed Dec. 12, 1969, now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to telemetry of signals in a fluid system and more particularly relates to a method and apparatus for reducing certain uphole noise from a downhole signal in a logging-while-drilling system.

The desirability of a system which is able to measure downhole drilling parameters and/or formation characteristics and transmit them to the surface while actual drilling is being carried out has long been recognized. Several such systems have been proposed and are commonly referred to as "logging-while-drilling" systems. In logging-while-drilling systems, one of the major problems exists in finding a means for telemetering the information concerning the desired parameter from a downhole location to the surface and have it arrive in a meaningful condition.

In this regard, it has been proposed to telemeter the desired information by means of a continuous pressure wave signal generated in and carried through the mud system normally associated with rotary drilling operations. The pressure wave signal which is representative of a particular parameter is generated in the mud near the bit by a generating means and the wave travels up the hole through the mud to a signal detector at the surface. One logging-while-drilling system utilizing this technique of telemetry is disclosed in U.S. Pat. No. 3,309,656 to John K. Godbey, issued Mar. 14, 1967.

However, systems utilizing the circulating mud as a medium for telemetry have obvious difficulties in that any extraneous vibrations, shocks, etc. of the drilling equipment or the like normally impart unwanted pressure waves or "noise" to the mud which may seriously distort the desired signal being transmitted in the mud at that time. This noise may be generally classified as either downhole noise, i.e., noise traveling upward from its downhole source, or uphole noise, i.e., noise traveling downward from its uphole source. Both "uphole" and "downhole" noises in the mud affect a signal being transmitted through the mud and both must be considered in the final processing of the signal. The present invention involves the treatment of a transmitted signal to remove or reduce the uphole noise therefrom.

Filtering to separate signals from noise has become a widely used technique. The Wiener optimum filter theory has been used in the recovery of seismic signals for example "Design of Suboptimum Filter Systems for Multitrace Seismic Data Processing," Foster, Sengbush and Watson, *Geophysical Prospecting*, Vol. XII, No. 2, 1964, pages 173–191, discusses optimum filtering for seismic signals in which there is no distortion in the propagation path. U.S. Pat. No. 3,275,980 Foster discusses a well logging problem involving a special form of distortion. The present invention involves the filtering of logging while drilling signals in a manner similar to that discussed in these references.

SUMMARY OF THE INVENTION

The present invention provides a method and apparatus for eliminating or substantially reducing distortion in a downhole signal being transmitted in the drilling mud in a logging-while-drilling system where the distortion is due to noise generated by uphole equipment, e.g., surges in the mud due to the mud pumps. In carrying out the present invention, two transducers are spaced along the line leading from the mud pumps to the swivel of a normal drilling rig. Each of the transducers measures the pressure of the mud in the line at that particular point and converts the pressure to a corresponding signal. One signal is then time shifted with respect to the other signal by a time equal to that required for the signal to travel through the mudline from the one transducer to the other. It should be recognized that the signal being measured at each transducer is both the desired signal coming from downhole and the noise generated by the uphole equipment upstream of the transducers. Normally, there will be downhole noise in the desired signal but since the present invention is not directed to the treatment of downhole noise, this noise will be considered as part of the desired signal.

The time-shifted signal is then inverted to reverse its polarity or to effectively change its sign and is then added to the other signal. The summed signal remaining after the addition of the two signals effectively cancels the noise and leaves two signal components each representative of the desired signal with one component time shifted from the other. The summed signal is recorded for further processing, the latter forming no part of the present invention. In accordance with one aspect of the present invention, the spacing of the transducers is such that after the signals are added, the two remaining signal components are in phase so the resulting signal is representative of twice the amplitude of the desired signal.

In accordance with another aspect of this invention compensation is made for the distortion which is present in the flow path between the two transducers. In order to do this one of the pressure measurement signals is filtered with a filter having characteristics related to this distortion. Then, when the two signals are added, a better cancellation of noise is obtained because both signals have been distorted in the same manner. That is, one is distorted by the distortion present in the system and the other is artificially distorted by the filter.

In carrying out the invention, individual filters, one related to the distortion in the flow path between the two transducers and one producing the required time shift, are applied to the two signals. In accordance with another aspect of this invention, the two individual filters just referred to are especially simple. This is accomplished by filtering the combined signal with a third filter which recovers the desired signal.

The actual construction, operation, and apparent advantages of the invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a rotary drilling apparatus including a logging-while-drilling system in which the present invention is utilized;

FIG. 2 is an enlarged and more detailed view of the present invention as applied in FIG. 1;

FIGS. 3 and 4 depict idealized waveforms helpful in the understanding of the present invention and

FIG. 5 depicts an improved filtering arrangement.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to the drawings, FIG. 1 discloses the present invention in connection with rotary drilling apparatus having a logging-while-drilling system incorporated therein. A derrick 21 is disposed over a well 22 being formed in the earth 23 by rotary drilling. A drill string 24 is suspended within the well and has a drill bit 27 at its lower end and a kelly 28 at its upper end. A rotary table 29 cooperates with kelly 28 to rotate string 24 and bit 27. A swivel 33 is attached to the upper end of kelly 28 which in turn is supported by hook 32 from a traveling block (not shown). This arrangement not only supports the drill string 24 in an operable position within well 22 but also forms a rotary connection between the source of circulating drilling fluid, such as mud, and the drill string 24. It should be understood that "mud" as used throughout this disclosure is intended to cover those fluids normally used in rotary drilling operations.

The pump 36 transfers drilling mud from a source such as pit 34 through desurger 37 into mudline 38. Desurger 37 is adapted to reduce the pulsating effect of pump 36 as is well known in the art. The mud flows through mudline 38, flexible hose 39, swivel 33, drill string 24, and exits through openings (not shown) in drill bit 27 to pass outwardly into well 22. The mud then circulates upward carrying drill cuttings with it through the annulus between the well and drill string 24 to the surface of the earth 23. At the surface, well head 41 is secured to casing 39 which is cemented in the well 22. Pipe 42 is connected to casing 39 for returning the mud to pit 34.

As schematically illustrated in FIG. 1, a logging and signal generating means 46 is located in the lower end of drill string 24 near bit 27. Means 46 is preferably of the type fully disclosed and described in U.S. Pat. No. 3,309,656 to John K. Godbey, but it should be understood that means 46 could be of any type which senses a downhole condition and generates a signal representative of that condition, be it analog or digital. Since the details of means 46 form no part of the present invention, only a brief description of means 46 will be set forth.

Transducer means, shown schematically at 47, senses a downhole condition, e.g., differential pressure across bit 27, and converts it to a corresponding electrical signal. This electrical signal in turn is applied to control circuitry 48 which allows current from electric power source 49 to drive variable speed motor 50 at a speed determined by the value of the electrical signal. Motor 50 is coupled to rotary valve 52 by shaft 51 so valve 52 will rotate at a set speed determined by the speed of motor 50. Valve 52 will interrupt flow of mud therethrough in such a manner that a pressure wave signal representative of the sensed condition will be generated in the mud. This signal then travels up through the mud in drill string 24 and is detected at the surface. For a more complete description of both the construction and operation of the described means 46, reference should be made to above-mentioned U.S. Pat. No. 3,309,656. Again, it is pointed out that the above description of means 46 is for illustrative purposes only and other types of sensing and signal generating means could be used in the present invention without departing therefrom.

In a system such as described above, difficulties in telemetering a meaningful signal from the downhole generating means to the surface occur due to "noise" normally present in the circulating fluid. This noise results from unwanted vibrations imparted to the mud from both downhole and uphole sources. Since the present invention is directed to the reduction of uphole noise, any downhole noise that may be present will be considered as part of the desired downhole signal in the present description.

Referring now to FIGS. 1 and 2, in accordance with the present invention, two transducers A and B are spaced from each other along mudline 38 at a distance d. It should be recognized that the length d of mudline 38 should be as smooth as possible to reduce friction loss and should be free of right angle turns and obstructions which may distort the measured signal in the mud as it passes between A and B. Transducer A, which may be of any commercially available type, measures the pressure in the mud at that point in mudline 38 and converts this pressure into a corresponding electrical signal which can be expressed as a function of a reference time t or as $f_A(t)$. Transducer B which is of the same type as transducer A also measures the pressure in the mud at B's position and converts it into a signal that can be expressed as $f_B(t)$ if the outputs of the two transducers are matched. If they are not matched, as is most often the case, the signal from transducer B is fed through an equalizing circuitry means such as an amplifier 60 having a gain control represented by knob 60a. The outputs of the two transducers may be matched by flowing a known fluid through mudline 38 and generating a known signal therein and then matching the signal from one transducer to the signal received from the other by adjusting the gain control on amplifier 60. After the outputs of the two transducers are matched, the uphole noise, $n(t)$, can be substantially reduced as follows.

Using transducer B as a reference point, the signal $f_B(t)$ at B after it has been equalized through amplifier 60, will be equal to the uphole noise at time t plus the downhole signal at time t, the latter being what is wished to be recovered. This relationship may be expressed as:

$$f_B(t) = s(t) + n(t) \tag{1}$$

where:

$s(t)$ = desired downhole signal at time t,

$n(t)$ = uphole noise at time t.

The signal $f_A(t)$ at transducer A, will have the same components, i.e., downhole signal plus uphole noise, but both components will vary as a function of time. The downhole signal, $s(t)$, at A has to travel a distance d from B before it is received at A while the uphole noise, $n(t)$, is received at A at a time before it is received at B. The actual time involved may be expressed as d/V where V is the velocity of sound in the particular mud present in mudline 38. Therefore, the signal $f_A(t)$, remembering that B is the reference point, may be expressed as:

$$f_A(t) = s(t - d/V) + n(t + d/V). \tag{2}$$

To align $f_A(t)$ and $f_B(t)$, $f_A(t)$ is applied to a time shift means **61** to shift the signal $f_A(t)$ for a time $-\tau$. Means **61** has been schematically illustrated as a rotating magnetic recording drum **62** on which the recording head **63** is spaced from the readout head **63***a* so that the output may be delayed from the input by the desired time τ. Other means may be used for delaying or time shifting $f_A(t)$, e.g., electrical delay lines (if delays are short enough) or digital computers, where $f_A(t)$ is digitized and the output of the computer lags the input by the desired time τ. The signal, $f_A(t)$, after it has been time shifted a value of $-\tau$, will appear as:

$$f_A(t-\tau) = s(t - d/V - \tau) + n(t + d/V - \tau) \ . \tag{3}$$

This signal is then applied to a polarity reversing network means **63***b*, e.g., voltage amplifier having a gain of one, to effectively reverse its sign. This inverted signal is then applied to input **64***a* of summing circuitry means **64.** Signal $f_B(t)$ is applied to input **64***b* of means **64** and the resulting summed signal is taken from output **65** of means **64.** This summed signal may be expressed as:

$$f_B(t) - f_A(t-\tau) = s(t) + n(t) - s(t - d/V - \tau) - n(t + d/V - \tau) \tag{4}$$

By design, the time shift τ is chosen to equal the time of travel for a signal across d or d/V. Various techniques can be used to find the value of τ which is equal to d/V. The travel time between detectors can be measured for the immediate conditions giving τ directly. Also by knowing d from direct measurement and either calculating V from mud properties or measuring V, d/V can be calculated. Substituting τ for d/V in equation (4) and simplifying, the uphole noise signal, $n(t)$, drops out or is effectively canceled and there remains:

$$f_B(t) - f_A(t-\tau) = s(t) - s(t - 2\tau \ ). \tag{5}$$

Two signal components remain, $s(t)$ and a time shifted signal $-s(t-2\tau)$, which may be recorded on recording means **66** or directed to other circuitry (not shown) for further processing. It should be recognized that there may be several methods of processing these components to retrieve $s(t)$ but these methods form no part of the present invention since the present invention is directed to the reduction of uphole noise which is accomplished when the summed signal is obtained at output **65** of summing means **64.** However, in accordance with one aspect of the present invention, the required processing of the summed signal may be simplified.

In logging-while-drilling systems such as described above, the transmitted signal is a sinusoid which makes the component $-s(t-2\tau)$ the same as component $s(t)$ with a phase shift determined by both the time shift -2τ and the minus sign. If the length d of mudline **38** is selected to equal $\lambda/4$ where λ is the wavelength of the signal, the 2τ shift is a phase shift of approximately 180° and the minus sign is another 180°, making component $-s(t-2\tau)$ approximately in phase with $s(t)$. Consequently, $s(t) - s(t-2\tau) \approx 2s(t)$ for the range of frequencies for which d is approximately a quarter wavelength.

As stated above, the present invention is directed to substantially reducing the uphole noise which occurs in the drilling fluid on the pump side of transducer A. This invention is unconcerned with noise which occurs in the drilling fluid on the downhole side of transducer B and treats it as part of the signal being transmitted from a downhole location. FIG. 3 discloses an idealized signal waveform as it might look at either of the two transducers A or B. This signal at either A or B would be comprised of both the downhole signal and the uphole noise. The waveform in FIG. 4 represents an idealized waveform which would theoretically represent the downhole signal having little or no uphole noise after the downhole signal was processed in accordance with the present invention. This signal represented in FIG. 4 may still need to be processed further to retrieve the actual signal being transmitted by the downhole logging means. However, it should be evident by eliminating or substantially reducing the uphole noise, especially that caused by pump **36,** that the present invention provides a much improved signal for such further processing.

The foregoing was a description of what may be considered a specialized case. There will now be presented a more generalized description of the invention. Note that in the foregoing description both signal and noise were referenced to transducer B. In the following description it is more convenient to reference the signal to transducer B and the noise to transducer A.

In what has been previously discussed, it was assumed that there was no distortion between the transducers A and B. In actual practice there will be distortion. Because of this distortion, the cancellation of the noise when the two signals are summed is not as good as it might otherwise be. In accordance with an important aspect of this invention, the distortion in the mudline **38** is compensated by filtering one of the pressure measurement signals with a filter having characteristics related to the distortion of the flow path between the transducers A and B. Then, when the one pressure measurement signal is added to the other pressure measurement signal a more complete cancellation of noise is obtained.

Referring to FIG. **5,** the output of the transducer A is shown being applied to the filter **67** and the output of this filter is applied to the filter **68.** The filter **68** performs the time shifting function previously described with reference to the magnetic drum **62** in FIG. **2.** As is well understood by those skilled in the art of digital filtering, the time shifting is described by the function $e^{-i\omega\tau}$ where e is the Naperian logarithm base, i is the imaginary number $\sqrt{-1}$, ω is the frequency of the desired acoustic signal and τ is the travel time of sound between the transducers A and B.

The signal and noise traveling through the mudline **38** is between transducers A and B are further distorted by the characteristics of the mudline. The nature of this distortion is easily determined. For example, a theoretical calculation of the distortion can be made from the known diameter and length of the pipe and the known acoustical transmission properties of the fluid. Alternatively, an experimental determination of the distortion can be made by applying a controlled frequency acoustical signal to the pipe and observing the amplitude shift and phase shift of the signal after travel through the pipe. The characteristics of this distortion are de-

noted A(ω). As indicated by the filter **67** in FIG. **5**, the output from the transducer A is filtered to introduce this distortion into that output. Again, those familiar with the principles of digital filtering will understand the manner in which the output from the transducer A is filtered to produce this result. Since the same distortion A(ω) has been introduced into the output from transducer A by the filter **67** and into the output from the transducer B by travel through the mudline **38**, the two output when added, as indicated at **69**, will produce a better cancellation of noise.

In accordance with an important aspect of this invention, filters **67** and **58** are extremely simple filters. However, it is apparent that filtering in this manner introduces a further processing type of distortion into the combined signal. In order to remove this, the summation signal is applied to a further filter **70**.

The filter **70** has the characteristics

$$\frac{1}{1-A(\omega)^2 e^{-2i\omega\tau}}$$

Filtering in this manner results in the optimum retrieval of signal from noise and also allows filtering with relatively simple filters. That the filter **70** does remove the processing distortion can be shown by the following mathematical description of the processes involved.

Consider first the time domain. The output at transducer A is given by:

$$F_A(t) = a(t) * s(t-\tau) + n(t) \tag{1}$$

In the foregoing, a(t) is the time domain representation of the distortion introduced by the mudline **38**. That is, $a(t)$ is the time domain transform of A(Ω). The asterisk sign (*) indicates convolution or filtering as is conventional. As described by equation (1) the signal $s(t)$ delayed by an amount τ by travel through the pipe **38** is further distorted by filtering with the distortion filter $a(t)$.

The output at the transducer B is given by:

$$F_B(t) = s(t) + a(t) * n(t-\tau) \tag{2}$$

In Equation (2) it is the noise $n(t)$ which has been delayed by τ and distorted by filtering with the distortion $a(t)$. When the output of the transducer A is filtered by the filter **67**, the resultant signal is described by:

$$F_A(t) * a(t) = a(t) * a(t) * s(t-\tau) + a(t) * n(t) \tag{3}$$

When the signal at transducer A is further filtered with the filter **68**, the result is described as:

$$F_A * a(t) * (-e^{-i\omega\tau}) = -a(t) * a(t) * s(t-2\tau) - a(t) * n(t-\tau) \tag{4}$$

The summation, that is, the signal produced at the output of summer **69**, is given by:

$$F_B(t) + F_A(t) * a(t) * (-e^{-i\omega\tau}) = s(t) - a(t) * a(t) * s(t-2\tau) \tag{5}$$

This can be rewritten as:

$$F_B(t) + F_A(t) * a(t) * (-e^{-i\omega\tau}) = [1 - a(t) * a(t) * (e^{-2i\omega\tau})] * s(t) \tag{6}$$

In the foregoing $[e^{-i\omega\tau} * s(t)]$ is merely the desired signal with a phase shift τ. The expression $1 - a(t) * a(t) * (e^{-2i\omega\tau})$ is the distortion which must be removed by the filter **70**. The frequency domain transform of the distortion filter is

$$1 - A(\omega)^2 e^{-2i\omega\tau} \tag{7}$$

Therefore the filter **70** has the inverse of the characteristics defined in Equation (7) in order to remove this distortion.

What is claimed is:

1. A method of substantially reducing uphole noise from a downhole signal in a logging-while-drilling system where said downhole signal is in the form of acoustical waves being transmitted in the drilling fluid of said system, said method comprising:

measuring the acoustical pressure in the drilling fluid at a first point and at a second point, respectively, and converting both pressure measurements to corresponding electrical pressure measurement signals, said first and second points being spaced from each other along the drilling fluid path between a source of drilling fluid and a well in which said downhole signal is originating;

filtering one of said electrical pressure measurement signals with a filter A(ω) having characteristics related to the distortion of the flow path between said two spaced points;

time shifting said one of the electrical pressure measurement signals by an amount corresponding with the travel time of sound in said drilling fluid from one of said points to the other; and

combining said time-shifted, electrical pressure measurement signal with the other said electrical pressure measurement signal to reduce substantially the uphole noise therein.

2. The method of claim **1** wherein the step of combining said electrical pressure measurement signals to reduce said accoustical noise substantially includes:

generating an output signal representative of the difference between said time-shifted, electrical pressure measurement signal and said other electrical pressure measurement signal.

3. The method of claim **1** wherein the step of combining said electrical pressure measurement signals to reduce said acoustical noise substantially includes:

reversing the polarity of said time-shifted, electrical pressure measurement signal; and

adding said polarity-reversed and time-shifted, electrical pressure measurement signal and said other electrical pressure measurement signal.

4. The method set forth in claim **1** wherein:
said first and second points are spaced from each other at a distance approximately equal to a quarter wavelength of the sound wave in the drilling fluid.

5. The method recited in claim **1** wherein said time shifting step is carried out by:
filtering said one electrical pressure measurement signal with a filter $-e^{-i\omega\tau}$ where:
ω is the frequency of the desired acoustic signal, and
τ is the travel time of sound between said two spaced points.

6. The method recited in claim **5** further comprising:
filtering the combined pressure measurement signals with a filter

$$\frac{1}{1-A(\omega)^2e^{-2i\omega\tau}}$$

7. In a logging-while-drilling system wherein a downhole signal representative of a downhole parameter is transmitted to the surface in the form of an acoustical wave in the drilling fluid of the system, apparatus for substantially reducing the uphole noise from said downhole signal comprising:
conduit means for conducting drilling fluid from a source to the well in which the downhole signal is originating;
a first transducer means at a first point on said conduit means for measuring the acoustical pressure at said first point and for converting said pressure into a corresponding electrical pressure measurement signal;
a second transducer means at a second point on said conduit means, spaced from said first point, for measuring said acoustical pressure at said second point and for converting said pressure into a corresponding electrical pressure measurement signal;
means for filtering one of said electrical measurement signals with a filter $A(\omega)$ having characteristics related to the distortion of said conduit means between said two spaced points;
means for time shifting said filtered electrical pressure measurement signal by an amount corresponding with the travel time of sound in said drilling fluid from one of said transducer means to said other transducer means; and
means for generating an output signal representative of the difference between said time-shifted, electrical pressure measurement signal and the other said electrical pressure measurement signal.

8. The apparatus of claim **7** wherein said means for generating an output signal representative of the difference between said electrical pressure measurement signals comprises:
means for reversing the polarity of said time-shifted, pressure measurement signal; and
adding means for summing said polarity-reversed and time-shifted electrical pressure measurement signal and said other electrical pressure measurement signal.

9. The apparatus set forth in claim **7** wherein:
said first and second transducer means are spaced from each other at a distance equal to a quarter wavelength of the sound wave in the drilling fluid.

10. In a logging-while-drilling system wherein a downhole signal is transmitted to the surface in the form of an acoustical wave in the drilling fluid of the system, apparatus for substantially reducing uphole noise from said downhole signal comprising:
conduit means for conducting drilling fluid from a source to the well in which the downhole signal is originating;
a first transducer means at a first point on said conduit means for measuring the acoustical pressure at said first point and for converting said pressure into a corresponding electrical pressure measurement signal;
a second transducer means at a second point on said conduit means, spaced from said first point, for measuring said acoustical pressure at said second point and for converting said pressure into a corresponding electrical pressure measurement signal;
amplifier means having a gain control for matching the outputs of said first and second transducers when uphole noise but no downhole signal is present in said conduit means;
means for processing said electrical pressure measurement signals to time shift one of said electrical pressure measurement signals relative to the other of said electrical pressure measurement signals by an amount corresponding with the travel time of sound in said drilling fluid from one of said transducer means to said other transducer means so that the uphole noise component in each of said electrical pressure measurement signals are in phase with each other;
means for further processing said electrical pressure measurement signals to shift the uphole noise components of said signals relative to each other so that said noise components are 180° out of phase with each other; and
means for combining said further processed electrical pressure measurement signals to generate an output signal from which said uphole noise components have been effectively cancelled.

11. The apparatus set forth in claim **10** wherein:
said first and second transducer means are spaced from each other at a distance equal to a quarter wavelength of the sound wave in the drilling fluid.

12. In a logging-while-drilling system wherein a downhole signal is transmitted to the surface in the form of an acoustical wave in the drilling fluid of the system, apparatus for substantially reducing the uphole noise in said drilling fluid which would normally interfere with said downhole signal comprising:
conduit means for conducting drilling fluid from a source to the well in which the downhole signal is originating;
a first transducer means at a first point on said conduit means for measuring the acoustical pressure at said point and for converting said pressure into a corresponding electrical signal;

a second transducer means at a second point on said conduit means, spaced from said first point, for measuring said acoustical pressure at said second point and for converting said pressure into a corresponding electrical pressure measurement signal;

an amplifier having an input and an output, said input of said amplifier connected to said first transducer, said amplifier further having a gain control for matching the outputs of said first and second transducers when uphole noise but no downhole signal is present in said conduit means;

means for summing electrical signals having at least two inputs and an output;

means connecting said output of said amplifier to one of said inputs of said summing means;

means for time shifting said electrical pressure measurement signal from said second transducer by an amount corresponding with the travel time of sound in said drilling fluid from one of said transducer means to said other transducer means so that the noise components of each signal are in phase with each other;

means for reversing the polarity of said time-shifted electrical pressure measurement signal so that the noise component of said time-shifted signal is 180° out of phase with the noise component of said other signal; and

means for connecting the output of said polarity reversing means to another of said inputs of said summing means to cancel said noise components.

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