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(54) **AIR HAMMER OPTIMIZATION USING ACOUSTIC TELEMETRY**

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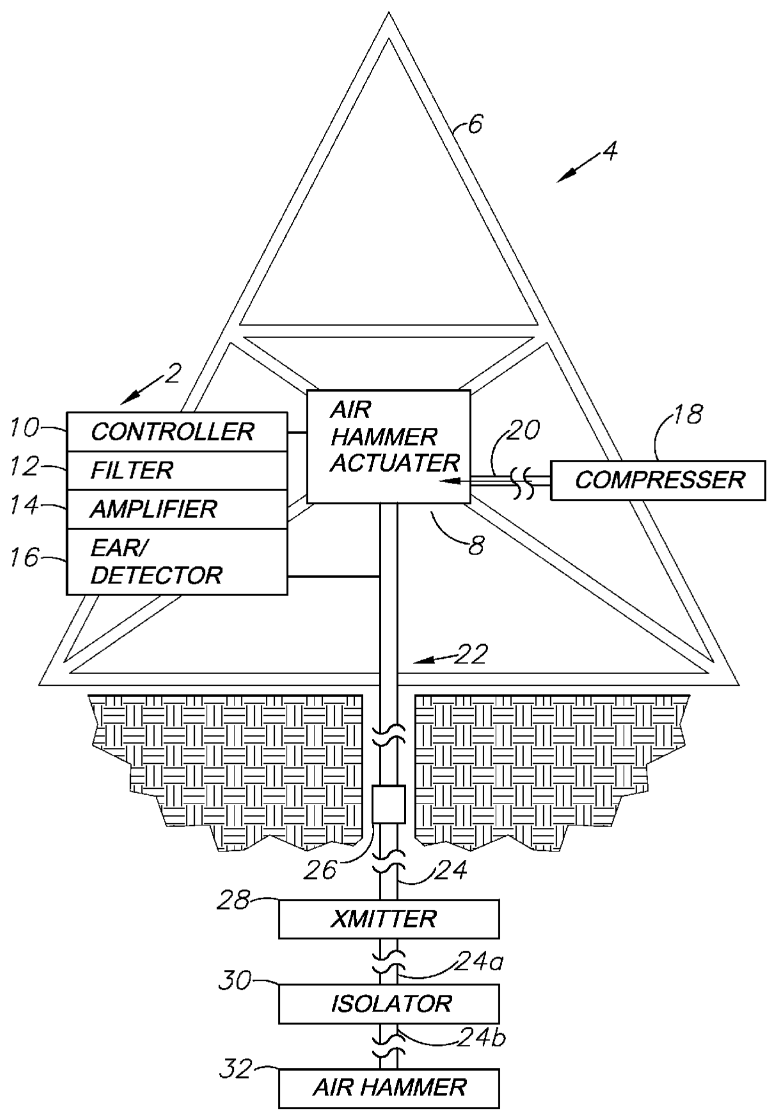
(52) **U.S. Cl.** **367/82**

(57) **ABSTRACT**

A system and method of optimizing air hammer performance in a well drilling rig whereby an electronic acoustic receiver (EAR) is used to monitor the effects of changing any of the operating parameters under his or her control. The signals are visually presented to the drill operator based on an EAR's output, along with current settings, allowing the drill operator to dial in the parameters of his or her choice until the optimal frequency of the air hammer is regained. The visual output displays the amplitude response of acoustic waves being detected and decoded at the surface by the EAR. The drill operator can observe and use this information to determine the changes necessary in the operating parameters to return the hammer to optimal frequency, and thus optimal performance.



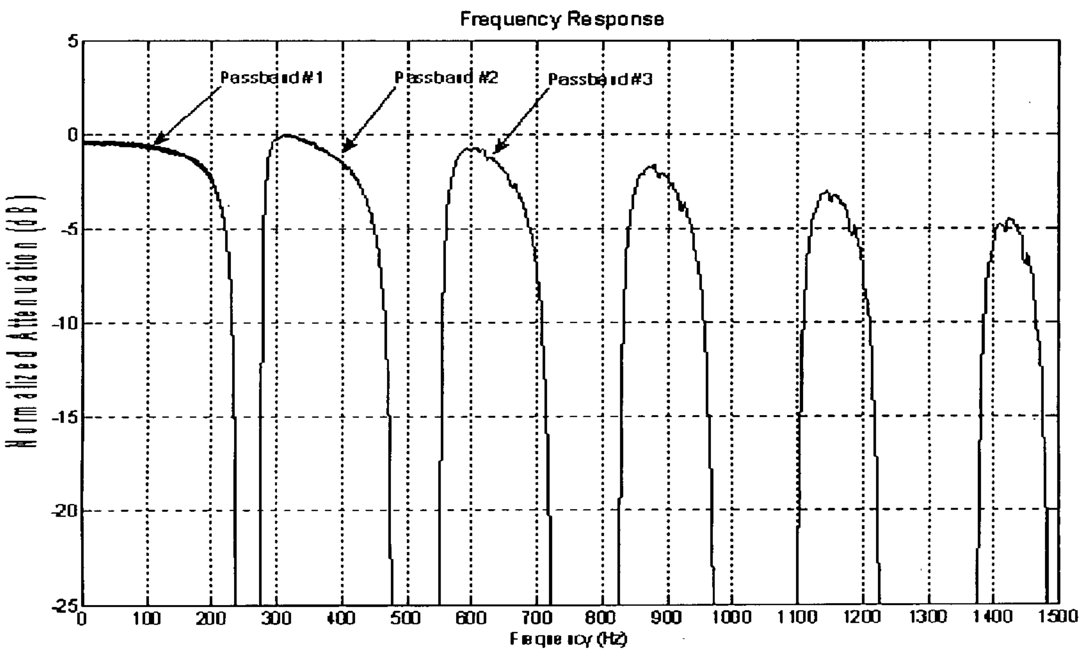

Frequency Response
Passband #1
Passband #2
Passband #3
Normalized Attenuation (dB)
5
0
-5
-10
-15
-20
-25
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Frequency (Hz)

FIG. 1

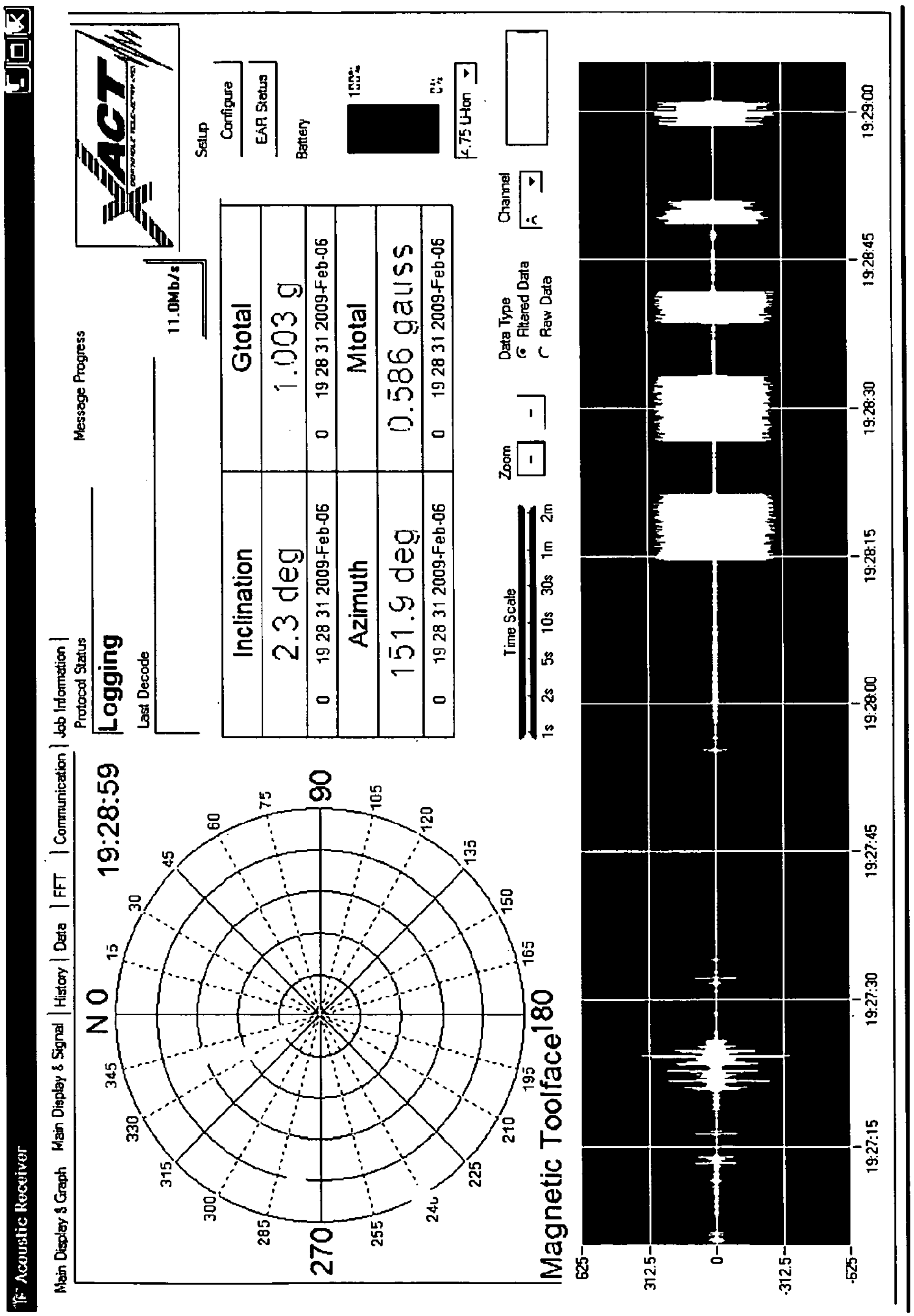

Acoustic Receiver
Main Display & Graph
Main Display & Signal
History
Data
FFT
Communication
Job Information
19:28:59
Protocol Status
Logging
Last Decode
Message Progress
11.0Mb/s
Setup
Configure
EAR Status
Battery
Inclination
2.3 deg
0 19 28 31 2009-Feb-06
Gtotal
1.003 g
0 19 28 31 2009-Feb-06
Azimuth
151.9 deg
0 19 28 31 2009-Feb-06
Mtotal
0.586 gauss
0 19 28 31 2009-Feb-06
Time Scale
1s 2s 5s 10s 30s 1m 2m
Zoom
Data Type
Filtered Data
Raw Data
Channel
Magnetic Toolface
N 0
90
180
270
625
312.5
0
-312.5
-625
19:27:15
19:27:30
19:27:45
19:28:00
19:28:15
19:28:30
19:28:45
19:29:00

FIG. 2

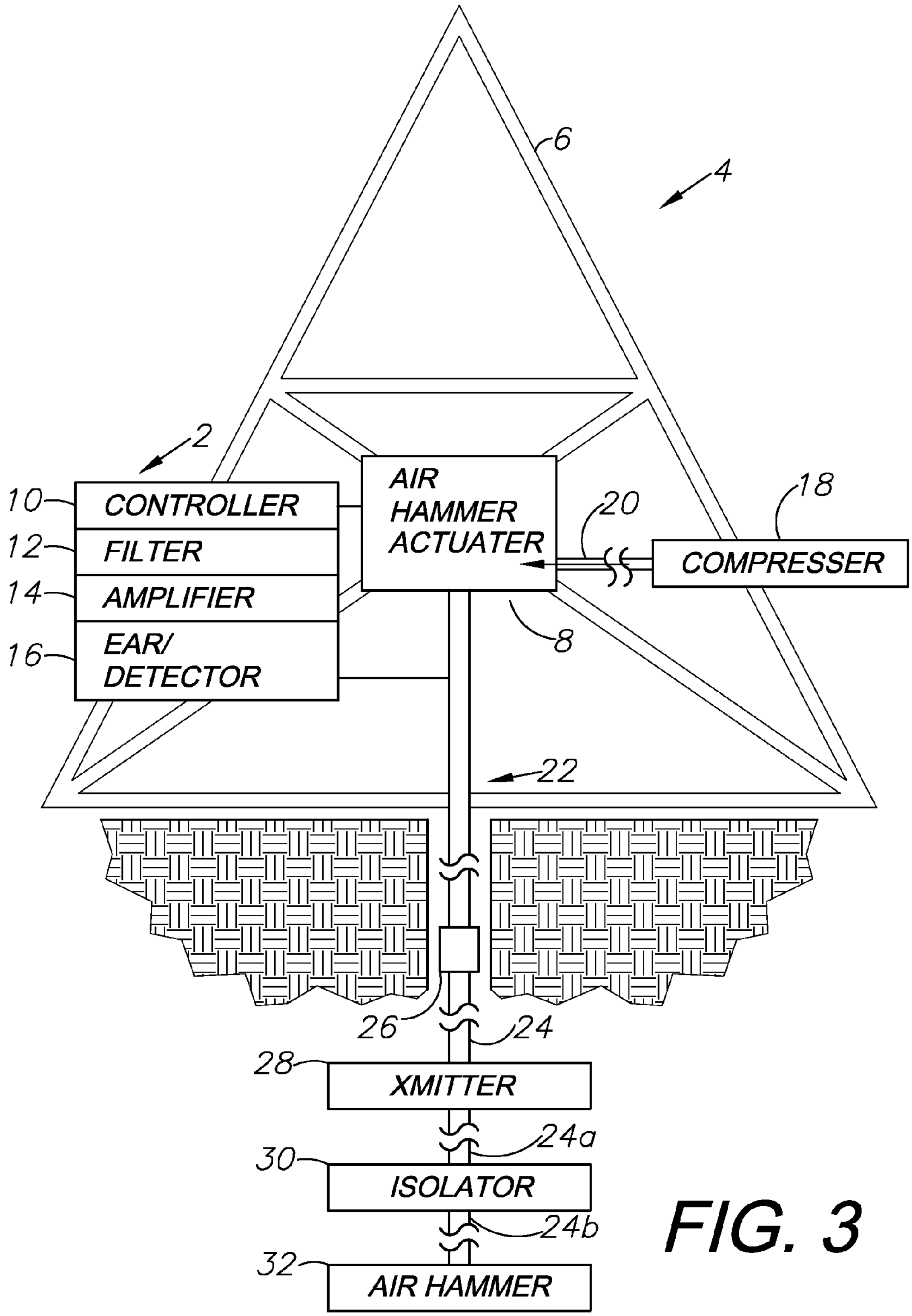

6
4
2
10
CONTROLLER
12
FILTER
14
AMPLIFIER
16
EAR/
DETECTOR
AIR
HAMMER
ACTUATER
20
18
COMPRESSER
8
22
26
24
28
XMITTER
24a
30
ISOLATOR
24b
32
AIR HAMMER

FIG. 3

AIR HAMMER OPTIMIZATION USING ACOUSTIC TELEMETRY

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority in U.S. provisional Patent Application No. 61/187,200, filed Jun. 15, 2009, which is incorporated herein by reference. This application relates to U.S. patent application Ser. No. 12/697,938, filed Feb. 1, 2010, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates generally to telemetry apparatus and methods, and more particularly to a method utilizing telemetry data for the optimization of the performance of air hammer type drilling systems for the well drilling and production (e.g., oil and gas) industry.

[0004] 2. Description of the Related Art

[0005] Acoustic telemetry is a method of communication used, for example, in the well drilling and production industry. In a typical drilling environment, acoustic extensional carrier waves from an acoustic telemetry device are modulated in order to carry information via the drillpipe as the transmission medium to the surface. Upon arrival at the surface, the waves are detected, decoded and displayed in order that drillers, geologists and others helping steer or control the well are provided with drilling and formation data.

[0006] It is well known that acoustic extensional waves can propagate through drill pipe if they contain frequencies that correspond with the passbands formed by the regular mechanical dimensions of drill pipe. Use of this communications channel enables real-time drilling telemetry to be the means by which drilling parameters (such as directional and formation) measured relatives close to the drill bit are sent to the surface. At the surface, the signals can be detected by a sensitive accelerometer whereby, after filtering and amplifying the signal, well information may be made available to the driller. An example of such a system is an Electronic Acoustic Receiver (EAR), which is detection and amplifying means to connect to a processor module and an RF system, thereby enabling two-way communication between the driller and the EAR.

[0007] Many practical mechanical means are utilized when drilling for oil and gas. A modern and popular approach is to 'hammer' at rock formations rather than using traditional rotary drills, which are limited to moving forward. Hammer drilling requires that the drilling fluid be a gas rather than a liquid, whereas rotary drilling requires the drilling fluid to be a liquid. Traditional rotary drill liquid motors used to rotate the drill bit are replaced by an air hammer in modern hammer drilling machines. This air hammer pounds the rock into small pieces by a rapid axial reciprocating motion.

[0008] Air hammers require a number of parameters to be in balance in order to achieve efficient forward progress. The main issues are to balance the air flow to the hammer with an appropriate weight on the hammer bit. If there is too much weight on the bit the hammer stroke is reduced, resulting in reduced penetration of the rock. Similarly, if there is too little weight on the bit then the work done by the hammer is reduced, again resulting in reduced rock penetration. If the air flow powering the hammer is too small, rock fragments may not clear the device and may jam the mechanism, whereas too much airflow can result in hammer bit damage. A balance of these parameters results in an ideal frequency and optimized rate of rock penetration.

BRIEF SUMMARY OF THE INVENTION

[0009] It is an object of the present invention to immediately provide feedback to drill operators utilizing air hammer drill systems. This invention provides the driller a direct visual indication of this event, and immediately shows effects due to changing any of the parameters under his or her control (e.g. air flow and hammer weight).

[0010] The signals are provided to the driller by the EAR's output being visually presented to the driller, along with current settings. This allows the driller to dial in the parameters of his or her choice until the optimal frequency is regained.

[0011] the visual output on screen displays the amplitude response of acoustic waves being detected and decoded at the surface by the EAR. It is then possible to process these amplitudes so that they show the Fourier transform of the amplitude response.

[0012] The advantage to such a system is that the transform shows the frequency response in real time of the air hammer working. As the hammer changes the rate at which it strikes the rock, the frequency display will faithfully follow by means of the acoustic channel from the hammer to the EAR at the surface.

[0013] It is this information that the drill operator can observe and use to determine the changes necessary in the system parameters to return the hammer to optimal frequency, and thus optimal performance. Any deviations from this necessitated by changing rock conditions can be accommodated by surface control, and the effect of these changes become immediately apparent, thereby enabling to just timely feedback to the driller but also the means to automate the changes necessary for optimal performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] In the accompanying drawings, which illustrate the principles of the present invention and an exemplary embodiment thereof.

[0015] FIG. **1** is a diagram of the normal passbands of Range 2 drilling pipe; and

[0016] FIG. **2** is an example of an EAR's output being visually presented on a computer screen.

[0017] FIG. **3** is a diagram of a typical drilling rig, including an air hammer optimization system embodying an aspect of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] In the following description, reference is made to "up" and "down" waves, but this is merely for convenience and clarity. It is to be understood that the present invention is not to be limited in this manner to conceptually simple applications in acoustic communication from the downhole end of the drillstring to the surface. It will be readily apparent to one skilled in the art that the present invention applies equally, for example, of subsurface stations, such as would be found in telemetry repeaters.

[0019] Referring to the drawings in more detail, FIG. **1** displays the normal passbands of Range 2 pipe. This is one example of what information may be provided during drilling operations, and the present invention is in now way limited to only Range 2 pipe.

[0020] FIG. **2** shows an example of a visual display a drill operator may see while operating the air hammer drill with the present invention. The display would appear on a computer screen, accessible by the driller, and directly connected to the air hammer drill system as well as the EAR. Results displayed on the screen are to be in real time, with the amplitude response of acoustic waves being detected and decoded at the surface displayed on the screen. Other information relevant to the operation of the air hammer drill system is individually selectable and viewable on screen.

[0021] the reference numeral **2** generally designates an air hammer optimization system. Without limitation on the generality of useful applications of the system **2**, an exemplary application is in a drilling rig **4** as shown in a very simplified form in FIG. **3**. For example, the rig **4** can include a derrick **6** suspending an air hammer actuator **8**, which receives gas via a compressor hose **20** for pumping downhole into a drillstring **22**. The drillstring **22** and the air hammer actuator **8** are connected to the system **2** which includes an EAR/detector **16**, an amplifier **14**, a filter **12**, and a controller **10**. The drillstring **22** connects to multiple drill pipe sections **24**, which are interconnected by tool joints **18**, thus forming a drillstring of considerable length, e.g. several kilometers, which can be guided downwardly and/or laterally using well-known techniques. The drillstring **22** terminates at an air hammer apparatus **32**. In FIG. **3** we have shown acoustic modules (isolator **30** and transmitter **28**) as separate from the like conventional sir hammer simply for clarity. Other rig configurations can likewise employ the air hammer optimization system of the present invention, including top-drive, coiled tubing, etc.

[0022] Information such as that contained in FIG. **1** will pass up a drillstring or up the drill pipe and be read by an EAR. This information will then be decoded, and relevant information will be displayed on screen. Relevant information includes, but is not limited to, bit weight, air flow, hammer rate, and relevant frequencies. This information can be used by the drill operator or by a system designed to automatically return the drill operation to optimal rock penetration by recalibrating bit weight, air flow, and other parameters.

Having thus described the invention, what is claimed new and desired to be secured by Letters Patent is:

1. A system for optimizing air hammer performance in a well drilling rig including a drillstring, which comprises:
- an air compressor connected to the drillstring;
- a bit connected to the drillstring;
- a controller connected to the compressor and the drillstring;
- an air hammer attached to a downhole end of the drillstring, said air hammer having performance parameters including a percussive rate corresponding to an air flow from said compressor and bit weight, a penetration rate, and a frequency response;
- an acoustic telemetry subsystem associated with the air hammer and adapted for transmitting said frequency response via acoustic waves along the drillstring; and
- said controller programmed to adjust an operating parameter of said air hammer in response to said frequency response, said operating parameters including air flow from said compressor and said bit weight.

2. The according to claim **1**, further comprising:
- an electronic acoustic receiver (EAR) connected to the drillstring and the controller, said EAR being adapted for receiving acoustic waves therefrom and detecting the air hammer frequency response.

3. The system according to claim **1**, further comprising:
- a display device connected to said controller and adapted for displaying a real-time graphic display of the frequency response of said air hammer.

4. The system according to claim **1**, further comprising:
- said controller being adapted to adjust said air flow to said air hammer, said air flow comprising an operating parameter of said air hammer.

5. The system according to claim **1**, further comprising:
- said controller being adapted to adjust said bit weight on said air hammer, said bit weight comprising an operating parameter of said air hammer.

6. The system according to claim **1**, further comprising:
- an actuator, connected to said compressor;
- said controller adapted for operating said actuator; and
- said controller including a manually selectable input for selecting parameters such as bit weight, air flow, and hammer rate, and a feedback input, the feedback input being responsive to said frequency response.

7. A system for optimizing air hammer performance in a well drilling rig including a drillstring, which comprises:
- an air compressor connected to the drillstring;
- a bit connected to the drillstring;
- a controller connected to the compressor and the drillstring;
- an air hammer attached to a downhole end of the drillstring, said air hammer having performance parameters including a percussive rate corresponding to an air flow from said compressor and bit weight, a penetration rate, and a frequency response;
- an acoustic telemetry subsystem associated with the air hammer and adapted for transmitting said frequency response via acoustic waves along the drillstring; and
- said controller programmed to adjust an operating parameter of said air hammer in response to said frequency response, said operating parameters including air flow from said compressor and said bit weight,
- an electronic acoustic receiver (EAR) connected to the drillstring and the controller, said EAR being adapted for receiving acoustic waves therefrom and detecting the air hammer frequency response,
- a display device connected to said controller and adapted for displaying a real-time graphic display of the frequency response of said hammer,
- said controller adapted to adjust said air flow to said air hammer, said air flow comprising an operating parameter of said air hammer,
- said controller adapted to adjust said bit weight on said air hammer, said-bit weight comprising an operating parameter of said air hammer,
- an actuator, connected to said compressor;
- said controller adapted for operating said actuator; and
- said controller including a manually selectable input for selecting parameters such as bit weight, air flow, and hammer rate, and a feedback input, the feedback input being responsive to said frequency response.

8. A method of optimizing air hammer performance in a drilling rig including a wellhead and a drillstring, which method includes the steps of:

providing a compressor at the wellhead;
providing an air hammer;
providing a bit connected to said drillstring;
mounting said air hammer on a downhole end of said drillstring;
pumping compressed air from said compressor to said air hammer via said drillstring;
producing a frequency response with said air hammer in operation;
transmitting said frequency response with acoustic telemetry to the wellhead via said drillstring;
providing a controller at said wellhead;
connecting the controller to the compressor;
providing a feedback signal from said air hammer via said drillstring to said controller; and
adjusting an operating parameter with said controller for optimizing performance of said air hammer, said operating parameters including air flow from said compressor and said bit weight.

9. The method of claim **8**, including the additional steps of:
providing an electronic acoustic receiver (EAR) at the wellhead;
connecting the EAR to the drillstring and the controller; and
detecting with the EAR an air hammer frequency response in the form of acoustic waves.

10. The method of claim **8**, including the additional steps of:
displaying as visual output on said display device an amplitude response of said acoustic waves being detected and decoded;
processing said amplitude to show a Fourier transform of said amplitude response; and
selecting other information relevant to the operation of the air hammer drill system on said display device.

11. A method of optimizing air hammer performance in a drilling rig including a wellhead and a drillstring, which method includes the steps of:
providing a compressor at the wellhead;
providing an air hammer;
providing a bit connected to said drillstring;
mounting said air hammer on a downhole end of said drillstring;
pumping compressed air from said compressor to said air hammer via said drillstring;
producing a frequency response with said air hammer in operation;
transmitting said frequency response with acoustic telemetry to the wellhead via said drillstring;
providing a controller at said wellhead;
connecting the controller to the compressor;
providing a feedback signal from said air hammer via said drillstring to said controller; and
providing an electronic acoustic receiver (EAR) at the wellhead;
connecting the EAR to the drillstring and the controller;
detecting with the EAR an air hammer frequency response in the form of acoustic waves,
displaying as visual output on said display device an amplitude response of said acoustic waves being detected and decoded;
processing said amplitude to show a Fourier transform of said amplitude response; and
selecting other information relevant to the operation of the air hammer drill system on said display device; and
adjusting the operating parameters with said controller for optimizing performance of said air hammer, said operating parameters including air flow from said compressor and said bit weight.

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