

(19)



(11)

EP 2 157 278 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.02.2010 Bulletin 2010/08

(51) Int Cl.:
E21B 47/12 (2006.01) E21B 47/16 (2006.01)

(21) Application number: **08162854.7**

(22) Date of filing: **22.08.2008**

(84) Designated Contracting States:
**AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HR HU IE IS IT LI LT LU LV MC MT NL NO PL PT
RO SE SI SK TR**
Designated Extension States:
AL BA MK RS

(72) Inventor: **Lemenager, Erwann**
75014 Paris (FR)

(74) Representative: **Hyden, Martin Douglas**
Rouse Patents
1st Floor
228-240 Banbury Road
Oxford
Oxfordshire OX2 7BY (GB)

(71) Applicants:

- **Schlumberger Holdings Limited**
Road Town, Tortola (VG)
Designated Contracting States:
GB NL
- **PRAD Research and Development N.V.**
Road Town, Tortola (VG)
Designated Contracting States:
AT BE CH CY EE ES FI HR IS LI LU LV MC MT PT SE
- **Schlumberger Technology B.V.**
2514 JG The Hague (NL)
Designated Contracting States:
BG CZ DE DK GR HU IE IT LT NO PL RO SI SK TR
- **Services Pétroliers Schlumberger**
75007 Paris (FR)
Designated Contracting States:
FR

(54) Wireless telemetry systems for downhole tools

(57) Apparatus for transmitting data in a borehole (10) between a downhole tool installation including one or more tools (20) (for example downhole testing tools) and a surface installation (62), wherein the downhole tool installation is connected to the surface installation by means of a tubular conduit (such as a drill string or production tubing (14), the apparatus comprising

- an acoustic modem (26) associated with each tool, the modem acting to convert tool signals such as electrical tool signals into acoustic signals; and
- a hub (90) forming part of the downhole installation to which the tools and tubular conduit are connected and comprising an acoustic receiver (74) and an electromagnetic transmitter (80);

wherein the acoustic modems operate to generate acoustic signals in the installation representative of the tool signals, the acoustic tool signal passing along the downhole installation to be received at the acoustic receiver of the hub, the received acoustic signals being used to operate the electromagnetic transmitter to trans-

mit electromagnetic signals to the surface for reception at the surface installation.

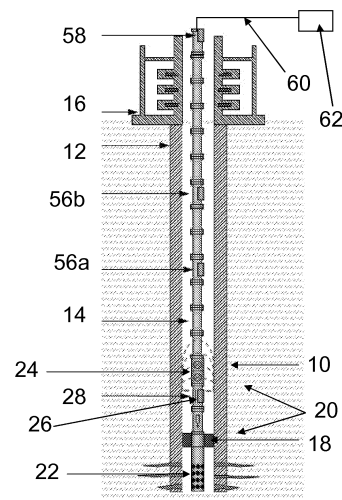


Figure 1

EP 2 157 278 A1

Description**Technical field**

[0001] This invention relates to telemetry systems for use with installations in oil and gas wells or the like. In particular, the invention relates to wireless telemetry systems for transmitting data and control signals between surface installations and downhole tools.

Background art

[0002] Downhole testing is traditionally performed in a "blind fashion": downhole tools and sensors are deployed in a well at the end of a tubing string for several days or weeks after which they are retrieved at surface. During the downhole testing operations, the sensors may record measurements that will be used for interpretation once retrieved at surface. It is only after the downhole testing tubing string is retrieved that the operators will know whether the data are sufficient and not corrupted. Similarly when operating some of the downhole testing tools from surface, such as tester valves, circulating valves, packer, samplers or perforating charges, the operators do not obtain a direct feedback from the downhole tools.

[0003] In this type of downhole testing operations, the operator can greatly benefit from having a two-way communication between surface and downhole. However, it can be difficult to provide such communication using a cable since inside the tubing string it limits the flow diameter and requires complex structures to pass the cable from the inside to the outside of the tubing. A cable inside the tubing is also an additional complexity in case of emergency disconnect for an offshore platform. Space outside the tubing is limited and cable can easily be damaged. Therefore a wireless telemetry system is preferred.

[0004] A number of proposals have been made for wireless telemetry systems based on acoustic and/or electromagnetic communications. Examples of various aspects of such systems can be found in: US5050132; US5056067; US5124953; US5128901; US5128902; US5148408; US5222049; US5274606; US5293937; US5477505; US5568448; US5675325; US5703836; US5815035; US5923937; US5941307; US6137747; US6147932; US6188647; US6192988; US6272916; US6320820; US6321838; US6912177; EP0636763; EP0773345; EP1076245; EP1193368; EP1320659; WO96/024751; WO92/06275; WO05/05724; WO02/27139; WO01/39412; WO00/77345.

[0005] In EP0550521, an acoustic telemetry system is used to pass data across an obstruction in the tubing, such as a valve. The data is then stored for retrieval by a wireline tool passed inside the tubing from the surface. It is also proposed to retransmit the signal as an acoustic signal. EP1882811 discloses an acoustic transducer structure that can be used as a repeater along the tubing.

[0006] It is an object of this invention to provide a system that combines different types of telemetry so as to

take advantage of the best features of the different types of telemetry while providing alternatives to avoid the limitations of any of them.

Disclosure of the invention

[0007] A first aspect of this invention provides apparatus for transmitting data in a borehole between a downhole tool installation including one or more tools (for example downhole testing tools) and a surface installation, wherein the downhole tool installation is connected to the surface installation by means of a tubular conduit (such as a drill string or production tubing), the apparatus comprising

- an acoustic modem associated with each tool, the modem acting to convert tool signals such as electrical tool signals into acoustic signals; and
- a hub forming part of the downhole installation to which the tools and tubular conduit are connected and comprising an acoustic receiver and an electromagnetic transmitter; wherein the acoustic modems operate to generate acoustic signals in the installation representative of the tool signals, the acoustic tool signal passing along the downhole installation to be received at the acoustic receiver of the hub, the received acoustic signals being used to operate the electromagnetic transmitter to transmit electromagnetic signals to the surface for reception at the surface installation.

[0008] Preferably, the hub further comprises an acoustic transmitter which is operable to transmit the acoustic signals received by the hub to the surface installation via the tubular conduit.

[0009] One or more acoustic repeaters can be disposed along the tubular conduit and operated to retransmit the acoustic signal received from the hub.

[0010] At least one tool can be located below and/or above the hub.

[0011] The downhole installation typically comprises at least one packer to isolate a zone of the borehole below the hub. In one embodiment multiple packers are arranged to isolate multiple zones of the well below the hub. In this case, the downhole installation can comprise separate tools in each zone.

[0012] The hub can further comprise an electromagnetic receiver for receiving electromagnetic signals from the surface installation, and an acoustic transmitter for transmitting acoustic signals derived from the received electromagnetic signals.

[0013] A second aspect of the invention provides a method of communicating between one or more tools comprising a downhole installation and a surface installation, wherein the downhole installation and surface installation are connected by means of a tubular conduit, the method comprising:

- using signals produced by the tools to generate acoustic signals which pass along the downhole installation to a hub;
- receiving the acoustic signals at the hub; and
- using the received acoustic signals to generate electromagnetic signals that pass from the hub to the surface location.

[0014] The tool signals can be preferably electrical signals or digital signals.

[0015] In one embodiment, the method further comprises generating acoustic signals at the hub which pass along the tubular conduit to the surface installation. In this case, the method can also include receiving the acoustic signals and retransmitting them at multiple locations along the tubular conduit.

[0016] One preferred embodiment further comprised transmitting electromagnetic signals from the surface installation to the hub and converting these signals into acoustic signals for transmission to the tools in the installation.

[0017] Further aspects of the invention will be apparent from the following description.

Brief description of the drawings

[0018]

Figure 1 shows a schematic view of an acoustic telemetry system for use in the invention;

Figure 2 shows a modem as used in the embodiment of Figure 1;

Figure 3 shows a variant of the embodiment of Figure 1;

Figure 4 shows a hybrid telemetry system according to an embodiment of the invention;

Figure 5 shows a schematic view of a modem;

Figure 6 shows a detailed view of a downhole installation incorporating the modem of Figure 5;

Figure 7 shows one embodiment of mounting the modem in downhole equipment;

Figure 8 shows one embodiment of mounting a repeater modem on drill pipe;

Figure 9 shows a dedicated modem sub for mounting in drill pipe; and

Figures 10, 11 and 12 illustrate applications of a hybrid telemetry system according to the invention.

Mode(s) for carrying out the invention

[0019] This invention is particularly applicable to testing installations such as are used in oil and gas wells or the like. Figure 1 shows a schematic view of such a system. Once the well has been drilled, the drilling apparatus is removed from the well and tests can be performed to determine the properties of the formation through which the well has been drilled. In the example of Figure 1, the well 10 has been lined with a steel casing 12 (cased hole)

in the conventional manner, although similar systems can be used in unlined (open hole) environments. In order to test the formations, it is necessary to place testing apparatus in the well close to the regions to be tested, to be able to isolate sections or intervals of the well, and to convey fluids from the regions of interest to the surface. This is commonly done using a jointed tubular drill pipe 14 which extends from the well-head equipment 16 at the surface (or sea bed in subsea environments) down inside the well to the zone of interest. The well-head equipment 16 can include blow-out preventers and connections for fluid, power and data communication.

[0020] A packer 18 is positioned on the drill pipe 14 and can be actuated to seal the borehole around the drill pipe 14 at the region of interest. Various pieces of downhole test equipment 20 are connected to the drill pipe 14 above or below the packer 18. These can include:

- Further packers
- Tester valves
- Circulation valves
- Downhole chokes
- Firing heads
- TCP (tubing conveyed perforator) gun drop subs
- Samplers
- Pressure gauges
- Downhole flow meters
- Downhole fluid analysers
- Etc.

[0021] In the embodiment of Figure 1, a sampler 22 is located below the packer 18 and a tester valve 24 located above the packer 18. The downhole equipment 20 is connected to a downhole modem 26 which is mounted in a gauge carrier 28 positioned between the sampler 22 and tester valve 24. The modem 26 operates to allow electrical signals from the equipment 20 to be converted into acoustic signals for transmission to the surface, and to convert acoustic tool control signals from the surface into electrical signals for operating the equipment downhole.

[0022] Figure 2 shows the modem 26 in more detail. The modem comprises a housing 30 supporting a piezo electric actuator or stack 32 which can be driven to create an acoustic signal in the drill pipe 14 when the modem 26 is mounted in the gauge carrier 28. The modem 26 can also include an accelerometer 34 or monitoring piezo sensor 35 for receiving acoustic signals. Where the modem is only required to act as a receiver, the piezo actuator 32 may be omitted. Transmitter electronics 36 and receiver electronics 38 are also located in the housing and power is provided by means of a battery, such as a lithium rechargeable battery 40. Other types of power supply may be used also.

[0023] The transmitter electronics 36 are arranged to receive an electrical output signal from a sensor 42, for example from the downhole equipment 20 provided from an electrical or electro/mechanical interface. Such signals are typically digital signals which can be provided

to a micro-controller 43 which uses the signal to derive a modulation to be applied to a base band signal in one of a number of known ways FSK, PSK, QPSK, QAM. This modulation is applied via a D/A converter 44 which outputs an analogue signal (typically a voltage signal) to a signal conditioner 46. The conditioner operates to modify the signal to match the characteristics of the piezo actuator 32. The analogue signals are stacked and applied as a drive signal to the piezo stack so as to generate an acoustic signal in the material of the drill pipe 14. The acoustic signal comprises a carrier signal with an applied modulation to provide a digital signal that passes along the drill pipe as a longitudinal and/or flexural wave. The acoustic signal typically has a frequency in the range 1-10kHz, preferably in the range 3-6kHz, and is configured to pass data at a rate of about 1 bps to about 1000 bps, preferably from about 10 to about 100 bps, and more preferably from over about 80 bps. The data rate is dependent upon the conditions such as the noise and the distance between the repeaters. A preferred embodiment of the invention is directed to a combination of a short hop acoustic telemetry system for transmitting data between a hub located above the main packer and a plurality of downhole tools and valves below and/or above said packer. Then the data and/or control signals can be transmitted from the hub to a surface module either via a plurality of repeaters as acoustic signals or by converting into electromagnetic signals and transmitting straight to the top. The combination of a short hop acoustic with a plurality of repeaters and/or the use of the electromagnetic waves allows an improved data rate over existing systems. The system may be designed to transmit data as high as 1000 bps. Other advantages of the present invention system exist.

[0024] The receiver electronics are arranged to receive the acoustic signal passing along the drill pipe 14 and convert it to an electric signal. The acoustic signal passing along the pipe excites the accelerometer 34 or monitor stack 35 so as to generate an electric output signal (voltage). This signal is essentially an analogue signal carrying digital information. The analogue signal is applied to a filter 48 and then to a A/D converter 50 to provide a digital signal which can be applied to a micro-controller 52. The micro controller 52 which implements signal processing. The type of processing applied to the signal depends on whether it is a data signal or a command signal. The signal is then passed on to an actuator 54.

[0025] The modem 26 can therefore operate to transmit acoustic data signals from the sensors in the downhole equipment 20 along the drill pipe 14. In this case, the electrical signals from the equipment 20 are applied to the transmitter electronics 36 (described above) which operate to generate the acoustic signal. The modem 26 can also operate to receive acoustic signals control signals to be applied to the downhole equipment 20. In this case, the acoustic signals are detected and applied to the receiver electronics 38 (described above) which op-

erate to generate the electric control signal that is applied to the equipment 20.

[0026] In order to support acoustic signal transmission along the drill pipe 14 between the downhole location and the surface, a series of repeater modems 56a, 56b, etc. are positioned along the drill pipe 14. These repeater modems 56 operate to receive an acoustic signal generated in the drill pipe by a preceding modem and to amplify and retransmit the signal for further propagation along the drill string. The number and spacing of the repeater modems 56 will depend on the particular installation selected, for example on the distance that the signal must travel. A typical minimum spacing to the modems is 500m in order to accommodate all possible testing tool configurations. When acting as a repeater, the acoustic signal is received and processed by the receiver electronics 38 and the output signal is provided to the micro-controller of the transmitter electronics 36 and used to drive the piezo stack in the manner described above. Thus an acoustic signal can be passed between the surface and the downhole location in a series of short hops.

[0027] The role of a repeater is to detect an incoming signal, to decode it, to interpret it and to subsequently rebroadcast it if required. In some implementations, the repeater does not decode the signal but merely amplifies the signal (and the noise). In this case the repeater is acting as a simple signal booster. However, this is not the preferred implementation selected for wireless telemetry systems of the invention.

[0028] Repeaters are positioned along the tubing/piping string. A repeater will either listen continuously for any incoming signal or may listen from time to time.

[0029] The acoustic wireless signals, conveying commands or messages, propagate in the medium (the drill pipe) in an omni-directional fashion, that is to say up and down. It is not necessary for the detector to detect whether the physical wireless signal is coming from another repeater above or below. The direction of the message is embedded in the message itself. Each message contains several network addresses: the address of the transmitter (last and/or first transmitter) and the address of the destination modem at least. Based on the addresses embedded in the messages, the repeater will interpret the message and construct a new message with updated information regarding the transmitter and destination addresses. Messages will be transmitted from repeaters to repeaters and slightly modified to include new network addresses.

[0030] If the repeater includes an array of sensors, and if the channel is non reverberant, then it is possible to determine the direction of the incoming signal, using classical array processing (similar to that found in borehole seismics, acoustic tools, phased array radars or ultrasonic, etc). This applies for a propagating wave (acoustic or high frequency electromagnetic, for example), but not for a diffusive wave such as a low frequency electromagnetic wave.

[0031] A surface modem 58 is provided at the well

head 16 which provides a connection between the drill pipe 14 and a data cable or wireless connection 60 to a control system 62 that can receive data from the downhole equipment 20 and provide control signals for its operation.

[0032] In the embodiment of Figure 1, the acoustic telemetry system is used to provide communication between the surface and the downhole location. Figure 3 shows another embodiment in which acoustic telemetry is used for communication between tools in multi-zone testing. In this case, two zones A, B of the well are isolated by means of packers 18a, 18b. Test equipment 20a, 20b is located in each isolated zone A, B, corresponding modems 26a, 26b being provided in each case. Operation of the modems 26a, 26b allows the equipment in each zone to communicate with each other as well as allowing communication from the surface with control and data signals in the manner described above.

[0033] Figure 4 shows an embodiment of the invention with a hybrid telemetry system. The testing installation shown in Figure 4 comprises a lower section 64 which corresponds to that described above in relation to Figures 1 and 3. As before, downhole equipment 66 and packer (s) 68 are provided with acoustic modems 70. However, in this case, the uppermost modem 72 differs in that signals are converted between acoustic and electromagnetic formats. Figure 5 shows a schematic of the modem 72. Acoustic transmitter and receiver electronics 74, 76 correspond essentially to those described above in relation to Figure 2, receiving and emitting acoustic signals via piezo stacks (or accelerometers). Electromagnetic (EM) receiver and transmitter electronics 78, 80 are also provided, each having an associated microcontroller 82, 84. A typical EM signal will be a digital signal at about 1 Hz. This signal is received by the receiver electronics 78 and passed to an associated microcontroller 82. Data from the microcontroller 82 can be passed to the acoustic receiver microcontroller 86 and on to the acoustic transmitter microcontroller 88 where it is used to drive the acoustic transmitter signal in the manner described above. Likewise, the acoustic signal received at the receiver microcontroller 86 can also be passed to the EM receiver microcontroller 82 and then on to the EM transmitter microcontroller 84 where it is used to drive an EM transmitter antenna to create a 1 Hz digital EM signal that can be transmitted along the well to the surface. A corresponding EM transceiver (not shown) is provided at the surface for connection to the control system.

[0034] Figure 6 shows a more detailed view of a downhole installation in which the modem 72 forms part of a downhole hub 90 that can be used to provide short hop acoustic telemetry X with the various downhole tools 20 (e.g test and circulation valves (i), flowmeter (ii), fluid analyser (iii) and packer (iv), and other tools below the packer (v)), and long hop EM telemetry Y to the surface.

[0035] Figure 7 shows the manner in which a modem can be mounted in downhole equipment. In the case shown, the modem 92 is located in a common housing

94 with a pressure gauge 96, although other housings and equipment can be used. The housing 94 is positioned in a recess 97 on the outside of a section of drill pipe 98 provided for such equipment and commonly known as a gauge carrier. By securely locating the housing 94 in the gauge carrier 97, the acoustic signal can be coupled to the drill pipe 98. Typically, each piece of downhole equipment will have its own modem for providing the short hop acoustic signals, either for transmission via the hub and long hop EM telemetry, or by long hop acoustic telemetry using repeater modems. The modem is hard wired into the sensors and actuators of the equipment so as to be able to receive data and provide control signals. For example, where the downhole equipment comprises an operable device such as a packer, valve or choke, or a perforating gun firing head, the modem will be used to provide signals to set/unset, open/close or fire as appropriate. Sampling tools can be instructed to activate, pump out, etc. and sensors such as pressure and flow meters can transmit recorded data to the surface. In most cases, data will be recorded in tool memory and then transmitted to the surface in batches. Likewise tool settings can be stored in the tool memory and activated using the acoustic telemetry signal.

[0036] Figure 8 shows one embodiment for mounting the repeater modem on drill pipe. In this case, the modem 100 is provided in an elongate housing 102 which is secured to the outside of the drill pipe 104 by means of clamps 106. Each modem is a stand-alone installation, the drill pipe providing both the physical support and signal path.

[0037] Figure 9 shows an alternative embodiment for mounting the repeater modem. In this case, the modem 108 is mounted in an external recess 110 of a dedicated tubular sub 112 that can be installed in the drill string between adjacent sections of drill pipe. Multiple modems can be mounted on the sub for redundancy.

[0038] The preferred embodiment of the invention comprises a two-way wireless communication system between downhole and surface, combining different modes of electromagnetic and acoustic wave propagations. It may also include a wired communication locally, for example in the case of offshore operations. The system takes advantage of the different technologies and combines them into a hybrid system, as presented in Figure 4.

[0039] The purpose of combining the different types of telemetry is to take advantage of the best features of the different types of telemetry without having the limitations of any of them. The preferred applications for embodiments of this invention are for single zone and multi-zone well testing in land and offshore environments. In the case of the deep and ultra-deep offshore environments, the communication link has to be established between the floating platform (not shown) and the downhole equipment 66 above and below the packer 68. The distance between the rig floor (on the platform) and the downhole tools can be considerable, with up to 3km of sea water

and 6km of formation/well depth. There is a need to jump via a 'Long Hop' from the rig floor to the top of the downhole equipment 66 but afterwards it is necessary to communicate locally between the tools 66 (sensors and actuators) via a 'Short Hop' within a zone or across several zones. The Short Hop is used as a communication means that supports distributed communication between the Long Hop system and the individual tools that constitute the downhole equipment 66, as well as between some of these tools within the downhole installation. The Short Hop communication supports:

- Measurement data:
 - Gauge pressure, temperature
 - Downhole flowrates
 - Fluid properties
 - etc
- Downhole tool status and activation commands:
 - IRDV
 - Samplers (multiple)
 - Firing Heads (multiple)
 - Packer activation
 - Other downhole tools (tubing tester, circulating valve, reversing valve etc)
 - etc

[0040] All telemetry channels, being wireless or not, have limitations from a bandwidth, deployment, cost or reliability point of view. The objective of the invention is to combine the various technology benefits. These are summarized in Figure 10.

[0041] At low frequency (~1 Hz), electromagnetic waves 120 propagate very far with little attenuation through the formation 122. The higher the formation resistivity, the longer the wireless communication range. The main advantages of electromagnetic wave communication relate to the long communication range, the independence of the flow conditions and the tubing string configuration 124. The main drawbacks of the electromagnetic wave communication are related to the required power and associated footprint.

[0042] Acoustic wave propagation 126 along the tubing string 124 can be made in such a way that each element of the system is small and power effective by using high frequency sonic wave (1 to 10kHz). In this case, the main advantages of this type of acoustic wave communication relate to the small footprint and the medium data

rate of the wireless communication. The main drawbacks of the acoustic wave communication are related to the impact of noise induced by production flows, the unpredictability of the communication carrier frequency and the requirements for continuity in the pipe structure.

[0043] Electrical or optical cable technology 128 can provide the largest bandwidth and the most predictable communication channel. The energy requirements for digital communication are also limited with electrical or optical cable, compared to wireless telemetry systems. It is however costly and difficult to deploy cable over several kilometers in a well (rig time, clamps, subsea tree) especially in the case of a temporary well installation, such as a well test.

[0044] In the case of deep-offshore single zone or multi-zone well testing, an appropriate topology for the hybrid communication system is to use a cable 128 (optical or electrical) from the rigfloor to the seabed, an electromagnetic wireless communication 120 from the seabed to the top of the downhole equipment and an acoustic communication 126 for the local bus communication.

[0045] Another way to combine the telemetry technologies is to place the telemetry channels in parallel to improve the system reliability through redundancy. Figures 11 and 12 represent two cases where two or three communication channels are placed in parallel. In Figure 11, both electromagnetic 120 and acoustic 126 wireless communication is used to the wellhead; and a cable 128 leads from the wellhead to the rig floor (not shown). In such configurations, common nodes 130 to the different communication channels can be used. Such nodes have essentially the similar functions to the hub described above in relation to Figure 6. In Figure 12, electromagnetic 120 and acoustic 126 wireless, and cable 128 are all provided down to the downhole location, the acoustic wireless signal being used between the downhole tools. The selection of the particular communication channel used can be done at surface or downhole or at any common mode between the channels. Multiple paths exist for commands to go from surface to downhole and for data and status to go from downhole to surface. In the event of communication loss on one segment of one channel, an alternate path can be used between two common nodes.

[0046] A particularly preferred embodiment of the invention relates to multi-zone testing (see Figure 4). In this case, the well is isolated into separate zones by packers 68, and one or more testing tools are located in each zone. A modem is located in each zone and operates to send data to the hub 72 located above the uppermost packer. In this case, the tools in each zone operate either independently or in synchronisation. The signals from each zone are then transmitted to the hub for forwarding to the surface via any of the mechanisms discussed above. Likewise, control signals from the surface can be sent down via these mechanisms and forwarded to the tools in each zone so as to operate them either independently or in concert.

[0047] Further changes within the scope of the invention are also possible.

Claims

1. Apparatus for transmitting data in a borehole between a downhole tool installation including one or more tools and a surface installation, wherein the downhole tool installation is connected to the surface installation by means of a tubular conduit, the apparatus comprising

- an acoustic modem associated with each tool, the modem acting to convert electrical tool signals into acoustic signals; and
- a hub forming part of the downhole installation to which the tools and tubular conduit are connected and comprising an acoustic receiver and an electromagnetic transmitter;

wherein the acoustic modems operate to generate acoustic signals in the installation representative of the electrical tool signals, the acoustic tool signal passing along the downhole installation to be received at the acoustic receiver of the hub, the received acoustic signals being used to operate the electromagnetic transmitter to transmit electromagnetic signals to the surface for reception at the surface installation.

2. Apparatus as claimed in claim 1, wherein the hub further comprises an acoustic transmitter which is operable to transmit the acoustic signals received by the hub to the surface installation via the tubular conduit.

3. Apparatus as claimed in claim 2, further comprising one or more acoustic repeaters disposed along the tubular conduit and operable to retransmit the acoustic signal received from the hub.

4. Apparatus as claimed in claim 1, 2 or 3, wherein at least one tool is located below the hub.

5. Apparatus as claimed in any preceding claim, wherein at least one tool is located above the hub.

6. Apparatus as claimed in any preceding claim, wherein the downhole installation comprises at least one packer to isolate a zone of the borehole below the hub.

7. Apparatus as claimed in claim 6, comprising multiple packers arranged to isolate multiple zones of the well below the hub.

8. Apparatus as claimed in claim 7, wherein the down-

hole installation comprises separate tools in each zone.

9. Apparatus as claimed in any preceding claim, wherein the hub further comprises an electromagnetic receiver for receiving electromagnetic signals from the surface installation, and an acoustic transmitter for transmitting acoustic signals derived from the received electromagnetic signals.

10. A method of communicating between one or more tools comprising a downhole installation and a surface installation, wherein the downhole installation and surface installation are connected by means of a tubular conduit, the method comprising:

- using electrical signal produced by the tools to generate acoustic signals which pass along the downhole installation to a hub;
- receiving the acoustic signals at the hub; and
- using the received acoustic signals to generate electromagnetic signals that pass from the hub to the surface location.

11. A method as claimed in claim 1, further comprising generating acoustic signals at the hub which pass along the tubular conduit to the surface installation.

12. A method as claimed in claim 11, further comprising receiving the acoustic signals and retransmitting them at multiple locations along the tubular conduit.

13. A method as claimed in claim 10, 11 or 12, further comprising transmitting electromagnetic signals from the surface installation to the hub and converting these signals into acoustic signals for transmission to the tools in the installation.

14. A method of testing a well, comprising:

- locating testing tools in a borehole in a number of zones to be tested;
- isolating the zones from each other and the rest of the well;
- operating the testing tools in each zone; and
- transmitting data from the testing tools in each zone to a surface installation by means of a method according to any of claims 10-13.

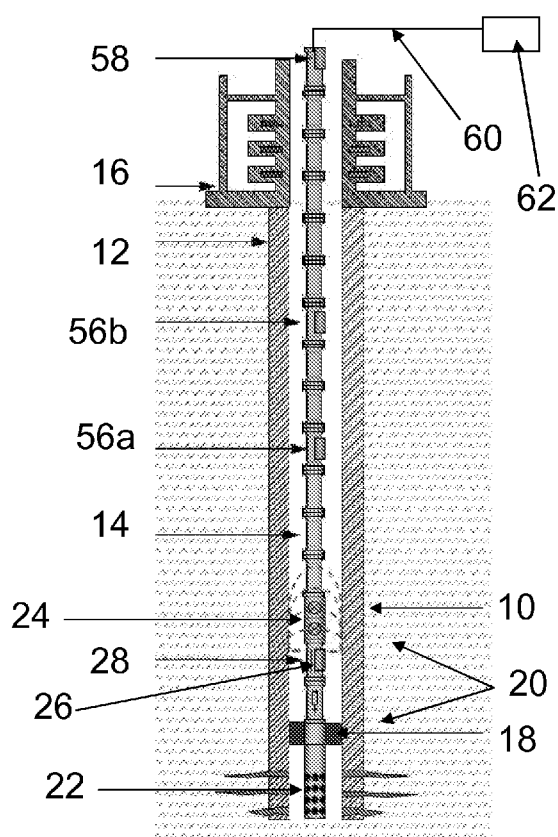


Figure 1

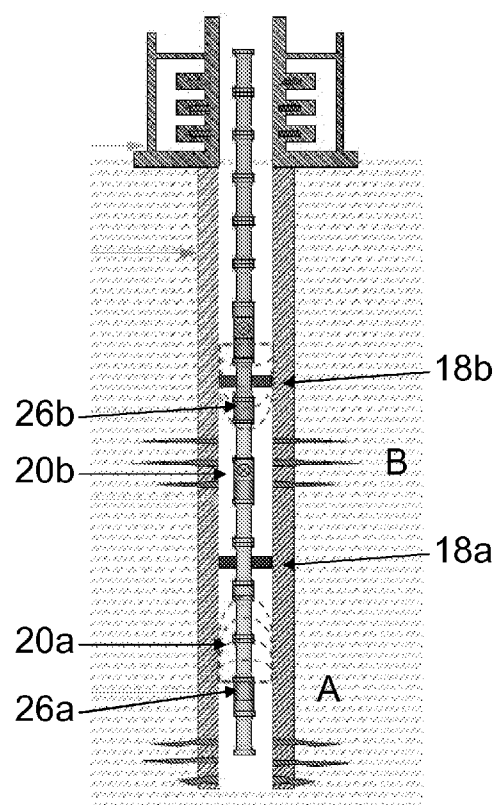
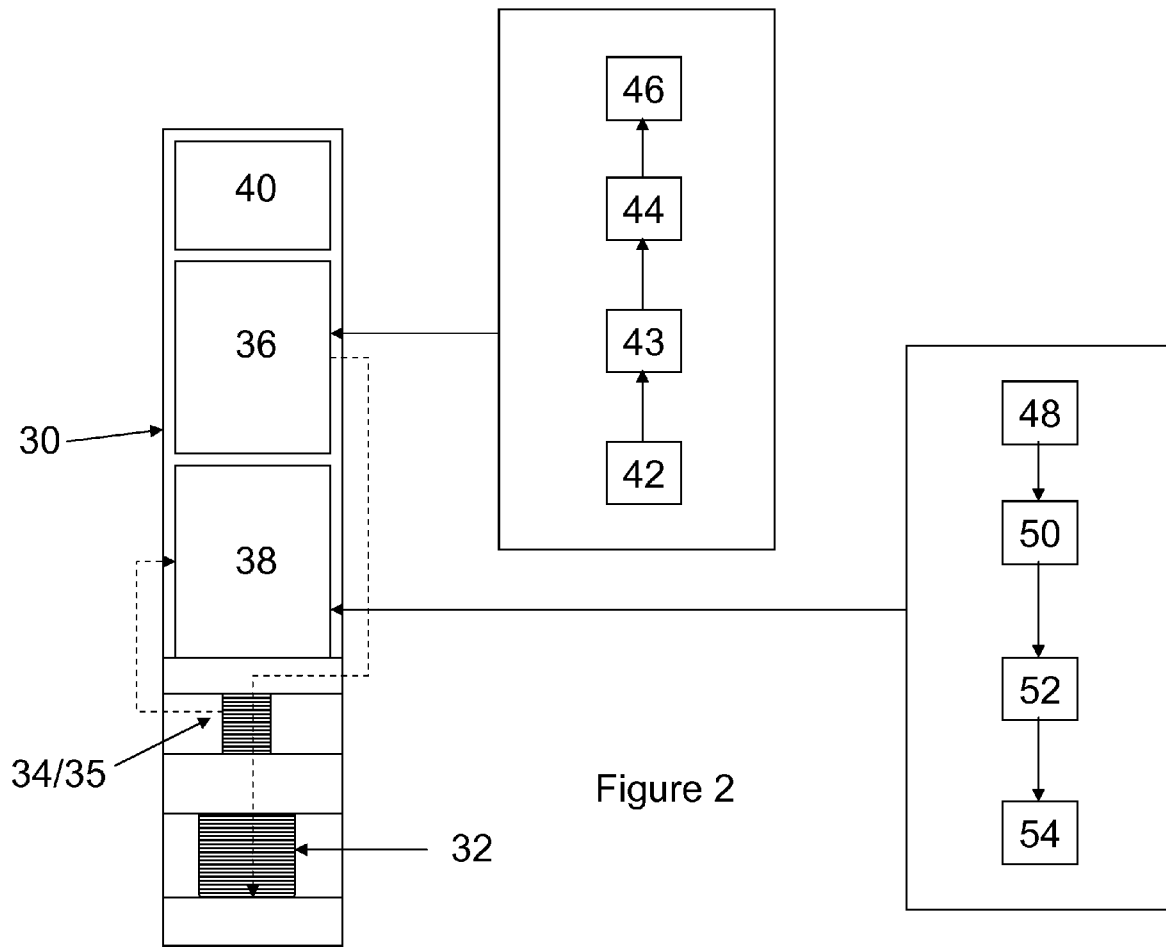


Figure 3



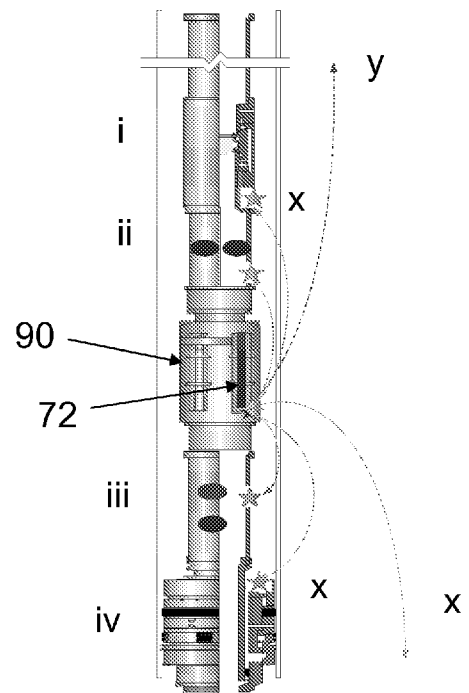
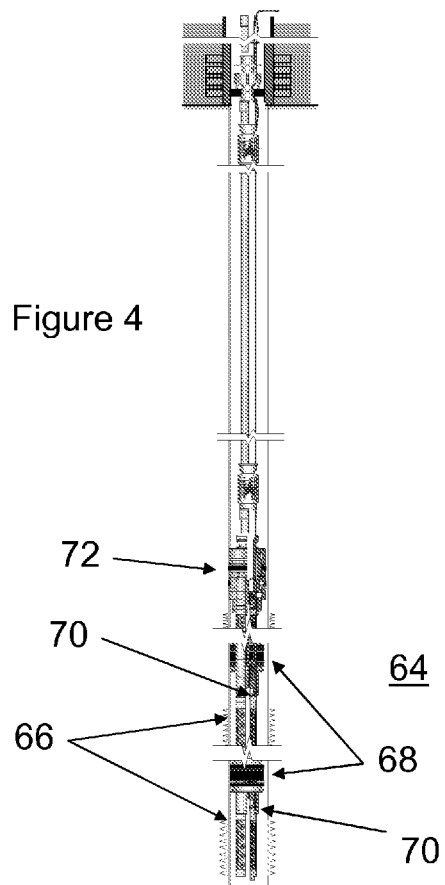
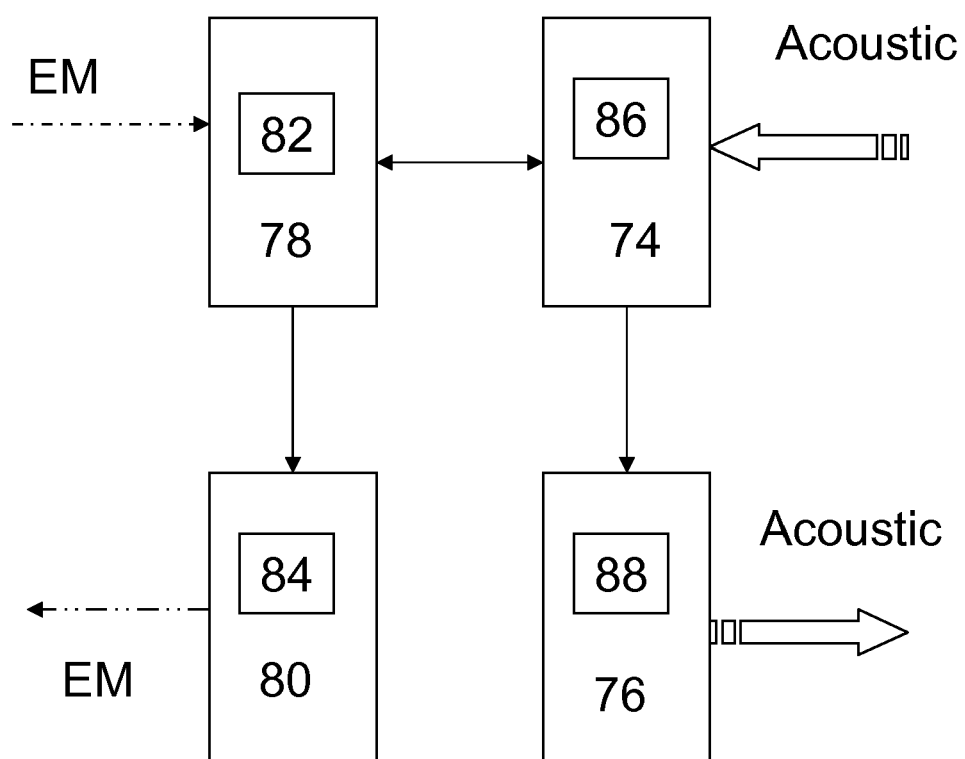


Figure 6

Figure 5



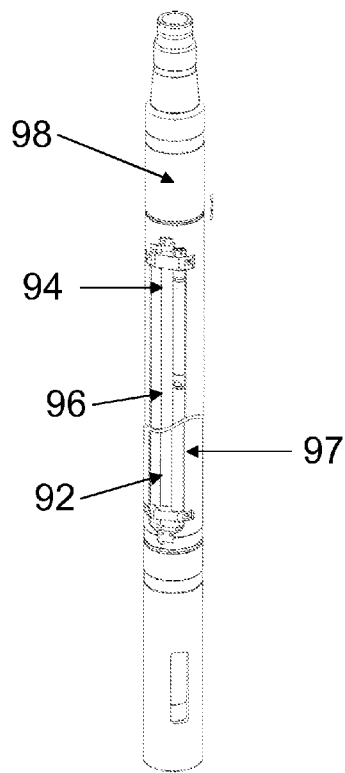


Figure 7

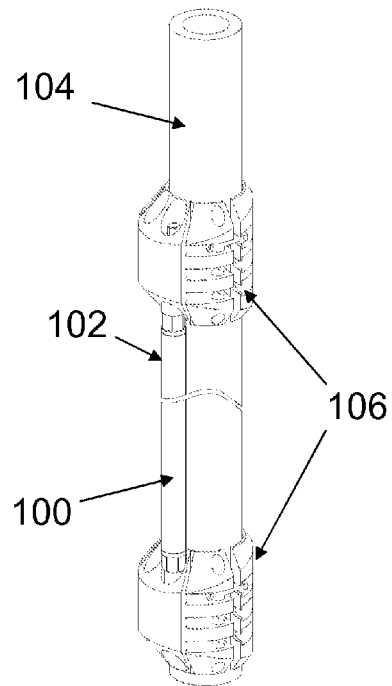


Figure 8

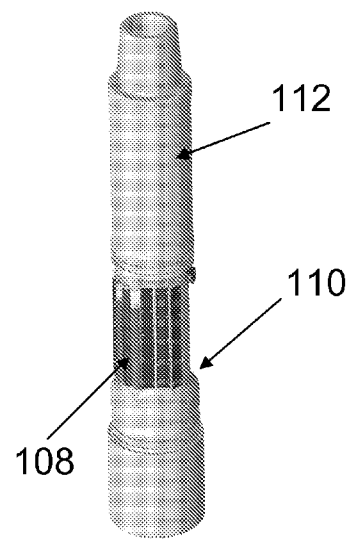


Figure 9

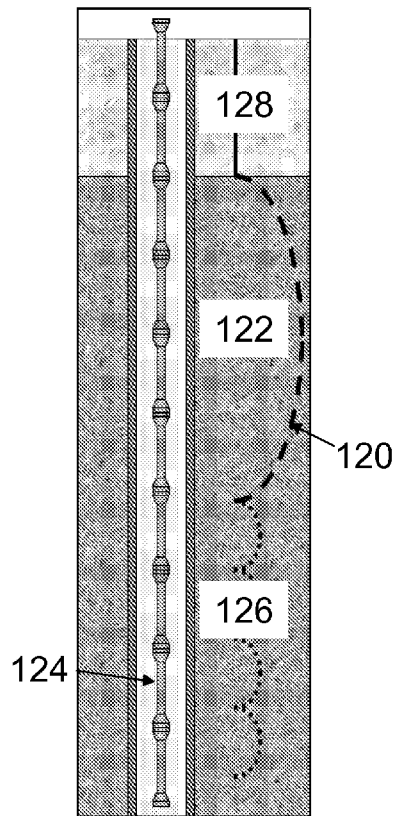


Figure 10

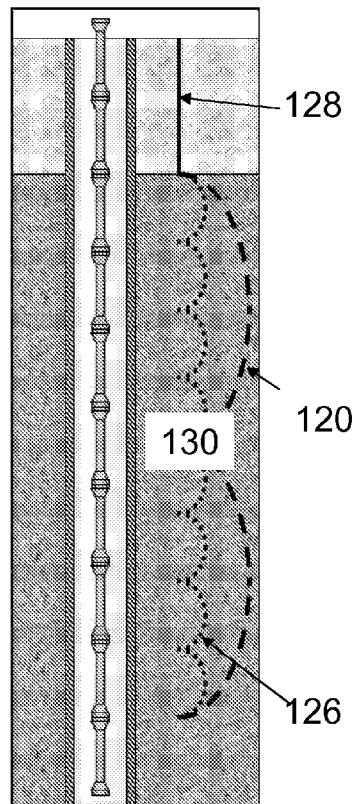


Figure 11

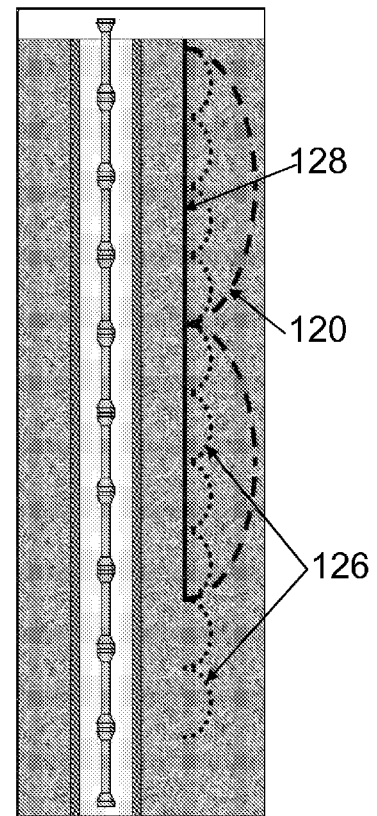


Figure 12



EUROPEAN SEARCH REPORT

Application Number
EP 08 16 2854

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 0 919 696 A (HALLIBURTON ENERGY SERV INC [US]) 2 June 1999 (1999-06-02) * column 6, paragraph 30 - column 9, paragraph 45; figure 1 *	1-14	INV. E21B47/12 E21B47/16
A	US 2003/151977 A1 (SHAH VIMAL V [US] ET AL) 14 August 2003 (2003-08-14) * page 4, paragraph 30 * * page 5, paragraph 32 - paragraph 34 * * page 6, paragraph 44 - page 7, paragraph 51 *	1,10,14	
A	EP 0 919 697 A (HALLIBURTON ENERGY SERV INC [US]) 2 June 1999 (1999-06-02) * column 9, paragraph 42 - column 12, paragraph 56; figures 1a,1b *	1,10,14	
			TECHNICAL FIELDS SEARCHED (IPC)
			E21B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 16 March 2009	Examiner Ott, Stéphane
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document</p>			

1
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 08 16 2854

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

16-03-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0919696 A	02-06-1999	NO 985279 A US 6144316 A	02-06-1999 07-11-2000

US 2003151977 A1	14-08-2003	AU 2003211048 A1 BR 0307503 A CA 2476259 A1 GB 2404682 A WO 03069120 A2	04-09-2003 11-04-2006 21-08-2003 09-02-2005 21-08-2003

EP 0919697 A	02-06-1999	NO 985278 A US 6177882 B1	02-06-1999 23-01-2001

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 5050132 A [0004]
- US 5056067 A [0004]
- US 5124953 A [0004]
- US 5128901 A [0004]
- US 5128902 A [0004]
- US 5148408 A [0004]
- US 5222049 A [0004]
- US 5274606 A [0004]
- US 5293937 A [0004]
- US 5477505 A [0004]
- US 5568448 A [0004]
- US 5675325 A [0004]
- US 5703836 A [0004]
- US 5815035 A [0004]
- US 5923937 A [0004]
- US 5941307 A [0004]
- US 6137747 A [0004]
- US 6147932 A [0004]
- US 6188647 B [0004]
- US 6192988 B [0004]
- US 6272916 B [0004]
- US 6320820 B [0004]
- US 6321838 B [0004]
- US 6912177 B [0004]
- EP 0636763 A [0004]
- EP 0773345 A [0004]
- EP 1076245 A [0004]
- EP 1193368 A [0004]
- EP 1320659 A [0004]
- WO 96024751 A [0004]
- WO 9206275 A [0004]
- WO 0505724 A [0004]
- WO 0227139 A [0004]
- WO 0139412 A [0004]
- WO 0077345 A [0004]
- EP 0550521 A [0005]
- EP 1882811 A [0005]