



Industria y Comercio
SUPERINTENDENCIA

Delegatura de Propiedad Industrial
División de Nuevas Creaciones

PCT
SOLICITUD

PATENTE DE INVENCION

21. EXPEDIENTE No.

04-130206

54. TITULO "SISTEMA DE TELEMETRÍA ELECTROMAGNÉTICA DE BAJA FRECUENCIA

QUE EMPLEA MODULACIÓN POR DESPLAZAMIENTO DE FASE DE ALTA CARDINALIDAD."

51. CLASIFICACION INTERNACIONAL _____

71. SOLICITANTE HALLIBURTON ENERGY SERVICES, INC.

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T.P.-20-281

22. BOGOTA, D.C., DICIEMBRE 30 DE 2004

PETITORIO

Industria y Comercio
SUPERINTENDENCIA

SUPERINDUSTRIA Y COMERCIO
Radicacion : 04130206 00000000 Folios: 97
] Fecha (RRD): 2004-12-30 17:04:17
Tramite : 011 PCT-PATENT 373 FASE NACI 411 PRESENTAC
Dependencia: 2020 DIVISION DE NUEVAS CREACIONES

FORMULARIO ÚNICO DE SOLICITUD DE PATENTE PCT ENTRADA EN FASE NACIONAL

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SOLICITUD DE :

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Patente de Invención

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Patente de Modelo de Utilidad

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Capítulo I.

☒

Capítulo II.

2

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5

PCT (85)

Solicitud Internacional No. PCT/US2003/020871

Fecha Julio 2, 2003

Publicación Internacional No. WO 2004/005966

Fecha Enero 15, 2004

6

Título (54)

SISTEMA DE TELEMETRÍA ELECTROMAGNÉTICA DE BAJA FRECUENCIA QUE EMPLEA MODULACIÓN
POR DESPLAZAMIENTO DE FASE DE ALTA CARDINALIDAD.

7

Clasificación Internacional (51)

G01V 1/22

8

Prioridad

SI

☒

NO

☐

(33) País de Origen

US

(32) Fecha

Julio 5, 2002

(31) Número de Solicitud

10/190,165

9

Comprobante de pago No. 04-69,700

Fecha SEPTIEMBRE 3 DE 2004

Instrucciones para el diligenciamiento del presente formulario, ver reverso de esta página

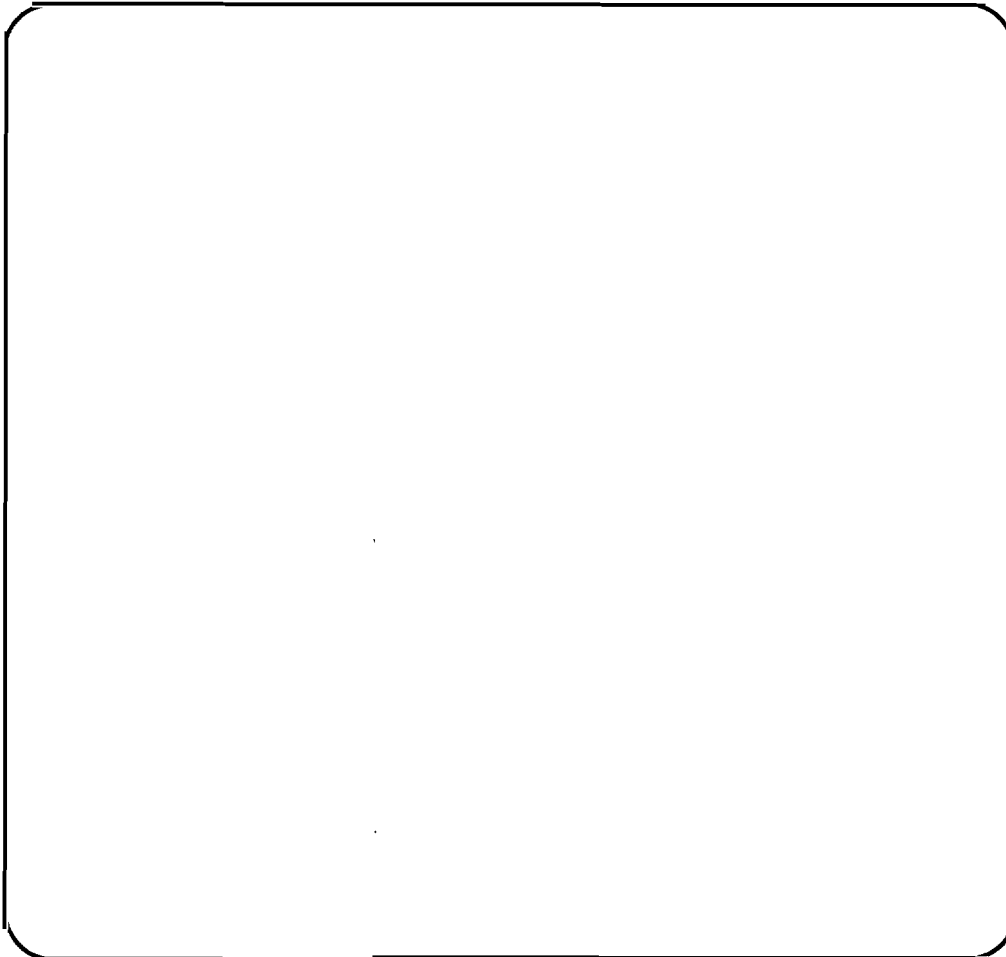
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ANEXOS

- ☒ Comprobante de pago de la tasa de presentación de la solicitud
- ☐ Documento que acredita la existencia y representación legal cuando el solicitante sea persona jurídica
- ☐ Poderes, si fuere el caso
- ☐ Documento de cesión del inventor al solicitante o a su causante
- ☐ Declaraciones
- ☒ Copia de la solicitud internacional. (Resumen, descripción, reivindicaciones, dibujos)
- ☒ Traducción de la solicitud internacional al castellano. (Resumen, descripción, reivindicaciones, dibujos)
- ☒ Copia del examen preliminar internacional efectuado por la Autoridad Internacional de Examen preliminar (IPEA)
- ☐ Traducción del examen preliminar internacional efectuado por la IPEA
- ☐ De ser el caso, copia del contrato de acceso
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- ☐ De ser el caso, certificado de depósito del material biológico
- ☒ Arte final 12 x 12
- ☐ De ser el caso, información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante, relacionadas parcial o totalmente con la invención de esta solicitud
- ☐ De ser el caso, modificaciones efectuadas a la solicitud internacional.
- ☒ Otros: VARIOS

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FIGURA CARATERISTICA



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Solicito la concesión de la patente,

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C.C. 79.143.366 de
Bogotá

T.P. 20.281

7431
-2000-1-3 3

MIT : 800176089-2

RECIBO OFICIAL DE CAJA : 04 - 69,700
FECHA : SEPTIEMBRE 3 DE 2004

SUPERINDUSTRIA Y COMERCIO
Radicación : 04130206 00000000 Folios: 97
Fecha (GHO): 2004-12-30 17:04:17
Trámite : 011 PCT-PATENT 175 FOME NACI 411 PRESENTAC
Dependencia: 2020 DIVISION DE NUEVAS CREACIONES

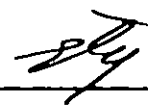
***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	Nº. PAGO	FECHA PAGO	Vr. PAGO
ALVARO CORREA ORDONEZ	CONSIGNACION	BANCO POPULAR	050-00110-6	28088256	03/09/2004	118,530,000.00

***** CONCEPTO *****

CANT. CONTABILITICO	CONCEPTO	TOTAL CONCEPTO
1 50005-01-01 SOLICITUDES	1 TRAMITES DE SOL. DE PATENTE DE IN	422,000.00
	TOTAL :	\$ 422,000.00

SOM: CUATROCIENTOS VEINTIDOS MIL PESOS

RESPONSABLE : 

RECIBO DE CAJA APLICADO AL EXPEDIENTE No. _____

2-00011

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
15 January 2004 (15.01.2004)

PCT

(10) International Publication Number
WO 2004/005966 A1

- (51) International Patent Classification: G01V 1/22

(21) International Application Number: PCT/US2003/020871

(22) International Filing Date: 2 July 2003 (02.07.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data: 10/190,165 5 July 2002 (05.07.2002) US

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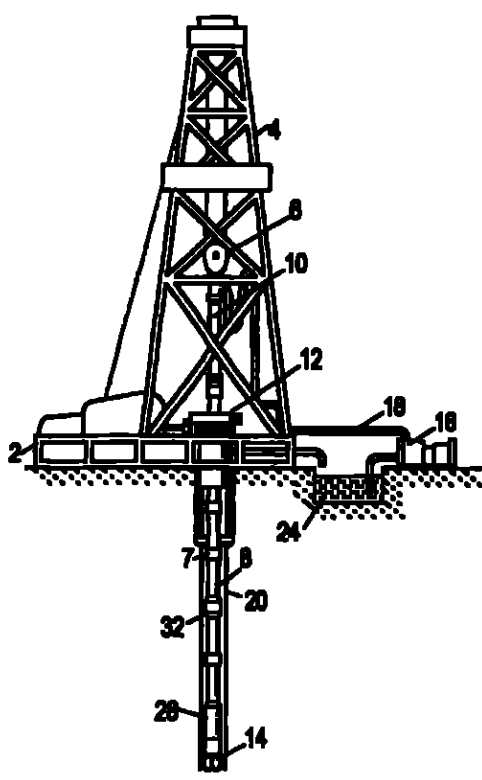
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- (81) Designated States (national): AE, AG, AI, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published: — with international search report

[Continued on next page]

(54) Title: LOW FREQUENCY ELECTROMAGNETIC TELEMETRY SYSTEM EMPLOYING HIGH CARDINALITY PHASE SHIFT KEYING



(57) Abstract: A downhole electromagnetic telemetry system with an increased data rate is disclosed. In one embodiment, a PSK data transmission system is used to transmit data in a downhole electromagnetic telemetry system for Measure While Drilling (MWD) applications. MWD applications suffer from data rates that are not well suited for the ever-increasing amount of data that needs to be transmitted. One method of increasing the data rate includes increasing the carrier frequency, but this can cause undesirable signal attenuation and distortion. Conversely, decreasing the carrier frequency provides the reward of a stronger signal at the risk of aliasing, especially with wide bandwidth signals. A derivation is disclosed predicting that the frequency may actually be decreased while increasing the number of phase states to achieve a higher data rate, without affecting the bandwidth. The system and method disclosed may advantageously provide a robust, low-power electromagnetic telemetry system with an increased data rate.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

**LOW FREQUENCY ELECTROMAGNETIC TELEMETRY
SYSTEM EMPLOYING HIGH CARDINALITY PHASE SHIFT KEYING****BACKGROUND OF THE INVENTION****Field of the Invention**

The present invention relates to formation logging techniques. More particularly, the present invention relates to a telemetry system for transmitting data from a downhole drilling assembly to the surface of a well.

Description of the Related Art

Modern petroleum drilling and production operations demand a great quantity of information relating to parameters and conditions downhole. Such information typically includes characteristics of the earth formations traversed by the wellbore, along with data relating to the size and configuration of the borehole itself. The collection of information relating to conditions downhole, which commonly is referred to as "logging," can be performed by several methods.

In conventional oil well wireline logging, a probe or "sonde" housing formation sensors is lowered into the borehole after some or all of the well has been drilled, and is used to determine certain characteristics of the formations traversed by the borehole. The upper end of the sonde is attached to a conductive wireline that suspends the sonde in the borehole. Power is transmitted to the sensors and instrumentation in the sonde through the conductive wireline. Similarly, the instrumentation in the sonde communicates information to the surface by electrical signals transmitted through the wireline.

The problem with obtaining downhole measurements via wireline is that the drilling assembly must be removed or "tripped" from the drilled borehole before the desired borehole information can be obtained. This can be both time-consuming and extremely costly, especially in situations where a substantial portion of the well has been drilled. In this situation, thousands of feet of tubing may need to be removed and stacked on the platform (if offshore). Typically, drilling rigs are rented by the day at a substantial cost. Consequently, the cost of drilling a well is directly proportional to the time required to complete the drilling process. Removing thousands of feet of tubing to insert a wireline logging tool can be an expensive proposition.

As a result, there has been an increased emphasis on the collection of data during the drilling process. Collecting and processing data during the drilling process eliminates the necessity of removing or tripping the drilling assembly to insert a wireline logging tool. It consequently allows the driller to make accurate modifications or corrections as needed to optimize performance while minimizing down time. Designs for measuring conditions downhole including the movement and location of the drilling assembly contemporaneously with the

drilling of the well have come to be known as "measurement-while-drilling" techniques, or "MWD." Similar techniques, concentrating more on the measurement of formation parameters, commonly have been referred to as "logging while drilling" techniques, or "LWD." While distinctions between MWD and LWD may exist, the terms MWD and LWD often are used interchangeably. For the purposes of this disclosure, the term MWD will be used with the understanding that this term encompasses both the collection of formation parameters and the collection of information relating to the movement and position of the drilling assembly.

When oil wells or other boreholes are being drilled, it is frequently necessary or desirable to determine the direction and inclination of the drill bit and downhole motor so that the assembly can be steered in the correct direction. Additionally, information may be required concerning the nature of the strata being drilled, such as the formation's resistivity, porosity, density and its measure of gamma radiation. It is also frequently desirable to know other downhole parameters, such as the temperature and the pressure at the base of the borehole, for example. Once this data is gathered at the bottom of the borehole, it is necessary to communicate it to the surface for use and analysis by the driller.

Sensors or transducers typically are located at the lower end of the drill string in MWD systems. Typically, the downhole sensors employed in MWD applications are positioned in a cylindrical drill collar that is positioned close to the drill bit. While drilling is in progress these sensors continuously or intermittently monitor predetermined drilling parameters and formation data and transmit the information to a surface detector by some form of telemetry. There are a number of telemetry systems in the prior art which seek to transmit information regarding downhole parameters up to the surface without requiring the use of a wireline tool. A widely used telemetry system used in MWD applications is the mud pulse system.

The mud pulse system of telemetry creates "acoustic" pressure signals in the drilling fluid, sometimes called "mud," that is circulated under pressure through the drill string during drilling operations. The information that is acquired by the downhole sensors is transmitted by suitably timing the formation of pressure pulses in the mud stream. The information is received and decoded by a pressure transducer and computer at the surface.

In a mud pressure pulse system, the drilling mud pressure in the drill string is modulated by means of a valve and control mechanism, generally termed a pulser or mud pulser. The pulser is usually mounted in a specially adapted drill collar positioned above the drill bit. The generated pressure pulse travels up the mud column inside the drill string at the velocity of sound in the mud. Depending on the type of drilling fluid used, the velocity may vary between approximately 3000 and 5000 feet per second. The rate of transmission of data, however, is relatively slow due to pulse spreading, distortion, attenuation, modulation rate limitations, and other disruptive

forces, such as the ambient noise in the drill string. A typical pulse rate is on the order of a pulse per second (1 Hz).

With recent developments in sensing and steering technologies available to the driller, the amount of data that can be conveyed to the surface in a timely manner at 1 bit per second is sorely inadequate. As one method for increasing the rate of transmission of data, it has been proposed to transmit the data using vibrations in the tubing wall of the drill string rather than depending on pressure pulses in the drilling fluid. However, early systems have proven to be unreliable at data rates greater than about 3 bits/s due to acoustic reflections at tool joints and variations in the geometry of the tubing and borehole.

Additionally, mud pulse telemetry requires fairly dense drilling fluid, rendering it useless in applications like Underbalanced Drilling (UBD) in which aerated, low density fluids are necessary or desired.

SUMMARY OF THE INVENTION

Accordingly, there is disclosed herein a reliable downhole electromagnetic telemetry system, which overcomes disadvantages of previous telemetry methods. In a preferred embodiment, a phase shift keying electromagnetic data transmission system is used to transmit data for MWD applications.

In accordance with the preferred embodiment, an antenna is configured to transmit low frequency electromagnetic signals while a phase-shift key (PSK) transmitter is configured to receive digital signals indicative of telemetry data and convert the digital signals into a PSK transmit signal. The PSK transmitter provides the transmit signal to the antenna, and the PSK transmit signal has a carrier frequency of no more than about 1 Hz, and a signal constellation with more than 4 phase states. The PSK transmit signal may also include a transmit signal with a symbol period of two or more carrier cycles.

In another embodiment of the present invention, a method of logging while drilling is disclosed where a hole is drilled through a formation with a drill bit attached to a drill string that includes a sensor package. Signals are then detected that indicate formation properties. These signals are then provided to the PSK transmitter, where they are encoded to obtain a digital transmit signal that is phase modulated on a low-frequency carrier signal to obtain a PSK signal with a frequency of no more than about 1 Hz and with no more than 4 phase states. The low-frequency PSK signal is then transmitted to the surface. The system and method disclosed may advantageously provide a robust, low-power electromagnetic telemetry system with an increased data rate relative to mud pulse telemetry systems and other conventional telemetry systems.

Therefore, despite the reluctance to drop the carrier frequency because of reduced data rate concerns, it is believed that any data rate reduction caused from dropping the frequency can

be overcome by increasing the number of phase states without increasing bandwidth. With the carrier frequency dropped according to the embodiments, the electromagnetic telemetry system can be enhanced by using multiple carriers and amplitude modulation.

BRIEF DESCRIPTION OF THE DRAWINGS

5 A better understanding of the present invention can be obtained when the following detailed description of the preferred embodiment is considered in conjunction with the following drawings, in which:

Figure 1 is a schematic view of an oil well in which an electromagnetic telemetry system may be employed;

10 Figure 2 is a view of a downhole tool used in electromagnetic telemetry;

Figure 3 is a functional block diagram of an electromagnetic telemetry system employing phase shift keying;

Figure 4 is a functional block diagram of a phase shift keying transmitter;

Figure 5 is a functional block diagram of a phase shift keying receiver;

15 Figure 6A is an example PSK transmission;

Figure 6B shows the in-phase and quadrature components of Figure 6A;

Figure 7 shows a four-phase message sequence assignment;

Figure 8 shows a decoding rule for the decoder of Figure 5;

20 Figure 9 shows the effects of frequency and formation resistivity on signal attenuation; and

Figure 10 shows an exemplary phase and amplitude modulated signal.

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. It should be understood, however, that the drawings and detailed description thereto are
25 not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

30 MWD applications suffer from data rates that are not well suited for the ever-increasing amount of data that needs to be transmitted. One method of increasing the data rate includes increasing the carrier frequency, but this can cause undesirable signal attenuation and distortion. On the other hand, decreasing the carrier frequency provides the reward of a stronger signal at the risk of aliasing, especially with wide bandwidth signals. A derivation is disclosed herein that

predicts that the frequency may actually be decreased while increasing the number of phase states to achieve a higher overall data rate, without affecting the bandwidth or causing signal aliasing.

Turning now to the figures, Figure 1 shows a well during drilling operations. A drilling platform 2 is equipped with a derrick 4 that supports a hoist 6. Drilling of oil and gas wells is carried out by a string of drill pipes connected together by "tool" joints 7 so as to form a drill string 8. The hoist 6 suspends a kelly 10 that is used to lower the drill string 8 through rotary table 12. Connected to the lower end of the drill string 8 is a drill bit 14. The bit 14 is rotated and drilling accomplished by rotating the drill string 8, by use of a downhole motor near the drill bit, or by both methods. Drilling fluid, termed mud, is pumped by mud recirculation equipment 16 through supply pipe 18, through drilling kelly 10, and down through the drill string 8 at high pressures and volumes to emerge through nozzles or jets in the drill bit 14. The mud then travels back up the hole via the annulus formed between the exterior of the drill string 8 and the borehole wall 20, through a blowout preventer (not specifically shown), and into a mud pit 24 on the surface. On the surface, the drilling mud is cleaned and then recirculated by recirculation equipment 16. The drilling mud is used to cool the drill bit 14, to carry cuttings from the base of the bore to the surface, and to balance the hydrostatic pressure in the rock formations. However, the system of Figure 1 is not restricted to the use of mud as a drilling fluid. For example, in the case of under balanced drilling (UBD), other media such as aerated fluids or air/mist mixtures may be preferred over mud.

In a preferred embodiment, a data telemetry system is used in the a downhole tool 28 such that MWD is accomplished by transmitting data from the downhole tool 28 electromagnetically. It should be noted that while downhole tool 28 is shown in close proximity to the drill bit 14, it may be placed at any point along the drill string as desired.

Referring now to Figure 2, downhole tool 28 is shown in more detail. As shown downhole tool 28 includes an insulator 200, antenna 201, annular port 202, internal port 204, electronics module 206, battery module 208, gamma sensor 210, and directional sensor 214, all of which are housed in a drill collar 212. However it should be noted that the contents of downhole tool 28 as shown are not an exhaustive list of its contents as would be evident to one of ordinary skill in the art.

The insulator 200 separates the upper and lower portions of the antenna 201, and data is transmitted to the surface by inducing an alternating voltage difference across the insulator 200, thereby generating the electromagnetic signal. At the surface, the electromagnetic signal is preferably received as a voltage potential between the conductive drill string and a ground electrode (not shown). One or more repeater modules 32 may be provided along the drill string to receive electromagnetic telemetry signals from downhole tool 28 and retransmit them to the

surface. The repeater modules 32 preferably include both an electromagnetic telemetry receiver and an electromagnetic telemetry transmitter.

The annular port 202 helps to measure annular pressure; while the internal port 204 helps measure internal pressure. Gamma sensor 210 measures radiation and directional sensor 214 measures the orientation of the drill string. Power is provided to the various sensors and electronics in the downhole tool 28 by the battery module 208. The various measurements from the sensors are reported to the electronics module 206 where they are processed. Processing the signals may include: digitizing analog sensor measurements into binary data, storing the information in local memory, compressing data for efficient transmission, as well as any other tasks evident to one of ordinary skill in the art.

In addition, electronics module 206 includes a transmitter to transmit data using electromagnetic signaling techniques, where the transmitter is preferably a phase shift keying (PSK) transmitter. As well as containing a PSK transmitter electronics module 206 may contain a PSK receiver further enabling uphole and downhole communications.

As shown in Figure 3, the electromagnetic PSK telemetry system may be modeled using three functional blocks: a channel 304, a PSK transmitter 302, and a PSK receiver 306. As mentioned above, to produce the electromagnetic signal, a voltage difference is generated across the insulator 200. The electromagnetic signal then travels to the surface through the formation being drilled while being guided along by the electrically conductive drillstring. On the surface, the electromagnetic wave is received as a voltage potential between the rig 4 and a ground electrode placed in the proximity of the rig. Thus, the channel 304 by which PSK transmitter 302 and PSK receiver 306 communicate includes the transmitting antenna, the formation being drilled, the drill string acting to guide the electromagnetic wave, and the receiving electrode.

Referring now to Figure 4, a block diagram illustrating a possible PSK transmitter 302 is shown. A binary data stream, which preferably has been processed and prepared for transmission, is passed through block 400, which stores the data stream in bit sequences or bit groups. In block 402, each bit sequence is then mapped to a phase, where each phase corresponds to a unique bit sequence. One of the paths coming from block 402 contains the Sine of each phase that is mixed with the Sine of a carrier signal using mixer 408. Another path coming from block 402 contains the Cosine of each phase that is mixed with the Cosine of a carrier signal using mixer 404. The output of the mixer blocks 404 and 408 are fed into an add/subtract block 406, and the signal out comprises combinations of Sine and Cosine functions which represent the signal to be transmitted over the channel 304.

Figure 7 shows a four-phase PSK sequence assignment and will be explained with respect to the transmitter of Figure 4. In four-phase PSK, the binary data stream is broken up into groups

of two binary bits where each group of bits is represented by a different transmitted phase. Since the number of bits "i" transmitted during each symbol interval equals 2, then this makes a total of 2^i possible groups of binary bits, or 4. Therefore there must be four different transmitted phases, or one for each bit group. If on the other hand there were 3 binary bits per symbol this would result in 2^3 or 8 possible groups of bits, which would require eight different transmitted phase states.

Typically the phase states are spaced equally apart such that the transmitted phases for four-phase PSK would be $360^\circ/4$ or 90° apart, thus one possible set as seen in Figure 7 is $\{\pm 45^\circ, \pm 135^\circ\}$. The transmitted signal out of block 406 $s(t)$ is

$$s(t) = A_c \cos[\omega_c t + \theta_i], \quad (1)$$

$i = 1, 2, 3, 4$, where the phases to the groups of binary bits are assigned according to Figure 7. The transmitted signal of Equation (1) can be rewritten using a trigonometric identity as

$$s(t) = A_c \cos\theta_i \cos\omega_c t - A_c \sin\theta_i \sin\omega_c t. \quad (2)$$

Thus, the in-phase and quadrature components are easily seen in Equation 2, and Figure 7 contains the signal transmitted during the symbol interval.

Referring now to Figure 5, a block diagram illustrating a possible PSK receiver 306 is shown. The signal in is passed through multiplier 500 and 502. Multiplier 500 mixes the incoming signal with the carrier frequency containing a 90° phase shift to produce the quadrature component f_q . Multiplier 502 meanwhile mixes the signal in with the carrier frequency to produce the in-phase component f_i . Both the in-phase and quadrature components are passed through low pass filters 506 and 508 respectively. At this point the in-phase and quadrature components may be gained up as necessary before arriving at decoder 510. Figure 8 contains an exemplary decoding rule assignment for the receiver according to Figure 5 and using the example phase assignment of Figure 7.

It should be mentioned that the transmitter of Figure 4 and the receiver of Figure 5, as well as the four-phase PSK example contained herein may not be optimum and are intended for discussion purposes only.

Current MWD applications have an increasing number of sensors generating an increasing amount of data and this often creates a data bottleneck because the achievable data rates cannot keep pace with the increased data output. Therefore in most telemetry systems, it is desirable to improve the data rate.

Referring now to Figure 6A, a PSK transmission is shown. The PSK transmission is a two-phase PSK transmission with Signal A and Signal B having the same frequency but they are out of phase by 180° . Referring briefly to Figure 6B, a constellation diagram illustrating the in-

phase (I) and quadrature (Q) components is shown for the two-phase system of Figure 6A with ϕ_1 corresponding to Signal A and ϕ_2 corresponding to Signal B.

As seen in Figure 6A, Signal A and Signal B are transmitted during the symbol interval T_1 and T_2 respectively, and each symbol interval contains 3 cycles. Also, Signal A when transmitted represents binary bit 0 while Signal B when transmitted represents binary bit 1. In light of Figure 6A there are several ways to improve the number of bits transmitted per unit time (i.e., data rate).

One method of increasing the data rate is to increase the carrier frequency such that the total symbol interval time decreases. Then again signal attenuation and distortion increase significantly as the carrier frequency is increased, setting fundamental limits on the improvements in data rate that are achievable by increasing the carrier frequency. Conversely, decreasing the carrier frequency provides the reward of a stronger electromagnetic signal with the added risk of aliasing with negative frequency components, and this can be especially problematic when dealing with high bandwidth signals.

Another method of increasing the data rate is by increasing the number of phase states, thereby assigning more bits to each symbol interval. For example, if the number of phase states in PSK transmission of Figure 6A were increased to four, then each symbol interval would contain two bits of data as was previously explained with respect to Figure 7.

An analysis of the spectral power properties of phase modulated signals is now presented with an eye toward increasing data rate. The following assumptions apply:

- the carrier frequency for the signal is ω_c in radians;
- the period of a cycle of the carrier is T ;
- the phase changes once every N cycles (N is a positive integer);
- there are M possible phase states, where M is an integer > 1 ;
- for a given M , the allowable phases are taken from the set

$$\left\{ 0, \frac{2 \cdot \pi}{M}, 2 \cdot \frac{2 \cdot \pi}{M}, 3 \cdot \frac{2 \cdot \pi}{M}, \dots, (M-1) \cdot \frac{2 \cdot \pi}{M} \right\};$$
 and
- the data are encoded into the signal in such a way that there is no correlation between the phase states.

Given these assumptions the power spectral density for a signal is represented in Equation (3).

$$PS(\omega) = \begin{cases} \frac{1}{N \cdot T} \left[\frac{\sin^2 \left[\frac{(\omega - \omega_c) \cdot N \cdot T}{2} \right]}{(\omega - \omega_c)^2} + \frac{\sin^2 \left[\frac{(\omega + \omega_c) \cdot N \cdot T}{2} \right]}{(\omega + \omega_c)^2} \right] & \omega \neq \omega_c \\ \frac{1}{4 \cdot N \cdot T} \left[\frac{\sin^2[\omega_c \cdot N \cdot T]}{\omega_c^2} + (N \cdot T)^2 \right] & \omega = \omega_c \end{cases} \quad (3)$$

This expression is accurate for $M > 2$. Note that due to the assumption that there is no correlation between the phase states, the case when there are two phase states (that either correlate or anticorrelate), deviates from the derived result of Equation (3). Assuming Equation (3) is accurate, it can be seen that the power spectrum of the carrier signal is independent of the number of phase states M , and as such only depends on the number of cycles N before the phase changes and the period of a cycle T . Thus, the bandwidth of the signal is not affected by increasing the number of phase states M .

As mentioned previously, the amount of noise decreases as the frequency decreases yet this may result in signal over modulation especially with wide bandwidth signals. However, in light of the derivation of Equation (3), another approach to improving data rate is to decrease the carrier frequency ω_c while increasing the number of phase states M . Effectively this results in a net data rate improvement without the risk of increasing the bandwidth to cause aliasing.

In the preferred embodiment, the carrier frequency is dropped lower than the typical electromagnetic telemetry frequencies in order to minimize the noise and maximize the received signal amplitude. It is also desirable to choose the carrier frequency such that the signal suffers the least amount of attenuation while propagating through the formation being drilled. For example, in a 5 km well with conductivity of 1mho/meter, a frequency of about 0.5 Hz would be about 44dB stronger than a 5Hz signal. Thus carrier frequencies lower than 1Hz are desired in the preferred embodiment.

With the use of the disclosed PSK telemetry system employing an increased number of phase states, a significant data rate increase is achievable. Equation 5 details the effect of the number of phase states and frequency on signal to noise ratio in going from a bi-phase signal with a carrier of f_0 to a signal with 2^N phases having a carrier of f_1 , (where f_0 and f_1 are in Hz and N is the number of bits transmitted per cycle).

$$\Delta SNR = 20 \cdot \log_{10} \left[\sin \left(\frac{\pi}{2^N} \right) \sqrt{\frac{f_0}{f_1}} \right] \quad (4)$$

Thus, in order to increase the number of bits a penalty is paid in the signal to noise ratio, but this can be offset by dropping the frequency, because the signal to noise ratio is reduced as the frequency is decreased.

For example, if the carrier frequency is dropped from 5 Hz to 1 Hz and the number of bits per cycle are changed from 1 to 10, a 43 dB loss in signal to noise ratio is expected from equation (4). Thus in order realize the benefits of a 100% data rate increase despite the drop in SNR, the increase in signal strength that comes from decreasing the frequency to 1 Hz should be at least 43 dB. Referring now to Figure 9, the effects of frequency and resistivity on the attenuation of a carrier signal decreasing from 5 Hz to 1 Hz, as a function of depth and formation resistivity is shown, and assuming a formation resistivity of 1 ohm per meter and a well depth of 5 km, an increase of about 100 dB is expected. Thus, the disclosed PSK telemetry system offers higher data rates while overcoming disadvantages typically associated with decreasing the carrier frequency.

The spectrum resulting from the PSK signal is fairly compact around the carrier frequency, which allows for other frequencies to be used concurrently. By using multiple frequencies, more information can be transmitted to the surface. Data rates may therefore be increased as long as minimal inter-symbol interference is achieved. Many feasible carrier frequency ratios exist between the multiple frequencies, although it is believed that a ratio of about 38/15 is preferable. For example, if a first carrier frequency is 0.5 Hz, another carrier frequency of $0.5 \text{ Hz} \times 38/15$ or about 1.267 Hz could be used concurrently. However the system is not so limited and may use multiple frequencies. For example if the lowest carrier frequency is 0.1 Hz then a preferred sequence could be multiples of 38/15 times the lowest carrier frequency (0.1 Hz, 0.2533 Hz, 0.64177 Hz, 1.6258 Hz), and the main communication channel is preferably 0.64177 Hz.

Aside from PSK signal transmission techniques, amplitude modulation (AM) techniques may also be used where the carrier frequency has been dropped into a regime where signal losses due to dissipation are small. Amplitude modulation of the carrier results in sideband generation that increases the bandwidth. However, a low bandwidth may be obtained by transmitting single-sideband because it contains the information as contained in the message signal. Methods for transmitting single-sideband amplitude modulation would be evident to one of ordinary skill in the art and are therefore not discussed here.

In yet another embodiment, the carrier signal(s) may be modulated in both phase and amplitude. The modulation may take the form of Quadrature Amplitude Modulation (QAM), or the phase modulation may be done independently of the amplitude modulation. As an example of this later case, one of the carrier frequencies (e.g., 0.5 Hz) may be phase modulated with a 32-

PSK constellation at 0.25 symbols per second, and amplitude modulated to four power levels at 0.125 symbols per second, for a total bit rate of 1.5 bits/sec on one carrier. An example of such a modulated signal is shown in Figure 10. Again, multiple carrier frequencies may be used concurrently.

- 5 It should be mentioned that any number of phase states greater than two may be advantageously used in the PSK electromagnetic telemetry system disclosed above, and that this number is not necessarily limited to a power of two. Other antenna configurations may also be used, while still employing the transmission techniques disclosed herein. The telemetry data may also be encoded with an error correction code or may be compressed. Numerous other variations and modifications will become apparent to those skilled in the art once the above disclosure is
10 fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

CLAIMS

WHAT IS CLAIMED IS:

1. A downhole telemetry system that comprises:

5 an antenna configured to transmit low frequency electromagnetic signals; and
 a phase-shift key (PSK) transmitter configured to receive digital signals indicative of
 telemetry data and configured to convert the digital signals into a PSK transmit
 signal, wherein the PSK transmitter provides the transmit signal to the antenna,
 wherein the PSK transmit signal has a carrier frequency of no more than about 1 Hz, and
10 wherein the PSK transmit signal has a signal constellation with more than 4 phase states.

2. The system of claim 1, wherein the signal constellation consists of 8 phase states.

3. The system of claim 1, wherein the signal constellation consists of 16 phase states.

15

4. The system of claim 1, wherein the signal constellation includes 32 phase states or more.

5. The system of claim 1, wherein the signal constellation includes 256 phase states.

20

6. The system of claim 1, wherein the signal constellation includes 1024 phase states.

7. The system of claim 1, wherein the PSK transmit signal has a symbol period of at least about
four carrier cycles.

25

8. The system of claim 1, wherein the PSK transmit signal has a symbol period of about three
carrier cycles.

9. The system of claim 1, wherein the PSK transmit signal has a symbol period of about two
carrier cycles.

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10. The system of claim 1, wherein the carrier frequency is about 0.5 Hz.

11. The system of claim 1, wherein the PSK transmit signal is also amplitude modulated.

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12. A method of logging while drilling, wherein the method comprises:

drilling a hole through a formation with a drill bit attached to a drill string that includes a sensor package;

5 detecting signals indicative of formation properties;

determining telemetry information from the detected signals;

providing the telemetry information to a PSK transmitter;

encoding the telemetry information to obtain a digital transmit signal;

10 phase modulating the digital transmit signal on a low-frequency carrier signal to obtain a PSK signal; and

transmitting the PSK signal to a surface receiver,

wherein the low-frequency carrier signal has a frequency of no more than about 1 Hz, and

wherein the PSK signal has a signal constellation with more than 4 phase states.

15 13. The method of claim 12, wherein the signal constellation includes 32 phase states or more.

14. The method of claim 12, wherein the signal constellation includes 256 phase states.

15. The method of claim 12, wherein the signal constellation includes 1024 phase states.

20

16. The method of claim 12, wherein the carrier frequency is about 0.5 Hz.

17. The method of claim 12, further comprising:

receiving the PSK signal at the surface;

25

determining telemetry information from the received PSK signal; and

associating the telemetry information with a position of the sensor package.

18. The method of claim 12, wherein the PSK transmit signal is also amplitude modulated.

30 19. A downhole telemetry system that comprises:

an antenna configured to transmit low frequency electromagnetic signals; and

a phase-shift key (PSK) transmitter configured to receive digital signals indicative of telemetry data and configured to convert the digital signals into a PSK transmit signal, wherein the PSK transmitter provides the transmit signal to the antenna,

35

wherein the PSK transmit signal contains multiple carrier frequencies, and

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wherein the PSK transmit signal has a signal constellation with more than 4 phase states.

20. The system of claim 19, wherein the signal constellation consists of 8 phase states.

5 21. The system of claim 19, wherein the signal constellation consists of 16 phase states.

22. The system of claim 19, wherein the signal constellation includes 32 phase states or more.

23. The system of claim 19, wherein the signal constellation includes 256 phase states.

10

24. The system of claim 19, wherein the signal constellation includes 1024 phase states.

25. The system of claim 19, wherein the PSK transmit signal has a symbol period of at least about four carrier cycles.

15

26. The system of claim 19, wherein the PSK transmit signal has a symbol period of about three carrier cycles.

27. The system of claim 19, wherein the PSK transmit signal has a symbol period of about two carrier cycles.

20

28. The system of claim 19, wherein the carrier frequencies are separated by a ratio of about 38/15.

25 29. The system of claim 19, wherein the PSK transmit signal is also amplitude modulated.

30. A method of logging while drilling, wherein the method comprises:

drilling a hole through a formation with a drill bit attached to a drill string that includes a sensor package;

detecting signals indicative of formation properties;

30

determining telemetry information from the detected signals;

providing the telemetry information to a transmit transmitter;

encoding the telemetry information to obtain a digital transmit signal;

phase modulating the digital transmit signal on multiple low-frequency carrier signals to obtain a transmit signal; and

35

transmitting the transmit signal to a surface receiver,

31. The method of claim 30, wherein the transmit signal has a signal constellation with more than 4 phase states.

5 32. The method of claim 31, wherein the multiple low-frequency carrier signals are separated by a ratio of about 38/15.

33. The method of claim 32, wherein the signal constellation includes 32 phase states or more.

10 34. The method of claim 32, wherein the signal constellation includes 256 phase states.

35. The method of claim 32, wherein the signal constellation includes 1024 phase states.

36. The method of claim 32, further comprising:

15 receiving the transmit signal at the surface;
determining telemetry information from the received transmit signal; and
associating the telemetry information with a position of the sensor package.

37. The method of claim 30, wherein the transmit signal is also amplitude modulated..

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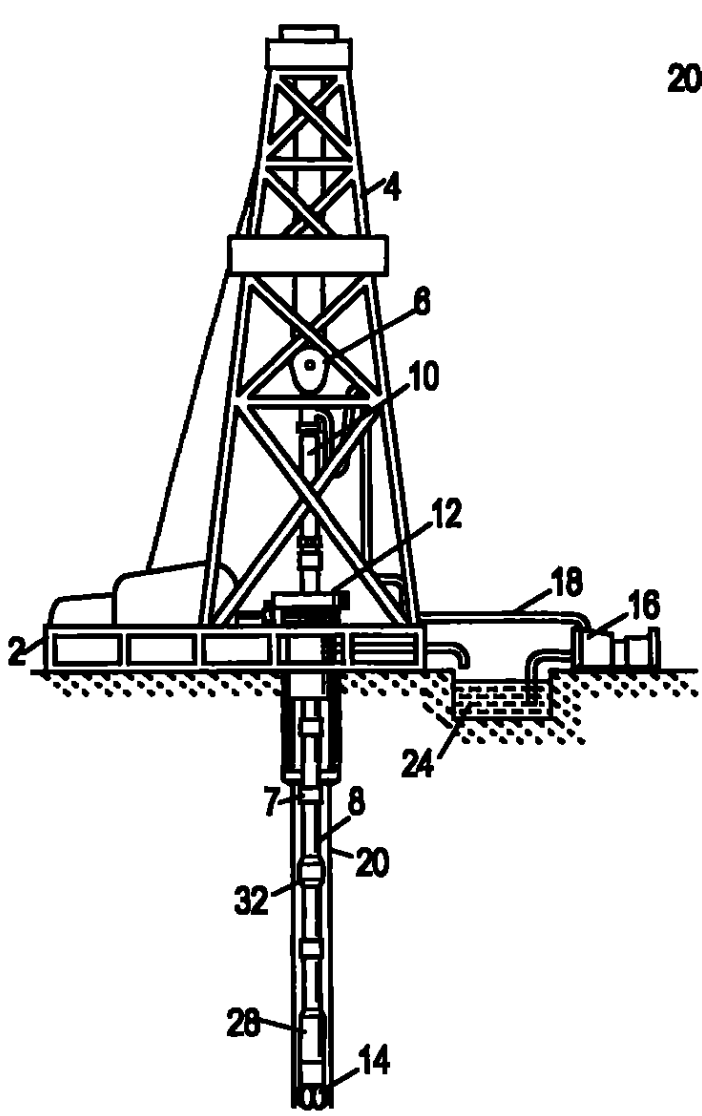


FIG. 1

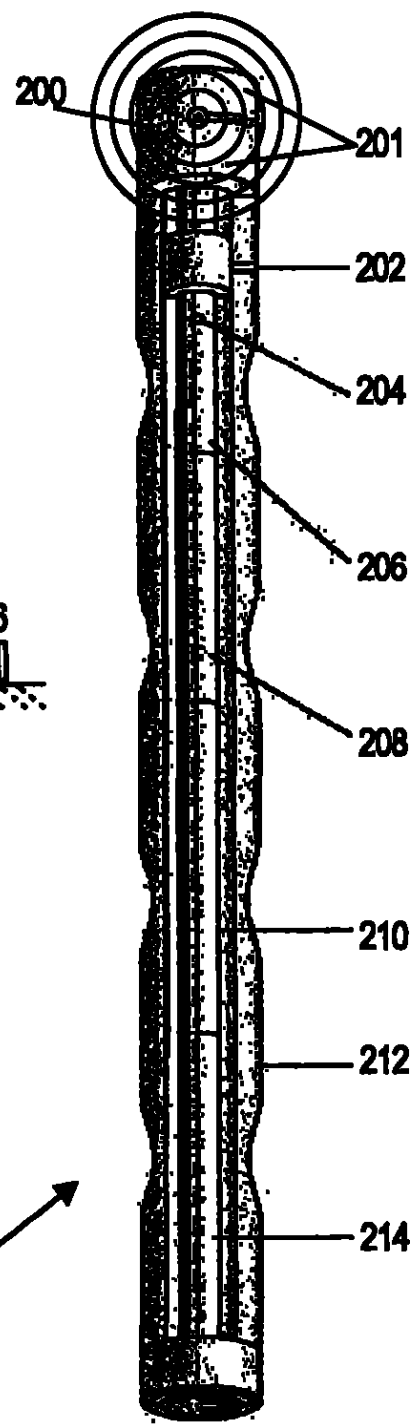


FIG. 2

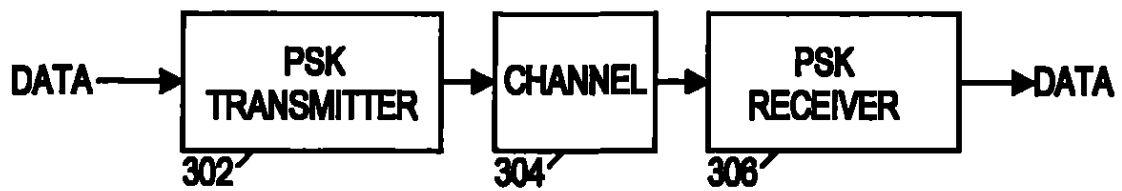


FIG. 3

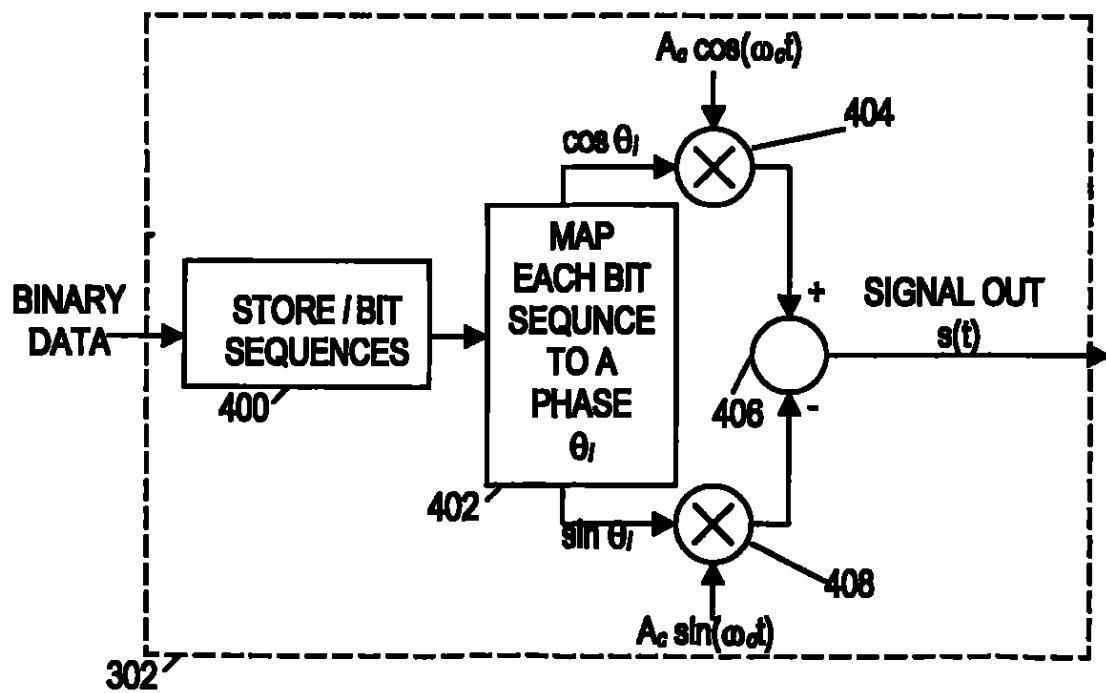
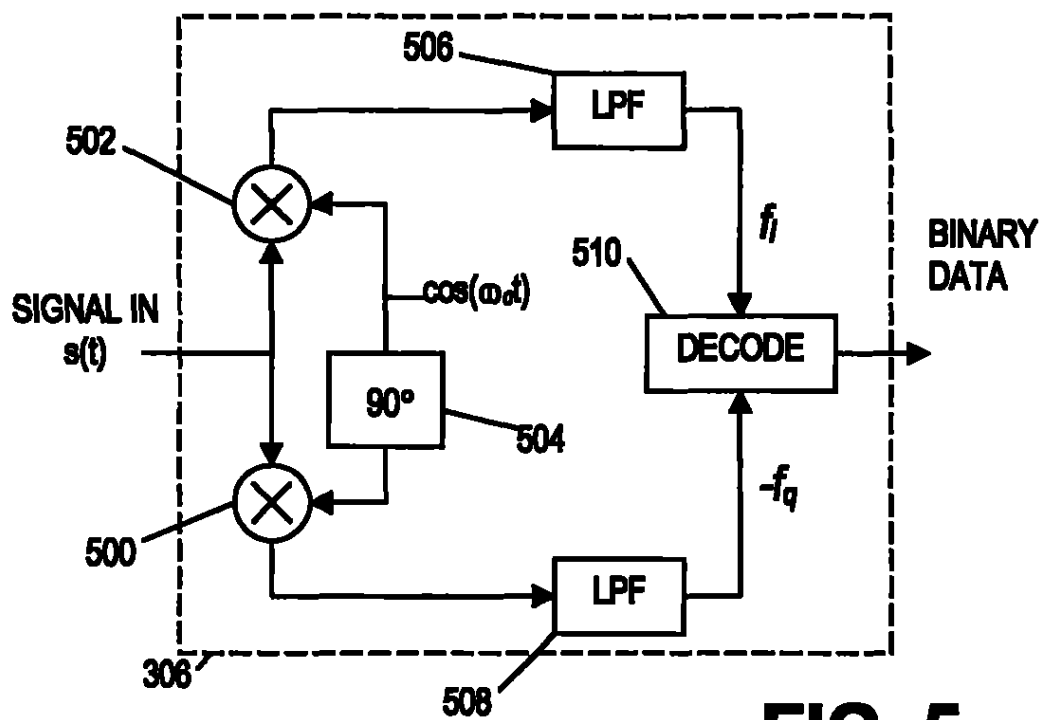


FIG. 4

4300 25
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2003 24

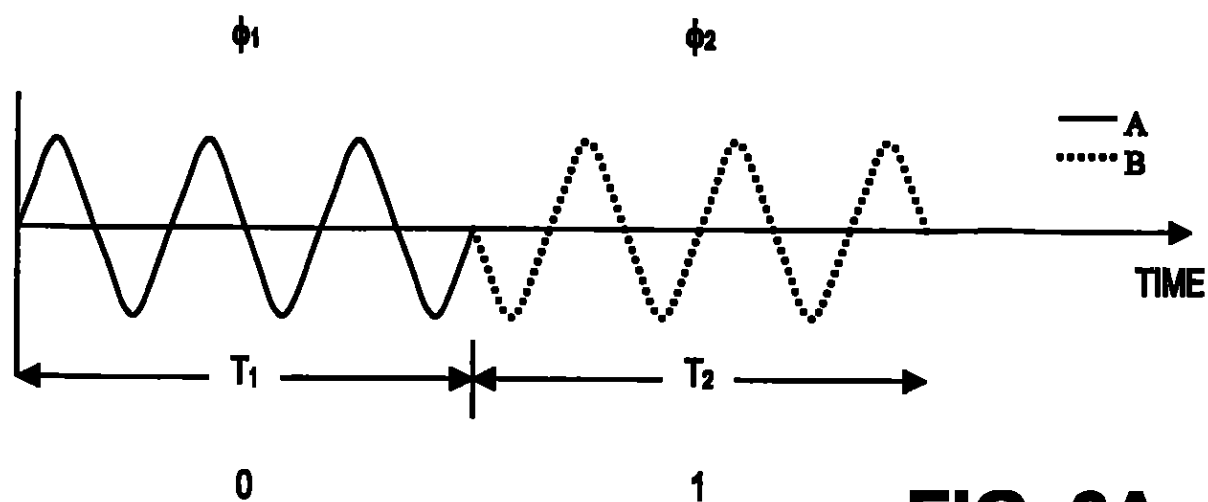


FIG. 6A

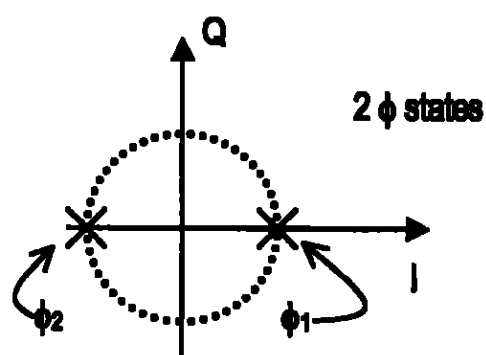


FIG. 6B

Attenuation of Signal at 5 Hz relative to 1 Hz as a Function of Depth and Formation Resistivity

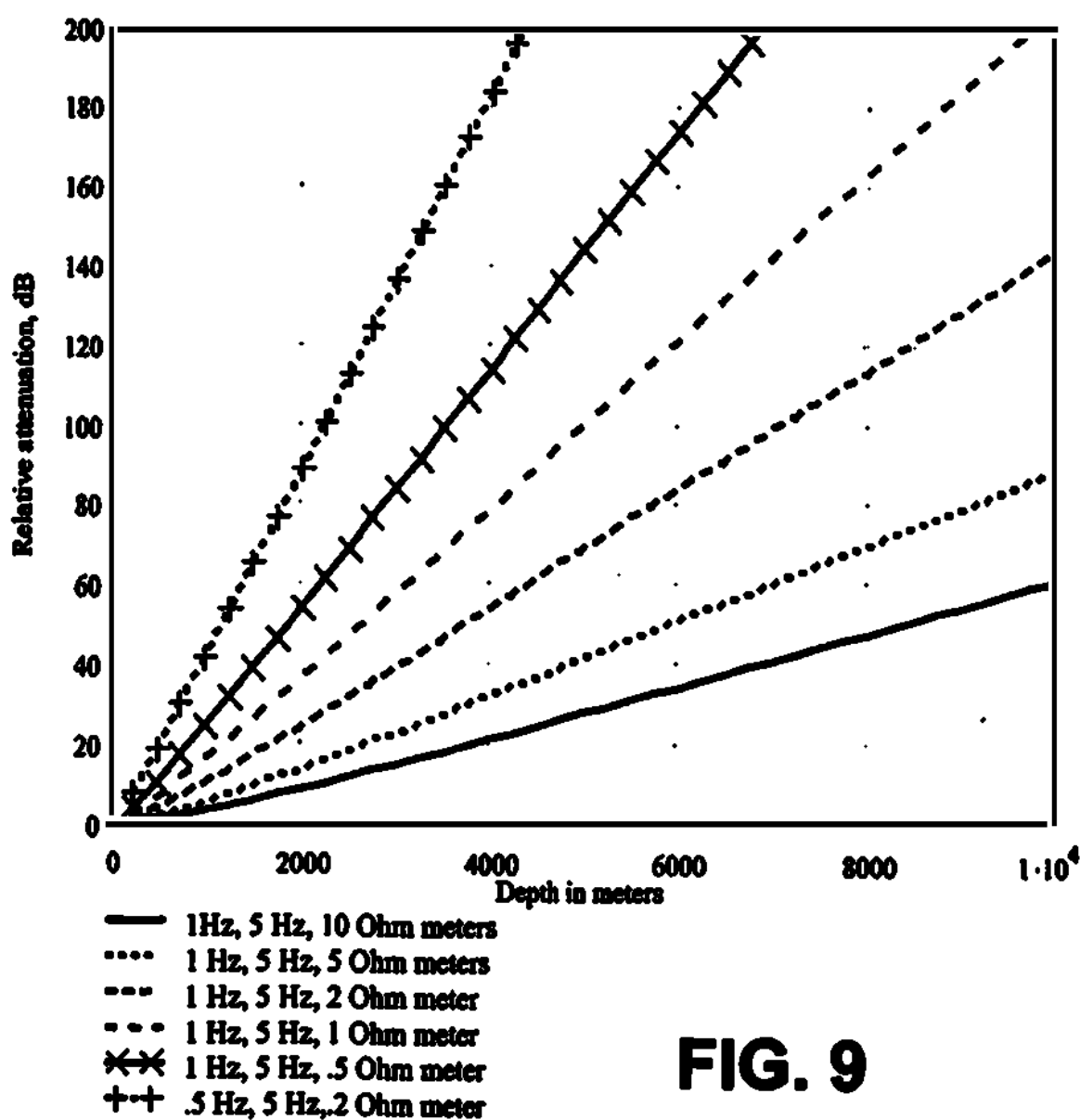


FIG. 9

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Four-Phase PSK Message Sequence Assignment		
Binary Bit Group	Carrier Phase	Transmitted Signal
00	+45°	$s(t) = \frac{A_s}{\sqrt{2}} [\cos\omega_c t - \sin\omega_c t]$
01	-45°	$s(t) = \frac{A_s}{\sqrt{2}} [\cos\omega_c t + \sin\omega_c t]$
10	+135°	$s(t) = -\frac{A_s}{\sqrt{2}} [\cos\omega_c t + \sin\omega_c t]$
11	-135°	$s(t) = -\frac{A_s}{\sqrt{2}} [\cos\omega_c t - \sin\omega_c t]$

FIG. 7

Decoding Rule for Figure 5 and the Phase Assignment of Figure 7			
$\hat{f}_i$	$\hat{f}_q$	θ_1	Decoded Bit Group
$\frac{A_s}{\sqrt{2}}$	$-\frac{A_s}{\sqrt{2}}$	45°	00
$\frac{A_s}{\sqrt{2}}$	$\frac{A_s}{\sqrt{2}}$	-45°	01
$-\frac{A_s}{\sqrt{2}}$	$-\frac{A_s}{\sqrt{2}}$	135°	10
$-\frac{A_s}{\sqrt{2}}$	$\frac{A_s}{\sqrt{2}}$	-135°	11

FIG. 8

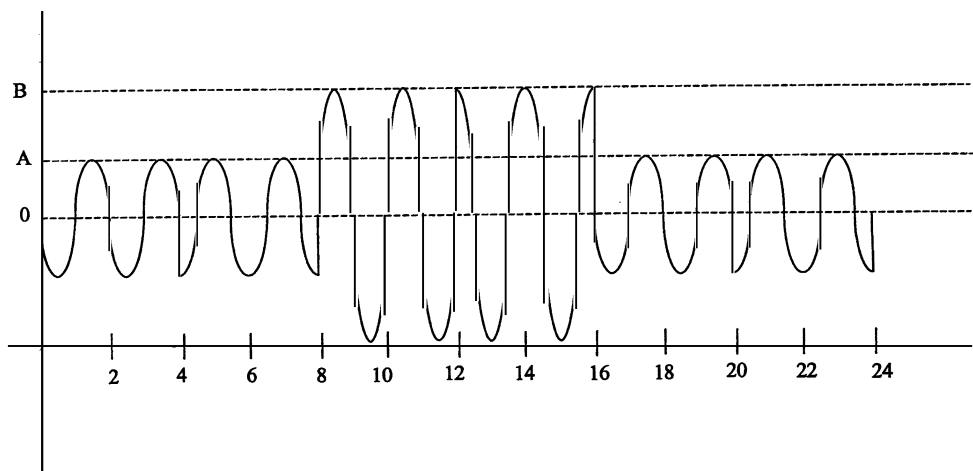


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/20571

A. CLASSIFICATION OF SUBJECT MATTER		
IPC(7) : G01V 1/22		
US CL : 340/853.2, 854.6; 367/83; 714/792; 375/261,270,301		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
U.S. : 340/853.2, 854.6; 367/83; 714/792; 375/261,270,301		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
Please See Continuation Sheet		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,468,663 (THAWLEY et al) 28 August 1984 (28.08.1984), column 4 lines 10-15 and column 6 lines 55-63.	1-24, 28-37
Y, P	US 6,360,293 B1 (ALHLYUNAS et al) 06 May 2003 (05.05.2003), column 5 lines 18-30.	1-6, 10-24, 28-37
Y	US 4,215,427 (WAGGNER et al) 29 July 1980 (29.07.1980), Figure 4A.	7-9
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"B" earlier application or patent published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another claim or other special reason (as specified)	"Z" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is considered in combination with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"d" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
24 August 2003 (24.08.2003)	01 OCT 2003	
Name and mailing address of the ISA/US	Authorized officer	
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450	Michael Horabik <i>Rugeneria Zogan</i>	
Facsimile No. (703)303-3230	Telephone No. (703) 303-1955	

INTERNATIONAL SEARCH REPORT

PCT/US05/20871

Continuation of B. FIELDS SEARCHED Item 3:

Searched EAST database; Searched terms are: PKK, PhaseShift, downhole, borehole, constellation, multi or multiple frequency

SISTEMA DE TELEMETRÍA ELECTROMAGNÉTICA DE BAJA FRECUENCIA
QUE EMPLEA MODULACIÓN POR DESPLAZAMIENTO DE FASE DE ALTA
CARDINALIDAD

Campo de la Invención

La presente invención se relaciona con técnicas de exploración de formaciones. Más particularmente, la presente invención se relaciona con un sistema de telemetría para transmitir datos desde un conjunto de taladro en el fondo del pozo a la superficie del pozo.

Descripción del Estado de la Técnica

Las operaciones modernas de taladrado y producción de petróleo, demanda una gran cantidad de información relacionada con los parámetros y condiciones del fondo del pozo. Tal información típicamente incluye características de las formaciones terrestres atravesadas por el pozo del pozo, junto con datos relacionados al tamaño y configuración del pozo mismo. La recolección de información relacionada con las condiciones del fondo del pozo, que se llama comúnmente "exploración", puede llevarse a cabo por diversos métodos.

En una exploración alámbrica convencional de pozos de petróleo, una sonda que tiene sensores de formación se baja por el pozo después de que alguna parte o todo el pozo ha sido taladrado, y se usa para determinar ciertas características de las formaciones atravesadas por el pozo. El extremo superior de la sonda está sujeto a un cable conductor que suspende la sonda en el pozo. La potencia es transmitida a los sensores y a la instrumentación en la sonda por medio del cable conductor. De manera similar, la instrumentación en la sonda comunica la información a la superficie por medio de señales eléctricas transmitidas por el cable.

El problema con la obtención de las medidas en el fondo del pozo por medio del cable es que el conjunto de taladrado debe ser removido o "retirado" del pozo taladrado antes de que se haya obtenido la información del pozo deseada. Esto puede llegar a ser consumidor de tiempo y extremadamente costoso, especialmente en situaciones en donde una porción sustancial del pozo ha sido taladrada. En esta situación, miles de pies de tubería pueden requerir ser retirados y apilados sobre la plataforma (fuera del pozo). Típicamente, el equipo de

taladrado se alquila por día a un costo sustancial. Por consiguiente, el costo de taladrar un pozo es directamente proporcional al tiempo requerido para completar el proceso de taladrado. Remover miles de pies de tubería para insertar una herramienta de exploración alámbrica puede llegar a ser una propuesta muy cara.

Como un resultado, ha habido un énfasis incrementado en la recolección de datos durante el proceso de taladrado. La recolección y procesamiento de los datos durante el proceso de taladrado elimina la necesidad de remover o retirar el conjunto de taladro para insertar una herramienta de exploración alámbrica. Consecuentemente permite al taladrador hacer modificaciones precisas o correcciones precisas según se requiera para optimizar la efectividad mientras se minimiza el tiempo de paro. Los diseños para medir las condiciones en el fondo del pozo incluyen el movimiento y la localización del conjunto de taladrado contemporáneamente con el taladrado del pozo se ha conocido como técnicas de "mida mientras se taladra" o "MWD". Técnicas similares que concentran más sobre la medición de los parámetros de formación, comúnmente se han llamado como técnicas de "explore mientras taladra" o "LWD". Aunque las distinciones entre MWD y LWD pueden

existir, los términos MWD y LWD frecuentemente son usados de manera intercambiable. Para propósitos de esta descripción, el término MWD será usado con el entendimiento de que este término involucra tanto la recolección de parámetros de formación y la recolección de información que se relaciona con el movimiento y la posición del conjunto de taladrar.

Cuando los pozos de petróleo u otros pozos están siendo taladrados, frecuentemente es necesario o deseable determinar la dirección e inclinación de la punta del taladro o la broca y el motor en el fondo del pozo de modo que el conjunto pueda ser manejado en la dirección correcta. Adicionalmente, se puede requerir información concerniente a la naturaleza de los estratos que están siendo taladrados, tal como la resistividad, porosidad, densidad de la formación y su medida de radiación gama. También es deseable frecuentemente conocer otros parámetros del fondo del pozo, tales como la temperatura y la presión en la base del pozo, por ejemplo. Una vez que estos datos son recolectados en el fondo del pozo, es necesario comunicarlos a la superficie para su uso y análisis por el taladrador.

Los sensores o transductores típicamente están localizados en el extremo inferior de la sarta del taladro en sistemas MWD. Típicamente, los sensores en el fondo del pozo empleados en aplicaciones MWD están posicionados en un collar del taladro cilíndrico que está posicionado cerca de la broca de taladrado. Aunque el taladrado esté en progreso estos sensores continua o intermitentemente monitorean parámetros de taladrado predeterminados y datos de formación y transmiten la información con respecto al fondo del pozo a la superficie por medio de alguna forma de telemetría. Hay un número de sistemas de telemetría en el estado de la técnica que buscan transmitir la información relacionada con los parámetros del fondo del pozo hasta la superficie sin requerir el uso de una herramienta alambrada. Un sistema de telemetría ampliamente usado en aplicaciones MWD es el sistema de pulso de lodo.

El sistema de pulso de lodo de telemetría crea señales de presión "acústica" en el fluido de taladro, algunas veces llamado "lodo", que es circulado bajo presión por la sarta del taladro durante las operaciones de taladrado. La información que es adquirida por los sensores en el fondo del pozo es transmitida por medio de

temporizar adecuadamente los pulsos de presión de la formación en la corriente de lodo. La información es recibida y decodificada por un transductor de presión y un computador en la superficie.

En un sistema de pulso de presión de lodo, en la presión del lodo de taladrado en la sarta de taladrado es modulada por medio de un mecanismo de válvula y control, generalmente llamado un pulsador o pulsador de lodo. El pulsador está usualmente montado en un collar del taladro adaptado especialmente y posicionado por encima de la broca. El pulso de presión generado viaja hacia arriba por la columna del lodo al interior de la sarta de taladrado a la velocidad del sonido en el lodo. Dependiendo del tipo de fluido de taladrado usado la velocidad puede variar entre aproximadamente 3000 y 5000 pies por segundo. La velocidad de transmisión de los datos, sin embargo, es relativamente lenta debido al esparcimiento, distorsión, atenuación, limitaciones de velocidad de modulación y otras fuerzas disruptivas del pulso, tal como el ruido ambiente en la sarta del taladro. Una velocidad del pulso típico está en el orden de un pulso por segundo (1 Hz).

Con los desarrollos recientes en las tecnologías de sensores y de manejo disponibles al taladrador, la cantidad de datos que pueden ser transportados a la superficie de una manera en tiempo de 1 bit por segundo son manejados inadecuadamente. Como un método para incrementar la velocidad de transmisión de los datos, se ha propuesto transmitir los datos usando vibraciones en la pared de la tubería de la sarta del taladro en vez de depender de los pulsos de presión en el fluido de taladrado. Sin embargo, sistemas anteriores han probado que no es confiable cuando las velocidades de los datos son mayores a 3 bits/s debido a las reflexiones acústicas en las uniones de la herramienta y las variaciones en la geometría de la tubería y del pozo.

Adicionalmente, la telemetría de pulso de lodo requiere un fluido de taladrado medianamente denso, volviéndolo inútil en aplicaciones como el taladrado sub balanceado (UBD) en el cual el fluido de baja densidad y aireado son necesarios o deseados.

RESUMEN DE LA INVENCION

De acuerdo a lo anterior, se describe aquí un sistema de telemetría electromagnético en el fondo del pozo confiable, el cual soluciona las desventajas de los métodos de telemetría anteriores. En una modalidad preferida, un sistema de transmisión de datos electromagnético con modulación de cambio de fase es usado para transmitir los datos para las aplicaciones MWD.

De acuerdo con la modalidad preferida, una antena es configurada para transmitir señales electromagnéticas de baja frecuencia mientras un transmisor de modulación por cambio de fase (PSK) es configurado para recibir señales digitales indicativas de datos telemétricos y convertir las señales digitales en señales de transmisión PSK. El transmisor PSK suministra la señal de transmisión a la antena, y la señal de transmisión PSK tiene una frecuencia portadora de no más de cerca de 1 Hz, y una señal de constelación con más de 4 estados de fase. La señal de transmisión PSK puede también incluir una señal de transmisión con un periodo de símbolo de 2 o más ciclos portadores.

En otra modalidad de la presente invención, un método de explorar mientras se taladra se describe en donde el pozo es taladrado a través de una formación con una broca sujeta a una sarta de taladro que incluye un paquete sensor. Las señales son entonces detectadas las cuales indican las propiedades de la formación. Estas señales se suministran entonces al transmisor PSK, en donde ellas son codificadas para obtener una señal de transmisión digital que es modulada en fase sobre una señal portadora de baja frecuencia para obtener una señal PSK con una frecuencia de no más de 1 Hz y con no más de 4 estados de fase. La señal PSK de baja frecuencia es entonces transmitida a la superficie. El sistema y el método descritos pueden suministrar de manera ventajosa un sistema de telemetría electromagnético, robusto, y de baja potencia con una velocidad de datos incrementada con relación a los sistemas de telemetría de pulso de lodo y otros sistemas de telemetría convencionales.

Por lo tanto, a pesar de la reluctancia a la caída de la frecuencia portadora debido a los problemas de velocidad de datos reducidos, se cree que cualquier reducción de la velocidad de datos causada por la caída de frecuencia puede solucionarse implementado el número

de estados de fase sin incrementar el ancho de banda. Con la frecuencia portadora caída de acuerdo con las modalidades, el sistema telemétrico electromagnético puede ser mejorado usando múltiples portadoras y modulación de amplitud.

BREVE DESCRIPCIÓN DE LOS DIBUJOS

Un mejor entendimiento de la presente invención puede ser obtenido cuando la siguiente descripción detallada de las modalidades preferidas es considerada en conjunto con los siguientes dibujos, en los cuales:

La figura 1 es una vista esquemática de un pozo de petróleo en el cual un sistema de telemetría electromagnético puede ser empleado;

La figura 2 es una vista de una herramienta de fondo de pozo usada en telemetría electromagnética;

La figura 3 es un diagrama de bloque funcional de un sistema de telemetría electromagnético que emplea modulación de cambio de fase;

La figura 4 es un diagrama de bloque funcional de un transmisor con modulación de cambio de fase;

La figura 5 es un diagrama de bloque funcional de un receptor con modulación por desplazamiento de fase;

La figura 6A es un ejemplo de transmisión PSK;

La figura 6B muestra los componentes en fase y en cuadratura de la figura 6A;

La figura 7 muestra una asignación de secuencia de mensaje de 4 fases;

La figura 8 muestra una regla de decodificación para el decodificador de la figura 5;

La figura 9 muestra los efectos de la frecuencia y la resistividad de la formación en una atenuación de señal; y

La figura 10 muestra una señal modulada en fase y amplitud ilustrativa.

Aunque la invención es susceptible a diversas modificaciones y formas alternativas, las modalidades específicas de la misma se muestran como ejemplo en los dibujos y serán aquí descritas en detalle. Debe entenderse, sin embargo, que los dibujos y la descripción detallada de ellos no tienen el propósito de limitar la invención a la forma particular descrita, sino por el contrario, la intención es cubrir todas las modificaciones, equivalentes y alternativas que caigan dentro del espíritu y alcance de la presente invención según se define en las reivindicaciones adjuntas.

DESCRIPCIÓN DETALLADA DE LAS MODALIDADES PREFERIDAS

Las aplicaciones MWD sufren por las velocidades de los datos que no están bien adecuadas para la cantidad siempre creciente de datos que requieren ser transmitidos. Un método para incrementar la velocidad de los datos incluye incrementar la frecuencia portadora, pero esto puede causar la atenuación y distorsión indeseable de la señal. Por otro lado, disminuir la frecuencia portadora suministra el premio de una señal más fuerte con el riesgo de interferencia, especialmente con señales de ancho de banda amplia. Una derivación se

ha descrito aquí la cual predice que la frecuencia puede realmente ser disminuida mientras se incrementa el número de estado de fase para lograr una velocidad de datos general más alta, sin afectar el ancho de banda o causar interferencia en la señal.

Volviendo ahora a las figuras, la figura 1 muestra un pozo durante las operaciones de taladrado. Una plataforma de taladrado 2 está equipada con un castillete 4 que soporta una grúa 6. El taladrado de los pozos de petróleo y de gas se lleva a cabo por una sarta de tuberías de taladrado conectadas juntas por uniones de "herramientas" 7 de modo que se forma una sarta de taladrado 8. La grúa 6 suspende una barra de arrastre 10 que es usada para bajar la sarta de taladrado 8 por a través de una tabla giratoria 12. Conectado al extremo inferior de la sarta de taladrado 8 se encuentra una broca de taladrado 14. La broca 14 es girada y el taladrado se lleva a cabo por medio de hacer girar la sarta de taladrado 8, por el uso de un motor en el fondo del pozo cerca de la roca de taladrado, o por ambos métodos. El fluido de taladrado, llamado lodo, es compuesto por el equipo de recirculación de lodo 16 por una tubería de suministro 18, por una barra de arrastre

de taladrado 10, y hacia abajo por la sarta de taladrado 8 a alta presión y volúmenes para emerger a través de las boquillas o chorros en la broca de taladrado 14. El lodo entonces viaja de nuevo hacia arriba por el pozo a través del aro formado entre el exterior de la sarta de taladrado 8 y en la pared del pozo 20, por un impedidor de soplado (no mostrado específicamente), y hacia a un pozo de lodo 24 en la superficie. Sobre la superficie, el lodo de taladrado es limpiado y luego recirculado por el equipo de recirculación 16. El lodo de taladrado es usado para enfriar la broca de taladrado 14, para llevar los cortes desde la base del pozo a la superficie, y para balancear la presión hidrostática en las formaciones de la roca. Sin embargo, el sistema de la figura 1 no es restrictivo al uso del lodo como fluido de taladrado. Por ejemplo, en el caso de taladrado sub balanceado (UBD). Otro medio tal como fluidos aireados o mezclas de aire/nieblas pueden ser preferidos en lugar del lodo.

En una modalidad preferida, un sistema de telemetría de datos es usado en la herramienta del fondo de pozo 28 tal que el MWD se lleva a cabo por medio de transmitir datos desde la herramienta en el fondo del pozo 28 electromagnéticamente. Debe notarse que mientras que la

herramienta de fondo del pozo 28 es mostrada en proximidad cercana a la broca de taladrado 14, esta puede estar colocada en cualquier punto a lo largo de la sarta de taladrado según se desee.

Haciendo referencia ahora a la figura 2, la herramienta de fondo de pozo 28 es mostrada en más detalle. Como se muestra la herramienta de fondo de pozo 28 incluye un aislador 200, una antena 201, un puerto anular 202, un puerto interno 204, un módulo electrónico 206, un módulo de baterías 208, un sensor de gama 210, y un sensor direccional 214, todos ellos dentro de un collar de taladrado 212. Sin embargo debe notarse que los contenidos de la herramienta de fondo de pozo 28 como se muestran no es una lista exhaustiva de sus contenidos y sería evidente para cualquier versado en la técnica.

El aislador 200 separa las porciones superior e inferior de la antena 201, y el dato es transmitido a la superficie induciendo una diferencia de voltaje alterno por el aislador 200, generando así la señal electromagnética. En la superficie, la señal electromagnética es recibida preferiblemente como un potencial de voltaje entre la sarta de taladrado

conductora y un electrodo de tierra (no mostrado). Uno o más módulos repetidores 32 pueden estar provistos a lo largo de la sarta de taladrado para recibir señales telemétricas electromagnéticas desde la herramienta del fondo del pozo 28 y retransmitirlas a la superficie. Los módulos repetidores 32 preferiblemente incluyen tanto un receptor de telemetría electromagnético y un transmisor de telemetría electromagnético.

El puerto anular 202 ayuda a medir la presión anular; mientras que el puerto interno 204 ayuda a medir la presión interna. El sensor de gama 210 mide las radiaciones y el sensor direccional 214 mide la orientación de la sarta de taladrado. La potencia es suministrada a los diversos sensores y al equipo electrónico en la herramienta de fondo de pozo 28 por el módulo de batería 208. Las diversas medidas de los sensores son reportadas al módulo electrónico 206 en donde son procesadas. El procesamiento de las señales puede incluir: digitalizar las medidas análogas del sensor convertirlas en datos binarios, almacenar la información en una memoria local, comprimir los datos para una transmisión eficiente, lo mismo que cualquier otra tarea evidente para aquellos versados en la técnica.

En adición, el módulo electrónico 206 incluye un transmisor para transmitir los datos usando técnicas de señalización electromagnética, en donde el transmisor preferiblemente un transmisor modulado por desplazamiento de fase (PSK). Lo mismo que contiene el modulo electrónico transmisor PSK 206 puede contener un receptor PSK que permita comunicaciones hacia la parte de arriba y hacia la parte de abajo del pozo.

Como se muestra en la figura 3, el sistema de telemetría PSK electromagnético puede ser modelado usando tres bloques funcionales: un canal 304, un transmisor PSK 302, y un receptor PSK 306. Como s menciono anteriormente, para producir la señal electromagnética, una diferencia de voltaje es generada a través del aislador 200. La señal electromagnética viaja entonces a la superficie por la formación que esta siendo taladrada mientras es guiada por la sarta de taladrado conductora eléctricamente. En las superficie, la onda electromagnética es recibida como un potencial de voltaje entre el equipo cuatro y un electrodo de tierra colocada en la proximidad del equipo. Así, el canal 304 por el cual el transmisor PSK 302 y el receptor PSK 306 se

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comunican incluye la antena de transmisión, la formación que esta siendo taladrada, la sarta de taladrado que actúa como guía de la onda electromagnética y el electrodo receptor.

Haciendo referencia ahora a la figura 4, un diagrama de bloques que ilustra un transmisor PSK 302 posible se muestra. Una corriente de datos binarias que preferiblemente ha sido procesada y preparada para la transmisión es pasada por el bloque 400, en el cual se almacena la corriente de datos en secuencias de bits o grupos de bits. En el bloque 402, cada secuencia de bit es entonces mapeada a una fase en donde cada fase corresponde a una secuencia de bit única. Uno de los trayectos que viene del bloque 402 contiene el seno de cada fase que es mezclado con el seno de una señal portadora usando el mezclador 408. Otro trayecto que viene del bloque 402 contiene el coseno de cada fase que es mezclado con el coseno de una señal portadora usando el mezclador 404. La salida del mezclador 404 y 408 son alimentados en un bloque de +/- 406, y la señal que sale comprende las combinaciones de las combinaciones de las funciones seno y coseno que representa la señal que va a ser transmitida por el canal 304.

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La figura 7 muestra una asignación de secuencia PSK de cuatro fases y será explicada con respecto al transmisor de la figura 4. En el PSK de cuatro fases, la corriente de datos binaria es rota en grupos de dos bits binarios en donde cada grupo de bits es representado por una fase transmitida diferente. Ya que el número de bits "i" transmitido durante cada intervalo de símbolo es igual a dos, entonces esto hace un total de 2^i grupos posibles de bits binarios, o 4. Por lo tanto hay o debe haber cuatro fases transmitidas diferentes, o una por cada grupo de bits. Si por otro lado hubiera tres bits binarios por símbolo esto resultaría en 2^3 u 8 grupos posibles de bits, lo que requeriría ocho diferentes estados de fase transmitida.

Típicamente en los estados de fase son espaciados igualmente de modo que las fases transmitidas para el PSK de cuatro fases sería de $360^\circ/4$ o 90° de separación, por lo tanto un conjunto posible como se ve en la figura 7 es $\{\pm 45^\circ, \pm 135^\circ\}$. La señal transmitida fuera del bloque 406 $s(t)$ es

$$S(t) = A_c \cos[\omega_c t + \theta_i], \quad (1)$$

$i = 1, 2, 3, 4$, en donde las fases de los grupos de bits binarios son asignadas de acuerdo con la figura 7. La señal transmitida de la ecuación (1) puede ser rescrita utilizando una identidad trigonométrica como

$$s(t) = A_c \cos\theta_i \cos\omega_c t - A_c \sin\theta_i \sin\omega_c t \quad (2)$$

Así, los componentes en fase o en cuadratura son fácilmente vistos en la ecuación 2, y la figura 7 contiene la señal transmitida durante el intervalo del símbolo.

Haciendo referencia ahora a la figura 5, un diagrama de bloques que ilustra un receptor PSK posible 306 se muestra. La señal de entrada es pasada por el multiplicador 500 y 502. El multiplicador 500 muestra la señal de entrada con la frecuencia portadora que contiene un desplazamiento de fase de 90° para producir el componente de cuadratura f_q . El multiplicador 502 mientras tanto mezcla la señal de entrada con la frecuencia portadora para producir el componente en fase f_i . Ambos los componentes en fase y cuadratura son pasadas por filtros pasabajos 506 y 508 respectivamente.

En este punto los componentes en fase y cuadratura pueden ser ganados según sea necesario antes de llegar al decodificador 510. La figura 8 contiene una asignación de regla de descodificación ilustrativa para el receptor de acuerdo con la figura 5 y usando asignación de fase ejemplo de la figura 7.

Debe mencionarse que el transmisor de la figura 4 y el receptor de la figura 5, lo mismo que el ejemplo PSK de cuatro fases contenido aquí pueden que no sean óptimos y tienen el propósito de discusión solamente.

Las aplicaciones MWD actuales tienen un número que se incrementa de sensores que generan una cantidad siempre incremental de datos y esto crea frecuentemente un cuello de botella de datos porque la velocidad de los datos alcanzables no puede mantenerse con el incremento de la salida de datos. Por lo tanto en la mayoría de los sistemas de telemetría, es deseable mejorar la velocidad de datos.

Haciendo referencia ahora a la figura 6^a, una transmisión PSK se muestra. La transmisión PSK es una transmisión TSK de dos fases con la señal A y la señal B

que tienen la misma frecuencia pero que están fuera de fase 180° . Haciendo referencia brevemente a la figura 6B, un diagrama de constelación que ilustra componentes de fase (I) y cuadratura (QU) se muestran para el sistema de dos fases de la figura 6A con Φ_1 correspondiente a la señal A y Φ_2 correspondiente a la señal B.

Como se ve en la figura 6A, la señal A y la señal B son transmitidas durante el intervalo de símbolo t_1 y t_2 , y cada intervalo de símbolo contiene tres ciclos. También, la señal A cuando es transmitida representa el bit binario 0 mientras que la señal B cuando es transmitida representa el bit binario 1. A la luz de la figura 6A hay varias maneras para mejorar el número de bits transmitidos por unidad de tiempo (es decir velocidad de datos).

Un método de incrementar la velocidad de datos es incrementar la frecuencia portadora de modo que el intervalo de tiempo de símbolo total disminuye. Entonces nuevamente la atenuación y la distorsión de la señal se incrementa significativamente a medida que la frecuencia portadora es incrementada, estableciendo límites fundamentales sobre las mejoras de las velocidades de

datos que son alcanzables por medio de incrementar la frecuencia portadora. Por otro lado, disminuir la frecuencia portadora suministra el premio de una señal electromagnética más fuerte con el riesgo agregado de interferencia con componentes de frecuencia negativos y esto puede ser especialmente problemático cuando se maneja con señales de banda de ancha alta.

Otro método de incrementar la velocidad de datos es por medio de incrementar el número de estados de fase asignando así más bits a cada intervalo de símbolo. Por ejemplo, si el número de estados de fases en la transmisión TSK de las figuras 6A fuera incrementada a 4, entonces cada intervalo de símbolo podría contener dos bits de datos como fue explicado previamente con respecto a la figura 7.

Un análisis de las propiedades de potencia espectral de las señales moduladas por fase se presenta ahora con un ojo hacia el incremento de la velocidad de datos. Las siguientes presunciones aplican:

- La frecuencia portadora es ω_c en radianes ;

- El periodo de un ciclo de la portadora es t ;
- Los cambios de fase una vez cada n ciclos (n es un entero positivo);
- Hay M posibles estados de fase, en donde M es un entero > 1 ;
- Para un M dado, las fases permitidas se toman del conjunto

$$\left\{0, \frac{2 \cdot \pi}{M}, 2 \cdot \frac{2 \cdot \pi}{M}, 3 \cdot \frac{2 \cdot \pi}{M}, \dots, (M-1) \cdot \frac{2 \cdot \pi}{M}\right\};$$

y

- Los datos son codificados en la señal de tal manera que no hay relación entre los estados de fase.

Dadas estas presunciones la densidad espectral de potencia para una señal es representada en la ecuación

(3)

$$PS(\omega) = \begin{cases} \frac{1}{N \cdot T} \left[\frac{\sin^2 \left[\frac{(\omega - \omega_c) \cdot N \cdot T}{2} \right]}{(\omega - \omega_c)^2} + \frac{\sin^2 \left[\frac{(\omega + \omega_c) \cdot N \cdot T}{2} \right]}{(\omega + \omega_c)^2} \right] & \omega \neq \omega_c \\ \frac{1}{4 \cdot N \cdot T} \left[\frac{\sin^2 [\omega_c \cdot N \cdot T]}{\omega_c^2} + (N \cdot T)^2 \right] & \omega = \omega_c \end{cases} \quad (3)$$

Esta expresión es precisa para $M > 2$. Note que debido a la presunción de que no hay correlación entre los estados de fase, el caso cuando hay dos estados de fase (que se o se correlacionan o son anticorrelacionados), deriva del resultado derivado de la ecuación (3). Asumiendo que la ecuación (3) es precisa, puede verse que el espectro de potencia de la señal portadora es independiente del numero de estados de fase M y como tal dependen del numero de ciclos N antes de los cambios de fase y el periodo de un ciclo T . Así, el ancho de banda de la señal no es afectado por el incremento del número de estados de fase M .

Como se menciona anteriormente, la cantidad de ruido disminuye a medida que la frecuencia disminuye aunque esto puede resultar en una sobre modulación de la señal especialmente con señales de banda ancha amplia. Sin embargo, a la luz de la derivación de la ecuación (3) otra enseñanza para mejorar la velocidad de datos es la de disminuir la frecuencia portadora ω_c mientras se incrementa el número de estados de fase M . Efectivamente esto resulta en una velocidad de datos mejorada neta sin el riesgo de incrementar el ancho de banda para causar interferencia.

En la modalidad preferida, la frecuencia portadora es caída más abajo que las frecuencias de telemetría electromagnética típicas para poder minimizar el ruido y maximizar la amplitud de la señal recibida. Esto también es deseable para escoger la frecuencia portadora de modo que la señal sufra la menor cantidad de atenuación mientras que se propaga por la formación que este siendo taladrada. Por ejemplo, en un pozo de 5 km, con conductividad de 1 mho/metro, una frecuencia de cerca de 0,5 Hz sería 44dB más fuerte que una señal de 5 Hz. Así las frecuencias portadoras inferiores a 1 Hz son deseadas en la modalidad preferida.

Con el uso del sistema de telemetría descrito que emplea un número incrementado de estados de fase, un incremento de velocidad de datos significativo se logra. La ecuación 5 detalla el efecto del número de estados de fase y frecuencias sobre la señal y la proporción frecuencias sobre la señal a ruido de entrada a una señal bifase con una portadora de f_0 a una señal con 2^n fases con una portadora de f_1 (donde f_0 y f_1 están en Hz y N es el número de bits transmitidos por ciclos)

$$\Delta SNR = 20 \cdot \log_{10} \left[\sin \left(\frac{\pi}{2^N} \right) \sqrt{\frac{f_0}{f_1}} \right] \quad (4)$$

Así, para poder incrementar el número de bit una multa es pagada en la proporción señal a ruido pero esto puede ser desplazado por medio de hacer caer la frecuencia, porque la proporción señal a ruido es reducida a medida que la frecuencia es disminuida.

Por ejemplo, si la frecuencia portadora se deja caer de 5 Hz a 1 Hz y el número de bits por ciclo es cambiado de 1 a 10, una pérdida de 43 dB en proporción señal a ruido es esperada de la ecuación (4). Así para poder realizar los beneficios de un incremento de velocidad de datos al 100% sin importar la caída en SNR el incremento en la fuerza de la señal que viene de disminuir la frecuencia a 1 Hz debería ser por lo menos 43 dB. Haciendo referencia ahora a la figura 9, los efectos de la frecuencia y la resistividad en la atenuación de la señal portadora que disminuye de 5 Hz a 1 Hz, como una función de la profundidad y la resistividad de la formación se muestra, y asume una resistividad de formación de un ohm por metro y una profundidad de pozo de 5 km, un incremento de cerca de 100 dB es esperado.

Así, el sistema de telemetría PSK descrito ofrece mayores velocidades de datos mientras se solucionan las desventajas típicamente asociadas con la disminución de la frecuencia portadora.

El espectro resultante de la señal PSK es medianamente compactado alrededor de la frecuencia portadora, lo que permite que otras frecuencias sean usadas concurrentemente. Por medio de usar múltiples frecuencias, más información puede ser transmitida a la superficie. Las velocidades de datos pueden por lo tanto ser incrementadas siempre que una interferencia intersímbolo mínima se logre. Muchas proporciones de frecuencia portadora factibles existen entre las frecuencias múltiples, aunque se cree que una proporción de cerca de $38/15$ es preferible. Por ejemplo, si una primera frecuencia portadora es 0,5 Hz, otra frecuencia portadora de $0,5 \text{ Hz} \times 38/15$ o cerca de 1,267 Hz podría ser usada concurrentemente. Sin embargo el sistema no está limitado y puede usar frecuencias múltiples. Por ejemplo si la frecuencia portadora más baja es 0.1 Hz entonces una frecuencia preferida podrían ser múltiplos de $38/15$ veces la frecuencia portadora más baja (0.1 Hz,

0,2533 Hz, 0,64177 Hz, 1,6258 Hz), y el canal de comunicación principal es preferiblemente 0,64177 Hz.

Aparte de las técnicas de transmisión de señal PSK, las técnicas de modulación por amplitud (AM) pueden también ser usadas en donde la frecuencia portadora se ha dejado caer a un régimen en donde la señal pierde debido a que la disipación es pequeña. La modulación de amplitud de la portadora resulta en la generación de bandas laterales que incrementan el ancho de banda. Sin embargo, un ancho de banda bajo puede ser obtenido transmitiendo bandas laterales únicas por que este contiene la información que se contiene en la señal de mensaje. Los métodos para transmitir modulación de amplitud de banda lateral única serían evidentes para aquellos versados en la técnica y por lo tanto no se discuten aquí.

En todavía otra modalidad, la señal o señales portadoras pueden ser moduladas tanto en fase como en amplitud. La modulación puede tomar la forma de modulación de amplitud en cuadratura (QAM), o la modulación en fase puede ser hecha independientemente de la modulación en amplitud. Como un ejemplo de este último caso, una de las frecuencias portadoras (por ejemplo 0,5

Hz) puede ser modulada en fase con una constelación PSK 32 en 0,25 símbolos por segundo, y la amplitud modulada a 4 niveles de potencia a 0,125 símbolos por segundo, para un total de velocidad de bits de 1,5 bits/sec sobre una portadora. Un ejemplo de tal señal modulada se muestra en la figura 10. Nuevamente, múltiples frecuencias portadoras pueden ser usadas concurrentemente.

Debería mencionarse que cualquier número de estados de fase mayor a dos puede ser usado ventajosamente en el sistema de telemetría electromagnético PSK descrito anteriormente, y que este número no está necesariamente limitado a una potencia de dos. Otras configuraciones de antena también pueden ser usadas, mientras que se puede emplear todavía las técnicas de transmisión descritas aquí. Los datos de telemetría pueden ser codificados con un código de corrección de error o pueden ser comprimidos. Numerosas otras variaciones y modificaciones serán evidentes para aquellos versados en la técnica una vez que la descripción anterior se entienda completamente. Es el propósito de que las siguientes reivindicaciones sean interpretadas para involucrar o abrazar todas las variaciones y modificaciones.

REIVINDICACIONES

LO QUE SE REIVINDICA ES:

1. Un sistema de telemetría en el fondo de un pozo que comprende:

Una antena configurada para transmitir señales electromagnéticas de baja frecuencia; y

Un transmisor de modulación por desplazamiento de fase (PSK) configurado para recibir señales digitales indicativas de datos telemétricos y configurado para convertir las señales digitales en una señal de transmisión PSK, en donde el transmisor PSK suministra la señal de transmisión a la antena,

En donde la señal de transmisión PSK tiene una frecuencia portadora de no más de cerca de 1 Hz, y

en donde la señal de transmisión PSK tiene una constelación de señal con más de 4 estados de fase.

2. El sistema de la reivindicación 1, en donde la constelación de señales consiste de 8 estados de fase.
3. El sistema de la reivindicación 1, en donde la constelación de señales consiste de 16 estados de fase.
4. El sistema de la reivindicación 1, en donde la constelación de señales incluye 32 estados de fase o más.
5. El sistema de la reivindicación 1, en donde la constelación de señales incluye 256 estados de fase.
6. El sistema de la reivindicación 1, en donde la constelación de señales incluye 1024 estados de fase.
7. El sistema de la reivindicación 1, en donde la señal de transmisión PSK tiene un periodo de símbolo de por lo menos cerca de 4 ciclos potadores.

8. El sistema de la reivindicación 1, en donde la señal de transmisión PSK tiene un periodo de símbolo de cerca de 3 ciclos portadores.

9. El sistema de la reivindicación 1, en donde la señal de transmisión PSK tiene un periodo de símbolo de cerca de 2 ciclos portadores.

10. El sistema de la reivindicación 1, en donde la frecuencia portadora es de cerca de 0,5 Hz.

11. El sistema de la reivindicación 1, en donde la señal de transmisión PSK es también modulada en amplitud.

12. Un método para explorar mientras se taladra, en donde el método comprende:

Taladrar un pozo a través de una formación con una broca de taladro sujeta a una sarta de taladrado que incluye un paquete sensor;
Detectar señales indicadoras de las propiedades de la formación;

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Determinar información de telemetría de a partir de las señales detectadas;

Suministrar la información de telemetría a un transmisor PSK;

Codificar la información de telemetría para obtener una señal de transmisión digital;

Modular en fases la señal de transmisión digital sobre una señal portadora de baja frecuencia para obtener una señal PSK;

Transmitir la señal PSK a un receptor de superficie, en donde la señal portadora de baja frecuencia de no más de cerca de 1 Hz, y en donde la señal PSK tiene una constelación de señales con más de 4 estados de fase.

13. El método de la reivindicación 12, en donde la constelación de señales incluye 32 estados de fase o más.

14. El método de la reivindicación 12, en donde la constelación de señales incluye 256 estados de fase.

15. El método de la reivindicación 12, en donde la constelación de señales incluye 1024 estados de fase.

16. El método de la reivindicación 12, en donde la frecuencia portadora es de cerca de 0,5 Hz.

17. El método de la reivindicación 12, que comprende adicionalmente:

Recibir la señal PSK en la superficie;

Determinar la información de telemetría a partir de la señal PSK recibida; y

Asociar la información de telemetría con una posición del paquete sensor.

18. El método de la reivindicación 12, en donde la señal e transmisión PSK es también modulada en amplitud.

19. Un sistema de telemetría en el fondo de un pozo que comprende:

Una antena configurada para transmitir señales electromagnéticas de baja frecuencia; y

Un transmisor modulado por desplazamiento de fase (PSK) configurado para recibir señales digitales o indicativos de

Datos telemétricos y configurados para convertir las señales digitales en señal de transmisión PSK, en donde el transmisor PSK suministra la señal de transmisión a la antena,

En donde la señal de transmisión PSK contiene múltiples frecuencias portadoras, y en donde la señal de transmisión PSK tiene una constelación de señales con más de 4 estados de fase.

20. El sistema de la reivindicación 19, en donde la constelación de señales consiste de 8 estados de fase.

21. El sistema de la reivindicación 19, en donde la constelación de señales consiste de 16 estados de fase.

22. El sistema de la reivindicación 19, en donde la constelación de señales incluye 32 estados de fase o más.

23. El sistema de la reivindicación 19, en donde la constelación de señales incluye 256 estados de fase.

24. El sistema de la reivindicación 19, en donde la constelación de señales incluye 1024 estados de fase.

25. El sistema de la reivindicación 19, en donde la señal de transmisión PSK tiene un periodo de símbolo de por lo menos cerca de 4 ciclos portadores.

26. El sistema de la reivindicación 19, en donde la señal de transmisión PSK tiene un periodo de símbolo de cerca de 3 ciclos portadores.

27. El sistema de la reivindicación 19, en donde la señal de transmisión PSK tiene un periodo de símbolo de cerca de 2 ciclos portadores.

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28. El sistema de la reivindicación 19, en donde las frecuencias portadoras están separadas por una proporción de cerca de 38/15.

29. El sistema de la reivindicación 19, en donde la señal de transmisión PSK es también modulada en amplitud.

30. Un método de exploración mientras se taladra, en donde el método comprende:

Taladrar un pozo a través de una formación con una broca de taladro sujeta a una sarta de taladrado que incluye un paquete sensor;

Detectar las señales indicadoras de las propiedades de la formación;

Determinar la información telemétrica a partir de las señales detectadas;

Suministrar la información telemétrica a un transmisor de transmisión;

Codificar la información telemétrica para obtener una señal de transmisión digital;

Modular en fase la señal de transmisión digital sobre señales portadoras de baja frecuencia múltiples para obtener una señal de transmisión; y

Transmitir la señal de transmisión a un receptor de superficie,

31. El método de la reivindicación 30, en donde la señal de transmisión tiene una constelación de señales con más de 4 estados de fase.

32. El método de la reivindicación 31, en donde las señales múltiples portadoras de baja frecuencia son separadas por una proporción de cerca de 38/15.

33. El método de la reivindicación 32, en donde la constelación de señales incluye 32 estados de fase o más.

34. El método de la reivindicación 32, en donde la constelación de señales incluye 256 estados de fase.

35. El método de la reivindicación 32, en donde la constelación de señales incluye 1024 estados de fase.

36. El método de la reivindicación 32, que comprende adicionalmente:

Recibir la señal de transmisión en la superficie;
Determinar la información de telemetría a partir de la señal de transmisión recibida; y
Asociar la información de telemetría con una posición del paquete sensor.

37. El método de la reivindicación 30, en donde la señal de transmisión es también modulada en amplitud.

- (11) 70

Resumen

Se describe un sistema de telemetría electromagnética en el fondo del pozo que tiene velocidad incrementada de datos. En una modalidad, un sistema de transmisión de datos por PSK es usado para transmitir datos en un sistema de telemetría electromagnética en el fondo del pozo para aplicaciones de Mida Mientras Taladra (MWD). Las aplicaciones MWD sufren por las velocidades de los datos que no están bien adaptadas para manejar la cantidad siempre creciente de datos que requieren ser transmitidos. Un método para incrementar la velocidad de los datos incluye incrementar la frecuencia de la portadora, pero esto puede causar la atenuación y la distorsión no deseada de la señal. De manera contraria, disminuir la frecuencia de la portadora suministra el premio de una señal más fuerte con el riesgo de interferencias, especialmente con señales de ancho de banda amplio. Se describe una derivación que predice que la frecuencia puede de hecho disminuirse mientras se incrementa el número de estados de fase para lograr una velocidad de datos mayor, sin afectar el ancho de banda. El sistema y el método descritos pueden suministrar, de manera ventajosa, un sistema de telemetría electromagnética de baja potencia con una velocidad de datos incrementada.

71
"009 71

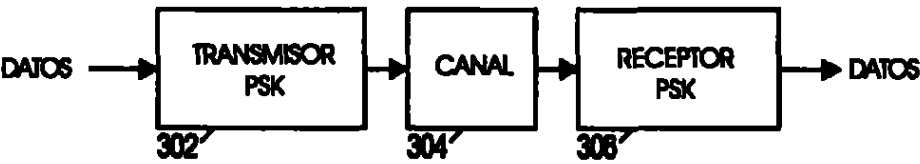


FIG. 3

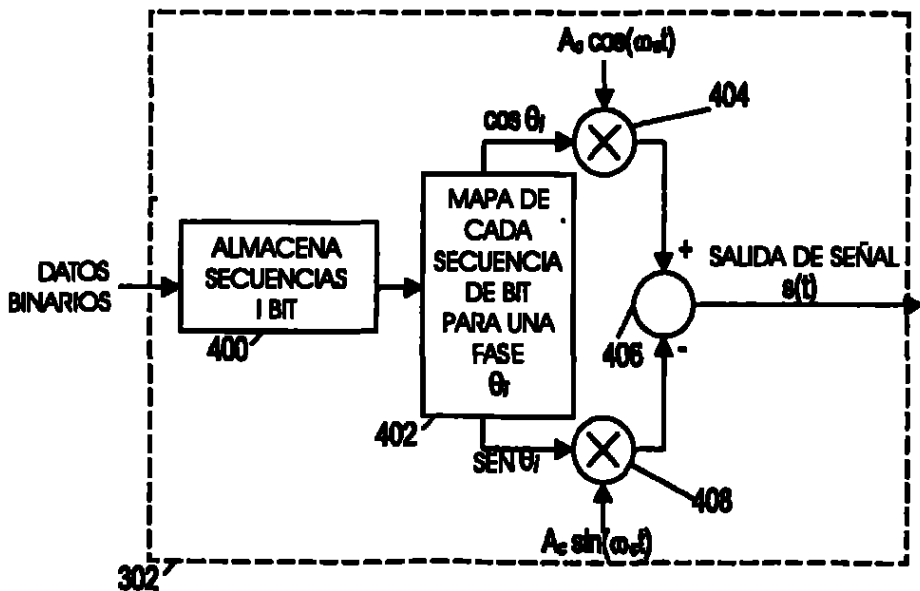


FIG. 4

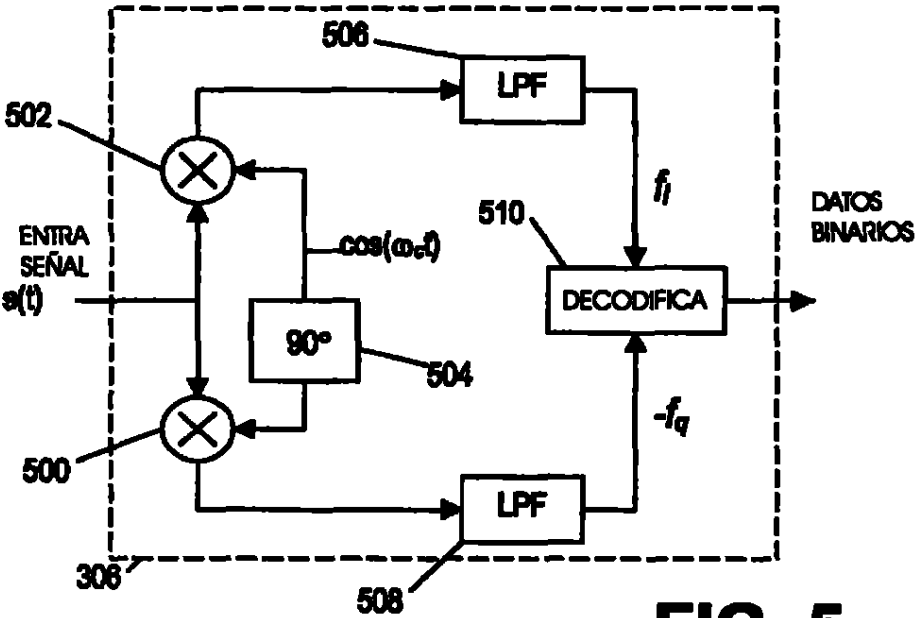


FIG. 5

73
73

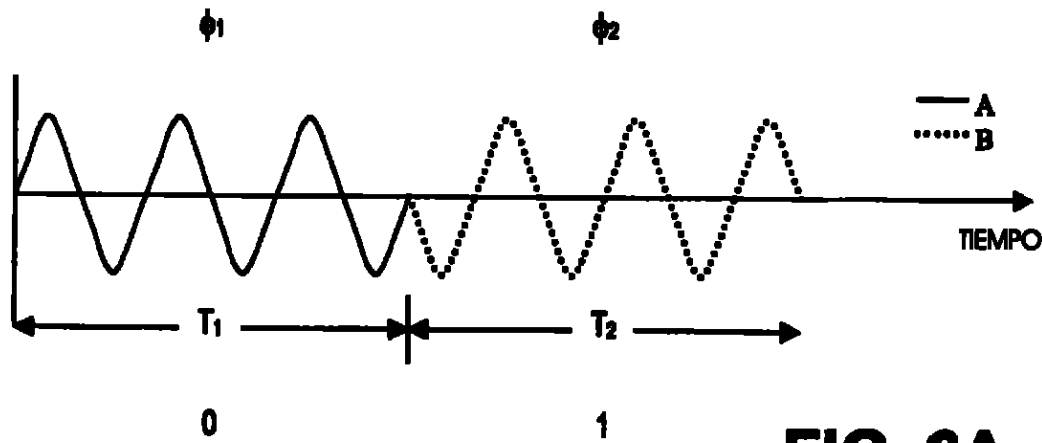


FIG. 6A

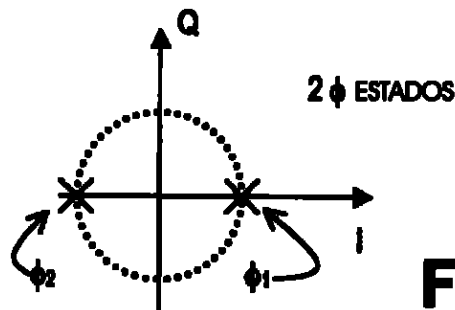


FIG. 6B

7A.
-000.24

**Atenuación de Señal en 5Hz con relación a 1 Hz
como una función de Profundidad y
Resistividad de Formación**

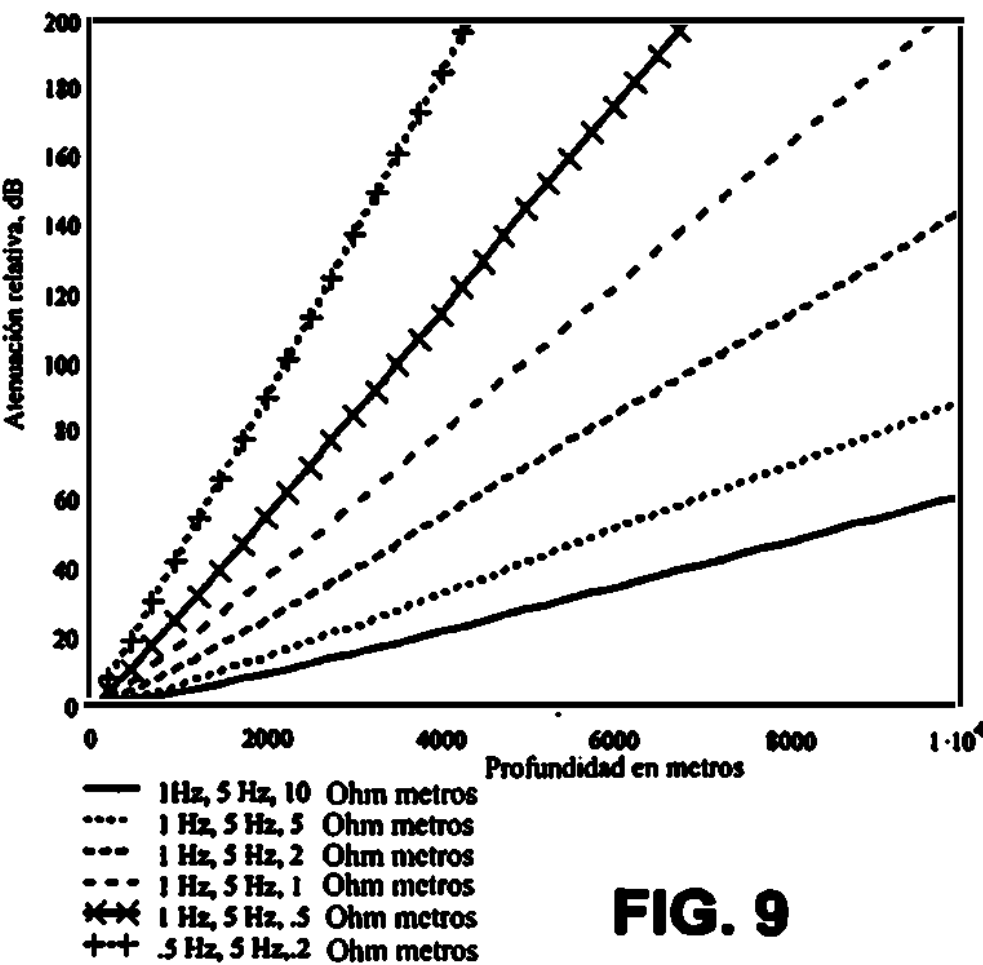


FIG. 9

75
-000-75

Traspaso de Secuencia de Mensaje PSK de Cuatro Fases		
Grupo de Bit Binario	Fase Portadora	Señal Transmitida
00	+45°	$s(t) = \frac{A_c}{\sqrt{2}} [\cos \omega_c t - \text{Sen} \omega_c t]$
01	-45°	$s(t) = \frac{A_c}{\sqrt{2}} [\cos \omega_c t + \text{Sen} \omega_c t]$
10	+135°	$s(t) = -\frac{A_c}{\sqrt{2}} [\cos \omega_c t + \text{Sen} \omega_c t]$
11	-135°	$s(t) = -\frac{A_c}{\sqrt{2}} [\cos \omega_c t - \text{Sen} \omega_c t]$

FIG. 7

Regla para Decodificar para la Figura 5 y el Traspaso de Fase de la Figura 7			
f_i	f_q	θ_i	Grupo de Bit Decodificado
$\frac{A_c}{\sqrt{2}}$	$-\frac{A_c}{\sqrt{2}}$	45°	00
$\frac{A_c}{\sqrt{2}}$	$\frac{A_c}{\sqrt{2}}$	-45°	01
$-\frac{A_c}{\sqrt{2}}$	$-\frac{A_c}{\sqrt{2}}$	135°	10
$-\frac{A_c}{\sqrt{2}}$	$\frac{A_c}{\sqrt{2}}$	-135°	11

FIG. 8

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
DANIEL J. KRUBGER
CONLEY ROSE, P.C.
P.O. BOX 3267
HOUSTON, TX 77253-3267

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing
(day/month/year) 01 NOV 2004

Applicant's or agent's file reference

1391-31801

IMPORTANT NOTIFICATION

International application No.

PCT/US03/20871

International filing date (day/month/year)

02 July 2003 (02.07.2003)

Priority date (day/month/year)

05 July 2002 (05.07.2002)

Applicant

HALLIBURTON ENERGY SERVICES, INC.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.
2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.
3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.
4. REMINDER

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US

Mail Stop PCT, Attn: IPEA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Facsimile No. (703) 305-3230

Form PCT/IPEA/416 (July 1992)

Authorized officer

Michael Horabik

Telephone No. 571-272-3069

R. J. Jagan

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 1391-31801	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/US03/20871	International filing date (day/month/year) 02 July 2003 (02.07.2003)	Priority date (day/month/year) 05 July 2002 (05.07.2002)
International Patent Classification (IPC) or national classification and IPC IPC(7): G01V 1/22 and US Cl.: 340/853.2, 854.6; 367/83; 714/792; 375/261, 270, 301		
Applicant HALLIBURTON ENERGY SERVICES, INC.		
1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36. 2. This REPORT consists of a total of <u>5</u> sheets, including this cover sheet. ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT). These annexes consist of a total of <u> </u> sheets.		
3. This report contains indications relating to the following items: I ☒ Basis of the report II ☐ Priority III ☐ Non-establishment of report with regard to novelty, inventive step and industrial applicability IV ☐ Lack of unity of invention V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement VI ☐ Certain documents cited VII ☐ Certain defects in the international application VIII ☐ Certain observations on the international application		
Date of submission of the demand 04 February 2004 (04.02.2004)	Date of completion of this report 18 September 2004 (18.09.2004)	
Name and mailing address of the IPEA/US Mail Stop PCT, Attn: IPEA/US Commissioner for Patents P.O. Box 1430 Alexandria, Virginia 22313-1430 Facsimile No. (703) 305-3230	Authorized officer Michael Hornik Telephone No. (571) 272-3068 <i>Rugenio Lopez</i>	

I. Basis of the report

1. With regard to the elements of the international application:*

- ☒ the international application as originally filed.
- ☒ the description:
pages 1-11 _____ as originally filed
pages NONE _____, filed with the demand
pages NONE _____, filed with the letter of _____.
- ☒ the claims:
pages 12-15 _____, as originally filed
pages NONE _____, as amended (together with any statement) under Article 19
pages NONE _____, filed with the demand
pages NONE _____, filed with the letter of _____.
- ☒ the drawings:
pages 1-7 _____, as originally filed
pages NONE _____, filed with the demand
pages NONE _____, filed with the letter of _____.
- ☐ the sequence listing part of the description:
pages NONE _____, as originally filed
pages NONE _____, filed with the demand
pages NONE _____, filed with the letter of _____.

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in printed form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages NONE
- ☐ the claims, Nos. NONE
- ☐ the drawings, sheets/fig NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International Application No.
PCT/US83/20871

71
79

V. Reasoned statement under Rule 66.2(a)(II) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims <u>1-37</u>	YES
	Claims <u>NONE</u>	NO
Inventive Step (IS)	Claims <u>1-18</u>	YES
	Claims <u>19-37</u>	NO
Industrial Applicability (IA)	Claims <u>1-37</u>	YES
	Claims <u>NONE</u>	NO

2. CITATIONS AND EXPLANATIONS

Please See Confirmation Sheet

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

1. Claims 1-18 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a downhole telemetry system as claimed in claims 1 and 12, wherein the PSK transmit signal has a carrier frequency of no more than about 1Hz, and wherein the PSK transmit signal has a signal constellation with more than 4 phase states.

2. Claims 19-24 and 28-37 lack inventive steps under PCT Article 33(3) as being obvious over Thawley et al. U.S. Patent 4,488,885 in view of Hessel et al. U.S. Patent 6,289,487.

Thawley et al. teaches a downhole telemetry system that comprises an antenna (subelement) configured to transmit low frequency electromagnetic signals; a phase-shift key (PSK) transmitter configured to receive digital signals indicative of telemetry data and configured to convert the digital signals into a PSK transmit signal, wherein the PSK transmitter provides the transmit signal to the antenna, wherein the PSK transmit signal contains multiple carrier frequencies (column 6 lines 55-63 and column 4 lines 10-15).

However, Thawley et al. does not specifically teach that the PSK transmit signal has a signal constellation with more than 4 phase states.

Hessel et al. teaches a data transmission method, wherein the transmit signal has a signal constellation with more than 4 phase states such as 8-PSK or 16-PSK in order to increase the data density and higher data rate (column 1 lines 43-50).

Since both Thawley et al. and Hessel et al.'s teaching involve data transmission, therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide a signal having more than 4 phase states to the data transmission system disclosed by Thawley et al., as evidenced by Alekyunas et al., in order to increase the data density and data transmission rate.

Regarding claims 20-24, even though Thawley et al. does not specifically mention that the signal constellation consists of 8, 16, 32, 256 and 1024 phase states, however, one of ordinary skill in the art would recognize that the data transmission rate is proportional to the number of phase states as suggested by Hessel et al. (shown above). The greater the number of phase states in a signal leads to faster data transmission rate.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide said phase states (8, 16, 32, 256 and 1024) to the signal disclosed by Thawley et al., as suggested by Hessel et al., in order to increase the data transmission rate.

Claims 30 and 36 lack inventive steps for the same reasons as claim 19.

Regarding claims 28, 30 and 32, even though Thawley et al. does not specifically teach using multiple frequency carrier signals, however, a skilled in the art would recognize that using multiple frequencies/carrier frequencies would enhance the bandwidth and therefore enhance the data transmission rate. Therefore, by conventionality, it would have been obvious to provide multiple carrier frequency signals to the system disclosed by Thawley et al. Regarding the claimed limitation wherein the multiple carrier frequency signals are separated by a ratio of about 38/15, a skilled in the art would recognize that such a ratio can easily be achieved by a designing practitioner. Therefore, it would have been obvious to provide such a limitation to the system disclosed by Thawley et al.

Regarding claims 29 and 37, amplitude modulation has been commonly applied in wireless data transmission. Therefore,

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

by conventionality, it would have been obvious to one of ordinary skill in the art to provide amplitude modulation to the signal in the system disclosed by Thawley et al.

Claims 31 and 33-35 lack inventive steps for the same reasons as claims 2-6.

3. Claims 25-27 lack an inventive steps under PCT Article 33(3) as being obvious over Thawley et al. U.S. Patent 4,468,665 in view of Heesal et al. U.S. Patent 6,289,487 and in further view of Waggoner et al. U.S. Patent 4,215,427.

Regarding claims 25-27, as mentioned above, Thawley et al. in view of Heesal et al. teaches a downhole telemetry system, except wherein the PFK transmit signal has a symbol period of at least about four carrier cycles (as shown in Figure 6A of this application).

Waggoner et al., in the same field of endeavor, teaches a downhole telemetry system, wherein the transmit signal has a symbol period of at least about four carrier cycles (Figure 4A).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide a transmit signal has a symbol period of at least about four carrier cycles to the telemetry system disclosed by Thawley et al. in view of Heesal et al., as evidenced by Waggoner et al., in order to enhance the data rate. As can be seen from Figure 4A of Waggoner et al. and Figure 6A of this application, then more data would be able transmitted because the less the carrier cycles being assigned with each symbol period, then the more symbols would be able to be assigned and vice versa.

NEW CITATIONS

US 6,289,487 B1 (HEESAL et al) 11 September 2001, see column 1, lines 43-59.

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITYTo:
DANIEL J. KRUBER
CONLEY ROSE, P.C.
P.O. BOX 3267
HOUSTON, TX 77253-3267

PCT

WRITTEN OPINION

(PCT Rule 66)

DAR/DEK

Date of Mailing
(day/month/year)

28 APR 2004

Applicant's or agent's file reference

1391-31801 ✓

REPLY DUE

within 2 months/days from
the above date of mailing

International application No.

PCT/US03/20871

International filing date (day/month/year)

02 July 2003 (02.07.2003)

Priority date (day/month/year)

05 July 2002 (05.07.2002)

International Patent Classification (IPC) or both national classification and IPC

IPC(7): G01V 1/22 and US Cl.: 340/853.2, 854.6; 357/83; 714/792; 375/261,270,301

Applicant

HALLIBURTON ENERGY SERVICES, INC.

1. This written opinion is the first (first, etc.) drawn by this International Preliminary Examining Authority.
2. This opinion contains indications relating to the following items:
 - I ☒ Basis of the opinion
 - II ☐ Priority
 - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
 - IV ☐ Lack of unity of invention
 - V ☒ Reasoned statement under Rule 66.2 (a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
 - VI ☐ Certain documents cited
 - VII ☐ Certain defects in the international application
 - VIII ☐ Certain observations on the international application
3. The applicant is hereby invited to reply to this opinion.

When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension. See rule 66.2(4).

How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

Also For an additional opportunity to submit amendments, see Rule 66.4.
For the examiner's obligation to consider amendments and/or arguments, see Rule 66.4 bis.
For an informal communication with the examiner, see Rule 66.6

If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.
4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 05 November 2004 (05.11.2004).

Name and mailing address of the IPEA/US

Mail Stop PCT, Attn: IPEA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22315-1450

Facsimile No. (703)305-3230

Authorized officer

Michael Horabik

Telephone No. 703-305-1836

Form PCT/IPEA/408 (cover sheet)(July 1998)

WRITTEN OPINION

International application No.

PCT/US03/20871

188
03

I. Basis of the opinion

1. With regard to the elements of the international application:*

- ☒ the international application as originally filed
- ☒ the description:
pages 1-11, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____
- ☒ the claims:
pages 12-15, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of _____
- ☒ the drawings:
pages 1-7, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____
- ☐ the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____

2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language _____ which is:

- ☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the written opinion was drawn on the basis of the sequence listing:

- ☐ contained in the international application in printed form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages NONE
- ☐ the claims, Nos. NONE
- ☐ the drawings, sheets/fig NONE

5. ☐ This opinion has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed."

WRITTEN OPINION

International application No.
PCT/US93/20671

84
OK

V. Reasoned statement under Rule 66.2(a)(II) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting each statement

1. STATEMENT

Novelty (N)	Claims 1-37	YES
	Claims NONE	NO
Inventive Step (IS)	Claims 1-18	YES
	Claims 19-37	NO
Industrial Applicability (IA)	Claims 1-37	YES
	Claims NONE	NO

2. CITATIONS AND EXPLANATIONS

Please See Continuation Sheet

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

TIME LIMIT:

The time limit set for response to a Written Opinion may not be extended. 37 CFR 1.484(d). Any response received after the expiration of the time limit set in the Written Opinion will not be considered in preparing the International Preliminary Examination Report.

V. 2. Citations and Explanations:

1. Claims 1-18 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a downhole telemetry system as claimed in claims 1 and 12, wherein the PSK transmit signal has a carrier frequency of no more than about 1Hz, and wherein the PSK transmit signal has a signal constellation with more than 4 phase states.

2. Claims 19-24 and 28-37 lack inventive steps under PCT Article 33(3) as being obvious over Thawley et al. U.S. Patent 4,488,865 in view of Alalyunas et al. U.S. Patent 6,580,283.

Thawley et al. teaches a downhole telemetry system that comprises an antenna (inherent) configured to transmit low frequency electromagnetic signals; a phase-shift key (PSK) transmitter configured to receive digital signals indicative of telemetry data and configured to convert the digital signals into a PSK transmit signal, wherein the PSK transmitter provides the transmit signal to the antenna, wherein the PSK transmit signal contains multiple carrier frequencies (column 6 lines 33-63 and column 4 lines 10-15).

However, Thawley et al. does not specifically teach that the PSK transmit signal has a signal constellation with more than 4 phase states.

Alalyunas et al. teaches a data transmission method, wherein the transmit signal has a signal constellation with more than 4 phase states such as 8-PSK or 16-PSK (column 3 lines 18-30 and Table 1 on column 6) in order to increase the data density and higher data rate.

Since both Thawley et al. and Alalyunas et al.'s teaching involve data transmission, therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide a signal having more than 4 phase states to the data transmission system disclosed by Thawley et al., as evidenced by Alalyunas et al., in order to increase the data density and data transmission rate.

Regarding claims 20-24, even though Thawley et al. does not specifically mention that the signal constellation consists of 8, 16, 32, 256 and 1024 phase states, however, one of ordinary skill in the art would recognize that the data transmission rate is proportional to the number of phase states as suggested by Alalyunas et al. (shown above). The greater the number of phase states in a signal leads to faster data transmission rate (as suggested by Alalyunas et al. below).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide said phase states (8, 16, 32, 256 and 1024) to the signal disclosed by Thawley et al., as suggested by Alalyunas et al., in order to increase the data transmission rate.

Claims 30 and 36 lack inventive steps for the same reasons as claim 19.

Regarding claims 28, 30 and 32, even though Thawley et al. does not specifically teach using multiple frequency carrier signals, however, a skilled in the art would recognize that using multiple frequencies/carrier frequencies would enhance the bandwidth and therefore enhance the data transmission rate. Therefore, by conventionality, it would have been obvious to provide multiple carrier frequencies signals to the system disclosed by Thawley et al. Regarding the claimed limitation wherein d . . . multiple carrier

Supplemental Box

(To be used when the space in any of the preceding boxes is not sufficient)

frequency signals are separated by a ratio of about 38/15, a skilled in the art would recognize that such a ratio can easily be achieved by a designing practitioner. Therefore, it would have been obvious to provide such a limitation to the system disclosed by Thawley et al.

Regarding claims 29 and 37, amplitude modulation has been commonly applied in wireless data transmission. Therefore, by conventionality, it would have been obvious to one of ordinary skill in the art to provide amplitude modulation to the signal in the system disclosed by Thawley et al.

Claims 31 and 33-35 lack inventive steps for the same reasons as claims 2-6.

3. Claims 25-27 lack an inventive steps under PCT Article 33(3) as being obvious over Thawley et al. U.S. Patent 4,468,665 in view of Alelyunas et al. U.S. Patent 6,560,293 and in further view of Waggoner et al. U.S. Patent 4,215,427.

Regarding claims 25-27, as mentioned above, Thawley et al. in view of Alelyunas et al. teaches a downhole telemetry system, except wherein the FSK transmit signal has a symbol period of at least about four carrier cycles (as shown in Figure 6A of this application).

Waggoner et al., in the same field of endeavor, teaches a downhole telemetry system, wherein the transmit signal has a symbol period of at least about four carrier cycles (Figure 4A).

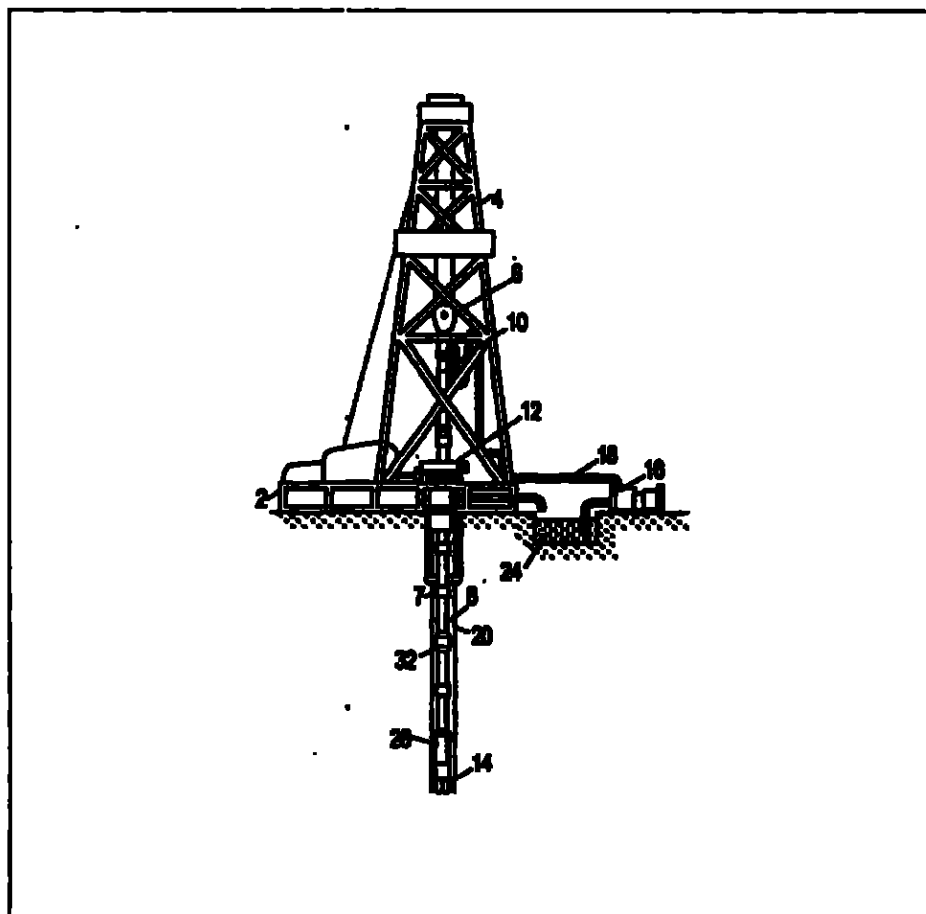
Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide a transmit signal has a symbol period of at least about four carrier cycles to the telemetry system disclosed by Thawley et al. in view of Alelyunas et al., as evidenced by Waggoner et al., in order to enhance the data rate. As can be seen from Figure 4A of Waggoner et al. and Figure 6A of this application, then more data would be able transmitted because the less the carrier cycles being assigned with each symbol period, then the more symbols would be able to be assigned and vice versa.

NEW CITATIONS

ARTE FINAL 12 x 12

SOLICITANTE: HALLIBURTON ENERGY SERVICES, INC.

TITULO: SISTEMA DE TELEMETRÍA ELECTROMAGNÉTICA DE
BAJA FRECUENCIA QUE EMPLEA MODULACIÓN POR
DESPLAZAMIENTO DE FASE DE ALTA CARDINALIDAD.



PATENT COOPERATION TREATY

24-88
1111 188

From the INTERNATIONAL SEARCHING AUTHORITY

To:
MARK E. SCOTT
CONLEY ROSE, P.C.
P.O. BOX 3267
HOUSTON, TX 77253-3267

PCT

NOTIFICATION OF TRANSMITTAL OF
THE INTERNATIONAL SEARCH REPORT
OR THE DECLARATION

(PCT Rule 44.1)

Date of Mailing (day/month/year) 01 OCT 2003	
Applicant's or agent's file reference 1391-31801	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US03/20571	International filing date (day/month/year) 02 July 2003 (02.07.2003)
Applicant HALLIBURTON ENERGY SERVICES, INC.	

1. ☒ The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34, chemin des Colombettes
1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 740.14.33

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

- ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.
☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

Shortly after 18 months from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90 bis.1 and 90 bis.3, respectively, before the completion of the technical preparations for international publication.

Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise the applicant must, within 20 months from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of 30 months (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the PCT Applicant's Guide, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
Facsimile No. (703) 305-3230

Form PCT/ISA/220 (April 2002)

Authorized official

Michael Horvath

Telephone No. (703) 305-1836

(See notes on accompanying sheet)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 1391-31801	FOR FURTHER ACTION	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, Item 5 below.
International application No. PCT/US03/20871	International filing date (day/month/year) 02 July 2003 (02.07.2003)	(Earliest) Priority Date (day/month/year) 05 July 2002 (05.07.2002)
Applicant HALLIBURTON ENERGY SERVICES, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
 - a. With regard to the language, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
 - b. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international search was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.
☐ filed together with the international application in computer readable form.
☐ furnished subsequently to this Authority in written form.
☐ furnished subsequently to this Authority in computer readable form.
☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.
2. ☐ Certain claims were found unsearchable (See Box I).
3. ☐ Unity of invention is lacking (See Box II).
4. With regard to the title,

☒ the text is approved as submitted by the applicant.
☐ the text has been established by this Authority to read as follows:
5. With regard to the abstract,

☒ the text is approved as submitted by the applicant.
☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. The figure of the drawings to be published with the abstract is Figure No. 2

☒ as suggested by the applicant.
☐ because the applicant failed to suggest a figure.
☐ because this figure better characterizes the invention.

☐ None of the figures

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/20871

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01V 1/22

US CL : 340/853.2, 854.6; 367/83; 714/792; 375/261,270,301

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/853.2, 854.6; 367/83; 714/792; 375/261,270,301

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
✓ Y	US 4,468,665 (THAWLEY et al) 28 August 1984 (28.08.1984), column 4 lines 10-15 and column 6 lines 55-63.	1-24, 28-37
✓ Y, P	US 6,560,293 B1 (ALELYUNAS et al) 06 May 2003 (06.05.2003), column 5 lines 18-30.	1-6, 10-24, 28-37
✓ Y	US 4,215,427 (WAGNER et al) 29 July 1980 (29.07.1980), Figure 4A.	7-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another claim or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"Z"

document member of the same patent family

Date of the actual completion of the international search

24 August 2003 (24.08.2003)

Date of mailing of the international search report

01 OCT 2003

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US

Commissioner for Patents

P.O. Box 1450

Alexandria, Virginia 22313-1450

Facsimile No. (703)305-5230

Authorized officer

Michael Horabik

Telephone No. (703) 305-1955

PATENT COOPERATION TREATY

PCT

NOTIFICATION CONCERNING
SUBMISSION OR TRANSMITTAL
OF PRIORITY DOCUMENT

(PCT Administrative Instructions, Section 411)

From the INTERNATIONAL BUREAU

To:

SCOTT, Mark, E.
CONLEY ROSE, P.C.
P.O. Box 3287
Houston, TX 77253-3287
United States of America

Date of mailing (day/month/year) 21 August 2003 (21.08.03)	
Applicant's or agent's file reference 1391-31801	IMPORTANT NOTIFICATION
International application No. PCT/US03/20871	International filing date (day/month/year) 02 July 2003 (02.07.03)
International publication date (day/month/year) Not yet published	Priority date (day/month/year) 05 July 2002 (05.07.02)
Applicant HALLIBURTON ENERGY SERVICES, INC.	

1. The applicant is hereby notified of the date of receipt (except where the letters "NR" appear in the right-hand column) by the International Bureau of the priority document(s) relating to the earlier application(s) indicated below. Unless otherwise indicated by an asterisk appearing next to a date of receipt, or by the letters "NR", in the right-hand column, the priority document concerned was submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b).
2. This updates and replaces any previously issued notification concerning submission or transmittal of priority documents.
3. An asterisk(*) appearing next to a date of receipt, in the right-hand column, denotes a priority document submitted or transmitted to the International Bureau but not in compliance with Rule 17.1(a) or (b). In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.
4. The letters "NR" appearing in the right-hand column denote a priority document which was not received by the International Bureau or which the applicant did not request the receiving Office to prepare and transmit to the International Bureau, as provided by Rule 17.1(a) or (b), respectively. In such a case, the attention of the applicant is directed to Rule 17.1(c) which provides that no designated Office may disregard the priority claim concerned before giving the applicant an opportunity, upon entry into the national phase, to furnish the priority document within a time limit which is reasonable under the circumstances.

<u>Priority date</u>	<u>Priority application No.</u>	<u>Country or regional Office or PCT receiving Office</u>	<u>Date of receipt of priority document</u>
05 July 2002 (05.07.02)	10/190,185	US	11 Augu 2003 (11.08.03)

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 338.89.75

Authorized officer

Aurora CENDANA (Fax : 338 89 75)

Telephone No. (41-22) 338 8905

PATENT COOPERATION TREATY

PCT

INFORMATION CONCERNING ELECTED
OFFICES NOTIFIED OF THEIR ELECTION

(PCT Rule 81.3)

From the INTERNATIONAL BUREAU

To:

SCOTT, Mark, E.
CONLEY ROSE, P.C.
P.O. Box 3287
Houston, TX 77253-3287
United States of America

Date of mailing (day/month/year)

27 April 2004 (27.04.2004)

DAR/DJK

Applicant's or agent's file reference

1391-31801

IMPORTANT INFORMATION

International application No.

PCT/US2003/020871

International filing date (day/month/year)

02 July 2003 (02.07.2003)

Priority date (day/month/year)

05 July 2002 (05.07.2002)

Applicant

HALLIBURTON ENERGY SERVICES, INC.

1. The applicant is hereby informed that the International Bureau has, according to Article 31(7), notified each of the following Offices of its election:

EP : AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE,
SI, SK, TR

National : BG, CA, CN, DE, GB, IL, JP, KP, KR, MN, NO, PL, RO, RU, SK

2. The following Offices have waived the requirement for the notification of their election; the notification will be sent to them by the International Bureau only upon their request:

AP : GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW

EA : AM, AZ, BY, KG, KZ, MD, RU, TJ, TM

OA : BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG

National : AE, AG, AL, AM, AT, AU, AZ, BA, BB, BR, BY, BZ, CH, CO, CR, CU, CZ, DK, DM, DZ, EC,
EE, ES, FI, GD, GE, GH, GM, HR, HU, ID, IN, IS, KE, KG, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD,
MG, MK, MW, MX, MZ, NI, NZ, OM, PG, PH, PT, SC, SD, SE, SG, SL, SY, TJ, TM, TN, TR, TT, TZ, UA,
UG, UZ, VC, VN, YU, ZA, ZM, ZW

3. The applicant is reminded that he must enter the "national phase" before the expiration of 30 months from the priority date before each of the Offices listed above. This must be done by paying the national fee(s) and furnishing, if prescribed, a translation of the international application (Article 38(1)(a)), as well as, where applicable, by furnishing a translation of any annexes of the international preliminary examination report (Article 36(3)(b) and Rule 74.1).

Some offices have fixed time limits expiring later than the above-mentioned time limit. For detailed information about the applicable time limits and the acts to be performed upon entry into the national phase before a particular Office, see Volume II of the PCT Applicant's Guide.

The entry into the European regional phase is postponed until 31 months from the priority date for all States designated for the purposes of obtaining a European patent.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 338.89.75

Authorized officer:

A. ZOLTANSKI (Fax : 338 89 75)

Telephone No. (41-22) 338 8808

From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE
COMMUNICATION OF THE INTERNATIONAL
APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:

SCOTT, Mark, E.
CONLEY ROSE, P.C.
P.O. Box 3267
Houston, TX 77253-3267
ETATS-UNIS D'AMERIQUEJAN 27 2004
CONLEY ROSE, P.C.

PAR/ PJK

Date of mailing (day/month/year)

15 January 2004 (15.01.2004)

Applicant's or agent's file reference

1391-31801 ✓

IMPORTANT NOTICE

International application No.

PCT/US2003/020871

International filing date (day/month/year)

02 July 2003 (02.07.2003)

Priority date (day/month/year)

05 July 2002 (05.07.2002)

Applicant

HALLIBURTON ENERGY SERVICES, INC.

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this notice:

AU, AZ, BY, CH, CN, CO, DE, DZ, EP, HU, JP, KG, KP, KR, MD, MK, MZ, RU, TM

In accordance with Rule 47.1(c), third sentence, those Offices will accept the present notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:

AE, AG, AL, AM, AP, AT, BA, BB, BG, BR, BZ, CA, CR, CU, CZ, DK, DM, EA, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, ID, IL, IN, IS, KE, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MG, MN, MW, MX, NI, NO, NZ, OA, OM, PG, PH, PL, PT, RO, SC, SD, SE, SG, SK, SL, SY, TJ, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW

The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this notice is a copy of the international application as published by the International Bureau on 15 January 2004 (15.01.2004) under No. WO 2004/005966

4. **TIME LIMITS** for filing a demand for international preliminary examination and for entry into the national phase

The applicable time limit for entering the national phase will, subject to what is said in the following paragraph, be 30 MONTHS from the priority date, not only in respect of any elected Office if a demand for international preliminary examination is filed before the expiration of 19 months from the priority date, but also in respect of any designated Office, in the absence of filing of such demand, where Article 22(1) as modified with effect from 1 April 2002 applies in respect of that designated Office. For further details, see *PCT Gazette* No. 44/2001 of 1 November 2001, pages 19926, 19932 and 19934, as well as the *PCT Newsletter*, October and November 2001 and February 2002 issues.

In practice, time limits other than the 30-month time limit will continue to apply, for various periods of time, in respect of certain designated or elected Offices. For regular updates on the applicable time limits (20, 21, 30 or 31 months, or other time limit), Office by Office, refer to the *PCT Gazette*, the *PCT Newsletter* and the *PCT Applicant's Guide*, Volume II, National Chapters, all available from WIPO's Internet site, at <http://www.wipo.int/pct/en/index.html>.

For filing a demand for international preliminary examination, see the *PCT Applicant's Guide*, Volume I/A, Chapter IX. Only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination (at present, all PCT Contracting States are bound by Chapter II).

It is the applicant's sole responsibility to monitor all these time limits.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Authorized officer

Gijsbertus Beijer - Carlos Roy

PCT REQUEST

1/4

Original (for SUBMISSION) - printed on 02.07.2003 02:48:40 PM

1391-31801

0	For receiving Office use only	
0-1	International Application No.	
0-2	International Filing Date	
0-3	Name of receiving Office and "PCT International Application"	
0-4	Form - PCT/RO/101 PCT Request	
0-4-1	Prepared using	PCT-EASY Version 2.92 (updated 01.04.2003)
0-5	Petition The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	United States Patent and Trademark Office (USPTO) (RO/US)
0-7	Applicant's or agent's file reference	1391-31801
I	Title of invention	LOW FREQUENCY ELECTROMAGNETIC TELEMETRY SYSTEM EMPLOYING HIGH CARDINALITY PHASE SHIFT KEYING
II	Applicant	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States
II-4	Name	HALLIBURTON ENERGY SERVICES, INC.
II-5	Address:	10200 Bellaire Boulevard Houston, TX 77072 United States of America
II-6	State of nationality	US
II-7	State of residence.	US
II-8	Telephone No.	(281) 575-3000
II-9	Facsimile No.	(281) 575-5499
III-1	Applicant and/or inventor	
III-1-1	This person is:	inventor only
III-1-4	Name (LAST, First)	RODNEY, Paul, F.
III-1-5	Address:	6134 Jadecrest Court Spring, TX 77389 United States of America

PCT REQUEST

2/4

1391-31801

Original (for SUBMISSION) - printed on 02.07.2003 02:49:40 PM

IV-1	Agent or common representative; or address for correspondence The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent international Authorities as:	agent
IV-1-1	Name (LAST, First)	SCOTT, Mark, E.
IV-1-2	Address:	CONLEY ROSE, P.C. P.O. Box 3267 Houston, TX 77253-3267 United States of America
IV-1-3	Telephone No.	(713) 238-8000
IV-1-4	Facsimile No.	(713) 238-8008
IV-1-5	e-mail	msscott@conleyrose.com
IV-1-6	Agent's registration No.	43,100
IV-2	Additional agent(s)	additional agent(s) with same address as first named agent
IV-2-1	Name(s)	ROSE, David, A. (26,223)
V	Designation of States	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	AP: GH GM KE LS MW NE SD SL SE TZ UG ZM ZW and any other State which is a Contracting State of the Harare Protocol and of the PCT EA: AM AZ BY KG KZ MD RU TJ TM and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT EP: AT BE BG CH LI CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL PT RO SE SI SK TR and any other State which is a Contracting State of the European Patent Convention and of the PCT OA: BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG and any other State which is a member State of OAPI and a Contracting State of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH LI CN CO CR CU CZ DE DK DM DZ EC EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX ME NI NO NZ OM PG PH PL PT RO RU SC SD SE SG SK SL SY TJ TM TN TR TT TZ UA UG UZ VC VN YU ZA ZM ZW

PCT REQUEST

3/4

Original (for SUBMISSION) - printed on 02.07.2003 02:49:40 PM

1391-31801

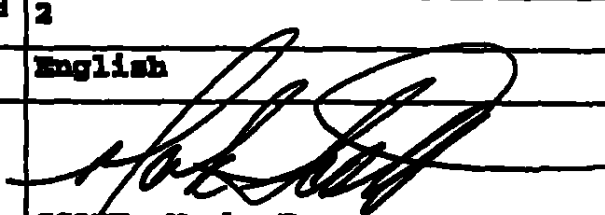
V-5	Pres cautionary Designation Statement In addition to the designations made under Items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under Item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	Exclusion(s) from pres cautionary designations	NONE
VI-1	Priority claim of earlier national application	
VI-1-1	Filing date	05 July 2002 (05.07.2002)
VI-1-2	Number	10/190,165
VI-1-3	Country	US
VI-2	Priority document request The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1
VII-1	International Searching Authority Chosen	United States Patent and Trademark Office (USPTO) (ISA/US)
VII-2	Request to use results of earlier search; reference to that search	
VII-2-1	Date	05 July 2002 (05.07.2002)
VII-2-2	Number	10/190,165
VII-2-3	Country (or regional Office)	US
VIII	Declarations	Number of declarations
VIII-1	Declaration as to the identity of the inventor	-
VIII-2	Declaration as to the applicant's entitlement, as at the international filing date, to apply for and be granted a patent	-
VIII-3	Declaration as to the applicant's entitlement, as at the international filing date, to claim the priority of the earlier application	-
VIII-4	Declaration of inventorship (only for the purposes of the designation of the United States of America)	-
VIII-5	Declaration as to non-prejudicial disclosures or exceptions to lack of novelty	-

PCT REQUEST

4/4

1391-31801

Original (for SUBMISSION) - printed on 02.07.2003 02:49:40 PM

IX	Check list	number of sheets	electronic file(s) attached
IX-1	Request (including declaration sheets)	4	-
IX-2	Description	11	-
IX-3	Claims	4	-
IX-4	Abstract	1	EXABST00.TXT
IX-5	Drawings	7	-
IX-7	TOTAL	27	
	Accompanying items	paper document(s) attached	electronic file(s) attached
IX-8	Fee calculation sheet	✓	-
IX-17	PCT-EASY diskette	-	Diskette
IX-19	Figure of the drawings which should accompany the abstract	2	
IX-20	Language of filing of the international application	English	
X-1	Signature of applicant, agent or common representative		
X-1-1	Name (LAST, First)	SCOTT, Mark, E.	

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10-1	Date of actual receipt of the purported international application	
10-2	Drawings:	
10-2-1	Received	
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/US
10-6	Transmittal of search copy delayed until search fee is paid	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	Date of receipt of the record copy by the International Bureau	
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98

REQUISITOS NECESARIOS PARA PRESENTACION Y AGILIZACION DEL TRAMITE

	USUARIO	RADIADOR
PATENTE DE INVENCION (X) MODELO DE UTILIDAD	()	()
- Indicación de que se solicita la concesión de una patente.	(X)	()
- Datos de identificación del solicitante o de la persona que se presenta la solicitud.	(X)	()
- Descripción de la invención.	(X)	()
- Dibujos de ser estos pertinentes.	()	()
- Comprobante de Pago de las tasas establecidas. (X)	()	()
COMPLETA (X)	INCOMPLETA ()	()

DISEÑO INDUSTRIAL ()

- Indicación de que se solicita el registro de Diseño Industrial	()	()
- Datos de identificación del solicitante o de la persona que presenta la solicitud.	()	()
- Representación gráfica y fotográfica del Diseño Industrial o muestra del Material que incorpora el diseño.	()	()
- Comprobante de pago de las tasas establecidas	()	()
COMPLETA ()	INCOMPLETA ()	()

ESQUEMA DE TRAZADO ()

- Indicación de que solicita el registro de un Esquema de trazado.	()	()
- Datos de identificación del solicitante o de la persona que presenta La solicitud.	()	()
- Representación gráfica del esquema de trazado	()	()
- Comprobante de pago de las tasas establecidas.	()	()
COMPLETA ()	INCOMPLETA ()	()

Firma Responsable:



Fecha: Bogotá, diciembre 30 de 2004

SUPERINDUSTRIA Y COMERCIO
Radicación: 04120206 00000000 Folios: 97
Fecha (GIR): 2004-12-30 17:04:17
Trámite: 011 DCT-PATENT 379 FASE INCI 411 PRESENTAC
Dependencia: 2020 DIVISION DE NUEVAS CREACIONES

2020
Bogotá, D.C.,

Doctor:
ALVARO CORREA ORDOÑEZ
Apoderado
HALLIBURTON ENERGY SERVICES, INC.

Oficio N° . . . 12'08

ASUNTO:	Radicación N°	04-130206
	Solicitud Internacional	PCT/US2003/020871
	Fecha Inicio fase nacional	05/02/2005
	Trámite	011
	Evento	379
	Actuación	430
	Folios	001

Como resultado del examen de forma, realizado con fundamento en el artículo 38 de la Decisión 486 de la Comisión de la Comunidad Andina, artículo 27 del Tratado de Cooperación en Materia de Patentes (PCT), regla 51 bis del Reglamento y Circular Única de la Superintendencia de Industria y Comercio, se le comunica que:

- La solicitud no contiene la copia del documento en que consta la cesión del derecho a la patente del inventor al solicitante o a su causante. (Art. 26-k) Decisión 486).
- La solicitud no contiene el poder debidamente otorgado, con el lleno de los requisitos exigidos por los artículos 63 y subsiguientes del Código de Procedimiento Civil. Adicionalmente, deberá presentar el documento que acredita la existencia y representación legal de la sociedad solicitante, cuando ésta fuere persona jurídica.

En cumplimiento de lo dispuesto por el artículo 39 de la Decisión 486, se le requiere para que dentro del término de dos meses siguientes a la fecha de notificación del presente oficio, complete los requisitos anteriormente enunciados. En caso de no dar cumplimiento al presente requerimiento, la solicitud se considerará abandonada y perderá su prelación.

Notifíquese el presente oficio conforme a lo dispuesto en el numeral 5.2, literal e), del capítulo quinto del título primero de la Circular Única N° 10 de 2001.


ALIX CARMENZA CÉSPEDES DE VERGEL
Jefe de la División de Nuevas Creaciones.

El anterior requerimiento fue notificado por fijación en lista de fecha 11 FEB. 2005

202030

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