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(54) Title: TELEVIEWER IMAGE WOOD-GRAIN REDUCTION TECHNIQUES

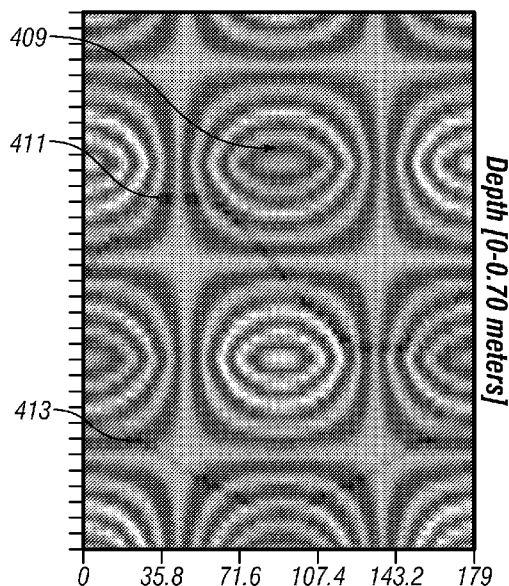


FIG. 4B

(57) Abstract: Measurements made by a transducer assembly for downhole imaging are affected by reverberations between the transducer and the window on the outside of the assembly. The reverberations result in a stationary noise on the image. Hardware solutions to improve signal-to-noise ratio includes using a composite transducer, adjusting the distance between the transducer and the window. SNR can also be improved by processing techniques that include stacking, fitting a sinusoid to the reverberation, by envelope peak detection, and by applying a notch filter.



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TELEVIEWER IMAGE WOOD-GRAIN REDUCTION TECHNIQUES

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FIELD OF THE PRESENT DISCLOSURE

[0001] A downhole acoustic logging tool is provided for imaging the texture and structure of the borehole sidewall. The signal components due to transducer ringdown and internal tool reverberations are processed to provide an image in which the “wood-grain” image artifact is reduced.

BACKGROUND OF THE PRESENT DISCLOSURE

[0002] Typical acoustic logging tools may include, by way of example, a televiewer which comprises a rotating ultrasonic acoustic transducer that operates in a frequency range on the order of 100 kHz or more. Higher acoustic frequencies are preferred in order to achieve better resolution in the confined space of a borehole. In operation, the televiewer rotates at a desired rate such as 5 to 16 rotations per second to continuously scan the borehole sidewall as the televiewer is drawn up the borehole at a rate that is typically 3/16 to 3/8 inch per scan. A beam of acoustic pulses is launched along the normal to the borehole sidewall as the transducer scans the interior surface of the borehole. The pulse rate depends upon the desired spatial resolution such as 1500 pulses per second or 128 to 256 pulses per scan. The insonified borehole sidewall returns pulses reflected therefrom, back to the transducer on a time-multiplexed basis. The reflected acoustic signals are detected, amplified and displayed to provide a continuous picture of the texture and structure of the borehole sidewall. Other application include determination of the goodness of a cement bond to a steel casing as well as monitoring the integrity of the casing itself.

[0003] The diameter of a borehole logger is on the order of $2\frac{7}{8}$ in (7.3 cm), so that it can be run into relatively small boreholes. However many borehole diameters are on the order of 10 – 14” (25.4- 35.6 cm) or more so that the length of the acoustic-pulse trajectory from the transducer, through the borehole fluid to the borehole sidewall, may be up to 10” (25.4 cm). In the normal course of events, the borehole fluid is contaminated by drill cuttings, air bubbles and foreign matter which severely attenuate the acoustic energy by scattering because the physical dimensions of the contaminants are comparable to the wavelength of the wavefields emitted by the transducer.

[0004] The televiewer signal is also contaminated by stationary noise. The stationary noise is due to the transducer ringing and the reverberations between the face of the transducer and a window on the outside of the televiewer assembly. The echo signal is the signal returned from the borehole formation or casing. Neglecting borehole fluid attenuation, deflection, diffraction, and window insertion loss, the amplitude of the echo signal is a function of the acoustic impedance of the formation or casing. The arrival time of the echo signal within the process window will change with the instruments centralization and the shape of the borehole. As the echo signal moves in time, it is modulated by the stationary noise, therefore the detected peak amplitude is a function of the formation reflection, and the position of the echo within the process window. If the S/N ratio is low enough, the modulation causes the resulting televiewer amplitude image to be dominated by the periodic “wood grain” interference pattern. A physical explanation of the “wood grain” is that the transducer ringing and reverberation noise is initiated when a pulse-echo signal is transmitted, so that the noise is stationary with respect to the echo signal. Strictly speaking, the term “ringdown” refers to the ringing of the transducer when it is activated. Reverberation refers to the sound that reflects back and forth between the transducer and window. Interference between the ringdown and reverberation noise and the echo signals results in a “wood grain” pattern on the amplitude image. The present disclosure addresses the problem of reducing the “wood grain” effects by improvements to the televiewer assembly, detecting the signal independently of the noise in real time, and/or filtering the stationary noise post acquisition.

SUMMARY OF THE PRESENT DISCLOSURE

[0005] One embodiment of the disclosure is an apparatus configured to evaluate an earth formation. The apparatus includes a rotatable transducer assembly; a transducer on the rotatable transducer assembly configured to propagate an acoustic signal through an acoustically transparent window into a borehole and produce a signal including an echo from a wall of the borehole and a ringdown signal within the transducer assembly; and at least one processor configured to use the signal produced at a plurality of orientations of the transducer during rotation of the transducer assembly to provide a two-dimensional image of the earth formation, the two-dimensional image being substantially free of a stationary noise resulting from an interference between the ringdown signal and the echo.

[0006] Another embodiment of the disclosure is a method of evaluating an earth formation. The method includes: conveying a rotatable transducer assembly into a borehole; using a transducer on the rotatable transducer assembly to convey an acoustic signal through an acoustically transparent window into a borehole and produce a signal including an echo from a wall of the borehole and a ringdown signal within the transducer assembly; and processing the signal produced at a plurality of orientations of the transducer during rotation of the transducer assembly to provide a two-dimensional image of the earth formation, the two-dimensional image being substantially free of a stationary noise resulting from interference between the ringdown signal and the echo.

[0007] Another embodiment of the disclosure is a computer-readable medium product having stored thereon instructions that when executed by at least one processor, cause the at least one processor to perform a method. The method includes: using a signal produced by a transducer on a rotating transducer assembly in a borehole, the signal including an echo from a wall of the borehole and a ringdown signal within the rotating transducer assembly at a plurality of orientations of the transducer assembly, for providing a two-dimensional image of the earth formation, the two-dimensional image being substantially free of a stationary noise resulting from the ringdown signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The present disclosure is best understood with reference to the accompanying figures in which like numerals refer to like elements and in which:

FIG. 1 shows an imaging well logging instrument disposed in a wellbore drilled through earth formations.

FIG. 2A shows the rotator assembly;

FIG. 2B shows the transducer assembly;

FIG. 3 illustrates a cross-section of the transducer assembly;

FIG. 4A shows an exemplary signal resulting from activation of the transducer;

FIG. 4B shows an exemplary amplitude image of the borehole wall dominated by an interference between the transducer ringdown and the echo signal, giving a characteristic “wood-grain” image;

FIG. 5A shows the amplitude and traveltimes images obtained using a ceramic transducer in heavy water-based mud;

FIG. 5B shows the amplitude and traveltimes images obtained using a composite transducer in heavy water-based mud;

FIG. 6A shows an exemplary signal including a ringdown and an echo signal;

FIG. 6B is an estimate of the ringdown obtained by fitting a sinusoid;

FIG. 6C shows the estimated echo signal obtained by subtracting the fitted sinusoid from the recorded signal;

FIGS. 7A-D shows four exemplary recorded signals, each including an echo and a ringdown,

FIGS. 7E-H shows the results of subtracting the average of the signals in Figs. 7A-D from the individual signals;

FIGS. 8A-8C show the results of processing a signal including a ringdown using ABS, Stack and subtract, and Fit and subtract respectively;

FIGS. 9A-9C show exemplary signals including a ringdown and an echo at different spacings from the ringdown;

FIG. 10 shows the Cauchy wavelet pair for the Hilbert Transform

FIG. 11A shows an exemplary signal dominated by a ringdown;

FIG. 11B shows the envelope of the signal in Fig. 10a;

FIG. 12 shows the envelope along with the result of applying a Gaussian Laplace operator;

FIG. 13 shows the geometry of an eccentric rotating transducer in a circular borehole;

FIG. 14 shows the effect of eccentricity of the transducer in a circular borehole;

(a) shows the peak amplitude as a function of azimuth as a result of eccentricity of the transducer by 24 mm in a borehole of diameter 108 mm, (b) shows the woodgrain effect, and (c) shows the spectrum of the woodgrain effect;

FIGS. 15A - 15B show a comparison of amplitude images obtained without downhole waveform processing and with stack-and-subtract waveform processing.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0009] Referring to **FIG. 1**, a well logging instrument **10** is shown being lowered into a wellbore **2** penetrating earth formations **13**. The instrument **10** can be lowered into the wellbore **2** and withdrawn therefrom by an armored electrical cable **14**. The cable **14** can be spooled by a winch **7** or similar device known in the art. The cable **14** is electrically connected to a surface recording system **8** of a type known in the art which can include a signal decoding and interpretation unit **16** and a recording unit **12**. Signals transmitted by the logging instrument **10** along the cable **14** can be decoded, interpreted, recorded and processed by the respective units in the surface system **8**.

[0010] **FIG. 2A** shows mandrel section **201** of the imager instrument with a Teflon® window **203**. Shown in **FIG. 2B** is the rotating platform **205** with the ultrasonic transducer assembly **209**. This may be referred to as a rotatable transducer assembly. The rotating platform is also provided with a magnetometer **211** to make measurements of the orientation of the platform and the ultrasonic transducer. The platform is provided with coils **207** that are the secondary coils of a transformer that are used for communicating signals from the transducer and the magnetometer to the non-rotating part of the tool. The transducer **209** is discussed further below.

[0011] Turning now to **FIG. 3**, a cross section of a transducer assembly is shown. Depicted therein is the Teflon® window **301**. One transducer is depicted by **307**. The assembly may include a second transducer on the opposite side (not shown). The front portion of the transducer is in contact with an impedance matching material **305** that is used to match the impedance of the transducer with that of oil in the space **305** between the transducer and the Teflon® window. It should be noted that the use of Teflon® is not to be construed as a limitation and any other material with the necessary abrasion resistance and acoustic properties could be used.

[0012] Still referring to **FIG. 3**, the transducer assembly also includes a backing material **309**. In one embodiment, the backing material is a 0-3 composite of tungsten particles in high temperature rubber. In another embodiment, liquid Viton®, a synthetic rubber may be used. The backing material absorbs acoustic signals propagating from the transducer away from the borehole wall and reduces reflections from the interface between the transducer and the backing material. Also shown in **FIG. 3** are the leads **311** from the transducer that go to transformer coils **207**. The transducer **307** sends an acoustic signal through the acoustically transparent Teflon® window. The borehole wall produces an echo signal that returns to the rotatable transducer assembly **209**.

[0013] A problem encountered with televiewer signals is that of reverberations within the transducer assembly, specifically between the transducer **307** and the Teflon® window **301**. **FIG. 4A** shows an exemplary signal recorded with a rotatable transducer assembly **209**. The reflection from the borehole wall is indicated by **401** while the extended signal **403** results from ringdown of the transducer. As a result of interference between this ringdown and the echo signal, the amplitude image of the borehole wall has the character shown in **FIG. 4B**. The abscissa of the two-dimensional image of **Fig. 4b** is depth and the ordinate is the azimuth: the borehole wall has been “unwrapped” to give the image. The actual reflection signals from the borehole wall corresponding to two dipping beds or fractures are shown by **411** and **413**. The image is dominated by a “wood-grain” pattern **409** which makes the identification of the dipping beds difficult.

[0014] In the present disclosure, several methods are disclosed for improving the signal-to-noise ratio of the desired signal (exemplified by **411**) and the noise (exemplified by **409**). The first solution is a hardware solution and is based upon using a transducer that has improved signal output. Specifically, a composite transducer of the type disclosed in United States Patent Application Ser. No. 12/392,487 of *Steinsiek* et al., having the same assignee as the present disclosure and the contents of which are incorporated herein by reference, is used. The transducer disclosed therein comprises a 1-3 Piezoelectric composite transducer of high Q ceramic rods in a polymer matrix. A comparison of signals recorded in a borehole with a prior art ceramic transducer (**FIG. 5B**) and the composite transducer (**FIG. 5A**) in heavy water-based mud (18.2 ppg) is informative. The amplitude image **505** and the travelttime image **507** recorded with the ceramic transducer show basically no reflected signal. In contrast, the amplitude image **501** and the travelttime image **503** with the composite transducer shows a near vertical feature **521** indicative of borehole ellipticity. Based on experience with the composite transducer, it is estimated that the signal to noise ratio (SNR) can be increased by about 20dB by using a composite transducer. An explanation of the reduction in ringdown is that reverberations are dampened by the polymer matrix portion of the transducer

[0015] Another hardware solution is to alter the distance between the transducer and the window. Changes in the reverberatory signal resulting from different distances have been discussed in *Steinsiek* but specific examples of improvements in image quality were not discussed. Based on experience with the composite transducer at different distances from the window, it is estimated that the SNR can be improved by about 8dB.

[0016] Turning now to **FIGS. 6A-6C**, a processing method to improve the SNR is discussed. **FIG. 6A** shows an exemplary signal **601** that includes an echo distorted by ringdown. In this example, the echo is centered around 100 on the x -axis. **FIG. 6B** shows an estimate **603** of the ringdown signal obtained by fitting a decaying sinusoid to the signal **601**. In one example, the fitting function is of the form:

$$e^{-\zeta t} \sin(\omega t - \phi)$$

where the fitting parameters are the decay constant ζ , frequency ω , and phase ϕ . In one embodiment of the disclosure, a constrained fit is done so that the curve **603** passes through the first peak **604** of the curve **601**. Subtracting the decaying sinusoidal fit **603** from the recorded signal **601** gives the estimated echo signal **605**. This process of fitting and subtracting (FAS) is repeated for each of the transducer excitations at the plurality of transducer orientations and processed to give amplitude and traveltime images.

[0017] Another method of processing the data is discussed with reference to **FIGS. 7A-H**. Four exemplary signals **701, 703, 705, 707** are shown in **FIGS. 7A-D**. The signals include ringdown and an echo signal at time 90, 120, 150 and 180 respectively. The average (“stack”) of the produced signals **701, 703, 705, 707** is determined (not shown) and subtracted from the individual signals **701, 703, 705, 707** to give the signals **701', 703', 705', 707'** respectively, shown in **FIGS. 7E-H**. As can be seen, the subtracted signals agree very well with the echo times of 90, 120, 150 and 180.

[0018] **FIG. 8A** shows the results of processing a signal including a ringdown using the ABS method. **FIG. 8B** shows the result of processing using SAS (Stack and Subtract) and ABS. **FIG. 8C** shows the result of FAS (Fit and Subtract), SAS and ABS.

[0019] Another method of processing the data uses echo peak detection methods discussed in US Patent Application Ser. No. 12/268,141 of *Zhao*, having the same assignee as the present disclosure and the contents of which are incorporated herein by reference. The method of *Zhao* is discussed with reference to **FIGS. 9A-9C**. Shown in **FIG. 9A** is a ringdown signal **903** and an echo **901**. The echo can be clearly distinguished from the ringdown. In **FIG. 9B**, the echo **911** is barely visible relative to the ringdown **913** and in **FIG. 9C**, the echo **921** is swamped by the ringdown **923**.

[0020] The method used in the present disclosure is to use the Hilbert Transform to estimate the envelope of the recorded signal and then identify arrival times as peaks in

the envelope that are indicative of the echo signal. As discussed in *Zhao*, the Hilbert transform is implemented in conjunction with a Cauchy wavelet (a modulated Gaussian filter) as a bandpass filter. For the particular transducer used, a wavelet is defined having 5-6 cycles of a center frequency of 300 kHz, a sampling interval of 4 MHz. Due to hardware constraints, the wavelet is truncated, and a Hanning weighting is used to reduce the Gibbs phenomenon. The resulting wavelet pair for applying the Hilbert transform is shown in **FIG. 10** by the in-phase **1003** and quadrature **1001** wavelets.

[0021] **FIG. 11A** shows an exemplary signal **1101** completely dominated by the ringdown. **FIG 11B** shows the envelope **1103** obtained by applying the wavelets **1001, 1003**. The perturbation **1105** is associated with the echo signal. Those versed in the art and having benefit of the present disclosure would recognize that peak finding techniques would not always be able to detect the echo. Accordingly, in one embodiment of the disclosure, the first and second moments are removed from the envelope curve using a Laplace Operator. The Laplace operator may be denoted by:

$$\nabla^2 = \frac{d^2}{dt^2} \quad (1).$$

This filter is very sensitive to high frequency noise, so that a low pass filtering may be applied prior to the Laplace operator. In one embodiment of the disclosure, a Gaussian filter is used, so that the combination of the Gaussian-Laplace operator may be denoted by:

$$\nabla^2 \cdot g(t) = \frac{d^2}{dt^2} e^{-\left(\frac{t}{\tau}\right)^2} \quad (2).$$

[0022] **FIG. 12** shows the results of applying the Gaussian Laplace operator to the envelope **1103**. The echo signal **1201** can be clearly seen, separate from the ringdown signal. For the purposes of display of the borehole image, the amplitude of the echo is defined by the difference between the peak and the average of the adjacent troughs. The time is defined by the time of the peak.

[0023] Another embodiment of the disclosure uses a notch filtering operation to remove the effect of the reverberation. The geometry that causes the reverberation is shown in **FIG. 13**. The transducer **1303** is positioned in a circular borehole **1300** of radius **R** and is offset by a distance **E** from the center of the borehole. At an angle ϕ of the transducer, the point **1313** at a distance **r** from the transducer defines the two-way traveltime for the reflected transducer signal. The direction of rotation of the acoustic beam is indicated by **1311**.

[0024] When $E \neq 0$ the radial length of the ultrasound beam **r** changes as a function of θ . The change in **r** between each azimuth location is expressed as $dr/d\theta$. If tr is the time between each azimuth location, then the change in **r** between each azimuth location is given by dr/dtr . dr is determined by the instruments radial distance measurement, and dtr is determined by the instruments transmit timing. The stationary noise and the moving ultrasound echo constructively interfere to create peaks in the detected line scan data every wavelength (λ). Due to the pulse-echo technique, for every half-wavelength ($\lambda/2$) change in **r**, the two-way distance changes a full wavelength (λ).

Therefore, the period of interference $P_i = ((\lambda/2)/dr) \cdot dtr$

This gives the instantaneous frequency of the interference between the ringdown signal and the echo as:

$$f_i = (2 \cdot dr/\lambda) / dtr = (2/\lambda) \cdot dr/dtr = (2/\lambda \cdot dtr) \cdot dr$$

An adjustable notch filter tuned to this frequency can be used to filter out the interference without filtering out the signal variation due to the formation features.

[0025] The curve **1401** in **FIG. 14a** gives the peak value of the reflected signal as the transducer rotates through 360° . **FIG. 14b** shows the modeled reflected amplitude over a portion of the borehole of uniform radius. Using known methods, the instantaneous frequency of the reflected signal can be estimated. The instantaneous frequency is the result of interference between the generated signal (having a known base frequency) and a modulating signal caused by the interference, i.e., it will have components at the sum and difference of the base frequency and the modulating frequency. The modulating frequency recovered is indicated by **1403**. A

corresponding notch filter is applied to the recorded signal as a function of azimuth to get rid of the reverberation.

[0026] **FIG. 15A** shows an exemplary amplitude image recorded downhole and displayed without any downhole processing. **FIG. 15B** shows the results of using SAS processing. Significant improvement is noted in the resolution of the bedding in the regions indicated by **1501** and **1503**. In fact, the estimated dip direction is opposite to that which would be inferred from the unprocessed section. The stationary noise of the woodgrain effect has been greatly attenuated. To the extent that the underlying formation bedding is visible in the image, it can be said that the stationary noise due to interference between the ringdown signal and the echo has been substantially eliminated.

[0027] The processing of the data may be done by a downhole processor and/or a surface processor to give corrected measurements substantially in real time. Implicit in the control and processing of the data is the use of a computer program on a suitable machine readable medium that enables the processor to perform the control and processing. The machine readable medium may include ROMs, EPROMs, EEPROMs, Flash Memories and Optical disks. Such media may also be used to store results of the processing discussed above.

CLAIMS

What is claimed is:

1. An apparatus configured to evaluate an earth formation, the apparatus comprising:
 - a rotatable transducer assembly;
 - a transducer on the rotatable transducer assembly configured to propagate an acoustic signal through an acoustically transparent window into a borehole and produce a signal including an echo from a wall of the borehole and a ringdown signal within the transducer assembly; and
 - at least one processor configured to use the signal produced at a plurality of orientations of the transducer during rotation of the transducer assembly to provide a two-dimensional image of the earth formation, the two-dimensional image being substantially free of a stationary noise resulting from an interference between the ringdown signal and the echo.
2. The apparatus of claim 1 wherein the at least one processor is further configured to provide the two-dimensional image by:
 - (i) fitting a decaying sinusoid to the produced signal at each of the plurality of orientations,
 - (ii) subtracting the decaying sinusoid from the produced signal at each of the plurality of orientations to give a plurality of processed signals, and
 - (iii) using the plurality of processed signals to provide the image.
3. The apparatus of claim 1 wherein the at least one processor is further configured to provide the two-dimensional image by:
 - (i) determining an average of the produced signals at the plurality of orientations of the transducer assembly,
 - (ii) subtracting the average of the produced signals from each of the produced signal at the plurality of orientations to give a plurality of processed signals, and
 - (iii) using the plurality of processed signals to provide the two-dimensional image.

4. The apparatus of claim 1 wherein the at least one processor is further configured to provide the two-dimensional image by:
 - (i) bandpassing the produced signal at each of the plurality of orientations using a modulated Gaussian filter and providing a bandpassed signal at each of the plurality of orientations;
 - (ii) estimating an envelope of the bandpassed signal at each of the plurality of orientations;
 - (iii) estimating from the envelope of the bandpassed signal at each of the plurality of orientations an arrival time of the echo at each of the orientations and an associated amplitude at each of the orientations;
and
 - (iv) producing the image using at least one of: (i) the estimated arrival time of the reflection at each of the orientations, and (ii) the estimated associated amplitude at each of the orientations.
5. The apparatus of claim 1 wherein the at least one processor is further configured to provide the two-dimensional image by:
 - (i) estimating a frequency of an interference between the ringdown signal and the echo as a function of azimuths, and
 - (ii) performing a filtering operation using a notch filter derived using the estimated frequency of the interference between ringdown signal and the echo signal.
6. The apparatus of claim 1 wherein the transducer further comprises piezoelectric transducer (PZT) rods in a polymer matrix.
7. The apparatus of claim 1 wherein the ringdown signal further comprises a reverberation between the transducer and the acoustically transparent window and wherein the transducer assembly is configured to have a distance between the transducer and the window adjustable to reduce the reverberation.

8. The apparatus of claim 1 wherein the rotatable transducer assembly further comprises:
 - (i) a fluid in a cavity adjacent to the acoustically transparent window, and
 - (ii) an impedance matching material disposed between the composite transducer and the fluid.
9. The apparatus of claim 1 wherein the rotatable transducer assembly is part of a logging string conveyed into the borehole on a wireline.
10. A method of evaluating an earth formation, the method comprising:
 - conveying a rotatable transducer assembly into a borehole;
 - using a transducer on the rotatable transducer assembly to convey an acoustic signal through an acoustically transparent window into a borehole and produce a signal including an echo from a wall of the borehole and a ringdown signal within the transducer assembly; and
 - processing the signal produced at a plurality of orientations of the transducer during rotation of the transducer assembly to provide a two-dimensional image of the earth formation, the two-dimensional image being substantially free of a stationary noise resulting from interference between the ringdown signal and the echo.
11. The method of claim 10 wherein processing the signal produced at each of the plurality of orientations of the transducer assembly further comprises:
 - (i) fitting a decaying sinusoid to the produced signal,
 - (ii) subtracting the decaying sinusoid from the produced signal to give a processed signal, and
 - (iii) using the processed signal to provide the two-dimensional image.

12. The method of claim 10 wherein processing the signal produced at each of the plurality of orientations of the transducer assembly further comprises:
 - (i) determining an average of the produced signals at the plurality of orientations of the transducer assembly ,
 - (ii) subtracting the average of the produced signals from each of the produced signal at the plurality of transducer orientations to give a plurality of processed signals at each of the plurality of transducer orientations, and
 - (iii) using the processed signals at each of the plurality of transducer orientations to provide the two-dimensional image.
13. The method of claim 10 wherein processing the signal produced at each of the plurality of orientations of the transducer assembly further comprises
 - (i) bandpassing the produced signal at each of the plurality of orientations using a modulated Gaussian filter and providing a plurality of bandpassed signals;
 - (ii) estimating an envelope of the plurality of the bandpassed signals;
 - (iii) estimating from the envelope of the plurality of bandpassed signals an arrival time of the echo and an associated amplitude at each of the orientations; and
 - (iv) producing the two-dimensional image by using at least one of: (i) the estimated arrival times of the reflection, and (ii) the estimated associated amplitudes.
14. The method of claim 10 wherein processing the signal produced at each of the plurality of orientations of the transducer assembly further comprises:
 - (i) estimating a frequency of an interference between the ringdown signal and the echo as a function of azimuth,
and
 - (ii) performing a filtering operation using a notch filter derived from the estimated frequency of the interference between ringdown signal and the echo signal.

15. The method of claim 10 further comprising using, for the transducer, piezoelectric transducer (PZT) rods in a polymer matrix.
16. The method of claim 10 wherein the ringdown signal further comprises a reverberation between the transducer and the acoustically transparent window, the method further comprising adjusting a distance between the transducer and the acoustically transparent window to reduce the reverberation.
17. The method of claim 10 further comprising conveying the rotatable transducer assembly on a logging string into the borehole.
18. A computer-readable medium product having stored thereon instructions that when executed by at least one processor, cause the at least one processor to perform a method, the method comprising:
 - using a signal produced by a transducer on a rotating transducer assembly in a borehole, the signal including an echo from a wall of the borehole and a ringdown signal within the rotating transducer assembly at a plurality of orientations of the transducer assembly, for providing a two-dimensional image of the earth formation, the two-dimensional image being substantially free of a stationary noise resulting from the ringdown signal.
19. The computer-readable medium of claim 18 further comprising at least one of:
 - (i) a ROM, (ii) an EPROM, (iii) an EEPROM, (iv) a flash memory, and (v) an optical disk.

1/16

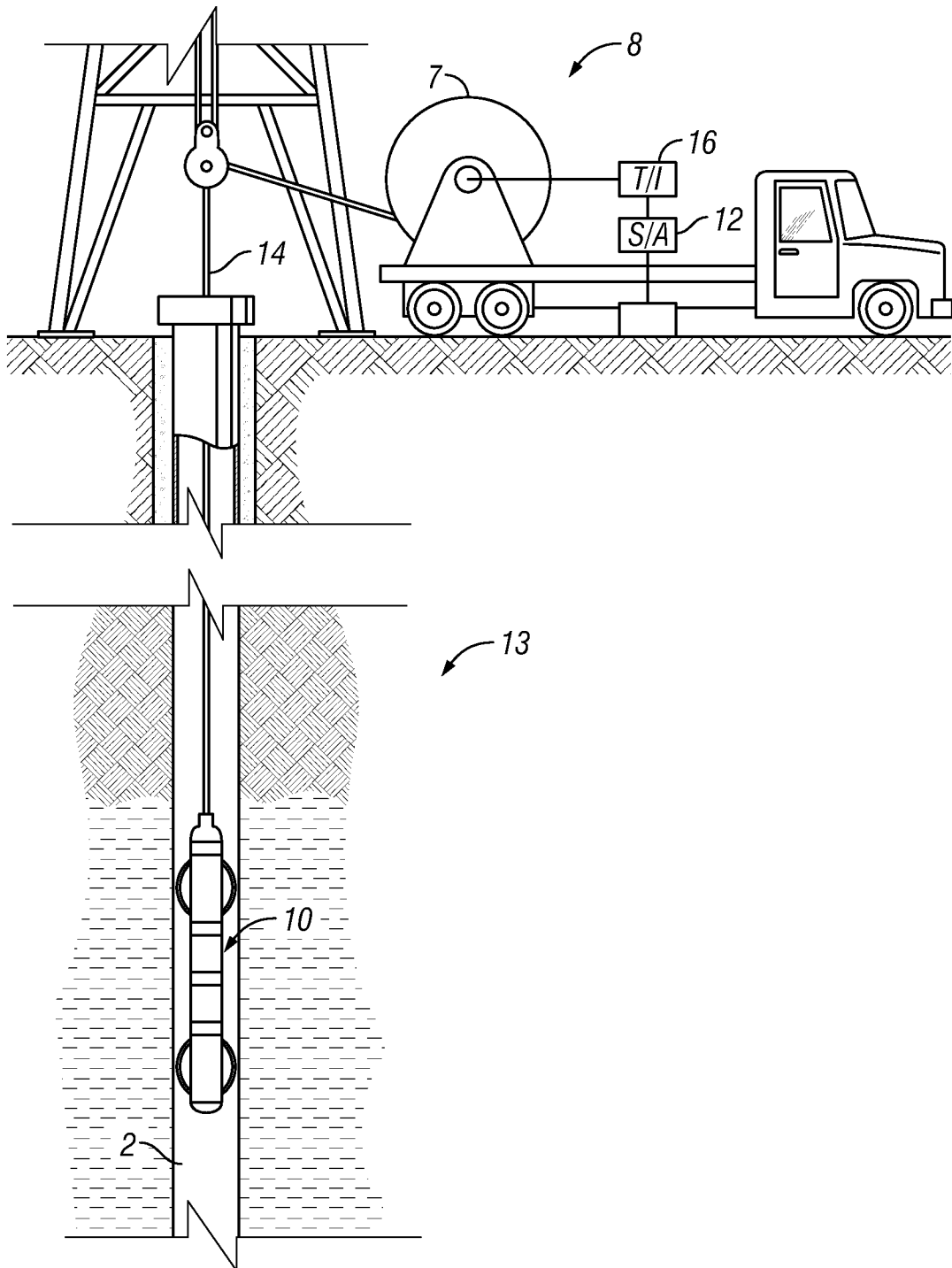


FIG. 1

2/16

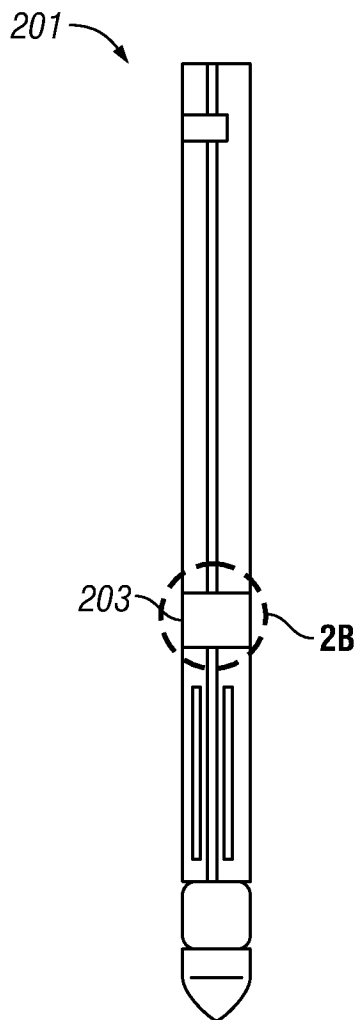


FIG. 2A

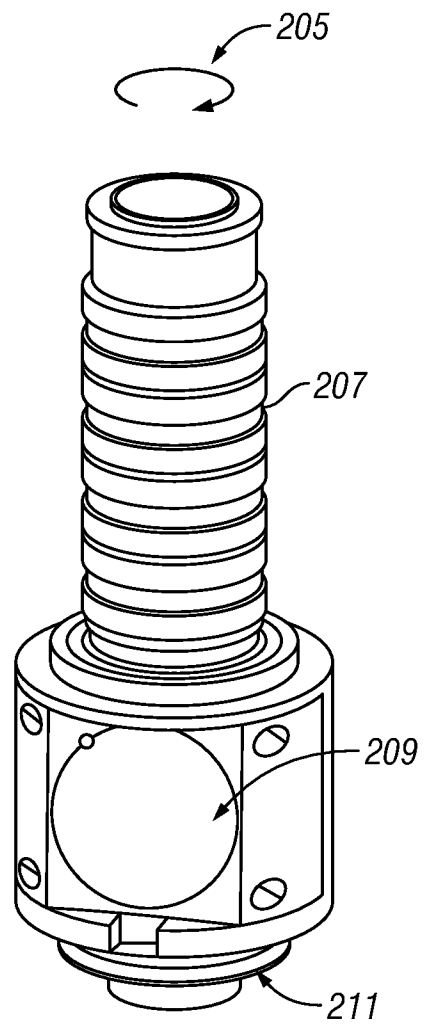


FIG. 2B

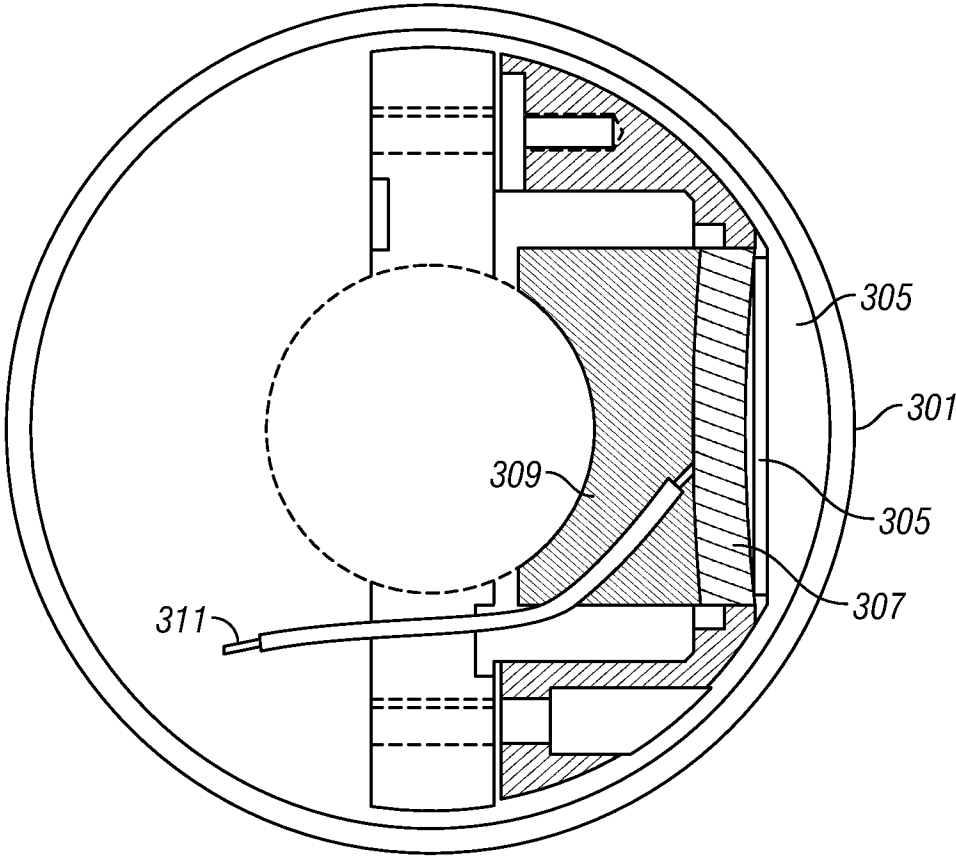


FIG. 3

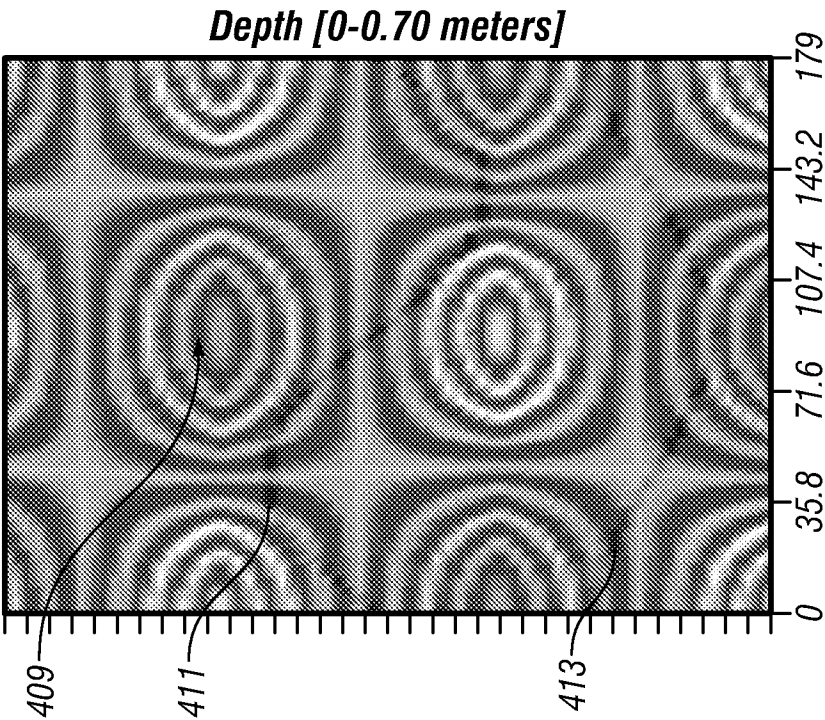


FIG. 4B

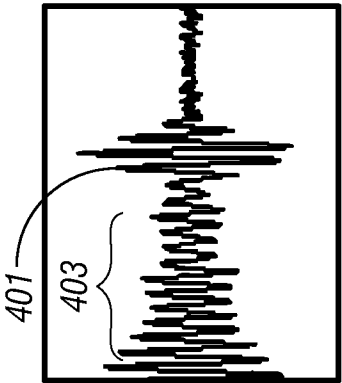


FIG. 4A

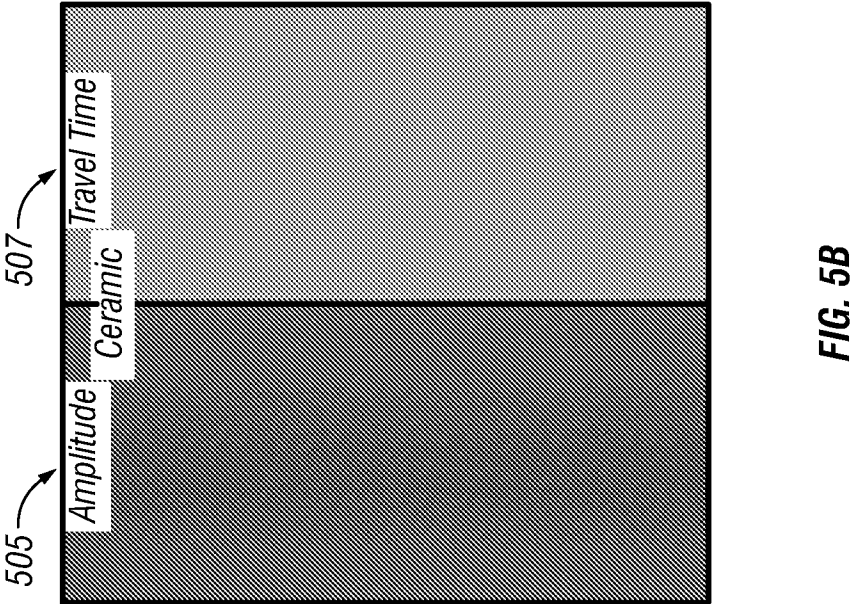


FIG. 5B

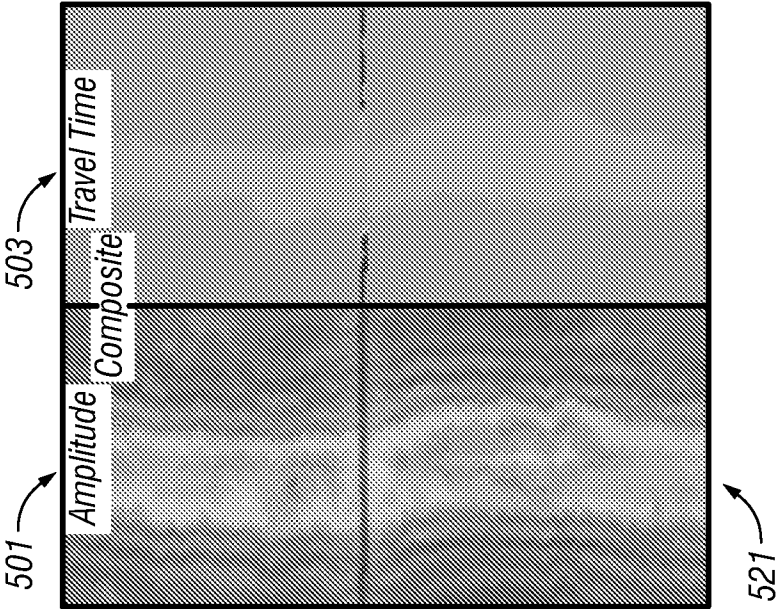
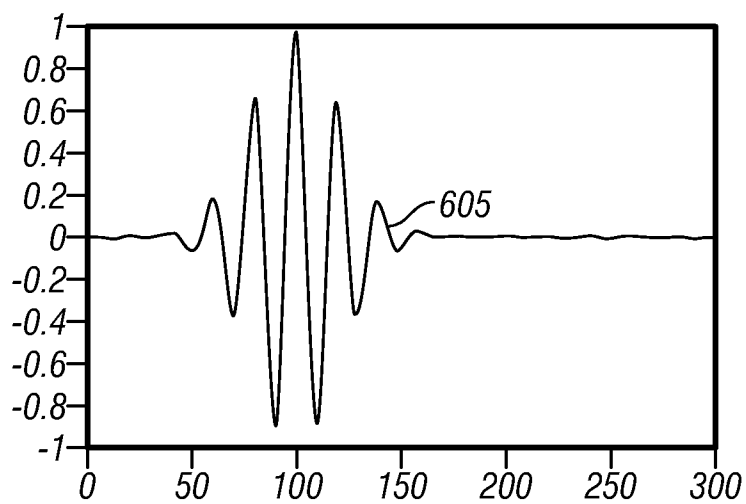
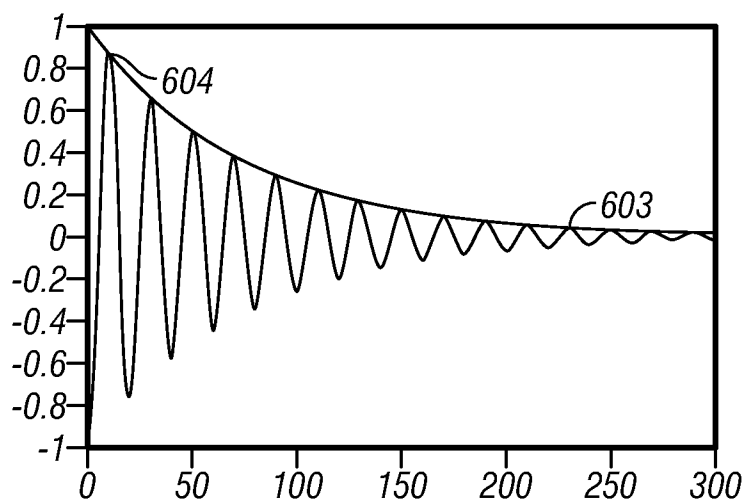
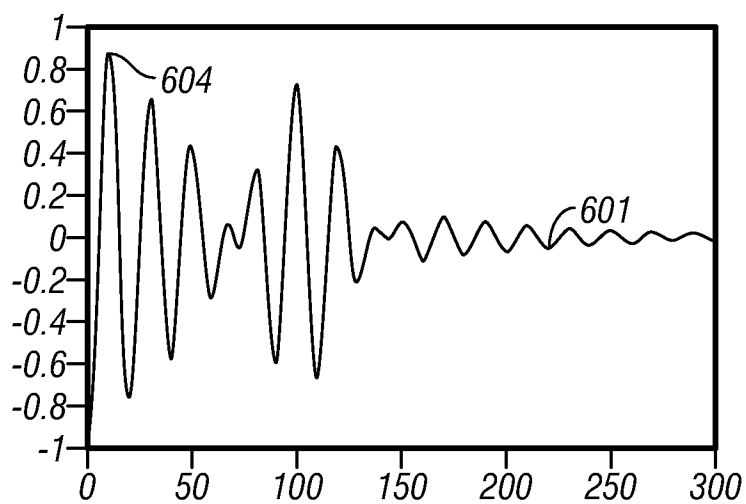
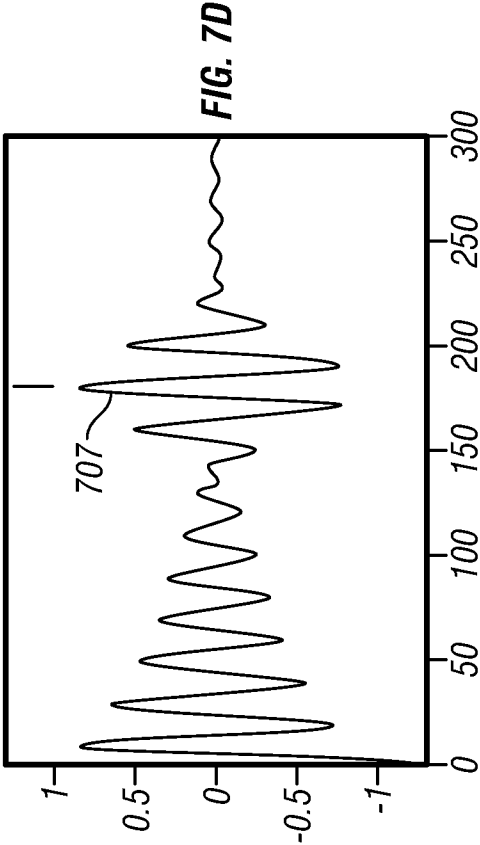
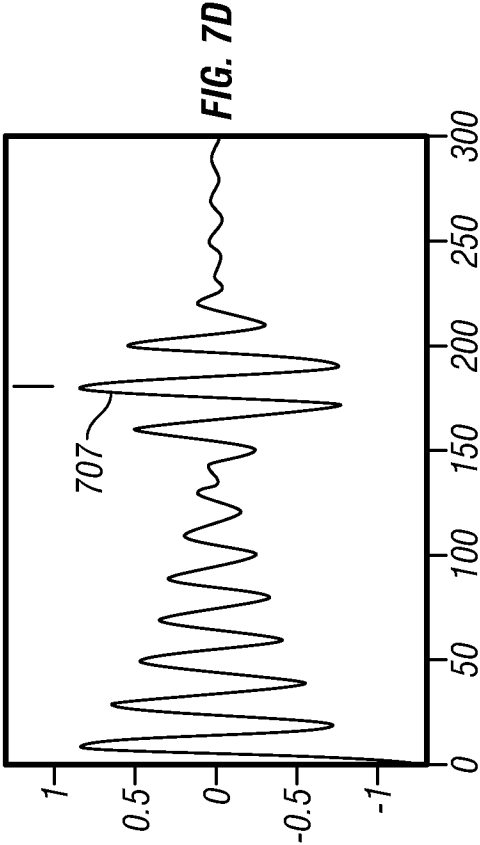
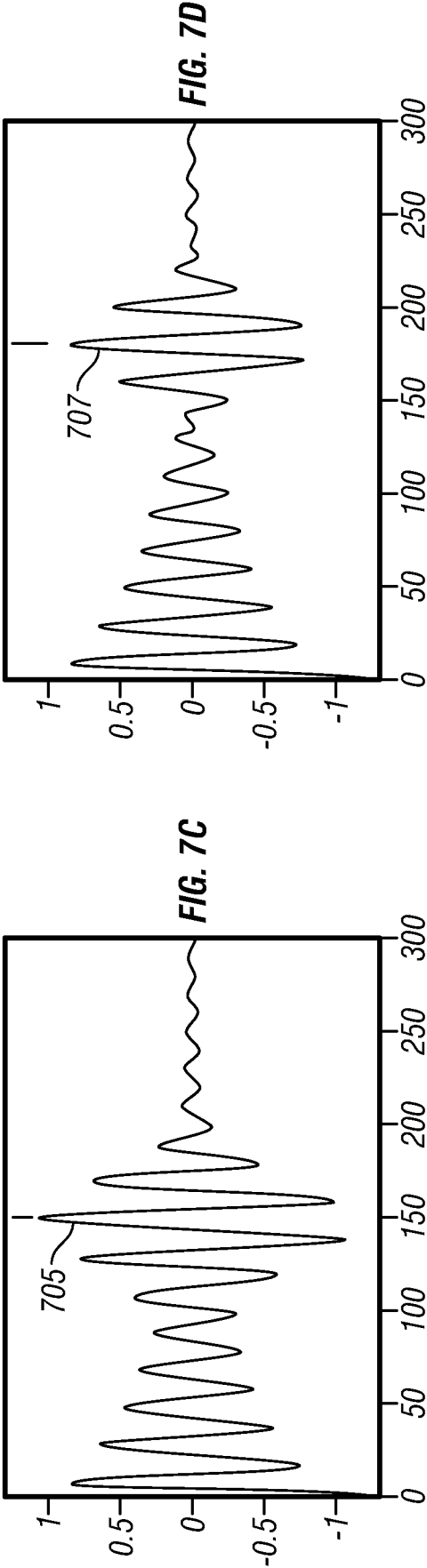
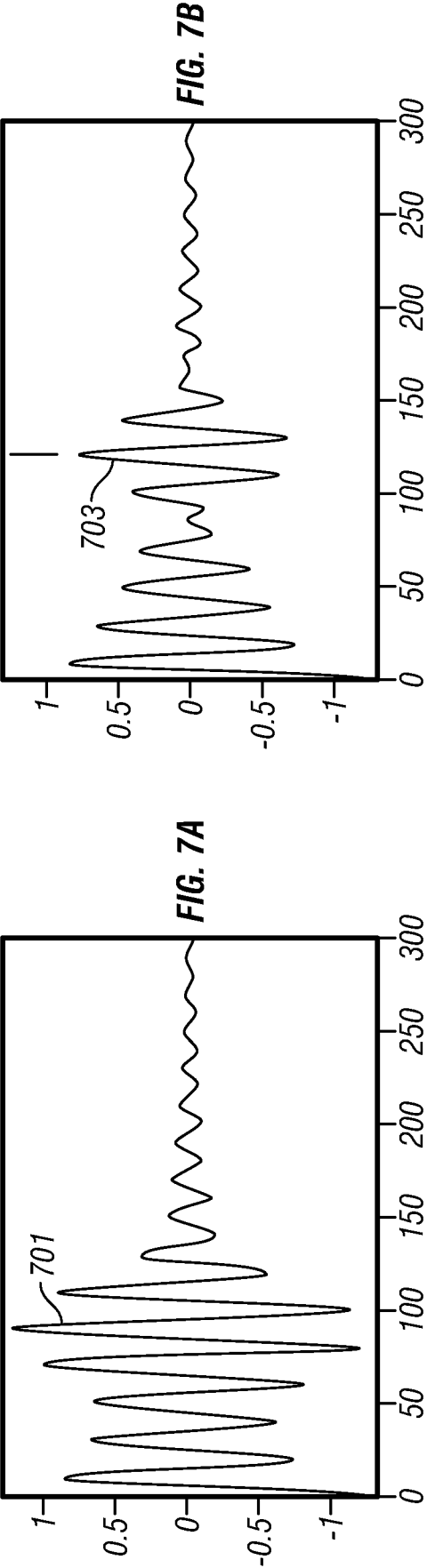
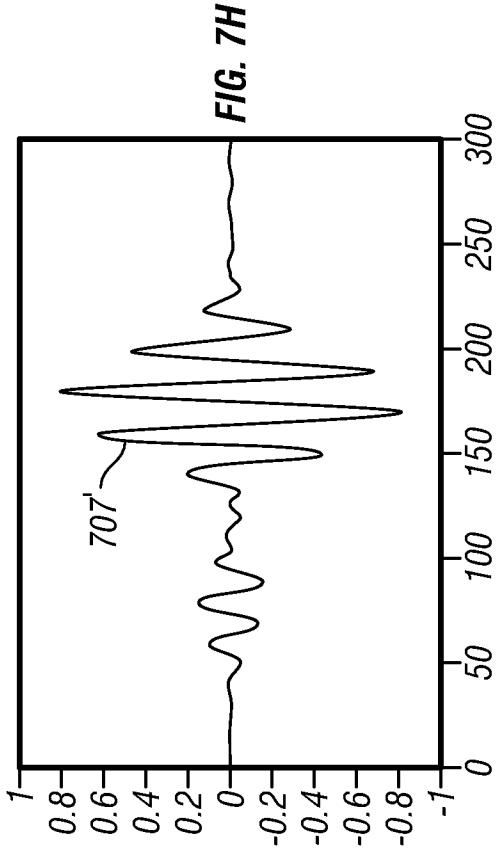
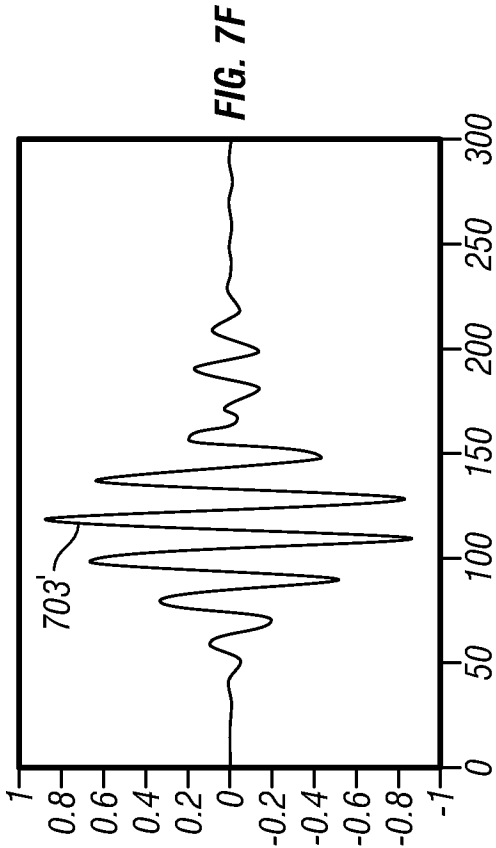
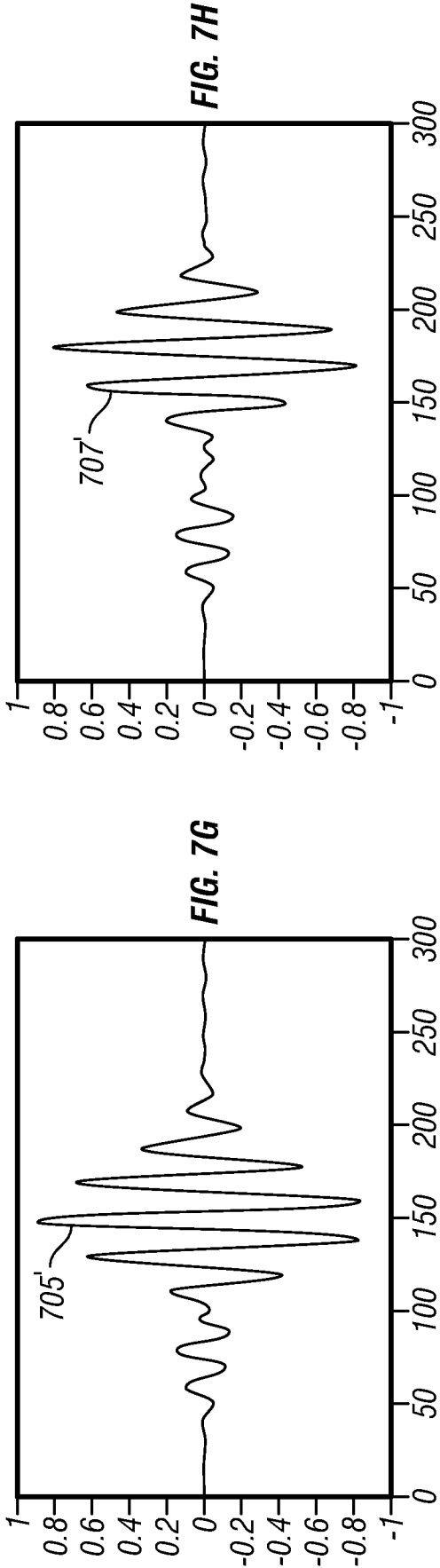
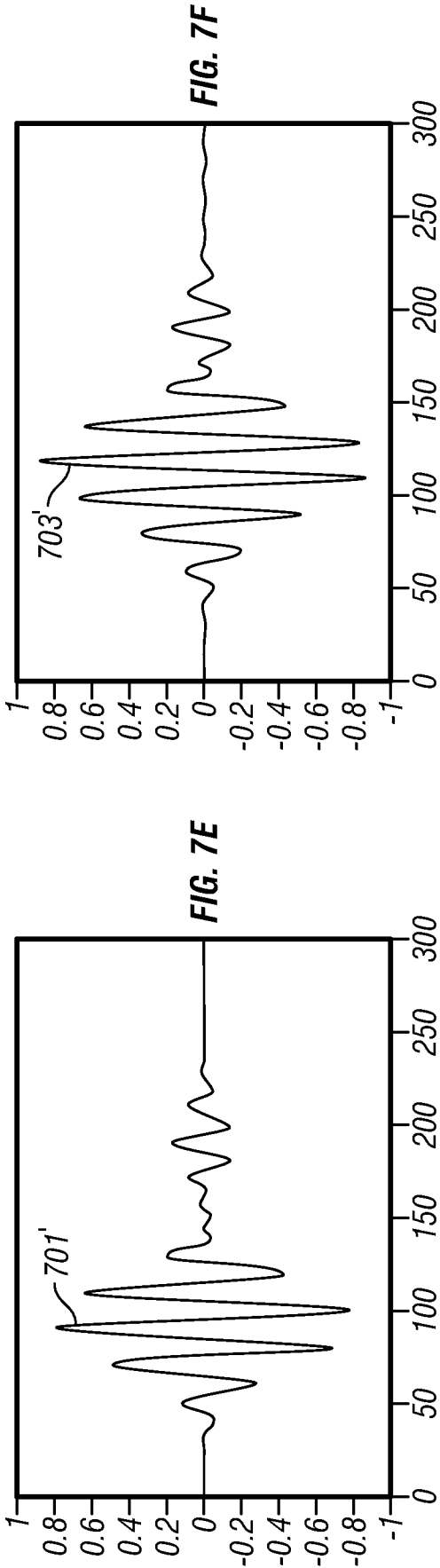
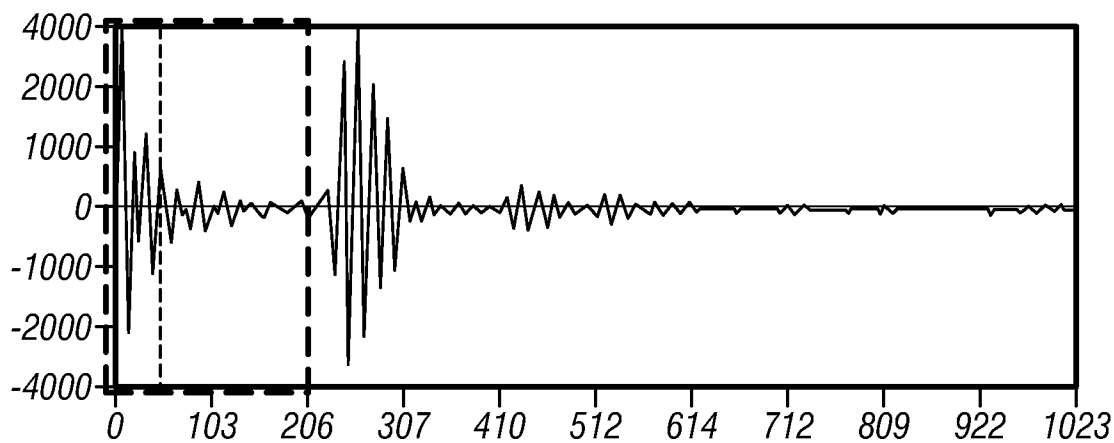
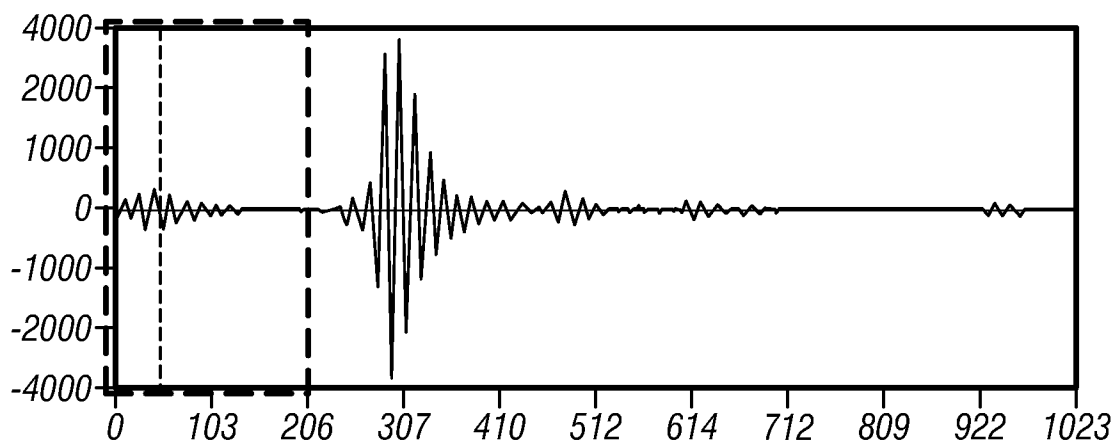
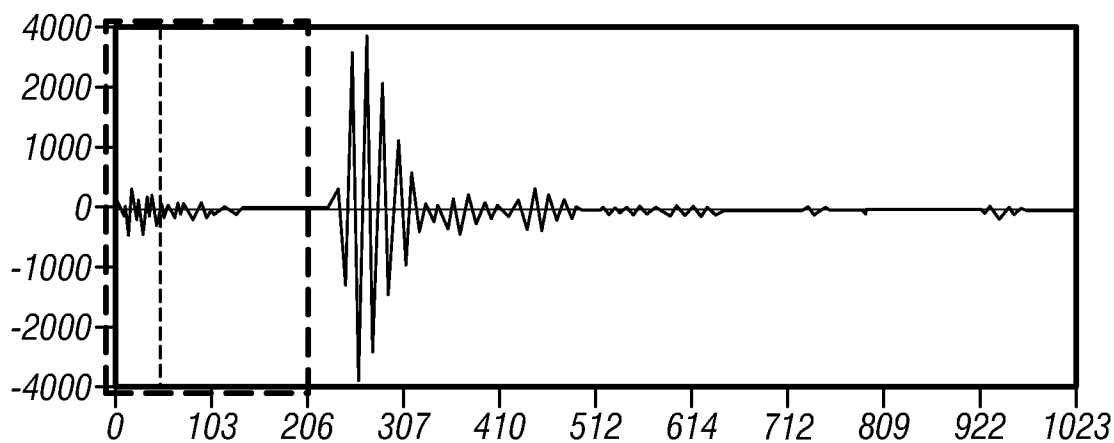


FIG. 5A

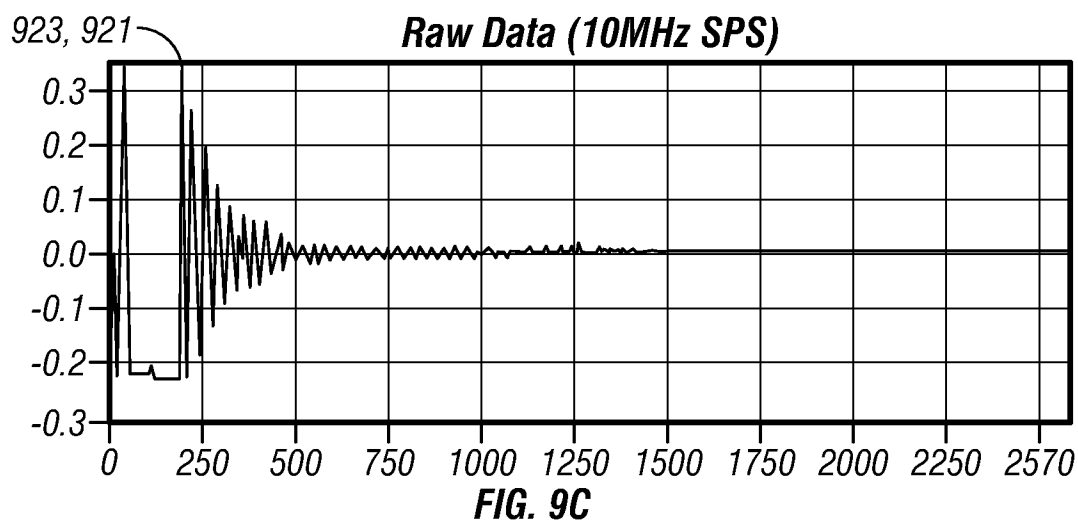
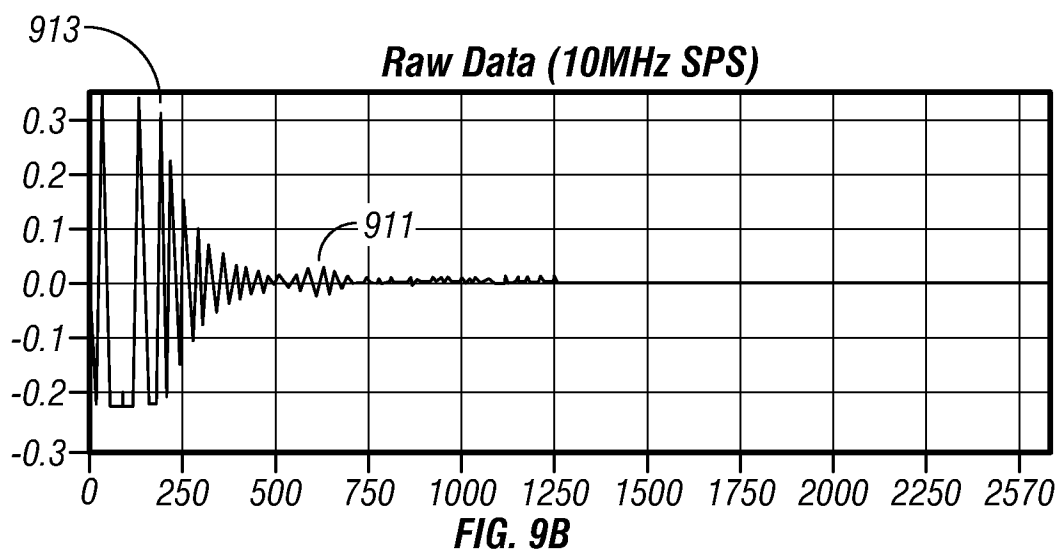
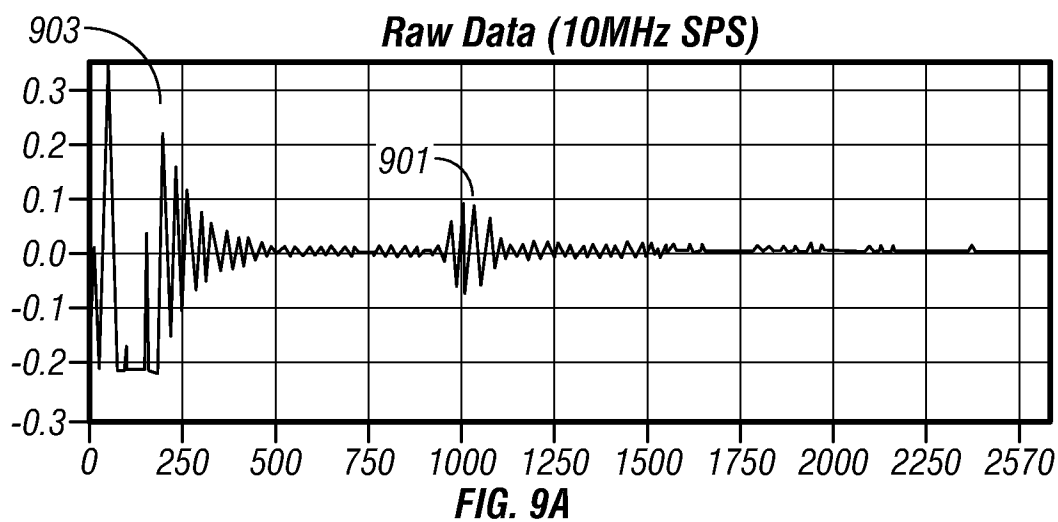
6/16





9/16**FIG. 8A****FIG. 8B****FIG. 8C**

10/16



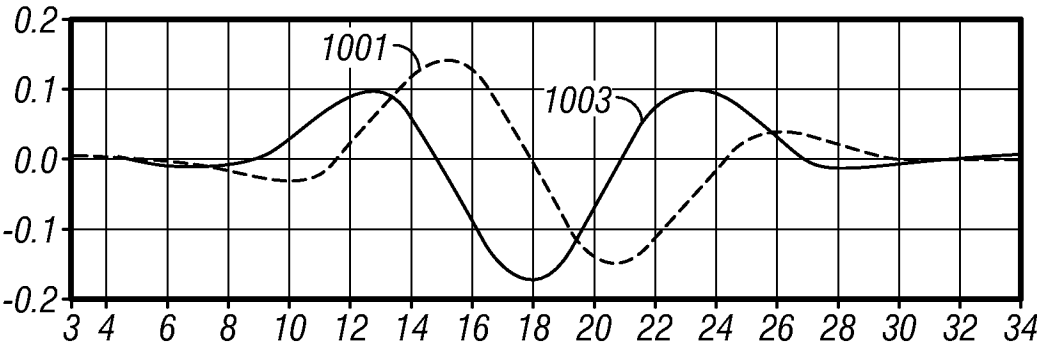


FIG. 10

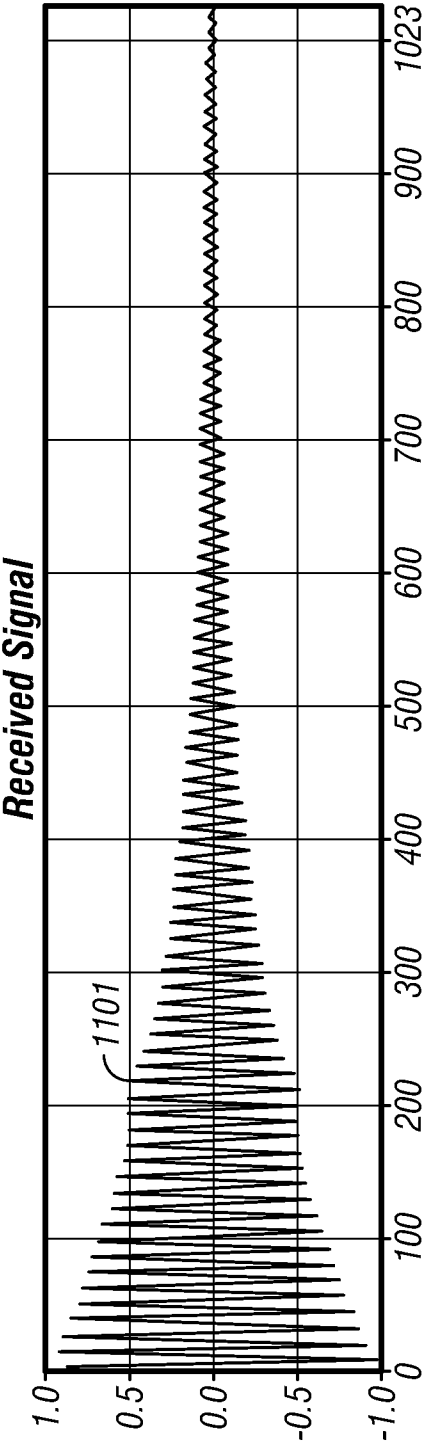


FIG. 11A

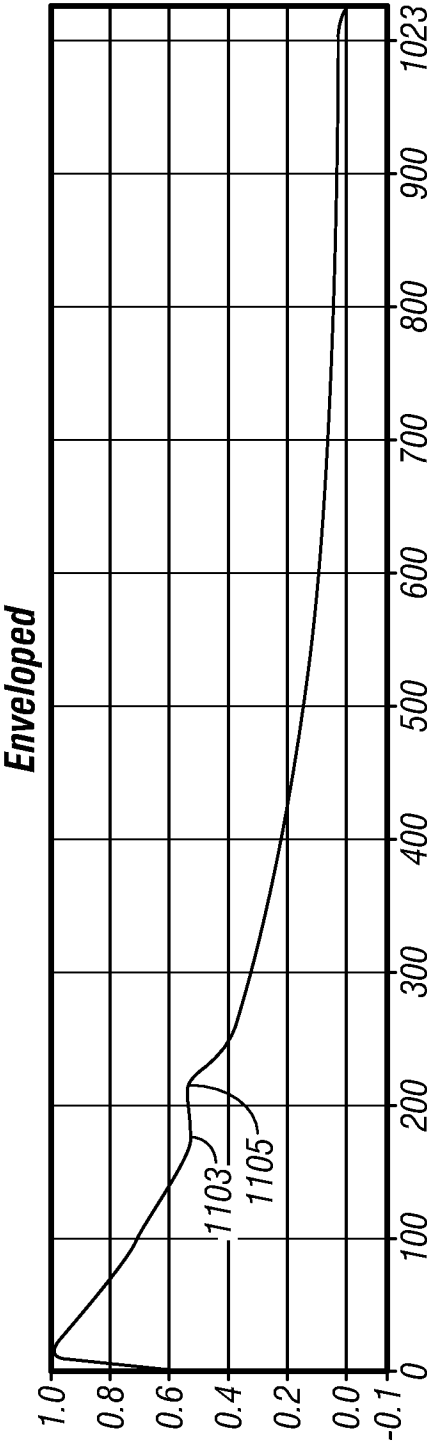


FIG. 11B

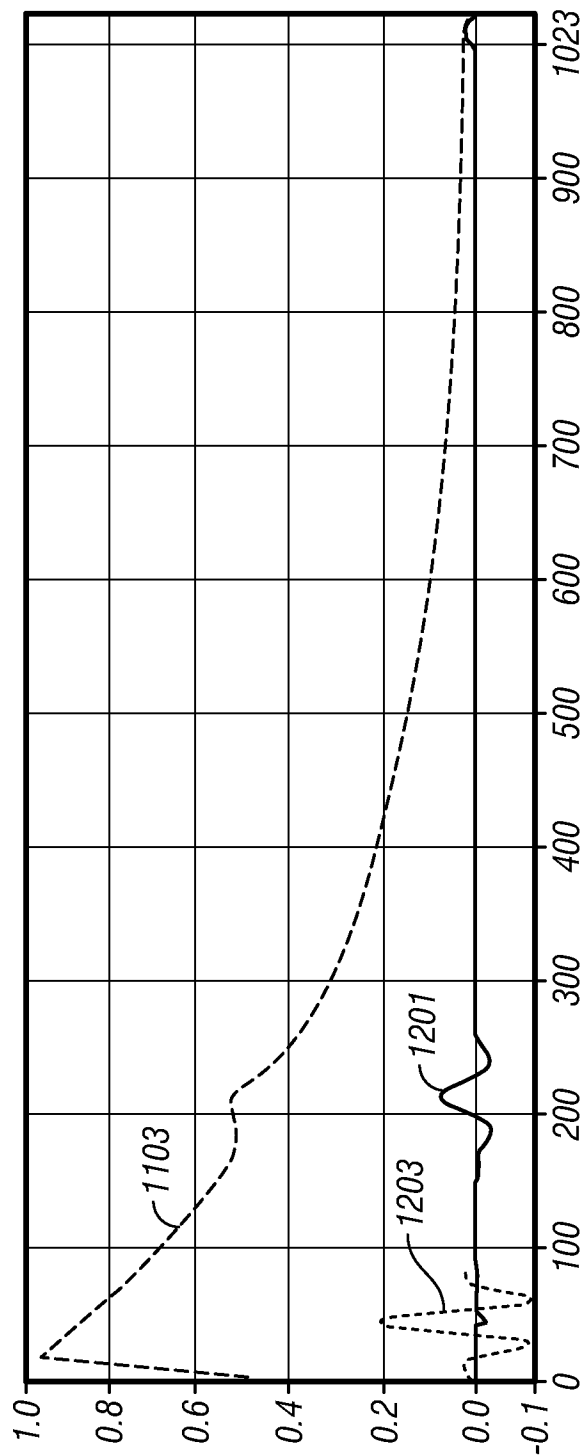


FIG. 12

14/16

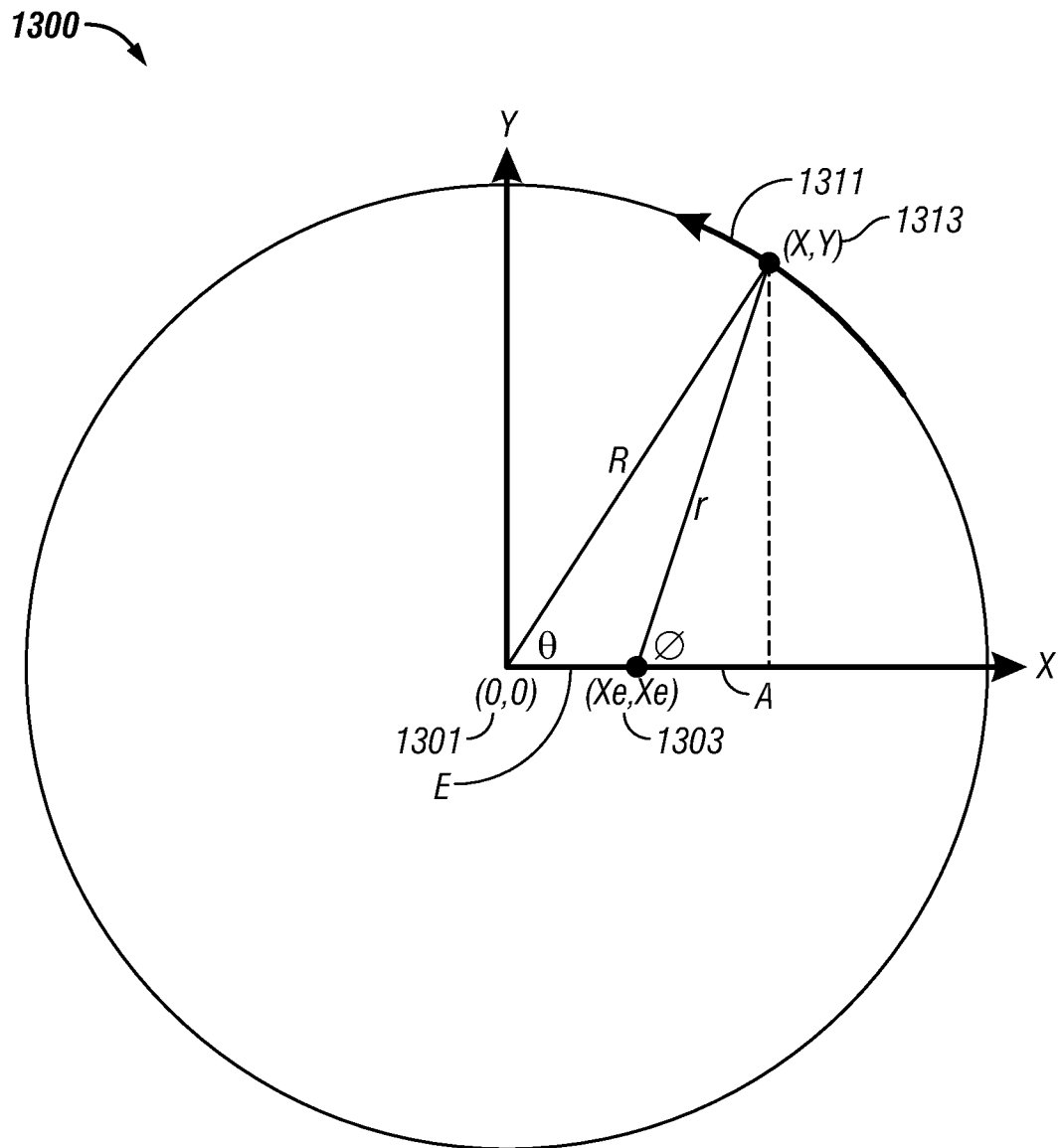


FIG. 13

15/16

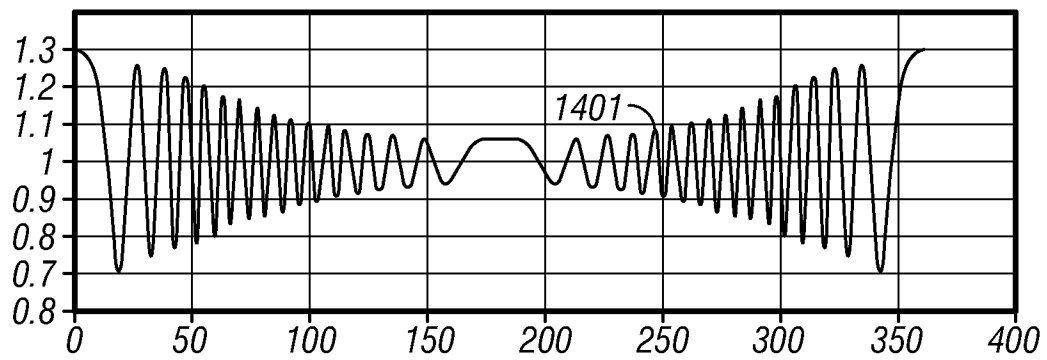


FIG. 14A

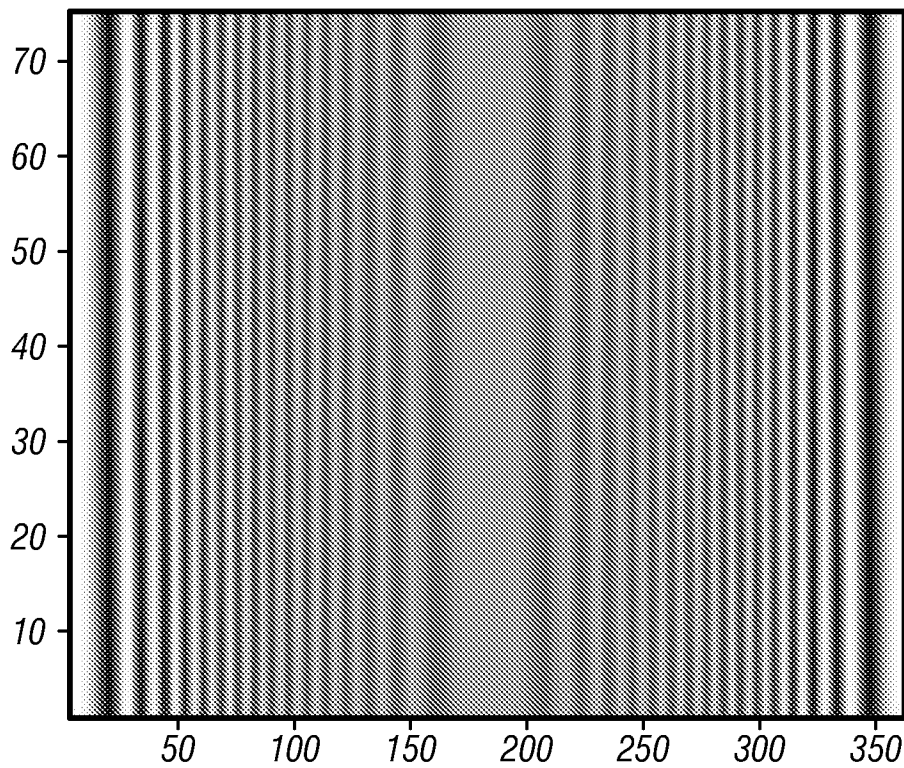


FIG. 14B

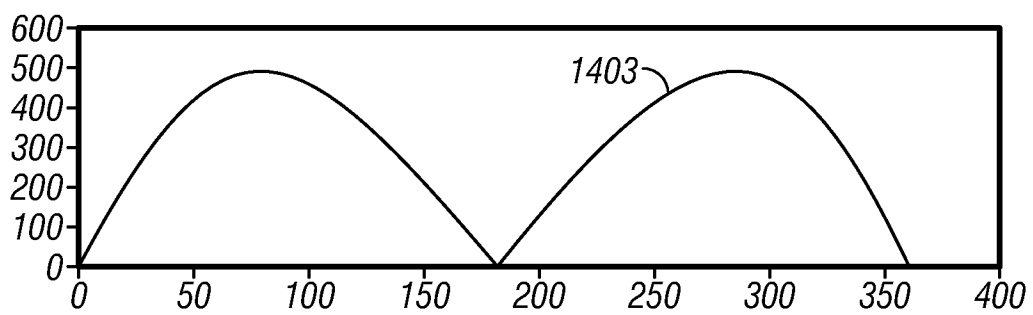


FIG. 14C

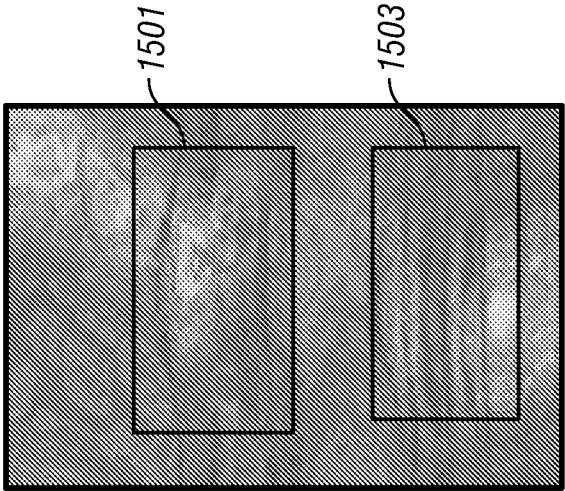


FIG. 15B

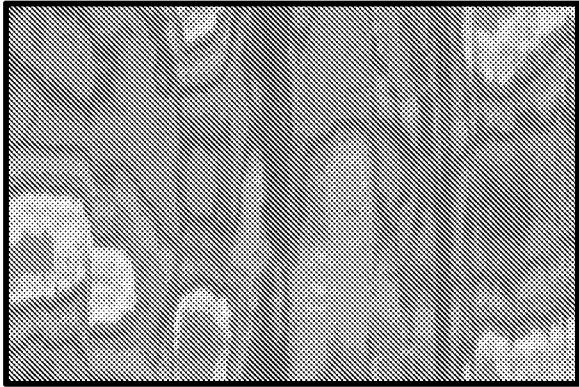


FIG. 15A