(19) **DANMARK**

(10) **DK/EP 2630452 T3**

Patent- og
Varemærkestyrelsen

(12) # Oversættelse af europæisk patentskrift

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(51) Int.Cl.: ***G 01 N 24/08 (2006.01)*** ***G 01 F 1/716 (2006.01)*** ***G 01 F 1/74 (2006.01)***
G 01 R 33/44 (2006.01)

(45) Oversættelsen bekendtgjort den: **2020-10-19**

(80) Dato for Den Europæiske Patentmyndigheds
bekendtgørelse om meddelelse af patentet: **2020-07-22**

(86) Europæisk ansøgning nr.: **11834879.6**

(86) Europæisk indleveringsdag: **2011-10-13**

(87) Den europæiske ansøgnings publiceringsdag: **2013-08-28**

(86) International ansøgning nr.: **US2011056065**

(87) Internationalt publikationsnr.: **WO2012054285**

(30) Prioritet: **2010-10-19 US 907707** **2010-12-17 US 971740**

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

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(54) Benævnelse: **NMR-STRØMNINGSMÅLING UNDER ANVENDELSE AF HASTIGHEDSVALG OG FJERNDETEKTERING**

(56) Fremdragne publikationer:
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DESCRIPTION

BACKGROUND OF THE DISCLOSURE

[0001] Multiphase fluid flows are common in pipes used in the transport of hydrocarbons for the petroleum industry. The current disclosure is directed to a method of using time of flight measurements to select a portion of the fluid that flows at a certain velocity. The velocity selection is accomplished by NMR spin-echo method. Difference in spin-lattice relaxation time T_1 and spin-spin relaxation time T2 for different phases are used to differentiate the signal contribution from the different phases, thus making it possible to estimate the flow rate for each individual phase.

[0002] From EP 0 691 526 A1 an apparatus and method for determining individual mass flow rates of a multicomponent flow is known. The apparatus comprises several polarizing magnets for fluid polarization and several NMR or EMR flow sensors which are aligned along a pipeline. The polarizing magnets generate a static magnetic field that is imposed on a multi-component flow. The linear movement of the flow generates a multi-exponential gain of magnetization along the pipeline. By sensing the multi-component flow at several positions with suitable pulse techniques the magnetization and velocity is simultaneously measured at several positions in the apparatus. The obtained magnetization and fluid velocity data are used in order to determine the mass flow rates for each individual component of the flow.

SUMMARY OF THE DISCLOSURE

[0003] One embodiment of the disclosure is a method of estimating a flow rate of a phase of a fluid having a plurality of components. The method includes: polarizing nuclei of the fluid by applying a magnetic field over a plurality of non-identical polarization lengths, wherein a number of the polarization lengths is equal to or greater than a number of the components; selecting a flow velocity and measuring, for the selected flow velocity, a magnetization of the polarized nuclei for each of the plurality of polarization lengths; estimating a relative fraction of each of the plurality of components corresponding to the selected velocity based on the plurality of measured magnetizations, wherein measuring the magnetization of the polarized nuclei comprises pulsing a first coil with a tipping pulse, pulsing a second coil with a refocusing pulse, and measuring an echo resulting from the refocusing pulse with a third coil, wherein a time interval between the tipping pulse and the refocusing pulse used for measuring the echo is defined by the selected velocity and a distance between the first coil and the second coil.

[0004] Another embodiment of the disclosure is an apparatus configured to estimate a flow rate of a phase of a fluid having a plurality of components. The apparatus includes: a pre-polarization section configured to polarize nuclei of the fluid by applying a magnetic field over a plurality of non-identical polarization lengths, wherein a number of the polarization lengths is equal to or greater than a number of the components; a coil arrangement configured to measure, for a selected flow velocity of the fluid, a magnetization of the polarized nuclei for each of the plurality of polarization lengths, wherein the coil arrangement comprises a first coil, a second coil, and a third coil; a circuitry configured to measure, for the selected flow velocity, the magnetization of the polarized nuclei for each of the plurality of polarization lengths by pulsing the polarized nuclei with a tipping pulse from the first coil, pulsing the polarized nuclei with a refocusing pulse from the second coil, and measuring an amplitude of an echo resulting from the refocusing pulse using the third coil, wherein a time interval between the tipping pulse and the refocusing pulse used for measuring the echo is defined by the selected velocity and a distance between the first coil and the second coil; and a processor configured to estimate a relative fraction of each of the plurality of components corresponding to the selected velocity based on the plurality of measured magnetizations.

[0005] Another embodiment of the disclosure is a method of estimating a flow rate of a phase of a fluid having a plurality of components. The method includes: using a magnet for polarizing nuclei of the fluid flowing over a selected distance; pulsing the polarized nuclei with a tipping pulse with a first coil, a refocusing pulse with a second coil at a first distance from the first coil, a refocusing pulse with a third coil at a second distance from the first coil, and measuring an echo signal for each of the plurality of distances for a selected flow velocity, wherein a time interval between the tipping pulse and the refocusing pulse used for measuring the echo is defined by the selected velocity and a distance between the first coil and the second coil; estimating a relative fraction of each of the plurality of components corresponding to the selected velocity based on the measured echo signals.

[0006] Another embodiment of the disclosure is an apparatus configured to estimate a flow rate of a phase of a fluid having a plurality of components. The apparatus includes: a magnet configured to polarize nuclei of the fluid flowing over a selected distance; a first coil, a second coil at a first distance from the first coil, a third coil at a second distance from the first coil, and at least one additional coil configured to measure an echo signal for each of the plurality of distances for a selected flow velocity; circuitry configured to pulse the polarized nuclei with a tipping pulse from the first coil, pulse the polarized nuclei with a refocusing pulse from the second coil and the third coil, and measure each echo signal resulting from the refocusing pulse using the second coil and third coil, wherein a time interval between the tipping pulse and the refocusing pulse used for measuring the echo is defined by the selected velocity and a distance between the first coil and the second coil, and a processor configured to estimate a relative fraction of each of the plurality of components corresponding to the selected velocity based on the measured echo signals.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For detailed understanding of the present disclosure, reference should be made to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

FIG. 1 shows an exemplary Nuclear Magnetic Resonance (NMR) flow meter device for estimating a flow rate of a fluid phase in a conduit using an exemplary method of the present disclosure;

FIG. 2 shows exemplary applied pulses and echo for the apparatus of Figure 1;

FIG. 3 shows an exemplary Nuclear Magnetic Resonance (NMR) flow meter device for estimating a flow rate of a fluid phase in a conduit using another exemplary method of the present disclosure that has a single coil;

FIG. 4 shows exemplary magnetic field, applied pulses and echo for the apparatus of Figure 2;

FIG. 5 shows an arrangement with four coils;

FIG. 6 shows a flowchart of a method of the present disclosure using two different pre-polarization lengths; and

FIG. 7 shows a flowchart of a method of the present disclosure using two different measurement lengths.

DETAILED DESCRIPTION

[0008] FIG. 1 shows an exemplary Nuclear Magnetic Resonance (NMR) flow meter device **100** for estimating a flow rate of a fluid phase using an exemplary method of the present disclosure. In one embodiment, the fluid may be a multiphase fluid. In another embodiment, the fluid may be a fluid flowing in a conduit for transportation of hydrocarbons. The exemplary NMR flow meter **100** may include a pre-polarization section **102** for polarizing nuclear spins of fluid along a selected direction, a detection section **110** for applying NMR excitation pulses to the fluid and obtaining NMR signals in response to the NMR excitation pulses from the fluid. The apparatus also includes a testing unit **126** for receiving the NMR response signals from the detection section **110** and performing calculations on the received NMR response signals to obtain a flow rate of a phase of the fluid.

[0009] In the illustrative example of **FIG. 1,** fluid flows from left to right so as to flow from pre-polarization section **102** into the detection section **110.** The pre-polarization section **102** includes a conduit **106** and a pre-polarization magnet **104** which may be exterior to the conduit **106** in one embodiment. The pre-polarization magnet **104** is arranged so as to provide a static magnetic field in a volume of the pre-polarization pipe section **106,** generally along a direction substantially axially along the pipe section **106.** As fluid passes through the static magnetic field, nuclear spins of atoms and molecules within the fluid align along the direction of the static magnetic field.

[0010] Continuing with **FIG. 1,** detection section **110** is downstream of the pre-polarization section **102** and receives polarized fluid from the pre-polarization section **102.** The detection section **110** includes a conduit **112,** a detection magnet **114** which may be exterior to the detection pipe section **112** for providing a static magnetic field in a volume of the conduit **112,** and a plurality of radio frequency (RF) coils **116a, 116b, 116c.** The diameter of the conduit **112** is the same as the diameter of the conduit **106.** The RF coil **116** encloses a volume within the conduit **112** and is arranged to provide one or more NMR excitation pulses to the fluid in the detection section **110** and to detect one or more NMR response signals from the fluid in the detection section **110.**

[0011] Testing unit **126** includes various circuitry for obtaining one or more NMR response signals from the fluid and estimating a flow rate of a phase of the fluid from the obtained NMR response signals. The exemplary testing unit **126** is coupled to the RF coil **116** via preamplifier **120.** The exemplary testing unit **126** includes a transmitter **124** for providing an NMR excitation pulse to the plurality of RF coils **116a, 116b, 116c** via preamplifier **120.** In one embodiment, the transmitter **124** provides multiple NMR excitation pulse sequences, each NMR excitation pulse sequence tuned to a selected nuclear resonance frequency. In one aspect, a first nuclear resonance frequency is that of the nuclei of H^1 atoms and a second nuclear resonance frequency is that of the nuclei of C^{13} atoms. The exemplary testing unit **126** also includes a receiver **122** for receiving NMR response signals detected at the RF coil **116a, 116b, 116c** via the preamplifier **120.** Testing unit **126** also includes an NMR spectrometer **128** for estimating one or more parameters of the fluid from the received NMR response signals using exemplary methods of the present disclosure. In one embodiment, the spectrometer **128** may include a processor **130** configured to execute instructions contained in a program stored on a suitable storage device (not shown), such as a solid-state memory, tape or hard disc for storing the one or more parameters obtained at the processor **130.**

[0012] The pre-polarization conduit **106** of **FIG. 1** may include multiphase fluid flowing through a conduit **106.** In the most general case, three phases may be present: water, oil and gas. Each phase of the fluid has a characteristic flow velocity profile. As would be known to those versed in the art, a fluid or fluid phase under laminar flow exhibits a velocity profile that has a flow section at the boundaries of the fluid and a fast section typically away from the boundaries. In general, the fast section of the fluid passes through a pipe section before the slowest portion does. The speed of the fluid affects a degree of alignment of the nuclei of the fluid. Nuclear alignment occurs over a characteristic time, as described below with respect to **Eqn. (1).** When a fluid is flowing in a volume of a static magnetic field, the slow portion of the fluid remains in the volume longer. It should be noted that the method of the present disclosure is not restricted to laminar flow and may also be used for turbulent flow as well as flow in which one phase is mixed with another phase. An example of this would be gas bubbles in oil, gas bubbles in water, water droplets in an oil phase as well as oil droplets in a water phase. This is in contrast to many prior art methods which are directed towards laminar flow in which each lamina consists substantially of only one phase.

[0013] After passage through the pre-polarization section **100** nuclei in the fluid are polarized with their spins substantially oriented in the longitudinal direction. These polarized nuclei pass into the detection section **110. FIG. 2** illustrates the pulsing and an echo signal that can be obtained using the apparatus of **FIG. 1.** In the apparatus shown in **FIG. 1,** the magnetic field in the detection section is uniform and oriented in a longitudinal direction along the conduit **112.** A 90° tipping pulse, indicated by **203,** may be applied to the first coil **116a.** This 90° tipping pulse results in the nuclei being tipped by 90°. These nuclei flow near the second coil **116b** where a 180° refocusing pulse may be applied. This is not intended to be a limitation and additional refocusing coils and refocusing pulses may be provided. The coil **116c** receives and echo signal denoted by **207.** The distance between two coils is denoted by L and the time interval between the 90° pulse and the 180° pulse (and the 180° pulse and the echo) is denoted by Δt. In the example shown, only one refocusing pulse **205** (and refocusing coil **116b** and receiving coil **116c** are shown). When the length of the coil *l* is sufficiently smaller than the length L between coils, we may consider that the echo signal shown in **FIG.** 2 only comes from the part of the fluid that moves with velocity L/Δt. By varying the time Δt between pulses, the entire velocity spectrum can be mapped out. It should also be noted that the tipping pulse is not restricted to 90° and refocusing pulse is not restricted to 180°.

[0014] In one embodiment of the disclosure, the magnetic field in the pre-polarization section **100** may be produced by a switchable permanent magnet. Such a magnet is disclosed in US patent application serial number 11/037,488 (US20050189945). Disclosed therein is a coil coupled with a current source and a magnetic core having residual magnetization. Switching current in the antenna coil results in magnetization reversal in the magnetic core and reversal of the magnetic field. The advantage of the switchable permanent magnet is the relatively low power requirement for reversing the magnetic field and altering the polarization of nuclear spins.

[0015] FIG. 3 shows an alternate embodiment of the disclosure in which instead of a plurality of coils as in **FIG. 1,** a single coil **316** is used. The axial variation of the magnitude of the axial static magnetic field is illustrated by **301.** The 90° tipping pulse is shown by **403** in **FIG. 4,** the 180° refocusing pulse is shown by **405,** and the echo is shown by **407.** By varying the external magnetic field, as shown here, the locations on resonance are restricted to a few points along the pipe and thus the length of the flow within Δt is certain. In an alternate embodiment of the disclosure, instead of varying the static magnetic field, a pulsed field gradient may be applied in the detection section.

[0016] The multi-coil design **FIG. 1** can be expanded. For example, in **FIG.** 5, a fourth coil **516d** is added at length 2L after coil **516c.** Now coil **516c** not only receives the echo signal, but also can transmit a 180° refocusing pulse and coil **516d** receives the echo. Such a setup will increase the efficiency of data gathering. Next, differentiation of the different phases of the fluid in the conduit using the apparatus described above is discussed.

[0017] Phase differentiation may be achieved by multiple measurements with varying prepolarization length or varying flow length in the measurement region, as the one shown in **FIG.** 5. The magnetization buildup inside the prepolarization magnet, for a fluid flowing at velocity v is

$$M_i = M_{0,i}\left(1 - e^{-L_p/vT_{1,i}}\right) \qquad (1),$$

where M_i is the magnetization of the i-th phase to be detected by NMR measurement, $M_{0,i}$ is the maximum prepolarization achievable, which is proportional to the amount of protons in the i-th phase, L_p is the prepolarization length, and $T_{1,i}$ is the proton spin-lattice relaxation time for i-th phase.

[0018] As an example, consider two phases in the conduit and two measurements being made with two prepolarization lengths, L_{p1} and L_{p2}. The NMR measured magnetization S is a combination of the contribution from two separate phases:

$$\begin{aligned} S_1 &= M_{0,1}\left(1 - e^{-L_{p1}/vT_{1,i}}\right) + M_{0,2}\left(1 - e^{-L_{p1}/vT_{1,2}}\right) \\ S_2 &= M_{0,1}\left(1 - e^{\ L_{p2}/vT_{1,i}}\right) + M_{0,2}\left(1 - e^{\ L_{p2}/vT_{1,2}}\right) \end{aligned} \qquad (2).$$

Here, L_{p1} and L_{p2} are known, v is the velocity that is selected, $T_{1,1}$ and $T_{1,2}$ are the properties of the phases and can be characterized, S_1 and S_2 are the measured signals, so $M_{0,1}$ and $M_{0,2}$ can be solved in the above equations. $M_{0,1}$ and $M_{0,2}$ are indicative of the relative fraction of the two components flowing at the selected velocity. Thus two phases can be differentiated and the flow rate can be obtained. This is illustrated in the flow chart of **FIG. 6.**

[0019] A velocity v is selected **601.** This defines the value of Δt used with the coil separation L in the measurement section. For the value of Δt, a signal S_1 is measured **603** with the first pre-polarization length L_{p1}. For the same value of Δt, a signal S_2 is measured **605** with the second pre-polarization length L_{p2}. Solution of the **eqn. (2) 607** then gives the relative magnetization of the two components at the selected velocity v. The measurement of the signal amplitude is defined by the amplitude of the echo of obtained by applying the 90° tipping pulse and a 180° refocusing pulse. This is an indication of the relative flow rates of the two components at the selected velocity. By repeating the measurements for different values of Δt, the velocity distribution of the two components can be obtained. The values of $T_{1,1}$ and $T_{1,2}$ needed can be measured separately. When it is desired to estimate flow rates of three fluids, three different pre-polarization lengths may be used.

[0020] Another way to differentiate the phases is to use a plurality of different lengths of measurement in the measurement section **110.** If magnet lengths in the coil region are negligible compared to the overall flow length, the magnetic moment after the fluid leaves the prepolarization region decays according to the following equation:

$$M_i = M_{0,i}\left(1 - e^{-L_p/vT_{1,i}}\right)e^{-L_1/vT_{2,i}} \qquad (3).$$

This gives the relations

$$\begin{aligned} S_1 &= M_{0,1}\left(1 - e^{-L_p/vT_{1,1}}\right)e^{-L_1/vT_{2,1}} + M_{0,2}\left(1 - e^{-L_p/vT_{1,2}}\right)e^{-L_1/vT_{2,2}} \\ S_2 &= M_{0,1}\left(1 - e^{-L_p/vT_{1,1}}\right)e^{-L_2/vT_{2,1}} + M_{0,2}\left(1 - e^{-L_{p2}/vT_{1,2}}\right)e^{-L_2/vT_{2,2}} \end{aligned} \qquad (4),$$

where S_1 and S_2 are signals measured with two different measurement lengths L_1 and L_2. This is illustrated in the flow chart of **FIG. 7.**

[0021] A velocity *v* is selected **701.** This defines the value of Δt used with a coil separation L_1 in the measurement section. For the value of Δt, a signal S_1 is measured **703** with the pre-polarization length L_p. For the same value of Δt, a signal S_2 is measured **705** with the same pre-polarization length L_{p1} and coil separation L_2. Solution of the **eqn. (4) 707** then gives the relative magnetization of the two components at the selected velocity v. This is an indication of the relative flow rates of the two components at the selected velocity. By repeating the measurements for different values of Δt, the velocity distribution of the two components can be obtained. The values of $T_{1,1}$ and $T_{1,2}$ needed can be measured separately.

[0022] A selected response signal may be related to one or more phases of the fluid. A typical multiphase fluid in petroleum exploration contains a hydrocarbon phase and a water phase. The water phase includes primarily water molecules and therefore primarily hydrogen and oxygen atoms. Thus, the water phase is responsive to an ^{1}H NMR excitation. Since carbon atoms are generally not present in the water phase, the water phase is generally unresponsive to ^{13}C NMR excitation. The hydrocarbon phase, on the other hand, includes molecules that are relatively rich in carbon atoms. Thus, the hydrocarbon phase is responsive to ^{13}C NMR excitations as well as to ^{1}H NMR excitations. Therefore, ^{13}C NMR response signals and H^1 NMR response signals may be used to determine water and hydrocarbon phase flow velocities and flow rates, as discussed below.

[0023] Where it is important to get the accurate estimate of oil or gas flow rates using a ^{13}C NMR response, the signal level from ^{13}C can be increased by using hyperpolarization. A suitable polarizing agent is added to the flow stream in the conduit **106.** Several methods of hyperpolarization have been discussed in US patent 7,126,332 to Blanz et al., having the same assignee as the present disclosure.

[0024] In one embodiment the polarizing agent is responsive to electron spin resonance, i.e. it contains atoms or molecules with unpaired electrons. The polarizing agent is added to the flow stream. In the magnet, the sample is first magnetized to thermal equilibrium. By subjecting the sample to high frequency (HF), meeting the ESR resonance condition, and making use of the Overhauser effect (OE), the polarization of the ^{13}C nuclei can be enhanced beyond equilibrium by a hyperpolarization factor of up to 2600 (theoretical maximum). Once the ^{13}C nuclei are hyperpolarized any known ^{13}C measurement can be executed by radiating the appropriate RF pulse sequence or by performing a CW NMR measurement at the ^{13}C resonance frequency. The amplitude of the received ^{13}C signals will be enhanced by the hyperpolarization factor.

[0025] In a second embodiment, the phenomenon of the Nuclear Overhauser Effect (NOE) is used to generate the hyperpolarization of the ^{13}C nuclei. The energy difference of the spin up and spin down states in ^{1}H is about 4 times of that of the energy difference of the two spin states in ^{13}C. Analogous to the OE of the previous section the ^{1}H transition can be saturated (instead of the unbound electrons) by radiating RF at the ^1H resonance frequency. The ^1H spin system can couple to the spin system of ^{13}C. The result is an increase in the population difference between spin up and spin down states of the ^{13}C system beyond the thermal equilibrium, i.e. the carbon nuclei are being hyperpolarized. Once the ^{13}C is hyperpolarized the ^{13}C NMR is processed with enhanced signal amplitude. The advantage of the described method is that hydrogen is usually present in any the flow stream. In contrast to OE no extra polarization agent needs to be used.

[0026] In a third embodiment, the polarizing agent can be polarized by optical pumping with circularly polarized light (most conveniently generated by a LASER) and making use of the Spin Induced Nuclear Overhauser Effect (SPINOE). The polarizing agent can be polarized in the agent chamber before being injected into the fluid sample. Alternatively it may be possible to polarize the polarizing agent after mixing with the formation fluid sample either still outside the magnet or inside. Different variants of optical pumping and SPINOE are needed depending on these alternatives (see below). Typically the polarizing agent is a noble gas with traces of other gases. In one instance, the polarizing agent can be xenon with traces of a vaporized alkali metal and nitrogen.

[0027] The discussion above is applicable to conduits in a variety of situations. One example would be the flow of fluids in a production well through production tubing. The production well may be producing hydrocarbons or may be a geothermal well in which a mixture of steam and water is produced. Another example is in the flow of produced hydrocarbons well to a collection point at the surface. The method discussed above may also be used to measure flow rate of drilling fluid. In an offshore well, the method may be used to measure the flow velocity of fluids coming up a riser.

[0028] Those versed in the art and having benefit of the present disclosure would also recognize that the principles disclosed herein may also be used for measurement of flow in an earth formation outside a cased borehole. The problem is discussed in US patent 7,186,971 to Riley et al. having the same as in the as the present application. The method used by *Riley* uses a pulsed neutron source to irradiate fluids in the borehole in the earth formation and tracks the radiation with the fluid flow. The method described above may be used with relatively minor modifications to track fluids outside the cased borehole. The modifications comprise using a magnet for producing a magnetic field outside the cased borehole and making measurements on polarize nuclei in the fluid outside the borehole.

[0029] The processing of the data may be conveniently done on a processor. The processor executes a method using instructions stored on a suitable computer-readable medium product. The computer-readable medium may include a ROM, an EPROM, an EAROM, a flash memory, and/or an optical disk.

REFERENCES CITED IN THE DESCRIPTION

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- US037488 [0014]
- US20050189945A [0014]
- US7126332B [0023]
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PATENTKRAV

1. Fremgangsmåde til estimering af en strømningshastighed for en fase af et fluid med en flerhed af komponenter, hvilken fremgangsmåde omfatter:

polarisering af kerner i fluidet ved påtrykning af et magnetfelt over en flerhed af ikke-identiske polariseringslængder, hvor et antal af polariseringslængderne er lig med eller større end et antal af komponenterne;

valg af en strømningshastighed og måling, for den valgte strømningshastighed, af en magnetisering af de polariserede kerner for hver af flerheden af polariseringslængder;

estimering af en relativ fraktion af hver af flerheden af komponenter svarende til den valgte hastighed baseret på flerheden af målte magnetiseringer;

hvor måling af magnetiseringen af de polariserede kerner omfatter pulsering af en første spole (116a) med en tipping-impuls, pulsering af en anden spole (116b) med en refokuseringsimpuls og måling af et ekko som følge af refokuseringsimpulsen med en tredje spole (116c),

hvor et tidsinterval mellem tipping-impulsen og refokuseringsimpulsen, der anvendes til måling af ekkoet, defineres ved den valgte hastighed og en afstand mellem den første spole (116a) og den anden spole (116b).

2. Fremgangsmåde ifølge krav 1, hvor fluidet strømmer i en ledning (106, 112) inde i magneten (104).

3. Fremgangsmåde ifølge krav 1, hvor fluidet strømmer i en jordformation uden for magneten (104).

4. Fremgangsmåde ifølge krav 1, der endvidere omfatter pulsering af den første spole (116a) og den anden spole (116b) ved en Larmor-frekvens svarende til kerner i ^{1}H og ^{13}C.

5. Fremgangsmåde ifølge krav 1, hvor fluidet indeholder kernerne i ^{13}C, hvilken fremgangsmåde endvidere omfatter forøgelse af polariseringen af kernerne i ^{13}C under anvendelse af mindst én af: (i) elektronspinresonans, (ii) en

nukleær Overhauser-effekt og (iii) optisk pumpning og spininduceret nukleær Overhauser-effekt.

6. Apparat (100), der er konfigureret til at estimere en strømningshastighed for en fase af et fluid med en flerhed af komponenter, hvilket apparat (100) omfatter:

et præ-polariseringsafsnit (102), der er konfigureret til at polarisere kerner i fluidet ved påtrykning af et magnetfelt over en flerhed af ikke-identiske polariseringslængder, hvor et antal af polariseringslængderne er lig med eller større end et antal af komponenterne;

et spolearrangement, der er konfigureret til, for en valgt strømningshastighed for fluidet, at måle en magnetisering af de polariserede kerner for hver af flerheden af polariseringslængder, hvor spolearrangementet omfatter en første spole (116a), en anden spole (116b) og en tredje spole (116c);

et kredsløb, der er konfigureret til, for den valgte strømningshastighed, at måle magnetiseringen af de polariserede kerner for hver af flerheden af polariseringslængder ved pulsering af de polariserede kerner med en tipping-impuls fra den første spole (116a), pulsering af de polariserede kerner med en refokuseringsimpuls fra den anden spole (116b) og måling af en amplitude for et ekko som følge af refokuseringsimpulsen under anvendelse af den tredje spole (116c), hvor et tidsinterval mellem tipping-impulsen og refokuseringsimpulsen, der anvendes til måling af ekkoet, defineres ved den valgte hastighed og en afstand mellem den første spole (116a) og den anden spole (116b); og

en processor, der er konfigureret til at estimere en relativ fraktion af hver af flerheden af komponenter svarende til den valgte hastighed baseret på flerheden af målte magnetiseringer.

7. Apparat (100) ifølge krav 6, der endvidere omfatter en ledning (106, 112) inde i magneten (104) til fremføring af fluidet.

8. Apparat (100) ifølge krav 7, hvor ledningen (106, 112) er valgt blandt: (i) produktionsrør i en carbonhydridproduktionsbrønd, (ii) produktionsrør i en geotermisk brønd, (iii) et rørboringsfremføringsborefluid og (iv) en riser ved offshore-boring.

9. Apparat (100) ifølge krav 6, hvor fluidet strømmer i en jordformation uden for magneten (104).

10. Apparat (100) ifølge krav 6, der endvidere omfatter pulsering af den første spole (116a) og den anden spole (116b) ved en Larmor-frekvens svarende til kerner i ^{1}H og ^{13}C.

11. Apparat (100) ifølge krav 6, hvor fluidet indeholder kerner i ^{13}C, hvilket apparat (100) endvidere omfatter en indretning til forøgelse af polariseringen af kerner i ^{13}C i fluidet under anvendelse af mindst én af: (i) elektronspinresonans, (ii) en nukleær Overhauser-effekt og (iii) optisk pumpning og spininduceret nukleær Overhauser-effekt.

12. Fremgangsmåde til estimering af en strømningshastighed for en fase af et fluid med en flerhed af komponenter, hvilken fremgangsmåde omfatter:

anvendelse af en magnet (104) til polarisering af kerner i fluidet, der strømmer over en valgt afstand;

pulsering af de polariserede kerner med en tipping-impuls med en første spole (516a), en refokuseringsimpuls med en anden spole (516b) i en første afstand fra den første spole (516a), en refokuseringsimpuls med en tredje spole (516c) i en anden afstand fra den første spole (516a) og måling af et ekkosignal for hver af flerheden af afstande for en valgt strømningshastighed, hvor et tidsinterval mellem tipping-impulsen og refokuseringsimpulsen, der anvendes til måling af ekkoet, defineres ved den valgte hastighed og en afstand mellem den første spole (116a) og den anden spole (116b);

estimering af en relativ fraktion af hver af flerheden af komponenter svarende til den valgte hastighed baseret på de målte ekkosignaler.

13. Fremgangsmåde ifølge krav 12, hvor fluidet strømmer i en ledning (106, 112) inde i magneten (104).

14. Fremgangsmåde ifølge krav 12, hvor fluidet strømmer i en jordformation uden for magneten (104).

15. Fremgangsmåde ifølge krav 12, der endvidere omfatter pulsering af den første spole (516a) og den anden spole (516b) ved en Larmor-frekvens svarende til kerner i ^{1}H og ^{13}C.

16. Fremgangsmåde ifølge krav 12, hvor fluidet indeholder kernerne i ^{13}C, hvilken fremgangsmåde endvidere omfatter forøgelse af polariseringen af kernerne i ^{13}C under anvendelse af mindst én af: (i) elektronspinresonans, (ii) en nukleær Overhauser-effekt og (iii) optisk pumpning og spininduceret nukleær Overhauser-effekt.

17. Apparat (100), der er konfigureret til at estimere en strømningshastighed for en fase af et fluid med en flerhed af komponenter, hvilket apparat (100) omfatter:

en magnet (104), der er konfigureret til at polarisere kerner af fluidet, der strømmer over en valgt afstand;

en første spole (516a), en anden spole (516b) i en første afstand fra den første spole (516a), en tredje spole (516c) i en anden afstand fra den første spole (516a) og mindst én yderligere spole (516d), der er konfigureret til at måle et ekkosignal for hver af flerheden af afstande for en valgt strømningshastighed;

kredsløb, der er konfigureret til at pulsere de polariserede kerner med en tipping-impuls fra den første spole (516a), pulsere de polariserede kerner med en refokuseringsimpuls fra den anden spole (516b) og den tredje spole (516c) og måle hvert ekkosignal som følge af refokuseringsimpulsen under anvendelse af den anden spole (516b) og den tredje spole (516c), hvor et tidsinterval mellem tipping-impulsen og refokuseringsimpulsen, der anvendes til måling af ekkoet, defineres ved den valgte hastighed og en afstand mellem den første spole (516a) og den anden spole (516b); og

en processor, der er konfigureret til at estimere en relativ fraktion af hver af flerheden af komponenter svarende til den valgte hastighed baseret på de målte ekkosignaler.

18. Apparat (100) ifølge krav 17, hvor fluidet strømmer i en ledning (106, 112) inde i magneten (104).

19. Apparat (100) ifølge krav 18, hvor ledningen (106, 112) er valgt blandt: (i) produktionsrør i en carbonhydridproduktionsbrønd, (ii) produktionsrør i en geotermisk brønd, (iii) et rørboringsfremføringsborefluid og (iv) en riser ved offshore-boring.

20. Apparat (100) ifølge krav 17, hvor fluidet strømmer i en jordformation uden for magneten (104).

21. Apparat (100) ifølge krav 17, der endvidere omfatter pulsering af den første spole (516a) og den anden spole (516b) ved en Larmor-frekvens svarende til kerner i ^{1}H og ^{13}C.

22. Apparat (100) ifølge krav 17, hvor fluidet indeholder kerner i ^{13}C, hvilket apparat endvidere omfatter en indretning til forøgelse af polariseringen af kerner i ^{13}C i fluidet under anvendelse af mindst én af: (i) elektronspinresonans, (ii) en nukleær Overhauser-effekt og (iii) optisk pumpning og spininduceret nukleær Overhauser-effekt.

DRAWINGS

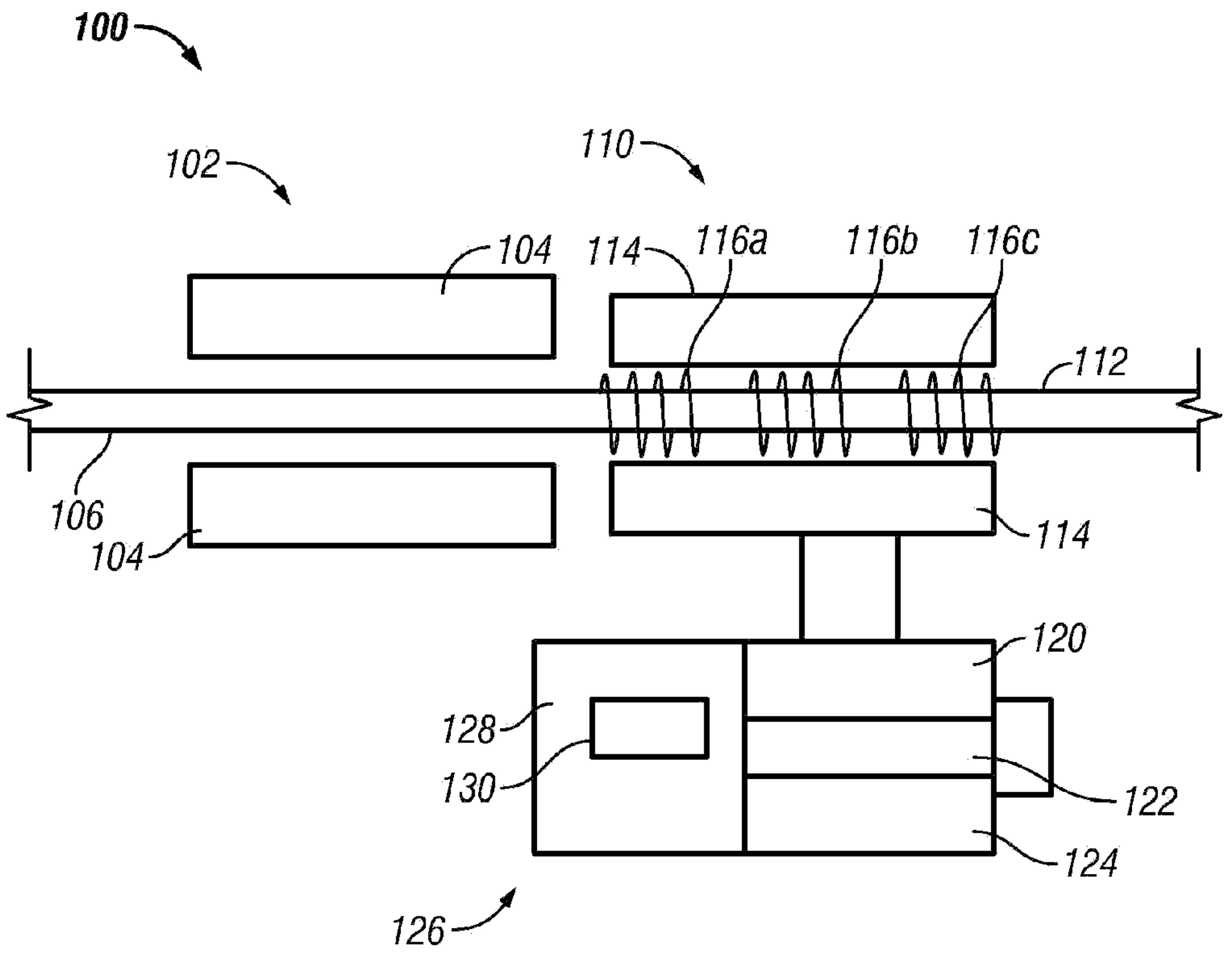

FIG. 1

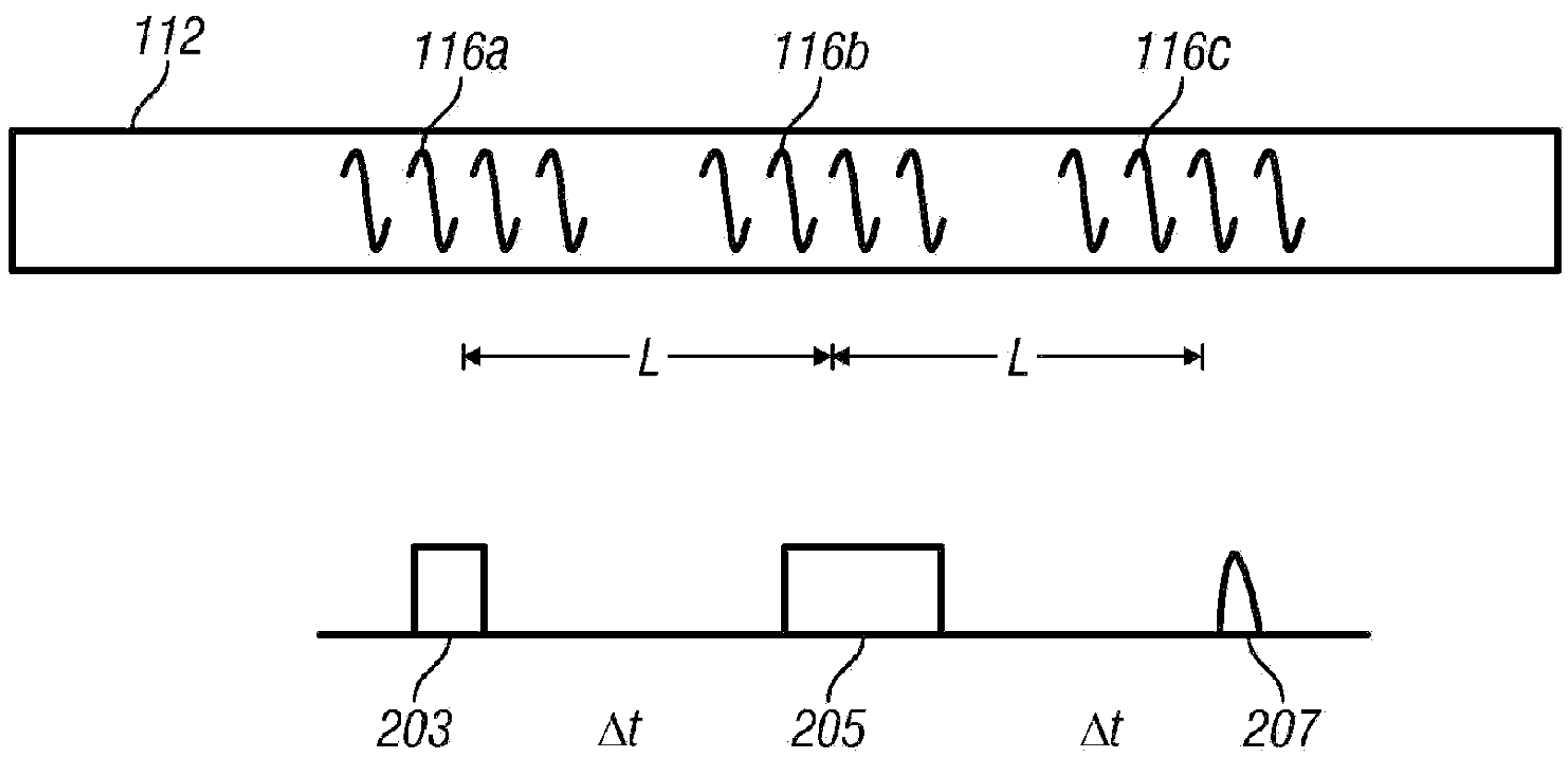

FIG. 2

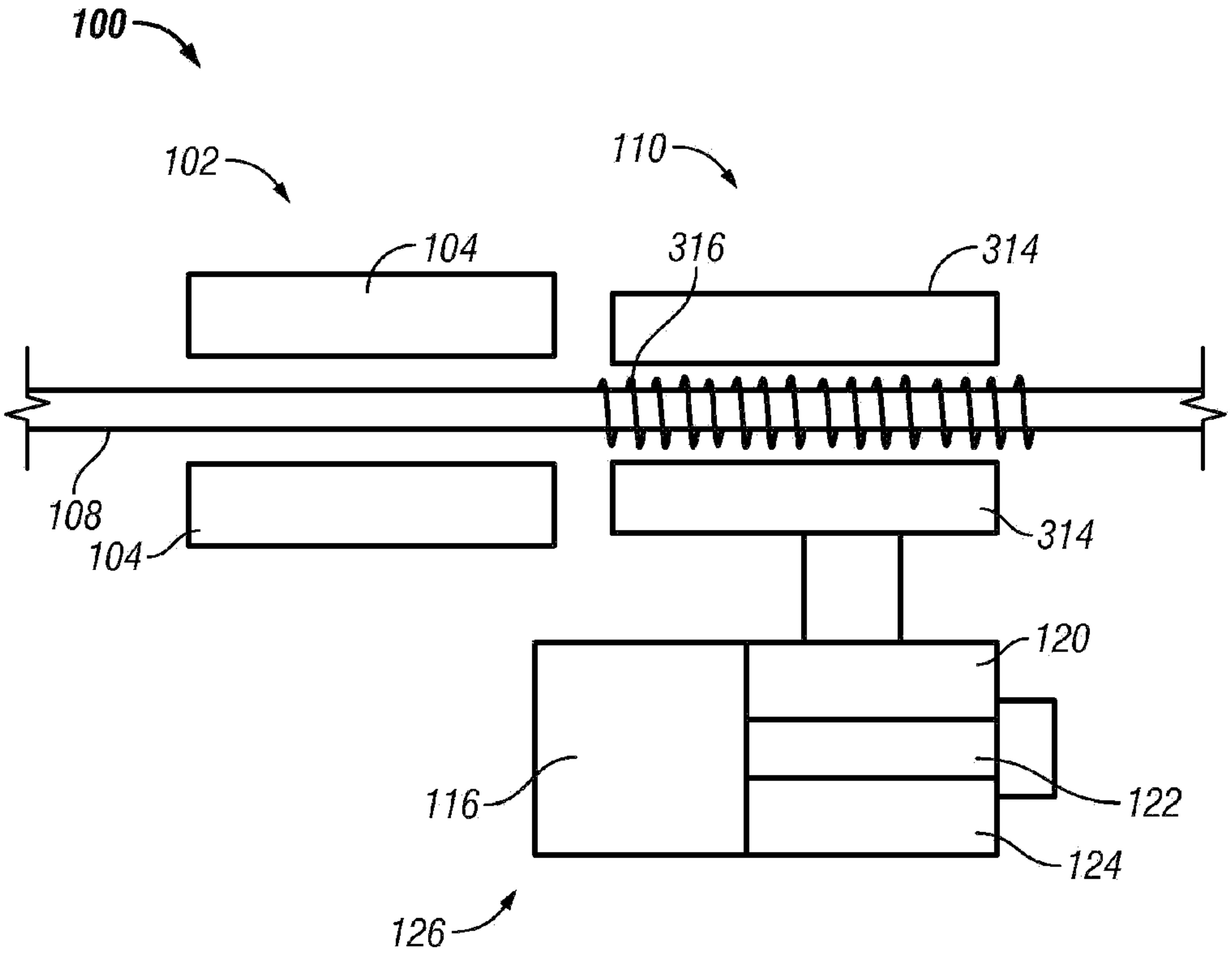

FIG. 3

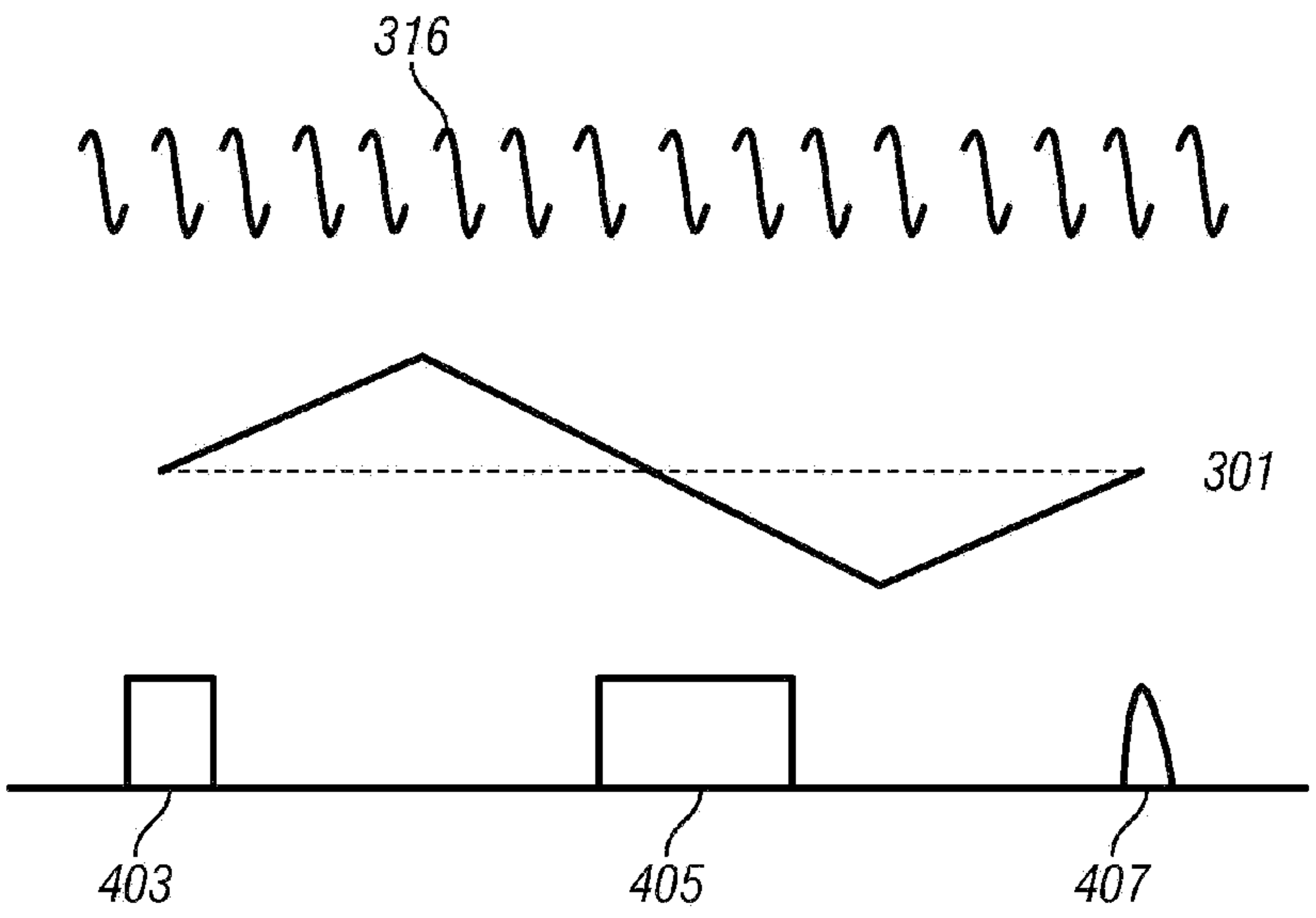

FIG. 4

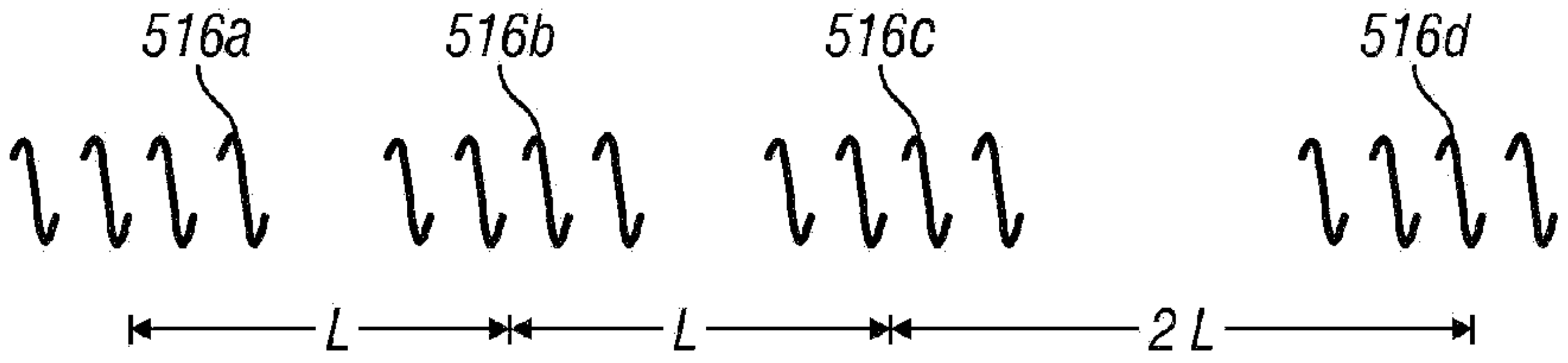

FIG. 5

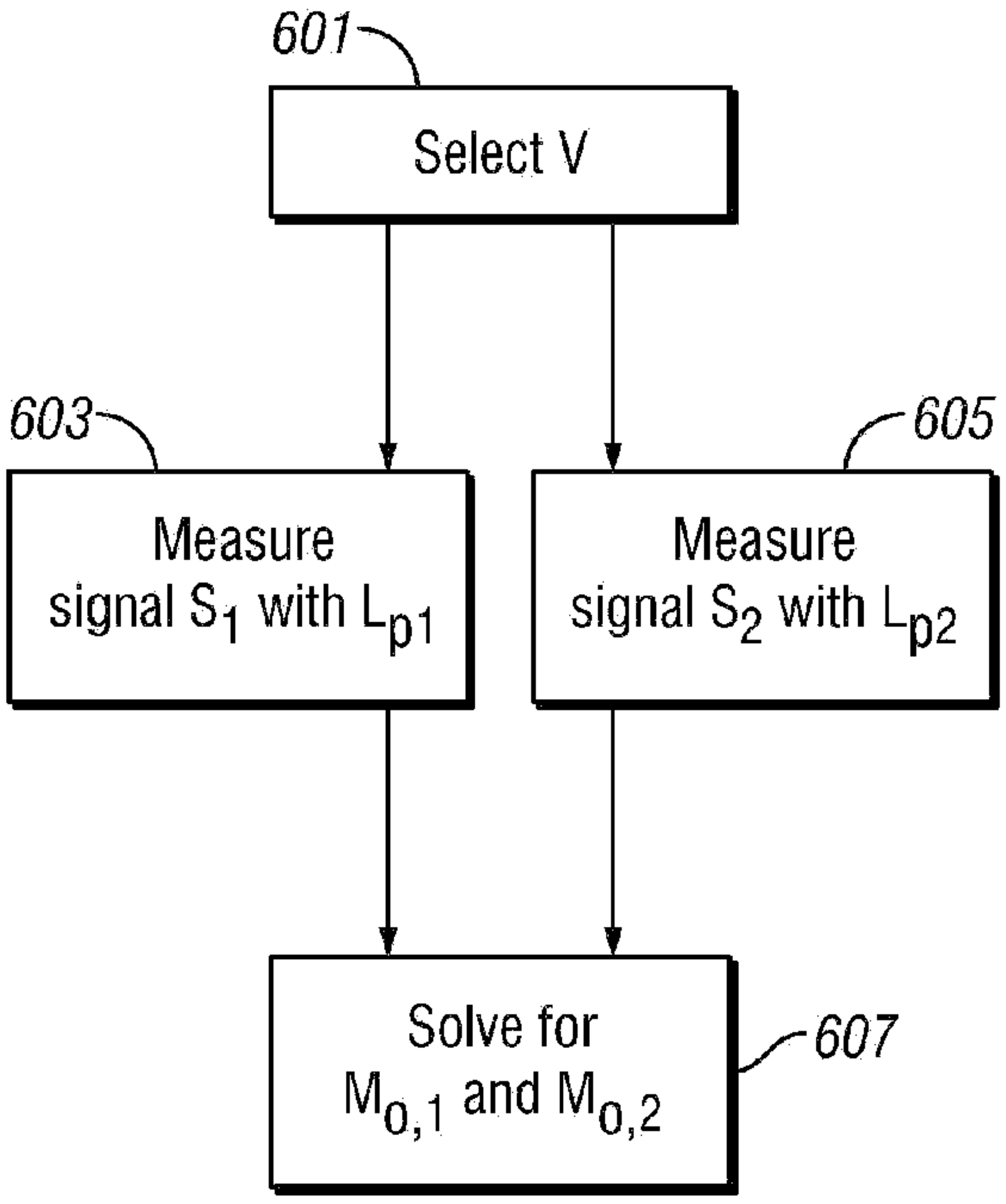
601
Select V
603
Measure signal S_1 with L_{p1}
605
Measure signal S_2 with L_{p2}
Solve for $M_{0,1}$ and $M_{0,2}$
607

FIG. 6

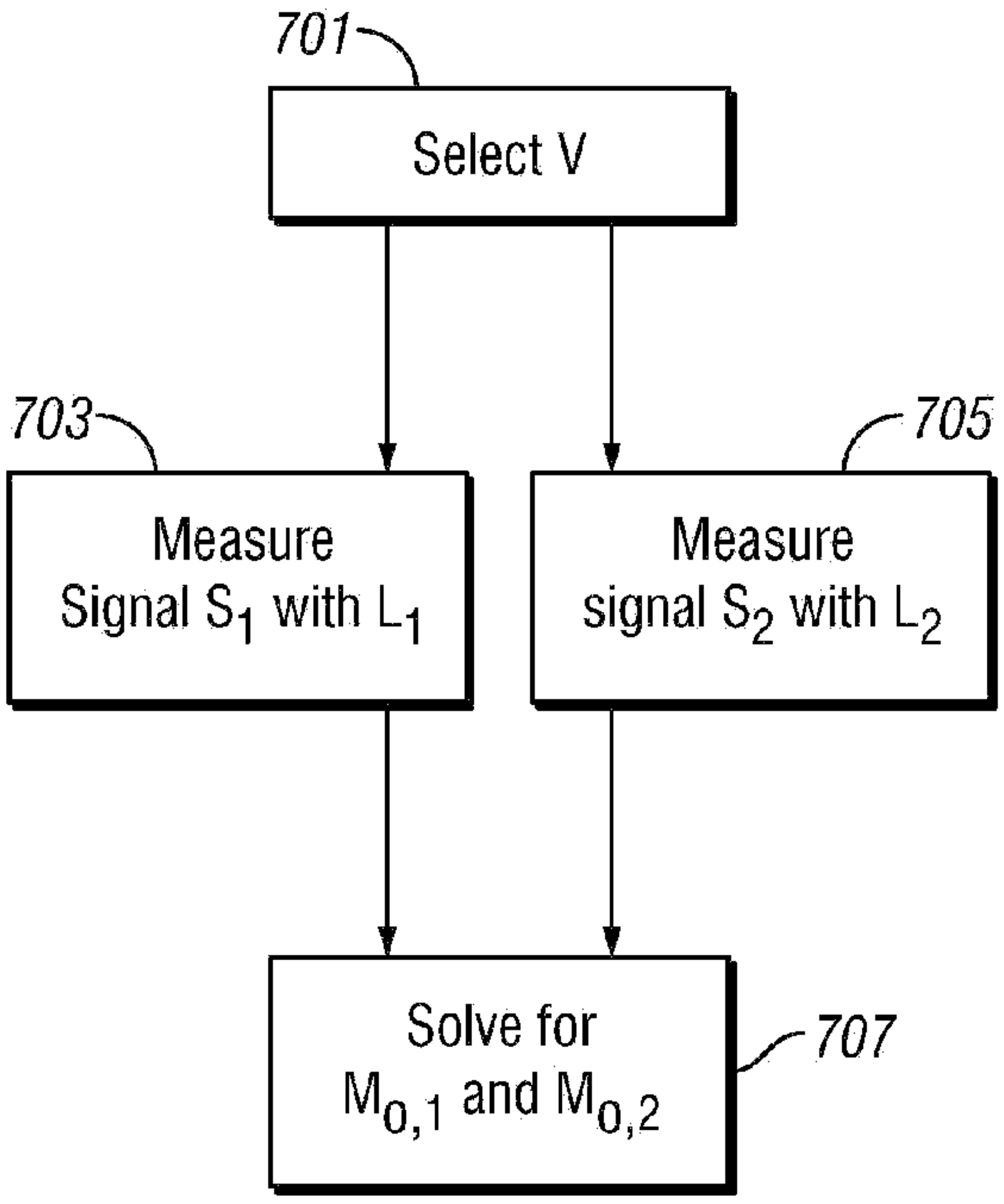
701
Select V
703
Measure Signal S_1 with L_1
705
Measure signal S_2 with L_2
Solve for $M_{0,1}$ and $M_{0,2}$
707

FIG. 7