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Hazen et al.

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(45) Date of Patent: Apr. 16, 2024

(54) COMMON SAMPLE DEPTH/ZONE NONINVASIVE GLUCOSE CONCENTRATION DETERMINATION ANALYZER APPARATUS AND METHOD OF USE THEREOF

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 640 days.

(21) Appl. No.: **16/777,855**

(22) Filed: **Jan. 30, 2020**

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US 2020/0337603 A1 Oct. 29, 2020

Related U.S. Application Data

(63) Continuation-in-part of application No. 16/691,611, filed on Nov. 22, 2019, now Pat. No. 11,633,130, and (Continued)

(51) **Int. Cl.**
A61B 5/1455 (2006.01)
A61B 5/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61B 5/1455*** (2013.01); ***A61B 5/0022*** (2013.01); ***A61B 5/0051*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ... A61B 5/1455; A61B 5/0022; A61B 5/0051; A61B 5/0053; A61B 5/14532; A61B 5/6824; A61B 5/6832; A61B 5/0004; A61B 5/7264; A61B 2562/0233; A61B 2562/0238; A61B 2562/046;
(Continued)

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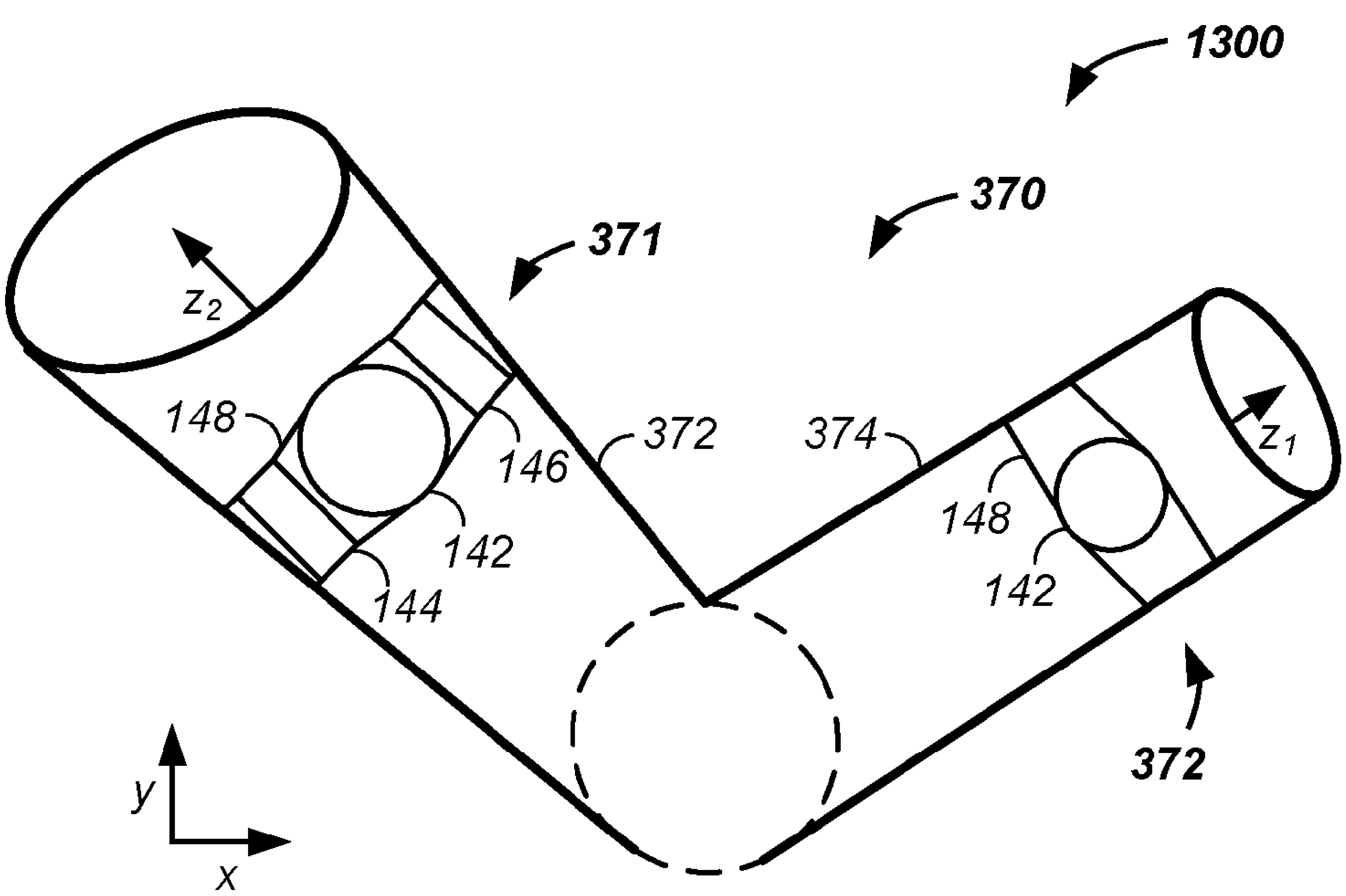
Primary Examiner — Roy M Punnoose

(57) **ABSTRACT**

The invention comprises a method and apparatus for sampling a common tissue volume and/or a common skin layer skin of a person as a part of noninvasively determining an analyte property with an analyzer including: a set of detectors at least partially embedded in a probe housing, the probe housing comprising a sample side surface, the detectors including a first and second range of detection zones of differing radial distances from a first illumination zone and second illumination zone, respectively coupled to separate sources, with surface paths between the sources and detectors overlapping a common skin area during use.

9 Claims, 16 Drawing Sheets



Related U.S. Application Data

a continuation-in-part of application No. 16/691,615, filed on Nov. 22, 2019, now Pat. No. 11,547,329, and a continuation-in-part of application No. 15/829,877, filed on Dec. 2, 2017, now abandoned, which is a continuation-in-part of application No. 15/636,073, filed on Jun. 28, 2017, now abandoned.

(60) Provisional application No. 62/355,507, filed on Jun. 28, 2016.

(51) **Int. Cl.**

A61B 5/145	(2006.01)
G01J 3/10	(2006.01)
G01N 33/49	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/0053*** (2013.01); ***A61B 5/14532*** (2013.01); ***A61B 5/6824*** (2013.01); ***A61B 5/6832*** (2013.01); ***G01J 3/10*** (2013.01); ***G01N 33/49*** (2013.01); *A61B 5/0004* (2013.01); *A61B 5/7264* (2013.01); *A61B 2562/0233* (2013.01); *A61B 2562/0238* (2013.01); *A61B 2562/046* (2013.01); *G01J 2003/102* (2013.01); *G01J 2003/106* (2013.01)

(58) **Field of Classification Search**

CPC A61B 2562/0242; G01J 3/10; G01J 2003/102; G01J 2003/106; G01N 33/49

See application file for complete search history.

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2017/0303834	A1 *	10/2017	Bechtel	A61B 5/1075	

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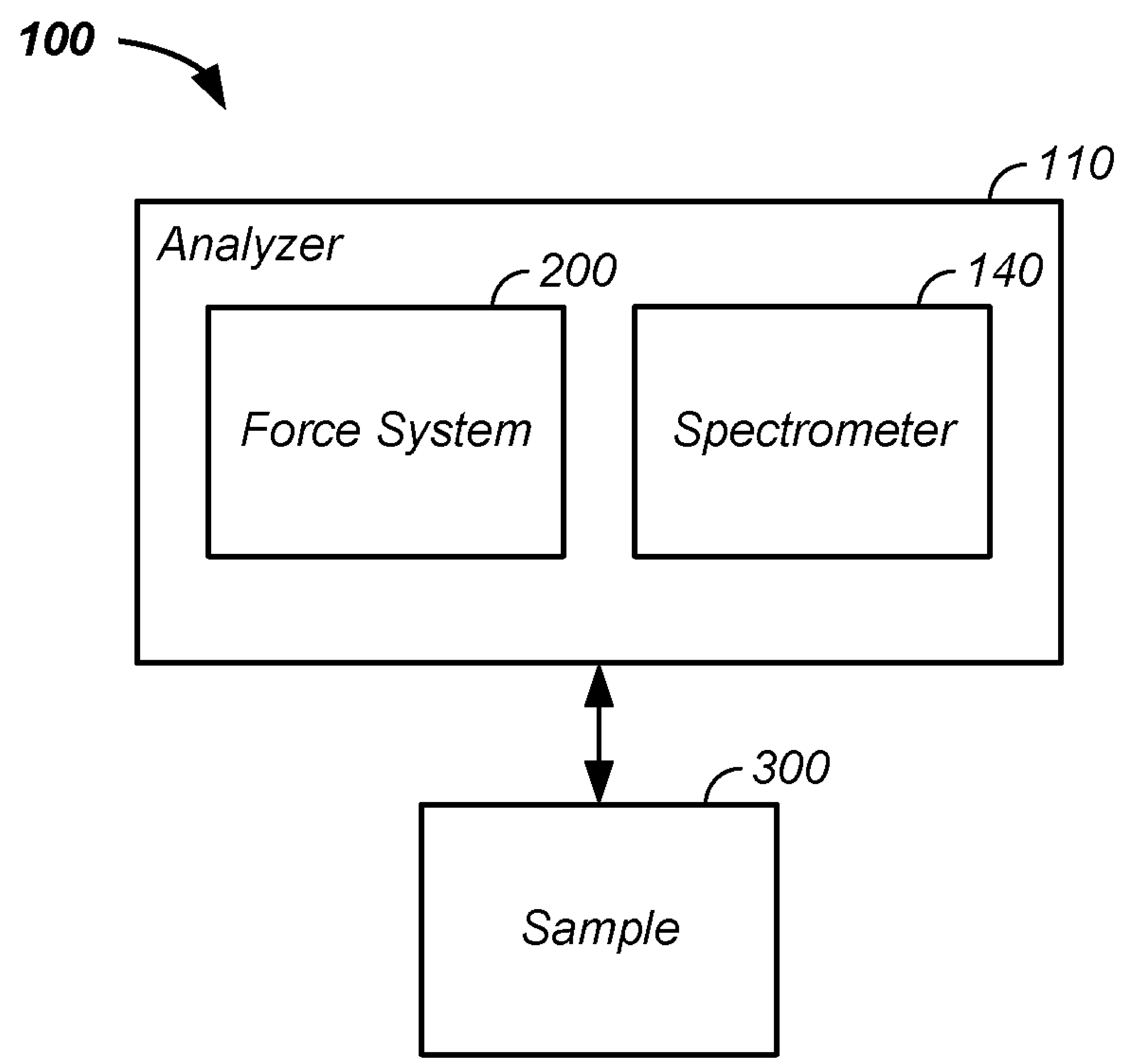
100
110
Analyzer
200
Force System
140
Spectrometer
300
Sample

FIG. 1

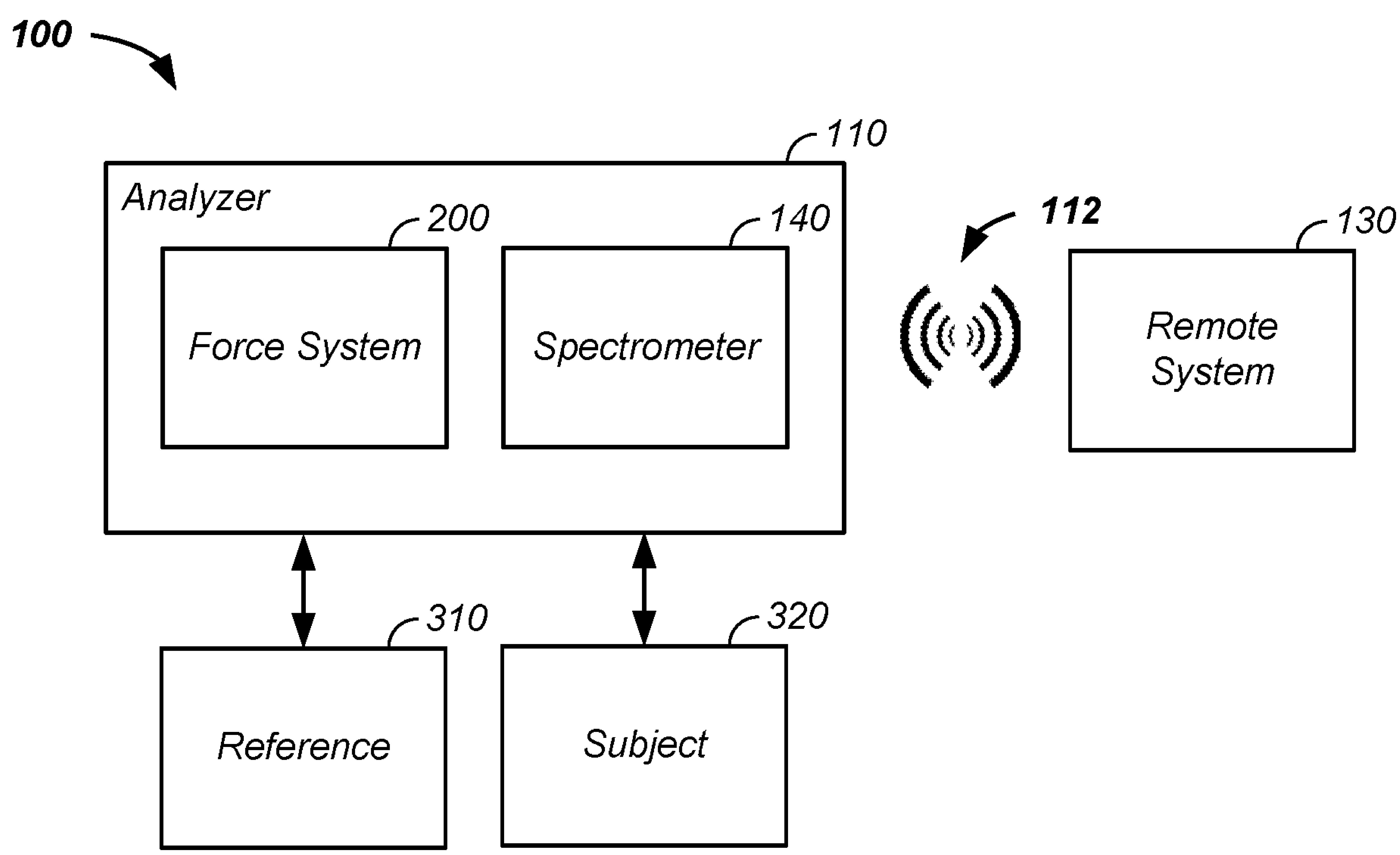
100
110
Analyzer
200
Force System
140
Spectrometer
112
130
Remote System
310
Reference
320
Subject

FIG. 2

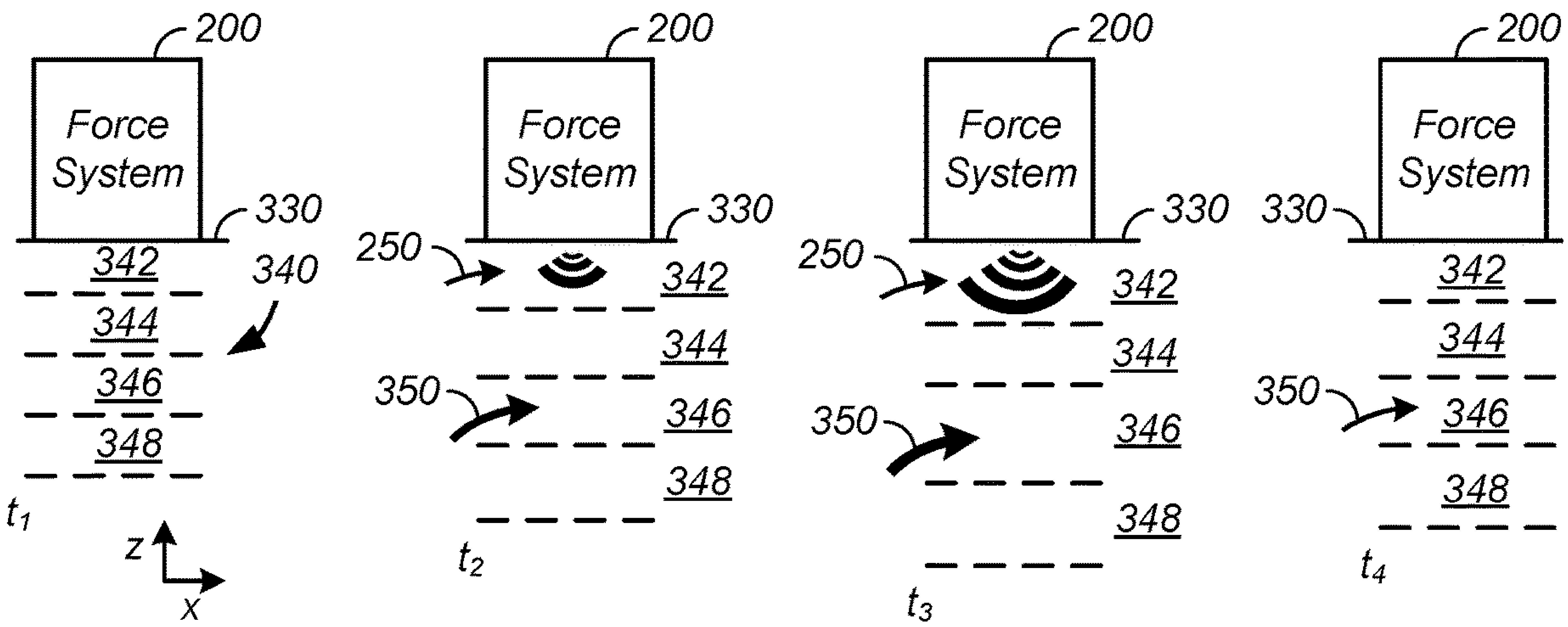

FIG. 3A

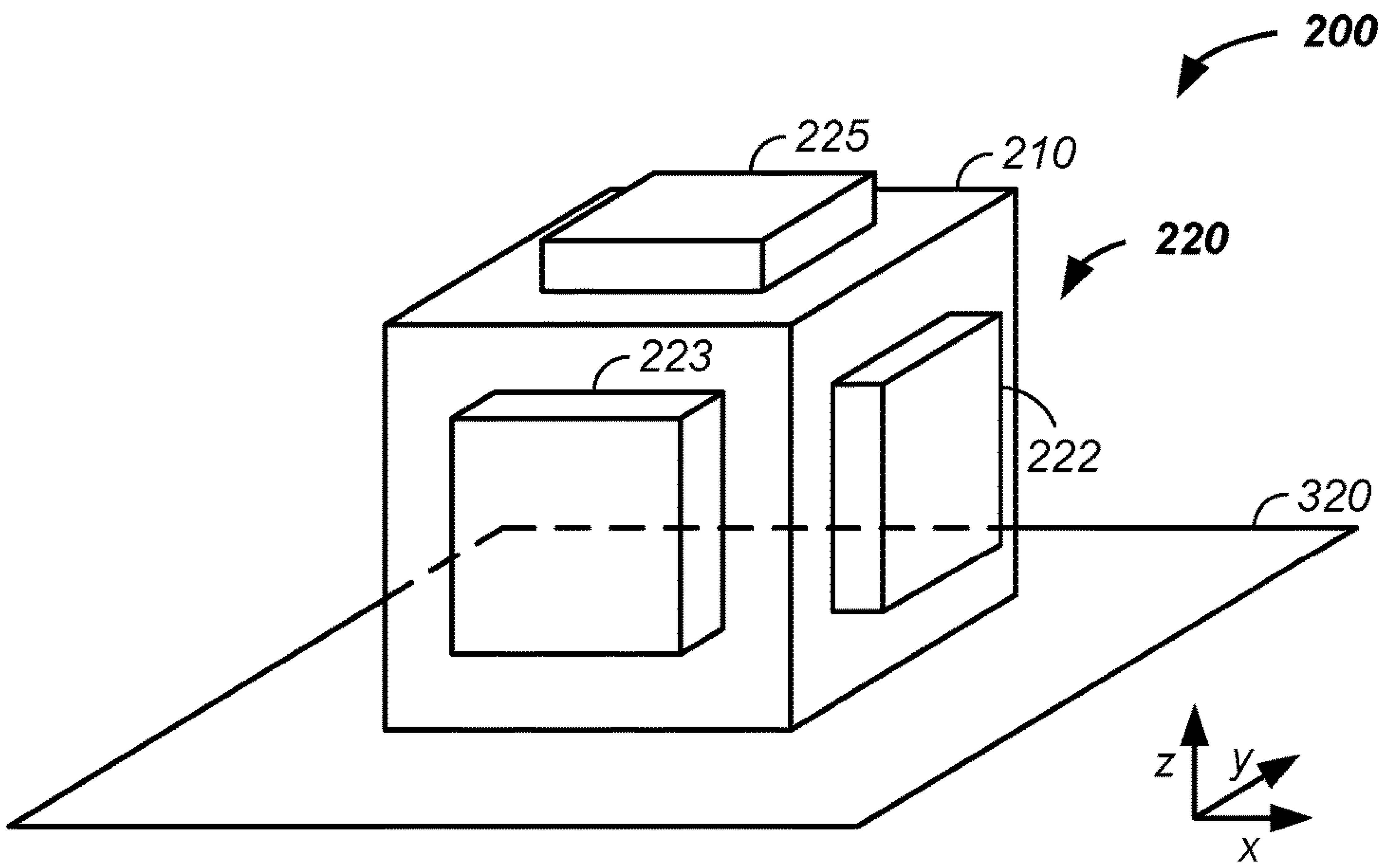

FIG. 3B

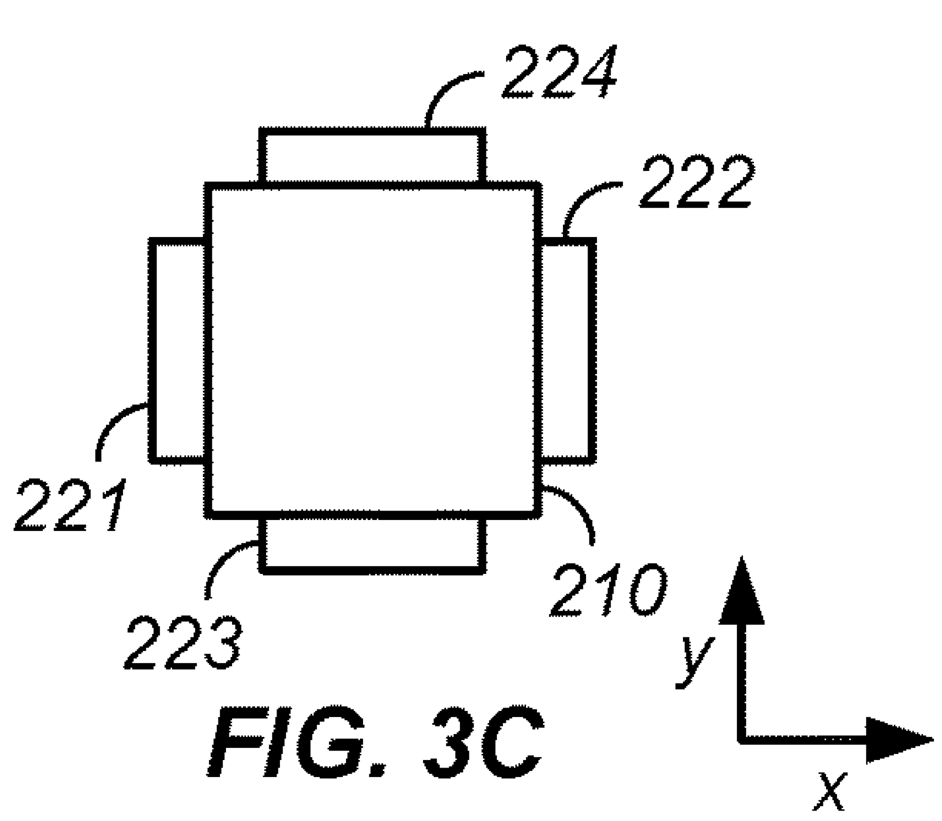

FIG. 3C

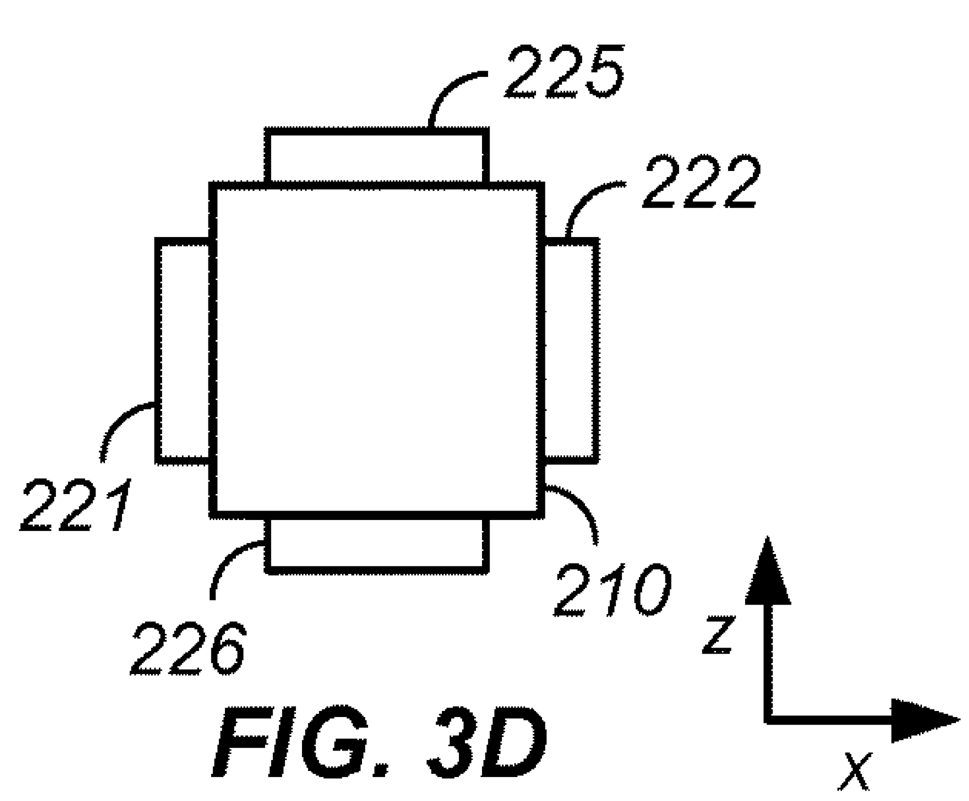

FIG. 3D

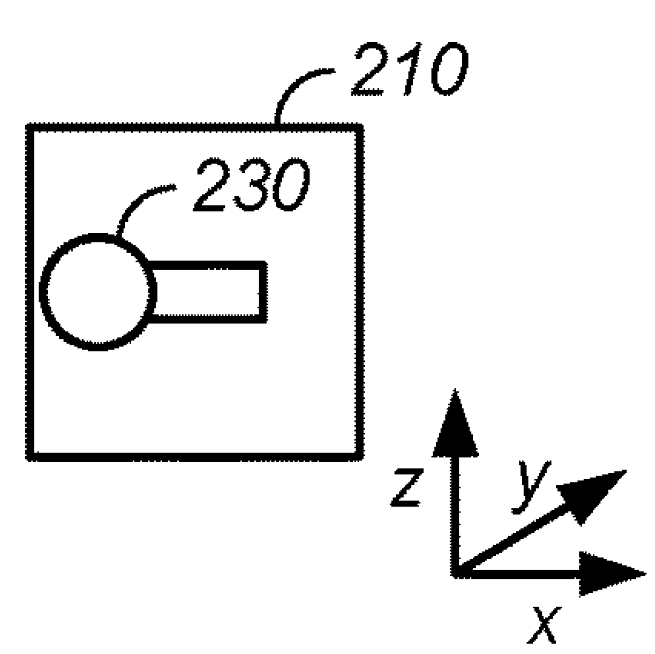

FIG. 3E

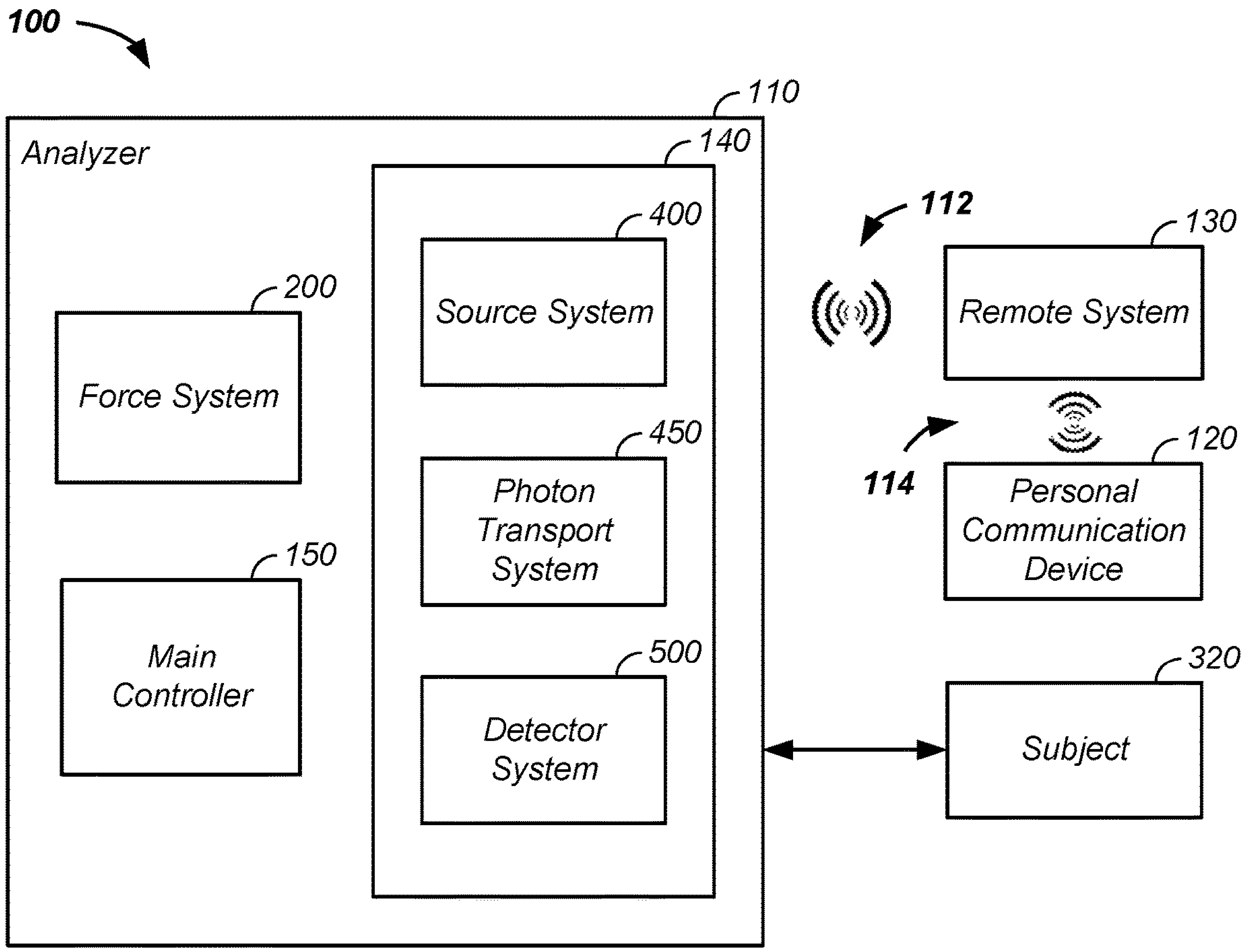

FIG. 4A

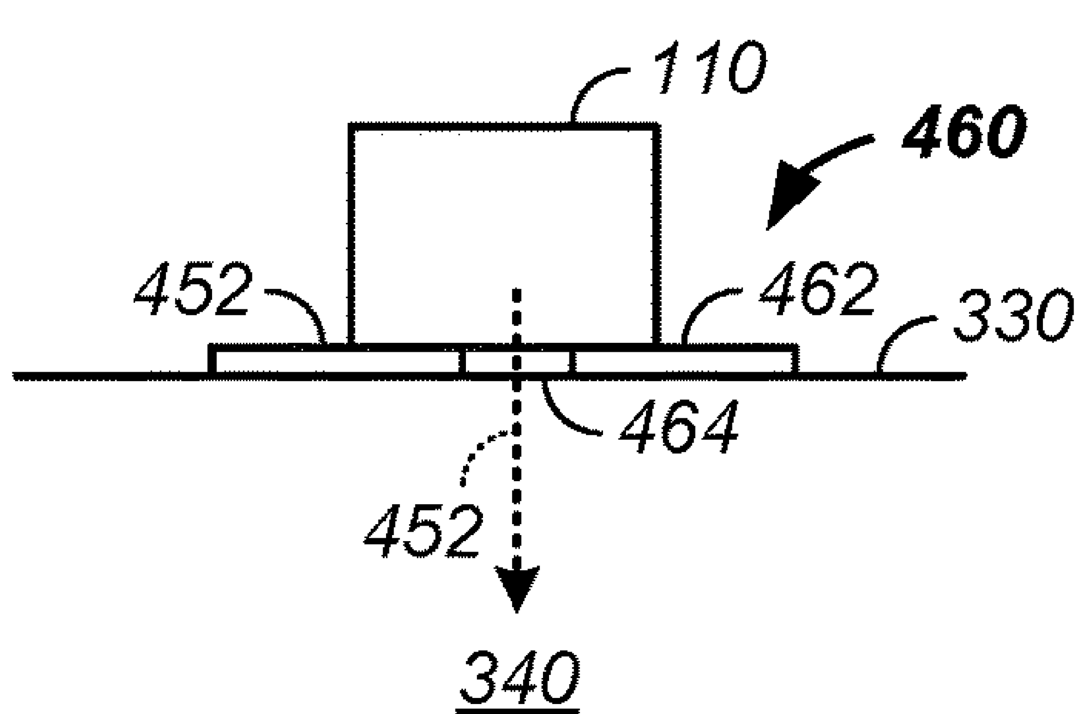

FIG. 4B

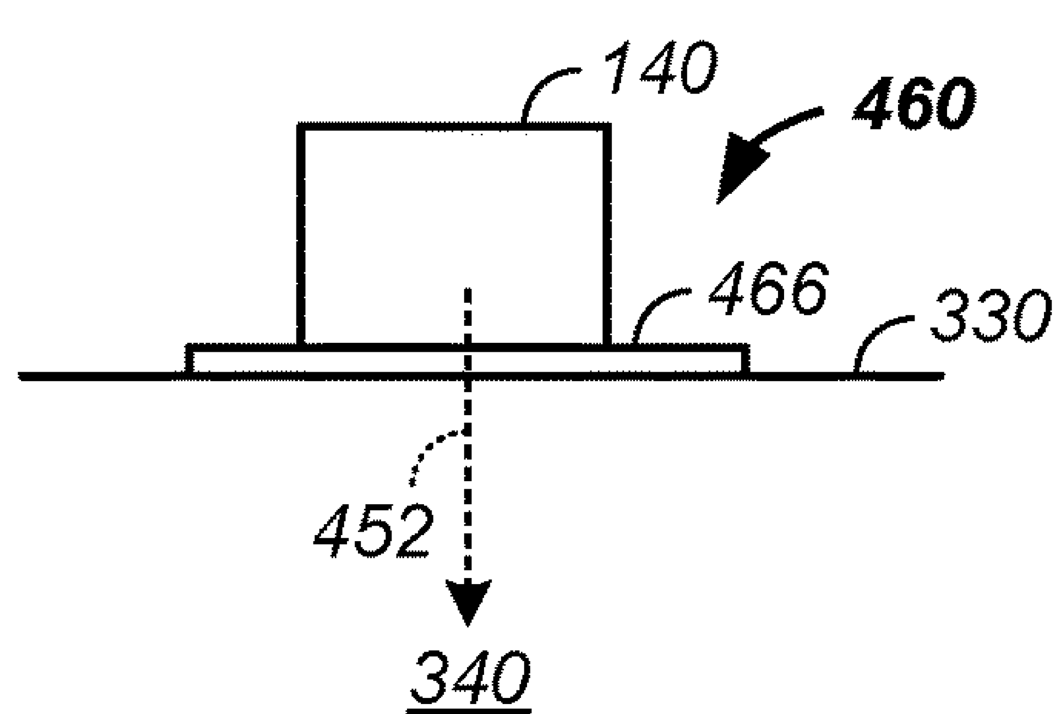

FIG. 4C

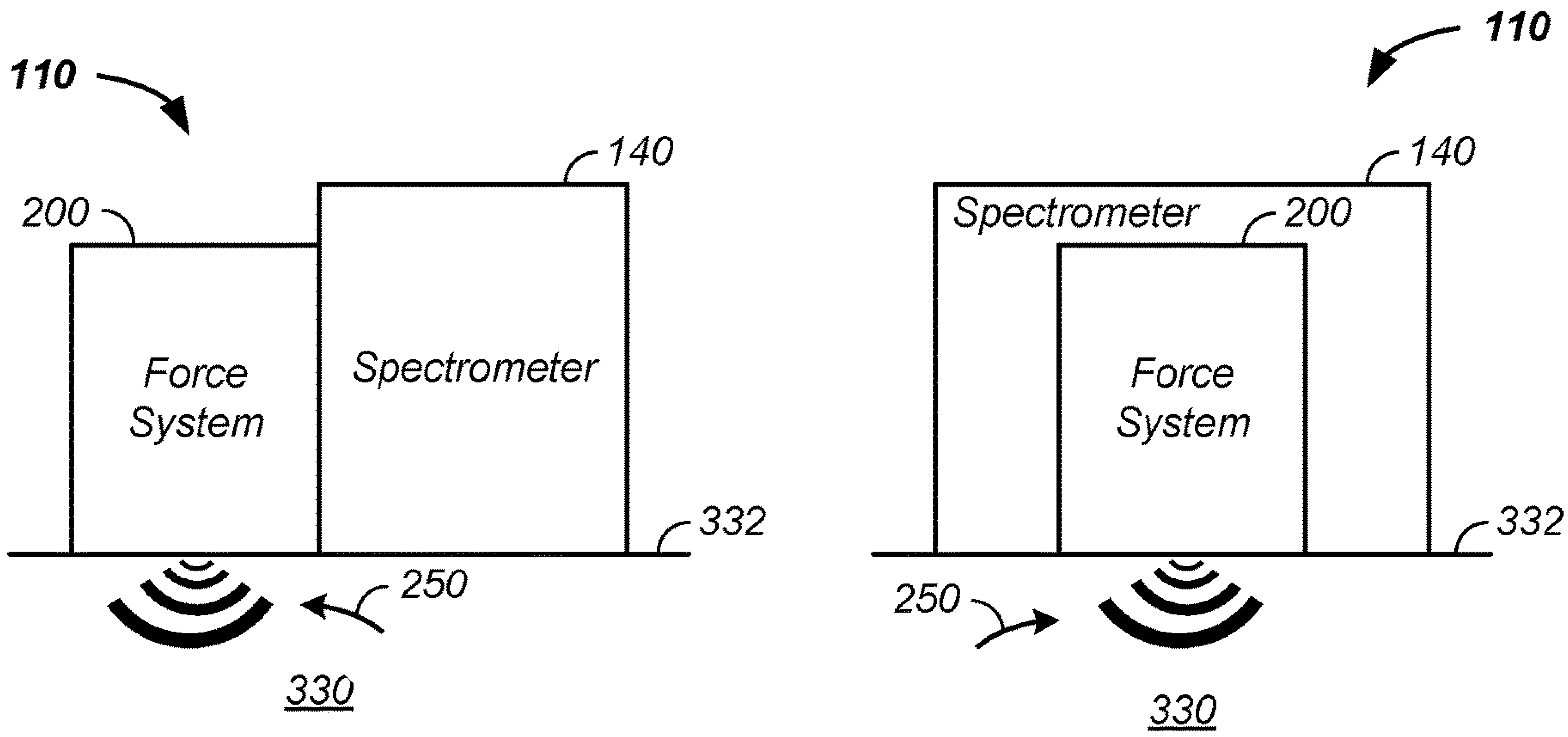

FIG. 5A

FIG. 5B

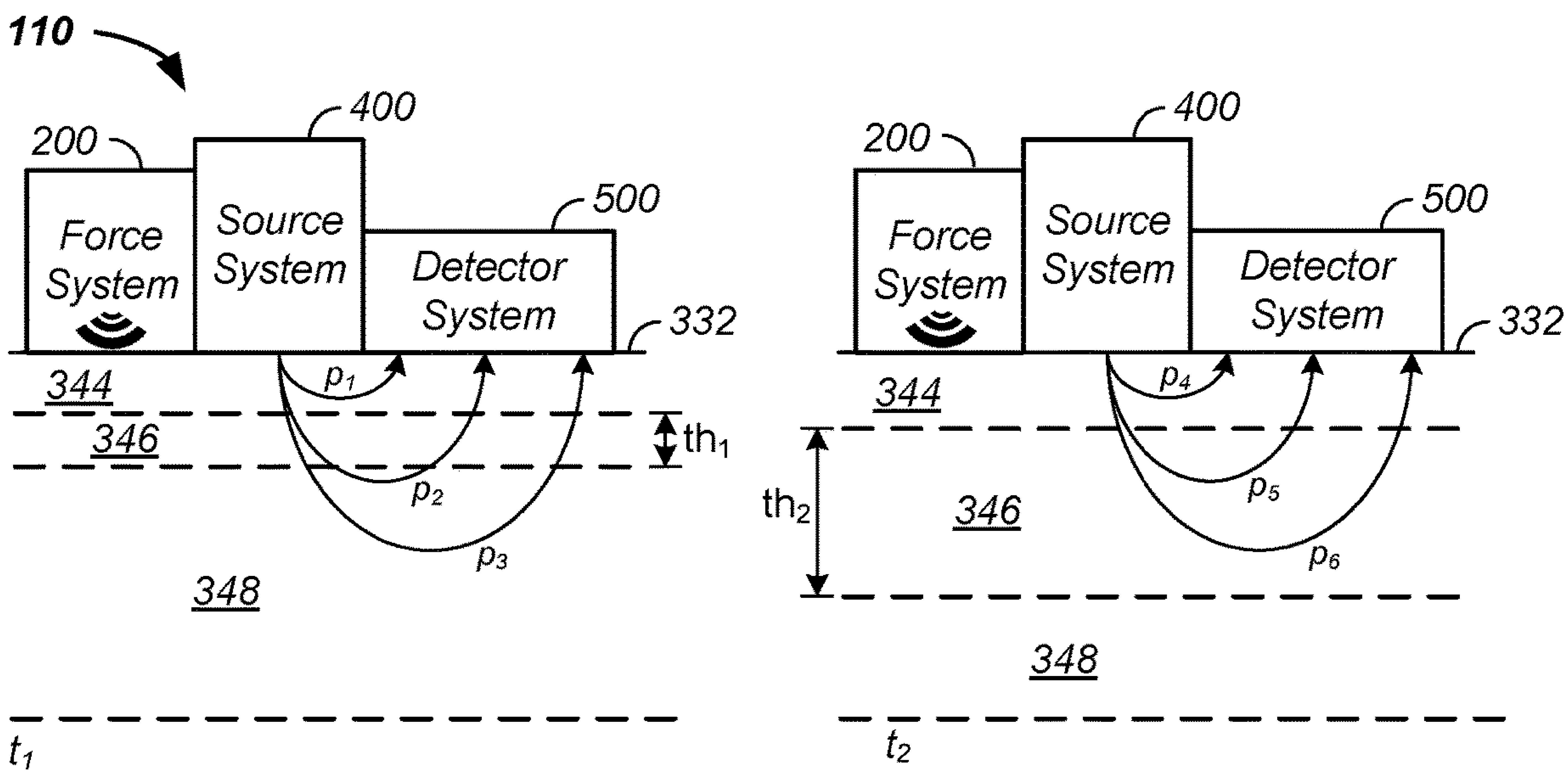

FIG. 6

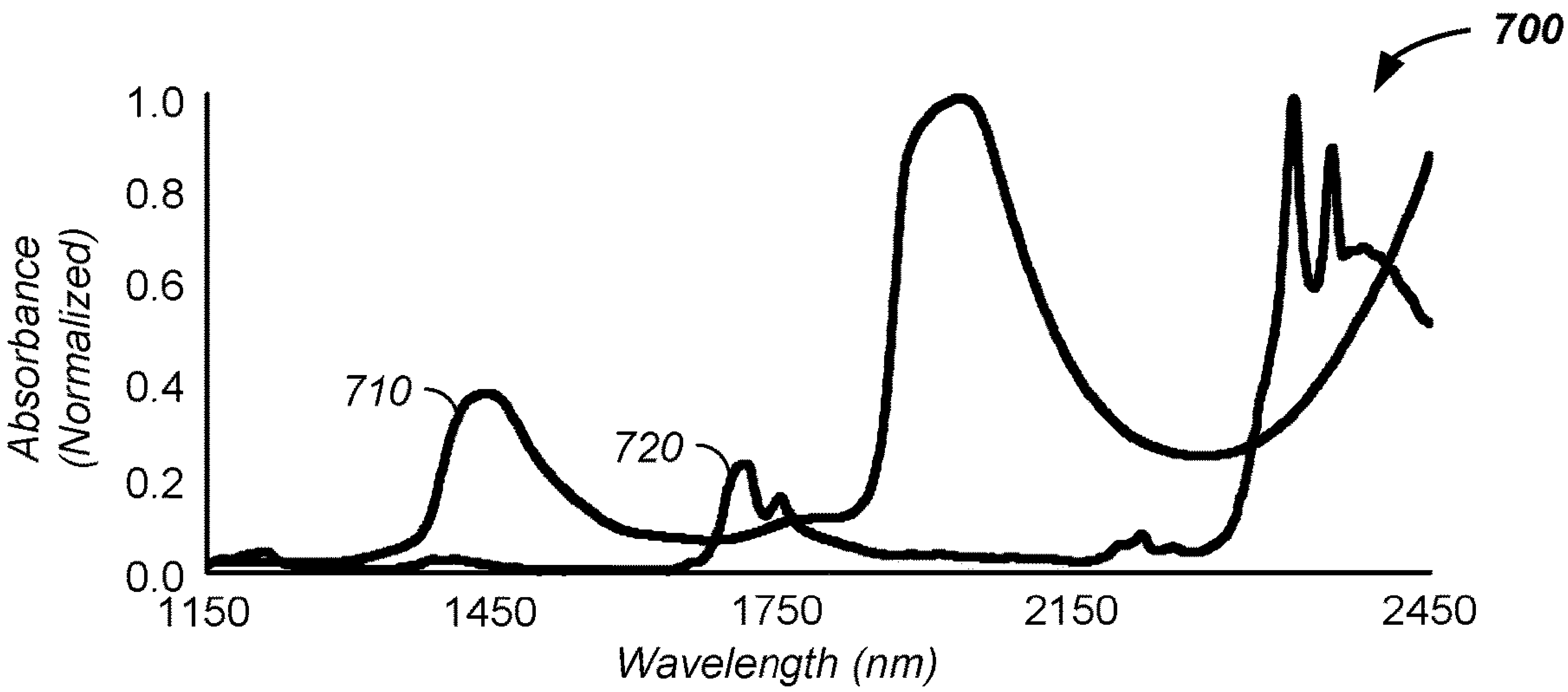

FIG. 7A

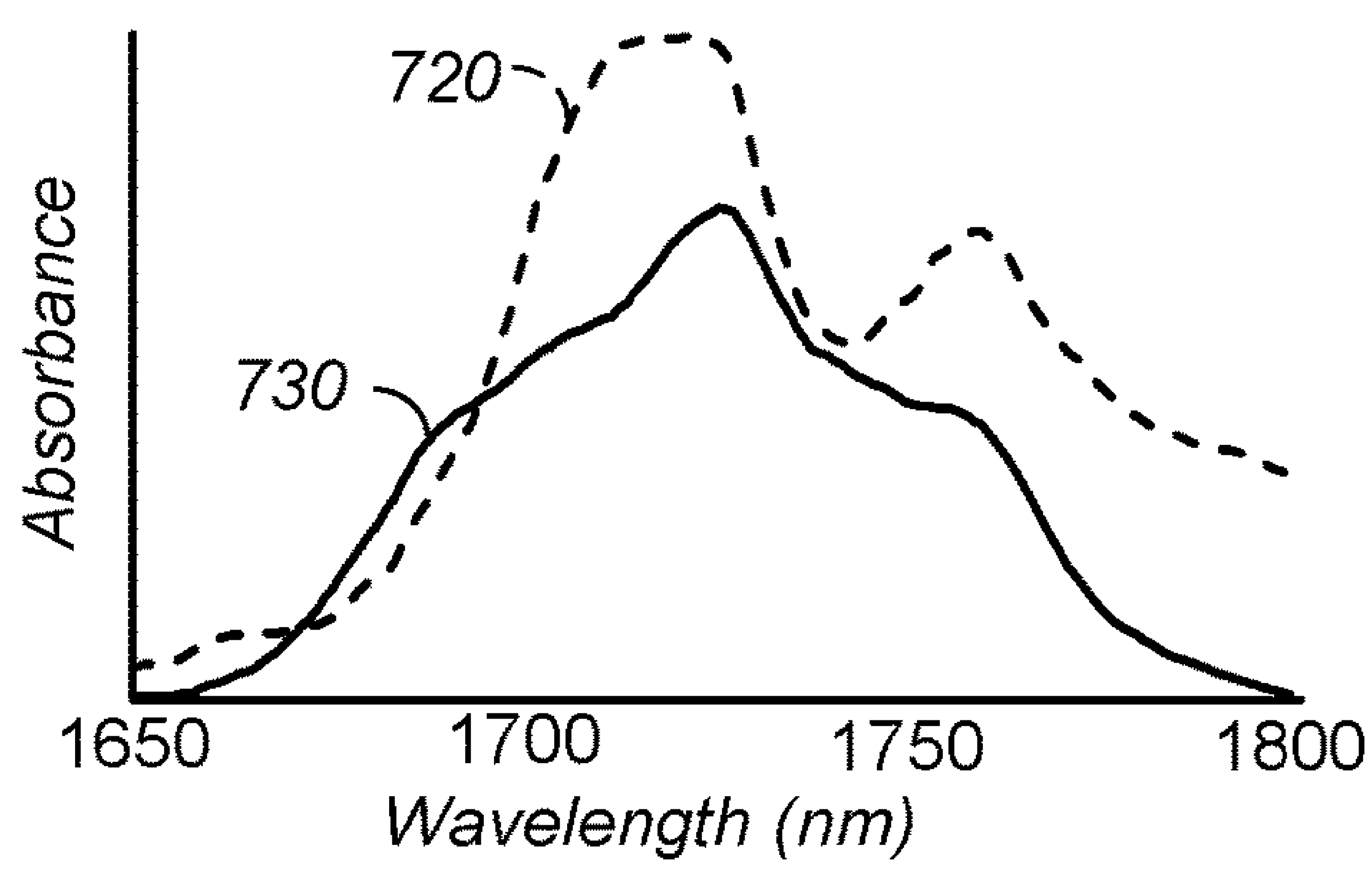

FIG. 7B

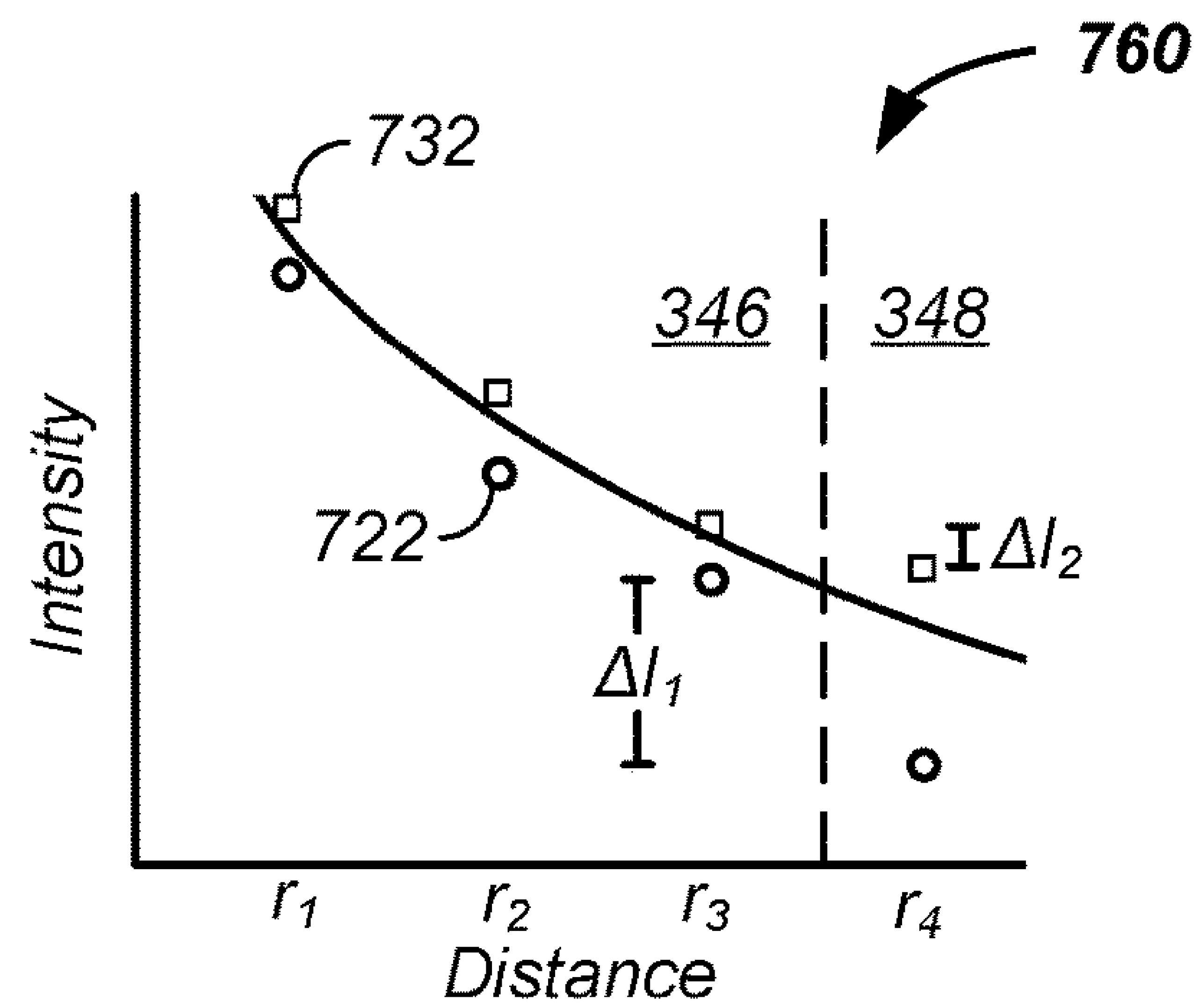

FIG. 7C

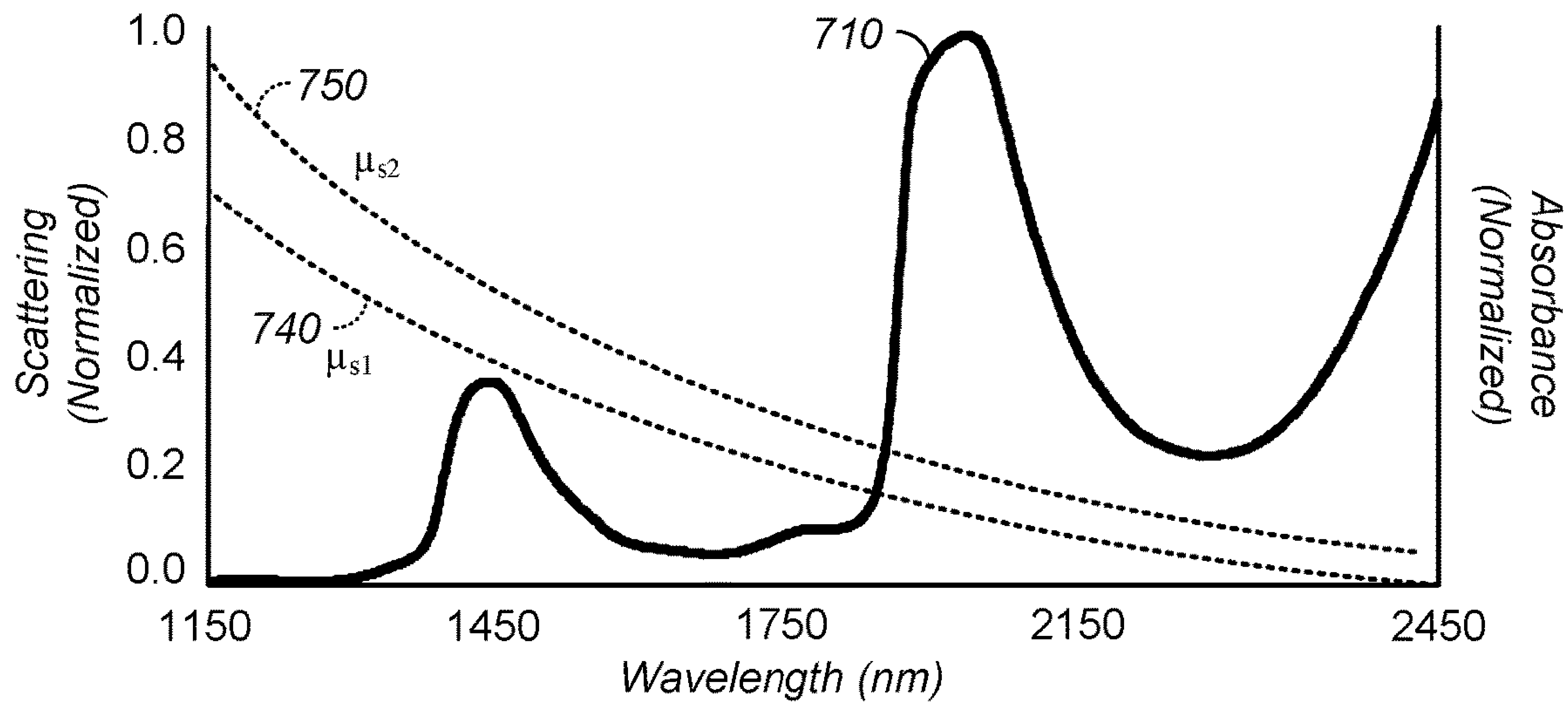

FIG. 7D

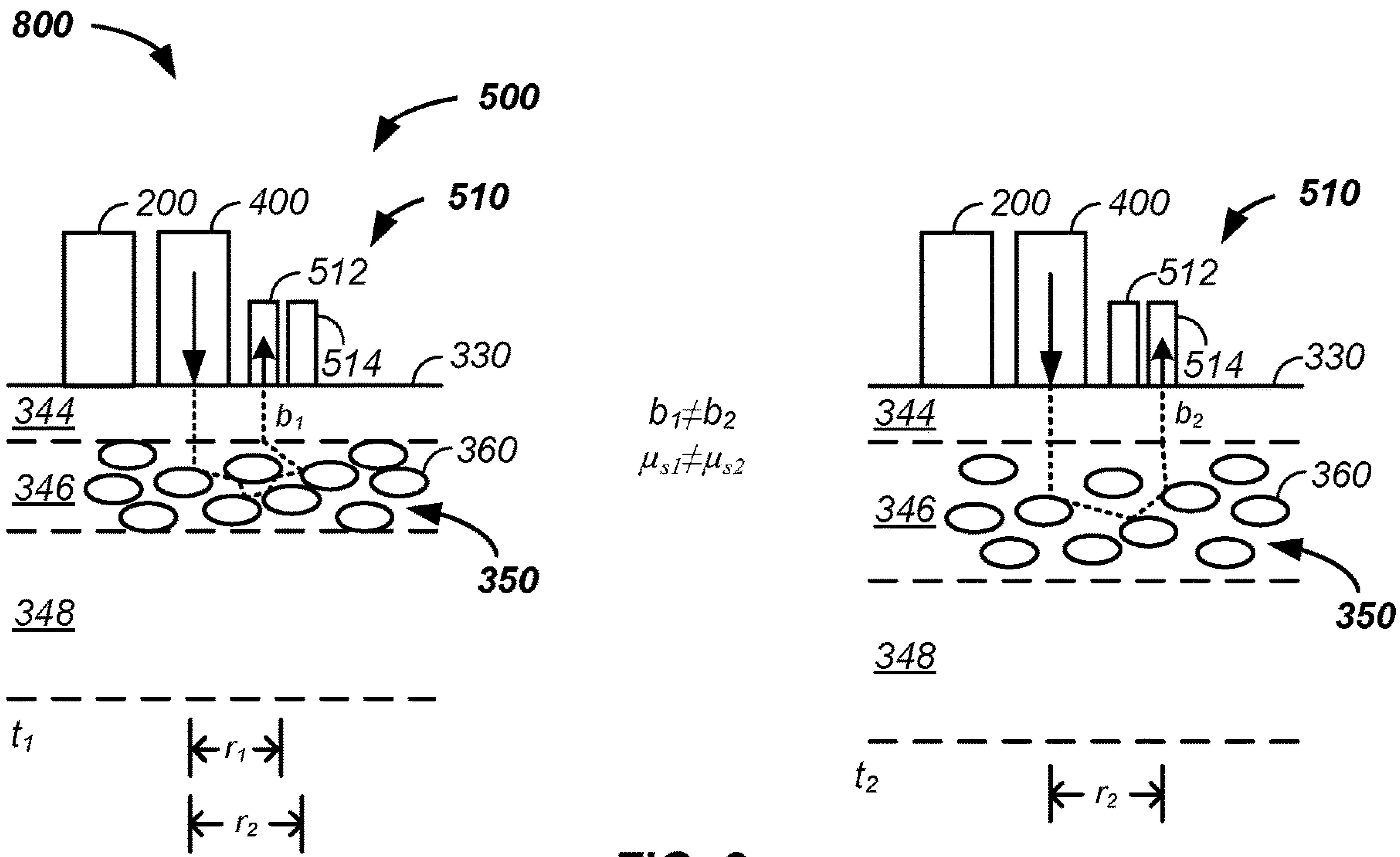
800
500
510
200
400
512
514
330
344
346
348
360
350
b_1
b_2
$b_1 \neq b_2$
$\mu_{s1} \neq \mu_{s2}$
t_1
t_2
r_1
r_2

FIG. 8

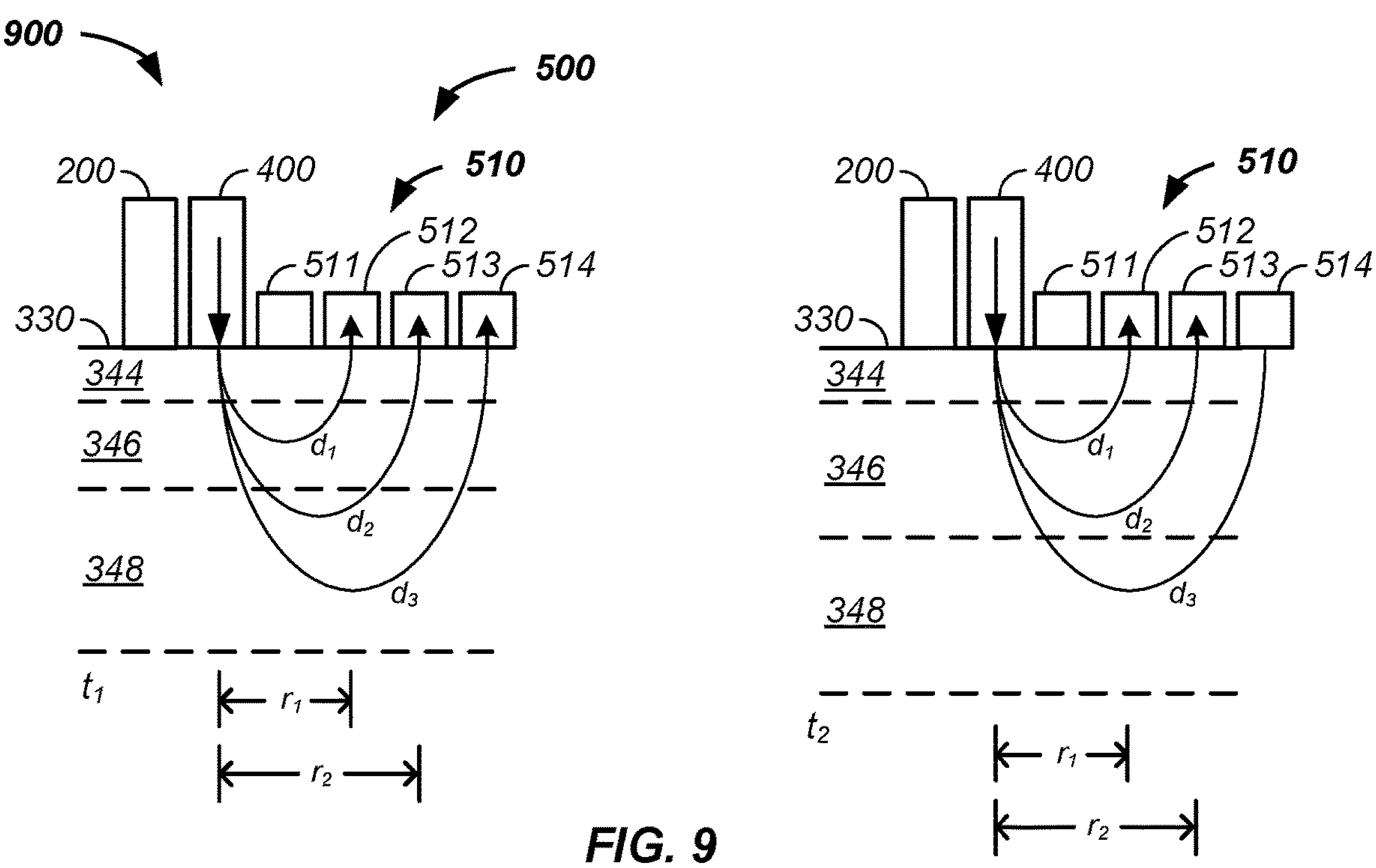
900
500
510
200
400
511
512
513
514
330
344
346
348
d_1
d_2
d_3
t_1
t_2
r_1
r_2

FIG. 9

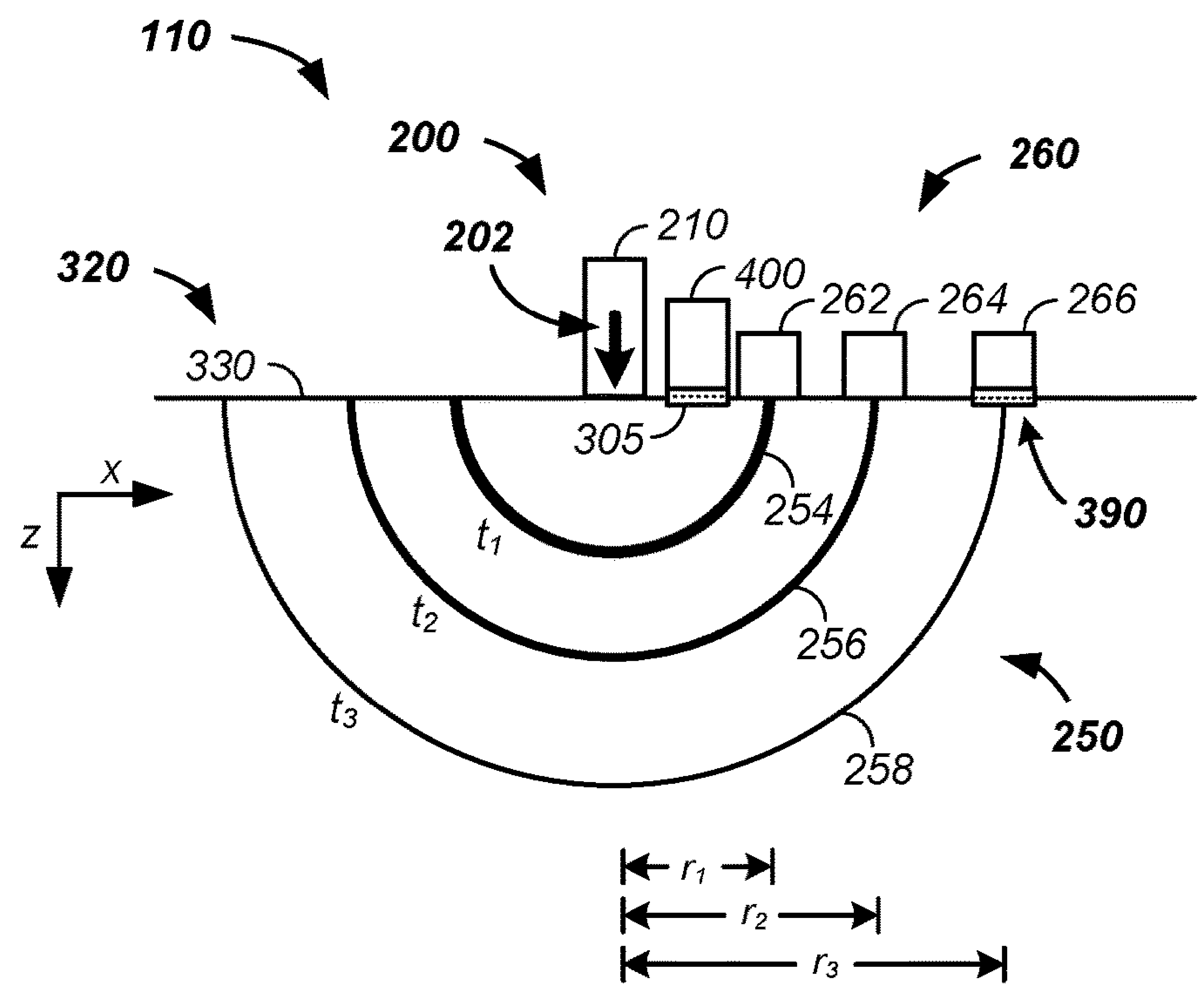

FIG. 10A

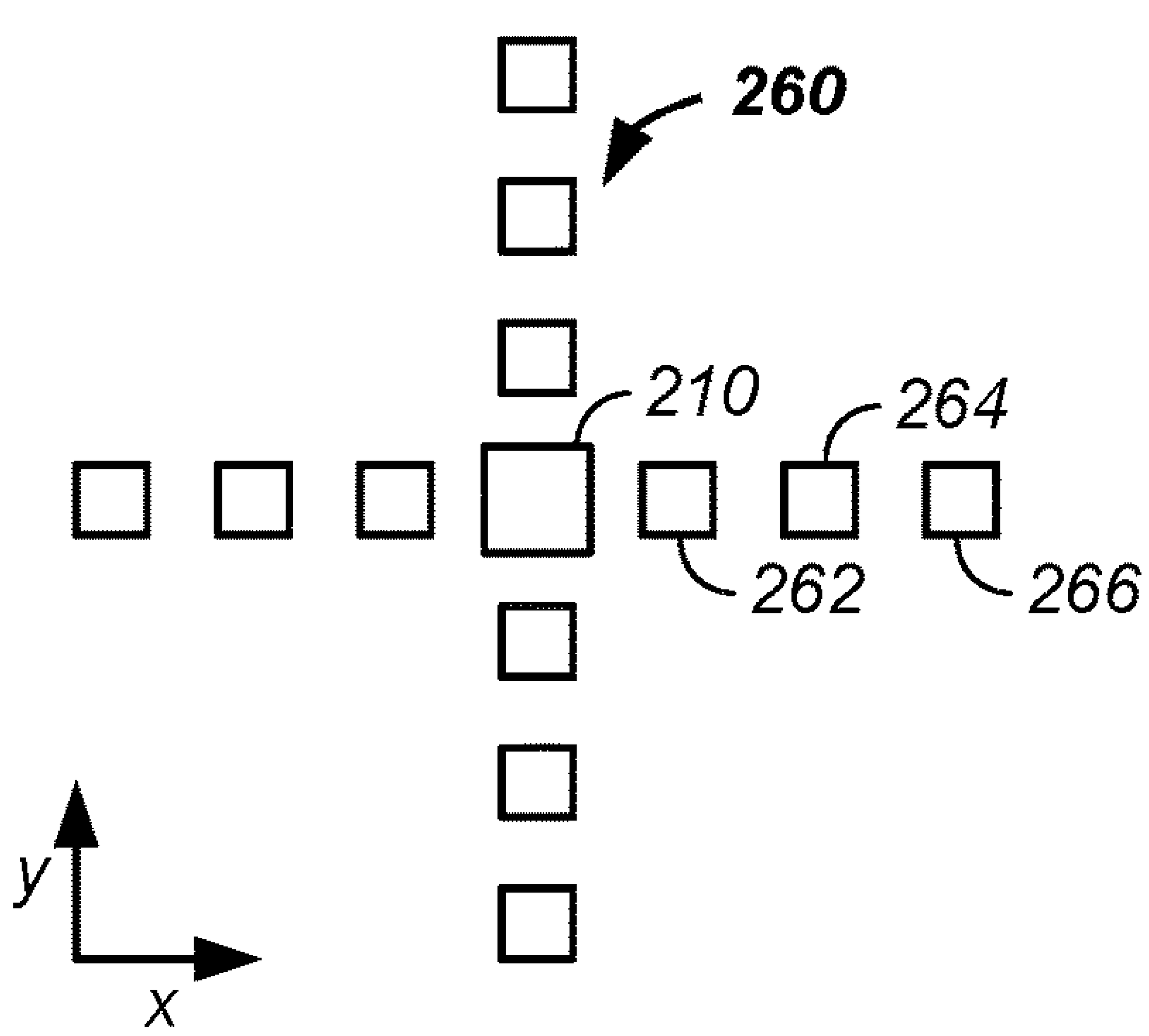

FIG. 10B

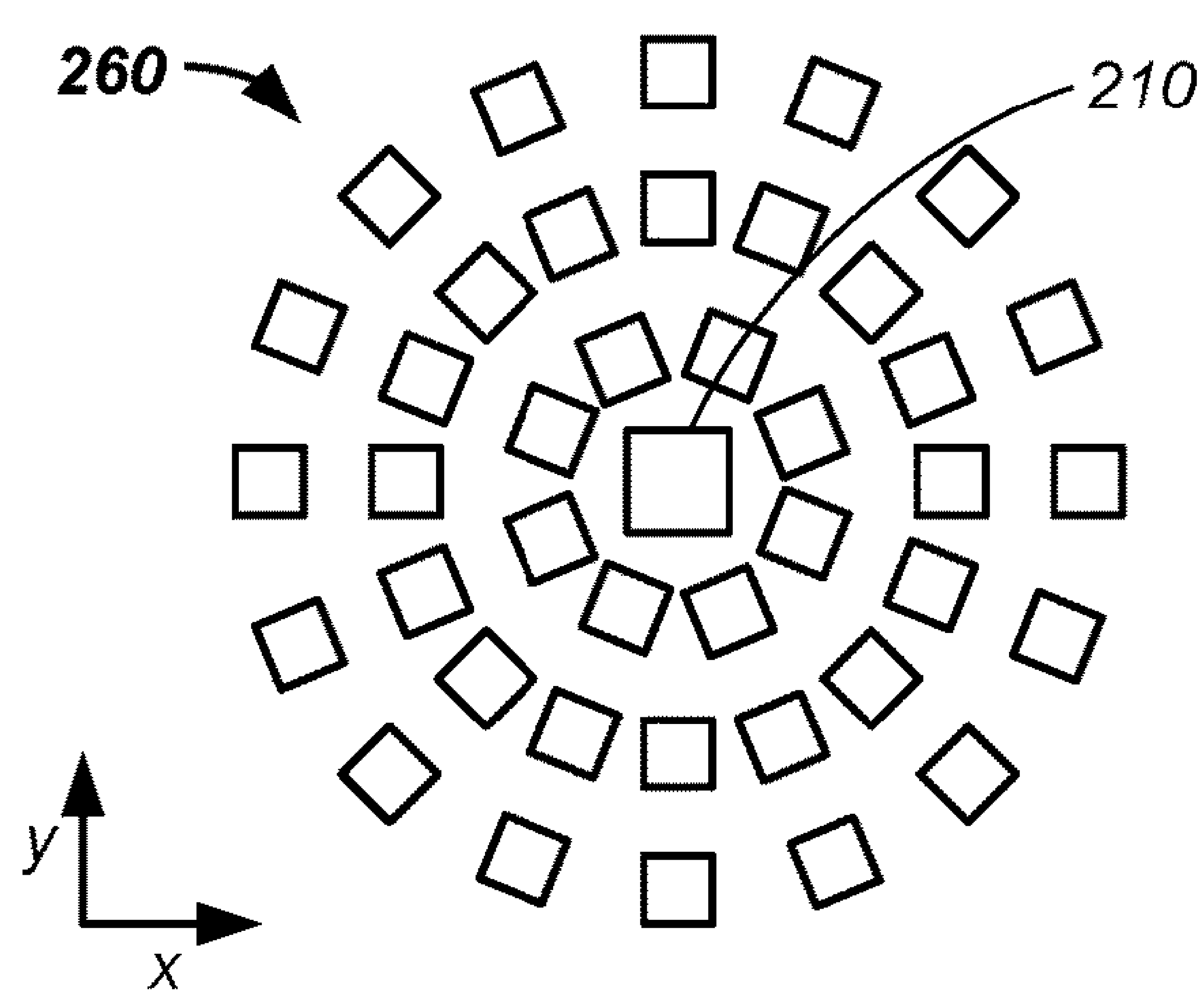

FIG. 10C

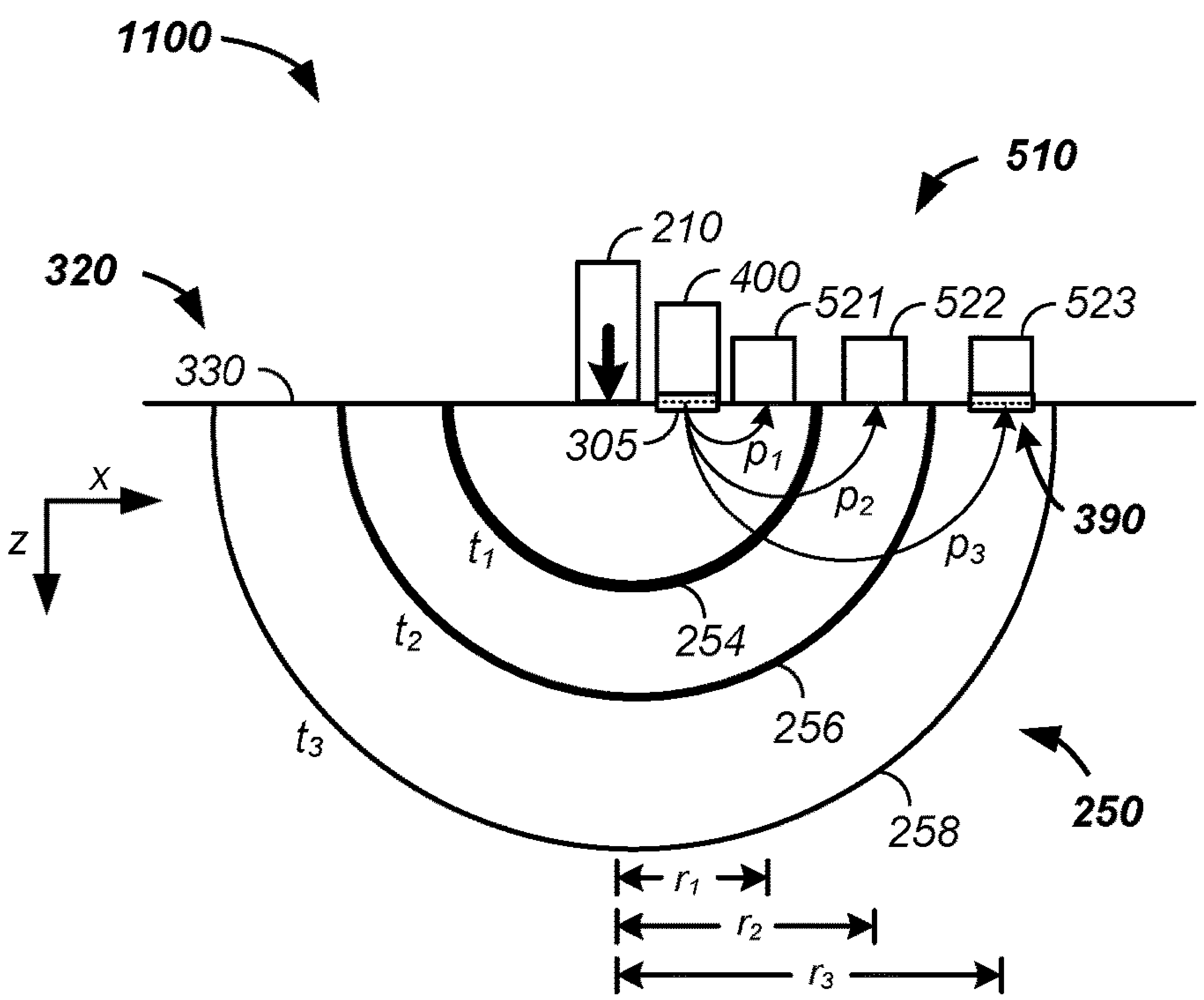

FIG. 11A

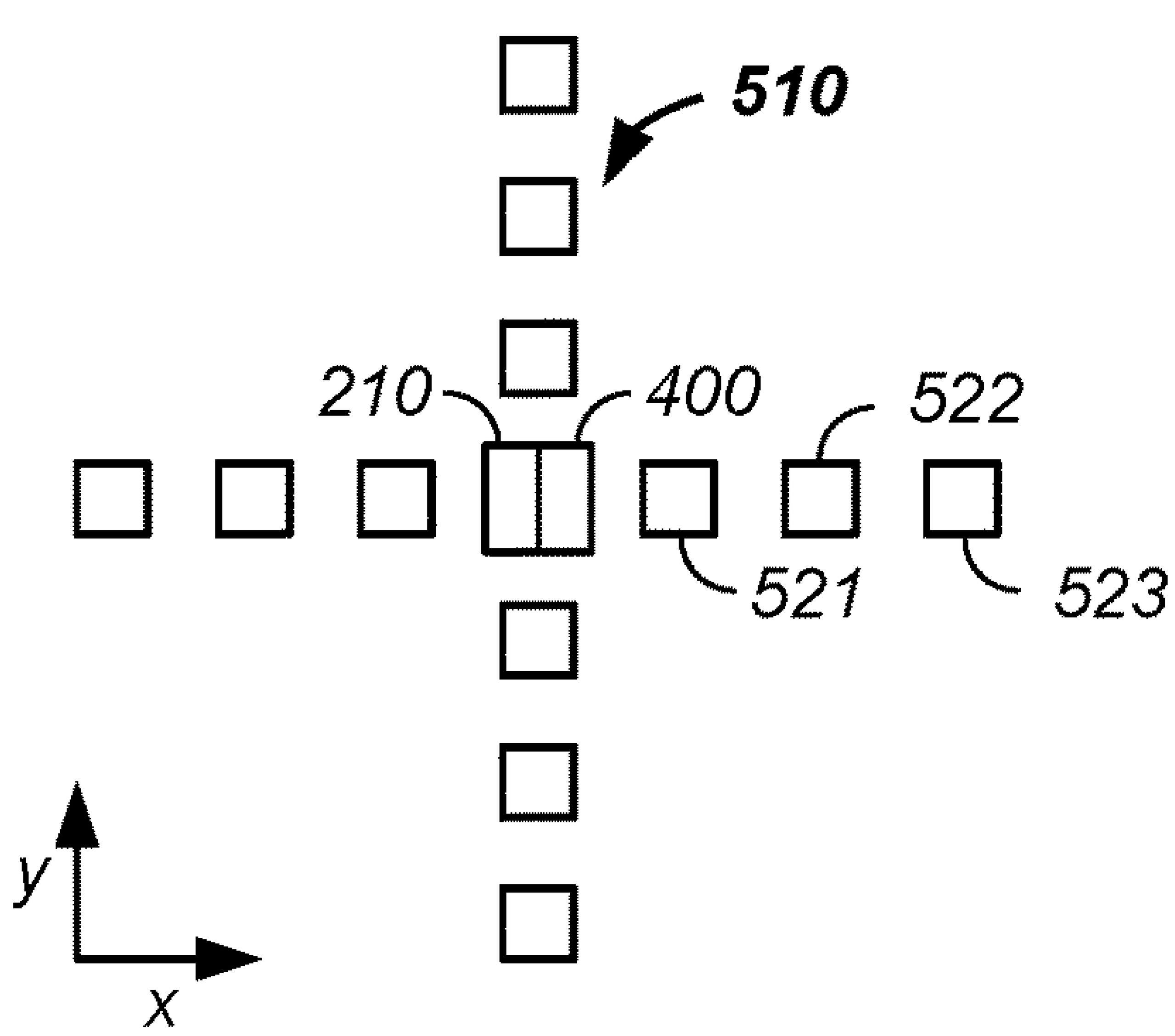

FIG. 11B

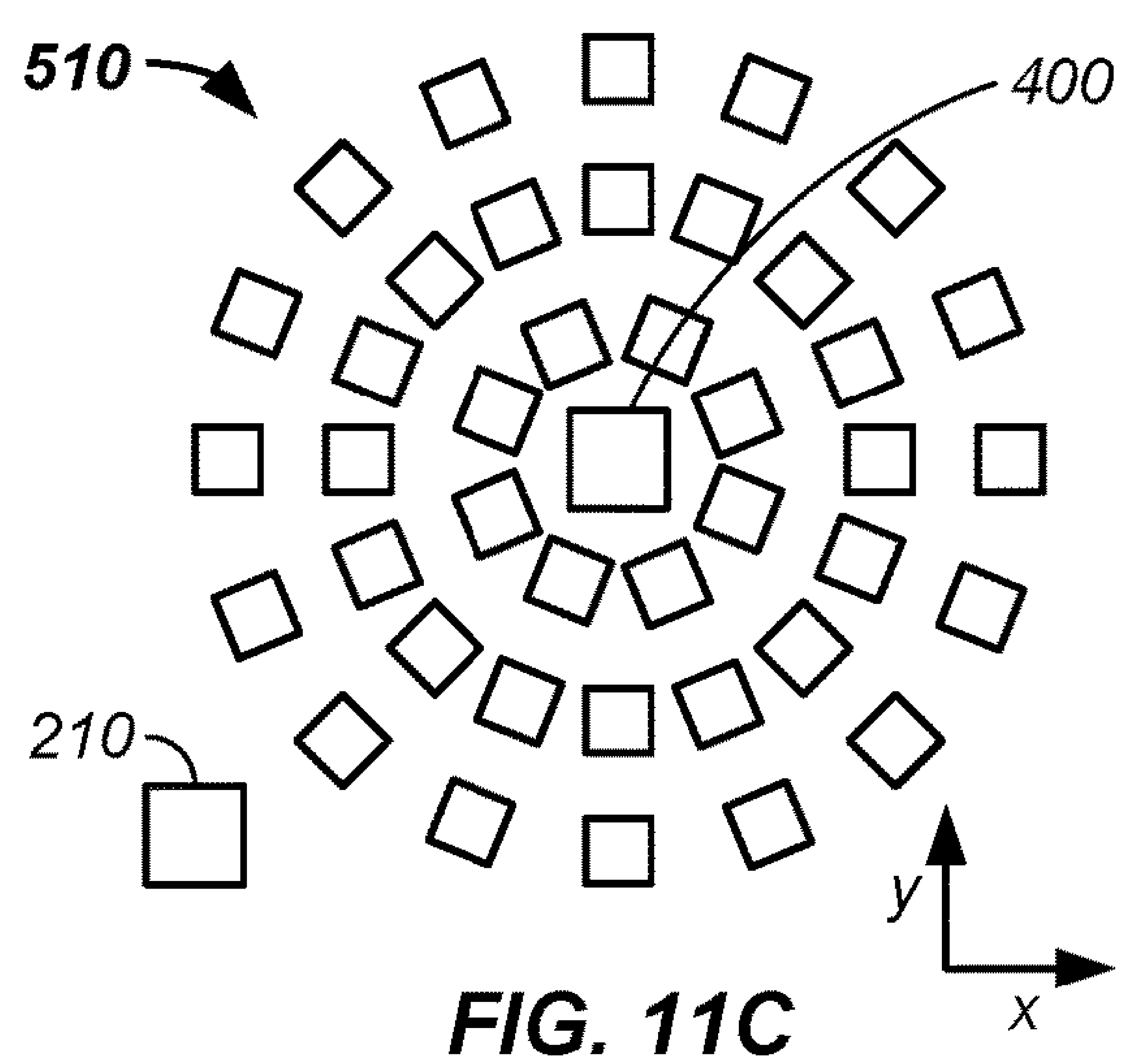

FIG. 11C

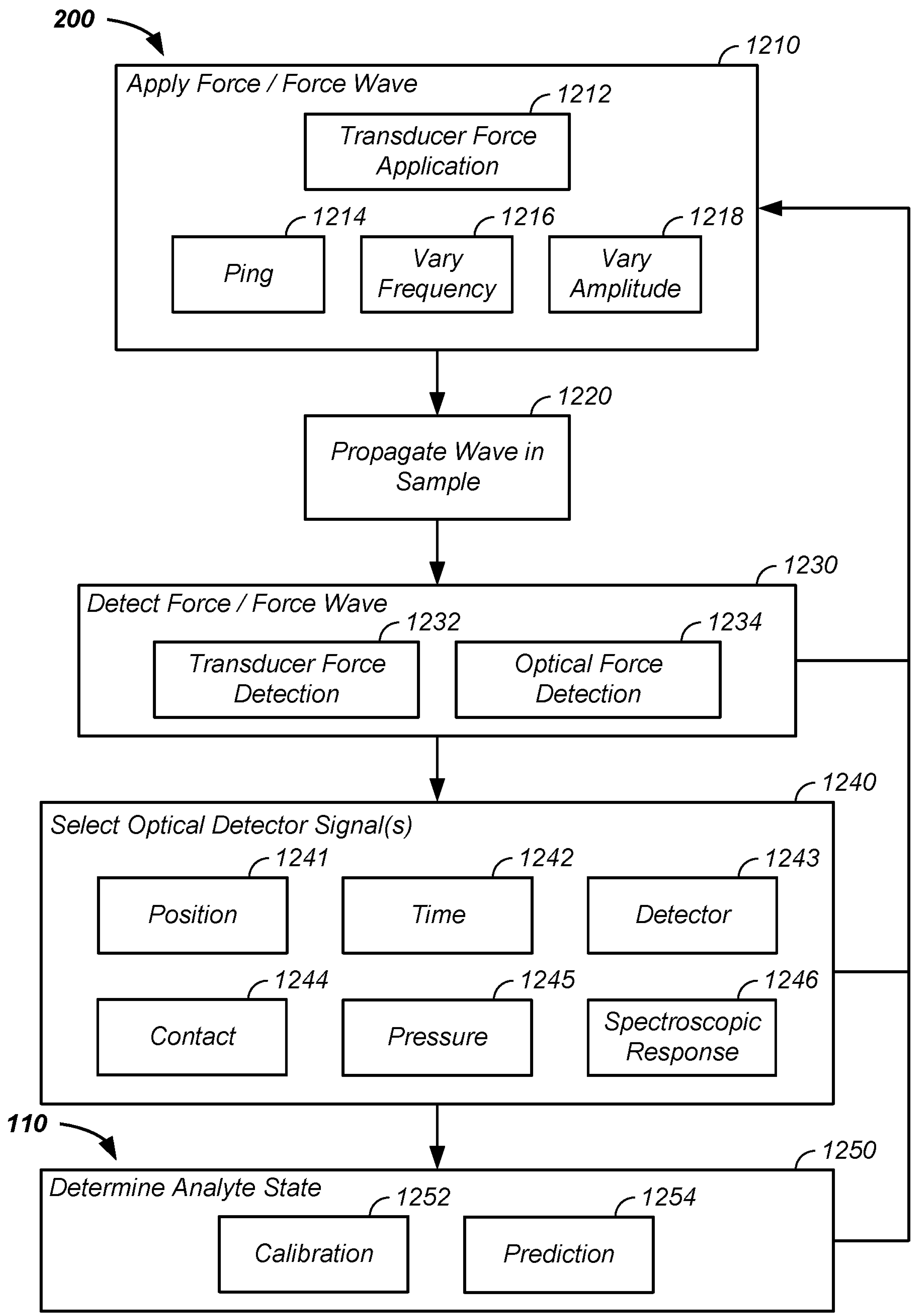
200
1210
Apply Force / Force Wave
1212
Transducer Force Application
1214
Ping
1216
Vary Frequency
1218
Vary Amplitude
1220
Propagate Wave in Sample
1230
Detect Force / Force Wave
1232
Transducer Force Detection
1234
Optical Force Detection
1240
Select Optical Detector Signal(s)
1241
Position
1242
Time
1243
Detector
1244
Contact
1245
Pressure
1246
Spectroscopic Response
110
1250
Determine Analyte State
1252
Calibration
1254
Prediction

FIG. 12

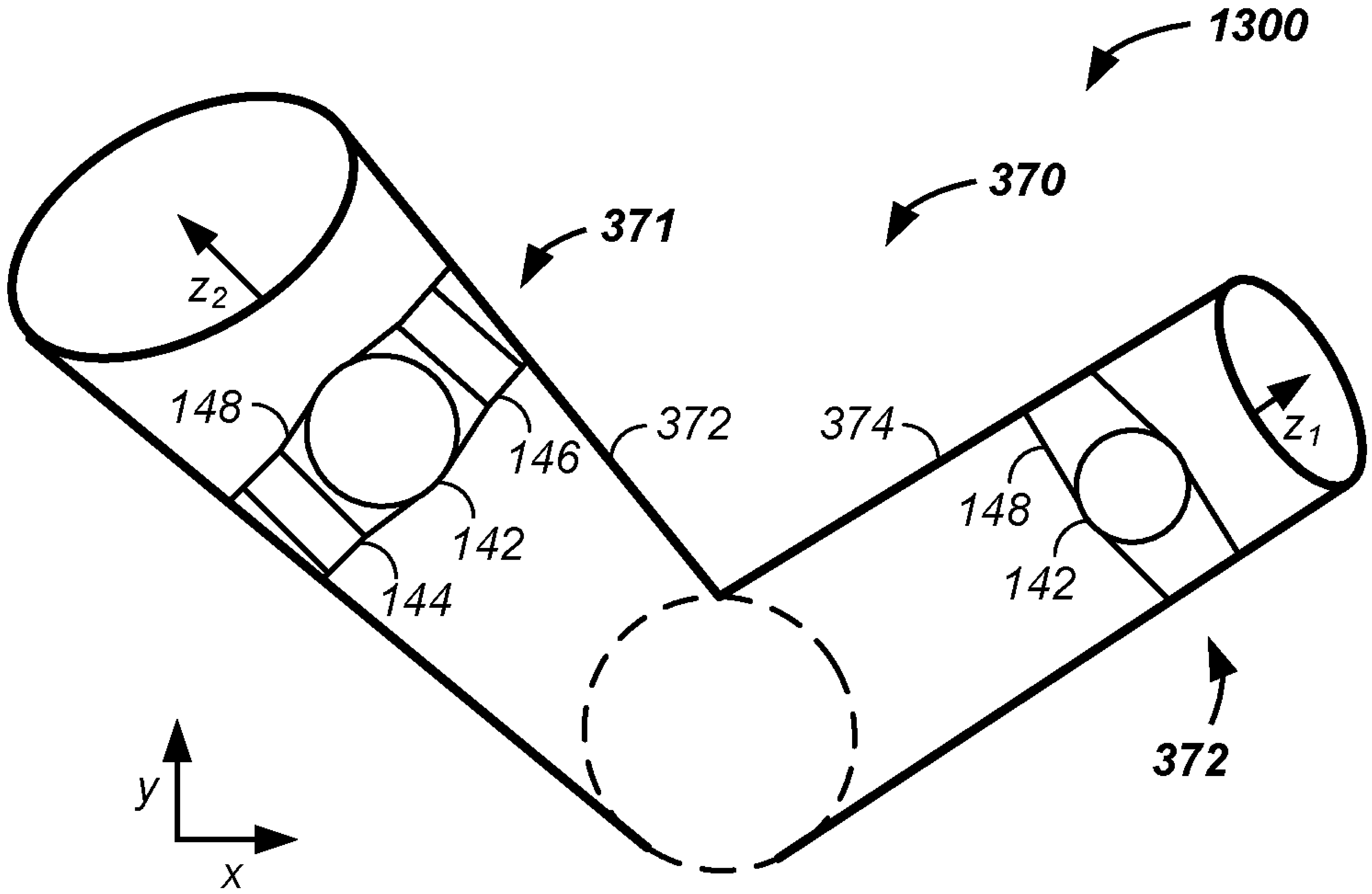

FIG. 13

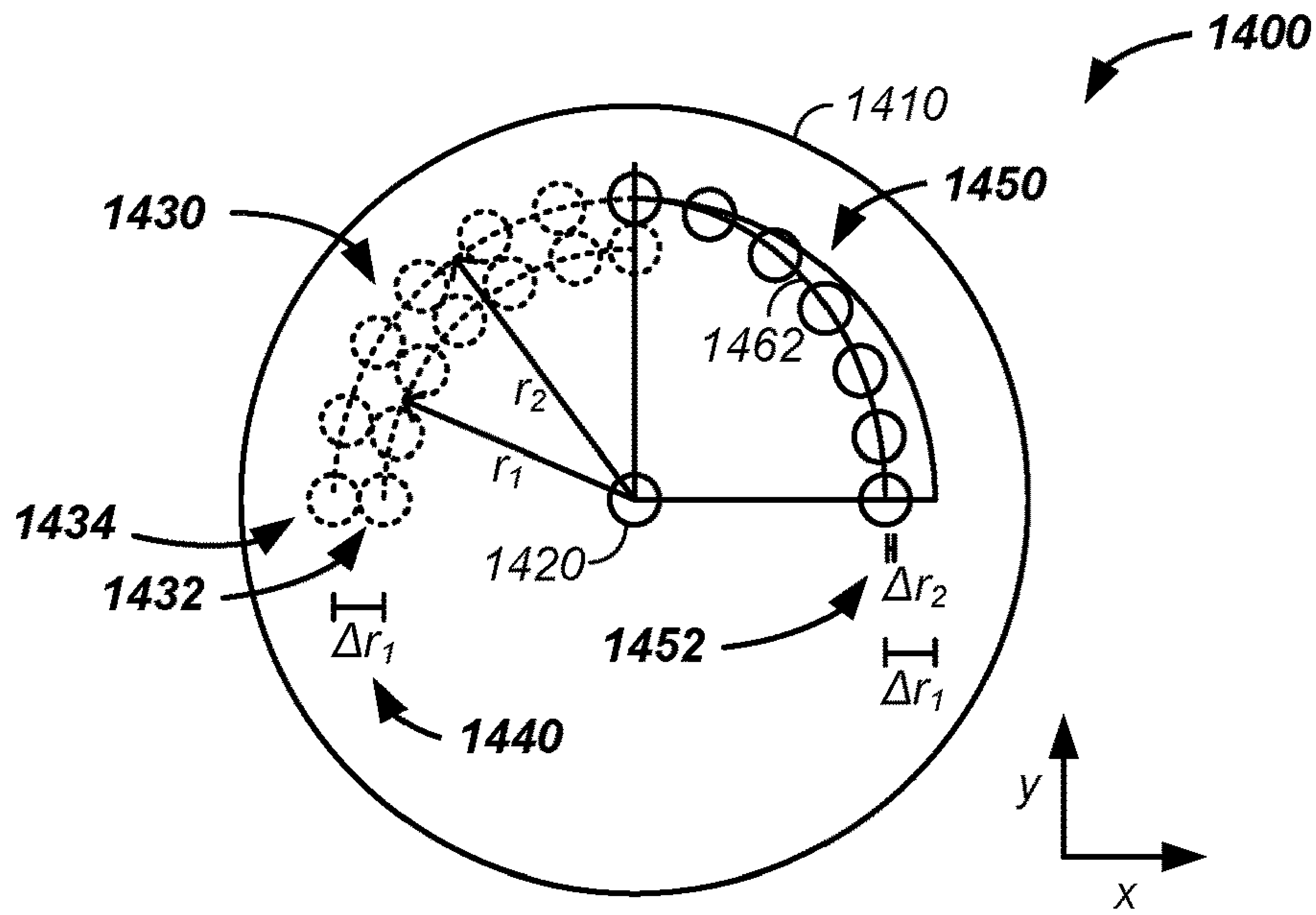

FIG. 14A

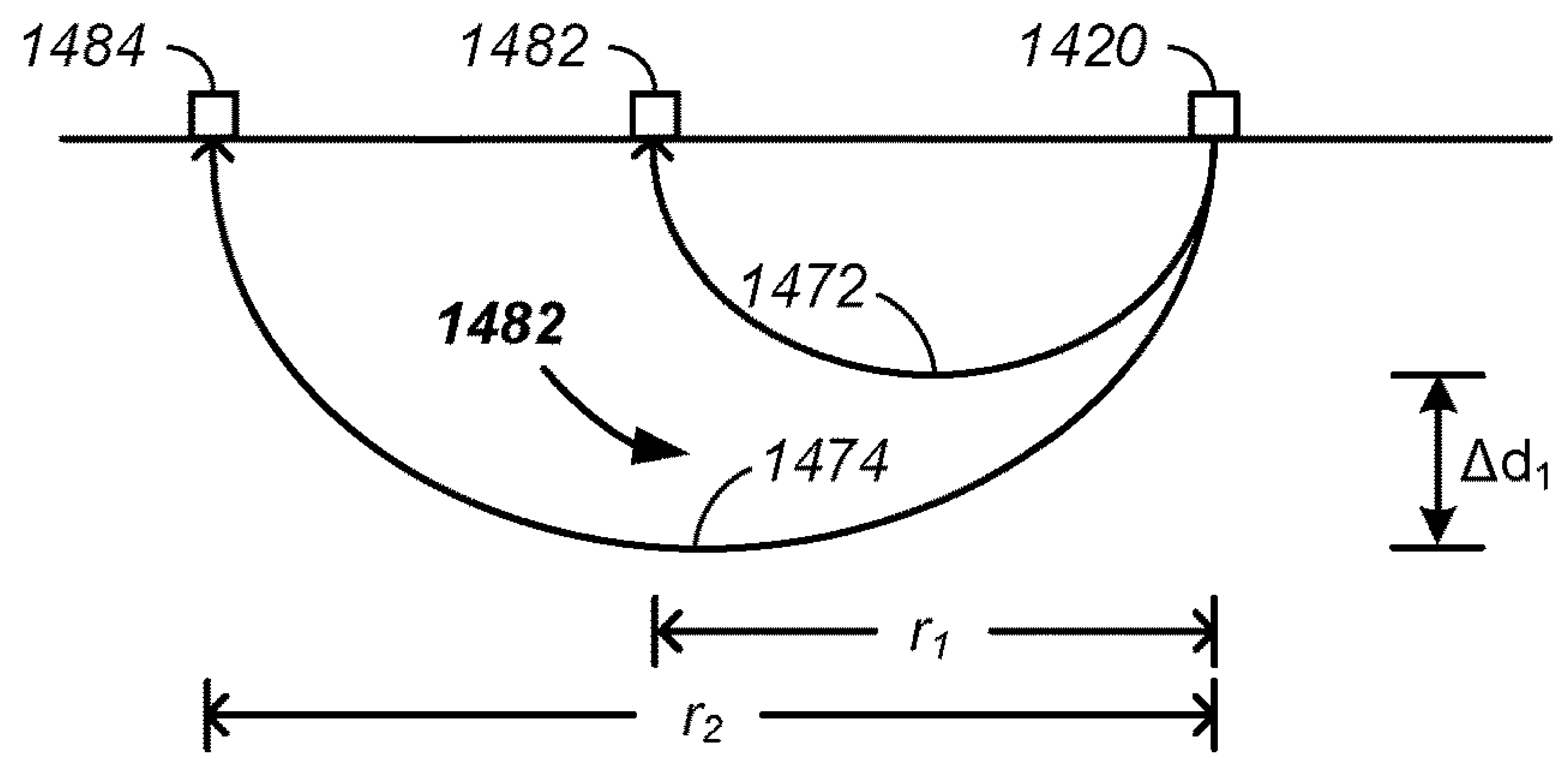

FIG. 14B

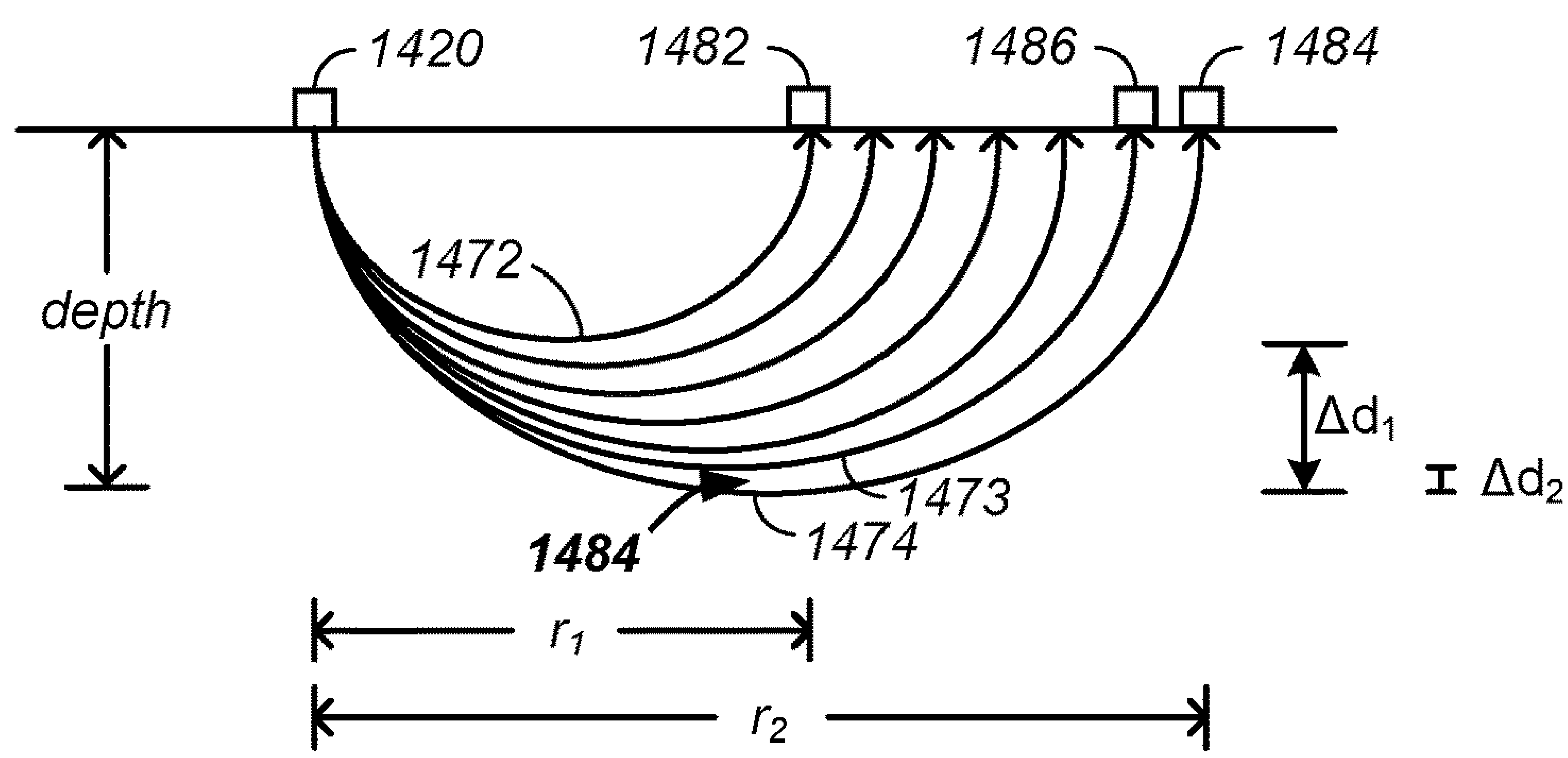

FIG. 14C

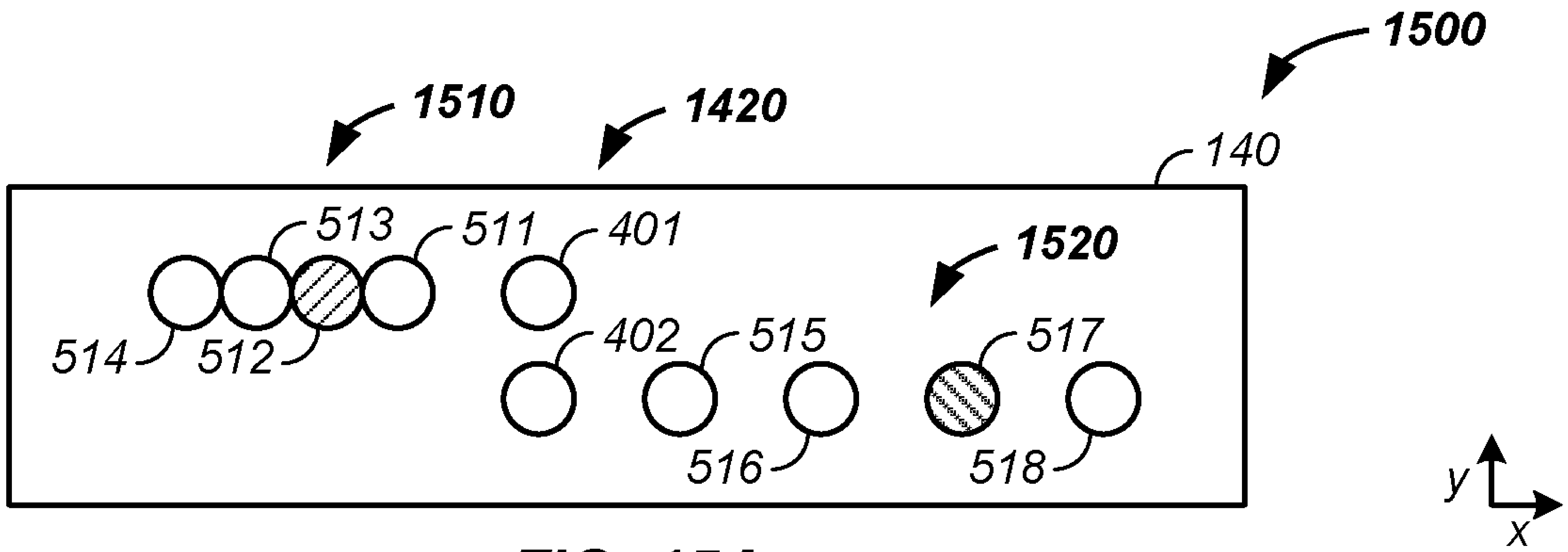

FIG. 15A

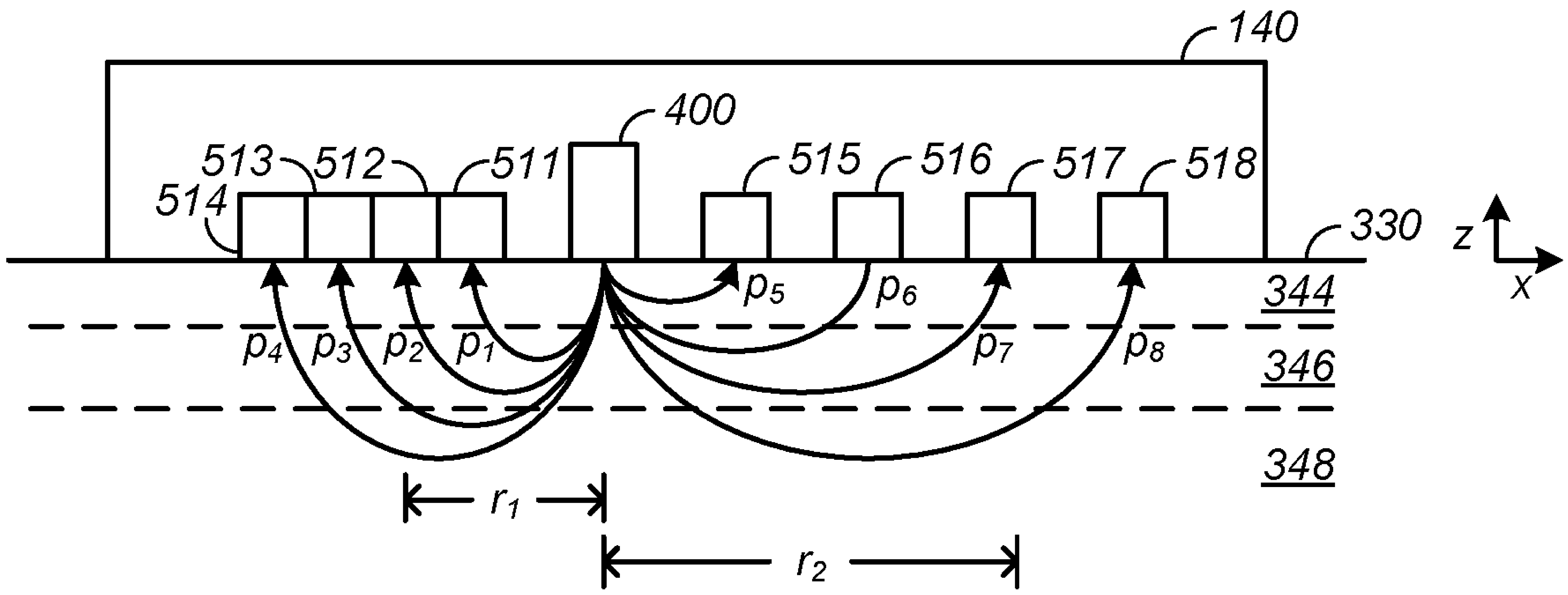

FIG. 15B

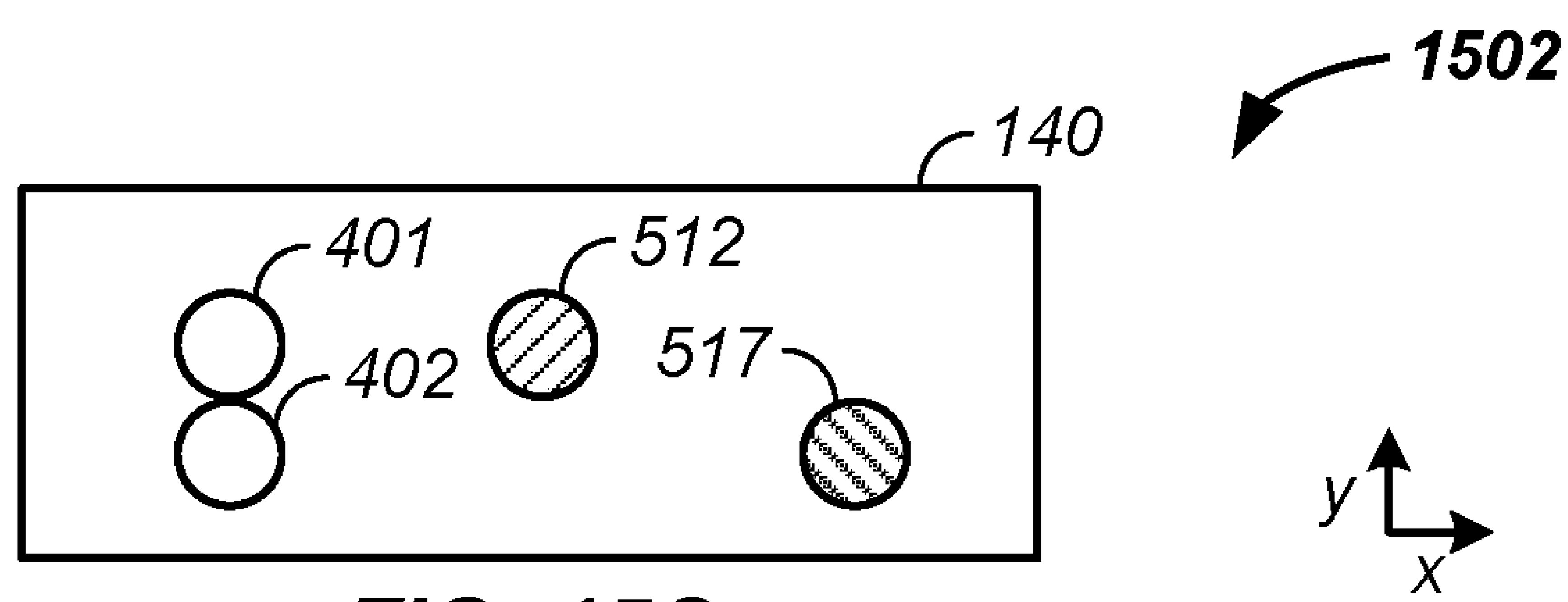

FIG. 15C

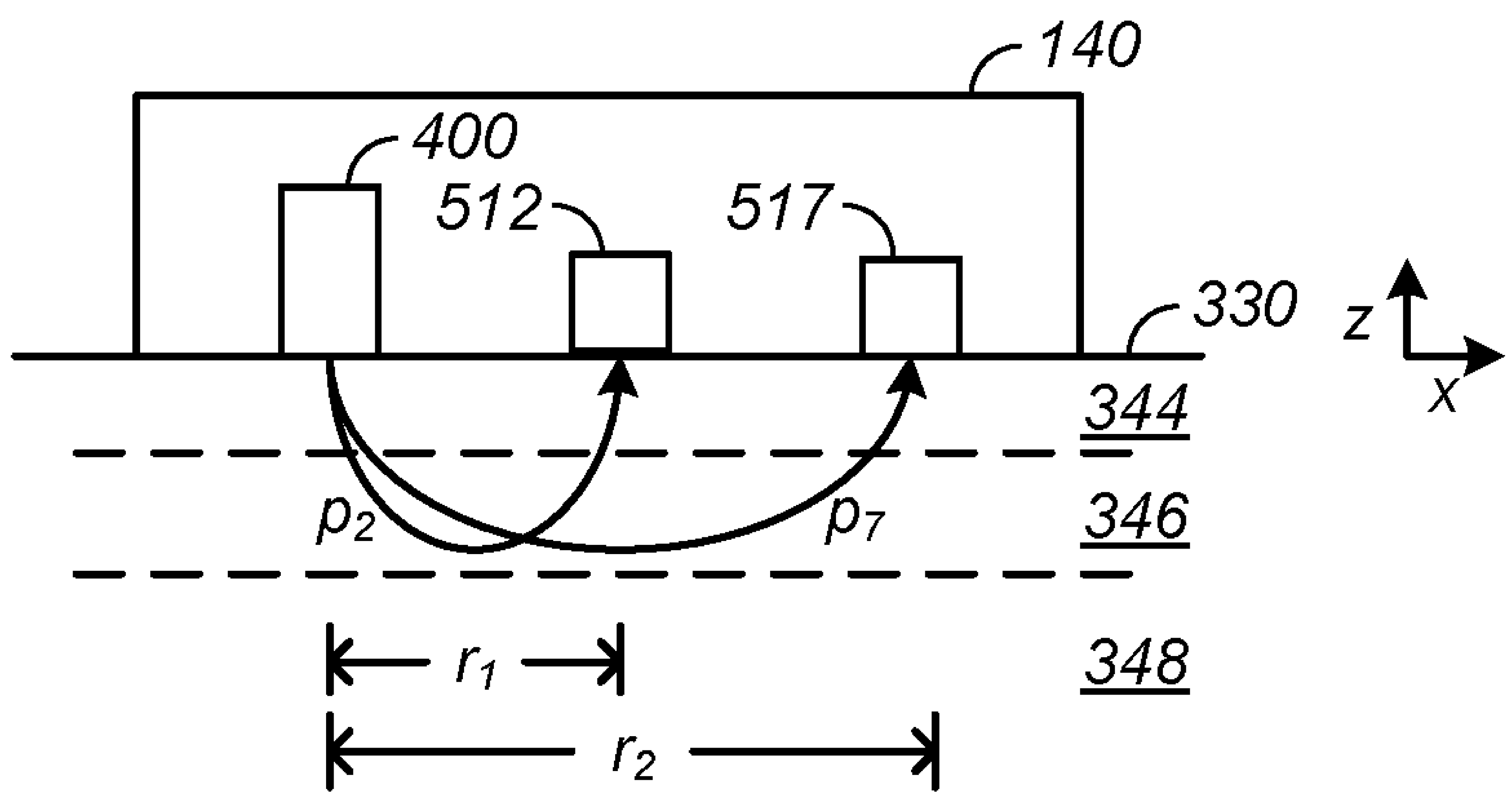

FIG. 15D

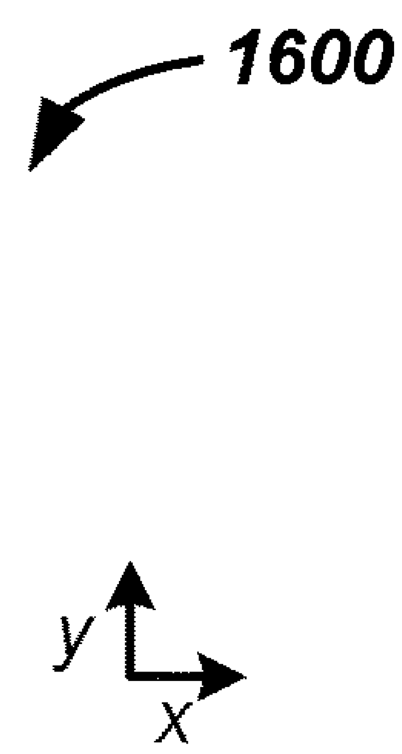

FIG. 16A

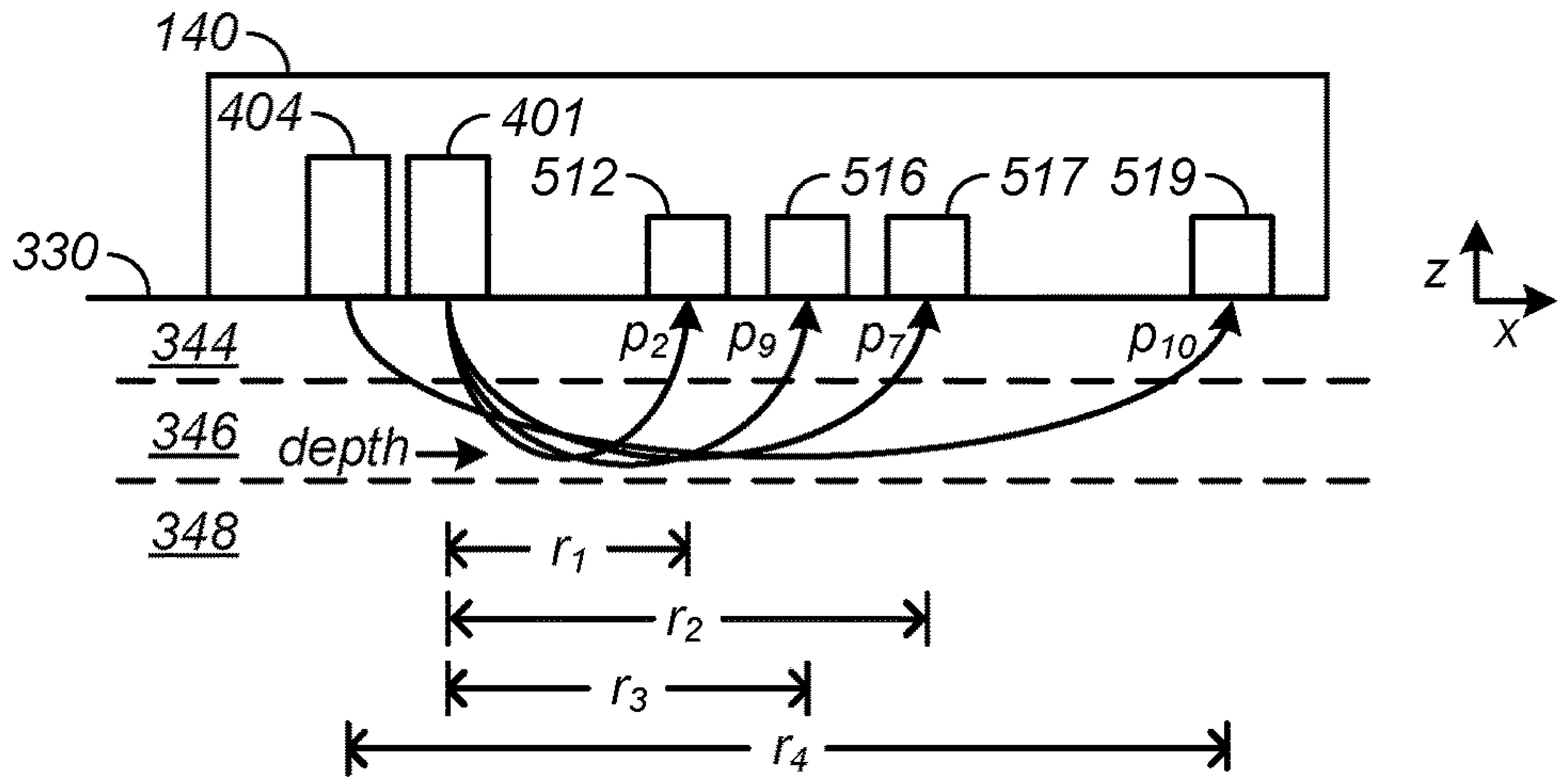

FIG. 16B

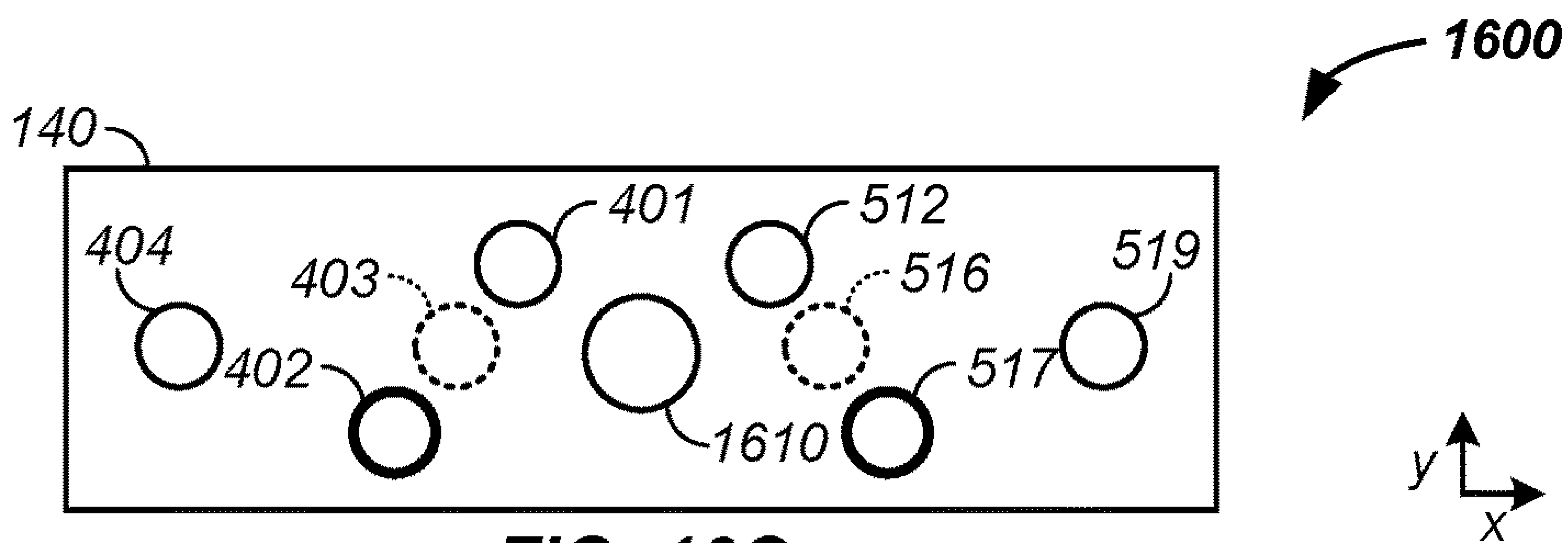

FIG. 16C

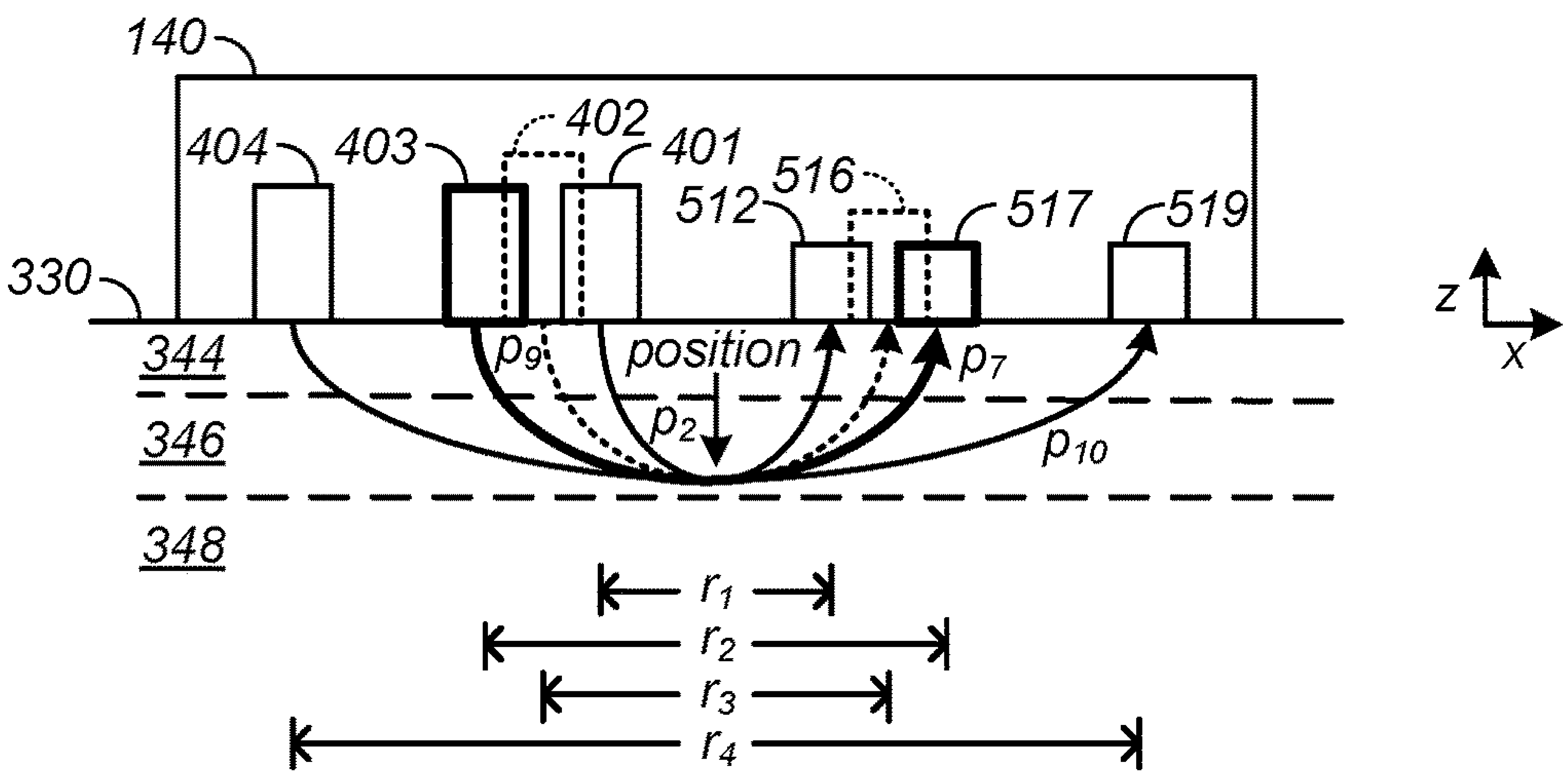

FIG. 16D

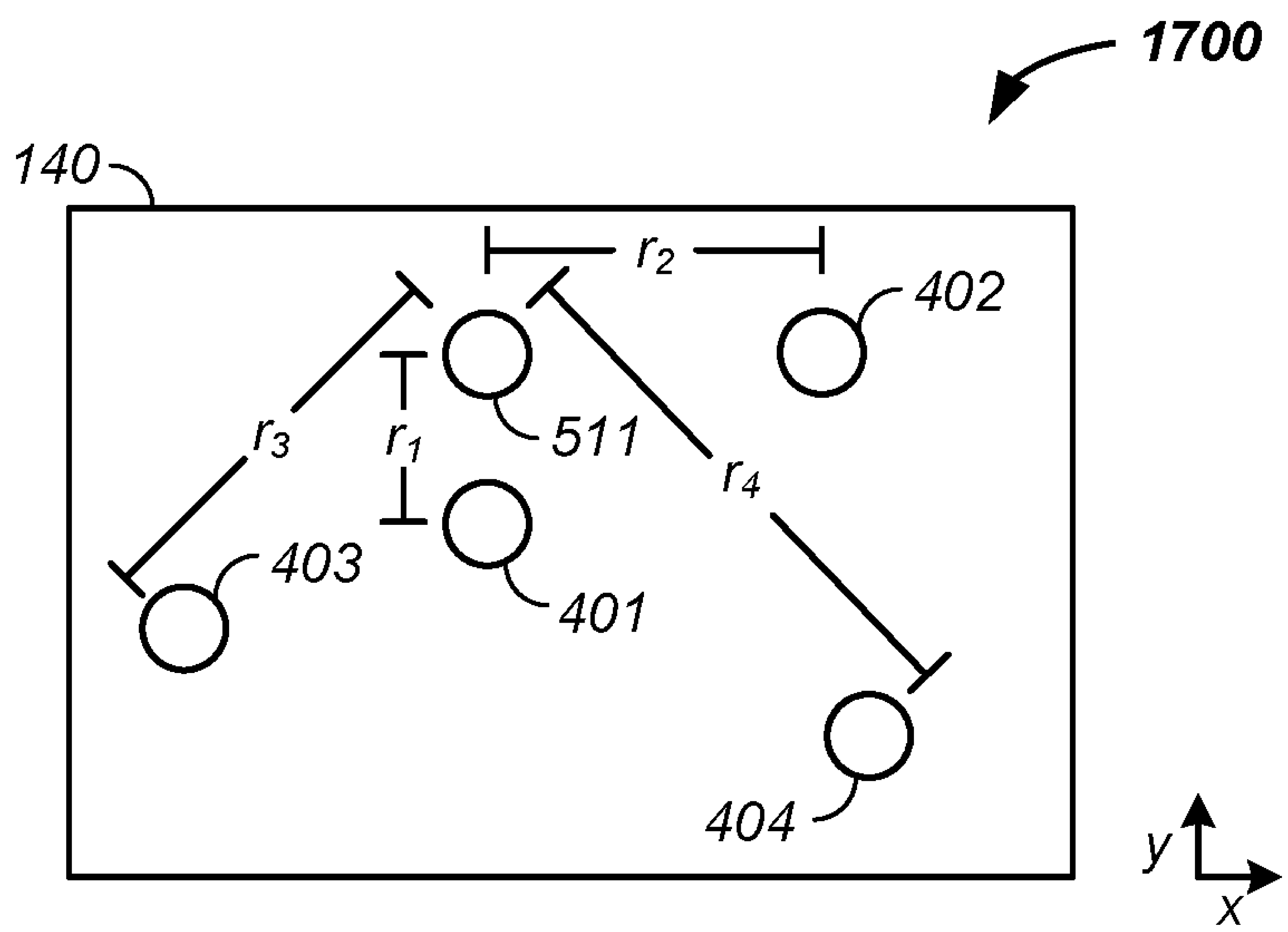
1700
140
r_2
402
r_3
r_1
511
r_4
403
401
404
y
x

FIG. 17

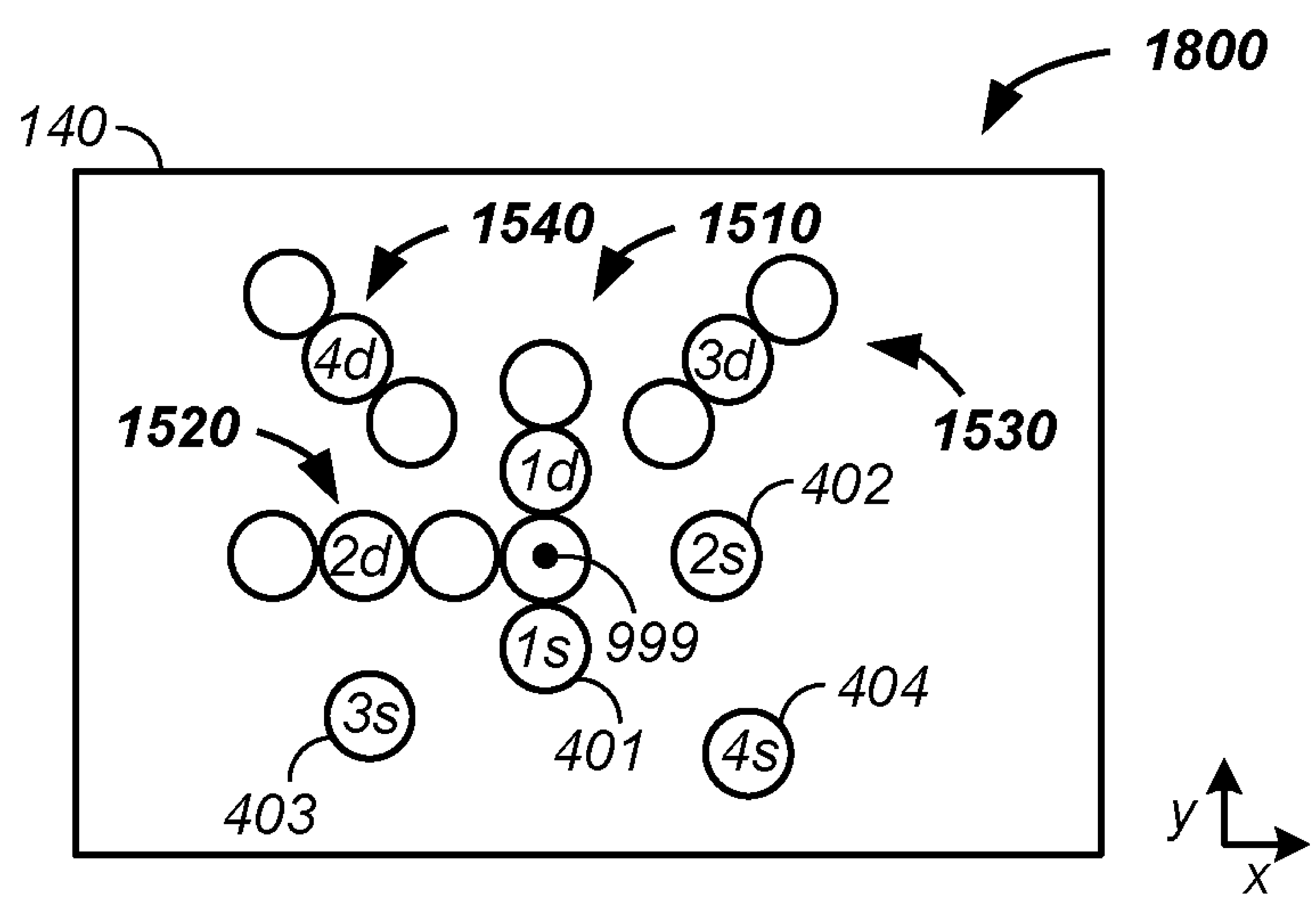
1800
140
1540
1510
4d
3d
1530
1520
1d
402
2d
2s
999
1s
404
3s
4s
401
403
y
x

FIG. 18

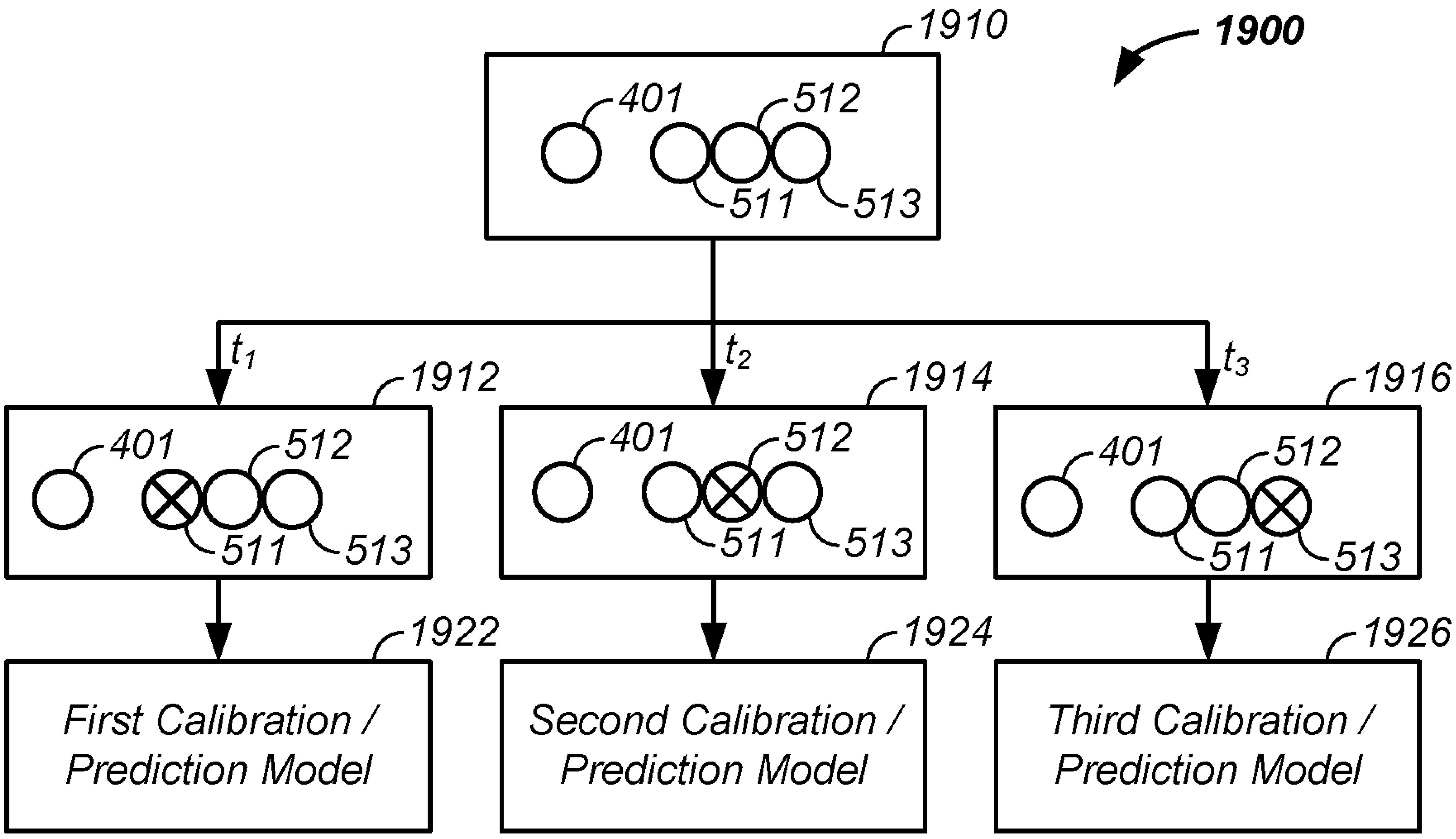

FIG. 19A

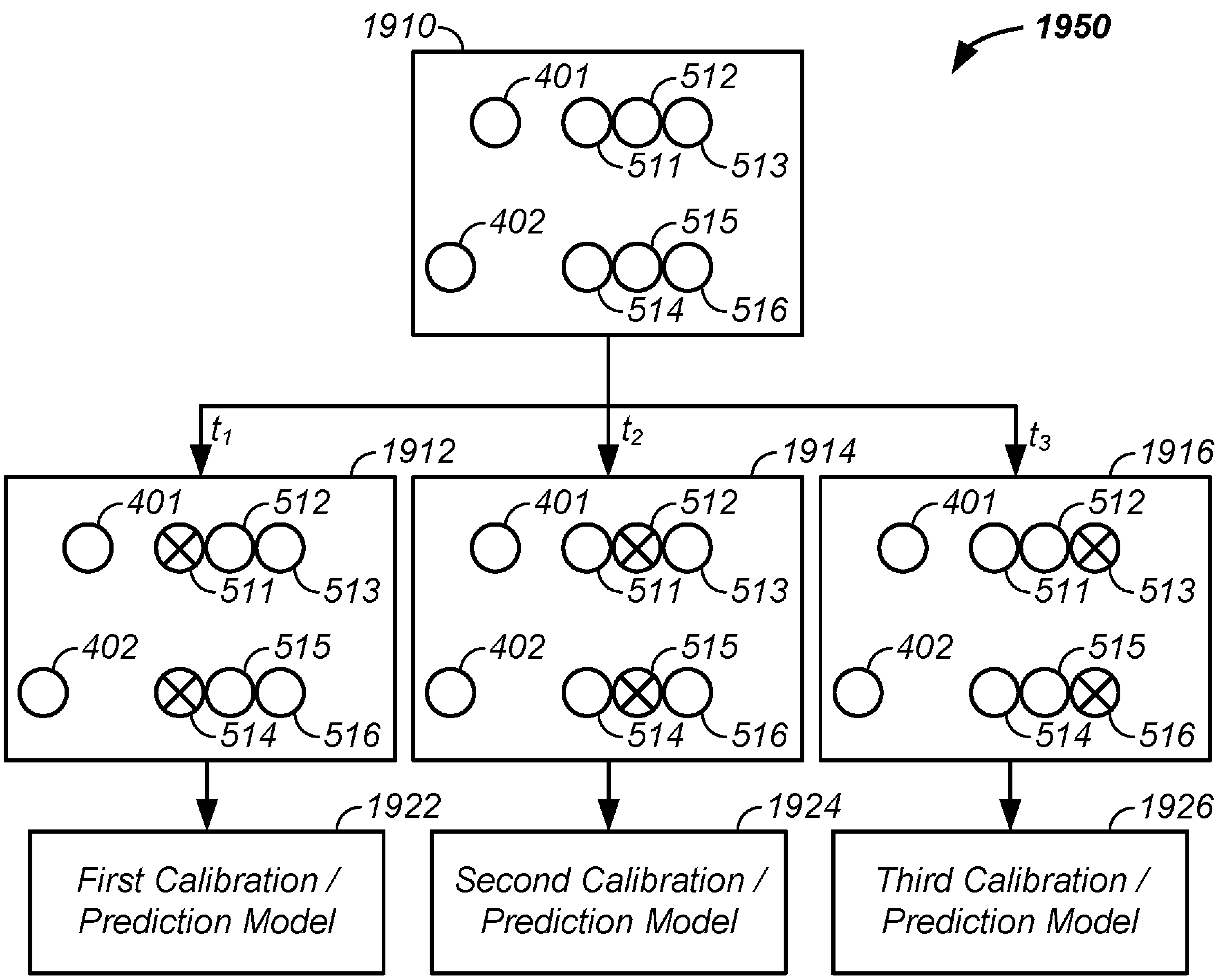

FIG. 19B

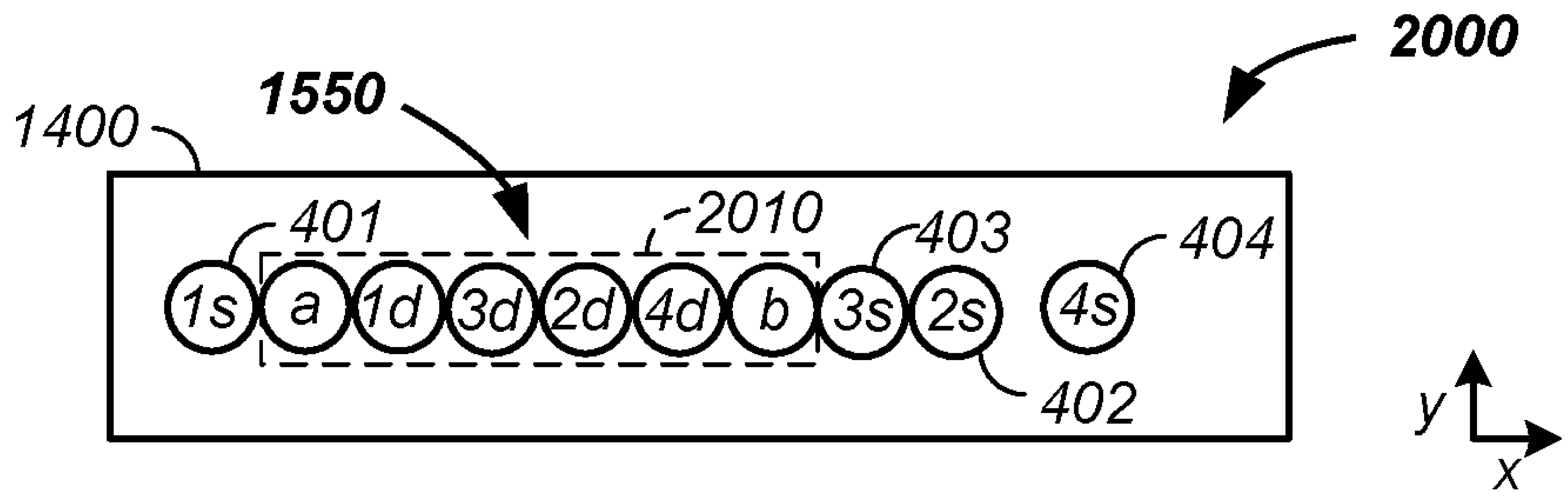

FIG. 20A

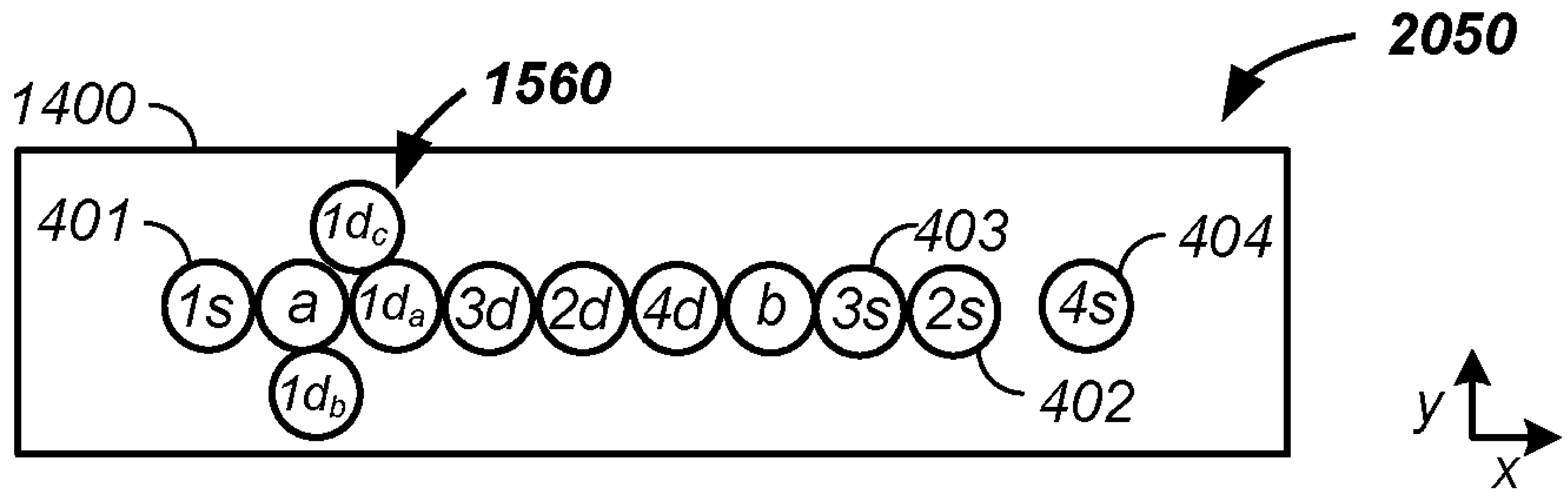

FIG. 20B

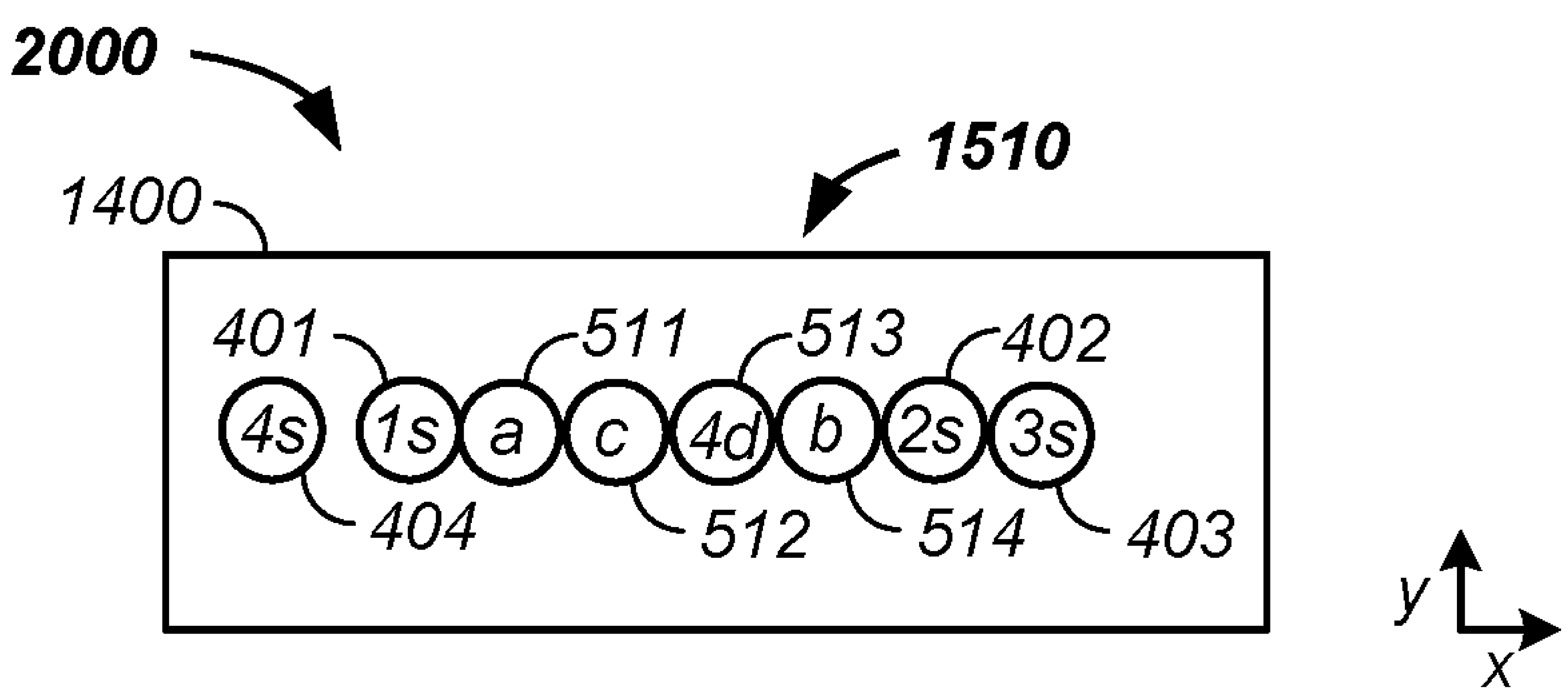

FIG. 21

COMMON SAMPLE DEPTH/ZONE NONINVASIVE GLUCOSE CONCENTRATION DETERMINATION ANALYZER APPARATUS AND METHOD OF USE THEREOF

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is:

a continuation-in-part of U.S. patent application Ser. No. 16/691,611 filed Nov. 22, 2019;

a continuation-in-part of U.S. patent application Ser. No. 16/691,615 filed Nov. 22, 2019; and

a continuation-in-part of U.S. patent application Ser. No. 15/829,877 filed Dec. 2, 2017, which is a continuation-in-part of U.S. patent application Ser. No. 15/636,073 filed Jun. 28, 2017, which claims benefit of U.S. provisional patent application No. 62/355,507 filed Jun. 28, 2016.

BACKGROUND OF THE INVENTION

Field of the Invention

The invention relates generally to noninvasively determining glucose concentration in a living body using an optical analyzer, such as a visible/near-infrared noninvasive glucose concentration determination analyzer.

Discussion of the Prior Art

There exists in the art a need for noninvasively determining glucose concentration in the human body.

SUMMARY OF THE INVENTION

The invention comprises a noninvasive glucose concentration analyzer apparatus and method of use thereof.

DESCRIPTION OF THE FIGURES

A more complete understanding of the present invention is derived by referring to the detailed description and claims when considered in connection with the Figures, wherein like reference numbers refer to similar items throughout the Figures.

FIG. **1** illustrates use of an applied force-optic analyzer;

FIG. **2** illustrates a noninvasive analyzer;

FIG. **3**A illustrates an applied force system, FIG. **3**B illustrates a transducer, FIG. **3**C illustrates transducer movement normal to an optical axis, FIG. **3**D illustrates a z-axis transducer, and FIG. **3**E illustrates a multi-axes off-center spinning mass transducer;

FIG. **4**A illustrates spectrometer components, FIG. **4**B illustrates an affixing layer, and FIG. **4**C illustrates a coupling fluid enhanced affixer;

FIG. **5**A illustrates a force system coupled to a spectrometer and FIG. **5**B illustrates a force system embedded in a spectrometer;

FIG. **6** illustrates photons interacting with applied force wave(s) in tissue;

FIG. **7**A illustrates absorbance of skin constituents, FIG. **7**B illustrates fat and protein absorbance, FIG. **7**C illustrates intensity as a function of depth/distance, and FIG. **7**D illustrates scattering;

FIG. **8** illustrates detector selection;

FIG. **9** illustrates changing detector selection with tissue change;

FIG. **10**A illustrates a transducer force applicator and FIG. **10**B and FIG. **10**C illustrate transducer force detectors in lines and arcs respectively;

FIG. **11**A illustrates radial optical detection of force waves, FIG. **11**B illustrates an array of optical detectors, and FIG. **11**C illustrates arcs of optical detectors;

FIG. **12** illustrates optical probes observing tissue modified by force waves in a noninvasive glucose concentration determination system/analyzer;

FIG. **13** illustrates a multi-sensor analyzer system;

FIG. **14**A illustrates spirally distributed detectors and FIG. **14**B and FIG. **14**C illustrate depth and radial distance resolution;

FIG. **15**A, FIG. **15**B, FIG. **15**C, and FIG. **15**D illustrate depth selection from various angles in two separate units;

FIG. **16**A, FIG. **16**B, FIG. **16**C, and FIG. **16**D illustrate tissue sample position selection; and

FIG. **17** illustrates a common depth and common detector analyzer probe tip;

FIG. **18** illustrates a common depth and common sample position probe tip;

FIG. **19**A and FIG. **19**B illustrate a first and second tissue classification system, respectively;

FIG. **20**A and FIG. **20**B illustrate a multiplexed common zone sample system; and

FIG. **21** illustrates a common detector/common zone sample system.

Elements and steps in the figures are illustrated for simplicity and clarity and have not necessarily been rendered according to any particular sequence. For example, steps that are performed concurrently or in different order are illustrated in the figures to help improve understanding of embodiments of the present invention.

Problem

There remains in the art a need for a noninvasive glucose concentration analyzer.

DETAILED DESCRIPTION OF THE INVENTION

The invention comprises a method and apparatus for sampling a common tissue volume and/or a common skin layer skin of a person as a part of noninvasively determining an analyte property with an analyzer including: a set of detectors at least partially embedded in a probe housing, the probe housing comprising a sample side surface, the detectors including a first and second range of detection zones of differing radial distances from a first illumination zone and second illumination zone, respectively coupled to separate sources, with surface paths between the sources and detectors overlapping a common skin area during use.

Herein, generally, when describing an optical portion of the applied force-optic analyzer, a z-axis is aligned with a mean direction of the photons in a given sub-portion of the analyzer, such as along a longitudinal path of the photons into skin of a subject, and x- and y-axes form a plane perpendicular to the z-axis, such as at an interface point of incident photons into the skin of the subject. At the point of contact of the applied force-optic analyzer with the biological sample, the z-axis is normal/perpendicular to the sample and the x/y-plane tangentially contacts the sample. For instance, the light moves dominantly along the z-axis along vectors approaching perpendicular to an upper arm of a subject or a patient and the x/y-plane tangentially touches the upper arm along the z-axis. In particular cases, a second x,y,z-axis system is used to describe the sample itself, such as a z-axis being along the longitudinal length of a body part, such as along a digit or a finger or along the length of an arm section and the x/y-plane in this case is a cross-section plane of the body part.

A sample is optionally any material responding to an applied physical force in a manner observed by a probing optical system. However, for clarity of presentation and without loss of generality, the sample is described as a person, subject, patient, and/or a living tissue, such as skin and/or a portion of a human or animal. While the analyzer is described as a noninvasive analyzer probing into and optionally through the outer layers of skin, the noninvasive analyzer is optionally used as and or in conjunction with a minimally invasive glucose concentration analyzer and/or in conjunction with an invasive glucose concentration analyzer.

Herein, an illumination zone and/or an imaging zone is a point, region, or area of intersection of the illumination/imaging beam and/or pulse with an incident surface of the sample to yield a spectrum and/or an image of a desired volume of the sample. Herein, a detection zone is a point, region, or area of the sample sampled and/or visualized by one or more detectors. Similarly, herein an applied force zone is an incident point, region, or area of intersection at which an applied force is applied to the sample and a detected force zone is a point, region, or area of the sample interfacing with a force detector.

Applied Force-Optic Analyzer

Referring now to FIG. **1**, a noninvasive analysis system **100** using an analyzer **110**, such as an applied force-optic analyzer system is illustrated. Generally, an optional force system **200** is used to apply one or more applied forces, physical distortions, and/or force waves to a sample **300**. The applied force travels with a wave front, as a wave, in a pattern of compression and rarefication, and/or as a traveling displacement through the sample **300** or portions thereof. With or without application of the force waves, a spectrometer **140** is used to noninvasively collect spectra of the sample **300** and photometrically determine one or more properties of the sample, such as a glucose concentration. As described infra, the applied force is optionally in the form of an acoustic wave. However, the applied force is optionally and preferably a physical displacement of a portion of skin of a person, where the physical displacement is caused by movement of a mechanical object relative to the body to yield a time varying displacement of skin and/or constituents of the skin by the mechanical object. As described, infra, a variety of force provider technologies are available to variably displace the skin in a controlled manner. For clarity of presentation and without loss of generality, a transducer is used as an example to represent an applied force section of the force system **200**, where a transducer comprises a device that receives a signal/force in the form of one type of energy and converts it to a signal/force in another form. Again for clarity of presentation and without loss of generality, a piezoelectric actuator is used to represent a transducer and an off-center spinning mass is used to represent a transducer. Hence, again for clarity of presentation and without loss of generality, a piezoelectric-optical analyzer or simply a piezo-optic analyzer, a transducer, and/or a transducer force applicator is used to describe any and all applied force electromechanical sources in the force system **200**. Optionally, more than one transducer is used to yield displacement of the surface of the skin/skin, such as at a function of time and/or position.

Referring now to FIG. **2**, use of the analyzer **110** is described. Generally, the analyzer **110** is optionally calibrated using a reference **310** and is used to measure a subject **320**, where the subject **320** is an example of the sample **300**. Optionally and preferably, the analyzer **110** and/or a constituent thereof communicates with a remote system **130** using a wireless communication protocol **112** and/or a wired communication protocol.

Force System

Referring now to FIGS. **3**(A-E), the force system **200** is further described. Generally, the force system **200** comprises a force delivery transducer that directly and/or indirectly contacts the sample **300**, such as an outer skin surface **330** of the subject **320** and/or a patient. The subject **320** has many skin layers **340**, which are also referred to herein as tissue layers. For clarity of presentation, the skin layers **340** are represented as having a first skin layer, such as a stratum corneum **342**; a second skin layer, such as an epidermis **344** or epidermal layer; a third skin layer, such as a dermis **346** or dermis layer; and a fourth layer, such as subcutaneous fat **348** or a subcutaneous fat layer. It is recognized that skin is a complex organ with many additional layers and many sub-layers of the named layers that vary in thickness and shape with time. However, for clarity of presentation and without loss of generality, the stratum corneum, epidermis, dermis, and subcutaneous fat layers are used to illustrate impact of the force delivery transducer on the skin layers **340** of the subject **320** and how the applied force waves alter optical paths of probing photons in the spectrometer **140** of the analyzer **110** in the noninvasive analysis system **100**.

Still referring to FIG. **3**A, at a first time, t_1, the tissue layers **340** are in a first state. As illustrated, the tissue layers **340** are in a compressed state **340**, such as a result of mass of the force system **200** sitting on the skin surface **330**, as a result of dehydration of the subject **320**, and/or as a result of a physiological and/or environmental force on the tissue layers **340** of the subject. At a second time, t_2, the force system **200** applies a force wave **250** to the skin surface **330** of the patient **320**, which sequentially propagates into the stratum corneum **342**, epidermis **344**, dermis **346**, and given enough force into the subcutaneous fat **348**. In additional to the force wave propagating into the skin layers **340** along the z-axis, the force wave propagates radially through the skin layers, such as along the x/y-plane of the skin layers. As illustrated at the second time, t_2, as the force wave **250** propagates into the tissue layers **340**, the tissue layers expand and/or rarefy, such that the thickness of the epidermis **344** and/or the dermis **346** layers expands. The rarefication of the epidermis **344** and particularly the dermis **346** allows an increased and/or enhanced perfusion of blood **350** into the rarefied layers. The increased prefusion increases water concentration in the perfused layers, increase and/or changes distance between cells in the perfused layers, and/or changes shapes of cells in the perfused layers, such as through osmolarity induced changes in concentration in and/or around blood cells, such as red blood cells. Generally, scattering coefficients of the epidermis layer and/or especially the dermis layer changes, which is observed by the spectrometer **140** in the range of 400 to 2500 nm with larger changes at smaller wavelengths in the visible, 400 to 700 nm, and/or near-infrared, 700 to 2500 nm, regions. As illustrated at the third time, t_3, as the force wave **250** continues propagation in the tissue layers **340**, the perfusion **350** continues to increase, such as to a maximum perfusion. As illustrated at the fourth time, t_4, after discontinuation of the force wave **250**, the skin layers **340** revert toward the initial state of the non-force wave induced perfusion to a local minimum perfusion, which may match the initial perfusion, is likely higher than the initial perfusion, and is at times less than the initial perfusion due to changes in state of the environment, such as temperature, and/or generalized state of the subject **320**, such as hydration, localized hydration of skin, such as due to food intake, insulin response to food intake, exercise level, blood pressure, and/or the like. Generally, the tissue layers **340** of the subject increase in thickness and/or rarefy during application of the transducer applied force wave **250** and decrease and/or compress after termination of the transducer applied force wave **250** to the skin surface **330** of the subject **320**. The process of applying the force wave **250** is optionally and preferably repeated n times, where n is a positive integer of greater than 1, 2, 5, 10, 100, 1000, or 5000 times in a measurement period of an analyte of the subject **320**, such as a glucose concentration. Generally, the cycle of applying the force wave **250** results in a compression-rarefication cycle of the tissue that alters an observed scattering and/or absorbance of probing photons in the visible and near-infrared regions. The force wave **250** is optionally and preferably applied as a single ping force in a tissue state classification step, as multiple pings in a tissue classification step, and/or as a series of waves during a tissue measurement step. Individual waves of a set of force waves are optionally controlled and varied in terms of one or more of: time of application, amplitude, period, frequency, and/or duty cycle.

Still referring to FIG. **3**A and referring now to FIGS. **3**(B-D), a force wave input element **210** of the force system **200** is illustrated. As illustrated, the force wave input element **210**, such as a transducer **220**, is equipped with one or of: a left transducer **221**, a right transducer **222**, a front transducer **223**, a back transducer **224**, a top transducer **225**, and/or a bottom transducer **226**. For instance, the left and/or right transducers **221**, **222** move the force wave input element **210** left and/or right along the x-axis; the front and/or back transducers **223**, **224** move the force wave input element **210** forward and/or back along the y-axis; and/or the top and bottom transducers **225**, **226** move the force wave input element **210** up and/or down along the z-axis along and/or into the skin surface **330** of the subject **320**, which moves the skin, skin layers **340**, and/or skin surface **330** of the subject relative the spectrometer **140** and/or is a source of the force wave **250** moving, in the skin layers **340**, along the z-axis into the skin, and/or radially outward from an interface zone of the force wave input element **210** of the force system **200**. A transducer itself is optionally used as the force wave impulse element **210**. Referring now to FIG. **3**E, one or more off-center mass elements **230** is optionally spun or rotated, such as with an electric motor, along one or more of the x,y,z-axes to move the force wave input element **210** relative to the skin surface **330** of the subject **320** resulting movement of the skin of the subject **320** relative to the spectrometer **140** and/or cycling and/or periodic displacement of the tissue layers **340** of the subject **320** due to movement of the force wave input element **210** resulting in the force wave(s) **250**. Generally, the force system **200** induces a movement of a sampled zone of skin of the subject **320**, applies a displacement of a sampled zone of the skin of the subject **320**, and/or applies a propagating force wave into and/or through a sample zone of tissue layers **340** of the subject, where the sampled zone/area is probed using photons from the spectrometer **140** and/or is measured using a set of detection zone/area transducers, described infra. The force wave(s) are optionally and preferably applied as a single input ping wave, a set of input ping waves, and/or are applied with a frequency of 0.01 Hz to 60 Hz. Optionally and preferably, the force waves **250** are applied with a frequency greater than 0.01, 0.02, 0.05, 0.1, or 1 Hz. Optionally and preferably, the force waves **250** are applied with a frequency of less than 200, 100, 50, 40, 30, or 20 Hz. Optionally and preferably, the force waves **250** are applied with a frequency within 5, 10, 25, 50, or 100 percent of 2, 4, 6, 8, 10, 12, 15, and 20 Hz.

Optical System

Referring now to FIG. **4**A, the spectrometer **140** of the analyzer **110** is further described. The spectrometer **140** comprises a source system **400**, which provides photons **452** in the visible and/or infrared regions to the subject **320**, such as via a photon transport system **450**, at an illumination zone/illumination area. After scattering and/or absorbance by the tissue layers **340** of the subject **320**, a portion of the photons are detected at a detection zone/detection area by a detector system **500**. The source system **400** includes one or more light sources, such as any of one or more of a light emitting diode, a laser diode, a black body emitter, and/or a white light source, that emits at any wavelength, range of wavelengths, and/or sets of wavelengths from 400 to 2500 nm. Each source system photon source is optionally controlled in terms of time of illumination, intensity, amplitude, wavelength range, and/or bandwidth. The photon transport system **450** comprises any fiber optic, light pipe, air interface, air transport path, optic, and/or mirror to guide the photons from the light source to one or more illumination zones of the skin surface **330** of the subject **320** and/or to guide the photons from one or more detection zones of the skin surface **330** of the subject **320** to one or more detectors of the detector system **500**. Optionally and preferably, the photon transport system **450** includes one or more optical filters and/or substrates to selectively pass one or more wavelength regions for each source element of the source system **400** and/or to selectively pass one or more wavelength ranges to each detector element of the detector system **500**. Herein, the reference **310** is optionally an intensity and/or wavelength reference material used in place of the sample and/or is used in a optical path simultaneously measured by the analyzer **110**.

Still referring to FIG. **4**A and referring now to FIG. **4**B and FIG. **4**C, the subject **320** optionally and preferably wears the analyzer **110** in the physical form of a watch head, band, and/or physical element attached to the body with a band and/or an adhesive. For example, the analyzer **110**, the spectrometer **140**, the source system **400**, and/or the photon transport system **450** is optionally attached to the subject **320**, such as at the wrist or upper arm, using thin affixing layer **460**, such as a double sided adhesive **462**. Referring now to FIG. **4**B, the double sided adhesive **462** optionally contains an aperture **464** therethrough. The photons **452** optionally and preferably pass through the aperture **452** to the skin surface **330** of the subject. The force wave **250** optionally moves the skin surface **330** through the aperture into intermittent contact with the analyzer **110**.

Optionally, referring now to FIG. **4**C, a thin affixing layer **466**, such as less than 1, 0.5, or 0.25 mm thick, is continuous in nature in front of the incident surface and/or incident photon coupling zone and/or is continuous in nature in front of the detection zone, where photons exiting the skin surface **330** are detected by the detector system **500**. The affixing layer **466** is optionally permeated with a fluid, such as a coupling fluid, an air displacement medium, an optical coupling fluid, a fluorocarbon liquid, a fluorocarbon gel, an index of refraction matching medium, and/or any fluid that increases a percentage of photons from the source system **400** entering the skin surface **330** compared to an absence of the fluid and/or is any fluid that increases a percentage of photons from the tissue layers **340** exiting the detection zone and reaching the detector system **500** as compared to a case where the fluid is not embedded into the affixing layer. Hence, the affixing layer serves several purposes: attaching the analyzer or a portion thereof to the skin surface **330** of the subject **320**, coupling forces from the force system **200** to the skin surface **330** of the subject **320**, forming a constant sampling interface location on the skin surface **330** of the subject, and/or altering a coupling efficiency, angular direction, and/or reproducibility of coupling of photons enter the skin of the subject **320** and/or exiting the skin surface **330**.

Coupled Force System/Spectrometer

Referring now to FIG. **5**A and FIG. **5**B, the force system **200** is illustrated working in conjunction with the spectrometer **140**. Referring now to FIG. **5**A, the analyzer **110** is illustrated with the force system **200** being attached to and/or within 1, 2, 3, 5, 10, 20, or 50 mm of the spectrometer **140**. Referring now to FIG. **5**B, the analyzer **110** is illustrated with the force system **200** being integrated into the spectrometer **140**, such as within 20, 10, 5, 2, or 1 mm of the source system **400** of the analyzer **110** and/or in a single housing unit of the analyzer **110**.

Several examples are provided that illustrate how the force system **200** alters the tissue layers **340** of the subject **320** and how a selection of detected signals from the spectrometer **140** is performed as a function of time and respective radial separation between the one or more illumination zones and the one or more detection zones, such as using water signal, fat signal, and/or protein signal to determine the correct detection signals to use for noninvasive glucose concentration determination.

Example I

Referring now to FIG. **6**, a first example of the analyzer **110** using the force system **200** and the source system **400** at the same time and/or within less than 60, 30, 15, 10, 5, or 1 second of each other is provided. In this example, the force system **200** applies a force to the tissue layers **340** at a first time, t_1, when the dermis has a first mean z-axis thickness, th_1. Optionally and preferably, the analyzer **110** acquires signals representative of the tissue layers **340** of the subject **320** using the source system **400** and the detector system **500**. Illustrated are three representative photon pathways, p_{1-3}, reaching the detector system **500**, such as at a first detector element, a second detector element, and a third detector element, respectively, at the first time, t_1, and/or within less than 60, 30, 15, 10, 5, or 2 seconds from the first time, t_1. Notably, at the first time, the first photon pathway, p_1, has an average path that does not penetrate into the dermis **346**, while the second and third photon pathways, p_{2-3}, have mean pathways that penetrate through the dermis into the subcutaneous fat **348**.

In at least one preferred use of the analyzer, noninvasive glucose concentration determination is performed using a mean photon pathway that penetrates into the dermis **346** and not into the subcutaneous fat **348** and/or uses signal from a detector element at a first/minimal radial distance from the illumination zone, where the first/minimal radial distance is the smallest radial distance observing an increase in a fat signal/dominantly fat related signal, such as from the subcutaneous fat **348**, compared to a water signal/dominantly water related signal from skin layers **340** closer to the skin surface **332** than that subcutaneous fat **348**.

Examples of wavelengths containing dominantly water absorbing signals are wavelengths correlating with the peaks of the water absorbance bands **710**, FIG. **7**A, and/or peaks of the protein absorbance bands, FIG. **7**B, and examples of wavelengths containing an increased fat absorbance to water absorbance ratio when a mean photon path enters the subcutaneous fat **348** are at the fat absorbance bands **720**. For instance, a protein band-to-fat band ratio optionally compares the protein absorbance band **730**, such as at 1690 nm, with the fat absorbance band **720**, such as at 1715 nm, where either range is ±5 or ±10 nm. Still referring to FIG. **6**, at a second time, t_2, the force wave **250** from the force system **200** has expanded the dermis layer to a second thickness, th_2, which is at least 0.1, 0.2, 0.3, 0.5, 1, 2, 5, 10, 20, or 50% thicker than the first thickness, th_1, and/or has an increased water absorbance, as measure by the first, second, and/or third detector element of the detector system **500**, representative of the first through third photon pathway, p_{1-3}, in the condition of the larger dermis thickness at the second time, t_2, as represented by a fourth, fifth, and sixth photon pathway, p_{4-6}. Notably, the fifth and sixth photon pathways, $p_{5,6}$, with the same illumination zone to detection zone radial distance as the first and second photon pathways, p_{1-2}, have mean photon pathways that penetrate into the dermis **346** and not into the subcutaneous fat **348**. Thus, the water-to-fat ratio and/or the protein-to-fat absorbance ratio of the observed signal continues to increase with radial distance for the second and third detectors after the force system **200** increased the thickness of the dermis **346** to the second thickness, th_2.

Again, at least one preferred measurement/metric is a measurement with a higher water-to-fat absorbance ratio and/or a higher protein-to-fat absorbance ratio as the metric indicates that the photons are sampling the dermis **346** without undue sampling of the subcutaneous fat **348**, where the metric is used with or without an applied displacement force from the transducer. In this example, at the second time, the water-to-fat absorbance ratio of the fifth optical path, p_5, is greater than observed with the second optical path, p_2, despite have the same source zone-to-detector zone radial distance. Further, in this example a preferred optical signal is from the sixth optical path, th_6, at the second time, t_2, with a largest ratio of mean pathlength in the dermis **346** to total mean detected pathlength. For illumination zone-to-detector zone distances established to sample the dermis **346**, as discussed infra, determining a current thickness of the protein/water rich dermis **346** yields knowledge of an appropriate glucose illumination zone-to-glucose detection zone, such as for photons in the range of 1500 to 1600 nm, probing the dermis **346** as glucose is soluble in the water rich dermis **346**.

Referring now to FIG. **7**C, for clarity of presentation and without loss of generality, a particular metrics **760**, such as a fat band metric, a protein band metric, and/or a water band metric are illustrated. As illustrated, a first signal **722** related to the fat absorbance band **720** decreases in intensity with radial distance between an illumination zone and a detection zone. The decrease in intensity with radius for a first radial distance, r_1, a second radial distance, r_2, and a third radial distance, r_3, relates dominantly to a decreased photon density as a function of distance from the illumination zone, scattering, and water absorbance. However, a rapid first change in intensity, ΔI_1, is observed between the third radial distance, r_3, and the fourth radial distance, r_4, which at wavelengths related to the fat absorbance band **720**, such as about 1710 nm, indicates that a larger concentration of fat is observed to begin between the third and fourth radial distances indicating that the mean maximum depth of penetration of the probing photons has crossed from the dermis

346 into the subcutaneous fat 348. Hence, the large first change in intensity, ΔI_1, at the fourth radial distance indicates that a radial distance corresponding to a maximum depth of penetration sampling the dermis 346 is the third radial distance, r_3. Similarly, the second signal 732 related to the water absorbance 710 and/or the protein absorbance 720 has a trend breaking second change in intensity, ΔI_2, between the third radial distance, r_3, and the fourth radial distance, r_4, which indicates that the second probing photons at a wavelength dominated by a water absorbance, such as at 1450±10, 20, 30, 40, 50, 60, or 70 nm, or a protein absorbance, such as at 1690±5 or 10 nm, are observing a lower concentration of the water and/or protein, such as by crossing the same dermis-subcutaneous fat interface. Hence, any of the metrics related to water, protein, and/or fat are used independently and/or in any mathematical relationship, such as a ratio or derivative, to find a first sample probe geometric distance, between a first illumination zone and a first detection zone, associated with a first maximum mean depth of penetration in the glucose rich dermis layer 346, such as at the first radius, r_3, and/or a second sample probe geometric distance associated with a second maximum mean depth of penetration in the glucose poor subcutaneous fat layer 348, such as at the fourth radius, r_4.

FIG. 7D illustrates increased scattering with decreasing wavelength at a first scattering coefficient, μ_{s1}, 740 and a second scattering coefficient, μ_{s2}, 750. Optionally and preferably, an expected decrease in observed intensity with increasing radial distance between a given illumination zone and a given detection zone includes use of a scattering coefficient, which is wavelength dependent.

Example II

Referring now to FIG. 8, a second example is provided where the analyzer 110 uses the force system 200 to alter the sample 300 to enhance a noninvasive analyte property determination using the spectrometer 140. As above, the force system 200 provides one or more force waves 250 into the subject 320, which alters positions of cells 260 in the dermis 346 relative to the illumination zone of the illumination system 400 and or relative to one or more detection zones associated with a single element detector and/or one or more detectors of an array of detector elements 510. As illustrated, the cells 360 have a first average intercellular distance at a first time, t_1, which is altered by application of the force wave 250 to a second average intercellular distance at a second time, t_2, where the net change in cell position alters detected spectrophotometric absorbance signals at a give detector element of the detector system 500 by greater than 0.01, 0.02, 0.05, 0.1, 0.5, 1, 2, 5, or 10 percent, such as by a change in observed scattering and/or observed absorbance at a fixed radial distance between an illumination zone and a detection zone. Similarly, the average percentage volume of the intercellular fluid 350 in the dermis layer differs by greater than 0.01, 0.02, 0.05, 0.1, 0.5, 1, 2, 5, or 10 percent as a result of the applied force wave(s) 250. All of a change in thickness, change in observed mean pathlength, change in radial distance of detection, change in mean intercellular spacing, change in scattering, and change in water concentration, related to perfusion, are illustrated between the first time, t_1, and the second time, t_2, as a result of the applied force wave 250. Notably, a selected detector signal from the array of detectors 510 changed from a second detector 512/second detector element/second detection system at a first radial distance, r_1, from the illumination zone to a fourth detector 514 at a second radial distance, r_2, from the illumination zone based on the above described larger observed water signal-to-observed fat signal ratio and/or as the second pathlength, b_2, is longer than the first pathlength, b_1, in the dermis layer. Similarly, absorbances of skin constituents, such as protein, albumin, globulin, keratin, and/or elastin increase relative to fat absorbance for the second pathlength, b_2, as the mean pathlength spends more time in the dermis layer compared to the subcutaneous fat layer 348, as described supra.

Example III

Referring now to FIG. 9, a third example of using the force system 200 to alter properties of the subject 330 to enhance performance of a noninvasive glucose concentration determination using the spectrometer 140 is provided. In this example, the detector array 510 of the detector system 500 contains n detector elements at differing radial distances from a time correlated illumination zone. For clarity of presentation, the detector array 510 is illustrated with four detector elements: a first detector 511/first detector element/first detector system, a second detector 512/second detector element second detector system, a third detector 513/third detector element/third detector system, and a fourth detector 514/fourth detector element/fourth detector system. At a first time, t_1, the large water absorbance, protein absorbance, and/or protein and water absorbance-to-fat ratio is observed using the second detector 512 having a first illumination zone-to-detection zone radial distance, r_1, and a first mean optical pathway, d_1, penetrating into the dermis 346 with minimal to no mean penetration into the subcutaneous fat 348. However, at a second time, t_2, after the provided force wave 250 has altered the skin of the subject 320, the third detector element is observed, at a selected detection point in time, to have the largest metric for detector selection, such as a smoothly falling observed intensity with radial distance at a fat absorbance wavelength, where a sudden decrease in observed intensity at the fat absorbance wavelength indicates mean penetration of the observed optical pathway into the subcutaneous fat 348, such as at the second radial distance, r_2. Notably, the largest radial distance is selected for a given water, protein, and/or fat based metric as at the larger radial distance a difference between a shortest possible pathlength between the illumination zone and the detection zone, the radial distance, is closest to the largest possible observed pathlength, which is based upon a maximum observable absorbance by a detector type for a fixed number of photons. For example, if the maximum observable absorbance is 3.9 and the absorbance per millimeter is 1.3, then a maximum observable pathlength is 3.0 mm. If the observed radial pathlength is 1.5 mm then a first range of observed pathlengths is 1.5 to 3.0 mm with a difference of 1.5 mm. Hence, a first ratio of observed pathlength difference to radial distance is 1:1 (1.5 mm:1.5 mm), which is a 100% error. However, if the observed radial pathlength is 2.5 mm, then a second range of observed pathlengths is 2.5 to 3.0 mm with a difference of 0.5 mm. Hence, a second ratio of observed pathlength difference-to-radial distance is 1:5 (0.5 mm:2.5 mm), which is a second pathlength error of 20% or one-fifth of the pathlength error of the first case. In general, the largest radial distance yielding and intensity-to-noise ratio beyond a threshold, such as 0.5, 1, 1.5 or 2, is preferred as error in a range of observed pathlengths decreases, which reduces the error in b, in Beer's Law: equation 1,

$$A = \text{molar absorptivity} * b * C \quad \text{(eq. 1)}$$

where A is absorbance, b is pathlength, and C is concentration, which is central to visible and near-infrared absorbance and/or scattering models used to determine an analyte property, such as a noninvasive glucose concentration as measured using photons optically probing skin.

Skin State Classification

Skin state is optionally classified using a single force pulse or single impulse function, also referred to herein as a ping. Generally, an applied force, such as the force wave **250** provided by the force system **200**, takes time to propagate through the subject **320**. The travel time of the force wave varies as a function of state of the body, such as hydration, temperature, glucose concentration, triglyceride concentration, hematocrit and/or any constituent of skin, blood, and/or interstitial fluid. Hence, the amount of time to travel radial distances to force wave detectors is optionally used to classify the state of the subject and/or to map the state of the subject in regions probed by the force wave. For clarity of presentation and without loss of generality, two example of force wave detection are provided here using: (1) a transducer force detector and/or (2) an optical force wave classifier.

Example I

Referring now to FIGS. **10**(A-C), transducer force detectors are optionally used to detect transit times of the force wave **250** from the force wave input element **210** to one or more detectors of a set of transducer force detectors **260**. Generally, a transducer force detector converts mechanical motion, such as passage of the force wave **250** and/or skin movement into a measured electrical signal. Referring now to FIG. **10**A, for clarity of presentation and without loss of generality, a first transducer force detector **262**, a second transducer force detector **264**, and a third transducer force detector **266** are illustrated that represent n transducer based force detectors, where n is a positive integer of greater than 1, 2, 3, 5, 10, or 20. As illustrated in FIGS. **10**B and **10**C, the n transducer based force detectors are optionally positioned in a linear array, in a two-dimensional array, and/or along arcs, such as at differing radial distances from one or more light sources in the source system **400**. Referring still to FIG. **10**A, as illustrated, at a first time, t_1, the force wave **250** has propagated to the first transducer force detector **262** as a first wave front position **254**; at a second time, t_2, the force wave **250** has propagated to the second transducer force detector **264** as a second wave front position **256**; and at a third time, t_3, the force wave **250** has propagated to the third transducer force detector **266** as a third wave front position **258**. Timing of each wave front to each transducer based force wave detector allows: (1) generation of a sub-surface tissue map of constituents of the skin of the subject **320** using mathematical techniques used for seismic mapping known to those skilled in the art of seismic mapping and/or (2) a classification of state of the subject **320** versus a calibration set of classifying states of force wave propagation radial translation times. For instance, the classification is as simple as slow, medium, or fast translation times to a given transducer detector or a more involved combination of translation times for one or more of: (1) responses at a single detector position and (2) responses at a set of detector positions and/or responses to varying inputs of the force wave, such as time, direction, amplitude, and/or frequency of one or more pings from the force wave input elements and/or time varying induced applied pressure and/or displacement of a portion of the skin of the subject **320** by the force system **200**.

Example II

Referring now to FIGS. **11**(A-C), propagation of the force wave(s) **250**, such as force wave fronts **254**, **256**, **258** is detected using a set of optical detectors and using the results in a manner similar to detecting the force wave **250** using the set of transducer based wave detectors. For instance, as the force wave **250** propagates through the tissue layers **340**, the density, absorbance, and/or scattering of voxels of the skin of the subject **320** change, which alters an observed mean optical path between a given source of photons and a photon/photonic detector. One or more sources of the source system **400** coupled to the array of optical detector elements **510** via the subject **320** is optionally used to detect propagation times of the force wave(s) **250**. For clarity of presentation and without loss of generality, a first optical detector **521**, a second optical detector **522**, and a third optical detector **523** are illustrated that represent n optical detectors, where n is a positive integer greater than 0, 1, 2, 3, 5, 10, 15, 16, 20, 25, 100, 500, 1000, and 5000. As illustrated in FIGS. **11**B and **11**C, the n optical detectors are optionally positioned in a linear array, in a two-dimensional array, and/or along arcs, such as differing radial distances from one or more light sources in the source system **400** and/or from one or more force wave sources. Notably, one or more detectors of the array of optical detector elements **510** are optionally and preferably used to detect photons from the source system **400** during a measurement phase of an analyte and/or tissue property with or without a tissue classification step. As illustrated, the first optical detector **521** detects a first optical signal, modified by the force wave **250**, with a first pathlength, p_1, at a given point in time; the second optical detector **522** detects a second optical signal, modified by the force wave **250**, with a second pathlength, p_2, at the given point in time; and the third optical detector **523** detects a third optical signal, modified by the force wave **250**, with a third pathlength, p_3, at the given point in time. Each detected optical signal contains absorbances due to any sample constituent, such as water, protein, fat, and/or glucose and/or is representative of state of the tissue, such as a measure of scattering and/or temperature. As the force wave(s) propagate through the tissue, the first, second, and third pathlengths, p_1, p_2, p_3, vary. Hence, the state of the subject **320** is optionally characterized and/or mapped in a manner similar to the transducer wave detection classification and/or mapping; however, optical signals with chemical meaning are used in the process, such as detected intensity, absorbance, and/or scattering related to temperature, one or more tissue layer properties, collagen, elastin, water, albumin, globulin, protein, fat, hematocrit, and/or glucose, such as a concentration, change in tissue state, or a physical structure.

Referring again to FIG. **11**A and FIG. **12**A, the applied pressure/force wave/displacement optionally generates a gap and/or varies an applied pressure at a first interface **305** of the source system **400** and the skin surface **330** and/or at a second interface **390** of the detector system **500** and/or any element thereof and the skin surface **330**. A resulting air gap between the analyzer **110** and the subject **320** and/or a time varying change between an air gap and contact between the analyzer **110** and the subject **320** is used to determine times of contact/relative contact, which is in turn optionally and preferably used in a selection of detected signals step, described infra. For example, loss of optical contact yields a sudden increase in observed intensity in a wavelength region of high absorbance, such at as region dominated by water absorbance in the range of 1350 to 1550 nm, 1400 to 1500 nm, and/or within 5, 10, 15, 25, and/or 50 nm of 1450 nm. Removal of non-contacting signals aids in the development of an outlier analysis algorithm and/or in determining state of the tissue and/or in determination of a degree of applied force from the source system **400**, detector system **500**, and/or analyzer **110** to the skin surface **330** of the subject **320** as a function of time and/or position.

Force Wave/Optical Probe Analyte State Determination

Referring now to FIG. **12**, a process of determining an analyte property, such as a glucose concentration, using one or more optical signals optionally and preferably modified by an applied force, force wave, and/or displacement is provided.

Referring still to FIG. **12**, in a process, such as a first process or a second process, a force is applied **1210**, such as in the form of a force wave and/or displacement induced force wave. For example, the force wave/displacement is generated with a transducer to generate application of a transducer force **1212**, which is a single ping **1214**/displacement and/or a series of pings and/or is a force/displacement varied in frequency **1216** and/or varied in amplitude **1218**, such as via a controller, such as a main controller of the analyzer **110**. Subsequently, the force wave **250**/tissue displacement induced pressure propagates in the sample **1220**.

Referring still to FIG. **12**, in another process, such as a first or second process, a result of the tissue displacement induced force wave is measured and/or detected **1230**, such as through a transducer force detection **1232** and/or an optical force detection **1234**.

Referring still to FIG. **12**, in still another process, such as a second and/or third process, selection of a sub-set of detected signals **1240** is performed, such as a function of position **1241**, time **1242**, detector **1243**, contact **1244**, pressure **1245**, and/or spectroscopic response **1246** and an analyte state is determined **1250**, such as via generation of a calibration **1252** and/or use of a generated calibration in a prediction step **1254**.

Multiple-Sensor System

Referring again to FIG. **4**A and referring now to FIG. **13**, the analyzer **110** optionally comprises multiple sub-sensor systems that operate independently to collect data but operate in concert for determination of state of the subject **320**. For instance the spectrometer **140** optionally comprises a first spectrometer version/system **142** connected/affixed to a first part of the subject **320**, such as on the arm of the subject **320**, and a second spectrometer system/version **144** connected/affixed to a second part of the subject **320**, such as on the leg of the subject **320**. Optionally, the spectrometer **140** is affixed to any part of the body, such as an ear lobe, webbing of the hand, forehead, torso, limb, arm, or leg.

Still referring to FIG. **13**, generally, the spectrometer **140** refers to n spectrometers/analyzers, where each of the n spectrometers optionally and preferably collects data independently, where n is a positive integer, such as 1, 2, 3, 4, 5, or more. Optionally, each of the n spectrometers collect and analyze data independently. However, preferably, each of the n spectrometers collect data and after little or no preprocessing, collected data is sent to the analyzer **110**, a central processor, a personal communication device, such as a cell phone **122**, and/or to the web for further processing, which allows a central system to process data from the multiple sub-spectrometer systems.

Still referring to FIG. **13**, optionally, each of the n spectrometers are of the same type and design. However, preferably, each of the n spectrometers are distinct in type and/or design. For instance, the first spectrometer version **142** comprises first sources, optics, and detectors that are directed to measurement of a first constituent/property of the subject **320** and the second spectrometer version **144** comprises second sources, optics, and detectors that are directed to measurement of a second constituent/property of the subject **320**.

Still referring to FIG. **13**, for example, the n spectrometer systems are optionally and preferably configured to interface to separate portions of the body and/or to measure separate and/or overlapping properties/constituents of the subject **320**, such as percent oxygen saturation, heart rate, heart rate variability, glucose concentration, protein concentration, fat, muscle, protein concentration, albumin concentration, globulin concentration, respiration rate, an electrocardiogram, blood pressure, and/or body temperature and/or environmental temperature and/or acceleration of the subject **320**, such as to indicate a fall of the subject **320** and/or an interfering movement of the subject **320** that affects the measurements of the one or more spectrometers **140**.

Still referring to FIG. **13**, herein, for clarity of presentation and without loss of generality, the spectrometer **140** is illustrated as a noninvasive glucose concentration analyzer. However, the spectrometer **140** optionally measures any constituent of the body noninvasively, in a minimally invasive manner, and/or operates in conjunction with a noninvasive, minimally invasive, and/or invasive reference system, such as for calibration and quality control procedures. Examples of a first spectrometer version **142** and a second spectrometer version **144** determining an analyte property is provided, infra.

Example I

Referring still to FIG. **13**, an example of interfacing **1300** the analyzer **110** to an arm **370** of the subject **320** is illustrated. As illustrated, a first analyzer/spectrometer version **371** of the analyzer **110** is coupled to a section of an upper arm **372** of the subject's arm and a second analyzer/spectrometer version **373** of the analyzer **110** is coupled to a forearm/wrist **374** of the patient's arm **320**. Notably, the first analyzer version **371** interfaces to the subject **320** at a first interface zone along a first z-axis perpendicular to a first x/y-axis plane that is tangential to the subject **320** and that is independent and different from a second interface of the second analyzer version **373**, which interfaces to the subject **320** along a second z-axis perpendicular to a second x/y-axis system that is tangential to a second interface zone of the subject. Generally, n analyzers **110**, optionally linked to a single main controller **112**, interface to n interface zones of the subject **320**, where the main controller **112** is optionally and preferably electrically, mechanically, and/or communicatively linked with any and preferably all subsystems of the analyzer **110** and is used to control the analyzer **110**, such as via computer hardware and associated software.

Example II

Still referring to FIG. **13**, each of the analyzers interfacing to the subject **320** optionally comprise any system of the analyzer **110**. As illustrated, the first analyzer version **371**, which is an example of the analyzer **110** comprises three analyzer versions, illustrated as the first spectrometer version **142**, the second spectrometer version **144**, and the third spectrometer version **146**. As illustrated, the first spectrometer version **142**, optionally in the form of a watch head, interfaces to the subject **320** along a first z-axis perpendicular to a first x/y-plane, which tangentially touches the upper arm **372** at a first interface point; the second spectrometer version **144** has the form of a watch band link and interfaces to the subject **320** along a second z-axis perpendicular to a second x/y-plane, which tangentially touches the upper arm **372** at a second interface point; and the third spectrometer version **146**, optionally in the form of a watch band attachment, interfaces to the subject **320** along a third z-axis perpendicular to a third x/y-plane, which tangentially touches the upper arm **372** at a third interface point. Each of the three spectrometer versions **142**, **144**, **146** are optionally attached to the upper arm **146** via double-sided adhesives and are thus attached in the manner of a sticker. As illustrated, the three spectrometer versions **142**, **144**, **146** are attached to the upper arm **372** with a flexible band **148**, such as a watch band or an elastic band. The individual spectrometer versions **142**, **144**, **146** are optionally connected using one or more hinge components and or rotating connectors. The individual spectrometer versions **142**, **144**, **146** are optionally replaceably connected to the subject along separate planes forming angles therebetween of greater than 1, 2, 5, 10, 15, 25, or 25 degrees. The hinge allows tangential interfacing of illumination zones of the respective spectrometer version along a curved surface of the subject **320**. Optionally, the hinge allows for rotation of a first spectrometer unit relative to a second spectrometer unit to maintain tangential contact of the illumination zones with the subject **320** as the skin of the subject moves, such as by allowing a rotation of greater than 0.1, 0.5, 1, 2, or 5 degrees. The multiple planes of attachment of the analyzer **110** to the subject **320** allow attachment of multiple sources and/or detectors to the subject **320** along a curved skin surface of the subject **320**, such as around the upper arm **372** and/or the lower arm **374**, as illustrated with the second analyzer/spectrometer version **373** attached to the wrist of the subject **320**, with minimal applied tissue deformation forces at each of the analyzer/subject interface zones. Reduced forces, such as an applied mass, stress, and/or strain aids precision and/or accuracy of the analyzer **110** by reducing movement of fluids within the tissue layers **340** of the subject **320**, reducing changes in pathlength, and/or reducing changes in pressure induced scattering of light.

Example III

Still referring to FIG. **13**, in a first case, each of the first spectrometer version **142**, second spectrometer version **144**, and third spectrometer version **146** optionally contain all of the functionality of the analyzer **110**. However, optionally, one or more optical sources are in one interfacing aspect of the first analyzer version **371**, such as in the second spectrometer version **144**, without any functional optical detectors in the second spectrometer version **144**. In this case, the optical detectors are in a second interfacing aspect of the first analyzer version **371**, such as in the first spectrometer version **142**. For clarity of presentation and without loss of generality, a particular example is provided. In this example, the detector system **500** is positioned in the analyzer **110** in the first spectrometer version **142** along with optional illuminators of the source system **400**. However, the source system also includes photon sources in the second spectrometer version **144**, such as in a watch band link position. In this manner, photonic illuminators with short optical distances to the detector system **500** are positioned in the first spectrometer version **142**, such as in close proximity to the detector system **500**. For instance, photonic sources emitting in wavelength ranges: (1) with an optical absorbance of greater than one unit per millimeter of pathlength and/or (2) in the 1350 to 1560 nm range, such as within 25 mm of 1510, 1520, 1530, or 1540 nm are positioned near the detector system **500**, such as in the same housing as the detector system **500**, in the first spectrometer version **142**, and/or with a radial distance between an illumination zone and a detection zone of less than 10, 8, 6, 5, 4, 3, 2, 1.5, or 1 millimeters. However, photonic sources emitting in lower absorbance regions, such as from 400 to 1350 nm and/or 1565 to 1800 and/or in regions of absorbance by skin at a level of less than one absorbance unit per millimeter of pathlength are positioned in the second spectrometer version **144**, thus giving the photons a longer pathlength to the detector system **500** in the first spectrometer version **142**. The longer selected pathlength, as selected by a detector element of the detector system **500**, from a given source reduces a range of observed pathlengths by photons from the given source, as described supra. Further, each spectrometer version **142**, **144**, **146** allows an independent mean photon path entering the skin of the subject **320** to be perpendicular to the subject **320** despite the radius of curvature of the skin of the subject **320** as the differing spectrometer versions **142**, **144**, **146** are each positioned with an x/y-plane interface tangential to the local curvature of the skin of the subject **320**, such as at different positions on a watch band equivalent. Optionally and preferably, the x/y-planes tangential to the subject **320** at local sample interface sites for the n interface points of the analyzer **110**, such as the first interface location of the first spectrometer version **142**, the second interface location of the second spectrometer version **144**, and the third interface location of the third spectrometer version **146** are separated by greater than 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, or 20 millimeters as measured along the skin surface. Hence, second photon sources for providing second wavelengths for measuring oxygen and/or scattering of light, such as from 400 to 1300 nm, are optionally placed in a second housing along a second position of the watch band while first photon sources for providing first wavelengths, such as at glucose absorbing wavelengths from 1500 to 2400 nm, are optionally placed in a first housing proximate detector elements, where the detector elements in the first housing detect photons from second, third, . . . , n^{th} housings, such as along a circumferential band around a curved body part, where n is a positive integer greater than 1, 2, or 3.

Example IV

In the first spectrometer version **371** of the analyzer **110**, three sample interface zones are used, a first sample interface zone, such as the back of a watch zone where the source system **400**, force system **200**, and/or a first set of optics, such as in the first spectrometer version **142**, interface to the subject **320**; a second interface zone, such as where a second set of optics, such as in the second spectrometer version **144**, interface to the subject **320**; and a third interface zone, such as where a third set of optics, such as in a third spectrometer version **146**, interface to the subject **320**. Generally, any number n of sets of optics interface to the subject **320** to yield n sets of data on a state of the subject **320** where n is a positive integer, such as 1, 2, 3, 4, 5 or more. Optionally, the n sets of optics generate simultaneous data on a single state of the subject **320**. However, each sub-set of optics in the n sets of optics are optionally configured to measure the same analyte and/or different analytes, such as one of more of percent oxygen saturation, heart rate, heart rate variability, glucose concentration, protein concentration, fat, muscle, protein concentration, albumin concentration, globulin concentration, respiration rate, an electrocardiogram, blood pressure, body temperature, environmental temperature, and acceleration of the subject **320**.

Depth Resolution

Photons scatter in tissue. However, a mean photon path between an illumination zone and a detection zone has a mean/medium/average depth of penetration into the skin layers **340** and glucose is present at differing concentrations as a function of depth into the skin layers **340**. A target zone of probing photons is the epidermis **344** and/or dermis **346** between the stratum corneum **342** and the subcutaneous fat **348**. Targeting these well perfused tissue layers is described herein by way of non-limiting examples.

Example I

Referring now to FIG. **14**A, an example of a probe tip **1400** of the source system **400** of the analyzer **110** is presented. The probe tip **1400** has a tissue contacting surface **1410** and at least one illumination zone of a set of illumination zones **1420**. For clarity of presentation and without loss of generality, a single illumination zone is illustrated which is optionally and preferably one illumination zone of a plurality of illumination zones, such as where a given illumination zone is a surface area of the skin/probe tip interface illuminated by a given source, such as a given light emitting diode. More particularly, 2, 3, 4, or 5, or more, light emitting diodes/laser diodes couple to the skin, optionally via intervening optics of the photon transport system **450**, to illuminate a corresponding second, third, fourth, and fifth, or more, skin/probe tip interface areas, referred to herein as illumination zones. Similarly, a given detector element optically couples, such as by the photon transport system **450** to a given surface area of the skin/probe tip interface, which is referred to as a detection zone. More particularly, 2, 3, 4, or 5, or more, detector elements, of the detector system **500**, optically interface, such as through optics of the photon transport system **450** with the skin, to detect photons emitting from a corresponding second, third, fourth, and fifth, or more, skin/probe tip interface area, referred to herein as detection zones. A mean optical path for a set of photons is a mean pathway through the tissue layers **340** of the subject **320** between a given illumination zone and a given detection zone. Optionally, the probe tip **1400** is of any geometry. Optionally, illumination zones are of any pattern on the probe tip **1400**. Optionally, detection zones are of any layout on the probe tip **1400**.

Example II

Referring still to FIG. **14**A and referring now to FIG. **14**B, resolution of a mean depth of penetration of probing photons between an illumination zone and rings of detectors **1430** is provided. As illustrated, a first ring of detectors **1432**, coupled to a first set of detection zones, is at a first radius, r_1, from the illumination zone and a second ring of detectors **1434**, coupled to a second set of detection zones, is at a second radius, r_2, from the illumination zone. For clarity of presentation and without loss of generality, the detectors and detector zones are illustrated with the same circular graphical representation herein. Further, the circular graphical representations are optionally illustrative of the ends of fiber optics coupled to corresponding detectors or sources. At close distances having an observed absorbance of less than one, the mean depth of penetration of probing photons increases with radial distance. The first and second ring of detectors **1432**, **1434** are separated by a radial distance difference, Δr_1. Referring now to FIG. **14**B, the first ring of detectors **1432** corresponds to a first mean optical path **1472** having a first depth of penetration into the tissue layers **340** and the second ring of detectors **1434** corresponds to a second mean optical path **1474** having a second depth of penetration into the tissue layers **340**. As illustrated, for a first radial detector **1482** at the first radial distance, r_1, the maximum depth of the first mean optical path **1472** and the second mean optical path, for a second radial detector **1484** at a second radial distance, r_2, have a depth of penetration difference, Δd_1. Notably, the second ring of detectors **1434** is spatially positioned at a closest linear distance, the line passing through an illumination zone of the set of illumination zones **1420**, to the first ring of detectors **1432**. Thus, the best resolution of depth is the depth of penetration difference, Δd_1, corresponding to a first range of tissue thicknesses **1482**. However, in many cases, as the thicknesses of the epidermis **344** and dermis **346** changes with applied pressure, force, hydration, spatial orientation, movement, and/or changes in blood constituent concentration, the targeted dermal layers are not resolved using the best resolution of concentric detector rings with a difference in radial distance, Δr_1, to the illumination zone corresponding to the resolved depth, Δd_1.

Example III

Referring still to FIG. **14**A and FIG. **14**B and referring now to FIG. **14**C, a comparison of resolution of a mean depth of penetration of probing photons between an illumination zone and rings of detectors **1430** and arcs of detectors **1450** is provided. Herein, an arc of detectors is a set of detectors along a curved path of multiple radial distances from an illumination zone. The arced path is not an arc of a circle. Rather, the arced path is along a spiral and/or curve covering a range of radial distances from an illumination zone. As illustrated an arc of detectors **1450**, along an optional arc layout **1462**, starts at the first radial distance, r_1, of the first ring of detectors **1432** and ends at the second radial distance, r_2, of the second ring of detectors. While the first and second ring of detectors have a first linear radial distance difference, r_1, that is based on the size of the detector element housing, fiber optic, and/or detection zone, the illustrated arc of detectors **1450** has a second linear radial distance difference, r_2, that is smaller than, r_1. Particularly, with the seven illustrated detectors in the arc of detectors, the second linear radial distance, r_2, is one-seventh that of the first radial distance, r_1. Generally, the difference in radial distance is better than ½, ⅓, ¼, ⅕, . . . , 1/n that of the spatially constrained concentric rings of detectors for n detector elements in an arc bounded by the first and second radial distances, r_1 and r_2, of the concentric rings of detectors, where n is a positive integer of greater than 2, 3, 4, 5, 10, or 20. Comparing now the first and second mean depths of penetrations **1472**, **1474** for the first and second ring of detectors **1432**, **1434** and the first and second detector **1482**, **1484**, with the range of mean depths of penetrations in FIG. **14**C corresponding to the individual illumination zones, of the set of illumination zones **1420**, to detection zones of detector elements in the ring of detector elements **1450**, the enhanced resolution is illustratively obvious. Particularly, the above described first resolved depth, Δd_1, corresponding to the first and second ring of detectors **1432**, **1434** is seven times larger than a second resolved depth, Δd_2, between a third mean path **1437** and a fourth mean path **1474** corresponding to the second radial detector **1484** and a closest intermediate radial detector **1486**, two detector elements in the arc of detectors **1450**. Particularly, a second range of tissue thicknesses **1484** is thinner than the first range of tissue thicknesses **1482**, described supra. Generally, the difference in resolved tissue depth is better than ½, ⅓, ¼, ⅕, . . . , 1/n that of the spatially constrained concentric rings of detectors for n detector elements in an arc bounded by the first and second radial distances, r_1 and r_2, of the concentric rings of detectors, where n is a positive integer of greater than 2, 3, 4, 5, 10, or 20. Thus, arcs of detection zones corresponding to arcs of detectors and/or coupling optics, such as fiber optics, spanning a range of radial distances from an illumination zone yield an enhanced resolution of tissue depth. Further, as described supra, dynamic selection of signals from detector elements radially inward from an outwardly positioned detector element observing a disproportionate increase in a fat band absorbance, which is an example of a spectroscopic marker, from the subcutaneous fat **348**, at a greater depth than the targeted dermis **346**, yields the largest radial distance observing the desired/targeted dermal layers. Further, as the epidermis **344** and dermis **346** change in thickness, such as due to subject movement, orientation, and/or hydration, and/or changes in body chemistry, the range of resolved depths of penetration corresponding to the range of radial distances between the illumination zone and individual detection zones allows dynamic selection of source-to-detector distances currently probing the desired dermal layers, such as the epidermis **344** and the dermis **346**.

Depth/Location Selection

Referring now to FIGS. **15**A, **15**B, **15**C, **15**D, **16**A, **16**B, **16**C, **16**D, and **17**, a method and apparatus are described for selecting, as a function of wavelength, illumination zone-to-detection zone distances yielding a common and/or overlapping depth of sampling and/or position of sampling. In the examples provided, for clarity of presentation and without loss of generality, notation of a first, second, third, . . . , n^{th} source and/or detector is used where the n^{th} source/detector in one example is optionally distinct from the n^{th} source/detector in another example. Further, it is understood that skin layers are not homogenous and that variations occur from tissue voxel to tissue voxel. However, sampling a common depth and location aids in measuring a common sample state within the non-homogenous tissue layers, especially when used in conjunction with one or more of: a larger illumination zone, a larger detection zone, sample movement relative to the analyzer, and/or analyzer movement relative to the sample.

Example I

Referring now to FIG. **15**A, FIG. **15**B, FIG. **15**C, and FIG. **15**D in this first example, a common depth selection system **1500** and method of use thereof is described.

Referring now to FIG. **15**A. The spectrometer includes a first source **401**/source element, illuminating a first illumination zone of the set of illumination zones **1420**. Light from the first illumination zone is detected by a first set of detectors **1510**, such as a first detector **511** detecting photons at a first detection zone, a second detector **512** detecting photons at a second detection zone, a third detector **513** detecting photons at a third detection zone, and/or a fourth detector **514** detecting photons at a fourth detection zone. Herein, the sources and detectors are illustrated at the skin surface for clarity of presentation and without loss of generality. However, it should be understood that the actual source and/or detector elements, are optionally positioned anywhere, and are optionally and preferably optically coupled to their respective source zone/detection zone via air and/or one or more optics. For instance, a source optionally uses a fiber optic, or any optic, to deliver light from the source to the outer skin surface **330**. Similarly, a detector optionally uses any optic to deliver a portion of the photons emitting from a detection zone, optically visible to the detector, to the detector element.

Referring still to FIG. **15**A and referring now to FIG. **15**B, depths of penetration of photons passing from the set of illumination zones **1420** to the second set of detectors **1520** is illustrated. As illustrated, photons have a first mean path, p_1, from the first illumination zone associated with and/or optically linked to the first source **401** and to a first detection zone associated with and/or optically linked to the first detector **511**. Similarly, as illustrated, photons have a second mean path, p_2, from the first illumination zone associated with and/or optically linked to the second source **402** and to a second detection zone associated with and/or optically linked to the second detector **512**. Similarly, a third mean path, p_3, and fourth mean path, p_4, link the third detector **513** and fourth detector **514** to the first source **401**. It should be understood that the actual mean optical paths are not clear arcs as illustrated and the mean paths rather illustrate the point that differing illumination zone-to-detector zone distances have differing coupling mean pathways and/or the pathways probed differing sample layers at different weights. As illustrated, the second mean path, p_2, is the longest path in the dermis layer **346** that does not substantially pass through the subcutaneous fat layer **348**, which is a first selection metric, which is an example of a selection metric. In this example, the second mean path, p_2, is a first selected path based upon the selection metric. Selection metrics are optionally generated using one or more readings related to absorbance of fat, water, and/or protein. It should be understood that the first source **401** is illustrated at a first illumination zone only for clarity of presentation and the first source is optionally and preferably embedded into the analyzer **110** and coupled to the illustrated illumination zone with or without a coupling optic and that this general presentation approach holds for each source and similarly holds for each detector where a given detector is illustrated at a detection zone where optionally and preferably the given detector is configured to view the detection zone with or without an intervening optic.

Referring still to FIG. **15**A and FIG. **15**B, depths of penetration of photons passing from the set of illumination zones **1420** to the second set of detectors **1520** is further described for a second wavelength range, where photons from the first source **401** have a first distribution of intensity as a function of wavelength and a first mean wavelength and photons from a second source **402** have a second distribution of intensity as a function of wavelength and a second mean wavelength differing from the first mean wavelength by greater than 1, 2, 5, 10, 20, 50, or 100 nm. Photons from the second source **402** interact with tissue differently from the photons from the first source **401**, in terms of absorbance and scattering, which results in differing total pathlengths and sample pathlength in tissue layers, such as the epidermis **344**, dermis **346**, and/or subcutaneous fat **348**. As illustrated, a second set of wavelengths, from the second source **402**, reaching the surface of the skin **330** have longer observed mean pathlengths than a first set of wavelengths, from the first source **401**, reaching the outer skin surface **330** or surface of the skin. For instance, the second set of wavelengths cover a wavelength range with lower overall absorbance of the sample constituents, such as a lower water absorbance, than the first set of wavelengths. As above, photons from the second source **402** have a fifth mean optical path, p_5,/fifth path/fifth mean path; a sixth mean path, p_6; a seventh mean path, p_7; and an eighth mean path, p_8, to a fifth, sixth, seventh, and eighth detection zone observed by a fifth detector **515**, a sixth detector **516**, a seventh detector **517**, and an eighth detector **518**, respectively. Generally, any number of sources, m; any number of detectors, n; and/or any number of radial distances, r, are optionally used, where m and n are positive integers and r is a distance of greater than 0.01, 0.1, 0.5, 1, 1.5, 2, 3, 4, 5, or 10 millimeters.

Still referring to FIG. **15**A and FIG. **15**B, using the same criteria of the longest observed path in the dermis layer **346** that does not substantially pass through the subcutaneous fat layer **348**, the seventh path, p_7, is a second selected path based upon the first selection metric. The first selected path, p_2, and the second selected path, p_7, are both weighted to a common sample depth, the dermis **346**. Hence, (1) the first source **401** coupled to the second detector **512** and (2) the second source **402** coupled to the seventh detector **517** each have weighted sampling to a common sample, the dermis **346**. In stark contrast, at a common radial distance, such as observed at the first detector **511** and fifth detector **515**, the mean photons sample differing samples; the first source **401** dominantly sampling both the epidermis **344** and dermis **348**, as illustrated by the first path, p_1, and the second source **402** dominantly sampling the epidermis **344**, as illustrated by the fifth path, p_5.

Referring now to FIG. **15**C, the chosen radial separations of the sources and detectors, such as chosen in the preceding paragraph of this first example, are illustrated in an optional second probe configuration **1502**. Particularly, (1) a first selected radial distance, r_1, between the first source **401** and the selected second detector **512** is maintained and (2) a second radial distance, r_2, between the second source **402** and the selected seventh detector **517** is maintained without the need of the additional detector elements. Thus, for a static sample, the benefits of the common depth selection system **1500** are maintained in the second probe configuration **1502**.

Example II

Referring now to FIG. **16**A, FIG. **16**B, FIG. **16**C, and FIG. **16**D in this second example, a common sample position selection system **1600** and method of use thereof is described, where the common sample position is optionally and preferably at the common depth, such as the dermis, described supra.

Referring still to FIG. **16**A and FIG. **16**B, the common sample position system **1600** is first described through an illustrated addition of two additional wavelength ranges to the common depth selection system **1500**, described supra, where the resulting four wavelength ranges have four distinct mean wavelengths reaching the detector and where each of the four distinct mean wavelengths are separated from each other by at least 10 nm. Particularly, the separation of the first source **401** from the second detector **512** by the first radial distance, r_1, is maintained from the prior example as is the separation of the second source **402** from the seventh detector **517** by the second radial distance, r_2. Added to the illustration is a separation of the third source **403** from the sixth detector **516** by a third radial distance, r_3, and a separation of a fourth source **404** from a ninth detector **519** by a fourth radial distance, r_4. Notably, all of the illustrated source-to-detector distances are selected, such as by the method of the first example and/or through use of a metric, such as a measure of water, protein, and/or fat absorbance, to sample a common depth, which as illustrated is the dermis **346**. An apparatus setting each of the four wavelength ranges to a same mean lateral x-position and/or y-position is described, infra.

Referring now to FIG. **16**C and FIG. **16**D, the four source-to-detector distances, described supra, selected to sample a common depth, such as the dermis, are positioned in a probe face to yield a common lateral position at depth within the tissue or a common central zone **1610** at the surface. Particularly, a mean position between each of the source-to-detector positions is overlaid on at a common x-axis, as illustrated, and/or a common y-axis position to within less than 2, 1, 0.5, 0.4, 0.3, 0.2, or 0.1 mm.

Referring now to FIGS. **15**(A-D) and FIGS. **16**(A-D), while skin is not homogeneous, overlapping the photonic pathways of a set of differing wavelengths detected by a set of detectors, in terms of a common depth and/or a common position, yields a higher probability of sampling a common tissue state.

Example III

Referring now to FIG. **17**, in this third example, a common depth selection and common detector system **1700** and method of use thereof is described.

Still referring to FIG. **17**, generally, different wavelengths of light, in the range of 1100 to 2500 nm, have different mean depths of penetration into skin due to skin having a large range of absorbance and/or a large range of scattering as a function of wavelength. For instance, first photons at a first wavelength where the skin absorbs heavily, such as at and/or near a peak of the water absorbance bands **710**, at 1450 nm, and/or at 1900 nm, have a shallow maximum mean depth of penetration into the skin layers, such as only penetrating into the epidermis **344**. Similarly, second photons at wavelengths having a lower absorbance, such as on a shoulder of the water absorbance bands **710**, have a mean detected photonic path that penetrates deeper into the skin, such as into the dermis **346**. Again similarly, third photons having wavelengths at a still lower absorbance, such as at and/or near a valley of the water absorbance bands **710**, have a mean detected photonic path that penetrates still deeper into the skin, such as into the subcutaneous fat **348**. Hence, traditional systems sampling different wavelength ranges sample different mean sample depths.

Generally, a magnitude of absorbance of the skin is inversely related to a maximum mean depth of penetration of detected photons into the skin and water absorbance, optionally modified by scattering, dominates an overall magnitude of absorbance of the skin due to waters high absorbance in the range of 1100 to 2500 nm relative to other skin constituents.

As a result of sampling differing sample depths, errors are introduced into traditional analyzers, such as a noninvasive glucose concentration analyzer, as the skin layers **340** differ in both chemical and physical makeup and hence the wavelengths actually probe different samples. Here, a system of sampling a common skin layer is described, where optionally and preferably signals with differing illumination zone-to-detector zone distances are measured with a common detection zone optically linked to a detection system, such as a detector and/or a detector optically coupled to the common detection zone with one or more optics.

Referring again to FIG. **17**, for clarity of presentation and without loss of generality, a specific case of a range of wavelengths sampling a common skin layer is described. Particularly, in this case the first source **401** comprises a higher relative sample absorbance, such as within 10, 20, 30, 40, 50, 75, or 100 nm of a peak water absorbance at 1450 or 1900 nm and a first detected signal of photons from the first source **401** is dominated by a water signal at a first radial distance, r_1, to the first detector **511**, where the first radial distance is set at a distance yielding a maximum mean photonic path in the dermis **346**. Further, in this case the second source **402** comprises a mid-range sample absorbance, such as within 10, 20, 30, 40, or 50 nm of a mid-point absorbance of the peak water absorbance bands, such as at 1410, 1520, 1870, 2020, or 2380 nm, where the second detected signal of photons from the second source **402** is still dominated by a water signal at a second radial distance, r_2, but, the second wavelength range also samples another sample constituent, such as glucose, while still yielding a maximum mean photonic path in the dermis **346**. Notably, to sample the same depth as the first illumination zone-to-detection distance, while being as a second wavelength of lower overall absorbance, the second radial distance is larger than the first radial distance. Still further, in this case the third source **403** comprises a still lower sample absorbance, such as within 10, 20, 30, or 40 nm of a first quartile point of the peak water absorbance bands, such as at 1380, 1550, 1850, 2090, or 2350 nm, where the third detected signal of photons from the third source **403** is still dominated by a water signal at a third radial distance, r_3, but, the third wavelength range also samples another sample constituent, such as protein, while still yielding a maximum mean photonic path in the dermis **346** by having the third radial distance be longer than the second radial distance, which is in turn larger than the first radial distance. Yet still further, in this case the fourth source **404** comprises the still lower sample absorbance, such as within 10, 20, 30, or 40 nm of the first quartile point of the peak water absorbance bands, such as at 1380, 1550, 1850, 2090, or 2350 nm, where the fourth detected signal of photons from the fourth source **404** is still dominated by a water signal at a fourth radial distance, r_4, but, the fourth wavelength range also samples another sample constituent, such as the subcutaneous fat **348**, by having the fourth radial distance be further from detection zone relative to the third radial distance. Stated again, although the third source **413** emits third detected photons at a higher water absorbance wavelength/value relative to a lower water absorbance/value in a range of fourth detected photons, the maximum mean depth of the fourth photons penetrates further into the sample, such as the subcutaneous fat **348** relative to the dermis **346** probed by the third photons, due to the larger radial distance of the fourth radial distance relative to the third radial distance. Optionally, the third radial distance is configured to measure protein, such as at a wavelength with 5, or 10 nanometers of 1690 nm. Optionally, the fourth radial distance is configured to measure subcutaneous fat, such as at a wavelength with 5 or 10 nanometers of 1710 nm.

Still referring to FIG. **7**A, optionally, a common detection zone linked to a common detector system is used to sample light from the first, second, third, and fourth radial distances from the first source **401**, the second source **402**, the third source **403**, and the fourth source **404**, respectively. Generally, targeting skin layers **340** is demonstrated for each of a set of range of wavelength ranges, where each member of the set of wavelength ranges comprising a source-to-detector distance set by prior analysis, skin absorbance, water absorbance, and/or scattering. Notably, enhanced precision of depth targeting is achieved by measuring a range of illumination zone-to-detection zone distances. In this example, the higher relative absorbance is at least 20, 30, 40, 50, 75, or 100 percent higher than the mid-range absorbance. In this example mid-range absorbance is at least 20, 30, 40, 50, 75, or 100 percent higher than the lower quartile absorbance. In this example, the second radial distance is at least 0.2, 0.3, 0.4, 0.5, 0.75, or 1 mm larger than the first radial distance; the third radial distance is at least 0.2, 0.3, 0.4, 0.5, 0.75, or 1 mm larger than the second radial distance; and/or the third radial distance is at least 0.2, 0.3, 0.4, 0.5, 0.75, or 1 mm larger than the fourth radial distance.

Optionally and preferably, the sources are light emitting diodes, laser diodes, and/or provide a narrow band of light through use of a long pass filter, a short pass filter, a bandpass filter, and/or an optical filter. Generally, a given optional source system intended to illuminate a given wavelength region may provide additional photons at other regions of higher water absorbance, where the water absorbance blocks the additional photons. Generally, a given source intended to illuminate a given wavelength range, in the 1100 to 2500 nm wavelength region, does not provide more than 20, 10, 5, or 0 percent of the light in a lower absorbing region. For instance, a source intended to provide photons for analysis of fat at 1710 nm may provide photons from 1700 to 1720 nm, where photons at 1900 to 2000 nm are optionally provided as they are absorbed by water in the skin, and where photons at 1500 to 1650 nm are provided only at low intensity or are optically blocked as the water of the skin allows more of the photons in the 1500 to 1650 nm region to reach the detector and are thus avoided for analysis of the fat. Similarly, each intend wavelength, for analytes such as water, protein, and glucose, have similar source requirements for a common detector system. In an optional case where one or more detector systems has blocking optics for different wavelengths, the limitations on the source systems described herein is removed.

Example IV

Referring now to FIG. **18**, in this third example, a common depth selection and common sample position analyzer **1800** and method of use thereof is described. Generally, for each member of a set of sources a common mid-zone **999** and/or mid-point to a detector for each source is used to provide a common/overlapping sample position. Further, a radial distance for each source/detector combination is set according to absorbance/scattering of the tissue. For instance, the first radial distance, r_1, in the previous example for the first source **401** and the common detector **511** is maintained and used here for the distance between the first source **401** and a first selected detector, **1***d*,/first selected detection zone to yield a maximum mean photonic path in the dermis **346**, as described supra, for a water dominated wavelength, such as about 1410±25 nm. Similarly, the second source **402**, third source **403**, and fourth source **404** are separated by the second, third, and fourth radial distances of the previous example from a second selected detector, **2***d*, a third selected detector, **3***d*, and a fourth selected detector, **4***d*, respectively, which yields a common mean maximum sample depth, such as in the dermis **346**. Combined, a common sample position and common depth system is illustrated as: (1) each source-to-detector distance comprises a mid-point in the probe tip **1400** about a central sampling location/central sampling zone **999**, which yields a common location and (2) the radial distances between a given illumination zone-to-detection zone being set with radial distances based upon the wavelength yields a common depth.

Still referring to FIG. **18**, the mid-zone **999**/sample zone is illustrated on a sample side face of a probe housing of the analyzer **110**, such as on a surface of the probe tip **1400**. When a linked illumination zone and detection zone reside on opposite sides of the sample zone, a common sampled tissue volume resides in the tissue on the z-axis down from the sample zone, such as if the illumination zone-to-sample zone distance is within ten or twenty percent of the sample zone distance-to-detection zone distance.

Still referring to FIG. **18**, selection of a common sample position and common depth is illustrated for a range of skin types/skin states. Through time, a given skin state changes from a thicker dermis to a thinner dermis as a function of time or vise-versa, due to factors such as age, temperature, hydration, and water shifting to the gastro-intestinal region for digestion of recently ingested food. Similarly, the transducer **220** is optionally used to dynamically change the thickness of the dermis **346** as a function of time, such as described supra. Hence, a given illumination zone-to-detection zone distance for a given source/detector combination for a given wavelength range is optionally and preferably dynamically selected based upon the current state of the skin and/or the current state/thickness of the dermis **346**. Particularly, for the first illumination zone-to-first detection zone distance, a first set of detectors **1510** includes the first selected detector, **1***d*, set at the first radial distance, r_1, from the first illumination zone associated with the first source **401**, but also optionally and preferably includes a second optionally selected detection zone positioned radially inward from the first detector and a third optionally selected detection zone positioned radially outward from the first detector, relative to the first illumination zone. As a result, when the dermis **346** is thinner, the radially inwardly positioned detection zone associated with the first set of detectors **1510** is selected/used to sample the dermis and when the dermis **346** is thicker, the radially outwardly positioned detection zone associated with the first set of detectors **1510** is selected/used to sample the dermis. Similarly, the second detector, **2***d*, the third detector, **3***d*, and the fourth detector, **4***d*, of the second set of detectors **1520**, a third set of detectors **1530**, and a fourth set of detector **1540**, respectively, each have radially inward and radially outward positioned detection zones, relative to the second source **402**, third source **403**, and fourth source **404**, respectively, which are optionally dynamically selected as a detected thickness of the dermis **346** changes and/or as a state of the sample changes. As a result of a crossing geometry of the assorted source-to-detector positions, such as illustrated, when a given selected source-to-detector distance is altered, such as to a radially inwardly positioned detection zone, to maintain a constant mean sampling depth, the sample path still crosses the common sample zone. Thus, a common depth and common sampling system is described, where the common sample zone comprises a cross-section length of less than 0.25, 0.5, 0.75, 1, 1.5, 2, 3, or 4 mm.

Tissue Classifier

Referring now to FIG. **19**A and FIG. **19**B a tissue state classification system **1900** is illustrated. Generally, skin changes with time and spectroscopic signals are used to classify the skin state into two or more groups/classes/states. Calibration models are constructed for each group and when a prediction spectrum is classified into a given group, the corresponding group model is used to predict/estimate a noninvasively determined analyte property. For clarity of presentation and without loss of generality, the following example classifies spectra into three groups based upon a metric determined as a function of illumination zone-to-detection zone distance. More generally, any number of sub-classes are identified using one or more metrics, such an m subclasses and n metrics, where m and n are positive integers, and any number of models corresponding to tissue states are generated as calibration models/applied as predictions from the associated calibration model.

Example I

Referring still to FIG. **19**A, a first example of use of the tissue state classification system **1900** is illustrated. Initially, a set of data is collected **1910**. As illustrated, photons are delivered to a first illumination zone by the first source **401** and photons are collected at a series of detection zones respectively linked to the first detector **511**, the second detector **512**, and the third detector **513**. As illustrated, at a first time, t_1, a best fit to a given metric, such as described supra, is to data from the first detector **511** optically sampling a first mean illumination zone-to-detection zone distance, which corresponds to a first tissue state **1912**; at a second time, t_2, the best fit to the given metric is to data from the second detector **512** optically sampling a second mean illumination zone-to-detection zone distance, which corresponds to a second tissue state **1912**; and at a third time, t_3, the best fit to the given metric is to data from the third detector **513** optically sampling a third mean illumination zone-to-detection zone distance, which corresponds to a third tissue state **1913**. Generally, the metric is applied at a range of radial distances between a given source illuminating at a given illumination zone and a given detector observing a given detection zone. Optionally and preferably, the metric is sensitive to at least a given tissue thickness/optical density, such as described above for a varying thickness of the dermis **346**. Optionally and preferably, the metric is alternatively/also sensitive to sample position as even a given layer of the skin, such as the dermis **346**, is not optically homogenous. As illustrated, when the metric best fits the first illumination zone-to-first detection zone distance, the data indicates that the sample falls into a first tissue state where a first calibration model/prediction model **1922** is applied, where in a calibration step, the data is optionally added to the calibration model and in a prediction step, the first calibration model is applied to the data. Similarly, when the metric best fits the second tissue state and third tissue state, the data is added to or acted upon by the second calibration/prediction model **1924** and third calibration/prediction model **1926**, respectively. Notably, a lack of match of the metric, applied to data, to any tissue state having a corresponding calibration is optionally and preferably used to determine the data as being outlier data. Generally, the classification method is applied to any optical layout described herein.

Example II

Referring still to FIG. **19**A and referring again to FIG. **19**B, the above described tissue classification system **1900** is applied to an overdetermined/multiplexed tissue state classification system **1950**. Generally, in the multiplexed tissue state classification system **1950**, a tissue state of the person at a point in time or over a short period of time, such as in a period of less than 120, 60, 30, 15, 10, 5, 4, 3, 2, or 1 minutes, is determined more than once, such as with two different wavelength regions, each wavelength region sampled as a function of radial distance to corresponding detector setups. Without loss of generality, two wavelength ranges are illustrated here. However, more generally greater than 2, 3, 4, 5, 7, 10, or 15 wavelength ranges are optionally used, where any given two wavelength ranges comprise at least one of mean wavelengths differing by at least 5, 10, 15, 20, 25, or 50 nm and/or a full-width at half height differing by at least 5, 10, 15, 20, 25, or 50 nm. As illustrated, the second illumination zone **402** optically linked to the second source **402** is separated from a fourth, fifth, and sixth detection zone optically linked to the fourth detector **514**, fifth detector **515**, and sixth detector **516**, respectively. As above, at the first time, t_1, a second metric applied to the collected data **1910** again indicates that the skin is in the first tissue state and that the first calibration/prediction model **1922** is to be updated/used. Similarly, as above, at the second and third times, the second metric identifies the skin as being in the second sample state and third sample state, respectively. Notably, as the first metric and second metric are applied to differing data, in terms of detected wavelengths and radially sampled distances in the skin, which sample overlapping and/or differing tissue depths, the first and second metrics are optionally and preferably combined to determine additional tissue states. For instance, if the first metric is used to identify m tissue states and the second metric is used to identify n tissue states, then the total number of identified tissue states is greater than m and/or n, such as by one or two additional states, and/or is used to identify m+n tissue states. Again, any number of metrics are used and are applied to any number of wavelength ranges where responses to each wavelength ranges are determined at one or more radially separated distances from a corresponding illumination zone.

Common Sample Zone

Referring now to FIG. **20**A, FIG. **20**B, and FIG. **21**, a common zone sampling system **2000** is described. Generally, in the common zone sampling system **2000**, an area of the probe tip **1400** of the spectrometer **140** contacting the outer skin surface **330** of the subject during use has a common sample zone **2010**. Generally, the common sample zone **2010** is positioned on the z-axis next to the skin, such as above the skin, and sample a common and/or overlapping tissue volume. Particularly, first tissue volumes probed with a first illumination zone-to-detection zone distance overlap second tissue volumes probed with a second illumination zone-to-detection zone distance, which reduces the impact of sample inhomogeneity within a given tissue layer, such as in the epidermis **344** and/or in the dermis **346**. Optionally and preferably, the common zone sampling system **2000** also probes a common tissue depth and/or a common sample location as described, supra. For clarity of presentation and without loss of generality, several examples illustrate the common zone sampling system **2000**, such as in combination with the common depth system described supra, with a fully or partially multiplexed analyzer, and/or with detectors coupled with two or more sources as a function of time.

Example I

Referring still to FIG. **20**A, a first example of the common zone sampling system **2000** is described. For clarity of presentation and without loss of generality, this exemplary system is laid out using the first illumination zone-to-detection zone radial system described in previous examples. More particularly, the first illumination zone-to-detection zone is illustrated as two fiber diameters, one intervening "fiber diameter" distance (further described infra), and an inner detector element and an outer detector element are positioned one fiber diameter closer to and further from the illumination source. Similarly, the second, third, and fourth illumination zone-to-detection zone distances from the previous examples is maintained with a separation of 2, 3, and 3.5 fiber diameters between respective illumination zones and detection zone. Similarly, an inwardly positioned detection zone and an outwardly positioned detection zone is provided, coupled to a common zone set of detectors, for each selected illumination zone-to-detection zone distance selected (the 1, 2, 3, and 3.5 fiber diameter spacings). Hence, as the tissue layer thicknesses change, such as with use of the transducer and/or through normal physiological variations with time, sampling of the common tissue layer, such as the dermis **346**, is maintained through appropriate selection of the detection element, as described supra. Herein, the fiber diameter optionally and preferably refers to a unit of measure with a corresponding readily manufactured component. Hence a separation referring to a separation of one "fiber diameter" refers to a distance without actually requiring a fiber optic, such as 100, 200, 300, 400, 500, 600, 700, 800, 900, or 1000 micrometers.

Still referring to FIG. **20**A, as illustrated, a common zone set of detectors **1550** is used and a common zone **2010** is an area below the common zone set of detectors **1550** where photons of differing wavelengths sample a common depth and/or a common position, such as by setting illumination zone-to-detection zone distances differently for each wavelength range, further described infra. For instance, when the second source **402** and the second detector position, **2***d*, is used, and when the third source **403** and the third detector position, **3***d*, is used, each illumination zone-to-detection zone pairing samples: (1) a common depth, as described supra, and (2) a common location, such as any position in common between the two illumination zone-to-detection zone pairings. Similarly, as the tissue state changes and the radially inwardly positioned detection element for the second illumination zone-to-detection zone distance is selected while the radially inwardly positioned detection element for the third illumination zone-to-detection zone distance is selected, a common position, b, is still maintained between the selected second source-detector pairing and the third selected source-detector pairing. Similarly, as the tissue state changes again and the radially outwardly positioned detection element for the second illumination zone-to-detection zone distance is selected while the radially outwardly positioned detection element for the third illumination zone-to-detection zone distance is selected, a common position, **3***d*, is still maintained between the selected second source-detector pairing and the third selected source-detector pairing. Generally, for two or more linearly arranged illumination-detection zone pairings, such as for detection zones placed between illumination zones, a common depth and/or a common position exists for the two or more linearly arranged illumination zone pairings even as tissue layer thicknesses change. As illustrated, four linearly arranged illumination-detection zone pairings are illustrated, **1***s*-**1***d*, **2***s*-**2***d*, **3***s*-**3***d*, and **4***s*-**4***d*, where a common zone **2010** comprises: (1) a common maximum mean depth beneath all of the detection positions between the linearly aligned sources and (2) a common sample position exists at or about mid-points between multiple pairs of the linearly aligned sources with detection positions between the paired sources.

Still referring to FIG. **20**A, in the common zone sampling system **2000**, three or more illumination zone-detection zone pairings sample a common depth and/or a common sample location. For instance, the **1**s-**1**d, **2**s-**2**d, **3**s-**3**d, and **4**s-**4**d illumination zone pairings all sample a common depth in the tissue, where the **1**s-**2**s-**2**d, **3**s-**3**d, and **4**s-**4**d all sample a common position in the tissue, such as common position b, which is positioned in a common position between each illumination zone-detection zone pairing.

Still referring to FIG. **20**A, in the illustrated example of the common zone sampling system **2000**, the analyzer **110** is fully multiplexed. Specifically, the first source **401**, the second source **402**, the third source **403**, and the fourth source **404**, are all simultaneously operable and detected at corresponding detectors, **1**d, **2**d, **3**d, and **4**d, at the same time while sampling the same tissue depth and overlapping tissue volumes. As the corresponding detectors, **1**d, **2**d, **3**d, and **4**d, each have a radially inwardly positioned detection zone and a radially outwardly positioned detection zone, the common depth and/or the overlapping sampled tissue volumes continue to overlap as the selected illumination zone-to-detection zone varies in correlation with changes in the tissue layer thicknesses.

Example II

Referring now to FIG. **20**B, a second example of the common zone sampling system **2000** is described where additional "fiber diameter" spacings are used, such as in the optional arc layout **1462** system described supra. For clarity of presentation, the spacings of the illumination and detection zones of the previous example is maintained, while additional detection zones are added. Generally, hardware, such as an optic, drill hole, and/or fiber optic has a diameter and two closely spaced optics, drill holes, and/or fiber optics then have a center-to-center closely packed minimum distance of a diameter of the closely spaced optics, drill holes, and/or fiber optics, such as a distance between a center of the "a" detection zone and the "**1**d" detection zone, which limits depth resolution in the tissue. However, following the logic of the optional arc layout **1462**, additional optional detection zones, $\mathbf{1}d_b$ and $\mathbf{1}d_c$, are illustrated at intermediate distances between a common illumination zone, **1**s, and: (1) the "a" detection zone and (2) the close packed "**1**d" detection zone, such as the illustrated 1⅓ and 1⅔ distances of the $\mathbf{1}d_b$ and $\mathbf{1}d_c$ detection zones, optionally positioned on opposite sides of a common line between illumination zones.

Still referring to FIG. **20**B, the set of illumination zones and detection zones positioned on a line is optionally repeated, such as on a second or n^{th} line for use with a second or n^{th} set of wavelength ranges. Further, if the n^{th} line is positioned close to the first line, such as in parallel to the first line and intersecting the $\mathbf{1}d_b$ or $\mathbf{1}d_c$ detection zones, then detectors in the n^{th} line are optionally and preferably used as higher depth resolution detectors for one or more illumination zones in a $n+1^{th}$ or $n-1^{th}$ line parallel and adjacent to the n^{th} line.

Example III

Referring now to FIG. **21**, a third example of the common zone sampling system **2000** is described where a reduced number of detection zones are used to reduce the size of the probe tip **1400** or the analyzer **110**. Particularly, again using the illumination-detection zone spacing of the previous two examples, a single detection zone, c, is used in place of all three of the **1**d, **2**d, **3**d detection zones while maintaining all of the illumination zone-to-detection zone distances of the previous two examples, the tradeoff being a partially multiplexed system as the "c" detector is used as a function of time with use of the first source **401**, the second source **402**, and the third source **403**, respectively.

Referring again to FIG. **20**A, FIG. **20**B, and FIG. **21**, first source-detector combinations having first wavelengths associated with high water absorbance per millimeter of pathlength generally have smaller illumination zone-to-detection zone distances than second source-detector combinations having second wavelength combinations associated with lower water absorbance per millimeter of pathlength. For instance, at a higher water absorbing wavelength, such as at about 1400±50, 1900±50, 2000±50, or 2500±50 nm, a first illumination zone-to-detector distance, associated with detected wavelengths of 1400±50, 1900±50, 2000±50, is less than a second illumination zone-to-detection distance for detection of wavelengths having a medium water absorbance, such as within 10, 20, 30, 40, or 50 nm of a mid-point absorbance of the peak water absorbance bands, such as at 1410, 1520, 1870, 2020, or 2380 nm, and the second illumination zone-to-detection distance used with the medium absorbing wavelengths of water is in turn less than a third illumination zone-to-detection zone distance used for source-detector combinations observing wavelength ranges of light associated with a still smaller water absorbance per millimeter of pathlength, such as within 10, 20, 30, or 40 nm of a first quartile point of the peak water absorbance bands, such as at 1380, 1550, 1850, 2090, or 2350 nm.

Acousto-Optic Analyzer vs. (1) UPI and (2) an AOTF

An applied force-optic analyzer is described herein. Optionally and preferably, the applied force results in a mechanical disturbance of the tissue resulting in a force being applied to the sample. However, in a sub-case of the applied force-optic analyzer, the applied force comprises an acoustic force yielding an acousto-optic analyzer. Notably, in the sub-case of the applied force-optic analyzer being an acousto-optic analyzer, as used herein an acousto-optic analyzer starkly contrasts with both: (1) an ultrasonic photoacoustic imaging (UPI) system and (2) an acousto-optic tunable filter (AOTF) spectrometer, as described infra.

Acousto-Optic Analyzer

As described, an acousto-optic analyzer (AOA) introduces an acoustic vibration wave to the sample to impact the state of the sample, such as tissue, and the state of the sample is measured using an optical probe.

Photoacoustic Imaging

In stark contrast, according to Wikipedia, ultrasonic photoacoustic imaging, also referred to as (UPI), photoacoustic imaging (PI), and/or optoacoustic imaging, delivers non-ionizing laser pulses to biological tissue, which results in absorbed energy and resultant heat in the form of transient thermoelastic expansions detected as wideband megaHertz ultrasonic emissions detected by ultrasonic transducers. The detected signals are used to produce images. As optical absorbance relationships exist with physiological properties, such as hemoglobin concentration and oxygen saturation, the detected pressure waves may be used to determine hemoglobin and oxygen concentration.

Hence, an acousto-optic analyzer starkly contrasts with photoacoustic imaging. Stated again, while the acousto-optic analyzer described herein may induce a heat wave like in photoacoustic imaging, in photoacoustic imaging the sound wave is detected whereas photons, from an external source, are detected in the acousto-optic analyzer described are detected after interacting with the sample being displaced/heated/disturbed by the sound wave.

Acousto-Optic Tunable Filter

According to Wikipedia, an acousto-optic tunable filter (AOTF), diffracts light based on an acoustic frequency. By tuning the frequency of the acoustic wave, the desired wavelength of the optical wave can be diffracted acousto-optically.

Hence, an acousto-optic analyzer (AOA) starkly contrasts with an acousto-optic tunable filter (AOTF) as, while the input sound wave of the AOA may diffract light, the separation of the input light is not the primary use of the sound wave. Indeed, a narrow-band light emitting diode (LED) is optionally used in conjunction with a broadband detector in the acousto-optic analyzer making any separation of the narrow band light source pointless. Further, in the AOA, the sound wave is used to change the state of the biological sample itself, whereas in the AOTF the sound wave is introduced to a birefringent crystal in a wavelength separation module of the spectrometer and is not introduced into the sample.

Still yet another embodiment includes any combination and/or permutation of any of the elements described herein.

The main controller, a localized communication apparatus, and/or a system for communication of information optionally comprises one or more subsystems stored on a client. The client is a computing platform configured to act as a client device or other computing device, such as a computer, personal computer, a digital media device, and/or a personal digital assistant. The client comprises a processor that is optionally coupled to one or more internal or external input device, such as a mouse, a keyboard, a display device, a voice recognition system, a motion recognition system, or the like. The processor is also communicatively coupled to an output device, such as a display screen or data link to display or send data and/or processed information, respectively. In one embodiment, the communication apparatus is the processor. In another embodiment, the communication apparatus is a set of instructions stored in memory that is carried out by the processor.

The client includes a computer-readable storage medium, such as memory. The memory includes, but is not limited to, an electronic, optical, magnetic, or another storage or transmission data storage medium capable of coupling to a processor, such as a processor in communication with a touch-sensitive input device linked to computer-readable instructions. Other examples of suitable media include, for example, a flash drive, a CD-ROM, read only memory (ROM), random access memory (RAM), an application-specific integrated circuit (ASIC), a DVD, magnetic disk, an optical disk, and/or a memory chip. The processor executes a set of computer-executable program code instructions stored in the memory. The instructions may comprise code from any computer-programming language, including, for example, C originally of Bell Laboratories, C++, C#, Visual Basic® (Microsoft, Redmond, WA), Matlab® (MathWorks, Natick, MA), Java® (Oracle Corporation, Redwood City, CA), and JavaScript® (Oracle Corporation, Redwood City, CA).

Herein, any number, such as 1, 2, 3, 4, 5, is optionally more than the number, less than the number, or within 1, 2, 5, 10, 20, or 50 percent of the number.

Herein, an element and/or object is optionally manually and/or mechanically moved, such as along a guiding element, with a motor, and/or under control of the main controller.

The particular implementations shown and described are illustrative of the invention and its best mode and are not intended to otherwise limit the scope of the present invention in any way. Indeed, for the sake of brevity, conventional manufacturing, connection, preparation, and other functional aspects of the system may not be described in detail. Furthermore, the connecting lines shown in the various figures are intended to represent exemplary functional relationships and/or physical couplings between the various elements. Many alternative or additional functional relationships or physical connections may be present in a practical system.

In the foregoing description, the invention has been described with reference to specific exemplary embodiments; however, it will be appreciated that various modifications and changes may be made without departing from the scope of the present invention as set forth herein. The description and figures are to be regarded in an illustrative manner, rather than a restrictive one and all such modifications are intended to be included within the scope of the present invention.

Accordingly, the scope of the invention should be determined by the generic embodiments described herein and their legal equivalents rather than by merely the specific examples described above. For example, the steps recited in any method or process embodiment may be executed in any order and are not limited to the explicit order presented in the specific examples. Additionally, the components and/or elements recited in any apparatus embodiment may be assembled or otherwise operationally configured in a variety of permutations to produce substantially the same result as the present invention and are accordingly not limited to the specific configuration recited in the specific examples.

Benefits, other advantages and solutions to problems have been described above with regard to particular embodiments; however, any benefit, advantage, solution to problems or any element that may cause any particular benefit, advantage or solution to occur or to become more pronounced are not to be construed as critical, required or essential features or components.

As used herein, the terms "comprises", "comprising", or any variation thereof, are intended to reference a non-exclusive inclusion, such that a process, method, article, composition or apparatus that comprises a list of elements does not include only those elements recited, but may also include other elements not expressly listed or inherent to such process, method, article, composition or apparatus. Other combinations and/or modifications of the above-described structures, arrangements, applications, proportions, elements, materials or components used in the practice of the present invention, in addition to those not specifically recited, may be varied or otherwise particularly adapted to specific environments, manufacturing specifications, design parameters or other operating requirements without departing from the general principles of the same.

Although the invention has been described herein with reference to certain preferred embodiments, one skilled in the art will readily appreciate that other applications may be substituted for those set forth herein without departing from the spirit and scope of the present invention. Accordingly, the invention should only be limited by the Claims included below.

The invention claimed is:

1. An apparatus for use in a noninvasive determination of an analyte property of a person having skin, comprising:

a noninvasive analyzer comprising:

a sample probe, said sample probe comprising:

a first diode source, at least partially embedded in an output surface of said sample probe, said first diode source emitting light in a wavelength range of 1300 to 1490 nm, from said output surface such that a first surface area of the skin is illuminated;

a second diode source, at least partially embedded in said output surface, said second diode source emitting light in a wavelength range of 1490 to 1600 nm from said output surface such that a second surface area of the skin is illuminated;

a first detector, at least partially embedded in said output surface, said first detector being receptive to light reaching said detector from a third surface area of the skin;

a second detector, at least partially embedded in said output surface, said second detector being receptive to light reaching said detector from a fourth surface area of the skin; and

a transducer, at least partially embedded in said sample probe, configured to temporarily displace a portion of the skin during use.

2. The apparatus of claim **1**,

wherein the first diode source, the second diode source, the first detector and the second detector are linearly aligned along said output surface of said sample probe.

3. The apparatus of claim **1**, further comprising:

a third diode source, at least partially embedded in said output surface of said sample probe, said third diode source emitting light in a range of 1600 to 1800 nm from said output surface such that a fifth surface area of the skin is illuminated.

4. The apparatus of claim **1**, further comprising:

a pair of detector elements, at least partially embedded in said output surface, said pair of detector elements receptive to light reaching said pair of detector elements from a corresponding pair of surface areas of the skin positioned on opposite sides of said fourth surface area of the skin.

5. An apparatus for use in a noninvasive determination of an analyte property of a person having skin, comprising:

a noninvasive analyzer comprising:

a sample probe head, said sample probe head comprising a sample side surface;

a set of sources at least partially embedded in said sample probe head, each source of said set of sources optically coupled to a corresponding illumination zone of a set of illumination zones on said sample side surface;

a set of detectors at least partially embedded in said sample probe head, each detector of said set of detectors optically coupled to a corresponding detection zone of a set of detection zones on said sample side surface, wherein a first set of at least two illumination zones of said set of illumination zones and a first set of at least three detection zones of said set of detection zones intersect on a first line;

a first diode source, configured to emit a first mean wavelength in a range of 1300 to 1490 nm, optically coupled to a first illumination zone on said first line, wherein a center point of said first illumination zone is at a first radial distance from a longitudinal center point of said at least three detection zones;

a second diode source, configured to emit a second mean wavelength in a range of 1300 to 1490 nm, optically coupled to a second illumination zone on said first line, wherein a center point of said second illumination zone is at a second radial distance from said longitudinal center point of said at least three detection zones, said second radial distance being at least one-half millimeter longer than said first radial distance; and

a transducer configured to vibrate the skin of the person during use, said transducer being mechanically coupled to said sample probe head.

6. The apparatus of claim **5**, said set of detection zones positioned between a first illumination zone and a second illumination zone of said set of at least two illumination zones.

7. The apparatus of claim **5**, further comprising:

a second line intersecting: a second set of at least two illumination zones of said set of illumination zones and a second set of at least three detection zones of said set of detection zones, said first line not intersecting said second line on said sample probe head.

8. The apparatus of claim **5**, further comprising:

a processor configured to: (1) operate a first source of set of sources and (2) respectively sample first, second, and third mean optical pathways between a first illumination zone of said at least two illumination zones and a first, second, and third detection zone of said set of at least three detection zones.

9. The apparatus of claim **5**, said processor further comprising:

computer code configured to: (1) operate a second source of set of sources and (2) respectively sample third, fourth, and fifth mean optical pathways between a second illumination zone of said at least two illumination zones and said first, second, and third detection zone of said set of at least three detection zones.

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