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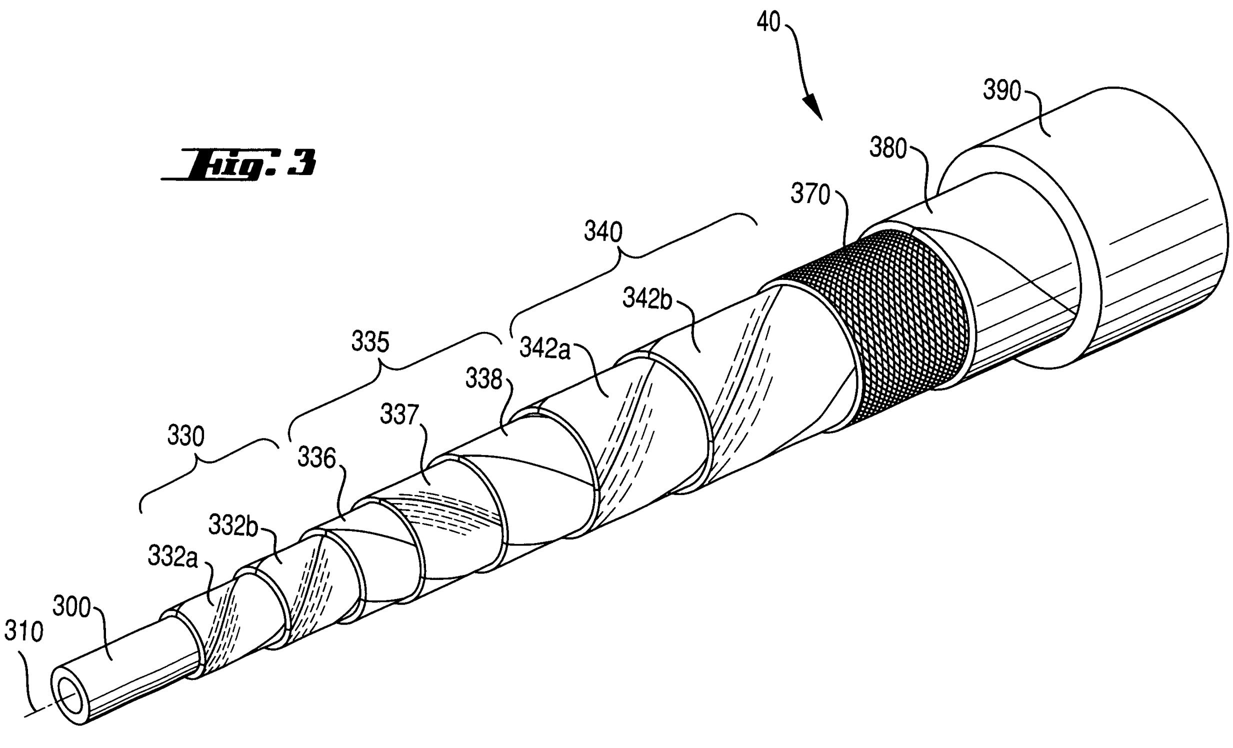
(54) **Ultrasound imaging apparatus and cable assembly therefor**

(57) A cable assembly (40) for connection to an imaging apparatus (10) is disclosed.

The cable assembly (40) has at least two layers (330, 340) each of which has at least lone ribbon cable (332a, 332b, 342a, 342b) separated from each other by a ground plane (337). The at least two layers (330, 340) are preferably serfed about a cylindrical spacer (300) in concentric arrays.

The ground plane (337) can advantageously also be made from a ribbon cable (337).

Fig. 3



EP 1 246 207 A1

Description

Field of the Invention

[0001] The invention relates to an ultrasound diagnostic apparatus having a transducer and a data processing unit connected to each other by a cable assembly.

Prior Art

[0002] Ultrasound diagnostic apparati are used by doctors and medical technicians as a diagnostic tool to view human body structures, such as organs and tissues. For example, diagnostic apparati provide real-time images of the heart and excellent soft tissue images of the abdomen, making ultrasound systems useful for diagnosing heart problems and indispensable for monitoring pregnancies. Images are produced without the harmful radiation of X-rays and without the long image acquisition time of magnetic resonance imaging (MRI).

[0003] In order to view the structure of the body, an electrical signal (a transmitted signal) is generated and propagated via an electrical signal cable to a transducer which converts the electrical signal into an ultra-high frequency sound or ultrasound signal that is directed to the body. The transducer also receives the ultrasound signal (an information signal) after it is attenuated and reflected back by the body structure and converts it into an electrical signal (a received signal) which is carried by the transducer cable to a data processing unit, such as an image display. The transmitted and received electrical signals are compared by the data processing unit which then generates an image of the body structure from the compared signals. Any disturbances on the electrical signal will degrade the image of the body structure and may thus impact diagnosis. The electrical signal cable must be shielded to prevent external electrical sources from interfering with the electrical signals and should be flexible so that the transducer may be easily manoeuvred and aimed.

[0004] In some applications of ultrasound systems e. g. continous wave or steerable applications, an ultrasonic signal is continuously transmitted from one section of a piezoelectric crystal in a transducer head. The received signal is detected by another section of the piezoelectric crystal in the transducer head. The quality of the images in these ultrasound systems that can be generated in the data processing unit as already described is dependent on the quality of the information received from the received signals in the transducer head and can be affected by degradation of the received signals as they pass along the electrical signal cable. In particular, in this application, cross-talk between the transmitted signals and the received signals may degradate the image quality.

[0005] The principles of ultrasound imaging are explained in the review article by P.N.T.Wells "Overview of Ultrasonic Imaging" in the Proceedings of the International Workshop on Physics and Engineering in Medical Imaging, March 15-18, 1982, Pacific Grove, California, published by the IEEE, 1982. A more detailed description is found in the article also by P.N.T.Wells on "Ultrasonic Imaging of the Human Body" in the Reports on Progress in Physics, vol. 62, no. 5, May 1999, pages 671-722.

[0006] Electrical signal cables for use in an ultrasound diagnostic apparatus are known, for example, from European Patent Application EP-A-0 735 544 (Cartier et al.) assigned to Hewlett-Packard Company. This patent application describes an ultrasound system with an electrical signal cable for providing an electrical connection between a transducer and a display processor. The third embodiment of the electrical signal cable disclosed in this application uses three layers of extruded ribbon assemblies separated from each other by shield conductors comprising thin strips of bare copper. The stack of ribbon assemblies and shield conductors are extruded with a ribbon jacket to form a desired length of the electrical signal cable.

Summary of the Invention

[0007] An object of the invention is to improve the quality of the image displayed by the ultrasound diagnostic apparatus whilst maintaining the flexiblity of the electrical signal cable. A further object of the invention is to improve the quality of the signals received by the data processing unit of an ultrasound diagnostic apparatus.

[0008] Yet a further object of the invention is to reduce the cross-talk between transmitted signals and received signals within an electrical signal cable connecting a data processing unit and a transducer head of an ultrasound diagnostic apparatus.

[0009] A further object of the invention is to provide a flexible electrical signal cable which has a long lifetime for the particular application.

[0010] A further object of the invention is to minimise the weight of the cable whilst providing a high quality image.

[0011] These and other objects of the invention are solved by providing an imaging apparatus having a transducer head and a data processing unit connected to each other by an electrical signal cable. The data processing unit has a signal transmitter for generating control signals provided to the transducer in the transducer head and a signal receiver for processing information signals received by the data processing unit from the transducer head. The electrical signal cable connecting the data processing unit and the transducer head comprises at least two cylindrical layers each of which each has one or more (a plurality) ribbon cables with electrical signal conductors encased within and separated at a pitch distance from each other by an insulating material. The layers are separated by a ground plane connected to AC ground to isolate them from one another.

[0012] A first plurality of the electrical signal conductors of a ribbon cable in a first one of the at least two cylindrical layers is connected to the signal transmitter and thus carries the transmitted signals. A first plurality of the electrical signal conductors of ribbon cable in a second one of the at least two cylindrical layers in the same embodiment of the invention is connected to the signal receiver and thus carries the received signals. The ground plane is disposed between the first one and the second one of the cylindrical layers and therefore shields the transmitted signals from the received signals. This ground plane therefore substantially minimises the cross-talk between signals in the two cylindrical layers. Hence the quality of the received signals received at the data processing unit and the transmitted signals is improved.

[0013] In one advantageous embodiment of the invention, the ground layer in the electrical signal is improved cable also comprises a further ribbon cable having a plurality of electrical signal conductors. Each of the plurality of electrical signal conductors is at AC ground potential.

[0014] The term "AC ground potential" means that the signal conductors carry an invariable signal which with respect to the varying information and control signals is constant and thus acts as an electromagnetic shield. The AC ground potential may or may not be at earth potential. The ground plane has therefore the same structure as the at least two ribbon cables carrying the transmitted signals and the received signals and can therefore be manufactured in the same manner. This is furthermore advantageous since the use of similar constructions is found to improve the flex-life of the electrical signal cable as during flexing similar materials move against each other. Yet a further advantage in using this type of construction in comparison to ground foils is that during cable flexing there is no generation of tribostatic charges between the foil and the insulator.

[0015] Further improvements to the electrical performance of the cable assembly in the diagnostic apparatus can be made by incorporating into the flat cables a second plurality of the electrical signal conductors which are connected to AC ground potential and which are intermingled with the first plurality of electrical signal conductors carrying transmitted signals or received signals. This provides for a reduction in cross-talk between the electrical signal conductors in the same layer and thus further improves the image quality generated in the data processing unit.

[0016] The use of an outer shield surrounding the at least two ribbon cables in the electrical signal cable shields the electrical signal conductors within the electrical signal cable from external electromagnetic interference and thus leads to yet a further improvement in signal quality.

[0017] In one embodiment of the invention, the plurality of cylindrical layers are cylindrically disposed and preferably surfed about a central axis. This circular construction is found to make cable more flexible and improves the flex-life properties of the electrical signal cable. A tubular spacer disposed within the plurality of ribbon cables is used to keep the construction stable. A jacket is disposed about the at least two ribbon cables to protect these from damage. It should be noted that the term "cylindrical" in this context means that the layers are substantially cylindrical but may deviate slightly from the exact geometrical form.

[0018] A further improvement to the flexibility of the cable assembly for the imaging apparatus can be made by placing two ribbon cables adjacent to each other in the same cylindrical layer.

[0019] One embodiment of the invention has an insulating material for the ribbon cables which comprises an upper insulator attached and preferably laminated to a lower insulator. The upper insulator and the lower insulator are formed from the group of insulating materials consisting of perfluoralkoxy, fluoroethylene-propylene, polyester, polyolefin including polyethylene and polypropylene, polymethylpentene, polytetrafluoroethylene or expanded polytetrafluorethylene. Most preferably they are formed from expanded polytetrafluorethylene. This material is known to have excellent dielectric properties which leads to fast and reliable signal propagation. The material has a low coefficient of friction which leads to an improvement in flex-life properties of the electrical signal cable since the individual layers of the electrical signal cable are able to slide against each other. Furthermore little or no triboelectricity is generated when layers of expanded polytetrafluoroethylene rub against each other.

<u>Description of the Drawings</u>

[0020]

- Fig. 1 shows an ultrasound diagnostic apparatus using an electrical signal cable assembly of the invention.
- Fig. 2 shows a first embodiment of the electrical signal cable for use in the ultrasound diagnostic apparatus.
- Fig. 3 shows the electrical signal cable according to a second embodiment of the invention.
- Fig. 4 shows an embodiment of the termination of the electrical signal cable to the termination board.
- Fig. 5 shows a further embodiment of the termination of the electronic signal cable to the system termination board.
- Fig. 6 shows an embodiment of the termination of the electronic signal cable to the transducer head.
- Fig. 7 shows the electrical signal cable according to an example of the invention.
- Fig. 8 shows measurements of cross-talk between

the individual signal conductors with a ground plane.

Fig. 9 shows measurements of cross-talk between the individual signal conductors without a ground plane.

Detailed Description of the Invention

[0021] Fig. 1 shows a prior art ultrasound diagnostic apparatus 10 having a transducer head 20 and a data processing unit 30 connected to each other by an electrical signal cable 40. The data processing unit 30 is connected at a proximal end 42 to the electrical signal cable 40. The electrical signal cable 40 is connected to the transducer head 20 at a distal end 44 by means of a termination board 25. The transducer head 20 receives transmitted signals from a signal transmitter 50 in the data processing unit 30. The transducer head 20 generates ultrasound signals which are reflected from an object and received at the transducer head 20. The transducer head 20 converts the received ultrasound signals into electrical received signals which are passed to a signal receiver 60 in the data processing unit 30 along the electrical signal cable 40.

[0022] Fig. 2 shows a first embodiment of an electrical signal cable 40 for use in the ultrasound diagnostic apparatus 10 of the invention. It comprises a plurality of ribbon cables 70. In Fig. 2 eight ribbon cables 70 are shown. However, this is merely illustrative of the invention and not intended to be limiting. A binder 200 is wrapped about the ribbon cables 70 and spacers 210. A shield 230 is disposed about the binder 200 and a jacket 240 extruded or wrapped about the shield 230.

[0023] Each ribbon cable 70 comprises a plurality of individual conductors 80 arranged in a parallel plane and surrounded by an upper insulating layer 90a laminated to a lower insulating layer 90b. The individual conductors 80 can be made from any conducting material such as copper, nickel-plated copper, tin-plated copper, silver-plated copper, tin-plated alloys, silver-plated alloys or copper alloys. Preferably the individual conductors 80 are made of round copper or alloy wire. It would also be possible to use flat conductors. The individual signal conductors 80 could also have a lacquered insulation layer.

[0024] The number of individual conductors 80 depicted in Fig. 2 is not intended to limiting of the invention. The axes of the individual conductors 80 are separated by a first pitch distance a which is in the range of 0.1 to 1 mm. The upper insulating layer 90a and the lower insulating layer 90b can be made of any insulating dielectric material such as polyethylene, polyester, perfluoralkoxy, fluoroethylene-propylene, polypropylene, polymethylpentene, polytetrafluoroethylene or expanded polytetrafluoroethylene. Preferably expanded polytetrafluoroethylene is used.

[0025] The flat cable 70 of this embodiment is manufactured by lamination as is taught in WO-A-99/59165 (Hoffmann) assigned to W.L. Gore & Associates GmbH. It would also be possible to use extrusion techniques to extrude the individual conductors 80 for example within a polyurethane, an FEP-based or a polyester layer. Alternatively foamed or solid polyethylene could be used. Furthermore the upper insulating layer 90a and the lower insulating layer 90b could be adhered together using a thermoplastic adhesive such as polyester adhesive or a polyurethane adhesive.

[0026] The ribbon cables 70 of the embodiment of Fig 2 are arranged in a planar manner, one above another, to form a bundle as taught in WO 99/59165 (Hoffmann) assigned to W.L. Gore & Associates GmbH.

[0027] Fig. 3 shows a further embodiment of an electrical signal cable 40 for use in the ultrasound diagnostic apparatus 10.

[0028] The electrical signal cable 40 of Fig. 3 comprises an optional tubular spacer 300 about a central axis 310 forming the central core of the electrical signal cable 40. Onto the tubular spacer 300 is disposed a first flat cable assembly 330. The structure of the first flat cable assembly 330 will be described later. The tubular spacer 300 is made from permeable ePTFE, PTFE, polyamide, polyurethane, persion or any other suitable material. The tubular spacer 300 may be solid or have a hollow interior to carry cooling fluids, electrical control lines, electrical power lines, gases etc. The tubular spacer 300 may further be made from a braided material and may also act as a strain relief.

[0029] In the embodiment of the invention depicted in Fig. 3, the first subcable assembly 330 is disposed within a third flat cable assembly 340 and is separated from the third flat cable assembly 340 by a second flat cable assembly 335. The first flat cable assembly 330 depicted in Fig. 3 comprises two layers 332a and 332b, which are each formed of a ribbon cable of the same construction to the ribbon cables 70 of the embodiment of Fig. 2. Each of the layers 332a and 332b is wrapped in the same direction. Similarly the third flat cable assembly 340 depicted in Fig. 3 comprises two layers 342a and 342b which are also formed by a flat cable 70 of the same construction as the ribbon cables 70 of the embodiment of Fig. 2. Each of the layers 342a and 342b is wrapped in the same direction as the layers 332a and 332b of the first flat cable assembly 330. The second flat cable assembly 335 is formed from a single ribbon cable 337 which is wrapped in a direction opposite to the layers 332a, 332b, 342a, 342b. The single ribbon cable 337 is formed by a flat cable 70 of the same construction as the ribbon cable 70 of the embodiment of Fig.2. The second flat cable assembly 335 could be replaced by a metal foil.

[0030] It is possible to conceive of an embodiment of the invention in which no further ribbon cables in further flat cable assemblies are present. It is also possible to conceive of an embodiment in which further ribbon cables are disposed about the third flat cable assembly 340 and separated from the second flat cable assembly

40 by further oppositely wrapped ribbon cables, as will be illustrated later.

[0031] An outer ground shield 370 is cylindrically disposed about the third flat cable assembly 340. The outer shield 370 is grounded and shields the flat cable assemblies 330, 335 and 340 within the cable assembly 40 from interfering electromagnetic fields. An insulating layer 380 is disposed about the outer ground shield 370 and the electrical signal cable 40 is then placed within a jacket 390.

[0032] The insulating layer 380 is made, for example, from PTFE, ePTFE, FEP or polyester. Preferably the insulating layer 380 is made from sintered GORE-TEX® tape which is obtainable from W.L.Gore & Associates and is wrapped about the electrical signal cable 40 using known wire-wrapping techniques.

[0033] The outer ground shield 370 is a braid, foil or wire shield made from a metal or a metallised polymer, such as copper, aluminium, tin-plated copper, silver-plated copper, nickel-plated copper, alloys or aluminised polyester. In one embodiment of the invention, the outer ground shield 370 is made from a copper braid with a braiding angle of about 35°. In some applications, the outer ground shield 370 can be omitted.

[0034] The jacket 390 is made from silicone or polyolefins such as polyethylene, polypropylene or polyethylpentene; fluorinated polymers such as fluorinated ethylene/propylene (FEP); fluorinated alkoxypolymer such as perfluoro(alkoxy)alkylanes, e.g. a co-polymer of TFE and perfluorproplyvinyl ether (PFA); polyurethane (PU), polyvinylchloride (PVC), silicone, polytetrafluoroethylene (PTFE) or expanded PTFE. In one embodiment of the invention the jacket 390 was made from PVC. In a further embodiment of the invention the jacket is made from ePTFE reinforced with silicone.

[0035] In the embodiment of the invention depicted in Fig. 3, the first flat cable assembly 330 and the third flat cable assembly 340 are depicted with two layers 332a, 332b and 342a, 342b respectively. The first flat cable assembly 330 and the third flat cable assembly 340 can have any number of layers 332a, 332b, 342a, 342b. Preferably the first flat cable assembly 330 and the third flat cable assembly 340 each have between one and three layers 332a, 332b, 342a, 342b. Two or more ribbon cables 70 could also be laid side-to-side in one of the layers 332a, 332b, 342a, 342b. Wrapping techniques for wrapping the layers 332a, 332b, 342a and 342b are known in the art and suitable machines are available from Ridgeway & Co., Leicester, UK, Roblon, Denmark, Innocable, France or Stolberger, Germany.

[0036] As taught earlier, the second flat cable assembly 335 is made of a flat cable 337 of identical construction to the flat cable 70. The flat cable 337 is surrounded by a first binder layer 336 on one side and a second binder layer 338 on the other side. The first binder layer 336 and the second binder layer 338 are made of the same materials as the upper insulating layer 90a and the lower insulating layer 90b and preferably of expanded polytetrafluorethylene. They are wrapped by known wrapping techniques. Manufacture of the layers of the first flat cable assembly 330, the second flat cable assembly 335 and the third flat cable assembly 340 is taught inWO 99/59165 (Hoffman) assigned to W.L. Gore & Associates GmbH.

[0037] The flat cable 337 of the second flat cable assembly 335 is connected to AC ground potential and thus isolutes the signals being carried on the conductors of 1the third flat cable assembly 340. If the flat cable 337 of the second flat cable assembly 337 is replaced by a metal foil, then this is also placed at AC ground potential.

[0038] Two embodiments of the termination of the electrical signal cable 40 to the data processing unit 30 are shown in Figs. 4 and 5. Fig. 4 shows a plurality of ribbon cables 70 which are connected to a rigid board 250. Both layers of the upper insulating layer 90a or the lower insulating layer 90b at one end of the ribbon cable 70 are stripped off, for example by laser ablation, to expose the individual conductors 80. The individual conductors 80 are then soldered or adhered to termination points 260 on the rigid board 250. The termination points 260 are connected to printed circuits (not shown) on the rigid board 250 which are in turn connected to electronic components such as inductors, capacitors or resistors, on the rigid board 250 or other circuitry within the data processing unit 30 or to a transducer. A plastic strip or molded potting 270 is glued across the top surface of the flat cables 70 in order to insulate the exposed ends of the individual conductors 80.

[0039] Fig. 5 shows another method of connecting the electrical signal cable 40 to the data processing unit 30. The flat cables 70 emanate from the electrical signal cable 40 through a sleeve 280. Both layers of the upper insulating layer 90a or the lower insulating layer 90b are stripped off to expose the individual conductors 80 which are then soldered onto termination points on a termination board 283. A plastic strip or molded potting 285 is placed over the upper surface of the individual conductors 80 to isolate the exposed ends of the individual conductors 80. The termination board 283 is electrically connected to a mother board 287 which contains inductors, capacitors or resistors. This is in turn electrically connected to a connector 290 which is plugged into the data processing unit 30. The termination method of Fig. 5 further includes a strain relief 293 made of a material of high tensile strength such as braided perlon cord which is attached to a post 295 on the termination board 283. The strain relief 293 may be connected to or threaded through the tubular spacer 300.

[0040] Termination of the electrical signal cable 40 to the transducer head 20 is shown in Fig. 6 in which the ribbon cables 70 emanate from the electrical signal cable 40 through a sleeve 280 and are connected on one or two sides of a flexible board 278. The flexible board 278 has a plurality of electrical tracks which are connected to the transducer head 20 and in particular to the transducer crystal (not shown) within the transducer head 20. The strain relief 293 is connected through a hole 277 in a rigid board 272 onto which is mounted the flexible board 278.

Example

[0041] The example depicted in Fig. 7 illustrates a construction of the electrical signal cable 40 with elements that can be made using the invention. The ribbon cables were served at angles between 30° and 35°.
The individual conductors were laminated at a pitch distance of 0.254 mm using the method taught in WO-A-99/59165 (Hoffmann) between a first insulation layer and a second insulation layer made of ePTFE. The insulation layers were each 0.1016 mm thick.
In this example, conductors made of silver-plated copper of AWG4201 (2mm diameter) were used. The spacer 1800 was made of woven Kevlar yarn over which was extruded a PU layer. The spacer 1800 had a nominal outside diameter of 1.5±0.1 mm. A first ribbon cable 1810 was wrapped about the spacer 1800. A first binder 1820 made of ePTFE was wrapped in the opposite direction about the first ribbon cable 1810. A second ribbon cable 1830 was wrapped in the opposite direction about the first binder 1820. A second binder 1840 was wrapped about the second ribbon cable 1830. A third ribbon cable 1850 was wrapped in the opposite direction about the second binder 1840. A third binder 1860 was wrapped in the opposite direction about the third ribbon cable 1850. A fourth flat cable 1870 was wrapped about the third binder 1860. A fourth binder 1880 was wrapped in the opposite direction about the fourth flat cable 1870. A fifth ribbon cable 1890 was wrapped about in the opposite direction about the fourth binder 1880. A fifth binder 1900 was wrapped about the fifth ribbon cable 1890 in the opposite direction and a sixth flat cable 1910 wrapped in the opposite direction about the fifth binder 1900. A sixth binder 1920 was wrapped in opposite direction about the sixth ribbon cable 1910 and a seventh ribbon cable 1930 in opposite direction about the sixth binder 1920. A seventh binder 1940 was wrapped in opposite direction about the seventh ribbon cable 1930. A eighth ribbon cable 1950 and a ninth ribbon cable 1960 were wrapped in the same direction adjacent to each other about the seventh binder 1940. An eighth binder 1970 was wrapped in opposite direction about the eighth ribbon cable 1950 and the ninth ribbon cable 1960. A tenth ribbon cable 1980 and an eleventh ribbon cable 1990 were wrapped in the same direction adjacent to each other about the eighth binder 1970. A ninth binder 2000 was wrapped in opposite direction about the tenth ribbon cable 1980 and the eleventh ribbon cable 1990. A twelfth ribbon cable 2010 and a thirteenth ribbon cable 2020 were wrapped adjacent to each other in an opposite direction about the ninth binder 2000. A tenth binder 2030 was wrapped in the opposite direction about the twelfth ribbon cable 2010 and the thirteenth ribbon cable 2020.

[0042] An outer shield 2040 was placed over the tenth binder 2030 and a jacket 2050 extruded over the outer shield 2040. The outer shield 2040 was made by braiding wire of tin plated copper at a braiding angle of 20° using 16 bobbins and 26 ends at 4 picks per inch (2.54cm). The outer jacket was made from extruded PVC and had a thickness of 0.76 mm.

[0043] In this example, the first ribbon cable 1810, the second ribbon cable 1830, the eighth ribbon cable 1950, the tenth ribbon cable 1980 and the twelfth ribbon cable 2010 were made of 16 individual conductors. The third ribbon cable 1850, the fourth ribbon cable 1870, the fifth ribbon cable 1890, the sixth ribbon cable 1910 and the eleventh ribbon cable 1990 were made with 24 individual con ductors. The seventh ribbon cable 1930 and the thirteenth ribbon cable 2020 were made with 32 individual conductors.

[0044] In operation the seventh ribbon cable 1930 was designed such that the individual conductors are placed at ground.

Further Examples

[0045] A further embodiment of the invention is conceivable which consists of alternate layers of binder and ribbon cables in concentric arrays. The binders and ribbon cables are wrapped in opposite directions. The ribbon cables are wrapped at slightly different angles in each concentric array so that the electrical conductors do not run parallel to each other over the whole of the electrical signal cable assembly.

Results

[0046] Figs. 8 and 9 shows exemplary results of cross talk measurements carried out on ribbon cables 70. In both cases three ribbon cables 1700a, 1700b and 1700c were disposed one on top of each other. Some of the electrical signal conductors 1710 carried AC ground signals. These are marked in the figs. with a black square. Other ones 1770 of the electrical signal conductors 1720 could carry received or transmitted signals. These are marked as an open square. On electrical signal conductor 1730 a signal was transmitted and the cross talk between this electrical signal conductor 1730 and some of the other ones of the electrical signal conductors 1720 was measured. The results in dB are given in the squares.

[0047] In the construction shown in Fig. 8, the middle one of the flat cables 1700b has electrical signal conductors 1710 which all carry an AC ground signal. In the upper one and the lower one of the ribbon cables 1700a, 1700c every other one of the electrical signal conductors 1710 kept at AC ground potential.

[0048] In the construction shown in Fig. 9, the middle one of the ribbon cables 1700b as well as the upper one and the lower one of the ribbon cables 1700a, 1700c have every other electrical signal conductor 1710 kept at AC ground potential.

[0049] It will be noted that the signal isolation achieved in the construction of Fig. 8 for corresponding electrical signal conductors is better than that achieved in the construction of Fig. 9.

[0050] Although a few exemplary embodiments of the present invention have been described in detail above, those skilled in the art readily appreciate that many modifications are possible without materially departing from the novel teachings and advantages which are described herein. Accordingly, all such modifications are intended to be included within the scope of the present invention, as defined by the following claims.

Claims

1. Imaging apparatus (10) having an ultrasonic transducer head (20) and a data processing unit (30) connected to each other by an electrical signal cable (40),
the data processing unit (30) comprising a signal transmitter (50) and a signal receiver (60)
the electrical signal cable (40) has at least two layers (330,340) each comprising at least one ribbon cable (332a, 332b, 342a, 342b)
wherein the at least two layers (330, 340) are separated by a ground plane (337) connectable to AC ground, and
wherein a first plurality of the electrical signal conductors of a first one of the at least two layers (330, 340) is connected to the signal transmitter (50) and a first plurality of the electrical signal conductors of a second one of the at least two layers (330, 340) is connected to the signal receiver (60).

2. Imaging apparatus (10) according to claim 1 wherein
said ground plane (335) is formed from a further ribbon cable (337) with a plurality of ground conductors being connectable to AC ground potential.

3. Imaging apparatus (10) according to claim 1 wherein
the at least two layers (330, 340) are disposed about a cylindrical spacer (300) in concentric arrays.

4. Imaging apparatus (10) according to claim 3 wherein
the at least two layers (330, 340) are served about the cylindrical spacer (300).

5. Imaging apparatus (10) according to claim 1 wherein
the at least two layers (330, 340) have a plurality of electrical conductors, whereby

- at least one of the plurality of electrical conductors is connectable to AC ground potential, and
- at least a further one of the plurality of electrical conductors is connectable to a signal.

6. Imaging apparatus (10) according to claim 5 wherein
said ground plane (335) is formed from a further ribbon cable (337) with a plurality of ground conductors being connectable to AC ground potential.

7. Imaging apparatus (10) according to claim 5 wherein
the at least two layers (330,340) are disposed about a cylindrical spacer (300) in concentric arrays.

8. Imaging apparatus (10) according to claim 7 wherein
the at least two layers (330, 340) are served about the cylindrical spacer (300).

9. Imaging apparatus (10) according to claim 1 wherein one of the at least two layers (330, 340) comprises two or more ribbon cables disposed adjacent to each other.

10. Imaging apparatus (10) according to claim 1 wherein a dielectric spacer (336, 338) is disposed between one of the at least two layers (330, 340) and the ground plane (335).

11. Imaging apparatus (10) according to claim 1 wherein the ribbon cables (332a, 332b, 342a, 342b) comprise a plurality of electrical conductors encased within an insulator comprising an upper insulator (90a) attached to a lower insulator (90b).

12. Imaging apparatus (10) according to claim 11 wherein
said insulator comprises an upper insulator (90a) sintered to a lower insulator (90b).

13. Imaging apparatus (10) according to claim 11 wherein
said insulator comprises an upper insulator (90a) adhered to a lower insulator (90b) by an adhesive.

14. Imaging apparatus (10) according to claim 13 wherein
said adhesive is selected from the group of thermoplastic adhesives comprising polyester, polyurethane or fluorinated ethylene/propylene.

15. Imaging apparatus (10) according to claim 11 wherein
the insulator of the ribbon cable is formed from the group of insulating materials consisting of perflouralkoxy, fluorethylene-propylene, polyester, polyole-

fin including polyethylene and polypropylene or polymethylpentene.

16. Imaging apparatus (10) according to claim 11 wherein
the insulator of the ribbon cable is formed from expanded polytetrafluorethylene.

17. Imaging apparatus (10) according to claim 11 wherein
the insulator of the ribbon cable is formed from full density polytetrafluorethylene.

18. Imaging apparatus (10) according to claim 11 wherein
the insulator of the ribbon cable comprises an extruded polymer.

19. Imaging apparatus (10) according to claim 11 wherein
the insulator of the ribbon cable comprises a foamed polymer.

20. Cable assembly (40) comprising

- at least two layers (330, 340) separated by ground plane (335)
- at least a first termination board (250, 283) having at least two groups of routing paths and electrically connected to the at least two ribbon cables (70, 332a, 332b, 342a, 342b); and
- at least a second termination board (25, 272) electrically connected to the at least two ribbon cables (70, 332a, 332b, 342a, 342b).

21. Cable assembly (40) according to claim 20 wherein said ground plane (335) is formed from a further ribbon cable (337) with a plurality of ground conductors being connectable to AC ground potential on the system termination board (250, 283).

22. Cable assembly (40) according to claim 20 wherein the at least two layers (330, 340) are disposed about a cylindrical spacer (300) in concentric arrays.

23. Cable assembly (40) according to claim 22 wherein at least two layers (330, 340) are served about the cylindrical spacer (300).

24. Cable assembly (40) according to claim 20 wherein the at least two layers (330, 340) have a plurality of electrical conductors, whereby

- at least one of the plurality of electrical conductors is connectable to AC ground potential, and
- at least a further one of the plurality of electrical conductors is connectable to a signal.

25. Cable assembly (40) according to claim 24 wherein said ground plane (335) is formed from a further ribbon cable (337) with a plurality of ground conductors being connectable to AC ground potential.

26. Cable assembly (40) according to claim 24 wherein the at least two layers (330, 340) are disposed about a cylindrical spacer (300) in concentric arrays.

27. Cable assembly (40) according to claim 26 wherein the at least two layers (330, 340) are served about the cylindrical spacer (300).

28. Cable assembly (40) according to claim 20 wherein one of the at least two layers (330,340) comprise two or more ribbon cables disposed adjacent to each other.

29. Cable assembly (40) according to claim 20 wherein a dielectric spacer (336, 338) is disposed between one of the at least two layers (330, 340) and the ground plane (335).

30. Cable assembly (40) according to claim 20 wherein the ribbon cables (332a, 332b, 342a, 342b) comprise a plurality of electical conductors encased within an insulator comprising an upper insulator (90a) attached to a lower insulator (90b).

31. Cable assembly (40) according to claim 30 wherein said insulator comprises an upper insulator (90a) sintered to a lower insulator (90b).

32. Cable assembly (40) according to claim 30 wherein said insulator comprises an upper insulator (90a) adhered to a lower insulator (90b) by an adhesive.

33. Cable assembly (40) according to claim 32 wherein said adhesive is selected form the group of thermoplastic adhesives comprising polyester, polyurethane or flourinated ethylene/propylene.

34. Cable assembly (40) according to claim 30 wherein the insulator of the ribbon cable is formed from the group of insulating materials consisting of perfluoralkoxy, fluorethylene-propylene, polyester, polyolefin including polyethylene and polypropylene or polymethylpentene.

35. Cable assembly (40) according to claim 30 wherein the insulator of the ribbon cable is formed from expanded polytetraflourethylene.

36. Cable assembly (40) according to claim 30 wherein the insulator of the ribbon cable is formed from full density polytetraflourethylene.

37. Cable assembly (40) according to claim 30 wherein the insulator of the ribbon cable comprises an extruded polymer.

38. Cable assembly (40) according to claim 30 wherein the insulator of the ribbon cable comprises a foamed polymer.

39. Cable assembly (40) according to claim 20 wherein the first termination board (250,283) is electrically connected to a data processing unit (30).

40. Cable assembly (40) according to claim 20 wherein the second termination board (25, 272) is electrically connected to a transducer head (20).

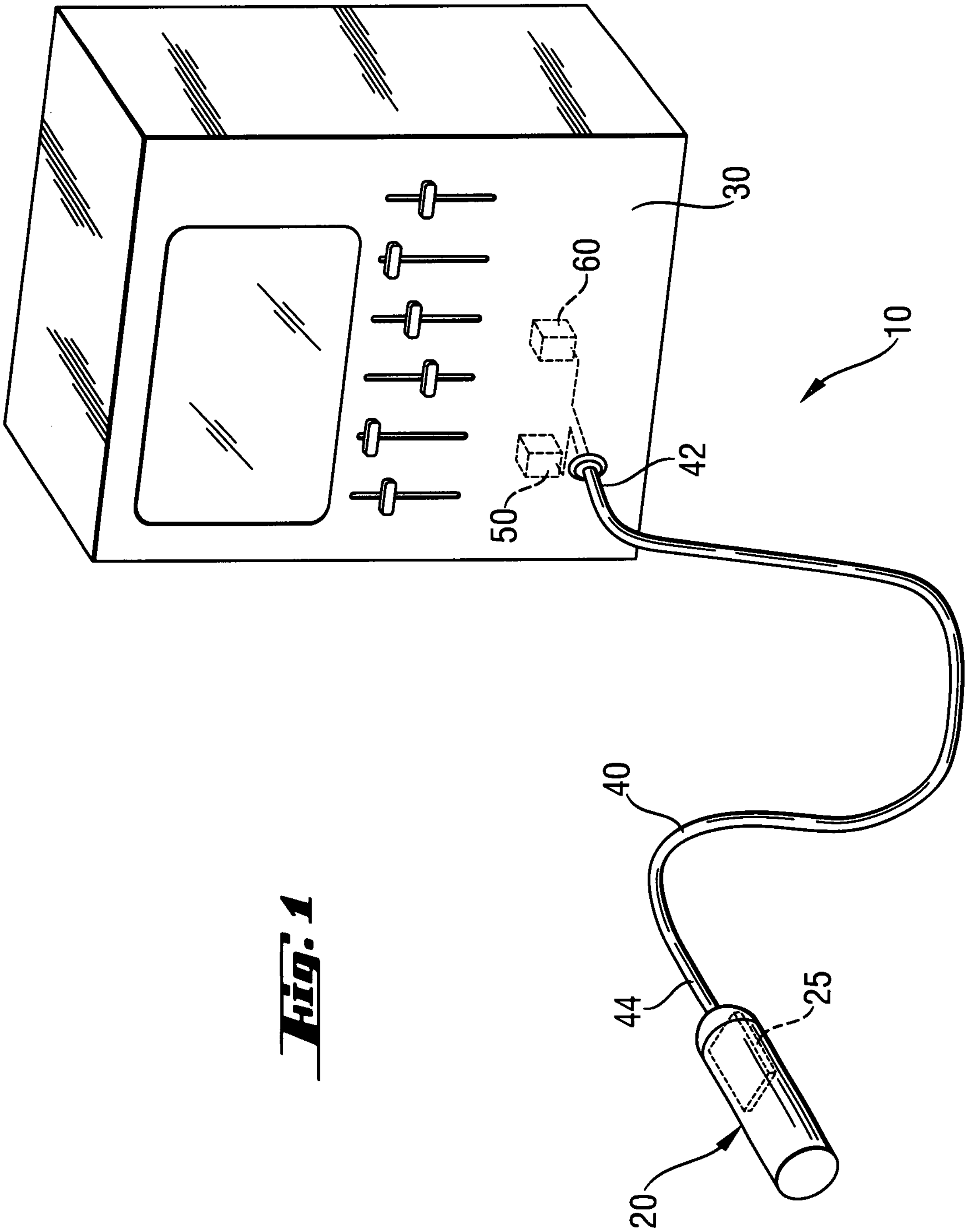


Fig. 1

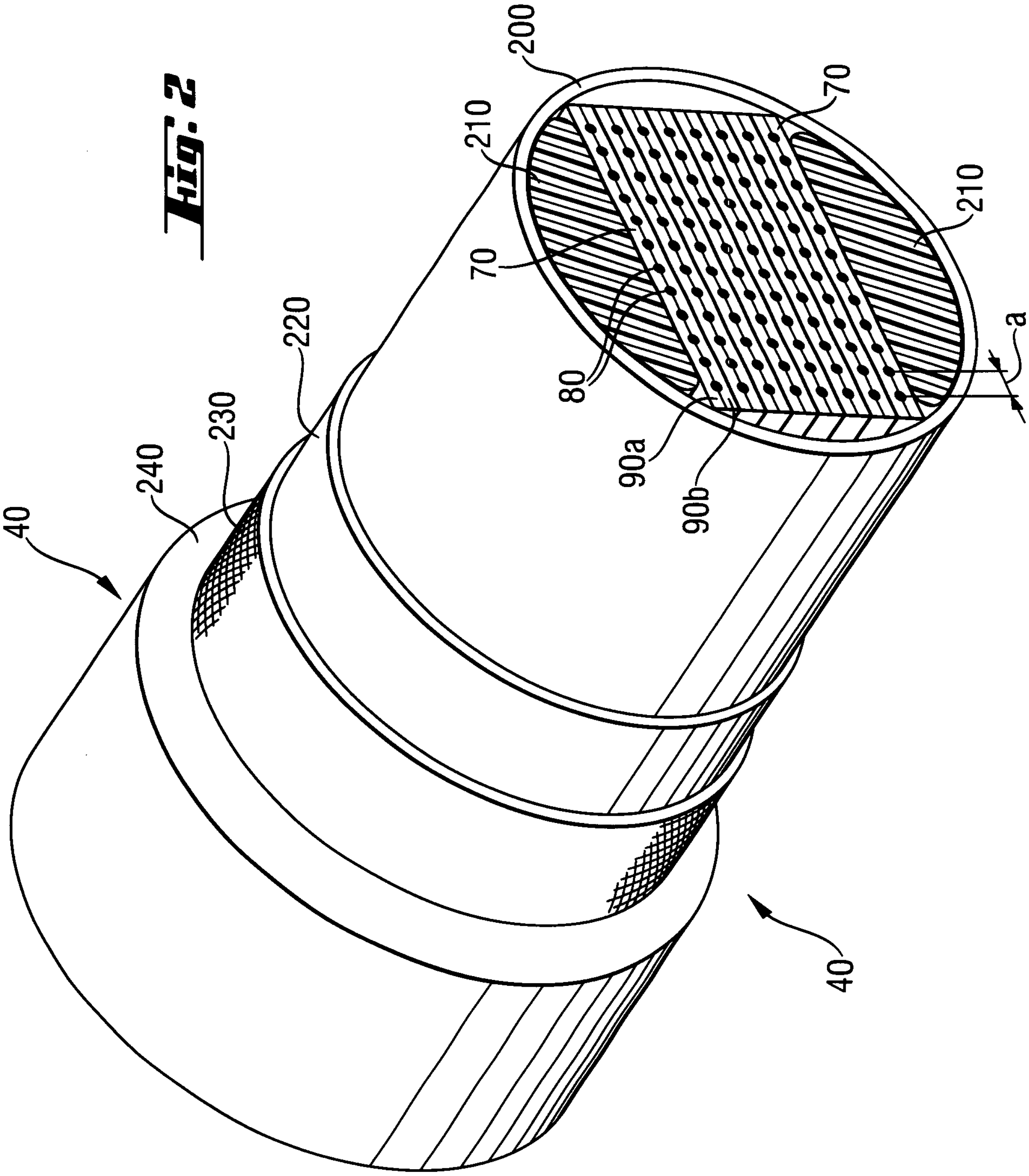
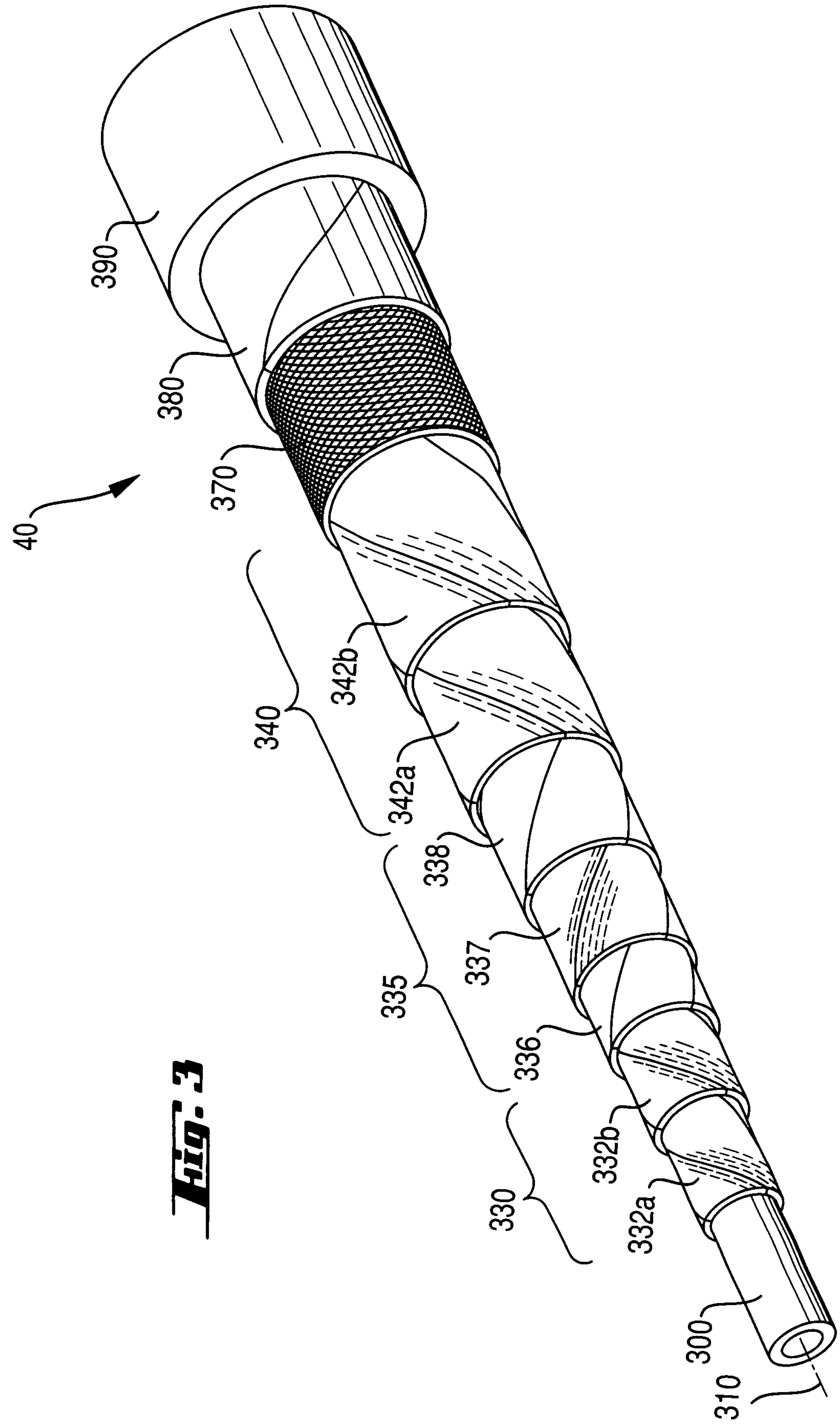


Fig. 2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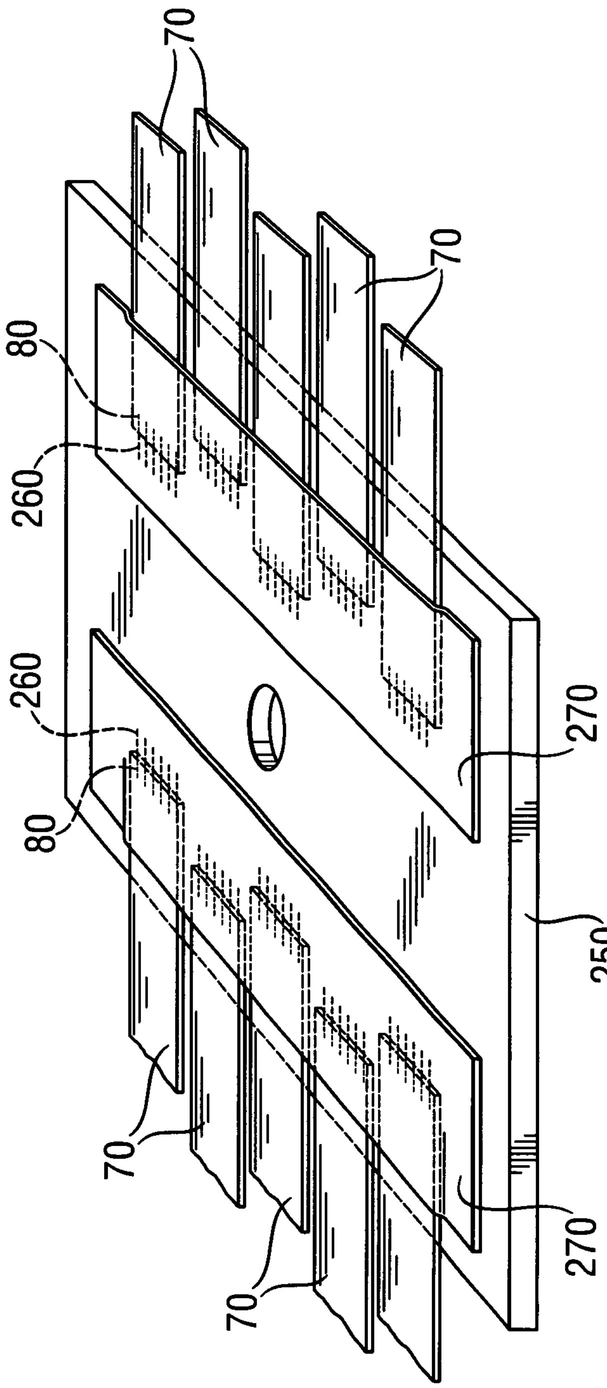
370
40
340
342b
342a
338
335
337
336
330
332b
332a
300
310

Fig. 3

Fig. 4



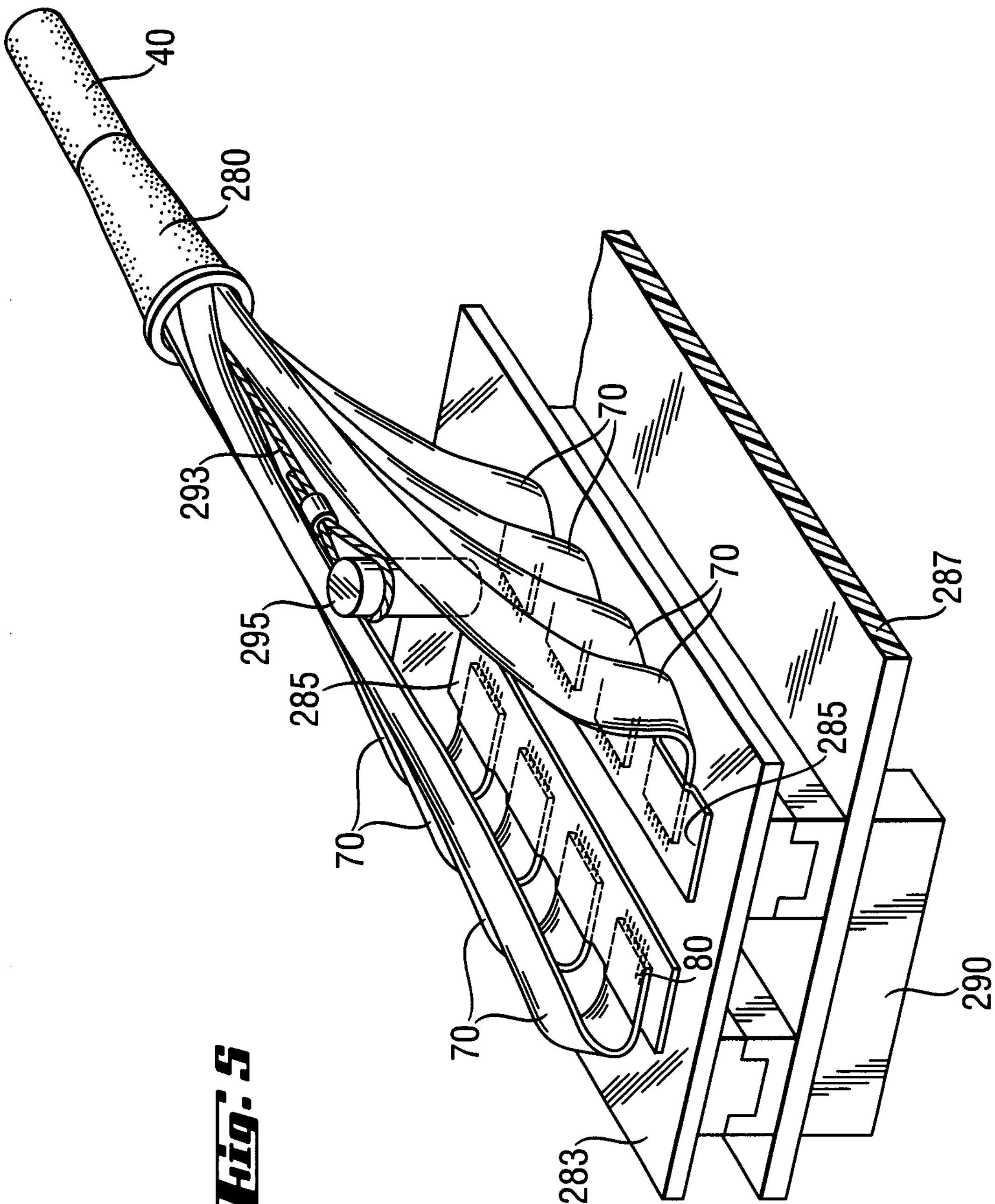


Fig. 5

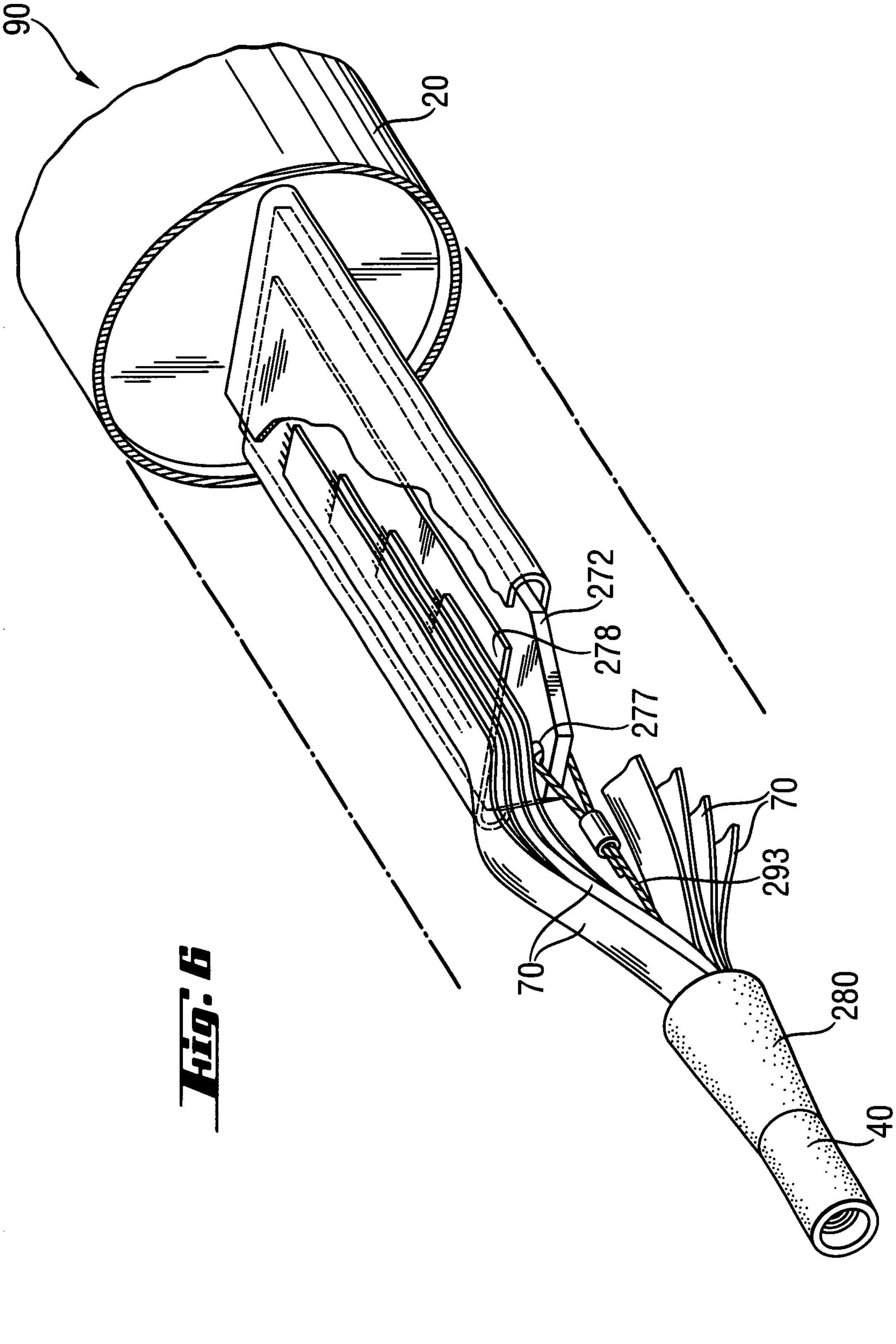
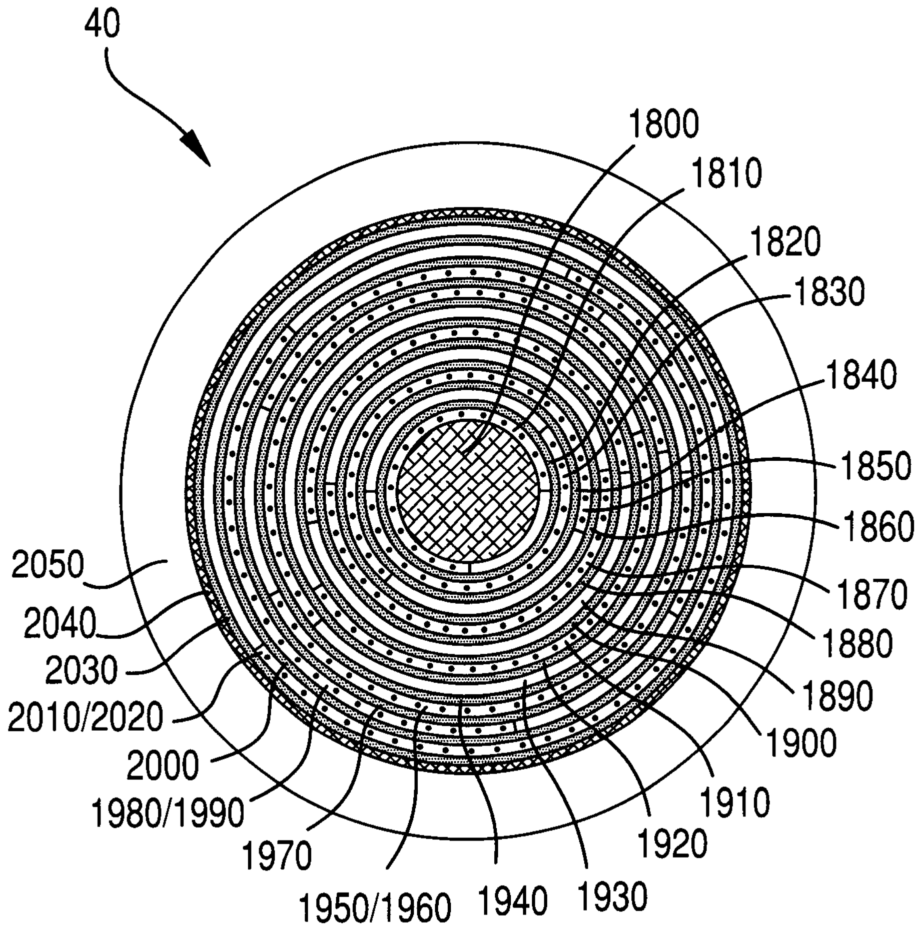


Fig. 6

Fig. 7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1950/1960
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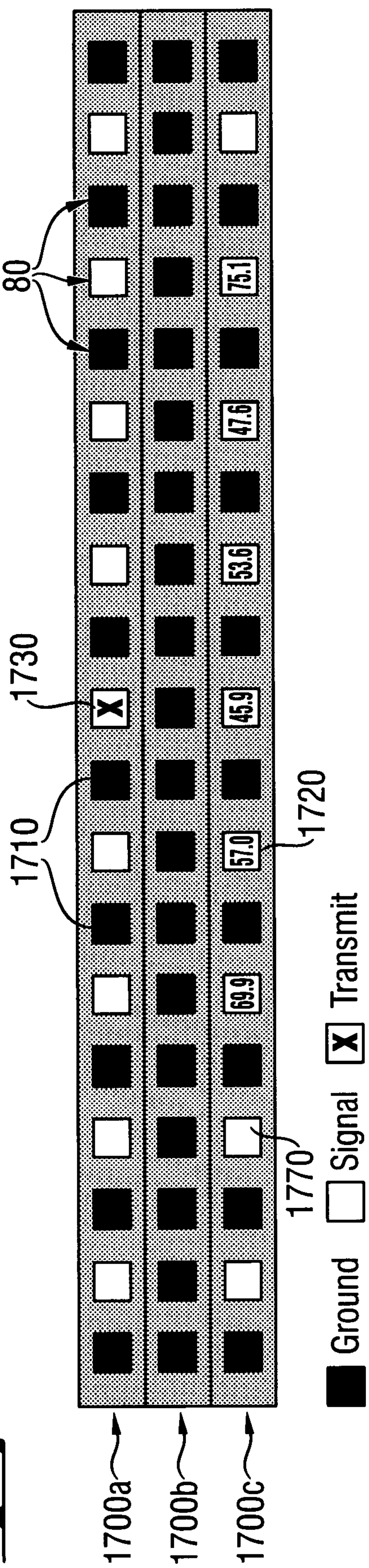
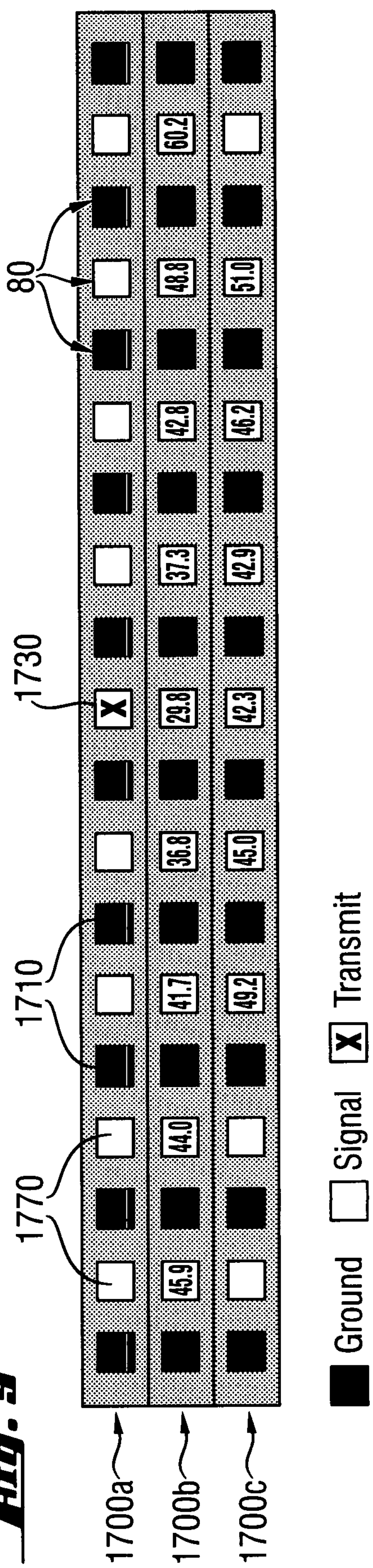
1980/1990
2000
2010/2020
2030
2040
2050



80
1730
1710
1720
1770
75.1
47.6
53.6
45.9
57.0
69.9
X
1700a
1700b
1700c
Ground
Signal
Transmit

Fig. 8



80
1730
1710
1770
60.2
48.8
42.8
37.3
29.8
36.8
41.7
44.0
45.9
51.0
46.2
42.9
42.3
45.0
49.2
X
1700a
1700b
1700c
Ground
Signal
Transmit

Fig. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 01 10 7990

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H01B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	7 September 2001	Demolder, J

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