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3 QUADRIFILAR HELIX ANTENNA

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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and
7 used by or for the Government of the United States of America
8 for governmental purposes without the payment of any royalties
9 thereon or therefor.

10
11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 This invention generally relates to antennas and more
14 specifically to quadrifilar antennas.

15 (2) Description of the Prior Art

16 Numerous communication networks utilize omnidirectional
17 antenna systems to establish communications between various
18 stations in the network. In some networks one or more stations
19 may be mobile while others may be fixed land based or satellite
20 stations. Omnidirectional antenna systems are preferred in
21 such applications because alternative highly directional
22 antenna systems become difficult to apply, particularly at a
23 mobile station that may communicate with both fixed land based
24 and satellite stations. In satellite communication
25 applications it is desirable to provide a unidirectional
26 antenna system that is compact yet characterized by a wideband
27 width and a good front-to-back ratio, i.e., the ratio of
28 overhead power to backside power, such that its pattern ideally
29 only occupies the upper hemisphere.

1 Some prior art omnidirectional antenna systems use an end
2 fed quadrifilar helix antenna for satellite communication and a
3 co-mounted dipole antenna for land based communications.
4 However, each antenna has a limited bandwidth and collectively
5 their performance can be dependent upon antenna position
6 relative to a ground plane. The dipole antenna tends to have
7 no front-to-back ratio which can cause total pattern
8 cancellation when the antenna is mounted on a ship,
9 particularly over low elevation angles. These co-mounted
10 antennas also have spatial requirements that can limit their
11 use in confined areas aboard ships or similar mobile stations.

12 The following patents disclose helical antennas that
13 exhibit some, but not all, the previously described desirable
14 characteristics:

15	3,599,220	(1971)	Demsey
16	3,623,113	(1971)	Faigen et al.
17	4,243,993	(1981)	Lamberly et al.
18	4,644,366	(1987)	Scholz
19	5,053,786	(1991)	Silverman et al.
20	5,134,422	(1992)	Auriol
21	5,170,176	(1992)	Yasunaga et al.

1 5,343,173 (1994) Balodis et al.
2 5,594,461 (1997) O'Neil, Jr.
3 5,635,945 (1997) McConnell
4

5 United States Letters Patent No. 3,599,220 to Dempsey
6 discloses a conical, spiral loop antenna comprising a plurality
7 of pairs of spirally wound radiating arms. The radiating arms
8 are wound in the shape of a cone and terminate at one end in a
9 truncated portion. Impedance matching is provided between each
10 of the pairs of radiating arms at the truncated end. A ground
11 plane is provided for each frequency of operation; multiple
12 ground planes are required for multiple frequencies. The
13 primary purpose of this patent is to provide a compact antenna
14 that is tunable. However, it appears that the antenna is
15 generally tuned for a specific frequency.

16 United States Letters Patent No. 3,623,113 to Faigen et
17 al. discloses a balanced, tunable, helical mono-pole antenna
18 that operates independently of a ground plane. This antenna
19 utilizes a centrally fed, multiple-turn, helical antenna with a
20 single element. End winding shorting means in the form of "top
21 hat"- or "can"-type housings tune the antenna by changing the
22 active electrical length of the antenna. A feed loop is
23 centrally disposed to the helical mono-pole antenna winding to
24 provide a balanced input to the antenna. Although this antenna
25 is compact and can be tuned through a wide bandwidth, it does
26 not provide an omnidirectional radiation pattern.

1 United States Letters Patent No. 4,243,993 to Lamberty et
2 al discloses a broad band antenna comprising center fed, spiral
3 antenna arms arranged on planar and conical surfaces. Each
4 antenna arm includes one or more choke elements that resonate
5 at a predetermined operating frequency to eliminate or minimize
6 undesired radiation and reception characteristics and provide
7 sum and difference mode operations with both right-hand and
8 left-hand circularly polarized radiation characteristics.
9 Feeding an antenna as disclosed in the Lamberty et al patent
10 with a phased sequence of signals produces a radiation pattern
11 that exhibits a null along an antenna bore sight axis and a
12 maximum field along a cone of revolution about the bore sight
13 axis. Although this antenna has a broad bandwidth and provides
14 circular polarization, it does not provide an omnidirectional
15 radiation pattern.

16 United States Letters Patent No. 4,644,366 to Scholz
17 discloses a miniature radio transceiver antenna formed as an
18 inductor wrapped about a printed circuit card. A peripheral
19 conductor on one side of the card provides distributed
20 capacitance to the end of the antenna that cancels inductive
21 effects and broadens bandwidth. A peripheral conductor on the
22 opposite side of the card provides a capacitance to ground to
23 tune the antenna to frequency. An unbalanced transmission line
24 connects between one end of the antenna and a tap or feed point
25 to provide impedance matching and tuning. This antenna has a

1 limited bandwidth for a given connection point. Moreover it
2 does not produce an omnidirectional radiation pattern.

3 United States Letters Patent No. 5,053,786 to Silverman et
4 al. discloses a broad band directional antenna in which two
5 contiguous conductive planar spirals are fed at their center.
6 The antenna is positioned near a cavity to absorb rear lobes in
7 order to improve the front-to-back ratio. Even with this
8 improvement in the front-to-back ratio, the antenna provides a
9 relatively narrow beam pattern having both horizontal and
10 vertical polarization. Apparently, this antenna is designed to
11 operate with a linearly polarized, high gain, narrow beam.
12 Thus the antenna does not provide an omnidirectional radiation
13 pattern or circular polarization. Moreover, by absorbing the
14 rear lobes, the power transmitted into the reserve lobes is
15 lost making the antenna less efficient in radiating during a
16 transmitting mode.

17 United States Letters Patent No. 5,134,422 to Auriol
18 discloses an antenna with helically wound, equally spaced,
19 radiating elements disposed on a cylindrical surface. Antennas
20 identified as prior art antennas in this reference include
21 helically wound, end driven antenna elements. The other ends
22 of the elements terminate as open circuits. These antennas
23 provide circular polarization, an omnidirectional radiation
24 pattern and a good front-to-back ratio. The Auriol patent is
25 particularly directed to a structure that uses a conductive,
26 meandering strip to connect the driven ends and establish
27 various phase relationships and tuning. This antenna is

1 designed to produce high quality circular polarization, an
2 omnidirectional radiation pattern and a good front-to-back
3 ratio, but only over a narrow frequency band.

4 In United States Letters Patent No. 5,170,176 (1992) to
5 Yasunaga et al. a quadrifilar helix antenna includes four helix
6 conductors wound around an axis in the same winding direction.

7 Each helix conductor has a linear conductor which is parallel
8 to its axis at either end or both ends of the helix conductor.

9 The purpose of this structure is to reduce the effect of
10 multipath fading due to sea-surface reflection in mobile
11 satellite communications. Although this patent discloses an
12 antenna that provides good front-to-back ratio, the
13 transmission pattern from the antenna is also characterized by
14 essentially forming two major lobes about 60° from the forward
15 direction so it is not truly omni-directional over a
16 hemisphere.

17 United States Letters Patent No. 5,343,173 (1994) to
18 Balodis et al. discloses a phase shifting network and antenna
19 including a series of helical antenna elements with a phase
20 shifting network defining transmission paths between a radio
21 connection terminal and the antenna elements. Each
22 transmission path phase shifts the signal relative to an
23 adjacent path pairs that are progressively joined at combiner
24 nodes of equal power division by shunt connection line
25 segments.

1 United States Letters Patent No. 5,594,461 (1997) to
2 O'Neill, Jr. discloses a low loss quadrature matching network
3 for a quadrifilar helix antenna. As in the above-identified
4 Balodis et al. patent, the O'Neill, Jr. patent utilizes
5 microstrip techniques to provide impedance matching in an
6 antenna system.

7 United States Letters Patent No. 5,635,945 (1997) to
8 McConnell et al. discloses a quadrifilar helix antenna with
9 four conductive elements arranged to define two separate
10 helically twisted loops, one differing slightly in electrical
11 length from the other. The two separate helically twisted
12 loops are connected to each other in a way as to provide
13 impedance matching, electrical phasing, coupling and power
14 distribution for the antenna. The antenna is fed at a tap
15 point on one of the conductive elements determined by an
16 impedance matching network which connects the antenna to a
17 transmission line. Like to foregoing Balodis et al. and
18 O'Neill, Jr. patents, this patent also utilizes microstrip
19 techniques to feed and match through a partly balanced
20 transmission line. As a result the resultant band width is
21 narrow.

22 The following patent discloses a broadband antenna system:

23 5,257,032 (1993) Diamond et al.

24 This broadband antenna system includes a frequency-
25 independent antenna coupled to the frequency-dependent antenna,
26 specifically, a spiral antenna and a dipole antenna. In one
27 embodiment the antenna system comprises a dipole or monopole

1 coupled to the inner or outer termination points of a spiral
2 antenna. The spiral antenna acts as a broadband transmission
3 line matching section and adds electrical length to the
4 monopole antenna. Thus, the spiral antenna is stated to
5 minimize the negative effects typically associated with the
6 removal of one of the elements of a stand alone dipole antenna
7 to create a monopole antenna. It is believed that when the
8 dipole antenna is added to the termination points of the spiral
9 antenna, the resulting antenna system extends the low frequency
10 capability of the spiral antenna for linear polarization. It
11 is also felt that the spiral antenna adds electrical length to
12 the dipole antenna and acts as a broadband transmission line
13 matching section so that the spiral antenna enhances receiving
14 capability by producing a maximum signal at the transmission
15 lines. This patent discloses the combination of two types of
16 antennas. However, the combination includes a spiral antenna
17 and either a monopole or dipole antenna. It also appears that
18 the antenna system is directional and not omni-directional over
19 both a broad frequency band and over a hemispherical volume.

20 Thus there exists a family of quadrifilar helixes that are
21 broadband impedance wise above a certain "cut-in" frequency,
22 and thus are useful for wideband satellite communication (DAMA
23 function of 240 to 320 MHz, other functions at 320 to 410 MHz).
24 Typically these antennas have:

- 25 1. a pitch angle of the elements on the helix cylindrical
26 surface from 50° down to roughly 20° ;

- 1 2. elements that are at least roughly $\frac{3}{4}$ wavelengths long;
- 2 and
- 3 3. a "cut-in" frequency roughly corresponding to when a
- 4 turn of an element on the helix cylinder is $\frac{1}{2}$ wavelength
- 5 long. (This dependence changes some with pitch angle.
- 6 Above the "cut-in" frequency, the helix has an
- 7 approximately flat VSWR, around 2:1 or less about the Z_0
- 8 value of the antenna, and thus the antenna is broadband
- 9 impedancewise above "cut-in".)

10 The previous three dimensions translate into a helix
11 diameter of .1 to .2 wavelengths at "cut-in".

12 For pitch angles of approximately 30° to 50° , good cardoid
13 shaped patterns exist for satellite communications. Good
14 circular polarization exists down to the horizon since the
15 antenna is greater than 1.5 wavelengths long (2 elements
16 constitute one array of the dual array, quadrifilar antenna)
17 and is at least one turn. At the "cut-in" frequency, the lower
18 angled helixes have sharper patterns. As frequency increases,
19 patterns start to flatten overhead and spread out near the
20 horizon. For a given satellite band to be covered, a tradeoff
21 can be chosen on how sharp the pattern is allowed to be at the
22 bottom of the band and how much it can be spread out by the
23 time the top of the band is reached. This tradeoff is made by
24 choosing where the band should start relative to the "cut-in"
25 frequency and by choosing the pitch angle.

1 For optimum front-to-back ratio performance, the bottom of
2 the band should start at the "cut-in" frequency. This is
3 because for a given element thickness, backside radiation
4 increases with frequency (the front-to-back ratio decreases
5 with frequency). This decrease of front-to-back ratio with
6 frequency limits the antenna immunity to multipath nulling
7 effects.

8
9 SUMMARY OF THE INVENTION

10
11 Therefore it is an object of this invention to provide a
12 broad band unidirectional hemispherical coverage antenna.

13 Another object of this invention is to provide a broad
14 band unidirectional hemispherical coverage antenna with good
15 front-to-back ratio.

16 Yet another object of this invention is to provide a broad
17 band unidirectional hemispherical coverage antenna that
18 operates with circular polarization.

19 Yet still another object of this invention is to provide a
20 broad band unidirectional hemispherical coverage antenna that
21 operates with a circular polarization and that exhibits a good
22 front-to-back ratio.

23 Yet still another object of this invention is to provide a
24 broad band unidirectional hemispherical coverage antenna that
25 is simple to construct.

1 In accordance with this invention, a helical antenna
2 includes a plurality of antenna elements supported as spaced
3 helices along an antenna axis. Antenna feed points are located
4 proximate the antenna axis at a first end of the helices. A
5 spiral connector between each antenna element and one of the
6 antenna feed points is located between each antenna element and
7 one of the antenna feed points. These spiral connectors lie in
8 a transverse plane at one end of the helices.

9 In accordance with another object of this invention a
10 quadrifilar helical antenna operates over a frequency bandwidth
11 defined by a minimum operating frequency and includes a
12 cylindrical support extending along an antenna axis between
13 first and second ends thereof. The cylindrical support carries
14 four equiangularly spaced helical antenna elements each having
15 a length of at least $3/4$ wavelength of the antenna minimum
16 operating frequency. A planar feed end support is located at
17 the first end of the antenna and transverse to the cylindrical
18 support for defining a feed point for each antenna element.
19 Four conductors are arranged in spiral paths that are
20 oppositely wound from the helical antenna elements. Each
21 conductor connects between a feed point and a corresponding
22 antenna element. A pair of radially opposite conductors
23 constitutes a transmission line, thus four conductors, or two
24 pairs constitute two transmission lines. The two transmission
25 lines are fed in phase quadrature at the antenna feed point.

1 BRIEF DESCRIPTION OF THE DRAWINGS

2 The appended claims particularly point out and distinctly
3 claim the subject matter of this invention. The various
4 objects, advantages and novel features of this invention will
5 be more fully apparent from a reading of the following detailed
6 description in conjunction with the accompanying drawings in
7 which like reference numerals refer to like parts, and in
8 which:

9 FIG. 1 depicts an antenna system constructed in accordance
10 with this invention for operating in an open mode;

11 FIG. 2 depicts an antenna system constructed in accordance
12 with this invention for operating in a shorted mode;

13 FIG. 3 depicts a transverse section of a particular
14 embodiment of spiral feed point connectors shown in FIG 1;

15 FIG. 4 depicts another embodiment of a spiral conductor
16 useful in the connector of FIG. 1;

17 FIGS. 5 through 8 provide comparisons of the front/back
18 ratios of a prior art antenna and an antenna constructed in
19 accordance with this invention in horizontal and vertical
20 polarization and in open and shorted operating modes;

21 FIG. 9 depicts the voltage standing wave ratio (VSWR) of
22 an antenna constructed in accordance with this invention
23 operating in the open and shorted modes; and

24 FIGS. 10 and 11 depict the radiation patterns for
25 horizontally and vertically polarized signals, respectively, to
26 compare the patterns from an antenna embodying this invention.
27 and the corresponding prior art antenna.

1 DESCRIPTION OF THE PREFERRED EMBODIMENT

2 FIG. 1 depicts, in schematic form, an antenna 20
3 constructed in accordance with this invention. A cylindrical
4 support 21 extends along a longitudinal antenna axis 22 between
5 a first or feed end 23 and a second or distal end 24. The
6 cylindrical support 21 is composed of an insulating material
7 that exhibits low losses at the RF frequencies involved, namely
8 between 200 and 500 MHz.

9 The support additionally includes a planar support 25 at a
10 feed end 23 that is transverse to the cylindrical support 21
11 and the antenna axis 22. The planar support 25 is also made of
12 a low loss insulating material. The planar support 25 includes
13 an antenna feed point shown generally at 26, for receiving
14 signals from a transmitter or transferring received signals to
15 a receiver (not shown) in quadrature phase and an array 27 of
16 spiral conductors.

17 In accordance with this invention, the antenna support 21
18 carries an even number of equiangularly spaced helically
19 wrapped antenna elements 30, 31, 32 and 33, respectively.
20 Typically the plurality will be constituted by four such
21 conductors. Each of the equiangularly spaced elements 30
22 through 33 will have a length exceeding three-quarters of a
23 wave length (i.e., $3/4 \lambda_{\text{min}}$) at a minimum operating frequency.

24 In FIG. 1, each of the antenna elements 30 through 33
25 terminates in an open circuit at the distal end 24. FIG. 2
26 depicts the antenna of FIG. 1 with the addition of shorting

1 conductors at the distal end. That is, a diametrically
2 disposed conductor 35 interconnects the distal ends of the
3 antenna elements 31 and 33 and a corresponding diametrically
4 disposed conductor 36 interconnects the distal ends of the
5 antenna elements 30 and 32. As known, but not specifically
6 shown in FIG. 2, the conductors 35 and 36 will be insulated
7 from each other.

8 Referring to FIGS. 1, 2 and 3, the array 27 at the feed
9 end 23 depicts four spiral conductor paths between the feed
10 point 26 and the conductors. In the embodiment of FIG. 3 a
11 spiral connector 37 extends between an antenna feed point 38
12 for about two and one-half turns to an antenna element
13 connection 39 with an overall length of at least one-half
14 wavelength at the minimum operating frequency (i.e., $0.5\lambda_{\min}$).
15 Other spiral connectors are shown in partial detail. The
16 result is that each spiral conductor, such as conductor 37,
17 connects between an antenna feed point and a connection at an
18 antenna element. Each pair of radially opposite spiral
19 conductors, i.e., (37;43) and (40,46), constitutes a
20 transmission line, designated T1 and T2, respectively. Thus,
21 the four spiral conductors constitute two transmission lines
22 that are crossed. For the antenna of FIG. 3, the connections
23 are as follows:

1

Feed Point Phase	Transmission Line	Spiral Conductor	Antenna Feed Point	Antenna Element	Antenna Element Connection
0°	T1	37	38	30	39
270°	T2	40	41	31	42
180°	T1	43	44	32	45
90°	T2	46	47	33	48

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Each of the spiral conductors lies along an Archimedean or equiangular spiral path. As is also particularly evident from conductor 37 in FIG. 3, the volume of the conductor increases from the antenna element connection 39 to the antenna feed point 38. Each of the other spiral conductors 40, 43 and 46 have the same characteristic. That is, the volume increases from the outside of the spiral where the connections are made to the antenna elements to the inside of the spiral where each of the conductors attaches as an antenna feed point. The increase in volume may be constituted merely by an increase in width or by an increase in thickness or both. Consequently the input impedance at the antenna element connections (39, 45) and (42, 48) of the spiral transmission lines T1 and T2 will match the input impedance to the antenna elements (30, 32) and (31, 33) while the input impedance at the antenna feed points (38, 44,) and (41, 47) will match the impedance of the two transmission lines (not shown) feeding the RF energy to the antenna. Processes for performing this matching operation by microstrip technology are well known in the art.

1 The variation in volume is depicted as a linear function
2 in FIG. 3. The variation could be exponential or follow other
3 mathematical rules. Moreover, in FIG. 3, the conductors could
4 have a variable width and constant thickness.

5 At the antenna feed point 26, the structure shown in FIG.
6 3 has a practical lowest input impedance of about 100 ohms,
7 which feeds nicely into the balanced 100 ohm port of a 50 to
8 100 ohm, 180° power splitter (not shown). Two such splitters
9 connected to a 90° power splitter will allow a 50 ohm line to
10 connect to the antenna in phase quadrature. An alternative
11 spiral that can obtain exactly 100 ohms or much lower values of
12 input impedance is shown in FIG. 4. The spiral is converted to
13 three dimensions having conductors that have a variable depth
14 along the helix axis 22. In such a structure an air foam
15 spacer would separate the conductors. The conductor 50 would
16 have a high impedance at an end 51 and a low impedance at an
17 end 52. This is believed to provide more evenly spaced current
18 distributions across the element surface, thereby reducing
19 ohmic loss in the signal and consequently producing lower
20 antenna losses.

21 As shown in FIGS. 1 and 2, the current path through the
22 spiral connector array 27 and the current path through the
23 antenna elements 30 through 33 are in reverse directions when
24 viewed along the antenna axis 22. That is, viewed from the
25 feed end 23, the current paths for the array are clockwise
26 about the axis while the current paths for the antenna elements
27 30 through 33 are counterclockwise. This reverse direction is

1 important in that backside radiation increases as the elements
2 are changed from reverse spiral arms to radial arms to same
3 direction spiral arms. It is believed that the small amount of
4 circular polarized radiation produced on the backside of the
5 antenna pattern by the helical elements is canceled to a large
6 extent by circular polarized radiation in the opposite
7 direction produced by connector array 27.

8 The performance and improvements over prior art antennas
9 can be better appreciated by referring to the following
10 example: An antenna according to this invention has the
11 cylindrical support of a 9" diameter and 39.25" length. The
12 diameter of the antenna elements 30 through 33 is 0.5 inches
13 and the pitch angle for these elements is 42.5°. Each spiral
14 element, such as element 31, is formed of a 0.003" copper tape
15 laid on a 0.003" mylar substrate. The prior art example has
16 the same construction except for the spiral conductors. In the
17 prior art example the interconnection from the feed point 26 to
18 each antenna element is a radial feed path, such as shown in
19 United States Letters Patent No. 5,635,945. For the above
20 example, the RF frequencies involved are between 200 and 500
21 MHz. Changing the size of the antenna will allow other
22 frequency ranges.

23 FIG. 5 compares the horizontal polarization front-to-back
24 ratios of the spiral fed, open-ended antenna shown in FIG. 1
25 fed in backfire mode, i.e., the main pattern beam comes off of

1 the feed and of the antenna, to the performance of a prior art
2 system wherein the spiral feed is replaced by radial feeds.
3 Specifically, Graph 60 in FIG. 5 depicts the radially-fed prior
4 art antenna to the performance of the spiral fed open-ended
5 antenna represented by Graph 61. It will be apparent that the
6 front-to-back ratio is improved over the entire frequency band
7 represented in FIG. 4 from 200 - 400 MHz.

8 FIG. 6 provides a similar comparison with vertical
9 polarization. In FIG. 6 Graph 62 represents the radial-fed
10 antenna and Graph 63 represents the front-to-back ratios for
11 the spiral fed antenna of FIG. 1. With the exception of a
12 portion of the low end of the frequency range (i.e, 200 - 230
13 MHz) front-to-back ratios are improved over the entire range of
14 the frequencies.

15 FIG. 7 compares the spiral fed, shorted antenna of FIG. 2
16 with a comparable prior art antenna in which the spiral feeds
17 are replaced with radial feeds. More particularly, FIG. 7
18 depicts the front-to-back ratios for horizontally polarized
19 signals and FIG. 8 for vertically polarized signals. In FIG. 7
20 graph 64 represents front-to-back ratios for the prior art
21 antenna; graph 65 for the antenna of FIG. 2. In FIG. 8, graph
22 66 represents front-to-back ratios for the prior art antenna;
23 graph 67 for the antenna of FIG. 2. Both these graphs
24 demonstrate that front-to-back ratios are improved over the
25 entire spectrum by the application of this invention.

26 FIG. 9 depicts the VSWR of the antenna as shown in FIGS. 1
27 and 2. Graph 70 depicts the VSWR of the antenna in FIG. 1;

1 Graph 71, the antenna in FIG. 2. The VSWR reaches an
2 acceptable level at about 200 MHz and remains at acceptable
3 levels to at least 500 MHz. In addition, it will be apparent
4 that whether the antennas are operated in the open or shorted
5 forms of FIGS. 1 and 2 the VSWR's have about the same values.
6 Therefore, antenna performance from this aspect seems
7 unaffected by being in the open or shorted versions.

8 FIGS. 10 and 11 compare sample radiation patterns for the
9 antennas in FIGS. 1 and 2 for both horizontal and vertical
10 polarizations at 270 MHz. More specifically, FIG. 10 depicts
11 the patterns for horizontal polarization, Graph 72 depicting
12 the radiation pattern for the prior art antenna and Graph 73
13 the antenna of FIG. 1. In FIG. 11, Graph 74 depicts the
14 radiation pattern for vertically polarized signals for the
15 prior art antenna and Graph 75 for the antenna in FIG. 1.
16 These comparisons show that most of the radiation from the
17 antenna is in the forward direction. Moreover, the comparisons
18 show that at this particular frequency the front-to-back
19 ratios, i.e., the ratio of gain at 0° to gain at 180° , are
20 improved throughout. Further, analyses for other frequencies
21 depict that this characteristic continues throughout the
22 spectrum.

23 In summary, the antennas depicted schematically in FIGS. 1
24 and 2 operate as do prior art antennas over a wide frequency
25 range with acceptable levels of VSWR in both an open mode and
26 shorted mode. However, the antennas of the present invention
27 improve front-to-back ratios are improved essentially over the

1 entire frequency range in all modes and in both horizontal and
2 vertical polarizations. Moreover, the radiation patterns from
3 these are improved. It will be apparent that this antenna has
4 been described with respect to two particular embodiments and
5 again in schematic form. This specific implementation of this
6 invention may take different forms. Particularly, several
7 alternative methods for feeding the antenna elements through
8 the spiral path have been disclosed. It is the object
9 _____ to cover all such variations and modifications
10 as come under the true spirit and scope of this invention.

1 Attorney Docket No. 78559

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QUADRIFIAL HELIX ANTENNA

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ABSTRACT OF THE DISCLOSURE

6 A quadrifilar helical antenna is provided having feed points
7 connected to the individual helical antenna elements through a
8 spiral coupling path. The spiral coupling path additionally is
9 wound contrarily to the winding of the helix. Moreover, each
10 path has variable dimensions to provide impedance matching.

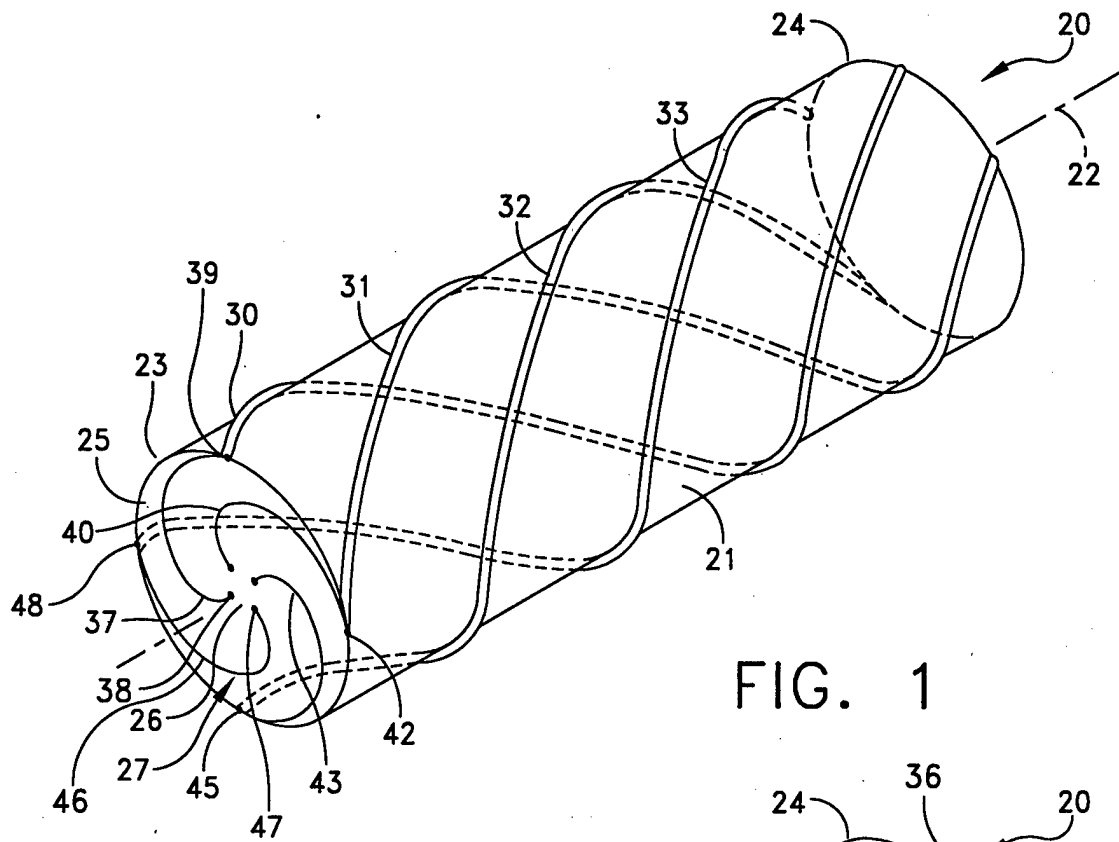


FIG. 1

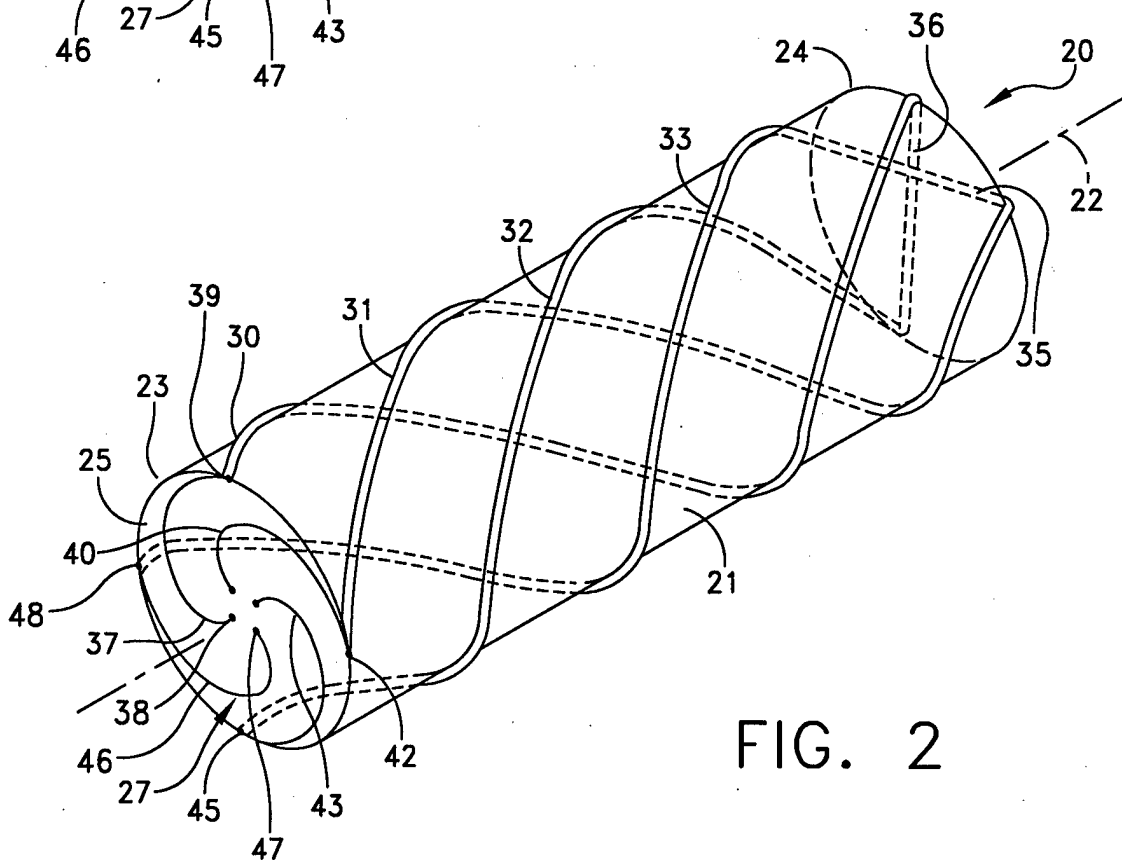


FIG. 2

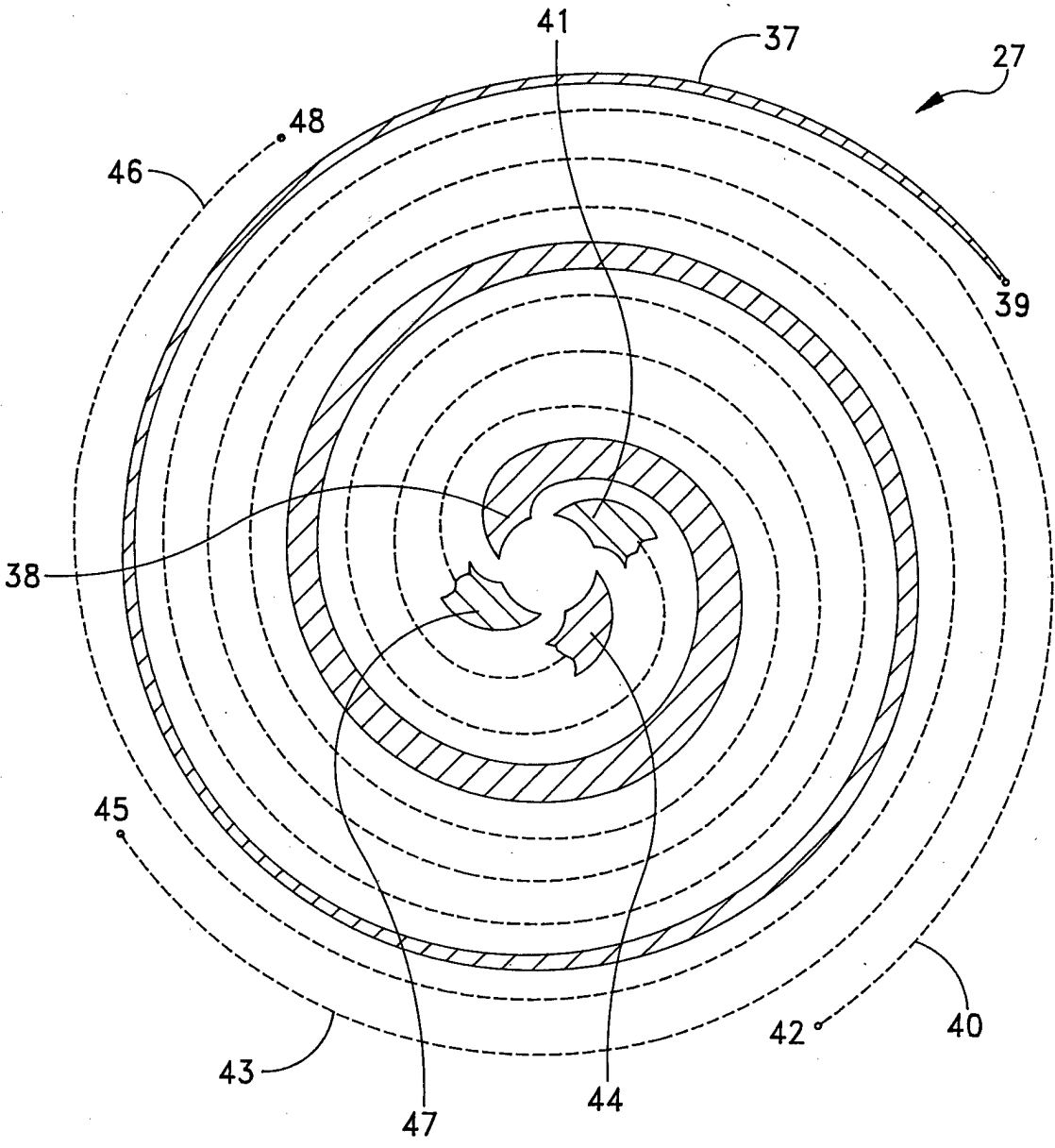


FIG. 3

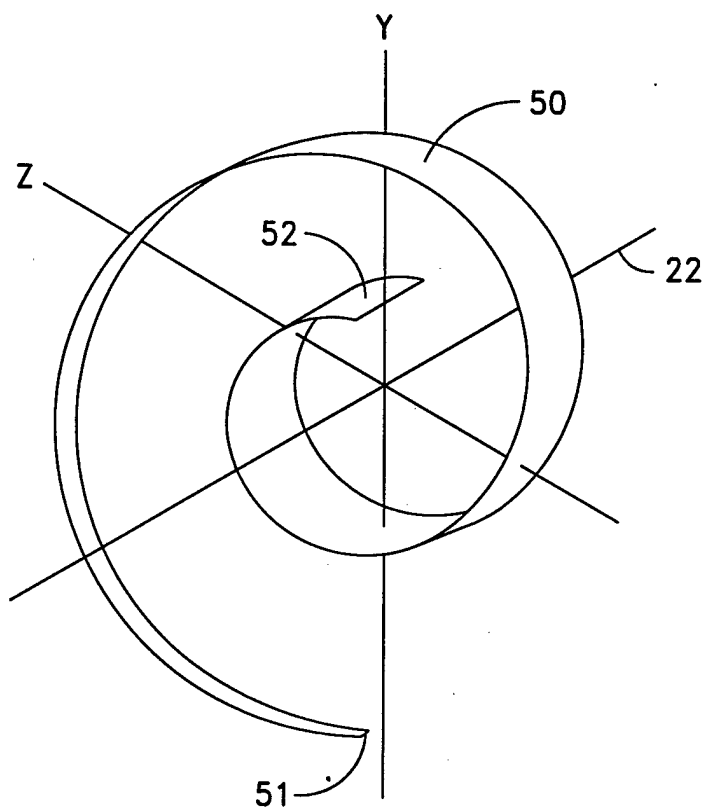


FIG. 4

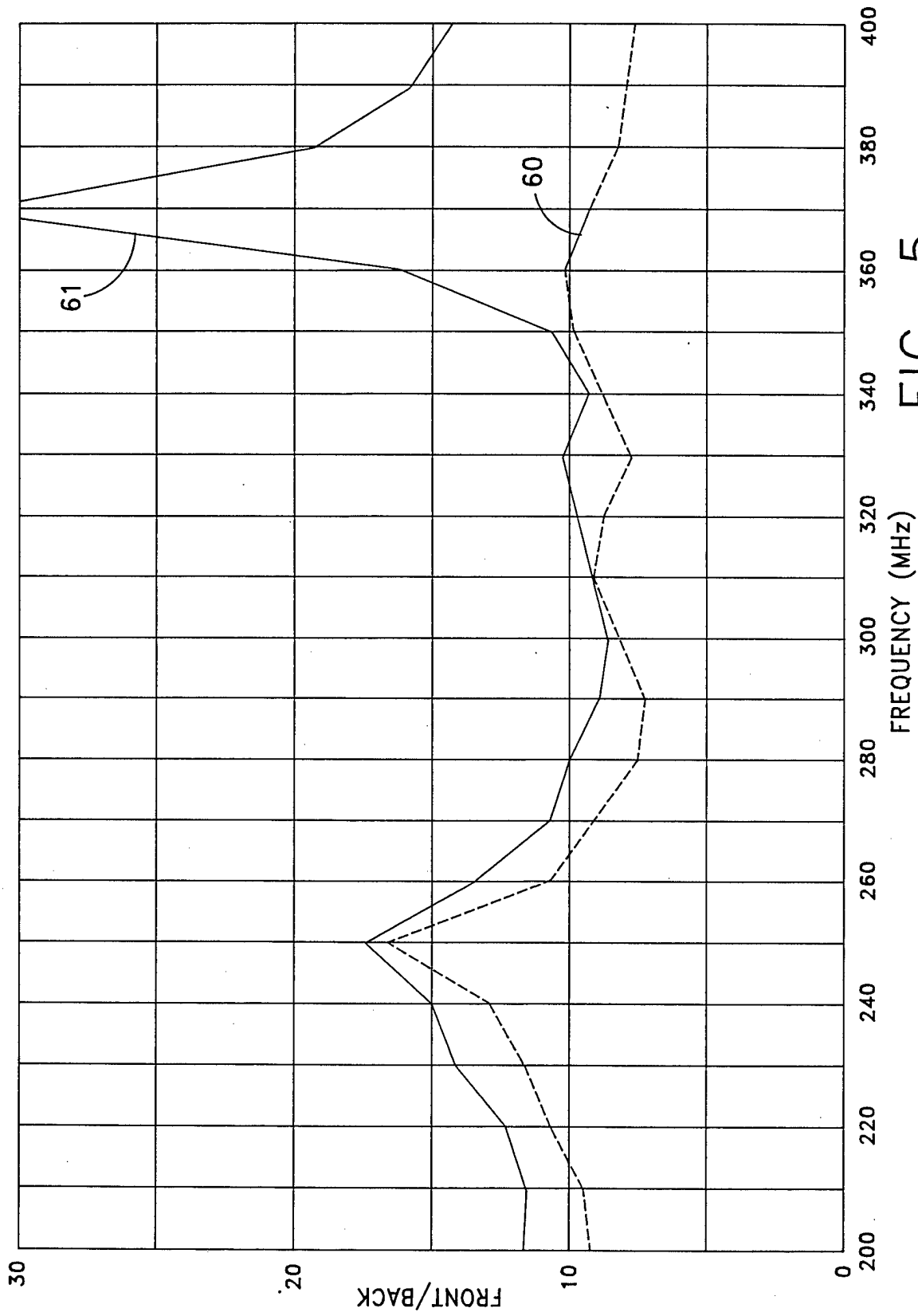


FIG. 5

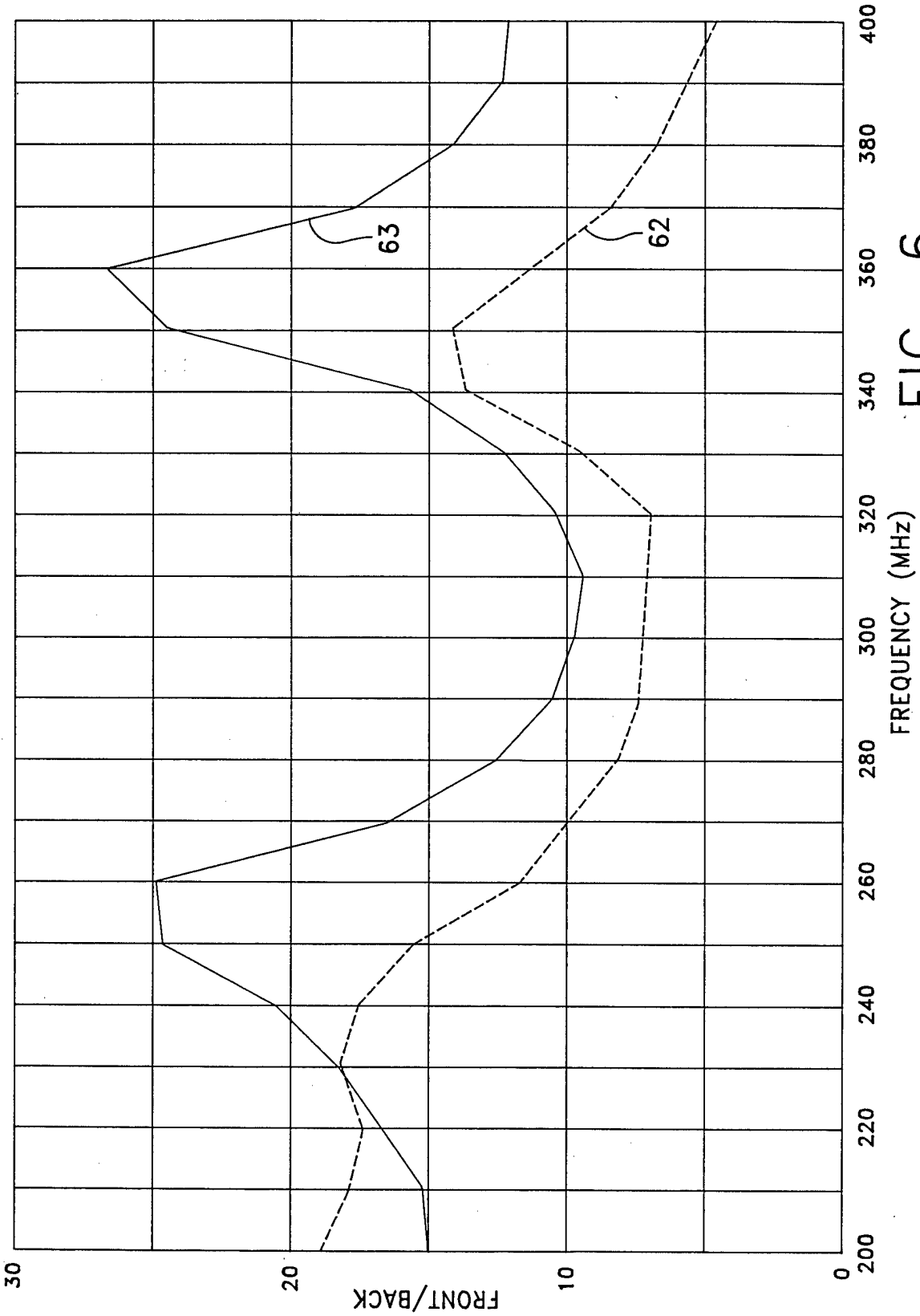


FIG. 6

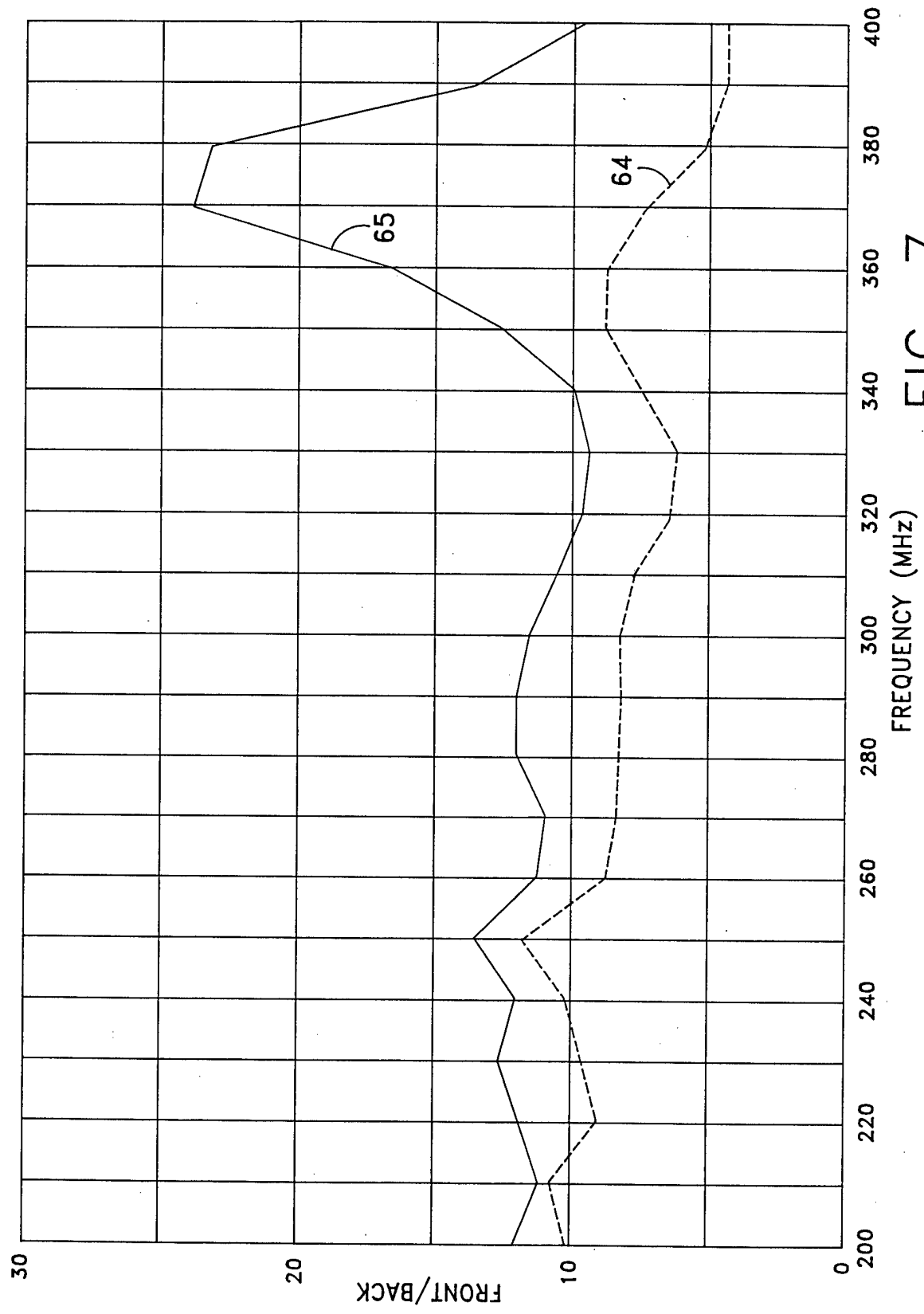


FIG. 7

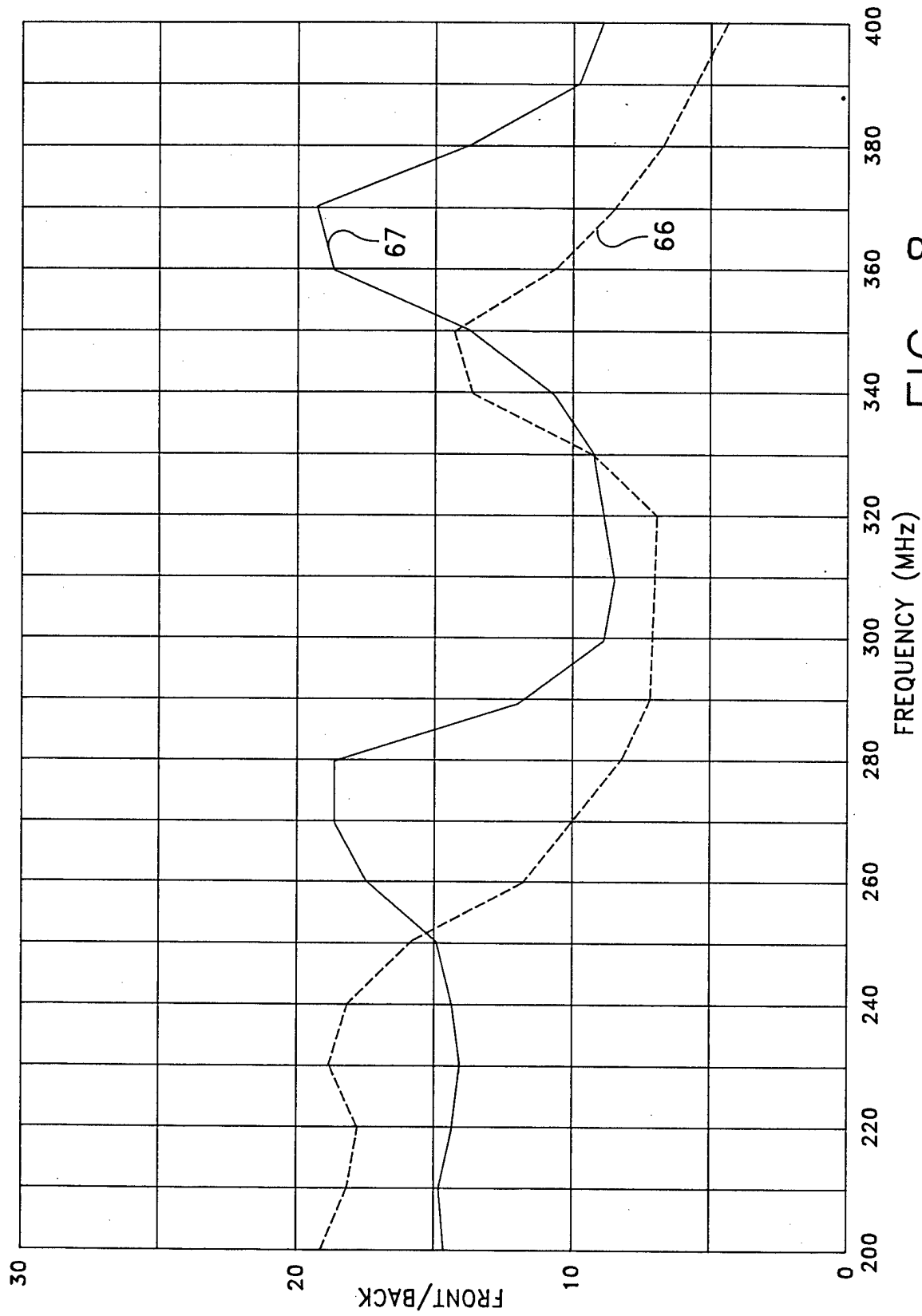


FIG. 8

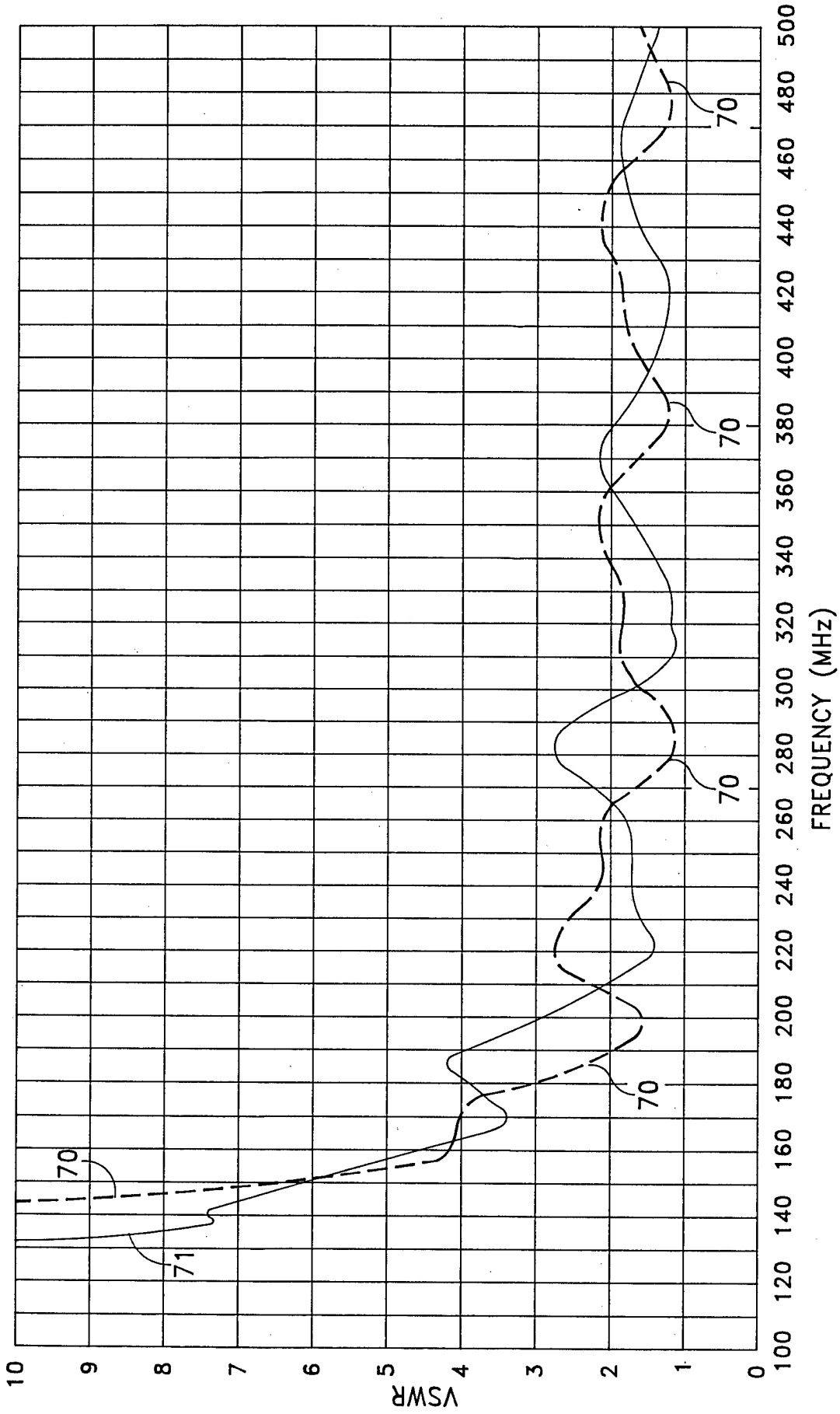


FIG. 9

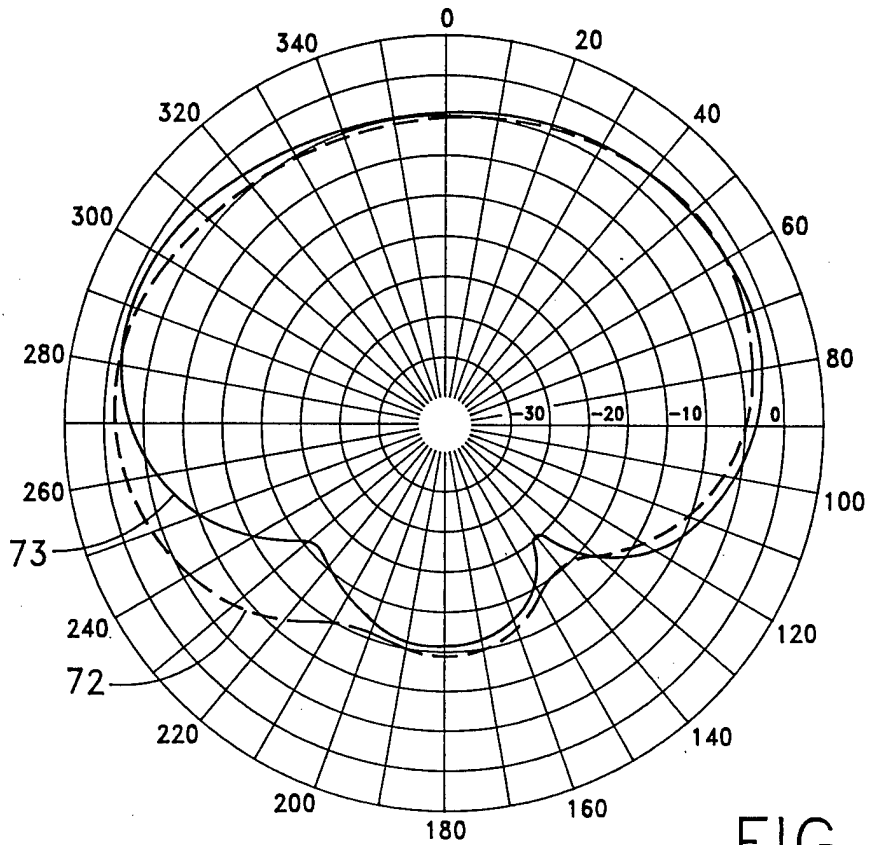


FIG. 10

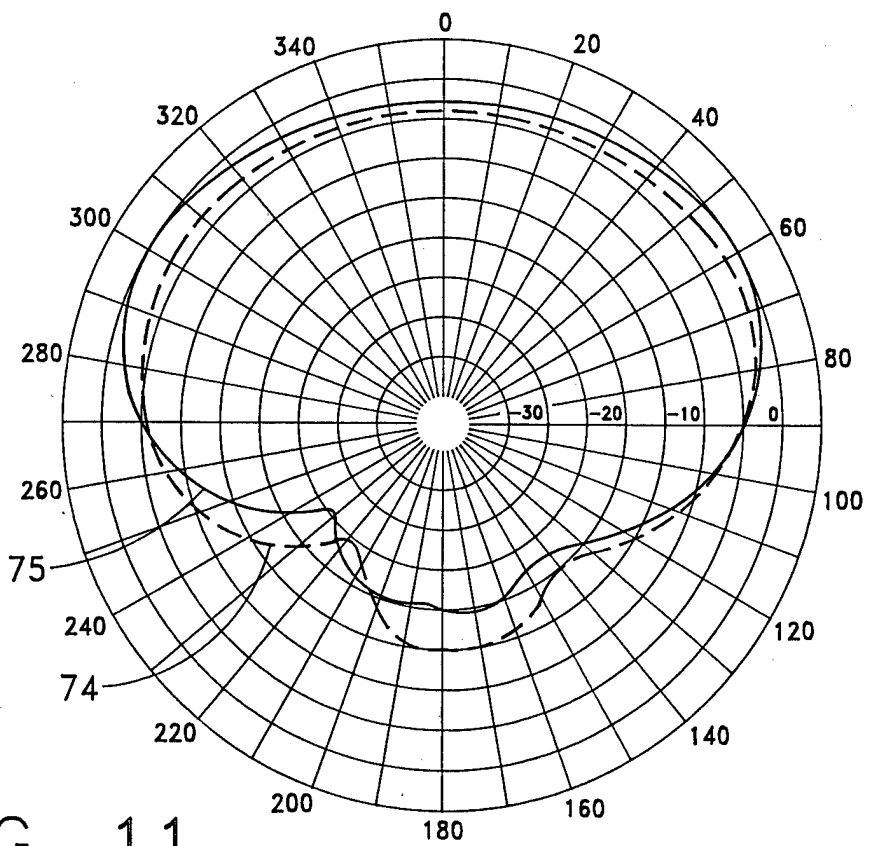


FIG. 11