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Highly isolated multiple frequency band antenna

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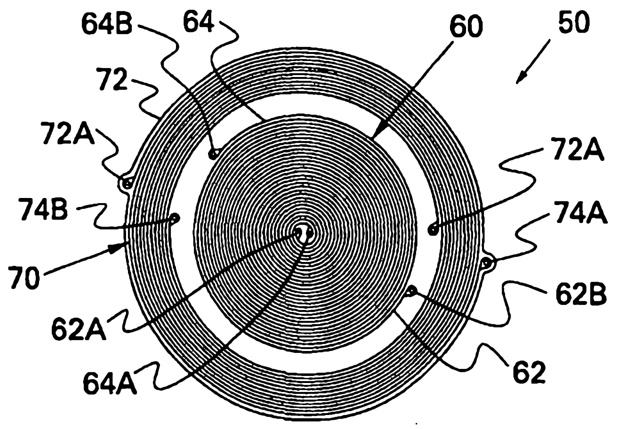
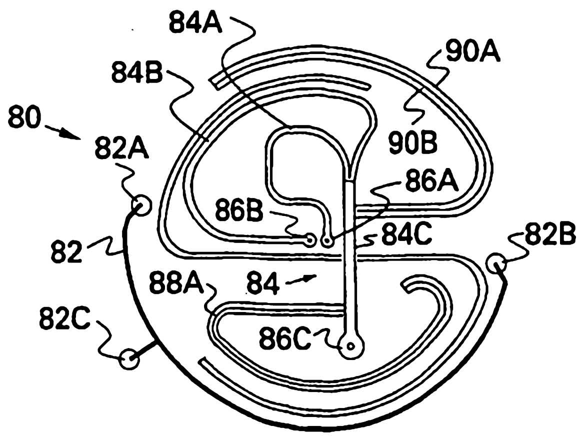
(54) Title: HIGHLY ISOLATED MULTIPLE FREQUENCY BAND ANTENNA

(57) Abstract

A multiple frequency band, multi-spiral antenna (50) that employs filters (88, 90) to pass the band of one spiral (60) and reject the band of the other spirals (70). Additional isolation is achieved by arranging adjacent spirals to have opposite senses. All the isolation and filtering is accomplished within the body of the antenna. The antenna includes two, two-arm spirals (60, 70). The higher frequency spiral resides in the interior of the lower frequency spiral. The two spirals are concentric about each other, and lie on the same plane. A balun and filter circuit (80) is connected to the two spirals, and is disposed within the antenna body.





HIGHLY ISOLATED MULTIPLE FREQUENCY BAND ANTENNA

TECHNICAL FIELD OF THE INVENTION

This invention relates to the field of microwave antennas, and more particularly to a multiple frequency band antenna with isolation between the bands.

BACKGROUND OF THE INVENTION

Antennas having the capability of multiple frequency band operation are known in the art. It is desirable to provide isolation between the multiple frequency bands. Conventionally this is done by filtering the bands by filters outside the antenna body, which requires added hardware and space.

It would be advantageous to provide a multiple frequency band antenna having isolation between the bands achieved within the body of the antenna.

SUMMARY OF THE INVENTION

According to the present invention there is provided a multiple frequency band antenna system (50) with isolation between multiple frequency bands of operation, characterized by:

an interior spiral antenna (60) comprising first and second spiral arms (62,64) wound around a center axis, each arm having a feed end (62A, 64A) and a termination end (62B, 64B), said interior spiral antenna for operation at a first frequency band;

an outer spiral antenna (70) comprising third and fourth spiral arms (72, 74) wound around said center axis and outward from said axis with respect to said interior spiral antenna, each spiral arm having a feed end (72A, 74A) and a termination end (72A, 74A), said outer spiral antenna for operation at a second frequency band which is lower in a frequency range than a corresponding frequency range of the first frequency band;

wherein said interior and outer spiral antennas are concentric about each other and are disposed on a common plane;

a balun and filter circuit (80), comprising a first balum (84) for connecting a first frequency band drive signal to said interior spiral antenna, said first balun including a first transmission line circuit (84A, 84B, 84C) for connecting said first drive signal to said respective feed ends of said first and second spiral arms of the interior spiral antenna, a second balun (82) for connecting a second frequency band drive signal to said outer spiral antenna, said second balun including a second transmission line circuit for connecting said second drive signal to said respective feed ends of said third and fourth arms of the outer spiral antenna, and a filter circuit (88, 90) for providing isolation between signals of said first frequency band and said signals of said first frequency band and said second frequency band.

BRIEF DESCRIPTION OF THE DRAWING

A preferred embodiment of the present invention will now be describe by way of example only with reference to the accompanying drawings, in which:

FIG. 1 is a top view of a multiple frequency band antenna embodying the invention.

Fig. 2 illustrates the balun and filter layout for the antenna of FIG. 1.

FIG. 3 is an exploded isometric view of an exemplary is implementation of a multi-band spiral antenna embodying the invention.

FIG. 4 is a side exploded view of the antenna of FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates an exemplary embodiment of a multiple frequency band antenna 50 embodying the invention. The antenna 50 is a multi-spiral antenna that employs filters to pass the band of one spiral and reject the band of the other spirals. Additional isolation is achieved by arranging adjacent spirals to have opposite senses. An important aspect of the invention is that all the isolation and filtering is accomplished within the body of the antenna.

The antenna 50 includes 2 two-arm spirals 60 and 70 in this exemplary configuration. The higher frequency spiral 60 resides in the interior of the lower frequency spiral 7G. The interior spiral 60 includes two spiral wound arms 62, 64, each formed by conductor patterns etched on a copper clad printed circuit board, in an exemplary implementation. The interior spiral 60 is center fed by signals input at microstrip pads 62A, 64A connected at the interior ends of the spiral arms 62, 64. The arms terminate at the outer end of the spiral with microstrip pads 62B, 64B used for attaching terminating resistors.

The outer spiral 70 includes two spiral wound arms 72, 74, each formed by conductive paths, and is fed from the outside by signals input at microstrip pads 72A, 74A. The arms 72, 74 terminate at microstrip pads 72B, 74B for terminating resistors.

The resistors are connected between the spiral plane represented by the paper on which FIG. 1 appears, and the system ground, by way of coaxial cables coming up through the antenna body. The use of resistors or other terminating methods is not critical to this invention. The system will function without resistors, but not as well. The resistors attenuate the energy that does not radiate that would otherwise reach the end of the spiral arms and reflect back to interfere with the incident energy. A lack of resistors becomes most noticeable when the region of radiation is near the end of the spiral arms and the energy has a short path length before it is bounced back into the incoming signal.

It is also noted that the outer spiral could alternatively be fed from the inner terminations of the spiral arms.

Both spiral antennas 60 and 70 are fed by coaxial cables which join the spirals to the baluns which are contained on a stripline board within the antenna body. The use of coaxial cables is not critical; striplines or other suitable transmission lines could be used.

Fig. 2 illustrates the balun and filter layout 80 for the antenna 50. Conductor line 82 with three large pads 82A, 82B and 82C is the balun for the low frequency antenna

70. Pad 82A is connected by a coaxial cable to pad 72A of the arm 72. Pad 82B is connected by a coaxial cable to pad 74A of the arm 74. Pad 82C is connected to the transmit drive source. There is 180 degrees of phase difference between the arm lengths of arms 72, 74 at the center frequency. The two ends of the spiral arms 72, 74 are driven 180 degrees out of phase. It is noted that, in this exemplary embodiment, the pad 82C is not located equidistant between the pads 82A and 82B since the difference in electrical length between the center pad and the two end pads is 180 degrees only at the center frequency of the outer spiral. This is a narrow band balun, and there will be some phase error at the upper and lower ends of the band of operation. A broad band balun could alternatively be used if the frequency band of operation is broad band. Such a broad band balun would use a magic tee coupler or a 180 degree hybrid type design.

Conductor line 84 with two small pads 86A, 86B and one large pad 86C is the filter and balun for the high frequency antenna 60. The small pads 86A, 86B are the attachment points for the coaxial cables which in turn attach to pads 62A, 64A feeding the center spiral 60. The thin conductor lines 84A, 84B transition into thicker conductor feed line 84C, and are attached to these pads 86A, 86B. The thin lines 84A, 84B are the balun and again have 180 degrees of phase length between their paths.

There are four open circuit conductor line stubs 88A, 88B, 90A, 90B attached to the feed line 84C like ribs on a spine. The stubs comprise the filter. The filter is a series of $1/4\lambda$ open circuit stubs separated by $1/2\lambda$ of transmission line. The $1/4\lambda$ and $1/2\lambda$ electrical lengths are at the center of the low frequency band of the outer spiral. The energy traveling down a stub travels $1/4\lambda$, reflects without a phase change and returns to the start of the stub with a 180 degree phase shift. This reflected energy now cancels the incident energy of the transmission line. The more stubs on the line, the greater the cancellation effect. Additionally, stubs can be grouped together. The structure would look like a fan with the individual stubs separated at the ends but converging to the same point on the transmission line. To further enhance the filtering with stubs, the stubs (or stub clusters) are separated by 1/2λ. The open circuit at the end of a stub is reflected to a short circuit at the beginning of the stub. 1/2λ away, the short circuit is reflected to an open circuit. Consider a three port structure that is a transmission line 1/2λ long with 1/4λ stubs at both ends. The input energy, which one is trying to block, sees a short down the path of the nearest stub. The second stub reflects back as an open circuit for the energy toward the through path. Hence, through the use of stubs, the undesirable energy is enticed to leave the transmission line for a short circuit stub, and is blocked by continuing down the transmission line by an open circuit created by the second stub. By putting multiples of this three ported device in series, one can achieve whatever filtering (isolation) value is desired.

More filters and baluns could be added with additional stripline layers if more spirals are needed for multiple frequency bands.

FIGS. 3 and 4 illustrate an exemplary implementation of a spiral antenna 100 embodying the invention. FIG. 3 is an exploded isometric view of the antenna elements, which are sandwiched between an antenna housing structure 102 and a radome 104. FIG. 4 is a side exploded view of the elements of the antenna 100. The spirals 60 and 70 are defined as copper conductor patterns etched from a copper layer on a dielectric substrate 106. In this embodiment, the substrate is bonded by bonding film 108 to an exposed surface of another dielectric substrate 110. A ground ring

112 is defined on the opposite surface of the substrate 110.

A circular slab of foam 116 is bonded to the ground ring and substrate 110 by bonding film 114. Surrounding the slab is a conductive isolation ring 120. A surface of a dielectric absorber slab structure 128 is bonded to the foam 116 by bonding film 118. The opposite surface of the absorber 128 is bonded by bonding film 130 to a ground plane 132 defined on a surface of substrate 134. The balun and filter circuits 80 are defined on the opposite surface of the substrate 134. An exposed surface of a dielectric substrate 138 is bonded to the surface of the circuits 80 by bonding film 136. A ground plane 140 is defined on the opposite side of the substrate 138.

An exemplary coaxial cable and termination resistor circuit 122 is illustrated in FIG. 4, for connection between a termination pad connected to a spiral arm and the ground plane 140. Element 126A illustrates a coaxial feed connector for connection to the filter/balun circuits 80. Coaxial line 126C and connector 126A (FIG. 3) are for feeding the lower frequency spiral 70. Coaxial line 126D and connector 126B (FIG. 3) are for feeding the interior spiral 60.

When the various elements of the antenna 100 are assembled together, the result is a compact, highly isolated multiple band antenna system, wherein the isolation between operating bands is achieved by elements located within the antenna body, which is generally defined by the housing 102 and radome 104.

A multiple band, multi-spiral antenna has been described, which uses filters to pass the band of one spiral and reject the band of the others. Additional isolation is achieved by arranging adjacent spirals to have opposite senses. The isolation is achieved by filters and balun circuits arranged within the body of the antenna. This minimizes the space required for the antenna. The antenna can achieve isolation between bands of over 70 dB even though the spirals for the different bands are concentric about each other and on the same plane. This isolation can be achieved, by way of example, in an embodiment wherein the frequency bandwidth of one spiral is 200 MHz, the bandwidth of the second spiral is 500 MHz, and the separation between the two bands is 300 MHz.

It is understood that the above-described embodiments are merely illustrative of the possible specific embodiments which may represent principles of the present invention. Other arrangements may readily be devised in accordance with these principles by those skilled in the art without departing from the scope and spirit of the invention.

CLAIMS

What is claimed is:

1. A multiple frequency band antenna system (50) with isolation between multiple frequency bands of operation, characterized by:

an interior spiral antenna (60) comprising first and second spiral arms (62, 64) wound around a center axis, each arm having a feed end (62A, 64A) and a termination end (62B, 64B), said interior spiral antenna for operation at a first frequency band;

an outer spiral antenna (70) comprising third and fourth spiral arms (72, 74) wound around said center axis and outward from said axis with respect to said interior spiral antenna, each spiral arm having a feed end (72A, 74A) and a termination end (72B, 74B), said outer spiral antenna for operation at a second frequency band which is lower in a frequency range than a corresponding frequency range of the first frequency band;

wherein said interior and outer spiral antennas are concentric about each other and are disposed on a common plane;

a balun and filter circuit (80), comprising a first balun (84) for connecting a first frequency band drive signal to said interior spiral antenna, said first balun including a first transmission line circuit (84A, 84B, 84C) for connecting said first drive signal to said respective feed ends of said first and second spiral arms of the interior spiral antenna, a second balun (82) for connecting a second frequency band drive signal to said outer spiral antenna, said second balun including a second transmission line circuit for connecting said second drive signal to said respective feed ends of said third and fourth spiral arms of the outer spiral antenna, and a filter circuit (88, 90) for providing isolation between signals of said first frequency band and said second frequency band.

2. An antenna system according to Claim 1, further characterized in that said feed ends (62A, 64A) of said spiral arms (62, 64) of said interior antenna are located at interior ends of said spiral arms, and said interior antenna is center fed by said first balun (84).

3. An antenna system according to Claim 1 or Claim 2, further characterized in that said first balun (84) is adapted to feed said respective interior ends of said spiral arms of said interior antenna with signals in anti phase.

4. An antenna system according to Claim 3,further characterized in that said first balun transmission line circuit (84) includes transmission line segments (84A, 84B) which differ in effective electrical length by one half wavelength at a center frequency of operation of said interior spiral antenna.

5. An antenna system according to any preceding claim, further characterized in that said feed ends (72A, 74A) of said spiral arms (72A, 74A) of said outer antenna are located at outer ends of said spiral arms, and said outer antenna is fed from outside said outer antenna by said second balun (82).

6. An antenna system according toany preceding claim, further characterized in that said second balun (82) is adapted to feed said respective feed ends (72A, 74A) of

said spiral arms of said outer antenna with signals in anti-phase.

7. An antenna system according to Claim 6, further characterized in that said second balun transmission line circuit (82) includes transmission line segments which differ in effective electrical length by one half wavelength at a center frequency of operation of said outer spiral antenna.

8. An antenna system according to any preceding claim, further characterized in that said filter circuit (88, 90) includes a first transmission line stub (88A) extending from a transmission line segment of said first transmission line circuit, said stub having an effective electrical length equivalent to one quarter wavelength of a frequency of operation of said second frequency band.

9. An antenna system according to Claim 8, further characterized in that said filter circuit (88, 90) includes a second transmission line stub (90A) extending from said transmission line segment of said first transmission line at a point spaced from said first stub a distance equivalent to an effective electrical length of one half wavelength at said frequency of operation of said second frequency band.

10. An antenna system according to any preceding claim, further characterized in that said first and second baluns (82, 84) and said filter circuit (88, 90) are defined on a planar stripline circuit board (134), said board located within the antenna body of the antenna system.

11. An antenna system according to claim 10, further characterised in that said first and second baluns are connected to said respective feed ends of said spiral arms of said interior and outer spiral antennas by coaxial cables.

12. A multiple frequency band antenna system substantially as hereinbefore described with reference to Figures 1 to 4 of the accompanying drawings.

Dated this 25th day of November 1998
RAYTHEON COMPANY
By its Patent Attorney
GRIFFITH HACK

FIG. 1.

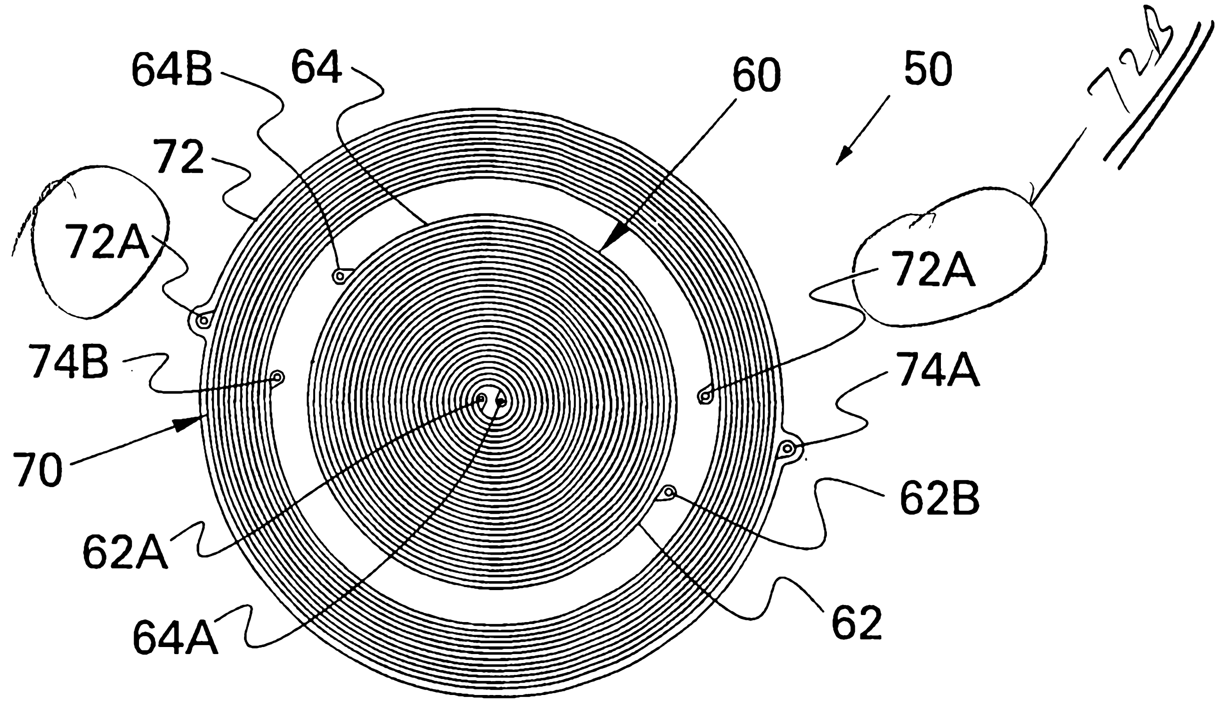

64B
64
60
50
72B
72
72A
72A
74B
74A
70
62B
62A
64A
62

FIG. 2.

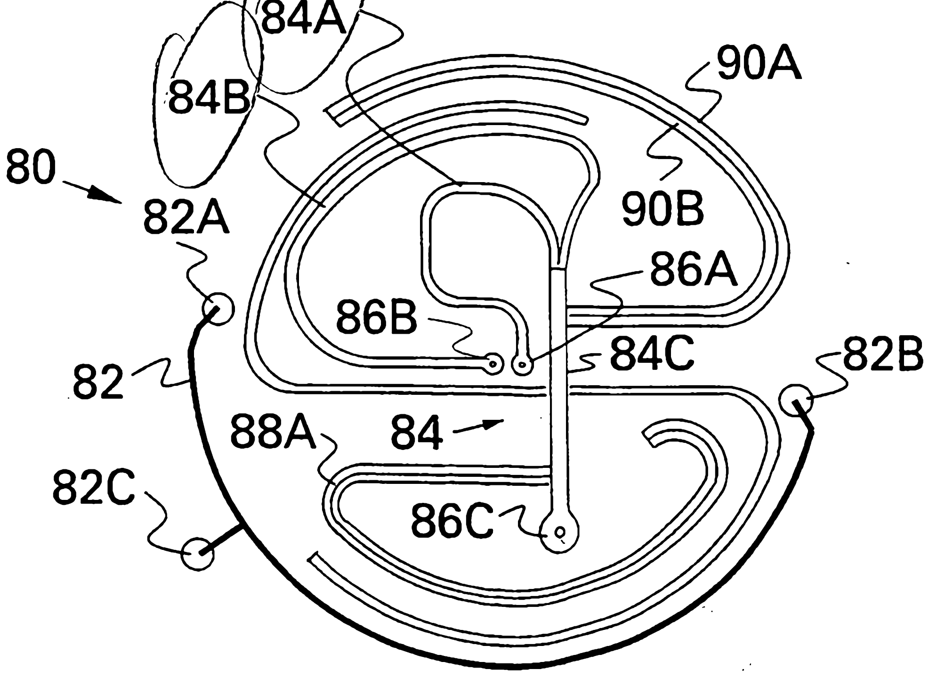

84A
84B
90A
80
82A
90B
86A
86B
84C
82
82B
88A
84
82C
86C

FIG. 3.

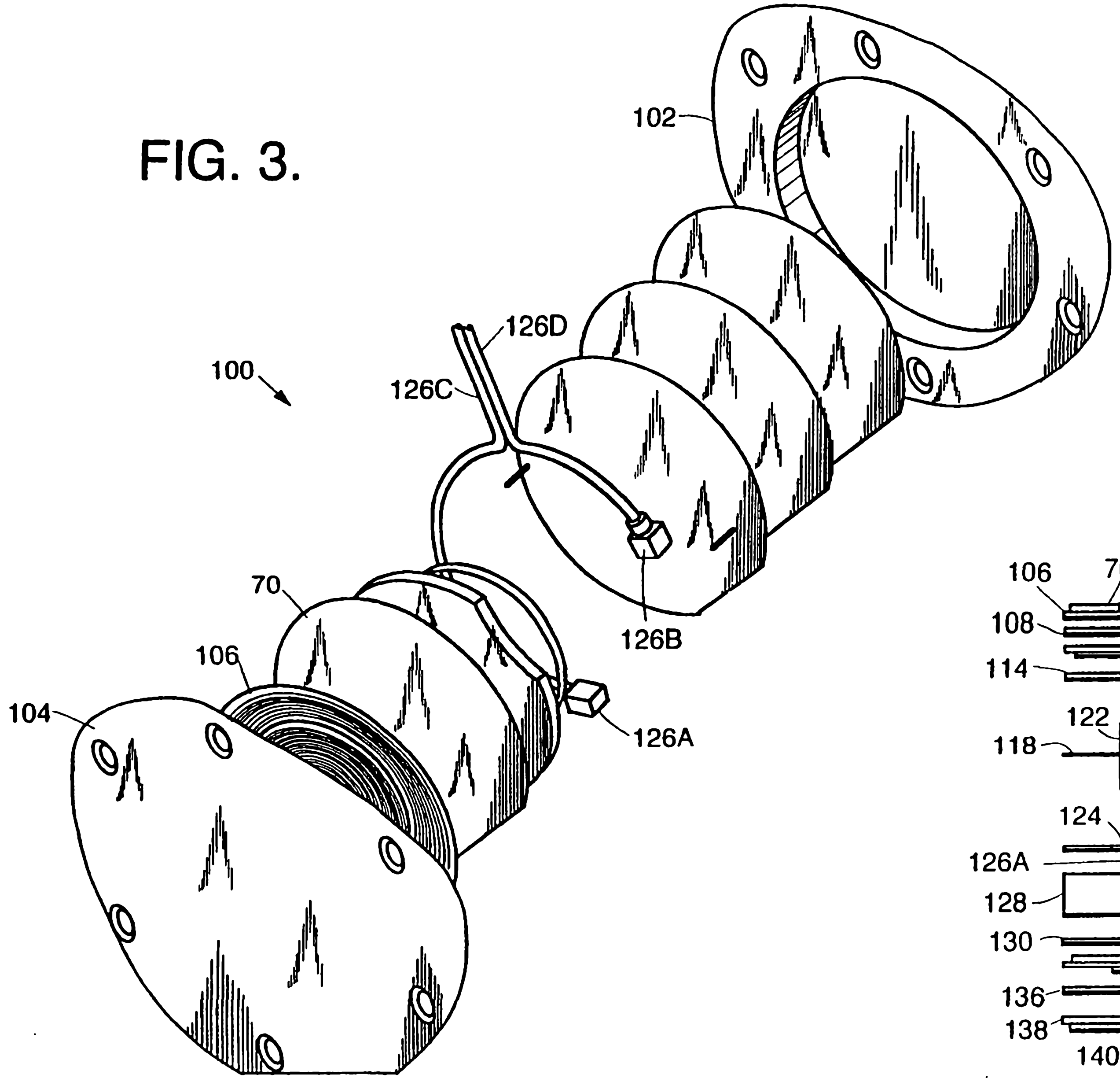
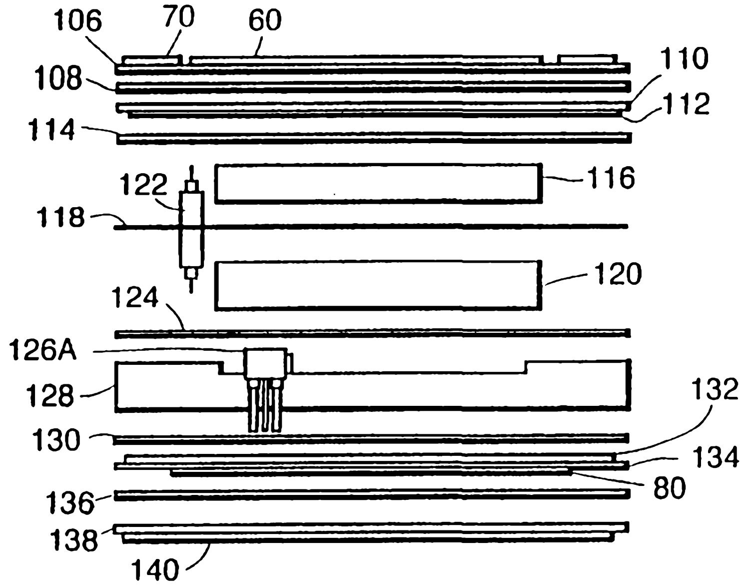

100
102
104
106
70
126A
126B
126C
126D

FIG. 4.


106
70
60
108
110
112
114
116
122
118
120
124
126A
128
130
132
134
80
136
138
140