AUSTRALIA

PATENTS ACT 1990

629760

PATENT REQUEST/NOTICE OF ENTITLEMENT

We HUGHES AIRCRAFT COMPANY

of 7200 Hughes Terrace, Los Angeles, CALIFORNIA 90045-0066, U.S.A.

being the Applicant and Nominated Person, request the grant of a patent for an invention entitled DIELECTRIC FLARE NOTCH RADIATOR WITH SEPARATE TRANSMIT AND RECEIVE PORTS which is described in the accompanying standard complete specification.

Convention priority is claimed from the following basic application

Basic Applicant	Application Number	Application Date	Country	Country Code
Clifton Quan	589,965	28 September 1990	U.S.A.	US

Clifton Quan is the actual inventor of the invention.

The applicant and nominated person is the assignee of the invention from the actual inventor.

The basic application was the first application made in a Convention Country in respect of the invention the subject of this request.

DATED this 3rd day of September 1991

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SYDNEY NSW 2000

Attorney Code: GH

HUGHES AIRCRAFT COMPANY
By their Patent Attorney

S024100 03/09/91

GRIFFITH HACK & CO

GH&CO REF: 3782-OI:CLC:RK

2245A:rk

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DIELECTRIC FLARE NOTCH RADIATOR WITH SEPARATE TRANSMIT AND RECEIVE PORTS

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(56) Prior Art Documents
AU 600990 80959/87 H01Q 13/08
AU 22673/83 H01Q 13/08
EP 343322

(57) Claim

1. An antipodal flared notch radiating element, comprising:

a center dielectric board having first and second opposed surfaces, the first surface having a first conductive pattern formed thereon, the second surface having a second conductive pattern formed thereon;

the first and second conductive patterns are further characterized in that they cooperate to form an antipodal slotline adjacent a flared end thereof and a broadside coupled strip region which transitions into said antipodal slotline, the broadside coupled strip region formed by conductive strips comprising said first and second conductive patterns overlying each other on opposite sides of the dielectric sheet;

said first conductive pattern further characterized in that first and second microstripline conductors are defined by said pattern adjacent a receive/transmit port end of said element;

said second conductive pattern further characterized by a ground plane region adjacent said port end of said

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element adjacent said microstripline conductors, said ground plane region transitioning to a conductor strip comprising said broadside coupled strip region; and

means for coupling said broadside coupled strip region to said first microstripline conductor, and for coupling said broadside coupled strip region to said second microstripline conductor, said coupling means further comprising means for isolating said first microstripline conductor from said second microstripline conductor.

5. In an antipodal flared notch radiating element characterized by flared conductive patterns defined on opposite first and second surfaces of a dielectric sheet to define an antipodal strip transmission line, each flared pattern transitioning to a strip conductor, wherein the strip conductors substantially overlay one another on said opposite surfaces, and wherein one strip conductor on said first surface of said dielectric sheet in turn transitions to a conductive ground plane region, an improvement comprising:

first and second microstrip conductor lines defined on said second surface of said sheet; and

a three port circulator connected to said first and second conductor lines and said strip conductors, the first microstrip conductor line comprising a transmit port of said element, wherein energy incident on said circulator from said first conductor is coupled by said circulator to said conductor strip and in turn to said antipodal transmission line, the second conductor line comprising a receive port of said radiating element, wherein energy incident on said flared notch radiator element via said antipodal strip transmission line is coupled via said conductor strip and said circulator to said second microstrip conductor line.

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COMPLETE SPECIFICATION

STANDARD PATENT

Invention Title: DIELECTRIC FLARE NOTCH RADIATOR WITH SEPARATE TRANSMIT AND RECEIVE PORTS

The following statement is a full description of this invention, including the best method of performing it known to us:

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2245A:rk

DIELECTRIC FLARE NOTCH RADIATOR WITH SEPARATE TRANSMIT AND RECEIVE PORTS

BACKGROUND OF THE INVENTION

The present invention relates to radiator elements of the type used in radar systems such as active array and phased radar applications.

The principle radiating elements heretofore used for broadband active arrays have been the dielectric bilateral and all metalized flared notch radiators. These radiators are described in, e.g., "Broadband Antenna Study," L.R. Lewis and J. Pozgay, Final Report AFCRL-TR-75-0178, Air Force Cambridge Research Laboratories, March 1975; "Analysis of the Tapered Slot Antenna," R. Janaswamy and D. Schaubert, IEEE Trans. Antennas and Propagation, Vol. AP-35, No. 9, September 1987, pages 1058-1059; "The Vivaldi Aerial," P.J. Gibson, Proceedings of the Ninth European Microwave Conference, 1979, at pages 101-105. Because of the coplanar nature of their slotline-type configuration, both of these radiators require balun transitions from stripline-type transmission line to the slotline flare notch in order to launch the RF signal from the stripline or microstrip mode to the slotline mode. The need for baluns tends to limit very wide band performance. The presence of the balun also tends to make the packaging more complicated and more costly.

Prior approaches to integrating a circulator or any other component to such radiator elements would be to first connect the component to the stripline portion of the balun which then transitions to the flared notch. This connection is either a direct connection or with the addition of some type of coaxial connector interface, with the attendant disadvantages that the structure is more difficult to assemble and with the possible degradation of the match.

The antipodal flared notch radiator, described in "Improved design of the Vivaldi antenna," by E. Gazit, IEE Proc., Vol. 135, Pt.H, No.2, April 1988, at pages 89-92, extends the concept of the Van Heuven microstrip to waveguide transition to antenna elements. The Van Heuven transition is described, e.g., in "A New Model for Broadband Waveguide-to-Microstrip Transition Design," G.E. Ponchak and Alan N. Downey, Microwave Journal, May, 1988, pages 333 et seq. FIG. 1 shows a top view of the antipodal flared notch radiator. FIGS. 2A-2F illustrate particular cross-sectional views of the radiator device of FIG. 1 The input microstrip line 22 is transformed into a broadside coupled strip 24 (odd mode needed only) by narrowing the groundplane. The broadside coupled strips 24 then are transformed into an antipodal slotline 26. Finally the antipodal slotline flares out as in the typical notch radiator. Note how the electric fields of the microstrip 22 are rotated and transformed into the electric fields of the slotline (FIGS. 2A-2F). Thus, FIG. 2A illustrates the field configuration of the input microstripline. FIG. 2B shows the transitioning of the microstripline to the broadside-coupled strips (FIG. 2C). FIG. 2D shows the field configuration at the antipodal slotline. FIG. 2E shows the transitioning from the antipodal slotline to the flared out structure near the radiator tip (FIG. 2F).

FIGS. 3A-3F show various slotline structures and the corresponding gaps G. FIG. 3A shows a conventional

coplanar slotline structure. FIG. 3B shows a sandwiched coplanar slotline, i.e., where the conductor strip and groundplane are sandwiched between dielectric layers. FIG. 3C shows a coplanar thick metal slotline structure. FIG. 3D shows a bilateral coplanar slotline structure. FIG. 3E shows an antipodal slotline structure. FIG. 3F shows a sandwiched antipodal slotline structure.

The antipodal structure is more versatile than convention coplanar or bilateral slotline structures because low impedances (characteristic impedance Z less than 60 ohms) can be realized more easily. Low impedances in conventional coplanar and bilateral slotlines require very narrow slot gap dimensions which are difficult to realize because of manufacturing tolerances. Low impedance in antipodal slotline are relatively easy to realize because it involves simply controlling the amount of overlap between the two conductors.

As shown in FIG. 1, there are no abrupt transitions or discontinuities to limit the bandwidth performance of the antipodal flared notch radiator element. All the transmission lines can be designed to be 50 ohms prior to entry into the flared region. Since there is no balun required, fabrication of this element is very simple and inexpensive because it involves only a single double-sided printed circuit board. One limitation of the conventional antipodal flared notch radiator is that the opening of the flared notch is a half-wavelength at the low end of the frequency band. As the low end of the frequency band is decreased, the physical size of the flared notch increases and may exceed the allowable physical space for some applications. Another limitation is that the conventional radiator has only a single port (microstripline 22) which must be used for both transmit and receive operations.

Because of its asymmetry, the antipodal flare notch radiator of FIG. 1 would be difficult to model analytically

in an array, and will not image properly in waveguide simulators. Waveguide simulators, as is well known in the art, are test apparatuses used to measure the active impedance of large or infinite arrays. Small clusters of radiating elements are placed in a waveguide, which acts as a mirror, simulating the performance of an infinite array. To work properly, the small cluster must be symmetric with respect to the walls of the waveguide.

Accordingly it is an object of this invention to provide a flared notch radiator element with separate transmit and receive ports.

SUMMARY OF THE INVENTION

According to the present invention there is provided an antipodal flared notch radiating element, comprising:

a center dielectric board having first and second opposed surfaces, the first surface having a first conductive pattern formed thereon, the second surface having a second conductive pattern formed thereon;

the first and second conductive patterns are further characterized in that they cooperate to form an antipodal slotline adjacent a flared end thereof and a broadside coupled strip region which transitions into said antipodal slotline, the broadside coupled strip region formed by conductive strips comprising said first and second conductive patterns overlying each other on opposite sides of the dielectric sheet;

said first conductive pattern further characterized in that first and second microstripline conductors are defined by said pattern adjacent a receive/transmit port end of said element;

said second conductive pattern further characterized by a ground plane region adjacent said port end of said element adjacent said microstripline conductors, said ground plane region transitioning to a conductor strip comprising said broadside coupled strip region; and

means for coupling said broadside coupled strip region to said first microstripline conductor, and for coupling said broadside coupled strip region to said

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second microstripline conductor, said coupling means further comprising means for isolating said first microstripline conductor from said second microstripline conductor.

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BRIEF DESCRIPTION OF THE DRAWING

These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIGS. 1 and 2A-2F illustrate a known antipodal flared notch radiator element.

FIGS. 3A-F illustrate several slotline transmission line structures.

FIG. 4 is an exploded perspective view of a radiator element embodying the invention.

FIG. 5 is a schematic diagram of the device of FIG. 4.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is a modified antipodal flared notch radiator with separate transmit and receive ports for phased array and active array antenna applications. The device uses a new approach for connecting a microstrip circulator directly into the flared notch radiator without the use of a conventional balun.

An exploded perspective view of a preferred embodiment of the invention is shown in FIG. 4. The radiator 50 is made applicable in an array environment by sandwiching the flared notch region 52 between two layers 54 and 56 of dielectric material in the manner illustrated in FIG. 3F.

The radiator 50 comprises a center dielectric board 58 having first and second planar surfaces 60 and 62. A conductive pattern is formed on each surface, to define the antipodal flared notch configuration of the radiating element 50. Thus, the conductive pattern 66 is formed on the upper surface 60, and the conductive pattern 64 is formed on the lower surface 62. Pattern 66 includes microstripline conductor 70 which is terminated in a

coaxial connector 72, used in this embodiment for transmit operation. Pattern 66 further includes microstripline conductor 74 which terminates in a coaxial connector 76, used in this embodiment for receive operation. The pattern 64 includes a conductive ground plane region 55 which underlays the microstripline conductors of the pattern 66. This ground plane region 55 transitions to a strip conductor region underlying the strip region 78 of the pattern 66.

The microstripline conductors 70 and 74 are brought adjacent each other at a region where the circulator 80 is connected, as is more fully described below with respect to FIG. 5. Thereafter the respective conductor strips of the upper and lower patterns 66 and 64 define broadside coupled strips, of which only strip 78 is visible in FIG. 4. The broadside coupled strips then transition to the flared conductive regions 84 and 86 which together define the antipodal slotline of the radiator 50.

The layers 54 and 56 are preferably fabricated from the same dielectric material as the center dielectric board 58 of the radiator 50, e.g., woven fiberglass TTFE, and force the radiating element to operate like a coplanar slotline-type of structure, by concentrating the fields. It is not necessary, in the practice of the invention, to use the boards 54 and 56, but their use makes it easier to design the element for some applications and to analytically model the structure in a large array.

As is well known in the art, an array is a cluster of elements laid out in an orderly lattice, and the lattice spacing is one distance between adjacent elements. By imposing the condition that the center dielectric board 58 between the two conductor patterns 64 and 66 is sufficiently thin compared to the array lattice spacing, the embedded antipodal slotline will closely approximate embedded coplanar slotline which is a structure that can be modeled

mathematically in an array environment. For example, given a lattice spacing of .5 inch, "sufficiently thin" would be 20% of .5 inch or less. The center broad thickness would be less, e.g., 50 mils. Likewise, waveguide simulators with this embedded flared notch can be built to closely simulate the array environment for various H-plane scan angles across the band of interest.

The construction of this antipodal flared notch radiator element has been configured so that all components are attached to the outside of the notch printed circuit board 58. This will allows for easy installation of a microstrip circulator or any packaged "drop-in" component. The circulator 80 is connected to the coupled strip region of the flared notch, or closer to the antipodal slotline as need be. Miniature drop-in circulators suitable for the purpose of circulator 80 are commercially available. For example. Teledyne Microwave, 1290 Terra Bella Avenue, Mountain View, CA 94043, markets exemplary devices as model nos. C-*M13U-^{xx}, C-**M13U-^{xx} and C-8M43U-10.

Other microwave devices may be used in place of the circulator 80. For example, PIN diode switches may be used to alternatively connect either the transmit or receive port to the radiating element. Of course, the device would then not be capable of simultaneous transmit and receive operation, and active circuitry would be required to operate the PIN diodes.

FIG. 5 shows a simplified schematic representation of the radiating element 50. The circulator 80 has three ports 80A, 80B, 80C. Port 80A is connected to micro-stripline conductor 74, port 80B is connected to micro-stripline conductor 72 and port 80C is connected to strip conductor 78 The element 50 defines a broadside coupled strip region 88, which transitions to the sandwiched antipodal slotline 90 defined by the flared portions of the conductor patterns 66 and 64. It will be apparent that by

operation of the circulator 80, energy incident on port 80B from the transmit port 72 will be coupled to the broadside coupled strip region 88 to be radiated out of the element 50. Energy received by the element 50 will be conducted to port 80C of the circulator 80 via the slotline region and the broadside coupled strip region 88, and will be coupled to the port 80A and via microstripline 74 to the receive port 76. The circulator 80 provides isolation between the receive and transmit ports.

As an isolated element, a prototype radiating element had a VSWR of 1.9:1 across a 7 GHz to 26.5 GHz bandwidth. The performance would be only limited by the performance of the circulator. Across the circulator operating bandwidth, the radiator circulator combination improves the VSWR by isolating the flared notch from mismatches from behind the circulator such as load and connector mismatches at the transmit and receive ports. Finally the active impedance become less sensitive to load variations from components behind the circulator at its transmit and receive ports such as transmit/receive modules, phase shifters, and feeds.

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.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. An antipodal flared notch radiating element, comprising:

a center dielectric board having first and second opposed surfaces, the first surface having a first conductive pattern formed thereon, the second surface having a second conductive pattern formed thereon;

the first and second conductive patterns are further characterized in that they cooperate to form an antipodal slotline adjacent a flared end thereof and a broadside coupled strip region which transitions into said antipodal slotline, the broadside coupled strip region formed by conductive strips comprising said first and second conductive patterns overlying each other on opposite sides of the dielectric sheet;

said first conductive pattern further characterized in that first and second microstripline conductors are defined by said pattern adjacent a receive/transmit port end of said element;

said second conductive pattern further characterized by a ground plane region adjacent said port end of said element adjacent said microstripline conductors, said ground plane region transitioning to a conductor strip comprising said broadside coupled strip region; and

means for coupling said broadside coupled strip region to said first microstripline conductor, and for coupling said broadside coupled strip region to said second microstripline conductor, said coupling means further comprising means for isolating said first microstripline conductor from said second microstripline conductor.

2. The radiating element of claim 1 wherein said coupling means comprises a circulator device having a first port coupled to said first microstripline conductor, a second port coupled to a conductor strip comprising said broadside coupled strip region, and a third port coupled to said second microstripline conductor.

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3. The radiating element of claim 1 further comprising first and second dielectric sheets disposed to sandwich the flared end of said element.

4. The radiating element of claim 1 further characterized in that said element is used in a large array of radiating elements, wherein adjacent elements are separated by a lattice spacing, and wherein the thickness of said center dielectric sheet is selected to be less than said lattice spacing.

5. In an antipodal flared notch radiating element characterized by flared conductive patterns defined on opposite first and second surfaces of a dielectric sheet to define an antipodal strip transmission line, each flared pattern transitioning to a strip conductor, wherein the strip conductors substantially overlay one another on said opposite surfaces, and wherein one strip conductor on said first surface of said dielectric sheet in turn transitions to a conductive ground plane region, an improvement comprising:

first and second microstrip conductor lines defined on said second surface of said sheet; and

a three port circulator connected to said first and second conductor lines and said strip conductors, the first microstrip conductor line comprising a transmit port of said element, wherein energy incident on said circulator from said first conductor is coupled by said circulator to said conductor strip and in turn to said antipodal transmission line, the second conductor line comprising a receive port of said radiating element, wherein energy incident on said flared notch radiator element via said antipodal strip transmission line is coupled via said conductor strip and said circulator to said second microstrip conductor line.

6. The improvement in a radiating element as claimed in claim 5 further comprising first and second dielectric sheets which sandwich said circulator, said conductor strips and said antipodal strip transmission line.

7. The improvement in a radiating element as claimed in

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claim 5 further characterized in that said element is used in a large array of radiating elements, wherein adjacent elements are separated by a lattice spacing, and wherein the thickness of said dielectric sheet is selected to be less than said lattice spacing.

8. The improvement in a radiating element as claimed in claim 5 further comprising first and second coaxial connectors coupled respectively to said first and second microstrip conductor lines.

9. An antipodal flared notch radiating element suitable for large active arrays, comprising:

a center dielectric board having first and second opposed surfaces, the first surface having a first conductive pattern formed thereon, the second surface having a second conductive pattern formed thereon;

the first and second conductive patterns are further characterized in that they cooperate to form an antipodal slotline adjacent a flared end thereof and a broadside coupled strip region which transitions into said antipodal slotline, the broadside coupled strip region formed by conductive strips comprising said first and second conductive patterns overlying each other on opposite sides of the dielectric sheet;

said first conductive pattern further characterized in that first and second microstripline conductors are defined by said pattern adjacent a receive/transmit port end of said element;

said second conductive pattern further characterized by a ground plane region adjacent said port end of said element adjacent said microstripline conductors, said ground plane region transitioning to a conductor strip comprising said broadside coupled strip region;

a circulator device having a first port coupled to said first microstripline conductor, a second port coupled to a conductor strip comprising said broadside coupled strip region, a third port coupled to said second microstripline conductor; and

first and second dielectric sheets disposed to

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sandwich the flared end of said element.

10. The radiating element of claim 9 wherein said active array is characterized by adjacent elements being separated by a lattice spacing and wherein the thickness of said center dielectric sheet is selected to be less than said lattice spacing.

11. A radiating element substantially as hereinbefore described with reference to figures 4 and 5 of the accompanying drawings.

DATED this 5th day of August 1992

HUGHES AIRCRAFT COMPANY

By their Patent Attorney

GRIFFITH HACK & CO

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DIELECTRIC FLARE NOTCH RADIATOR WITH SEPARATE TRANSMIT AND RECEIVE PORTS

ABSTRACT OF THE DISCLOSURE

A dielectric antipodal flared notch radiator with separate transmit and receive ports for phased array and active array antennas. A circulator is integrated directly to the broadside coupled-strip transmission line portions of the antipodal flared notch radiator without the use of baluns. The look-in impedance of the radiator element is improved as a result of the circulator and lack of a balun. By sandwiching the antipodal flared notch between two additional layers of dielectric, the device can be made a building block for broadband active array antennas.

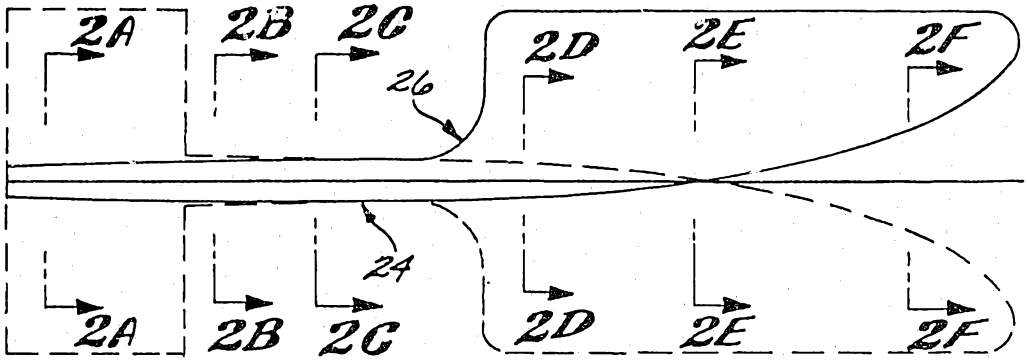


FIG. 1 PRIOR ART

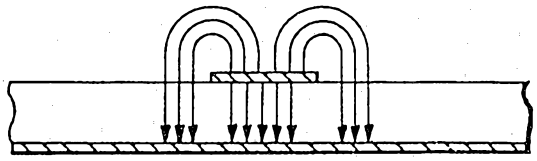


FIG. 2A

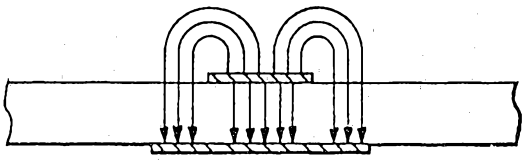


FIG. 2B

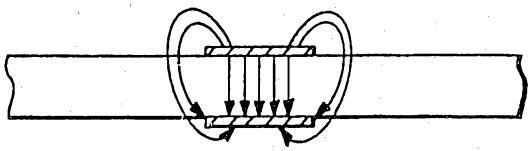


FIG. 2C

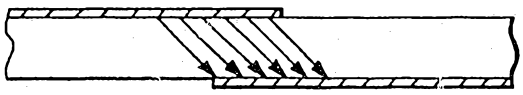


FIG. 2D

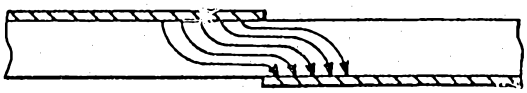


FIG. 2E

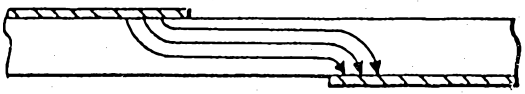


FIG. 2F

FIG. 3A

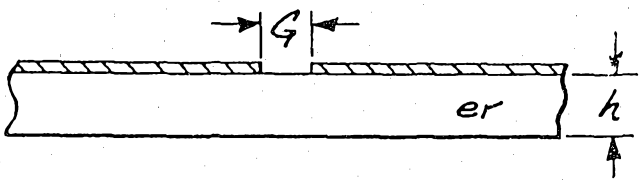


FIG. 3B

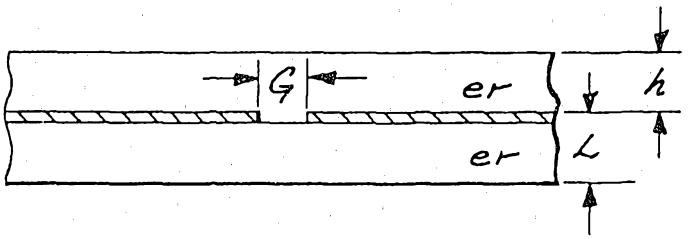


FIG. 3C

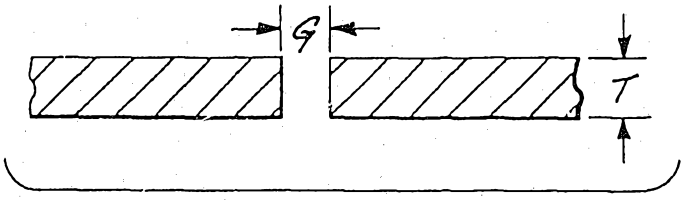


FIG. 3D

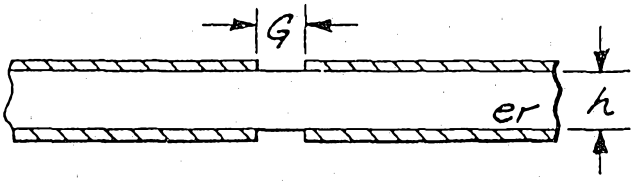


FIG. 3E

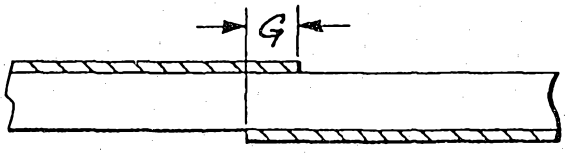


FIG. 3F

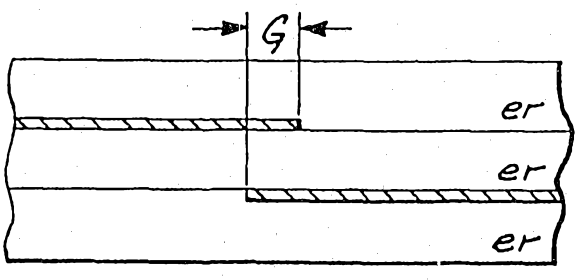


FIG. 5

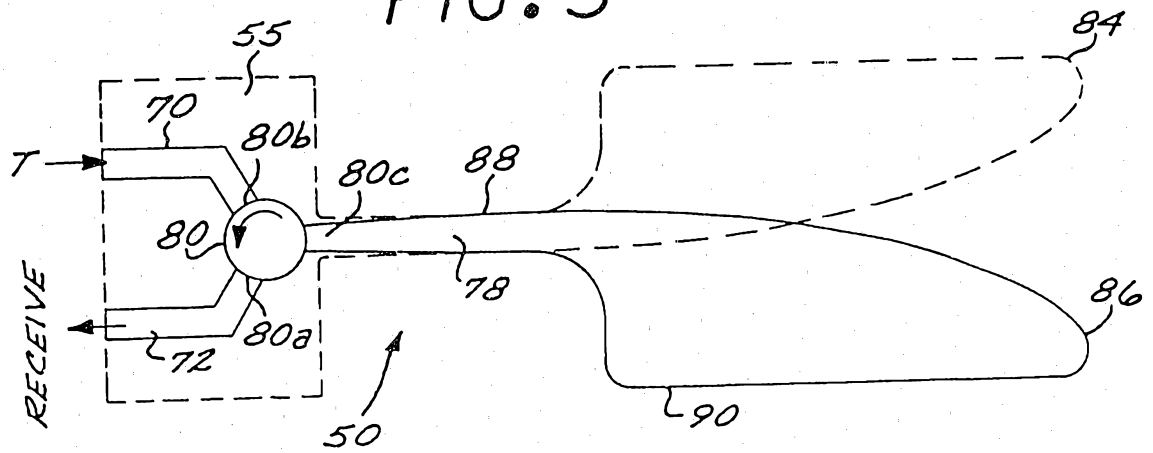
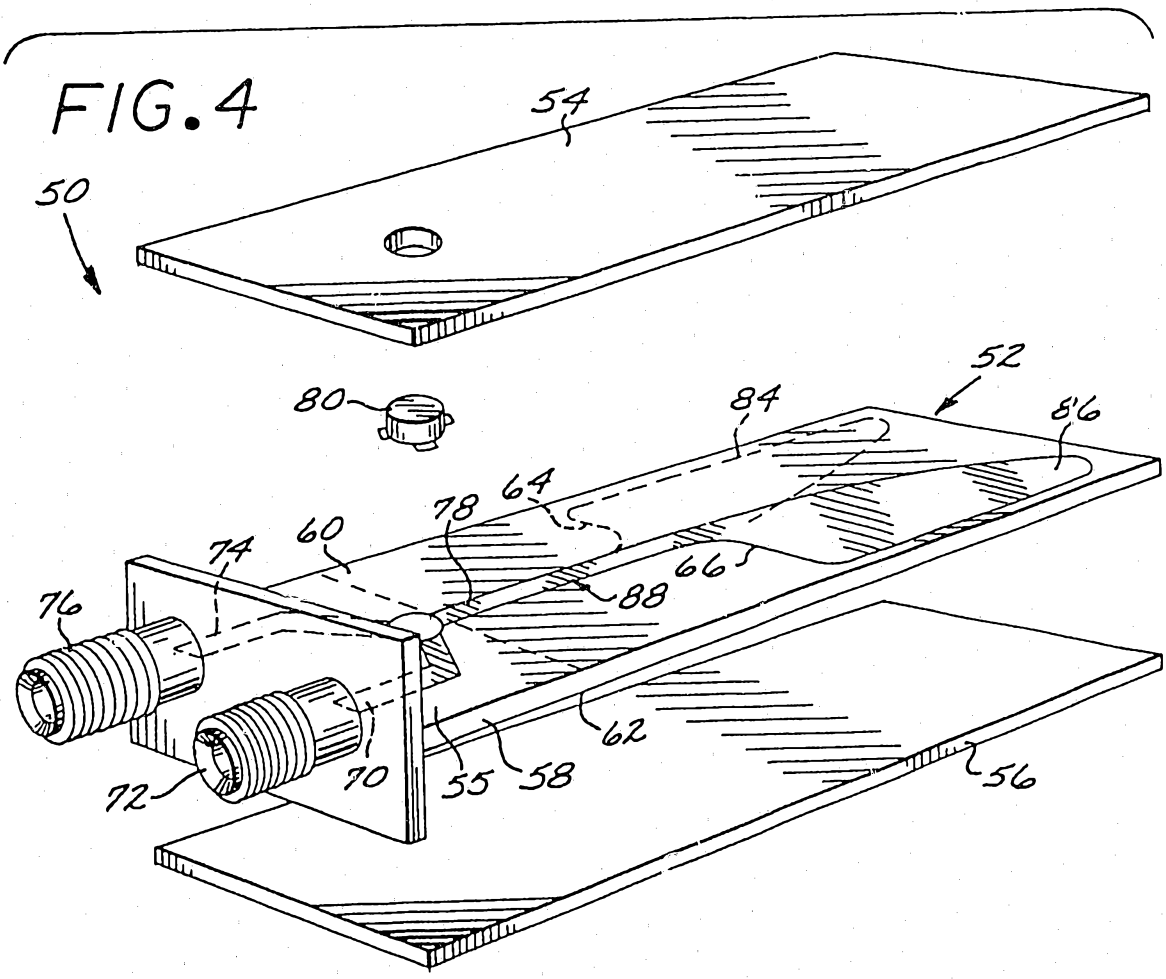

55
84
70
80b
T
80c
88
80
78
86
RECEIVE
80a
72
50
90

FIG. 4


54
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66
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56