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Description

This invention relates to an antenna comprising:

a) a substantially planar microstrip circuit for coupling radio frequency energy between a pair of ends of the circuit, the circuit having a strip conductor separated from a ground plane conductor by a dielectric;

b) a conductive structure comprising opposing walls providing side portions of a cavity formed in the structure, the cavity having a pair of openings, the said walls having outer ends which terminate at a distal one of the pair of openings of the cavity and are disposed on a common surface, said common surface and said strip conductor being disposed above the level of the ground plane conductor at the said dielectric; and

c) a radio frequency energy feed coupled to one of the pair of ends of the microstrip circuit, and wherein radio frequency energy passing between free space and the feed, passes through the said openings of the cavity and the microstrip circuit.

In many radio frequency systems, limited space is available for antennas. Antennas designed for small spaces, however, must meet various performance requirements. For example, the antenna must have a specified angular coverage and frequency bandwidth. Thus, existing antennas may not meet both the size and performance requirements in a system.

One common size constraint in airborne systems is that the antenna not protrude beyond the aircraft carrying the RF system. Thus, a "flush mount" antenna is required.

Various forms of flush mount antennas are known. For example, annular slot antennas, cavity inductors, strip inductors, patch antennas, surface-wave antennas and slot antennas can all be mounted flush with a surface. However, these types of antennas generally have narrow frequency bandwidths. They are thus not well suited for systems requiring frequency bandwidths of 3:1. Printed log-periodic dipoles can be cavity backed and flush mounted. These antennas can be built with 3:1 frequency bandwidths, but cannot be made small enough to meet the size constraints of some applications.

GB-A-1598545 describes a waveguide aerial consisting of a rectangular waveguide formed in a circular brass flange and filled with polytetrafluoroethylene (PTFE) made flush with one face of the flange, the longitudinal axis of the waveguide being at an acute angle to the axis of the flange. Energy is coupled into the waveguide by a probe extending from a seating in the other face of the flange.

US-A-4415900 describes an antenna of the kind defined hereinbefore at the beginning, the antenna being a multi-mode cavity antenna consisting of a microstrip antenna mounted within an open waveguide having one end with a square end closure and the other with a ramp closure. The open side of the waveguide has a dielectric cover. Energy is coupled to the microstrip antenna by a coaxial-to-microstrip adapter that is mounted through the bottom of the waveguide, which faces the dielectric cover. The microstrip antenna comprises a first square microstrip element fed asymmetrically by coaxial feed, and a second square microstrip element fed from the first square element via a microstrip transmission line.

It is an object of this invention to provide an antenna that can be mounted flush with a surface.

It is also an object of this invention to provide an antenna which can conform to non-planar surfaces.

It is a further object of this invention to provide an antenna with a broad frequency bandwidth and wide angular coverage.

It is a further object of this invention to provide an antenna which fits in a relatively small volume.

It is yet a further object of this invention to provide an antenna which can be designed for end-fire or near broadside radiation patterns over a 3:1 frequency bandwidth.

According to the present invention an antenna of the kind defined hereinbefore at the beginning is characterised in that the said walls have surface portions inclined with respect to the substantially planar microstrip circuit, and in that the other of the pair of ends of the microstrip circuit is electrically coupled to a proximal one of the said pair of openings, the arrangement being such that the said radio frequency energy serially passes through the pair of openings and the microstrip circuit or vice versa.

A preferred embodiment takes the form of an antenna having a radiating cavity filled with dielectric. The radiating cavity has two opposing taper walls. Radio frequency energy is fed to the radiating cavity via a microstrip horn. The dielectric in the radiating cavity conforms with the upper surface of the antenna. The upper surface of the antenna, in turn, conforms with the surface in which the antenna is mounted.

Brief Description of the Drawings

The invention will be better understood by reference to the following more detailed description and accompanying figures in which

FIG. 1 shows an exploded view of an antenna constructed according to the invention;

FIG. 2 is the top view of the antenna of FIG. 1 with top 20 removed;
FIG. 3 is a cross-sectional view of the antenna of FIG. 1 taken along the line 3-3;
FIG. 4A is a plot showing the azimuthal beam pattern of the antenna of FIG. 1;
FIG. 4B is a plot showing the elevation beam pattern of the antenna of FIG. 1; and
FIG. 5 shows another embodiment of the invention mounted in an object with a curved surface.

Description of the Preferred Embodiment

FIG. 1 shows an exploded view of an antenna 10 constructed according to the present invention. The antenna 10 has a base 12 and a top 20 formed from a conductive metal.

A dielectric board 14 is mounted, for example by gluing or mounting screws, to the base 12. The relative dielectric constant of board 14 is ε_{rs}. A microstrip horn 16 is patterned, in a known manner, on the upper surface (not numbered) of dielectric board 14. In operation, base 12 is at ground potential and forms the second conductor of the microstrip. A signal is applied to microstrip horn 16 through feed 28. For example, a coaxial cable (not shown) could pass through feed 28 and have its center conductor connected to microstrip horn 16.

A dielectric slab 18 with relative dielectric constant ε_r is also mounted, such as by gluing or captivation by top 20, to base 12. Dielectric slab 18 has a taper surface 34 which conforms to taper surface 32 of base 12. Dielectric slab 18 has a second taper surface 30 which conforms to a tapered surface (element 50, FIG. 3) in top 20.

Top 20 is secured to base 12 by screws through screw holes 22 and 24 or by any other convenient means such as conductive epoxy. With top 20 secured to the base, a radiating cavity 26 is formed. The radiating cavity 26 is bounded on the bottom by base 12. Two sides of radiating cavity 26 are bounded by the inside surface of prongs 42A and 42B of top 20. A third side of radiating cavity 26 is bounded by taper surface 50 (FIG. 3) of top 20. The fourth side of radiating cavity 26 is bounded by taper surface 32. Dielectric slab 18 thus fills radiating cavity 26.

The base 12, top 20 and dielectric slab 40 are constructed to form a flush upper surface. In particular, with the components of antenna 10 assembled, upper surfaces 36, 38 and 40 form a surface without discontinuities. In FIG. 1, that surface is shown to be a plane. Antenna 10 could thus be recessed into a planar surface to create a flush surface. The invention, however, is not limited to a planar flush surface.

FIG. 2 shows additional details of the antenna 10, as would be seen by looking at the top of antenna 10 (FIG. 1) with top 20 removed. In all the figures, like reference numbers denote like elements. Superimposed on the structure of FIG. 2 is an x-axis and an angle ϕ_{AZ} measured relative to the x-axis. The angle ϕ_{AZ} indicates the azimuthal direction relative to the antenna 10.

FIG. 2 also indicates various dimensions of components in antenna 10. Dielectric board 14 has a width W_S and a length L_S. Dielectric slab 18 has a width W. Upper surface 40 has a length L. The total length of dielectric board 14 and dielectric slab 18 is L_T.

FIG. 3 shows a cross-sectional view of antenna 10 taken along the line 3-3 of FIG. 1. Details of top 20 can be seen in FIG. 3. Top 20 has a taper surface 50 which conforms with taper surface 30 of dielectric slab 18. Additionally, top 20 has formed in it a cavity 54 of length L_{MC} and extending a height H_{MC} above microstrip horn 16. Inside cavity 54, there is an absorber 52, which is any known material which absorbs radio frequency energy. Cavity 54 and absorber 52 present a load to microstrip horn 16 very similar to the load that would be present if microstrip horn 16 were in free space. In addition, absorber 52 is selected to prevent resonance in cavity 54 while absorbing a minimum of RF energy.

Top 20 is in electrical contact with dielectric horn 16. Electrically, taper surface 50 is like an extension of microstrip horn 16. Taper surface 50 therefore launches electrical signals travelling down microstrip horn 16 into radiating cavity 26.

Various other dimensions of antenna 10 are shown in FIG. 3. Dielectric slab 18 is shown to have a height H_C. The bottom of dielectric slab 18 excluding taper surface 34 is shown to have a length L_B. Dielectric board 14 is shown to have a height of t. In addition, taper surface 50 is shown to make an angle α_{FE} with base 12. Taper surface 32 is shown to make an angle α_f with the x-axis. Also, the angle θ_{EL} is shown. Angle θ_{EL} defines the elevation direction relative to antenna 10.

In constructing an antenna according to the invention, the various dimensions of the antenna are selected based on two major considerations. First, the dimensions are selected based on the wavelength, λ_0, of the center frequency, f_o, of operation of the antenna. Additionally, some parameters are selected such that antenna 10 projects a beam in the desired azimuthal and elevational angles.

EXAMPLE I

As an example, Table I shows dimensions selected for the various parameters of antenna 10. FIG. 4A shows the azimuthal beam pattern resulting when an antenna with the dimensions of Table I is operated at a frequency equal to $0.917f_o$. The abscissa of the plot shows azimuthal angle. The ordinate shows the gain relative to an isotropically radiating antenna measured in the far field at the azimuthal angle with the elevation angle of 0°.

FIG. 4B shows the elevation pattern when an antenna with the dimensions of Table I is operated at a frequency of $0.917f_o$. The abscissa of the plot shows elevation angle. The ordinate shows the gain relative to an isotropically radiating antenna measured in the far field at the elevation angle with an azimuthal angle of 0°.

TABLE I

ANTENNA PARAMETER	DIMENSIONS
L	$1.17\ \lambda_o$
W	$0.51\ \lambda_o$
L_B	$0.61\ \lambda_o$
H	$0.31\ \lambda_o$
t	$0.03\ \lambda_o$
H_C	$0.19\ \lambda_o$
H_{MC}	$0.18\ \lambda_o$
W_S	$0.51\ \lambda_o$
L_S	$0.39\ \lambda_o$
L_{MC}	$0.36\ \lambda_o$
L_T	$1.78\ \lambda_o$
α_{FE}	40.4°
α_F	14.9°
ε_r	3.0
ε_{rs}	2.22

As seen by line 400A in FIG. 4A, antenna 10 has a 3dB beamwidth in the azimuthal plane of approximately 160°. Line 400B in FIG. 48 shows antenna 10 has a 3dB beamwidth in the elevation plane of approximately 60°. The beam center in the elevation plane occurs at an elevation angle of approximately 20°.

The performance of antenna 10 can be changed by varying the parameters of antenna construction. If the parameter L is shortened, the 3dB beamwidth in the elevation plane increases. In addition, the beam becomes centered closer to the value of θ_{EL} equal to 90°. In other words, the antenna has a near broadside radiation pattern. Conversely, an increase in L tends to concentrate the beam in the elevation plane closer to values of θ_{EL} near zero. In other words, the antenna has a end-fire radiation pattern.

Additionally, the width W of dielectric slab 18 can be varied. Increasing the value of W tends to decrease the 3dB beamwidth in the azimuthal plane. FIG. 5 shows an alternative embodiment of the antenna. Antenna

10A contains a dielectric slab 10A which tapers outwards away from microstrip horn 16 (not shown). The added width of the taper tends to decrease the 3dB beamwidth in the azimuthal direction.

EXAMPLE II

Near hemispherical elevation coverage over $\theta_{EL} = 0°$ to $\theta_{EL} = 170°$ can be achieved by varying some of the parmeters shown in Table I. With $L = 0.53\ \lambda_o$ and $\varepsilon_r = 6$, there will be less than 8dB of gain variation and a front to back ratio of less than 3.5dB (at $\theta_{EL} = 20°$ and $\theta_{EL} = 160°$). An antenna constructed with the dimensions of this example can achieve an impedance matched peak gain of not less than 2dBi and a half power beamwidth of not less than 62° measured in the plane $\theta_{EL} = 0°$ over a 3:1 frequency band.

FIG. 5 also shows how an antenna can be flush mounted to a surface. Antenna 10A is recessed into surface 56. Here, surface 56 is curved. Upper surface 36A, 38A, and 40A are shaped to conform to surface 56.

Having described embodiments of the invention, it will be apparent to one of skill in the art that various modifications to the disclosed embodiments could be made. For example, the antenna has been described only in relation to the transmission of signals, but could be used to receive signals. Additionally, the antenna has been shown to mount flush with planar or curved surfaces, but could be readily extended to conform to any shape surface. The flush mount antenna could be arrayed, resulting in a flush mount array antenna.

Claims

1. An antenna comprising:
   a) a substantially planar microstrip circuit (14,16) for coupling radio frequency energy between a pair of ends of the circuit, the circuit having a strip conductor (16) separated from a ground plane conductor (12) by a dielectric (14);
   b) a conductive structure (12,20) comprising opposing walls (32,50) providing side portions of a cavity (26) formed in the structure (12,20), the cavity (26) having a pair of openings, the said walls (32,50) having outer ends which terminate at a distal one of the pair of openings of the cavity (26) and are disposed on a common surface, said common surface and said strip conductor (16) being disposed above the level of the ground plane conductor (12) at the said dielectric (14); and
   c) a radio frequency energy feed coupled to one of the pair of ends of the microstrip circuit (14,16), and wherein radio frequency energy passing between free space and the feed, passes through the said openings of the cavity (26) and the microstrip circuit (14,16), characterised in that the said walls have surface portions (32,50) inclined with respect to the substantially planar microstrip circuit (14,16), and in that the other of the pair of ends of the microstrip circuit (14,16) is electrically coupled to a proximal one of the said pair of openings, the arrangement being such that the said radio frequency energy serially passes through the pair of openings and the microstrip circuit (14,16) or vice versa.

2. An antenna according to Claim 1, characterised by a dielectric material (18) disposed in said cavity (26), said dielectric material (18) having a surface (40) terminating at the outer ends of the walls.

3. An antenna according to Claim 2, characterised in that the substantially planar microstrip circuit (14,16) comprises a microstrip horn (16) having a narrow portion coupled to the feed and a wide portion disposed adjacent the proximal opening of the cavity (26).

4. An antenna according to Claim 2, characterised by being adapted for flush mounting with a conformal surface (56), and in that the surface (40A) of the dielectric material (18A) disposed in the cavity (26) is flush with the conformal surface (56).

Patentansprüche

1. Antenne mit
   a) einer im wesentlichen planaren Mikrostreifenschaltung (14,16) zur Kopplung von Hochfrequenzenergie zwischen einem Paar von Enden der Schaltung, wobei die Schaltung einen Streifenleiter (16) aufweist, der von einem Erdungsebenenleiter (12) durch ein Dielektrikum (14) getrennt ist;
   b) einer leitfähigen Struktur (12,20), welche einander gegenüberliegende Wandungen (32,50) aufweist, die Seitenteile einer in der Struktur (12,20) vorgesehenen Kammer (26) bilden, die ein Paar von

Öffnungen hat, wobei die genannten Wandungen (32,50) äußere Enden haben, die in einer äußeren Öffnung des Paars von Öffnungen der Kammer (26) enden und in einer gemeinsamen Fläche gelegen sind, und wobei die gemeinsame Fläche und der Streifenleiter (16) sich oberhalb des Niveaus des Erdungsebenenleiters (12) bei dem genannten Dielektikum (14) befinden; und
c) einer Hochfrequenzenergieeinspeisung, welche an eines der beiden Enden der Mikrostreifenschaltung (14,16) angekoppelt ist, wobei Hochfrequenzenergie, die zwischen der freien Umgebung und der Einspeisung sich ausbreitet, durch die genannten Öffnungen der Kammere (26) und die Mikrostreifenschaltung (14,16) tritt,
dadurch gekennzeichnet, daß die genannten Wandungen Oberflächenbereiche (32,50) aufweisen, die relativ zu der im wesentlichen planaren Mikrostreifenschaltung (14,16) geneigt sind, und daß das jeweils andere der beiden Enden der Mikrostreifenschaltung (14,16) elektrisch mit einer inneren der genannten beiden Öffnungen gekoppelt ist, wobei die Anordnung so getroffen ist, daß sich die Hochfrequenzenergie der Reihe nach durch die beiden Öffnungen und die Mikrostreifenschaltung (14,16) oder umgekehrt ausbreitet.

2. Antenne nach Anspruch 1, gekennzeichnet durch ein dielektrisches Material (18), das in der genannten Kammer (26) angeordnet ist und eine Oberfläche (40) aufweist, die an den äußeren Enden der Wände abschließt.

3. Antenne nach Anspruch 2, dadurch gekennzeichnet, daß die im wesentlichen planare Mikrostreifenschaltung (14,16) einen Mikrostreifen-Hornstrahler (16) enthält, der einen mit der Einspeisung gekoppelten schmalen Teil und einen breiten Teil aufweist, der nahe der inneren Öffnung der Kammer (26) angeordnet ist.

4. Antenne nach Anspruch 2, gekennzeichnet durch eine Gestaltung zur fluchtenden, bündigen Montage in einer entsprechenden Oberfläche (56), sowie dadurch gekennzeichnet, daß die Oberfläche (40A) des dielektrischen Materials (18A), das sich in der Kammer (26) befindet, mit der angepaßten Oberfläche (56) bündig ist.

Revendications

1. Antenne comprenant :
a) un circuit à micro-bande essentiellement planar (14,16) pour coupler une énergie à haute fréquence entre un couple d'extrémités du circuit, le circuit possédant un conducteur en forme de bande (16) séparé d'un conducteur (12) de plan de masse par un diélectrique (14);
b) une structure conductrice (12,20) comprenant des parois opposées (32,50) formant des parois latérales d'une cavité (26) formée dans la structure (12,20), la cavité (26) possédant un couple d'ouvertures, lesdites parois (32,50) possédant des extrémités extérieures qui se terminent à une extrémité distale du couple d'ouvertures de la cavité (26) et sont disposées sur une surface commune, ladite surface commune et ledit conducteur en forme de bande (16) étant disposés au-dessus du niveau du conducteur (12) de plan de masse au niveau dudit diélectrique (14); et
c) une alimentation en énergie à haute fréquence couplée à l'un des couples d'extrémités du circuit à micro-bande (14,16), et dans lequel une énergie à haute fréquence passant entre l'espace libre et l'alimentation, traverse lesdites ouvertures de la cavité (26) et du circuit à micro-bande (14,16);
caractérisée en ce que lesdites parois possèdent des éléments de surface (32,50) inclinés par rapport au circuit à micro-bande essentiellement planar (14,16), et en ce que l'autre extrémité du couple d'extrémités du circuit à micro-bande (14,16) est couplée électriquement à une extrémité proximale dudit couple d'ouvertures, l'agencement étant tel que ladite énergie à haute fréquence est transmise en série par le couple d'ouvertures et par le circuit à micro-bande (14,16) ou vice versa.

2. Antenne selon la revendication 1, caractérisée par un matériau diélectrique (18) disposé dans ladite cavité (26), ledit matériau diélectrique (18) possédant une surface (40) se terminant au niveau des extrémités extérieures des parois.

3. Antenne selon la revendication 2, caractérisée en ce que le circuit à microbande essentiellement plan (14,16) comprend un cornet à micro-bande (16) possédant une partie étroite couplée à l'alimentation et une partie large disposée au voisinage de l'ouverture proximale de la cavité (26).

4. Antenne selon la revendication 2, caractérisée en ce qu'elle est adaptée pour un montage de niveau avec une surface adaptée (56) et en ce que la surface (40a) du matériau diélectrique (18A) disposé dans la cavité (26) est de niveau avec la surface adaptée (56).

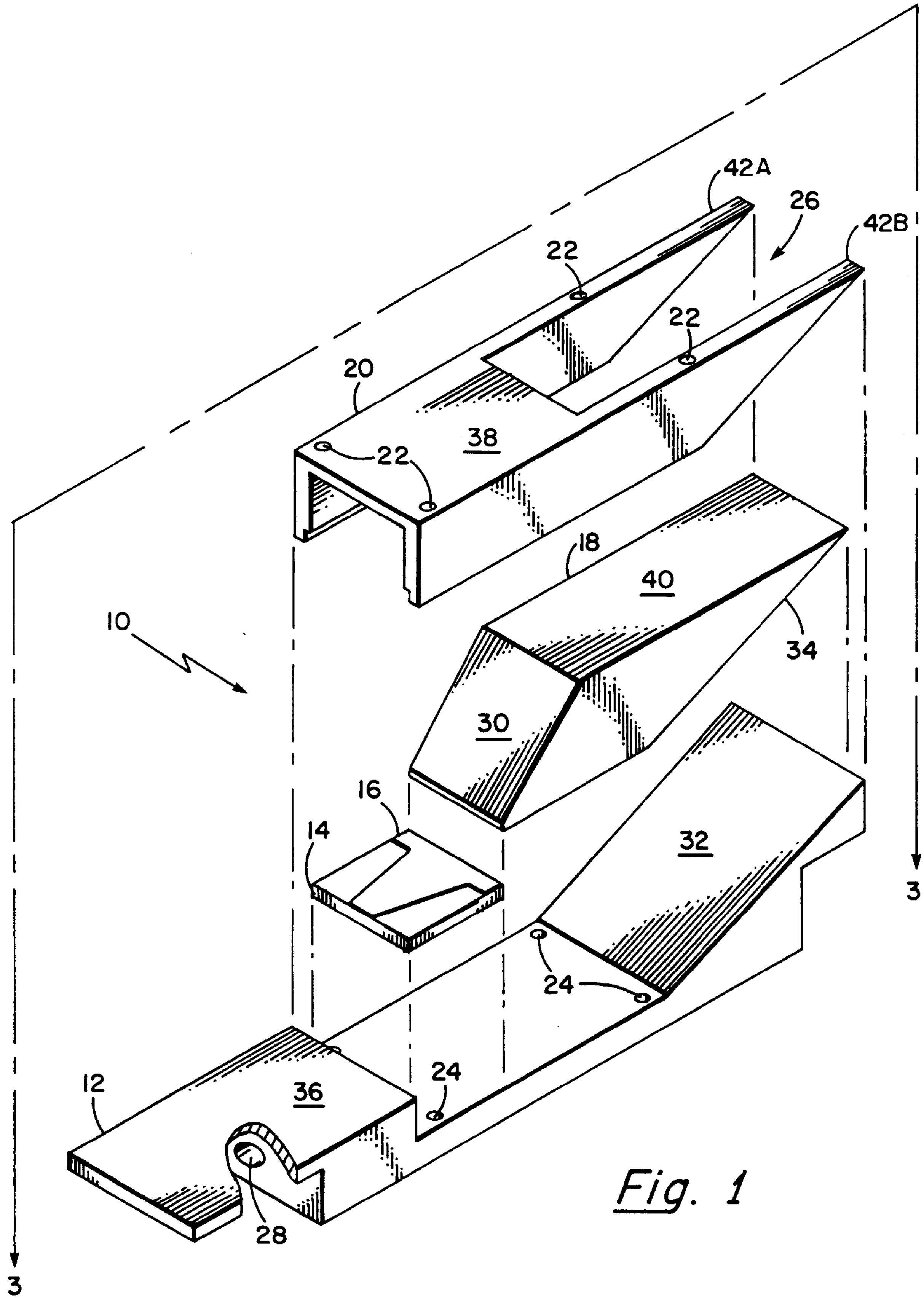


Fig. 1

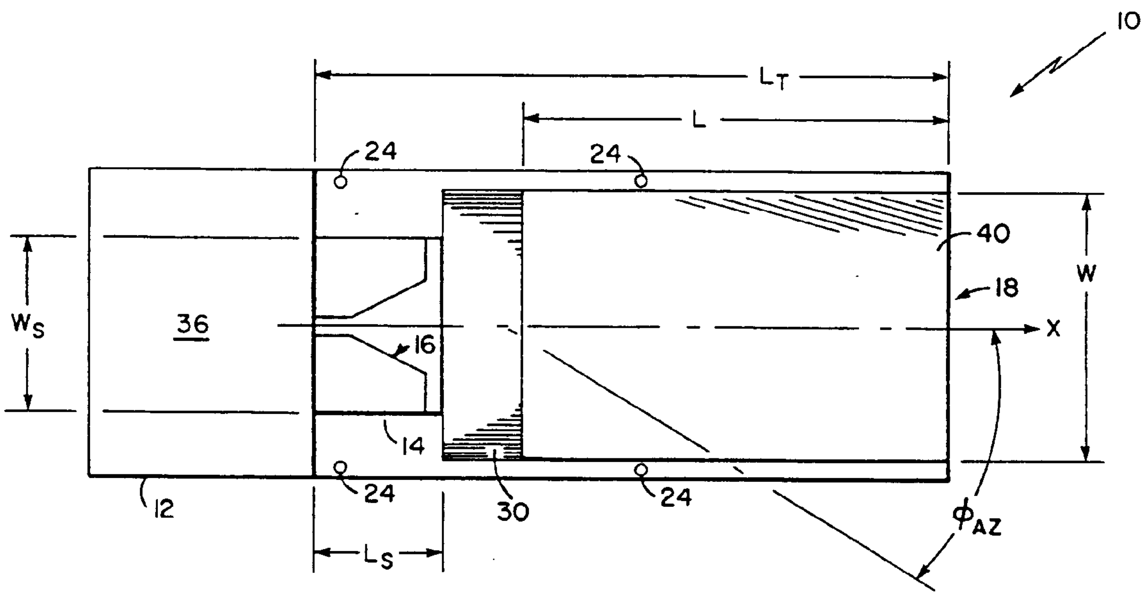

10
L T
L
24
24
40
W
18
X
W S
36
16
14
24
24
12
30
φ AZ
L S

Fig. 2

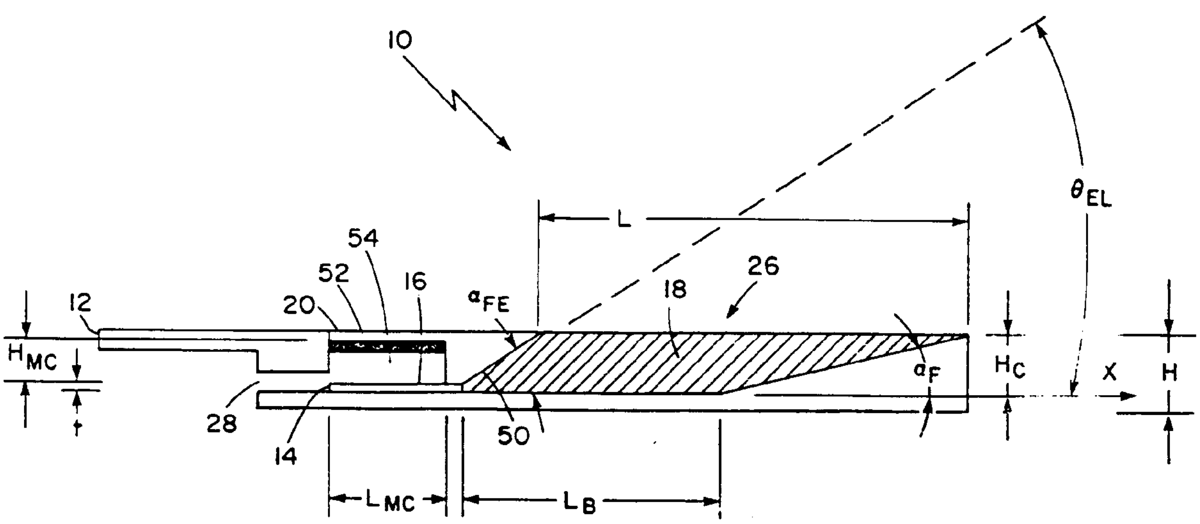
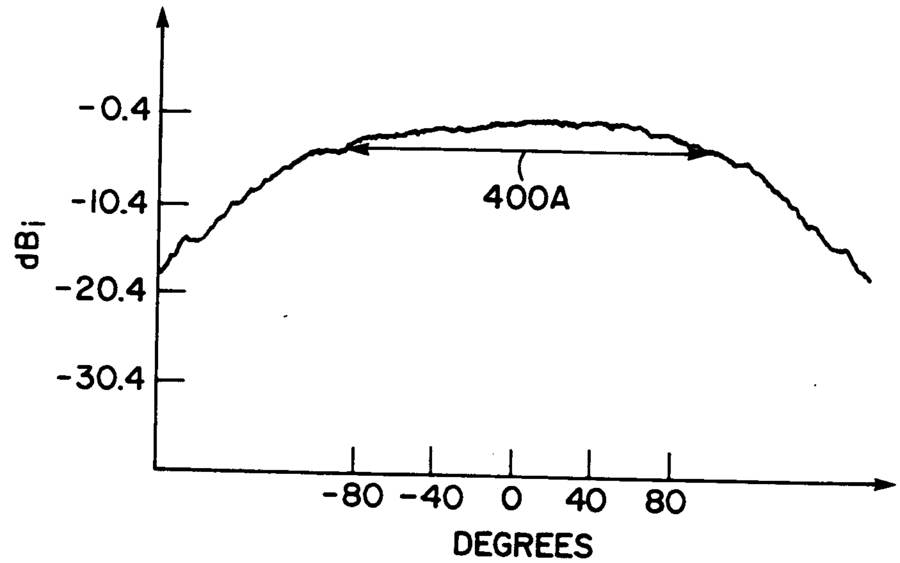

10
θ EL
L
26
54
52
16
12
20
α FE
18
H MC
H C
X
H
α F
t
28
14
50
L MC
L B

Fig. 3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-10.4
-20.4
-30.4
dBi
400A
-80 -40 0 40 80
DEGREES

Fig. 4A

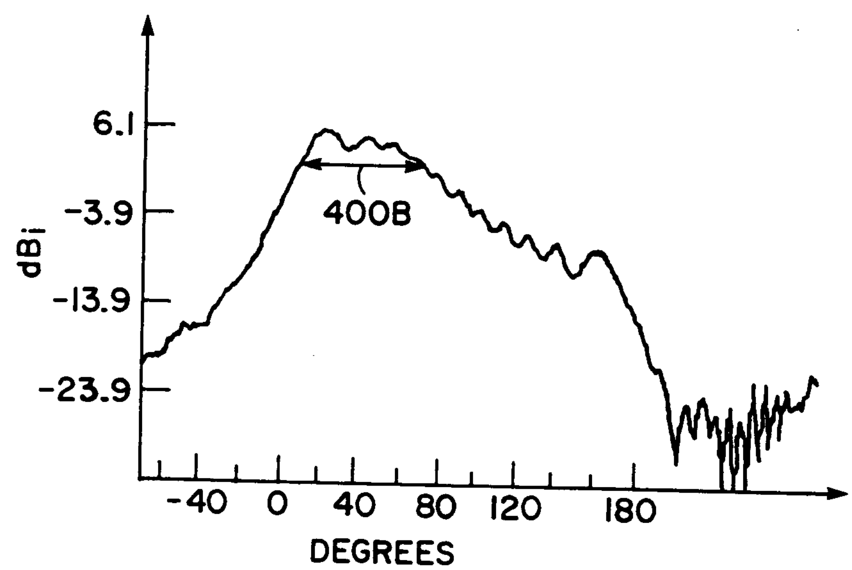
6.1
-3.9
-13.9
-23.9
dBi
400B
-40 0 40 80 120 180
DEGREES

Fig. 4B

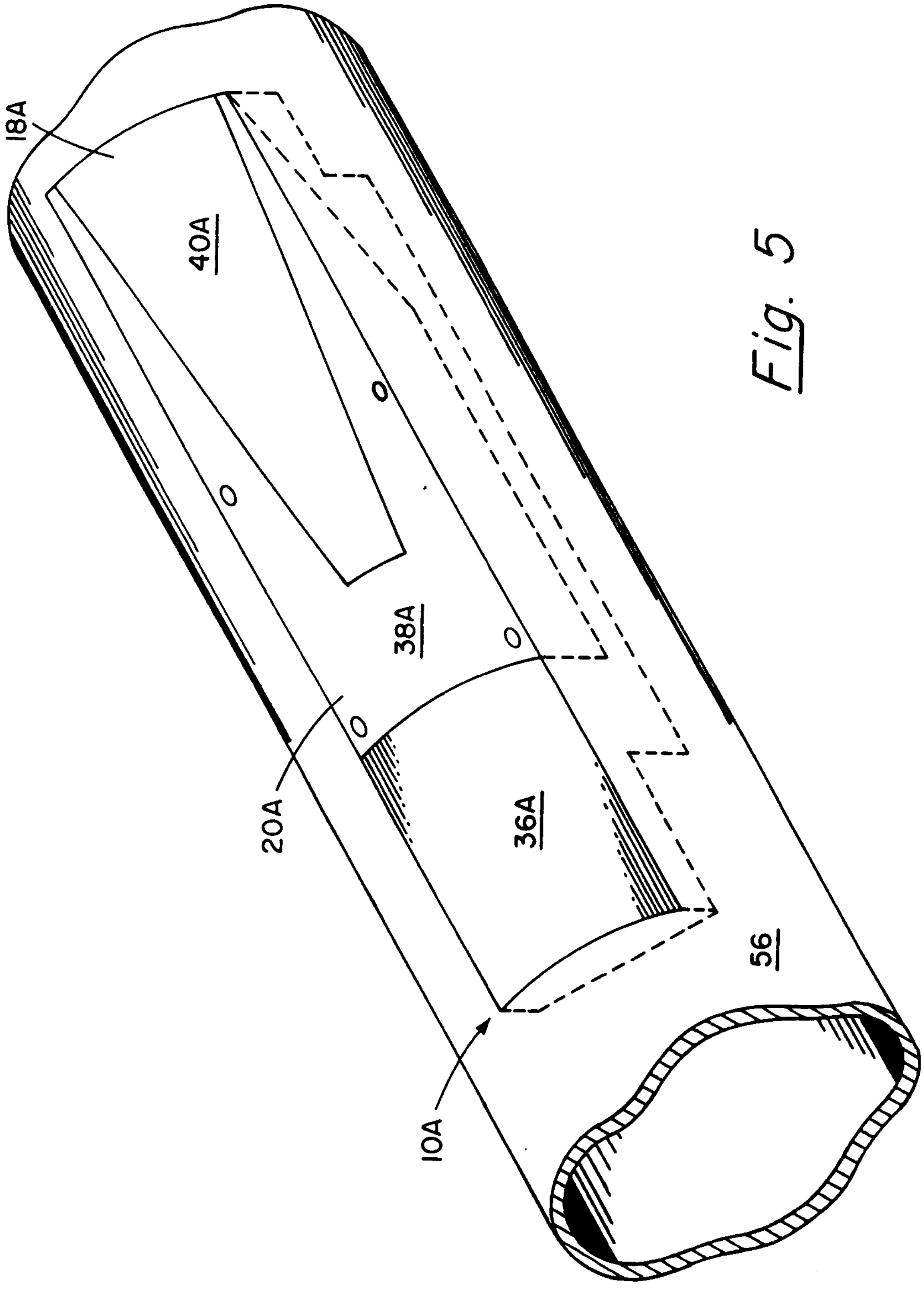

Fig. 5