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Epis

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[54] **BROADBAND CUP-DIPOLE AND CUP-TURNSTILE ANTENNAS**

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[73] Assignee: **GTE Sylvania Incorporated,** Mountain View, Calif.

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[52] **U.S. Cl.** **343/797,** 343/789, 343/818, 343/822

[51] **Int. Cl.** **H01q 21/26**

[58] **Field of Search** 343/792, 797, 789, 343/818, 820, 821, 822

[56] **References Cited**

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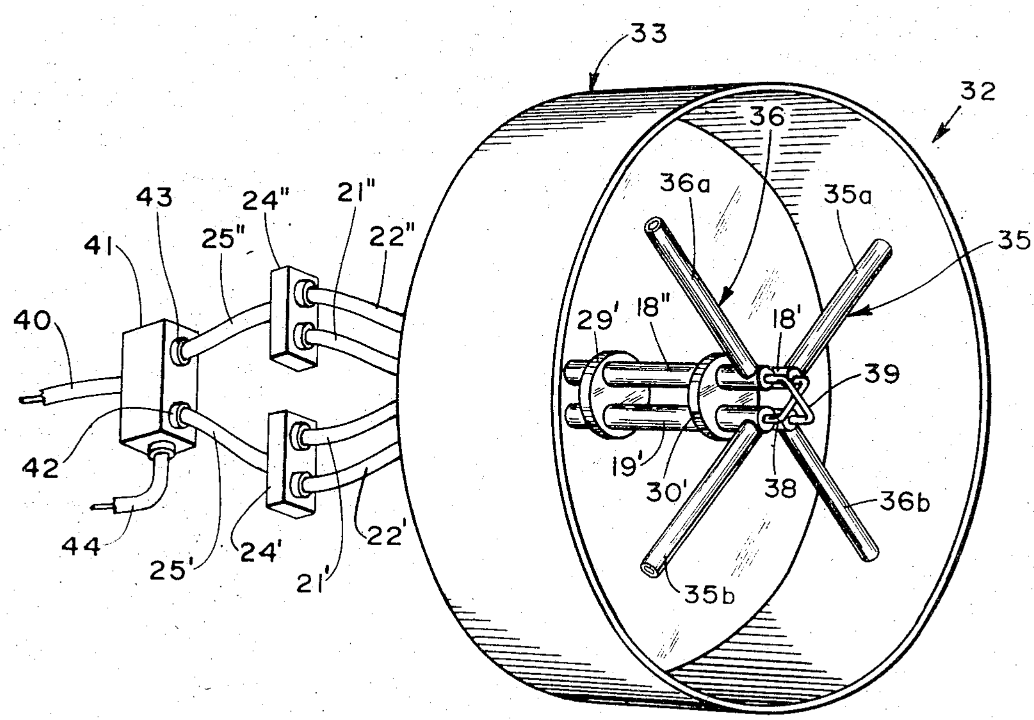
Primary Examiner—Eli Lieberman

Attorney—Norman J. O'Malley, John F. Lawler and Elmer J. Nealon

[57] **ABSTRACT**

A cup-dipole antenna features two colinear monopole elements mounted close to the plane of the cup mouth or aperture and electrically connected at their inner ends to the outer conductors, respectively, of a pair of coaxial lines whose inner conductors are electrically connected together adjacent the monopole elements. The input ends of these coaxial lines are connected to the output or secondary-winding terminals of an impedance transformer constituting a lumped-circuit component with a secondary winding having an r.f. grounded center tap. The two monopole elements are thereby excited as a center-fed dipole. In addition, a shorting plate electrically interconnects the outer conductors of the coaxial lines between the dipole and the bottom of the cup in order to neutralize adverse effects of mutual coupling between currents flowing on the inside surface of the cup and on the outer conductors of the coaxial lines. In practice, each coaxial line is housed in a rigid pipe to which the outer conductor is electrically connected and which electrically and mechanically supports the associated monopole element. The cup turnstile form of the invention comprises four monopole elements which comprise two such dipoles disposed at right angles to each other with the two pairs of end-connected coaxial feed lines adapted to be energized in phase quadrature to produce a circularly polarized radiation pattern.

7 Claims, 8 Drawing Figures



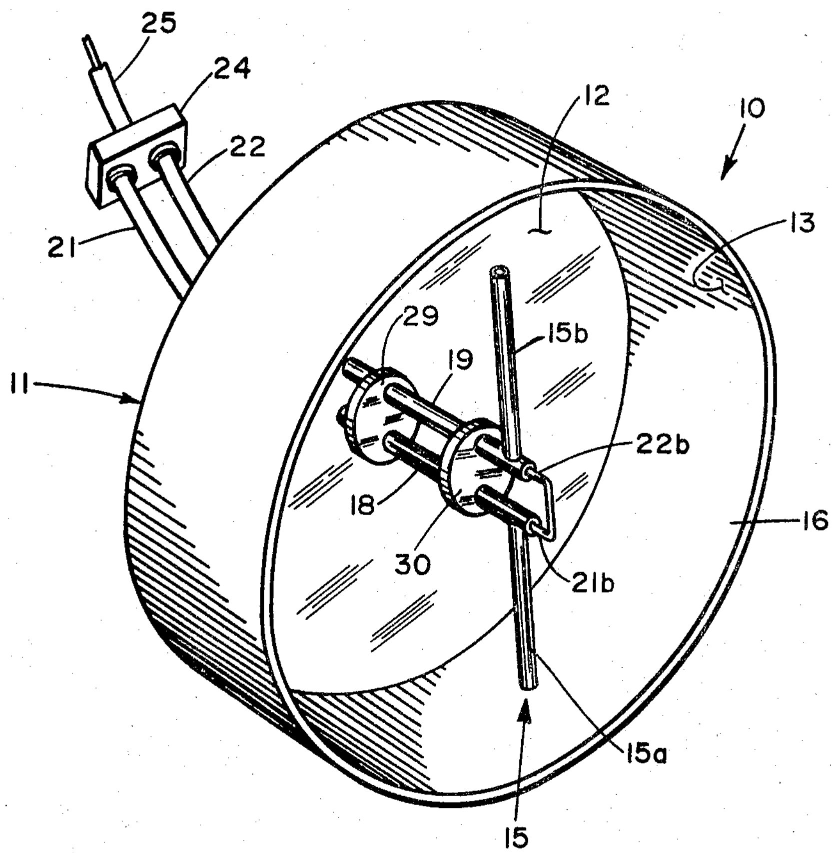

25
24
22
21
12
10
13
29
15b
19
11
22b
18
16
30
21b
15a
15

FIG. 1

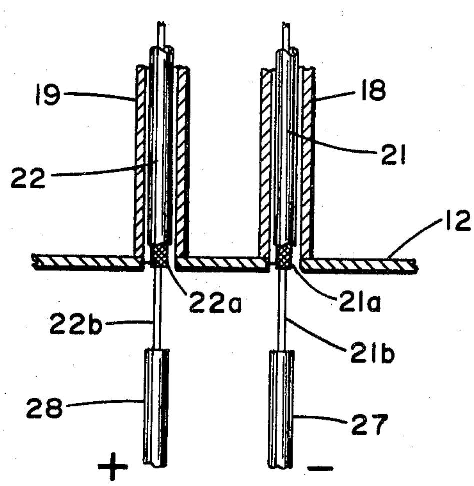

19
18
22
21
12
22a
21a
22b
21b
28
27
+
−

FIG. 4

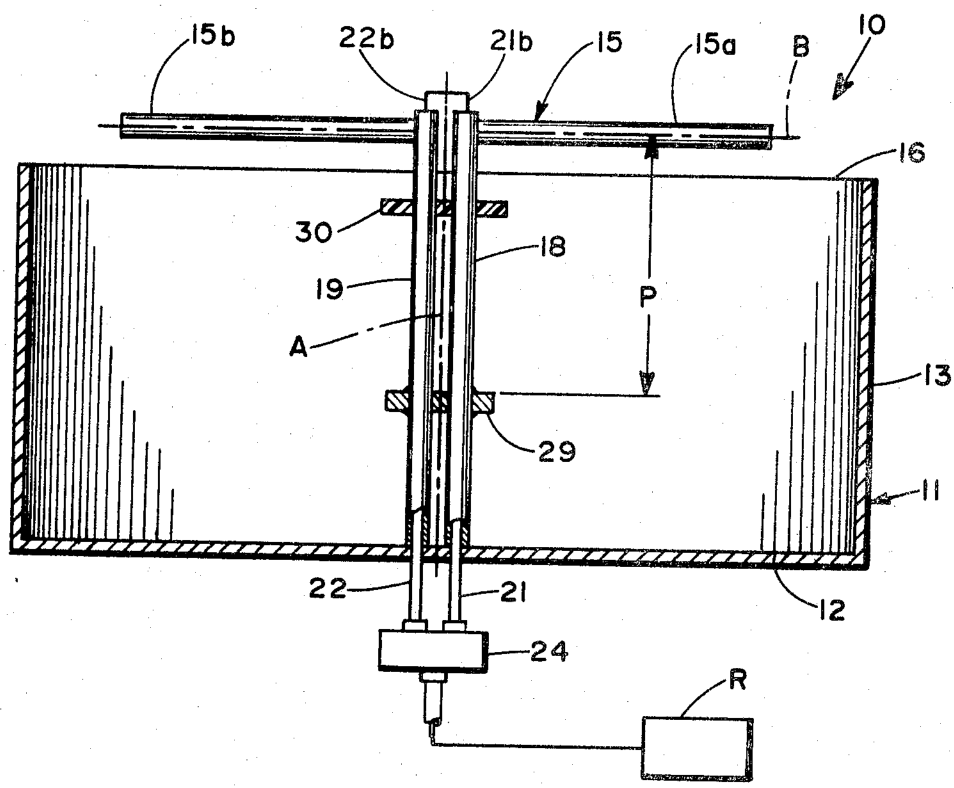

15b
22b
21b
15
15a
B
10
16
30
18
19
P
A
13
29
11
22
21
12
24
R

FIG. 2

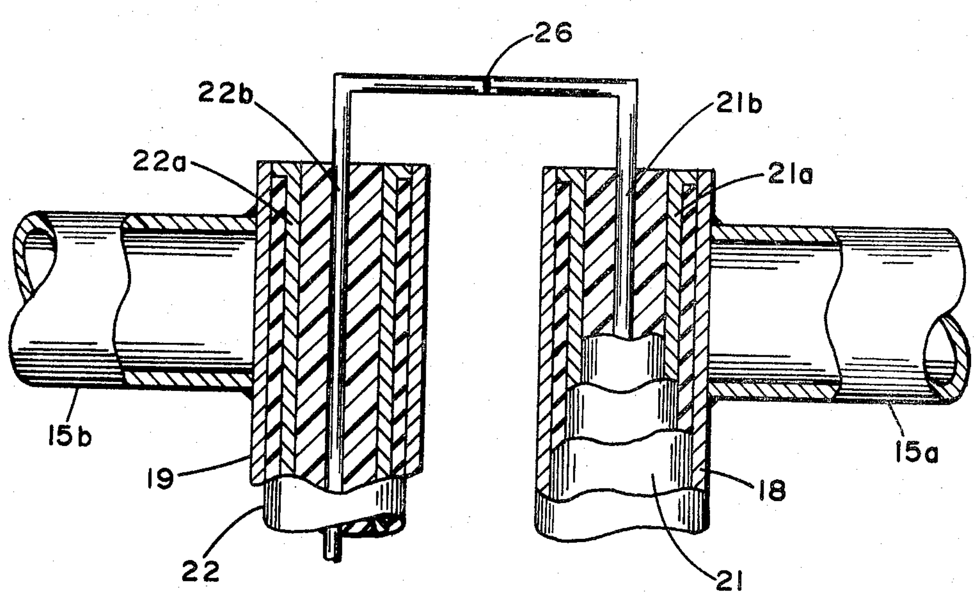

26
22b
21b
22a
21a
15b
15a
19
18
22
21

FIG. 3

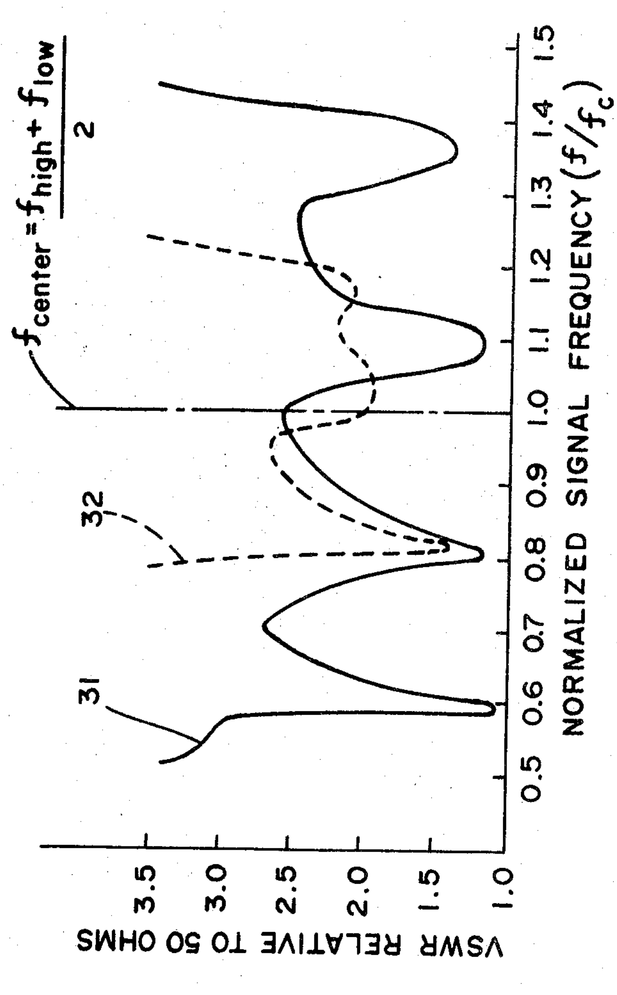

$f_{center} = \frac{f_{high} + f_{low}}{2}$
31
32
VSWR RELATIVE TO 50 OHMS
1.0
1.5
2.0
2.5
3.0
3.5
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
NORMALIZED SIGNAL FREQUENCY (f/f_c)

FIG. 5

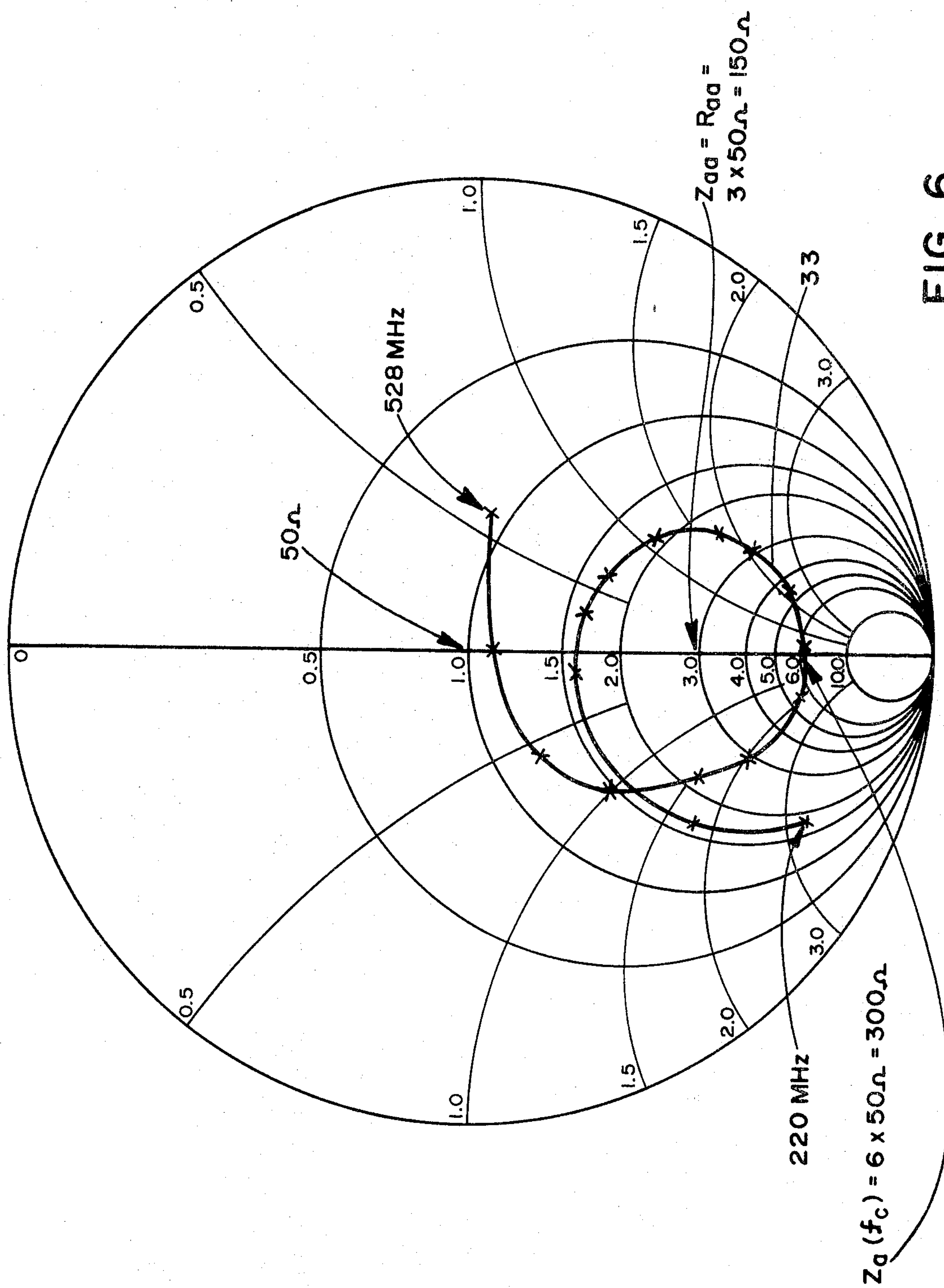

528 MHz
50Ω
$Z_{aa} = R_{aa} = 3 \times 50\Omega = 150\Omega$
33
220 MHz
$Z_a(f_c) = 6 \times 50\Omega = 300\Omega$
0
0.5
1.0
1.5
2.0
3.0
4.0
5.0
6.0
10.0

FIG. 6

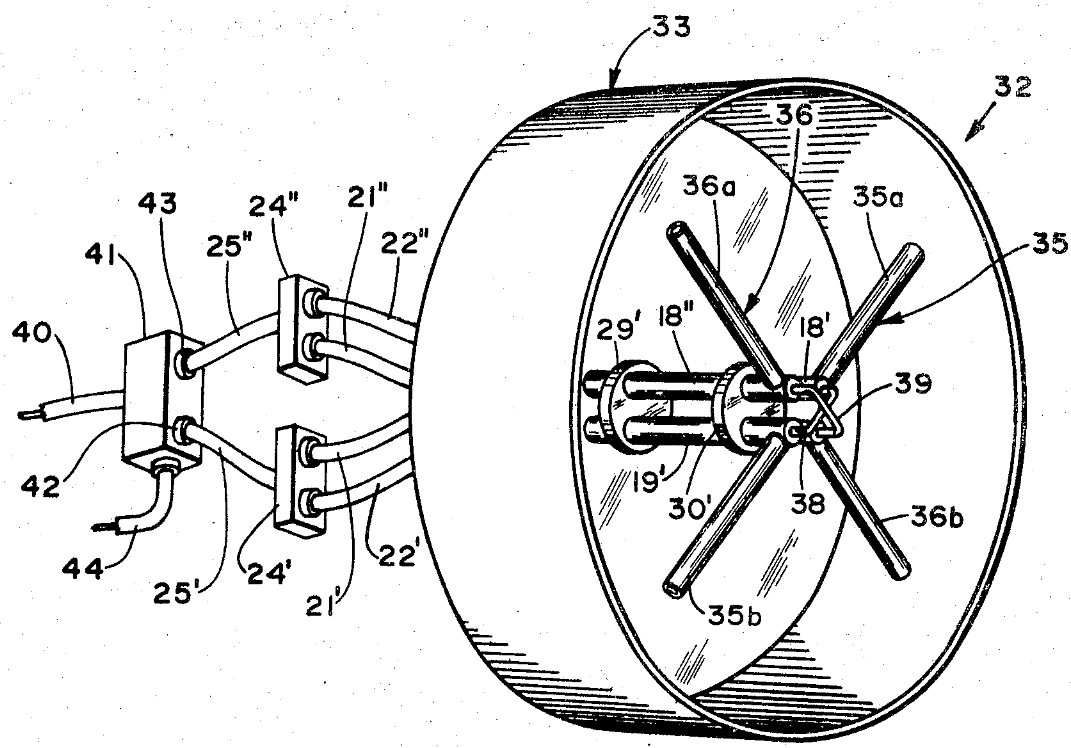

33
32
36
36a
35a
35
43
24"
21"
22"
41
25"
40
29'
18"
18'
39
42
19'
30'
38
36b
44
25'
24'
22'
21'
35b

FIG. 7

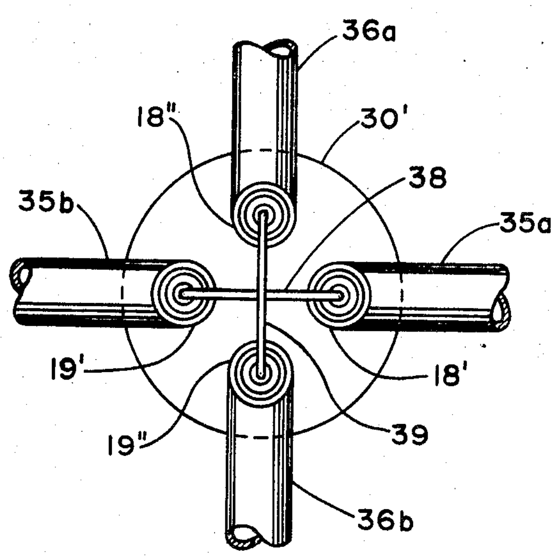

36a
18"
30'
38
35b
35a
19'
18'
19"
39
36b

FIG. 8

BROADBAND CUP-DIPOLE AND CUP-TURNSTILE ANTENNAS

BACKGROUND OF THE INVENTION

This invention relates to antennas and more particularly to cup-dipole and cup-turnstile type antennas.

The cup-dipole antenna is well known in the art for its equality of radiation patterns in the electric (E) and magnetic (H) planes. The cup-turnstile antenna, for this reason, is capable of producing radiation which is substantially circularly polarized in all directions on the associated radiation pattern. The dipole pairs in such a cup-turnstile antenna are fed in phase quadrature. A disadvantage of the cup-dipole and cup-turnstile antennas in the past, however, had been their limited operating bandwidth. More specifically, the bandwidth over which these prior antennas operate with a maximum voltage standing wave ratio (VSWR) of 3.0 or less with respect to the characteristic impedance of standard feed lines has often been less than the bandwidths desired for receiving antenna system applications.

An object of this invention is the provision of cup-dipole and cup-turnstile antennas having substantially improved operating bandwidths.

SUMMARY OF THE INVENTION

Improvement of the operating bandwidths of cup-dipole and cup-turnstile antennas is achieved with a unique feed arrangement in which each dipole is effectively center fed by a pair of coaxial lines having center conductors electrically interconnected adjacent the feed point and outer conductors electrically connected to the cup. These coaxial lines may be fed by a balanced two-wire input connected to the center conductors, respectively. However, for most applications wherein the antenna input transmission line is a coaxial line of a standard characteristic impedance, the two coaxial lines feeding the dipole are connected to the input line through an electrical equivalent of a lumped-circuit transformer having a center-tapped secondary winding.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a cup-dipole antenna embodying the invention;

FIG. 2 is a transverse section of the cup-dipole antenna shown in FIG. 1;

FIG. 3 is a greatly enlarged view partly in section of the coaxial feed lines at the point of connection to the monopole elements showing the interconnection of the center conductors;

FIG. 4 is an enlarged section of a modified form of feeding arrangement in which the coaxial lines are connected to balanced twin-lead input lines;

FIG. 5 depicts frequency — VSWR performance curves of an antenna embodying this invention and a comparable prior art antenna, the frequency scale being a ratio of signal frequency to the center frequency;

FIG. 6 shows a plot on a 50-ohm Smith Chart of the locus of normalized inherent impedance Zaa/50 for an antenna embodying this invention.

FIG. 7 is a perspective view of a cup-turnstile antenna embodying the invention; and

FIG. 8 is an enlarged plan view of the central portion of the antenna of FIG. 7 showing the connections of the feed lines to the two pairs of dipoles.

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIGS. 1 and 2, an embodiment of the invention is shown as a cup-dipole assembly **10** comprising a conductive cup **11** with a bottom wall **12** and a cylindrical side wall **13**, and a dipole **15** disposed near the plane of the open end or aperture **16** of cup **11**, as shown. Dipole **15** consists of tubular monopole elements **15*a*** and **15*b*** supported at their inner ends on rigid pipes **18** and **19**, respectively, which extend parallel to the cup axis A from a point of connection to cup bottom wall **12**.

In accordance with this invention, monople elements **15*a*** and **15*b*** are energized by coaxial feed lines **21** and **22**, respectively, which are connected through a lumped-circuit impedance transformer **24** to an external standard coaxial input line **25** linking the antenna assembly to utilization apparatus R such as a receiver. Impedance transformer **24** is of the type having a pair of anti-phase outputs and is a commercially available component; this transformer serves to excite monopole elements **15*a*** and **15*b*** in the manner of a center-fed dipole and also transforms the average inherent impedance of the antenna from its relatively high value to the value of the characteristic impedance of coaxial input line **25**. For example, the average antenna impedance may be approximately 150 ohms and that of the coaxial input line **25** may be 50 ohms. In this case, for the reason described hereafter, the charcteristic impedance of each of coaxial lines **21** and **22** is preferably 75 ohms.

Feed lines **21** and **22** extend through and coaxially of pipes **18** and **19**, respectively, and have outer conductors **21*a***, **22*a*** and inner conductors **21*b***, **22*b***; see FIG. **3**. Outer conductors **21*a*** and **22*a*** are electrically connectd to pipes **18** and **19**, respectively. Thus, monopole elements **15a** and **15b** are electrically connected to the outer conductors **21*a*** and **22*a***, respectively, of the coaxial feed lines. Center conductors **21*b*** and **22*b*** extend beyond the upper ends of the outer conductors and pipes as shown in FIG. **3** and are electrically connected together as indicated at **26**.

An alternate feed line arrangement is shown in FIG. **4** in which coaxial line center conductors **21b** and **22b** are directly connected to balanced twin input feed lines **27** and **28**, respectively, thus eliminating the need for impedance transformer **24**. Outer conductors **21*a*** and **22*b*** are electrically connected to pipes **18** and **19**, respectively, and to cup bottom wall **12** as described above.

Pipes **18** and **19** are electrically interconnected by a shorting plate **29** which is spaced a distance P from the dipole axis B as shown in FIG. **2**. The distance P is determined empirically in order to compensate the adverse effects of a mutual coupling between currents on the surfaces of the cup and pipes as well as to make the average inherent impedance of the antenna a pure resistance as described in more detail hereinafter. The pipes may also be further mechanically coupled together adjacent the dipole by a dielectric plate **30**.

FIG. **5** shows a measured input VSWR performance curve **31** of the cup-dipole antenna illustrated in FIG. **1**. Also shown in FIG. **5** is a measured input VSWR performance curve **32** of a prior cup-dipole antenna believed to possess the broadest bandwidth of comparable prior art antennas. The improvement in bandwidth resulting from the practice of the invention is evident from a comparison of these performance curves.

An explanation of the substantially improved VSWR performance or bandwidth of the antenna embodying this invention is facilitated by reference to FIG. **6** and consideration of the inherent impedance, Z_a, defined as the impedance measured directly at the dipole terminals of a cup-dipole antenna. The average value, Z_{aa}, of this impedance over a broad frequency is inherently high compared to the characteristic impedance of the most often used type of transmission line, i.e., 50-ohm coaxial line. FIG. **6** illustrates this fact with a plot **33** of the locus of inherent impedance Z_a on a 50-ohm Smith Chart. Note that the inherent impedance corresponding to Z_a (f_c) is $Z_a = 6 \times 50 = 300$ ohms. The average inherent impedance Z_{aa} corresponds approximately to the center of the nearly circular impedance locus, i.e., for the antenna of FIG. **1** having the design parameters herewith described, $Z_{aa} = R_{aa} = 3 \times 50 = 150$ ohms. Making Z_{aa} a pure resistance is achieved by setting shorting plate **29** at a corresponding optimum distance P from the dipole, that is, $Z_{aa} = R_{aa}$ a proper selection of the distance P. The condition $Z_{aa} = R_{aa}$ is important in the practice of this invention.

Feeding the dipole(s) in the manner provided by this invention permits the inherent impedance Z_a to be shared in equal portions by each of coaxial lines **21** and **22**. Thus, selecting (1) the characteristic impedance of each of these coaxial lines to equal $R_{aa}/2$ and (2) an impedance-transformation-ratio equal to R_{aa}/Z_o, where Z_o is the characteristic impedance of the input coaxial line **25**, results in achievement of the following highly desirable properties:

a. The R_{aa} (at the dipole terminals) transforms to Z_o at the input terminal.

b. The nearly circular locus of inherent impedance approximately centered at R_{aa} at the dipole terminals, upon selecting the distance P optimumly, transforms to a nearly circular impedance locus with center at Z_o at the input terminal; hence, reasonably small antenna VSWR characteristics over a broad and extended frequency band are achievable in the antenna embodying the invention. Achieving the foregoing desirable results (a) and (b) also requires that the outer conductors of coaxial lines **21** and **22** be connected to r.f. ground at the location of impedance transformer **24**. This, in turn, requires that such transformer be the electrical equivalent of a lumped-circuit transformer having a center-tapped secondary winding, with center tap connected to the outer conductors of coaxial lines **21** and **22** and the ends of the secondary windings connected to the center conductors of the coaxial lines **21** and **22**, respectively.

The same improved performance described by paragraph (b), above, is obtained in the case of a system employing a twin-lead input transmission line as shown in FIG. **4** by simple selection of the characteristic impedance of the twin-lead line to be equal to R_{aa}.

A cup-dipole antenna embodying this invention and having the following dimensions and characteristics was constructed and successfully operated:

Inside diameter of cup reflector 24.2 inches

Depth of cup 9.2 inches

Center-line of dipole to bottom flat-surface of cup 9.8 inches

Distance **P** between dipole and shorting plate 8.5 inches

Dipole diameter 1.0 inch

Dipole length 17.8 inches

Characteristic impedance of "two wire" line formed by pipes **18** and **19** 148 ohms

Diameter of each pipe 1.0 inch

Center-to-center spacing of pipes 1.8 inch

Characteristic impedance of each coaxial line **21,22** 75 ohms

Length of each coaxial line **21, 22** 21.0 inches

Impedance transformation ratio of tranformer **24** 3:1

The performance of the above-identified antenna in terms of bandwidth and voltage standing wave ratio (VSWR) is shown in FIG. **5** and is summarized in Table I:

TABLE I

VSWR	BANDWIDTH Freq. Range	Percent	Bandwidth expressed as ratio of high to frequencies
I Under 4.4:1	219.8 to 566.8 MHz	88.3	2.58:1
II Under 3.51:1	222.9 to 560.4 MHz	86.2	2.514:1
III Under 3.00:1	b **224.5** to 556.2 MHz	85.1	2.48:1

Another embodiment of the invention is shown in FIGS. **7** and **8** as a cup-turnstile antenna **32** comprising a conductive cup **33** similar to cup **11** and two crossed dipoles **35** and **36** with their respective axes at right angles to each other and disposed near the plane of the cup aperture. Dipoles **35** and **36** are constructed, supported and fed substantially identically as described above for dipole **15** and therefore like parts are indicated by the primes and double primes of like reference characters on the drawings. Thus monopole elements **35***a* and **35***b* of dipole **35** are mechanically and electrically connected to pipes **18'** and **19'**, respectively, through which coaxial lines **21'** and **22'** extend from impedance transformer **24'**. Similarly, monopole elements **36***a* and **36***b* of dipole **36** are displaced 90° from dipole **35** and are connected to pipes **18''** and **19''** through which coaxial feed lines **21''** and **22''** extend from transformer **24''**. The center conductors of the coaxial feed lines for the respective dipoles are electrically interconnected adjacent the cup aperture by crossed extensions **38** and **39** which are axially spaced from each other as shown and preferably are equal in length.

Dipoles **35** and **36** are connected to utilization apparatus (not shown) by an input coaxial line **40** through a 3 db quadrature hybrid coupler **41** having output ports **42** and **43** connected to feed lines **25'** and **25''** Decoupled input port **44** is connected to either a matched termination or to a second utilization apparatus. The radiation pattern applicable to (measured at) such second utilization apparatus is identical to that applicable to first utilization apparatus, except the screw-sense of the two circularly polarized radiation patterns are the opposite of one another. Shorting plate **29'** electrically interconnects the four pipes **18'**, **18''**, **19'** and **19''** and dielectric supporting plate **30'** connectd to the pipes adjacent the dipoles provides additional mechanical stability.

What is claimed is:

1. An antenna comprising

a conductive cup having a bottom wall and a side wall the end of said cup opposite the bottom wall being open and defining the cup aperture,

a dipole having two monopole elements disposed adjacent the plane of said aperture, a pair of spaced coaxial lines extending within said cup parallel to the cup axis, each of said coaxial lines having an outer conductor and an inner conductor,

said outer conductors being electrically conducted to the bottom wall of said cup and to the inner ends of said monopole elements, respectively,

means for connecting said coaxial lines to utilization apparatus, and

means for electrically interconnecting said inner conductors adjacent said monopole elements.

2. The antenna according to claim **1** with a shorting plate electrically connected to said outer conductors and located intermediate said dipole and said cup bottom wall.

3. The antenna according to claim **2** with a pair of conductive pipes connected to said bottom wall and extending within said cup parallel to the cup axis, said coaxial lines extending through said pipes, respectively, the outer conductor of each coaxial line being electrically connected to the associated pipe, said monopole elements being connected to pipes, respectively, said shorting plate being directly connected to said pipes.

4. The antenna according to claim **2** in which said utilization apparatus connecting means comprises a balanced transmission line directly electrically connected to the inner conductors, respectively, of said coaxial lines.

5. The antenna according to claim **2** in which said utilization apparatus connecting means comprises an impedance transformer and a coaxial input line between said utilization apparatus and the transformer, said transformer having two antiphase outputs connected to the inner conductors, respectively, of said pair of coaxial lines.

6. An antenna comprising

a conductive cup having a bottom wall and a side wall, the end of said cup opposite the bottom wall being open and defining the cup aperture,

a pair of dipoles disposed near the plane of said aperture with the dipole axes at right angles to each other, each of said dipoles having two monopole elements,

four rigid conductive pipes connected to said bottom wall and extending within the cup parallel to the cup axis, the inner ends of said monopole elements being connected to said pipes, respectively,

means for electrically interconnecting said pipes at a predetermined location between the aperture and bottom wall of the cup,

four coaxial lines extending through said pipes, respectively, each of said coaxial lines having an outer conductor electrically connected to the associated pipe and each having an inner conductor,

means for electrically interconnecting the inner conductors of each pair of coaxial lines associated with the monopole elements of each dipole adjacent said aperture, and

means for electrically energizing said coaxial lines.

7. The antenna according to claim **6** in which the inner conductors of one of said pairs of coaxial lines are electrically interconnected by one transverse extension, the inner conductors of the other of said pairs of coaxial lines being electrically interconnected by another transverse extension axially spaced from and equal in length to said one extension.

* * * * *