# United States Patent

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[73] Assignee **Sony Corporation**
**Tokyo, Japan**
[32] Priority **Feb. 8, 1968**
[33] **Japan**
[31] **43/7861**


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[54] **LOOP ANTENNA**
**1 Claim, 20 Drawing Figs.**


[52] **U.S. Cl.** ..... **343/741,** 343/869
[51] **Int. Cl.** ..... **H01q 7/00**
[50] **Field of Search** ..... 343/741-
-4,866-871, 732, 855



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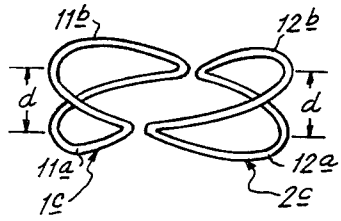
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**ABSTRACT:** In a directional loop antenna, particularly for television receivers, in which a pair of arcuate conductive members are mounted in opposed relation with their concave sides facing each other to define a loop, a dummy load is connected between two of the adjacent ends of the conductive members and output terminals are connected to the opposite adjacent ends, the conductive members are formed with relatively narrow end portions and relatively wide middle portions to increase the frequency band width and gain of the antenna.

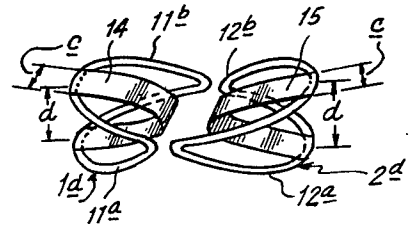



FIG. 1.

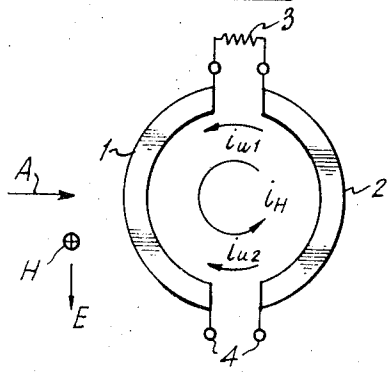



FIG. 2.

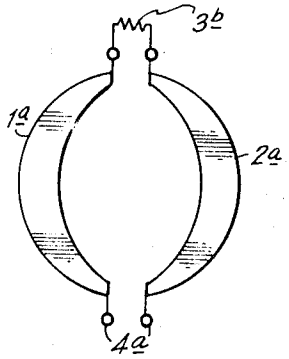
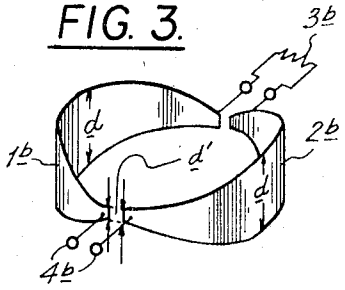



FIG. 3.



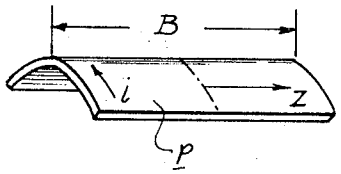




FIG. 6.

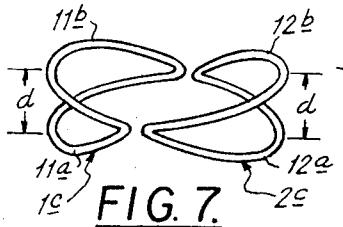



FIG. 7.

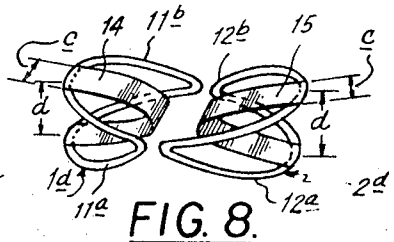
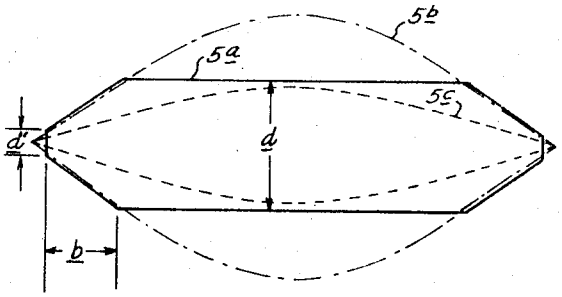



FIG. 8.

FIG. 5.



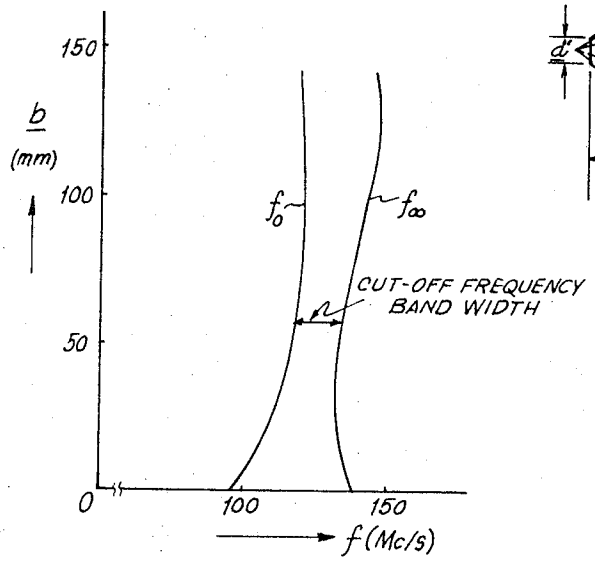




FIG. 4.

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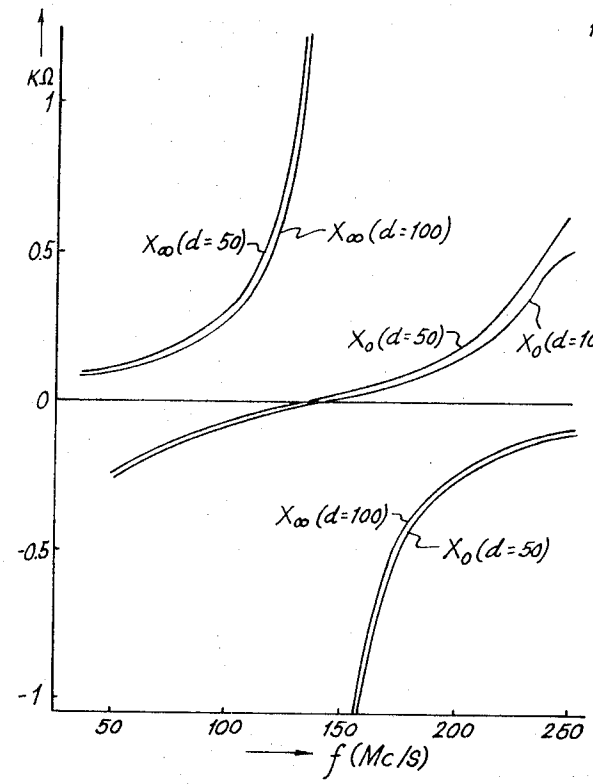



FIG. 9A.

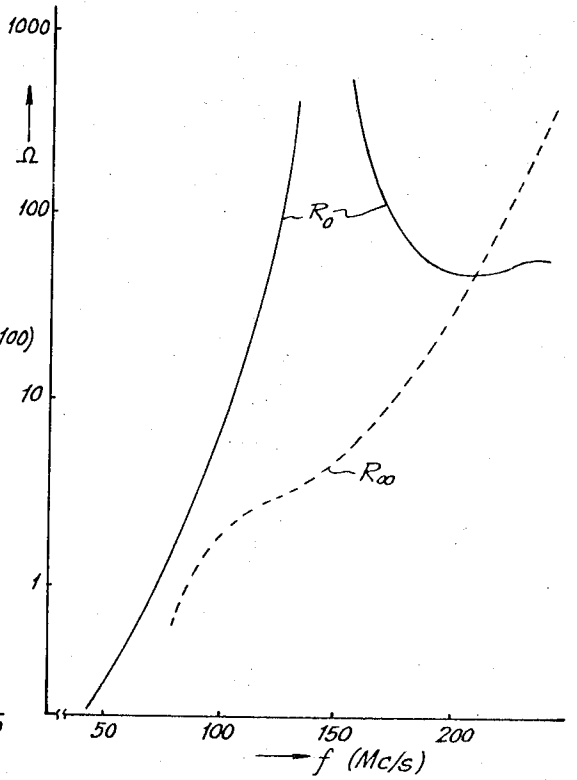



FIG. 9B.

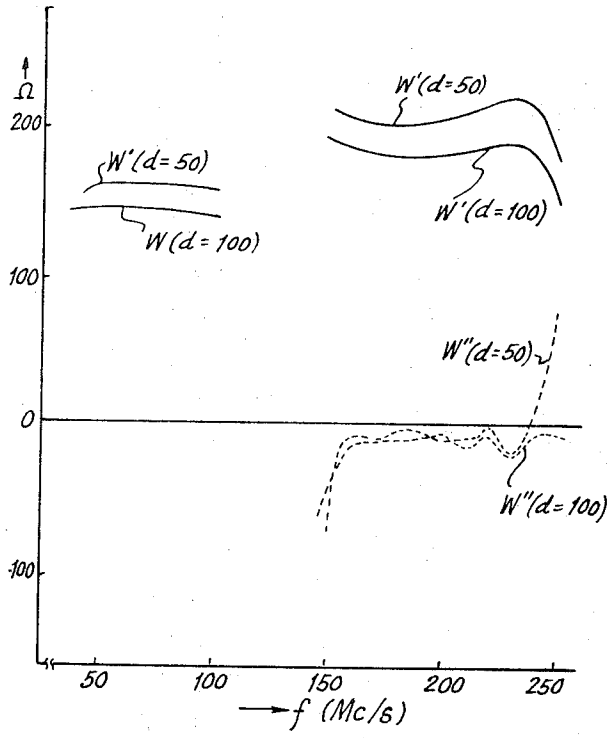



FIG. 10.

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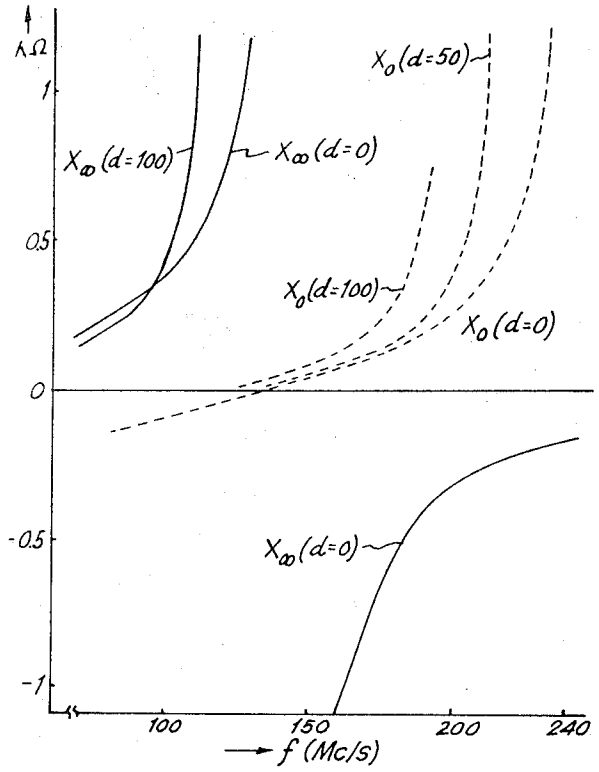



FIG. 11.

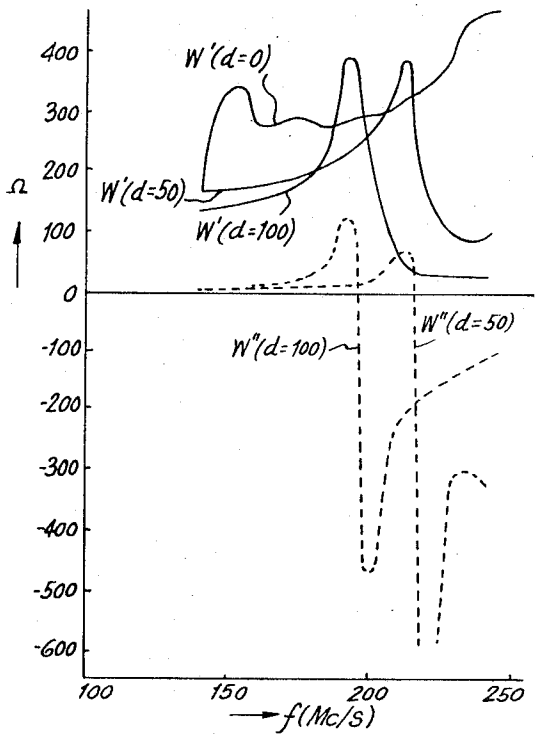



FIG. 13.

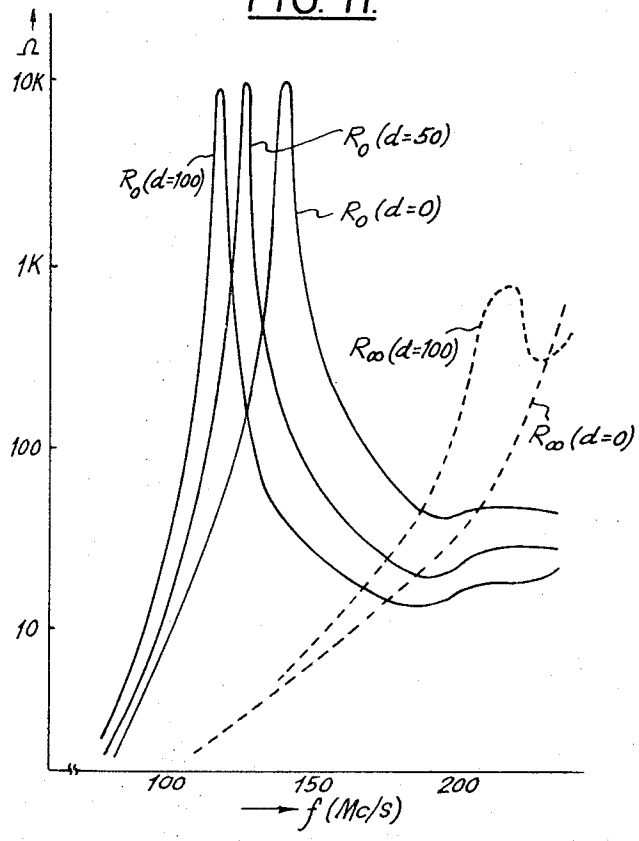



FIG. 12.

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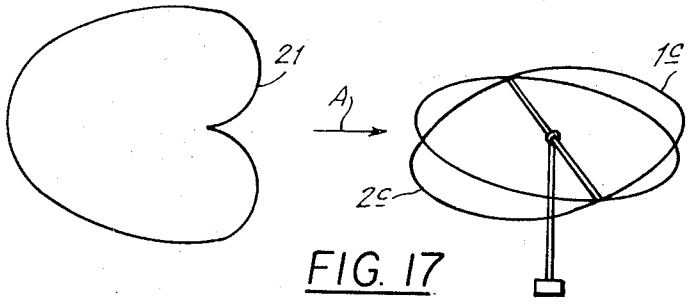



FIG. 17

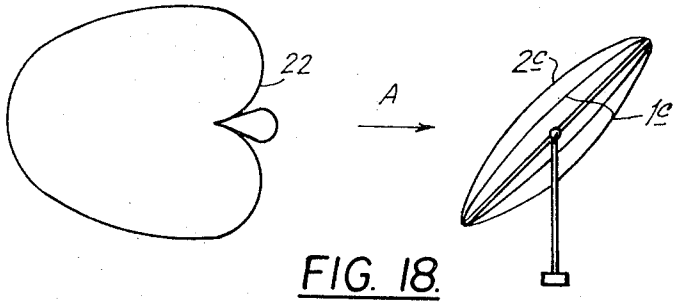



FIG. 18

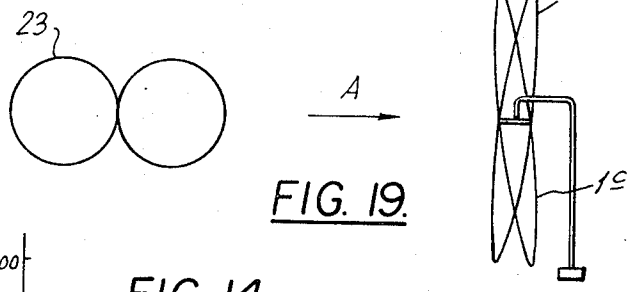



FIG. 19

FIG. 14

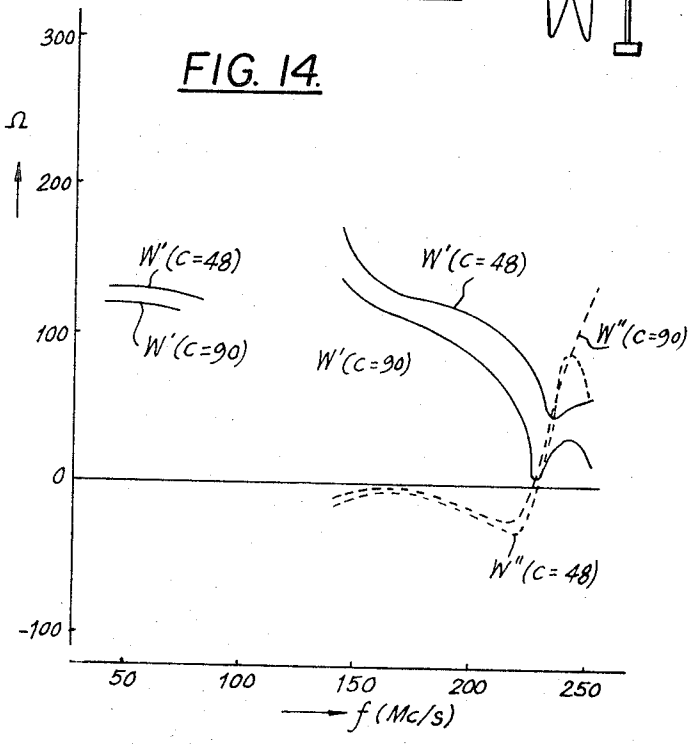



FIG. 15

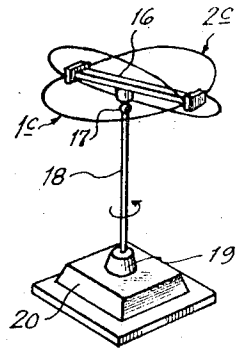
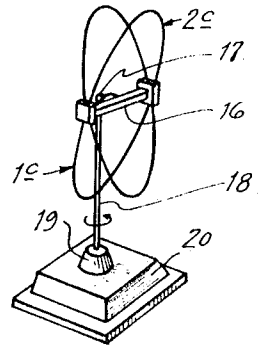



FIG. 16




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# LOOP ANTENNA

This invention relates generally to directional antennas suitable for use as the antennas of television receivers, and more particularly is directed to improvements in directional loop antennas.

If a four-terminal circuit is considered as an antenna, the image impedance of such circuit consists of an imaginary part indicating that the antenna has a wide frequency band in which a sharply decreased gain is encountered and, therefore, there is a deterioration in the directivity of the antenna and also an extremely reduced impedance for a fairly wide range of frequencies so that such four-terminal circuit is not usable as an actual antenna. In the following description, the frequency bandwidth within which the sharply decreased gain of an antenna is encountered will be referred to as the "cutoff frequency bandwidth." If the image impedance of the antenna consists of a real part and an imaginary part, the cutoff frequency band width will extend over those frequencies at which the imaginary part of the image impedance is greater than the real part thereof.

It has been proposed to provide a loop antenna which comprises a pair of substantially semicircular, elongated metal plates of uniform width mounted in opposing relation with their ends adjacent each other to define a loop having a diameter very substantially less than the transmitted wavelength, for example, one fifth of such wavelength, in order to obtain a directional characteristic of the cardioid type. In such previously proposed loop antenna, the cutoff frequency bandwidth is, nevertheless undesirably wide.

Accordingly, it is an object of this invention to provide a loop antenna, particularly suited for use with television receivers, and in which the cutoff frequency bandwidth is substantially reduced so as to have a wide frequency band and high gain.

Another object is to provide a loop antenna of small size having the foregoing characteristics.

A further object is to provide a loop antenna, as aforesaid, having a unidirectional characteristic and avoids the reception of ghost images.

In accordance with an aspect of this invention, a loop antenna is provided in which a pair of arcuate, preferably substantially semicircular conductive members are mounted in opposed relation with their concave sides facing each other to define a loop, a dummy load is connected between two of the adjacent ends of the conductive members, output terminals are connected to the other adjacent ends of the conductive members, and the conductive members have relatively narrow, preferably tapering end portions and relatively wide middle portions so that the characteristic impedance of the antenna is substantially uniform, whereby to reduce the cutoff frequency band width and thus increase the frequency bandwidth and gain of the antenna.

The above, and other objects, features and advantages of the invention, will be apparent in the following detailed description of illustrative embodiments which is to be read in connection with the accompanying drawings, wherein:

FIG. 1 is a diagrammatic view illustrating a loop antenna as previously proposed;

FIG. 2 is a view similar to that of FIG. 1, but showing a first embodiment according to this invention;

FIG. 3 is a diagrammatic perspective view showing another embodiment of this invention;

FIG. 4 is a graph showing the relation between the cutoff frequency bandwidth of a loop antenna as shown in FIG. 3 and the length of the tapered ends of its conductive members;

FIG. 5 is a diagrammatic view showing shapes of conductive members for loop antennas according to this invention, as developed on a flat plane;

FIG 6 is a diagrammatic perspective view referred to explaining the current distribution in an arcuate conductive member;

FIGS. 7 and 8 are diagrammatic perspective views showing the conductive members for two further embodiments of this invention;



FIGS. 9A and 9B are graphs respectively showing the reactance and resistance components of the dipole and loop impedances of an antenna of the type shown on FIG. 7;

FIG. 10 is a graph showing the image impedance characteristic of the loop antenna shown on FIG. 7;

FIGS. 11, 12 and 13 are graphs similar to FIGS. 9A, 9B and 10, respectively, for an antenna similar to that of FIG. 7, but in which, contrary to this invention, the width of each conductive member does not decrease from a maximum at the middle toward minimums at the ends;

FIG. 14 is a graph similar to that of FIG. 10, but for a loop antenna according to the embodiment of this invention shown on FIG. 8;

FIGS. 15 and 16 are perspective views showing a loop antenna according to this invention particularly adapted for use with portable television receivers and which is shown in two different positions; and

FIGS. 17, 18 and 19 are schematic views illustrating the directional characteristics of the antenna of FIG. 7 for waves arriving in three different directions in relation to the antenna.

Referring to the drawings in detail, and initially to FIG. 1, it will be seen that a previously proposed loop antenna, as there illustrated, comprises a pair of substantially semicircular conductive members 1 and 2 arranged in opposing relation with their concave sides facing each other, a dummy load 3 connected between two of the adjacent ends of members 1 and 2, and output terminals 4 connected to the other adjacent ends of the conductive members. The conductive members 1 and 2 of such known loop antenna are of uniform width along their lengths both in the direction of their curvature and in directions perpendicular thereto. In the case of a loop antenna of the above-described type, the cutoff frequency bandwidth is influenced by the following factors:

1. The types of wave modes, other than the TEM mode, arriving at the antenna;
2. The radiation load on the antenna; and
3. Variations in the characteristic impedance of the antenna.

With respect to factor (1) above influencing the cutoff frequency bandwidth, it will be seen that the various types of wave modes result in a discrepancy between the direction of the currents flowing in the antenna and the propagating directions of the waves arriving at the antenna. One of these waves is a horizontally polarized wave. When the antenna of FIG. 1 receives a horizontally polarized wave propagated in the plane of arcuate conductive members 1 and 2, for example, as indicated by the arrow A, electrical inductive currents $i_{u_1}$ and $i_{u_2}$ and a magnetic inductive current $i_H$ are generated in conductive members 1 and 2 by a magnetic field H and an electrical field E, respectively, of the wave. A figure-eight directive characteristic is obtained from the electrical inductive currents $i_{u_1}$ and $i_{u_2}$ and a circular characteristic is obtained from the magnetic inductive current $i_H$, and such figure-eight and circular characteristics combine to provide the desired cardioid characteristic. Thus, although the cutoff frequency bandwidth could be narrowed by suppressing the horizontally polarized wave, this would undesirably remove the cardioid characteristic of the antenna.

The radiation load mentioned in (2) above, is caused by an increase in the resistance component of the antenna impedance which, in turn, depends upon wave frequency. Although the cutoff frequency bandwidth can be narrowed by decreasing the radiation load, this is achieved at the expense of a deterioration of the antenna function.

With respect to factor (3) mentioned above as influencing the cutoff frequency bandwidth, it should be noted that, in the case of a pair of parallel conductive members, the characteristic impedance $W$ is expressed as follows:

$$W = 276 \log_{10} \frac{2\rho}{r} \qquad (I)$$

where $2\rho$ is the lateral distance between the conductive members, and $2r$ is the width of each member. Hence, for the loop antenna shown on FIG. 1, where the lateral distance $2\rho$

between members 1 and 2 varies from one end to the other end thereof, and where the width 2*r* of each of members 1 and 2 is constant, the characteristic impedance *W* of the loop antenna varies and thereby contributes to a relatively wide cutoff frequency bandwidth for the antenna.

Thus, in accordance with the present invention, the cutoff frequency bandwidth of a loop antenna is narrowed by providing the same with a substantially uniform characteristic impedance, that is, by influencing the above-mentioned factor (3). As is apparent from equation (I) above, the substantially uniform characteristic impedance is conveniently achieved by varying the width of each of the conductive members in accordance with the varying distance between the conductive members. More specifically, in the loop antenna having arcuate conductive members arranged in opposing relation with their concave sides facing each other so that the maximum distance between the conductive members is at the middle of the latter and such distance decreases progressively from the middle of the conductive members to the ends thereof, a substantially uniform characteristic impedance is achieved by providing the conductive members with relatively wide middle portions and with relatively narrowed end portions.

Referring now to FIG. 2, it will be seen that, in an embodiment of this invention as there shown, the arcuate conductive members 1*a* and 2*a* have relatively wide middle portions and relatively narrow end portions, with the dummy load 3*a* being connected between two of the adjacent ends of members 1*a* and 2*a* and the output terminals 4*a* being connected to the other adjacent ends of the conductive members. In the embodiment of FIG. 2, the variations in the width of each of members 1*a* and 2*a* are in directions that are generally radial with respect to the curvature thereof, that is, each conductive member may be formed of a conductive plate lying in a flat plane and having arcuate inner and outer edges with different centers of curvature to establish the curvature of the plate in such flat plane and the width variations thereof. The embodiment of FIG. 2, however, tends to reduce the area enclosed by the loop, and hence tends to reduce the characteristic of the antenna.

Accordingly, as shown on FIG. 3, it is preferred that the widths of conductive members 1*b* and 2*b* be varied between their middle and end portions in directions that are perpendicular to the direction of curvature thereof. Thus, in the embodiment of FIG. 3, the conductive members 1*b* and 2*b* may be formed of metal plates that are arcuately bowed out of flat planes so as to be substantially of semicircular shape and that have varying widths, in directions parallel to the axis of curvature, between maximum widths *d* at the middle portions of the curved plates and minimum widths *d'* at the ends of tapered end portions of the plates. As before, the dummy load 3*b* is connected between two of the adjacent ends of plates 1*b* and 2*b*, and the output terminals 4*b* are connected to the other two adjacent ends of the plates.

In a typical example of a loop antenna according to the embodiment of the invention shown on FIG. 3, the diameter across the loop, that is, the maximum diametrical distance between the middle portions of conductive members 1*b* and 2*b* is 300 mm., the width *d* at the relatively wide middle portion of each conductive member is 114 mm., the width *d'* at the ends of each conductive member is 20 mm., and the end portions of each plate or conductive member taper from the maximum width *d* to the minimum width *d'* over a length *b*, for example, as shown on FIG. 5.

FIG. 4 illustrates the variations in the cutoff frequency bandwidth of the above dimensional example that result from changes in the value of *b*, that is, in the length of the tapered end portions. On FIG. 4, the curve $f_o$ is for a first resonance frequency of a dipole impedance $Z_o$, that is, the impedance of the antenna with an infinite dummy load, and the curve $f_\infty$ is for a first antiresonance frequency of a loop impedance $Z_\infty$, that is the impedance of the antenna with a zero dummy load. It will be appreciated that, for each value of *b*, the frequencies between curves $f_o$ and $f_\infty$ constitute the cutoff frequency bandwidth of the antenna. Thus, if *b* is zero, that is, if conductive members 1*b* and 2*b* have the width *d* (114 mm.) uniformly along their entire lengths, the cutoff frequency bandwidth of the antenna extends from about 95 Mc/s. to about 140 Mc/s., which represents a bandwidth of about 45 Mc/s. It will further be seen that, for values of *b* between 30 and 90 mm., the cutoff frequency bandwidth is reduced in accordance with this invention to about 20 Mc/s., and that the minimum cutoff frequency bandwidth is achieved when *b* has a value of about 60 mm.

The characteristic impedance of the loop antenna according to the above dimensional example, and having the tapered end portions each extending over the length *b* of 60 mm., is about 200 ohms. Of course, where the conductive members of the loop antenna according to this invention have middle portions with parallel edges and the width of each of such conductive members varies only at end portions each extending over the length *b*, for example, as indicated at 5*a* on FIG. 5 where the conductive member is shown developed in a flat plane, the characteristic impedance is not exactly uniform, but only approximates the uniform condition. Shapes for the conductive members that would result in exactly uniform characteristic impedances are shown in dot-dash lines and in dotted lines at 5*b* and 5*c*, respectively. In accordance with the foregoing equation (I) it will be appreciated that the shapes 5*b* and 5*c* have edges in the form of sine curves. In order to obtain the minimum cutoff frequency bandwidth for a loop antenna having its conductive members in accordance with the shape indicated at 5*a* on FIG. 5, it is desirable that the tapered end portions of each conductive member extending over the length *b* have edges corresponding to respective portions of a sine curve, for example, corresponding to respective portions of the since curve defining the edges of shape 5*b*, as shown. By way of comparison, it may be noted that loop antennas having conductive members with shapes as indicated at 5*b* and 5*c* will have characteristic impedances of 200 and 300 ohms, respectively. Thus, the shape indicated at 5*a* achieves substantially the same characteristic impedance as the shape indicated at 5*b*, but is formed from less material and has a smaller maximum width *d* so as to minimize the overall dimensions of the loop antenna.

In the embodiments of the invention illustrated by FIGS. 2 and 3, the conductive members have been constituted by solid metal plates that are suitably shaped. However, in the case of a curved plate P (FIG. 6) having an axial dimension B, the distribution of circumferential currents *i* at various distances *Z* from the circumferential median of the plate P is given by the equation:

$$i_z = C\left[e^{\gamma\left(z-\frac{B}{2}\right)} + e^{\lambda\left(z+\frac{B}{2}\right)}\right] \qquad \text{(II)}$$

in which C is a constant. From equation (II) it will be apparent that the currents through the middle portion of plate P between the opposite circumferential edges thereof (that is, when $Z \cong 0$) are so small that the middle portion of such plate can be omitted, or provided with an opening, without substantially altering the conditions for current flow through plate P.

Thus, in loop antennas according to this invention, each of the arcuate conductive members may have an opening extending therealong and being of a shape that is similar to that of the perimeter of the conductive member. For example, as shown on FIG. 7, the conductive members 1*c* and 2*c* of a loop antenna according to this invention may be conveniently formed of wirelike elements 11*a* and 11*b* *and wirelike elements* 12*a* and 12*b*, respectively, which have circular or other cross sections and which are joined to each other at the ends of the respective conductive members 1*c* and 2*c* and diverge therefrom so as to have the maximum spacing *d* at the middle portions of the conductive members. It will be apparent that the conductive members 1*c* and 2*c* of FIG. 7 are relatively lighter than the conductive members 1*b* and 2*b* of FIG. 3, and further have the

advantages of a more attractive appearance and a lower production cost.

In suitable dimensional examples of the embodiment of the invention illustrated by FIG. 7, the wirelike elements **11***a*, **11***b* and **12***a*, **12***b* have diameters of 6 mm., the loop diameter, that is, the diametrical distance between the middle portions of members **1***c* and **2***c*, is 300 mm., and the maximum width *d* at the middle portion of each conductive member is 50 mm. or 100 mm. FIG. **9A** shows the reactance component $X_0$ of the dipole impedance $\mathcal{Z}_0$ and the reactance component $X_\infty$ of the loop impedance $\mathcal{Z}_\infty$ for each of the two values of *d*; and FIG. **9B** shows the resistance component $R_0$ of the dipole impedance $\mathcal{Z}_0$ and the resistance component $R_\infty$ of the loop impedance $\mathcal{Z}_\infty$ for the two values of *d* which do not influence the resistance components. Further, FIG. **10** shows the real part $W'$ and the imaginary part $W''$ of the image impedance $\overline{W}=W'+W''$ for the loop antennas having $d=50$ mm. and $d=100$ mm., respectively.

Of course, in the embodiment of FIG. **7**, the characteristics of which are shown by FIGS. **9A**, **9B** and **10**, the conductive members **1***c* and **2***c* have widths that decrease from the maximum values *d* at the middle portions to minimum values at the opposite ends. In order to appreciate the differences between the characteristics of such loop antennas according to this invention, and of similar loop antennas, but in which the widths of the arcuate conductive members are not thus varied, reference may be had to FIGS. **11**, **12** and **13**. The suitably labeled curves of FIGS. **11**, **12** and **13** all refer to loop antennas in which the conductive members are each formed of either single wirelike elements ($d=o$) or of two parallel wirelike elements spaced apart by the uniform distances $d=50$ mm. or $d=100$mm. and joined at their ends by wirelike elements extending therebetween. FIG. **11** shows the reactance components $X_0$ and $X_\infty$ of the dipole impedance and loop impedance for the various values of uniform *d*; FIG. **12** shows the resistance components $R_0$ and $R_\infty$ for the various values of uniform *d* which, in this case, affect the values of the resistance components because of the varying lengths of the wirelike elements which join the ends of the parallel elements; and FIG. **13** shows the real and imaginary parts $W'$ and $W''$ of the image impedances for the various values of uniform *W*.

Referring now to FIG. **8**, it will be seen that, in another embodiment of this invention, the maximum width *d* at the middle of the conductive members **1***d* and **2***d* constituted by wirelike elements **11***a*, **11***b* and **12***a*, **12***b* may be reduced by providing auxiliary conductors **14** and **15** in the form of U-shaped, sheet metal elements joined at their ends to the middle portions of wirelike elements **11***a* and **11***b* and to the middle portions of wirelike elements **12***a* and **12***b*, respectively, and directed inwardly from such wirelike elements toward the center of the loop defined thereby. On FIG. **14**, there are shown the real and imaginary part $W'$ and $W''$ of the image impedance of a loop antenna in accordance with the embodiment of FIG. **8**, and in which the dimensions C of the auxiliary conductors **14** and **15**, that is, the dimensions along the respective members **1***d* and **2***d*, are either 48 mm. or 90 mm. As will be apparent from FIG. **14**, loop antennas of the type shown by FIG. **8** are particularly suited for use in connection with television receivers, because such antennas have image impedances that are substantially the same for all standard television channels.

Referring now to FIGS. **15** and **16**, it will be seen that, in a practical embodiment of this invention particularly suited for use with portable television receivers, the loop antenna is constituted by a pair of conductive members **1***c* and **2***c* of the type described above in connection with FIG. **7**, and which have their adjacent ends joined to each other by way of an elongated, insulated holder **16** which extends diametrically across the loop. The holder **16** is mounted, at its middle, by way of a universal joint **17**, on the upper end of a rod **18** which, at its lower end, is rotatably mounted, as at **19**, on a base **20** by which the loop antenna may be supported on a table or other horizontal surface. By reason of the universal joint **17** and rotatable mounting of rod **18**, the loop antenna constituted by conductive members **1***c* and **2***c* is rotatable about three orthogonally related axes so as to be positionable for best receiving television waves arriving in any direction.

As shown on FIG. **17**, when the arriving wave A is generally in the plane of the antenna loop, a cardioid directivity characteristic **21** is obtained. However, when the arriving wave A is at an acute angle to the plane of the antenna loop, the directivity pattern is a shown at **22** on FIG. **18**, and a figure-eight directivity characteristic **23** results when the arriving wave A is substantially perpendicular to the plane of the antenna loop, as shown on FIG. **19**.

Although illustrative embodiments of this invention have been described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments and that various changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the invention.

We claim:

**1**. A loop antenna comprising a pair of conductive members, each of said conductive members being arcuate and including a pair of elongated arcuate wirelike elements joined together at the opposite end portions of the respective conductive member and diverging from said end portions to the middle portion of the respective conductive member to vary the width of the latter in directions that are perpendicular to the direction of curvature thereof, means mounting said conductive members in opposed relationship with their concave sides facing toward each other to cooperate in defining a loop, each of said conductive members further including a generally U-shaped, sheet metal element having its ends joined to said wirelike elements of the respective arcuate conductive member adjacent said middle portion of the latter and directed inwardly from said wirelike elements toward the center of said loop, a dummy load connected between one end of one of said conductive members and the adjacent one end of the other of said members, and output means connected to the other ends of said conductive members.