March 21, 1950 A. ALFORD 2,501,430

SHORT WAVE ANTENNA

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Fig. 1.

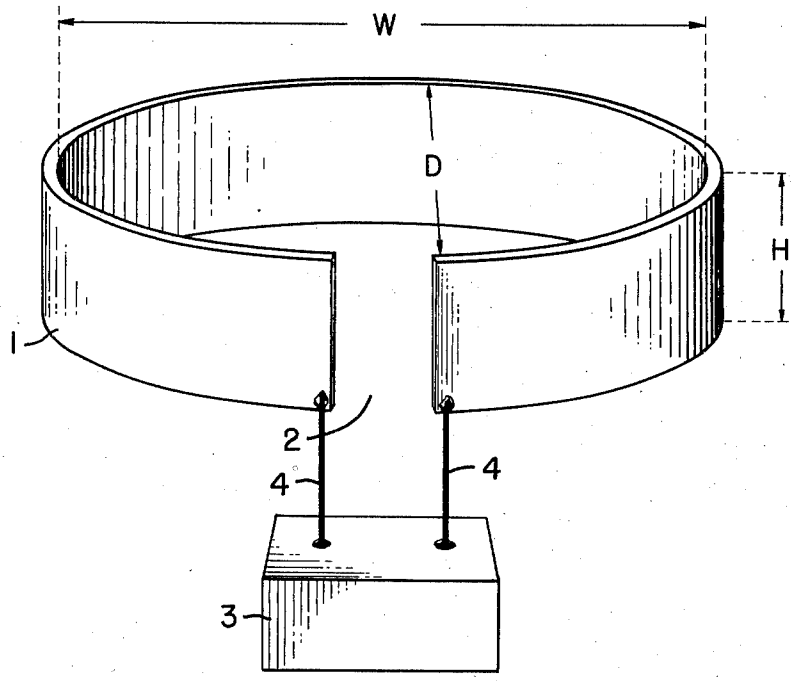


Fig. 2.

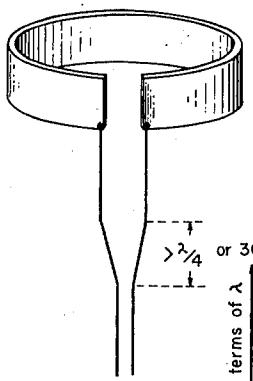


Fig. 9.

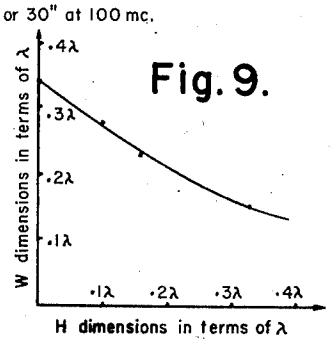
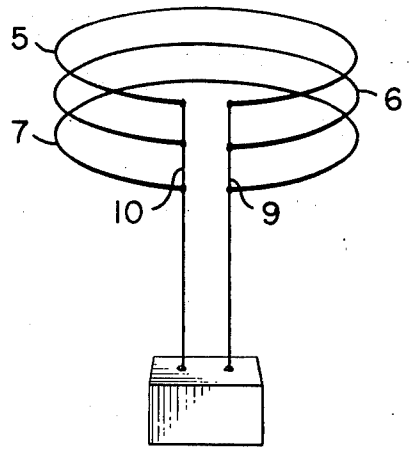


Fig. 3.



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Fig. 4.

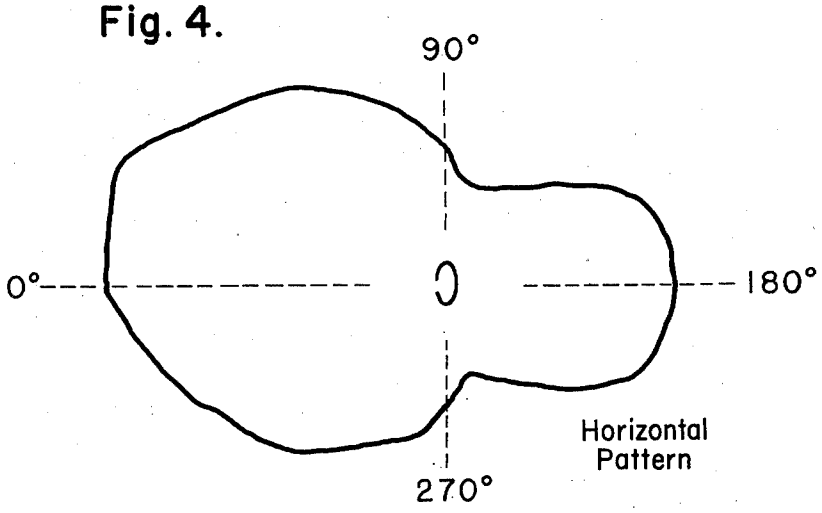
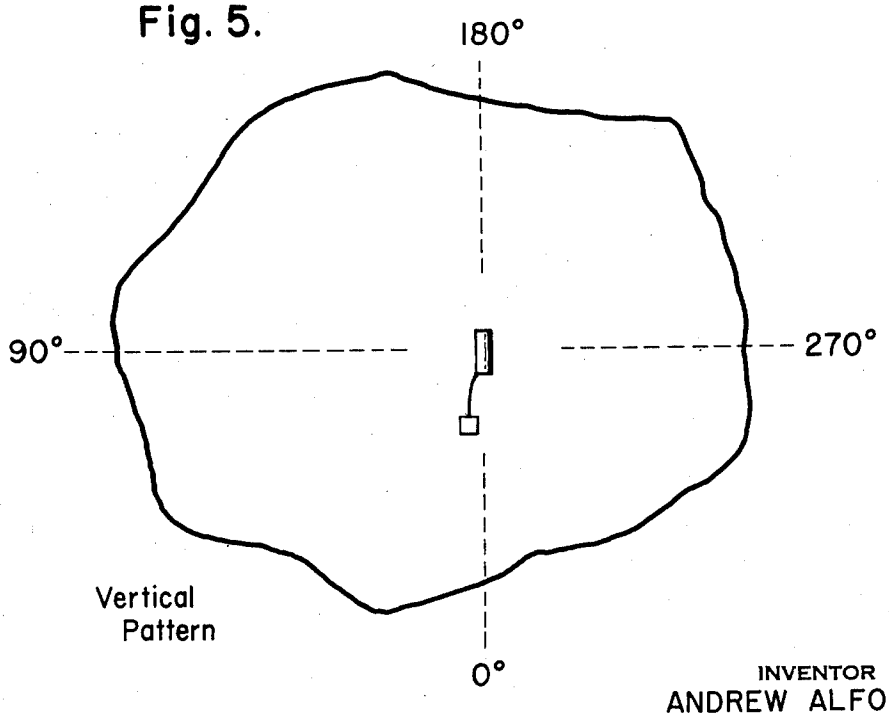


Fig. 5.



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Fig. 6.

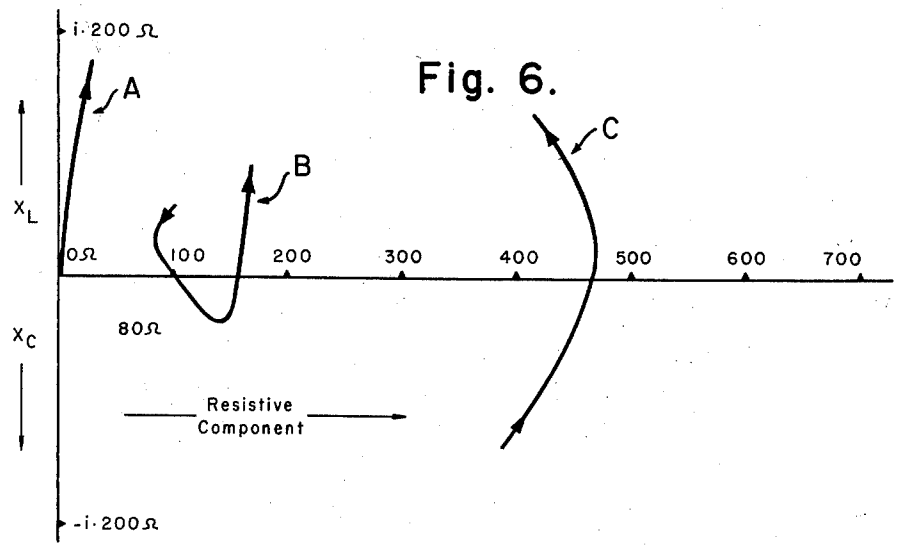


Fig. 7.

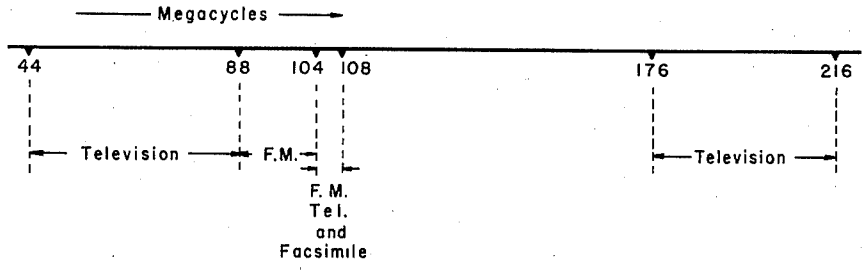
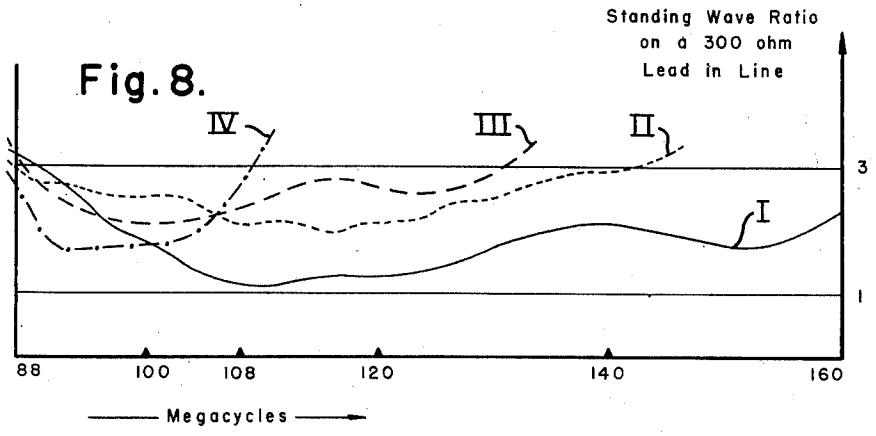


Fig. 8.



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Patented Mar. 21, 1950 2,501,430

UNITED STATES PATENT OFFICE

2,501,430

SHORT-WAVE ANTENNA

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Application June 22, 1946, Serial No. 678,581

4 Claims. (Cl. 250—33)

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This invention relates to new and useful improvements in antennas for operating on a broad band of horizontally polarized high frequency waves.

In the art of FM and television receiving, a number of antenna requirements remain unsatisfied. Generally speaking, it is desirable that such antennas should not have pronounced horizontal directivity. One reason for this is that broadcast stations are not necessarily grouped together and that, therefore, signals will not reach receivers from just one or two directions. Even where it might seem apparent that signals should be coming from a few directions, field strength tests might prove otherwise, because some signals arrive indirectly after reflection. It is not at all practical to expect that the purchaser of a home receiver will pay for an actual survey so that he can use a directive antenna. Moreover, the average radio shop technician is not prepared to maintain such an antenna in its original optimum operating condition or to modify it to pick up signals from new transmitting stations which may come into being within the range of this receiver.

Horizontally polarized half-wave dipoles have been commonly used for FM and television home receivers. Such a dipole has maximum horizontal directivity in opposite directions along a line which is at right angles to it and passes through its center point. There are nulls in its horizontal radiation patterns in both directions along its main axis. Even strong signals are not picked up by a dipole whose axis points at the station sending them.

Dipoles are objectionable as mechanical structures, since they are large, unwieldy, unsightly, and fragile. The FM frequency band extends from 88 mc. to 108 mc. A half-wave dipole designed for a midfrequency of about 100 mc. would be about five feet long. Such an antenna is both large and unwieldy and, when installed on the roof of a house, is unattractive. Moreover, it is composed of two separate metallic quarter wave length arms which are mechanically held together by dielectric supporting means. Usually insulating materials are more fragile than metal and preferably should not be used where bending stresses occur, such as the stresses at the center of the dipole.

An ordinary dipole is a tuned element of relatively high Q and, therefore, can operate efficiently only over a limited frequency band. Both FM and television broadcasts, however, occupy broad bands in the frequency spectrum.

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Though a horizontal dipole does have desired upward and downward nulls in its vertical patterns, its main lobes, in those patterns, since they are substantially circular, are too broad. As a result the gain offered by a dipole to signals coming from the horizon is not very much greater than the gain offered by it to many signals coming from below the horizon. There are components of both automobile ignition noise and household appliance noise which fall within the frequency bands of FM and television. Interference of this kind which is strong enough to matter usually comes from nearby and approaches rooftop antennas from directions appreciably below the horizon. Other interference like it may be generated at distance points near the horizon but is attenuated markedly long before it reaches the antenna. Thus interference which might be strong enough to spoil reception can be eliminated by the use of a receiving antenna which is directive toward the horizon. Such an antenna is also beneficial for the increased antenna gain it offers. An FM receiver, due to the action of its limiter, can discriminate against amplitude modulated waves and thus can eliminate much noise and static ordinarily transmitted on this kind of wave. But, frequency modulated signals entering the receiver must be strong enough for the limiter to function. The IF gain of inexpensive receivers is often quite low and, therefore, their limiters will not operate unless the input signals are strong. It is particularly for such receivers that high antenna gain is important. However, an inexpensive FM receiver will cease to be inexpensive if it requires a costly antenna to over come its shortcomings. Therefore, it is essential that the desired high gain antenna must be of simple construction; must be cheap to build; and must use a simple and inexpensive lead-in line.

It is obvious, in the light of the foregoing, that a much improved FM and/or television receiving antenna is needed. It is desirable that the improved antenna should be horizontally polarized in order to favor FM and television waves, which are horizontally polarized, and to reject all components of random interference waves which may be vertically polarized (automobile ignition noise actually has a preponderance of vertically polarized components). It is also desirable that the improved antenna should match an inexpensive transmission line without elaborate matching devices; that it employ a minimum of dielectric material which is structurally essential; that it be small and compact; that it be substantially non-

directive in horizontal planes; that it offer appreciable antenna gain; that it have directivity toward the hoizon in vertical planes; and that it have a broad frequency pass band.

The objects of this invention are to provide an antenna which is improved so as to have the features described above.

Other objects, features and advantages will be apparent to those skilled in the art from the following description taken in connection with the drawings, in which:

Fig. 1 is an isometric representation of one embodiment of the invention;

Fig. 2 is an isometric representation of a second embodiment of the invention;

Fig. 3 is an isometric representation of a third embodiment of the invention;

Fig. 4 is a horizontal radiation pattern of an antenna as in Fig. 1;

Fig. 5 is a vertical radiation pattern of an antenna as in Fig. 1;

Fig. 6 is an input impedance chart which shows changes in input impedances of an antenna according to this invention as the frequency of the energy feeding it is varied in three separate ranges in the frequency spectrum. The resistive component is plotted from left to right on a horizontal axis and the reactive components are plotted vertically;

Fig. 7 is a representation of a portion of the radio frequency spectrum showing the allocation of bands thereof to television, FM and facsimile broadcasts;

Fig. 8 is a chart showing four plots of standing wave ratios vs. frequencies with respect to standing waves on a 300-ohm lead-in line feeding, respectively, a simple loop antenna and three other antennas which were progressively modified according to principles underlying this invention; and

Fig. 9 is a curve showing corresponding values of the H and W dimensions appropriate for antennas as in Fig. 1.

I have discovered that an open-ended and longitudinally slotted "cylinder" which is distorted so that its transverse cross section is a flat ellipse, and which is of the proper size and proportions, will attain these objects and that it may be directly and simply connected to a receiver (or transmitter) by a transmission line whose conductors are connected across one end of the slot.

Fig. 1 shows that the radiating element 1 is an open-ended elliptical cylinder, one broad sidewall of which has a longitudinal gap 2 extending between its ends. A receiver (or transmitter) 3 is connected to cylinder 1 by a parallel transmission line 4—4. In the drawing, elliptical cylinder 1 is shown to have three dimensions W, D and H. W and D are, respectively, the long and short axes of the elliptical cross section of the cylinder while H is the height of the cylinder or the length of the edges of the gap extending along its wall.

The selection of these dimensions has a controlling influence upon attaining the various objects of this invention. The absolute dimensions of the elliptical cylinder as well as its relative proportions control its input impedance, its radiation patterns, and its band width.

There is a well known simple type of horizontally polarized thin loop antenna which has a perimeter of such length as to carry one complete standing wave loop of voltage having a single maximum opposite to the feed point and a single minimum at the feed point. Because of uneven current distribution along its radiating

element, it behaves in many respects like a dipole. Therefore, its horizontal radiation patterns are all shaped like a figure eight and this antenna is not omni-directional. This kind of a loop can be distorted into an oval flattened shape and it will still have the same horizontal directivity. The nulls in the figures eight can be made to disappear if the perimeter of the loop is decreased but, for this kind of loop, the input impedance then becomes prohibitive. Of course, auxiliary matching means can be used to adapt the antenna which has thus been decreased in size to a particular frequency but such a match remains valid only for frequencies close to that frequency and becomes very bad but a few percent away from it. Such compensation, in other words, results in a narrow pass band. Besides this, even the slightest distortion in the shape of the small compensated loop would seriously affect the adjustment and destroy the impedance match, even for that small pass band.

I have found a method whereby it is possible to reduce dimensions W and D of an antenna as in Fig. 1, thus making its elliptical perimeter small enough for the antenna to have desirable horizontal nondirectivity. Obviously, at the same time the antenna acquires desired physical compactness. This reduction of the perimeter is made possible by increasing dimension H. When H is increased the input impedance stays within a useable range and, besides, the band width remains adequate.

According to one feature of this invention the dimension W of the flattened cylinder, i. e. its greatest dimension, is less than one-quarter of a wave length. According to another feature of this invention, the length H of the flattened cylinder can also be of the order of one-quarter of a wave length, and usually will be less. Considering W to be the width of the cylinder; D to be its depth; and H its height; the ratio W/H, e. g. width-to-height, may vary from one-to-one to two-to-one, and the ratio W/D, e. g. width-to-depth, may vary from two-to-one to six-to-one. Antennas proportioned within those ranges and having a gap a small fraction of a wave length wide—.0125 λ was tried and found satisfactory—can be built to operate efficiently with inexpensive transmission lines in either of two convenient input impedance regions without elaborate matching devices.

Referring to Fig. 8, plot I therein shows that for an antenna, which may also be considered to be designated I, a satisfactory standing wave ratio, e. g. one and three, exists over the frequency band between 88 mc. and 160 mc. Antenna I was a simple thin loop of large perimeter, like the one described above, and had excessive horizontal directivity. Tests disclosed that when the perimeter of this thin loop antenna was reduced to modify its directivity the standing wave ratio became inordinately large in parts of this frequency band and that, accordingly, the antenna became a narrow band device requiring compensation to attain even a small operating range. The curve of antenna I after its perimeter was reduced is not shown.

Plot II of Fig. 8 is a curve, corresponding to curve I, for a loop antenna of somewhat reduced perimeter whose H dimension was increased by a predetermined amount. The modification in its perimeter, as expected, reduced its horizontal directivity while the change in dimension H preserved the input impedance for almost its complete pass band. This is shown in the

curve by the fact that the standing wave ratio remains satisfactory from about 88 mc. to about 148 mc.

Plots III and IV show the performance of antennas in which the modifications described above were carried progressively further. Antenna III is, in fact, the embodiment shown in Fig. 1.

Though the operating band widths of antennas III and IV have been materially reduced, they are adequate to cover the combined bands allocated to FM and FM television and facsimile, on the one hand, and to the upper television band shown in Fig. 7 on the other hand.

A single antenna of identical proportions in terms of λ but in which λ corresponds to the midfrequency, 196 mc. of the television band, 176 mc. to 216 mc., would have a band width of approximately 1.5 (ratio of highest to lowest frequency) without compensation whereas that television band has a width of only 1.2.

In the antennas modified as described above, i. e. the antennas related to plots II, III, and IV of Fig. 8, it was found that control over both their radiation patterns and their input impedances could be exercised by distorting and flattening them into an oval or elliptical shape. Therefore, these combined modifications and design principles permit construction of an antenna having the necessary polarizations; the desired directivity; and an appropriate input impedance which remains relatively constant throughout an adequate pass band.

Antennas proportioned and designed according to these instructions have been found to receive satisfactorily frequency modulated signals through the band from 88 mc. to 108 mc. and also television signals in the band from 176 mc. to 216 mc. Antennas for receiving on these two bands have slightly different dimensions but when proportioned with respect to the wave lengths corresponding to the midfrequencies of these respective pass bands they operate successfully over these bands. In this connection, it is noted that when, in the specification and claims, reference is made to frequency and to wave length, the center frequency of a band, or the wave length corresponding to it, is meant—unless some other meaning is indicated in the context.

Another feature of antennas constructed according to the present invention is that they afford two-to-one impedance matches for transmission lines readily available on the market. One embodiment can be connected directly to an 80 ohm parallel transmission line with no impedance matching devices of any kind. Another embodiment can be connected to another well known type of inexpensive parallel transmission line, the 300-ohm line, provided that its conductors are gradually spread apart, as they approach their points of connection to the antenna, to form a quarter wave length transformer effecting a gradual transformation to increase the characteristic impedance of the line to 460 ohms. Such an embodiment is shown in Fig. 2. Since the antenna is like that of Fig. 1 and the feed means are conventional, this Fig. will not be described in detail and no reference numbers are used in it. The quarter wave length tapered transformer would be 30 inches long if the center frequency were 100 mc.

As explained above the proportions of these antennas may be anywheres within certain indicated ranges. However, it may be helpful to know that certain antennas of this type were tested with especially good results and they had the following specific dimensions: An antenna with an input impedance in the high impedance region, e. g. near 700 ohms, had the following dimensions and proportions: $W=.245\lambda$; $D=.06\lambda$; $H=.176\lambda$; gap width$=.0125\lambda$; the area of a cross section $=.0146\lambda^2$; W/D=approximately 4/1 and W/H=1.5/1.

(For a midfrequency of 100 mc. the dimensions in inches would be W=29''; D=7''; H=21'' and the gap width=1½''.)

If connected to an inexpensive 300-ohm line through a quarter wave length transformer this antenna performs satisfactorily over a band width of 1.25.

An antenna with an input impedance in the low impedance region which was connected directly to an 80-ohm line had the somewhat wider band width of 1.5. Its measurements were $W=.355\lambda$; $H=.238\lambda$ and $D=.05\lambda$. For a midfrequency of 100 mc. these measurements in inches would be W=42''; H=28''; and D=6''.

Cylinder 1 should be made at least in part of conducting material and its surfaces must be effectively continuous electrically. However, its surfaces need not necessarily be physically continuous and, for example, may be of wire netting. An embodiment constructed as shown in Fig. 3 consisted of three elliptical conductive hoops each shaped like a transverse cross section of the solid sheet metal antenna shown in Fig. 1. The top and bottom hoops correspond, respectively, to the edges of upper and lower ends of the cylinder of Fig. 1, and the middle hoop corresponds to a transverse section of the central portion thereof. The open ends of these hoops are interconnected by the wires corresponding to the edges of gap 2. In the structure of Fig. 3 the hoops are numbered 5, 6 and 7 and the interconnecting wires are numbered 9 and 10.

Antennas of the types shown in Figs. 1, 2 and 3 may be attached to any suitable support, e. g. to a steel mast along the line diametrically opposite to and parallel with the center line of gap 2.

Fig. 4 shows that the horizontal radiation pattern of an antenna according to Fig. 1 is of a very desirable kind of reception in or near to a metropolitan area where several broadcasting stations are located. The antenna is installed so that the gap extends vertically. The gap may be faced in the direction of the weakest desired station since it is approximately in that direction that the antenna is most sensitive. As already explained, however, signals from all directions will be received including those which reach the antenna on its sides which are least sensitive. On the other hand, a dipole which is positioned to receive a weak station will not pick up any signal at all from even most powerful stations positioned to transmit into the nulls of the dipole. It is not necessary to face the gap in any particular direction in installing this type of antenna. Since some embodiments of the antenna are appreciably less sensitive in the directions toward which the long axes of its elliptical cross sections point, it may be advantageous to point them toward the most powerful station.

The antenna of Fig. 5 has appreciable directivity toward the horizon and, therefore, has greater gain than otherwise. Moreover, if it is installed about ten feet over a conductive roof this directivity will increase and upward and

downward nulls will occur in the vertical patterns.

Fig. 6 shows that when this antenna is operated at very low frequencies the input impedance, as indicated by curve A, rapidly changes and, as frequency changes in one direction, it becomes more and more inductive. Therefore, at these low frequencies the antenna cannot be conveniently matched to ordinary lines. However, in another frequency region, see curve B of Fig. 6, the impedance varies, as frequency is changed, so that it has no reactive components at all at two points. At two particular frequencies in this region the input impedance is purely resistive being, respectively, near to 100 and 150 ohms. For an appreciable band width in this region the reactive component is never very large and the resistive component remains substantially between 80 and 150 ohms. Therefore, in this region the antenna may be conveniently used with a low impedance line. In fact, the antenna presents a satisfactory match, e. g. never greater than two-to-one, to an 80-ohm line and has a satisfactory band width within this region. It will be noted that there is another frequency range, curve C, in which the impedance curve again crosses the abscissa of this chart. At this point the input impedance once more becomes purely resistive and is about 460 ohms. For a frequency range which is adequate to cover an existing transmission band in that region the impedance remains sufficiently constant and can easily be matched to a 300-ohm parallel transmission line in the manner described above and shown in Fig. 2.

Fig. 7 is included in the drawing as a convenient reference to show transmission bands which have been allocated to television, FM and facsimile transmissions, inasmuch as the antenna herein is intended for FM and television.

Fig. 9 shows the relationship between dimensions H and W of differently proportioned antennas of the type shown in Fig. 1 which have substantially the same lower frequency limit as determined by their input impedances in relation to the output impedance of a 300-ohm feed line. This figure has been plotted from actual values of W and H in terms of the wave length of the lowest frequency. Antennas whose H-to-W or W-to-H ratios fall on the curve of Fig. 9 will generally have satisfactory input impedances as explained above. Those having relatively low values of H will have horizontal patterns approximating figures-of-eight with deep nulls while those with relatively large values of H have more satisfactory, nearly circular horizontal patterns in accordance with principles explained above.

The theory of operation of my antenna has not as yet been completely worked out. However, as shown above, several principles governing its operation can be explained and its design factors have been worked out in detail. In the following part of this application certain additional considerations also bearing generally on the problem are touched upon.

Since preferably nothing should be received from below an FM or television antenna, and nothing need be received from above it, substantially equal RF currents should be caused to flow in opposite directions in parallel radiating portions of it, these portions, of course, lying in one or more horizontal planes. Moreover, these elements must be bent into something approximating an oval or rectangular loop since two straight opposing horizontal elements would result in undesirable nulls in horizontal patterns. It is not absolutely essential to employ an oval or rectangular shape if an antenna with only a downward null (without an upward null) is desired. Such an antenna would have less gain than one with both downward and upward nulls and for this reason should not be preferred.

I have ascertained that generally the band width of a loop depends in part on three factors: (*a*) the area included with the loop; (*b*) the width of the conductive structure comprising the loop; and (*c*) the degree of compensation, e. g. the extent to which band stretching circuits are used.

Both the radiation resistances and the band widths of small loops vary approximately as the fourth power of their diameters and, therefore, small loops have small band widths and must be variably tuned to be useful over a broad frequency band.

As indicated above, by increasing the size of the conductive radiating element, the thickness of the wire or the width of the metal strip of the loop, it is possible to decrease its perimeter without causing prohibitive changes in the input impedance and, therefore, by this means, a small loop can be matched to an ordinary transmission line. By this single expedient, compactness, matching and directional properties are all obtained.

Moreover, distortions in the shape of this thickened type of antenna, e. g. distorting it so that its transverse cross section is oval or elliptical, further changes both its input impedance and its radiation patterns.

These increases in the size of the conductive structure also increase its vertical dimension and thus somewhat concentrate the distribution of energy in vertical planes and increase horizontal directivity in them.

If gap 2 should be located in flattened cylinder 1 in the plane containing the long axes of its elliptical cross sections the antenna would receive vertically polarized waves (or transmit them) almost as well as horizontal waves. This would adversely affect the signal to noise ratio and, therefore, and for reasons explained in detail above, this construction is undesirable. This would be true even though cylinder 1 were not very flattened and the ratio of the long and short axes of its elliptical cross sections were near to 1.

What I claim is:

1. A horizontally polarized antenna which has substantial omnidirectivity in horizontal planes, comprising a flattened tubular radiator which is from 2 to 6 times as wide as it is deep and from 1 to 2 times as wide as it is high, the width of the tube as measured in terms of a wavelength corresponding to the center frequency of its operating band being less than one quarter of said wavelength, a longitudinal gap extending between the open ends of the radiator in the center of one of its wide side walls parallel to the axis of the radiator, the gap having a width substantially of one hundredth of said wavelength, the exterior surface of the radiator being effectively continuously conductive for the highest frequency in said band, and two feed points respectively located opposite to each other on the edges of the gap for connection to the conductors of a parallel transmission line.

2. A horizontally polarized antenna which has substantial omnidirectivity in horizontal planes and substantially matches over a frequency band having a ratio of highest to lowest frequency of

between 1.25 and 1.5 parallel-conductor transmission lines of both 80 and 460 ohms surge impedance, comprising an open ended cylinder which has an elliptical transverse cross-section and is from 2 to 6 times as wide as it is deep and from 1 to 2 times as wide as it is high, the height of the cylinder being a little less than a quarter of one wavelength corresponding to the center frequency of the operating band, a longitudinal slot extending between the ends of the cylinder in the center of one of its wide side walls parallel to the longitudinal axis of the cylinder, the gap having a width substantially of one hundredth of one of said wavelengths, the exterior surface of the cylinder being effectively continuously-conductive for the highest frequency in said operating band, and the respective points of connection for the conductors of the transmission line being oppositely positioned points on the edges of the gap.

3. A horizontally polarized antenna which has substantial omnidirectivity in horizontal planes and substantially matches over a band having a ratio of highest to lowest frequency width of 1.5 an 80 ohm parallel-conductor transmission line comprising an open-ended cylinder which has an elliptical transverse cross-section and is .355 wavelength wide, .05 wavelength deep and .238 wavelength high, the cylinder having a longitudinal gap extending between its ends in the center of one of its wide side walls parallel to the longitudinal axis of the cylinder, the gap having a width of .0125 wavelength, the exterior surface of the cylinder being effectively continuously-conductive for the highest frequency in its operating band, said wavelength being that of the center frequency of said operating band, and the respective points of connection for the conductors of the transmission line being oppositely positioned points on the edges of the gap.

4. A horizontally polarized antenna which has substantial omnidirectivity in horizontal planes and substantially matches over a band having a ratio of highest to lowest frequency width of 1.25 an end of a 300 ohm parallel transmission line which has its conductors spread over a distance at least as great as a quarter wavelength corresponding to the center frequency of the operating band of the antenna to increase the surge impedance of the transmission line by substantially 50 percent, comprising an open-ended cylinder which has an elliptical transverse cross-section and is .245 wavelength long, .06 wavelength wide, and .176 wavelength high, the cylinder having a longitudinal gap extending between its ends in the center of one of its wide side walls parallel with the longitudinal axis of the cylinder, the gap having a width of .0125 of said wavelength, the exterior surface of the cylinder being effectively continuously-conductive for frequencies in said operating band, and the respective points of connection for the spread conductors of the transmission line being oppositely positioned points on the edges of the gap.

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