

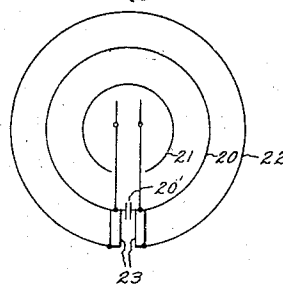
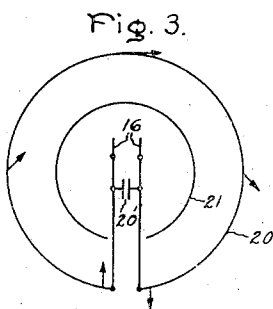
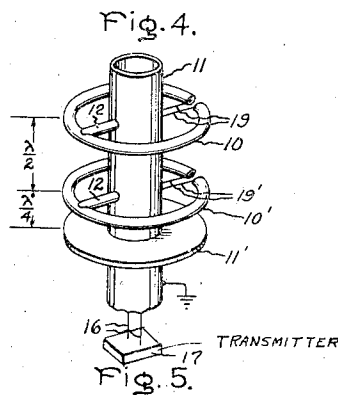
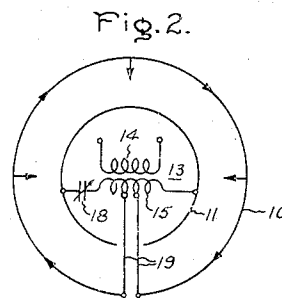
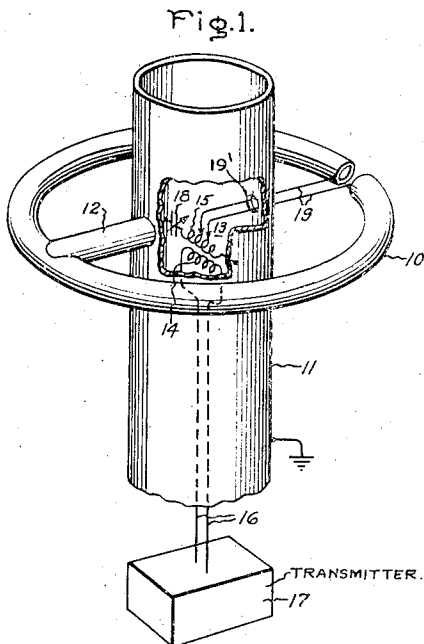
Aug. 16, 1949.

G. W. FYLER
ANTENNA SYSTEM

2,479,337

Filed Oct. 16, 1945

2 Sheets-Sheet 1



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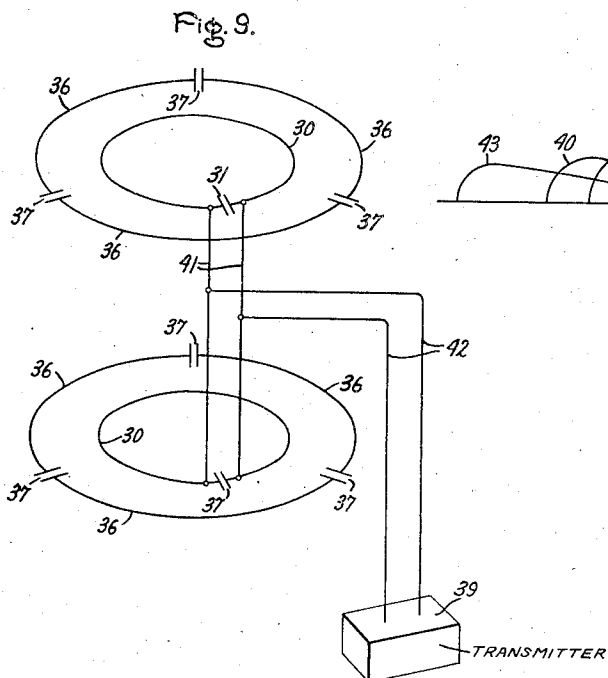
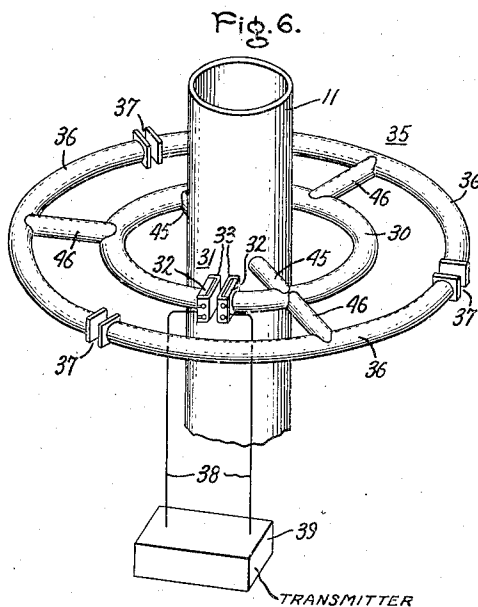
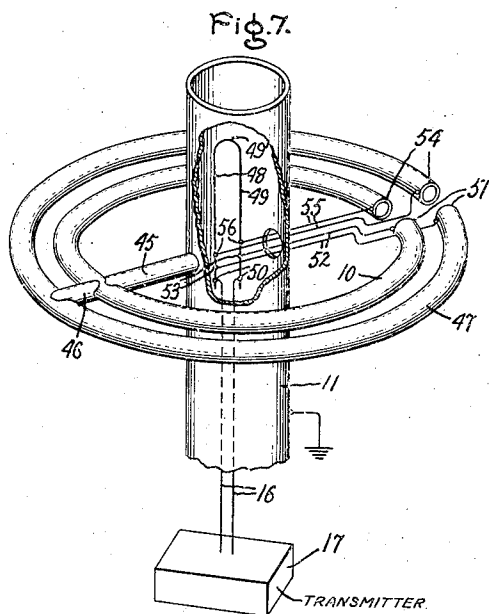
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G. W. FYLER
ANTENNA SYSTEM

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,479,337

ANTENNA SYSTEM

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Application October 16, 1945, Serial No. 622,543

12 Claims. (Cl. 250-33)

1 My present invention relates to high frequency antenna systems, and particularly to high frequency antenna systems designed to provide substantially circular radiation patterns. This application is a continuation in part of my U. S. Patent No. 2,405,123, granted August 6, 1946.

In broadcasting radio programs within the higher frequency channels utilized for frequency modulation and television broadcasts, it is generally desirable to distribute the energy radiated from the transmitting antenna as uniformly as possible in all horizontal directions. At the same time, it is desirable to concentrate the radiated energy at low angles in the vertical plane. In other words, for most effective service, the radiating system should have a high degree of vertical directivity and the horizontal field strength pattern should be as nearly circular as possible.

Accordingly, it is an object of my invention to provide an improved high frequency antenna which possesses these and other desirable electrical characteristics.

In general, simple two-terminal antennas, such as dipoles theretofore commonly used, have non-uniform radiation characteristics. It has heretofore been customary to resort to compound antenna arrangements in order to secure a reasonably uniform horizontal wave pattern with horizontal polarization. It is another object of my invention to provide an improved and simplified compound antenna structure which is capable of producing a substantially uniform radiation pattern and which is relatively economical to build and easy to adjust.

Still another object of my invention is to provide a new and improved antenna system which has only two connection terminals and which nevertheless provides a substantially circular radiation pattern and the radiation of which is concentrated substantially in the horizontal plane.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 is a perspective view of an antenna system embodying the principles of my invention; Fig. 2 shows vectorially the relationship of the current and voltage present on the antenna of Fig. 1; Figs. 3, 4 and 5 show modifications of the system disclosed in Fig. 1; Figs. 6 and 7 show different embodiments of my invention; Fig. 8 is a diagram

2 illustrating characteristics of antenna systems of the type illustrated in Fig. 5; and Fig. 9 shows another embodiment of my invention.

As is well understood in the art, a properly terminated transmission line does not have any standing waves. In Figs. 1 and 2 there is shown an antenna system in which a transmission line section is utilized as a radiator, the line section being formed into a circular loop and the ends coupled to a suitable source of signal voltage. Such an antenna has substantially uniform current and hence a substantially circular radiation pattern in the plane of the loop, provided proper adjustments have been made of the termination of the line and its coupling to a source of high frequency waves.

In Fig. 1 there is shown such a transmission line antenna or radiating transmission line. The antenna comprises a substantially closed circular loop 10 formed from electrically conductive material of any desired cross-sectional shape. For example, the loop may be a suitably formed pipe disposed in a circular configuration. The loop is coaxially disposed around a suitable electrically conductive member such as a cylindrical grounded mast 11 to form therewith a short section of transmission line.

The loop 10 is suitably supported from the mast by means of a supporting member 12 of insulating material, suitably connected at its respective ends to the loop and to the mast and of such length that the loop and mast are spaced apart approximately a quarter of a wave length, or less. Thus there is provided a transmission line conductor and a grounded mast, the mast serving as a reflector for the loop.

There is illustrated in Figs. 1 and 2 means for energizing a system in which the length of the loop 10 is an integral number of full wave lengths. There is provided a transformer 13, having a primary 14 and a secondary 15, carried by the mast 11. Any suitable transmission line 16 may be utilized to effect the transfer of energy between the primary 14 and a suitable source of signal voltage which may comprise the high frequency radio apparatus or transmitter represented by the box 17. One end of the secondary 15 is suitably connected to the mast 11 and the other terminal of the secondary is connected to the mast through a variable condenser 18. Thus winding 15 and condenser 18 constitute a tuned circuit which enables proper termination of the transmission line 16. In installations where wide band operation is desired, this tuned circuit and the antenna should have a low Q. In such a sys-

tem, since the radiator operates as a transmission line rather than as a resonant dipole, no sharp resonance effects are present in the antenna, and the system exhibits relatively broad frequency band width characteristics.

The ends of the loop 10 are connected to suitable points on the coil or winding 15 by means of suitable conductors 19 extending between the ends of the loop and the winding through a suitable opening 19' in the mast.

In Fig. 2 there is shown the vector currents flowing in the antenna 10 of Fig. 1. The arrow heads on the circle 10 represent the directions of current flow within the loop and the arrows pointing inwardly from the circle 10 represent the voltage phase relationships at the indicated points. The loop 10 is energized from coil 15 by means of conductors 19 connected to desired taps on winding 15. With this arrangement there exists a difference of voltage across the ends of the loop and the loop has a circulating current with only the radiated energy and heat loss being supplied from the feed line. It is apparent that currents are uniformly distributed around the loop and, at diametrically opposite points of the loop, are 180° out of phase and may be represented by vectors pointing in opposite directions. In effect, therefore, the currents are in phase at opposite points of the loop 10, in that these currents produce additive radiation fields along the axis of the loop, as well as radiation in all horizontal directions.

In Fig. 3 there is depicted schematically an arrangement which enables the application of the above principles to a loop having an electrical length equal to an odd number of half waves. A balanced input circuit to the loop is shown. The ends of the transmission line 16 are connected directly to the ends of the loop 20, a suitable condenser 20' being used properly to terminate the line in conjunction with a short length of line joining the antenna 20 and the transmission line 16. The vector voltage and current relationships are shown by means of arrows. The phase of the loop current and voltage changes uniformly and progressively throughout the length of the transmission line antenna and the vectors make a half revolution in approximately one half wave length of line. The amplitude does not change appreciably, however, and, as long as the spacing between the loop and mast 21 is not great enough to introduce substantial radiation resistance and, hence, attenuation, a uniform substantially circular radiation pattern results.

In Fig. 4 I have shown a modification of the antenna structure of Fig. 1, in which a pair of substantially circular loop elements 10, 10' each have an electrical length equal to an integral number of full wave lengths at the operating frequency of the antenna and, spaced from the conductive mast 11 by a distance equal approximately to a quarter wave length or less, are spaced apart vertically by a distance $\lambda/2$ equal to a half wave length. Positioned below the lower element 10' by a distance $\lambda/4$ equal to a quarter wave length is a conductive reflector plate 11'. The ends of loop 10 are connected to a source of signal 17 by means of conductors 19, 16 and the ends of loop 10' are connected to the source by means of conductors 19', 16. The length of connection from the source to loop 10 is made half a wave length longer than the connection to loop 10' so that these coaxial loops carry currents which are opposite in phase. Since the currents in the loops are 180° out of phase, the horizontal

radiation of the loops is substantially completely cancelled, while their vertical radiations are additive to give a concentrated highly directive beam of radiation. By means of the reflector 11', this vertical radiation is confined to a single direction, namely, upwardly along the axis of the loops. Normal to the plane of the loop, therefore, is a concentrated beam of radiation. Such an antenna is relatively small and simple in structure and is particularly useful where concentrated radiation in a small area is desired, for example, for better illumination of a parabolic reflector, or for use for diathermy and therapeutic work. Any larger even number of loops spaced apart axially by a distance equal to a half wave length with adjacent loops energized in opposite phase may be used, of course, to obtain a desired strength of radiation beam.

Fig. 5 shows the system of Fig. 3 with the addition of a driven substantially circular director 22 coaxially disposed and outwardly spaced a fraction of a wave length from the loop 20 which in turn is spaced approximately a quarter of a wave length with respect to mast 21 by which additional vertical directivity is achieved. With this arrangement a suitable phase delay line or matching section, indicated by the numeral 23, is required.

Still more vertical directivity can be obtained by using stacked elements with half wave vertical spacing and excited in-phase.

In Fig. 6 there is shown a modification of my antenna system which provides substantially uniform current therein and, consequently, a substantially circular radiation pattern. It is well known that a linear antenna which is actually one-half wave long at the operating frequency has a current distribution which is essentially sinusoidal, the current being maximum at its mid-point and zero at its ends. If the antenna is less than one-half wave long and capacity is added between the ends of the antenna loop in an amount such that the effective electrical length of the entire system is equal to one-half wave, the current at the free ends of the antenna is not zero, but has some finite value and the current distribution is more nearly uniform.

Accordingly, in Fig. 6, the loop or radiator 30 disposed in a substantially closed, peripherally incomplete loop constitutes a coiled up dipole and preferably has either a length of substantially less than one-half wave or a nearly uniform current obtained as discussed in conjunction with the description of Fig. 2. The electrical length may be much greater than the actual length because of the stray and, where desired, added capacity 31 between the ends of the loop. If the actual length is much less than one-half wave even when the stray capacity is considered, the free ends of the loop may be terminated in elements forming a condenser 31 of substantial capacity to provide a transmission line radiator of desired length.

In order to provide the desired capacity between the ends of the loop, blocks or plates 32 may be secured, as by welding, to the ends of the pipe and U-shaped plates 33 fitted over the opposing faces of the blocks. In order to provide an adjustable condenser, one or both of the plates 33 may be provided with slots (not shown) or other suitable openings registering with screws threaded into the blocks 32. Of course, any other desired means may be employed for varying or adjusting the effective capacity.

A small loop does not radiate to any substantial

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degree in a vertical direction, provided the current is substantially uniform and in phase around the loop. This is represented in Fig. 8, in which the numeral 34 indicates the vertical directivity pattern of the loop 30.

In order to obtain a greater degree of vertical directivity with this type of antenna, there may be provided a substantially circular director 35 spaced outwardly from the loop 30 and comprising a plurality of elements 36 having capacitors 37 between adjacent ends. The director is substantially concentrically arranged with the loop 30 and disposed in substantially the same plane. The director is spaced apart from the loop a distance of the order of $\frac{1}{10}$ to $\frac{1}{2}$ of a wavelength, preferably approximately $\frac{1}{4}$ wave. This is for the reason that the antenna system may tune too sharply if the spacing is too little and little gain in directivity is obtained if the distance is too great.

The length of the director elements 36 should be somewhat less than $\frac{1}{2}$ wavelength so as to maintain relatively uniform current distribution and to permit correct tuning. Accordingly, the spacing from the loop and the length of the director elements are inter-related.

Any suitable form of transmission line 38 may be utilized to effect transfer of energy between the high frequency radio apparatus or transmitter, represented by the box 39, and the loop.

The above described system has a vertical directivity pattern as represented by the lobes 40 in Fig. 8.

In Fig. 7 there is shown another modification of my antenna having transmission line characteristics and the radiation of which is concentrated substantially in the horizontal plane, there being very little radiation in the direction transverse to the planes of the radiators. The antenna there shown comprises the loops 10, 47 which surround the mast 11. The loops 10, 47 are relatively closely spaced with respect to each other and the loop 10 is spaced from the mast 11 by a distance of the order of .25 to .3 wavelength at the operating frequency of the system. The loops 10 and 47 may be supported from the mast 11 by insulated supports 45, 46 to form a section of transmission line surrounding the mast 11. At the same time they form a section of transmission line with mast 11. Preferably, the diameter of the mast 11 and the spacing to the center of the transmission line elements 10, 47 is such that the length of the composite line 10, 47 is an integral number of half wavelengths, the number, because of the physical dimensions of the system, being two full wavelengths or more.

The high frequency waves from the transmitter 17 are supplied over the leads 16 to a resonant circuit which may comprise the stub transmission line formed of the parallel conductors 48, 49. These conductors are short-circuited and connected to mast 11 at one end at the point 49 and are open-circuited at the other end. The leads 16 from the transmitter are connected to the points 50 and the ends 51 of the loops 10, 47 are connected by means of leads 52 to symmetrically spaced points 53 on the conductors 48 and 49, the points 53 being displaced from the points 50. Similarly, the ends 54 of the loops 10, 47 may be connected by conductors 55 to symmetrically spaced points 56 on the conductors 48, 49.

The points 50, 53, 56 are so located on the transmission line conductors 48, 49 that impedance matching between the component parts of the system is obtained at each of these points.

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Thus, depending upon the voltage desired to be impressed across the conductive loops 10, 47, the points 53 may be located between the open end of the conductors 48, 49 and the points 50, instead of the location shown in Fig. 7. Usually, however, the points 56 are located between the points 53 and the short-circuited end of the conductors 48, 49, the distance between the points 53, 56 being determined by the voltage drop in the loops 10, 47 around the mast 11. Similarly, depending upon the length of the elements 10, 47, it may be necessary to transpose the conductors 55 so that the conductors 52, 55 connected to conductor 48, for example, are connected respectively to the point 51 on the loop 10 and the point 54 on loop 47. Such transposition may be required for matching the phase of currents at the ends of the loops 10, 47 with currents in the conductors 48, 49. In all cases, of course, the location of the taps on the transmission line conductors 48, 49 is such that the desired termination impedance and voltage of the connected elements is obtained.

In the operation of the antenna of Fig. 7, the loops 10, 47 jointly form a section of transmission line with respect to the grounded mast 11. This section is terminated for reflectionless transmission of energy. At the same time, the closely spaced loops 10, 47 form a section of transmission line in which currents flow in opposite directions. In a vertical direction, that is, a direction parallel with the axis of the mast 11, the electromagnetic fields produced by these currents are neutralized and cancelled so that there is no radiation along the axis of the mast 11. However, in a horizontal direction, the fields of the currents in the two loops 10, 47 are additive so that the antenna system produces radiation which is concentrated substantially in a horizontal plane. The conductive mast 11 reflects energy radiated inwardly from the loops, the distance between the loops 10, 47 and mast 11 being such that this energy reflected from mast 11 reinforces energy radiated outwardly from the loops.

In order to obtain still more vertical directivity in an antenna of the type shown in Fig. 6, a plurality of assemblies may be employed, spaced apart vertically approximately $\frac{1}{2}$ wavelength. Two such assemblies are shown schematically in Fig. 9. The assemblies are interconnected in the same phase by a suitable impedance matching line 41. A suitable transmission line 42 may be used to transfer energy between transmitter 39 and is connected to the line 41 at a point midway between the assemblies. The directivity pattern for the system of Fig. 9 is represented by the lobes 43 in Fig. 8.

In order to support the assemblies in operative position, there may be provided a mast 11 as in Fig. 6. The loops 30 may be secured to the mast by means of members 45 of insulative material and the parasitic director elements 36 may be supported from the loop 30 by similar supports 46 which are preferably connected to the elements 36 at points of minimum voltage.

A plurality of assemblies of the driven director type illustrated in Fig. 7 may likewise be employed to form a composite antenna structure for radiating greater amounts of power. Such assemblies individually have a very small amount of radiation along the axis of a supporting mast. They should be spaced apart vertically on the mast, therefore, by such distances that their fields in a horizontal direction are additive.

While I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention in its broader aspects, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A high frequency antenna system comprising a substantially closed loop, a second loop spaced outwardly from said first loop to form a section of transmission line therewith terminated for reflectionless transmission of energy thereover, the ends of said first loop terminating in means providing substantial capacity therebetween, and a transmission line connected to said first loop on each side of said capacity, said first loop being sufficiently less than one-half wave length in circumference to provide substantially uniform current therein.

2. A high frequency antenna system comprising a substantially closed loop, the ends of said loop being closely spaced and terminating in means providing substantial capacity therebetween, a transmission line connected to said loop on each side of said capacity, said loop being substantially less than one-half wave length in circumference, and directive means for said system comprising a plurality of separated conductors uniformly spaced outwardly from said loop a distance substantially equal to one-quarter of a wave length and lying substantially in the same plane therewith.

3. A high frequency antenna system comprising a substantially closed loop, the ends of said loop being closely spaced and terminating in means providing substantial capacity therebetween, a transmission line connected to said loop on each side of said capacity, said loop being substantially less than one-half wave length in circumference, and directive means for said system comprising a plurality of separated conductors uniformly spaced outwardly from said loop a distance substantially equal to one-quarter of a wave length and lying substantially in the same plane therewith, said conductors terminating in means providing substantial capacity between the ends thereof.

4. A high frequency antenna system comprising a pair of substantially concentric, substantially co-planar loops, said loops forming a section of transmission line terminated for substantially reflectionless transmission of energy thereover, both of said loops being peripherally incomplete, and means connected to both of said loops at the free ends thereof for supplying high frequency energy thereto, whereby said inner loop acts as a radiator and the outer of said loops acts as a director.

5. A high frequency antenna system comprising a vertical cylindrical conductive member, a pair of substantially concentric, substantially co-planar loops encircling said member, both of said loops being peripherally incomplete, the outer of said loops being closely spaced with respect to the inner of said loops and the inner of said loops being spaced from said member by a distance substantially equal to one-quarter of a wave, and means connected to said loops at the free ends thereof for supplying high frequency energy thereto, whereby said inner loop acts as a radiator and the outer of said loops acts as a director.

6. A high frequency antenna comprising a con-

ductive mast, a pair of substantially concentric, substantially co-planar conductive loops surrounding said mast, said loops being peripherally incomplete, the inner of said loops and said mast forming a section of transmission line terminated for reflectionless transmission of energy thereover, and means supplying high frequency currents to both of said loops, the currents in said loops having a difference in phase determined by the spacing between said loops.

7. A high frequency antenna system comprising a plurality of vertically spaced assemblies, each of said assemblies comprising a metallic loop-like member, having a pair of ends spaced apart by a small distance, conductive means coupled to said respective metallic members and concentric and co-planar therewith, a source of high frequency signals, and means supplying high frequency currents from said source to the respective ends of said members, said members being spaced apart vertically by an electrical distance and the phase of the currents supplied to adjacent of said members being such the fields of said assemblies are additive in the same direction.

8. A high frequency antenna system comprising a vertical cylindrical electrically conductive member, a metallic loop-like member substantially encircling and coaxially disposed with respect to said vertical member to form therewith a section of transmission line terminated for reflectionless transmission of energy thereover, said metallic member having a pair of ends spaced apart by a small distance, a source of high frequency signals, means supplying signals from said source to said ends, and conductive means coupled to said metallic member and concentric and co-planar therewith for increasing the directivity of said system.

9. A high frequency antenna system comprising a cylindrical electrically conductive member, a pair of concentric co-planar conductive loops coaxially surrounding said member, said loops and said member forming a section of transmission line terminated for reflectionless transmission of energy thereover, the outer of said loops being spaced from the inner of said loops and the inner of said loops being spaced from said member by an electrical distance substantially equal to one-quarter of the wave length at which said antenna operates, and means connected to said inner loop for supplying high frequency energy thereto, whereby the inner of said loops acts as a radiator and the outer of said loops acts as a director.

10. A high frequency antenna system comprising a vertical electrically conductive member, a pair of substantially concentric, substantially co-planar conductive loops coaxially surrounding said member, said loops and said member forming a section of transmission line terminated for reflectionless transmission of energy thereover, both of said loops being peripherally incomplete and having a pair of spaced ends, a resonant circuit, and means connecting said ends to spaced points in said circuit.

11. A high frequency antenna system comprising a pair of substantially concentric, substantially co-planar conductive loops coaxially spaced from an electrically conductive member, each of said loops being peripherally incomplete and having a pair of spaced ends, a resonant circuit, and means connecting corresponding ends of said loops to symmetrically spaced points of said circuit, said loops forming a section of transmission

line terminated for reflectionless transmission of energy thereover.

12. A high frequency antenna system comprising an electrically conductive member, a pair of concentric co-planar conductive loops coaxially surrounding said member, each of said loops being peripherally incomplete and having a pair of spaced ends, a section of transmission line, means supplying high frequency waves to a first point on said line, means connecting corresponding ends of said loops to symmetrically spaced points on said line, the points of connection of said energy to said line and of said ends to said line being so spaced that high frequency waves are transmitted from said first means to said loops substantially without reflection.

GEORGE W. FYLER.

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