Jan. 24, 1950 H. A. WHEELER 2,495,399

ANTENNA SYSTEM

Filed Sept. 17, 1946 2 Sheets-Sheet 1

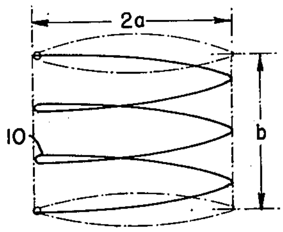

FIG. 1a

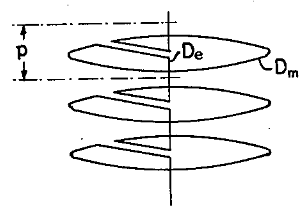

FIG. 1b

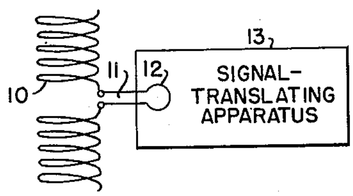

FIG. 2a

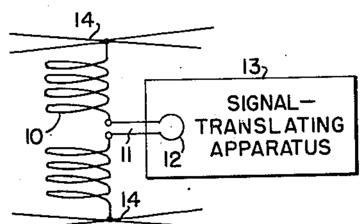

FIG. 2b

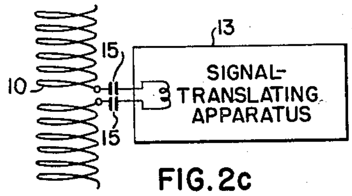

FIG. 2c

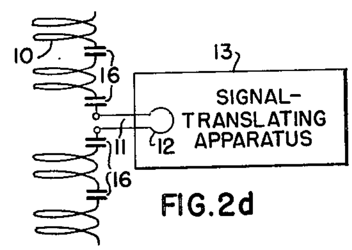

FIG. 2d

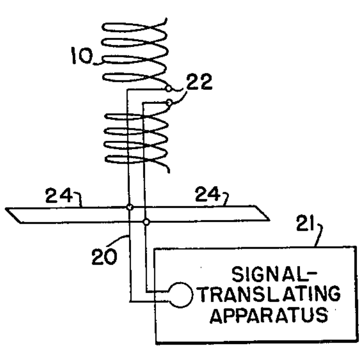

FIG. 3a

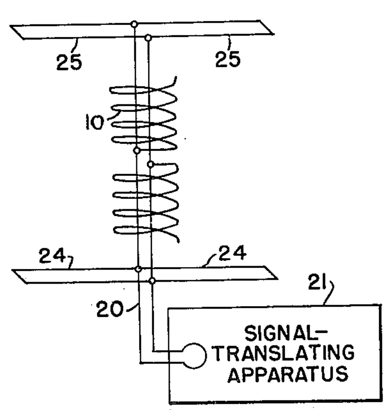

FIG. 3b

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Jan. 24, 1950 H. A. WHEELER 2,495,399

ANTENNA SYSTEM

Filed Sept. 17, 1946 2 Sheets-Sheet 2

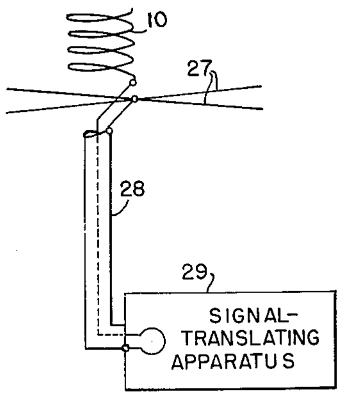

FIG.4

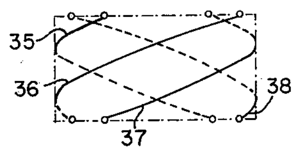

FIG.5a

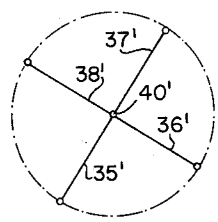

FIG.5b

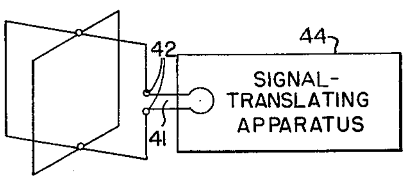

FIG.6a

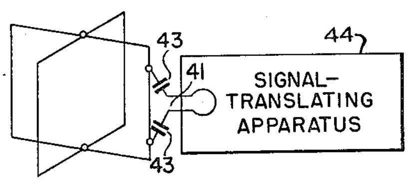

FIG.6b

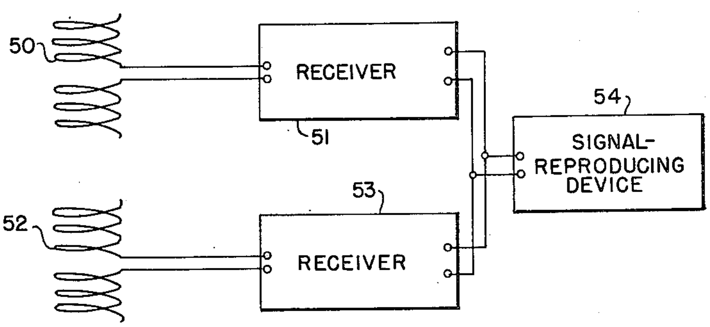

FIG.7

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UNITED STATES PATENT OFFICE

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ANTENNA SYSTEM

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Application September 17, 1946, Serial No. 697,454

19 Claims. (Cl. 250—33)

1

This invention is directed to antenna systems which exhibit the property of radiation with approximately circular polarization. The desired polarization is obtained by the use of an electromagnetic dipole, effectively including both an electric and a magnetic dipole in a novel and convenient manner which inherently ensures the required amplitude and phase relations of the components of radiation contributed by each.

Electric dipole antennas are well known in the art but they are characterized by plane polarization. This is also true of the conventional magnetic dipole or loop antenna, even though that antenna may take the form of a multiturn coil, because the dimensions and the feed connections to the coil tend to suppress any electric dipole effects that may otherwise result from the coil configuration. Since circular polarization connotes the notion of a rotating field, neither of the prior dipole antennas, considered alone, is capable of transmitting or receiving such radiation. A pair of separate dipoles, one of the electric and one of the magnetic type, may conceivably be associated in an antenna system with such relative phase as to radiate with circular polarization but the use of separate dipoles may not always be convenient.

It is an object of the present invention therefore to provide a novel and improved antenna system exhibiting the property of radiation with approximately circular polarization.

It is another object of the invention to provide a novel antenna system of simple unitary construction which inherently functions with circular polarization.

An antenna system in accordance with the present invention comprises a conductive structure having a maximum dimension much less than one-half of the operating wave length and including at least one conductor of helical configuration. The structure is proportioned so that the average conductor turn of the structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length, whereby the system exhibits the property of radiation with substantially circular polarization.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings, Fig. 1*a* is a representation of the conductive structure of an antenna system

2

in accordance with the invention; Fig. 1*b* represents an antenna which is theoretically the equivalent of the arrangement of Fig. 1*a*; Figs. 2*a*–2*d*, inclusive, represent various methods of connecting an antenna embodying the invention in a balanced system with a signal-translating apparatus; Figs. 3*a* and 3*b* show modified connections from the antenna to the signal-translating apparatus; Fig. 4 illustrates the application of the antenna to an unbalanced system; Figs. 5*a* and 5*b* are views of a fractional-turn multifilar modification of the antenna of the invention; Figs. 6*a* and 6*b* represent balanced antenna systems embodying a construction of the type represented in Figs. 5*a* and 5*b*; while Fig. 7 represents a diversity receiver including a pair of antennas individually embracing the invention.

Referring now more particularly to Fig. 1*a*, there is represented the conductive structure of an antenna system in accordance with the invention exhibiting the property of radiation with substantially circular polarization. In this simple form the antenna structure comprises a single conductor 10 of helical configuration including a plurality of conductor turns and defining a multiturn coil. The dot-dash construction lines of this figure indicate an imaginary cylinder which bounds the coil or conductor 10. Preferably, the coil is self-resonant at the operating wave length of the system or is self-resonant at the mean wave length where operation over a range of wave lengths is contemplated. The coil dimensions are designated by dimension lines 2*a* and *b*, the former corresponding with the diameter of the imaginary cylinder and the latter being equal to the product of the number of turns of conductor 10 times the helical pitch. These dimensions are less than the operating radian length of the system where "radian length" is defined as

$$\frac{1}{2\pi}$$

times the wave length. Such a helical coil radiates or receives a wave of circular polarization if the area and pitch of its conductor turns are properly related to the radian length. The relationship to be satisfied will be established with reference to Fig. 1*b*.

Fig. 1*b* shows how each turn of the helical conductor or coil 10 may be resolved into two radiating components, one an axially extending conductive element D_e of a length equal to the pitch p of the coil and the other a flat turn or loop D_m normal to the axis of the helix and having an area A. The component D_e radiates as an electric dipole while the component D_m radiates as a magnetic dipole. Since each radiating component or elemental antenna has dimensions much less than the radian length, each behaves essentially as a dipole with a coaxial doughnut pattern of radiation. For the electric dipole or current element D_e the polarization of the electric vector is in the plane of the element, while the corresponding polarization of the electric vector for the magnetic dipole or current loop D_m is normal to the axis of the loop. Thus, it becomes at once apparent that the helical antenna of Fig. 1*a* is a superposition of electric and magnetic dipoles and may, therefore, be considered as "an electromagnetic dipole."

In discussing the electromagnetic dipole thus far, mention has been made of only the electric vectors of the two waves of crossed polarization resulting from (1) the electric dipole D_e and (2) the magnetic dipole D_m. Of course, the two waves of crossed polarization also have magnetic vectors. To realize circular polarization from the electromagnetic dipole the waves of crossed polarization must satisfy two conditions. First of all, they must have substantially equal intensity and the corresponding vectors of the two waves of crossed polarization must be in time-phase quadrature. Both conditions may be satisfied by properly proportioning the helical conductor 10 with reference to the area of its turns, the pitch and the radian length.

The condition of equal field intensities from the electric dipole D_e and the magnetic dipole D_m requires that

$$\frac{A}{L^2}=\frac{p}{L} \qquad (1)$$

where:

A=the area defined by the projection of the average conductor turn on a plane normal to the axis of the helix;

L=the operating radian length; and

p=the pitch of the helix.

Solving Equation 1 for the turn area A gives

$$A=pL \qquad (2)$$

Equation 2 is the basic relationship for a small helix equivalent to superimposed coaxial electric and magnetic dipoles exhibiting radiation with circular polarization. It means that the conductor 10 of the radiating structure is to be so proportioned that the average conductor turn has an area A substantially equal to the product of the pitch p of the turns times the operating radian length L of the system. While a rigorous proof may be given to show that such a helical conductor inherently causes the corresponding fields of the two waves of crossed polarization to be in phase quadrature in time, this may be deduced from the simple relation (2). From that equation it is seen that the ratio of the two fields involves the first power of the radian length or frequency which is inevitably associated with the relationship of time-phase quadrature. The direction of rotation of the circular polarization depends on the phase sequence of the cross components of the radiation fields of the electric and magnetic dipoles and is determined by the sense in which the coil is pitched. The radiation pattern is doughnut-shaped, coaxial with the helix.

Where the turns of the helical conductor 10 are identical, each must be proportioned in accordance with Equation 2. However, it is not necessary that the turns be identical because approximately circular polarization is achieved so long as the area of the average conductor turn and the average pitch of the several turns are related to the radian length in the manner of Equation 2, assuming nearly the same current in all turns.

The foregoing relations for circular polarization are based upon the assumption that all of the radiation comes from the helical conductor 10 and assume uniform current distribution around each turn of the helix. The latter assumption requires that each turn be much less than the resonant length of the conductor, which is approximately one-half wave length. Ideally, a self-resonant helical conductor should be small enough so that the resonant length of the conductor is wound in a substantial number of turns and this means a coil radius which is a small fraction of the operating radian length. A conductor of one-half wave length wound in accordance with the critical relation of expression (2) may define a helix having a radius a and an axial length b as follows:

$$a=\frac{2}{\pi}b=\frac{L}{2n} \qquad (3)$$

$$b=\frac{\pi}{2}a=\frac{\pi L}{4n} \qquad (4)$$

In Equations 3 and 4 the factor n is the number of turns of the helix. An antenna conductor of this shape inherently provides substantially circular polarization. The conductor thickness may be a substantial fraction of the pitch as is customary in helical-coil construction.

In connecting signal-translating apparatus to an antenna of the type represented in Fig. 1*a*, certain precautions are to be taken in order to avoid destroying the circular polarization by the presence of other radiations which may be caused by the feed connections. In Fig. 2*a*, for example, the helical antenna is utilized in a balanced system and balanced connections are made to terminals in the vicinity of the mid-point of the radiator by means of a balanced transmission line 11 of the open-wire type having closely spaced conductors. An inductive loop 12 connected to one end of the transmission line serves to couple this line and the antenna to a signal-translating apparatus 13, shown in block diagram since the nature of that apparatus is immaterial to the operation of the antenna. Antenna systems exhibit the same characteristics when utilized either for wave-signal reception or transmission and, therefore, the unit 13 may constitute either a receiver or a transmitter in accordance with the requirements of the particular installation.

Some economy of space may be obtained by curtailing the ends of the helical conductor 10 which make a very small contribution to the total radiation and by replacing them with capacitive loading. This is represented by the arrangement of Fig. 2*b* which is generally similar to that of Fig. 2*a*, corresponding components thereof being identified by the same reference characters. The coil 10 of Fig. 2*b* has a shorter length than is required for self-resonance at the operating wave length but resonance is achieved by loading. For this purpose each end has capacitive loading in the form of nonradiating radial conductive spokes 14, 14 disposed in a plane transverse to the axis of the helix. The spokes contribute a negligible amount of radiation and do not adversely affect the desired circular polarization.

The modifications of Figs. 2c and 2d are also directed to balanced antenna systems but of the type in which the helical conductor has a length exceeding that required for self-resonance. Capacitive reactance means are associated with the radiator 10 for tuning out the excess reactance and for establishing a condition of self-resonance at the operating wave length. In Fig. 2c, this capacitive reactance means is shown as series condensers 15, 15 interposed between the center terminals of the antenna conductor and the signal-translating apparatus 13. In the modification of Fig. 2d, the helix is even longer and its excess inductive reactance is tuned out at intervals by series condensers 16, 16 separated, preferably, by a length of conductor of approximately one-quarter wave length or less so that the current in between is nearly uniform.

In the arrangement of Fig. 3a the helical conductor 10 represents schematically a radiating structure of the type represented in any of Figs. 2a–2d, inclusive. It is connected through a balanced transmission line of the open-wire type 20 to a signal-translating apparatus 21. The length of transmission line 20 is approximately one-half of the operating wave length and it projects axially within the radiating structure to be connected by very short lead lengths to central terminals 22, 22. Stub transmission lines 24, 24 are also included in the balanced conductor system employed for feeding the antenna so as effectively to isolate unbalanced currents of this conductor system from the radiating structure. Each of the stub lines is connected at its near end to the balanced line 20 and is short-circuited at its far end. Also, each has an electrical length of one-quarter of the operating wave length. A generally similar arrangement is represented in Fig. 3b but modified so as to preserve the symmetry. In particular, the transmission line 20 extends entirely through the radiating structure and additional stub lines 25, 25 connected thereto maintain the balance of the system. In the arrangements of Figs. 3a and 3b capacitive currents which may flow between the radiating structure and transmission line 20 are unbalanced on the transmission line and tend to cause some radiation opposing the electric dipole radiation of the structure 10. Where this is encountered. It may be compensated by slightly increasing the pitch of the helix.

An unbalanced system is represented in Fig. 4. It again includes the conductive structure 10 in the form of a self-resonant helical coil and a nonradiating, conductive shield spaced from one end thereof. The shield is made of several radially extending conductive spokes 27, 27 extending transversely of the coil axis and individually having an electrical length of approximately one-quarter of the operating wave length. The transmission line 28 for connecting the signal-translating apparatus 29 with the antenna system is of the coaxial or unbalanced type. Its outer shield conductor is connected with the shield 27 while its inner conductor connects with the lower end of the helical conductor 10.

All of the described embodiments of the invention utilize an antenna structure in the form of a multiturn helical conductor or coil. To obtain an increased radiation power factor and higher efficiencies, the dimensions of the antenna should be comparable with the radian length. To secure this result in a helical antenna with a length of wire consistent with half-wave resonance, the helix must be made of very few turns or even a fraction of one turn. For this purpose a multifilar conductive structure of the type represented in Figs. 5a and 5b may be used.

As illustrated, the multifilar structure includes a plurality of similar coaxial conductors of helical configuration, four such conductors being shown and being indicated by the reference characters 35, 36, 37, and 38. In order to maintain the axial symmetry of current distribution, the several conductors are symmetrically arranged relative to their common axis and are connected in parallel at the opposite poles of the electromagnetic dipole. Fig. 5b which is an end view of the multifilar structure shows the end terminations 35′, 36′, 37′, and 38′ of the several conductors and their arrangement as radial spokes connected together at a central hub indicated 40. The conductors are all of the same length, and, preferably, do not exceed one turn, a length of one-half turn being represented. This length corresponds to one-half the operating wave length and causes the helical structure to be self-resonant. The conductor thickness may be a substantial fraction of the circumferential separation so long as the thickness is not made so great as to obstruct the magnetic field or cause excessive capacitance. The radial spokes formed at the poles of the electromagnetic dipole in order to connect the wires in parallel in a desired manner do not radiate in any appreciable amount but do constitute a capacitive loading. Each conductor is proportioned to satisfy the basic relation of Equation 2 but for a fractional-turn embodiment the pitch becomes greater than the axial length of the multifilar structure. The formulas of Equations 3 and 4 are not applicable to the multifilar construction because a substantial part of the length of each conductor is used in the end spokes. Also, the diameter may slightly exceed the radian length so that the assumed equivalence of small dipoles is inadequate. For the self-resonant half-turn construction of Fig. 5, the radius and axial length for circular polarization are approximately six-tenths the radian length.

There is an optimum fractional number of turns and a corresponding optimum shape for the self-resonant multifilar structure to achieve maximum radiation power factor and maximum efficiency. The optimum number of turns is in the range from one-quarter to one turn and the optimum shape has an axial length about equal to the radius.

The multifilar modification simulates a helical coil of n turns, where n is the number of turns included in each parallel-connected conductor of the multifilar structure and is a fraction less than unity. The number of conductors connected in parallel to simulate n effective turns is preferably at least equal to $2/n$. For example, a structure for one-half turn effective should have at least four conductors connected in parallel, as represented in Fig. 2, but a larger number may be employed if practical. In general, an improvement of radiation power factor and efficiency are realized with an increased number of parallel-connected conductors.

The multifilar structure operates in a manner generally similar to that of the multiturn coil of Fig. 1a. The dash-dot construction line of Fig. 5a represents an imaginary cylinder bounding the structure and the area of that cylinder is the factor A to be utilized in proportioning the conductors to satisfy Equation 2.

Connections to the structure of Fig. 5a may be established in several ways, for example, as indicated in Figs. 6a and 6b. It should be noted, however, that the multifilar structure in these representations has been simplified by unwinding the helixes. This showing has been chosen in an effort to clarify the disclosure.

In Fig. 6a, a signal-translating apparatus 44 is connected to the conductive structure through a balanced transmission line 41 connected to center terminals 42, 42 of only one of the parallel-connected conductors. In the arrangement of Fig. 6b, the balanced transmission line 41 is tapped on one of the parallel-connected conductors at separated points in order to obtain an impedance match. Series condensers 43 may be utilized to cancel the reactance components of the impedance between the tapping points. If desired, an unbalanced connection of the type shown in Fig. 4 may be made to the multifilar structure and self-resonance may be obtained by selecting the several conductors of the proper length or by loading in the manner of Figs. 2b and 2c.

The several modifications of the invention represented in Figs. 1–6, inclusive, have small physical dimensions and require but a small space for any installation. At the same time, each conductor of the conductive structure contributes to both of the crossed field components in a manner which inherently provides circular polarization with one direction of rotation. In a complete communication system of the direct-signal type, wherein a signal from a transmitting antenna is directly intercepted by a receiving antenna without any intervening reflection, like antennas are to be employed. That is, the helical conductors of the receiving antenna are to be pitched in the same sense as those of the transmitting antenna. On the other hand, where it is desired to detect reflected signals and to reject direct ones, the conductors of the receiving and transmitting antennas are to have opposite pitches. The discrimination between direct and reflected signals results from the fact that a circularly polarized radiation reverses its direction of rotation upon reflection.

Reception of signals of various origins and over various transmission paths may be accomplished in a diversity receiving system in the manner of Fig. 7. In this figure one antenna structure 50 including helical conductors pitched in one sense is connected to a first diversity receiver 51 while a second antenna structure 52, having helical conductors of an opposite pitch, is connected with a second diversity receiver 53. The structures 50 and 52 may have any of the forms described above. The output circuits of the receivers 51 and 53 are connected in parallel with a common signal-reproducing device 54 in the usual fashion. The common receiving portion 54 contains the mixing and switching circuits customarily utilized in diversity reception. Since the individual antenna structures 50 and 52 are reversely pitched, the system may respond to wave signals of circular polarization having either direction of rotation, as well as signals of plane polarization at any angle.

For convenience of explanation, all structures of the drawings, except that of Fig. 7, have been described principally in connection with wave-signal transmission. As already indicated, the functions of reception and transmission with any such antenna are unavoidably associated by the reciprocity theorem. Therefore, such terms as "radiating conductor," "radiation with circular polarization" and similar expressions are used in the text and in the appended claims in a generic sense to define an antenna structure in accordance with the invention whether that antenna be utilized for signal transmission or reception. Additionally, the term "area" of the claims is intended to have the meaning set forth in the definitions associated with Equation 1.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. An antenna system comprising: a conductive structure having a maximum dimension much less than one-half of the operating wave length, including at least one conductor of helical configuration and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system, whereby said antenna system exhibits the property of radiation with substantially circular polarization.

2. An antenna system comprising: a conductive structure having a maximum dimension much less than one-half of the operating wave length and being approximately self-resonant at said operating wave length, said structure including at least one conductor of helical configuration, and being proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

3. An antenna system comprising: a conductive structure having a maximum dimension much less than one-half of the operating wave length, including at least one conductor of helical configuration and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; and a substantially nonradiating conductor system for connecting signal-translating apparatus with said structure; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

4. An antenna system comprising: a radiating conductor of helical configuration having a maximum dimension much less than one-half of the operating wave length, including a plurality of conductor turns and proportioned so that the average turn has an area substantially equal to the product of the average pitch of said turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

5. An antenna system comprising: an antenna conductor of helical configuration the dimensions of which are less than the operating radian length of said system, including a plurality of conductor turns and proportioned so that the average turn has an area substantially equal to

the product of the average pitch of said turns times said radian length; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

6. An antenna system comprising: an antenna conductor of helical configuration having a maximum dimension much less than one-half of the operating wave length, having a helical radius which is a small fraction of the operating radian length of said system, including a plurality of conductor turns and proportioned so that the average turn has an area substantially equal to the product of the average pitch of said turns times said radian length; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

7. An antenna system comprising: an antenna conductor of helical configuration having a maximum dimension much less than one-half of the operating wave length, including a plurality of conductor turns, having a length substantially less than required for self-resonance at said operating wave length, and proportioned so that the average turn has an area substantially equal to the product of the average pitch of said turns times the operating radian length; and nonradiating conductive means connected to the opposite ends of said conductor for capacitively loading said conductor to cause said conductor to be substantially self-resonant at said wave length; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

8. A balanced antenna system comprising: a conductive structure having a maximum dimension much less than one-half of the operating wave length, including at least one conductor of helical configuration and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; and a substantially nonradiating balanced conductor system for connecting signal-translating apparatus in balanced manner to the mid-point of said structure; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

9. An unbalanced antenna system comprising: a conductive structure having a maximum dimension much less than one-half of the operating wave length, including at least one conductor of helical configuration and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; a shield spaced from one end of said structure including non-radiating, radial conductive spokes having a length of substantially one-quarter of said wave length and positioned in a plane transverse to the axis of said structure; and a coaxial transmission line for coupling signal-translating apparatus to said antenna system, having an inner conductor connected to said one end of said structure and an outer conductor connected to said shield; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

10. An antenna system comprising: a multifilar conductive structure having a maximum dimension much less than one-half of the operating wave length, including a plurality of similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

11. An antenna system comprising: a multifilar conductive structure having a maximum dimension much less than one-half of the operating wave length, including a plurality of similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure, having a thickness which is a substantial fraction of the circumferential spacing of said conductors, and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

12. An antenna system comprising: a multifilar conductive structure having a maximum dimension much less than one-half of the operating wave length, including a plurality of similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure, having a helical length not exceeding one turn and proportioned so that the average conductor turn of said structure has an area substantially equal to the products of the average pitch of the conductor turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

13. An antenna system comprising: a multifilar conductive structure having a maximum dimension much less than one-half of the operating wave length, including a plurality of similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure, having a helical length substantially equal to one-half turn and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

14. An antenna system comprising: a multifilar conductive structure having a maximum dimension much less than one-half of the operating wave length, simulating a helical coil with an axial length substantially equal to the helical radius and including a plurality of similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure. having a length within the range from one-quarter to one turn and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

15. An antenna system comprising: a multifilar conductive structure having a maximum dimen-

sion much less than one-half of the operating wave length, simulating a helical coil of (n) turns and including a plurality of at least ($2/n$) similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure, and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system where (n) is a fraction less than unity; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

16. An antenna system comprising: an antenna conductor of helical configuration having a maximum dimension much less than one-half of the operating wave length, including a plurality of conductor turns, having a length substantially less than required for self-resonance at the operating wave length of said system, and proportioned so that the average turn has an area substantially equal to the product of the average pitch of said turns times the operating radian length; and nonradiating, conductive, radial spokes connected to the opposite ends of said conductor for capacitively loading said conductor to cause said conductor to be substantially self-resonant at said wave length; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

17. An unbalanced antenna system comprising: a conductive structure having a maximum dimension much less than one-half of the operating wave length, including at least one conductor of helical configuration and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; a nonradiating conductive shield spaced from one end of said structure; and a two-conductor transmission line for coupling signal-translating apparatus to said antenna system, having one conductor connected to said one end of said structure and another conductor connected to said shield; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

18. An antenna system comprising: a multifilar conductive structure having a maximum dimension much less than one-half of the operating wave length, substantially self-resonant at said operating wave length and including a plurality of similar coaxial conductors of helical configuration symmetrically arranged relative to the common axis, connected in parallel at the poles of said structure, individually having a conductor length of substantially one-half of said wave length, and proportioned so that the average conductor turn of said structure has an area substantially equal to the product of the average pitch of the conductor turns times the operating radian length of said system; whereby said antenna system exhibits the property of radiation with substantially circular polarization.

19. An antenna system comprising: an antenna conductor of helical configuration having a maximum dimension much less than one-half of the operating wave length, including a plurality of conductor turns, having a length substantially different from that required for self-resonance at said wave length, and proportioned so that the average turn has an area substantially equal to the product of the average pitch of said turns times the operating radian length; whereby said antenna system exhibits the property of radiation with substantially circular polarization; and nonradiating loading means connected in series relation with said conductor and proportioned to cause said conductor to be substantially self-resonant at said wave length.

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