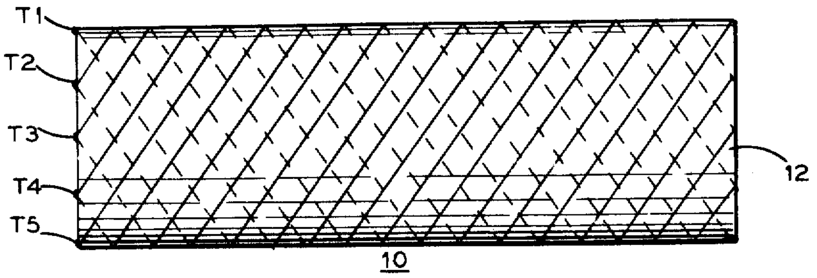
March 24, 1970 C. W. GERST **3,503,075**

HELIX ANTENNA WITH POLARIZATION CONTROL

Filed Oct. 28, 1966 3 Sheets-Sheet 1

FIG. 1



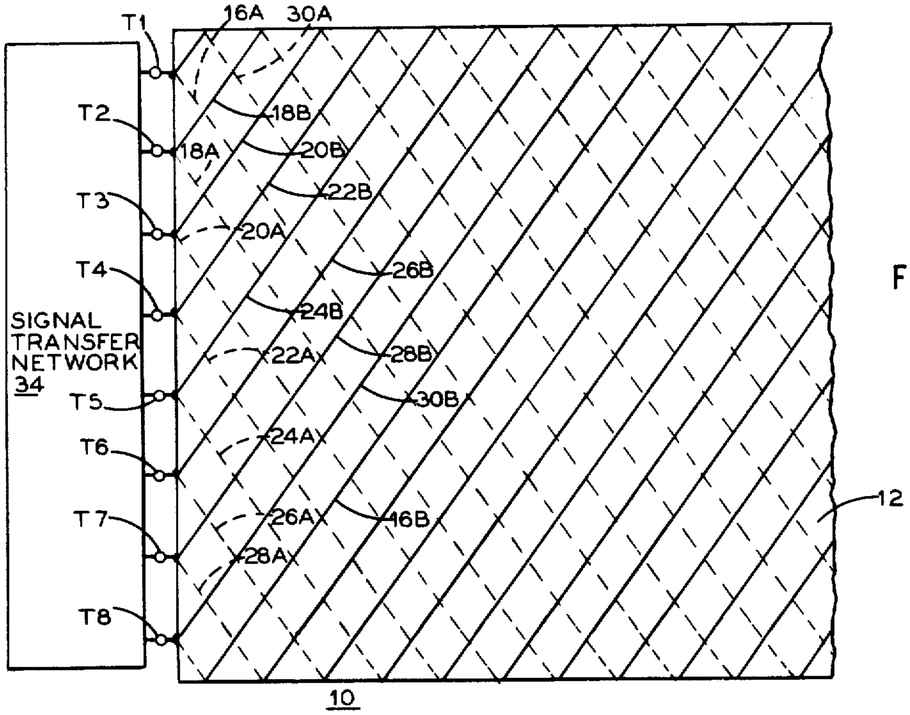
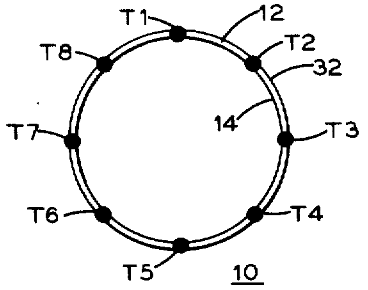


FIG. 2

FIG. 3



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ATTORNEYS

FIG. 4

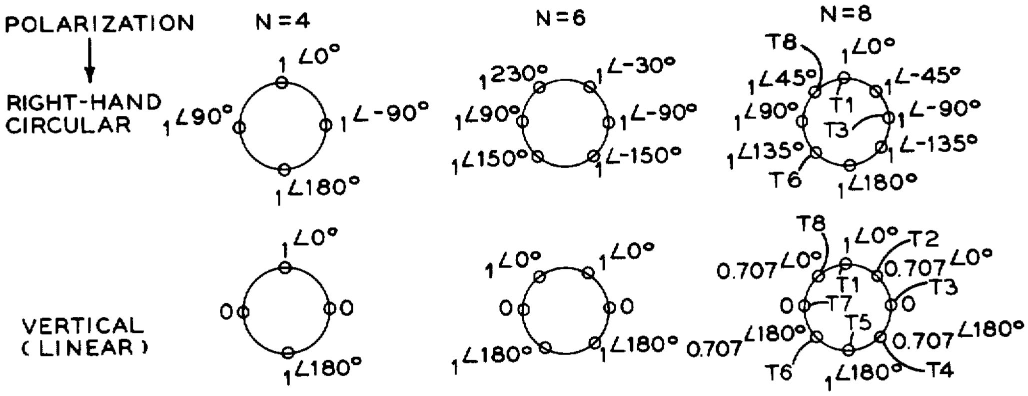

POLARIZATION
N=4
N=6
N=8
RIGHT-HAND CIRCULAR
1∠0°
1∠90°
1∠-90°
1∠180°
1∠230°
1∠-30°
1∠90°
1∠-90°
1∠150°
1∠-150°
T8
1∠0°
1∠45°
1∠-45°
1∠90°
T1
1∠-90°
T3
1∠135°
1∠-135°
T6
1∠180°
VERTICAL (LINEAR)
1∠0°
0
0
1∠180°
1∠0°
1∠0°
0
0
1∠180°
1∠180°
T8
1∠0°
T2
0.707∠0°
0.707∠0°
T1
T3
0
T7
0
T5
0.707∠180°
0.707∠180°
T6
1∠180°
T4

FIG. 5

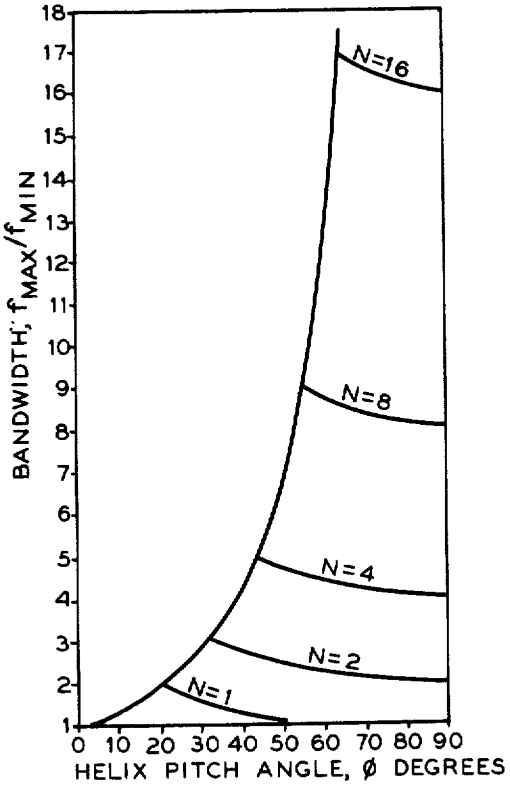

BANDWIDTH, f_{MAX}/f_{MIN}
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
N=16
N=8
N=4
N=2
N=1
0
10
20
30
40
50
60
70
80
90
HELIX PITCH ANGLE, ∅ DEGREES

FIG. 6

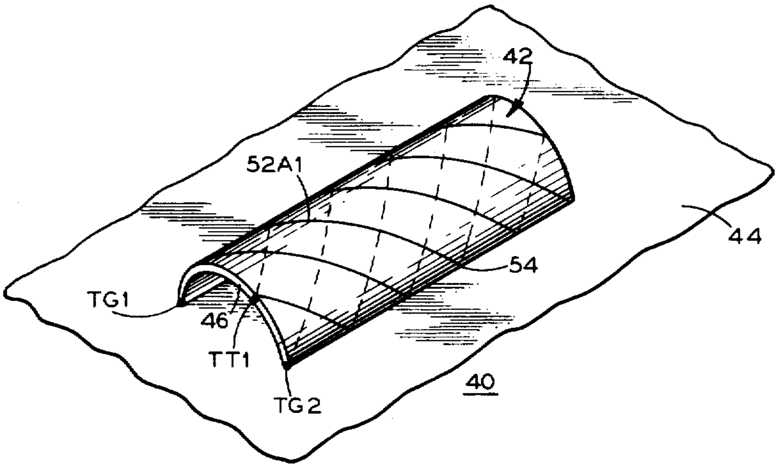


FIG. 7

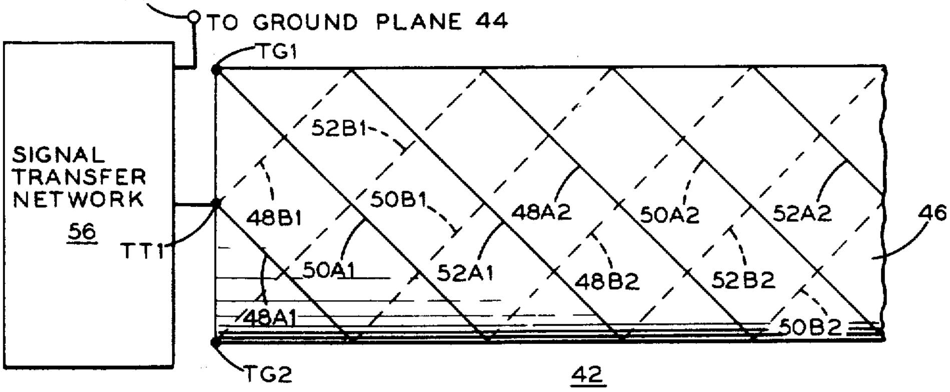
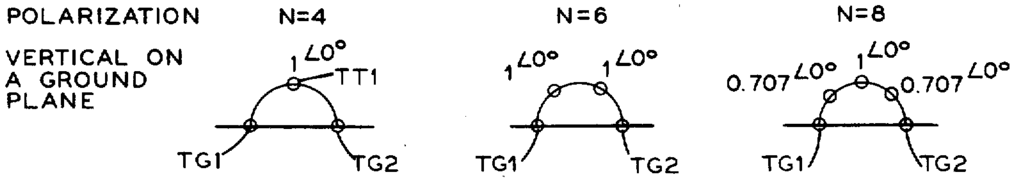


FIG. 8



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HELIX ANTENNA WITH POLARIZATION CONTROL

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Int. Cl. H01q *3/26*
U.S. Cl. 343—854 13 Claims

ABSTRACT OF THE DISCLOSURE

A broadband high gain antenna comprises a plurality of filament conductors wherein each conductor is a pair of counterwound helical windings connected at one end. The connected ends of the helical windings are fed with differently phased signals to achieve different types of polarization.

This invention pertains to helix antennas and more particularly to high-gain broadband multifilar helix antennas.

Many antennas require both high gain and broad bandwidth. Generally, both requirements cannot be satisfied and some compromises must be made. Even after making these compromises the antenna may be too bulky for many applications.

For example, the most commonly used commercial television receiving antenna is a log-periodic antenna designated to operate between 50 and 350 mhz. for receiving the VHF (very high frequency) channels 2 to 13 and F-M broadcasts. Such an antenna is about thirteen feet long and about ten feet wide at its widest point. If the television receiver is also to receive the UHF (ultra high frequency) channels two log-periodic antennas must be stacked on a single mast to handle both bands since a single antenna cannot operate over the combined bandwidth. One of the antennas is designed to receive the VHF band while the other is designed to receive the UHF band.

In many military communications, telemetry and tracking applications, polarization diversity is required. The radiation being transferred may be switched between different directions of linear polarization or different senses of circular polarization depending on atmospheric conditions and interference. It is, therefore desirable and often necessary to have an antenna which can efficiently operate with all modes of polarization.

It is, accordingly, a general object of the invention to provide an improved high-gain broadband antenna.

It is another object of the invention to provide an improved high-gain broadband antenna which is smaller than presently available broadband antennas and antenna systems.

It is a further object of the invention to provide an improved high-gain broadband antenna to replace the log-periodic antenna currently used with commercial television receivers.

It is a still further object of the invention to provide a universal antenna that can operate with radiation that is circularly polarized in either sense or that is linearly polarized in either of two orthogonal directions.

It is a still another object of the invention to satisfy any or all of the above objects with an antenna which is easily inexpensively fabricated utilizing printed circuit techniques.

Briefly, in accordance with one aspect of the invention there is contemplated a broadband high gain helix antenna comprising a plurality of filament conductor means. Each of the filament conductor means includes a pair of windings which are helically and mutually counterwound about a common axis. One of the windings of each pair of windings has a first end substantially adjacent a first end of the other winding of the pair. There are a plurality of signal transfer terminal means, each of which is connected to the first ends of one of the pairs of windings respectively.

Viewed differently, the antenna comprises a first plurality of similar helical filament conductors interwound in the same first direction about a common axis and a second plurality of helical filament conductors similar to the first plurality and interwound in the same second direction, opposite to the first direction, about the common axis. The first and second pluralities of helical filament conductors are in coaxial proximity and insulated from each other. A plurality of signal transfer terminal means are connected to adjacent ends of a helical filament conductor of each of the first and second pluralities.

Such an antenna, in addition to having a bandwidth capability which is comparable with any previously known antenna, has many other advantages. It has much higher gain and greater directivity than the usual end-fire array of the same electrical length. It is more versatile than heretofore known antennas since there is available polarization diversity. The polarization of the radiation can be controlled to be linear, elliptical or circular by merely changing the signal feeding network of the antenna. Furthermore, the diameter of the antenna is much smaller than the usual antenna. In fact, reduction in diameter of greater than five-to-one is obtainable over conventional helix or log-periodic antennas.

While such dramatic diameter reductions are obtainable there are some instances which require as small a diameter as possible. In high speed aircraft and missiles, protrussions from the aerodynamic surfaces of the vehicles introduce turbulences and drag. Therefore, such vehicles require extremely low profile antennas.

It is, therefore, an object of another aspect of the invention to provide an improved end-fire high-gain antenna which when mounted on the aerodynamic surface of an aircraft introduces little aerodynamic drag.

It is another object of this aspect of the invention to provide a broadband high-gain antenna for mounting on an aircraft wherein the antenna has a small diameter and a low profile.

Generally, the low-profile antenna can be considered as one half of the helix antenna described above wherein the half of the antenna on either side of a radial plane is mounted on a conductive ground element.

More particularly, the aspect of the invention contemplates a high-gain wideband antenna comprising an electrically conductive ground plane. On the ground plane are at least a first serial array of partial helical turns disposed about a common axis in a first helical rotation direction and spaced from each other in mutually parallel relationship along the common axis, and at least a second serial array of partial helical turns disposed about the same common axis in a second and opposite helical rotation direction and spaced from each other in mutually parallel relationship. The arrays are coextensive along the common axis. At least the ends of the intermediate partial helical turns are coplanar with and connected to the electrically conductive ground plane. Signal transfer is obtained by signal transfer terminal means connected to the outermost ends of the partial helical turns at the same end of each of the serial arrays.

Such antennas are ideally suited for mounting on aircraft since they can have diameters of less than one-twentieth of an operating wavelength or less than one-fifth the diameter of a conventional helix antenna and their ground plane elements can be directly incorporated in a metallic aerodynamic surface.

It should be noted that the antennas according to both aspects of the invention will be described for the purposes of transmission of electro-magnetic energy. However, since they are reciprocal devices, the antennas can be equally used for the reception of electromagnetic energy.

Other objects, the features and advantages of the invention will be apparent from the following detailed description when read with the accompanying drawings which show, by way of example and not limitation, the now preferred embodiments of the invention.

In the drawings:

FIGURE 1 shows a side view of a multifilar counterwound helix antenna developed about a cylindrical support member;

FIGURE 2 shows a top view of the antenna of FIGURE 1 with the support member cut along a line parallel to the cylinder axis and flattened into a plane to show the orientation of the windings;

FIGURE 3 shows an end view of the antenna of FIGURE 1;

FIGURE 4 shows graphically the amplitude and phase relationships of signals at signal transfer terminals connected to the antenna windings for various winding configurations of the antenna of FIGURE 1;

FIGURE 5 is a graph of bandwidth as a function of pitch and the number of windings for antennas constructed according to the teaching of FIGURE 1;

FIGURE 6 is a perspective drawing of a variation of the antenna of FIGURE 1 which employs a ground plane element;

FIGURE 7 shows a top view of the antenna of FIGURE 6 when flattened into a plane; and

FIGURE 8 shows graphically the amplitude and phase relationships of signals at signal transfer terminals connected to the antenna windings for various winding configurations of the antenna of FIGURE 7.

Referring now to FIGURES 1, 2 and 3, a multifilar helix antenna **10** is shown as a plurality of counterwound helical conductors. In particular, antenna **10** comprises a sheet of insulating material **12** which is preferably formed into a right circular cylinder. Fixed on the inner surface **14** of sheet **12** are eight similar helical filament conductors **16A** to **30A** or windings helically wound, say clockwise, about the common cylindrical axis. Fixed on the outer surface **32** of sheet **12** are eight similar helical filament conductors **16B** to **30B** or windings helically wound, counterclockwise, about the common cylindrical axis. It should be noted that each pair of helical filament conductors or windings such as **18A** and **18B** start from a common point at one of their ends and progress as a pair of counterwound helices about the cylinder axis to form a filament conductor means. Connected to the common point of each winding pair is a signal transfer terminal **T**. For example, the terminal **T1** is connected to helical filament conductors or windings **16A** and **16B** of the filament conductor means **16**.

The antenna as described is octafilar, that is, there are eight pairs of windings wherein each pair defines a filament conductor means. As little as three filament conductor means can be employed. The upper limit on the number of filament conductor means or pairs of windings is only determined by the mechanical aspects of manufacture. Generally, it can be stated that the gain G of the antenna is determined by the following equation:

$$G=\left(\frac{2L}{\lambda}+1\right)K$$

L=antenna length
λ=operating wavelength
K=cell gain. Typically K=2

The bandwidth of the antenna is determined by the number of turns and the helix pitch angle of the helices defined by the windings. In FIGURE 5 there is shown a function of the number of filament conductor means and helix pitch angle. For example, antennas with 4 and 8 winding pairs and a pitch angle of 40 degrees would both have a bandwidth of 4:1. At a pitch angle of 50 degrees, the bandwidth would be 4.5:1 for a quadrifilar antenna and 7:1 for an actafilar antenna.

The versatility of the antenna **10** arises from its ability to handle electromagnetic radiation having different modes of polarization. In order to transmit each mode of polarization it should be realized that the multifilar counterwound helix antenna **10** can be considered as two cross-polarized antennas. With this being the case the mode of polarization is determined by the ampltiude and phase relations of the signals fed to the signal transfer terminals **T**.

FIGURE 4 graphically summarizes these relationships for quadrifilar, sexafilar and octafilar counterwound helix antennas. For example, for the octafilar antenna, in order to obtain right-hand circular polarization, each signal transfer terminal receives equi-amplitude signals which are mutually displaced in phase by 45 degrees. In fact, to obtain circular polarization the phase relationship is directly related to the angular position of the signal transfer terminal. In addition, left-hand circular polarization requires the same phase relationship as right-hand circular polarization, but the phase differences progress in the reverse order. Linear polarization is achieved by summing the amplitude and phase vectors for right and left-hand circular polarization. In order to transmit vertically polarized radiation from an octafilar counterwound helix antenna, terminals **T1** and **T5** should receive signals having a relative amplitude of 1, terminals **T3** and **T7** receive no signals, and terminals **T2, T4, T6** and **T8** reecive signals having a relative amplitude of 0.707. In addition, terminals **T8, T1** and **T2** have the same phase signals, and terminals **T4, T5** and **T6** receive the same phase signals which are 180 degrees out of phase with the signals received by the terminals **T8, T1** and **T2**. For horizontal polarization, it should be apparent that all terminals be "rotated" by 90 degrees.

The proper amplitude and phase relationships are obtainable by many well known networks and are, therefore, shown by the generalized signal transfer network **34** (FIG. 2) having outputs connected to the terminals **T1** to **T8**.

By realizing the symmetray properties of the multifilar counterwound antenna, as disclosed, it is possible to develop a low profile antenna.

Antenna **40** shown in FIGURES 6 and 7 can be considered as comprising a radial-plane-truncated multifilar counterwound antenna element **42** connected to ground-plane element **44**. Element **42** comprises a hollow half cylinder **46** of insulating material having inner and outer surface portions. Fixed to the outer surface portion of cylinder **46** are the serial arrays **84A, 50A** and **52A** of conductive filaments. A typical array comprises conductive filaments **48A1, 48A2,** . . . each of which is a partial helical turn which is diameter-truncated to form a semihelical turn about the axis of the half cylinder. The partial turns of the arrays are interleaved. They are rotationally displaced from each other, i.e., the start point of the terminal turns such as **48A1** and **50A1** are at different angular positions. All of the turns, however, have the same helical winding sense, say clockwise. Fixed to the inner surface portion of cylinder **46** are the serial arrays of conductive filaments. A typical array comprises conductive filaments **48B1, 48B2,** . . . each of which is also a partial helical turn which is diameter-truncated to form a semihelical turn in a counter-clockwise direction about the cylindrical axis. Again the partial turns of the arrays are interleaved and rotationally displaced from each other. Both ends of each of the intermediate turns such as turns **52A1, 48A2, 50A2, 48B2,** etc., have both ends connected to the ground plane **44**. Note, for example, the end of the turn **52A1** contacts the ground plane **44** at point **54** as does the end of turn **52B2**. In this way mirror symmetry is obtained with respect to the ground plane **44**.

Each of the start turns such as turns **48A1** and **48B1** of the arrays are connected to a signal transfer terminal such as terminal TT1. It should be noted that the ends of start turns such as turns **50A1** and **52B1** are theoretically connected to signal terminals TG. However, these terminals merge with the ground plane **44**.

Generally, antenna **40** has the same gain and bandwidth properties of antenna **10** of FIGURE 1. Therefore, the discussion will not be repeated. except to say that the number of winding pairs is indicated by taking into account the mirror effect introduced by the ground plane. For example, although the actual embodiment shown in FIGURES 6 and 7 can be realized as having three pairs of windings, i.e., a pair extending from each of the terminals TG1, TT1 and TG2, it is considered as a quadrifilar antenna. Electrically, an image terminal is considered diametrically opposite terminal TT1 with an image pair of windings extending therefrom.

Vertical polarization can be obtained from antenna **40** by suitably feeding the signal transfer terminals. Accordingly, FIGURE 8 shows diagrammatically, in the same manner as FIGURE 4, the required amplitude and phase relationship. Since the same theory applies, the discussion will not be repeated. The required signals are obtained from signal transfer network **56** whose outputs are connected to the signal transfer terminals TT and TG.

There has thus been shown improved high-gain broadband antennas which accomplish their objects by utilizing multifilar counterwound helical conductive filaments. With such antennas greater gain and broader bandwidth are obtainable over heretofore available antennas such as log-periodic antennas. In fact, it is a property of these antennas that gain actually increases with frequency.

Furthermore, ease of fabrication is obtainable since the filament conductors can be actually printed on hollow cylindrical substrates using conventional printed circuit techniques. However, it should be realized that no insulating support is electrically required for the filament conductors. The cylinders of insulating material are merely used for mechanical support. If the filament conductors are sufficiently rigid they can be mounted in free-standing relationship from their appropriate transfer terminals. Similarly, all the filament conductors can be disposed on the same side of the insulative sheet provided the filaments are mutually insulated at the geometric crossovers.

While only a limited number of embodiments of the invention have been described in detail there will now be obvious to those skilled in the art many modifications and variations which satisfy many or all of the objects of the invention, but which do not depart from the spirit thereof as defined by the appended claims.

What is claimed is:

1. A broadband high-gain end-fire helix antenna comprising: a plurality of filament conductor means, each of said filament conductor means including a pair of windings which are helically and mutually counterwound about a common axis, one of the windings of each pair of windings having a first end substantially adjacent a first end of the other winding of the pair, each of said windings being electrically insulated from every other windings; and a plurality of signal transfer terminal means being connected to the first ends of one of the pairs of windings respectively.

2. The antenna of claim **1** comprising at least two filament conductor means, and wherein the helices defined by said windings having pitch angles of at least thirty degrees.

3. The antenna of claim **1** comprising at least four filament conductor means, and wherein the helices defined by said windings have pitch angles of at least forty degrees.

4. The antenna of claim **1** wherein all of said windings have the same common axis and said signal transfer terminal means are disposed at given angular positions about said common axis; and electrical signal phasing means connected to each of said signal transfer terminal means for introducing angles of phase shift in the signals passing therethrough related to the angular positions of the associated signal transfer terminal means.

5. The antenna of claim **1** further comprising a hollow tube of insulating material having inside and outside surface portions, and wherein all windings having the same first sense of rotation are disposed on the inside surface portion of said hollow tube and all the remaining windings having the same second and opposite sense of rotation are disposed on the outside surface portion of said hollow tube so that said windings are insulated from each other except at their associated signal transfer terminal means.

6. A broadband high-gain end-fire helix antenna comprising a first plurality of similar helical filament conductors interwound in the same first direction about a common axis and spaced from each other, a second plurality of helical filament conductors similar to said first plurality and interwound in the same second direction opposite to said first direction about said common axis and spaced from each other, said first and second pluralities being in coaxial proximity and insulated from each other, and a plurality of signal transfer terminal means, each of said signal transfer terminal means being connected to adjacent ends of a helical filament conductor of each of said first and second pluralities.

7. The antenna of claim **6** comprising at least two helical filament conductors in each plurality and wherein the helices defined by said helical filament conductors have pitch angles of at least thirty degrees.

8. The antenna of claim **6** comprising at least four helical filament conductors in each plurality and wherein the helices defined by said helical filament conductors have pitch angles of at least forty degrees.

9. The antenna of claim **6** wherein said signal transfer terminal means are disposed at given angular positions about said common axis; and electrical signal phasing means connected to each of said signal transfer terminal means for introducing angles of phase shift in the signals passing therethrough related to the angular positions of the associated signal terminals.

10. The antenna of claim **6** further comprising a hollow tube of insulating material having inside and outside surface positions and wherein said first plurality of helical filament conductors are disposed on said inside surface portion and said second plurality of helical filament conductors are disposed on said outside surface portion.

11. A high-gain wideband antenna comprising an electrically conductive ground plane, at least a first serial array of conductive filaments in the form of partial helical turns disposed about a common axis in a first helical rotation direction and spaced from each other in mutually parallel relationship along said common axis, at least a second serial array of conductive filaments in the form of partial helical turns disposed about said common axis in a second and opposite helical rotation direction and spaced from each other in mutually parallel relationship coextensive with said first serial array along said common axis, at least the ends of the intermediate partial helical turns being coplanar with and connected to said electrically conductive ground plane, and signal transfer terminal means connected to the outermost ends of the partial helical turns at the same end of each of said serial arrays.

12. The high-gain wideband antenna of claim **11** comprising a plurality of said first serial arrays which are rotationally displaced from each other about said common axis and a plurality of said second serial arrays which are rotationally displaced from each other about said common axis.

13. A broadband high gain end-fire helix antenna comprising an electrically conductive ground-plane element, at least similar first and second interleaved and rotationally displaced diameter-truncated helical filament conductors having a first winding sense about a common axis in said ground plane element whereby each of said helical filament conductors is a serial array of partial helical turns, having at least one end in contact with said conductive ground plane element, said first helical filament conductor starting at a first point in said ground-plane element, said second helical filament conductor starting at point outside said ground-plane element, at least third and fourth interleaved and rotationally displaced diameter-truncated helical filament conductors similar to said first and second helical filament conductors, said third and fourth helical filament conductors having a second and opposite winding sense about said common axis whereby each of said third and fourth helical filament conductors is a serial array of partial helical turns having at least one end in contact with said ground-plane element, said third helical filament conductor starting at a second point in said ground-plane element, said fourth helical filament starting at substantially the same point outside said ground plane element as said second helical filament, and a common signal transfer terminal means connected to the start of said second and fourth helical filament conductors.

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ELI LIEBERMAN, Primary Examiner

U.S. Cl. X.R.

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