Nov. 5, 1957 C. E. SMITH 2,812,514

SPIRAL SLOT ANTENNA

Filed April 14, 1953 2 Sheets-Sheet 1

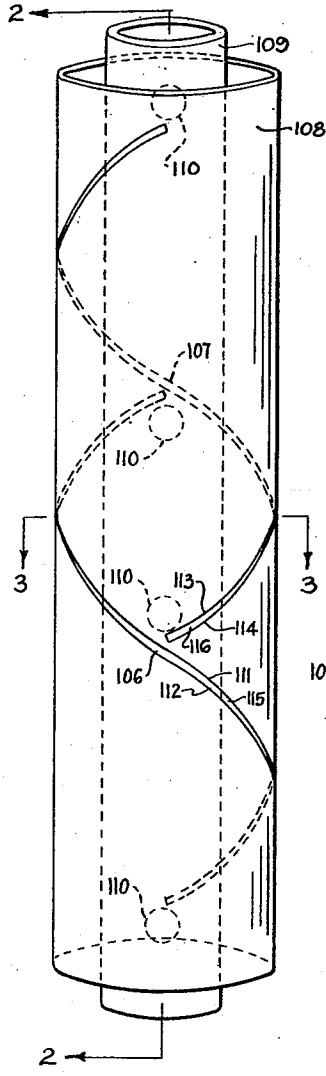


FIG. 1

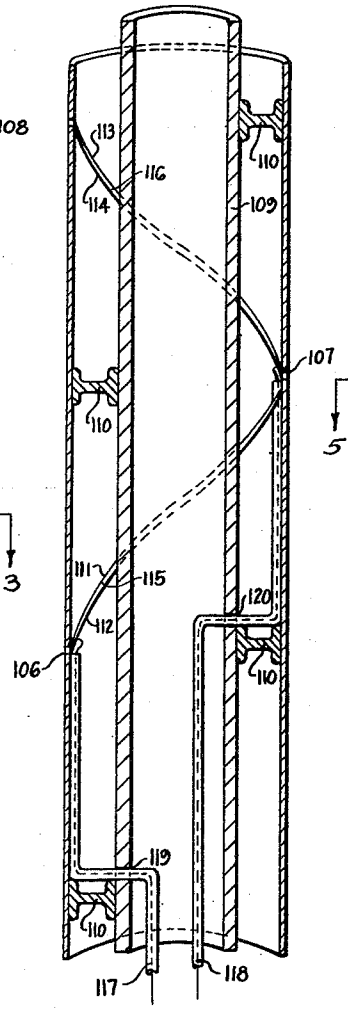


FIG. 2

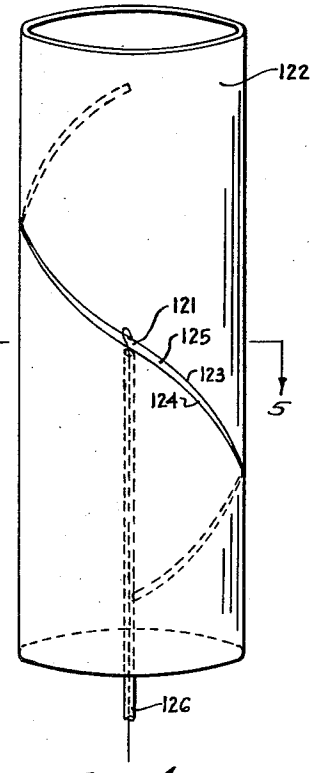


FIG. 4

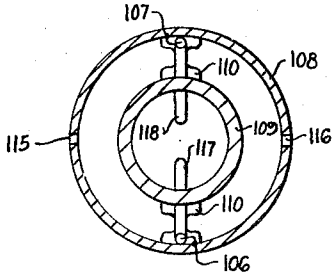


FIG. 3

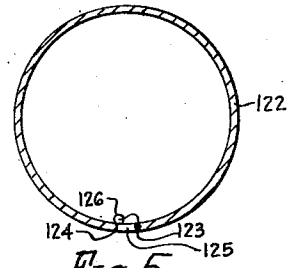


FIG. 5

INVENTOR
Carl E. Smith
BY
Woodling and Knox,
Attys.

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SPIRAL SLOT ANTENNA

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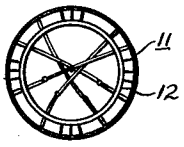


FIG. 7

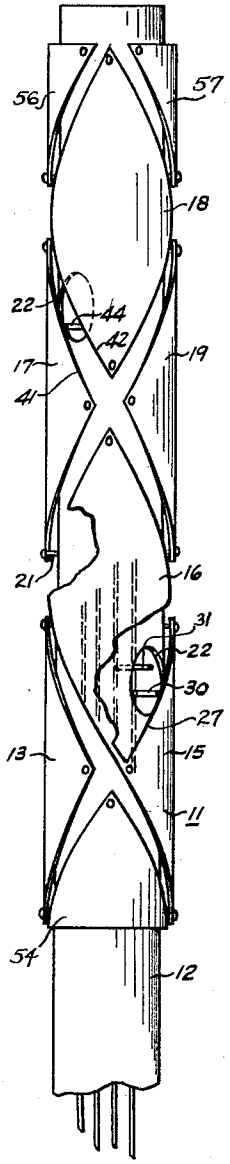


FIG. 6

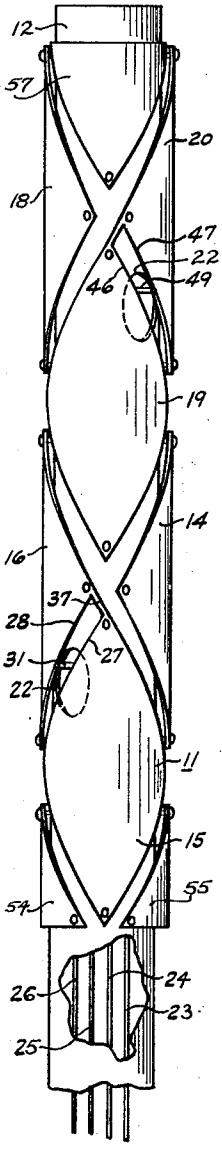
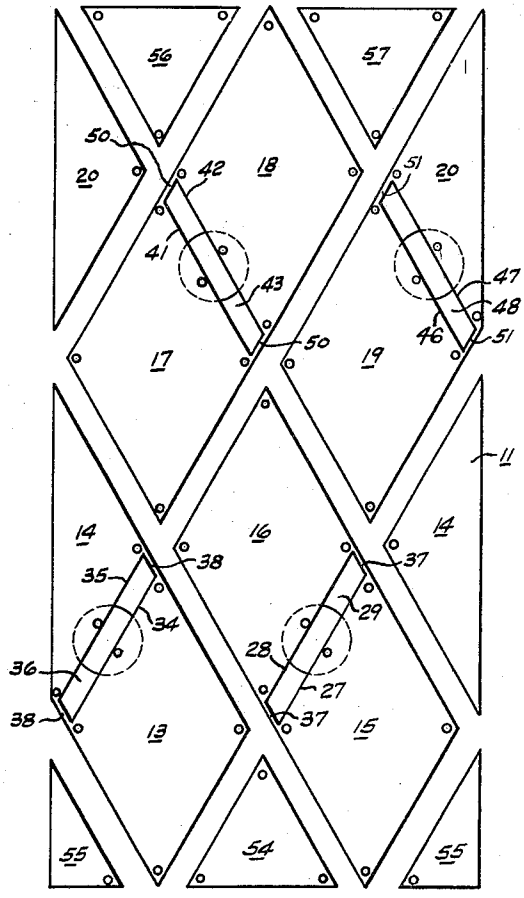


FIG. 8



DEVELOPMENT

FIG. 9

INVENTOR.

BY CARL E. SMITH

Woodling and Knost, attys.

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2,812,514

SPIRAL SLOT ANTENNA

Carl E. Smith, Cleveland Heights, Ohio

Application April 14, 1953, Serial No. 348,606

29 Claims. (Cl. 343—767)

The invention relates in general to antennas for use with electromagnetic wave energy, and more particularly to conduits or hollow cylinders having slots therein for the radiation of the radiant energy waves.

An object of the invention is to provide an antenna having a high gain in the horizontal plane, with low wind resistance and with greater flexibility of control of the horizontal field intensity pattern for a given number of feed lines than is possible with normal dipoles.

Another object of the invention is to provide an antenna having a uniform gain in the horizontal plane and which is capable of being vertically stacked to increase the gain in the horizontal plane.

Another object of the invention is to provide an antenna to radiate circularly polarized electromagnetic waves with the horizontal field intensity pattern highly controllable as to nulls and/or circularity.

A further object of the invention is to provide a hollow cylindrical antenna having a spiral slot for effecting radiation of electromagnetic waves having both horizontal and vertical components.

A further object of the invention is to provide a hollow cylindrical antenna having edges defining slot means with both a vertical and a horizontal component to effect circular polarization of the radiated electromagnetic wave with a high uniform gain in the horizontal plane.

A further object of the invention is to provide a hollow cylindrical antenna having a plurality of slots twisting in a first direction and a plurality of slots twisting in the opposite direction.

A further object of the invention is to provide a conduit means having spiral slots therein wherein the slots are connected to transmission lines which may be either open wire lines or coaxial cable.

Another object of the invention is to provide an electrically conducting conduit means having an axis with a first slot having a right hand spiral relative to the axis and a second slot having a left spiral relative to the axis and each connected to transmission lines of different phase in order to achieve an antenna coupled to free space for either elliptically polarized or circularly polarized electromagnetic waves.

Other objects and a fuller understanding of the invention may be had by referring to the following description and claims, taken in conjunction with the accompanying drawing, in which:

Figure 1 is a perspective view of a hollow cylindrical antenna having a right and left hand spiral slot;

Figure 2 is a cross-sectional elevational view taken along the line 2—2 of Figure 1;

Figure 3 is a cross-sectional view taken along the line 3—3 of Figure 1;

Figure 4 is a perspective view of a hollow cylindrical antenna having one spiral slot;

Figure 5 is a cross-sectional view taken along the line 5—5 of Figure 4;

Figure 6 is a front elevational view of another form of spiral slot antenna;

Figure 7 is an end view of Figure 6;

Figure 8 is a side elevational view of Figure 6; and

Figure 9 is a developed view of the spiral slot antenna of Figures 6 and 8.

The invention deals with antennas that have a slot or slots in a conduit, which conduit has been shown in the drawings and is preferably in the form of a hollow cylinder for the sake of symmetry. For further modifications of the invention reference may be had to the parent application filed October 16, 1947, entitled "Slotted Cylindrical Antennas," Serial No. 780,264, now Patent No. 2,665,381, issued January 5, 1954, of which this application is a continuation-in-part, and "Three Slot Cylindrical Antenna," filed October 16, 1947, Serial No. 780,265, now Patent No. 2,665,382, issued January 5, 1954. The preferred embodiment of the invention is shown in the Figures 1, 2, and 3 wherein two oppositely rotating spiral slots are fashioned in a hollow cylinder **108**. The cylinder **108** is shown as being supported by a mast **109**, and is fastened to the mast **109** by supports **110**. First and second edges **111** and **112** define a first slot **115**, which is a left hand spiral slot. Third and fourth edges **113** and **114** define a second slot **116**, which is a right hand spiral slot. The first and second spiral slots **115** and **116** are each made one wave length long, and each is inclined 45 degrees to the axis of the cylinder **108**. The diameter of the cylinder **108** has been chosen such that each slot **115** and **116** makes one complete revolution about the periphery of the cylinder **108**. The supports **110** that fasten the cylinder **108** to the mast **109**, are placed at a voltage minimum point of the antenna, which voltage minimum points are produced at points equidistant from the various slot edges. There are four such points in the antenna as shown in the Figures 1, 2, and 3, and the supports **110** have been located at such voltage minimum points. First and second coaxial cables **117** and **118** are used to feed the first and second slots **115** and **116**. These first and second coaxial cables **117** and **118** have been omitted from the perspective view of Figure 1 for the sake of clarity in this view. The first coaxial cable **117** extends through a hole **119** in the mast **109** at a point adjacent to one of the supports **110**, and electrically contacts the inner surface of the cylinder **108** at this point. The first coaxial cable **117** then extends upwardly to reach the mid-point **106** of the first spiral slot **115**. The outer shell of the coaxial cable **117** ends at the second edge **112**, and the inner conductor of the coaxial cable **117** extends across the slot **115** to connect to the first edge **111**. A second coaxial cable **118** extends through a hole **120** in the mast **109** adjacent to a support **110** and connects to the inner surface of the cylinder **108**. From this point adjacent the support **110** the coaxial cable **118** extends upward vertically to reach the mid-point **107** of the second slot **116**. The outer shell of the coaxial cable **118** ends at the fourth edge **114**, and the inner conductor of the coaxial cable **118** extends across the second slot **116** to connect to the third edge **113** at the mid-point **107**.

In the antenna of Figures 1, 2, and 3, it will be noted that the lower half of upper slot **116**, and the upper half of lower slot **115** together form a substantially continuous slot which is generally elliptical, and has parallel sides **111** and **112**, and **113** and **114**. Such substantially continuous slot extends completely around the antenna periphery, and is fed by the coaxial cables **117** and **118**. Thus because of this continuous slot, the cylindrical antenna **108** may be considered as being formed from an electrically conductive conduit defined by first and second sections, one above, and one below, the continuous slot.

The first and second slots **115** and **116** each have a horizontal component and a vertical component, and hence the electromagnetic wave emanating from the spiral slots have both vertical and horizontal components. The horizontal field intensity patterns of both the horizontal and vertically polarized electromagnetic waves of this antenna are very nearly circular.

The antenna shown in Figures 4 and 5 is a simplified version of the antenna shown in Figures 1, 2, and 3, inasmuch as the antenna comprises a cylinder **122** having only one spiral slot. First and second edges **123** and **124** define a slot **125** which has been shown as a left hand spiral slot. Slot **125** makes a 45 degree angle with the axis of the cylinder **122**. The length of the slot **125** has been made equivalent to one wave length, and the diameter of the cylinder **122** has been chosen such that the slot **125** will complete one revolution about the periphery of the cylinder **122**. A coaxial cable **126** is used to feed the slot **125**, and is shown as being fastened to the inner surface of the cylinder **122** and axially aligned therewith. The outer shell of the coaxial cable **126** ends at the mid-point **121** of the slot edge **124**, and the inner conductor of the coaxial cable **126** extends across the slot **125** to connect to the edge **123** at the mid-point **121**. A novel feature of the antenna shown in Figures 4 and 5 is that the cylinder **122** needs no separate support, the cylinder **122** may support itself. The slot **125** in the cylinder **122** simulates a slot formed in a hollow flagpole-like structure.

Satisfactory radiation may be obtained from the antenna shown in Figures 4 and 5, and substantially circular horizontal field intensity patterns of both the horizontal and vertically polarized waves may be attained.

The slots may be of any practical width and in practice are made sufficiently wide in order to develop the necessary potential difference thereacross without arcing. The slot width is also sufficient to prevent icing or bridging across the slot by sleet formation which would short the slot..

The Figures 6 to 9 show another form of the invention wherein an antenna **11** is carried on a mast **12**. The antenna **11** is particularly adapted for use with elliptically polarized or circularly polarized electromagnetic waves, either as a transmitting or a receiving antenna. The antenna **11** may be placed at any convenient height above the ground, and for this purpose the lower end of the mast **12** would be extended to the desired length. The Figure 9 shows a developed view of the diamond-shaped panels which form the antenna **11**, and in this view the mast has been removed for clarification. The antenna **11** is made from eight panels, **13** to **20**, inclusive. Each of the panels **13** to **20** is supported from the mast **12** by insulating spacers **21**. These spacers **21** are located at each corner of each panel. Four feed holes **22** are cut in the mast **12** to expose first, second, third, and fourth feed lines **23**, **24**, **25**, and **26**. The panel **15** has a side **27**, and the panel **16** has a side **28** which are adjacent to form a slot **29**. A feeder line **30** extends from the center of side **27** through one of the feed holes **22** and is connected to the first feed line **23**. A second feeder line **31** extends from the side **28** through the same feed hole **22** to the second feed line **24**.

The first panel **13** has a side **34** adjacent a side **35** on the panel **14** to form a second slot **36**. The center of the side **34** is connected by a feeder line, not shown, to the first feed line **23**; and the center of the second side **35** is connected by a feeder line, not shown, to the second feed line **24**. The panels **15** and **16** then become a dipole, and the panels **13** and **14** become another dipole; and these pairs of dipoles are energized in phase and in the same spiraling direction. Each of the slots **29** and **36** circumscribe approximately one-quarter of the periphery of the conduit and are approximately a half wave length long although they may be anywhere from four-tenths to seven-tenths of an effective wave length. It will be noted that straps **37** connect panels **15** and **16** to the ends of the slot **29** and that straps **38** connect the panels **13** and **14** at the ends of the slot **36**.

The panel **17** has a side **41**, and the panel **18** has a side **42** adjacent thereto to form a slot **43**. A feeder line **44** extends from the center of the side **41** through a feed hole **22** and is electrically connected to the third feed line **25**. Similarly, a feeder line, not shown, extends from the center of the side **42** to the fourth feed line **26**. The seventh panel **19** has a side **46**, and the eighth panel **20** has a side **47** adjacent thereto to form a slot **48**. A feeder line, not shown, extends from the center of the side **46** to the third feed line **25**, and a feeder line **49** extends from the center of the side **47** to the fourth feed line **26**. Straps **50** join the panels **17** and **18** at the ends of the slot **43**, and straps **51** join the panels **19** and **20** at the ends of the slot **48**.

Triangular panels **54**, **55**, **56**, and **57** are used at the top and the bottom of the antenna to complete the cylindrical antenna **11** but are only parasitic panels. If the antenna were to be extended upwardly, the triangular panels **56** and **57** would become diamond-shaped to form the next half dipoles. It will be observed that the panels **17** and **18** form a third dipole and the panels **19** and **20** form a fourth dipole, which are energized in phase and which spiral upwardly to the right which is a spiraling direction opposite that of the dipoles formed by panels **13**, **14**, **15**, and **16**. Also, the slots **43** and **48** between these panels each extends about one-fourth the way around the periphery of the antenna and spirals upwardly to the left.

The first and second feed lines **23** and **24** feed the lower dipoles **13** to **16**, and the third and fourth feed lines **25** and **26** feed the upper dipoles formed from the panels **17** to **20**. Thus, the feed lines **23** and **24** form one open wire line, and the feed lines **25** and **26** form another open wire line. Preferably, these two pairs of lines are connected in a 90 degree phase relationship in order to radiate circularly polarized electromagnetic waves in the event that the antenna **11** is used as a transmitting antenna.

The antenna **11** of Figures 6 to 9 is shown as being energized across the center of each slot **29**, **36**, **43**, and **48**. The panels may be energized at the corners as shown in the parent application Serial No. 780,264, but in this event the straps **37**, **38**, **50**, and **51** would need to be removed. The panel **13** and the panel **17** could be energized at their adjacent corners to become a vertical dipole, and the panels **14** and **16** could be energized at their adjacent corners to form a horizontal dipole. Similar connections could be formed between other panels to produce other dipoles.

The angle of the slots **29**, **36**, **43**, and **48** has been shown as being 60 degrees; however, this can be changed in order to control the ellipticity or circularity of the electromagnetic waves.

Although this invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. An antenna comprising, a conduit having a peripheral surface and a given resistivity, first and second spaced edges in the peripheral surface of said conduit defining a dielectric filled spiral slot therein of a different resistivity circumscribing at least half the periphery of said surface, and transmission line means connected across said edges.

2. An antenna comprising, a dielectric filled conduit having a peripheral surface and of a given resistivity, first and second spaced edges in the peripheral surface of said conduit defining a dielectric filled slot therein of a different resistivity and the lengthwise dimension of which slot extends both transversely half way around and longi-

tudinally in said conduit, and transmission line means connected across said edges.

3. An antenna comprising, an electrically conducting conduit, first and second spaced edges in said conduit defining a dielectric filled slot therein, the lengthwise dimension of which slot extends both transversely and longitudinally in said conduit with the transverse extension circumscribing at least one quarter of the periphery of said conduit, and transmission line means connected across said edges.

4. An antenna comprising, a hollow electrically conducting conduit, first and second substantially parallel edges in said conduit defining dielectric filled spiral slot means therein, said slot means and said conduit constituting the entire coupling between said antenna and the ambient for a substantially uniform radiation or reception pattern perpendicular to said conduit, and transmission line means connected across said edges.

5. An antenna for use with electromagnetic waves having horizontal and vertical components and having a substantially non-directional pattern in a given plane, said antenna comprising, a hollow electrically conducting conduit, means for mounting said conduit with the axis thereof perpendicular to said given plane, and substantially parallel edges in said hollow conduit defining twisting slot means extending substantially entirely around said conduit.

6. An antenna for use with electromagnetic waves having horizontal and vertical components and having a substantially non-directional pattern in the horizontal plane, said antenna comprising, a hollow electrically conducting conduit, means for mounting said conduit with the axis thereof in a vertical position, and first and second substantially parallel edges in said hollow conduit defining a twisting slot therein having first and second portions together substantially circumscribing said conduit.

7. An antenna for use with circularly polarized electromagnetic waves having a substantially non-directional pattern in the horizontal plane, said antenna comprising, a hollow electrically conducting conduit, means for mounting said conduit with the axis thereof in a vertical position, and first and second substantially parallel edges in said hollow conduit defining a slot therein which extends longitudinally in said conduit as well as transversely substantially entirely around said conduit.

8. An antenna for use with circularly polarized electromagnetic waves having a substantially non-directional pattern in the horizontal plane, said antenna comprising, a hollow cylindrical electrically conducting member, means for mounting said cylindrical member with the axis thereof in a vertical position, and first and second substantially parallel edges in said hollow cylindrical member defining a generally spiral slot therein extending at least half way around said member.

9. An antenna comprising, a dielectric filled conduit having a peripheral surface of a given resistivity, first and second spaced edges in the peripheral surface of said conduit defining a dielectric filled slot therein of a different resistivity, said slot extending in a general direction of forty-five degrees with the axis of said conduit, said conduit having a peripheral dimension such that said slot completes substantially one revolution around said conduit.

10. An antenna for use with electromagnetic waves comprising, a dielectric filled conduit having a peripheral surface of a given resistivity, first and second spaced edges in the peripheral surface of said conduit defining a dielectric filled slot therein of a different resistivity, said slot extending in a general direction of forty-five degrees with the axis of said conduit, said slot having a length substantially equal to an effective wave length of said electromagnetic wave, said conduit having a peripheral dimension such that said slot completes substantially one revolution around said conduit.

11. An antenna for use with circularly polarized electromagnetic waves having a substantially non-directional pattern in the horizontal plane, said antenna comprising, a hollow cylindrical electrically conducting member, means for mounting said cylindrical member with the axis thereof in a vertical position, first and second substantially parallel edges in said hollow cylindrical member defining a twisting slot therein, the lengthwise dimension of said twisting slot having an acute angle with the axis of said cylindrical member, said slot having a length at least thirty percent of an effective wave length of said electromagnetic wave, a transmission line having first and second conductors and being located within said hollow cylindrical member, and means for connecting said first and second edges to said first and second conductors, respectively, of said transmission line, said cylindrical member having a diameter such that said slot effectively extends completely around said cylindrical member.

12. An antenna for use with circularly polarized electromagnetic waves having a substantially non-directional pattern in the horizontal plane, said antenna comprising, a hollow cylindrical electrically conducting member, means for mounting said cylindrical member with the axis thereof in a vertical position, first and second substantially parallel edges only in said hollow cylindrical member defining a spiral slot therein, said spiral slot having an angle of forty-five degrees with the axis of said cylindrical member, said slot having a length substantially equal to an effective wave length of said electromagnetic wave, a transmission line having two conductors and being located within said hollow cylindrical member, and means for connecting the mid-point of each edge to one of each said two conductors of said transmission line, said cylindrical member having a diameter such that said slot completes one revolution around said cylindrical member.

13. An antenna for use with electromagnetic waves, said antenna comprising, a hollow cylindrical electrically conducting member, means for mounting said cylindrical member with the axis thereof in a vertical position, first and second substantially parallel edges in said hollow cylindrical member defining a first spiral slot therein, third and fourth substantially parallel edges in said hollow cylindrical member defining a second spiral slot therein having a reverse rotational direction relative to said first spiral slot, the lengthwise dimension of each said spiral slot having an acute angle with the axis of said cylindrical member, said slots having a length at least four-tenths of an effective wave length of said electromagnetic wave, said second spiral slot being axially displaced from said first spiral slot and peripherally positioned one hundred eighty degrees therefrom such that the end of said second spiral slot is adjacent the mid-portion of said first spiral slot, a first and a second transmission line each having two conductors and being located within said hollow cylindrical member, means for connecting each edge of said first slot to one of each of said two conductors of said first transmission line, means for connecting each edge of said second slot to one of each said two conductors of said second transmission line, said cylindrical member having a diameter such that said slots complete one revolution around said cylindrical member, and means for connecting said slots in an effective phase displacement of substantially ninety degrees.

14. An antenna for use with circularly polarized electromagnetic waves having a substantially non-directional pattern in the horizontal plane, said antenna comprising, a hollow cylindrical electrically conducting member, means for mounting said cylindrical member with the axis thereof in a vertical position, first and second substantially parallel edges in said hollow cylindrical member defining a first spiral slot therein, third and fourth substantially parallel edges in said hollow cylindrical member defining a second spiral slot therein having a reverse rotational direction relative to said first spiral slot,

each said spiral slot having an angle of forty-five degrees with the axis of said cylindrical member, said slots having a length substantially equal to an effective wave length of said electromagnetic wave, said second spiral slot being axially displaced from said first spiral slot and peripherally positioned one hundred eighty degrees therefrom such that the end of said second spiral slot is adjacent the mid-portion of said first spiral slot, a first and a second transmission line each having two conductors and being located within said hollow cylindrical member, means for connecting the mid-point of each edge of said first slot to one of each of said two conductors of said first transmission line, means for connecting the mid-point of each edge of said second slot to one of each said two conductors of said second transmission line, said cylindrical member having a diameter such that said slots complete one revolution around said cylindrical member, and means for connecting said slots in an effective phase displacement of substantially ninety degrees.

15. An antenna for use with electromagnetic waves comprising, a hollow cylindrical electrically conducting member, first and second substantially parallel edges in said hollow cylindrical member defining a first spiral slot therein, third and fourth substantially parallel edges in said hollow cylindrical member defining a second spiral slot therein having a reverse rotational direction relative to said first spiral slot, the lengthwise dimension of each said spiral slot defining an acute angle of sixty degrees with the axis of said cylindrical member, said slots having a length substantially equal to one-half an effective wave length of said electromagnetic wave, said second spiral slot being axially displaced from said first spiral slot and peripherally positioned therefrom, a first and a second transmission line each having two conductors and being located within said hollow cylindrical member, means for connecting the mid-point of each edge of said first slot to one of each of said two conductors of said first transmission line, means for connecting the mid-point of each edge of said second slot to one of each said two conductors of said second transmission line, said cylindrical member having a diameter such that each of said slots completes one-quarter revolution around said cylindrical member, and means for connecting said slots in an effective phase displacement of substantially ninety degrees.

16. A transducer for transferring electromagnetic wave energy between free space and an electrical device utilizing said electromagnetic waves, said transducer comprising electrically conducting conduit means, at least first and second substantially parallel edges in said conduit means defining slot means therein, said slot means having a narrow width relative to the length thereof, said slot means having a lengthwise dimension with a component aligned parallel to the axis of said conduit means and another component aligned transversely to the axis of said conduit means, the transverse component of the slot means extending at least one-fourth the distance around said conduit means, and transmission line means connected across said slot means.

17. A transducer for transferring electromagnetic wave energy between free space and an electrical device utilizing said electromagnetic waves, said transducer comprising electrically conducting conduit means, at least first and second substantially parallel edges in said conduit means defining slot means therein, said slot means having a narrow width relative to the length thereof, said slot means having a lengthwise dimension with a component aligned parallel to the axis of said conduit means and another component aligned transversely to the axis of said conduit means, the transverse component of the slot means extending substantially completely around said conduit means, at least part of said conduit means defining a single dielectric filled cavity for said slot means, and transmission line means connected across said slot means.

18. An antenna comprising electrically conducting conduit means having an axis, a plurality of substantially parallel edges in said conduit means defining a plurality of slots, said slots being other than axially parallel on the periphery of said conduit means, each of said slots having a length at least equal to four-tenths of said given wave length, said slots extending at least one-fourth the distance around the periphery of said conduit means, and transmission line means within the confines of said conduit means connected across the edges of said slots.

19. An antenna comprising electrically conducting conduit means having an axis, a plurality of substantially parallel edges in said conduit means defining a plurality of slots, said slots being equally spaced and other than axially parallel on the periphery of said conduit means, each of said slots having a length at least equal to a half of said given wave length, each of said slots extending substantially completely around the periphery of said conduit means, and transmission line means within the confines of said conduit means connected across the center of each of said slots.

20. An antenna for circularly polarized electromagnetic waves of a given wave length with a substantially circular horizontal field intensity pattern, said antenna comprising electrically conducting conduit means, means for mounting said conduit means with the axis thereof in a vertical position, first and second substantially parallel edges in said conduit means defining a first slot, third and fourth substantially parallel edges in said conduit means defining a second slot, said slots being substantially parallel and equally spaced on the periphery of said conduit means and other than axially parallel, each of said slots having a length at least equal to a half of said given wave length, first feed means within the confines of said conduit means connected across at least the center of each of said slots, fifth and sixth substantially parallel edges in said conduit means defining a third slot, seventh and eighth substantially parallel edges in said conduit means defining a fourth slot, said third and fourth slots being substantially parallel and equally spaced on the periphery of said conduit means and other than axially parallel, said first and second slots twisting in one direction and said third and fourth slots twisting in the opposite direction, each of said slots extending substantially completely around the periphery of said conduit means, second feed means within the confines of said conduit means connected across at least the center of each of said third and fourth slots, and phasing means for connecting said first and second feed means substantially ninety degrees out of phase.

21. An antenna comprising an electrically conductive conduit defined by first and second sections, the adjacent ends of said sections terminating in substantially parallel edges at an acute angle to the axis of said conduit to define an angular slot, one of said edges being electrically connected to one conductor of a feed line and the other edge being electrically connected to the other conductor of said feed line.

22. An antenna according to claim 21, in which a rigid pipe passes centrally through one antenna section and having a flange fastened to the inner periphery of said one section for support thereof, one conductor of said feed line passing out through said pipe, and means connecting the end of said one conductor to the inner periphery of the other antenna section.

23. An antenna for elliptically polarized field patterns, comprising cylindrical tubular means having edges defining two twisted slots together providing generally elliptical slot means extending substantially entirely around the antenna periphery, and coaxial feed line means having the outer conductor connected to the tubular means on one side of said slot means and the center conductor connected to the tubular means on the opposite side of said slot means.

24. An antenna for use with electromagnetic waves comprising, a hollow cylindrical electrically conducting member, first and second substantially parallel edges in

said hollow cylindrical member defining a first twisting slot therein, third and fourth substantially parallel edges in said hollow cylindrical member defining a second twisting slot therein having a reverse rotational direction relative to said first twisting slot, the lengthwise dimension of each said slot defining an acute angle with the axis of said cylindrical member, said first and second slots together extending substantially completely around said member, a first and a second transmission line each having two conductors and being located within said hollow cylindrical member, means for connecting each edge of said first slot to one of each of said two conductors of said first transmission line, means for connecting each edge of said second slot to one of each said two conductors of said second transmission line, and means for connecting said slots in an effective phase displacement of substantially ninety degrees.

25. An antenna for ellipticaly polarized electromagnetic waves, said antenna comprising electrically conducting conduit means, means for mounting said conduit means with the axis thereof in a vertical position, first and second substantially parallel edges in said conduit means defining a first slot, third and fourth substantially parallel edges in said conduit means defining a second slot, said first and second slots twisting in opposite directions and together forming slot means extending substantially completely around the periphery of said conduit means, and transmission line means within the confines of said conduit means connected across said slot means.

26. An antenna comprising a hollow cylinder having a surface the majority of which is conducting except for a narrow strip, said strip extending at an acute angle to the cylinder axis to extend at least one-half the distance around said cylinder, and transmission line means electrically connected to said conducting surface adjacent said strip.

27. An antenna comprising a three-dimensional body having a longitudinal axis, a conducting external surface on said body having edges defining narrow strip means, said strip means extending at an acute angle to said axis to extend at least one-fourth the distance around said body in a direction transverse to said axis to thus have longitudinal and transverse components, and transmission line means electrically connected to the edges of said strip for transfer therebetween of elliptically polarized electromagnetic wave energy having longitudinal and transverse components.

28. An antenna structure for transmitting and receiving elliptically polarized waves which may be defined from the transmission point of view, as comprising a conduit having an axis and having a slot shaped aperture extending at an angle to said axis for radiating a first wave polarized at a first angle to said axis, means including a second slot shaped aperture extending at a second angle to said axis for radiating a second wave polarized at a second angle to said axis, transmission line means connected to said apertures to provide a time quadrature displacement of said first and second polarized waves thereby to effectively radiate an elliptically polarized wave.

29. An antenna structure for transmitting and receiving elliptically polarized waves which may be defined from the transmission point of view, as comprising a conduit having an axis and having a slot shaped aperture for radiating a first wave polarized at a first angle to said axis, means for radiating a second wave polarized at a second angle to said axis, transmission line means connected to said aperture and to said means to provide a time quadrature displacement of said first and second polarized waves thereby to effectively radiate an elliptically polarized wave.

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