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W. F. PATTERSON ET AL

3,465,346

CIRCULARLY-POLARIZING SPIRAL ANTENNA HAVING SAWTOOTH CONDUCTORS

Original Filed May 5, 1967

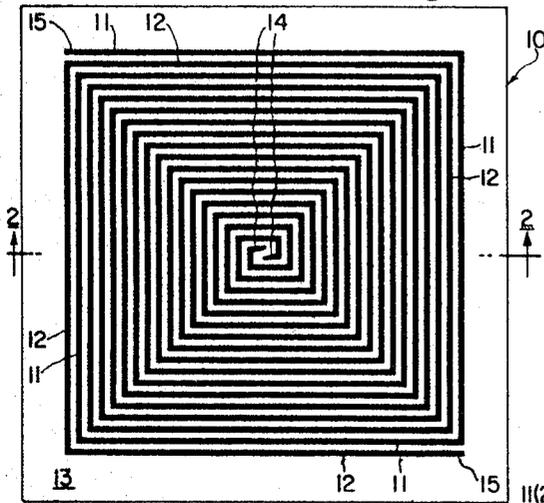


FIG. 1



FIG. 2

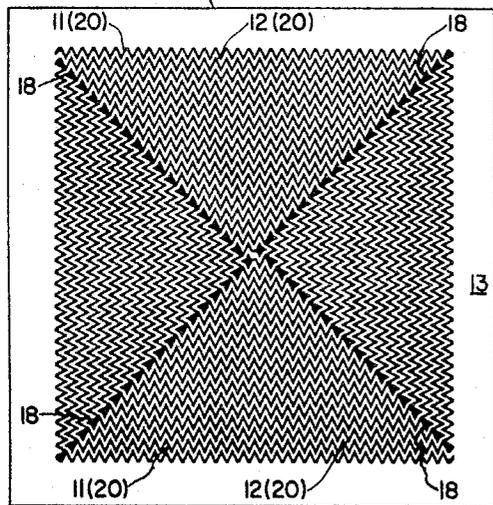


FIG. 3

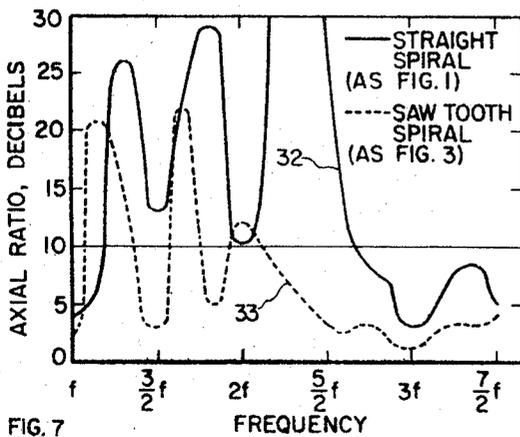


FIG. 7

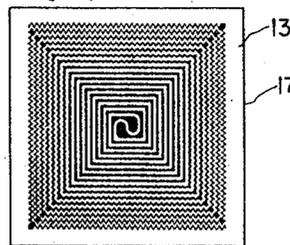


FIG. 4

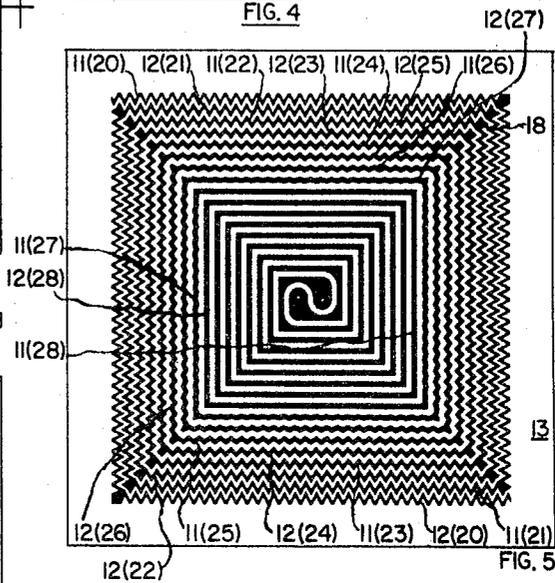


FIG. 5

TYPE	CONFIGURATION	VELOCITY CONSTANT
20		0.45
21		0.50
22		0.55
23		0.62
24		0.71
25		0.80
26		0.89
27		0.97
28		1.00
29		0.83
30		0.64
31		0.49

FIG. 6

1

2

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**CIRCULARLY-POLARIZING SPIRAL ANTENNA  
HAVING SAWTOOTH CONDUCTORS**

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Divided and this application Nov. 12, 1968, Ser. No. 775,078

Int. Cl. H01q 1/36

U.S. Cl. 343—895

4 Claims

**ABSTRACT OF THE DISCLOSURE**

An antenna having surface-supported conductors that radiate a circularly-polarized electromagnetic energy field, the conductors being characterized in whole or in part by a geometrical configuration that, in comparison to antenna straight-line or uniformly-curved conductor configurations, achieves an extended antenna operating bandwidth capability in terms of available support area or alternately achieves a significantly reduced support area requirement for a given antenna operating bandwidth capability.

**Cross-references**

This is a divisional application of application for United States patent Ser. No. 636,422, filed May 5, 1967.

**Summary of the invention**

The antenna of this invention utilizes surface-mounted electrical-energy conductors such as are typically printed on or otherwise bonded to a dielectric support means. Each conductor is provided with a sawtooth geometrical configuration, in whole or in part, to significantly reduce the dielectric means support area requirement necessary to maintain a given antenna operating bandwidth capability or alternately to effect a low-frequency extension of the antenna operating bandwidth capability achieved within a specified dielectric means support area. The antenna conductors are typically electrically energized from a conventional coaxial balun feed. Also, known conductor spacing, perimeter maximizing, end-loading, and dielectric confinement techniques may be utilized in combination with the instant invention, if desired.

**Summary of the drawings**

FIG. 1 is a plan view of a flat double-wound spiral reference antenna having a conventional straight-line conductor configuration;

FIG. 2 is a sectional view taken at line 2—2 of FIG. 1;

FIG. 3 is a plan view of an antenna embodying the instant invention;

FIG. 4 is a plan view of an alternate embodiment of an antenna incorporating the instant invention;

FIG. 5 is an enlarged plan view showing the conductor configuration of the antenna of FIG. 4 in greater detail;

FIG. 6 is a table identifying different wave propagation velocity constants that are obtained with conductors having various illustrated sawtooth conductor configurations; and

FIG. 7 graphically illustrates antenna operating performance advantages that have been obtained by the practice of this invention.

**Detailed description**

FIG. 1 illustrates a reference conventional circularly-polarizing antenna 10 basically comprised of double-wound spiral conductors 11 and 12 secured to flat dielectric board 13. Conductors 11 and 12 are typically con-

nected at their center terminals 14 to a conventional coaxial feed (not shown). The outer terminals 15 of conductors 11 and 12 frequently are coupled to resistance-loading circuits to improve antenna low frequency operating characteristics in a conventional manner but generally with reduced antenna gain. The reference antenna 10 utilizes conductors 11 and 12 having a conventional straight-line configuration for each leg of the several illustrated turns.

We have discovered that by providing a circularly-polarizing antenna with conductors having, in whole or in part, a sawtooth geometrical configuration rather than just a straight-line or a uniformly-curved configuration, the operating bandwidth capability of the antenna below cut-off may be significantly extended for an available conductor support area. Alternately, the support area requirements for a specific antenna operating bandwidth capability below a given cut-off value can be significantly reduced if the antenna conductors are provided, in whole or in part, with a sawtooth geometrical configuration rather than with just a conventional straight-line or uniformly-curved geometrical configuration. Antenna embodiments 16 and 17 of the drawings involve applications of the instant invention. Details regarding several different sawtooth geometrical configurations 20 through 27 and 29 through 31 having application to the practice of the invention are provided in FIG. 6 and also elsewhere in this description.

Antenna embodiment 16 of FIG. 3 utilizes a double-wound spiral conductor arrangement wherein the conductors 11 and 12 each have a uniform sawtooth configuration such as 20 (FIG. 6) throughout. Corner details 18 for each conductor are provided to maintain uniform spacing between adjacent conductor turns at the antenna corner regions. Antenna 16, having the conductor spacing and number of conductor turns of antenna 10, develops a significant extension to the low-frequency end of the antenna operating bandwidth. (See FIG. 7). The FIG. 3 embodiment, however, does not have the high-frequency operating capability associated either with reference antenna 10 or antenna embodiment 17.

FIG. 4 illustrates the relative support area requirement of a flat double-wound spiral antenna 17 in accordance with the invention and having the same acceptable circularly-polarized field and specified operating bandwidth characteristics as antenna 10. The antenna embodiment of FIG. 4 requires only from one-third to one-fourth the corresponding conductor support area as antenna 10 for the same number of double-wound conductor turns. In order to obtain a high-frequency performance capability similar to that of antenna 10, the innermost conductor turns of conductors 11 and 12 are provided with a straight-line configuration 28 in a conventional manner. The outermost two legs of the outermost turn of each of conductors 11 and 12 may be provided with a sawtooth geometrical configuration such as 20 of FIG. 6. The intermediate legs of the different conductor turns have the different sawtooth configurations 21 through 27 with successively decreasing wave propagation velocity constants as indicated by the reference numerals of FIG. 5 and by the corresponding configurations of FIG. 6. Such intermediate legs in effect provide for a gradual transition in waveform propagation velocity in the conductor region from straight-line configuration 28 through sawtooth geometrical configuration 20. Basically, the outermost turn of each of conductors 11 and 12 in antenna 17 has a total length corresponding to the perimeter length of the corresponding outermost straight-line conductor turns 11 and 12 in the FIG. 1 antenna. Normally, it is preferred that uniform spacing between conductors be maintained throughout.

Details regarding different sawtooth geometrical configurations for conductors 11 and 12 are provided in FIG. 6. The different sawtooth configurations 20 through 27 vary in slope as to each sawtooth leg. The slope varies from a ratio of 4:2 for configuration 20 to a ratio of 0:2 for configuration 28 in abscissa increments of one-half. Configuration 28 is a straight-line configuration of zero slope. Additional configurations 29 through 31 for the antenna conductors have the basic characteristics of a sawtooth configuration. However, small radii are utilized to join the different sawtooth leg increments. Velocity constant values computed from actual standing wave field measurements made with respect to configurations 20 through 31 correspond closely to the calculated values of the table.

FIG. 7 provides a graphical illustration of the performance capability that may be obtained with an antenna incorporating this invention in comparison to an antenna such as conventional antenna 10. FIG. 7 plots on-axis axial ratio measurements taken for antennas having the conductor configurations of antennas 10 and 16 and having equal support area dimensions of approximately  $3\frac{3}{4}$ " square. Measurements relating to a base frequency  $f$  were taken over a frequency range extending to approximately  $3.5 f$ . An axial ratio of ten decibels or less for the circularly-polarized radiated field was established as acceptable antenna performance. As shown by curve 32 for the antenna 10 conductor configuration, cut-off for a desired axial ratio of less than ten decibels occurs approximately midway between  $2.5 f$  and  $3.0 f$ , such cut-off frequency essentially begin correlated to a wavelength determined by the spiral conductor perimeter turn diameter. Curve 33 illustrates the actual performance of an antenna 16 of similar dimensions to the antenna of curve 32 but with a conductor sawtooth geometric configuration throughout. The cut-off frequency has been reduced to approximately  $2 f$  by the invention with a reduced axial ratio in comparison to curve 32 throughout the remainder of the operating bandwidth of interest.

The instant invention is illustrated as applied to a flat circularly-polarizing antenna having double-wound spiral conductors of uniform spacing from the point of feed to antenna perimeter. The instant invention is also considered to have application to other conductor arrangements including equiangular, conical, Archimedean spiral, and scimitar configurations. Conventional techniques such as perimeter squaring, lumped or distributed resistance end loading, and conductor dielectric imbedment may be utilized with the invention to further antenna operating performance for a specified operating bandwidth and axial ratio.

We claim:

1. In an antenna capable of radiating a circularly-polarized electromagnetic-energy field at different frequencies in an operating bandwidth extending from minimum frequency  $f_1$  to maximum frequency  $f_2$ , in combination:
  - (a) Dielectric support means having a support surface area,
  - (b) A pair of feed terminals for receiving two equal-amplitude electrical currents continuously  $180^\circ$  out of phase with respect to each other at each of the different frequencies in said operating bandwidth,
  - (c) A pair of perimeter terminals, and
  - (d) A pair of interlaced multiple-turn spiral conductor elements secured to said dielectric support means support surface area throughout each current conducting path from said pair of feed terminals to said pair of perimeter terminals and having (1) a first

section comprised of adjacent spiral conductor element turns respectively coupled at one extreme to said pair of feed terminals and provided with geometric configurations that propagate traveling waves from said electrical currents at frequency  $f_2$  along said first section spiral conductor element turns at a velocity approximately 1.0 times a reference traveling wave propagation velocity along a conductor of straight-line geometric configuration, (2) a second section comprised of adjacent spiral conductor element turns respectively coupled at one extreme to said pair of perimeter terminals and provided with sawtooth geometric configurations that propagate traveling waves from said electrical currents at frequency  $f_1$  along said second section conductor element turns at a velocity substantially less than said reference traveling wave propagation velocity along a conductor of straight-line geometric configuration, and (3) a transition section comprised of adjacent spiral conductor element turns respectively coupled at opposite extremes to the other extremes of said first and second section conductor element turns and provided with sawtooth geometric configurations that propagate traveling waves from said electrical currents at a frequency intermediate said frequency  $f_1$  and said frequency  $f_2$  along said transition section conductor element turns at a velocity proportionally intermediate said traveling wave propagation velocities along said first and second section conductor element turns.

2. The invention defined by claim 1, wherein said second section conductor element turns are provided with sawtooth geometric configurations that propagate traveling waves from said electrical currents at frequency  $f_1$  along said second section conductor element turns at a velocity approximately from 0.45 to 0.55 said reference traveling wave propagation velocity along a conductor of straight-line geometric configuration.

3. The invention defined by claim 1, wherein said transition section is comprised of successively different conductor element turns of different sawtooth geometric configurations that propagate traveling waves from said electrical currents at successively different frequencies intermediate said frequency  $f_2$  and said frequency  $f_1$  along said transition section conductor element turns at corresponding successively different velocities proportionally intermediate said traveling wave propagation velocities along said first and second section conductor elements turns.

4. The invention defined by claim 1, wherein said transition section is comprised of successively different conductor element turns of different sawtooth geometric configurations that propagate traveling waves from said electrical currents at successively different frequencies intermediate said frequency  $f_2$  and said frequency  $f_1$  along said transition section conductor element turns at corresponding successively different velocities of approximately 0.97, 0.89, 0.80, 0.71, 0.62, 0.55, and 0.50 proportionally intermediate said traveling wave propagation velocities along said first and second section conductor element turns.

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