July 8, 1969 W. F. PATTERSON ET AL 3,454,951

SPIRAL ANTENNA WITH ZIGZAG ARMS TO REDUCE SIZE

Filed May 5, 1967

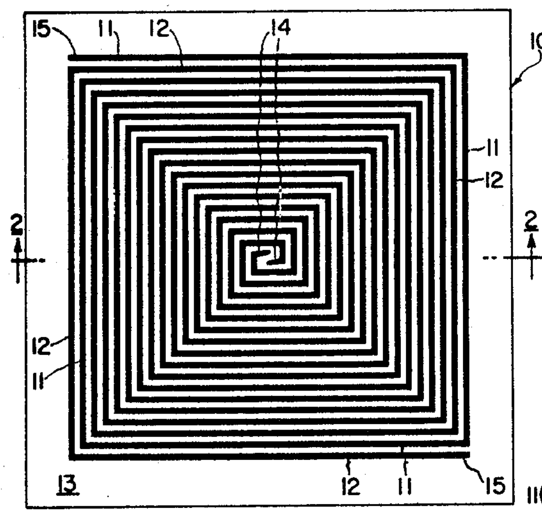

FIG. 1

FIG. 2

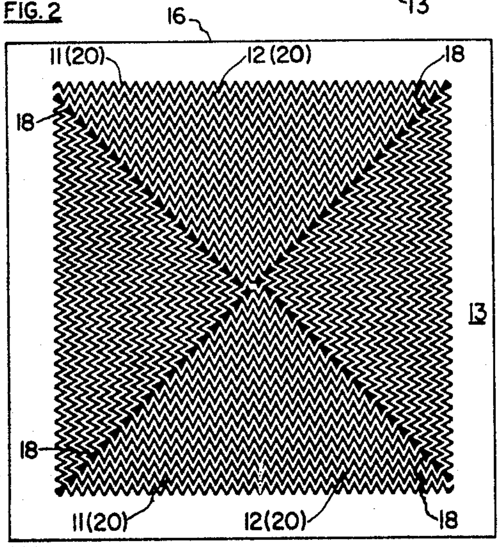

FIG. 3

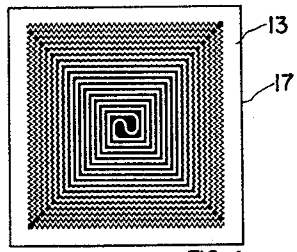

FIG. 4

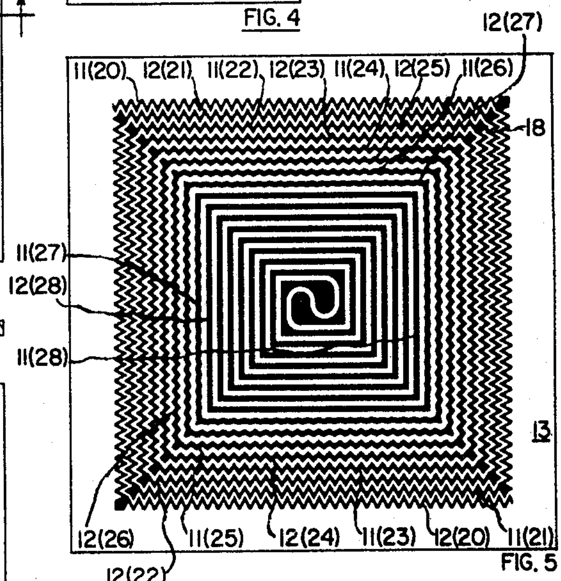

FIG. 5

TYPE	CONFIGURATION	VELOCITY CONSTANT
20	4, 2	0.45
21	3½, 2	0.50
22	3, 2	0.55
23	2½, 2	0.62
24	2, 2	0.71
25	1½, 2	0.80
26	1, 2	0.89
27	½, 2	0.97
28	(0), 2	1.00
29		0.83
30		0.64
31		0.49

FIG. 6

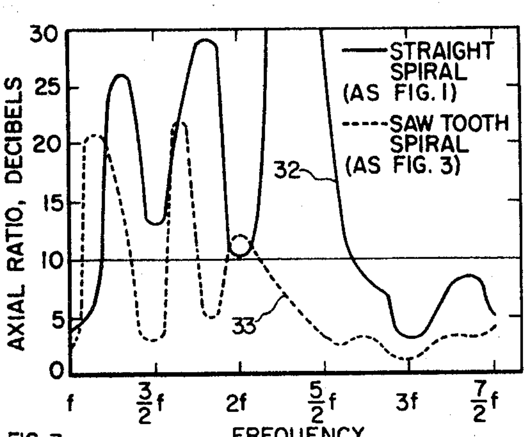

FIG. 7

3,454,951
Patented July 8, 1969

3,454,951

SPIRAL ANTENNA WITH ZIGZAG ARMS TO REDUCE SIZE

William F. Patterson, Reynoldsburg, and Ernesto T. Roland, Columbus, Ohio, assignors to North American Rockwell Corporation, a corporation of Delaware

Filed May 5, 1967, Ser. No. 636,422
Int. Cl. H01q 1/36
U.S. Cl. 343—895 3 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.

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 coxial 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 connected 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 of 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 plate 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 3¾" square. Measurements relating to a base frequency f were taken over a frequency range extending to approximately $3.5f$. 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 $2.5f$ and $3.0f$, such cut-off frequency essentially being 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 $2f$ 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° out of phase with respect to each other at different frequencies in said operating bandwidth,

(c) a pair of perimeter terminals, and

(d) a pair of spaced-apart multiple-turn spiral conductor elements that are each coupled to a different one of said feed terminals and to a different one of said perimeter terminals, that are each of substantially square-turn configuration secured to said dielectric support means support surface area in each turn from a feed terminal to a perimeter terminal, and that are each provided with a current-conducting path geometric configuration comprised of joined sawteeth of constant amplitude throughout the element length and of constant rate of repetition per unit length throughout the element length,

said current-conducting path geometric configurations of constant sawtooth amplitude and rate of repetition propagating traveling waves along said spiral conductor element turns from said electrical currents at a constant velocity substantially less than a reference traveling wave propagation velocity along a conductor of straight-line geometric configuration to radiate the circularly-polarized electromagnetic energy field.

2. The invention defined by claim **1**, wherein said pair of conductor elements has current-conducting paths with geometric configurations of constant sawtooth amplitude and rate of repetition that propagate traveling waves from said electrical currents along said conductor element turns at a constant velocity of approximately 0.45 to 0.55 times said reference traveling wave propagation velocity along a conductor of straight-line geometric configuration.

3. The invention defined by claim **1**, wherein said conductor elements are each comprised of spiral turns having a substantially square shape formed by joined essentially linear side portions, each said side portion being uniformly spaced apart from each radially adjacent side portion and having said current-conducting path geometric conductor element and with two additional sawteeth relative to the next radially, inward side portion in the same conductor element and with two additional sawteeth relative to the next radially inward side portion in the other conductor element.

References Cited

UNITED STATES PATENTS

2,277,826	3/1942	Giroux	343—908
3,039,099	6/1962	Chait et al.	343—895
3,106,714	10/1963	Minerva	343—908
2,977,594	3/1961	Marston et al.	343—895
3,019,439	1/1962	Reis et al.	343—895

ELI LIEBERMAN, *Primary Examiner.*