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SEARCH ROOM

March 28, 1961 A. E. MARSTON ET AL 2,977,594

SPIRAL DOUBLET ANTENNA

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FIG. 1

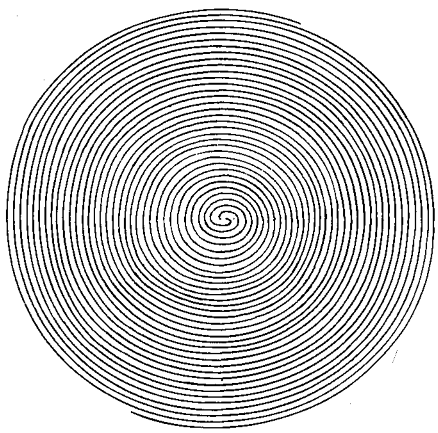


FIG. 2

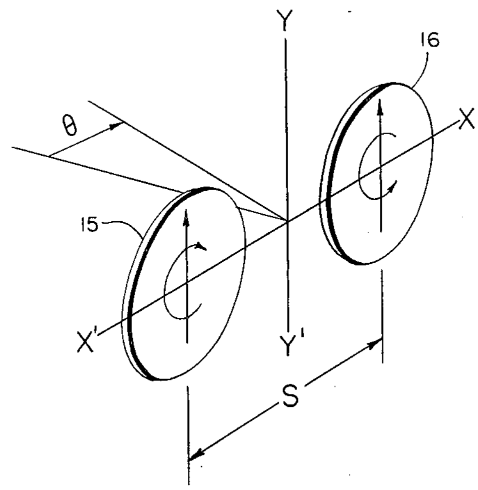


FIG. 3

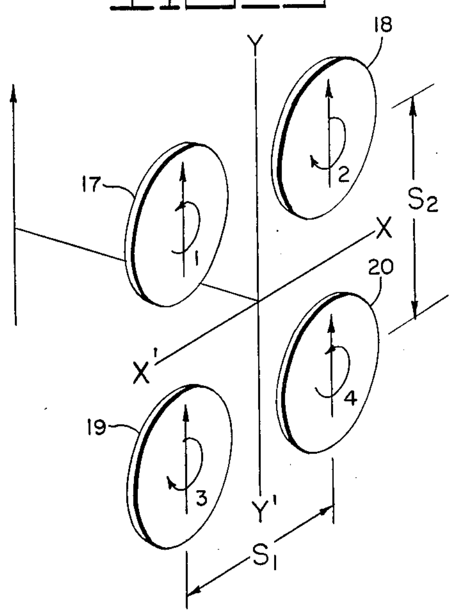
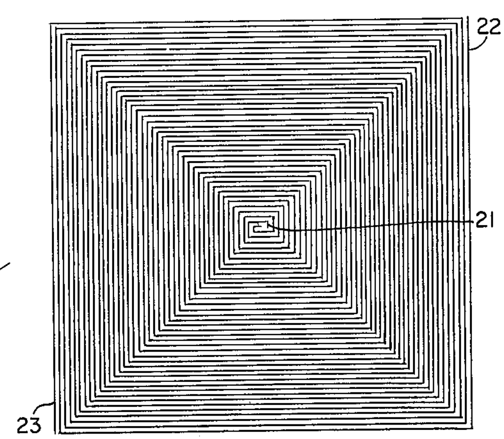


FIG. 4



INVENTORS
ARTHUR E. MARSTON
JULIUS A. KAISER

BY Richard C Reed ATTORNEYS

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FIG. 5

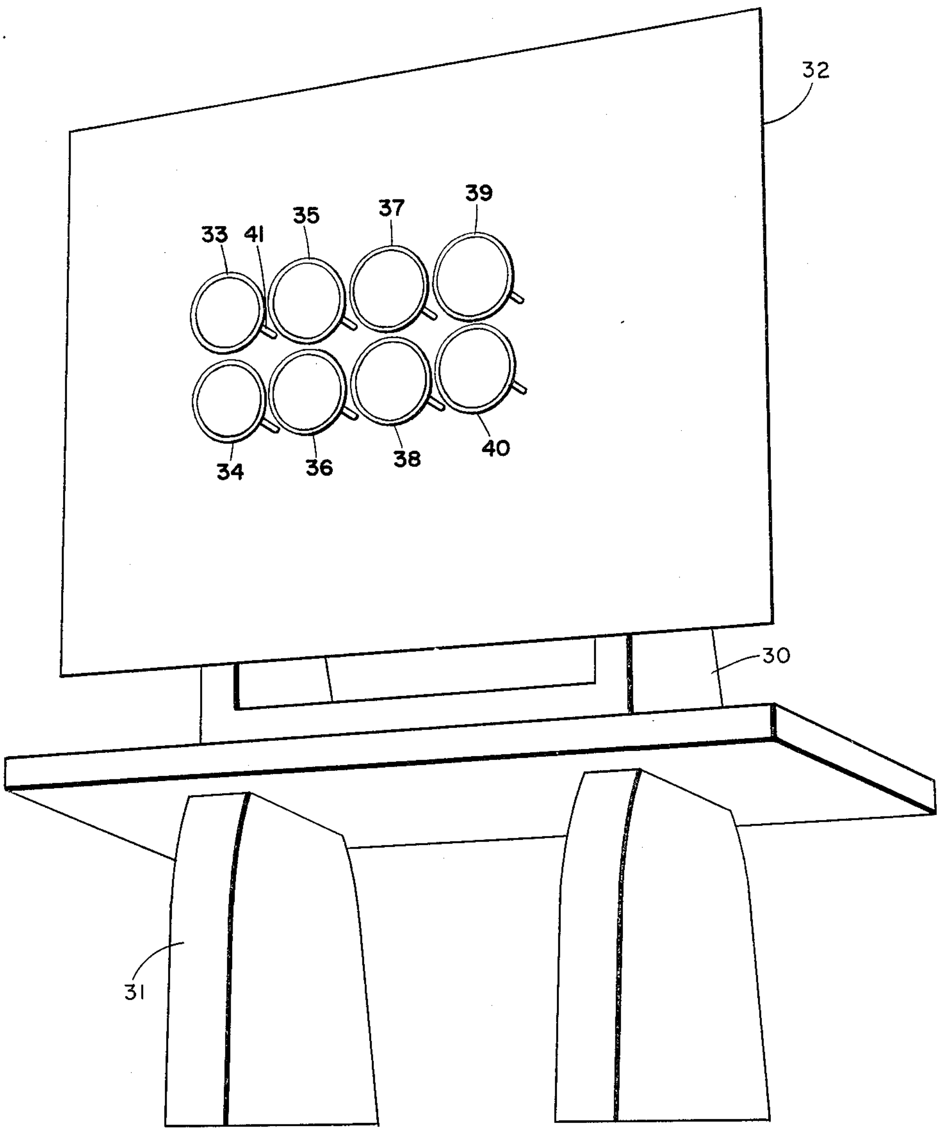

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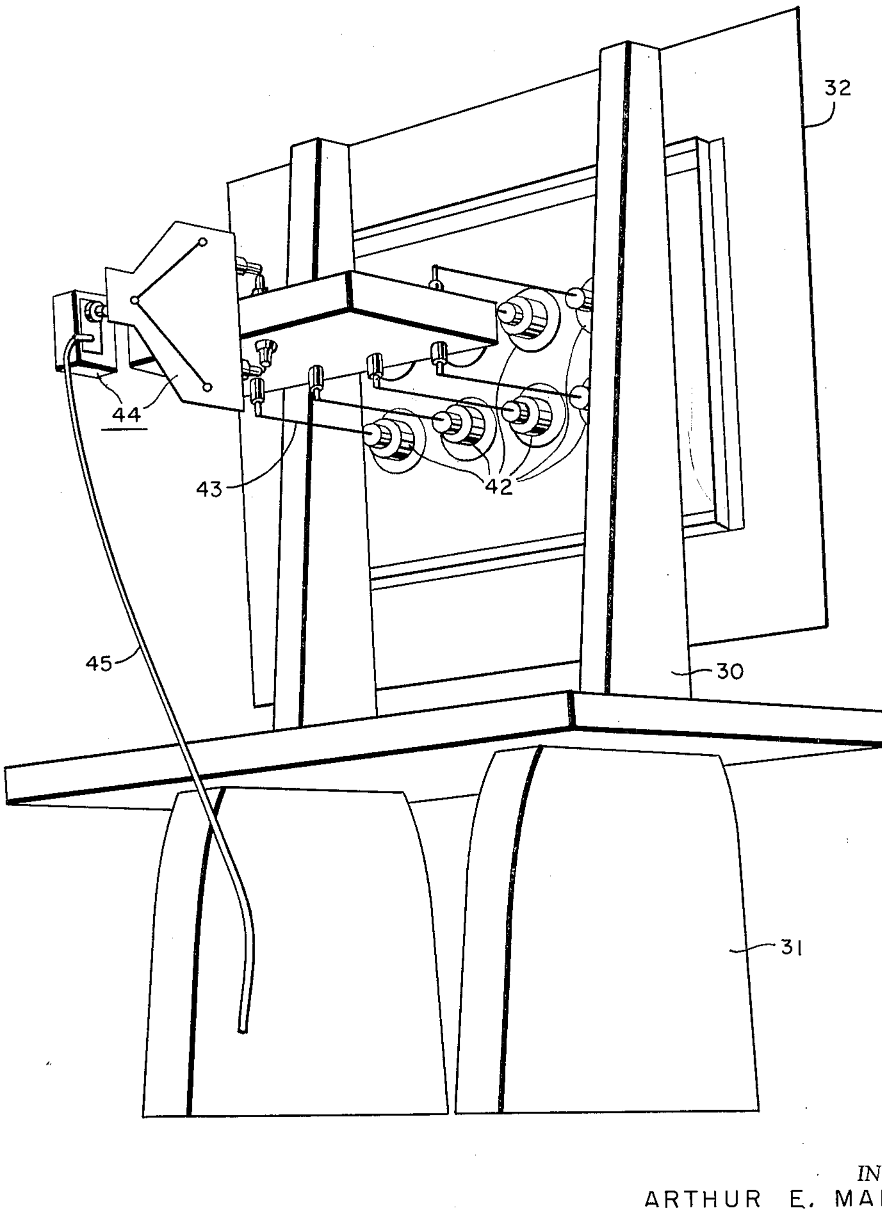
FIG. 6



INVENTORS
ARTHUR E. MARSTON
JULIUS A. KAISER

BY

Richard C. Reed ATTORNEYS

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SPIRAL DOUBLET ANTENNA

Arthur E. Marston, 718 Putnam Place, Alexandria, Va., and Julius A. Kaiser, 10408 Detrick Ave., Kensington, Md.

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4 Claims. (Cl. 343—756)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to antenna systems in general and in particular to spiral antennas.

It is an object of the present invention to provide a scanning antenna array.

Another object of the present invention is to provide a scanning antenna of simple construction and reliable operation.

Another object of the present invention is to provide an antenna array wherein the phase and polarization in the far field can be readily controlled.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 shows a circular spiral antenna.

Fig. 2 shows in schematic form a spiral doublet antenna.

Fig. 3 shows schematically a spiral doublet antenna array.

Fig. 4 shows a rectangular equivalent of a circular spiral antenna.

Figs. 5 and 6 show a spiral doublet array with mounting and feed system.

In accordance with the basic teachings of the present invention, an antenna system is provided wherein precise control over plane of polarization and phase of energy at any point in the far field is possible. This control permits considerable simplification in scanning antenna systems. The present improvements are brought about by the combination of spiral antennas of different configuration sense and the rotation thereof in specific relationship.

The term configuration sense is used to indicate the direction of rotation as one proceeds outward from the center of the spiral as viewed from one side. Thus a single antenna element can actually have both configuration senses depending upon which side is viewed. The important point as to configuration sense of various elements which cooperate is that the relative senses be determined with the elements in the relative positions as will be utilized in the array. Thus when one element is indicated as having an opposite configuration sense from another element, such means that the elements cooperatively assembled have opposite sense as viewed from the same side of the assembly.

Additionally the plane of a spiral antenna is defined as that in which the outward spiral occurs along a progressively increasing radius.

A spiral antenna as typified in Fig. 1, is a planar assembly consisting of two or more interspaced conductors disposed layer upon layer in such manner as to present a spiral configuration having a first or a second sense depending upon whether the outward spiral from the

center is in a clockwise or counter-clockwise direction. For example, the two conductors could be printed circuit conductors on a base member or disc. Each conductor has a starting point near the center of the disc and a termination at the periphery of the disc, the terminations of the two conductors occurring at diametrically opposed portions of the periphery. Such a spiral antenna may be energized at the center by means of a coaxial cable with one conductor of the coaxial cable connected to one conductor of the spiral and the other conductor of the coaxial cable connected to the second conductor of the spiral. When such a spiral is energized by radio frequency energy it radiates a broad circularly polarized pencil beam to each side of the plane of the spiral. Each radiated beam is normal to the plane of the spiral and the sense of circularity of polarization of the beam on any one side corresponds to the winding sense of the spiral as viewed from the opposite side. Accordingly, the two radiated beams are identical except that the rotational sense of polarization of the radiated field on one side is the opposite of that on the other. In many applications it is desirable that the spiral radiate to one side only, such being readily accomplished by appropriately backing the spiral on one side with a ground plane to produce reflection of energy or with a cavity to produce absorption of energy.

Although the exact theory of operation of such a spiral antenna is not universally established at the present time, a possible explanation is that the spiral antenna behaves as if it were a two wire transmission line which gradually—by virtue of its spiral geometry—transforms itself into a radiating structure or antenna. Ordinarily a two wire transmission line wherein the wire spacing is a small fraction of a wavelength yields a wholly negligible amount of radiation when excited at its terminals. This is due to the fact that the currents in the two wires of the line at any normal cross-section are 180° out-of-phase so that the radiation from one line is essentially cancelled by the radiation from the other. In such an antenna as that shown in Fig. 1, if the spacing between adjacent wires is substantially smaller than the radius of the outer turn of the spiral, the difference in length between the two conductors from the origin to a point in the outermost circle is approximately equal to half the circumference of the spiral. With out-of-phase excitation of the spiral antenna wires at the center, the phasing gradually changes along the length of the two conductors proceeding outwardly so that where the radius of the outer conductor is $\lambda/2\pi$ the currents in the two conductors are precisely in phase and radiation is at a maximum. Such a spiral antenna when excited at higher frequencies wherein the outer conductor radius is greater than $\lambda/2\pi$ would achieve such an in-phase condition at a smaller radius than the periphery so that portions of the conductors located at the smaller radius produce maximum radiation. Such an antenna thus is characterized by wideband operation with respect to frequency because selected portions thereof become effective at different portions of the frequency band.

The spiral antenna provides circularly polarized radiation. With a uniformly constructed antenna of the configuration of Fig. 1, there is circular symmetry of the radiation polarization about the spiral axis. Such symmetry allows rotation of the spiral antenna about its axis producing a change in the phase of the radiated field everywhere in space without producing variations in the amplitude of the signal in the far field. In such rotation, one degree of mechanical rotation of the spiral antenna about an axis normal to the plane of the drawing of Fig. 1 produces a change in phase of the far field of one electrical degree.

With reference now to Fig. 2 of the drawing, the basic elements of a spiral array are shown therein including two spiral antennas of the type previously discussed in connection with Fig. 1. The two spiral antennas **15** and **16** are similar to the antenna shown in Fig. 1 and are similarly excited, however the antennas **15** and **16** are of opposite configuration sense, that is one antenna spirals outward in a clockwise direction whereas the other antenna spirals outward in a counter-clockwise direction. With such a spiral doublet antenna applicants have found that the combined far field is not circularly polarized but is linearly polarized, the direction of polarization of the far field at any particular distant point being a function of the relative electrical phasing of the two spirals and the position of that distant point in space relative to the plane containing the spirals. If the distant point is in an on-axis fixed position which is normal to the plane containing the two oppositely sensed spirals, if the phase of the fields of one spiral relative to the other is varied by rotation of one spiral through an angle of θ degrees, the combined radiated field will remain linearly polarized, however the direction of the polarization will rotate through an angle of $\theta/2$ degrees.

A second important characteristic of the spiral doublet antenna is the effect upon the far field of rotation of the two spirals in opposite directions through equal angles. Where such occurs, the direction of the linear polarization in the far field is not changed however the phasing of the signal at any selected distant point is changed. When the two spirals simultaneously are rotated in opposite directions through an angle of θ from their previous positions, the phase of the far field at all points changes by precisely θ electrical degrees. Additionally since a spiral antenna is inherently a broad-band radiator, the foregoing properties will be maintained over a wide band of operational frequencies.

With the spiral doublet antenna arrangement of Fig. 2, the field strength is to some extent dependent upon the angle of polarization. With the axes of antennas **15** and **16** spaced apart in the horizontal plane by a distance S, the amplitude variation of the horizontal component will be greater than the amplitude variation of the vertical component of the field. The exact variation is dependent upon the magnitude of S and in general is less for smaller values of S, however there is a limit to the minimum size of S. This limit is imposed by the spiral radius requirements necessary to obtain in-phase excitation of the periphery of the spirals **15** and **16**. Typically a value of S of $\lambda/3$ is a practical minimum value.

Although there are many instances where the basic principles of the spiral doublet antenna may be utilized to advantage directly, a specific embodiment wherein these properties may be utilized to advantage is shown in the apparatus of Fig. 3. Fig. 3 employs four spiral antennas **17**, **18**, **19** and **20** disposed in the same plane in symmetrical fashion, that is, the spacing of antennas **17** and **18** is equal to the spacing of antennas **19** and **20** which likewise is equal to the spacing between the antennas **17** and **19** and the spacing between the antennas **18** and **20**. Antennas **17** and **20** are constructed with spirals of a first configuration sense typically counter-clockwise, whereas the direction of winding of the other antennas **18** and **19** is in the opposite direction. With such antennas similarly appropriately disposed as to angular orientation and with excitation at their centers, a typical linear polarization in the far field may be vertical. This apparatus of Fig. 3 can be considered as an elementary scanning system since the phasing of one doublet can be changed with rotation while holding the phase of the other doublet fixed. For example, if the phase of the doublet containing spirals **18** and **20** is changed relative to the doublet containing spirals **17** and **19**, the beam is caused to scan horizontally while maintaining vertical polarization. Similarly, if the phase of the upper two spirals **17** and **18** is changed relative to the phasing of the lower two spirals **19** and **20**, the beam scans in a vertical direction however still maintaining vertical polarization.

It is thus apparent that the antenna system of Fig. 3 is well suited for scanning in two planes, typically a vertical plane and a horizontal plane, as is commonly employed and required in a radar system. By control of the relative orientation of the various spiral components **17**, **18**, **19** and **20** the previously described horizontal and vertical scanning may be combined to effect a conical scan which likewise is of considerable importance in radar systems.

Fig. 4 indicates a square counterpart of the basic spiral antenna shown in Fig. 1 which has characteristics substantially similar to those of the apparatus of Fig. 1 and in certain instances may possess desirable characteristics where particular space requirements may be encountered. The combination of such square antennas in apparatus of the type of Figs. 2 and 3 is accomplished with substantially similar results to those previously indicated in connection with these figures. The square antenna of Fig. 4 contains two conductors which spiral outward from a central starting point **21**, having suitable insulating spacing therebetween. These conductors progress outward in a clockwise or counter-clockwise direction (configuration sense) as desired terminating in what may be termed diametrically opposed points **22** and **23**. Where the spacing between the individual elements of the spiral is uniform and small compared to half the spacing between the outermost conductors on opposite sides of the square spiral, the currents existing in the outer or exposed portions of the two conductors are in phase when the circumference reaches a full wavelength or a path length difference of one-half wavelength. Thus, like the circular spiral antenna, the square spiral antenna will have portions thereof from which radiation is a maximum over a wide band of frequencies so that wide-band response with a constant beamwidth is maintained as with the circular spiral antenna.

The apparatus shown in Fig. 5 is a more complex version of the scanning antenna array wherein a supporting framework **30** is mounted for suitable orientation in a vertical plane as well as a horizontal plane by structure **31**. The supporting structure **30** contains a ground plane or base member **32** which operates to limit the radiation from the spiral elements **33**, **34**, **35**, **36**, **37**, **38**, **39** and **40** to the forward direction. Each of the spiral antenna elements **33** through **40** is a two conductor circular spiral such as that shown in Fig. 1. The odd numbered elements **33**, **35**, **37** and **39** have a first configuration sense whereas the even numbered elements **34**, **36**, **38** and **40** have the opposite configuration sense.

Each of the elements **33** to **40** is supported upon a shaft indicated typically for element **33** by the numeral **41** which in addition to being journaled for controlled rotation by mechanism **42** which is indicated in Fig. 6, contains two conductors which may comprise a coaxial cable, to feed the two conductors of the spiral antenna. Mechanism **42** contains suitable drive mechanism and gear ratio mechanism or electrically synchronous motor devices to rotate the spiral antennas at the indicated speeds to obtain scanning. The coaxial feeds are typified by that identified with reference character **43** which is connected to a feed system **44** which provides matched impedance coupling of the various spiral antenna elements to a transmission line **45**. Typically in accordance with the principles previously described, each of the vertical pairs **33—34**, **35—36**, **37—38**, **39—40** is connected and excited in such manner as to produce of its own accord a vertically polarized far field. The spiral antennas are rotated through selected angles to produce scanning in the horizontal plane as viewed in Fig. 5. Typically elements **33** and **34** will be stationary whereas antenna elements **35** and **36** rotate at a selected speed ω, elements **37** and **38** rotate at twice the speed, 2ω, and elements **39** and **40** rotate at 3 times the speed, 3ω. The paired spirals rotate in opposite directions, spirals having a clockwise configuration sense rotating in a clockwise direction, spirals having a counter-clockwise configuration sense rotating in a counter-clockwise direction. Thus elements **35**, **37** and **39** will rotate in a first direction but at different angular rates whereas elements **36**, **38** and **40** will rotate in the opposite direction likewise at different angular rates. The result will be scanning in the horizontal plane with the selected vertical polarization being maintained during the scanning cycle.

Typically with operation at 1000 megacycles per second, spiral element spacing center to center of .4λ and spiral spacing from ground plane of 4 to 4½ inches, scan angles of approximately ±50° can be realized for vertical polarization and ±37° for horizontal polarization.

Although specific configurations of apparatus have been selected to illustrate features of the present invention, it is understood that other configurations are within the spirit and scope of the invention as defined in the claims.

What is claimed is:

1. In combination, a spiral antenna element having a first configuration sense, a spiral antenna element having the opposite configuration sense, means mounting said antenna elements in a common plane, means connected to said last named means for rotating at least one of said elements in the common plane about an axis perpendicular to the common plane, and an electrical energy transmission line connected to each antenna element.

2. In combination, first and second spiral antenna elements having a first configuration sense, third and fourth

spiral antenna elements having a second configuration sense, means mounting said antenna elements in parallelogram relationship in a common plane, means individually rotating two of said elements in the common plane about axes perpendicular to the common plane.

3. In combination, first and second spiral antenna elements having a first configuration sense, third and fourth spiral antenna elements having a second configuration sense, means mounting said antenna elements in a common plane wherein each element has an opposite configuration sense from the two elements nearest it, means rotating two of said elements each in direction dependency on the configuration sense thereof.

4. In combination a plurality of pairs of spiral antenna elements, one element of each pair having the opposite configuration sense from the other element of each pair, means supporting said elements in a common plane, and means for providing rotation of at least one pair of said elements in the common plane each element rotation being in direction dependency on the configuration sense thereof, and an electrical energy transmission line connected to each spiral antenna element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,663,869	Adcock et al.	Dec. 22, 1953
2,856,605	Jacobsen	Oct. 14, 1958