

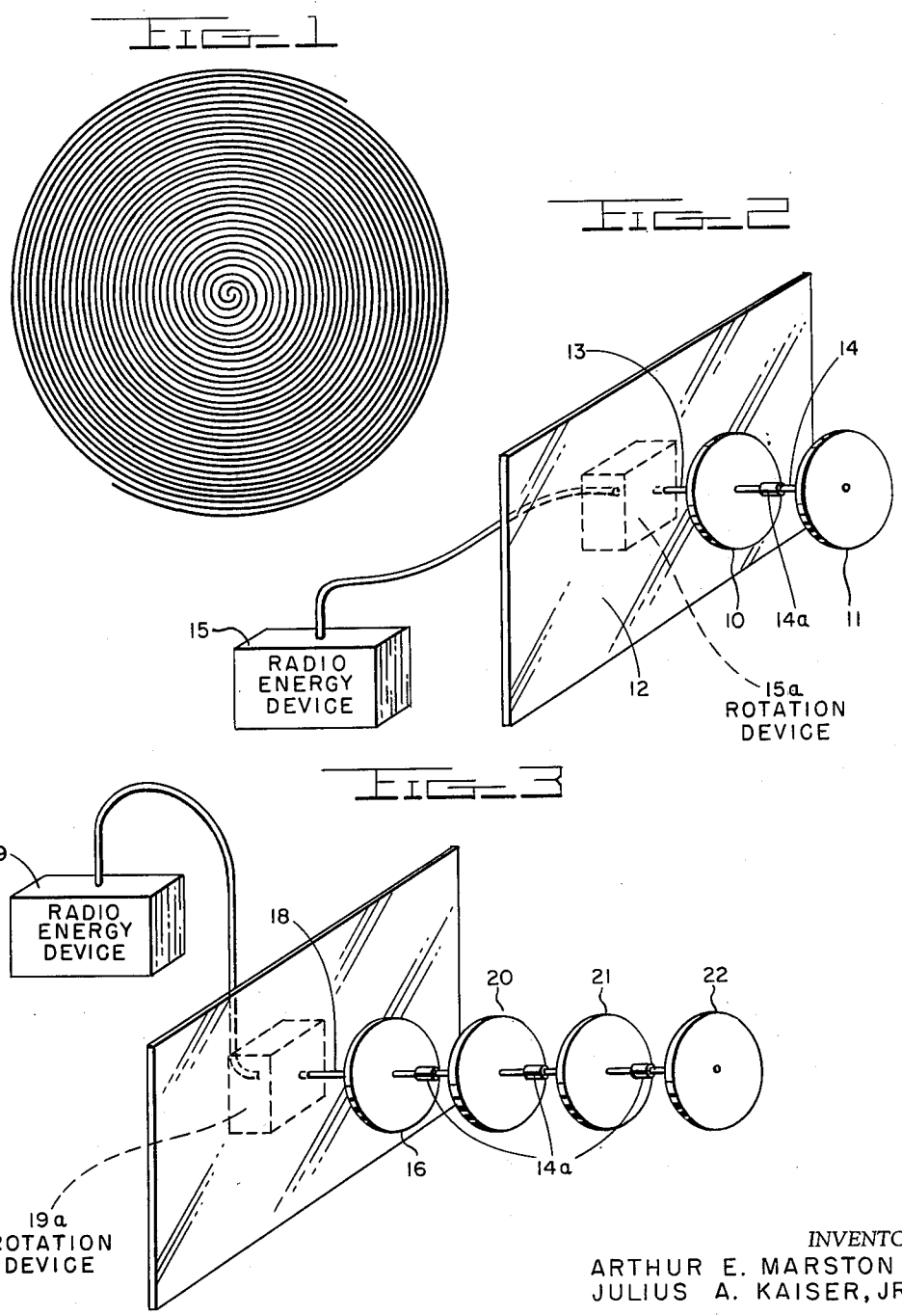
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SPIRAL ANTENNA ARRAY WITH POLARIZATION ADJUSTMENT

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SPIRAL ANTENNA ARRAY WITH POLARIZATION ADJUSTMENT

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The invention described herein may be manufactured and used by or for the Government of the United States of America 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 an antenna system wherein the antenna pattern in the far field can be readily varied.

Another object of the present invention is to provide an antenna system wherein the polarization in the far field can be readily varied.

Another object of the present invention is to provide an antenna system wherein the far field polarization can be changed from linear to circular by simple adjustments.

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 spiral antenna.

FIG. 2 shows a simple parasitic array involving spiral antenna elements and a reflector.

FIG. 3 shows a more elaborate array employing several parasitic elements.

In accordance with the basic teachings of the present invention, an antenna system is provided wherein precise control over the polarization and phasing of radiation at any point in the far field is possible. With this antenna system it is possible to obtain either circular or linear polarization or any intermediate thereof in the far field and the direction of linear polarization if such is used is readily controllable. Complex systems involving the principles of the present invention may be constructed which provide a wide range of antenna patterns from such diverse conditions as a narrow pencil beam in the major axis of directivity to a conical pattern having a null in the major axis of directivity. The foregoing flexibility of operation and result is brought about by employing a plurality of spiral antenna elements, one or more thereof being a parasite, disposed substantially parallel to a driven spiral antenna element but spaced therefrom along the major axis of directivity very much the same as the various elements of a linear array of the yagi type are displaced relative to the driven element. Such an array of driven and parasitic spiral antennas can be caused to have various radiation polarization characteristics depending upon the combinations of configuration sense of individual elements and their spacings relative to each other and to the driven element.

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 a 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 of insulating material. 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 periph-

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ery. 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. In such a situation, a balanced to unbalanced converter feed is normally preferable. When such a spiral is energized by radio frequency energy it radiates a broad circularly polarized 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 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 such as with parasitic elements as in the present invention is it 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, or with a cavity. Where a ground plane is used, it is normally preferable to space the spiral antenna element and the ground plane apart by a distance equal to $\lambda/4$ or odd multiple thereof.

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 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 anti-phase excitation of the spiral antenna conductors at the center, the phasing gradually changes along the length of the two conductors proceeding outwardly so that when 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 wide band operation with respect to frequency because selected portions thereof become effective at different portions of the frequency band.

The spiral antenna basically 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 normal to the plane of the spiral 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 of phase in the far field of one electrical degree.

FIG. 2 shows a basic parasitic array embodying the principles of the present invention in which two spiral antenna elements 10 and 11 are placed in front of a re-

flector 12. Each of the spiral antenna elements 10 and 11 is similar to the basic spiral indicated in FIG. 1, that is, each has two conductors arranged in a spiral outward from a central starting point to a large radius. In each antenna the two conductors are relatively insulated from each other and are held in position by some suitable means, as an example in certain instances it may be desirable to employ a structure formed by printed circuit techniques namely that wherein the two conductors are disposed on a suitable backing member of insulating material. Typically the first spiral antenna element 10 is connected to an electrical lead such as a coaxial cable at its center point. This coaxial cable may be typically sufficiently rigid to provide support for the spiral antenna element 10 in front of the reflector 12. Additionally the coaxial cable 13 may contain an extension portion 14 for supporting the second spiral antenna element 11 in proximity to the first element 10. The coaxial cable 13 is connected by suitable lead-in to a radio energy operative device 15 which may typically be a transmitter or a receiver or both connected to utilize energy intercepted by the antenna array or to radiate energy to a distant receiver. The spiral antenna 10 radiates essentially only in a forward direction by virtue of its location in front of the reflector 12. The spiral antenna element 11 is excited totally by energy coupled to it from the first spiral antenna element 10, there being no direct feed. Thus the second spiral is parasitically driven by the first. In this arrangement, it is important that the side of the parasitic spiral antenna element 11 which faces the driven antenna element 10 have the same configuration sense as the side of the driven spiral antenna element 10 which faces element 11. Accordingly, in this arrangement the forward radiating face of the parasitic spiral has a configuration sense which is opposite to that of the forward face of the driven spiral antenna element 10. This arrangement of faces insures that energy can be coupled to the parasitic spiral antenna element 11. The field resulting from this configuration will be a union of the driven field of element 10 with the field from the parasite antenna element 11 and since both of these fields are circularly polarized but of opposite sense, the composite or sum field will in general be basically elliptically polarized, depending upon the amount of energy that is coupled to the parasitic spiral antenna element and reradiated. The amount of energy coupled from the driven spiral antenna element 10 to the parasitic spiral antenna element 11 is essentially a function of the spacing between the two spirals. In practice a variation in this coupling can be achieved as facilitated by a slip joint device 14a which produces far field polarizations ranging from very near linear (for 50% coupling) to circular (no coupling between spiral elements).

A spiral antenna such as that of FIG. 2 has the following important properties; first if the parasitic element 11 alone is rotated through an angle of θ degrees, then the major axis of the ellipse of polarization for the radiated field on-axis will rotate through the same angle θ . Second, if the parasitic element 11 is held stationary and the driven element 10 is rotated through an angle θ then the polarization ellipse of the far field remains stationary, but the phase of the energy in the far field experiences a change, which in the case of a linearly polarized far field is in the amount of θ electrical degrees.

Thus in the arrangement of FIG. 2 including a driving spiral antenna element and a single spiral parasite it is possible to have essentially linear polarization of the far field, where the direction of polarization of the far field and the phase of the far field can be adjusted at will by an appropriate rotation of the constituent spiral antenna elements as indicated above. This rotation is provided by rotation device 15a which permits independent or coordinated rotation of the elements 10 and 11.

The apparatus of FIG. 3 is similar to that of FIG. 2 differing primarily in the number of parasitic elements

placed in front of the driven spiral antenna element 16. Element 16 is mounted in front of reflector 17 and is driven by means of coaxial line 18 from the radio energy device 19. In front of antenna elements 16 and suitably mounted are the spiral antenna parasite elements 20, 21 and 22. As before these elements are all disposed in such manner as to have similar configuration senses facing each other. Thus as viewed from the end of the array looking at the element 22, spiral elements 16 and 21 will have one configuration sense whereas the elements 20 and 22 will have the opposite configuration sense.

In the above apparatus of FIG. 3 the driven spiral antenna element 16 radiates energy forward into the linear array of parasitic elements and this energy is coupled forward from one parasitic element to the next with the amount of coupling obtained between any two parasites being a matter essentially of the spacing between the two parasites. By successive application to this array of the principles set forth in connection with FIG. 2 for control of phasing and polarization in the far field by rotation of the antenna elements, it is possible to control the phase of the energy radiated from the individual elements of the parasitic array and so control the radiation patterns of the array itself. Thus both pencil beam patterns and conical patterns with a null on axis can be achieved in this arrangement by appropriate spacing and angular orientation of the several parasitic spirals, facilitated by rotational device 19a and slip devices 14a.

Typical dimensions for a device of FIG. 2 are as follows:

Spiral antenna element diameter	4 in.
Spacing of spiral antenna element 10 from ground plane	2 in.
Spacing of elements 10 and 11 for substantially linear polarization	$\lambda/32$
Spacing of elements 10 and 11 for substantially circular polarization	$>3\lambda$
Frequency of operation	1430 mc.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An antenna system comprising, first and second two conductor spiral antenna elements each having direct space coupling, means supporting said antenna elements in proximity to each other in substantially parallel planes and with the same configuration sense each as seen from the other whereby there is coupling therebetween, and means coupling one of said elements to a radio frequency operative device, the coupling of the other element to the radio frequency operative device being indirect through the coupling between the elements.

2. An antenna system comprising first and second two conductor spiral antenna elements in parallel planes with the antenna element centers on a selected axis each of said antenna elements having direct space coupling, the antenna elements having the same configuration sense as viewed one from the other, and means connecting one of said antenna elements to a radio frequency operative device.

3. An antenna system comprising, first and second two conductor spiral antenna elements, means supporting said antenna elements in parallel planes with the antenna element centers on a selected axis perpendicular to the planes, the antenna elements having the same configuration sense as viewed one from the other, rotation control means for rotating at least one of said elements about the selected axis and means connecting one of said antenna elements to a radio frequency operative device.

4. An antenna system comprising first and second spiral antenna elements, means supporting said antenna elements in parallel planes with the antenna element centers

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on a selected axis perpendicular to the planes, the antenna elements having the same configuration sense as viewed one from the other, means cooperative with said last named means for providing adjustment of the spacing of said antenna elements along the selected axis, rotation control means for rotating at least one of said elements about the selected axis, and means connecting one of said antenna elements to a radio frequency operative device.

5. An antenna system comprising first and second spiral antenna elements, means supporting said antenna elements in parallel planes with the antenna element centers on a selected axis perpendicular to the planes, the antenna elements having the same configuration sense as viewed one from the other, means cooperative with said last named means for providing adjustment of the spacing of said antenna elements along the selected axis, rotation control means for rotating at least one of said elements about the selected axis, means connecting one of said antenna elements to a radio frequency operative device and means disposed in proximity to said spiral antenna element for limiting the space radiation pattern of the antenna system to one side of the parallel planes.

6. An antenna system comprising a plurality of spiral antenna elements, means supporting said antenna elements in separate parallel planes with the antenna element centers on a selected axis perpendicular to the

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planes, adjacent antenna elements having the same configuration sense as viewed from one to the other, means cooperative with said last named means for providing adjustment of the spacings of said antenna elements along the selected axis, rotation control means for rotating at least one of said elements about the selected axis, means connecting one of said antenna elements to a radio frequency operative device, and a reflector disposed in proximity to said spiral antenna elements for limiting the space radiation pattern of the antenna system to one side of the parallel planes.

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