

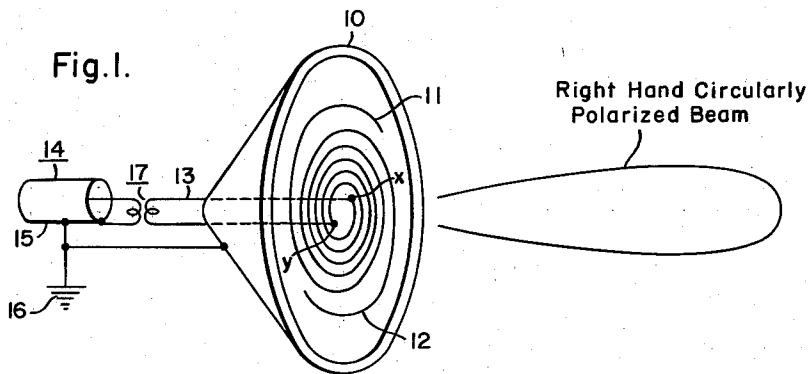
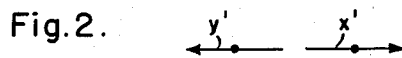
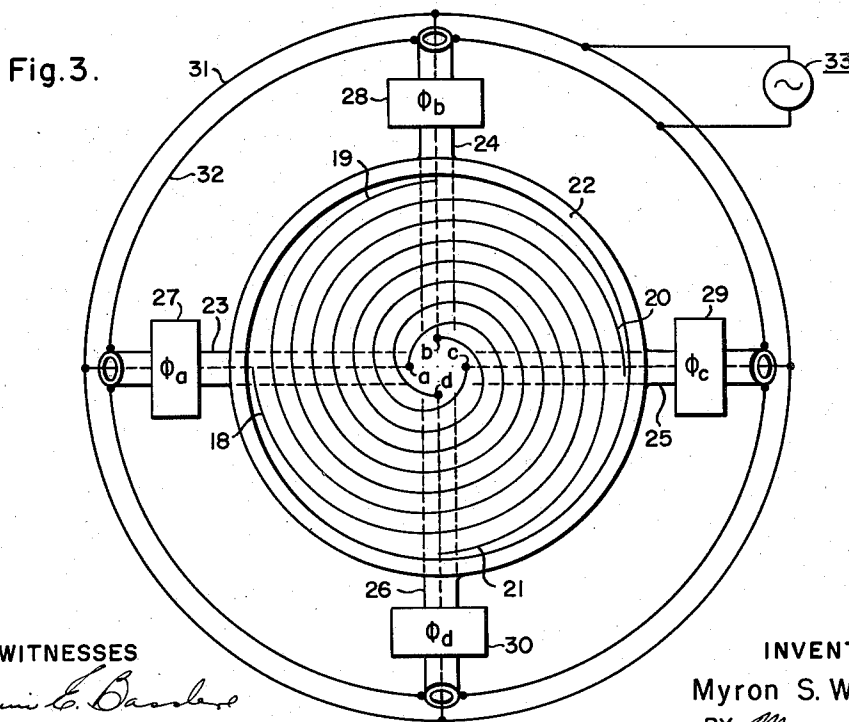
June 27, 1961

M. S. WHEELER
SPIRAL ANTENNA APPARATUS FOR ELECTRONIC
SCANNING AND BEAM POSITION CONTROL

2,990,548

Filed Feb. 26, 1959

2 Sheets-Sheet 1



WITNESSES

Ernest E. Bassler
James F. Young

INVENTOR

Myron S. Wheeler

BY *Mary I. Hull*
ATTORNEY

June 27, 1961

M. S. WHEELER
SPIRAL ANTENNA APPARATUS FOR ELECTRONIC
SCANNING AND BEAM POSITION CONTROL

2,990,548

Filed Feb. 26, 1959

2 Sheets-Sheet 2

Fig. 4.

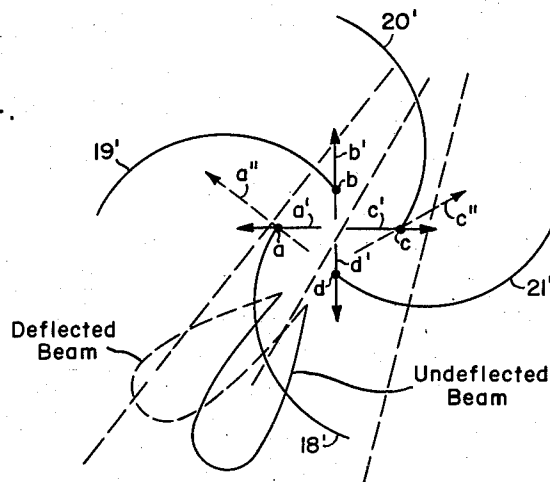


Fig. 5.

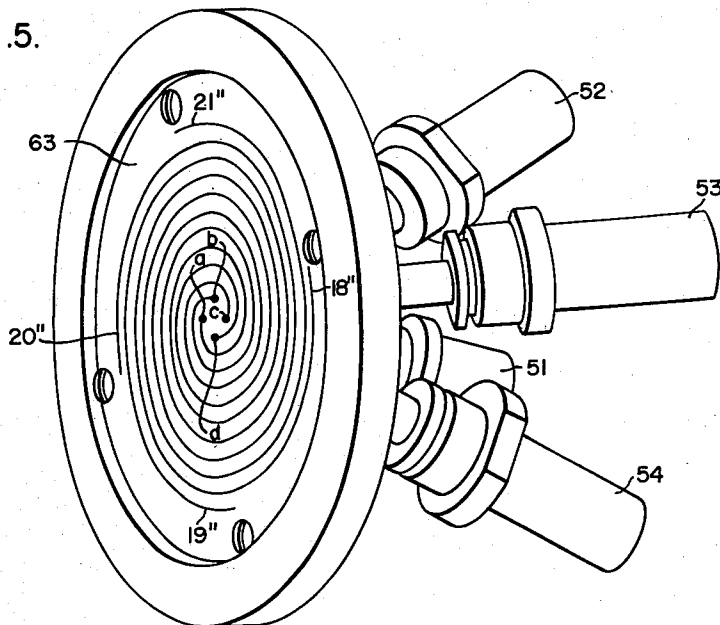
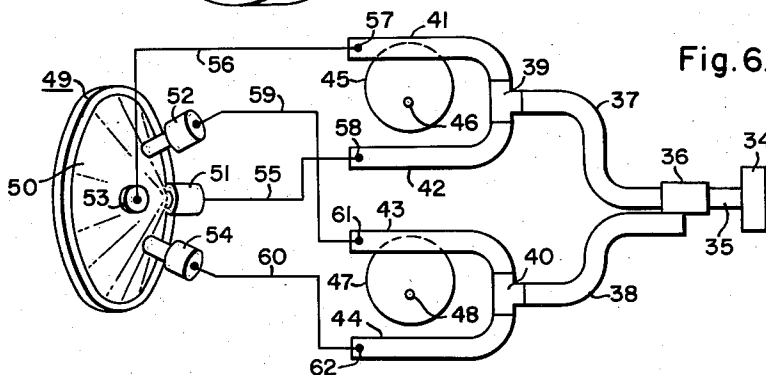


Fig. 6.



1

2,990,548

SPIRAL ANTENNA APPARATUS FOR ELECTRONIC SCANNING AND BEAM POSITION CONTROL

Myron S. Wheeler, Catonsville, Md., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Filed Feb. 26, 1959, Ser. No. 795,632

12 Claims. (Cl. 343-895)

This invention relates to improvements in spiral antenna apparatus, and more particularly to spiral antenna apparatus having no moving parts for producing a scanning beam by electronic means.

In summary, the apparatus of the instant invention employs four spiral antennas or conductors (which together constitute the antenna apparatus) disposed in a single plane with means for separately feeding each of the conductors and means in each of the feed means for shifting the phase of radio frequency energy in the feed means in a predetermined manner with respect to the phase of the energy in all of the other feed means to thereby provide a desired scanning pattern of radiation or to provide a beam which is deflected in a desired direction.

Accordingly, one of the primary objects of the instant invention is to provide new and improved spiral antenna apparatus.

Another object is to provide new and improved antenna apparatus having electronic scanning means.

Other objects and advantages will become apparent after a study of the following specification, when read in connection with the accompanying drawings, in which:

FIG. 1 is a view of a two spiral antenna of the prior art;

FIG. 2 is a graph illustrating the operation of the apparatus of FIG. 1;

FIG. 3 is a view, partly schematic and partly side-elevational, of apparatus according to the preferred embodiment of the invention;

FIG. 4 is a graph illustrating the operation of apparatus similar to that of FIG. 3;

FIG. 5 is a perspective view of an antenna assembly according to an embodiment of the invention; and

FIG. 6 is a view of apparatus for feeding radio frequency signals in desired phase relationships to the antenna of FIG. 5.

Referring now to the drawings for a more detailed understanding of the invention, in which like reference numerals are used throughout to designate like parts, and in particular to FIG. 1, there is shown at 10 an antenna reflector having disposed therein or thereon a pair of spiral antennas 11 and 12 which it is understood are mounted by any convenient means, not shown. The spiral antennas 11 and 12 have feed points x and y , respectively, and these are connected by feed means 13 and balun 17 to an R-F transmission line generally designated 14. Preferably, the outer conductor 15 of the transmission line 14 is connected to ground 16.

Preferably, the antenna in FIG. 1 is driven symmetrically (that is, balanced with respect to ground), the phases of the voltages at feed points x and y being represented by the corresponding arrows x' and y' in FIG. 2, and it will be noted that these voltages are 180° out of phase with one another. Under such circumstances the prior art antenna of FIG. 1 has the general characteristics of a wide beam, circular polarization, constant beam width with frequency, and a useful frequency band which may be for example 10:1. The spirals 11 and 12 may be wound arms of a dipole antenna, and the spirals are usually in one of two forms, a logarithmic spiral, or an Archimedes spiral. The spirals themselves

2

radiate in two principal beams, one forward and one backward, so that the reflector 10 is usually employed, placed on one side to limit the beam to one principal direction, and this beam is indicated in FIG. 1. The beam is right hand circularly polarized or left hand circularly polarized depending upon whether the spirals are wound in clockwise or counterclockwise direction. The balun, shown at 17, may be omitted for simplicity if desired.

Particular reference should be made now to FIG. 3 in which the preferred embodiment of the instant invention is shown. Four spiral antennas, 18, 19, 20 and 21 are provided in space quadrature, the antennas 18, 19, 20 and 21 being disposed in the same plane and having feed points a , b , c , and d , respectively. A reflector is shown at 22, and feed means for the antennas 18, 19, 20 and 21 are shown at 23, 24, 25, 26, respectively, each of these feed means having a phase shifting device 27, 28, 29 and 30 respectively therein, all four of the feed means 23, 24, 25 and 26 being connected by lead means 31 and 32 to a source of radio frequency energy of suitable frequency, generally designated 33. The feed means 23, 24, 25 and 26 may all be similar transmission lines. The spiral antenna of FIG. 3, with the spirals wound in the sense shown, tends to radiate a beam of right-hand circularly polarized energy in the direction of one looking at the figure. The correct relative phase of the driving voltage at each spiral arm may be determined by the adjustable phase shifters 27, 28, 29 and 30.

Particular reference is made now to FIG. 4 in which the arrows a' , b' , c' and d' represent the phases of the voltages at feed points a , b , c , and d , respectively when the four spiral conductors, arms or antennas are energized by four signals, each signal being 90° out of phase with the signals on the adjacent two of the spiral arms. The antenna arms related to the feed points a , b , c and d are designated 18', 19', 20' and 21', respectively. It will be noted that the spirals of FIG. 4 are wound in counterclockwise directions, and accordingly the beams of radio frequency energy of FIG. 4 may be expected to be left hand circularly polarized and centered perpendicular to the plane of the spiral when the antenna is fed as has been described.

Assume now by way of description that the phase of the voltage at feed point c is advanced, and the phase at feed point a is retarded, as shown by the dashed line arrows c'' and a'' in FIG. 4. The beam is deflected in, for example, azimuth toward the region in the antenna with the retarded phase. If the voltages at feed points b and d were similarly advanced and retarded respectively, the beam would be deflected in elevation toward the region of the antenna with the retarded phase. Thus, shifting the phases of the voltages at points a and c may be employed for providing, for example, azimuth deflection, and phase shifting the voltages at feed points b and d may be used for providing elevation deflection.

It should be noted that no specific direction of deflection has been associated with a specific pair of input feedlines. This is because of the nature of this antenna whereby the given deflection, produced by phase shifts in one pair of inputs, rotates with the applied signal frequency. That is, it has been found that the spirals of the type described radiate principally from a traveling wave on an equivalent ring which is one wavelength in circumference, and in the plane of the spiral.

As the conducting arms tie into this mathematically symbolic ring at different rotational points, depending upon the applied frequency, the effect of phase shifts in a particular pair of feeds is rotated with respect to their position at the center of the antenna. Thus, at any one frequency, the pair of feed points may be made by design as azimuth. The other feed points are automatically 90°

to this or elevation. Over a band of frequencies this may or may not be a problem in the application depending upon the use to which the antenna is put.

Particular reference should be made now to FIG. 6, in which apparatus for producing automatically the phase shifts at the various antennas, to provide a conical scanning beam is shown. In FIG. 6, a source of radio frequency energy of suitable frequency is shown at 34, feeding waveguide section 35 which feeds into a device 36 for producing a 90° phase shift in two output waveguide sections 37 and 38. The device 36 may be a short slot hybrid junction which will produce the required 90° phase shift between the signals in waveguide sections 37 and 38. Each of the waveguide sections 37 and 38 feeds into a device, which may be an E plane T, for producing a required 180° phase shift in the signals in the two oppositely disposed arms attached thereto, the 180° phase shift device fed from waveguide 37 being designated 39, and the 180° phase shift device fed from waveguide section 38 being designated 40. As a result of this arrangement the wave energy in feed section 41 is 180° out of phase with the energy in feed section 42, and the wave energy in feed section 43 is 180° out of phase with the energy in feed section 44, and in the absence of any rotation of dielectric discs 45 or 47 the wave energy in both sections 43 and 44 is normally 90 degrees out of phase, leading or lagging, with the energy in feed sections 41 and 42.

Each of the feed sections 41 and 42 has a longitudinal slot running along the side thereof, and the eccentrically mounted dielectric disc 45 as it rotates about the axis of rotating shaft 46 alternately passes through the slots, not shown, in sections 41 and 42, periodically alternately varying the phase of energy in the feed sections 41 and 42. In like manner the feed sections 43 and 44 each has a longitudinally extending slot, not shown, in which the eccentrically mounted dielectric disc 47 passes as it rotates about the axis of rotating shaft 48, alternately varying the phase of the energy in section 43 and thereafter varying the phase of the wave energy in section 44. The four-spiral antenna of FIG. 6 is generally designated 49, having a reflector 50 with four feeding devices 51, 52, 53 and 54 attached to the four spiral antennas, not shown in FIG. 6. Feed device 51 may be for arm or antenna 18" and feed point *a* of FIG. 5; feed device 52 may be for arm 19" and feed point *b* of FIG. 5; feed device 53 may be for arm 20" and feed point *c* of FIG. 5; and feed device 54 may be for arm 21" and feed point *d* of FIG. 5. The feed devices 51 and 53 are connected to suitable energy conducting means, for example coaxial transmission lines 55 and 56 respectively, and are thence coupled to the waveguide sections 42 and 41 respectively, at 58 and 57, respectively. In like manner, the antenna feed means 52 and 54 which may be for antennas 19" and 21", respectively, are connected by suitable coupling means, for example coaxial lines 59 and 60, respectively, to waveguide feed lines 43 and 44, respectively, by coupling devices 61 and 62 respectively.

Particular reference should be made now to FIG. 5 in which a perspective view of the antenna is shown. The spirals are shown wound counterclockwise on a low dielectric board 63 which may be $\frac{1}{32}$ of an inch in thickness. For radio frequencies in the order of 8300 megacycles, the outer diameter of the spiral used may be 1.6 inches. Conductor widths may be .020 inch, and space widths may be .020 inch.

In the operation of the apparatus of FIG. 6, rotation of the dielectric disc 47 may control by design the deflection of the beam from antenna 49 in elevation, whereas rotation of the dielectric disc 45 controls the deflection of the radio beam in azimuth. In practice it has been found that deflection of a 70° beam of about $\pm 30^\circ$ in both azimuth and elevation can easily be obtained with phase shifts of about 80° in the phase shifters.

In FIG. 3, the phase shifters 27, 28, 29 and 30 may be any convenient phase shifting device or dividing networks chosen in accordance with the application of the

apparatus. Hybrid T dividers may be used, or combinations of E and hybrid T's may be used depending upon the application.

It will be readily apparent to those skilled in the art that the apparatus of FIG. 3 may be used to provide any desired scanning or deflection pattern, suitable adjustment of the phases of the various phase shifters being made. For example, the apparatus of FIG. 3, in addition to providing the conical scan described in connection with FIG. 6, may provide a spiral scan, or may provide a scanning beam of the type which may be used in providing a C type indication on a cathode ray tube. If desired, any convenient means, not shown, may be provided and connected to all of the phase shifters 27, 28, 29 and 30, for varying the phase in all feed means 23, 24, 25 and 26 in synchronism in any desired manner.

The antenna apparatus is especially suitable for mounting in the nose of a small missile which is steering a proportional course of collision with a target, since the antenna is not moved physically but electronic scanning is employed which may provide the desired information for directing the missile.

If desired, the spiral antennas, instead of being wound, may be photoetched on a mounting board 63 composed of a suitable material.

Whereas the invention has been shown and described with respect to some embodiments thereof which give satisfactory results, it should be understood that changes may be made and equivalents substituted without departing from the spirit and scope of the invention.

I claim as my invention:

1. Spiral antenna apparatus comprising, in combination, four spiral antennas disposed in the same plane and wound about each other, said four spiral antennas having four feed points respectively disposed in 90° space quadrature with respect to each other, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of predetermined frequency, and four phase shifting means disposed in said four feed means respectively for shifting the phase of radio frequency energy at said four feed points, the shifting of the phase at at least one of said feed points with respect to the phase of the energy at another one of said feed points deflecting the beam of said antenna in a predetermined manner.

2. Antenna apparatus according to claim 1 including in addition means operatively connected to said four phase shifting means for periodically shifting the phases of the signals in said four feed means in predetermined manners to thereby provide a recurring scanning pattern of radiation for the antenna.

3. Spiral antenna apparatus comprising, in combination, four spiral antennas of substantially the same overall length disposed in a predetermined manner in the same plane and having four feed points respectively, a source of radio frequency energy, 90° phase shifting means operatively connected to said source of radio frequency energy for obtaining first and second radio frequency signals displaced 90° in phase from each other, first means operatively connected to said 90° phase shifting means for obtaining from the first signal a pair of radio frequency signals displaced in phase 180° from each other, second means operatively connected to said 90° phase shifting means for obtaining from the second signal an additional pair of signals displaced 180° in phase from each other, phase shifting means operatively connected to said first means for periodically shifting the phases of the first named pair of signals with respect to each other, other phase shifting means operatively connected to said second means for periodically shifting the phases of the signals of the second pair with

5

respect to each other, and means coupling the signals of the first and second pairs to said spiral antennas, said spiral antennas providing a scanning beam which moves in accordance with variations in the phases of all said signals with respect to each other.

4. Spiral antenna apparatus comprising, in combination, four spiral antennas disposed in the same plane and wound about each other, said four spiral antennas having four feed points respectively disposed in 90° space quadrature with respect to each other, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, each of said four radio frequency feed means having a longitudinal slot therein, said four radio frequency feed means being disposed in pairs, the feed means of each pair being disposed in predetermined positions with respect to each other, one pair of said feed means being connected to a selected two of said feed points whereby variation of the relative phases of the radio frequency energy in said one pair varies the direction in a predetermined first plane of a beam emanating from said antenna apparatus, the other pair of feed means being connected to the other two feed points whereby variations of the relative phases in the other pair of feed means deflects the beam from said antenna apparatus in a second plane substantially perpendicular to the first-named plane, first dielectric disc means of predetermined shape disposed for rotation in the slots of the first pair of feed means to thereby periodically shift the phases in the first pair of feed means, and second dielectric disc means of predetermined shape disposed for rotation in the slots of the second pair of feed means for periodically varying the phases in the second pair of feed means with respect to each other, said first and second dielectric disc means rotating in predetermined synchronism with respect to each other to periodically deflect the beam of the antenna apparatus in both said first and second planes and provide a predetermined scanning pattern of radiation for the beam.

5. Spiral antenna apparatus comprising, in combination, four spiral antennas disposed in the same plane and wound about each other, said four spiral antennas having four feed points respectively disposed in 90° space quadrature with respect to each other, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, said four feed means being disposed in predetermined positions with respect to each other, each of said four feed means having a longitudinal slot therein, and two rotating dielectric discs having predetermined shapes and disposed in predetermined positions with respect to said four feed means, each of said discs being adapted to rotate in a predetermined manner in two of the slots to thereby shift the phases of radio frequency energy in the feed means, the varying of the phases of the energy in the four feed means periodically by the two rotating dielectric discs providing for a predetermined scanning pattern of movement for the beam of said antenna apparatus.

6. Spiral antenna apparatus for providing a beam of radiation having a scanning pattern of movement comprising, in combination, four spiral antennas disposed in the same plane and wound about each other in the same sense, said four spiral antennas having four feed points respectively, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, and phase shifting means including a pair of rotating dielectric discs disposed in predetermined positions with respect to said four radio frequency feed means, said four radio frequency feed means and said pair of dielectric discs being constructed and arranged to periodically shift the phases of the radio frequency energy in the four feed means to thereby vary the deflection of the beam in predetermined manners and provide said scanning pattern of movement.

6

7. Spiral antenna apparatus for providing a beam of radiation having a predetermined pattern of movement comprising, in combination, four spiral antennas disposed in the same plane and wound about each other in a predetermined manner, said four spiral antennas having four feed points respectively disposed in 90° space quadrature with respect to other other, each of said four spiral antennas being wound in a counterclockwise direction from its respective feed point, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, said four spiral antennas when energized providing a beam of left-hand circularly polarized energy, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, and phase shifting means including a pair of rotating dielectric discs of predetermined shape disposed in predetermined position with respect to said four feed means, said four feed means having slots therein through which said dielectric discs periodically pass, the rotation of the pair of dielectric discs shifting the phases of radio frequency energy at said four feed points, the periodic shifting of the phases of radio frequency energy at the four feed points deflecting the beam of said antenna apparatus in a predetermined manner.

8. Spiral antenna apparatus for providing a beam of radiation having a predetermined pattern of movement, comprising, in combination, four spiral antennas disposed in the same plane and wound about each other, said four spiral antennas having four feed points respectively disposed in 90° space quadrature with respect to each other, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, and phase shifting means including rotating dielectric disc means for shifting the phases of radio frequency energy at at least some of said feed points to thereby move the beam of radiation in at least one plane of movement in accordance with the variations in the phases in said feed means.

9. Spiral antenna apparatus comprising, in combination, reflector means, said reflector means being adapted to reflect radio frequency energy of predetermined frequency in a predetermined manner, mounting means disposed in predetermined position with respect to the reflector means, said mounting means being composed of a material having a very low dielectric constant, four spiral antennas photoetched on said mounting means, each of said four spiral antennas being of the same overall length and wound in the same sense, said four spiral antennas having four feed points respectively, and means connected to said four feed points for feeding radio frequency energy to the four spiral antennas.

10. Spiral antenna beam producing apparatus comprising, in combination, four spiral antennas disposed in the same plane and wound about each other in a predetermined manner, all of said four spiral antennas being wound in the same sense, said four spiral antennas having four feed points respectively disposed in 90° space

quadrature with respect to each other, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency to be transmitted, reflector means for said four spiral antennas, radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, and four phase shifting means disposed in said four feed means respectively for shifting the phases of radio frequency energy at said four feed points, the shifting of the relative phases at a first two of said feed points diametrically disposed with respect to each other shifting the beam in a first plane and the shifting of the relative phases at the other two of the feed points which are diametrically disposed with respect to each other shifting the beam in a second plane substantially perpendicular to the first plane.

11. Spiral antenna beam producing apparatus comprising, in combination, disc-like mounting means composed of a material having a very low dielectric constant, four spiral antennas photoetched on said mounting means, said four spiral antennas being disposed in the same plane and wound about each other in a predetermined direction, reflector means for said four spiral antennas, said four spiral antennas having four feed points respectively disposed in 90° space quadrature with respect to each other, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency to be transmitted, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points and adapted to be energized from a source of radio frequency energy of said predetermined frequency, and four phase

shifting means disposed in said four feed means respectively for shifting the phase of radio frequency energy at at least two of said feed points with respect to each other to thereby position the beam of said spiral antenna apparatus in a predetermined manner.

12. Spiral antenna beam producing apparatus comprising, in combination, four spiral antennas disposed in the same plane and wound about each other, mounting means including a disc of material having a very low dielectric constant, said four spiral antennas being photoetched on said disc, said four spiral antennas having four feed points respectively, each of said spiral antennas being of substantially the same overall length in accordance with a predetermined radio frequency, four radio frequency feed means for said four spiral antennas respectively connected to said four feed points, a source of radio frequency energy of said predetermined frequency operatively connected to said four feed means, and phase shifting means disposed in at least some of said feed means for shifting the phase of radio frequency energy at at least some of said feed points, the shifting of the phase of the radio frequency energy at the feed points deflecting the beam of the antenna apparatus in a predetermined manner.

References Cited in the file of this patent

UNITED STATES PATENTS

2,488,419	Lindenblad	Nov. 15, 1949
2,863,145	Turner	Dec. 2, 1958

OTHER REFERENCES

Pub. I, Spiral Antenna for Guided Missile Aviation Week, Nov. 17, 1958, pp. 75 and 77.