

Aug. 11, 1964

K. DOLLINGER

3,144,648

DUAL MODE SPIRAL ANTENNA

Filed Sept. 28, 1962

4 Sheets-Sheet 1

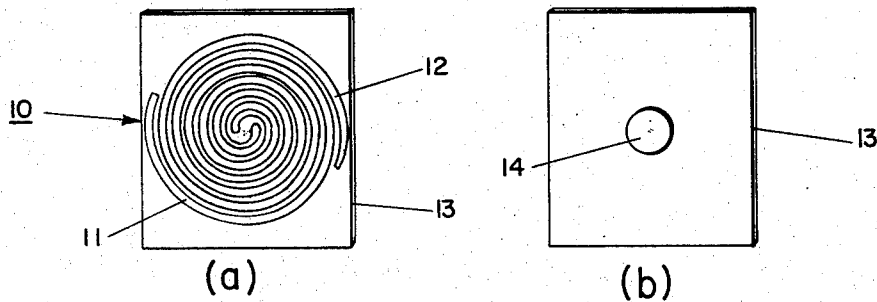


FIG. 1

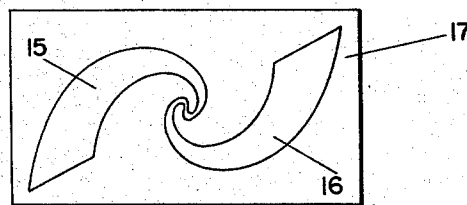


FIG. 2

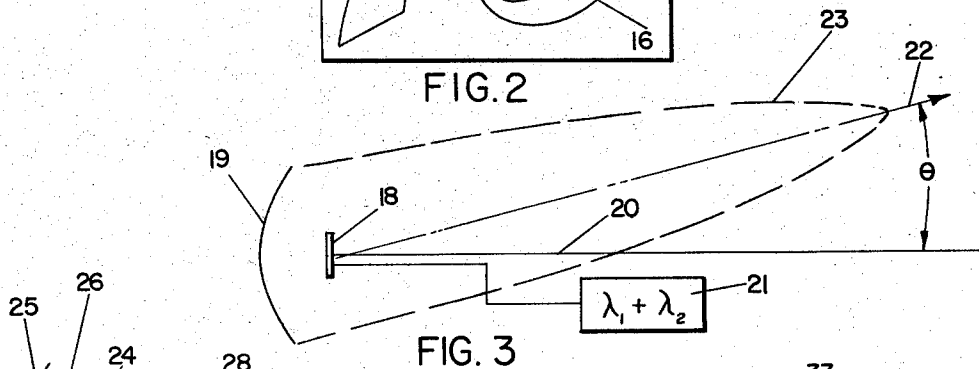


FIG. 3

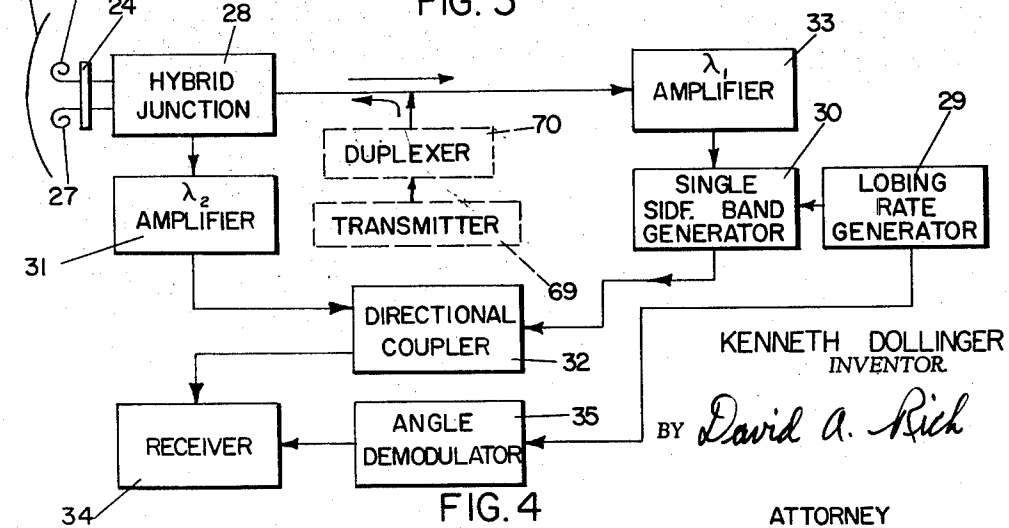


FIG. 4

Aug. 11, 1964

K. DOLLINGER

3,144,648

DUAL MODE SPIRAL ANTENNA

Filed Sept. 28, 1962

4 Sheets-Sheet 2

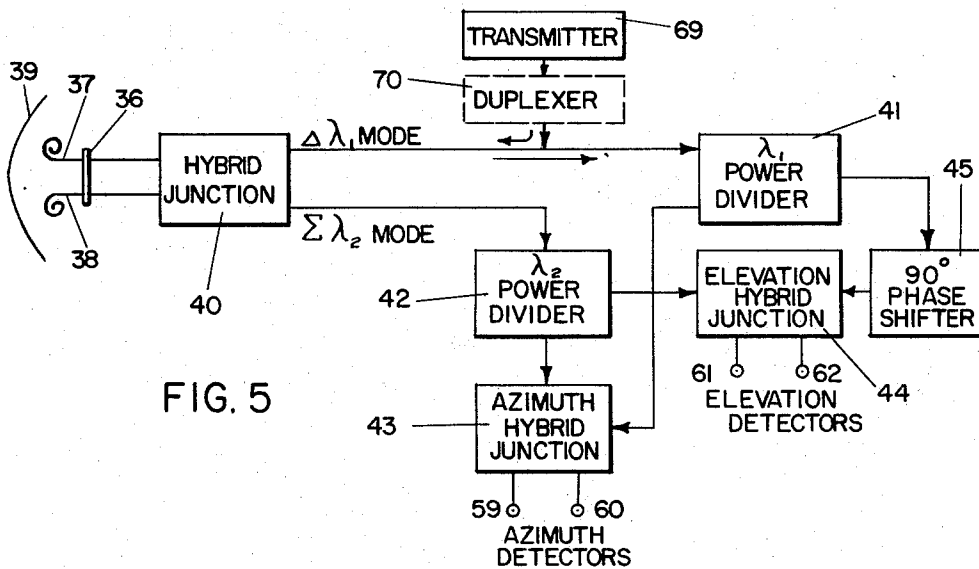


FIG. 5

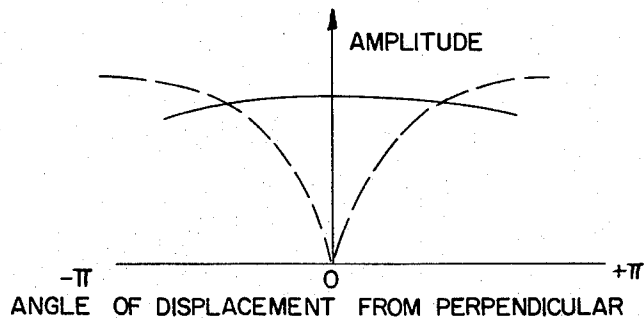


FIG. 6

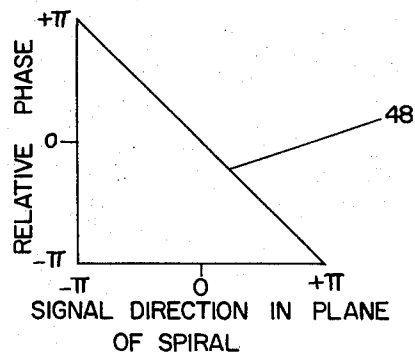


FIG. 7

KENNETH DOLLINGER
INVENTOR

BY *David A. Spick*

ATTORNEY

Aug. 11, 1964

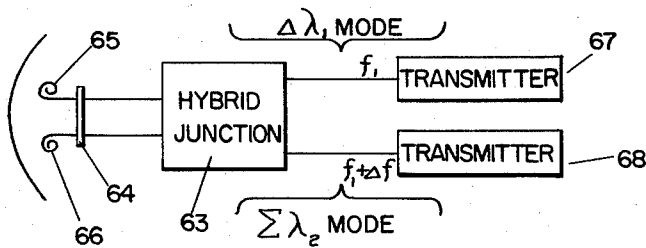
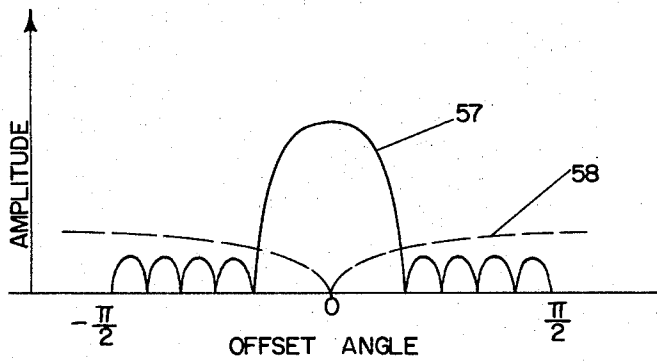
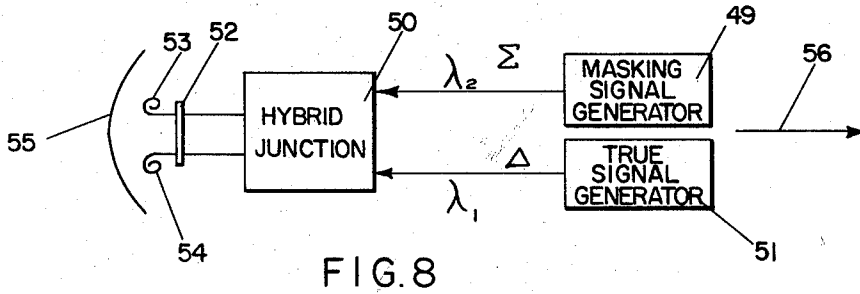
K. DOLLINGER

3,144,648

DUAL MODE SPIRAL ANTENNA

Filed Sept. 28, 1962

4 Sheets-Sheet 3



KENNETH DOLLINGER
INVENTOR

BY *David A. Rich*

ATTORNEY

Aug. 11, 1964

K. DOLLINGER

3,144,648

DUAL MODE SPIRAL ANTENNA

Filed Sept. 28, 1962

4 Sheets-Sheet 4

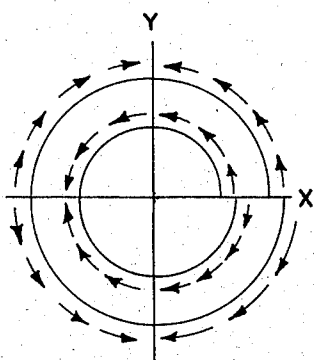


FIG. 11a

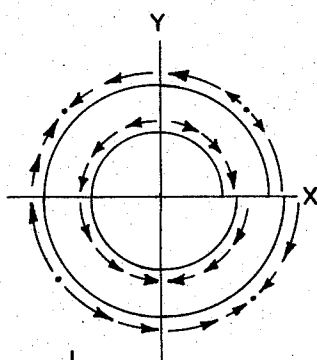
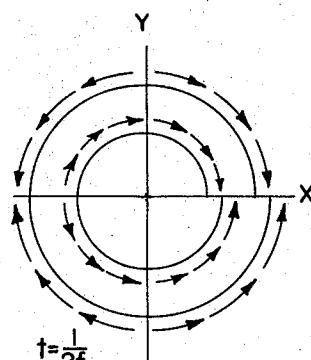
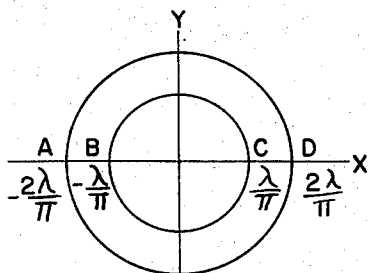


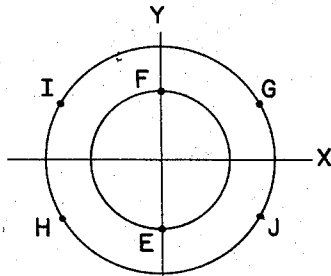
FIG. 11b



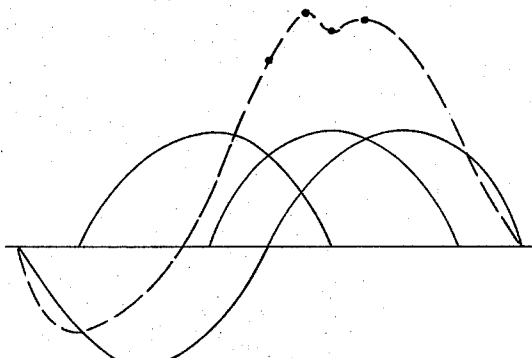
CURRENT DISTRIBUTIONS
ON SPIRAL DURING
ONE-HALF R.F. CYCLE
FIG. 11c



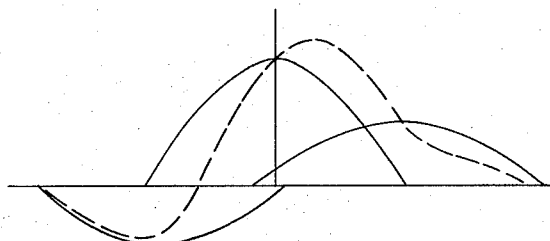
REFERENCE POINTS FOR
VERTICAL POLARIZATION
PATTERN DISPLACEMENT
FIG. 12



REFERENCE POINTS FOR
HORIZONTAL POLARIZATION
PATTERN DISPLACEMENT
FIG. 14



DISPLACEMENT OF VERTICALLY
POLARIZED PATTERN
FIG. 13



DISPLACEMENT OF HORIZONTALLY
POLARIZED PATTERN
FIG. 15

KENNETH DOLLINGER
INVENTOR.

BY *David A. Rich*

ATTORNEY

1

3,144,648

DUAL MODE SPIRAL ANTENNA

Kenneth Dollinger, Nashua, N.H., assignor to Advanced Development Laboratories, Inc., Nashua, N.H., a corporation of Delaware

Filed Sept. 28, 1962, Ser. No. 226,915

17 Claims. (Cl. 343-100)

The present invention relates to wave translation devices. More particularly, the invention relates to wave translation devices having directional characteristics for transmission and reception. More especially, the invention relates to novel wave translation devices and systems utilizing dual mode excitation of a so-called spiral antenna.

In the prior art, a number of systems have been proposed for directional wave transmission and reception of electromagnetic energy in a form typically termed conical scanning. The directional pattern of transmission or reception is produced by the apparent motion of an off-set beam rotating about the bore sight axis to provide a cone of radiation with very fine discrimination along the bore sight axis.

In the past, conical scanning has been accomplished primarily by mechanical means. Thus, for example, an eccentrically mounted dipole may be rotated about an axis. In patents numbered 2,878,470, 2,818,563, issued to Jesse L. Butler on March 17, 1959, and December 31, 1957, respectively, a system is disclosed and claimed wherein the apparent rotation of the beam takes place at three times the mechanical rotation of the wave translation element.

In such conical scanning systems of the prior art, the rate of rotation, i.e., the conical scanning frequency, is limited to the rate attainable by mechanical means. The wave translation device of the present invention may be used for conical scanning without any mechanical moving parts. The generation of conical scanning rates in this form of the invention may be accomplished electrically. In this manner, extraordinarily high conical scanning frequency may be accomplished with a resultant extraordinary increase in information rate.

Prior art conically scanning antennas present severe problems in the reception of circularly polarized energy. An important advantage of the instant invention lies in greatly improved reception of circularly polarized energy. This is particularly important for large antenna installations.

In general, the prior art antennas useful for conical scanning are frequency-sensitive. The frequency response of such antennas is relatively narrow; off the center frequency the efficiency of such prior art antennas rapidly degenerates. In contrast, the present wave translation device of the present antenna has a relatively broad frequency response pattern.

Another feature of the invention relates to its application to so-called monopulse radar systems. The prior art monopulse system is typically characterized by four separate wave translation or antenna systems. In contrast, the wave translation device of the present invention provides a monopulse system with only a single antenna system.

It is highly desirable for some applications of directional wave translation to provide a confusing signal in all directions except a desired direction.

The principles of the present invention are applicable to a system for directive wave translation in which a desired signal may be received only along a preferred direction. In all other directions only a confused signal may be received. Such a system has broad application for point-to-point communication with improved secrecy.

2

It is therefore an object of the invention to provide an improved wave translation device.

A further object of the invention is to provide an improved wave translation device capable of high conical scanning frequencies.

Another object of the invention is to provide conical scanning with improved response to circularly polarized energy.

Still another object of the invention is to provide an improved wave translation device useful for monopulse systems.

Yet another object of the invention is to provide an improved wave translation device for directional or point-to-point communication wherein the signal is confused in all directions except a preferred direction.

Yet another object of the invention is to provide an improved method of signaling.

Still another object of the invention is to provide an improved conical scanning system of simple and economical structure.

Another object of the invention is to provide an improved conical scanning system having no moving mechanical parts.

In accordance with the invention, there is provided a wave translation device. The device includes a pair of curved wave translation elements. Synchronous means are coupled to the elements for coupling the elements and a pair of signals in synchronous phase relation. Anti-synchronous means are coupled to the elements for coupling the elements and a pair of signals in 180° phase relation. Variable means are coupled to the elements for varying a selected characteristic for one pair of signals relative to the other pair of signals.

In one form of the invention, the phase of one pair of signals is varied relative to the other pair.

In another form of the invention the amplitude of one pair of signals is varied relative to the other pair.

In still another form of the invention the frequency of one pair of signals is varied relative to the other pair.

In still another form of the invention, wave translation is provided along a pair of preferred axes.

In still another form of the invention, deceptive signal means are coupled to the wave translation elements for translating a deceptive signal other than in a preferred direction.

For a better understanding of the invention, together with other and further objects thereof, reference is made to the following description of the invention, taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawings:

FIGURE 1a is a front elevational view of an antenna useful in the present invention, and FIGURE 1b is a rear elevational view of the antenna;

FIGURE 2 is a front elevational view of a modification of the antenna in FIGURE 1;

FIGURE 3 is a schematic block diagram of a wave translation system embodying the invention;

FIGURE 4 is a schematic diagram of a conically scanning wave translation system embodying the invention;

FIGURE 5 is a schematic diagram of a monopulse wave translation system embodying the invention;

FIGURE 6 is a graph illustrating radiation amplitude versus offset angle for the system in FIGURE 5;

FIGURE 7 is a graph illustrating the relative phase of a dual mode signal versus angle for the system in FIGURE 5;

FIGURE 8 is a schematic diagram of a wave translation system embodying the invention as modified for deceptive radiation;

FIGURE 9 is a graph illustrating the operation of the system in FIGURE 8;

FIGURE 10 is a transmitter system embodying the invention;

FIGURES 11a, 11b, and 11c are a series of graphs illustrating the antenna current distribution in the operation of the invention;

FIGURES 12 and 13 are graphs illustrating vertical polarization pattern displacement; and

FIGURES 14 and 15 are graphs illustrating horizontal polarization pattern displacement.

Principles of Operation

The so-called spiral antenna has come into prominence recently. This antenna characteristically has the structure of a pair of curved wave translation elements. Such an antenna may be excited in two modes which are characteristically referred to as Lambda_1 (λ_1) and Lambda_2 (λ_2).

In an article entitled "Design Techniques for a Lightweight High-Powered Spiral Antenna," by J. P. Jones, P. I. Taylor, and C. W. Morrow, published in IRE Wescon Convention Record, page 107, on August 23, 1960, a description of a spiral antenna with dual mode excitation is presented.

In another article entitled "Second Mode Operation of the Spiral Antenna," by John R. Donnellan, published in IRE "Transactions on Antennas and Propagation," November 1960, the structure of a dual mode spiral antenna is described and its operating characteristics illustrated.

The λ_1 mode is excited when the two arms are fed in phase opposition, i.e., a pair of signals are coupled to the wave translation elements which are 180° out of phase. The λ_2 mode relates to in-phase excitation of the wave translation elements. The λ_1 mode exhibits a radiation pattern having a path along the axis of the spiral or boresight axis of the antenna. The λ_2 mode exhibits an omnidirectional pattern with a null in the direction of the boresight axis. It turns out that both of the modes may be excited simultaneously to produce a single lobed beam which is offset from the boresight axis.

It has been proposed that the spiral antenna radiates principally from a band on the spiral surface where the currents in adjacent elements are most nearly in phase. Thus, if a spiral is fed so that energy entering the two spiral elements at the origin are 180° out of phase, the first current band occurs where the current in one arm returns to an in-phase condition with the other arm. This condition occurs because of the geometry of the spiral elements, each successive turn of the spiral being progressively longer. On geometric grounds, it would appear that the currents of adjacent conductors reach an in-phase condition where the circumference of the ring is equal to one wavelength. On the other hand, if the spiral is fed such that the elements are in phase at the origin, twice the distance is required for the currents in adjacent conductors to be in phase. It turns out that this condition is realized where the circumference of the effective ring is equal to approximately two wavelengths. The tendency to radiate at the center of the spiral is suppressed by means of a metal plate placed immediately behind the spiral element.

In order to analyze the operation of the antenna with dual mode excitation, it is useful to consider the antenna to be a combination of an inner conductor one wavelength long and an outer conductor two wavelengths long. From the following analysis, it will be seen that the resultant antenna pattern indicates that dual mode excitation produces an apparent shift of the center of radiation off the boresight axis.

At time $t=0$, $t=\frac{1}{4}f$ and $t=\frac{1}{2}f$, the current distributions are illustrated in FIG. 11a, b and c. Note that the currents of both elements are in phase where the elements intersect the +X axis. The currents are 180° out of phase at the intersections of the Y axis.

The analysis of the mechanism by which the antenna

beam is offset is effected with the use of superposition patterns with even (+ +) symmetry and odd (+ -) symmetry. The field intensity and polarization patterns obtained in the antenna used to feed a parabolic reflector may be determined to reasonable accuracy by treating each point on each of the two conductors as a linearly polarized source which produces a secondary field pattern of the form:

EQUATION 1

$$E_\phi = \frac{2\lambda}{\pi D} \left[\frac{J_1 \left[\frac{(\pi D)}{\lambda} \sin \phi \right]}{\sin \phi} \right]$$

where

D = diameter of aperture,

λ = free space wavelength,

J_1 = first-order Bessel function, and

ϕ = angle with respect to the normal to the aperture,

minus the effective angular displacement of the point from the focal axis. The effective angular displacement of the feed point will be about 0.8 of the actual angular displacement.

This method of analysis is subject to correction due to coma distortion of the reflector and the directivity of the point feed caused by backing the spiral antenna with a reflector or cavity.

A qualitative analysis of the beam displacement effect obtained with the two mode spiral as a paraboloidal feed may be obtained as follows:

(1) Assume that for vertical polarization only points on the X-axis contribute:

A fair approximation for the beamwidth of a paraboloidal antenna is

$$70 \frac{\lambda}{D}$$

degrees. For an

$$\frac{F}{D}$$

of 0.4 and a displacement factor of 0.8, the fractional beamwidth beam-offset is then about

$$1.6 \frac{S}{\lambda}$$

where S is the linear displacement of the feed point from the focal axis.

Referring to FIG. 12, points A, B, C and D are displaced

$$-\frac{2\lambda}{\pi}, -\frac{\lambda}{\pi}, \frac{\lambda}{\pi} \text{ and } \frac{2\lambda}{\pi}$$

respectively. The resulting secondary patterns are then displaced plus and minus one-half and one beamwidth, as shown in FIG. 13. The summation on superposition of these four patterns is a displaced pattern, as shown in FIG. 13.

(2) Similarly, the horizontally polarized patterns may be approximated crudely by assuming that only points at $Y = \pm \lambda/2$ contribute. Thus, three pairs of sources E and H, F and I, G and J as shown in FIG. 14 are summed. The omission of any component from the 2λ conductor beyond

$$Y = \pm \frac{\lambda}{2\pi}$$

is justifiable on the basis that the patterns produced are displaced by close to a beamwidth in the vertical plane and thus make a negligible contribution to the pattern taken on the horizontal axis.

The relative amplitudes of the horizontally polarized components at points E, F, and G should be respectively

$\frac{1}{2}$, 1 and $\frac{1}{2}$. The X-axis coordinates of the three points are

$$\frac{\sqrt{3}\lambda}{\pi}$$

o and

$$\frac{\sqrt{3}\lambda}{\pi}$$

The horizontal beam offset at points E and G should be

$$\frac{1.6 \times \sqrt{3}}{\pi}$$

or 0.88 beamwidth. FIG. 15 shows the pattern resulting from the superposition of these three patterns. The contributions from E and H are oppositely polarized from the contributions at F, I, G and J, resulting in a final pattern that is displaced to the right of boresight.

It will be apparent, then, that the dual mode spiral antenna using a primary feed for a parabolic reflector produces an offset secondary pattern. The offset pattern conically scans by continuously varying the phase of the λ_2 mode excitation relative to the λ_1 mode excitation.

The above analysis indicates that in the λ_1 mode, the antenna radiates primarily from the vicinity of the inner ring having a circumference of one wavelength. When the curved element is fed in phase exciting the λ_2 mode, a double-lobed radiation pattern is produced with null in the direction of the spiral antenna. This radiation apparently operates primarily in the vicinity of the outer ring having a circumference of two wavelengths.

Under the condition of dual mode excitation, i.e., both λ_1 and λ_2 modes simultaneously excited, the resultant pattern is a beam offset from the axis of the spiral antenna. The direction in which the beam is pointed or the degree of rotation is a function of the relative phase of the λ_1 and λ_2 modes of excitation.

Though an offset beam may be obtained from the spiral antenna, this is not a sufficient condition to produce an offset beam when the spiral antenna is used for a primary radiator for a parabolic reflector. In order to produce an offset beam from the combination of a primary spiral antenna and a parabolic reflector, the apparent center of radiation of the primary antenna must be displaced from the focal point of the reflector.

From the above analysis, it will be apparent that the center of radiation of the spiral is apparently displaced off the axis of the spiral when the λ_1 and λ_2 mode rings are excited simultaneously. Furthermore, it appears that the resultant center of radiation moves about a circle with its center coinciding with the axis of the spiral as the phase between the two modes is varied through 2π radians.

An electrically lobed antenna system providing electronic conical scanning may be obtained by separately exciting the antenna simultaneously with the λ_1 and λ_2 modes. This may be accomplished by feeding the spiral at the origin from a well-known hybrid junction. The sum arm excites the antenna terminals in phase to produce the λ_2 mode while the difference arm produces the λ_1 mode.

The angle of the beam or degree of offset may be varied by adjusting the degree of coupling between the two modes. A crossover of approximately 3 db may be achieved by summing the signals in a 3 db coupler. By loosely coupling the λ_1 and λ_2 modes, a crossover level of 1.0–1.50 db may be realized.

Description and Explanation of the Antenna and System in FIGS. 1, 2 and 3

Referring now to the drawings and with particular reference to FIG. 1, there is here illustrated an embodiment of a spiral antenna. The antenna generally indicated at 10 has a pair of curved wave translation elements 11 and 12. The elements as shown are involute and in the

form of an Archimedes spiral. Such a spiral is of the form

$$R=k\theta$$

where R is the radius vector from the origin to a point on the curve, θ the angle of rotation, and k a constant defining the rate of expansion of the curve. The elements may be formed from copper foil by well-known etching techniques. The elements are adhered to a base 13 formed of insulating material such as XXXP Bakelite or one of the fluoro-carbons. As shown in the rear view of FIG. 1b, a metal plate 14 may be centrally mounted in the vicinity of the inner turns of the antenna to suppress spurious radiation.

In the configuration of FIG. 2 a so-called scimitar antenna is illustrated. The antenna has a pair of scimitar shaped wave translation elements 15 and 16 mounted on a base 17. This antenna is broadly defined to be of equi-angular configuration and has the form

$$R=e^{k\theta}$$

where R is the radius vector from the origin to a point on the curve, θ the angle of rotation, and k a constant defining the rate of expansion of the element.

Referring now to FIG. 3, there is here illustrated a wave translation system embodying dual mode excitation of a spiral antenna. Here a spiral antenna 18 or the type illustrated in FIG. 1 is used as a primary radiator for a paraboloidal reflector 19. The antenna 18 is situated with its center coincident with the focal point of the reflector 19. The spiral axis perpendicular to its plane is coincident with the axis of the reflector 19 and is termed the boresight axis 20. The antenna 18 is coupled to an excitation source 21 which provides both modes of excitation simultaneously. This has the effect of producing an offset radiation along an axis indicated at 22 for a beam 23 indicated by the dashed line. The angle ϕ between the boresight axis 20 and offset axis 22 is determined by the relative amplitude of the λ_1 and λ_2 modes. As noted above, the beam 23 may be rotated about the boresight axis 20 by varying the phase of the λ_2 mode relative to the phase of the λ_1 mode to provide conical scanning.

The invention as described herein is taken particularly with respect to the receive only condition of operation. It is, of course, applicable to the transmitting case as well. For active conical scanning of the transmitted beam, the system is reciprocal in concept.

As will be described more completely below, the invention has particular application to receive only for monopulse radar tracking systems and conical scanning systems wherein transmission takes place in the λ_1 mode and a duplexer protects the receiver.

Description and Explanation of the System in FIG. 4

Referring now to FIG. 4, there is here illustrated a schematic block diagram of a conical scanning antenna system embodying the present invention. Here a spiral antenna 24 of the type illustrated in FIG. 1 provides the primary feed for a paraboloidal reflector 25. The wave translation elements 26 and 27 are connected to the input arms of a hybrid junction 28. The hybrid junction is of the type described in Handbook of Tri-Plate Components, page 73, a publication of Sanders Associates, Inc., 1956. The sum or Σ arm ties the λ_2 mode to the junction 28. The difference or Δ arm ties the λ_1 mode to the junction 28.

The arms of the junction 28 are coupled through a pair of amplifiers 31 and 33. The amplifier 33 is coupled to a single side band generator 30, of the type described in article by A. Clavin, IRE Transactions on Microwave Theory and Techniques, March 1962, page 98, which derives an input from a lobing rate generator 29. The generator 29 may be a simple Hartley type oscillator such as described in F. E. Terman's "Electronic & Radio Engineering," McGraw-Hill, 1955. The generator 29

produces a displacement frequency f for the generator 30. The output of the single side band generator 30 is coupled through a directional coupler 32 to a receiver 34. The output of the amplifier 31 is coupled through the coupler 32 to the receiver 34. The generator 29 and receiver 34 are coupled to an angle demodulator 35 to produce an indication of the direction of radiation of the beam.

The antenna 24 is used as the primary feed for the reflector 25. The hybrid junction couples the λ_1 and λ_2 modes to feed the elements of the antenna 24 in phase via the sum arm and out of phase via the difference arm. The system as shown is designed to provide passive conical scanning; that is to say, the system as shown is a receiver. The carrier f_c is received via the antenna coupled to the junction 28 and separated into the two modes λ_1 and λ_2 . The energies are amplified in the amplifiers 31 and 33. The output of the amplifier 33 is applied to the single side band generator 20, which derives another input from the generator 29. The output of the generator 30 is coupled through the coupler 32 to the receiver 34. The single side band generator produces an output frequency $f_c + \Delta f$ displaced from the incoming carrier by the frequency of the lobe rate generator. The λ_2 mode signal is added to the output of the generator 30 by means of the directional coupler 32. A resultant signal is produced which is indistinguishable from a prior art conical scanning antenna having a nutating feed.

The above description relates particularly to a "receive only" system; the effect of conical scanning is then passive. A transmitter may be added for the λ_1 mode and fed through a duplexer to the antenna. Thus, here there is shown in dashed lines, indicating a possible addition, a transmitter 69 coupled to a duplexer 70. The duplexer operates to transmit a high power signal only through the antenna 24. On receive, low power energy is coupled from the antenna 24 through the duplexer 70 to the amplifier 31.

Description and Explanation of the Monopulse System in FIG. 5

Referring now to FIG. 5, there is here illustrated a schematic block diagram of a monopulse wave translation system embodying the invention. Here a spiral antenna 36, of the type shown in FIG. 1 and having a pair of wave translation elements 37 and 38, provides the primary feed for a paraboloidal reflector 39. The antenna 36 is coupled to a hybrid junction 40. The difference or Δ arm of the junction 40 is coupled to a λ_1 mode power divider 41. The sum or Σ arm couples the λ_2 mode to the λ_2 mode power divider 42. An output of the divider 42 is coupled to a 90° phase shifter 45. Another output of divider 41 is coupled to the azimuth junction 43. The output of the shifter 45 is coupled to the elevation junction 44. The outputs of the azimuth hybrid junction 43 are applied to the azimuth detector crystals through a pair of terminals 59 and 60. The outputs of the elevation comparator 44 are applied to the elevation detector crystals through a pair of terminals 61 and 62.

As shown in dashed lines, the transmitter 69 is coupled to the duplexer 70. The duplexer operates to short out the receiver during transmission and shunt the energy to the antenna 24. During receive, when the transmitter is quiescent, the receiver circuit is enabled to receive energy from the antenna.

For monopulse application the system utilizes the phase and amplitude characteristics of the radiation patterns of the spiral antenna for dual mode excitation. The amplitude characteristics are illustrated for the plane perpendicular to the plane of the spiral in the graph illustrated in FIG. 6. The curve 46 is the amplitude characteristic of the λ_1 mode with respect to the angle of displacement from the perpendicular to the plane of the spiral. The curve 47 illustrates the amplitude of the λ_2 mode with respect to the angle of displacement. By com-

paring the relative amplitudes of the two modes, the angle of offset off the axis or the direction of the received signal is indicated.

As shown in FIG. 7, the relative phase between the λ_1 and λ_2 modes goes through 2π radians as the signal direction changes in the plane of the spiral. A comparison of the phases of the signals in both modes provides an indication of the direction of the signal in the plane of the spiral. In the system as illustrated in FIG. 5, the error signals are transformed into azimuth and elevation information by splitting the λ_1 and λ_2 mode signals. One set is compared directly and the second set with a 90° phase shift. In this manner an indication of the projection of the signal directions with respect to a pair of orthogonal reference directions in the plane of the spiral is obtained.

This can be seen by considering the behavior of the system for a signal coming from a direction in the reference plane perpendicular to the plane of the spiral. The phase of the λ_2 mode signal with respect to the λ_1 mode signal will remain at zero degrees as the signal direction changes from within the plane of the spiral along the reference axes to boresight and will remain at 180° as the signal moves from boresight to the plane of the spiral in a direction opposite to the reference axis. If we assume that the reference axis corresponds to the azimuth axis, then at boresight, the λ_2 mode signal is zero so that equal signals are applied to both the azimuth and elevation detector crystals. As signal moves toward the plane of the spiral in the direction of the reference axis, remaining in the reference plane, the λ_1 and λ_2 mode signals will remain in phase. However, the amplitude of the λ_2 mode signal will progressively increase. The signals applied to the azimuth detector crystals will be unbalanced in a particular direction. If the signal moves toward the plane of the spiral in a direction opposite to the reference axis, but still in the reference plane, the λ_1 and λ_2 mode signals will be in phase opposition and signals applied to the azimuth detector crystals will be unbalanced in the opposite direction. The signals applied to the elevation hybrid will be in quadrature for all the above conditions and thus the inputs to the elevation crystal detectors will remain equal. If the signal comes from a direction in a plane at right angles to the reference plane then the λ_1 and λ_2 mode signals will be in phase quadrature. Because of the presence of the 90 degree phase shifter 45, the signals applied to the elevation hybrid junction will either be in phase or in phase opposition. Thus unbalanced signals will be applied to the elevation crystal detectors and equal signals to the azimuth crystal detectors.

Description and Explanation of the Deceptive System of FIG. 8

Referring now to FIG. 8, there is here illustrated a schematic block diagram of a wave translation system embodying the invention for providing deceptive signals other than in a preferred direction of transmission. Here a masking signal generator 49 is coupled to the sum arm of a hybrid junction 50. A true signal generator 51 is coupled to the difference arm of the junction 50. The output of the junction 50 is coupled to an antenna 52 of the type illustrated in FIG. 1. The antenna 52 with its wave translation elements 53 and 54 provides the primary feed for a paraboloidal reflector 55.

A desired signal is generated by the generator 51 coupled to the difference arm of the junction 50 to be transmitted via the antenna 52 and reflector 55 in a preferred boresight direction indicated at 56. The masking signal generator 49, for example, a noise generator, is coupled to the sum arm of the junction 50 and radiated by the antenna 52 and reflector 55 in the manner indicated by the graph illustrated in FIG. 9. There the curve 57 represents the amplitude of signal with respect to the offset angle from the boresight axis 56. The masking signal may be comprised of pure noise, other fre-

quencies and random phase and/or amplitude changes to provide deceptive transmission. As indicated in FIG. 9, the curve 58 illustrates the amplitude of the masking signal. This signal has a null on boresight. For this reason the masking signal does not interfere with the desired signal in the main lobe of the radiation of the antenna. As noted above, for signal directions off the boresight axis, the masking pattern masks the side lobe transmissions of the desired signal.

From the above description it will be apparent that the present invention has wide application to the field of wave translation. The directional transmission and reception of signals is greatly enhanced.

While there has hereinbefore been described what are at present considered to be preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that many and various changes and modifications may be made with respect to the embodiments described and illustrated without departing from the spirit of the invention. It will be understood, therefore, that all such changes and modifications as fall fairly within the scope of the present invention, as defined in the appended claims, are to be considered as a part of the present invention.

What is claimed is:

1. A wave translation device, comprising:

a pair of involute circular, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation; and

variable means coupled to said elements for varying a selected characteristic of one said pair of signals relative to the other said pair of signals.

2. A wave translation device, comprising:

a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation; and

variable means coupled to said elements for varying a selected characteristic of one said pair of signals relative to the other said pair of signals.

3. A wave translation device, comprising:

a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation; and

variable means coupled to said elements for varying a selected phase characteristic of one said pair of signals relative to the other said pair of signals.

4. A wave translation device, comprising:

a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation; and

variable means coupled to said elements for varying a selected amplitude characteristic of one said pair of signals relative to the other said pair of signals.

5. A wave translation device, comprising:

a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for

coupling said elements and a pair of signals in 180° phase relation; and

variable means coupled to said elements for varying a selected frequency characteristic of one said pair of signals relative to the other said pair of signals.

6. A wave translation device, comprising:

a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;

synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided; and

focal directive means coupled to said elements for increasing directive wave translation along said displaced axis.

7. A wave translation device, comprising:

a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;

synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided; and

parabolic focal directive means coupled to said elements for increasing directive wave translation along said displaced axis.

8. A wave translation device, comprising:

a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;

synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided and the center of radiation of said elements is displaced from said axis; and

focal directive means coupled to said elements for increasing directive wave translation along said displaced axis, said center of radiation being displaced from a focus point of said directive means.

9. A wave translation device, comprising:

a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;

synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided;

focal directive means coupled to said elements for increasing directive wave translation along said displaced axis; and

variable means coupled to said elements for varying a selected characteristic of one said pair of signals relative to the other said pair of signals.

10. A wave translation device, comprising:

a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;

anti-synchronous means coupled to said elements for

coupling said elements and a pair of signals in 180° phase relation; and
 deceptive signal means coupled to said elements for translating a deceptive signal other than in a preferred direction.

11. A wave translation device, comprising:
 a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation; and
 variable signal generator means coupled to said elements for varying the phase of one said pair of signals relative to the other said pair of signals, thereby to cause directive wave translation along an axis having an angular displacement varying in accordance with the phase variation between said signals.

12. A wave translation device, comprising:
 a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;
 synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided and the center of radiation of said elements is displaced from said axis;
 focal directive means coupled to said elements for increasing directive wave translation along said displaced axis, said center of radiation being displaced from a focus point of said directive means; and
 variable signal generator means coupled to said elements for varying the phase of one said pair of signals relative to the other said pair of signals, thereby to cause angular displacement of displaced axis in accordance with said signal phase variation.

13. A wave translation device, comprising:
 a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;
 synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided and the center of radiation of said elements is displaced from said axis;
 focal directive means coupled to said elements for increasing directive wave translation along said displaced axis, said center of radiation being displaced from a focus point of said directive means; and
 hybrid coupling means coupling said elements, synchronous and anti-synchronous means for coupling said signal pairs.

14. A wave translation device, comprising:
 a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;
 synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180°

phase relation, whereby wave translation along an axis displaced from said normal axis is provided and the center of radiation of said elements is displaced from said axis;
 focal directive means coupled to said elements for increasing directive wave translation along said displaced axis, said center of radiation being displaced from a focus point of said directive means; and
 deceptive signal means coupled to said elements for translating a deceptive signal other than along said displaced axis.

15. A wave translation device, comprising:
 a pair of involute, curved, wave translation elements for directive wave translation with respect to a normal axis;
 synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided and the center of radiation of said elements is displaced from said axis; and
 parabolic focal directive means coupled to said elements for increasing directive wave translation along said displaced axis, said center of radiation being displaced from a focus point of said directive means.

16. A wave translation device, comprising:
 a pair of involute curved, wave translation elements for directive wave translation with respect to a normal axis;
 synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation, whereby wave translation along an axis displaced from said normal axis is provided;
 focal directive means coupled to said elements for increasing directive wave translation along said displaced axis; and
 rotary means coupled to said elements for rotating said elements about an axis.

17. A wave translation device, comprising:
 a pair of involute curved, wave translation elements; synchronous means coupled to said elements for coupling said elements and a pair of signals in synchronous phase relation;
 anti-synchronous means coupled to said elements for coupling said elements and a pair of signals in 180° phase relation;
 variable means coupled to said elements for varying a selected characteristic of one said pair of signals relative to the other said pair of signals; and
 hybrid coupling means coupling said elements, synchronous and anti-synchronous means for coupling said synchronous and out of phase signals.

References Cited in the file of this patent

UNITED STATES PATENTS

2,476,337	Varian	July 19, 1949
2,988,739	Hoefler et al.	June 13, 1961
2,990,548	Wheeler	June 27, 1961
3,013,265	Wheeler	Dec. 12, 1961
3,014,214	Ashby et al.	Dec. 19, 1961
3,055,003	Marston	Sept. 18, 1962
3,089,136	Albersheim	May 7, 1963

OTHER REFERENCES

Aviation Week, July 14, 1958, pp. 75, 77, 79, 81, 82.