Feb. 4, 1947. C. B. H. FELDMAN 2,415,089

MICROWAVE ANTENNAS

Filed May 28, 1942

FIG. 1

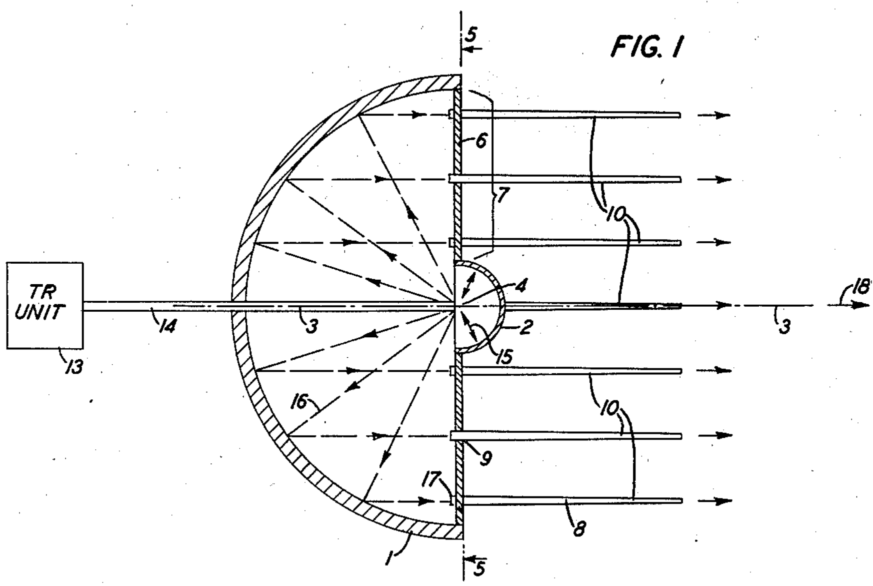
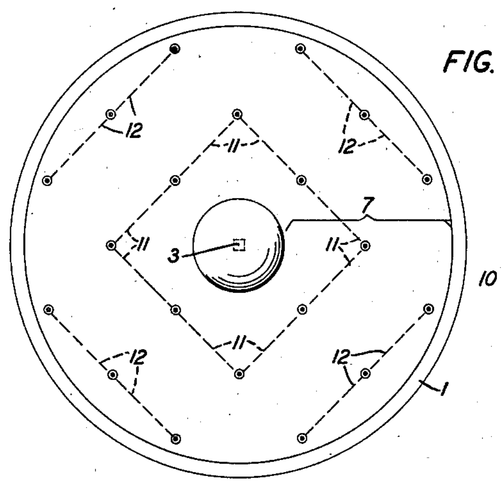


FIG. 2



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MICROWAVE ANTENNAS

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8 Claims. (Cl. 250—11)

This invention relates to antennas and particularly to directive microwave antenna arrays.

As is known in the microwave or centimetric field, horns and horn arrays have for some time past been used for radiating and collecting energy. Also, as disclosed in the copending application of G. C. Southworth, Serial No. 420,747, filed November 28, 1941, air-filled leaky wave guides or pipes having a plurality of transverse apertures or a single longitudinal aperture have been suggested for broadside, oblique and end-on radiant action. In addition, dielectric (polystyrene) unsheathed wire or rod dimensioned to have a phase velocity equal to the free space wave propagation velocity has been employed as a pure end-on antenna. While in a sense the leaky guide radiator having transverse apertures may be considered as an array, each aperture being a discrete elemental antenna, and the leaky guide having a single longitudinal aperture, and the dielectric wire, may similarly be considered as arrays, each comprising an infinite number of infinitesimally spaced apertures or segmental antennas, these linear structures are, from a transmission line or wave guide feed standpoint, essentially "unit" antennas comparable to the horn antenna inasmuch as the energy is supplied to, or received from, one extremity of the transmitting or receiving structure over a single line or guide. It now appears desirable to arrange these end-on units in arrays or superarrays and to provide suitable and simple transmission means for energizing, with minimum loss, a plurality of leaky pipes and dielectric rods with cophasal energies.

As used herein, an end-on antenna or array is defined as one having the principal axis or radius of its maximum directive lobe aligned substantially with the longitudinal axis of the antenna or array; a broadside array is one having the principal axis of its maximum lobe perpendicularly related to the longitudinal array axis, and an oblique array is one having the principal axis of its maximum lobe at an acute angle to the longitudinal array axis. The definitions given above for an end-on array and a broadside array are in agreement with, but more comprehensive than, those given on page 219 of the book "American Standard Definitions of Electrical Terms" published in August, 1941 by the American Institute of Electrical Engineers. In the above-mentioned publication an end-on directional antenna is defined as "an antenna array directional substantially along the line in which its elements are arranged;" a broadside directional antenna is defined as "an antenna array directional substantially at a right-angle to the line along which its elements are arranged;" and an array is defined as "a system of elemental antennas usually similar, excited by the same source, for the purpose of obtaining directional effects."

It is one object of this invention to secure highly directive radio action.

It is another object of this invention to obtain an antenna or array lobe having an exceedingly small conical or solid angular width.

It is a further object of this invention to deliver to, or receive from, a plurality of elemental dielectric antennas cophasal energies.

It is still another object of this invention to secure a highly efficient two-dimensional broadside array of end-on elemental or unit antennas.

It is an other object of this invention to transfer, without relative phase angle change, distinct cophasal energies between a translation device and a plurality of spaced elemental antennas arranged in an array.

In accordance with one embodiment of the invention, a paraboloidal reflector and a spherical reflector face each other and have a common finite focus. A translation device, which may be a transmitter or a receiver, or a transmitter-receiver unit, is connected to the reflector system by means of an open-ended wave guide having its aperture located at the focus. The transmitter-receiver unit, hereinafter called a transceiver, includes switching means for alternately connecting the transmitter and receiver to the reflector system. The portion of the paraboloidal reflector aperture surrounding the aperture of the spherical reflector is covered by a plane annular metallic shield and the input-output ends or terminals of a plurality of end-on polystyrene radiating rods are inserted in the plane shield. The dielectric rods or wires are preferably spaced in two directions or dimensions so as to constitute a two-dimensional broadside array of end-on elemental antennas. The dielectric wires may be spaced radially or symmetrically relative to the common reflector axis perpendicular to the shield, or arranged to form a square, circle or other geometrical figure. In operation, assuming the system is used for transmission, energy from the transmitter is radiated non-directionally at the focus and the wavelets emitted have a cophasal relation upon arrival at the terminals of the various dielectric antennas, since the lengths of the diverse paths extending from the common finite focus to the plane of the paraboloidal reflector aperture are equal, whereby all of the elemental antennas are energized in phase and broadside radiation is secured. If desired, the dielectric rods may be arranged linearly to form a single-dimension broadside array, and a cylindrical parabolic reflector may be employed in place of the paraboloidal reflector.

The invention will be more fully understood from a perusal of the following specification taken in conjunction with the drawing on which like reference characters denote elements of similar function and on which:

Figs. 1 and 2 are respectively cross-sectional and front views of the preferred embodiment of the invention.

Referring to Figs. 1 and 2, reference numeral 1 denotes a paraboloidal metallic reflector and numeral 2 designates a spherical metallic reflector having a focal length or radius of one-quarter wave-length, the reflectors having a common axis 3 and a common finite focus 4. The concave reflectors 1 and 2 face each other and have their apertures included in the same transverse plane 5 perpendicular to the axis 3. Numeral 6 denotes an annular metallic plane shield positioned in plane 5 so as to cover completely the annular portion 7 of the paraboloidal reflector aperture external to and surrounding the aperture of the spherical reflector 2. A plurality of polystyrene elemental end-on antenna rods 8 of the type disclosed in the G. C. Southworth application mentioned above are attached to, and project through, shield 6, each rod 8 being tightly inserted through an aperture 9 in shield 6 and rigidly secured to the shield at its junction therewith. The antenna elements are preferably evenly spaced to form an array 10 or, as shown in Fig. 2, are grouped about the center point or axis 3 to form an array comprising a square subarray 11 and four linear subarrays 12. Numeral 13 denotes a transceiver (TR) unit of the type commonly employed in radio scanning systems, the unit 13 being electrically associated by wave guide 14 with the finite focus 4 and the guide being open-ended for energizing the focus or absorbing energy from waves arriving thereat. The unit 13 is connected with conventional direction-range finding apparatus (not shown) such as a pulse generator, timing circuits and a cathode ray tube indicator.

In operation, assuming microwave energy is supplied by the unit 13 through guide 14 to focus 4, the wavelets are radiated in all directions and impinge on segmental portions of reflectors 1 and 2. The wavelets 15 which impinge on the spherical reflector are returned to the focus 4 and, at the focus 4, are in phase agreement with the wavelets 16 propagated radially, and directly, from the focus to the paraboloidal reflector 1. As is known, the paraboloidal reflector functions to change the radial wavelet directions to parallel directions perpendicular to shield 6, and the various paths extending from the focus 4 via the paraboloidal reflector 1 to the aperture plane 5 are equal in length. Hence, the wavelets arriving at plane 5 and at the terminals 17 of the end-on polystyrene antennas 8 are energized in phase and the radiation from array 10 is broadside. By reason of the substantially symmetrical spacing of the rods 8 about axis 3, which is aligned with the axis of the array space factor lobe, the gain in all planes containing the axis 3 and the desired direction 18 is relatively large, as compared to the gain of a single rod antenna over a comparison microwave dipole. At the same time, considering the solid characteristic, the conical or apex angle of fire is considerably smaller than that of a single member 8. Stated differently, the space factor lobe has a relatively small width in each plane passing through axis 3. When the array is used for receiving, the wavelets received at the focus 4 from the terminals 17 of the antennas 8, have a phase relation corresponding to the phase relation of these wavelets at terminals 17. If the incoming wave has a direction opposite to that indicated by arrow 18 the wavelets are in phase agreement at terminals 17 and are transferred without relative phase change to focus 4 and the transceiver 13.

Although the invention has been described in connection with a specific embodiment, it should be understood that it is not to be limited to the structure described. Thus, if desired, leaky pipes or horn antennas, instead of the dielectric wires 8, may be associated with the apertures 9 of shield 7 for in-phase operation.

What is claimed is:

1. In combination, a parabolic reflector, a plane shield in the reflector aperture and a plurality of spaced dielectric rod antenna elements extending from said shield parallel to the axis of said reflector, and a translation device at the reflector focus.

2. In combination, at least two linear antenna elements, and means for cophasally energizing said elements, said means comprising a parabolic reflector having the plane of its opening perpendicular to said elements and equally spaced from corresponding ends of said elements, and energizing means at its finite focus.

3. In combination, a concave radio reflector having a finite focus, means at said focus for radiating or receiving radio waves, and at least two linear wave guides extending perpendicular to the reflector opening and having one pair of corresponding terminals equally distant from said opening, whereby the wavelets transferred between said means and said elements are in phase agreement at said terminals.

4. In combination, at least two parallel linear antenna elements for radiating or receiving microwave energy, and means for cophasally energizing said elements, said means comprising a paraboloidal reflector having its axis parallel to said elements, and a microwave translation device associated with the finite focus of said reflector, the lengths of the propagation paths extending from said focus to said elements via said reflector being equal.

5. In combination, a concave radio reflector having a finite focus, a transceiver at said focus and at least two parallel dielectric channels extending in a plane perpendicular to the reflector opening and having their extremities included within the reflector cavity.

6. In combination, an antenna array comprising a plurality of parallel linear antenna elements and means for energizing said elements with cophasal waves polarized in a plane perpendicular to the longitudinal axes of said elements, said means comprising a paraboloidal reflector having its axis positioned parallel to said axes, a centimetric transmitter, and an open-ended wave guide having its open end positioned at the reflector focus and its other end connected to said transmitter.

7. In combination, an antenna array comprising linear elements spaced in two angularly related directions or dimensions, means for cophasally energizing said elements comprising a parabolic reflector, means at the focus of said reflector for radiating radio waves, said reflector hav-

ing the plane of its opening perpendicularly related to and intersecting said elements, whereby the diverse paths extending from said focus to said elements via said reflector are equal in length.

8. In combination, a paraboloidal reflector, a spherical reflector, said reflectors facing each other and having a common focus and their openings in a common plane, means at said focus for alternately radiating and receiving radio energy, an annular plane metallic shield extending between said reflectors in said common plane, and a plurality of parallel spaced linear antenna elements each projecting through a separate aperture in said shield, whereby the diverse propagation paths extending from said focus via said

paraboloidal reflector to said elements are equal in length, said elements are energized cophasally and enhanced end-on radio action is secured.

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