The present invention relates to novel antenna apparatus operable at ultra-high and super-high frequencies, and to commutator means operable at such frequencies. This invention relates, more particularly, to directional antennas apparatus adapted to produce overlapping highly directional radiation or receptivity patterns, such as are useful in radio-location of distant objects, radio guidance and navigation, and radio direction-finding.

The present application is a division of application Serial No. 485,554, filed May 1, 1943, now Patent No. 2,500,178, issued March 14, 1950, which is itself a division of application Serial No. 426,986, filed January 16, 1942, now Patent No. 2,468,751, issued May 3, 1949. These applications disclose systems wherein the present invention may be utilized.

An object of the present invention is to provide an antenna system wherein, in operation, alternate and overlapping directive beams may be produced. A still further object of this invention is to provide radiating or receiving wave-guides together with control means adapted to vary the phase velocity of the electromagnetic waves within said wave-guides at will.

A further object is to provide a cylindrical parabolic reflector with a pair of antennae located on either side of the focus thereof and means to increase the interchange of energy between the antennae and the reflector so that substantially all the energy is directed by the reflector whose radiation pattern is shifted by alternately energizing said antennae.

Other objects and advantages will become apparent from the specification, taken in connection with the accompanying drawings wherein the invention is embodied in concrete form.

In the drawings:

Fig. 1 is an elevation view of an antenna array, including a transmitting antenna, an azimuth receiving antenna and an elevation receiving antenna, according to the present invention.

Fig. 2 is a cross-sectional view of the elevation antenna of Fig. 1, taken along line 2-2 thereof.

Fig. 3 is a fragmentary cross-sectional view of Fig. 2, along line 3-3 thereof.

Fig. 4 is a plan view of the commutator shown in Fig. 1.

Fig. 5 is a plan view in cross-section of a portion of Fig. 4.

Fig. 6 is a cross-section of Fig. 5 along line 6-6 thereof.

Figs. 7 and 8 are fragmentary views of the capacitance-changer of Figs. 5 and 6, in two different positions.

Figs. 9 and 10 are idealized elevation and azimuth views of the radiation patterns of the azimuth antenna of Fig. 1.

Fig. 11 is a longitudinal elevational view partly in cross-section of another form of the present invention, not requiring separate commutating means.

Figs. 12 and 13 are sectional views of one form of wave guide phase velocity modulating rods useful in Fig. 11.

Figs. 14 and 15 are sectional views of another form of wave guide phase velocity modulating rods useful in an arrangement similar to Fig. 11.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

In prior parent applications, Serial Nos. 485,554 and 426,986, there are disclosed several systems for radio-location of objects using overlapping, alternate, highly directive radiation or receptivity patterns. The present invention is directed more specifically toward novel antenna and switching apparatus for producing such patterns.

One form of such apparatus is shown in Figs. 1–10, wherein is illustrated a receiving system for receiving energy from a distant point, either by reflection from an object at such point or by radiation from a transmitter there. Fig. 1 illustrates a system of the former type, where energy derived from a transmitter 101 is supplied to a radiator 12 placed at the focus of a cylindrical parabolic reflector 102, forming a space-radiation pattern that is substantially fan-shaped, being sharply directive in azimuth and broadly directive in elevation. Energy from radiator 12 is reflected by a distant object to be located and is then received by receiving antennae 13, 13'.

Receiving antennae 13 and 13', placed on either side of the focus of a cylindrical parabolic reflector 103, form partially overlapping receptive spatial patterns that are substantially fan-shaped. Each of these patterns is similar to the radiation pattern from transmitting antenna 12, being sharply directive in azimuth and broadly directive in elevation. The axes of symmetry of the principal receptive lobes are equi-angularly displaced to either side of the azimuth axis of the locating system so that the gain characteristics of the antennae 13 and 13' are equal along this azimuth axis. Fig. 9 and Fig. 10 illustrate diagrammatically these partially overlapping spatial patterns. Principal lobe 160, having an axis of symmetry 301, is associated with, say, antenna 13, and lobe 161, having an axis 302, is associated...
with antenna 13'. A line 300 represents the azimuth axis of the locating system, and it will be seen to correspond to an equi-signal path.

Receiving devices 13 and 13' feed the incoming energy through concentric lines 126 and 127, respectively (Fig. 4), to suitable energy control means shown in the form of an ultra-high-frequency commutator 16. Commutator 16, driven by the shaft 144 of a motor 15, alternately connects lines 126 and 127 to an output line 17, switching inputs at a suitable frequency. This commutator is illustrated in Figs. 4-8. This device, utilizing the impedance-transforming properties of quarter-wavelength lines, causes the output impedances of coaxial lines 126 and 127 to alternate between low and substantially infinite values. This is accomplished by connecting quarter-wavelength lines to the coaxial cables 126 and 127, respectively, these coupling lines being terminated at their free ends by variable impedances rotated by the motor 15. The frequencies thus commutated are supplied through the output coaxial line 17 to the receiver described in detail in the above-mentioned parent applications or to any other utilization device.

Receiving antennas 14 and 14', placed on either side of the focus of a cylindrical parabolic reflector 164, as shown in Fig. 1, are identical to antennas 13 and 13' and reflector 163, respectively, except that the former are arranged to be sharply directive in elevation while the latter are sharply directive in azimuth. Receiving devices 14 and 14' for the vertical plane feed through lines 197 and 196, respectively, to an ultra-high frequency commutator 30 similar to the device 16 and switched synchronously therewith by the motor 15. Commutator 30 is connected by a suitable coaxial line 51 to a similar receiver, as described in said parent applications.

Fig. 1 shows the physical arrangement of the antennas. Wheels 170 support a platform 171 upon which rests a rotatable pedestal 172 bearing a yoke 173. An annular gear 174 fastened to the pedestal 172 engages a worm gear 150 on the axle of the motor 50. The motor 51 is fastened to the yoke 173 by a bracket 175. The arrays are mounted in a manner as between the arms of the yoke 173 on a left trunion 176 and a right trunion 177. The trunion 177 passes through the yoke and serves as a shaft for a gear 178 which engages a worm gear 179 on the axle of the motor 51. As described in said parent applications, the receiver may contain suitable circuits for automatically controlling motors 50, 51 to maintain the antenna array directed at a desired distant object, or alternatively, motors 50 and 51 may be manually controlled to orient the antenna array by hand, to sweep the sky in any desired manner.

The arrays consist of similar reflectors 182 and 183 placed side by side containing the transmitting radiator 12 and the receiving antennae 13 and 13', respectively, as well as the reflector 184, rotated 90° in the plane of the figure with respect to the reflectors 182 and 183, containing the receiving antennae 14 and 14'. The reflectors 182, 183 and 184, strengthened by the braces 185 are held by a frame associated 185. The openings of the reflectors are narrow rectangles while the section at right angles to the plane of Fig. 1 is parabolic as is shown in Fig. 2. The reflectors are, therefore, highly directive in the plane of Fig. 2 and broadly directive at right angles to this plane. The antennae 14 and 14' are placed, preferably, one-eighth wavelength to either side of the focus of the reflector 186 on the latus rectum of the parabola. The antennae 13 and 13' are similarly located. The effect is to produce directive spatial patterns whose axes of symmetry are not parallel to the principal axis of the parabola. The patterns shift, as shown in Figs. 9 and 10, when the focus antenna and then the other is activated by the commutator of Figs. 4-8. Truncated cones 193 and 192, shown in section by Fig. 3, facilitate the interchange of energy between the antennae 14 and 14' and the reflector 186. Segments are cut from the portions of these truncated cones that face the mouth of the reflector, as shown most clearly in Fig. 2. The sides of these "slices" are bounded by planes drawn from the focus of the cylindrical parabolic reflector to its outer edges at right angles to the reflector's flat surfaces. A cylindrical arc concentric with the focus bounds the inner edges of the cut-away parts. This design is to reduce direct radiation from the antennae (which would spread over a wide angle) and to restrict it to the reflected beam.

Fig. 3 shows two concentric lines with inner conductors 194 and 195 and outer conductors 196 and 197, respectively. A dielectric 198 may fill the space between the inner and outer conductors. The conductors 194 and 195 merge with the upper truncated conducting cone 193 while the conductors 196 and 197 unfold into the lower cone 192. In the space between the cones the conductors 194 and 195 are unshielded and, consequently, become the radiators 14' and 14, respectively. The concentric lines, similar to or connected to lines 126 and 127 in Fig. 4, may be adjusted in length at the commutator 16 to make sure that a substantially infinite input impedance when the other radiator is energized, and vice versa. Under these conditions the inactive antenna does not absorb radiated energy. The devices in Figs. 1-3 may be interchangeably used for either reception or radiation, by reason of the reciprocity theorem.

Referring now to Fig. 4, there is shown the commutator 16 of Fig. 1. Concentric line 126 from antenna 13 connects to a line 122 through the horizontal branches of a cross-shaped adjustable coupling 124, shown in detail in Fig. 5 in greater detail. In a similar way the concentric line 127 from antenna 13' connects to a line 123 through the horizontal branches of a cross-shaped adjustable coupling or junction device 125, similar to 124. Lines 122 and 123 join to form the coaxial cable 17 which feeds the receiver. Vertical stubs 102, 103 of the couplings 124 and 125, projecting above the junction with the horizontal branches, contain adjustable shorting plugs 126 and 127, respectively. Vertical sections extending below the crossing adjustable attachments to lines 131 and 132, which latter issue from shielding boxes 133 and 134, respectively. Shafts 141 and 142, having attached pinions 137 and 138, respectively, project from the shielding boxes 133 and 134, respectively. Gears 139 and 140 on a shaft 136 mesh with pinions 137 and 138, respectively. A gear 143 on the shaft 144 of the motor 145 engages teeth 146, and consequently the shafts 141 and 142 through shafts 150 and 151 and associated gearing are rotated synchronously with the motor 15. Coupling 124, line 131, box 133, shaft 141, and gear 137 are designed to be horizontally displaceable as a unit for a distance of one wavelength at the operating carrier frequency, for tuning purposes, as is the combination of coupling 125, line 132, box 134, shaft 142 and gear 138. The
pinions 137 and 138 have lengths adequate to allow for these displacements. The junctions of devices 124 and 125 may also be vertically ad-
justed by means of the slide-able attachment be-
tween the lower vertical arms of these devices and coaxial lines 131 and 132, respectively, to alter their distance to the shielding boxes 133 and 134, respectively.

Fig. 5 is a detailed sectional view of the left portal of the structure showing the method of joining the coaxial lines of junction device 124 and the in-
terior arrangement of the shielding box 133. The inner conductors 122, 126 and 131 of the coaxial lines 122, 126 and 131, respectively, are holl-
row and of such an interior diameter as to permit the two horizontal and lower vertical inner con-
ductors 124' of the junction device 124 to slide therein. The exteriors of lines 122, 126 and 131 are likewise enlarged to allow the exterior of the Junction device 124 to slide therein. Insulating washers 146 and 147 support the inner conductors 124 coaxial with the exterior of device 124. An insulating washer 148 supports the inner conductor 131' within line 131. The ratio of the outside diameter of conductors 124 to the inside diameter of the exterior conductor of Junction device 124 is made substantially equal to the ratio of the outside diameter of conductors 122, 126 and 131 to the inside diameter of their respective exterior conductors, to maintain the characteristic impedances of the various sections equal. The shorting plug 128 is made with a hollow bore to facilitate longitudinal adjustment within the upright stub of junction device 124. The conductor 131 projects into the shielding box 133 where a condenser plate 149 is fixed to its end. The plan view of a preferred form of the plate 149 is shown in Figs. 7 and 8. The other plate of the condenser may be considered the adjacent grounded side of the shielding box 133. The coaxial line 131 and the section of junction device 124 below the Junction point, there-
fore, is terminated by a capacitance whose magni-
tude depends on the area of the plate 149 and the spacing and dielectric constant between the plate 149 and the side of the box 133. The shaft 141, driven by the motor 15 through the gears 137, 139, shaft 136, gears 140, 143 and shaft 144, as mentioned above, rotates in ball-bearings 151 and spins a double-bladed chopper 152 between the plate 149 and side of the box 133. Chopper 152 is roughly analogous to a light chopper used in motion picture art. Fig. 5 shows one of the blades of the chopper 152 meshed as in Fig. 8. Fig. 6 is an alternate view of the box 133 taken at right angles to the plane of Fig. 5 looking from the base of the box at the end of the conductor 131.

The chopper 152 may be constructed of a high-
dielectric-constant, low-loss, non-conductor or may be made of a conductor which is insulated from the shaft 141. The effect of a non-con-
ductor is to increase the capacitance when meshed with plate 149, because the dielectric constant of the air is less than that of the dielectric of the line. An insulated conductor is to create two condensers in series which have increased capacitance due to the reduced air gaps, the series combination being greater in capacitance than the capacitance in the open position. The shielding box 133 is di-
munely arranged to be non-resonant to the transmitter frequency.

The operational alignment of the commutator 16 of Fig. 4 is simplified by utilizing the teach-
ing of the reciprocity theorem which allows the

substitution of an ultra-high-frequency oscillator in place of the receiver on the end of the coaxial line 17, to provide a temporary local power source. The alignment (which is undisturbed, in this substitution) may be performed by the following steps:

First, mesh the left-hand chopper 152 as in Fig. 8 and adjust the length of the line from the plate 149 to the Junction point of the junction device 124 until no energy flows from the left line 125 to the radiator 13. This means there is an effective short at the center of the junction device 124.

Repeat this adjustment for the right-hand side of Fig. 4.

Next, unmesh the left-hand chopper 152 as in Fig. 7 and adjust the plug 128 in the stub of the coupling 124 until there are no standing waves in the line 122. This means there is no reflection from the Junction point of the junction device 124, and energy may flow unimpeded to the left radiator 13.

Repeat this adjustment for the plug 128.

Then, with chopper 152 meshed and the corre-
spanding chopper in box 134 unmeshed, adjust the combined lengths of the right branch of junction device 124 and line 123, until there are no standing waves in the “oscillator” line 17. This means that, when the Junction point of coupling 124 is effectively shorted, the “oscillator” end of the line 122 is made to appear as an open circuit and there is no loss of power due to the short at the center of coupling 124.

Repeat this adjustment for the right side of Fig. 4.

Adjust the length of coaxial line 126 to the antenna 13 with the chopper 152 meshed until the line has no field present, indicating that the inactive antenna 13 is absorbing no energy radiated by the active antenna 13'. This means that when the Junction point of coupling 124 is effective-
ly shorted, the antenna end of the line 126 is made to appear as an open circuit, and there is no loss of radiated power from the energized antenna 13.

Repeat this adjustment for the right-hand line 121.

These above steps are repeated until the align-
ment conditions are satisfied. The purpose of the stub line on coupling 124 is to couple a conjugate impedance to the junction point of cou-
pling 124 which will compensate for the fact that the chopper 152 produces only a finite change of capacity.

By such a commutating arrangement as has just been described, the radiators are alternately effective, each being active substantially half of the time and inactive during the period of the other's activity. Sinusoidal switching may be employed for mechanical simplicity although the total radiation is reduced. The utilization of the former method causes the beam shown in Figs. 9 and 10 to jump alternately between the smoothline position and the dashed-line position, while the latter method shifts the beam smoothly from one position to the other.

Figs. 11-15 illustrate a method of obtaining the necessary oscillating beam without resorting to the commutator of Figs. 1-5. Referring to Fig. 11, a radiator 228 is located at the junction of wave guide branches 229 and 230, the longitudinal section. Flat conducting rods 228 and 229, extending the length of the branches, are equipped with trunnions on their ends to permit free rotation in supports 230 and 231, re-


spectively. Figs. 12 and 13 show in section the positions of rods 228 and 229, respectively. A drive shaft 232, seen in section, impels a driver 233 of a Geneva movement which is engaged to a driven wheel 234. A shaft 236, seen in section, connects the wheel 234 to a bevel gear 237 as well as extending beyond the plane of the paper to actuate a second gear for the other space coordinate. The gear 237 meshes with a gear 236 on a shaft 238. The rod 228 is driven by the shaft 236 through bevel gears 243 while the rod 228 is driven by this shaft through gears 242, 244 and 246 on shafts 248 and 241.

In operation the rods 228 and 229 intermittently and alternately occupy the positions in the wave guides shown in Figs. 12 and 13. Altering the position modifies the effective cross-section which results in a change of the phase velocity of propagation within the wave guide branches, 225, 227.

The direction of propagation of the radiated waves in free space forms an angle with their direction in the hollow wave guide whose cosine is the ratio of the phase velocity of the waves in free space to that of the phase velocity of the waves in said guide. Since the phase velocity of propagation in free space is constant, the direction of free space propagation must shift according to this cosine law relating phase velocities and directions of propagation within and without the radiating guide.

The rods in Fig. 11 may be driven smoothly without the use of the Geneva movement. In this case the mechanical simplification may compensate for reduced electrical sensitivity.

An alternate type of rod is shown in Figs. 14 and 15, corresponding to Figs. 12 and 13. Conducting rods 250 and 251, half found in section, alternately fit into cavities of wave guides 252 and 253, respectively. Here the cross-sectional area is actually reduced, whereas in Figs. 12 and 13 the effect is due to field distortion.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. High frequency apparatus comprising a conductive parabolic reflector, a pair of parallel conductive walls having parabolically curved edges joined to said parabolic reflector, antenna means placed on either side of the focus of said reflector and between said walls, cone-shaped energy translating means associated with said antenna means for increasing the interchange of energy between said antenna means and said reflector, the bases of said cone-shaped means being in contact with said walls, said reflector producing partially overlapping radiation patterns, the axes of symmetry of said patterns being mutually angularly displaced to either side of the positional axes of the locating system.

2. High frequency apparatus comprising a conductive parabolic reflector, a pair of parallel conductive walls having parabolically curved junctions to said parabolic reflector, antenna means placed substantially at the focus of said reflector, and conductive cone-shaped energy translating means associated with said antenna means for increasing the interchange of energy between said antenna means and said cone-shaped energy translating means comprising a pair of cones oppositely directed along a common axis and having their bases in contact with the respective ones of said conductive walls.

3. High frequency antenna apparatus comprising two conducting radiating wave guides forming a predetermined angle with respect to each other, means for launching electromagnetic waves of substantially linear polarization for traveling along said guides, conducting rods within and extending along said guides, said rods being turnable around their longitudinal axes for altering the phase velocities of said waves within said guides, said guides having distributed radiating means extending along the length of the same at right angles to the electric vector of said waves for propagation of said waves, the direction of said propagation being shifted as the phase velocities of said waves within said guides are altered by said turnable rods.

4. High frequency antenna apparatus as defined in claim 3, further including means intercoupling said rods for maintaining a predetermined relation between the angular positions thereof, one of said rods being at the angular position for maximum wave guide phase velocity when the other of said rods is in the position for minimum wave guide phase velocity.

5. Ultra high frequency apparatus comprising a hollow wave guide and an axially extending rotatable member therein for varying the phase velocity of waves propagated along said guide, said member being eccentrically mounted whereby its position relative to the walls of said guide is varied upon rotation thereof.

6. Ultra high frequency apparatus comprising a hollow wave guide and an axially extending rotatable member therein for varying the phase velocity of waves propagated along said guide, said member having a non-circular cross-section.

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