

July 28, 1953

C. B. H. FELDMAN

2,647,212

ANTENNA SYSTEM

Filed Jan. 17, 1946

4 Sheets-Sheet 1

FIG. 1

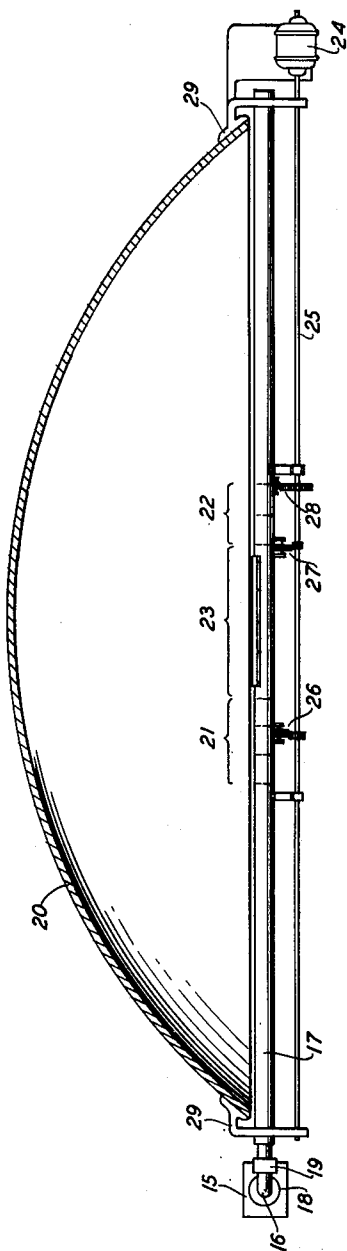
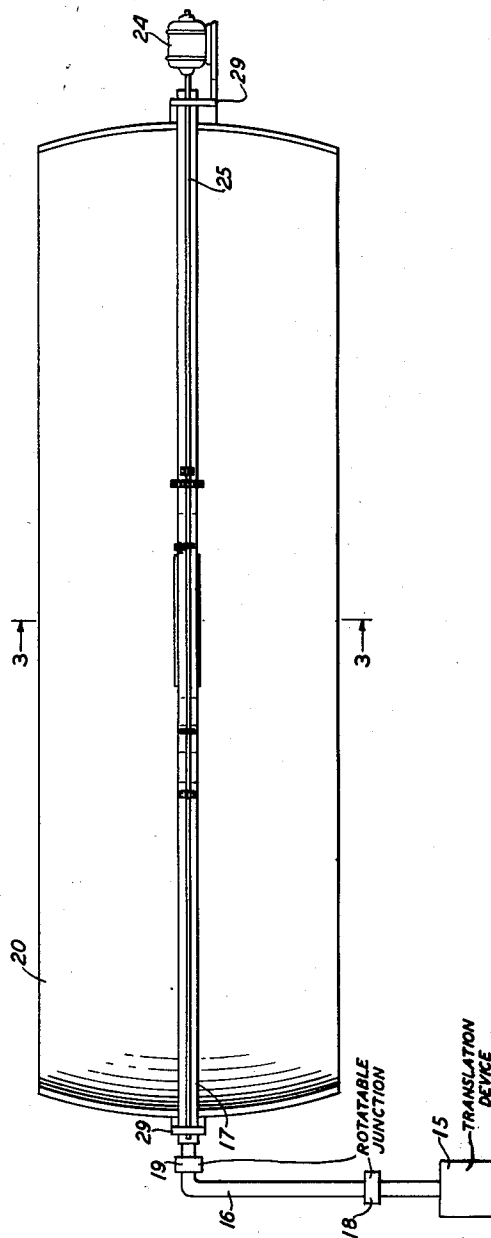


FIG. 2



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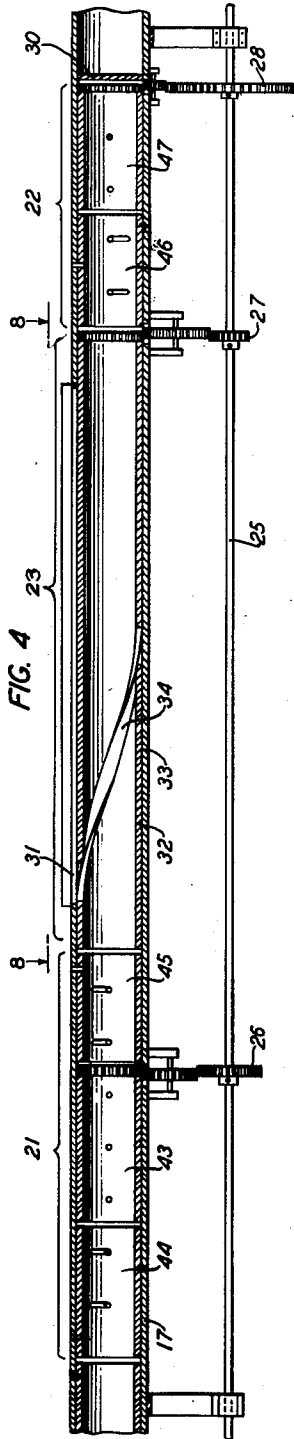


FIG. 4

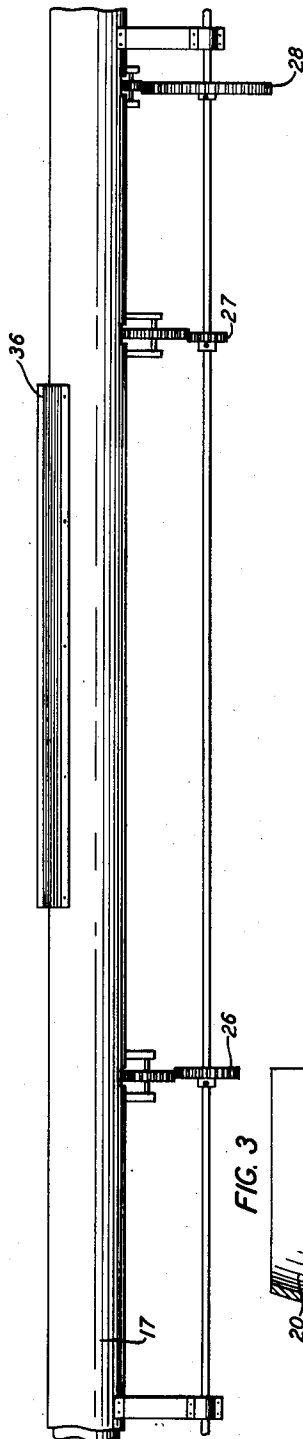


FIG. 5

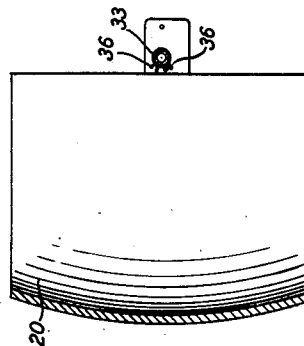


FIG. 3

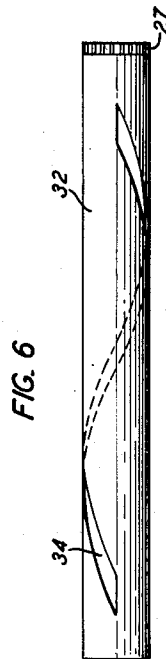


FIG. 6



FIG. 7

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FIG. 8

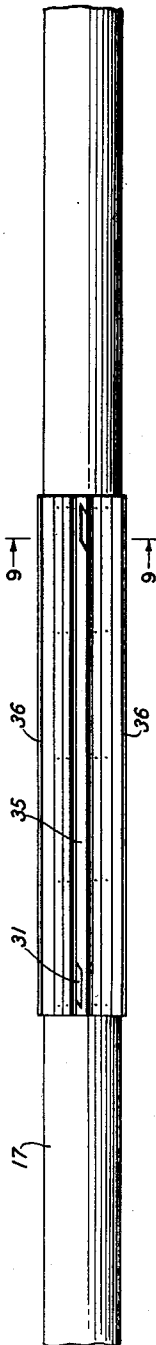


FIG. 11

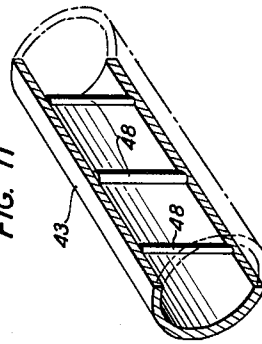


FIG. 10

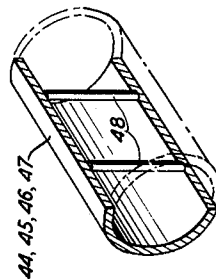
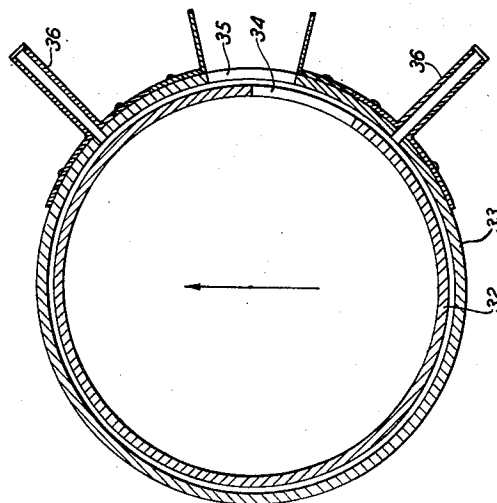


FIG. 9



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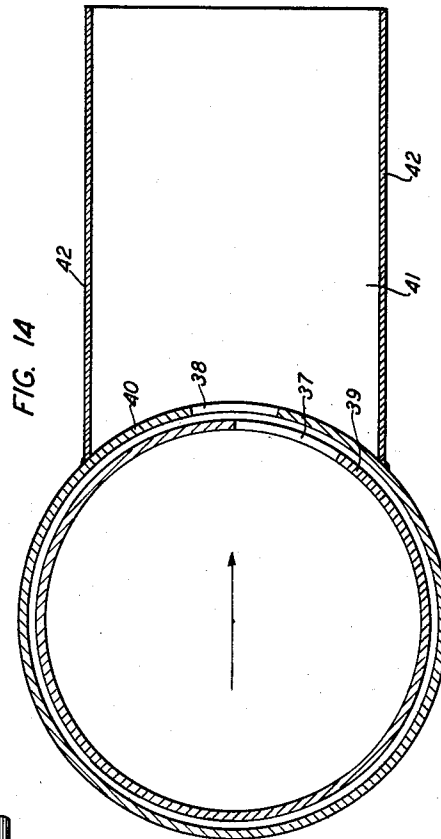
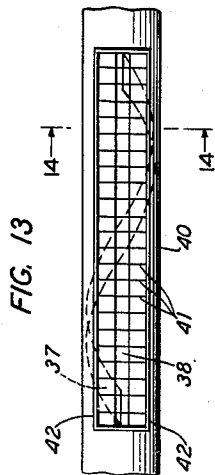
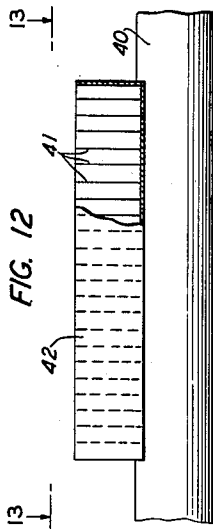
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4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

2,647,212

ANTENNA SYSTEM

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Application January 17, 1946, Serial No. 641,844

14 Claims. (Cl. 250—33.63)

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This invention relates to an antenna system, and particularly to a system wherein rapid scanning is effected by the movement of a primary antenna in relation to a passive secondary antenna or fixed parabolic reflector.

In antenna systems where repeated scans of an exploratory area or angle involve the rocking or oscillation of a conventional parabolic reflector the mass of the reflector imposes a limitation upon the rate at which the successive scans may be made. The present invention contemplates rapid scanning by the employment of a passive secondary antenna or parabolic or paraboloidal reflector no movement of which is required in the repetitive movement of the scanning beam over a given exploratory angle, the sweep of the scanning beam being effected by the movement of a primary antenna in the form of an aperture in relation to the focus of a passive secondary antenna or stationary reflector.

The principal object of the invention is to provide an antenna system wherein the scanning operation may effect a rapidly repetitive sweep of a narrow directive lobe over the chosen exploratory area or angle by a succession of unidirectional movements at a constantly uniform velocity.

Other objects of the invention include the securing of such scanning operation by the employment of a primary antenna in the form of an aperture adapted to be moved rapidly, successively in the same direction and at uniform velocity across the focus of a passive secondary antenna, and to supply ultra-high frequency wave energy to the aperture with substantially unchanged amplitude unaffected by the change in wave path length incident to the physical movement of the aperture in relation to the secondary antenna focus. Conversely, it is an object of the invention to provide such an antenna system capable of efficiently intercepting and conveying to associated receiving apparatus the echo energy reflected from objects in the exploratory area upon which the radiated energy impinges.

As will be disclosed in the description that follows, these objects are attained, in the specific exemplary structural forms to be described, by positioning along the latus rectum of a reflector a wave guide extension comprising two coaxial members, one of which is fixed and carries a longitudinal linear slot facing the reflector, and the other of which is rotatable and is provided with a helical slot. When the helically slotted member is rotated, the intersection of the two

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slots forms an aperture that travels from one end to the other of the linear slot facing the reflector. This aperture, which constitutes a primary antenna, is in communication with the wave guide through the interior of the coaxial members, travels through the focus of the reflector from one side to the other, and rapidly, continuously, and at a constant velocity repeats this traverse as the helically slotted member continues to rotate. The positional change of the aperture along the wave guide extension constituted by the two members is compensated for by one or more associated phase shifters that continually operate during the movement of the aperture to maintain unchanged the virtual length of the electrical transmission system on each side of the aperture, and thus operate to maintain substantially constant energy amplitude at the aperture throughout its movement along the wave guide extension.

The antenna system disclosed herein as a preferred form in which the invention may be embodied will be more fully understood by reference to the following description taken in conjunction with the drawings, in which like reference characters denote the same or similar elements. In the drawings:

Fig. 1 is a plan view of an antenna structure including the reflector, associated wave guide, primary antenna and driving mechanism, the reflector being shown in section;

Fig. 2 is a front view of the structure shown in Fig. 1;

Fig. 3 is a sectional end view on line 3—3 of Fig. 2;

Fig. 4 shows a longitudinal section of the wave guide extension, including the helically and linearly slotted members, phase shifters and driving connections;

Fig. 5 is a plan view of the assemblage of elements shown in Fig. 4;

Figs. 6 and 7 show, respectively, the inner helically slotted and the outer linearly slotted members;

Fig. 8 is a plan view of the primary antenna portion of the wave guide extension including the slotted members, as seen from the reflector looking in the direction of the arrows 8—8 of Fig. 4;

Fig. 9 is a cross-sectional view on line 9—9 of Fig. 8;

Figs. 10 and 11 are diametrically cross-sectioned views of two elements of the phase shifter; and

Figs. 12, 13 and 14 show a modified form of

moving aperture primary antenna, Fig. 12 being a plan view partially in section, Fig. 13 a front view on line 13—13 of Fig. 12 and Fig. 14 a cross-section on line 14—14 of Fig. 13.

Referring to the embodiment of the invention illustrated in Figs. 1 to 11, inclusive, reference numeral 15 indicates a translation device such as an ultra-high frequency or centimetric wave transmitter or receiver, or a radar transceiver, and reference numeral 16 indicates a wave guide extending to the wave guide extension 17 forming part of the antenna proper. If desired, the main wave guide may be provided with rotatable junctions 18 and 19 so constructed as to permit the antenna proper to be turned in suitably arranged mountings either in a horizontal or a vertical plane or both without altering the alignment of a linearly polarized wave.

The portions of the antenna structure which cooperate in the transmission and reception of the ultra-high frequency energy waves include, referring particularly to Fig. 1, the parabolic or paraboloidal reflector 20, the phase shifters 21 and 22 and the slotted members 23, the phase shifters and slotted members being rotated by the motor 24 through the medium of the drive shaft 25 and gears 26, 27 and 28.

The wave guide extension 17 extends diametrically across and along the latus rectum of the paraboloid reflector 20 and is supported at its ends by the brackets 29. These brackets may also constitute part of the structural support for the reflector 20 and the driving motor 24. Functionally, the wave guide extension 17 terminates at the right-hand end of the phase shifter 22. As the parts are represented in the drawings, the tubular portion of the extension that extends from this point to the right-hand bracket 29 serves merely a supporting function. It will be understood that structurally the showing of the various supporting elements of the over-all antenna arrangement is somewhat schematic, terminating and strengthening flanges along the sections of the outer tube of the wave guide extension where the operating elements are carried, and ball bearings to insure easy rotation of the rotatable parts being omitted for the sake of simplicity in the disclosure of the essential elements of the antenna system.

Proceeding now to a description of the elements of the antenna system involved in the transmission and reception of the ultra-high frequency energy waves, the energy waves passing between the transceiver 15 and the radiating and intercepting aperture 31 flow by way of the wave guide 16 and the inner member of the wave guide extension 17. The waves with which the antenna system of the present invention is designed to operate are centimetric waves of the H₁ type; that is, they are waves of such high frequency as to have a wavelength of only a few centimeters in space, and are waves having a linear electrical polarization transverse to the direction of propagation. The direction of the linear electrical polarization used is indicated by the arrow in Fig. 9 in connection with the first alternative form of the invention, and by the arrow in Fig. 14 in connection with the second alternative form.

The electrically functioning portion of the wave guide extension is best shown in Fig. 4 of the drawing. The outgoing waves pass from the inner member of the wave guide extension 17 through the elements of the phase changer 21 and the interior of the slotted members 23, be-

yond which a portion pass to and are reflected from an end wall or reflecting termination 30 immediately beyond the terminating phase shifter 22. This reflecting wall 30 may conveniently be an end wall of the terminating phase shifter 22. The function of the phase shifters 21 and 22 in connection with the operation of the longitudinally movable primary antenna aperture 31 will be described hereinafter.

The slotted members 23 comprise a rotatable helically slotted member and a fixed or non-rotatable linearly slotted member. Preferably, and as shown, the helically slotted rotatable member designated 32 is the inner member of the two, forming an extension of the inner wave guide channel. The fixed linearly slotted member designated 33 forms a portion of the outer shell or tube of the wave guide extension. The helical slot 34 is a one-turn slot, and is so cut that its two end walls lie in the same axial plane of the tubular member 32. Thus the total area of the opening formed by the intersection of helical slot 34 and linear slot 33 remains constant at all times throughout the 360-degree rotation of the helically slotted member. The axial length of the linear slot is the same as, or at least no less than, the axial length of the helical slot, the length being such that the linear traverse of the aperture from one end of the slot to the other is equal to an even number of half-wavelengths in the guide.

In the present illustrative embodiment, where a substantial breadth of angular scan in azimuth is desirable, the linear traverse of the aperture is equal to seven half-wavelengths (that is, $3\frac{1}{2}$ wavelengths) in the guide. In the actual operation of the specific arrangement herein disclosed a frequency giving a wavelength of 9.32 centimeters or 3.87 inches in free space was used. The corresponding wavelength in the guide is 15.8 centimeters or 6.22 inches. Therefore the total $3\frac{1}{2}$ -wavelength traverse of the aperture 31 along the linear slot was 21.77 inches. With the elements of the structure disposed along the latus rectum of the parabolic reflector in such a way that the primary antenna aperture 31 passes through the reflector focus at the midpoint of its traverse, the scanning movement of the directive lobe of the scanning beam is approximately one degree per inch of aperture movement. The above is upon the assumption of a principal focal length for the parabolic reflector of 49 inches.

The connection between the driving motor 24 and the helically slotted member 32 may conveniently be such that the member rotates at the rate of 600 revolutions per minute or ten per second. Each complete revolution of the member 32 causes the aperture 31 to move the entire length of the linear slot 35, from one end to the other. Assuming the direction of rotation is clockwise when viewed from the end connected with the main wave guide, the aperture 31 moves along the linear slot from left to right, as shown in Fig. 8; and as one sweep is terminated at the slot intersection at the right, a new sweep is initiated by the intersection of the slots at the left in the continuous rotation of the helically slotted member. Thus, the movement of the directive lobe of the antenna consists of a constantly repeated succession of identical sweeps at a constant velocity and always in the same direction.

The release of electromagnetic wave energy from the primary antenna for reflection from the

parabolic reflector and propagation into space, is by way of the outlet or so-called "leak" constituted by the moving aperture. There is a well-understood relation between the contour or relative dimensions and location of a wave guide aperture capable of serving as such a leak, and the direction of electrical polarization of the wave in the guide. A circular or rectangular cross-section wave guide having one or more antenna slots, usually one, extending parallel to the longitudinal axis of the guide is conventionally referred to as a "leaky pipe or guide of the first kind," and a circular or rectangular cross-section guide having one or more antenna slots each of the slots extending in a direction transverse to the longitudinal axis of the guide, and with the array of such slots, if more than one, parallel with each other and extending in a direction parallel to the longitudinal axis of the guide is conventionally referred to as a "leaky pipe of the second kind." For escape of energy through a "leak" of the first kind, the electrical polarization of the linearly polarized or H_1 waves in the guide lies in an axial plane of the guide perpendicular to the axial plane including the longitudinally extending slot; and for escape of energy through a "leak" of the second kind the linear electrical polarization of the waves lies in the same axial plane in which the one or more transverse slots lie. By reference to Fig. 9 it may be seen that the axial plane of electrical polarization of the waves in the guide, as indicated by the arrow, is perpendicular to the axial plane including the linear antenna slot of the outer member 33, thus identifying the structure as a leaky pipe of the first kind; and by reference to Fig. 14 it may be seen that the axial plane of linear electrical polarization of the waves in the guide, as indicated by the arrow, is the same plane in which lies the array of transverse antenna slots (see Figs. 12 and 13) in the outer member 33, thus identifying the structure as a leaky pipe or guide of the second kind. It may here be noted that in the antenna systems, as shown, the electrical polarization in space of the propagated waves in the resultant scanning beam is vertical in the case of a structure such as that represented by Fig. 9 and is horizontal with a structure such as that represented by Fig. 14.

Reference will first be made to the nature of the passage of wave energy through a primary antenna structure of the type shown in Figs. 1 to 9, inclusive. As the helical slot 34 of the inner member 32 from one end to the other extends through an angle of 360 degrees of revolution and therefore of orientation with regard to the wave polarization plane, there is always a portion of the length of the slot that, with respect to the passage of linearly polarized waves, forms a leaky pipe of the first kind, and another portion that to a less degree forms a leaky pipe of the second kind. This relates merely to the passage of energy between the wave guide interior and the interspace between the tubular concentric members 32 and 33. As this annular interspace is constantly in communication with the entire length of the linear slot in the outer slotted member 33, a certain energy leakage may accompany the useful energy radiation that takes place at the direct opening from the wave guide defined by the intersection of the two slots. Any such radiated leakage energy is electrically polarized in the same direction as the usefully radiated energy, and is objectionable; but its radi-

ation may be prevented or substantially reduced by the provision of wave traps such as those identified by the numerals 36 on the drawings. These wave traps, most clearly shown on Fig. 9 of the drawings, are long, narrow slot-like chambers extending along and on either side of the linear slot in the outer member. Each of the chambers is disposed in a radial plane with respect to the longitudinal axis of the concentric primary antenna members. The outer end of each chamber is closed and the inner end is in communication with the annular interspace between the two concentric members. It has been found by trial that the most effective operation of these members as wave traps is secured when each is spaced a distance approximately equal to a quarter wavelength in air from the adjacent edge of the linear slot in member 33, and when the depth or radial dimension of each chamber is approximately one-quarter wavelength in air of the wave that is being propagated. The presence of these wave traps substantially reduces the amount of leakage energy reaching the linear slot 35 from the interspace between the concentric members.

The shape and area of the primary antenna aperture 31 are determined by the width of the intersecting slots and the pitch of the helical slot. As actually constructed and operated the breadth of each of the slots was approximately three-quarters of an inch and the pitch of the helical slot, as previously stated, was such as to produce one complete turn in an axial distance of 21.77 inches. As a result of this relatively long pitch, the length dimension of the resultant aperture is substantially greater than its breadth dimension, and the shape of the aperture is one better adapted for use in connection with a "leaky pipe of the first kind" where the linear electrical polarization lies in a plane perpendicular to the plane including the aperture. By modifying the structure, however, it is possible to take advantage of the principle of the "leaky pipe of the second kind," and thereby discriminate more effectively between usefully propagated energy from the wave guide and the energy which escapes through the helical slot into the interspace between the concentric members.

Such a modified arrangement of the primary antenna elements is illustrated in Figs. 12, 13 and 14 of the drawings. As indicated on Fig. 13, the one-turn helical slots 37 in member 39 is axially shorter by a certain number of half-wavelengths and of steeper pitch than the helix 34 of the modification previously described. The linear slot 38 in the outer concentric member 40 is correspondingly shorter, and the aperture formed by the intersection of the two slots is less elongated and more nearly square than the aperture formed by the intersection of the two slots 34 and 35 in the previously described modification. Where the scanning requirements of the associated antenna system are satisfied by a smaller breadth of aperture movement the length of the one-turn helical slot may be further shortened and its pitch made still steeper to approximate more nearly a square shape of the aperture formed by the intersection of the two slots.

With an aperture of this shape it is possible to propagate electromagnetic waves having a horizontal, instead of a vertical, field polarization in space, and therefore polarized in a plane parallel to the horizontal plane of the longitudinal axis of the primary antenna members. To

this end, the electromagnetic waves propagated through the guide are given a linear electrical polarization oriented to lie in the same axial plane that includes the linear slot of the outer member, as indicated by the arrow in Fig. 14, the arrangement thus becoming a "leaky pipe of the second kind." The leakage displacement currents for waves which escape from the interior through the longitudinally extending helical slot and reach the linear slot in the outer member are still polarized perpendicularly to the axis of the concentric antenna members, and are therefore polarized vertically in space, and perpendicularly to the horizontal electrical polarization of the waves radiated from the aperture formed by the intersection of the slots. It therefore becomes possible to discriminate against such leakage radiation without affecting the useful and desired radiation.

This is accomplished in the form of the invention illustrated in Figs. 12, 13 and 14 by associating with the linear slot 38 and mounting upon the outer concentric member 40 a plurality of closely spaced transverse partitions 41 extending along the slot 38 and perpendicularly thereto. These partitions are terminated in side walls 42 to form in effect a plurality of wave guides the outer ends of which are open and the inner ends of which communicate with the linear slot 38. As the electrical polarization of the usefully radiated waves is horizontal and parallel with the axis of the concentric members and the distance between the side walls 42 is greater than one-half wavelength in space of the radiated frequency, the passing of the energy waves of this polarization is not affected by the presence of the partitions. But for the vertically polarized leakage waves the polarization of which is perpendicular to the longitudinal axis of the concentric members, and therefore in planes parallel with the planes of the partitions spaced at intervals considerably less and of a depth greater than one-half wavelength in space, these partitions act as cut-offs to prevent radiation of leakage energy. In other words, the partitioned member comprising the partitions 41 and the side walls 42 is so dimensioned with respect to its plurality of elemental channels or wave guides as to permit the free passage of usefully radiated wave energy linearly polarized in the plane of the primary antenna axis, and to act as a cut-off for leakage energy of the same wavelength linearly polarized in a plane perpendicular thereto. The partitions 41 are made of thin metal in order to minimize obstruction to the waves, and are spaced closely in order to prevent discontinuities in the pattern of the directive scanning lobe. Obviously, the outer primary antenna member 40 of the modification illustrated in Figs. 12, 13 and 14 may also be provided with the wave traps 36 of the other modification, as illustrated more particularly in Fig. 9, if it is desired further to reduce the passage of leakage energy from the wave guide to the linear slot 38.

Coming now to the matter of the phase shifters identified generally as 21 and 22 on Figs. 1 and 4 of the drawing, it is evident that in the physical movement of the primary antenna aperture 31 along the longitudinal slot the length of the electrical transmission system supplying energy to the aperture is changed. As the aperture moves from left to right along the slot the electrical distance between it and the transceiver 15 increases and the electrical distance between the aperture and the reflecting wall 30 diminishes.

Consequently, in the absence of means to prevent it, the movement of the aperture would be accompanied by a continual change in amplitude and phase of the radiated energy and a resultant continual change in the electrical characteristics of the scanning lobe. It is to avoid such a result as this that the phase shifters are employed. By their use the electrical distance from aperture to transceiver and from aperture to reflecting wall is maintained constant at all times during the movement of the aperture.

The phase shifters that are shown diagrammatically in Fig. 4 and certain elements of which are shown somewhat more clearly in structural detail in Figs. 10 and 11 are of the type disclosed in Patent 2,438,119 granted on March 23, 1948, to A. G. Fox, and may preferably be modified for wide frequency band operation as disclosed in Patent 2,425,345 granted on August 12, 1947, to D. H. Ring. The phase shifter 21 comprises a central rotatable section or rotor 43 and two end stationary sections 44 and 45, one of which is a polarizer or circularizer for converting a wave having a fixed linear polarization to one having a circular or rotating linear polarization, and the other of which is a depolarizer or decircularizer for converting a circularly polarized wave to one having a fixed linear polarization. The identical end sections function as polarizers or depolarizers depending upon the direction of wave propagation in the phase shifter, and therefore upon whether the antenna is transmitting or receiving high frequency pulses. As shown in Figs. 10 and 11, each of the two end sections 44 and 45 is provided with two diametral reactance rods 48 spaced apart a distance approximately equal to $\frac{3}{8}$ wavelength in the guide of the wave used, while the rotor 43 has three such diametral rods similarly spaced. The phase shifter 22 comprises two two-rod sections 46 and 47, section 46 being stationary while section 47 is rotatable. Depending upon the direction of wave propagation each of these sections likewise is adapted to operate either as a polarizer or as a depolarizer.

Each of the rotors 43 of phase shifter 21, and 47 of phase shifter 22 may be operated to shift the phase angle of the electrical waves passing through it, the rotor 47 shifting the phase angle 360 degrees for each 360-degree physical rotation of the rotor, while the rotor 43 accomplishes the same 360-degree shift of the phase angle by a 180-degree physical rotation of the rotor. Therefore in the specific exemplification of the invention employing a 9.82 centimeter wave, a 360-degree rotation of rotor 47 or a 180-degree rotation of rotor 43, producing in each case a phase shift of 360 degrees equal to one wavelength of 6.22 inches in the guide, increases or diminishes the electrical length of the corresponding portion of the transmission system by 6.22 inches.

The longitudinal traverse of the aperture 31 from one end to the other of the linear slot, as previously stated, is 21.77 inches or $3\frac{1}{2}$ wavelengths in the guide. To effect a corresponding change in the electrical length of the guide on either side of the aperture therefore requires $3\frac{1}{2}$ complete turns of the rotor 47 or $3\frac{1}{2}$ half-turns ($1\frac{1}{4}$ full turns) of the rotor 43 during the time the helically slotted member 32 is making one complete turn to move the aperture 31 from one end to the other of the linear slot 35.

The two rotors 43 and 47 and the helically slotted member 32 are driven continuously and at constant velocity by the motor 24 through the

medium of shaft 25 and the gears 26, 28 and 27, respectively, the gear ratios being such as to turn the rotor 43 $1\frac{3}{4}$ turns and the rotor 47 $3\frac{1}{2}$ turns, while the helically slotted member 32 is making one complete turn. If the phase shifters are so adjusted as to produce appropriate phase angles at the initiation of the $3\frac{1}{2}$ wavelength movement of the aperture along the slot, they will reproduce the same appropriate phase angles for subsequent repetitions of the aperture movement because the movement is an exact multiple of the half-wavelength.

To change the virtual length of the wave guide on each side of the aperture in the right direction as to lengthening or shortening requires the establishment of a definite relation between the direction of rotation of the phase shifter rotor sections and the particular orientation of the reactance rods of the stationary phase shifter sections 44, 45 and 46 with respect to the plane of linear polarization of the electromagnetic waves employed. The proper relationship of the various elements for the particular case in question is indicated in Fig. 4. Assuming the electrical plane of polarization of the waves in the guide to be perpendicular to the plane of the paper and the rotatable elements all arranged to rotate in the same direction, the reactance rods of stationary sections 44 and 45 are all oriented at the same angle of 45 degrees in a clockwise direction (looking into the open left-hand end of the wave guide extension) with reference to the linear polarization plane, and the reactance rods of the stationary section 46 are oriented at 45 degrees in a counter-clockwise direction with respect to the linear plane of polarization. Suppose that the direction of drive of the rotors 43 and 47 and of the slotted member 32, with the reactance rods thus oriented, is in a clockwise direction viewed from the left-hand end of the wave guide. With these elements thus arranged and with the helical slot cut as a left-hand thread, the shift of the phase angle produced by the rotors 43 and 47 is such as electrically in effect to move the transceiver 15 continuously toward the receding aperture 31 and the reflecting wall 30 away from the aperture 31 in exact correspondence as to wavelength with the linear movement of the aperture along the slot, so as at all times to maintain the aperture at an unvarying electrical distance from the transceiver and the reflecting end wall. If the reflecting wall 30 is a stationary part of the structure, the linearly polarized electrical vector that rotates with the phase shifter rotor 47 also rotates with reference to the reflecting end wall and therefore the end wall must have circular symmetry. If the reflecting wall 30 forms part of and rotates with the rotor 47, then only that portion aligned with the linear electrical vector needs to be reflective.

In effect, the action is such as to keep the aperture throughout its movement aligned with a voltage loop of a standing wave pattern produced by the interference of the "go" waves with the "return" waves reflected from the end wall 30. As the position of the loops and of the nodes or nulls in this standing wave pattern is purely a function of the distance in wavelengths to the reflecting wall, a physical recession of the wall by an amount exactly equal to the movement of the aperture toward the wall would cause an energy loop centered on the aperture at the start of the aperture movement to remain centered on it throughout its movement. In terms of electrical wavelength between aperture and reflect-

ing wall this is the effect of the phase shifter 22. It in effect moves the reflecting wall backwardly by the same amount and at the same rate that the aperture moves forwardly. If the impedance

match at the aperture with respect to transmitted energy were perfect, the phase shifter 21 between the aperture and the transceiver would not be required. The phase shifter 22 between the aperture and the reflecting wall would be all that was necessary to keep the energy loop aligned with the aperture during the aperture movement. But in practice, it is difficult to establish such a degree of impedance match at the aperture as would prevent energy reflection at this point, and therefore the phase shifter 21 is used to preserve the same impedance at the transceiver 15.

Obviously, if desired, various combinations of phase shifter elements such as disclosed in the previously mentioned Fox Patent 2,438,119, may be employed to accomplish the same result as the particular combination herein set forth. Furthermore, it will be understood that in the modified form of the invention illustrated in Figs. 12, 13 and 14 wherein the shorter slots of the slotted members give a shorter traverse of the aperture as measured in wavelengths (specifically $2\frac{1}{2}$ wavelengths) and the electrical linear polarization of the waves is perpendicular to the polarization in the first-described modification, the orientation of the reactance rods in the stationary sections of the phase shifters and the driving gear ratios for the phase shifter rotors and the rotating helically slotted member will be correspondingly modified. Specifically, the gear ratios will be such that the rotor 47 makes $2\frac{1}{2}$ turns and the rotor 43 makes $1\frac{1}{4}$ turns, while the helically slotted member makes one turn. In either form, reversing the direction of rotation of the drive shaft reverses the direction of movement of the aperture along the linear slot without modifying the operation of the system.

In accordance with the reciprocity principle, the same arrangement and adjustment of elements of the antenna system employed to give maximum efficiency with respect to the radiated or transmitted waves also gives maximum efficiency of reception for the waves reflected from objects upon which the transmitted wave impinge.

What is claimed is:

1. In combination, a parabolic reflector, a wave guide extending along the latus rectum of said reflector and comprising slotted elements the intersection of which forms a primary antenna aperture facing said reflector and the relative movement of which repeatedly moves said aperture at a constant speed and in the same direction along a line perpendicular to the reflector axis and including the reflector focus, and means for producing relative movement of said elements.

2. In combination, a parabolic reflector and a linearly slotted wave guide extension mounted in fixed relation to each other, a helically slotted rotatable element coaxially located within said wave guide extension, and means for rotating said element to cause the intersection of the slots to move repeatedly and in the same direction along the latus rectum and through the focus of said reflector.

3. In combination, a concave reflector, a wave guide extension lying along the latus rectum of said reflector, said extension comprising a fixed slotted element and a rotatable helically slotted element forming a primary antenna aperture fac-

ing said reflector, and means including a motor unit to drive the rotatable element for producing relative movement of said elements whereby said aperture is moved repeatedly and in the same direction along the latus rectum and through the focus of said reflector.

4. In combination, a passive secondary antenna having a principal focus, a wave guide extension comprising two concentrically mounted elements, one helically slotted and the other linearly slotted, the intersection of said slots forming an aperture constituting a primary antenna facing said secondary antenna, and means including a motor drive unit for rotating said helically slotted element for causing said aperture to move unidirectionally, repeatedly and at a uniform speed across the focus of said secondary antenna.

5. In combination, a parabolic reflector, a wave guide extension disposed along the latus rectum of said reflector and having an aperture facing said reflector, means for moving said aperture along said extension and across the focus of said reflector repeatedly and unidirectionally, and phase shifting means associated with said wave guide extension and operating to compensate for amplitude change due to the movement of the aperture along the wave guide extension, thus to maintain substantially the same amplitude at the aperture during the aperture movement.

6. In combination, a parabolic reflector, a wave guide extension disposed along the latus rectum of said reflector and terminating in a wave reflecting wall, said wave guide extension having a movable aperture constituting a primary antenna facing said reflector, means for moving said aperture along said extension and across the focus of said reflector, phase shifting means between said aperture and said wave reflecting wall, and means for operating said phase shifter in the movement of said aperture to maintain substantially unchanged the electrical distance between the aperture and the terminal wall throughout the movement of the aperture along the wave guide extension.

7. In combination, a parabolic reflector, a wave guide extending from a transceiver to a wave reflecting termination forming part of a wave guide extension disposed along the latus rectum of said reflector, a movable primary antenna aperture formed in said wave guide extension and facing said reflector, means for moving said aperture along said extension and across the focus of said reflector, phase shifting means included in said wave guide between said transceiver and said aperture and between said aperture and said wave reflecting termination, and means for operating said phase shifting means in the movement of said aperture along the extension to maintain substantially the same amplitude at the aperture throughout the aperture movement.

8. In combination, a parabolic reflector, a wave guide extension having an aperture constituting a primary antenna facing said reflector, means for moving said aperture along said wave guide extension and across the focus of said reflector, a wave reflecting termination at one end of said wave guide extension, a transceiver connected with the other end of said extension, and phase shifting means operated in the movement of said aperture to maintain the aperture throughout its movement at a substantially unvarying electrical distance both from said transceiver and from said reflecting termination.

9. In combination, a parabolic reflector, a wave guide extension having an aperture constituting a primary antenna facing said reflector, means

for moving said aperture along said wave guide extension and across the focus of said reflector, a wave reflecting wall at one end of said extension, a source of ultra-high frequency electrical waves connected with the other end of said extension, the reflection of waves from said wall creating a pattern of standing waves in said extension, and phase shifting means operated in the movement of said aperture to move said standing wave pattern in correspondence with the aperture movement to maintain an energy loop at said aperture throughout the aperture movement.

10. In combination, a parabolic reflector, a wave guide extension extending along the latus rectum of said reflector, said wave guide extension including a linearly slotted outer member and a coaxial helically slotted rotatable inner member, the aperture formed by the intersection of said slots facing said reflector and constituting a primary antenna, and means for rotating said inner member to cause said aperture to move at a uniform speed, repeatedly and in the same direction across the focus of said reflector.

11. In combination, a parabolic reflector, a wave guide extension lying along the latus rectum of said reflector, said wave guide extension including an outer member having a linear longitudinal slot and a coaxial rotatable inner member having a one-turn helical slot, the aperture formed by the intersection of said slots facing said reflector and constituting a primary antenna, means for supplying ultra-high frequency linearly polarized electromagnetic waves to said wave guide extension, means for rotating said inner member to cause said aperture to move at a uniform speed repeatedly and in the same direction across the focus of said reflector, and means disposed along said outer member in association with said linear slot for preventing leakage radiation through said slot of energy from the interior of said wave guide extension.

12. In combination, a parabolic reflector, a wave guide extension lying along the latus rectum of said reflector, said wave guide extension including an outer member having a longitudinal linear slot and a coaxial rotatable inner member having a one-turn helical slot, the aperture formed by the intersection of said slots facing said reflector and constituting a primary antenna, means for rotating said inner member to cause said aperture to move at a uniform speed repeatedly and in the same direction across the focus of said reflector, means for supplying ultra-high frequency linearly polarized electromagnetic waves to said extension, the electrical polarization of said waves lying in a plane including said linear slot and the longitudinal axis of said extension, and a plurality of partitions extending transversely across the linear slot in said outer member, said partitions being spaced apart by intervals equal to a small fraction of the wavelength of the energy usefully radiated through said slot and acting to cut off leakage energy polarized in planes parallel to the planes of said partitions.

13. In combination, a parabolic reflector, a wave guide extension extending along the latus rectum of the reflector, said wave guide extension including a linearly slotted outer member and a coaxial helically slotted rotatable inner member, the aperture formed by the intersection of said slots facing said reflector and constituting a primary antenna, means for rotating said inner member to cause said aperture to move at a uniform speed repeatedly and in the same direc-

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tion across the focus of said reflector, and means disposed along the linear slot of said outer member adapted to permit the passage of electromagnetic wave energy by way of said aperture and to discriminate against the passage of energy 5 through other parts of the linear slot.

14. In combination, a parabolic reflector and a wave guide extension having a linearly slotted portion mounted in fixed relation to each other, a helically slotted rotatable element coaxially located within said linearly slotted portion, means 10 for rotating said element to cause an aperture formed by the intersection of the slots to move repeatedly and in the same direction across the focus of said reflector, and means disposed along the linear slot adapted to prevent radiation of energy due to leakage along said slot and permit

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radiation of energy passing through said aperture.

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