

Dec. 31, 1963

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3,116,485

OMNIDIRECTIONAL HORN RADIATOR FOR BEACON ANTENNA

Filed June 27, 1960

4 Sheets-Sheet 1

FIG. 1.

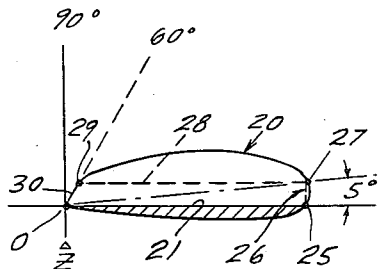


FIG. 2.

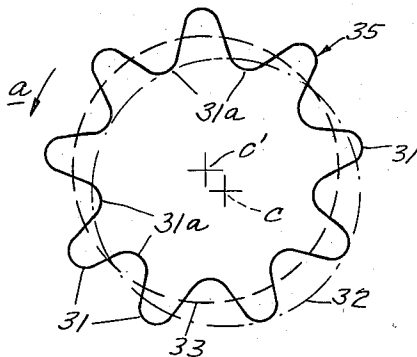


FIG. 3.

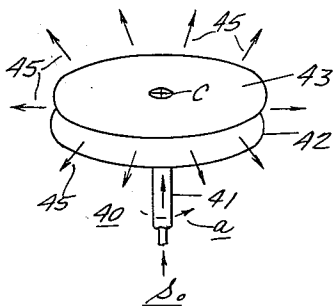


FIG. 4.

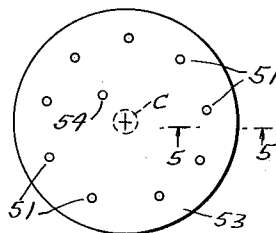
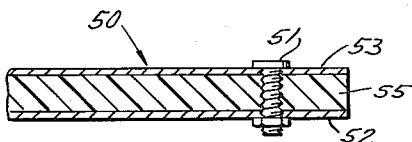


FIG. 5.



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FIG. 6.

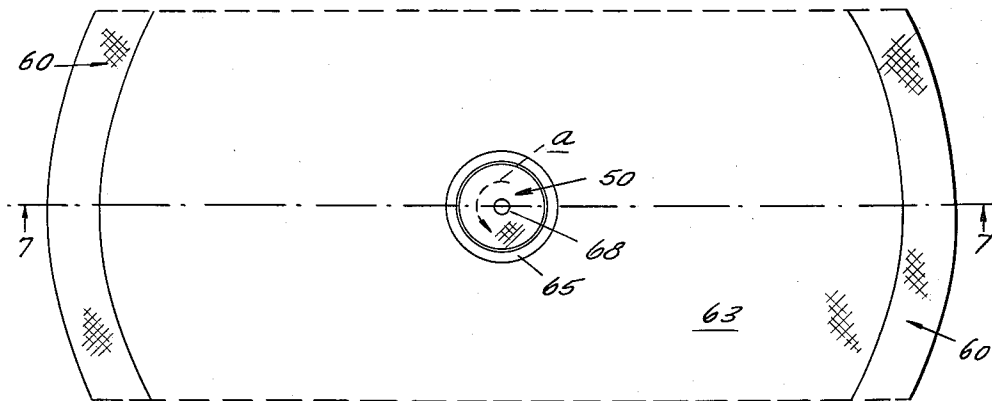
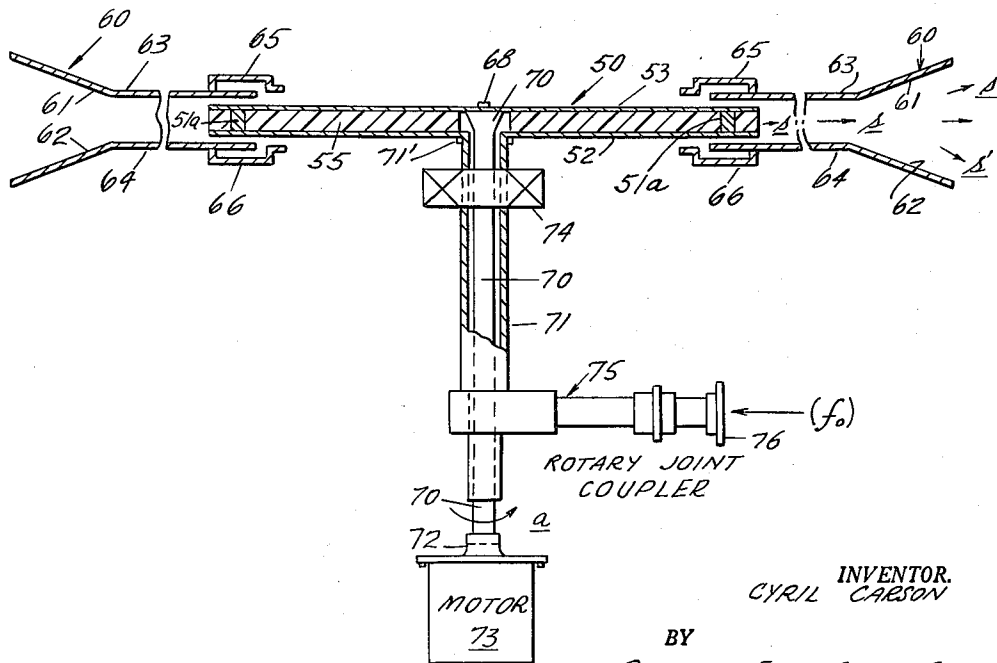


FIG. 7.



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FIG. 8.

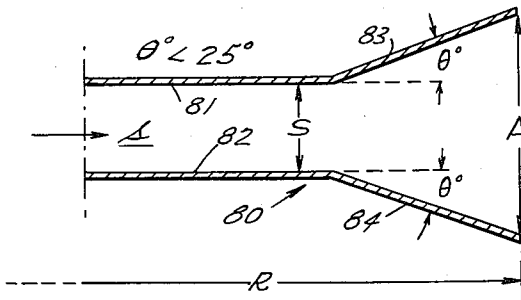


FIG. 9.

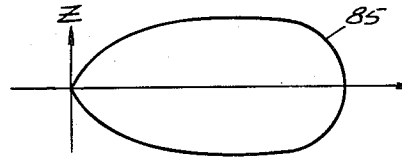


FIG. 10.

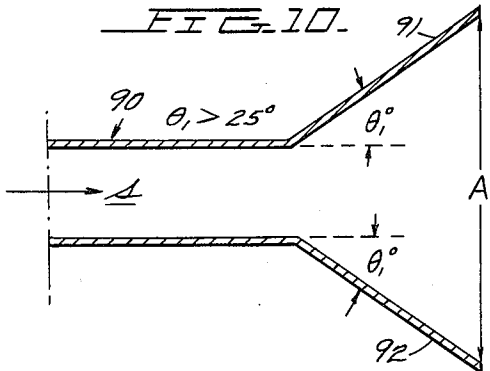


FIG. 11.

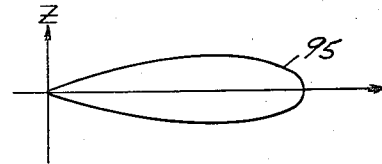


FIG. 12.

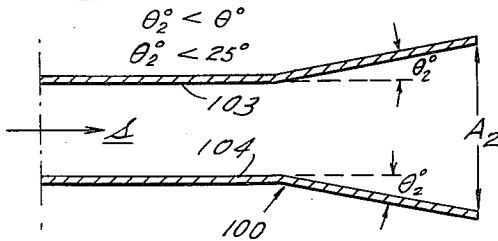
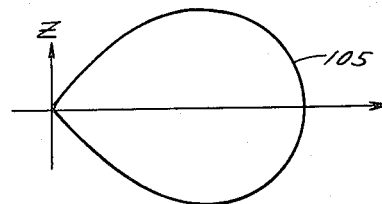


FIG. 13.



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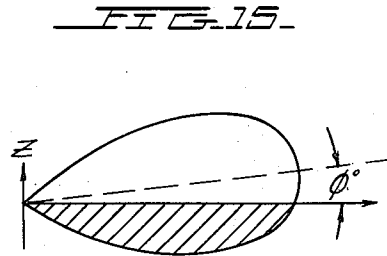
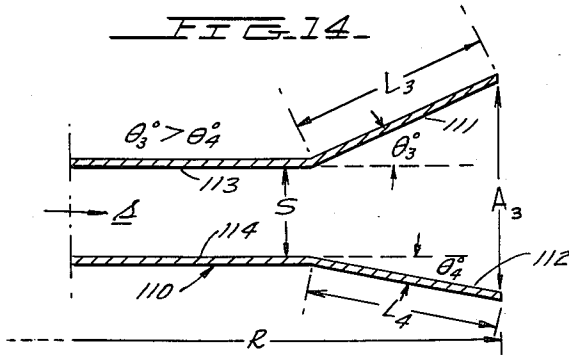


FIG. 16.

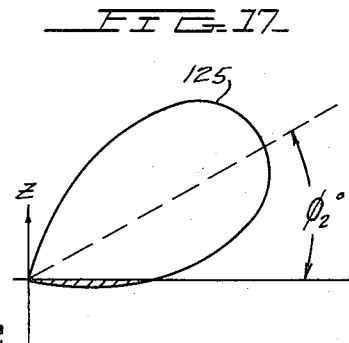
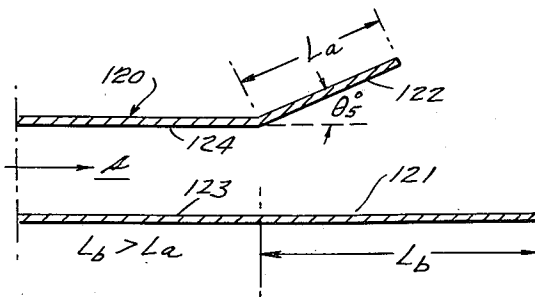
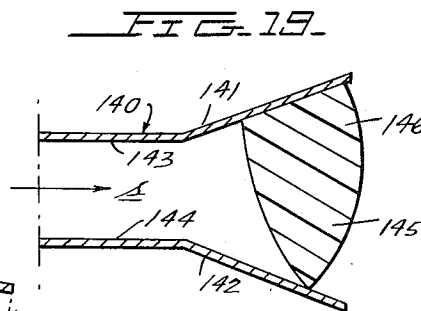
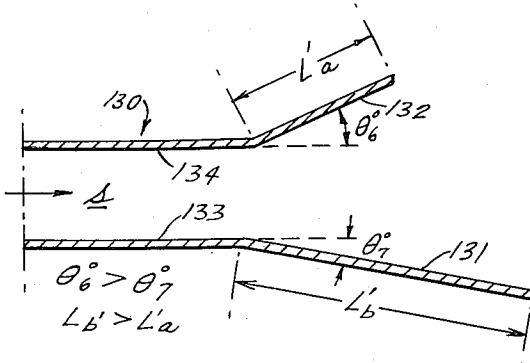


FIG. 18.



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OMNIDIRECTIONAL HORN RADIATOR FOR BEACON ANTENNA

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8 Claims. (Cl. 343-754)

This invention relates generally to omnidirectional transmitting antenna for microwave signals, and more particularly relates to novel horn radiators with toroidal configurations that effectively radiate "Tacan" navigational radio patterns.

The "Tacan" system derives from the military tactical air navigation system for aircraft. It utilizes the UHF range of 960 mc. to 1215 mc. The Civil Aeronautics Administration now requires that "Tacan" transmitter antennas be directly adaptable to efficiently transmit the patterned signals over any frequency in the low band (960 to 1024 mc.) or high band (1150 to 1215). A suitable radiator therefore needs to be relatively broadbanded. A further important requirement is that the transmitted "Tacan" pattern be effective over an elevation range from the horizon to at least 60° above the horizon.

Prior antennas that provide the correct azimuth pattern generally fail to give a suitable vertical radiation pattern. A further serious limitation has been that the phase of the signal components that constitute the "Tacan" azimuth pattern was not constant with frequency over the bands. Critical dimensional relations with frequency prevented their general application over the "Tacan" bands as a particular antenna suitable for transmitting at a specific frequency, would radically distort the requisite pattern if used at a different frequency, even with moderate alteration.

The antenna of the present invention overcomes the aforesaid prior art shortcomings. The modulation of the carrier wave required for the azimuth is effected within a relatively small radius, and the energy is thereupon radiated over a suitably shaped toroidal aperture or omnidirectional horn. The 360° horn configuration of the invention is stationary, and is coupled to the central modulation unit through a pair of parallel discs. The horn aperture is circular in the XY plane, and can be suitably flared in the Z or vertical plane to obtain a desired vertical radiation characteristic.

The radius of the omnidirectional radiator hereof controls the match of the signal components to free space. By utilizing a relatively large radius, at least about seven times wave length the lowest carrier frequency used, excellent radiation characteristics result over the whole Tacan operation range. The modulator of relatively small radius is made concentric within the horn. The vertical height of the horn aperture is preferably made about half-wavelength or greater. There is no feed-back to the coupling system, and the radiation is practically all outwardly in the desired pattern.

The invention radiator is not critical or frequency selective over a relatively broadband for UHF signals. It is efficient, stable, and mechanically rugged. The principles and features of the invention system, to be set forth in more detail, permit one to construct a radiator with any one of a wide diversity of omnidirectional radiation patterns. It is relatively simple to meet the rigid requirements of the CAA stated herein above, therewith, where a rotating central modulator is used a toroidal choke couples the stationary discs for the horn with the peripheral region of the modulator.

It is accordingly a principal object of the present in-

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vention to provide novel toroidal radiators of microwave signals.

Another object of this present invention is to provide novel omnidirectional horn radiators suitable for producing "Tacan" system radiation patterns.

A further object of this present invention is to provide novel 360° horn radiators efficient over a relatively broadband of UHF signals.

Still another object of this present invention is to provide novel omnidirectional horn radiators that are efficient, and with a vertical radiation characteristic effective up to at least 60° to the horizon.

Still a further object of this present invention is to provide novel omnidirectional horn microwave radiation systems that are relatively of simple construction, and rugged.

These and other objects of the invention will become more apparent from the following description of exemplary embodiments thereof, illustrated in the drawings, in which:

FIGURE 1 is a polar representation of an idealized Tacan radiation pattern, in a single elevation plane.

FIGURE 2 is a polar representation in an azimuth plane of the Tacan modulated signal pattern.

FIGURE 3 is a diagrammatic illustration in perspective of an XY omnidirectional signal source.

FIGURE 4 is a plan view of an XY signal source like that of FIGURE 3, with a modulator to produce a Tacan signal pattern.

FIGURE 5 is an enlarged cross-sectional view through the line 5-5 of FIGURE 4, illustrating a modular element.

FIGURE 6 is a partial plan view of an exemplary form of the horn radiator system of the invention.

FIGURE 7 is an enlarged cross-sectional view taken along the line 7-7 of FIGURE 6.

FIGURES 8 through 19 are illustrations of a number of exemplary configurations that the invention horn radiator may embody, and accompanying polar representations of the corresponding radiation patterns.

The CAA specifications for the radiated Tacan pattern is represented in polar form in FIGURE 1, in an elevation plane. Radial distance from the origin represents signal field strength as a function of elevation angle. The minimum requirement pattern is outlined as follows: starting at the origin O, by the horizontal abscissa 21 to point 25 corresponding to six db gain over an isotropic course by an arc 26 to point 27, 5° above the horizon by cosecant line 28 parallel to the horizon to point 29, 60° above the horizon, and by a radial line 30 to the origin O. Radiation pattern 20 is a typical one, that encloses the minimum requirement pattern, and thus meets the specifications.

The basic "Tacan" signal pattern 35 comprises a uniform nine lobed spatial modulation 31, 31a as shown in FIGURE 2. The zero cycle is represented by the broken circle 32 centered at C. A one cycle modulation is seen as essentially circular at 33, with its center at C displaced from the reference center C. Polar curve 35 is for a typical azimuth plane with point C as origin. The radiation per pattern 35 is rotated about origin C to effect the "Tacan" system operational signal distribution, in azimuth. The vertical distribution is represented by the polar configuration 20 of FIGURE 1.

The "Tacan"-type spatially modulated signals are generated by a suitable rotatable modulator. Reference is made to the copending patent applications Serial Number 742,646, filed June 17, 1958, entitled "Broad-Band Antenna," inventor David F. Bowman, now Patent No. 2,990,545; and Serial Number 809,690, filed April 29, 1959, entitled "Micro-Wave Strip Line Modulator," in-

ventor David F. Bowman, both assigned to the assignee of the instant application for illustrations thereof. The omnidirectional radiators of this invention may be used with such, and other omnidirectional modulators or generators. The spatial carrier modulator 50 incorporated in the exemplary radiator system illustrated in FIGURES 6 and 7, corresponds to that described more fully in the aforesaid copending patent application, S. N. 742,646.

Reference is now made to FIGURES 3, 4 and 5 for an understanding of the operation of such modulators. FIGURE 3 illustrates converter 40 that is fed with a UHF or microwave signal S_0 at central coaxial transmission line 41. Two spaced metal discs 42, 43 are individually connected to the two terminals of coaxial line 41. A uniform axial or 360° signal pattern is projected by the transmission discs 42, 43, as indicated by the radial lines 45. Rotation of the disc array 42, 43 as indicated by arrow a effects a direct spatial rotation of the source pattern 45.

The signals from source S_0 impinge at center c of the discs 41, 42, and then radiate across the discs to their perimeters, as will be understood by those skilled in the art. To effect the multi-lobed spatial modulation for the Tacan modulator 50, a series of beam modulator elements 51 are incorporated across a set of spaced discs 52, 53 as shown in FIGURES 4 and 5. Elements 51 are arranged in the peripheral region to modulate an incident uniform radial carrier signal with the nine multiple lobes (31, 31a) in accordance with FIGURE 2. The modulator elements 51 may be bolts secured through opposed apertures in the discs.

Nine uniformly positioned modulator elements 51 produce the requisite lobes. A tenth modulator element 54 is located radially closer to center c , and constitutes the fundamental modulator corresponding to curve 33 of FIGURE 2. A layer 55 of low dielectric loss material is sandwiched between discs 52, 53 for mechanical advantage. Suitable material therefore is polyfoam, Styrofoam, etc. As hereinabove stated, the particular omnidirectional signal pattern, or the spatial modulator source, utilized for the unit 50 in conjunction with the omnidirectional radiator system of this invention, is optional.

The exemplary omnidirectional radiator system is illustrated in FIGURES 6 and 7. The rotatable modulator 50 is centrally positioned within the annular horn radiator 60. As will be described in detail, the shape and flare of toroidal horn 60 may assume many forms for desired radiation patterns. Horn 60 comprises two annular sides 61, 62 extending from respective parallel metal discs 63, 64 which are mounted as a stationary assembly. Efficient electrical coupling is effected between the disc radial transmission line 63, 64 and the peripheral signal output of rotatable modulator 50 through annular chokes 65, 66. Chokes 65, 66 are proportioned to produce an electrical short circuit across respective plates 53, 63, and 52, 64 despite the mechanical break thereacross. Electrical signal continuity is thus maintained between modulator 50 when rotated, and the stationary discs 63, 64. No signal leakage takes place in view of the peripheral location of the chokes 65, 66.

The carrier signal (f_0) is fed to the modulator discs 52, 53 through a coaxial transmission line composed of rotatable shaft 70 and a metal tube 71 concentric therewith. The top end 70' of shaft 70 is secured with the center of disc 53 at 68, and forms a terminal for microwave input. Sleeve 71 has its rim connected along a corresponding central aperture at 71' with lower disc 52, to complete the RF coupling. The shaft 70 is connected by coupling 72 to drive motor 73. Rotation of motor 73, as in the direction of arrow a , rotates modulator 50 as a unit, including shaft 70, discs 52, 53 with dielectric layer 55, modulator elements 51a, and sleeve

71. A bearing 74 supports sleeve 71 in the vertical rotation.

The basic carrier signal (f_0) is fed to modulator 50 through the rotatable coaxial line 70, 71 connected therewith, through a rotary joint coupler 75. The carrier signal is coupled to coupler 75 across end flange 76. For Tacan transmission modular 50 is rotated at 900 r.p.m. Nine modular elements indicated at 51a, produce the nine lobes per FIGURE 2. The azimuth pattern of the signal s output of the rotating modular 50 may be expressed as:

$$A(\theta) = A_1 + A_2 \cos \theta + A_3 \cos 9\theta$$

where: A_1 , A_2 and A_3 are suitably chosen constants and θ is the angle measured about the modulator periphery.

The modulated signals a radially pass through outer discs 63, 64 to horn 60, and are controllably radiated as indicated at s' in FIGURE 7.

FIGURE 8 illustrates a vertical section of a typical horn configuration contemplated by the present invention, corresponding to the annular horn 60 of FIGURES 6 and 7. Omnidirectional radiator 80 comprises two metal discs 81, 82 spaced apart by distance S . The horn sides 83, 84 extend from plates 81, 82 by equal angles θ° , in flared relation. The vertical height A of the horn aperture is an important dimension in the invention system. For an effective vertical pattern, whereby appreciable signal strength is radiated up to at least 60° above the horizon, the dimension A is made at least equal to $\lambda/2$, where λ is the wave length of the carrier frequency for which the system is to be used.

In Tacan transmitters, such lowest frequency is 960 mc., where the wave length λ is about one foot. Thus for "Tacan" fullband operation, A is made at least 6 inches, and preferably greater. Also, importantly, the angle θ° of the horn sides 83, 84 is preferably less than about 25°, to create the vertical pattern requirements for Tacan. The angle θ is not critical in this regard, as long as less than the 25° figure. However in particular cases, a greater than 25° angle is useable.

The preferable minimum for dimension A may be reduced from the $\lambda/2$ figure where efficiency is not important. The length L of the horn sides 83, 84 are equal, and established once the other parameters θ° , A and S are selected. The amount of spacing S is not critical, and is optional in the invention system. The polar curve 85 is a representation of the signal s pattern radiated by horn 80 where θ is 25° or less, and A is $\lambda/2$ or greater.

A further important dimension of the invention array is the radius R of the horn 83, 84 from the center 68 of the system, see FIGURE 6. The radius R controls the match of the multi-lobe frequency component $A_3 \cos 9\theta$ to free space, and the cross-polarized components thereof. It is desirable to keep R large in relation to the wavelength λ of the carrier frequency, namely $\cos \theta$. A preferable relation is to make the R dimension at least 7 times the wavelength of the lowest carrier frequency used. For a "Tacan" broadband array, R is preferred to be at least seven feet, making the horn 60 diameter about 15 feet in the exemplary radiator. Smaller diameters are of course usable, but are less efficient in giving coverage to high elevation angles for the 9 cycle component.

It is thus now apparent to those skilled in the art that the invention arrangement, while having preferred dimensional relationships, is neither selective or critical frequencywise. A reasonably broad-band radiator is practicable, with no problem over the "Tacan" range of 960 to 1215 mc. One omnidirectional arrangement hereof will efficiently and effectively handle all Tacan transmitter frequencies, and their higher frequency components. To alter the operation frequency of the radiator system, it may be necessary to modify the modulator array 50; the invention section coupled thereto need not be changed. The bolt type 51 modulator elements would need simple

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repositioning. The invention radiator system is of course useable for other than Tacan omnidirectional applications.

With horn aperture the dimension A at least $\lambda/2$, there is negligible feed-back on leakback of signal to the radial transmission discs, and radiation is practically all outwardly. This results in high radiation efficiency. With the radius R dimension at least 7λ , there is no deterioration of the higher frequency signal components ($A_3 \cos 90$). There is thus no phase distortion among the Tacan signal components radiated thereby. Also, making the horn side flare angles θ not greater than about 25% insures suitable signal strength to the 60° elevation referred to.

The horn radiator 90 of FIGURE 10 has equal horn sides 91, 92 each extending by the same angle θ , from horizontal discs 93, 94 to an aperture A_1 . The value of θ is shown at 35°, being substantially larger than that of θ' of FIGURE 8 at 25°. The result is to flatten the pattern radiated, as shown by polar curve 95 in FIGURE 11. Further enlargments of the flare angles θ , of sides 91, 92 would still further flatten this output pattern. In special applications where such is desired, this principle may be utilized.

With the flare angles reduced to a lower value than that of θ of FIGURE 8, a further bulge occurs in the radiated pattern, as indicated by polar curve 105 of FIGURE 13. The corresponding smaller angle θ_2 , illustrated in FIGURE 12 at 10° gives such result. The unit 100 comprises a shallow flared horn 101, 102 extending symmetrically from discs 103, 104. It is to be noted that the radiation patterns 85, 95 and 105 are all symmetrical about the horizontal. This in turn is due to the symmetrical arrangement of their corresponding horn radiators.

The radiation patterns may be readily tilted to the horizontal with the invention system. One method is to use a different flare angle for the horn sides. This is illustrated by horn 110 in FIGURE 14. The angle θ_3 of horn side 111 to disc 113 is greater than angle θ_4 of side 112 to disc 114. The sides 111, 112 extend equally to radius R, and form aperture A_3 . The lengths L_3 and L_4 of these sides are determined once spacing S is selected. The resultant pattern 115 is tilted upwardly by an angle ϕ_1 as noted in FIGURE 15. This tilt angle is controlled by the selected angles θ_3 and θ_4 .

Another way to tilt the radiated pattern is shown by horn system 120 of FIGURE 16. The lower horn side 121 is made longer (LB) than that of (LA), the upper one 122. Also, lower side 121 is an extension of disc 123, and upper horn side 122 is at an angle θ_5 to disc 124. The result is pattern 125 of FIGURE 17 with a tilt angle ϕ_2 greater than an angle ϕ_1 of FIGURE 15. The degree tilt ϕ_2 is controlled by the relative proportioning of L_a to L_b and θ_5 .

In FIGURE 18, the lower horn side 131 of array 130 is longer than side 132, as in horn 120, but is flared by an angle θ_7 to disc 133. Upper side 132 is arranged at an angle θ_6 to disc 134, greater than θ_7 . A tilted pattern in the manner of FIGURE 17 results. The relative lengths of the horn sides are more effective in producing the tilt than the relative angles thereof. A further form of horn array for radiation pattern tilting is shown at 140 in FIGURE 19. A symmetrical horn arrangement 141, 142 extends from discs 143, 144. A toroidal lens 145 is positioned between horn sides 141, 142 suitably shaped to slow down the waves along the upper horn section, as along side 141. The lens 145 is seen to be thicker at its base 146 contiguous with side 141. Lens 145 is of low-loss dielectric material, as polystyrene, Teflon, etc.

In summary, it is now evident that a wide variety of radiation pattern characteristics can be obtained by suitable shaping of the horn aperture in the vertical or Z plane. Further, the opposed horn sides may be made curved in conventional horn practice. The aperture of

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the horn antenna hereof can be considered equivalent to ring layers of local electric and magnetic currents, the amplitude of which is a function of azimuth angle and is directly related to the azimuth pattern. With the aperture vertical height (A) at least $\lambda/2$, there is little feed back effect, and the radiation pattern can be considered to be due entirely to such electric and magnetic current rings associated with the aperture. With the radius (R) of the horn aperture sufficiently large, all components in the azimuth pattern produce essentially the same vertical pattern.

While this invention has been described in connection with exemplary embodiments, it is to be understood that it may be practiced with modifications and variations that fall within the broader spirit and scope of the invention as defined in the following claims.

I claim:

1. An omnidirectional horn radiator system for microwave signals comprising a pair of stationary planar discs spaced for forming a radial signal transmission line effective over 360° in the azimuth plane, the remote radial regions of said discs being shaped with an annular outwardly flared aperture constituting a horn radiator of signals impressed across said discs having a predetermined vertical radiation pattern throughout the omnidirectional azimuth sweep of the radiator, said discs each being formed with a central aperture, and a rotatable signal modulator source of annular shape concentric to said discs and electrically coupled to said discs across their aperture periphery for omnidirectional radiation to free space of the signals in said predetermined pattern, the diameter of said discs being sufficiently greater than the wavelength of said signals for providing means for broad-band omnidirectional matching to free space, while permitting substantial aperture variation for transverse beam shaping.

2. An omnidirectional horn radiator system, as claimed in claim 1, in which the radius of said aperture to the radiator center is at least the order of seven times the wavelength the lowest frequency of said signals; said signal modulator being of a substantially lesser diameter.

3. An omnidirectional horn radiator, as claimed in claim 1, in which the angle of one of the aperture walls is less than the order of 25° with respect to the plane of its associated member.

4. An omnidirectional horn radiator, as claimed in claim 1, in which the angle of the aperture walls are each less than the order of 25° with respect to the plane of its associated disc.

5. An omnidirectional horn radiator, as claimed in claim 1, in which the upper aperture annular wall is at a greater angle to the discs than is the lower aperture wall and the lower annular aperture wall is substantially longer radially than the upper one for producing a vertical radiation pattern with its longer axis tilted above the horizon.

6. An omnidirectional horn radiator, as claimed in claim 1, in which the radius of said aperture to the radiator center is at least the order of seven times the wavelength the lowest frequency of said signals; the lower annular aperture wall is substantially longer radially than the upper one, and wherein the aperture height of the effective annular horn is at least of the order of one-half that of said wavelength.

7. An omnidirectional radiator, as claimed in claim 1, further including a lens of dielectric material arranged in said aperture for producing a vertical radiation pattern with its longer axis tilted above the horizon.

8. An omnidirectional horn radiator, as claimed in claim 1, further including a lens of dielectric material and toroidal form arranged in said aperture with a thicker section adjacent the upper aperture wall for producing a vertical radiation pattern with its longer axis tilted above the horizon.

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