

June 27, 1961

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2,990,545

BROAD-BAND OMNIDIRECTIONAL SPHERICAL LENS ANTENNA  
WITH ROTATING AMPLITUDE MODULATION PATTERN

Filed June 17, 1958

4 Sheets-Sheet 1

FIG. 1

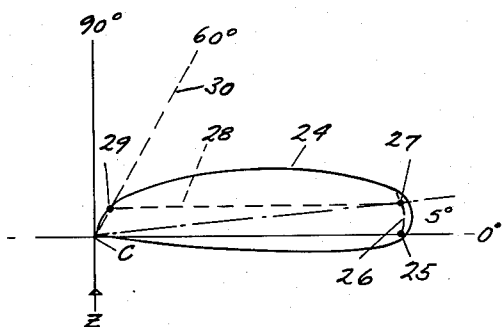


FIG. 2

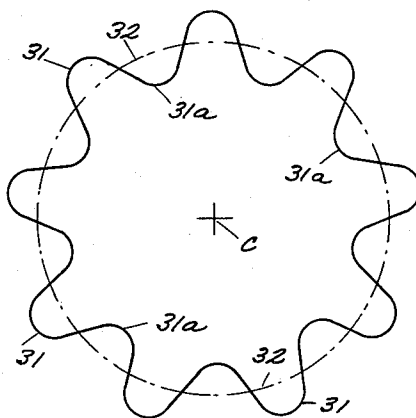


FIG. 4

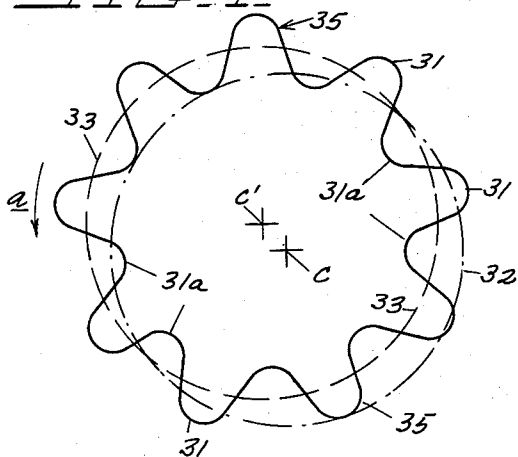


FIG. 3

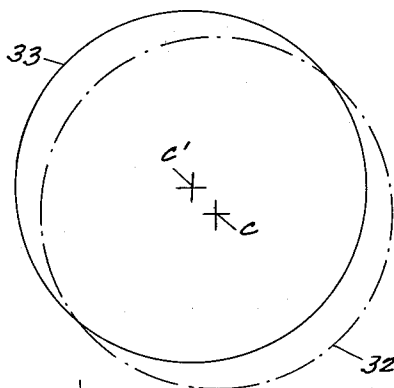
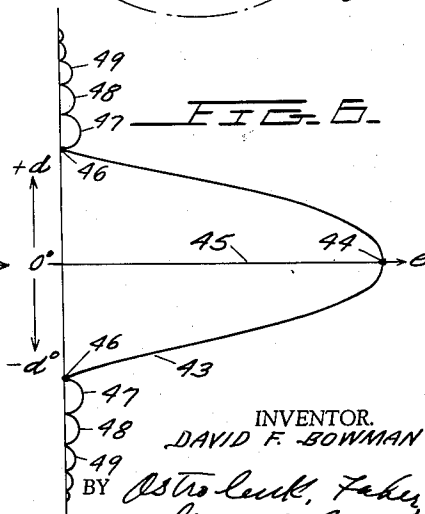
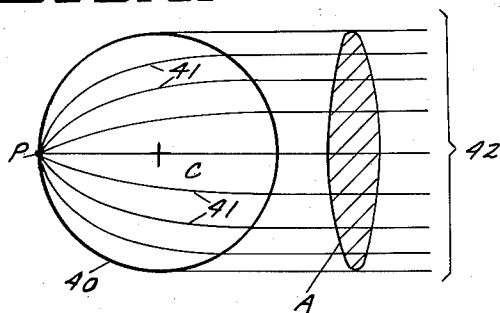


FIG. 5



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4 Sheets-Sheet 2

FIG. 7.

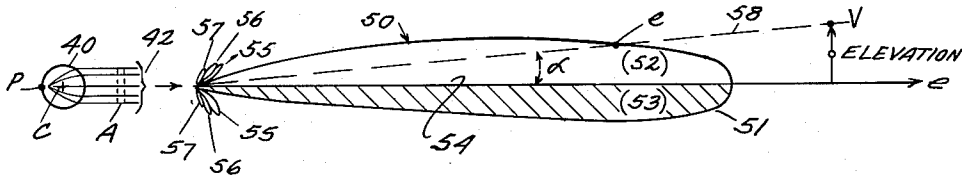


FIG. 8.

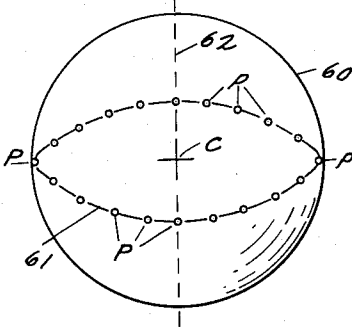


FIG. 10.

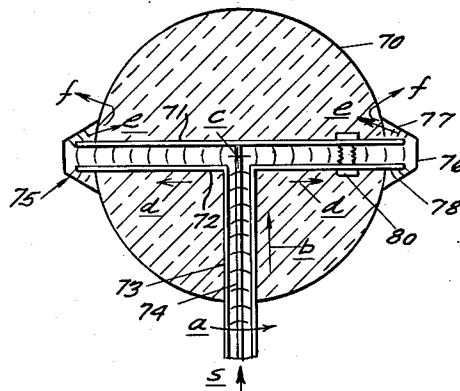


FIG. 9.

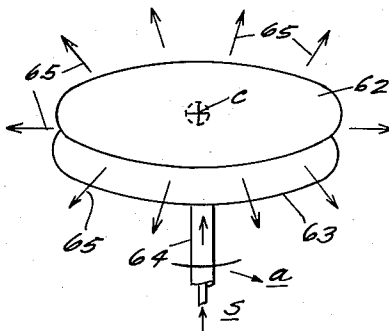


FIG. 11.

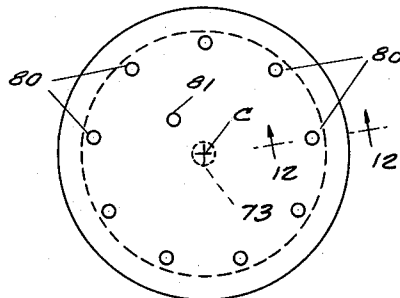
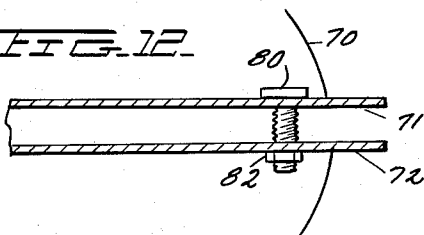


FIG. 12.



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Filed June 17, 1958

4 Sheets-Sheet 3

FIG. 13.

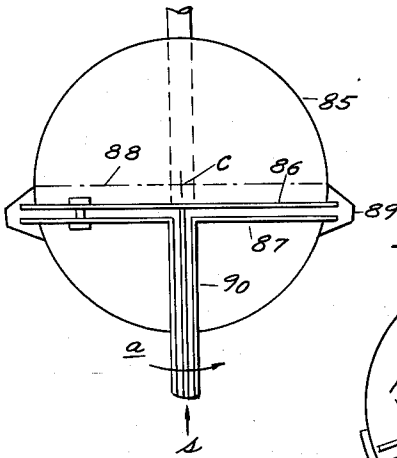


FIG. 14.

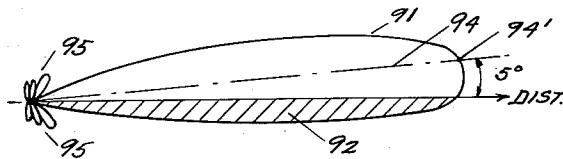


FIG. 15. FIG. 16.

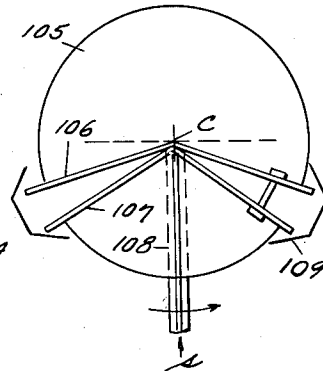
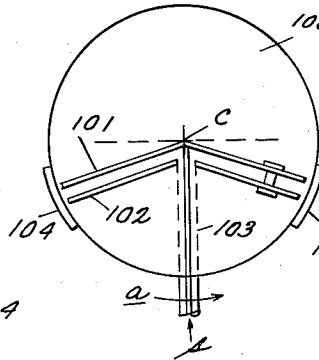


FIG. 17.

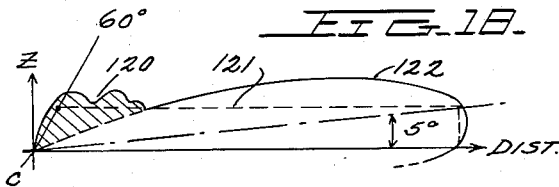
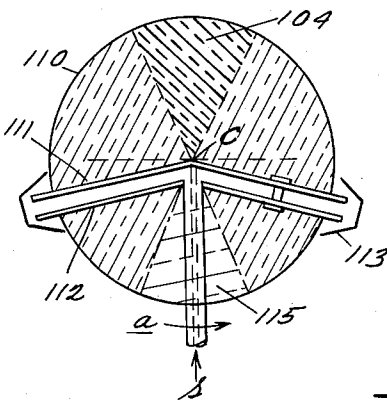


FIG. 19. FIG. 20.

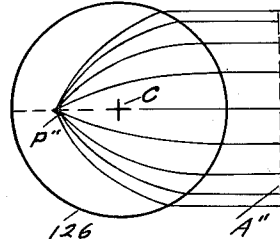
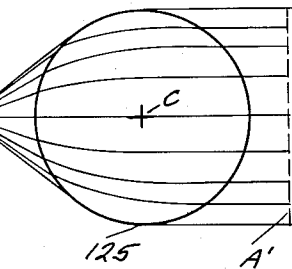
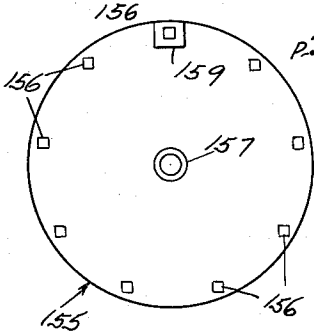


FIG. 21.



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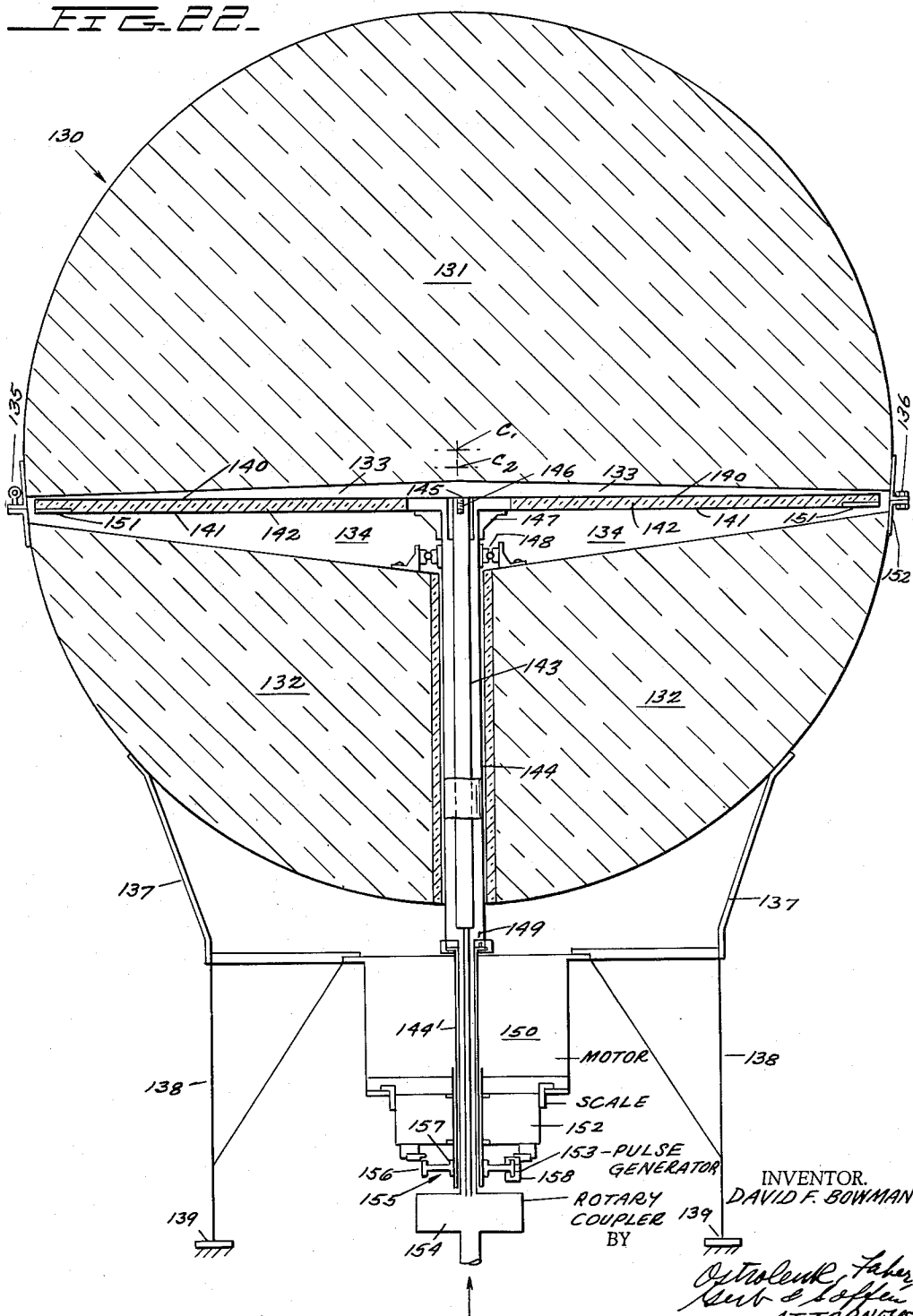
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4 Sheets-Sheet 4

FIG. 22.



1

2,990,545

**BROAD-BAND OMNIDIRECTIONAL SPHERICAL LENS ANTENNA WITH ROTATING AMPLITUDE MODULATION PATTERN**

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Filed June 17, 1958, Ser. No. 742,646

13 Claims. (Cl. 343-755)

This invention relates generally to directional transmitting antenna, and more particularly relates to novel antenna for transmitting the directional radio pattern for the radio navigational system known as Tacan.

The Tacan system has been developed in recent years, initially for military aircraft, being an abbreviation of tactical air navigation. It operates in the UHF spectrum, being assigned the range 960 mc. to 1215 mc. The low band Tacan range is 960 to 1024 mc.; the high band, 1150 to 1215 mc. The intermediate band 1024 to 1150 mc. is used for interrogation of the Tacan station by an aircraft for distance determinations.

The Civil Aeronautics Administration is setting up a system of transmitting stations combining Tacan with civilian "VHF omnirange" or VOR. The latter system is known as Vortac. One of the new requirements for the Tacan transmitter antenna is that it be directly adaptable to efficiently transmit its patterned signals over any frequency in either of the Tacan high or low bands. The present invention provides novel antenna systems with broad-band characteristics to accomplish this feature.

Another important Civil Aeronautics Administration requirement is to have the transmitted Tacan pattern be effective over an elevation range from the horizon to at least 60° above the horizon. Such wide elevation coverage has been unattainable with prior antennae. Further, the new Tacan transmitted signals are to be of higher gain than heretofore, namely, to be six db over that of an isotropic source. The antenna systems of the present invention accomplish these important and desirable objectives.

In accordance with my invention, I utilize a dielectric sphere known as a Luneberg lens, and provide multiple or infinite point sources of the radio waves to be radiated from a circular path on the sphere. The result is 360° horizontal radio pattern of general toroidal form. I further incorporate therein modulators to shape the toroidal form with fundamental and nine lobed modulations to constitute the characteristic Tacan pattern. Rotation of the modulated point sources at 900 r.p.m. about the sphere results in the Tacan signal transmission intercepted at 15 and 135 cycles per second.

It is accordingly a primary object of the present invention to provide a novel transmitter antenna incorporating a dielectric sphere with multiple radio point source thereabout to produce a generally toroidal pattern.

Another object of the present invention is to provide a novel Tacan antenna utilizing a dielectric sphere to transmit a Tacan pattern with a gain at the 0° to 5° elevation angles of six db over an isotropic source.

A further object of the present invention is to provide a novel antenna incorporating a dielectric sphere to transmit a generally toroidal 360° radio pattern with effective signal strength from horizon to at least 60° above the horizon.

Still another object of the present invention is to provide a novel antenna system capable of efficiently transmitting a Tacan radio array at any frequency over the whole UHF Tacan band.

Still a further object of the present invention is to provide a novel Tacan transmitter antenna that is effi-

2

cient, rugged and capable of long-time uninterrupted operation.

The above and further objects of the present 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 radio Tacan pattern in a single elevation plane.

FIGURE 2 is a polar representation of the antenna radiation pattern in a single azimuth plane as modulated with nine lobes.

FIGURE 3 is a polar representation of the antenna radiation pattern in a single azimuth plane as modulated by the fundamental frequency.

FIGURE 4 is a polar representation of the composite antenna radiation pattern per FIGURES 2 and 3.

FIGURE 5 is a diagrammatic showing of the operation of a Luneberg lens with a single radio point source.

FIGURE 6 is a curve illustrating the relative signal strength of the Luneberg lens beam at angular deviations from the normal direction.

FIGURE 7 is a polar representation of the beam emitted from the lens of FIGURE 5.

FIGURE 8 is a perspective schematic diagram of the multiple or infinite radio point sources for the spherical lens, in accordance with my invention.

FIGURE 9 is a perspective illustration of an exemplary means for generating the radio point sources in the lens of FIGURE 8.

FIGURE 10 is a cross-section view through a spherical antenna arrangement utilizing the signal feed means of FIGURE 9.

FIGURE 11 is a plan view of the signal feed system of FIGURES 9 and 10 incorporating modulator elements.

FIGURE 12 is an enlarged cross-sectional view through the line 12-12 of FIGURE 11, illustrating an exemplary modulator element.

FIGURE 13 is a diagrammatic showing of a modified spherical lens antenna in accordance with my invention.

FIGURE 14 is a polar representation in a single elevation plane of the radiation pattern of the antenna of FIGURE 13.

FIGURES 15, 16 and 17 are illustrations of further forms which my antenna may assume in practice.

FIGURE 18 is a polar representation in a single azimuthal plane of the radiation pattern of the antenna of FIGURE 17.

FIGURES 19 and 20 are schematic showings of alternate radio signal feed positions with respect to the antenna hereof.

FIGURE 21 is plan view of the trigger disc of the pulse generator of the invention system per FIGURE 22.

FIGURE 22 is a cross-sectional view vertically through a complete antenna structure in accordance to the present invention.

In FIGURE 1, I have represented in polar form the new Civil Aeronautics Administration requirements as to the radiated Tacan pattern in an elevation plane. Radial distance from the origin represents signal field strength as a function of elevation angle. A typical pattern 24 is shown enclosing the minimum requirement pattern. The minimum requirement pattern is outlined starting at the origin by the horizontal abscissa to point 25 corresponding to six db gain over an isotropic source, 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 radial line 30 to the origin.

The basic Tacan pattern comprises a uniform nine lobed modulation 31, 31a as shown in FIGURE 2. The lobes 31, 31a are specified to be greater in amplitude than the carrier level, represented in FIGURE 2 by the broken uniform circle 32 with center c. The troughs 31a

are specified to be 21% less in amplitude than the carrier level.

The Tacan pattern also requires a fundamental modulation as represented by FIGURE 3. This may be the essentially circular pattern 33, having its center  $c'$  displaced from reference center  $c$  whereby in amplitude the peak of curve 33 is 21% greater and the valley of curve 33 is 21% less than the radius of the reference circle 32.

The Tacan 360° radiation pattern is represented in FIGURE 4 by polar curve 35, in a typical azimuth plane, with point  $c$  as the origin. Curve 35 is the composite fundamental and nine loge modulation of the basic omnidirectional uniform 360° radio pattern represented by basic circle 32. The pattern 35 is rotated about its origin at  $c$  to effect the Tacan system results. The antenna of the present invention produces a rotating spatially modulated Tacan pattern as represented by the FIGURES 1 through 4.

FIGURE 5 illustrates the action of a Luneberg lens 40 on a single radio point source  $P$ . The Luneberg lens, as known in the art per se, is a sphere of dielectric material in which the dielectric constant varies gradually with the radius from center  $c$ . It is densest, namely of the value 2.0 at the center, to least dense at the surface, namely with a value of 1.0. In such a sphere 40, the index of refraction  $n$  of the radio waves 41 passing there-through varies with the normalized radius  $r$  according to the formula  $n = \sqrt{2 - r^2}$ .

At the microwave frequencies utilized in Tacan transmission, namely, of the order of 1,000 megacycles, the lens 40 produces a uniform emergent radio beam 42. Thus, any circular aperture at or near the lens, represented at  $A$ , along beam 42 will have a radio pattern of uniform phase and uniform amplitude.

FIGURE 6 represents the relative amplitude or signal strength  $e$  of a beam such as 42, when measured at angular deviations  $\alpha$  with respect to the beam (42) axis (fairly remotely from lens 40). It is noted, as FIGURE 6 curve 43 shows for a horizontal beam (42), in that there is an elevation signal variation from the peak value of  $e$  at 44 on the beam axis 45. The main lobe of curve 43 in effect reaches the zero level at points indicated at 46, 46 which, depending upon the sphere (40) diameter and other factors may occur, for example, at  $\pm 6^\circ$ ,  $\pm 8^\circ$ , etc.

It is also to be noted that minor lobes 47-47, 48-48 and 49-49 are also represented in curve 43 for greater elevation deviation from a horizontal beam (42).

FIGURE 7 shows a polar curve 50 in elevation for a horizontal beam (42) from a spherical lens (40). The main lobe 51 extends uniformly above (52) and below (53) the beam axis 54. The minor lobes 55, 56 and 57 correspond to those indicated at 47, 48, 49 in FIGURE 6. The relative signal strength  $e$  is determined by the intersection of curve 50 with the elevation line 58 at  $\alpha$  degrees from a vehicle  $V$  such as an aircraft.

An important feature of my invention is to utilize a radio microwave lens such as a Luneberg sphere and apply simultaneously thereto an infinite number of radio point sources along a circular region thereof.

FIGURE 8 diagrammatically represents the lens 60 with the multiple or infinite radio point sources,  $P$ ,  $P$  along the equatorial circle 61. The lens center is at  $c$ , and its zenith at line 62.

The 360° array 61 of point sources,  $P$ ,  $P$  produces a toroidal pattern of an otherwise linear beam (42) due to a single point source noted above in connection with FIGURE 5. For uniformly phased and equal amplitude radio point sources,  $P$ ,  $P$  along circle 61, there results a symmetrical toroid pattern having a common vertical polar configuration along any elevation plane. Means are provided by my present invention to compositely modulate and rotate such uniform toroid patterns to effectuate the requisite Tacan specifications described in connection with FIGURES 1 through 4 hereinabove.

FIGURE 9 is a perspective illustration of a uniform

continuous or infinite point source feed or line for the microwave lens hereof. This feed or line system comprises two spaced metal discs 62, 63 fed by a center coaxial transmission line 64. A uniform axial radio source is projected by the transmission discs 62, 63 as indicated by radial lines 65, 65. Rotation of the disc array 62, 63 as indicated by arrow  $a$  effects a direct spacial rotation of the source pattern 65.

FIGURE 10 is a cross-sectional view through a simplified version of the invention Tacan antenna. The dielectric sphere 70 is of the Luneberg type with radial dielectric constant change, as described in connection with lens 40 of FIGURE 5. Two discs 71, 72 are arranged horizontally along the diameter of sphere 70. A coaxial transmission line with outer conductor 73 and inner conductor 74 couples to the opposed discs 71, 72 to feed a source of radio signals  $s$  to discs 71, 72.

The signals from source  $s$  are indicated as moving to the discs 71, 72 by arrow  $b$ , and then to radiate across the discs to their perimeters as indicated by arrows  $d$ ,  $d$  as in the manner of FIGURE 9. The perimeter region of each disc 71, 72 preferably, though not necessarily, extends beyond the surface of lens 70. A horn reflector band 75 surrounds the periphery of discs 71, 72 to reflect the incident radio signal waves back to the lens 70 along the sphere. This reflection by band 75 effects the infinite radio point sources along a circular path of sphere 70 in the manner of FIGURE 8.

The reflector 75 is trough-shaped with a cross-section corresponding to a horn radiator. Horn reflector band 75 has a central flat region 76 constituting the reflector section opposite the signal emergent region of discs 71, 72, and two angular regions 77, 78 constituting the horn walls. Properly matched construction will produce substantially total transmission into the lens as indicated by arrow  $e$  with negligible reflection back into the narrowly spaced discs 71, 72 and with negligible undesired transmission, for example as shown by arrow  $f$ . An efficient radio transmission system, with low VSWR is thus effected, providing the continuous point source band about lens 70. A Tacan type toroidal pattern results.

A series of beam modulator elements 80 are provided along the transmission discs 71, 72. Elements 80 modulate the otherwise azimuthally uniform toroidal beam emanating from lens 70 with the multiple lobes in accordance with FIGURE 4. An exemplary modulator element 80 is a bolt 80 mounted between discs 71, 72 in the radial path of a portion of the radio waves there-between.

FIGURE 11 is a plan view of the disc assembly 71, 72, showing the top disc 71 and the multiple lobe modulator elements 80, 80. Nine elements 80 produce nine uniform lobes (31). The desired amplitude of the lobes is determined by suitable radial spacing of the elements 80 on discs 71, 72, their diameter, and their metal composition, as will now be understood by those skilled in the art. A tenth modulator bolt 81 is located closer radially to center  $c$  of discs 71, 72 and constitutes the fundamental modulator for the lower frequency, corresponding to curve 33 of FIGURES 3 and 4.

FIGURE 12 illustrates an enlarged cross-section of modulator bolt 80 having nut 82 set between discs 71, 72.

For maximum utilization of the emitted signal strength, and also to better meet the six db gain requirement, the radio transmission discs are moved below the equatorial area of the spherical lens.

FIGURE 13 illustrates lens 85 with transmission discs 86, 87 set below the equatorial diameter 88. The rim reflector 89 surmounts the projecting periphery of discs 86, 87. The coaxial signal  $s$  feed line 90 suitably couples with discs 86, 87. It is noted that for Tacan operation, the modulator transmission disc combination is rotated about its zenith axis, along  $a$ . The lens 85 and reflector 89 are preferably stationary. The reflector 89 is advantageously supported on lens 85.

FIGURE 14 illustrates in polar form the upward-tilt effected by the lowering of transmission discs 86, 87. The below horizon area 92 of curve 91 is reduced as compared to area 53 of FIGURE 7. Further, the 5° elevation line intersection point 94' is increased in gain to better meet the requisite six db. The curve 91 peak is shifted close to the 5° line 94, though not necessarily on it.

FIGURES 15 and 16 show alternate forms for the lowering of the transmission circumference to effect the upward beam tilt as per FIGURES 13, 14. The lens 100 of FIGURE 15 has two spaced conical metal members 101, 102, with a central coaxial feed line 103. The reflector band 104 for lens 100 is shown as flat. This permits the cone peripheries to remain interior of sphere 100. In sphere 105 of FIGURE 16, the two conical metal members 106, 107 have a common apex position, as at center c. They are fed by line 108. A trough horn-type reflector band 109 is used therefor.

Another important feature of the invention antenna is to be effective to the 60° elevation line per FIGURE 1. This requires a smoothing in of the lobes 95, 95' of FIGURE 14 polar curve and of the nulls between lobes as indicated in FIGURE 18 at shaded area 120. Thus, signals are radiated about the 360° toroid pattern to the 60° altitude with minimum cosecant 121 magnitudes maintained.

In FIGURE 17 is shown one form of the antenna hereof which smooths in the lobes 95. This antenna comprises a lens 110 of the Luneberg type with selected areas of different dielectric configuration. The modulator transmission plate array shown is with spaced cones 111, 112, and horn rim reflector 113. In the upper section of lens 110, is a conical or other suitably shaped region 114 of greater dielectric constant material than that generally present in a Luneberg lens. In the lower lens section, there is a conical region 115 of material having a generally lower dielectric constant than present for a Luneberg lens.

The result of the denser dielectric region 114 and lighter dielectric region 115 in sphere 110 is to change the minor lobed polar pattern, see 95, 95' in FIGURE 14, to a smoothed-in area indicated irregularly as 120 in FIGURE 18. This causes a continuous cosecant 121 relation as desired. Only the upper section of curve 122 is shown in FIGURE 18. The lower minor lobe polar portion is not significant in the Tacan display.

Other methods and arrangements may be used to effect the smoothing of lobes 95 (FIGURE 14) into toroidal area 120 (FIGURE 18). For example, the horn section of reflector (89 of FIGURE 13) may have its upper portion tilted at an angle away from sphere (85) to tilt or modify the phase front of the energy emerging from the horn reflector. Alternatively, the shape of either the upper or the lower section of the sphere (as at 85) and the dielectric constant within this section may be progressively altered to effect such smoothing in (120) of the lobes (95).

While I have above illustrated the invention with the multiple radio point sources at or reasonably close to the surface of the microwave lens, these may be different if the dielectric constant is varied within the lens in the proper manner as well known in the art.

FIGURE 19 illustrates these point sources represented by P' remote from lens 125. The resultant beam at aperture A' is uniform as required. Also, the radio point sources, represented by P'' in FIGURE 20 may be well within the lens 126. The resultant beam at aperture A'' is uniform.

A physical assembly of a Tacan antenna in accordance with my invention hereof is illustrated in vertical cross-section in FIGURE 22. The lens 130 comprises two hemispheres 131, 132 of dielectric material. The practical radial variation of the dielectric constant of hemi-

spheres 131, 132, in the Luneberg lens manner already described, is understood by those skilled in the art and is not detailed.

The upper hemisphere 131 has its center  $c_1$ , spaced above the center  $c_2$  of the lower one 132. Open regions 133, 134 are formed between hemispheres 131, 132 to contain the rotating modulator transmission discs. The hemispheres 131, 132 are suitably fastened together by hardware 135, 136. The assembly is supported in a dielectric support cone 137 on frame 138 mounted on base 139.

The rotatable spaced transmission metal discs 140, 141 have a firm foam dielectric layer 142 therebetween for composite support. The discs 140, 141 are signal fed by and secured with coaxial transmission line 143, 144. Inner conductor 143 is connected to upper disc 140 by screw 145 and transformer sleeve 146. The outer conductor 144 connects by bracket 147 to lower plate 141. Outer conductor 144 is rotatably supported by roller bearings 148, 149.

The coaxial line 143, 144 extends through hollow shaft motor 150. The outer line 144 has a reduced diameter section 144' that is rotated by motor 150 and rotates discs 140, 141 at 900 r.p.m. Discs 140, 141 have slab modulator elements 151, 151 to perform the results of bolts 80 of the other modifications described above. The ring reflector 152 is flat as in FIGURE 15. A motor speed regulator is preferably employed to stabilize the rotation at requisite uniform speed. A sine wave generator 152, a pulse generator 153 and rotary electrical line coupler 154 are mounted beneath motor 150. The pulse generator 153 uses a disc 155 having elements 156 to effect the Tacan signal triggering.

The foam dielectric between the rotating radio transmission discs 140, 141 has no electrical function. Its dielectric constant is thus kept low, such as 1.05. A firm foam layer of styrene is suitable. The pulse generator 153 and the sine generator 152 are connected to the Tacan electrical and electronic equipment (not shown), in the usual manner. The pulse generator 153 comprises a disc 155 of dielectric material with nine metallic members 156 spaced near its periphery 40° apart.

FIGURE 21 shows this arrangement. Disc 155 is secured to the rotating central transmission line at hub 157. The rotating trigger members 156 coact with the stationary yoke 158 to effect the identifying timed pulses for the distance measurement determinations of the moving vehicle. The fundamental frequency triggering is performed by passage of member 159.

The basic microwave signal to be modulated and broadcast by the antenna system thereof is fed by a coaxial transmission line into the input of rotary coupler 154. The radio signal, at the selected Tacan broadcast frequency, is thus fed to internal rotating coaxial cable 143, 144 through the coupler 154. Suitable matching transformations are maintained to the coupler 154, through the motor with the line 143, 144, and on to the rotating discs. The discs rotate unhindered in the clear space set thereabout within lens 130.

The antenna system of my invention is not frequency sensitive over the Tacan microwave band, and accordingly one basic construction can be used for all Tacan and Vortac installations, regardless of the frequency selected to transmit. The radial distance of the modulator elements 180 may be shifted in some cases, before installation, for some selected frequency region. Pre-drilled series of openings for this purpose may be provided.

In a physical embodiment of the invention antenna, a Luneberg-type sphere was used, 18" in diameter. The rotatable radio transmission discs were located below the sphere center and coaxial with its zenith, being 26" in diameter to project beyond the sphere. These discs were spaced  $\frac{5}{16}$ " interiorly.

A horn-sectioned reflector ring surrounded the projecting periphery of the transmission discs, with an outer

circumference of 27". Thus, the outer horn rim was  $\frac{1}{2}$ " from the disc periphery. The reflector base opening was about 4" across, and supported on the sphere. The modulator bolt elements were mounted at a radius of  $8\frac{1}{2}$ " from the center of the discs; with the fundamental modulator at 2" radius.

While I have described my invention in connection with several exemplary embodiments, modifications and variations thereof may be made without departing from the broader spirit and scope of the invention, as described in the following claims.

I claim:

1. A transmitter antenna comprising a radio wave lens extending for 360° about its zenith, a radio transmission structure rotatable with respect to said lens for applying impressed signal energy about a 360° segment of said lens, said structure including a pair of opposed metallic plates supported within the lens, and motor means for continuously rotating said transmission structure, said metallic plates being supported horizontally within the lens at a position below the equatorial plane of the lens to effectuate an upwards tilt of the radiated radio pattern.
2. A transmitter antenna of the character described comprising a microwave lens composed of a generally spherical body of dielectric material having its dielectric constant vary substantially inversely with its radial extent from a central value of 2 to a peripheral value of 1, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio energy along a horizontal 360° spherical segment, a reflector rim arranged about said segment to reflect the 360° beam energy through the lens and produce a generally toroidal radiation pattern about the sphere zenith, modulator elements mounted with said structure to amplitude modulate the radiated pattern, a coaxial transmission line coupled to said structure and rotatably supported in said spherical body along its zenith diameter, an electrical coupler for the coaxial line, and motor means connected to said coaxial line to continuously rotate said line and structure to produce a rotating amplitude space modulated toroidal radiation pattern.
3. A transmitter antenna as claimed in claim 2, in which the region of said dielectric spherical body about the rotatable structure is hollow.
4. A transmitter antenna as claimed in claim 2, in which the upper hemispherical portion of said body is spaced from the lower hemispherical portion thereof.
5. A transmitter antenna as claimed in claim 4, in which the said radio transmission structure is centered below the center of the lower hemispherical portion.
6. A transmitter antenna as claimed in claim 2, in which the upper portion of the dielectric body is deformed from the spherical form to emphasize the radiated pattern strength at the upper altitude angles.
7. A transmitter antenna as claimed in claim 2, in which the upper hemispherical portion of the dielectric body contains a region of dielectric material substantially greater than that of the body material surrounding it to emphasize the radiated pattern strength at the upper altitude angles.
8. A transmitter antenna comprising a microwave lens composed of a generally spherical body of dielectric material, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio signal energy along a horizontal 360° spherical segment, a reflector arranged about said segment to reflect the 360° signal energy through the lens and produce a generally toroidal radiation pattern about the lens zenith, modulator elements mounted with said structure to amplitude modulate the 360° radiated pattern, transmission line means coupling signal energy to said interior structure, and motor means for rotating said structure and elements to produce a rotating amplitude space modulated toroidal radiation pattern.
9. A transmitter antenna comprising a microwave lens

composed of a generally spherical body of dielectric material, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio signal energy along a horizontal 360° spherical segment, a reflector arranged about said segment to reflect the 360° signal energy through the lens and produce a generally toroidal radiation pattern about the lens zenith, modulator elements mounted with said structure to amplitude modulate the 360° radiated pattern, transmission line means coupling signal energy to said interior structure, and motor means for rotating said structure and elements to produce a rotating amplitude space modulated toroidal radiation pattern, in which the radio transmission structure includes a pair of opposed metallic plates providing a 360° signal radial transmission line.

10. A transmitter antenna comprising a microwave lens composed of a generally spherical body of dielectric material, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio signal energy along a horizontal 360° spherical segment, a reflector arranged about said segment to reflect the 360° signal energy through the lens and produce a generally toroidal radiation pattern about the lens zenith, modulator elements mounted with said structure to amplitude modulate the 360° radiated pattern, transmission line means coupling signal energy to said interior structure, and motor means for rotating said structure and elements to produce a rotating amplitude space modulated toroidal radiation pattern, in which the radio transmission structure includes a pair of opposed metallic plates providing a 360° signal radial transmission line; with said reflector arranged adjacent the lens surface and opposite the peripheral region of said plates and directed to effect the said reflection of the radially radiated structure signal energy into the lens.

11. A transmitter antenna comprising a microwave lens composed of a generally spherical body of dielectric material, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio signal energy along a horizontal 360° spherical segment, a reflector arranged about said segment to reflect the 360° signal energy through the lens and produce a generally toroidal radiation pattern about the lens zenith, modulator elements mounted with said structure to amplitude modulate the 360° radiated pattern, transmission line means coupling signal energy to said interior structure, and motor means for rotating said structure and elements to produce a rotating amplitude space modulated toroidal radiation pattern, in which said reflector is arranged adjacent the lens surface and opposite the peripheral region of said structure and directed to effect the said reflection of the radially radiated structure signal energy into the lens.

12. A transmitter antenna comprising a microwave lens composed of a generally spherical body of dielectric material, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio signal energy along a horizontal 360° spherical segment, a reflector arranged about said segment to reflect the 360° signal energy through the lens and produce a generally toroidal radiation pattern about the lens zenith, modulator elements mounted with said structure to amplitude modulate the 360° radiated pattern, transmission line means coupling signal energy to said interior structure, and motor means for rotating said structure and elements to produce a rotating amplitude space modulated toroidal radiation pattern, in which said transmission line means includes a coaxial line mechanically and electrically coupled to said structure and connected with said motor means.

13. A transmitter antenna comprising a microwave lens composed of a generally spherical body of dielectric material, a radio transmission structure rotatably supported within the lens symmetrically about its zenith diameter to radiate radio signal energy along a horizontal 360°

spherical segment, a reflector arranged about said segment to reflect the 360° signal energy through the lens and produce a generally toroidal radiation pattern about the lens zenith, modulator elements mounted with said structure to amplitude modulate the 360° radiated pattern, transmission line means coupling signal energy to said interior structure, and motor means for rotating said structure and elements to produce a rotating amplitude space modulated toroidal radiation pattern, in which the radio transmission structure includes a pair of opposed metallic plates providing a 360° signal radial transmission line, with said reflector arranged adjacent the lens surface and opposite the peripheral region of said plates and directed to effect the said reflection of the radially radiated structure signal energy into the lens, in which said transmission line means includes a coaxial line mechani-

cally and electrically coupled to said structure and connected with said motor means said coaxial line extending along the zenith diameter of the lens.

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