

July 23, 1968

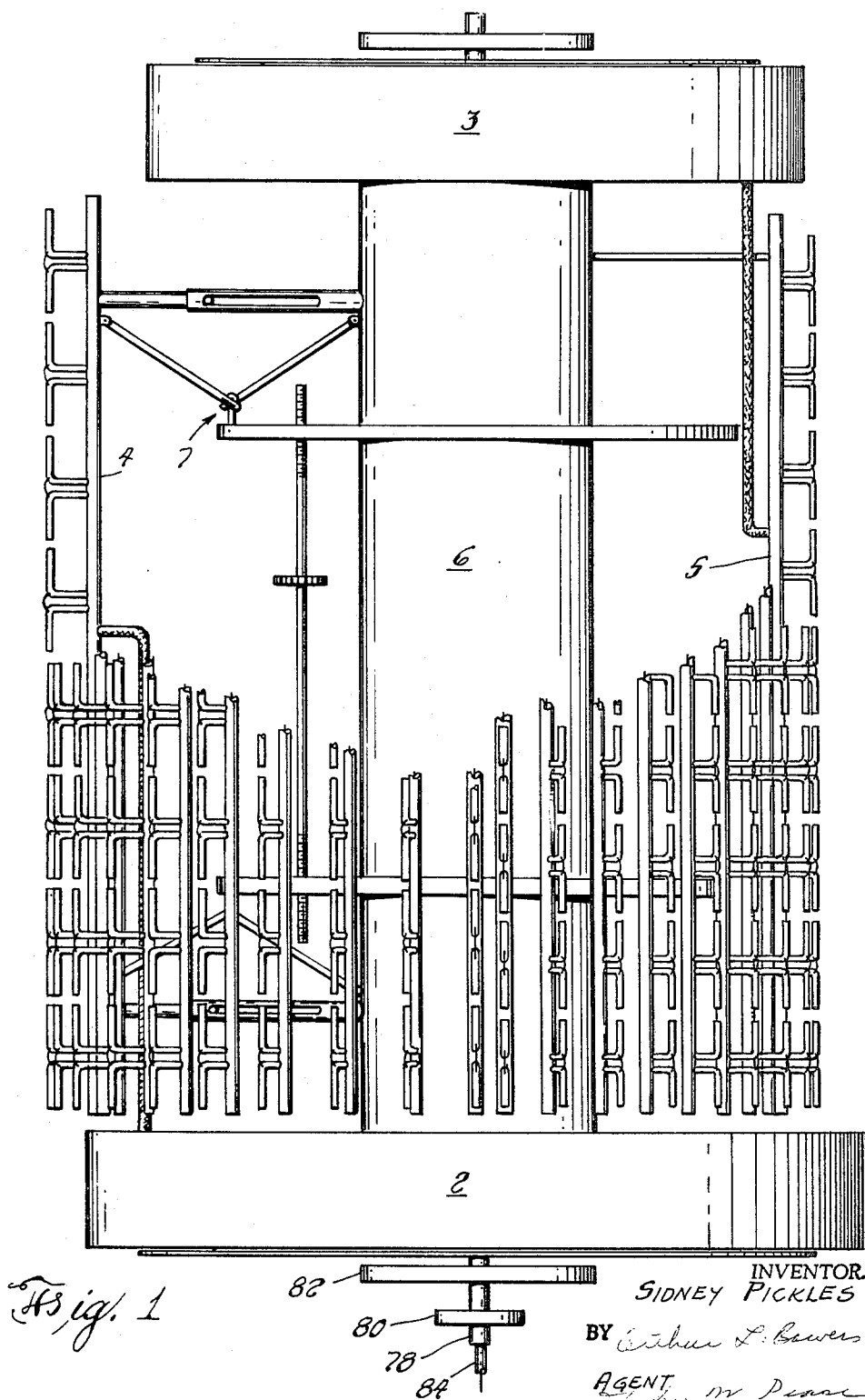
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3,394,380

MECHANICAL MODULATOR FOR STATIONARY TACAN ANTENNA

Filed Oct. 18, 1965

3 Sheets-Sheet 1



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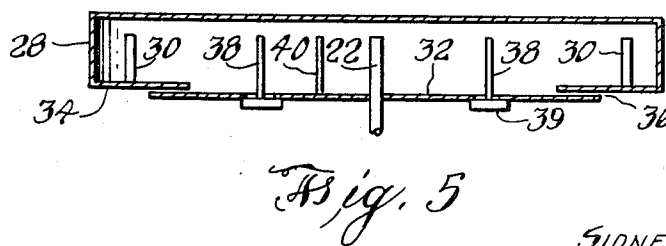
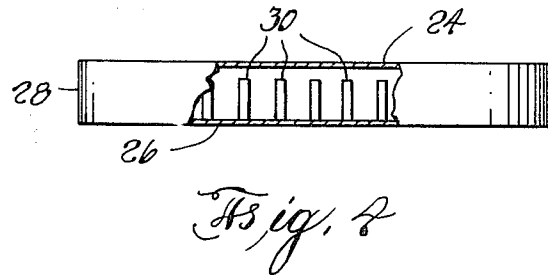
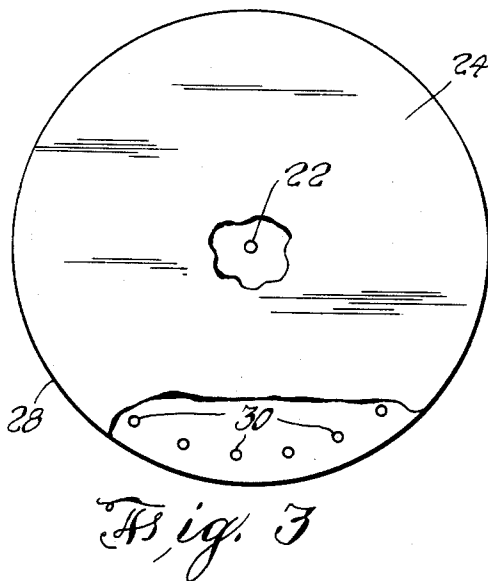
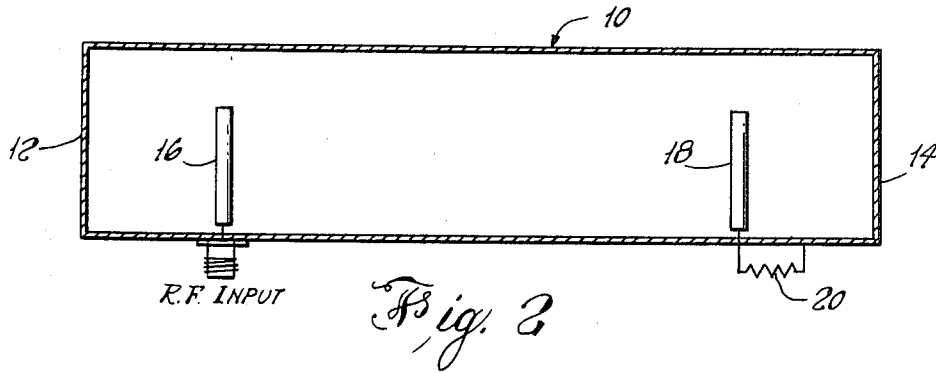
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MECHANICAL MODULATOR FOR STATIONARY TACAN ANTENNA

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3 Sheets-Sheet 2



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MECHANICAL MODULATOR FOR STATIONARY TACAN ANTENNA

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3 Sheets-Sheet 3

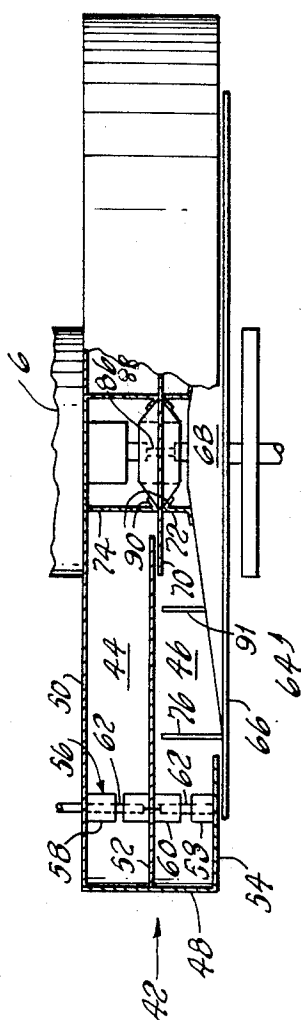


Fig. 6

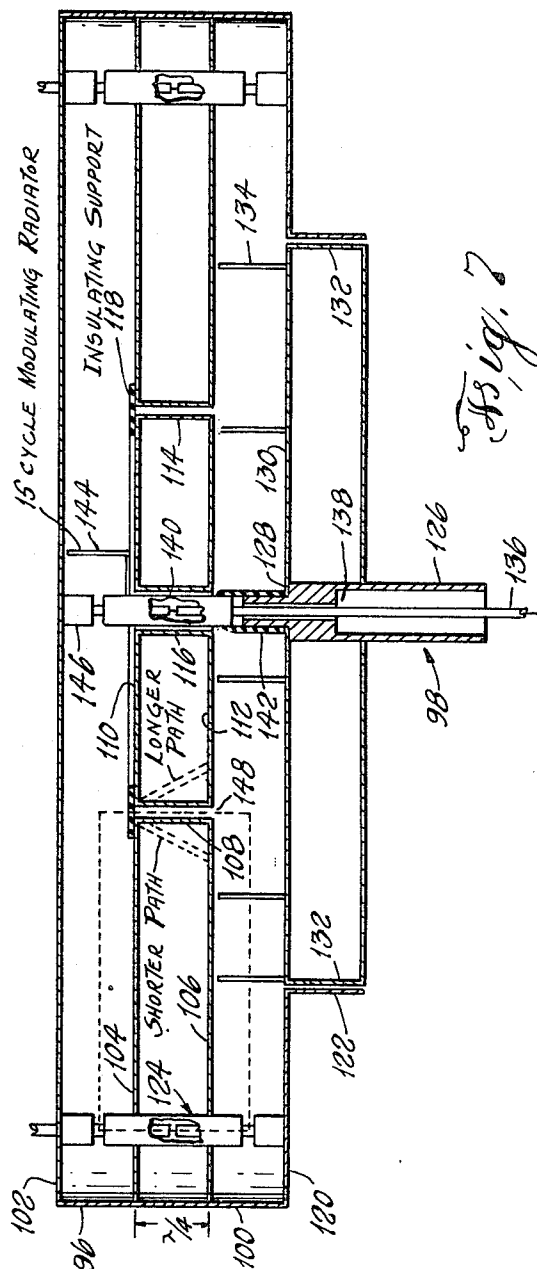


Fig. 7

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MECHANICAL MODULATOR FOR STATIONARY TACAN ANTENNA

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Filed Oct. 18, 1965, Ser. No. 497,570

10 Claims. (Cl. 343-854)

ABSTRACT OF THE DISCLOSURE

A pair of rotatable mechanical R.F. modulators in the R.F. feed to a stationary two-band TACAN antenna to shape the R.F. radiation pattern from the antenna into a rotating TACAN-type radiation pattern of the type illustrated in U.S. Patent 3,066,291. Each modulator has two circular waveguides that are coaxial, contiguous, of similar dimensions and includes a stationary assembly supporting a central omniazimuthal feed and a ring of equally spaced probes in the two circular waveguides and a rotary assembly carrying reflector stubs between the feed and the probes.

An object of this invention is to provide a more compact, relatively low cost, simple, essentially trouble-free mechanical modulator for a stationary TACAN antenna.

A further object is to provide a mechanical modulator wherein the percentage modulation is adjustable to make possible tighter tolerances for improved uniformity in percentage modulation.

A further object is to provide a mechanical modulator wherein the cross modulation products of 15 cycle and 135 cycle modulations are minimal.

A further object is to provide a mechanical modulator which is compatible with a dual band stationary TACAN antenna.

Other objects and advantages will appear from the following description of an example of the invention, and the novel features will be particularly pointed out in the appended claims.

FIG. 1 is a plan view in elevation, partly broken away of a dual band stationary antenna and a modulator in accordance with this invention for each band,

FIG. 2 is a simplified schematic showing of a conventional waveguide arrangement having a feed probe at one end and a dissipation system at the other end,

FIGS. 3 and 4 are top and side plan views partly broken away of a circular waveguide having one centrally located feed and a plurality of circularly distributed dissipation systems,

FIG. 5 is a simplified showing of a modulator embodying the principles of this invention for a single band antenna,

FIGS. 6 and 7 are embodiments of modulators in accordance with this invention.

In FIG. 1, there is shown a stationary dual band TACAN antenna which is described in U.S. Patent application, Ser. No. 497,572, filed Oct. 18, 1965 for A Dual Band Stationary TACAN Antenna, by Sidney Pickles, in combination with two mechanical modulators 2 and 3 for lower and higher bands respectively for which the antenna is designed. The antenna has thirty-six (which number is exemplary rather than limiting) low-band directional radiator arrays 4 and high-band directional radiator arrays 5 supported by a hollow central metallic support column 6. The gain, up tilt etc., of the directional radiating arrays are limited only by the physical size. Gain and up tilt characteristics are improved in direct proportion to the increased length of the directional arrays. The high band arrays are angularly interleaved behind

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the reflecting supports of the low-band arrays. When the assembly is operated on high band, the low band radiator arrays are retracted by a ganging means 7 which radially displaces all the low band arrays in one operation to an inner position where they are screened by the reflecting supports of the high-band radiator arrays. At that time, an R.F. switch, not shown, operates to transfer the main transmission line feed from the low-band to the high-band unit. In the alternative, separate feeds may be provided for each band, one connected into the low band modulator as shown and another, not shown, connected into the high-band modulator controlled by R.F. switch means.

Modulators 2 and 3 are essentially wave guide structures operating on the following principles. In FIG. 2 there is shown a waveguide 10 having two closed ends 12 and 14, a feed probe 16 mounted near the closed end 12 and a dissipation system including a termination probe 18 mounted near the other closed end 14 connected to a resistor type dissipator 20, all of which is well known. The input impedance is determined primarily by the dimensions of the feed probe 16 and the distance between the feed probe and the closed end 12 of the waveguide. No standing waves exist in the waveguide if the dissipation system is properly proportioned.

A waveguide system may include one feed probe and a dissipation system having a plurality of termination probes properly located with respect to the end of the waveguide and a dissipator for each termination probe. In a dissipation system having a plurality of probes, the dissipator impedances for the probes are different from the dissipator impedance required for a dissipation system having one probe. The dissipation system may include two probes, three probes arranged as a wye, or a plurality of probes arranged in a circle provided that the dissipation system presents an impedance that matches the input impedance. The latter is illustrated in FIGS. 3 and 4 wherein an R.F. feed probe 22 is mounted axially in a circular waveguide formed by two flat plates 24 and 26 joined by a cylindrical member 28. The flat plate 26 supports a large number of termination probes 30 near the cylindrical member in equally spaced relation. Dissipators are not shown. Transformers for dividing the input energy among the output probes are not required. In a sense, the triangular sector region from the R.F. feed probe 22 to any one of the termination probes located around the perimeter of the circular waveguide is an impedance transformer. This dissipation system functions similarly to that of two plates used as a flat horn of essentially infinite dimensions provided the spacing between adjacent termination probes about the circumference does not exceed the dimensions of the waveguide corresponding to the dimension of the terminating end shown in FIG. 1 to preclude the waveguide breaking into other modes during operation.

A simplified modulator in accordance with this invention shown in FIG. 5, is obtained by forming one of the circular plates of the waveguide shown in FIG. 3 of two concentric parts, one of which is a rotatable circular disk 32 and the other an annulus 34 secured to the cylindrical member 28, with a choke joint 36 therebetween, and by mounting a metallic reflector 38 on the disk or several reflectors equally spaced from the center and from each other, there is obtained a lobed radiation pattern between the feed probe and the termination probes.

The lobed radiation pattern rotates with the disk 32. The 135 cycle modulation for TACAN is obtained by using nine modulator reflectors and by rotating the disk at 900 r.p.m. Where the dissipators connected to the termination probes and that provide the impedance for the probes in the circular waveguide are radiators as in FIG. 1, distribution of field with respect to the feed

probe in the waveguide is essentially the same as if the waveguide plates were extended to infinity.

The percentage of modulation is a function of the distance between the feed probe and the modulator reflectors. Since the outside of disk 32 is accessible, the modulator reflectors are adjustable in and out relative to the feed probe by a gang means, e.g., a face cam 39, or various other ganging techniques to obtain a greater uniformity of percentage modulation among all the antennae of a particular system.

A single metallic modulator reflector 40 similar to the reflectors 38 is mounted on the rotary disk 32 close to the feed probe for producing the approximately cardioidal distribution of energy within the circular waveguide for the 15 cycle modulation. Though the combination illustrated in FIG. 5 is operable to provide the 15 cycle and 135 cycle modulation, two concentric modulating systems as in FIG. 5 produce cross modulation products, namely 120 cycles and 150 cycles.

In the modulator embodiment 42 shown in FIG. 6, fundamental or 15 cycle and the harmonic or 135 cycle modulation means are separate and the separately modulated energies are combined in a manner whereby there is no cross feed between the modulation sources.

The modulator 42 has two circular waveguides 44 and 46 that are coaxial, contiguous and of similar dimensions. It includes stationary and rotatable assemblies. The stationary assembly of the modulator includes a cylinder 48, a plate 50 secured to column 6 and to one end of cylinder 48 and having an axial perforation for shaft and feed cable and a circular series of openings for connections to the probes, an intermediate plate 52 having a central opening and a circular series of openings for termination probes, and an annulus 54 secured to the other end. A circular series of termination probes 56, each of which is a series connected dual probe, are mounted equiangularly spaced in the modulators. Each probe includes tubular stubs 58 joined to the plate 50 and annulus 54, and an intermediate tubular section 60 connected in the opening provided therefor in the plate 52.

A bared coaxial conductor 62 extends through plate 50 and connects to annulus 54; intermediate the ends thereof the center conductor of the coaxial conductor 62 is exposed. The conductor 62 and the tubular parts 58 and 60 are coaxial.

The rotary assembly 64 of the modulator includes a circular plate 66 forming a rotary choke joint with the annulus 54, a frusto-conical member 68 affixed coaxially to the plate 66 for transformer action, a circular plate 70 secured coaxially between the ends of the modulator by means of fibre glass cylindrical means 72 and 74 secured thereto and to the frusto-conical member 68 and plate 50, and forming a rotary choke joint with plate 52. A reflector modulator not shown in FIG. 6 for producing the fundamental or 15 cycle modulation is cemented on the fibre glass cylinder 74 and connected to plate 50; nine reflector modulator stubs 76, only one of which is shown, for the harmonic or 135 cycle modulation are mounted on the plate 66. A hollow shaft 78 carrying a drive member 80 and a pulser wheel 82 is connected to the rotary assembly 64.

A coaxial feed cable 84 extends through the hollow shaft into the column 6. The hollow shaft 78 is interrupted to expose feed 86 for radiating into both circular waveguides. The hollow shaft and the coaxial cable do not extend beyond the one modulator if the antenna is single-band and there is no second modulator. A metal tubular element 88 is supported by fibre glass elements 90 around the feed 86 to channel the R.F. to the two circular waveguides. The fundamental or 15 cycle modulated energy is picked up by the portion of each probe in the upper circular waveguide and flows down between the tubular member 60 and the intermediate conductor of the probe to the division in the intermediate conductor of the probe. Here the energy divides and a major part

flows up the transmission line formed by the inner and intermediate conductors of the probe to the respective radiator of the antenna. A minor fraction of the energy flows down between the outer and intermediate conductors to the lower portion of the dual probe.

Located near the center of the lower rotating system is another but considerably smaller single reflector 91. This 15 cycle reflector in the 135 cycle system transmits as much 15 cycle modulated energy outward as the upper circular waveguide transmits to the lower circular waveguide through the dual probes. The relationship of diameters of the modulating systems is such that where the two 15 cycle modulated energies meet in the vicinity of the lower or 135 cycle portions of the probes, the energies are of equal amplitude and opposite R.F. phase whereby the 135 cycle system is in a zero energy region for 15 cycle modulation.

An alternate method for canceling 15 cycle modulated energy that flows downward through the dual probes is to leak a small amount through the rotary choke joint between the 15 cycle and 135 modulator systems, sufficient to cancel the 15 cycle modulated energy that flows downward through the probes.

The 135 cycle modulated energy flows out through the probe portions in the lower waveguide, up the probe transmission lines to the gap in the center transmission line where the 135 cycle modulated energy divides; a major portion of the 135 cycle energy flows up through these transmission lines along with the carrier and the 15 cycle modulation from the upper system. Some of the 135 cycle modulated energy flows out the upper portions of the probes into the upper waveguide. As this 135 cycle, nine-lobed radiation structure flows toward the center of the upper circular plate. The lobes are forced to flow together and become carriers at a region which is on the order of three-fourths wavelength radius from the central feed in accordance with Bessel function theory. Therefore, it cannot in any way modulate the 15 cycle energy which is being produced in the upper circular waveguide.

This modulation system is essentially free of cross modulation products. The modulated energy obtained from this system can be used with other types of radiation systems e.g., a horn system.

The high band modulating assembly 3 is identical to the low band modulating assembly 2 and is secured to the opposite end of column 6; the rotating assemblies of the two modulators are joined by the extension of the rotary shaft from the low band modulating assembly 2 through the column 6 to the high band modulating assembly 3. Separate coaxial cables connect each of the probes of the low band modulating assembly to the corresponding low band radiators and connect each of the probes of the high band modulating assembly to the corresponding high band radiators.

In FIG. 7 there is shown another modulator embodiment 94 including a stationary assembly 96 and a rotatable assembly 98. The modulator 94, as illustrated, is for a single band antenna. The stationary assembly includes an outside cylinder 100. A plate 102 having peripheral perforations as the plate 50 in FIG. 5 is secured to one end of the cylinder 100. A pair of essentially identical opposed flat annular members 104, 106 having probe perforations and whose inner perimeters are bridged by a cylinder 108 are secured approximately one-quarter wavelength apart to the inside of the cylinder 100 intermediate the ends thereof. A channel-like assembly including another pair of essentially identical opposed flat annular members 110 and 112 whose outside diameter is slightly smaller than the diameter of cylinder 108 and whose outer perimeters are bridged by a cylinder 114 and whose inner perimeters are bridged by a cylinder 116, both equal in length to cylinder 108, is secured to the annular member 104 with an insulating ring 118. A flat annulus 120 is secured at its outer periphery to the op-

posite end of cylinder 100 and has a cylindrical skirt 122 secured to its inner periphery. A series of dual probes 124 corresponding to those in FIG. 6 and secured equiangularly spaced apart in the stationary assembly. The rotatable assembly 98 includes a shaft 126; the drive element and pulser wheel shown in FIG. 1 is omitted in this figure. The outside diameter of the shaft 126 is reduced near one end to provide a shoulder 128 against which is seated and secured a flat plate 130 having a cylindrical skirt 132 of the same length as 122, namely one-quarter wavelength at the frequency of the R.F. Nine modulator reflectors 134 are secured to the plate 130 adjacent the perimeter equiangularly spaced apart. An R.F. cable 136 extends through a constricted section 138 of the shaft 126 one-quarter wavelength long to form a rotary choke joint. A metal cylinder 140 is secured coaxially about the coaxial cable in spaced relation to the reduced end of the shaft 126 with an insulating tube 142 whereby the tube 140 rotates with shaft 126 around the R.F. cable 136. The outside diameter of the tube 140 is smaller than the inside diameter of the cylinder 116 and forms a choke joint therewith.

The inner conductor of the coaxial cable 136 is exposed intermediate the ends of the tube 140 whereby the R.F. is transmitted to the upper and lower circular waveguides by the outer conductor of coaxial conductor 136 and the tube 140. A modulator reflector 144 is secured to the tube 140. The cable 136 is secured to the plate 102. A tubular stub 146 is connected to the plate 102 coaxial with the cable 136. For a dual band antenna, the stub 146 is attached to tube 140 with an insulating tube such as 142; it does not terminate at plate 102. The plate 102 would have axial perforation and the cable and stub 146 would extend to another essentially identical modulator in the manner illustrated in FIG. 1.

When the rotating assembly 98 is rotated at 900 r.p.m., 15 cycle and 135 cycle modulation is produced. As was stated previously, the 135 cycle modulation does not modulate the 15 cycle system. However, the 15 cycle modulation can modulate the 135 cycle system. Though this does not preclude use of the modulator it is desirable to prevent this cross modulation. As shown in FIG. 7, there is a gap 148 between the two circular waveguides for intentional leakage. Fifteen cycle modulation signal with carrier radiates toward the receiving probes in the 15 cycle section; some small portion flows through the gap 148 into the 135 cycle waveguide. This energy radiates outward toward the 135 cycle modulating reflectors. Another portion of the 15 cycle modulating signal passes the transmission line connections at the centers of the probes and flows into the 135 cycle waveguide. In radiating outward, the phase of the 15 cycle modulated energy is inverted relative to its phase in the 15 cycle waveguide. Because of this phase inversion, the path lengths from the starting point in the 15 cycle side of the gap has to differ by multiples of a wavelength in order for cancellation to occur. There is some phase shift at the centers of the probes if impedances across the central gaps are not resistive. The energy that flows through the gap experiences some phase shift. This phase shift results in less than optimum cancellation. To improve cancellation an exploratory probe may be inserted from the center portion of the modulator into the 135 cycle waveguide to determine the position of the 15 cycle modulating energy minimum. If this position is closer to the center than the 135 cycle modulator reflectors, the path length of the gap should be shorter; conversely if this position is outside the 135 cycle modulator reflector region, the path length of the gap should be longer. The gap length may be made shorter or longer as shown in broken lines in FIG. 7 to optimize cancellation.

It will be understood that various changes in the details, materials and arrangements of parts (and steps), which have been herein described and illustrated in order to explain the nature of the invention, may be made by those

skilled in the art within the principle and scope of the invention as expressed in the appended claims.

I claim:

1. A modulator for an omniazimuthal antenna having a series of radiators comprising
 - a cylindrical member,
 - a flat member secured across one end of the cylindrical member,
 - a flat annular member secured to the other end of the cylindrical member,
 - a series of equiangularly spaced probes mounted on one of the flat members adjacent to and equidistant from the cylindrical member,
 - a flat disk supported for rotation coaxially with the cylindrical member adjacent the outer face of the annular member and forming a rotating choke joint therewith,
 - an R.F. feed means located axially between the flat member and the disk for radiating omnidirectionally toward the probes, and
 - at least one modulator reflector stub secured to the disk to extend toward the flat member.
2. A modulator as defined in claim 1 further including means carried by said disk for adjusting the position of the modulator reflector stub relative to the R.F. feed.
3. A modulator as defined in claim 1 wherein nine modulator reflector stubs are secured to the disc equiangularly spaced, and gang means is carried by said disk for adjusting the position if the modulator reflector stubs relative to the R.F. feed.
4. A modulator as defined in claim 3 further including another modulator reflector carried by said disk closer to the R.F. feed than the nine modulator reflectors.
5. A modulator for a stationary TACAN antenna comprising
 - two adjacent coaxial waveguides of equal diameter,
 - one axial feed for both waveguides,
 - a circular series of dual probes secured in the waveguides equiangularly spaced with respective parts of the dual probes located in the respective waveguides, and
 - rotary means supporting a single modulator reflector in one of the waveguides and supporting a plurality of equiangularly spaced modulator reflectors in the other of the waveguides.
6. A modulator as defined in claim 1, wherein the two waveguides have a common wall therebetween for leaking modulated energy from the waveguide with the single modulator reflector to the other waveguide to minimize modulated energy from the waveguide with the single modulator reflector in the region of the modulator reflectors in the other waveguide.
7. A modulator as defined in claim 6 wherein the common wall between the waveguide is approximately one-quarter wavelength at the frequency of the R.F. energy from the feed.
8. A modulator for a stationary TACAN antenna comprising
 - coaxial stationary and rotatable assemblies forming two adjacent coaxial circular waveguides,
 - said rotatable assembly supporting an axial R.F. feed for radiating radially into both circular waveguides,
 - said stationary assembly supporting a circular series of equiangularly spaced series-connected dual probes equidistant from the axis and wherein corresponding parts of the dual probes are in the respective waveguides,
 - said stationary and rotatable assemblies having a choke joint therebetween, and
 - nine modulator reflectors carried by the rotatable assembly in one of the waveguides and modulator reflector carried by the waveguide in the other stationary assembly.
9. A modulator as defined in claim 8 further including

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another modulator stub carried by the rotatable assembly in the waveguide having the nine modulator reflectors operable to balance out, in the region of the nine modulator reflectors, modulated energy deriving from the waveguide with the one modulator reflector.

10. A modulator as defined in claim 8 wherein said stationary assembly carries a quarter-wavelength wall that separates the waveguides and wherein the wall has a gap for leaking modulated energy from the waveguide with the one modulator reflector into the other waveguide to

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balance out in the region of the nine modulator reflectors, modulated energy that flows through the probes into the waveguide with the nine modulator reflectors.

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10 ELI LIEBERMAN, *Primary Examiner*.