

Aug. 15, 1939.

E. BRUCE

2,169,553

DIRECTIVE RADIO SYSTEM

Filed Sept. 11, 1936

3 Sheets-Sheet 1

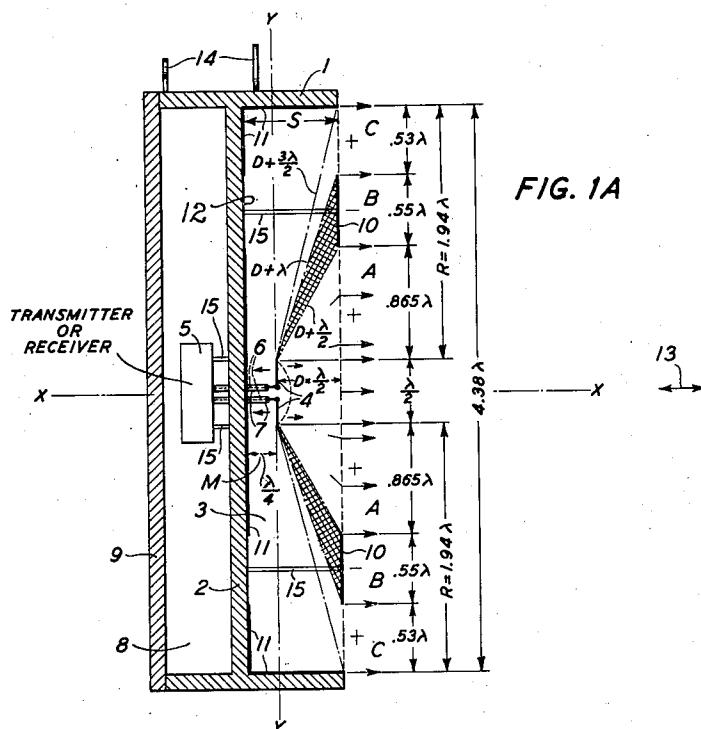


FIG. 1A

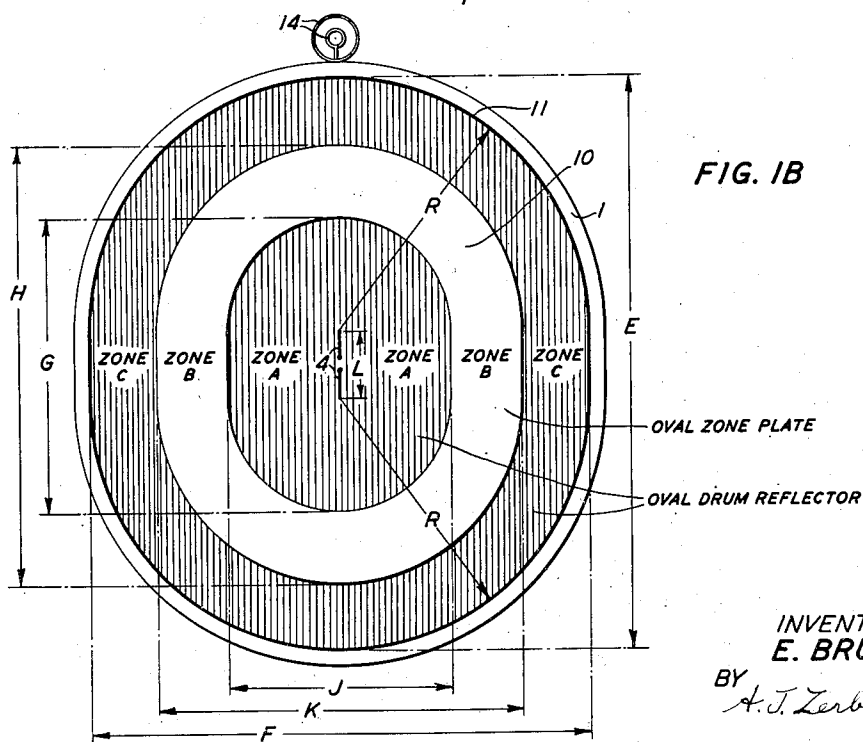


FIG. 1B

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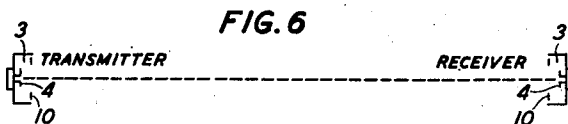
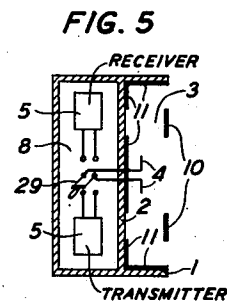
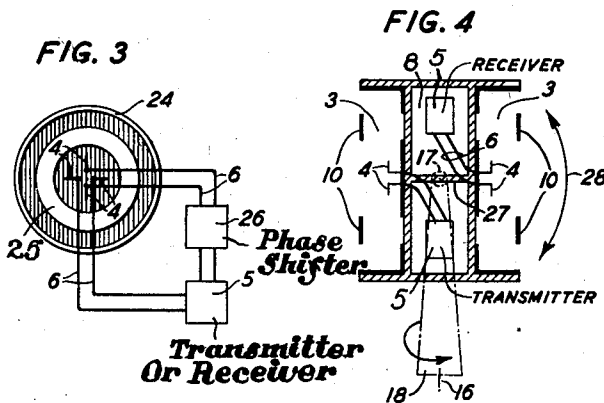
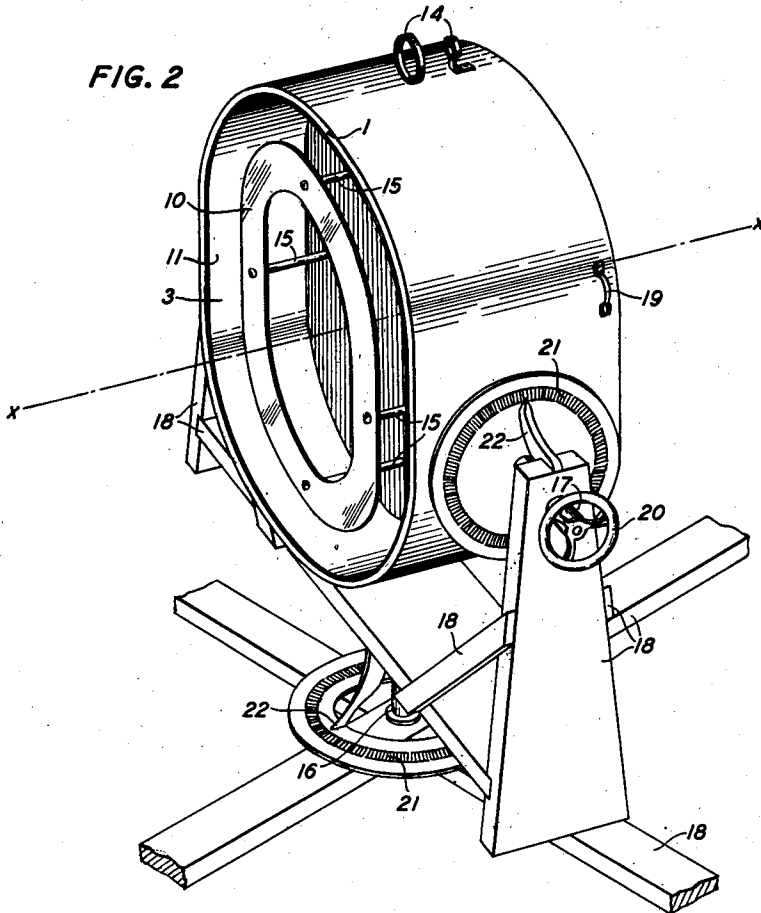
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FIG. 7

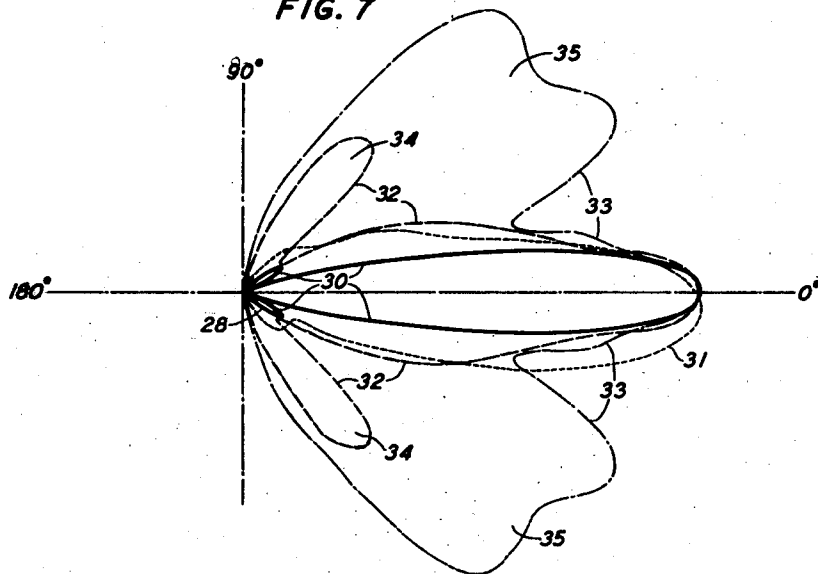


FIG. 8A

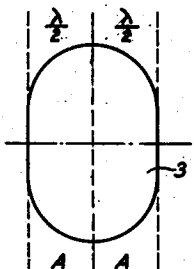


FIG. 8B

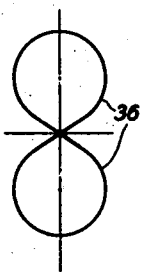


FIG. 9A

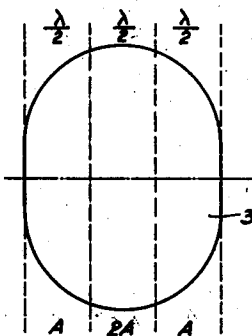


FIG. 9B

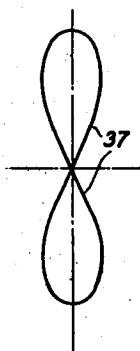


FIG. 10A

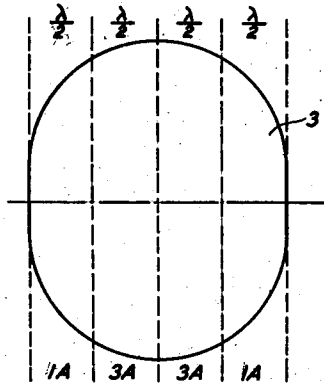
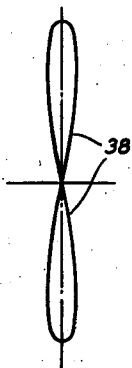


FIG. 10B



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DIRECTIVE RADIO SYSTEM

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Application September 11, 1936, Serial No. 100,287

17 Claims. (Cl. 250—11)

This invention relates to radio transmitting and receiving systems and especially to ultra-short wave reflecting and diffracting apparatus.

As is well known waves having a length less than ten meters and commonly referred to as ultra-short waves are quasi-optical in nature and various systems comprising plane, parabolic and spherical mirrors, gratings and zone plates, as for example the systems disclosed in Patent 2,043,347, to A. G. Clavier and R. H. Darbord, granted June 9, 1936, have been combined with radiating or absorbing non-directive antenna structures for the purpose of unidirectively transmitting and receiving such waves. The mirrors, gratings and zone plates ordinarily employed each possess a point focus at which the antenna is usually positioned. In practical systems, however, linear antennas are employed. These antennas do not possess a non-directional characteristic in all planes of propagation and absorb or emit energies at points other than the point focus of the quasi-optical apparatus. Moreover, in the systems heretofore proposed, waves having appreciable intensity and diverse propagation directions other than the desired direction are ordinarily emitted or absorbed; and, as a result, the directive characteristic of the complete system includes, in addition to the major lobe, several minor lobes of large dimensions.

It is an object of this invention to achieve maximum unidirectivity in an ultra-short wave communication system.

It is another object of this invention to conform the finite focus of quasi-optical radio apparatus to the finite dimensions of the antenna associated therewith.

It is still another object of this invention to reduce or eliminate substantially the minor or secondary lobes ordinarily unavoidably present in the directive characteristic or diagram of an ultra-short wave radiating or absorbing system.

According to one embodiment of this invention, the above and other objects are accomplished by positioning a linear doublet antenna in a drum or cylindraceous container having an open end and a closed end, and by positioning a properly designed orbicular diffraction zone plate in the plane of the container opening. The differences between the maximum and minimum diameters of the zone plate, and between the maximum and minimum transverse dimensions of the container, are each equal to the linear dimension of the doublet. The closed container end functions as a true reflector and the container side or wall functions as a shield. The

diffraction zone plate or diffractor may be dielectric or conductive. If dielectric, the focal length is the same as that of the reflecting end plate of the container and, if metallic or conductive, the focal length is preferably equal to or greater than a half wave-length. The antenna is preferably placed a quarter wave-length from the reflector and coincident with the common line focus of the diffractor and the end plate of the container or reflector.

The invention will be more readily understood from the following detailed specification taken in conjunction with the drawings on which like reference characters denote elements of similar function and on which:

Figs. 1—A and 1—B are, respectively, cross-sectional and front view of one embodiment of the invention comprising an orbicular drum reflector; and Fig. 2 illustrates a perspective view of the embodiment of Figs. 1—A and 1—B;

Fig. 3 illustrates another embodiment comprising a cylindrical drum reflector;

Figs. 4 and 5 illustrate combined transmitting and receiving systems;

Fig. 6 illustrates a one-way communication system utilizing the invention;

Fig. 7 illustrates the directive characteristics of various embodiments of the invention; and

Figs. 8—A, 8—B, 9—A, 9—B, 10—A and 10—B are diagrams useful for explaining the invention.

Referring to Figs. 1—A and 1—B, reference numeral 1 designates the cylindraceous side or wall, and reference numeral 2 the end or bottom plane reflecting plate, of a drum container 3. A doublet or linear antenna 4 a half wave-length long is positioned within the drum 3 and centered on the longitudinal axis X—X in a transverse plane Y—Y of the drum. The doublet is connected to a translation device 5, which may be a transmitter or receiver and which is mounted on the passive side of reflector plate 2, by means of line conductor 6. Each conductor 6 is preferably enclosed in a coaxial shield 7. The translation device 5 is for convenience enclosed within a compartment 8 formed by the extension of the drum 3 and a back cover member 9. Members 1, 2 and 9 are constructed of wood or other suitable material.

Reference numeral 10 designates a triple-zone plate which is metallic or conductive and is positioned in the plane of the opening of drum 3. The diffractor 10 is constructed or dimensioned so as to block or prevent the propagation of energy in the second zone, or zone B, and so as

to permit energy propagation in the adjacent central zone A and the third zone C. The wall 1 and end or reflector plate 2 are veneered or lined with copper 11. Inasmuch as the plate 10 shadows the reflector plate 2 for waves propagated in a direction along X—X, the complementary reflector area 12, which is identical in extent and configuration with diffractor zone B, may for economy be left exposed or unlined with copper. As will be explained more fully the drum is preferably arranged for rotation in a horizontal plane and in a vertical plane and may be accurately aligned with a desired direction 13 by means of a gun sight 14. Reference numerals 15 designate struts for rigidly associating device 5 and diffractor 10 with member 2.

Considering the drum dimensions in the plane of the drum opening, as illustrated by Fig. 1—B, the inside maximum diameter E exceeds the inside minimum diameter F by an amount equal to the length L of the linear antenna or doublet 4. Ordinarily the doublet is a half wave-length long. Similarly, considering the diffractor 10, both the inside maximum diameter G and the outside maximum diameter H exceed, respectively, the inside minimum diameter J and the outside minimum diameter K by an amount equal to the length L. The geometrical construction of the zone plate 10 and the reflector 2 are such that the reflector 2 and zone plate 10 each possess a line focus having a length corresponding to that of the doublet. Moreover, the reflector 2 and zone plate 10 are spaced and positioned so as to have a common focus and the doublet 4 is positioned so as to coincide with this common line focus. The focal length M of the reflector is a quarter wave-length while the focal length D of the metallic zone plate 10 is at least one half wave-length. While the theory is not fully understood, it is believed that eddy or edge currents in the metallic zone plate 10 displace the diffractor focus and render the focal length D of the diffractor unequal to the focal length M of the reflector. The zones of diffractor 10 and reflector 2, however, remain complementary. Diffractor plate 10 may be composed of dielectric material and when so formed its focal length D equals that of the reflector.

It will be observed that all points on the inner circumference of the plate 10 are at the same distance, D plus a half wave-length, from the doublet 4. Similarly the distances between all points on the outer circumference and the doublet are the same and equal to the focal distance D plus a wave-length. The radial width

$$\frac{H-G}{2}$$

of zone plate 10 depends on the focal distance D and may be easily computed. In an experimental model, the dimensions given on Fig. 1—A, such as $R=1.94\lambda$, were found satisfactory. The dimensions of the drum and diffractor may of course be different from those indicated in Fig. 1—A.

Assuming the system of Figs. 1—A and 1—B is employed for receiving energy, the incoming wave propagated in a direction 13 coincident with axis X—X and having a wave front perpendicular to said axis, intercepts the zone wave 10. The energies passing through zones A and C are focussed upon the doublet and arrive in phase at the doublet inasmuch as these zones are, in effect, located at distances from the doublet differing by a wave-length. The energy included in zone B is in phase opposition to the energy passing

through zones A and C and is prevented from reaching doublet 4 by the plate 10. Since each point on the path of propagation is itself a source of non-directional radiation, portions of the energies passing through zones A and C impinge upon the copper 11 of reflector 2 and are directed or focussed so as to combine at doublet 4 in phase. When used as a transmitting system the converse or reciprocal operation obtains. The wall or shield 1 effectively prevents the propagation of energy in undesired directions whereby, as will be explained more fully, the dimensions of the minor lobes of the directive characteristic of the system are greatly reduced. The orbicular configuration of the diffractor 10 and the orbicular drum cross-section eliminate, or at least further decrease, the minor lobes. Obviously, in so far as the shielding function of drum 3 is concerned, the configuration in a cross-sectional or transverse plane of drum 3 may be other than orbicular as for example circular or polygonal.

Referring to Fig. 2, the structure for steering or directionally adjusting the embodiment illustrated by Figs. 1—A and 1—B is shown. The drum 3 is supported on the vertical axle 16 and the horizontal axle 17 which in turn are supported by the wooden supporting structure 18. The drum may be rotated about axle 16 by means of handle 19 and rotated about axle 17 by means of wheel 20 so that axis X—X of the drum may be aligned with any direction. A scale 21 and pointer 22 are provided for indicating the elevation angle of adjustment, and a scale 22 and pointer 23 are included for indicating the azimuth angle. Obviously other means for accurately pointing or directing the drum 3 may be employed.

Referring to Fig. 3, reference numeral 24 denotes the drum reflector which is the same as reflector 3 except that it has a circular cross-section. This reflector is suitable for use with a "point" antenna structure, such as a doublet antenna having an overall length of the order of one hundredth of a wave-length, or an antenna structure arranged to emit or receive circularly polarized waves. Numeral 25 denotes a zone plate which is the same as plate 10 except it is circular instead of orbicular and numerals 4 designate a pair of doublets mounted perpendicular to each at the focus of the system. One doublet is connected through a quadrature phase shifter 26 to the translation device 5, whereby the waves emitted or absorbed by the antenna structure are circularly-polarized.

In the combined transmitter and receiver illustrated by Fig. 4, two drums of the type employed in the system of Fig. 1 or Fig. 3 are utilized. Reference numeral 27 denotes a partition which divides the compartment 8, in two parts, one of which contains a transmitter and the other of which contains a receiver. As illustrated, the transmitter 5 is associated with one doublet 4 and associated drum 3 and the receiver 5 is associated with the other doublet 4 and drum 3. The duplex or combined system is mounted or supported by structure 18, and as in the system of Fig. 2, may be rotated as indicated by arrows 28 about a horizontal axle 17 and about a vertical axle 16 so that the direction of transmission or reception may be successively aligned with the same desired path of radiant action.

Fig. 5 illustrates a system in which the same antenna and drum 3 are used, successively, for transmission and reception. The doublet 4 may be connected to either the transmitter 5 or receiver 5, as desired, by means of switch 29.

Fig. 6 illustrates a one-way system comprising a transmitting system and a receiving system either or both of which may be movable or stationary. Each system comprises the embodiment illustrated by Figs. 1—A, 1—B and 2 and need not be explained in detail here. The systems are aligned for directive communication.

Referring to Fig. 7, the solid or full line curve 30 designates the azimuth or horizontal directive characteristic of the system illustrated by Figs. 1—A and 1—B and employing vertically polarized waves, and the dot-dot curve 31 illustrates the vertical or elevation characteristic. Curve 32, shown in dash-dash line, illustrates the azimuth directive characteristic of a cylindrical system of the same construction as that illustrated by Fig. 3. The dot-dash curve 33 illustrates the directive characteristic in azimuth of a circular system in which the diffractor plate is omitted. It will be noted that the directive characteristic or curve 32 for the circular arrangement includes the large minor lobes 34, and the corresponding directive diagram 30 for the orbicular system does not include large minor lobes. Also, it will be noted that the omission of the diffractor plate 10 produces the broad directive characteristic 33 and the exceedingly large minor lobes 35.

The theory explaining the function of the orbicular shield in eliminating the minor lobes will be explained in connection with Figs. 8—A, 8—B, 9—A, 9—B, 10—A and 10—B and is analogous to that underlying the binominal antenna array disclosed in Patent 1,643,323 granted September 27, 1927, to John S. Stone. Referring to Fig. 8—A and assuming the drum diameter is one wavelength, the effective area at the opening of the drum as modified may be considered as being divided into two equal parts, A, each a half wavelength wide. The two areas A may be likened to two equally energized linear antennas. Curve 36 of Fig. 8—B represents the figure of eight diagram produced by such a system. Referring to Fig. 9—A, if the drum is one and a half wavelengths in diameter, it may be divided into three areas each a half wave-length wide, the two end areas being equal and the central area 2A being twice as great as each of the end areas A. These areas may also be likened to linear antennas, the energization of the central linear antenna being twice that of either of the end linear antennas, as in a binomial array of three elements, whereby a fairly sharp directive diagram 37 as illustrated by Fig. 9—B is obtained. Referring to Fig. 10—A and assuming the drum diameter to be two wave-lengths, each of the central areas 3A is three times either end area 1A. The system of Fig. 10—A produces the exceedingly sharp diagram 38 illustrated by Fig. 10—B. It will be noted that the directive diagrams of Figs. 8—B, 9—B and 10—B do not contain minor lobes. The relation of the effective areas is not materially changed when diffractor plates are utilized. It follows that the wall 1 of the drum 3, in a sense conforms or proportions the effective reception or radiation area of the system to the binomial theorem, whereby minor lobes are eliminated and an exceedingly sharp major lobe is secured.

Although the invention has been described in connection with certain embodiments thereof, it is to be understood that it is not to be limited to such embodiments and that other apparatus and arrangements may be utilized without exceeding the scope of the invention.

What is claimed is:

1. In a radio system, a linear antenna, a flat zone reflector having a line focus equal in length to said antenna, said antenna being superimposed on said focus.

2. In a radio system, a linear antenna, a zone diffractor having a line focus equal in length approximately to said antenna, said antenna being superimposed on said focus.

3. In a radio system, an antenna, a reflector, a diffractor, said antenna being included between said reflector and diffractor.

4. In a radio system, a linear antenna, an orbicular reflecting zone plate, an orbicular diffracting zone plate, said plates being positioned in parallel planes and having a common line focus, said antenna being included between said plates and positioned coincident with said focus.

5. In a radio system, a metallic container having an opening at one end only and being otherwise closed a reflection grating and means for aligning the periphery of the opening so that the opening is substantially included in a plane parallel to said grating, and an antenna positioned in said container and at the focus of said grating.

6. In a radio system, a linear antenna, a cylindrical metallic container having an open and a closed end, the difference between the maximum and minimum transverse dimensions of said container being approximately equal to the length of said antenna and the closed end member of said container constituting a zone plate, said antenna being positioned in said container and at the focus of said plate.

7. In a radio system, a linear antenna, a reflecting plate, a conductive diffracting plate, said antenna being positioned a quarter wave-length from the reflecting plate and at least a half wave-length from said diffracting plate and at the common focus of said plates.

8. In combination, a linear antenna, and an orbicular diffraction zone plate, the difference between the maximum and the minimum diameters of any zone being equal to the length of said antenna, said antenna being positioned coincident with the line focus of said plates.

9. In combination, a linear antenna, an orbicular diffraction zone plate, a complementary reflection zone plate, the difference between the maximum and minimum diameters of each zone of each plate being equal to the length of said antenna, said antenna being positioned coincident with the common line focus of said plates.

10. In combination, a linear antenna, an orbicular diffraction zone plate, a complementary reflection zone plate, the difference between the maximum and minimum diameters of each zone of each plate being equal to the length of said antenna, said antenna being positioned a quarter wave-length from said reflecting plate and at the line focus of said diffraction plate.

11. In combination, a linear antenna, an orbicular dielectric diffractor, a complementary metallic reflector, said diffractor and reflector having equal finite focal lengths and being positioned to have a common line focus, and said antenna being positioned coincident with said focus.

12. In a radio system, a linear antenna, a plane zone reflecting plate, a plane zone diffraction plate, the differences between the maximum and minimum diameters for each zone of each of said plates being equal to the length of the linear antenna whereby said plates each possess a line focus, said plates being positioned to have a

common focus and said antenna being superimposed on said focus, and a shield extending between said plates for preventing radiant action in undesired directions.

13. In a radio system, a drum comprising a tubular wall structure open at one end and having an end member serving as a closure for the other end, the wall of said drum constituting a shield and the closed end member constituting a zone reflector, an antenna positioned at the focus of said reflector, and means for adjusting the direction of radiant action of said system.

14. In a radio system, a drum comprising a tubular wall structure open at one end and having an end member serving as a closure for the other end, the wall of said drum constituting a shield and the closed end member constituting a zone reflector, a diffractor positioned parallel to said reflector, an antenna included in said drum and at the focus of said reflector and diffractor, and means for aligning the longitudinal axis of said drum with any desired direction.

15. In a radio system, an antenna, a circular drum open at one end and having an end member serving as a closure for the other end, the wall of said drum constituting a shield and the

closed end member constituting a zone reflector, said antenna being included in said drum and positioned in a plane parallel to the plan of the reflector.

16. In a radio system, a cylindrical walled container open at one end and having an end closure member fixed thereto at the opposite end to constitute a drum, the wall of said drum constituting a shield and the closed end member constituting a zone reflector, a pair of perpendicularly related linear antennas, a phase shifter, a translation device, said antennas being positioned within said drum, one of said antennas being directly connected to the translation device and the other being connected thereto through the phase shifter.

17. In a radio system, a tubular walled container open at one end and having an end member fixed thereto and forming a closure for the other end to constitute a drum, the wall of said drum constituting a shield and the closed end member constituting a zone reflector, an antenna positioned therein, a radio terminal apparatus, and means for connecting the terminal apparatus to said antenna.

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