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3,189,907

ZONE PLATE RADIO TRANSMISSION SYSTEM

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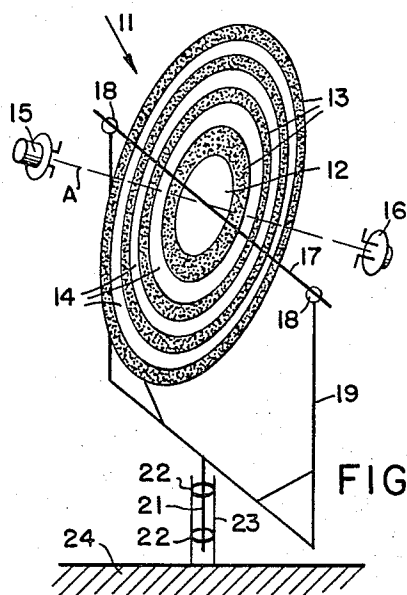


FIG. 1.

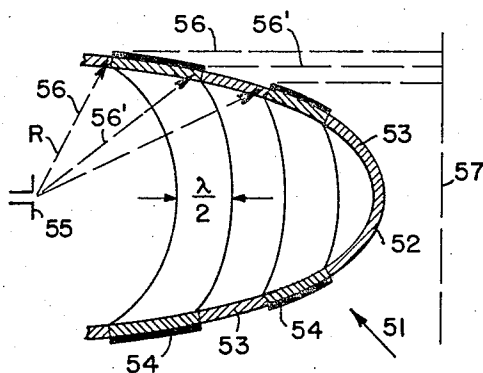


FIG. 4.

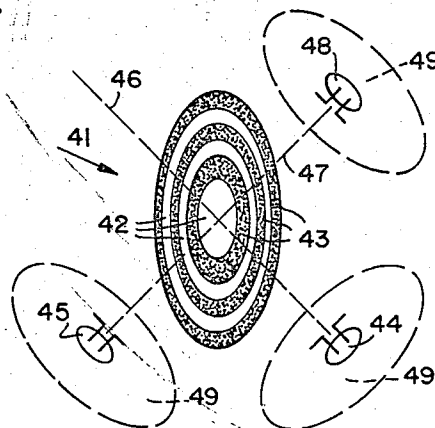


FIG. 3.

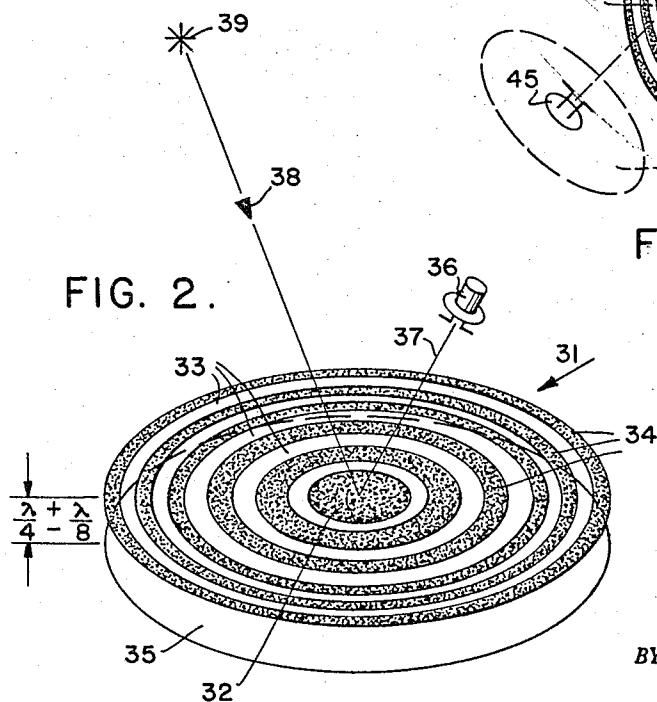


FIG. 2.

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ZONE PLATE RADIO TRANSMISSION SYSTEM
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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a directional radio transmission system and more particularly to a zone plate apparatus which provides a radio frequency antenna with beam width quality comparable to paraboloids, but of much lower cost and easier construction, and which is capable of simultaneous transmitter-receiver usage.

The zone plate is a diffraction device and comprises an arrangement of concentric rings or zones of metallic or electrically conducting surfaces and non-metallic or non-conducting bodies or surfaces arranged in a plane. The central portion of the zone plate may be conducting or opaque, so as to reflect radiation, or it may be non-conducting or transparent, so as to transmit radiation, and the zones are arranged concentrically around the central portion in alternation. An interesting characteristic of the zone plate is that each point of a transparent zone which receives radiation acts as a secondary source of radiation which emits a spherical wave. If the zones are designed to be of such diameters that radiation from all the transparent zones arrives in phase, there will be constructive interference which will be greatest at a focal point located at a distance from the zone plate equivalent to the designed focal length of the zone plate. This requires that the distance from the focal point or focus to the edges of the successive zones be integral multiples of a half-wavelength, $\lambda/2$. The radii of the zones may be calculated; see IRE Transactions on Antennas and Propagation, May 1961, volume AP-9, No. 3, pages 319-320, "The Zone Plate as a Radio-Frequency Focusing Element," or determined graphically. The focusing action of the zone plate is independent of whether the central portion is opaque or transparent; that is, the focusing actions of complementary zone plates are identical. This means that a given zone plate has a focus for reflection as well as transmission since the opaque or metallic rings are conducting.

It is an object of the present invention to utilize the characteristics of the zone plate to provide a radio frequency antenna.

Another object is to provide an antenna for simultaneous transmission and reception using a zone plate.

A further object is the provision of a tracking antenna utilizing a zone plate for telemetering.

A still further object is to provide an astronomical radio telescope using a reflecting zone plate.

According to one feature of the present invention, antenna feeds are located at the foci of the zone plate, one feed may be at a different frequency than the other or it may add to the same frequency.

According to another feature of the invention, a transmitting antenna feed may be located at one focus of a zone plate and a receiving antenna feed at the other focus.

According to still another feature of the invention, a zone plate with antenna feeds is gimbal-supported for tracking a moving object and receiving telemetering information therefrom.

According to a further feature of the invention, a moving antenna feed is employed with a reflecting zone plate and ground plane for tracking celestial bodies.

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Other objects, features and many of the attendant advantages of this invention will become readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a view schematically illustrating one form of zone plate with a pair of antenna feeds;

FIG. 2 is a view schematically illustrating another form of zone plate having associated therewith a ground plane and a movable antenna feed;

FIG. 3 is a view schematically illustrating a zone plate of elliptical form with transmitting and receiving antenna feeds providing for simultaneous transmission and reception; and

FIG. 4 is a view illustrating the layout of a zone plate on a radome surface.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 a planar zone plate 11 which comprises a circular non-conducting or transparent central portion or zone 12. Arranged concentrically about central portion 12 are rings or zones 13 of metallic, electrically conducting or opaque material, and non-conducting or transparent rings or zones 14, the rings or zones being circular and arranged in alternation. Disposed on the central axis of the zone plate, illustrated by dotted line A, are a pair of antenna feeds 15, 16, antenna feed 15 being disposed at the focal point or focus of the zone plate 11 on the front side of the plate and antenna feed 16 being disposed at the focal point or focus of the zone plate on the rear side thereof.

The zone plate may be made in various ways. One way is to cement aluminum foil to Plexiglas, lay out the rings or zones on the foil, then cut and peel away the unwanted foil. Different types of feed antennas may be employed; two types were used—a straight dipole above a ground plane and a turnstile type in which the arms were drooped toward the ground plane.

Antenna feed 16 may be focussed to a different frequency than antenna feed 15 or may add to the same frequency. Or antenna feed 16 may be a transmitting or radiating element while antenna feed 15 is a receiving element.

Zone plate 11 is secured to a support means such as bar 17, or the like, which is journaled for rotation in bearings 18 carried by frame 19 having a shaft 21 journaled for rotation in bearings 22 mounted in a support structure 22 which is secured to a base 24. Zone plate 11 is thus supported for rotation about an axis perpendicular to its central axis A and for rotation about the axis of shaft 21 whereby it may be positioned as necessary to track a moving object for receipt of telemetering information therefrom and/or transmitting commands thereto.

Turning now to FIG. 2, there is shown a reflecting zone plate 31 which is complementary to zone plate 11, that is, its central circular portion or zone 32 is metallic or opaque and the transparent rings or zones 33 and opaque rings or zones 34 are concentrically arranged around opaque portion 32. Such a zone plate may be used in an astronomical radio telescope by making the plate of sufficiently large diameter and supporting it spaced from the ground or other plane surface 35 by about a quarter wavelength, $\lambda/4$, or odd multiples thereof, and arranging an antenna feed 36 for movement generally in the surface of a sphere at the end of a radius 37. Radius 37 is equivalent in length to the focal length of the zone plate 31 and is moved about to pick up radio signals; for example, signal 38 emanating from a celestial body 39. When antenna feed 36 is located on the central axis of the zone plate it will be at the focal point or focus of the plate.

The radiation that is reflected from the opaque zones

32, and 34 will undergo a 180° phase change. The radiation that passes through the transparent zones 33 travels a quarter wavelength to the ground plane 35, undergoes a phase reversal upon reflection from the ground plane, and returns a quarter wavelength to the plane of the zone plate, whereby the portions of the radiation reflected by the opaque zones and the ground plane are in phase at the focal point of the zone plate.

One manner of supporting antenna feed 36 is to mount it for movement on an arch which is itself movable about the zone plate as shown on page 320 of the aforementioned IRE publication. However, any other means providing for similar movement of the antenna feed 36 would serve as well.

FIG. 3 illustrates a zone plate antenna for a two-way communications system providing for simultaneous transmission and reception of radio signals. The system comprises a planar zone plate 41 made up of transparent zones 42 and opaque zones 43, which are elliptical rather than circular, and a transmitting antenna feed 44 and a receiving antenna feed 45. Zone plate 41 may be supported after the fashion of the zone plate in FIG. 1, or in any other suitable manner, and is disposed so that the long axis of the ellipse is at an angle of 45° with respect to a line 46 passing through its center and extending from antenna feed 44 to a remote station (not shown), antenna feed 44 being located at the focal point of the zone plate. Antenna feed 45 is located on a line 47 which is perpendicular to line 46 at the center of the zone plate and at an angle of 45° with respect to the long axis of the ellipse. Thus, the disposition of the zone plate 41 is such that the long axis of the ellipse is contained in the plane defined by lines 46 and 47.

The projection of the elliptical zone plate 41 on a plane perpendicular to line 46 and passing through the end of the long axis of the ellipse nearest antenna feed 44 is in effect a circular zone plate having a focal point coincident with the location of antenna feed 44. Similarly, antenna feed 45 is at the focal point of the projection of the zone plate in a plane perpendicular to line 47 and passing through the near end of the long axis of the ellipse.

In operation, transmitting antenna feed 44 radiates signals, some of which are reflected by the opaque zones and some of which are diffracted by the transparent zones into a beam directed at the remote station (not shown). Some of the signals from the remote station (not shown) beamed at the communications system are reflected by the opaque zones and focussed at the receiving antenna feed 45. By selecting proper frequencies, simultaneous transmission and reception may take place. Additionally, an antenna feed 48 may be located at the focal point on line 47, but on the side of the zone plate opposite to antenna feed 45, to receive the signals from antenna feed 44 which are reflected by the zone plate for purposes such as monitoring. Large ground planes 49 may be located at antenna feeds 44, 45 and 48 to enhance the efficiency of the system.

Although the zone plates described so far are planar, there is no restriction to a plane surface. The graphical layout technique may be employed to lay out a zone plate

51 on any surface, for example, on an aircraft radome 52, shown in FIG. 4. The zone plate 51 comprises transparent zones 53 and opaque zones 54 of metallic foil or the like, arranged in alternation. An antenna feed 55 is located at the focal point of the zone plate and incident radiation is diffracted by the transparent zones and focussed at the antenna feed. In laying out zone plate 51 on radome 52, successive radii R are generated such that the segmented distances 56, 56', and so on, from the antenna feed 55 to the zone edges to a wave plane 57 differ by half wavelengths, $\lambda/2$.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In combination, a zone plate, an antenna feed on one side of said zone plate at the focus thereof for transmitting beamed radio signals, said zone plate being disposed at an angle to said beamed radio signals, and an antenna feed on the other side of said zone plate at the focus thereof for receiving radio signals beamed at the zone plate from a remote station.

2. In a two-way communication system adapted for transmission and simultaneous reception, a zone plate, an antenna feed on one side of said zone plate for transmitting high frequency energy beamed at a remote station, said zone plate being disposed at an angle of 45° with respect to the direction of transmission, and an antenna feed on the other side of said zone plate for simultaneously receiving high frequency energy beamed at the zone plate from the remote station.

3. The system of claim 2, wherein said second-named antenna feed is on a line passing through the center of the zone plate and perpendicular to the direction of transmission of the high frequency energy.

4. The system of claim 3, wherein the zone plate is in the form of an ellipse and the long axis of the ellipse lies in the plane defined by said line and the direction of transmission of high frequency energy.

5. The system of claim 4, wherein a third antenna feed is associated with said zone plate, said third antenna feed being disposed on the same side of the zone plate as said first-named antenna feed but on the line extending through the center of the zone from said second-named antenna feed.

6. The system of claim 5, wherein ground planes are associated with said antenna feeds.

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