

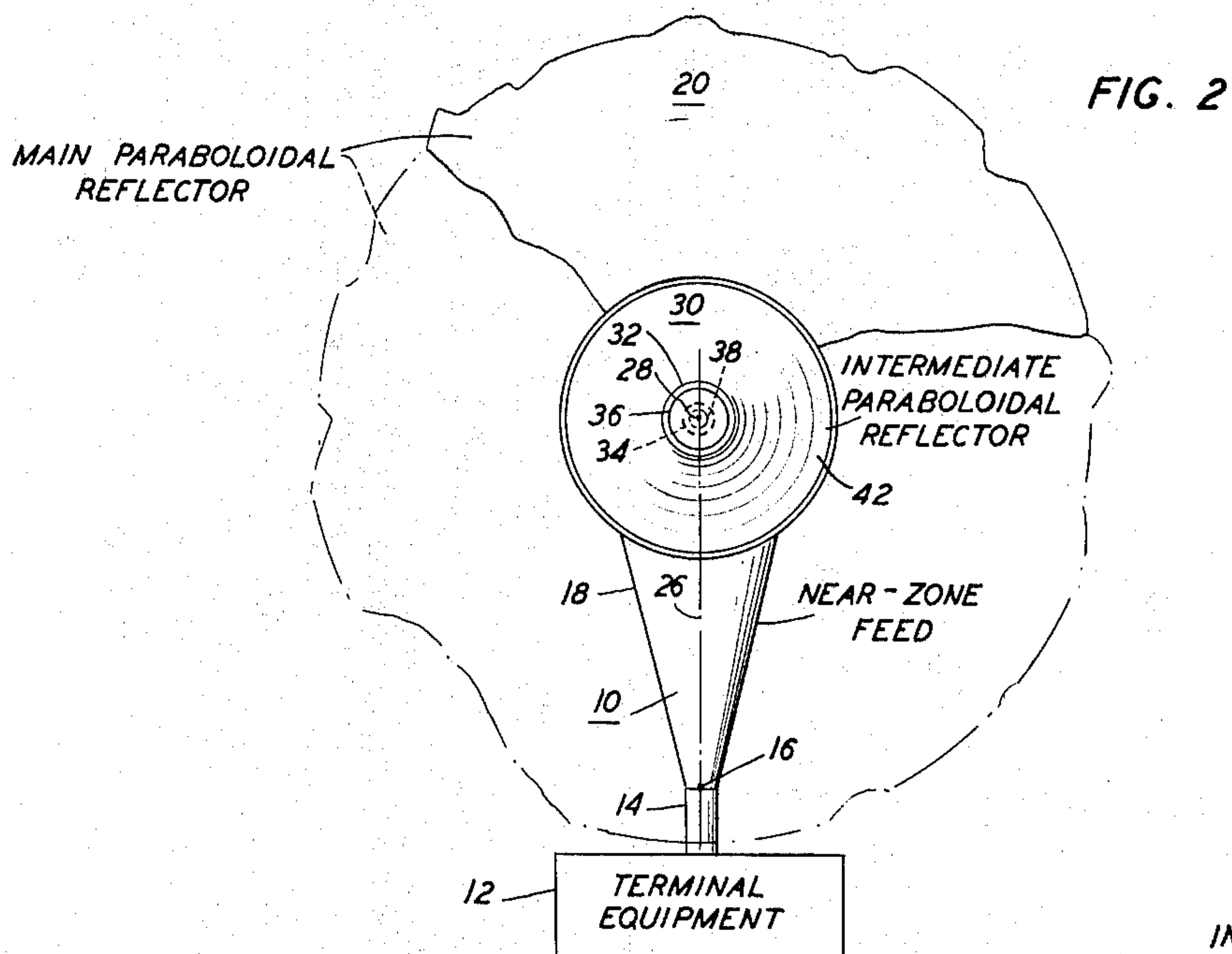
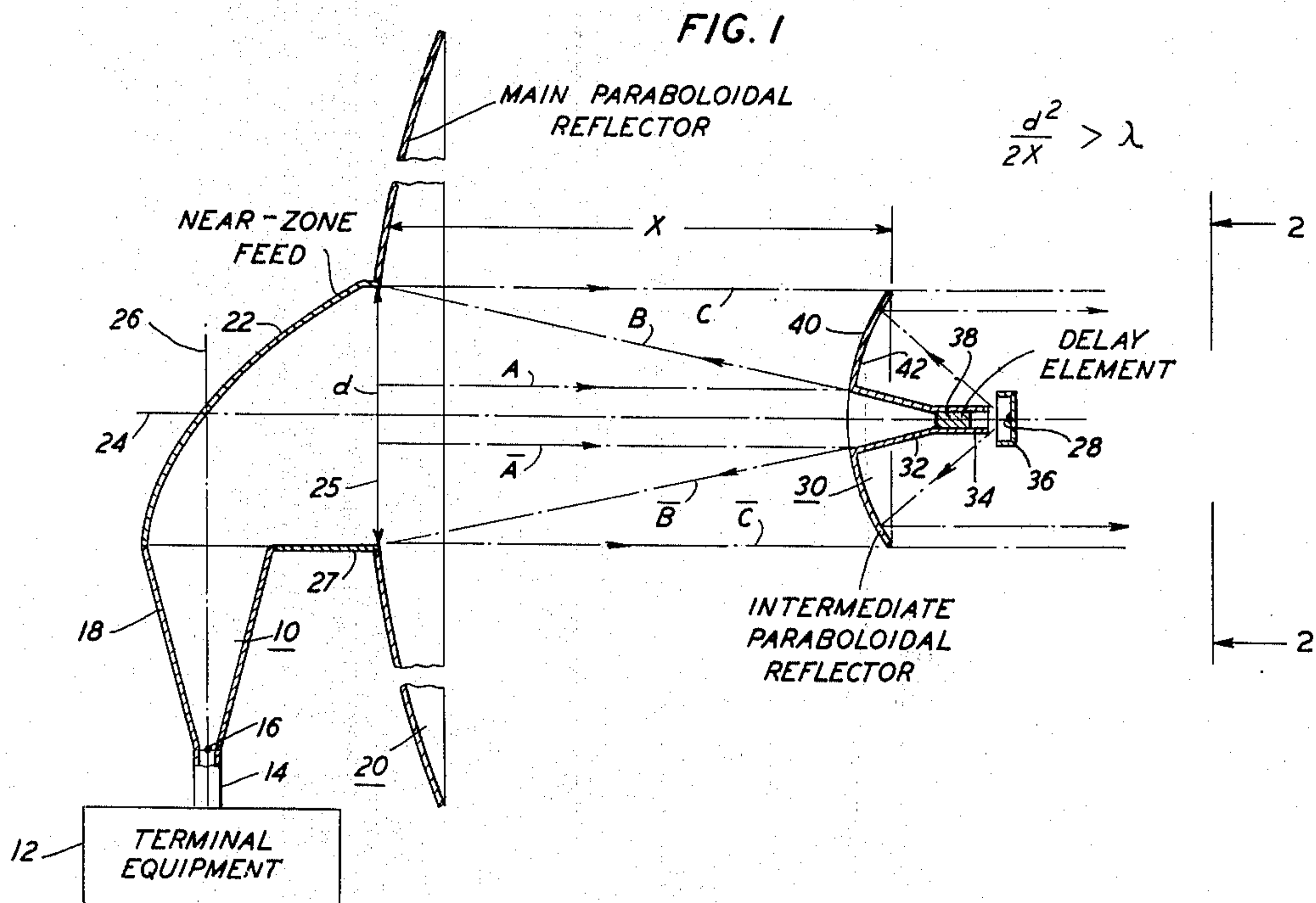
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CASSEGRAINIAN ANTENNA WITH APERTURE BLOCKING COMPENSATION

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CASSEGRAINIAN ANTENNA WITH APERTURE BLOCKING COMPENSATION

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This invention relates to antenna systems and, more particularly, to an improved Cassegrainian antenna.

It has recently been discovered that Cassegrainian telescope principles may be employed to advantage in radio-frequency antennas as the basis of a feed system for a paraboloidal reflector. In such an arrangement the source or collector of radio waves, i.e. the feed element, is located behind the reflecting surface of the paraboloidal reflector at its vertex and is aimed through an opening in the paraboloidal reflector in the direction of radiation of the antenna. An intermediate reflector, positioned in front of the paraboloidal reflector in the path of the feed element, serves to direct radio waves between the feed element and the paraboloidal reflector. By virtue of this arrangement transmitting and/or receiving equipment located behind the paraboloidal reflector may be connected directly to the feed element and the requirement of a transmission line to interconnect this transmitting and/or receiving equipment with feed equipment located at the focus of the paraboloidal reflector following conventional practice, is obviated. The resistance or heat loss, and therefore thermal noise, associated with conveying electrical signals through transmission lines is thereby eliminated, and the antenna performance capabilities are accordingly enhanced.

The Cassegrainian antenna, arranged as described above, has been received with much enthusiasm in the field of space communications wherein satellites orbiting in outer space act as relay stations for radio signals. Reduced noise generation and signal attenuation in the Cassegrainian antenna permits more directivity in the transmission of radio signals and greater sensitivity in the reception of radio signals. These qualities are much in demand for carrying on communications between vastly distant stations, as are found in space communications systems.

There are several disadvantages, however, inherent in the conventional radio-frequency Cassegrainian antenna which tend to offset its favorable characteristics. "Spillover" of the intermediate reflector occurs in attempting to efficiently couple radio waves between the feed element and the intermediate reflector. Also, the intermediate reflector, being located in the direct line of radiation of the antenna, produces a shadow in the antenna beam. This phenomenon is referred to as "aperture blocking." Spillover and aperture blocking increase the side lobes of the antenna radiation pattern, thus reducing the effectiveness of the Cassegrainian antenna for highly directional, low noise antenna operation.

It is, therefore, the object of the present invention to improve the characteristics of a Cassegrainian antenna and, more specifically, to reduce the spillover of and aperture blocking by the intermediate reflector in a Cassegrainian antenna.

In accordance with the above object, the spillover radiation of the intermediate reflecting surface of a Cassegrainian antenna accommodating radio waves is diminished by situating the intermediate reflecting surface in the near-zone of the field of the feed element. In its near-zone the field of a radio-frequency radiator conforms closely to the field suggested by geometric optics, i.e. the effects of diffraction are not controlling. The intermediate

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reflecting surface is placed in the near-zone of the feed element field by designing the effective aperture of the feed element to be large and the distance between the feed element and the intermediate reflecting surface to be small with respect to wavelength of the radio waves accommodated by the antenna. Accordingly, a well-defined beam is transmitted between the feed element and the intermediate reflecting surface so that spillover of the intermediate reflector may be controlled.

According to another feature of the invention, electromagnetic waves which would normally be blocked from transmission between the feed element and the useful far-zone of the antenna field by the intermediate reflecting surface are conveyed between the intermediate reflecting surface and the antenna far-zone field by a second paraboloidal reflecting surface mounted on the structure that supports the intermediate reflecting surface and oriented to face the direction of radiation of the antenna, thereby reducing aperture blocking. These electromagnetic waves are coupled between the intermediate reflecting surface and the focus of the second paraboloidal surface by a waveguide horn whose aperture lies on the intermediate reflecting surface and tapers down to connect with a waveguide that terminates in feed equipment at the second paraboloid's focus. The inefficiency of coupling of electromagnetic waves between the feed element and the antenna far-zone field caused by the large effective aperture required of the feed element for near-zone conditions is also alleviated by this arrangement.

If the feed is designed to accommodate an electromagnetic wave having a plane wave front, as for example a horn-reflector with a paraboloidal reflecting section, the contour of the intermediate reflecting surface is paraboloidal, having a focus at the focus of the main paraboloid. In this case, the intermediate structure may comprise a paraboloidally-shaped sheet of reflective material, the convex surface of which may be employed to convey electromagnetic waves between the feed element and the main paraboloidal reflector and the concave surface of which may be utilized to reduce aperture blocking and inefficient coupling to and from the feed element, as described above.

The invention may be more fully understood by reference to the following detailed description taken in conjunction with the drawing in which:

FIG. 1 shows a side elevation in partial section of an antenna constructed according to the invention; and

FIG. 2 shows a front elevation of the antenna illustrated in FIG. 1.

The antenna of the invention will be described operating as a transmitting antenna. It will be understood, of course, that the antenna will perform as a receiving antenna in a fashion reciprocal to the mode of operation about to be described. In the drawing, terminal equipment 12 provides a radio-frequency signal to be transmitted which is launched in a short section 14 of circular waveguide. Waveguide section 14 carries the signal along an axis of symmetry 26 to a connecting waveguide horn 18. Waveguide horn 18 tapers outward from an apex 16 along axis 26 until it meets a concave paraboloidal section 22 situated transverse thereto, having its focus at 16, the apex of horn 18. Horn 18 and section 22 comprise a conventional paraboloidal horn-reflector, which is referred to hereafter as a near-zone feed 10. Its aperture is directed through an opening 25 in a main paraboloidal reflector 20 having a focus 28 and along an axis of symmetry 24 of reflector 20. The horn-reflector is connected to reflector 20 by a section 27. The signal travels through waveguide section 14 and horn 18 to section 22 where it is reflected and redirected in a plane wave-front along axis 24. An intermediate paraboloidal struc-

ture 30 is situated on axis 24 with a reflecting surface 40 facing reflector 20. Radio waves emanating from opening 25 impinge upon reflecting surface 40, whereupon they are redirected back upon and illuminate reflector 20 and finally are radiated into the far-zone of the antenna. Since the entire deliverance of the radio waves from opening 25 in main reflector 20 to the reflecting surface of main reflector 20 is accomplished without resorting to a transmission line, the overall loss introduced by the antenna is small.

The effective radiating aperture d presented at opening 25 in main reflector 20 is designed large enough and the axial distance x between the vertex of main reflector 20 and the plane through reflecting surface 40 of structure 30 perpendicular to axis 24 which is furthest from the vertex is designed small enough with respect to the wavelength λ of the radio waves being transmitted to place reflecting surface 40 in the near-zone field of the radio waves radiated from near-zone feed 10. It is characteristic of the near-zone of a radio-frequency antenna field to conform closely to that predicted by geometric optics. In other words, the effects of diffraction are not felt in the near-zone. Therefore, a well-defined, collimated beam impinges upon reflecting surface 40 from near-zone feed 10. Reflecting surface 40 can be efficiently, i.e. uniformly, illuminated without appreciable spillover radiation with this sharp, near-zone beam. Because of the large reflecting area of reflecting surface 40 and its closeness to reflector 20, reflector 20 is also illuminated with the near-zone field and accordingly little spillover from reflector 20 occurs. Small spillover from the reflectors of the antenna permits more efficient, i.e. higher gain, radiation in a transmitting antenna and allows less noise to be intercepted by a receiving antenna.

The transition from the near-zone to the far-zone of the field of a radiator is gradual, but generally near-zone conditions can at least be considered to exist so long as $d^2/2x$ remains larger than λ . Beyond this point the radiated beam starts to show the effects of diffraction.

Reflecting surface 40 is shaped to reflect the radio waves radiated from near-zone feed 10 in a wavefront diverging from reflecting surface 40 and impinging upon main paraboloidal reflector 20, as though it were emanating from a point source located at focus 28. In other words, if the radio waves reflected from reflecting surface 40 to main reflector 20 were to be represented by a ray diagram, extensions of the rays would pass through focus 28. This function is accomplished, in the case of a plane wavefront radiating from near-zone feed 10, with a reflecting surface 40 presenting a convex paraboloidal contour having a focus coincident with focus 28 to opening 25. Near-zone feed 10 need not be a horn-reflector. For example, a small paraboloidal reflector fed in a conventional manner can alternatively be employed to form the plane wavefront to irradiate reflecting surface 40.

Nor is it necessary to the practice of the invention that reflecting surface 40 be illuminated with a plane wavefront. Near-zone feed 10 may comprise a radiator of signals having other wavefront configurations, for example, a diverging wavefront produced by a waveguide horn or a converging wavefront produced by substituting an ellipsoidal section for the paraboloidal section in the horn-reflector illustrated in the drawing. In these instances, the contour of reflecting surface 40, must be modified to produce irradiation of reflector 20, as discussed above, by a wavefront having an apparent or virtual source at focus 28. Generally, any radiator has a near-zone field that is well-defined and by this characteristic may be utilized in diminishing spillover in the Cassegrainian antenna for radio waves.

A shortcoming of conventional Cassegrainian antennas is large scale aperture blocking by the intermediate reflector. The intermediate reflector in a Cassegrainian antenna presents a much larger obstruction in the beam of the antenna than most other arrangements used to

feed paraboloidal reflectors. An increased side lobe level occurs in the antenna radiation pattern as a result of aperture blocking. There may be added in the arrangement thus far described, the ill effects caused by the large aperture required of near-zone radiator 10 if intermediate reflecting surface 40 is to be situated in the near-zone field of near-zone feed 10. This large aperture tends to increase the amount of energy reflected back into near-zone feed 10 instead of to reflector 20 after reflection from reflecting surface 40, resulting in an inefficient coupling of radio waves between near-zone feed 10 and reflector 20. These radio waves can also be considered as being blocked from radiation to the antenna far-zone by intermediate reflecting surface 40.

To mitigate these effects, the aperture of a waveguide horn 32 is placed flush with reflecting surface 40 to intercept all the radio waves radiated from near-zone feed 10 that would normally be blocked by intermediate structure 30 from radiation into the far-zone of the antenna. This otherwise wasted energy is delivered by horn 32 to a waveguide section 34 which carries it to the vicinity of focus 28 where a reflecting cup 36 redirects the radio waves back to irradiate a concave paraboloidal reflecting surface 42 of intermediate structure 30. A dielectric slab 38 is inserted in waveguide section 34 to delay the electromagnetic waves propagating therethrough sufficiently to bring the wavefront radiated from reflecting surface 42 into phase with the wavefront of the radio waves radiated from main reflector 20. In this way, reflectors 20 and 30 cooperate to produce a shadow-free beam with a unified wavefront. When a plane wavefront near-zone feed is employed, as shown in the drawing, opposite surfaces of a paraboloidal sheet may be used as an intermediate structure. If, however, a converging or diverging wavefront is radiated from near-zone feed 10, the shape of reflecting surface 40 is independent of paraboloidally-shaped reflecting surface 42.

In FIG. 1 dashed lines A, $\bar{A}$, B, $\bar{B}$, C and $\bar{C}$ represent a ray diagram showing the optimum design of horn 32 for the dimensions of reflecting surface 40 and opening 25 in main reflector 20. Since the near-zone field of feed 10 is involved, a ray diagram can accurately show the boundaries of the field. The radio waves emanating from near-zone feed 10 and enclosed within a cylinder centered about axis 24 and designated by lines A and $\bar{A}$, are intercepted by horn 32. Otherwise these radio waves, when reflected from reflecting surface 40, would be enclosed within a cone also centered about axis 24 and represented by lines B and $\bar{B}$ and would be reflected back into near-zone feed 10. Lines B and $\bar{B}$, if extended, would meet at focus 28. Any radio waves enclosed within the cone not recoupled into near-zone feed 10 would be reflected from main reflector 20 within the cylinder centered about axis 24 and designated by lines C and $\bar{C}$ and prevented from passage to the antenna far-zone by reflecting surface 40. The aperture of horn 32 is coextensive in cross section with the truncated top of the cone represented by lines B and $\bar{B}$. For most efficient performance, opening 25 will usually be of about equal size with reflecting surface 40. A diameter d of opening 25 of 14λ and a distance x between near-zone feed 10 and reflecting surface 40 of 30λ were found to produce satisfactory antenna performance, with reflector 20 having a diameter of 100λ and reflecting surface 40 having a diameter of 15λ .

What is claimed is:

1. In an antenna system, a first concave paraboloidal reflector having an opening in its vertex, a second paraboloidal reflector having a convex reflecting surface facing toward said first reflector and a concave reflecting surface facing away from said first reflector situated confocal with said first reflector, a paraboloidal horn-reflector having an aperture coextensive with said opening, the near-zone field of said horn-reflector irradiating said convex

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surface through said hole from behind said first reflector, a waveguide horn having an aperture lying flush with said convex surface of said second reflector to collect electromagnetic waves which would otherwise not be transmitted to the far field of said antenna, and means for illuminating said concave reflecting surface with the electromagnetic waves collected by said waveguide horn.

2. In a Cassegrainian antenna system, a first reflector having a hole through its surface, an intermediate structure having second and third reflecting surfaces on opposite sides of its exterior, said second reflecting surface facing toward said first reflector, said third reflecting surface facing away from said first reflector, a first feed element located behind said first reflector, said first feed element being directed through said hole at said second reflecting surface, said second reflecting surface being shaped to reflect electromagnetic waves between said first reflector and said first feed element, a second feed element for accommodating the electromagnetic waves which would otherwise be blocked by said intermediate structure from transmission between the far-zone of said antenna system and said first feed element, and a third feed element for conveying electromagnetic waves between said third reflecting surface and said second feed element coupled to said second feed element.

3. In a Cassegrainian antenna system, a concave main paraboloidal reflector having a focus and a vertex, an intermediate structure having first and second reflecting surfaces on opposite sides of its exterior centered on the axis of said main reflector, said first reflecting surface facing toward the concave surface of said main reflector, said second reflecting surface forming a paraboloid having a focus and facing away from said main reflector, a first feed element located near the vertex of said main paraboloid, said first feed element being oriented along said axis toward said first reflecting surface, said first reflecting surface being contoured to create at the focus of said main paraboloid a virtual feed for electromagnetic waves conveyed between said main reflector and said first feed element, means located at said first surface capable of radiating and collecting electromagnetic waves which would otherwise be blocked by said intermediate structure from transmission between the far-zone of said antenna system and said first feed element, a second feed element situated near the focus of said second reflecting surface, and means for coupling said radiating and collecting means to said second feed element.

4. In a Cassegrainian antenna, a first concave paraboloidal reflector having an opening in its vertex, a first feed element for accommodating collimated electromagnetic waves situated behind the reflecting surface of said first paraboloidal reflector and directed through said opening along the axis of said first paraboloid, a second paraboloidal reflector with two opposite paraboloidal faces serving as reflectors centered on said axis and having a focus coincident with the focus of said first paraboloid, the convex reflecting surface of said second paraboloidal reflector facing toward the concave surface of said first paraboloidal reflector, the concave reflecting surface of said second paraboloidal reflector facing away from the concave surface of said first paraboloidal reflector, means capable of collecting and radiating electromagnetic waves located at said convex reflecting surface of said second paraboloidal reflector facing said first feed element, and a second feed element located near said focus and interconnected with said collecting and radiating means to direct energy between said concave reflecting surface of said second paraboloidal reflector and said collecting and radiating means.

5. In a Cassegrainian antenna system, a first reflector having a hole through its reflecting surface, an intermediate structure having second and third reflecting surfaces on opposite sides of its exterior, said second reflecting surface facing toward said first reflector, said third reflecting surface facing away from said first reflector, a first feed

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element located behind said first reflector, said first feed element being directed through said hole at said second reflecting surface, said second reflecting surface being located in the near-zone of the field of said first feed element and being shaped to reflect electromagnetic waves between said first reflector and said first feed element, a radiator for accommodating the electromagnetic waves which would otherwise be blocked by said intermediate structure from transmission between the far-zone of said antenna system and said first feed element, and a second feed element for conveying electromagnetic waves between said third reflecting surface and said radiator coupled to said radiator.

6. In a Cassegrainian antenna system, a first concave paraboloidal reflector having a focus and a vertex, an intermediate structure having first and second reflecting surfaces on opposite sides of its exterior centered on the axis of said first paraboloid, said first reflecting surface facing toward said first paraboloidal reflector, said second reflecting surface forming a second concave paraboloid having a focus and facing away from said first paraboloidal reflector, a first feed element located near the vertex of said first paraboloid, said first feed element being directed along said axis toward said first reflecting surface, said first reflecting surface being located in the near-zone of the field of said first feed element, said first reflecting surface being contoured to create at the focus of said first paraboloid a virtual feed for electromagnetic waves conveyed between said first paraboloidal reflector and said feed element, means located at said first reflecting surface capable of radiating and collecting electromagnetic waves which would otherwise be blocked by said intermediate structure from transmission between the far-zone of said antenna system and said first feed element, a second feed element for said second reflecting surface situated near the focus of said second reflecting surface, and means for coupling said radiating and collecting means to said second feed element.

7. A Cassegrainian antenna comprising a main paraboloidal reflector having an opening cut in its vertex, an intermediate paraboloidal reflector having a focus coincident with the focus of said main paraboloid centered on the axis of said main paraboloid, said intermediate reflector having a convex reflecting surface facing toward and a concave reflecting surface facing away from said main paraboloidal reflector, a horn-reflector having a paraboloidal reflecting section located behind said main paraboloidal reflector, the apex of said horn-reflector being connected through a waveguide section to electronic terminal equipment, the aperture wall of said horn-reflector being connected with the wall of said opening in said main reflector, said horn-reflector being directed along the axis of said main paraboloid, a tapered horn with its aperture lying flush with the convex surface of said intermediate reflector and its apex extending toward said focus, a feed element that directs electromagnetic waves between said concave surface and said horn-reflector located near said focus, and a waveguide section connecting the apex of said tapered horn with said feed element.

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