June 20, 1961 G. J. DOUNDOULAKIS ET AL 2,989,748

FEED SYSTEM FOR BROAD BAND ANTENNA

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Fig. 1.

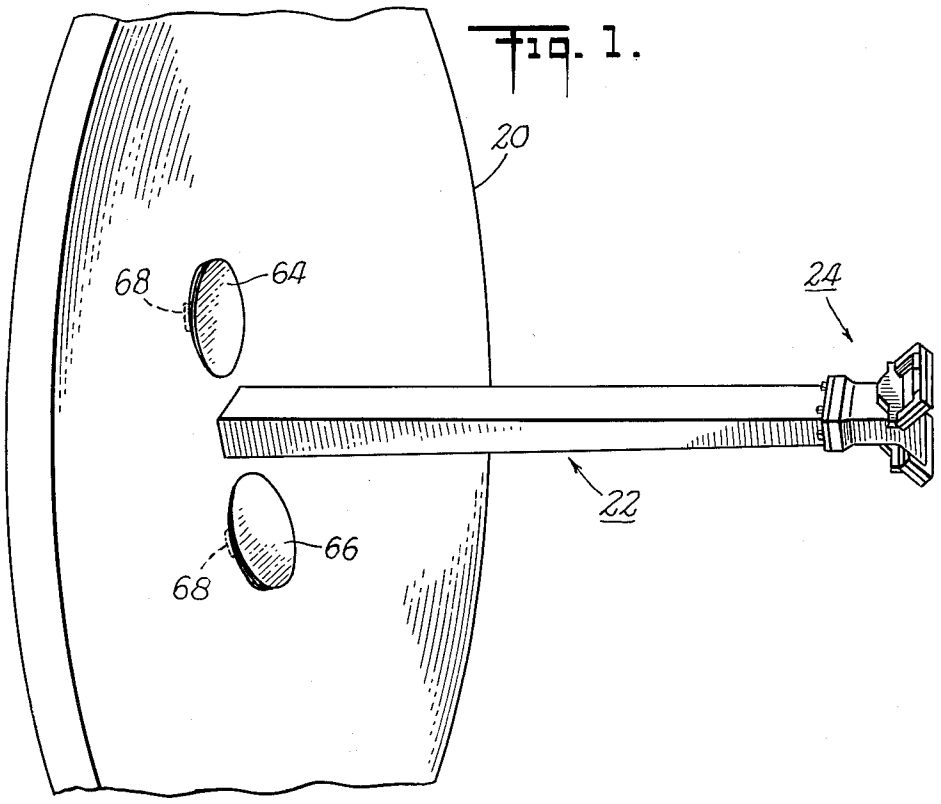
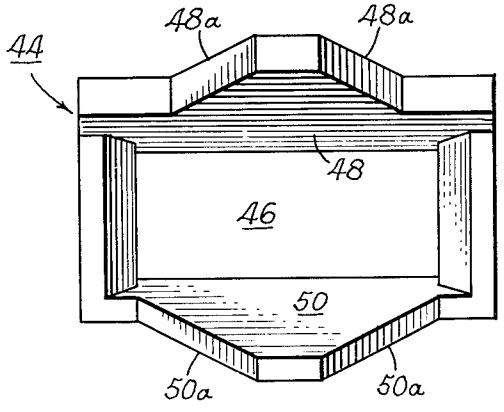


Fig. 2.



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Fig. 4.

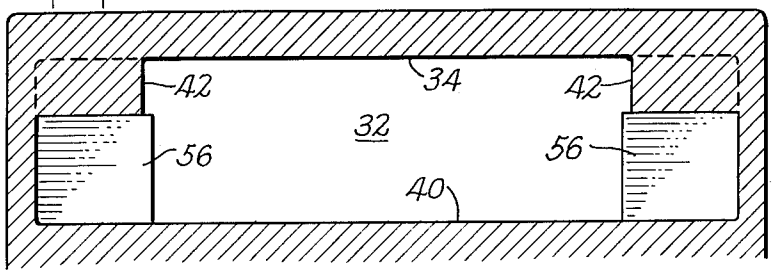


Fig. 3.

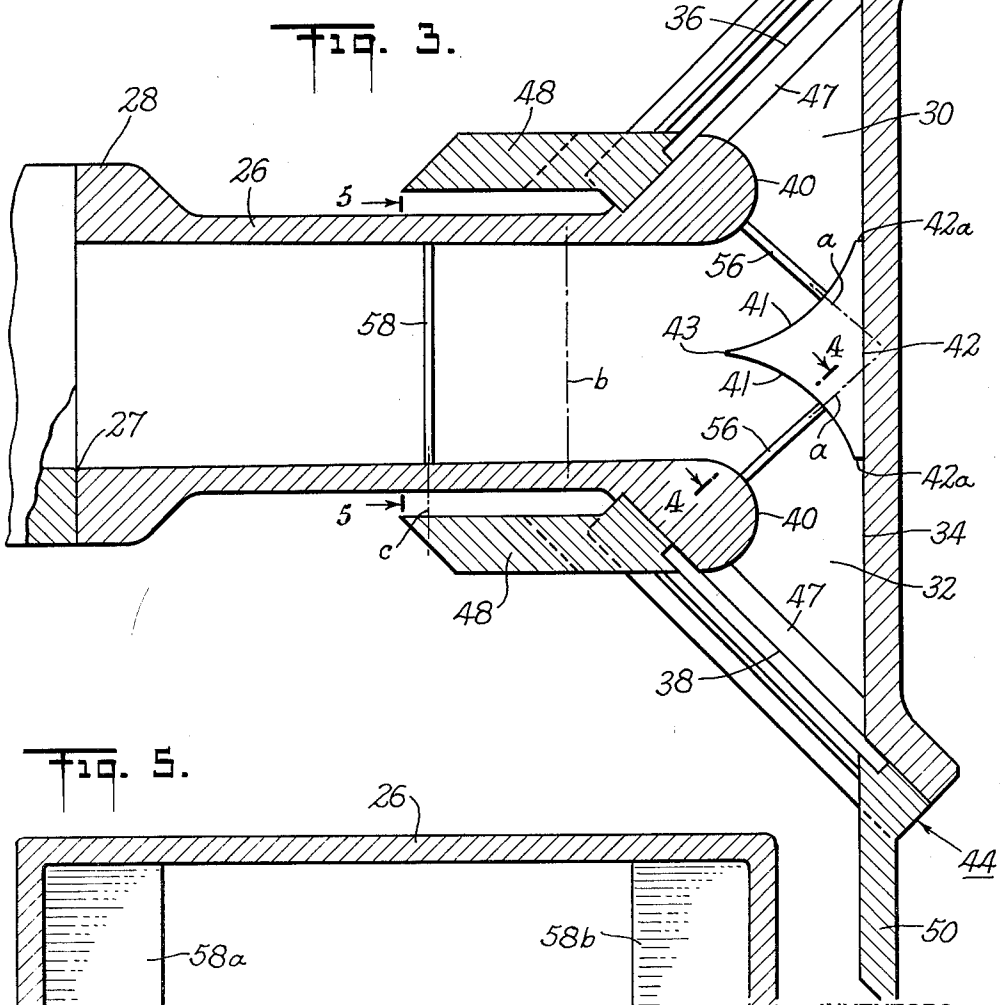


Fig. 5.

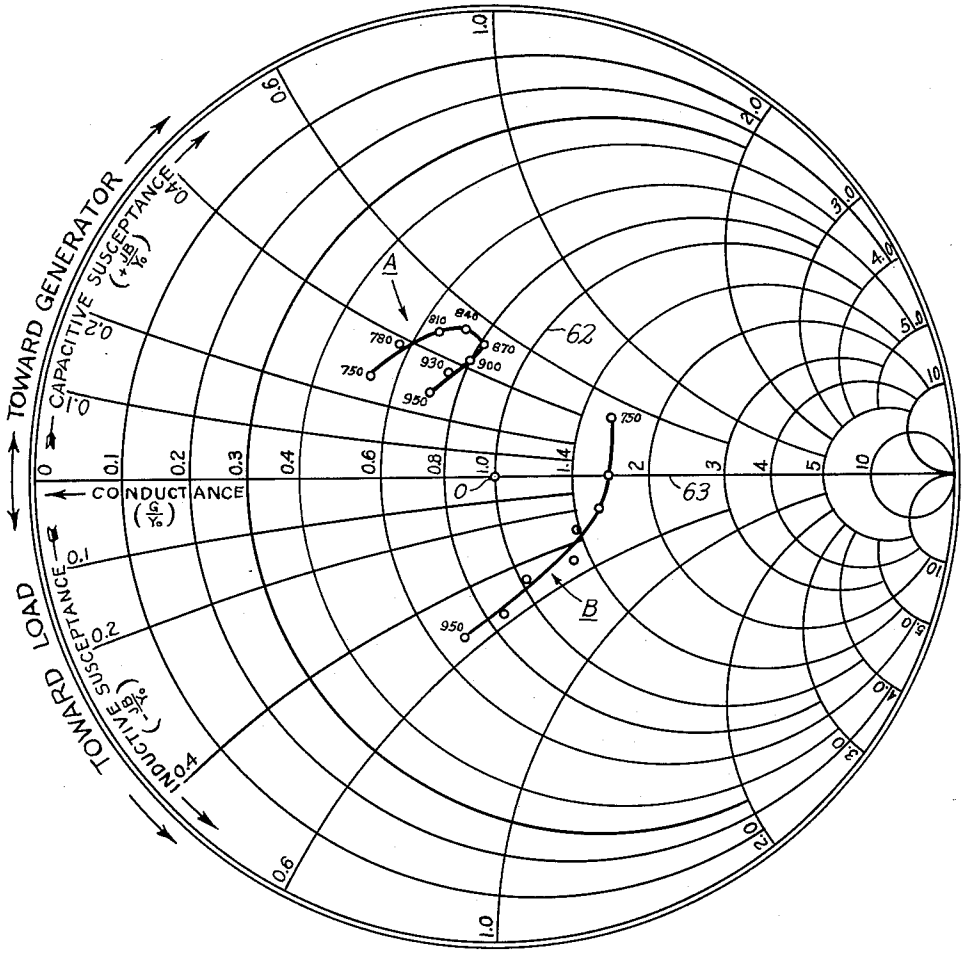
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Fig. 6.



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Fig. 7.

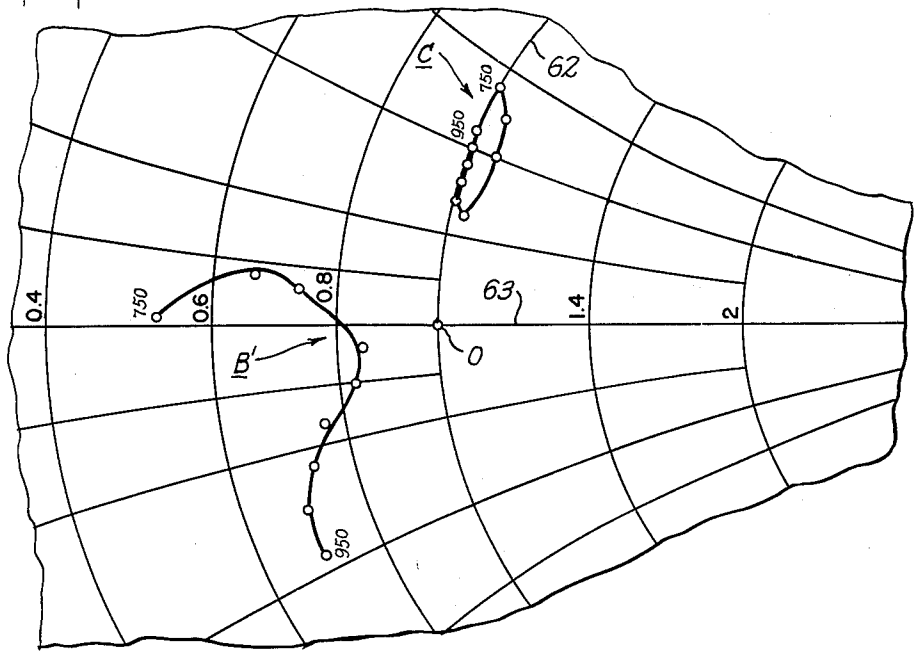
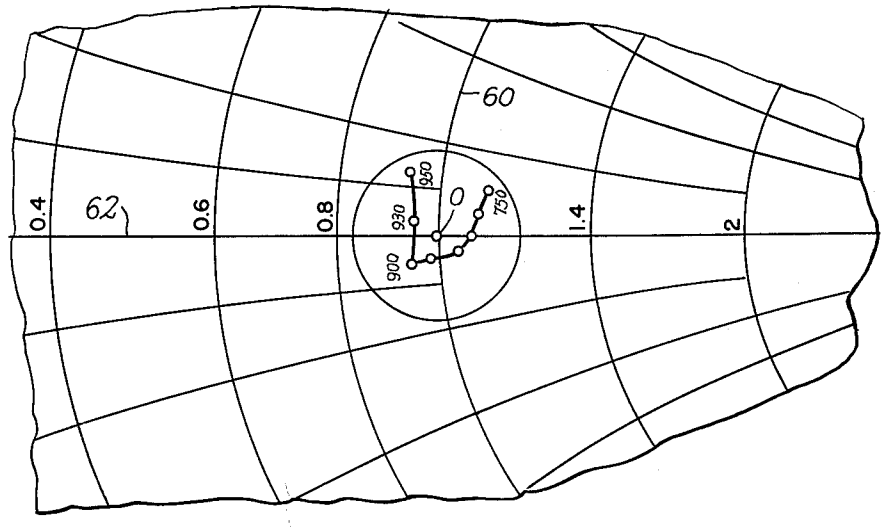


Fig. 8.



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FEED SYSTEM FOR BROAD BAND ANTENNA

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Filed Oct. 22, 1956, Ser. No. 617,554
4 Claims. (Cl. 343—781)

This invention relates to a feed system for a parabolic reflector type antenna operable over a wide band of frequencies.

The invention is useful, for example, in connection with antennas used in radio communications by scatter propagation, wherein the antenna is used for both transmission and reception on different frequencies over a wide band, and even for simultaneous transmission and reception on different frequencies within said band. In the ensuing description, the invention is described as specifically applied to an antenna intended for operation in the UHF band over an approximate range of 750 to 950 megacycles (a wavelength of approximately 30 to 40 centimeters), although the invention is equally applicable to antennas designed for other frequency bands and for many other purposes, such as frequency-scanned radar.

It will be immediately appreciated by anyone familiar with this art that very substantial problems are involved in achieving an acceptable impedance match between the waveguide and the antenna for a low standing wave ratio throughout a band of frequencies of such breadth (the total bandwidth of 200 megacycles being almost 25% of the center frequency of 850 megacycles).

It is therefore among the objects of this invention to provide a feed system which is capable of providing an acceptable match to an antenna throughout a band of frequencies of the breadth indicated—a system which is also basically simple mechanically, well-adapted for commercial manufacture and for continuous, trouble-free use under field conditions.

In the drawings:

FIGURE 1 is a fragmentary perspective view of a parabolic reflector-type UHF antenna embodying features of the present invention.

FIGURE 2 is a fragmentary plan view of one of the flanges on the horn of the antenna of FIGURE 1;

FIGURE 3 is a fragmentary longitudinal sectional view of the horn;

FIGURES 4 and 5 are transverse sectional views of the horn, takes respectively on the lines 4—4 and 5—5 of FIGURE 3;

FIGURES 6, 7 and 8 are Smith chart plots of the admittance coordinates of the feed system, as measured at various reference planes in the horn before and after addition of certain reactance elements, FIGURE 6 showing the complete Smith chart, and FIGURES 7 and 8 showing only the central portion thereof, at an expanded scale.

As may be seen in FIGURE 1, the illustrative antenna of the present invention includes a parabolic reflector **20** which is fabricated of a suitable metal such as sheet steel, which is supported on a tower. Projecting forwardly from the center of the parabola **20** along its axis of symmetry is a rectangular waveguide **22**, which is mechanically self-supporting.

The internal transverse dimensions of the waveguide are sufficient to carry the particular frequencies involved. In an exemplary antenna adapted to carry frequencies within the band of 750 to 950 megacycles, the waveguide suitably has a larger internal transverse dimension (its width or *a* dimension) of 9.75 inches. At its inner end, adjacent the surface of the parabola **20**, the waveguide suitably has a shorter internal transverse dimension (its height or *b* dimension) of 4.875 inches, which is linearly

tapered to 3 inches at the outer end of the waveguide. This gives the waveguide a cut-off wavelength of $2a=49.5$ centimeters, which corresponds to a frequency of approximately 600 megacycles.

Fixed at the outer end of the waveguide **22** to serve as the compound radiating element, is a horn assembly generally indicated **24**.

This horn assembly is shown in greater detail in FIGURES 2 through 5. As may best be seen in FIGURE 3, the horn assembly **24** includes at its input end a length of waveguide **26** which forms an effective continuation of the main portion **22** (FIGURE 1) of the waveguide, being similarly tapered in its shorter dimension and being fitted to the end of the main waveguide so as to form an internally smooth joint **27**. The horn **24** is equipped with a flange **28** by which it is bolted to a similar flange on the outer end of the main waveguide **22**.

The outer end of the horn **24** is divided into upper and lower branches **30** and **32** of equal size, these two branches being defined by a common forward wall **34** and by rearward walls **36** and **38** which are inclined at an angle of 45 degrees relative to the longitudinal axis of the waveguide. In the region where the two branches **30** and **32** merge into the waveguide **26**, each of the two inner corners **40** is rounded in the shape of a right circular cylinder whose axis is parallel to the longer dimension of the waveguide to give a smooth transition from the waveguide into the two branches **30** and **32**. The main body of the horn is suitably formed of cast aluminum, with internal surfaces machined.

Secured to the end wall **34** adjoining the two shorter side walls of the waveguide are a pair of separator members **42** which are of cuspate shape—i.e., they are generally wedge-shaped with their peaked surfaces **41** being concavely curved in the form of right circular cylindrical surfaces coaxial with the opposing curved surfaces **40**. Thus, the concavely curved surfaces of the separators **42** are at all points equidistant from the convexly curved surfaces **40**. The peaks **43** of the separator members, which point rearwardly along the waveguide **26**, bisect the shorter dimension of the waveguide, the cancave surfaces **41** being substantially tangential to each other and to the inner surface of the end wall **34** of the horn, although they are cut off at each side, as shown at **42***a* to facilitate assembly of the horn by permitting movement of the separator members through the waveguide **26**. From the foregoing description, it can be seen that the shorter dimension of each of the two branches is one-half that of the outer end of the waveguide **26**, or 1½".

Secured to the two inclined rear faces **36** and **38** of the horn are a pair of flanges **44** having rectangular apertures **46** therein, these apertures forming smooth continuations of the two branches **30** and **32** of the horn. The apertured flanges with their divergent surfaces **48** and **50** serve as the radiating elements by which the radio frequency energy is directed against the face of the parabola **20** (FIGURE 1). The inner face of each of the flanges **44** is recessed to receive a dielectric plate which is used to seal the waveguide hermetically and permit it to be pressurized, for example with dehumidified air.

At each of the short sides of each of the apertures **46**, as shown in FIGURE 3, the sidewalls of the waveguide are tapered inwardly toward the aperture for a short distance as shown at **47**. This has the effect of laterally broadening the beam of energy emitted from the aperture, and makes possible a more uniform illumination of the parabola **20**. To the same end, the divergent surfaces **48** and **50** of the flanges, shown in FIGURE 2, are also cut away at their corners to leave inclined surfaces **48***a* and **50***a*.

The apertures **46** are by nature somewhat capacitive in their admittance characteristic, despite the fact that the

beveled surfaces 47 projecting inwardly from their shorter sidewalls introduce a certain amount of inductive susceptance which to some extent counteracts the inherent capacitive susceptance of the apertures 46.

The separators 54 suitably have a width of 1½ inches and are mounted flush against the shorter sidewalls of the waveguide. This leaves a free space between the inner faces of the two separators of 6.75 inches. These separators not only introduce a certain amount of complex admittance into the circuit, the principal component of which is capacitive susceptance, but they also serve as supports for a pair of inductive irises 56 which are mounted on each of the branches 30 and 32 of the horn.

As best shown in FIGURE 2, these irises 56 extend from the convexly-curved inner surfaces 40 of the horn to the concavely-curved peaked surfaces 41 of the separators 42, in a plane *a* coincident with the axis of the adjacent curved surface 40.

As best shown in FIGURE 4, the outer edges of the plates which form the irises 56 are flush with the shorter sidewalls of the two branches of the horn . In one illustrative system, the irises are formed of sheet aluminum 0.142 inch thick and extend transversely into the guide for a distance of 1⅝ inches, leaving a space of 6.50 inches between their inner edges. The irises 56 introduce inductive susceptance into the system. Their purpose, in general terms, is to invert the order of the admittance coordinates of the feed system as measured in the plane of the irises.

This effect can best be understood by reference to the Smith chart plots of admittance coordinates as set forth in FIGURES 6 and 7. FIGURE 6 shows, in the area designated A, a plurality of admittance coordinates measured at spaced frequencies over the entire frequency band in which the feed system is to be used, the measurement being made in the plane *a* (FIGURE 3) which the irises 56 will occupy, but before addition of the irises. The small circles in the group A, which represent the admittance coordinates corresponding to the various frequencies, are marked to indicate the frequencies which they respectively represent, ranging from 750 to 950 megacycles in steps of approximately 30 megacycles. As may readily be understood by those familiar with this type of chart, all of these admittance coordinates have capacitive susceptance components of the same order of magnitude, and the standing wave ratios, as measured over this band of frequencies, are also of the same general order of magnitude. Thus, the admittance coordinates over the entire frequency band are closely "bunched." It is important that the irises 56 be located sufficiently close to the apertures 46 that the admittance coordinates are not spread too widely apart—in other words, that their respective vectors are substantially in phase.

As is well known, as the reference is moved back along the waveguide in a direction toward the generator and away from the load, the admittance coordinates as measured at the various frequencies move in a clockwise direction in a generally circular path centered about the point O of the chart, representing a normalized admittance of 1 (that is, an admittance equal to the characteristic admittance of the waveguide), with the radius of the circle being equal to the reflection coefficient. The circles in the group generally designated B represent the admittance coordinates as measured at an arbitrary reference plane *b* (FIGURE 3) which is spaced along the waveguide in the direction of the generator through a distance from the irises 56 corresponding to approximately one-quarter wavelength.

The effect of shifting the reference plane is greater at the higher frequencies than at the lower frequencies, because the distance through which the plane is shifted is greater in proportion to the wavelengths of the higher frequencies than those of the lower frequencies. Thus, the admittance coordinates as measured at the higher frequencies move clockwise through a greater angle than do the coordinates as measured as the lower frequencies. Thus, as the reference plane is shifted to *b*, the admittance coordinates become spaced apart in a generally curved line in which the high frequencies "lead"—that is, the coordinates as measured at the higher frequencies are more advanced in a clockwise direction than the coordinates as measured at the lower frequencies.

The addition of the irises 56 and separators 54 (FIGURE 2) has the composite effect of introducing into the feed system net inductive susceptances of sufficient magnitude to give all of the admittances, as measured at plane *a* over the entire frequency band, susceptance components which are inductive rather than capacitive.

This will shift the admittance coordinates, as measured at plane *b*, from the positions indicated at B in FIGURE 6, to the positions shown at B′ in the expanded chart of FIGURE 7. As may be seen, this shift has the effect of inverting the order of the respective coordinates so that the low frequency coordinates now "lead" in the clockwise direction.

If the reference plane is shifted still further back along the waveguide in the direction of the generator, all of the coordinates will move generally arcuately in a clockwise direction about the point O on the chart, the high frequency coordinates moving through a greater angle than the low frequency coordinates. Thus, a point can be found at which the higher frequencies will "catch up" with the lower frequencies. This effect is illustrated by the coordinates in the group designated C in FIGURE 7, which represent the admittance cordinates as measured at the reference plane *c* (FIGURE 3) over the frequency band.

The substantial coincidence of the several coordinates indicates that the susceptance components of all the coordinates are of approximately the same magnitude, and, as may be seen, all of the susceptance components are positive in polarity, i.e. capacitive. It will also be noted that the group of coordinates *c* is centered about the circular line 62 corresponding to conductance components having a normalized value of 1—that is, a value equal to the characteristic conductance of the waveguide.

As may be seen in FIGURES 3 and 5, mounted in the waveguide at plane *c* is an inductive iris assembly 58 comprising a pair of iris plates 58*a* and 58*b* mounted with their outer edges flush against the inner faces of opposite short side walls of the waveguide 26. The iris 58 introduces into the waveguide at plane *c* an inductive susceptance of a magnitude sufficient to counteract the capacitive susceptance which is present at that point before addition of the iris. In the illustrative system previously refered to, the two iris plates 58*a* and 58*b* are each formed of sheet aluminum ⅛ inch thick and extend into the waveguide 26 a distance of 1⅛ inches, leaving a space of 7½ inches between their inner edges.

The effect of introducing this inductive susceptance, as illustrated in FIGURE 8, is to shift all of the admittance coordinates in a counterclockwise direction along the circular line 62 in the direction of the reference line 63 corresponding to zero susceptance. The inductive iris 56 has a greater effect on the susceptances as measured at the lower frequencies than at the higher frequencies. Thus, the lower frequencies tend to move farther in the direction of the base line than the higher frequencies. The inductive susceptance of the iris 58 is of sufficient magnitude to bring all of the admittance coordinates into approximate alignment with the reference line 63. Therefore, all of the admittances, as measured over the band of frequencies, are substantially pure conductances, without any substantial susceptance components, and their conductance components have a normalized value of the order of unity—that is to say, the admittance of the feed system as measured at plane C over the entire band of frequencies after addition of the inductive iris 58, is approximately equal to the characteristic admittance of the waveguide. This match of the feed system admit-

tance to the charcteristic admittance of the waveguide gives the electrical effect of a waveguide of infinite length, substantially eliminating reflection and affording a standing wave ratio not substantially greater than unity. Thus, as may be seen in FIGURE 8, a circle drawn about the origin O corresponding to the characteristic admittance of the waveguide, with a radius corresponding to a standing wave ratio of 1.2, will enclose all of the admittance coordinates of the feed system, as measured over the entire band of frequencies.

In many antennas, particularly of the parabolic reflector type, problems are introduced because of reflections from the parabola back into the apertures of the radiating horn. This reflected energy creates standing waves on the line, and has an adverse effect on the coherence or intelligibility of the signal—for example, it might create a "ghost" on a television signal or garble a radio teletype signal. According to the present invention, this problem is overcome by the use of a pair of reflector plates **64** and **66** (FIGURE 1). These plates are formed of sheet aluminum, with their front faces substantially planar for ease of manufacture, and they are cut to a circular shape. They are supported on the parabola **20** by means of brackets **68** which support the plates so that the surface at the center of each plate is substantially normal to a line intersecting the focus of the parabola **20**. Minute adjustments may be made in such positions to achieve the maximum radiation of energy from the reflector plates **64** and **66** back into the apertures **46** of the horn **24**. The spacing of the reflector plates forwardly of the parabola **20** is adjusted so that the energy reflected from the plate **60** back into the apertures **46** is 180° out of phase with the integrated energy reflected by the parabola **20** back into the apertures **46**, and the size of the plates **60** is so chosen that the amount of energy reflected from the plates **60** is equal to the amount of energy reflected from the parabola **20** into the apertures **46**.

In a typical antenna intended for use in the frequency range previously indicated, employing a parabolic reflector 30′ in diameter, with a focus of 9′ from the center of the front face of the parabola, the reflector plates have diameters of 22⅜″ and are spaced with their inner edges 11⅛″ from the axis of the parabola and 2$\frac{9}{16}$″ forward of the face of the parabola, and tipped inwardly so that their outer edges are 3¾″ forward of their inner edges.

Since the energy reflected from the plates **64** and **66** is equal and opposite to the energy reflected from the parabola **20** into the apertures **46**, it will exactly counteract the effect of the latter. Thus, the net reflection is zero, and the standing wave ratio of the system remains substantially unity.

It will thus be understood that the feed system disclosed provides an excellent impedance match between the antenna and the waveguide over the entire range of frequencies for which the system is designed.

It will therefore be understood that the present invention has accomplished the aforementioned and other obvious desirable objectives. It should be emphasized, however, that the particular embodiment of the invention which is shown and described herein is intended as merely illustrative rather than as restrictive of the invention and that various changes may be made in this embodiment in order to adapt it to varying conditions of use, without departing from the scope of the invention as defined by the appended claims.

We claim:

1. A feed system for an antenna operable over a broad band of frequencies, comprising a length of rectangular waveguide, at lease one aperture therein for radiation of radio frequency energy, a first reactance means electrically coupled to said waveguide at a point at which the admittance vectors of said feed system, as measured at a plurality of frequencies throughout said band, are of the same general angularity and all have susceptance components of a polarity opposite to that of said reactance means, the reactance of said reactance means being of a magnitude sufficient to give all of said admittance vectors, as measured after addition of said reactance means, susceptance components of the same polarity as that of said reactance means, and second reactance means associated with said waveguide at a point spaced from said first reactance means in a direction away from said aperture such distance that the admittances of said feed system over said band of frequencies, as measured at said point after addition of said first reactance means but before addition of said second reactance means, have normalized conductance components of the general order of unity, the reactance of said second reactance means being sufficient substantially to counteract the susceptance components of the latter said admittances and render said admittances, as measured after addition of said second reactance means, substantially pure conductancs of a normalized value of the general order of unitary.

2. A feed system for an antenna operable over a broad of frequencies, comprising a length of rectangular waveguide, at least one aperture therein for radiation of radio frequency energy, a first inductance means coupled to said waveguide at a point sufficiently close to said aperture that the admittance vectors of said feed system, as measured at a plurality of frequencies throughout said band in the absence of said first inductance means, all have capacitive components and are of the same general order of angularity, the inductive susceptance of said first inductance means being of a magnitude sufficient to render all of said admittances inductive, as measured after addition of said first inductance means, second inductance means associated with said waveguide at a point spaced from said first inductance means in the direction away from said aperture a distance sufficient that the admittances of said feed system at said frequencies, as measured in the absence of said second inductance means, have capacitive susceptance components, with normalized conductance components of the general order of unity, the inductive susceptance of said second inductance means being of a magnitude sufficient substantially to counteract the capacitive components of the latter said admittances, and render said admittances, as measured after addition of said second inductance means, substantially pure conductances of a normalized value of the general order of unity.

3. A rear feed system for a parabolic reflector-type antenna operable over a broad band of frequencies, comprising a length of rectangular waveguide, the output end of said waveguide being divided on its shorter dimension into two branches of equal size, a pair of rearwardly directed apertures, one in each of said branches, a first pair of inductive irises one mounted in each of said branches, each of said inductive irises being located at a point sufficiently close to the aperture in its respective branch that the admittances of said branch, as measured at a plurality of frequencies throughout said band in the absence of said first inductance means, all have capacitive components and are of the same general order of angularity, the inductive susceptance of said iris being of a magnitude sufficient to render all of said admittances inductive, as measured after addition of said iris, a third inductive iris mounted in said waveguide at a point spaced from said first pair of inductive irises in a direction away from said apertures a distance sufficient that the admittances of said feed system at said frequencies, as measured at the latter said point in the absence of said third inductive iris, have capacitive susceptance components, with normalized conductance components of the general order of unity, the inductive susceptance of said third inductive iris being of a magnitude sufficient substantially to counteract the capacitive components of the latter said admittances and render said

admittances, as measured after addition of said third inductive iris, substantially pure conductances of a normalized value of the general order of unity.

4. A rear feed system for a parabolic reflector-type antenna operable over a broad band of frequencies, comprising a length of rectangular waveguide, the output end of said waveguide being divided on its shorter dimension into two branches of equal size, a pair of rearwardly directed apertures, one in each of said branches, the inner wall of each branch being convexly curved in the shape of a right circular cylinder, a pair of cuspate separator members projecting from opposite short sidewalls of said waveguide where said waveguide divides into said branches, with the peaks of said separator members pointing in a direction back along said waveguide and substantially bisecting the short dimension of said waveguide, and with the peaked surfaces of said separator members being concavely curved about the same axis as said inner walls and being at all points substantially equidistant therefrom, a pair of inductive iris plates in each of said branches, said iris plates extending from opposite short sidewalls of said branch between said separator members and said inner wall along a plane substantially coincident with said axis, said irises and said separators being of such relative size as to render inductive the susceptance components of said admittances, as measured after addition of said irises and separators, another inductive iris mounted in said waveguide at a point spaced from said inductive iris plates in a direction away from said apertures sufficient that the admittances of said feed system at said frequencies, as measured in the absence of said other inductive iris, have capacitive susceptance components, with normalized conductive components of the general order of unity, the inductive susceptance of said other inductive iris being of a magnitude sufficient substantially to counteract the capacitive components of the latter said admittances and render said admittances, as measured after addition of said other inductive iris, substantially pure conductances of a normalized value of the general order of unity.

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CERTIFICATE OF CORRECTION

Patent No. 2,989,748 June 20, 1961

George J. Doundoulakis et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 22, after "broad" insert -- band --.

Signed and sealed this 10th day of April 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents