

May 19, 1959

E. DYKE
ANTENNA SYSTEM

2,887,683

Filed Dec. 22, 1952

3 Sheets-Sheet 1

FIG. 1

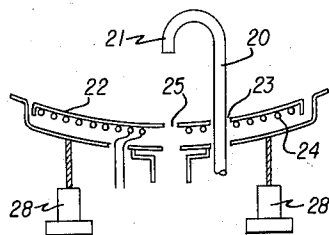


FIG. 2

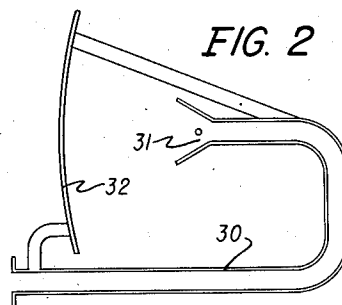


FIG. 3

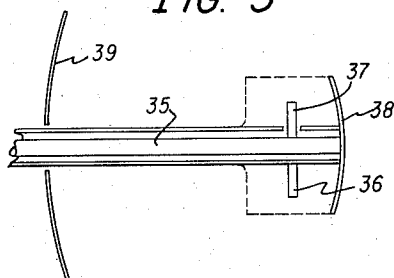


FIG. 4

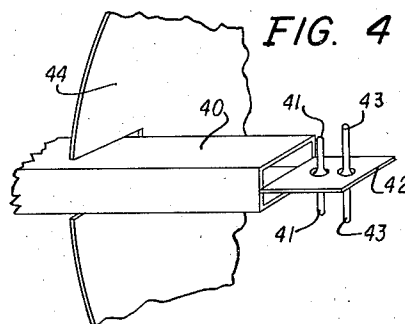


FIG. 8

FIG. 9

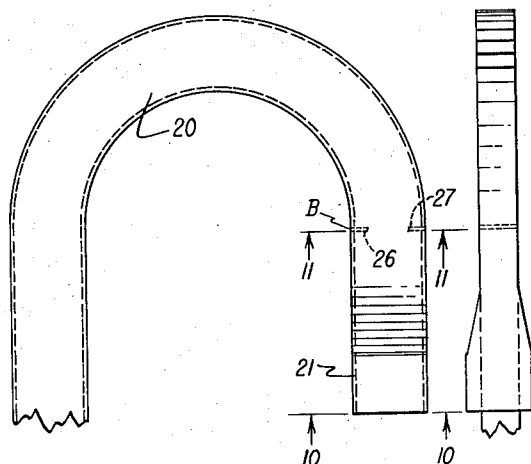


FIG. 10

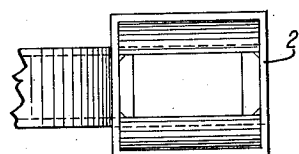
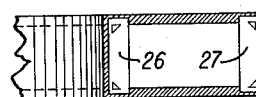


FIG. 11



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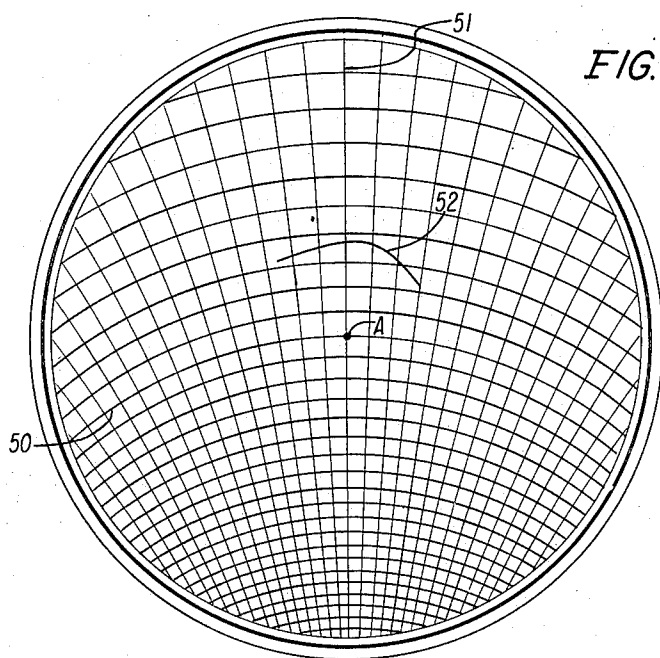


FIG. 5

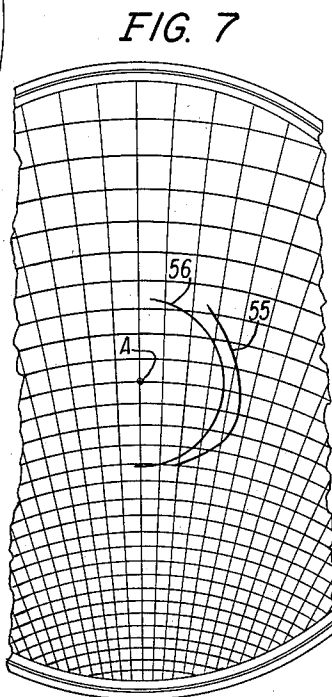


FIG. 7

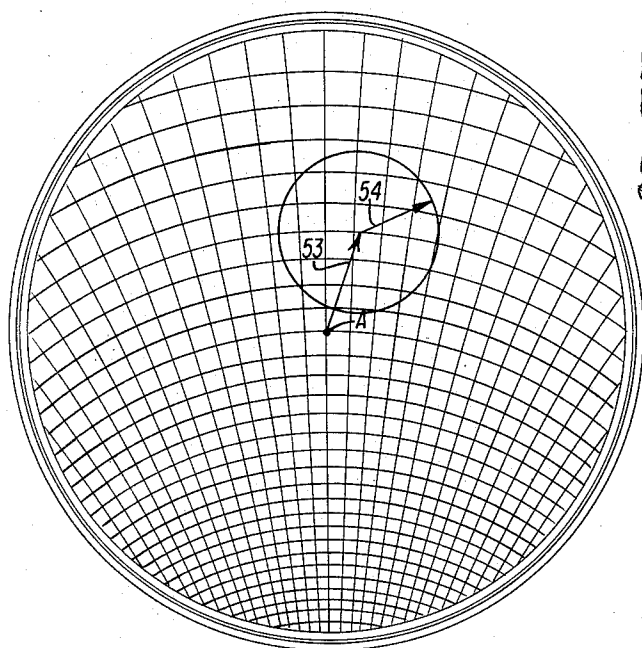


FIG. 6

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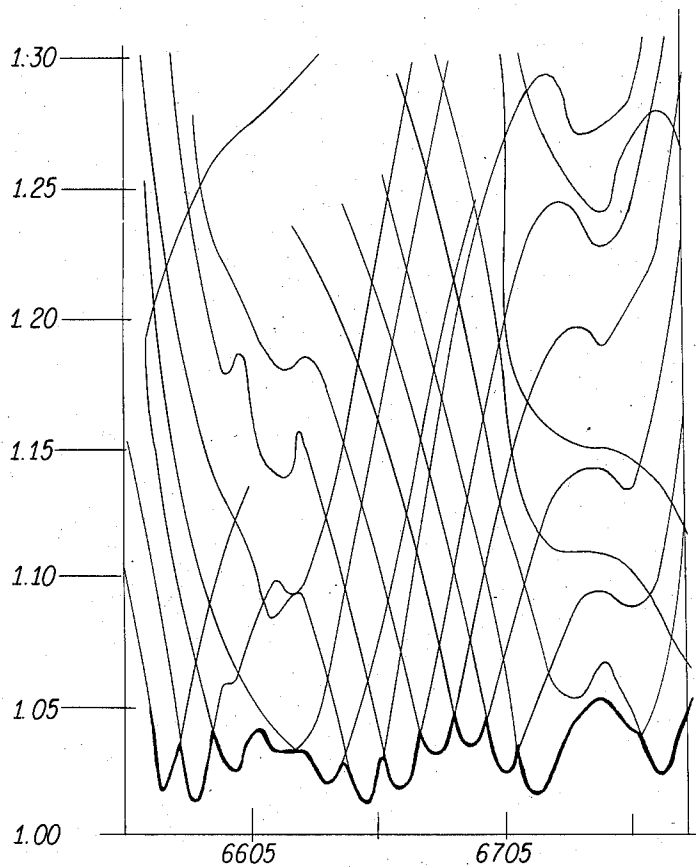
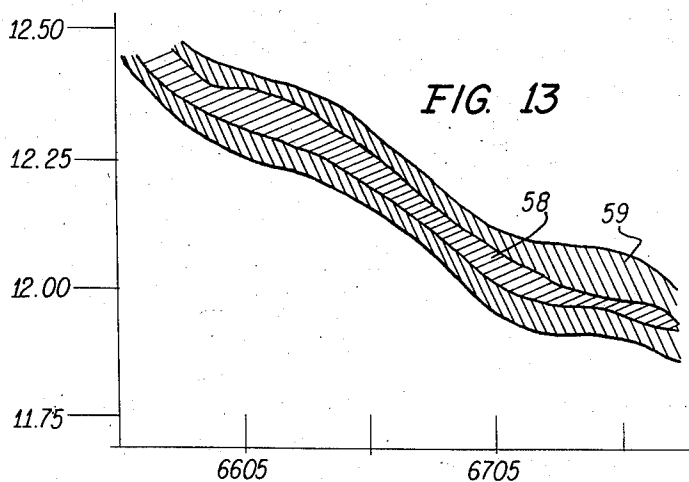
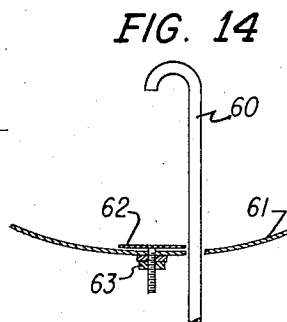
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ANTENNA SYSTEM

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2 Claims. (Cl. 343—781)

This invention relates generally to high frequency antennas, and more particularly to providing impedance matching in antenna systems used for microwave radio communications.

In a microwave radio communications waves may be conducted through wave guides and radiated therefrom into space. Such wave guides may be shaped at the end thereof to form a horn and the waves radiated therefrom may be formed in a beam by reflectors or the like. In order to concentrate the waves from a wave guide horn into a beam, parabolic reflectors are often used. In such systems the construction of the wave guide horn and of the reflector, and the cooperation therebetween is related to the frequency of the waves radiated thereby. This is because the impedance of the horn or other radiating element changes with frequency and the reflections back from the reflector into the radiating element cause further changes in impedance with frequency.

Mismatch of the antenna system adversely affects the operation of a transmitter coupled thereto. This is particularly true in a frequency modulation system as the susceptance of the antenna is reflected back into the transmitter to change the frequency thereof. Therefore, it has been necessary to provide impedance matching means for each different operating frequency. This increases the complexity of such systems and is therefore undesirable.

It is an object of the present invention to provide an improved microwave antenna structure which is suitable for use over a relatively wide range of frequencies.

Another object of the invention is to provide a method of adjusting an antenna structure including a wave radiating unit and a beam forming reflector so that the impedance thereof is substantially matched over a wide range of frequencies.

A further object of this invention is to provide impedance matching means for a wave guide horn of the hook feed type with a box aperture.

A feature of this invention is the provision of an antenna system including a wave radiating portion and a beam forming portion with the radiating portion being displaced from the beam forming portion by varying amounts depending upon the frequency to compensate for the changing impedances resulting from reflections of the waves at different frequencies.

A further feature of this invention is the provision of a method for matching the impedance of an antenna system including a wave radiating portion and a beam reflecting portion in accordance with which the radiating portion is de-focused with respect to the reflecting portion to introduce an impedance change which compensates for the impedance change resulting from reflections at different frequencies, with the extent of de-focusing being correlated with the operating frequency to provide an optimum impedance match over a wide frequency range.

A still further feature is the provision of a microwave antenna system having a wave guide horn and a reflector with the horn being of such configuration that the reflection coefficient of the horn in free space is substantially

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of the same magnitude as the reflection coefficient of the reflector into the horn over a frequency range, so that the impedance changes resulting from such reflection can be balanced out over the frequency range by proper spacing between the horn and reflector.

Another feature of this invention is the provision of a wave guide horn and reflector means including a fixed paraboloid and a movable vertex plate which may be adjusted to change the impedance characteristics to provide an impedance match over a range of frequencies.

Further objects and features and the attending advantages of the invention will be apparent from a consideration of the following description when taken in connection with the accompanying drawings, in which;

Fig. 1 illustrates in general an antenna system in accordance with the invention;

Figs. 2, 3 and 4 illustrate other antenna systems to which the invention may be applied;

Figs. 5, 6, and 7 are charts illustrating impedance characteristics of the radiating element and reflector;

Figs. 8, 9, 10 and 11 illustrate the construction of a horn suitable for use in the system of Fig. 1;

Fig. 12 is a curve illustrating the impedance matching obtained for a particular sample over a range of frequencies by variable spacing, each curve representing one value of spacing;

Fig. 13 is a curve illustrating the relationship of optimum spacing to frequency for this sample; and,

Fig. 14 illustrates a modification of the antenna system of Fig. 1.

In practicing the invention, an antenna structure is provided which is suitable for use in a microwave relay system. The structure includes a wave radiating unit, such as a wave guide horn, which directs transmitted waves and received waves from a distant transmitter. To concentrate the beam from and to the horn a reflector is provided which may generally be of parabolic configuration. Maximum gain is provided by the antenna system when the horn is at the focal center of the reflector and the horn so positioned provides satisfactory communication at a predetermined frequency for which it is designed. It has been found, however, that the same horn and reflector construction may be used over a wide range of frequencies by de-focusing the horn so that a phase shift is provided which compensates for the change in the impedance characteristics of the horn caused by the change in frequency, and results in an impedance match at the frequency involved. The reflection characteristics of the horn may be controlled by the design thereof so that the compensation is substantially perfect. This may be accomplished by choosing the dimensions of the horn and by the use of an iris or other device which changes the susceptance of the horn. This arrangement substantially eliminates the transmitter distortion which would be produced by impedance mismatch and introduces only slight loss in signal strength. The impedance of the reflector may be controlled by moving only a part thereof, such as a vertex plate, but this plate and its effect must be kept small in order to not adversely influence the antenna radiated beam and the side lobes.

Referring now to the drawings, in Figs. 1 to 4 inclusive there are illustrated four antenna systems wherein the teachings of the invention may be practiced. It is to be pointed out that these four systems are merely illustrative and various other systems may be used. The system of Fig. 1 includes a wave guide 20 having a horn 21 which is directed toward a reflector 22 of generally parabolic configuration. The wave guide extends through an opening 23 in the reflector. The reflector may include heating means 24 on the back side for melting ice and snow which forms on the reflector surface, with the water therefrom draining through an opening 25.

In Fig. 2 the wave guide 30 is connected to the horn 31 which is of such configuration that it clears the reflector 32 so that it is not necessary to provide an opening in the reflector for the wave guide. The system of Fig. 3 differs in that the feed to the antenna is through a coaxial line 35, with the waves radiating from the projecting elements 36 and 37. A double reflecting structure is provided including the back reflector 38 and the main reflector 39. In Fig. 4 the antenna is fed by a wave guide 40 with the waves being radiated from pin 41 which extends on either side of a plate 42 positioned at the open end of the wave guide 40. A second pin 43 may serve as a reflector for concentrating the waves from the pin 41 toward the main reflector 44.

The systems of Figs. 2, 3 and 4 are similar to that of Fig. 1 in that there is a wave radiating member which is positioned on the concave side of a curved reflector so that the waves from the radiating element are formed in a beam by the reflector. In most cases the reflector will be of parabolic configuration so that the waves which radiate outwardly from a source which is substantially at a point are concentrated into a beam.

Reference is now made to Figs. 5, 6 and 7 which disclose the characteristics of the antenna system. Fig. 5 is a Smith chart which illustrates the admittance of a horn type radiator such as illustrated in the system of Fig. 1. The generally horizontal curved lines indicate resistance and illustrate variations from the normal shown by the curved line 50. The generally vertical curved lines represent susceptance and vary plus and minus from the line 51 which extends directly vertical.

Point A of Fig. 5 represents the normalized unity impedance when the antenna is perfectly matched to a transmission line. The curve 52 represents the variation of the impedance of the horn, measured at a fixed reference plane, with respect to the normalized unit impedance for a variation of frequencies. The curve shown covers frequency varying from 5925 megacycles to 6425 megacycles.

In the antenna system as shown in Fig. 1 a second impedance is encountered which results from the reflection coefficient of the reflector. This is illustrated in Fig. 6 in which the coordinates represent the same quantities as in Fig. 5. The vector 53 represents the impedance of a horn, similar to that shown in Fig. 2, for a fixed frequency, and the vector 54 represents the impedance change resulting from reflection coefficient of the reflector for various frequencies. The reflections from the reflector into the wave guide horn are of different phase for different spacings therebetween and for different frequencies. Therefore, for a fixed frequency it is possible to rotate the vector 54 through a complete circle by changing the spacing between the horn and reflector. This means that the horn must be moved slightly from the electrical focus of the reflector, but this has been found to have no substantial adverse effect.

It is apparent from Fig. 6 that by positioning of the horn with respect to the reflector, so that the vectors 53 and 54 are in phase opposition, the impedance resulting from the reflection and the impedance of the horn will substantially cancel each other to provide a good impedance match. This impedance match will be more perfect as the vectors become more nearly the same size, it being obvious that if the vectors are exactly the same size, it will be possible to completely balance out the reflection coefficients by control of the phase thereof so that perfect impedance matching is provided.

Fig. 7 illustrates how the balancing of the reflection coefficients can be improved by construction of the horn and wave guide structure coupled therewith. In Fig. 7 curve 55 is the same curve as shown in Fig. 5 except that it has been rotated about the center point A so that it is entirely on the positive susceptance side of the Smith chart. This is accomplished by change of the position of the reference plane (by approximately $\frac{1}{4}$ wavelength

in this example). More specifically, the reference plane in Fig. 5 was 9.47 centimeters from the edge of the horn and in Fig. 7 it is moved to a position 10.41 centimeters from the edge of the horn.

When the curve is in the position as shown at 55 in Fig. 7, the position of the curve with respect to the point A can be changed by adding capacity or inductance to the horn by the use of an iris. The admittance of the horn with the iris can be controlled so that the combined reflection characteristic is substantially constant in magnitude. Curve 56 of Fig. 7 represents the use of an iris which reduces the reflection coefficient of the horn so that now the vectors 53 and 54 as shown in Fig. 6 will be substantially the same length. Accordingly, the impedance match resulting from proper horn spacing, so that the two coefficients are in opposite phase, will provide almost exactly the desired matched impedance. It may be noted from Fig. 7 that the curve 56 is substantially circular so that the reflection coefficient of the horn will match the reflection coefficient of the reflector over a wide frequency range and therefore the same structure may be used over a wide frequency range by properly positioning the horn and reflector so that the vectors are of opposite phase.

In Figs. 8 to 11 inclusive there is illustrated a horn structure which may be used in antenna systems such as illustrated in Fig. 1. It will be noted that the wave guide leading to the horn is restricted at point B by plates 26 and 27. These plates form an iris which is capacitive and provides the change in the reflection characteristics of the horn as shown by the curve 56 of Fig. 7. By providing restrictions along the long sides of the wave guide cross section, an inductive iris could be provided which would tend to shift the curve in the opposite direction. It is therefore seen that the reflection characteristics of the horn can be controlled by the construction thereof so that the impedance matching can be quite accurate.

In Fig. 12 there is shown a family of curves which illustrates the impedance of a horn and a reflector combination over a range of frequencies, with the horn and reflector positioned at various spacings. These curves cover spacings varying from 11.70 to 12.45 inches and used over a frequency range from 6560 to 6800 megacycles. The base line of the chart indicates a perfect impedance match with the curves showing the mismatch provided by particular spacings at various frequencies. The ordinate is shown in voltage standing wave ratio (VSWR) which is a measure of variation of impedance from the optimum value. The lower envelope shown by heavy line indicates the best impedance match which can be obtained by the most advantageous spacing for the particular frequency for this particular experimental sample. It will be apparent that very good impedance matching characteristics may be provided over a wide band of frequencies by selecting the spacings for providing the best impedance match. It will be noted that the VSWR values are 1.05 or less for all frequencies. Such values provide highly satisfactory operation with very little distortion. The curves of Fig. 12 are all taken with the same antenna structure having an iris as indicated in Figs. 8, 9 and 10.

Fig. 13 illustrates the horn and reflector spacing which provides best impedance matching over the same range of frequencies as in Fig. 12 (6560 to 6800 megacycles). The cross hatched interior portion 58 of the curve represents spacings which provide very close impedance matching wherein the VSWR is 1.05 or less. The cross hatched outer section 59 represents spacings which are usable providing a VSWR of 1.10 or less, but the match at such spacings is not as perfect as for the spacings represented by the sections 58. It is to be noted that the variation of the spacing, although not precisely linear with frequency, is such that the lower the frequency, the greater the spacing should be. It will be apparent from a con-

sideration of Figs. 12 and 13 that at the point around 6725 to 6750 megacycles the antenna provides the poorest impedance match. However, even at this frequency, the match may be satisfactory for an intended purpose.

In Fig. 14 there is illustrated an antenna system which is generally similar to that of Fig. 1, except that the reflector means includes a vertex plate, the configuration and position of which affects the impedance of the antenna. In this figure the wave guide horn 60 directs the waves on the reflector means which includes a large fixed reflector 61 which may be of parabolic configuration and a movable center portion 62 generally called a vertex plate. The vertex plate may be circular and curved to conform to the curvature of the center portion of the parabolic reflector, or may be flat. Adjustable means 63 is shown providing for adjustment of the position of the vertex plate 62. The position of the vertex plate with respect to the horn adjusts the reflection coefficient in somewhat the same manner as adjustment of the position of the entire reflector as set forth above. Accordingly, by properly positioning the vertex plate the antenna impedance match over a range of frequencies can be improved.

It is therefore seen that by proper construction of the radiating element and by proper spacing of the radiating element with the reflecting member, good impedance matching can be provided over a wide range of frequencies by a single construction. In a construction as shown in Fig. 1 the reflector may be mounted on adjustable supports 28 so that the spacing between the horn and the reflector can be very easily and accurately adjusted to provide the desired spacing for best impedance matching at any particular frequency within the frequency range. Therefore, the equipment may be standardized and the construction may still be quite simple. In a construction as shown in Fig. 14 it is necessary to move only a portion of the wave reflecting means, that is, the vertex plate.

In addition to the advantage of standardization of the equipment the matching system in accordance with the invention is effective to retain the bandwidth at any operating frequency. The structure may be used satisfactorily with a horn of the hook feed type with box aperture without a de-icer since all of the parts are exposed to the atmosphere. Great economy is provided as compared to pressurized feed lines which require aperture windows and many extra parts such as gaskets and the like. Further, the adjustment to provide the optimum conditions is not critical and therefore is superior to the use of ordinary tuning screws since such screws are ordinarily adjusted with instruments to provide best results.

It is to be pointed out that the same factors involved in the antenna structure of Fig. 1 are also applicable in the structures of Figs. 2, 3 and 4 and in other known antenna structures. In each of these cases the reflection coefficient of the horn alone can be controlled by the specific construction of the radiating elements, and the complex reflection coefficient of the reflector can be adjusted in magnitude by the antenna system dimensions

and in phase by the precise focal spacing to provide compensation so that almost perfect impedance matching is provided over a wide range of frequencies.

Although certain embodiments of the invention have been disclosed which are illustrative thereof, it is obvious that various changes and modifications can be made therein without departing from the intended scope of the invention as defined in the appended claims.

I claim:

1. An antenna system including in combination, fixed wave guide horn means, wave reflector means positioned with respect to said wave guide horn means for directing the waves therefrom into a concentrated beam, said wave reflector means being integral and of parabolic configuration and having an electrical focus point, said reflector means reflecting a part of the waves into said wave guide horn means, and adjustable mounting means for said wave reflector means for moving the same in a direction toward and away from said horn means, said wave guide horn means having a first impedance which varies with frequency, the reflections from said wave reflector means into said wave guide horn means producing in effect a second impedance which varies with frequency and with the spacing between said wave reflector means and said wave guide horn means, said wave guide horn means being constructed so that the variations of said first impedance are of substantially the same amplitude as the variations of said second impedance for a given change in frequency, said mounting means being adjusted for any frequency within a range of frequencies to position said integral wave reflector means so that said focal point thereof is spaced from said wave guide horn means, with the spacing between said wave guide horn means and said wave reflector means being selected so that said second impedance is substantially in phase opposition with said first impedance, so that the impedance variations of said wave guide horn means and that of said wave reflector means substantially compensate for each other.

2. The antenna system in accordance with claim 1 wherein said wave guide horn means includes an iris for affecting the impedance variations of said wave guide horn means.

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