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(54) Dual reflector microwave antenna.

(57) A microwave antenna which comprises a paraboloidal main reflector (10); a subreflector (13) located between the main reflector (10) and the focal point (F) of the main reflector (10) and forming a reflecting surface which is shaped symmetrically about the center thereof, the central portion of the reflecting surface sloping axially away from the main reflector (10) at a rate which reduces as the radius of the subreflector (13) increases, the radially outer portion of the subreflector (13) sloping axially toward the main reflector (10) at a rate which increases as the radius of the subreflector (13) increases; and a feed horn (11) for transmitting microwave signals to, and receiving microwave signals from, the subreflector (13), the reflecting surface of the subreflector being positioned and dimensioned to intercept substantially all the energy launched through the feed horn (11) or reflected by the main reflector (10). The feed horn (11) is preferably a smooth-walled waveguide having an aperture diameter substantially equal to one wavelength of the midband signals propagated therethrough.

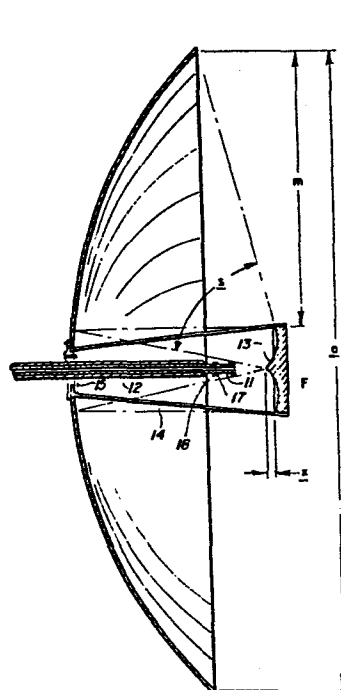


FIG. 1

DUAL REFLECTOR MICROWAVE ANTENNA

The present invention relates generally to microwave antennas and, more particularly, to dual-reflector microwave antennas.

It is a primary object of the present invention to
5 provide an improved dual-reflector microwave antenna which
can be efficiently and economically produced at a
relatively low cost, and yet, because it is a dual-
reflector antenna, permits most of the radio-frequency
equipment normally used with such antennas to be located
10 behind the main reflector dish. In this connection, a
related object of this invention is to provide such an
improved antenna which minimizes blockage of the antenna
aperture; facilitates alignment of the antenna; and
virtually eliminates the necessity of exposing service and
15 maintenance personnel to any safety hazards due to direct
exposure to the electromagnetic energy of signals being
transmitted and/or received by the antenna.

It is another object of this invention to provide
such an improved dual-reflector microwave antenna that
20 permits the use of small, smooth-walled feed horns.

It is still another object of this invention to
provide an improved dual-reflector microwave antenna which
can be used for transmission and/or reception of microwave
signals, in one or more frequency bands, with or without
25 orthogonally polarized signals in each frequency band.

A further object of this invention is to provide such
an improved dual-reflector microwave antenna which provides
good performance characteristics which can be tailored to
different desired combinations of VSWR, directive gain,
30 and RPE (radiation pattern envelope). A related object
is to provide such an antenna which also has a relatively
high efficiency.

Yet another object of the present invention is to
provide such an improved dual-reflector microwave antenna
35 which is capable of satisfying the latest RPE specifications

set by the U.S. Federal Communications Commission for earth station antennas.

In accordance with the present invention, there is provided a microwave antenna which comprises the combination of a paraboloidal main reflector; a subreflector located between the main reflector and the focal point of the main reflector and forming a reflecting surface which is shaped symmetrically about the center thereof, the central portion of the reflecting surface sloping axially away from the main reflector at a rate which reduces as the radius of the subreflector increases, the radially outer portion of the subreflector sloping axially toward the main reflector at a rate which increases as the radius of the subreflector increases; and a feed horn for transmitting microwave signals to, and receiving microwave signals from the the subreflector, the reflecting surface of the subreflector being positioned and dimensioned to intercept substantially all the energy launched through the feed horn or reflected by the main reflector.

The feed horn is preferably a smooth-walled waveguide having an aperture diameter substantially equal to one wavelength of the midband signals propagated therethrough.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:

Fig. 1 is a vertical section taken through the middle of a dual-reflector microwave antenna according to the present invention with the spacing between the feed horn and the subreflector, and between the subreflector and the focal point of the main reflector, enlarged for clarity;

Fig. 2 is an enlarged section of the subreflector portion of the antenna of Fig. 1;

Fig. 3 is an enlarged section of the feed horn portion of the antenna of Fig. 1; and

Fig. 4 is a full end elevation of the subreflector

portion of the antenna of Fig. 1.

Figs. 5 and 6 are E-plane and H-plane patterns, respectively, produced by an exemplary antenna embodying the invention, at a frequency of 12.25 GHz;

5 Figs. 7 and 8 are E-plane and H-plane patterns, respectively, produced by the same antenna that produced the patterns of Figs. 5 and 6, but at a frequency of 14.5 GHz; and

10 Figs. 9 and 10 are amplitude and phase patterns produced by a scaled version of an exemplary subreflector, like that illustrated in Figs. 1, 2 and 4, at a scaled frequency of 3.95 GHz.

Turning now to the drawings and referring first to Fig. 1, there is illustrated a dual-reflector antenna
15 comprising a paraboloidal main reflector dish 10, a primary feed horn 11 connected to and supported by a circular waveguide 12 extending along the axis of the dish 10, and a subreflector 13. (The term "feed" as
20 used herein, although having an apparent implication of use in a transmitting mode, will be understood to encompass use in a receiving mode as well, as is conventional in the art.) In the transmitting mode, the feed horn 11 receives microwave signals via the circular waveguide 12 and launches those signals onto the sub-
25 reflector 13; the subreflector reflects the signals onto the main reflector dish 10, which in turn reflects the signals in a generally planar wave across the face of the paraboloid. In the receiving mode, the paraboloidal main reflector 10 is illuminated by an incoming
30 planar wave and reflects this energy in a spherical wave to illuminate the subreflector 13; the subreflector reflects the incoming energy into the feed horn 11 for transmission to the receiving equipment via the circular waveguide 12.

35 As is conventional in dual-reflector antennas, the

subreflector 13 is located between the main reflector dish 10 and the focal point F of the paraboloidal surface of the main reflector. To support the subreflector 13 in this desired position, the subreflector is mounted on the large end of a dielectric (e.g., fiberglass) cone 14 fastened at its smaller end to a hub 15 fitted within a standard mounting ring 16 for the main reflector dish 10. The fiberglass cone 14 is relatively thin and introduces only a negligible amount of VSWR and pattern degradation into the antenna system. Alternatively, the subreflector can be supported by a tripod or a quadpod arrangement (each pod running from about the main reflector edge to the rear of the subreflector). The subreflector 13 is positioned and dimensioned to intercept substantially all the energy launched through the feed horn 11 in the transmitting mode, and substantially all the incoming energy reflected by the main reflector 10 in the receiving mode, while at the same time minimizing blockage of the aperture of the main reflector 10. (In the present example the ratio of subreflector to main reflector diameter, for example, is about 0.05). As in most dual reflector antennas, the subreflector preferably intercepts at least 98% of the energy from the feed horn and, to achieve this result, the subreflector has a diameter of about nine wavelengths at the midband frequency and is positioned very close to the feed horn.

The feed horn 11 is preferably a smooth-walled circular waveguide having an inside diameter equal to approximately one wavelength of the midband signals propagated therethrough. Such a feed horn launches signals onto the subreflector with substantially equal E and H plane patterns, and is extremely economical to manufacture. The axial length of the horn 11 is not critical since it is simply a continuation of the circular waveguide 12. The horn 11 and the waveguide

12 have the same inside diameter and are connected by a pair of coupling flanges 17 and 18 fastened together by a plurality of screws 19.

5 To suppress radiation (in the direction of the main dish) from the external surface of the horn 11, the mouth or free end of the horn is surrounded by a quarter-wave choke 20 comprising a short conductive cylinder 21, concentric with the horn 11, and a shorting ring 22. The inner surface of the cylinder 21 is spaced away from the
10 outer surface of the horn 11 along a length of the horn about equal to a quarter wavelength from the end of the horn, and then the cylinder 21 is shorted to the horn 11 by the ring 22 to form a quarter-wave coaxial choke which suppresses current flow in the outer surface of the horn.

15 If desired, a flared feed horn may be used in place of the straight horn in the illustrative embodiment, or a tapered waveguide section can be used between a straight horn of one diameter and a straight supporting waveguide of a different diameter.

20 In accordance with one important aspect of the present invention, the subreflector 13 forms a reflecting surface 30 which is shaped symmetrically about the center thereof, the central portion of the reflecting surface 30 sloping axially away from the main reflector 10 at a
25 rate which reduces as the radius of the subreflector increases, and the radially outer portion of the reflecting surface 30 sloping axially toward the main reflector 10 at a rate which increases as the radius of the subreflector increases. Thus, in the illustrative
30 embodiment the subreflector surface 30 slopes away from the main reflector 10 between the center of the subreflector and a radius r₁, and then slopes back toward the main reflector 10 from the radius r₁ out to the outer periphery of the subreflector. More specifically, from
35 the center of the subreflector out to the radius r₁, the

subreflector surface slopes away from the main reflector at a rate which decreases as the radius increases; then from the radius r₁ out to the periphery of the subreflector, the reflecting surface slopes toward the main reflector at a rate which increases as the radius increases. The end result is a subreflector surface with a concave radial cross-section.

As can be seen in Fig. 1, the center of the subreflector is preferably located closer to the plane a of the aperture of the main reflector 10 than is the outer periphery of the subreflector. That is, there is an axial offset x between the center and the outer periphery of the subreflector 13. The combination of this axial offset and the concave radial cross-sectional configuration of the subreflector results in substantially equal ray paths between the feed horn 11 and the main reflector 10 (via the subreflector 13) across the unblocked portion of the aperture of the main reflector, and minimal energy loss in the blocked portions of the apertures of both the main reflector and the subreflector. More particularly, the subreflector 13 reflects most of the energy from the feed horn 11 in a spherical wavefront within the annular sector s between the small central blockage caused by the feed horn 11 (or the subreflector 13, whichever is larger) and the periphery of the main reflector 10; and, similarly, the main reflector 10 reflects most of the energy from the subreflector in a planar wavefront within the annular region m between the outer edges of the subreflector 13 and the main reflector 10, i.e., outside the blockage of the subreflector 13. Thus, the blockages produced by the feed horn 11 and the subreflector 13 are small to start with (typically less than 5% of the total area of the main reflector aperture at frequencies of 12 to 14 GHz), and the configuration of the subreflector reduces the effect of those blockages even further.

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Moreover, this result is achieved while also achieving a relatively uniform distribution of electromagnetic field (in both amplitude and phase) across the unblocked portion of the aperture.

5 The antenna described is not only relatively simple and inexpensive to manufacture, but it also provides excellent performance characteristics. This antenna can be tailored to provide different RPE's, gains, and VSWR's for different applications. Any one of these performance
10 characteristics can be optimised, with only a relatively small downgrading of the other characteristics. In general, the trade-off in performance is between gain and VSWR or RPE.

15 Figs. 5 through 8 are far field patterns produced by an antenna like that illustrated in Figs. 1-4 but with a 3-inch tapered waveguide section inserted between a 3-inch horn 11 of WC940 waveguide and a 4.5 foot length of WC680 waveguide. The mouth of the feed horn was positioned one
20 inch from the center of the subreflector, and the center of the front of the subreflector was positioned 0.79 inch in front of the focal point of the main reflector. This antenna had a main reflector with a 15 foot diameter and a subreflector with an 8.86-inch diameter supported on struts rather than a dielectric cone. Figs. 5 and 6 are
25 E and H plane patterns taken at 12.25 GHz, and Figs. 7 and 8 are E and H plane patterns taken at 14.5 GHz. In each of these figures the expanded scale is for the expanded pattern, and the compressed scale is for the compressed pattern. The broken-line curves superimposed on Figs.
30 5-8 represent the U.S. Federal Communications Commission specification $(dB_1(\theta) = 32 - 25 \log_{10} \theta)$ for the maximum level of side lobes between 1° and 7° ; from 7° out, no more than 10% of the side lobes can exceed the specified level. The antenna tested satisfied all these criteria
35 at both 12.25 and 14.5 GHz, and also exhibited a narrow

main beam. The first side lobes were relatively high, which is characteristic of many dual-reflector antennas; if desired, the first side lobes can be reduced by using a slightly different subreflector shape, although this
 5 will reduce the gain of the antenna.

The directive gains of the antenna (including RMS surface degradations of both the main reflector and the sub-reflector) that produced the patterns of Figs. 5-8 were as follows:

10	<u>Freq.</u>	<u>E-PL</u>	<u>H-PL</u>	<u>Ave Dir.</u>
	12.25 GHz	53.69 dB	53.64 dB	*53.67 dB (67.6% efficiency)
	14.50 GHz	54.95 dB	54.74 dB	*54.85 dB (63.3% efficiency)

15 Return loss measurements indicated that the antenna had a VSWR in the range of 1.25 to 1.30 at both frequencies.

In another example an antenna like the one described above but with a 30 inch subreflector spaced 2.67 inches
 20 in front of the focal point of the main reflector, and with a flared feed horn with a 1.75 inch aperture, was tested at various frequencies ranging from 3.7 GHz to 4.4 GHz. The results are set forth in Table I.

The same subreflector, mounted on a fiberglass cone
 25 rather than struts was also tested at 3.95 GHz and produced the amplitude and phase patterns shown in Figs. 9 and 10. These are E-plane patterns; the H-plane patterns (not shown here) would be expected to be similar, particularly in view of the other test results described
 30 above. As can be seen in Figs. 9 and 10, the sub-reflector blockage extended out to about 16° from the center of the pattern, and the edge of the main reflector was located at about 74° . Both the amplitude pattern and the phase pattern were measured on a constant radius
 35 relative to the focal point of the paraboloid of the

main reflector. As can be seen in Fig. 9, the amplitude increased rapidly near the outer edge of the subreflector blockage, and then continued to increase at a slower rate across the major portion of the unblocked segment of the aperture, i.e., between the edge of the subreflector blockage and the periphery of the main reflector. At the periphery of the main reflector, the amplitude dropped off rapidly. This behaviour ensures a uniform wave over the unblocked main reflector aperture region m.

10 The phase pattern remained relatively constant across the unblocked portion of the aperture, as can be seen in Fig. 10.

 Scaled versions of the above antennas can be made to operate at other frequencies with comparable results.
15 Also, shrouds may be added to such antennas to reduce the main reflector spillover and improve the RPE in this region.

 While the invention has been described in connection with certain preferred embodiments, it will be understood
20 that it is not intended to limit the invention to those particular embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

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TABLE I

AVERAGE		E-PLANE				H-PLANE					
Gain (dB)	(%)	Gain (dB)	(%)	First S.L. (dB)	Spillover (dBs)	Cross Pol. (dB)	Gain (dB)	(%)	First S.L. (dB)	Spillover (dBs)	Cross Pol. (dB)
43.60	73.0	43.3	68.0	11.3	+3.5	32.5	43.9	78.0	13.7	+7.0	-----
44.12	78.0	44.2	79.5	13.5	+6.8	31.5	44.0	76.5	13.8	+6.4	33.0
44.41	77.2	44.5	78.9	14.2	+6.7	32.5	44.3	75.5	14.6	+7.3	40.5
44.85	75.6	45.0	78.2	15.0	+7.0	36.0	44.7	73.0	13.9	+8.5	35.0
45.0	74.6	45.1	75.9	14.9	+7.9	36.0	44.9	73.3	14.6	+8.6	34.2
45.33	76.8	45.2	73.9	14.9	+8.2	35.5	45.5	79.5	14.8	6.8	34.3

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CLAIMS

1. A microwave antenna comprising
a paraboloidal main reflector (10),
a subreflector (13) located between said main
reflector (10) and the focal point (F) of said main
5 reflector (10) and having a reflecting surface (30), a
feed horn (11) for transmitting microwave signals to, and
receiving microwave signals from said subreflector (13),
the reflecting surface (30) of said subreflector (13)
being positioned and dimensioned to intercept substantially
10 all the energy launched through said feed horn (11) or
reflected by said main reflector (10), characterised in
that said reflecting surface (30) is shaped symmetrically
about the center thereof, the central portion of said
reflecting surface (30) sloping axially away from said
15 main reflector (10) at a rate which reduces as the radius
of said subreflector (13) increases, and the radially
outer portion of said subreflector (13) sloping axially
toward said main reflector (10) at a rate which increases
as the radius of said subreflector (13) increases.
2. A microwave antenna as claimed in claim 1,
characterised in that said feed horn (11) is a smooth-
walled waveguide.
3. A microwave antenna as claimed in either preceding
claim, characterised in that the aperture of said feed
horn (11) has a width of about one wavelength at the
midband frequency.
4. A microwave antenna as claimed in any preceding claim,
characterised in that said feed horn (11) is supported by
a rigid waveguide (12) extending through the center of
said main reflector (10) and along the axis thereof.
5. A microwave antenna as claimed in any preceding claim,
characterised in that said subreflector (13) is supported
by a dielectric conical section (14) fastened to said main
reflector (10).

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6. A microwave antenna as claimed in any preceding claim, characterised in that said subreflector (13) is positioned and dimensioned to intercept at least about 98% of the energy from said feed horn (11).

7. A microwave antenna as claimed in any preceding claim, characterised in that the center of said subreflector (13) is closer to the plane (a) of the aperture of said main reflector (10) than the periphery of said subreflector (13).

8. A microwave antenna as claimed in any preceding claim, characterised in that the reflecting surface (30) of said subreflector (13) forms a smooth continuous concave curve between the center of said subreflector (13) and any point on the periphery of said subreflector (13).

9. A microwave antenna as claimed in any preceding claim, characterised in that said feed horn (11) launches signals onto said subreflector (13) with substantially equal E and H plane patterns.

10. A microwave antenna as claimed in any preceding claim, characterised in that said feed horn (11) is located on the axis of said main reflector (10) between said main reflector (10) and said subreflector (13) and has a VSWR of less than about 1.3 over the operating frequency band.

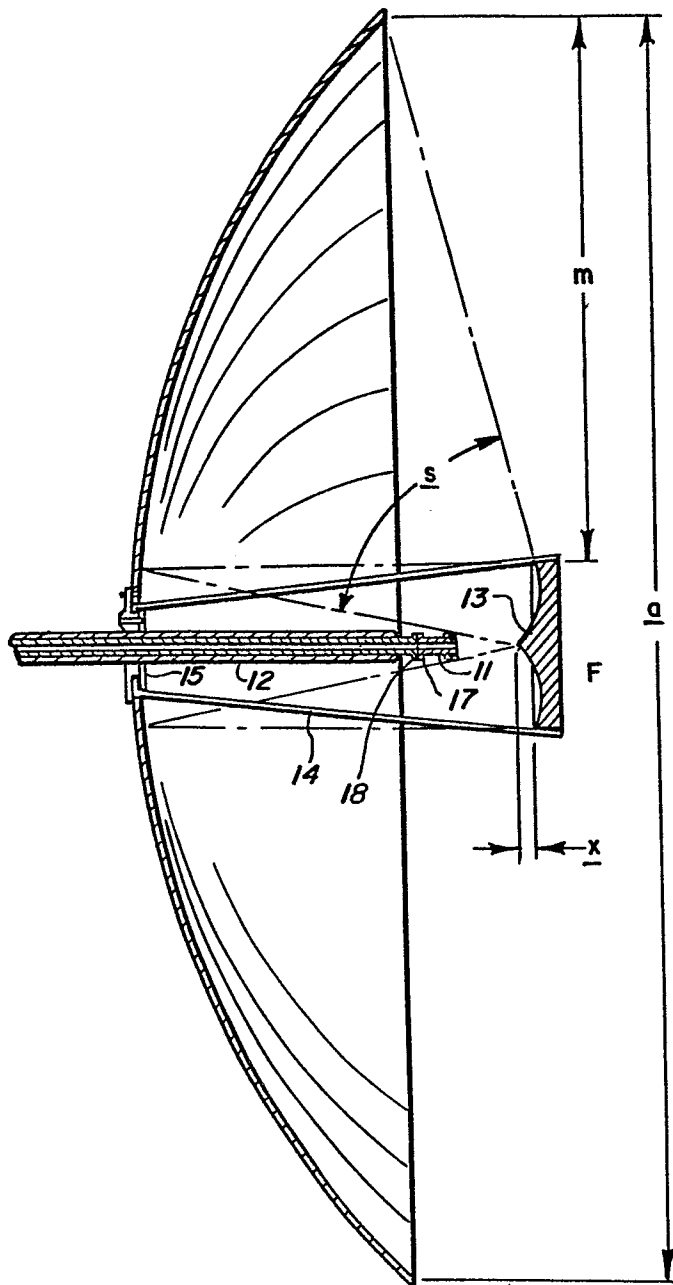


FIG. 1

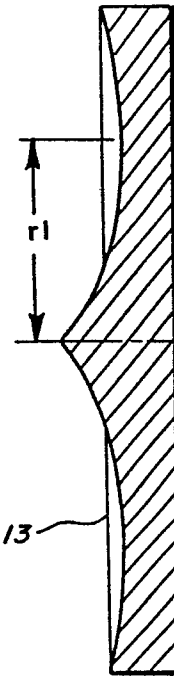


FIG. 2

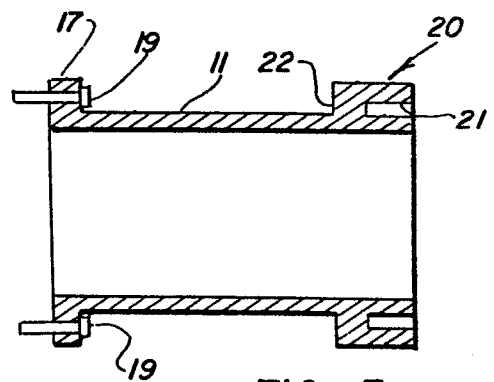


FIG. 3

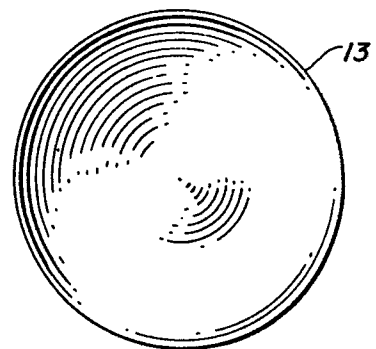


FIG. 4

FIG. 5

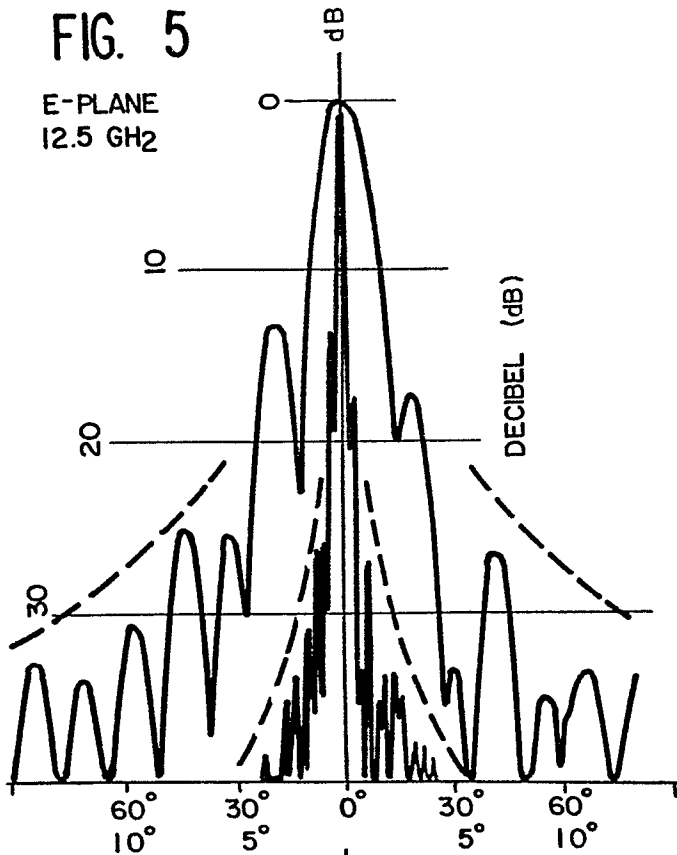
E-PLANE
12.5 GHZ

FIG. 6

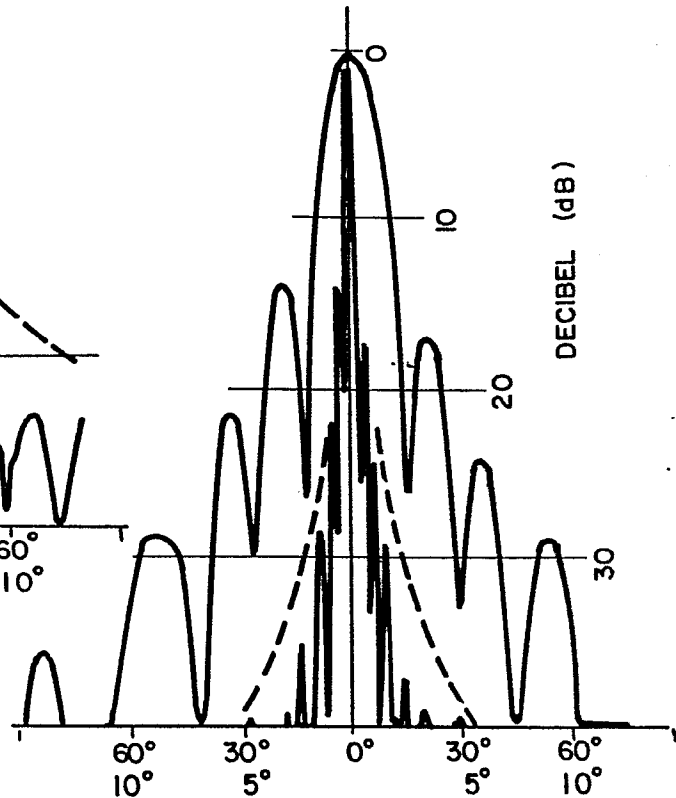
H-PLANE
12.25 GHZ

FIG. 7

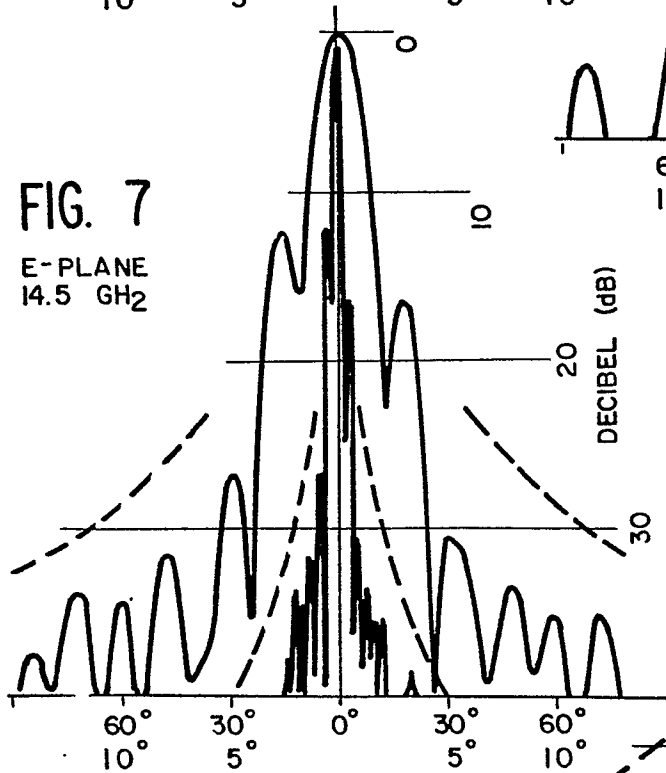
E-PLANE
14.5 GHZ

FIG. 8

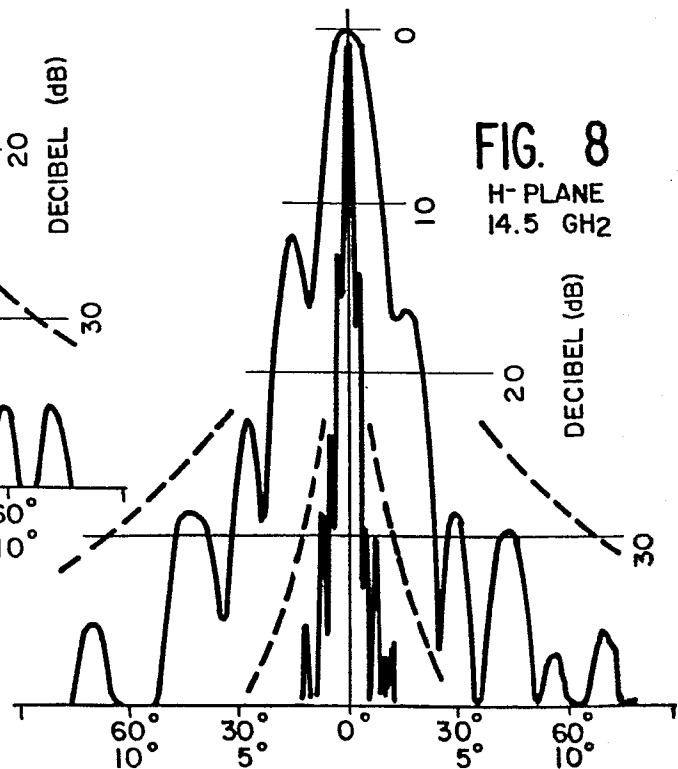
H-PLANE
14.5 GHZ

FIG. 9

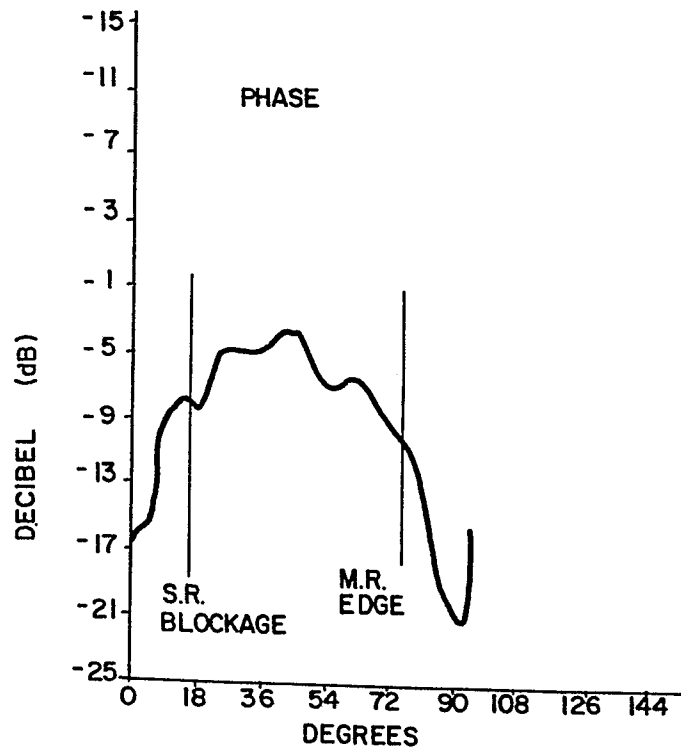
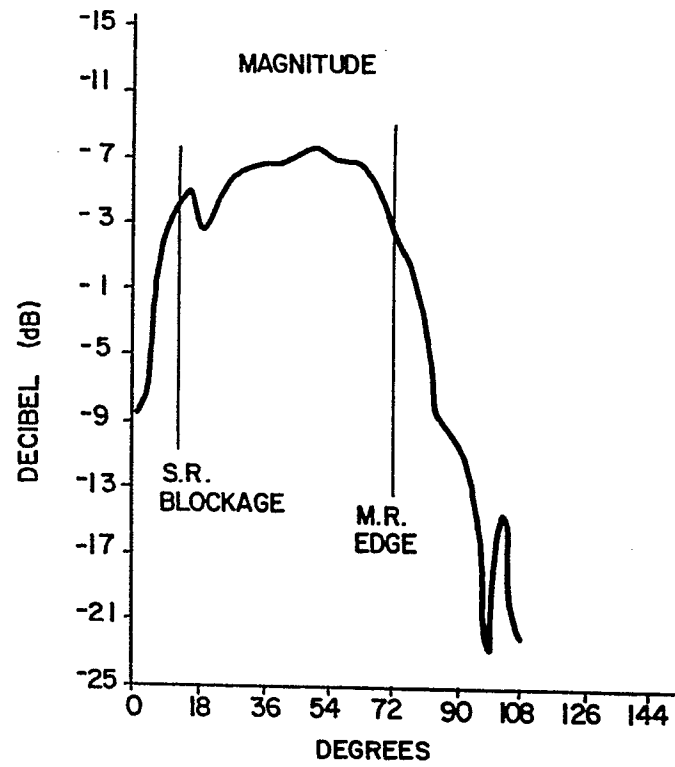


FIG. 10



European Patent
Office

EUROPEAN SEARCH REPORT

0102846

Application number

EP 83 30 5153

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X	US-A-3 983 560 (J.B. MacDOUGALL) * Figures 1, 5 *	1, 2, 4, 10	H 01 Q 19/19
A	FR-A-1 392 013 (G.R.P. MARIE) * Figure 1 *	1	
A	GB-A- 973 583 (POSTMASTER GENERAL OF THE POST OFFICE) * Figure 2; page 3, column 1, lines 17-23 *	5	
A	GB-A-1 218 351 (ELECTRIC & MUSICAL INDUSTRIES) * Figure 5 *	7	
A	US-A-3 241 147 (S.P. MORGAN) * Figure 4 *	8	TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
A	FR-A-1 407 753 (CIE GENERALE D'ELECTRICITE) * Figure 4 *		H 01 Q 19/18 H 01 Q 19/19
A	US-A-3 705 406 (J.C. FLETCHER) * Figure 3a *		
A	Patent Abstracts of Japan Vol. 4, no. 8, 22 January 1980 Page 100 E 166 & JP-A-54-148460		
The present search report has been drawn up for all claims			
Place of search BERLIN		Date of completion of the search 09-11-1983	Examiner BREUSING J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			