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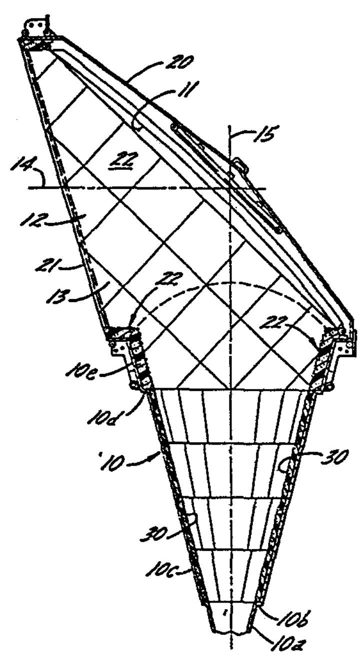
(54) Horn-reflector microwave antennas with absorber lined conical feed.

(57) A horn-reflector antenna comprising the combination of a paraboloidal reflector (11) forming a paraboloidal reflecting surface for transmitting and receiving microwave energy; a conical feed horn (10) for guiding microwave energy from the focus of the paraboloidal reflecting surface to the reflector (11); and a lower end portion (10a) of the inside surface of the conical horn (10) being formed by a smooth metal wall, the balance of the inside surface of the conical horn being formed by a layer of absorber material (30) on at least the opposed side walls of said conical horn (10) that effect the E-plane radiation pattern envelope (RPE) of a horizontally polarized signal, the surfaces of the metal wall (10a) and the absorber material (30) defining a single continuous conical surface, and the absorber material (30) increasing the Eigen value E and the spherical hybridicity factor (Rs) sufficiently to cause the E-plane and H-plane RPE's to approach each other. The exposed surface or the absorber material (30) inside said conical feed horn is preferably substantially flat.



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HORN-REFLECTOR MICROWAVE ANTENNAS WITH ABSORBER LINED CONICAL FEED

The present invention relates generally to microwave antennas and, more particularly, to reflector-type microwave antennas having conical feeds.

Conical feeds for reflector-type microwave antennas have been known for many years. For example, a 1963 article in The Bell System Technical Journal describes the selection of a conical horn-reflector antenna for use in satellite communication ground station (Hines et al, "The Electrical Characteristics of The Conical Horn-Reflector Antenna", The Bell System Technical Journal, July 1963, pp. 1187-1211). A conical horn-reflector antenna is also described in Dawson U.S. Patent No. 3,550,142, issued December 22, 1970. Conical feed horns have also been used with large parabolic dish antennas.

One of the problems with a smooth-walled conical horn reflector antenna is that its radiation pattern envelope (hereinafter referred to as the "RPE") in the E-plane is substantially wider than its RPE in the H-plane. When used in terrestrial communication systems, the wide beamwidth in the E-plane can cause interference with signals from other antennas. Also, when a smooth-walled conical horn is used as the primary feed for a parabolic dish antenna, its different beamwidths in the E and H-planes make it difficult to achieve symmetrical illumination of the parabolic dish.

In European Patent Publication No. 66455A there is described an improved horn-reflector antenna having a lining of absorber material within the conical feed horn. That antenna produces narrower E-plane RPE's, thereby bringing the E-plane and H-plane RPE's closer together, without significantly degrading other performance characteristics of the antenna.

It is a primary object of the present invention to provide an economical and effective way to achieve further narrowing of the E-plane RPE of a horn-reflector antenna having a conical feed, without significantly degrading the H-plane RPE or any other performance characteristic of the antenna. In this connection, a related object of this invention is to provide an improved conical feed which is capable of bringing the RPE's in both the E and H-planes even closer together.

It is another important object of this invention to provide an improved horn-reflector antenna which introduces only a small gain drop into the microwave system in which it is used.

It is yet another object of this invention to provide such an improved horn-reflector antenna which can be efficiently and economically fabricated.

Other objects and advantages of the invention will be apparent from the following detailed description and the accompanying drawings.

In accordance with one aspect of the present invention, certain of the foregoing objects are realised by a horn-reflector antenna in which the lower end portion of the inside surface of the conical horn is formed by a smooth metal wall, and the balance of the inside surface of the conical horn is formed by a layer of absorber material, the surfaces of the metal wall and the absorber material defining a single continuous conical surface. The absorber material increases the Eigen value E and the spherical hybridicity factor Rs sufficiently to cause the E-plane and H-plane RPE's to approach each other.

In accordance with another aspect of the invention, the cost of a horn-reflector antenna having an absorber lining in the conical feed horn is reduced by providing the absorber lining on only the opposed walls of the feed horn that affect the patterns of the antenna in the horizontal plane.

Brief Description of the Drawings

Fig. 1 is a front elevation, partially in section, of a horn-reflector antenna embodying the present invention;

Fig. 2 is a vertical section taken along line 2-2 in Fig. 1;

Fig. 3 is a perspective view of the antenna illustrated in Figs. 1 and 2, with various reference lines superimposed therein;

Fig. 4 is an enlarged end view of one of the pads of absorber material used to form an absorber lining in the conical section of the antenna of Figs. 1-3;

Fig. 5 is a vertical section, similar to Fig. 2, of a modified horn-reflector antenna embodying the present invention; and

Fig. 6 is a section taken generally along line 6-6 in Fig. 5.

While the invention will be described in connection with certain preferred embodiments, it will be understood 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 scope of the invention as defined by the appended claims.

Turning now to the drawings and referring first to Figs. 1 and 2, there is illustrated a conical horn-reflector microwave antenna having a conical section 10 for guiding microwave signals to a parabolic reflector plate 11. From the reflector plate 11, the microwave signals are transmitted through an aperture 12 formed in the front of a cylindrical section 13 which is attached to both the conical section 10 and the reflector plate 11 to form a completely enclosed integral antenna structure.

The parabolic reflector plate 11 is a section of a paraboloid representing a surface of revolution formed by rotating a parabolic curve about an axis which extends through the vertex and the focus of the parabolic curve. As is well known, any microwaves originating at the focus of such a parabolic surface will be reflected by the plate 11 in planar wavefronts perpendicular to the axis 14.

Thus, the conical section 10 of the illustrative antenna is arranged so that its apex coincides with the focus of the paraboloid, and so that the axis 15 of the conical section is perpendicular to the axis of the paraboloid. With this geometry, a diverging spherical wave emanating from the conical section 10 and striking the reflector plate 11 is reflected as a plane wave which passes through the aperture 12 and is perpendicular to the axis 14. The cylindrical section 13 serves as a shield which prevents the reflector plate 11 from producing interfering side and back signals and also helps to capture some spillover energy launched from the conical section feed. It will be appreciated that the conical section 10, the reflector plate 11, and the cylindrical shield 13 are usually formed of conductive metal (though it is only essential that the reflector plate 11 have a metallic surface).

To protect the interior of the antenna from both the weather and stray signals, the top of the reflector plate 11 is covered by a panel 20 attached to the cylindrical shield 13. A radome 21 also covers the aperture 12 at the front of the antenna to provide further protection from the weather. The inside surface of the cylindrical shield 12 is covered with an absorber material 22 to absorb stray signals so that they do not degrade the RPE. Such absorber materials are well known in the art, and typically comprise a conductive material such as metal or carbon dispersed throughout a dielectric material having a surface in the form of multiple pyramids or convoluted cones.

In keeping with the present invention, the lower end portion of the inside surface of the conical feed horn is formed by a smooth metal wall, and the balance of the inside surface of the horn is formed by a layer of absorber material, the surfaces of the metal wall and the absorber material defining a single continuous conical surface. Thus, in the illustrative embodiment of Figs.

1-3, the bottom section 10a of the conical feed horn 10 has a smooth inside metal surface. The balance of the inside surface of the conical horn 10 is formed by an absorber material 30, with the innermost surfaces of the metal section 10a and the absorber material 30 defining a single continuous conical surface. To support the absorber material 30 in the desired position and shape, the metal wall adjoining the lower horn section 10a forms an outwardly extending shoulder 10b at the top of the section 10a, and then extends upwardly along the outside surface of the absorber 30. This forms a continuous conical metal shell 10c along the entire length of the absorber material 30. At the top of the absorber material 30, the metal wall forms a second outwardly extending shoulder 10d to accommodate the greater thickness of the absorber material 22 which lines the shield portion of the antenna above the conical feed horn.

This recessed arrangement of the absorber material 30 permits further narrowing of the E-plane RPE and/or reductions in the gain drop of the antenna as compared with the structure shown in the aforementioned European Patent Publication No. 66455A. More specifically, for a given gain drop, the structure of the present invention permits the absorber material to be extended farther down into the throat of the conical feed horn 10, thereby further narrowing the E-plane RPE. On the other hand, for a given RPE (in other words, if it is desired to minimise the gain drop of the antenna), the metal surface of the section 10 can be extended farther up from the bottom of the conical feed horn so that the narrowness of the E-plane RPE is essentially the same as that produced by the structure described in European Patent Publication No. 66455A, but at the same time reducing the gain drop relative to that of the structure described in said copending Application.

The lining 30 may be formed from conventional absorber materials, one example of which is AAP-ML-73 absorber made by Advanced Absorber Products Inc., 4 Poplar Street, Amesbury, Maine. This absorber material has a flat surface, as illustrated in Fig. 4 (in contrast to the pyramidal or conical surface of the absorber used in the shield), and is about 3/8 inches thick. The absorber material may be secured to the metal walls of the antenna by means of an adhesive. When the exemplary absorber material identified above is employed, it is preferably cut into a multiplicity of relatively small pads which can be butted against each other to form a continuous layer of absorber material over the curvilinear surface to which it is applied. This multiplicity of pads is illustrated by the grid patterns shown in Figs. 1-3.

In accordance with a further aspect of the present invention, the absorber material 30 is provided only on the two diametrically opposed regions of the interior walls of the conical horn 10 that affect the patterns of the antenna in the horizontal plane. In terrestrial communication systems, the only significant patterns of the antenna are those taken in the horizontal plane, which is the Y-Z plane in Fig. 3. That is, for a horizontally polarized signal, the Y-Z plane is the E-plane, and the X-Z plane is the H-plane; for a vertically polarized signal, the Y-Z plane is the H-plane, and the X-Z plane is the E-plane. The portions of the conical feed horn 10 that principally affect the E-plane RPE (of a horizontally polarized signal) are the left and right hand walls of the horn through which the X-Y plane extends. Thus, as illustrated in Fig. 5, the absorber material 30 can be limited to diametrically opposed regions 40 of the inside surface of the feed horn. Restricting the absorber material in this manner reduces the cost of the antenna by reducing both the amount of absorber material required and the labour required to instal the absorber lining within the conical horn.

When the absorber material 30 does not extend around the entire circumference of the horn 10, the absorber can be recessed (flush mounted) into the horn wall in the two regions 40 so as to maintain a single continuous conical surface on the inside of the horn 10. Alternatively, the metal wall can form the entire conical surface, as in the structure described in the aforementioned European Patent Publication No. 66455A, and the absorber material 30 applied only to the limited regions 40 on the inner surface thereof. These constructions will not offer the full advantages of the recessed absorber arrangement illustrated in Figs. 1-3, but they reduce the manufacturing cost of the antenna.

As described in the aforementioned European Patent Publication No. 66455A, the absorber material 30 within the conical section 10 causes the field distribution within the cone to taper off more sharply adjacent to the inside surface of the cone, due to the fact that the wall impedance of the absorber lining tends to force the perpendicular E field to zero. Furthermore, it does this while abstracting only a small fraction of the passing microwave energy propagating through the cone.

There is a substantial difference in the taper or drop-off of the field distributions in the E and H-planes in the absence of the absorber material 30. With the absorber material 30 in the horn, the E-plane field distribution tapers off much more sharply, approaching that of the H-plane field, while there is only a slight degradation in the H-plane taper which brings it even closer to the E-plane field. In the theoretically ideal situation, the profile of the E-plane field distribution would coincide with that of the H-plane. In actual practice, this theoretically ideal condition can only be approximated, though the approximation is closer with the present invention than with the structure described in the aforementioned European Patent Publication No. 66455A.

Mathematically, the operation of the feed horn can be

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characterised as follows. If we let $E\theta$ (r,θ,ϕ) and $E\phi$ (r,θ,ϕ) be the polar and azimuthal components of electric field (with the origin at the apex of the cone, and θ and ϕ the polar and azimuthal angles, respectively) then, it can be shown that they can be mathematically expressed as:

(1) $E\theta\ (r,\theta,\phi) = A\ f(w)\ \cos\phi$

(2) $E\phi\ (r,\theta,\phi) = -A\ g(w)\ \sin\phi$

where

(3) $A = E_o \exp(-jkr)/kr$

E_o - Arbitrary driving constant, $k = 2\pi/\lambda$, λ = free space operating wavelength and the functions f(w) and g(w) are given by:

(4) $f(w) = J_1(X)/X + R_s J'_1(X)$

(5) $g(w) = R_s J_1(X)/X + J'_1(X)$

with

(6) $X = E\ \theta/\alpha_o$

(7) $J_1(X)$ = Bessel function of Order 1, argument X

(8) $J'_1(X)$ = Derivitive of $J_1(X)$ with respect to X

One then notes that the fields are uniquely known for the range of $0 \leq \theta \leq \alpha_o$ and $0 \leq \phi \leq 360^o$ if the parameters E (the Eigen value) and Rs (the spherical hybridicity factor) are known. These parameters are uniquely determined by the nature of the conical wall material.

<u>No Absorber</u>

For no absorber present one can show that E = 1.84 and Rs = O, thus giving:

(9) $f(w) = J_1(1.84\ \theta/\alpha_o)/(1.84\ \theta/\alpha_o)$

(10) $g(w) = J'_1(1.84\ \theta/\alpha_o)$

where amplitude distributions (in dB normalized to on axis, O = O) are shown as the solid lines in Fig. 6 (Note: E-plane = $-20\log_{10}$/ f(w)/f(w)/ w = O/ H plane = $-20\log_{10}$/ g(w)/g(w)/ w = O/).

<u>Perfect Absorber</u>

For the perfect absorber case (also a corrugated horn with quarter wave teeth) it can be shown that E = 2.39, Rs = +1, thus giving

(11) $f(w) = g(w) = J_o\ (2.39\ \theta/\alpha_o)$, perfect absorber

where the identity

(12) $J_1(X)/X + J'_1(X) = J_o(X)$

has been used, with $J_o(X)$ = Bessel function of order zero, argument X. One notes that the dB plot of (11) is virtually identical to that of (10), thus showing that the H-plane of the smooth wall and perfect absorber wall are virtually identical. Also, for this perfect absorber case, we then see that the E-plane is identical to the H-plane.

Actual Absorber

An actual absorber has E differing from the no absorber case of 1.84 and the perfect absorber case of 2.39, with a hybridicity factor, Rs, neither zero (no absorber) or unity (perfect absorber). In general both will be complex with finite loss in the absorber.

The RPE improvements described above can be achieved over a relatively wide frequency band. For example, the improvements described above for the antenna illustrated in Figs. 1-3 can be realised over the common carrier frequency bands commonly referred to as the 4 GHz, 6 GHz and 11 GHz bands.

Absorber materials are generally characterised by three parameters: thickness, dielectric constant, and loss tangent. The absorber used in the present invention must have a thickness and loss tangent sufficient to suppress undesirable surface (slow) waves. Such surface waves can be readily generated at the transition from the metallic portion of the inside surface of the cone wall to the absorber-lined portion of the cone wall, but these waves are attenuated by the absorber so that they do not interfere with the desired field pattern of the energy striking the reflector plate 11. The end result is that all the improvements described above are attained without producing any undesirable distortion in the field patterns.

The narrowing E-plane effect can, in fact, be achieved with zero loss tangent material, but with no loss the surface waves are not attenuated and the operating bandwidth is reduced. Consequently, it is preferred to use an absorber material with some loss.

Although the invention has been described with particular reference to a horn-reflector antenna, it will be appreciated that the invention can also be used to advantage in a primary feed horn for a dish-type antenna. Indeed, in the latter application the substantially equal main beam widths in the E and H planes provided by the absorber lined feed horn are particularly advantageous because they provide symmetrical illumination of the parabolic dish. The consequent approximately equal second patterns with their reduced sidelobes, over a wide bandwidth, and with negligible gain loss, are also important in this primary feed horn application.

Although the invention has thus far been described with particular reference to a conical feed horn feeding a reflector antenna, it can be appreciated that use of absorber lining on pyramidal (or other shapes) feed horns feeding a reflector antenna will produce the same desirable effect (i.e., narrowing of the E plane RPE to make it approximately equal to the H-plane RPE).

CLAIMS

1. A horn-reflector antenna characterised by the combination of

a paraboloidal reflector (11) forming a paraboloidal reflecting surface for transmitting and receiving microwave energy,

a conical feed horn (10) for guiding microwave energy from the focus of said paraboloidal reflecting surface (11) to said reflector, and

a lower end portion (10a) of the inside surface of said conical horn (10) being formed by a smooth metal wall, and the balance of the inside surface of said conical horn (10) being formed by a layer of absorber material (30) on at least the opposed side walls of said conical horn (10) that affect the E-plane RPE of a horizontally polarized signal, the exposed surfaces of said metal wall (10a) and said absorber material (30) defining a single continuous conical surface,

said absorber material increasing the Eigen value E and the spherical hybridicity factor (Rs) sufficiently to cause the E-plane and H-plane RPE's to approach each other.

2. A conical horn-reflector antenna as claimed in claim 1, characterised in that the exposed surface of said absorber material (30) inside said conical feed horn (10) is substantially un-profiled.

3. A conical horn-reflector antenna as claimed in either preceding claim, characterised in that said layer of absorber material (30) is provided only on the opposed side walls that affect the E-plane RPE of a horizontally polarized signal.

4. A conical horn-reflector antenna as claimed in any preceding claim, characterised in that said lining of absorber material (30) is recessed into the inside walls

of said feed horn (10) so that the surface of said absorber material (30) forms part of said single continuous conical surface inside said feed horn (10).

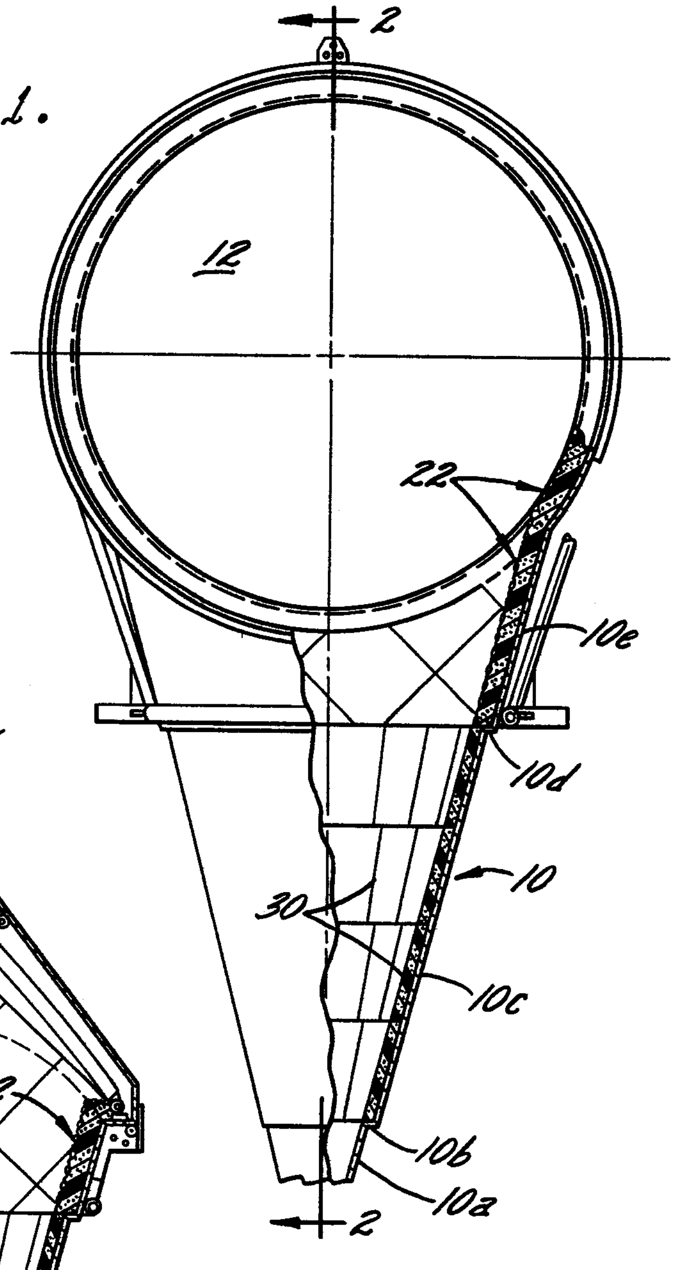
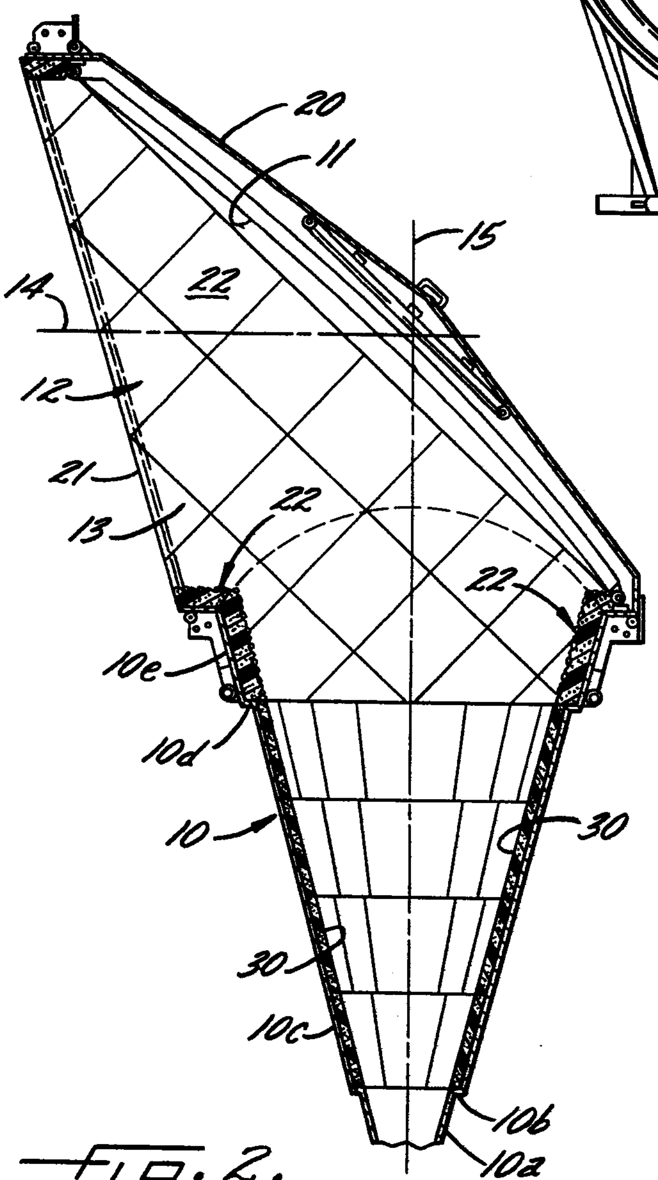

2
12
22
10e
10d
10
30
10c
10b
10a
2

Fig. 1.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10a

Fig. 2.

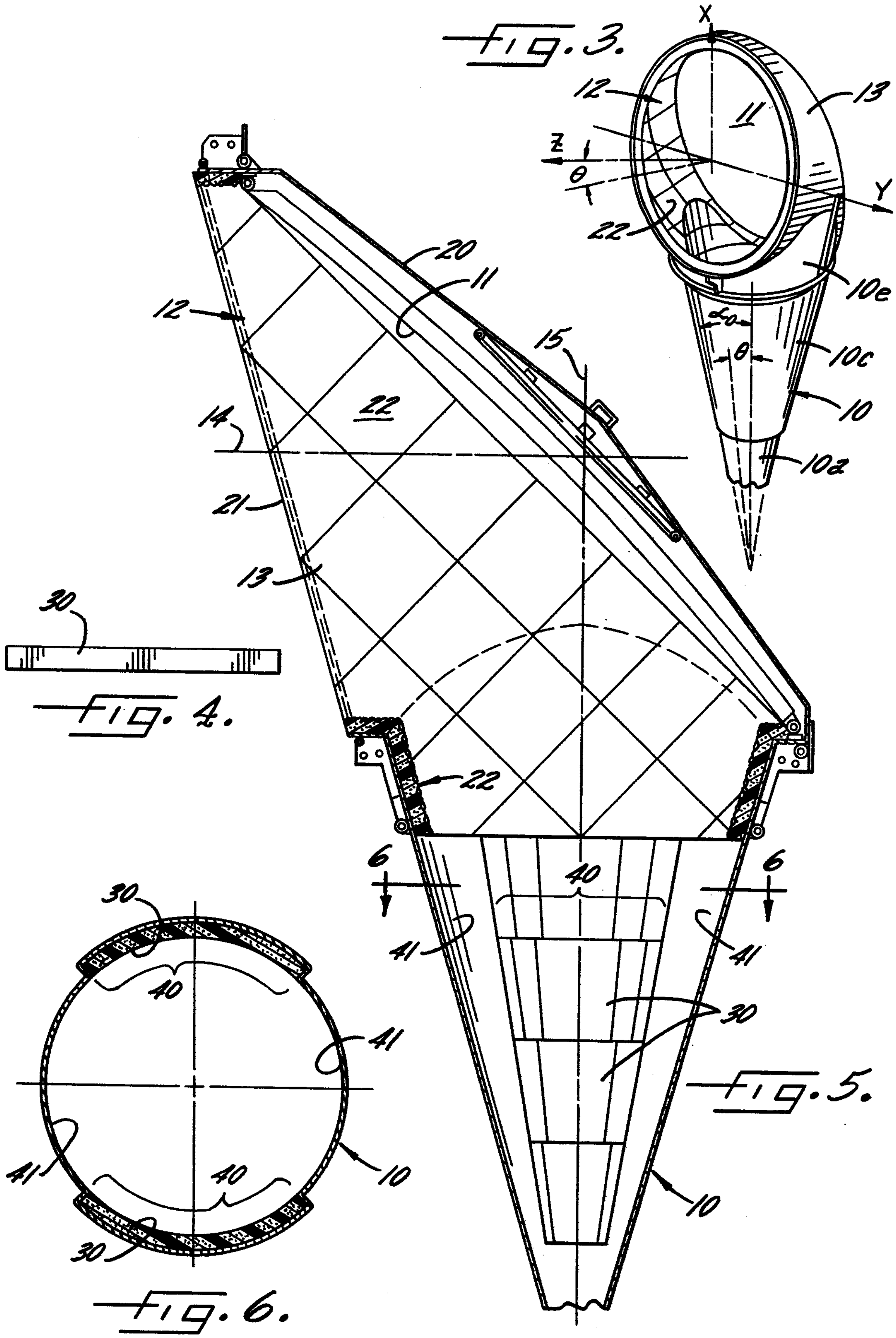

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

European Patent Office

EUROPEAN SEARCH REPORT

0140598

Application number

EP 84 30 6759

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.4)**
			H 01 Q 19/13 H 01 Q 17/00
Y	EP-A-0 066 455 (ANDREW CORP.) * Figure 2; page 4, line 20 - page 5, line 9; claim 1 * ---	1	
Y	EP-A-0 000 305 (THOMSON-CSF) * Figure 2; page 4, line 30 - page 5, line 8 * ---	1	
A	EP-A-0 072 191 (ANDREW CORP.) * Figure 5; page 4, line 33 - page 5, line 26; claims 2, 5, 8, 10 * ---	1	
A	US-A-4 012 738 (R.W. WRIGHT) * Figure 1; column 3, lines 55-65 * ---	2	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A	US-A-3 936 837 (H.P. COLEMANN et al.) * Figure 1; column 3, lines 21-23 * -----		H 01 Q 19/13 H 01 Q 17/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	10-01-1985	BREUSING J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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