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(54) Shaped reflecting antenna with sector coverage

(57) A shaped reflecting antenna with sector coverage that, located nearby a settlement, makes possible the distribution of the signal towards users positioned in the sector of antenna coverage for a maximum distance that depends on the power of the transmitting system. The purpose of the invention is to create an antenna able to radiate energy towards various users in such fashion as to assure a signal/noise ratio independent of the distance of the user from the sending antenna. It is then an antenna with a radiation pattern constant in azimuth for an angular sector chosen on the basis of the angle of view of the zone served, and shaped in the vertical plane in such fashion as to assure a signal/noise ratio independent of the distance of the user from the sending antenna. The reflector may have a grille structure. The invention finds its use in the field of microwave and millimeter-wave antennas, with shaped reflectors, and with sector coverage.

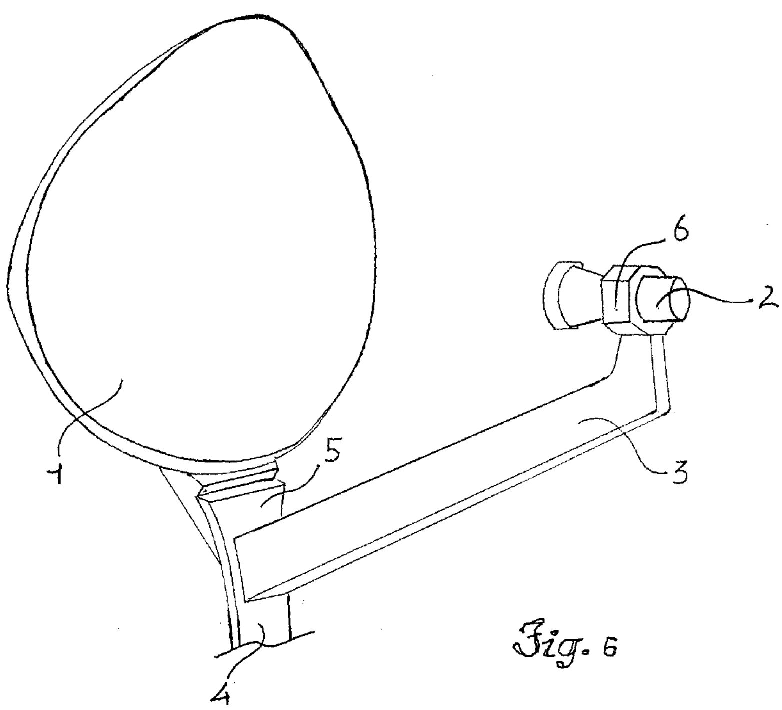

Fig. 6

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Description

The invention concerns a shaped reflector antenna with sector coverage that, set up nearby a settlement, makes possible the distribution of the signal towards the users located in the antenna's sector of coverage for a maximum distance that depends on the power of the transmitting system. The invention finds its use in the field of microwave and millimeter-wave antennas, with shaped reflectors, with sector coverage.

What is proposed with this invention is to create an antenna able to radiate energy towards its various users in such fashion that they enjoy an identical signal/noise ratio on reception, i.e. one that is independent of the distance between transmitting and receiving antennas. The subject then of the invention is an antenna having a radiation pattern constant in azimuth over an angular sector chosen on the basis of the angle of view of the served area, and shaped in the vertical plane in such fashion as to assure a signal/noise ratio independent of the distance between the two antennas of the link.

The originality of the antenna lies in the shaping, or configuration, of the reflector, which, rather than being concave, as in traditional single-reflector antennas, has its vertical sections vaguely concave, and its horizontal sections convex.

The shape of the surface of the shaped reflector is the result of a process of optimization based on a two-dimensional series expansion of the surface function, one that is not susceptible of representation in closed form with a simple algebraic expression.

The antenna in question was conceived essentially to solve such problems as that of the "last mile", which comes up in the laying of the national fiber optics network, where enormous difficulties of application are encountered. At issue is an alternative to the laying of fiber optics.

By the "last mile" is meant, as those concerned know, that territory in which it is necessary to carry out work to connect users to a central cable laid by any telephone company that does not concern itself with the connection of the central cable to the user, which may be, for example, a condominium apartment building. A telephone company undertakes to convert its systems up to the point that is within its jurisdiction; however, the condominiums that must permit the laying of the cables will generally not agree to undertake the expensive masonry works needed to modify their systems.

To give an example, in Venice the laying of fiber optics was forbidden for reasons having to do with the protection of artworks.

With the solution proposed here, all the work required for the last mile is saved.

One solution to the problem of the last mile is then a microwave connection between a transmitting station and the various surrounding users. But this antenna, conceived essentially to resolve the problem of the last mile, can find many other applications as well: for example, it could be used in private communications systems for data transmission. Analogously, it could find use too in military applications, for connections, whether improvised or stable, over distances of the order of tens of kilometers or even more.

To the inventor's knowledge, to date there are no similar solutions, or even analogous ones.

The invention is now to be discribed on the basis of a version currently preferred by the inventor, reference being made to the figures listed below:

Fig. 1 - Sector antenna as a whole set up in operating position.
Fig. 2 - Position of the antenna in a service area.
Fig. 3 - Schematic representation of the shaped reflector, as this results from calculations
Fig. 4 - Schematic representation of the reflector seen in profile.
Fig. 5 - Radiation pattern in the vertical plane.
Fig. 6 - Schematic representation of the antenna.
Fig. 7 - Radiation pattern in the horizontal plane.

On the basis of fig. 1, the sector antenna structure is composed of a shaped reflector 1 connected to boom 3 supporting the horn 2, the whole being supported by an element 5 that forms the interface with the tower 4 that supports the entire antenna, needed to so position the antenna as to enable it to "see" the buildingtops in the settlement of concern,and member 6 (shown inFig.6) for positioning the horn.

The shaped reflector 1 (fig. 4) displays a convexoidal configuration. By "convexoidal" is meant that it has a partly convex configuration. In order to better understand the shaping of the reflector, observe that the central horizontal section AB through the reflector is definitely convex. The central vertical section through the reflector is so delineated (fig. 4) as to present a parabolic section, one slightly deformed as follows:

Section EF is parabolic, and therefore concave, while section FD is convex in such fashion as to generate the shaping of the reflector and of the beam in the vertical plane.This aspect is to be considered original, especially when compared with earlier solutions, which instead all present a concave configuration.

This convexity of the central horizontal section through the reflector AB, is what enables the distribution of the signal with constant amplitude over a rather extensive angular sector. On the other hand, the central vertical section enables the distribution of the signal with an amplitude such as to assure the same signal/noise ratio whatever the "transmitting-antenna/user" distance, over the entire angular sector served.

Fig. 3 shows a graphic representation obtained from the computer on the basis of the method to be described further on. Fig. 2 furnishes an example of how the antenna is to be set up in the neighborhood of a settlement.

Figure 1 furnishes an overall view of the antenna installed. Fig. 5 is a radiation pattern in the vertical plane, shown in order to display the shaping of the radiated beam that is necessary to assure a constant signal/noise ratio, whatever the distance between user and sector antenna. Fig. 7 is a radiation pattern in the horizontal plane, included to show the uniformity of the radiation obtained in an angular sector of some 70 degrees of aperture.

The function describing the shaped reflector surface is not susceptible of being represented in closed form using a simple algebraic expression, but is found through an optimization process based on its two-dimensional series expansion, and thus has nothing in common with the functions describing radar antennas in which the optimization process develops but one of the two reflector sections, since the other is exclusively parabolic in form. It is important to bring out that the reflector can also be built with a gridded structure, so as to radiate, where such is needed, very low levels of cross-polarization.

The optimization process mentioned, needed to synthesize the function describing the antenna forming the subject of the patent application, starts with a quadric surface in such manner as to generate a defocussing of the reflector-horn optical system; this tends to generate a rather wide antenna beam, one such as to cover the angular sector served. To make this clear, the desired result can be obtained by the method described below.

An arbitrary surface g(x,y) can be represented with a Zernike series

$$g(x,y) = \sum_{m=-\infty}^{\infty} \sum_{n=|m|}^{\infty} b_{mn} V^{m}_{n}(x,y), \qquad (1)$$

which converges within a circle $x^2 + y^2 \leq 1$. The coefficients of expansion b_{mm} can be determined by the relation of orthogonality

$$\iint_{\text{unit circle}} V^{m*}_{n}(x,y)\, V^{m'}_{n'}(x,y)\, dxdy = \frac{\pi}{n+1} \delta_{mm'} \delta_{nn'} \qquad (2)$$

where

$$\delta_{ij} = \begin{cases} 1 & \text{for } i = j \\ 0 & \text{otherwise} \end{cases} \qquad (3)$$

In *(1)* the asterisk(*) denotes the complex conjugate. A special property of the Zernike polynomials is that they have a polar form:

$$V^{m}_{n}(x,y) = R^{|m|}_{n}(\rho)\, e^{jm\varphi} \qquad (4)$$

$$x = \rho \cos\varphi,\ y = \rho \sin\varphi, \qquad (5)$$

where R^{m}_{n} is a polynomial of nth degree in ρ.

Since the reflector surface is real, it is convenient to use the imaginary and real parts of $V^{m}_{n}(x,y)$

$$Z^m_n (x, y) = Re(V^m_n (x,y)) = R^{|m|}_n (\rho) \cos m\varphi \qquad (6)$$

$$U^m_n (x, y) = Im(V^m_n (x,y)) = R^{|m|}_n (\rho) \sin m\varphi.$$

It is clear that

$$Z_n^{-m} = Z_n^{m}, \qquad U_n^{-m} = -U_n^{m} \qquad (7)$$

so that only the functions Z and U with positive and zero values of m are needed in the expansion of a real function.

On the basis of the equations *(6)* it is seen that the first polynomials become:

$$\begin{aligned}
Z_0^0 (x,y) &= 1 & U_0^0 (x,y) &= 0 \\
Z_2^0 (x,y) &= 2(x^2+y^2)-1 & U_2^0 (x,y) &= 0 \qquad (8) \\
Z_1^1 (x,y) &= x & U_1^1 (x,y) &= y \\
Z_3^1 (x,y) &= 3x^3+3y^2x-2x & U_3^1 (x,y) &= 3x^2y+3y^3-2y \\
Z_2^2 (x,y) &= x^2-y^2 & U_3^2 (x,y) &= 2xy \\
Z_3^3 (x,y) &= x^3-3xy^2 & U_3^3 (x,y) &= 3x^2y-y^3
\end{aligned}$$

The polynomials Z_n^m are even functions of y, while the polynomials U_n^m are odd functions of y.

$$Z_n^m (x,-y)= Z_n^m(x, y) \qquad (9)$$

$$U_n^m (x,-y)= -U_n^m(x,y).$$

An arbitrary real function g(x,y) can be approximated by a truncated Zernike series as follows:

$$g(x,y) = \sum_{m=0}^{M} \sum_{n=m}^{N(m)} c_{mn} Z_n^m (x,y) + d_{mn} U_n^m (x,y) \qquad (10)$$

A special feature of the method used, for the antenna design in question, is the limited number of coefficients considered in the optimization process, that is, only Zernike polynomials of order less than ten need be considered.

The reflector has an overall shaping function, one that cannot be broken down into two separate shaping functions; it is thus the result of an overall two-dimensional shaping process.

In the following the values of the Zernike coefficients evaluated on designing a sector coverage antenna for a typical application are reported:

m	n	Z_n^m	U_n^m
0	0	0.166653645833E+01	0.000000000000E+00
0	2	0.251972546624E-01	0.000000000000E+00
0	4	0.180462575128E-02	0.000000000000E+00
0	6	0.635446823087E-02	0.000000000000E+00
1	1	-.999384348552E-04	-.272141265036E+00
1	3	0.108674637681E-03	0.174750487714E-01
1	5	0.664450600678E-04	0.789642304137E-02
1	7	0.731744904972E-04	0.224406667992E-03
2	2	0.140147303804E+00	-.265080933787E-03
2	4	-.251904878240E-01	-.203532197848E-03
2	6	0.489716606092E-02	-.874822147488E-04
3	3	0.155150046706E-03	-.223479722318E-01
3	5	-.151274166763E-03	-.577334818813E-02
3	7	-.131756954054E-03	-.369877622337E-02
4	4	-.535731911983E-02	0.513167042934E-04
4	6	0.899871263933E-02	-.846142192490E-04
5	5	0.250394161150E-03	0.448075001875E-02
5	7	0.151598961145E-03	-.372382381867E-02
6	6	0.579152387610E-02	-.192390416255E-03
7	7	-.354204500992E-03	-.440845011085E-02

Claims

1. Shaped reflector antenna with sector coverage, including (fig. 1) a shaped reflector (1) with circular aperture (boundary), a corrugated conical horn (2), a support boom (3) for the horn , a support member (4) and a mechanical interface (5) for fastening the reflector (1) to the support member (4), characterized by the fact that said reflector (1) has a definitely convex central horizontal section AB (fig. 4), while regarding the central vertical section the portion EF follows a parabolic curve and is therefore concave, while portion FD is convex.

2. Shaped reflector antenna with sector coverage, according to claim 1, characterized by the fact that the shaped reflector surface is obtained by means of an optimization process based on a two-dimensional series expansion of the function describing the surface (the function itself not being closed form); being said optimization process carried out by starting with a quadric surface able to generate a defocussing of the optics of the reflector that tends to generate a rather wide antenna beam, one such as to cover the angular sector served.

m	n	Z_n^m	U_n^m
0	0	0.166653645833E+01	0.00000000000E+00
0	2	0.251972546624E-01	0.00000000000E+00
0	4	0.180462575128E-02	0.00000000000E+00
0	6	0.635446823087E-02	0.00000000000E+00
1	1	-.999384348552E-04	-.27214126503 6E+00
1	3	0.108674637681E-03	0.174750487714E-01
1	5	0.664450600678E-04	0.789642304137E-02
1	7	0.731744904972E-04	0.224406667992E-03
2	2	0.140147303804E+00	-.265080933787E-03
2	4	-.251904878240E-01	-.203532197848E-03
2	6	0.489716606092E-02	-.874822147488E-04
3	3	0.155150046706E-03	-.223479722318E-01
3	5	-.151274166763E-03	-.577334818813E-02
3	7	-.131756954054E-03	-.369877622337E-02
4	4	-.535731911983E-02	0.513167042934E-04
4	6	0.899871263933E-02	-.846142192490E-04
5	5	0.250394161150E-03	0.448075001875E-02
5	7	0.151598961145E-03	-.372382381867E-02
6	6	0.579152387610E-02	-.192390416255E-03
7	7	-.354204500992E-03	-.440845011085E-02

3. Shaped reflecting antenna with sector coverage, according to claim 2 , characterized by the fact that the Zernike polynomials used are only those of rather small orders m and n: i.e., less than 10.

4. Antenna, according to claim 1, characterized by the fact that the reflector can also be made up from a gridded structure.

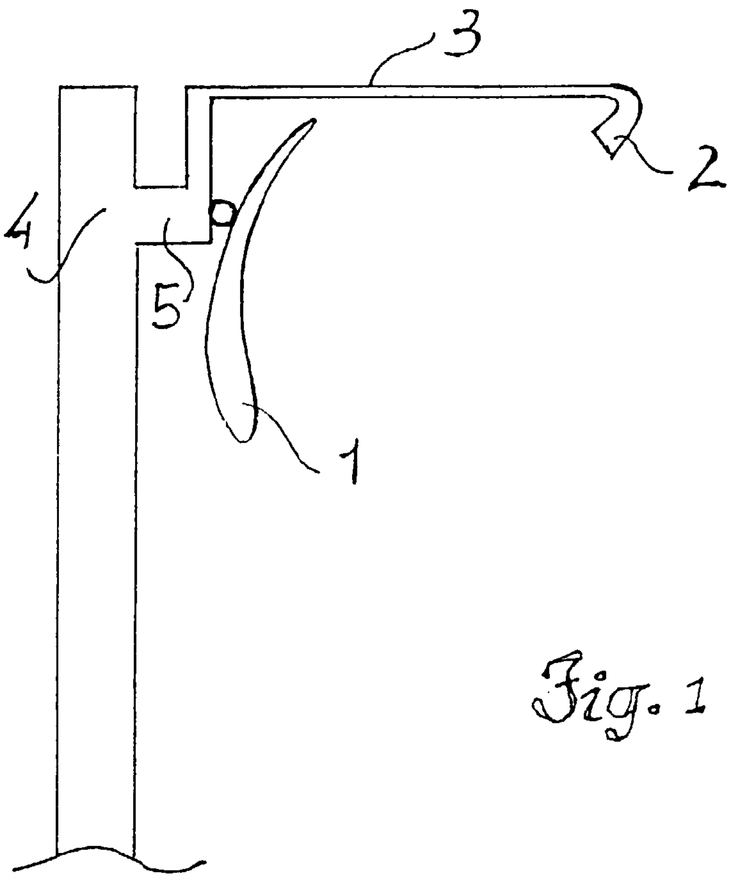


Fig. 1

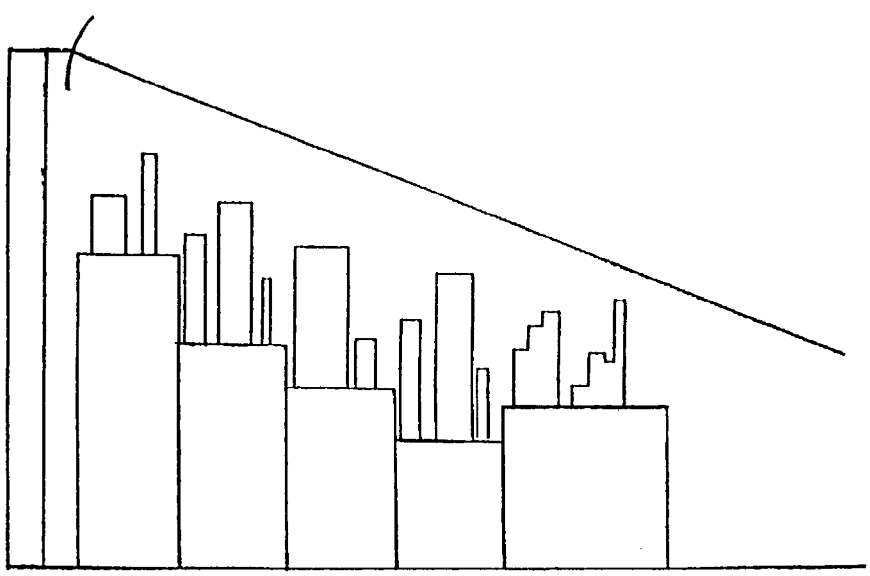
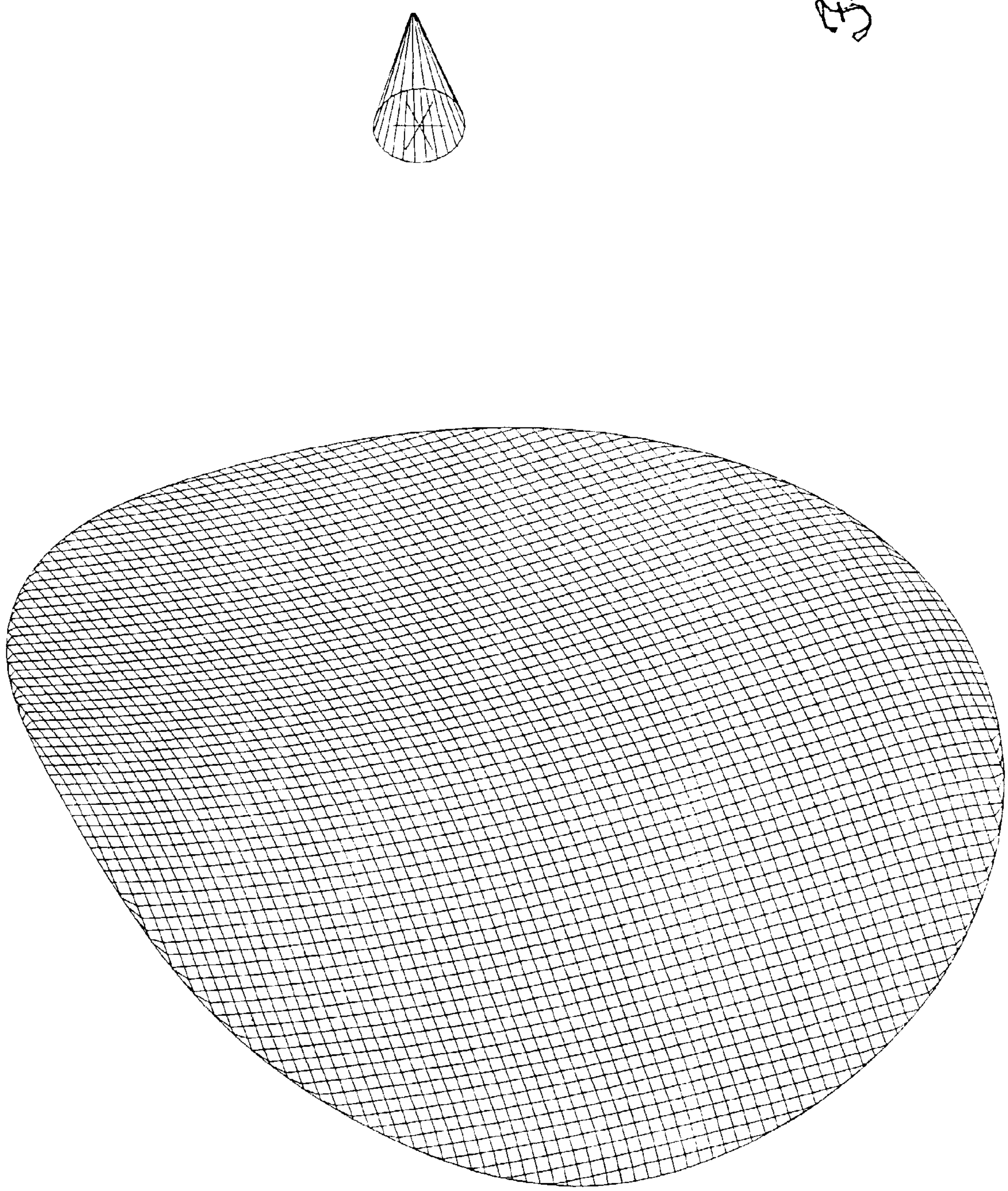


Fig. 2

Fig. 3



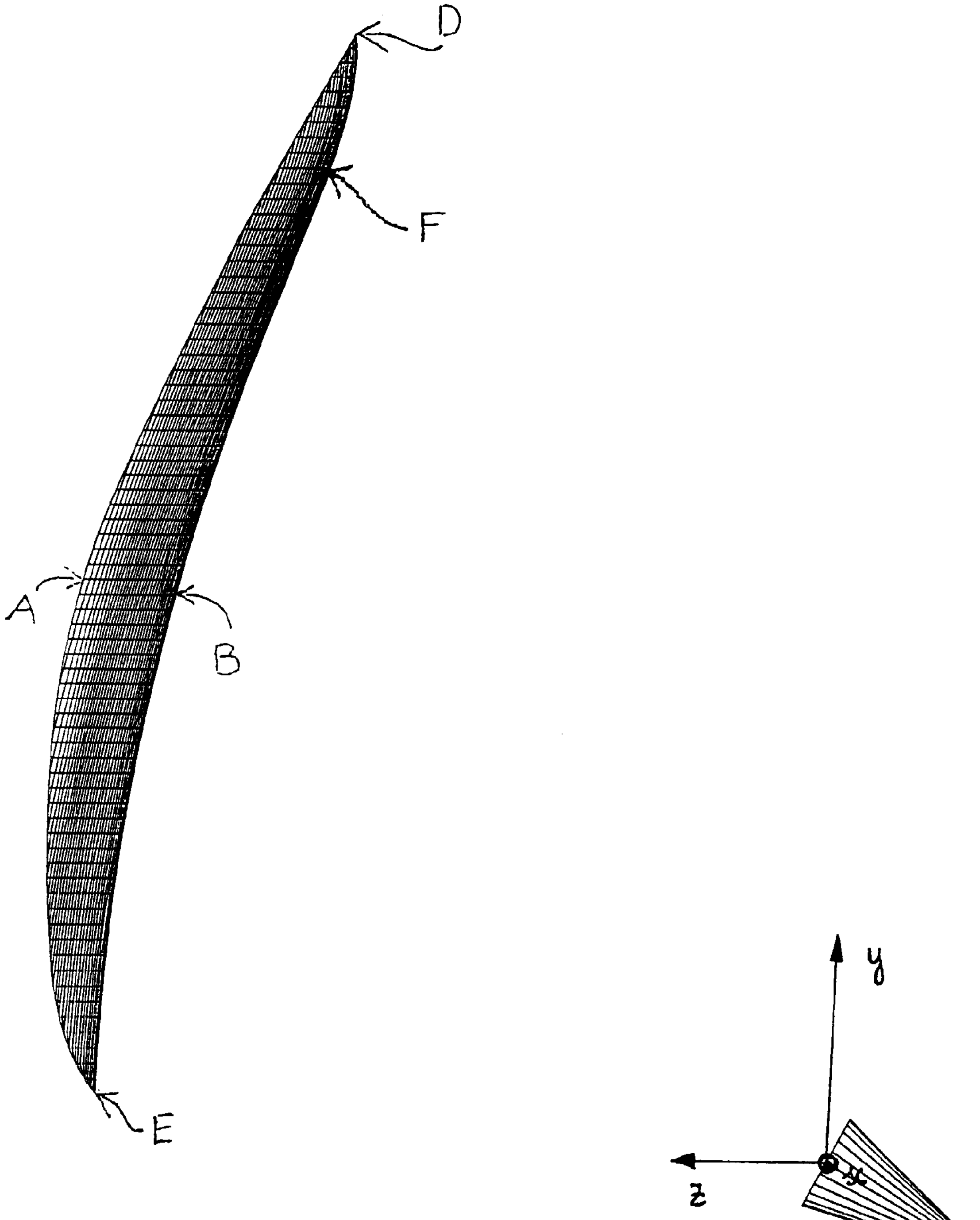


Fig. 4

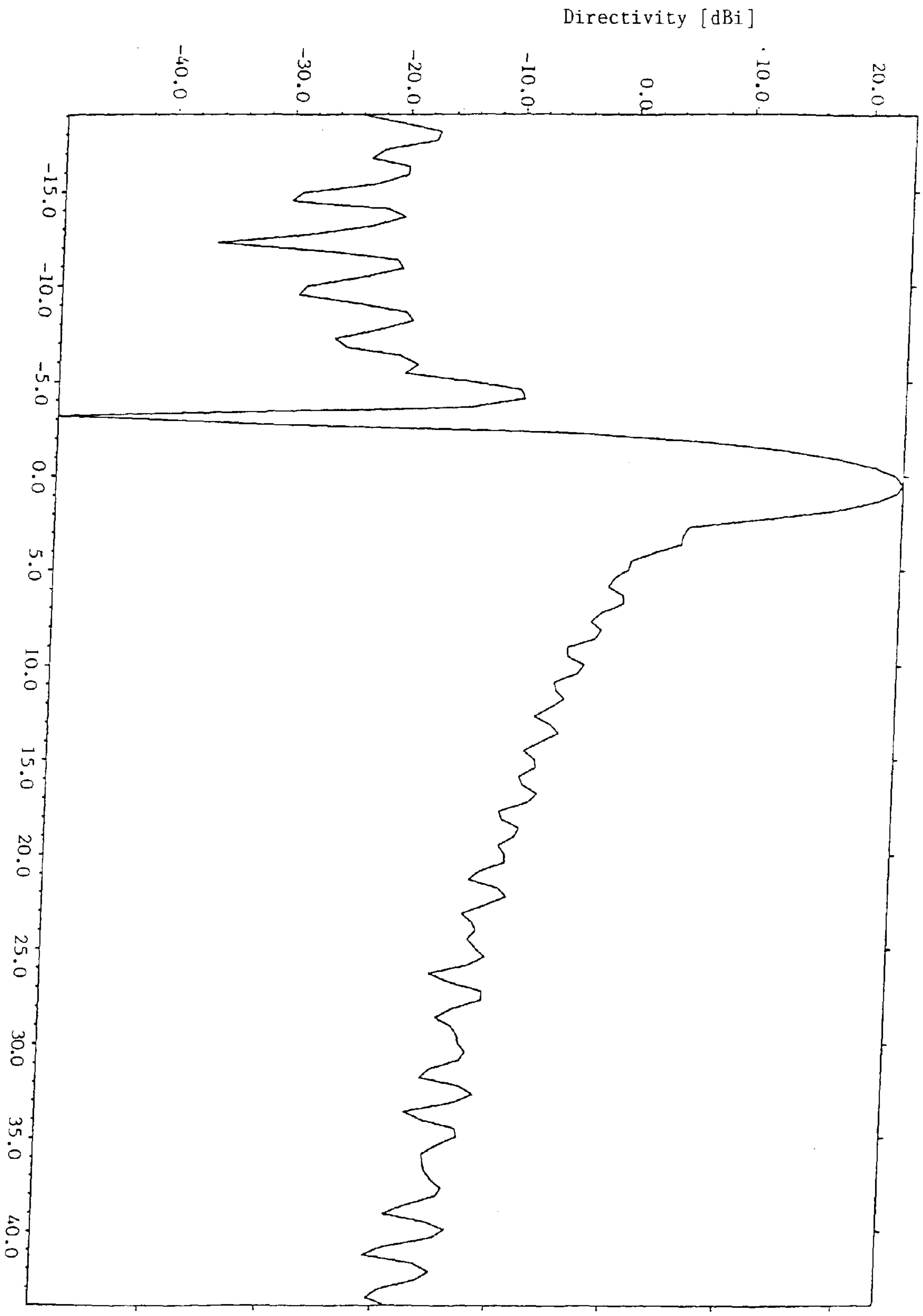

Directivity [dBi]
-40.0
-30.0
-20.0
-10.0
0.0
10.0
20.0
-15.0
-10.0
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

Fig. 5

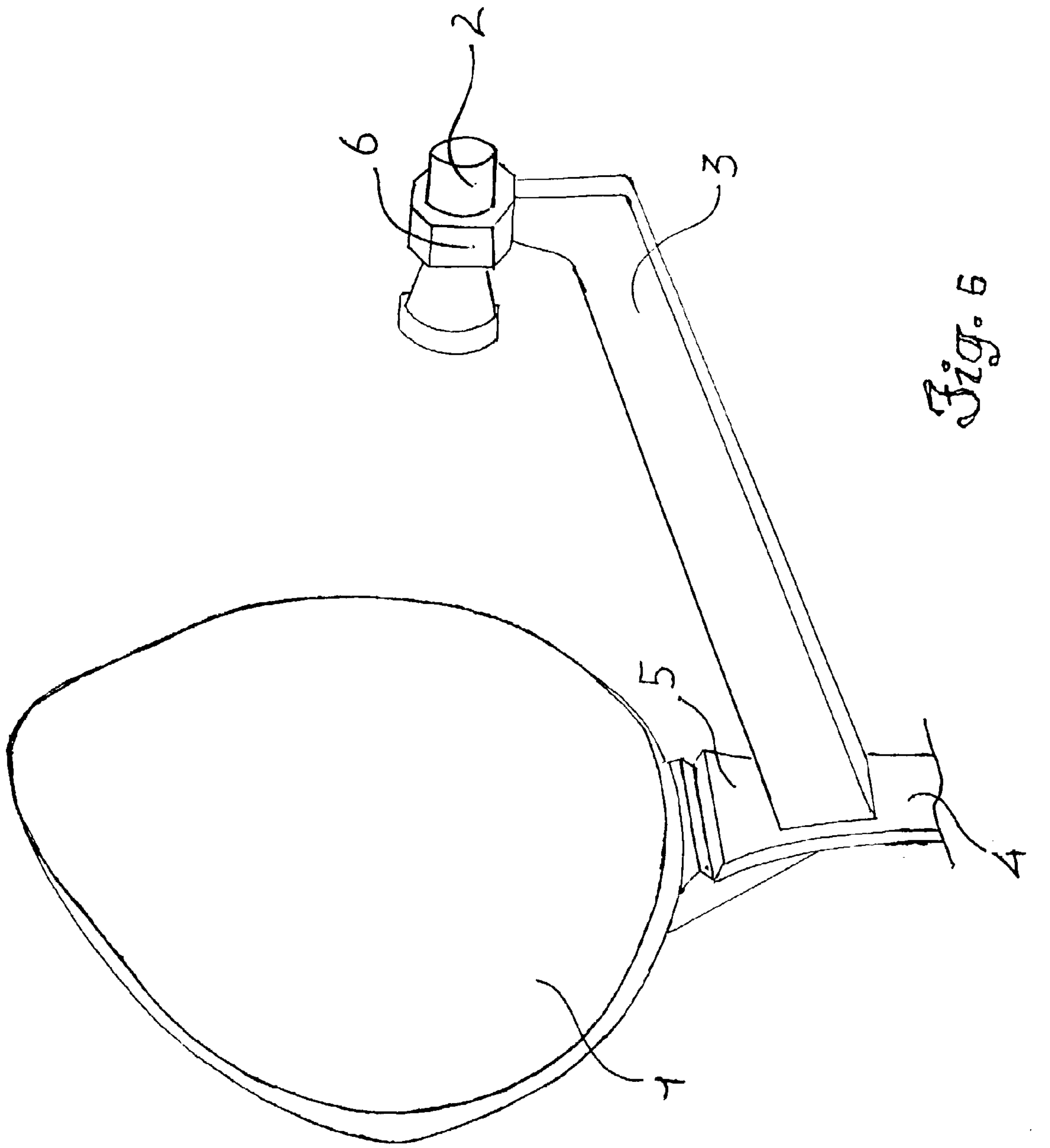


Fig. 6

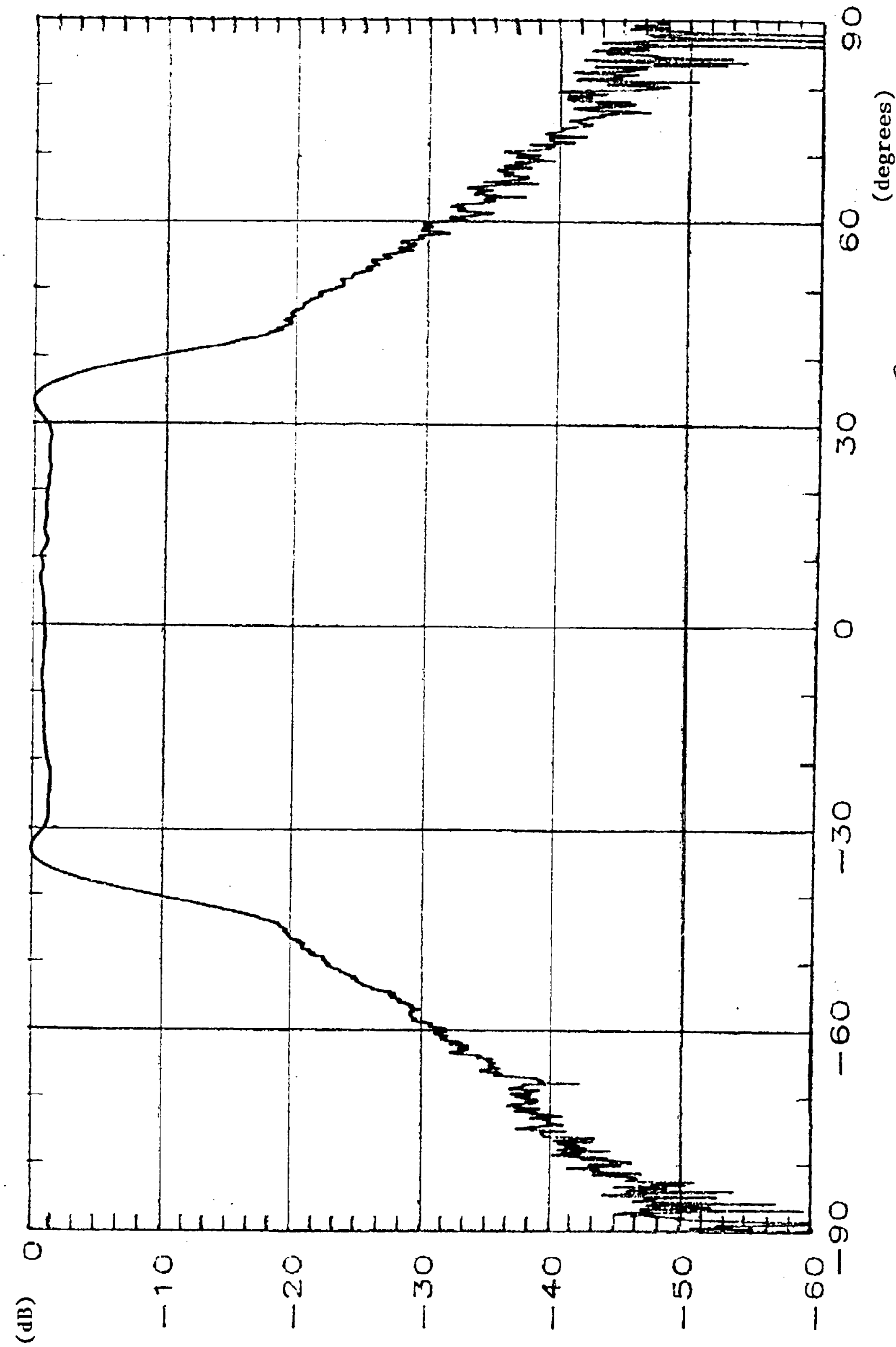


Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 98 83 0136

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.6)
X	SHINICHI NOMOTO ET AL: "HIGHLY CONTOURED BEAM ANTENNAS FOR 21 GHZ-BAND LDR HUB STATIONS" ELECTRONICS & COMMUNICATIONS IN JAPAN, PART I - COMMUNICATIONS, vol. 73, no. 3 PART 01, 1 March 1990, pages 59-72, XP000149070 * sections 2.2-2.4 * * figures 1,2,7 * ---	1-4	H01Q15/14 H01Q15/16 H01Q19/13
A	FR 2 603 741 A (APPLIC RECH ELECTRONIQUE) 11 March 1988 * page 1, line 17-26 * * page 5, line 16 - page 6, line 28; figures 2,3 * ---	1	
A	PONTOPPIDAN K ET AL: "DESIGN OF RECONFIGURABLE SATELLITE REFLECTOR ANTENNA FOR VARIABLE BEAM CONTOURING" PROCEEDINGS OF THE ANTENNAS AND PROPAGATION SOCIETY ANNUAL MEETING, 1991. VENUE AND EXACT DATE NOT SHOWN, vol. VOL. 2, no. -, 1 January 1991, INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, pages 678-681, XP000239751 * page 679, line 48 - page 680, line 9 * ---	2,3	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H01Q
A	US 4 625 214 A (PAREKH SHARAD V) 25 November 1986 * column 2, line 21-58; figures 2,4-6 * --- -/--	4	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	9 June 1998	Van Dooren, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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EUROPEAN SEARCH REPORT

Application Number
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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.6)
A	CORKISH R P: "A SURVEY OF THE EFFECTS OF REFLECTOR SURFACE DISTORTIONS ON SIDELOBE LEVELS" IEEE ANTENNAS AND PROPAGATION MAGAZINE, vol. 32, no. 6, 1 December 1990, pages 6-11, XP000169285 * section 5: conclusions * -----		

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

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