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(54) **IMPROVED REFLECTOR ANTENNA WITH A SELF-SUPPORTED FEED**

VERBESSERTE REFLEKTORANTENNE MIT SELBSTTRAGENDEM SPEISEELEMENT

VERSION AMELIOREE D'UNE ANTENNE A REFLECTEUR DOTEE D'UNE ALIMENTATION
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(56) References cited:
EP-A1- 0 439 800 WO-A1-87/07771
DE-A- 2 240 893 US-A- 2 482 158

• **PATENT ABSTRACTS OF JAPAN, Vol. 7, No. 154,**
(E-185); & JP 58064809 A (MATSUSHITA DENKI
SANGYO K.K.) 18 April 1983.

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Description

FIELD OF THE INVENTION:

[0001] The invention consists of improvements of reflector antennas with self-supported feeds of the types described in European Patent EP 87903452.8 publ no 0268635 for the transmission or reception of electromagnetic waves. The antennas are principally intended for the use in radio link systems between base stations for mobile communications, but also in other applications such as e.g. microwave level gauging systems.

BACKGROUND OF THE INVENTION:

[0002] Reflector antennas with self-supported feeds are chiefly used because they are straightforward and inexpensive to manufacture. They also provide higher antenna efficiency and lower side lobes in the radiation pattern than is the case when the feed has to be supported by diagonal struts. The drawback with the latter configuration is that the main reflector becomes blocked by the struts. A self-supported feed is also easily accessible from the back of the reflector, thus is frequently selected when it is best to locate the transmitter and/or the receiver there. This also reduces the loss that otherwise occurs when the electromagnetic waves have to be led in a cable along one of the support struts.

[0003] The European Patent EP 87903452.8 publ no 0268635 describe different versions of reflectors with self-supported feeds, where the feed consists of a waveguide tube, a dielectric joint and a sub-reflector. The tube is attached to the center of the rotationally symmetric reflector and extends to the focal region of it. The sub-reflector is located in front of the tube, and the surface of this sub-reflector is provided with rotationally symmetric grooves also called corrugations. By these means the electromagnetic waves are prohibited from propagating along the sub-reflector surface independent of whether the electric field is normal to the surface or is tangential to it. The result is that the radiation pattern has higher directivity, lower spillover and lower far out sidelobes than otherwise would be possible.

[0004] The present invention relates to several improvements of the antennas described in European Patent EP 87903452.8 publ no 0268635. The improvements are for improved readability in the below description denoted: ring focus reflector, elevated central region, metal screws, rim corrugations, simple tube, dual band and feed protection.

[0005] **Ring focus reflector:** The antennas described in the above referenced European patent make use of a main reflector which is rotationally symmetric and has a substantial parabolic shape. However, the antenna will have higher gain if the main reflector shape is improved. The present invention describes how to improve the shape of the main reflector.

[0006] **Elevated central region:** It is not possible to

design the antennas in the above referenced European patent with low reflection coefficient at the waveguide input. The reason for this is reflections from the region around the tube in the center of the main reflector. In the improvement of the antenna this problem is solved by modifying the reflector in its central region.

[0007] **Metal screws:** In the above referenced European patent the sub-reflector is supported to the end of the waveguide tube by means of a dielectric joint, which partly or totally fills the gap between the sub-reflector and waveguide tube end, and which is interlocked with and glued to the sub-reflector and waveguide tube end. This gluing does not provide a sufficiently strong mechanical support in all applications. In the present invention this is improved for linearly polarized applications by means of metal screws or thin cylinders or plates which provide a strong metal connection between the sub-reflector and the end of the tube.

[0008] **Rim corrugations:** In the above referenced European patent there will be large back-lobes in the direction opposite to the main lobe. The invention reduces these lobes by means of one or more corrugations or grooves or metalized dielectric rings around (or in the structure behind) the rim of the reflector.

[0009] **Simple tube:** In the previous embodiments of the referenced European patent the waveguide support tube has an inner diameter which changes near the end of the tube which is closer to the sub-reflector, and in some cases it was also necessary to insert one or more irises into this end of the tube, all in order to properly match the antenna to obtain a low reflection coefficient. The present invention describes an improvement by which the waveguide tube can be a circular cylindrical tube of constant cross section along its length. This improvement significantly reduces manufacturing cost.

[0010] **Dual band:** In the above referenced European patent the antenna is fed through a circular waveguide for operation in a single frequency band of up to 20% bandwidth. In some applications dual band operation is of interest, e.g. one band for transmission and another for reception of signals. The invention describes a modified antenna which is fed by two waveguides; one inner circular waveguide and outside this a coaxial waveguide.

[0011] **Feed protection:** In some applications the antenna may be located in rough environments, and water, dust and other undesired material may gather in the region between the end of the tube and the subreflector and thereby destroy the performance. The present invention describes how the antenna in the above referenced European patent can be improved to be less sensitive to such effects.

SUMMARY OF THE INVENTION:

[0012] The invention is defined by the appended claims.

Ring focus reflector:

[0013] The present invention improves the main reflector shape of a parabolic antenna according to method c of the following methods a to c :

a) By using the phase of the computed aperture field of the complete antenna with a paraboloidal main reflector. This aperture field is the field in a plane normal to the radiation axis in front of the main reflector. The phase of this copolar aperture field is studied by modern numerical methods by a complete numerical electromagnetic analysis of the aperture field of the complete antenna with a paraboloidal main reflector, and an optimum reflector which makes the phase constant is designed. The reflector shape is determined by the equation

$$r(\theta) = \frac{2F}{(1 + \cos \theta)} + \frac{\varphi(\theta) - \varphi(0)}{360(1 + \cos \theta)} \lambda$$

where $\varphi(\theta)$ is the phase in degrees of the computed copolar aperture field in the 45 deg plane in a paraboloidal reflector, F is the focal length, λ is the wavelength, $r(\theta)$ is the radial distance from the focal point to the point on the main reflector, and θ is the angle between the symmetry axis and the line between the focal point and the point on the reflector.

b) By using the phase of the computed radiation field of the feed. The radiation field function of the feed, i.e. the sub-reflector when this is located in front of the end of the tube, is determined by modern numerical methods which can include the effect of the tube and the dielectric joint between the tube and the sub-reflector. In this computation the main reflector is not present so it is simpler to perform than the analysis in method a. From the phase of the radiation field of the sub-reflector the optimum main reflector shape can be determined. The equation is the same as for method a, but with $\varphi(\theta)$ being the phase in degrees of the computed copolar radiation field in the 45 deg plane of the sub-reflector with tube and joint.

c) By using the formula of a ring focus reflector. The optimum reflector resulting from both above methods a and b satisfies to a very high accuracy the formula of a ring focus paraboloid, which is

$$z = -F + \frac{1}{4F}(\rho - \rho_0)^2 \quad \text{where } z \text{ is the axial}$$

coordinate along the symmetry axis (i.e. the z-axis) when there is no vertex plate, ρ is the cylindrical radial coordinate measured from the z-axis, F is the focal length, and ρ_0 is fixed and between 0.2 and 0.6 wavelengths depending on the dimensions of the sub-reflector and tube and on the depth of the main

reflector. The optimum parameter ρ_0 can be calculated from the phase of the radiation field function of the feed or from the phase of the aperture field, and it is different in different frequency bands and for different dimensions of the feed. Therefore, if the same reflector is used in several frequency bands, the reflector cannot be optimum in all bands. When the reflector shall be used in several frequency bands, the best shape of the reflector is obtained by optimizing it as explained above at the frequency which represents the geometrical mean of the overall lowest and overall highest frequency. Thus, if the lowest frequency is 21.2 GHz and the highest 40 GHz, the main reflector should preferably be optimized at 30.6 GHz. Then, for this example, the reduction in the aperture efficiency due to phase errors will be less than typically 0.15 dB at 21.2 GHz and 39 GHz and less than 0.05 dB at the design frequency 30.6 GHz. In a paraboloidal reflector the reduction is about 1 dB in all bands.

[0014] The optimum reflector as determined from the above methods a, b or c is very similar to a best fit standard paraboloid, with a maximum difference from it of typically up to 0.25 wavelengths. The differences are larger when the reflector is deep than when it is shallow. Deep reflectors are for applications which require low sidelobes. The optimum reflector is more flat in the center than the best fit parabolic reflector. Even if the differences are small, the gain of the antenna is typically between .2 and 1 dB larger when the reflector is optimized according to methods a, b or c, where the low number is for shallow reflectors and the high number for deep reflectors. Such ring focus reflectors are needed when using self-supported feeds, and not when using conventional primary feeds which are supported by diagonal struts. The reason is that the axial support tube of the former makes the phase fronts of the radiation from the feed ellipsoidal rather than spherical.

Elevated central region:

[0015] The invention may also provide an improved antenna with a low reflection coefficient at the waveguide input, obtained by modifying the reflector in its central region. The central region around the support tube is elevated compared to the original paraboloidal or ring focus shape. The central elevated region can be realized in several ways as described below.

It may be made as a separate reflecting (e.g. metal) plate around the tube, or it may be integrated with the foot of the selfsupported tube, or it may form a central part of the reflector surface itself. The elevated region has an outer radius of typically between .8 and 3.5 wavelengths when the reflector diameter is between 30 cm and 120 cm in frequency bands between 7 and 40 GHz. The elevated region can be flat, or it can have a constant height

over the unperturbed reflector. The maximum height of the elevated region over the unperturbed reflector is typically between 0.10 and 0.25 wavelengths. The central elevated region of the reflector may have sharp corners at its rim, or it may be tapered off gradually to zero.

It is also possible to realize the elevated region by using a dielectric plate, in which case the thickness of the plate will be different from the metal case. The dielectric plate must be designed to provide a phase difference of the reflected waves leaving its surface relative to those reflected from the reflector itself of typically between 70 and 180 deg.

The central elevated region of the main reflector will increase the sidelobes of the antenna. This effect can be reduced by profiling the height of the elevated region. A Gaussian profile gives particular low sidelobes. This follows approximately the formula

$$\Delta z = \Delta z_0 e^{-(\rho - \rho_t)^2 / \rho_g^2}$$

where Δz is the central correction to the z-coordinate of the reflector (i.e. the height profile of the elevated region), Δz_0 is the maximum correction in the center, ρ is the radial coordinate as before and varies between the radius of the tube and an outer maximum limit, ρ_t is a parameter which can have any value between zero and the tube radius, and ρ_g is the Gaussian width of the elevated central region, i.e. the width at

which Δz has decreased to $1/e=0.37$ times the value of Δz_0 . The Gaussian elevated region may either be made of reflecting material such as metal, or of dielectric material, in the same way as described above. The optimum thickness at the center is in the case of the Gaussian profile larger than for the constant thickness case.

If the reflector is used in several frequency bands, the dimensions of the elevated central region will be different in each band. Therefore, the central region of the reflector will normally be interchangeable in the same way as the waveguide tube and sub-reflector.

Metal screws:

[0016] In the present invention the fastening of the sub-reflector to the end of the tube may be improved for linearly polarized applications by means of metal screws or thin metal cylinders or thin plates which provide a strong metal connection between the sub-reflector and the end of the tube. The metal screws or cylinders are located in the H-plane of the antenna, on either side of the symmetry axis, in such a way that they do not cause field blockage and thereby the radiation pattern and reflection coefficient at the waveguide input are not significantly affected. The screws, cylinders or plates are mounted to the waveguide tube by holes in its narrow end wall. This improvement destroys the rotational symmetry of the antenna and is only possible in linearly po-

larized applications.

Rim corrugations:

[0017] The invention may reduce the far-out sidelobes of the antenna and in particular the lobes in the backwards direction by means of one or more corrugations or grooves or metalized dielectric rings around (or in a structure behind) the rim of the reflector. The grooves and dielectric rings can often be integrated with the support of a protecting dielectric sheet referred to as a radome in front of the reflector.

Simple tube:

[0018] In the previous embodiments of the referenced European patent the waveguide support tube has an inner diameter which changes near that end of the tube which is closer to the sub-reflector, and in some cases it is also necessary to insert one or more irises into this end of the tube, all in order to properly match the antenna to obtain a low reflection coefficient. The invention may comprise an improvement by which the waveguide tube can be a circular cylindrical tube of constant cross section along its length. This improvement significantly reduces manufacturing cost.

Dual band:

[0019] In the present invention dual-band operation may be obtained by designing the tube in such a way that it contains two waveguides; an inner circular waveguide surrounded by a coaxial waveguide. The circular waveguide is used for the higher frequency band and supports the TE₁₁ circular waveguide mode as in the referenced patents. The coaxial waveguide is used for the lower frequency band and supports the TE₁₁ coaxial waveguide mode. The former is the lowest order basic mode, whereas the latter is not, as a coaxial line can support a TEM mode with no lower cut-off. The TEM mode is undesirable and prohibited from propagation on the line by proper excitation of the TE₁₁ mode only, and in other ways. The center of the sub-reflector, corrugations, the end of the tube near the sub-reflector and the dielectric joint are designed in order to give a good radiation pattern in both frequency bands. There are several geometries possible. The sub-reflector may be provided with corrugations of different depths in order to work properly as desired in both frequency bands. The shallowest corrugations should be between 0.25 and 0.5 wavelengths deep in the higher frequency band, and the deeper corrugations should be between 0.25 and 0.5 wavelengths deep in the higher frequency band.

Feed protection:

[0020] In the present invention the sensitive region between the end of the tube and the corrugations and the

corrugations themselves may be completely or partly filled by dielectric material, so as to protect them from gathering of water, dust or other undesired material which may destroy the performance. The invention may also be used for antennas in kind environments because the performance of the improved antenna is not necessarily worse in other respects than a standard antenna according to the referenced European patent.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0021] The present invention will be explained in more detail by making reference to the drawings, where:

Figure 1 and 2 show axial cross-sections of two examples of reflector antennas.

Figure 3 show an axial cross section of an example of a feed made according to the referenced European patents and with a tube made according to Claim 7.

Figure 4 shows the right side of the axial cross-section of an optimized ring focus reflector, and with dashed line a standard point focus reflector.

Figure 5, 6, 7 and 8 show an axial cross section of the antenna in the center of the main reflector with no elevated central region (Figure 5), with an elevated region of constant height (Figure 6), with a Gaussian elevated region (Figure 7), and a comparison of the three different cases in the same drawing (Figure 8), with the elevated regions profiled.

Figures 9 and 10 show both an axial H-plane cross section and a top view of the sub-reflector and tube when the sub-reflector and tube are connected with two metal screws (Figure 9) and with two thin metal plates (Figure 10).

Figure 11, 12, 13 and 14 show an axial cross section of the outer part of the main reflector, when the rim is provided with grooves, corrugations and metalized dielectric rings.

Figure 15 and 16 show axial cross sections of two examples of with a tube which contains both a circular waveguide and a coaxial waveguide for dual-band operation.

Figure 17, 18 and 19 show axial cross sections of examples of feeds with dielectric protection.

DETAILED DESCRIPTION OF THE DRAWINGS:

[0022] The antennas in Figures 1 and 2 consist of a main reflector 10. In the middle of this there is a self-supporting tubular feed element 11. The central region

of the main reflector is elevated with a Gaussian shape 21 in Figure 1, and a constant height in Figure 2. The main reflector in Figure 1 is realized by massive metal, and the rim of the reflector is provided with 3 grooves 40 according to an embodiment of the invention. There is one groove around the actual rim, and two more at the side of the reflector structure. Each groove is separately as well as combined with the others examples of realizations of the invention. The reflector in Figure 2 is made from a thin metal plate where the outer edge region is curved sharply backwards to form a flange, in order to stiffen the reflector. There is a thin dielectric sheet 50 commonly referred to as a radome located in front of the reflector and fastened to the rim of it by means of a metal ring 51 and hooks which are not shown in the drawing. Between the metal ring 51 and the reflector flange there is a metalized dielectric sheet curved to a ring 41 around the rim according to an embodiment of the invention. The dielectric ring is metalized on the outer side, and may or may not be metalized on the bottom and inner side.

[0023] The feed in Figure 3 of a cylindrical tube 12, and a sub-reflector 13. The inner surface of the tube 12 forms a circular cylindrical waveguide 15. The waveguide is designed to propagate the basic TE₁₁ mode. The waveguide must have a larger diameter than 0.6 (approx.) wavelengths and be smaller than 1.2 (approx.). The tube 12 and the waveguide 15 are mostly made of conducting materials. The surface of the sub-reflector has at least one circular corrugation 16 in it, according to the referenced European patent. These air- or dielectric-filled corrugations ensure that the electromagnetic waves are prohibited from propagating along the surface, regardless of whether the electric fields are normal to the surface or are tangential to it. This is important in order to achieve low sidelobes. The diameter of the sub-reflector is always larger than the diameter of the tube. There is a gap 14 between the sub-reflector and the end of the waveguide 15. The gap 14 is partly or totally filled with dielectric matter. Though this is necessary to attach the sub-reflector to the tube 12, this is also a means of controlling the radiation characteristics and impedance match.

[0024] The optimum ring focus reflector 10 in Figure 4 is seen to be flatter in the bottom than the standard paraboloid 19. The two reflectors have been adjusted to each other in such a way that they coincide at the edge and that the focal point of the paraboloid lies in the same plane normal to the axis as the focal ring of the ring focus paraboloid. This makes the focal length of the ring focus paraboloid slightly shorter than that of the paraboloid, as illustrated.

[0025] Figure 5 shows a main reflector 10 without an elevated region in the center, whereas Figure 6 and 7 show two different elevated regions. The elevated region in Figure 6 is clearly recognized as a plate 20 with constant height over the original reflector shape. Figure 7 shows an example of a Gaussian height profile 21. The elevated region is not so visible as in Figure 6, but be-

comes much more visible when plotting the three profiles in the same diagram, as in Figure 8. The maximum of the Gaussian profile occurs at the symmetry axis and is therefore not actually present due to the central hole. All Figures 5, 6 and 7 show elevated regions according to preferred embodiments of the invention, invention, but it should be understood that the invention is not limited to these height profiles. In particular, the Gaussian profile can be shifted by varying the parameter p , in its formula.

[0026] Figure 9 shows the location of two metal screws 30 which connect the sub-reflector 13 to the end of the tube 12 according to a preferred embodiment of the invention. The two screws are located in H-plane where the electric field becomes orthogonal to the screws so that they have minimum effect on the performance. Figure 10 shows two thin connecting plates 31 according to a preferred embodiment of the invention. They are penetrating into small narrow slots in the sub-reflector and tube end, and are soldered or in other ways fastened there. These plates are also located in H-plane and are oriented in such a way that they have as small azimuthal extent as possible, causing negligible field blockage. The invention is not limited to the realizations shown. In particular, one of the screws shown in Figure 9 may be removed, or more screws may be located side by side in the same H-plane. The two plates may also be combined to one plate which extends through the center of the sub-reflector and tube, or there may be more plates side by side.

[0027] Figure 11, 12, 13 and 14 show 4 different realizations of so-called chokes near the reflector rim. The corrugations 40 in Figure 11 are all located according to a preferred embodiment of the invention, as well as each one of them. The choke is in Figure 12 realized as a dielectric material making up a ring 41 around the reflector rim, and this has a metalized outer surface 42. The choke is in this case open-ended, and must therefore be between 0.5 and 0.75 dielectric wavelengths in order to work as a choke. In Figure 12 the dielectric ring 41 is provided with metal even at the bottom 43. Its length should be between 0.25 and 0.5 dielectric wavelengths. The corrugations and dielectric rings can be combined with a support 51 for a radome 50 in front of the reflector. The invention is not limited to those realizations shown. In particular, there may be more dielectric rings outside each other with or without metal sheets in between them.

[0028] Figure 15 and 16 show two realizations for the case that the tube 12 contains both a circular waveguide 15 and a coaxial waveguide 60. The inner circular cylinder 61 between the waveguides are made of conducting material (metal). The end of the tube, the end of the inner cylinder and the dielectric joint 14 are shaped so as to enable optimum radiation performance in both frequency bands. This is done in Figure 15 by shaping the inner tube to a cone 62 which extends to the circumferential aperture and divides the dielectric joint in two pieces. The solution in Figure 16 contains corrugations 16 of two different depths, in order to work optimally in both bands.

The invention is not limited to the two realizations shown in Figures 15 and 16. E.g., the solution in Figure 15 can have dual depth corrugations, and the solution in Figure 16 can have metal elements inside the joint.

[0029] The feeds in Figures 17, 18 and 19 have dielectric material not only in the central part of the gap between the end of the tube and the subreflector, but even in a region with diameter larger than the diameter of the tube and partly or completely covering the corrugations 16. The waveguide may also be entirely filled with dielectric material in some applications, in order to prevent water to build up inside the tube. The cross section of the dielectric filling may have any shape, whereas the drawings show only three examples.

[0030] The figures show a few different designs of the invention. It should nevertheless be apparent that there are numerous other forms of designs possible.

EXPLANATION OF PRINCIPLE OF OPERATION:

[0031] The principle of operation of the antenna as described in the referenced European patent will not be repeated here, but the improvements will be explained.

[0032] Ring focus reflector: The ring focus reflector works in such a way that the waves propagate a slightly different distance than in a paraboloid, in such a way that this corrects for the ellipsoidal phase fronts of the radiation field of the feed and makes the phase of the aperture field constant.

[0033] Elevated central region: The elevated central region of the main reflector cause a small perturbation of the reflected waves from the main reflector surface. This perturbation has the extent of the elevated region and an amplitude which is proportional to the height of the perturbation (for small heights). The radiation from the perturbation will when transformed to the aperture for certain dimensions have the same amplitude but opposite phase compared to the unperturbed aperture field. In this way it will create an interference minimum at the focal point. Many different height profiles can provide this. The perturbed reflected field corresponds to a small aperture radiating from the central reflector region. The field distribution over this aperture is proportional to the height, which means that we can control it with the height distribution. In aperture theory Gaussian aperture fields are known to give in particular low sidelobes, so also with this perturbational aperture field. Therefore, a Gaussian height profile gives lower sidelobes than a constant height profile.

[0034] Metal screws: Metal cylinders are known to cause very little field blockage and scattering if the electric field is orthogonal to them. Metal plates are known to cause very little field blockage and scattering if the field is orthogonal to the plate and is incident from a direction in the plane of the plate. Therefore, when we locate screws and plates in H-plane as in the invention, they will have very little effect on the performance. If we located the cylinders and plates incorrectly in E-plane,

they will destroy the performance of the antenna completely.

[0035] Rim corrugations: Corrugations and grooves are often referred to as chokes or soft surfaces. In order to work properly they must be between 0.25 and 0.5 wavelengths deep. They work the best when the depth is 0.25 wavelengths and thereby transforms the electric conducting short to an open-circuit or equivalent magnetic current at the opening of the grooves. This open-circuit stops the surface currents from floating and thereby E-fields which are orthogonal to the surface cannot propagate along it. If we instead use open-ended dielectric-filled grooves, the grooves must be between 0.5 and 0.75 wavelengths deep in order to provide an open-circuit or equivalent magnetic conductor at the opening. Thus, such chokes make the E-field zero of the waves propagating in a direction orthogonal to them. This will reduce the fields diffracted around the reflector rim and thereby give lower sidelobes.

[0036] Dual band: The dual band antenna work in the same way as the antennas described in the referenced European patent, except that in one frequency band the radiation is excited by means of the coaxial waveguide. The region in between the sub-reflector and the end of the tube as well as this end must be designed so as to provide optimum operation in both bands.

[0037] Protected feed: The antenna with the dielectric filling between the subreflector and the end of the tube works in the same way as without the filling, but it is more difficult to design because there may be present undesired resonant modes in the dielectric region. Such modes may destroy the antenna performance, but they can be partly or completely removed by reducing the volume of the dielectric filled region or designing it with air pockets or using material with low permittivity.

Claims

1. An antenna system comprising a main reflector (10) and a feed element (11) for radiating or intercepting electromagnetic waves, the feed element (11) comprising a waveguide (15) inside a tube (12), a sub-reflector (13) with circular grooves or corrugations (16), and a dielectric joint (14) in the space between said sub-reflector and an end of said waveguide tube, **characterized in that** the main reflector is shaped as a ring focus paraboloid according to the formula

$$z = -F + \frac{1}{4F}(\rho - \rho_0)^2$$

with z the axial coordinate measured along the symmetry axis, ρ the radius coordinate measured from the axis, F the focal length of the reflector, and ρ_0

the radius of the ring focus, where the ring focus radius is typically between 0.5 times and 1.5 times the radius of said tube, depending on the dimensions of said sub-reflector and said joint, where the main reflector may deviate from the ring focus paraboloid formula due to finite tolerances and different design methods by up to an RMS value of about 0.02 wavelengths, and where the reflector may be used together with different tubes and subreflectors designed for different frequency bands, in which case the ring focus paraboloid formula is valid with the above limitations in at least one of the frequency bands.

2. The antenna system of claim 1, wherein it further comprises an elevated region in the center of said main reflector (10) around said tube (12) having a first end and a second end, said first end connected to said main reflector, where said elevated region may have different cross-sectional shapes such as e.g. being flat, or having a constant height (20) over the otherwise substantially paraboloidal or ring focus main reflector shape (10), or having a height which tapers off gradually from a maximum near the tube to zero a certain radius away from the tube e. g. according to a Gaussian function, (21) or having any other cross-sectional shape, where in all cases the height of the elevated region has a maximum of typically between 0.1 and 0.25 wavelengths over the otherwise substantially paraboloidal or ring focus shaped main reflector (10), and has a diameter between the points where the height is reduced to 0.37 of its maximum value, of typically between 1.9 and 7 wavelengths dependent on the frequency and the focal length of the reflector.
3. The antenna system of claim 1 or 2, wherein it further comprises a dielectric plate in said main reflector around said tube, where the plate may have different cross-sectional shapes such as e.g. flat, with a constant height (20) over the otherwise substantially paraboloidal or ring focus main reflector shape, or with a height which tapers off gradually from a maximum near the tube to zero a certain radius away from the tube e. g. according to a Gaussian function (21) where in all cases the height of the plate has a maximum over the otherwise substantially paraboloidal or ring focus main reflector shape which provides a phase delay of between 70 and 180 degrees compared to when the dielectric plate is not present, and where the diameter out to the point where the height is reduced to 0.37 of its maximum value is typically between 1.9 and 7 wavelengths dependent on the frequency and the focal length of the reflector.
4. The antenna system of any one of the claims 1-3, wherein it further comprises fastening means, such as e.g. screws (30) or flat metal objects (31), with the purpose of creating a strong metal connection

between said sub-reflector (10) and said tube (12) being located in a plane through the center axis of said tube and said sub-reflector and on opposite sides of this axis, where this plane is orthogonal to the plane of the axial electric field inside said waveguide for linear polarization.

5. The antenna system of any one of the claims 1-4, wherein it further comprises one or more air-filled or dielectric-filled grooves (40), or dielectric rings (41) with metalized outer surface (42) and bottom (43), effectively forming a dielectric-filled groove, located in or around the rim of said main reflector (10), where the depth of these grooves are typically between 0.25 and 0.5 wavelengths of the material inside the groove.
6. The antenna system of any one of the claims 1-5, wherein it further comprises one or more dielectric rings (41) which may or may not have metal films or sheets between the rings, and which are metalized on the outermost side (42) in such a way that they form coaxial layers of dielectric material and metal, located around the rim of said main reflector, where the depth of the open-ended dielectric-filled coaxial waveguides formed by the dielectric layers are typically between 0.5 and 0.75 wavelengths of the dielectric material.
7. The antenna system of any one of the claims 1-6, wherein said tube (12) containing the waveguide (15) is made as one single circular metal cylinder with constant thickness along its length, and where this cylinder is fastened to a support plate in the center of the main reflector or to the main reflector itself by different means.
8. The antenna system of any one of the claims 1-7, wherein it further comprises an inner cylindrical tube (61) located inside said tube (12) in such a way that a coaxial waveguide (60) is formed between the outer wall of said tube (61) and the inner wall of said tube (12), and where the dielectric joint (14) may contain metal parts (62) or may be divided in two by such metal parts which may or may not be connected to said inner tube (61).
9. The antenna system of any one of the claims 1-8, wherein the whole region between said subreflector (13) and end of said tube (12) is completely or partly filled with dielectric material which may or may not extend into one or more or all of the corrugations (16).

Patentansprüche

1. Antennensystem mit einem Hauptreflektor (10) und einem Rückkopplungselement (11) zum Aussenden

oder Auffangen von elektromagnetischen Wellen, wobei das Rückkopplungselement (11) einen Wellenleiter (15) in einem Rohr (12), einen Unterreflektor (13) mit ringförmigen Nuten oder Rillen (16) und eine dielektrische Verbindung (14) in dem Raum zwischen dem Unterreflektor und einem Ende der Wellenleiterrohrs aufweist,

dadurch gekennzeichnet, dass der Hauptreflektor als Ringfokusparaboloid nach der Formel

$$z = -F + \frac{1}{4F}(\rho - \rho_0)^2$$

gestaltet ist, worin z die Achskoordinate, gemessen entlang der Symmetrieachse, ist, ρ die Radialkoordinate, gemessen von der Achse, ist, F die Fokaldistanz des Reflektors ist und ρ_0 der Radius des Ringfokus ist, wobei der Ringfokusradius in Abhängigkeit von den Abmessungen des Unterreflektors und der Verbindung normalerweise das 0,5- bis 1,5-fache des Radius des Rohrs beträgt, wobei der Hauptreflektor infolge von endlichen Toleranzen und verschiedenen Gestaltungsverfahren bis zu einem Effektivwert von etwa 0,02 Wellenlängen von der Ringfokusparaboloid-Formel abweichen kann und wobei der Reflektor zusammen mit verschiedenen Rohren und Unterreflektoren, die für verschiedene Frequenzbänder ausgelegt sind, verwendet werden kann und in diesem Fall die Ringfokusparaboloid-Formel mit den vorgenannten Einschränkungen in mindestens einem der Frequenzbänder gültig ist.

2. Antennensystem nach Anspruch 1, **dadurch gekennzeichnet, dass** es weiterhin einen erhöhten Bereich in der Mitte des Hauptreflektors (10) um das Rohr (12), das ein erstes Ende und ein zweites Ende hat, aufweist, wobei das erste Ende mit dem Hauptreflektor verbunden ist, wobei der erhöhte Bereich verschiedene Querschnittsformen haben kann, d. h. z. B. flach sein kann oder eine konstante Höhe (20) über der ansonsten im Wesentlichen paraboloidischen oder Ringfokus-Hauptreflektor-Form (10) haben kann oder eine Höhe (21) haben kann, die sich von einem Maximum in der Nähe des Rohrs bis auf null einen bestimmten Radius von dem Rohr entfernt z. B. nach einer Gaußschen Funktion schrittweise verringert, oder irgendeine andere Querschnittsform haben kann, wobei in allen Fällen die Höhe des erhöhten Bereichs ein Maximum von normalerweise 0,1 bis 0,25 Wellenlängen über dem ansonsten im Wesentlichen paraboloidischen oder Ringfokusförmigen Hauptreflektor (10) hat, und der erhöhte Bereich in Abhängigkeit von der Frequenz und der Fokaldistanz des Reflektors einen Durchmesser zwischen den Punkten, wo die Höhe auf 0,37 ihres Höchstwerts verringert ist, von normalerweise 1,9

bis 7 Wellenlängen hat.

3. Antennensystem nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** es weiterhin eine dielektrische Platte in dem Hauptreflektor um das Rohr aufweist, wobei die Platte verschiedene Querschnittsformen haben kann, d. h. z. B. flach sein kann, eine konstante Höhe (20) über der ansonsten im Wesentlichen paraboloidischen oder Ringfokus-Hauptreflektor-Form haben kann oder eine Höhe (21) haben kann, die sich von einem Maximum in der Nähe des Rohrs bis auf null einen bestimmten Radius von dem Rohr entfernt z. B. nach einer Gaußschen Funktion schrittweise verringert, wobei in allen Fällen die Höhe der Platte ein Maximum über der ansonsten im Wesentlichen paraboloidischen oder Ringfokus-Hauptreflektor-Form hat, die eine Phasenverzögerung von 70 bis 180 gegenüber dem Fall, dass die dielektrische Platte nicht vorhanden ist, ermöglicht, und wobei in Abhängigkeit von der Frequenz und der Fokaldistanz des Reflektors der Durchmesser bis zu dem Punkt heraus, an dem die Höhe auf 0,37 ihres Höchstwerts verringert ist, normalerweise 1,9 bis 7 Wellenlängen beträgt.
4. Antennensystem nach einem der Ansprüche 1 - 3, **dadurch gekennzeichnet, dass** es weiterhin Befestigungsmittel, wie z. B. Schrauben (30) oder flache Metallteile (31), zum Zweck des Herstellens einer festen Metallverbindung zwischen dem Unterreflektor (10) und dem Rohr (12), die sich in einer Ebene durch die Mittelachse des Rohrs und des Unterreflektors und auf gegenüberliegenden Seiten dieser Achse befindet, aufweist, wobei diese Ebene zur linearen Polarisierung senkrecht auf der Ebene des elektrischen Längsfelds in dem Wellenleiter steht.
5. Antennensystem nach einem der Ansprüche 1-4, **dadurch gekennzeichnet, dass** es weiterhin eine oder mehrere mit Luft oder einem Dielektrikum gefüllte Nuten (40) oder dielektrische Ringe (41) mit einer metallisierten Außenfläche (42) und Unterseite (43), die effektiv eine mit einem Dielektrikum gefüllte Nut bilden, die in oder um den Rand des Hauptreflektors (10) angeordnet ist, aufweist, wobei die Tiefe dieser Nuten normalerweise 0,25 bis 0,5 Wellenlängen des Materials in der Nut beträgt.
6. Antennensystem nach einem der Ansprüche 1 - 5, **dadurch gekennzeichnet, dass** es weiterhin einen oder mehrere dielektrische Ringe (41) aufweist, die Metallfilme oder -folien zwischen den Ringen haben können oder auch nicht und die auf der äußersten Seite (42) so metallisiert sind, dass sie koaxiale Schichten aus dielektrischem Material und Metall bilden, die um den Rand des Hauptreflektors angeordnet sind, wobei die Tiefe der mit einem Dielektrikum gefüllten offenen koaxialen Wellenleiter, die von den

dielektrischen Schichten gebildet werden, normalerweise 0,5 bis 0,75 Wellenlängen des dielektrischen Materials beträgt.

7. Antennensystem nach einem der Ansprüche 1 - 6, **dadurch gekennzeichnet, dass** das Rohr (12), das den Wellenleiter (15) enthält, als ein einziger kreisförmiger Metallzylinder mit konstanter Dicke entlang seiner Länge gestaltet ist, wobei dieser Zylinder mit verschiedenen Mitteln an einer Stützplatte in der Mitte des Hauptreflektors oder an dem Hauptreflektor selbst befestigt ist.
8. Antennensystem nach einem der Ansprüche 1 - 7, **dadurch gekennzeichnet, dass** es weiterhin ein zylindrisches Innenrohr (61) aufweist, das so in dem Rohr (12) angeordnet ist, dass ein koaxialer Wellenleiter (60) zwischen der Außenwand des Rohrs (61) und der Innenwand des Rohrs (12) entsteht, wobei die dielektrische Verbindung (14) Metallteile (62) enthalten kann oder mittels dieser Metallteile, die mit dem Innenrohr (61) verbunden sein können oder auch nicht, in zwei Teile geteilt werden kann.
9. Antennensystem nach einem der Ansprüche 1 - 8, **dadurch gekennzeichnet, dass** der gesamte Bereich zwischen dem Unterreflektor (13) und dem Ende des Rohrs (12) vollständig oder teilweise mit einem dielektrischen Material gefüllt ist, das sich in eine oder mehrere oder alle Rillen (16) ausdehnen kann oder auch nicht.

Revendications

1. Système d'antenne comprenant un réflecteur principal (10) et un élément d'alimentation (11) pour rayonner ou intercepter des ondes électromagnétiques, l'élément d'alimentation (11) comprenant un guide d'ondes (15) à l'intérieur d'un tube (12), un réflecteur secondaire (13) avec des rainures ou cannelures circulaires (16), et un raccord diélectrique (14) dans l'espace compris entre ledit réflecteur auxiliaire et une extrémité dudit guide d'ondes, **caractérisé en ce que** le réflecteur principal a la forme d'une parabole à foyer circulaire conformément à la formule :

$$z = -F + \frac{1}{4F}(\rho - \rho_0)^2$$

où z est la coordonnée axiale le long de l'axe de symétrie, ρ est la coordonnée radiale mesurée depuis l'axe, F est la longueur focale du réflecteur, et ρ_0 est le rayon du foyer en anneau, où le rayon du foyer en anneau est généralement compris entre 0,5 fois et 1,5 fois le rayon dudit tube, en fonction des

- dimensions dudit réflecteur auxiliaire et dudit raccord, où le réflecteur principal peut s'écarter de la formule du parabole à foyer circulaire en raison des tolérances limitées et de différents procédés de conception jusqu'à une valeur efficace d'environ 0,02 longueurs d'onde, et où le réflecteur peut être utilisé en même temps que différents tubes et réflecteurs auxiliaires conçus pour différentes bandes de fréquences, la formule du parabole à foyer circulaire étant alors valide avec les limites ci-dessus dans au moins une des bandes de fréquences.
2. Système d'antenne selon la revendication 1, qui comprend en outre une zone élevée au centre dudit réflecteur principal (10) autour dudit tube (12) comportant une première extrémité et une seconde extrémité, ladite première extrémité raccordée au dit réflecteur principal, où ladite zone élevée peut avoir différentes formes de coupe transversale telles que, par exemple, une forme plate, ou une hauteur constante (20) supérieure à la forme du réflecteur principal de révolution ou sensiblement parabolique (10), ou une hauteur qui diminue progressivement depuis un maximum près du tube jusqu'à zéro à un certain rayon du tube, par exemple, selon la fonction gaussienne (21), ou toute autre forme de coupe transversale, où dans tous les cas la hauteur de la zone élevée est une valeur maximale généralement comprise entre 0,1 et 0,25 longueurs d'onde supérieure à la forme du réflecteur principal de révolution ou sensiblement parabolique (10), et un diamètre entre les points où la hauteur est réduite jusqu'à 0,37 de sa valeur maximale, généralement comprise entre 1,9 et 7 longueurs d'onde selon la fréquence et la longueur focale du réflecteur.
 3. Système d'antenne selon la revendication 1 ou 2, qui comprend en outre une plaque diélectrique dans ledit réflecteur principal autour dudit tube, où la plaque peut avoir différentes formes de coupe transversale telles que, par exemple, une forme plate, ou une hauteur constante (20) supérieure à la forme du réflecteur principal de révolution ou sensiblement parabolique, ou une hauteur qui diminue progressivement depuis un maximum près du tube jusqu'à zéro à un certain rayon du tube, par exemple, selon la fonction gaussienne (21) où dans tous les cas la hauteur de la plaque est une valeur maximale supérieure à la forme du réflecteur principal de révolution ou sensiblement parabolique qui fournit un temps de propagation de phase compris entre 70 et 180° par rapport aux cas où la plaque diélectrique n'est pas présente, et où le diamètre est en dehors du point où la hauteur est réduite jusqu'à 0,37 de sa valeur maximale, généralement comprise entre 1,9 et 7 longueurs d'onde selon la fréquence et la longueur focale du réflecteur.
 4. Système d'antenne selon l'une quelconque des revendications 1 à 3, qui comprend en outre un moyen de fixation, telles que, par exemple, des vis (30) ou des objets métalliques plats (31), avec l'objectif de créer un raccord métallique solide entre ledit réflecteur auxiliaire (10) et ledit tube (12) situé dans un plan traversant l'axe central dudit tube et dudit réflecteur auxiliaire et sur les côtés opposés de cet axe, où ce plan est perpendiculaire au plan du champ électrique axial à l'intérieur dudit guide d'ondes pour la polarisation rectiligne.
 5. Système d'antenne selon l'une quelconque des revendications 1 à 4, qui comprend en outre une ou plusieurs rainure(s) remplie(s) d'air ou remplie(s) de diélectrique (40), ou des anneaux diélectriques (41) comportant une surface externe (42) et une partie inférieure (43) métallisées, formant de manière efficace une rainure remplie de diélectrique, située dans ou autour du rebord dudit réflecteur principal (10), où la profondeur de ses rainures est généralement comprise entre 0,25 et 0,5 longueurs d'onde du matériau à l'intérieur de la rainure.
 6. Système d'antenne selon l'une quelconque des revendications 1 à 5, qui comprend en outre un ou plusieurs anneau(x) diélectrique(s) (41) qui peut/peuvent ou non comporter des pellicules ou enveloppes métalliques entre les anneaux, et qui est/sont métallisé(s) sur la partie la plus extérieure (42) de telle manière qu'il(s) forme(nt) des couches coaxiales de matériau diélectrique et de métal, situées autour du rebord dudit réflecteur principal, où la profondeur des guides d'ondes coaxiaux remplis de diélectrique ouverts formés par les couches diélectriques est généralement comprise entre 0,5 et 0,75 longueurs d'onde du matériau diélectrique.
 7. Système d'antenne selon l'une quelconque des revendications 1 à 6, dans lequel ledit tube (12) contenant le guide d'ondes (15) est constitué d'un seul cylindre métallique circulaire d'une épaisseur constante sur toute la longueur, et dans lequel ce cylindre est fixé à une plaque de support au centre du réflecteur principal ou sur le réflecteur principal lui-même par différents moyens.
 8. Système d'antenne selon l'une quelconque des revendications 1 à 7, qui comprend en outre un tube cylindrique interne (61) situé à l'intérieur dudit tube (12) de telle manière qu'un guide d'ondes coaxial (60) est formé entre la paroi externe dudit tube (61) et la paroi interne dudit tube (12) et dans lequel le raccord diélectrique (14) peut contenir des pièces métalliques (62) ou peut être séparé en deux pièces métalliques qui peuvent ou non être raccordées au dit tube interne (61).

9. Système d'antenne selon l'une quelconque des revendications 1 à 8, dans lequel la zone totale située entre le réflecteur auxiliaire (13) et l'extrémité dudit tube (12) est entièrement ou partiellement remplie de matériau diélectrique qui peut s'étendre ou non dans une ou plusieurs cannelure(s) de l'ensemble de cannelures (16).

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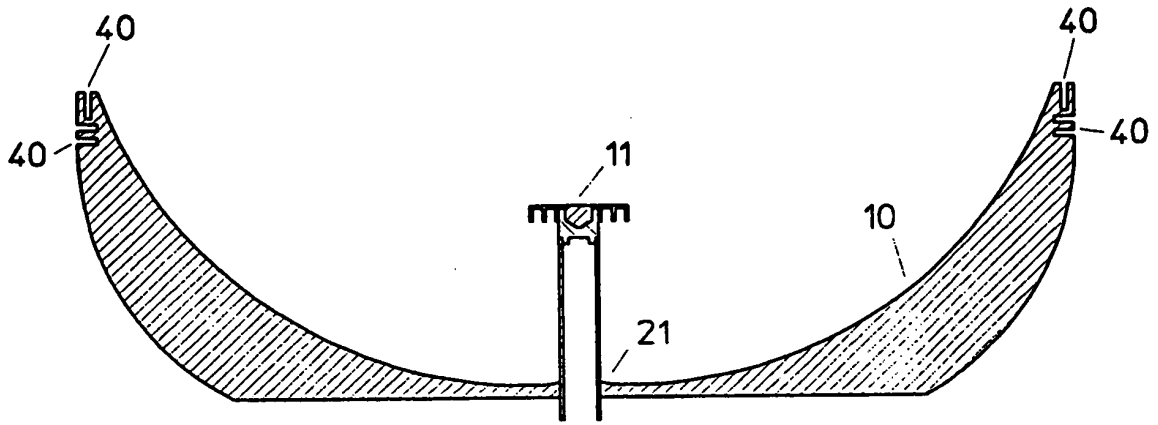


Fig. 1

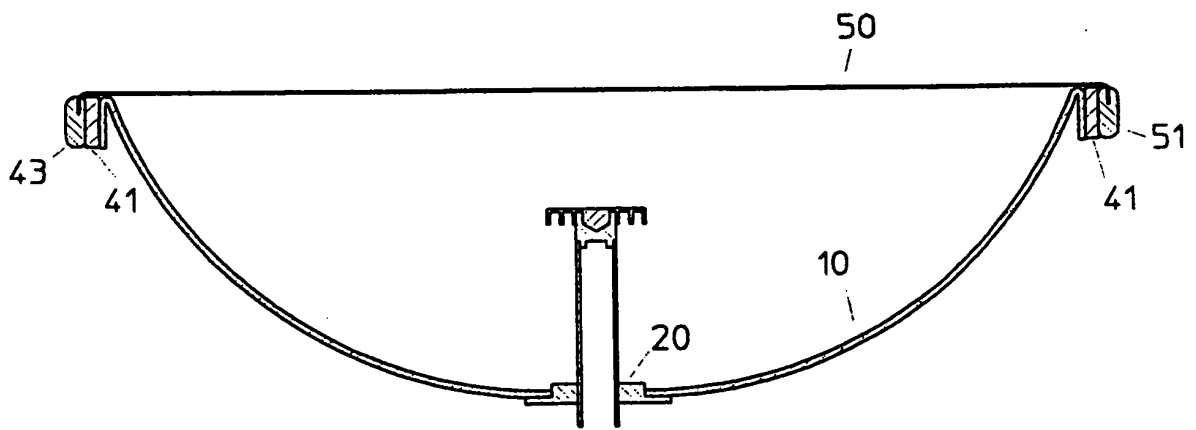


Fig. 2

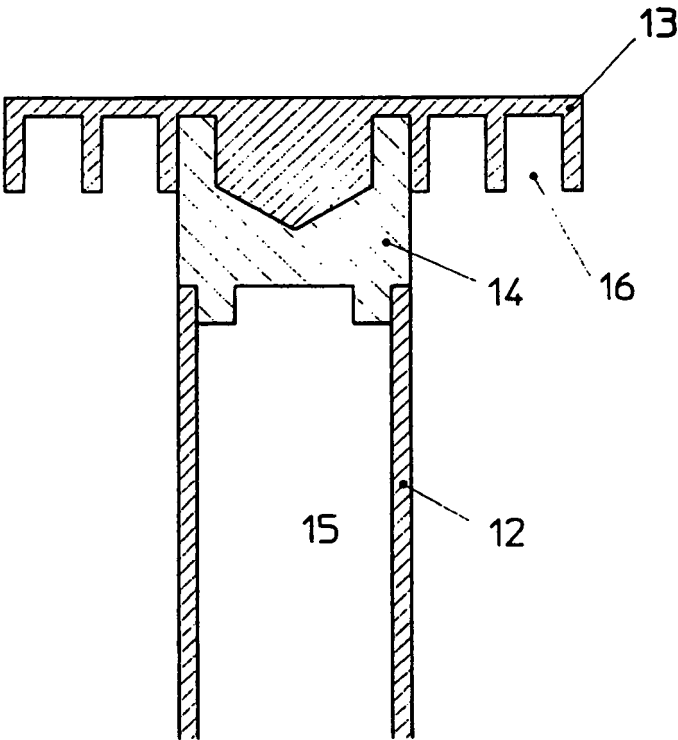


Fig. 3

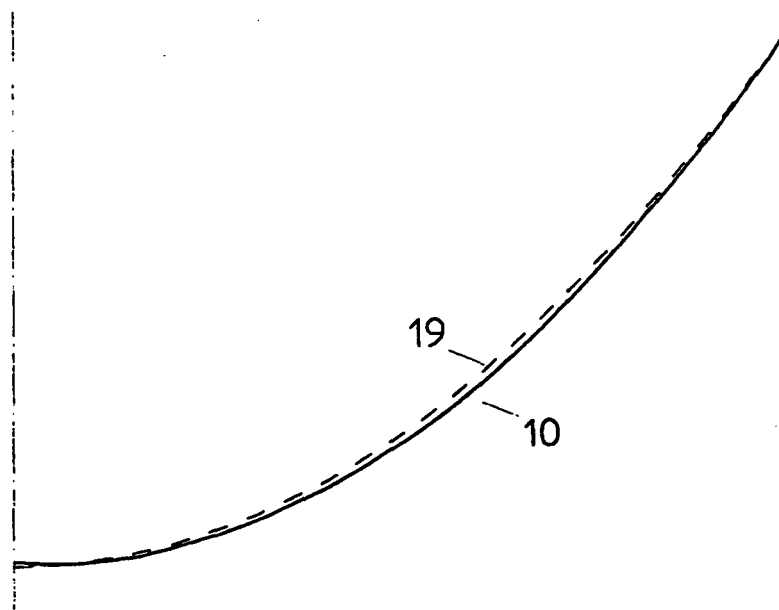


Fig. 4

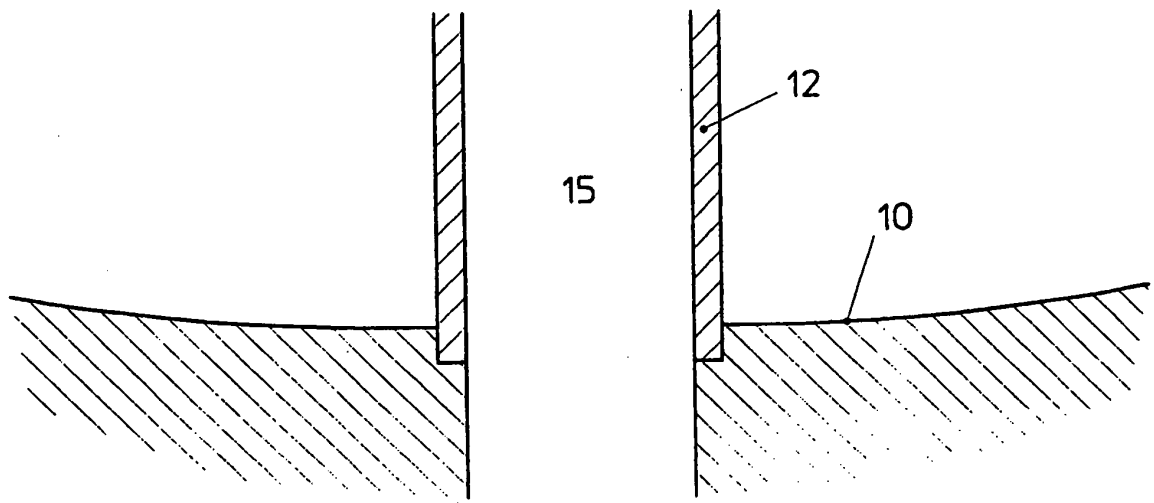


Fig. 5

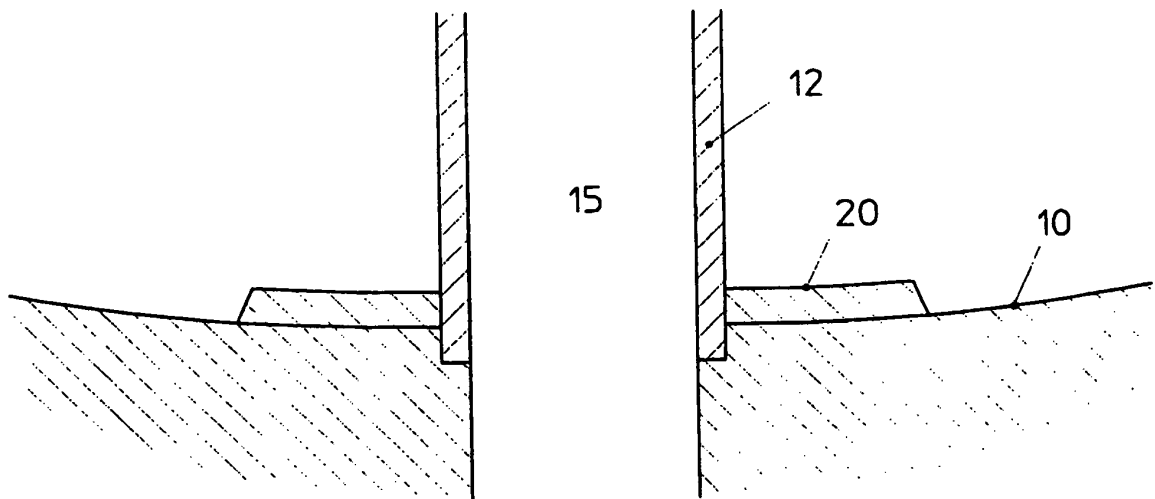


Fig. 6

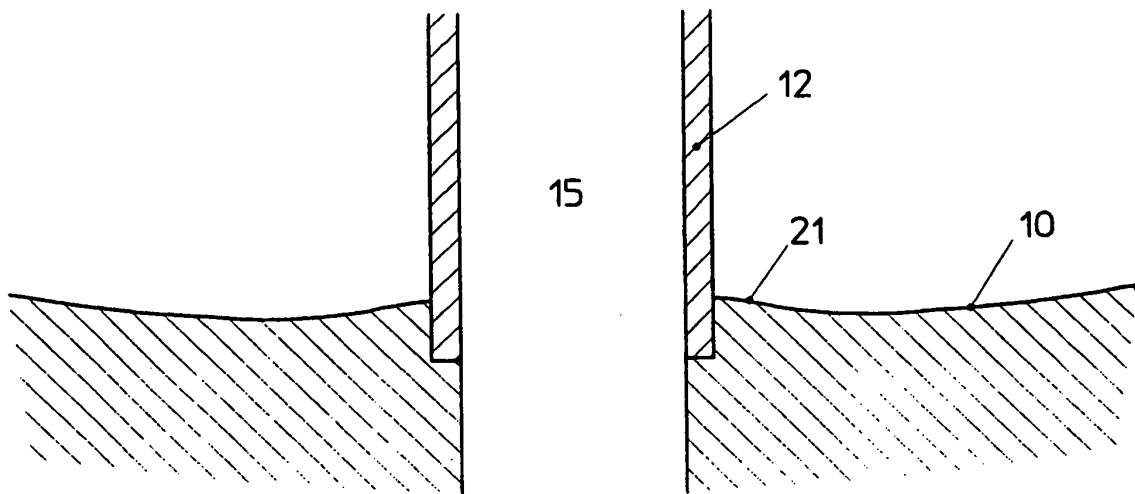


Fig. 7

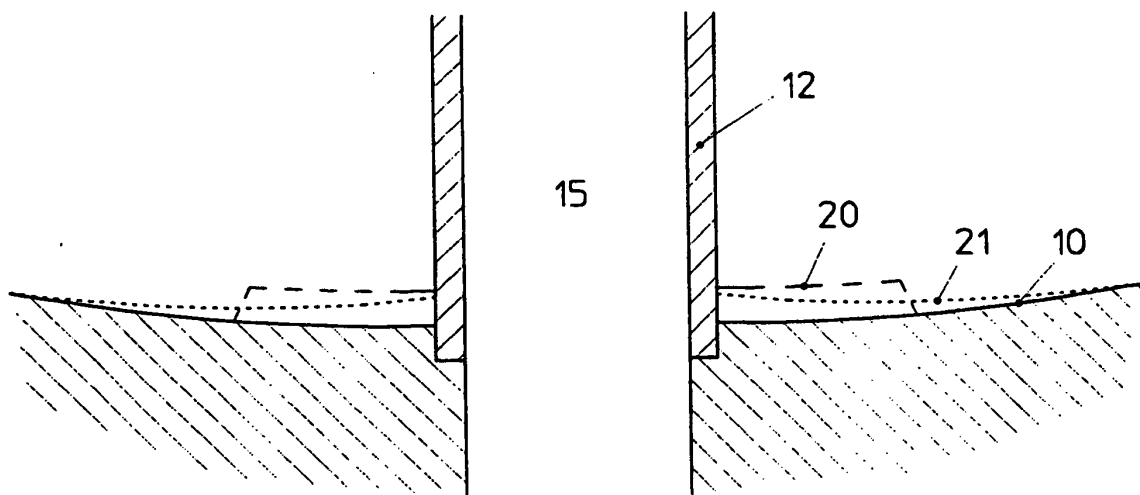


Fig. 8

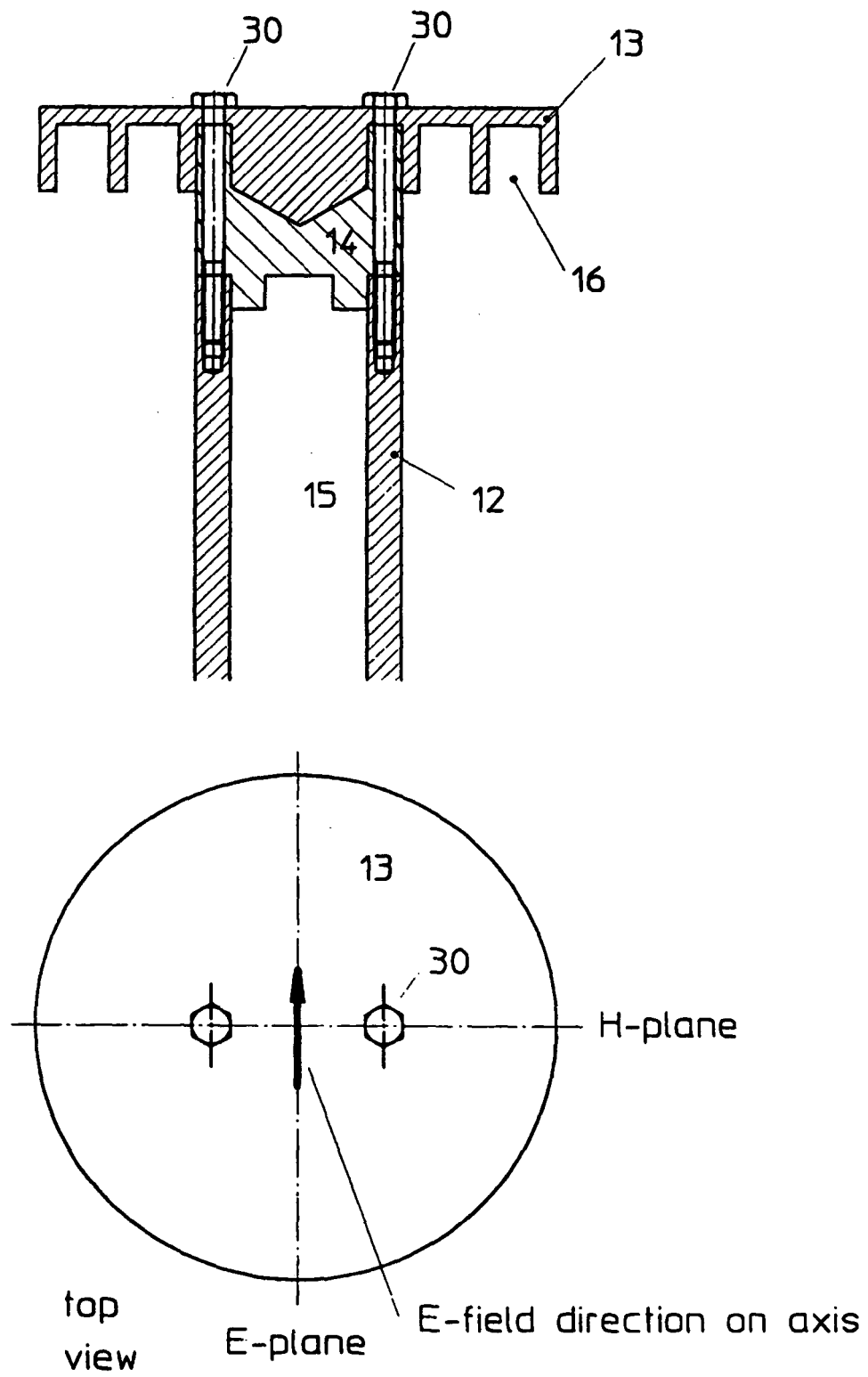


Fig. 9

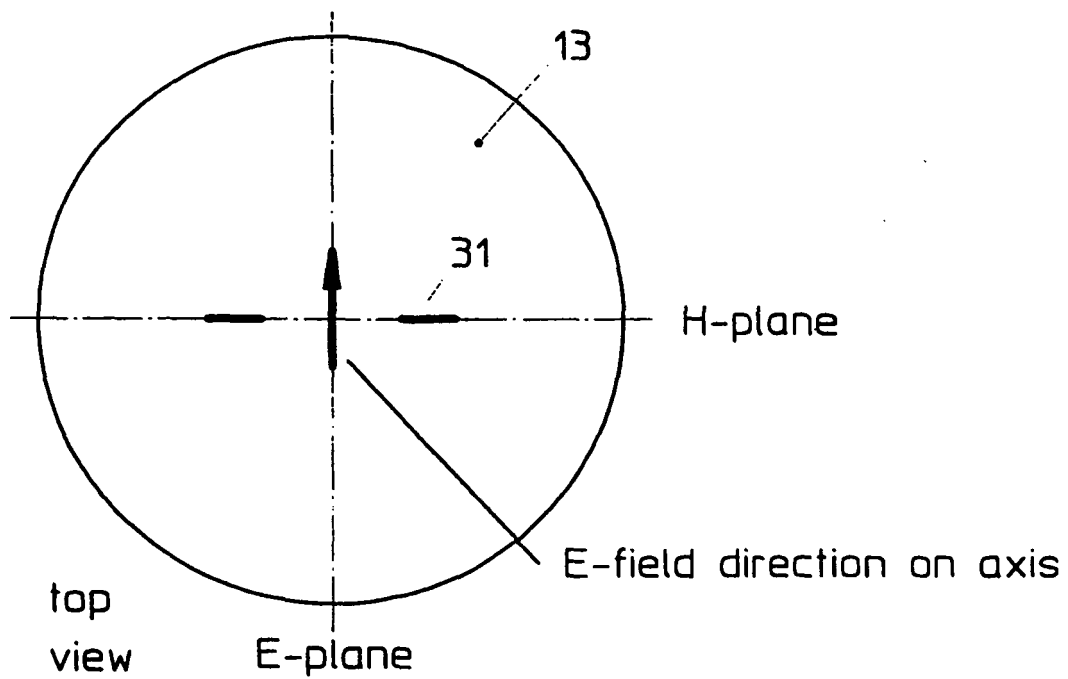
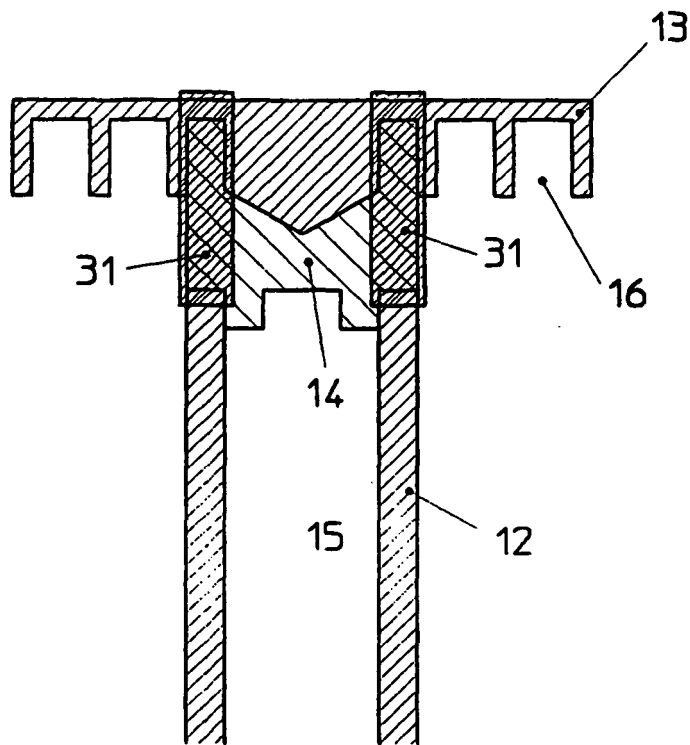


Fig. 10

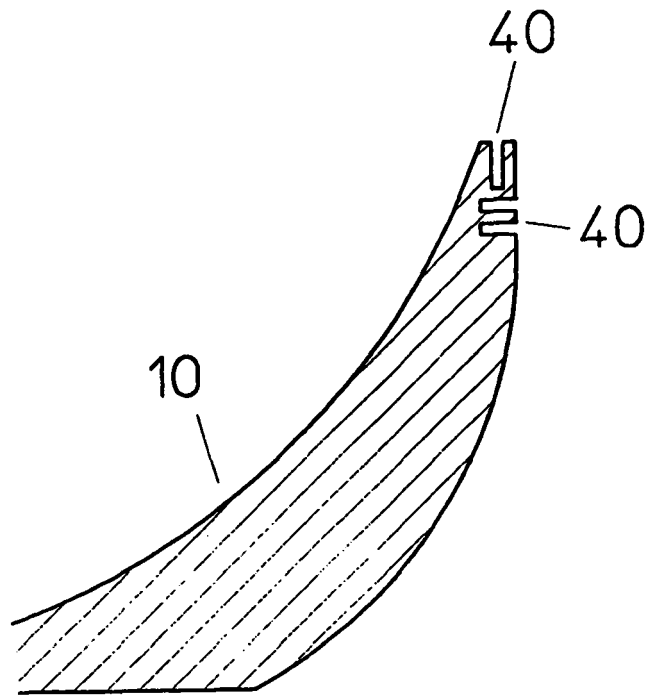


Fig. 11

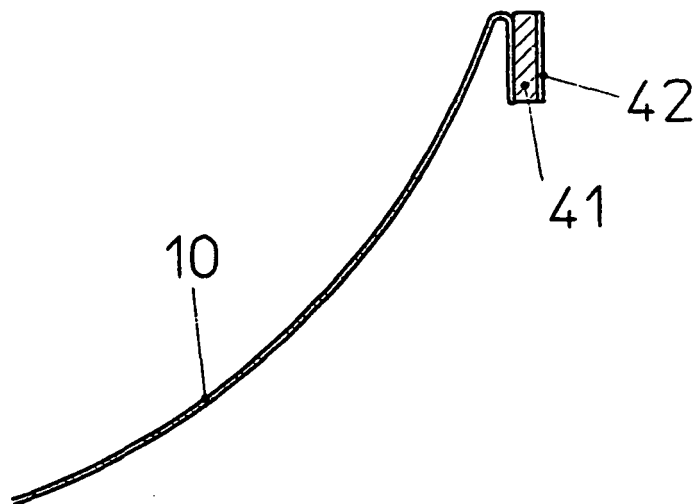


Fig. 12

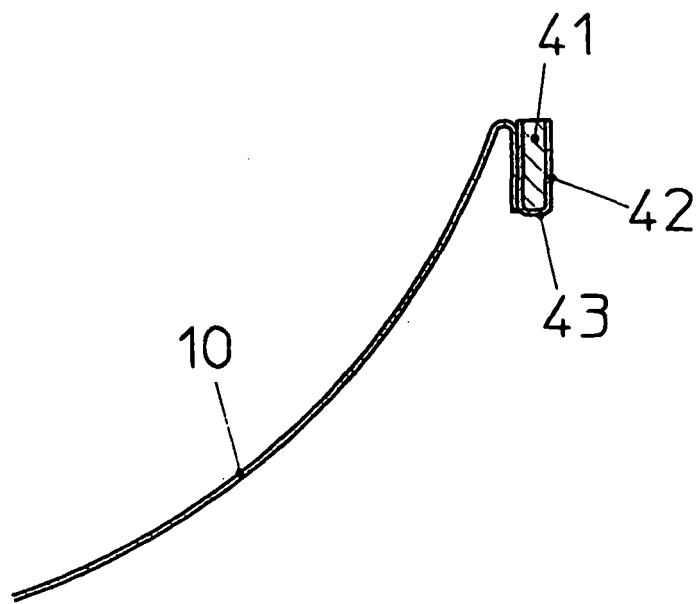


Fig. 13

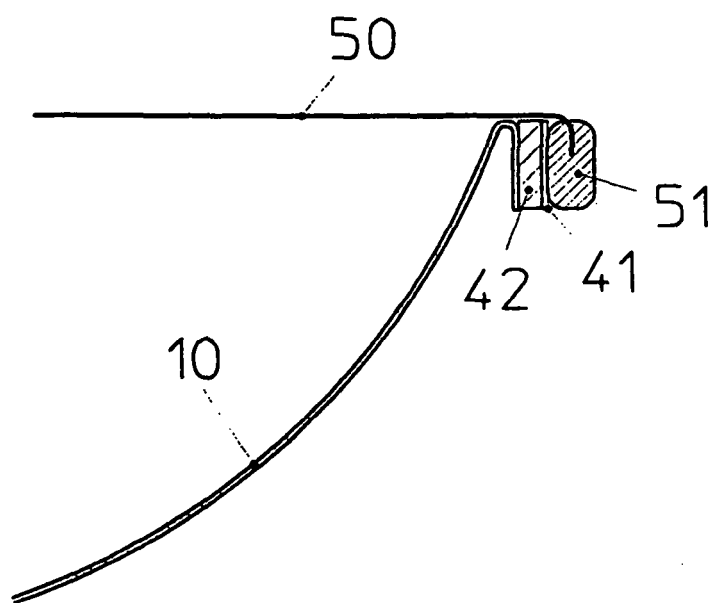


Fig. 14

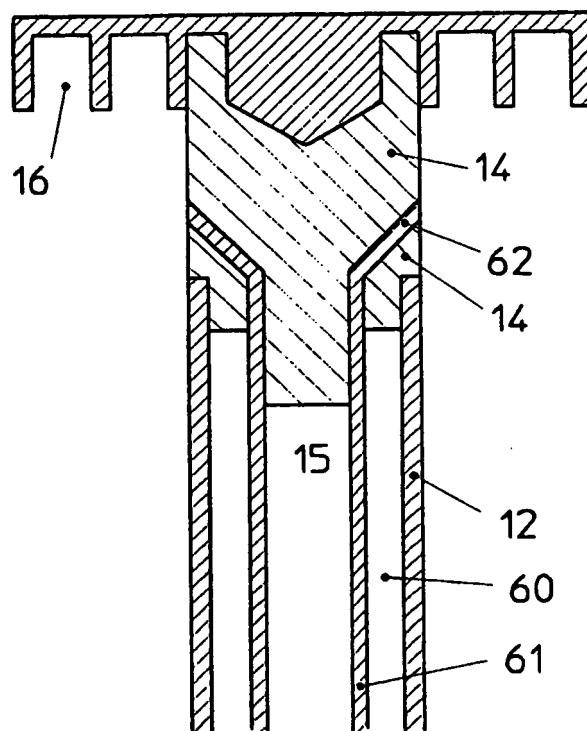


Fig. 15

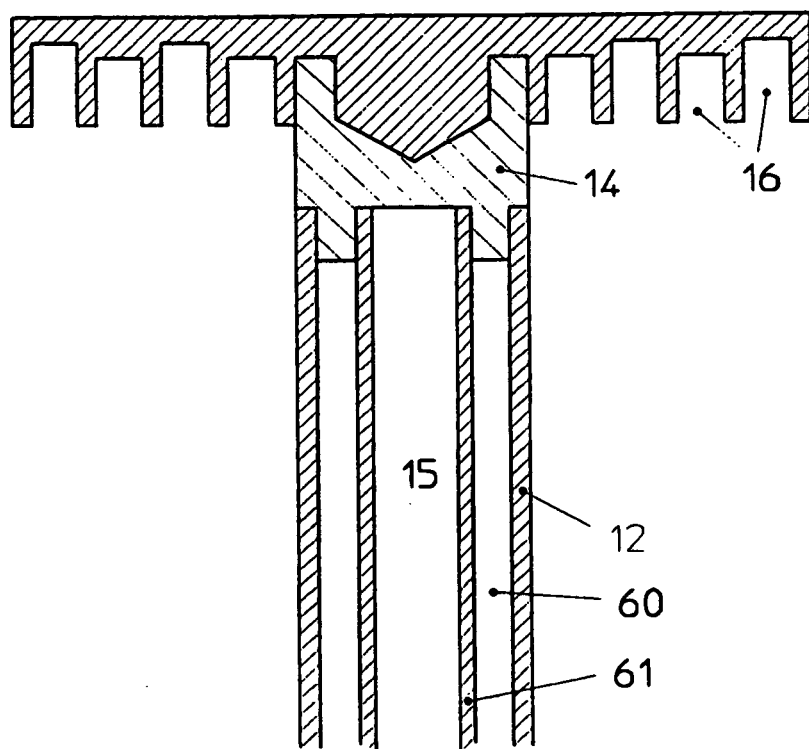


Fig. 16

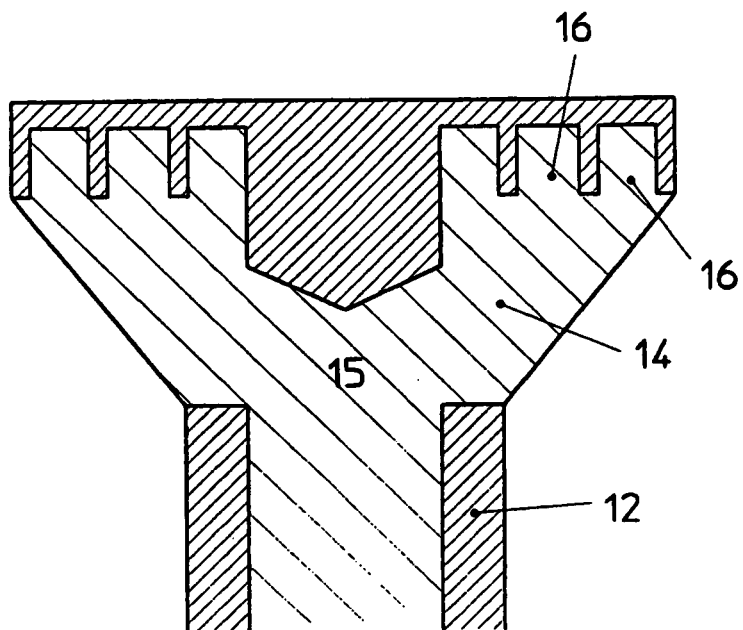


Fig. 17

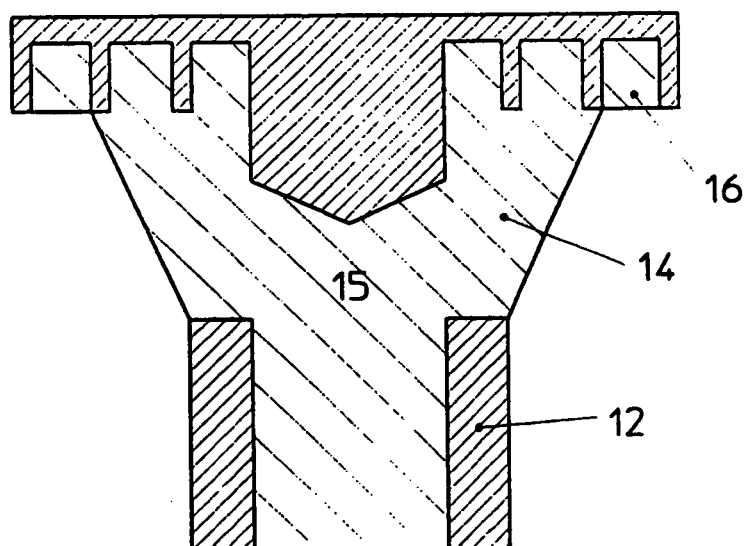


Fig. 18

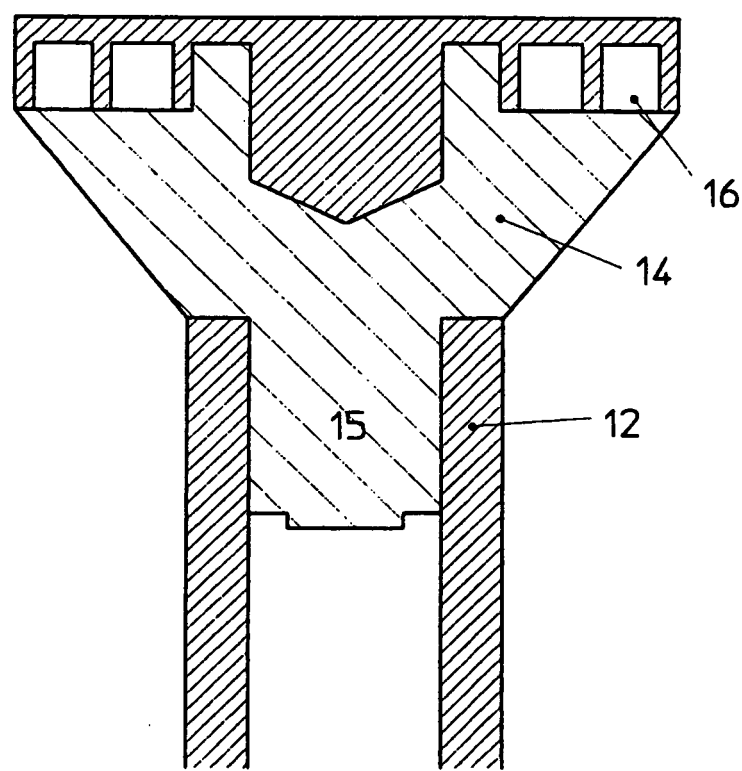


Fig. 19