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(54) **Adjustable fresnel zone plate**

(57) The invention relates to a reflective Fresnel zone plate for concentrating microwaves into a focal point. The Fresnel zone plate consists of a large number of mechanically adjustable subreflectors (4) each having two possible positions. The subreflectors constitute a first set of zones (1) and a second set of zones (2), with each zone construed for optimally contributing to the concentration of the microwaves.

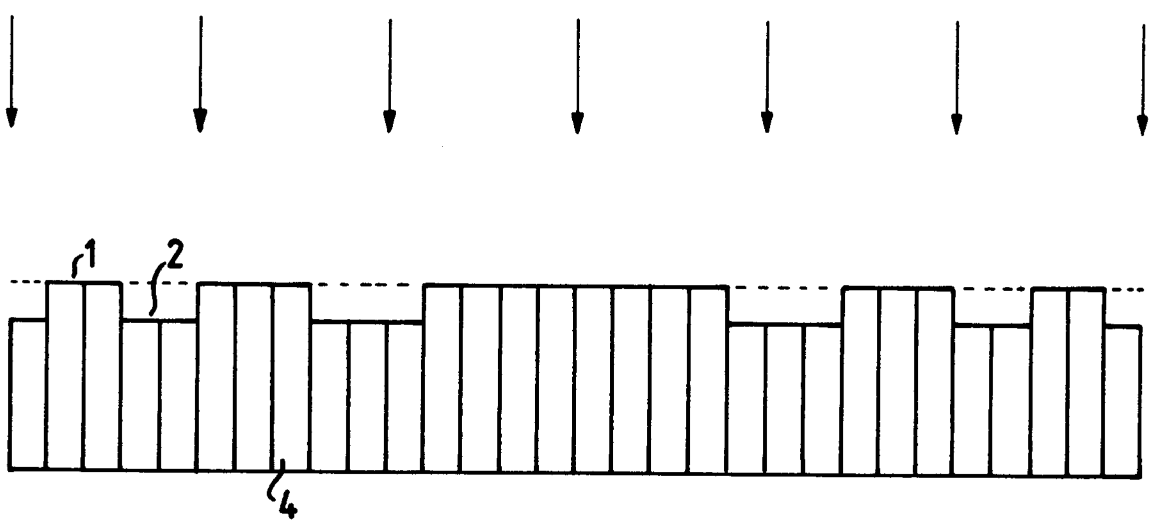

Fig. 2

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The invention relates to a reflective Fresnel zone plate for concentrating electromagnetic radiation into a focal point, comprising a first system of reflective subsidiary surfaces lying in a first plane and a second system of reflective subsidiary surfaces lying in a second plane, these subsidiary surfaces constituting the zones of the Fresnel zone plate.

The use of a Fresnel zone plate for concentrating electromagnetic radiation into a focal point is known from for instance US-A 4,905,014. This conventional Fresnel zone plate has the drawback that it is designed for perpendicularly incident radiation only. The present invention obviates this drawback and is characterised in that the Fresnel zone plate is provided with means for focusing electromagnetic radiation from a selectable direction.

For selecting a different direction, it will be required to change the system of reflective subsidiary surfaces. A favourable embodiment of the invention is characterised in that the means comprise mechanically adjustable subreflectors and in that the subsidiary surfaces are formed by at least substantially abutting subreflectors.

A further favourable embodiment of the invention is characterised in that in the standard mode of operation, the subreflectors are always positioned either in the first plane or in the second plane so that the mechanical setting can assume two positions only.

A still further embodiment of the invention is characterised in that the electrical distance between the first surface and the second surface is at least substantially a quarter of the wavelength of the electromagnetic radiation to be focused.

US-A 5,063,389 discloses a reflective Fresnel lens provided with mechanically adjustable subreflectors. In case of this conventional lens, a subreflector shall be proportionally driven across a distance that is half the wavelength of the electromagnetic radiation to be focused. Apart from the proportional drive that renders the system unduly expensive and consequently unsuitable for mass production, this entails the drawback that the subreflector has to be shifted over a distance that is twice as long as the distance specified in the present invention. The invention will generally require an increased number of subreflectors, although these can be obtained in a low-cost and lightweight design thus enabling a considerably faster drive.

A still further low-cost embodiment of the invention is characterised in that the first plane and the second plane are both flat.

The invention will now be explained in more detail with reference to the following figures, of which:

Fig. 1 schematically represents a Fresnel zone plate according to the state of the art;

Fig. 2 schematically represents a Fresnel zone plate according to the invention;

Fig. 3 represents a possible embodiment of an electromagnetically-adjustable subreflector;

Fig. 4 represents a further embodiment of an electromagnetically- adjustable subreflector.

A Fresnel zone plate can be used for concentrating microwave radiation into a focal point. Fig. 1 represents a cross-section of a conventional Fresnel zone plate provided with a first system of subsidiary surfaces 1 and a second system of subsidiary surfaces 2 formed by a system of circular grooves in a metal plate 3. The grooves have a depth of a quarter of the wavelength to be focused. Such a Fresnel lens enables the concentration of perpendicularly incident radiation into a focal point. The principle underlying the Fresnel zone plate is also described in great detail in Fundamentals of Optics, third edition, 1957, Jenkins and White, page 360.

For focusing electromagnetic radiation from a previously determined direction, a suitable system of Fresnel zones shall be calculated and the Fresnel zone plate shall be constructed accordingly. The calculation of the Fresnel zones follows directly from the known Fresnel theory based on a transformation from an incident flat wave front to a mostly spherical wave front that concentrates the electromagnetic energy into a previously selected focal point. For a perpendicularly incident wave front, the Fresnel zones constitute the known system consisting of a disc-shaped central spot surrounded by a number of concentric circles, the radius of circle m being proportional to the square root of m. The circles consequently become narrower and closer together. In case of non-perpendicularly incident radiation, these circles appear to have changed into complex, more or less elleptical contours. The contours can for each direction be simply calculated by dividing the surface of the Fresnel zone plate to be determined into an array of elements and by determining, per element, the path length of the electromagnetic radiation leaving the focal point, via the element, to a reference plane perpendicular to the desired radiation direction. The elements for which this path length deviates not more than 1/4 wavelength with respect to a reference length to be selected, are situated in a first plane, the other elements in a second plane, both planes constituting the Fresnel zone plate. It will be obvious that the path lengths are determined modulo the wavelength of the electromagnetic radiation.

According to the invention, each element is composed of a mechanically-adjustable subreflector. Fig. 2 schematically represents, fully analogous to Fig. 1, a cross-section of a Fresnel lens composed of a system of abutting subreflectors 4 of which the sides facing the incident radiation can assume two possible positions with an interspace of 1/4 wavelength of the radiation to be focused. This consequently yields a two-dimensional array of subreflectors 4, thousands of which will usually be required for constituting a Fresnel lens.

The dimension of a subreflector can be selected according to the following procedure. Depending on the application, a diameter and a focal point for the Fresnel lens are selected. Subsequently, the Fresnel patterns are calculated for a number of directions of the incident radiation. The subreflector dimensions shall now be such that the finest structures in the Fresnel patterns can still be detected in a correspondingly driven system of subreflectors.

A cross-section of a possible embodiment of an electromagnetically-adjustable subreflector 4 is schematically represented in Fig. 3. The actual subreflector 5 is made of metal and faces the incident radiation and is mounted on a pin 6 made of a ferromagnetic material, such as soft iron, which slides in a through-hole drilled in plate 7, also made of a ferromagnetic material.

An extension 8, made of a substantially non-ferromagnetic material is mounted coaxially with pin 6; extension 8 slides in a through-hole drilled in plate 9. Between plate 7 and plate 9 a magnetic return path, not shown here, is provided. This results in an at least substantially closed magnetic path that includes pin 6. By incorporating the remaining non-ferromagnetic gap in a coil 10 and by subsequently energizing this coil 10, it is possible to close the magnetic path as a result of which actual subreflector 5 shifts 1/4 wavelength. In case of a current interruption, the spring 11 transfers the actual subreflector 5 to the initial position, spring 11 ending against a plate 12.

A favourable embodiment is obtained by using synthetic materials for the production of actual subreflector 5, pin 6 and extension 8, which material is wherever required covered with ferromagnetic material and metal.

A further favourable embodiment of subreflector 4 is shown in Fig. 4; this embodiment comprises two coils 10 and 13 and two pins 6 and 14, both connected with an extension 8. Pin 14 slides in plate 12 that is provided with a through-hole and consists of a ferromagnetic material, for instance soft iron. A magnetic return path has again been provided between plate 9 and plate 12. This embodiment has the advantage that excitation of a coil is required only when subreflector 4 switches from one to the other position.

It will be obvious that analogous embodiments in which the coil is movable and the ferromagnetic material is fixed are also feasible.

Another possibility is to use subreflector 4 as shown in Fig. 3 without a spring 11. In that case the subreflector interior is pressurized by means of a gas, which pressure will exert an outward force on pin 6. Against this force, pin 6 can be pulled inwards by exciting coil 10. By furthermore allowing any leak between a hole and associated pin 6, 14 or extension 8, the escaping gas can moreover be used as an air bearing and coolant for the coils 10, 13. By regulating the gas pressure, it is also possible to compensate for accelerations that exert a perpendicular force to the surface of the Fresnel zone plate and which, without this provision, would cause all subreflectors to change position.

The adjustable Fresnel zone plate can advantageously be incorporated in a reservoir containing a microwave radiation-transmissive fluid that reduces both the wavelength of the microwave radiation and the required range of an adjustable subreflector. In addition, a fluid can improve the subreflector damping and can serve as lubricant. A suitable compartmentation of the reservoir moreover allows an overpressure in the subreflector required for forcing out pin 6.

The Fresnel zone plate can also be irradiated by means of a radiation source with a spherical wave front, for instance a microwave feedhorn. According to the reciprocity principle, a flat wave with a selectable direction can then be realised.

Claims

1. Reflective Fresnel zone plate for concentrating electromagnetic radiation into a focal point, comprising a first system of reflective subsidiary surfaces lying in a first plane and a second system of reflective subsidiary surfaces lying in a second plane, these subsidiary surfaces constituting the zones of the Fresnel zone plate, characterised in that the Fresnel zone plate is provided with means for focusing electromagnetic radiation from a selectable direction.

2. Fresnel zone plate as claimed in claim 1, characterised in that the means comprise mechanically adjustable subreflectors and in that the subsidiary surfaces are formed by at least substantially abutting subreflectors.

3. Fresnel zone plate as claimed in claim 2, characterised in that in the standard mode of operation, the subreflectors are always positioned either in the first plane or in the second

plane.

4. Fresnel zone plate as claimed in claim 3, characterised in that the electrical distance between the first plane and the second plane is at least substantially a quarter of the wavelength of the electromagnetic radiation to be focused.

5. Fresnel zone plate as claimed in claim 4, characterised in that the first plane and the second plane are both flat.

6. Fresnel zone plate as claimed in one of the above claims, characterised in that the subreflectors are provided with electromagnetic setting means having two possible positions.

7. Fresnel zone plate as claimed in claim 6, characterised in that the electromagnetic setting means comprises a moving part, containing ferromagnetic material, and at least one fixed coil.

8. Fresnel zone plate as claimed in claim 6, characterised in that the electromagnetic setting means comprises at least one moving coil and a fixed ferromagnetic part.

9. Fresnel zone plate as claimed in claim 6, characterised in that means are provided for moving a subreflector to a defined position without activating the electromagnetic setting means.

10. Fresnel zone plate as claimed in claim 9, characterised in that the means comprise an overpressure of a medium in the subreflector.

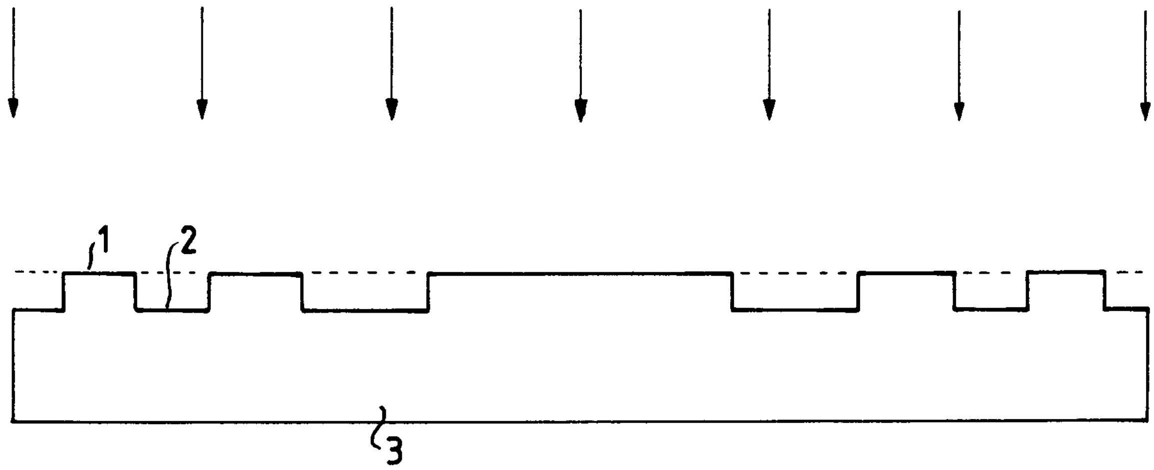

Fig. 1

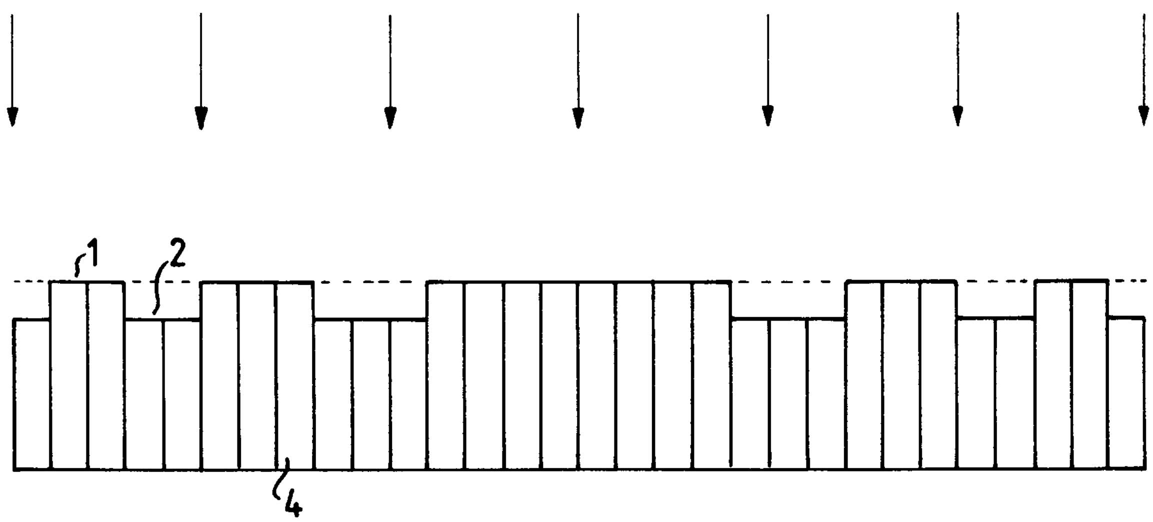

Fig. 2

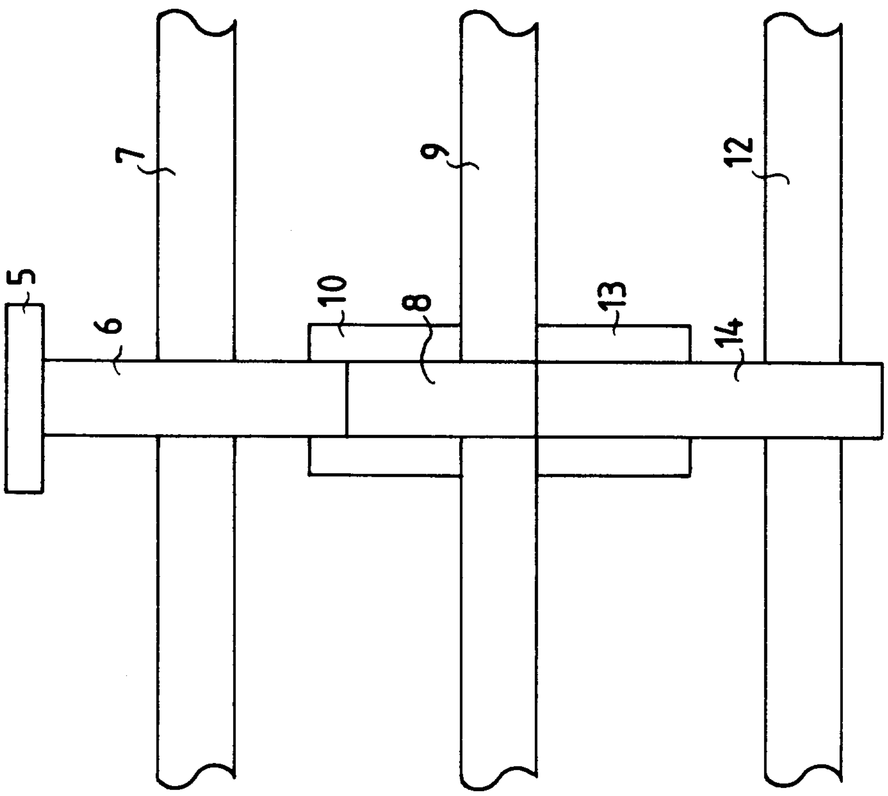

Fig. 4

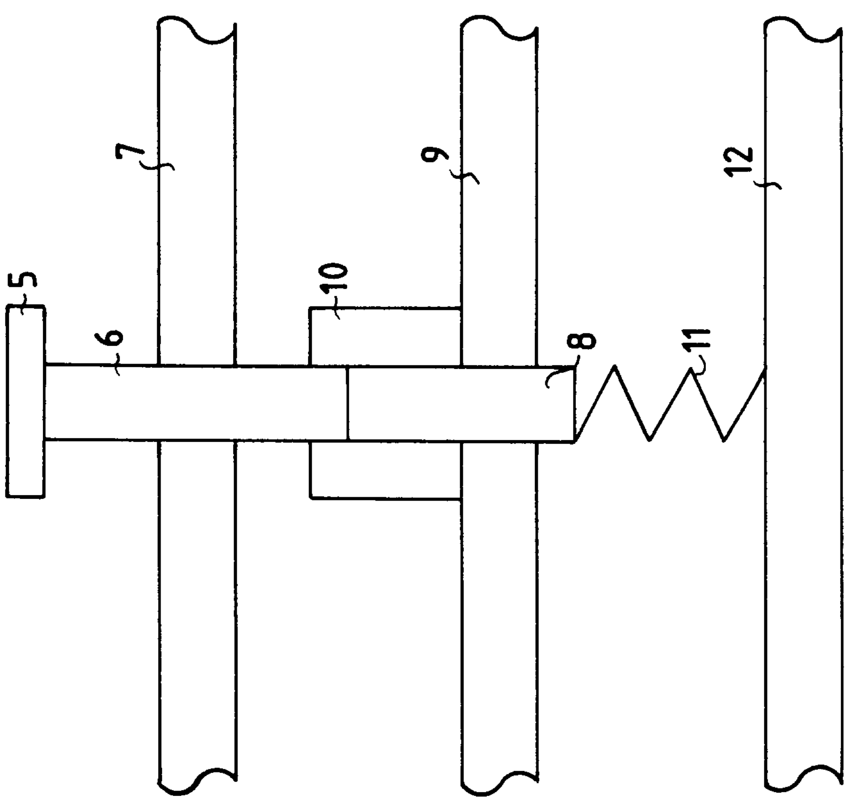

Fig. 3