United States Patent

[11] 3,594,804

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[21] Appl. No. **754,399**
[22] Filed **Aug. 21, 1968**
[45] Patented **July 20, 1971**

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[32] Priority **Aug. 22, 1967**
[33] **Great Britain**
[31] **38619/67**

[54] **ELECTRICALLY CONTROLLED REFLECTIVE SURFACE EMPLOYING FERRITE MATERIAL**
3 Claims, 8 Drawing Figs.

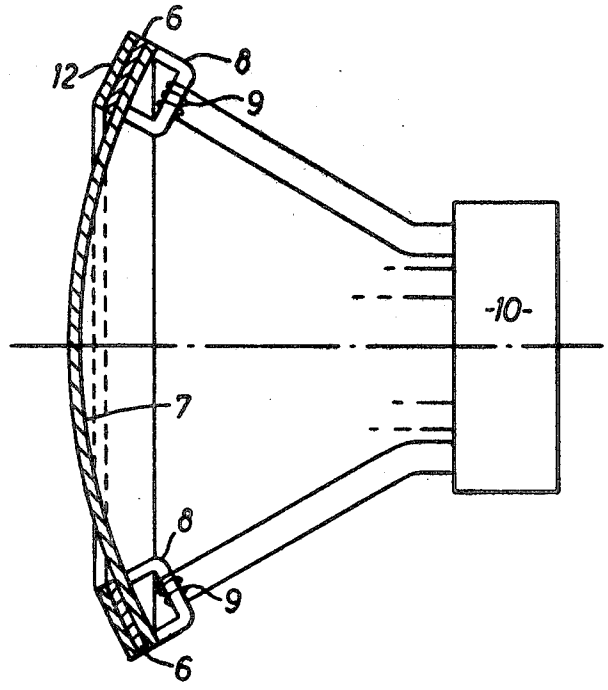
[52] **U.S. Cl.** **343/754,** 343/755, 343/787, 343/781
[51] **Int. Cl.** **H01q 19/06**
[50] **Field of Search** 343/754, 755, 785, 787, 909, 911, 781

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ABSTRACT: In a microwave system a microwave reflector is provided which is capable of selective displacement. The reflector is formed by a layer of ferrite material, and a nonferromagnetic microwave reflecting surface behind said layer. The selective displacement is produced by means for selectively inducing a magnetic field within said ferrite layer, the arrangement being such that changes in the magnetic condition of said ferrite layer cause said layer to change from a transparent state to a reflecting state for microwave energy.



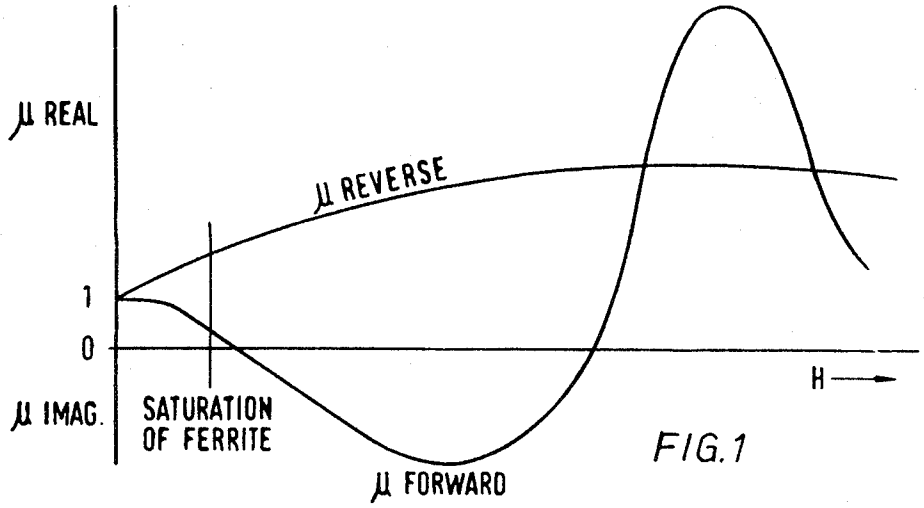


FIG. 1

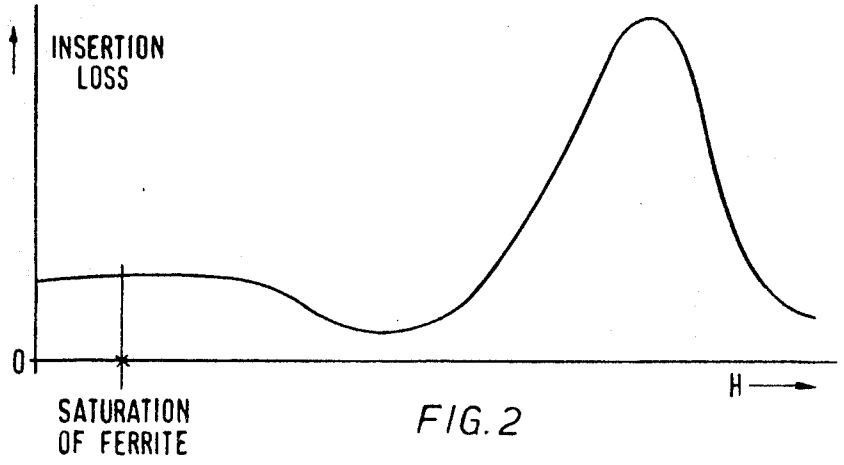


FIG. 2

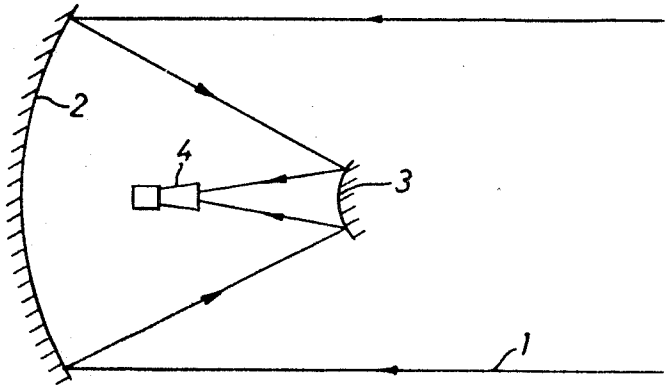


FIG. 3

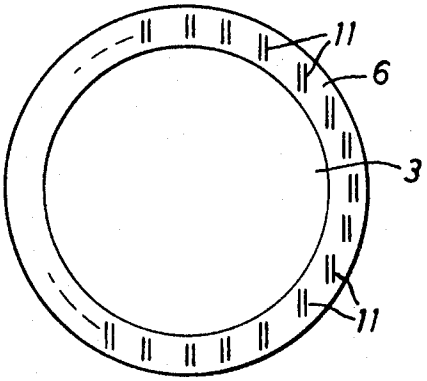


FIG. 4

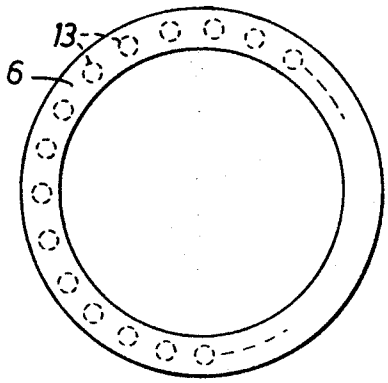


FIG. 6

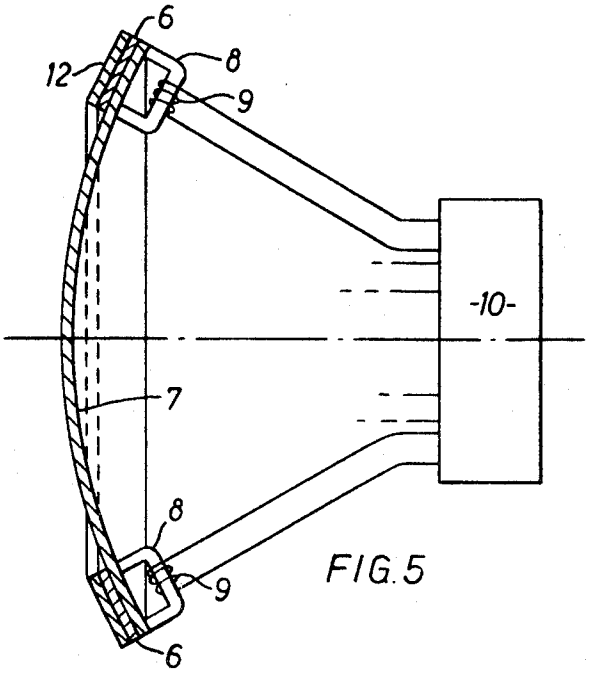


FIG. 5

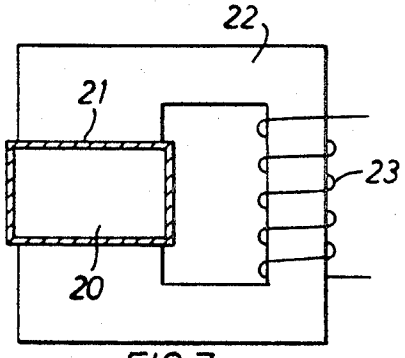


FIG. 7

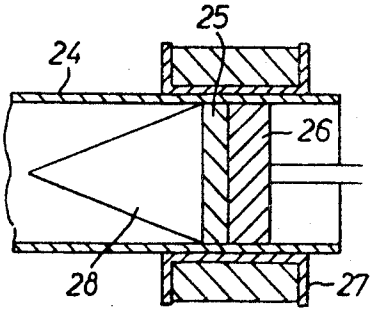


FIG. 8

ELECTRICALLY CONTROLLED REFLECTIVE SURFACE EMPLOYING FERRITE MATERIAL

This invention relates to improvements in surfaces for reflecting microwave energy and especially though not exclusively to subreflectors for antenna arrays.

A Cassegrain aerial system is often employed for tracking communication satellites. The satellite must be continuously tracked and the error signals for this purpose are derived from a conical beam scanning motion produced by spinning a subreflector about an axis, slightly inclined to the normal axis of the subreflector, by means of a small, high speed motor. In this way the frequency of the error signal may be made consistently higher than other periodic signal variations, for example those caused by vibration of the mountings, dish distortion due to gusting of the wind, the failure of the satellite aerial stabilizing system or even relatively fast fluctuations in signal path attenuation.

The need to make the subreflector moveable makes it impractical to employ any form of microwave feed which requires only very light supporting struts. In addition the off axis inclination of the subreflector causes a permanent slight signal loss, since the antenna beam can never exactly point at the satellite.

It is an object of the present invention to provide a surface for reflecting microwave energy which allows selective displacement of a reflected beam without mechanical movement. It is also an object of the invention to provide an improved aerial system which enables a tracking function to be achieved simply and without spinning a subreflector.

One object of the invention is to provide in a microwave system, a microwave reflecting surface which is capable of selective displacement, including a nonferromagnetic microwave reflecting surface and a ferrite ring on said surface said ring comprising a plurality of sectors, means for inducing a magnetic field in a selected one of said sectors so as to change the magnetic condition of the ferrite in the selected sector from a substantially transparent to a substantially reflecting condition for microwave energy and vice versa, wherein the distance between the front surface of said ring and said reflecting surface is electromagnetically equivalent to the required displacement.

Another object of the invention is to provide in a microwave system, a microwave reflecting surface which is capable of selective displacement, including a layer of ferrite material, a nonferromagnetic reflecting surface situated behind said layer of ferrite material, and commutating means for selectively changing the magnetic condition of different parts of said layer in a prearranged order to produce a scanning system, the arrangement being such that a change in the magnetic condition of a part of said layer causes said part to change from a substantially transparent to a substantially reflecting condition for microwave energy and vice versa, the distance between the front surface of said layer and said reflecting surface being electromagnetically equivalent to the required displacement.

A further object of the invention is to provide a microwave antenna system including a reflector comprising a layer of ferrite backed by a nonferromagnetic microwave reflecting surface, respective control means for producing a magnetic field in respective parts of said layer, and means for selectively energizing said control means, whereby microwave energy, incident on a part of said layer, is reflected either from the front surface of said layer or from said reflecting surface in dependence upon the presence or absence in said part of a magnetic field produced by said control means, the thickness of the layer being such that said incident microwave energy is reflected to different spatial positions, separated by a required distance, in dependence upon the surface from which it is reflected.

In order that the present invention may be clearly understood and readily carried into effect practical embodiments thereof will now be described by way of example, with reference to the accompanying drawings of which:

FIGS. 1 and 2 are graphs explanatory of the invention,

FIG. 3 illustrates a form of Cassegrain antenna system to which the invention may be applied,

FIGS. 4 and 5 are diagrammatic views depicting one embodiment with the invention applied to an aerial system,

FIG. 6 is a diagrammatic view of another embodiment of the invention, and

FIGS. 7 and 8 illustrate applications of the invention to waveguide systems.

The propagation of microwaves through a ferrite can result in an interaction between the magnetic fields within the ferried caused by the gyromagnetic behavior of the electrons, and the magnetic component of the microwave. If the ferrite is magnetized by an externally applied field, then interaction is dependent on the magnitude of the magnetization, the polarity of the magnetic field and the polarization of the microwave with respect to the polarity of the magnetic field. Interaction takes place when the external field vector is orthogonal to the H-vector of the microwave; the direction of propagation of the microwave is also significant.

Thus, a circularly polarized wave travelling through a ferrite in the forward direction may, say, interact very strongly with the field of the precessing electrons, but only weakly when travelling in the opposite direction. This phenomenon gives rise to two different "effective permeabilities" depending purely on the direction of propagation through the ferrite in relation to the sense of polarization, even if all other conditions remain constant.

This is illustrated in FIG. 1, which shows changes in the normalized permeability of a ferrite with applied field H for electromagnetic energy of a particular polarization propagating in two different directions, denoted as the forward and reverse directions. The curves of FIG. 1 show that the effective permeability can be made zero, i.e. the ferrite becomes opaque, to microwaves travelling in the "forward" direction. The magnetization to achieve the opaque condition is slightly greater than that required for saturation of the ferrite. A study of the curves in FIG. 1 shows that there are, in fact, two values of magnetization for which $\mu=0$ and the ferrite is opaque, but for practical purposes the lower one is the significant one.

Transmission through ferrites also causes a loss of microwave power. Since the permeability changes in an anomalous manner with the applied magnetization, it is not surprising to find that the insertion loss exhibits peaks and troughs. A typical dependence of the insertion loss of the magnetization H is shown in FIG. 2. The insertion loss is however small for the range of practical significance.

Not all ferrites exhibit a pronounced "dip" at magnetizations beyond the saturation point, but one might select a ferrite that behaved in this manner.

Hence there are two ways in which the invention can be made to work in order to alternate between the states of transmission and opacity. Firstly the ferrite is normally unmagnetized and is then switched to a magnetization which makes it opaque. Secondly, the ferrite is normally biassed to a point where it is opaque to microwaves the the magnetization is then increased to make it transparent in the region where it also exhibits a lower insertion loss. However, the arrangements illustrated by FIGS. 3 to 7 operate in the first mode. The second mode though feasible is less significant practically because the loss introduced by specially developed microwave ferrites is already very small and one would naturally select a material that has a negligible loss when unmagnetized.

The shapes of the curves shown in FIGS. 1 and 2 remain unaffected by the strength of the microwave field but a very powerful field would tend to introduce additional losses due to spin resonances set up within the ferrite material. Such changes are however second order effects.

The fact that interaction can only occur between two orthogonal fields is important to the fulfillment of the invention. If the H-vector of the microwave field is assumed to be in the plane of the paper, then the controlling field can either also be in the plane of the paper but transverse to the H-vector of the microwave field, or it can be at right angles to the plane

of the paper. A controlling magnetizing field of the first sense is referred to as a transverse field and a controlling magnetizing field of the second sense is referred to as a longitudinal field. As will appear, both senses of controlling the field can be utilized in performing the invention, but each one only for specific cases of polarization of the microwave energy. In neither case can the microwave energy take over the control of the ferrite.

A typical Cassegrain antenna system to which the invention can be applied is illustrated in FIG. 3. Such a system could be used for receiving signals from a communication satellite. A parallel beam 1 of energy from the satellite or other source in concentrated by a main reflector 2 on to a subreflector 3 which in turn reflects the energy into the receiver feed 4. In accordance with the invention, the shape of the polar diagram of the Cassegrain system can be distorted in a systematic way by making use of the property of ferrite material which has been discussed in the preceding paragraph. Thus in accordance with the invention the subreflector 3 is provided on an outer annulus with a ring 6 of ferrite material, the subreflector comprising a thin nonferromagnetic metallic disc 7 of convex shape. As indicated particularly in FIG. 5, a number of U-shaped electromagnets having cores 8 and energizing windings 9 are located behind the part of the metallic disc 7 which is covered by the ferrite ring 6. The poles of each U-shaped magnet are aligned so that each magnet, when energizing current is fed to the respective winding 9, produces flux lines in the ferrite ring which are parallel to one another in the plane of the paper as shown in FIG. 4. Only two of the magnets are illustrated in FIG. 5. All the windings are coupled to the output leads of an electric commutating device indicated by the block 10. In operation of the aerial, current is fed to the magnets 9 by the commutating device in some prearranged order so that sectors of the ferrite ring 6 are successively magnetized so as to change the sectors from an opaque condition to a transparent condition. When a sector of the ferrite is in an opaque condition microwave energy is reflected from the front surface, but when it is transparent, the microwave energy is transmitted through the ferrite and is reflected from the front surface of the metal disc 7. The form of the invention illustrated in FIGS. 4 and 5 can be used with microwaves which are linearly polarized with the H-vector in the plane of the paper, seen in FIG. 4, but perpendicular to the flux lines produced by the electromagnets. A few of the flux lines are indicated in FIG. 4 and are all noted by the reference 11. As a result of changing the magnetic condition of sectors of the ferrite ring 6 the antenna beam becomes distorted and the normally circular cross section of the polar diagram of the beam will display an inward or outward distortion over an angular range corresponding to the energized sector.

It will readily be appreciated that by selectively energizing the electromagnets 8 to change the conditions of corresponding sectors of ferrite, a lobing or nutating effect can be produced from which an error signal for control purposes may be derived using conventional servo and guidance techniques. By employing a suitable core material for the electromagnets 8, 9 high switching frequencies may be employed, allowing nutation to occur in the frequency range of up to a few kHz. or more. Such high frequencies would not normally be possible with prior mechanical arrangements. In addition, operation in a variety of modes is possible, and the nutation frequency may be varied rapidly in order to synchronize with, or to discriminate against, various kinds of signal variation.

Since the dielectric constant of the ferrite material is of the order of 12, a small mismatch is present when the ferrite is transparent on the microwaves. This can be reduced when desired, by coating the ferrite with a quarter wave thick layer of dielectric material 12 whose dielectric constant is or approximates to the geometric mean of that of the ferrite and that of air.

The thickness of the ferrite ring 6 may be from one-eighth inch to one-fourth inch thick and the magnetic field required to produce the desired change of magnetization in the ferrite may be between 1,000 to 2,000 Gauss.

The alternative form of the invention illustrated in FIG. 6 is also applicable to a Cassegrain system such as illustrated in FIG. 3. In this case however, different sectors of the ferrite ring 6 are arranged to be selectively magnetized by means of rod type electromagnets 13 which have a single pole adjacent the rear surface of the disc 7. Thus, the electromagnets produce a magnetic field normal to the surface of the subreflector. The arrangement shown in FIG. 6 can be used where the microwave energy is linearly polarized with its H-vector in any direction in the plane of the paper. It can however also be used when the microwave energy is circularly polarized.

The invention can also be employed for varying the reflecting position of surface in waveguides and FIGS. 7 and 8 illustrate two such applications of the invention. According to FIG. 7 a ferrite layer 20 is provided normal to the longitudinal dimension of a rectangular waveguide 21 and the rear surface of the layer 20 is metallized so that it forms a reflecting surface. A magnet 22 having an energizing winding 23 is provided outside the waveguide to change the magnetic condition of the waveguide 20 so as to render it transparent and opaque. The electromagnet 22, 23 is arranged to magnetize the ferrite transversely. Fig. 8 shows a similar application of the invention, but to a waveguide 24 of circular cross section. In this case the ferrite is in the form of a disc 25 applied to the front surface of a plunger 26. The electromagnet is represented generally by the reference 27 and in this case it is arranged to magnetize the ferrite material 25 longitudinally. Matching of the discontinuity of the ferrite member 20 or 25 to the hollow waveguide can be achieved by providing a tapered dielectric wedge or cone, depending on the type of waveguide, a matching cone 28 being illustrated in the case of the circular waveguide 24.

Ferrite material used as illustrated in FIGS. 7 and 8 is employed to move the apparent position of a short circuit, in the same way as illustrated in the case of a Cassegrain aerial system in FIGS. 3 to 6.

Modifications of the embodiments illustrated may of course be made whilst keeping to the basic principles of the invention. A number of electromagnets provided for the Cassegrain subreflector may vary within relatively wide limits and the ferrite material forming the ring 6 may be divided into a number of sectors corresponding to the number of electromagnets. The invention is also applicable to transmitting systems as well as receiving systems and it may be applied to aerial systems other than the Cassegrain type. For example, it may be applied to antenna systems of the Georgian telescope type in which the subreflector is concave.

In addition the film of ferrite 6 may be mounted on a dielectric support separated from the metallic disc 7. Furthermore the front surface of the ferrite and the metallic reflecting surface placed behind it, may be inclined at an angle one to the other, so that the effective reflecting plane is not only displaced, but is also deflected when the ferrite is made transparent by saturation. The ferrite may cover larger areas of the subreflector than in the example shown.

What I claim is:

1. In a microwave system, a microwave reflecting surface which is capable of selective displacement, including a nonferromagnetic microwave reflecting surface and a ferrite ring on said surface, said ring comprising a plurality of sectors, means for inducing a magnetic field in a selected one of said sectors so as to change the magnetic condition of the ferrite in the selected sector from a substantially transparent to a substantially reflecting condition for microwave energy and vice versa, wherein the distance between the front surface of said ring and said reflecting surface is electromagnetically equivalent to the required displacement.

2. In a microwave system, a microwave reflecting surface which is capable of selective displacement, including a layer of ferrite material, a nonferromagnetic reflecting surface situated behind said layer of ferrite material, and commutating means for selectively changing the magnetic condition of different parts of said layer in a prearranged order to produce a

scanning system, the arrangement being such that a change in the magnetic condition of a part of said layer causes said part to change from a substantially transparent to a substantially reflecting condition for microwave energy and vice versa, the distance between the front surface of said layer and said reflecting surface being electromagnetically equivalent to the required displacement.

3. A microwave antenna system including a reflector comprising a layer of ferrite backed by a nonferromagnetic microwave reflecting surface, respective control means for producing a magnetic field in respective parts of said layer, and means for selectively energizing said control means, whereby microwave energy, incident on a part of said layer, is reflected either from the front surface of said layer or from said reflecting surface in dependence upon the presence or absence in said part of a magnetic field produced by said control means, the thickness of the layer being such that said incident microwave energy is reflected to different spatial positions, separated by a required distance, in dependence upon the surface from which it is reflected.