

United States Patent [19]**Gilbert**[11] **3,708,796**[45] **Jan. 2, 1973**[54] **ELECTRICALLY CONTROLLED
DIELECTRIC PANEL LENS**[76] Inventor: **Bony Gilbert**, 67, Boulevard Gallieni, Issy, France[22] Filed: **Oct. 15, 1970**[21] Appl. No.: **81,062**[30] **Foreign Application Priority Data**

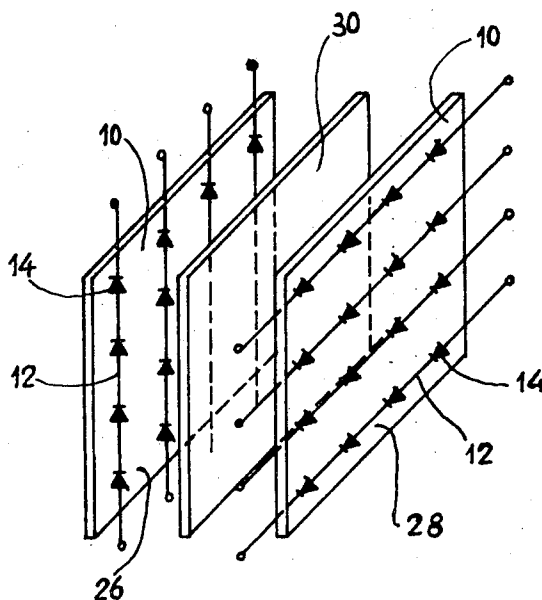
Oct. 15, 1969 France.....6935239

[52] U.S. Cl.**343/754, 343/756, 343/909**[51] Int. Cl.**H01q 19/06**[58] Field of Search.....343/757, 754, 755, 854, 909,
343/756[56] **References Cited****UNITED STATES PATENTS**

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3,392,393 7/1968 Spitz.....343/754*Primary Examiner*—Eli Lieberman*Attorney*—Young & Thompson[57] **ABSTRACT**

The apparatus and process for phase shifting a radiated microwave includes passing the microwave beam through a dielectric panel in which is imbedded at least one plane network of conductive leads running parallel with the electric field of the incident wave. Switches mounted on each lead are spaced from each other at distances less than two wavelengths in the dielectric material, of the incident energy. By these switches, the leads may be divided in little sections.

3 Claims, 6 Drawing Figures

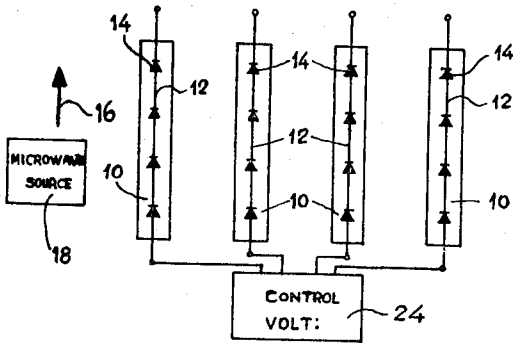


FIG. 1

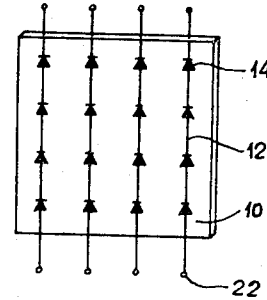


FIG. 2

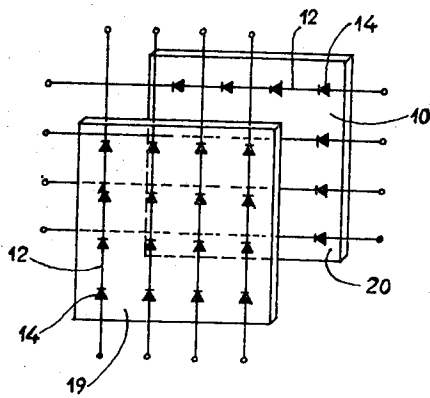


FIG. 3

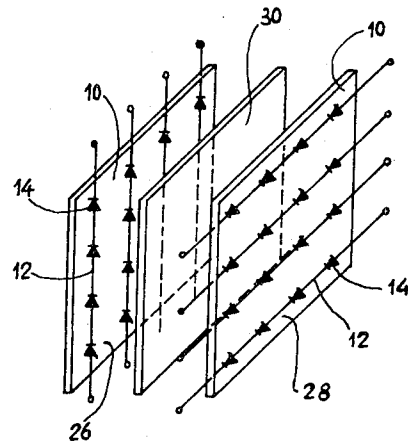


FIG. 4

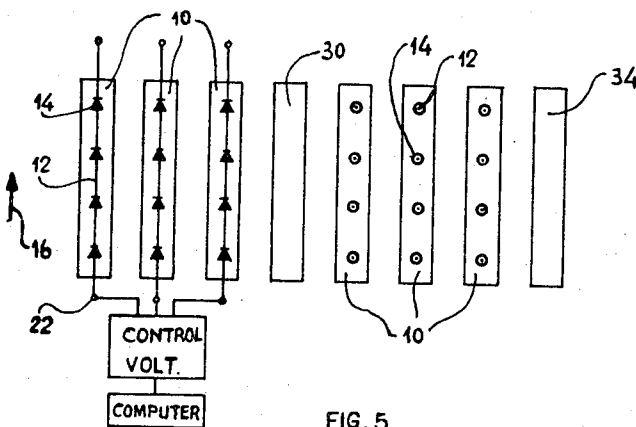


FIG. 5

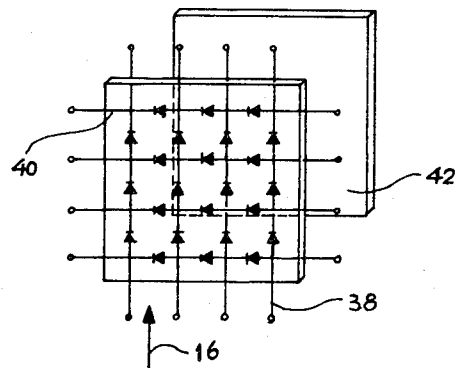


FIG. 6

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ELECTRICALLY CONTROLLED DIELECTRIC PANEL LENS

BACKGROUND OF THE INVENTION

This invention relates to a process for phase-shifting, as required, a beam emitted by a microwave radiating source, and also to the applications of such process to the design and development of structures capable of changing the direction of a beam from a microwave source, such structures being adapted for use as electronic-scanning equipment.

A process for focusing or deflecting a wave from a microwave radiating source is already known in the prior art and consists in interposing in the wave path a lens or active reflector consisting of similar juxtaposed elements, each consisting of a receiving antenna and a wave-guide. The deflection brought about by the lens or active reflector is altered by the effect of phase-shifters mounted in each wave-guide.

This process has many drawbacks which prevent it from vying successfully with known mechanical-scanning devices. One of these drawbacks is that the very small size of the juxtaposed antennas and wave-guides making up the active lenses require very close manufacturing tolerances and a lossless material. It should also be pointed out that the control leads of all these antennas and wave-guides are very large in number and that adjusting and checking them is a tricky business.

The main object of the present invention is to eliminate the drawbacks of the previous process and to provide a process for changing effectively, as required, the direction of a beam emitted by a microwave radiating source. This process also eradicates the constraints of mechanical scanning.

Another object of the present invention is to provide a process for phase-shifting, as required, the incoming beam from a microwave radiating source by interposing one or several dielectric panels in the path of the electromagnetic wave. Each panel includes one or several plane networks of conductive leads running parallel with the electric field of the incident wave which can be connected and disconnected, as required, by means of switches located on these leads at distances less than 2λ , where λ is the wavelength, in the dielectric material, of the radiated incident energy.

A further object of the present invention is to provide an apparatus and process for phase-shifting a beam emitted from a microwave radiating source which includes passing the beam through a dielectric panel and connecting and disconnecting, as required, each conducting lead by switches located thereon and spaced, at distances less than twice the wave-length, in the dielectric material, of the radiated microwave energy; these leads constituting a plane network imbedded in the panel's dielectric and parallel with the field of the incident wave.

These and other objects of the present invention will be readily apparent upon a consideration of the following specification taken in conjunction with the accompanying drawings in which:

FIG. 1 is a block diagram illustrating a phase shifting apparatus of the present invention;

FIG. 2 is a view in front elevation illustrating one of the dielectric panels of FIG. 1;

FIG. 3 illustrates two spaced dielectric panels having orthogonally arranged conductive networks;

FIG. 4 is a diagrammatic illustration of an active lens constructed in accordance with the present invention;

FIG. 5 is a diagrammatic illustration of an active reflector constructed in accordance with the present invention; and

FIG. 6 illustrates a second embodiment of an active reflector constructed in accordance with the present invention.

For purposes of this invention, a "panel" is any element with a plane, or locally like surface, which lies throughout to a plane with respect to the wave-length of the radiated microwave energy.

It follows that the leads forming the "plane network" imbedded in the dielectric of a panel likened to a plane are to be located at the intersections of the panel in planes parallel with the electric field and this, throughout the said panel.

The conductive leads making up the plane networks imbedded in the dielectric and which can be, as required, joined or divided in sections by switches located thereon, are selected so as to constitute self-inductive barriers from the standpoint of microwaves. These leads are arranged to produce any of the effects, known of the prior art, obtainable by setting conductive leads in dielectric panels.

In the aforesaid processes of the invention, the switches are on conductive leads constituting the plane networks, the switches preferably being spaced apart, within the dielectric at one quarter of the wavelength, in the dielectric material, of the radiated microwave energy.

The panels employed to implement the processes of the invention (FIGS. 1 and 2) consist of dielectric sheets 10 in which are imbedded plane networks of conductive leads 12 which may be interrupted or not, as required, by means of switches 14 located on the leads in the dielectric and spaced less than twice the wavelength from the radiated microwave energy. These leads constitute a plane network imbedded in the dielectric of the panel which is parallel with the field 16 of the incident wave from a microwave source 18.

When interposing concurrently several panels in the path of a microwave wave, these panels may be positioned one behind the other in the path of the microwave and suitably apart from each other while, of course, leaving the respective networks of leads, (connected and disconnected as required) parallel with the electric field of the incident wave. Alternatively, the panels may be positioned with the sides thereof, which are parallel to the networks of leads, contacting, the networks of leads being also parallel with the electric field of the incident wave.

Rather than setting several panels one behind the other, according to the invention, it is also feasible to devise a single multiple panel by imbedding in a dielectric sheet comprising several successive planes, several planar networks of leads which can be connected and disconnected as required.

When interposing concurrently several panels, according to the process of the invention, across the path of two cross-polarized microwaves that can be phase-shifted as required, the networks of leads, connected and disconnected as required, must be placed so as to be parallel with the electric fields of both incident waves, i.e., normal to one another as illustrated in FIG. 3. Here panels 19 and 20 are arranged with orthogonal leads 12.

The switches spaced on the leads and imbedded in the dielectric panels are controlled either separately or, preferably, in groups. Electrically or electronically controlled switches are preferred, and each switch is controlled either through its relevant lead, or leads normal to the electric field of the incident wave.

The switches 14 may consist of diodes controlled by a voltage sufficient to make them conductive or not. The diodes in series on the same lead are mounted in the same direction and concurrently controlled by the same voltage on input 22. Of course, several rows of diodes, of one or several panels, can be controlled concurrently by the same voltage source 24 as illustrated in FIG. 1.

To do away with the reflections caused by interposing the dielectric panels, according to the process of the invention, across the path of the beam, all that is required is to space apart two or several parallel panels as previously described in such a way that the reflections arising from each panel combine in regard to amplitudes and relative phases such that there is no longer any reflected wave. This may be achieved using the so-called "sandwich technique" known to the art.

To do away with the reflections, it is also possible, as known in the prior art, to make up the panel from dielectric sheets whose width is a half-wavelength multiple, within the dielectric, from the radiated microwave energy. This is done, as stated above, by imbedding, in this sheet of specific thickness, one or several networks of conductive leads, connected and disconnected as required, and arranged in planes parallel with the electric field of the incident wave.

The applicant has discovered that the effect on the phase shift of an incident wave of a planar network of parallel leads, imbedded in a dielectric panel, changes when the leads are interrupted at intervals sufficiently close that there are no longer any induced currents in the leads. For instance, when the state of a dielectric panel including a planar network of parallel conductive leads, selected and positioned across the path of the incident wave so as not to give rise to any reflection and virtually no phase shift thereon, is altered through interruption of the conductive leads at intervals of one quarter wavelength, in the dielectric material, a substantial phase shift of the said incident wave is brought about.

By way of non-limitative example, a sandwich panel is described hereunder which permits implementing the process for changing, as required, the phase shift of a beam incoming from a microwave radiating source.

In two sheets of fiber-glass-reinforced polyester, each 6.5 mm thick, forming a laminate whose dielectric constant is 3.5, copper leads of 0.5 mm gauge were imbedded at mid-thickness of each sheet to a pitch of 30 mm. Standard silicon diodes were inserted and spaced to a pitch of 26 mm in those leads, their connections being soldered to the end of the sections of the leads. Such diodes were all connected in the same direction on all leads, thus making up a circuit which becomes conductive when supplied with a 20-volt potential difference at the proper polarity and, on reversal of the latter, this circuit becomes non-conductive. This diode control voltage is handily applied to the tips of the leads which are on the side of the panel and were made to protrude for this very purpose.

These two sheets, so fitted with wired-on diodes, are identical and were spaced parallel 31 mm apart; the leads being likewise parallel.

Such a panel, as with any sandwich panel, is matched at all times, i.e., no objectionable spurious reflections occur irrespective of the state the diodes in the sheet are in, provided, however, that in both sheets, the corresponding diodes are in the same state.

The panel operates as follows. The phase shift varies according to the state of the diodes in both sheets. It peaks when the diodes are cut off and drops to a minimum when the diodes are conducting. The phase shift is not identical throughout the surface of the panel when some banks of diodes are cut off and some conducting. The phase shift peaks where portions of the wave have come across cut-off banks and is minimal across conducting banks. This shows how it is possible, in accordance with the teachings of the invention, to control the phase shift of an incident wave with such a panel.

When a 3 GHz wave passes through this panel, the phase shift is 60° when the diodes are cut off and 6° when conducting.

The present invention provides a phase shifting unit which is much simplified and has tolerance limits which are definitely less stringent than known units. The panels and sheets are readily assembled rigidly and fully enclosed. Losses in the dielectric can easily be made very small.

The outer connections to the radiating unit are fewer, and the leads imbedded in the dielectric fulfil two functions; function control of diodes and function microwave components. The unit is fully integrated, there being no need to subdivide it into several modules. In addition, with the diodes being connected in series on each lead, the control currents are low, and the microwave energy flowing in the diodes matches the energy required for correcting the disconnections. This accounts for but a small portion of the aggregate energy conveyed by the incident wave. The upshot is that the losses ascribable to the diodes are very small, even when using standard and inexpensive diodes.

The principles and structures heretofore described can be employed to form lenses which are active in the plane normal to the network of connected and interrupted leads, and which provide focusing and deflecting in all planes and active reflectors.

Provision of such an active lens, according to the invention, is achieved merely by forming a device whereby the phase shift of an incident wave is varied locally from 0° to 360° in as small increments as required. This is accomplished by the proper selection of dielectric panels of a given thickness, including leads interrupted, as required, by the banks of diodes described above, and by setting a number of such panels of the type illustrated by FIG. 2, such phase shifts of the incident wave are brought about, as required, from 0° to 360°. A computer may be employed to control the switching voltages and accomplish phase shifting from 0° to 360°.

The incident wave is split into as many parallel strips as there are leads including banks of diodes. The phase shift is uniform on each strip and may vary from one to the other and, by acting upon the diodes' control voltage, the incident wave can be focused or deflected, or

both in the plane normal to the disconnected leads. Thus is achieved an active lens normal to the leads.

To constitute an active lens that will focus and deflect in all planes, all that is needed is to set two active lenses 26 and 28, as described above, one behind the other so that the leads of the former be normal to the leads of the other and both lenses be separated by a device 30 operative to rotate the polarization of the incident wave through 90° (FIG. 4). It follows that both focusing and deflection can be separate functions and that a conventional device, such as a reflector or a standard lens can take care of focusing.

An active reflector, according to the invention, is readily constructed by the provision of an active lens 32 formed from a plurality of panels 10 arranged one behind the other as described above and, setting the active lens in front of a mirror 34 as illustrated by FIG. 5.

Another active reflector is also achievable, according to the invention, by using one or several dielectric panels 36 comprising at least two planar networks 38 and 40 of perpendicular conductive leads, and setting this special-type panel opposite a mirror including a rotatory-polarization device 42 (FIG. 6). The leads 38 parallel the electric field of the incident wave while the leads 40 are parallel, after reflection, with the electric field of the wave.

I claim:

1. A lens apparatus for phase shifting a wave transmitted by a microwave radiating source, comprising at least one dielectric panel interposed across the path of the beam of microwave energy, said at least one dielectric panel including at least one network of conductive leads imbedded therein, throughout the panel, and located in planes parallel to the electric field vector of the incident wave, and switches mounted on each said conductive lead and spaced apart thereon by a distance no more than twice the wavelength, in the dielectric

material, of the radiated incident energy, allowing the conductive leads to be either divided in sections or not divided along the whole length of the panel, said dielectric panel having a thickness which is a multiple of a half wavelength, in the dielectric material, of the radiated microwave energy, to prevent any reflection of the incident wave.

2. A lens apparatus for phase shifting a wave transmitted by a microwave radiating source, comprising at least one dielectric panel interposed across the path of the beam of microwave energy, said at least one dielectric panel including at least one network of conductive leads imbedded therein, throughout the panel, and located in planes parallel to the electric field vector of the incident wave, and switches mounted on each said conductive lead and spaced apart thereon by a distance no more than twice the wavelength, in the dielectric material, of the radiated incident energy, allowing the conductive leads to be either divided in sections or not divided along the whole length of the panel, said switches including diodes controlled by a control voltage to render such diodes conductive, said control voltage being supplied to the diodes through said conductive leads, there being a plurality of said dielectric panels placed behind one another across the path of the beam, said control voltage being selectively applied to each conductive lead to vary the phase shifting of said wave from 0° to 360°.

3. A lens apparatus as claimed in claim 2, which includes a first set of said dielectric panels arranged behind one another across the path of the incident beam, a polarization device operating to rotate through 90° the plane of polarization of the wave and a second set of dielectric panels arranged behind one another across the path of the beam, the conductive leads of said second set of panels being orthogonal to the conductive leads of the first set of panels.

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