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WAVEGUIDE SWITCH HAVING MOVABLE MAGNETIC SHUTTER SELECTIVELY  
POSITIONED BY EXTERIOR MAGNETIC FIELD CONTROL MEANS

Filed April 13, 1961

2 Sheets-Sheet 1

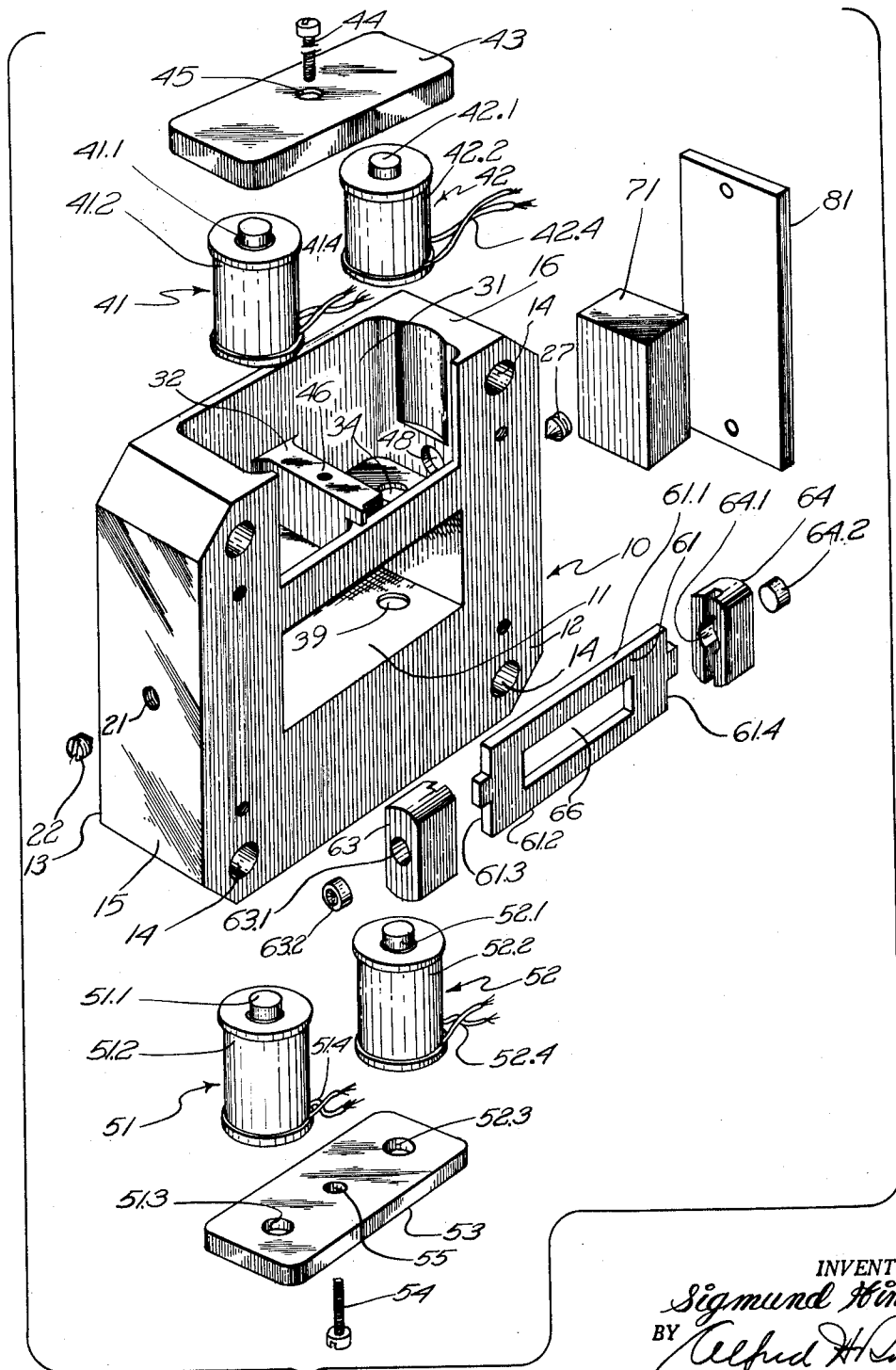


Fig. 1

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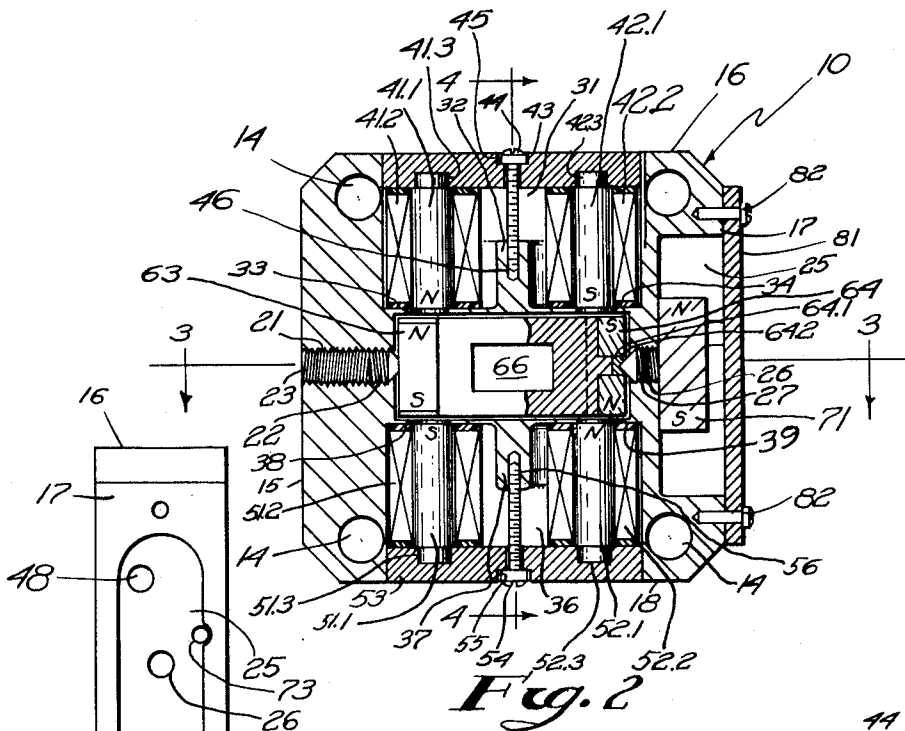


Fig. 2

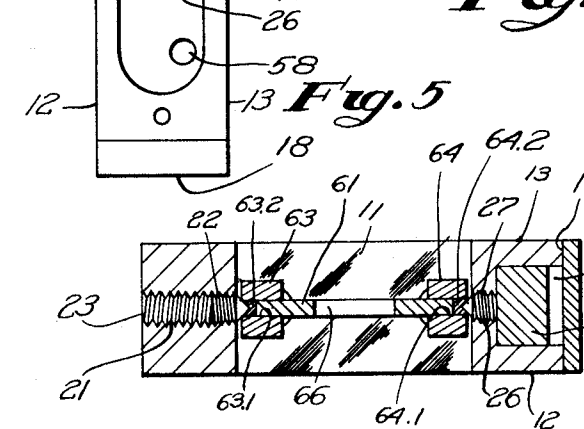


Fig. 3

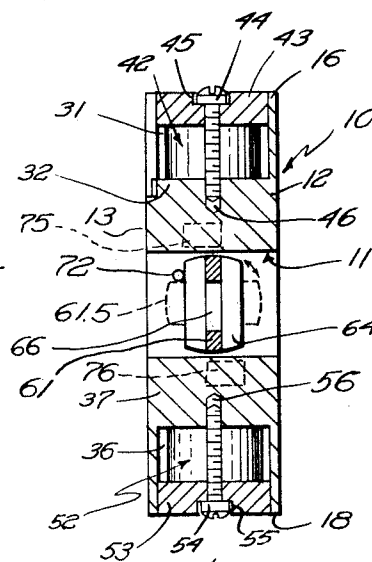


Fig. 4

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**WAVEGUIDE SWITCH HAVING MOVABLE MAGNETIC SHUTTER SELECTIVELY POSITIONED BY EXTERIOR MAGNETIC FIELD CONTROL MEANS**

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2 Claims. (Cl. 333-98)

This invention relates in general to devices for attenuating electromagnetic wave energy propagating in waveguides, and more particularly to waveguide switches of the shutter type. Examples of the latter type are shown and described in copending application Serial No. 783,520 filed December 28, 1958, which will be issued as U.S. Patent No. 2,980,873 on April 18, 1961, and which is owned by the assignee of the present application.

As is stated in said copending application, shutter type waveguide switches are used, for example, in the transmission line between the antenna and receiver input of a duplex-type radar system (i.e., a system employing a common antenna for sending and receiving) to protect the input stages of the receiver when the system is turned off, and the keep-alive electrode of the TR cell is not energized. The shutter is a vane which is inserted across the waveguide and prevents the passage of electromagnetic wave energy. More specifically, the shutters with which the present invention is concerned are pivotally mounted within the waveguide and arranged to assume one of two positions, one of which is a closed position transverse to the longitudinal axis of the waveguide and the other of which is an open position parallel to said waveguide axis.

It is the principal object of the present invention to provide improved means for controlling such a shutter vane to position it in one or the other of said two positions, namely, the open position and the closed position. Additional objects are to provide such improved means which are simple in design, compact and easy to assemble in the space normally found between the waveguide mounting flanges and the outer periphery of a short section of waveguide, positive in action, and inherently rugged in nature. A further important object of the invention is to provide such a shutter vane in a structure which is capable of operating throughout an extended range of temperatures, for example, from approximately  $-70^{\circ}$  C. to in excess of  $200^{\circ}$  C.

According to the invention, it is contemplated to provide, in an electromechanical switch device for waveguide having a flat vane mounted in a section of waveguide to pivot about an axis across the waveguide between a closed position transverse to the longitudinal axis of the waveguide and an open position parallel to said longitudinal axis, means selectively to place said vane in one or the other of said positions comprising, means to establish on said vane a pair of opposite, or unlike, permanent magnet poles, said poles being located with said vane axis between them, said vane axis being directed substantially normal to a line connecting said poles, nonpermanent magnet means and cooperating means selectively to magnetize the same, said nonpermanent magnet means being disposed relative to said waveguide section in a position to establish, when energized, lines of magnetic flux passing across said waveguide section transverse both to said vane axis and to said longitudinal axis, whereby magnetization of said nonpermanent magnet means urges said vane into one of said positions, and means applying a force urging said vane into the other of said positions, the waveguide section being itself made of nonmagnetic material. Preferably, the last-mentioned means applies a continuous force which tends to hold said vane in the closed position; this means may be a spring or a permanent magnet. The

nonpermanent magnet means is conveniently electromagnetic and is preferably arranged so that, when energized, it will place the vane in the open position. The force exerted by the nonpermanent magnet means will be in opposition to, and should be greater than, the force exerted by the continuously acting (closing) means. This preferred arrangement affords "fail-safe" features, in that failure of local power (in a radar set, for example) assures that the shutter vane will be in the closed position, thus protecting the receiver from stray radiation introduced via the antenna, as intended in the shut-down condition.

Other and further objects and features of the present invention will become apparent from the following description of an embodiment thereof. This description refers to the accompanying drawings, wherein:

FIG. 1 is an exploded view of a waveguide switch device according to the invention;

FIG. 2 is a side-sectional view of said device, assembled;

FIG. 3 is a section along line 3-3 in FIG. 2;

FIG. 4 is a section along line 4-4 in FIG. 2; and

FIG. 5 is an end view from the right-hand end of FIG. 2, with certain parts removed.

In the drawings, a body 10, of nonmagnetic material, such as aluminum, copper or brass, has a rectangular waveguide passage 11 centrally disposed in it and passing through it from one mating side 12 to the other mating side 13. The peripheral dimensions and shape of the mating sides 12 and 13 correspond to the peripheral dimensions and shape of the corresponding sides of connecting flanges (not shown) customarily used to join waveguide sections, and holes 14 are provided near each outer corner of the body 10 to cooperate with holes in such flanges for this purpose. The mating sides 12 and 13 are preferably flat and parallel to each other, for the same purpose. It will be appreciated that the body 10 provides extreme rigidity, so that there is virtually no possibility of distorting the assembled switch device when it is incorporated into a transmission line.

Referring particularly to FIG. 2, the body 10 is apertured at each lateral side 15, 16, 17 and 18, respectively, as follows:

The left-hand side 15 is provided with a threaded bore 21 for a first threaded bearing pivot 22 and a threaded locking screw 23. The right-hand side 17 is provided with a wide deep aperture 25 and at the bottom with a threaded bore 26 for a second threaded bearing pivot 27. The threaded bores 21 and 26 are centrally disposed in the opposite narrow walls of the waveguide section 11, and define the ends of the pivot axis for a shutter vane to be presently described.

The upper side 16 is provided with a wide deep aperture 31 having a rib 32 transversely dividing the lower portion of this aperture into two parts and meeting the outer surface of the top wide wall of the waveguide section 11. Bores 33 and 34, located one in each of said two parts, pass through said top wide wall into the waveguide section 11. The lower side 18 is provided with a similar wide deep aperture 36, rib 37 and bores 38 and 39.

First and second electromagnets 41 and 42, each having a core 41.1, 42.1, respectively, and a coil 41.2, 42.2, respectively, are located in the upper side aperture 31, one on each side of the rib 32. The lower end (in FIG. 2) of the first core 41.1 passes through the first bore 33 at the bottom of the aperture 31 and is substantially flush with the inner surface of the top wide wall of the waveguide section 11. The lower end (in FIG. 2) of the second core 42.1 similarly passes through the second bore 34 at the bottom of the aperture 31. Preferably, these core ends fit snugly in their respective apertures. The first and second cores 41.1 and 42.1, respectively, extend substantially parallel to each other away from the waveguide

section 11, and are capped at their upper or free ends with a cover 43 of magnetically permeable material. This cover closes the top of the aperture 31, and is provided with recesses 41.3 and 42.3 which receive, respectively, the free ends of the first and second cores 41.1 and 42.1. The cover 43 is held in place by a screw bolt 44 passing through a shouldered aperture 45 therein and threadedly engaged in a bore 46 in the rib 32. Wires 41.4 and 42.4 connected, respectively, to the first and second coils 41.2 and 42.2, are led into the aperture 25 in the right-hand side 17 of the body 10 through a bore 48 passing between the bottom of the aperture 25 and the adjoining end of the upper side bore 31 (see FIGS. 1 and 5).

The lower side 18 is similarly provided with third and fourth electromagnets 51 and 52 having respective cores 51.1 and 52.1, and respective coils 51.2 and 52.2 with respective connecting wires 51.4 and 52.4. The cores 51.1 and 52.1 each fit at one end into one of the bores 38 and 39, respectively, in the lower wide wall of the waveguide section 11, and extend in parallel away from that wide wall (downwardly in FIG. 2), and are capped at their lower or free ends with a magnetically permeable cover plate 53 which is similar to the upper cover plate 43. Thus the lower cover plate 53 has recesses 51.3 and 52.3 for receiving the lower or free ends of the cores 51.1 and 52.1, respectively, and an intermediate shouldered bore 55 for a screw bolt 54 which holds the cover plate in place covering the lower aperture 36 and supporting the cores, by engaging a threaded bore 56 in the lower aperture rib 37. The connecting wires 51.4 and 52.4 are led into the aperture 25 in the right-hand side 17 through a bore 58 (see FIG. 5) in the common wall between the side aperture 25 and the adjoining end of the lower aperture 36.

A vane 61 of electrically conductive material, of generally rectangular shape, has two parallel long edges 61.1 and 61.2, and two short edges 61.3 and 61.4. A first permanent magnet 63 is affixed to the vane by a suitable cement at the first short edge 61.3 and a second permanent magnet 64 is similarly affixed to the vane at the second short edge 61.4. A suitable cement has been procured from Emerson & Cuming, Inc., of Canton, Massachusetts, under the designation "Eccobond Solder 58C," and is described in Technical Bulletin 3-2-5A of that company as a one-component conductive epoxide based adhesive. Each permanent magnet has a north pole at one end and a south pole at the other, in the present embodiment oriented as shown in FIG. 2. Each pole is near the end of the short edge of the vane to which the magnet bearing is attached, where said short edge joins a long edge of the vane. Each magnet 63, 64, has a bore 63.1, 64.1, respectively, in it, passing between the poles in a direction substantially normal to a line connecting the poles, that is, in the direction of the vane axis between the bearing pivots 22 and 27. Bearing seats 63.2 and 64.2 are fitted, respectively, into these bores 63.1 and 64.1 and cooperate with the bearing pivots 22 and 27, respectively, to mount the vane 61 for rotation about the axis between the pivots. This axis, in the present embodiment, is centrally disposed coincident with the long axis of the vane, so that the vane balances on the axis. The pivots 22 and 27 are tightened on their threads as required to provide the desired precision of support and freedom of movement of the vane.

A third permanent magnet 71 is affixed (as by a suitable cement, or, if desired, with bolts, not shown) to the lower surface of the aperture 25 in the right-hand side 17 (FIG. 2) of the body 10, covering the bearing pivot 27 in that side. This magnet has two unlike poles, oriented in the present instance as shown in FIG. 2. With this orientation, the third permanent magnet applies a continuous magnetic forced tending, by mutual attraction with the poles of the nearer vane magnet 64, through the intervening wall material of the body 10, to hold the vane 61

in the closed position across the waveguide 11, as shown in the drawings. It will be appreciated, that, while the intervening wall material of the body 11 should accordingly be nonmagnetic, this restriction does not apply to the bearing seats and bearing pivots, since, if the latter are of magnetizable material they will not interfere with the completion of desirable magnetic paths. The thickness of the intervening wall material, however, has a useful function to be explained below, in that it is greater than the distance between each vane magnet pole face and the confronting electromagnet pole face, when the vane 61 is in the closed position.

If the connecting wires 41.4, 42.4, 51.4 and 52.4 are connected in the aperture 25 to provide, when current is applied, the electromagnet pole configuration shown in FIG. 2 each electromagnetic pole will be like the confronting vane permanent magnet pole, and will repel the same. Since these pairs of confronting like poles are closer together than the confronting unlike pairs of poles involving the third permanent magnet 71, the repulsive force of the electromagnet can easily be greater than the attractive force of the third permanent magnet. The flux across the waveguide 11 established by the electromagnet therefore tends to rotate the vane 61 away from the closed position. Referring to FIGS. 4 and 5, a stop-pin 72, mounted in a threaded bore 73 in the common wall between the right-hand aperture 25 and a small side of the waveguide 11, is positioned adjacent one side of the right-hand vane magnet 64, so that the vane can rotate only in the clockwise direction, as seen in FIG. 4. Upon being rotated approximately 90°, to the open position 61.5 shown in dotted line, the vane is prevented by the stop-pin 72 from rotating further. In this position, the vane poles which were repelled by like poles of the electromagnet structure come into position to be attracted by opposite, or unlike, poles thereof, so that the vane is held in the open position against the stop-pin, while the electromagnet structure is energized. The fact that the third (or restoring) permanent magnet 71 is placed some distance from the adjoining vane magnet 64 prevents the former from exerting a "dragging" force on the vane 61 in the open position.

The electromagnet poles are located approximately 1/8 inch off-center with respect to a plane parallel to the mating faces 12 and 13 and equidistant between them, as shown by the dotted-line boxes 75 and 76 in FIG. 4. This will assure that the force tending to move the vane into the open position is always clockwise, and cannot start in the opposite direction, where the vane might be held, in effect "locked," against the stop-pin 72. It will also provide a somewhat greater attractive force tending to hold the vane open while the coils are energized with electric current.

When the current energizing the electromagnet coils is interrupted, the third permanent magnet 71 becomes the sole magnetic influence on the vane 61, and restores the vane to the closed position. Thus, in the event of power failure the vane is automatically restored to the closed position, with the illustrated arrangement of pole dispositions.

As illustrated, the vane 61 has an iris opening 66 in it. This opening may be dimensioned to be tuned to resonate in series with the capacitance existing between the long edges 61.1 and 61.2 of the vane and the adjoining wide walls of the waveguide 11 when the vane is in the closed position, thereby achieving an effectively purely resistive low impedance across the waveguide, and minimizing reflection of wave energy from the vane. This is shown and described in the above-mentioned copending application. It will be appreciated that other vane configurations, including but not limited to those shown and described in said copending application, may be used with the present invention, if desired.

When the vane is in the open position, the vane magnets 63 and 64, due to their having greater thickness than

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the vane 61, constitute lumped inductive impedance elements, whereas the vane itself introduces a capacitive reactance across the waveguide 11. Desirably, the magnets and vane are proportioned in relative sizes so that the inductive reactance matches out the capacitive reactance, for example, as described and claimed in said copending application.

In a practical embodiment of the invention, it will be desirable to supply a cover 81 over the right-hand aperture 25 (FIG. 2) in which the electrical connections to the electromagnet coils are made. This cover can be held by bolts 82. It may be furnished with an aperture (not shown) for the passage of wires to connect to the coil leads 41.4, 42.4, 51.4, and 52.4. With these covers the device can be pressurized without exceeding the waveguide size. The bearings can be sealed to maintain the pressure.

Jewel ring bearings, of the kind used in watches, for example, may be substituted for the bearing pivots 22 and 27 and bearing seats (or V-jewels) 63.2 and 64.2 shown in the drawings, as those skilled in the art will appreciate. The bearing ring jewels can be fitted into the bores 63.1 and 64.1, in place of the V-jewels 63.2 and 64.2, respectively, and may be sealed in place with a cement similar to that used to hold the magnets 63 and 64 on the vane 61. The bearing pins or shafts of such bearings would then be fitted in the holes 21 and 26, in place of the conical pivots 22 and 27, respectively.

The cement identified above has high temperature characteristics suitable for the objects of the invention, being specified to be useful (once cured) at temperatures from  $-65^{\circ}$  C. to above  $1000^{\circ}$  C. Correspondingly, it is preferred to employ high temperature coil wiring in the electromagnets 41, 42, 51 and 52, for the same purpose. In addition, in a preferred construction, the spaces within the side apertures 25, 31 and 36 surrounding the parts fitted therein are filled with a suitable high temperature potting compound.

Devices according to the invention may have shapes other than the shape that is illustrated, which is by way of example only. Such devices have been built in which the external shape is round, and the waveguide passage and vane are rectangular, as shown. Others can be built employing round waveguide and vanes having a round or disc-like configuration.

It has been found that the magnetic field engendered by the electromagnets 41, 42, 51 and 52 during operation of a system employing the shutter of the invention has no noticeable effect on the propagation of electromagnetic waves through the waveguide passage 11.

The embodiments of the invention which have been illustrated and described are but a few illustrations of the invention. Other embodiments and modifications will occur to those skilled in the art. No attempt has been made to illustrate all possible embodiments of the invention, but rather only to illustrate its principles and the best manner presently known to practice it. Therefore, while certain specific embodiments have been described as illustrative of the invention, such other forms as would occur to one skilled in this art on a reading of

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the foregoing specification are also within the spirit and scope of the invention, and it is intended that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

What is claimed is:

1. An electromagnetic switch device for rectangular waveguides of non-magnetic material, said device comprising a rectangular vane mounted in a section of said waveguide for pivotal movement about an axis transverse to the longitudinal axis of said waveguide between a closed position transverse to said longitudinal axis and an open position parallel to said longitudinal axis, said vane having a substantially flat central portion of non-magnetic material, elongated permanently magnetized portions disposed adjacent each edge of said vane and extending transversely to the pivotal axis thereof, each magnetized portion being thicker than said central portion of said vane and having two unlike poles located one near each end of its respective said edge, the thickness dimensions of said permanently magnetized portions being such that the lumped inductive reactance of said magnetized portions with respect to electromagnetic wave energy intended to be propagated in said waveguide when said vane is in said open position will be substantially matched to the capacitive reactance of the flat portion of said vane, means cooperating magnetically with one of said magnetized portions for biasing said vane toward said closed position, electromagnet means mounted exteriorly of said waveguide and having its pole faces so oriented that when it is energized it will repel the poles of said magnetized portions to urge said vane towards said open position, and stop means in said waveguide to hold said vane in said open position against the force imposed by said electromagnet means.

2. In an electromagnetical switch device for non-magnetic waveguides having shutter means mounted in a section of waveguide for movement about a pivotal axis across the waveguide between a closed position transverse to the longitudinal axis of the waveguide and an open position parallel to said longitudinal axis, said shutter means comprising a substantially flat pivotally mounted non-magnetic vane, a pair of permanently magnetized elongated elements so mounted on said vane as to extend transversely of said pivotal axis respectively adjacent opposite edges of said vane, said elements being so proportioned in thickness relative to the thickness of said vane that the lumped inductive reactance of said elements matches the capacitive reactance of said vane when the latter is in said open position, means for biasing said vane towards said closed position, and magnetizable means positioned for magnetically cooperating when magnetized with said elements for urging said vane into said open position.

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