Feb. 24, 1953 A. LONGACRE 2,629,774

TUNABLE PROTECTIVE ELECTRIC BREAKDOWN DEVICE

Original Filed May 6, 1943

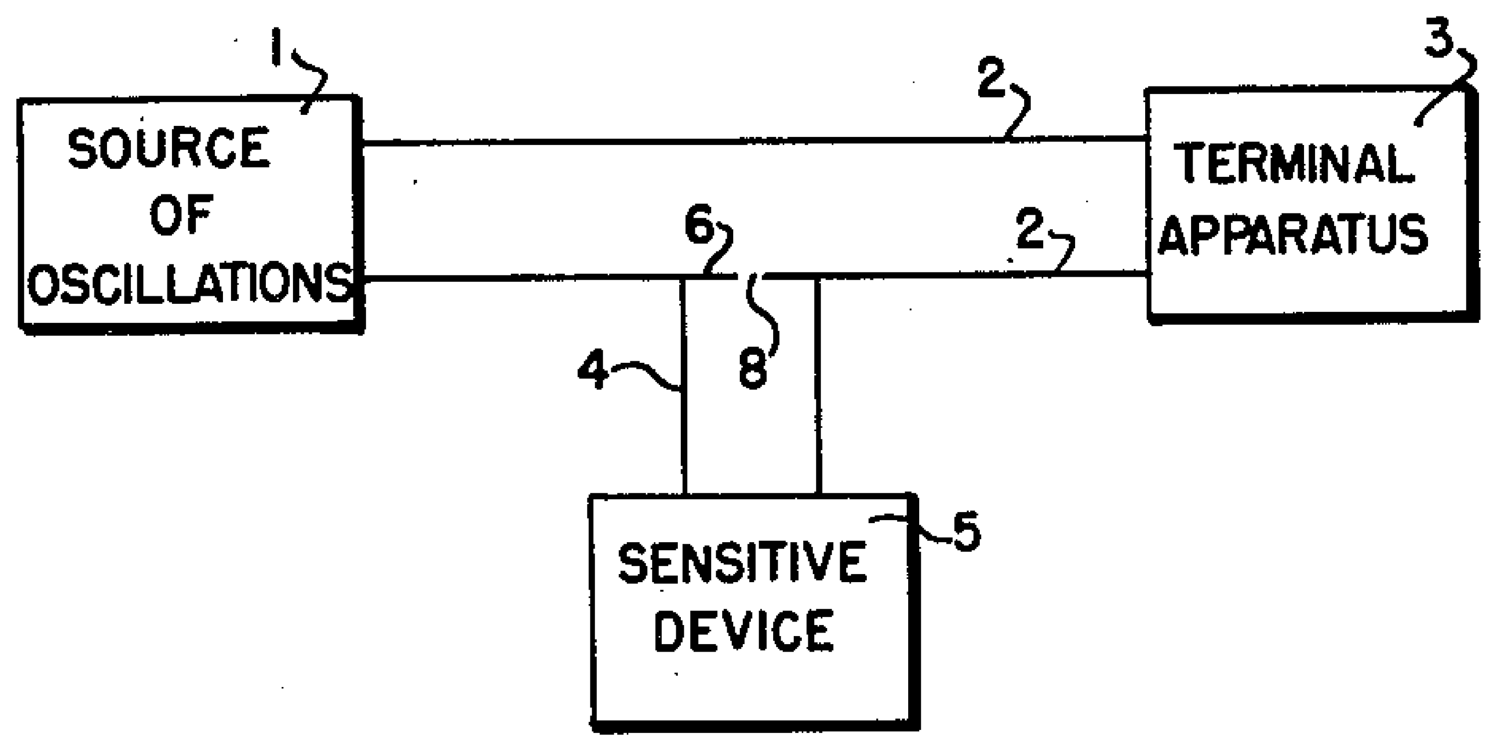

FIG. 1

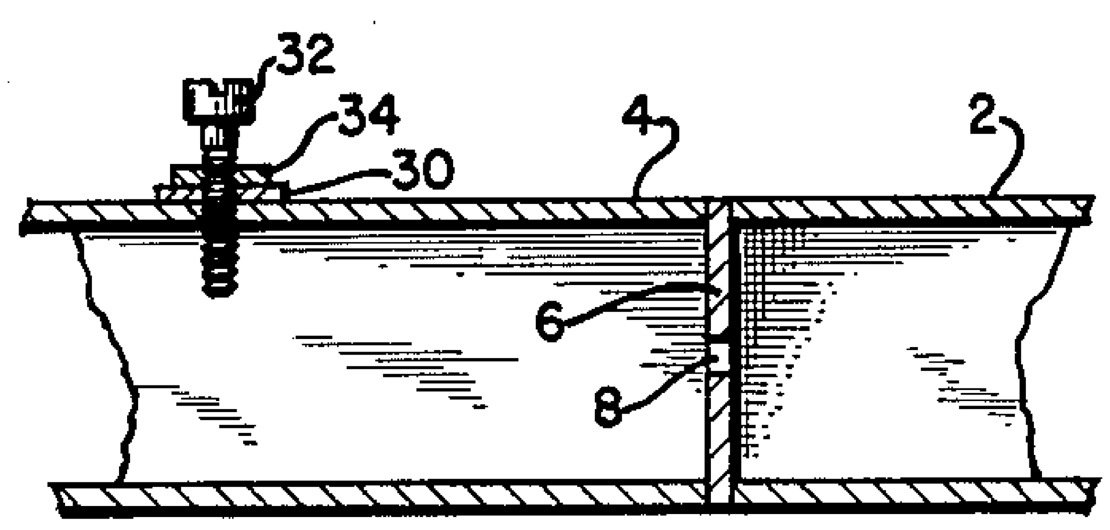

FIG. 2

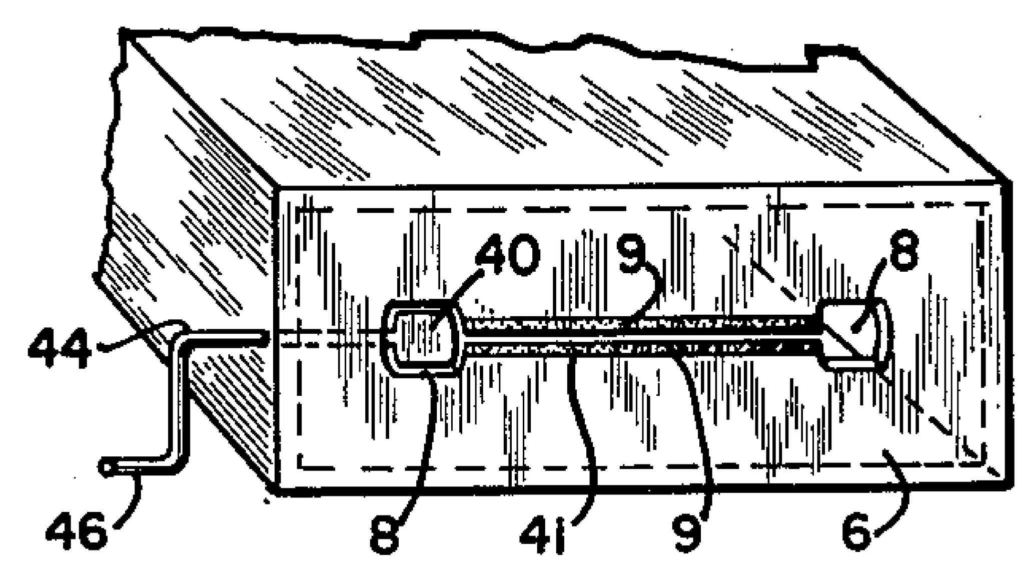

FIG. 3

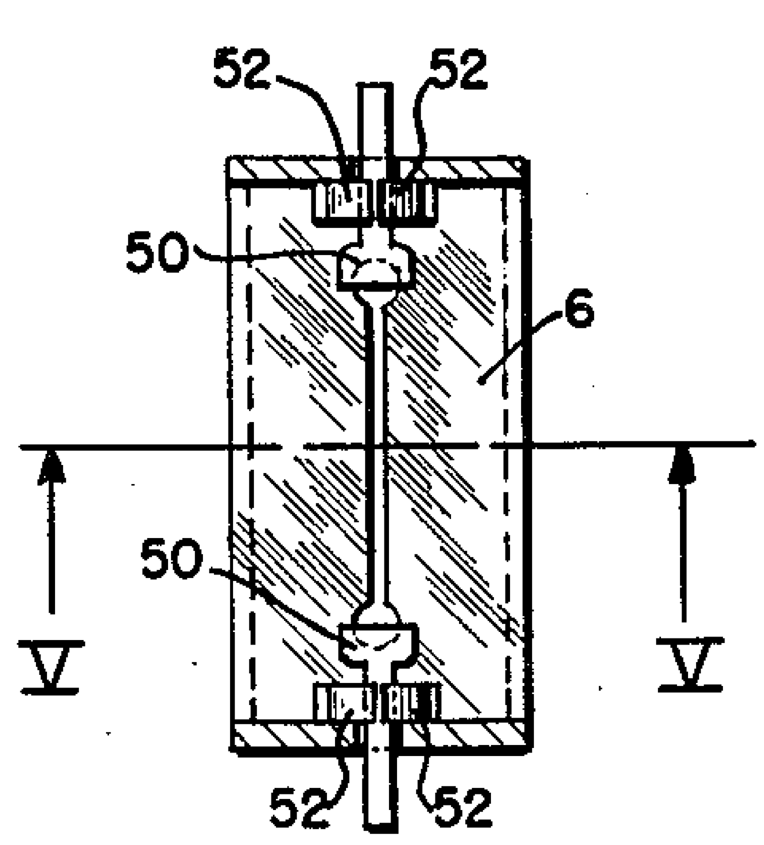

FIG. 4

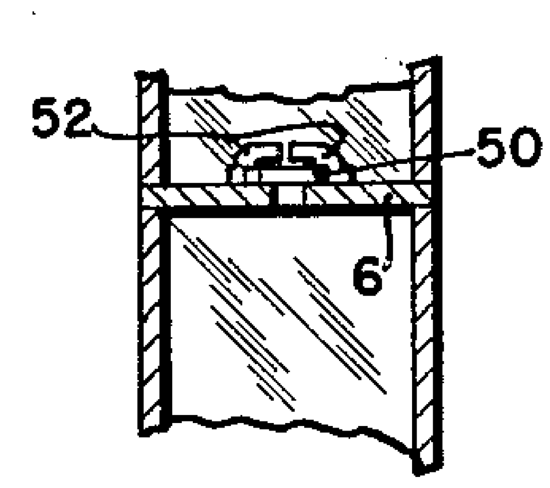

FIG. 5

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TUNABLE PROTECTIVE ELECTRIC BREAKDOWN DEVICE

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Original application May 6, 1943, Serial No. 485,933. Divided and this application December 3, 1947, Serial No. 789,487

5 Claims. (Cl. 178—44)

1

This invention relates to switches of the automatic breakdown type for association with an electrical transmission line or "wave guide" for the purpose of protecting a sensitive apparatus connected to said transmission line. More particularly, this invention relates to automatic breakdown switches adapted for use in "wave guides" having the form of hollow pipes.

This application is a division of my copending application, Serial No. 485,933, filed May 6, 1943, and entitled Protective Electric Breakdown Devices.

Because of the modern emphasis on phenomena in the space surrounding a transmission line as contrasted with the phenomena within the conductor, the term "wave guide" is now frequently used to refer to a transmission line, especially one used at high frequencies. This term is frequently applied to transmission devices in the form of a hollow pipe, which are practical only for high frequency applications. Properly speaking, any transmission line is a wave guide. Modifying phrases are therefore liberally used in this specification to make it clear that the type of wave guide in conjunction with which the breakdown switch of this invention is particularly concerned is the form of wave guide constructed as a hollow pipe. In conformance with the terminology of the high frequency art, the term "wave guide" will generally be used herein in place of the term "transmission line."

When intermittent trains of oscillations are being transmitted from a source of oscillation of relatively high amplitude, such as a generator of high frequency electromagnetic oscillations, to a terminal apparatus, such as an antenna system, over a wave guide and it is desired to connect with said wave guide a sensitive device such as a receiver for such high-frequency oscillations, it is desirable to protect the receiver against damage from oscillations of great amplitude by providing a switch or a protective gap between said receiver and said wave guide which will short circuit oscillations exceeding a predetermined amplitude across the receiver input. It is an object of this invention to provide a protective breakdown discharge device which will occupy very little space when associated with a hollow pipe wave guide system and which is simple in construction. It is a further object of this invention to provide such a device for use in hollow pipe wave guides which will take advantage of the symmetrical nature of hollow pipe wave guides and will take advantage of the symmetrical and essentially two-dimensional nature of resonant

2

circuit constituted by an elongated aperture in a sheet of metal. It is still another object of the present invention to provide means for tuning the protective device of the present invention. With these and other objects in view the invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a diagram showing the location of the protective breakdown discharge device of this invention in a radio system employing hollow pipe wave guides;

Fig. 2 shows in cross section an arrangement for adjusting the resonant frequency of the protective breakdown device—that is, for "tuning" the device;

Fig. 3 shows, in elevation, an alternative arrangement for tuning the protective device; and

Figs. 4 and 5 show, in elevation and in plan respectively, still another arrangement for tuning the protective breakdown device.

In the protective breakdown device of this invention, there is used as a circuit adapted to promote breakdown when subjected to oscillations exceeding a predetermined amplitude. a sheet of conducting metal transversely closing the hollow pipe wave guide leading to the sensitive device (as shown in Fig. 1) and provided with an aperture of elongated contour so dimensioned and shaped that the metal sheet, in the neighborhood of said aperture, constitutes a resonant circuit which is resonant at a frequency corresponding closely to that of the oscillations desired to be transmitted in said hollow pipe wave guide. Such an aperture has the advantageous property that in the absence of breakdown it produces little if any interference with transmission of oscillations therethrough at its resonant frequency, having low losses and presenting zero shunt susceptance across the wave guide. The long dimension of the aperture is oriented perpendicularly to the direction in which currents tend to flow in the wave guide walls, so that the resonant circuit will be excited by oscillations in the guide and a high voltage gradient will appear across the middle part of said aperture. The aperture is constructed with a very narrow clearance in its middle portion so that when the oscillations reach a predetermined amplitude, a breakdown will occur across the narrow portion of said aperture. The resulting short circuit will in effect electrically close off the hollow pipe wave guide leading to the sensitive device or receiver. At the same time, if the apertured metal partition is properly located in the hollow pipe wave guide leading to the receiver, as hereinafter described, the wave guide leading from the source of oscillation to the terminal apparatus (see Fig. 1) will, when breakdown occurs as aforesaid, act electrically like an essentially uninterrupted wave guide.

Fig. 1 shows the general type of system in which the breakdown switch of this invention finds its particular utility and shows the general location of such a breakdown switch in such a system. The block 1 indicates in a general manner a source of high amplitude, which could be a vacuum tube oscillator. The wave guide 2 is a transmission apparatus of the hollow pipe type which is preferably rectangular in cross section (though the invention is equally applicable to systems with wave guides of circular cross section) and of such dimensions that it readily sustains and transmits oscillations of the frequency of those generated in the source 1 which are so polarized in said wave guide that the electric vector of such oscillations lies in the direction of the short dimension of said wave guide, but does not readily sustain or transmit other modes of oscillation at said frequency. The wave guide 2 serves to transmit oscillations from the source 1 to a terminal apparatus generally indicated at 3, which may be an antenna system. Intermediate the ends of the guide 2 at a suitable point determined by methods known to those skilled in the art, another hollow pipe wave guide 4 is joined to the guide 2. The guide 4 likewise functions to transmit oscillations of which the electric vector is parallel to its shorter cross-sectional dimension. The guide 4 serves to lead or transmit oscillations taking place in the guide 2 to a sensitive device generally indicated at 5, which may be a receiver for detecting and amplifying high-frequency signals. In the guide 4, in this case at its extremity where it joins the guide 2, there is placed a transverse barrier 6 of a thin conducting material, preferably copper or brass, provided with an elongated aperture, appearing in cross section at 8. When so positioned, the barrier 6 forms a continuation of the wall of the guide 2 across the mouth of the guide 4.

As above described, the aperture is so dimensioned and shaped as to produce resonance at the frequency of the oscillations desired to be transmitted in the guide 2, and its width is so dimensioned, at least in the middle portion of its length, so that breakdown will readily occur when oscillations of such amplitude as might damage the sensitive device 5 occur in the guide 2. Oscillations of such amplitude might, for instance, occur whenever the source of oscillation 1 is delivering energy to the guide 2, if this source is a source of relatively high-amplitude oscillations. When oscillations of such amplitude are present in the guide 2 and a breakdown occurs across the narrow portion of the aperture in the barrier 6, the guide 2 electrically acts as if it were completely cut off from the pipe 4 by a continuous conducting barrier, except for the relatively low and practically negligible resistance associated with the breakdown discharge. When oscillations of sufficient amplitude to cause a breakdown across the aperture are not present, however, the aperture will readily permit the transmission therethrough of oscillations of frequencies in the neighborhood of the frequency at which the circuit surrounding the aperture resonates so that the sensitive device 5 is effectively connected with the terminal apparatus 3 for receiving electromagnetic oscillations of such frequencies.

For the best operation of the breakdown switch of this invention, it is important that the aperture 8 should be rather accurately tuned to the frequency of the oscillations which are desired to be handled in the guides 2 and 4. Means for adjusting this tuning of the aperture 8 without removing the barrier 6 from the inside of the pipe system are therefore desirable, both for adjusting the breakdown switch to the particular frequency of oscillations transmitted, and for correcting any change in the dimension of the aperture 8 caused by the subjection of the narrow part of that aperture to repeated electric breakdown discharges.

A few of the many possible methods for accomplishing such tuning are shown in Figs. 2 to 5 inclusive. In Fig. 2 a threaded stud 30 is shown fastened to one of the walls of the wave guide 4. The surface of the wall to which the stud 30 is fastened is perpendicular to the electric vector of the oscillations in the pipe. It is preferable to place the threaded stud 30 centrally with respect to the wave guide wall in order to locate it at or near the maximum electric field. The wall of the wave guide is perforated so that a screw 32 may be inserted into the pipe through the stud 30. A locking nut 34 serves to preserve the adjustments and to maintain firm electrical contact at the screw threads. Instead of providing actual contact at the wave guide wall between the wall and the screw 32, other arrangements providing effective energy transfer at radio frequencies by the use of suitable small resonators around the screw, with or without direct electrical contact, may be employed.

The distance between the screw 32 and the barrier 6 has an important influence upon the effect of the screw 32 upon the resonant structure of the barrier 6 and its aperture 8. If this distance is about one-half of the wave length in the wave guide of the oscillations in question, the effect of the screw will be that of an adjustable capacitance in parallel across the jaws of the aperture 8. If the distance between the screw 32 and the barrier 6 is approximately one-quarter of a wave length of the oscillations in question, in the wave guide the adjustable screw, as it affects the aperture 8, will act as a variable inductance across the width of the aperture 8. The effect of the screw 32 when placed at positions intermediate of those just mentioned is somewhat more complicated, and consequently I prefer either quarter-wave or half-wave spacing or both.

A similar screw introduced into the guide in a direction perpendicular to the electric vector of transmitted oscillations might also be used for tuning. Such a screw usually has an inductive effect at the place of its insertion. Another possible tuning arrangement is a branch or "stub" guide having a short-circuiting termination which is adjustable in position. These various tuning arrangements may be located at some distance from the barrier 6, preferably one or more quarter-wave lengths, and yet effectively provide an adjustable susceptance in shunt with the tuned circuit constituted by the barrier 6 and its aperture 8.

Fig. 3 shows another method for varying the tuning of the aperture 8. The jaws 9 bordering the narrow part of the aperture may advantageously be formed of pieces or slugs 41 of a refractory metal such as tungsten (as shown in Fig. 3) in good electrical and physical contact with the highly conducting metal of the barrier 6, which is preferably copper. The slugs 41 form a facing along the narrow portion of the aperture, in the region where breakdown discharges occur. Since tungsten or other similar refractory metal will withstand the high temperatures present in an arc discharge without corrosion or disintegration, the facing greatly lengthens the useful life of the barrier. In one of the broadened ends of the aperture **8** is provided a swinging vane **40**. A channel is cut in the metal of the barrier **6** in a direction parallel to the long dimension of the aperture **8** and preferably located centrally with respect to the short dimension thereof. In the channel is laid a shaft **44** which is fastened to the vane **40** and serves to rotate the vane **40** in the aperture **8**. The shaft **44** is provided with a manipulating and indicating means, such as the crank **46**, in any well-known manner. Other mechanical arrangement could also be employed for actuating a vane similar to the vane **40** in the aperture **8**.

Figs. 4 and 5 show, in elevation and plan respectively, still another way of tuning the aperture **8**. In this arrangement. sliding shutters **50**, **50** made of metallic conducting material may be moved so as to short-circuit the ends of the aperture **8** at an adjustable location. The sliding shutters **50**, **50** are guided by the lugs **52**, **52**, **52**, **52** which are suitably fastened to the barrier **6**, as by soldering. The ends of the shutters **50**, **50** are brought outside of the wave guide through suitable holes in the wave guide wall. It is important that the shutters **50**, **50** should make good electrical contact with the barrier **6**, and for that purpose spring pressure may be applied by suitable means (not shown).

The protective breakdown device of this invention is particularly well suited for simple incorporation into wave guides of the hollow pipe variety. The resonant aperture **8** is an essentially two-dimensional system, and, moreover, a symmetrical one, so that a minimum of mechanical construction is necessary to arrange such an electrical breakdown discharge device in a wave guide system. The two-dimensional resonant aperture has, in comparison with other resonant cavities that might be used for electrical breakdown switches in wave guide systems, the advantage of mechanical compactness and the further advantage of extreme simplicity in the method of connecting the resonant aperture electrically in such a way as to respond to the oscillations transmitted by the wave guide system.

What I desire to claim and secure by Letters Patent is:

1. In a system for the transfer of high frequency electromagnetic waves including a pipe wave guide, a protective electrical breakdown device which includes a metallic conducting barrier located transversely of said pipe wave guide and having an aperture of elongated contour with its long dimension oriented perpendicularly to the electric vector of oscillations transmitted in said wave guide, the width of said aperture being sufficiently small at least for a part of its length to permit the occurrence of an electrical breakdown discharge across said aperture when oscillations in said guide exceed a predetermined amplitude, said aperture being dimensioned and shaped to resonate at a frequency in the neighborhood of that of oscillations desired to be transmitted through said wave guide system, and at least one retractable conducting mass in energy-transferring relationship with said wave guide for electric currents of said frequency and adapted to protrude adjustably into said wave guide in the direction of said electric vector, said mass being located in said wave guide at an approximate distance from said conducting barrier of an integral number of quarter-wave lengths in said guide of said oscillations.

2. In a system for the transfer of high frequency electromagnetic waves including a rectangular wave guide, a protective electrical breakdown device comprising, a conducting barrier located transversely of said wave guide and having an aperture of elongated contour with its long dimension oriented perpendicularly to the electric vector of oscillations transmitted in said wave guide, the width of said aperture being sufficiently small for a portion of its length to permit an electrical breakdown discharge across said aperture when oscillations in said guide exceed a predetermined amplitude, said aperture being dimensioned and shaped to resonate at a frequency in the neighborhood of that of oscillations desired to be transmitted through said wave guide system, and a metallic screw threadably mounted in a broad wall of said wave guide and adapted to project adjustably into said wave guide in the direction of said electric vector, said screw being located an integral number of quarter-wave lengths of said oscillations from said conducting barrier as measured along the longitudinal axis of said guide.

3. In combination, a hollow rectangular wave guide adapted to propagate high frequency electromagnetic waves, a metallic wall positioned in said guide transversely to the direction of wave propagation through said guide and having an aperture therein which has an appreciable dimension perpendicular to the electric component of the field incident to the propagation of said waves through said guide, said aperture being dimensioned and shaped to resonate at a frequency in the neighborhood of that of oscillations desired to be transmitted through said wave guide, and at least one conducting shutter in electrical contact with said wall adapted to establish a short circuit across said aperture, said shutter being adjustable along said aperture in the direction of said appreciable dimension.

4. In combination, a hollow rectangular wave guide adapted to propagate electromagnetic waves, a conducting barrier positioned in said wave guide transverse to the direction of wave propagation through said guide and provided with an elongated slit having substantially circular openings at each end thereof, said slit and associated openings constituting an aperture resonant at a frequency in the neighborhood of that of oscillations desired to be transmitted through said wave guide, at least one conductive shutter positioned in electrical contact with said barrier and adapted to establish a short circuit across one of said circular openings, and externally accessible means secured to said shutter for adjusting said shutter along said aperture in the direction of the long dimension of said slit.

5. In combination, a hollow rectangular wave guide adapted to propagate electromagnetic waves, a conducting barrier positioned in said wave guide transverse to the direction of wave propagation through said guide and provided with an elongated slit having substantially circular openings at each end thereof, said slit and associated openings constituting a resonant aperture, and means for controlling the effective dimensions of said aperture, said last-mentioned means comprising a pair of sliding conductive shutters positioned in electrical contact with said barrier each being adapted to establish a short circuit at an adjustable location across one of said cir-

cular openings, said shutters being provided with extensions projecting externally of said wave guide for adjusting said shutters along said aperture in the direction of the long dimension of said slit.

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