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W. D. LEWIS ET AL
MICROWAVE BAND REFLECTION FILTER

2,510,288

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FIG. 1

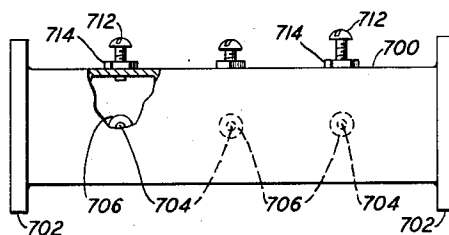


FIG. 2

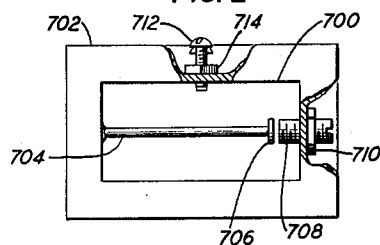
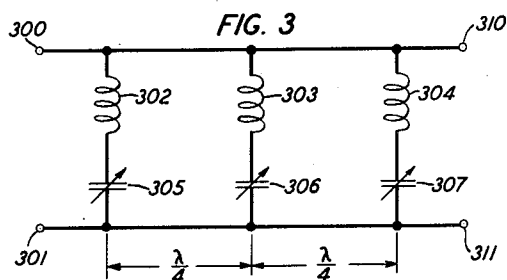


FIG. 3



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MICROWAVE BAND REFLECTION FILTER

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Application December 5, 1947, Serial No. 789,986

4 Claims. (Cl. 178—44)

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This invention relates to a filter for use at ultra-high frequencies and microwave frequencies in transmission systems employing wave guide transmission lines.

A principal object of the invention is to provide simple compact filters which can be readily integrated into wave guide transmission systems.

Another object is to provide filters of the above-mentioned character which are readily adjustable with respect to resonant frequencies and impedance level.

A further object is to provide filters of the above-mentioned character which are well suited for use as band or channel reflecting filters where the band or channel of frequencies to be reflected is relatively very narrow, i. e., where the ratio of the band or channel width in cycles to the mid-frequency of the band or channel in cycles is in the order of a few per cent or less.

Other and further objects of the invention will become apparent during the course of the following description of a preferred embodiment of the invention and from the appended claims.

The filters of the invention are primarily intended for use in systems employing wave guides to transmit $TE_{1,0}$ waves as defined, for example, at pages 316 to 322 of "Electromagnetic Waves" by S. A. Schelkunoff, published by D. Van Nostrand Company, Incorporated, New York City, 1943. Where a wave guide of rectangular cross-section, in which one cross-sectional dimension is shorter than the other, is used, it is the usual practice to employ $TE_{1,0}$ type waves with the electrical vector (E-plane) of the wave parallel with the shorter sides. It is intended that this practice be adhered to in connection with the illustrative embodiments described below.

The basic structural unit of these filters is a "resonator" which comprises a slender rod placed centrally within the wave guide perpendicularly to the direction of the electric vector of the wave, one end of the rod connecting directly to the side wall of the wave guide, the other end of the rod being capacitatively coupled to a corresponding point on the opposite side wall of the wave guide. A small disc mounted on the free end of the rod and a short stud member extending from the nearest adjacent point on the opposite side wall of the guide provide the capacitive coupling. As the resonator would normally have no coupling to the wave passing through the guide, a coupling is established by inserting an adjustable stud member through a wall of the guide in the vicinity of the resonator and per-

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pendicularly to the rod. This distorts the field in the guide and thus affords a coupling of the wave to the resonator rod.

Two or more resonators can be employed spaced along the wave guide at quarter wavelength intervals of the mid-frequency of the band to be reflected.

The principles of the invention will be more readily understood in connection with the description of specific illustrative embodiments thereof described in detail below and illustrated in the accompanying drawings in which:

Fig. 1 shows a side view of a band or channel-reflecting filter of the invention;

Fig. 2 shows an end view of the same filter; and
Fig. 3 shows an equivalent electrical schematic diagram of the filter.

A particular use of this specific filter is disclosed and described in the copending application of W. D. Lewis (one of the applicants of the present application), Serial No. 789,985, filed December 5, 1947 and assigned to applicants' assignee. Figs. 7 and 8 of the sole application are substantially identical with Figs. 1 and 2, respectively, of this application.

In more detail, the reflection filter illustrated in Figs. 1 and 2 comprises a straight section of rectangular wave guide 700, which for use at frequencies in the neighborhood of 4000 megacycles can appropriately have the internal dimensions of 2.290" in the H-plane and 1.145" in the E-plane, as explained in the above-mentioned application of W. D. Lewis.

Assembled within this section of wave guide 700 are, in the particular filter shown by way of example, three resonators, each comprising a slender rod 704, terminated at one end by a small disc 706 and firmly attached at the other end to an E-plane wall of the guide at a point on the longitudinal center-line of the wall. As shown clearly in Fig. 2, the rod of each resonator is parallel with the H-plane dimension of the wave guide, centrally located between the H-plane sides of the guide, and extends nearly across the full H-plane dimension of the guide. A screw 708, having a diameter substantially equal to the diameter of disc 706 is threaded through the E-plane wall of the wave guide just opposite the point at which rod 704 is fastened to the other E-plane wall. The screw is provided with a lock nut 710 to hold it in place when it has been adjusted as described above.

As stated above, the structure shown in Figs. 1 and 2 is to be used to transmit a type of wave having its electrical vector perpendicular to the

broadier sides of the guide. In order to couple the rod 706 to such a wave it is necessary to distort the wave form by inserting one or more members, such as screw 712 through either or both of the H-plane sides of the guide in the immediate vicinity of the rod 704. Increasing the extent to which screw 712 extends into the guide increases the distortion of the wave form and thereby increases the degree of coupling of the wave with rod 704. Increasing the coupling effectively increases the broadness of the response of the resonator, or the frequency region over which the resonator affects the transmission. A lock nut 714 is provided to hold the screw at its desired position of adjustment.

The combination of rod 704, which contributes an inductive reactance, and disc 706 together with the inner end of screw 708, which contribute a capacitive reactance, can be adjusted by turning screw 708 into or out of the wave guide to increase or decrease the capacity, respectively, to cause the combination to resonate at any frequency within the range being transmitted. At the frequency of resonance and at frequencies closely adjacent above and below the resonant frequency, the resonator will cause reflection of the wave back in the direction from which it entered the section of guide, while other frequencies will pass freely through the guide.

A smoother, or flatter, reflection band is obtained by adding additional resonator structures like the one just described, spaced along the guide by one-quarter wavelength of the mid-frequency of the band or channel of frequencies to be reflected, a "maximally" flat band is obtained by greatly increasing the number of resonators and tuning them all to the mid-frequency of the band. With a relatively few resonators a slightly broader but less smooth (or flat) band can be obtained by spacing some of the resonances near the edges of the band. For a system such as that described in the above-mentioned copending application of W. D. Lewis, in which bands or channels 20 megacycles wide centered about specific frequencies in the neighborhood of 4000 megacycles, are to be reflected, three resonators, as indicated in Figs. 1 and 2, have been found to be sufficient. In this instance, one resonator was tuned to resonance at the mid-frequency of the band and the other two were adjusted to resonance near the upper and lower edges of the band, respectively. To reflect broader frequency bands or channels, or to provide more uniform reflecting characteristics over any given frequency band or channel, additional resonators, spaced along the guide as described above, can be added and adjusted at appropriate resonant frequencies and with appropriate effective couplings to provide the desired bandwidth and uniformity of reflection over the band.

The effective inductance of the rod at ultrahigh and microwave frequencies is, of course, affected by its diameter, as well as its length. A rod diameter of $\frac{1}{8}$ inch and a disc diameter of $\frac{3}{4}$ inch were found suitable with the wave guide dimensions and frequency range mentioned above, by way of example, and in the illustrative system of the above-mentioned copending application of W. D. Lewis.

The equivalent electrical schematic diagram of the filter of Figs. 1 and 2 is shown in Fig. 3. Coils 302 to 304, inclusive, with their associated variable condensers 305 to 307, inclusive, respectively, represent the three resonators and the spacing along the line extending from terminals 300, 301

to terminals 310, 311, between resonators is $\gamma/4$.

A flange 702 is provided at each end of the section of wave guide 700 to facilitate joining wave guides of similar inside dimensions to the ends of this reflecting filter. Sections of the front flange in Fig. 2 are broken away to show the screws 708 and 712 and their associated lock nuts more clearly.

Those skilled in the art can readily devise many equivalent structures with which to practice the principles of the invention. It is obvious, of course, that lengths of wave guide of square or of circular cross-section can be employed in constructing filters of the invention, the sole requirements being that the resonators are aligned perpendicularly with respect to the electrical vector of the wave passing through the guide and that the coupling adjustment screws are located and aligned to produce a distortion of the field sufficient to effect the desired degree of coupling to the resonators. Any other means for effecting a suitable distortion of the field can, of course, be employed. Also, in the case of a round waveguide, the portion containing the resonators can be arranged to be turned with respect to the remainder of the waveguide and the desired coupling established by thus turning the resonator slightly away from precise perpendicularity with respect to the electric vector of the wave. The scope of the invention is defined in the following claims.

What is claimed is:

1. A wave guide electrical filter, for use in wave guide transmission lines transmitting waves having a definitely oriented electric vector, comprising a section of wave guide, a resonant structure within said wave guide, said resonant structure comprising an electrically conductive rod conductively coupled at one end to a first interior point of said wave guide and capacitatively coupled at the other end to a second interior point diametrically opposite to said first point within said wave guide, said rod being oriented to have zero coupling to the electrical wave energy normally transmitted through said wave guide and adjustable means projecting within said wave guide in the vicinity of said rod and substantially perpendicularly thereto, for establishing a coupling between said rod and said electrical wave energy by distortion of the field in said guide in said vicinity.

2. The filter of claim 1 and means for adjusting the capacitive coupling to said other end of said rod.

3. A wave guide electrical filter, for use in wave guide transmission lines transmitting waves having a definitely oriented electric vector, comprising a section of wave guide, a plurality of resonant structures within said wave guide, said resonant structures each comprising an electrically conductive rod conductively coupled at one end to a first interior point of said wave guide and capacitatively coupled at the other end to a second interior point, diametrically opposite to said first point within said wave guide, said rod being oriented to have zero coupling to the electrical wave energy normally transmitted through said wave guide and adjustable means projecting within said wave guide in the vicinity of said rod and substantially perpendicularly thereto for establishing a coupling between said rod and said electrical wave energy by distortion of the field in said guide in said vicinity, said plurality of resonant structures being spaced longitudinally along said section of wave guide at intervals of

substantially one-quarter wavelength of a predetermined frequency within the range of frequencies to be transmitted through said wave guide.

4. The filter of claim 3 and means associated with each rod of said plurality of resonant structures for adjusting the capacitative coupling of one end of the rod to said wave guide.

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LE ROY C. TILLOTSON. 10

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