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ELECTROMAGNETIC WAVE FILTER

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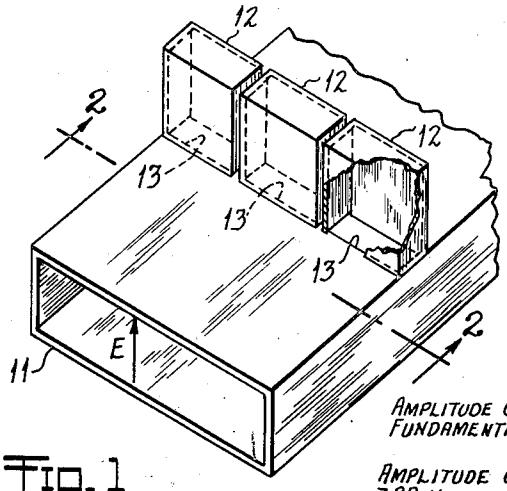

Fig. 1

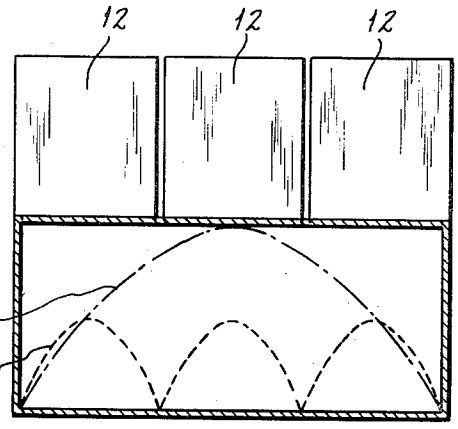

Fig. 2

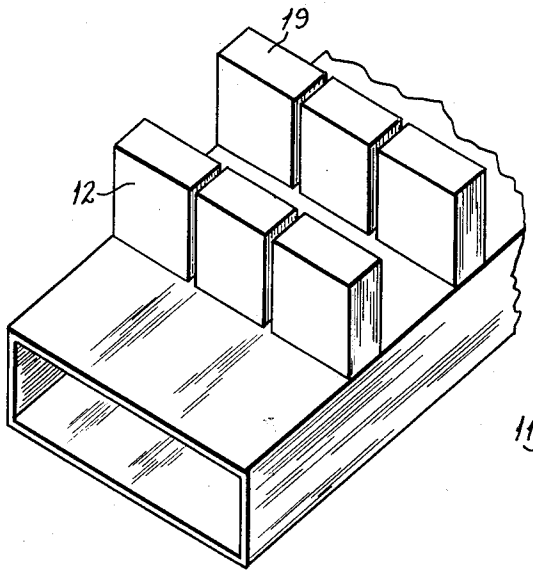

Fig. 4

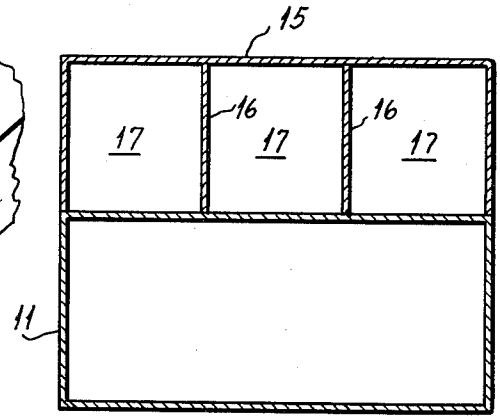

Fig. 3

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ELECTROMAGNETIC WAVE FILTER

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6 Claims. (Cl. 333—73)

This invention relates to electromagnetic wave filters. More particularly it relates to filters on a waveguide for the purpose of suppressing certain frequencies contained in the electromagnetic energy that is transmitted through the waveguide.

In general it is desirable that an electromagnetic wave filter offer an infinite impedance to the particular frequency that it is desired to suppress from the output of the energy transmission system and at the same time offer zero impedance to the frequency which is selected for operation upon apparatus that is located at the output of the energy transmission system. Filter arrangements on or in waveguides are not new, per se. For example it is well known that a quarter-wave shorted waveguide stud section extending perpendicularly away from the wide side of a rectangular waveguide acts as a filter on the waveguide by allowing all frequencies to pass except the one frequency band whose quarter wave length substantially equals the length of the shorted stub. In other words, in order to eliminate any particular frequency from the energy being transmitted along a waveguide a shorted waveguide stub section equal in length to a quarter wave length of said particular frequency may be connected perpendicularly to said main waveguide portion. Another well known type of filter is formed of a metal partition mounted inside the waveguide perpendicular to the length of the waveguide. Partitions may be designed to act as capacitors or inductors whereby a proper combination of properly designed partitions will function as a resonant circuit. By this means it is possible to selectively eliminate particular bands of frequencies. In the case of each type of filter however not only is impedance offered to the particular band which it is desired to suppress but additionally to the remainder of the energy being transmitted along the waveguide so that in effect the desirable energy is attenuated. It is this particular attenuation effect that is mitigated or even eliminated by the use of the filter arrangement of the present invention.

This invention is directed to the use of quarter-wave length shorted stubs for the purpose of suppressing undesirable bands of frequencies from the energy being transmitted along a waveguide. However where the prior art employed stub sections which extended across the entire width of the main waveguide, this invention adopts a plurality of shorted quarter-wave stubs which are arranged transversely of the waveguide the dimensions of each being equal and the combined plurality of stubs extending across the entire width of the waveguide. By making use of the cutoff principle familiar to those skilled in the art of waveguides it is possible to design the filter stubs so that each small stub by virtue of its small transverse dimensions is considerably beyond cutoff. By so doing the response of each small stub to the fundamental frequency will definitely be a second order effect. This invention further utilizes the principles of compensation effect by using two sets of small stubs spaced a quarter-wave length along the waveguide and extending from the same wide side of the waveguide.

As pointed out above the prior art is acquainted with ways and means of evolving a filter arrangement suitable for the suppression of harmonics but such ways and means usually involve a somewhat complicated structure having the necessary faults of complicated tuning and reaction at the fundamental frequency. In contrast to this, the present invention involves an extremely simple method of accomplishing such harmonic suppression for any order of harmonics, even or odd, as desired.

An object of this invention is to provide an improved electromagnetic wave filter.

A further object is to provide an electromagnetic wave filter for use on a waveguide for suppressing an undesirable band of frequencies while offering substantially zero discontinuity to the desirable energy that is being transmitted along the waveguide.

A further object is to provide a waveguide filter which has substantially zero effect on the useful portion of the energy being transmitted along the waveguide.

A further object is to suitably modify the well-known quarter-wave shorted stub filter so that it offers greater attenuation of the undesirable frequency band and substantially no attenuation of the useful frequency band.

A further object is to provide a waveguide filter arrangement suitable for suppressing undesired harmonics which may be associated with the fundamental frequency of transmission and which filter arrangement would further provide a high degree of attenuation for the particular harmonic frequency under consideration, and at the same time would offer negligible discontinuity to the waves at the fundamental frequency.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a pictorial view of a portion of a waveguide including one filter modification of this invention,

Fig. 2 is a sectional view of the arrangement shown in Fig. 1 taken along line **2—2** of Fig. 1,

Fig. 3 is a showing similar to Fig. 2 but including a second filter modification, and

Fig. 4 is a pictorial view similar to that shown in Fig. 1 but including two sets of stubs.

For the purposes of this discussion it is assumed that the mode of transmission is standard TE_{01}. It is further assumed for the purpose of this disclosure that it is desired to suppress or filter out the third harmonic of the selected fundamental frequency.

In Fig. 1 there is shown a portion of a rectangular waveguide **11**. At a suitable location along the waveguide **11** there is provided three transversely aligned quarter-wave length shorted stubs **12** extending perpendicularly from the wide face of the waveguide **11**. Each of the stubs **12** are identical in all dimensions. They are so proportioned that three stubs extend across the entire width of the waveguide. Coinciding with each of the passages in the shorted waveguide stubs **12** is an opening **13** in the top surface of the waveguide **11**.

A modified stub arrangement is shown in Fig. 3. Instead of employing three separate stubs **12** there is provided instead a single stub **15** having two partitions **16** for providing three identical chambers **17**. By using this arrangement it is only necessary to cut one rectangular opening across the entire width of the waveguide **11**. In the case of the three shorted stubs **12** it is necessary to cut three separate rectangular openings each of which is separated from the next opening by a thin strip.

A plot of the fundamental and third harmonic distribution of the electric field in the waveguide **11** is shown in dotted lines in Fig. 2. The plot as shown is based upon the premise that the third harmonic issues from the same

source as does the fundamental. Where the frequency or mode represented by the plot of the third harmonic does not issue from the same source as does the frequency or mode represented by the fundamental as in the case where more than one energy source is feeding into the same waveguide, it is conceivable that the third harmonic frequency or mode could have a larger magnitude than the fundamental. From Fig. 2 it is evident that each of the shorted quarter-wave length stubs **12** presents a discontinuity or open circuit to the energy being transmitted along the waveguide as third harmonic. Each of the stubs **12** functions as a discontinuity to the transmission of energy at the frequency corresponding to the third harmonic and serves as a barrier to the portion of the electric field of said third harmonic with which it is aligned. Since the stubs **12** are arranged in a straight line across the width of the waveguide **11** the combination of the three stubs effectively serves to eliminate the third harmonic from the output of the waveguide **11**. The three stubs **12** will have negligible effect on the fundamental since the width of the stubs **12** is such that they are at cutoff for the frequency of the fundamental.

Though the width of each of the stubs **12** measured along the length of the waveguide **11** as shown in Fig. 1 is narrower than the width of the main waveguide it could also be made of equal width. The showing in Fig. 1 contemplates the possibility as mentioned above that the third harmonic will issue from the same source as the fundamental and therefore have a considerably smaller amplitude of electric field. The width of the waveguide is selected to keep the maximum voltage between the wide sides of the waveguide from causing arc-overs in the guide at the locations where the amplitude of the electric field is at the maximum. In the example described above where the third harmonic would issue from the same source as the fundamental the magnitude of the third harmonic woud be considerably less even at its peak location than the voltage which would cause arc-over between the wide sides of the waveguide **11**. Therefore it is possible to make the stubs **12** of a smaller width than the width of the main waveguide **11**.

Though the filter stubs of the arrangement shown in Fig. 1 offer negligible discontinuity to the fundamental by comparative standards they may still show up as a reactance to this fundamental. To compensate for the effect of this reactance there is shown in Fig. 4 an arrangement for producing what is in effect resonance at the fundamental frequency. A second set of shorted waveguide stubs **19** aligned across the width of the main waveguide, the second set of stubs being identical to the first set of stubs, are located at a distance equal to one quarter-wave length at the fundamental frequency from the first set of stubs. This quarter-wave length spacing causes the reactances of the sets of stubs to resonate. As a result the combined filter arrangement has a negligible effect on the fundamental frequency.

In operation the filter modifications shown in the drawing suppress the third harmonic. As is shown for the case of suppressing a third harmonic, the main waveguide should have three small, short circuited waveguide stubs attached to its wide side, each small stub being adjusted at or near a length of an odd multiple of quarterwave lengths at the third harmonic frequency. At the third harmonic frequency, the stubs will present a very high impedance in series with the main waveguide. At the fundamental frequency, however, each small stub is by virtue of its small transverse dimension considerably beyond cutoff so that response to the fundamental frequency will definitely be a second order effect. With the small reaction at the fundamental frequency in mind, however, a preferred arrangement may be one such as shown in Fig. 4, which includes two identical sets of small stubs

spaced a quarter wave length apart at the fundamental frequency. Such quarter wave spacing produces the well-known compensation effect such as to mutually correct the minor discontinuities present at each set of stubs. It should be obvious to those skilled in the art that the disclosed embodiments are taken to illustrate the suppression of a third harmonic only, and that other harmonics may be suppressed in a similar manner simply by employing a number of stubs corresponding to the order of the undesired harmonics and adjusting their respective lengths to be an odd number of quarter wave lengths at such harmonic frequency.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. A wave filter for blocking a selected harmonic propagated in a particular mode in a rectangular waveguide, said wave filter comprising a section of rectangular waveguide transversely slotted on one of its wide sides, shorted stub means transversely mounted on said section of rectangular waveguide over the transversely slotted portion thereof to communicate with the interior of said section of rectangular waveguide, said shorted stub means being formed to have a length that is an odd multiple of waveguide quarter wavelengths at the selected harmonic frequency propagated in the particular mode, said stub means defining a plurality of chambers equal in number to the harmonic to be blocked whereby the stub means has a negligible effect on frequencies below the frequency of the selected harmonic.

2. The wave filter as defined in claim 1 wherein said stub means includes a single stub which extends transversely across the entire width of the wide side of said section of rectangular waveguide, said stub having a plurality of partitions which are equally spaced from one another and from the ends of the stub.

3. The wave filter as defined in claim 1 wherein said stub means include three identical stubs which are aligned transversely of the wide side of said section of rectangular waveguide and each stub being closely spaced from the next adjacent stub.

4. A wave filter as defined in claim 1 wherein a second stub means identical to said first stub means is similarly mounted on said section of rectangular waveguide in longitudinal aligned relationship with said first stub means, the spacing between the two said stub means being equal to an odd multiple of waveguide quarter wave lengths of the fundamental frequency of transmission in the dominant mode so as to further reduce the effect of said stub means on the fundamental frequency.

5. A wave filter as defined in claim 4 wherein each said stub means includes a single stub which extends transversely across the entire width of the wide side of said section of rectangular waveguide, each said stub having a plurality of partitions which are equally spaced from one another and from the ends of the stub.

6. A wave filter as defined in claim 4 wherein each said stub means includes a plurality of identical stubs which are aligned transversely of the wide side of said section of rectangular waveguide and each stub of each said stub means being closely spaced from the next adjacent stub in the same stub means.

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