QUASI-OPTICAL LOW-PASS FILTERS WHICH ATTENUATE BY ABSORPTION*

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This paper deals with low-pass filters for quasi-optical microwave, millimeter-wave, or possibly infrared systems where the energy is channeled by focused-beam transmission lines,[1,2] or by oversized waveguide.[3] Most filters previously studied for applications of these types have been of the kind which attenuate in their stop-bands by reflecting the energy,[4,5,6] whereas the type of quasi-optical filter to be discussed herein is quite different in that the stop-band attenuation is achieved by absorbing the incident energy. This feature eliminates possible undesirable interaction effects between the filter and the rest of the system. Also, this particular type of filter structure is very attractive in that it has a large stop-band width, and it appears that the stop-band is relatively unaffected by the presence of higher-order modes.

The filter structure under consideration is in some ways closely related to the reflecting-beam waveguide structure described by Degenford, Sirkis, and Steier. The reflecting-beam waveguide structure that they describe channels electromagnetic energy by focusing and refocusing it along a zig-zag path by a series of focusing mirrors. In our structure, a focusing mirror system is also used, except that the mirrors are comprised of parallel metallic plates with their edges parallel to the E field. These plates are spaced so that in the pass-band of the system the distance between the plates is less than a half wavelength, and the incident wave at each mirror face is reflected. As indicated by the dashed arrows in Fig. 1, in the pass-band the energy is reflected and focused so as to travel a zig-zag path from one mirror to the next. At higher frequencies where the spacing between the metal plates is greater than a half wavelength, the energy is no longer reflected at the mirror faces, and much of the incident energy is transmitted between the plates and absorbed by absorbing material therein. In Fig. 1, two metal ground planes are above and below the mirror systems shown in the figure, and these provide the appropriate boundary conditions for the vertically polarized electric field. The mirror-face curvature was designed in accordance with available theory.[2,7]

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NOTES

An important problem in designing a system such as is suggested in Fig. 1 is the proper launching of the electromagnetic waves into the focused-beam system and the recovery of the waves from the system. The work of Boyd and Kogelnik,[7] along with that described in Ref. 2, shows that at the midplane between reflectors the beam shape should be approximately Gaussian. In order to launch a beam of energy having an approximately Gaussian cross-sectional field strength, dielectric mode launchers were used as indicated in Figs. 1 and 2. Dielectric material with a relative dielectric constant of approximately 1.1 was placed in the region between the metal ground planes and up into the mouth of each launching horn. Figure 2 shows the computed E-field strength in the dielectric material and the surrounding air, as compared with a Gaussian characteristic. It will be noted that the comparison is reasonably good, and by using more than one dielectric material, it is believed that the match could be made to be very accurate. Obtaining a good match between the fields of the mode launching device and the lowest-order-mode field configuration generated by the reflecting mirrors is important for having a low launching loss and for avoiding unwanted resonances in the pass-band due to trapped modes. (Trapped modes can occur when higher-order modes which cannot propagate in the end parts of the system are excited in the middle of the system. Such higher-order trapped modes have an effect on the system like band-stop resonators and tend to cause attenuation spikes in the pass-band.)

Figure 3 shows how the absorbing material was introduced in our trial reflector structures. The absorbers were made from pine wood with a sawtooth configuration on their front edges for impedance matching. The region between the plates in front of the absorbers was filled with polyfoam and the metallic plates were formed by wrapping the polyfoam and absorber pieces with aluminum foil. Of course, more sophisticated fabrication procedures would be used for a practical design.

Figure 4 shows the measured attenuation characteristic of a trial three-reflector design. The launching horns were formed using commercial horn antennas with dielectric material in them, as suggested in Figs. 1 and 2. These horns were not sufficiently long to provide very good mode matching and as a result there was considerable evidence of trapped mode activity in the pass-band. In spite of the many attenuation spikes due to trapped modes in the pass-band, the minimum attenuation points in the pass-band ran about 1 db, indicating that the basic pass-band loss of this structure is low. It is believed that by using horns with a longer taper it should be possible to reduce the pass-band trapped-mode spikes considerably. Of course, if the filter is terminated in oversized waveguides, only dielectric inserts would be required to make mode launchers.

The stop-band was very clean and free of spurious responses as can be seen from the figure. The peaks of attenuation in the cutoff region are believed to be due to mismatch and resonance effects between the leading edge of the reflectors and the absorbing loads between the plates. Though equipment was not available to measure the stop-band at the higher frequencies, it is believed that the stop-band should be strong up to considerably higher frequencies.

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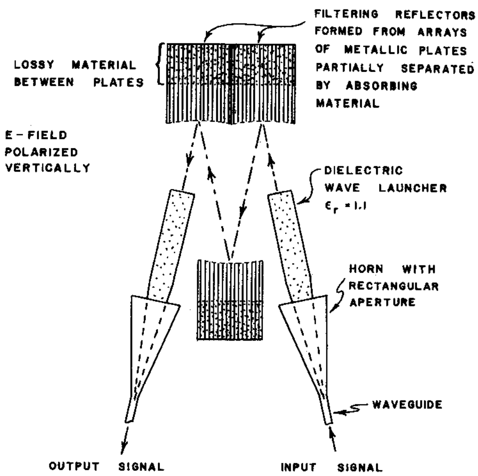

Fig. 1 Low-pass, AbsorptionType Filter for Quasi-Optical Applications. (The structure shown above is placed between two metal ground planes.)

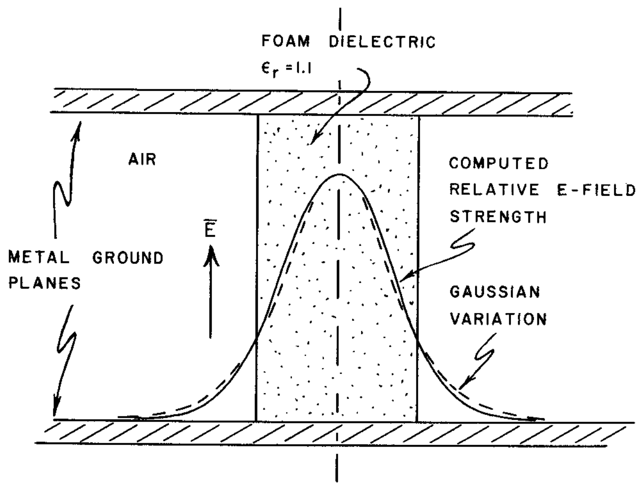

Fig. 2 Electric Field Strength Variation in Dielectric, "Gaussian-Mode" Wave Launcher.

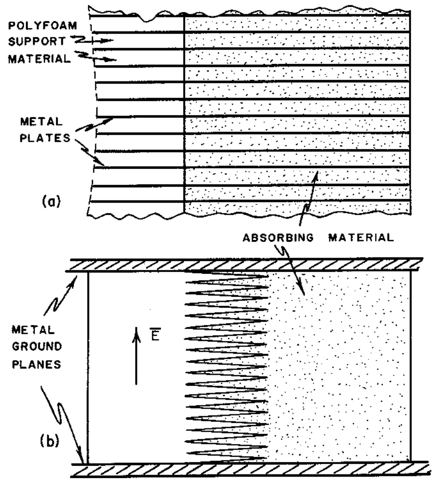

Fig. 3 Configuration of Aborbing Loads Within Reflectors.
(a) top view. (b) side view.

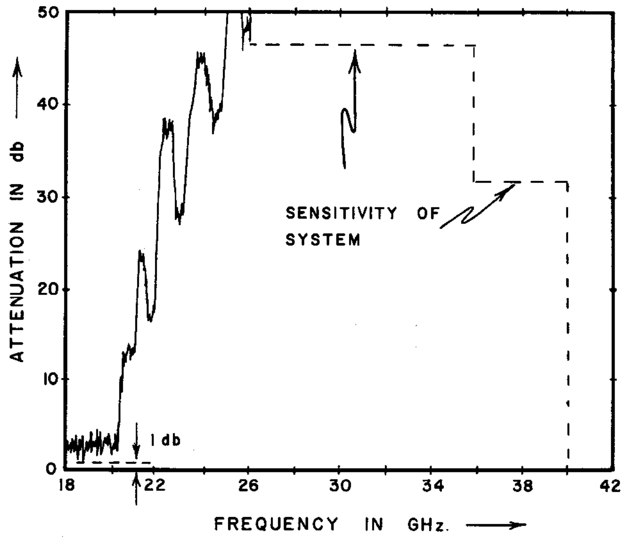

Fig. 4 Measured Attenuation Characteristic for a Trial, Three-Reflector Filter.