WAVEGUIDE BANDSTOP FILTER UTILIZING $Ba_2Ti_9O_{20}$ RESONATORS

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ABSTRACT

Waveguide bandstop filter structures utilizing dielectric resonators proposed in the literature have problems in realization. An improved filter configuration is presented with two realizable design examples.

Introduction

Recent advances in the development of low loss and temperature stable dielectric materials [1], [2], [3], has renewed interests in microwave application of dielectric resonators. The advantages of using dielectric resonators in place of metallic cavities was recognized more than a decade ago [4]. Since that time, design theories and various applications in waveguides and coaxial structures have been proposed [5], [6], [7], [8], [9], [10], [11]. However, interest in further development of microwave application soon dissipated because dielectric material available then was either too lossy or had very poor temperature stability [12]. Since early 1970, new dielectric materials have been developed which exhibit low loss characteristic approaching that of waveguide cavities, and temperature stability similar to Invar [1], [2], [3]. With these new technological advances in the dielectric material, practical applications of dielectric resonators in both TEM structures and waveguide was finally deemed feasible [3], [13]. However, practical designs of microwave filters utilizing dielectric resonators have yet to be fully developed. Particularly, the filter configuration for the waveguide bandstop filter proposed in [4] and [5] can cause problems in realization.

The aim of this paper is to present a suitable configuration for waveguide bandstop filters utilizing $Ba_2Ti_9O_{20}$ resonators and practical design technique.

Waveguide Bandstop Filter Configuration Utilizing Dielectric Resonators

Okaya and Barash proposed the first waveguide bandstop filter utilizing dielectric resonators by placing rutile crystals inside the main waveguide [4]. Cohn reported a design of a bandstop filter with TiO_2 resonators, also being placed inside the main waveguide, Figure 1 [5]. However, the presence of the dielectric resonators in the waveguide, forming a bandstop filter, was found to have the following drawbacks:

(1) Perturbation of the waveguide modes by the presence of the dielectric resonator is too large to be compensated for, resulting in poor match in the passband. Besides, a frequency tuning device for the resonator will be required in the waveguide which causes additional perturbation to the passband performance.

(2) Inter-resonator couplings in a bandstop filter must be avoided. This would be difficult to accomplish if the resonators were placed in the propagating waveguide.

From the above observations, it becomes very clear that the solution is to place the dielectric resonators outside the main waveguide. The proposed configuration is shown in Figure 2, which will eliminate these problems. The resonators are isolated in their own metal enclosure and coupled to the main waveguide through small apertures on the waveguide walls. Figure 2 shows two such bandstop filter configurations where the dielectric resonator is a circular disk resonating in the H_{01} mode [5], [6]. The dielectric resonator in Figure 2a is coupled to the transverse magnetic field of the dominant mode in the waveguide, H_x, while the dielectric resonator in Figure 2b is coupled to the longitudinal magnetic field of the dominant mode in the waveguide, H_z.

While both configurations exhibit bandstop filter characteristics, they differ in spurious mode excitations in the propagating waveguide which affects the filter performance. The filter configuration with H_z coupling is asymmetrical in the propagating waveguide about the plane of symmetry bisecting the broad sides of the waveguide wall. The major evanescent mode being excited is the H_{20} mode. In contrast, the structure using H_x coupling is symmetrical and the major evanescent mode being excited is the H_{30} mode which has a higher cutoff frequency than the H_{20} mode and therefore contributes to a lower level of inter-resonator coupling. For this reason, the filter configuration with H_x-coupling (Figure 2a) is generally preferred over H_z-coupling.

Furthermore, it is well known that in iris coupled metal cavity waveguide bandstop filters, the cavity and its coupling iris can be represented as an ideal resonant circuit and a residual reactance element. The latter causes an asymmetrical frequency response. The dielectric resonators have a similar asymmetrical response. A tunable shunt inductive element in the propagating waveguide is designed to compensate for this residual reactance.

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Design Examples

Design examples for two types of filters are presented. Both filters have two dielectric resonators coupled to H_x of the dominant mode in retangular waveguide. The dielectric resonators in one filter are spaced 3/4 λ_{go} apart and the filter is of Butterworth design. The second filter is designed to block two undesirable tones at f_1 and f_2 outside the signal band of f_o. It consists of two dielectric resonators which resonate at two different frequencies, f_1 and f_2, and are spaced λ_{go} /2 apart at f_o. Except for differences in dielectric resonator spacing, these two filters are of similar design as shown in Figure 3.

(1) Two-Resonator Bandstop Filter

Following standard design procedures, the coupling parameter of each resonator is obtained [14]. Physical realization of the coupling parameters is accomplished using measured design data. The measured performance of the two-resonator bandstop filter is shown in Figure 4. The filter was designed to have a stopband centered at 4.175 GHz and to pass all signals in the remainder of the common carrier band from 3.7 to 4.2 GHz. It was purposefully designed with the stopband near the edge of the common carrier band so as to demonstrate that, with the aid of the tuning inductive posts, low reflection can be obtained in the passband in an extreme case. As anticipated, there are no spurious resonances occurring in the band. The peak insertion loss of 60 dB is twice the peak insertion loss of each resonator, this indicates that the inter-resonator coupling is indeed negligible.

(2) Bandpass Filter With Two Tone-Rejection Bands

This filter was designed to pass a signal band centered at f_o but rejecting two tones $\pm\Delta f$ away from f_o. The two stopbands for the undesirable tones are provided by two dielectric resonators coupled to the waveguide, which have resonant frequencies of $f_o-\Delta f$ and $f_o+\Delta f$, respectively. The two resonators are spaced $\lambda_{go}/2$ apart such that, at f_o, the residual discontinuities from the two resonators form a bandpass filter. As explained above, due to the asymmetrical band reject response of the dielectric resonator, in order to achieve good return loss in the passband centered at f_o, two inductive tuning posts must be used. Typical filter performance of the tone-reject bandpass filter is shown in Figure 5.

Conclusion

Using the proposed filter configuration and the tuning devices, bandstop filters utilizing dielectric resonators can be made practical. For the purpose of illustration, only two-resonator filters were presented. Nevertheless, the scheme is applicable to general multiresonator bandstop filter design. It may also be applied to other microwave networks utilizing bandstop filter characteristics. One typical example is the waveguide complementary filter utilizing dielectric resonators [5], as shown in Figure 6 with bandpass and band reject filters.

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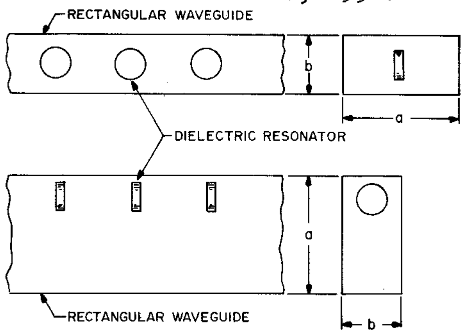

FIGURE 1
WAVEGUIDE BANDSTOP FILTERS UTILIZING DIELECTRIC RESONATORS

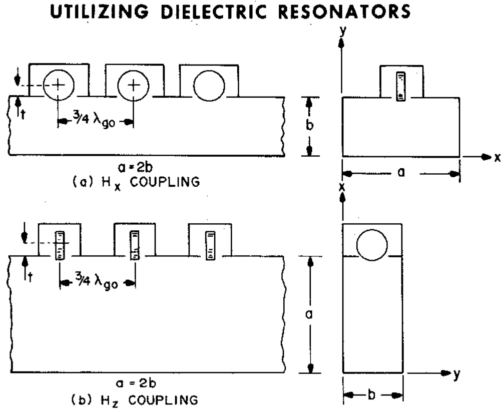

FIGURE 2
PROPOSED FILTER CONFIGURATIONS

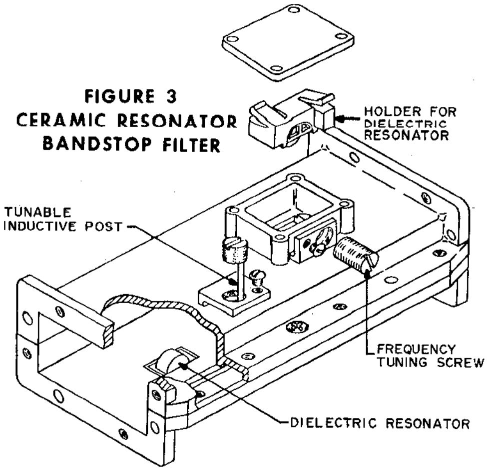

FIGURE 3
CERAMIC RESONATOR BANDSTOP FILTER

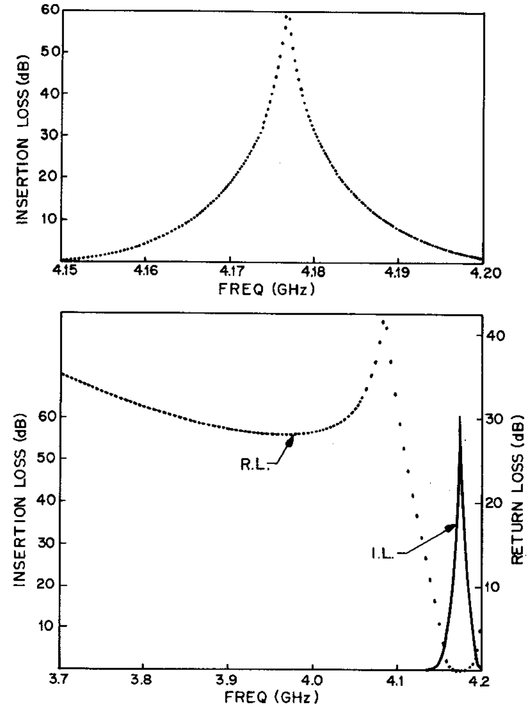

FIGURE 4
MEASURED PERFORMANCE

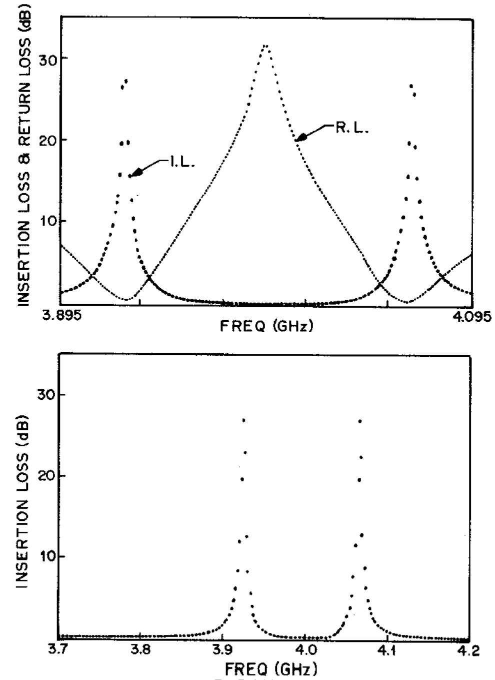

FIGURE 5
MEASURED PERFORMANCE

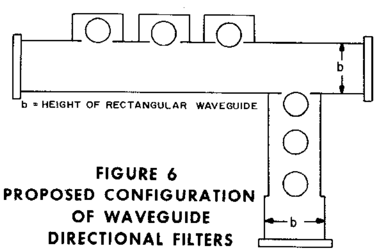

FIGURE 6
PROPOSED CONFIGURATION OF WAVEGUIDE DIRECTIONAL FILTERS