DESIGN OF NONRADIATIVE DIELECTRIC WAVEGUIDE FILTER

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Abstract

An efficient design technique of nonradiative dielectric waveguide filter circuits for use at millimeter wavelengths is developed. A 3-pole, 0.1-dB Chebyshev ripple bandpass filter with 2-percent bandwidth at center frequency of 49.5 GHz was designed and fabricated with Teflon dielectric according to this theory. The calculated and measured filter responses agree quite well, and the excess insertion loss is found to be as small as 0.3 dB.

Introduction

Various filter circuits have been proposed for microwave and millimeter-wave applications (1),(2),(3). A filter structure based on the nonradiative dielectric waveguide(NRD-guide)(4) is also promising because of its applicability to millimeter-wave integrated circuits. Actually, an NRD-guide filter has been previously fabricated and tested at 50 GHz(5). But, since there was no reliable design theory at that time, the results were not necessarily satisfactory, and the excess insertion loss was unexpectedly as large as 1 dB due to the lack of optimization of design parameters. An efficient design technique is needed to educe the potentiality of the NRD-guide filter.

The filter structure to be considered here consists of longitudinally coupled dielectric chip resonators inserted between the input and output ports as shown in Fig.1. The synthesis technique developed for gap-coupled coplanar waveguide filters(3) can also be applied to the NRD-guide filter, if the coupling property between adjacent dielectric sections is known. This coupling property can be elucidated by means of a variational technique to complete the design theory.

In order to verify the theory and check the filter performance as well, a bandpass filter was designed, fabricated and tested at center frequency of 49.5 GHz. After a slight adjustment of the gap lengths, the specified filter response was realized with an excess insertion loss as small as 0.3 dB.

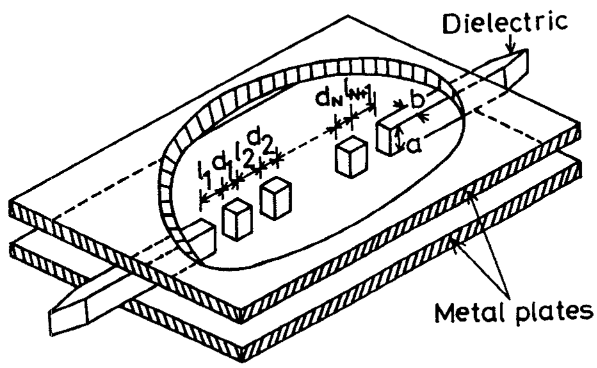

Fig.1 Structure of nonradiative dielectric waveguide bandpass filter

Design Considerations

The gap region in the NRD-guide filter structure can be represented by an impedance inverter network with transmission line sections connected on both sides as shown in Fig.2(3). The inverter parameter K and the electrical line length $-\phi$ are calculated by means of a variational technique and plotted as a function of the gap length in Fig.3. In this calculation, Teflon strips(ϵ_r = 2.04) 2.7 mm in height and 3.5 mm in width and a frequency of 49.5 GHz are assumed for later reference.

By replacing each gap in the original filter structure with the equivalent impedance inverter, a canonical bandpass filter circuit can be derived as shown in Fig.4. Based on this circuit representation, design of the filter can be carried out as described elsewhere(3).

A 3-pole, 0.1-dB Chebyshev ripple bandpass filter with 2-percent bandwidth at center frequency of 49.5 GHz was built using Teflon strips which had the same dimensions as those assumed in Fig.3. The resulting filter dimensions are $d_1 = d_2 = d_3$ = 2.72 mm, $l_1 = l_4$ = 1.60 mm and $l_2 = l_3$ = 3.35 mm(see Fig.4 for definitions).

Characteristics of Fabricated Filter

In the first measurement, the 3-dB bandwidth of the fabricated filter was found to be a little wider than the specified value of 1 GHz. This discrepancy could be eliminated by expanding the inner two gap lengths, l_2 and l_3, by 50 μm, while keeping other dimensions unchanged. The measured filter response is shown in Fig.5, together with the return loss curve which has the highest value, 38 dB, at center frequency. The computed response curve is also plotted for

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comparison. Agreement between theory and measurements is quite satisfactory. The excess insertion loss was found to be 0.3 dB which is very close to the theoretically predicted value of 0.28 dB.

Conclusions

A low loss NRD-guide bandpass filter was designed and fabricated at center frequency of 49.5 GHz with Teflon material. Measurements showed that the desired filter performance could be achieved after a slight adjustment of the gap lengths. The excess insertion loss of the filter was measured to be 0.3 dB at center frequency of 49.5 GHz. This supports the assertion that the NRD-guide filter is of practical use at millimeter wavelengths.

References

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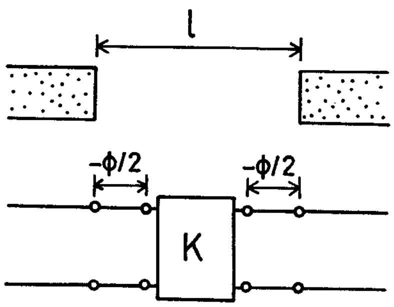

Fig.2 End-couple semi-infinite dielectric strips(top) and its equivalent impedance inverter circuit(bottom)

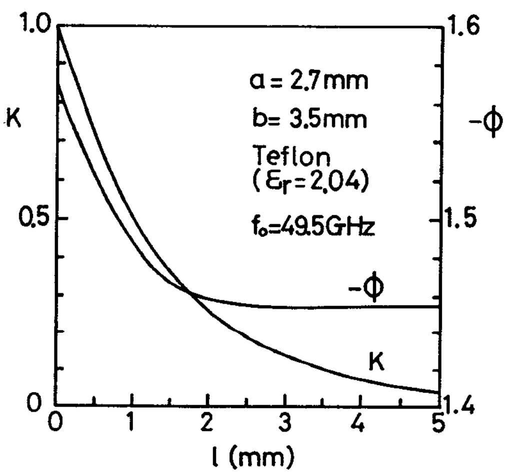

Fig.3 Impedance inverter parameter K and electrical line length $-\phi$ as a function of gap length

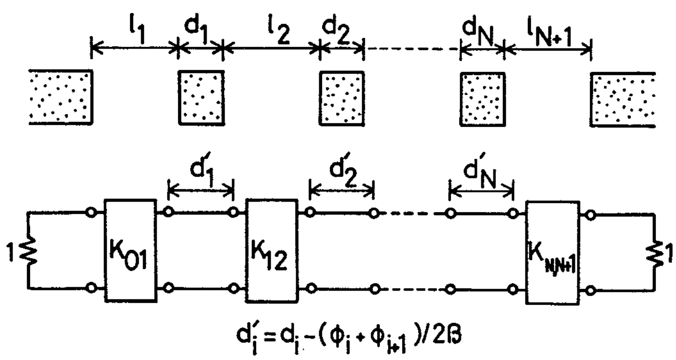

Fig.4 Equivalent circuit representation for nonradiative dielectric bandpass filter

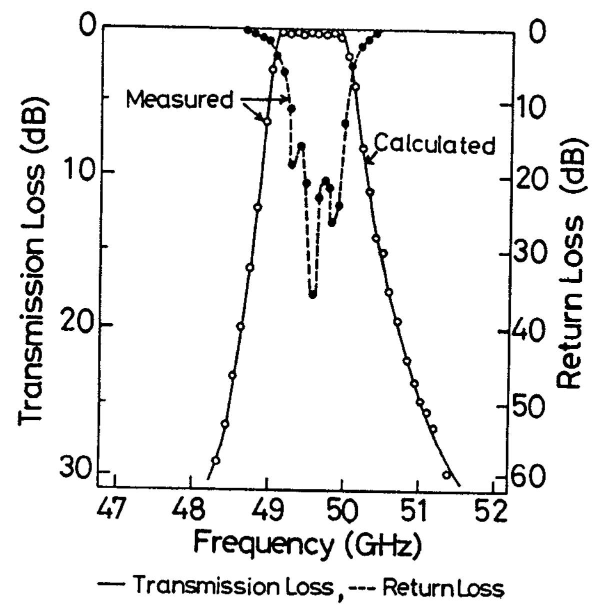

Fig.5 Calculated and measured characteristics of fabricated nonradiative dielectric waveguide bandpass filtern