9-3

ANALYSIS AND DESIGN OF EVANESCENT-MODE WAVEGUIDE DIELECTRIC RESONATOR FILTERS

Y. C. Shih
K. G. Gray

Naval Postgraduate School
Electrical and Computer Engineering Department
Monterey, California 93943

ABSTRACT

The analysis and design of an evanescent-mode waveguide dielectric resonator filter are presented. The filter, consisting of low permittivity dielectric resonators placed in waveguide below cutoff, can be designed up to about 20% bandwidth. Measurements performed in K band are in good agreement with the theory.

INTRODUCTION

Microwave bandpass filters employing dielectric resonators have been designed successfully [1, 2]. In these filters the dielectric resonators of high relative permittivity ($\epsilon_r \approx 100$) and low loss tangent ($\tan\delta \approx 0.0001$) are placed in a circular or rectangular waveguide below its cutoff frequency. Because the filter design was based on an approximate resonant frequency of the resonator and on approximate coupling coefficients of the input and interstage couplings, it was difficult to design filters of more than about 2% bandwidth.

In this paper, we present the analysis and design of an "evanescent-mode waveguide dielectric-resonator filter." The filter, shown in Fig. 1, consists of a number of dielectric resonators placed in rectangular waveguide below cutoff, such that the dielectric material totally fills the waveguide section. The input and output portion of the filter is coupled to the external circuit via a double-step waveguide junction. This structure may be considered as an evanescent-mode waveguide filter [3, 4] where the required lump capacitance effect is now realized by the dielectric resonator. An advantage to the present structure is that an accurate analysis can be obtained with a mode-matching method [5]. With the theoretical analysis, a given design can be verified accurately without going through a tedious measurement.

With the present design technique, bandpass filters up to moderate bandwidths (≈ 20%) can be easily obtained. Filters designed have been fabricated and tested in K band (18-26.5 GHz). Good agreement between the measurements and the theory is observed.

THEORY

The theoretical analysis is based on a generalized scattering matrix technique [6] that considers the fundamental mode as well as all the higher-order modes. In Fig. 2, the top view of a two-cavity structure is given together with its equivalent circuit representation. The large input and output waveguides and the smaller waveguide sections filled with dielectric materials are both described by transmission lines representing their fundamental and higher-order modes of propagation. The empty smaller guide section, which is below its cutoff frequency, is described by a generalized scattering matrix. In this study the s-parameters for the double-step waveguide junction are obtained by a mode-matching method [5], while for the resonator junction a simple transmission impedance formula is applied. The overall s-parameters for the filter structure are found by combining the scattering matrices at the individual junctions, including the multiple-scattering effects through the transmission line sections. A key point is that the higher-order modes, as well as the fundamental mode, are included in the analysis. This allows an exact coupling coefficient between junctions to be found as a function of frequency, which is necessary in wideband design.

Considering the structure as a direct-coupled-cavity filter, we design the filter with a procedure based on a distributed half-wave step-impedance filter prototype [7]. The design procedure is a modified version of that by Levy [8], which is valid up to moderate bandwidths (≈ 20%).

RESULTS AND DISCUSSIONS

Based on the design, several filters have been built, tested and analyzed. Fig. 3 and 4 show the results for two of the filters designed in K band using two and three dielectric resonators, respectively. The dimensions of the filter structures are given as parameters. In both cases the larger waveguide is WR-42 (0.42" x 0.17") and the smaller guide is WR-22 (0.224" x 0.112"). The material used for the dielectric resonators is Teflon ($\epsilon_r \approx 2.2$). The circles represent the measured data and the solid curves are the results obtained by the analysis. They are in good agreement. Fig. 3 shows the response of the two-cavity equiripple filter with 800 MHz bandwidth; the measured maximum insertion loss in the passband is about 0.9 dB. Fig. 4 is the response of the three-cavity filter, the measurement shows about 1.3 dB maximum insertion loss across the 1 GHz passband. It is noted that the bandwidth of this filter is about 5%. Wider bandwidth and better transmission performances can be achieved by increasing the number of resonators.

As the design frequency increases, the volume and weight of the filter structure will be reduced. Therefore, low permittivity dielectric is used to ease the dimensional tolerances and the temperature sensitivity. Teflon is used here because it is

0149-645X/84/0000-0187 $01.00 © 1984 IEEE

easily cut, sheared and machined to shape. Because of the accurate design, fine tuning is normally not required. In cases where tuning is necessary, a metal screw can be applied approaching the resonator close enough to perturb slightly its H or E external field. Or alternatively, a dielectric tuning rod can be applied, as described in [2].

CONCLUSION

The analysis and design of the evanescent-mode waveguide dielectric-resonator filter are presented. The filter response obtained by the measurement is in good agreement with that obtained by the analysis. Filters up to moderate bandwidths (≈ 20%) can be easily obtained by the present design. It is believed that this filter will find its application at millimeter-wave frequencies.

ACKNOWLEDGEMENT

This work was supported by the Naval Postgraduate School Foundation Research Program.

REFERENCES

[1] S.B. Cohn, "Microwave bandpass filters containing high-Q dielectric resonators, "IEEE Trans. Microwave Theory Tech., Vol. MTT-16, pp. 218-227, Apr. 1968.

[2] W.H. Harrison, "A miniature high-Q bandpass filter employing dielectric resonators," IEEE Trans. Microwave Theory Tech., Vol. MTT-16, pp. 210-218, Apr. 1968.

[3] G.F. Craven and C.K. Mok, "The design of evanescent mode waveguide bandpass filters for a prescribed insertion loss characteristic," IEEE Trans. Microwave Theory Tech., Vol. MTT-19, pp. 295-308, March 1971.

[4] R.V. Snyder, "New application of evanescent mode waveguide to filter design," IEEE Trans. Microwave Theory Tech., Vol. MTT-25, pp. 1013-1021, Dec. 1977.

[5] Y.C. Shih and K.G. Gray, "Convergence of numerical solutions of step-type waveguide discontinuity problems by modal analysis," 1983 IEEE/MTT-S Intl. Microwave Symposium Digest, pp. 233-235, May 1983.

[6] R. Mittra and S.W. Lee, Analytical Techniques in the Theory of Guided Waves, New York: MacMillan, 1971, pp. 207-217.

[7] Y.C. Shih, "On the design of direct-coupled-cavity filters," Submitted for presentation at the 1984 International Microwave Symposium.

[8] R. Levy, "Theory of direct-coupled-cavity filters," IEEE Trans. Microwave Theory Tech., Vol. MTT-15, pp. 340-348, June 1967.

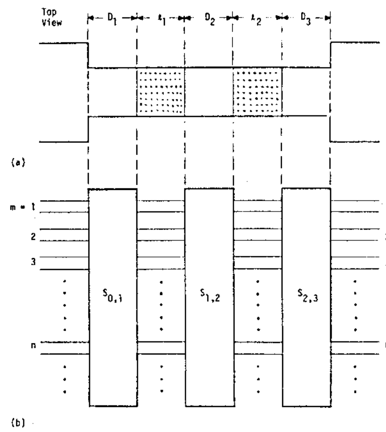

Fig.2 (a) Top view of a two-cavity filter and (b) its equivalent circuit.

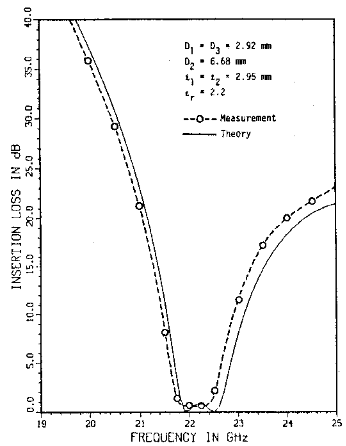

Fig.3 Computed and measured insertion losses for a two-cavity filter.

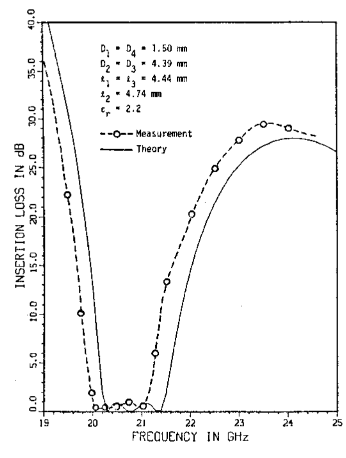

Fig.4 Computed and measured insertion losses for a three-cavity filter.

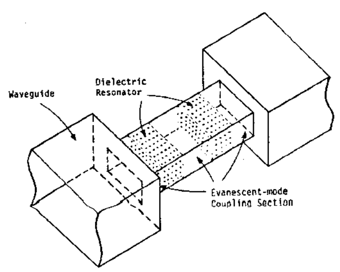

Fig.1 Perspective view of a evanescent-mode waveguide dielectric-resonator filter.