HIGH-DIELECTRIC CONSTANT STRIPLINE BAND-PASS FILTERS

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ABSTRACT

High-dielectric constant (K = 38) stripline was employed to realize selective band-pass filters. Seven-pole, gap-coupled filters centered at 6.0 and 8.0 GHz were designed for 140 MHz 3-dB bandwidths. The data shows excellent agreement without the need for tuners. Miniaturization of high-performance filters has been demonstrated. This technique is applicable to MMIC-based microwave systems.

INTRODUCTION

This paper describes the design and construction of stripline band-pass filters using high-dielectric constant (K = 38) substrates. This work was undertaken to develop miniature filters with sharp selectivity. Miniature filters are becoming increasingly important for use with MMIC-based hardware. The choice of propagation media for this effort is balanced stripline. The substrate material is composed of zirconium tin titanium oxide [$(ZrSn)TiO_4$)] and possesses a dielectric constant of 38. The loss tangent of the material as quoted by the manufacturer is 0.0001. This corresponds to a dielectric quality factor of the order of 10,000. The material is also very stable with temperature, demonstrating a temperature variation of 6 pm/°C. This material is extensively used by researchers to form dielectric resonators; however, using this material in balanced high-K stripline is thought, by the authors, to be the first such application. The filter type chosen for this present application is Cohn's gap-coupled design, as discussed in his noteworthy paper (1). This particular design was chosen because of its eventual application in the design of compact multiplexers.

TECHNICAL DISCUSSION

To demonstrate feasibility, K = 38 substrates were used to design a gap-coupled band-pass filter. This particular filter is inherently narrowband. Such filters typically operate over bandwidths on the order of 10 percent or less. The effects of dissipation are generally more crucial for narrow-band designs. Thus, the choice of materials with unloaded Q's (Qu's) which meet the necessary requirements is a crucial consideration. The importance of this consideration cannot be overemphasized. The intended filter design would be halted in its tracks if dissipation effects were found to be at an unacceptably high level. Fortunately, this is not the case. The low-loss nature of the material is adequate for the intended purpose. Conductor losses also limit the Qu and they vary with the choice of transmission line. Stripline was chosen since it offered adequate performance electrically and reasonable mechanical requirements. Figure 1 shows the stripline cross section. The impedance level is typically found to be in the 10 to 20 Ω range. The conductor losses for stripline are acceptable for such impedance levels. The conductor losses may easily be estimated with the use of data provided by Cohn (2). Filter performance for the given conductor and dielectric dissipations may be estimated from the design curves provided by Sleven (3). The final consideration in the design involves consideration of higher order modes. The waveguide cut-off frequencies are lowered with the presence of higher dielectric constant substrates. They are, however, still high enough for useful operation at the frequencies of interest. In fact, higher frequency operation is possible with the use of higher mode suppression techniques that are themselves easily implemented.

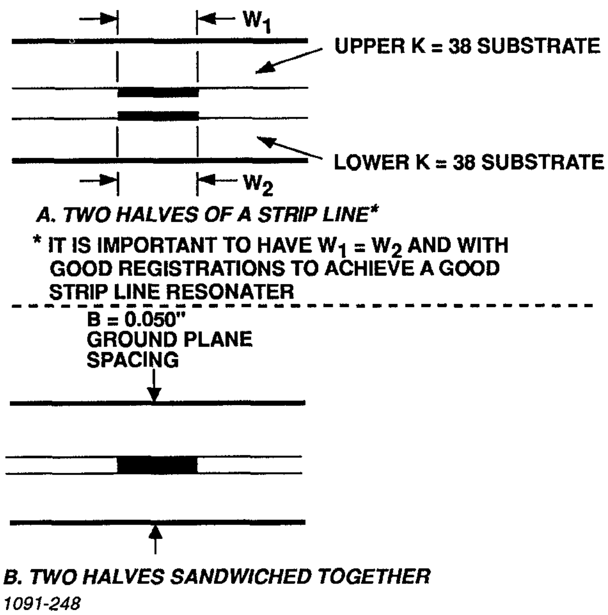

Figure 1. Stripline Cross Section

EXPERIMENTAL RESULTS

The circuit used in the experimental phase consisted of a gap-coupled band-pass filter that was designed to work over a 140 MHz bandwidth and was centered at 6.0 GHz. The filter design was a 0.1 dB Tchebycheff design of order n = 7 for the low-pass prototype. A schematic diagram of the physical layout is shown in Figures 2 and 3. The measured response is shown in Figure 4. The measured response agreed very well with the predicted response with dissipation as found in (3). The predicted dissipation was 6.0 dB as estimated from a Qu of 500. A filter centered at 8 GHz was also designed and fabricated with equally good results. The comparison between the predicted response and the theoretical response was made on the basis of the measured loss and measured bandwidth as they were compared to the performance estimates made on the basis of the material in (3). These results were obtained without the need for tuners. The material in (3) allows one to estimate the unloaded Q factor. This factor was then estimated from Cohn's formula for the

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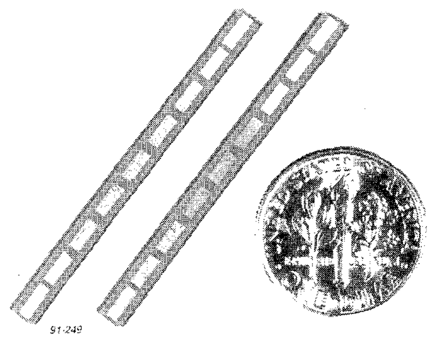

Figure 2. AIL Systems Inc. Developed 6-GHz, 7-Pole Band-Pass Filter Using E_r = 38 Stripline

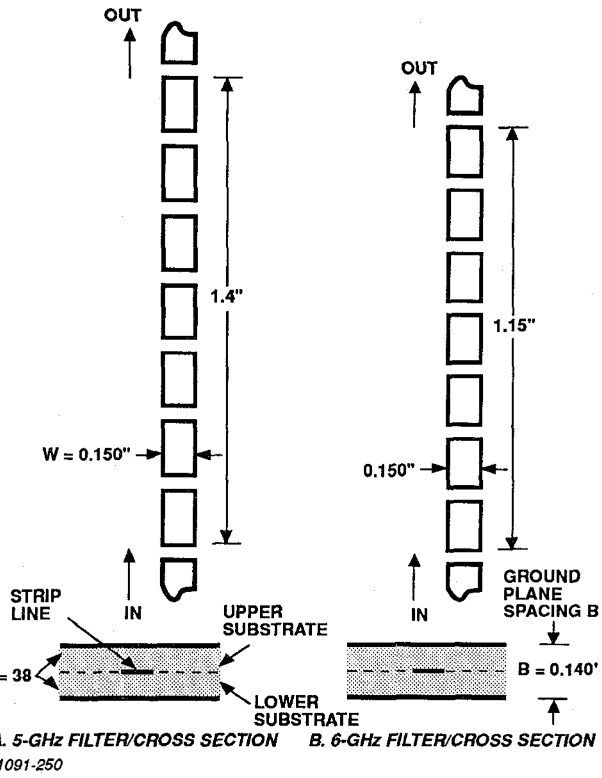

Figure 3. Stripline Patterns for the Lowest and Highest Frequency Filters Using E_r = 38 Substrates

Qu of stripline. The measured Qu was found to be approximately half of the predicted value of 1000. Achievement of 50 percent of the theoretical Qu is expected when working with imperfect conductors. Improvements in achieved Qu may be realized with the use of gold plating on the conductors or any other scheme which improves their approximation of the ideal. The achievement of the maximum Qu was not an immediate goal, however, and this was considered to be a good practical result. The researcher is now able to estimate the Qu for future designs based upon the ground work laid out by the present experiment. Additionally, the Qu levels that are realizable for this type of filter were found to be in useful ranges.

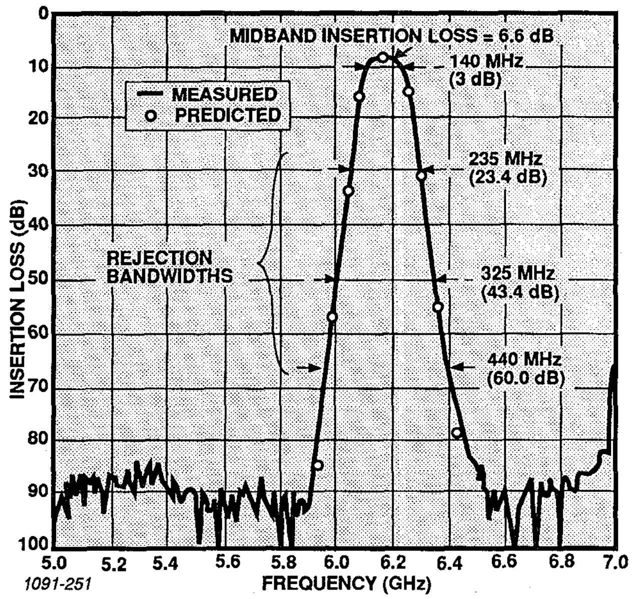

Figure 4. Measured Response of a Seven Resonator Miniature Stripline Band-Pass Filter

SUMMARY AND CONCLUSIONS

The practical implementation of high-K stripline band-pass filters has been demonstrated. The unloaded Q, choice of operating impedance, and the role played by higher order modes has been both analytically and experimentally considered. It has been found that experiment and theory are in good agreement and allow for the use of the present results in predicting performance levels for use in future designs. Such filters are expected to find applications in frequency multiplexers as well as in individual circuits, particularly with MMIC-based systems.

ACKNOWLEDGMENTS

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(2) S. B. Cohn, "Problems in Strip Transmission Line," IRE Transactions, Vol. 3, No. 2, pp. 119 – 126: March 1955.

(3) R. L. Sleven, "Pseudo-Exact Filter Design Saves Time," Microwaves (an eight part series which first appeared in August 1968 and concluded in July 1969).