Compact Low-Pass Filter Using a Slow-Wave Structure

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Abstract - In this paper a compact low-pass filter that makes use of coupled microstrip lines is investigated. A slow-wave structure is used to equalize the even and odd mode phase velocities of a pair of coupled microstrip lines and thereby improve the directivity of the coupled lines. Two low-pass filters were fabricated: one using the slow-wave structure and one using conventional coupled lines. The results reveal that the rejection of the low-pass filter is significantly improved by using the slow-wave structure.

I. Introduction

Low-pass filters are found extensively in microwave systems where they are used, for example, to suppress harmonics and spurious signals. To obtain a high rejection and steep roll-off when using a high-impedance/low-impedance filter or a stub filter, the number of filter sections needs to be increased. In order to maintain a high rejection and yet reduce the size of the filter, a new low-pass filter topology shown in Figure 1 has been proposed that uses two quarter-wavelength couplers [1]. In this paper, the bottom coupled line section in Figure 1 is replaced by a coupler with very high directivity (Figure 2) and the filter rejection is seen to increase by a significant amount. The directivity of the coupler was improved by using a slow-wave structure which equalizes the even and odd mode phase velocities of the coupled lines [2].

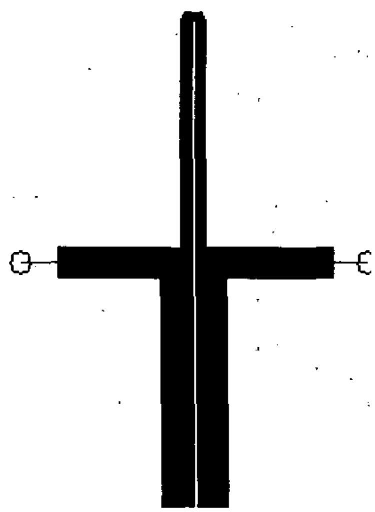

Figure 1 – Compact low-pass filter

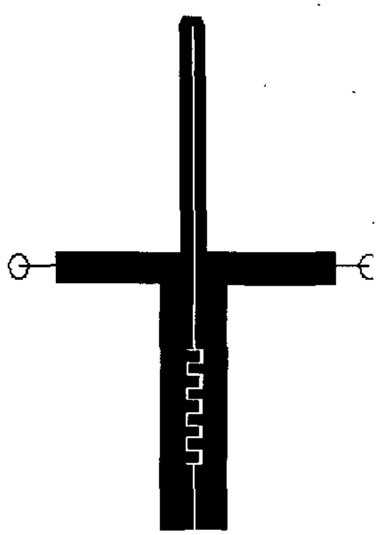

Figure 2 – Proposed low-pass filter

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II. Coupler Design

Coupled lines support an even and an odd mode of propagation with different characteristic impedance. In stripline and other waveguide structures where the transmission lines are embedded in a uniform dielectric media the phase velocities of the two modes of propagation are equal. In microstrip, however, the dielectric medium is not homogenous which leads to a difference in the even and odd mode phase velocities because the effective dielectric constants for the two modes are not equal [3].

Several techniques exist for compensating the phase velocities of the even and odd modes in microstrip coupled lines. One method is to use discrete capacitors at the input and output of the coupled region. Another method is to use a sawtooth, serpentine, or interdigital geometry to create a slow-wave structure to slow the phase velocity of the odd mode [2]. The particular geometry chosen is not particularly important, leaving the designer with ample choices as to which type of structure to use. In this paper an interdigital, or combline, approach was selected to achieve phase velocity equalization.

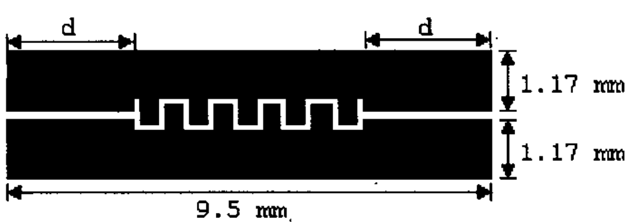

Figure 3 - Coupler using combline slow-wave structure for even and odd mode phase velocity compensation.

The coupler structure used in this work is shown in Figure 3. A commercial method-of-moments field solver was used to simulate couplers with different lengths, *d*, while keeping the overall coupler length the same, until the best directivity was achieved. The substrate used had a thickness of 0.5 mm and a relative dielectric constant of 3.4. The length of the coupler was 9.5 mm, the coupling gap was 0.15 mm, and the period of the combline structure was 0.64 mm. The width of the transmission lines was 1.17 mm. The graph in figure 4 shows the computed directivity of the coupler as a function of *d* at a frequency of 5 GHz. It is seen that an optimum directivity of 49 dB is achieved for *d* = 2.5 mm.

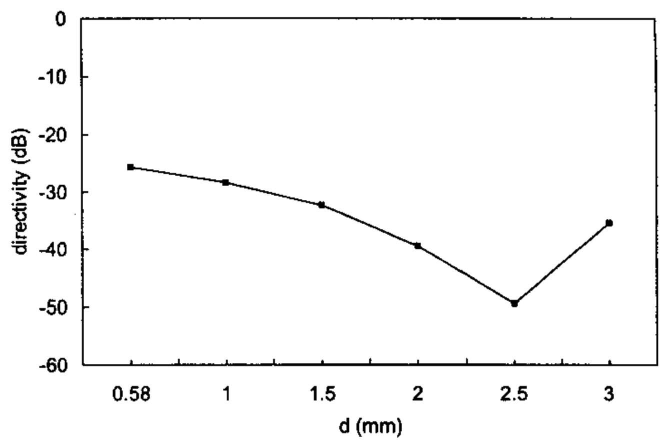

Figure 4 – Coupler directivity at 5 GHz as a function of corrugation geometry

III. Low-pass Filter

Two low-pass filters were built for comparison purposes: one using conventional coupled lines as shown in Figure 1 and one incorporating the slow-wave structure depicted in Figure 2. For the filter in Figure 1, the bottom coupler had a length of 9.5 mm, a width of 1.17 mm and the gap was 0.15 mm. For both filters, the top coupler was identical. The length of the top coupler was 9.5 mm, the coupling gap was 0.15 mm and the width was 0.60 mm.

The experimental results in Figure 5 reveal that for the filter in Figure 1, the 3-dB cutoff frequency is 2.4 GHz and for the filter in Figure 2, the 3-dB cutoff is 2.3 GHz. The rejection for the filter with the combline coupler structure is significantly better than for the filter using conventional couplers. At 3.65 GHz, the rejection for the filter with the slow-wave structure is 58 dB whereas the rejection for the filter using conventional couplers is 21.5 dB at the same frequency.

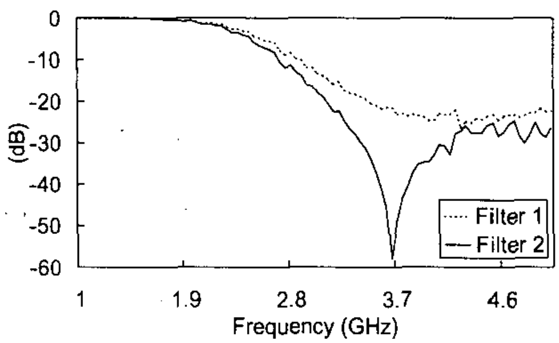

Figure 5 – Low pass filter insertion loss for filter using conventional (dotted line) coupled lines and slow-wave structure (solid line).

IV. Conclusion

The need for compact low-pass filters has led to the use of quarter-wavelength coupled lines to implement new filter structures. In this paper a filter has been designed that makes use of a coupler incorporating a slow-wave structure. It is observed that the rejection of the filter using the corrugated coupler improves significantly when compared with the filter without corrugated coupler.

V. References

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