A COPLANAR WAVEGUIDE BROADSIDE END-COUPLED BAND-PASS FILTER

Cam Nguyen

Electromagnetics and Microwave Laboratory
Department of Electrical Engineering
Texas A & M University
College Station, Texas 77843-3128

ABSTRACT

A new broadside end-coupled band-pass filter using coplanar waveguide (CPW), suitable for wide-band microwave and millimeter-wave integrated circuits, has been developed. The shielded CPW and broadside CPW, employed in the filter, were analyzed using the quasi-static spectral-domain method. An X-band (8-12 GHZ) three-resonator band-pass filter has been built and tested with a good agreement between the measured and calculated results.

INTRODUCTION

Coplanar waveguide has recently received a lot of attention as a viable candidate for both hybrid and monolithic microwave and millimeter-wave integrated circuits due to its many appealing properties, including (1) elimination of via holes in connecting circuit elements to ground, (2) easy realization of compact baluns for balanced circuits, and (3) good line-to-line isolation.

In comparison with the popular microstrip line, filter development on CPW have been very sporadically, in spite of its attractive advantages. Only a few CPW filters have been reported, such as the CPW end-coupled band-pass filters [1], CPW short-circuited stub band-stop filters and open-circuited stub band-pass filters [2], and CPW-slot line band-pass filters [3].

In this paper, we present, for the first time, the development of a new CPW broadside end-coupled band-pass filter (Figure 1) suitable for broad-band applications. Compared to the conventional CPW end-coupled filter [1], this filter structure can achieve the tight coupling between resonator elements required for wide-band filters. The characteristic impedances and phase velocities for the two transmission line structures, the shielded CPW and broadside CPW, employed in the filters are obtained using the quasi-static spectral-domain approach (SDA) [4]. Measured results of an X-band three-section CPW broadside end-coupled band-pass filters are compared favorably with the values calculated theoretically.

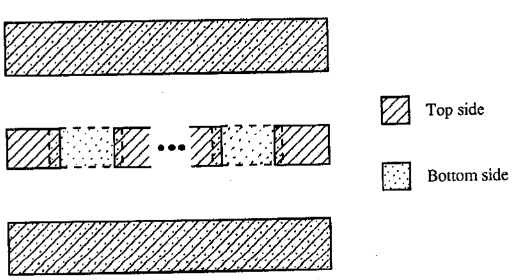

Figure 1. A CPW broadside end-coupled band-pass filter configuration.

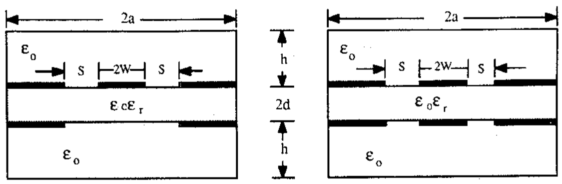

Figure 2. Cross sections of shielded CPW (a) and broadside CPW (b).

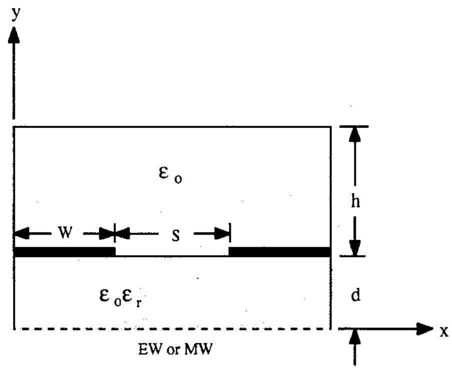

Figure 3. A quarter cross section of shielded broadside CPW. EW and MW stand for electric wall and magnetic wall, respectively.

ANALYSES OF SHIELDED CPW AND BROADSIDE CPW

Figure 2 shows cross sections of the considered shielded CPW and broadside CPW. The conductors are assumed to be perfectly conducting and infinitesimally thin, and the dielectric substrates are assumed to be lossless. The analysis for these structures are similar, so only the broadside analysis described. The broadside structure supports the quasi-TEM even and odd propagation modes. In view of the symmetry of the structure, only one quarter of the cross section, as shown in Figure 3, is needed to be considered. By using the quasi-static SDA, which utilizes the Galerkin's method, described in [4], one can derive the following system of coupled linear algebraic equations

$$\sum_{m=1}^{M} P_{11}^{im}(\alpha_n)\, c_m \;+\; \sum_{k=1}^{K} P_{12}^{ik} d_k = Q_i, \qquad i = 1, 2, \cdots, M$$
$$\sum_{m=1}^{M} P_{21}^{jm}(\alpha_n)\, c_m \;+\; \sum_{k=1}^{K} P_{22}^{jk} d_k = 0, \qquad j = 1, 2, \cdots, K$$

where

$$P_{11}^{im} = \sum_{n=1}^{\infty} \tilde{\rho}_{si}(\alpha_n)\,\tilde{G}(\alpha_n)\,\tilde{\rho}_{sm}(\alpha_n)$$

$$P_{12}^{im} = \sum_{n=1}^{\infty} \tilde{\rho}_{si}(\alpha_n)\,\tilde{G}(\alpha_n)\,\tilde{\rho}_{gk}(\alpha_n)$$

$$P_{21}^{jm} = \sum_{n=1}^{\infty} \tilde{\rho}_{gj}(\alpha_n)\,\tilde{G}(\alpha_n)\,\tilde{\rho}_{sm}(\alpha_n)$$

$$P_{22}^{jm} = \sum_{n=1}^{\infty} \tilde{\rho}_{gj}(\alpha_n)\,\tilde{G}(\alpha_n)\,\tilde{\rho}_{gk}(\alpha_n)$$

$$\tilde{G}(\alpha_n) = \begin{cases} \alpha_n^{-1}(\coth\alpha_n h + \epsilon_r \tanh\alpha_n d)^{-1}, & \text{even mode} \\ \alpha_n^{-1}(\coth\alpha_n h + \epsilon_r \coth\alpha_n d)^{-1}, & \text{odd mode} \end{cases}$$

with α_n being the transform variable and ϵ_r being the relative dielectric constant of the substrate. c_m and d_k are unknown coefficients, associated with the Fourier-transformed known basis functions $\tilde{\rho}_s$ and $\tilde{\rho}_g$ that describe the charge distributions on the strip $(0 \le x \le W)$ and the ground plane $(W + S \le x \le a)$, respectively. They can be determined by solving the above equation system. The even- and odd-mode capacitances per unit length can then be obtained as

$$C = \frac{4_{\epsilon_0}}{a} \sum_{m=1}^{M} c_m Q_m$$

where ϵ_0 represents the free space permittivity, from which the corresponding even- and odd-mode characteristic impedances and phase velocities can be determined.

FILTER DESIGN AND PERFORMANCE

The CPW broadside end-coupled band-pass filter, as shown in Figure 1, is actually a direct-coupled-resonator filter that consists of a sequence of CPW broadside coupled sections, periodically located along CPW. To demonstrate the performance of the proposed new filter, an X-band (8-12 GHz) three-section filter, with a pass-band ripple of 0.4 dB, was designed and tested. Figures 4 and 5 show its photograph and performance, respectively. Insertion losses of less than 1.5 dB were achieved in the pass band. It can be seen that the theoretical performance is in good agreement with the experimental results.

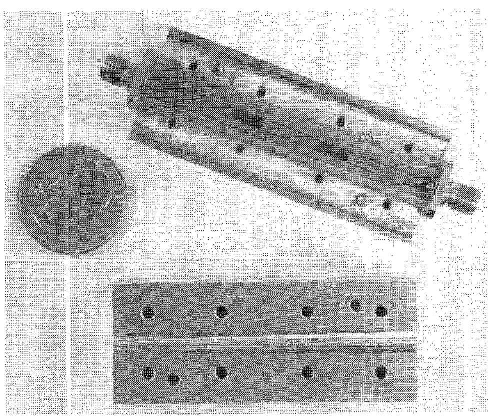

Figure 4. A photograph of the CPW broadside end-coupled band-pass filter.

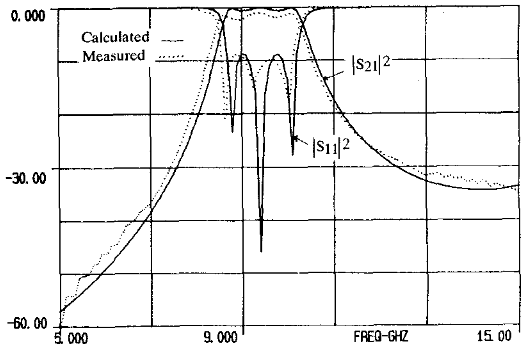

Figure 5. Measured and calculated performance of the CPW broadside end-coupled band-pass filter.

CONCLUSIONS

The development of a new broadside end-coupled band-pass filter using CPW technology is presented for the first time. The characteristic impedances and phase velocities of the shielded CPW and broadside CPW, necessary for the filter analysis and design, are derived based on the quasi-static SDA. The measured results obtained for a three-resonator filter is in good agreement with the computed performance. The new filter structure should find many applications in narrow- as well as wide-band microwave and millimeter-wave integrated circuits.

REFERENCES

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