Coupling in Some Edge-Coupled Microshield Transmission Lines

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Abstract: Using the finite-difference time-domain(FD-TD) method in the Cartesian coordinate system, the coupling effects in some (a)symmetrical edge-coupled V-shape and trapezoidal microshield transmission lines (MTLs) are studied. The hybrid effects of different geometrical parameters of the MTLs and the permittivity of the filling materials on the coupling coefficient are examined and compared. It is shown that the edge-coupled V-shape geometry is effective in reducing coupling over a wide frequency range.

I. INTRODUCTION

Recently, several unconventional microstrip lines have been proposed using novel fabrication technology. These microstrip lines can be used in wideband high-frequency circuits. For example, the finite-ground V-shape *Si*-micromachined lines developed by Katehi *et al*, by selective etching of silicon substrate in CMOS technology, can achieve zero dispersion in the frequency range of 10 to 60GHz. In particular, the loss in the V-shape geometry can be reduced considerably to 0.115dB/mm [1, 2].

To analyse the wideband dispersion characteristics of most microstrip structures, several numerical methods, such as finite-difference time-domain (FD-TD) method [3] can be employed to calculate the effective permittivity, attenuation constant, characteristic impedance as well as the mode coupling coefficient. In using the FD-TD method, the numerical error in treating curved inclined boundaries can be reduced using polygonal approximation.

In this work, the wideband coupling characteristics of some novel (a)symmetrical edge-coupled MTLs are studied using the FD-TD method in Cartesian coordinate system. The geometry of these MTLs include the edge-coupled V-shape and the trapezoidal structures. The filling isotropic non-magnetic material is usually low loss, and can be described by different permittivities. In particular, the low temperature co-fired ceramics (LTCCs) are included. In our study, the coupling effects are examined and compared in detail.

II. GEOMETRIES

The cross-sectional views of two (a)symmetrical edge-coupled MTLs are shown in Figs. 1(a, b), where the structures are uniform in the *z*-axis direction, respectively. In Figs. 1(a, b), the metallic ground surface is perfectly

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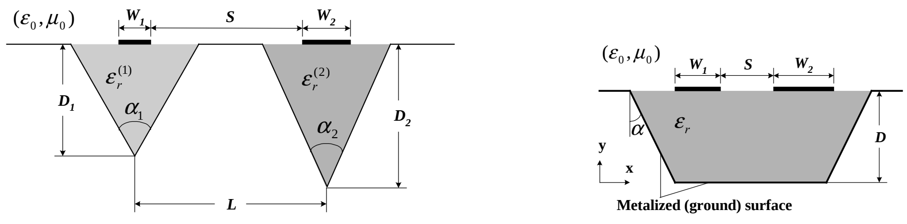
conducting, and it serves to isolate the waveguide from its neighbouring circuits. Hence, the coupling, crosstalk, and parasitic substrate modes are reduced or eliminated. In Fig. 1(a, b), the metal strips with widths $W_{1,2}$ are also perfectly conducting.



(a) V-shape (b) trapezodial

Fig. 1. Cross-sectional view of two microshield transmission lines.

III. NUMERICAL RESULTS AND DISCUSSIONS

The FD-TD method is employed and its methodology will be included in detail here [3]. The inclined shielding ground sections in Figs. 1(a, b) is modelled using the polygonal approximation in our computation. On the other hand, the perfectly matched layer (PML) is employed to terminate the computational domain. To verify our FD-TD code, the characteristic impedance Z of a single V-shape MTL is first computed, as shown in Fig. 2, where all parameters are chosen to be the same as those given in [4], and $\alpha_1 = 60^o$.

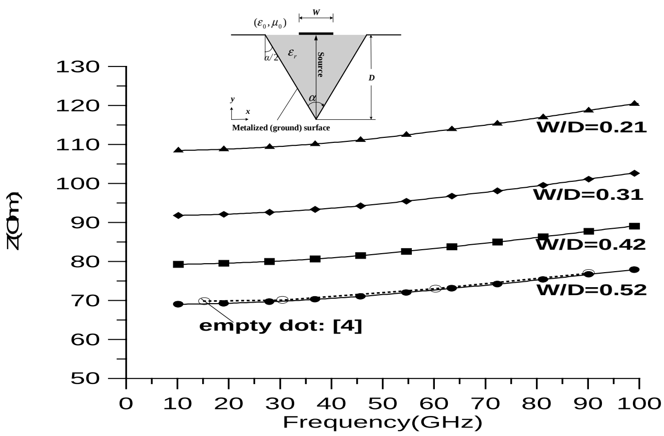


Fig. 2. Characteristic impedance as a function of frequency of the V-shape MTL for different values of *W/D*.

In Fig. 2, the dimensions of the FD-TD cells are chosen as follows: $\Delta y = 0.0545mm$, $\Delta z = 0.0324mm$ and $\Delta x = 0.0315\,mm$. The time step is set to

$\Delta t = 0.0525ps$, and the excitation is a standard Gaussian pulse with a width of $2ps$ and a time delay $t_0 = 8ps$. The characteristic impedance Z is computed by

$$Z(\omega) = \frac{V_k(\omega)e^{-j\omega\Delta t/2}}{\sqrt{I_{k-1}(\omega)I_k(\omega)}} \tag{1a}$$

where

$$V_k(\omega) = FFT[V_k(t)], I_k(\omega) = FFT[I_k(t)] \tag{1b,c}$$

and FFT stands for fast Fourier transform. It is obvious that an excellent agreement is obtained by comparing our result with that shown in [4], and the value of Z increases as W/D decreases.

Fig. 3 shows the coupling coefficient between the symmetrical edge-coupled V-shape MTLs as a function of W/D. Here, we choose $W_1 = W_2 = W$, $\alpha_1 = \alpha_2 = 60^o (180^o$: edge-coupled microstrip line), and $\varepsilon_{r1} = \varepsilon_{r2} = 2.55$. Under such circumstances, the structure becomes symmetrical.

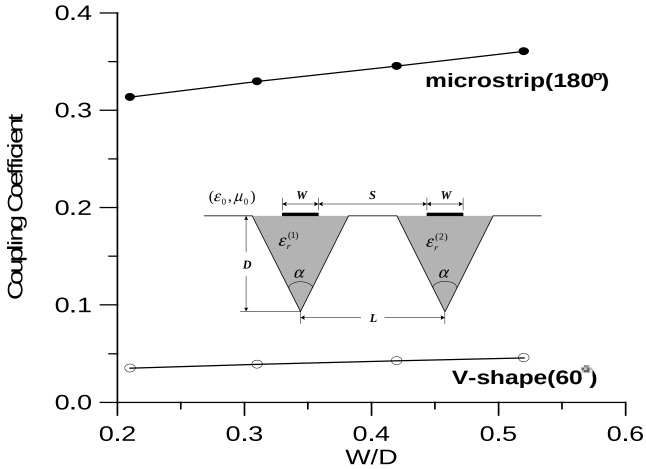


Fig. 3. Coupling coefficient versus ratio W/D of the symmetrical edge-coupled V-shape MTLs at 80 GHz.

In Fig.3, the V-shape MTLs, as pointed out in [4], possess better coupling performance over the ordinary edge-coupled microstrip line of $\alpha_{1,2} = 180^o$. Physically, it is reasonable that the coupling between two lines is enhanced as the line width increases.

Fig.4 shows the coupling coefficient as a function of frequency of the asymmetrical edge-coupled V-shape MTLs($D_1 = D_2 = 0.6\,mm$, $W_1 = 0.189\,mm$, and $W_2 = 0.315\,mm$). In Fig. 4, the coupling coefficient is very sensitive to both ε_{r1} and ε_{r2}. In the case of LTCCs: ε_{r1}=4.2 and ε_{r2}=10.6, the coupling coefficient at certain frequency at z = 5.508 mm is nearly zero.

Fig. 5 shows the coupling coefficient of an edge-coupled trapezodial MTLs as a function of frequency corresponding to different S/W ($\alpha = 30^o$,

$W_1 = W_2 = W$, and $\varepsilon_r = 2.55$). In Fig. 5, the coupling coefficient increases monotonously with frequency. On the other hand, the coupling decreases with *S*, it is much higher than that of the V-shape geometry.

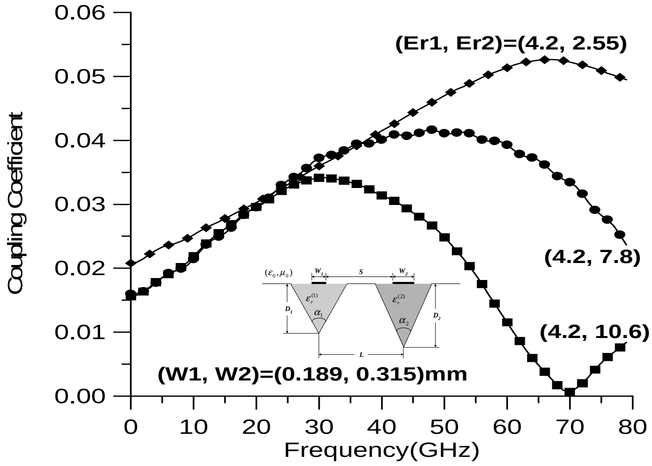


Fig. 4. Coupling coefficient versus frequency for an asymmetrical edge-coupled V-shape MTLs.

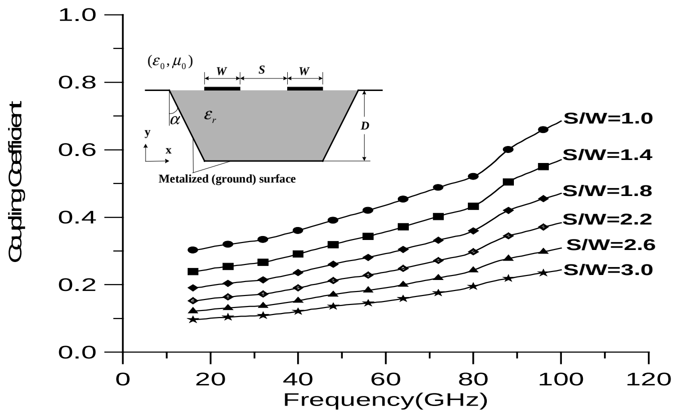


Fig. 5.Coupling coefficient versus frequency for an edge-coupled trapezodial MTLs for different S/W =1.0, 1.4, 1.8, 2.2, 2.6 and 3.0, respectively.

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