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MODELLING THE DISPERSION IN A SUSPENDED MICROSTRIPLINE

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Abstract

Dispersion in an open suspended microstripline is modelled. New frequency-dependent equations for the effective dielectric constant are reported. The equations are derived for four commonly used substrates (namely RT-Duroid, Fused Quartz, Alumina, and Gallium Arsenide) and reproduce the exact fullwave data within ±2 percent (±1 percent for most cases).

Introduction

Suspended microstrip structure is one of the most important planar transmission media used in the millimeter-wave band (upto 100 GHz or so). The cross-section of this structure is shown in Fig. 1, with parameters W, a, b, t and ε_r defined therein. The advantages of this structure (compared to the conventional microstripline) are:

a. lower propagation loss;

b. wider strips (for a given impedance); and

c. reduced dispersion.

Of all these advantages, the phenomenon of reduced dispersion has provoked a considerable amount of quasistatic research on suspended substrate microstrips (see, e.g., [1]-[4]). The underlying assumption in all these analyses has been that the dispersion is sufficiently low and can be neglected for all practical purposes. The present authors have, however, been quantitatively studying the dispersion in suspended microstrip (using a fullwave spectral-domain analysis) and have observed that the dispersion is not always negligible [5]-[6]. The following conclusions have emerged:

a. For a given W/b and a/b, the effects of dispersion become more pronounced as ε_r increases.

b. For a given ε_r and a/b, the dispersion effects decrease as W/b increases.

c. For a given W/b and ε_r, the dependence of dispersion on a/b is quite involved and no simple relationship can be foreseen.

d. For practically used values of t, the dependence of dispersion on t is generally negligible.

The aim of this paper is to quantitatively model the above stated dispersion effects. A previously available closed-form equation for the effective dielectric constant of the conventional microstrip [7] has been suitably modified. The modelling is based on the fullwave data generated by the authors at the University of Ottawa (using a spectral-domain approach) and is done for four substrate materials, namely RT-Duroid (dielectric constant 2.22), Fused Quartz (dielectric constant 3.78), Alumina (dielectric constant 9.8) and Gallium Arsenide (dielectric constant 12.9). The work on modelling the impedance is also in progress and results will be presented at the symposium.

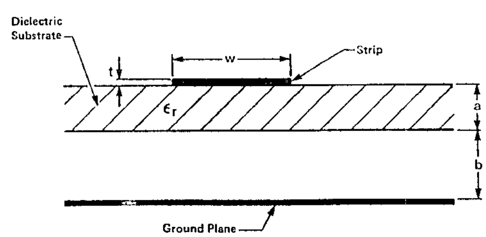

Fig. 1 Cross-Section of Open Suspended Microstrip

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Dispersion Model For The Effective Dielectric Constant

Following Getsinger [7], the frequency-dependent effective dielectric constant is written as

$$\varepsilon_{re}(f) = \varepsilon_r - \frac{\varepsilon_r - \varepsilon_{re}(o)}{1 + G(f/f_p)^2} \qquad (1)$$

where ε_r is the substrate dielectric constant, $\varepsilon_{re}(o)$ is the quasistatic value of the effective dielectric constant (calculable from formulas given in [4]), f is the operating frequency in Hz and

$$f_p = \frac{Z}{2\pi\mu_0(a + b)} \frac{a}{0.064} \qquad (2)$$

where a and b are in Cm

In (2), Z is the quasistatic value of the characteristic impedance (calculable from [4]) and μ_0 is the free-space permeability in H/Cm. The parameter G is given by

$$G = C_0 + C_1 Z + C_2 Z^2 \qquad (3)$$

with

$$C_i = \sum_{j=0}^{4} d_{ij} (a/b)^j \qquad (4)$$

$i = 0, 1, 2$

where the coefficients d's are known for a given ε_r. For $\varepsilon_r = 12.9$, i.e. GaAs substrate, the d values are tabulated in Table I. Similar tables, although not included here, are available for $\varepsilon_r = 2.22$, 3.78, and 9.8 also.

Table I. Values of Coefficients d's For GaAs Substrate

j / i	0	1	2	3	4
0	0.0194	-0.2398	0.8977	-0.9924	0.3468
1	-0.0008	0.0096	-0.0346	0.0384	-0.0135
2	0.0000	-0.0000	0.0004	-0.0004	0.0001

The above model is valid for $1<W/b<1$, 20 GHz<f<100 GHz, and reproduces the exact theoretical data within ±2 percent (±1 percent for most cases).

Sample Results

Two comparisons between the modelled and exact values of $\sqrt{\varepsilon}_{re}(f)$ are shown in Figs. 2 and 3, respectively. For the case shown in Fig. 2, the error was found to be less than ±0.5 percent whereas the error for the case of Fig. 3 was seen to be within ±1.4 percent. It should be noted that the exact theoretical data has been computed with a finite value of t (5 µm in Fig. 2 and 16 µm in Fig. 3) whereas the modelled value is for t=0. This is done to show that although eq (1) is supposed to be valid only for t=0, it gives sufficiently accurate results for t>0 as well, provided t is reasonably small. One should also be reminded of the fact that the comparisons shown in Figs. 2 and 3 are by no means typical. Rather, they represent two more or less extreme situations. Fig. 2 presents a small ε_r, small a/b, large W/b situation for which the dispersion is only moderate. Fig. 3, on the other hand, depicts a large ε_r, large a/b, small W/b case, for which the dispersion is quite severe. The fact the eq(1) holds with reasonable accuracy in both the extreme situations inspires confidence in this equation.

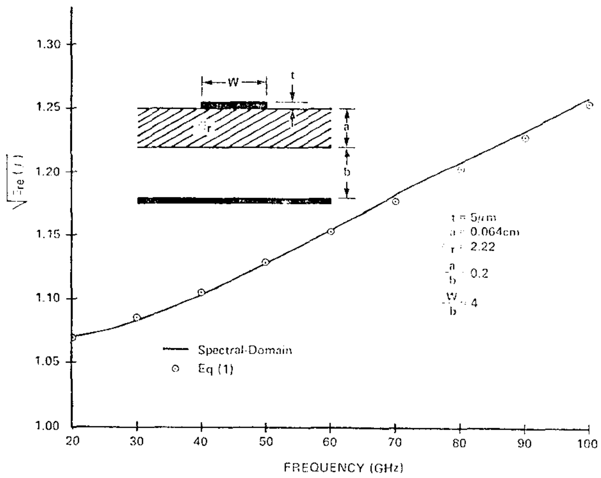

Fig. 2 Comparison of Modelled and Exact Data (ε_r=2.22, a/b=0.2, W/b=4, t=5µm).

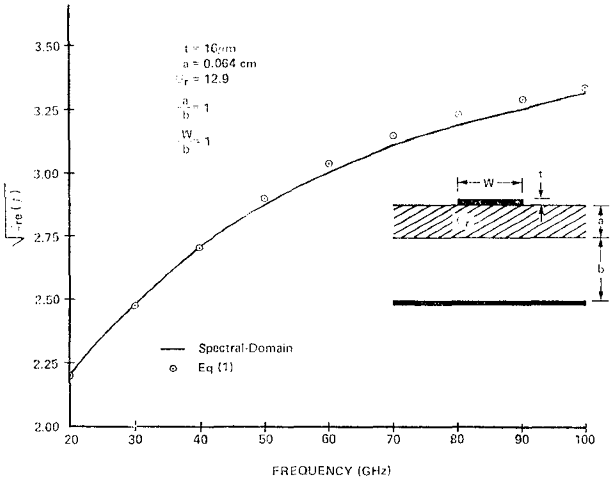

Fig. 3 Comparison of Modelled and Exact Data (ε_r=12.9, a/b=1, W/b=1, t=17 μm).

The accuracy of eq(1) was verified over a large range of parameter values and it was seen that the error does remain below ±2 percent for all cases and below ±1 percent for most cases.

Conclusions

No attempts to model the dispersion in a suspended microstrip structure seem to have been made so far. The present paper models the frequency-dependent effective dielectric constant of this structure. The models developed herein, coupled with the earlier-reported quasi-static models [4], should form a strong basis for the computer-aided design of circuits using suspended microstrip, especially when high-dielectric constant substrates like GaAs are involved.

References

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