Spectral Domain Approach Of Multilayered Superconducting Microstrip Line Using a New Set of Edge-Conditioned Basis Functions

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A new set of edge-conditioned basis functions is used to determine the dispersion properties of microstrip line. Since An alternative formulation of the spectral domain approach (SDA) method presented for high-temperature superconducting microstrip line Green's function derivation. The method relies on reflection factor rather than the transverse impedance used in the immittance approach. The inner products is involved in the Galerkin procedure are pole-free. The numerical examples are presented and close agreement is obtained between simulated and published data.

Keywords: Spectral domain approach, Galerkin procedure, Raised Cosine, high-temperature superconducting.

I. Introduction

Thin high-temperature superconducting film in MMIC transmission lines and circuits offer attractive solutions in applications such as microwave resonator, filter, delays lines and antennas systems.
For transmission lines planar, simple layer or multi-layer, the method approved and used is the spectral method, this method is employed according to a choice of basic functions, which satisfies the conditions of singularity on the edge of the conductor, and this choice is a key factor in the process of convergence, In this technique the superconducting strip is treated as an impedance sheet which introduces new boundary conditions at the surface of the strip. Enforcing these new boundary conditions in the Fourier domain introduces some modification in the diagonal of the Green's impedance matrix, in the spectral domain of the microstrip structure

II. Theory

II-1. Reflection Factors Oriented Spectral Domain

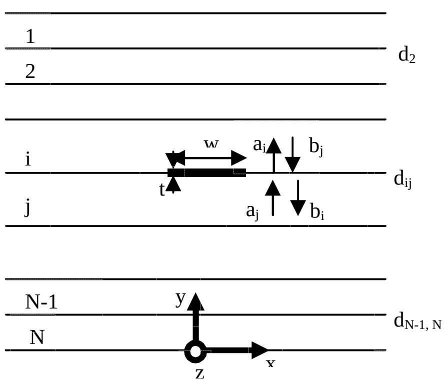

Fig.1: Transverse section of multilayered line.

The field components are derived using the curl operators

$$\vec{E}_i = \frac{-1}{j\omega\varepsilon_i}\nabla\times\nabla\times\psi_i^e\vec{e}_y - \nabla\times\psi_i^h\vec{e}_y \qquad \text{(1a)}$$

$$\vec{H}_i = \frac{-1}{j\omega\mu_i}\nabla\times\nabla\times\psi_i^h\vec{e}_y - \nabla\times\psi_i^e\vec{e}_y \qquad \text{(1b)}$$

At the strip interface, the boundary conditions are rearranged in the following form, where the incoming waves are expressed as functions of the outgoing waves and the current density.
We obtain the general TM scattering equation at the strip plane including the current source contribution [1]:

$$\begin{pmatrix} b_i^e(d_{ij}) \\ a_j^e(d_{ij}) \end{pmatrix} = (S^e)\cdot\begin{pmatrix} a_i^e(d_{ij}) \\ b_j^e(d_{ij}) \end{pmatrix} \qquad (2)$$

Where

$$S^e = \frac{1}{Z_{oi}^e + Z_{oj}^e} \cdot\begin{pmatrix} Z_{oj}^e\Gamma_i^e(d_{ij}) - Z_{oi}^e & Z_{oj}^e(1+L_j^e(d_{ij})) \\ Z_{oi}^e(1+\Gamma_i^e(d_{ij})) & Z_{oi}^e L_j^e(d_{ij}) - Z_{oj}^e \end{pmatrix} \qquad (3)$$

Performing the same manipulations for TE equations, the general scattering equation including the source effects at the strip plane is given by

$$\begin{pmatrix} b_i^h(d_{ij}) \\ a_j^h(d_{ij}) \end{pmatrix} = (S^h)\cdot\begin{pmatrix} a_i^h(d_{ij}) \\ b_j^h(d_{ij}) \end{pmatrix} \qquad (4)$$

Where

$$S^h = \frac{1}{Y_{oi}^h + Y_{oj}^h} \cdot\begin{pmatrix} Y_{oi}^e\Gamma_i^h(d_{ij}) - Y_{oj}^h & Y_{oj}^h(1+L_j^h(d_{ij})) \\ Y_{oi}^h(1+\Gamma_i^h(d_{ij})) & Y_{oj}^h L_j^h(d_{ij}) - Y_{oi}^h \end{pmatrix} \qquad (5)$$

Regarding the strip interface as a two-pot device, the power conservation principle is given by

$$S^{*}S = I \qquad (6)$$

Where superscript * denotes the hermitian matrix and I is the identity matrix.

Applying (6) to each of the TM and TE waves, we obtain the following identities which represent the most significant result given by the present analysis [1]:

$$Z_{xz}J_z + Z_{xx}J_x = 0 \qquad (7)$$

Where

$$Z_{zx} = Z_{xz} = \frac{\alpha\beta}{\alpha^2+\beta^2}(Z^e - Z^h) \quad (8a)$$

$$Z_{xx} = \frac{1}{\alpha^2+\beta^2}(\alpha^2 Z^e + \beta^2 Z^h) \quad (8b)$$

$$Z_{zz} = \frac{1}{\alpha^2+\beta^2}(\beta^2 Z^e + \alpha^2 Z^h) \quad (8c)$$

With

$$Z^e = [Z^e_{oi}(\Gamma^e_i(d_{ij})+1) + Z^e_{oj}(L^e_j(d_{ij})+1)] \times [Y^{h^2}_{oi}(\Gamma^h_i(d_{ij})-1) + Y^{h^2}_{oj}(L^h_j(d_{ij})-1)] \quad (9a)$$

$$Z^h = [Y^h_{oi}(\Gamma^h_i(d_{ij})+1) + Y^h_{oj}(L^h_j(d_{ij})+1)] \times [(\Gamma^e_i(d_{ij})-1) + (L^e_j(d_{ij})-1)] \quad (9b)$$

The system (10) is resolved by applying the Ritz-Galekin procedure.

II-2. Metallization

After obtaining the dyadic Green's function of multilayered substrate by applying SDA, the function is modified by considering a complex boundary condition [4] to incorporate the finite thickness of the conductor. If the thickness t of the trip of finite conductivity σ is greater than three or four penetration depths, the surface impedance is adequately represented by the real part of the wave impedance: $Z = {\omega\mu/2\sigma}^{1/2}$. if **t** is less than three penetration depths, the surface impedance is given by $Z = 1/(t\sigma)$. Where σ is real for conventional conductor s and

$$\sigma = \sigma_n (T/T_c)^4 + (1-(T/T_c)^4)/(j\omega\mu\lambda^2_{eff}) \qquad (10)$$

for superconductors [5]. σ_n is often associated with the normal state conductivity at T_c; λ_{eff} is the effective field penetration depth.

II-3. Modified Spectral Domain

Finally, the spectral-domain electric field at the conductor-dielectric interface is related to the current distribution by the modified dyadic Green's function elements

$$\begin{aligned}\tilde{E}_x &= (\tilde{Z}_{xx} - Z)\tilde{J}_x + \tilde{Z}_{xz}\tilde{J}_x \\ \tilde{E}_z &= \tilde{Z}_{zx}\tilde{J}_x + (\tilde{Z}_{zx} - Z)\tilde{J}_z\end{aligned} \qquad (11)$$

The validation of our approach is settled by recovering some confirmation data. The phase constant β is computed for the bound dominant mode [1], using the above theory.

The choice of the basis functions is important in achieving a highly efficient numerical solution, with minimum computer time, and convergence. Therefore, we proposed a new basic function, Raised Cosine that satisfy the boundary conditions and whose Fourier transforms are available in close forms, They are

$$f(x) = \begin{cases} 1. & -A \le x \le A \\ \frac{1}{2}\left\{1+\cos\left[\frac{\pi(|x|-A)}{M}\right]\right\} & A < |x| < B \\ 0. & otherwise \end{cases} \qquad (12)$$

with

$$\begin{cases} A = xc(1-a) \\ B = xc(1+a) \\ M = 2\cdot a\cdot xc \end{cases} \qquad (13)$$

We will run through the interval [0,1] to find the optimal value of a susceptible to provide us with the fastest possible decay. The obtained results are shown in Figure .2. Immediately, we note that is clear that the optimal value is equal to 1.

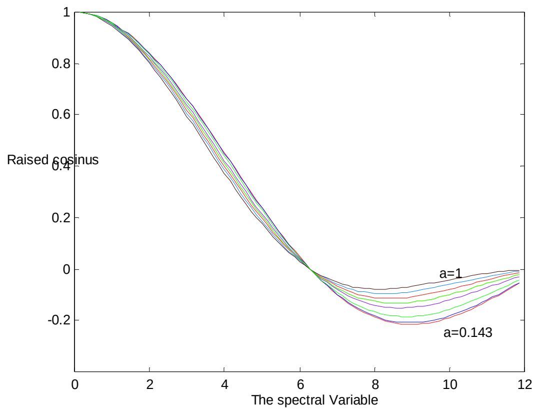

Fig.2: Effect of factor "a "

III. Numerical results and discussion

We focus attention on the structure shown in fig.1, which consists of an open and infinitely long micro strip line of width W on top of a lossless substrate of thickness d and dielectric constant ε_r. We also assume

that the metallic strip and the ground plane are perfectly conducting and neglect the thickness of the strip.

An efficient computer program was built which is based on the above analysis. Muller's method has been used to search for the complex root of the complex eigen value equation and Gauss Legendre method to calculate the asymptotic integrals.

Table.1.shows the Variation of dielectric constant over number of basis functions computed by the present method for open microstrip line, the effective dielectric constant is defined by

$$\varepsilon_{eff} = \left(\frac{\lambda}{\lambda_g}\right)^2 = \left(\frac{\beta}{k}\right)^2$$

Where λ_g is the guide wavelength.

Number of basis functions	Effective Constant of microstrip line	Propagation constant of microstrip line
nv=23	8.76098902001465	248.150758305947
nv=31	8.77413709197243	248.336894871660
nv=41	8.78383685868629	248.474124581956
nv=51	8.79027377718038	248.565150565463

Table1: Variation of Variation of dielectric constant Over number of basis functions

It is clear that when the numbers of basis functions increase the solution agree quite well with Denlinger's resulted.

Fig.3 shows the effective dielectric constant computed by the present theory, The above comparisons show a good agreement between our results and those of the literature [7]; this validates the theory presented in this paper.

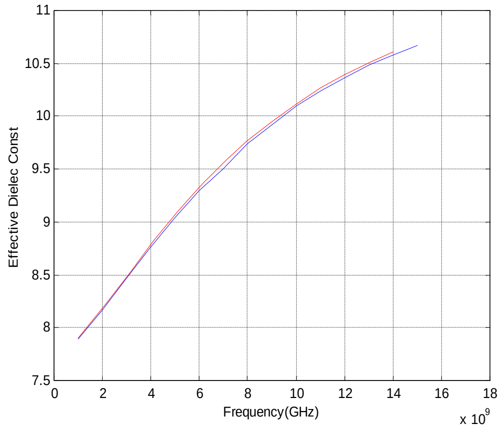

Fig.3: Calculate Effective Constant of microstrip line

$\varepsilon_r = 11.7, \mu_r = 1, w = 3.17mm, d = 3.04mm$

In order to confirm the computation accuracy, our numerical results Fig.4 are compared with those obtained from [3].

The superconducting microstrip line has the following parameters:

$$\varepsilon_r = 10, \mu_r = 1, w = 160\mu m, d = 500\mu m, t = 0.3\mu m$$

$$\sigma_c = 1.0, \lambda_0 = 0.2, T_c = 93.0, T°k = 77°k$$

The above comparisons show a good agreement between our results and those of the literature; this validates the theory presented in this paper.

The effect of the thickness of the superconducting on the effective dielectric constant characteristics of high Tc superconducting microstrip line is investigated in fig.5.

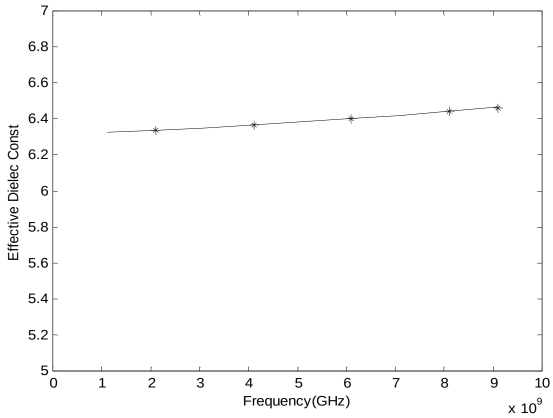

Fig.4: Calculated effective constant of superconducting microstrip line

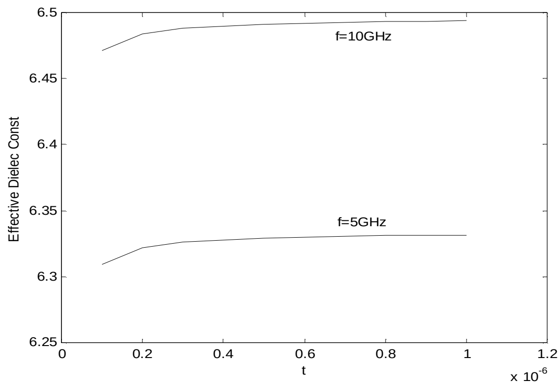

Fig.5: Calculated Effective Constant of superconducting microstrip line

$\varepsilon_r = 10, \mu_r = 1, w = 160\mu m, d = 500\mu m$

$\sigma_c = 1.0, \lambda_0 = 0.2, T_c = 93.0, T°k = 77°k$

IV. Conclusion

We have presented a Reflection factors oriented Spectral Domain approach for analyzing a multilayered superconducting microstrip line. To include the effect of the superconductivity of the microstrip line in this method, surface complex impedance has been considered, this impedance has been determined by using London's equation and the mode of Garter and Gasimir.

A new set of basis function within alternative formulation of the spectral domain approach (SDA)

method is presented. These basis functions are chosen so that, first, satisfies the edge conditions at the metallic corners, second are analytically Fourier -transformable

The method contains several attractive features from both analytical and numerical points of view.

Although a microstrip structure is treated in the paper, the method itself is quite general and is applicable to other types of printed structures such as the coplanar and slot lines.

V. References

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