Interpolation for Fast Efficient Excitation Modelling Technique of Open Planar Circuits and Antennas in SDM

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Abstract : The Spectral Domain Method is widely applied to analyse planar microwave circuits but open planar circuit analysis with SDM requires an efficient excitation modelling technique. Recent excitation modelling technique is very efficient but needs an improvement at low frequencies.This paper introduces an interpolation technique to improve the deficiency of the recent excitation modelling at low frequencies.

1 Introduction

The high–speed computer has influenced the computation of electromagnetic problems, to the point that most practical computations of fields are now done numerically on computers. This is because most of the practical problems in the electromagnetics can be solved numerically but can not be done analytically. Therefore computers are necessary for numerical solutions. As a result the science of numerically computation of electromagnetics is a mixture of electromagnetic theory, mathematics and numerical analysis.

Open planar microwave circuits and planar antennas are essential components of electronic communication systems utilising the microwave region of electromagnetic spectrum and these applications are requires *full–wave* techniques because of high operating frequency. The Spectral Domain Method is one of the full–wave techniques and is widely applied to the analysis of planar microwave circuits. The circuits are mostly presented by N–port network parameters which are S–parameters, but the details available in the literature for the extraction of the S–parameters of open planar circuits using the SDM or the other related techniques are limited in scope as the topic is avoided or ignored in most papers. However the author has introduced a novel compensation function in [1] to remedy all existing drawbacks. SDM is a frequency domain technique and requires repeated impedance matrix calculation at each spot frequency, therefore to speed up the impedance matrix calculation is crucial to the efficiency of the technique. This paper introduces an interpolation technique in conjunction the with efficient excitation technique introduced by Balik in [1]

The impedance matrix calculation is requires two dimensional numerical integration over an infinite surface. The infinite integration is limited to the finite computer resources and speeded up by Adaptive integration technique in [2]. The current wave of a finite length which is a number of half wavelength is used to excite the open microwave circuit. The length of the current wave is a function of the operating frequency and at low frequencies this length is bigger and its Fourier transform is finer. Therefore fine integration steps are unnecessary to use in order to accurately model the excitation. The requirement to use fine integration steps are eliminated and course steps which are enough to model the rest of the parameters are used. The value of the integration corresponding to the fine step location is interpolated. With this choice up to 96% improvement is gained.

2 Excitation Modelling

This section starts with a brief information on the recent excitation model of the open planar circuits introduced by Balik in [1]. The interpolation technique is developed to improve the efficiency at relatively low frequencies although it works fine compared with other available excitation mechanisms for open structures such as Jackson's technique [3]. The fundamental microstrip mode is assumed to propagate on the feedlines and thus the travelling current waves are chosen as current basis functions. These functions are given in both space and spectral domain in equation 1.

$$
\begin{aligned}
J_i(z) &= \begin{cases} e^{-jk_n(z-z_i)} & -L+z_i \le z \le z_i \\ 0 & \text{otherwise} \end{cases} \Longrightarrow \mathbf{J}_i(k_n,k_z) = \frac{2}{k_z-k_n}\sin\left((k_z-k_n)\frac{L}{2}\right)e^{-j(k_z-k_n)\frac{L}{2}}e^{jk_z z_i} \\
J_r(z) &= \begin{cases} -a_r e^{jk_n(z-z_i)} & -L+z_i \le z \le z_i \\ 0 & \text{otherwise} \end{cases} \Longrightarrow \mathbf{J}_r(k_n,k_z) = \frac{2}{k_z+k_n}\sin\left((k_z+k_n)\frac{L}{2}\right)e^{-j(k_z+k_n)\frac{L}{2}}e^{jk_z z_i} \\
J_t(z) &= \begin{cases} a_t e^{-jk_n(z-z_o)} & z_o \le z \le L+z_o \\ 0 & \text{otherwise} \end{cases} \Longrightarrow \mathbf{J}_t(k_n,k_z) = \frac{2}{k_z-k_n}\sin\left((k_z-k_n)\frac{L}{2}\right)e^{j(k_z-k_n)\frac{L}{2}}e^{jk_z z_o}
\end{aligned} \quad (1)
$$

where L is the length of the feedlines which is theoretically extends to infinity, but in practice is chosen to be an integer number of half wavelengths [3] and k_n is the pre–calculated wavenumber of the feedline. There is not truncation of the current wave existed and the compensation functions are used to transfer the effects of the excitation into the circuit. This is found by the author to be significant improvement, but as seen in equation 1, k_n is a function of the operating frequency and at low frequencies L tends to infinity whereas the length of the Fourier transform tends to zero. In the numerical integration unnecessary fine integration steps must be used to model this fine Fourier transform functions. The range of the numerical integration is determined by the current basis function which is a rooftop function as explained in [2].

In the numerical integration, an appropriate integration step is determined for the integration by using the Fourier transform of the rooftop function and the requirement to use fine integration steps are eliminated. The value of the integration corresponding to the fine step location is interpolated.

3 Numerical Results

The present implementation is applied to the step–discontinuity which is modelled by Balik in [4]. The circuit shown in figure 1 is completely open on a substrate thickness 1.272 mm and relative permittivity 10. The dimensions of the metallisation are given in figure 1.

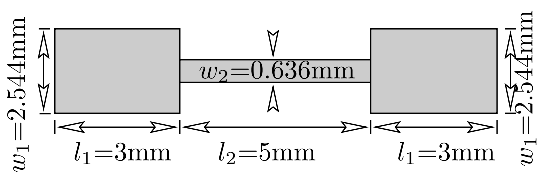

Figure 1: Microstrip step discontinuity

For this analysis, the length of the feedlines is 4 half wavelength of the current wave, the rooftop function dimensions are 0.318 mm in x and 0.5 in z direction. The range of the integration is one cycle of the Fourier transform of the Rooftop functions which is $2\pi/l_s$ $(s = x, z)$. The number of integration steps are chosen to be

200 and the number of integration step for each cycle of the Fourier transform of the current wave is 20. The minimum and maximum operation frequencies are 1 GHz and 20 GHz respectively.

At the minimum operating frequency, the length of the feedline is 224 mm which is 448 times bigger than the rooftop function size in the propagation direction. Since 20 fine integration steps are set to model each cycle of the Fourier transformed current wave, the total number of fine integration steps are 4480 without interpolation. The saving with this enhancement is 96%. The operating frequency where no interpolation required is 20 GHz which is maximum operating frequency. The number of interpolation decays exponentially as frequency increases. The S–parameter results are compared with published date in [4] and plotted in figure 2. As shown in figure 2 the agreement is very good.

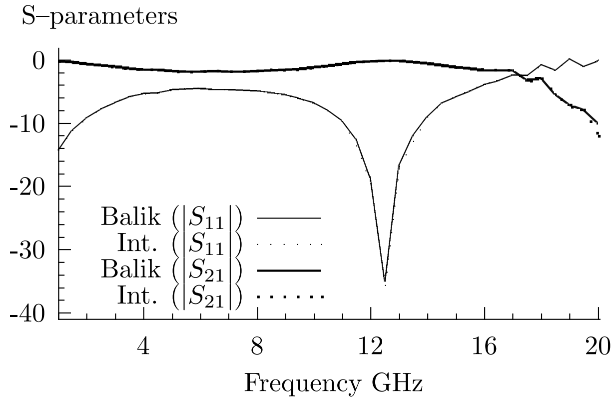

Figure 2: Plot of S–parameter magnitude for step discontinuity

4 Conclusion

This paper presents an interpolation technique to improve the deficiency of the recent excitation modelling technique at low frequency. The improvement is up to 96% for the microstrip step discontinuity. In addition this improvement is gained without loosing any accuracy.

References

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