A NOVEL MODEL FOR DETERMINING THE REFLECTION AND TRANSMISSION CHARACTERISTICS OF RO-4350B MATERIALS BY MICROSTRIP LINE TECHNIQUE

MÔ HÌNH MỚI ĐỂ XÁC ĐỊNH ĐẶC TÍNH TRUYỀN VÀ PHẢN XẠ CỦA VẬT LIỆU RO-4350B BẰNG KỸ THUẬT ĐƯỜNG TRUYỀN VI DẢI

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Abstract:

In this work, we present a method for determining the complex permittivity of RO-4350B materials using microstrip line technique. The reflection and transmission coefficients (S_{11} and S_{21}) of materials are determined from the measured scattering parameters, which obtained by the solution of the spatial distribution of the electric field to the boundary conditions. The complex effective permittivity is calculated from the complex propagation constant, in turns received from S_{11} and S_{21}. Our results indicate that the dielectric constant and loss tangent of RO-4350B materials are quite stable in the frequency range of 0.5-12.5 GHz.

Keywords:

Complex permittivity, complex effective permittivity, complex propagation constant, dielectric constant and loss tangent.

Tóm tắt:

Trong nghiên cứu này, chúng tôi trình bày cách xác định điện môi phức của vật liệu RO-4350 sử dụng kỹ thuật đường truyền vi dải. Hệ số truyền và phản xạ (S_{11} và S_{21}) của vật liệu được xác định từ các tham số tán xạ đo được bởi giải pháp không gian phân bố điện trường đối với điều kiện bờ. Điện môi hiệu dụng phức được tính toán từ hằng số truyền sóng phức, trong đó hằng số truyền sóng phức nhận được từ các tham số S_{11} và S_{21}. Kết quả chỉ ra hằng số điện môi và tổn hao của vật liệu RO-4350B khá ổn định trong dải tần 0.5 đến 12.5 GHz.

Từ khóa:

Điện môi phức, điện môi hiệu dụng phức, hằng số truyền sóng phức, hằng số điện môi và tổn hao.

1. INTRODUCTION

The measurement of complex permittivity and permeability of material can be

achieved by using the transmission/ reflection method developed by Weir [1]. The basic concept of this method is to measure the S-parameters of a sample placed in a transmission line. The transmission lines have been used as

sample holders and can be coaxial, waveguide or free-space [2-8]. For general transmission lines, Enders [9] presented a method for determining all properties of an unknown line and their junctions to the line using three different lengths of the unknown line. On the other hand, Das [10] developed a two-line method to measure substrate permittivity. This method is based on the use of transmission lines having the same geometry with different lengths, and the aim is to determine the complex propagation constant. Although the method is simple, quick and reliable to use, it still has several drawbacks. One is that the technique works well on the condition that the transition effect of coax-to-microstrip is relatively small. This means that the approximate substrate permittivity must be known before the measurement, so that the characteristic impedance of the test section can be designed in the vicinity of 50 Ω [11-18]. The other is that the method gives us an accurate result only if the electrical length of lines is long.

In this paper, we propose a new method for determining complex permittivity of material. This method uses a microstrip line technique, which based on the concepts of the reflection and transmission coefficients of a material sample. Therefore, our method is different from conventional methods. Our method relies solely on the measurement of only one microstrip line complex propagation constant, and the characteristic impedance unnecessary to be designed in the vicinity of 50 Ω. The designed structure is determined with the Computer Simulation Technology (CST) software. Results of S-parameters were calculated with adaptive mesh refinement. The calculation of complex permittivity based on the frequency dependent value of the complex effective permittivity.

The paper is organized as follows. The second section describes the theory of proposed method a microstrip line technique. The results and discussions follow in the next section.

2. THEORY

The complex effective permittivity (ε_{eff}^{*}) and the complex permittivity or complex relative permittivity (ε_{r}^{*}) are defined as

$$\varepsilon_{eff}^{*} = \varepsilon_{eff}^{'} - j\varepsilon_{eff}^{''} = \varepsilon_{eff}^{'}(1 - jtan\delta_{\varepsilon_{eff}}) \qquad (1)$$

$$\varepsilon_{r}^{*} = \varepsilon_{r}^{'} - j\varepsilon_{r}^{''} = \varepsilon_{r}^{'}(1 - jtan\delta_{\varepsilon_{r}}) \qquad (2)$$

Where:

$\varepsilon_{eff}^{'}$ and $\varepsilon_{eff}^{''}$ are the real and imaginary parts of complex effective permittivity.

$\varepsilon_{r}^{'}$ and $\varepsilon_{r}^{''}$ are the real and imaginary parts of complex permittivity (complex relative permittivity).

$tan\delta_{\varepsilon_{eff}}$ and $tan\delta_{\varepsilon_{r}}$ are the effective dielectric and dielectric loss tangent.

Figure 1 shows a microstrip line with characteristic impedance (unnecessary to be 50 Ω) and the length L. The measured two ports parameters expressed in scattering matrix S form can be considered as a product of the reflection and transmission coefficients S_{11}, S_{22} and S_{21}, S_{12} (S-parameter). It can be shown that the S-parameters are related to the

parameters Γ and T by the following equations:

$$S_{11} = S_{22} = \frac{\Gamma(1-T^2)}{1-\Gamma^2 T^2} \qquad (3)$$

$$S_{21} = S_{12} = \frac{T(1-\Gamma^2)}{1-\Gamma^2 T^2} \qquad (4)$$
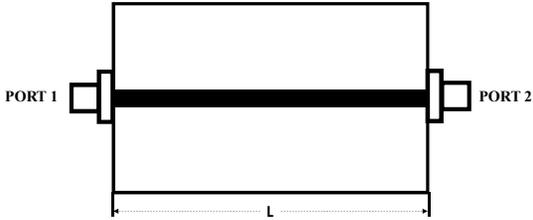

Figure 1. Schematic diagram of a microstrip line

From (3) and (4), Γ and T can be written as

$$\Gamma = K \pm \sqrt{K^2 - 1} \qquad (5)$$

Where

$$K = \frac{S_{11}^2 - S_{21}^2 + 1}{2 S_{21}} \qquad (6)$$

$$T = \frac{S_{11} + S_{21} - \Gamma}{1 - (S_{11} + S_{21})\Gamma} \qquad (7)$$

The complex propagation constant γ of the microstrip line can be written as

$$\gamma = \frac{log_e(1/T)}{L} = \frac{\omega \sqrt{\varepsilon_{eff}^*}}{c} \qquad (8)$$

The complex effective permittivity of material is found from (8)

$$\varepsilon_{eff}^* = \left(\frac{c.log_e(1/T)}{\omega L} \right)^2 \qquad (9)$$

where c is the light velocity, ω is the signal angular frequency and L is the length of the microstrip line.

The complex relative permittivity is calculated based on the frequency dependent value of the complex effective permittivity [19], as follows:

$$\varepsilon_{eff}'(f) = \varepsilon_r' - \frac{\varepsilon_r' - \varepsilon_s'}{1 + P(f)} \qquad (10)$$

$P(f)$ is the frequency-dependent term and it is given by (11).

$$P(f) = P_1 P_2 \left[(0.1844 + P_3 P_4) 10 fh \right]^{1.5763} \qquad (11)$$

with

$$P_1 = \left(0.6315 + \frac{0.525}{(1+0.157 fh)^{20}} \right) * \\ * \frac{w}{h} - 0.065683 e^{-8.7513\left(\frac{w}{h}\right)} + 0.27488 \qquad (12)$$

$$P_2 = 0.33622 \left(1 - e^{-0.03442 \varepsilon_r'} \right) \qquad (13)$$

$$P_3 = 0.363 e^{-4.6\frac{w}{h}} \left(1 - e^{-\left(\frac{fh}{4.87}\right)^{4.97}} \right) \qquad (14)$$

$$P_4 = 1 + 2.751 \left(1 - e^{-\left(\frac{\varepsilon_r'}{15.916}\right)^8} \right) \qquad (15)$$

where ε_s' is static dielectric constant $(\varepsilon_{eff}'(f=0))$ and it can be written as

$$\varepsilon_s' = \frac{\varepsilon_r' + 1}{2} + \frac{\varepsilon_r' - 1}{2} \left(\frac{1}{\sqrt{1+12\frac{h}{w}}} \right) - \frac{\varepsilon_r' - 1}{4.6} \left(\frac{\frac{t}{h}}{\sqrt{\frac{w}{h}}} \right) \qquad (16)$$

where w is the width of track, t is the thickness of track and h is the thickness of material.

3. RESULTS AND DISCUSSIONS

3.1. A brief introduction to RO-4350B material

The RO-4350B nonmagnetic material (a type of roger) is widely used in communication devices, electronics devices, aerospace and military equipments. In these devices and equipments, this material plays a vital role in many components, such as power divider, combiner, power amplifier, line amplifier, base station, RF antenna, etc.

The proposed method is used to determine the complex permittivity of RO-4350B nonmagnetic material in the frequency range of 0.5-12.5 GHz ($\varepsilon_r^* = 3.65(1 - j0.0037)@10\,\text{GHz}$ from data sheet).

3.2. Simulations and Results

We use the Computer Simulation Technology (CST) software to determine the S-parameters. The structure dimensions are: height h = 0.254 mm, thickness t = 18 μm, width w = 0.5 mm, length L = 6.5 mm and copper is the conductor being used. The following figure shows what it looks line.
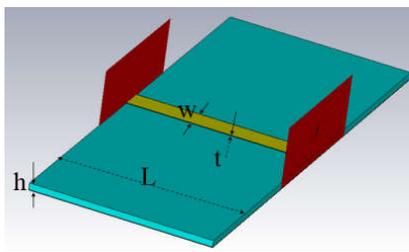

Figure 2. A microstrip line determining the S-parameters of material by CST

The reflection and transmission coefficients (S_{11} and S_{21}) of material are measured using a microstrip line

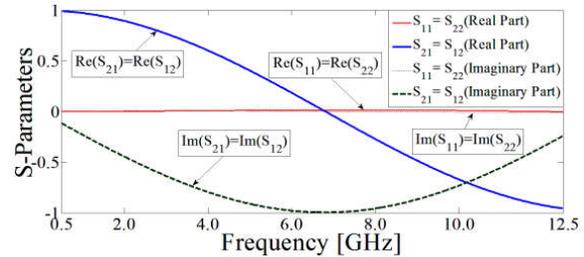technique in figure 2. The S-parameters obtained from CST software are shown in figure 3.

Figure 3. The S-parameters of material

The calculated values of S_{11} and S_{21} by equation (8), (9) and (10) in section 2 are determined the complex permittivity of RO-4350B material.
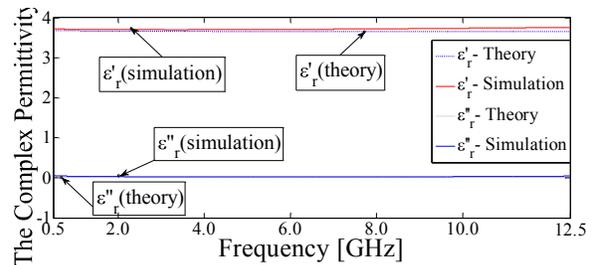

Figure 4. The complex permittivity of RO-4350B material

Figure 4 shows the data obtained using the proposed method. The real part of the complex permittivity is stable and the mean error difference of 1.7% in the entire frequency band. The imaginary part of the complex permittivity is acceptably stable and this error is small for simulation in the entire frequency band. The error of complex permittivity for material with dielectric constant and loss tangent as shown in figure 5.

Figure 5 shows that the error of simulated results compared to the theory is small. Those results show that the dielectric constant and loss tangent of RO-4350B

materials are nearly identical with the theoretical values.
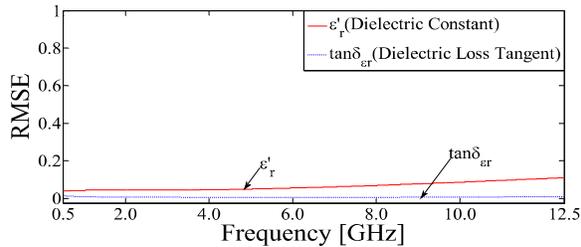
Figure 5. The root mean squared error of dielectric constant and loss tangent RO-4350B material

4. CONCLUSION

We proposed a new method for determining the parameters of nonmagnetic material using a microstrip line technique. The usage of only one microstrip line is proposed to accurately determine the complex permittivity of wideband, nonmagnetic materials. Our proposed method can be used for a microstrip line with arbitrary width. The method has some benefits for determining the parameters of materials. It is simple, quick, and reliable to use. This method could be used in many scientific fields such as: electronics, communications, metrology, etc.

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Biography:

Ho Manh Cuong was born in Ha Noi, Vietnam, in 1977. He received the Master in 2006 from the Faculty of Electronics and Telecommunications, Military Technical Academy, Vietnam. Currently, he is a Ph.D candidate at the Faculty of Electronics and Telecommunications, Military Technical Academy, Vietnam. His research interests are microwave engineering, electromagnetic theory.