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Reflection and Transmission Coefficients Simulation and Comparison of Two Different Dielectric Materials in X-Band Frequencies

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Abstract: The reflection and transmission coefficients are determined and compared using CST MWS (Computer Simulation Technology Microwave Studio) 2014 Software for two different materials. The materials are Arlon Iso 933 with Epsilon 2.33 and El. tand 0.0016 and the other Gil GML2032 with Epsilon 3.2 and El. tand 0.0029. Additionally, whole previous calculations of parameters are determined in the range of frequencies of X-band. The results show that the reflection and transmission coefficients directly proportional with dimension's value of the layer. It seems that the reflection coefficient has one minimum value when the layer made of Arlon Iso 933 while has two minimum values when the layer made of Gil GML 2032. The transmission coefficient is recorded a good value at same frequencies. With the minimum value of reflection coefficient and maximum value of transmission coefficient, the absorption coefficient is approximately 53% is measured in Arlon Iso 933 material while in Gil GML2032 material, the absorption coefficients are 56, 63%, respectively.

Key words: Reflection coefficient, S_{11}, S_{21}, transmission coefficient, absorption coefficient, minimum values

INTRODUCTION

Studying the capability of material properties for absorbing and reflection leads to exploits these properties with high frequencies for microwave techniques such as (stealth technology, Electromagnetic Interference (EMI) shielding and human health protection (Yang *et al*., 2009). There are two main categories for electromagnetic properties measurement techniques, first is resonance technique and the second is transmission technique. The transmission technique has different types such as (free-space, waveguide, coaxial cable and planar structure. These types are dealing with large specimen size which owns low losses. While, the resonant technique has two classes: dielectric resonance (the specimen is a dielectric resonator) and the other is perturbation technique (the metal walls is a resonator of the cavity) (Gangwar *et al*., 2010).

Both resonance and transmission techniques used to study the characteristic properties of dielectric constant of specimen by using test transmit or reflect signals. Measuring frequency range in transmission technique is achievable with the swept frequency ability. In contrast to resonance techniques which do not have swept frequency ability which mean that the resonance technique works with particular frequency. Resonant technique is more accuracy than transmission technique for dielectric loss (Sheen, 2007).

According to previous studies in last decade, most of researches results have been achieved at different bands of frequency, different materials and different parameters.

Simrat and Jatinder worked on metamaterial absorber at Giga Hertz frequency. Designing of metamaterial is achieved by negative permittivity and negative permeability and the absorber is recorded high value at 93% (Simrat and Raina, 2015). While by Jin *et al*. (2006) is used Micro-arc Discharge Oxidization (MDO) to design EM wave absorbing. The radar absorbing material is studied by Folguerasa *et al*. (2007). The sample consists of carbon fiber with polyaniline. Reflection coefficient was the experiment results at the frequency range 8-12 GHz.

In this study, the transmission line technique is used to calculate the reflection coefficient and transmission coefficient. The calculation of these parameters is carried out using electromagnetic wave on a single layer made from material. The simulation results are divided into two parts, first part simulates with a material Arlon Iso 933 and the second part simulates with a material Gil GML2032. All the results are calculated using CSTMWS 2014 Software.

MATERIALS AND METHODS

Theoretical analysis: Absorber material is defined as how much electromagnetic radiation can be absorbing. It

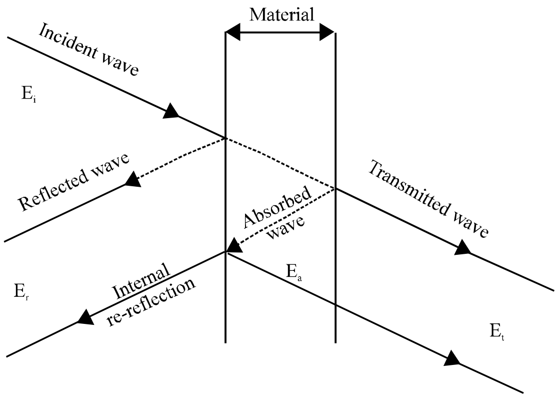

Fig.1: Incident and reflected electromagnetic wave in a material

contains both complex permeability and permittivity in effective medium. The effective permittivity and permeability can be describing as: $\varepsilon = \varepsilon_1+j\varepsilon_2$, $\mu = \mu_1+j\mu_2$, respectively. The imaginary part for permittivity and permeability is very small comparison to real part and can be neglected (Simrat and Raina, 2015).

In a free space when the electromagnetic wave passing through it (Oh *et al*., 2004). The impedance of ζ_0 is appeared and incident on another medium of impedance ζ_1, then reflection coefficient occurs as shown in Fig. 1 (Folguerasa *et al*., 2007).

The reflection coefficient is determined as:

$$T = \frac{\zeta_0-\zeta_1}{\zeta_0+\zeta_1} \qquad (1)$$

Where:

T = Reflection coefficient

ζ_0 = Impedance in free space and can calculated as:

$$\zeta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}} \qquad (2)$$

ζ_1 = Impedance in another medium and ca calculated as:

$$\zeta_1 = \sqrt{\frac{\mu_1}{\varepsilon_1}} \qquad (3)$$

When $\zeta_1 = \zeta_0$, that's mean the reflection coefficient is zero. Transmission coefficient is the ratio of transmitted (voltage, current or power) wave amplitude to incident (voltage, current or power) wave amplitude (Chen *et al*., 2017). It is equal to:

$$\tau = \frac{2\zeta_1}{\zeta_0+\zeta_1} \qquad (4)$$

where, τ = Transmission coefficient. There is very simple relation between reflection and transmission coefficients as in Eq. 5:

$$\tau = 1+T \qquad (5)$$

That's mean the magnitude of reflection coefficient is greater than one (Chen *et al*., 2017; Cho and Kim, 2015). There are two conditions to achieve perfect absorber of electromagnetic efficiency in material (Oh *et al*., 2004; Cho and Kim, 2015):

- The layer of material must be thinner
- The permeability to permittivity of material must be larger

In fact, the magnitude of permittivity is more than the magnitude of permeability at microwave frequencies (Oh *et al*., 2004). One of the most technique used to describe the microwave absorbers is resonant absorbers.

Resonant absorbers are depended on absorbing layer, the layer must be having a combination of magnetic permeability and dielectric permittivity, the surface of absorbing layer is full impedance matching (Cho and Kim, 2015). There are two main categories for resonant absorbers, first is the salisbury screen and the second is dual-magnetic absorber (Chen *et al*., 2017). The salisbury screen is the simplest type because it consists a resistive sheet with 377Ω spaced 1/4λ from ground plane which is conductive. While the dual-magnetic absorber has multiple frequencies to absorb. It produced by hegemony the high value of magnetic/dielectric loading and the layer thickness (Chen *et al*., 2017). Both these types used to describe the absorption and reflection of materials. The main disadvantages of the salisbury screen at lower frequency are:

- Bad elasticity
- Bad ecological resistance
- Increased thickness

To produce a more practical absorber like elastomer, dielectric and/or magnetic distributing must be filling into an elastic matrix. The increasing of permeability and permittivity of the material causes increases of the refractive index r and decreases the thickness of the layer (Chen *et al*., 2017).

RESULTS AND DISCUSSION

The simulation in this study divided into two parts, first part simulates with a material Arlon Iso 933 with Epsilon 2.33 and El. tand 0.0016 and the second part

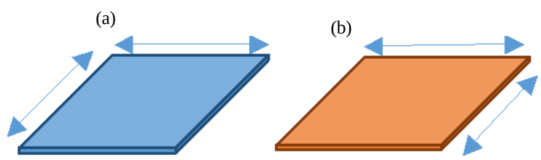

Fig. 2: Layer dimensions: a) Arlon Iso 933 and b) Gil GML2032

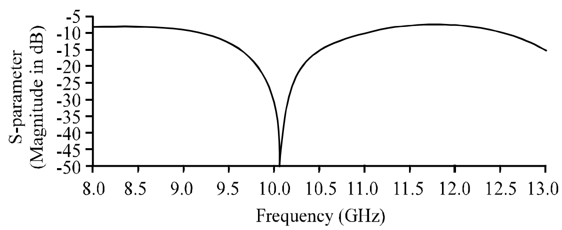

Fig. 3: S_{11} reflection coeffcient for Arlon Iso 933 material

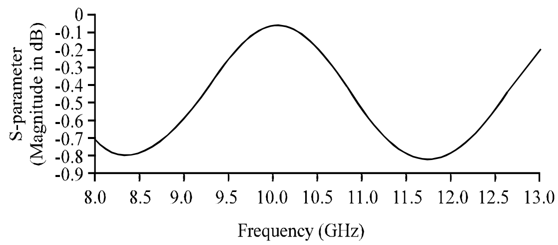

Fig. 4: S_{21} transmission coeffcient for Arlon Iso 933 material

simulates with a material Gil GML2032 with Epsilon 3.2 and El. tand 0.0029. The dimensions of the layer in two cases are (29.2×29.27×1) mm as shown in Fig. 2a, b.

The EM signal is passed from a vacuum to a layer at TEM mode. The calculation of reflection and transmission coefficient using CST MWS (Computer Simulation Technology Microwave Studio) 2014 Software. CST MWS is a good Software for a 3D electromagnetic simulation of high frequency structures. S_{11} and S_{21} are the output results of Simulation in CST. The reflection coefficient equal to $|S_{11}|^2$ and transmission coefficient equal to $|S_{21}|^2$. The value of absorption coefficient is equal to Eq. 6:

$$Ab = 1 - \tau - T \quad (6)$$

The results are shown in Fig. 3-8, the S-parameter values are calculated. The S-parameters played a very important function for defining the i/p and o/p relevance between ports. These functions are presented of power incident at port 1 but at port 2 no power incident.

The reflection coefficient that is also known as return loss as shown in Fig. 3 and 6. Figure 3 shows the reflection coefficient of minimum value at 10.1 GHz for a

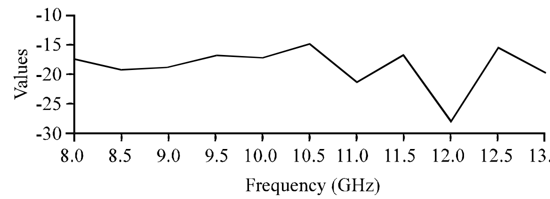

Fig. 5: Absorption coeffcient for Arlon Iso 933 material

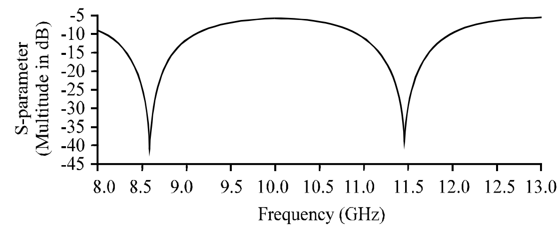

Fig. 6: S_{11} reflection coeffcient for Gil GML2032 material

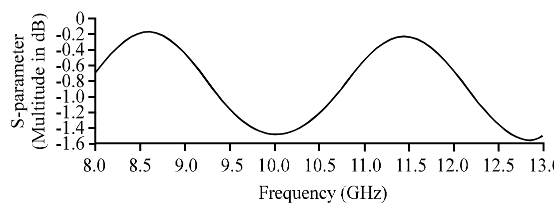

Fig. 7: S_{21} Transmission coeffcient for Gil GML2032 material

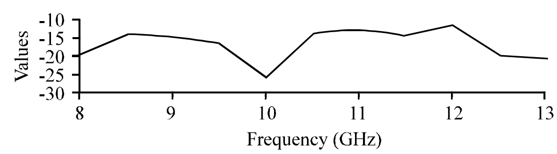

Fig. 8: Absortion coeffcient for Gil GML2032 material

dielectric material Arlon Iso 933 while in Fig. 6 the reflection coefficient is shown at two minimum values at 8.6 and 11.4 GHz for a dielectric material Gil GML2032. At same these frequencies in two cases, the transmission coefficient can be convexity in Figs. 4 and 7. According to Eq. 6, the absorption coefficient can be shown as in Figs. 5 and 8, respectively.

CONCLUSION

Single layer EM was designed in this research, the single layer made of Arlon Iso 933 material once and the other case the layer made of Gil GML2032 in the range of frequencies of X-band. Transmission line is the technique used to calculate the reflection coefficient and transmission coefficient. The results show that the reflection and transmission coefficients directly proportional with dimension's value of the layer. It seems that the reflection coefficient has one minimum value when the layer made of Arlon Iso 933 while has two minimum values when the layer made of Gil GML2032. The transmission coefficient is recorded a good value at same frequencies. With the minimum value of reflection coefficient and maximum value of transmission coefficient, the absorbing coefficient is approximately 53% is measured in Arlon Iso 933 material while in Gil GML2032 material, the absorbing coefficient are 56, 63%, respectively.

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