Full Model in General Case of Anisotropic Electrical Properties for Heterogeneous Multilayer Composites Materials Used in Satellites Antennas Reflectors

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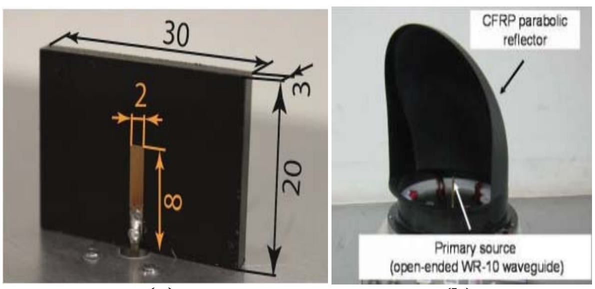
Abstract

The aim of this paper proposed a full model for anisotropic electrical proprieties of Heterogeneous multilayer composites materials used in satellite antennas reflectors, the model take into account the anisotropic nature of these materials as a tensor in conductive and ferromagnetic cases such as electrical permittivity, electrical conductivity and magnetic permeability, a unidirectional quasi-isotropic multilayer composite is used as modeled simple.

1. Introduction

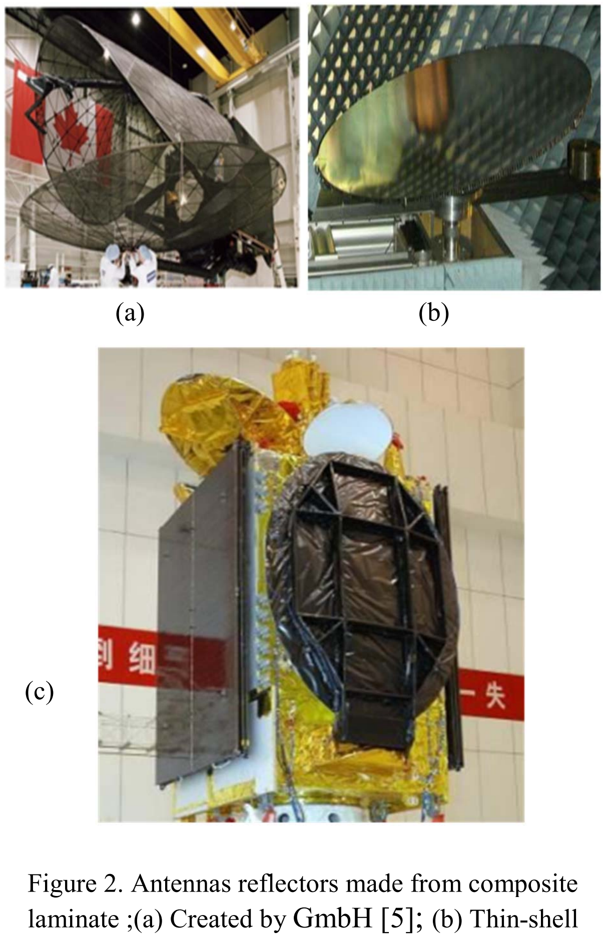
Metal-based materials are widely used as reflectors antennas and other telecommunication systems due to their high electrical conductivity [1-3]. However, they are also susceptible to chemical corrosion and heavy weight [4-13]. The multilayer composites materials are widely used in the world of manufacturing and space industries due to their high mechanical strength and the great resistance against the natural factor and corrosion resistance which they highly considered in space [1-7],[14-16].
The composite materials are used to manufacture many components in space industries such as telecommunications satellites. The composite materials are highly used in telecommunications satellites antenna reflectors regarding their good electromagnetic performance in radio frequency telecommunications [1-5,16].



(a) **(b)**

Figure 1. (a) patch antenna with composite substrate [2], (b) small antenna reflector composite [15] .

The composite materials could generally be reinforced by fibers, these latter could be conductive such as the carbon fibers, ferromagnetic fibers or even dielectric depend on the applications and the frequency [8-10].
The coefficient reflection of anisotropic materials used in RF telecommunication such as substrate for patch antennas are shown in figures 1 and 2. The substrate for printed filters, antennas [1-7],[14-16] and reflectors [17] are depending on to the geometric dimensions and the electrical properties such as conductivity, permittivity and magnetic permeability [10-12].
In the electromagnetic modeling all these electrical properties are presented as tensors, a unidirectional quasi-isotropic multilayer composite is used as modeled simple as shown in figure 2.



(a) (b) (c)

Figure 2. Antennas reflectors made from composite laminate ;(a) Created by GmbH [5]; (b) Thin-shell deployable reflector [17] ;(c) DFH-4 Alcomsat-1 reflector.

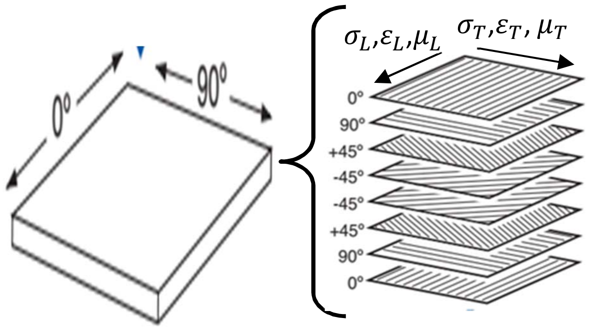


Figure 3. Quasi-isotropic laminate composite and layers orientations.

2. Electrical Properties

The electrical properties of a unidirectional multilayer heterogeneous composites are anisotropic, it's composed from compacted unidirectional plies, one composite ply has three electrical properties components as shown in figure 3.
Generally the electrical properties are given by the following equations:

$$\varepsilon = \varepsilon_0 \varepsilon_r$$

$$\mu = \mu_0 \mu_r$$

where ε_0, ε_r , μ_0 and μ_r the electrical primitively of air, relative electrical primitively (depend of material types), magnetic permeability of air and relative magnetic permeability (depend of material types).

The electrical properties of a unidirectional multilayer heterogeneous composites laminate are anisotropic, it's composed from compacted unidirectional plies, one composite ply as shown in figure 2 where(σ_L, ε_L, μ_L) are the electrical properties in longitudinal direction (fibers directions),(σ_T, ε_T, μ_T) the electrical properties in the transverse direction and (σ_{th}, ε_{th}, μ_{th}) the electrical properties in thickness direction, the equivalent form of these components are given on tensors form for one unidirectional ply [18-22] :

$$[\sigma_p] = \begin{bmatrix} \sigma_L & & \\ & \sigma_T & \\ & & \sigma_{th} \end{bmatrix}$$

$$[\varepsilon_{rp}] = \begin{bmatrix} \varepsilon_L & & \\ & \varepsilon_T & \\ & & \varepsilon_{th} \end{bmatrix}$$

$$[\mu_{rp}] = \begin{bmatrix} \mu_L & & \\ & \mu_T & \\ & & \mu_{th} \end{bmatrix}$$

Where $[\sigma_p]$, $[\varepsilon_p]$ and $[\mu_p]$ are respectively the equivalent tensors of the electrical conductivity, the electrical permittivity and the magnetic permeability of one ply composite.

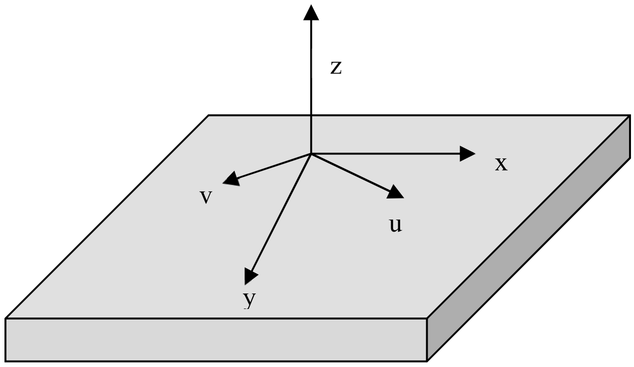


Figure 4. global axis (x,y,z) of composite laminate and local axis (u,v) follow the plies orientations.

For a multilayer unidirectional composite laminate (the electrical properties tensors are depending on the fibers orientation of each play (quasi-isotropic), the fiber orientation direction is presented on (u, v) axis as and the global coordinate system of laminate presented by (x, y, z).

According to the ply orientation, the electrical conductivity tensor is given by:

$$\sigma = \begin{bmatrix} \sigma_{xx} & \sigma_{xy} & 0 \\ \sigma_{yx} & \sigma_{yy} & 0 \\ 0 & 0 & \sigma_{zz} \end{bmatrix}$$

Where :

$$\sigma_{xx} = \sigma_L cos^2(\theta) + \sigma_T sin^2(\theta)$$

$$\sigma_{xy} = \sigma_{yx} = \frac{\sigma_L - \sigma_T}{2} \sin(2\theta)$$

$$\sigma_{yy} = \sigma_L sin^2(\theta) + \sigma_T cos^2(\theta)$$

The component σ_{zz} still the same we suggest that because it's not affected by the fibers orientation of each ply, both suggestions for ε_{zz} and μ_{zz}.

The electrical permittivity tensor for a laminate composite is given:

$$\varepsilon_r = \begin{bmatrix} \varepsilon_{xx} & \varepsilon_{xy} & 0 \\ \varepsilon_{yx} & \varepsilon_{yy} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{bmatrix}$$

$$\varepsilon_{xx} = \varepsilon_L cos^2(\theta) + \varepsilon_T sin^2(\theta)$$

$$\varepsilon_{xy} = \varepsilon_{yx} = \frac{\varepsilon_L - \varepsilon_T}{2} \sin(2\theta)$$

$$\varepsilon_{yy} = \varepsilon_L sin^2(\theta) + \varepsilon_T cos^2(\theta)$$

The magnetic permeability tensor for a laminate composite is given:

$$\mu_r = \begin{bmatrix} \mu_{xx} & \mu_{xy} & 0 \\ \mu_{yx} & \mu_{yy} & 0 \\ 0 & 0 & \mu_{zz} \end{bmatrix}$$

$$\mu_{xx} = \mu_L cos^2(\theta) + \mu_T sin^2(\theta)$$

$$\mu_{xy} = \mu_{yx} = \frac{\mu_L - \mu_T}{2}\sin(2\theta)$$

$$\mu_{yy} = \mu_L sin^2(\theta) + \mu_T cos^2(\theta)$$

These tensors of the electrical properties are useful in low frequencies problems but in high frequencies such in C, L, Ku and Ka bands the relative electrical properties are divided into real and imaginary part as shown in the following equations:

$$\sigma = \sigma_{dc} + \sigma_{ac},$$

Where σ_{dc} is the conventional electrical conductivity (depend in conducing current) $\sigma_{ac}$is the alternative current conductivity (depend on the displacement current) is obtained from the dielectric losses according to the relation:

$$\sigma^* = \omega\varepsilon_0\varepsilon_r'' + j\omega\varepsilon_0\varepsilon_r'$$

The real part of the dielectric losses is σ_{ac} given by:

$$\sigma_{ac} = \omega\varepsilon_0\varepsilon_r''$$

where ε_r' and ε_r'' representing the charging and the loss current.
The conductivity tensor at high frequencies becomes:

$$[\sigma] = [\sigma_{dc}] + [\sigma_{ac}]\text{=}[\sigma_{dc}] + \omega\varepsilon_0[\varepsilon_r'']$$

with:

$$[\sigma] = \begin{bmatrix} \sigma_{xx} + \omega\varepsilon_0\varepsilon_{rxx}'' & \sigma_{xy} + \omega\varepsilon_0\varepsilon_{rxy}'' & 0 \\ \sigma_{yx} + \omega\varepsilon_0\varepsilon_{ryx}'' & \sigma_{yy} + +\omega\varepsilon_0\varepsilon_{ryy}'' & 0 \\ 0 & 0 & \sigma_{zz} + \omega\varepsilon_0\varepsilon_{rzz}'' \end{bmatrix}$$

At high frequencies the material complex permittivity tensor and permeability constants tensor can be calculated by:

$$\varepsilon_r = [\varepsilon_r'] - j[\varepsilon_r'']$$
$$\mu_r = [\mu_r'] - j[\mu_r'']$$

Where $[\varepsilon_r']$ is a measure of the energy stored from the applied electric field in the material and identifies the strength of the alignment of dipoles in the dielectric. The loss factor $[\varepsilon_r'']$, is the energy dissipated in the dielectric associated with the frictional dampening that prevent displacements of bound charge from remaining in phase with the field changes.
Due to the anisotropic and the heterogeneous nature of unidirectional laminate composite:

$$[\varepsilon_r] = \begin{bmatrix} \varepsilon'_{rxx} & \varepsilon'_{rxy} & 0 \\ \varepsilon'_{ryx} & \varepsilon'_{ryy} & 0 \\ 0 & 0 & \varepsilon'_{rzz} \end{bmatrix} - j \begin{bmatrix} \varepsilon''_{rxx} & \varepsilon''_{rxy} & 0 \\ \varepsilon''_{ryx} & \varepsilon''_{ryy} & 0 \\ 0 & 0 & \varepsilon''_{rzz} \end{bmatrix}$$

With

$$\varepsilon'_{rxx} = \frac{C_{mxx}}{C_{0xx}}$$

Where C_{mxx} and C_{0xx} is the measured value of capacitance in the strong accumulation region, corresponding to the oxide capacitance, all the components of the real part of permittivity are calculated in the same way.
The imaginary part of permittivity are calculated by:

$$\varepsilon''_{rxx} = \frac{G_{mxx}}{\omega C_{0xx}}$$

where G_{mxx} the measured conductance in xx direction and the same method to calculate the other directions.

The tensor of the dissipation factor or loss tangent (tanδ) can be expressed as follows:

$$[tan\delta] = \frac{[\varepsilon_r'']}{[\varepsilon_r']} = [\varepsilon_r''][\varepsilon_r']^{-1} = [\varepsilon_r'']\frac{adj([\varepsilon_r'])}{\det([\varepsilon_r'])}$$

where $adj([\varepsilon_r'])$ is the adjugated matrix $[\varepsilon_r']$ and $\det([\varepsilon_r'])$ is the determinant of the matrix $[\varepsilon_r']$

$$\det([\varepsilon_r']) = \varepsilon'_{rzz}\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - {\varepsilon'_{rxy}}^2\right)$$

The $adj([\varepsilon_r'])$ is given by:

$$adj([\varepsilon_r']) \begin{bmatrix} \varepsilon'_{ryy}\varepsilon'_{rzz} & \varepsilon'_{rxy}\varepsilon'_{rzz} & 0 \\ \varepsilon'_{ryx}\varepsilon'_{rzz} & \varepsilon'_{rxx}\varepsilon'_{rzz} & 0 \\ 0 & 0 & \varepsilon'_{rxx}\varepsilon'_{rzz} - {\varepsilon'_{rxy}}^2 \end{bmatrix}$$

The inverse matrix $[\varepsilon_r']^{-1}$ become

$$[\varepsilon_r']^{-1} = \begin{bmatrix} \frac{\varepsilon'_{ryy}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - {\varepsilon'_{rxy}}^2\right)} & \frac{\varepsilon'_{rxy}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - {\varepsilon'_{rxy}}^2\right)} & 0 \\ \frac{\varepsilon'_{ryx}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - {\varepsilon'_{rxy}}^2\right)} & \frac{\varepsilon'_{rxx}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - {\varepsilon'_{rxy}}^2\right)} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

by replacing the $[\varepsilon_r']^{-1}$ in the equation tan than:

$$[tan\delta] = \begin{bmatrix} \frac{\varepsilon''_{rxx}\varepsilon'_{ryy} + \varepsilon''_{rxy}\varepsilon'_{ryx}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - \varepsilon'^{2}_{rxy}\right)} & \frac{\varepsilon''_{rxx}\varepsilon'_{rxy} + \varepsilon''_{rxy}\varepsilon'_{rxx}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - \varepsilon'^{2}_{rxy}\right)} & 0 \\ \frac{\varepsilon''_{ryx}\varepsilon'_{ryy} + \varepsilon''_{ryy}\varepsilon'_{ryx}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - \varepsilon'^{2}_{rxy}\right)} & \frac{\varepsilon''_{ryx}\varepsilon'_{rxy} + \varepsilon''_{ryy}\varepsilon'_{rxx}}{\left(\varepsilon'_{rxx}\varepsilon'_{ryy} - \varepsilon'^{2}_{rxy}\right)} & 0 \\ 0 & 0 & \varepsilon''_{rzz} \end{bmatrix}$$

Magnetic permeability constant tensor can be formulated as:

$$[\mu_r] = \begin{bmatrix} \mu'_{rxx} & \mu'_{rxy} & 0 \\ \mu'_{ryx} & \mu'_{ryy} & 0 \\ 0 & 0 & \mu'_{rzz} \end{bmatrix} - j \begin{bmatrix} \mu''_{rxx} & \mu''_{rxy} & 0 \\ \mu''_{ryx} & \mu''_{ryy} & 0 \\ 0 & 0 & \mu''_{rzz} \end{bmatrix}$$

The wave number tensor of unidirectional laminate composite is given by:

$$[k] = k_0\sqrt{[\mu_r][\varepsilon_r]}$$

$$k_0 = \omega_0\sqrt{\mu_0\varepsilon_0}$$

Where k_0 is the wave number of free-space.

$$[k] = k_0\left(\begin{bmatrix} \mu'_{rxx}\varepsilon'_{rxx} - \mu'_{rxy}\varepsilon'_{ryx} & \mu'_{rxx}\varepsilon'_{rxy} - \mu'_{rxy}\varepsilon'_{ryy} & 0 \\ \mu'_{ryx}\varepsilon'_{rxx} - \mu'_{ryy}\varepsilon'_{ryx} & \mu'_{ryx}\varepsilon'_{rxy} - \mu'_{ryy}\varepsilon'_{ryy} & 0 \\ 0 & 0 & \mu'_{rzz}\varepsilon'_{rzz} \end{bmatrix} - j\left(\begin{bmatrix} \mu'_{rxx}\varepsilon''_{rxx} - \mu'_{rxy}\varepsilon''_{ryx} & \mu'_{rxx}\varepsilon''_{rxy} - \mu'_{rxy}\varepsilon''_{ryy} & 0 \\ \mu'_{ryx}\varepsilon''_{rxx} - \mu'_{ryy}\varepsilon''_{ryx} & \mu'_{ryx}\varepsilon''_{rxy} - \mu'_{ryy}\varepsilon''_{ryy} & 0 \\ 0 & 0 & \mu'_{rzz}\varepsilon''_{rzz} \end{bmatrix} + \begin{bmatrix} \mu''_{rxx}\varepsilon'_{rxx} - \mu''_{rxy}\varepsilon'_{ryx} & \mu''_{rxx}\varepsilon'_{rxy} - \mu''_{rxy}\varepsilon'_{ryy} & 0 \\ \mu''_{ryx}\varepsilon'_{rxx} - \mu''_{ryy}\varepsilon'_{ryx} & \mu''_{ryx}\varepsilon'_{rxy} - \mu''_{ryy}\varepsilon'_{ryy} & 0 \\ 0 & 0 & \mu''_{rzz}\varepsilon'_{rzz} \end{bmatrix}\right) + \begin{bmatrix} \mu''_{rxx}\varepsilon''_{rxx} - \mu''_{rxy}\varepsilon''_{ryx} & \mu''_{rxx}\varepsilon''_{rxy} - \mu''_{rxy}\varepsilon''_{ryy} & 0 \\ \mu''_{ryx}\varepsilon''_{rxx} - \mu''_{ryy}\varepsilon''_{ryx} & \mu''_{ryx}\varepsilon''_{rxy} - \mu''_{ryy}\varepsilon''_{ryy} & 0 \\ 0 & 0 & \mu''_{rzz}\varepsilon''_{rzz} \end{bmatrix}\right)^{1/2}$$

With proposing:

$$[\zeta]^* = \sqrt{[\mu_r][\varepsilon_r]}$$

The complex propagation tensor constant in the laminate composite is given by:

$$[\gamma] = \gamma_0\sqrt{\mu_0[\mu_r]\mu_0[\varepsilon_r]} = \gamma_0\sqrt{\mu_0\varepsilon_0}[\zeta]^*$$

$$\gamma_0 = \omega_0\sqrt{\mu_0\varepsilon_0}$$

γ_0 is the propagation constant of free space

The intrinsic wave impedances of the laminate composite material can be computed by :

$$\eta = \omega_0\sqrt{\frac{\mu_0}{\varepsilon_0}}\sqrt{\frac{[\mu_r]}{[\varepsilon_r]}} = \omega_0\sqrt{\frac{\mu_0}{\varepsilon_0}}\sqrt{[\mu_r][\varepsilon_r]^{-1}}$$

The determinant of $[\varepsilon_r]$ is given by

$$det[\varepsilon_r]^{-1} = (\varepsilon'_{rxx} - j\varepsilon''_{rxx})(\varepsilon'_{ryy} - j\varepsilon''_{ryy})(\varepsilon'_{rzz} - j\varepsilon''_{rzz})$$

Proposing:

$$\varepsilon^*_{rij} = \varepsilon'_{rij} - j\varepsilon''_{rij}$$

$$\mu^*_{rij} = \mu'_{rij} - j\mu''_{rij}$$

which $[\varepsilon_r]$ and $[\mu_r]$ become:

$$[\varepsilon_r] = \begin{bmatrix} \varepsilon^*_{rxx} & \varepsilon^*_{rxy} & 0 \\ \varepsilon^*_{ryx} & \varepsilon^*_{ryy} & 0 \\ 0 & 0 & \varepsilon^*_{rzz} \end{bmatrix}$$

$$[\mu_r] = \begin{bmatrix} \mu^*_{rxx} & \mu^*_{rxy} & 0 \\ \mu^*_{ryx} & \mu^*_{ryy} & 0 \\ 0 & 0 & \mu^*_{rzz} \end{bmatrix}$$

So $[\varepsilon_r]^{-1}$ is given:

$$[\varepsilon_r]^{-1} = \begin{bmatrix} \frac{1}{\varepsilon^*_{rxx}} & \frac{\varepsilon^*_{rxy}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} & 0 \\ \frac{\varepsilon^*_{ryx}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} & \frac{1}{\varepsilon^*_{ryy}} & 0 \\ 0 & 0 & \frac{1}{\varepsilon^*_{rzz}} \end{bmatrix}$$

The intrinsic wave impedances of the laminate composite material become:

$$\eta = \omega_0\sqrt{\frac{\mu_0}{\varepsilon_0}\begin{bmatrix} \frac{\mu'_{rxx}}{\varepsilon^*_{rxx}} + \frac{\mu^*_{rxy}\varepsilon^*_{ryx}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} & \frac{\mu^*_{rxx}\varepsilon^*_{rxy}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} + \frac{\mu^*_{rxy}}{\varepsilon^*_{ryy}} & 0 \\ \frac{\mu'_{ryx}}{\varepsilon^*_{rxx}} + \frac{\mu^*_{ryx}\varepsilon^*_{ryx}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} & \frac{\mu^*_{ryy}\varepsilon^*_{rxy}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} + \frac{\mu^*_{ryy}}{\varepsilon^*_{ryy}} & 0 \\ 0 & 0 & \frac{\mu^*_{rzz}}{\varepsilon^*_{rzz}} \end{bmatrix}}^{1/2}$$

The impedance tensor is given by the following matrix:

$$[Z] = \begin{bmatrix} \frac{\mu'_{rxx}}{\varepsilon^*_{rxx}} + \frac{\mu^*_{rxy}\varepsilon^*_{ryx}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} & \frac{\mu^*_{rxx}\varepsilon^*_{rxy}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} + \frac{\mu^*_{rxy}}{\varepsilon^*_{ryy}} & 0 \\ \frac{\mu'_{ryx}}{\varepsilon^*_{rxx}} + \frac{\mu^*_{ryx}\varepsilon^*_{ryx}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} & \frac{\mu^*_{ryy}\varepsilon^*_{rxy}}{\varepsilon^*_{rxx}\varepsilon^*_{ryy}} + \frac{\mu^*_{ryy}}{\varepsilon^*_{ryy}} & 0 \\ 0 & 0 & \frac{\mu^*_{rzz}}{\varepsilon^*_{rzz}} \end{bmatrix}^{1/2}$$

The transmission coefficient tensor [T] is given by:

$$[T] = e^{-[\gamma]x} = e^{-\gamma_0\sqrt{\mu_0\varepsilon_0}[\zeta]^* x}$$

The tensor of the Reflection coefficient of the laminate composite is given by:

$$[\Gamma] = \frac{([Re]-1)^2 + [Img^2]}{([Re]+1)^2 + [Img^2]}$$

where ***Re*** and ***Img*** are the real and the imaginary part of the Reflection coefficient are given by:

$$[Re]^2 = \frac{1}{2}\left(\sqrt{[\mu_r]^2[\varepsilon_r]^2 + 4\frac{[\mu_r]^2[\sigma]^2}{\omega^2}} + [\mu_r][\varepsilon_r]\right)$$

$$[Img]^2 = \frac{1}{2}\left(\sqrt{[\mu_r]^2[\varepsilon_r]^2 + 4\frac{[\mu_r]^2[\sigma]^2}{\omega^2}} - [\mu_r][\varepsilon_r]\right)$$

The reflection loss (S11) tensor and insertion loss (S21) tensor parameters are related to the parameters [Γ] and [T] by the following equations:

$$[S_{11}] = \frac{[\Gamma](1-[T]^2)}{1-[\Gamma]^2[T]^2}$$

$$[S_{12}] = \frac{[T](1-[\Gamma]^2[T]^2)}{1-[\Gamma]^2[T]^2}$$

3. Electromagnetic modeling

The electromagnetic Maxwell's equations are given by:

$$\nabla\wedge\vec{E} = -j\omega\mu_0[\mu_r]\vec{H}$$

$$\nabla\wedge\vec{H} = [\sigma]\vec{E} + j\omega\varepsilon_0[\varepsilon_r]\vec{D}$$

The transmission line TE mode of Helmholtz equations for electrical field and magnetic field given as follows:

$$\frac{\partial^2\overrightarrow{E_y}}{\partial x^2} + \frac{\partial^2\overrightarrow{E_y}}{\partial z^2} = \mu_0\varepsilon_0[\mu_r][\varepsilon_r]\frac{\partial^2\overrightarrow{E_y}}{\partial t^2}$$

$$\frac{\partial^2\overrightarrow{H_y}}{\partial x^2} + \frac{\partial^2\overrightarrow{H_y}}{\partial z^2} = \mu_0\varepsilon_0[\mu_r][\varepsilon_r]\frac{\partial^2\overrightarrow{H_y}}{\partial t^2}$$

The Maxwell's equations and transmission line equations for electrical field and magnetic field written as tensor form to take into account the anisotropy nature of composite laminate.

As mentioned earlier, Maxwell's equations are coupled first-order differential equations which are difficult to apply when solving boundary-value problems.
The difficulty is overcome by decoupling the first-order equations, thereby obtaining the wave equation, a second-order differential equation which is useful for solving problems. The full-wave problem, it is referred to as numerically by the finite elements method computing the wave equation derived from Maxwell's equation.

$$\nabla\wedge\nabla\wedge\vec{E} - k_0^2[\mu_r]\left([\varepsilon_r] - \frac{j[\sigma]}{\omega\varepsilon_0}\right)\vec{E} = 0$$

$$\nabla\wedge\nabla\wedge\vec{H} - k_0^2[\mu_r]\left([\varepsilon_r] - \frac{j[\sigma]}{\omega\varepsilon_0}\right)\vec{H} = 0$$

The electric field intensity *E* and magnetic field intensity *H*:

$$[\vec{E}] = P_i e^{-j[k](-x\cos\theta + z\sin\theta)} + P_r e^{-j[k](x\cos\theta + z\sin\theta)}$$

$$[\vec{H}] = [Z]^{-1}\left(P_i e^{-j[k](-x\cos\theta + z\sin\theta)} + P_r e^{-j[k](x\cos\theta + z\sin\theta)}\right)$$

Where P_i and P_r are respectively the amplitudes of the incident and reflected propagated waves.
With the reflection coefficient can be written as the following equation:

$$|\Gamma| = -20\log\left|\frac{P_r}{P_i}\right|$$

The model of laminate composite of all the transmissions parameters in this case is written as tensors because of the heterogeneous and anisotropic effect of the electrical properties.

4. Conclusion

In this paper a full model had taken into account the high anisotropy of heterogeneous composite laminate, the electrical properties are written as tensor form to take into consideration all the electrical properties components
The electrical properties are depending on fiber orientations, all transmission parameters are molded by tensors because the anisotropy effect.
The model takes into consideration the electrical properties at low frequencies (simple form) and high frequencies (complexes form).
In future work will focus on a numerical model with experimental validation of our model.

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