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Communication Department

Measuring and Comparing the Electromagnetic Properties of Double Layer Solid Dielectric Material

In partial fulfillment of the requirement of the degree of the BSc communication Engineering

A project presented by

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ (١١)

صَدَقَ اللّهُ العَظِيمْ

سُـورَةْ المجُـادَلة

Supervisor certificate

We certify that preparation of this project entitled "**Measuring and Comparing the Electromagnetic Properties of Double Layer Solid Dielectric Material**" was made under our super vision on the communication engineering department in the university of diyala .As a partial fulfillment of the requirement needed for the award of the B.Sc. degree in communication engineering.

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Certification of examination committee

We certify that we have read the project entitled "**Measuring and comparing the electromagnetic properties of double layer solid dielectric material**" and examining committee, examined that student (**Mohammed Ibrahim**, **Karrar Iz Aldeen**) in its content and our opinion it meets the standard of a project for the degree B.Sc. of science in communication engineering

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الإهداء

إلـى

من أرسله الله نوراً للدجى ورسولًا للهدى محمد (صلى الله عليه وسلم)

إلى

التي آزرتني في حياتها وزرعت فيّ الأمل ومدتني بسر الحياة ....أمـــي

إلى

الذي أخط طريق حياتي وأحاطني بدفء قلبه..امتناناً وعرفاناً...أبـــي

إلى

من سقاني من بحار علمه الزاخر وأظمأني بإخلاص وصبر ومحبة ...أستاذي محمد سعدون

إلى

أخونا و صديقنا الشهيد السعيد...... خليل إبراهيم

إلى

نور عيني وسندي وعزتي ومصدر قوتي ...إخوتي الأعزاء

إلى

كل القلوب المخلصة التي قدمت لي العون والمساعدة ......

اهدي لهم عصارة جهدي المتواضع

الشكر والتقدير

ونحن على أبواب إنهاء دراستنا الجامعية وبداية مرحلة جديدة في حياتنا فأننا نقدم جزيل الشكر و الاحترام للذين كانوا شموعاً أضاءت لنا طريق العلم والمعرفة ،شكراً لكل من كان نبراساً اهتدينا بعلمه ومعرفته مهما كثرت المصاعب والعقبات في طريق الإنسان فلا بد أن يصل إلى نهاية الطريق وعندها لابد من قول كلمة الحق لمن وجه الإنسان إلى الطريق الصحيح

لهذا نقف لنقول شكراً...

للأُستاذ (محمد سعدون محمد) الذي اشرف على هذا المشروع...

لكل من وقف معنا من رئاسة القسم والأَساتذة في قسم هندسة الاتصالات

لهم منا جزيل الشكر والتقدير...

Abstract:

We used a free-space method for measurement the properties of double-layer dielectric materials at microwave frequencies where the two layers are glass and fiberglass and the frequency range in gigahertz is between 12 and 17.

We her will noticing the variations in measurements of transmission coefficient and reflection coefficient when doing the measurements with using the double-layer (glass and fiberglass) and its effect on material.

الملخص:

إستخدمنا طريقة الفضاء الحر لقياس خصائص المواد العازلة ذات الطبقتين بواسطة الترددات الدقيقة حيث الطبقتين هما (الزجاج والألياف الزجاجية) ومدى التردد يتراوح بين (١٢ – ١٧) غيغا هيرتز .

سوف نلاحظ اختلافات في قياسات معامل الانتقال ومعامل الانعكاس عند القيام بالقياسات مع استخدام طبقة مزدوجة (الزجاج والألياف الزجاجية) وتأثيرها على المواد.

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Table of Abbreviation

Symbol	Abbreviation
E	electric field
D	electric displacement
μ	magnetic permeability
μ *	complex permeability
ϵ_r	relative permittivity
ϵ_0	Permittivity of free space
ε	absolute permittivity
Γ	Reflection coefficient
T	Transmission coefficient
k	dielectric constant
$\boldsymbol{\tau}$	transmission factor
C	Speed of light
p_t	Transmitted power
p_i	Incident power
σ	conductivity
ε''_{rd}	dielectric loss
$\vec{r}_{0t}$	direction of propagation
z_0	characteristics impedance of free space (377ohm)
W	Wave resistance of the medium
β	phase constant
μ_r	Relative Magnetic Permeability

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1.1 Introduction:

The electromagnetic properties of each material include dielectric permittivity and magnetic permeability and conductivity. The dielectric properties of the materials can be interpreted as a macroscopically and microscopically. From a macroscopic point of view, they are the relationship between the applied electric field E (V / m2) and the electric displacement D (C / m2) in the material. Microscopically dielectric polarization properties are the ability of molecules in the material is of appropriate electric field E. In the engineering practice, generally describe the macroscopic dielectric properties of materials are used. For dielectric materials lossy or lossless, Naib – lee identification parameter is the Permittivity Bridge or magnetic permeability. Complex permittivity is a critical parameter in many radio frequencies and microwave applications [3] to create a fairly accurate and fast measurements of broadband. The magnetic permeability (μ) describes the interaction of the material with a magnetic field. The complex permeability (μ * and μ) consists of a real part (μ '), representing the energy storage term and imaginary part (μ″), representing a loss of energy term. Some materials, such as iron (ferrite), cobalt, nickel and their alloys have a noticeable magnetic properties, however, many materials are not magnetic, making permeability is very close to (μr = 1) the permeability of free space. All materials on the other hand, have dielectric properties, so that in this discussion will center mainly on permittivity measurements. The permeability of the material describes the interaction with the electric field E and a complex value. The dielectric constant (k) is equivalent to the relative permittivity (εr) or absolute permittivity (ε) in relation to the permeability of free space (ε°).Material is classified as a "dielectric" if it has the ability to store energy when the external electric field, when reported and real part of the permittivity (εr ^ ̓) is a measure of how much energy from the external electric field is stored in the material. Charge carriers that can migrate -vat at a distance through the material at a low frequency electric field. Interfacial or space time-charge polarization occurs when the movement of migratory charges difficult. Charges may become trapped within the boundaries of the material section. Movement may also be difficult when the charges cannot be freely discharged or replaced on the electrodes. The distortion field caused by the accumulation of these charges increases the overall capacity of the material, which looks like an increase ἔr. Mixtures of materials with conductive regions which are in contact with each other.

For dielectric materials, the imaginary part of permittivity (ἕr) is always greater than zero, and usually much less than (εr ^ ̓), i.e. (Er ^ ″ ≥0 and ε_ (r ») ^ ’ ἕr).

K = ε / ε ° = ε (r) = εr ^-jἕr ……………(1.1)

Where:

ε = ε ^ * = ε_ ° ε_ (r) is the absolute dielectric permittivity (and dielectric constant), ε_ (r) is the relative permittivity, ε_ ° = 8.85 × 〖10〗 ^ (- 12) F / m is the free space the dielectric constant.

1.2 Technique of free space:

In case of changing in time (i.e., a sine wave), electric fields and magnetic fields appear together. This electromagnetic wave can propagate through space (the speed of light, C = 3 x 10 ^ (8) m / s), or through the material at a lower speed. When the geometric structure of the test -Alan mother is in sheet form, free space methods

$$\boldsymbol{Z_o} = \sqrt{\frac{\mu_o}{\varepsilon_o}} = \mathbf{120\pi} \;\; \text{……….. (1.2)}$$

$$\mathbf{v} = \frac{\boldsymbol{C}}{\sqrt{\acute{\varepsilon}_r}} \;\; \text{…………………….... (1.3)}$$

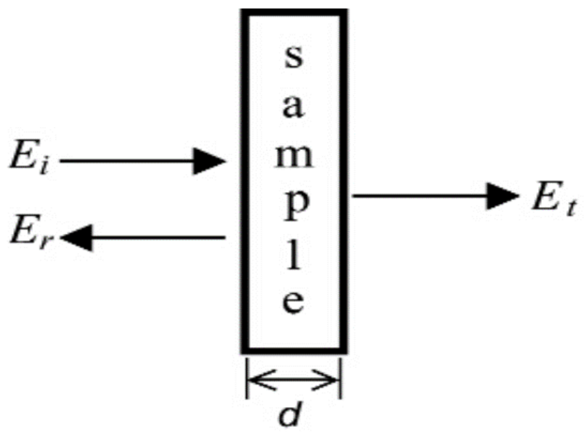

Figure 1. Schematic of the incident, reflected and transmitted waves

The reflection coefficient can be written as:

$$\boldsymbol{\Gamma = \frac{E_r}{E_i}} \text{ …………… } \mathbf{(1.4)}$$

And the transmission factor can be written as:

$$\boldsymbol{\tau = \frac{E_t}{E_i}} \text{ …………. } \mathbf{(1.5)}$$

Where Ei, and Es are the amplitudes of electric fields of the incident, reflected and transmitted waves, respectively.

1.3 Dielectric polarization:

The material may have several mechanisms or dielectric polarization effects:

1- Dipole polarization orientation

2- Ion conductivity of polarization

3- Nuclear polarization

4- Electron polarization

1.4 Dipole polarization orientation:

The molecule is formed when atoms come together to share one or more of its electrons. Such a redistribution of electrons can lead to an uneven distribution of charge, creating a permanent dipole moment. Such moments in the absence of an electric field oriented randomly, so polarization occurs. The electric field E will cause the torque T at the time of an electric dipole and dipole will rotate to line up the electric field, resulting in a polarization orientation (Figure 8). If the field changes direction-set, torque is also changes. Friction accompanying dipole orientation, will contribute to the dielectric losses. Dipole-ix root causes a change ἑ _r ἕ _r and at a frequency of relaxation that usually occurs in the microwave range. As already mentioned, water.

1.5 Electronic and atomic polarization:

Electronic polarization appears in the neutral atoms, when an electric field displaces the nucleus relationship to the surrounding electrons. Nuclear polarization occurs when neighboring positive and negative ions in- _ "stretched" by the action of the applied electric field. Many dry solids these polarization mechanisms dominate at microwave frequencies, although the actual resonance occurs at a much higher frequency. In the infrared and optical regions must take into account the inertia of the electrons arbitrary.

1.6 Polarization ionic conductivity (ionic conductivity):

The measured losses in the material can be represented as a function of the dielectric loss (ἕrd) and conductivity (σ).

$$\varepsilon''_{r} = \varepsilon''_{rd} + \frac{\sigma}{\omega\varepsilon_{\circ}} \ldots\ldots\ldots\ldots (1.6)$$

2.1 Literature review:

We used the free space method for measuring the properties of insulating materials of classes by micro frequencies where classes are (glass, fiberglass) and the frequency range between (12-17) GHz We will observe differences in the measurements of transfer coefficient and the reflection coefficient when doing measurements with the use of a double layer (glass and glass fiber) and its impact on materials.

3.1 Introduction:

The design tasks necessary to model processes excitation fields of different nature, and their distribution in the different media, diffraction or penetration of various objects .A task greatly simplified if the spatial dependence of the field It corresponds to the geometric shape of object or obstacle. The efforts of many generations of scientists developed coordinate method Differential equations describing the field and their solutions have been investigated in a variety of orthogonal coordinate systems by separation of variables. Each coordinate system is well built study the function of the system. If the object's borders coincide with Coordinate surface, the field inside and outside the object may be it represented as an expansion in these systems. This chapter covers the case of a plane-layered structures .It is the simplest example of this approach. Nevertheless ‹research fields in such structures is an extensive literature. A fairly complete and overview is given in [1, 2]. In this tutorial we will show that the matrix multilayer structure description of the model traditionally used in literature, it is not unique and can be replaced by the recurrent form of the model, by means of which can be explored by all parameters of multilayer structure . The geometry of plane-layered structure correspond to fields in the form plane waves which spread through the structure can be described by analytically. The electromagnetic field of monochromatic plane wave with linearly polarized in a homogeneous medium is the simplest solution Maxwell's equations, and is characterized by complex vectors $\vec{E}(r), \vec{H}(r)$.

Complex field amplitudes E(r) and H(r) are related

$$H(\vec{r}) = \frac{E(\vec{r})}{w} \quad \text{……… (3.1)}$$

$w = \sqrt{\mu / \varepsilon}$ - Wave resistance of the medium;

μ, ε - electromagnetic constants which can be generally complex.

In what follows we consider the complex dielectric constant

$$\varepsilon = \varepsilon' - i\frac{\sigma}{\omega} \text{ .... (3.2)}$$

Where σ - medium conductivity.

Let $\vec{r}_1$, $\vec{r}_2$ - two arbitrary points. Then the vectors of a plane wave fields at these points are related as follows:

$$\begin{aligned} \vec{E}(\vec{r}_2) &= \vec{E}(\vec{r}_1)e^{-ik(\vec{r}_0,\vec{r}_2-\vec{r}_1)}; \\ \vec{H}(\vec{r}_2) &= \vec{H}(\vec{r}_1)e^{-ik(\vec{r}_0,\vec{r}_2-\vec{r}_1)}, \end{aligned} \text{ .... (3.3)}$$

Where $\kappa = \omega\sqrt{\varepsilon\mu}$ - the wave number of the medium, which is a complex value, the imaginary part of which is characterized by the wave attenuation in the environment . Removing the root of the complex quantity , included in the Expressions for w and k, can be carried out using the formula:

$$\sqrt{\varepsilon} = \sqrt{\frac{\sqrt{(\varepsilon')^2 + (\sigma/\omega)^2} + \varepsilon'}{2}} - i\sqrt{\frac{\sqrt{(\varepsilon')^2 + (\sigma/\omega)^2} - \varepsilon'}{2}} \text{ .... (3.4)}$$

The complex amplitude $H(\vec{r})$ shifted in phase relative $E(\vec{r})$ due to the complex nature of the wave resistance.

3.2 Distribution of a plane wave through a layered structure:

Consider a plane-layered structure, which obliquely falls flat linearly-polarized wave of half-an options ε_0, μ_0, with the direction of propagation $\vec{r}_{0t}$

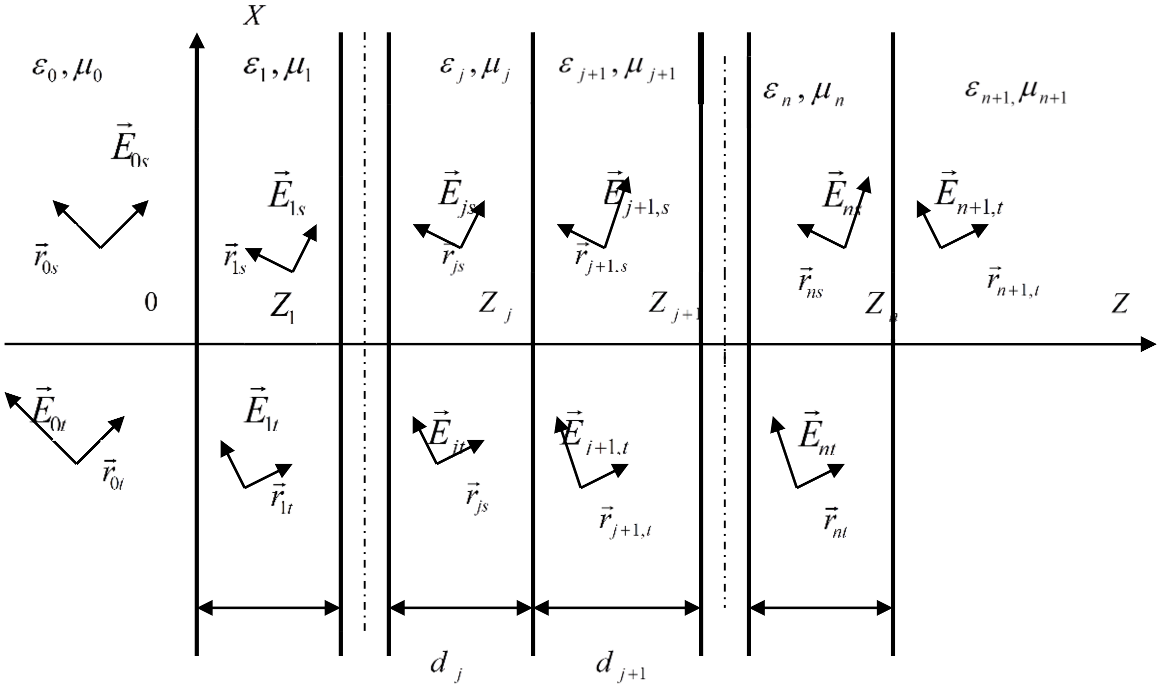

Figure (2.1) Excitation of a plane-layered structure plane electromagnetic wave.

$$E_{it\ell}(x) = E_{itr}(x)e^{ik_i c_i d_i};$$
$$E_{is\ell}(x) = E_{isr}(x)e^{-ik_i c_i d_i}. \quad \text{……….. (3.4)}$$

When passing through the interface between adjacent layers tangents constitute the entire field must be continuous:

$$c_i E''_{itr} + c'_i E''_{isr} = c_{i+1} E''_{i+1,t\ell} + c'_{i+1} E''_{i+1,s\ell};$$
$$\frac{E''_{itr} - E''_{isr}}{w_i} = \frac{E''_{i+1,t\ell} - E''_{i+1,s\ell}}{w_{i+1}}. \quad \text{……..….. (3.5)}$$

The second line expresses the condition of continuity of the tangent component of the magnetic field. Similarly, for the component perpendicular to the plane of incidence, we have:

$$
\begin{aligned}
&E_{itr}^{\perp} + E_{isr}^{\perp} = E_{i+1,t\ell}^{\perp} + E_{i+1,s\ell}^{\perp};\\
&\frac{-c_i E_{itr}^{\perp} + c_i' E_{isr}^{\perp}}{w_i} = \frac{-c_{i+1} E_{i+1,t\ell}^{\perp} + c_{i+1}' E_{i+1,s\ell}^{\perp}}{w_{i=1}}.
\end{aligned} \quad \ldots\ldots\ldots\ldots (3.6)
$$

It can be seen that after each polarization determined independently.

In particular, for the first inequality we obtain:

$$
c_i E_{itr}''(0) e^{-ik_i s_i x} + c_i' E_{isr}''(0) e^{-ik_i s_i' x} = c_{i+1} E_{i+1,t\ell}''(0) e^{-ik_{i+1} s_{i+1} x} + c_{i+1}' E_{i+1,s\ell}''(0) e^{-ik_{i+1_i} s_{i+1}' x} . \ldots (3.7)
$$

This equation must be satisfied identically for all x. It is therefore necessary to

$s_i = s_i'$ Each layer in the angle of incidence equals the angle reflection α' , $\kappa_i s_i =$ k(i+1)s(i+1)(generalized Snell's law of refraction).

$$
\begin{aligned}
E_{itr}'' &= \frac{1}{2}\left(\frac{c_{i+1}}{c_i} + \frac{w_i}{w_{i+1}}\right) E_{i+1,t\ell}'' + \frac{1}{2}\left(\frac{c_{i+1}}{c_i} - \frac{w_i}{w_{i+1}}\right) E_{i+1,s\ell}'';\\
E_{isr}'' &= \frac{1}{2}\left(\frac{c_{i+1}}{c_i} - \frac{w_i}{w_{i+1}}\right) E_{i+1,t\ell}'' + \frac{1}{2}\left(\frac{c_{i+1}}{c_i} + \frac{w_i}{w_{i+1}}\right) E_{i+1,s\ell}''.
\end{aligned} \quad \ldots\ldots\ldots.. (3.8)
$$

Similarly, for the field components polarized perpendicularly the plane of incidence:

$$\begin{aligned} E^{\perp}_{itr} &= \frac{1}{2}\left(1+\frac{c_{i+1}w_i}{c_i w_{i+1}}\right)E^{\perp}_{i+1,t\ell} + \frac{1}{2}\left(1-\frac{c_{i+1}w_i}{c_i w_{i+1}}\right)E^{\perp}_{i+1,s\ell}; \\ E^{\perp}_{isr} &= \frac{1}{2}\left(1-\frac{c_{i+1}w_i}{c_i w_{i+1}}\right)E^{\perp}_{i+1,t\ell} + \frac{1}{2}\left(1+\frac{c_{i+1}w_i}{c_i w_{i+1}}\right)E^{\perp}_{i+1,s\ell}. \end{aligned} \quad \text{………... (3.9)}$$

Further calculations will be the same for the fields of both polarizations.

Therefore, both systems can be conveniently represented in summary form without kinds of polarization:

$$\begin{aligned} E_{itr} &= \alpha E_{i+1,t\ell} + \beta E_{i+1,s\ell}; \\ E_{isr} &= \beta E_{i+1,t\ell} + \alpha E_{i+1,s\ell}, \end{aligned} \quad \text{……………. (3.10)}$$

Where

$$\alpha = \begin{cases} \frac{1}{2}\left(\frac{-_{i+1}}{c_i} + \frac{w_i}{w_{i+1}}\right) \\ \frac{1}{2}\left(1 + \frac{c_{i+1}w_i}{c_i w_{i+1}}\right) \end{cases} \text{............................(3.11)}$$

$$\beta = \begin{cases} \frac{1}{2}\left(\frac{-_{i+1}}{c_i} - \frac{w_i}{w_{i+1}}\right) \\ \frac{1}{2}\left(1 - \frac{c_{i+1}w_i}{c_i w_{i+1}}\right) \end{cases} \text{...........................(3.12)}$$

The ratio of the complex amplitudes E_{isr}/E_{itr} we will be called field reflectivity i-м Elephant and denote R_{ir}. As themselves complex amplitudes, it is a function of z. meaning Ri left near and the right boundary layer will be denoted by R_{il} , R_{ir}. Then follows that

$$R_{i\ell} = R_{ir} e^{-i2k_i c_i d_i} \text{ .... (3.13)}$$

Using the newly entered value for the relationship of the complex amplitudes of the incident and reflected fields, we obtain the following relationship:

$$R_{ir} = \frac{R_{i,i+1} + R_{i+1,\ell}}{1 + R_{i,i+1} R_{i+1,\ell}} \text{..............(3.14)}$$

We call the private transmission coefficient T_i the ratio of the incident field amplitude in (i+1)-м layer $E_{i+1,\,t\,\ell}$ to the amplitude of the incident field in the I-M layer E_{itr}:

$$T_i = E_{i+1,t\ell} / E_{itr} \text{..........} \quad (3.15)$$

Given this notation, we have:

$$1 - R_{i,i+1} R_{ir} = \alpha (1 - R_{i,i+1}^2) T_i \text{.......} \quad (3.16)$$

Substituting R_{ir} making elementary transformations, we obtain the formula for the calculation of the partial transmission coefficients:

$$T_i = \frac{T_{i,i+1}}{1 + R_{i,i+1} R_{i+1,\ell}} \text{..........} \quad (3.17)$$

Where $T_{i,\,i+1} = 1/\alpha$ - known Fresnel transmission coefficient on the border ір-го, i+1-layers.T_i (i = 0, N)

Form the product:

$$\prod_{j=0}^{i} T_j = \frac{E_{1t\ell}}{E_{otr}} \cdot \frac{E_{2t\ell}}{E_{1tr}} \cdots \frac{E_{i+1,t}}{E_{itr}} \text{..........} \quad (3.18)$$

The regrouping of the factors in the numerator of the right-hand side, we have:

$$\prod_{j=0}^{i} T_j = \frac{E_{i+1,t\ell}}{E_{otr}} \prod_{j-1}^{i} \frac{E_{jt\ell}}{E_{jtr}} = T^{(i)} \prod_{j=1}^{i} e^{ik_j c_j d_j} \text{.........} \quad (3.19)$$

From which we obtain:

$$T^{(i)} = e^{-i\sum_{j=1}^{i} k_j c_j d_j} \prod_{j=0}^{i} T_j \ldots\ldots\ldots\ldots (3.20)$$

Obviously, the transmission coefficient of the entire plane-layered structure
There is $T^{(N)}$:

$$T^{(N)} = e^{-i\sum_{j=1}^{N} k_j c_j d_j} \prod_{j=0}^{N} T_j \ldots\ldots\ldots\ldots (3.21)$$

3.3 Distribution of a local source field through the layered structure:

As can be seen, spread payment of a plane wave through a layered the structure is relatively simple. However, the results of this analysis are relatively small value because not include any geometric screen size or the directional properties of the transmitted radiation . Therefore, the spread of the analysis in plane-layered structure of a local source field can be considered as the next step, which allows to evaluate the effects of shielding the real sources. For simplicity, we restrict ourselves to the case when the source of the field dimensions are much smaller than the wavelength. Then, at some distance from the source field with sufficient accuracy is approximated by a dipole field. Note that the field is an arbitrary distribution of sources can be submitted with the required accuracy the set of fields of electric and magnetic dipoles. As already noted, for the solution of the coordinate method must be present exciting dipole field as a set of fields with spatial dependence, corresponding to the geometry of the plane-layered structure, i.e. as a superposition of plane waves. Then it becomes possible to use directly obtained in the previous section, the calculated ratio.

Model excitation two-layer structure of a plane wave using Mathcad program:

Speed of light $c := 29979245$

Magnetic permeability of free-space $\mu o := 4\cdot\pi\cdot10^{-7}$

The permittivity of free-space $\varepsilon o := \frac{1}{\mu o\cdot c^2}$ $\varepsilon o = 8.854\times 10^{-12}$

Frequency $f := 12\cdot10^9$ $\lambda(f) := \frac{c}{f}$ $\lambda(f) = 0.025$ $\lambda\left(12\cdot10^9\right) = 0.025$

The imaginary unit $i := i$

Excitation layered medium:

The number of layers, permeability, conductivity, impedance,

the thickness of the layers, Fresnel coefficients

$$\varepsilon i := \begin{pmatrix} \varepsilon o \\ 4\cdot\varepsilon o \\ 3\cdot\varepsilon o \\ \varepsilon o \end{pmatrix} \qquad \sigma := \begin{pmatrix} 0 \\ 10^{-9} \\ 6\times 10^{-15} \\ 0 \end{pmatrix} \qquad \sigma_1 := 1\cdot10^{-9} \quad \sigma_2 := 6\cdot10^{-15} \quad m := 0,1..3$$

$$\varepsilon ic(f) := \varepsilon i - \left(\frac{i}{2\cdot\pi\cdot f}\right)\cdot\sigma \qquad \varepsilon ic(f) = \begin{pmatrix} 8.854\times 10^{-12} \\ 3.542\times 10^{-11} \\ 2.656\times 10^{-11} \\ 8.854\times 10^{-12} \end{pmatrix}$$

$$kc(f) := 2\cdot\pi\cdot f\cdot\sqrt{\mu o}\cdot\begin{pmatrix} \sqrt{\varepsilon ic(f)_0} \\ \sqrt{\varepsilon ic(f)_1} \\ \sqrt{\varepsilon ic(f)_2} \\ \sqrt{\varepsilon ic(f)_3} \end{pmatrix} \qquad kc(f) = \begin{pmatrix} 251.501 \\ 503.003 - 9.418i\times 10^{-8} \\ 435.613 \\ 251.501 \end{pmatrix}$$

$$w(f) := \sqrt{\mu o}\cdot\begin{pmatrix} \sqrt{\frac{1}{\varepsilon ic(f)_0}} \\ \sqrt{\frac{1}{\varepsilon ic(f)_1}} \\ \sqrt{\frac{1}{\varepsilon ic(f)_2}} \\ \sqrt{\frac{1}{\varepsilon ic(f)_3}} \end{pmatrix} \qquad w(f) = \begin{pmatrix} 376.73 \\ 188.365 + 3.527i\times 10^{-8} \\ 217.505 \\ 376.73 \end{pmatrix}$$

Layer thickness $di := \begin{pmatrix} 0 \\ 0.002 \\ 0.008 \end{pmatrix}$ the left border of layers $zi := \begin{pmatrix} 0 \\ 0.002 \\ 0.01 \end{pmatrix}$

Fresnel reflection coefficients Fresnel transmission coefficients

$$Rf(f) := \begin{bmatrix} \left(\dfrac{1 - \dfrac{w(f)_0}{w(f)_1}}{1 + \dfrac{w(f)_0}{w(f)_1}} \right) \\ \left(\dfrac{1 - \dfrac{w(f)_1}{w(f)_2}}{1 + \dfrac{w(f)_1}{w(f)_2}} \right) \\ \left(\dfrac{1 - \dfrac{w(f)_2}{w(f)_3}}{1 + \dfrac{w(f)_2}{w(f)_3}} \right) \end{bmatrix} \qquad Tf(f) := \begin{bmatrix} \left(\dfrac{2}{1 + \dfrac{w(f)_0}{w(f)_1}} \right) \\ \left(\dfrac{2}{1 + \dfrac{w(f)_1}{w(f)_2}} \right) \\ \left(\dfrac{2}{1 + \dfrac{w(f)_2}{w(f)_3}} \right) \end{bmatrix}$$

$$Tf(f) = \begin{pmatrix} 0.667 + 8.322i \times 10^{-11} \\ 1.072 \\ 1.268 \end{pmatrix} \qquad Rf(f) = \begin{pmatrix} -0.333 + 8.322i \times 10^{-11} \\ 0.072 - 9.314i \times 10^{-11} \\ 0.268 \end{pmatrix}$$

The reflection coefficients near the left boundary of the layers parallel to the polarization

$$Rl2(f) := Rf(f)_2 \cdot e^{-2i \cdot kc(f)_2 \cdot di_2} \qquad Rl2(f) = 0.207 - 0.17i$$

$$Rl1(f) := \left(\frac{Rf(f)_1 + Rl2(f)}{1 + Rf(f)_1 \cdot Rl2(f)} \right) \cdot e^{-2i \cdot kc(f)_1 \cdot di_1} \qquad Rl1(f) = -0.267 - 0.18i$$

Full reflection coefficient of a two-layer structure

$$Rl0(f) := \left(\frac{Rf(f)_0 + Rl1(f)}{1 + Rf(f)_0 \cdot Rl1(f)}\right) \cdot e^{-2i \cdot kc(f)_0 \cdot di_0} \qquad Rl0(f) = -0.558 - 0.135i$$

The coefficients of the transfer of two-layer structure:

$$T3(f) := \frac{Tf(f)_0 \cdot Tf(f)_1 \cdot Tf(f)_2 \cdot e^{-i \cdot kc(f)_1 \cdot di_1 - i \cdot kc(f)_2 \cdot di_2}}{\left(1 + Rf(f)_0 \cdot Rl1(f)\right) \cdot \left(1 + Rf(f)_1 \cdot Rl2(f)\right)} \qquad T3(f) = -0.145 + 0.806i$$

$$КП(t) := 10 \log\left(\left|T3\left(12 \cdot 10^9 + t \cdot 10^9\right)\right|\right) \qquad КО(t) := 10 \cdot \log\left(\left|Rl0\left(12 \cdot 10^9 + t \cdot 10^9\right)\right|\right)$$

$$t := 0, 0.05 .. 5$$

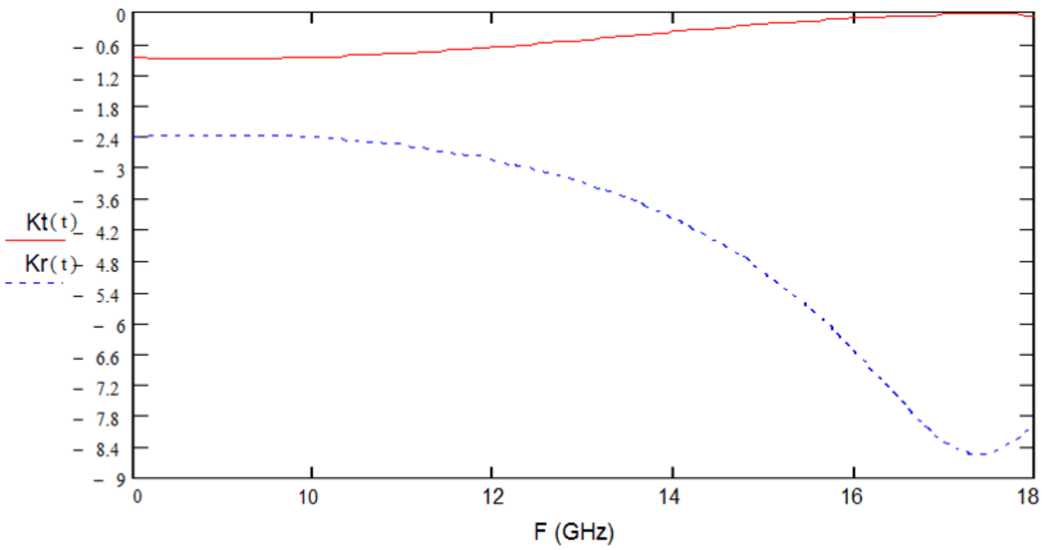

Figure (3.1) Kt and Kr for double layer composite material (glass and fiberglass)

Frequency (GHz)	(double layer)	
	Kt(DB)	Kr(DB)
12	-0.9	-2.4
13	-0.7	-2.4
14	-0.6	-2.6
15	-0.3	-3.6
16	-0.1	-6.6
17	0	-8.1

Kt and Kr for double layer composite material (glass and fiberglass)

5.1 CONCLUSION:

The results of the study can be summarized as follows:

1. Based on the analysis of the literature concluded the promising for measuring the electrical properties of dielectric materials in free space and what it can help us for future.

2. Views of polarization of dielectric materials and types of losses in the material which can be studied by the free space.

3. Implement a two-layer model of the dielectric material by-- using MATHCAD.

4. Because there was no suitable devices in laboratory as signal generator and spectrum analyzer in our frequency range (12 GHz – 17 GHz) was impossible doing the measurements therefore we implemented the measurement by using MATHCAD program.

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Introduction

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Chapter Three

SIMULATION OF ELECTROMAGNETIC FIELDS IN THE FLAT-LAYERED STRUCTURES

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Results

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جمهورية العراق

جامعة ديالى

كلية الهندسة

قسم هندسة الاتصالات

قياس ومقارنة الخصائص الكهرومغناطيسية للمواد الصلبة العازلة ذات الطبقتين

في الانجاز الجزئي من متطلبات درجة البكالوريوس في هندسة الاتصالات

المشروع مقدم من قبل :

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م.م محمد سعدون محمد

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