DIFFRACTION BY THIN DIELECTRIC STRIP AND ITS APPLICATION TO MODELING OF MICROWAVE SCATTERING AND ABSORPTION BY PLANT ELEMENTS

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ABSTRACT

The aim of the present study is to develop a scattering model with a wider range of applicability than those avaliable in the literature. The simple case of scattering by a thin dielectric strip is examined. This problem is considered on the basis of the expansion of scattering operator into multiple scattering series. The calculations of inner field and the extinction cross section are conducted for certain dielectric costants and dimensions of strip corresponding to the parameters of vegetation elements. It has been shown that for values of $kD|\epsilon - 1| \leq 0.5$,where k is the wave number, D is the strip thickness, and ϵ is the strip dielectric constant, the generalized Rayleigh-Gans approach can be successfully applied to calculate the extinction cross section of a dielectric strip. Radiation patterns of scattering by perfectly conducting strip and a thin dielectric strip is compared. An asymptotic solution is presented for the diffraction by a resistive strip which is useful in the simulation of thin dielectric layers. It is shown that the asymptotic solution is in good agreement with known solutions.

ÖZ

Bu çalışmanın amacı literatürde var olanlardan daha geniş bir uygulamaya sahip yeni bir saçılma modeli geliştirmektir. İnce bir dielektrik şeritten saçınım probleminin basit durumu çalışıldı. Problemin çözümü saçınım operatörünün çoklu saçınım serilerini açınımı üzerine dayandırıl- mıştır. Dielektrik içindeki alan ve zayıflama katsayısı bitki elementlerine bağlı olarak belirli bir dielektrik sabit ve şerit boyutları alınarak bulundu. $kD|\varepsilon - 1| \leq 0.5$, koşulu sağlanırsa bulunan sonuçlar genelleştirilmiş Rayleigh-Gans yöntemi ile bulunan sonuçlarla iyi bir benzerlik olduğu gösterilmiştir. Mükemmel iletken şeritle ve bir ince dielektrik şeritten saçılmaya ait ışıma diagramları karşılaştırılmıştır. İnce dielektrik tabakaların simulasyonunda iyi sonuçlar veren rezistif şeritten saçınım problemi için asimptotik bir çözüm önerilmiştir. Önerilen asimptotik çözüm ile bilinen çözümler arasında büyük benzerlikler olduğu gösterilmiştir.

1. INTRODUCTION

Development of reliable models for microwave emission and scattering from terrain, i.e.,soil, vegetation, snow, forest, etc.., is one of the important problems of microwave remote sensing. From theoretical point of view, this problem is of independent interest, because it concerns the studies about scattering by dielectric bodies of different shape and dimension, microwave propagation in random media, polarization properties of scattered waves, etc. On the other hand, the presence of reliable radiative models enables one to formulate the inverse problem of microwave remote sensing which is important for practical applications. Current investigations in microwave remote sensing field are mainly in the following directions : modeling of microwave emission and scattering from plant elements and vegetation as a whole, modeling of effective dielectric permittivity of natural media, modeling of microwave attenuation of forests.

The sizes of leaves and stalks in the microwave band are comparable with the wavelength; therefore, the scattering and absorption cross sections of plant elements must be calculated from diffraction models. Since the plant elements are similar in shape to flat discs, strips(for example, leaves), and cylinders(for example, stalks), it is necessary to discuss the diffraction problems for bodies with the above shapes. The rigorous analytical solution of the diffraction problem for dielectric disc and strip is not yet known. In this case the cross sections can be found under some restrictive assumptions between the size of the element and the wavelength.The following models are most oftenly used[1]: (i) small particle approximation, (ii) very large plane particle approximation, (iii) plane thin particle approximation. The latter one is also known as the generalized Rayleigh-Gans approach[2].

To establish the limits of applicability of these models a critical assesment of known solutions and further, development of theoretical approaches are required. This will be demonstrated for a simple case by considering the scattering by a thin dielectric strip. This problem has been examined by many authors via different approaches; but, only approximate solutions were being obtained so far. The problem may be treated either numerically or analytically, As an example for numerical approach, the moment method solution presented by Richmond can be mentioned [3]. By expanding the inner field of the dielectric strip into a sum of plane waves [4] obtained an asymptotic analytical solution. On the other hand, Wiener-Hopf technique is used to obtain an analytical solution in a formal way for a dielectric strip of certain thickness [5]. Alternative approach used to consider dielectric strip is to simulate it with an infinitely thin strip where resistive boundary conditions [6,7] are imposed on it. With such a simulation, the new boundary value problem can again be treated either numerically or analytically [8].

Although there are many solutions present in the literature , there are still open questions about the limits of validity of these solutions. On the other hand the proposed problem is of great importance due to numerous practical applications besides modeling of plant elements in the microwave band. Dielectric strip-like structures is widely used in antenna technique (different covers, microstrip, etc.), microwave circuits (resonators, filters).

In this work, a thin dielectric strip will be considered as a model for leaves. Section 2 includes two different approaches for the investigation of the problem. In the first approach, the scattering by a thin dielectric layer of infinite extent is considered and then the solution is revised for the strip case with assuming $ka \gg 1$. The second approach involves the simulation of the dielectric strip by a resistive sheet of width $2a$ and obtaining an approximate solution for $kd \ll 1$ which means a relatively thin strip. In Section 3, the absorption, extinction and scattering cross sections are calculated for both approaches to model leaves with such a strip configuration. Finally, numerical results are given in Section 4 and concluding remarks in Section 5, respectively.

2. INVESTIGATION OF THE PROBLEM

2.1. Diffraction by a Thin Dielectric Layer

2.1a. Formulation

Let us consider a time-harmonic wave incident on a thin dielectric layer, as illustrated in Fig.1. The time dependence $e^{-i\omega t}$ is assumed and supressed. In this two-dimensional problem, let the electric field E have only a z-component which is independent of z. Since the electric field has only z component, the scalar notation is suitable, and at each point in space,

$$E = E^i + E^s \tag{1}$$

is written where E, E^i, and E^s denote the total field, incident field, and scattered field respectively.

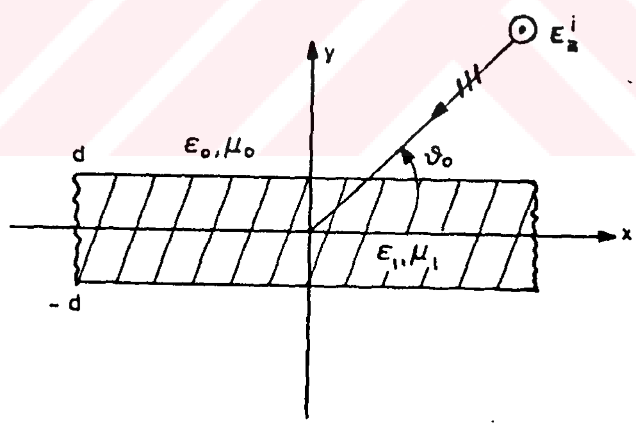

Figure 1

The total field can be written as follows,

$$E(x,y) = E^i + \frac{ik^2(\varepsilon - 1)}{4} \int_S E(x',y') H_0^{(1)}[k\sqrt{(x-x')^2 + (y-y')^2}]dx'dy' \qquad (2)$$

where k is the wave number ($k = 2\pi/\lambda$), ε is the relative dielectric permittivity, and S is the cross section of the layer.

We can rewrite equation (2), as

$$E(x,y) \quad = \quad E^i + TE(x',y'), \qquad (3)$$

where T is the following integral scattering operator. In this case accuracy of inner field estimation by some first terms of the series can be evaulated by considering the contribution of the next terms of the series.

$$TE(x',y') = \frac{ik^2(\varepsilon - 1)}{4} \int_S E(x',y') H_0^{(1)}[k\sqrt{(x-x')^2 + (y-y')^2}]dx'dy'. \qquad (4)$$

In the simple case of a very thin strip, the inner field is considered to be equal to the incedent field. This approximation is widely used in modeling of scattering by plant elements named as the generalized Rayleigh-Gans approach:

$$E(x,y) = E^i(x,y) \quad = \quad e^{-ik(x\cos\vartheta_0 + y\sin\vartheta_0)}, \qquad (5)$$

where ϑ_0 is the angle of incidence.

Considering the point $(x\ ,\ y)$ at any point in space, the multiple scattering Born series is obtained from (3)

$$E(x,y) = E^i + TE^i(x',y') + TTE_i(x''y'') + \ldots \qquad (6)$$

If there is a small parameter in the problem (for example, the strip thickness) it may be shown that series converges rapidly. In this case, accuracy estimation of the inner field by some first terms of the series can be evaulated by considering the contribution of the next terms of the series.

2.1b. Solution

The analytical solution of the integral series in (6) will be obtained by truncating it after the first two terms, which yields

$$E(x,y) = E^i(x,y) + \frac{ik^2(\varepsilon-1)}{4}\int_S E(x',y')H_0^{(1)}[k\sqrt{(x-x')^2+(y-y')^2}]dx'dy' \quad (7)$$

In order to calculate the surface integral the following integral representation of the Hankel function will be used[9]:

$$H_0^{(1)}[k\sqrt{(x-x')^2+(y-y')^2}] = \frac{1}{\pi}\int_{-\infty}^{\infty} e^{ik[(x-x')\alpha+|y-y'|\sqrt{1-\alpha^2}]}\frac{d\alpha}{\sqrt{1-\alpha^2}} \quad (8)$$

By substituting the well-known identity

$$E(x,y) = E^i(x,y) + \frac{ik^2(\varepsilon-1)}{4\pi}\cdot \int_S\int_{-\infty}^{\infty} e^{-ik(x'\cos\vartheta_0+y'\sin\vartheta_0)}e^{ik[(x-x')\alpha+|y-y'|\sqrt{1-\alpha^2}]}\frac{d\alpha dx'dy'}{\sqrt{1-\alpha^2}}, \quad (9)$$

is obtained. From Fig.1, it is seen that the surface S covers the region defined by $y\in(-d,d)$ and $x\in(-\infty,\infty)$; so far the integral

$$I = \frac{ik^2(\varepsilon-1)}{4\pi}\cdot \int_{-d}^{d}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-ikx'\cos\vartheta_0}e^{-iky'\sin\vartheta_0}e^{ik(x-x')\alpha}e^{ik|y-y'|\sqrt{1-\alpha^2}}\frac{d\alpha dx'dy'}{\sqrt{1-\alpha^2}} \quad (10)$$

is written. By interchanging the order of integration and considering the integration over y' separately first gives

$$I_{y'} = \int_{-d}^{d} e^{-iky'\sin\vartheta_0}e^{ik|y-y'|\sqrt{1-\alpha^2}}dy'$$

or

$$I_{y'} = \int_{-d}^{y} e^{-iky'\sin\vartheta_0} e^{ik(y-y')\sqrt{1-\alpha^2}} dy' + \int_{y}^{d} e^{-iky'\sin\vartheta_0} e^{-ik(y-y')\sqrt{1-\alpha^2}} dy'$$

By extracting the terms independent of y'

$$I_{y'} = \int_{-d}^{y} e^{-iky'(\sin\vartheta_0+\sqrt{1-\alpha^2})} e^{iky\sqrt{1-\alpha^2}} dy' + \int_{y}^{d} e^{-iky'(\sin\vartheta_0-\sqrt{1-\alpha^2})} e^{-iky\sqrt{1-\alpha^2}} dy'$$

is found and the integration simply gives

$$I_{y'} = e^{iky\sqrt{1-\alpha^2}} \left\{ \frac{1}{ik(\sin\vartheta_0+\sqrt{1-\alpha^2})} \left[e^{ikd(\sin\vartheta_0+\sqrt{1-\alpha^2})} - e^{-iky(\sin\vartheta_0+\sqrt{1-\alpha^2})} \right] \right\}$$

$$+ e^{-iky\sqrt{1-\alpha^2}} \left\{ \frac{1}{ik(\sin\vartheta_0-\sqrt{1-\alpha^2})} \left[e^{-iky(\sin\vartheta_0-\sqrt{1-\alpha^2})} - e^{-ikd(\sin\vartheta_0-\sqrt{1-\alpha^2})} \right] \right\}$$

When the terms are rearranged

$$I_{y'} = \frac{e^{-iky\sin\vartheta_0}}{ik(\sin\vartheta_0+\sqrt{1-\alpha^2})} \left(e^{ik(\sin\vartheta_0+\sqrt{1-\alpha^2})(d+y)} - 1 \right)$$

$$+ \frac{e^{-iky\sin\vartheta_0}}{ik(\sin\vartheta_0-\sqrt{1-\alpha^2})} \left(1 - e^{-ik(\sin\vartheta_0-\sqrt{1-\alpha^2})(d-y)} \right)$$

or

$$I_{y'} = \frac{e^{-iky\sin\vartheta_0}}{ik(\alpha^2-\cos^2\vartheta_0)} \left[2\sqrt{1-\alpha^2} + (\sin\vartheta_0-\sqrt{1-\alpha^2}) e^{ik(\sin\vartheta_0+\sqrt{1-\alpha^2})(d+y)} \right.$$

$$\left. -(\sin\vartheta_0+\sqrt{1-\alpha^2}) e^{-ik(\sin\vartheta_0-\sqrt{1-\alpha^2})(d-y)} \right]$$

is obtained. For simplicity it will be represented as

$$I_{y'} = e^{-iky\sin\vartheta_0} \cdot f(\alpha, y), \tag{11}$$

with

$$f(\alpha, y) = \frac{1}{ik(\alpha^2 - \cos^2\vartheta_0)} \Big[2\sqrt{1-\alpha^2} + (\sin\vartheta_0 - \sqrt{1-\alpha^2})e^{ik(\sin\vartheta_0 + \sqrt{1-\alpha^2})(d+y)}$$

$$-(\sin\vartheta_0 + \sqrt{1-\alpha^2})e^{-ik(\sin\vartheta_0 - \sqrt{1-\alpha^2})(d-y)}\Big]. \tag{12}$$

Now, integration over x' separately gives

$$I_{x'} = \int_{-\infty}^{\infty} e^{-ikx'(\cos\vartheta_0 + \alpha)} dx' = \frac{2\pi}{k}\delta(\cos\vartheta_0 + \alpha). \tag{13}$$

Finally, the triple integral I in eq.(10) is reduced to an integration over α :

$$I = \frac{ik^2(\varepsilon - 1)}{4\pi} \int_{-\infty}^{\infty} \frac{2\pi}{k} e^{ikx\alpha} e^{-iky\sin\vartheta_0} f(\alpha, y)\delta(\cos\vartheta_0 + \alpha)\frac{d\alpha}{\sqrt{1-\alpha^2}}.$$

The presence of the delta distribution function simplifies the calculation of this integral and enables one to write it by substituting $\alpha = -cos\vartheta_0$ which yields:

$$I = \frac{ik(\varepsilon - 1)}{2sin\vartheta_0} E_i(x, y) f(-\cos\vartheta_0, y). \tag{14}$$

But, it should be noted that when $\alpha = -cos\vartheta_0$ is substituted in $f(\alpha, y)$

$$f(\alpha = -\cos\vartheta_0) = \frac{0}{0}$$

the result is undefined. It is necessary to expand $f(\alpha, y)$ by small parameter $k(d \pm y)$. First, the following new variables will be introduced

$$(\sin\vartheta_0 \pm \sqrt{1-\alpha^2}) = \beta^{\pm}, \qquad k(d \pm y) = x^{\pm}$$

to write $f(\alpha, y)$ as:

$$f(\alpha, y) = \frac{1}{ik(\alpha^2 - \cos^2\vartheta_0)}\left[2\sqrt{1-\alpha^2} + \beta^- e^{i\beta^+ x^+} - \beta^+ e^{-\beta^- x^-}\right]. \qquad (15)$$

For small $x^{\pm}$, the following approximations can be done from

$$e^{\pm i\beta^{\pm} x^{\pm}} \simeq 1 \pm i\beta^{\pm} x^{\pm},$$

which yields

$$f(\alpha, y) \simeq \frac{1}{ik(\alpha^2 - \cos^2\vartheta_0)}\left[2\sqrt{1-\alpha^2} + \beta^-(1 + i\beta^+ x^+) - \beta^+(1 - i\beta^- x^-)\right],$$

or

$$f(\alpha, y) = \frac{1}{ik(\alpha^2 - \cos^2\vartheta_0)}\left[2\sqrt{1-\alpha^2} + \beta^- + i\beta^+\beta^- x^+ - \beta^+ + i\beta^-\beta^+ x^-\right].$$

Now, the terms appearing in $f(\alpha, y)$ can be easily rearranged as

$$\beta^- - \beta^+ = (\sin\vartheta_0 - \sqrt{1-\alpha^2}) - (\sin\vartheta_0 + \sqrt{1-\alpha^2}) = -2\sqrt{1-\alpha^2}$$

and

$$\begin{aligned} i\beta^+\beta^- x^+ + i\beta^-\beta^+ x^- &= i(\sin\vartheta_0 + \sqrt{1-\alpha^2})(\sin\vartheta_0 - \sqrt{1-\alpha^2})k(d+y) \\ &+ i(\sin\vartheta_0 - \sqrt{1-\alpha^2})(\sin\vartheta_0 + \sqrt{1-\alpha^2})k(d-y) \\ &= 2ikd(\sin^2\vartheta_0 - (1-\alpha^2)), \end{aligned}$$

which gives

$$f(\alpha, y) = \frac{1}{ik(\alpha^2 - \cos^2\vartheta_0)} \cdot 2ikd(\alpha^2 - \cos^2\vartheta_0),$$

$$\text{yielding} \lim_{\alpha \to -\cos\vartheta_0} f(\alpha, y) \cong 2d. \tag{16}$$

By substituting in (14) and using it together with eqs.(9,10)

$$E(x,y) = E^i(x,y) + \frac{ik(\varepsilon-1)d}{\sin\vartheta_0} E^i(x,y) \quad \vartheta_0 \neq n\pi; n = 0, 1, 2, \ldots \tag{17}$$

is obtained.

2.2. Diffraction by a Thin Dielectric Strip

In the previous section, the scattered field for a dielectric layer of infinite extent is obtained as given in (17). Now, this solution will be used to calculate the scattered field by a thin dielectric strip. Again E-polarized time-harmonic plane wave incidence is assumed , as illustrated in Fig.2. The time dependence is assumed as $e^{-i\omega t}$ and supressed throughout the analysis.

The total field will be written as given in (2)

$$E(x,y) = E^i + \frac{ik^2(\varepsilon-1)}{4}\int_S E(x',y')H_0^{(1)}(k\sqrt{(x-x')^2+(y-y')^2})dx'dy' \quad (18)$$

where S is the cross section of the strip. Analysis will be performed in a manner similar to the approach used for infinite layer case. So, first the well-known integral representation of the Hankel function is substituted

$$\begin{aligned} E(x,y) \;&=\; E^i + \frac{ik^2(\varepsilon-1)}{4\pi}\cdot \\ &\int_{-d}^{d}\int_{-\infty}^{\infty}\int_{-a}^{a} e^{-ik(x'\cos\vartheta_0+y'\sin\vartheta_0)}e^{ik[(x-x')\alpha+|y-y'|\sqrt{1-\alpha^2}]}\frac{dx'd\alpha dy'}{\sqrt{1-\alpha^2}} \end{aligned} \quad (19)$$

and,integration over y' is written separately

$$\int_{-d}^{d} e^{-iky'\sin\vartheta_0}e^{ik|y-y'|\sqrt{1-\alpha^2}}dy' = e^{-iky\sin\vartheta_0}f(\alpha,y)$$

where $f(\alpha,y)$ is identical to (12).

$$E(x,y) = E^i + \frac{ik^2(\varepsilon-1)}{4\pi} \cdot$$

$$\int_{-\infty}^{\infty}\int_{-a}^{a} e^{-ikysin\vartheta_0} f(\alpha,y) e^{-ikx'\cos\vartheta_0} e^{ik(x-x')\alpha} \frac{dx'd\alpha}{\sqrt{1-\alpha^2}} \tag{20}$$

Now,integration over x' separately gives

$$\int_{-a}^{a} e^{-ikx'(cos\vartheta+\alpha)}dx' = \frac{2sinka(cos\vartheta_0+\alpha)}{k(cos\vartheta_0+\alpha)}$$

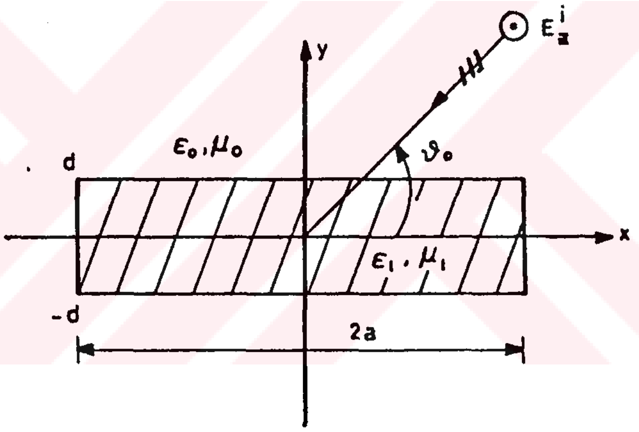

Figure 2

The total field becomes,

$$E(x,y) = E^i(x,y) + \frac{ik^2(\varepsilon-1)}{2\pi}\int_{-\infty}^{\infty}\frac{\sin(ka(\cos\vartheta_0+\alpha))}{k(\cos\vartheta_0+\alpha)} e^{-iky\sin\vartheta_0} f(\alpha,y) e^{ik\alpha x}\frac{d\alpha}{\sqrt{1-\alpha^2}}. \tag{21}$$

the following identity is taken into account

$$\lim_{ka\to\infty}\frac{\sin(ka(\cos\vartheta_0+\alpha))}{(\cos\vartheta_0+\alpha)} = \pi\delta(\cos\vartheta_0+\alpha), \tag{22}$$

which means that the wavelength is very small compared to the width of the strip or the strip width extends to infinity. With this approximation, the integration in (21) can easily be written which yields the total field as identical to the infinite layer case :

$$E(x,y) = E^i + \frac{ik(\epsilon-1)d}{\sin\vartheta_0} E^i(x,y) \quad \vartheta_0 \neq n\pi; n = 0,1,2,\dots \qquad (23)$$

It is obvious from this result that the approximation ($a/\lambda \ll 1$) given in (22) implies that edge diffraction effects are neglected.

Now, in order to investigate the effects of the medium and material properties on the scattering mechanism, the scattering amplitude will be calculated which in general defined as

$$P(\vartheta,\vartheta_0) \sim E^s(\rho,\vartheta)[A(\rho)exp(ik\rho + i\alpha)]^{-1}.$$

So, the first step is to calculate this scattered field and as previously done, the closed form expression of it will be taken from (4) by inserting $E(x',y') = E^i(x',y')$:

$$E^s(x',y') = \frac{ik^2(\epsilon-1)}{4}\int_{-d}^{d}\int_{-a}^{a} E^i(x',y')H_0^{(1)}[k\sqrt{(x-x')^2+(y-y')^2}]dx'dy'.$$

Since the scattering amplitude is defined for the far field region, the integrand of the above expression can be simplified. Substitute $x = \rho cos\vartheta$ and $y = \rho sin\vartheta$ in the argument of the Hankel function :

$$k\sqrt{(x-x')^2+(y-y')^2} = k\rho\sqrt{1 - \frac{2x'}{\rho}cos\vartheta + (\frac{x'}{\rho})^2 - \frac{2y'}{\rho}sin\vartheta + (\frac{y'}{\rho})^2}$$

which is approximately equal to $k\rho(1 - \frac{x'}{\rho}cos\vartheta - \frac{y'}{\rho}sin\vartheta)$ for $\rho \gg \lambda$. This gives the asymptotic expansion of the Hankel function for large arguments as

$$H_0^{(1)}[k\rho(1 - \frac{x'}{\rho}cos\vartheta - \frac{y'}{\rho}sin\vartheta)] \simeq \sqrt{\frac{2}{\pi k\rho(1 - \frac{x'}{\rho}cos\vartheta - \frac{y'}{\rho}sin\vartheta)}}\, e^{ik\rho(1-\frac{x'}{\rho}cos\vartheta - \frac{y'}{\rho}sin\vartheta) - i\frac{\pi}{4}}$$

$$= \sqrt{\frac{2}{\pi k\rho}} e^{ik\rho - i\frac{\pi}{4}} e^{-ik(x'\cos\vartheta + y'\sin\vartheta)} + O[\frac{1}{(k\rho)^{3/2}}].$$

The scattering field integral is

$$E^s(x,y) = \frac{ik^2(\epsilon-1)}{4}\sqrt{\frac{2}{\pi k\rho}} e^{i(k\rho-\pi/4)} \int_{-d}^{d}\int_{-a}^{a} e^{-ik(x'\cos\vartheta_0 + y'\sin\vartheta_0)} e^{-ik(x'\cos\vartheta + y'\sin\vartheta)} dx'dy'$$

which gives the scattering amplitude as

$$P(\vartheta,\vartheta_0) = \frac{ik^2(\epsilon-1)}{4} e^{-ikx'(\cos\vartheta + \cos\vartheta_0)} e^{-iky'(\sin\vartheta + \sin\vartheta_0)} dx'dy'.$$

When the integrations are accomplished

$$P(\vartheta,\vartheta_0) = (\epsilon-1)\frac{\sin[ka(\cos\vartheta + \cos\vartheta_0)]}{(\cos\vartheta + \cos\vartheta_0)} \cdot \frac{\sin[kd(\cos\vartheta + \cos\vartheta_0)]}{(\cos\vartheta + \cos\vartheta_0)}$$

is obtained and assuming the thickness of the strip very small ($kd \to 0$) it yields:

$$P(\vartheta,\vartheta_0) \sim ikd(\epsilon-1)\frac{\sin[ka(\cos\vartheta + \cos\vartheta_0)]}{(\cos\vartheta + \cos\vartheta_0)}.$$

2.3. Diffraction by a Resistive Strip

2.3a. Formulation

Thin strips of lossy material are of obvious interest for cross section reduction purposes. A mathematical model of such a configuration is a resistive strip which is very useful in the simulation of thin dielectric strips. An electrically resistive strip is simply an electric current sheet whose strength is proportional to the tangential electric field at its surface. Its electromagnetic properties are completely specified by its resistivity R in ohms . In the special case R = 0 the strip is perfectly conducting, whereas if R = ∞ the strip is no longer present. For a material of large conductivity σ,

$$R = (\sigma 2d)^{-1}$$

where 2d is the thickness of the strip, and an alternative expansion is

$$R = \frac{iZ}{(\epsilon - 1)k2d}$$

valid if $|\epsilon - 1| \gg 1$. Where k and Z (= 1/Y) are the propagation constant and intrinsic impedance of the, respectively, and ϵ is the relative permittivity of the strip material.

The strip illustrated in Fig.3 will be simulated by a resistivity R occupying the portion $-a \leq x \leq a$, $-\infty < z < \infty$ of the plane y = 0 of a Cartesian coordinate system (x,y,z). The resistive strip is illuminated by an E-polarized plane electromagnetic wave as given (5).

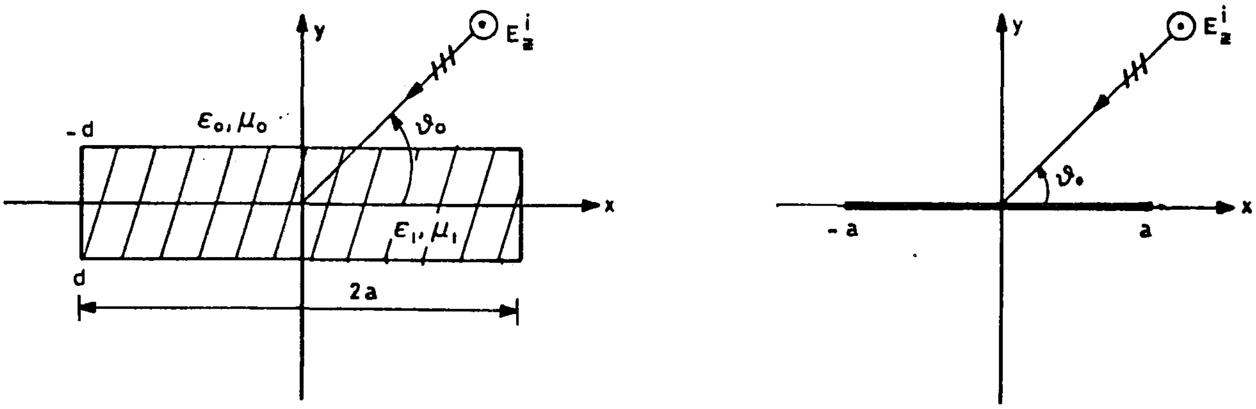

Figure 3

Since the total electric field also has only a z component, the conditions at the surface of the strip can be written as

$$E_z(x,0_+) = E_z(x,0_-) = RJ_z(x) \qquad (24)$$

$$\vec{n} \times \vec{H}(x,0_+) - \vec{n} \times \vec{H}(x,0_-) = \vec{J}(x) \qquad (25)$$

where the subscripts (+) and (-) denote the upper (approaching from $y > 0$ half space) and lower (approaching from $y < 0$ half space) surfaces of the strip. $\vec{n}$ is the unit vector normal drawn upward from the upper side of the strip and $J_z(x)$ is the total current being supported by the strip.
The total current can be rewritten as follows,

$$J_z(x) = -[H_x(x,0_+) - H_x(x,0_-)] \ .$$

The scattered field which will be created by such a current distribution for $y > 0$ and $y < 0$ is [10]

$$E^s = -\frac{kZ}{4}\int_{-a}^{a} J(x')H_0^{(1)}[k\sqrt{(x-x')^2+y^2}]dx' \qquad (26)$$

where $H_0^{(1)}$ is the cylindrical Hankel function of the first kind of zero order and Z is the intrinsic impedance of free space as usual. The following expressions, $x = \rho cos\vartheta$ and $y = \rho sin\vartheta$, are substituted in the arguments of the Hankel function:

$$k\sqrt{(x-x')^2+y^2} \quad = \quad k\sqrt{(\rho cos\vartheta - x')^2 + \rho^2 sin^2\vartheta}.$$

Assuming that observation points are far away from the current sheet

$$k\sqrt{(x-x')^2+y^2} = k\rho\sqrt{1 - \frac{2cos\vartheta x'}{\rho} + (\frac{x'}{\rho})^2} \simeq k\rho(1 - \frac{x'cos\vartheta}{\rho})$$

is obtained.

For the Hankel function $H_0^{(1)}[k\rho(1-(x'/\rho)cos\vartheta)]$ the following asymptotik expansion is given for large arguments [11]:

$$H_0^{(1)}[k\rho(1-\frac{x'cos\vartheta}{\rho})] \quad \simeq \quad \sqrt{\frac{2}{\pi k\rho(1-\frac{x'cos\vartheta}{\rho})}}e^{ik\rho(1-\frac{x'cos\vartheta}{\rho})}e^{-i\frac{\pi}{4}}.$$

The magnitude of the above expression can be approximated as:

$$\sqrt{\frac{2}{\pi k\rho(1-\frac{x'cos\vartheta}{\rho})}} \quad = \quad \sqrt{\frac{2}{\pi k\rho}}\ \frac{1}{1-\frac{x'cos\vartheta}{2\rho}}$$

$$\simeq \quad \sqrt{\frac{2}{\pi k\rho}}+O(\frac{1}{k\rho^{3/2}}).$$

which gives the following asymptotic expansion for $H_0^{(1)}$

$$H_0^{(1)}[k\rho(1-\frac{x'cos\vartheta}{\rho})] \quad = \quad \sqrt{\frac{2}{\pi k\rho}}e^{ik\rho-\frac{i\pi}{4}}\quad e^{-ikx'cos\vartheta} \tag{27}$$

$$= \quad \sqrt{\frac{2}{\pi k\rho}}e^{ik\rho-\frac{i\pi}{4}}\quad e^{-ikx'cos\vartheta}+0(\frac{1}{k\rho^{\frac{3}{2}}}). \tag{28}$$

So, the far zone field expression is

$$E^s \sim \sqrt{\frac{2}{\pi k\rho}}e^{i(k\rho-\frac{\pi}{4})}P(\vartheta,\vartheta_0), \tag{29}$$

with the complex scattering amplitude P as

$$P(\vartheta,\vartheta_0) = -\frac{kZ}{4}\int_{-a}^{a} J(x')e^{-ikx'cos\vartheta}dx', \tag{30}$$

where ϑ and ϑ_0 denote the observation and incidence angles, respectively.

In terms of $P(\vartheta,\vartheta_0)$ the two-dimensional scattering cross section (or length) is[10] defined as

$$\sigma(\vartheta,\vartheta_0) = \frac{2\lambda}{\pi} \mid P(\vartheta,\vartheta_0) \mid^2 . \tag{31}$$

As is obvious from(31) the determination of the scattering cross section requires to know the current sheet $J_z(x)$.

2.3.b. Solution

Since $J_z(x)$ is the current supported by the resistive strip, it can be calculated by using the boundary conditions imposed on the strip. The application of the boundary condition (24) to the total electric field at $y = 0$ gives :

$$RJ_z(x) = e^{-ikxcos\vartheta_0} - \frac{kZ}{4}\int_{-a}^{a} J_z(x')H_0^{(1)}(k \mid x - x' \mid)dx'. \tag{32}$$

The following equality is written for the Hankel function from (8)

$$H_0^{(1)}(k \mid x - x' \mid) = \frac{1}{\pi}\int_{-\infty}^{\infty} e^{ik(x-x')\alpha}\frac{d\alpha}{\sqrt{1-\alpha^2}}, \tag{33}$$

and when substituted to the above equation

$$RJ_z(x) = e^{-ikxcos\vartheta_0} - \frac{kZ}{4}\int_{-a}^{a} J_z(x') \quad \frac{1}{\pi}\int_{-\infty}^{\infty} e^{ik(x-x')\alpha}\frac{d\alpha}{\sqrt{1-\alpha^2}}dx'$$

is obtained. Now, by interchanging the order of integration

$$RJ_z(x) = e^{-ikx\cos\vartheta_0} - \frac{kZ}{4\pi}\int_{-\infty}^{\infty} e^{ikx\alpha}\frac{d\alpha}{\sqrt{1-\alpha^2}}\int_{-a}^{a} J_z(x')e^{-ikx'\alpha}dx'$$

and defining

$$J_z(\alpha) = \int_{-a}^{a} J_z(x')e^{-ikx'\alpha}dx' \tag{34}$$

it yields

$$RJ_z(x) = e^{-ikx\cos\vartheta_0} - \frac{kZ}{4\pi}\int_{-\infty}^{\infty} J_z(\alpha)e^{ikx\alpha}\frac{d\alpha}{\sqrt{1-\alpha^2}}. \tag{35}$$

By multiplying the both sides of the integral equation (36) by $e^{-ikx\beta}$, and integrating it with respect to x in the range $[-a, a]$

$$\int_{-a}^{a} RJ_z(x)e^{-ikx\beta}dx = \int_{-a}^{a} e^{-ikx\cos\vartheta_0}e^{-ikx\beta}dx - \frac{kZ}{4\pi}\int_{-a}^{a}\int_{-\infty}^{\infty} J(\alpha)e^{ikx\alpha}e^{-ikx\beta}\frac{d\alpha dx}{\sqrt{1-\alpha^2}}$$

is found. By performing the integrations with respect to x and using the integral transform defined in (35), it yields

$$RJ_z(\beta) = \frac{2}{k}\frac{\sin[ka(\cos\vartheta_0+\beta)]}{(\cos\vartheta_0+\beta)} - \frac{kZ}{4\pi}\int_{-\infty}^{\infty} J_z(\alpha)\frac{2}{k}\frac{\sin[ka(\alpha-\beta)]}{(\alpha-\beta)}\frac{d\alpha}{\sqrt{1-\alpha^2}}$$

Now, if the limit equality in (22) is taken into account

$$RJ_z(\beta) = \frac{2}{k}\frac{\sin[ka(\cos\vartheta_0+\beta)]}{(\cos\vartheta_0+\beta)} - \frac{kZ}{4\pi}\int_{-\infty}^{\infty} J_z(\alpha)\frac{2}{k}\pi\delta(\alpha-\beta)\frac{d\alpha}{\sqrt{1-\alpha^2}}$$

is obtained which gives

$$RJ_z(\beta) = \frac{2}{k}\frac{sin[ka(cos\vartheta_0 + \beta)]}{(cos\vartheta_0 + \beta)} - \frac{Z}{2}J_z(\beta)\frac{1}{\sqrt{1-\beta^2}}$$

or

$$(R + \frac{Z}{2\sqrt{1-\beta^2}})J(\beta) = \frac{2}{k}\frac{sin[ka(cos\vartheta_0 + \beta)]}{(cos\vartheta_0 + \beta)}.$$

$J_z(\beta)$ can easily be found as

$$J_z(\beta) = \frac{2}{k}\frac{1}{(R + \frac{Z}{2\sqrt{1-\beta^2}})}\frac{sin[ka(cos\vartheta_0 + \beta)]}{(cos\vartheta_0 + \beta)},$$

or

$$J_z(\beta) = \frac{4\sqrt{1-\beta^2}}{k(2R\sqrt{1-\beta^2} + Z)} \cdot \frac{sin[ka(cos\vartheta_0 + \beta)]}{(cos\vartheta_0 + \beta)}.$$

If $\beta = cos\vartheta$ is subsituted in (31) with taking (35) also in consideration, then complex scattering amplitude $P(\vartheta, \vartheta_0)$ can be written as

$$P(\vartheta, \vartheta_0) = -\frac{kZ}{4}J(cos\vartheta) \tag{36}$$

or

$$P(\vartheta, \vartheta_0) = \frac{Zsin\vartheta}{2Rsin\vartheta + Z}\frac{sin[ka(cos\vartheta_0 + cos\vartheta)]}{(cos\vartheta_0 + cos\vartheta)} \tag{37}$$

is obtained.

3. MICROWAVE MODELING OF A LEAF

The use of microwaves for object identification purposes being subject to enormous researches and publications include different remote sensing techniques. The main aim of all these techniques consists of determining the geometrical and physical properties of remote or inaccesible bodies by considering their effect on the propagation of waves which requires knowledge of the interaction of waves with complex structures. This knowledge at all frequencies and at all aspects can be provided by measuring or calculating the scattered field or radar cross section of the object.

Microwave progation through vegetation layer can not be analyzed rigorously; therfore, approximate models are used. These models relate the radiative parameters of vegetation such as brightness temperature or backscattering coefficient to biometrical ones such as type and stage of growth, shape and size of leaves and stalks,...etc. Electrodynamic models rely on the assumption of vegetation either as a collection of randomly distributed lossy scatterers(discrete approach) or as a slab with random dielectric permittivity(continuous approach). Discrete approach is characterized by the scattering mechanism of a single scatterer; so, it is important to examine microwave scattering and absorption by different individual plant elements.

In this work, a leaf is modeled as an individual plant element. Leaves are key feature of any vegetation canopy and it is necessary to develop an efficient and efective technique for predicting the scattering from a single leaf. Le Vine et al.[12] and Willis et al.[13] at microwave frequencies have proposed several methods based on physical optics approximation applied to a uniform slab. On the other hand, Senior et al.[14] and Sarabandi et al.[15] have shown that physical optics in conjuction with a resistive sheet simulation can be used for modeling leaves. For millimeter wavelengths, where the thickness is a significiant fraction of a wavelength, Sarabandi et al.[16] introduced a model again based on physical optics approximation. The models proposed here neglects edge diffraction effects and the first method considers the scattering operator corresponding to a dielectric strip, while the second method relies on resistive sheet simulation.

The absorption cross section of the dielectric strip is given by the expression[1,17]

$$\sigma_a = \frac{k \int_S \mid \mathbf{E} \mid^2 \epsilon'' dx' dy'}{\mid \mathbf{E}^i \mid^2} \tag{38}$$

When $E(x,y) = E^i(x,y)$ is assumed

$$\sigma_a = k\epsilon'' S \tag{39}$$

is obtained which corresponds to the absorption length of a "Rayleigh" particle. Scattering cross section may be calculated with this approximation by the summation of scattering intensity:

$$\sigma_s = (2kd)^2 \mid \epsilon - 1 \mid^2 \frac{1}{2\pi k} \int_0^{2\pi} \frac{sin^2[ka(cos\vartheta_0 + cos\vartheta)]}{(cos\vartheta_0 + cos\vartheta)^2} d\vartheta \tag{40}$$

where $2d$ is the thickness of the strip, $2a$ is the width, k is the wave number, ϵ is the dielectric permittivity, and ϑ_0 is the angle of incidence.

The extinction cross section is given by the expression[8],

$$\sigma_e = \sigma_a + \sigma_s \tag{41}$$

It is necessary to recall that in the above mentioned approach, the optical theorem(the law of energy conservation) is violated that may result in an error in the calculation of radiative parameters of a vegetation canopy modeled by the collection of strips.

4. NUMERICAL RESULTS

The accuracy of approximating a leaf by a dielectric strip may be established by taking into account the first three terms of the series given in (6). Some results of the calculation of the relative extinction cross section $(\sigma_r/2a)$ are presented in Fig.4. Curve (1) corresponds to the Rayleigh-Gans approximation while curve (2) corresponds to the dielectric strip model with the first two terms of the series expression being taken into consideration. The comparison of these two curves shows that these approaches are in good agreement for relatively small values of $2kd$. It can be seen that the two methods can be used for cases where $2kd \leq 0.03$ and $ka > 2$ which implies a restriction for the frequency region which they are applicable. By using the dielectric permittivity values at this frequency range, the condition can also be expressed as $2kd|\epsilon - 1| \leq 0.5$. Considering that for the thickness($2d$) a typical leaf is between $0.5mm$ and $1mm$, the frequency range is determined easily as $f \leq 8.5GHz$. This shows that the Rayleigh-Gans approximation is applicable at microwave frequencies where the thickness of a typical leaf is comparable to the free space wavelength. At millimeter wavelengths the thickness can be a significiant fraction of a wavelength, where the method proposed in this work may yield a better simulation.

Let us now examine the capability of a resistive strip model to simulate accurately a thin dielectric strip. For this purpose, the echo-width for the E_z field is investigated by simulating a dielectric strip of $\lambda/40$ thickness and 5λ width with relative permittivity $\epsilon = (4 - j0.4)$. These parameter values are chosen identical to the values used by Richmond where he has studied dielectric strip problem by moment method [ ]. For resistive strip simulation the echo-width

$$\sigma = \frac{2\lambda}{\pi}\left[P(\vartheta, \vartheta_0)\right]^2$$

is calculated by using the expression given in eq.(38). Fig.5 shows the E_z backscatter echo-width for resistive strip simulation (solid line) and moment method solution(dashed line with cross signs). It is obviously seen that our results are in good agreement with the results given by Richmond[]. On the other hand, in Fig.6,7,8 and 9 the results related to different resistivities and strip widths are given and all of them agree with the moment methods results given by Richmond[]. The comparison of Fig.6 and Fig.7 with Fig.8 and Fig.9, respectively, shows the effect of the width of the strip on scattering phenomena. It is obvious that if the strip width is large compared to the free space wavelength, multiple scattering will occur and so edge diffraction contribution will be important. The increase in the number of ripples with the increase in the width of the strip is due to this multiple edge diffraction effect. On the other hand, the comparison of the curves given by Fig.6 and Fig.8 with Fig.7 and Fig.9, respectively, shows that pure real resistivity values and compared the pure imaging ones result a decrease in amplitude although the behaviour of echo-width is unchanged.

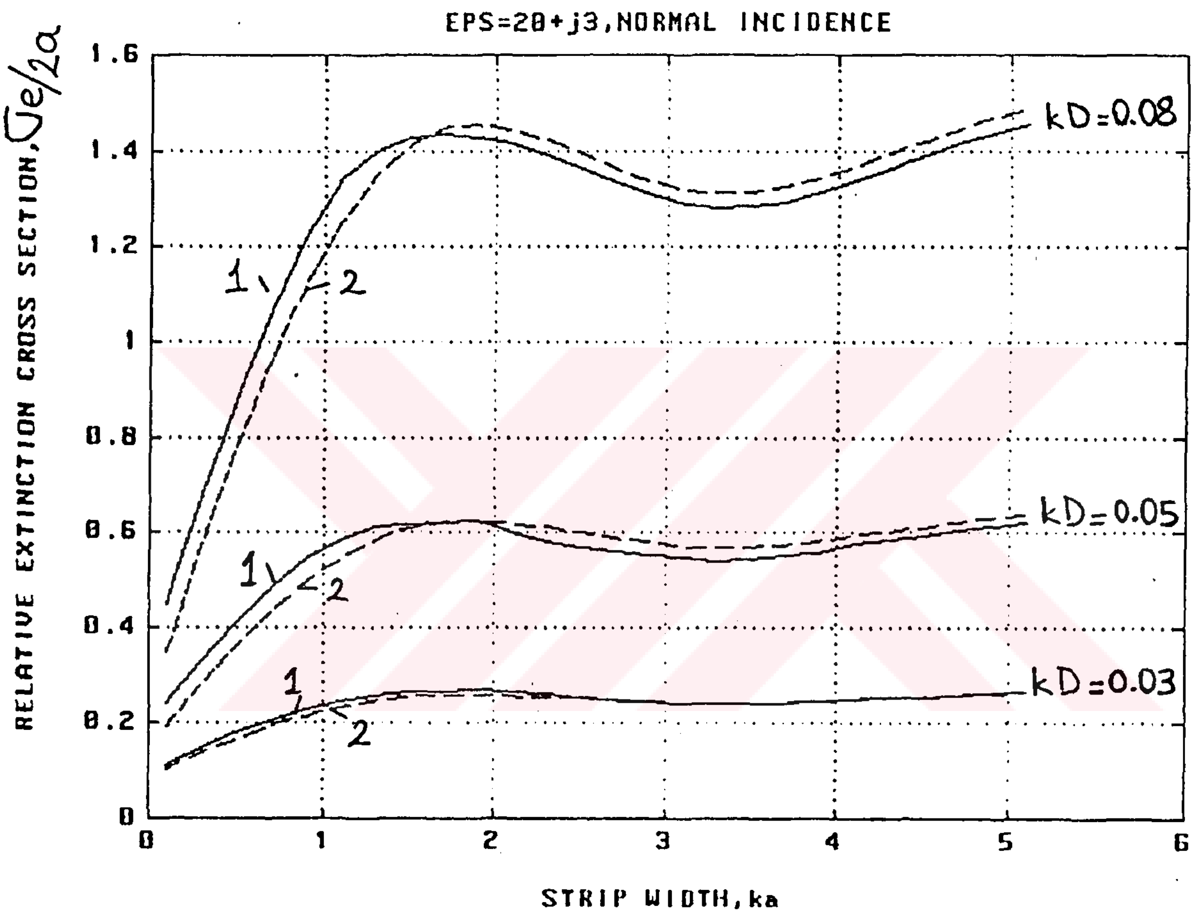

Figure 4. Spectral dependence of relative extinction cross section ($\sigma/2a$) for strip-like plant elements when $\epsilon = 20 + j3$. Curves denoted by (1) and (2) corresponds to the Rayleigh-Gans approximation, and the current method with the second terms of the series taken into account, respectively.

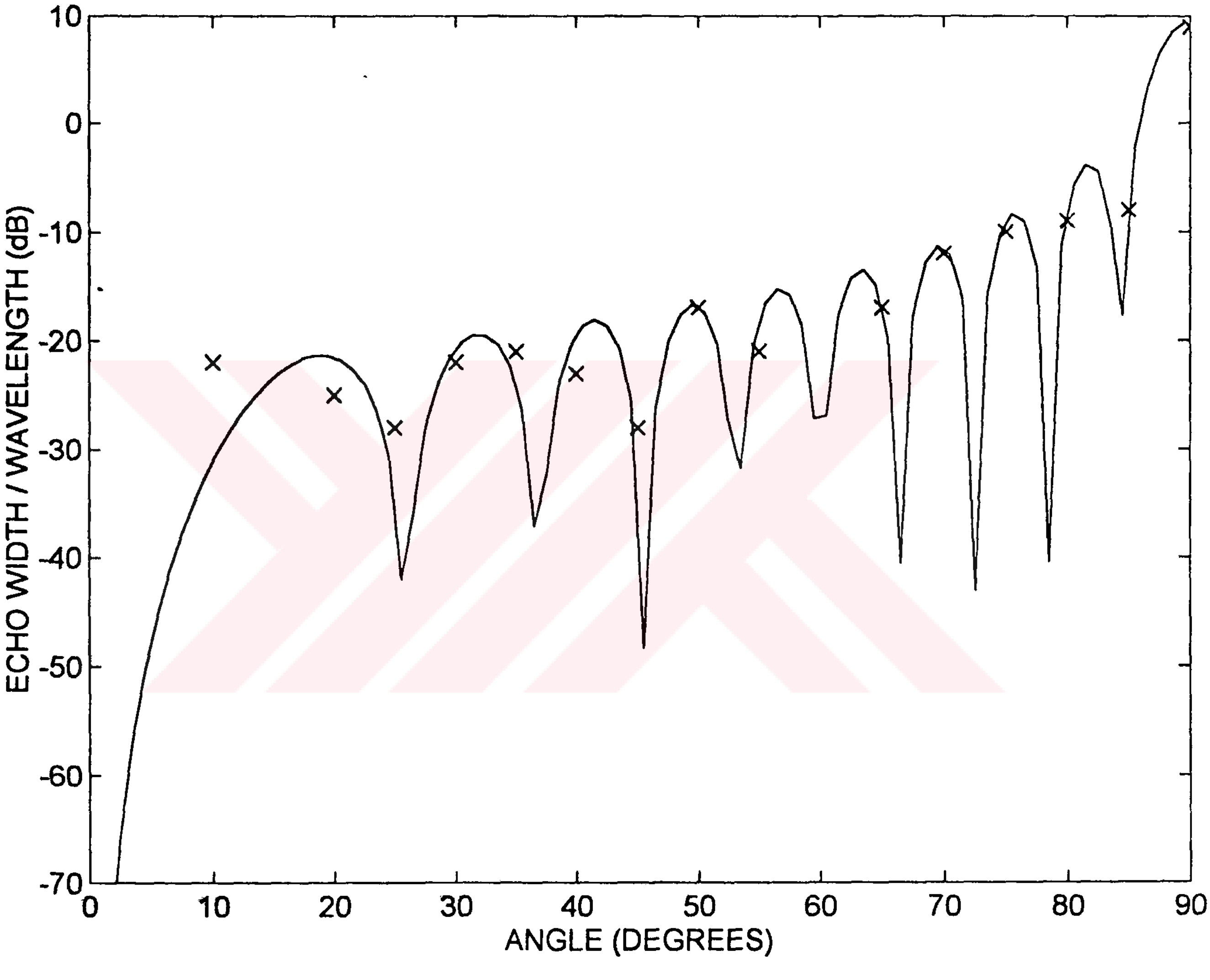

Figure 5. E_z backscatter echo width of a dielectric strip of $\lambda/40$ thickness being simulated by a resistive strip(full line). Moment method result for the same configuration is shown with cross(x) on the same diagram for comparison.

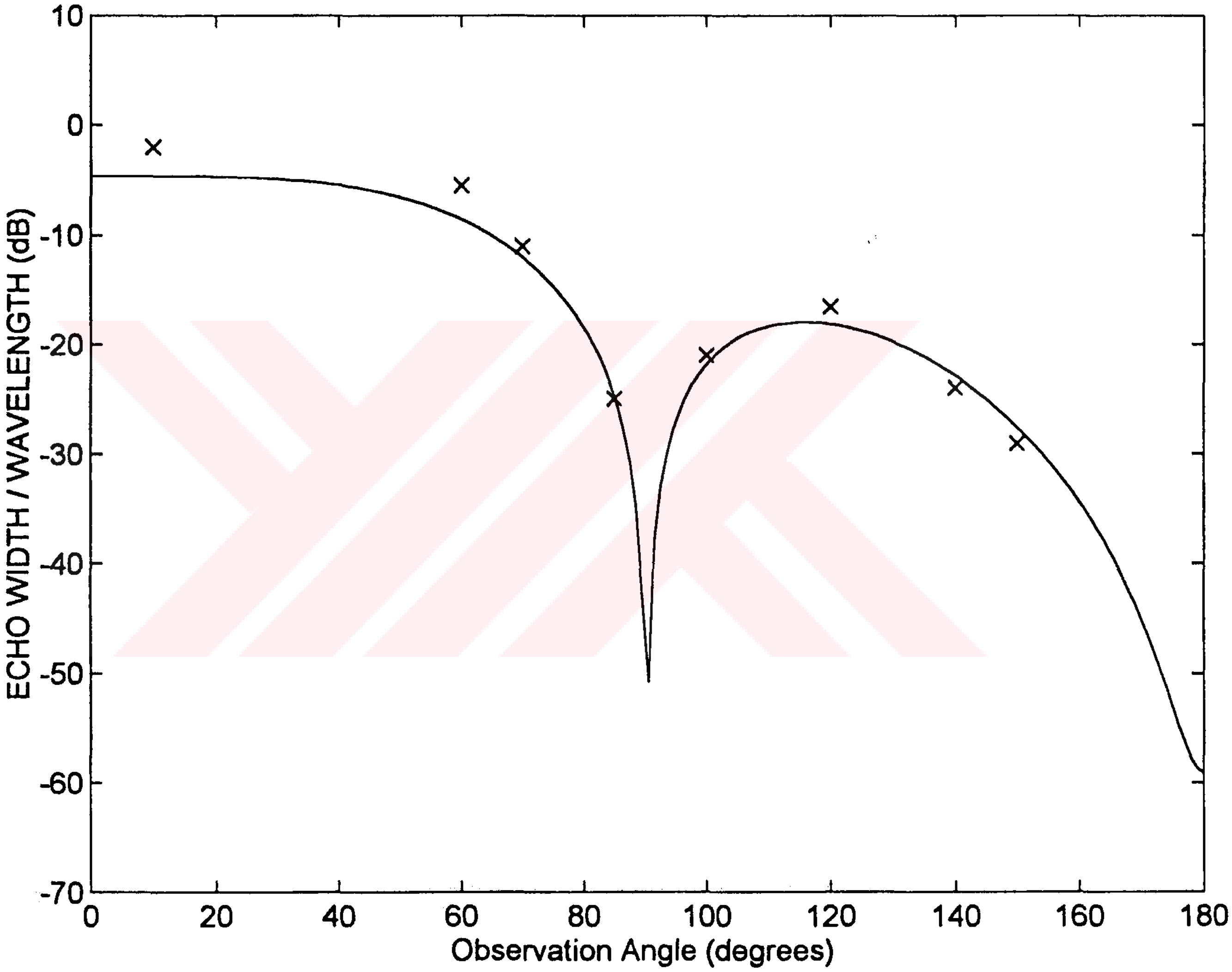

Figure 6. E_z bistatic echo width of the high-frequency solution(full line) compared with the moment method data (x) for a 1 λ -wide resistive strip with η = i4; angle of incidence = 175°.

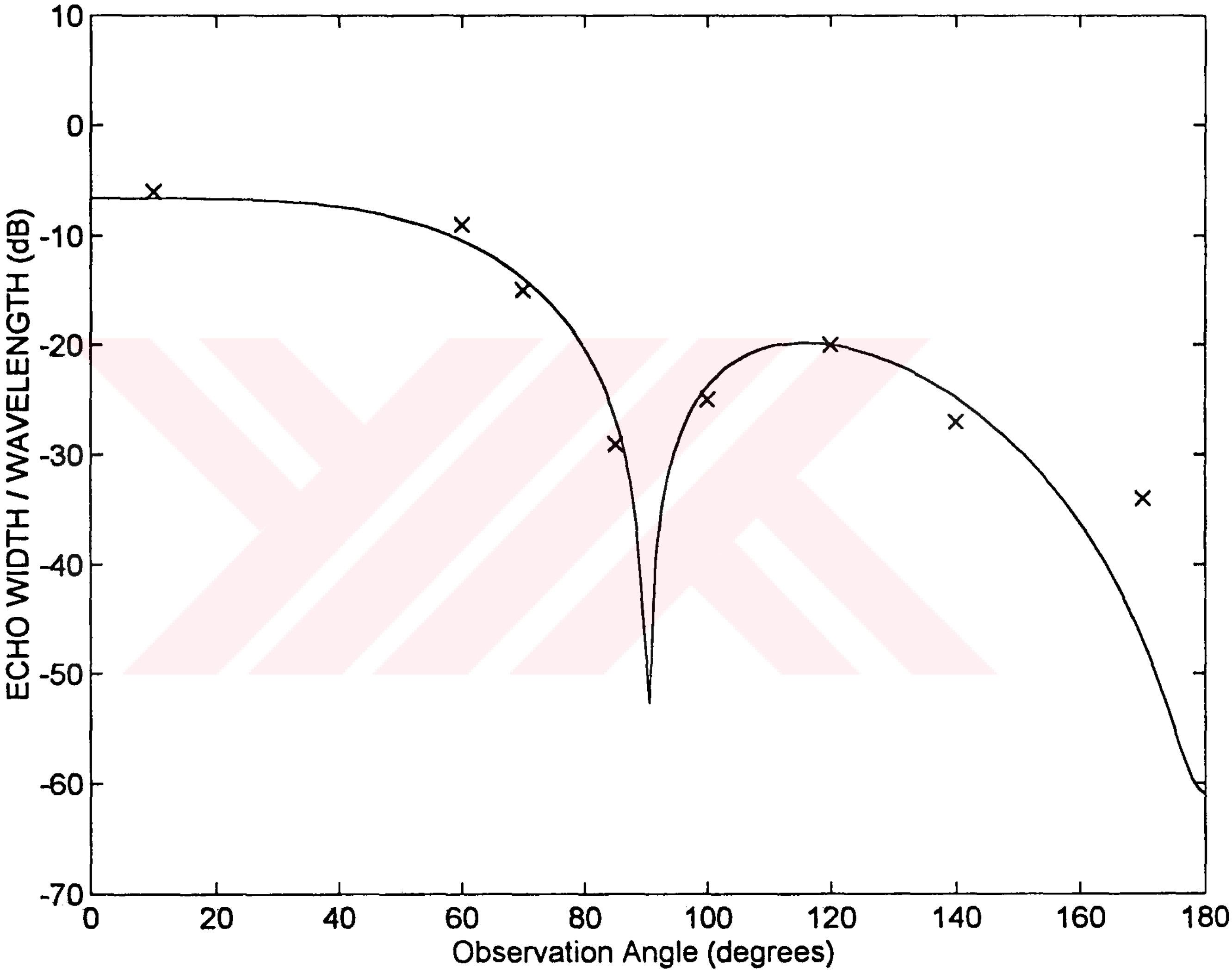

Figure 7. E_z bistatic echo width of the high-frequency solution(full line) compared with moment method data (x) for a 1 λ -wide resistive strip with η =4; angle of incidence = 175°.

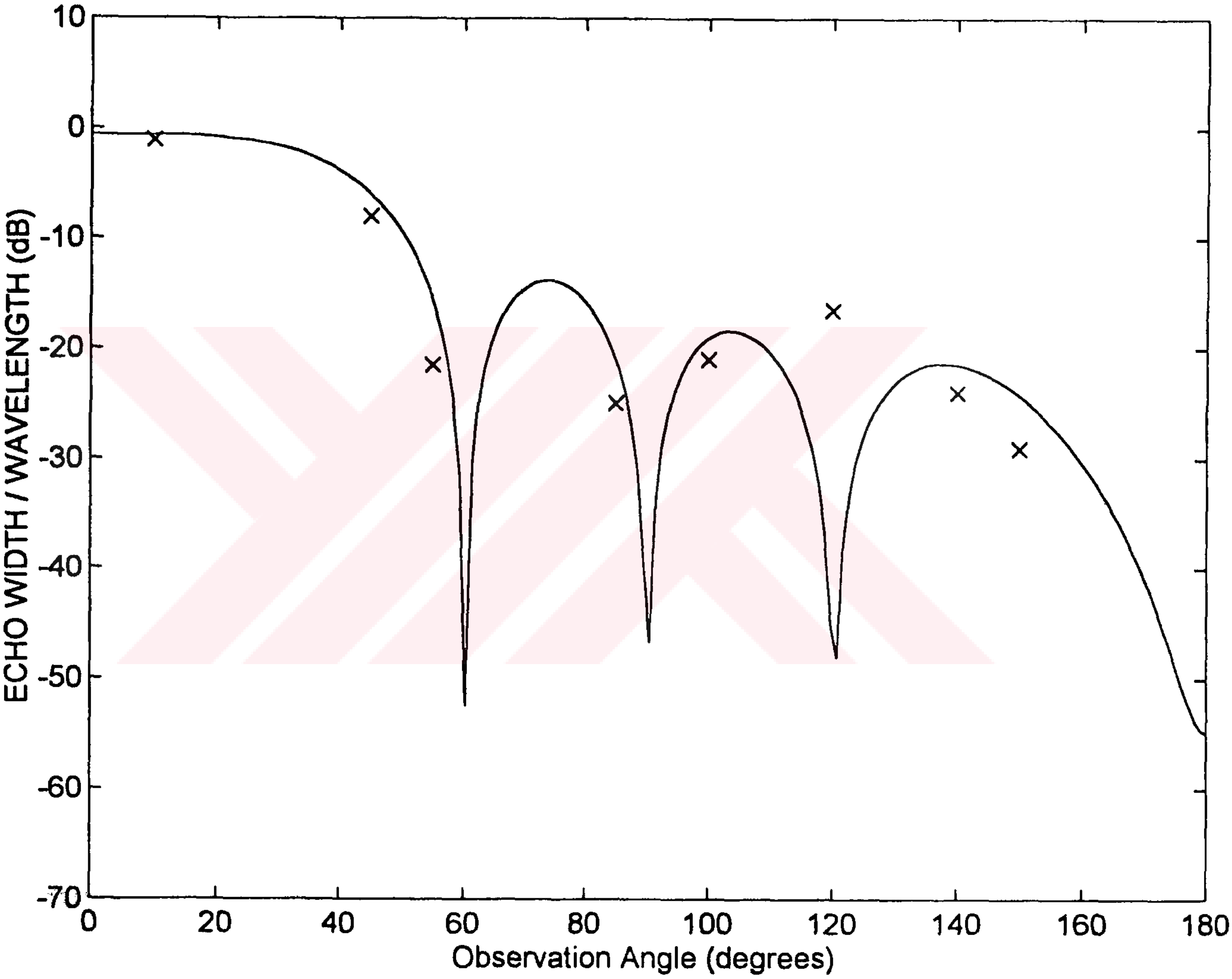

Figure 8. E_z bistatic echo width of the high-frequency solution(full line) compared with moment method data (x) for a 2 λ -wide resistive strip with $\eta = 4$; angle of incidence = 175°.

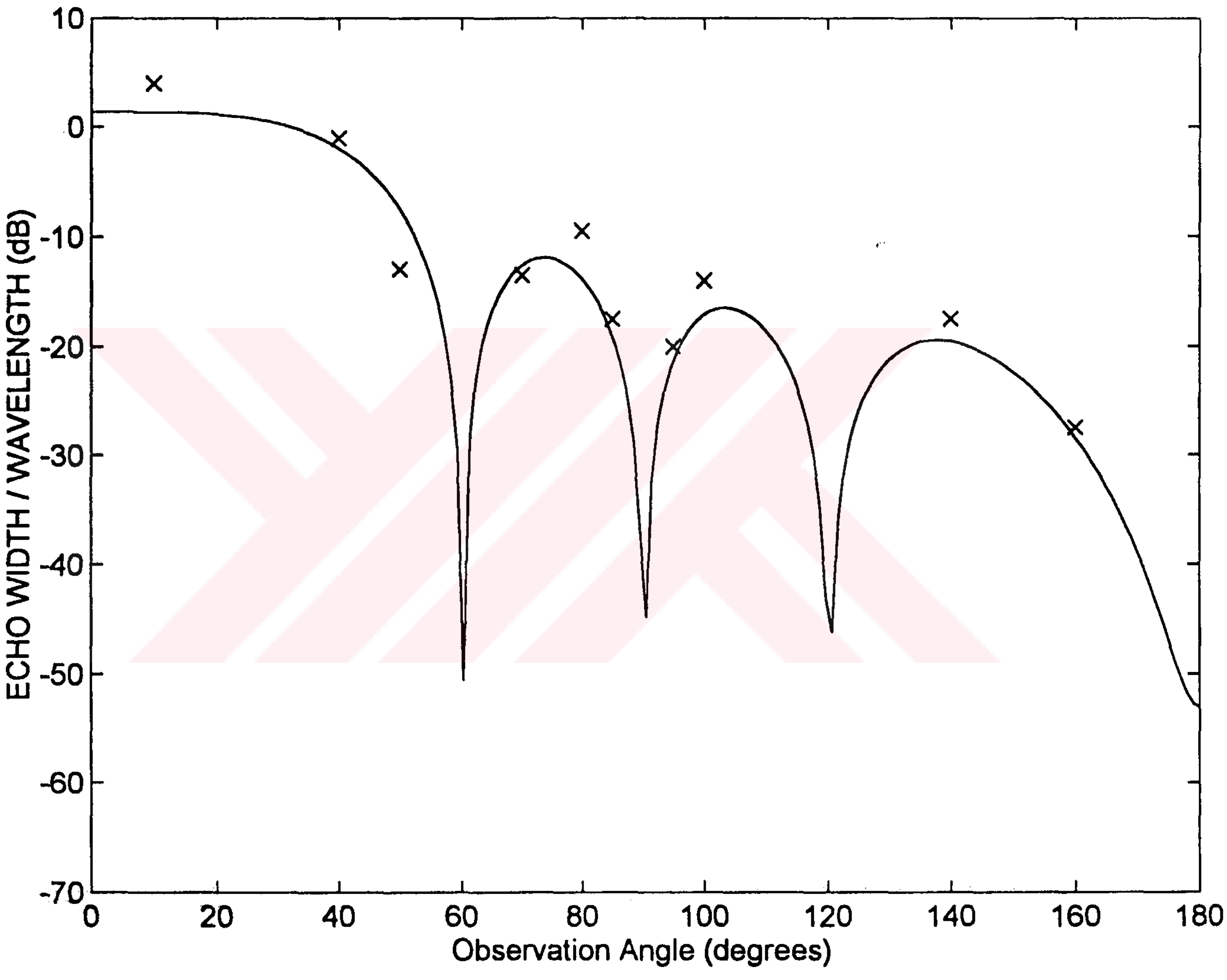

Figure 9. E_z bistatic echo width of the high-frequency solution(full line) compared with moment method data (x) for a 2 λ -wide resistive strip with $\eta = i4$; angle of incidence = 175°.

5. CONCLUSION

The results obtained are in a good agreement with the results provided by known methods; morever, the accuracy of the solution obtained here can be estimated. Particularly, the limits of the applicability of the so-called generalized Rayleigh-Gans approach are established. The results obtained are also in a good agreement with the experimental data[1].

The advantege of method considered is the possibility to determine exactly the limits of validity and the accuracy of obtained solution.

Dielectric strip may be a good model for some natural media constituents, for example, elements of plant. Hence, the solution of considered problem may be applied to modeling of natural structures in microwave remote sensing, wave propagation, etc...

4. SUMMARY

Development of reliable models for microwave emission and scattering from terrain, i.e.,soil, vegetation, snow, forest, etc.., is one of the important problems of microwave remote sensing. The sizes of leaves and stalks in the microwave band are comparable with the wavelength, and,therefore, the scattering and absorption cross sections of plant elements must be calculated from diffraction models. Since the elements of plant are similar in shape to flat discs, strips(for example, leaves), and cylinders(for example, stalks), it is necessary to discuss the diffraction problem for bodies with the above shapes.

From the point of view of classical physical theory, the scattering and diffraction of waves from objects have long been fully understood in the sense that underlying differential equation and boundary conditions of the relevant variables are known. In principle, it is merely necessary to solve the equations subject to the boundary conditions appropriate to any particular source and object in order to determine the complete picture of the diffracted field. In practice, this has proved to be a very formidable problem even under simple and idealized conditions. Approximate mathematical solutions and experimental techniques that serve very well in the study of optical phenomena related to scattering and diffraction are inadequate to deal with the more general electromagnetic problems that are encountered, for example , in radar. It is natural to begin the study of electromagnetic scattering and diffraction with objects of very simple shape and structure. This offers the opportunity of determining exact and complete theoretical solutions that are useful in several ways in dealing with more complex objects for which only incomplete and approximate data may be determined.

Diffraction of electromagnetic waves by dielectric structures is now under and urgent interest of researchers. This is caused by two reasons. From a theoretical point of view the solution of this problem requires developing new theoretical approaches. Application of known methods, for example a resistive sheet model, a Wiener Hopf theory, etc., which are successful for perfectly conducting and impedance bodies, to do diffraction by dielectric configurations, sometimes, a reasonable solution. However, the question about the limits of validty of this solution is oftenly left to be open. The known moment method also becomes inefficient when, for example, the width of thickness of dielectric strip increases.

On the other hand the propesed problem is of great importance due to numerous practical applications. Dielectric strip-like structures is widely used in antenna technique (different covers, microstrip, etc.), microwave circuits (resonators, filters). Furthermore, dielectric strip may be a good model for some natural media constituents, for example, elements of plants. Hence, the solution of considered problem may be applied to modeling of natural structures in microwave remote sensing, wave propagation, etc.

The simple case of scattering by a thin dielectric strip is examined. This problem is considered on the basis of the expansion of scattering operator into multiple scattering series. The calculations of inner field and the extinction cross section are conducted for certain dielectric costants and dimensions of strip corresponding to the parameters of vegetation elements. It has been shown that for values of $kD|\epsilon-1|\leq 0.5$,where k is the wave number, D is the strip thickness, and ϵ is the strip dielectric constant, the generalized Rayleigh-Gans approach can be successfully applied to calculate the extinction cross section of a dielectric strip. Radiation patterns of scattering by perfectly conducting strip and a thin dielectric strip is compared.

An asymptotic solution is presented for the diffraction by a resistive strip which is useful in the simulation of thin dielectric layers. Consider a strip of width 2a and resistance R occupying the portion $-a \leq x \leq a$, $-\infty < z < \infty$ of the plane y = 0 of a cartesian coordinate system (x,y,z). The strip is illuminated by an E-polarized plane electromagnetic wave

$$E^i = e^{-ik(xCos\vartheta_0 + ySin\vartheta_0)}$$

where $0 \leq \vartheta_0 \leq \pi$ and a time factor $e^{-i\omega t}$ has been suppressed.

Since the total electric field also has only a z component, the conditions at the surface of the strip can be written as

$$E_z(x,0_+) = E_z(x,0_-) = RJ$$

We remark that when R = 0 the strip is perfectly conducting, and when R = ∞ it no longer exists.

The scatterd field is,

$$E^s = -\frac{kZ}{4}\int_{-a}^{a} J(x')H_0^{(1)}(k\sqrt{(x-x')^2+y^2})dx'$$

where $H_0^{(1)}$ is the cylindrical Hankel function of the first kind of order zero and Z is the intrinsic impedance of free space.

The far-zone scattered field is obtained by solving the resulting integral equation. Numerical data are presented to illustrate the scattering properties of lossless and lossy dielectric strip as a function of the angle of incidence and the width of the strip. The results obtained are in a good agreement with the results provided by moment method.

4. ÖZET

Bitkisel örtülerden saçılma için uygun modellerin geliştirilmesi, uzaktan algılamanın çok önemli problemlerinden biridir. Yaprakların ve dalların mikrodlaga bandında karşılaştırılabilir olması, bitki elemanlarının geriye doğru saçıma ve soğurma katsayılarının uygun saçılma modellerinden hesaplanmasına olanak vermektedir. Bitki elemanlarının disc ve şerit(örneğin, yapraklar), ve silindirleörneğin, gövdeler benzer şekilde olması nedeniyle difrkasiyon problemine bu şekillere sahip nesnelerden başlamak gerekir.

Klasik fizik teori ışığında maddelerden dalgaların saçılması ve difraksiyonu, uygun değişkenlerin sınır koşulları ve diferensiyel denklemin bilinmesi durumunda tam olarak anlaşılmıştır. Difrakte edilmiş alanın hesaplanması için herhangi bir kaynak ve maddeye ait sınır koşullarının denklemlarinin tam olarak çözülmesi gerekmektedir. Pratik olarak basit ve ideal koşullarda bile bunu kanıtlamak çok zor bir problemdir. Saçılma ve difraksiyon problemleriyle ilgili olarak optik olayların çalışılmasında iyi sonuçlar veren yaklaşıl matematiksel çözümler ve deneysel teknikler genel olarak karşılaşılan elektromagnetik problemlerinde, örneğin radar, yeterli olmamaktadır. Elektromagnetik saçılma difraksiyon problemlerine çok basit şekil ve yapılardan başlamak gereklidir. Bu bize karmaşık yapılarla ilgili olarak kesin ve tam olarak teorik çözülerin hesaplanmasına imkan verecektir.

Dielektrik yapılardan saçılma araştırmacıların ilgisini çeken bir alandır. Bunun iki nedeni vardır. Kuramsal açıdan problemin çözümü yeni kuramsal yaklaşımları geliştirmeyi gerektirmektedir. İnce şerit modelinin ve Wiener-Hopf yönteminin mükemmel iletken ve empedans yüzeylerden saçılma problemlerinde kullanılmasi bazen mantıklı sonuçlar vermektedir. Bununla birlikte bu çözlerin geçerlilik aralığı açık bırakılmıştır. Bilinen moment yöntemi dielektrik şeritin kalınlığı ve genişliği artırıldığında yetersiz kalmaktadır.

Diğer taraftan hazırlanan bu problem pratik uygulamalar açından büyük önem taşımaktadır. Dielektrik şerit yapılar anten tekniğinde ve mikrogalga devrelerinde yaygın bir şekilde kullanılır. Dielektrik ya[pılar doğal yapılar için uygun bir model olabilir. Bu yüzden düşünülen problem mikrodalga uzaktan algılamada ve dalga iletiminde doğal yapılarin modellemesine olanak verir.

İnce bir dielektrik şeritten saçınım probleminin basit durumu çalışıldı. Problemin çözümü saçınım operatörünün çoklu saçınım serilerini açınımı üzerine dayandırılmıştır. Dielektrik içindeki alan ve zayıflama katsayısı bitki elementlerine bağlı olarak belirli bir dielektrik sabit ve şerit boyutları alınarak bulundu. $kD|\varepsilon - 1| \leq 0.5$, koşulu sağlanırsa bulunan sonuçlar genelleştirilmiş Rayleigh-Gans yöntemi ile bulunan sonuçlarla iyi bir benzerlik olduğu gösterilmiştir. Mükemmel iletken şeritle ve bir ince dielektrik şeritten saçılmaya ait ışıma diagramları karşılaştırılmıştır.

İnce dielektrik tabakaların simulasyonunda iyi sonuçlar veren rezistif şeritten saçınım problemi için asimptotik bir çözüm önerilmiştir. 2a genişliğinde direnci R olan ve y=0 düzlemi üzerinde $-a \leq x \leq a$, $-\infty < z < \infty$ bir şerit düşünülmüştür. Serit E-polarizeli bir düzlemsel elektromagnetic dalga ile aydınlatılmıştır.

$$E^i = e^{-ik(xCos\vartheta_0 + ySin\vartheta_0)}$$

Burada $0 \leq \vartheta_0 \leq \pi$ ve zaman faktörü olarak e^{-iwt} seçilmiştir.

Tolam elektrik alanının sadece z bileşeni olduğu için şeritin yüzeyindeki koşullar yeniden yazılabilir.

$$E_z(x, 0_+) = E_z(x, 0_-) = RJ$$

Biz söylemeliyiz ki R = 0 olduğu zaman şerit mükemmel iletken , R = ∞ herhangi bir durum söz konusu değil.

Saçılan alan,

$$E^s = -\frac{kZ}{4}\int_{-a}^{a} J(x')H_0^{(1)}(k\sqrt{(x-x')^2 + y^2})dx'$$

burada $H_0^{(1)}$ sıfırıncı dereceden birinci tip silindirik Hankel fonksiyonunu ve Z karakteristik empedansı göstermektedir.

Uzak alan ifadesi sonuç integral denkleminin çözülmesiyle elde edilebilir.Sayısal sonuçlar verilmiştir. Elde edilen sonuçlarla moment methoduyla elde edilen çözümler arasında büyük benzerlikler olduğu gösterilmiştir.

REFERENCES

1. A.A.Chuklantsev,"Scattering and absorption of microwave radiation by elements of plants," Radiotekh.Elekt., vol.31,pp.1095-1104,1986.

2. H.J.Eom, and A.K.Fung, "A scatter model for vegetation up to Ku-band," Remote Sensing Environ.,vol.14,pp.185-200,1984.

3. J.H.Richmond, "Scattering by a dielectric cylinder of arbitrary cross section shape", IEEE Trans. on Antennas and Propagat.,vol.AP-13, pp.334-341, May 1965.

4. J.H.Richmond, "Scattering by thin dielectric strip",IEEE Trans.on Antennas and Propagat., vol.AP-33,pp.64-68,Jan.1985.

5. G.Mitsioulis," A Wiener-Hopf theory for a semi-infinite dielectric slab", Can.J.Phys., vol.68, pp.1348-1351,1990.

6. T.B.A.Senior,"Combined resistive and conductive sheets", IEEE Trans. on Antennas and Propagat., vol.AP-33, no.5, May 1985.

7. J.L.Volakis, T.B.A.Senior," Diffraction by a thin dielectric half-plane", IEEE Trans. on Antennas and Propagat., vol.AP-35, no.12, December 1987.

8. T.B.A.Senior, and J.L.Volakis,"Sheet simulation of a thin dielectric layer", Radio Science, vol.22, pp.1261-1272, December 1987.

9. Bateman, H and A.Erdelyi, Higher trascandental functions, vol.2, McGraw-Hill, New York, 1953-1955.

10. T.B.A.Senior, "Backscattering from resistive strips", IEEE Trans. on Antennas and Propagat., vol. AP-27, No.6, November 1979.

11. D.S.Jones, Acoustic and electromagnetic waves, Clarendon Press, Oxford, 1986 pp.80-81.

12. D.M.Le Vine, A.Snyder,R.H.Lang, and H.G.Garter, " Scattering from thin dielectric disks", IEEE Trans. on Antennas and Propagat., vol.33, pp.1410-1413, 1985.

13. T.M.Willis, H.Weil, and D.M.Le Vine, " Applicability of physical optics thin plate scattering formulas for remote sensing", IEEE Trans. Geosci.Remote Sens., vol.26, pp.153-160, 1988.

14. T.B.A.Senior.,K.Sarabandi, and F.T.Ulaby,"Measuring and modeling the backscattering cross section of a leaf", Radio Science, vol.22, pp.1109-1116, 1987.

15. K.Sarabandi,T.B.A.Senior, and F.T.Ulaby,"Effect of curvature on the backscattering from a leaf", J.Electromagn. Waves Appl., vol.2, pp.653-670, 1988.

16. K.Sarabandi, F.T.Ulaby, and T.B.A.Senior,"Millimeter wave scattering model for a leaf ", Radio Science, vol.25, pp.9-18, 1990.

17. F.T.Ulaby, R.K.Moore, A.K.Fung, "Microwave remote sensing, active and passive", Volume I, Microwave Remote Sensing Fundemantals and Radiometry, 1981.

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RESUME

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