Time-domain Multiple-order Diffraction for Two Wedges of Arbitrary Angles

Vinod Kumar, N. S. Raghava, Sanjay Soni

Abstract: Generally, higher order diffraction coefficient is used for the consideration of multiple diffraction. Due to this, the calculation becomes complex as well as not consider all possible order of diffraction among the wedges. In this paper, frequency and time-domain multiple-order diffraction for double wedge has been proposed. Only, single-order diffraction coefficient is used for higher-order diffraction calculation. So the proposed method is very simple and considers all possible order of diffraction. Both the IFFT-FD solution and proposed TD solution has been compared to confirm the accuracy.

Index Terms: Higher-order diffraction, IFFT-FD, multiple diffraction, and TD solution.

I. INTRODUCTION

The demand for high data rates in wireless communication over the wireless channel is increasing significantly from the past several decades. The signal characteristics changes as it passes through the wireless medium and depends upon the distance between transmitter and receiver, the paths travelled by the signal, as well as the environment including building and other objects between source and destination. The received signal is obtained by the convolution of transmitted signal with the impulse response of the wireless channel. Therefore, the modelling of the wireless channel is very important.

Recently, Ultra-wide band communication has attracted the interest of researcher from all over world for short-range wireless communication. Pulse distortion is a major problem due to the large bandwidth of UWB signals [7]. This distortion occurs by diffraction from the edges of the objects. The time domain analysis is more efficient to find this distortion as it considers the all frequencies of UWB signals simultaneously. A frequency domain solution can be converted into time domain solution using inverse fast Fourier transform. This approach takes more time as it calculates each frequency separately. Thus, direct time domain solution is preferred over IFFT of frequency domain solution [8-10].

A multiple diffraction solution has been given over knife-edge obstacles in [1]. UTD coefficient has been used for multiple wedge diffraction in [2]. Multiple diffraction fields has been calculated on a perfectly conducting scatterer in [3]. A hybrid solution for multiple diffraction has been proposed using the UTD and physical optics concept. In this, non-light of sight situation has been presented in [4]. The time domain solution for multiple diffraction has been proposed in [8]. In [5], a multiple diffraction case has also been considered using UTD-PO solution in time domain.

In the above literatures, higher order diffraction coefficients are used for finding for multiple diffraction. But in this paper, without using any higher order diffraction coefficients, we can find the double diffraction of all possible order. In the next section, FD solution of double diffraction for arbitrary wedge angle has been developed based on successive approximation [11]. Further, TD formulation has been done by taking inverse Laplace transform of FD solution. Finally IFFT-FD and TD solution has been compared. Results show very good agreement.

II. PROBLEM FORMULATION

A. Frequency Domain Solution

Considering the Fig. 1, the diffracted field at wedge 1 is calculated as

$$\begin{aligned} E_1^{s,h}(s_1,\theta) = {} & E_0^{s,h} \times D_{10}^{s,h} \\ & \times \left(L_{10}, \varphi_{10} = x_0+\theta, \varphi'_{10}, n_1\right) \\ & \times A_{10}(s_1) e^{-jks_1} \\ & + E_2^{s,h}(s_2 = d, \theta = 0) \\ & \times D_{12}^{s,h}\left(L_{12}, \varphi_{12} = x_0, \varphi'_{12}, n_1\right) \\ & \times A_{12}(s_1) e^{-jks_1} \end{aligned} \tag{1}$$

where

$$\begin{aligned} E_2^{s,h}(s_2,\theta) = {} & E_1^{s,h}(s_1 = d, \theta = \pi) \\ & \times D_{21}^{s,h}\left(L_{21}, \varphi_{21} = x_0+\theta, \varphi'_{21} = x_0, n_2\right) \\ & \times A_{21}(s_2) e^{-jks_2} \end{aligned} \tag{2}$$

where

$$\begin{aligned} E_1^{s,h}(s_1 = d, \theta = \pi) = {} & E_0^{s,h} \times D_{10}^{s,h}\left(L_{10}, \varphi_{10} = x_0+\pi, \varphi'_{10}, n_1\right) \\ & \times A_{10}(s_1 = d) e^{-jkd} \\ & + E_2^{s,h}(s_2 = d, \theta = 0) \\ & \times D_{12}^{s,h}\left(L_{12}, \varphi_{12} = x_0, \varphi'_{12}, n_1\right) \\ & \times A_{12}(s_1 = d) e^{-jkd} \end{aligned} \tag{3}$$

where

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$$E_2^{s,h}(s_2=d,\theta=0)=E_1^{s,h}(s_1=d,\theta=\pi)\times D_{21}^{s,h}\left(L_{21},\varphi_{21}=x_0,\varphi'_{21}=x_0,n_2\right)\times A_{21}(s_2=d)e^{-jkd} \quad (4)$$

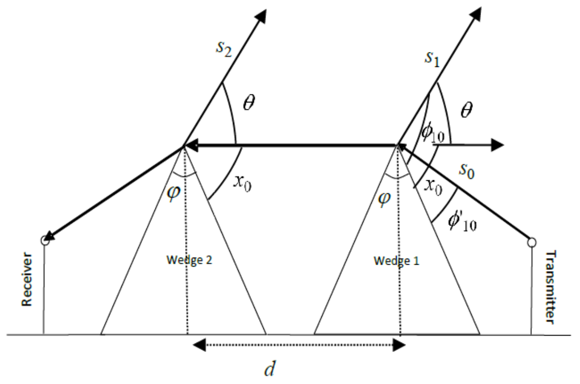

Fig. 1 Double diffraction from two wedges.

Simplified form of (3) and (4)

$$E_1^{s,h}(s_1=d,\theta=\pi)=E_0^{s,h}\times T_{10}^{s,h}+E_2^{s,h}(s_2=d,\theta=0)\times R_{12}^{s,h} \quad (5)$$

Where,

$T_{10}^{s,h}=D_{10}^{s,h}\left(L_{10},\varphi_{10}=x_0+\pi,\varphi'_{10},n_1\right)\times A_{10}(s_1=d)e^{-jkd}$ and

$R_{12}^{s,h}=D_{12}^{s,h}\left(L_{12},\varphi_{12}=x_0,\varphi'_{12},n_1\right)\times A_{12}(s_1=d)e^{-jkd}$

$$E_2^{s,h}(s_2=d,\theta=0)=E_1^{s,h}(s_1=d,\theta=\pi)\times R_{21}^{s,h} \quad (6)$$

where,

$$R_{21}^{s,h}=D_{21}^{s,h}\left(L_{21},\varphi_{21}=x_0,\varphi'_{21}=x_0,n_2\right)\times A_{21}(s_2=d)e^{-jkd}$$

Writing in matrix form to the (5) and (6)

$$\begin{bmatrix}1 & -R_{12}\\ -R_{21} & 1\end{bmatrix}\times\begin{bmatrix}E_1^{s,h}\\ E_2^{s,h}\end{bmatrix}=\begin{bmatrix}E_0^{s,h}T_{10}\\ 0\end{bmatrix} \quad (7)$$

Or

$$\begin{bmatrix}E_1^{s,h}\\ E_2^{s,h}\end{bmatrix}=\begin{bmatrix}1 & -R_{12}\\ -R_{21} & 1\end{bmatrix}^{-1}\times\begin{bmatrix}E_0^{s,h}T_{10}\\ 0\end{bmatrix} \quad (8)$$

In the above equations, E_0 =incident signal, D_{xy} =diffraction coefficient, L_{xy} = Distance parameter, ϕ'_{xy} = incident angle, ϕ_{xy} = diffracted angle. From (2) and (8), we can find the double diffracted field at the receiver using single order diffraction coefficient. Thus, the proposed method is simple because it is only using single order diffraction coefficient instead of using higher order diffraction coefficient as in other literature [8] for multiple diffraction.

B. Time Domain Solution

Taking inverse Laplace transform of (1), (2) and (8), we have

$$e_1^{s,h}(s_1,\theta,t)=A_{10}(s_1)\times\begin{bmatrix}e_0^{s,h}(t)*d_{10}^{s,h}\left(L_{10},\varphi_{10}=x_0+\theta,\varphi'_{10},n_1,t\right)\\ *\delta(t-s_1/c)\end{bmatrix}+A_{12}(s_1)\times\begin{bmatrix}e_2^{s,h}(s_2=d,\theta=0,t)\\ *d_{12}^{s,h}\left(L_{12},\varphi_{12}=x_0,\varphi'_{12},n_1,t\right)\\ *\delta(t-s_1/c)\end{bmatrix} \quad (9)$$

$$e_2^{s,h}(s_2,\theta,t)=A_{21}(s_2)\times\begin{bmatrix}e_1^{s,h}(s_1=d,\theta=\pi,t)\\ *d_{21}^{s,h}\left(L_{21},\varphi_{21}=x_0+\theta,\varphi'_{21}=x_0,n_2,t\right)\\ *\delta(t-s_2/c)\end{bmatrix} \quad (10)$$

$$\begin{bmatrix}e_1^{s,h}(s_1=d,\theta=\pi,t)\\ e_2^{s,h}(s_2=d,\theta=0,t)\end{bmatrix}=\begin{bmatrix}1 & -r_{12}(t)\\ -r_{21}(t) & 1\end{bmatrix}^{-1}*\begin{bmatrix}e_0^{s,h}(t)*\tau_{10}(t)\\ 0\end{bmatrix} \quad (11)$$

where,

$$r_{12}(t)=A_{12}(s_1=d)\times\begin{bmatrix}d_{12}^{s,h}\left(L_{12},\varphi_{12}=x_0,\varphi'_{12},n_1,t\right)\\ *\delta(t-d/c)\end{bmatrix}$$

$$r_{21}(t)=A_{21}(s_2=d)\times\begin{bmatrix}d_{21}^{s,h}\left(L_{21},\varphi_{21}=x_0,\varphi'_{21}=x_0,n_2,t\right)\\ *\delta(t-d/c)\end{bmatrix} \quad (12)$$

$$\tau_{10}(t)=A_{10}(s_1=d)\times\begin{bmatrix}d_{10}^{s,h}\left(L_{10},\varphi_{10}=x_0+\pi,\varphi'_{10},n_1,t\right)\\ *\delta(t-d/c)\end{bmatrix}$$

and

$$d^{s,h}(t)=d^{(1)}(t)+r_0(t)*r_n(t)*d^{(2)}(t)+r_n(t)*d^{(3)}(t)+r_0(t)*d^{(4)}(t) \quad (13)$$

where, $d^{(i)}(t)$, $(i=1-4)$ are defined as [8]

$$d^{(i)}(t)=-\frac{Ln}{2\pi\sqrt{2c}}\frac{\sin(2\varsigma_i)}{\sqrt{t}\left(t+2Ln^2\sin^2(\varsigma_i)/c\right)}\cdot u(t) \quad (14)$$

$r_0(t)$ and $r_n(t)$ are the TD reflection coefficients for 0-face and n-face that can be defined for both soft and hard polarizations as in [8]

III. RESULTS AND DISCUSSION

The second order derivative of Gaussian pulse with given parameters in [6] is used as the incident pulse. From Fig. 2-5, we see that the proposed TD solution is matching with its corresponding FD solution. We see that proposed method has two advantage over the solutions presented in several literatures. First, the proposed method is simple because it is using only simple diffraction coefficient in FD and TD solution. Second it is not using any higher order diffraction coefficient for multiple diffraction.

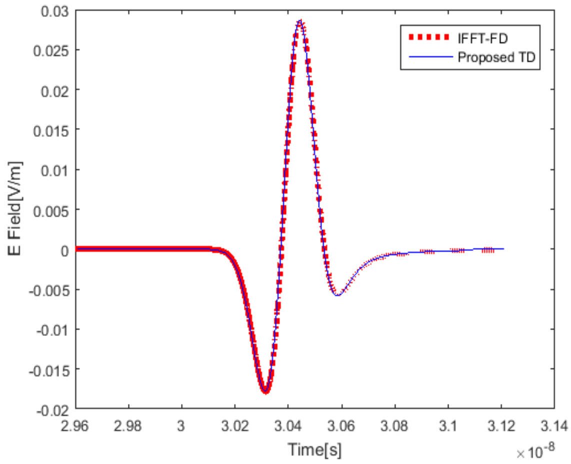

Fig. 2 Double diffracted field for the scenario with Tx height= 3m, Rx height=1m , wedge height= 4m,and d=4m.

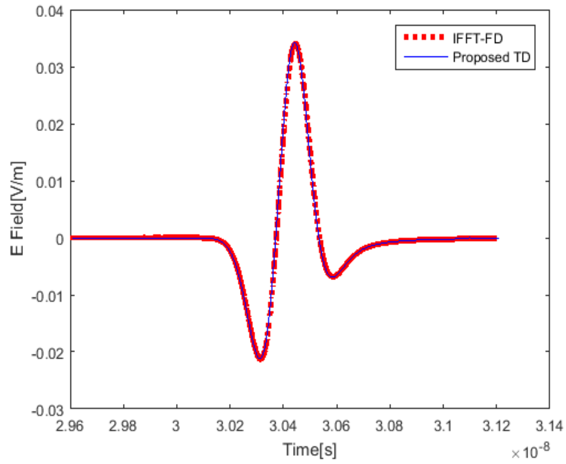

Fig. 3 Double diffracted field for the scenario with Tx height= 3m, Rx height=1m , wedge height= 4m,and d=4m and wedge angle=90 degree.

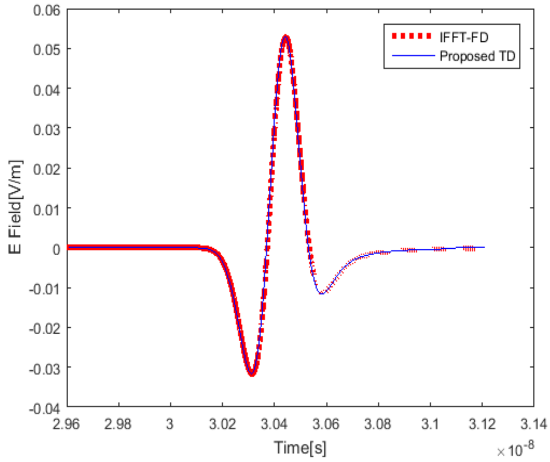

Fig. 4 Double diffracted field for the scenario with Tx height= 5m, Rx height=1m , wedge height= 4m,and d=4m.

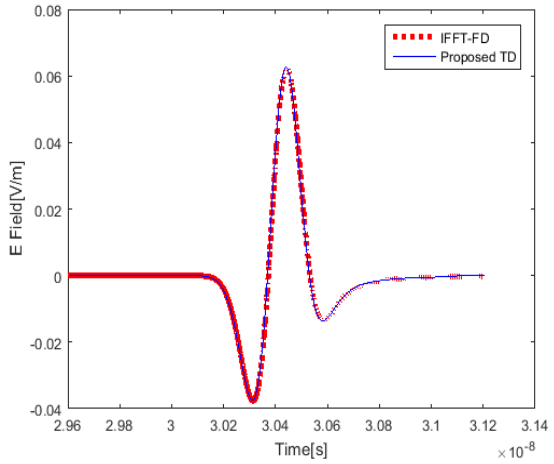

Fig. 5 The diffracted field for the scenario with Tx height= 5m, Rx height=1m , wedge height= 4m, d=4m and wedge angle=90 degree.

IV. CONCLUSION

The proposed method is using single diffraction coefficient for higher-order diffraction. It has good matching with its corresponding FD-IFFT solution. It considers all possible order of diffraction between two wedges. This method can be extended for calculating diffracted fields among more than two wedges with all possible order of diffraction.

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Vinod Kumar was born in Uttar Pradesh, India. He received his Diploma in electronics engineering from Government Polytechnic Ghaziabad, Uttar Pradesh, India in 2002, BTech degree in electronics and communication engineering from Noida Institute of Engineering and Technology, Gautam Budh Nagar, India in 2008, and MTech degree in electronics and communication engineering from Jaypee University of Information Technology, Waknaghat, Himachal Pradesh, India, in 2012. Currently he is an assistant professor at Dr B.R. Ambedkar Institute of Technology, Pahargaon, Port Blair, A&N, India and working toward the PhD degree at Delhi Technological University, Delhi, India. His research interests include deterministic and empirical modelling of wireless channels.

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