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TIME-DOMAIN FORMULATION OF DIFFRACTION BY A DIELECTRIC WEDGE

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ABSTRACT

This article presents a new time-domain formulation for the analysis of multiple-edge diffraction based on successive scattering procedure in terms of uniform theory of diffraction (UTD) coefficient for mobile radio wave propagation where shadowing of transmitter from receiver is available. A case of single building profile has been taken. The TD resultant field at the receiver is compared with the inverse fast Fourier transform (IFFT) of frequency-domain (FD) solution. Finally, the computational efficiency of TD and IFFT-FD has been compared.

Keywords: Multiple-edge diffraction, UTD, Time-domain (TD), IFFT-FD

There is strong need to design propagation models that can accurately predict the amplitude and delay of multipath echoes in urban environments due to the deployment of high-speed digital communication systems. Several frequency-domain propagation models are presented in [1]-[4]. In ultra wide band (UWB) communication due to the large bandwidth, the time-domain (TD) propagation models are currently receiving great attention from both the industry and research community. Wave propagation models in time-domain are preferred to the frequency-domain (FD) due to the analysis of transient scattering behavior of microwave signals. Considering the merits of time domain (TD) solution for UWB propagation [5], we propose a new TD solution for multiple diffractions by dielectric wedge that is based on the frequency-domain solution presented in [6]. Results are shown for a single building profile and the accuracy of TD results is confirmed by comparison with the inverse fast Fourier transform (IFFT) of the corresponding frequency-domain (FD) result. Finally it has been shown that the TD solution is computationally efficient than the FD solution.

TIME-DOMAIN FORMULATION

Fig. 1 is representing a single building profile having finite thickness edge for multiple diffractions. It has two diffracting edges at the top of the building model because of its rectangular shape. From Fig. 1, the total TD diffracted field by wedge 1 that is due to radiation from the transmitter and due to all orders of diffraction from wedge 2 is given as from frequency domain solution [6]

$$u_1^{s,h}(r_1,\varphi,t)= A_{10}(r_1)\begin{bmatrix} u_0^{s,h}(t) \\ * d_{10}^{s,h}(L_{10},\phi_{10}=\frac{\pi}{2}+\varphi,\phi_{10}^{'}=\theta,n_1,t) \\ * \delta(t-\frac{r_1}{c}) \end{bmatrix} + \frac{1}{2}A_{12}(r_1)\begin{bmatrix} u_2^{s,h}(r_2=d,\varphi=0,t) * \\ d_{12}^{s,h}(L_{12},\phi_{12}=\pi-\varphi,\phi_{12}^{'}=0,n_1,t) * \\ \delta(t-\frac{r_1}{c}) \end{bmatrix} \quad (1)$$

where,

$u^{s,h}(t)$ =The TD electric field for soft polarization and the TD magnetic field for hard polarization.

$u_1^{s,h}(r_1,\varphi,t)$ =Total TD diffracted field by wedge 1,

$u_0^{s,h}(t)$ =Field by transmitter at wedge 1,

$u_2^{s,h}(r_2=d,\varphi=0,t)$ = Total TD diffracted field from wedge 2 toward wedge 1,

$d_{10}^{s,h}$ = TD diffraction coefficient at wedge 1 due to radiation from transmitter.

$d_{12}^{s,h}$ = TD diffraction coefficient at wedge 1 due to radiation by wedge 2.

A_{10} and A_{12} =Amplitude spreading factors of wedge 1 due to radiation from transmitter and wedge 2.

'*'=convolution operator.

$\phi^{'}$ = Incidence angle at wedge 1 or wedge 2.

ϕ = Diffraction angle at Wedge 1 or Wedge 2.

Similarly from Fig. 1, the TD total diffracted field by wedge 2 that is due to all orders of diffraction from wedge 1 is given as from frequency domain solution [6]

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$$u_2^{s,h}(r_2,\varphi,t)= \frac{1}{2}A_{21}(r_2)\left[\begin{array}{l} u_1^{s,h}(r_1=d,\varphi=\pi,t) \\ *\, d_{21}^{s,h}(L_{21},\phi_{21}=\varphi,\phi_{12}^{'}=0,n_2,t) \\ *\, \delta(t-\frac{r_2}{c}) \end{array}\right] \quad (2)$$

where,

$u_1^{s,h}(r_1=d,\varphi=\pi,t)$ = Total TD diffracted field from wedge 1 toward wedge 2,

$d_{21}^{s,h}$ = TD Diffraction coefficient at wedge 2 due to radiation by wedge 1,

A_{12} =Amplitude spreading factor of wedge 2 due to radiation by wedge 1.

The two unknowns $u_1^{s,h}(r_1=d,\varphi=\pi,t)$ and $u_2^{s,h}(r_2=d,\varphi=0,t)$ of Equations (2) and (1), can be given as

$$u_1^{s,h}(r_1=d,\varphi=\pi,t)= u_0^{s,h}(t)*t_{10}^{s,h}(t) + u_2^{s,h}(r_2=d,\varphi=0,t)*r_{12}^{s,h}(t) \quad (3)$$

and

$$u_2^{s,h}(r_2=d,\varphi=0,t)= u_1^{s,h}(r_1=d,\varphi=\pi,t)*r_{21}^{s,h}(t) \quad (4)$$

where,

$$t_{10}^{s,h}(t)= \left[d_{10}^{s,h}(L_{10},\phi_{10}=\frac{3\pi}{2},\phi_{10}^{'}=\theta,n_1,t)*\delta(t-\frac{d}{c})\right]A_{10}(r_1=d)$$

= TD transmission coefficient by wedge 1toward wedge 2 due to radiation from transmitter.

$$r_{12}^{s,h}(t)= \frac{1}{2}A_{12}(r_1=d)\left[d_{12}^{s,h}(L_{12},\phi_{12}=0,\phi_{12}^{'}=0,n_1,t)*\delta(t-\frac{d}{c})\right]$$

=TD reflection coefficient from wedge 1toward wedge 2 due to diffraction from wedge 2.

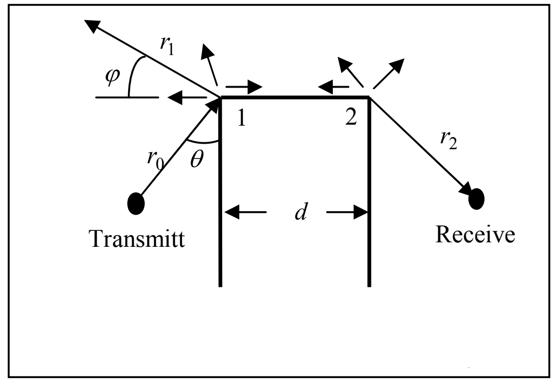
$$r_{21}^{s,h}(t)= \frac{1}{2}A_{21}(r_2=d)\left[d_{21}^{s,h}(L_{21},\phi_{21}=0,\phi_{21}^{'}=0,n_2,t)*\delta(t-\frac{d}{c})\right]$$

=TD reflection coefficient from wedge 2 toward wedge 1 due to diffraction from wedge 1.

In matrix form, the equations (3) and (4) can be given as

$$\begin{bmatrix} u_1^{s,h}(r_1=d,\varphi=\pi,t) \\ u_2^{s,h}(r_2=d,\varphi=0,t) \end{bmatrix} = \begin{bmatrix} 1 & r_{12}^{s,h}(t) \\ -r_{21}^{s,h}(t) & 1 \end{bmatrix}^{-1} * \begin{bmatrix} u_0^{s,h}(t) \\ 0 \end{bmatrix} \quad (5)$$

By solving Equation (5), we can get $u_1^{s,h}(r_1,\varphi,t)$ and $u_2^{s,h}(r_2,\varphi,t)$ from Equations (1) and (2).



RESULTS AND DISCUSSION

Considering single building profile of Fig. 1, Fig. 2 shows the diffracted field at Receiver which is positioned in deep shadow region of the wedge structure made of [7] in that the transmitter illuminates only 0-face of wedge 1. Here, the Gaussian doublet pulse as in [5] with full width half maximum pulse duration of 0.1 ns is used for simulation. The received TD pulse waveform is compared with the IFFT- FD solution that is based on the FD solution presented in [6]. The good agreement between these TD and IFFT-FD results confirms the accuracy of proposed TD solution.

From Table I, the TD solution is computationally efficient than the IFFT-FD solution which is due to the efficient convolution technique used in TD approach.

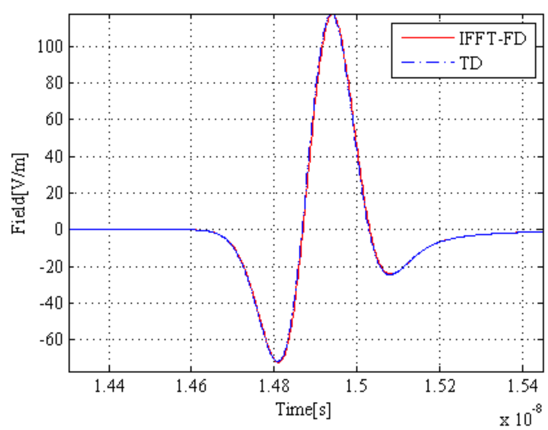


Fig. 2: IFFT-FD and TD Fields for wedge angle 90°.

Table I: Computational Efficiency Of Td Solution

Wedge Angle	IFFT-FD/TD
90°	17.62

CONCLUSION

The proposed time-domain solution for the analysis of multiple-edge diffraction based on successive scattering procedure in terms of uniform theory of diffraction (UTD) coefficient for single building profile is accurate and efficient to the inverse fast Fourier transform (IFFT) of frequency-domain (FD) solution .

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