PROPAGATION MODEL FOR TREE BLOCKAGE IN MOBILE COMMUNICATION SYSTEMS USING UNIFORM THEORY OF DIFFRACTIONS

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Abstract-A deterministic model for spherical wave propagation in microcellular urban environment is presented. This methodis based on ray tracing and uniform theory of diffraction. The various ray contributions includes the diffraction from corner of obstacle, reflection from ground and direct wave. According to the height of transmitting station, different ray paths will be presented in the received signal. Calculation is carried out using hard and soft polarization. Results can be used for the planning of new cellular system.

Key words- Ray tracing, UTD, urban environment.

I. INTRODUCTION

Multiple–input-multiple -output (MIMO) technology enhances the channel capacity by taking the advantage of multipath radio channels. In the last decade, the world of telecommunication has known for the success of 2G and transition to 3G and beyond 3G services [1]. The requirement of high data rate can be fulfilled by the help of MIMO technology. MIMO technology offers the significant increase in data rates and link range without additional bandwidth and transmit power [2]. To meet all these requirements, accurate modeling of propagation channel is required.

There are three broad classes of methods to predict the path loss in mobile communications system. In [3], [4], empirical models are discussed. Statistical models are discussed in [4]. Deterministic models provide very accurate description of various effects such as reflection, diffraction and scattering from the buildings and terrains [4]. When scattering body is electrically large then deterministic model based on ray approximation of electromagnetic field is mostly used. So ray tracing finds applications in the urban scenario where obstacles are involved. First step in ray tracing approach is identification of various ray paths between transmitter and receiver, electromagnetic modeling is then applied.

In this work, we present a deterministic model for spherical wave propagation in an outdoor urban environment based on UTD. This model can be used for finding the field in the shadow of a tree. The two-dimensional propagation models for tree, given in [5] will be used here for characterizing cellular environment. The main difference between both cases is the dimension of problem setting. In [5] author has used plane wave propagation. In our paper we will use spherical wave propagation.

The Incident shadow boundary (ISB) defines the limit angle $Ø_{ISB}$below which the direct wave will be obstructed by the building while the Reflection Shadow boundary (RSB) defines the angle $Ø_{RSB}$for reflected wave contributions [5]. In this paper we will take carrier frequency 2GHz for 3G systems and 5 GHz and 60 GHz for 4G systems.The work is organized as follows. Section II presents propagation environment. Section III presents the proposed model and section IV concludes the work.

II. PROPAGATION ENVIRONMENT

The geometry of the propagation model is given in figure1 for tree blockage.

The main purpose of this work is to give accurate results for cell planning based on actual propagation phenomenon. This would help to adjust the height of transmitter antenna to get good signal strength at receiver side. In this paper we have assumed that signals at the MS are independent of mobile station's speed. Depending on the height of BS, different ray component can reach the MS. By the help of ØISBandØRSBwe will find outHISBandHRSB.

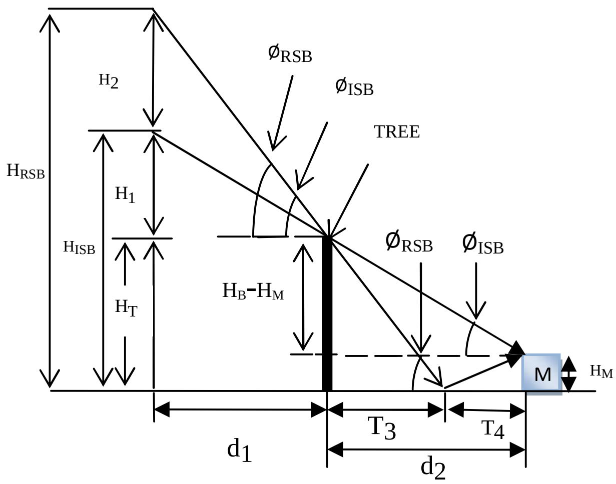

Figure 1. Ray components in tree blockage.

The various ray contributions to the received signal as a function of transmitter height in case of tree blockage as a single knife edge can be formulated as follows

- $H_T \leq H_{ISB}$

1. Single diffraction at knife edge.
2. Single diffraction at knife edge followed by ground reflection after tree blockage.
3. Ground reflections before tree blockage followed by single diffraction at top of tree.
4. Ground reflections before tree followed by single diffraction at top of tree and ground reflections after tree.

- $H_{ISB} \le H_T < H_{RSB}$

Four component as mentioned above and

5. Direct wave (LOS).

- $H_{RSB} \le H_T$

Five component as mentioned above and

6. Reflection from the ground without any diffraction.

Table I shows the various ray contributions.

Table-I VARIOUS RAY CONTRIBUTIONS

Transmitter Height	Ray components at the receiver
$H_T \le H_{ISB}$	First four components (1-4)
$H_{ISB} \le H_T < H_{RSB}$	First five components (1-5)
$H_{RSB} \le H_T$	First six components (1-6)

These six ray contributions will result in six field component at the receiver. D is the UTD diffraction coefficient at the knife edge.

1. **Uniform theory of diffraction**

According to the UTD theory [6], [7] the UTD coefficient for a single absorbing knife edge is given by

$$D(\sim) = -\frac{e^{-j\frac{®}{4}}}{2\sqrt{2®k}\cos(\frac{\sim}{2})} F[2\,\mathrm{kLcos}^2(\frac{\sim}{2})] \qquad (1)$$

Where, $\sim\, = Ø - Ø'$ (2)

Ø andØ' are the diffracted and incident angle with respect to 0 – face of the knife edge respectively. F[x] is the Fresnel transition integral. For the calculation of various field components, UTD coefficients for complex wedge is required and it is given as [8]

$$D = \frac{\exp[-j\frac{®}{4}]}{2n\sqrt{2®k}}[D_1 + D_2 + M_3 D_3 + M_4 D_4] \qquad (3)$$

Where D_i, (i=1, 2, 3, 4) is as given in [7], [8]. Where $M_{3,4}=R^{\parallel,\perp}$ for parallel and perpendicular polarization respectively [9].

$$R^{\parallel,\perp} = \frac{(1,\varepsilon_r)\tau - \sqrt{(\varepsilon_r - 1 + \tau^2)}}{(1,\varepsilon_r)\tau + \sqrt{(\varepsilon_r - 1 + \tau^2)}} \qquad (4)$$

$$\tau = 2\sin(\frac{Ø}{2})\sin(\frac{Ø'}{2}) \qquad (5)$$

Where Ø' and Ø are the incident and diffracted angle respectively.

2. **Field by all possible ray contributions**

The total field in the shadow of tree and building blockage is given as follows

The total field by the first ray component is given as

$$E_{r1} = \left(\frac{E_0}{r_1}\right)\exp(-\mathrm{jk}(r_1 + r_2)).\mathrm{D}.\sqrt{\frac{r_1}{r_2(r_1 + r_2)}} \qquad (6)$$

Where, E_0 is the field emitted by transmitter, r_1 is the distance of knife edge from transmitter; r_2 is the distance of mobile station from knife edge. D is the UTD diffraction coefficient for single knife edge [10]. The total field by the second component is given as

$$E_{r2} = \left(\frac{E_0}{r_1}\right)\exp(-\mathrm{jk}(r_1 + r_2 + r_3)).\mathrm{D}.\sqrt{\frac{r_1}{r_2(r_1 + r_2)}}.R_c \qquad (7)$$

Where, r_1 is the distance of knife edge from transmitter; r_2 is the distance of ground reflection point from knife edge. r_3 is the distance of mobile station from ground reflection point. D is the UTD diffraction coefficient for single knife edge.

$R_c$is the reflection coefficient at the ground and given as

$$R_c = \frac{\cos\Psi - \frac{1}{a}\sqrt{\in_r - \sin^2\Psi}}{\cos\Psi + \frac{1}{a}\sqrt{\in_r - \sin^2\Psi}} \qquad (8)$$

Where, Ψ is the incidence angle at the ground, measured with respect to the normal at the reflection point. For typical mobile communications environments, the value of ground relative permittivity is given by [5].

$$\in_r = 15 - j\frac{90}{f\,(\mathrm{MHz})} \qquad (9)$$

So the total field in the third ray path is given by

$$E_{r3} = \left(\frac{E_0}{r_1 + r_2}\right)\exp(-\mathrm{jk}(r_1 + r_2 + r_3)).\mathrm{D}.\sqrt{\frac{r_1 + r_2}{r_3(r_1 + r_2 + r_3)}}.R_c \qquad (10)$$

Where, r_1 is the distance of ground reflection point from transmitter; r_2 is the distance between ground reflection point and top of knife edge. r_3 is the distance of mobile station from knife edge.

So the total field in the fourth ray path is given by

$$E_{r4} = \left(\frac{E_0}{r_1 + r_2}\right)\exp(-\mathrm{jk}(r_1 + r_2 + r_3 + r_4)).\mathrm{D}\sqrt{\frac{r_1 + r_2}{(r_3 + r_4)(r_1 + r_2 + r_3 + r_4)}}.R_{c1}R_{c2} \qquad (11)$$

Where, r_1 is the distance of ground reflection point from transmitter; r_2 is the distance between ground reflection point and top of knife edge. r_3 is the distance of second ground reflection point from knife edge and r_4 is the distance of mobile station from second ground reflection point. R_{c1} and $R_{c2}$are the reflection coefficients as mentioned above.

The line of sight (LOS) component will be given as

$$E_{r5} = \left(\frac{E_0}{r_1}\right)\exp(-jkr_1) \quad (12)$$

So the total field in the sixth ray path is given by

$$E_{r6} = \left(\frac{E_0}{r_1 + r_2}\right)\exp(-jk(r_1+r_2)).R_c \quad (13)$$

Where, r_1 is the distance of ground reflection point from transmitter; r_2 is the distance between ground reflection point and to mobile station.

So the total field in the shadow of building is given as a combination of above six components according to the height of base station.

III. RESULTS

In this paper we determine the total field at receiver by varying the height of transmitter using UTD.In this work following parameters are used: tree height HB=10m, MS receiver antenna height HM=3m, building distance from BS transmitter d1=10m, MS location d2= 5 m from the tree blockage. The carrier frequency is assumed to be 2 GHz for 3G communication, 5 GHz and 60 GHz for 4G communication. The fig.2 and fig.3 shows the normalized field at the receiver, varying with respect to transmitter height. Fig.2 is for hard polarization and fig.3 is for soft polarization. The field at the receiver is divided into three regions. When the height of transmitter is below the height of tree, the region is known as deep shadow region. In that region, attenuation is more. As we increase the height of transmitter, attenuation decreases as shown in ISB region. Attenuation is least at LOS region. From the results it is clear that attenuation is greater at higher frequencies. In this work we have considered hard and soft polarizations, which are also known as vertical and horizontal polarization respectively.

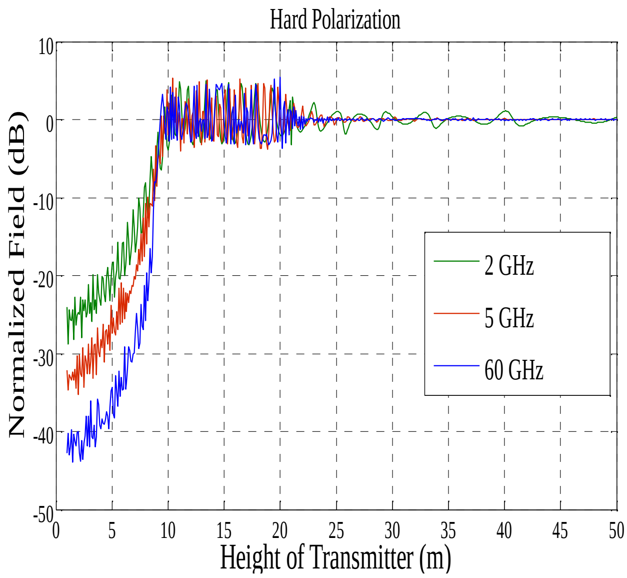

Fig. 2.Normalized field at the receiver with varying transmitter height at hard polarization

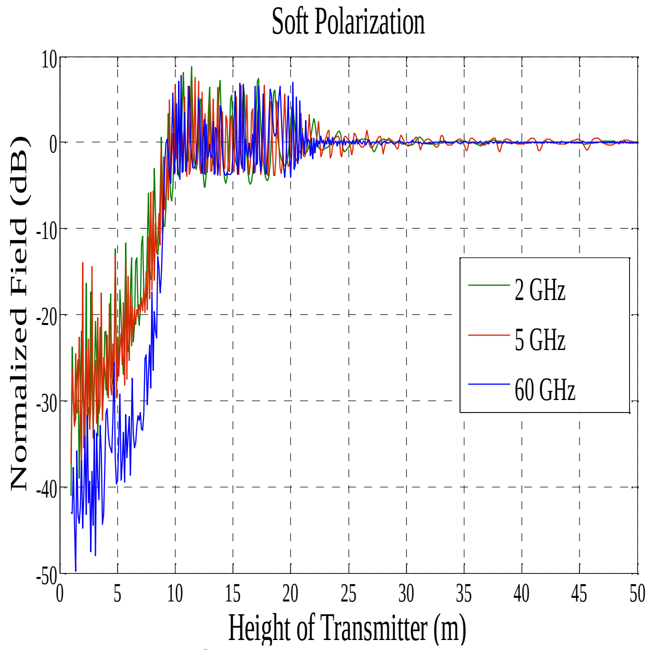

Fig. 3.Normalized field at the receiver with varying transmitter height at soft polarization

IV. CONCLUSION

A propagation model for tree blockage has been considered.In this work, we presented an improved deterministic model which is based on UTD. Ray contribution includes the direct waves, diffracted waves at the top of tree and ground reflections. Dependency of the received field strength on the height of transmitting station, operating frequency and type of polarization is presented in detail. The result can be used for cell planning and understanding the behavior at different operating frequencies.

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