A PROPAGATION MODEL OF CELLULAR MOBILE RADIO COMMUNICATION IN URBAN AREAS

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Abstract:

A numerical modeling of the propagation path loss using Uniform Theory of Diffraction (UTD) has been presented here. Computed results at 835 MHZ have been presented for various parameters of interest. The results at 2.154GHz have been obtained and compared with that of Walfish and Bertoni [1]. These are found to be in excellent agreement thereby establishing the validity of the code. Method is simple, efficient and reliable. Both shadow zone and line of sight zone have been considered.

Key Words: Propagation Model, Mobile communication, urban area, shadow zone

Introduction

For satisfactory working of the cellular mobile radio systems, an accurate predict ion of the path losses is necessary. Most of the cellular mobile users are located in the urban areas, also the urban environment is more complicated. Hence the predication of urban path loss needs more attention. There are number of models available but none of these predict the total losses completely. In this paper a theoretical model for predicting narrow band path loss for mobile communication in urban areas have been presented. The method is based on Uniform Theory of Diffraction [2] and is applicable to the shadow zone of the buildings as well in the illu -minated zone when the mobile antenna is in a moving vehicle.

Modeling [2]

In urban environment, the buildingare aligned in a row. Various possible paths in the presence of the buil -dings are shown in Fig.(1). Ray 1 to ray 4 represent the diffracted ray path due to building next to the mobile to the base station, reflected wave due to building on other side of mobile, incoming signal arriving over the top of the building to the mobile and ground reflected energy, respectively.

The simplifying assumptions can be made in the model for urban areas which are satisfied in actual cases to the great extent. These can be summarized as [2]-

1. The earth surface is plane.

2. The buildings are assumed to be of uniform height.3. The contributions of ray 3 and ray 4 can be neglected due to their in significant amplitude.

4.Backward diffracted field is neglected.

5. The buildings are replaced by opaque absor -bing screens.

With these assumptions, model appears to be as in Fig. (2).

Where,

$$D_{1} = \sqrt{d_{t}^{2} + (h_{t} - h_{b})^{2}}$$

$$D_{2} = \sqrt{d_{r}^{2} + (h_{b} - h_{r})^{2}}$$

$$r_{2} = \sqrt{(2d - dr)^{2} + (h_{b} - h_{r})^{2}}$$
(1)

 D_1 , D_2 , r_2 are the path lengths between the base station antenna and the local screen, between local screen and mobile antenna and the reflected ray due to the wall of the building next to the mobile respectively. The angle θ , α and β are indicated in Fig. 2.

Path Loss Prediction:

The total path loss L_t in db is defined as –

 $L_t = L_0 + L_1 + L_{md} + L_r$ -----(3)

Where, L_0 , L_1 and L_{md} are the losses due to free space propagation, local screen (building) in the

vicinity of the mobile, and multiple diffractions caused by the buildings respectively. L_r is the loss caused by the reflection of the diffracted electric fields from the walls of the building next to mobile. These losses are given as –

(a) Free space propagation loss-

$$L_0 = 92.4 + 20 \log_{10} f(GHz) + 20 \log_{10} D(K_m)$$
------(4)

Where,

$$D = \sqrt{(h_t + h_r)^2 + (h_t - h_r)^2}$$
-----(5)

(b) The loss due to local screen-

$$L_1 = -20\log_{10} |D^1 sh| + 10 \log_{10} D_2(m) +$$

 $10 \log_{10} \left[\frac{D_1(D_1 + D_2)}{D^2} \right] ----- (6)$

(c) The loss due to multiple diffractions caus -ed by buildings between base station and mobile -

$$L_{\rm md} = -20 \, \log_{10} \left| \frac{E_{n+1}}{E_0} \right| -----(7)$$

(d) The loss caused by multiple reflections-

$$L_{r} = -20 \log_{10} \left| 1 + R_{H,V} \sqrt{\frac{D_{2}(D_{1} + D_{2})}{r_{2}(D_{1} + r_{2})}} \frac{D_{s,h}^{H}}{D_{s,h}^{I}} \exp(-jk(r_{2} - D_{2})) \right|$$
------(8)

In this, $R_{H,V}$ is the reflection coefficient. H''V' stand for the horizontally and vertically polarized electric field

$$R_{H,V} = \frac{\cos^{\theta} - \alpha_{H,V} \sqrt{\varepsilon_r - \sin^2 \theta}}{\cos^{\theta} + \alpha_{H,V} \sqrt{\varepsilon_r - \sin^2 \theta}}$$
$$\alpha_H = 1 and \alpha_V = 1/\varepsilon_r$$
------(9)

 ϵ_r for concrete walls in the range 300MHZ TO 3ghZ IS 5.

Diffraction coefficient $D_{s,h}^1$ is defined as as –

$$D_{s,h}^{I} = \frac{-\exp(-j\pi/4)}{2\sqrt{2\pi K}} \left[\frac{F(X_{1})}{-\sin(\beta - \alpha)/2} \right] \mp \left[\frac{F(X_{2})}{-\cos(\beta + \alpha)/2} \right]$$

where ------(10)

$$X_{1} = 2k \frac{D_{2}}{1 + D_{2} / D_{1}} [\sin((\beta - \alpha) / 2)]^{2}$$
$$X_{2} = 2k \frac{D_{2}}{1 + D_{2} / D_{1}} [\cos((\beta + \alpha) / 2)]^{2}$$
------(11)

 $D_{s,h}^{II}$ is the same as (10) except X₃ and X₂ are replaced by X₃ and X₄ and β by θ .

$$X_{3} = 2k \frac{r_{2}}{1 + r_{2} / D_{1}}$$
$$X_{4} = 2k \frac{r_{2}}{1 + r_{2} / D_{1}}$$
(12)

$$F(X) = \sqrt{\pi X} \exp(j\pi/4 + X) - 2j\sqrt{X}e^{jX} \int_{6}^{\sqrt{X}} e^{-j1/2} d\tau$$

 E_{n+1}/E_0 is the normalized electric field amplitude at the screen position n+1 and N \approx dt/d

The model is applicable for the mobile located in the shadow zone characterized by-

 $\theta > \alpha$

or
$$d_t \left\langle \frac{h_t - h_b}{(d_b - d_r)} (2d - d_r) \right\rangle$$

For $h_b = 10m$, $h_t = 50m$, $h_r = 1.6m$, $d_r = 5m$, equation (15) tells us that $D_t > 547.6m$ And for $d_t = 1000m$, $h_t < 83.04m$

Line of sight (LOS) propagation model [4]:

when the mobile is located in the vehicle over the flat terrain LOS propagation using 2-ray model is given in fig. (3). r_1 represents path length of the direct ray and r_2 is the path length due to ground reflected ray. The received power can be expressed as-

$$\frac{P_r}{P_t} = \left[\frac{\lambda}{4\pi}\right]^2 \frac{1}{r_1} \exp(-jkr_1) + R\frac{1}{r_2} \exp(-jkr_2)^2$$
------(15)

 P_t and P_r denote the base station power and power received by the mobile antenna.

$$r_1 = \sqrt{d^2 + (h_t - h_r)^2}, \qquad X = \frac{h_t d}{h_t + h_r}$$

and 'R' the reflection coefficient may be expressed as-

$$R = \frac{\cos\theta - \alpha_{H,V}\sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \alpha_{H,V}\sqrt{\varepsilon_r - \sin^2\theta}}$$
------(16)

Results

For the validity of the code, Weizhang's [4] results have been compared (fig 3). The computed results are in good agreement, thereby establishing the validity of simulation. Various losses and their dependence on various parameters are given in Figs (3-4.1-4.6(a,b,c)The losses are less at 900 MHz compared to that at 2.154 GHz which can be attributed as there is decrease in propagation loss at low frequencies. Total loss increases with distance dt, decreases with increase in base station height but shows an erratic behaviour when the mobile is moved away from the local screen, which is mainly due to multiple reflections and diffraction taking place.

Off course the pattern of local screen loss remains constant with changes in h_t , d_t , d_r but the respective magnitudes change. Same is the case with free space propagation .Fig.4.1 shows the path loss as a function of distance for a two ray model of LOS propagation. **Conclusion:**

Propagation models have been proposed for mobile communication in shadow zone as well as line of sight zone.Computed results are reliable and are modified compared to previously available models.some conclusions have been drawn,but the illuminated zone have not been considered.

References

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