CELLULAR MOBILE RADIO SYSTEM DESIGN USING PATH LOSS CALCULATIONS

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ABSTRACT

In this study, the propagation path loss models developed for cellular communication have been investigated in detail. The accuracy of the models were examined and compared for different, environmental parameters, frequencies, separation distances and base station transmitter heights. By taking the application values of the GSM operators and cellular phones, mobile radio system design parameters were calculated and presented in order to decide cell radius, received signal power and dynamic range.

I. INTRODUCTION

The development of cellular mobile radio telecommunication systems led the working out of a new class electromagnetic field propagation models. Cellular systems are based on the decomposition of the coverage area in a certain number of sub-areas, called cells associated with the radio base stations. The radio base stations provide radio link between the wired infrastructure and the mobile terminals inside the cell. So it is of primary importance to identify accurate predictive models to plan the coverage areas, to analyse multi path phenomena, to check the interferences and to locate optimal sites for base station positioning. Radio propagation conditions also affect the battery power requirements for mobile transceivers and base station transmitter circuitry.

Field predictive or path loss propagation models are used to predict the power transfer between a transmitter and a receiver. Cellular mobile radio system propagation models are usually investigated in terms of large-scale effects and small-scale effects. Large scale effects involve the variation of mean received signal strength over large distances or long time intervals, whereas small-scale effects involve the fluctuations of the received signal strength about a local mean over small distances or short time intervals.[1],[2],[3],[4]. In this study large-scale propagation models were used to calculate large scale coverage for cellular mobile radio system design.

II. OUTDOOR PROPAGATION MODELS

The Okumura method:

This model is an empirical prediction method for signal strength prediction at frequencies up to 3000MHz.. The basic formulation of the technique can be expressed as

$$L = L_{FS} + A_m - ((H_B - H_M) + K_U + K) \qquad (1)$$

where, L_{FS} free space loss; $A_m(f,d)$ median attenuation relative to free space in urban area; $H_B(h_B,d)$ Base station antenna height gain factor; $H_M(h_M,f)$ The vehicular antenna height gain factor; $K_U(f)$ Urbanization type correction factor,(for urban area, suburban area, open area); K Additional correction factor (for hilly, sloping terrain, land-sea, street orientation, presence-absence of foliage.)

Hata's method:

This method describes the graphical information given by Okumura. Hata's basic formula for the median propagation loss is given as;

$$L = 69{,}55 + 26{,}16 \cdot \log(f) - 13{,}82 \cdot \log(h) - H_M + (44{,}9 - 6{,}55 \cdot \log(h_B)) \cdot \log(d) - K_U(f) \qquad (2)$$

H_m is the correction factor for mobile antenna height, the factor K_U is used to correct the small city formula for suburban and open areas and are computed as follows:

- for small or medium city

$$H_M(h_M,f) = (1{,}1 \cdot \log(f) - 0{,}7) \cdot h_M - (1{,}56 \cdot \log(f) - 0{,}8) \qquad (3)$$

- for large city (building heights greater than 15m)

$$f \le 200MHz$$

$$H_M(h_M,f) = 8{,}29(\log(1{,}54 \cdot h_M))^2 - 1{,}1 \qquad (4)$$

$f > 400 MHz$

$$H_M(h_M, f) = 3.2(\log(11{,}75 \cdot h_M))^2 - 4{,}97 \qquad (5)$$

$K_U(f)$ Urbanization correction factor with respect to urban area:

- Suburban area

$$K_U(f) = 2(\log(f/28))^2 + 5.4 \qquad (6)$$

- open areas

$$K_U(f) = 4.78(\log(f))^2 - 18.33 \cdot \log(f) + 40.94 \qquad (7)$$

The Extended Hata Model (COST 231 Hata): This model was developed to correct the situation that the Hata model which consistently underestimates path loss. The basic formula for the median propagation loss in dB given by extended Hata propagation loss model is

$$L = 43.6 + 33.9 \cdot \log(f) - 13.82 \cdot \log(h_b) - H_M$$
$$+ (44.9 - 6.55 \cdot \log(h_b))\log(d) + C_m$$

where (8)

H_M is the correction factor for mobile antenna height

$C_M = 0$ Medium city and suburban areas (9)

$C_M = 3$ Metropolitan centers

Walfisch-Ikegami Model (LOS) :

The Walfisch-Ikegami model has been shown to be good fit to measure propagation data for frequencies in the range of 800 to 2000 MHz and path distances in the range of 0.02 to 5 km.

In a LOS situation, there is no obstruction in the direct path between the transmitter and the receiver.

$$L_{LOS} = 42.64 + 26 \cdot \log(d_{km}) + 20 \cdot \log(f_{Mhz}), \qquad (10)$$

The propagation loss in free space is given by

$$L_{FS} = 32.45 + 20 \cdot \log(d_{km}) + 20 \cdot \log(f_{Mhz}) \qquad (11)$$

The LOS propagation loss can be written as

$$L_{LOS} = L_{FS} + 10.19 + 6 \cdot \log(d_{km})$$

$$L_{LOS} = L_{FS} + 6 \cdot \log(50 d_{km}) = L_{FS} + 6 \cdot \log(d_m / 20) \qquad (12)$$

Walfisch-Ikegami Model (NLOS):

For non line of sight situations the Walfish-İkegami model gives the path loss formula

$$L_{NLOS} = \begin{cases} L_{FS} + L_{rts} + L_{msd}, & L_{rts} + L_{msd} \geq 0 \\ L_{FS}, & L_{rts} + L_{msd} < 0 \end{cases}$$

where; the terms L_{rts}, L_{msd} are functions of NLOS parameters.

L_{rts} Roof to street diffraction and scatter loss, L_{msd} Multiscreen diffraction loss

The formula given for L_{rts} involves an orientation loss, L_{ori};

$$L_{rts} = -16.9 - 10 \cdot \log(w) + 10 \cdot \log(f_{Mhz})$$
$$+ 20 \cdot \log(h_B - h_m) + L_{ori} \qquad (14)$$

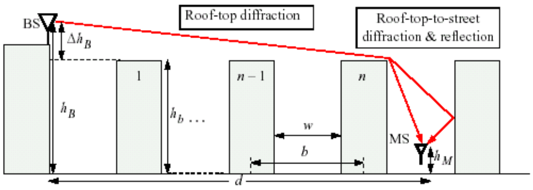

Figure-1-Total loss in a situation without line-of-sight

h_b base station antenna height over street level

h_m mobile station antenna height in meters

h_B nominal height of building roofs in meters

b building seperation in meters

w street width

where;

$$L_{ori} = \begin{cases} -10 + 0.354 \cdot \phi, & 0 \leq \phi \leq 35^o \\ 2.5 + 0.075 \cdot (\phi - 35^o), & 35^o \leq \phi \leq 55^o \\ 4 + 0.114 \cdot (\phi - 55^o), & 55^o \leq \phi \leq 90^o \end{cases}$$

The formula given for the multiscreen diffraction loss term L_{msd} is

$$L_{msd} = L_{bsh} + k_a + k_d \cdot \log(d_{km}) + k_f \cdot \log(f_{Mhz}) - 9 \cdot \log(b) \qquad (15)$$

$$L_{bsh} = \begin{cases} -18 \cdot \log(1 + h_b - h_B), & h_b - h_B > 0 \\ 0, & h_b - h_B \leq 0 \end{cases}$$

L_{bsh} is shadowing gain that occurs when the base station antenna is higher than the rooftops and k_a, k_d, k_f are the multiscreen diffraction, distance and frequency factors.[5]

III. PRACT ICAL LINK BUDGET DESIGN USING PATH LOSS MODELS

The limiting factor on a wireless link is the signal to noise ratio (SNR) required by the receiver for a reliable reception. The desired signal level in the communication channel is represented as a function of transmitter power and path loss as follows:

$$P_r(dBm) = P_t(dBm) + G_t(dB) + G_r(dB) - \overline{PL}(d) \quad (16)$$

Thermal noise is considered as the only noise power in link budget design and the calculations were done by this assumption

$$N(dBm) = -174(dBm) + 10\log B + F(dB) \quad (17)$$

$$SNR = P_r - N(dBm) \quad (18)$$

The relationship between received power by an isotropic antenna and field strength at the receiving site is calculated as

$$P_r = \left(\frac{\lambda}{4\pi}\right)^2 \frac{E^2}{30} \quad (19)$$

The received power is also defined in terms of transmitted power and propagation path loss as

$$P_r = P_t - \overline{PL(d)} \quad (20)$$

For propagation path loss calculations the mobile and base station antenna heights were assumed 1,7m and 30m in all cases. The field strength values are calculated for 13 watt transmitter power and 15,5dB antenna gain

IV. CONCLUSION

In this study four different types of propagation models for outdoor scenarios were presented and compared. The sensitivity of the models was analyzed by changing the environmental parameters and frequency. The calculated electric field intensity and path loss values with respect to separation distance are presented in Figures 2 and 3. The sensitivity of the path loss models with respect to frequency and noise power level variation versus bandwidth are given in Figures 4 and 5 respectively. Results show that Hata and COST 231 Hata models become more sensitive to separation distance and therefore suitable for macro cells. Walfisch-Ikegami and Hata models are suitable for micro and pico cells at 900 MHz frequencies. Free space path loss model can only be used for prediction of rough path loss values. These calculations are found to be good agreement with literature. The studied models were implemented in a software package so the results can be compared to another tools and models.

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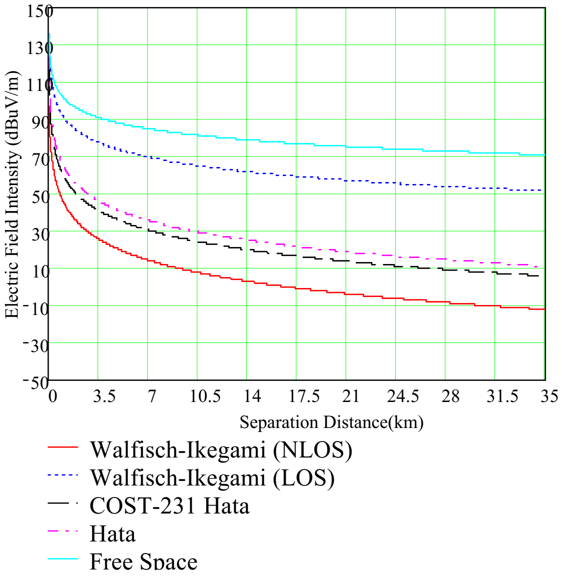

Figure-2- Comparison of Electric Field Intensity

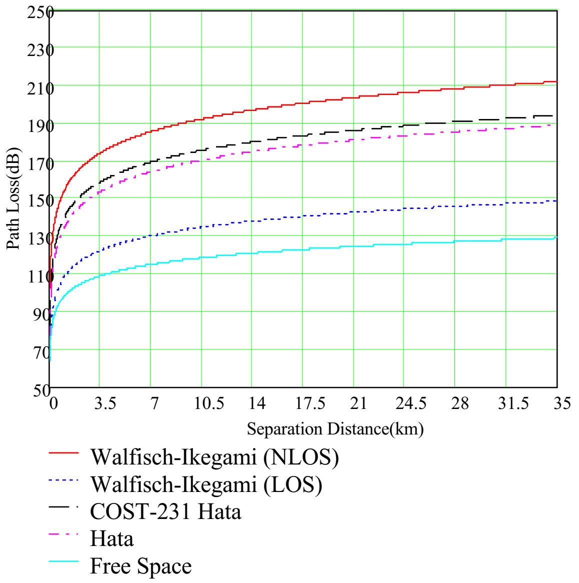

Figure-3-Comparison of Path Losses

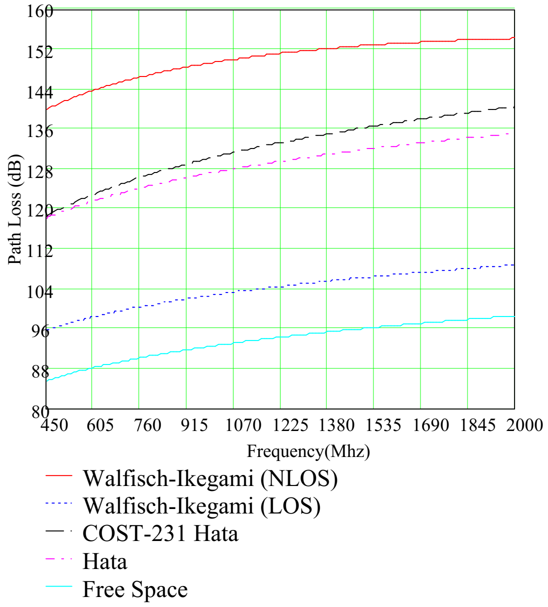

Figure-4-Path loss versus frequency

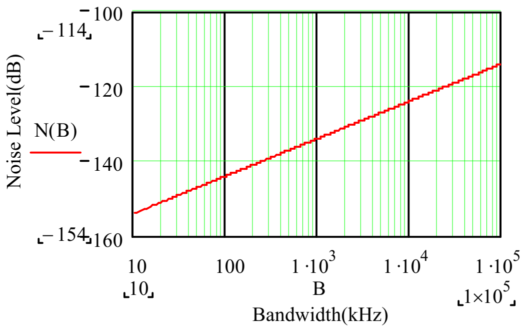

Figure-5-Noise power level versus bandwidth