Prediction of Mobile Radio Wave Propagation in Complex Topography

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Abstract: This work studies the prediction of the mobile radio performance and examines the two dimensional mobile radio coverage in case of free space propagation and interference wave propagation for different types of polarization, different types of reflection coefficients, different types of reflecting rough and smooth surfaces. The results show that free space range is less than the interference range but the interference coverage has the lobe structure which causes nulls in the coverage and no signal will be detected in these nulls. Also the results show that the range for the free space propagation is the same for vertical and horizontal polarization but it is greater than the range in case of using circular polarization. The detection range is decreased because of the increasing of the transmitting frequency due to the atmospheric attenuation. This research is widely applicable for V/UHF wireless radio systems, Also it is new approach in simulating and modeling the mobile radio wave propagation and it is very useful as a research and training simulator for the undergraduate and postgraduate students.

Keywords: Performance, Simulator, V/UHF Wireless Radio System

1. Introduction

The performance of wireless communication systems is limited by the mobile radio channel. The radio waves are controlled by physical laws (Parsons, 1992). Terrestrial losses are highly suffered by the general topography of the terrain. The low mobile antenna height, usually very close to ground level, adds additional propagation-path loss. In general, the propagate energy is dissipated due to the texture and roughness of the terrain and the signal strength will be decreased (Jouko, 2006). The propagation of the signal between the mobile unit and the base station is affected by multipath fading phenomena and interference which are caused by land features and man-made structures amplitude which is valid only for a very limited range of time (Fumio & Susumu, 1980).

2. Theoretical Principles

A. *Propagation of Line of Sight*

The line-of-sight path assumes that antennas of the transmitter and receiver are without any obstacles as shown in Figure 1.

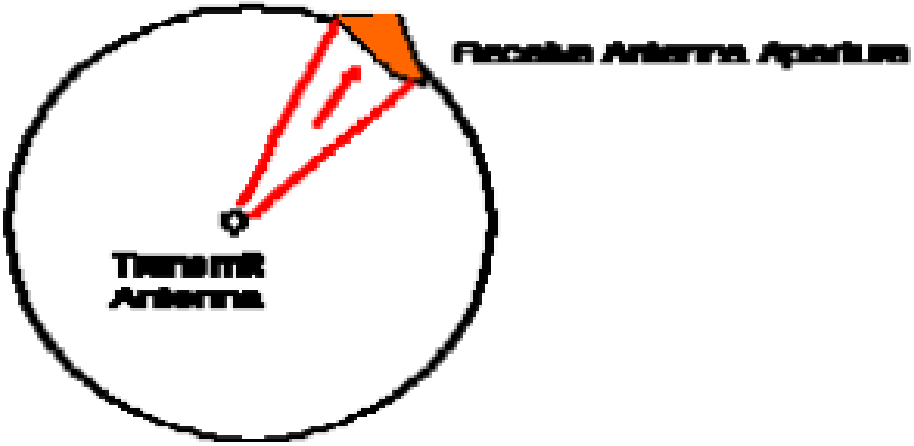

Figure 1: Line of sight propagation

Line of sight path loss in decibels can be written as (Barry, 1997):

$$Lp = 32.45 + 20\log10 f\,(\text{MHZ}) + 20\log10 d\,(\text{km}). \quad (1)$$

The transmitting frequency is f and is measured by MHz, and *d* is the range between transmitter and receiver in km.

B. *Propagation over Plane Reflecting Surface*

The reflection coefficient of the earth and wave polarization affect the amplitude and phase of the reflected wave and it depends on the type of either horizontal or vertical polarization (Kraus, 1988). The incident field has two components as shown in Figure 2.

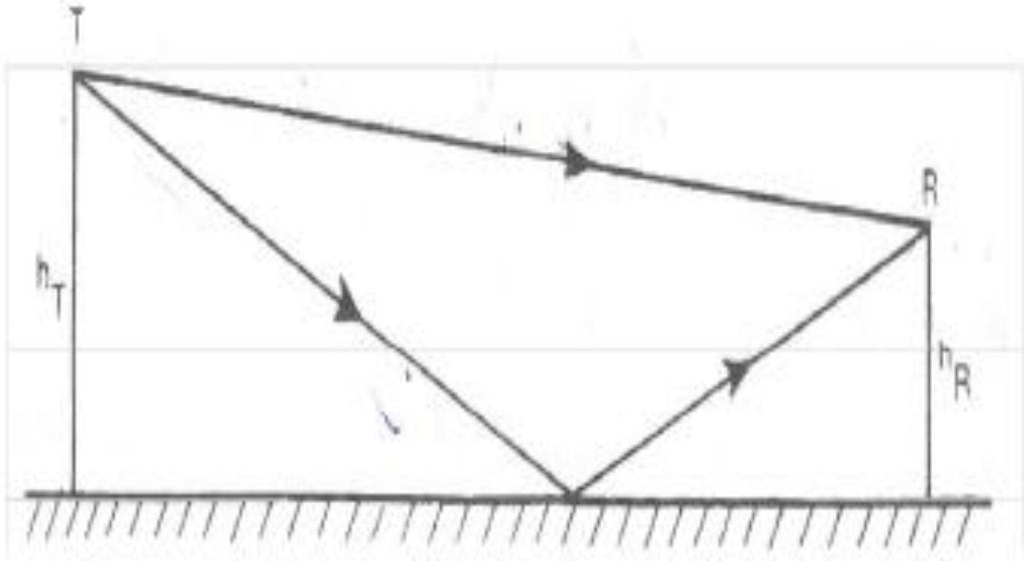

Figure 2: Propagation over a plane surface, hT and hR are transmitter (T) and Receiver (R) heights respectively (Kraus, 1988).

C. *Multipath Propagation Path loss Prediction Models*

The planning of propagation model and prediction of the path loss are main targets to design the performance of the propagation channel. Each model differs depending on different terrain and environmental specifications.

The median path loss is to be predicted and not exceeded at 50% of sites and/or for 50% of the time. It is possible to calculate the likelihood of interference from a distant transmitter (Kraus, 1988). Three models will be studied, namely Hata's model provided by Okumura, Egli and Lee′s models.

1) Hata`s Model

Hata`s model predict and classify small to medium-sized city, and Large-sized city. The models are defined as follows;

a) Open area: open site, in the path, distance is 300-400m ahead, (Hanci & Cavdar, 2004).

*b) Suburban area: town and homes, with obstacles close to the station (*Hanci & Cavdar, 2004).

c) Urban area: Big city with large (Hanci & Cavdar, 2004).

d) Small to medium-sized city: with business districts characterized by numbers of high buildings and few, if any, skyscrapers. Traffic density is usually moderate to heavy, depending upon flow patterns and time of day (Jouko, 2006).

e) Large-sized city: Industrial city with high population and business districts are characterized by many skyscrapers. Traffic density is heavy virtually at all times. Cities like New York, Boston, Philadelphia, Los Angeles, and Newark, New Jersey, are typical large cities (Jouko, 2006).

2) Lee′s model

The Lee model is defined by using two components (Dorsey, 1990; Kraus, 1988). The first component is an area-to-area path loss prediction, and the second component is point-to-point prediction (Dorsey, 1990; Kraus, 1988).

The median loss at a distance d is given by (Kraus, 1988);

$$L50 = L0 + \gamma \log d + F0. \quad (2)$$

The median transmission loss is assumed 0 *L at range of 1km* and the slope of the path loss curve is measured by dB/decade and *F0* is measured in dB.

3) Egli Model

This model is obtained by empirical formulas and theoretical plane-earth field strength (Dorsey, 1990; Kraus, 1988; Barry, 1997). The terrain factor for 900 MHz has median value of 27.5 dB.

3. Results & Discussion

A. Effects of Polarization on Mobile Radio Coverage

Figure 3 shows the free space coverage and the lobbing pattern of mobile radio station which is using transmitting frequency of 1300 MHz, transmitting power of 100W and vertical polarization. The results obtained agree with previous studies (Parsons, 1992; Tarng, Chang, & Hsu, 1997; AL-Samerai, 1988; Griffiths, 1987).

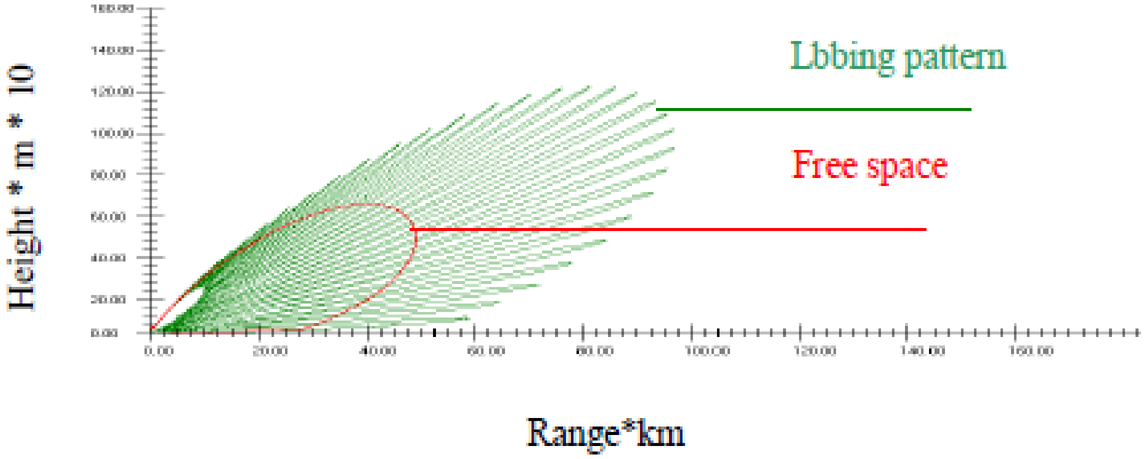

Figure 3: Mobile radio coverage diagram for lobbing pattern and free space cases for f= 1300 MHz, horizontal polarization and pt=100W, h= 30

The lobbing patterns are different for all types of polarization. Figure 4 shows that the horizontal polarization gives greater ranges and heights than that obtained when using the vertical, assuming the same reflecting surface. Also the vertical polarization gives greater ranges and heights than that when using the circular polarization which means that different reflection coefficients with three different polarizations produce different mobile radio lobbing patterns.

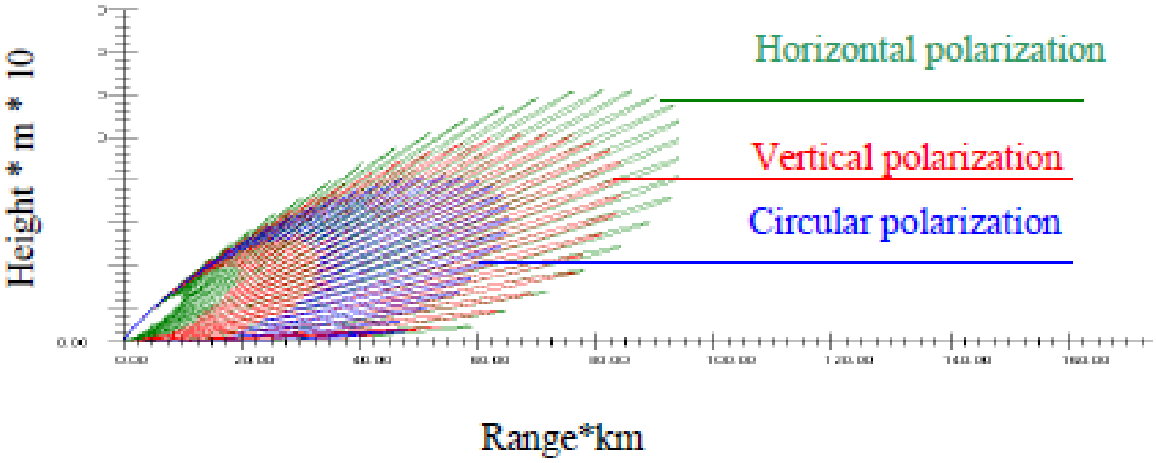

Figure 4: Mobile radio coverage diagram for lobbing pattern with different polarization for f= 1300 MHz, horizontal polarization and pt=100W, h= 30m.

B. Effects of the Path Loss Prediction Models on Mobile Radio Coverage

1. Effects of the Okumara's Model on Mobile Radio Coverage

This model includes four models: open-area model, suburban-area model and urban-area model, also urban- area model includes large, medium and small city. These models are shown in Figure 5. Transmitting frequency is 900MHz, transmitting power is 100W, base station antenna height is 30m, distance is 1km and the polarization is vertical. In this figure the open area coverage gives greater ranges and height than the suburban, small and large cities, because the path loss in open area model is lesser than the other models, also when the path loss is small then the range is large. The maximum range decreases sharply to 4km when using small and medium city model, and when the large city model is introduced, the maximum range is decreased to 3km.

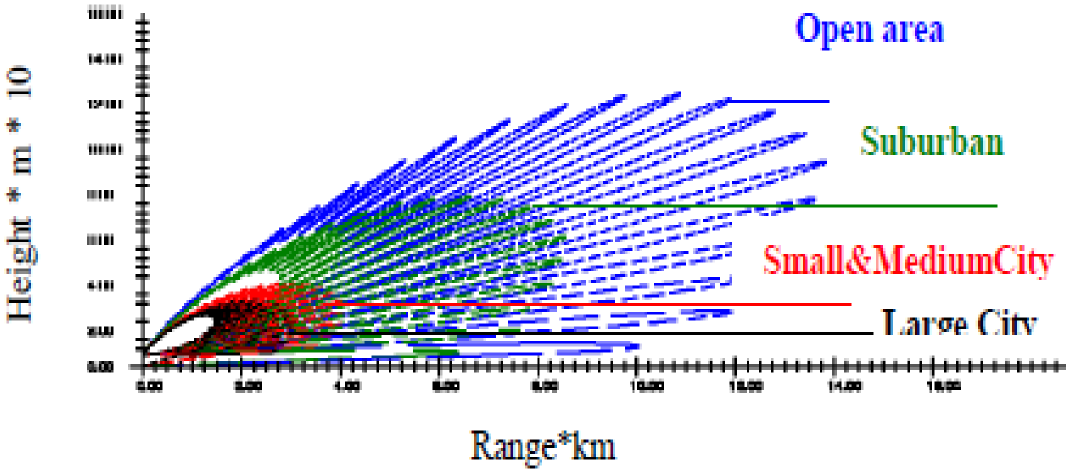

Figure 5: Mobile radio coverage diagram for different Okumara's model in lobbing pattern for vertical polarization, h=30m, pt=100W, d=1km, and f=900MHz.

2. Effects of the Lee's Model on Mobile Radio Coverage

This model includes an adjustment factor that can be adjusted to make the model more flexible to different regions of propagation, also includes point-to-point model and area to- area model, as shown in Figure 6. The path loss in area-to-area model is 94.6672dB and in the point-to-point model is 105.12dB.The area to- area coverage is greater than that of point-to-point model. The maximum range is 16.6km for the area-to-area model and decreases sharply to 4.6km for the point-to-point model.

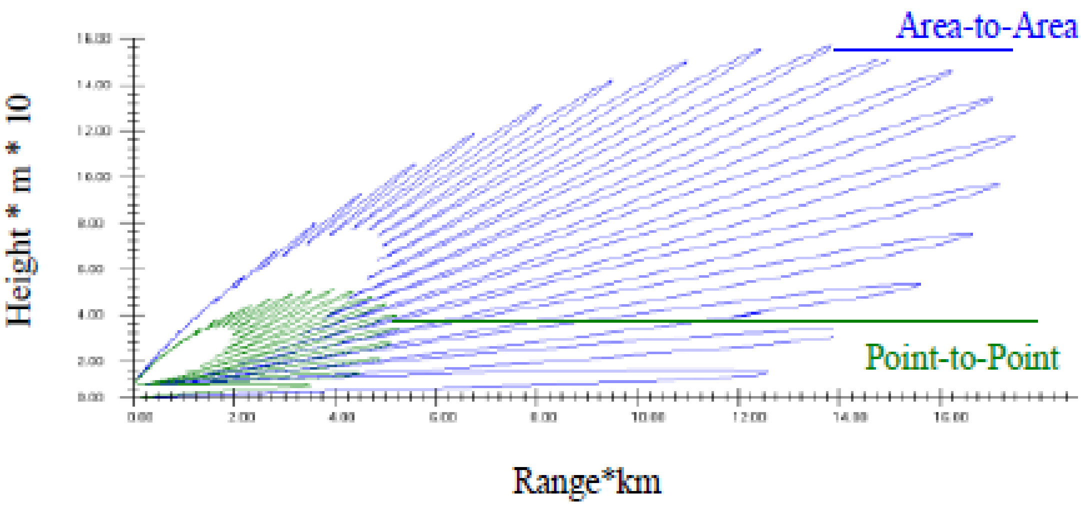

Figure 6: Mobile radio coverage diagram for different Lee 's model in lobbing pattern for h=30m, vertical polarization, pt=100W, d=1km

3. Effects of the Egli Model on Mobile Radio Coverage

In Figure 7, this model is compared with another path loss prediction model, the path loss in this model is very small and equals to 27dB, when transmitting power is 100W, transmitting frequency is 900MHz, Baste station antenna height is taken 30m, distance between base station and mobile station is 1km and polarization is vertical. The maximum detection range in this model is greater than 60 km and is greater than that in the case of Okumara's model in Figure 5 and Lee`s model in Figure 6 taking the same parameters and conditions into account.

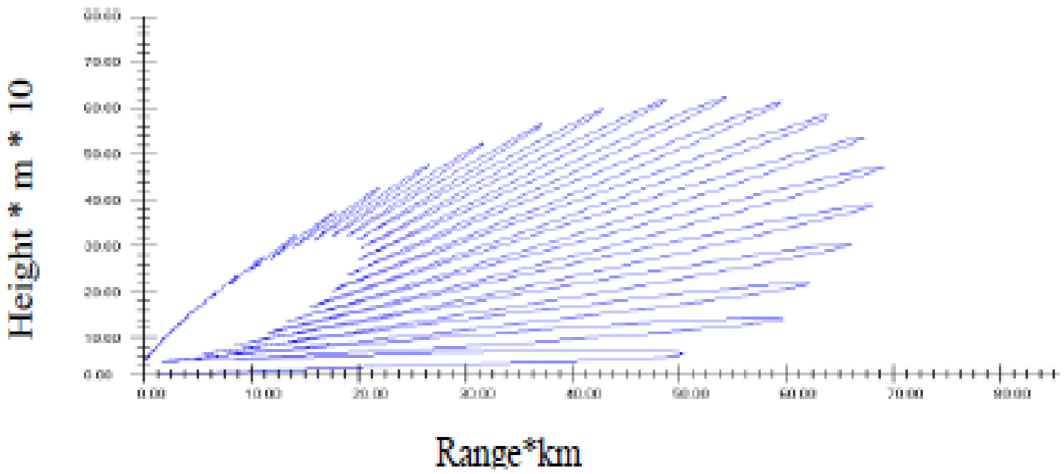

Figure 7: Mobile radio coverage diagram for Egli model in lobbing pattern for vertical polarization, h=30m, and pt=100W, d=1km, f=900MHz.

4. Conclusion

A. The horizontal and vertical polarizations can be used for long range communication and high altitude detections, while the circular polarization can be used for short range and high altitude detection.

B. Radio coverage depends on the reflecting surface and gives greater ranges when it is compared with the free space propagation.

C. The path loss prediction in the simulation of the radio coverage produces shorter ranges and heights than other the models, and gives a good prediction of the radio coverage. The path loss prediction shows that the Egli model produces longer range than the Okumara′s-Hata model and the Lee′s model.

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