Performance Analysis of Different Propagation Models and the Correlation with Cellular Mobile Communication Systems

M. Mowrin Hossain and P. Mohan

Abstract—In this paper, the performance of different propagation models were analysed by calculating the variation of path loss with distances and frequencies. To correlate the propagation model with the wireless technique, a cellular communication system comprising five adjacent regions with actual population area and environmental conditions were considered. Path losses are increasing with the increase of distances and also depend on the systems where path losses are obtained from free spaces, flat earth and the ITU model. The value of path losses obtained from the Walfisch-Ikegami model is lower for the frequence of 900 MHz 1800 MHz. On the other hand, higher values of path losses were observed for Okumura-Hata and Lee's model. The Walfisch-Ikegami model is less dependent on distances and frequencies. The effective isotropic radiated power (EIRP) and coverage threshold was calculated using Hata-Okumura, Walfisch-Ikegami and Lee's model at 3 and 6 cell sectoring communication systems. The performance of the handoff mechanism was analyzed using the propagation model.

Keywords—Propagation model, Handoff, Path loss Eirp, coverage threshold.

1 INTRODUCTION

TODAY we live in the era of communication. The cellular concept of modern electronic communication was a major break through in solving spectral congestion and user capacity. It offers very high capacity in a limited spectrum allocation, without any major technological changes. It is essential for engineers to understand the propagation model in order to predict cellular communication systems[1]. The propagation model focuses on path losses between the transmitter and receiver during the period of propagating radio waves. Models are empirical in nature, which means they are developed by collecting extensive data for specific geographical and environmental scenarios.

Cellular mobile communication techniques are becoming increasingly popular. Cellular systems provide more channels per unit coverage area in terms of splitting and sectoring. The processing of handoffs is an important test in any cellular mobile radio system. Handoff must be performed as seldom as possible to avoid the "ping-pong" effect [2]. When a particular signal level is identified as the minimum acceptable range, it is established as the threshold at which handoff is made. The present work compares the performance of different propagation models. To correlate the propagation model with wireless techniques, the area comprising Rajshahi City Corporation and its adjacent upazila, Poba of Bangladesh was considered for developing a model as an example of cellular systems [3, 4]. The effective isotropic radiated power (EIRP) coverage threshold was calculated and the handoff strategies of this system were predicted using Hata-Okumura, Walfisch-Ikegami and Lee's model.

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2 ANALYSIS OF PROPAGATION MODELS

During the travelling of radio waves from transmitter to receiver, attenuation suffers as a result of propagation loss. Different propagation models are used to predict the above mentioned propagation loss. Different models were developed to understand propagation behavior in various environmental conditions [5].

Okumura-Hata, Walfisch-Ikegami and Lee's models are currently the most popular propagation model for predicting path loss. The Okumura-Hata model was developed in 1980 by Hata [6] and based on measurements reported by Okumura et al. [7] in 1968, and can be simplified for the use of a particular frequency [1] such as 900 MHz and the typical mobile antenna height of 1.5 meters to measure loss.

$$Loss = 146.8 - 13.82 \log h + (44.9 - 6.55 \log h) \log d \quad -----(1)$$

Digital mobile radio systems modify the model above for a typical frequency 1800 MHz [1] as follows:

$$Loss = 157.3 - 13.82 \log h + (44.9 - 6.55 \log h) \log d \quad ----(2)$$

Further progress was made by combining two separate models by Walfisch and Ikegami (COST-231). This involves an equation similar to the Okumura-Hata equation, but also includes terms accounting for 'rooftop-to-street diffraction' and 'multi-screen diffraction'. The main advantage is that it retains validity even when the transmitting antenna is below the surrounding roof height. The predicted loss Walfisch-Ikegami model is demonstrated by the equation:

$$Loss = 42.6 + 20\log_{10}(f) + 26\log_{10}(d) \quad --------(3)$$

Lee's path loss model was based on empirical data chosen as a flat terrain area. It is also known as "North American model" [10].

$$Loss = 107.7 + 38.4\log(d_1/1600) - 20\log(h_b/30) - 10\log(h_m/3) - g_{bs} - g_{mt} \quad ----(4)$$

Handoff initiation was also analyzed, using the above mentioned path loss models. The actual data for population and coverage area [3] were used for planning cellular systems in five different zones. The different parameters were calculated by considering 3 and 6 cell sectoring systems. The following simple link budget equation is used to calculate coverage threshold and effective isotropic radiated power (EIRP) [1];

$$Coverage\ \ Thershold\ \ (dBm) = EIRP - Path\ \ loss\ (dB) \quad -----(5)$$

Traffic per subscriber is also calculated using the well known Erlang formula [8].

3 Results and Discussion

The performance of the free space, flat earth, ITU model, Egli model, ITU Terrain, and Young propagation models were analyzed by calculating path loss. Results demonstrate that the path loss is dependent on distance and system losses.

A comparison of the distance dependent path losses was obtained from calculated results produced by the Okumura-Hata, Walfisch-Ikegami and Lee's propagation models shown in figure-1 and figure-2 at 900 MHz and 1800 MHz respectively. The path loss dependent on the base and mobile station antenna height was also calculated.

It was found that the path loss increases with an increase in distance. On the other hand, it decreases when there is an increase in base and mobile station (antenna) height. Calculated results show that the path loss is totally dependent on environmental conditions and frequencies. The path loss is slightly dependent on frequency, in the case of the Walfisch-Ikegami propagation model. However it is heavily dependent on the frequency in Lee's model. The minimum propagation loss is obtained from the Walfisch-Ikegami model. It is approximately the same for Hata-Okumura and Lee's propagation model at the same distance and frequency (Fig-1, Fig-2).

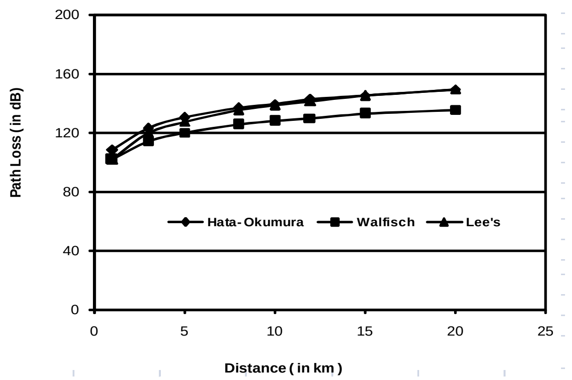

Figure 1: Performance analysis of distance dependent path loss at 900 MHz for Hata-Okumura, Walfisch-Ikagami and Lee's Model.

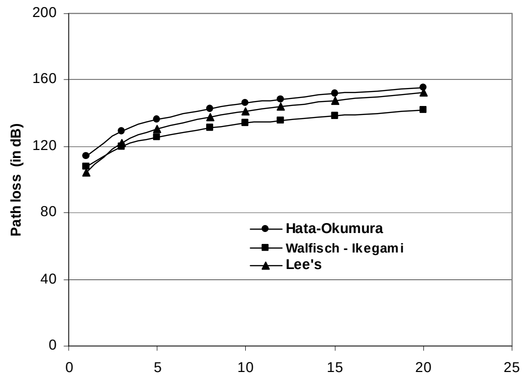

Figure 2: Performance analysis of distance dependent path loss at 1800 MHz for Hata-Okumura, Walfisch-Ikagami and Lee's Model.

An analysis of handoff initiation is contained in figure-3. The result was obtained using different path loss models, such as the Okumura-Hata, Walfisch-Ikegami and Lee's models. This figure shows that the Handoff occurs at a lower distance for Okumura-Hata model than Walfisch-Ikegami model. It occurs in Lee's model at a further distance than the other two models.

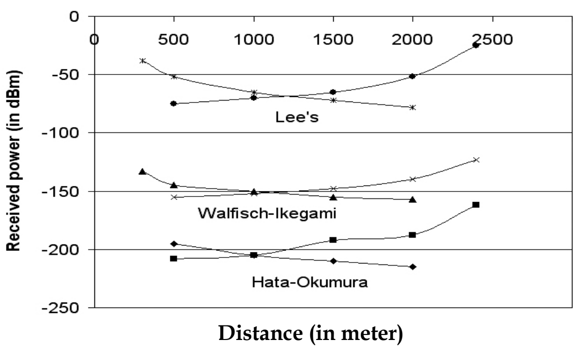

Figure 3: Performance analysis of handoff mechanism by using different propagation models

The method of analyzing path loss is vital for predicting the cellular communication system. It was observed that the effective isotropic radiated power (EIRP) and coverage threshold of the cellular system is easily calculated by using different propagation models. The path loss is also dependent on cell radius. The cell radius dependent path loss at three sectoring cellular system is shown in figure-4. The path loss was obtained by using different propagation models. Path loss increases as the radius increases. The path loss obtained from Walfisch-Ikegami and Lee's models are approximately the same. Conversely, the value is higher in the case of the Okumura-Hata model (Fig-4)

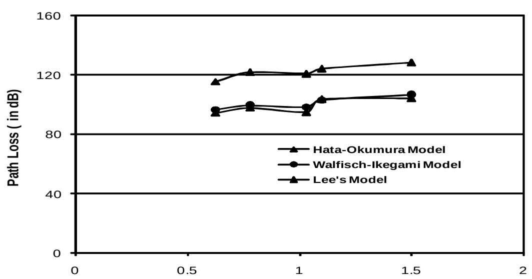

Figure 4: Perfomance analysis of cell radius dependent path loss at 3 cell clusters cellular system for Hata-okumura, Walfisch -Ikegami and Lee's model.

Cell-radius dependent effective isotropic radiated power (EIRP) is shown is figure-5 and figure-6 for three and six sectoring cellular systems respectively. It is evident from the results that the values of EIRP calculated by using Walfisch-Ikegami and Lee's propagation model is negligible within the cell-radius of 1.03 km for three sectoring system. On the other hand, it is within 0.88 km for six sectoring system.

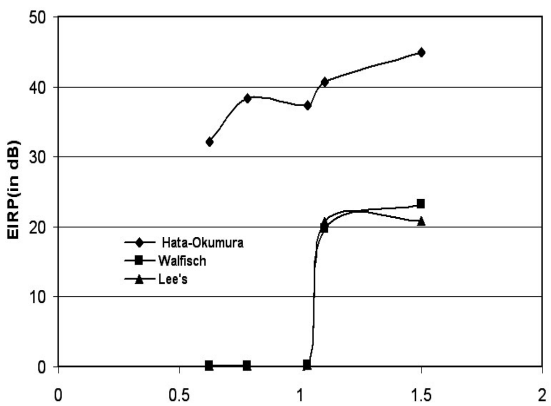

Figure 5: Performance analysis of cell radious dependent EIRP at 3 sector cellular system was calculated using Hata-okumura, Walfisch-Ikegami and Lee's model.

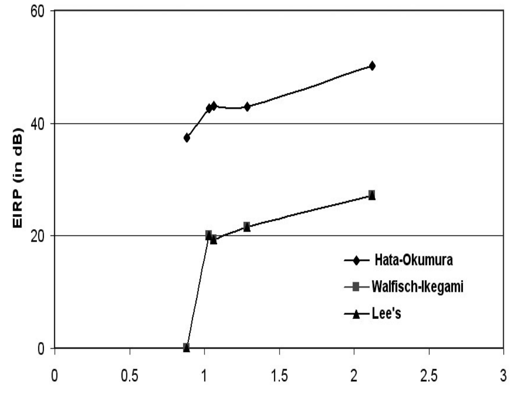

Figure 6: Performance analysis of cell radious dependent EIRP at 6 sector cellular system was calculated using Hata-okumura, Walfisch-Ikegami and Lee's model.

4 Conclusion

The path loss calculated using different propagation model varies with distance, frequency and environmental factors. The data analysis confirms that the path loss calculated by Walfisch-Ikegami model is lower and less dependent on distance. Lee's model is preferable for calculating long distance handoff mechanisms. By contrast, the Okumura-Hata model may be used for short distance communication systems. We may also conclude that the Hata-Okumura propagation model is appropriate for the region of cellular systems, as proposed in this paper. The effective isotropic radiated power (EIRP) and coverage threshold are dependent on the radius of the cell for mobile communication techniques.

References

[1] Christopher Haslett, "Essentials of Radio wave propagation," Cambridge University press, pp. 26-48, 2008.

[2] Kamil Sh. Zigangirov (2004) "Theory of code division multiple access communication", A Jonn Wiley and Son's, Inc. Publication.

[3] Population Census, "Community Series, Rajshahi", Bangladesh Bureau of Statistics, 2001.

[4] M. Mowrin Hossain, et. al. "A proposed cellular link for Bangladesh", *CMARS*, 9th-11th Dec. Jodhpur, India, pp. 120-121, 2008.

[5] M.M. Hossain et. al, "Analysis of Large-Scale propagation Models for Mobile communications in Arban Area," *International Journal of Computer Science and Information Security*, vol-7, no-1, pp. 135-139, 2010.

[6] Hata, M., "Empirical formula for propagation loss in land mobile radio service," *IEEE Transaction on Vehicular Technology*, 29, pp. 317-325, 1980.

[7] Okumura et. al., "Field strength and its variability in VHF and UHF land-mobile service," *Review of the Electrical Communication Laboratory*, 16, pp. 825-873, 1968.

[8] Parkinson, R, "Traffic Engineering Techniques in Tele Commu-

nication," Infotel systems Inc, 2005.

[9] Dongroo Har et. al, "comment on diffraction loss of roftop-to-street in COST 231-Walfisch-Ikogami model", *IEEE Transaction on Vehicular Technology*, vol. 48, no. 5, pp. 1451-1452,1999.

[10] Anderson, H.R, "A ray-tracing propagation model for digital broadcasting systems in urban areas", *IEEE Transaction on Broadcasting*, vol-93, no-3, pp. 309-317, 1993.

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