Prediction Of 3D Digital Map Coverage For UHF Wireless Radio Performance Under Multipath Propagation

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Abstract

This paper presents prediction of 3D digital terrain mapping for mobile radio coverage in the case of multipath fading under different frequencies, 900MHz and 1300MHz. Three multipath models are introduced in this study, Egli, Hata, and Lee. The results obtained in the present work involve analyzing the effects of path loss prediction models such as Okumara`s-Hata model, Lee`s model and Egli model on multipath propagation. The DMC contours for multipath of a Base station are constructed. The results show that the Egli model produces greater ranges than Okumara`s-Hata model and Lee`s model. Also DMC contours for multipath model are greater and has a higher probability of detection and higher detection ranges than Okumara`s-Hata model, taking the same receiver height. This study is a new approach and development for predicting the 3D land topography and digital terrain mapping of Wireless Radio systems such as landing and Beacon systems offering time, cost and accuracy for the UHF mobile radio sitting.
Keywords: DMC, Generation, Propagation.

INTRODUCTION

A wireless channel is modelled as a time-varying communication path between two stations such as from/to one terminal to/from another terminal. The first terminal is the fixed antenna at a base station (BS), while a subscriber represents the second station. The radio propagation properties introduce new challenges for isotropic directed antennas, choice of appropriate carrier frequency, and transmission techniques under the condition of fast fading. Propagation in a multipath channels depends on the actual environment, such as the antenna height, the profile of buildings, the trees, the roads, and the terrain [4]. Moreover, polarization is one of important factors that affect the propagation of radio wave [5].

THEORETICAL PRINCIPLES

A. Path loss Prediction Models

Typical propagation of radio is shown in Fig.1 [4], the path loss is explained and calculated by Ref.[1]. Existing prediction models differ in their applicability over different terrain and environmental conditions[1]. Most models aim to predict the median path loss [1].

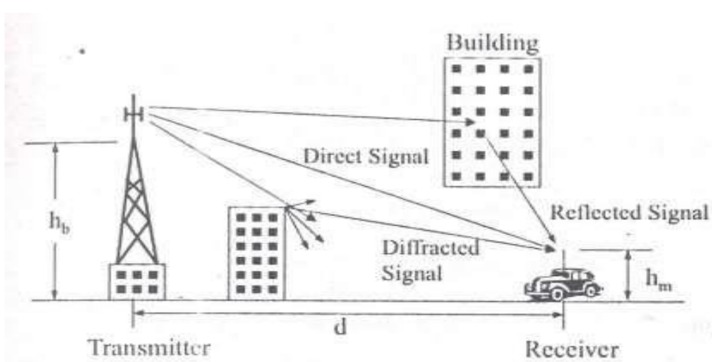

Fig. 1: Reflection and diffraction of the radio signals

A-1. Okumara’s-Hata Model

Hata’s model was based on empirical data from measurements in Tokyo, Japan and has been claimed to give an accurate estimate of the path loss to within 1.0 dB when compared with the actual measurements [7]. Unfortunately it does not apply too well to the North American suburban terrain [1, 4, 7].

B. Lee’ s Model

Lee’s model has been known to be more of a “North American model” than that of Hata [7].

C. Egli Model

This model consists of empirical formulas that provide a “terrain factor” to be applied to the theoretical plane-earth field strength [1, 2, and 3]. The terrain factor for 900 MHz has median value of 27.5 dB. The variation of field strength with antenna heights and distance is that of the underlying plane earth model [1].

SIMULATION OF MULTIPATH MODELS

Matlab & C++ languages are used to compute and plot detection map contours at different receiver heights around the base station site for 360° azimuth angle, for different types of polarization, different models in addition to changing the transmitting frequency and transmitting power.

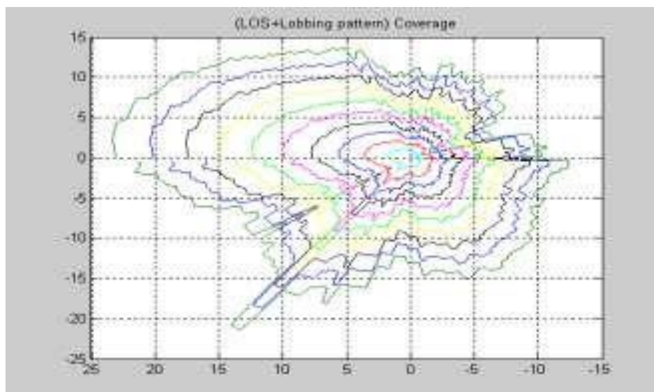

Fig. 2: DMC for horizontal polarization

A. Effects of Path Loss Prediction Models on the 3DMRC

A-1. Effects of EGLI Model on the for Multipath Reflection Case

Fig. 2 shows the DMC contours for the Egli-model when path loss is 27dB, transmitting frequency is 900MHz, transmitting power is 100W, and polarization is horizontal. In this figure the maximum range is 75km, also in this model the path loss is smaller than the range when this model is compared with Okumara’s-Hata model and Lee’s model by reference [6].

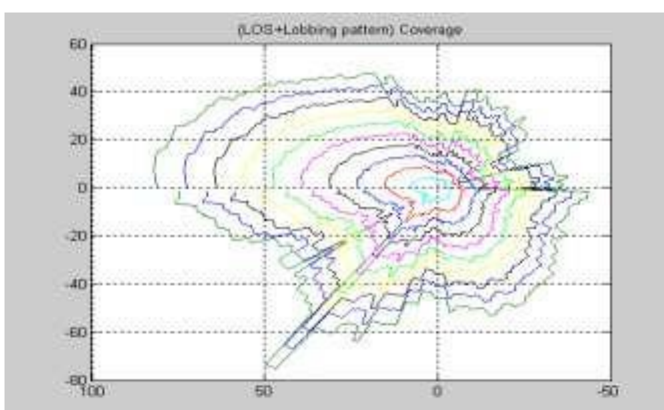

Fig. 3: DMC for horizontal polarization, f=900MHz, pt=100W, open-area Hata model and multipath reflection

A-2. Effects of Okumara's-Hata Model on the 3DMRC for Multipath Reflection Case

Figs 3, 4, 5 and 6 are obtained and base station antenna height is 30m, direct distance between base station and mobile station is 1km and polarization is horizontal. Where the heights of the receiver in the DMC are assumed 10 altitudes beginning from first height of 50m from the centre of the DMC. The DMC contours for open area model (Fig. 3), have maximum range of 23km which is greater than that for the suburban-area model which is 15km in Fig. 4, while for the small-city model which the maximum range is 8km in Fig. 5 and the last case is greater than that for the large city model (Fig. 6), which gives maximum range of 7km at the same azimuth angle of 270° and same receiver height of 500m.

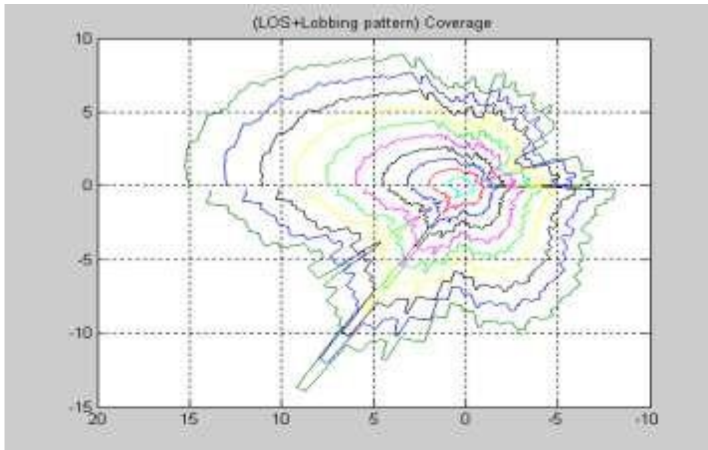

Fig. 4: DMC for horizontal polarization, f=900MHz

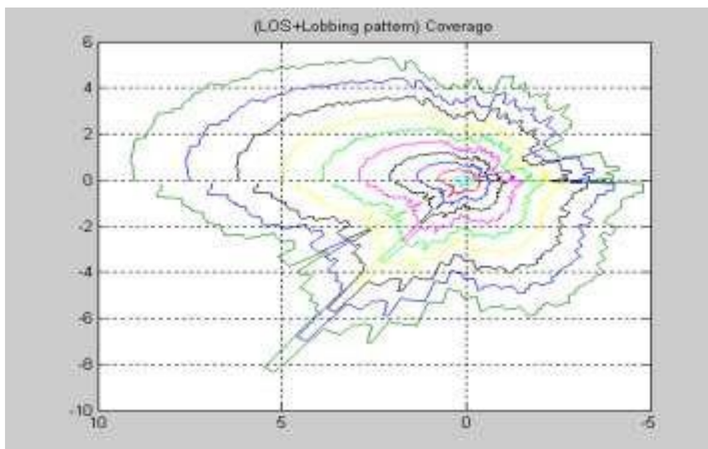

Fig. 5: DMC for horizontal polarization, f=900MHz, pt=100W, small city, Hata model and multipath reflection

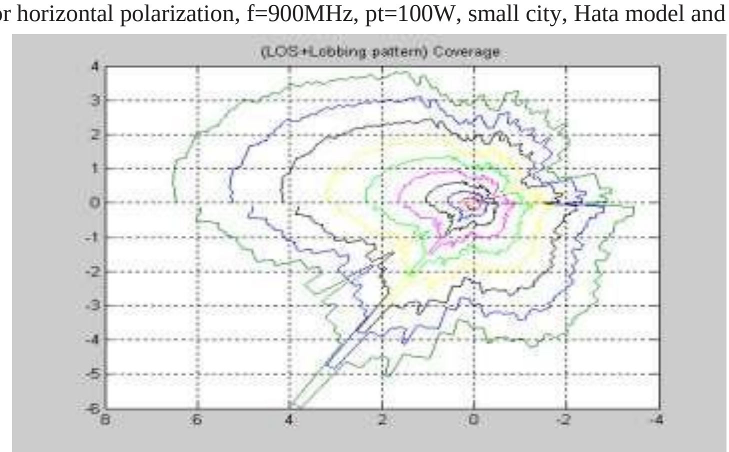

Figure 6: DMC for horizontal polarization, f=900 MHz, pt=100W, large city, Hata model and multipath reflection

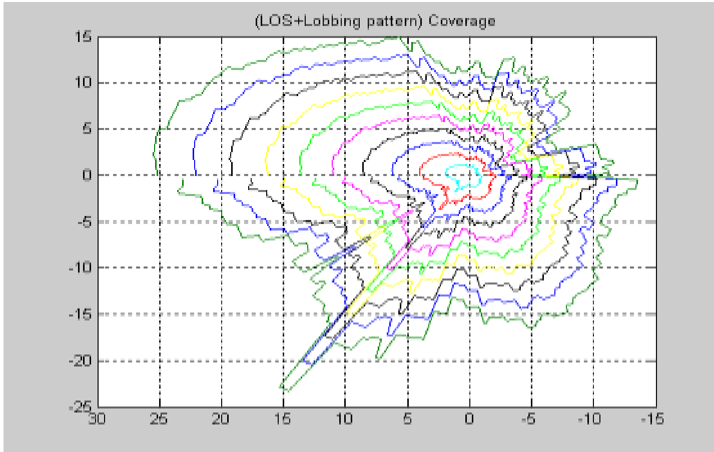

Fig. 7: DMC for horizontal polarization, f=900MHz, pt=100W, area-to-area lee model and multipath reflection.

A-3. Effects of Lee's Model on the 3DMRC for Multipath Reflection Case

The transmitting frequency is 900MHz, the transmitting power is 100W, base station antenna height is 30m, direct distance between base station and mobile station is 1km and polarization is horizontal for both cases, and also effective base station antenna height is 100m in point-to-point prediction model. Fig. 8 shows the reduction in the detection map contours when the path loss model is point-to-point model. The maximum range in Fig. 7 is 25km at receiver height equals to 500m, while the maximum range in figure 8 is 6.5km at the same receiver height and direction of 270° azimuth angle.

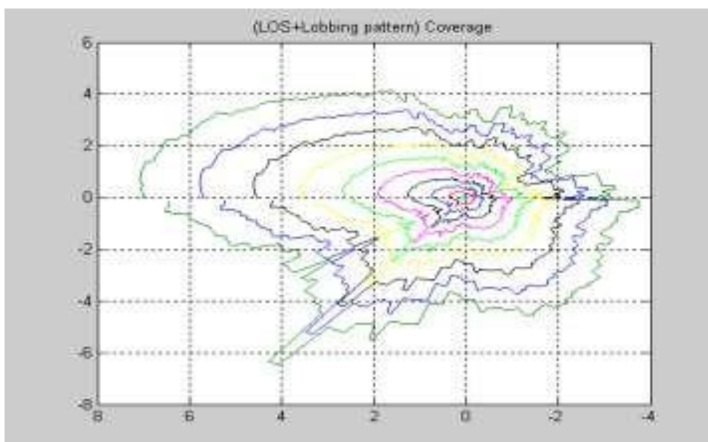

Fig. 8: DMC for horizontal polarization=900MHz, pt=100W, point-to-point lee model and multipath reflection

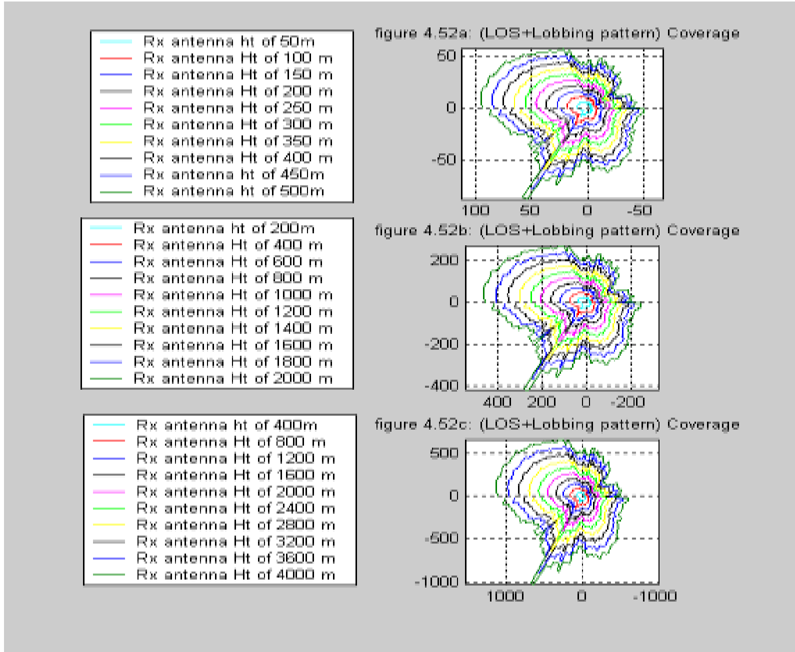

Fig. 9: DMC for horizontal polarization=1300 MHz, pt=100W, multipath reflection and different heights of receiver

Results and Discussions

A. Effects of the Mobile Receiver Heights on the 3DMRC for Multipath Reflection Case

This section use different values of mobile receiver heights and showing the effects of increasing or decreasing the receiving antenna height on the DMC diagrams. Fig. 9a shows the first receiver height is 50m while Fig. 9b shows the first receiver height is 200m and Fig. 9c shows the first receiver height is 400m for same horizontal polarization, same transmitting frequency of 1300MHz and transmitting power of 100W. DMC diagram is increased when the receiver heights is increased from 50m to 200m and to 400m, also Fig. 9a shows that maximum 455km when the receiver height becomes 2000m and Fig. 9c shows that the maximum range is 1100km when the receiver height range is 95km at direction of 270° azimuth angle when the receiver height becomes 500m, while Fig. 9b shows that the maximum range is becomes 4000m.This is because the line of sight increases and the multipath reflection is decreased at higher receiver altitudes.

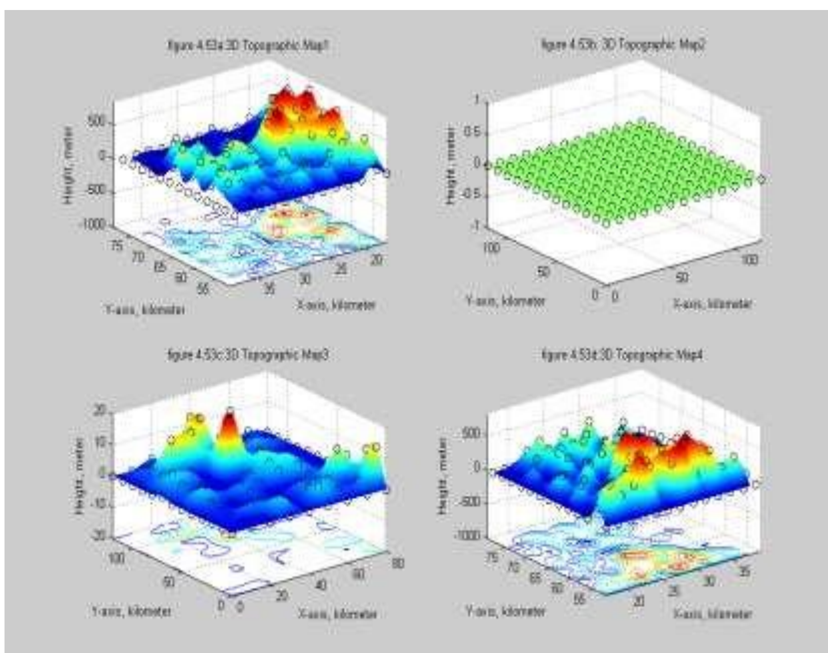

Figure 10. Four deferent digital maps

B. Prediction of Mobile Radio System Performance and Sitting

Fig. 10 shows four different ground topography. The transmitting frequency is 1300MHz, the transmitting power is pt is 100W, and the polarization is horizontal for the four cases. The first topography case in Fig. 10a, shows that the mountains appear in the northeast of the selected topography, and the DMC for this topography shows smaller ranges are obtained in north east zone due to the effects of the mountains which obstructs the radiation and reduce the maximum effective ranges, and this occurs for different receiver heights and is shown in Fig. 10a. The maximum receiver range is obtained for this case to be equal to 97km, at azimuth angle of 278^{o}, and receiver height of 500m. Also this figure shows complete blockage occurs at this azimuth angle of 67^{o} from the north, and the maximum receiver range decreases to 35km at the receiver height of 500m.The second topography case is shown in Fig. 10b, and this case is taken for smooth surface. The DMC obtained for this topography are smooth concentrated circles without any irregularities as shown in Fig. 11b.The maximum receiver range for this case is 48km at receiver height of 500m and it is not changed in all directions. But the third topography case is shown in Fig. 10c, the DMC obtained in Fig. 11c shows smaller maximum effective ranges in the North West zone, of the selected ground topography map, but maximum effective range in this case, is greater than maximum effective range in the first topography case because the heights of mountains in the third topography case is smaller than the first topography case. The maximum mountains height is 500m in the first case and it is taken to be equal to 20m in the third case. The maximum receiver range for this case equals to 598km at receiver height of 500m, at azimuth angle of zero, but it was 97km in the first case for azimuth angle of 278^{o} for the same receiver height of 500m. Also complete blockage for the third case is observed at the south east for azimuth sector from 265^{o} to 281^{o}. The maximum receiver range at the blockage area equals to 240km for the same receiver height of 500m, and at the direction of 268^{o}. The maximum receiver range is decreased from 598km to 290km for the same receiver height of 500m, due to the mountains obstruction in this zone. The DMC in Fig. 11d, shows that the maximum effective ranges are smaller in the south east zone, and the maximum receiver range is obtained to be equal to 98km at azimuth angle of 8^{o}, and receiver height of 500m. While the complete blockage occurs at the azimuth sector150^{o} to 160^{o}, due to the mountains obstruction. This is also clear in Fig. 10d, which results Fig. 11d.

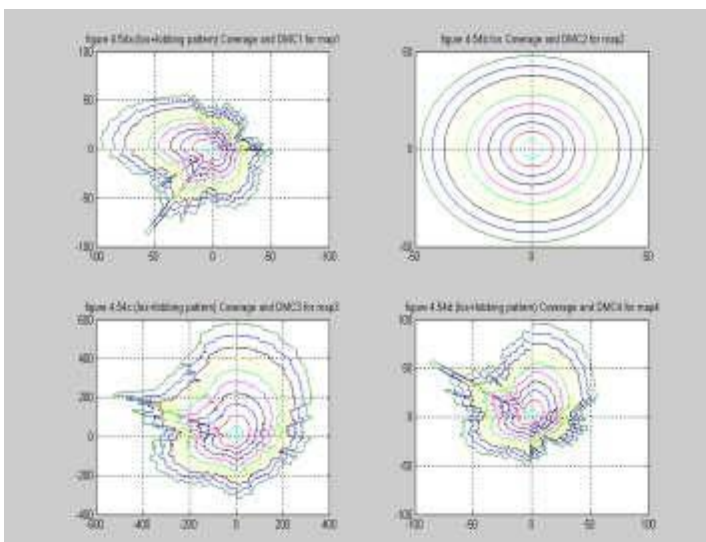

Fig. 10: Four deferent DMC maps for horizontal polarization, f=1300 MHz, the same heights of receiver and pt=100W.

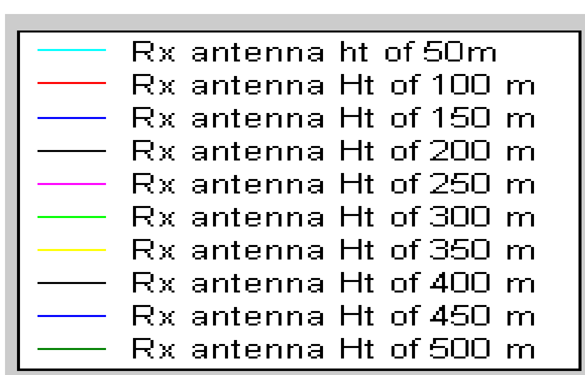

Fig. 11: DMC for horizontal polarization, f=1300 MHz, the same heights of receiver and pt=100W.

Fig. 10: Four deferent **DMC maps** for horizontal polarization, f=1300 MHz, the same heights of receiver and pt=100W. Four deferent digital maps.

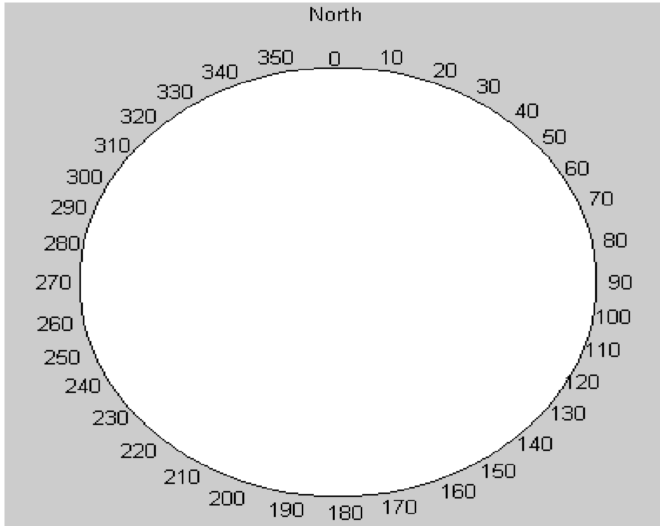

Figure 12: Different antenna receiver heights and colors

Figure 12, shows the reference colors and their antenna heights, while DMC ground directions for one degree accuracy.

CONCLUSIONS

The main conclusions from the recent work can be listed as: The path loss prediction shows that the model produce longer range than the Okumara's-Hata model and the Lee's model. These models are very applicable for Direction Finding Systems for airport Landing systems and UHF Wireless systems in addition to the cellular mobile systems. When greater ranges at different receiver heights are required for certain applications, the design of the radio system and its performance is very affected by the transmitting power. The applications of this paper are widely required for the site prediction of the UHF wireless communication landing systems, direction finding systems and Beacon systems, in addition to the mobile cellular systems. Most cellular operators use a version of Hata model for conducting propagation characterization. Neither of the prediction models used has been suitable for both urban, suburban and rural propagation in our experiment that means neither of models were accuracy enough for prediction of path loss. From the results obtained, it is recommended that for accurate prediction of radio signal characteristics for cellular transmission, one of existing models needs to be adjusted if the cost for the field measurement is too high.

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