Seasonal Pathloss Modeling at 900MHz for OMAN

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Abstract. In this paper, we aim to adapt a propagation model for Oman. This can be benefited by telecom providers in order to produce a better GSM network design for the country. We will modify the propagation models namely Okumura Hata model. We will accomplish this by investigating the variation in pathloss for the months of summer and winter, between the measured and predicted values, according to the Okumura-Hata propagation model for different cells. Then, we intend to modify the Okumura-Hata model according to the results obtained in our investigation hence obtaining two modified Okumura-Hata equations. So the paper addresses the applicability of Okumura-Hata model in Salalah, Oman for GSM frequency band of 890-960MHz. The study was carried out for sub-urban area only, since measurements provided from local service provider were about the sub-urban areas. The mean square error (MSE) was calculated between measured path loss values and those predicated on basis of Okumura-Hata model for this area. The MSE is up to 6dB, which is an acceptable value for the signal prediction. The obtained experimental data is compared and analyzed further using different cells and from the months of January, the low rain season and August, which is a high rainy season and a difference of approximately 9dB, is observed between two seasons.

Keywords: Pathloss, Propagation models, Okumura Hata Model, Urban Area

1. Introduction

The wireless communication relies on the propagation of waves in the free space and the possibility of transmitting data. Wireless communication provides mobility for users and satisfies the demand of the subscribers at any location covered by the wireless network. Historically, growth in the mobile communications field has now become slow, and has been linked to technological advancements [1,2]. The need for high quality and high capacity networks, estimating coverage accurately has become extremely important. Therefore, for more accurate design coverage of modern cellular networks, signal strength measurements must be taken into consideration in order to provide an efficient and reliable coverage area.

This article addresses the comparisons between the theoretical and experimental analysis at GSM frequency of 900MHz. It was achieved that, the most extensively used propagation data for mobile communications is Okumura's measurements and this is recognized by the International Telecommunication Union (ITU) [3].

2. Empirical Propagation Models

Empirical propagation models will be discussed in this section; among them are Okumura and Hata models.

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2.1. Cellular Propagation Models

The two basic propagation models (free space loss and plane earth loss) would require detailed knowledge of the location, dimension and constitutive parameters of every tree, building, and terrain feature in the area to be covered. This is far too complex to be practical and would yield an unnecessary amount of detail. One appropriate way of accounting for these complex effects is via an empirical model. There are various empirical prediction models among them are, Okumura – Hata model, Cost 231 – Hata model, Cost 231 Walfisch – Ikegami model, Sakagami- Kuboi model. These models depend on location, frequency range and clutter type such as urban, sub-urban and countryside.

2.2. Okumura's Measurements

Okumura carried out extensive drive test measurements with range of clutter type, frequency, transmitter height, and transmitter power. It states that, the signal strength decreases at much greater rate with distance than that predicted by free space loss [3-5].

2.3. Hata's Propagation Model

Hata model was based on Okumura's field test results and predicted various equations for path loss with different types of clutter. The limitations on Hata Model due to range of test results from carrier frequency 150MHz to 1500MHz, the distance from the base station ranges from 1Km to 20Km, the height of base station antenna (h_b) ranges from 30m to 200m and the height of mobile antenna (h_m) ranges from 1m to 10m. Hata created a number of representative path loss mathematical models for each of the urban, suburban and open country environments, as illustrated in following equations, respectively. Okumura takes urban areas as a reference and applies correction factors as following:

Urban areas: $L_{dB} = A + B \, log_{10} \, R - E_{1,2,3}$

Suburban areas: $L_{dB} = A + B \, log_{10} \, R - C$

Open areas: $L_{dB} = A + B \, log_{10} \, R - D$

Where

$A = 69.55 + 26.16 \, log_{10} \, f_c - 13.82 \, log_{10} \, h_b$　　　$B = 44.9 - 6.55 \, log10 \, h_b$

$C = 2 \, (log10 \, (f_c / 28 \,))2 + 5.4$　　　　　　$D = 4.78 \, (log10 \, f_c) \, 2 + 18.33 \, log10 \, f_c + 40.94$

$E_1 = 3.2 \, (log10 \, (11.7554 \, h_m)) \, 2 - 4.97$　　*for large cities, $f_c \geq 300MHz$.*

$E_2 = 8.29 \, (log10 \, (1.54 \, h_m)) \, 2 - 1.1$　　　*for large cities, $f_c < 300MHz$.*

$E_3 = (1.1 \, log10 \, f_c - 0.7) \, h_m - (1.56 \, log10 \, f_c - 0.8)$　　*for medium to small cities.*

Definition of parameters:

h_m *;mobile station antenna height [m];*　　　　d_m *;distance between the mobile and the building [m]*

h_0 *; typical height of a building above local terrain height [m];　h_b ;base station antenna height above*

local terrain height [m];　r; great circle distance between base station and mobile [m]

R=r x 10-3 great circle distance between BS and mobile [km]; f ;carrier frequency [Hz]

f_c*=f x 10-6 carrier frequency [MHz]; λ ; free space wavelength [m]*

The practical path loss can be calculated using the equation:

$L_P \, (dB) = P_t - P_r$

Where P_t is the transmitted power which is equal to 47dB and P_r is the received power. Whereas, the path loss for Okumura-Hata Model can be calculated by the following equation (1) for small and medium city:

　　$A= 69.55+26.16 \, log10 \, f_c \, -13.82 \, log10 \, h_b$, *and* $E_3= (1.1 \, log10 \, f_c - 0.7) \, h_m - (1.56 \, log10 \, f_c - 0.8)$

(1)

Hata model is not suitable for micro-cell planning where antenna is below roof height and its maximum carrier frequency is 1500MHz. It is not valid for 1800 MHz and 1900 MHz systems.

3. Results and Discussions

To generate measurements of signal strength level for downlink and uplink at coverage areas for a cell, TEMS tools were used. However, the road of Al Khuwair can be considered as an urban area of Okumura-Hata model was used. After determining the path loss for the month of January and August and repeated calculations for second cells, following interesting results were obtained (figures 1-4):
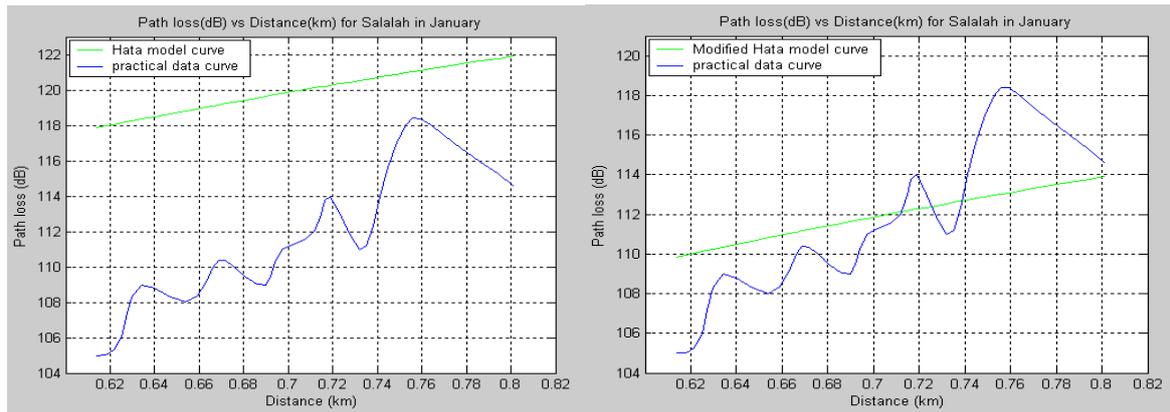
MONTH OF JANUARY (WINTER)

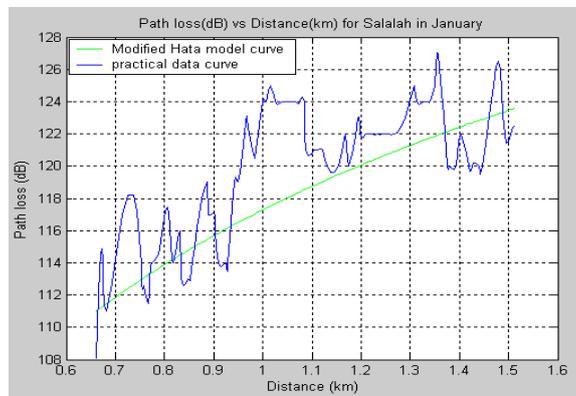Fig. 1: Theoretical and Experimental path loss versus distance for an open area for **Cell-1** (modified right figure)

Fig. 2: Theoretical and Experimental path loss versus distance for an open area for **Cell-2** (modified model)
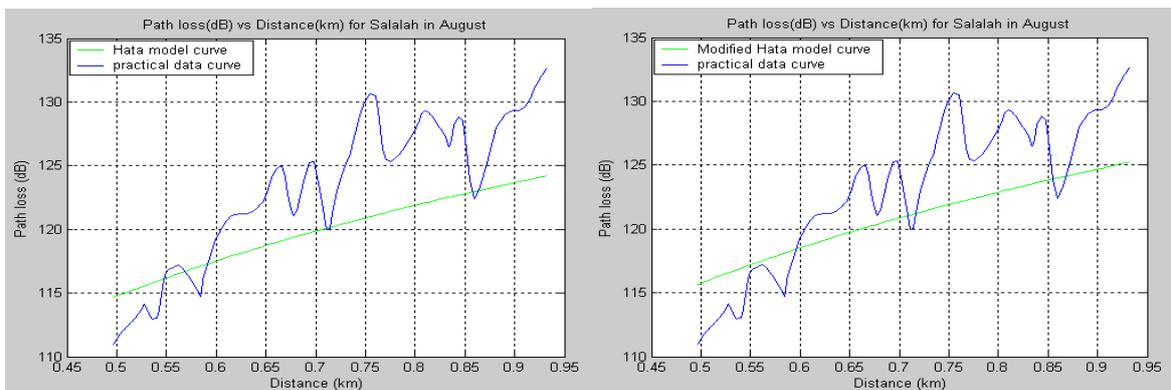
MONTH OF AUGUST (SUMMER)

Fig. 3: Theoretical and Experimental path loss versus distance for an open area for **Cell-1** & modified right figure
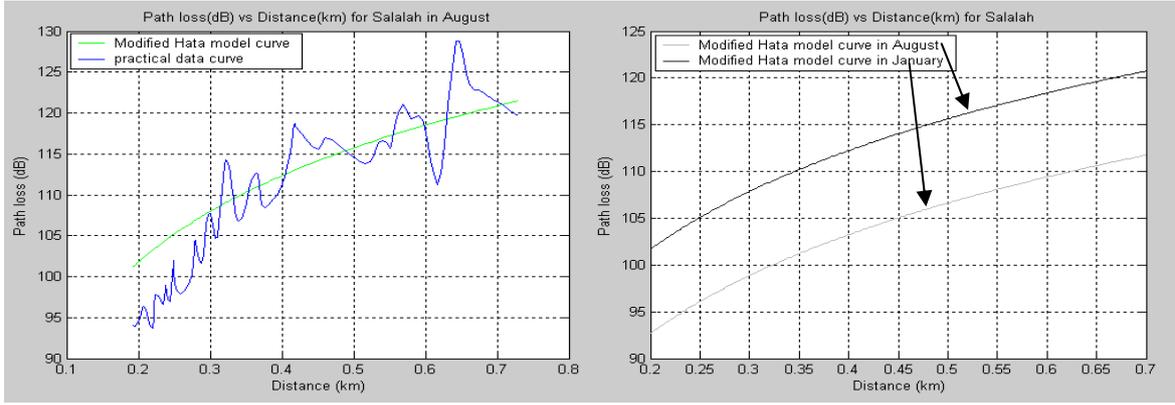
Fig. 4: Theoretical and Experimental path loss versus distance for an open area for **Cell-2** (modified model) & the trend for the months of January and August (on right)

From the above plots (1-4), the results clearly show that the measured path loss is less than the predicted path loss by a difference varying from 4 to 20 dB. However, there are several reasons which may cause those significant differences. First of all, in Japan there are few areas virtually satisfying the conditions; and if any, they are narrow. Because of that reason Okumura selected the value for urban area as standard for open area [5]. Moreover, the geographical situation of Japan is different from that in Oman. Then, mean square error (*MSE*) was calculated between measured path loss value and those predicted by Hata model using the following equation-2 [6]:

$$MSE = \sqrt{\left(\sum \left(P_m - P_r\right)^2 / (N-1)\right)} \qquad (2)$$

Where; P_m: *Measured path loss (dB)* ; P_r: *Predicted path loss (dB) N: Number of Measured Data Points*

The *MSE* was found 113.459dB but the acceptable range is up to 6 dB [6]. Therefore, the *MSE* is adjusted with the Okumura-Hata equation for urban area and the modified equation will be as following:

$$L_{p\textbf{Modified}}(Urban) = 69.55 + 26.16\log_{10}(f) - 13.82\log_{10}(h_b) + (44.9 - 6.55\log_{10}(h_b))\log_{10}(d) \pm MSE$$
$$-(1.1\log_{10}(f) - 0.7)h_m - (1.56\log_{10}(f) - 0.8) \qquad (3)$$

The modified result of Hata equation is shown in Fig. 2 and the *MSE* in this case is less then 6dB, which is acceptable [6].In order to verify that the modified Hata's equation (3) is applicable for other in Oman, another data generated from TEMS tool for another cell in the road of Salalah has been used. Based on that practical data, the propagation path loss and the distance have been re-verified for another cell as shown in Figures above [7-8]. Also, it can be seen from Figure 4 (right) that the path loss in August is greater than the path loss in January by about 9 dB. Since the data for January and August was taken from the same cell, it is safe to conclude that the factor responsible for the variation in path loss between January and August is the weather. Moreover, the temperatures in these two months are almost the same (23° C in January and 24° C in August). Therefore, it can be concluded that the humidity led to the variation in path loss since the humidity for January was 49% and for August 85%.

4. Conclusion

This work was focused for predicting the mean signal strength in different areas. However, most propagation models aim to predict the median path loss. But, existing predictions models differ in their applicability over different terrain and environmental conditions. Although there are many predictions methods based on deterministic processes through the availability of improved databases, but the Okumura-Hata model is still mostly used [7]. That is because of the ITU-R recommendation for its simplicity and its proven reliability.

The effects of terrain situation predicted at 900MHz were analyzed. Results of radio signals propagation measurements for an urban area in Oman were compared to those predicted based on Okumura-Hata model.

However, the Okumura-Hata propagation model might not be generally adapted in Oman because there is no rain attenuation impact in Oman environment due to lack of rain except for certain parts and for less than two months. In the month of August which was selected for our measurements, few episodes of rain were recorded. Therefore, further improvement of Okumura-Hata model in the urban area has been suggested for both in rainy season of July-August and winter season. The improvement was achieved by using mean square error (*MSE*) between measured and predicted path loss values in order to provide sufficient *MSE* for radio prediction. The modified equation (3) was verified for a cell in another urban area and the *MSE* was found to be 3.21dB which is accepted value for signal predication [9-10].

The measured data that provided by Oman Mobile just covered the urban area. However, the area under investigation can be treated as a combination of Open and urban area. Therefore, measurements for other areas (rural and suburban) should also be obtained in order to compare all results (urban, suburban and open areas) with the predicted data based on Okumura-Hata model for Oman. Also, if more detailed environmental information is included in the model, better prediction results might be achieved. Cubic regression might also gives us the missing experimental points [8-9].

5. Acknowledgements

6. References

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