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Impact of Using Modified Open Area Okumura-Hata Propagation Model in Determination of Path-loss: Malaysia as Case Study

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ABSTRACT: *This paper examines the applicability of the Okumura - Hata model in Malaysia in GSM frequency band. The study was carried out in the open area only since measurements provided from Malaysia Mobile were about the open areas. The mean square error (MSE) was calculated between measured path loss values and those predicted on basis of Okumura-Hata model for an open area. The MSE is up to 6dB, which is an acceptable value for the signal prediction. Therefore, the model gave a significant difference in an open area that allowed necessary changes to be introduced in the model. That error was minimized by subtracting the calculated MSE (15.31dB) from the original equation of open area for Okumura-Hata model. Modified equation was also verified for another cell in an open area in Malaysia and gave acceptable results.*

Keywords: *Path loss, Okumura-Hata, and Open Area*

I. INTRODUCTION

Communications is currently at its fastest increment flow in history; due to enabling technologies, which permit wide, banquet deployment. Historically, growth in the mobile communication line of business has now become slow and has been linked to technological advancements [1]. The need for high quality and high capacity networks, estimating reportage accurately has become extremely important. Therefore, for more accurate design reportage 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 the empirical generation example. The most extensively used propagation data for mobile communications is Okumura's measurements and this is recognized by the International Telecommunication Union (ITU) [2].

The cellular concept was a major breakthrough in solving the problem of spectral congestion and user's capacity. It offered high capacity with a limited spectrum allocation without any major technological change. The cellular concept is a system level idea in which a single, high power transmitter (large cell) is replaced with many low power transmitters (small cells). The area serviced by a transmitter is called a cell. Each small powered transmitter, also called a base station provides coverage to only a small portion of the service area. The power loss involved in transmission between the base station (BTS) and the mobile station (MS) is known as the path loss and depends particularly on the antenna height, carrier frequency and distance. At higher frequencies the range for a given path loss is reduced, so more cells are required to cover a given area. Base stations close to one another are assigned different groups of channels. Consequently, all the available channels (in frequency, time and space) are assigned to a relatively small number of neighboring base stations. Neighboring base stations are assigned different groups of channels so that the interference between base stations or interaction between the cells is minimized. As the demand for service increases, the number of base stations may be increased, thereby providing additional capacity with no increase in the radio spectrum. The key idea of modern cellular systems is that it is possible to serve the unlimited number of subscribers, distributed over an unlimited area, using only a limited number of channels, by efficient channel reuse [1].

The rest of the paper is organized as follows. Theoretical propagation models are mainly discussed in section II. Section III covers discussion of various empirical propagation models. Relevant studies were mainly covered in Section IV. Section V focused on results and discussions. Finally Section VI elaborates limitations and conclusions.

II. THEORETICAL PROPAGATION MODELS

A.Free Space Propagation Model

In free space, the wave is not reflected or absorbed. Ideal propagation implies equal radiation in all directions from the radiating source and propagation to an infinite distance with no degradation. Spreading the power over greater areas causes the attenuation. Equation (1) [1] illustrates how the power flux is calculated.

$$Pd = Pt / 4\pi d^2 \ (W/m^2) \qquad (1)$$

Where Pt is known as transmitted power and Pd is the power at a distance d from antenna. If the radiating element is generating a fixed power and this power is spread over an ever-expanding sphere, the energy will be spread more thinly as the sphere expands. Therefore, in any given direction the energy will diminish with distance, even in an ideal propagation environment.

By having identified the power flux density at any point of a given distance from the radiator, if a receiver antenna is placed at this point, the power received by the antenna can be calculated. The formulas for calculating the effective antenna aperture and received power are shown in equations (2) and (3) below. The amount of power 'captured' by the antenna at the required distance d, depends upon the 'effective aperture' of the antenna and the power flux density at the receiving element. Actual power received by the antenna depends on; Aperture of receiving antenna A_o, wavelength of received signal λ, and power flux density at receiving antenna P_d.

Effective area A_e of an isotropic antenna is:

$$A_e = \lambda^2 / 4\pi \qquad (2)$$

While power received is:

$$Pr = Pd*A_e = Pt*\lambda^2/(4\pi d)^2 \qquad (3)$$

$$Pr\ (dB) = Pt - 20\ \log10(4\pi) - 20\ \log10(d) + 20\ \log10(\lambda) \qquad (4)$$

While equation (5) illustrates the path loss (Lp):

Lp = Power_transmitted (Pt) - Power_received (Pr) (5)

When substituting equation (4) in equation (5), it yields equation (6):

$$Lp(dB) = 20\ \log10(4\pi) + 20\log10(d) - 20\log10(\lambda) \qquad (6)$$

Then substituting (λ (in km) = 0.3 / f (in MHz)) and rationalizing the equation produces the generic free space path loss formula, which is stated in equation (7):

$$Lp(dB) = 32.5 + 20\ \log10\ (d) + 20\ \log10\ (f) \qquad (7)$$

B. Plane Earth Propagation Model

The free space spread model does not consider the impacts of proliferation over ground. At the point when a radio wave proliferates over ground, a portion of the power will be reflected because of the nearness of ground and after that got by the collector. Deciding the impact of the reflected power, the free space proliferation model is altered and alluded to as the 'Plain-Earth' spread model. This model better speaks to the genuine attributes of radio wave proliferation over ground. The plane earth display registers the got flag to be the total of an immediate flag and that reflected from a level, smooth earth. The applicable information parameters incorporate the reception apparatus statures, the length of the way, the working recurrence and the reflection coefficient of the earth. This coefficient will differ as per the territory sort (e.g. water, betray, wet ground and so forth). Way Loss Equation for the plane Earth Model is shown in condition (8).

$$Lpe = 40\ \log10(d) - 20\ \log10(h1) - 20\log10(h2) \qquad (8)$$

Where *d* speaks to the way length in meters and h1 and h2 are the radio wire statures at the base station and the portable, individually. The plane earth demonstrate in not fitting for portable GSM frameworks as it doesn't consider the reflections from structures, various proliferation or diffraction impacts. Besides, if the versatile stature changes (as it will by and by) then the anticipated way misfortune will likewise be changed.

III. EMPIRICAL PROPAGATION MODELS

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

A. Cellular Propagation Models

The two essential spread models (free space loss and plane earth loss) would require nitty gritty information of the area, measurement and constitutive parameters of each tree, building, and territory highlight in the range to be secured. This is dreadfully intricate to be reasonable and would yield a pointless measure of detail. One suitable method for representing these mind boggling impacts is by means of an observational model. There are different observational forecasts models among them are, Okumura – Hata show, Cost 231 – Hata display, Cost 231 Walfisch – Ikegami demonstrate, Sakagami-Kuboi show. These models rely on upon area, recurrence range and mess sort, for example, urban, sub-urban and field.

B. 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 [3,4,6,7].

C. Hata's Propagation Model

Hata model was corner stoned on Okumura's theatre of operations test termination and predicted various equality for way of life going with different types of welter . The limitations on Hata Model due to range of test results from carrier frequency 150Mhz to 1500Mhz, the distance from the base station image from 1Km to 20Km, the height of base station antenna (hb) ranges from 30m to 200m and the height of mobile antenna (hm) ranges from 1m to 10m. Hata created a number of representative route loss mathematical models for each of the urban, suburban and open country environments, as illustrated in equations (8-10), respectively. Course Loss for urban clutter:

$$L_p(\text{urban}) = 69.55 + 26.16\log(f) - 13.82\log(h_b) - a(h_m) + (44.9 - 6.55\log(h_b))\log(d) \quad (9)$$

$$a(h_m) = (1.1\log(f) - 0.7)h_m - (1.56\log(f) - 0.8) \quad (10)$$

Path loss for suburban clutter:

$$L_p(\text{suburban}) = L_p(\text{urban}) - 2\{\log(f/28)\}^2 - 5.4 \quad (11)$$

Path loss for the open country is:

$$L_p(\text{open country}) = L_p(\text{urban}) - 4.78\{\log(f)\}^2 + 18.33\log(f) - 40.94 \quad (12)$$

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 [4].

IV. RELEVANT STUDIES

This is section will highlight some recent relevant research study that conducted by several researchers. In fact will elaborate and discuss their claimed findings and testimonial. Shairudin [10] in 2015 conduct a comparison study among various path loss outdoor models. A definitive objective was to figure out which model is more appropriate to be utilized for provincial territories in Malaysia.. His final findings conclude that Hata model is considered the best choice.

In 2013 Jalel Chebil [11] performs a comparative study between measured and predicted path loss models for mobile communication in Malaysia. Their principle discoveries were demonstrated that Stanford University Interim (SUI) display gives a superior expectation for a separation between 300and 1100 meters. Short separations are for the most part better secured by log typical shadowing models. Hata model was not among their effective models. Path loss propagation model prediction study was conducted by Dominic [12] in 2015. Worth to specify that their principle discoveries bolster that changed model for log typical shadowing models thought to be the best decision among different models.

Early 2013 Julie [13] published an article that investigates propagation models for GSM. Their review intended to decided appropriate proliferation way misfortune models for urban communities of Port Harcourt. That examination was for the most part talked about the variety amongst measured and anticipated qualities per each model. At long last, the missed information were anticipated and recuperated by utilizing information addition. Their discoveries demonstrated that the altered Hata model is thought to be the most appropriate one.Singh [14] draft a comparison study among Okumura, Hata, and COST-231 models in late of 2012. Clearly claimed that Okumura model shows the least path loss and COST-231 shows the largest path loss. In other words, Hata shows an intermediate path loss model.

Zia [15, 16] proves experimentally that usage of modified Hata model with a Spline interpolation technique for recovering missed data had shown a better prediction outcome.

In conclusion and reviewing previously mentioned related works and research, trial utilization of adjusted Hata model can be a helpful technique for forecast and arranging. In any case, we ought to likewise guarantee that expectation and arranging are testing and needs additionally examine.

V. RESULTS AND DISCUSSIONS

TEMS tools were used to generate measurements of signal strength level for downlink and uplink at coverage areas for a cell in the road of Ampang, MALAYSIA. However, the road of Ampang can be considered as an open area and therefore equations (8), (9) and (11) of Okumura-Hata model were used. After determining the path loss of the practical measurements for each distance, the study was carried on in order to make a comparison between the practical and theoretical values and the result is shown in Fig-1.

TEMS devices were utilized to produce estimations of flag quality level for downlink and uplink at scope territories for a cell in the Road of Ampang, MALAYSIA. Be that as it may, the Road of Ampang can be considered as an open range and in this manner conditions (8), (9) and (11) of Okumura-Hata model were utilized. In the wake of deciding the way loss of the functional estimations for each separation, the review was carried on keeping in mind the end goal to make a correlation between the down to earth and hypothetical qualities and the outcome is appeared in Fig-1.

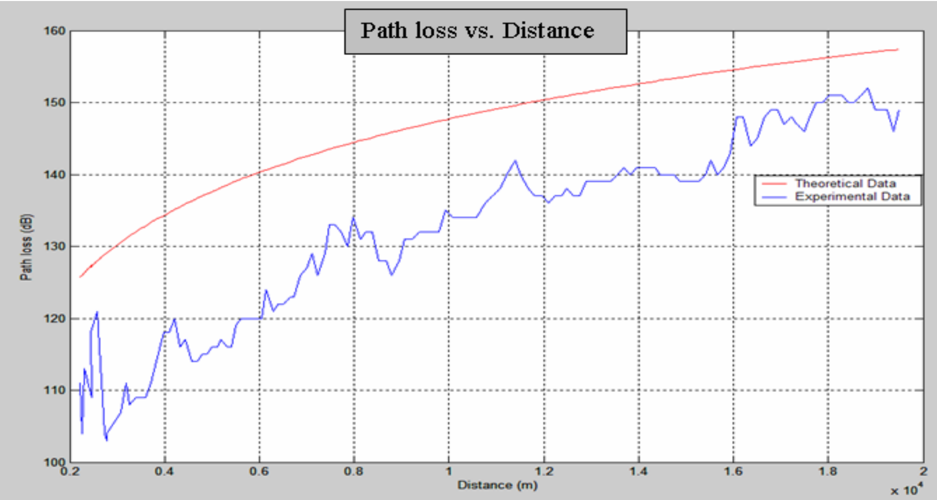

Figure 1: Practical and Theoretical path loss versus distance

From the above plot, 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 open area 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 Malaysia. In Japan, rain which is the most effective factor that increases the path loss appears most of the time during the year, whereas in Malaysia most of the time the weather is clear. Therefore the radio signal propagation mechanism is different. Then, mean square error (MSE) was calculated between measured path loss value and those predicted by Hata model using the following equation [5]:

$$MSE = \sqrt{\left(\sum (P_m - P_r)^2 / (N-1)\right)} \qquad (13)$$

Where; *Pm*: Measured path loss (dB), Pr: Predicted path loss (dB), and N: Number of Measured Data Points. The MSE was found 15.3148dB but the acceptable range is up to [5]. Therefore, the MSE is subtracted from the Hata equation for open area and the modified equation will be as following:

Lp Modified (open area)= Lp (urban) – 4.78{log(f)}2+18.33lof(f)–56.26 (14)

The modified result of Hata equation in open area is shown in Figure 2 using modified equation and the MSE in this case is 5.6193dB, which is acceptable [5].

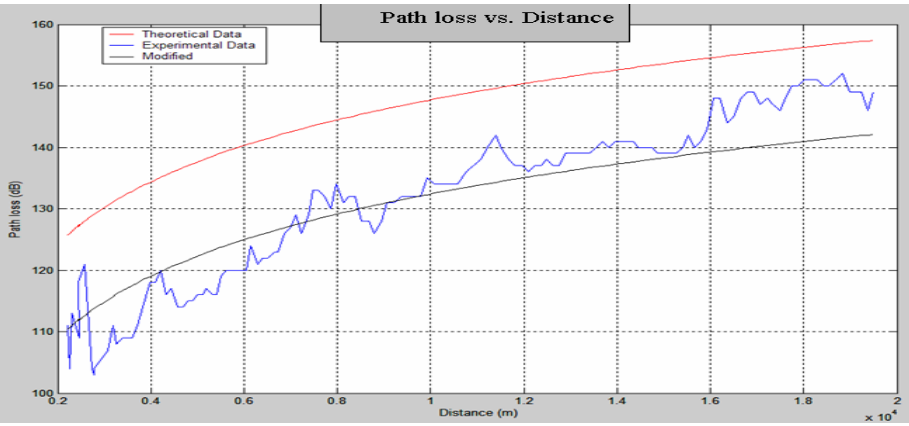

Figure 2: Modified Hata's open area equation path loss versus distance.

In order to verify that the modified Hata's open area equation (13) is applicable for other open areas in Malaysia, another data generated from TEMS tool for another cell in the road of Ampang road has been used. Therefore, based on that practical data, the propagation path loss and the distance have been determined and the result is shown in Figure 3.

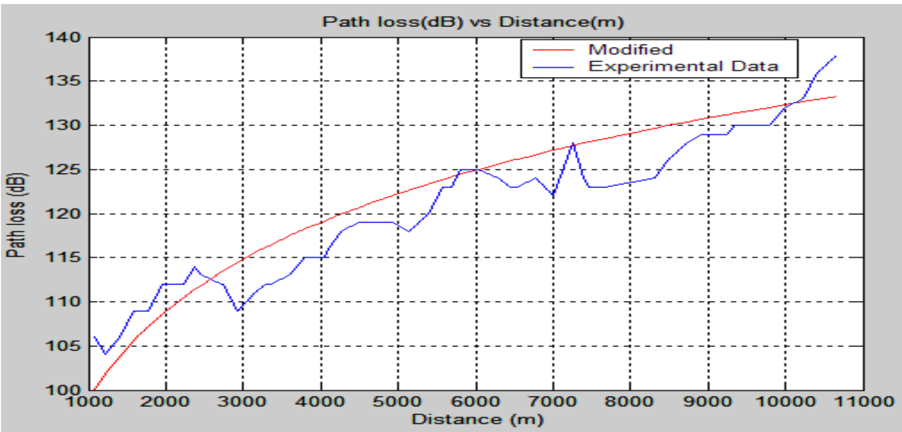

Figure 3: Modified Hata's open area equation path loss versus distance for another cell.

By calculating the MSE for the second cell, it was found to be (3.2058dB) which is acceptable [5]. Therefore, the modified Hata's open area equation (13) was verified in order to be applicable in other open areas in Malaysia.

VI. CONCLUSIONS

Generally, this work was focused for predicting the mean signal strength in different areas and with the signal variability as the mobile moves. 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 [2]. 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 open area in Malaysia were compared to those predicted based on Okumura-Hata model. However, the Okumura-Hata propagation model might not be fully adapted in Malaysia because there is no rain attenuation impact in Malaysia environment due to lack of rain. Nevertheless, a further modification of Okumura-Hata model in the open area has been suggested. This 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 [5]. The proposed equation (13) was verified for a cell in another open area and the MSE was found to be 3.21dB which is accepted value for signal predication [5].

The measured data that provided by Malaysia Mobile company just covered the open area. Therefore, measurements for other areas (urban and suburban) should be obtained in order to compare all results (urban, suburban and open areas) with the predicted data based on Okumura-Hata model for Malaysia. Also, if more detailed environmental information is included in the model, better prediction results might be achieved.

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