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Prediction Model for Broadcasting Propagation in Urban Area

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Abstract: This study proposes an optimization of the path loss propagation model for prediction digital terrestrial television broadcasting in urban area Southern of Thailand. The measurement areas are considered both Songkla and Surathani Provinces that we conducted the data collection of the received signal radio broadcasting in 4 channels (510-790 MHz). The optimization of the path loss propagation model is based on Least Square (LS) method. The statistical results such Hata path loss model is optimized as a comparison with others model. We confirm that the proposed method provides for a data processing suitably in a prediction path loss model.

Key words: Broadcasting propagation, optimization methods, path loss model, statistical, prediction

INTRODUCTION

The radio broadcasting in Thailand has become the analogue to the digitalization that is a Digital Video Broadcasting Terrestrial generation 2 (DVB-T2) standard (Eizmendi *et al*., 2014). The license had been launched since April 1, 2014 by the National Broadcasting and Telecommunication (NBTC) that covers from 510-790 MHz of frequency band. There are 39 of domestic base stations places and 132 sub-station places. Nevertheless, the system needs to be have a gap filler operation in order to support a spot point in urban areas. Especially, the urban area has more an obstruction such as high office buildings, traffic density and community that obstructs the radio broadcasting cannot through. This is a main problem that the receiving cannot receivable in a currently. Thus, the gap filler stations are a solution to be used in the urban areas, in addition, the planning and designing of gap filler must be also prepared. The prediction in radio propagation is very important in firstly of the planning and designing. While a prediction models had been widely used in many mobile communication such as Okumura model, Hata model and Cost-231 model.

The prediction and propagation models can be classified into three types of models, namely the empirical models, semi-deterministic models and deterministic models. Empirical models are based on measurement data, statistical properties and few parameters. Examples of this model category will be Okumura model (Cota *et al*., 2013; Farhoud *et al*., 2013) and Hata model (Panda *et al*., 2005). Semi-deterministic models are based on empirical models and deterministic aspects, examples of this is Cost-231 (Rao *et al*., 2000; Al-Salameh and Al-Zu'bi, 2015) and Egli (Obot *et al*., 2011; Mardeni, 2010). Then, the deterministic models on the other hand are site-specific, require enormous number of geometry information about the area, computational effort and more accuracy. In the literature reviews, there are many research proposed the prediction model based on empirical method as by Riihijarvi and Mahonen (2013), Aloisi *et al*. (2011). However, the path loss models have no any measuring yet for the DVB-T2 propagation in Thailand.

This study proposed how optimization the existing path loss model based empirical measurement data for urban area DVB-T2 broadcasting 4 channel on air in Southern of Thailand. The optimized path loss model is based on the measurement data collected in both the city of Songkla and Surathani Provinces. The measurement channels are with CH40 (626 MHz) and CH44 (658 MHz) operated in Surathani, CH42 (642 MHz) and CH46 (674 MHz) operated in Songkla, respectively. We propose that the path loss model with free space Okumura Hata and Egli models are taken into optimize by using an asymptotic of least square method.

Radio propagation and measurement campaign: A DVB-T2 radio channel is characterized by communication from the transmitter to the receiver television. Free space is an ideal propagation model the received signal power at distance R is given by:

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$$P_r = \frac{A_e P_t G_t}{4\pi R^2} \quad (1)$$

Where:

A_e = Effective area
G_t = The transmitting antenna gain

The relationship between an effective aperture and the receiving antenna gain G_r derived by Aloisi *et al*. (2011), can be given by:

$$G_r = \frac{4\pi A_e}{\lambda^2} \quad (2)$$

where, λ is the wavelength of the electromagnetic wave. By substituting A_e of Eq. 2 into Eq. 1 we obtain:

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2 \quad (3)$$

Free space path loss L_f is defined as:

$$L_f = \frac{1}{G_t G_r}\left(\frac{4\pi R}{\lambda}\right)^2 \quad (4)$$

Where:

$$G_t = G_r = 1, L_f = \left(\frac{4\pi R}{\lambda}\right)^2$$

is a close-form. Free space path loss in decibels can be written as:

$$L_f = 32.45 + 20\log_{10} f_c + 20\log_{10} R \quad (5)$$

where, f_c is the center of frequency in MHz. The DVB-T2 network infrastructure in the southern of Thailand had been a determination from NTBC regulator that the radio broadcasts in 4 channels within the combiner of a single transmitter.

The measurement campaign is described to collect the data on signal measurement in urban both Songkla and Surathani Province. Note that the transmitter in Songkla Province is located on Mt. CorHong at the latitude of 7 0'57.95" and the longitude of 100 31'12.17" with 417 m above the sea level and the transmitter in Surathani Province is located on Mt. ThaPatch at the latitude of 9 5'32.77" and the longitude of 99 20'55.59" with 244 m above the sea level.

The DVB-T2 systems operate by the broadcasting power through a rigid line, size 1 5/8" with the combiner, Spinner; the parameters had been with a transmission loss (Cl_1) 0.55 dB and the output from the combiner further sends through an RFS transmission line, Flexwell HF 5" where a total loss (Cl_2) was 1.186 dB feeding into an antenna horizontal RFS; PHP48U with a total gain of antenna was 18.35 dBi. Moreover, the relation of the received signal Power (P_r) and the path loss of the transmission channel (L) can be expressed:

$$EIRP = P_t + G_t - Cl_1 - Cl_2 \quad (6)$$

$$PL(dB) = EIRP + G_r - P_r \quad (7)$$

where, EIRP is the effective isotropic radiated power: the measurement data is conducted through a drive test function of the measuring tool to collect the received signal data along with the drive test path in Songkla and Surathani Provinces. The measuring tool, DVB-T2 PROMAX Model HD RANGER+ was used with GPS and USB drive for the data collection. The commercial Omni-directional antenna from SPECTRUM model was used as a received antenna with -3 dB of the relative gain radiation.

The receiving antenna is mounted on the roof car test where the antenna height was set to 2 m from the floor. In the measuring data, the speed of car is moved not above 20 km/h and uses the drive test tools. Here, we show the measurement data on the drive test function, note that the distance between the transmitting antennas to the receiving antenna was 2-7 km.

MATERIALS AND METHODS

Hata path loss model: The empirical Hata model is a significant improvement over Okumura model for the prediction of the propagation losses. Typically, the transmitting antenna is mounted on the top of existing buildings, the distance between 1-20 km, the frequency bands are 150-1500 MHz and the antenna height is 1-10 m. In Hata model, the median path loss is given by:

$$PL(dB) = 69.55 + 26.16\log_{10} f_c - 13.82\log_{10} h_t + (44.9 - 6.55\log_{10} h_t)\log_{10} R - E \quad (8)$$

where, E is represented with a large scale, medium scale and small scale that is given by for the large scale then $f_c \geq 400$ MHz:

$$E = 3.2\left[\log_{10}(11.75h_r)\right]^2 - 4.97 \quad (9)$$

For the medium and small scales is:

$$E = 1.1\left[\log_{10}(f_c) - 0.7\right]h_r - \left[1.56\log_{10}(f_c) - 0.8\right] \quad (10)$$

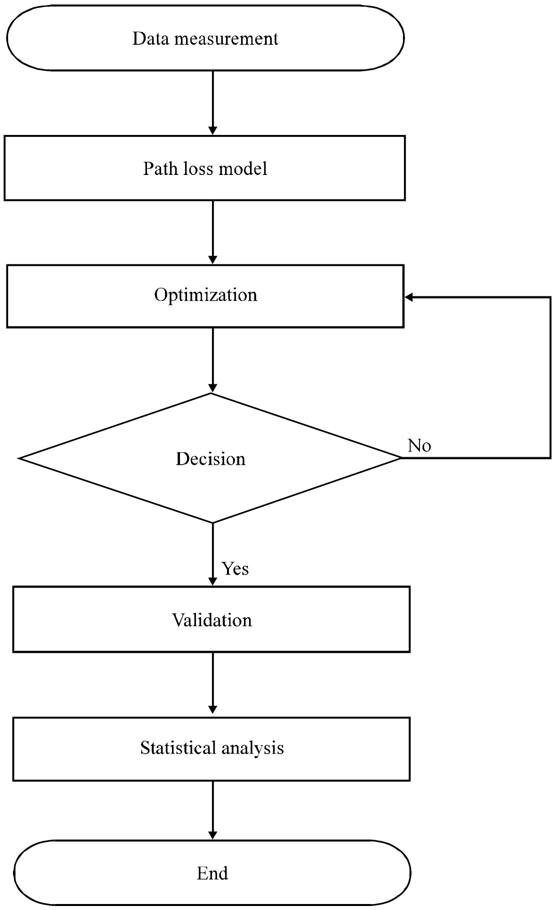

Fig. 1: Flow chart of data processing in optimization path loss model

Proposed model: This study proposes the optimization of path loss model in substitutions 8 and 10, respectively. We show the optimization procedure in Fig. 1. In firstly step, the measurement data collections were conducted to analyze by using the conventional path loss model. Secondly, a process of optimization is obtained to estimate by using least square method and evaluate the validation of the data integration.

Finally, statistical analysis such as relative error, standard deviation and variance are used to compare between the optimized path loss model and the conventional path loss model.

The least square estimation is to fine the estimates a and b such that the sum of the square distance from the actual response data y_i, we can obtain the expression of the optimization path loss model as:

$$(a, b) = \underset{(a,b)}{\text{argmin}} \sum_{i=1}^{n} \left[y_i - (a + bx_i)\right]^2 \quad (11)$$

Where:

y_i = The data measurement of i = 1, 2, ..., n numbers of data collection

x_i = The values from the path loss model

Mathematically, the least square estimates of the condition linear regression strategy are given by solving the system model as:

$$\frac{\partial}{\partial a} \sum_{i=1}^{n} \left[y_i - (a + bx_i)\right]^2 = 0 \quad (12)$$

$$\frac{\partial}{\partial b} \sum_{i=1}^{n} \left[y_i - (a + bx_i)\right]^2 = 0 \quad (13)$$

Suppose that a and b are the solution of the substitutive condition Eq. 12 and 13 we can describe the relationship between a variable y and x by using the regression line y = a+bx which is called the fitting curve by convention. We conduct to solve the unknown variable a and b from defining:

$$y_i = a^* + b(x_i - \bar{x}) + \varepsilon_i \quad (14)$$

Where:

$a = a^* - b\bar{x}$, $\bar{x}$ = The estimation values from the path loss model

ε = The random error

we need to solve for:

$$\frac{\partial}{\partial a^*} \sum_{i=1}^{n} \left[y_i - \left(a^* + b(x_i - \bar{x})\right)\right]^2 = 0 \quad (15)$$

$$\frac{\partial}{\partial b} \sum_{i=1}^{n} \left[y_i - \left(a^* + b(x_i - \bar{x})\right)\right]^2 = 0 \quad (16)$$

Taking the partial derivations with respect to a and b we have to define as:

$$\sum_{i=1}^{n} \left[y_i - \left(a^* + b(x_i - \bar{x})\right)\right] = 0 \quad (17)$$

$$\sum_{i=1}^{n} \left[y_i - \left(a^* + b(x_i - \bar{x})\right)\right](x_i - \bar{x}) = 0 \quad (18)$$

Note that:

$$\sum_{i=1}^{n} y_i = na^* + \sum_{i=1}^{n} b(x_i - \bar{x}) = na^* \quad (19)$$

Therefore, we get:

$$a^* = \frac{1}{n}\sum_{i=1}^{n} y_i = \bar{y}$$

substituting a^* by $\bar{y}$ in Eq. 25, we can obtain that:

$$\sum_{i=1}^{n}\left[y_i - \left(\bar{y} + b\left(x_i - \bar{x}\right)\right)\right]\left(x_i - \bar{x}\right) = 0 \qquad (20)$$

Denote a and b be the solution of the substitution (Eq. 12 and 13), it can be seen that:

$$a = \frac{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)\left(x_i - \bar{x}\right)}{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2} \qquad (21)$$

and $b = \bar{y} - a\bar{x}$ is the substituting condition.

RESULTS AND DISCUSSION

This study shows the measurement path loss results in urban area between Songkla and Surathani Provinces, Southern of Thailand. The comparative results in Surathani Province are shown in Fig. 2 that we have measured the received signal strength in both CH40 (626 MHz) and CH42 (642 MHz), respectively. Figure 2a shows the conventional path loss model and the optimized path loss model from the distance 2-7 km. Observed that the measured data are scattered from the minimum path loss 100 dB to the maximum path loss 160 dB we can see that the empirical path loss model by which the Hata model is the mostly close to the measured data. The linear regression fit can be shown that the average mean values of the measured data has been estimated. In addition, we have known that the optimized in Hata model is given the best accuracy of the prediction model. Meanwhile, we have measured the path loss model CH42 in Surathani Province as shown in Fig. 2b. We can observe that the measured data are scattered less than the CH40, especially between the distances 5-7 km.

The propagation environment might depends on the surrounding areas such as the traffic on the road, the different of temperatures or so on that these are very important factors of the measurement data collection. Where by the measured path loss data are captured between the minimum path loss 110 dB and the maximum path loss 150 dB as well as the conventional path loss we

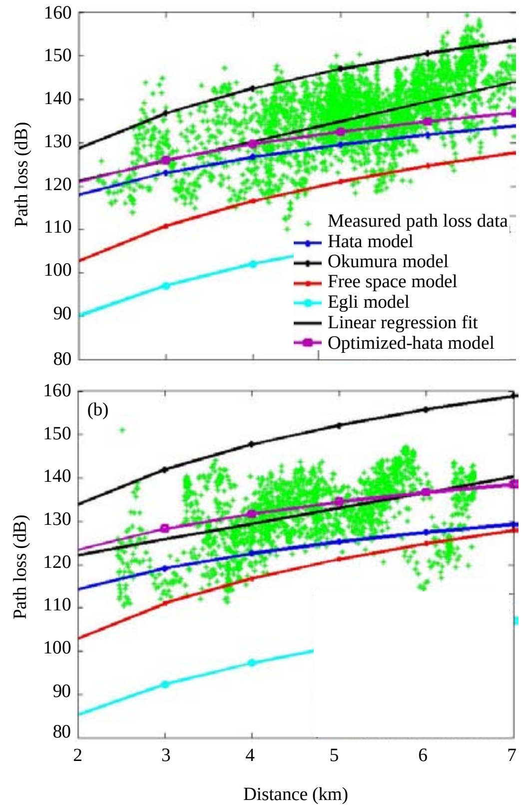

Fig. 2: Comparative optimized path loss model in urban area of Surathani Province: a) CH40 at 626 MHz and b) CH42 at 642 MHz

found that the Hata model is also accorded to the measured data. The linear regression curve fitting has been done to the measured data, hereby, the mean values are properly a simple model. In order to optimize the Hata model, obviously, the optimized Hata model is guaranteed the accuracy of statistic propagation.

In Fig. 3a, the measured data is scattered to the maximum as 160 dB and the minimum as 110 dB. We observe that the measured data is almost resemble the Okumura model but the response has a higher loss than the central of the linear regression model. Likewise, Hata model is a reciprocal measurement data than the Okumura model. The reason why Hata model has a suitable more that is a term of distance in each areas by which is shown in substitutions (Eq. 8-10). From this result we have conducted to optimize Hata model as given to following the linear regression of curve fitting. In CH46 measured results, the scattering of measured path loss data are lightly captured. The proposed with the optimized path loss model is compared in Fig. 3b.

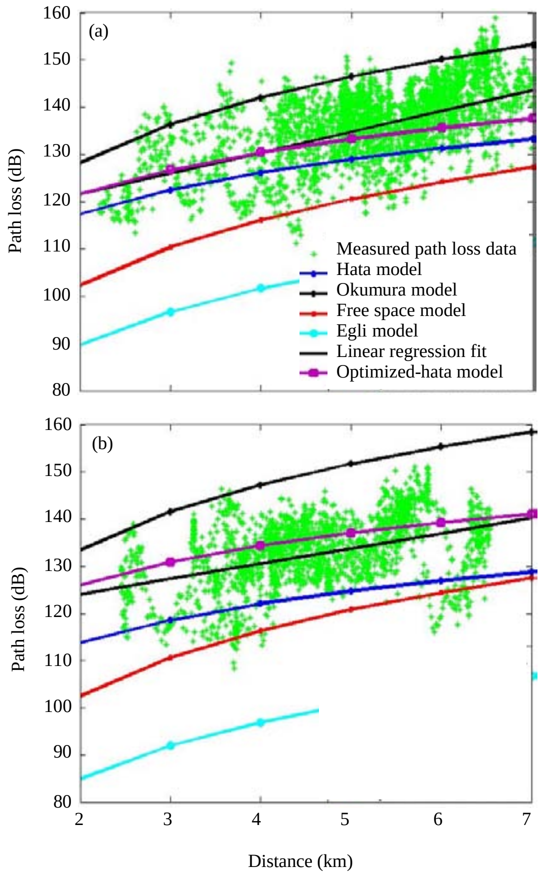

Fig. 3: Comparative optimized path loss model in urban of Songkla Province: a) CH44 at 658 MHz and b) CH46 at 674 MHz

CONCLUSION

The investigated path loss model for prediction DVB-T2 broadcasting in urban areas between Surathani and Songkla cities area have been presented in this study. The empirical measurement data have been compared with the conventional path loss model such as Okumura, Hata, Egli, free-space and linear regression models. From the proposed optimization based applied least square method. This proposed is very useful for enhances the accuracy of planning and designing gap filler in Southern of Thailand.

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