Hata’s Path Loss Model Calibration for Prediction DTTV Propagation in Urban Area of Southern Thailand

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Abstract. This article presents Hata’s path loss model calibration in order to predict a design of the Digital Terrestrial Television (DTTV) Propagation in an urban area of the south of Thailand through measuring power signal of the network operators’ broadcasting in 4 channels within Haadyai urban area, Songkla Province. The chosen location is a density area, a distance of 2.5-6.5 km. from the broadcasting station. The calibration was conducted through a statistical method of Root Mean Square Error (RMSE) from received power signal and compared with a path loss model from the prediction, followed by looking for relative errors to indicate the efficiency of the calibration model. The RMSE analytical result of CH 26 with the frequency of 514 MHz; CH 42 with the frequency of 642 MHz; CH 46 with the frequency of 674 MHz; CH 54 with the frequency of 738 MHz shows that Hata’s path loss model calibration is closer to the measured data than the original and the other model whereas the relative errors are closer to zero than the predicted path loss model. This makes the Hata’s path loss model calibration become more accurate in the prediction and subsequently more suitable for use in planning the network design.

1. Introduction
Thailand inaugurated the broadcasting of the standard Digital Terrestrial Television of DVB-T2 on April 1, 2014 under the supervision of the Office of the National Broadcasting and Telecommunication Commission (NBTC) who then organized and planned the frequency network covering the whole nation. The main station was designed as a Multi Frequency Network (MFN) and the sub stations within each main station were a Single Frequency Network (SFN) [1]. It becomes necessary that the design of the network must consist of sub stations in the areas of low signal and the existence of the gap filler stations in the areas of dead spots causing from obstructive surroundings [2].

An urban area is normally encountered with a dead spot causing from various obstructions i.e. high-rise buildings built-in in one area. Therefore, in order to plan the efficient gap filler stations covering areas properly while using the cost reduction transmitted power, it is essential that an
accurate prediction path loss model is used for a network design. This path loss model offers the suitable accuracy for many areas in various researches [3-4] etc. And a statistical method of Root Mean Square Error (RMSE) applied in many researches [5-6] etc.

This paper presents Hata’s path loss model calibration for prediction DTTV propagation in an urban area of southern Thailand through a method of looking for RMSE statistical value as well as relative errors from the data of power signal obtained from the measurement. The second part of the paper explains the path loss model while the third part is about the details of a signal transmitted stations, a signal measurement method, and the parameter of the DTTV signal transmission. The fourth part describes the findings whereas the fifth is the research conclusion.

2. Path Loss Models

2.1. Free Space Model

The free space model is the signal loss in a form of the line of sight (LOS). The received power signal ($P_r$) is related to the transmitted power signal ($P_t$), as shown in the following equation of Friis’s Transmission [7].

$$P_r = \frac{P_tG_tG_r\lambda^2}{(4\pi R)^2} \quad (1)$$

$G_t, G_r$ are the transmitted antenna gain and the received antenna gain, $\lambda$ is the wave length of used frequency, and the free space path loss model equation is as followed:

$$L(dB) = 10\log\frac{P_t}{P_r} = -10\log\frac{G_tG_r\lambda^2}{(4\pi R)^2} = 32.44 + 20\log f_c + 20\log R \quad (2)$$

$f_c$ is the used frequency, with a unit of MHz and $R$ is the distance between the transmitter and the receiver, with a unit of km.

2.2. Okumura Model

Okumura’s path loss model [8] is a system of wave propagation for urban areas. This model was initiated using the information of Tokyo City in Japan and it can be used in an area with a frequency of ($f_c$) 150 – 1920 MHz at the transmitted antenna height of ($h_t$) 30 – 1000 metre, the received antenna height of ($h_r$) 1 – 10 metre, and the distance ($R$) between the transmitter and the receiver (TX – RX) of 1 –100 km. An equation of this model is:

$$L(dB) = L_F + A_{MLt}(f_c,d) - G(h_t) - G(h_r) - G_{Area} \quad (3)$$

$L_F$ is a free space path loss model, with a unit of dB; $A_{MLt}$ is a loss amount through the free space, with a unit of dB; $G(h_t)$ is a factor of gain for the transmitted antenna height, with a unit of dB; $G(h_r)$ is the factor of gain for the received antenna height, with a unit of dB; $G_{Area}$ is the gain that is related to the environment.
2.3. Hata Model
Hata’s path loss model [9] was developed by Y. Okumura and M. Hata based on the signal measurement in the urban and suburban areas of Japan in 1968. The model is set for work in an area where the frequency is \((f_c)\) 150 – 1500 MHz at the transmitted antenna height \((h_t)\) of 30 – 200 metre, the received antenna height \((h_r)\) of 1 – 10 metre and the distance between the transmitter and the receiver \(1 – 20\) km. This model is divided based on urban, suburban and rural areas.

Urban areas

\[
L(dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_t + (44.9 - 6.55 \log h_t) \log R - E
\]

Large urban areas

\[
E = 3.2[\log(11.7554h_m)]^2 - 4.97 \quad f_c \geq 400 \text{ MHz} \tag{6}
\]

\[
E = 8.29[\log(1.54h_m)]^2 - 1.1 \quad f_c \leq 200 \text{ MHz} \tag{7}
\]

Medium and small urban areas

\[
E = [1.1\log f_c - 0.7]h_m - [1.56\log f_c - 0.8] \tag{8}
\]

Suburban areas

\[
L(dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_t + (44.9 - 6.55 \log h_t) \log R - 2 \left( \log \frac{f_c}{28} \right)^2 + 5.4 \tag{9}
\]

Rural areas

\[
L(dB) = 69.55 + 26.16 \log f_c - 13.82 \log h_t + (44.9 - 6.55 \log h_t) \log R - 4.78(\log f_c)^2 + 18.33 \log f_c + 40.94 \tag{10}
\]

2.4. Egli Model
Egli’s path loss model [10] was presented by John Egli in 1957 as the model that is used in an area where the frequency \((f_c)\) ranges between 40 – 900 MHz and the distance \((R)\) between the transmitter and the receiver is less than 60 km. The predicted equation of wave propagation is as:

\[
h_m \leq 10
\]

\[
L(dB) = 20\log f_c + 40 \log R - 20\log h_t + 76.3 - 10\log h_m \tag{11}
\]
3. DTTV Propagation

3.1. Signal Transmitted Station

NBTC specifies that the propagation of DTTV in Thailand is organized from one station and shares the infrastructure of transmission lines and antennas. The transmitter of each network operator connects with a combiner system to commonly use a transmission line and an antenna, as shown in the figure 1. The DTTV transmission in Songkla Province, in this research, is located on KhaoKorhong at the latitude of 7° 0’ 57.95”, the longitude of 100° 31’ 12.17”, and 366m above sea level whereas the transmitted height is 66m.

Digital transmitter broadcast in CH46 using a frequency of 674 MHz, NEC brand, DTL-10/1R0S model, and broadcasting power of 1KW; CH26 with the frequency of 514 MHz; CH42 with the frequency of 642 MHz and the latter two stations use the same transmitter of HRRIS, UAX-2000T2HE model, transmitted power of 1.3KW whereas CH54 with the frequency of 738 MHz, NEC brand, DTL-30/1R4SD model also uses the transmitted power of 1.3KW. The transmitted power of every channel is conducted through a 1 5/8” rigid line onto a combiner using a Spinner brand, CCS-6WAY model with the loss \( (Cl_1) \) of 0.55 dB. The output of the combiner is sent through the transmission line, RFS brand, Flexwell HF 5” model with the total loss \( (Cl_2) \) of 1.186 dB and onto the horizontal antenna, RFS brand, PHP48U model with the total gain \( (G_t) \) at 18.35 dBi. The relation between the received power signal \( (P_r) \) and the signal path loss \( (L) \) can be described as:

\[
h_m \geq 10
\]

\[
L(dB) = 20\log f_c + 40\log R - 20\log h_t + 85.9 - 10\log h_m
\]

\( f_c \) is the used frequency, with a unit of MHz; \( h_t \) is the transmitted antenna height, with a unit of m; \( h_m \) is the received antenna height, with a unit of m; \( R \) is the distance between the transmitter and the receiver, and a unit of metre (m).
\[ EIRP = P_t + G_t - CL_1 - CL_2 \]  
\[ L(dB) = (EIRP + G_r) - P_r \]  

EIRP is the effective isotropic radiated power, with a unit of dBm; \( G_t, G_r \) are the transmitted antenna gain and the received antenna gain, with a unit of dBi; \( P_t, P_r \) are the TV transmitted power and the received signal power, with a unit of dBm; \( CL_1, CL_2 \) are the transmitted loss in the combiner and in the transmission line, with a unit of dB.

### 3.2. Signal Measurement

The measurement of the signal is performed by a signal analyzing tool, DVB-T2 PROMAX, HD RANGER+ model, which consists of GPS and USB Drive as a data collector. The received antenna is a commercial one from a Korean company, SPECTRUM.CO.LTD, Omni-Saturn model with the gain (\( G_r \)) of 3dBi being installed on top of the pickup at 2 meter height off the ground. Drive Test function is used to measure the received signal power of the pathways where a high number of build-ins are located on both sides of the street in the urban of Haadyai City, Songkla province and the speed limit of 20km/hr.

![Figure 2. DTTV signal measurement equipment](image)
4. Analysis Findings

The path loss model calibration is done by using RMSE from the received power signal and compared with the predicted path loss model. The following equation shows how to get RMSE[6].

\[
RMSE = \sqrt{\frac{\sum (PL_m - PL_{approx})^2}{N-1}} \tag{15}
\]

\(PL_m\) is the path loss obtained from the measurement; \(PL_{approx}\) is the predicted path loss; \(N\) is the data amount obtained from the measure which, in this research, is 2300 points from each channel. The comparison result of the measured path loss is close to Hata’s path loss model that the calibrated Hata’s path loss model can be described as:

\[
\text{Calibrated Hata} = \text{Hata Model} + \text{RMSE(dB)} \tag{16}
\]

The relative error, to indicate the efficiency of the calibrated model, is calculated from the following equation [10].

\[
\delta = \left| \frac{PL_m - PL_{approx}}{PL_m} \right| \tag{17}
\]

\[
\text{Accuracy} = 1 - \delta \tag{18}
\]

From the equation, the RMSE of each frequency is obtained. Table 1 shows that RMSE of a low frequency channel is higher than the one of a high frequency channel. RMSE value of Hata’s path loss model is lesser than other models which shows the suitability of using the model to calibrate. Using the RMSE value in the calibration showing in figure 4, 5, 6, 7, it can be observed that the calculation result of Hata’s path loss model is closer to the measured information than those of other models. The figures also show the compared result between Hata’s path loss model calibration and the predicted
path loss model of each channel. It is clear that the Hata’s path loss model calibration is the closest to the measured data and its relative error is closer to zero than the original Hata’s path loss model, as shown in Table 2.

Table 1. The result of RMSE for path loss model calibration  

| Frequency       | Hata  | Okumura | Egli | Free space |
|-----------------|-------|---------|------|------------|
| CH26 (514 MHz)  | 15.40 | 20.90   | 34.80| 51.20      |
| CH42 (642 MHz)  | 11.07 | 16.57   | 30.29| 46.64      |
| CH46 (674 MHz)  | 10.16 | 15.60   | 29.03| 45.48      |
| CH54 (738 MHz)  | 9.57  | 15.40   | 28.60| 45.40      |
| Average         | 11.55 | 17.12   | 30.68| 47.18      |

Table 2. The comparison of relative errors and accuracy value  

| Frequency       | Relative Errors | Accuracy (%) |
|-----------------|-----------------|--------------|
| CH26 (514 MHz)  | Calibrated Hata | 0.010        | 99.0         | 89.6         |
|                 | Hata            | 0.104        | 98.5         | 93.2         |
|                 | Calibrated Hata | 0.068        | 98.1         | 94.2         |
| CH42 (642 MHz)  | 0.019           | 98.3         | 94.5         |
| CH46 (674 MHz)  | 0.017           | 98.3         | 94.5         |
| CH54 (738 MHz)  | 0.055           | 98.3         | 94.5         |

Figure 4. The comparison between Hata’s path loss model calibration and the predicted path loss model of CH 26, the frequency of 514 MHz
Figure 5. The comparison between Hata’s path loss model calibration and the predicted path loss model for Channel 42, the frequency of 642 MHz.

Figure 6. The comparison between Hata’s path loss model calibration and the predicted path loss model for Channel 46; the frequency of 674 MHz.
Figure 7. The comparison between Hata’s path loss model calibration and the predicted path loss model of CH54; the frequency of 738 MHz

5. Conclusion
The obtained result of Hata’s path loss model calibration is appropriate for designing the DTTV propagation in Haadyai City, Songkla Province where there is a dead spot. The result is also referred to use in other urban areas in the southern part of Thailand in order to properly cover different areas as well as to use the suitable power of the cost reduction transmitter. The calibration is done through finding the statistic of RMSE from the received power signal compared with the predicted path loss model in order to indicate the efficiency of the calibration. The analytical result of RMSE in CH26, the frequency of 514 MHz ; CH42, the frequency of 642 MHz; CH46, the frequency of 674 MHz; CH54, the frequency of 738 MHz shows the value of 15.40,11.0710.16 and 9.57dB, respectively. The result also shows that the Hata’s path loss model calibration is closer to the measured data than the predicted model whereas the relative error is closer to zero than the original path loss model.

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