Calibrating the Standard Propagation Model (SPM) for Suburban Environments Using 4G LTE Field Measurement Study Case in Indonesia

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Abstract. Effective and efficient network planning for appropriate area coverage can use the standard propagation model (SPM) calibrating or tuning method. SPM functions to increase the accuracy of predictions from the appropriate coverage planning results in field implementation. This study uses a calibration method resulting from field measurements with 4G LTE 1800 MHz technology. The results of the simulation found that the percentage of SPM propagation model for Reference Signal Received Power (RSRP) is above -80 dBm, the difference is 4.30%, RSRP values range from -80 dBm to -95 dBm at 21.52%, -95 to -110 dBm at 25.45%, and RSRP is smaller than -110 dBm at 0.37% by measuring field signal distribution. Coverage prediction of Calibrated SPM propagation model has the higher accuracy than COST 231, it represents the accuracy of SPM about 87% and COST 231 about 79%. The improvement of RSRP in the simulation is caused by changes in the correction values K1 to K7 which are in accordance with the criteria of the Purwokerto City area after calibrating.

1. Introduction
Telecommunications technology changes the human life trends that make the telecommunication services to be the primary needs. Long Term Evolution (LTE) is the fourth generation mobile technology designed to improve information access services to the internet network (mobile broadband) which can fulfill the human needs for telecommunication services. LTE technology has criteria like latency less than 10 ms, the data rate reached 100 Mbps when users were moving and 1 Gbps when users were static. LTE Bandwidth is flexible and has a better efficiency spectrum than 3.5 G technology from release 6. LTE can work in a variety of frequency spectrum and this technology can collaborate with non-3GPP systems that already exist [1][2].

LTE Network Service criteria in Indonesia now is still not optimal. It needs optimal network coverage planning to make this technology can cover all area network. Coverage planning is a method of network planning for predicting and simulating the coverage of each eNodeB in close to real conditions. eNodeB is the transceiver station to connect the user equipment with the LTE network. The first step in the coverage planning process is calculating the link budget. This Link budget calculation estimates the value of the Maximum Allowed Path Loss (MAPL) between a transmitter and a receiver on the downlink and uplink communication. The output of the link budget calculation is the number of eNodeB to cover all area by we know the cell radius. The cell radius can be estimated based on a review of the area and the propagation model used. This process needs the accurate
propagation model as the real condition to get the accurate cell radius and coverage prediction each eNodeB. In this study, we calibrating the standard propagation model (SPM) in 1800 MHz frequency by tuning the parameter K1-K7 of SPM formula using radio planning software based on the measurement data drive test method in real condition [3].

SPM is a model of development of propagation modeling formula path loss Hata. It is the Empirical model of the propagation path loss at frequency 1500-2000 MHz, it defines large-scale fading in a signal received with the distance 1-20 km. SPM Equation assumes that the proper settings in some parameters for intended for factor K and the effect on the propagation of the signal. SPM can enhance the accuracy of the predictions in a planning network with the process of calibrating or tuning the propagation model. Calibrating is an approach of calculation that affects a formula from the propagation model, this calculation can conduct an approach quite close to the real measurement results. Previous research[4] already calibrated the SPM Model for Built-Up and Urban Environments using Field measurement and geospatial data.

That research shows that after proper calibration, the SPM provides a much better fitness, achieving average Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Standard Deviation (SDE) values and significantly better than the reference values without calibration. Other research from [5] Standard Propagation Model (SPM) is proposed to simulate 4.5G coverage available for the entire Singapore airspace up to 400 feet altitude. This calibrated SPM considers path loss correction due to angular-depression between Unmanned Aerial Systems (UAS) altitude and cell tower height to improve coverage prediction accuracy. The accuracy of less than 8dB error invariance between simulation and experimental results have been achieved. The calibrated model will be used to support the uTM-UAS to indicate suitable airspace in terms of communication coverage and performance to ensure safe UAS operations.

2. Literature Review
The propagation model is an empirical mathematical formula to simulate the characteristics of radio wave propagation based on altitude, distance, frequency, and other conditions. There are several types of propagation models used in cellular network planning such as Okumura-Hata, COST 231, and Standard Propagation Models [4][6].

In this study, the propagation model for network planning uses the SPM propagation model with equation (1) below.

\[
L = K1 + K2 \log d + K3 \log h_te + K4. Diffraction Loss + K5 \log d. \log h_te + K6. h_re + K7. \log h_re + K_{clutter}. f_{clutter} + K_{hill,LOS}
\]  

(1)

The model parameters are defined as follows:
- \(K1\): Constant offset (dB)
- \(K2\): Multiplying factor for \(\log d\)
- \(d\): Distance between receiver and transmitter (m)
- \(K3\): Multiplying factor \(\log h_{te}\)
- \(h_{te}\): Effective height of the transmitter antenna (m)
- \(K4\): Multiplying factor for diffraction calculation
- \(K5\): Multiplying factor for \(\log d. \log h_{te}\)
- \(K6\): Multiplying factor for \(h_{re}\)
- \(K7\): Multiplying factor for \(\log h_{re}\)
- \(h_{re}\): Effective height of the receiver antenna (m)
- \(K_{clutter}\): Multiplying factor for \(f_{clutter}\)
- \(f_{clutter}\): Average of weighted losses due to clutter
- \(K_{hill,LOS}\): Corrective factor for hilly regions
Refers to equation (1), the correction factor of the UE antenna height and clutter is ignored so the equation of the path loss model is given as follows

\[
L = A_1 + A_2 \log(f) + A_3 \log h_{te} + [B_1 + B_2 \log h_{te}] \log d
\] (2)

Equation (2) has the values:

- \( A_1 = 46.30 \)
- \( A_2 = 33.90 \)
- \( B_1 = 44.90 \)
- \( B_2 = -6.55 \)

So, the equation between COST 231 and SPM was formulated as the equation (3)

\[
L = A_1 + A_2 \log(f) - 3B_1 + [A_3 - 3B_2][\log h_{te}] + B_1 \log d + B_2 \log h_{te} \cdot \log d
\] (3)

\( K_1 = A_1 + A_2 \log(f) - 3B_1 \)
\( K_2 = B_1 \)
\( K_3 = A_3 - 3B_2 \)
\( K_5 = B_2 \)

The formula for implementing LTE 1800 given as equation (4) belows

\[
L = 22 + 44.9 \log(d) + 5.83 \log h_{te} - 6.55 \log(d) \cdot \log h_{te}
\] (4)

The Approaching method used the standard propagation model to calibrate K1 until K7 parameter like the measurement data drive test in certain areas. It made the prediction coverage more accurate to plan the coverage of the eNodeB in certain areas. Table 1 and Table 2 are the range of calibrated SPM parameter.

**Table 1. SPM Range Reference [7]**

| Parameter | Minimum | Typical | Maximum |
|-----------|---------|---------|---------|
| K2        | 20      | 44.9    | 70      |
| K3        | -20     | 5.83    | 20      |
| K4        | 0       | 0.5     | 0.8     |
| K5        | -10     | -6.55   | 0       |
| K6        | -1      | 0       | 0       |
| K7        | -10     | 0       | 1       |

**Table 2. K1 Parameter of Standard Propagation Model [7]**

| Frequency  | 900 MHz | 1800 MHz | 1900 MHz | 2100 MHz |
|------------|---------|----------|----------|----------|
| K1         | 12.5    | 22       | 23       | 23.8     |

3. Methodology

3.1. LTE Networks Planning and Link Budget

The network planning process uses existing data which is simulated with the Atoll radio network planning software to get coverage predictions. The simulation of radio network planning was configured by model propagation at the 1800 MHz LTE frequency. The existing data use to give information about the real condition like in the measurement data. The software Atoll can simulate the existing network like the real condition on surface and altitude in certain areas. In this study, we simulate the coverage prediction of the existing network in Purwokerto by calibrating the correction
factor value of SPM like the measurement data drive test. The value calibrating data Correction factor can represent the condition in the typical area, especially at Purwokerto.

In coverage planning, the first process to do is calculating the link budget. The purpose of calculating the link budget is to get the real Most Allowable Path loss (MAPL), this is the maximum loss value between the transmitter and receiver for uplink and downlink directions. From the calculation of MAPL it can predict cell radius based on the real area and the propagation model used. If we get the cell radius, we can get the number of sites to plan how many sites or eNodeB we needed to cover all areas. The calculation of the MAPL is calculated on the downlink side only[2].

![Figure 1. Link Budget Downlink](image)

The link budget downlink equation is given as follow:

\[
\text{EIRPD} = \text{PUE} - \text{GeNodeB} - Lb 
\]

\[
\text{SRMINDL} = \text{RXsen} - \text{GUE} - Lc + IM
\]

\[
\text{RXsen} = \text{SINR} + \text{RxNF} - \text{NTH} + 10 \log (15000)
\]

\[
\text{MAPL} = \text{EIRPD} - \text{SRMINDL} - L - \text{MSF}
\]

Equation (5), (6), (7) and (8) are defined as:
- **PUE**: UE transmitter power each resource block
- **GUE**: UE antenna gain
- **GeNodeB**: eNodeB antenna gain
- **Lc**: feeder cable loss
- **Lb**: body loss
- **EIRPD**: effective isotropic radiated power downlink
- **SINR**: Signal to Interference ratio
- **RxNF**: receiver noise figure
- **NTH**: thermal noise
- **RXSEN**: receiver sensitivity
- **SRMINDL**: minimum signal reception downlink
- **IM**: interference margin
- **L**: penetration loss
- **MSF**: shadow fading margin
- **MAPL**: maximum allowable path loss downlink
3.2. Propagation Model Tuning

The Propagation Model Tuning method is an approach to calibrate the propagation model calculations and formula as the real propagation in a certain area. This calculation can take an approach that is quite close to the measurement results in the field, the calibrating parameter that affects the propagation model is considered. This method uses a field measurement data (drive test) which contains information on signal level distribution from measurement data [9].

4. Results & Analysis

4.1. Measurement data using Drive Test

Drive test is a measurement method to find out the real performance of the network based on the user experience of handphones in a cellular network on the side of the air interface (MS to BTS or vice versa) using a tool called drive test tools. The results of the driving test will be used as an evaluation of the existing network to improve the performance and maintenance of the network.

In this study, there were three measurement areas. Measurement areas were in Sokaraja Tengah, Sampoerna Berkoh, and Teluk site. The signal quality measurement used Nemo Outdoor drive test tools. The drive test tools would record all the activities carried out by the handset (mobile phone) because the drive test tools could be directly integrated with the notebook. The parameter measured to calibrated the SPM Model as a reference signal received power (RSRP).

![Figure 2. RSRP’s measurement data drive test plotting at a digital map.](image)

The Range of RSRP key performance indicator (KPI) was from -45 to -110 dBm. The classification of RSRP KPI to obtain good or poor criteria on the RSRP LTE network can be seen in table 3.

| Category   | RSRP Range Value (dBm) |
|------------|------------------------|
| Excellent  | -80 <= x                |
| Good       | -95 <= x < -80         |
| Fair       | -110 <= x < -95        |
| Poor       | x < -110               |

It was the power of the signal received from the eNodeB towards the UE. The closer the serving cell the better the signal strength would be received by the UE, and vice versa if the serving cell was
getting farther away, the worse signal would be received. The RSRP calculation values could be formulated in equation (9)\[8\] :

\[
RSRP = RSSI - 10.\log(12.\,N)
\]

The correction factor constant value is determined by approaching the constant value function. A function of this constant value becomes a reason to increase or decrease the modified parameter, we called it the calibrating standard propagation model. The standard propagation model is calibrated by the radio network simulation software Atoll in two scenarios. The first scenario is a simulation of coverage prediction using COST 231 propagation model before using the standard propagation tuning model. The second scenario is a simulation of the calibrating parameter from standard propagation model tuning according to the range of parameters permitted by the standard propagation model so the values of the correction parameters are matched with the measurement area. The simulation at scenario 1 uses the K Parameter value from COST 231 Parameter model like table 4 below.

| Table 4. The K Parameter COST 231 Propagation Model |
| --- | --- |
| Parameter | Value |
| K1 | 22 |
| K2 | 44.9 |
| K3 | 5.83 |
| K4 | 0 |
| K5 | -6.55 |
| K6 | 0 |
| K7 | 0 |

Figure 3. Scenario 1 coverage prediction and measurement data plotting before calibrating.

Signal levels prediction at some sites have the RSRP value above -80 dBm is 0%. The RSRP Signal level from -80 dBm until -95 dBm is 29.77%, The RSRP Signal level from -90 dBm until -110 dBm is 65.30% and The RSRP Signal level below -110 dBm are 4.93%. The RSRP prediction produced by Figure 3 is the propagation COST 231 with separation distance resulting in 231 propagation COST that has been calculated is 1.9 km with the transmitter antenna height on average is 52 meters, and the receiver antenna height is 2 meters. Approach to the measurement signal with the drive test method and the simulation results have results that are not as good as the results of the simulation signal distribution in figure 4.
Signal spread on the Sokaraja Tengah site, Sampoerna Berkoh, and Teluk this second scenario has an approach between measured signals and simulation signals that approach each other's value. RSRP with values above -80 dBm in the area reviewed is 45.07%. RSRP is the range of -80 dBm to -95 dBm.
at 52.96%, RSRP -95 dBm to -110 dBm at 1.97%, and below RSRP -110 dBm has a percentage of 0%. This value is higher than the results in scenario 2 which includes 3 sites reviewed. This is caused by the propagation of the model used calibrated drive test data with the correction value used that has been tuned using a range of minimum to maximum values according to the standard propagation model rules. From the results of the calibrating the new correction values are obtained according to the characteristics for the city of Purwokerto as table 5 follows:

\[ L = 22 + 44.9 \log(d) + 5.83 \log hte - 6.55 \log(d) \cdot \log hte \]  
\[ (10) \]

\[ L = 22 + 50 \log(d) - 4.72 \log hte - 10 \log(d) \cdot \log hte \]  
\[ (11) \]

Table 5 is The result of SPM Parameter Calibration for Suburban typical area especially at Purwokerto, that value is the new correction parameter obtained for constant offset (K1) is 22 dB due to the 1800 MHz frequency used in this study. The multiplier of \log d (K2) is 51, the multiplier factor of the newly generated \log hte (K3) is -4.98, the multiplier factor of diffraction calculation (K4) is 0, the multiplier of \log d multiplied by \log hte (K5) has a value by -10. The parameter K6 or the multiplier of the receiver antenna and K7 which is the multiplier of the hre log is 0 because the value has no impact on path loss. The Separation distance generated by SPM tuning propagation that has been calculated by equation (10) and (11) is 6.6 km with the transmitter antenna height about 52 meters, and the receiver antenna height about 2 meters.

**Table 5. The Calibration of SPM Parameter for Suburban typical area especially at Purwokerto.**

| Parameter | Value |
|-----------|-------|
| K1        | 22    |
| K2        | 51    |
| K3        | -4.98 |
| K4        | 0     |
| K5        | -10   |
| K6        | 0     |
| K7        | 0     |

**Figure 7.** The comparison of drive test measurement RSRP Histogram between COST 231 and SPM Tuning RSRP Prediction.
The comparison of coverage prediction in figure 7 using the propagation model COST 231 with a range of RSRP values greater than -80 dBm has not approached the actual measurement results (drive test) compared to the use of SPM propagation models that have been calibrated. The results of the SPM for RSRP are above -80 dBm, the difference is 4.30% with the drive test data. The RSRP value in the range of -80 dBm to -95 dBm in the 231 propagation COST model obtained a better difference of 1.67% and the SPM propagation model of 21.52%. RSRP is -95 to -110 dBm in the SPM propagation model is much better than the use of the propagation model COST 231. SPM propagation has a difference of 25.45% with the results of actual measurements or drive tests. Poor coverage with RSRP values above -110 dBm in the SPM propagation model getting a difference of 0.37% and the propagation model COST 231 amounting to 4.56%. it can analyze that SPM has a prediction accuracy of about 87% and COST 231 about 79%. It concludes the Calibrated SPM makes a higher accuracy to measurement data than COST 231 model.

5. Conclusion
The results of calibrated SPM Parameter values for Suburban Purwokerto typical area are K1= 22, K2= 51, K3= -4.98, K5= -10, and zero value for the K4, K6, and K7 parameter. Every area has a different calibrated parameter. In this study, The Results of coverage prediction and measurement data can be seen that SPM has been calibrated and tuned with prediction accuracy about 87% and COST 231 about 79%. The SPM correction Parameter that has been calibrated with the results of the driving test in this simulation can increase the accuracy of the results of network planning.

6. References
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