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ANALYZED OF PATH LOSS IN OUTDOOR TO INDOOR MODEL FOR MOBILE DATA COMMUNICATION

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Abstract

Analyzed of outdoor to indoor track loss has been carried out at a lecture building location in an urban area, the University of North Sumatra. This paper described examines the magnitude of the signal strength along the track at a frequency of 2100 MHz. The propagation model used is the COST231 model. By changing the parameters of external wall penetration losses in the COST231 formulation, a trajectory loss profile is obtained that is close to the measurement conditions at the research location.

Keywords: *Outdoor to Indoor Model, COST231 Model, 2100 MHZ Frequency*

I. INTRODUCTION.

A need method for communication services causes users to carry out communication activities as often as possible and anywhere. This activity is not only done outdoors but now many users are communicating inside the building. Often the signal received inside the building is not as optimal as the signal received outside the building. This happens because users inside the building only utilize transmitters that are outside the building. For this reason, research is needed to predict path losses from outside into buildings (outdoor to indoor models) to see how much transmitter power is lost.

One model of path losses from the outside into buildings (O2I) is the COST231 model. Many studies have been conducted to model the O2I scenario COST231. The COST231 model is an empirical model that provides analytical equations with reasonable accuracy. Because it requires little information in the analysis equation, this model is considered as the most accurate model and is widely used to predict O2I path losses. In this study the COST231 model was applied at a frequency of 2100 MHZ. There are parameters that affect the prediction of path losses in the COST231 model equation, namely the loss losses of the extrenal and internal walls. By replacing the variable values of the two types of penetration losses, a trajectory loss profile is obtained in accordance with the conditions of the study site.

II. LITERATURE REVIEW.

2.1. Free space model

A path loss in Free Space L defines how much strength of signal is lost during propagation from transmitter to receiver. Free Space Model is diverse on frequency and distance. It is calculated by using equation 1. $L = 32.45 + 20\log(d)+20\log(f)$ (1) Where, f is the Frequency in (*MHz)* and d is the distance in (*Km*).

2.2. Extended COST-231 Hata model

Extended COST-231 Hata model uses a propagation equation which is divided into two terms. A first term has a logarithmic dependence on distance, d, while a second term is independent of distance. It also includes adjustments to the basic equation to account for Urban, suburban, dense-urban, and rural propagation losses. The complete derivation of these equations has been done in [10].

The general propagation loss in *dB* is given by [4] and shown by using formula 2.
Lp=46.30+33.9*log(f)-13.82*log(hm)-a(hm)+(44.9-6.55*log(hb))*log(d)+Cm (2)
Where,
Lp is a propagation loss in environment of type *p*, in *dB* (0: Urban, 1: Suburban, 2: Dense-urban, 3: Rural). *f* is the frequency of the transmission in *MHz.*
hm is the height of the mobile or receiver in meters (1 - 10*m*).
hb is the height of the base station or transmitter in meters (30 - 200*m*)
d is the distance between the receiver and the transmitter in kilometres (1 - 20 *km*).
a(hm) is a mobile antenna correction factor which different for each environment.
Cm is the correction factor which has different value for each environment. As we can observe, the path loss in the free space model depends on the frequency and distance. Although, further parameters are introduced in other propagation models, such as the height of the mobile, *hm*, and the height of the base station, *hb*. Additionally,
The range of value for the validity of Hata model is [18]: $150 \leq f \leq 1500MHz$, $30 \leq hb \leq 200m$,$1 \leq hm \leq 10m$ and $1 \leq d \leq 20km$.
There, the values of the height of the mobile and the height of the base station are fixed within the given ranges for the sake of comparison.
Extended COST-231 Hata for Urban environment: a(hm)=(1.1*log(f)-0.7)*(hm)-(1.56*log(f)-0.8)dB (3) and *Cm* = 0. Extended COST-231 Hata for Suburban environment: L1 = L0 - 2.(log(f28))2-5.4 (4) Where, a(hm)=(1.1 . log(f)-0.7).(hm)-(1.56 .log(f)-0.8)dB (5)

III. Experimen Research.

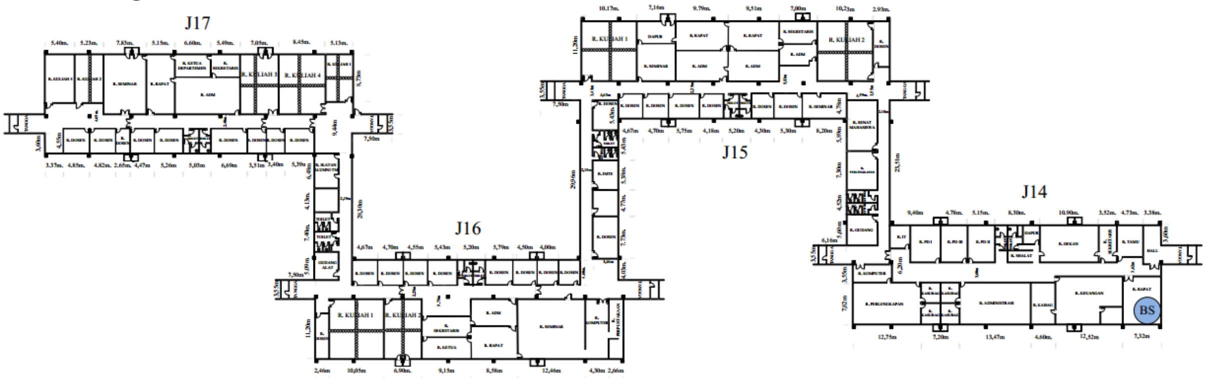
A location of the measurement of signal strength was carried out in one of the lecture buildings at the University of North Sumatra in Medan Indonesia. This building has a three-level building where the antenna position is above the building. The measurement sample is only taken in the building corridor because it is assumed that many users exchange information in this mobile area. The research location is a multipurpose building that functions as an office, classroom and conference roo

This building was designed with a partially closed and partially open corridor, meaning a part of the building with complete walls and partly with one side of the wall open as shown in Fig.1. The structure of the building consists of concrete walls and some space is insulated by walls made of plywood. Windows in this building are made of dominant glass. This type of building does not guarantee whether radio waves will reach the receiver by penetrating walls or through propagation mechanisms such as reflection, diffraction and scattering.

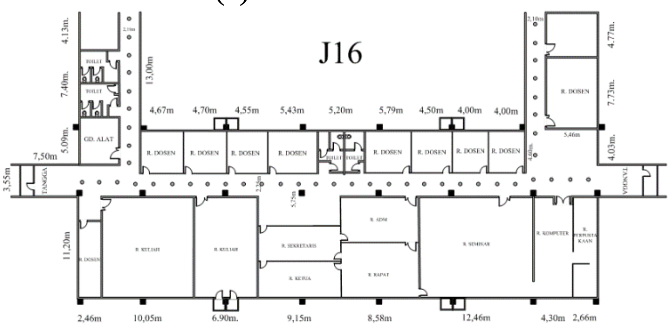
(a) Corridors with Covered Walls (b) Corridors with Semi Closed Walls

Fig. 1. Research Building Corridor

In this study, the measurement of the received signal strength was carried out by the walk-test method. The device used is a laptop that has the Tems Investigation application version 10.05 installed and then uses a USB cable connected to the Sony Ericsson W995 cellular as a receiver. The device was taken to walk from the 1st floor to the 3rd floor, starting from the closest point to the transmitter (BS) then walking away from the BTS. From the beginning of the measurement process, the recipient (MS) calls as an information exchange process. Measurement samples are taken every 2 meters. The measurement route is carried out along the building corridor which can be seen in Fig. 2



(a) Location Of Research



(b) Measurement route at Building J16

Fig. 2. Signal Strength Measurement Route

The transmitting antenna (BS) which can be seen in Fig.2 is above the building J14. The communication service used in this study is a local service provider with a working frequency of 2100 MHz for 3G systems. While the antenna that acts as a receiver is a cellular. On both transmitters and receivers antennas there are several parameters that influence the calculation of path losses. These parameters can be seen in Table 1.

Table 1. Transmitter and Receiver Antenna Specifications

Parameters	**Transmitter**	**Receiver**
Type of	TYDB-	Omnidirectional

Antena	182020DE4-33FT2	
Frequency	System 3G : 2100 MHz Uplink : 1920 MHz Downlink : 2170 MHz	2100 MHz
Height of Antena	22 m	1.5 m
Resonance	66 dBm	–

IV. RESULTS

COST231 trajectory losses consist of outdoor trajectories (Lout), indoor track losses (Lin), wall propagation losses (Ltw) and total propagation losses in line of sight (L_ (L_) conditions tot (LOS))).

$$L_{tot\ (LOS)} = L_{out} + L_{tw} + L_{in} \quad (1)$$

To explain the principle of the COST231 O2I model is shown in Fig. 3

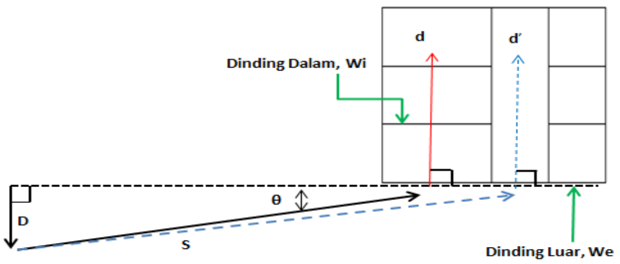


Fig. 3. COST231 O2I Model Working Principles

$$L_{out} = 32{,}4 + 20\log(S + d)_m + 20\log f_{GHz} \quad (2)$$

$$L_{tw} = W_e + WG_e(1 - \frac{D}{S})^2 \quad (3)$$

$$L_{in} = max(\Gamma_1, \Gamma_2) \quad (4)$$

$$\Gamma_1 = W_i p \quad (5)$$

$$\Gamma_2 = \alpha(d - 2)(1 - \frac{D}{S})^2 \quad (6)$$

Where, W_e represents external wall penetration losses (4 - 10 dB), 〖WG〗 _e is additional losses on external wall (20 dB). D is the perpendicular distance between Tx and the external wall, S is the oblique distance between Tx and the external wall, d is the distance between the external wall and Rx while f is the working frequency. W_i is internal wall losses (4-10 dB). p is the number of walls penetrated by the signal and α represents propagation losses in space when there is no internal wall when the signal travels from the external wall to Rx.

Tables 2. Value of Cost231 and RSS Parameters for each Floor

Floor	we (dB)	wge (dB)	wi (dB)	Measured Mean RSS (dBm)	Predicated Mean RSS (dBm)	RMSE

1	7	20	7	-74.2241	-41.3962	33.0984
	8	20	8		-43.3962	31.1157
	9	20	9		-45.3962	29.1355
	10	20	10		-47.3962	27.1582
2	7	20	7	-72.1207	-41.1358	32.2145
	8	20	8		-43.1358	30.2958
	9	20	9		-45.1358	28.3883
	10	20	10		-47.1358	26.4944
3	7	20	7	-65.3586	-40.8672	24.6832
	8	20	8		-42.8672	22.7089
	9	20	9		-44.8672	20.7396
	10	20	10		-46.8672	18.7767

In this study a COST231 model was tested for the research location, which is a building corridor consisting of 3 floors. In Table 4 we can see the parameter values for internal wall lighting and external wall penetration giving different estimates of the received signal power in the COST231 prediction model. The parameters W_e, W_i and W_Ge are influential contributors in calculating overall outdoor-indoor path losses. The COST231 model suggests the values of W_e and W_i in the range of 4-10 dB, concrete walls of normal window size are given a value of 7 dB. At the research location, the prediction calculation of the COST231 model is performed with values of W_e and W_i ranging from 7-10 dB. The results obtained are still far from the measurement conditions. Of the three parameters namely W_e, W_i and W_Ge, the COST231 model assumes that the external wall is the part that is directly seen by the transmitter and is considered responsible for penetration. Then the optimization is performed on external penetration losses (W_e).

A study has been made to optimize the trajectory losses of the COST231 model. In the COST231 optimization model, parameters in the building are divided into more specific segments. These parameters are the loss losses from the extrenal wall (W_e). From the experiments, data were collected to obtain an empirical formulation of external wall penetration losses (W_e) using multiple regression techniques.

$$W_e = 15.53 + 10{,}143 \log(f_{MHz}) - 0{,}158W_{pr} - 0{,}3549W_t + 3{,}439W_{mat}$$

Where f is the working frequency in MHz, W_pr is the proportion of the window on the extrenal wall, W_t is the type of window and W_mat is the type of material or material from an external wall. Tables 3 shows the values of each variable for different material types.

Tables 3. Variables of different material types

f W_{pr} W_t W_{mat}	f In MHz W_pr In percentage (%) W_t Without Glass: 1 Glass: 2 Plated Glass: 3 Wire window: 3 W_mat Bata: 1 Cinder block: 1 Concrete Block: 2 Reinforced Concrete: 3

Tables 4. Average RSS levels from Measurement, Prediction Models and Optimization Models

floor	Measured Mean RSS (dBm)	Predicated Mean RSS (dBm)	Proposed Mean RSS (dBm)	RMSE
1	-74.22	-41.40	-79.92	7.09
2	-72.12	-41.14	-79.66	11.60
3	-65.36	-40.87	-79.39	14.63

Optimization of the COST231 model has been carried out by calculating the external penetration losses of W_e using the formulations obtained in previous studies [8]. This formulation adds criteria for the type and proportion of windows as well as the type of material from the wall which can be seen in Table 5. Based on Table 6 it can be seen that adding the parameters W_pr, W_t, and W_mat into the W_e formation affects the receiver power level (RSS). The average RSS in the optimization model is closer to the measurement conditions. In addition, the value of RMSE is also getting smaller.

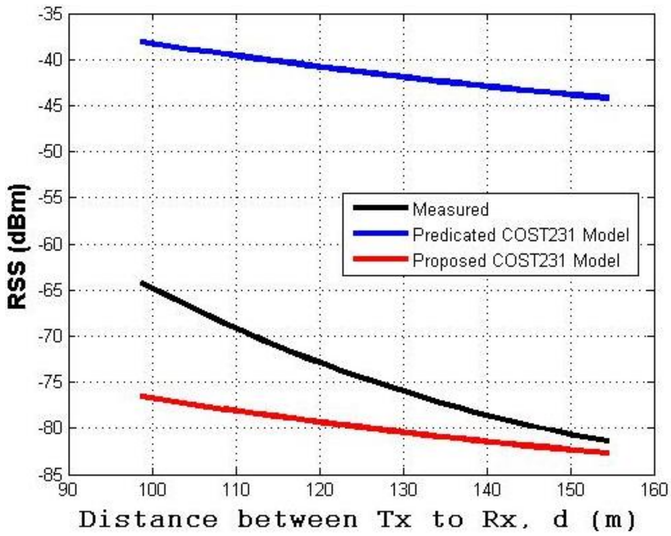


Fig 4. Distance Between tx to rx

Fig. 4 RSS vs. Measurement COST231 model and COST231 optimization model on the 1st floor Two COST231 models for O2I pathloss compared to measurements can be seen in Figure 4. Based on Figure 4 clearly shows that the optimized model provides better conditions compared to the COST231 model. The W_e calculation formula in the optimized COST231 model is precisely used for the conditions of this study.

V. CONCLUSION

In this study, measurements of path loss in the corridors of the University of North Sumatra have been presented and have succeeded in obtaining a COST231 optimization model. The results of track loss measurements at the study site were carried out in the corridor of the building, the results were compared with the COST231 model and the COST231 optimization model. In the COST231 model, the external penetration loss parameter has been determined to have a constant value of around 4-10 dB. The COST231 optimization model of this parameter is calculated into the formulation by adding building segments, namely the type of wall material, the type of window and the proportion of building windows. By optimizing the COST231 model the path loss profile at the studied location is obtained.

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