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Matlab Simulink of COST231-WI Model

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Abstract

Simulink is the integrated environment of system modelling and simulation, which is being widespread used. This paper describes the MATLAB visual simulation of the propagation path loss model for telecommunication systems. We simulated the whole process of COST231-Walfisch-Ikegami model with high accuracy, built a visual simulation frame and the path loss curves are given. This method can be used in studying other propagation path loss models in propagation environments.

Index Terms: Path loss; wireless communication; model; COST231-Walfisch-Ikegami ; Simulink

1. Introduction

The tremendous growth of wireless communication systems and especially mobile radio systems requires radio coverage prediction models that provide accurate results and fast processing time for several types of environments, which includes a large number of parameters describing the propagation environment. Due to the complexity and instability of radio transmission in wireless communications channels, it is very important to get the knowledge about the characteristics of wireless communication and use the suitable propagation models.

Path loss is a major component in the analysis and design of the link budget of a telecommunication system. Path loss models are useful planning tools allow the radio network designer to reach optimal levels for the base station deployment and configuration while meeting the expected service level requirements. There are some well-known conventional prediction models such as the Okumura-Hata model[1], COST231-Hata model[2], ITU Terrain Model[3], Egli model[3], Sakagami model[4], and COST231-Walfisch-Ikegami model[5]. But there have some deficiencies in these models. For example, the response of Okumura-Hata model is much slowly to the fast change signal of the suburb area, the error is 10 ~14dB, and being a set of curve, it is inconvenience to use. ITU Terrain Model is considered valid for losses over 15 dB and is not applicable to terrains where irregularities are high. Egli Model predicts the path loss as a whole and does not subdivide the loss into free space loss and other losses. COST-Hata model requires the base station antenna higher than all adjacent rooftops.

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ITU Terrain Model's output is only as good as the data on which it is based and the LOS model it is used to correct.

Compared to other models, the accuracy of the COST231–Walfish-Ikegami Model is quite high. It is because in urban environments especially the propagation over the rooftops (multiple diffractions) is the most dominant part. Only wave guiding effects due to multiple reflections are not considered[5]. So, we selected COST231–Walfish-Ikegami Model for numerical analysis and Matlab Simulink simulation.

2. Cost231-Walfisch-Ikegami model

The COST231-Walfisch-Ikegami model (COST231-WI)[5][6][7] is a statistical model on combination of the Walfisch-Bertoni model[8] and Ikegami model[9]. It is proposed by COST 231and has been accepted by the ITU-R. It is with no considerations of topographical database of buildings, and is restricted to flat urban terrain.

COST231-WI model is one of the most popular models in radio propagation prediction in urban UMTS network planning and is included into Report 567-4. The estimation of path loss agrees rather well with measurements for base station antenna heights above roof-top level. The model allows for improved path-loss estimation by consideration of more data to describe the character of the urban environment, namely, the base station (BS) antenna height $\boldsymbol{h_b}$, the mobile station (MS) antenna height $\boldsymbol{h_m}$, the mean building height $\boldsymbol{h_B}$, the street width $\boldsymbol{w}$, the separation distance between the rows of buildings $\boldsymbol{b}$, the the distance between BS and MS $\boldsymbol{d}$, and the angle of incidence from the BS to the first diffraction edge $\boldsymbol{\phi}$. COST231-WI model can be used in the follow scenario, where $800\text{MHz} \le f \le 2000\text{MHz}$ and $0.02\text{km} \le d \le 5\text{km}$. The detail parameters and formulation of this model can be seen in[5][6][7].

COST231-WI model[5][6][7] distinguishes between line-of-sight (LOS) and non-line-of-sight (NLOS) situations.

In the LOS case, the loss is based on measurements performed in the city of Stockholm:

$$L_{LOS} = 42.6 + 26\log(d) + 20\log(f), \quad \text{for} \quad d \ge 20m \tag{1}$$

For the NLOS situations, the path loss of COST231-WI Model is composed of the terms free space loss $\boldsymbol{L_{fs}}$, roof-top-to-street diffraction and scatter loss $\boldsymbol{L_{rts}}$ and the multiple screen diffraction loss $\boldsymbol{L_{msd}}$:

$$L_{NLOS} = \begin{cases} L_{fs} + L_{rts} + L_{msd} & (L_{rts} + L_{msd} \ge 0) \\ L_{fs} & (L_{rts} + L_{msd} \le 0) \end{cases} \tag{2}$$

The free-space loss $\boldsymbol{L_{fs}}$ is given by:

$$L_{fs} = 32.44 + 20\lg f + 20\lg d \tag{3}$$

Where, $\boldsymbol{f}$ is frequency in **MHz**, $\boldsymbol{d}$ is distance in **km**.

The term $\boldsymbol{L_{rts}}$ describes the coupling of the wave propagating along the multiple-screen path into the street where the mobile station is located.

$$L_{rts} = -16.9 - 10\lg w + 10\lg f + 20\lg \Delta h_b + L_{ori} \tag{4}$$

Where, $\Delta h_b = h_b - h_B$, w, Δh_b is in m, and the street-orientation fading $\boldsymbol{L_{ori}}$ is defined by:

$$L_{ori} = \begin{cases} -10 + 0.354\phi & 0^\circ \le \phi \le 35^\circ \\ 2.5 + 0.075\left(\phi - 35^\circ\right) & 35^\circ \le \phi \le 55^\circ \\ 4.0 - 0.114\left(\phi - 55^\circ\right) & 55^\circ \le \phi \le 90^\circ \end{cases} \quad (5)$$

The heights of buildings and their spatial separations along the direct radio path are modeled by absorbing screens for the determination of $\boldsymbol{L_{msd}}$.

$$L_{msd} = L_{bsh} + k_a + k_d \lg d + k_f \lg f - 9 \lg b \quad (6)$$

Where

$$L_{bsh} = \begin{cases} -18\lg(1 + \Delta h_b) & \Delta h_b > 0 \\ 0 & \Delta h_b \le 0 \end{cases} \quad (7)$$

$$k_a = \begin{cases} 54 & \text{for } \Delta h_b > 0 \\ 54 - 0.8\Delta h_b & \text{for } \Delta h_b \le 0 \text{ and } d \ge 0.5 \\ 54 - 1.6 d \Delta h_b & \text{for } \Delta h_b \le 0, \text{and } d < 0.5 \end{cases} \quad (8)$$

$$k_d = \begin{cases} 18 & \Delta h_b > 0 \\ 18 - 15\dfrac{\Delta h_b}{h_B} & \Delta h_b \le 0 \end{cases} \quad (9)$$

$$k_f = -4 + \begin{cases} 0.7\left(\dfrac{f}{925} - 1\right) & \text{for medium sized city and suburban} \\ & \text{centres with medium tree density} \\ 1.5\left(\dfrac{f}{925} - 1\right) & \text{for metropolitan center} \end{cases} \quad (10)$$

3. Modelling of Cost231-WI model

Matlab Simulink provides an interactive graphical environment and a customizable set of block libraries that can design, simulate, implement, and test a variety of time-varying propagation models with advanced capabilities.

3.1. modelling scheme of COST231-WI Model

There are five steps for modelling COST231-WI model:

- Establish mathematical model. Transfer the nonlinear formulations into computer graphics forms.

- Decompose the COST231-WI model into fundamental subsystems, analyse and find the relationship between them.
- Using Matlab Simlink to establish simulation sub-model layers and determine the value algorithm.
- Setup and modulate parameters.
- Setup observe windows, analyse data and waves.

In this paper we decompose the COST231-WI model according to it's structure characteristic, abstract the model's fundamental operation units and analyse connections of them. Then we determine interface, input and output of each unit, simulation these units in Matlab Simulink and doing holistic analysis[10].

Management of the simulation model is hierarchical. We use two layers of management level. The first level is doing factors modulate, including parameter, types, and properties of the definition. The second level is doing files management according to requirement, and share resource platform through .m and .mdl program.

The whole visual procedure is interactive. Users can pause or stop the program in it's running time, and could read, search and doing comprehensive analysis after the running.

Using the Matlab Simulink to simulate COST231-WI model, we can get the path loss cures directly. It allows users doing real time communication to the propagation model through SGUI, and allow users intervene simulation process at any running time. Fig.1 shows the procedure of the COST231-WI simulation.

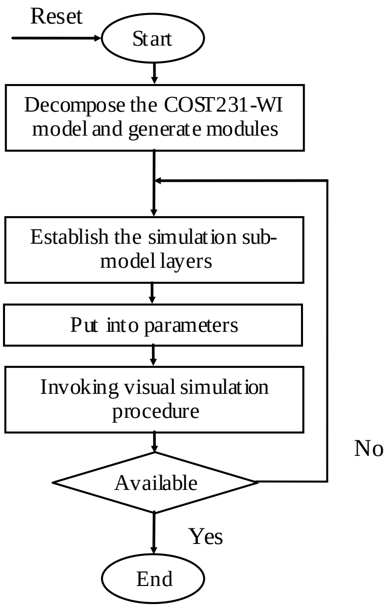

Fig 1. Flow diagram for COST231-WI model

3.2. Matlab Simulink system model

According to path loss formula of COST231-WI model and the modelling scheme mentioned above, the established model composed by four subsystems including twelve basic algorithm logic units. Fig.2 shows the general COST231-WI model.

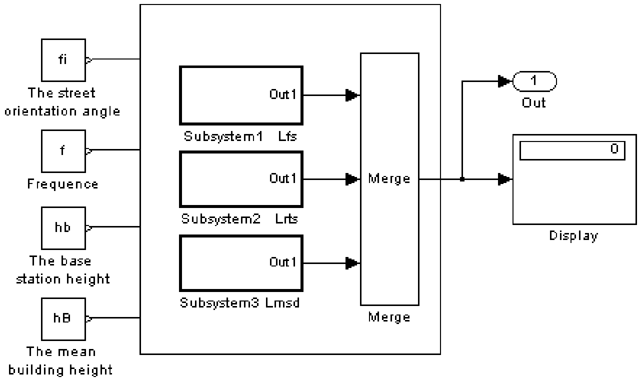

Fig 2. Modeling the COST231-WI model

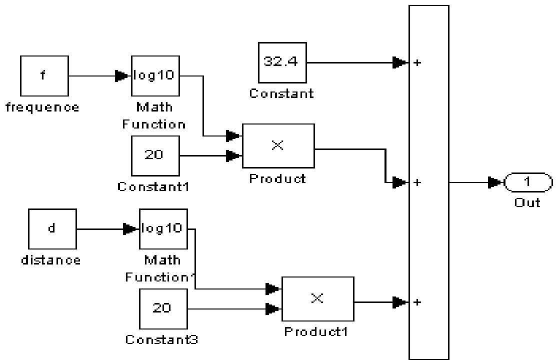

Fig 3. Modeling subsystem of Lfs

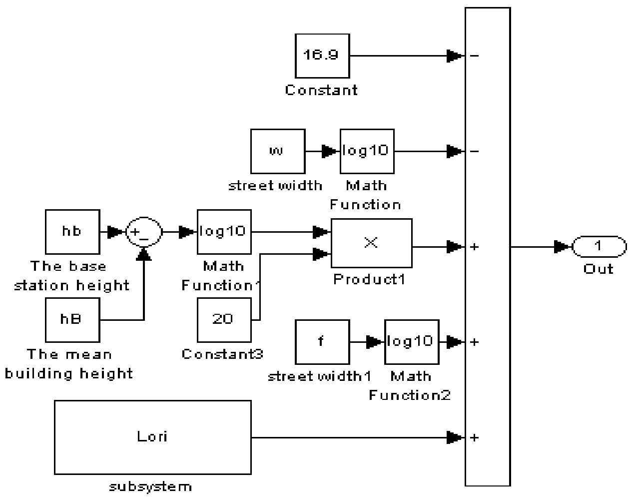

Fig 4. Modeling subsystem of Lrts

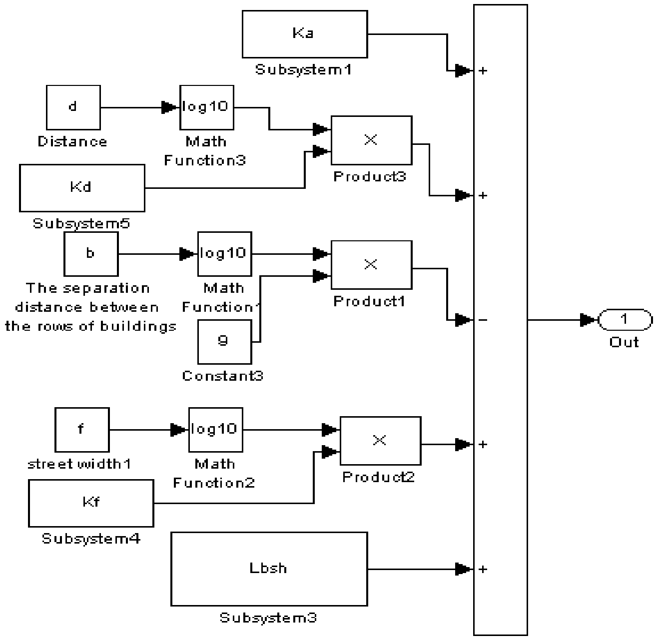

Fig 5. Modeling subsystem of Lmsd

3.3. Simulation Results

Fig.6 shows the path loss mean curves of COST231-WI model in different base station height, when other parameters are the same. From Fig.6 we can see that the higher the base station the lower the attenuation. It is mainly because that obstacles are less when the base station is higher.

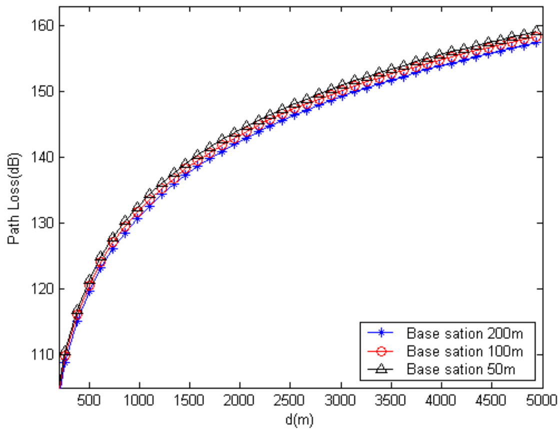

Fig 6. Path loss for different base station height

Fig.7 shows the path loss mean curves of COST231-WI model in different frequencies, when other parameters are the same. From Fig.7 we can see that the higher the frequence the higher the attenuation.

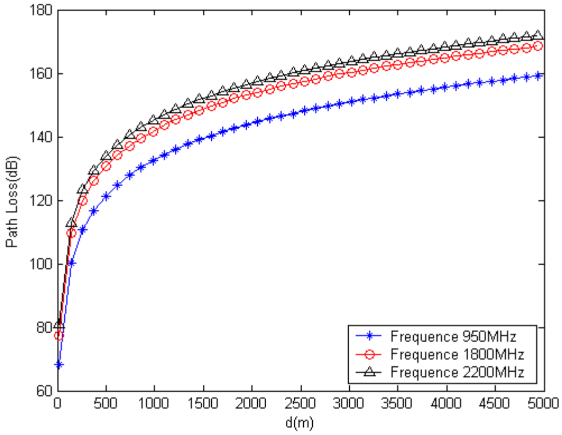

Fig 7. Path loss for different frequencies

Fig.8 shows the path loss mean curves of COST231-WI model in two different areas: the metropolitan center areas and medium sized city and suburban centres which with medium tree density. From Fig.8 we can see that the metropolitan center areas' path loss is higher than the medium sized city's. It is mainly because there are more obstacles in former environment.

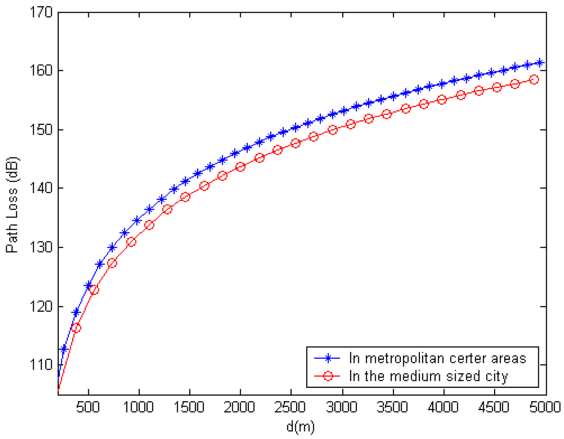

Fig 8. Path loss in different environment

4. Conclusion

In this paper, one of the most famous propagation model COST231-WI model has been implemented in SIMULINK. A detailed description for both total system and subsystem units was given. Different propagation model effects (such as the BS antenna height $\boldsymbol{h_b}$, the MS antenna height $\boldsymbol{h_m}$, the mean building height $\boldsymbol{h_B}$, the street width w , etc.) were introduced in the model. The performance was tested and compared under different conditions. The implemented model showed a good capability in prediction the path loss.

Compared with other traditional advanced programming languages, such as C++ and Fortran, Simulink environment provides powerful high-level mathematical modeling environment for digital communication systems, it can realize Graphical modeling and visual simulation in dynamic, it provides a comprehensive solution for propagation path loss predict to mobile communication systems, and can be widely used for algorithm development and verification.

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