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Path Loss Models Comparison in Radio Mobile Communications

Mohamed Ouwais Kabaou, Belgacem Rhaimi Chibani and Mohamed Naceur Abdelkrim
Research Unit: Modèlisation, Analyse et Commande des Systèmes (MACS-ENIG),
Ecole Nationale d'Ingénieurs de Gabès (ENIG), ENIG-6029 Gabès

Abstract: The Telecommunication word refers to field who lend a big help for users. This sector sustained continuously in a fullness without to carry on development. Third generation, the Mobile Station (MS) are developed and the mobile services are increased. In order to reach a best quality of service, we must consider a lot of parameters, how the transmitted signal is affected and plan the communication network. In this fact, the empirical path loss propagation models have important effect in Radio Mobile systems and have found favour in both research and industrial communities owing to their speed of execution. This study present a comparison between empirical models.

Key words: EMW, mobile radio channel, models, path loss models, communications

INTRODUCTION

In order to more exploiting and to validate their ideas, strategists and analysts cooperate permanently (Chibani, 2002). An appeal of Mobile Radio channels is in fact a result that needs and imposes rigorous study of channel characterization. This study will show what reasons could cause and make information losses in such channels. This will obviously, be useful for those concerned by a complete interface's modelling, the channel, between source and destination. Designs will arrive to make best decisions and even advising recommendations and directives for dimensioning exploited network (antennas heights, carriers, network architecture, etc...).

With the aim of supply in a link between receiver and transmitter with a minimum erosion of the transmitted signal, a lot of techniques are used. Among solutions is the Radio Mobile channel characterization. We are concentrate about this approach in other studies (Kabaou, 2006). In addition, it exist an other method for network planning, we quote in this study the propagation models. They are very useful for performing interferences studies as the deployment proceeds. We emphasized about the propagation models in this study and we describe the different categories. An example of this type are Standard University Interim (SUI) channel model, who are developed under IEEE 802.11 working group, COST-231 Hata, ECC-33 and Walfish Ikegami model.

VARIOUS PROPAGATION MODELS

One of the most important issues in the design, implementation and operation of land mobile system is the knowledge of the received signal and its fluctuations. Propagation models take into account the type of the environment, the materials. The propagation models can be broadly classified in 4 types:

- Statistical models.
- Physical models.
- Mixed models.
- References models.

We restrict our study to the first and second categories in this study.

Statistical model: Also named Empirical models, these are based on a Statistical Analysis of a great number of experimental measures that takes in account many parameters such as buildings, Base Stations (BS) and mobile stations heights. The more known model is that of Okumura-Hata. This was suggested based on statistical analysis of a great number of experimental measures accomplished in and around the Tokyo town. For this model, the attenuation's retained expression depends on (Tabbane, 2000):

f : Frequency (MHz) between 150 and 1500 MHz.
h_b : Height (m) of the base station, between 30 and 300 m.

Corresponding Author: Mohamed Ouwais Kabaou, Research Unit: Modèlisation, Analyse et Commande des Systèmes (MACS-ENIG), Ecole Nationale d'Ingénieurs de Gabès (ENIG), ENIG-6029 Gabès

h_m : Height (m) of the mobile station, between 1 and 20 m.

d : Base Station-Mobile distance (km), between 1 and 20 km and corrective term which depends on the area's considered town and the frequency used band.

Okumura-hata model: Okumura-Hata formula and its versions are basically built on a free space loss calculation. Another loss factor will be added after. For urban areas, the loss L_u is defined as the difference between the transmitted power and the received one. It's written like (Tabbane, 2000):

$$L_u(dB) = 69.55 + 26.16 \log_{10}(f) - 13.82 \log_{10}(h_b) - A(h_m) + (44.9 - 6.55 \log_{10}(h_b)) \log_{10}(d) \ (dB) \quad (1)$$

A correction factor $A(h_m)$, which varies according to area, is also defined. A correction factor, which varies according to area, is also defined as (Kabaou, 2006; Tabbane, 2000):

Small or medium size areas (such Berlin, Rome ...) :

$$A(h_m) = [1.1. \log_{10}(f) - 0.7]\, h_m - [1.56. \log_{10}(f) - 0.8] \ (dB) \quad (2)$$

and for Large size areas (such Tokyo, New York ...):

$$A(h_m) = 8.29. (\log_{10}(1.54. h_m))^2 - 1.1 \ (dB) \ f \leq 200 \ MH_z$$

or

$$A(h_m) = 3.2 . (\log_{10}(11.754 \, h_m))^2 - 4.97 \ (dB) \ f > 200 \ MHz \quad (3)$$

A general expression of that was obtained for suburban case by taking for the propagation loss an expression given by (Tabbane, 2000):

$$L_{su} = L_u - 2\left[\log10\left(\frac{f}{28}\right)\right]^2 - 5.4 \ (dB) \quad (4)$$

These models give field values illustrated by number of curves depending on a set of frequencies, transmitter-receiver distances and BS's antenna heights. Even if these models were and are always useful to have idea, an accuracy lack let them however not suitable in practical use (Fig. 1-3).

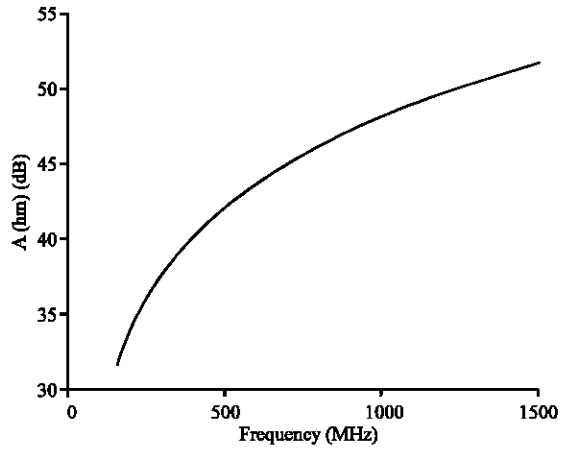

Fig. 1: Correction factore in small and medium size area

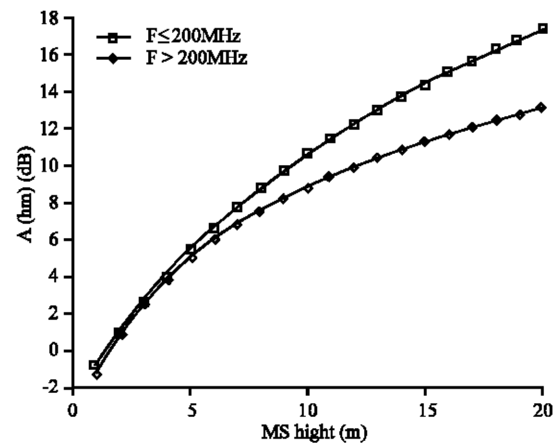

Fig. 2: Correction factor in large size area

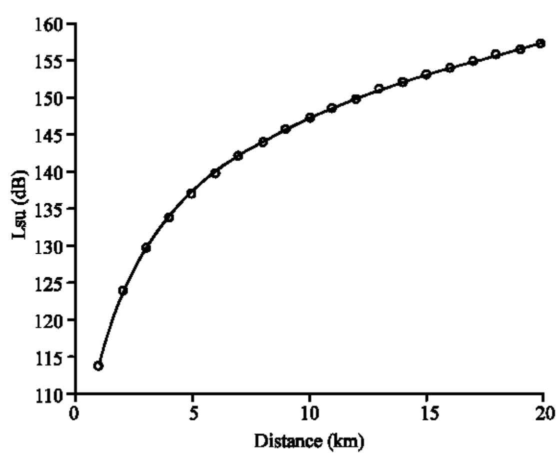

Fig. 3: Path loos propagation in suburban area vesus distance

Physical model: Walfish-Ikegami/COST-231 Model European research group named COST 231 has defined a model combining 2 approaches named empirical and deterministic one in order to evaluate propagation loss value for urban morphology and when frequency leave from 900-1800 MHz (Tabbane, 2000).

The model takes in account mainly:

- Free space loss.
- Losses added by diffraction.
- Losses introduced by rooftops near the studied area.

Three parts compose this model and are given as:

$$L_u(dB) = \begin{cases} L_f + L_{rts} + L_{msd}; & L_{rts} + L_{msd} > 0 \\ L_f; & L_{rts} + L_{msd} \le 0 \end{cases} \quad (5)$$

Where, L_f is the free space path loss, L_{rts}(dB) is the diffraction loss and L_{msd} (dB) is a reflection term. If detailed data of the building structure is not available, COST-231 recommend the following default values (Tabbane, 2000).

STANFORD UNIVERSITY INTERIM (SUI) MODEL

In this study we will present also a path's loss statistical model. In suburban areas and according to ground category, the presented model seems applicable one (Erceg, 2003).

The linear part of the characteristic's model that will be described by (8), corresponds to exponent losses named γ, the second principal parameter noted σ, corresponds to fading standard deviation. These two parameters statically modelling, depend basically on The Base Station height going from 10-80 m, Propagation medium category and also on distance between the base station and the terminal ranging from 0.1-8 km.

Generally, mediums are like: mountains with important vegetation density (category A), Flats (category B) and a weak tree density defining (category C).

Losses have maximum values for the A medium type. Minimal values of losses are often got for the C medium type. B category appears as an intermediate position between the 2 last presented situations.

In suburban propagation context, the following model is retained. This model is deduced from data measured at 1.9 GHz par AT and T Wireless Services in U.S in 95 existing macrocells, with an omnidirectional reception antenna having at 2 m height. It's then advised only for such conditions. Losses model, referred to path's length, varies as following (Greenstein and Erceg, 2003):

$$PL = \left[A + 10.\ \gamma.\log_{10}\left(\frac{d}{d_0}\right) + s \right](dB) \quad (6)$$

Where, d is the distance between the AP and the CPE antennas in meters, d_0 = 100 m and s is a lognormally distributed factor that is used to account for the shadow fading owing to trees and other clutter and has a value between 8.2 dB and 10.6 dB, where A and s are defined in Erceg (2003) and Kabaou (2006).

$$A = \left[20.\log_{10}\left(\frac{4.\pi.d_0}{\lambda}\right) \right] (dB) \quad (7)$$

$$\gamma = \left[(a - b.\ h_b + \frac{c}{h_b}) + x.\sigma\gamma \right] \quad (8)$$

The parameter h_b is the base station height above ground in meters and should be between 10 and 80 m. The constants used for a, b and c are given in Erceg (2003).

For a given terrain type the path loss exponent is determined by h_b.

Ecc-33 path loss model: Initial Experimental of Okumura model are done suburban areas at Tokyo. A partition of urban areas has let authors reporting 2 categories for towns such:

- Large towns (like Tokyo, New York, etc...).
- Medium towns (like Berlin, Rome, etc...).

A correction factor for open and suburbains areas was also defined. Even if the Okumura-Hata model is well known for UHF frequency bands, its a validity for High Frequencies (HF) is however discussable. The COST-231 model extends this to frequencies up to 2GHz, where mobile system is supposed equipped with omnidirectional antenna installed more than 3 m above the ground.

ECC-33 model is an empirical model composed from four terms and known as following (Abhayawardhana *et al*., 2003):

$$PL = A_{fs} + A_{bm} - G_b - G_r \quad (9)$$

Where, A_{fs}, A_{bm}, G_b, G_r are, respectively the free space attenuation, the basic median path loss, the BS height gain factor and the terminal (CPE) height gain factor. They are individually defined in (Erceg, 2003; Kabaou, 2006).

$$A_{fs} = 92.4 + 20\log_{10}(d) + 20\log_{10}(f) \quad (10)$$

$$A_{bm} = 20.41 + 9.83\log_{10}(d) + 7.894\log_{10}(f) + 9.56\,[\log_{10}(f)]^2 \quad (11)$$

$$G_b = \log_{10}(h_b/200)\ .\ (13.958 + 5.8\,[\log_{10}(d)]^2) \quad (12)$$

For medium city environment

$$G_r = [42.57 + 13.7 \log_{10}(f)]\,[\log_{10}(h_r) - 0.585] \quad (13)$$

The medium city model is more appropriate for European cities wheras the large cities environment should be used only for cities having tall buildings.

COMPARISON WITH SIMULATION RESULTS

After presented the different path loss models, we entered a comparative study to compare the path loss model results obtained through appropriate parameters in rural, urban and suburban environments. Figure 4 compares the path loss obtained in rural environment. It clearly shows that the COST-231 Hata model predict a higher path loss than the Standard University Interim model (SUI).

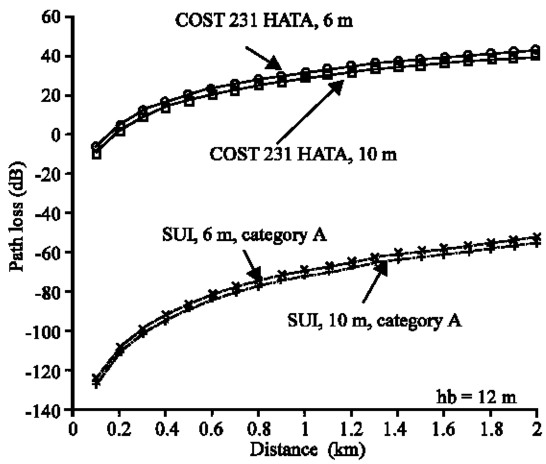

Fig. 4: Comparison of path loos propagation for rural environments

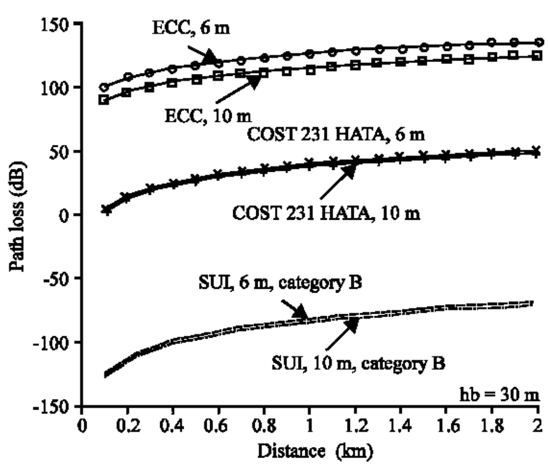

Fig. 5: Comparison of path loos propagation for suburban environments

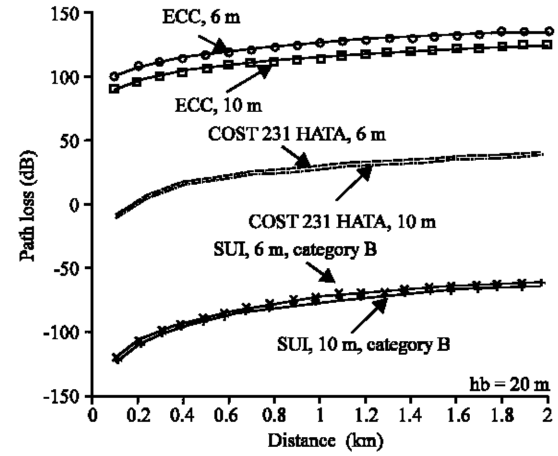

Fig. 6: Comparison of path loos propagation for urbn environments

Note that the SUI model does not specifically have a classification for urban environment, but terrain type B is considered the most appropriate.

The assumptions for urban and medium city are used for the COST-231 Hata model and the ECC-33. The SUI model in comparison with the ECC-33 and COST-231 model are shown in Fig. 5. The SUI model shows the lowest path loss for a BS antenna height of 30 m in suburban environment.

The results of comparison between three path loss models in urban environment are shown in Fig. 6. The BS antenna height are considered equal to 20 m. The ECC-33 model grossly over predict the path loss at 20 m, however the SUI m odel shows the lowest path loss.

CONCLUSION

We have presented in this research a comparative study between different path loss models. Each one of this models are described by an appropriate parameters and a specific environment of propagation. The ECC-33 model showed quite large path loss in urban and suburban environment. The COST-231 model predict a higher path loss in rural environment.

Finally, physical models (Walfish-Ikegami), can attaint a more greater degree of accuracy than a statistical model (Okumura-Hata), because researcher can retain his electromagnetism's laws knowledge that he has. Statistical Models are more easy to be used than the physical ones. They don't need e.g. geographic databases. However, validity domain is often limited: Okumura-Hata model can't, e.g., be used for distances less than 1 km.

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