A Consideration of Propagation Loss Models for GSM during Harmattan in N'djamena (Chad)

D.D. DAJAB AND NALDONGAR PARFAIT*
Department of Electrical and Computer Engineering,

AHMADU BELLO
University, Zaria, Nigeria.

Abstract

The paper discusses the influence of propagation environment in a GSM mobile network. It considers the measurement and prediction results for a special case of propagation, that is, the harmattan, in a live network. The harmattan precipitation intensity may be so great that visibility at ground level is reduced to less than a hundred meters by dust clusters. In this paper, the path loss during harmattan in N'djamena (Chad) is computed from the received signal strength at various distances for three major roads. The Hata and Free-space models were applied, and compared with received signal measurement data. The results indicate that measurement data and the Hata prediction model agree closely while the free space model generally underestimates the path loss phenomena. The significance here is that various forms of precipitation such as rain, snow, cloud and fog absorb and scatter electromagnetic energy leading to attenuation in its signal strength. The study indicates that harmattan precipitates do inflict attenuation significantly.

Categories and Subject Descriptors: C.4 [**Performance of Systems**]: Modeling Techniques; D4.8 [**Performance**]: Measurements; Modeling and Prediction; I6.4[**Simulation and Modeling**]:Model Validation and Analysis
General Terms: Harmattan, Propagation, Signal Strength, Pathloss
Additional Key Words: Global System for Mobile –Telephony (GSM),

IJCIR Reference Format:

D.D. Dajab and Naldongar Parfait. A Consideration of Propagation Loss Models for GSM during Harmattan in N'djamena (Chad). International Journal of Computing and ICT Research, Vol. 4, No. 1, pp. 43 - 48. http://www.ijcir.org/volume4-number1/article5.pdf.

1. INTRODUCTION

* Authors Address: D.D. Dajab and Naldongar Parfait, Department of Electrical and Computer Engineering, Ahmadu Bello University, Zaria, Nigeria.Email: dddajab@abu.edu.ng , pnaldongarmbete@yahoo.com

International Journal of Computing and ICT Research, ISSN 1818-1139 (Print), ISSN 1996-1065 (Online), Vol.4, No.1, pp. 43 – 48, June, 2010

In the savannah region, the atmosphere is affected by harmattan. In his work Dajab,[2005], defined the harmattan as a weather condition in the tropics in which dust particles (precipitates) are blown up into the air by winds defined as air in horizontal motion relative to the earth surface and pushed southwards from the Sahara desert by the northeast winds. It has been observed that Harmattan intensity may be so great that visibility at ground level is reduced to less than a hundred meters by the dust clusters. Harmattan occurs in Chad during the dry season that is, between the months of November and March.

2. REVIEW OF RELATED LITERATURE

Harmattan dust with its micro size particles and harmattan dust clusters resemble that of fog and the space they cover can be considered, according to Neyman, [1981] as a dielectric since the clusters consist predominantly of quartz layer which non-coherently scatters and disturbs propagation of RF signals. The result is that the incoming radio signal which enters the receiver circuitry varies in magnitude. These variations are attributed to changes in propagation conditions. In extreme cases it can lead to complete cancellation of a signal at the receiving point. These signals variation can occur fast or slow and the speed at which they take place is known as "rate of fading" [Shittu, 2006]. The reception of microwaves depends on the propagation environment between a transmitter and a receiver. Propagation models can be used extensively in network planning, particularly for conducting feasibility studies and during initial deployment. They are also very useful for performing interference studies and optimization of radio resources [Mishra, 2004].Attenuation is less pronounced at frequencies around 3GHz, however, to a communications system designer, attenuation due to precipitation and atmospheric gases at frequencies above 1GHz is very important[Eyo et al, 2003].

3. METHODOLOGY

Pavlos et al. [2007] provides that Measurement reports over the GSM network are transmitted periodically (480ms) from the Mobile Terminal (MT) to the Base Transceiver Station (BTS) on the Stand Alone Common Channel (SACCH) assigned to each communication, according to which the measured Received signal Level (RXLEVs) from the serving BTS and from a neighbor BTS (in situations requiring handover) are submitted. In this paper, RXLEV data or signal strength data have been collected for a year from the Chadian Celtel GSM network in Djamena. These were collected experimentally by Naldongar, [2007] using vendor Transmission Evaluation and Monitoring System (TEMS) and drive testing equipment for certain urban routes . The losses in signal strength that do occur during transmission from the Transmitting antenna T_X to the Receiving antenna RX are given by the path loss, while the receive power is the result of the path loss phenomenon. It is anticipated that propagation loss models would provide physical explanations for results obtained from measurements. These were conducted within the period of harmattan. The models used in the work are considered below.

3.1 Free Space Model

The path loss may be obtained from the effective isotropic radiated power (EIRP) using the expression [Godara, 2002]:

$$L_p = EIRP - S_R \quad \ldots \quad (1)$$

Where S_R is the measured received signal strength also in dBm and $EIRP$ is the Effective Isotropic Radiated Power also in dBm

L_p denotes the loss associated with propagation of electromagnetic waves from the transmitter to the receiver, called the free-space path loss and is given by:

$$L_P = \left[\frac{\lambda}{4\pi d}\right]^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$P_P = 20Log\left[\frac{\lambda}{4\pi d}\right] + P_T + G_T + G_R(dBm) \quad \ldots \quad \ldots \quad (3)$$

$$L_P = 20Log\left[\frac{4\pi d}{\lambda}\right](d\,B) \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

3.2 COST- 231 Hata Model

This is a popular model for predicting the path loss of mobile wireless systems of not more than 10km between the transmitter and the receiver. The model was described by Hata for the prediction of path loss and land mobile radio of not more than 1500MHz.It was later modified by the COST-231 project to include predictions of path loss up to 2000MHz and the provision of correction factors for urban, suburban and rural areas. The basic equation for path loss model in dB for urban areas is [Okumura, 1968; Hata, 1980]:

$$L_P = A + B\log(d) + C \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

$$A = 46.3 + 33.9\log(f_c) - 13.82\log(h_b) - a(h_m) \quad \ldots \quad \ldots \quad (6)$$

$$B = 44.9 - 6.55\log(h_b) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

$$a(h_m) = 3.2[\log(11.75h_m)]^2 - 4.97 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

4. RESULTS AND DISCUSSIONS

The suite of measurements performed in the environment in which the radio (GSM) system is deployed is necessary for the validation of radio wave propagation tools or predicted results. When characterizing path loss in outdoor radio channels, the free space and Hata models are a common approach. In this paper measurements carried out were used as the basis for comparison between propagation loss predictions with these two selected models as represented in Figs 1 to 3.Comparing the loss predictions indicate a mean difference of 20dB between the two models consistently. Fig 1 shows that the Hata model below 1.5km slightly underestimates while above 2km also slightly overestimates the path loss scenario. As evident from Figs 2 & 3 whereas the Hata model closely predicts the path loss compared with measurement, the free-space model significantly underestimates the path loss along the streets considered in the experiment.

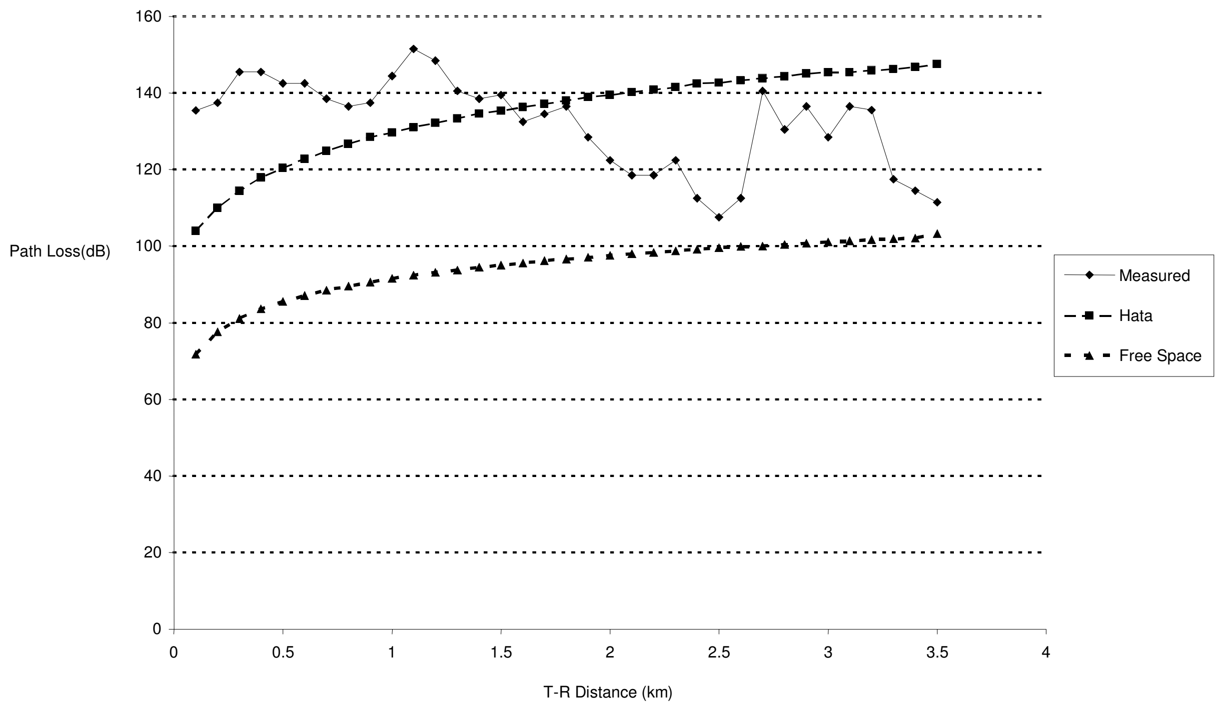

Figure 1: PATH LOSS VARIATION ON MOURSAL ROAD FOR MARCH, 2006

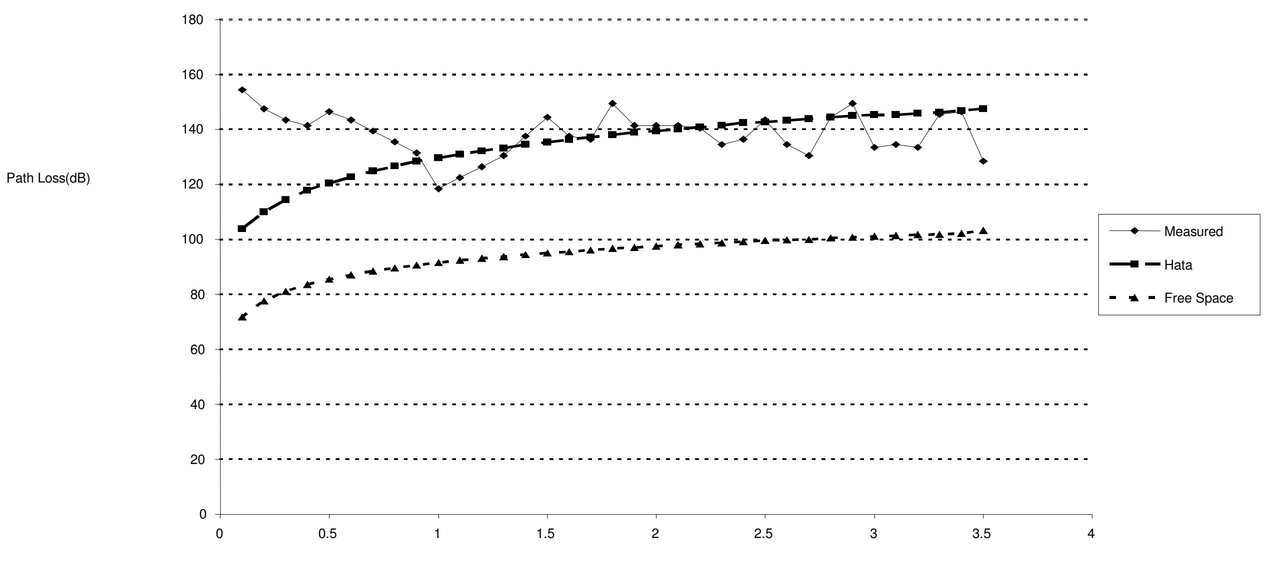

Figure 2: PATH LOSS VARIATION ON MOURSAL ROAD FOR JANUARY,2006

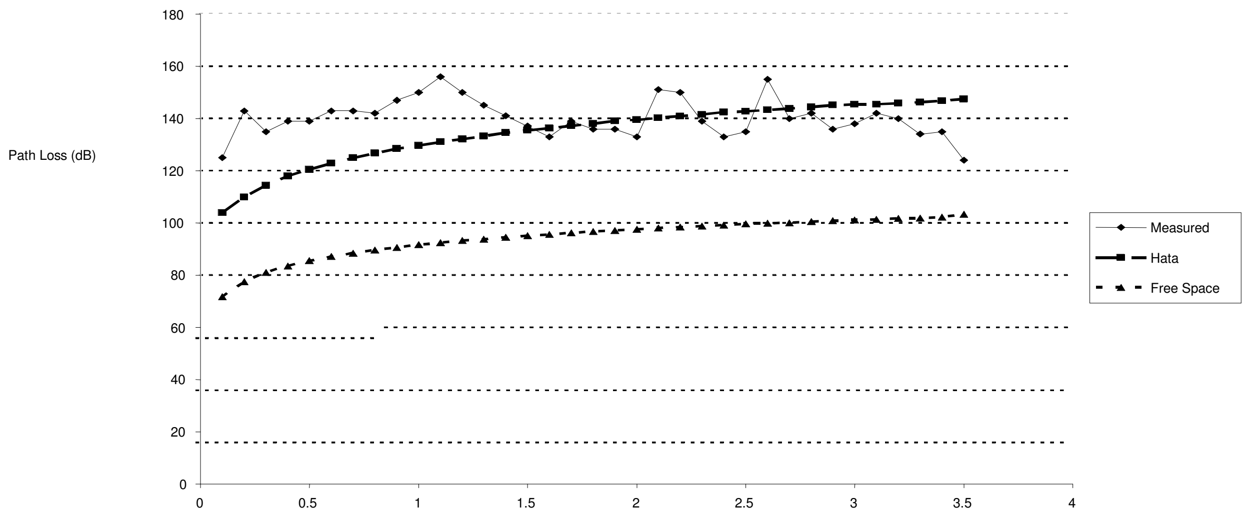

Figure 3: PATH LOSS VARIATION ON CHAGOUA ROAD FOR NOVEMBER,2006

The significant differences in the predictions can be explained by reasons of the many phenomena affecting propagation such as interference from neighbor base stations, difference in fading and shadowing patterns of the received power as a function of distance along the streets considered. Path loss in real propagation environments such as considered here increase depending upon obstructions in the environment, such as terrain, buildings, foliage and precipitations like the harmattan dust clusters which is the predominant factor of all these. In their work, Yu-Huei et al ,[2003] observed concerning field measured results that the effect of the precipitations is that the changes and fluctuations obvious in the measurement results indicate that the radio coverage field strength is poor and the path loss fluctuates constantly reflecting that. It can also be due to varying and environmental factors at the various base stations and the increase of dust particles in the air which constitute an obstacle between transmitter and receiver. This results in a lower signal level at the distant end than anticipated due to path loss and the Fresnel zone is literally blocked, even if the other antenna (Mobile) in the distance can also literally be "seen". It is, however, still possible to get a signal under these conditions because in the access part, GSM networks operate in what is called the Radio Frequency (RF) part of the spectrum which exhibit multipath effect as against the Microwave Frequency (MF) obtained in the backhaul and transmission parts of the network which are Line-Of-Sight (LOS) dependent.

5. CONCLUSION

There are two major motivations for performing measurements: i) propagation surveys for the purpose of radio system development and deployment and ii) model validation for propagation prediction tools. In the foregoing study, the later motivation has been carried out, even as it is found that atmospheric particles density do affect GSM signal strength especially during harmattan period in N'djamena. Taking into account the micro size of particles in the harmattan dust, and on the other hand, it's quite high density resembling that of fog, the particles covering the atmosphere may be considered as a dielectric thereby inducing some electrostatic conditions. The effect on signal propagation demands that in regions with these conditions higher gain antennas need to be deployed in addition to the introduction of precisely defined local correction factors for consistent quality of service in and out of season.

6. ACKNOWLEDGEMENTS

We wish to acknowledge the cooperation of Celtel Network of Chad Republic for assisting with test equipment and provision of enabling environment for the study as well as Ahmadu Bello University,Zaria Nigeria, where the research was defended in partial fulfillment for the award of a Masters degree in Electrical Engineering

8. REFERENCES

DAJAB, D.D. 2005. Characterisation and Modelling of 900MHz Indoor Wireless communication channels in the savannah region. PhD Dissertation, Electrical Eng. Dept. Ahmadu Bello University, Zaria. 45-52; 144-152.

EYO,O.E., MENKITI.A.I., UDO.S.O. 2003. Microwave Signal Attenuation in Harmattan Weather Along Calabar-Akampkpa Line-Of-Sight Link. Turk Journal of Physics,Vol.27, 153-160.

GODARA, L.C. 2002. Handbook of Antennas in Wireless Communication. CRC press LLC.

HATA, M. 1980. Empirical Formula for Propagation Loss in Land Mobile Radio Service, IEEE Transactions on Vehicular Technology, Vol. VT-29, No3, 317-325.

MISHRA, A.R. 2004. Fundamentals of Cellular Network planning and optimization. John Wiley and sons Ltd.

NALDONGAR, P. 2007. An assessment of the Impact of Harmattan Particles on Microwave Propagation in the Savannah Region, M.Sc thesis, Electrical Engineering Department, Ahmadu Bello University, Zaria.,(unpublished).

NEYMAN, A.B. 1981. Study of short wave reception in Zaria.PhD dissertation, Electrical Engr Dept. Ahmadu Bello University,Zaria. 1-2; 62-63

OKUMURA, Y., OHMORI, E., and KAWANO, T. 1968. Field Strength and its Variability in VHF and UHF Land Mobile Radio Services. A Review of the Electrical Communications Laboratory, Vol 16, 825-873.

PAVLOS, F., SOFOKLIS, K ., and GEORGE, K . 2007. Enhanced Handover Performance in Cellular Systems based on Position Location of the Mobile Terminals. Seminar paper, Telecommunications Laboratory, National Technical University of Athens. 2-3.

SHITTU, W. A., 2006. Cellular Mobile Radio propagation characteristics. M.Sc thesis, Electrical Engineering, Ahmadu Bello University, Zaria.

YU-HUEI, T., WEN-SHYANG, H., and CE-KUEN, S. 2006. The Influence of Propagation Environment in a Live GSM Network. Research Paper, Department of Electrical Engineering, National Kaohsiung University of Applied Sciences, Kaohsiung, R.O.C.3-5.