HATA, COST - 231, EGLI and ILORIN - A PERFORMANCE ASSESMENT

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ABSTRACT
Information carried through the wireless medium are subject to impairments due to several events along the route of transmission, leading to path losses. For effective network planning therefore, these events and their effects on radio propagation need to be known and accounted for. In this work, we studied the radio propagation profile, along selected routes in Ilorin, Kwara State due to transmissions from the NTA, Ilorin, the Harmony FM and the University of Ilorin FM transmitters. Each of the routes are divided into segments, as seen, in the figures. The measurements were made, using the N9432C Agilent spectrum analyzer. Analysis, of obtained data, showed that the nature of the environment, affects radio propagation. Even within the same route and all other conditions the same, the models' relative performances vary, from one segment to the other. The performances of the models corroborate the notion that empirical models are environment-specific.

***Keywords*:** Path loss prediction, Radio propagation profile, Wireless network planning, Received signal level

INTRODUCTION

The wireless medium had, since, become the transmission medium of preference, on account of ease and possibly, costs of deployment and safety. The transition, from fixed telephone to wireless telephone had become one of the most dramatic impacts technology had on man. Starting with the first generation mobile telephone (FDMA) to the second, (TDMA) third and the Long Term Evolution of today, high data rate, economy of spectrum, low power consumption, long range, resistance to interference, increased voice quality remained some of the critical parameters, driving the metamorphosis and it has been startling. The limitations set, on achieving these desired goals in information transmission, through the wireless medium, due to various factors characterizing the path, however, constitute challenges and desire to be understood and accounted for, in the course of radio network design and planning. It had been sufficiently established that not only meteorological but environmental factors affect radio propagation. This is the main plank of investigations into the phenomenon of radio propagation and factors that affect it.

A plethora of works done, in this area, have led to formulations leading to path loss estimation and hence effective wireless network planning. Classical researchers, such as Okumura, Hata, Longley-Rice, Durkin etc, can be credited with pioneering work in this area. They formulated path loss estimation models at the VHF, UHF and lower microwave bands. We, also, have some contemporary researchers, who have being working, with the aim of testing, for purpose of validation or moderation of the existing formulas, for use in different frequencies and terrains.

The rest of the paper is organized thus: Section II discusses related work, section III, experimental data, section IV, discussion of results and section V draws conclusion from the results.

RELATED WORK

Radio waves propagate in modes that are classified into three broad categories: reflection, refraction and ducting. It is also noted that the terrestrial configuration, along the path of propagation plays a large role. This necessitates that modeling of radio path, takes into consideration, the atmospheric behaviour of radio waves and the terrain configuration, so that field strength prediction can be comprehensive. Several models have been formulated for the prediction of path loss, in both indoor and outdoor propagation scenarios. The potency of these models, lie in the fact that they account for environmental factors, in addition, to normal atmospheric factors, which set limit to radio propagation, thus ensuring a complete definition, of the radio path, for purpose of prediction. The demerit of this, is that these models remain environment specific.

Ayeni et al.(2012), compared the performance of some existing empirical models, using measurements, taken in Kano city of Nigeria. Their findings showed that mean losses of 137.7dB and 138.7dB were incurred using Hata and COST 231, respectively. For Hata, COST 231, Walfisch Ikegami, mean signal levels of -72.06 dBm, --76.57dBm and -47.41 dBm, respectively, were obtained with, respective, mean square error values of 0.071dB, 0.038dB and 0.7dB. They found that COST 231 performed better for the Kano terrain.

Surajudeen Bakinde et al. (2012), also did a comparison of the empirical models in some selected urban areas. They found that path loss varies, directly, with frequency and that Hata and COST 231 compete, for predictability throughout their measurements.

Shabbir et al. (2011), compared the different candidate propagation models for the LTE, using different terrains. They found that the lowest path loss was incurred with the Stanford University Interim model with the COST231 Hata, the highest in the urban area while the COST and Walfisch-Ikegami incurred the highest path losses in the sub-urban and rural terrains.

Isabona et al. (2014), conducted measurements of received power levels, over a distance, from a fixed WLAN AP, used the values of power levels, so obtained, with some path loss model equations, with a view to obtain the path loss exponent of 1.85, mean path loss intercept of 84dB.

Fransceschetti et al. (2004), using a simple stochastic model, based on the theory of random walks, were able to quantify power losses, using an exponential path loss formula, in place of existing empirical formulae.

Ayeni et al. (1995), discusses the radio propagation aspect of the cellular mobile communication

Vinko Erceg et al. (1999), using experimental data collected across the United States, presented a statistical path loss model, using a linear curve fitting the decibel path loss to the decibel-distance with a Gaussian random variation about that curve due to shadow fading.

Faruk et al. (2013a) while investigation the behaviour of TV signals, obtained the path loss exponent, standard deviation and partition loss for the city of Ilorin at the VHF/UHF band.

Faruk et al. (2013b) employed nine (9) different empirical path loss models and five (5) metrics to determine their suitability to predicting TV signal. An extensive field strength measurement was conducted at the VHF/UHF bands along six (6) different routes in the rural, suburban and urban areas of Kwara state of Nigeria. The research shows that no single model provides consistent prediction accuracy along all the routes. However, it should be mentioned that, along some selected routes, Davidson and Hata met the recommended accuracy by the ITU-R.

Faruk et al. (2013) used seven (7) empirical models to predict TV coverage in a bid to obtain an accurate prediction/estimation of service contours to facilitate non-interfering effective utilization of TV white space by secondary users. The work revealed divergence between the predictions of the widely known empirical models and the measured model (an optimized model obtained from measurement of the studied area).

Free Space loss

Free space, implies an unobstructed line-of-sight T-R terrain, in which distance is considered the only hindrance to radio, as the field strength decreases with distance (Okumura et al, 1968).
The generic free space path loss (FSPL) in dB can be obtained from equation (1) below.

$$P_L(dB) - 32.44 + 20log(f_c) + 20log(d) \ldots\ldots\ldots\ldots (1)$$

Where, P_L (dB) is the FSPL in dB, f_c is the carrier frequency in MHz and d is the T-R distance in km.

The Okumura model

One of the most-widely used models, in predicting radio propagation status, the Okumura model is applicable in the range of frequencies between 150 MHz and 1920MHz, within distances 1 km and 100 km from the transmitter. This model also has two more varieties for transmission in urban areas and open areas. Three versions of the model, applicable in rural, sub urban and urban environments are available (Okumura et al, 1968, Ayeni et al, 2015 and Surajudeen Bakinde et al, 2012).

Okumura define path loss as;

$$L_p = L_{50} + L_F + A_{mu}(f,d) - G(h_t) - G(h_r) - G_{AREA}. \quad (2)$$

where, $L50$ is the 50th percentile (i.e. media) loss, A_{mu} is the median attenuation relative to free space, L_F $G(h_t)$ is the base station antenna height gain factor, $G(h_r)$ is the mobile antenna height gain factor, G_{AREA} is the gain due to the type of environment, A_{mu} and G_{AREA} are obtainable from relevant curves, developed by Okumura relating median attenuation and area gain to frequency respectively.

He also prescribed that:

$$G(h_t) = 20\log\frac{h_t}{200}, 100 \le h_{t\ge} 30m \text{ G(h}_t\text{)}$$

$$G(h_r) = 10\log\frac{h_r}{3}, h_r \le 3m$$

$$G(h_r) = 20\log\frac{h_r}{3}, 10m > h_r > 3m$$

Hata model

Hata, valid in the range 150MHz to 1500MHz, is an empirical formulation of the graphical path loss data provided by Okumura. He gave the urban area propagation standard formula and provided
correction factors for other situations (Hata, 1980, Ayeni et al, 2015 and Surajudeen Bakinde et al, 2012).

$$L_{50} = 69.55 + 26.16\log f_c - 13.82\log h_t - a(h_t) + (44.9 - 6.55\log h_t)\log d \text{.........................(3)}$$

Frequency range, f_c =800-2000MHz, Transmitter antenna height, h_t =4-50m, Receiver antenna height, h_r =1-3m,
Tx-Rx distance=20-5000m

Building parameters:

Mean value of building height, h_{roof} ,
Mean value of street width w,
Mean value of building separation, b .
For NLOS situation;

$$L(dB) = \begin{cases} L_{FS} + L_{rts} + L_{MSD} & L_{rts} + L_{MSD} \ge 0 \\ L_{FS} & L_{rts} + L_{MSD} < 0 \end{cases}$$
....(5)

We shall use the medium-size city criterion for the purpose of this work therefore

$$a(ht) = (1.1\log f_c - 0.7)h_r - (1.56\log f_c - 0.8)dB$$

The COST - 231 model

The COST - 231 model is the product of the COST - 231 committee, of the European Co-operative for Scientific and Technical Research, to develop an extended version of the Hata model, to enhance applicability to 2GHz . Path loss, in this model is computed as: (Ayeni et al, 2015 and Surajudeen Bakinde et al, 2012).

$$L_{50}(urban) = 46.3 + 33.9\log f_c - 13.82\log h_t - a(h_r) + (44.9 - 6.55\log h_t)\log d + C_m \text{.........(4)}$$

$C_m = 0dB$ for medium sized city and suburban areas and $3dB$ for metropolitan centres, h_t is the height of the transmitter and h_r is the height of the receiver, d the separation distance between the transmitter and the receiver and f_c is the carrier frequency in MHz.

Walfisch-Ikegami model

This model takes into consideration, The structure of buildings on the propagation path, is considered by this model, making it amenable for use, in urban propagation prediction. The parameters of interest are:

L_{FS} is the free space path loss, L_{rts} is the roof -to - street diffraction and scatter loss and L_{MSD} is multiscreen diffraction loss.

III METHODOLOGY.

A measurement campaign involving, two (2) radio stations; Unilorin FM and Harmony FM and One (1) Television station, NTA Ilorin covering five (5) different routes within Ilorin metropolis was conducted. Received signal level at different transmitter - receiver distance of these broadcasting stations was measured and recorded. Fig 1a, Fig 1b, Fig 2a, Fig 2b, Fig 2c, Fig 2d, Fig 2e, Fig 3a, Fig 3b and Fig 3c shows a plot of the measured and estimated (using the four models earlier discussed) received signal level against distance in Km for the seven routes covered. The graphs also showed the topography of the area investigated as indicated by the plot of altitude against distance for some of the routes.

IV Discussion of results

As can be seen in figure 1a, Harmony FM, while the COST 231 and Hata performed, creditably well, throughout the segment, Egli and Ilorin performed, fairly, well. Ilorin underestimated after 23.6 km.

In fig 1b Harmony FM, almost all of the four models performed, reasonably well, in this segment, but for the Ilorin model, underestimating, from kilometer 23.6.

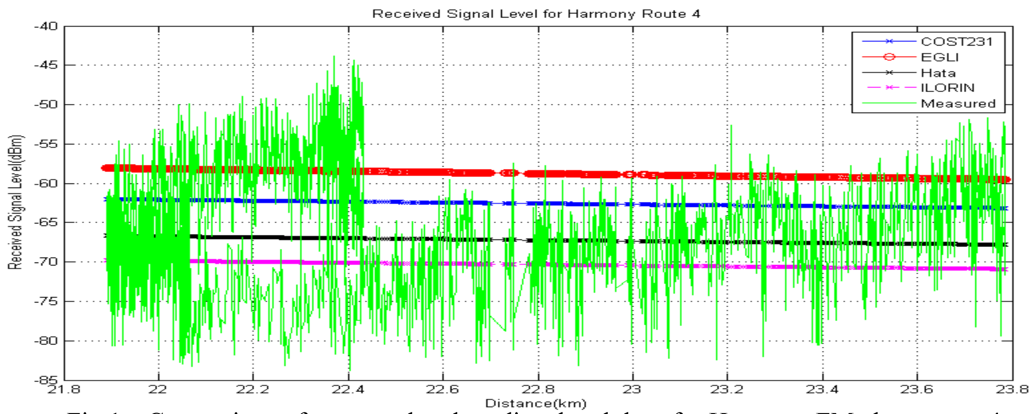

Fig 1a, Comparison of measured and predicted path loss for Harmony FM along route 4

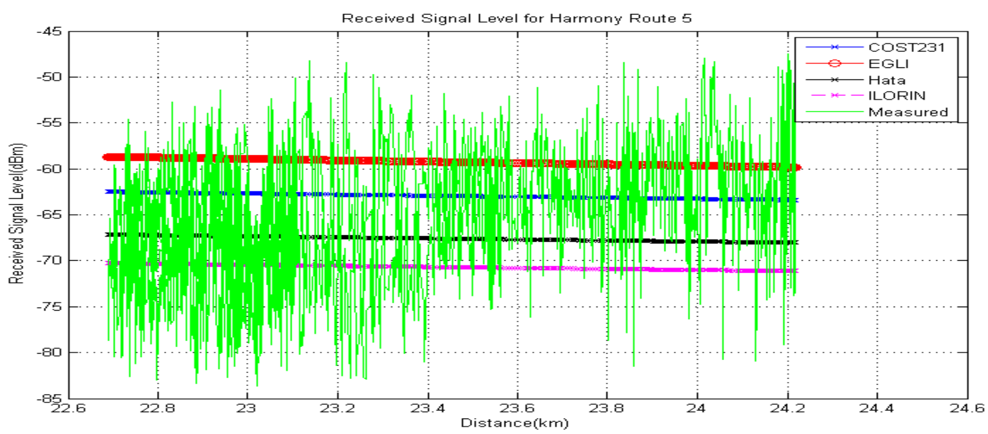

Fig 1b, Comparison of measured and predicted path loss for Harmony FM along route 5

In fig 2a Unilorin, Egli overestimated for most part of the route, COST 231 overestimated, for a large part, Hata and Ilorin did, fairly well, all through the route while, as shown in fig 2b, both COST 231 and Egli overestimated for most part while Hata and Ilorin did, fairly, well. The third segment, fig 2c, shows Hata and Ilorin performing creditably well, all through the, while COST 231 overestimated most times and Egli overestimated at all through the segment. In the fourth segment of the route, fig 2d, the curves get steeper, with Egli overestimating all through, while COST 231overestimated up to kilometer 13.5, underestimated up to kilometer 15 and did, fairly well, thereafter. The final segment, fig 2e sees Egli overestimating, almost all through, COST 231, Hata and Ilorin all, did, fairly, well, up to kilometer 9.9 and overestimated, thereafter.

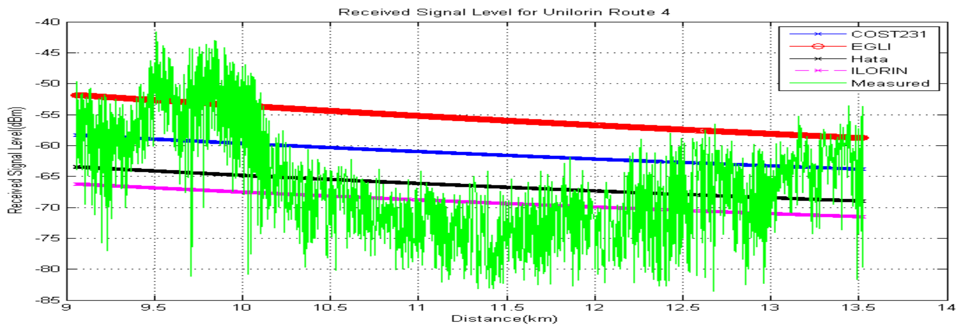

Fig 2a: Comparison of measured and predicted path loss for Unilorin FM along route 4

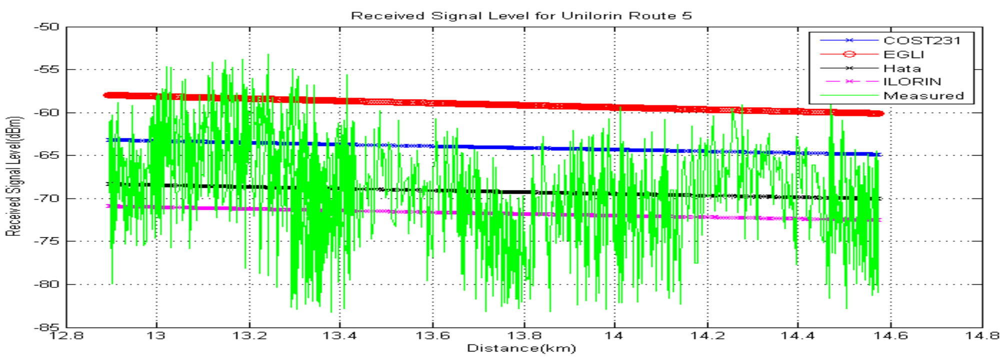

Fig 2b: Comparison of measured and predicted path loss for Unilorin FM along route 5

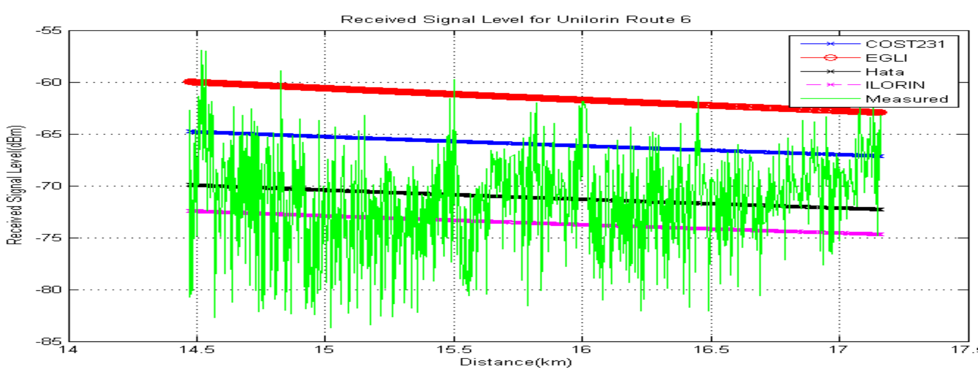

Fig 2c: Comparison of measured and predicted path loss for Unilorin FM along route 6

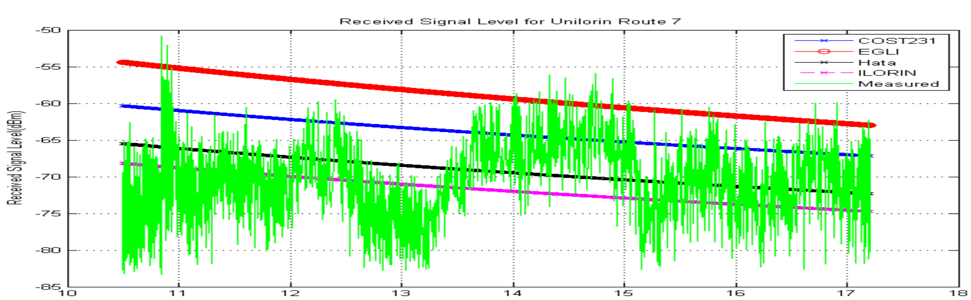

Fig 2d: Comparison of measured and predicted path loss for Unilorin FM along route 7

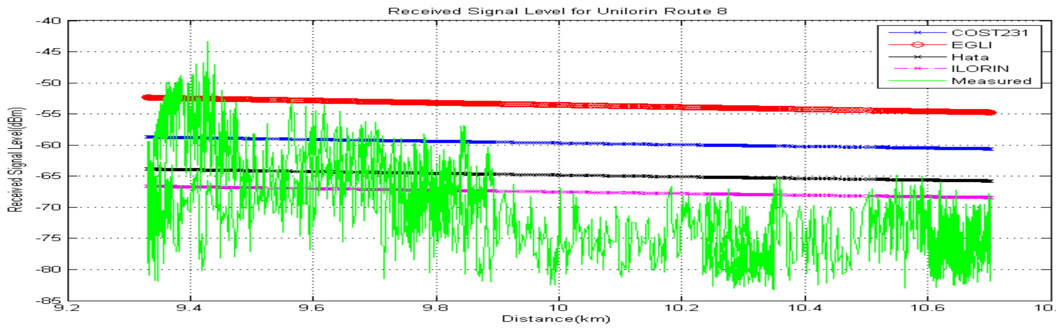

Fig 2e: Comparison of measured and predicted path loss for Unilorin FM along route 8

Fig 3a NTA, Ilorin, Hata and COST 231 did well all through, Egli overestimated all through, Ilorin underestimated for most part of the route. In the second segment, fig 3b, Hata and COST 231 did well, Ilorin did fairly well while Egli overestimated, all the way. In the final segment, fig 3c Hata and COST 231 did well, Ilorin, though, did, fairly well, underestimated, over a distance of 3km, starting, from kilometer 4. Egli overestimated, all through, the route. COST 231 and Hata performed fairly well in all.

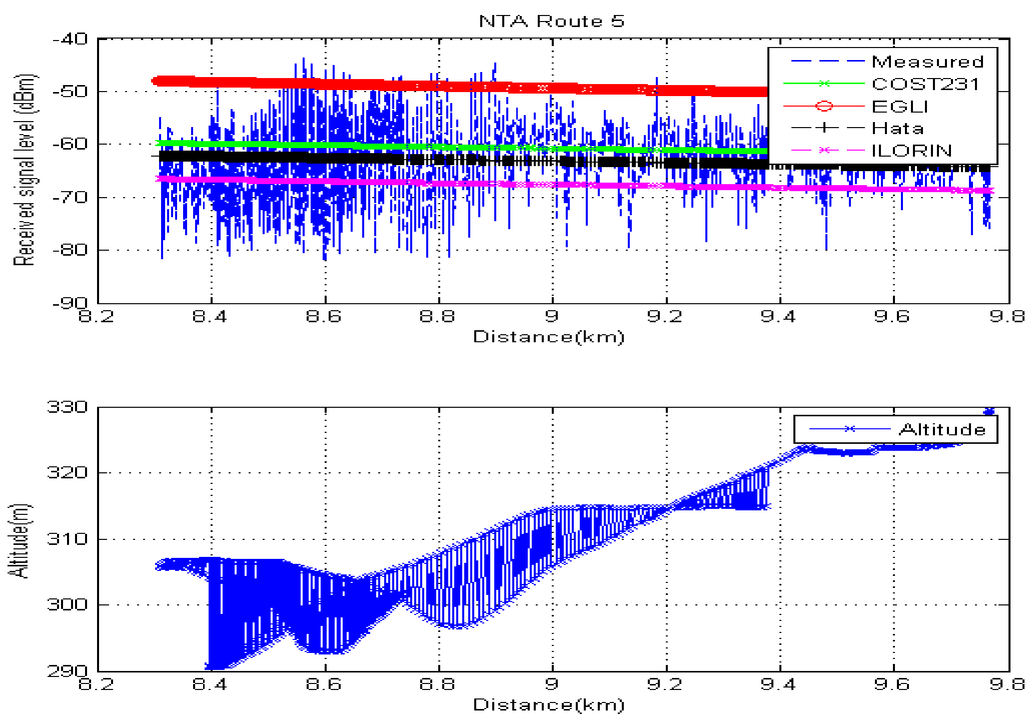

Fig 3a: Comparison of measured and predicted path loss for NTA, Ilorin along route 5 and the topography of the route.

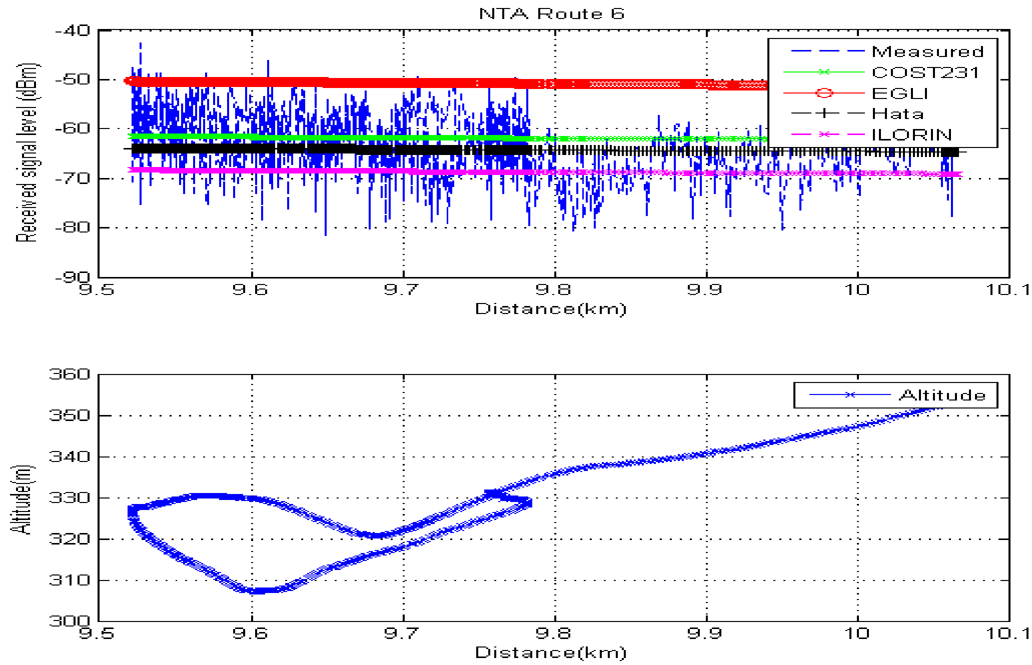

Fig 3b: Comparison of measured and predicted path loss for NTA, Ilorin along route 6 and the topography of the route.

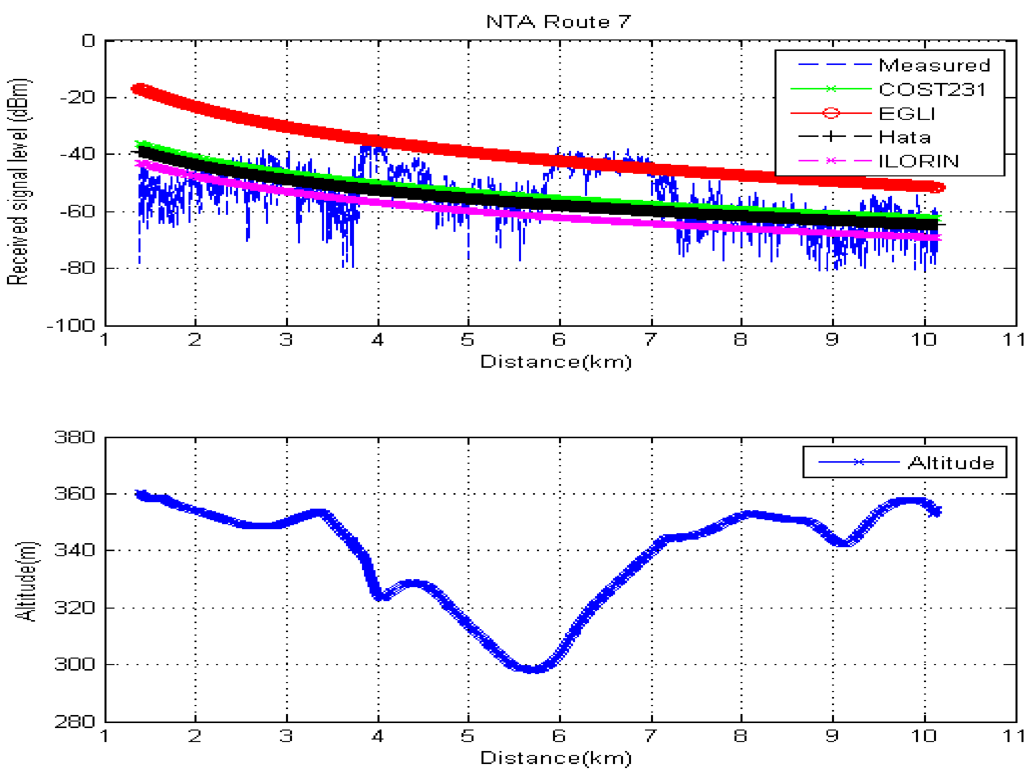

Fig 3c: Comparison of measured and predicted path loss for NTA, Ilorin along route 7 and the topography of the route.

CONCLUSION

That environment play a major role in the radio propagation profile is obvious from the results. In fact, appreciable differences, sometimes, as much as multiples of tens, in decibel, were noticeable, between one environment and the other. Egli performed poorly, as it overestimated, all through. Though Ilorin underestimated some of the time, it did fairly well too. In general, frequency played some role in which model perform better.

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