IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735. Volume 6, Issue 3 (May. - Jun. 2013), PP 04-09
www.iosrjournals.org

Determination of Propagation Path Loss and Contour Map for FUTA FM Radio Federal University of Technology, Akure Nigeria

Oyetunji S.A.
Federal University of Technology Akure, Nigeria

Abstract: *FM signal propagation through the troposphere interacts with the terrain as obstacles and reflection planes. To understand the degree of interaction, signal strength measurements of the 93.1MHz frequency modulated Radio located at Federal University of Technology; Akure, Nigeria was carried out in the area surrounding the station. The paper reviews the various models for predicting transmission loss and employed the long rice irregular terrain model for its versatility for the study. The losses along the paths were determined and this was compared with the path loss predicted by the irregular terrain model and this was highly correlated. The result offers useful data for developing the contour map of the propagation loss which was developed for the station. It was concluded that with the irregular terrain model predictions can be used for accurate spectrum management in Nigeria.*
Keywords*: Signal Strength, Transmission Loss, Terrain, Spectrum Management.*

I. Introduction

Frequency Modulation (FM) conveys information over a carrier wave by varying its frequency. The broadcast band falls within the VHF part of the radio spectrum usually 87.5 MHz to 108.0 MHz. The FM signal propagation through the troposphere interacts with the terrain as obstacles and reflection planes [1]. Thus, the location of a Transmitter for radio communication in any locality depends on a number of considerations such as altitude, latitude, longitude and centrality to coverage area [2]. This study investigates the correlation of signal strength predicted by the Longley-Rice model with field measurements at different locations. The study was carried out in a frequency modulated (FM) radio station located at Federal University Technology, Akure, Nigeria. Signal strength refers to the magnitude of the electric field at a reference point that is a significant distance from the transmitting antenna. Typically, it is expressed in decibels (dB). Mathematically, signal strength is calculated as [3];

Signal strength = EIRP – FSL + RX Antenna gain – Coaxial cable loss (1)

Where EIRP is the Effective Isotropically Radiated Power, in watts (W), FSL is the Free Space Loss, in decibels (dB), RX Antenna gain is the Gain of receiving antenna, in decibels (dB)

Factors affecting signal strength include:

1. The transmitting power of the transmitter.
2. The Directivity or Gain of the antenna.
3. The Effective or Equivalent Isotropically Radiated Power (EIRP) of the signal.
4. The Effective Radiated Power (ERP) of the signal.
5. The presence of thick forest, large vegetation or plantation.
6. Accidental radiators.
7. Reflections from other nearby antennas, mast or transmitters.
8. Lightning and fading.
9. Presence of tall building or skyscrapers.
10. Changes in atmospheric conditions.

1.1 MECHANISM OF RADIO WAVE PROPAGATION

Ground waves exist only for vertical polarization, produced by vertical antennas when the transmitting and receiving antennas are close to the surface of the earth. The transmitted radiation induces currents in the earth's surface being attenuated according to the energy absorbed by the conducting earth [5]. Ground wave propagation is common for frequencies of a few MHz. Sky wave propagation is mainly dependent on reflection from the ionosphere, a region above earth's surface of ratified air that is the ionosphere. The ionosphere is responsible for long distance communication in the high frequency band between 3 and 30MHz, but it is very dependent on time of day, season, longitude on the earth [5]. It makes possible, long-range communication using very low power transmitters. The most important propagation mechanism for short-range communication on the VHF and UHF bands is that which occurs in an open field, where the received signal is a vector sum of a direct line-of-sight signal and as signal from the same source that is reflected off the earth [6]. This shows that there exist a relationship between signal strength and range in line-of-sight and open field topographies. For this free-space case, the signal strength, E decreases in inverse proportion to the distance away from the transmitter antenna which is derived by [6]:

$$E = \frac{\sqrt{30 P_t G_t}}{d} \qquad \textbf{(2)}$$

Where: P_t is the Transmitter power (Watts), G_t is the Transmitter Antenna gain, d is the distance. The received power (P_r) is given by:

$$\Pr = \frac{PtGtGr\lambda^2}{(4\lambda d)^2} \qquad \textbf{(3)}$$

Where: λ is the Wavelength and G_r is the Receiver Antenna gains.

It is very important to take into consideration the field strength versus distance for open field propagation. As the range increases, the signal strength followed an Inverse Square Law [7]. The propagation of radio waves is influenced by a lot of factors which are frequency dependent. These include:

(a) Curvature of the earth terrain
(b) The dielectric and resistivity constant of the earth and sea.
(c) Troposphere absorption

1.2 MODELS FOR PREDICTING RADIO PROPAGATION LOSS

Various models have been developed for predicting the propagation of radio signal in the atmosphere [8]. These models considered factors limiting the propagation of radio waves and are useful in the determination of the primary and secondary coverage areas for Broadcasting Stations [9]. A station's coverage map is an essential ingredient in comparing the station's predicted signal strength with the actual measured values. Some of the prediction models are discussed below.

1.2.1 LONGLEY-RICE MODEL

In January 1, 1967, the American National Bureau of Standards published Technical Note 101, [10] on propagation treatise that is being referred to as the "Longley-Rice Model". The Longley-Rice Model considers atmospheric absorption including atmospheric absorption by water vapour and oxygen, loss due to sky-noise temperature and attenuation caused by rain and clouds. It considers terrain roughness, ground reflections, knife-edge, loss due to isolated obstacles, diffraction, forward scatter and long-term power fading in its pre-defined signal level representations. It is usually used for calculating coverage areas and interference for broadcasting stations. The model predicts long-term median transmission loss. The model was designed for frequencies between 20 MHz to 40 GHz and for path lengths between 1Km to 2,000 Km. The Longley-Rice Model requires the input of certain general parameters so as to set-up the programme for propagation calculations. These parameters include: Frequency; Effective Radiated Power; Antenna Direction; Heights; Polarization; Refractivity; Permittivity; Conductivity; Variability and Climate

1,2,2 OKUMURA PROPAGATION MODEL

The basic Okumura Model uses the height above average terrain to calculate path loss and it does not consider specific terrain obstacles, a set of equations have been provided for the computer use of Okumura Model Predictions [11]. The Okumura model for Urban Areas is a Radio Propagation Model that was built using the data collected in the city of Tokyo, Japan. Okumura model was built into three modes which are urban, suburban and open areas. The frequency range of Okumura Model is between 200MHz and 1,900MHz [12] and it is mathematically expressed as:

$$L = L_{FSL} + A_{MU} - H_{MG} - H_{BG} - \sum K_{correction} \qquad (4)$$

where,

L = The median path loss unit: Decibel (dB)
L_{FSL} = The free space loss unit: Decibel (dB)
A_{MU} = Median attenuation unit: Decibel (dB)
H_{MG} = Mobile station antenna height gain factor.
H_{BG} = Base station antenna height gain factor.
$K_{correction}$ = Correction factor gain (such as type of environment, water surfaces, isolated obstacle etc.)

1.2.3 INTERNATIONAL TELECOMMUNICATIONS UNION (ITU-RP 1546-1)

The ITU Model is widely used in Europe and Central America [13]. The model developed field strength predictions for terrestrial sources in the 30MHz to 3,000MHz frequency range [13]. It used a set of propagation curves that are based on measurement data mainly relating mean climatic conditions in temperature climates. The model considers the transmitter height above average terrain, the receiver antenna height and incorporates a correction for terrain clearance angle when making field strength predictions.

1.2.4 COST-231 PROPAGATION MODEL

This model uses the (Height Above Average Terrain) HAAT along each radial to determine the attenuation based on the following [14](ITU, 1998):

Path Loss (dB):- $46.3+33.9\log(f)-13.82\log(H)+[44.9-6.55\log(H)]\log(d)+C$ **(5)**

Where: f is the Frequency (MHz); d is the distance between base station and receiver; H is the HAAT in the direction of the receiver (m); C is the environmental Correction factor (dB). This model impalements the cost-231/HATA version of COST – 231 Propagation Model. The HATA correction for receiver height and frequency is then applied for the attenuation.

1.2.5 TIREM MODEL

TIREM stands for Terrain Integrated Rough Earth Model [13]. This model with Tech Note 101 base but has been modified over the years to make up for believed inaccuracies in the Longley-Rice Model. These techniques considered factors/components such as free-space spreading, reflection, diffraction, surface-wave, tropospheric-scattering and atmospheric absorption to arrive at the path loss. As opposed to Longley-Rice, TIREM has built-in routines for evaluating radio paths over sea water. TIREM is used by the US Department of Defense. However, as a proprietary model, it is less attractive.

II. Justification

This research work was embarked upon to establish the following:

a) to know their actual coverage area as compared to the specified value.
b) to establish the level of compliance with the National broadcasting Commission (NBC) regulation;
c) to reveal places with poor signal quality and suggest possible solutions on improvement
d)

2.1 FUTA RADIO 93.1 FM IN BRIEF

Futa FM 93.1 commenced broadcast operation on the 19^{th} of November, 2010. The station was issued a Community Radio licensed by the National Broadcasting Commission for teaching, research and community development. Table 1 shows the technical parameter of the station [4].

Table 1.0: List of technical parameters of the radio station

PARAMETER	VALUE
Frequency of operation	93.1 fm
Frequency Bandwidth	200 kHz
Transmitting Power (TX Power)	250W
Effective Isotropically Radiated Power (EIRP)	500W
Maximum Deviation	295 kHz
Antenna Gain	1.93 dB
Antenna Directivity	1.56 dB
Antenna Polarization	Horizontal or 90^0 to the vertical
Antenna type/ model	Yagi-Uda antenna
Maximum Height of antenna / mast	48.768m
Number of antennas installed	Seven (7)
Coverage Area	25km (25000m)

III. Methodology

The methodology adopted includes the following:

a. segmentation of the coverage area into eight (8) different sectors for measurement of signal strength, longitude and latitude,
b. point-to-point measurements for determining the signal strength at different locations using a GPS Receiver and Digital Signal Strength Meter;
c. collection of relevant information about the station under consideration as presented in table 3;
d. development of coverage contour map for the station under consideration

3.1 METHOD OF DATA COLLECTION

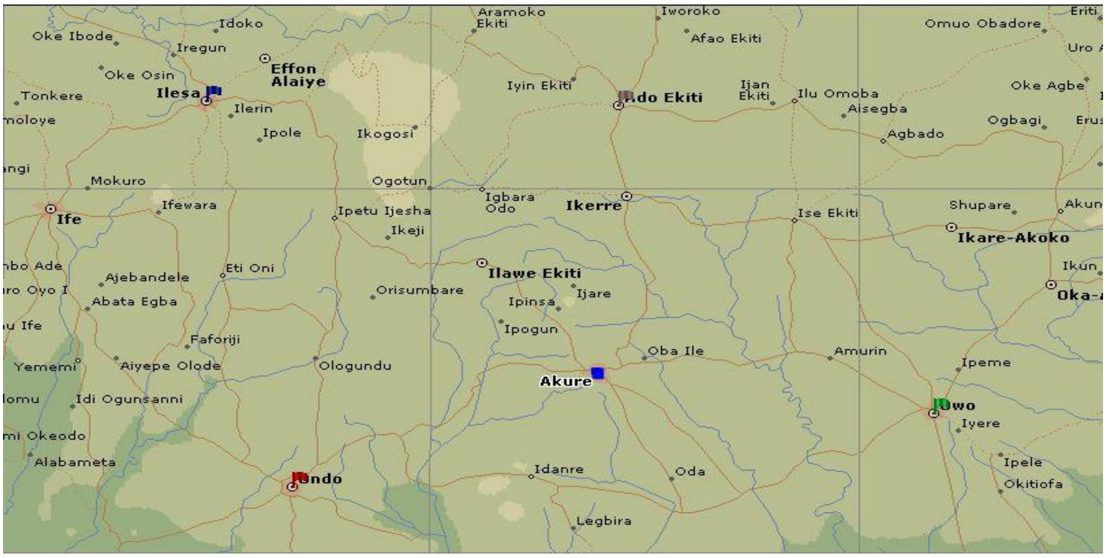
Four locations marked out to be visited were Ondo town, Owo town, Ilesha and Ikere-Ekiti. These locations were chosen because of their geographical positions which represent the South-Western part; the North-Western part, the South-Eastern and Northern part of Akure. These locations provide an adequate estimation of Futa radio signal strength on all sides. The equipments used in the acquisition of data are:

1. A Digital Signal Level Meter (GILBERIT, GE - 5499)
2. A GPS (Global Positioning System) Receiver (UBLOX ANTARIS 4)
3. Laptop Computer
4. Laptop Computer
5.

The collected data includes the following:

Geographical Cordinates: comprises the Latitude, Longitude and Elevation of the points. This data was provided by the ANTARIS GPS Device.

SIGNAL STRENGTH: the strength of the Futa 93.1 fm radio station signal as indicated by the digital signal level meter device at the various points.



DISATANCE ITM: this is the distance,
Along the line-of-sight, between the transmitter and a point as provided by the ITM software.

Figure 1.0 geographical map of Ondo showing the locations visited.

IV. Data Presenttation And Analysis Of Results

Three softwares were used in the analysis of the results and values obtained. They are the Surfer 8 software, Irregular terrain Model and Microsoft excel. ITM estimates radio propagation losses over irregular terrain. It is an improved version of the Longley-Rice Model which gives an algorithm developed for computer applications [15]. The output is a list of estimated transmission losses for specifies values of reliability and confidence levels. For this project work, the Point-to-Point prediction mode was used because the specific value of each location was known. The comparison of the measured and predicted is shown in Figure 2.

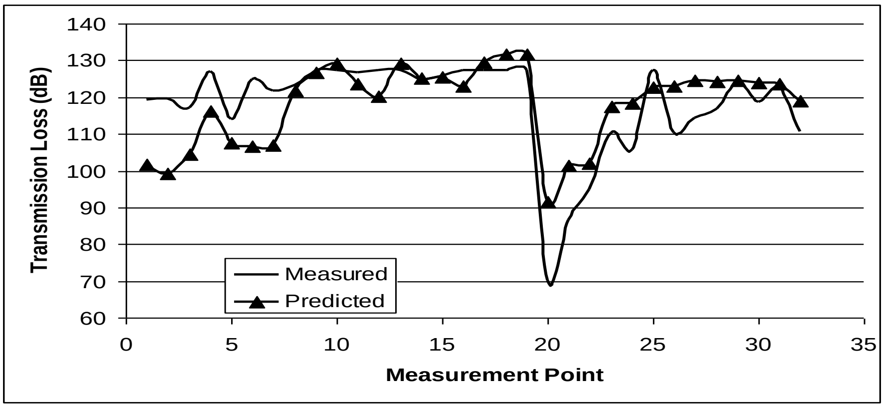
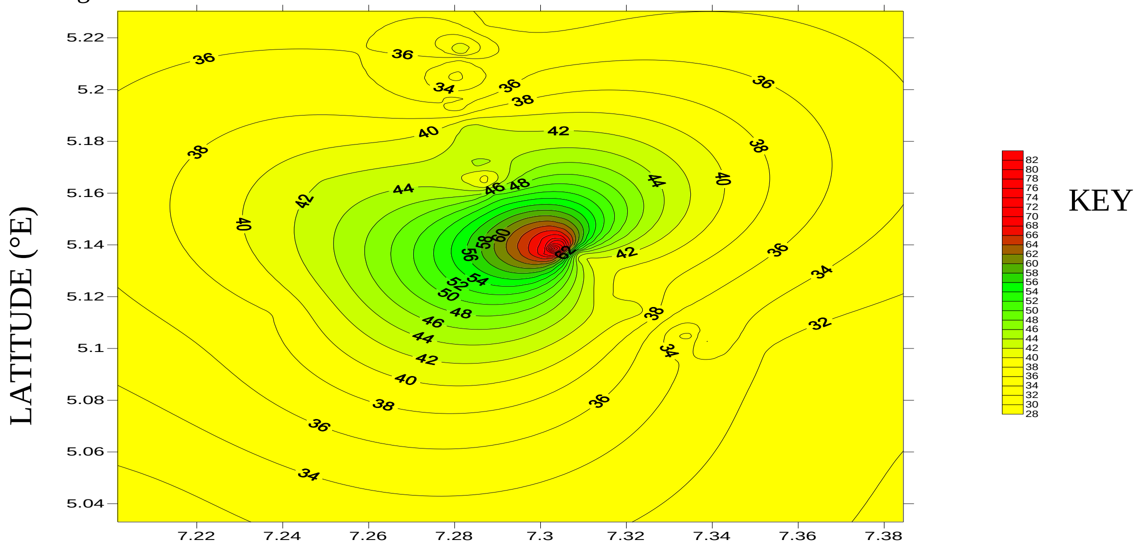


Figure 2 Comparison of the basic transmission losses

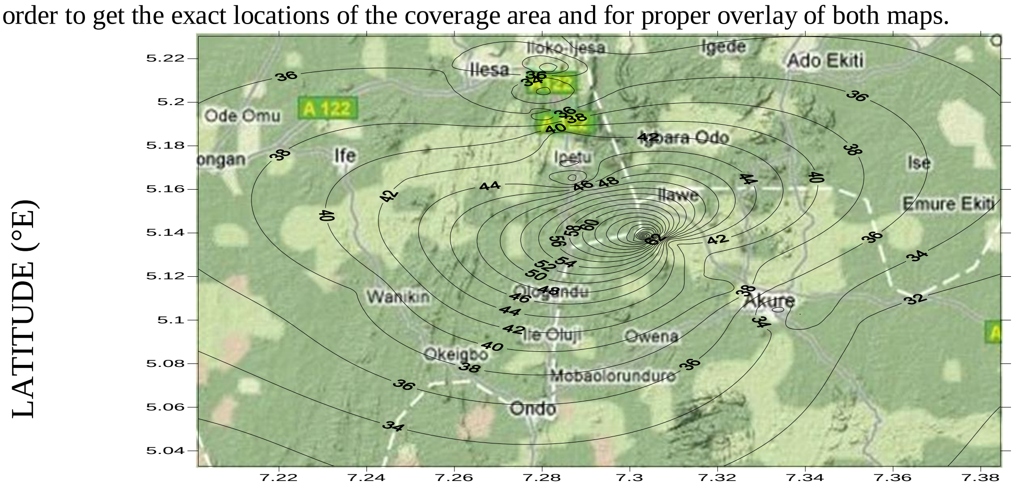
The contour map generated from the Latitude, Longitude and Signal strength values at the various locations is as shown Figure 3.



LONGITUDE (°N)

FIGURE 3.0 – the contour map of Ondo, Ilesha, Owo and Ado-Ekiti.

The map in Figure 2 shows the distribution of the signal across Akure and its environs. The red colored regions shows the areas with very strong signal strength, the green areas are for locations with less strong signal strengths while the yellow region is for locations with the least signal strengths. The middle region is Akure where the radio station transmitter is located and from the contour map it is obvious that the signal strength is high at the middle region. The overlay of the geographical map and the contour map for the same coverage area having maximum value of (7.09456, 4.81809) to (7.606518, 5.498938) is shown in Figure. This value was used in order to get the exact locations of the coverage area and for proper overlay of both maps.



LONGITUDE (°N)

Figure 4.1 – an overlay of the contour map on the terrain map

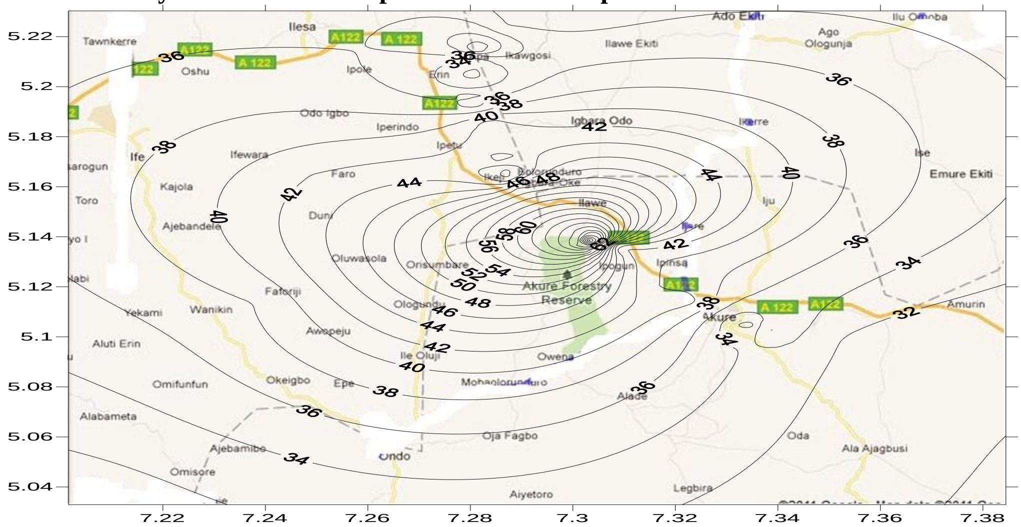


Figure 4.0 – an overlay of the contour map on the geographical map

The overlay of the geographical map and the contour map for the same range of values or coverage area is shown in Figure .The geographical map was derived using the Longitude, Latitude and elevation of the land at the various locations while the contour map was gotten from the Latitude, Longitude and Signal strength of the Signals at the various locations. The contour map indicates the magnitude of the signal strength by the distance between consecutive lines or curves.

V. Conclusion

It was observed that the signal was strongest along the Ondo town axis. The route to Ado-Ekiti had the lowest signal strength observed while Owo and Ilesha had an average signal strength value. With the analysis of the readings obtained, the antennas should be repositioned to enhance the reception along Ado-Ekiti and keep the signal within the coverage area.

Acknowledgement

The contribution of Late Engr. (Dr) Alowolodu Kehinde Ezekiel, my research partner and brother, is appreciated.. He will forever be remembered. His work lingers on…

References

[1] A. F. Bruce, "RF Basis: Radio Propagation" 2008,www.connectos.com/spix/rd/gi/nme.
[2] George, A. G., Rice, P. L., Norton, K. A and Barsts, A. P., "Transmission loss Prediction for tropic communication circuits Tech. Note 101" U.S. Government Printing Office 1967 http://www.softwright.com/faq/engineering/prop_longley_rice.html
[3] Longley Rice
[4] Harry W, "Field Prediction in Irregular Terrain", 2002, http://www.fcc.gov/oet/fm/ptp/report.pdf
[5] D. John, and D. G Smith., ''Telecommunication Engineering" London 1997.
[6] T. S. Rappaport, "Wireless Communications Principles and Practice" Prentice Hall, Upper Saddle River, NJ. 1996
[7] J. S Seybold,., (2005) "Introduction to RF propagation", Wiley
[8] J. Klima and Mozucha Marian'' Influence of Terrain on Multipath Propagation of FM'', Signal journal of Electrical Engineering, VOL56 NO 5-6 pp. 113-120,2005
[9] R. Grosskopf, ''Field Strength Prediction in the VHF and UHF Range Including Multipath'', Propagation, Proc. 7th International Conference on Antennas and Propagation (ICAP 1991), York Conference Publication, 333, vol 2,pp. 965-967, London 1991.
[10] N. Blaunstern, et al. ,''Characteristics Prediction in Urban and suburban Environment'', IEEE Trans. Veh. Technol, Vol(47) pp 225-234,1998
[11] ITU-R Propagation over Irregular Terrain with and without Vegetation, Report 1145, Geneva (CD), 2000
[12] ITU-R Propagation Statistics Required for Broadcasting Services Using the Frequency Range 30 to1000 MHz, Rec. 616, Rep 239-6, Geneva (CD), 2000
[13] ITU-R VHF and UHF Propagation Curves for Land Mobile Services, Rec. 529, Report 567-3, Geneva (CD), 2000
[14] Gibson, J.D. (1996) "The mobile Communications handbook" CRC Press Inc