EXPERIMENTAL MEASUREMENT OF SIGNALS ATTENUATION OF SOBI FM AT VHF ALONG ILORIN - JEBBA ROAD, NIGERIA.

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ABSTRACT
The study of propagation loss and fade margin of 101.9MHz (Sobi FM) signals along Ilorin (Lat 80541 & Long 40551E) – Jebba (Lat 90111N & Long 40821E) road at very high frequency (VHF) band was done experimentally using spectrum analyzer. Alongside theoretical calculation to determine the attenuation was also done using Friis and Free Space attenuation equations. The attenuation and fade margin were measured regularly at intervals of two kilometers (2 km) from the base station up to a total of sixty kilometers (60 km) along the chosen axis. The analytical models were obtained in form of polynomial equations for received power, measured attenuation and the fade margin of the signals. The calculated results correlated with the measurements (Correlation coefficient value R2 = 1), but gave deviation when compared with the measurements. The variance of the results for the existing formula with the measurements was adjudged to hills, valleys, trees and bends along the links. The highest value of the fade margin obtained (75.89 dB) did not exceeded the receiver's sensitivity of 80 dB, which implies that the radio-signals can be improved, by increasing the height and the power of transmitting antenna. This research provides information on improving Sobi FM transmission coverage and a guide to upgrade or redirect their transmission signals appropriately.

Keywords: Measurement, Attenuation, Fade Margin, Sobi FM.

INTRODUCTION

Attenuation is the reduction in power density of an electromagnetic wave as it propagates through space. Attenuation may be due to certain effects such as free space loss, reflection, diffraction, refraction, absorption, aperture-medium or coupling loss. Attenuation could also be influenced by terrain, contours, environment (urban or rural, vegetation and foliage), propagation medium, the distance between the transmitting and the receiving stations, height and location of antenna (Rhodes, 2001). The ratio of received power to transmitted power is called path loss. In path loss, radio waves become weaker as they move away from the transmitter. Line of Sight (LOS) paths at VHF (30-300 MHz) and UHF (300-3000 MHz) require relatively little power since the total path loss at the radio horizon is only about 25 decibels (dB) greater than the path loss over the same distance in free space, where there is no obstruction (Poole, 2010). If the reflecting object is very large in terms of wavelength, the path loss, including the reflection, can be very low. If a structure or hill exists adjacent to an LOS path, the reflected energy may either add to or subtract from the energy arriving from the direct path. If the reflected energy arrives at the receiving antenna with the same amplitude (strength) as the direct signal, but has the opposite phase, both signals will cancel and communication will be impossible (Rhodes, 2001). Generally, in the VHF and UHF range, the reflected wave is out of phase (destructive) with respect to the direct wave at vertical angles less than a few degrees above the horizon. However, since the ground is not a perfect conductor, the amplitude of the reflected wave seldom approaches that of the direct wave. Thus, even though the two arrive out of phase, complete cancellation does not occur. Some improvement may result from using vertical polarization rather than horizontal polarization (Rhodes, 2001). Diffraction is another factor that causes attenuation of radio signals. Energy decays very rapidly as the angle of propagation departs from the straight LOS path. Typically, a diffracted signal may undergo a reduction of 30 to 40 dB by being bent only 7.5metres by a mountain ridge. The actual amount of diffracted signal depends on the shape of the surface, the frequency, the diffraction angle and many other factors. It is sufficient to say that there are times when the use of diffraction becomes practical as a means for communicating in the VHF and UHF over long distances (Aboaba, 2003). Tropospheric refraction also causes attenuation via bending of a wave as it passes through air layers of different density (refractive index). In semitropical regions, a layer of air of 5 to 100 meters thick with distinct characteristics may form close to the ground because of temperature inversion. Thus, the air near the ground is considerably denser than the air higher up (Barilla et al, 2011). When such an air mass forms, it usually remains stable until dawn, when the ground begins to cool and the temperature inversion ends. When a VHF or UHF radio wave is launched within such air mass, it may bend or become trapped (forced to follow the inversion layer). This layer then acts as a duct between the transmitting antenna and a distant receiving site. The effects of such ducting manifests in certain locations where TV or VHF FM stations are received over paths of several hundred kilometers. The total path loss within such a duct is usually very low and may exceed the free space loss by only a few decibels. It is also possible to communicate over long distances by means of tropospheric scatter (Rhodes, 2001; Ulaby, 2010). Noise is another factor that causes attenuation. Noise masks and degrades useful information reception. The radio signal's strength is of little importance if the signal power is greater than the received noise power. This is why signal to noise ratio is the most important quantity in a receiving system. (Rhodes, 2001; Shoewu and Edeko, 2011). In this study, both experimental and theoretical computational methods were adopted.

MATERIALS AND METHOD

The instruments used to carry out the fieldwork:

i **Spectrum Analyzer**: This measure the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals. A GSP 730 spectrum analyzer ranging from 150 kHz – 3GHz was adopted in this experiment to measure the peak radiated power received $P_R(dBm)$ from frequency 101.9MHz.

ii **Half-Wave Dipole Antenna**: A half wave dipole was used because it is very useful as a mobile antenna and the car body can be used as conducting plane.

iii **Inverter System**: A 2 kVA inverter was used to power the spectrum analyzer to prevent interference.

iv **Generator:** A 1.5 kVA *ELEPAQ* generator was employed as a backup for the inverter system.

All instruments were connected appropriately and used to carry out the fieldwork.

Data Acquisition

Sobi FM is operating on frequency 101.9 MHz, with actual radiated power of 2.5 kW from the transmitting antenna (100 m high), using a transmitter rated 5kW. The fieldwork was carried out to obtain the actual power received from Sobi FM station along Jebba axis over a distance of sixty kilometers (60 km) at intervals of two kilometers (2 km). A half wave dipole antenna was connected to the spectrum analyzer to pick the received power.

Figure 1: Set up of the instruments used for the field work

Considering 2.5 kW power directly radiated (P_R) from the transmitting antenna, transmission line loss L_T between the transmitter and the transmitting antenna T_A is negligible. And since the length of cable connecting the receiving antenna to the receiver is about 1.44 m, the line loss L_R between the spectrum analyzer (receiver) and the receiving antenna R_A is negligible. Therefore, the received power is given by (Grayson, 2012):

$$P_R = P_T + G_T + G_R - 32.4 - 20logf - 20logd \text{ dBm} \quad (1)$$

Where P_T is 2.5kW(dBm), G_T is 9.54dBi, G_R is 1.76 dBi, f is $101.9MHz$, and d varies from 2km to 60km. These are substituted into equation (1) to compute P_R. In equation (2), P_R obtained were converted to Watt (W). P_T is 2500 W. These were substituted into equation (2) to yield the Friis Attenuation (FA) of the radio waves (Grayson, 2012). Equation (3) is the Free Space Attenuation (FSA) of the radio waves.

Experimental Measurements

The experimental measurements were carried out by moving the suitably designed receiving dipole antenna well connected (matched) to the receiver system (spectrum analyzer) to measure the signal power (dBm) received at 2 km interval from the transmitting antenna up to 60 km along possible line of sight (LOS). 2 kVA inverter was used to power the analyzer to prevent interference, while the car radio was used to monitor the audio signals transmitted. The signal power P_R received in dBm was converted to Watt.

$$P_R = 10^{dBm/10} \ (mW) \quad (2)$$

Theoretical Computation of Relevant Parameters

Attenuation (A) may be represented as (Sanjaya and Jingsu, 2004):

$$\mathrm{A(dB)} = 10 \log_{10}\left[\frac{\mathrm{P_r}}{\mathrm{P_t}}\right] \quad (3)$$

A is the attenuation in decibel, P_r is the power received by receiver at a particular distance, P_t is the power transmitted from the station.

The (LOS) free space path loss is calculated, having considered the scattering effects of reflection, refraction and diffraction along the radio free space communication links as suggested by the Huygens' Principle. At a distance d from the transmitter, the radiated power is distributed uniformly over an area of $4\pi d^2$ (i.e. the surface area of a sphere of radius d), so that the power flux density (Balanis, 2005), S is given as:

$$S = \frac{P_T}{4\pi d^2} \quad \text{Watt}/m^2 \qquad (4)$$

If the capture area, or effective aperture of this antenna is A_R, then the power P_R, which can be delivered to the receiver (assuming no mismatch or feed line losses), is given as (Grayson, 2012):

$$P_R = S\,A_R \qquad \text{Watt} \qquad (5)$$

For the hypothetical isotropic receiving antenna (Kraus, 1988),

$$A_R = \frac{\lambda^2}{4\pi} \qquad m^2 \qquad (6)$$

Combining equations (4) and (5) into (6) yields:

$$P_T\left(\frac{\lambda}{4\pi d}\right)^2 \qquad \text{Watt} \qquad (7)$$

The free space path loss between the isotropic antennas is P_R/P_T, substituting $\lambda = c/f$ (where c, is the speed of light~$3.0\times10^8 ms^{-1}$) into equation (7) to get:

$$FSL = \left(\frac{4\pi}{c}\right)^2 f^2 d^2 \qquad (8)$$

When equation (8) is expressed logarithmically, it yields:

$$FSL(dB) = 32.4 + 20logf + 20logd \qquad (9)$$

Substituting equation (9) into the Friis transmission formula, and expressed logarithmically yields:

$$P_R = P_T - 32.4 + 20logf + 20logd + G_T + G_R - L_T - L_R \quad \text{dBm} \qquad (10)$$

Where, f *is* the resonant frequency in MHz, d the distance covered by the radio waves in km, P_T the transmitter power output in dBm, G_T and G_R the transmit and receive antennas gain in dBi respectively, L_T the transmission line lose between transmitter and transmit antenna in dB and L_R is the transmission line loss between receiver input and receive antenna in dB. Now, the ratio P_R/P_T yields:

$$\frac{P_R}{P_T} = \left(\frac{c}{4\pi f d}\right)^2 \qquad (11)$$

When equation (8) is substituted into equation (1), it yields a standard free space attenuation formula.

$$A = 147.5571 - 20log_{10}f - 20log_{10}d \quad \text{dB} \qquad (12)$$

Where, f *is* resonant frequency in Hz, d *is* distance covered by the radio waves in meters.

Fade Margin

Fading is defined as the variation of the strength of a received radio carrier signal due to atmospheric changes and/or ground and water reflections in the propagation path. Fading is dependent on path length and is estimated as the probability of exceeding a given (calculated) fade margin (Grayson, 2012). Fading types include:

i Multipath Fading

This is the dominant fading mechanism for frequencies lower than 10 GHz. A reflected wave causes a multipath, i.e. when a reflected wave reaches the receiver as the direct wave that travels in a straight line from the transmitter. If the two signals reach in phase, then the signal amplifies. This is called up-fade (Grayson, 2012).

$$Upfademax = 10logd - 0.03d\ (dB) \qquad (13)$$

d is path length in km. If the two waves reach the receiver out of phase they weaken the overall signal, a location where a signal is canceled out by multipath is called null or down fade (Middleton, 2003).

ii Flat fading

This type of fading occurs when frequencies in the channel are equally affected. There is barely noticeable variation of the amplitude of the signal across the channel bandwidth. But, flat fade margin of a link can be improved by using larger antennas, a higher-power microwave transmitter, lower-loss feed line and splitting a longer path into two shorter hops (Middleton, 2003).

iii Frequency-selective fading

There are amplitude and group delay distortions across the channel bandwidth. It affects medium and high capacity radio links ($> 32\ Mbps$). The sensitivity of digital radio equipment to frequency-selective fading can be described by the signature curve of the equipment. This curve can be used to calculate the Dispersive Fade Margin (DFM) (Middleton, 2003).

$$DFM = 17.6 - 10log[2(\Delta f)e - B/3.8/158.4]dB \quad (14)$$

Δf is the signature width of the equipment and B the notch depth of the equipment.

iv Rain Fading

Rain attenuates the signal caused by the scattering and absorption of electromagnetic waves by rain drops. It is significant for long paths (>10 km). It starts increasing at about 10 GHz and for frequencies above 105 GHz, rain fading is the dominant fading mechanism. Rain outage increases dramatically with frequency and then with path length (Middleton, 2003; Al-Basheir, Shubair and Shariff, 2006).

v Refraction-Diffraction Fading (K-Type Fading)

Refraction-Diffraction Fading is also known as k-type fading. For low k values, the earth's surface becomes curved and terrain irregularities, man-made structures and other objects may intercept the Fresnel Zone. For high k values, the Earth's surface gets close to a plane surface and better LOS (lower antenna height) is achieved. The fade margin of the transmitted frequency signal of 101.9 MHz was calculated from the measured value using (Grayson, 2012) .

$$FADE\ MARGIN = Pt(dBm) + Gt(dBm) + Gr(dB) - FSL(dB) - RS(dB) \quad (15)$$

Where, *RS* is the receiver's sensitivity (-80 dB).

RESULTS AND DISCUSSION

As the signal is propagated, it is attenuated exponentially (Sanjaya and jinsu, 2004; Stutzman and Thiele, 2012). The measured and calculated attenuation values of Sobi FM (101.9 MHz) along Jebba road over a distance of 60 km are presented on Table 1. Distance (D) km, with Power Received (PR) dBm and Watt, Power Calculated (PC) in dBm and Watt, Attenuation Measured (AMe) in dB, Friis Attenuation calculated (FAC) in dB, Free Space Attenuation calculated (FSAC) in dB and Fade Margin (FMa) in dB.

Table 1: Power, Attenuation (Received and Calculated), Fade and Distance (2-20km)

D(km)	PR (dBm)	PR (W)	PC (dBm)	PC (W)	AMe(dB)	FAC (dB)	[FSAC (dB)	FMa (dB)
2	-22.26	$6.31*10^{-6}$	-4.11	$3.88*10^{-4}$	-85.99	-68.09	-78.627	75.89
4	-25.70	$2.69*10^{-6}$	-10.13	$9.71*10^{-5}$	-89.66	-74.10	-84.647	69.87
6	-26.92	$2.03*10^{-6}$	-13.65	$4.32*10^{-5}$	-90.84	-77.62	-88.169	66.35
8	-28.70	$1.35*10^{-6}$	-16.15	$2.42*10^{-5}$	-92.68	-80.14	-90.668	63.85
10	-34.20	$3.80*10^{-7}$	-18.08	$1.56*10^{-5}$	-98.18	-82.04	-92.666	61.92
12	-36.4	$2.29*10^{-7}$	-19.67	$1.08*10^{-5}$	-100.38	-83.65	-94.190	60.33
14	-36.4	$2.29*10^{-7}$	-21.01	$7.93*10^{-6}$	-100.38	-84.99	-95.529	58.99
16	-39.70	$1.07*10^{-7}$	-22.17	$6.07*10^{-6}$	-103.69	-86.15	-96.689	57.83
18	-40.01	$9.98*10^{-8}$	-23.19	$4.80*10^{-6}$	-103.99	-87.17	-97.712	56.81
20	-40.08	$9.98*10^{-8}$	-24.10	$3.89*10^{-6}$	-103.99	-88.08	-98.627	55.90

Comparison of Calculated (Using Friis Formula) and Measured Parameters

There was a sharp deviation between calculated power received and measured power received when chi square and standard deviation were applied as shown in Table 2. The plot of power measured and power calculated against distance is shown on figure 2. The deviation maybe due to factors like hills, valleys, and vegetation. However, there is a correlation between the two powers because they are functions of distance. As the distance increases from the transmitting station, the signal power decreases.

Using the method of least fit on the graph plotted in Figure 2 yields an analytical model of the form:

$$P(x) = p_1x^n + p_2x^{n-1} + - - - - + p_nx + p_{n+1} \quad (16)$$

$$P(x) = 0.0034x^2 - 1.0136x - 22.269 \quad (17)$$

Table 2: Comparison of experimental and calculated values of power received

	Mean	Std. Deviation	N	Df	Chi-Square	Asymp. Sig	Pearson correlation Sig.
POWER MEASURED (dBin)	-49.465	14.651	32	18	13.753a	309	1
POWER CALCULATED (dBin)	-25.721	7.3854	32	32	000b	1.000	823

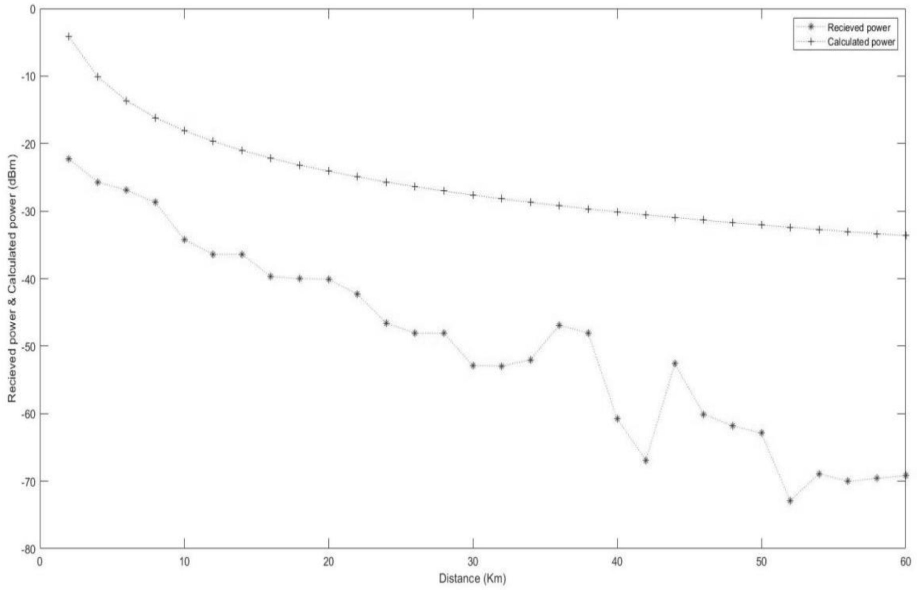

Figure 2: Graph of power measured and power received against distance

Using the method of least square fit on the graph in Figure 3, an analytical model was obtained in the form of polynomial equation of second degree from attenuation measured (experimental measured data).

$$A(x) = A_1x^n + A_2x^{n-1} + - - - - + A_nx + A_{n+1} \quad (18)$$

$$A(x) = 0.007x^{\,2} - 1.140x - 85.513 \quad (19)$$

Table 3: Comparison of experimental and calculated values of attenuation

	Mean	Std. Deviation	N	Chi-square	Df	Asymp. Sig	Pearson Correlation Sig.	Std Error of Mean
MEASURED ATTENUATION(dB)	-112.096	13.281	32	11.563^2	16	774	1	2.424807
CALCULATED ATTENUATION FA(dB)	-89.694	7.383	32	$.000^b$	31	1.000	.106	1.347935
CALCULATED ATTENUATION FSA(dB)	-100.245	7.385	32	$.000^b$	32	1.000	.101	1.348255

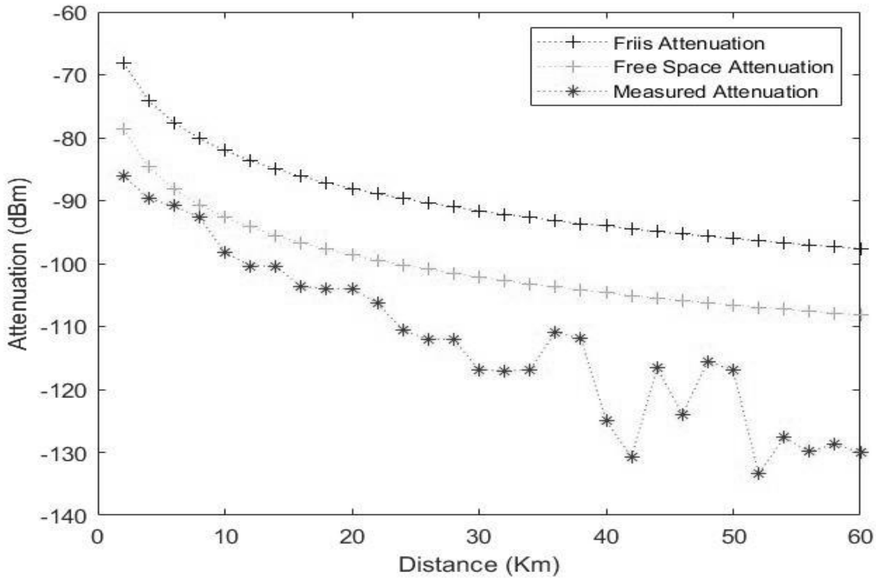

Figure 3: Graph of FA, FSA and Measured attenuation against Distance.

Fade Margin of Sobi Fm Radio signals from Experimental data

Using the method of least square fit on the graph in figure 4, an analytical model was obtained in the form of polynomial equation of second degree from fade margin measured (experimental measured data).

$$F(x) = F_1x^n + F_2x^{n-1} + - - - - + F_nx + F_{n+1} \quad (20)$$

$$F(x) = 0.0091x^2 - 0.9531x + 72.298 \quad (21)$$

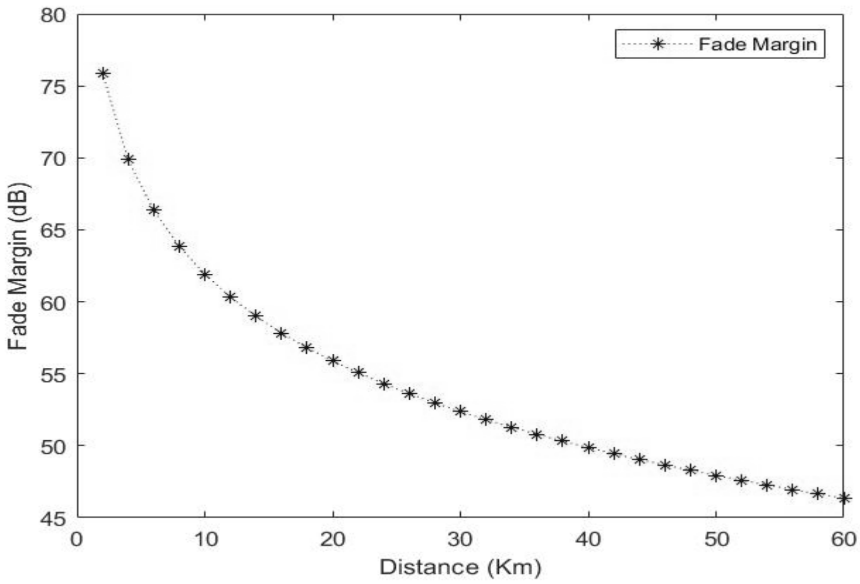

Figure 4: Graph of Fade Margin against Distance.

CONCLUSION

The attenuation values (measured and calculated) and the fade margin of Sobi 101.9MHz radio frequency signals along Ilorin-Jebba link were determined. The measured results were compared with the calculated result using the existing Friis formula and derived Free Space attenuation formula. The existing model correlated very well with the measurement. The inaccuracy of the existing formula may be due to valleys, high rising buildings and trees along the road. However, the radio signals were well received within the space margins calculated, even though the links goes down sometimes due to the valleys and bends along the road. Repeater stations are recommended to be installed for improved transmission and wider coverage.

REFERENCES

Aboaba, O.A. (2003). Experimental Studies in VHF/UHF frequencies in A Tropical Climate, XV URSI 2003, XXVLth General Assembly Toronto, Canada. Pp 375.

AbdAlaziz, W. (2011). Design and Development of Multi-Band Microstrip Rectangular Fractal Antenna for Wireless Applications. 10.13140/RG.2.2.21507.45606.

Al-Basheir M.S., Shubair, R.M. and Shariff, S.M. (2006). Measurement and Analysis for signal Attention through Date Palm Trees at 2.1 GHz Frequency, Sudan Engineering Society Journal, 52(45):17 – 22.

Balanis, C. (2005). Antenna Theory. 3rd Edition, ISBN 0-471-66782-X, John Wiley & Sons Ltd., USA

Barilla, T., Barwick, S. and Saltzberg, D. (2011). Ross Ice Shelf (Antarctica) in Situ Radio, Frequency Attenuation. Journal of Glaciology, 57(201):61-66.

Csurgai, H. and Bito, J. (2004). Fog Attenuation on V-Band Terrestrial Radio and a low Cost Measurement set-up. Budapest University of Technology and Economics. Department of

Gurung, S. and Zhao, J. (2011) Attenuation of microwave Signal and its impact on Communication System. Retrieved on September 14, 2011 from http: //www.sanjayagurung.coms

Grayson, C. (2012). Formula for calculating Fade Margin retrieved January 2021, from www.ehow.comm

Kai, C. (2000). RF and Microwave Wireless Systems. ISBN: 0-47135199-7, John Willey

Kraus J. D, Marhefka, R. J., Muuk, B. A., Lehto, A., Vainikainen, P., Newman, E. H. and Walker, C. (2002). Antennas for All Applications. Third Edition, ISBN: 0-07-232103-2, McGrawHill, USA.

Lehpaner, H. (2010). Microwave Transmission Networks; planning, Design and Deployment, retrieved, January 2021 from www.ehow.coom.

Lee, (1998). Mobile Communications Engineering: Theory and Applications. McGraw-Hill, USA.

Middleton, J. (2003). The propagation aspects of broadcasting at VHF and UHF, in propagation of Radio Waves. 2nd edition, The Institute of Electrical Engineer London, UK,pp.253-255.

Prasad, M., Rama, Rao, T., Ahmad, I. and Paul, K. (2006). Investigation of VHF signals in bands I AND II in southern India and model comparisons. Indian Journal of Radio and Space Physics. 35:198 - 205.

Poole, I. (2010). Radio Signal Pathloss retrieved December 2011, from Radio Electonics.com.

Rhodes, J.E. (2001). Basic Antenna Handbook,

Sanjaya, G. and Jinhsu, Z. (2004). Attenuation of Microwave Signal and its impacts on Communication System. Department of Electrical Engineering, College of Engineering University of North Texas.

Shoewu, O. and Edeko, F.O.(2011). Microwave Signal Attenuation at 7.2GHz in rain and hamattan Wheather,American Journal of Scientific and Industrial Research http://www.scihub.org/AJSIR-SSN:2153-649X

Stutzman, W.L. and Thiele, G.A. (2012). Antenna Theory and Design. 3rd Edition, John Wiley and Sons, Hoboken.

Ulaby, F., Michielssen, E. and Ravaioli, U. (2010). Fundamental of Applied Electromagnetics. 6th

Edition, Prentice Hall.