The Impact of Soil Texture on Path Loss Modelling of an FM Signal Using Diffraction Technique: A Case Study of Prime FM Radio Nigeria

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Abstract—A novel solution to predict path loss of an FM signal using diffraction technique is proposed. Diffraction technique and soil texture impact are used to improve the Friis free-space model to predict the received signal strength and propagation path loss of an FM signal between a transmitter site and receiver site, while studying the impact of soil texture to the FM signal in the case of surface wave propagation. Measurement of signal strengths with an interval of 5KM along two different routes (1 and 2) were taken with a Digital Field Strength Meter (DW-400), in some selected open/rural environments of Kogi State. A solid-state transmitter (BE 20S), with broadcast frequency of 101.5MHz at antenna height of 120m was considered as the transmitting point source. Bluetooth signal strength meter software was used to visualize this impact of soil texture, where different types of soil were considered within the coverage area of the FM radio station, with the application of a Wireless Personal Area Network (WPAN) technology. Measurements taken along the two different routes were compared against predictions made by the modified model of Friis Free Space. The model showed quite large mean path loss prediction errors, and places with poor signal strength for Prime FM Radio Nigeria were revealed. The result shows that an FM signal induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the soil, depending on the soil type.

Index Terms—Propagation Path Loss; Diffraction Technique; FM Signal; Personal Area Network; Soil Texture.

I. INTRODUCTION

Application of diffraction technique and impact of soil texture on path loss modeling of an FM signal consist of received signal strength measurement of an FM signal within the paging of the radio coverage. Using a digital DW-400 field strength meter and soil absorption test for an FM signal, smart phone is buried underground and interfaced with a Bluetooth signal strength meter over personal Area Network (PAN) where the impact of soil on an FM signal is investigated. The focus of this thesis is not on the detailed behavior of electromagnetic wave on a channel length of an FM signal communication system, but it aimed at revealing on how the composition of earth plays a vital role on the propagation of an FM signal that radiates from a

transmitting antenna end of any radio broadcast station, like Prime FM Radio Nigeria. This involves the use of diffraction technique and impact of soil to adopt a model that will predict the attenuation or the loss of an FM signal within the broadcasting region and reveal places that may likely experience poor signal strength.

Radio frequency waves that have been modulated by varying the carrier frequency to contain information are called FM signal. These FM signals have behaviors that can be predicted and detected. They become stronger, and they become weaker. They react to different materials differently, and they can interfere with other signals.

In communication using radio waves, an antenna at the transmitter radiates the electromagnetic waves (EM wave), which travel through the space and reach the receiving antenna at the other end [1].

If all cables connectors, and devices in the chain from the FM transmitter to the antenna point do not have the same impedance rating, there is said to be an impedance mismatch. This results to an increase in the ratio of peak-peak measure of the forward voltage to the reflected voltage, known as VSWR. Maximum power output can only be achieved when the impedance of all broadcasting devices in the Prime FM Radio Nigeria is exactly the same.

Fig. 1: Reflection, Diffraction, and Scattering of Radio Wave

Many broadcast Engineers and Researchers deploy different propagation models to predict and determine the attenuation path loss by comparing the measured data and calculated data. A reliable propagation model is one, which calculates the path loss with small standard deviation and deploys its ability to predict received signal strength.

As a result, it is necessary to understand the reasons for radio path loss, and to be able to determine the levels of the signal loss for a given radio path [2].

The signal path loss can often be determined mathematically and these calculations are often undertaken when preparing for system design activities. Of course this depends on knowledge of the signal propagation properties [2].

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Path loss calculations are used in many radio and wireless survey tools for determining signal strength at various locations. These wireless survey tools are being increasingly used to help determine what radio signal strengths will be, before installing the necessary equipment.

Radio wave loses amplitude as they propagate farther and farther where higher frequencies attenuate more than lower frequencies. One of the things to look for when considering the specifications of client devices and access point for any radio receiver is to look at the receiver's sensitivity. The sensitivity tells us the required signal energy to demodulate the signal [2].

Suppose $r(t)$ of power P_r is transmitted through a given channel., the received signal $r(t)$ of power P_r is averaged over any random variations due to shadowing. Then we defined the linear path loss of the channel as the ratios of transmit power to receive power;

Fig. 2. Terrain Profile features and propagation effects

Fig. 3. Shadow boundaries for diffraction by an infinite conducting half-plane [7]

Region I contains direct, reflected, and diffracted rays, region II contains direct and diffracted rays only. This explains why a knife edge that is below the line of sight may still affect the received wave (see figure 3.9). The knife-edge diffracting point may be above, below, or directly on the line of sight between the transmitter and receiver integral;

$$E_d = F(V) = E_o \frac{(1+j)}{2} \int_0^\infty e^{\left(\frac{-j\pi t^2}{2}\right)} dt \quad (1)$$

Where E_o is the electric field at the receiver based on free space loss only and V is the Fresnel Kirchoff diffraction parameter, which will be defined later (see equation 3.35).

Recent developments related to propagation path loss prediction using different techniques are presented. The majority of such developments are not actually application of diffraction technique to model path loss prediction, especially with the effect of soil content.

VinkoErceg et al [3] presented a statistical path loss model, derived from 1.9GHz. Experimental data were collected across the United States of America in 95 existing macro cells and then analyzed extensively with the data collected by AT&T Wireless Services in several suburban

environments. They didn't consider the losses that might occur within the feed line, due to high-reflected power to the transmitter, which sometimes resulted from the high voltage standing wave ratio. With an omnidirectional azimuthal pattern and gain of 8.4dBi, for 12m to 79m height, they were able to deduce that, using Grayson receiver, set for 1-s averaging as the van moved throughout the environment, the reference path loss was close to the calculated free space path loss.

$$L_p = A + 10n \log_{10} \left(\frac{d_i}{d_o} \right) + s ; d \geq d_o$$

They calculated the path loss exponent n , as a Gaussian random variable over the population of macro cells within terrain category. They also deduced that the power law exponent is strongly dependent on the base station antenna height and the terrain category, so they proposed equation below, for path loss exponent;

$$n = \left(a - bh_1 + c/h_b \right) + X\sigma_n, \quad 10m \geq h_b \geq 80m$$

Where h_b is the base station antenna height in meters and the terms in parenthesis is the mean of n (with a , b and c in consistent unit). They concluded that such model can be used to predict path loss, but limited to certain frequency range.

In [4], the simulation of path loss propagation models in LTE-Advanced Networks for suburban and rural areas was presented. Calculations were done using MATLAB based simulation; for various prediction techniques such as Cost 231, Hata Model, Stanford University Interim (SUI) and Ericsson Model. On the three prediction models they adopted, they failed to consider the frequency suitability for each of the models. According to the results they obtained, gap between two frequencies did not exceed 5dB for each scenario, and the gap between the best and the worst propagation methods was 80dB for the best case, where the worst case is envisioned approximately 100dB.

Sigh and Purnima [5] compared some of the existing empirical path loss propagation models; Okumura, Hata, Cost-231, Log-distance and ECC-33 models; with their measured field data. Measurements were taken in the three regions, depicting the high, medium and low density of Urban, Suburban and Rural setting of India at 900MHz and 1800MHz frequencies, using a spectrum analyzer. They deployed a transmitter with power rating of 5KW, taking measurements at regular interval of 1Km to 5 Km with a reference distance of 1Km. Although they limited their work on the measurement of the field strength, without considering the parameters that cause the degradation of the signal, but with the use of Matrix Laboratory (MATLAB) graphical representation, they deduced that ECC-33, SUI and Okumura models showed better results in Urban areas, while Hata and Log-distance models gave better results in rural environments.

A path loss model, based on field measurements carried out by Vishal Gupta [6] for the suburban city of Mehuwala was compared with the Hata model, which is a widely used model in path loss prediction in CDMA based systems. A comparison of Gupta's developed model with Hata model

gave significant difference; hence they recommended that for accurate path loss prediction, field measurements must be performed. The measured data was then used to correct the existing model for the fringe environment of Dehra, Uttarakhand. All measurements taken were only limited to a mobile terminal, using 3GHz Micronix Spectrum Analyzer MSA 338, noise figure < 4dB, and antenna gain factor of 16.5dB.

Minoru Inomata et al [7] presented an effect of building shapes on path loss up to 37GHz band in street Microcell environments. They used ray tracing to analyze the effects of building shapes on path loss characteristics at an intersection where a comparison between measured and calculated results clarified the dominant paths in which spectacular reflection from a chamfered shaped building contributes the power. This confirms that the building shapes significantly affect the path loss characteristics in NLOS street microcell environment. With consideration of different cases where chamfered, they were able to describe the path loss characteristics up to 37GHz band in street microcell environments and then classified the effects of building shapes at an intersection.

Okorogu V. N, Onyishi D. U et al [8] presented an empirical characterization of propagation path loss and performance evaluation for co-site urban environment. They deployed the design of future generation communication systems depending so much on the suitability of path loss method. The research work characterized the propagation path loss and received signal strength (RSS) measurements in Enugu from Mobile Telecommunications of Nigeria (MTN) Network and Visafone Network in sites where each network operates alone. They used the received signal strength gathered to characterize Enugu Urban environment and a propagation path loss model, suitable for scenario with base station height above the average rooftop was subsequently developed. They generated the SINR to evaluate the link performance of co-site operation in comparison to single Network operation in a site. No losses with the system was investigated, but they concluded that the link quality assessment showed better quality of service when system are operating alone than in Co-Site arrangement due to increased level of interference in relation to SINR parameter.

ZheGeng and Hai Deng [9] investigated on the power of the wireless interference received by the victim communication system in the spectrum-sharing scenario between two wireless communication systems. Their investigation was limited to the attenuation due to external walls, thereby given the variation in path loss. They concluded that, in the spectrum-sharing scenario, for the victim not to be affected by the LTE wireless communication system operating at the same frequency, the interference power given in this work must be less than the victim receiver thermal noise floor by a certain interference margin.

II. EQUIPMENT AND METHOD

A. Equipment

The equipment and the software used in the acquisition of

data and results are;

- A Digital DW-400 Field Strength Meter.
- A GPS (Global Positioning System) Receiver.
- MatLab Software – R2015a (8.5.0.197613). License Number: 161052
- Laptop Computer.
- Smartphone
- Bluetooth Signal Strength Meter Software by NeoFrontier Technologies.

A commercial radio paging Service located in Lokoja, Kogi State, operating at 101.5MHz was considered. Mobile signal strength measurements were carried out, using a DW-400 field strength meter connected to a 7-element Yagi antenna for better reception on two different routes (route 1 and route 2).

Fig. 4. Measurement area to be covered (route 1 and route 2)

A commercial paging receiver was also used at each site to confirm signal availability and operational range. Fifteen (15) receiver sites were visited within a 70 KM radius of the transmitting station over terrain, which included hills. Typical propagation path features that were considered include signal reflections and earth curvature.

The area of locations marked out to be visited were Lokoja town, Kogi Central, Kogi East, and Kogi West. These listed locations were chosen because of their geographical positions and the nature of their soil.

TABLE 1: LOCATION OF THE SITES AND THE NATURE OF THEIR SOIL

LOCATION		GEOGRAPHICAL POSITION		NATURE OF SOIL
		LATITUDE	LONGITUDE	
LOKOJA TOWN		7°41'42"N	6°43'48"E	SANDY-CLAY
KOGI EAST	BASSA	8°09'52"N	7°52'30"E	CLAY-SILT
	DEKINA	7°36'40"N	7°33'26"E	CLAY
KOGI CENTRAL	OKENE	7°32'27"N	6°11'55"E	SANDY
	ADAVI	7°54'26"N	6°49'33"E	SANDY-CLAY
KOGI WEST	KABBA	7°50'50"N	6°05'31"E	SILT
	IJUMU	7°55'03"N	6°06'55"E	SANDY-SILT

Soil absorption tests were also carried out on the above listed sites, while considering the nature and type of their soil.

These locations provide an adequate estimation of Prime FM radio signal strength on all sides.

Radio Nigeria Prime 101.5 FM in Brief

TABLE 2: LIST OF TECHNICAL PARAMETERS FOR THE RADIO STATION

PARAMETER	VALUE
Broadcast Frequency	101.5 MHz
FM Frequency Band Range	87.5 to 108 MHz
FM Bandwidth	200 KHz
Transmitting power (TX Power)	10KW
Reflected Power (RLF Power)	137W
Effective Isotropic Radiated Power (EIRP)	18.20 dB
Antenna Gain	8.20 dBi
Antenna Directivity	6.60 dB
Antenna Polarization	Penetrator-Circular
Maximum Deviation	75 KHz
Antenna Model	Yagi antenna
Antenna Height	150m
Number of Bays/Element	Twelve (12)
Antenna Maximum Input Power	40 KW
Input Impedance	50Ω (Antenna)
Output Impedance	50Ω (Transmitter)
VSWR	1.1:1
RF Output Impedance	50 Ohms
Type of Modulation	Direct Frequency Modulation of Carrier Frequency
Power Factor	0.98

B. Methods

The collected data includes the following;

1) Soil Absorption Test

A personal Computer was placed on soil surface, with a smartphone buried in the ground. The position depth of the phone with reference to its soil surface is designated as L_1 , which represents the distance between the position of the phone and the soil surface in centimeter.

The distance between the Laptop to that of the surface, directly to the smartphone is designated as L_2 , in meter.

A Bluetooth Signal Strength meter was deployed to measure the connecting strength in dBm between the position of a smartphone and the Laptop.

Fig. 5: Measurement site for soil absorption test

This measurement was repeated while keeping L_1 constant and varied L_2 , then keeping L_2 and varied L_1 for better observation.

Fig. 6: signal flow reception

2) Estimating the Path Loss

The study of the propagation of EM waves through the

soil begins with the basic model of the propagation of EM waves over the air, followed by the addition of the path loss factor, specifically considering the properties of soil. From Friis equation, it is well known that the received signal strength (RSS) in free space at a distance r from the transmitter is expressed in logarithmic form as;

$$P_r = P_t + G_r + G_t - L_o \quad (2)$$

Where P_t is the transmitter power, G_r and G_t are the gains of the receiver and transmitter antennae, and L_o is the path loss.

In this work, the path loss in the Friis equation is improved to constitute both the atmospheric path loss and to that in soil.

$$\text{Path Loss, } L_o = L_a + L_s \quad (3)$$

Considering the path loss in free space in dB, $L_o = L_a$ this is given by;

$$L_o = 32.4 + 20 \log(d) + 20 \log(f) \quad (4)$$

Where ' d ' is the distance between the transmitter and the receiver in kilometer, and ' f ' is the operating frequency in MHz

Now considering the propagation through soil, an additional path loss factor should be included in Friis equation due to the attenuation of the EM wave caused by the soil medium. The Friis equation is now expressed as;

$$P_r = P_t + G_r + G_t - L_o - L_s \quad (5)$$

Where L_s stands for the additional path loss constituted by the soil as the signal induces current in the ground, which is calculated by considering;

- The wavelength of the signal in soil, λ , compared to the wavelength in free space,
- Attenuation constant, α , through a distance, d .

Let L_β represents the attenuation loss due to the wavelength of the signal in soil compared to that in free space, and L_α represents the transmission loss due to the attenuation constant and the distance of its propagation through soil.

Therefore, the additional path loss constituted by the soil, l_s , is written as;

$$l_s = l_\beta + l_\alpha \quad (6)$$

$$l_\beta = 20 \log \left(\frac{\lambda_o}{\lambda} \right) \text{ and } l_\alpha = e^{2\alpha d}$$

$$l_s = 20 \log \left(\frac{\lambda_o}{\lambda} \right) + e^{2\alpha d} \quad (7)$$

We know that; as in the lossless cases, the phase shift factor is given by; $\beta = \frac{2\pi}{\lambda}$, then the wavelength, $\lambda = \frac{2\pi}{\beta}$

Free space wavelength, $\lambda_o = \frac{c}{f}$, where β is the phase shifting constant, $c = 3 \times 10^8 \text{ m/s}$ and ' f ' is the operating frequency in hertz.

Hence, l_s can be rewritten as;

$$l_s = 154 - 20 \log(f) + 20 \log(\beta) + 8.69\alpha d \quad (8)$$

Knowing that the path loss in free space is; $l_o = 20 \log\left(\frac{4\pi d}{\lambda_o}\right)$, l_o can be rewritten as;

$$l_o = -147.555 + 20 \log(d) + 20 \log(f) \quad (9)$$

The main formula for the path loss, l_p , of an EM wave can therefore be deduced by summing the equations 3.9 and 3.10; Hence,

$$l_p = l_o + l_s$$

$$l_p = [-147.555 + 20 \log(d) + 20 \log(f)] + [154 - 20 \log(f) + 20 \log(\beta) + 8.69\alpha d]$$

$$l_p = 6.4 + 20 \log(d) + 20 \log(\beta) + 8.69\alpha d \quad (10)$$

Where distance, d , is given in meters, the attenuation constant, α , is in 1/m and the phase shifting constant is in radian/meter.

The values of these parameters depend on the dielectric properties of soil, which are based on the Peplinski Semi-empirical soil dielectric model [10].

The average relative error used to investigate the predicted and the measured path loss of the proposed modified model is given as;

$$E_{ri} = \frac{E_p - E_{mi}}{E_{mi}} \quad (11)$$

Where E_{ri} is the relative error, E_p is the predicted field strength, and E_{mi} is the measured field strength, for I denotes the route number.

$$\varepsilon_r = \left(\frac{\lambda_f}{\lambda_s}\right)^2 \quad (12)$$

Where ' λ_f ' is the wavelength of the propagation in free space. ' λ_s ' is the wavelength of the propagation in soil medium (dry ground). The standard deviation, σ , is equally minimized using the formula;

$$\sigma = \sqrt{\sum \frac{(P_m - P_r)^2}{N}} \quad (13)$$

Where N is the number of measured data points.

$$\sigma = \sqrt{29.74}, \sigma = 5.45$$

3) Estimating the Diffraction Loss

The path loss due to diffraction in the knife-edge model is controlled by the Fresnel Diffraction Parameter, which measures how deep the receiver is within the shadowed region. A negative value for the parameter shows that the obstruction is below the line of sight and if the value is below -1, there is hardly any loss. A value of 0 (zero) means that the transmitter, receiver and tip of the obstruction are all in line and the Electric Field Strength is reduced by half or the power is reduced to one fourth of the value without

obstruction [11]- [12]

As the value of the Fresnel Diffraction Parameter increases on the positive side the path loss rapidly increases reaching a value of 27 dB for a parameter value of 5.

Sometimes the exact calculation is not needed and only an approximate calculation, as proposed by Lee in 1985, is sufficient.

Fig. 7. Comparison between path length and the height of the obstacle

Fresnel Diffraction Parameter (V) is defined as;

$$V = h\sqrt{2(d_1 + d_2)/\lambda d_1 d_2}, V = 2\sqrt{|\Delta d|/\lambda} \quad (4)$$

Where;

d_1 is the distance between the transmitter and the obstruction along line-of-sight.

d_2 is the distance between the receiver and the obstruction along line-of-sight.

h is the height of the obstruction above the line-of-sight

λ is the wavelength.

V is negative when edge is below the direct path.

$$C(V) = \int_0^V \cos\left(\frac{\pi s}{2}\right) ds \quad \text{and} \quad S(V) = \int_0^V \sin\left(\frac{\pi s}{2}\right) ds$$

The E field can be expressed by summing from the top of the knife-edge to infinity.

$$F(V) = \frac{1+j}{2} \int_V^\infty e^{-\frac{i\omega t}{2}} dt$$

$$F(V) = \frac{1}{2} \left[\frac{1}{2} + C^2(v) - C(v) + S^2(v) - S(v) \right] \quad (15)$$

As long as the path length is much greater than the height of the obstacle, which it is usually is, we can make an approximation for the height of the edge above the reference plane. It is this height that is used in the diffraction calculation [12].

$$h \approx h_n + \left(\frac{d_{tn}d_{nr}}{2r_e}\right) - \left(\frac{h_t d_{nr} + h_r d_{tn}}{d_{tn} + d_{nr}}\right) \quad (16)$$

So the diffraction parameter, V is given by;

$$V = h\sqrt{\frac{2(d_{tn} + d_{nr})}{\lambda d_{tn} d_{nr}}} \quad (17)$$

4) Estimating the Received Field Strength

Power transmitted from an antenna spreads out in a sphere. If the antenna is directional, the variation of its power with direction is given by its gain, $G(\theta, \phi)$.

Poynting's theorem defines the relationship between the power density to the E – field and H – field vectors.

At any point on the surface of a sphere with radius, R , the power density (P.D) in watts/square meter is given by;

$$PD = \frac{P_T G_T}{4\pi R^2} \quad (18)$$

This expression is simply the power radiated by the transmitter, divided by the surface area of a sphere with radius, R .

The power density at a distance, R , from the transmitter can also be expressed as the square of the field strength, E , of the radiated signal at R , divided by the impedance of free space (air), designated as Z_0 . The value of Z_0 is 120π , or about 377Ω .

$$PD = \frac{E^2}{Z_0} \quad (19)$$

Equating the two equations result in a simple conversion of the EIRP, which is $P_T G_T$ to field strength, E , in volts/meter. Hence;

$$E = \frac{\sqrt{30P_T G_T}}{R} \quad (20)$$

In the case of Prime FM Radio Nigeria, the transmitter power, P_T , and the antenna gain, G_T , are;

$$P_T = 7000W$$

$$G_T = 8.2 dB$$

III. RESULTS AND DISCUSSION

TABLE 3: SOIL ABSORPTION TEST

SOIL TYPE	L ₁ (cm)	L ₂ (m)	S (dB _m)	STATUS
SANDY	12.00	1.00	-45	STRONG
		2.00	-52	
		3.00	-56	
CLAY	12.00	1.00	-81	VERY WEAK
		2.00	-84	
		3.00	-89	
SILT	12.00	1.00	-64	WEAK
		2.00	-72	
		3.00	-75	

(a)

SOIL TYPE	L ₁ (cm)	L ₂ (m)	S (dB _m)	STATUS
SANDY	4.00	2.00	-42	STRONG
	8.00		-49	
	12.00		-53	
CLAY	4.00	2.00	-78	VERY WEAK
	8.00		-82	
	12.00		-86	
SILT	4.00	2.00	-62	WEAK
	8.00		-68	
	12.00		-72	

(b)

TABLE 4: AVERAGE RECEIVED SIGNAL STRENGTH (RSS) IN DBM/M V/S DISTANCE IN KM

S/N	Distance (Km)	Distance (m)	FIELD STRENGTH in dBμV/m			Average Relative Error, E _{r1}	Average Relative Error, E _{r2}
			Predicted Value	Measured value (route 1)	Measured value (route 2)		
1	0	0	125.40	114.56	117.42	1.00	1.00
2	5	5000	108.31	105.43	103.51	0.03	0.05
3	10	10000	102.36	99.25	98.42	0.03	0.04
4	15	15000	98.84	96.70	94.55	0.02	0.05
5	20	20000	96.34	94.84	95.12	0.02	0.01
6	25	25000	94.40	93.36	98.27	0.01	0.04
7	30	30000	92.82	85.32	84.34	0.08	0.10
8	35	35000	91.48	81.41	79.82	0.17	0.24
9	40	40000	90.32	77.45	73.40	0.02	0.08
10	45	45000	89.30	79.35	75.32	0.02	0.16
11	50	50000	88.38	76.98	74.25	0.07	0.19
12	55	55000	87.55	74.62	72.47	0.17	0.21
13	60	60000	86.80	71.83	68.15	0.21	0.27
14	65	65000	86.10	73.35	63.65	0.17	0.35
15	70	70000	85.46	69.42	57.74	0.23	0.48

Table 3 shows the calculated value of the received signal strength with the use of equation 2, while the measured values were obtained with the deployment of the digital signal strength meter along the two different proposed routes.

Fig.8: Field strength model for route 1 and 2 in dBμV/m vs Distance in Km

TABLE 5: PATH LOSS IN DB V/S DISTANCE IN KM

S/N	Distance (Km)	Distance (m)	Predicted Path Loss, P _p (dB)	Measured Path Loss, P _m (dB)	$\frac{(P_m - P_p)^2}{N}$	Average Relative Error, E _r	% Absolute Relative Error
1	0	0	74.48	85.37	7.91	0.13	13.00
2	5	5000	109.16	116.34	3.44	0.06	6.00
3	10	10000	112.45	122.37	6.56	0.08	8.00
4	15	15000	118.34	125.89	3.80	0.06	6.00
5	20	20000	121.23	128.39	3.42	0.06	6.00
6	25	25000	125.41	130.32	1.61	0.04	4.00
7	30	30000	127.55	131.91	1.27	0.03	3.00
8	35	35000	131.36	133.25	0.24	0.01	1.00
9	40	40000	131.83	134.41	0.44	0.02	2.00
10	45	45000	132.72	131.43	0.11	0.01	1.00
11	50	50000	134.37	136.34	0.26	0.02	2.00
12	55	55000	134.93	137.17	0.34	0.02	2.00
13	60	60000	135.84	137.92	0.29	0.02	2.00
14	65	65000	137.25	136.62	0.03	0.01	1.00
15	70	70000	137.76	138.27	0.02	0.01	1.00

Fig. 9: Comparison results between predicted and measured path loss at 101.5 MHz

In table 3 (a and b), soil impact on electromagnetic wave was investigated and the result shows that an FM signal induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the soil. The absorption rate depends on the nature of the soil i.e. the soil type. Sandy soil tends to absorb more energy compare to clay and silt. With sandy soil, high percentage of the signal is expected to be absorbed and the rest are reflected. Silt soil also absorbs more of the transmitted electromagnetic wave compare to the reflected part but not as much in the case of sandy soil. Clay soil tends to reflect more of the signal when an electromagnetic wave glides over its surface during surface wave propagation. Rural/Urban environments that are predominantly with clay soil are expected to experience strong received signal strength (RSS) of an FM signal compare to those areas with either sandy or silt soil.

Table 4; is a result for the measurement of received signal strength with an interval of 5KM along the two different routes (1 and 2) in some selected open/rural environments of Kogi State, using a Digital Field Strength Meter (DW-400), and their corresponding calculated values. It is observed that the received signal strength decreases with an increase in distance. The signal is strongest in Lokoja town due to its closeness to the transmitting station. Some part of the state that is expected to receive at least average signal strength mostly experience very weak received signal, especially in some part of Kogi Central, like Okene and Adavi that is predominantly with sandy soil and silt, which is 55KM to 60KM from the transmitting station. In fig. 8, The plot shows that the weak signal is as a result of the mountain with higher altitude (greater than the transmitting antenna height of 120m) surrounding the environment, which is obstructing the line-of-sight and part of the signal that's been received by the ionospheric reflection is mostly absorbed by the soil.

Along Ajaokuta axis (route 1), about 40KM to 50KM from the transmitting station, the received signal strength is usually compensated by diffraction effect from the high structures and reflected signal from the ground, which is predominantly with clay soil. Part of Kogi East, predominantly with clay soil experience very strong signal due to the nature of their terrain, which is directly proportional to its distance from the transmitting station. The graph shows that the measured and predicted transmission loss is highly correlated.

Table 5; is a comparison results between predicted values and measured values for the path loss against the moving distance, which shows that the path loss increases with distance due to the corresponding decrease in received signal strength (RSS). Its plot is shown in fig. 8, which shows the reduction in power density of an FM signal as it propagates through space with respect to the distance and nature of the earth within the coverage area.

IV. VALIDATION OF RESULTS

Figure 10 shows the comparison of the measured path loss along different Tx – Rx distances and that of the results obtained by Pardeep Pathania et al [12], after comparing different path loss models and envisaged that Cost-231

model is the most suitable model for plane area in northern region of India. They used high power RF FM transmitter (10KW) working on 100.1 MHz at transmitting antenna height of 100m.

This clearly shows that the variation in both results is due to higher power of the transmitter used (BE-20 KW) at transmitting antenna height of 150m.

The Hata Davidson model shows better results than the extension of Hata model for longer distance, but the mean square error of Cost-231 was found to be minimum as compared to other models.

Fig. 10: Comparison of Pardeep's Cost-231 result with measured result for the path loss

From the figure 5.2, the variation is due to the higher transmitted power and higher operating frequency (101.5MHz against 100.1MHz). The attenuation of surface waves increases very rapidly with increase in frequency. The maximum range of coverage depends on the transmitted power and frequency.

Table 5.1: Comparison of Pardeep's Cost-231 result with measured received field strength

TABLE 6: COMPARISON OF PARDEEP'S COST-231 RESULT WITH MEASURED RECEIVED FIELD STRENGTH

S/N	Distance (Km)	Pardeep's Measured Value (dBμV/m)	Measure Field Strength (dBμV/m)
1	5	90	104
2	10	86	98
3	15	68	95
4	20	64	95
5	25	78	98
6	30	63	84
7	35	64	80
8	40	62	73
9	45	63	75
10	50	60	74
11	55	57	72
12	60	54	68

Fig. 11: Comparison of Pardeep's Cost-231 result with measured result for the field strength

The standard deviations and correlation coefficient were 11.29, 12.60 and 0.859271, which was approximately 86% correlated.

The findings are in agreement with the results obtained by Pardeep et al; but considering the impact of soil texture on an FM signal, to improve the Friis free-space path loss modelling gives better result to predict the received signal strength and propagation path loss of an FM signal. This is due to the influence of ground on the propagation of an FM signal, in the case of surface wave propagation. A wave induces current in the ground over which it passes and it is attenuated as a result of absorption of energy by the earth.

V. CONCLUSION

Application of diffraction technique and impact of soil texture on path loss modeling of an FM signal is presented. The outdoor measurements were taken across the fifteen (15) stated areas with appropriate soil absorption test, in order to compare the predicted values with the measured value. Though propagation models are available to predict the losses, they are not very accurate in determining the coverage area of a system, especially in an area that are predominantly with certain nature of soil that contributes vital impact on the propagation of an FM signal. Measurements taken along the two different routes in Kogi State were compared against the prediction made by this improved model. The model showed quite large mean path loss prediction errors, generally over-predicting the path loss.

The performance of this improved Friis free-space model shows its suitability for the path loss attenuation loss prediction of an FM signal in Kogi State. It also shows that model can be useful to an FM radio station provider to improve their services for better signal coverage around Kogi State. With the analysis of the readings obtained, the antennas should be repositioned at a higher terrain or the antenna height should be above the stated 120m above the earth surface with the deployment of omnidirectional antenna to enhance the reception along Okene-Kabba axis and keep the signal within the coverage area.

During surface wave propagation, the FM signal induces current in the ground over which it passes and it will be attenuated as a result of absorption of energy by the earth. The absorption rate depends on the nature of the soil. Sandy soil tends to absorb more energy compare to clay and silt. With sandy soil, high percentage of the signal is expected to be absorbed and the rest are reflected. Silt soil also absorbs more of the transmitted electromagnetic wave compare to

the reflected part but not as much in the case of sandy soil. Clay soil tends to reflect more of the signal when an electromagnetic wave glides over its surface during surface wave propagation. Rural/Urban environments that are predominantly with clay soil experience strong received signal strength (RSS) of an FM signal compare to those areas with either sandy or silt soil.

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