Determination of Radio Frequency Attenuation Signals of Ajilete FM (92.1MHz) and Compared with Existing Friis Formula, along Gambari-Oyo Road, Nigeria

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***Abstract*—** *This work measured experimentally, and calculated theoretically using the existing Friis Fomula, the Attenuation of 92.1 MHz (Ajilete FM) Signals along Gambari(Lat 8°29¹N; Long 4°29¹) – Oyo-Road(Lat 7°50¹N; Long 3°56¹E), Oyo State Nigeria. The two results were compared. The experimental Measurement campaign was achieved by using an appropriate design dipole antenna, well matched to (810 GSP Analyser), to determine the attenuation. The calculated results correlated very well with the measurements (Correlation Coefficient Value R^2=1). But, they are not accurate when compared with the measurements (Chi- square values equal zero for received power, measured attenuation). The inaccuracies of the results for the existing formula with the measurements may be due to hills, valleys, trees and bends along the links. Hence the accuracy of the model used can only be effectively confirmed in areas free of the obstacles mentioned above. By applying LEAST SQUARE fit method to the experimental measured data, the analytical models,* P(x)= $0.0154x^2$-1.3575x-38.7620 and A(x)= $0132x^2$ -1.2464x-104.8487, in the form of polynomial of degree two, *were obtained respectively for received power and measured attenuation. The analytical model obtained is therefore recommended for use in an area characterised with bends, valleys, hills and trees, since the model has taken into consideration all these factors. In addition, repeater stations should be installed for effective transmission and for wider coverage in forested and valley areas. Moreover, transmitter of higher value like ten kilowatts should be employed for long distance transmission.*

Keywords*— *Attenuation, Dipole, transmitter, model polynomial, Friis Fomula.

I. INTRODUCTION

Attenuation is the reduction in power density of electromagnetic waves as it propagates through space. This term is commonly used in wireless communication and signal propagation. Attenuations may be due to many effects such as free space loss, refraction, diffraction, reflection, aperture-medium, coupling loss and absorption. Attenuation is also influenced by terrain, contours, environments (urban or rural, vegetation and foliage), propagation medium, the distance between the transmitter and the receiver and height and location of antenna (Rhodes, 2001). The causes of attenuation are enumerated further.

However, the reflected waves may reduce or increase attenuation. Often it is possible to communicate beyond the normal LOS distance by exploiting the reflection from a tall building, nearby mountain, or water tower. If the top portion of a structure or hill can be seen readily by both transmitting and receiving antennas, it may be possible to achieve practical, communication by directing both antennas towards the point of maximum reflection. If the reflecting object is very large in term s of a wavelength, the path loss, including the reflection can be very low. If a structure or hill exists adjacent to an LOS path, 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 sandals will cancel and communication will be impossible.

However, if the same conditions exist but both signals arrive in phase, they will add and double the signal strength. These two conditions represent destructive and constructive combinations of the reflected and direct waves. Reflection from the ground at the common midpoint between the receiving and transmitting antenna may also arrive as constructive or destructive manner. Generally, in the VHF 7 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. Meanwhile, 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 (Rhode, 2001)

Several models have been obtained by different researchers for predicting signal attenuations of radio signal by various attenuating factors. Some of these models do agree with the experimental measured values. This is evident in Sarat *et al.*, (2004) as the model used could not be used to determine the rain attenuation of Hassan town in Indian and another model was necessary for the town. Barwick, *et al*., (2004) measured the attenuation of radio frequency through the situ-ice at scout-Amuden station. The measured power was compared with power expected in the absence of attenuation using Frii equation shown below

$$Pr/Pt = GtGr\lambda^2/16\pi^2d^2L \quad (1)$$

Where

P_r= the power received
P_t= the power input to the transmitter
G_t= the gain of the transmitter
G_r = the gain of the receiver
D= the distance from the transmitter to receiver
λ= the broadcast wavelength
L= the known system loss faction

The experimental results showed that attenuation length decreases as temperature decreases and it also confirmed that the attenuation length at radio frequencies is approximately larger than the attenuation length at optical frequencies (Barwick al., 2004)

The choice of the instrument used to measure the strength of radio signal among others is the type of the factor causing the attenuation. Barrel et al (2011), used a Horn Antenna due to the high reflectivity at the ice and sea surface at Moore Embayment, South of Minna Bluff to measure the in-situ average electric attenuation length for radio frequency signals broadcasted vertically the Rose-Ice Shelf Antarctica. After comparing the confirmed and the returned pulse, he ascribed the loss to be attenuation. He used the formula below to find the attenuation length of (75-1250) to be between 500 to 300m. In the cause of determining the best condition for radio communication, Shoewu and Edoko (2009) concluded that fog weather is better for radio communication compare to rain weather. The measured the radio frequency signals of Nigeria telecommunication at 7.2Ghz between Lagos (Latitude 6^o26^1N, longitude 3^o 27^1E) and distance of forty-eight kilometres, from Epe (Latitude 6^o32^1, Longitude 3^o52^1E).

The inaccuracy of these model is further confirmed Al-Basheir 2004) when he measured radio attenuation signal at (2.1 GHz) through a date palm trees in Abu Dhabi in Saudi Arabia. The measured results was were compared with existing model namely Exponential decay Model and maximum attenuation Model(EDM) , the model gives a poor fitting and which suggests that ITU-R model need to be re-visited.

Regression analysis can also be used to determine attenuation as Okumbor et al., (2014) used the method with Mat lab programme to characterise signal attenuation using pathloss exponent in South-South part of Nigeria to ascertain the rate of signal attenuation during dry season.

Cloud attenuation due to cloud liquid water content has been obtained from the radiosonde measurements using Salonel Model at a tropical location. The linear relationship was obtained between LWC and attenuation over the frequency range 10-100GHz give an estimate of cloud contribution to signal attenuation if cloud water content is known (Bijoy et al., 2014).

II. METHODOLOGY

The following procedures were taken in order to determine the attenuation values (measured) of 92.1 radio frequency signals along Ogbomosho/Gambari- oyo links

The attenuation was calculated using the Sanjaya and Jingsu formula of 2004 expressed as

$$A(dB)= 10\log_{10}[P_r/P_t] \quad \text{(Sanjaya and Jingsu, 2004)} \quad (2)$$

where:

A- The attenuation in decibel

P_{r-} =power received by a receiver at a particular distance

P_t- power transmitted from the station

For Ajilete FM, the transmission power is 2500W and the operating frequency is 92.1MHz.

The Friis formula was used to calculate the power received which were expressed as below

$$P_r(dBm) = P_t + G_t(dB) + G_r(dB) - FSL(dB) - A_t(dB) - A_r(dB) \quad (3)$$

(Sanjaya and Jingsu, 2004)

Where

P_r= power received

P_t= power transmitted

G_t= Transmitting antenna gain

G_r= receiving antenna gain

FSL= free space loss (path loss)

A_t= transmission line loss between transmitter and transmitting antenna

A_r = transmission line loss between receiver and receiving antenna

Where

$$FSL\ (dB) = 32.4 + 20\log d \quad (4)$$

Where f is measured in MHz and d in km

Substituting for FSL in equation (3) using equation (4)

$P_r(dB) = P_t(dBm) + G_t(dB) + G_r(dB) - (32.4 + 20\log f + 20\log d)$ where $A_t(dB)$&$A_r(dB)$ are negligible or equal zero.

$$P_r(dB) = P_t(dB) + G_t(dB) + G_r(dB) - 32.4 - 20\log f - 20\log d \quad (5)$$

Where 20 log d varies with distance

For the power received to be calculated, the power transmitted needs to be converted to dBm with the formula stated below

Power transmitted (P_t) in milliwat= $10^{dB/10}$ (Sanjaya and Jingsu, 2004) (6)

$$dBm = 10\log P(mw) \quad (7)$$

dBm= 10log2500000

=63.979dBm

Where 20logf=39.28dB

From equation 3

Pr(dBm) = (63.979) +9+1.5- 32.4-39.285-20log d

Where 20logd varies with distance

$$Pr(dBm) = 2.794 - 20\log d \quad (8)$$

Equation 8 was used to calculate the power received at regular interval of 2km and the values are recorded in table 1

Recall from equation (2)

$A(dB) = 10\log_{10} [Pr/Pt]$

Substitute for Pr in equation (2) using equation (8)

$A = 10\log_{10} [2.794 - 20\log d/2500]$ since P_t = 2500W (9)

Equation 9 was used for attenuation calculation and the values obtained are shown in table 2

III. EXPERIMENTAL MEASURED VALUE OF ATTENUATION

To measure the attenuation, the half wave dipole was used because it is very useful as a mobile antenna and the car body can be used as conducting plane. The antenna was used to pick the being transmitted from 92.1MHz broadcasting station. The antenna was connected to the analyser to determine the attenuation of the signal as the distance from the transmitting station increases. Lead accumulator cell was used to power the analyser to prevent interference, while the earpiece was used to monitor the audio signals transmitted.

To measure the attenuation, a designed and constructed dipole antenna was needed and to determine the length, the following parameters were taken into consideration, the wavelength (λ) the speed of light in vacuum (c) and frequency (f) are related by C=f λ, where c is the speed of light in vacuum, f is the frequency and λ is the wavelength. Since the radio station in concern is operating at frequency of 92.1MHz then, the wavelength of the signal is

$$\lambda = 3x10^8/92.1x10^6 = 3.2572 \text{ m} \quad (10)$$

The length of the antenna constructed is λ /4=0.814m

The antenna constructed was attached to analyser and it was used to take measurement of power received in (dBm) from 92.1 MHz at regular interval of 2km.

The readings taken were in (dBm) shown in table 1. It was converted to milliwatt using equation 6 ($P_r=10^{dBm/10}$), and then to watt. The attenuation of the measured received power was determined using equation 2 expressed below as

$A(dB)= 10log_{10}[P_r/P_t]$.

IV. RESULTS AND DISCUSSION

The various readings taken are as shown in the tables below

TABLE 1
VARIATION OF DISTANCE WITH POWER RECEIVED AND POWER CALCULATED

Distance (KM)	Power Received(W)	Power Calculated(W)
2.0	$1x10^{-5}$	$4.758x10^{-4}$
4.0	$1.3183x10^{-7}$	$1.189x10^{-4}$
6.0	$1.2023x10^{-7}$	$5.286x10^{-5}$
8.0	$3.1623x10^{-10}$	$2.978x10^{-5}$
10.0	$1.0x 10^{-9}$	$1.903x10^{-5}$
12.0	$2.5119x10^{-10}$	1.321x10-5
14.0	$1.0233x10^{-9}$	$9.707x10^{-6}$
16.0	$1x10^{-9}$	$7.432x10^{-6}$
18.0	$6.3096x10^{-10}$	$5.872x10^{-6}$
20.0	$6.3096x10^{-10}$	$4.757x10^{-6}$
22.0	$6.3096x10^{-10}$	$3.937x10^{-6}$
24.0	$6-3096x10^{-10}$	$3.304x10^{-6}$
26.0	$6.3096x10^{-10}$	2.815x10-6
28.0	$3.9811x10^{-10}$	$2.427x10^{-6}$
30.0	$3.9811x10^{-10}$	$2.114x10^{-6}$
32.0	$2.5119x10^{-10}$	$1.858x10^{-6}$
34.0	$2.5119x10^{-10}$	$1.646x10^{-6}$
36.0	$1.4791x10^{-10}$	$1.468x10^{-6}$
38.0	$1.4791x10^{-10}$	$1.318x10^{-6}$
40.0	$1.4791x10^{-10}$	$1.189x10^{-6}$
42.0	$1.4791x10^{-10}$	$1.09x10^{-6}$
44.0	$2.5119x10^{-10}$	$9.829x10^{-7}$
46.0	$2.5119x10^{-10}$	$8.993x10^{-7}$
48.0	$1.5849x10^{-7}$	$8.259x10^{-7}$
50.0	$1.5849x10^{-7}$	$7.610x10^{-7}$
52.0	$1x10^{-10}$	$7.037x10^{-7}$
54.0	$1x10^{-10}$	$6.25x10^{-7}$
56.0	$1.4791x10^{-10}$	$6.067x10^{-7}$
58.0	$8.5114x10^{-10}$	$5.656x10^{-7}$
60.0	$1x10^{-10}$	$5.286x10^{-7}$
62.0	$1.0233x10^{-10}$	$4.950x10^{-7}$
64.0	$1.0233x10^{-10}$	$4-645x10^{-7}$

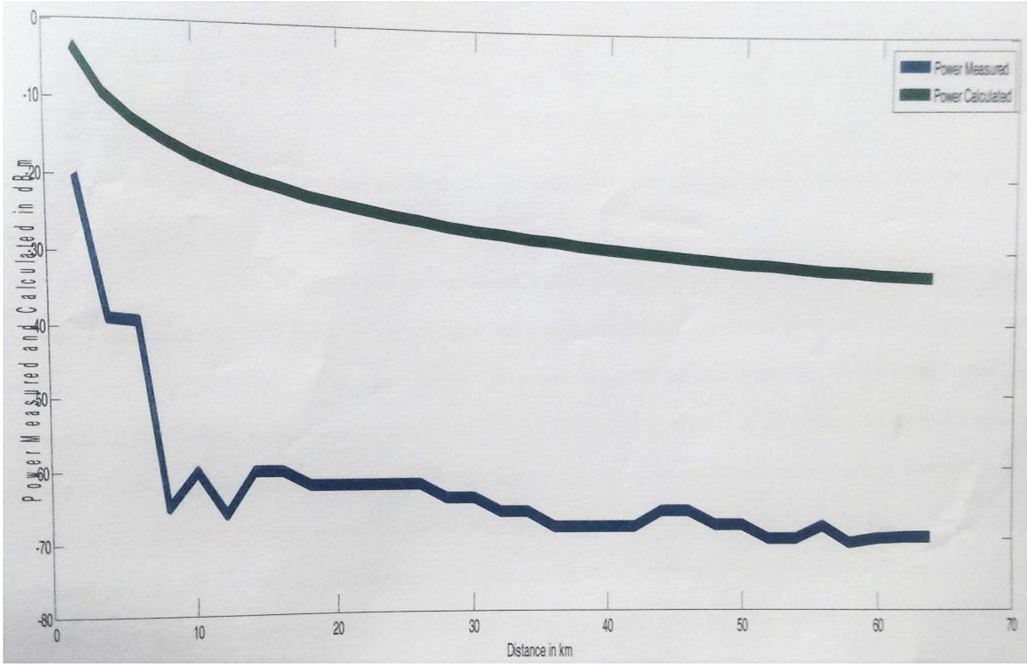

FIG 1: POWER MEASURED AND POWER RECEIVED AGAINST DISTANCE

TABLE 2
VARIATION OF DISTANCE WITH ATTENUATION MEASURED AND ATTENUATION CALCULATED

Distance (KM)	Attenuation Measured (dB)	Attenuation Calculated(dB)
2.0	-83.979	-67.205
4.0	-102.78	-73.227
6.0	-113.18	-76.748
8.0	-128.98	-79.24
10.0	-123.98	-81.185
12.0	-129.98	-82.77
14.0	-123.88	-84.109
16.0	-123.98	-85.268
18.0	-125.98	-86.292
20.0	-125.98	-87.206
22.0	-125.98	-88.034
24.0	-125.98	-88.789
26.0	-125.98	-89.484
28.0	-127.98	-90.129
30.0	-127.98	-90.728
32.0	-129.98	-91.289
34.0	-129.98	-91.815
36.0	-132.28	-92.312
38.0	-132.28	-92.78
40.0	-132.28	-93.228
42.0	-132.28	-93.605
44.0	-129.98	-94.054
46.0	-129.98	-94.44
48.0	-131.98	-94.81
50.0	-131.98	-95.165
52.0	-133.98	-95.506
54.0	-133.98	-95.834
56.0	-132.28	-96.149
58.0	-134.68	-96.454
60.0	-133.98	-96.748
62.0	-133.88	-97.033
64.0	-133.88	-97.31

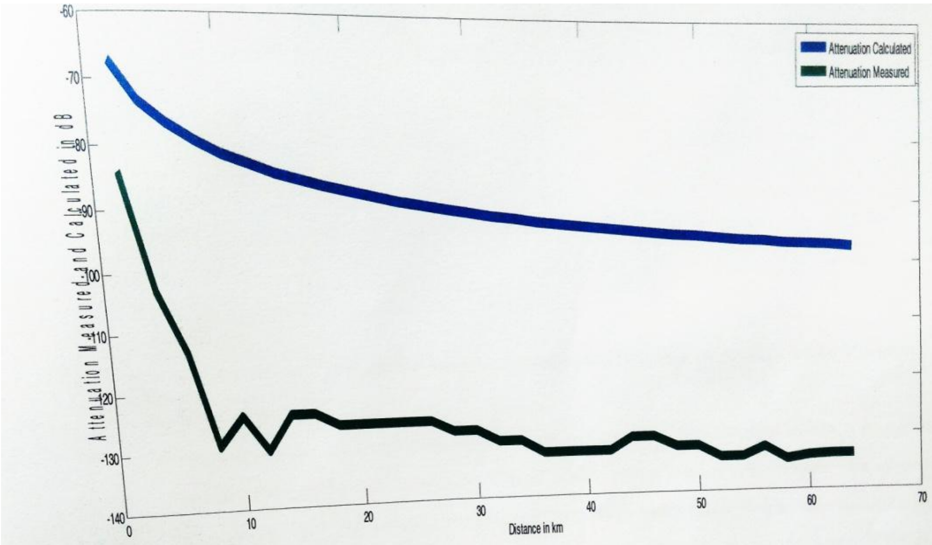

FIGURE 2: GRAPH OF ATTENUATION MEASURED AND ATTENUATION CALCULATED AGAINST DISTANCE

TABLE 3
STANDARD DEVIATION, CHI- SQUARE, PEARSON CORRELATION COMPARING POWER MEASURED AND POWER CALCULATED

	mean	Std. Deviation	N	Df	chi-square	Asymp. Sig	Peareson Correlation significant
Power Measured (dBm)	-62.7781	10.73895	32	13	14.375a	0.348	1
Power Calculated (dBm)	-25.3627	7.4334	32	31	.000b	1.666	0.881

TABLE 4
STANDARD DEVIATION, CHI- SQUARE, PEARSON CORRELATION AND STANDARD ERROR COMPARING MEASURED ATTENUATION AND CALCULATED ATTENUATION

	Mean	Std. Deviation	N	Df	Chi-Square	Asymp. Sig	Peareson Correlation significant
Power Measured (dBm)	-62.7781	10.73895	32	13	14.375a	0.348	1
Power Calculated (dBm)	-25.3627	7.4334	32	31	.000b	1.666	0.881

V. COMPARISON OF CALCULATED POWER (USING FRIIS FORMULA) AND MEASURED POWER RECIED RESULTS

There was a sharp deviation between calculated power received results and measured power received result when chi square test and standard deviation were calculated and the graph was plotted in which all these may be due to some factors not considered in the formula like, hills, valleys and forested areas. However, there is correlation between the two power because they are function of distance- as the distance increase from the transmitting station, the signal power continue to decrease

Using the method of least square fit, the analytical model was obtained from the graph of the received power(experimental measured data) in the form of polynomial equation of degree two

$P(x) = p_1x_n + p_2x^{n-1} + ----+p_nx+p_{n+1}$

$P(x) = 0.0154x^2-1.3575x-38.7620$

VI. COMPARISON OF CALCULATED AND EXPERIMENTAL VALUE OF ATTENUATION PLOTTED AGAINST DISTANCE

The attenuation against distance for the experimental values plotted is not a smooth curve in comparison with the experimental value. Also, there were deviations when chi square test, standard deviation and Pearson correlation coefficient was calculated, the unsmooth curve and the deviation may be due to hills, valleys, trees and bends along the along the road. The standard mean square error of calculated attenuation was very high when compared with measured attenuation result.

The variation in the measured results and the calculated results which could be due to the above mentioned factor has revealed that the accuracy of friis model is subject to the availability of obstacles. This implies that the model would not be suitable for use

In an area that is characterised with hills, valley, trees and bends. Hence the obtained model, which takes into consideration the presence of the obstaches will always give a better result in experimental determination of attenuation.

The model obtained by Barrela et al (2011) was quiet difference from the model obtained in this work. This is understandable because the charatrics feature of that area was high reflectivity which is complexly deferent from the condition surrounding this research work.

Using the method of least square fit, the analytical model was obtained from the graph of attenuation measured (experimental measured data) in the form of polynomial of degree two

$P(x)= p_1x^n+p2x^{n-1}+----+ p_nx+p_{n+1}$

$A(x)= 0132x^2 -1.2464x-104.8487$

Comparison of calculated and experimental values of attenuation plotted against distance

VII. CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The measured results were compared with the calculated results, using existing Friiis formula. The existing formula correlated very well with the measurement (R^2=1). But the existing model is not accurate when compared with the measurements, chi-square gives value of zero. The inaccuracy of the existing formula may be due to hill, valleys, trees and bends along the road. The obtained analytical models($A(x)= 0132x^2 -1.2464x-104.8487$ and $P(x)= 0.0154x^2-1.3575x-38.7620$) obtained for both power measured and attenuation measured are more reliable having taken into consideration the factors such as hill, bends, valleys , forest and trees which have limited the accuracy of the friis model.

7.2 Recommendations

To obtain reliable results of signal attenuation measurement in an area characterised with valleys, hills bends and forest, the models obtained in this work is recommended. Hence the Friis Model needs to be reviewed. A repeater station should be installed for effective transmission and for wider coverage in forested and valley areas. Moreover, transmitter of higher value like ten kilowatts should be employed for long distance transmission.

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