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PATHLOSS EXPONENT DETERMINATION USING RADIO STATION SIGNALS IN ADAMAWA NORTH SENATORIAL DISTRICT, ADAMAWA STATE, NIGERIA.

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Abstract

Information is power. Communication is said to be the means of conveying information from a source to destination, thus, communication is vital to life. Radio communication happens to be one cardinal point of passing information from a station to the community, therefore it is imperative that such channels be studied with all diligence. In North-Eastern Nigeria, passing information is very necessary because of the present insecurity (Boko Harm) situation of the region and even the world at large. Thus, channels of conveying information needed to be put in check. The Pathloss exponent determination of radio signal strength of FM Gotel and FM Fombina was studied in this work. Primary and secondary data were taking from the field on quarterly basis and from the radio stations respectively. The field data were that of signal strength of both stations at mean distance of 20km through 250km radius of coverage along Adamawa Central and Adamawa North senatorial districts using a field strength metre (TM-195 Field Strength Meter 3-axis). The result shows that signal pathloss increases with linear distance. The highest pathlosses for Gotel stood at 19.08dB and for Fombina 17.18dB. The highest pathloss exponents value was found on Fombina's link and it stood at 4.22 and the lowest stood at 2.57; these values are in agreement with pathloss exponents standards in literatures. It is also worthy of note that the results of this study shows that the radio stations under study do not cover 250km radius of coverage as recorded but 180km and 140km for Gotel and Fombina respectively. This study will have application in telecommunication, especially in the areas procurement and installation of transmitters both for public and private sectors within this region of the country.

Keywords: *Signal strength, Path loss, Path loss Exponent, Linear Distance*

INTRODUCTION

Radio station communication just like any other communication system, is a link between a transmitter (TX) and a receiver (RX) via a channel. The transmitter is the source, the receiver is the destination and the channel is the medium through which

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information is transferred. Radio station transmission is one of the earliest mode of wireless communication system (Sarkar, 2006). Wireless communication system are taking the lead now and making a great impact in today's communication industry there by, enhancing proper dissipation of information and creating more awareness in terms of security (Rappaport, 1991)

Radio station transmission is of great significance importance in global communication because of its vast employment in sending information across a wide area. These are many operators of Radio station today, an approximate of two to the three Radio station can be found operating in develop areas. In Adamawa state, we have four Radio Stations in operation today. Two out of these four operators are the case study of this Research work. FM Gotel and FM Fombinia respoectirighy. Interestingly, as powerful as wirews communication is, Radio signals suffers levels of limitations as they are propagated from the transmitter (TX) to the receiver (RX) like any other Electromagnetic waves (Rappaport, 2003), these limitations arise from building, mountains, foliage and weather obstruction in the communication channel reducing it from a direct line-of-sight to an almost blocked channel in severe cases. This obstruction causes the signal strength transmitted to reduce in speed and energy there by creating what is known as *signal pathloss* or *attenuation* (Timtere *et al*, 2020). This makes the wireless communication channel hardly predicted. These limitations faced by signals as they are propagated differs from one environment to the other, thus the need to study signals sent unto various environment for proper analysis and implementation.

SIGNAL PROPAGATION MODELS

In Wireless Communication System, the signal pathloss (PL) in a channel is the product of the impearl distance (d) (Benvenu and santucci, 1999). There are pathloss models that assumes that signal strength attenuates with transmitter (TX) to receiver (RX), distance (D) as γ^d where γ is the pathloss exponent of the channel (Sunil and martin, 2009)

Frills free space model

The frill free space propagation model assumes an un-obstructed los to predict the pathloss of signals (7) (Armogunct al, 2008). The pathloss for frill free space model is given e.g. equation (1).

$$PL(dB) = -10\log\left[\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right] \quad (1)$$

Where PL= the pathloss in disibel, = transmitter Anthena gain, = receiver Anthena gain, **λ**=wavelength of the signal and d= Transmitter- receiver distance.

This model represent an indoor communication system without channel obstruction. (Armogum *et al*, 2008)

Hata's propagation model

Hata created some mathematical path loss models for urban, suburban and open country environment which represents an outdoor propagation model (Hata, 1980) in (Rakesh and Srivasta, 2013). These equations are given by equation 2, 3 and 4:

Urban areas: $= A + BR - E_{1,2,3}$ (2)

Suburban: $= A + BR - C$ (3)

Open Areas: $= A + BR - D$ (4)

Where;

$A = 69.55 + 26.16\log_{10} f_c - 13.82\log_{10} h_b$

$B = 44.9 - 6.55\log_{10} h_b$

$C = 2\{\log_{10}(\frac{f_c}{28})\}^2 + 5.4$

$D = 4.78(\log_{10} f_c)^2 + 18.33\log_{10} f_c + 40.94$

$E_1 = 3.2\{\log_{10}(11.7554h_m)^2 - 4.97$

For large cities, $f_c \geq 300MHz$

$E_2 = 8.29\ \{\log_{10}(1.54h_m)^2 - 1.1$

For large cities, $f_c \geq 300MHz$

$E_3 = (1.1\log_{10} f_c - 0.7)h_m - (1.56\log_{10} f_c - 0.8)$

For small and large cities

R is the great circle distance between BS and Mobile (km).

The practical pathloss can be calculated using equation (5) as:

$$L_p(dB) = P_t - P_r \quad (5)$$

Where P_t is the transmitted power and P_r is the received power. Hata's model is not suitable for micro-cell planning base stations where the antenna is below roof height.

Pathloss (PL)

Signal Pathloss is always expressed as the ratio of transmitter signal power to the received signal power on a given path. It is mathematically written as, (feher and Kamilo, 1995) and (famoriji and olasoji, 2013)

$$PL = \frac{Pt}{Pr} \quad (6)$$

Where PL= Path loss, =Transmitted power and =received power. Signal pathloss in decibels (dB) is given by equation (6)

$$PL(dB) = 10\log_{10}(\frac{Pt}{Pr}) \quad (7)$$

(Murat, 2008)

Pathloss Exponent (γ)

This is the rate or factor at which or by which the signal pathloss increases with distance in a propagation channel. Pathloss exponent is a function of received signal and the linear distance (Murat, 2008) gives the relationship as

$P_r\ \alpha\ d^{-\gamma}$

And later gives it as

$$(\frac{Pt}{Pr}) = e^{-rd} \quad (8)$$

Where Pt=transmitted power, Pr = received, power r= pathloss exponent and d=distance between the transmitter and receiver, pathloss exponent (γ) is greatly influenced by environment, the values for different environment are given in table 1.

Table 1: Values of γ for different environment

S/N	Environment	Pathloss
1	Free space	2
2	Urban Area	2.7-3.5
3	Suburban Area	3-5
4	Indoor (line-&-sight)	1.6-1.8
5	Obstructed in building	4-6
6	Obstructed in factories	2-3

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METHODOLOGY

This section gives a detailed explanation of the materials used, site or field description and the method use in carrying out the practical measurements of this research work.

Materials

The materials use for this research work are listed in table 2.

Table 2: List of Materials

S/N	MATERIALS	MODEL	QUANTITY	USE
1.	Field Strength Metre (3-axis)	TM-195	1	Measuring signal strength in mV
2.	GPS and Land Metre	NP-198	1	Measuring Distance and Location
3.	A car with radio stereo and antenna	Toyota Starlet	1	Moving the distance and monitoring radio stations progreamme

Field reading method was adopted for this study spanning through three different environments, free space, urban and suburban environments respectively. Reading were taken through this environment for accuracy sake. Readings for signal strength in mV for both stations were taken throughout year 2019 on quarterly bases, April for first quarter, August for and December for the quarter respectively, through 250km of distances covering almost all environment listed. Readings were taken at intervals of 20km of linear distances from a references point, which is at the mast in the Base Station (BS) of the two radio stations. The pathloss were calculated from the received signal strength and consequently, the pathloss exponent calculated from the pathloss using relevant equations. The site description is shown in figure 1 and the operation parameters for both radio stations is seen in table 3.

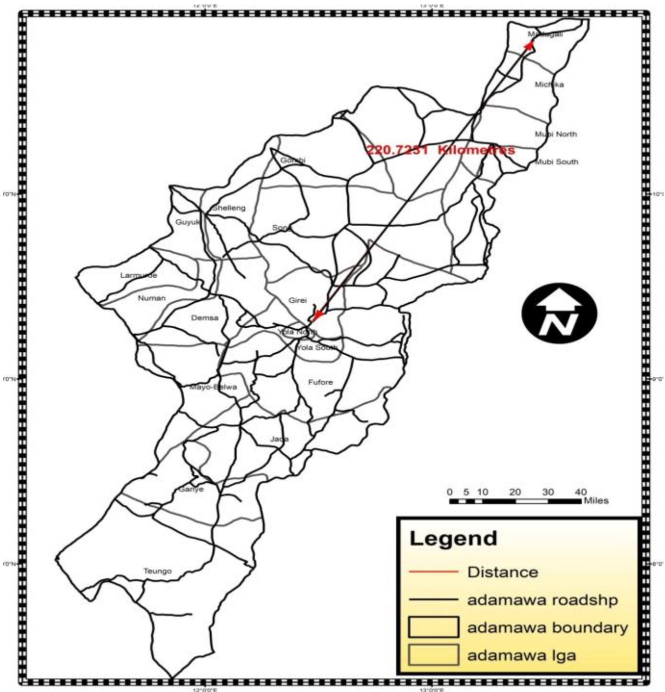

Fig. 1: The map of Adamawa showing the distance covered during this research work.

Table 3: Operation Parameters of the Radio Stations

S/N	SYSTEM PARAMETER	GOTEL	FOMBINA
1.	Antenna type	Unidirectional	Yagi Uda
2.	Radius of coverage	250km	250km
3.	Transmitting Frequency	91.1MHz	101.5MHz
4.	Transmitting Power	10kW	8kW
5.	Mast Height	150m	150m
6.	Location	$E12^{0}28^{'}27.1^{''}$ $N09^{0}18^{'}19.2^{''}$	$E12^{0}29^{'}19.3^{''}$ $N09^{0}18^{'}35.6^{''}$
7.	Year of Commissioning	2012	2003
8.	Ownership	Gotel Communication.	Federal Radio Cooperation of Nigeria.

Field description

The distance of covered was approximately 250km within adamawa North Senational district from Girei LGA to madagali LGA covering at last seven (7) LGA's. the environments through which the signal is propagation as it is already known that radio station signal are unidirectionally propagated to cover free space (in between cities and villages) urban (Cities congested) and suburban (villages) along the road. The field comprises of suburban environment than other environments. No industries along the area of coverage, this industrial environment is not part of the analysis.

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RESULTS

Table 4: First Quarter Readings of Signal Strength for April 2019

S/N	DISTANCE(KM)	SIGNAL STRENGTH (mV)		PATHLOSS (mV)		PATHLOSS (dB)	
		Gotel	Fombina	Gotel	Fombina	Gotel	Fombina
1.	20.00	9.58	8.03	1.01	1.04	0.04	0.17
2.	40.00	9.57	8.00	1.02	1.05	0.08	0.12
3.	60.00	9.41	7.26	1.03	1.15	0.12	0.60
4.	80.00	9.01	6.02	1.07	1.40	0.29	1.46
5.	100.00	8.68	5.00	1.12	1.70	0.49	2.30
6.	120.00	8.12	3.28	1.19	2.57	0.75	4.09
7.	140.00	7.56	1.02	1.28	8.26	1.07	9.19
8.	160.00	4.10		2.36		3.72	
9.	180.00	2.31		4.20		6.23	
10.	200.00	0.12		80.91		19.08	

Table 5: Second Quarter Readings of Signal Strength for August, 2019

S/N	DISTANCE(KM)	SIGNAL STRENGTH (mV)		PATHLOSS (mV)		PATHLOSS (dB)	
		Gotel	Fombina	Gotel	Fombina	Gotel	Fombina
1.	20.00	9.61	8.02	1.01	1.02	0.04	0.08
2.	40.00	9.59	8.04	1.02	1.04	0.08	0.17
3.	60.00	9.46	7.47	1.03	1.12	0.12	0.49
4.	80.00	9.08	5.88	1.07	1.43	0.29	1.55
5.	100.00	8.56	3.92	1.14	2.15	0.56	3.32
6.	120.00	8.22	1.68	1.19	5.02	0.75	7.00
7.	140.00	7.38	0.17	1.32	49.69	1.20	16.95
8.	160.00	3.98		2.45		3.89	
9.	180.00	1.12		8.74		9.41	
10.	200.00	0.14		69.92		18.44	

Table 6: Third Quarter Readings of Signal Strength for December, 2019

S/N	DISTANCE(KM)	SIGNAL STRENGTH (mV)		PATHLOSS (mV)		PATHLOSS (dB)	
		Gotel	Fombina	Gotel	Fombina	Gotel	Fombina
1.	20.00	9.62	8.41	1.02	1.03	0.08	0.12
2.	40.00	9.60	7.86	1.03	1.07	0.12	0.29
3.	60.00	9.51	7.24	1.04	1.17	0.17	0.68
4.	80.00	8.99	6.44	1.09	1.31	0.37	1.17
5.	100.00	8.53	5.17	1.15	1.48	0.60	1.70
6.	120.00	8.02	3.82	1.23	2.21	0.89	3.44
7.	140.00	7.76	1.97	1.27	4.29	1.03	6.32
8.	160.00	6.34	0.14	1.55	60.42	1.90	17.81
9.	180.00	5.26		1.87		2.55	
10.	200.00	4.30		2.29		3.59	

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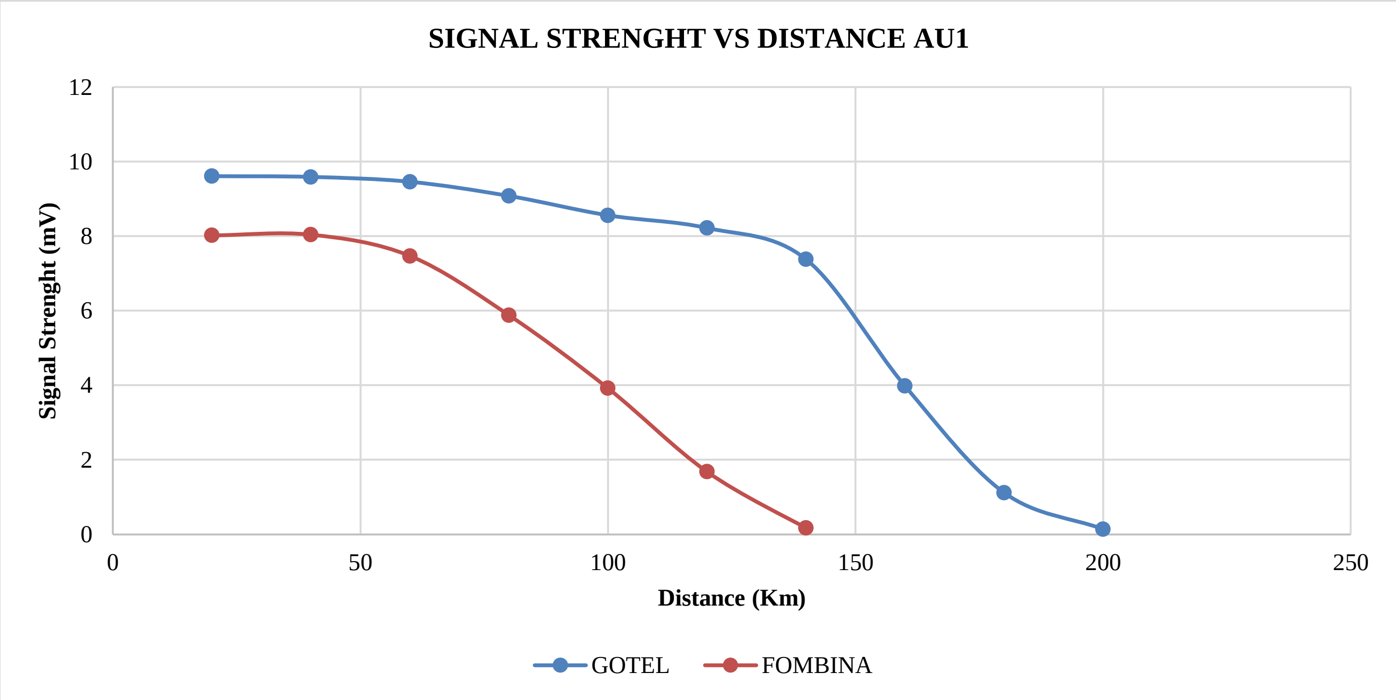
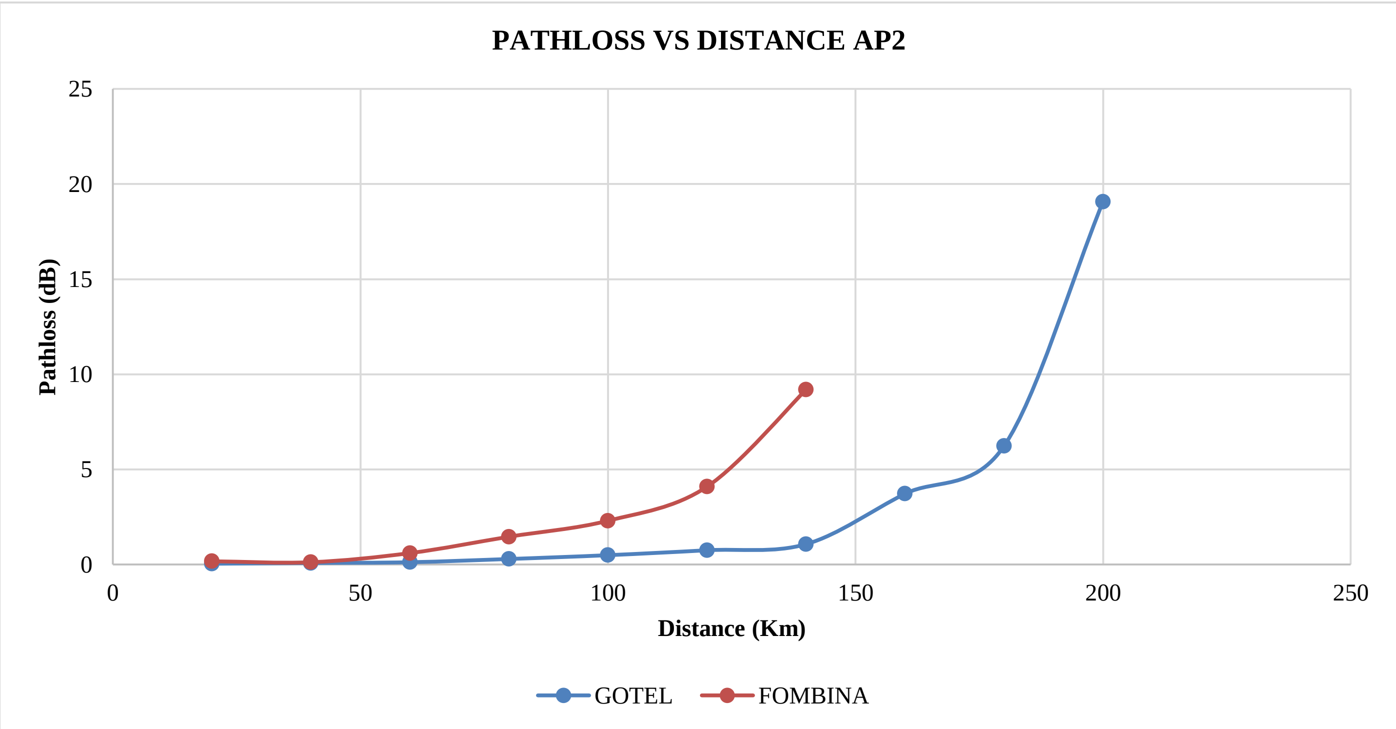
11.	220.00	1.98		4.98		6.97	
12.	240.00	0.22		44.90		16.52	

Table 7: Pathloss Exponents values for the three Quarters.

S/N	**QUARTER**	**PATHLOSS EXPONENT (γ)**	
		GOTEL	FOMBINA
1.	First/April	3.18	2.57
2.	Second/August	3.48	4.22
3.	Third/December	2.89	3.94





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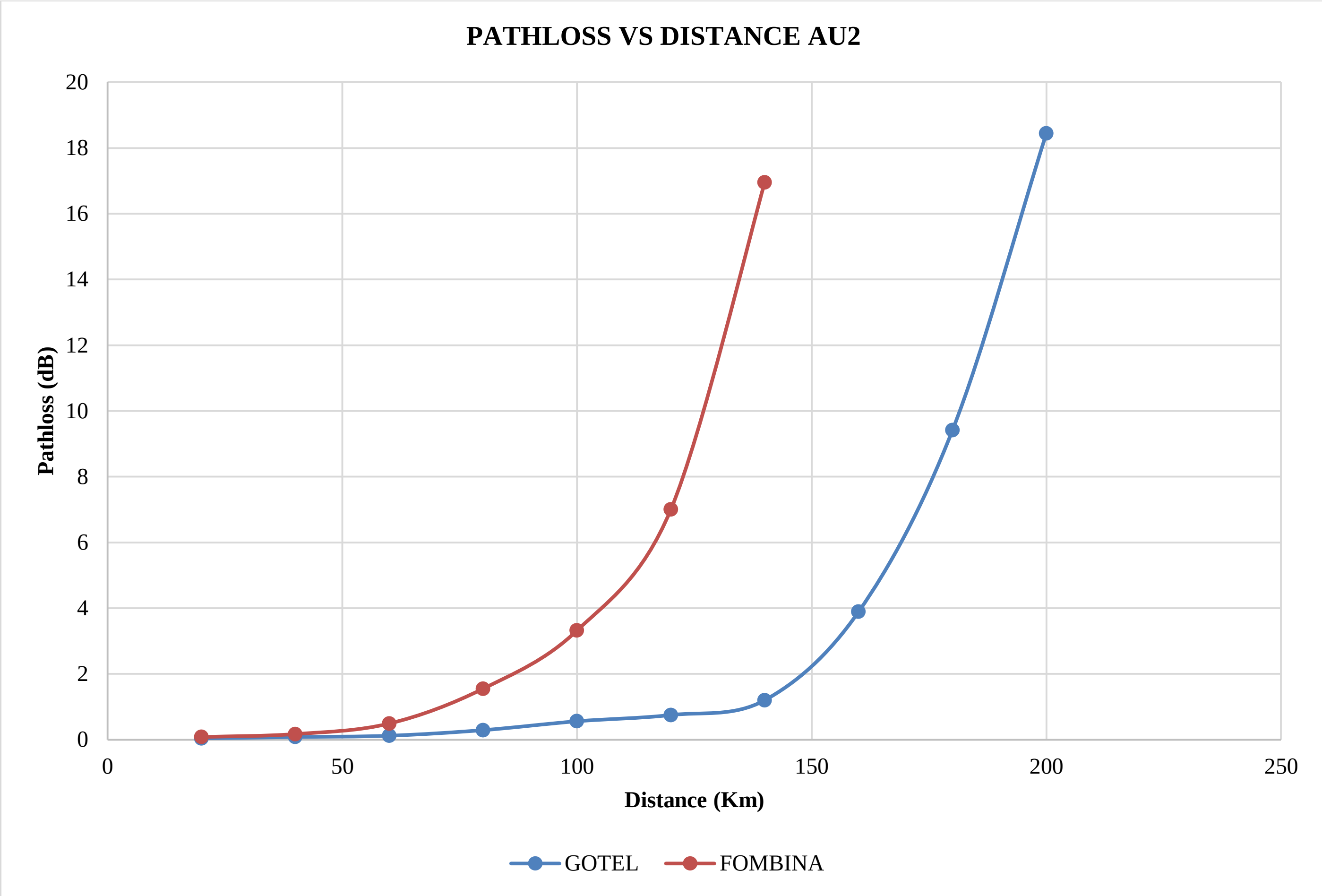

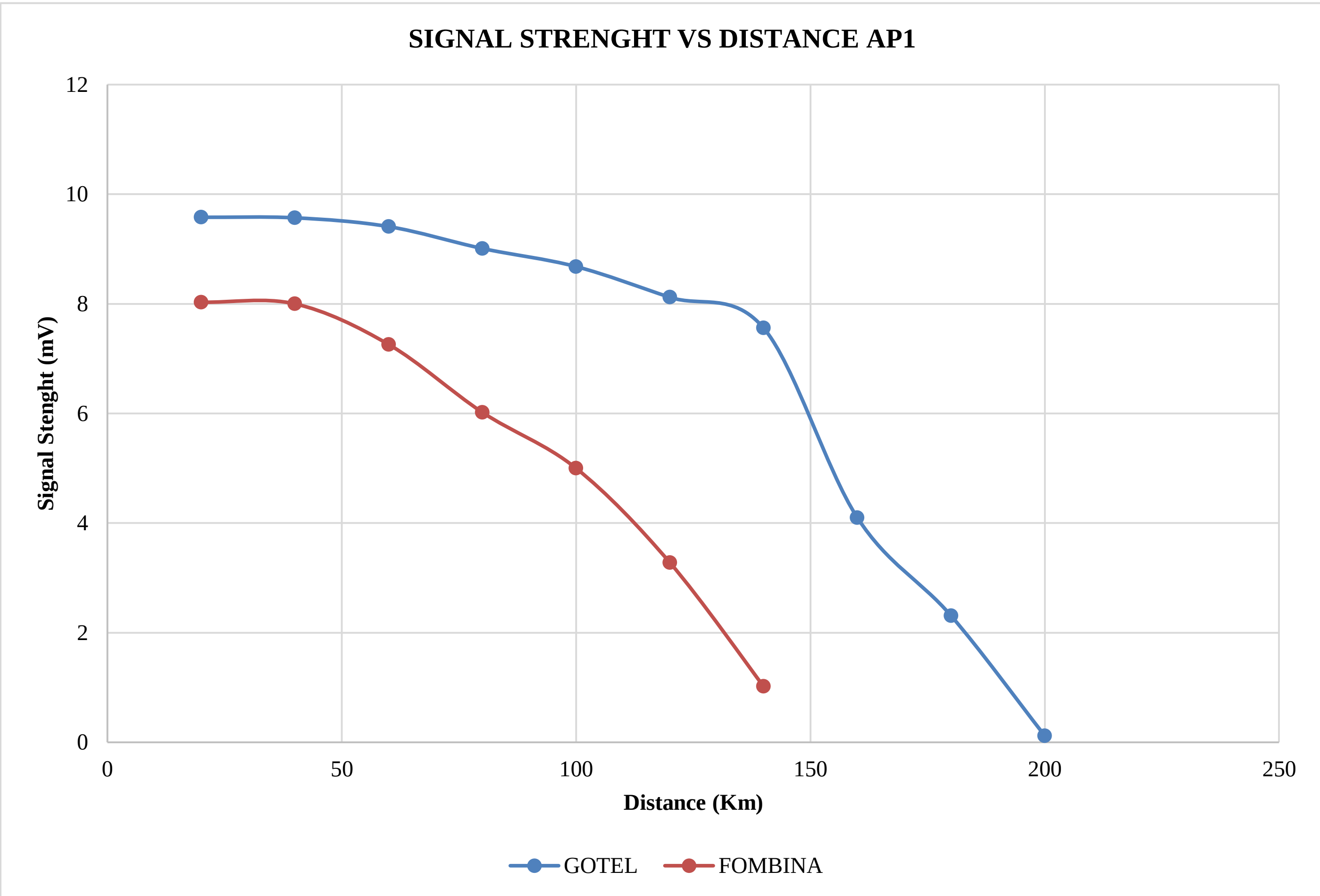

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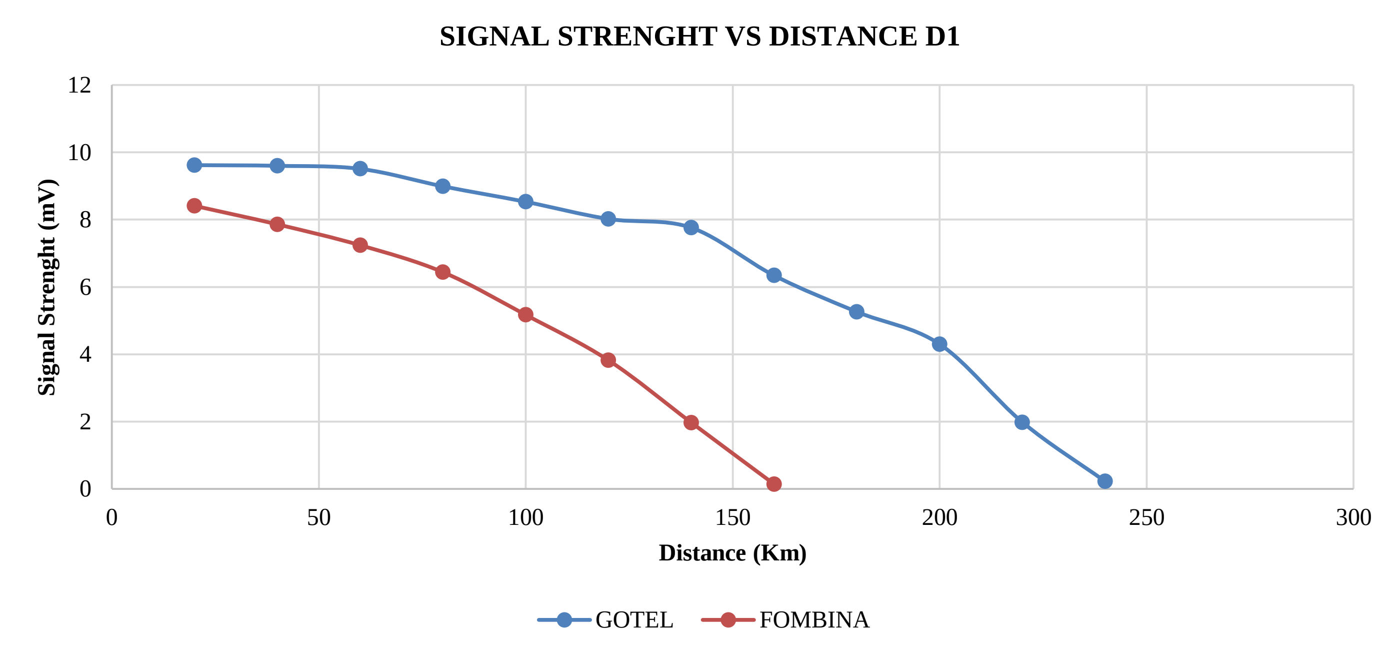

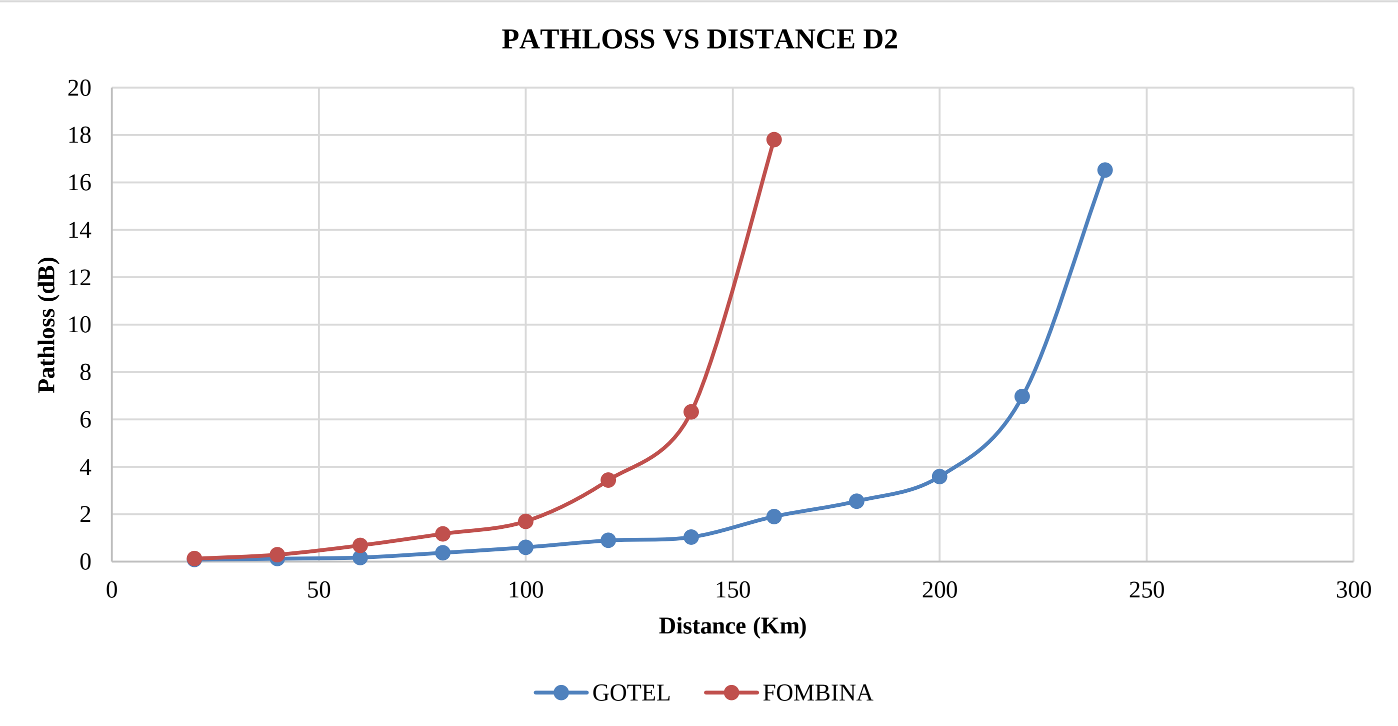

DISCUSSION

From table 4,5 and 6,it can be clearly seen that the signal strength is inversely proportional to the linear distance covered by the signal; the more the distance, the more less the strength of received signal this is in agreement with Kenedy and Dave, 2003. It can also be deduced that the transmission power is directly proportional to the linear distance covered because Fombina with 8kW covers less distance as compared with Gotel having 10kW.

Pathloss

Figs. 3,5and 7 shows the pathloss behaviors of the signal from both radio station. The pathloss is directly propagation to the linear distance and the transmitted power of both station as it was recorded In (Idirm and anyasi, 2014) Gotel has it highest pathloss at 19.08dB, 18'44dB and 16.52dB while Fombrna at 9.16dB and 17.18dB for first, second and third quarters of the year respectively. This suggest that other than linear distance and transmitted power, there are other factors like weather that affects the reception of RF signal when transmitted. This agrees with (Usman *et al*., 2015). It can be seen very clearly that because of the pathloss experienced by the signal, they could not cover the said 250km linear distance of coverage, this agrees with the work of (Iwuji and Emeruwa, 2016). In fact, Götel has more coverage of 200-240km as compared to Fombrna with 140-160km as seen in tables 4-6 leaving out over 10km for Gotel and over 50km for Fombrna uncovered. These areas has no reception whatsoever, which effects the level of awareness and sentititization in such places.

Table 7 shows the values of the pathloss exponent calculated from the pathloss (dB) in table 4-6 on quarterly bases. The highest pathloss exponent value of 4.22 obtained on Fombrna link and the lowest value of 2.57 still on Fombrna link comparing the values of

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pathloss exponent gotten from this research with that of standards for the three different environments, free space with Lowest of 2 almost similar with that of the first quarter of Fombrna urban environment standard with value of 2.7-3.5 equates with the values of Gotel 1st quarter, 2nd quarter, 3rd quarter with values of 3.18, 3.48 and 2.89 respectively and Fombrna quanter and quanter with values 4.22 and 3.94 falls within the suburban environment standard. This can be carefully drown that Fombrna's signal strength attenuates greatly in the suburban areas than that of Gotel than in urban areas. This is in agreement with that of standards and the works of (Jorge and Tiago, 2013) and (Idim and Anyasi, 2014). The pathloss exponent is within 2-5, which means the three environments in this study (free space, urban and suburban) falls correctly. The rest environment in standards (obstructed in building, indoors and obstructed in factories) does not play here because of the absence of factories within the field in the study and of the facts that all reading were taken outdoors.

CONCLUSION

The result of this work shows that as the reception of the radio station signal is moved from point to point away from the Base Station (BS), it strength reduce and pathloss increase and that the pathloss exponent is a function of both, transmitted power, linear distance and environment. The result of this work shows that the two radio stations need more work on their transmitters to be able to cover the said linear distance of 250km raiding of coverage especially, Fombina FM. Procuring a transmitter with 15-20kw power will do well to cover all areas even with shadowing, environment and other effects.

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