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DETERMINATION OF THE EFFECTS OF RADIO SIGNAL STRENGTH AND ATTENUATION AS A FUNCTION OF LINEAR DISTANCE AND SOME ATMOSPHERIC CONDITIONS ON TSBS, JALINGO, TARABA STATE

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ABSTRACT

Taraba state broadcasting station (TSBS) is situated in Jalingo with coordinates (8º 56N 11º 55E) with transmission frequency of 90.6 MHz covering a distance of 250 km and operates for up to fifteen hours a day. The signal strength of TSBS Jalingo was taken as a function of distance and some variables which are temperature, refractivity, humidity, solar radiance and other ionospheric factors in cognizance. The measured values shows negative correlation between the signal strength of TSBS with the linear distance as measured both in volt per meter and in decibels these values were calculated based on a reference distance of 1 km with value of 0.7746 (v/m) or -2.62 (dB).The signal strength values with the daily hourly record did not match, which is in excellent agreement from literature. While atmospheric factor (refractivity) as thus observed is seen that high refractivity leads to less radio wave propagation and vice versa. This research work can be employed in communications technology, to determine the effects of "topographical terrain on frequency propagation" when citing any other Radio Station in Nigeria.

Keywords: Attenuation, Time, atmosphere, signal strength meter, radio

INTRODUCTION

Wave is an oscillation accompanied by a transfer of energy that travels through a medium (space or mass) (Luomala, 2015). In wireless transmission waves, all waves that do not require any material medium such as wires or any conductor for their transmission are electromagnetic in nature such waves includes radio wave, microwave and infrared waves (Kennet, 2008). Radio wave propagation is influenced by the properties of the earth and the atmosphere. The curvature of the earth and the condition of the atmosphere can refract electromagnetic waves either up, away from, or down toward the earth's surface (Nor *et al*, 2015).

Radio signal propagation through atmosphere is a major concern.

Electromagnetic radiation transmitted into the atmosphere are perturbed signals by the constituent's gasses (Oluwole and Olayinka, 2013). In this studies variables as such are considered as we study the signal strength of Taraba State Broadcasting Station (TSBS) Jalingo transmitters at various distances. Radio waves are a type of Electromagnetic radiation with wavelength in the electromagnetic spectrum longer than infra-red light. They have frequencies from 300GHz to as low as 3 KHz, and corresponding wavelength from 1 millimeter to 100 kilometer (The ARRL Handbook for Radio Amateurs, 2001).

Extensive research work shows that the atmosphere affects radio frequency propagation Dajab (2006) worked on how radio waves can be affected by harmattan and found out that harmattan attenuates Radio Frequency propagation and thus reduces the perfect propagation of the Radio Frequency. Kenneth (2008) studied the effects of temperature on Radio Frequency propagation and found out that when temperature rises above 25ºC there used to be a decrease in radio signal due to poor propagation caused by temperature rise.

Theoretical Approach

Basic Operations of a Radio Frequency Signal Strength Meter

A simple signal strength meter can be described using a block diagram as shown in fig (1) below, showing the various components and their functions.

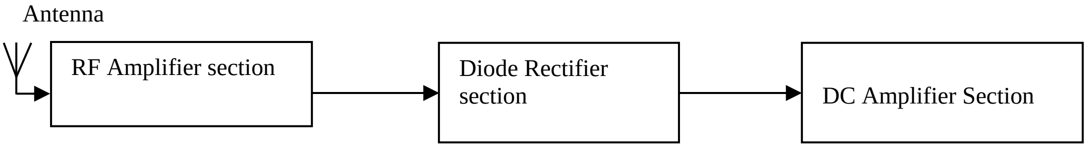

Figure1: A block description of wave receiver

The function of the various blocks are briefly described below.

i. RF Amplification Section: This section amplifies the Radio Frequency signal received by the aerial
ii. Rectifier: It rectifies the Radio Frequency Signal which is alternating in nature to a signal which could be measured by a DC Volt-meter.
iii. DC Amplifier Section: It amplifies the electric potential

Attenuation is a general term that refers to any deduction in the strength of a signal. In telecommunication signal strength attenuation plays an important role, it is a natural consequence of signal transmission over long distances. Attenuation is represented in decibels (dB/km). This reduction in the strength of radio signal in the atmosphere could be caused by some atmospheric conditions such as Temperature, Noise from electrical Networks, Fog and so on. In the works of Eyo *et al* (2015), Grabner (2003), Smith (1957) and Ekpe (2007). Radio signal strength attenuation is expressed in equation (1)

$$A = M\left\{a + \frac{b}{f} - cT - d\right\}\text{dBkm}^{-1} \qquad (1)$$

Where f is the frequency in Hz, a = 0.06×10^{6} dBkm^{2}g^{-1}s, b = 11.2×10^{6} dBkm^{2}g^{-1}s^{-1}, c = 0.022×10^{6} dBkm^{2}g^{-1} ºC^{-1}, d =

1347dBkm^{2}g^{-1}, T is the Temperature in ºC, and M is the fog density represented in terms of Visibility v (km) defined in equation **(2)**

$$M = \left\{\frac{0.024}{v}\right\}^{1.54} gm^{-3} \quad (2)$$

Equation (3) below was used in computing the signal strength:

$$s = \sqrt{\frac{\mu_o c P_{av}}{2\Pi R^2}} \quad (3)$$

Where $\mu_\circ$ is a constant given by 4πx10^{-7}, C= velocity of light, ρ_{av}= transmission power and R = distance from the radio antenna. Sharad (2004). We shall also use a new linear equation developed by Joseph (2015) to calculate the RF Refractivity, N, given by equation (4) below as

$$N = K \times P^2 \times \sqrt{T} \times \sqrt[3]{H} \quad (4)$$

Where P is the atmospheric pressure in Hg, K is a constant = 0.01064097915, T is the temperature in ºC, and H stands for relative humidity in %. According to Joseph (2015), equation (4) has an accuracy of± 5, and could be used in any climatic region.

Survey Region: TSBS radio broadcasting station is situated in Jalingo, Taraba State capital and broadcasts at a frequency of 90.6 MHz, with mast height of 152.4 m. The radio station operates for 15 hours in a day thus a suitable fit for this studies. The operational parameters of TSBS is shown in Table 1

Table 1: Functional specifications of TSBS Jalingo

System parameters	Stations
Receiver type	8 Bay dipole antenna
Range	250,000 meters
propagation frequency	90.6 MHz
propagating power	10 kW for AM and 2.5KW for FM
Mast Height	152.4 m
VSWR	0
Year of commissioning	1991

MATERIALS AND METHODS

In this research work the following materials of merit were considered; Constructed radio signal strength meter, Core I 5 Hp system, MATLAB programming Language, automatic stop watch and QGIS version 2.8 with map layer.

Configuration of Radio Meter: These were the items used in constructing the signal meter:

Capacitors: – 1 pF, 2 x 100 pF, 22 nF and 100 nF.

Resistive materials-2 x 2 K , 220 K , 2 x 100 K , 47 K , 10 k and 33k

Reactor – 14 × 12 turns

Semiconductors – PN3563, BC547

10 cm folded dipole antenna, 2 1N4148 Diodes, Voltmeter (0 – 10 V), 6 V Battery

Table 2: List of other Materials necessary for the construction

Material	Value	Quantity
Enameled wire	1-25cm	1
1SPDTminislideswitch	-	1
Jumper wires	-	1
Vero strip board	5x5 cm	1

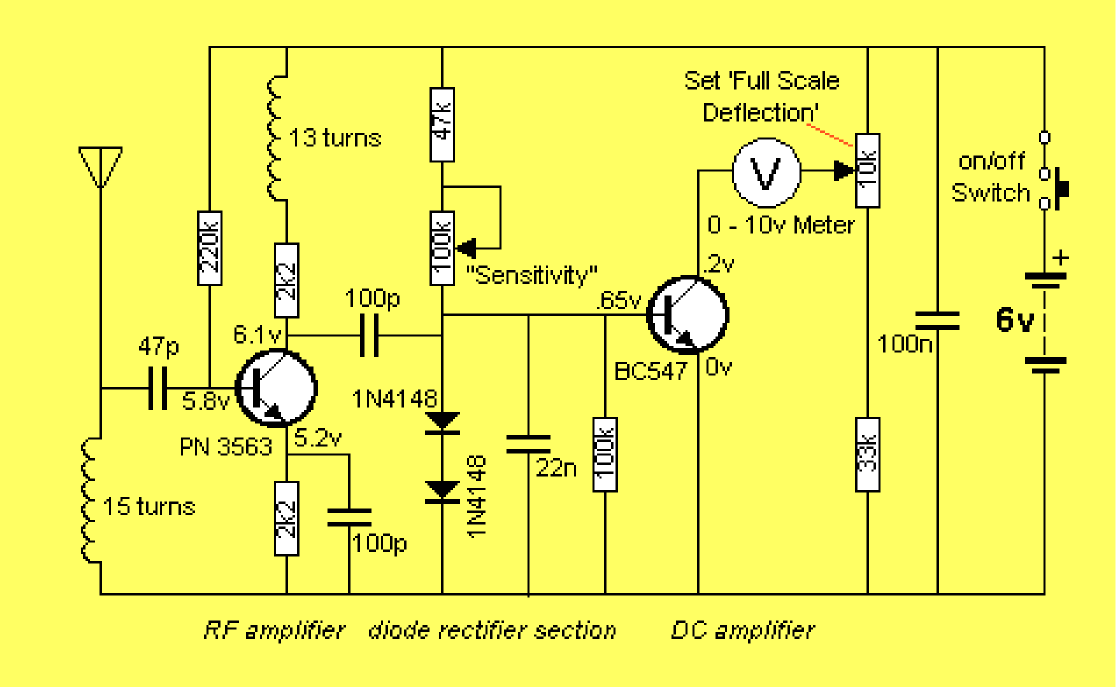

Figure 2: A circuit diagram of an RF signal meter

Circuit Description of Signal Strength Meter: The circuits basically consist of three sections as in Figure 2, the radio frequency the pn diode semiconductor and the direct current amp section.

The RF amplifier section is made of, inductor, transistor and capacitor of 1pf. The capacitor helps to detect the frequency of the radio station while the inductor tends to create voltage across the capacitor while the transistor amplifies any signal from 1pf.

Diode rectification section consist of two diodes that are responsible for rectification when forward biased with a 47k and 100k sensitivity control from the positive rail. The inductors and the capacitors are used to capture the RF TSBS Signal of 90.6MHz; Transistor PN3563 amplifies the RF signal from TSBS Jalingo. The two diodes in the RF section are to convert the alternating current to direct current signals; resistors to provide biasing. DC amplifier stage amplifies the DC fed into it from the diode rectifier section. Using Transistor BC547

Methods

According to Dajab (2006), there are different methods of evaluating weather effects on communication systems, namely mathematical analysis, computer simulations and measurement. Two methods were employed in this work; the mathematical analysis and computer simulations were carried out to compute the values of attenuation, refractivity and signal strength. Received signal strengths of TSBS covers up to a distance of 67km. The different distance points were along Jalingo to Zing route all in Taraba State, of North – Eastern Nigeria. The desired atmospheric parameters of minimum and maximum temperature, humidity, atmospheric pressure were collected from the NIMETS for a period of 2 years on monthly base so that it covers all the atmospheric conditions in both rainy and dry seasons.

The radio frequency signal strength meter was constructed based on the appropriate values of capacitor and inductor used to capture the frequency of TSBS in the circuit, was determined using:

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (5)$$

Where, f is the frequency of the broadcasting station is 90.6MHz, L is the inductance of the inductor used and C the Capacitance of the capacitor used. Since the frequency of the radio station is 90.6 MHz, an inductor of 3μH and capacitor of 1pf were used to capture the frequency of TSBS Similarly measurement of the radio signal with respect to time of the day for one day in April, 2023) were recorded and the readings were plotted

Table 3: Calculated values for Signal Strength at different Distances from TSBS Jalingo.

Linear distance (km)	Signal Strength(mv/m)	Signal Strength (dB)
20	3.87	-13.01
50	1.55	-16.99
70	1.11	-18.45
90	0.86	-19.54
120	0.65	-20.79
150	0.52	-21.76
180	0.43	-22.55
200	0.38	-23.01
220	0.35	-23.42
250	0.31	-23.98

Table 4: Obtained Record of hourly Radio Signal Strength of TSBS for 12/04/2023

Time (hours)	Signal strength(mV/m) (12/04/2023)
8:00 am	4.59
9:00 am	4.63
10:00 am	4.99
11:00 am	4.58
12:00 noon	6.52
1:00pm	7.00
2:00pm	7.10
3:00pm	9.23
4:00pm	9.30
5:00pm	8.16
6:00pm	8.21
7:00pm	8.10
8:00pm	7.21
9:00pm	8.54
10:00pm	8.00

Table 5: Calculated Average Monthly Refractivity values for the year May/ 2022 to April/ 2023at Minimum Temperature

Month	Minimum Temperature(ºC)	Atmospheric Pressure (Hpa)	Relative Humidity (%)	Refractivity
JAN	19.8	993.6	33	296.76
FEB	21.9	989.7	27	290.87
MAR	26.9	987.7	37	310
APR	28.7	989.2	51	336.75
MAY	26.8	989.4	70	358.5
JUNE	25.7	991.8	78	365.38
JUL	24.1	992.6	81	362.03
AUG	24.2	992.6	85	367.6
SEPT	23.7	992.5	82	361.43
OCT	24.4	991.6	76	356.72
NOV	21.7	991.6	55	322.44
DEC	20.6	995.0	37	301.84

Table 6: Calculated Average Monthly Refractivity values for the year May/ 2022 to April/ 2023 at Maximum Temperature

Month	Maximum Temperature(ºC)	Atmospheric Pressure(Hpa)	Relative Humidity(%)	Refractivity
JAN	33.6	993.6	33	319.44
FEB	39.0	989.7	27	318.60
MAR	39.9	987.7	37	348.57
APR	40.2	989.2	51	389.10
MAY	39.4	989.4	70	437.18
JUNE	35.1	991.8	78	423.21
JUL	33.3	992.6	81	416.36
AUG	31.8	992.6	85	413.28
SEPT	30.9	992.5	82	401.56
OCT	33.7	991.6	76	408.69
NOV	36.4	991.6	55	379.00
DEC	34.8	995.0	37	331.94

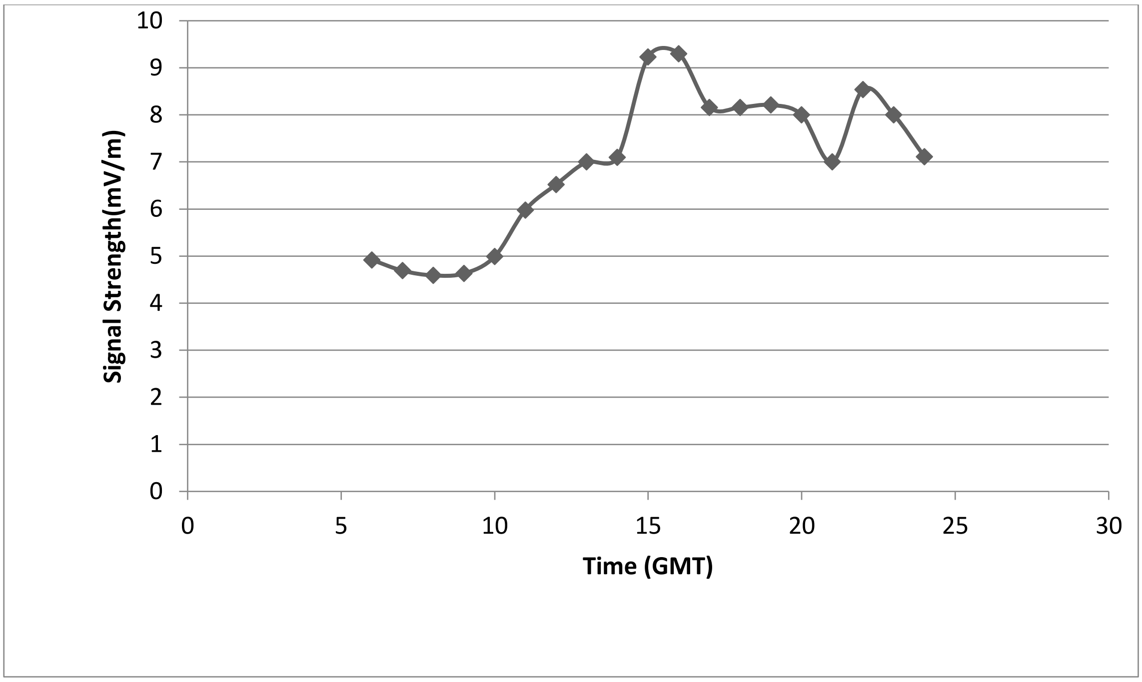

Figure 3: Variation of Signal Strength vs time, on hourly bases for (**12/04/2023**) located in Jalingo

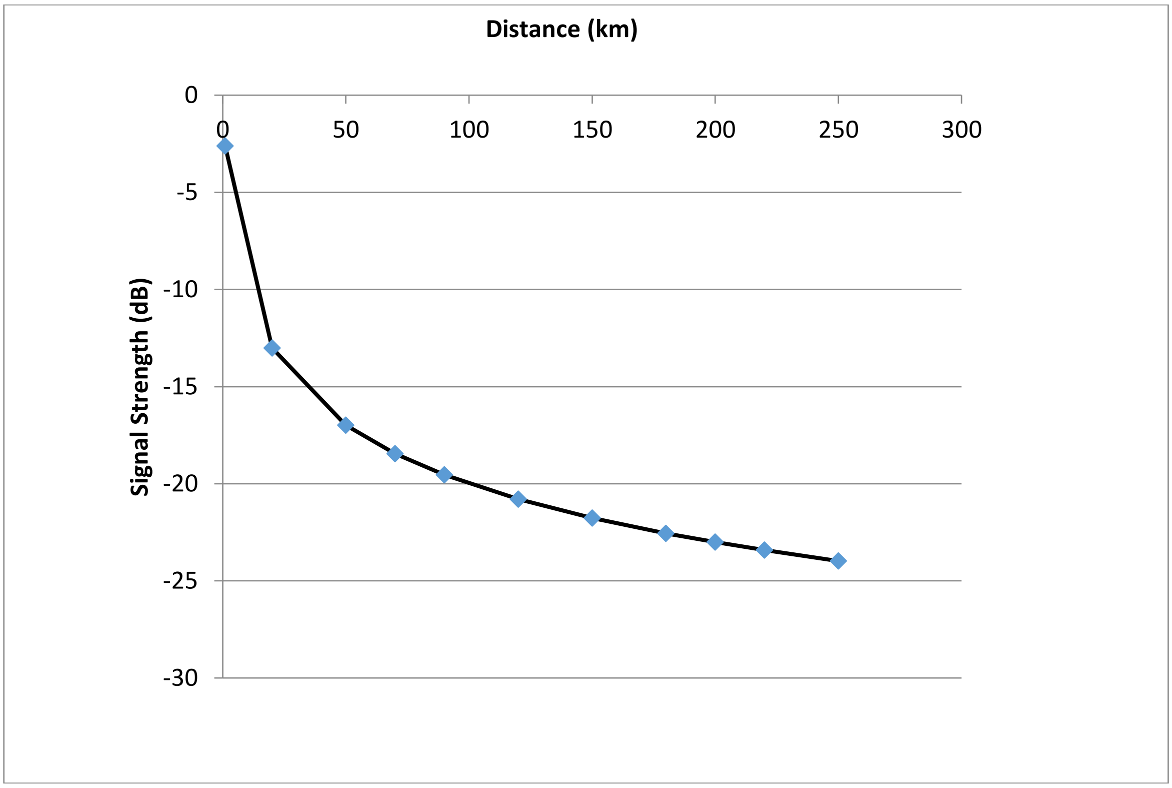

Figure 4: Graph of variation of signal strength (dB) against Distance (km).

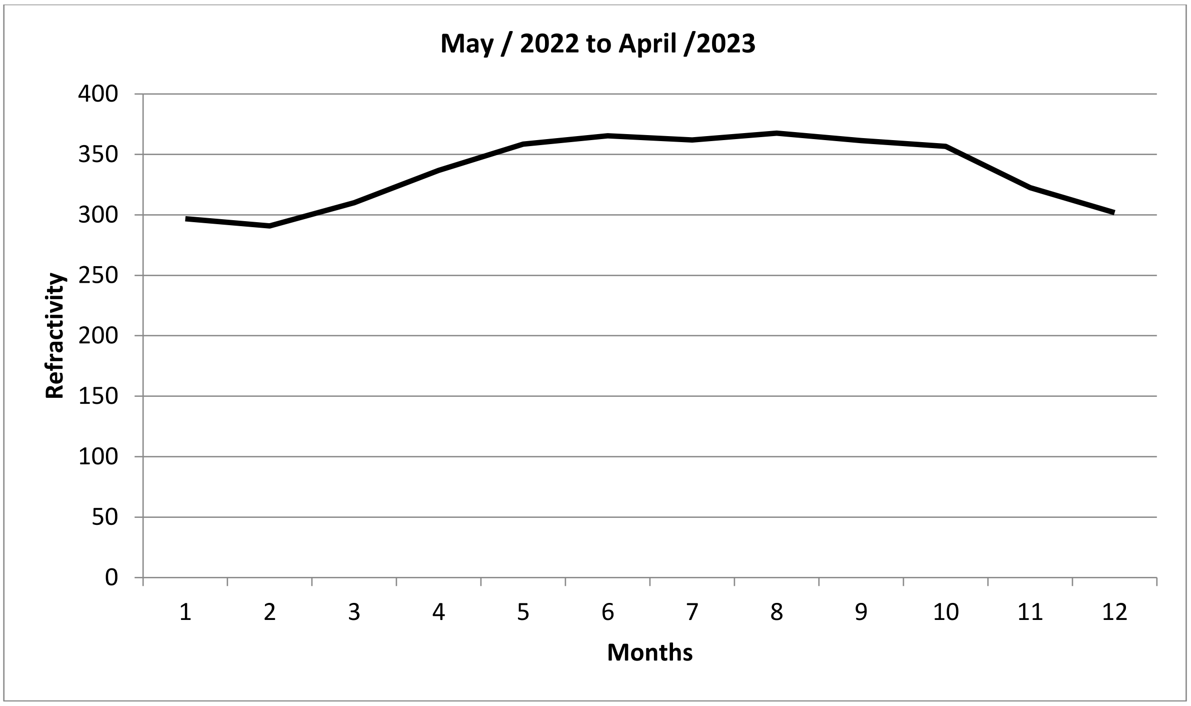

Figure 5: Graph of Refractivity of minimum Temperature for May/ 2022 to April/ 2023

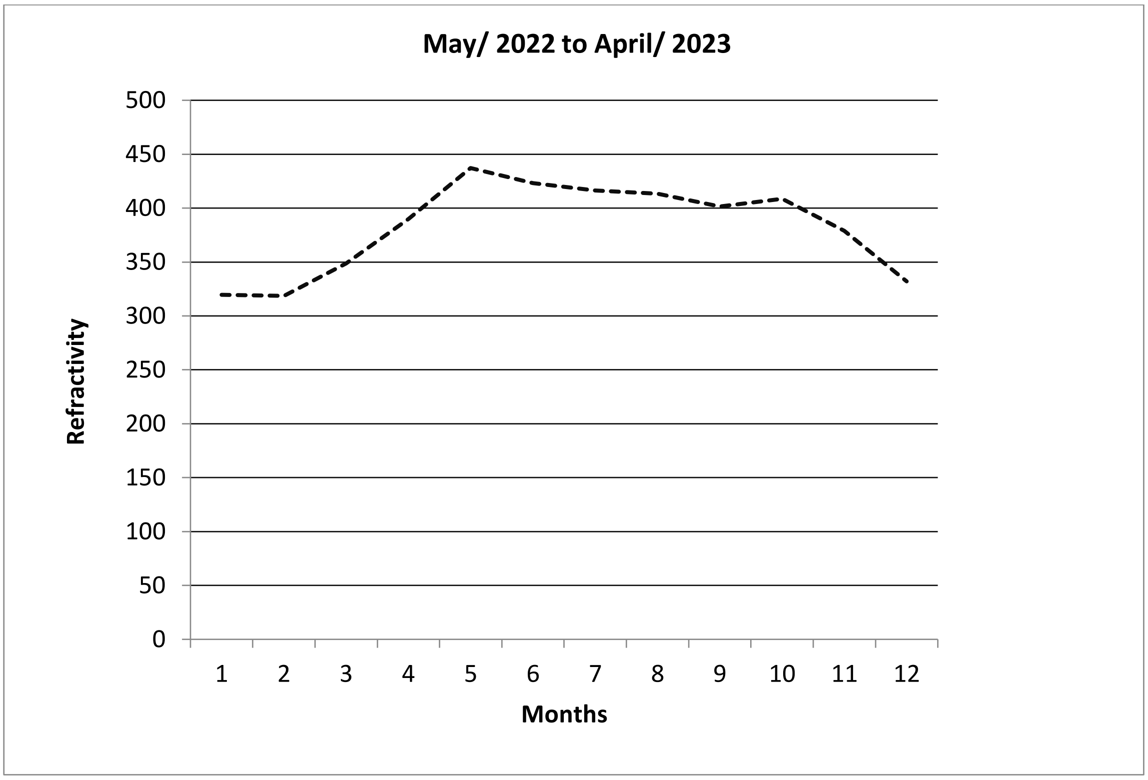

Figure:6 Graph of Refractivity of Maximum Temperature for May/ 2022 to April/ 2023

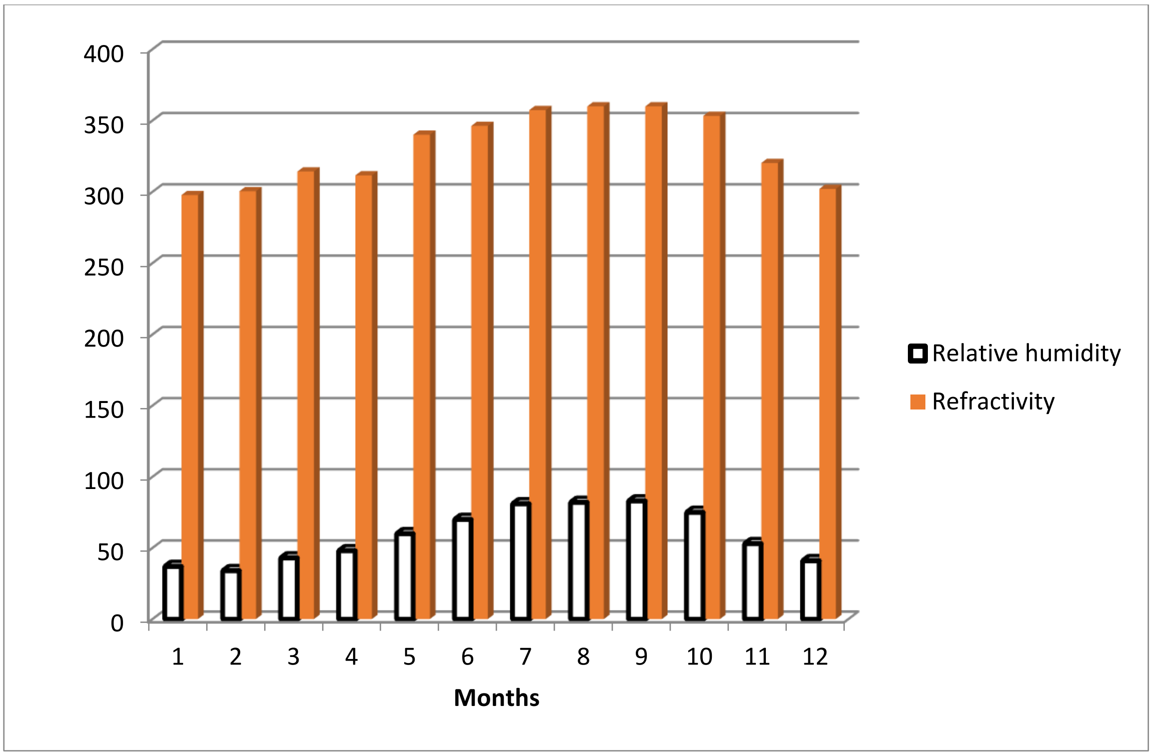

Figure 7: Bar chart of the variation of Relative Humidity and Refractivity for the year 2022 on monthly bases.

RESULTS AND DISCUSSIONS

During the computation and measurement of results, there are key atmospheric factors such as temperature, humidity, wind and heat intensity that perturbed the signal reception these observations when taken into cognizance gave our results a positive correlation between signal strength and distance over a period of time. Atmospheric conditions have a significant effect on refractivity. Table 3 is the calculated values for signal strength at different distances using equation (3) which is an ideal equation; and does not consider any atmospheric condition. However, it also shows that signal strength reduces with increase in distance both in volt per meter and in decibels the values were calculated based on a reference distance of 1 km. with value of 0.7746 (v/m) or -2.62 (dB)

Table 4 is the values of signal strength measured by using the constructed signal strength meter. The readings were obtained for a single day at different hourly time interval at TSBS Jalingo for a period between 8:00 am to 10:00 am. From the readings taken, significant change can be seen at various time of the day. It is observed that the computed signal strength varies inversely with linear distance, which justifies that atmospheric conditions attenuates radio signal strength. Our research work has shown the validity of the constructed signal meter as an index of numeric computation in radio systems transmissions.

Tables 5-6 show the refractivity values of the years 2014, 2015 and 2016 obtained for both minimum and maximum temperatures respectively. Figures 3 show the graph of signal strength plotted against time. Based on the graph, strength is high at around 16:00 hrs and lowest at 9:00 hrs and it does not follow any particular pattern just as in the works of Eyo *et al* (2013). This hourly variation of radio signal strength is independent of time of the day.Figure 5 and 6 is the graph of refractivity for the year 2022 for minimum and maximum temperature on monthly basis.

Based on the graph, it means that the refractivity values of higher temperatures are greater than those of lower values of temperature. Figure 5 shows that the refractivity values for the year 2022 at minimum temperature and show that in the month of September has the highest refractivity value of about 370, while around February has the lowest refractivity value of 280.

Figure 6 shows that the refractivity values for the year 2022 at maximum temperature and show that in the month of May has the highest refractivity value of about 470, while around February has the lowest refractivity value of 320 and at maximum temperature thus it can be observed that high refractivity leads to less radio wave propagation and vice versa. Figure 7 is the plot of relative humidity against refractivity and depends directly on relative humidity

CONCLUSION

Finally, based on this research work, atmospheric conditions such as temperature, atmospheric pressure and relative humidity and so on play a vital role in the transmission of radio signal attenuation and refractivity. The work has shown that the more the effects of the atmospheric conditions, the less radio wave can be propagated and the less the effect of the atmospheric conditions the more radio w**a**ve is being transmitted or propagated in the atmosphere which serve as the major transmission path of the radio waves thus in comparison with work done by Ekpe et al (2015) the average hourly variation of refractivity follow similar trends.

Most of the effects found in this work were based on the location in the north eastern region of Nigeria. It is an arid dry land and the people are mostly farmers and herders and solely depend on firewood for source of energy to cook. These factors have helped in enhancing the negative effect of these atmospheric conditions on the proper propagation of radio signal in the region. The work has succeeded in getting the Relationship between the atmospheric parameters and refractivity and also signal strength.

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REFERENCES

Dajab, D.D (2006). Perspective on the Effects of Harmattan on Radio Frequency Waves. *Journal of Applied Sciences Research*, 2(11): 1014-1018

Ekpe, O. E; Agbo, G. A. ;Ayantunji, B. G.; Yusuf, N and Onugwu, A. C. (2015). Variation of Tropospheric Surface Refractivity at Nsukka South Eastern Nigeria. *The Nigerian Journal of Space Research*. 7 (3): 42 – 48.

Eyo, O. E; Menkiti, I. A. and Udo, O. S (2003). Microwave Signal Attenuation in Harmattan Weather along Calabar – Akampkpa Line - of – Sight Link. *Turk. J. Physics* 27: 153-160

Grabner, M. and Kvicera, V. (2003). Refractive Index Measurement at TV Tower Prague. *Radioengineering*. 12 (1) 5 – 7

Joseph, A (2016). Impacts of Atmospheric Temperature on (UHF) Radio Signal. *International Journal of Engineering Research and general science*. 4(2): 619-622

Kennet B. (2008). Wireless sensor networking for hot applications: Effects of Temperature on Signal Strength. Data collection and localization: *Researchgate.net/publication*/229039635.

Luomala, J. and Hakala, I. (2015): Effects of Temperature and Humidity on Radio Signal Strength in Outdoor Wireless Sensor Networks. *Proceedings of Federal Conference on Computer Technology and Information System* Vol. 5 pp. 1247-1255

Nor H.S,W.A.Atiq S.S.Shahirah and I.A.Zainol,2015. The effects of solar radiation on Radio signal for Radio Astronomy purposes. Malaysian Journal of Analytical Sciences, 19(6)1394-2506.

Oluwole, J. F. and Olayinka, M. O (2013). A Test of the Relationship between Refractivity and Radio Signal Propagation for Dry Particulates. *Research Desk*, 2 (4): 334-338

Smith, S. and Weitramb, D. (1957). An Improved Equation for the Radio Refractive Index of Air. *Radio Science*, 9 (1): 803 - 807

Timptere, P; Ibrahim .Y. and Yabwa, D (2018): Correlation between radio signal strength and attenuation as a function of linear distance and time. World applied sciences Journal 36 (3): 434-440. Pp 434-440

The ARRL Handbook for Radio Amateurs 2001. 78th Ed. Ch. 21: 1-37.