ESTIMATION AND INVESTIGATION OF VARIABILITY OF TROPOSHERIC RADIO REFRACTIVITY AND RADIO FIELD STRENGTH OVER ZARIA, NIGERIA

BY:

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CERTIFICATION

This is to certify that this project was carried out by group A with the above names and matriculation numbers, submitted to the Department of Science Laboratory Technology, Physics/Electronics unit, Institute of Applied Science (IAS), Kwara State Polytechnic, Ilorin, in partial fulfilment for the requirement of the award of Higher National Diploma (HND) in Science Laboratory Technology (SLT).

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DEDICATION

This project research is dedicated to Almighty God the giver of life, for seeing me through my Higher National Diploma. And to my beloved parents, siblings, friends and also to peo ple who have contributed in one or the other to enable me accomplish this project work.

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ABSTRACT

In this study, the yearly and monthly variation of tropospheric radio refractivity and field strength variability was estimated using the monthly average of daily temperature, relative humidity and atmospheric pressure meteorological parameters during the period of eleven years (2013 – 2024). The results shows that higher values of monthly tropospheric radio refractivity were recorded during the rainy and dry seasons, respectively, with highest and lowest value in the month of the months of September and February with 340.0675 N-units and 270.0318 N-units, respectively. The highest and lowest annual average value of tropospheric radio refractivity were found in the year 2022 and 2015 with 318.93 N-units and 304.00 N-units respectively. The study area under investigation yields average gradient of -39.2031 N-units/km. Additionally, the average effective earth radius K was found to be 1.332. These values align with the condition of Sub-refraction propagation.

CHAPTER ONE

1.1 INTRODUCTION

Refractivity is defined as the physical property of a medium as determined by its index of refraction and it is responsible for the different phenomena in radio wave propagation which comprises of refraction and fading, ducting and scintillation, range and elevation errors in radar acquisition (D. . Akpootu & Rabiu, 2019). The radio refractivity is a physical phenomenon that affects the propagation of radio signals in the Atmosphere. This process takes place in the layer of the atmosphere called the troposphere, which extends from the earth surface to a height of about 10 km along the poles of the earth and 17 km as we move towards the equator. The refractivity itself is being affected by the tropospheric parameters (Temperature, Relative Humidity and Atmospheric Pressure) (Daniel Effiong Oku, Amajama Joseph, 2015). Changes in the Radio refractivity parameters often leads to an alteration of the refractivity pattern. Well documented is the fact that for a tropical climate characterized by two seasons, which are the dry and rainy seasons, Radio refractivity increases in the rainy season and drops in the dry season, as a result of the presence of more water vapor in the atmosphere (Oku, 2015). The behavior of radio waves in the tropospheric layer of the Earth’s atmosphere is very important in this modern age that is highly influenced by radio communications ranging from mobile telephoning through terrestrial digital broadcasting to the propagation of satellite radio signal through the troposphere (Abimbola, 2021). Radio wave is a very important component of our civilization it is used for point to point communication as well as for data exchange (Falaiye et al., 2016). The structure of the radio refractive index, n, at the lower part of the atmosphere is a very important parameter in planning of the communication links. It is defined as a ratio of the radio wave propagation velocity in free space to its velocity in a specified medium (Valma, 2011). It is a well-established fact that radio wave in the Very High Frequency (V.H.F)., Ultra High Frequency (U.H.F)., and Super High Frequency (S.H.F) bands propagating through the troposphere can be greatly influenced by the variations in the tropospheric weather condition (Onujagbe, 2021). The composition of the atmosphere has a significant impact on radio wave signal transmission in the lower atmosphere, or troposphere (Bello et al., 2024). Increased dependence on radio communication in Nigeria through the use of communication technologies such as laptops, smartphones and computers 1in our day to day life ease the way of doing businesses and social activities such as mobile banking, e-businesses, access to news and usage of social media (Sa’adu et al., 2020).

1.2 STATEMENT OF PROBLEM

The troposphere plays a critical role in the propagation of radio waves, particularly in the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands, which are widely used for communication and broadcasting. Radio refractivity, a key parameter in tropospheric r adio wave propagation, is influenced by meteorological factors such as temperature, pres sure and humidity. Variability in these meteorological parameters can lead to significant fluctuations in radio refractivity, which in turn affects radio field strength and signal quali ty. In regions like Zaria, Nigeria, where meteorological conditions exhibit seasonal and diu rnal variations, understanding the behavior of tropospheric radio refractivity and its impa ct on radio field strength is crucial for optimizing communication systems.

Despite the importance of this phenomenon, there is limited research on the estimation a nd investigation of both daily and monthly tropospheric radio refractivity and its variabilit y over Zaria, Nigeria at the same time. Existing studies in other regions may not accuratel y reflect the local conditions due to differences in climate, topography, and atmospheric d ynamics. This gap in knowledge poses challenges for the design and optimization of reli able communication networks in the area. Furthermore, the lack of localized data on radi o field strength variability hinders the ability to predict signal degradation and implement effective mitigation strategies.

1.3 SIGNIFICANCE OF STUDY

Estimation and Investigation of Variability of Tropospheric Radio Refractivity and Radio Field Strength over Zaria, Nigeria" holds significant importance for both scientific and pra ctical applications, particularly in the fields of meteorology, telecommunications, and rad io wave propagation. This study will provide a comprehensive understanding of troposph eric radio refractivity and its variability, as well as its implications for radio field strength over Zaria, Nigeria. The results will contribute to the development of more reliable and eff icient communication systems in the region, particularly in the face of changing climatic conditions. It will also help in determining the performance of radio communication syste ms. Variability in radio refractivity can lead to signal fading, interference, and loss. This w ill provides data and models that can help engineers and researchers develop strategies t o mitigate these issues, ensuring more reliable communication networks. The result findi ngs can inform policymakers and regulatory bodies in Nigeria about the challenges and opportunities related to radio communication in the region, which can lead to better plan ning and allocation of resources for communication infrastructure development.

1.4 AIM AND OBJECTIVES

Aim:

To estimate and investigate the variability of tropospheric radio refractivity and radio fiel d strength over Zaria, Nigeria, and assess their implications for radio communication sys tems while the specific objectives are to:

OBJECTIVES:

1. Collect and analyze meteorological data (temperature, pressure, and humidity) require d for the computation of tropospheric radio refractivity over Zaria,

2. Estimate the tropospheric radio refractivity and its seasonal variations in the study are a,

3. Investigate the relationship between meteorological parameters and radio refractivity,

4. Evaluate the variability of radio field strength and its dependence on tropospheric radio refractivity,

5. Provide recommendations for optimizing radio communication systems in the region based on the findings and

6. Compare the results with existing models and studies in other regions to identify uniq ue characteristics of Zaria's tropospheric conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

(D. Akpootu & Iliyasu, 2017) estimated tropospheric radio refractivity under varying mete orological conditions in Ikeja, Nigeria. The results indicated that an average value of 385. 99 N-units and an average value of 382.94 N-units were observed during the rainy and dr y seasons respectively. (D. . Akpootu & Rabiu, 2019) developed empirical models for esti mating tropospheric radio refractivity for Zaria, Nigeria, using meteorological parameter. The study showed that radio refractivity with relative humidity was found more suitable f or the one variable correlation.

(Academy et al., 2024) provided valuable insights into the behavior of vertical radio refrac tivity gradients in the lower atmospheric layer across different cities in Nigeria. The findin gs contribute to a deeper comprehension of how atmospheric factors influence radio sig nals behavior and propagation paths, thus aiding in the optimization of communication networks and signal reliability under varying meteorological conditions.

(Onujagbe et al., 2021) observed that surface radio refractivity over Zaria mean monthly values of the surface refractivity, Ns for the Zaria station were observed to be generally hi gh. The implication of this is that radio wave propagating through the atmosphere will be nd closer towards the earth surface.

(X. Zou, Y H. Kuo, 1995) monthly average radio refractivity of Zaria, latitude 13.030 N, Lo ngitude 5.20 E and elevation 270.0 m, Ikeja, latitude 6.580

N, Longitude3.330E and elevation 4.0 m, and Niger, latitude 7.80 N, Longitude 6.730E and elevation 128.0m have been determined using the data of temperature, pressure and relat ive humidity for ten years (1971 to 1980) of NIMET. The result showed that there was vari ation in the radio refractivity of the study areas but more noticed in Niger compared to

Ikeja and Lokoja

2.1 TEMPERATURE

Temperature is a measure of the average kinetic energy within a body. It describes the pot ential for heat energy to move from one body to another down a gradient from an area of

high temperature to an area of lower temperature. It is measured using a temperature sca le which is defined against fixed physical events such as absolute zero or the triple point of water (Gardner, 2020). A thermometer is a device that has some property that changes with temperature so that, when properly calibrated, it can be used to measure temperatur e. One such device could be a mercury-in-glass thermometer. As the temperature of the m ercury increases the mercury expands and this expansion in the glass is a measure of the temperature (Halliday et al., 2005).

2.2 RELATIVE HUMIDITY

Relative humidity (RH) indicates the amount of water vapor (percent) that's actually in th e air compared to the maximum amount that the air could hold under the same condition s. The warmer the air, the more moisture it can hold (Aprilaire, 2013).

2.3 WATER VAPOR

Water vapor is one of the gases in air. Unlike nitrogen and oxygen which are constant in t he bottom 100 km of the atmosphere, water-vapor concentration can vary widely in time and space. Most people are familiar with relative humidity as a measure of water-vapor c oncentration because it affects our body's moisture and heat regulation. But other humidi ty variables are much more useful in other contexts. Storms get much of their energy fro m water vapor when water vapor condenses or freezes it releases latent heat. For this rea son we carefully track water vapor as it rises in buoyant thermals or is carried by horizont al winds. The amount of moisture available to a storm also regulates the amount of rain or snow precipitating out. What allows air to hold water as vapor in one case, but forces t he vapor to condense in another? This depends on a concept called "saturation" (Wang, 2 017).

2.4 SATURATED WATER VAPOR

A saturated vapor is a vapor that is in contact with its own liquid within a confined space. When the enclosed space above a liquid is saturated with vapor molecules and can hold no more molecules, the pressure exerted by this saturated vapor is said to be the saturate d vapor pressure (s. v. p) of the liquid. The vapor is said to be saturated when the number of molecules escaping from the liquid per unit is equal to the number returning to the liqu id per unit time. The saturated vapor is thus said to be in a state of dynamic equilibrium with its own liquid. Saturated vapor pressure increases with temperature (Ummah, 2019).

2.5 ATMOSPHERIC PRESSURE

The air around you have weight, and it presses against everything it touches. That pressu re is called atmospheric pressure, or air pressure. It is the force exerted on a surface by th e air above it as gravity pulls it to Earth. Atmospheric pressure is commonly measured wit h a barometer. In a barometer, a column of mercury in a glass tube rises or falls as the we ight of the atmosphere changes. An atmosphere is a unit of measurement equal to the av erage air pressure at sea level at a temperature of 15 degrees Celsius. One atmosphere is 760 millimeters of mercury (Atkinson & Aschmann, 1985)

CHAPTER THREE

3.1 STUDY AREA

The study area is Zaria, Kaduna State, Nigeria. It is one of the aviation campus representi ng the North-West aviation college. It is located between Latitude 11° 0'N and 11° 10'N a nd between Longitudes 7º34'E and 7º48'E. It comprises two Local Government Areas (LG As) of Sabon-Gari and Zaria. Bounded to the west and North- west by Giwa LGA, to the S outh by Igabi, to the North- east by Kudan, and to the South-east by Soba L.G.A of the Sta te. The study area is characterized by tropical continental climate (the Koppen's Aw clima te), with two well pronounced seasons (i.e. wet and dry) (Hazo et al., 2020).

3.2 DATA ACQUISATION

The data used for this study were 11-year period (2013 to 2024) of daily temperature, at mospheric pressure and relative humidity and 9- years (2013-2022) of the Monthly avera ge temperature, atmospheric pressure and relative humidity of the study area. The data w ere retrieved from the archive of the Nigeria Meteorological Agency (NIMET) Oshodi, Lag os, Nigeria.

3.3 THEORETICAL BACKGROUND

N = Refractivity, measured in N-unit

$$N = \frac{77.6}{T}\left(P + 4810\,\frac{e}{T}\right) = N_{dry} + N_{wet} \quad \text{……………………. (1)}$$

Expand to get N_{dry} and N_{wet}

With the "dry term" of radio refractivity given by:

$$N_{dry} = 77.6\,\frac{p}{T} \quad \text{……………………………………………… (2)}$$

With the "wet term" of radio refractivity given by:

$$N_{wet} = 3.73\times10^{5}\,\frac{e}{T^{2}} \quad \text{…………………………………… (3)}$$

Where P= Atmospheric Pressure (hPa)

T= Absolute Temperature (K)

e= Water Vapour (hPa)

The relationship between water vapour pressure (e) and relative humidity (RH) is given by the expression:

e= $\frac{He_s}{100}$ ………………………………………………… (4)

Where H = Relative Humidity

e_s = Saturated Water Vapor

$e_s = a\ \exp\ (\frac{bt}{t+c})$ ………………………………… (5)

Where, a = 6.1121

b = 17.502

c = 24097

t = Temperature (℃)

Refractivity Gradient:

The radio refractivity N, also decrease exponentially in the troposphere with height:

N_o = N_s exp ($\frac{h_o}{H}$) OR N_s = 315$\exp^{-0.136h}$

Where, N_s = Refractivity at surface of the earth

N_o = Average values of atmospheric extrapolated to sea level

h_o = Height of the earth's surface above sea level

H_o = Scale height = 7.35km

$\frac{dN_o}{dh}$ = $\frac{-N_s}{H_o}$ exp($\frac{-h_o}{H_o}$) refractivity gradient

Thus, k may be expressed in terms of refractivity gradient, dN/dh as:

K = [1+ $\frac{(\frac{dN}{dh})}{157}]^{-1}$ ………………………………………… (6)

FSV – Field Strength Variation =

($N_{s(max)}$ - $N_{s(max)}$) $\times$ 0.2 d_b ……………………… (7)

d_b= decibel

CHAPTER FOUR

4.1 RESULTS AND DISCUSIONS

Radio refractivity and its variation with other meteorological parameters

Figure 1 shows the yearly variation of radio refractivity for Zaria, Nigeria during the period under investigation. The figure shows fluctuations in the pattern of variation which is attr ibuted to the yearly variation of atmospheric weather parameters. The highest yearly aver age value of 16.05 N – units was observed in the year 2014 and the lowest yearly averag e value of 11.09N – units in 2013.

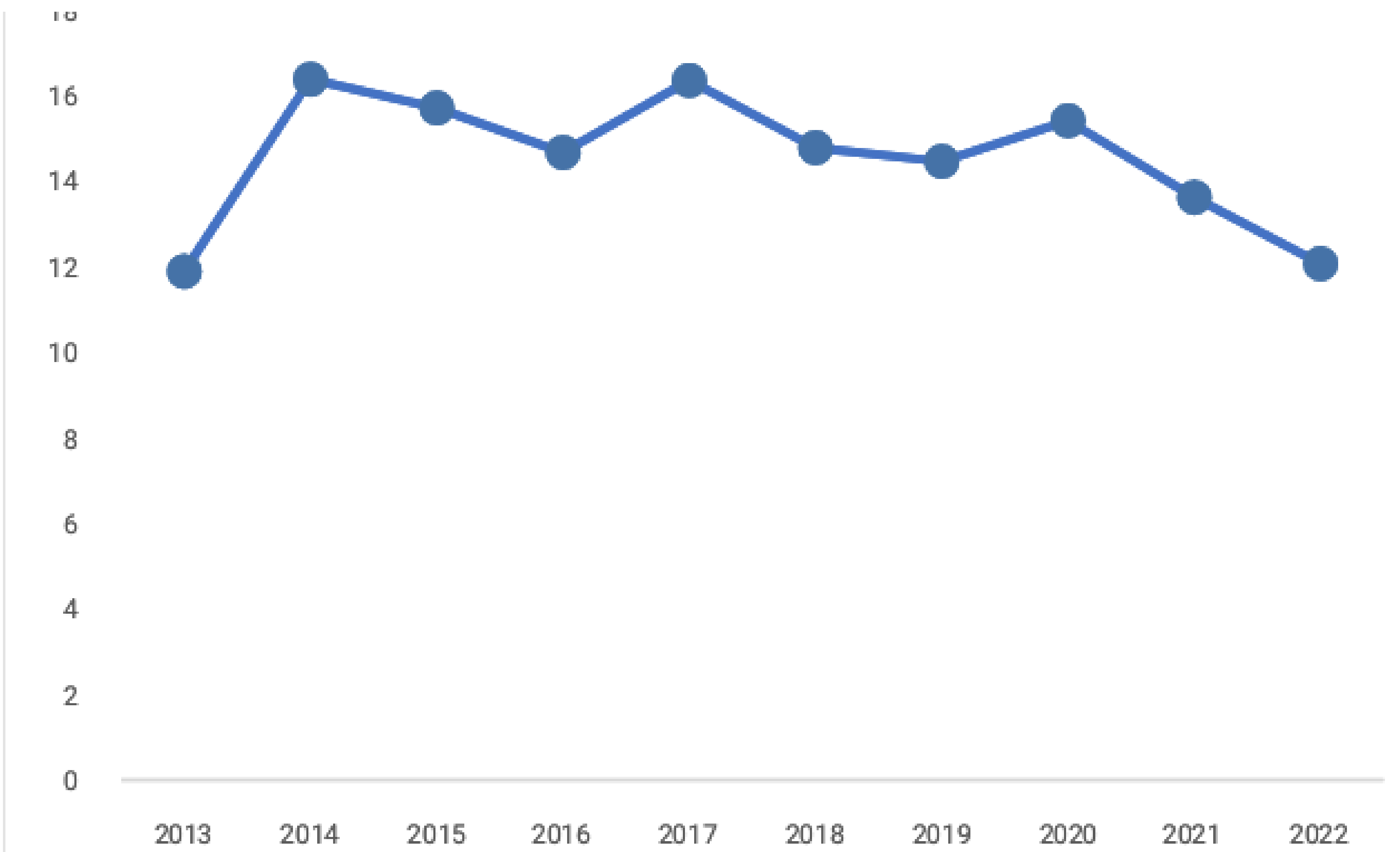

FIG 1

FIG 1: Yearly variation of radio refractivity over Zaria, Nigeria

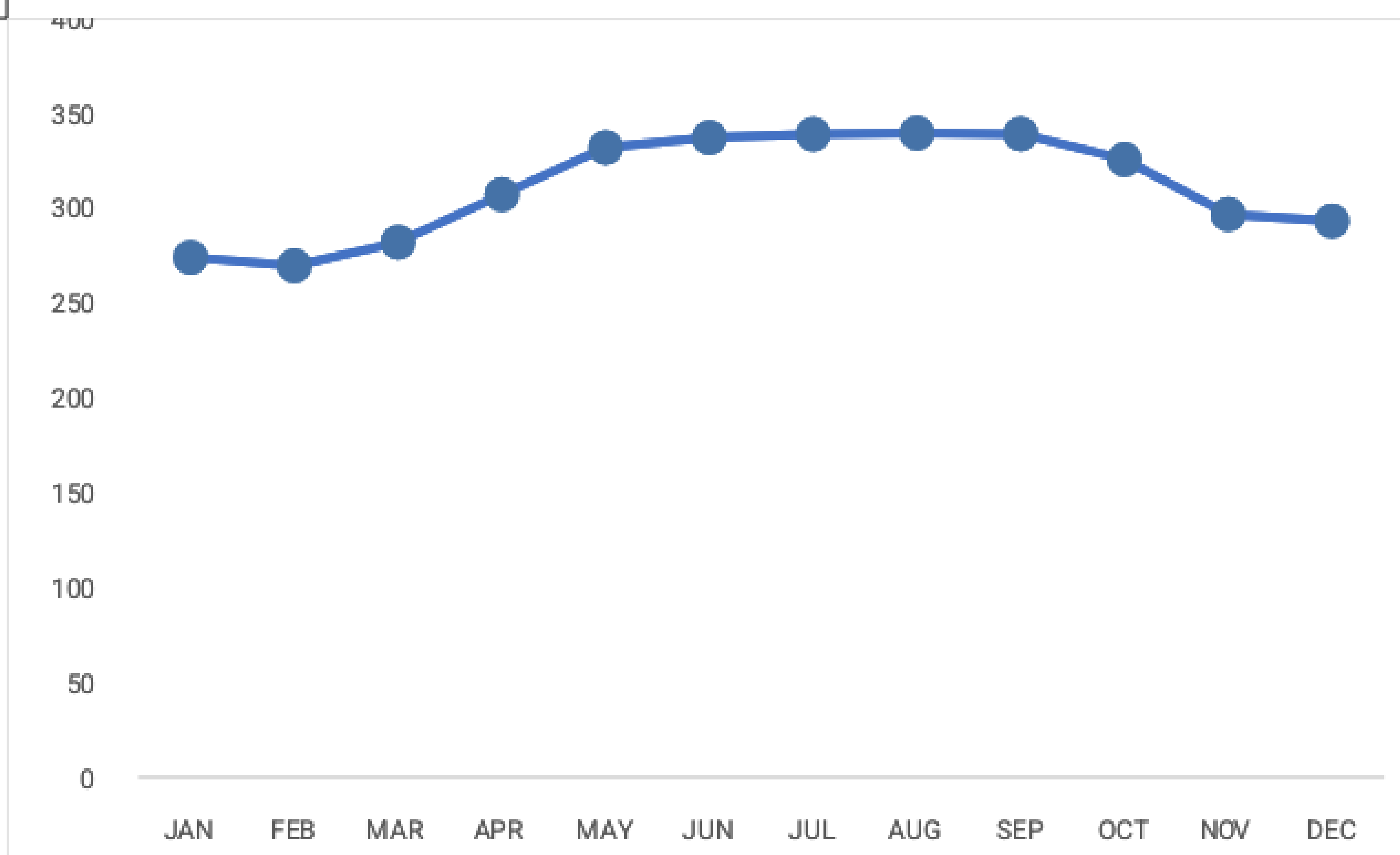

FIG 2

Fig. 2: Variation of Mean monthly surface refractivity value for Zaria

The mean monthly refractivity value at the Zaria station was observed to increase slowly from its minimum value of 270.0318 N-units in the month of February through March an d thereafter rose sharply through April to its maximum value of 340.0675 N-units in Septe mber; it however decreases slowly through the month of October till decreases sharply thr ough December.

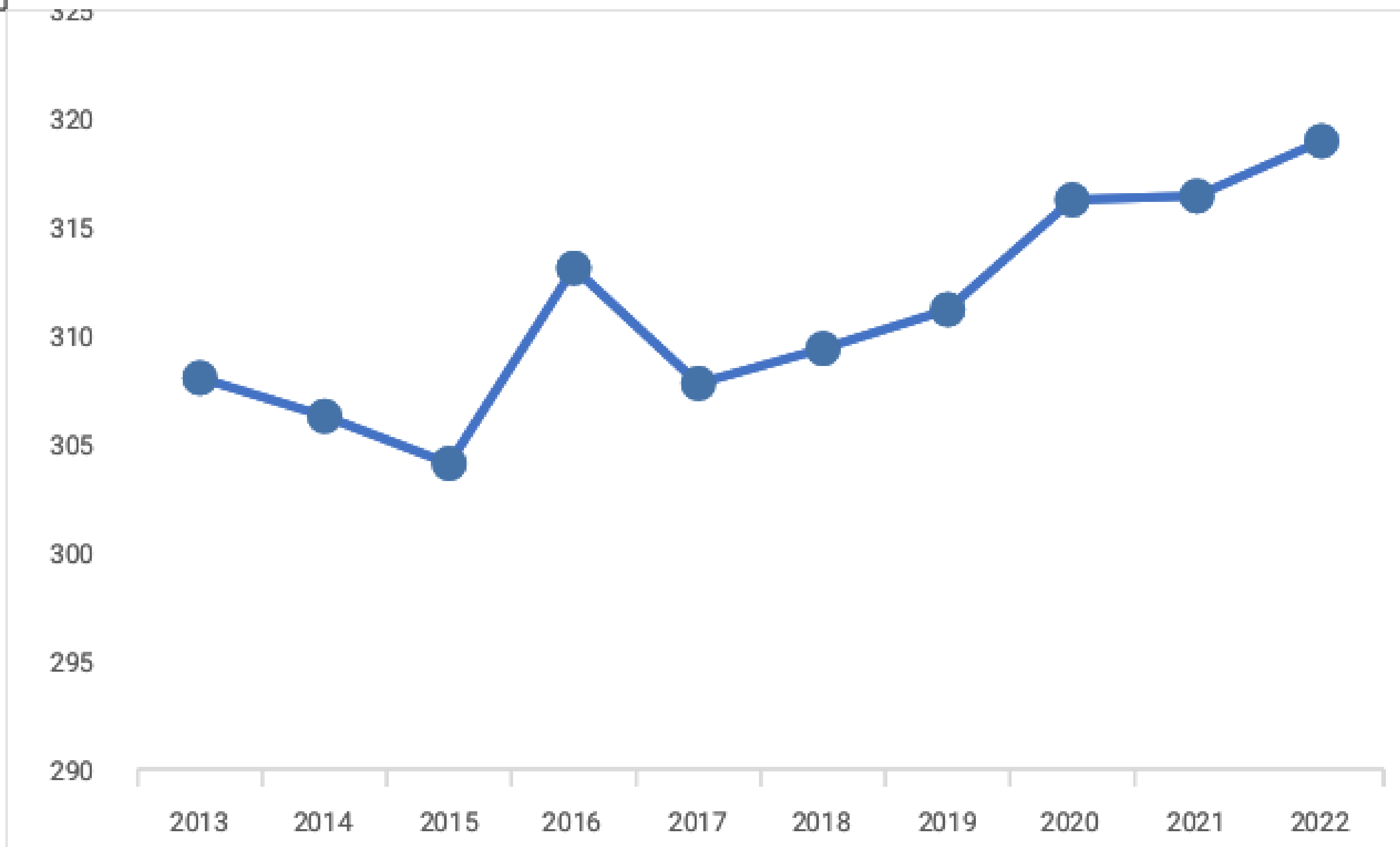

FIG 3

Fig. 3: Variation of Mean yearly surface refractivity value for Zaria

The mean yearly refractivity value at the Zaria station was observed to increase slowly fr om its minimum value of 304.0778N-units in the year 2015 and thereafter rose sharply to its maximum value of 318.9371 N-units in the 2022.

CONCLUSION

The international telecommunication union (ITU) method has been employed to estimate the yearly and monthly tropospheric radio refractivity over Zaria, Nigeria using meteorological parameters of temperature, relative humidity and atmospheric pressure during the period of eleven years (2013 – 2024). The yearly and monthly variations of radio refractivity was also studied. The refractivity gradient, and the field strength variability were also reported. The results in this study revealed that slightly higher values of monthly tropospheric radio refractivity were recorded in the rainy season than in the dry season with the highest and lowest values in the month of February and September with 340.0675 N-units and 270.0318 N-units respectively. The highest and lowest annual average values of tropospheric radio refractivity were found in the year 2022 and 2015 with 318.93 and 304.00 N – units respectively.. The refractivity gradient and effective earth radius found for Zaria, Nigeria during the period under investigation were -39.2031 N-units/km indicating that the propagation in this region is mostly Sub-refraction. This is also supported by the value of effective earth radius, which is less than 4/3 The highest and lowest values of field strength variability (FSV) was estimated in the year 2014 and 2014 as 16.37 dB and 11.88 dB respectively.

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