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Variations of Tropospheric Radio Wave Refractivities across Southern Nigeria – the Rainforest to Mangrove

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***Abstract*— The variations of tropospheric radio wave refractivities in eleven (11) cities across the rainforest and mangrove in Southern Nigeria has been examined. Data abstracted from Weather API (Weather2), Yr. no and NIMET (Nigeria meteorological agency) websites has been analyzed. Generally, there was an increase in the average tropospheric radio wave refractivities as one confronts the coastline of the Atlantic Ocean. This indicates that, gradually tropospheric radio wave propagation worsens towards the Atlantic Ocean. The correlation between the average tropospheric radio wave refractivities and the perpendicular distances away from the coastline of the Atlantic Ocean was 0.79 with an approximate model of y = -0.0694x + 380.93. The correlation was not absolute because of the non-uniformity of the weather patterns across the Southern Nigeria. Reliefs and rivers account for some of the anomalies in the non-uniform trends. More so, isotherms and isohume in the weather map are non-linear and can cut across the rainforest and mangrove belts. By and large, results registered that the mangrove will record slightly better signal stability than the rainforest due to steadier average tropospheric radio wave refractivity, but will record higher degradation/dissipation of tropospheric radio signal due to its short proximity to the Atlantic Ocean and consequent;y, very high humidity. Finally, the dry will favour radio signal propagation through the troposphere better than the wet due to slight reduction in mean monthly relative humidities which is the weightiest component in atmospheric radio wave refractivity.**

***Index Terms*— Variation, Troposphere, radio wave, refractivity, Rainforest, Mangrove and Southern Nigeria.**

I. Introduction

Science literatures have shown that weather components: atmospheric pressure, atmospheric temperature, atmospheric humidity and even wind (if direction is contrary to the travelling radio wave) bear negatively on radio waves, invariably radio signals as it travels through the atmosphere (troposphere) [1] [2] [3] [4] [5]. Mathematically, atmospheric radio wave refractivity is a function of atmospheric pressure, atmospheric temperature and relative humidity [6]. The atmospheric temperature, atmospheric pressure and relative humidity vary inversely as the atmospheric radio wave refractivity [6]. Generally, atmospheric radio wave refractivity varies inversely as radio signal or wave. However, research has also shown that the wind direction has a slight negative impact on the association between Radio signals and refractivity [7].

Without tropospheric radio wave refractivity, it will be near impossible for radio waves or signals to propagate round the globe [8]. The atmosphere as a channel bends the radio wave back to the earth after being transmitted into space from an earth station [8] [9] [10] [11]. Every atmosphere is a channel with a characteristic resistance or impedance that depends upon the weather of a place and/or climate. From science lexicon weather is the atmospheric condition within an area [12], while climate is the weather condition over a period of time in an area [13]. Meteorologically, atmospheric pressure, atmospheric temperature, relative humidity and wind account for the weather of a place and invariably climate.

Southern Nigeria is divided into several climatic belts depending on its vegetations [14]. The vegetation of a place is a mirror of the state of the atmosphere of that place and invariably the weather or climate of that place. The different vegetative climatic belts in Southern Nigeria are predominantly: Rainforest, Mangrove (freshwater and saltwater types) and Montane [14].

Southern Nigeria falls on the tropical plate of Africa and lies in the neighbourhood between longitudes 4^0 00′ 00″ E and 14^0 00′ 00″ E and latitudes 3^0 00′ 00″ N and 7^0 00′ 00″ N respectively [14]: a location slightly above the equator.

The focus of this research narrows on the investigation of the variation of the tropospheric radio wave refractivities across Southern Nigeria; from the rainforest belt, through to the mangrove belt and the relatively striking montane or mountain or alpine regions.

The relevance of the work is to establish the better belt suitable for radio wave propagation and the worse. More so, it intends to probe and draw a verdict on which atmospheric or climatic conditions are favourable for radio wave propagation through the troposhere, since Nigeria generally has predominantly two seasons: the wet and the dry and they both have characteristic different atmospheric conditions.

II. A Literature Review of the Climate of Southern Nigeria

The Tropical monsoon climate is found in the Southern Nigeria. This climate is influenced by the monsoons

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originating from the South Atlantic Ocean, which is brought into the country by the maritime tropical air-mass, a warm moist sea to land seasonal wind. Its warmth and high humidity gives it a strong tendency to ascend and produce copious rainfall, which is a result of the condensation of water vapour in the rapidly rising air [15].

The Tropical monsoon climate has a very small temperature range. The temperature ranges are almost constant throughout the year. On the average, the southern part of Nigeria, records a maximum of 28 °C (82.4 °F) for its hottest month while its lowest temperature is 26 °C (78.8 °F) in its coldest month. The temperature difference is not more than 2 °C (5 °F) [15].

The southern part of Nigeria experiences heavy and abundant rainfall. These storms are usually convectional in nature due to the regions proximity to the Equator. The annual rainfall received in this region is very high, usually above the 2,000 mm (78.7 in) rainfall totals giving for tropical rainforest climates worldwide. Over 4,000 mm (157.5 in) of rainfall is received in the coastal region of Southern Nigeria. The coastal region of the Niger delta area in southern Nigeria receives well over 4,000 mm (157.5 in) of rainfall annually. The rest of the southern Nigeria receives between 2,000 and 3,000 mm (118.1 in) of rain per year [15].

The southern region of Nigeria experiences a double rainfall maxima characterized by two high rainfall peaks, with a short dry season and a longer dry season falling between and after each peaks. The first rainy season begins around March and last to the end of July with a peak in June, this rainy season is followed by a short dry break in August known as the August break which is a short dry season lasting for two to three weeks in August. This break is broken by the Short rainy season starting around early September and lasting to Mid October with a peak period at the end of September. The ending of the short rainy season in October is followed by Long Dry Season. This period starts from late October and lasts till early March with peak dry conditions between early December and late February [15].

Southern Nigeria, like the rest of Nigeria and other tropical lands, has only two seasons. These are the Dry season and the Rainy season. The dry season is accompanied by a dust laden air-mass from the Sahara Desert, locally known as Harmattan, or by its main name, The Tropical Continental air-mass or North East trade winds, while the rainy season is heavily influenced by an air-mass originating from the South Atlantic Ocean, locally known as the south west wind, or by its main name, the Tropical Maritime air-mass. These two major wind systems in Nigeria are known as the trade winds [15].

Montane Climate or Alpine climate or highland climate or mountain climate are found on highlands regions in Nigeria generally. Highlands with the montane climate in Nigeria are well over 1,520 metres (4,987 ft) above sea level. Due to their location in the tropics, this elevation is high enough to reach the temperate climate line in the tropics thereby giving the highlands, mountains and the plateau regions standing above this height, a cool mountain climate. One of the Southern Nigeria cities with such a climate as mentioned above is Obudu [15].

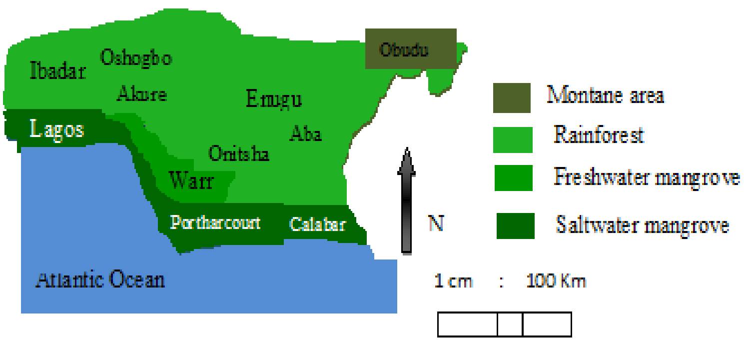

Fig. 1. The map of Southern Nigeria showing the locations of the various cities on the rainforest and mangrove belts.

III. Methodology

Relevant data for mean monthly weather parameters was accessed from Yr. no, Weather2 and NIMET (Nigeria Meteorological Agency) websites. The radio wave refractivity was computed using the Eqn. 1 below [14].

$$N = K \times P^2 \times \sqrt{T} \times \sqrt[3]{H} \quad (1)$$

Where K = Constant = 0.01064097915

P = Atmospheric pressure in inHg

T = Atmospheric temperature in ^{0}F

H = Relative humidity in %

N = Radio refractivity

The above formulation has an accuracy of ±5 in comparison with the existing International Telecommunication Union (ITU) expression for calculating Radio refractivity. The ITU expression may be used for all radio frequencies: for frequencies up to 100 GHz, the error is less than 0.5 % [16].

IV. Results and Analysis

The Figs. 2, 3, 4, 5 and 6 show the comparison between the average monthly tropospheric radio wave refractivities of all cities; comparison between average monthly tropospheric radio wave refractivities of the cities in the wet; comparison between the average monthly tropospheric radio wave refractivities of the cities in the dry, relationship between perpendicular distance away from the Atlantic Ocean and average tropospheric radio wave refractivity and line of best fit between perpendicular distance away from the Atlantic Ocean and average tropospheric radio wave refractivity respectively. The legends series of the cities in the figures below are in order of increasing magnitude of average tropospheric radio wave refractivity from the bottom to the top.

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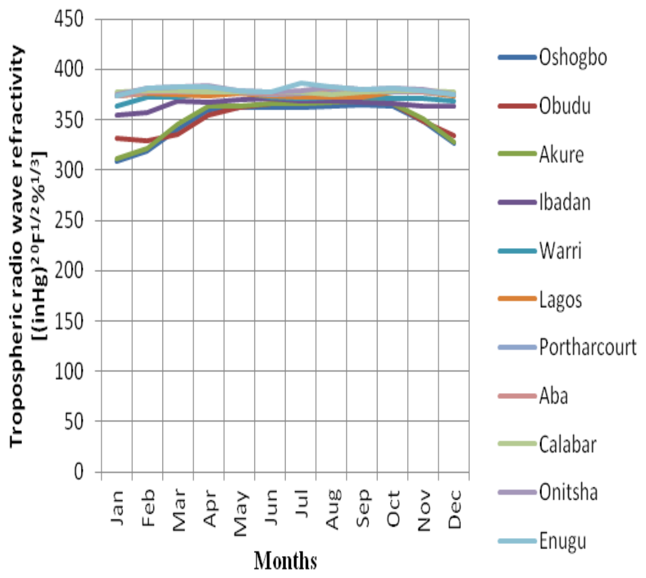

Fig. 2: Tropospheric radio wave refractivities of the cities throughout the year

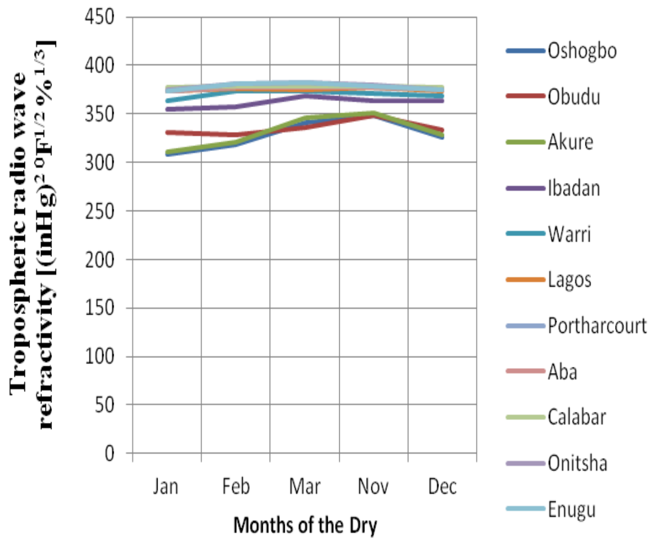

Fig. 3: Tropospheric radio wave refractivities of the cities in the dry

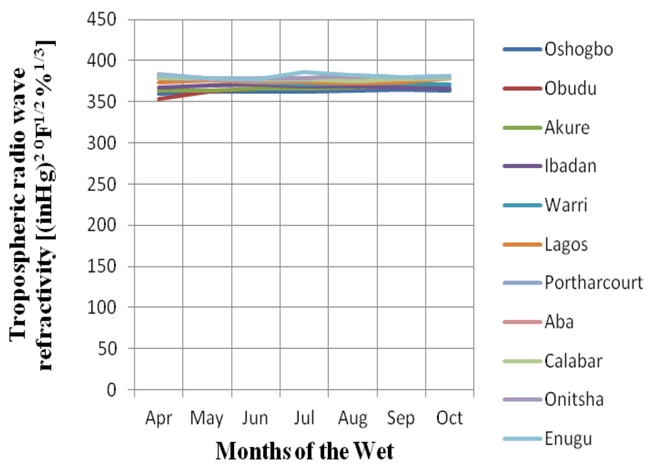

Fig. 4: Tropospheric radio wave refractivities of the cities in the wet

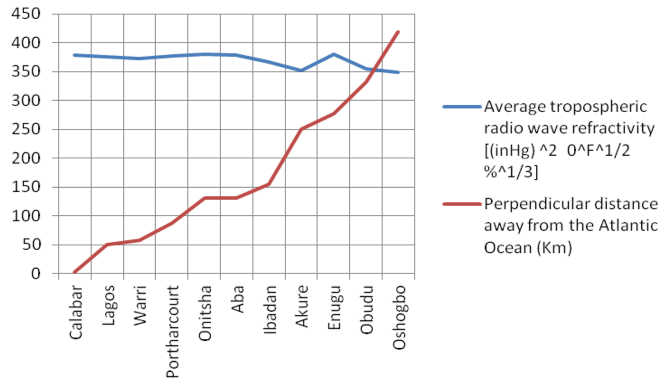

Fig. 5: Average tropospheric radio wave refractivity and distance away from the coastline of the Atlantic Ocean

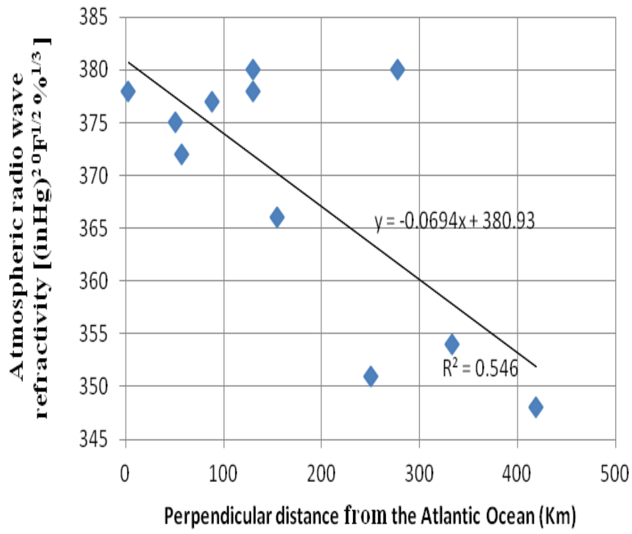

Fig. 6: Line of best fit between Average tropospheric radio wave refractivity and distance away from the coastline of the Atlantic Ocean

In a peck order of increasing magnitude of average tropospheric radio wave refractivities, the cities are arranged thus: Oshogbo, Obudu, Akure, Ibadan, Warri, Lagos, Portharcourt, Aba, Calabar, Onitsha and Enugu.

Fig. 1 shows the map of Southern Nigeria showing the locations of the various cities on the rainforest and mangrove (saltwater and freshwater) belts. Southern Nigeria neighbors the Atlantic Ocean as captured by the Fig. 1.

Fig. 2 shows the atmospheric radio refractivities of the cities throughout the year. It is observed that the coastal cities of the Atlantic Ocean: Calabar, Portharcout and Lagos have stable and the highest average atmospheric radio wave refractivity throughout the year with the exception of Onitsha that shores the western bank of the River Niger and Enugu that sits in the Escarpment of the Eastern highland of Nigeria [17]. In addition Enugu is located in a tropical rain forest zone with a derived savannah and has a tropical savanna climate [17]. The locations of Onitsha and Enugu make them share similar relative humidities (isohume) with the coastal cities but they differ because of their higher mean monthly temperatures which amount to the higher average tropospheric radio wave refractivities. Obudu a mountain climate in the rainforest has contrasting lower average tropospheric temperature even though it is in the shadow of the savannah of Savannah of Northern Nigeria with extreme atmospheric temperatures. The average tropospheric radio wave refractivity of Obudu is the least in the Southern hemisphere of Nigeria. By and large, there is a gradual decrease in tropospheric radio wave refractivity away from the Atlantic Ocean coast. Since signal strength is inversely proportional to radio signal strength [7], higher signal strength will have to be transmitted to neutralize the effect of high average tropospheric radio wave refractivity throughout Southern Nigeria. None-the-less, the signal strength here will be stable, with the exception of rain and wind that disrupt signal transmission through the troposphere [1] [7] [18]. The high average tropospheric radio wave refractivity in Southern Nigeria is mainly due to its high average humidity because it borders the Atlantic Ocean.

Fig. 3 shows tropospheric radio wave refractivities of the cities in the dry. Oshogbo, Obudu and Akure have the least average radio wave refractivities during this season (the dry). This is owing to their far distance from the Atlantic Ocean and close proximity to the Savannah of Northern Nigeria. Because of the better weather quality in Southern Nigeria this season, that is, no rains and less wind and slight;y lower average relative humidities and atmospheric temperature, signal propagation through the troposphere will be favourable. And tropospheric signal propagation through Oshogbo, Obudu aand Akure in the rainforest belt will be the better.

Fig. 4 shows tropospheric radio wave refractivities of the cities in the wet. Observe that the average tropospheric radio wave refractivities of the cities throughout the season (the wet) is near stable and equal. In this season the average relative humidities and temperatures of the cities are almost parallel and high. The higher atmospheric radio wave refractivities this season spells higher degradation/dissipation of signal strength [7]. In other words, for tropospheric propagation, there will be a rise in the power of signal to compensate for the losses to achieve good signal quality, since signal strength is inversely proportional to tropospheric radio wave refractivity. However, rain and wind are still not a friend of tropospheric propargation of signal [1] [7] [11] [18].

Fig. 5 shows average tropospheric radio wave refractivity and distance away from the coastline of the Atlantic Ocean. There is a slight reduction of average tropospheric radio wave refractivities with increasing distance away from the Atlantic Ocean with the exception of Enugu and Onitsha that rest in an Escarpment and sit bedside the River Niger. This indicates to a vast extent that tropospheric radio signal propagation betters with distance away from the Atlantic Ocean and worsens towards it.

Fig. 6 shows line of best fit between Average tropospheric radio wave refractivity and distance away from the coastline of the Atlantic Ocean. Mathematically the relationship is given by the model $y = -0.0694x + 380.93$ and the correlation (r) was 0.79.

V. Conclusion

Generally, there was an increase in the average atmospheric radio wave refractivities as one confronts the coastline of the Atlantic Ocean. Hence radio wave propagation through the troposphere will gradually worsen towards the Atlantic Ocean, since atmospheric radio wave refractivity is inversely proportional to radio signal through the troposphere, provided the wind direction is the same [7] and rain falls not.

The correlation between the perpendicular distances away from the coastline of the Atlantic Ocean and the average tropospheric radio wave refractivities is 0.79. The approximate model of average tropospheric radio wave refractivity away from the Atlantic Ocean coastline is $y = -0.0694x + 380.93$: where y is the average atmospheric radio wave refractivity and x is the perpendicular distance away from the Atlantic Ocean coastline.

Finally, radio signal propagation will generally propagate better throughout Southern Nigeria in the troposphere during the dry than the wet with the exception of winds and rainfall that affect communications [1] [7] [8] [11] [19]. This is on the account that the mean monthly relative humidities generally falls during the dry, but rises in the wet and similarly average atmospheric temperature.

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