Seasonal Variation of Surface Radio Refractivity and Water Vapour Density for 48 Stations in Nigeria

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***Abstract*— The monthly and seasonal variation of surface refractivity and water vapour density were studied using thirty-nine years meteorological data for forty-eight stations in Nigeria. The factors which influence the transmission of radio signals operating within the troposphere are water vapour and refractivity. The results show that the surface refractivity and water vapour density generally have higher values during the rainy season than dry season at all station studied. Furthermore the results show that the value of surface refractivity and water vapour density varies from about 263 N-units and 3 g/m^3 in arid region of Nigeria (North East) to about 393 N-units and 23 g/m^3 in the coastal area of Nigeria (South West) respectively. For optimal performance of terrestrial radio link across Nigeria it is required to account for the variability of these parameters for optimal systems design.**

Keywords- Radio refractivity, water vapour density, radio link

I. INTRODUCTION

Water vapour is one state of water within the hydrosphere [1]. It penetrates the earth's surface by absorption and radiation of energy through evaporation, precipitation and condensation, in vapour phase. The atmosphere transport long range water vapour by constant recycle and renew fresh water resources as the temperature of the earth's surface increases [2]. It is lighter than air and triggers convection currents that can lead to clouds. Water vapour is lighter or less dense than dry air. The green- house gas, that is, the atmospheric water vapour, absorbs energy that cause reduction in attenuation of transmitted signal, which may otherwise result to degrade performance and reliability of communication link. [3] Observed that water vapour in the air decreases rapidly with height, on the average at the surface level it increases from less than 0.001% in the arctic to more than 6% in the tropics.

Permanent dipole moments possess by atmospheric water vapour is of major concern in the radio wave propagation of the atmospheric refractive index [4]. In lower atmosphere, refractive index of the troposphere is an important factor for estimating the performance of terrestrial radio links. Thus, the knowledge of the refractivity is essential in order to design reliable and efficient radio communication [5]. Refractive index variations of the atmosphere affect radio frequencies above 30MHz, although these effects become significant only at frequencies greater than 100MHZ in the troposphere.

Radio refractivity is related to these meteorological parameters with the following formula [6, 7]:

$$N = \frac{77.6P}{T} + 3.73\times10^5 \frac{e}{T^2} = N_{dry} + N_{wet}(N - units) \quad (1)$$

N_{dry} and N_{wet} are often referred to as dry and wet terms of atmospheric radio refractivity, respectively. The dry component (N_{dry}) and the wet component (N_{wet}) of eq. (1) are shown on the right hand side respectively. N_{dry} make a contribution of about 66% against N_{wet} whose contribution is about 34% of the total value of refractivity (N) [3, 8]. The variation of N within the troposphere is mostly caused by N_{wet}.

The dry term is due to non-polar nitrogen and oxygen molecules. It is proportional to pressure, P, and therefore, related to the air density. The wet term is proportional to vapour pressure and dominated by polar water contents in the troposphere.

The surface water vapour density most especially in the tropical region depends on temperature and relative humidity. [3, 9] clearly show in eq. (2) the relationship between surface water vapour density (SWVD), water vapour pressure, e, in (hPa) and temperature, T, in Kelvin as stated below:

$$SWVD = \frac{216.7e}{T} \quad (2)$$

Research works on surface radio refractivity shows dependence on atmospheric parameters such as temperature, pressure, and relative humidity. Change in refractive index with height may cause radio waves to bend downwards to some degree, due to the vertical profile of radio refractivity gradient [10]. Curving of refractivity leads to expansion of the radio horizon above the optical horizon. [11] and [12] have shown that surface radio refractivity N_s has high relationship with radio field strength values. On propagation of VHF, UHF and microwaves in the atmosphere, each of normal, sub-refractive, super-refractive or ducting layer, has important influences on refractivity.

The chaotically fluctuation in time and in all three spatial directions of atmospheric refractive index, and the values of the functional parameters structure, that is, temperature, water vapour and relative humidity normally moves from mixed layer forms and increase quickly to higher values thereafter reducing once more at an increasing heights near the top of convective boundary layer [13, 14, 15].

II. DATA ACQUISITION

The data used in this study were collected from Meteorological data obtained from NOAA (USAF) Climatology center. Radiosonde data for at least 39 years between 1973-2012 for forty-eight stations within Nigeria were utilized for analysis as shown in figure 1. Measured metrological data such as pressure, temperature, vapour pressure and relative humidity were used as input parameters to calculate surface refractivity and surface water vapour density for all the locations.

In the data processing that follows, Data assembled on minute-by-minute basis was used to generate the daily average data, which were in turn used to obtain the monthly and the seasonal averages. Hence the monthly means of the measurements, over the thirty-nine years, with their mean, is considered to be a good representative of the seasonal behaviour.

The dry and wet terms of N were calculated for monthly, seasonal and yearly values. The country was grouped into six geo-political regions which include; South West (SW), South East (SE), South South (SS), North West (NW), North East (NE) and North Centre (NC) or Middle-Belt (MB). Comparison of the surface refractivity and water vapour density for the six regions and how they affect radio propagation across the six-region in Nigeria were also study.

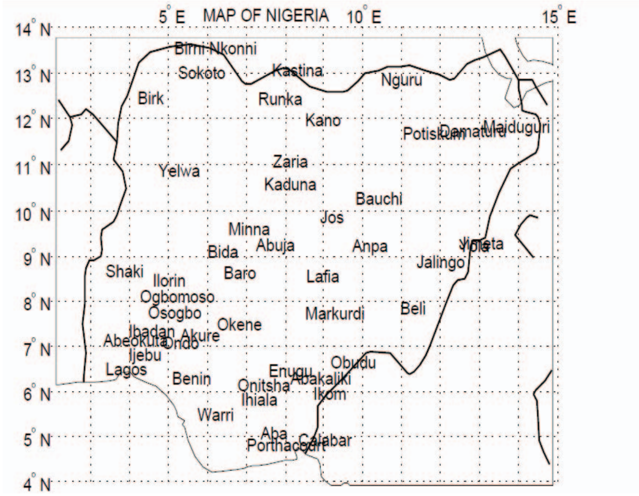

Figure 1: Map of Nigeria showing the study areas.

III. RESULTS AND DISCUSSION

The mean monthly value of surface refractivity NS and water vapour density shows a significant diurnal trend during the wet and dry season as shown in the map of Nigeria in figure 2 and 3 respectively, radiosonde data for at least 39 years between 1973-2012 for forty-eight stations within Nigeria were utilized for analysis. The result show that the value increases from the arid region in the northern part of the country to the coastal area in the southern part of the country.

In the south east Nigeria, average refractivity Ns and water vapour density (WVD) at Abakaliki shows a similar pattern with that of the coastal region in the south west at Lagos (fig. 4 and 6). But Fig 4 shows double peaks with a dip around June-August with a slight increase in July. The highest mean values for both N_s and WVD are 385.81N and 21.60g/m^3 respectively in May. The result also indicate higher N_s value during the raining reason around April and May and lower N_s during months of December to February. However, double peaks display here with dip is more obvious in the coastal region. This attribute to the fact that they are close to the Atlantic Ocean.

Fig. 5 gulf of Guinea savannah region otherwise known to be south-south region almost follow the same pattern with south east but with higher refractivity. The highest mean values for both N_s and WVD are 387.75N and 22.50g/m^3 respectively in April. The result also indicates heavy rain from June to August while the refractivity falls greatly around December at Port-Harcourt.

In the coastal region, fig. 6 graph shows a sine wave with both the refractivity and water vapour density display double peaks with a very strong dip around August. This drop in August is attributed to August break in the south west where there is little or no rain for a very short period of time in the region. The highest mean values for both N_s and WVD are 392.84N and 23.00g/m^3 respectively in March. The N_s and WVD at the double peak are conspicuously high as expected because water vapour decreases with increasing height from the surface. Lagos experience heavy rain around March to May during the raining season and the refractivity valve falls between December to February the dry season. As discussed above with fig.4 in the south east, they may also be attributed to their closeness to the Atlantic Ocean.

The result of analysis shown in the middle belt region in Fig.7, indicate a gradual increase from the month of January to April. Makurdi in May recorded the highest refractivity of 384.6N and water vapour density of about 21.60g/m^3 in May. A trend noticeable here in this North Central region shows a slight decrease in refractivity value compare to the southern region as we move towards northern area.

Fig. 8, shows variations of the observed refractivity and water vapour density in sub-sahelian region, a bed shape pattern shown made the North East a unique zone. In weather pattern of Nigeria, The dry season is influenced by a dust laden airmass from the Sahara Desert characterized as period of no rain, known as the tropical continental (CT) air mass, while the rainy season is heavily accompanied by an air mass coming from the south atlantic ocean, called south west wind, the tropical maritime (MT) air mass. These two major systems of wind in Nigeria are known as the trade winds. Yola experienced highest mean values for both N_s and WVD are 376.76N and 20.90g/m^3 respectively in July and comparison between them shows the same pattern. The region also experience heavy rain fall from June to August while December to January was observed as dry season in the zone.

Fig. 9, refractivity and water vapour density reached climax in August at about 371.02N and 20.00g/m^3 respectively in the sahara region at Birk. The highest rainfall was experienced from June to August while December to February in the North West dry season was noticed.

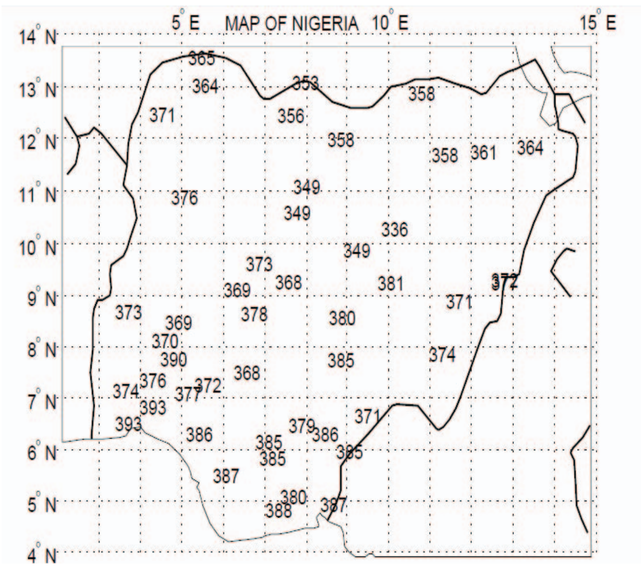

Figure 2: Map of Nigeria showing the Surface

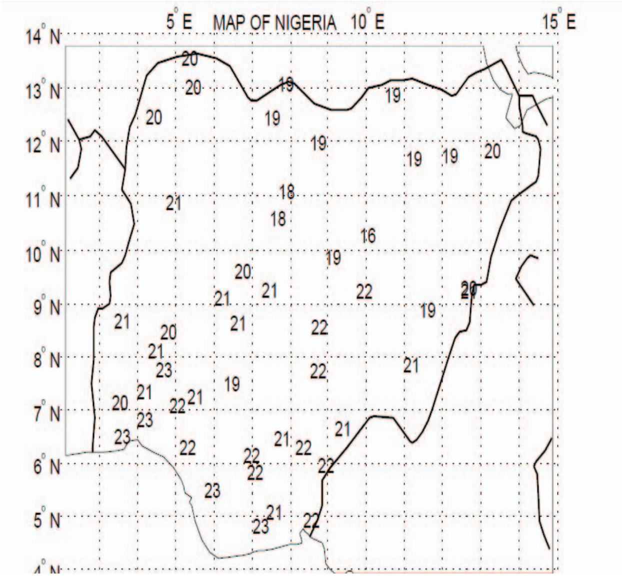

Figure 3: Map of Nigeria showing maximum Water Vapour Density.

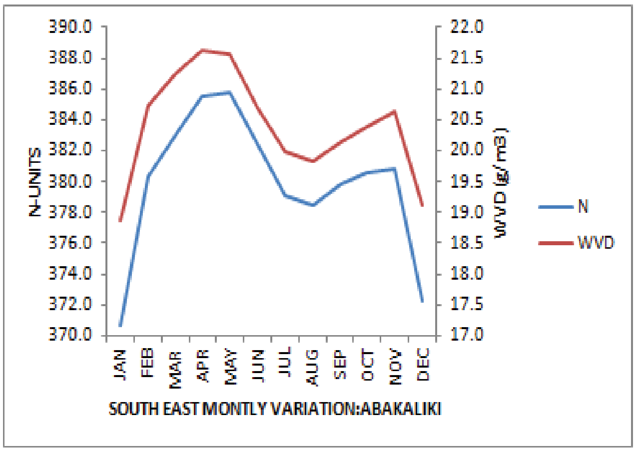

Figure 4: Average Monthly Variation of Refractivity And Water Vapour Density For South East Nigeria.

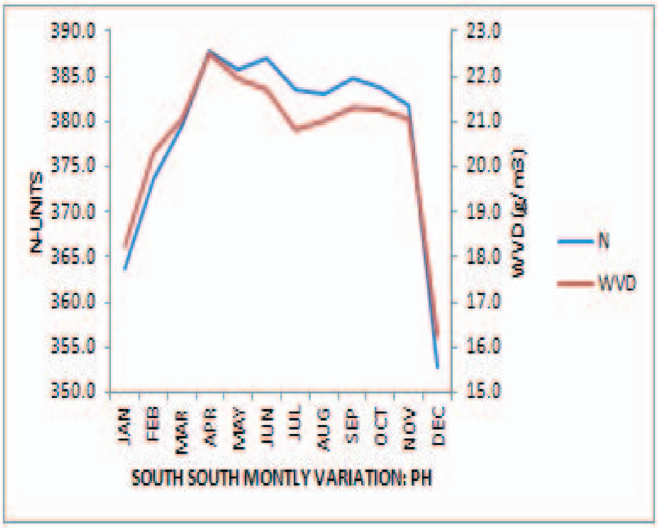

Figure 5: Average Monthly Variation of Refractivity And Water Vapour Density for South South Nigeria.

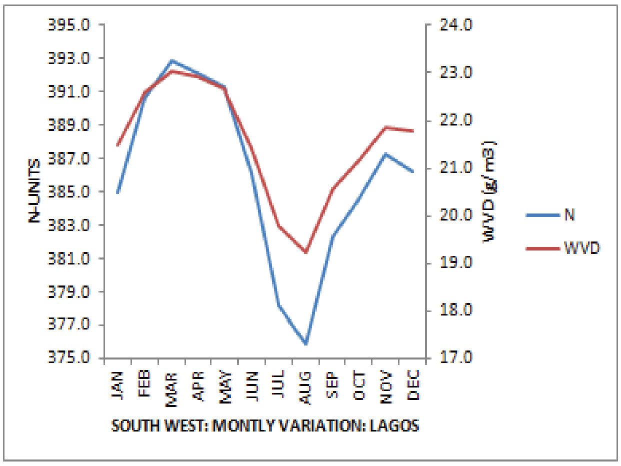

Figure 6: Average Monthly Variation of Refractivity and Water Vapour Density For South West Nigeria

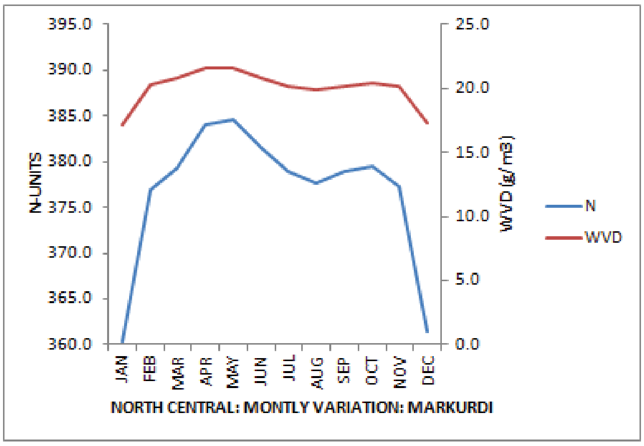

Figure 7: Average Monthly Variation of Refractivity and Water Vapour Density for North Central Nigeria.

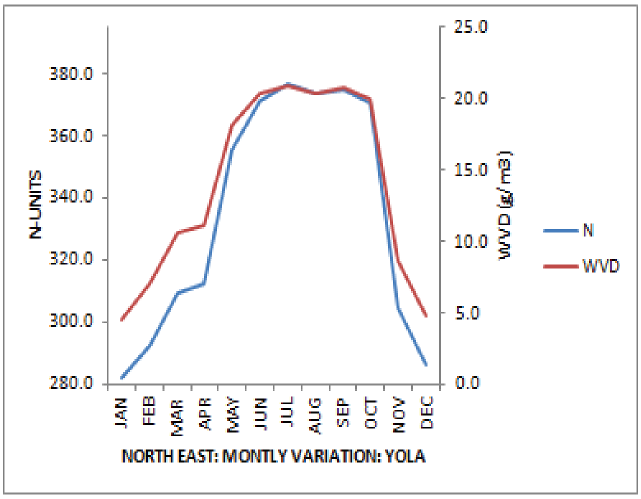

Figure 8: Average Monthly Variation of Refractivity And Water Vapour Density For North East Nigeria.

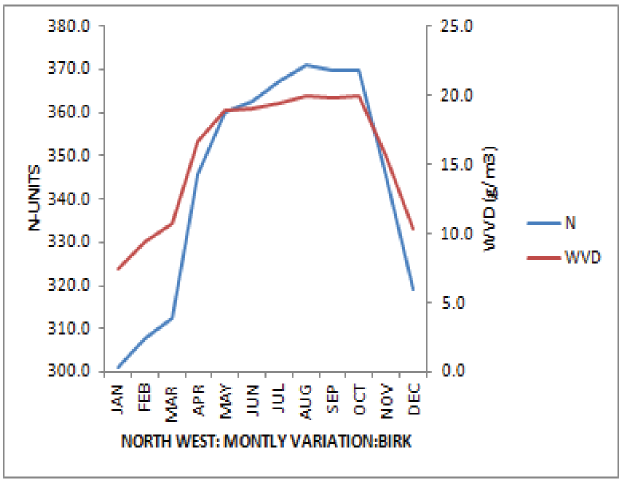

Figure 9: Average Monthly Variation of Refractivity And Water Vapour Density for North West Nigeria.

IV. CONCLUSION

The major effect of the troposphere on communication has been seen from analysis to be the radio refractive and the water vapor density. The analysis shows that surface climatology in the six regions studied is attributable to tropographical and atmospheric variations; this is revealed in the patterns of refractivity obtained for each station. This result confirms the observation made by [2] and [16] in their investigation of the seasonal variation of surface refractivity over some stations in Nigeria. Refractivity value over Nigeria increases from about 262.5N units in the North East to about 392.84N units in the South West, likewise, the surface water vapour density also increases from about 3.12g/m^3 in the North West to about 23.07g/m^3 in the South West. Refractivity reveals a seasonal variation with high value during the rainy season and low value in the dry season. While, the atmosphere water vapour content also decreases from the coast in the South towards the inland area to the north.

The Northern region experience high refractivity and water vapour density around June to August while the Southern region experience high refractivity and water density vapour around March to May. Meanwhile, all the six zones experiences low refractivity and water vapour density around December to February. The variation of refractivity from Southern Nigeria to Northern Nigeria has a minimum of about 130N units and has a maximum of about 20g/m^3 variation of water vapor density from Northern Nigeria to Southern Nigeria. Radio refractivity in 48 locations in Nigeria at ground level can help engineers in sitting antenna for AM, FM, VHF and UHF bands.

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