



Study of Surface Refractivity Over Lapai and Makurdi (North-Central) Nigeria

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ABSTRACT

This paper studied the diurnal and seasonal variations and the tropospheric surface refractivity (Ns) over Lapai and Makurdi (8.82° N, 6.68° E and 7.74° N, 8.51° E), Central part of Nigeria. The results indicated that both the hourly and monthly averages of radio refractivity during the rainy season months (April to October) are greater than the Ns values of the dry season months (November to March) for the two locations and years of the study. The computed mean diurnal Ns over Makurdi and Lapai in the first 1 km are respectively 343 and 342 N-units, which respectively give the refractivity gradients (dN/dh) of -47 N/km and -46 N/km; this shows that the stations are, on average, characterised by low scale super-refraction. The mean k-factor over the two regions in the first 1 km is 1.4. The mean Field Strength Variability (FSV) in first 1 km in the region is 14 dB. The mean Radio Horizon distance within 1 km height for a transmitter height of 100 m over the stations is 42 km. Diurnal and seasonal Ns variations in Makurdi and Lapai were shown using 2-D contouring. The refractivity shows a seasonal variation with higher values in the rainy season and lower values in the dry season and it can be concluded that refractivity varies according to height above the over sea-level from one station to another

Keywords: Temperature, Pressure, relative humidity, tropospheric and surface refractivity

INTRODUCTION

Radio communications use electromagnetic waves propagation through the earth's atmosphere to send information over long distances without the use of wires (Agbo, 2004). Tropospheric radio signal transmissions at frequencies above 30 MHz are prone to the fluctuations of weather and climate, because water vapour molecules with their permanent electric dipoles account for the atmosphere having a complex dielectric constant and hence a complex refractive index. The molecules whose amounts vary temporally and spatially refract as well as absorb the radio waves, and this subsequently leads to variability and attenuation of signals. Radio propagation parameters are dependent on radio refractivity, which in itself is a function of the weather (Willoughby, 1996). The effect of meteorological variables of pressure, temperature and relative humidity on radio wave propagation at UHF and microwave frequencies are analyzed from the study of radio refractive index derived from these three parameters (Bean and Dutton, 1966). When

designing radio communication systems operating in these frequency bands, the radio engineer normally subjects long-term data relating to atmospheric refractive index and its properties to statistical analysis in order to be able to predict these parameters. A significant property of the refractive index used in studying the effects of the troposphere on radio propagation is its vertical gradient. The variations in the vertical profile of the refractive index and its gradients are responsible for the change in the trajectory of radio rays in the troposphere (Aro and Willoughby, 1992). The study of the radio refractivity has aroused considerable interest primarily because of its influence on radio wave communication in the lower atmosphere. The manner in which the refractive index changes with height has much

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consequence for radio wave propagation at frequencies greater than 30 MHz.

The refractive index 'n' of a medium can be defined as the ratio of the speed of propagation of radio energy in a vacuum to the speed in the medium. The refraction of radio wave in space is governed by the variation of refractive index. Refractive index determines the speed of propagation in a medium (Bowers, 1964). The atmospheric radio refractive index depends on air temperature, humidity, pressure and water vapour pressure. In addition, meteorological parameters depend on the height of a point above the ground surface. Variation in any of these meteorological parameters can make a significant variation on radio-wave propagation, because radio signals are refracted over the whole signal path (Priestley and Hill, 1985). In the atmosphere, pressure, temperature and humidity decrease exponentially as height 'h' increases (Falodun and Ajewole, 2006). The vertical gradient of the refractive index, G, is responsible for bending of propagation direction of the electromagnetic wave. If the value G is negative, the signal bends downward (Guanjun and Shukai, 2000).

METHODOLOGY

Source of Data

The diurnal data for Lapai and Makurdi are 5-minute interval data collected with Integrated Sensor Suite (ISS-Vantage Pro2) instrument installed at surface level in the Geography Department of Ibrahim Badamasi Babangida University, Lapai and at the Federal University of Agriculture Makurdi.

Nigeria Meteorological Agency (NIMET) has observatory stations (synoptic stations) across the country (at least one in each state). These stations are called Data points and recognised by the World Meteorological Agency (WMO). The observatory stations or Data points that are WMO certified in the North Central Region are: Abuja, Minna (Niger State), Ilorin (Kwara State), Lokoja (Kogi State), Lafia (Nassarawa State), Jos (Plateau State) and Makurdi (Benue State).

These weather stations are manned by professional weather observers (WMO Certified). The observatories or data points have all the weather measuring instruments ranging from rain gauge for measuring rain,

thermometers for measuring temperature, barometer for measuring atmospheric pressure and hygrometer for measuring relative humidity. NIMET weather data are observed and recorded within some selected time intervals i.e. half hourly, hourly and daily throughout the year. The data from the stations are collected by NIMET throughout the country.

Some of the data used in this study were collected from Makurdi (Benue State) station for a period of six (6) years from 2005 to 2010.

Analysis of Data collection

The table below shows the Sample data used for the analysis

Table 1 Daily Sample data over Lapai.

| IBBU LAPAI TIMESTAMP | 56111 RH % | Main T107_C_Avg °C | BarPress_Avg Mbar |
|-------------------------|---------------|--------------------------|----------------------|
| 10/03/2010 21:25 | 86 | 31.03 | 988 |
| 10/03/2010 21:30 | 86.4 | 30.99 | 988 |
| 10/03/2010 21:35 | 86.2 | 30.96 | 988 |
| 10/03/2010 21:40 | 85.7 | 30.93 | 988 |
| 10/03/2010 21:45 | 86.2 | 30.9 | 988 |
| 10/03/2010 21:50 | 86.3 | 30.87 | 988 |
| 10/03/2010 21:55 | 86.8 | 30.84 | 988 |

Diurnal mean five-five minute's data for Makurdi and Lapai were used to compute surface refractivity (N_s) for the both stations. Monthly mean of surface refractivity (N_s) at 09:00 hrs of the study stations were computed using Microsoft excel for each year (2005 to 2010). Monthly mean of surface refractivity (N_s) at 15:00 hrs of the study stations were computed for each year (2005 to 2010). Monthly mean of surface refractivity (N_s) for the monthly average of 09:00 hrs and 15:00 hrs were computed for each year (2005 to 2010). Annual mean of surface refractivity of the two study stations was computed for the period under review (2005 to 2010). Monthly mean of refractivity reduced-to-sea level (N_o) for the monthly average of 09:00 hrs and 15:00 hrs

were computed for each year (2005 to 2010). Annual mean of refractivity reduced-to-sea level (N_o) of the two study stations was also computed for the period under review (2005 to 2010). Analysis was done using Surfer11 Software application, this software was used to contour the refractivity values.

Techniques of Data Processing

Radio Refractivity N:

The Refractivity, N (which is actually the refractive index in excess of unity by a million) is given by the formula

$$N = (n-1) \times 10^6 = \frac{77.6}{T} (P + \frac{4810e}{T}) \quad (2.1)$$

Where P is the atmospheric pressure in mill bars (mb), e is the water vapour pressure in mb and T is the absolute temperature in Kelvin. Equation (3.1) may be expanded and rewritten as

$$N = \frac{77.6}{T} P + \frac{3.73 \times 10^5}{T^2} e \quad (2.2)$$

The vapour pressure, e is estimated from

$$e = (R.H \times e_s) / 100 \quad (2.3)$$

Where R.H is relative humidity and e_s is the saturated vapour pressure.

e_s is calculated from

$$e_s = 6.11 \exp((19.7t)/(t+273)) \quad (2.4)$$

Where t is the temperature in °C

Computation of Refractivity reduced-to-Sea level at the Stations under study (N_o)

Using the formula in equation (2.5):

$$N_o = N_s \exp\left(\frac{h_s}{h_o}\right) \quad (2.5)$$

Where N_o is the average value of atmospheric refractivity extrapolated to sea level,

N_s is the Surface refractivity calculated using equation (2.2) above, h_o is the scale height in (km) and h_s is the height of the earth's surface above the sea level (km).

Computation of Gradient (dN/dh) and k-factor

Using the formula in (2.6) by (Seybold, 2005):

$$N = N_s e^{(-h/H)} \quad (2.6)$$

Where h is the height above the surface, which is taken to be 1 km for the Surface refractivity Calculations (Seybold, 2005).

H is the scale height; H is 7 km, obtained for tropical conditions (Kolawole and Owonubi, 1982).

N_s is the calculated surface refractivity from equation (2.2).

$$\frac{dn}{dh} = \left(\frac{dN}{dh}\right) 10^{-6} \quad (\text{N-Units/km}) \quad (2.7)$$

Therefore, the equation becomes

$$\left(\frac{dN}{dh}\right) = \left(\frac{-N_s}{H}\right) e^{(-h/H)} \quad (2.8)$$

In addition, the K-factor is giving as:

$$k = \frac{1}{(1+a\left(\frac{dN}{dh}\right)10^{-6})} \quad (2.9)$$

Where k is the k-factor, a is the earth radius and the term the $\left(\frac{dN}{dh}\right)$ in equation (2.8) is the gradient.

Field Strength Variation (FSV)

Using the formula in (3.0) by (Bean and Dutton 1968), the field strength variation is defined as:

$$\text{FSV} = (N_{\text{SMAX}} - N_{\text{SMIN}}) \times 0.2\text{dB} \quad (3.0)$$

Where N_{SMAX} and N_{SMIN} are the maximum and minimum values of surface refractivity respectively

Radio Horizon Distance (d_{RH}) Calculation

Using the formula in (3.1) by (Bean and Dutton 1968), The radio horizon distance,

d_{RH} was obtained from the equation:

$$d_{\text{RH}} = \sqrt{2k ah} \quad (3.1)$$

Where k is the effective earth's radius factor, a is equivalent earth radius and h is the transmitter height.

N_s Contouring

The surfer 11 software applications were used to contour the values of (N_s) surface refractivity with respect to other variables, that is, months, time, temperature, humidity and pressure

RESULTS AND DISCUSSIONS

The data obtained from climatic observations at 5 minutes' interval of time in Makurdi and Lapai are utilised together with relevant

mathematical tools to compute the values of surface refractivity due to dry and wet terms. These measurements were carried out between January 2005 and December 2010 and they cover both weather conditions (rainy and dry seasons) occurring in Makurdi and Lapai. The monthly and hourly mean values of radio refractivity due to both the dry and wet terms were also determined and the results are shown in Figures 1.

**Hourly Variations of Surface Refractivity
Dry Season Refractivity**

The Tables for the discussions of Figure 1 to Figure 14 are presented. Figure 1 shows the graph of hourly variations of N_s for the month of January, which is a typical dry season month in Makurdi.

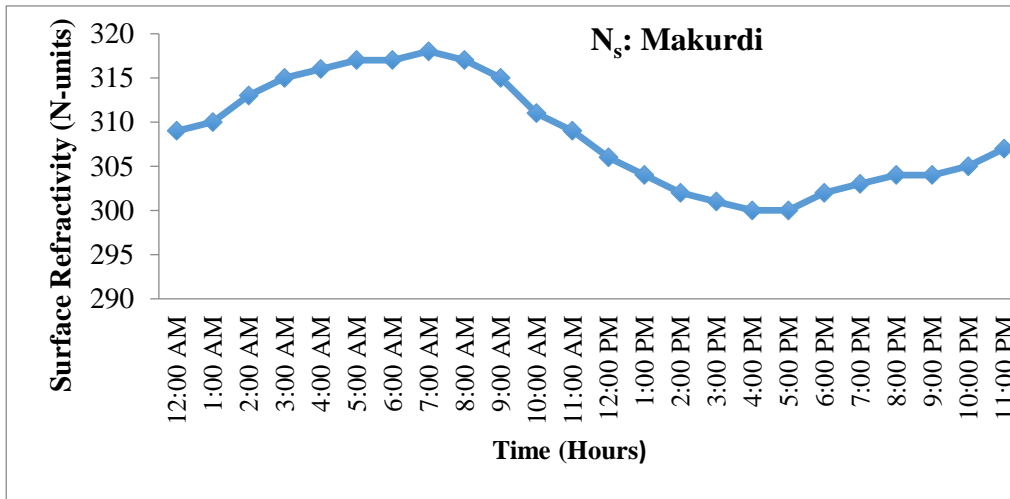


Figure 1: Hourly Variation Surface Refractivity in January in Makurdi

Dry Season Refractivity

Figure 1 clearly shows a gradual increase of N_s from the early hours of the day and a peak of about 318 N-units around 7:00am local time, followed by a gradually decrease to a minimum of about 300 N-units around 4:00pm and

5:00pm local time, before rising towards mid-night.

Figure 2 shows the hourly N_s variations for the month of February, which is also a typical dry season month in Makurdi.

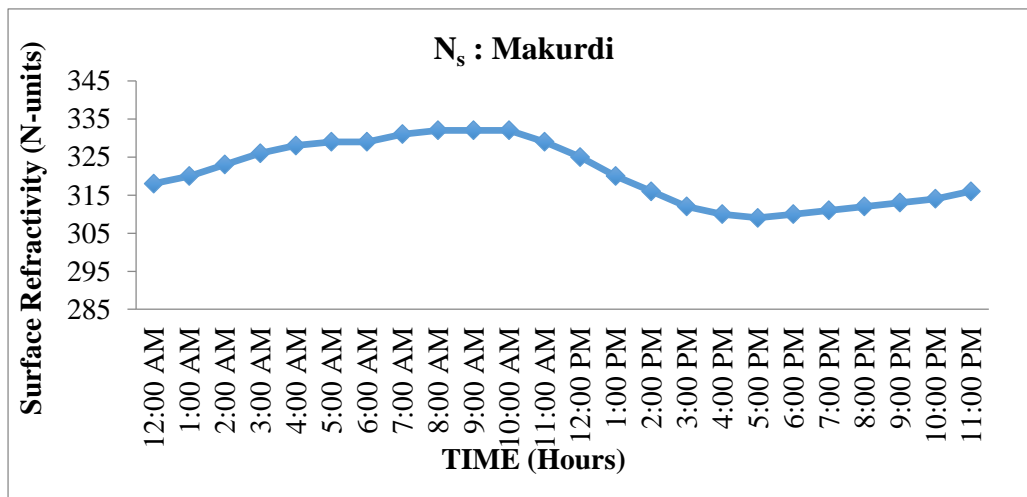


Figure 2: Hourly surface refractivity in February in Makurdi

Figure 2 clearly shows a steady increase from the early hours of the day and a peak of about 332 N-units around 8:00-10:00am local time, and a gradual decrease to minimum of about

309 N-units around 5:00pm local time, before rising towards mid-night.

Figure 3.3 shows the hourly variation N_s for the month of March, which is a typical dry season month in Makurdi.

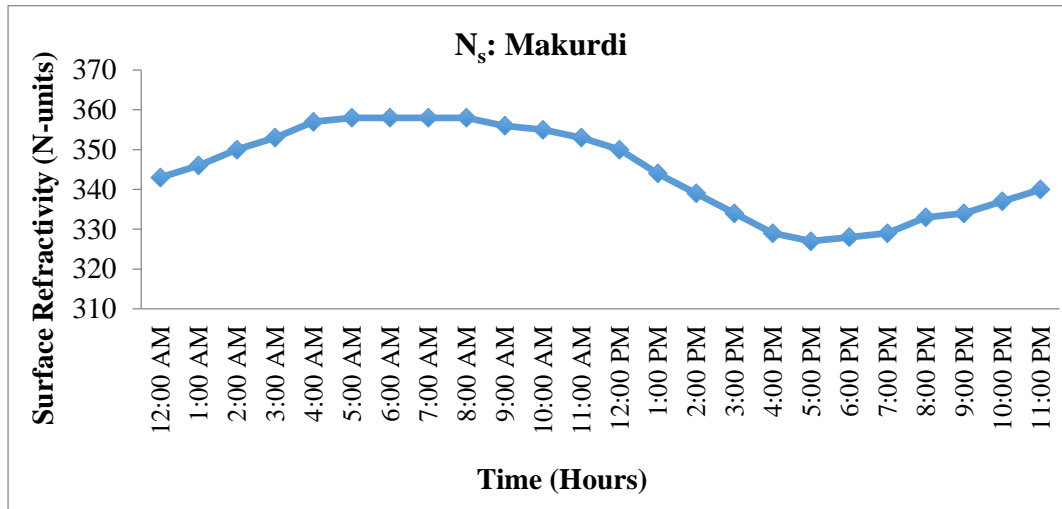


Figure 3: Hourly Surface Refractivity in March (Makurdi)

Figure 3 clearly shows a steady increase of N_s from the early hours of the day and a peak of about 358 N-units around 5:00-8:00am local time and a gradual decrease to minimum of about 327 N-units around 5:00pm local time before rising towards mid-night.

Figure 4 respectively show the computed values of hourly surface refractivity and the graphical representation for the month of November, which is more or less a dry season. Figure 4 shows the hourly variations of N_s for the month of November in Makurdi, which is a typical dry season month.

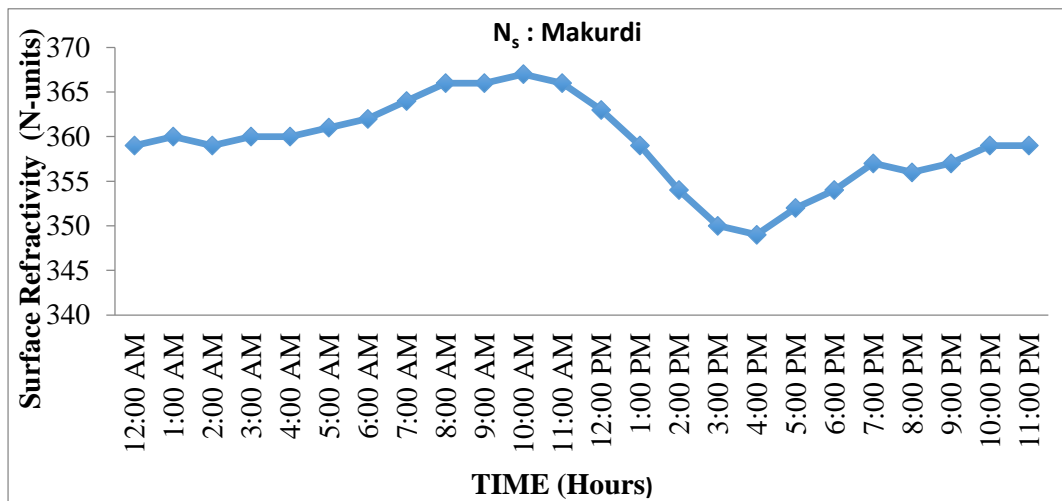


Figure 4: Hourly Surface Refractivity in November in Makurdi

Figure 4 clearly shows a gradual increase from the early hours of the day and a peak of about 367 N-units around 10:00am local time and a faster decrease to minimum of about 349 N-units around 4:00pm local time before rising towards mid-night. Figure 5 respectively show

the computed values of hourly surface refractivity and the graphical representation for the month of December, which is a typical dry season month in Figure 5 shows the hourly variations of N_s for the month of December, which is a typical dry season month in Makurdi.

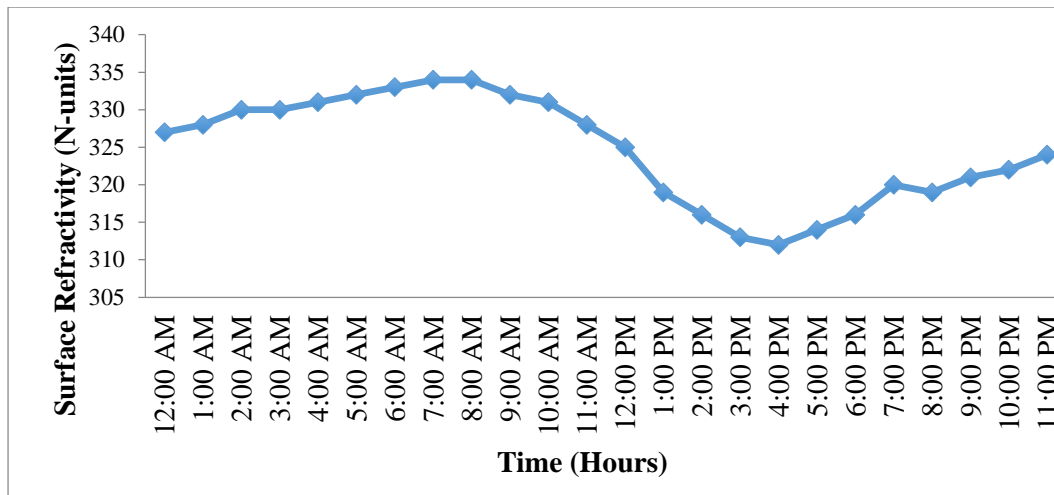


Figure 5: Hourly Surface Refractivity in December in Makurdi

Figure 5 clearly shows a gradual increase from the early hours of the day and a peak of about 334 N-units around 7:00-8:00am local time and a faster decrease to minimum of about 312 N-units around 4:00pm local time before rising towards mid-night.

Figure 3.6 shows the mean hourly N_s variations for the dry season months (November, December, January, February, and March) in Makurdi.

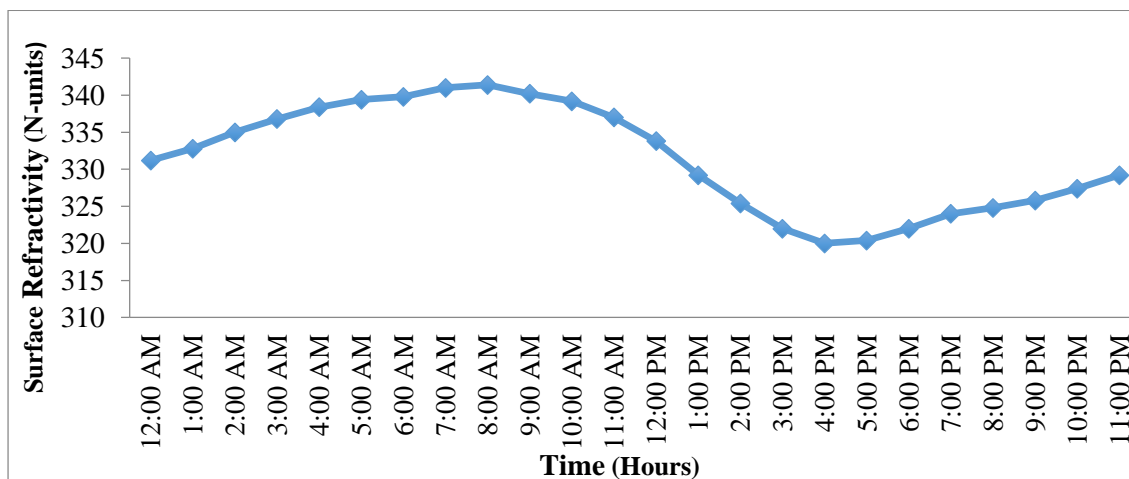


Figure 6: Mean Hourly Surface Refractivity for Dry Season Months

Considering Figure 6 the hourly refractivity, N increased uniformly from 331N-units at 12:00am to a peak of 341N-units at 8:00am and then decreased gradually to the least value of 320N-units at 4:00pm after which it increased gradually again all through 11:00pm to a value of 329N-units. This trend of high refractivity in the morning and late at night can be attributed to the high humidity level in the atmosphere at this time coupled with the higher sensitivity of refractivity to water vapour partial pressure in the dry season at those periods. Low refractivity values observed during the day is due to the high insolation, causing some of the surface-based vapour to be heated up, expand and rise

to the higher altitude thereby decreasing the surface based moisture. Maximum refractivity value (367N-units) was observed to occur in November as confirmed in Figure 3.4 above, while the minimum value occurred in January (300N-units) as shown in Figure 3.1 above, the least N_s values obtained from the dry season months have direct negative effect on VHF/UHF signal field strength profile in makurdi.

Rainy Season Refractivity.

Figure 3.7 shows the hourly N_s variation for the month of April, which is the beginning of the

wet season in Makurdi. This result agrees with work of (Kolawole, 1980).

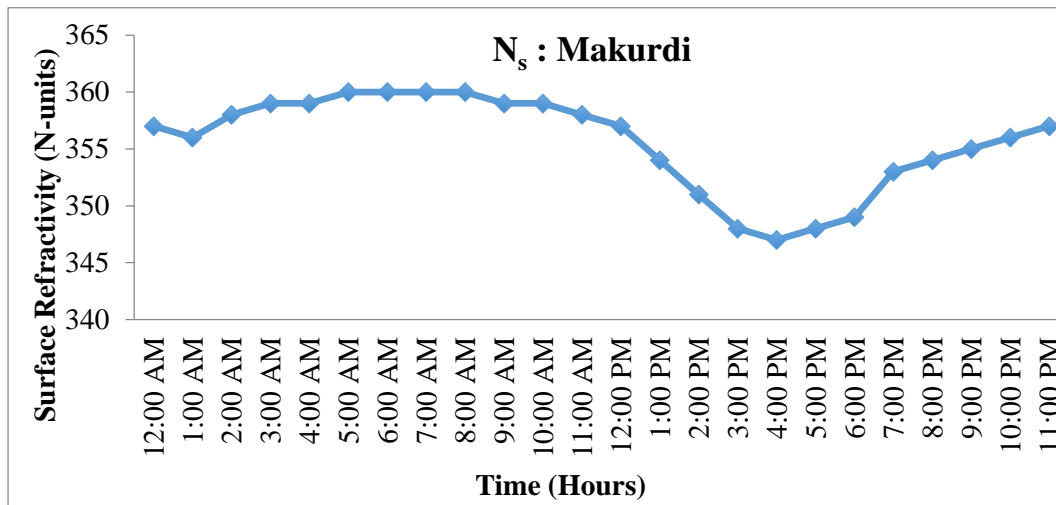


Figure 7: Hourly Surface Refractivity in April

From Figure 7, there is a small decrease from 357 N-units at 12:00am to 356 N-units at 1:00am, then a faster increase from the early hours of the day to a constant peak of about 360 N-units around 5:00-8:00am local time and

faster decrease to minimum of about 347 N-units around 4:00pm local time before rising towards mid-night. Figure 8 shows the hourly N_s variation for the month of May, which is a typical rainy season month in Makurdi.

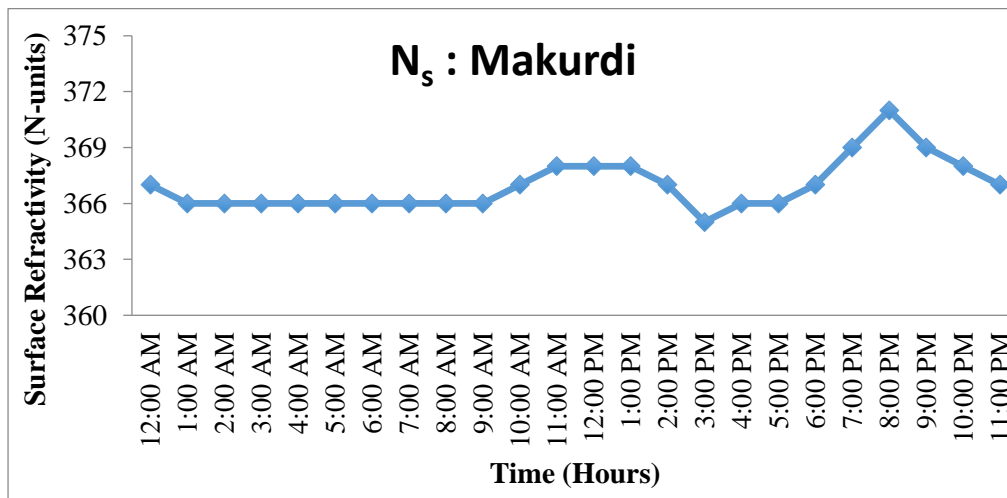


Figure 8: Hourly Surface Refractivity in May in Makurdi

From Figure 8, that N_s has a small decrease from 367 N-units at 12:00am to 366 N-units at 1:00am, which remains constant till about 9:00am, after which there is a steady rise to 368 N-units at 11:00am, continued at a constant rate until 1:00pm, the least value of 365 N-units at

3:00pm, refractivity then increased steadily to a peak value of 371 N-units at 8:00pm and dropped towards midnight. The hourly N_s variation for the month of June, which is a usual rainy season month in Makurdi is shown below in Figure 3.9.

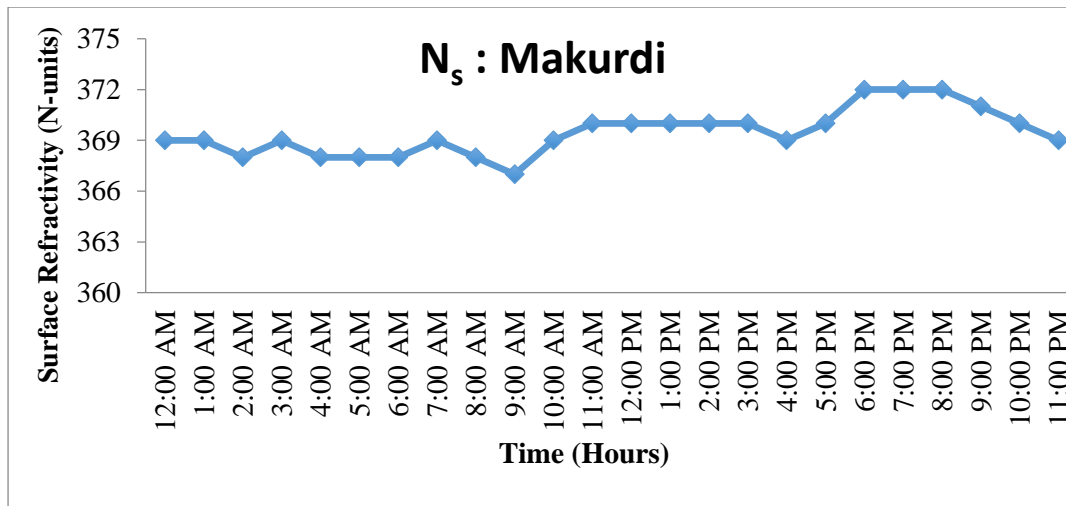


Figure 9: Hourly Surface Refractivity in June in Makurdi

It can be observed from Figure 9 that there is a small decrease of N_s from 369 N-units at 12:00-1:00am to 368 N-units at 2:00am then a small rise to 369 N-units at 3:00am, followed by a constant value of 368 N-units up until 6:00am. Refractivity recorded a very small rise to 369 N-units at 7:00am, dropped afterwards to a least value of 367 N-units at 9:00am, then rise faster to a constant value of 370 N-units at 11:00am till 3:00pm. At 4:00pm, refractivity dropped to

369 N-units, increased steadily to a constant peak of 372 N-units at 6:00pm through 8:00pm, then dropped the rest of the day. N_s is generally high ranging between 366 and 372 N-units. The hourly N_s variation for the month of July, which is a usual rainy season month in Makurdi is shown below in Figure 3.10.

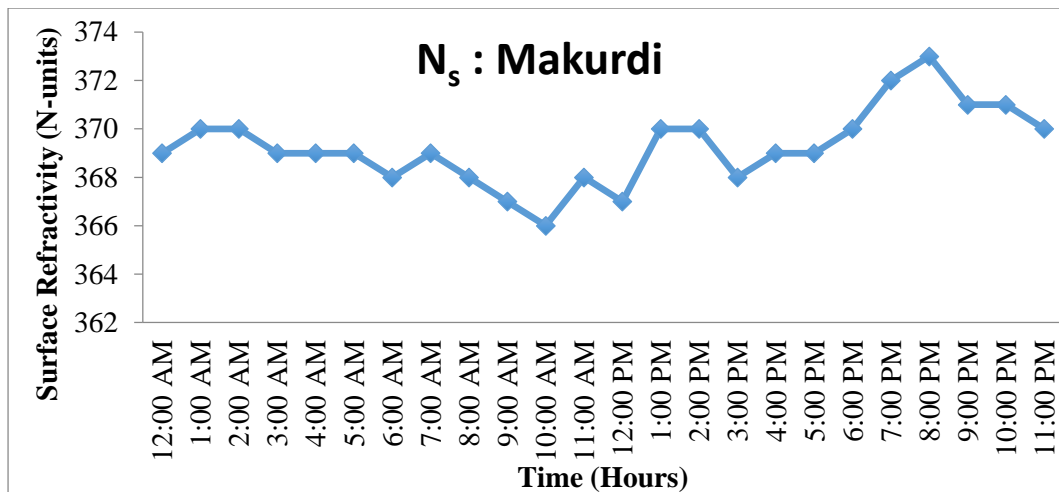


Figure 10: Hourly Surface Refractivity in July in Makurdi

Form Figure 10 that there is a small increase from 369 N-units at 12:00am to a constant value of 370 N-units at 1:00-2:00am, then a small drop to 369 N-units at 3:00am, constant until 5:00am followed by another small drop of 368 N-units at 6:00am. Refractivity recorded a very small rise to 369 N-units at 7:00am, dropped sharply afterwards to a least value of 366 N-units at 10:00am, rise gradually to 368 N-units

at 11:00am, dropped again to 367 N-units at 12:00am. At 1:00-2:00pm, refractivity was steady until 3:00pm when a drop to 368 N-units was observed, followed by a steady rise in refractivity to a peak of 373 N-units at 8:00pm, and a fall towards the mid-night. The graphical representation for the month of August, which is a usual rainy season month in Makurdi is shown below in Figure 11.

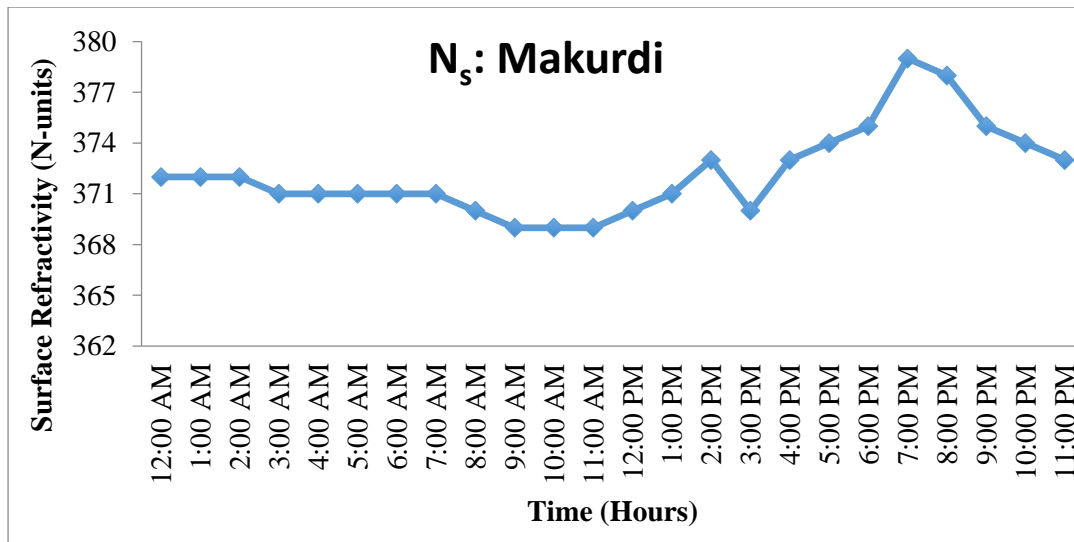


Figure 11: Hourly Surface Refractivity in August in Makurdi

Figure 11 indicate a constant value of refractivity of 372 N-units from 12:00-2:00am, with a small fall to 371 N-units at 3:00am, which remained constant until 7:00am, then dropped to 370 N-units at 8:00am. Refractivity remained constant at a least value of 369 N-units at 9:00-11:00am, increased steadily to a peak of 373 N-units at 2:00pm, dropped to the second least value of 370 N-units 3:00pm,

followed by a faster increase to the second peak of 379 N-units at 7:00pm and a steady drop towards the mid-night.

Figure 12 show the hourly N_s variation for the month of September, which is a usual rainy season month in Makurdi.

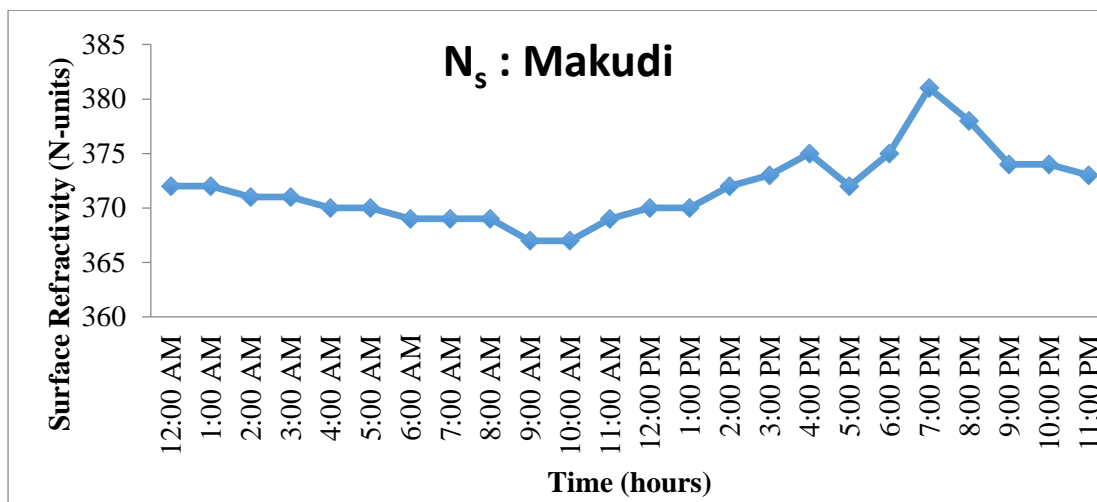


Figure 12: Hourly Surface Refractivity in September in Makurdi

It can be observed from Figure 3.12 that the refractivity decreased from the early hours of the morning to a least value of 367 N-units around 9:00-10:00am local time, followed by a rise to a peak value of 375 N-units at 4:00pm and a small drop to 372 N-units at 5:00pm. At 7:00pm, a second peak of 381 N-units was

recorded then a gradual drop towards mid-night.

Figure 13 shows the hourly N_s variation for the month of October, which is a typical rainy season month in Makurdi.

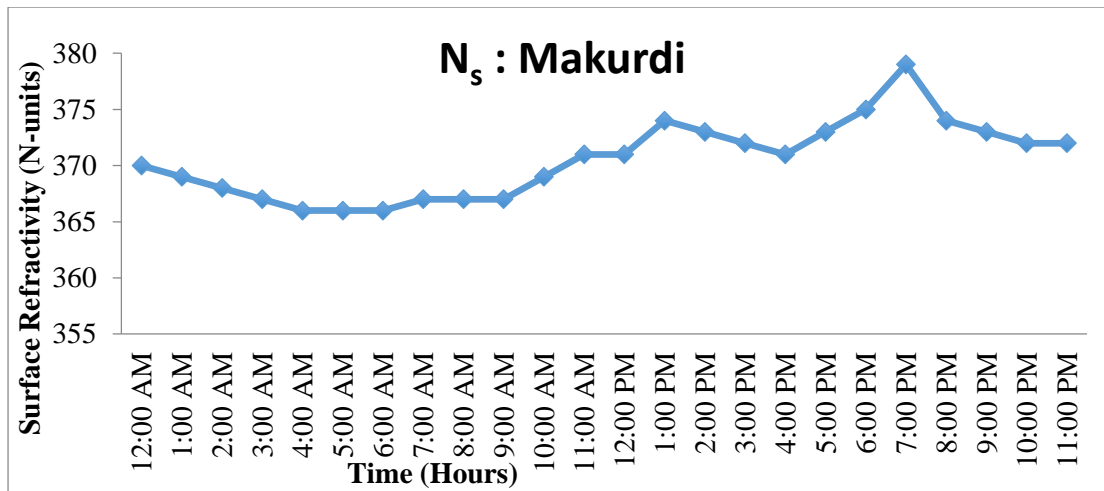


Figure 13: Hourly Surface Refractivity in October

Figure 13 clearly shows that refractivity decreased from the early hours of the morning to a constant least value of 366 N-units around 4:00-6:00am local time, followed by a small rise to a constant value of 367 N-units around 7:00-9:00am and a gradual constant rise to 371 N-units at 11:00am-12:00pm. A peak of 374 N-units was observed at 1:00pm, dropped to 371

N-units at 4:00pm, increased again to a second peak of 379 N-units at 7:00pm then a gradual drop for the rest of the day.

Figure 14 shows the mean hourly N_s variations for the wet season months in Makurdi.

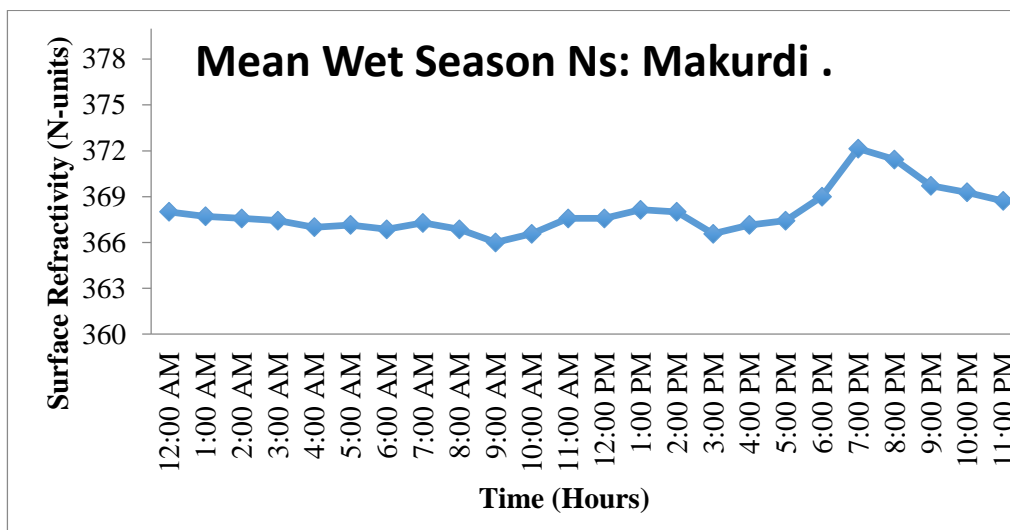


Figure 14: Mean Hourly Surface Refractivity for Wet Season Months

It could be observed from Figure 14 that the mean surface refractivity (N_s) decreased steadily from 12:00am to 9:00am, rose slightly till 2:00pm, then dropped at 3:00pm before rising steadily to a highest value of 372N-units at 7:00pm. However, there was a sharp drop from 7:00pm to 11:00pm. The minimum value of 366N-units occurred at 9:00am. The N_s is generally high ranging between 366 and 372 N-Units. This trend of high refractivity throughout the day can be attributed to the high humidity

level in the atmosphere at this time coupled with the higher sensitivity of refractivity to water vapour pressure in the wet season, which also cause reduction in temperature. High refractivity values observed during the day is due to the low insolation, causing some of the surface-based vapour to be unheated up, less expand and remain at the lower altitude thereby increasing the surface based moisture content. The high N_s values obtained from the wet season months are due to absorption/

evaporation from the sea. This have direct positive effect on VHF/UHF signal field strength profile in Makurdi, because it enhances the all terrestrial communication in Makurdi, reduced energy lost in the side of both transmitter and receiver and a greater efficiency

of radio propagation is observed in Makurdi within the wet season months.

Figure 14a shows the mean hourly N_s variations for the dry season months in Lapai

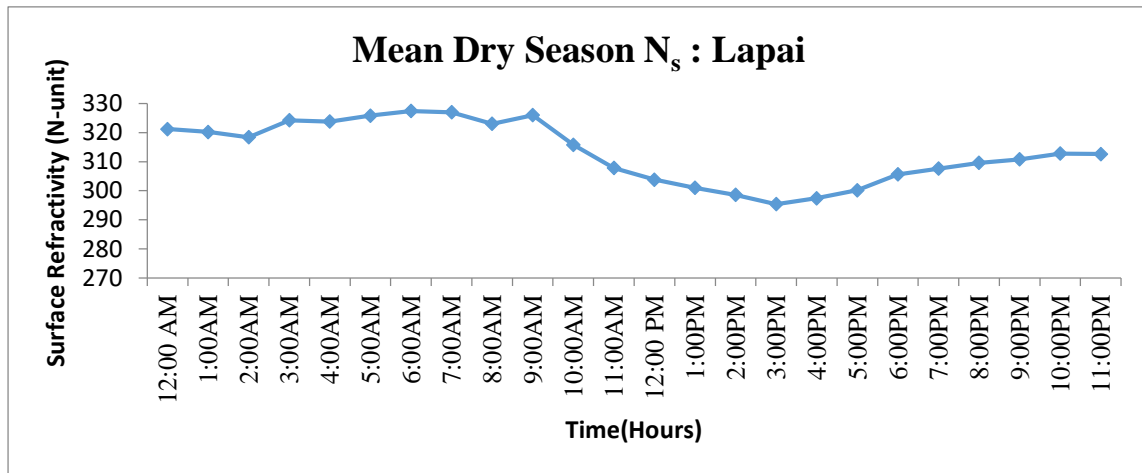


Figure 14a: Mean Hourly Surface Refractivity for Dry Season Months in lapai

Considering Figure 14a the hourly refractivity, N increased uniformly from 320N-units at 12:00am to a peak of 326N-units at 9:00am and then decreased gradually to the least value of 295N-units at 2:00pm after which it increased gradually again all through 11:00pm to a value of 313N-units. This trend of high refractivity in the morning and late at night can be attributed to the high humidity level in the atmosphere at this time coupled with the higher sensitivity of refractivity to water vapour partial pressure in the dry season at those periods. Low refractivity values observed during the day is due to the

high insolation, causing some of the surface-based vapour to be heated up, expand and rise to the higher altitude thereby decreasing the surface based moisture. The least N_s values obtained from the dry season months have direct negative effect on VHF/UHF signal field strength profile in Lapai.

Figure 14b shows the mean hourly N_s variations for the wet season months in Lapai.

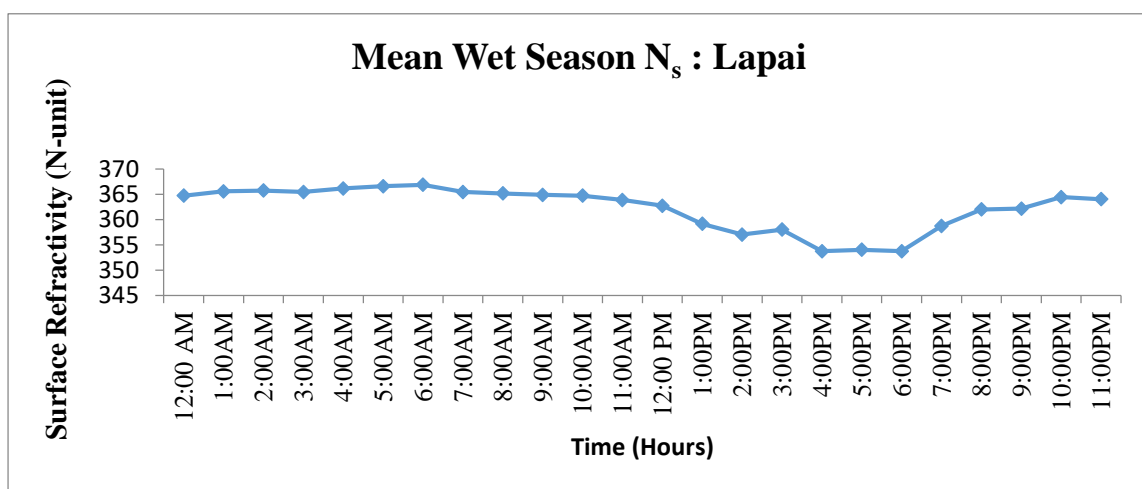


Figure 14b: Mean Hourly Surface Refractivity for Wet Season Months in lapai

It could be observed from Figure 14b that the mean surface refractivity (N_s) over Lapai decreased steadily from 12:00am at 365N-unit to 2:00pm at 357N-units, increase slightly till 3:00pm at 358N-units, then dropped at 4:00pm with 354N-unit and remain low up till 6:00am before rising steadily to a high value of 364N-units at 11:00pm. This trend of high refractivity throughout the day can be attributed to the high humidity level in the atmosphere at this time coupled with the higher sensitivity of refractivity to water vapour pressure in the wet season, which also causes reduction in the surface temperature. High refractivity values observed during the day is due to the low insolation, causing the surface-based vapour to be unheated up, less expand and remain at the lower altitude thereby increasing the surface

based moisture content. The high N_s values obtained from the wet season months have direct positive effect on VHF/UHF signal field strength profile in Lapai, because it enhances terrestrial communication in Lapai, causing reduced energy loss from transmitter to receiver and thus a greater efficiency of radio propagation is observed in Lapai within the wet season months.

The Monthly Variations of Surface Refractivity (N_s) over Makurdi

The Tables for the discussions of Figure 15 to Figure 22 are presented in the Appendix B. Figure 15 shows the N_s variation for the years 2005 to 2010 in Makurdi at the elevation of 0.104 km above mean sea level.

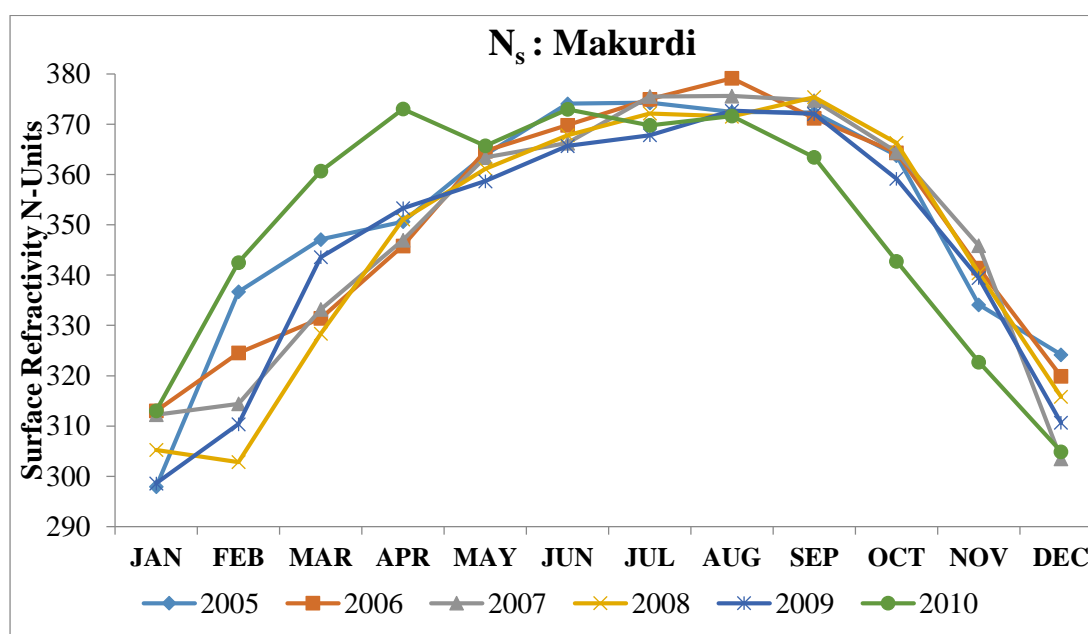


Figure 15: Variation of Monthly Surface Refractivity over Makurdi (2005-2010)

Figure 15 that generally N_s increased steadily from January to May. This is followed by a gradual increase to the month of October, before a steep decrease to the month of December. The least value of 298 N-units is observed in January, while the highest value of 375 N-units occurred in the month of August, which is a typical rainy season month in the Middle Belt region of Nigeria. Thus, N_s is generally higher during the rainy season months of (April to October). This could be due to high air humidity observed in Makurdi during the periods. Hence, in this period, Makurdi could have been under the influence of moisture-

laden tropical maritime air, resulting from South to North migration of the inter-tropical discontinuity (ITD) with the sun. In the month of December, N_s dropped because this is the period when the dry and dust-laden northeasterly winds become dominant and the dry harmattan sets in, hence the low N values observed in January and February. On the other hand, between the month of April and October, the whole city would have been subjected to widespread rainfall, which leads to increase moisture in atmosphere, that results to in increase humidity, hence N_s increased. The month of January is the driest month, followed

by February; while the months of March and April are transition months between dry and wet season, hence the observed N_s seasonal

profile. This result is in agreement with the result obtained by (Isikwue *et al.*, 2013).

The Mean variation of Earth’s Radius Factor over Lapai and Makurdi

The Figures 16a-b below shows the mean variations of the effective earth’s radius factor (k-Factor) over the study area for the years 2005-2010.

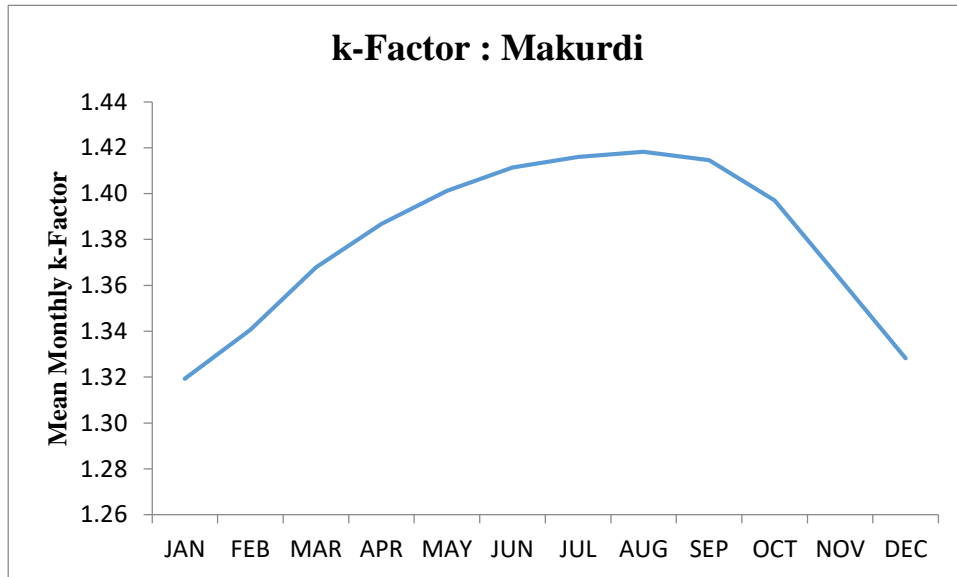


Figure 16a: Mean monthly variation of k-factor over Makurdi for 2005-2010

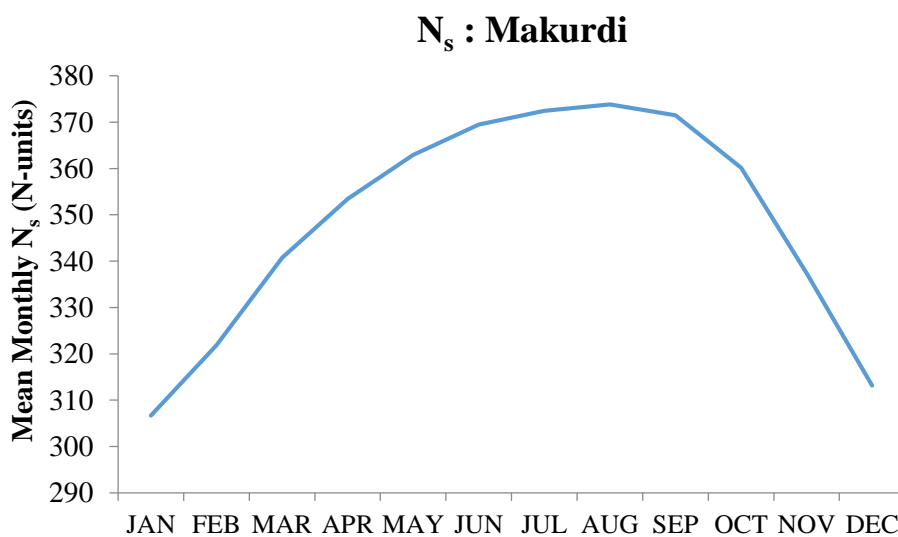


Figure 16b: Mean Monthly variation of N_s over Makurdi for 2005-2010

The k-factor is computed using equation (3.9). From the results, it is deduced that k-factor increases with increase in the refractivity; like the surface refractivity, the k-factor is observed to be lower throughout the stations in the dry

season and higher throughout the wet season. The result obtained is in agreement with work of Kolawole and Owonubi (1987).

N_s Contour Representations

The surfer 11 software was used to further show the 2-D Contour of the surface refractivity, the diurnal and seasonal variations. Surface refractivity was also contoured with atmospheric pressure, temperature and relative humidity to show the relationship between them.

Contouring of Diurnal and Seasonal Variation of N_s over Makurdi and Lapai.

The contour maps of Figure 3.17a and Figure 3.17b present the summary of the seasonal and diurnal variation of surface refractivity over the stations under study.

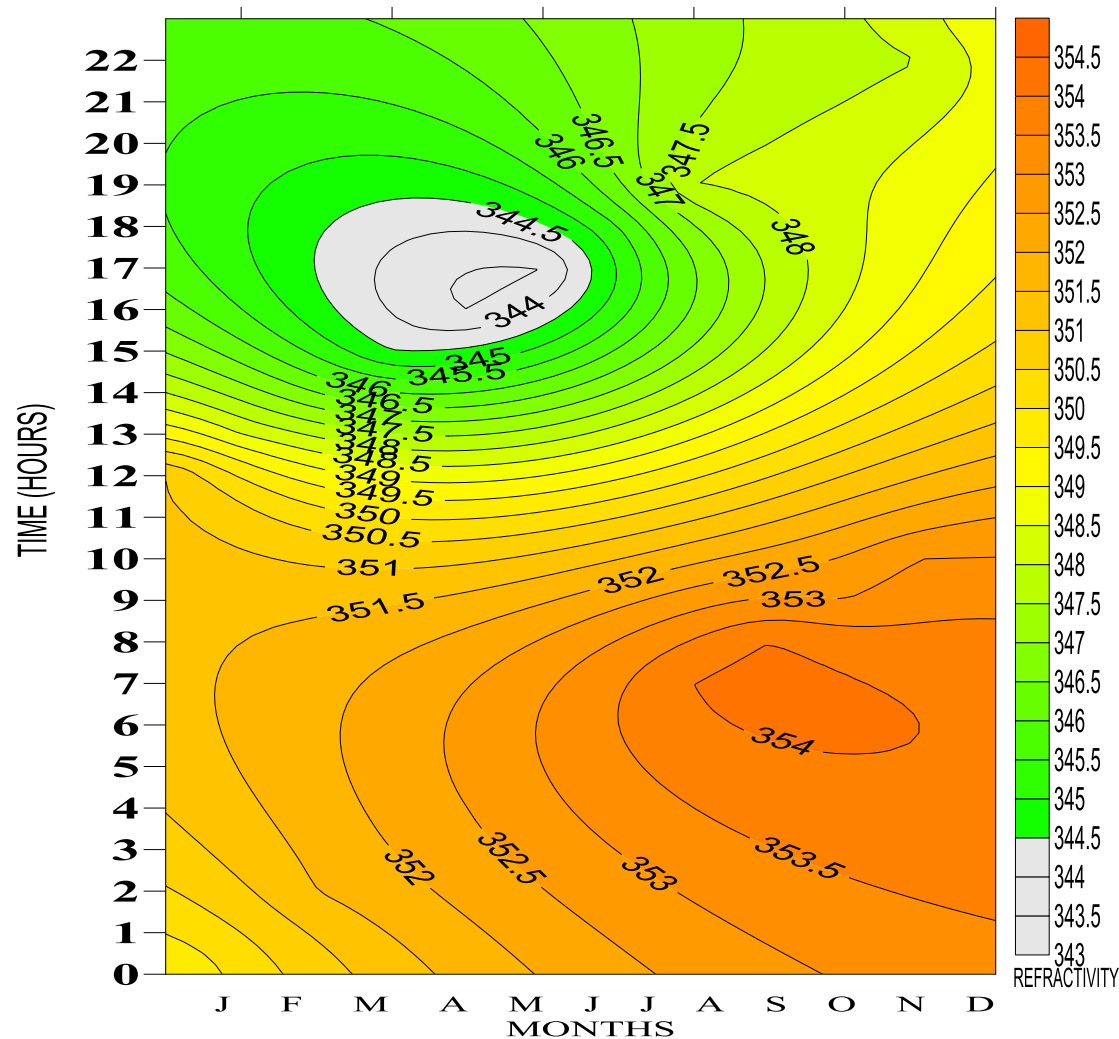


Figure 17a: Diurnal and Seasonal Variation of N_s over Makurdi for 2005-2010

Figure 17a shows that the wet season months have higher values of N_s ; the N_s values are between 352-354 N-units as can be seen from the legend, the brown colour part of the contour represents the high N_s value, while dry season months have the least values between 344-351 N-units as indicated from the legend. In

addition, it is observed that least N_s occurs between hours of 18:00 and 23:00 every day, the part is represented with white colour in the contour, which is towards the mid-night.

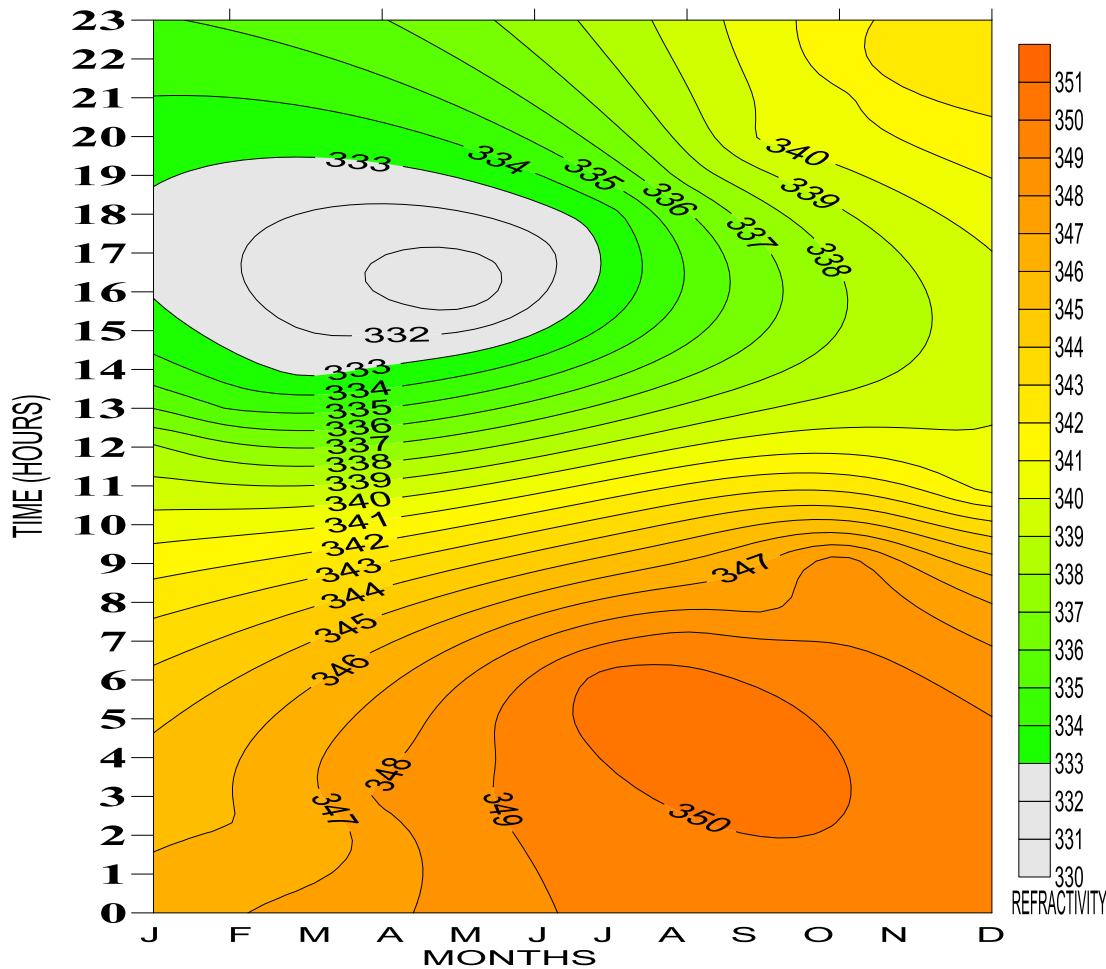


Figure 17b: Diurnal and Seasonal Variation of N_s over Lapai for 2005-2010

Figure 17b shows that the wet season months have the higher values of N_s ; the N_s values are between 348-350 N-units as can be seen from the legend, the brown colour part of the contour represent the highest N_s value, while dry season months have the least values between 330-347 N-units as indicated from the legend. Also, it is observed that the least N_s value occurred between hours of 18:00 and 23:00 hrs every day, the part is represented by the white colour in the contour and gradually increased faster towards mid-night as represented with green colour.

Conclusion and Recommendations

Generally, from the results obtained, the refractivity value in the two region (Lapai and Makurdi) is between 290 to 390 N-units. The diurnal variations of refractivity are driven by the dry component in the rainy season and the wet term component in the dry season. That the refractivity shows a seasonal variation with higher values in the rainy season and lower values in the dry season. The computed mean

diurnal N_s over Makurdi and Lapai in the first 1 km are 343 and 342 N-units, which gives the refractivity gradients ($\frac{dN}{dh}$) of -47 and -46 N/km and this shows the stations are averagely characterised by low level Super-refraction.

It can be concluded that refractivity varies according to height above the over sea-level from one station to another.

The mean FSV over the region is 14dB. The mean Radio Horizon for a transmitter height of 100 m over the stations is 42 km. The result implies that the higher the refractivity values, the better would be radio wave propagation, that is, radio signals are better received in the wet season months than in dry season months. The results provide useful information needed by radio engineers to set up new terrestrial radio propagation links or to improve on the existing ones in the region under study.

There is the need to spread surface weather data measuring locations over more parts of the

study region, there is also need to install radiosonde stations to obtain upper air data with which N at higher levels can be derived as recommended by (ITU-R P.453, 2013), which recommends the need for local reference data on refractivity and refractivity gradients all over the world.

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