Variation of Surface Radio Refractivity in Minna, North Central Nigeria

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Abstract: ***The radio refractivity at the surface is vital in the design and planning of terrestrial radio links in the lower atmosphere (troposphere). For this reason, measurement of atmospheric parameters (Pressure, Temperature and Relative Humidity) were obtained inMinna "(9 ^{0}36'50'N and 6 ^{0}33'25'E)" to determine the surface radio refractivity. The measurement was taken by positioning wireless meteorological sensors at the ground surface. The measurement was made at 30 minutes interval for a complete 24 hours cycle. The diurnal and seasonal variation of the surface radio refractivity were studied using two years of data measured from January 2008 to December 2009. The result obtained show that the value of surface radio refractivity is relatively high during the rainy season (April-October) and low during the dry season (November-March). The results obtained also show that the diurnal variation during the dry season is attributed to the dry term of refractivity, while the diurnal variation during the rainy season is attributed to both the dry and wet term.***

Keywords: radio refractivity, wet term, dry term, seasonal variations, diurnal variations

1. Introduction

The transmission of radio wave signals in the lower atmosphere (troposphere) is greatly affected by the composition of the atmosphere [1]. It occurs due to the dynamics of meteorological parameters such as temperature, pressure and relative humidity. The troposphere extends from the earth surface to an altitude of about 10 km at the earth poles and 17 km at the equator [2]. The atmosphere is a non-homogenous medium and the radio wave passing through it are not straight but bent. The velocity of radio waves in a medium depends on the refractive index (n) which is a function of refractivity N. Due to the fluctuation of the meteorological parameters, the refractive index in this layer varies from one point to another. The refractive index variation of the atmosphere affects radio wave above 30 MHz. These effects become significant only at a frequency higher than about 100 MHz in the lower troposphere. The random spatial variation of the refractive index in the troposphere is responsiblefor mechanisms such as scintillation, fading, multipath, etc. which causes attenuation in transmitted signals and co-interference [3]. The extent to which the atmosphere affects radio signals depends mainly on the frequency and the power of the transmitted signals and also on the state of the troposphere where the signal will propagate through. The radio refractive index is an essential parameter in determining the quality of UHF, SHF, and VHF signals. The characterization of the variability of the surface radio refractivity in the lower atmosphere (troposphere) is very useful for the prediction of propagation effect [3].

Result of many researchers showed that the refractivity fluctuation in the lower atmosphere (troposphere) is a function of atmospheric parameters. Falodun and Ajewole [4] reported that in the atmosphere, pressure, temperature and humidity decrease exponentially as height (h) increases. Ayantunji and Okeke studied diurnal and seasonal variation of surface refractivity over Nigeria [5]. The study of surface radio refractivity is important to all transmitting stations as it will enable radio engineers to accurately determine the quality of UHF, VHF and SHF signals for a proper design of their communication stations.

Hence, this study present the result of in-situ measurement of meteorological parameters (temperature, pressure and humidity) at the surface. Wireless weather station also known as Integrated Sensor Suite were used for the measurement. The data obtained were used to compute the Surface radio refractivity Ns.

2. Relevant Theory

Electromagnetic waves are waves that do not require a material medium for their propagation. Electromagnetic waves would travel in straight lines if the atmosphere were homogenous. As to what is known, the atmosphere and its permittivity are stratified, the electromagnetic wave passing through it are always bent [6]. As a result, the refractive index of air which is the ratio of the speed of electromagnetic radiation in a vacuum to that in the air is related to the permittivity ε_r as

$$n^2 = \varepsilon_r \quad (1)$$

The relationship between Radio refractivity N and radio refractive index (n) is given as [7][8].

$$N = (n - 1) \times 10^6 \quad (2)$$

The radio refractivity N is expressed as

$$N = 77.6\frac{P}{T} + 3.73 \text{ X } 10^5 \frac{e}{T^2} \quad (3)$$

The Eqn. 3 is categorized in two (2)

$$N = N_{dry} + N_{wet} \quad (4)$$

where;

$N_{dry} = 77.6\frac{P}{T}$ and $N_{wet} = 3.73 \times 10^5 \frac{e}{T^2}$

P is the atmospheric pressure (hPa), e is the water vapour pressure (hPa) and T is the absolute temperature (K).Eqn.3 may be used for radio frequency up to 100GHz [9].

The vapour pressure is also related to the relative humidity H

$$e = \frac{He_s}{100} \quad (5)$$

$e_s$is the saturated vapour pressure at the given air temperature , and is expressed as

$$e_s = 6.1121\,\text{EXP}\left[\frac{17.502t}{(t+240.97)}\right] \quad (6)$$

Pressure (P) and vapour pressure (e) decrease rapidly with height while temperature (T) decreases slowly with height [10].

Surface radio refractivity N_s is known to have high correlation with radio field strength while the surface refractivity gradient which depends on N_s, determines the refractivity condition of the atmosphere which may result in a normal, sub-refractive or ducting layer [11] each of which has important influence on propagation of UHF and VHF and microwave in the atmosphere.

3. Instrumentation and scope of data

The instrument used for the measurement is the Davis 6162 Wireless Vantage Pro2 equipped with the IntegratedSensor Suite (ISS), a solar panel (with an alternative battery source)and the wireless console, which provide the user interface, data display and analogue to digital conversion. The ISSs are positioned at the groundlevel and houses the external sensor array for continuous measurement of the surface weather parameters: atmospheric pressure, temperature and relative humidity. The temperature and relative humidity sensors are located inside the radiation shield while the sensor interface module is located below the radiation shield. The datais then transmitted by wireless radio to the data logger attached to the receiver located on the ground.Fromthe receiver, the data are then copied to the computer. The instrument has integration time of 30 minutes.

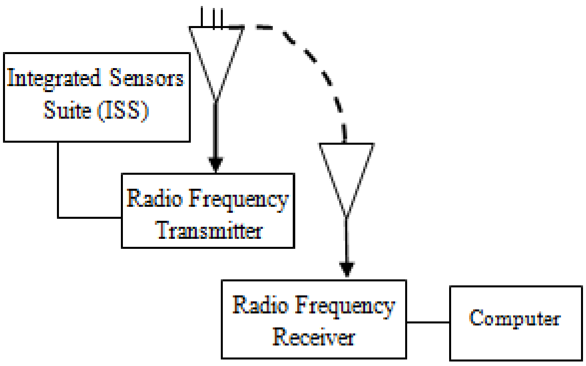

Figure 1:Set-Up of the Measuring Equipment

The measurement of the meteorological parameters were made from January 2008 to December 2009.the data were collected at the aforementioned level. And the record covers 24 hr. each day from 00:00 hr. to 23:00 hr. local time. Although the ISS measures about nine meteorological parameters, only the daily records of pressure temperature and relative humidity are used for this study.

4. Result and Discussion

4.1 Diurnal Variation of Refractivity

The data used for this study were from the in-situ measurement of meteorological parameters made from January 2009 to December 2009 .the measurement covered both main seasons occurring in Minna every year i.e. the rainy and the dry season. The climate in Minna is tropical and is governed by the movement of the intertropical discontinuity, a zone where warm, moist air from the Atlantic converges with hot, dry, and often dust-laden air from the Sahara known locally as the harmattan. Using the data extracted for this study, the surface refractivity N_s was calculated using Eqn. (3).

The diurnal Variation of surface refractivity is shown in figure 2 and 3 for dry and rainy season respectively.

In figure 2, the profile shows a gradual increase from early hours of the day and a peak of about 304 N-units around 12:00 hr. local time and gradually decrease to a minimum of 292 N-units around 18:00 hr. local time and increase gradually to 23:00 hr. local time before peaking down to 00:00 hr. The diurnal variations in the dry season refractivity can be attributed to the influence of the wet term of refractivity N, which is mainly influenced by humidity.

The diurnal variation for the rainy season is presented in figure 3. It was observed that the refractivity shows a gradual increase in the early hours of the morning and has a peak value of about 376 N-units at 07:00 hr. local time and started decreasing gradually to about 369 N-units around 12:00 hr. At 15:00 hr., the value of the refractivity started increasing for the rest of the day.

The refractivity variation of Minna during the rainy season could best be understand using the atmospheric profiles showed in figure 4, 5 and 6.

In figure 4, the temperature gradually decrease from 00:00 hr. to its lowest at 7:00 hr. local time before increasing to its maximum around 16:00 hr. local time. The variation of the relative humidity in figure 5 follows the opposite trend with a maximum value around 7:00 and a minimum value around 16:00 hr. Figure 6 shows the pressure profile. The figure display an oscillatory behavior. Maximum values of pressure are observed around noon, late night and early mornings.

The high values of refractivity observed during the late hours of the morning occur as a result of high pressure at this time of the day. This implies that the refractivity variation is driven by the dry term.

During the early hours of the day as shown in figure 3, the early hour’s refractivity value increase to its maximum of about 376 N-units between the hours of 6:00-8:00 hr. local time which is consistent with the variations in the humidity profile (figure 5) which determine the wet term of refractivity. Significant drop is observed in the refractivity values in the late noon corresponding to low values of pressure at that hour (figure 6) which determines the dry term of refractivity. Therefore, the diurnal variation of refractivity over Minna for rainy season is as a result of the combination of both wet and dry terms.

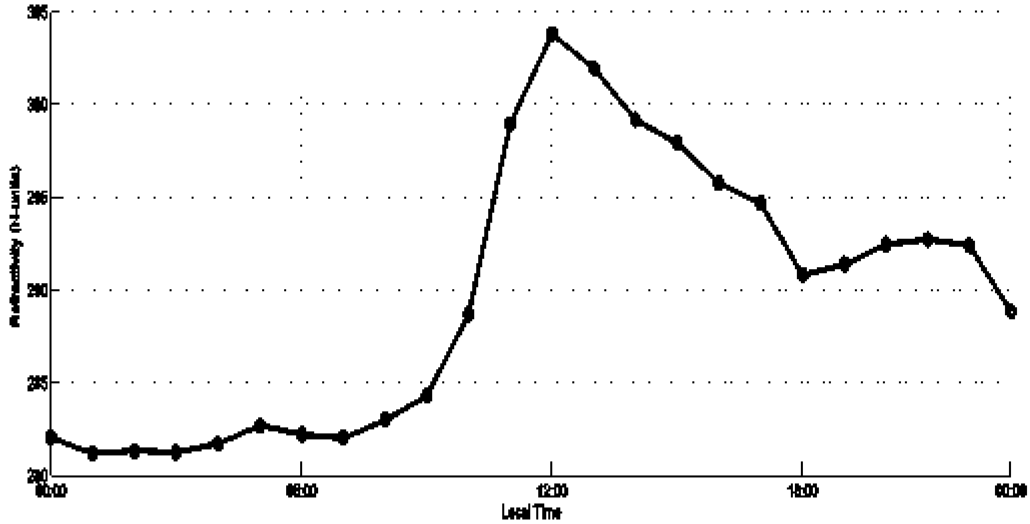

Figure 2: Diurnal Variation of Surface Refractivity over Minnafor Dry Season

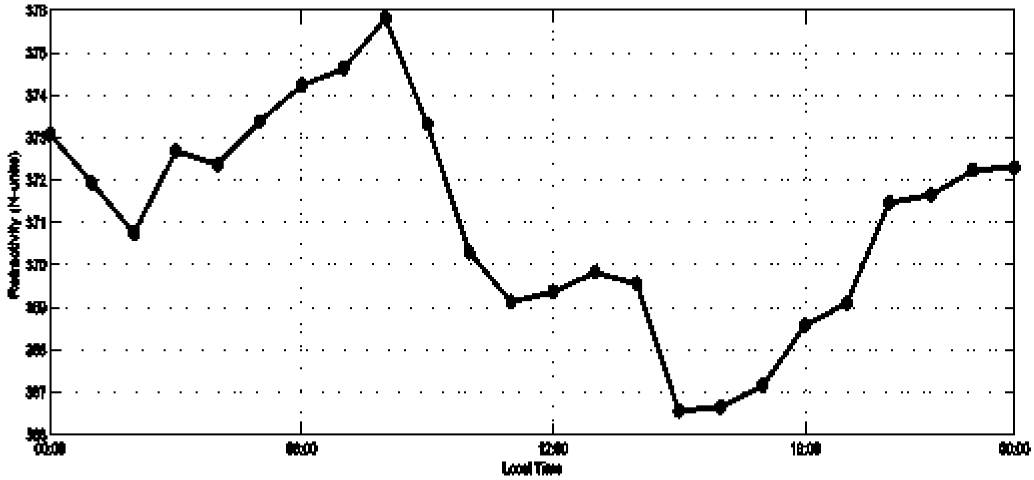

Figure 3: Diurnal Variation of Surface Refractivity over Minnafor Rainy Season.

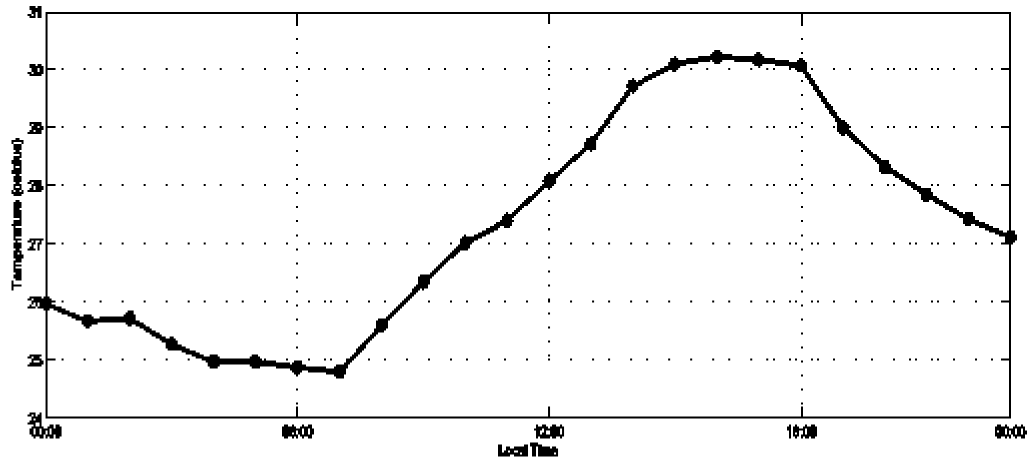

Figure 4: Diurnal Variation of Temperature over Minna for Rainy Season.

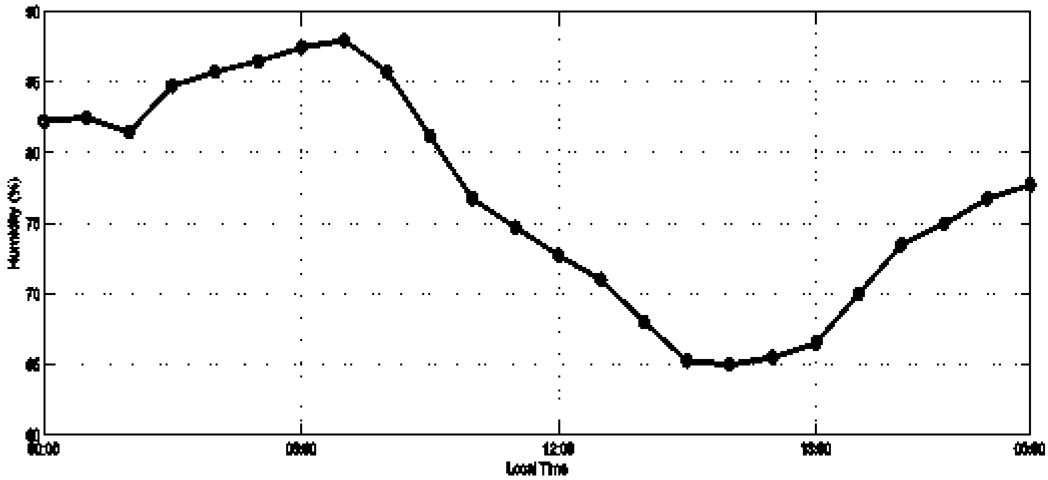

Figure 5: Diurnal variation of Humidity over Minna for Rainy Season.

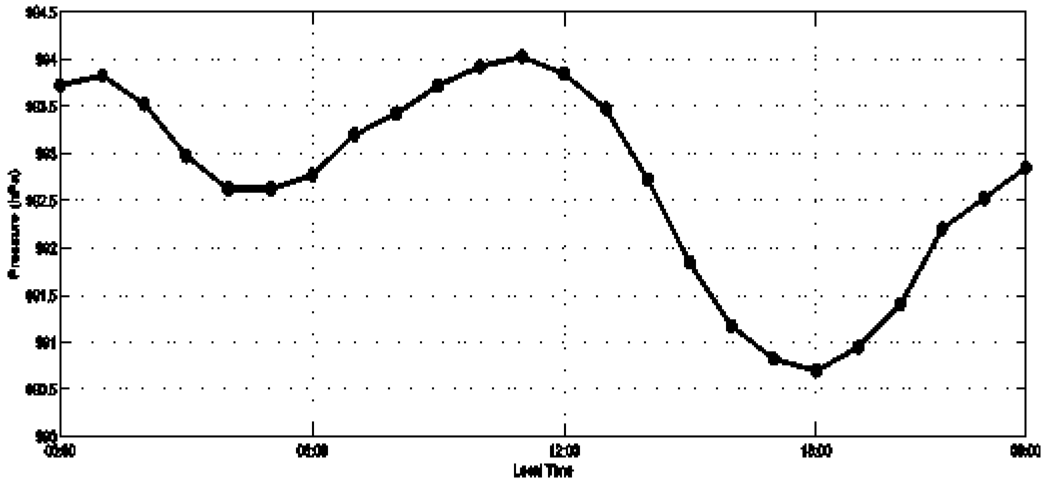

Figure 6: Diurnal variation of Pressure over Minna for Rainy Season.

4.2 Seasonal variation of refractivity

Theresults obtained for the average monthly records are shown in figure 7 and 8. The values were observed to be generally high during the rainy season (April-October), and low during the dry season (November-March).

In figure 7, the minimum value of refractivity is observed in February with value of about 280 N-units, while the maximum value is observed in the month of August which correspond to the rainy season with value of about 368 N-units. In figure 8 the minimum value were observed in December with a value of 300 N-units ,while maximum value is observed in August with value of about 378 N-units.

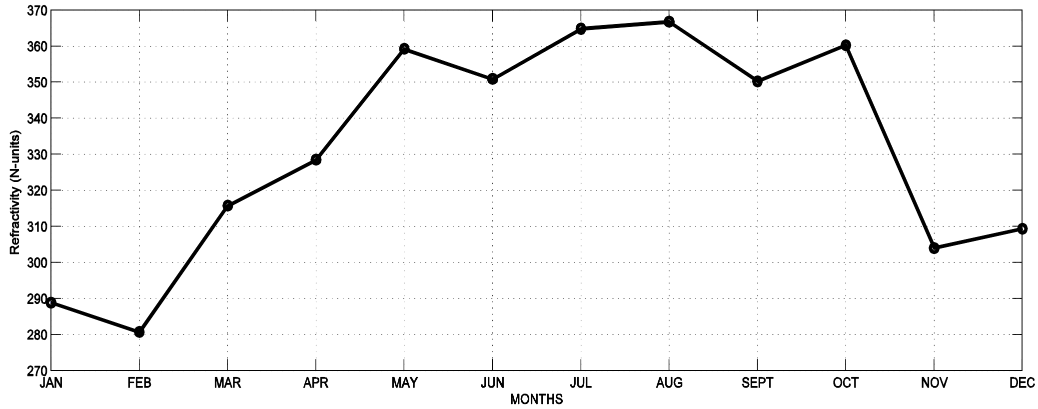

Figure 7: Seasonal Variation of Surface Radio Refractivity over Minna for the Year 2008

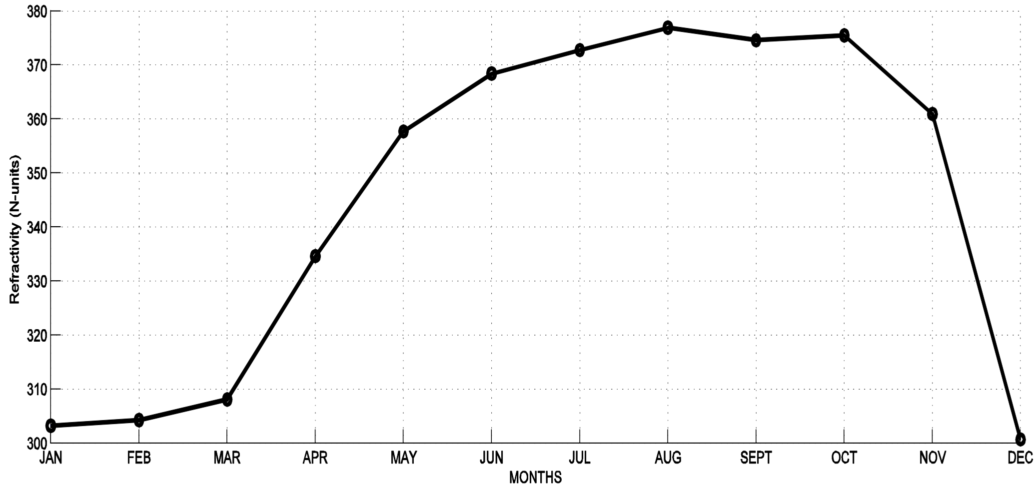

Figure 8: Seasonal Variation of Surface Radio Refractivity over Minnafor the Year 2009

5. Conclusion

In-situ measurement of meteorological parameters were made at the ground surface in Minna, North Central Nigeria with the objective of determining the surface radio refractivity. From the completed study, the following were observed:

- It was observed that the refractivity is generally high during the rainy season (April-October) and the refractivity values are low during the dry season (November-March).
- The diurnal variation during the dry season is attributed to the wet component of refractivity (wet term)
- The diurnal variation during the rainy season is attributed to both the dry and wet component of refractivity (dry and wet term)

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