International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:7, No:10, 2013

Variation of Metrological Parameters as They Affect the Tropospheric Radio Refractivity for Akure South-West Nigeria

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***Abstract*—**This research work examines the effect of variations of metrological parameters on the tropospheric radio refractivity during dry and raining seasons for Akure in 2013. The daily averages of radio refractivity during dry (January) and raining (August) seasons were calculated from the data obtained from the Nigeria Metrological Agency (NIMET). The data that was used for the computation of radio refractivity is a daily interval of the variations of metrological parameters for each day in the troposphere for Akure. Consequently, the daily averages of radio refractivity during raining season (August) were greater than the results in dry season (January) as a result of the variations in meteorological parameters such as temperature, humidity and atmospheric pressure in the lower troposphere.

***Keywords*—**Troposphere, Radio refractivity, Akure, Meteorological parameters.

I. Introduction

RADIO frequency or radio wave signal propagation in the troposphere is affected by many factors which include the variations of metrological parameters such as humidity, temperature and atmospheric pressure. Metrological parameters are associated with the change in weather in different seasons of the year and these changes have resulted in refractivity changes. Grabner and Kvicera [1] reported that multipath effects also occur as a result of large scale variations in atmospheric radio refractive index, such as different horizontal layers having different refractivity. This effect occurs most often, when the same radio wave signals follow different paths thereby having different time of arrivals to its targeted point. This may result to interference of the radio wave signals with each other during propagation through the troposphere. The consequence of this large scale variation in the atmospheric refractive index is that radio waves propagating through the atmosphere become progressively curved towards the earth. Thus, the range of the radio waves is determined by the height dependence of the refractivity. Thus, the refractivity of the atmosphere will not only vary as the height changes but also affect radio signal.

The quality of radio wave signal reception and probability of the failure in radio wave propagations are largely governed by radio refractivity index gradient which is a function of meteorological parameters changing in lower atmosphere such as temperature, pressure and humidity.

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Radio wave propagation is determined by changes in the refractive index of air in the troposphere [2]. Changes in the value of the troposphere radio refractive index can curve the path of the propagating radio wave. At standard atmosphere conditions near the Earth's surface, the radio refractive index is equal to approximately 1.0003 [3]. Since the value of refractive index is very close to unity, then the refractive index of air in the troposphere is often measured by a quantity called the radio-refractivity N, which is related to refractive index, n as:

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

As the conditions of propagation in the atmosphere vary, the interference of radio-wave propagation is observed. Such interferences are incident with some meteorological parameters (inversion of temperature, high evaporation and humidity, passing of the cold air over the warm surface and conversely) [4].

Radio waves travel through vacuum with a speed equal to the speed of light. In material medium, the speed of the radio waves is approximately c/n where c is the speed of light in vacuum and n is the radio refractive index of the medium. The value of radio refractive index (n) for dry air is almost the same for radio waves and the light waves. But the value of radio refractive index (n) for water vapor, which is always present in some quantity in the lower troposphere, is different for the light waves and radio waves. This arises from the fact that water vapor molecule has a permanent dipole moment which has different responses to the electric forces of different radio wave frequencies propagated within the atmosphere.

The atmospheric radio refractive index depends on air temperature, humidity, atmospheric pressure and water vapour pressure. Subsequently, meteorological parameters depend on the height at 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 can be refracted over whole signal path. [5]. Falodun and Ajewole [6] reported that in the atmosphere, pressure, temperature and humidity decrease exponentially as height h increases.

According to Willoughby, [7], atmosphere has an important feature:-the vertical gradient of the refractive index, G. The vertical gradient of the refractive index is responsible for bending of propagation direction of the electromagnetic wave. If the value G is negative, the signal bends downward [8]. The characterization of the seasonal variation in fading and its dependence on meteorological parameters provides the way to improve transmission performance by better tailoring of performance equipment design and usage to the amount of fading expected at a given location and time of the year.

II. Research Methodology

The meteorological parameters (pressure, temperature relative humidity) used to calculate radio refractivity for Akure South-West Nigeria was provided by Nigeria Metrological Agency (NIMET). The analysis were done in all the months of the year 2013, but the months of January and August results were chosen to represent the dry and rainy season in South-West Nigeria.

The daily variations of meteorological parameters for each month day were recorded for dry and rainy seasons in Akure. The average variation of each day was calculated from the recorded data. The partial pressure of water e was determined from the equation as follow:

$$e = e_s H \qquad (2)$$

where H is the relative humidity, and e_s is the saturation vapour pressure determined by Clausius-Clapeyron equation given as:

$$e_s = 6.11 \exp\left[\frac{17.26(T-273.16)}{T-35.87}\right] \qquad (3)$$

In relation with the measured meteorological parameters such as the temperature, pressure and relative humidity radio refractivity was calculated using;

$$N = 77.6\frac{P}{T} + 3.37 \times \frac{10^5 e}{T^2} \qquad (4)$$

where
P = atmospheric pressure (hPa)
e = water vapour pressure (hPa)
t = absolute temperature (K)

Equation (4) may be employed for the propagation of radio frequencies up to 100GHz as presented by Willoughby et al. [7]. The error associated with the application of the above formula is less than 0.5% (ITU-R, 2003).

III. Results and Discussion

Averages of daily variations of meteorological parameters for each day were obtained, from the data collected for dry and rainy seasons in 2013, for Akure. The results were used to calculate radio refractivity for each day. The plots of daily variations of radio refractivity for both dry and rainy seasons are shown in Figs. 1 and 2 respectively while Fig. 3 shows the comparison between the dry and the wet seasons.

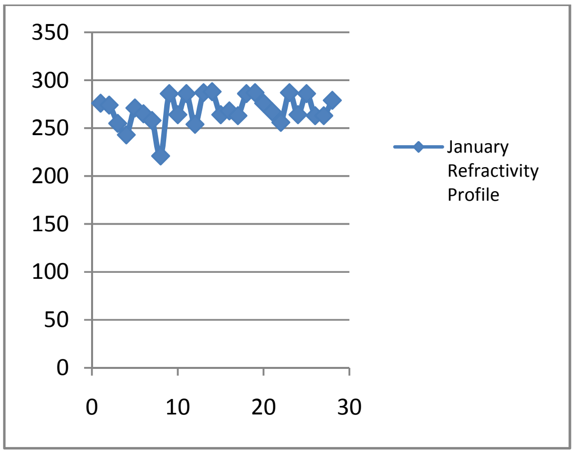

Fig. 1 Daily variations of radio refractivity for dry season (January)

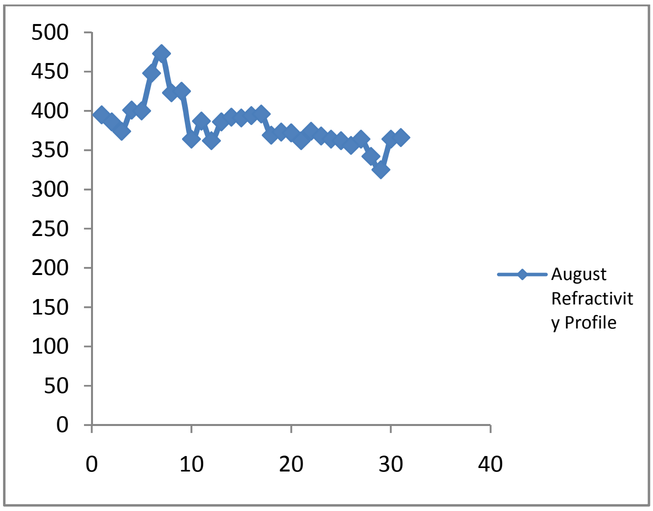

Fig. 2 Daily variations of radio refractivity for wet season (August)

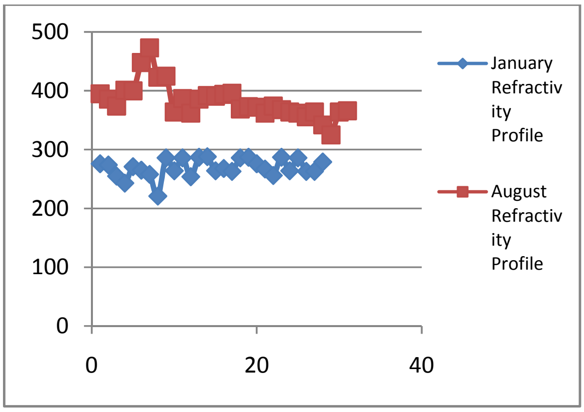

Fig. 3 Daily variations of radio refractivity for both the dry and wet seasons

Akure is situated in the tropics at Lat 7.250N, Long 5.20E, altitude 420m above sea level; an agricultural trade centre with light industries and is minimally influenced by industrial pollutants or aerosols. Akure is dominated by dry season within the year. The measured relative humidity was converted to water vapour pressure by applying (2) for both dry and rainy seasons.

Usually, water exists in the troposphere in liquid form (fog, clouds, rain) and solid form (snow, hail, ice) and the most important effect in relation to weather activities, not only presence of rain and snowfall but also because large amount of energy are released in condensation process. Obviously, there is a significant difference between the raining and dry season's refractivity due to the fact that in the raining season, the atmosphere is mostly dominated by moisture content of water vapour which eventually increases humidity in the atmosphere while in the dry season, there is a decrease in radio refractivity was observed corresponding to the period when there is sunshine. According to Smith and Weintrant 1953, the result contains both dry air and water vapor. Dry air has no significant variations in composition with altitude, the amount of water vapor, on the other hand, varies widely, both spatially and temporally. The disparity shown in Fig. 3 is basically as a result of change in weather condition.

IV. Conclusion

This paper established the effect of the variation in meteorological parameters as they affect radio refractivity in Akure South-West Nigeria. The seasonal variation in weather was observed to be more significant during the rainy season than the dry season in Akure due to the increase in the tropospheric temperature and humidity and it is therefore resulted to very high radio refractivity within that period.

Acknowledgment

The author wishes to express his gratitude to the Nigerian Meteorological Agency for the provision of the meteorological data used for this work.

References

[1] M. Grabner and V. Kvicera, (2008).Radio Engineering 12, No.4, 50.
[2] Adediji .T.A and Ajewole. M.O. (2008). Vertical Profile of Radio Refractivity in Akure south-West Nigeria, Vol. 4, p 157-168.
[3] Freeman R. L. (2007). Radio System Design for Telecommunications. – Hoboken, New Jersey, John Wiley&SonsInc Pb, p 880.
[4] Valma E., Tamošiūnaitė M., and TamošiūTamošiūnienė M., Žilinskas M. nas S. (2010). Determination of radio refractive index using meteorological data Electronics and Electrical Engineering. – Kaunas: Technologija,.– No. 10 (106). – P. 125–128.
[5] Priestley, J. T and Hill R. J. (1985) Measuring High–Frequency Refractive Index in the Surface Layer Journal of Atmospheric and Oceanic Technology, Vol. 2. – No.2. – P. 233–251.
[6] Falodun S. E., Ajewole M. O. (2006). Radio refractive index in the lowest 100–m layer of the troposphere in Akure, South Western Nigeria Journal of Atmospheric and Solar–Terrestrial Physics, Vol. 68.– No. 2. – P. 236–243.
[7] Willoughby A. A., Aro T. O., Owolabi I. E. (2002). Seasonal variations of radio refractivity gradients in Nigeria Journal of Atmospheric and Solar– Terrestrial Physics.Vol. 64. – P. 417–425
[8] GuanjunGuo, Shukai Li. (2000). Study on the vertical profile of refractive index in the troposphere International Journal of Infrared and Millimeter Waves, Vol. 21. No.7. – P. 1103–1112.