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Refractivity Variation Effect on Radio Wave Propagation

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Abstract: ***The study of the vertical variation of refractivity in the troposphere is required for radio systems planning. Atmospheric refractivity variation in troposphere is one of the aspects that influence electromagnetic wave propagation and consequently performance of communication links and systems. This work makes use of meteorological data (atmospheric pressure, temperature, humidity) of Akure, South Western Nigeria to compute radio refractivity and gradient in Akure while also making use of UHF band signal measurements for both days and nights in the month of March, 2013 with respect to the location in Akure. The results of refractivity for both periods were compared and so also were the field strength profiles. This was being used to deduce the relationship between the refractivity and UHF band signal strength. Results obtained ascertained that each atmospheric parameter has a role to play in refractivity with humidity as the major factor that is having more influence than other factors. In addition, the surface refractivity is also being influenced by the latitudinal and seasonal variations. Generally, radio refractivity and broadcast signal strength are inversely related with correlation factors of -0.81 and -0.97 for day and night respectively.***

Keyword: Refractivity, Troposphere, Akure, UHF broadcast signal strength

1. Introduction

During the design of radio communication networks, it is important to know the atmospheric radio refractivity index which is the ratio of the velocity of propagation of a radio wave in free space to the velocity in a specified medium.Radio wave propagation changes in the refractive index of air in the troposphere [1]. Changes in the value of the troposphere radio refractive index can curve the path of the propagating radio wave. At standard atmospheric conditions near the Earth's surface, the radio refractive index is approximately 1.0003 [2]. Since the value of refractive index is almost 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) [3].

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. [4]. Falodun and Ajewole[5] reported that in the atmosphere, pressure, temperature and humidity decrease exponentially as height h increases.

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 [6] 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.

2. Research Methodology

The meteorological parameters collected for the month of March, 2013 from Nigeria Metrological Agency (NIMET) were used to calculate radio refractivity (eqn. 4). On daily basis, when meteorological parameters were taken, corresponding UHF broadcast signal strength were also taken both in the days and nights at the same point of observation (3.7km line-of-sight with GPS) using a Yagi array antenna coupled through a 50-ohm feeder to the UNAOHM model EP742A field strength meter.

The partial pressure of water e was determined from the equation as follow:

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

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

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

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

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

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, 2002 [7]. The error associated with the application of the above formula is less than 0.5% (ITU-R, 2003).

3. Results and Discussion

Figures: 1 and 2 show the variations in the profile of radio refractivity in the day and night respectively for the month of March 2013—this implies that the refractivity is higher in the nights compared to the days because of the high humidity and low temperature at nights. Figures: 3 and 4 shows the signal strength measured during the day and night respectively—this shows the effect of different degrees of refractivity on the broadcast signal strength measured. Generally, radio refractivity and broadcast signal strength are inversely related with negative correlation coefficient which implies inverse relationship.

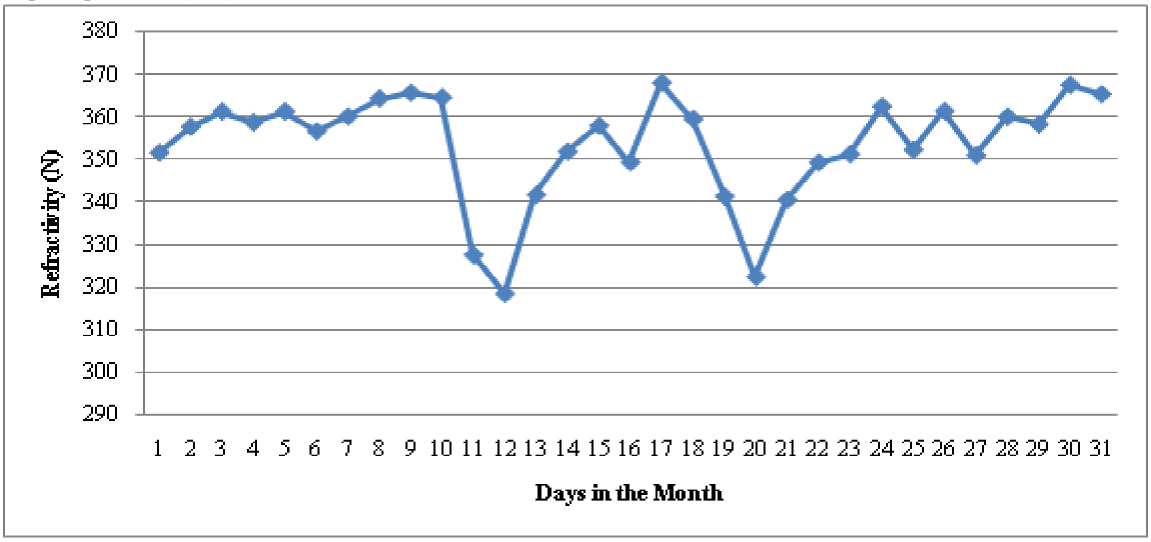

Figure 1: Variation of Radio Refractivity for days in the Month

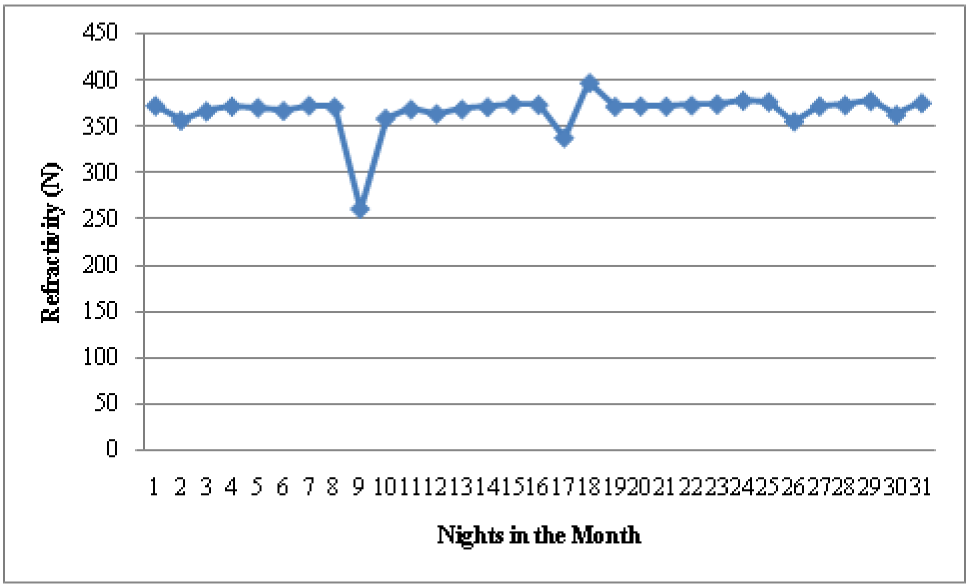

Figure 2: Variation of Radio Refractivity for Nights in the Month

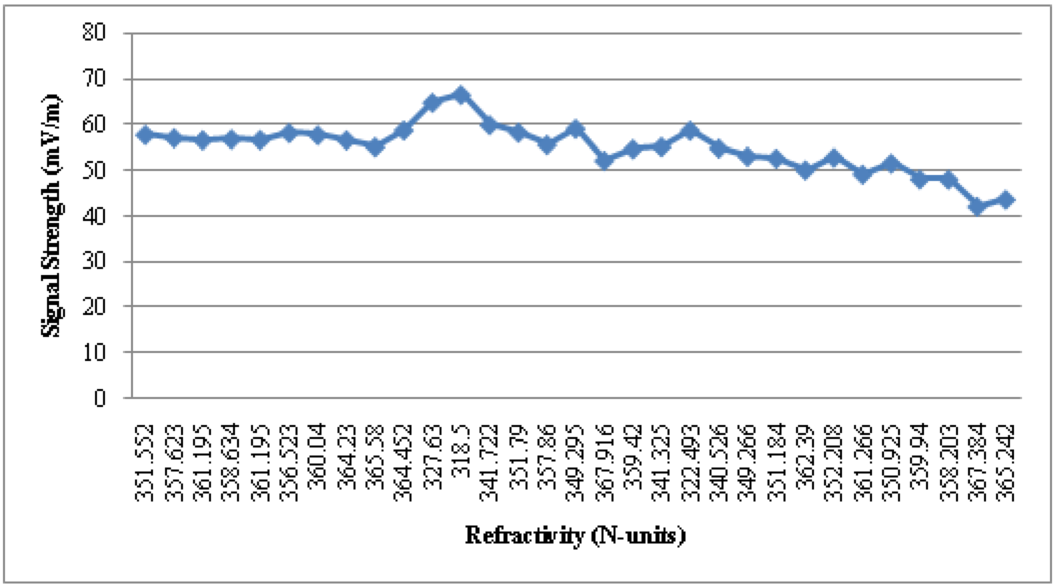

Figure 3: Plot of Signal Strength against Refractivity during the Day

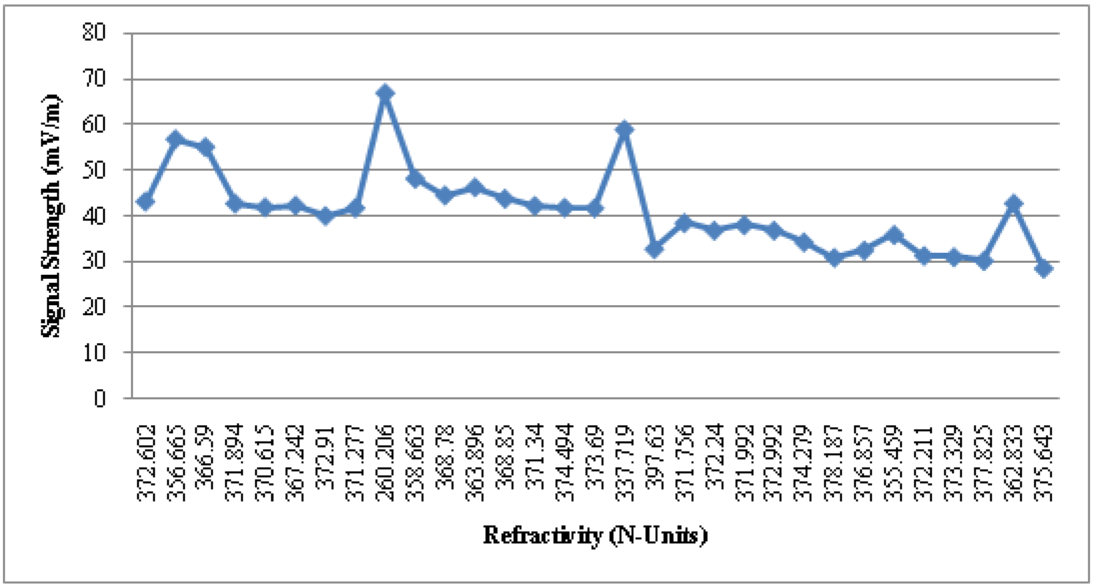

Figure 4: Plot of Signal Strength against Refractivity at Night

4. Conclusion

This paper investigated the effect of vertical variation of radio refractivity in the troposphere on broadcast signal strength. Refractivity is an important factor in predicting the performance of radio link in an environment where it's to be deplored. The change in atmospheric condition leads to radio wave propagation. The diurnal variations are influenced by three atmospheric parameters; water vapor has the greatest effect on refractivity variations followed by temperature. The effect of refractivity should be compensated for when designing wireless communication links in an environment.

References

[1] Adediji .T.A and Ajewole. M.O. (2008). Vertical Profile of Radio Refractivity in Akure south-West Nigeria, Vol. 4, p 157-168.

[2] Freeman R. L. (2007). Radio System Design for Telecommunications. –Hoboken, New Jersey, John Wiley&SonsIncPb, p 880.

[3] 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.

[4] 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.

[5] Falodun S. E.andAjewole 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.

[6] Grabner M. and Kvicera V., (2008).Radio Engineering 12, No.4, pp50.

[7] A. A Willoughby., T. O Aro.andOwolabi I. E. (2002). Seasonal variations of radio refractivity gradients in

Nigeria, Journal of Atmospheric and Solar– Terrestrial Physics. Vol. 64, P. 417–425
[8] ITU-R (2003),"Effects of tropospheric refraction on radiowave propagation," International Telecommunications Union, Geneva.