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Advances in Applied Science Research, 2013, 4(4):346-349

ISSN: 0976-8610
CODEN (USA): AASRFC

Regional implication of tropospheric surface refractivity on radio propagation (A case study of Nigerian atmosphere)

Deborah O. Olorode and Moradeyo A. Adeniji

Department of Physics, Faculty of Science, University of Lagos, Lagos, Nigeria

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ABSTRACT

The wet and dry constituents of the atmosphere affect the propagation of microwave signals especially in the Troposphere. The variations of tropospheric surface refractivity in four cities, (Nsukka, Akure, Minna and Sokoto) modeling Nigerian atmosphere were investigated. The data of 2008 measured on two levels, 0 m (ground level) and 100m altitude of the troposphere captured with the vantage Pro II automatic weather station procured from Centre for Basic Space Science (CBSS), UNN Nsukka were analyzed. The results of the investigation revealed that each Region, namely: Coastal, Inland, Central and far North exhibits a peculiar characteristics that has serious implication on Radiopropagation and receptivity of microwave signal such that ignoring the characteristics could precipitate socio-economic problems of inestimable magnitude. There is high value of refractivity in the coastal region, a reason for the heightening of energy of propagation. It can possibly generate loss of communication and also social insecurity. This Paper, therefore, seeks to itemize step-by -step these implications with a view to proffer suggestions towards aversion or at least ameliorating the effects on human socio-economic relations.

Key words: microwave, refractivity, radio propagation, troposphere.

INTRODUCTION

The subject of Tropospheric surface Refractivity is a major challenge to the phenomenon of communication globally. The interaction between Tropospheric factors and radio frequencies above 30Mhz exposes the waves to important propagation characteristics which often degrades communication links especially at higher frequency [1]. The propagation of electromagnetic waves in the atmosphere (mainly the troposphere) is greatly affected by the composition of the atmosphere [2].

The water molecules in the atmosphere are polar: they have dipole moments. Other gases in the atmosphere are basically non-polar but dipole moments are induced in their molecules only when electromagnetic radiation propagates through them. This causes change in the radio refractive index, ”n”. As a result, reflection, polarization and scattering of the incident radiation begin to occur [3].

The tropospheric refractive index is a function of pressure, temperature and humidity[4 – 7].

This, therefore, means that the signal propagating through the troposphere does not arrive at its destination with the same amount of energy with which it was propagated. In fact it falls short.

Therefore proper assessment and understanding of the limitations imposed by local atmospheric condition are vital steps towards ensuring optimal frequency deployment in order to adequately guard our signal and thereby preserve our information for effective communication.

MATERIALS AND METHODS

The data used for the study were procured from the Centre for the Basic Space Science, University of Nigeria Nzukka. At each station, the relevant weather information i.etropospheric variables such as temperature, pressure and relative humidity were captured at two different levels of the atmosphere i.e. 0 m and 100 m altitude. Data collection was achieved by means of the Vantage PRO II Automatic Weather station. The instrument is divided into Integrated Sensor Suite (ISS) and a Console. The ISS collects the weather data and the console records the information. The data is therefore transmitted from ISS through a narrow window in the radio frequencies between (868.0 MHz and 868.8 MHz) for onward downloading into the computer where Microsoft Excel and Statistica were used for the analysis.

Anytime light waves travel through a medium of material composition, part of its energy is lost to the medium in the process termed Refraction, a medium short of vacuum possesses refractive index n. Hence a micro wave signal propagating through the Atmosphere (troposphere) suffers Refractivity N, a consequence of the atmospheric constituents (Temperature, Pressure and Humidity).The principal consequence for radio communication is the potential for reference, where frequencies are being shared between two or more services [8]. In particular, it can be shown[9 and 10]that the refractivity N of a wave propagating in an idealized medium of refractive index N is given by:

$$N=77.6P/T+3.73x10^5 e/T^2 \quad 1$$

where T is the temperature in Kelvin, P is the air pressure in milli-bar, and e is the absolute humidity. By definition, n and N are related in such a way that

$$N = (n-1)x10^6 \quad 2$$

The absolute humidity 'e' can be calculated using its relationship with the relative humidity, e_r and saturated vapor pressure, e_s

$$e = e_r \times e_s/100 \quad 3$$

the saturated vapor pressure is given by Clausius – Clapeyron formulation as:

$$e_s = 6.112\exp(17.5t/(t + 240.97)) \quad 4$$

where the temperature t is measured in Celsius,

RESULTS AND DISCUSSION

The results of the investigation are as presented graphically in the figures 1and 2 below. The average half hourly variations of Refractivity in the four stations earmarked for the investigation fig. 1 a diurnal refractivity variation at 0 m and fig. 2 at 100 m altitude are plotted against time for the annual period of investigation (for the year 2008). each station exhibits a characteristic profile of refractivity value diurnally with Nzukka displaying the highest value followed by Akure while both Minna and Sokoto overlapped which indicates that they both shared the same atmospheric conditions.

Another feature observable from the graph is the fact that Nzukka presents acyclic profile as against near constant values of the remaining two stations this by implication shows that the refractivity at the coastal region comprises of both hydrostatic and non hydrostatic components of refractivity (equation 1 refers) this is traceable to the characteristic heavy contents of humidity in the region which varies with the time of the day (sunrise effects).

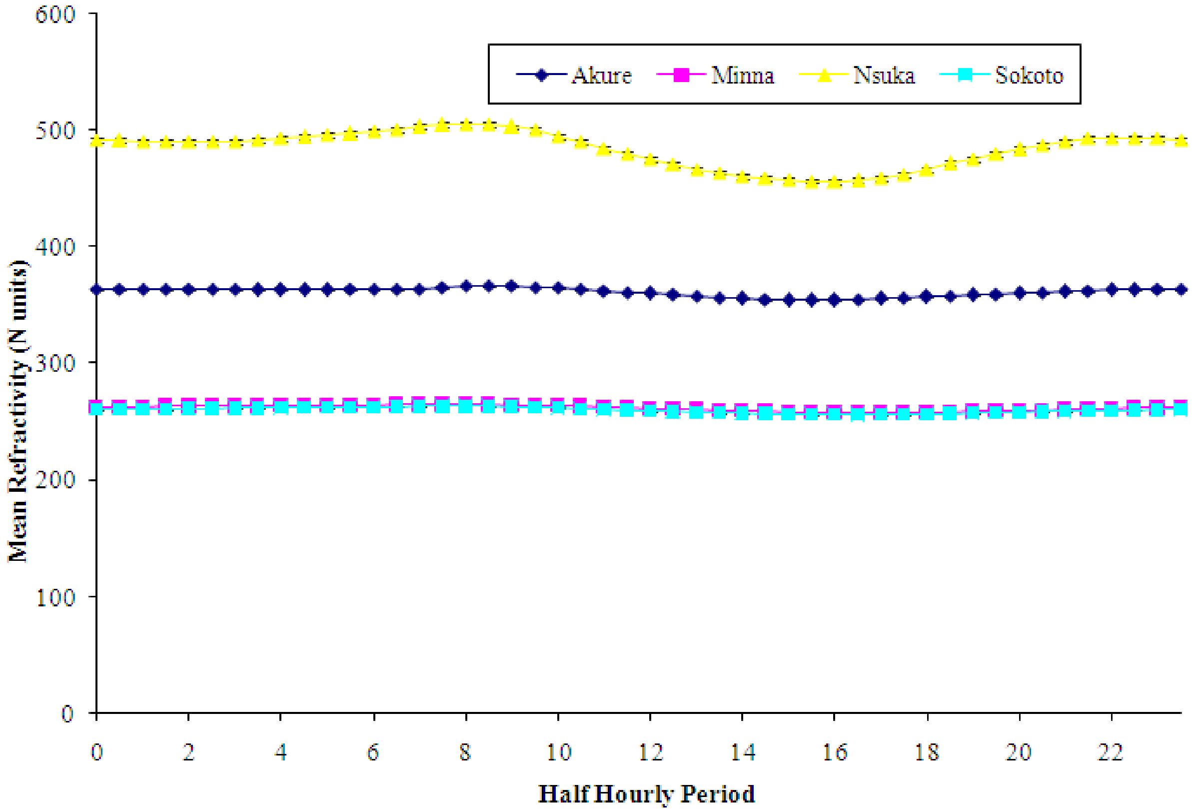

Fig. 1 : Refractivity at 0m altitude across the half houly period under different locations.

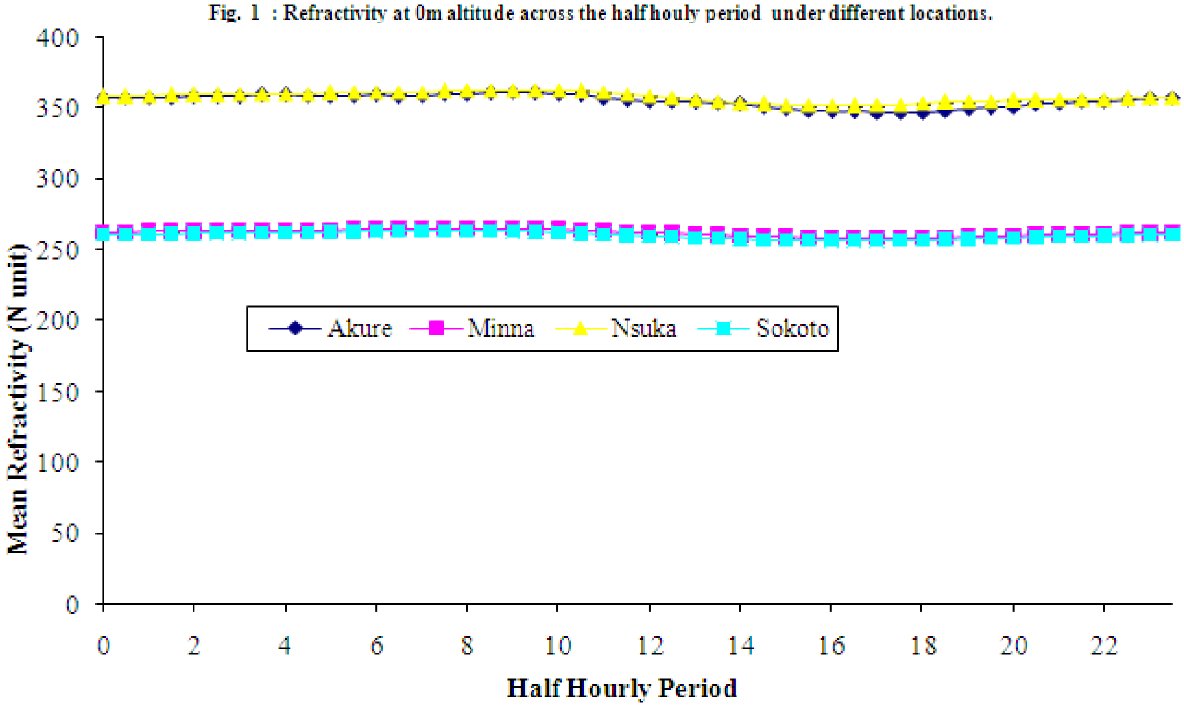

Fig. 2 : Mean refractivity at 100m altitude across the half hourly period under different locations

On the other hand, Nigerian atmosphere displays two characteristics at 100 m altitude as can be observed from the graph. In this case there is no distinction between Nzukka and Akure on one part and Minna and Sokoto on the other part even though the former was of higher refractivity than the latter. This by implication shows that Nigerian atmosphere splits in to two parts at this altitude. More importantly the refractivity falls compared with what obtained at the fig.1 (0m ground level). This is consequent upon the fact that the refractive index of atmosphere decreases with altitude. Observable here too is the fact that the cyclic characteristics of refractivity at the coastal region is almost nonexistent meaning that atmosphere loses its humidity and gets dry with altitude.

CONCLUSION

The results obtained show that refractive index of the atmosphere varies not only with the altitude but also with the regions. This is of immense implication on radio communication because the radio waves propagating through the atmosphere suffer delay (refractivity), total absorption or loss of signal. Therefore, the implication is that energy of the transmitter must be adjusted accordingly; if communication is not to be interrupted. Hence the frequency of propagation in the Coastal region demands to be higher than what is required in the Inland and Northwards. It requires that the Base Stations at each of these regions must operate at appropriate frequencies for effective communication.

The variability of the refractivity in these regions is simply a response to the "sunrise" effect owing to the density of the atmospheric contents as occasioned by the humidity of the atmosphere. In effect, this would engender absorption of the energy of the propagating signal or the delay of it which in ordinary situation of hydrostatic component of refractivity simply would arrive at the destination but which in this case can only be avoided by increase in energy of propagation. Thus, in the coastal region high value of refractivity is a cause for the heightening of energy of propagation, precipitating economic implication thereby. If this is ignored it could lead to loss of communication fostering social breakdown and hence, uncertainty in security.

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