Preliminary Results Of Surface Rfractivity In Minna, Niger State, Nigeria

O.D. Oyedum, K. C. Igwe, J. O. Eichie and A.S. Moses
Department of Physics
Federal University of Technology Minna

Abstract
Knowledge of the temporal and spatial variations of surface refractivity N_s is important for good planning of terrestrial radio links over a region. Reduced-to-sea-level refractivity N_o removes elevation dependence of N_s and enhances comparison and/or contouring of values for different stations. Earlier efforts in this regard in the Nigerian context could not explore diurnal trend due to lack of data. There is need to sustain the effort in the light of climate change and to establish the mean diurnal, seasonal and climatic trends in Nigeria. This paper highlights preliminary results of N_o obtained in Minna based on in-situ measurements of the relevant atmospheric parameters between 2008 and 2009.
Keywords: Reduced-to-Sea Level Refractivity, Air Temperature, Pressure and Vapour Pressure, Scale Height.

Introduction

Knowledge of the temporal and spatial variations of surface refractivity N_s is important for good planning of terrestrial radio links over a region. Reduced-to-sea-level refractivity N_o values remove elevation dependence of N_s and enhance comparison and/or contouring of values for different stations. Earlier efforts in this regard [e.g. Owolabi and Williams (1970); Kolawole (1980)] must be sustained in the light of climate change and to establish the mean diurnal and seasonal trends in Nigeria.

The field strength of radio signals at VHF and higher frequency bands generally vary in the troposphere due to variations in the refractivity conditions of the air, which in turn depend on variations in temperature, pressure and water vapour pressure. These variations show climatic, seasonal and diurnal trends. In tropical continental climatic region (5°-20° latitude) N_o is much higher during the rainy season than during the dry season and has annual range of about 70-110 N-units (Ajayi, 1997; Kolawole and Owonubi, 1982). Refractivity variations are more pronounced in tropical climates and diurnal variations have been observed on VHF paths in tropical countries like Nigeria, Ghana and Kuwait (Owolabi and Williams, 1970; Oyedum and Gambo, 1994). Surface refractivity is also known to generally correlate well with the parameter dN representing the refractivity gradient in the first one kilometer of height above the Earth's surface (Hall, 1979), as well as in Nigeria (Adebanjo, 1977; Kolawole, 1981). More recently Falodun and Ajewole (2006) have reported considerable diurnal variations of refractive [illegible]s at 100 m altitude in Nigeria.

Reduced-to-sea level refractivity N_o is given by (Bean and Dutton, 1968):

$$N_o = N_s \exp(h/H) \qquad (1)$$

Where N_s = surface refractivity (N-units), h= [illegible]on elevation (km) and H= scale height (km).

The surface refractivity N_s is given by (Smith and Weintraub, 1953):

$N = (77.6/T)(P + 4810e/T)$ (2)

Where T= surface air temperature (K), P= surface air pressure (hPa) and e= water vapour partial pressure (hPa). The water vapour partial pressure is given by (Hall, 1979):

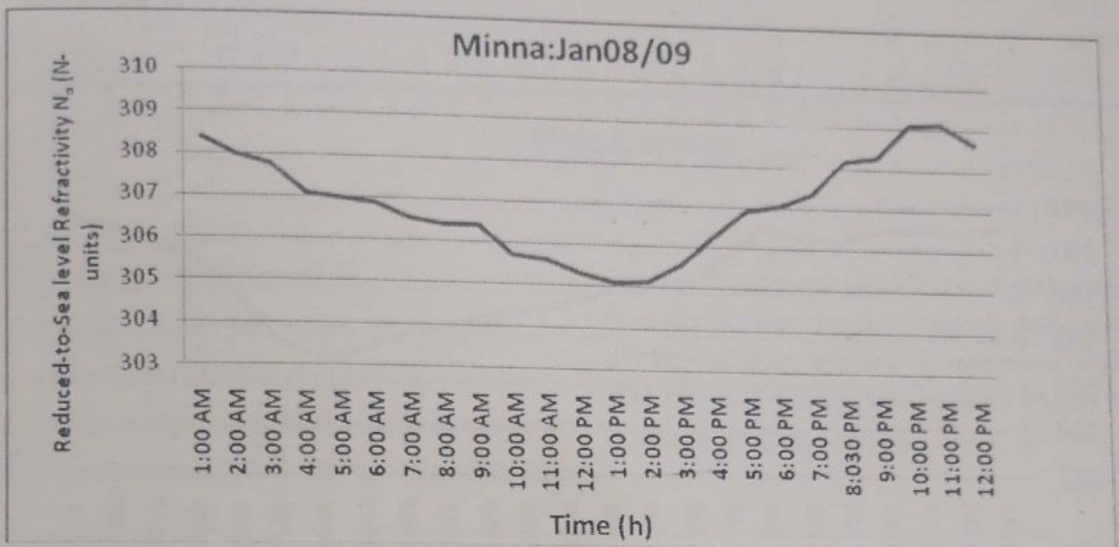

Figure 2: Annual Mean Diurnal N_o in Minna for a Typical Wet Season Month

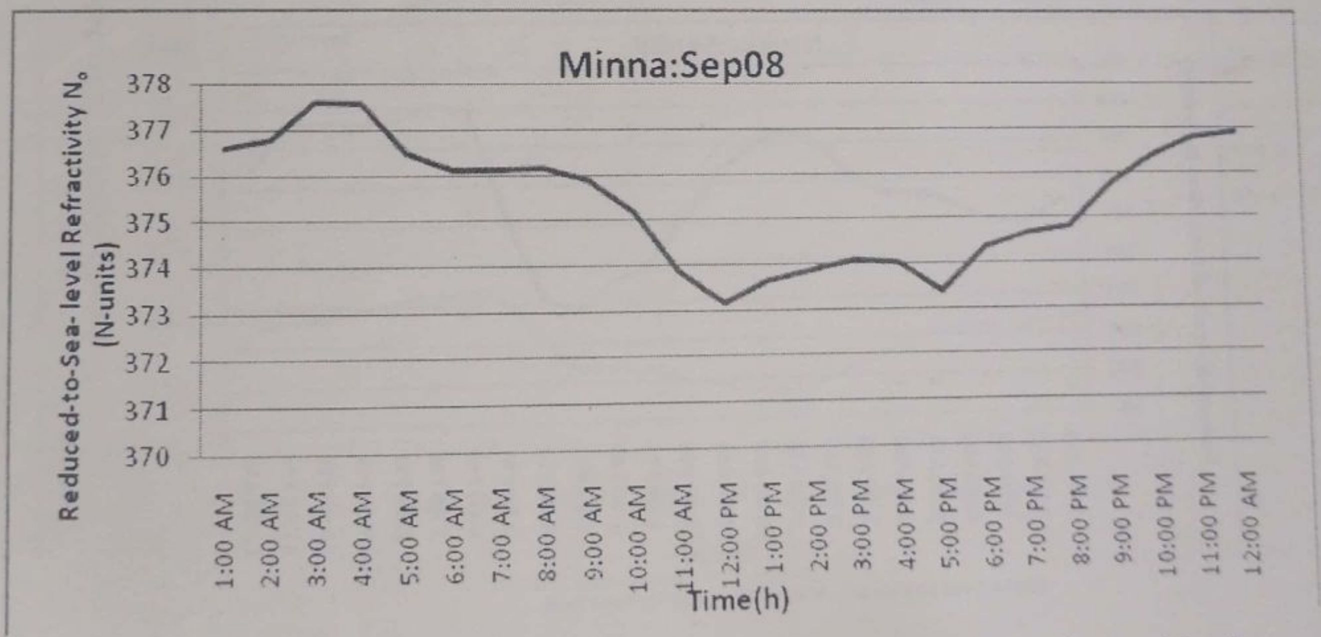

Figure 3: Annual Mean Diurnal N_o in Minna for a Typical Wet Season Month

However, in September 2009 the wet season diurnal profile minimum values slightly shifted toward early evening, as well as higher values compared to the preceding year. This may be attributed to unusually heavy rains experienced in Minna in 2009 as a result of global warming and climate change. Consequently, the mean wet season diurnal trend of N_o in Minna during the period 2008-2009 (Figure 5) is significantly affected by the heavy rainfall in 2009; and further data collection is required to establish a more reliable wet season diurnal trend.

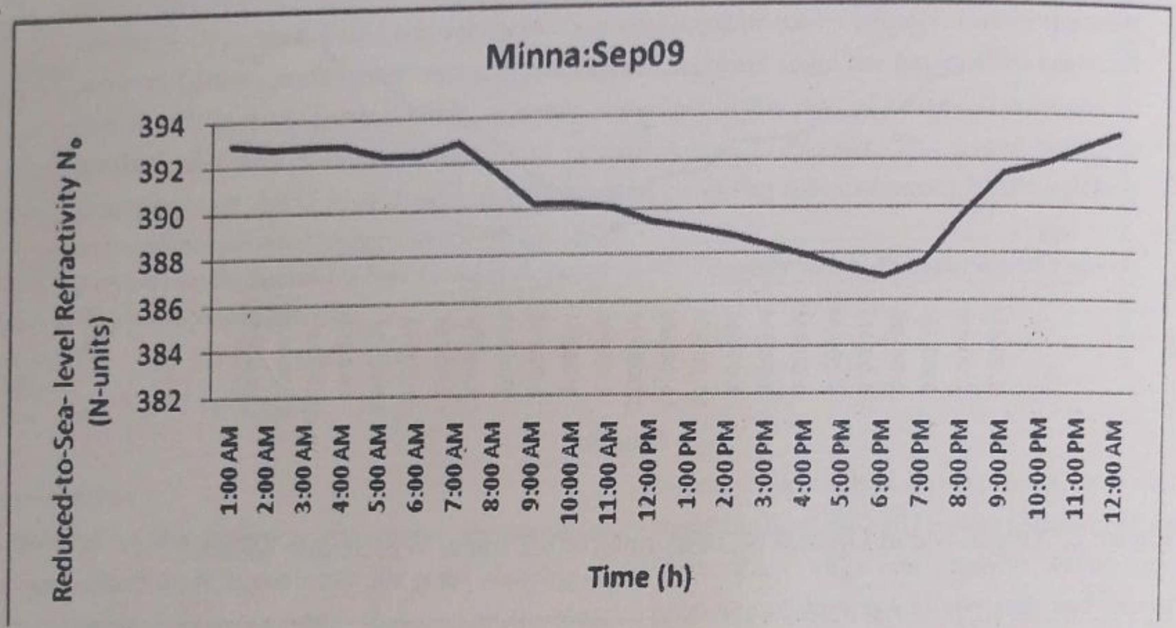

Figure 3.1: Structure of the LAI and CGI

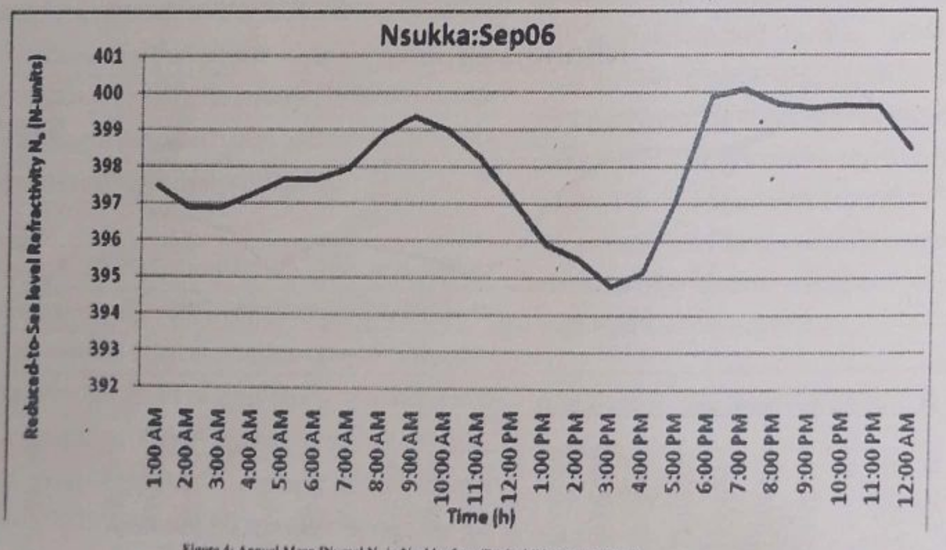

Figure 4: Annual Mean Diurnal N_o in Nsukka for a Typical Wet Season Month

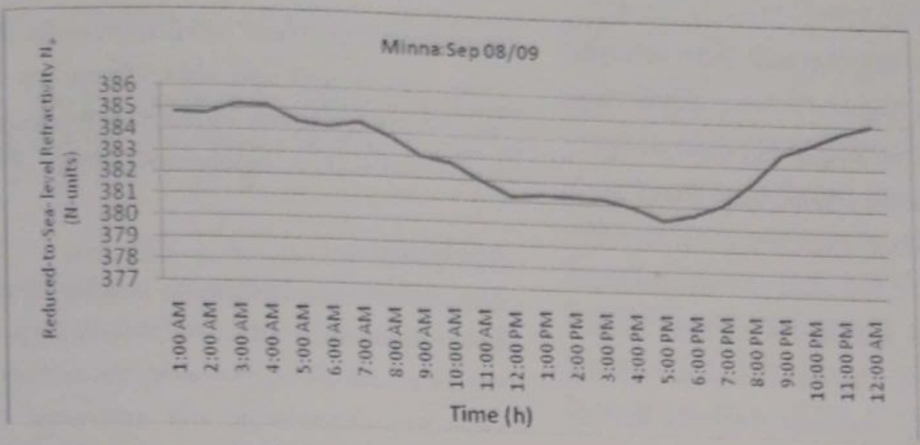

Figure 5: Two-Year Mean Diurnal N_o in Minna for a Typical Wet Season Month

Seasonal Trend and Variability of N_o

Monthly averages of N_o were also investigated to explore the seasonal trend and seasonal variability. The result shows a clear seasonal trend with higher N_o values in wet season and lower values in dry (Fig. 6). Maximum values are slightly higher than 400 N-units during the wet season and slightly lower in the dry season, while the minimum values fall below 300 N-units during the season. Mean N_o values are between 300 and 400 N-units.

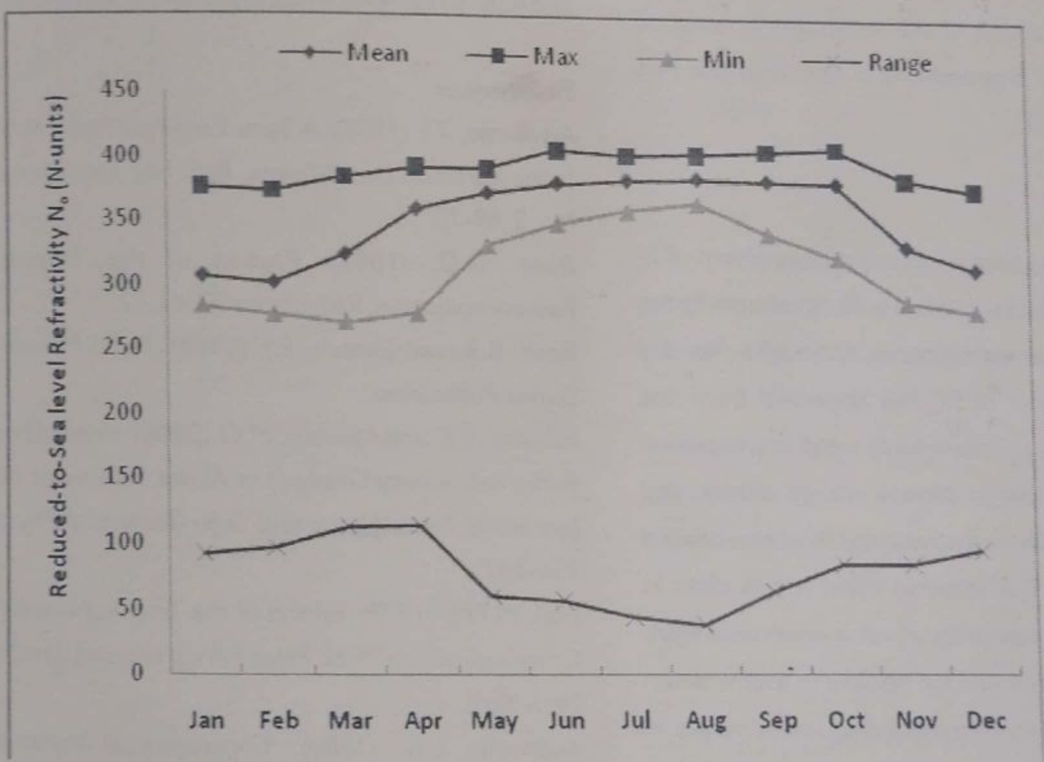

Figure 6: Mean Monthly N_o in Minna

minimum range occurs in wet season; least variability occurs in the month of August. Minimum annual range of 38 Maximum range (variability) of N_o occurs in dry season while and maximum annual range of 114 are in agreement with 70- 110 for Tropical Continental Africa reported by Ajayi (1997). The observed seasonal trend is due to the yearly N-S migration of the Inter Tropical Discontinuity (ITD). The northward movement of the low pressure belt brings moisture from the Atlantic Ocean to the hinterland, reaching about 25°N around September when the southward movement also begins. The southward migration brings dry, cold air (sometimes characterized by Harmattan dust haze from the Sahara Desert) and reaches its southern limits around about 4°N in January. The observed seasonal profile of reduced-to-sea level refractivity in Minna is thus largely a reflection of the atmospheric moisture level in the lower troposphere in line with the N-S migration of the ITD.

Conclusion

Preliminary results based on in-situ measurement of 2-year atmospheric data show that surface refractivity has both diurnal and seasonal tendency. Although a clear dry season diurnal trend of N_o has appeared from the preliminary results, a more reliable trend in wet season is yet to emerge due to climate change effects, and additional data acquisition is required to obtain desired long-term results. The seasonal trend is also clear as well as the climatic tendency which is discernible from higher N_o values observed for Nsukka in southeastern Nigeria, compared to corresponding lower values in Minna in north-central Nigeria. The observed diurnal and seasonal variations of surface refractivity have important implications on radio propagation. Terrestrial relay links at VHF and higher frequency bands which abound in Nigeria may be particularly affected (Owolabi and Williams, 1970; Oyedum and Gambo, 1994).

Appreciation

This research has been made possible by contributions from certain individuals who have directly or indirectly enhanced the effort. However, the authors particularly wish to acknowledge and commend the erudite contributions of Professors I.E. Owolabi and L.B. Kolawole in this field of research in the Nigerian context. Recent inputs by Professors M.O. Ajewole and P.N. Okeke towards sustaining the efforts are also acknowledged and commended. It is our hope that the Nigerian Government will sooner than later renew Radiosonde acquisition of upper air data in Lagos, Minna and Kano to complement and sustain the current drive.

References

Adebanjo, T.I. (1977): A Semi-Empirical Radio Refractive Index Variation over Nigeria. Bull. Nig. Inst. Phys., Vol.2 No. 2, 69-78.

Ajayi, G.O. (1997): Physics of the Tropospheric Radiopropagation. RadioAfrica'97, 42-72.

Bean, B.R. and Dutton, E.J. (1968): Radio Meteorology. Dover Publication.

Falodun, S.E. and Ajewole, M.O. (2006): Vertical Profile of Radio Refractivity Gradient in Akure Southwest Nigeria. Journal of Atmospheric and Solar-Terrestrial Physics 68, 236-243.

Hall, M.P.M. (1979): Effects of the Troposphere on Radio Communications. IEEE Peter Peregrinus Ltd, London and New York.

Kolawole, L.B. (1980): Climatological Variations of Surface Radio Refractivity in Nigeria. Bull. Nig. Inst. Phys., Vol.4, 97-117.

Kolawole, L.B. (1981): Vertical Profiles of Refractivity over Nigeria. J. West African Science Association, Vol. 26, 41-60.

Kolawole, L.B. and Owonubi, J.J. (1982): The Surface Radio Refractivity over Africa, Nigerian Journal of Science, 16, 441-454.

Owolabi, I.E. and Williams, V.A. (1970): Surface Radio Refractivity Patterns in Nigeria and The Southern Cameroons. J. West African Science Association, 15, 3-17.

Oyedum, O.D. and Gambo, G.K. (1994): Surface Radio Refractivity in Northern Nigeria. Nig. J. Phys, Vol.6, 36-41.

Oyedum, O.D. (2008): Climatic and Seasonal Variations of Effective-Earth-Radius Factor and Scale Height in Three Meteorological Stations in West Africa. Nigerian Journal of Physics, 20 (1), 102-111.

Smith, E.K. and Weintraub, S. (1953): The Constants in Equation for Atmospheric Refractive Index at Radio Frequencies, Proc. IRE, 41, 1053.