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INTRA-LAYER (LOW-LEVEL/UPPER LEVEL) REFRACTIVITY RELATIONS OVER LAGOS AND KANO

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ABSTRACT

The radio refractive index of the troposphere was computed from the upper air data for two Nigerian stations for the period 1990-1993. The periodicity and the vertical distributions of radio refractivity values were investigated. Comparison of the radio refractivity values showed that high positive and significant correlation existed between the surface and the lower and upper level refractivity for Kano, and fairly high and weakly significant correlations existed between them for Lagos. Linear regression equation of the form $Y = \alpha X^b$ (α, b are constants) have also been obtained by which measurement of surface refractivity, N_s, can be used to estimate the low level, upper level and refractivity at the first 10km at each of these stations.

KEYWORDS: radio refractivity, troposphere, regression, vertical distributions, correlation

INTRODUCTION

A reliable operation of ground-based communication systems for various purposes largely depends on the physical state of the boundary layer. Meteorological situations of the troposphere in radio paths are determined by various properties of the under-surface layer, its physical properties, the geographical as well as the climatic features of the region under consideration, and are changed within a wide range depending upon the time of the day and the season of the year (Zhamsuyeva and Zayakhnov, 1998). Radio physical properties of the atmosphere determining peculiarities of wave propagation are characterized by the refractivity value. In the atmosphere, the path followed by a radio ray is dependent upon the gradient of refractivity along the path. The propagation characteristics of electromagnetic waves are generally affected by the fluctuations in the atmospheric refractive index caused by variations in meteorological conditions (Adeyefa, 1995).

Studies of the surface radio refractivity (N_s) for Nigeria and southern Cameroon for ten years have been carried out by Owolabi and Williams (1970) using monthly records of surface weather data for 30 stations. Kolawole (1980) has also carried out studies of climatological variations of surface radio refractivity in Nigeria using data from 65 stations. Investigations of the surface radio refractivity using monthly climatic data (1978 – 1979) over 202 stations over the African continent were carried out by Kolawole and Owonubi (1982). Adeyemi (1992), computed the different components of the refractivity (N) for Akure on diurnal, daily and seasonal basis from September 1991- March 1992. Adeyefa (1995) studied the relationship between refractive index structure and the migration of Inter – Tropical Discontinuity during harmattan.

All these studies showed that the values of the refractivity N are dependent on the climatic region as well as on the prevailing seasons. Although, the simulations of the vertical profile of radio refractivity of the troposphere has gone a long way in providing explanations for the various radio wave propagation mechanisms, only few researchers have carried out studies on the vertical distributions of the tropospheric radio refractivity N in Nigeria due to the paucity of upper air meteorological data. The purpose of this paper is to study the variations of refractivity at different columns of the troposphere for two Meteorological stations which are Lagos, a coastal station, and Kano in the sub – sahelian region in Nigeria. The columns are between the surface and 3km level (0-3km), between surface and 10km and the upper column between 3km and 10km. An attempt is made to find out the relationship between the surface radio refractivity and the columnar radio refractivity.

METHOD OF ANALYSIS

For V.H.F – U.H.F frequencies at standard conditions, the atmospheric property which is basic to radio ray tracing is the radio refractive index n ($\cong$ 1.0003). When evaluating refraction effects from the meteorological variables, the refractivity N is commonly used. N is given by [7, 8, 9, 2] as

$$N = 77.6\, P/T + 3.73 \times 10^5\, e/T^2 \qquad (1)$$

where P is the total atmospheric pressure in hPa; T is the absolute temperature in Kelvin and e is the vapour pressure in hPa. The first term in equation (1) is called dry component N_d while the second term is the wet component N_w. In the tropics, the concentration of water vapour at the surface and aloft is high and also remarkably variable. Hence the wet component N_w should be strongly influenced by the variability of e (vapour pressure).

The monthly mean refractivity gradient in the first kilometer is a parameter of great importance. One can assume, as it is often done, that N decreases linearly with height. Therefore, from the data showing the variation of N with height, the refractivity at one kilometer, N (1), can be estimated by linear interpolation (Babalola,1999). Hence refractivity gradient in the first kilometer ΔN can be calculated using the equation below

$$\Delta N = N(1) - Ns \qquad (2)$$

The radiosonde data used for this study were obtained from the upper air section of the Department of Meteorological services Lagos.

RESULTS AND DISCUSSION.

Seasonal variations of columnar radio refractivity;

Tables 1 and 2 and fig.1, and 2 show the values of

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Table 1: Columnar refractivity parameters at LAGOS

Months	N_s	0-3km			3-10km			0-10km		
		N_L	N_d	N_w	N_u	N_d	N_w	N_T	N_d	N_w
JAN	374	334	220	114	306	202	104	323	211	112
FEB	365	330	219	111	305	201	104	320	211	109
MAR	375	345	228	117	310	205	105	331	219	112
APR	387	349	230	119	310	205	105	334	220	114
MAY	381	351	232	119	313	206	107	336	222	114
JUN	379	345	228	117	312	206	106	332	219	113
JUL	377	350	231	119	315	208	107	337	222	115
AUG	372	344	227	117	311	205	106	332	219	113
SEP	377	346	228	118	312	206	106	333	220	113
OCT	384	349	230	119	312	206	106	335	221	114
NOV	383	346	228	118	311	205	106	333	220	113
DEC	374	334	220	114	306	202	104	323	211	112

Table 2: Columnar refractivity parameters at KANO.

Months	N_s	0-3km			3-10km			0-10km		
		N_L	N_d	N_w	N_u	N_d	N_w	N_T	N_d	N_w
JAN	287	288	190	98	309	204	105	296	195	101
FEB	280	285	188	97	306	202	104	293	193	100
MAR	288	286	189	97	308	203	105	295	195	100
APR	303	293	193	100	308	203	105	299	197	102
MAY	329	311	205	106	309	204	105	310	205	105
JUN	373	340	224	116	319	211	108	331	219	112
JUL	366	338	223	115	313	206	107	328	217	111
AUG	372	342	226	116	315	208	107	331	219	112
SEP	365	335	221	114	314	207	107	326	215	111
OCT	317	303	200	103	308	203	105	305	201	104
NOV	367	339	224	115	315	208	107	330	218	112
DEC	288	285	188	97	306	202	104	294	194	100

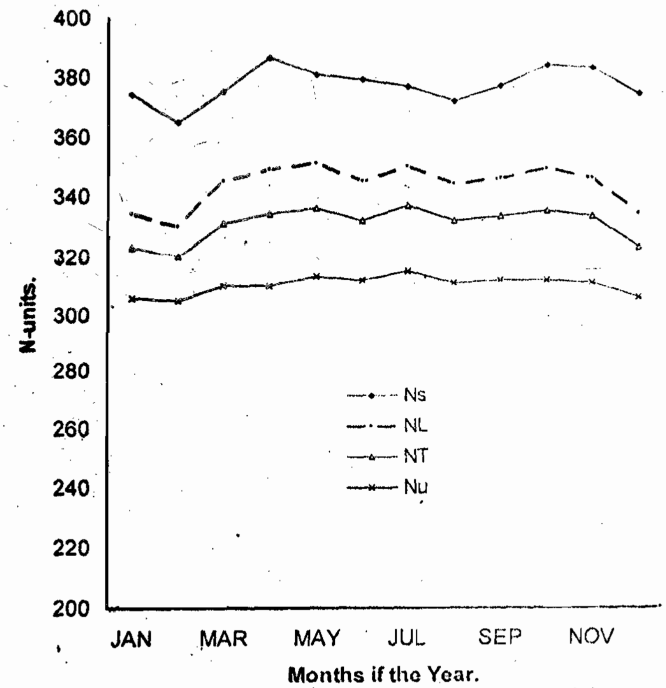

Fig.1 Seasonal variations of columnar radio refractivity at OSHODI.

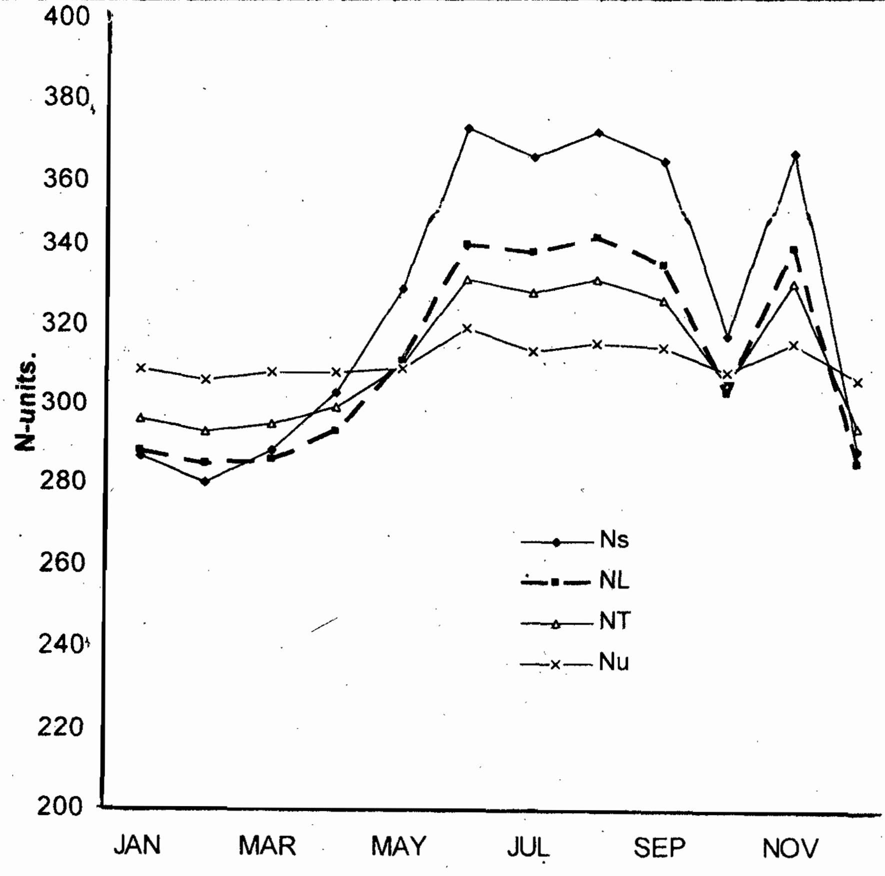

Fig. 2. Seasonal variations of columnar radio refractivity at KANO.

radio refractivity parameters at the different atmospheric columns for the two stations observed. Here, it is found that variations in the refractivity parameters for the different columns follow closely the seasons at every station. At Kano higher values of columnar refractivity are observed during the rainy months of June – September than those of the dry months of December – April. The refractivity values at the different atmospheric columns for Lagos are almost uniform through out the year (the range is very small between 330 in the dry months and 351 in the wet months).

Generally, it can be inferred that the refractivity of column at Kano increases as ITD moves northward and decreases when it moves southward (see Fig 2). For the columns 0-3km and 0-10km (the lower atmospheric column and the first 10km), refractivity values are generally higher at Lagos than at Kano, while the upper atmospheric values at Kano compare well with those of Lagos all the year round. Over Kano, and during the dry season months of December – April, values of refractivity at the upper column are higher than those of the lower and the first 10km column. The reverse is the case at Lagos. This may be explained using the atmospheric static stability at Kano during harmattan. Hence during this period, strong convection would transport water vapour upwards causing it to deplete at the lower atmosphere. This results in a higher refractivity value at the upper atmospheric column than at the lower atmospheric column.

From Tables 1 and 2, it is obvious that at every column, the dry term (N_d) is the major contributor to refractivity. N_d is therefore the dominant term. Adeyefa, (1995) and Adeyemi, (1992), in their studies have shown that the contribution of the dry term (N_d) to refractivity value is about 60 - 70% irrespective of the season of the year with the remaining percentage coming from the wet term (N_w). Also, it could be seen that the variations in the columnar refractivity is due majorly to the variations in the wet terms (N_w).

Intra-Layer Correlation of Radio Refractivity

The correlation between the parameters N_s (surface radio refractivity) ΔN, (the refractivity gradient), at Lagos is -0.1 while at Kano it is –0.35. Those for N_s and N_u (refractivity at upper atmospheric column, 3-10km) N_L (refractivity at lower atmospheric column, 0-3km) and N_T (refractivity at the first 10km of the atmosphere) are shown in Table 3. At both stations, the relationship between N_s and refractivity gradient ΔN is low and negative. At Lagos, surface refractivity N_s has a fairly strong relationship with N_L (refractivity at the lower atmospheric column) and N_T. It should be noted here that the correlation between N_s and N_u (refractivity at the upper

Table 3. Correlation coefficient between surface refractivity, N_s and refractivity gradient, ΔN, refractivity of the lower atmosphere, N_L, refractivity of the upper atmosphere, N_u, and refractivity of the first 10km column, N_T.

	N_s & ΔN	N_s & N_L	N_s & N_u	N_s & N_T
OSHODI	-0.100	0.770	0.562	0.727
KANO	-0.350	0.996	0.917	0.996

atmospheric column) is not as strong as those of N_L and N_T. This is so, because refractivity values here are strongly height dependent. The values are also influenced to a large extent at the lower column of the atmosphere by the movement of the ITD.

At Kano, for the three atmospheric columns, the relationship between N_s and those of the different columns of the atmosphere are surprisingly strong. Due to the existence of significant correlation between the columnar radio refractivity and N_s, a linear regression model was then applied to investigate the fit of the relationships. We, hence, obtained an analysis of variance (ANOVA) table for each station (not shown) and on the basis of the resulting F-ratios; null hypothesis test was carried out.

From the relation

$$\mathrm{Ln}(N_u) = a + b\mathrm{Ln}(N_s) \quad \ldots\ldots\ldots\ldots\ldots(3)$$

where a, and b are constants; we obtain

$$N_u = \alpha N_s^b \quad \ldots\ldots\ldots(4)$$

where

$$\alpha = e^a \quad \ldots\ldots\ldots(5)$$

Physically, b≈1 (constant mixing ratio) is indicative of active convection, while b>1 (mixing ratio decreasing with height) probably typifies convection not yet active (Adedokun, 1983).Table 4 shows the best-fit parameters α, b obtained for each station as well as the coefficient of variation (CV) and the probability p at which the null hypothesis was rejected. The proportion of variance given by the regression of $\mathrm{Ln}N_L$ on $\mathrm{Ln}N_s$ is given by the square of r (correlation coefficient). This procedure was similarly carried out to relate N_u and N_s, N_T and N_s (see table 4b,c). It is observed that a high degree of relationship is suggested by the results in Table 4. The null hypothesis is rejected at $p<0.05$ for all cases. The coefficient of variation is higher in the Kano zone, than in the Lagos zone, suggesting a higher amount of variation in the more arid (Sahelian) zone. This may be due to strong atmospheric turbidity experienced at Kano (McTainsh, 1984).

EFFICIENCY OF THE MODEL

To verify the reliability of the relations obtained in Table 3 above, the model developed was applied to evaluate the lower level N_L upper level N_u and N_T (refractivity at the first 10km) using the mean of monthly N_s values obtained for each station. The results of these as compared with the actual values obtained are as shown in Table 4. The agreement with actual values depicted is quite encouraging. Following this, we carried out an evaluation of refractivity at different columns for each month. Plots of the actual refractivity at each column for both stations along with the calculated values obtained by using the different versions for each station respectively, of the proposed model are presented in Figures 3 and 4. As can be observed in the figures, those of Kano, a sahelian station, were well monitored by the models (see Fig.4). The slope of the equation and the coefficient of variation, R^2, (shown on the graph) relating the actual and the calculated values of the refractivity at the different columns of the atmosphere are v high in this station. At Lagos, (see Fig. 3), the evaluation of columnar refractivity were only fairly monitored considering slope and the coefficient of variation, R^2, of the equa relating the actual and the calculated values of refractivit the different columns of the atmosphere. These deviat may be due to the fact that Lagos is a coastal station an might be experiencing local variability (Adejokun, 1966).

Table 4. Values of the best fit parameter α, and b in the equation of the form

(a) $N_L = \alpha N_s^b$ (b) $N_u = \alpha N_s^b$ (c) $N_T = \alpha N_s^b$

(a)

Stations	N	α	b	r	C.V%	p-value
Lagos	12	0.9308	0.9963	0.77	59.5	0.003
Kano	12	6.276	0.6746	0.99	99.9	0.000

(b)

Stations	N	α	b	r	C.V%	p-value
Lagos	12	37.812	0.3547	0.57	32.2	0.05
Kano	12	169.96	0.1043	0.92	83.1	0.000

(c)

Stations	N	α	b	r	C.V%	p-value
Lagos	12	3.1955	0.782	0.73	53.4	0.007
Kano	12	23.934	0.4433	0.99	98.9	0.000

Table 5.Application of the proposed model for each of the stations.

Stations	N	N_L		N_u		N_T	
		Actual	Cal.	Actual	Cal.	Actual	Cal.
Lagos	12	343.58	343.60	310.25	310.17	330.75	330.78
Kano	12	312.08	312.48	310.83	310.99	311.5	312.43

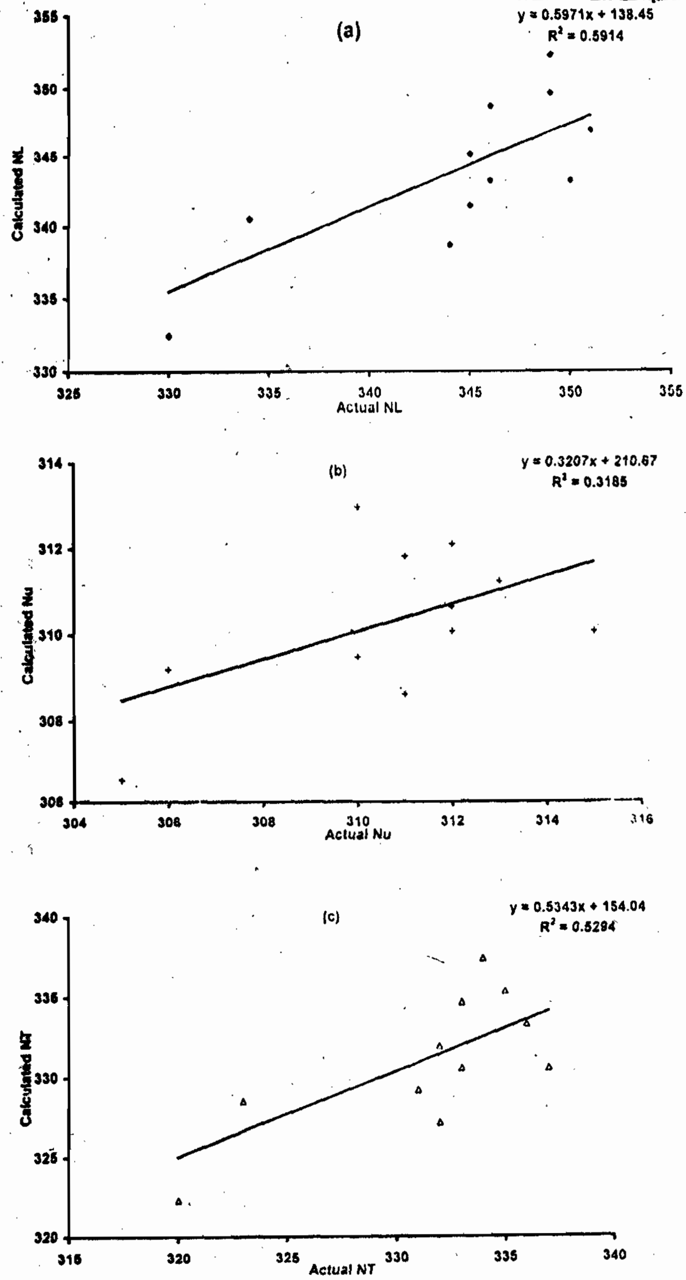

Fig. 3: Plots of Actual and Calculated (a)Low level, NL, (b) Upper level, Nu, (c) Total column, NT, refractivities at Lagos.

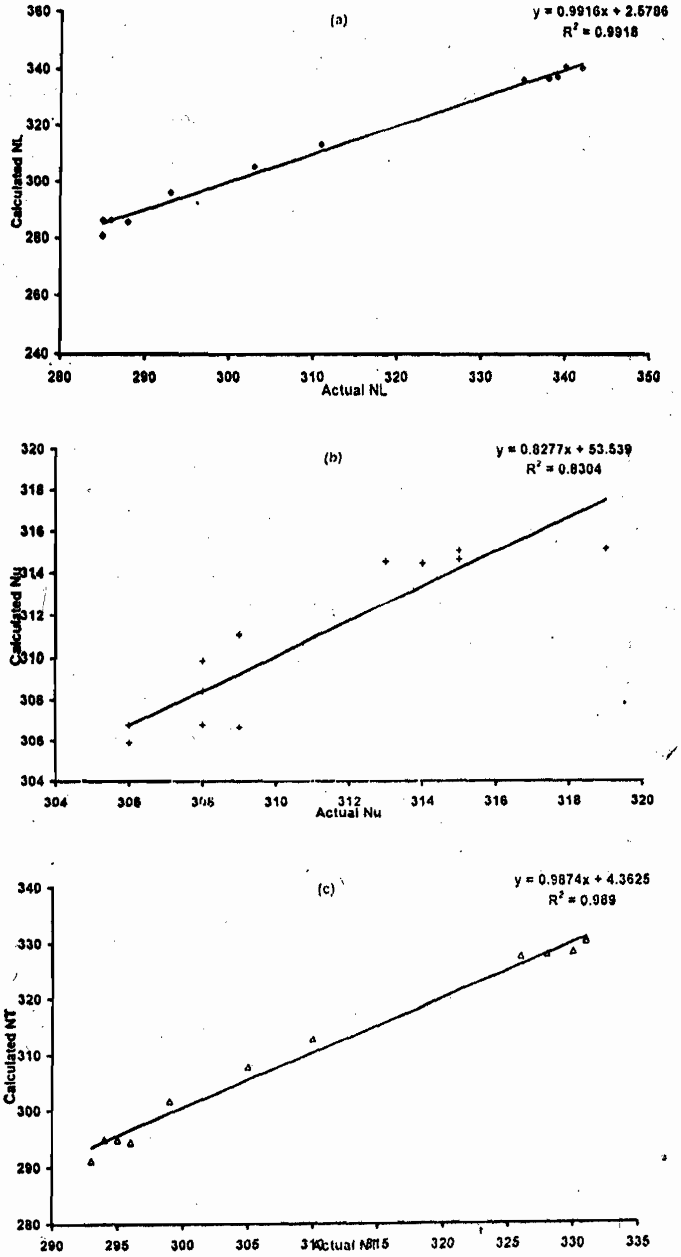

Fig. 4: Plots of Actual and Calculated (a)Low level, NL, (b) Upper level, Nu, (c) Total column, NT, refractivities at Kano.

CONCLUSION

Refractivity in both the lower and upper columns of the first 10km of the troposphere over Lagos has been found to be considerably different from those over Kano. Over both tropical stations, the columnar refractivity shows fairly strong seasonal variations, though the seasonal pattern is less distinct in the upper columns than in the lower columns. For all the atmospheric columns, the dry term of refractivity N_d is the major contributor to the refractivity values of the columns. It is less affected by changing atmospheric conditions.

For the two stations, negative correlation exists between refractivity gradient of the troposphere and surface refractivity N_s. Fairly strong correlation exists between N_s and columnar refractivity parameter at Lagos, while at Kano; very strong relationship exists between them. The equations of regression developed for both stations, can be used to estimate to within 10%, the refractivity at different levels of the troposphere by substituting into the equations the measured values of surface refractivity. This should be a useful procedure in places having similar climatic conditions to these stations but lacking radiosonde facilities.

REFERENCES

Adedokun, J. A., 1983. Intra layer (low-level/mid-tropospheric) Precipitable water vapour relations and Precipitation in West/Africa. Arch., Met. Geoph. Biocl. ser.B .33, 117 130..

Adejokun, J. A., 1966. The three dimensional structure of the inter tropical discontinuity. Nig. Met.Serv. Tech. Note No. 39, Lagos, Nigeria.

Adeyefa, Z. D., 1995. On the Interrelation of the Refractive Index Structure and the migration of the Intertropical Discontinuity during harmattan. Proceedings of the Regional Workshop on Radio communication in

Africa. Radio Africa 1995. 28th Nov. – 2nd Dec. 1995, at Obafemi Awolowo University, Ife.Pp57-66.

Adeyemi, R. A.. 1992. Seasonal and Diurnal variations of surface radio refractivity in Akure, South Western Nigeria. An unpublished M.Tech, thesis submitted to the Dept. of Physics, Fed. Univ. of Tech., Akure.

Babalola, M. T., 1999. Studies on the Vertical model of the Radio refractivity in Nigeria. African Jour. of Sci., 2(1): 1-10.

Bean, B. R., 1962. The radio refractive index of air. Proc., IRE, 50(3): 260-273.

Bean, B. R. and Dutton, J., 1966. Radio Meteorology. National Bureau of Standard monograph No 92 US government printing office Washington DC, 200-275

Kolawole, L. B., 1980. Climatological variations of surface radio refractivity in Nigeria. Bull. Nig. Inst of Phys. 4: 97-117.

Kolawole, L.B. and Owonubi, J.J., 1982. The surface radio refractivity over Africa. Nig. J. Sci., vol. 16, Nos 1&2 Pp. 441-454.

McTainsh, G., 1984. The nature and origin of the Aeolian mantle of central Northern Nigeria. Geoderma, vol. 33: 13-33.

Owolabi, I. E. and Williams, V. A., 1970. Surface Radio Refractivity Patterns in Nigeria and Southern Cameroon. J. West Afr., Sci. Assoc., 15(1):3-17

Smith, E. K. and Weintraub, S., 1953. The constants in the equation for atmospheric refractive index at radio frequencies. Proc. IRE 41, 1033-1037.

Zhamsuyeva, G. S. and Zayakhanov, A. S., 1998. Investigation of the refractive index in 100m lower layer of the Atmosphere. Proceedings of the 8th URSI commission F Triennial Open symposium 22-25 Sept. 1998. Aviero, Portugal. Pp63-66.