# Variation of Radio Refractivity Gradient and Effective Earth Radius Factor (kfactor) over Akure, South Western Nigeria.

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**Abstract**

Measurements of atmospheric pressure, temperature and relative humidity were made in Akure (7.15$^{o}$N, 5.12$^{o}$E), South Western Nigeria using Wireless weather stations positioned at different height levels beginning from the ground surface and at intervals of 50 m to an altitude of 200 m on a TV tower. From the data collected, radio refractivity, its gradient and effective earth radius factor (k-factor) was calculated. The results show that refractivity values were generally high during the rainy season and decrease with increasing altitude. The average refractivity gradient is -52.8 N/km and the average value of k-factor is 1.51 for the two years of this report.

**Keywords:** Troposphere, Refractivity, Sub-refraction, Super-refraction, Ducting

## 1. Introduction

The radio refractive index is an important parameter in determining the quality of UHF, VHF, and SHF signals. In characterizing a radio channel, surface (ground level) and elevated refractivity data are often required; and in particular, the surface refractivity is very useful for prediction of some propagation effects. Local coverage and statistics of refractivity, such as refractivity gradient, provide the most useful indication of the likely occurrence of refractivity-related effects required for prediction methods [1].

This work presents the result of in-situ measurement of atmospheric temperature, relative humidity and pressure at five different height levels beginning from the ground to 200 m altitude at intervals of 50 m.

## 2. Radio Refractivity, refractivity gradient and k-factor.

The refractivity, N is related to the refractive index, n of air as; [1, 2]

$$N = (n-1)\times 10^6 = 77.6\frac{p}{T} + 3.73\times 10^5 \frac{e}{T^2} \tag{1}$$

where: p = atmospheric pressure (hPa), e = water vapour pressure (hPa) and T = absolute temperature (K).
The water vapour pressure e is calculated from the relative humidity, and saturated water vapour, using the expression:

$$e = H \times \frac{6.1121\exp\left(\frac{17.502t}{t+240.97}\right)}{100} \tag{2}$$

where: H = relative humidity (%), t = temperature in degree Celsius ($^oC$) and $e_s$ = saturation vapour pressure (hPa).
The effective earth radius factor k can be used to characterise refractive conditions as **normal refraction or standard atmosphere, sub-refraction, super-refraction and ducting** respectively.
Thus, k may be expressed in terms of refractivity gradient, dN/dh as [3, 4]

$$k \approx \frac{1}{1 + \left(dN/dh\right)/157} \tag{3}$$

Near the earth's surface, dN/dh is about -39N/km which gives an effective earth radius factor, k = 4/3. This is referred to as normal refraction or standard atmosphere. Here, radio signals travel on a straight line path along the earth's surface and go out to space unobstructed.

If $\frac{4}{3} > k > 0$ (4a)

Sub-refraction occurs, meaning that radio waves propagate abnormally away from the earth's surface.

When $\infty > k > \frac{4}{3}$ (4b)

In this case, super-refraction occurs and radio waves propagate abnormally towards the earth's surface thus extending the radio horizon.

Subsequently, if $-\infty < k < 0$ (4c)
ducting occurs and the waves bend downwards with a curvature greater than that of the earth.

## 3. Instrumentation and methods.

The detailed description of the instrumentation set up and the experimental site is available in [5]. The fixed measuring method by a high tower is employed for the measurement with the sensors positioned at the ground level for the measurement of the surface weather parameters and at the altitudes of 50 m, 100 m, 150 m and 200 m on the tower for continuous measurement of these weather parameters.

## 4. Results and discussion

### *4.1 Variation of Refractivity.*

The variation of refractivity from the ground surface to altitude of 200 m is summarised in Table1. It shows that the values of refractivity are higher at the ground surface than at elevated altitudes. The mean value of surface refractivity obtained in this study is 365 N-units for year 2007 and 367 N-units for year 2008. The results compare favourably well with the works of [6] where they obtained the mean value of surface refractivity for Akure as 369 N-units.

*4.2 Variation of Refractivity gradient*

Table 2 show the vertical gradient of refractivity calculated on the basis of the mean monthly statistical distribution of refractivity at each of the levels. It shows that the monthly variation gives large negative values in January corresponding to the period of intense harmattan observed around Akure which is often characterised by very cool nights and morning times and very dry day time. The average value of refractivity gradient for year 2007 is -54.12 N/km and -48.59 N/km for year 2008. From these average values, it could be deduced that propagation condition in this geographic zone is mostly super-refractive.

***4.3 Variation of effective earth radius factor, k***

The seasonal variation of the effective earth radius factor (k-factor) for the two years being reported is as shown table 3 and it is observed that the k-factor is low in the dry period. The k-factor values rise during the wet season with values ranging from 1.6 - 1.9. The highest value of 1.9 was observed in both years in the month of August. The result compares well with the result of [7] in his study of the vertical distribution of the tropospheric radio refractive index over Nigeria. He found that the effective earth's radius factor, k, like those of refractivity at the surface tended to be lowest over the country in January with k-factor values in the range 1.12 – 1.38 and highest in August with k-factor value varying from about 1.30- 1.50. From this study, the average value of k-factor is about 1.53. The implication of the result is that propagation in this geographic zone is mostly super-refractive.

**5. Conclusion**

The deductions from this study are as follows:

- The average value of refractivity gradient for year 2007 is -54.12 N/km and -48.59 N/km for year 2008 with an average value of -51.36 N/km for the two year period of the report.
- The average value of the k-factor for the two year period of measurement is 1.53.
- For microwave propagation in the Akure environ, the propagation condition could be mostly super-refractive.

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**Table 1: Summary of the variation of refractivity from the ground surface to altitude of 200m for years 2007 and 2008**

| Altitude (m) | Refractivity (N-Units) | |
|---|---|---|
| | 2007 | 2008 |
| 0 (Ground surface) | 370-387 | 368-370 |
| 50 | 366-369 | 366-369 |
| 100 | 364-368 | 364-368 |
| 150 | 359-365 | 355-365 |
| 200 | 358-362 | 357-366 |

**Table 2: Average monthly variation of computed refractivity gradient for years 2007 and 2008**

| Months | dN/dh @ 50m | | dN/dh @100m | | dN/dh @ 150m | | dN/dh @ 200m | |
|---|---|---|---|---|---|---|---|---|
| | Year 2007 | Year 2008 | Year 2007 | Year 2008 | Year 2007 | Year 2008 | Year 2007 | Year 2008 |
| **Jan.** | -197.55 | -189.55 | -128.92 | -113.99 | -122.18 | -123.58 | -97.72 | -92.42 |
| **Feb.** | -37.77 | -22.72 | -34.50 | -29.15 | -82.25 | -77.16 | -63.46 | -58.26 |
| **Mar.** | -55.77 | -50.87 | -45.81 | -40.61 | -83.09 | -76.95 | -63.50 | -58.61 |
| **Apr.** | -45.57 | -40.85 | -43.51 | -38.91 | -76.87 | -71.78 | -55.11 | -50.81 |
| **May** | -23.47 | -18.44 | -28.76 | -23.67 | -67.17 | -64.67 | -49.71 | -40.71 |
| **Jun.** | -58.02 | -53.31 | -26.58 | -21.59 | -73.08 | -66.19 | -53.45 | -50.54 |
| **Jul.** | -59.34 | -54.71 | -35.17 | -30.22 | -65.39 | -60.36 | -49.62 | -44.02 |
| **Aug.** | -59.24 | -54.43 | -53.88 | -48.78 | -60.20 | -57.24 | -46.63 | -43.34 |
| **Sep.** | -64.73 | -55.81 | -35.26 | -30.27 | -60.12 | -56.72 | -47.03 | -42.03 |
| **Oct.** | -26.58 | -18.90 | -22.13 | -17.45 | -34.30 | -27.39 | -26.99 | -21.99 |
| **Nov.** | -19.08 | -3.29 | -16.27 | -11.23 | -29.28 | -26.88 | -23.46 | -18.46 |
| **Dec.** | -44.46 | -40.67 | -28.30 | -23.46 | -42.02 | -39.63 | -34.47 | -29.48 |
| **Average** | **-57.63** | **-50.29** | **-41.59** | **-35.77** | **-66.33** | **-62.37** | **-50.93** | **-45.88** |

**Table 3: Average monthly variation of computed k factor for years 2007 and 2008**

| Months | k @ 50m | | k @100m | | k @ 150m | | k @ 200m | |
|---|---|---|---|---|---|---|---|---|
| | Year 2007 | Year 2008 | Year 2007 | Year 2008 | Year 2007 | Year 2008 | Year 2007 | Year 2008 |
| **Jan.** | 1.13 | 1.17 | 1.12 | 1.13 | 1.13 | 1.24 | 1.13 | 1.17 |
| **Feb.** | 1.06 | 1.09 | 1.14 | 1.18 | 1.15 | 1.25 | 1.16 | 1.17 |
| **Mar.** | 1.54 | 1.24 | 1.59 | 1.49 | 1.52 | 1.56 | 1.50 | 1.65 |
| **Apr.** | 1.61 | 1.49 | 1.65 | 1.37 | 1.59 | 1.92 | 1.53 | 1.49 |
| **May** | 1.67 | 1.27 | 1.77 | 1.23 | 1.75 | 1.72 | 1.63 | 1.43 |
| **Jun.** | 1.79 | 1.56 | 1.78 | 1.34 | 1.78 | 1.78 | 1.80 | 1.45 |
| **Jul.** | 1.80 | 1.85 | 1.75 | 1.73 | 1.82 | 1.72 | 1.84 | 1.68 |
| **Aug.** | 1.98 | 1.92 | 1.92 | 1.91 | 1.95 | 1.76 | 1.93 | 1.75 |
| **Sep.** | 1.94 | 1.56 | 1.85 | 1.38 | 1.81 | 1.63 | 1.82 | 1.40 |
| **Oct.** | 1.45 | 1.55 | 1.62 | 1.44 | 1.58 | 1.54 | 1.52 | 1.36 |
| **Nov.** | 1.58 | 1.60 | 1.58 | 1.24 | 1.65 | 1.56 | 1.61 | 1.38 |
| **Dec.** | 1.17 | 1.51 | 1.18 | 1.62 | 1.19 | 1.56 | 1.19 | 1.43 |
| **Average** | **1.56** | **1.48** | **1.58** | **1.42** | 1.57 | **1.60** | **1.55** | **1.45** |