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VALIDATION OF ITU-R MODEL FOR ATMOSPHERIC REFRACTIVITY PROFILE IN A TROPICAL REGION

*Agunlejika O., Raji T. I.
Department of Electronic & Electrical Engineering
Ladoke Akintola University of Technology, Ogbomoso, Nigeria
*Corresponding Author betlay@yahoo.com

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Abstract

This paper presents the results of an investigation of the applicability of the International Telecommunication Union Recommendation P453 model for the refractivity profile of a typical troposphere of the tropics. Measurements of refractivity at the first 200 m altitude taken over one year in Akure, southwest Nigeria have been used. The results showed that the model using the scale height of 7.35 km and 7 km as recommended for global and tropical environments respectively gave reasonably accurate results for the refractivity at the altitude of 50m and 200m for seven out of the twelve months of the year. The scale height of 7 km gave a better result at 50 m altitude while 7.35 km scale height gave a better performance at 200 m. The refractivity values given by the models deviate from the measured values at other altitudes. The results also show discrepancy between model values and measured at all level in the months of October, November, December and January. These results suggest that there might be a need for a re-evaluation of the refractivity model for the tropical region.

Key Words: Refractivity profile, ITU-R model, Tropical region, Troposphere, radiowave propagation

1. Introduction

The local meteorological condition affects microwave propagation. The atmosphere, which is the propagation medium, is characterized by different refractive indices at different levels. These varying indices significantly affect radiowave propagation. Chigbu et al [2] gave a submission that the microwave communication equipments designed for use in temperate region may not be very suitable in the tropics because the characteristics of the troposphere as the medium of propagation differ appreciably. Hence, there is a need to have an adequate and comprehensive knowledge of the variation of the atmospheric refractive index in the tropical regions, since it can give an insight into the behavioral pattern of the signal being propagated which may then influence the design of the equipments suitable for use in the tropics.

Most of the work done on the refractivity profile in Nigeria has been based on the surface refractivity, Ns value [3]. Some of these are "Studies of Super-refractivity and Ducting of Radiowaves in Nigeria" by Falodun and Kolawole [4], "Seasonal Variations of Radio Refractivity Gradients in Nigeria" by Willoughby et al [5] and "Radio refractive index in the lowest 100m layer of the troposphere in Akure, South Western Nigeria" by Falodun and Ajewole [6]. It has been found that surface refractivity (N_s) is often useful for predicting regional, seasonal and daily variations in transmission loss in the temperate climatic region, but it is of limited use for predicting these variations in tropical and equatorial regions [1]. This is because the correlation between the transmission loss and the N_s was observed to be meaningful only when a good correlation has been established between the vertical gradient of the refractive index and the value of the index at the surface. Therefore, there is a need for an evaluation of the refractivity profile model and its applicability to the tropical region troposphere in order to determine the extent of its validity in the absence of the upper-air data of meteorological parameters such as temperature, pressure and the relative humidity.

2. Literature Review

2.1 Refractivity formula

In the International Telecommunication Union (ITU) Radiocommunication recommendation P 453, the atmospheric refractive index is computed using [7]:

$$n = 1 + N \times 10^{-6} \tag{1}$$

where N is the radio refractivity given as

$$N = \frac{77.6}{T}\left(P + 4810\ell / T\right) \quad \text{(N-units)} \tag{2}$$

Where:

P is the atmospheric pressure (hPa)
ℓ is water vapour pressure (hPa) and
T is the absolute temperature (K)

Also the relationship between water vapour pressure, ℓ and relative humidity, H is given by the expression:

$$\ell = \frac{H\ell_s}{100} \quad \text{(hPa)} \tag{3}$$

$$\ell_s = a\exp\left[bt/(t+c)\right] \quad \text{(hPa)} \tag{4}$$

where:

H : Relative humidity (%)
t : Celsius temperature (°C)
ℓ_s : Saturation vapour pressure (hPa)

The coefficients a, b, c are 6.1121, 17.502 and 240.97 respectively for water (valid in the temperature range –20° to +50°, with an accuracy of ± 0.20%).

2.2. Refractivity as a function of height

The refractive index n as a function of height h has been found to be well expressed by an exponential law [7]:

$$n(h) = \left[\left(1 + N_o \times 10^{-6}\right)\exp\left(-h/h_o\right)\right] \tag{5}$$

where:

N_o: average value of atmospheric refractivity extrapolated to sea level
h_o: scale height (km).

For reference purposes, a global value of $h_o = 7.35$ km was given and the relationship between the value of refractivity at the surface, N_s and the N_o is

$$N_s = N_o \exp\left(-h_s/h_o\right) \tag{6}$$

where:

h_s is height of the Earth's surface above sea level (km). Kolawole [8] recommended a scale height of 7 km for tropical condition.

3. Methodology

The data used were those obtained through the devices for the measurement of basic physical parameters of the atmosphere, which were located on National Television Authority Tower, Akure. The device used is the Davis 6162 wireless Vantage pro2plus, which is equipped with an Integrated Sensor Suite (ISS), a solar panel, an alternative battery source, and wireless console which serves as the receiver from the ISS and also provides the user interface data display. The ISS houses the external sensors for measurement of temperature, pressure and relative humidity. A data logger for storing the data transmitted via radio was connected to the console. Sensors were located at the surface, 50m, 100m, 150m and 200m above the ground level. The data on temperature, pressure and relative humidity were collected and logged every 30 minutes, and later downloaded to a personal computer. The study was carried out from January, 2008 to December, 2008. The monthly mean refractivity values for each of the altitude levels were computed using the measured refractivity parameters. The refractivity profiles were obtained using an h_o of 7.35 km and an h_o of 7 km recommended for global and tropical region respectively. The two profiles were then compared with the measured value of refractivity at different altitudes.

4. Results and Discussion

The results obtained for the refractivity profile using the ITU-Recommendation P 453 model with the h_o of 7.35 km recommended for global use [7], the h_o of 7 km recommended for the tropical environment by Kolawole [8] and those obtained from the measured pressure, temperature and relative humidity at the different levels considered were all plotted on the same graphs for easy comparison as shown in Figure 1 – 12. The models were observed to be reasonably accurate for the refractivity structure at the altitude of 50 m and 200 m for seven out of the twelve months of the year. The h_o of 7 km gave a better result compared to the h_o of 7.35 km at the altitude of 50 m. At the altitude of 200 m, the reversed was the case with h_o of 7.35 km giving closer results to the measured values.

As depicted in Figure 1, in the month of January, the measured values gave the reduction of refractivity with the altitude that is more than the values given by the two models. In the months of October, November, and December, the measured refractivity reduces with the altitude less than the values given by the models as shown in Figure 10, 11and 12. For the months of March through September (Figure 3 – 9), it was observed that the deviation of the measured values from the models values occur within the window of 100m and 150m altitude. The deviations in the values observed at 100 m altitude are significant in the months of July and August. The deviation observed between the models and the measured values show that there might be a need for a re-evaluation of the refractivity model in the tropical region in order to have more dependable results.

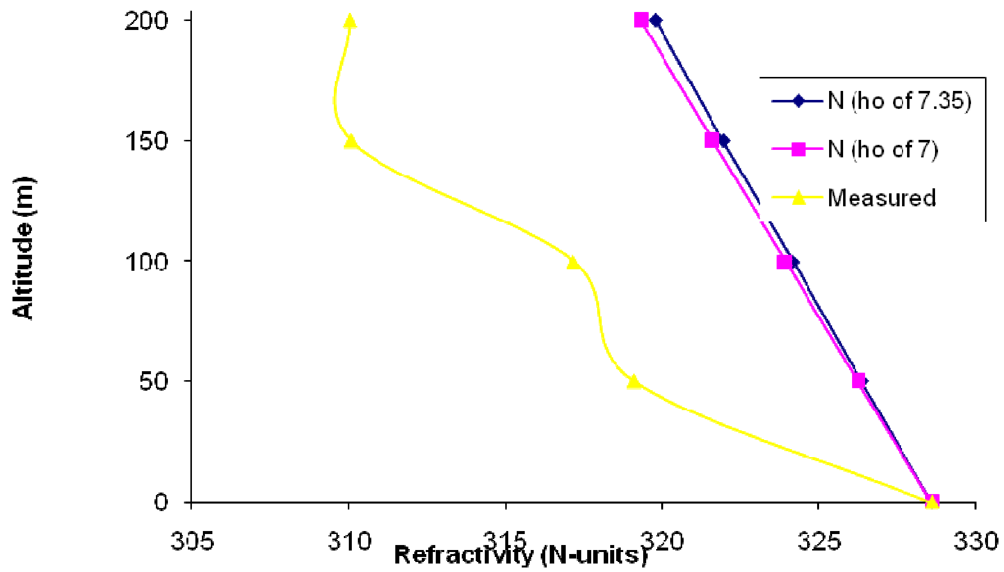

Fig. 1. The Refractivity Structure for January 2008

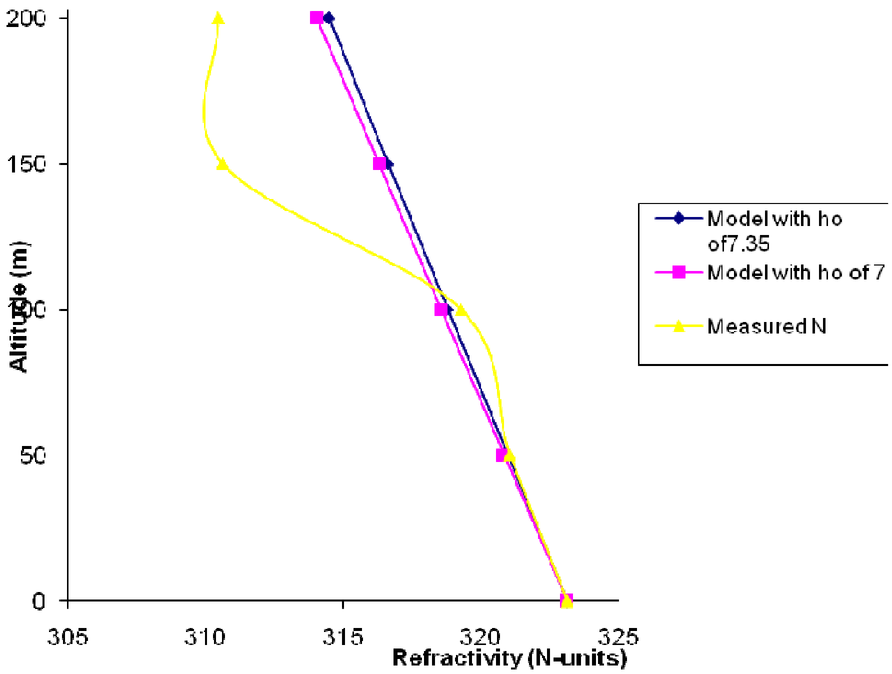

Fig. 2. The Refractivity Structure for February 2008

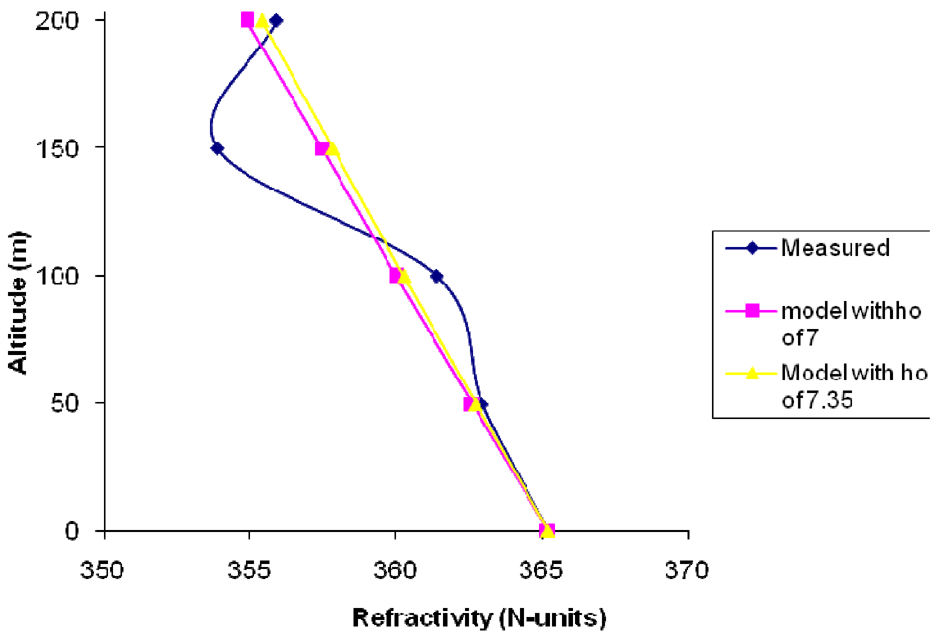

Fig. 3. The Refractivity Structure for March 2008

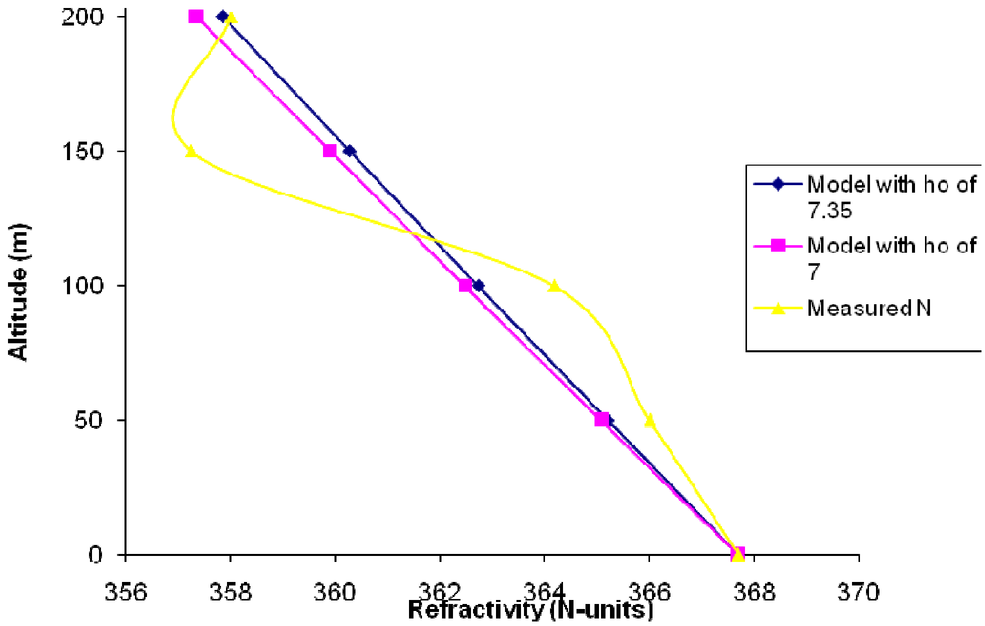

Fig. 4. The Refractivity Structure for April 2008

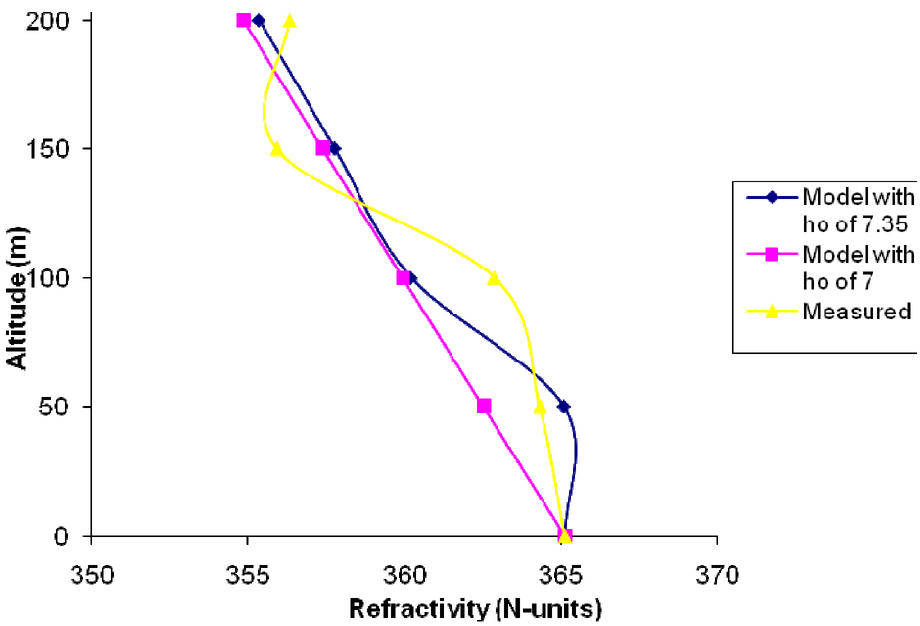

Fig. 5. The Refractivity Structure for May 2008

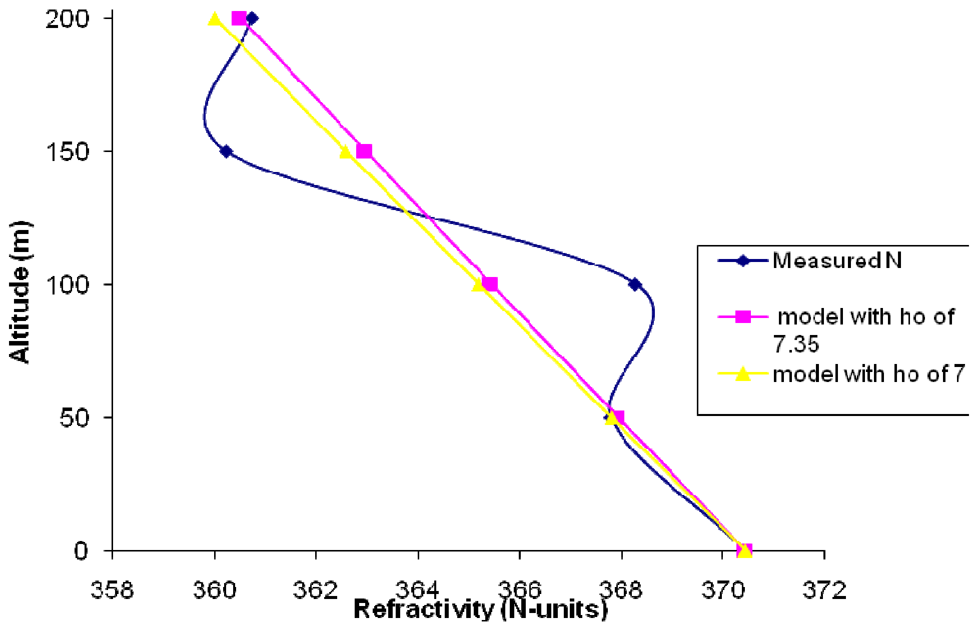

Fig. 6. The Refractivity Structure for June 2008

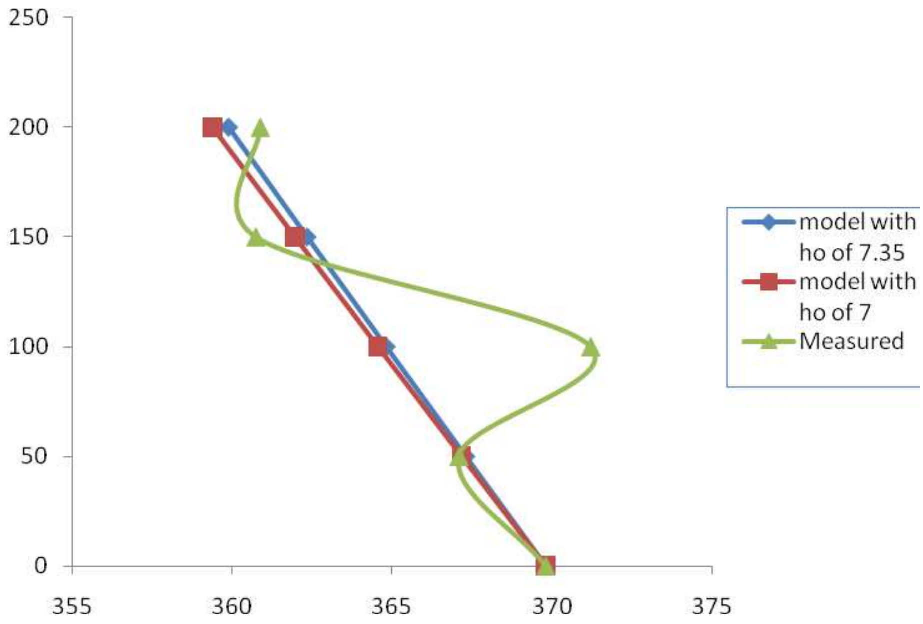

Fig. 7. The Refractivity Structure for July 2008

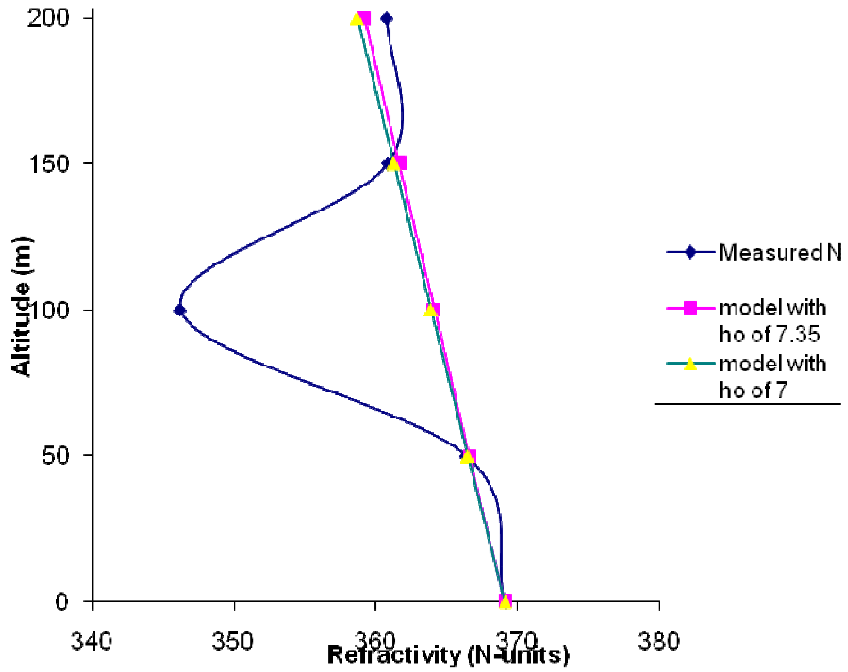

Fig. 8. The Refractivity Structure for August 2008

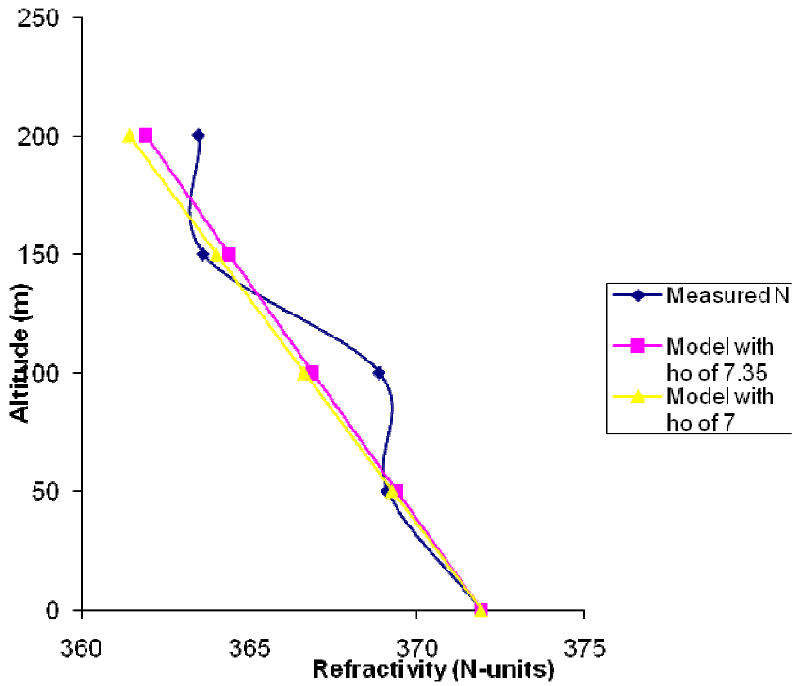

Fig. 9. The Refractivity Structure for September 2008

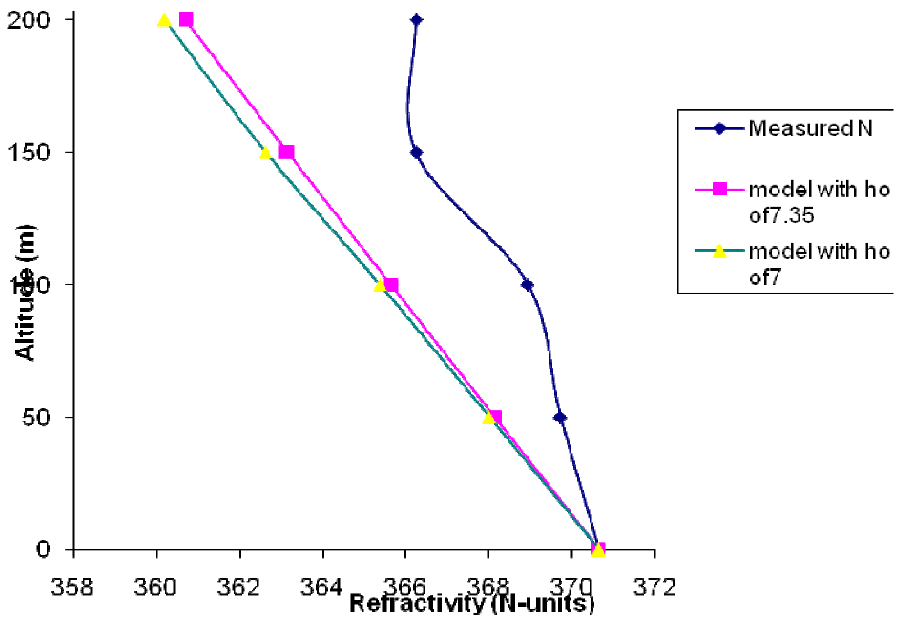

Fig. 10. The Refractivity Structure for October 2008

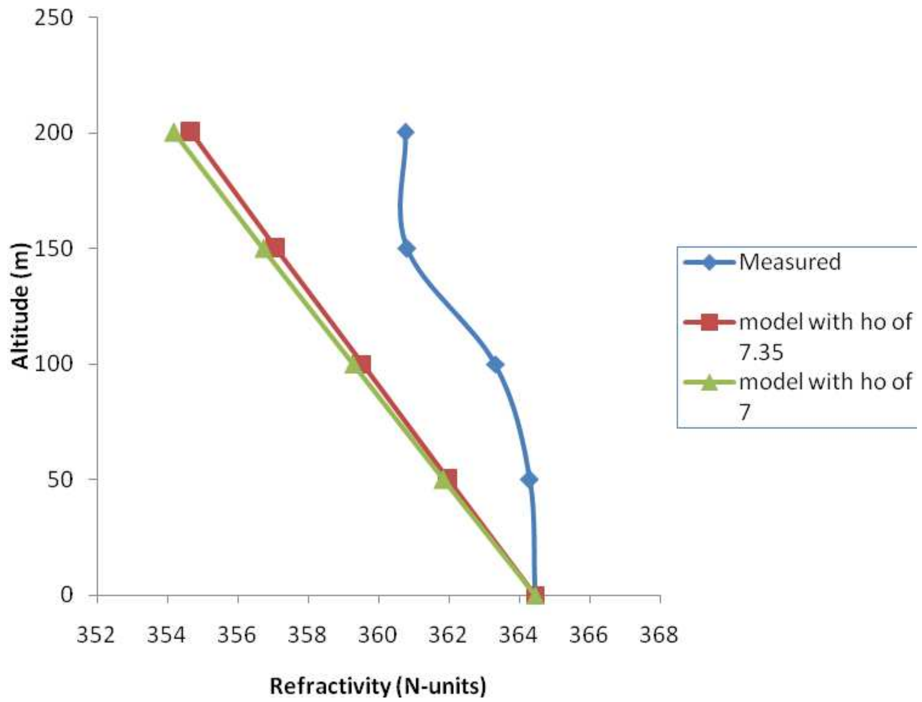

Fig. 11. The Refractivity Structure for November 2008

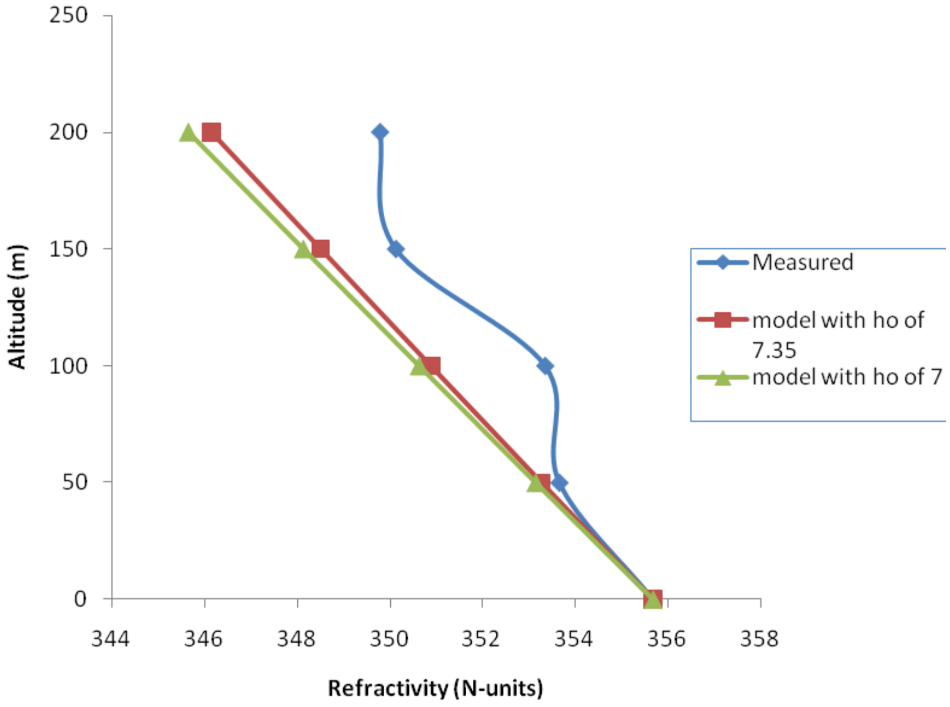

Fig. 12. The Refractivity Structure for December 2008

5. Conclusion

Measured data of refractivity at the first 200 m altitude in Akure, southwest Nigeria for a period of one year was used to investigate the applicability of the International Telecommunication Union Recommendation P453 model for the refractivity profile of a typical troposphere in the tropics. The results of this work show that there is a need for a re-evaluation of the refractivity model used in the tropical region. The work is continuing and the effect of the seasonal and yearly variations will be considered.

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