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Determination of Atmospheric Effective Earth Radius Factor (k -factor) Under Clear Air in Lagos, Nigeria

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Abstract

Due to its cost effectiveness and ease of accessibility, as well as adaptability, radio wave communication at microwave frequencies has earned enormous attention over time. Importantly, secondary radio variables remained very significant in carrying out calculations especially on effective earth radius factor. This study was carried out in Lagos, South West of Nigeria. Three year atmospheric parameters data from Nigerian Meteorological Agency (NIMET) was used. International Telecommunication Union (ITU) recommendation models were applied in determining point refractivity gradient and effective earth radius factor based on radiosonde data obtained from NIMET for Lagos state. The calculated values of effective earth radius factor showed a variation between 1.31 and 1.73 while the point refractivity gradient varied between -398.5034 and -56.42. Also, the yearly average value of $dN1$ and k -factor for Lagos are -210.111392 and 1.494358 respectively.

Keywords: earth radius factor, refractivity gradient.

1 Introduction

The concept of radio wave communication over time has been in application in greater magnitude as compared to other communication modes. The wireless communication links are utilized for various services; voice, data and video. The point to point radio line of sight link is also being used to fix terrestrial communications, as well as mobile communications [1]. The areas of application earlier stated can be seen in both civil and military operations across the globe.

During microwave link design, some parameters such as the effective earth radius factor, (k -factor), and the point refractivity gradient, (dN/dh), must be set carefully to optimize the performance of the microwave link [2]. The effective earth radius factor, (also called k -factor) greatly influence the transmission of radio signals through the atmosphere. Due to its significance, the understanding of the effective earth radius factor distribution in a given area is of great importance in the telecommunication industry. However, the k -factor is largely dependent on refractivity gradient. As a result of variations in atmospheric refractivity, radio waves usually bend while propagating through the different layers in the atmosphere [2]. Most of the atmospheric effects are very much noticeable when transmitted signals take different route to its target receiver and the arrival time also being different. Consequently, in this paper, ITU models are applied in determining point refractivity gradient and effective earth radius factor based on radiosonde atmospheric parameters data obtained from NIMET for Lagos state.

2 Effective Earth Radius

The concept of effective earth radius explains a situation where the clearance of the radio beam over the earth's surface is dependent on the relative distance between two curves. An analysis for clearance is made convenient if one of the curves is assumed to be straight and the other given an extra curvature for compensation. The radio ray is imagined to be straight line relative to an effective earth's radius, which has been adjusted by the refractivity gradient. This radius is the real earth's radius which has been multiplied by an earth radius factor (k) that is dependent on the refractivity gradient [3]. According to Abu-Almal and Al-Ansari [2], the earth radius factor (k) is the radius of a hypothetical spherical earth, without the atmosphere, for which propagation paths follows straight lines, the heights and ground distances being the same as for the actual earth in an atmosphere with a constant vertical gradient of refractivity [2, 4]. Hence, the effective earth radius factor can be estimated as follows [2, 4, 5, 6, 7]:

$$K = \left[1 + \frac{\left(\frac{dN}{dh}\right)}{157} \right]^{-1} \quad (1)$$

3 Methodology

More so, the estimation of effective earth radius factor is dependent on primary radio climatic variables, namely; temperature, pressure and humidity. The three primary radio climatic variables help to obtain another radio climatic variable called radio refractivity, N . The atmospheric refractivity N (N -units) is usually computed as follows [8, 9, 10]:

$$N = (n - 1)10^6 \quad (2)$$

However, since n has a standard value of 1.000312 and if substituted in equation 2, it gives the value of refractivity (N) to be $312N$ -units. The refractive index n of air is related to refractivity, N as follows [8, 9, 10, 11]:

$$N = (n - 1)10^6 = 77.6 \left(\frac{P}{T}\right) + 3.732(10^5) \left(\frac{e}{T^2}\right) \quad (3)$$

where T is absolute temperature (K), P is atmospheric pressure (hpa), and e is the atmospheric water vapour pressure (hpa).

The water vapour pressure is calculated as follows [12]:

$$e = H \left(\frac{6.1121 \exp\left(\frac{17.502t}{t+240.97}\right)}{100} \right) \quad (4)$$

where t is temperature in Celsius ($^{\circ}$ C) and H is the relative humidity.

To obtain the gradient of refractivity, we consider the equation thus defined by [10]:

$$G = \frac{dN}{dh} \quad (5)$$

where the refractivity is expressed as a function of height. Hence, G is given as:

$$G = \frac{dN}{dh} = \frac{N2-N1}{h2-h1} \quad (6)$$

where $N2$ is the refractivity at 65m, $N1$ is the refractivity at the ground level, $h2$ is the 65m altitude, and $h1$ is the ground level.

In essence, the refractivity gradient shows the relationship of how refractivity changes with height which is of greater interest to line of sight link design engineers. Finally, the effective earth radius factor (k) can be calculated by substituting $\frac{dN}{dh}$ is Equation 1.

4 Results and Discussion

The refractivity gradient for Lagos from the distribution Table 1 shows the highest occurrence in December with -56.4268N units and February with the lowest $dN1$ having -398.5034N units. The yearly average value of $dN1$ and k -factor for Lagos are -210.111392 and 1.494358 respectively.

Table 1 The Effective Earth Radius Factor (k_e) and Refractivity Gradient (DN) for various months in Lagos

Months	k_e for Lagos	DN for Lagos
Jan	1.3627	-275.8573
Feb	1.3605	-398.5034
Mar	1.3337	-313.51
Apr	1.6113	-99.8233
May	1.6365	-89.6555
Jun	1.748	-172.883
Jul	1.4977	-158.4198
Aug	1.3128	-344.8771
Sep	1.4059	-229.8108
Oct	1.5395	-134.0033
Nov	1.3881	-247.5664
Dec	1.7356	-56.4268
Yearly Average	1.494358	-210.111392

Also, the effective earth radius distribution for the various months in each of this location shows monthly and seasonal variations, Figure 1 and Figure 2.

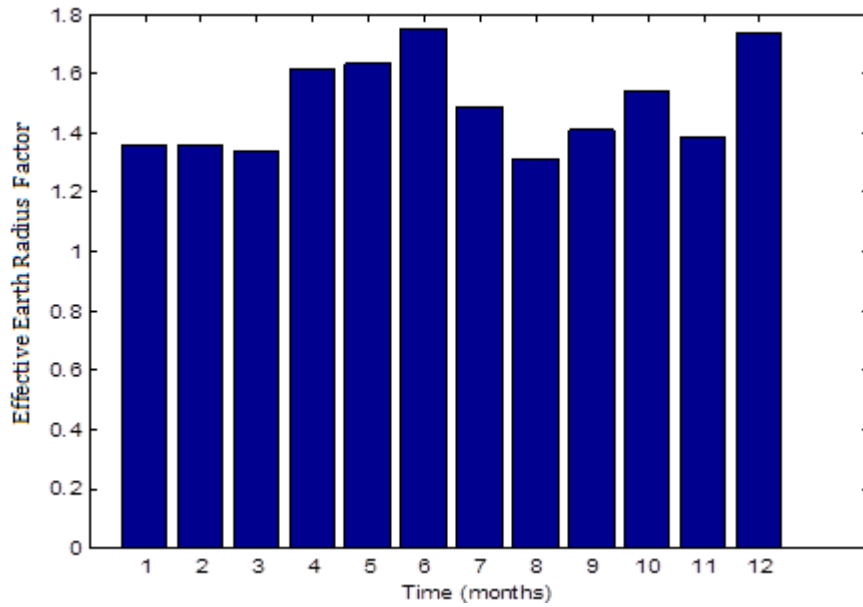


Figure 1 The distribution of effective earth radius factor in Lagos

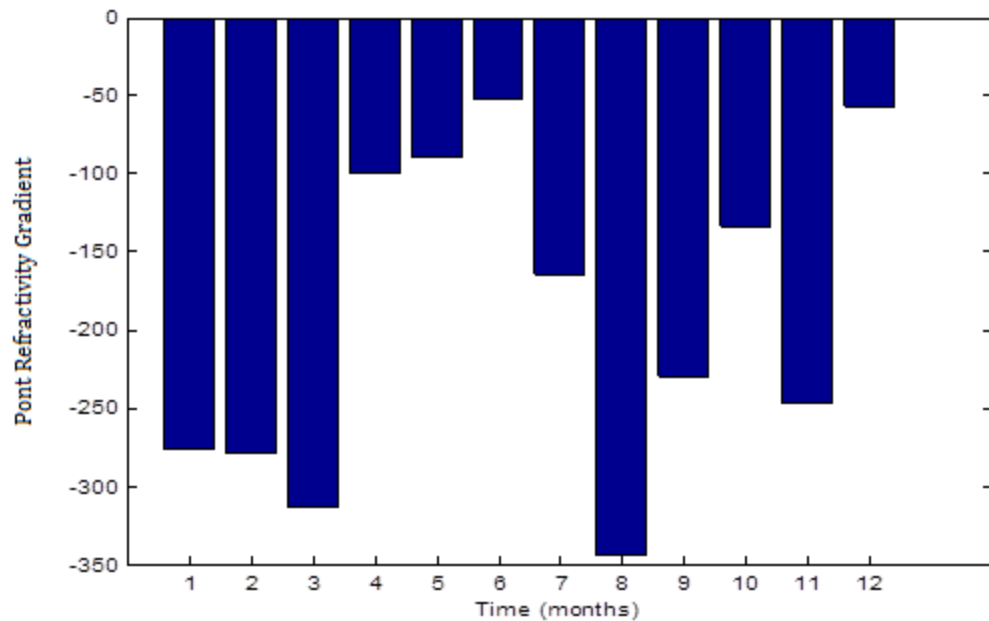


Figure 2 Shows refractivity gradient for different months in Lagos

5 Conclusion

In this study, the estimation of effective earth radius factor and refractivity gradient are carried out under clear air condition using local radiosonde data gotten from Nigerian Meteorological basically for Lagos within the period of three years from 2012 to 2014. The calculated values of effective earth radius factor shows variation in values between 1.31 and 1.73 while the point refractivity gradient values vary between -398.5034 and -56.42. The result distribution shows high refractivity occurrence in the rainy period while in the dry season the reverse is the case.

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