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EFFECTS OF RADIO REFRACTIVITY GRADIENT AND K-FACTOR ON RADIO SIGNAL OVER IBADAN, SOUTH WESTERN, NIGERIA.

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ABSTRACT: Determination of radio refractivity, refractivity gradient and k-factor are very significant parameters in planning radio communication links. This study presents an estimation of radio refractivity gradient and k-factor so as to determine the effects of these secondary weather parameters on radio signal strengths over Ibadan (7.4546°N, 3.8919°E). Two years atmospheric primary weather parameters data from Nigerian Meteorological agency (NIMET) was used to calculate the refractivity, N, refractivity gradient, G, and k-factor at different heights from the ground level, the heights considered are; 50, 100, 150 and 200 m. The results obtained indicated that the average radio refractivity, N, was higher during the rainy season due to the rise in the atmospheric moisture content in the region and the value of N also decreases with height. The mean radio refractivity gradient and the average k-factor obtained were -50.417 Nunit/km and 1.5285 respectively. The value of k-factor obtained is greater than the global standard value, 4/3. In this case, super-refraction occurs in this study area and the radio signal propagate abnormally towards earth's surface which might leads to signal interference over this region of study. An empirical relationship for predicting further the radio refractivity at different heights over this region of study has also been developed.

Key words: height, k-factor, refraction, refractivity gradient, radio refractivity, rainy season, super refraction.

INTRODUCTION

Radio signal propagation in the troposphere is affected by primary and secondary weather parameters, the primary weather parameters include; atmospheric pressure, temperature and water vapor. The variation of these parameters are associated with change in weather condition at different seasons of the year and these changes are resulted in variation of secondary weather parameters which includes; radio refractivity, refractivity gradient and k-factor [1]. Understanding of the weather parameters (primary and secondary) will definitely assist cellular network providers and radio engineers in improving their quality of services. Variations in the value of radio refractive index and k-factor can cause the path of

This study seeks to investigate the effects of radio refractivity, refractivity gradient and k-factor on signal strength over Ibadan using primary radio climatic variables during two years. It should be noted that, for any locations where atmospheric data were not available, k-factor value of 1.333 is taken as a standard value and estimated value of point radio refractivity as provided by International telecommunication union (ITU) can be used [6].

2. RESEARCH METHODOLOGY

2.1 Measurement campaign

The meteorological data, that is, primary weather parameters used to compute radio refractivity, refractivity gradient and k-factor for Ibadan, Nigeria was provided by Nigeria Meteorological agency (NIMET). The data contains the following monthly weather parameters; temperatures, pressure and relative humidity for a period of two years, 2016 and 2017.

2.2 Computation of radio refractivity (N)

The radio refractivity, N , is related to the refractive index, n of air as [7]

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

In terms of meteorological parameters, the ITU recommended the radio refractivity, N , as [7]

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

propagating radio wave to bend either towards the earth or away from the earth. Therefore, it is necessary for the management of radio communication systems to take into consideration the deviation or bending of the propagating radio wave due to the changes in the distribution of refractivity [2]. For microwave system design, refractivity gradient and k-factor must be well understood to optimize the communication system performance. Several work has been done on variations of secondary weather parameters for different regions and climates using measured local meteorological data [3] [4] [5] to mention but just a few, the results of their work shows that local climate has an impacts on the secondary weather parameters and hence on the transmitted radio signals. Hence,

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

The water vapor pressure, e , is obtained from the relative humidity, H , and temperature, T , by [8][9]

$$e = H \left(\frac{6.1121 \exp\left(\frac{17.502T}{T + 240.97}\right)}{100} \right) \quad (2)$$

The radio refractivity decreases exponentially in the troposphere with height given as [7] [9]

$$N = N_s \exp\left(\frac{h}{H}\right) \quad (3)$$

where N is the refractivity at the height h (km) above the level where the refractivity is N_s and H is the applicable scale height.

2.3 Refractivity gradient (G)

The refractivity gradient is gotten by differentiating equation (3) with respect to h as shown in equation (4)

$$\frac{dN}{dh} = \frac{-N_s}{H} \exp\left(\frac{-h}{H}\right) \quad (4)$$

The point refractivity gradient, dN/dh was obtained using [9]

$$G = \frac{dN}{dh} = \frac{N_2 - N_1}{h_2 - h_1} \quad (5)$$

where N_1 is the refractivity at the ground level, N_2 is the refractivity at the reference height (50, 100, 150 and 200m), h_1 is the ground level while h_2 is the height at which the measurement took place. The vertical gradient of refractivity in the lower layer of the atmosphere is an important parameter in estimating path clearance and propagation effects such as sub-refraction, super-refraction and tropospheric ducting [9].

For sub-refraction $\frac{dN}{dh} > -40$, the refractivity N increases with height and in this case, the radio wave moves away from the earth's surface and the line of sight, the range of propagation decreases accordingly [10][11].

For super-refraction, $\frac{dN}{dh} < -40$. During this condition, radio waves are bent downward towards the earth. The degree of bending depends upon the strength of the super-refractive condition. On reaching the earth's surface and being reflected from it, the waves can skip large distances thereby giving abnormally large ranges beyond the line of sight due to multiple reflections [12].

For tropospheric ducting, $\frac{dN}{dh} < -157$. During the tropospheric ducting, the waves bend downwards with a curvature greater than that of the earth.

2.4 k-factor

k-factor can be used to characterize refractive conditions as normal refraction or standard atmosphere, sub-refraction super-refraction and ducting, it is given as [13]

$$k = \frac{1}{\left[1 + \frac{\left(\frac{dN}{dh}\right)}{157}\right]} \tag{6}$$

Around the earth's surface the value of dN/dh is approximately -40 N-units/km, which will give a k-factor of 1.333; this is referred to as normal refraction or standard atmosphere. Here, radio signals are transmitted along a straight line path on the earth's surface and go into space unhindered. If $1.333 > k > 0$, we will have sub-refraction; which indicates that the radio waves propagate abnormally away from the earth's surface. But when $\infty > k > 1.333$ super-refraction occurs and this signifies that the radio wave signals spread irregularly towards the earth's surface. Hence, extending the radio horizon and increasing path clearance thereby giving irregularly huge

ranges above the line of view as a result of several reflections. But, if $-\infty < k < 0$ there will ducting and this will make the radio waves to bend downwards with a curvature bigger than the earth's own. The radio signals can become trapped between a layer in the lower atmosphere and the surface duct which is the earth's or sea's surface or between two layers in the lower atmosphere which is the elevated duct. In this wave guide-like propagation, very lofty radio signal strengths can be obtained at a very long range which is far above the line of view [14].

3. RESULTS AND DISCUSSION

The results obtained shows that, the average radio refractivity, N , was higher during the rainy season, this is due to the rise in atmospheric moisture content in the region. It was also shown that, the value of N are higher at ground level and it decreases with vertical height. Figure 1 shows the variation of radio refractivity with height. It was discovered that the value of radio refractivity decreases with height. Starting from the ground level ($h = 0$), the average value of N obtained was 390 Nunit/km it was 368, 364, 350 and 320 Nunit/km at the vertical height 50, 100, 150 and 200 m respectively. Hence, radio refractivity, N , is inversely proportional to tropospheric vertical heights, h , as shown in equation (7)

$$N \propto \frac{1}{h} \tag{7}$$

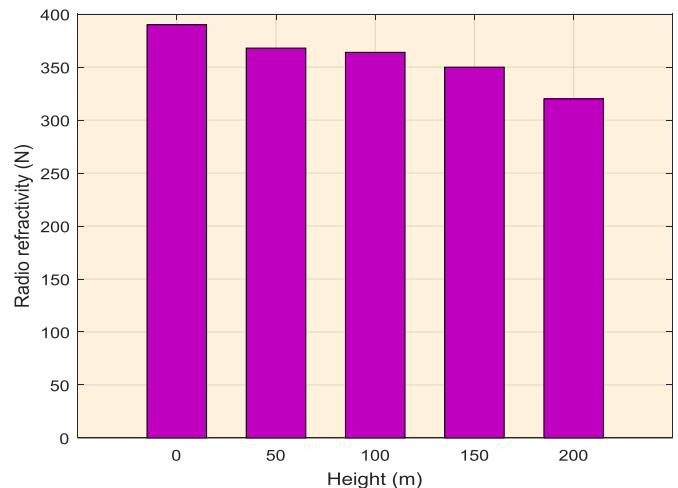


Fig. 1: Variation of radio refractivity with height

Equation (8) shows an empirical relationship for predicting further the radio refractivity at different heights over this region of study. The empirical relationship was developed

by utilized Matlab R2017b software, a linear model Polynomial degree 1 at off robust and coefficient with 95 % confidence bounds was used.

$$N = -0.316h + 390 \tag{8}$$

where h (m) is the vertical height above sea level and N is the radio refractivity.

Figure 2 to 5 shows the graphical representation of radio refractivity gradient, G , and k -factor against the months. For all the heights considered in this work, the month February shows high refractivity gradient with mean value -41.75 Nunit/km while the month of June shows low refractivity gradient with mean value -73.50 Nunit/km. Generally, the refractivity gradient obtained in this region was less than -40 Nunit/km and the average value of refractivity gradient obtained for the year was -50.417 Nunit/km. From these findings, it could be deduced that propagation condition in this geographic zone is mostly super-refractive.

For the k -factor, it was observed that the effective earth's radius (k -factor) values increases in the rainy season with the values ranges between 1.250 and 2.000. The mean k -factor obtained was 1.528 which is greater than the global standard value (1.333) and this implies that the propagation in this study area is mostly super-refractive.

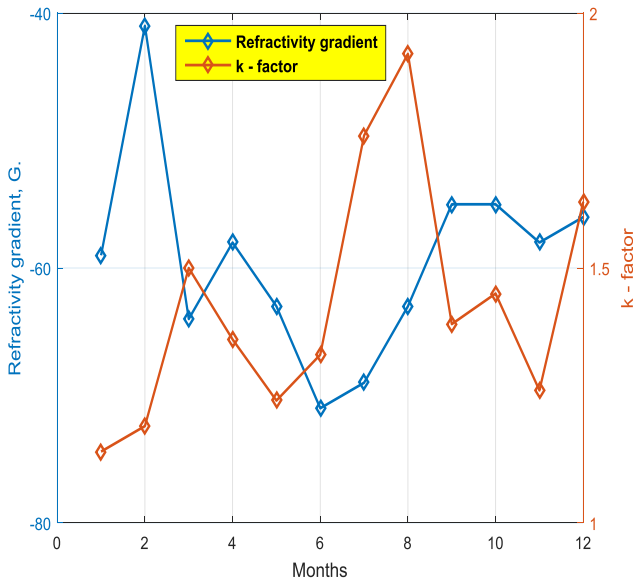


Fig. 2: Plot of radio refractivity and k -factor against the month at the altitude of 50m

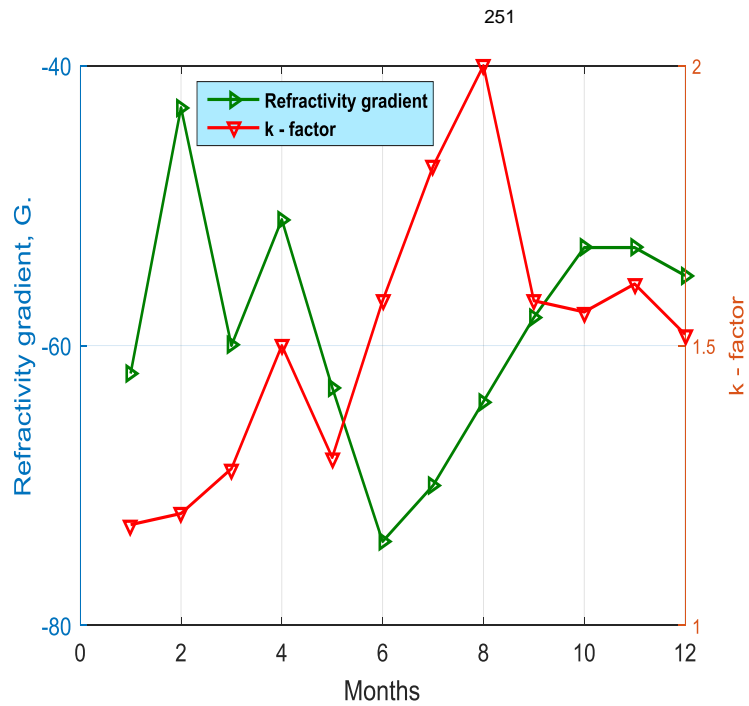


Fig. 3: Plot of radio refractivity and k -factor against the month at the altitude of 100 m

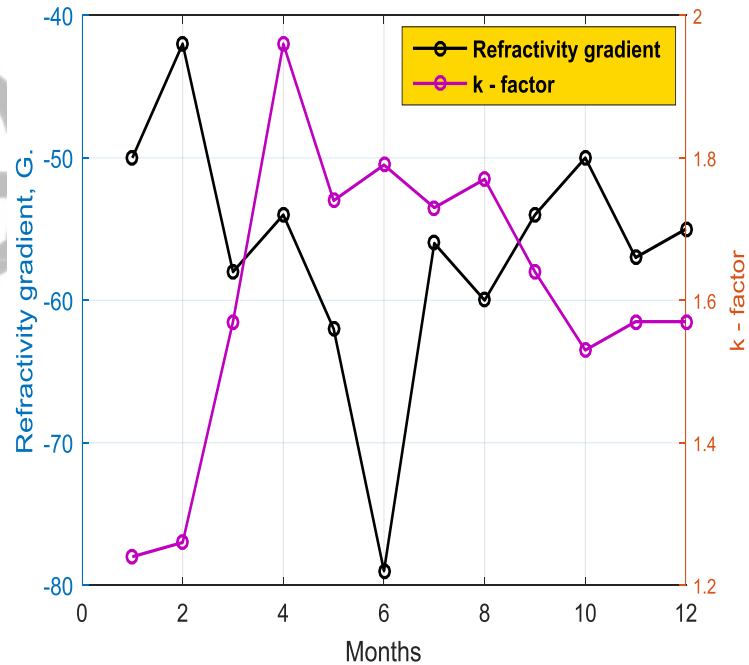


Fig. 4: Plot of radio refractivity and k -factor against the month at the altitude of 150 m

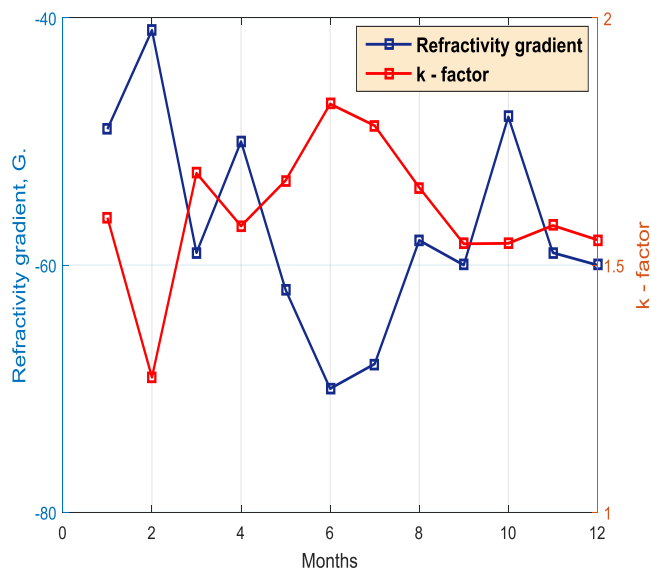


Fig. 5: Plot of radio refractivity and k-factor against the month at the altitude of 200m

4. CONCLUSION

The investigation has revealed that the surface radio refractivity gradient, G , has higher values in the dry season and lower values in the rainy (wet) season, this is due to the rise in atmospheric moisture content in the region. It was also shown that, the value of N are higher at ground level and it decreases with vertical height. With the exception of the measurement at 200 m altitude in which the minimum k-factor was observed in the month of February the average minimum k-factor for the heights 50, 100 and 150 m was observed in the month of January. . An empirical relationship for predicting further the radio refractivity at different heights over this region of study has also been developed. The mean radio refractivity gradient for the two years of measurement was -50.417 Nunit/km while the mean k-factor obtained was 1.528. Therefore, the propagation conditions could be mostly super-refractive over Ibadan, south western, Nigeria.

Remarks

The monthly mean k values obtained can be used for planning wireless links on short term basis. The average annual value of k-factor, 1.528 should be used for planning long term wireless communication in Ibadan South western, Nigeria.

REFERENCES

- [1] Manning, T (1999). "Microwave radio transmission guide". British library cataloging in the publication data, pp.89 - 115
- [2] Afullo, G.A., Motsoela, T, Moltosi, D.F (1999). "Refractivity gradient and K-factor in Botswana Radio Africa". pp.107-110.
- [3] Agbo, G.A.(2011) "Tropospheric refractivity dependence on atmospheric weather conditions in Jos-Nigeria". Journal of Basic Physical Research. pp.2-6.
- [4] Luhunga P.M., Mutayoba E., Masoud H., Changa L., Prodanov A.D. (2014) "Analysis of tropospheric radio refractivity over Julius Nyerere International Airport, Dares Salaam" pp.-21-31.
- [5] Zilinskas M., Tamosiunnas, Tamosiunaite M., (2011) "Seasonal and daily variations of radio refractivity". Physical Aspect of Microwave and Radar Applications. pp. 533-536.
- [6] Aboualmal, A., Abd-Alhameed, R.A., Jones, S.M., Al-Ahamad, H.,(2015). "New Methodology for predicting vertical atmosphere profile and propagating parameters in sub-tropical Arabam Gulf region". Antennas and propagations, IEEE Transaction, 63(9), pp.4057-4068.
- [7] International telecommunication union recommendation (ITU-R). (2003) "The radio refractive index, its formula and refractivity data". pp. 453-459
- [8] Hall, M.P.M. (1989): "Effect of the troposphere on radio communication", IEEE Electromagnetic wave series, Peter Peregrinus Ltd, United Kingdom 105-116.
- [9] Afullo, T. J, Motsoela, T and Molotsi, D.F (1999). "Refractivity gradient and k-factor in Botswana". Radio Africa.107-110.
- [10] Bean, B. R., Dutton, E.J. (1968). "Radio Meteorology National Bureau of Standards Monograph". 92. US. Government printing office, Washington, pp. 9-13.
- [11] ITU-R, "Radio-frequency arrangements for fixed service systems," ITU-R rec. F.746-10, 2012.
- [12] Freeman, R.L (2007). "Radio system design for telecommunications", Third Edition, WILEY-INTERSCIENCE: John Wiley & Sons Inc., New York.

- [13] Pupala, R.N. (2005). "Introduction to Wireless Electromagnetic Channels and Large Scale Fading", Department of Electrical Engineering, Rutgers University, Piscataway, NJ 08854.
- [14] Adediji A.T., Ajewole M.O., Falodun S.E (2011). "Distribution of Radio Refractivity Gradient and Effective Earth Radius Factor (k-factor) over Akure, South Western Nigeria", Journal for Atmospheric and Solar-Terrestrial Physics, 73(2011), pp 2300

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