Influence of Geoclimatic Factor on Fade Depth for Wireless Link Design using Radiosonde Data

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Abstract: **The concept of fading and signal propagation design remain very vital to a radio Engineer because of the unstable nature of environment the signal traversing. Precise estimation of Geoclimatic factor (K) and effective earth's radius factor (k) which depends on temperature, relative humidity and pressure are highly essential for radio signal propagation in clear air so as to provide for fade margin. In this work, the Geoclimatic factor has been obtained using Radiosonde data for two different locations (Ibadan and Ilorin), Nigeria. The K-factor obtained was used to determine the multipath fade depth exceeded for 0.01% of time and the result revealed that the k and K have monthly variations and they are locations dependent. Specifically, Ibadan and Ilorin has annual mean geoclimatic factor of 0.000293 and 0.000185 respectively. Also, the annual mean k-factor obtained in the two locations are 1.475 and 1.548 respectively. These values are higher than the standard value of 1.33 as predicted by ITU-R and the implications of the result is that, propagation in this geographic locations are mostly Super-refractive. From the monthly and annual K-factor presented, the percentage of time a given fade depth exceeded for the 20 GHz increases rapidly with increasing link distance in the two locations and the fade depth also increases with increase in frequency at a fixed distance. This is due to the fact that as the path length increased, the multiple reflections leading to multipath also increases and this leads to multipath fading. The overall results can be used for microwave link design in these locations.**

Key words: **Fade depth, Frequency, Geoclimatic factor, k-factor, Radiosonde.**

I. INTRODUCTION

The propagation of electromagnetic waves around the earth is influenced by the properties of the Earth and the atmosphere [1-5]. Therefore, an appropriate planning is required or needed for effective radio wave propagation of terrestrial radio links for effective communication. Radio propagation links at microwave frequency band are the easiest mean of effective propagation and communication. They are employed in conveying enormous numbers of quality audio, video and high definition of Television channels [6, 7]. However, the operation of this radio communication at this higher operating frequency are affected by various atmospheric elements such as fog, haze, rain and gases [8]. Primary atmospheric weather parameters such as temperature, relative humidity and atmospheric pressure are variable in time and space that brought about variation in k-factor and geoclimatic factor and the changes in geoclimatic factor is responsible for bending of radio waves in various direction over the curvature of earth and this results in clear-air multipath fading [9]. ITU-R [10] gave method for predicting the probability of time exceedance percentage of a fade depth in the average worst month. In this study, the focus is to determine the geoclimatic factor using the primary weather parameters obtained in two different locations and to use the values of K obtained to estimate the fade depth exceeded for 0.01% of the time required.

II. THEORETICAL BACKGROUND

The tropospheric propagation of radio waves in troposphere is influenced by the changes in meteorological weather parameter (temperature, relative humidity and atmospheric pressure). The primary weather parameters are related to radio refractivity (N) as [11] [12]

$$N = (n-1)\times 10^6 = \left(\frac{77.6}{T}\right)\left(P + 4810\frac{e}{T}\right) \qquad (1)$$

where N is the radio refractivity, n is the refractive index, T is the absolute temperature, e is the water vapor pressure given as [12]

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

The refractivity gradient, G which is a measure of how the refractive index varies with increasing height is given as

$$\frac{dN}{dh} = 77.6\frac{1}{T}\frac{dP}{dh}\left[\frac{77.6}{T^2}+\frac{746512e}{T^3}\right]\frac{dT}{dh}+\frac{373256}{T^2}\times\frac{de}{dh} \qquad (3)$$

The effective earth radius factor (k-factor) can be determined as [13]

$$k = \frac{1}{1-\frac{a}{\rho}} = \left[\frac{1}{1+a\frac{d\varepsilon_r/dh}{2}}\right] \qquad (4)$$

where a is the actual earth radius, ρ is the radius of curvature of the ray and ε_r is the relative permittivity at height, h.

The geoclimatic factor K which is a measure of the geographical and climatic condition of the terrain is given as [14]

$$K = 10^{-4.6-0.0027\, dN1} \tag{5}$$

where dN1 is the point refractivity gradient in the 100 m of the atmosphere not exceeded for 1% of the average year.

The percentage of time Pw that fade depth A (dB) is exceeded in the average worst month is given as

$$P_w = Kd^{3.1}\left(1+\left|\varepsilon_p\right|\right)^{-1.29} f^{0.8} \times 10^{-0.00089\ h_L} - \frac{A}{10} \tag{6}$$

where f is the frequency in GHz

$$\left|\varepsilon_p\right| = \frac{|h_r - h_t|}{d} \tag{7}$$

where hr is the height of receiver, ht is the transmitter height and d is the path length (km).

III. METHODOLOGY

In this study, twelve months, tropospheric data variables–temperature, relative humidity and atmospheric pressure were obtained from meteorological department in Ibadan and Ilorin. These parameters were obtained using Radiosonde data. Inverse distance weighting (IDW) technique was used for interpolation of the radiosonde data to obtain the data at specific heights required. The primary weather parameters obtained were used to calculate the secondary radio climatic variables, which includes: Radio refractivity (N); refractive gradient (G); effective earth radius factor (k) and geoclimatic factor (K). The fade depth exceeded for 0.01% of time required as a function of frequency and link distance was obtained using equation (6) at operating frequency 20 GHz

IV. RESULTS AND DISCUSSION

4.1 Variation of k-factor and geoclimatic factor with months of the year

Figure 1 shows the variation of geoclimatic factor and k-factor against the months of the year for the data in Ibadan, south western Nigeria while figure 2 depicts contour map of the variation of geoclimatic factor and k-factor with months of the year. Minimum geoclimatic factor obtained ranges from 0.0000815 to 0.0000912 between the months of April and August. This was due to high water content because of high rainfall and relative humidity experienced in these months. The corresponding k-factor within these months ranges between 1.032 and 2.360. Also, in Ibadan lowest K with value 0.0000779 was noted in April while the maximum K with value 0.000720 was observed in the month of October. This is clearly shown in the contour map in figure 2 as the black and light blue regions shows the minimum geoclimatic factor while the yellow region depicts the months with maximum geoclimatic factor.

Figure 3 shows the bar graph of the value of geoclimatic factor and k-factor for the months of the year obtained in Ilorin North central, Nigeria. Minimum geoclimatic factor 0.0000982 was noted in the month of July as depicted in the black and blue area of the contour map shown in figure 4 while the maximum geoclimatic factor (0.000499) was obtained in the month of March.

Generally, the results shows that the geoclimatic and k-factor variables are function of locations. The average k-factor and geoclimatic factor obtained in Ibadan for the months of the year are 1.4391 and 0.000293 respectively while the annual average k-factor and the geoclimatic factor obtained in Ilorin are 1.5103 and 0.000185 respectively. For the two area considered, the average values of secondary weather parameters are greater than the predicted international standard value by ITU-R which is 1.333. Since geoclimatic factor is used to estimate fade depth of radio signal, therefore, the mean value obtained at each location can be used for fade margin required for a proper radio link performance.

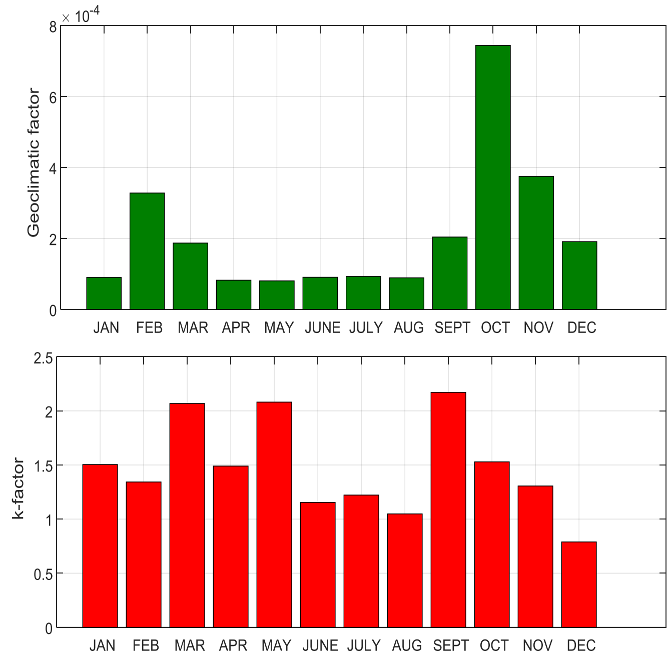

Figure 1: Variation of k-factor and geoclimatic factor for various months of the year in Ibadan

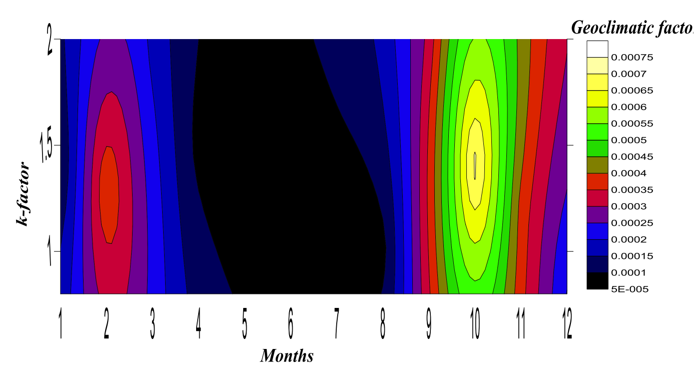

Figure 2: Contour map of k-factor and geoclimatic factor for the various months in Ibadan

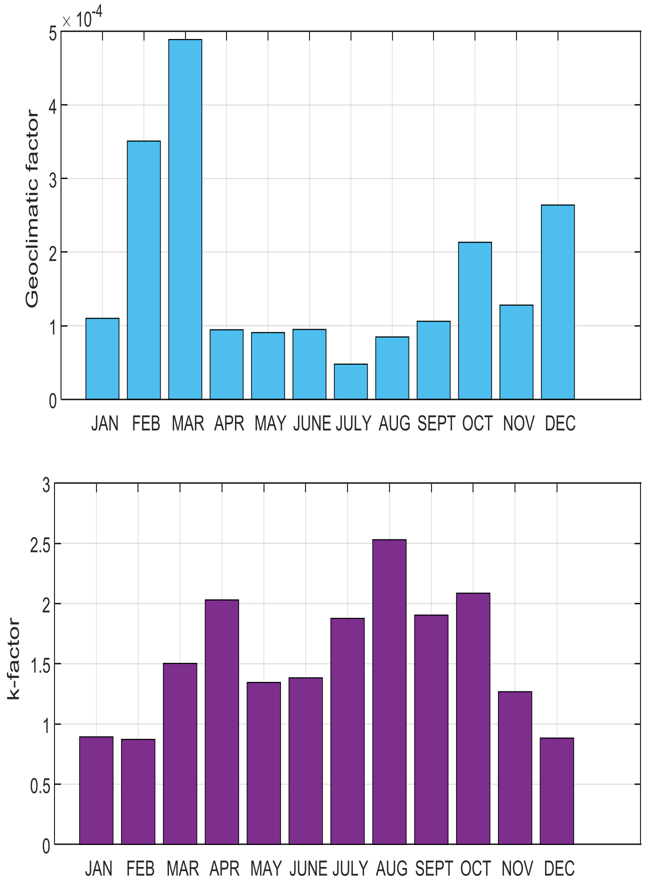

Figure 3: Variation of k-factor and geoclimatic factor for various month of the year in Ilorin

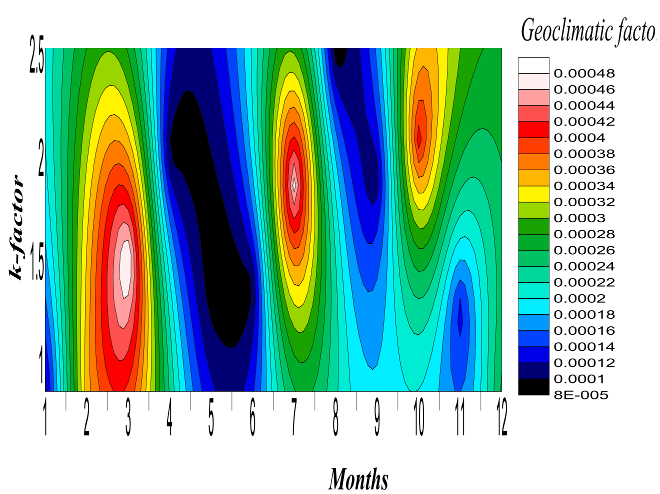

Figure 4: Contour map of k-factor and geoclimatic factor for the various months in Ilorin

4.3 Variation of fade depth with frequency and distance

There is need to determine the correct value of geoclimatic factor so as to provide for fade margin required for a proper radio link performance since K-factor is used to estimate fade depth of radio signal. The fade depth exceeded for 0.01% of the time is also required in predicting system availability for a certain percentage of time. The value of fade depth exceeded for 0.01 % of time have been determined. Figure 5 shows the variation of fade depth exceeded with operating frequency at a fixed distance 30 km from the transmitter. The results shows that, the fade depth exceeded increases rapidly with increase in frequency and distance for the two locations considered. This was attributed to the fact that for long distance, refraction and reflections of signal due to radio refractivity gradient is more pronounced. The mean fade depth exceeded for 0.01% at different frequency was 46.36 dB in Ibadan while that of Ilorin was 43.02 dB. It was also observed that, the average fade depth as a function of link for Ibadan and Ilorin were 33.58 dB and 31.24 dB respectively. Hence, the fade depth exceeded for 0.01% of the time required for the system availability is location dependent.

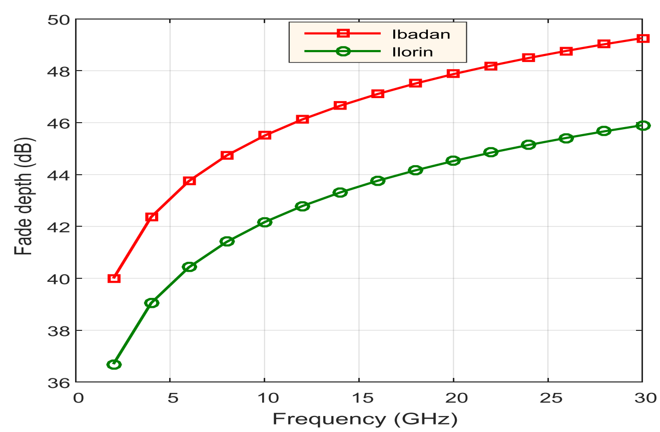

Figure 5: Variation of fade depth exceeded for 0.01% with different frequency at fixed distance (30 km)

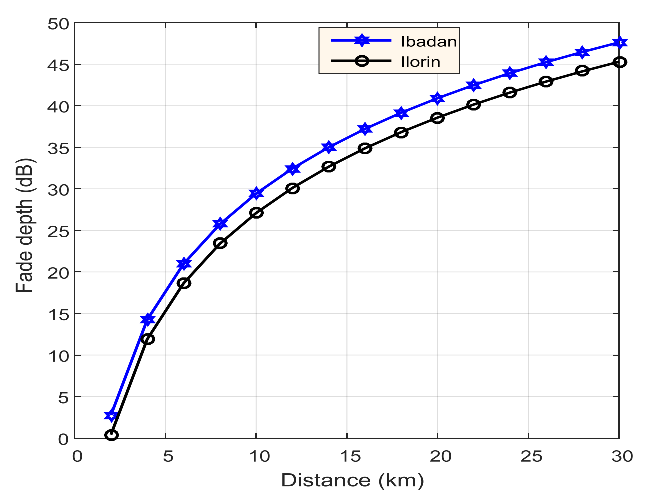

Figure 6: Variation of fade depth exceeded for 0.01% with distance at fixed frequency (20 GHz)

V. CONCLUSION

In this work, clear air fading for the two locations bas been investigated. The radio refractivity, k-factor and geoclimatic factor in the lowest 100 m above the sea level has been determined for Ibadan and Ilorin. It has been shown that, the geoclimatic factor which is responsible for climatic and geographic conditions in multipath fading varies with time and location. The mean fade depth exceeded for 0.01% of time as a function of frequency in Ibadan was found to be 46.36 dB while it was 33.58 dB with varying link distance at constant frequency.in Ilorin, the average fade depth exceeded for 0.01% of time as a function of frequency was 43.02 dB while it was 31.21 dB with respect to link distance. The average annual k-factor obtained for the two locations are 1.475 and 1.548, these values are greater than the predicted value by the ITU-R, therefore, super-refraction occurs in the two area considered. The whole results will be useful to determine the location dependent fade margin required for radio link.

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