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The Impact of K-Factor on Wireless Link in Indian Semi-desert Terrain

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ABSTRACT

The wireless links are used widely for point to point line-of-sight communication. The propagation loss on a terrestrial line-of-sight wireless link depends on atmospheric and seasonal conditions. The value of K-factor (effective earth radius) affects the reliability of the link. The value of K-factor where specific data is not available taken as 4/3, however its value depends on local climatic condition and it is terrain specific. In this paper K-value for the entire seasonal cycle 2008-2009 in Indian semi-desert has been analyzed. The study has been carried out to observe the distribution of K-factor and study its impact on terrestrial point to point line-of-sight wireless link in Indian semi-desert conditions.

Keywords – **Line-of-sight radio link, refraction, K-factor, refractive index, semi-desert terrain**

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1. Introduction

The digital terrestrial line-of-sight radio links are widely used for point to point communication in civil as well as military operations. These wireless links are utilized for various services voice, data and video. This point to point radio-line-of-sight link can be used in fixed terrestrial as well as mobile role. The mobile wireless link fitted on vehicle is widely used for engineering point to point radio link in military operations. The line-of-sight wireless links are considered as highly flexible, reliable and economical means of communication for engineering point-to-point radio relay link [1,2,3,4]. The digital radio link system is capable of carrying from a few to a large number of voice video and data transmissions when used with appropriate multiplex equipment [1]. There are number of factors which contribute to propagation loss in terrestrial line-of-sight wireless link. The properties of earth and atmosphere, both affects the propagation of electromagnetic waves. The seasonal and terrain characteristic of Indian semi-desert terrain is different than the planes. The desert sands are dielectric which has almost zero conductivity however dissipates energy by virtue of polarization. The climate of Indian semi-desert region is very extreme. The summer temperature reaches up to 50º Celsius and winter temperature dips just around 0º Celsius. The average annual rainfall is only 20 cms. The line-of-sight wireless link suffers propagation loss due to atmospheric gases, diffraction, multipath fading and precipitation. The attenuation due to these factors has its own characteristics as a function of frequency, path length, terrain and climatic conditions [1].

2. Effective Earth's Radius Factor or K-Factor

The wireless propagation is governed by the principles of reflection, refraction, and diffraction. The direct straight beam between antennas represents line-of-sight wireless link between two locations. A refracted wave is associated with gradient of the refraction index which depends on atmospheric temperature and pressure [5,8,9]. The bending of propagated waves takes place due to the varying index of refraction. The gradient of the refraction index(n) changes with atmospheric temperature and moisture content. The bending of rays away from the earth occurs when refractivity index gradient increases with height. This results in fading of signal intensity at the receiver. The steeper change in gradient due to meteorological conditions results in bending of rays towards the earth more strongly. This results in formation of wave duct which restricts the wave propagation over the earth's surface. This results in achieving large ranges beyond the line-of-sight. The effect of the same is more pronounced in VHF to microwave spectrum [5].

In [6] it is mentioned that the direct beam in line-of-sight wireless link bends slightly due to refractive index gradient however it is shown as straight line on profile charts. The actual curvature of the beam is transferred to the terrain profile of the path. With the constraint of maintaining, point for point, the actual height of the beam above the ground. The measurement of bending is known as the effective earth's radius factor, or K factor, it relates atmospheric refraction to the average value of the earth's radius.

The variation in atmospheric refractive conditions causes changes in the k-factor from the median value that's result into k-factor fading [5]. The sufficiently sub-refractive atmospheric conditions results in low k-factor values, this leads to the condition of ray path bending in a such a way that the earth appears to obstruct the direct line-of-sight between transmitting antenna. This gives rise to kind of diffraction fading. The antenna heights are determined based on this factor [5].

3. Measurement of K-Factor

The k-factor for a particular geographical location can be determined from measurements of the refractive index gradient in the first 100 meter of the atmosphere [1]. The averaged gradient gives effective value of k for the path length. In [10, 11] the mathematical equation to calculate radio refractivity, vapor pressure, refractive index gradient, and effective earth gradient is given. The radio refractivity can be calculated as:

$$N = N_{dry} + N_{wet} = 77.6\frac{P}{T} + 3.732\times10^{5}\frac{e}{T} \quad (1)$$

Where P is atmospheric pressure, e the water vapor pressure, and T is the absolute temperature in Kelvin (K).

The vapor pressure can be calculated by:

$$e = \frac{H\times e_s}{100} \quad (2)$$

$$e_s = 6.1121\exp\left(\frac{17.502t}{t+240.97}\right) \quad (3)$$

where H is the relative humidity, t, temperature in Celsius (º C), and e_s saturation vapor pressure (hPa) at the temperature , t (ºC).

The refractive index gradient at the surface was calculated by:

$$\frac{dN}{dh} = -7.32e^{0.005577N_s} \quad (4)$$

Where Ns is the refractive index at the surface,

The refractive index gradient in the upper air is calculated by:

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

Where N_1 is the lower atmospheric refractive index, h_1 lower height, N_2 upper atmospheric refractive index, and h_2 upper height.

The Effective earth radius factor (k) can be calculated by:

$$K = \left[1+\left(\frac{dN}{dh}\right)\Big/157\right]^{-1} \quad (6)$$

The monthly radio-meteorological data for the complete seasonal cycle for the year 2008-2009 was collected from the local meteorological department. The value of pressure, temperature and humidity at surface as well as suitable antenna height was analyzed for the observed readings at 0600 hours, 1200 hours, 1800 hours and 2330 hours at latitude 29.3167 and longitude 73.9000 in Indian semi-desert terrain.

4. Measurement Results

The measured observed data was analyzed as per the local geographical seasonal distribution which is prevalent in Indian semi-desert terrain, summer (March, April and May), Monsoon (June, July, August and September), Post-monsoon (October and November) and winter (December, January and February).The mean monthly variation of K factor for the year 2009 is shown in table 1.The observed minimum mean value of K factor was 1.40 for the month of April whereas the observed maximum value of K factor was 1.57 for the month of June. The seasonal variation of K factor for the seasonal cycle 2008-2009, is shown in table 2. The observed minimum mean seasonal K factor value was 1.47 for the summer season whereas the maximum observed mean seasonal K factor value was 1.54 for the post-monsoon season .The monthly mean value of K factor for the seasonal cycle 2008-2009 is shown in figure1. The mean seasonal K factor profile for the seasonal cycle 2008-2009 is shown in figure 2. The observed average annual mean value of K factor was 1.50 for the seasonal cycle 2008-2009.

Table1: Monthly mean value of K factor

Month	Time of the Day (Hours)				Mean
	0600	1200	1800	2300	
January	1.48	1.45	1.52	1.51	1.49
February	1.46	1.42	1.33	1.41	1.41
March	1.60	1.46	1.35	1.61	1.51
April	1.51	1.35	1.27	1.47	1.40
May	1.74	1.45	1.44	1.35	1.50
June	1.83	1.57	1.42	1.44	1.57
July	1.63	1.47	1.54	1.58	1.56
August	1.62	1.42	1.36	1.45	1.46
September	1.61	1.45	1.41	1.63	1.52
October	1.59	1.55	1.52	1.60	1.57
November	1.53	1.56	1.31	1.63	1.51
December	1.52	1.56	1.43	1.65	1.54

Table2: K factor Seasonal Variation

Seasons	Time of the day (Hours)				Mean
	0600	1200	1800	2300	
Summer	1.62	1.42	1.35	1.48	1.47
Winter	1.48	1.47	1.42	1.51	1.48
Monsoon	1.67	1.48	1.43	1.53	1.53
Post Monsoon	1.56	1.56	1.42	1.62	1.54

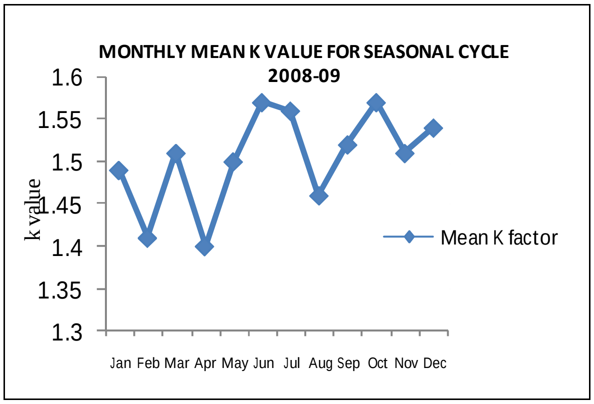

Figure: 1

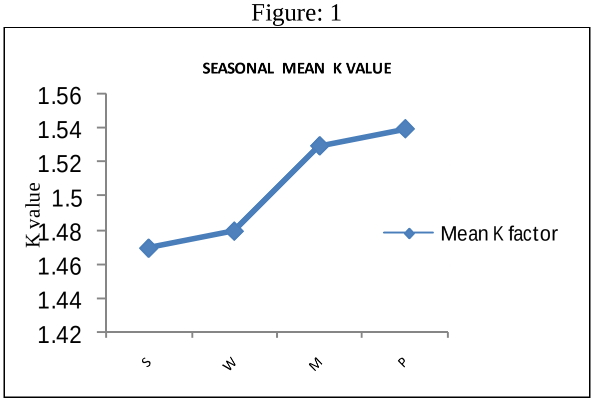

Figure: 2

5. Conclusion

The monthly mean K factor was found to vary from 1.40 to 1.57 for the seasonal cycle 2008-2009. The lowest K factor was observed in April however the highest value of K factor was observed in June and October. The mean seasonal K factor varied from 1.47 to 1.54 over the whole seasonal cycle. The seasonal distribution of the K factor indicates that it was lowest during summer and winter however it increased appreciably during monsoon and post-monsoon season. The K factor value was highest during the monsoon and post monsoon season however in other part of the country, usually the reverse phenomenon is observed during the monsoons, the K value remains lowest during this season. The observed value of K factor indicates very low atmospheric tending from standard to super-refractive condition, however for monsoon and post monsoon season the tendency of persistent super-refractive conditions exists in semi-desert terrain. The monthly or seasonal mean k values can be used for planning wireless links on short term basis. The average annual value of K factor, 1.50 should be used for planning long term wireless point to point link in Indian semi-desert terrain.

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Biographies and Photographs

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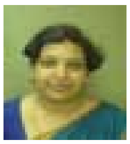

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