Microwave Signal Attenuation Due to Fog in Indian Semi-Desert Terrain

Authors

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ABSTRACT

Radio links operating in semi-desert region are expected to operate under harsh climatic conditions. Line-of-sight (LOS) attenuation at 35GHz was measured at Bikaner (N73º19' E28º1') for fog (Nov'12-Feb'14). The measurement was made with the intent of highlighting microwave signal attenuation in Harmattan weather conditions. The results are presented in terms of mean signal level and fog attenuation. The observed attenuation values due to Harmattan (fog) and the calculated (using Altshuler's model) are in fairly good agreement. This shows that microwave LOS link in this region and regions with similar climatic characteristics are prone to signal degradation as well as fading in the Harmattan season. Fog is one of the factors which affect the reliability of the radio link in semi-desert terrain during winters. At millimeter wavelengths, fog attenuation is a function of the fog density, extent, index of refraction of the fog medium, and wavelength. The attenuation is usually determined by first estimating the index of refraction of water for the wavelength and temperature of interest and then calculating the attenuation using the Rayleigh approximation. In this communication fog attenuation is computed for a large set of wavelengths and indices of refraction. In this paper a case study has been carried out to ascertain signal attenuation in radio relay link due to fog in Indian semi-desert terrain. The radio meteorological data was obtained during winter season to study phenomenon of fog attenuation on the radio relay link.

Keywords: Radio link, fog, Visibility, fog attenuation, Temperature.

1. INTRODUCTION

The radio links are widely used in civil as well as military application for engineering point to point communication. These radio line-of-sight link works on the principle of radio line-of-sight communication. The vehicle based mobile Radio terminals are extensively used for engineering communication network in
military operations. The deployment of these radio mobile terminals is based on distance-based deployment rule. These links are expected to operate satisfactorily under local climatic condition, however it has been observed that reliability of the link is affected in foggy condition due to attenuation.

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. Fog is a natural phenomenon which has been observed during winter season in northern region of India and Indian semi-desert region of Rajasthan. In [1], it is described that fog forms from the condensation of atmospheric water vapor into water droplets that remain suspended in the air. Fog is suspension of very small microscopic water droplets in the air. Fog forms during early morning hours or night when radiative cooling at the earth’s surface cools the air near the ground to a temperature at or below its dew point in the presence of a shallow layer of relatively moist air near the surface. The characterization of fog is based on water content, optical visibility, temperature and drop size distribution [2]. In [3], the types of fog, strong advection fog, light advection fog, strong radiation fog, and light radiation fog is mentioned. Attenuation in the foggy days may cause significant anomalous attenuation for radio relay links in climatic regions such as semi-desert terrain. Radiation fog which is more pertinent to semi-desert climate during night is formed as a result of ground becoming cold at night and cooling the adjacent air mass until super saturation is reached. This necessitates analyzing the impact of the fog on radio relay line of sight communication link [4].

Attention due to fog is a complex function of the particle size distribution, density, extent, index of refraction, and wavelength. At microwaves, fog attenuation is relatively low; however, at millimeter wavelengths it becomes appreciable, continually increasing as the wavelength becomes shorter. Fog attenuation is usually determined by first estimating the index of refraction of water for the temperature and wavelength of interest and then calculating the attenuation using the Rayleigh approximation. Fog droplets rarely have diameters larger than 0.1 mm so the Rayleigh approximation is valid throughout essentially the whole millimeter wavelength region [5].

2. METHOD FOR CALCULATING FOG ATTENUATION

There are various methods to determine fog attenuation, however calculation methods are extensively used. In [6], a radiation fog model was discussed in detail considering description of interaction between microphysical structure of fog and atmospheric radioactive transfer. In [7], model describing attenuation due to clouds and fog expressed in terms of water content was discussed. In [8], under foggy air conditions the propagation properties of millimeter wave and microwave frequencies were discussed. In [5], it is mentioned that attenuation due to fog is a complex function of the density, extent, index of refraction and wavelength. An empirical formula to calculate fog attenuation in the microwave and millimeter wavelength regions can be obtained by [5], [9].

\[ F_a = M \left[ 0.0372 T + 180 / \lambda t - 0.022 T - 1347 \right] \text{dB Km}^{-1} \]
Where $F_a$ is attenuation in (dB/km), $M$ is liquid water content in (g/m3), $\lambda_t$ is wavelength in mm, and $T$ is temperature in degree Celsius ($^\circ$ C). The relation in Equation (1) is valid only if $3 \text{ mm} < \lambda_t < 3 \text{ cm}$ and $-8 ^\circ C < T < 25 ^\circ C$. The liquid water content $M$ is given in terms of visibility in Km, when fog density data are not available but visibility data are available[5],[10].

$$M = (0.024/V)^{1.54} \text{ g-3 } (2)$$

Where $V$ is the visibility in km and $M$ is the liquid water content in g/m3. The definition of visibility is given in [5], which define visibility as the greatest distance at which it is just possible for an observer to see a prominent dark object against the sky at the horizon. The visibility is also defined as that distance from an observer at which a minimum contrast ratio $C$ between a black target and a bright background is equal to $C=0.02$ [11].

### 3. EXPERIMENT SETUP

![Block Diagram of 35 GHz Link System](image)

The block diagram of the transmitter and receiver sections of the 35GHz system are shown in figure1. The millimeter wave link system comprises a continuous wave 35 GHz transmitter using a 100 mW (20dBm) Gunn source with a transmitting antenna of 18 degree beam width and 22 dB gain. The receiver section has the requisite down conversion and de-spreading circuitry. The signal received by the horn antenna is down converted to the intermediate frequency (IF) followed by a cavity mixer with a local oscillator operating at 34 GHz. The IF of 1.0 GHz output of the mixer is fed to a pre-amplifier followed by a driver amplifier. The amplified IF signal is displayed on a spectrum analyzer. The spectrum analyzer shows both received power in dBm and central peak’s frequency. The spectrum analyzer also allows the received power and spectrum to be saved into a laptop or computer. Receiver is capable of providing a useable base band output with received millimeter wave signal levels as low as -80 dBm.
4. CLIMATE CONDITIONS IN BIKANER REGION

The climate in Bikaner is characterized by significant variations in temperature. In the summer season it is very hot when the temperatures lie in the range of 28–48.5 °C (82.4–119.3 °F). In the winter it is fairly cold with temperatures lying in the range of 5–23.2 °C (41.0–73.8 °F). Extreme summer heat of up to 50 °C and winter cold as low as 1 °C. May and June are hottest; December and January are coldest. About 80% of the fog occurs in the fog season (Nov to Feb) of the year. During winters, temperatures in some areas can drop below freezing due to waves of cold air from Central Asia. There is a large diurnal range of about 14 °C (25.2 °F) during summer; this widens by several degrees during winter.

5. MEASUREMENT RESULTS

The radio signal data used for this analysis are for the period November 2012 to February 2014. The field strength variations were recorded for both diurnal and seasonal behavior at the receiving end, Lagos once a week on 12 hours basis. Information on some meteorological parameters like air temperature, relative humidity and water vapor pressure during the fog season i.e. harmattan (Nov-Feb) were obtained from the daily visibility records.

Gunn Voltage = 3.87 Volt
Current = 0.53 Ampere
IF frequency = 1.08GHz
Reference Level = -12dBm
Height of Transmitting and Receiving Antenna = 1.5m

Fog occurs only in clear sky natural condition signal level = 52 db & attenuation is increased by variation factor additive to clear sky level condition.

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Visi. (Km)</th>
<th>M</th>
<th>Temp.</th>
<th>Fog Att.(db/Km) Calculated</th>
<th>Fog Att.(db/km) Measured</th>
<th>Variation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 Dec</td>
<td>2:30 am</td>
<td>.5</td>
<td>.013</td>
<td>13</td>
<td>.255</td>
<td>.29</td>
<td>16</td>
</tr>
<tr>
<td>29 Dec</td>
<td>8:30 am</td>
<td>.5</td>
<td>.013</td>
<td>7</td>
<td>.257</td>
<td>.29</td>
<td>16</td>
</tr>
<tr>
<td>17 Feb</td>
<td>5:30am</td>
<td>.2</td>
<td>.038</td>
<td>11</td>
<td>.749</td>
<td>.8</td>
<td>8.1</td>
</tr>
<tr>
<td>24 Feb</td>
<td>8:30 am</td>
<td>.05</td>
<td>.322</td>
<td>11</td>
<td>6.34</td>
<td>6.32</td>
<td>-.31</td>
</tr>
</tbody>
</table>
**Fig. 2** Visibility vs Attenuation (2012-13)

**Fig. 3** Visibility vs Temperature (2012-13)

**Table 2 : Fog Attenuation 2013-14**

<table>
<thead>
<tr>
<th>Day</th>
<th>Time</th>
<th>Visi (Km)</th>
<th>M</th>
<th>Temp</th>
<th>Fog Att.(db/Km) calculated</th>
<th>Fog Att.(db/km) Measured</th>
<th>Variation %</th>
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</thead>
<tbody>
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<td>.038</td>
<td>12</td>
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</tr>
<tr>
<td>20 Dec</td>
<td>8:30 am</td>
<td>.5</td>
<td>.013</td>
<td>10</td>
<td>.25</td>
<td>.32</td>
<td>28</td>
</tr>
<tr>
<td>22 Dec</td>
<td>8:42 am</td>
<td>.02</td>
<td>1.32</td>
<td>10</td>
<td>26.07</td>
<td>27.4</td>
<td>5.10</td>
</tr>
<tr>
<td>23 Dec</td>
<td>8:50 am</td>
<td>.2</td>
<td>.038</td>
<td>7</td>
<td>.752</td>
<td>.79</td>
<td>5.3</td>
</tr>
<tr>
<td>18 Jan</td>
<td>6:10 am</td>
<td>.2</td>
<td>.038</td>
<td>8</td>
<td>.752</td>
<td>.8</td>
<td>6.6</td>
</tr>
<tr>
<td>19 Jan</td>
<td>8:35 am</td>
<td>.2</td>
<td>.038</td>
<td>8</td>
<td>.752</td>
<td>.79</td>
<td>5.3</td>
</tr>
<tr>
<td>20 Jan</td>
<td>8:30 am</td>
<td>.2</td>
<td>.038</td>
<td>6</td>
<td>.747</td>
<td>.78</td>
<td>-</td>
</tr>
<tr>
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<td>.05</td>
<td>.322</td>
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<td>6.366</td>
<td>6.32</td>
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<tr>
<td>24 Jan</td>
<td>8:40 am</td>
<td>.05</td>
<td>.322</td>
<td>12</td>
<td>6.34</td>
<td>6.9</td>
<td>-</td>
</tr>
</tbody>
</table>
Fig. 4 Visibility vs Attenuation (2013-14)

Fig. 5 Visibility vs Temperature (2013-14)

Analysis of meteorological data measured in Bikaner weather stations show that the climate of Bikaner is variable and contrasting. Depending on the relief of locality, there are differences in the distribution of the foggy days. In average, there are 13-15 foggy days in 2 years. Only 15-20 foggy days in 2 years were registered in Metrological Department. In Bikaner November to February are the foggiest months in a year. January is the foggiest month in a year. According to the data measured in Bikaner weather stations, in average, there are 4 to 6 foggy days a year in Bikaner 4-6 hours is the average duration of a fog event. However, the maximum duration of the fog event is several days.
6. CONCLUSION

Foggy condition affects the reliability of radio line-of-sight link in Indian semi-desert terrain. The results obtained from tables, indicates that attenuation due to fog predominantly occurs in the month of January and February when the impact of fog is more prevalent in these areas. The results obtained in this paper can be utilized by the planners to cater for suitable fade margin during winter season to overcome the problem of fog attenuation. The study results can also be utilized to improve the performance of existing radio line-of-sight links operational in Indian semi-desert terrain during the months of January and February.

REFERENCES