The Impact of Harmattan Particles on Microwave Propagation in the Savannah Region

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ABSTRACT

Harmattan intensity may be so great that visibility at ground level is reduced to less than a hundred meters by the dust clusters. The precipitations like snow, rain absorb and scatter electromagnetic energy leading to cancellation in its signal strength. In this paper, the records of ground level visibility during harmattan will be analyzed with respect to the approximated particle rate (or density) of harmattan. The specific particle attenuation possible on radio frequency signals during harmattan was analyzed, computed and plotted results obtained. The attenuation variations obtained indicates a significant loss in power during harmattan periods

Key words: *harmattan, specific particle attenuation and radio frequency*

INTRODUCTION

In the savannah region, the atmosphere is seasonally affected by harmattan [1]. The harmattan is a weather condition in the tropics in which dust particles (precipitates) are blown up into the air by winds defined as air in horizontal motion relative to the earth surface and pushed southwards from the Sahara desert by the northeast winds [2]. Harmattan intensity may be so great that visibility at ground level is reduced to less than a hundred meters by the dust clusters [2]. Harmattan occurs in Chad during the dry season that is, between the months of November and March and with its micron size particles, harmattan dust clusters resemble that of fog and the space they cover can be considered as a dielectric. Since the clusters consist predominantly of quartz layer which non-coherently scatters RF signals [3]. Propagation studies are required to identify the likely channel characteristics that would be encountered in any operating environment in order to form the channel model of the physical layer of the communication system. Established wireless systems in the frequency range between 500MHZ and 5GHZ, radar system, heating, energy transfer, remote sensing, control and recording systems have resulted in the development of different approaches to the prediction of wave propagation. Studies has shown [3], that precipitations such as those of rain, harmattan dust etc absorb and scatter electromagnetic energy which leads to attenuation in its signals strength.

MATERIALS AND METHOD

The records of monthly Meteorological observations [4], obtained from the Meteorological Department International Airport of N' Djamena ASECNA (Chad). These data include: Temperature, Visibility, Relative Humidity, Wind speed and direction, serve as the inputs to the foregoing analysis. The data cover the period from 2004 to 2006.

Mathematical analysis is used to evaluate the performance of radio communication systems. The characteristics of this technique (method) can be summarized as follows:

MATHEMATICAL ANALYSIS

This offers quick results with a very good insight into what is actually happening with the process being evaluated, for example, it enables the relationship between the various parameters in the system to be seen. However, in most cases it is necessary to make many simplifying assumptions to enable such an analysis to be used [5]. This is inevitably the case when communication is taking place over propagation channels with multipath and fading.

Generally the problem of estimating the attenuation of RF waves caused by the various forms of precipitation (rain, snow, fog and harmattan dust etc) is quite difficult. In practice it has been convenient to express the attenuation due to rain as a function of precipitation rate. In the case of harmattan, no known attempt at quantifying or measuring its precipitation rate is available except the measure of how it distracts visibility (with respect to distance). To fully under stand the mechanism of harmattan attenuation therefore, it is essential to estimate the rate of the harmattan precipitation.

The effect of rain precipitation is usually expressed in terms of specific attenuation, which is predicted with the aid of an empirical relationship given by

$$\alpha_{rain} = a\rho^{b} dB/km \text{……… (1)}$$

Where ρ – the rainfall rate (mm/hr); a, b – regression coefficients which are a function of the frequency f, of the temperature T, of the drop size distribution and to a lesser extent, of the wave polarization.

The specific attenuation due to harmattan dust particles may be predicted using the specific particle attenuation variation (dB/m) given as:

$$\alpha_{particle} = a\,\rho_{.i}^{b} \text{ ………………………………………(2)}$$

Here the coefficients a and b are function of frequency f, of temperature T, and of the particle size distribution. The values of a and b for a given meteorological data are given by [3]:

$$b = \frac{n\left(\sum_{i-1}^{n} x_i y_i\right) - \left(\sum_{i=1}^{n} xi\right)\left(\sum_{i=1}^{n} yi\right)}{n\left(\sum_{i=1}^{n} x_i^{2}\right) - \left(\sum_{i=1}^{n} x_i\right)^{2}}$$

$$a = \frac{\sum_{i=1}^{n} y_i - b\sum_{i=1}^{n} x_i}{n} \text{ ……………………………(3)}$$

Where n – is the number of pairs of observation
x – is the temperature of observations
y – particle size distributions

The spatial harmattan particle density may be approximated by the empirical relationship [6].

$$\rho_i = \frac{(V_{fm} - V_i)\rho_p}{h} g/m^3 \text{ …..(4)}$$

Where V_{fm}- the best visibility figure for the year (period) [m]
V_i – observed (measured) visibility profile[m]
ρ_p- mean particle density [g/m^3]
h- humidity profile (in decimals) [g/m^3]

RESULTS AND THEIR DISCUSSION

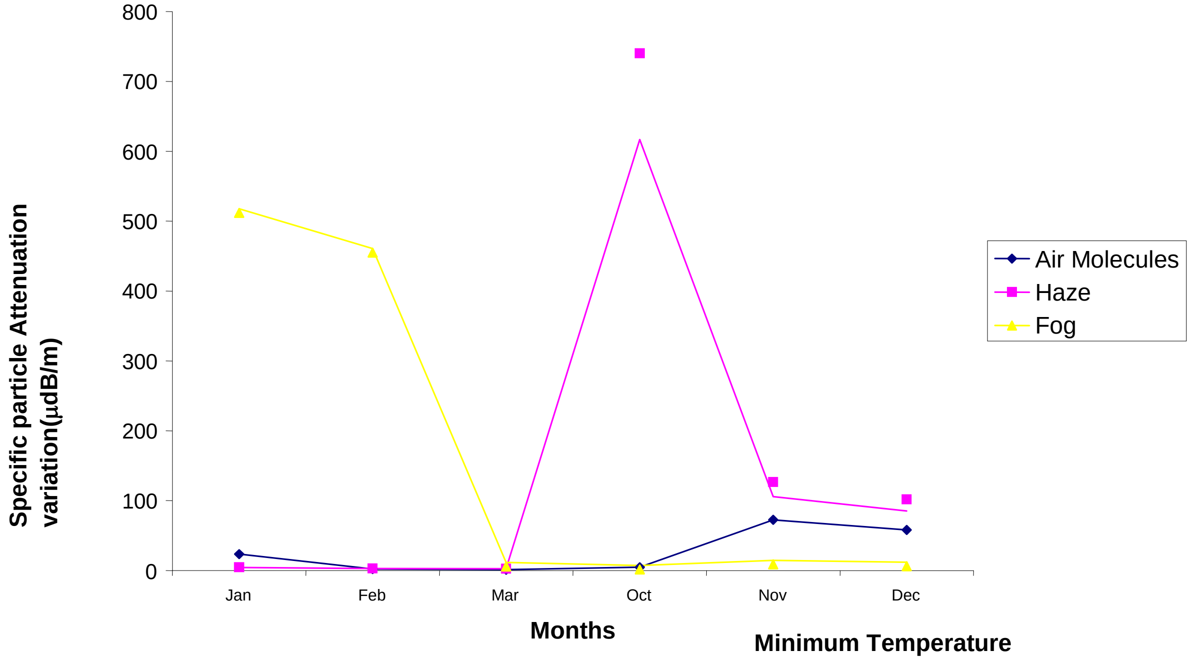

Fig. .1: Specific Particle Attenuation variation For 2004:

Shown in fig 1 is the plot of the specific particle attenuation during the months of harmattan, of 2004. The attenuation is much higher due to haze compared to both fog and air molecules. The maximum specific particle attenuation is 740 µdB and the minimum is approximately 0µdB between February and March. The attenuation due to fog displays a maximum between 510 to 454 µdB between January and March.

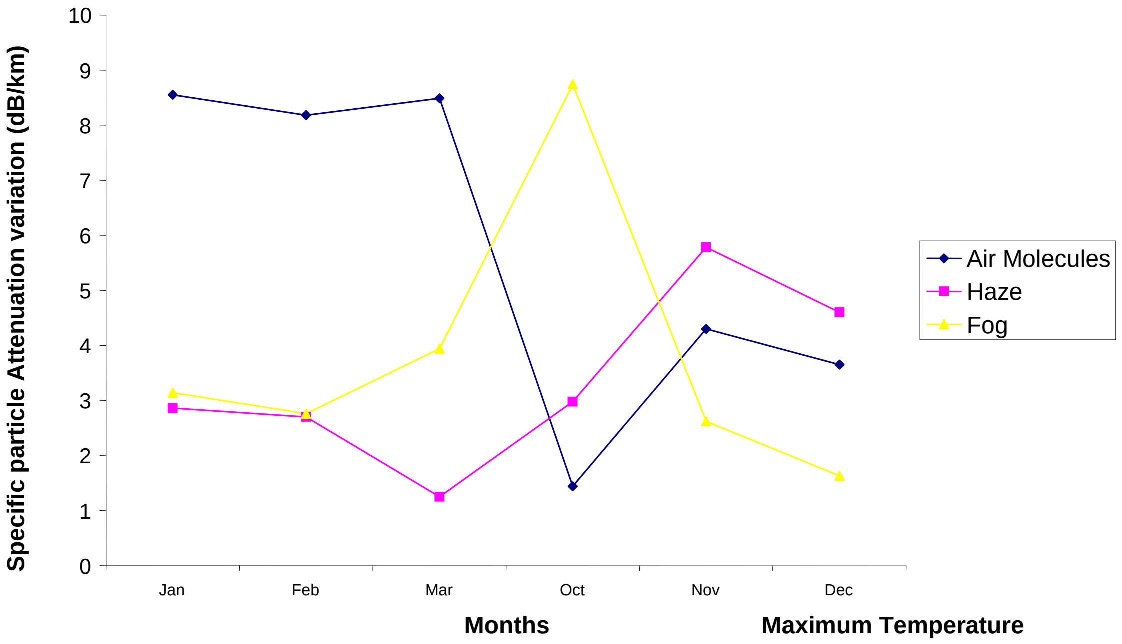

Fig..2: Specific Particle Attenaution variation For 2004:

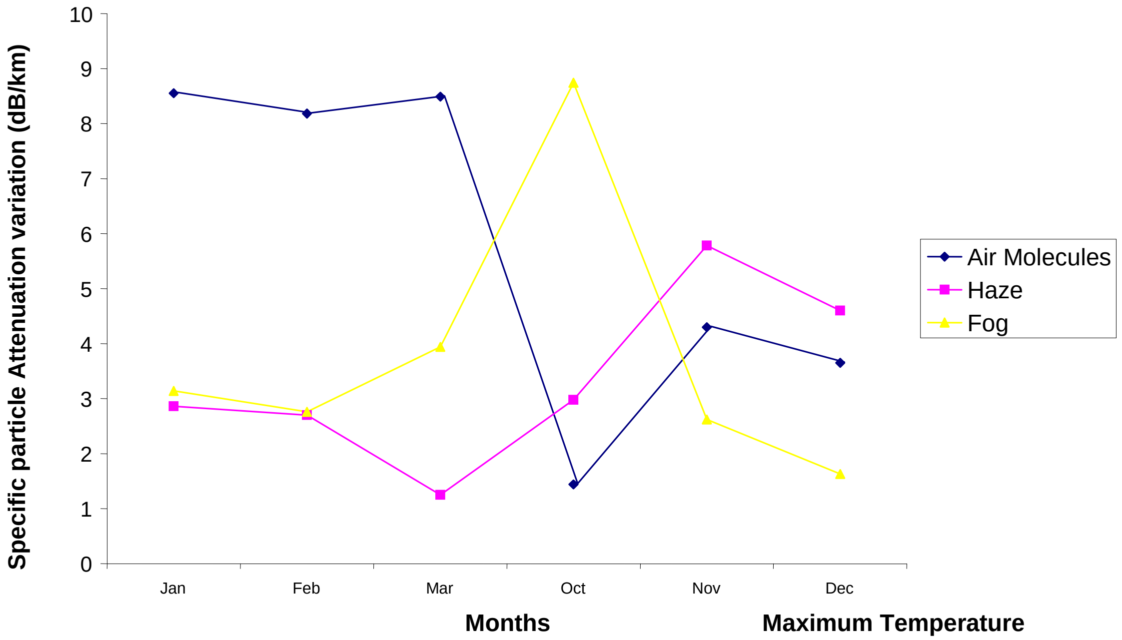

Fig..2: Specific Particle Attenaution variation For 2004:

The plot shown in fig 2 indicates that during the months of harmattan, the attenuation is higher due to fog compared to both air molecules and haze. The maximum average values are 9 and 4 dB between October and March; that is, the maximum is 9dB and average is 4dB between October and March while; the minimum is 1.8dB in December. The attenuation due to air molecules displays two maxima between January and March. The maximum value is 8.5 dB, while it is 4.3 dB in November. The minimum attenuation is 1.5 dB in October.

The attenuation due to haze displays a maximum of 5.8dB, which is the maximum, and the average is 3dB between November and October. The minimum is 1.25 dB corresponding to the month of March.

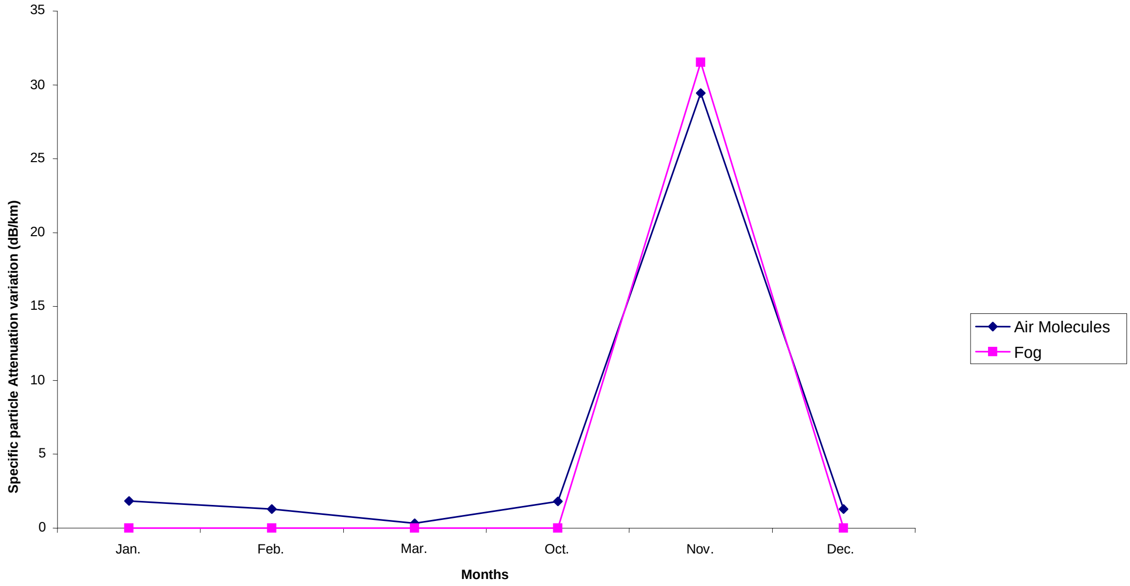

Fig. 3: Specific particle Attenuation variation for 2006 Minimum Temperature

The plot of Fig 3 shows that during the months of harmattan, the attenuation due to fog is higher compared to air molecules. The maximum attenuation is 33dB corresponding to the month of November. While the attenuation due to air molecules displays a maximum of 30dB in the same period, that is November.

In the course of investigation, it was identified that precipitates that adversely affect propagation within the period include air molecules, fog and haze. The values of the specific particle attenuation variation for 2004 indicated that the maximum attenuation occurs at periods corresponding to maximum temperatures with a value of 9dB (see fig.1). During minimum temperature, the attenuation can be in micro decibels. In comparison to 2004, for the year 2006 the value of the specific particle attenuation for minimum temperature is 33dB and represent the maximum attenuation.

These aggregate specific particles attenuations on radio signals manifest itself as path loss at the receiver end.

Conclusion

Attenuation is caused by obstructions in the signal path (harmattan dust clusters) in addition to other impairments. In this investigation, it was discovered that the attenuation increase when the temperature increases. The significance of the increment of attenuation is that, when the temperature increase and the pressure decreases these cause the movement of winds, which serves as a means of transporting dust particles into the atmosphere. These dust particles serves as obstructions in the signal path and leading to a drop in the signal power.

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