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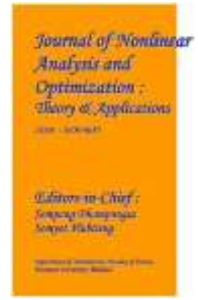

Effects of Atmospheric Parameters on Microwave Signal

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ABSTRACT:

In case of wireless communication , the channel is atmosphere. There will be effect by this atmosphere on the signal as it propagates . The refractive index of the atmosphere is not constant throughout the path length of the signal propagation. Due to variation of the refractive index , The signal will under go bending i.,e) the signal in a different direction other than the desired direction. Dry air , humidity , and other particulates (sand , dust ,aerosols , and volcanic ash) In the atmosphere introduce microwave propagation delays . These delays must be properly characterized to achieve the highest accuracy in surveying and atmospheric sensing using "REFERENCE SIGNALS".

In this project we review the theory microwave propagation delays induced bythe above atmospheric constituents and estimate their maximum delays

Because the structure of atmospheric refractivity can be highly complex and difficult to model , and because measurement tools are unavailable for characterizing most of the refractive components , we use simplified examples to illustrate its effects . The main objective of this project is to find out the propagation delays due to various atmospheric parameters at microwave frequencies .The matlab software will be used to implement the project

INTRODUCTION:

Telecommunications and broadcasting services are in a rapid phase of expansion. Users are demanding ever more multimedia services such as high-speed internet, on demand digital TV services, video conferencing and tele-education to name a few. Such services require high-speed data rates to cope with demand whilst

guaranteeing customers a high quality of service. The current microwave frequency spectrum allocated for telecommunication and broadcast services has become congested and proposed broadband systems will require higher bandwidths. SHF and EHF services are relatively free of congestion and can cope with higher data rates than current microwave systems. However, above Ka- band, attenuation due to atmospheric gases, clouds and rain increases significantly. Whilst attenuation is caused more frequently by clouds and gases, it is rain that causes the largest attenuation. *Attenuation* is the reduction of signal strength during transmission. It is just the opposite of amplification. Its unit is dB (decibel) or more generally it is measured in dB/km. During the transmission, the signal gets attenuated exponentially. Attenuation is an inherent characteristic of RF (radio frequency) signal and also is very important in the design aspect. So it should be taken into consideration while designing and calculating the RSL (Receive Signal Level) of the RF signal between two stations. Attenuation is directly proportional to the frequency.

ELEVATION ANGLE DEPENDENCE :

The following two types of problems will restrict the direct application of all types of microwave propagation models into the military communication link scenario. The first problem is that for most of time (98%) the military receivers work below elevation angles of 20°, and 85% of time they work below elevation angles of 50.The second problem is that most propagation models can only apply for satellite zenith link with a total atmospheric path, instead of a limited (or partial) atmospheric path linking between the aircraft and the ground.

To solve these problems, in this study we have developed a method of scaling the total atmospheric path loss into the partial oblique path loss as shown below.

We assume that all atmospheric propagation parameters have an exponential decrease with altitude and with a vertical scale height H, that is, $A = a0 \cdot \exp(-z/H)$, where $a0$ is a coefficient and z is the vertical distance.

ATMOSPHERIC EFFECTS ON WAVE PROPAGATION:

Effect by rainfall:

Rain and other hydrometeors, such as hail, ice, and snow, can cause severe attenuation for higher frequency signals. Water drops will absorb and scatter energy from incident waves. This absorption and scattering causes the attenuation to increase exponentially as the frequency increases. The attenuation coefficient is also strongly dependent on rainfall rate. ITU models on “Attenuation by Hydrometeors, in Particular Precipitation, and Other Atmospheric Particles” were used to plot the attenuation of rain different elevation angles and different rainfall rates over the specified frequency range.

We have performed a study for rain attenuation at SHF band. The severity of radio signal loss through the rain is strongly dependent on the local rainfall rates, rain cloud heights, and signal frequencies.

Rain attenuation:

Radio waves at EHF and SHF are susceptible to the effects of the troposphere such as gaseous absorption, cloud attenuation, increased apparent noise temperature, scintillation and, most importantly, attenuation due to rain. Rain has the most significant effect on a satellite signal especially at extra high frequencies.

ELECTROMAGNETIC SCATTERING AND ABSORPTION:

Attenuation on communications links is caused by the scattering and absorption of electromagnetic waves. A plane wave incident on a raindrop (Ei) induces a transmitted field in the interior of the drop and a scattered field. Es denotes the electric field of the scattered wave in the far field region.

$$E^{s} = f(\hat{k}_1, \hat{k}_2)\frac{exp(ikr)}{r}E_i$$

where k = 2π/λ, is the free space propagation constant, λ is the incident wavelength, r is the distance from origin of the observation point, Ei is the electric field of the incident wave, $f(\hat{k}_1, \hat{k}_2)$ is a matrix function denoting scattering amplitude and the polarization state of the scattered wave, which is obtained from the solution of the boundary value.

Therefore the scattering amplitude is a function of $\hat{k}_1, \hat{k}_2,$ the frequency, size, shape and material of the raindrop, and the polarization of the incident wave.

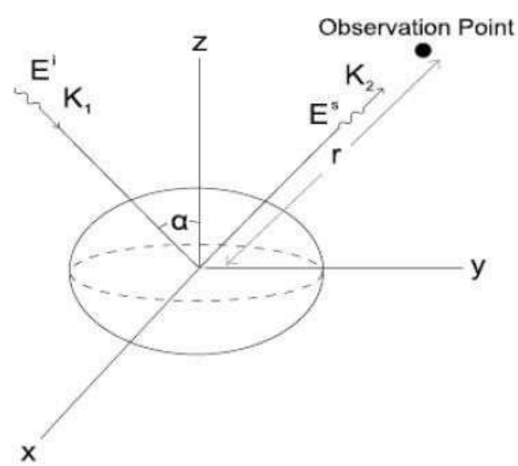

Figure 2.9: Electromagnetic scattering geometry.

ATTENUATION DUE TO CLOUDS AND FOG :

Clouds and fog can be described as collections of smaller rain droplets. Different interactions from rain as the water droplet size in fog and clouds is smaller than the wavelength at 3–30 GHz. Attenuation is dependent on frequency, temperature (refractive index), and elevation angle, and it can be expressed in terms of the total water content per unit volume based on Rayleigh Approximation:

$$\gamma_c = K_l M \qquad dB/km$$

Where:

γc: specific attenuation (dB/km) within the cloud

Kl: specific attenuation coefficient [(dB/km)/(g/m3)]

M: liquid water density in the cloud or fog (g/m3)

To obtain the attenuation due to clouds for a given probability value, the statistics of the total columnar content of liquid water *L* (kg/m2), which is an integration of liquid water density, *M*, in kg/m3 along a column with a cross section of 1 m2 from the surface to the top of clouds, or, equivalently, mm of precipitable water for a given site must be known yielding:

$$A = LK_l/\sin\theta \qquad dB \qquad for \quad 90^0 \geq \theta \geq 5^0$$

Where θ is the elevation angle and *Kl*. Based on the *L* values from world maps, we have calculated attenuation values due to clouds for four benchmark case studies.

Points:

DELAY OF MICFROWAVE SIGNAL DUE TO ATMOSPHERIC PARAMETERS:

Scientific applications which requires high accuracy (Example: studies of climate, weather, plate tectonics, sea level, crustal deformation, ice dynamics, isostasy, etc) involves using of Microwave signals transmitted by Reference Systems (RS). The system broadcast 1.575 (L1) GHz and 1.228 (L2) GHz carrier signals based on atomic clocks. The cost of commercially available receivers for accurate tracking of these two carriers (L1 and L2) is relatively low. Reference system (RS) surveying over span of 50 km or more has been regularly attained with centimeter precision, and in some cases, where atmospheric delays are accurately corrected; it has been revealed with millimeter precision. In addition, for atmospheric sensing the use of ground-based and space-based receivers are rapidly increasing.

Phase Delay Induced by the Hydrostatic Atmosphere ;

The hydrostatic constituents such as gases of atmosphere induces largest amount of delay. The delay due to hydrostatic conditions of the atmosphere is directly proportional to the atmospheric pressure. It is easy to model the hydrostatic delay with high accuracy. The refractivity due to the hydrostatic condition of the atmosphere can be expressed, as

$$N_{dry} = k_1 \frac{P_d}{T}$$

Where k1 =577.6 K mbar-1, Pd represents the pressure of the hydrostatic air in millibars, and T is temperature in Kelvin. The total hydrostatic atmospheric delay can be obtained by integrating the hydrostatic equation through the atmosphere vertically.

$$ZD_{hydrostatic}(cm) = k_1 \int_0^{\infty} \frac{P_d}{T} dh = 77.6 R_d \int_0^{\infty} \rho(h) dh$$

$$= 77.6 \frac{R_d P_s}{g}$$

where Ps is surface pressure in millibars, g is the location-dependent gravitational constant, ρ is density in grams per cm3, and Rd = 2.87 X 106 cm2 s-2 K-1 represents the gas constant for dry air. To measure the hydrostatic delay of the atmosphere, a barometric method will be used. Delay due to hydrostatic conditions of the atmosphere can be measured with an accuracy of 2.3 mm when the barometric pressure is known to be 1 millibar.

Phase Delay Induced by Humidity

Humidity of the atmosphere contributes largest amount of tropospheric delay which is highly variable. The wet refractivity of humidity can be represented as

$$N_{vap} = k_2 \frac{P_v}{T} + k_3 \frac{P_v}{T^2}$$

Where Pv represents the partial pressure of humidity (e) in mbars, k2 = 64.8 K mbar-1, k3 = 3.776 X 105 K2 mbar-1, and T is in Kelvin [Thayer, 1974]. In the equation 5.5 the second term come from the dipole moment of humidity and is approximately 20 times bigger than the first term. The phase delay which depends on the temperature is about 6.5 times the path-integrated humidity. Generally, the values of Pv are <12 millibar, even though the values are as large as 40 millibar would occur at high temperatures. With certain devices like Lidars, radiometers and Fourier transform infrared spectrometers; it is possible to measure the integrated humidity directly.

RESULTS:

Figure 1: Signal Dispersion signal at the receiver

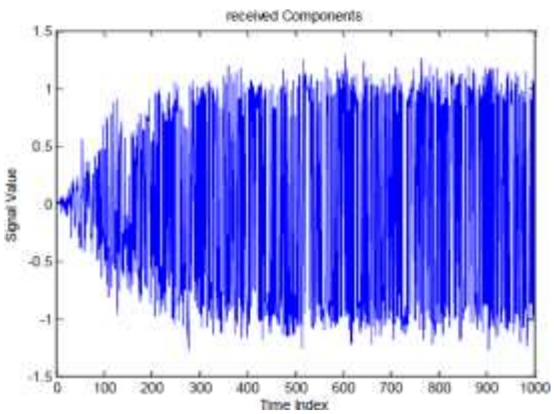

Figure 1: Dispersion of signal

For the evaluation of the developed approach a simulation observation is modeled where the dispersed signal at the receiver is observed as shown in figure 1.

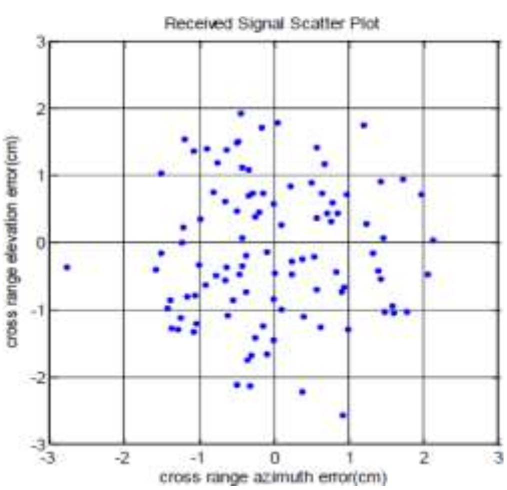

Figure 2: Received signal scatter plot

The scatter plot for such signal is presented in figure 2. When the signal enters in to the atmosphere from the transmitting antenna, it will spread around certain area due to scattering. We can observe the range error in both in azimuth and elevation direction.

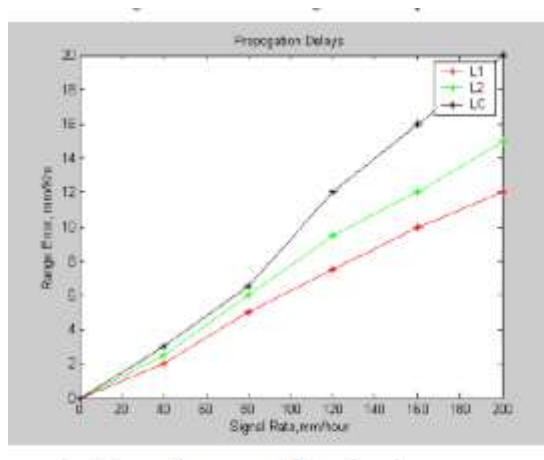

Figure 3: Propagation delays and range error due to the rain.

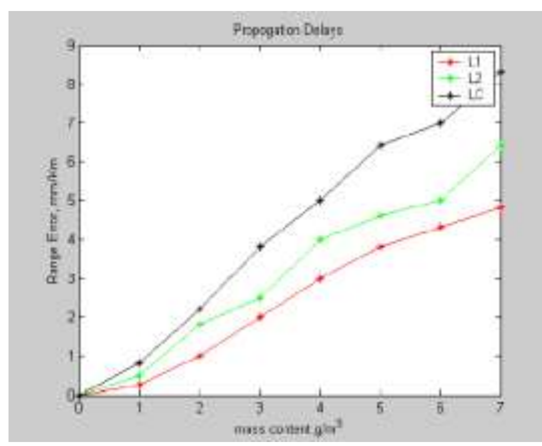

Figure 4: Propagation delays and range error due to fog condition in the atmosphere.

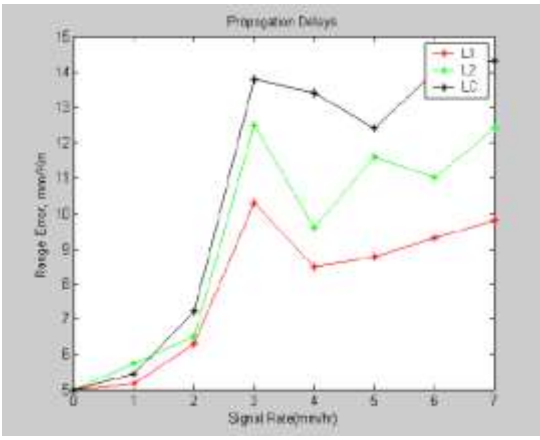

Figure 5: Propagation delays and range error due to hydrostatic

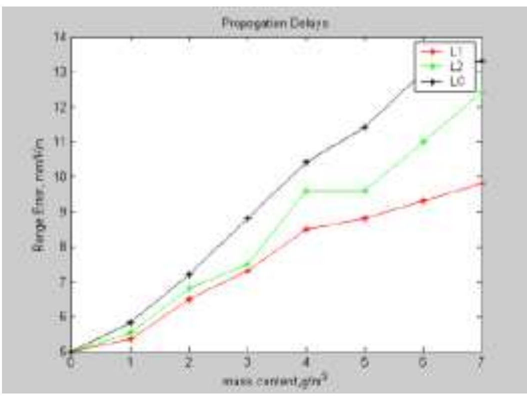

Figure 6: Propagation delays and range error due to humidity

Figure 3 shows the propagation delay due to rain. The range error has been evaluated for various values of rain rate. From the figure it is observed that, with LC the maximum range error has been obtained. Figure 4 represents the propagation delays due to fog of different mass content. It is observed that, with LC the maximum range error has been obtained. Figure 5 represents the propagation delays due to hydrostatic nature. It is observed that, with LC the maximum range error has been obtained. Figure 6 represents the propagation delays due to humidity of different mass content. It is observed that, with LC the maximum range error has been obtained.

CONCLUSION:

In summary, propagation delays generated by dry of the atmosphere air are comparatively big and depend on leisurely changing pressure fields that are comparatively easy to model. Humidity induces delays as large as 50% of the dry air. Due to geometric effects, the delays due to humidity are highly variable and hence it is difficult to model these delays. Delays generated by hydrometeors and other parameters are broadly changeable and are < 3% of the highest delays generated by humidity and dry air. Because these exceptionally changeable components are hard to quantify, range errors from these components cannot be modeled effectively. Proportionate to their amplitude, atmospheric delays provide difficulties in high-accuracy RS measurement for atmospheric remote sensing utilizing RS.

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