International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 5, Number 4 (2012), pp. 381-387

http://www.irphouse.com

Algorithms for Propagation Effects and Remedies in Microwave Applications

[1]K. Sudhakar and [2]Dr. M.V. Subramanyam

[1]Associate Professor, ECE Department,
St. Johns College of Engineering and Tech., Yemmiganur, Kurnool, A.P., India
[2]Santhiram Engineering College, Nandyal, Kurnool, A.P., India
E-mail: sudhakar_403@yahoo.co.in

Abstract

The lower frequency bands becomes saturated with users, it is require to use microwave frequency bands. The problem associated with high frequencies in wireless communication is atmospheric attenuation, propagation delay, signal dispersion, signal scattering, etc. In this paper we developed an algorithm for analyzing the propagation effects and how to overcome this effect to retrieve the maximum signal strength. In this paper we focused on how to calculate the range error due to certain atmospheric parameters such as humidity, dry air, hydrostatic atmospheric. Also we focused on increasing of signal strength at the receiver by calculating the angle of arrival. The developed algorithms were applied and tested by developing the communication system.

Keywords: Dry air, humidity, Scattering, Attenuation, Angle of arrival

Introduction

The systems in which the signals are transmitted with reference is mostly used in the applications related to high accuracy such as ice dynamics, plate tectonics, climate, crustal deformation etc. The proposed system broadcast two carrier frequencies such as 1.575 (L1) and 1.228 (L2) GHz based on atomic clocks. Receivers for high accuracy tracking of these two carriers are commercially available at relatively low cost. Reference system surveying over distances of 50 km or more has been routinely achieved with centimeter precision [1], and in some cases, where atmospheric delays are properly corrected, it has been demonstrated with millimeter precision [2]. Space-based RS receivers using the radio occultation method [5] can sense atmospheric temperature, pressure, and humidity profiles [6]. In addition, the use of ground- and space-based receivers for atmospheric sensing is rapidly increasing. Ground-based RS receivers can sense column humidity [3] and integrated humidity along RS ray paths [4]. In order to achieve the best-accuracy reference system measurements, the effects of various atmospheric constituents must be considered. In this paper estimate the magnitude of RS propagation delays generated by dry air, humidity, hydrometeors, hygroscopic aerosols, sand, and volcanic ash. During a series of measurements of millimeter wave propagation through dust and smoke by, j. j. gallagher and r.w. mcmillan [8], then working at the georgia tech research institute, observed large intensity fluctuations of 94 and 140 GHz signals propagating through clear air. Although this observation was not surprising in light of atmospheric variation theory which predicts contributions to the index of refraction structure parameter from both the temperature structure parameter and the humidity structure parameter as well as their cross-correlation at millimeter wave frequencies. It was unexpected to the microwave and millimeter wave communities because it is not, been observed before. A report on these measurements led to support from the U.S. army research office for more detailed measurements of these phenomena including careful micro meteorological instrumentation for characterization of the structure parameters mentioned above and correlation of these observations with millimeter wave measurements. This series of experiments was carried out with the support and collaboration of the national oceanic and atmospheric administration, primarily responsible for meteorological instrumentation, by the author and colleagues at the Georgia tech research institute. The results of these measurements, which were made at a site near champagne-Urbana, Illinois, chosen for the homogeneity of its terrain, are given in several papers. These results will be discussed in more detail in subsequent sections. A potentially serious problem for microwave and millimeter wave radar systems in particular is that of angle-of-arrival of the signals scattered by targets caused by variation-induced wavefront distortion. for most radar scenarios, the effect is negligible, but in those cases where the wavefront must travel through great distances in the atmospheric boundary layer, for example in long range, low angle tracking applications, effect can be significant. Measurements of effect fluctuations at x-band over both one-way and two-way paths have been made by the author and his coworkers [9].

Algorithm for propagation effect analysis

- Atmosphere induces very high delay due to atmospheric conditions such as humidity, heat and layers.
- The dry air due to heat and humidity provides an extensive blockage to flow of data in high frequency transmission.
- Atmospheric errors can be reduced through modeling and correction with radiometers.
- To evaluate atmospheric effect on the propagation a formulation of propagation on microwave range is developed as outlined.

Analysis algorithm

- Generate an atmospheric signal path delay described by

$$N_{mm} = \int_0 NdZ$$

where N is the refractivity of the medium and Z is the vertical single path transmission range (km)

- Calculate atmospheric signal delay by the elevation angle using mapping functions.
- Evaluate the mapping function as a parallel medium with respect to elevation angle.

It is observed that atmospheric curvature and ray bending are more complex for mapping function design. Whereas at low angles the mapping functions are not adequate for high variable delay generated.

- Compute a refractive delay induced by the ionosphere under neutral atmospheric conditions.
- Evaluate total refractivity due to ionospheric condition and dry air for dual frequency measurement defined by

$$N(f) = N_0 + N(f) + iN(f)$$

Where f is the transmission frequency, N_0 is the non dispersed component and N' is dispersed part due to refraction N_0 and N' are real part of permittivity and N'' is attenuation to the frequency content.

- Compute the refractivity component due to cloud droplets, rain, snow etc due to charge displacement in the dielectric medium.
- Compute the hydrostatic delay for stated parameters (cloud droplets, rain, snow) directly proportional to the atmospheric pressure by using the refractivity of hydrostatic atmosphere defined by

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

Where k1 is constant, P_d is hydrostatic pressure and T is the temperature in Kelvin.

- Compute the total hydrostatic refraction delay defined by

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

Where g is the gravitational constant, P_s is the surface pressure and R_d is gas constant which is equal to 2.87×10^6 cm^2 s^{-2} k^{-1}

- Once the refractive effects are computed, compute delay due to humidity by using the refractivity of humidity given by

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

Where k_2 and k_3 are atmospheric constants, P_v is the partial pressure and T is temperature.

- The total refractive component is thus defined by

$$N_{total} = N(f) + N_{hsd} + N_{dry}$$

- Compute scattering effects due to atmospheric medium.
- The phase delay for scattering medium is defined by

$$\emptyset = k\frac{\pi}{\beta}\int f(D)N(D)dD$$

Where k is constant, $\beta = 2\pi/\lambda$, f(D) is the propagation phase and N(D) is millimetric concentration in cubic mm

- On the modeling of propagation effect analysis by refraction and scattering a remedial approach is developed with the steps of algorithm as outlined:
  - To compensate the delay factors a response signal is transmitted with information with circular polarization.
  - A delay on horizontally polarized component is minimized as a remedial approach by the usage of distinct two line carriers to evaluate phase delay.
  - The horizontal and vertical delay variations is computed with the orientation and elevation angle variations observed at the receiving antenna for these two carriers.
  - The correction factor for the two carriers is computed by a linear combination of L_1 and L_2 to cancel dispersive ionospheric propagation effect.
  - The correction due to the medium effect is computed by

$$L_C = \frac{f_1^2}{f_1^2 - f_2^2}L_1 - \frac{f_2^2}{f_1^2 - f_2^2}L_2$$

Where f_1 & f_2 are transmitting carrier frequencies and L_1 & L_2 are dispersive parameters.

  - To evaluate the proposed remedy, the propagation error with respect to the range variation over different signal rate is evaluated.
  - For the developed remedial approach "microwave radar angle of arrival" for efficient signal estimation under atmospheric effect is developed.
  - The angle of arrival error for accurate tracking is an important parameter and need to be estimated accurately.
  - For computing angle of arrival error an estimation algorithm is developed by perfectly focused beams and ideal plane waves with Gaussian profiles.

Estimation algorithm

A refractive medium with varying index is designed with the signal tilt angle

$$d\alpha = \frac{\Delta n_1 + \Delta n_2}{W_r}$$

Where Δn_1 & Δn_2 are the refractive index difference for transmitted and reflected beam and w_r is the diameter of reflected beam.

- Compute total such tilt angles through the path defined by

$$\alpha = \frac{1}{W_r} \int (\Delta n_1 + \Delta n_2) dz$$

- Each tilt in the signal provides a variance effect defined by

$$\sigma_t^2 = k C_n^2 L D^{-1/3}$$

Where k is proportionality constant, L is the slant range , D is the diameter of the atenna and C_n is the refractive index.

- The variance need to be minimized so as to reduce signal error which proportional the channel C_n .
- For the determination of C_n a range of signal variations were computed on a log amplitude variance for optimal standered deviations for AOA w.r.t distance variations.
- A reference table for optimal C_n parameter w.r.t. range for optimal AOA is derived.
- It is observed that as C_n parameter increases keeping L&D constant, the AOA deviation increases.
- The cross range azimuth error is minimized with the decrement in cross range AOA error.

The algorithm is evaluated over refractive and scattering effect under urban region conditions for humidity, dry air, hydrostatic conditions.

For simulation perspective, dry air is considered as humidless water having gas constant

R= 2.87 x 10^6 cm^2 s^{-2} k^{-1}.The broadcasting frequencies are L_1 = 1.57GHz & L_2 =1.288GHZ

Simulation Results

The figure1 shows the dispersed signal at the receiver. From this figure we can observe that, the signal have been dispersed due to the propagation effects. The figure 2 represents the scatter plot of the received signal. At the transmitter the signal will be transmitted with power concentrated at center point but as the signal is go on travelling through the atmosphere and due the scattering of the signal the signal or power is spreaded about certain area.

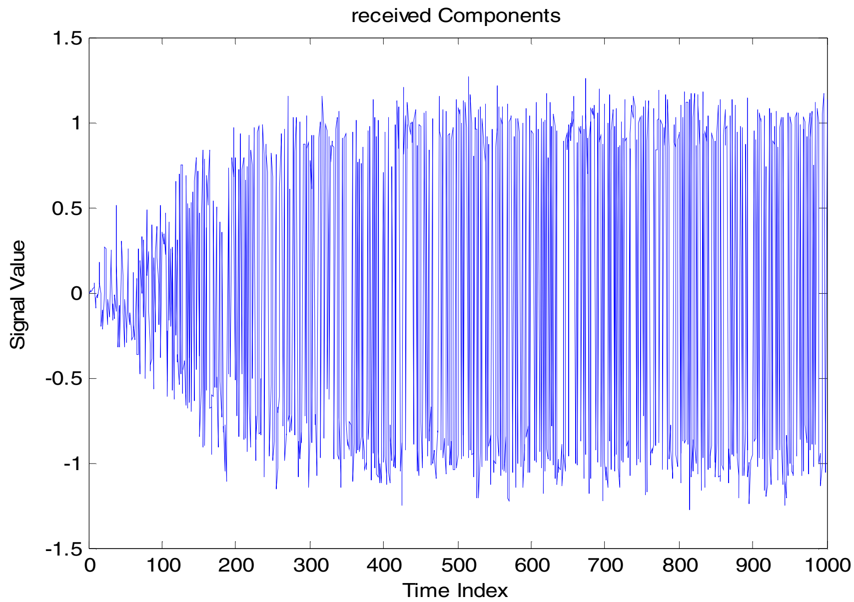

Figure1: Dispersed signal at the receiver

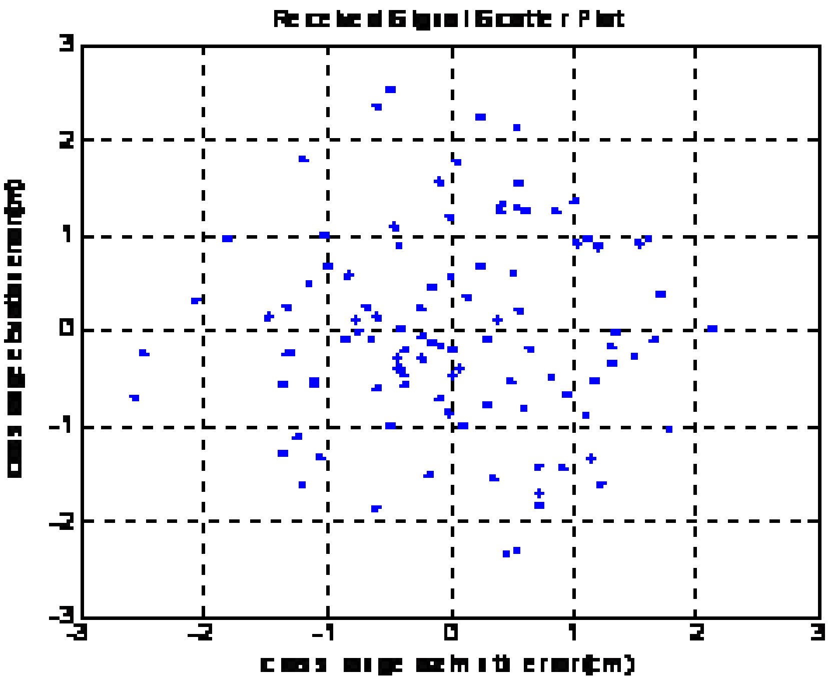

Figure 2: Received signal scatter plot

The figure2 shows the error due to propagation effect along the azimuthal direction and elevation direction.

Conclusion and Future Scope

In this work we focus on developing an approach towards communication mode to evaluate the propagation effect of microwave signal in various atmospheric conditions. The effect of ionospheric condition for the multiple frequency signal transmission is observed over isolated frequency. The effect of estimation error with respect to delay is analyzed. In the following work we would like to focus on the development of communication algorithm affecting these signals in a mixture model. The effect of refraction and dispersion due to various combined medium effect is also to be developed. A propagation approach to the mode of communication for multiple frequencies at higher frequency rate is also to be developed.

References

[1] Spilker, J., GPS signal structure and performance characteristics J. Inst. Navi., 25, 121–146, 1978.
[2] Segall, P., and J. Davis, GPS applications for geodynamics and earthquake studies, Annu. Rev. Earth Planet. Sci., 25, 301–336, 1997.
[3] Bevis, M., S. Businger, T. A. Herring, C. Rocken, R. A. Anthes, and R. H. Ware, GPS meteorology: Remote sensing of atmospheric humidity using the Global Positioning System, J. Geophys. Res., 97, 15,787–15,801, 1992.
[4] Alber, C., Millimeter precision GPS surveying and GPS sensing of slant path humidity, Ph.D. thesis, Univ. of Colo., Boulder, Dec. 1996.
[5] Melbourne, W., E. Davis, C. Duncan, G. Hajj, K. Hardy, E. Kursinski, T. Meehan, L. Young, and T. Yunck, The application of spaceborne GPS to atmospheric limb sounding and global change monitoring,JPL Pub. 94–18, 147 pp., 1994.
[6] Ware, R., C. Rocken, and K. Hurst, A GPS baseline determination including bias fixing and humidity radiometer corrections, J. Geophys.Res., 91, 9183–9192, 1986.
[7] Hill.r.j, bohlander r.a, Clifford .s.f, mcmillan r.w, priestley.j.t, schoenfeld.w.p, may 1988"variation-induced millimeter-wave scintillation compared with micrometeorological measurements", ieee trans. geosciences and remote sensing, vol. 26, no. 3, pp. 330-342,
[8] Bohlander.r.a, mcmillan .r.w, Gallagher. J.j, january 1985 "atmospheric effects of near- millimeter wave propagation" proc. ieee, vol. 73,no.1,p.49,
[9] Mcmillan .r.w., smith .r.a., . shipman .m., holder .e.j, kerce .j.c, Williams .j, may 2000 "angle-of- arrival of a radar beam in atmospheric variation", proc. 2003 ieee radar conference, long beach,ca,
[10] Churnside j. h and lataitis r. j., july 1987, 1264 "angle of arrival fluctuations of a reflected beam in atmospheric variation", j. opt. soc. am. 4,.
[11] Mcmillan r. w. and freeman g. l., jr., june 2001 "angle of arrival of a focused gaussian beam in atmospheric variation",fourthin ternational symposium on the physics and engineering of millimeter waves, kharkov, ukraine,.
[12] Yariv a., 1989, quantum electronics, 3rd edition, new york, john wiley, , chapter 6.