The Effect of Weather Conditions on Millimeter Wave Propagation

Yosef Golovachev, Ariel Etinger, Gad A. Pinhasi, and Yosef Pinhasi

Abstract— Electromagnetic wave propagation in the atmosphere is affected by the composition of the air and by meteorological conditions like fog and rain. In the current work the effects of different phases of water in the atmosphere (vapor, suspended droplets, fog and rain) on the propagation of electromagnetic radiation at broadband millimeter wave spectrum, have been studied. Analytical expressions are derived for the attenuation and group delay along the path of propagation. Using the derived expressions a modified millimeter-wave propagation model (MPM) is employed for the prediction of the suspended water droplets and rain effects.

Keywords— Atmospheric wave propagation, Dielectric permittivity of water, Dispersive complex refractivity, Extremely high frequency, ITU recommendations, Millimeter waves.

I. Introduction

UTILIZATION of higher microwave and millimeter-wave spectrum at the Extremely High Frequencies (EHF) above 30GHz can meet the growing demand for broadband wireless communication links and the deficiency of wide frequency bands within the conventional spectrum. In addition to the fact that the EHF band (30-300GHz) covers a wide range, which is relatively free of spectrum users, it offers many advantages for the 5th generation of the cellular communications.

When millimeter-wave radiation passes through the atmosphere, it suffers from frequency-dependent absorptive and dispersive phenomena, causing distortions in amplitude and phase [1]. Several empirical and analytical models were suggested for estimating the millimeter and infrared wave transmission of the atmospheric medium [2]. However most of the proposed models addressed only to the attenuation effect and not to the phase dispersion and group delay effects. Consequently, comprehensive models are needed for propagation predictions.

Golovachev et al. presented a theoretical study on the millimeter wave propagation in fog conditions and an experimental verification with very low visibility artificial fog [3,4,5]. Using a modified millimeter-wave propagation model (MPM) the calculated results showed a good agreement with experimental measurements with respect to attenuation and time delay effects.

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In current work, a space-frequency theory for modeling wireless communication channels operating in the EHF band is presented. The model was used to study the effect of clouds, fog and rain on the electromagnetic signal, in particular the attenuation and time delay.

Analytic expressions of dielectric medium parameters like permittivity, refractivity, and susceptibility, and the relation between them are presented. Using the derived expressions a modified millimeter-wave propagation model (MPM) is employed for the prediction of the suspended water droplets and rain effects.

The model results were compared with the practical ITU recommendations. The model was used to predict the results for the ongoing experimental study.

II. Propagation through a Dielectric Media

Millimeter wave signals propagating in the atmosphere suffer frequency-dependent absorptive and dispersive phenomena, causing distortions in amplitude and phase.

A. Electromagnetic Wave Propagation factors

The parameters of a radio wave are modified while propagating through a dielectric media. In general, such influences are due to refraction, absorption and scatter. Both phase and amplitude responses of a plane radio wave propagating the distance d at frequency f follow from

$$E(d) = E_0 \exp\left[-jk(f)d\right] \tag{1}$$

where E_0 is the initial amplitude, c is the speed of light in vacuum, $k(f)$ is the *propagation factor* and $n(f)$ is the *refractive index*.

$$k(f) = \frac{2\pi f}{c} n(f) \tag{2}$$

The complex *refractive index*, is a measure of the interaction of electromagnetic radiation with the medium:

$$n(f) = 1 + N(f) \times 10^{-6} \tag{3}$$

The refractivity depends on the frequency and medium