Waves Depolarization Prediction Based on Numerical Approach

R. Talhi , C.H. Kuo [1] , A. Lebrère , M.R Tripathy , M. Pyée
C.N.R.S - L.P.C.E , 3A, Avenue de la recherche scientifique, 45071 Orleans Cedex 2, France
Tel : (00 33) 02 38 25 52 56, Fax : (00 33) 02 38 63 12 34, e-mail: rtalhi@cnrs-orleans.fr
[1] Ming Chi Institute of Technology – Taïpec - Taïwan

Abstract

Phenomena of waves depolarization mainly due to multiple scattering effects in a propagation medium with discrete scatterers (like raindrops, ice crystals, etc.) , have always been an important topic for radio communications. For example, it may be at the origin of interference between two orthogonal channels . In this paper, we present a numerical and stochastic model, using Stokes parameters, for prediction of the waves depolarization phenomena when the medium contains different discrete scatterers. Our model is easy to implement and can be used in different frequency bands. It may contribute to get a better understanding of physical mechanisms involved in such depolarization phenomena .

1. Introduction

Depolarization of a signal is an important topic in radio-communications systems with single or dual polarization. For instance, in satellite communication links, depolarization due to raindrops and ice crystals may increase the cross-polarization, which means increasing of interference, between two orthogonal channels. In the same way, in remote sensing of some atmospheric parameters, like hydrometeors, the depolarization phenomenon is also essential, and may have a direct impact on the accuracy of interpretation of the data (kind and characteristics as size, shape and orientation of hydrometeors) obtained from satellites or cloud radar systems. In these examples, waves depolarization phenomena are mainly due to multiple scattering effects in a propagation medium with random discrete scatterers (hydrometeors). In order to study many aspects of waves propagation and scattering in different kind of random media , we developed a general stochastic model [1] , and we tested it in various simulations [2]. In this paper, we focus on estimation and prediction of polarization effects using Stokes vectors. Depolarization prediction dealing with millimeter-wave band (30 – 300 GHz) is emphasized , and we get an estimation of some parameters as wave depolarization according to each axis (OX , OY , OZ) , signal to depolarization noise ratio , monostatic scattering coefficient , etc. Obtained results may contribute to a better understanding of physical mechanisms involved in hydrometeors depolarization, and to improve the reliability of radio waves links and remote sensing systems.

2. Numerical approach

To study the question of the depolarization induced by a hydrometeors medium, we consider a monochromatic plane wave propagating through this random medium, before reaching a receiving plane where an antenna is located. Our numerical and stochastic model, used in this context, is mainly based on four parts : **(i)** series of photons are used instead of an electromagnetic wave ; **(ii)** the scattering and absorption aspects of a wave are processed as collisions process between photons and hydrometeors ; this second part is a consequence of the previous one ; moreover, the geometrical aspects (size and shape), the orientation and the statistical distribution of the scatterers (hydrometeors) are considered in the simulation ; **(iii)** pseudo-random numbers generators are used to simulate random events that photons may undergo in the medium ; in fact this third part describes the statistical interactions between photons and hydrometeors ; **(iiii)** Stokes vectors , which describe polarization effects in the radiative transfer theory , are used ; moreover, in order to estimate the global depolarization concerning all photons , we used the incoherent addition of Stokes parameters, which means that depolarized intensities are assumed independent. Among details concerning the collisions process inside the hydrometeors medium, we have to mention that we need to know some factors as the incidence angle of a photon , the probability for a photon to be scattered or absorbed , the probability for a photon to have one or more collisions with the scatterers , etc. Then the simulation allows to estimate some depolarization results in forward and in backward directions [3] .

3. Some numerical results and discussion

In the following simulation , we considered a plane wave with a linear polarization according to OX axix , OZ is the direction of propagation. Figures 1 to 4 show depolarizations in forward and in backward directions of propagation. The number of emitted photons is N = 10 millions , and the mean free path of the medium is approximatively 1140m. The total intensities of depolarization are normalized with respect to N. As a general comment, we can readily say that signal depolarization is in the aggregate more important in multiple scattering than in single scattering, especially for cross-polarization (I_y) where the relative difference is quite important. In case of single scattering (Fig. 1 & 2) , we can observe that the initial polarization (I_x)

Fig. 1 :

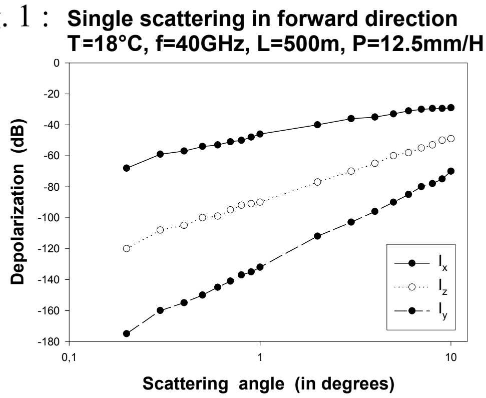
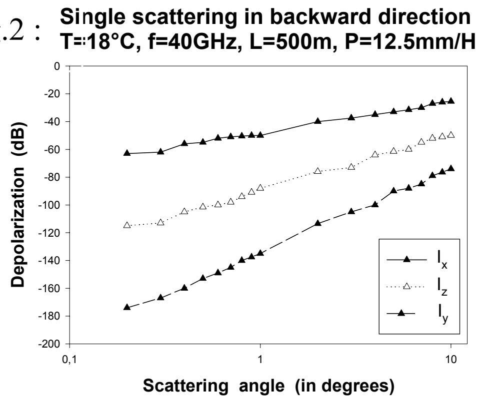


Fig.2 :



is dominant , and the polarization level in the direction of propagation (I_z) is approximatelly 20 to 60 dB , depending on the scattering angle , below the dominant polarization (I_x). In the opposite side , the gap between scattered intensities decreases when the scattering angle increases.The cross-polarization level (Iy) is low compared to the dominant one (I_x)

Fig. 3 :

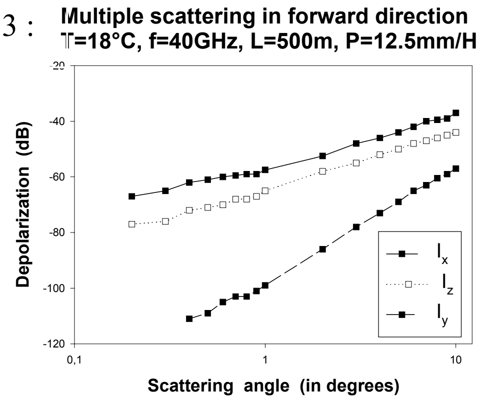
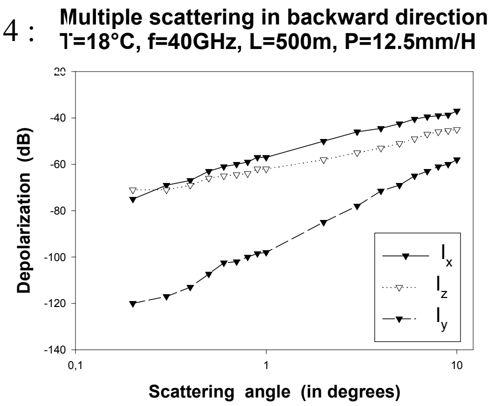


Fig. 4 :



In case of multiple scattering (Fig. 3 & 4), the depolarization level in the direction of propagation (I_z) is nearer , with respect to the previous case, to the dominant polarization (I_x) , and sometimes greater. While the cross-polarization level (I_y) is still low with respect to I_x

For this kind of simulation, the computing time may be long; it depends on some influent factors like the number of collisions, the number of emitted photons, the rain rate (P) , the frequency, etc.

4. Conclusion

We presented a numerical and stochastic prediction model dealing with waves depolarization phenomena in a random medium where the scatterers are hydrometeors , mainly raindrops with different models. We tried to clarify the multiple scattering effects related to hydrometeors depolarization , by using Stokes vectors . Our model is relatively easy to implement , and can be used in different frequency bands , particularly in millimeter-wave band which is sensitive to signal depolarization induced by hydrometeors .

References

[1] R. Talhi , M. Pyée , M.R. Tripathy , PIERS 2001 – Osaka , Japan
[2] R. Talhi , C.H. Kuo , M.R. Tripathy , M. Pyée , AP-RASC 2001 - Tokyo , Japan
[3] C.H. Kuo , Thesis , University of Paris 7 , 1995