RAIN EFFECT ON POLARIMETRIC SAR OBSERVATION

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1. INTRODUCTION

There are various spaceborne SARs in operation now. It is expected that high-frequency and high-resolution SARs will become successful in the future. On the other hand, the influence of rain on measurement cannot be ignored, especially in the case of intense rain as the observation frequency increases[1]. Evaluation of these influences becomes an important issue for the accurate Polarimetric SAR observation. The purpose of this paper is to consider the radio wave of Polarimetric SAR propagation in rain and to verify the influence of the rainfall quantitatively.

2. RADIO WAVE PROPAGATION IN RAIN

For a common monostatic Polarimetric SAR system in the antenna coordinate system, the measured scattering matrix, **M**, can be written as;

$$\mathbf{M} = \mathbf{R}^t\mathbf{FPQSQPFT} + \mathbf{N} \tag{1}$$

where **R** is the receiving antenna distortion matrix, **F** represents the one-way Faraday rotation matrix, **P** is the ice distortion matrix, **Q** is the rain distortion matrix, **S** is the scattering matrix of the target, **T** is the transmitting antenna distortion matrix and **N** represents additive noise terms present in each measurement due to earth radiation, thermal fluctuations in the receiver, digitization noise, and so on.

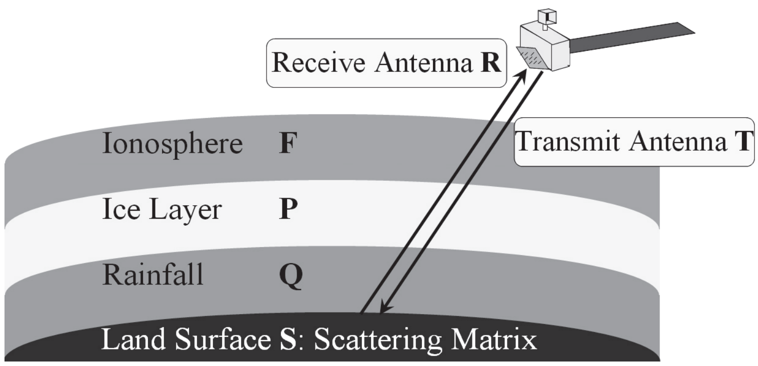

Fig. 1. Polarimetric SAR observation model

In this paper, we assume that the SAR system is ideal, and the rainfall is only a cause of the measurement error source. Figure 2 shows the rain effect area on SAR observation. The radio wave is absorbed and scattered by raindrops in the range where the radio wave is irradiated (area A). In addition, as in Figure 3, raindrops that are the same distance from SAR to the observation target point of land surface (area B) affect the SAR measurement as backscattering phenomena.

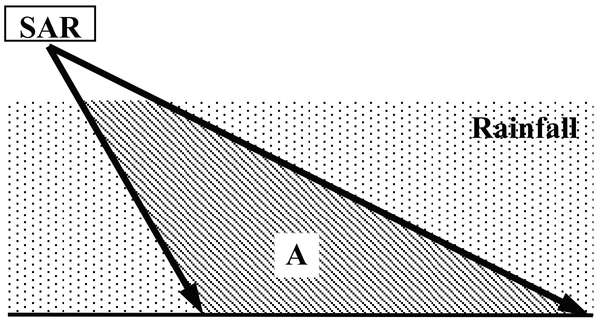

Fig. 2. SAR observation model in the rainfall area

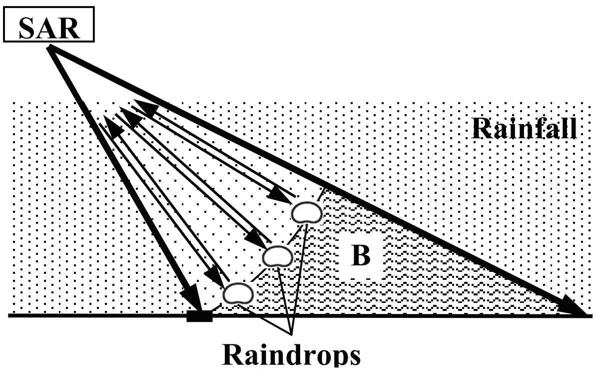

Fig. 3. Backscatters in the rainfall area

Backscatters from the raindrops in area B are considered to be incoherent signals. Assuming that they contribute only to an increase in the noise terms, and the total of noise terms, **N**, are negligible, (1) can be written

$$\mathbf{M} = \mathbf{QSQ} \tag{2}$$

or

$$\begin{pmatrix} M_{HH} & M_{HV} \\ M_{VH} & M_{VV} \end{pmatrix} = \begin{pmatrix} Q_{HH} & Q_{HV} \\ Q_{VH} & Q_{VV} \end{pmatrix} \begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix} \begin{pmatrix} Q_{HH} & Q_{HV} \\ Q_{VH} & Q_{VV} \end{pmatrix} \tag{3}$$

$|Q_{HH}|$ is the amount of rain attenuation of horizontal polarization along one-way propagation path. Rain attenuation of C, X, and Ku bands are shown in Figure 4.

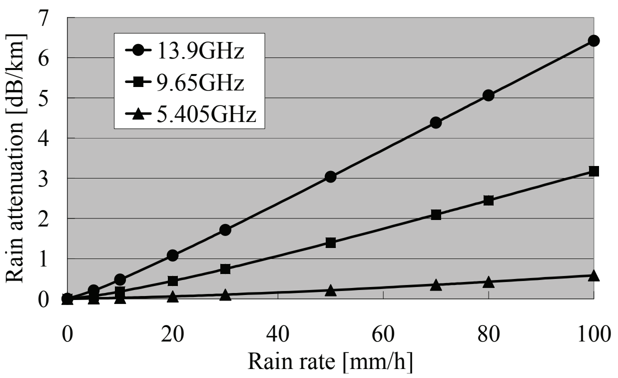

Fig. 4. Specific Rain Attenuation (horizontal pol.)

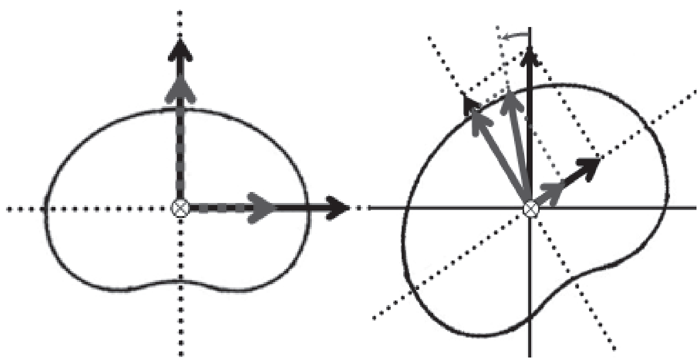

Fig. 5. Attenuation in a raindrop

$|Q_{VV} / Q_{HH}|$ corresponds to the attenuation difference of the horizontal polarization and the vertical one. When the radio waves enter into the raindrop, the horizontal polarization is attenuated more greatly than the vertical polarization because of the non-spherical raindrop shape as shown in Figure 5 on the left-hand side.

Moreover, if the raindrops incline with a certain canting angle, depolarization will occur as seen in Figure 5 on the right-hand side. $|Q_{HV} / Q_{HH}|$ shows amplitude of this depolarization. We estimate the attenuation difference ($|Q_{VV} / Q_{HH}|$) and the depolarization ($|Q_{HV} / Q_{HH}|$) by using the method in reference[2]. In this method, each phase of matrix components can be derived. The estimated results are shown in Figure 6 and Figure 7, provided that the rain area length is 5km, the elevation angle is 50°, the average canting angles of the raindrops θ=0° or 45°, **S** is a unit matrix, and Marshall-Palmer drop size distribution is assumed.

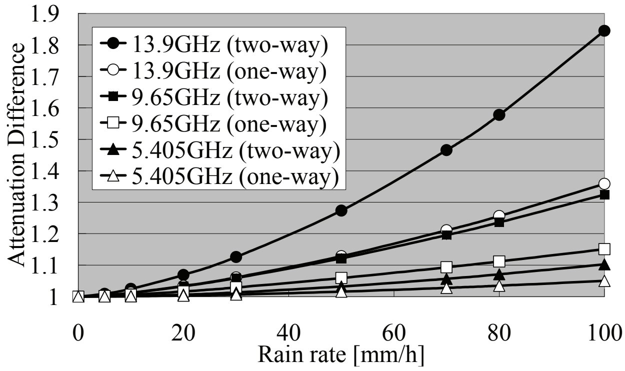

Fig. 6. Attenuation Difference (θ=0°)

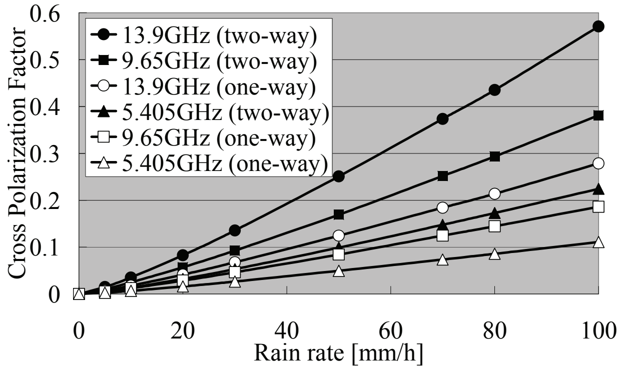

Fig. 7. Cross Polarization Factor (θ=45°)

The estimated results can be expressed by polarization signatures as in Figure 8 and Figure 9, provided that the observation frequency is 13.9Ghz, the rain rate is 50mm/h, and θ=22.5°.

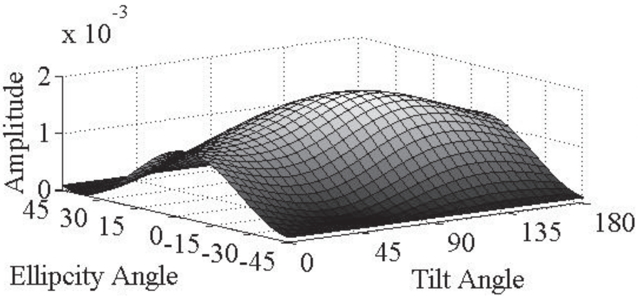

Fig. 8. Co-polarization signature

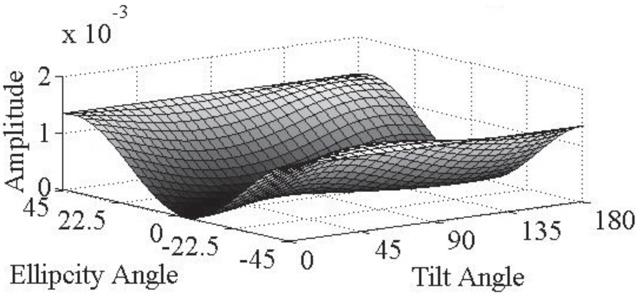

Fig. 9. Cross polarization signature

3. CONCLUSIONS

The rain effect on Polarimetric SAR observation was quantitatively evaluated by using the SAR observation model in non-spherical raindrop environments.

4. REFERENCES

[1] Andreas Danklmayer, Bjorn J. Doring, Marco Schwerdt, and Madhu Chandra, "Assessment of Atmospheric Propagation Effects in SAR Images," *IEEE Trans. Geosci. Remote Sensing*, vol.47, pp.3507-3518, 2009.

[2] T. Oguchi, "Scattering properties of Pruppacher-and-Pitter form raindrops and cross polarization due to rain: Calculation at 11, 13, 19.3 and 34.8GHz," *Radio Science*, *Vol.12*, pp. 41-51, 1977.