Measurement of scattering in X, C and L bands on wet and inundated soil surface for the monitoring of paddy fields using SAR data

Junichi Susaki (1)

(1) Graduate School of Global Environmental Studies, Kyoto University
C1-1-206, Kyotodaigaku-Katsura, Nishikyo-ku, Kyoto, 615-8530 JAPAN
Tel/Fax:(81)-75-383-3300, E-mail: susaki@envinfo.uee.kyoto-u.ac.jp

Abstract
Laboratory experiments were conducted to measure microwave scattering on specimens to simulate paddy fields for the purpose of developing microwave scattering model of paddy fields. In the experiment, the specimens were produced into fiber reinforced plastic (FRP) tube with 70 x 60 x 60 cm^3 volume. The specimens contained soils, water layer and paddy. X-band antennas measured the backscatter from the specimens, and the fully polarimetric data were decomposed into four components by applying the methodology proposed by Yamaguchi *et al*. [1]. The results show that the scattering of paddy to X-band microwave is composed of volume scattering mainly. However, it was also shown that the effects reflected from the edge of the FRP tube cannot be neglected. Therefore, further experiment will be necessary to examine the scattering of paddy, in which the tube should be replaced with another case material such as polystyrene case.

Keywords: Scattering model of paddy fields, measurement using scatterometer, Decomposition into four-components.

1. INTRODUCTION

Based on the backscattering coefficient obtained by satellite-borne synthetic aperture radar (SAR) sensor data, soil moisture can be estimated through physical models or empirical models. So far, the authors have examined the Integral Equation Method (IEM) model [2], one of the most useful models of microwave scattering, to estimate volumetric soil moisture from temporal Japanese Earth Resources Satellite-1 (JERS-1)/SAR data. As a result to compare with actual volumetric soil moisture, it was found that the IEM model cannot function to properly represent microwave scattering on paddy fields, especially inundated paddy fields because the IEM model assumes scattering on bare soil. While results to measure backscatter of L, C, X and Ku bands of microwave on paddy fields were reported [3], there is no available model of microwave backscatter on paddy fields, i.e. landcover functioning as bare soil, inundated soil, inundated vegetation and vegetation without inundation. In the present research, the authors have conducted laboratory experiments to measure microwave scattering on the simulated paddy field and the results are reported.

2. EXPERIMENTS

In the current research, two different experiments were conducted. One of the experiments was conducted from August 8 to 12, 2007 in an anechoic radio wave chamber of Microwave Energy Transmission Laboratory (METLAB), Research Institute for Sustainable Humanosphere (RISH), Kyoto University. A vector network analyzer produced 50 MHz to 40 GHz incident microwave. X-band (8.5-9.6 GHz), C-band (4.0-5.8 GHz) and L-band (1.7-2.6 GHz) antennas were used. Single antenna transmitted and received HH-polarized microwaves. However, it was found after the data processing that the experiment was not successful because of the poor calibration. Therefore, in this paper, the other experimental results are reported.

The experiment was conducted in an anechoic radio wave chamber of Prof. Yoshio Yamaguchi, Niigata Univ during September 25 to 26, 2007. Fully polarimetric FM-CW SAR system [4] was used to measure the backscatter from a specimen to simulate paddy field. Four antennas, two for transmitting and the other two for receiving, can be attached onto the antenna box, and the box can move horizontally to measure. The measured data were processed as SAR data to achieve higher azimuth resolution. X-band and K-band antennas were used for the experiment. In this paper, the results using X-band antennas are reported. The details on the measurement parameter are shown in Table 1.

Table 1. Measurement parameter

Center frequency	10 GHz
Sweep frequency	2 GHz
Sweep time	5 ms
FFT point	16384
Scanning point	256
Range resolution	75.0 mm
Azimuth resolution	20.0 mm
Antenna height	1.90 m
Incident angle	35 deg

Specimens of soil were produced in a fiber reinforced plastic (FRP) tube, which is normally supposed to be used as a bath tube. The tube had 70 x 60 x 60 cm^3 volume. A 30-cm depth of soil layer was put into the tube, and compaction was given to the soil layer. Different depths of water was covered with the soil surface, such as 1 cm, 3 cm, 5 cm and 10 cm to examine the effects of interaction between water, soil and paddy. Two conditions, specimens with/without paddy, were examined. Figure 1 shows the measurement of the specimen with paddy.

Four-component decomposition method, proposed by Yamaguchi *et al*. [1], was applied for the measured fully polarimetric data to analyze which kind of scattering can be found in paddy fields. The method is an extension of "Three-component scattering model" reported by Freeman *et al*. [5]. It deals with non-reflection symmetric cases, and converts into surface scattering, double bounce scattering, volume scattering and helix scattering. The decomposed results are shown in Figures 2 to 5. Figures 2 and 3 show surface scattering, double bounce scattering and volume scattering of specimens covered with 1-cm depth of water. In the same manner, Figures 4 and 5 show the scatterings in the case of specimens covered with 10-cm depth of water.

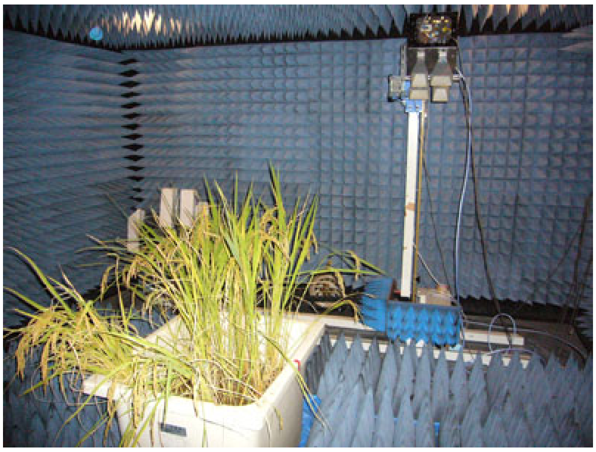


Figure 1. Measurement of specimen using fully polarimetric FM-CW SAR system with X-band, developed by Yamaguchi et al. [4]

3. DISCUSSION AND CONCLUSIONS

All of the surface scattering results shown in Figures 2 to 5 have strong rectangular-shape scattering in the near-range region. This can be the reflection from the upper edge of the FRP tube. Double bounce scattering results in Figures 2 and 4 represent that strong rectangular-shape scattering can be found in the middle-range region. This can be double bounce scattering between water surface and backward wall of the tube. With consideration of these two phenomena, the FRP tube used in this experiment caused noise, and it was found to be inappropriate for the experiment. Therefore, further experiment will be necessary to examine the scattering of paddy, in which the tube should be replaced with another material such as polystyrene case.

In general, vegetation scatters X-band microwave mainly on its surface while volume and double bounce scattering can be found mainly in vegetation areas for L-band. However, Figures 3 and 5 demonstrate volume scattering is dominant among three scatterings. In near future, such phenomena will be examined through further measurements. Also, measurement using L-band and comparison of X-band results and L-band results will be expected to extract the information of paddy above water surface.

Acknowledgement

This research is conducted under the agreement of JAXA Research Announcement titled 'Mapping of agricultural drought risk in northeastern Thailand using JERS-1/SAR, PALSAR, AVNIR-2 and meteorological data' (JAXA-PI number 370). Author expresses thanks to Prof. Yoshio Yamaguchi, Niigata Univ. and his group for the measurement using their own multi-polarization SAR system. Author also expresses thanks to Microwave Energy Transmission Laboratory (METLAB), Research Institute for Sustainable Humanosphere (RISH), Kyoto Univ. and Dr. Tomohiko Mitani, Kyoto Univ. for supporting the measurement.

References

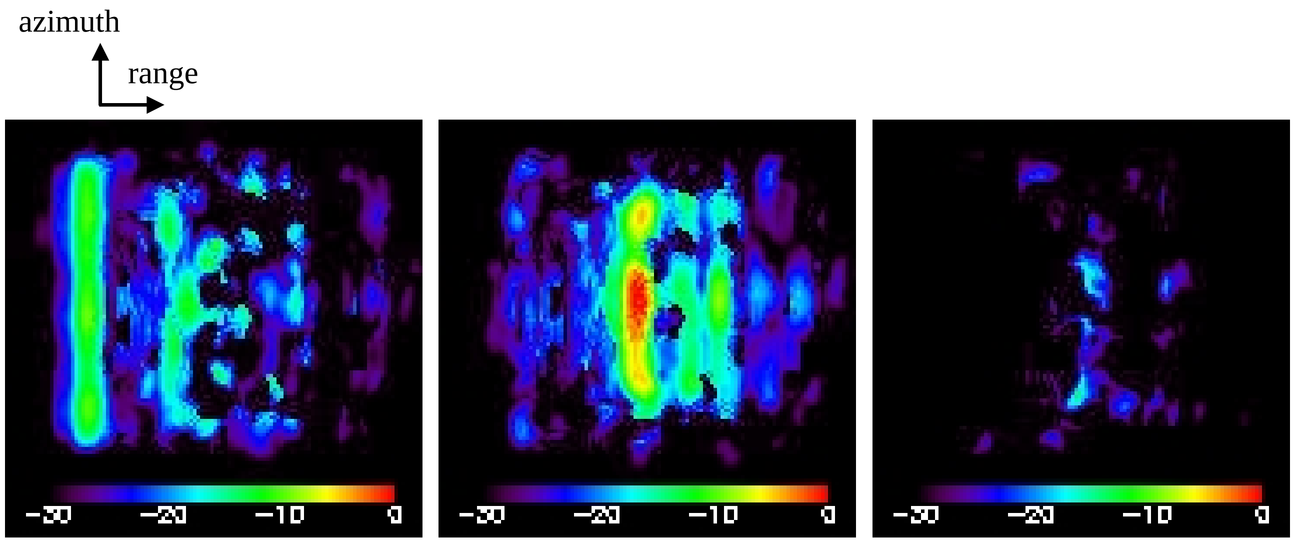
[1] Y. Yamaguchi, Y. Yajima, and H. Yamada, "Four-component scattering model for polarimetric SAR image decomposition", *IEEE Transactions on Geoscience and Remote Sensing*, vol. 43, no. 8, pp. 1699-1706, 2005

[2] A. K. Fung, Z. Li, and K. S. Chen, "Backscattering from a randomly rough dielectric surface", *IEEE Transactions on Geoscience and Remote Sensing*, vol. 30, pp. 356-369, 1992

[3] Y. Inoue, T. Kurosu, H. Maeno, S. Uratsuka, T. Kozu, K. Dabrowska-Zielinska, and J. Qi, "Season-long daily measurements of multi-frequency (Ka, Ku, X, C, and L) and full-polarization backscatter signatures over paddy-rice field and their relationship with biological variables", *Remote Sensing of Environ.*, vol. 81, pp. 194-204, 2002

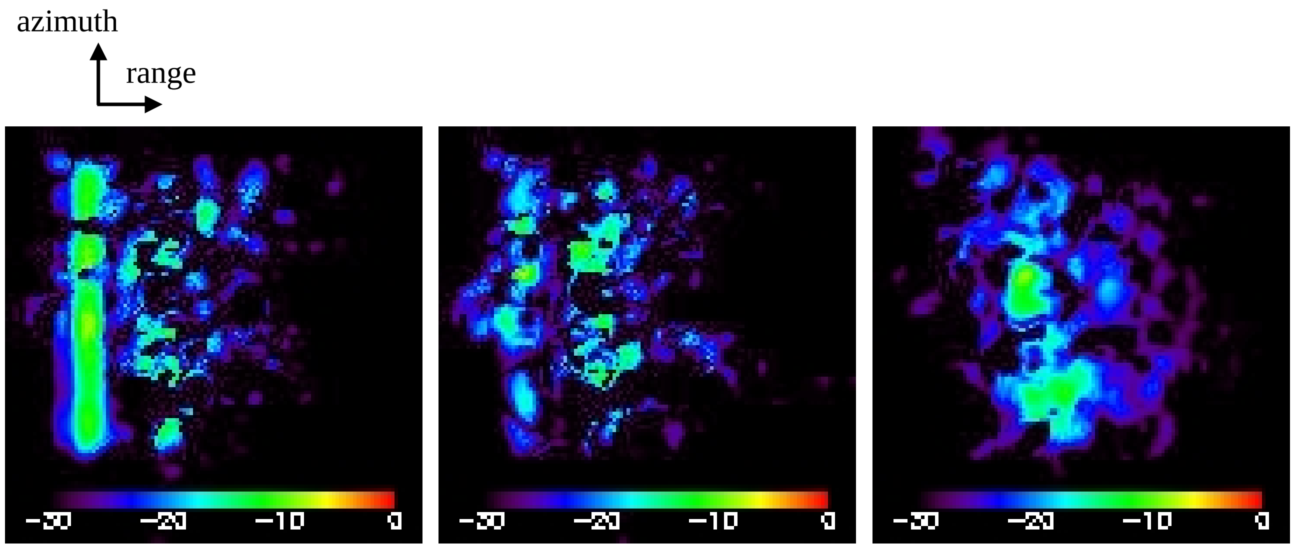
[4] J. Nakamura, K. Aoyama, M. Ikarashi, Y. Yamaguchi, and H. Yamada, "Fully polarimetric and interferometric FM-CW SAR system and its preliminary measurement results", Proceedings of ISAP2007, pp. 816-819, 2007

[5] A. Freeman and S. L. Durden, "A three-component scattering model for polarimetric SAR data", *IEEE Transactions on Geoscience and Remote Sensing*, vol. 36, no. 3, pp. 356-369, 1992



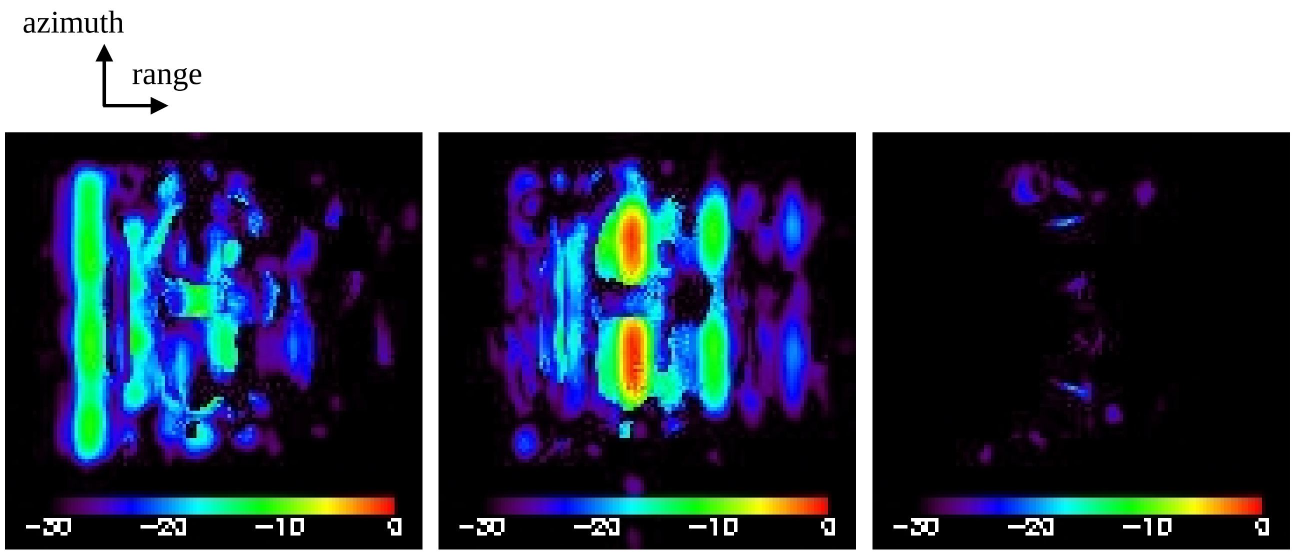
(a) Surface scattering (b) Double bounce scattering (c) Volume scattering

Figure 2. X-band scattering from the specimen with 1-cm depth of water, and without paddy. The color bar represents backscatter coefficient from -30 dB to0 dB



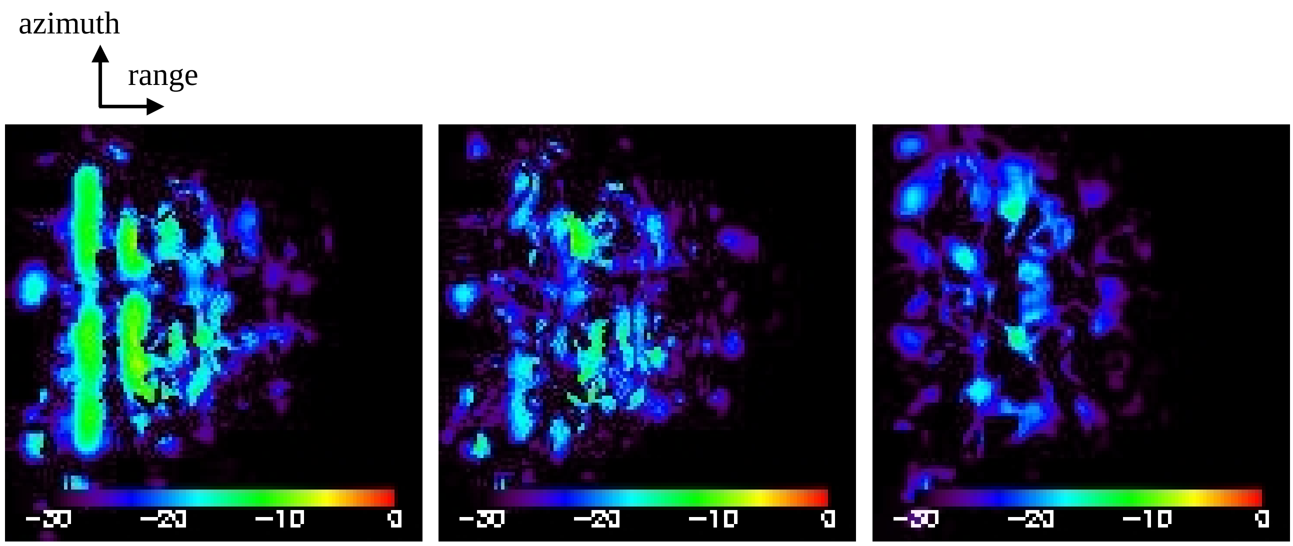
(a) Surface scattering (b) Double bounce scattering (c) Volume scattering

Figure 3. X-band scattering from the specimen with 1-cm depth of water, and with paddy



(a) Surface scattering (b) Double bounce scattering (c) Volume scattering

Figure 4. X-band scattering from the specimen with 10-cm depth of water, and without paddy
The color bar represents backscatter coefficient from -30 dB to0 dB



(a) Surface scattering (b) Double bounce scattering (c) Volume scattering

Figure 5. X-band scattering from the specimen with 10-cm depth of water, and with paddy