Radar Backscattering Measurements of Paddy Rice Field using L, C, and X-band Polarimetric Scatterometer

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ABSTRACT: The objective of this study is to measure backscattering coefficients of paddy rice using L, C, X-bands scatterometer system during a rice growth period. The measurement was conducted at an experimental field located in National Institute of Agricultural Science and Technology (NIAST), Suwon, Korea. The rice cultivar was a kind of Japonica type, called Chuchung. The scatterometer system consists of dual-polarimetric square horn antennas, HP8720D vector network analyzer (20MHz ~ 20GHz), RF cables, and a personal computer that controls frequency, polarization and data storage. The scatterometer system is calibrated using a calibration kit (3.5mm, 85052D). The backscattering coefficients were calculated by applying radar equation for the measured at incidence angles between 20° and 60° for four polarization (HH, VV, HV, VH), respectively, and compared with rice growth data such as plant height, stem number, biomass, dry weight and LAI that were collected at time of each scatterometer measurement simultaneously.

KEY WORDS: Rice, Backscattering coefficients, Scatterometer system, Frequency, Polarization

INTRODUCTION

Rice is one of the major crops in Korea. In spite of its importance as a food source, there have been few attempts to monitor rice growth and study backscattering characteristics with a microwave instrument from space-ground platform. Microwave radar can penetrate cloud cover regardless of weather conditions and it can be used day and night. Especially a ground-based polarimetric scatterometer has advantage of monitoring crop conditions continuously using full polarization and various frequencies. Many plant parameters such as leaf area index (LAI), biomass, plant height are highly correlated with backscattering coefficients and according to frequency, polarization between plant parameters and backscattering coefficients was different (Ulaby, 1984; Bouman, 1991). Le Toan et al. (1997) showed the potential SAR backscatter data for rice crop monitoring based on both satellite and ground based scatterometer measurements. Hong et al. (2000) analyzed RADARSAT data (5.3 GHz, hh-polarization, and incidence angles between 36° and 46°) for monitoring the rice growth in Korea. In this study, we examine the temporal behaviour of the radar backscatter from rice crops during the growth period at multi-frequency (L, C, X-band) with angular response.

MATERALS AND METHODS

The test site was located in NIAST experimental field (37° 15' 28.0" N, 126° 59' 21.5" E) Suwon, Korea. The rice cultivar was a kind of Japonica type, called Chuchung. The size field was about 660m^2.
Table 1 show the scatterometer system specification.

Table 1. Specification of the scatterometer system

Specification	L-Band	C-Band	X-Band
Center Frequency	1.27 GHz	5.3 GHz	9.65 GHz
Bandwidth	0.12 GHz	0.6 GHz	1 GHz
Number of Frequency Points	201	801	1601
Antenna Type	Dual polarimetric horn	Dual polarimetric horn	Dual polarimetric horn
Antenna Gain	12.4dB	20.1dB	22.4dB
Polarization	HH, VV, HV, VV	HH, VV, HV, VV	HH, VV, HV, VV
Incident Angle	20° ~ 60°	20° ~ 60°	20° ~ 60°
Platform Height	4.16m	4.16m	4.16m

The system mainly composed of dual-polarimetric square horn antennas, vector network analyzer (VNA), RF cables, and a personal computer. The VNA-based polarimetric scatterometer operates in a stepped-frequency sweep mode. Polarimetric scatterometer provides a time domain radar return from a target as a fully polarimetric (HH, HV, VH, VV) amplitude and phase data. Changing of frequency bands, polarization of antennas and data storage can be controlled by the computer. The system is calibrated using a calibration kit (3.5mm, 85052D) and backscattering coefficients were calculated by applying radar equation. Radar backscattering measurements began on 15 May 2007 before the transplanting with HH, HV, VH, VV polarizations and at incidence angle of 20 ~ 60°. Growth data for the rice canopy, such as LAI, wet and dry biomass and plant height, were acquired at time of each scatterometer measurement simultaneously.

RESULTS AND DISCUSSION

Backscattering coefficients of paddy fields at L-band, C-band and X-band range from about -55db ~ 0db, -50db ~ +5db, -50db ~ -10db, respectively. At large incident angles, range of backscattering coefficients higher than that of small incident angle. Fig. 1 shows the temporal variations of the backscattering coefficients of the rice crop at L-band after transplanting, at various incidence angles. VV-polarized backscattering coefficients higher than hh- and hv/vh-polarized backscattering coefficients during rooting stage (mid-Jun).

At small incident angle (20°, 25°, 30° and 35°), vv-polarized backscattering coefficients tend to increase more than at the hh-polarized during rice growth stage. Contrarily, larger incident angles (50°, 55° and 60°) at hh-polarized $\sigma°$ steadily increase at ripening stage (mid-Aug). Changes of backscattering coefficients at C-band during growing periods were shown in Figure 2. The hh-polarized backscattering coefficients at all incident angles (except 20°) increase as growth advanced and saturate at the ripening stage.

Fig. 3 shows change in backscattering coefficients at C-band with growth. Backscattering coefficients of range at X-band as higher-frequency band lower than that of L-, C-band.

CONCLUSIONS

Backscattering coefficients of rice crop were investigated with a ground-based scatterometer. The measurements were carried out at L-, C-, X-band with full polarizations and different incident angles. The temporal variations of the backscattering coefficients of the rice crop at L-, C-, X-band during rice growth period. At large incident angles, range of backscattering coefficients higher than that of small incident angle. VV-polarized backscattering coefficients higher than hh-polarized backscattering coefficients in early rice growth stage. HH-polarized backscattering coefficients higher than vv-polarized backscattering coefficients after panicle initiation stage (mid-Jul).

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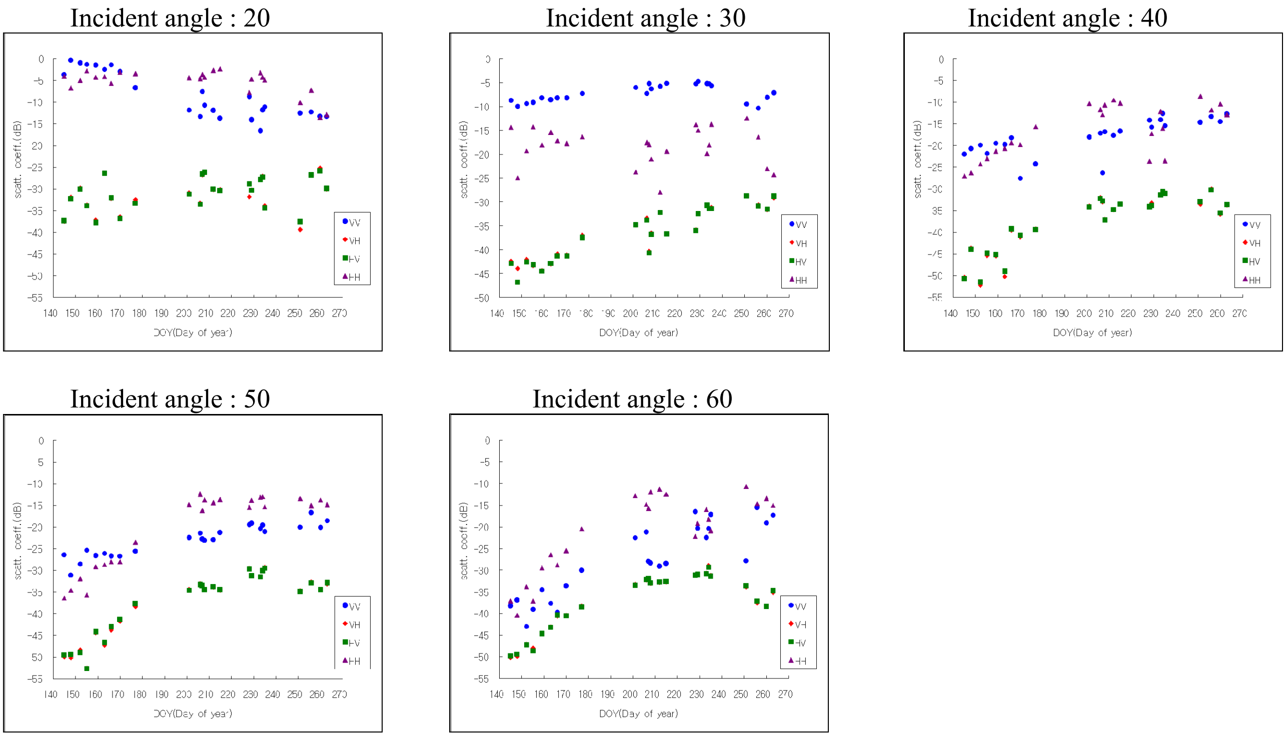

Fig 1. Temporal variations of backscattering coefficients at polarization and incident angle for the L-band.

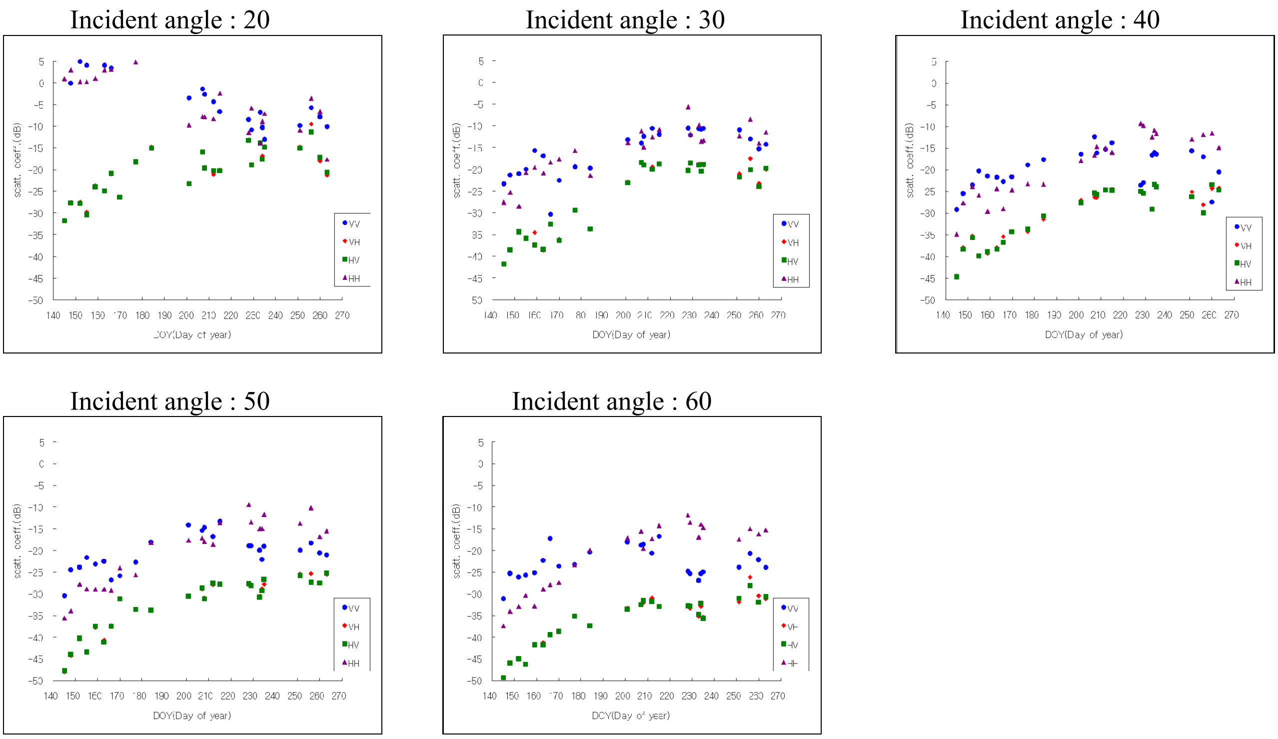

Fig 2. Temporal variations of backscattering coefficients at polarization and incident angle for the C-band.

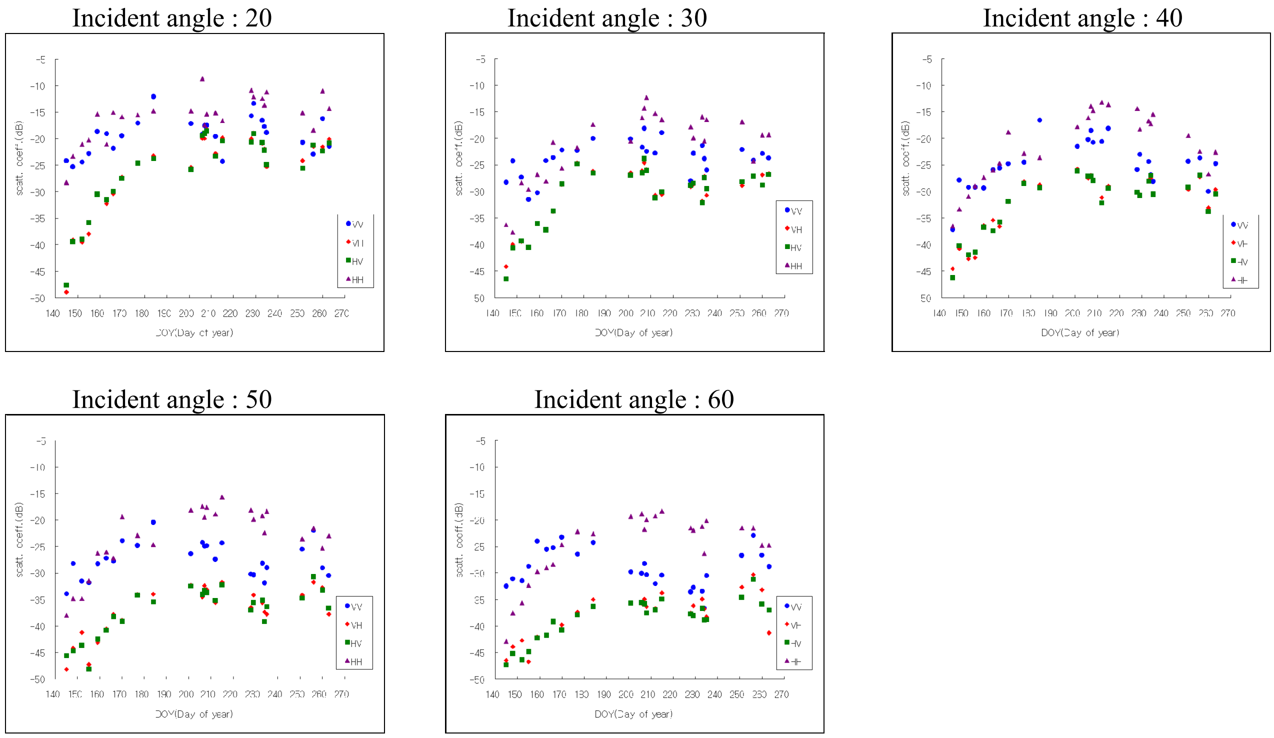

Fig 3. Temporal variations of backscattering coefficients at polarization and incident angle for the X-band.