Monitoring of the rice growth using polarimetric scatterometer system

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Abstract **:** The objective of this study is to investigate the temporal behavior of radar backscatter from paddy rice using polarimetric scatterometer and relate backscattering coefficients to rice growth parameters in two years (2007-2008). We measured the change of backscattering coefficients with L, C, X-band during rice growth period in 2007. We plotted the relationship between backscattering coefficients with L-, C-, X-band and rice growth parameters. We constructed automatic scatteromter system and analyzed scattering characteristics of paddy rice obtained from an X-band antenna system in 2008. The HH, VV-polarized σ° steadily increased toward panicle initiation stage and thereafter decreased and again increased about mid-September. Grain weight was correlated with backscattering coefficients with vv-polarization in X-band.

Keywords **:** Polarimetric scatterometer, backscattering coefficients, growth parameters, polarization

1. Introduction

Microwave remote sensing has great potential, especially in monsoon Asia, since optical observations are often hampered by cloudy conditions. 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 although the degrees of correlation and different and according to frequency and polarization between plant parameters and backscattering coefficients was different (Ulaby, 1984; Bouman, 1991; Brisco & Brown, 1998). Le Toan *et al* (1997) was among the first that showed the potential of using SAR backscattering data for rice crop monitoring based on both satellite and ground based scatterometer measurements. In this study we measured backscattering coefficients of paddy rice using L-, C-, and X-band scatterometer system with full polarization and various angles during the rice growth period and to relate backscattering coefficients to rice growth parameters.

2. Material and Methods

The measurement was conducted at an experimental field located in National Academy of Agricultural Science (NAAS), Suwon, Korea. The rice cultivar was a kind of Japonica type, called Chuchung. The size field was about 660m^2. Growth data for the rice canopy, such as LAI, fresh and dry weight and plant height, have been acquired in a regular basis.

Table 1 showed the scatterometer system specification in 2007. The system mainly composed of dual-polarimetric square horn antennas, vector network analyzer (VNA), RF cables, and a personal computer. Polarimetric scatterometer provides a time domain radar return from a target as a fully polarimetric (HH, HV, VH, VV) amplitude and phase data.

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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)

Table 1. Specification of polarimetric 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 polarimetri c horn
Antenna Gain	12.4 dB	20.1 dB	22.4 dB
Slant range resolution	0.15 m	0.25 m.	1.25 m
Wavelength	0.031 m	0.056 m	0.23 m

The automatic scatterometer system was installed inside a shelter in an experimental paddy field at the NAAS before transplanting in 2008. This system automatically measures fully-polarimatric backscattering coefficients of rice crop every 10 minutes. Backscattering coefficients were calculated by applying radar equation (Ulaby *et al*., 1990).

3. Results and Discussion

We analyzed temporal variations of backscattering coefficients at full polarization and various incident angles for the L, C, X-band in 2007. In three bands, VV-polarization backscattering coefficients higher than HH, cross polarization during early growth stage HV/VH-polarization backscattering coefficients with L-band increased towards the heading stage (mid-Aug) and thereafter saturated, again increased near the harvesting season. The HH-polarization backscattering coefficients with C-band at all incident angles increased as growth advanced and saturate at the ripening stage.

As backscattering coefficients from a ground scatterometer are often affected by weather condition such as precipitation and wind the necessity of near-continuous automatic measurement has arisen by the experiment in 2007. So we analyzed scattering characteristics of paddy rice obtained from

an X-band automatic scatterometer system and investigated the relationships between backscattering coefficients and the plant parameters.

Fig. 1 shows temporal variations of backscattering coefficients at polarization and incident angle 45° for the X-band. Backscattering coefficients of paddy fields at X-band range from about -50dB ~ -5dB. Change of σ° in X-band at 45° is similar to previous year.

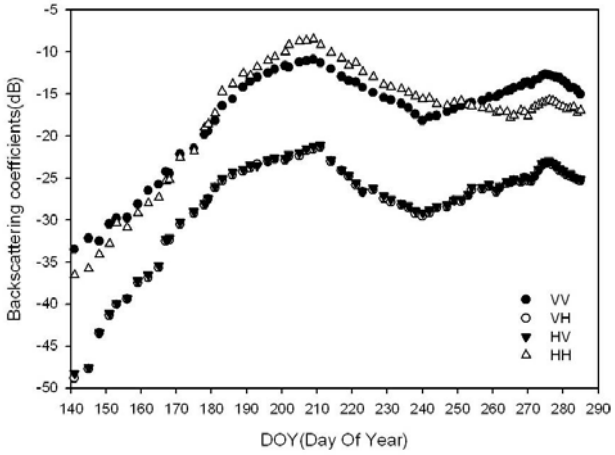

Fig 1. Temporal variations of backscattering coefficients at polarization and incident angle 45° for X-band.

We conducted a correlation analysis between the backscattering coefficients from L, C, X-band and plant variables such as LAI, biomass and grain weight. Biomass was correlated with L-band HH-polarization at a large incident angle. LAI was highly correlated with C band HH- and cross-polarizations. Table 2 shows the optimum condition between backscattering coefficients in three bands and rice growth parameters. Biomass was highly correlated with 50° of incident angle in HH polarization for L-band. The highest correlation coefficients for LAI were found at the 50° with HH-polarization in C-band. X-band backscattering coefficients close correlation with the grain weight (ultimately the grain yield). The highest correlations for each band were VV-polarization at incident angle 45° at X-band.

Table 2. Relationship between backscattering coefficients at each band and plant variables (Optimum condition)

Optimum condition	Band	Polarization	Incident angle	Correlation coefficient
Plant height (cm)	C-band	HV/VH	45	$r=0.95^{***}$
LAI	C-band	HH	50	$r=0.95^{***}$
Biomass ($g\ m^{-1}$)	L-band	HH	50	$r=0.97^{***}$
Grain dry weight ($g\ m^{-1}$)	X-band	VV	45	$r=0.89^{***}$

In summary, the lower frequency bands, such as L and C, were closely related with the mass information of the whole canopy such as LAI, biomass, while the higher-frequency band, such as X, is weakly correlated with them but closely correlated with the other variables such as grain weight.

This result is mainly attributed to the difference in relative size of wavelength and the penetration depth of each band. HH polarization responds more with vertical structure of rice plants than the others. Another trend was that the VV polarization was less well correlated with plant variables than the other polarizations in most cases.

This may be interpreted by the process that HH- and cross-polarizations penetrate more effectively into canopies and consequently have greater seasonal changes than the VV does. These results could provide the useful information for the interpretation of backscattering coefficients over vegetations, and monitoring of rice production areas using space-borne SAR.

4. Conclusion

Backscattering coefficients of rice crop were measured with a ground-based scatterometer. The temporal variations of the backscattering coefficients of the rice crop at L-, C-, and X-band during a rice growth period. VV-polarization backscattering coefficients were higher than HH-polarization backscattering coefficients in early rice growth stage. We conducted the relationship between backscattering coefficients with L-, C-, X-band and rice growth parameters. Biomass was highly correlated with L-band HH-polarization at a larger incident angle. LAI was highly correlated with C band HH- and cross-polarizations. X-band was sensitive to grain maturity at near harvesting season.

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