Monitoring of the rice growth using polarimetric scatterometer system

Yihyun Kim1, S.Yong Hong2, Eunyoung Choe3 and Hoonyol Lee4

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 scatterometer 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 660m². 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.

3. Results and Discussion

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-polarimetric backscattering coefficients of rice crop every 10 minutes. Backscattering coefficients were calculated by applying radar equation (Ulaby et al., 1990).

Table 1. Specification of polarimetric scatterometer system

<table>
<thead>
<tr>
<th>Specification</th>
<th>L-band</th>
<th>C-band</th>
<th>X-band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center frequency</td>
<td>1.27 GHz</td>
<td>5.3 GHz</td>
<td>9.65 GHz</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>0.12 GHz</td>
<td>0.6 GHz</td>
<td>1 GHz</td>
</tr>
<tr>
<td>Number of Frequency Points</td>
<td>201</td>
<td>801</td>
<td>1601</td>
</tr>
<tr>
<td>Antenna Type</td>
<td>Dual polarimetric horn</td>
<td>Dual polarimetric horn</td>
<td>Dual polarimetric horn</td>
</tr>
<tr>
<td>Antenna Gain</td>
<td>12.4 dB</td>
<td>20.1 dB</td>
<td>22.4 dB</td>
</tr>
<tr>
<td>Slant range resolution</td>
<td>0.15 m</td>
<td>0.25 m</td>
<td>1.25 m</td>
</tr>
<tr>
<td>Wavelength</td>
<td>0.031 m</td>
<td>0.056 m</td>
<td>0.23 m</td>
</tr>
</tbody>
</table>

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-polarimetric backscattering coefficients of rice crop every 10 minutes. Backscattering coefficients were calculated by applying radar equation (Ulaby et al., 1990).

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

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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 $\sigma^0$ in X-band at 45°
is similar to previous year.

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
related 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)

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

In summary, the lower frequency bands, such as L and C,
close 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
related 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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References
with radar. In: F. M. Henderson & A. J. Lewis (Eds), Principles and applications in imaging radar (pp. 381-406).
New York: Wiley.