POTENTIAL OF MULTI-BAND SAR DATA FOR CLASSIFYING FOREST COVER TYPE

Jung-il Shin, Jong-suk Yoon, Sung-jin Kang and Kyu-sung Lee

Department of Geoinformatic Engineering, Inha University
253 Yonghyun-dong Namgu Incheon, Republic of Korea
Tel : +82-32-860-8805, E-mail : jungil79@inhaian.net

ABSTRACT ... Although there have been lack of studies using X-band SAR data particularly for forestry application as compared to C-, and L-band SAR data, it has a potential to distinguish tree species because most signals are backscattered on the top of canopy. This study aimed to compare signal characteristics of multi-band SAR data including X-band for classifying tree species. The data used for the study are SIR-C/X-SAR data (X-, C-, L-band) obtained on Oct. 3, 1994 over the forest area near Seoul, S. Korea. Thirty ground sample plots were collected per each tree species. Initial comparison of backscattering coefficients among three SAR bands shows that X-band data showed better separation of tree species than C- and L-band SAR data irrespective of polarization. The weak penetrating in canopy layer might be possible source of information for X-band data to be useful for the classification of forest species and cover type mapping.

KEY WORDS: SAR, X-band, Backscattering coefficient, Tree species

1. INTRODUCTION

Synthetic Aperture Radar (SAR) is an active remote sensing system obtaining data regardless of weather condition. In forest related applications, C-, L-, P-band SAR data were primarily used due to the penetration capability in tree canopy. Applications of SAR data in forestry have been focused on the estimation of forest stand parameters, such as canopy height, stand density, volume, and biomass (Neeff et al, 2005; Walker et al., 2007; Ranson et al., 1997). However, there have been a few studies regarding the signal characteristics of X-band SAR data in forest related fields, because of the lack of data availability. In recent studies using X-band interferometric SAR and LiDAR data, forest canopy height was accurately estimated (Balzter et al., 2007; Hyde et al., 2006). Although with limited number of studies, it is rather well known that the high frequency radar signal, such as X-band, is mostly affected by leaves in canopy layer of forest. Also, Pierce et al. (1998) showed that X-band SAR data were crucial to improved the accuracy of forest type classification when it was used with C- and L-band SAR data.

Until now, most of X-band SAR data provided were primarily experimental stage and, therefore, few researches have presented about signal characteristics related to forestry and stand characteristics with X-band SAR data in forestry. Recently, several satellite SAR missions are planned, which includes TerraSAR-X of Germany, COSMO of Italy, and Kompsat-5 of S. Korea. In forestry, more studies are needed for signal characteristics of X-band SAR data. Therefore this study investigated signal characteristics of SAR data including X-band for potential on the classification of tree species and other forestry related applications.

2. STUDY AREA AND DATA

The study area is a mountainous national forest area near Seoul Metropolitan area, S. Korea. Since the study area has been well conserved by the Korea Forest Research Institute, it has sufficient and accurate forest information database to verify samples from SAR data. Dominant tree species are oak(*Quercus*), larch(*Larix leptolepis*), and Korean pine(*Pinus koraiensis*).

Synthetic Aperture Radar data, SIR-C/X-SAR, was obtained simultaneously on 3rd October 1994. SIR-C data (C- and L-band) were obtained with dual-polarized (HH, HV) mode and X-SAR data were obtained with VV polarization. All five datasets(XVV, CHH, CHV, LHH and LHV) were almost identical value of incidence angle and look directions. Table 1 shows specification of three data sets over the study area. Figure 1 shows the color composite of three bands of SIR-C/X-SAR data and it reveals significant effect of radar backscattering due to the topographic relief. As a preliminary study to compare the signal characteristics of three SAR bands, we are trying to collect sample ground plots that have almost identical topographic conditions.

Table 1. Specification of SIR-C/X-SAR data.

Sensor	SIR-C	X-SAR
Frequency(GHz)	5.304(C), 1.254(L)	9.602(X)
Polarization	HH, HV	VV
Date/Time(GMT)	Oct. 3, 1994 / 04:54:15.473	Oct. 3, 1994 / 04:54:18.240
Line/pixel spacing(m)	12.5 / 12.5	12.5 / 12.5
Orbital direction	Descending	Descending
Incidence angle at image center(deg.)	40.3460000	38.9921778

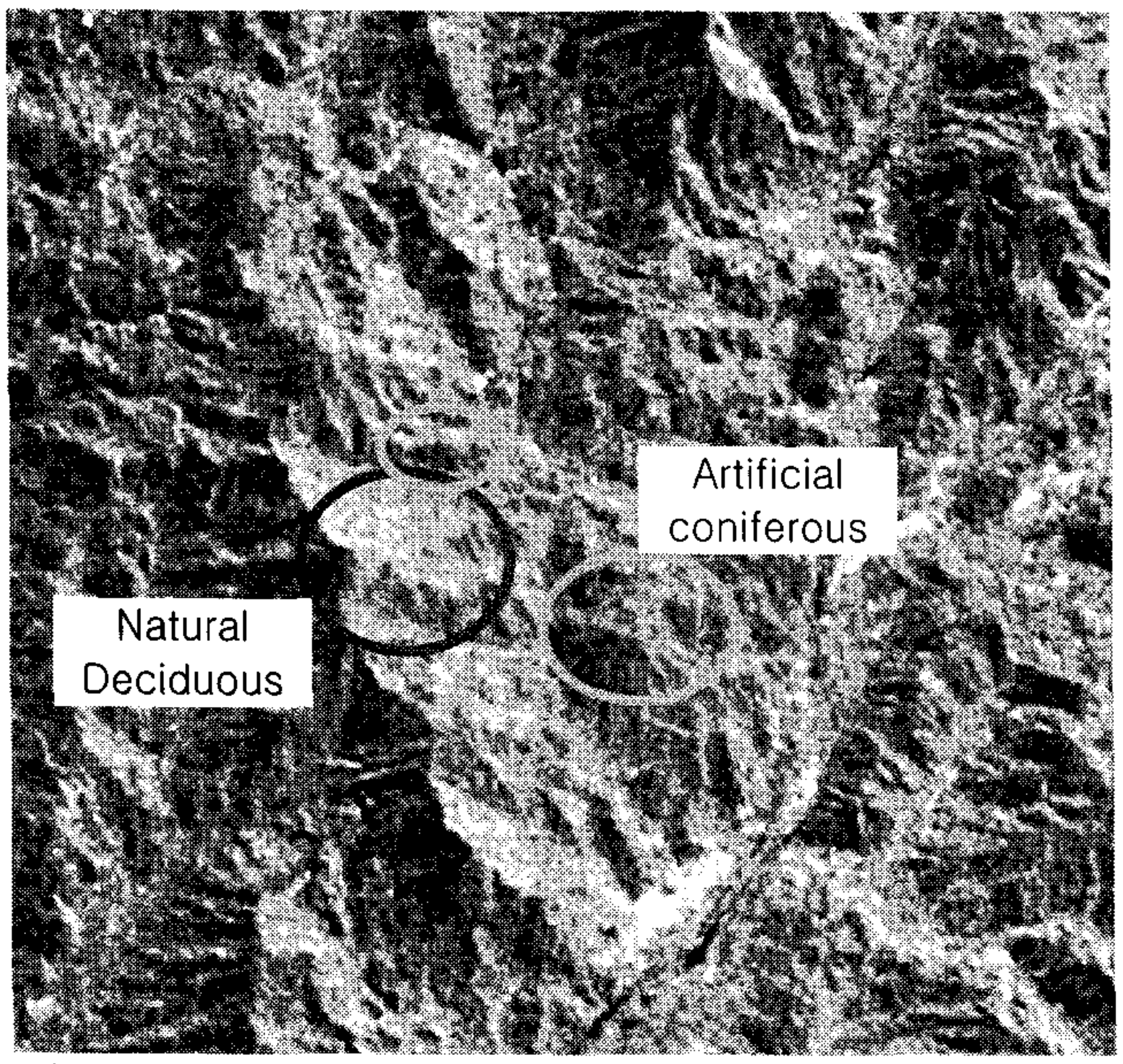

Figure 1. SIR-C/X-SAR data of study area(Kwangneung national forest, 9x10km^2), color composite(R : XVV, G : CHH, B : LHH).

3. METHODS

3.1 Pre-processing of SIR-C/X-SAR

As an initial process, the SIR-C and X-SAR data were radiometric calibrated as suggested by the data distributor (DLR and ASI, 1995) to convert pixel's DN value to backscattering coefficients (1).

$$I = K_S \times \sin(\theta_i) \times \frac{\sigma^0}{\sin(\theta_i - \alpha)} + \langle N_{raw} \rangle \times K_{N,0} \times K_N(i) \qquad (1)$$

where, I = DN^2, K_s = calibration constant, Θ_i = incidence angle, σ^0 = backscattering coefficient, α = local terrain slope, $\langle N_{raw} \rangle$ = average raw data noise power, $K_{N,0}$ = processor noise gain, $K_N(i)$ = cross-track radiometric correction vector(function of range).

SIR-C/X-SAR image was then filtered by the enhanced Frost filter which is known to be effective to reduce speckles and preserve edges information (Frost et al., 1982). The filtered image was registered with 1/5,000 topographic map. Total RMSE was 3.75 m.

3.2 Extraction of sample ground plots

To investigate the characteristics of backscattering coefficients among X-, C-, L-bands in the forest, we collected 30 ground sample forest stands per each species of three forest types (*Quercus, Larix leptolepis, Pinus koraiensis*). The precise location of these sample stands were extracted from the forest stand map generated by the large scale aerial photographs with ground survey. To avoid topographic effect on radar backscattering, we selected only those samples that are relatively flat or minor undulated terrain. Backscattering coefficients between X-, C-, L-band of each species using basic statistics and scatter plot.

4. RESULTS AND DISCUSSION

Descriptive statistics (mean and standard deviation) of backscattering coefficients were estimated from 30 samples per each tree species. In X-band(XVV), deciduous (*Quercus*) and two coniferous species (*Larix leptolepis and Pinus koraiensis*) have distinguishable mean and standard deviation of backscattering coefficient but two coniferous species showed similar each other. In C- and L-band irrespective of polarization, all tree species have quite similar backscattering coefficients. Table 2 shows mean and standard deviation of three species among X-, C-, and L-bands.

Figure 2 is scatter plots between two bands and polarization of X-, C-, L-band. In the scatter plots, backscattering coefficients of deciduous shows a separated cluster from coniferous between XVV and other bands(CHH, CHV, LHH, LHV), but for both C- and L-bands, backscattering coefficients of all species are mixed irrespective of polarization.

Table 3 and 4 show separabilities(JM-distance) among tree species using all three bands and only two bands excluding XVV. It is apparent that the class separabilties increase when the XVV data are included. In particular, the separability between deciduous and coniferous stand is higher with all three bands as compared to the two–band data set without XVV data.

Broad leaves of oak trees are larger than 3cm so almost X-band signals are reflected from canopy leaf layer. On the other hand, C- and L-band signals penetrated tree canopy and there can be backscattering contribution from stems and ground (Figure 3). Consequently, X-band of SAR is more useful to classify tree species than C- or L-band, at least for this temperate forest, because backscattered signal from top of the tree canopy has more information of tree species.

Table 2. Mean and standard deviation of backscattering coefficient between X-, C-, and L-band.

Freq. / Pol.	Species	Backscattering coefficient(dB)	
		Mean	Standard deviation
XVV	PK	-9.642	1.664
	PL	-9.228	1.687
	Q	-6.312	2.245
CHH	PK	-6.406	1.439
	PL	-6.413	2.028
	Q	-5.469	1.689
CHV	PK	-12.088	2.025
	PL	-10.764	1.802
	Q	-10.821	1.583
LHH	PK	-3.404	1.982
	PL	-4.097	1.836
	Q	-4.012	2.012
LHV	PK	-9.617	1.411
	PL	-9.613	1.921
	Q	-10.290	1.639

* PK : *Pinus koraiensis.*, PL : *Larix leptolepis*, Q : *Quercus*

Table 3. JM-distance among species with whole channel(XVV, CHH, CHV, LHH, LHV)

	PK	PL	Q
PK	-	0.4185	1.1267
PL	0.4185	-	0.8970
Q	1.1267	0.8970	-

Table 4. JM-distance among species with C- and L-band (except XVV)

	PK	PL	Q
PK	-	0.3413	0.5519
PL	0.3413	-	0.2601
Q	0.5519	0.2601	-

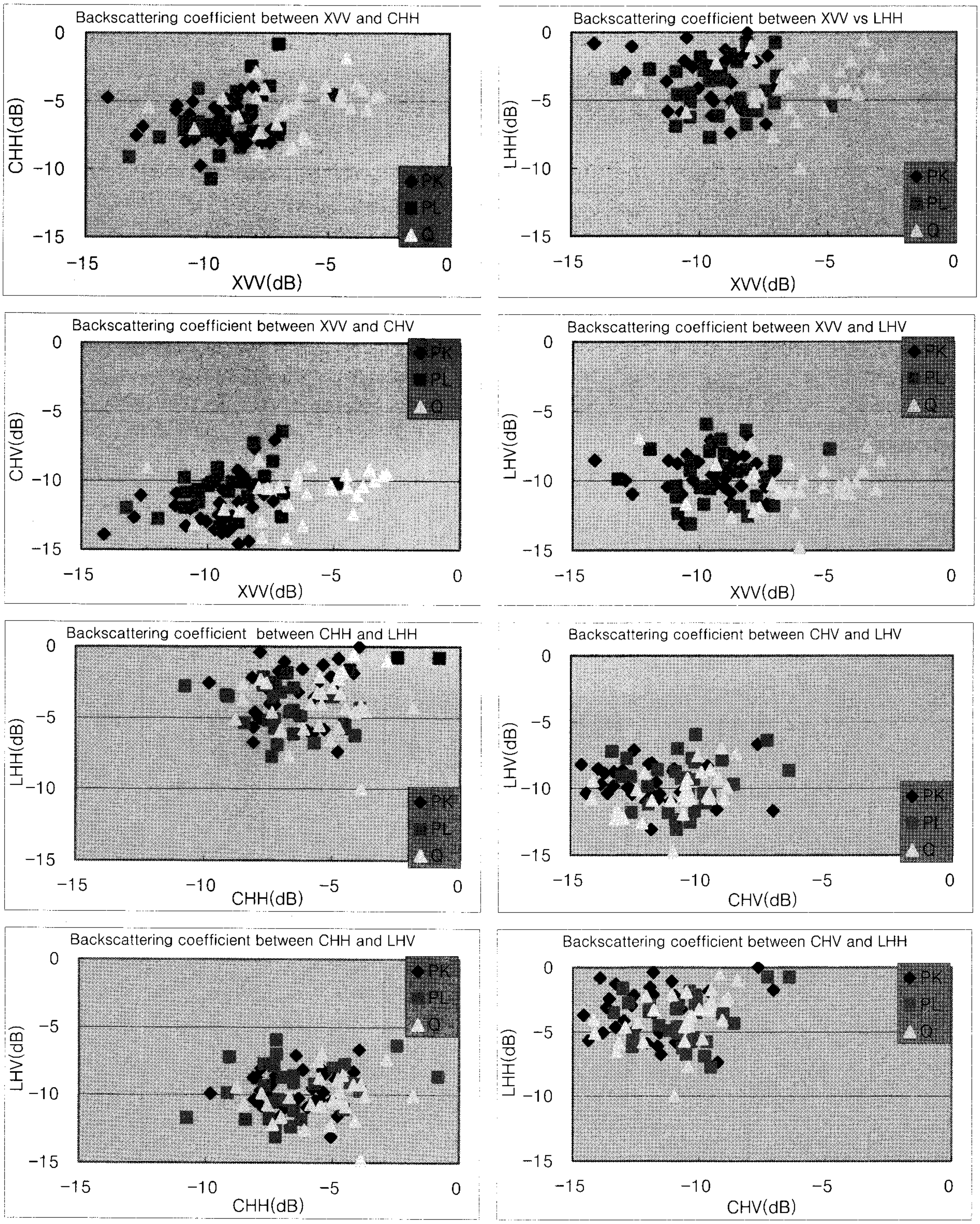

Figure 2. Scatter plot among X-, C- and L-band with polarization : XVV only can distinguish tree species among the 5 datasets(XVV, CHH, CHV, LHH, LHV).

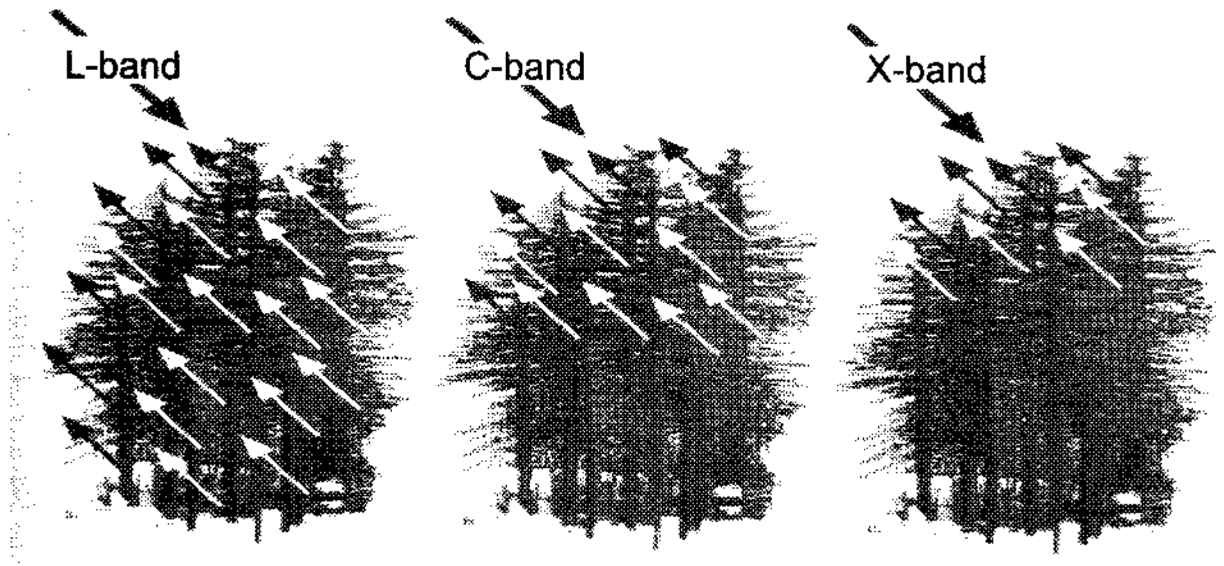

Figure 3. Penetration of L-, C-, and X-band signal in tree canopy(Jensen J.R.., 2000)

5. CONCLUSION

In this study, characteristics of radar signal from X-, C- and L-bands SAR data are compared over the temperate forest in S. Korea. To avoid topographic effects, 30 selected sample plots were mostly located in relatively flat area or minor undulated slope. Among three species compared, X-band SAR data were showed maximum differences between radar backscattering. The less penetration in stand canopy could be a possible explanation of the X-band signal as compared to the two other bands. X-band SAR data could be better suited for the mapping of forest cover type and species separation. Further study could consider characteristics by polarization and more various species. This study will be further extended to the application of X-band SAR in forestry along with the expected launch of KOMPSAT-5 satellite.

6. REFERENCES

H. Balzter, C.S. Rowland, and P. Saich, 2006, Forest canopy height and carbon estimation at Monks Wood National Nature Reserve, UK, using dual-wavelength SAR interferometry, Remote Sensing of Environment, 108(3), pp. 224-239.

DLR and ASI, 1995, X-SAR CEOS format, DLR, pp. 1-33.

V.S. Frost, J.A. Stiles, K.S. Shamugan, and J.C. Holtzman, 1982, A model for radar images and its application to adaptive digital filtering of multiplicative noise, IEEE Transition Pattern Analysis and Machine Intelligence, 4(2), pp. 157-166.

F.M. Henderson and A.J. Lewis, 1998, Principal and Application of Imaging Radars – Manual of Remote Sensing, ASPRS, pp. 480-481

P. Hyde, R. Nelson, D. Kimes, and E. Levine, 2007, Exploring LiDAR-RaDAR synergy – predicting aboveground biomass in southwestern ponderosa pine forest using LiDAR, SAR and InSAR, Remote Sensing of Environment, 106(1), pp. 28-38.

J.R. Jensen, 2000. Remote sensing of the environment – an earth resource perspective, Prentice Hall, pp. 285-316.

T. Neeff, P. Gracia, L. Dutra, and C. Freitas, 2005, Carbon budget estimation in central Amazonia : Successional forest modeling from remote sensing data, Remote Sensing of Environment, 94(4), pp. 508-522.

L.E. Pierce, K.M. Bergen, M.C. Dobson, F.T. and Ulaby, 1998, Multitemporal land-cover classification using SIR-C/X-SAR imagery, Remote Sensing of Environment, 64(1), pp. 20-33.

K.J. Ranson, G. Sun, J.F. Weishampel, and R.G. Knox, 1997, Forest Biomass from combined ecosystem and radar backscatter modeling, Remote Sensing of Environment, 59(1), pp. 118-133.

W.S. Walker, J.M. Kellndorfer, and L.E. Pierce, 2007, Quality assessment of SRTM C- and X-band interferometric data : Implications for the retrieval of vegetation canopy height, Remote Sensing of Environment, 106(4), pp. 428-448.