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Development of the Fully Polarimetric FM-CW SAR and the Coherent Decomposition of Target

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1. Introduction

The L-and X-band are mainly used in microwave radar remote sensing. In addition, Ku-band radar is attracting attention as next generation's Synthetic Aperture Radar(SAR), Because Ku-band radar achieves very high resolution by allotted frequency band. For this reason, a fully polarimetric FM-CW SAR system of the X-and Ku-band has been developed in Niigata University.

In this paper, the developed X-and Ku-band fully polarimetric FM-CW radar system is shown. The obtained data is polarimetrically calibrated by using a parallel plate target. In addition, the four-component decomposition by a coherency matrix is formulated, and availability is verified by experiments in anechoic chamber.

2. Hardware Composition of FM-CW Radar System

A block diagram of the developed FM-CW radar system [1], [2] is shown in Fig.1. Considering mobility and stability, this system is divided into three main parts. They are vicinity of PC, RF/Antenna box and IF box. These parts are shown in Figs.2-4.

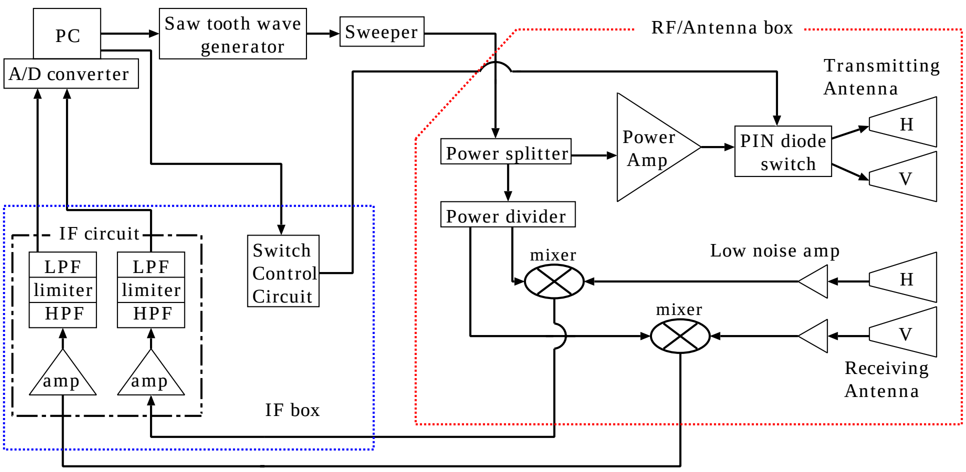

Figure 1: Block diagram of FM-CW radar

The radar system acquires scattering matrix quickly by PIN diode switching system. The acquisition time is about 20 msec. This radar system achieves very high resolution in range (7.5cm by default mode). The resolution range can be adjusted arbitrarily by changing the sweep frequency band. Furthermore, radar position in the azimuth direction is acquired by a rotary encoder system. This enable us to take scattering matrix quickly and easily. RF/Antenna box has two versions of X- and Ku-band. This system can accommodate both frequency band by replacing these boxes. In addition, this system can be extended to interferometry mode by adding two antennas [3].

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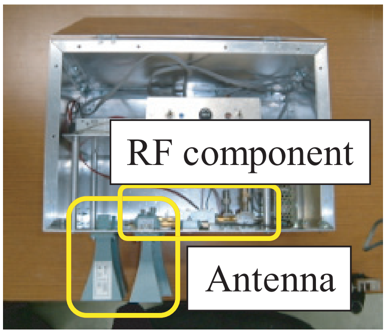

Figure 2: Ku-band antenna box

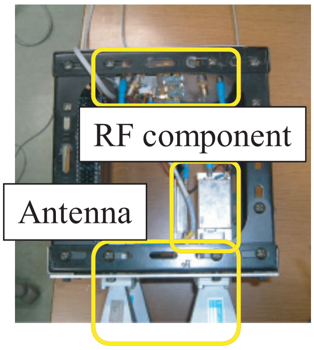

Figure 3: X-band antenna box

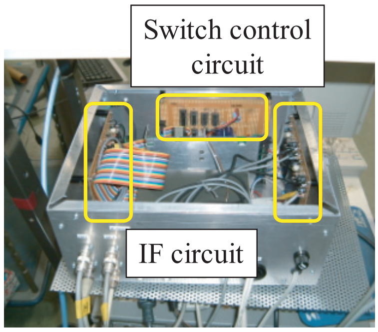

Figure 4: IFbox

3. Control Software of Radar System

Real time analysis mode of a scattering matrix was developed for data acquisition stage. Furthermore calibration mode and measurement mode for SAR image was developed. These modes support the task for measurement. Each mode image is shown in Figs.5-6

Figure 5: Realtime analysis mode

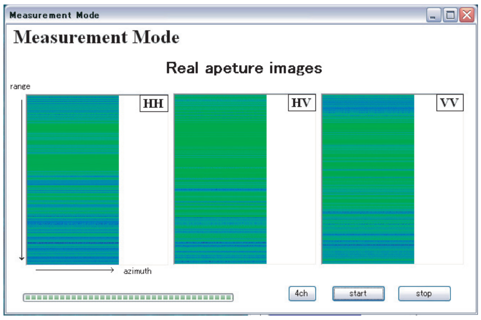

Figure 6: Measurement mode

4. Polarimetric Calibration

Since obtained scattering matrix contains some measurement errors, it is necessary to calibrate. The polarimetric calibration is carried out by a parallel plate target [4] in this experiment. From the polarization signature after the calibration, the obtained data is corrected.

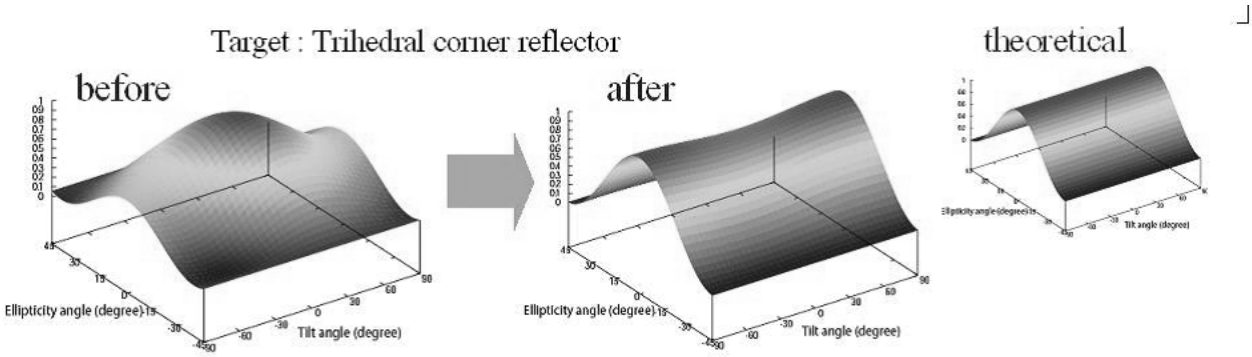

Figure 7: Polarimetric calibration

5. Four-Component Decomposition by Coherency Matrix

A four-component decomposition is a method that decompose received scattering matrix into four scattering powers [5]. These models are surface, double, volume and helix. Using a coherency matrix(1), we decompose it into four scattering powers.

The coherency matrix is

$$\langle [T] \rangle^{HV} = \begin{bmatrix} \frac{1}{2}\langle |S_{HH}+S_{VV}|^2 \rangle & \frac{1}{2}\langle (S_{HH}+S_{VV})(S_{HH}-S_{VV})^* \rangle & \langle (S_{HH}+S_{VV})S^*_{HV} \rangle \\ \frac{1}{2}\langle (S_{HH}-S_{VV})(S_{HH}+S_{VV})^* \rangle & \frac{1}{2}\langle |S_{HH}-S_{VV}|^2 \rangle & \langle (S_{HH}-S_{VV})S^*_{HV} \rangle \\ \langle S_{HV}(S_{HH}+S_{VV})^* \rangle & \langle S_{HV}(S_{HH}-S_{VV})^* \rangle & \langle 2|S_{HV}|^2 \rangle \end{bmatrix} \quad (1)$$

where $\langle\rangle$ is ensemble average. This matrix is decomposed by following:

$$\langle [T] \rangle^{HV} = P_s[T]_{plate} + P_d[T]_{diplane} + P_w[T]_{wire} + P_c[T]_{helix} \quad (2)$$

The expansion matrixes are derived from theory.

$$[T]_{plate} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \qquad [T]_{diplane} = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \cos^2 2\varphi & -\frac{\sin 4\varphi}{2} \\ 0 & -\frac{\sin 4\varphi}{2} & \sin\ 22\varphi \end{bmatrix}$$

$$[T]_{wire} = \frac{1}{2}\begin{bmatrix} 1 & \cos 2\theta & -\sin 2\theta \\ \cos 2\theta & \cos\ 22\theta & -\frac{\sin 4\theta}{2} \\ -\sin 2\theta & -\frac{sin 4\theta}{2} & \sin^2\theta \end{bmatrix}, \qquad [T]_{helix} = \frac{1}{2}\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & \mp j \\ 0 & \pm j & 1 \end{bmatrix} \quad (3)$$

Ps, Pd, Pw and Pc are power contributions from plate, diplane, wire and helix. φ and θ are rotation angle of diplane and wire from the horizontal direction. This method is available only for coherent data.

6. Experiment of Target Classification

Experiment of a basic target classification using the four-component decomposition by the coherency matrix was carried out in anechoic chamber. The targets are conductive sphere, diplane and parallel plate. Experiment condition and measurement parameter are shown in Fig.8 and Table.1 respectively.

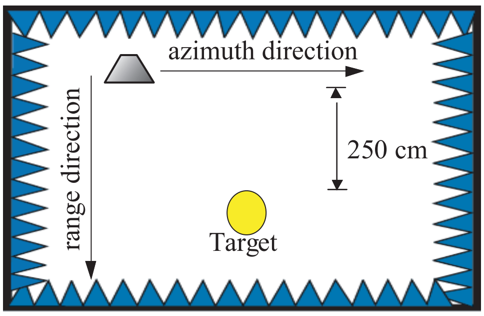

Figure 8: Experiment condition

Table 1: Measurement parameter

Center frequency	10 GHz
Sweep frequency	2 GHz
Sweep time	5 ms
Scan points	64
Scan interval	1 cm
FFT point	16384
Incident angle	0 deg.

The analysis result is shown in Figs.9-11. These results are SAR processed and polarimetrically calibrated. For these images, all targets are well classified with high accuracy.

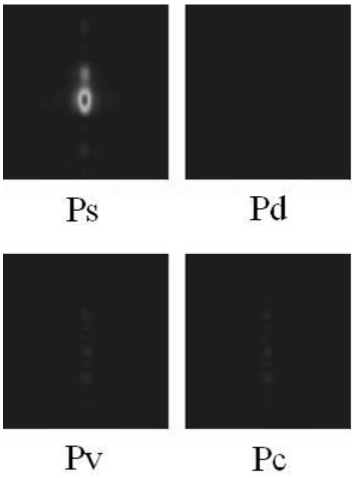

Figure 9: sphere

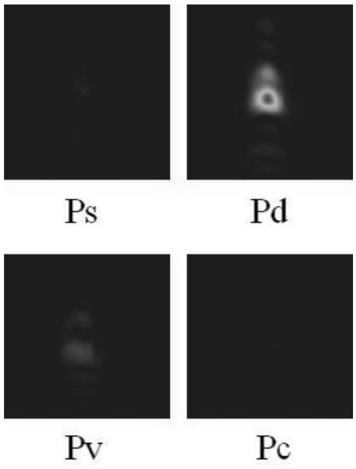

Figure 10: diplane

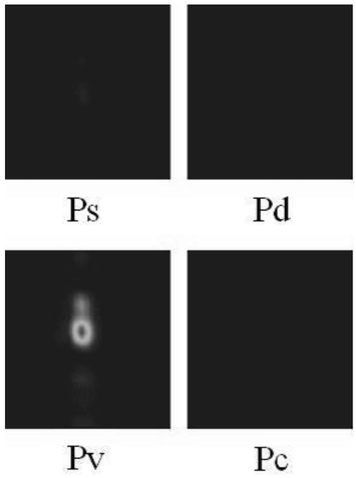

Figure 11: parallel plate

7. Conclusion

The Ku-and X-band fully polarimetric FM-CW radar system is developed. The system has very high resolution imaging capability. In addition, the developed control software and the rotary encoder system enabled us to acquire data quickly. Furthermore the availability of the four-component decomposition by the coherency matrix is confirmed by the experiment in anechoic chamber.

Acknowledgments

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References

[1] M. Ikarashi, J. Nakamura, K. Aoyama, Y. Yamaguchi, and H. Yamada, "Laboratory Measurements by a Fully Polarimetric FM-CW SAR in the Ku-Band, ", PIERS2006, Tokyo, Japan, pp.175, 2006.

[2] M. Nakamura, Y. Yamaguchi and H. Yamada, "Real-Time and Full Polarimetric FM-CW Radar and its Application to the Classification of Targets, ", IEEE Trans. Instrum Measur., Vol. 47, No. 2, pp.572–577, April 1998.

[3] M. Ikarashi, K. Aoyama, J. Nakamura, Yamaguchi, and H. Yamada, "A New FM-CW Pol-InSAR System for Laboratory Measurement, ", PIERS2006, Tokyo, Japan, pp.174, 2006.

[4] K. Kitayama, Y. Takayanagi, Y. Yamaguchi and H. Yamada, "Polarimetric calibration using a corrugated parallel plate target, ", IEICETrans., Vol. j81-BII, No. 10, pp.914–921, Oct. 1998.

[5] Y. Yamaguchi, T. Moriyama, M. Ishido, H. Yamada, "Four-component scattering model for polarimetric SAR image decomposition, ", IEEE Trans. Geosci. Remote Sens., Vol. 43, No. 8, pp.1699–1706, Aug. 2005.