Calibration of Ground-Based Full-Polarimetric Scatterometer for L-, C-, and X-Bands

#Ji-Hwan Hwang, Soon-Gu Kwon, Yisok Oh

Department of Electronic Information and Communication Engineering, Hongik University.

72-1 Sangsu-Dong, Mapo-Gu, Seoul, Korea; ji-hwan_hwang@mail.hongik.ac.kr

Abstract

A measurement technique for calibrating the HPS(Hongik Polarimetric Sactterometer) for L-, C-, X-band frequencies is presented in this paper. Especially, to overcome the integration problem with a large L-band sensor part, we propose a new compact OMT (Orthogonal Mode Transducer) for L-band. The performances of the integrated HPS system for multi-bands on single platform was evaluated and calibrated by the STCT (Single Target Calibration Technique) and the 2DTST (2D Target Scanning Technique). The evaluation of the calibration accuracy in the field experiment can secure the precise calibration accuracy within 0.5 dB for magnitude correction and less than 4^{o} for phase correction in each bands.

Keywords : HPS, calibration accuracy, 2DTST, STCT, reliability zone.

1. Introduction

HPS (HongIk Polarimetric Scatterometer) has been developed for backscattering coefficient measurements of various kinds of earth surfaces for remote sensing purposes such as the soil moisture estimation at L-, C-, and X-bands [1]. Our systems are going to be extended its capability for multi-band operations at L-, C-, and X-bands, because it is increasingly required to develop scattering and inversion models for the various satellite SAR systems at those frequency bands. In the previous studies, we had focused on the development of X-band (9.65 GHz) system as a test-bed of the Korea Multi-purpose Satellite-5 (KOMPSAT-5) and then the system-integration of the existing HPS systems for C- and X-bands was successfully achieved to share a single platform. The existing HPS system has an active sub-circuit which consists of a frequency-conversion part, a switch part, an amplification part, and a power supply part. The switch part is for the frequency and polarization selections and it makes possible to efficiently and rapidly operate system. However, it has been difficult to share the system with the L-band scatterometer because its sensor part is too big to be installed, although we adopt a class-1 of the commercial OMT, a square horn antenna and two waveguide adaptors. Especially, to integrate L-band system into the existing HPS system, we newly designed a compact OMT structure and the performances of the integrated system with this OMT were measured [2].

In this paper, we present the system integration work for multi-band operation, the calibration results for field experiments, and the evaluation method for their accuracies. The accuracy of the system calibration in the field-condition depends on the precise measurement of a calibration target such as a metal sphere, a metal cylinder, and a corner reflector [3, 4]. We also show an automatic measurement technique with an error reduction on target alignment, using the 2-D target scanning technique (2DTST)[5], and also briefly introduce the automated calibration procedure using 2DTST and STCT(Single Target Calibration technique)[6].

2. New Compact OMT

The sensor part of the HPS has a horn antenna and OMT structure for each frequency band. The existing L-band OMT is large with a total length of 1.3m, which makes the system integration difficult. Therefore, we reduced the size of the L-band OMT using the ridged-waveguide as shown in Figure 1; about 66% (0.86m) and 62% of the existing OMT for the total length and cross-section, respectively[2,7]. Inserting ridges inside a waveguide lowers the cutoff-frequency of waveguide and we can take advantages of this fact in OMT design. Figure 1 shows the prototype and the internal view of a new OMT for L-band and it has a simple shape without any branch ports. Table 1 shows the performances and total lengths of sensor parts for L-, C-, and X-bands.

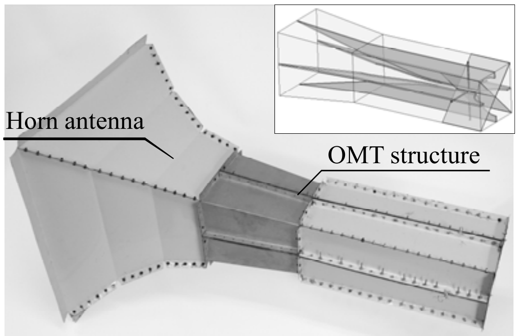


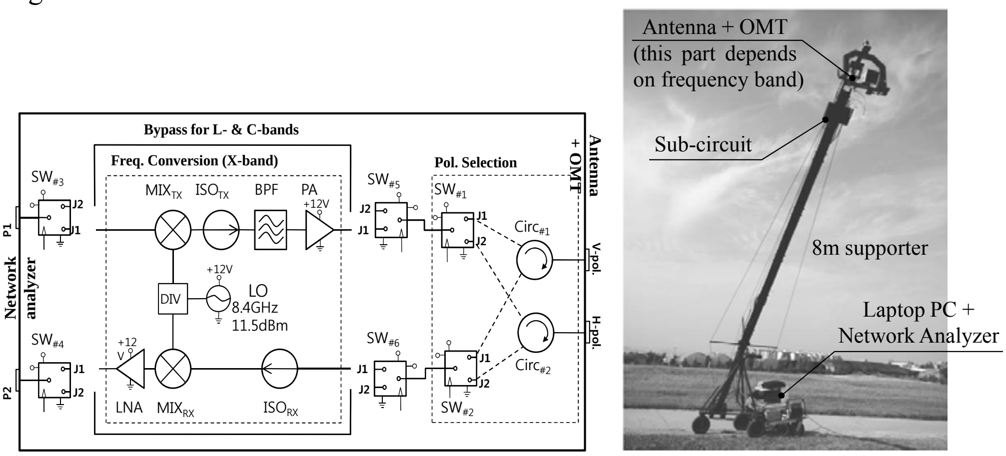
Figure 1: Prototype of the newly designed OMT for L-band.

Table 1: Specification of L-, C-, and X-bands OMT+horn antennas

Freq. [GHz]	HPBW[deg]		Gain [dBi]	Total length [mm]
	E-plane	H-plane		
1.27	29.0	35.0	16.1	860
5.25	25.0	29.0	17.5	440
9.65	11.9	13.2	22.8	540

3. Multi-Band HPS System

The platform of the HPS system consists of an 8-m movable tower, microwave and control circuits, antenna/OMT structure, a vector network analyzer (Agilent 8753E) and self-programmed GUI software with a laptop computer. We modified the sub-circuit of the HPS system to add L- and C-bands, especially, because the X-band system has an additional active circuit for frequency conversion from 9.65GHz to 1.25GHz and vice versa. Four frequency selection switches for L- & C- and X-bands have been added, and the signals of the L- and C-bands are bypassed the frequency converting circuit.



a) b)

Figure 2: Integrated HPS system for multi-bands & multi-polarizations: a) a block diagram of the sub-circuit for frequency selection and converting and b) the external view of the HPS.

Figure 2 shows an external view of HPS system and a block diagram of the sub-circuit for multi-bands. To control all system and measurement procedure, the self-programmed GUI is used and these configurations can be referred to [5].

4. Evaluation of Calibration Accuracy

The operating software supports an automated measurement in the all operating frequencies and offers an additional function for system calibration in the field experiment, using the so-called '2-D Target Scanning Technique' which is based on the automatic incident angle control [5]. Figure 3 represents the concepts of coordinate system for 2DTST. The antenna system of the HPS scans the space of a calibration target with an angular resolution of 1° to get the boresight *'centered'* data by rotation of the antenna on elevation and azimuth direction. The automatic scanned data provides a well-aligned measured data, in which the '*centered*' data of a maximum value is graphically searched by drawing 3D plot [5]. And, the logical space is used to generate a virtual grid of the physical space and to control the motion of the HPS system.

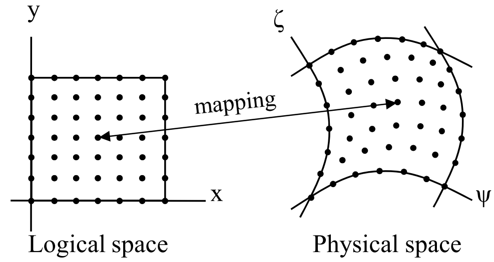


Fig. 3. Concept view of coordinate mapping for 2DTST.

To evaluate the performance of the integrated HPS system, we calibrated the system using point targets such as a metal sphere and a trihedral corner reflector. For the system calibration, a metal sphere of 30cm diameter was used as a reference target and two kinds of corner reflectors, having the sizes of 30cm and 55cm, were also used to evaluate the calibration accuracy of each bands.

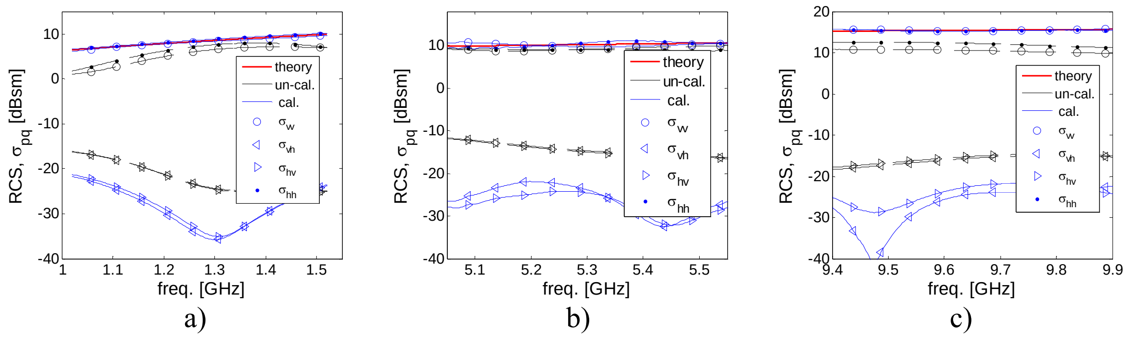


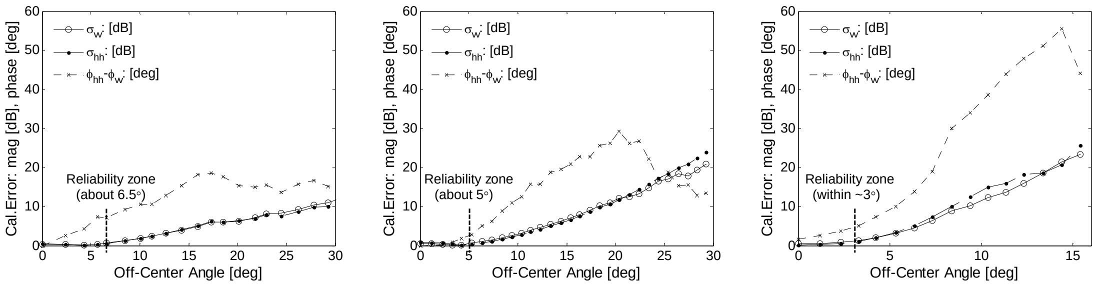
Figure 4: Calibration results using HPS system for muti-frequency bands and various sizes of test-targets: a) L-band (CR55cm), b) C-band (CR30cm) and c) X-band (CR30cm).

These automatically measured well-aligned *centered* data were used to calibrate the scatterometer system. Figure 4 show the full-polarimetric frequency responses of the test targets at each frequency bands. Corner reflectors theoretically have no cross-polarized backscatteres while the measured data have a low level, depending on the sensitivity of measurement system and experimental condition, and they were reduced by calibration work. Accordingly, an effective polarization isolation of the calibrated system increases about 10dB than before at all frequency bands. Next, we defined the calibration accuracy for a simple representation of the comparison result using data arrays as in (1). The calibration accuracy of each band of the integrated HPS system is evaluated by the RMS value of the norm of residuals, which is commonly used to evaluate the similarity of two different data arrays, between the *theoretical* and well-aligned *measured* responses of test targets using 2DTST and STCT.

$$Cal.\ accuracy = \frac{norm\left\| \bar{M}_{pq:theory} - \bar{M}_{pq:meas.} \right\|}{\sqrt{\#\text{of data points}}} \tag{1}$$

The calibration accuracy of each band of the integrated HPS system is evaluated by the RMS value of the norm of residuals, which is commonly used to evaluate the similarity of two different data arrays, between the *theoretical* and well-aligned *measured* responses. The calibration accuracy of co-polarization (vv-, hh-) for each bands were calculated by (1), and the results show the calibration error of 0.22dB for L-band, 0.48dB for C-band, and 0.19dB for X-band, respectively.

Figure 5 show the calibration accuracy changes depending on the degree of mis-alignments. As farther away from the '*centered*' data, the calibration errors in terms of magnitude and phase for co-polarizations increased. By using these results, we can assign the *'reliability zone'*, which is *well-aligned* region to guarantee the calibration accuracy of 0.5dB in field experiments, for each band of the integrated HPS system. The *reliability zone* of each band exists within 6.5° for L-band, 5° for C-band, and 3° for X-band, respectively. The co-polarized phase differences (Φ_{hh}-Φ_{vv}) are less than 4° inside the *reliability zone* for C-, X-band, except for L-band result shows the phase error of 8°. It will be the guide line for system operators doing calibration works in the field condition and also the system setup of 2DTST for automatic measurements.



a) b) c)

Figure 5: Calibration accuracy of HPS depending on the degree of mis-alignment: a) L-band, b) C-band and c) X-band.

5. Concluding Remarks

The integrated HPS system supports the capability of multi-band & multi-polarization operation with a single platform. And the 'reliability zone' of this integrated system for accurate calibration shows the angular ranges of 6.5°(L-band), 5°(C-band) and 3°(X-band), respectively, to guarantee the calibration accuracy of 0.5dB. The integrated HPS system for L-, C- and X-bands will give a great help to investigate the full-polarimetric and multi-band responses of various distributed targets.

References

[1] P. O'Neill, T. Jackson, D. Entekhabi, and E. Njoku, "Survey of L-Band Tower and Airborne Sensor System Relevant to Upcoming Soil Moisture Missions," *IEEE Newsletter Geosci. Remote Sensing*, Cumulative Issue #151, ISSN 0274-6338, pp. 13-16, Jun. 2009.

[2] J. -H. Hwang, Y. Oh, "Compact Orthomode Transducer Using Single-Ridged Triangular Waveguide", *IEEE Microw Wireless Compon Lett.*, accepted for publication.

[3] G. T. Ruck, D. E. Barrick, W. D. Stuart, and C. K. Krichbaum, *Radar Cross Section Handbook*, Plenum Press, New York, USA, 1970.

[4] F. T. Ulaby, and C. Elachi, *Radar Polarimetric for Geoscience Applications*, Artech House, Norwood, MA, USA, 1990.

[5] J.-H. Hwang, S.-M. Park, S.-G. Kwon, Y. Oh, "Study on the calibration of a full-polarimetric scatterometer system at X-band (in Korean)", *Korea Institute of Electromagnetic Engineering and Sciences (KIEES)*, vol. 21, no. 4, pp. 408-416, Apr. 2010.

[6] K. Sarabandi, and F. T. Ulaby, "A convenient technique for polarimetric calibration of single-antenna radar systems," *IEEE Trans. Geosci. Remote Sensing*, vol. 28, no. 6, pp. 1022-1033, Nov. 1990.

[7] A. M. Bøifot, E. Lier, T. Schaug, "Simple and broadband orhtomode transducer", *IEE Proc., Microw. Antennas Propag.*, vol.137, no. 6, pp. 396-400, Dec. 1990.

Acknowledgments

This work was supported by the Mid-career Researcher Program through NRF grant funded by the MEST of Korea (No. 2011-0000087).