SUPPRESSION OF UNDESIRED POLARIZATION FROM GRID REFLECTOR

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1. Introduction

Conducting grid reflects radio waves that are polarized in parallel to the grid, and transmits that polarized perpendicularly to them. Because of its simple structure and high polarization discrimination ratio, conducting grids have being used in wide variety of applications. Fujita and his group developed a polarimetric radar calibration algorithm that uses two point targets [1] and its extended version that can correct the influence of Faraday rotation as well [2] applicable to polarimetric calibration of PALSAR sensor onboard the ALOS satellite to be launched in 2005. For applying grid reflectors to the PALSAR calibration, we have conducted extensive measurements of grid reflectors to find out appropriate grid parameters that satisfy the requirements [3].

This paper presents the design and measurement results of grid reflectors. A new method to suppress undesired polarization component is proposed and its validity is proved through measurements conducted in a radio anechoic chamber.

2. Reflection from Conducting Grids

It is well known that conducting grids can discriminate a wave polarized linearly in the grid direction from that polarized perpendicularly to it. So, by using this simple structure, we can easily form a polarization selective reflector (PSR). The parameters that determine its reflection and transmission coefficients are grid period **P**, grid width **L**, and polarization angle α (see Fig. 1). One of the most important parameters of PSR is a polarization discrimination ratio (PDR), which is a ratio of the amplitudes of waves of the desired and undesired polarizations. To properly design PSR, we need to know the reflection and transmission characteristics of conducting grids as a function of grid parameters. There are numbers of methods to calculate the reflection and transmission coefficient of arbitrary polarized waves. Among them, we used the method in [4] because of its relatively simple nature to calculate the coefficients. The geometrical relation of polarization grid and incident wave is shown in Fig.2. When we use this type of reflector in SAR calibration, the incident angle of SAR signal will be in the normal direction to the face of the reflector ($\theta = \phi = 0$).

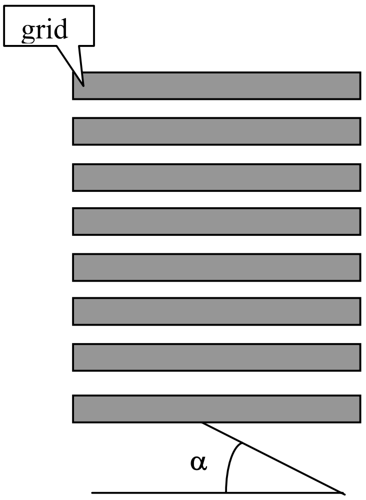

Fig. 1. Definition of grid parameters

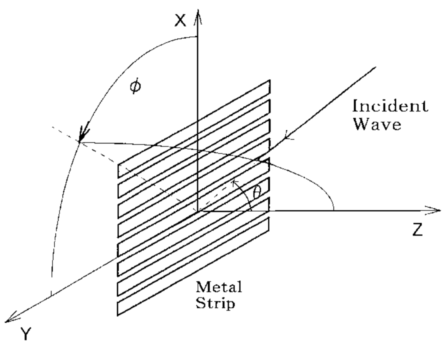

Fig. 2. Geometrical relation between polarization grid and incident wave

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3. Polarization Selective Reflector

We manufacture polarization selective reflectors (PSRs) following the grid theory [5] by putting aluminum tapes on Styrofoam boards. The assuming radar frequency is 1.27 GHz (wave length: 23.6 cm), so the Styrofoam board is transparent or invisible to the radio wave. This will enable to simulate grids that are floating in air. The grid parameters adopted in the test are 0.6, 0.8, 1.0, 2.0, and 4.0 cm for grid period P and 0.3, 0.4, 0.5, 1.0, and 2.0 cm for grid width L, respectively. The reflector size is 90-cm square. Outer view of the PSR is shown in Fig. 3.

Fig. 3. Outer view of a PSR under test.

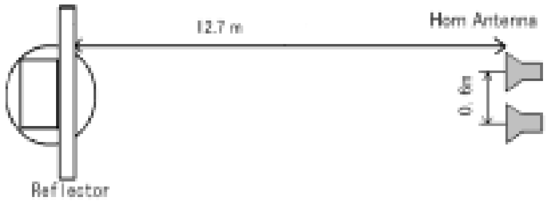

Fig. 4. Measurement system

Reflection characteristics of the PSR were evaluated using a network analyzer by connecting horn antennas to the S1 and S2 ports. We measured the S21 characteristics of the overall path including the PSR as a function of the rotating angle of it. Fig.4 shows the conceptual image of the measurement in a radio anechoic chamber seen from atop. The measured S21 values were converted to RCS by comparing with that of the reference aluminum plate of the same size. Because RCS of a metal plate agrees well with theoretical value, we can use it as an RCS reference.

Theoretical and measured PDRs and the RCSs versus of the PSRs are listed in table 1 as a function of the structure parameters.

Table 1. RCS, PDR values of PSRs as a function of structure parameters

P [cm]	**L** [cm]	**RCS** [dBm^2]	PDR	
			Theoretical	**Measured**
0.6	0.3	22.2	35.2 dB	35.3 dB
0.8	0.4	22.3	32.7 dB	33.0 dB
1.0	0.5	22.3	30.8 dB	31.1 dB
2.0	1.0	22.4	24.7 dB	23.9 dB
4.0	2.0	22.5	18.7 dB	18.9 dB

To Calibrate space SAR, the target RCS must be no less than 35dBm^2. Presuming a square-plate reflector operating at L-band (1.27GHz), we need an area of 1.9×1.9 m^2. Because the SAR calibration algorithm needs the PDR value better than 30 dB [1], we have to adopt the grid period P and width L to be less than 1 cm and 0.5 cm, respectively. This means that more than 380 conducting grids would be needed with length 190 cm and width less than 0.5 cm. This kind of long and narrow grids are not impossible to make, but would not be easy. To solve this problem, we came up with the idea of canceling the perpendicular polarization (undesired polarization) component with double-grid-layer structure with spacing of a quarter wavelength.

4. Double Layer PSR

Placing a conducting grid parallel to the surface grid with spacing of λ/4, thus forming two layers of conducting grid surfaces parallel to each other. The λ/4 spacing was obtained by a Styrofoam board with λ/4 of thickness, and grids were put on both sides of it. With this structure, we can suppress the undesired polarization and improve the PDR as compared to the single layer structure described in the previous section. This structure is called DPSR hereafter. Double layer structure of dielectric sheets was proposed [5], but not of grids. Brief explanation of the DPSR is given below by referring to Fig. 5. Even with narrow grids, a small portion of undesired polarization perpendicular to the grid is reflected from the surface grid, and rest of the most will transmit it.

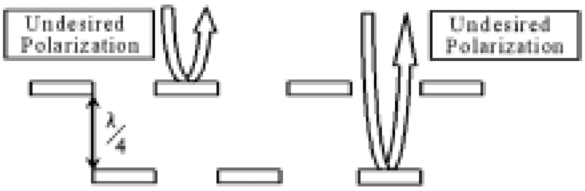

Fig. 5. Principle of suppression of the undesired polarization component using DPSR

The element that transmits the surface grid reaches the second grid, and again a small amount of it will be reflected from the second grid. The transmission ratio of the undesired polarization is nearly one, so the reflection amplitude from the two grids are nearly the same and have opposite phases, thus the reflected undesired polarizations are cancelled out to be almost zero. Although the desired polarization component is reduced, but the amount is negligible because almost all of the desired polarization component is reflected with the surface grid, and a fraction that causes the cancellation of desired polarization is transmitted to the second grid, it is negligibly small.

Fig. 6 shows an example of the reflection characteristics of DPSR with grid parameters of P=2.0cm (0.085 λ), L=1.0cm (0.042 λ) on both sides of a Styrofoam board of 6-cm thickness.

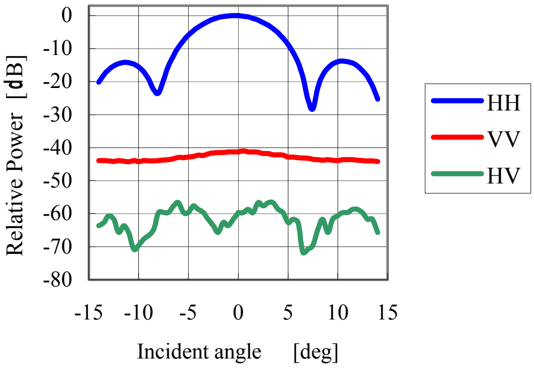

Fig. 6. Example of reflection characteristics of DPSR (P: 2 cm, L: 1 cm)

It can be clearly seen that VV (undesired polarization) is well suppressed by about –40 dB relative to HH (desired polarization). The measured PDR and RCS of DPSR are summarized in Table 2 as a function of the structure parameters of P and L..

Table 2. Grid parameters and RCS, PDR values of Double Layer PSR at 1.27 GHz.

P [cm]	L [cm]	RCS [dBm^2]	Measured PDR [dB]
2.0	1.0	22.3	41.3
4.0	2.0	23.0	29.6

Comparing Tables 1 (PSR result) and 2 (DPSR result), DPSR has better PDR by more than 10dB than (single layer) PSR with the same grid parameters P and L. Therefore, we can verify that the undesired polarization, the polarization perpendicular to the grid, was well canceled with the double layer structure shown in Fig. 5.

DPSR cancels the undesired polarization by superposing opposite phase waves from its both sides. The phase difference between the two undesired polarizations is therefore determined by the thickness of the Styrofoam board, so the PDR must have frequency dependence. Frequency characteristic of the PDR was measured for the DPSR (grid parameter: P=2.0cm (0.084), L=1.0cm (0.042)) and the result is shown in Fig. 7.

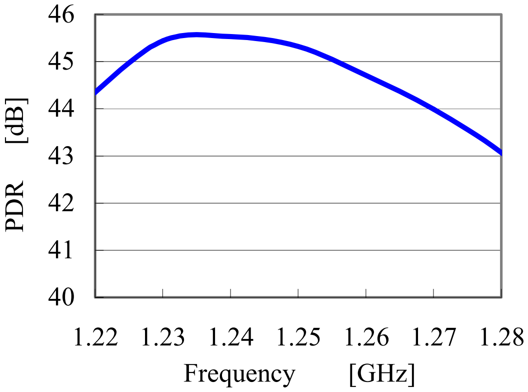

Fig. 7. Frequency characteristic of PDR of DPSR (P: 2 cm, L:1 cm)

Because the thickness of the Styrofoam was 6 cm, the measured DPSR was set tuned to 1.25 GHz, rather than 1.27 GHz. Fig. 7 shows that the peak is shifted to the lower frequency and the PDR level varies by about 1dB within the 0.05GHz range. The reason of the peak shift may be due to the manufacturing accuracy of the reflector. The adherent substance of the strip and the inaccurate thickness (± 1mm) of the Styrofoam are thought to be the causes. Because bandwidth of SAR is several tenths of MHz, the present PDR characteristic of over 40dB is enough as of a reference target for polarimetric SAR calibration.

4. Concluding Remarks

This paper evaluated primarily the polarization discrimination ratio of a conducting grid PSR from an experimental point of view. The experimental results for single layer PSR agreed well with theoretical calculations, and we experimentally confirmed the grid parameters that achieve a polarization discrimination ratio of 30dB required in polarimetric calibration algorithms. RCS values of the grid reflectors was almost the same with an aluminum plate of the same dimension. To achieve better PDR characteristic with thicker grids, we proposed the double layer PSR. By using this structure, we can improve the PDR value by more than 10 dB compared to a single layer PSR having the same grid parameters. This result shows that reflectors of the present design are applicable to PALSAR polarimetric calibration

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