A NEW CALIBRATION ALGORITHM OF WIDEBAND POLARIMETRIC MEASUREMENT SYSTEM

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I. INTRODUCTION

Although the importance of polarimetric properties associated with the scattering target was noticed in the beginning of 1960s [1–2], accurate calibration and measurement of target polarimetric scattering matrix in laboratory was not available until the modern vector network analyzer was introduced [3–4]. Nowadays, polarization diversity technique becomes prominent in the areas of inverse scattering, remote sensing, target classification and identification.

In this paper, a new calibration algorithm is developed based on three calibrators: a flat plate, a 0 degree dihedral corner reflector and a θ degree dihedral corner reflector. This new calibration algorithm has the advantages that three calibrators are not required at the same range nor with the same RCS. The rotation angle θ of the third calibrator can be derived in the calibration process using the intrinsic property of a rotated dihedral corner reflector. This calibration technique is particularly suitable for the calibration of a polarimetric radar under field conditions as the flat plate is replaced by a trihedral corner reflector.

II. CALIBRATION ALGORITHM

The relationship between the correct target polarimetric scattering matrix [S] and the measured target polarimetric scattering matrix [S^m] can be expressed as

$$\begin{bmatrix} S^m_{hh} & S^m_{hv} \\ S^m_{vh} & S^m_{vv} \end{bmatrix} = \begin{bmatrix} I_{hh} & I_{hv} \\ I_{vh} & I_{vv} \end{bmatrix} + \begin{bmatrix} R_{hh} & R_{hv} \\ R_{vh} & R_{vv} \end{bmatrix} \begin{bmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{bmatrix} \begin{bmatrix} T_{hh} & T_{hv} \\ T_{vh} & T_{vv} \end{bmatrix} \quad (1)$$

where [I] is the additive isolation error matrix resulting from the residual reflections and the coupling between transmitting and receiving channels, [T] and [R] are the transfer matrices of transmitting and receiving antennas including system frequency response, mismatch and cross–polarization coupling of antennas. In (1) the subscripts h and v correspond to the horizontal and vertical polarizations, with S_{hv} representing the complex amplitude for v–transmit, h–receive polarization in the measurement system.

The polarimetric scattering matrices of three calibrators are given as

$$\alpha\,[S_1] = \alpha \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \text{: for flat plate (or trihedral corner reflector)} \quad (2)$$

$$\beta\,[S_2] = \beta \begin{bmatrix} -1 & 0 \\ 0 & 1 \end{bmatrix} \text{: for } 0^\circ \text{ dihedral corner reflector} \quad (3)$$

$$\gamma\,[S_3] = \gamma \begin{bmatrix} -\cos2\theta & \sin2\theta \\ \sin2\theta & \cos2\theta \end{bmatrix} \text{: for } \theta^\circ \text{ dihedral corner reflector} \quad (4)$$

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where α, β, γ are complex constants used to account for the contribution in the measured responses due to the different range and RCS of three calibration targets. The relative values of β/α and γ/α can be derived in the calibration procedure.

Assume $[A_1]$, $[A_2]$, and $[A_3]$ are the measured polarimetric scattering matrices of three calibrators with [I] suppressed. From (1) and (2), [R] is related to [T] as

$$[R] = -\frac{1}{\alpha}[A_1][T]^{-1} \tag{5}$$

By substituting (3) and (4) into (1) and using (5), after proper manipulation one can obtain the following equations

$$E_{12}u^2 + (E_{22} - E_{11})u - E_{21} = 0 \tag{6}$$

$$E_{12}v^2 + (E_{22} - E_{11})v - E_{21} = 0 \tag{7}$$

$$\tan 2\theta = \frac{2uvwF_{11} + (u+v)wF_{21}}{u(v^2-w^2)F_{11} + (uv-w^2)F_{21}} = \frac{(u+v)vwF_{12} + 2uwF_{22}}{u(uv-w^2)F_{12} + (u^2-w^2)F_{22}} \tag{8}$$

where $[E] = [A_1]^{-1}[A_2]$, $[F] = [A_1]^{-1}[A_3]$, $u = T_{hh}/T_{hv}$, $v = T_{vh}/T_{vv}$, and $w = T_{hh}/T_{vv}$. Values of u, v, w, and the rotation angle θ of dihedral corner reflector can be solved from (6)–(8). Therefore the transmitting and receiving antenna transfer matrices [T] and [R] are determined in their normalized form as

$$[T] = T_{vv}\begin{bmatrix} w & w/u \\ v & 1 \end{bmatrix} = T_{vv}[T'] \tag{9}$$

$$[R] = -\frac{1}{\alpha}[A_1][T]^{-1} = \frac{1}{\alpha T_{vv}}[R'] \tag{10}$$

The correct target polarimetric scattering matrix can then be found as

$$[S] = [R]^{-1}([S^m] - [I])[T]^{-1} = \alpha\,[R']^{-1}([S^m]-[I])[T']^{-1} \tag{11}$$

III. EXPERIMENTAL RESULTS

The experimental arrangement used to acquire wideband polarimetric scattering data of test target is shown in Fig.1. Experimental result of the rotation angle of calibration dihedral corner reflector calculated from (8) is shown in Fig.2. Its standard deviation is about 0.074 degree over 6 to 18 GHz. Figure 3 shows the results of measured and calibrated polarimetric scattering matrices of a dihedral corner reflector at about 0 degree. The polarization purity is shown improved about 20dB over the frequency band after calibration.

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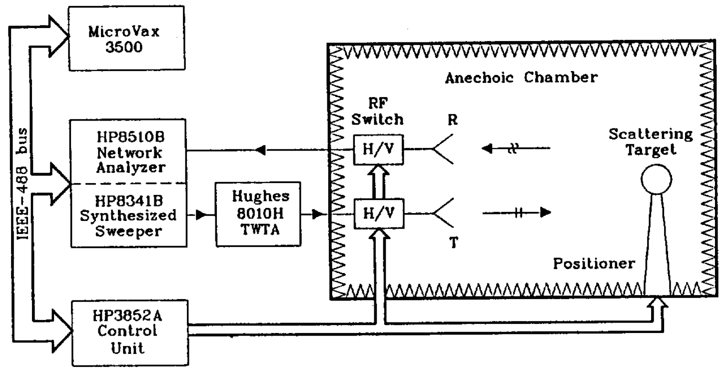


Fig.1 Automated wideband polarimetric scattering measurement system.

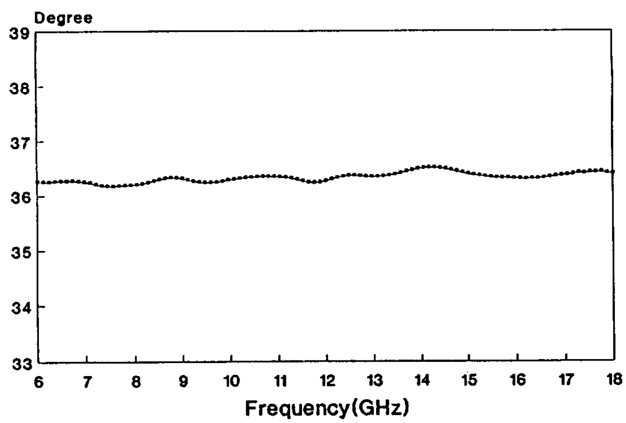
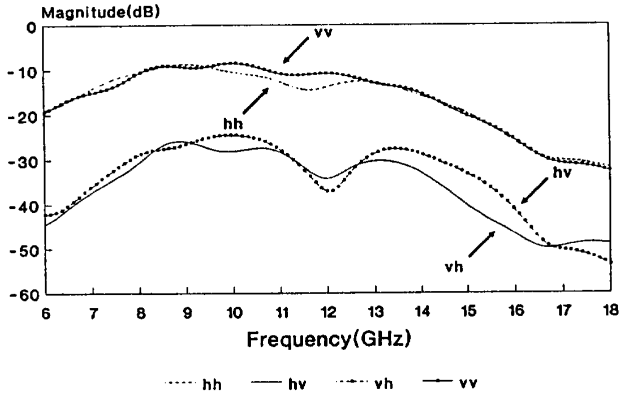
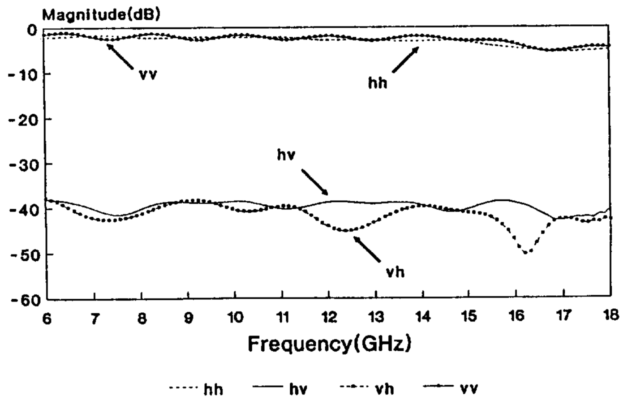


Fig.2 Results of calculated rotation angle θ of a calibration dihedral corner reflector.



(a)



(b)

Fig.3 Results of (a) measured and (b) calibrated polarimetric scattering matrices of a dihedral corner reflector at about 0°.