Polarization Ratio Determination with Two Identical Linearly Polarized Antennas

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***Abstract*— This paper describes a method for determining the complex polarization ratio using two identical, linearly polarized antennas. By Fourier transform analysis of s_{21} measurements with one of the antennas rotating about its axis a circular polarization ratio is derived which can be transformed into an equivalent linear polarization ratio. A linearly polarized reference antenna is not required.**

The technique was verified by electromagnetic simulations and illustrated by measurements in an anechoic chamber with two 3.3 GHz square patch antennas.

I. INTRODUCTION

In communication systems the polarization ratio of an antenna is of interest for potential frequency / polarization re-use. Newell [1] and Joy [2] developed the three-antenna method for measuring polarization parameters of an antenna. The technique required a polarization reference and was explicitly limited to linearly polarized antennas. Recently, a two-antenna technique for measuring the polarization ratio of a circularly polarized antenna was proposed [3]. This technique does not require a polarization reference nor does it depend upon the alignment of the antenna polarization axis with that reference.

In the present paper it will be shown that the later technique can also be used to determine the polarization ratio of a linearly polarized antenna.

II. RELATION BETWEEN CIRCULAR AND LINEAR POLARIZATION RATIO

Numerically different complex polarization ratios are defined by the ratio of either the linear or circular components of the same electric field

$$\rho_L = \frac{E_Y}{E_X} \text{ or } \rho_C = \frac{E_L}{E_R}. \tag{1}$$

However, the orthogonal field components can be transformed from one coordinate system to the other by a Jones matrix

$$\begin{bmatrix} E_X \\ E_Y \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix} \begin{bmatrix} E_R \\ E_L \end{bmatrix}. \tag{2}$$

That is, the linear and circular polarization ratios are related by

$$\rho_L^* = j\,\frac{\rho_C - 1}{\rho_C + 1}. \tag{3}$$

Thus, if it is more convenient to measure the circular polarization ratio ρ_C of an antenna, then an equivalent linear polarization ratio ρ_L^* can be calculated from (3).

The definition of ρ_L in (1) implicitly assumes that the co-polar axis of the antenna is aligned with the E_Y component. The derivation of ρ_L^* does not make such an assumption. It is therefore a more reliable indicator of the intrinsic polarization ratio of an antenna.

III. CIRCULAR POLARIZATION RATIO MEASUREMENTS

The circular polarization ratio of an antenna can be obtained by considering two identical antennas facing each other as shown in Fig. 1. This arrangement is commonly used to determine the antenna gain [4] by measuring the s_{21} voltage transfer ratio. In that case, the co-polar axis of the antennas are assumed to be aligned. In the present case, the relative polarization can be changed by mechanically rotating one antenna about its boresight axis.

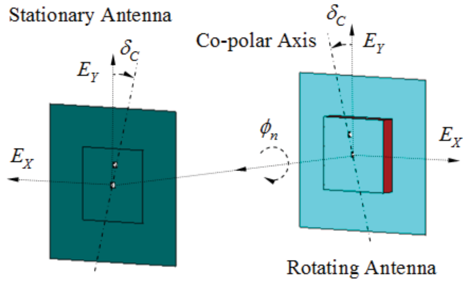

Fig. 1. Antenna Geometry for Polarization Measurements

The measured voltage transfer ratio cannot distinguish between linear and circular polarization. However, theoretically it can be expressed as the sum of a right-hand (RH) and a left-hand (LH) circularly polarized component

$$s_{21} = s_{21}|_{RH} + s_{21}|_{LH}\,. \tag{4}$$

For the antenna configuration in Fig. 1 the normalized voltage transfer ratio becomes [3]

$$s_{21}(n) = \exp(j\phi_n) + |\rho_C|^2 \exp[j(2\delta_C - \phi_n)]. \tag{5}$$

where ϕ_n is the mechanical rotation angle, $|\rho_C|$ the polarization ratio and δ_C is the rotational misalignment between the RH and LH component. Equation (5) shows that a mechanical rotation changes the electrical phase of the RH and LH components by the same amount but in the opposite directions.

The polarization parameters $|\rho_C|$ and δ_C could be determined directly from a discrete Fourier transform (DFT) of (5). However, leakage between closely spaced DFT bins requires improving the frequency resolution. This can be accomplished by appending to the original data $M-1$ copies of the measurements such that

$$\tilde{s}_{21}(n+Nm)=s_{21}(n), \quad \begin{array}{l} n=1,2,\ldots,N \\ m=0,1,\cdots,M-1 \end{array} . \tag{6}$$

The DFT of (6) has only two non-zero and well separated bins

$$\mathcal{F}(\tilde{s}_{21})=\begin{cases} 1 & k=M \\ |\rho_C|^2\exp(j2\delta_C) & k=-M \\ 0 & \text{otherwise} \end{cases} . \tag{7}$$

Thus the complex circular polarization ratio can determined from (7) and it can be transformed into an equivalent linear polarization ratio by (3).

IV. EXPERIMENTAL RESULTS

The above concept was evaluated using two identical linearly polarized square patch antennas as illustrated in Fig. 1. The antennas separation was 61 cm. The patch size was 29.2 mm x 29.2 mm, the patch thickness 6.0 mm and the relative dielectric constant 2.6. The feed was located 8.4 mm from the center for impedance matching at 3.3 GHz.

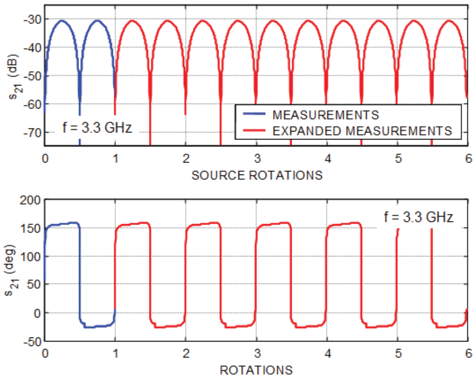

Fig. 2. Expanded $\tilde{s}_{21}$ Measurements

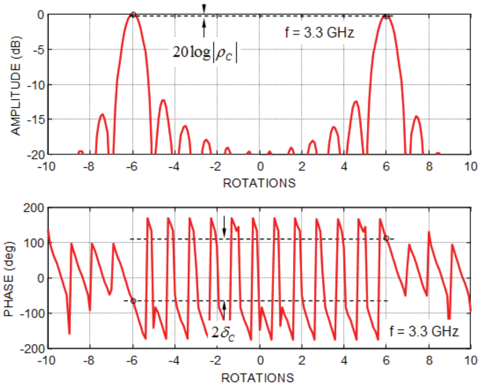

Fig. 3. DFT of Expanded Measurements

Initially, the polarization ratio of this patch antenna was determined by electromagnetic simulation with WIPL-D [5]. The polarization ratio of a square patch has been shown to be extremely sensitive to feed location tolerances [6]. Therefore, the simulation was carried out with the feed location offset from the co-polar axis by 0.1 mm (1 deg). This offset degraded the linear polarization ratio obtained from simulated antenna patterns to $\rho_L = -34.2$ dB. The linear polarization ratio derived from simulated s_{21} parameters as described above was $\rho_L^* = -34.5$ dB.

Actual measurements with two patch antennas were then carried out in an anechoic chamber. An example of the expanded s_{12} measurements and the corresponding DFT are shown in Fig. 2 and 3. Fig. 4 shows that the average polarization ratio over the 3.2 GHz to 3.4 GHz bandwidth of the patch antenna was $\rho_L^* = -32.5$ dB.

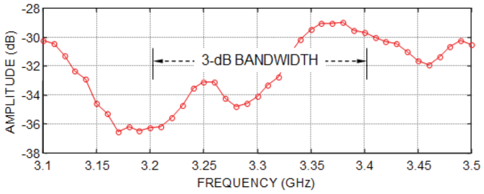

Fig. 4. Frequency Dependence of Polarization Ratio

V. CONCLUSIONS

The two-antenna method for determining the polarization ratio and tilt angle was extended to linearly polarized antennas. The technique exploits the periodicity of a Fourier transform and a mechanical antenna rotation to separate the principal and opposite circular polarization components followed by a basis transformation from circular to linear polarization. It was verified by simulations and measurements.

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