Adding Phase to the Rotating-Source Antenna Polarization Measurement Method

ABSTRACT – The rotating-source measurement method is usually described as an amplitude only measurement method and the axial ratio is the only characteristic that can be measured. The article illustrates how adding a phase measurement allows to get the sense of polarization and to calculate the circular partial gains over a full cut-plane of the antenna under test. Simulations and a measurement example are shown.

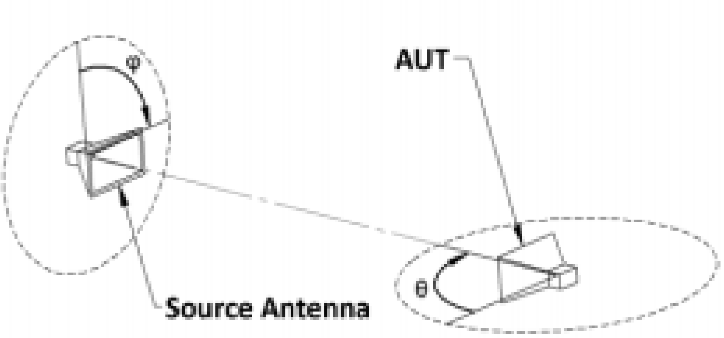

Figure 1. Rotating Source Measurement Method Setup

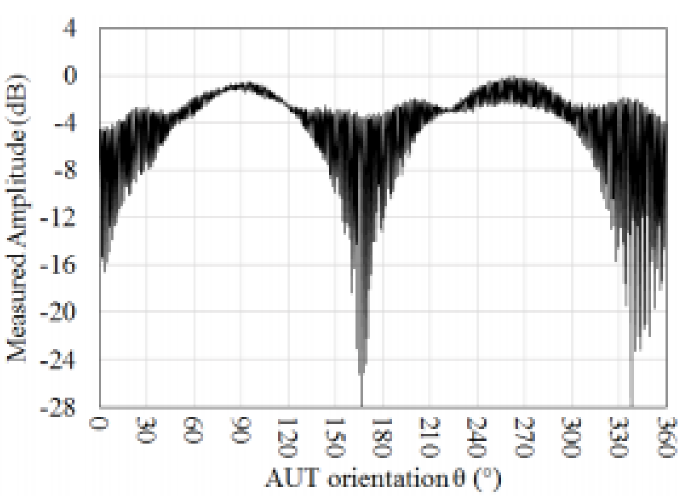

Figure 2. Typical Measurement Result Using the Rotation Source Method

I. INTRODUCTION

When working with a circularly polarized antenna, knowing its axial ratio is important as it warns about the possible polarization mismatch. Along with the Axial Ratio AR, the sense of polarization (right hand or left hand) and the partial circular gain give a more detailed characterization of the antenna performances.

The rotating-source measurement method, described in [1] and [2], is an amplitude only measurement method. From this amplitude measurement it is possible to get the AR of the Antenna Under Test AUT but not its sense of polarization nor its partial circular gains. The main interest of this article is to illustrate how the addition of a phase measurement allows the measure of these characteristics.

The article contains three parts. The first is a quick reminder of the method. The second will describe how to add a phase measurement. It will mainly illustrate the phase response of a rotating antenna mentions in [3] and shows how to apply it the rotating- source setup. The third part will be about an example. The circular gains of a spiral antenna are measured.

Recently a few new papers used similar technique to measure an antenna polarization [4][5]. Here the main difference is that the polarization will be measured on a full cut-plane of the AUT.

II. THE ROTATING-SOURCE METHOD

The AUT is placed in front of a source antenna. The amplitude of the transmitted signal is measured while both the AUT and the source are rotating. The Figure 1. shows the setup and the way the antenna rotates. For a successful measure, the source antenna must rotate a lot faster than the AUT. A typical result is shown in Figure 2. A clear inner and outer envelope are usually described. The axial ratio is the difference in dB between the two, Figure 3.

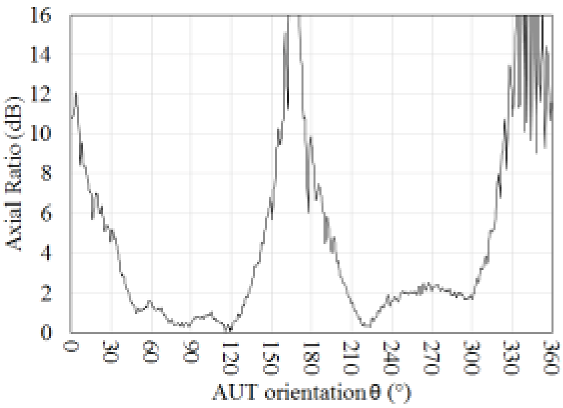

Figure 3. Axial Ratio Derived from Measurement Shown in Figure 2.

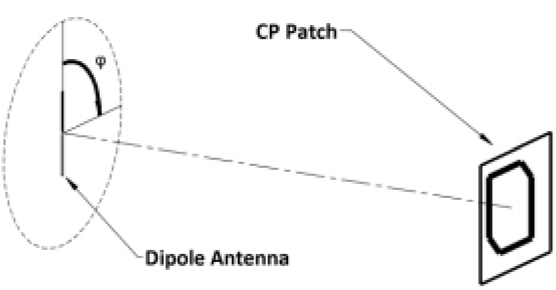

Figure 4. Setup of the Simulation

III. ADDITION OF A PHASE MEASUREMENT

A. Simulation of a phase measurement Figure 4. shows the setup for a simulation that was perform on IE3D. An elliptically polarized patch antenna is placed in front of a dipole antenna, the distance between the two antennas is around three wavelengths. The phase of the transmission coefficient is calculated for different orientations of the dipole ϕ. The simulation was repeated four times for different patch antennas: one Left Hand Circularly Polarized LHCP patch with AR=4dB (not quite circular), one LHCP patch with AR=12dB (almost linear), one Right Hand Circularly Polarized RHCP patch with AR=4dB and finally one RHCP patch with AR=12dB. Figure 5. and Figure 6. show the results of the simulations. The phase variation was also added on the same graphs.

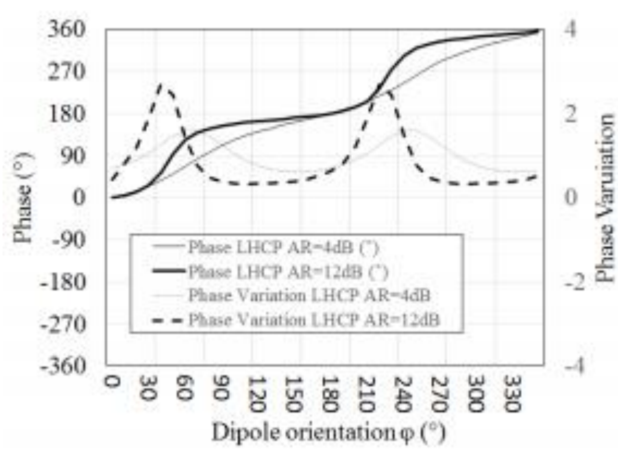

Figure 5. Simulated Phase & Phase Variation Between a Dipole & a Non-Optimized LHCP Patch vs. the Dipole Orientation

The main observation about these results is the sign of the phase slope. When the co-pol of the patch is LHCP the variation of the phase of the transmission coefficient is positive. It is negative when the co-pol of the patch antenna is right-handed RHCP. This is mentioned in [3] 1-11.5. The result is bound up with the sense of rotation of the dipole. According to the setup and graphs, the dipole is rotating Clockwise CW when looking from the patch antenna, the angle ϕ is going from 0˚ to 360˚. If the dipole was going CCW the results would have been the opposite (phase variation is negative for LHCP, positive for RHCP). Another interesting fact is that the difference between the max and the min of the phase variation increases with the AR of the patch. One could estimate the AR of an antenna just by looking at this difference.

B. *Application to the Rotating Source Measurement Method*

The dipole will be replaced by a linearly polarized source antenna and the patch by the AUT. As the AUT rotates a few degrees around, for example, θ1 the source rotates a few full turns. Looking at the sign of the phase variation of the transmission coefficient, it is then possible to get the sense of polarization at θ1. The next sections will describe how to get to the partial circular gain from this result.

C *Partial Circular Gains*

In the simulation described in paragraph III.A, if one look at the amplitude of the transmission coefficient as a function of ϕ he would see something like the curve named polarization pattern in Figure 7. This pattern is related to the polarization ellipse of the electric far field created by the AUT by the amplitude Emin and Emax.

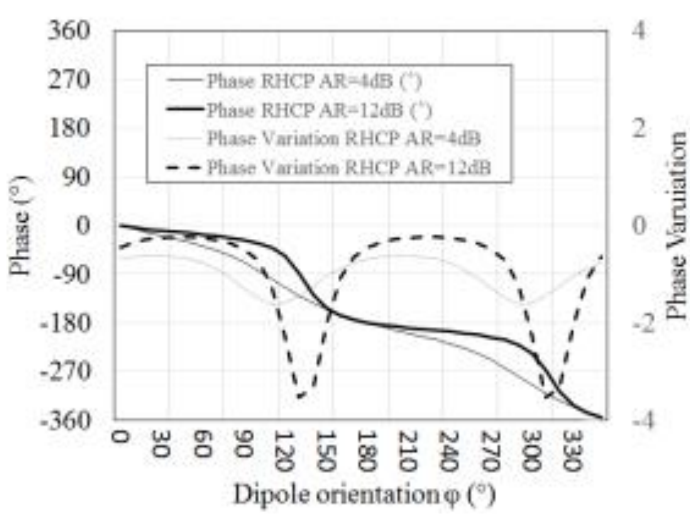

Figure 6. Simulated Phase & Phase Variation Between a Dipole & a Non-Optimized RHCP Patch vs. the Dipole Orientation

Emin and Emax are described by the inner and outer envelope measured during a rotating-source amplitude measurement. They are related to the circular components ER and EL by (1).

$$|E_R| = \frac{E_{max}+cE_{min}}{\sqrt{2}}, |E_L| = \frac{E_{max}-cE_{min}}{\sqrt{2}}, c = \begin{cases} 1 \; if \; RHCP \\ -1 \; if \; LHCP \end{cases} \quad (1)$$

If the amplitude and phase data are taken in a calibrated setup, the measured amplitudes are orthogonal partial linear gains of the AUT (Gmin and Gmax). As the partial circular gain GR and GL of an antenna is proportional to the square of the magnitude of the partial electric far field component ER and EL it creates (2) (proportional to the radiation intensity contained in ER or EL field component), the partial circular gain GR and GL are related to Gmin and Gmax by (3).

$$G_R = \frac{4\pi}{P_{in}} U_R \quad (2)$$

$$G_R = \left(\frac{\sqrt{G_{max}}+c\sqrt{G_{min}}}{\sqrt{2}}\right)^2, \quad G_L = \left(\frac{\sqrt{G_{max}}-c\sqrt{G_{min}}}{\sqrt{2}}\right)^2 \quad (3)$$

If the tilt angle τ is needed, one way would be to track the source antenna rotation ϕsource and record the position. The tilt angle is then ϕsource corresponding to Emax. This is also mentioned in (3).

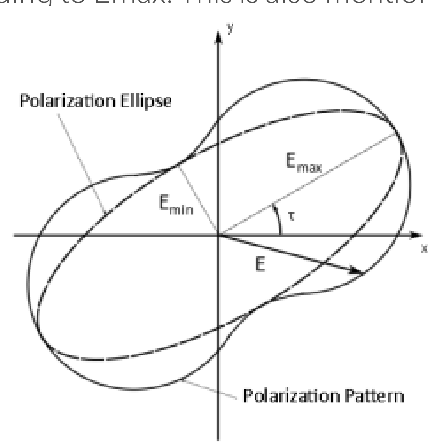

Figure 7. Polarization Ellipse & Pattern

IV. MEASURMENT EXAMPLE

Figure 8. shows a spiral antenna that will be our AUT for this example. A linearly polarized horn antenna was used as the source. Another well-known linearly polarized antenna was used to realize a gain transfer calibration. The amplitude measured are then partial linear gains. Data (amplitude and phase) were taken each time the AUT turned 0.25˚. The source antenna was rotating at a rate such that it completed a full rotation when the AUT turned 1˚.

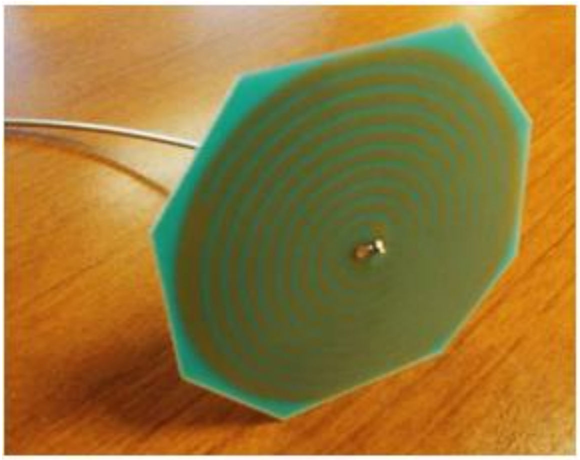

Figure 8. Spiral Antenna Used for the Example

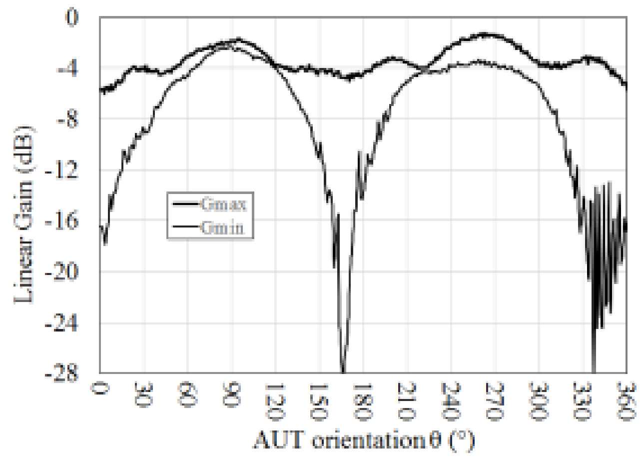

Figure 9. Measured Gmin & Gmax

The first result, shown in Figure 2. is the amplitude measurement in dB plotted against the AUT orientation angle θAUT. Figure 9. shows the outer and inner envelope of this curve. The twos curves can be called Gmin and Gmax, the difference of the twos is the axial ratio, in Figure 3. These will also be used to compute the partial circular gains.

Next, Figure 10. displays the measured phase "unwrapped" against θAUT. The phase decreases from θAUT =0˚ to around θAUT=180˚, then increase and goes down again. The phase variation is plotted in Figure 11. where these trends can be observed more carefully. As θAUT is closely related to the orientation angle ϕ of the source antenna ϕsource, one can deduct the sense of polarization using what was described in III.A. The antenna is predominantly RHCP for θAUT<180˚ and predominantly LHCP for θAUT>180˚. The partial circular gains can now be computed from Gmin and Gmax using (3).

Figure 12. compares the measured circular gain with simulated circular gain. The simulation was not well detailed as an infinite substrate was used and the cable (that you can see in Figure 8.) was omitted. The differences between the results are due to these facts but they are close enough to validate the measurement method as the levels of the gains are comparable for the co- and cross-polarization.

Finally, the phase variation plot (Figure 11.) shows clearly an inner and outer envelope. The two envelopes could also be used to get the axial ratio. These envelopes are linked to the difference between the max and min of the phase variation shown in Figure 5. and Figure 6.

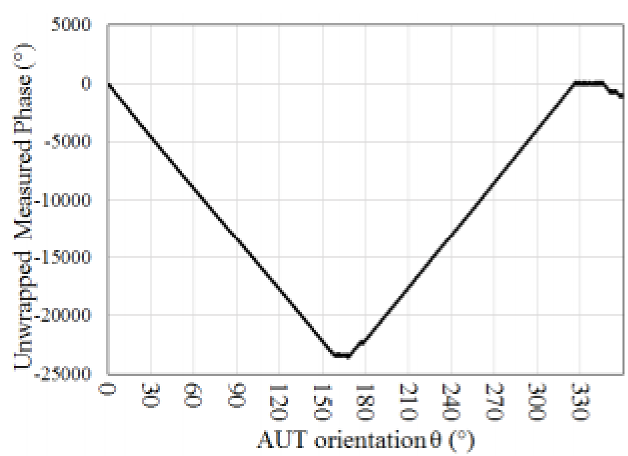

Figure 10. Unwarped Phase vs. the Spiral Orientation Angle

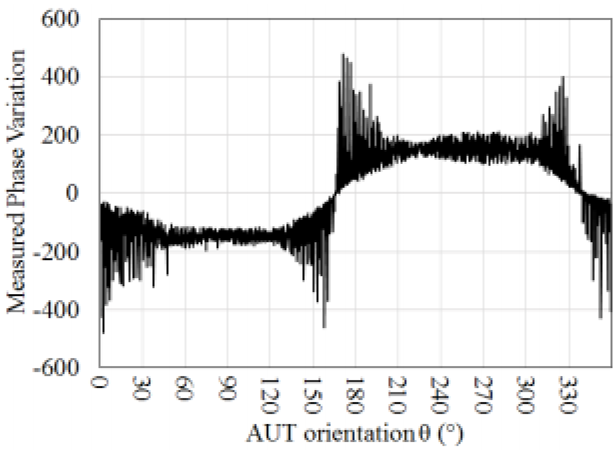

Figure 11. Phase Variation vs. the Spiral Orientation

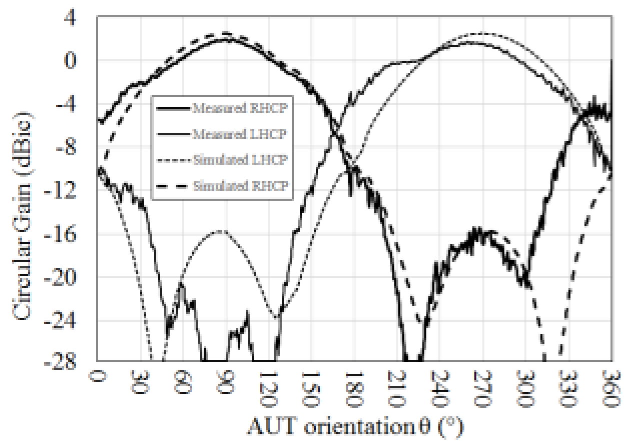

Figure 12. Measured & Simulated Partial Circular Gain

V. CONCLUSION

Adding a phase measurement to the rotating-source measurement method was demonstrated. First a simulation illustrated how to get the sense of polarization of an antenna using a rotating source. Then partial circular gains were discussed. Finally, an example was shown.

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REFERENCES

[1] "IEEE Standard Test Procedures for Antennas," ANSI/IEEE Stand. 149- 1979, 1979.

[2] Constantine A. Balanis, "Antenna theory", Wiley, 2005

[3] Thomas A. Milligan, "Modern Antenna Design", Wiley-IEEE Press, 2005

[4] H.M. Aumann, K.A. Tettle, "A rotating source polarization measurement technique using two circularly polarized antennas", AMTA 2016

[5] Gustavo G. S. Forte, Glauco Fontgalland, Silvio E. Barbin, "Antenna Polarization Characterization with Vector Network Analyzer Measurements", Electromagnetics in Advanced Applications (ICEAA) 2018 International Conference on, pp. 597-600, 2018