Comparison of Antenna Measurements Obtained Using an Electro-Optical Probe System to Conventional RF Methods

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***Abstract*—There are certain applications where the use of electro-optical (EO) probes to acquire near-field measurements can provide major advantages as compared to conventional RF measurement techniques. One such application is in the area of high power RF measurements that are required for calibration and test of active electronically scanned arrays (AESA). The family of EO probes presented herein utilizes the Pockels effect to measure the time-varying electric fields of the antenna under test (AUT). The use of a non-invasive, broadband EO probe facilitates measurement of the tangential electric field components very close to the AUT aperture in the reactive near-field region. This close proximity between the AUT and the measurement probe is not possible with conventional metallic probes. In this paper, the far field gain patterns acquired using the EO probe will be compared to the corresponding gain patterns obtained from conventional far-field and near-field methods. The measurement results, along with the advantages and disadvantages of the EO system configuration, will be presented.**

Keywords – Near-Field Measurements, Electro-Optical E-field Sensors, Antenna Measurements, Photonic Probes, Pockels Effect

I. Introduction

Recently, there have been several publications related to the collection of near-field data using optical probes [1],[2]. However, since the use of optical probes to perform planar near-field measurements is relatively new, sufficiently large scanner systems of this type are not readily available. For the purpose of the measurements discussed herein, a conventional 20’ x 12’ planar scanner was modified for use in conjunction with an optical scanning system.

Section II provides an overview of the AUT as well as a description of the conventional RF measurement process. Section III details the modifications to the conventional RF scanner system to accommodate the EO probe and its associated subsystems. Section IV provides an overview of the EO measurement process as well as a brief summary of the selected EO crystal. The results of the EO measurements and the comparison to traditional RF techniques are included in Section V.

II. Conventional RF Measurement

After performing the initial range setup and acquiring preliminary measurements using both standard gain horns and a wideband microstrip antenna, an X-band planar slotted waveguide array was selected as the antenna under test (AUT) for the comparative measurements. This AUT, shown in Figure 1. , has been previously characterized in several ranges, including an indoor far-field extrapolation range [3] and the 20’ x 12’ planar near-field range used for the EO measurements described in Section IV.

Figure 1. X-band slotted planar waveguide array.

The RF probe chosen for the traditional near-field measurement was a WR-90 open ended waveguide (OEWG) probe. The AUT-to-probe separation distance for this measurement was within the conventionally defined 3λ to 5λ spacing, and the Δx and Δy grid sampling density was 0.48λ. After the near-field acquisition was completed, the resultant data was processed using custom software scripts to generate the far-field gain patterns.

The setup for this conventional measurement is shown in Figure 2. and Figure 3.

III. Modification of RF Scanner System to Accommodate EO Probe Subsystem

The optical scanning subsystem used for EO data collection was initially designed to be integrated with a small tabletop X-Y scanner. However, since a dedicated EO scanner system of sufficient size was not readily available, the 20’ x 12’ scanner system used to acquire the traditional RF measurement was modified to accommodate the EO probe and associated optical scanning subsystem. A block diagram of this hybrid system is shown in Figure 4.

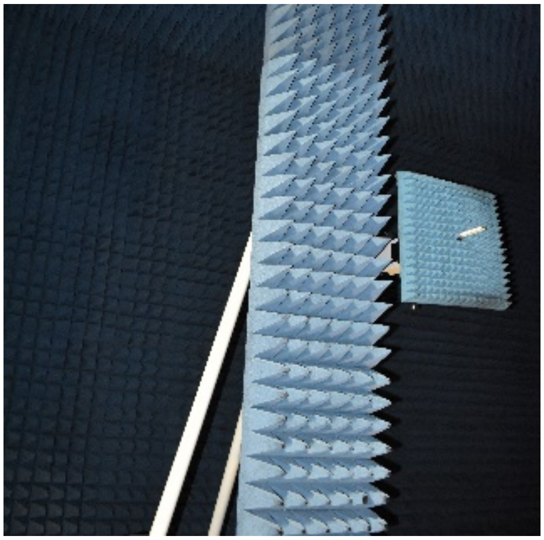

Figure 2. Baseline near-field measurement using WR-90 OEWG.

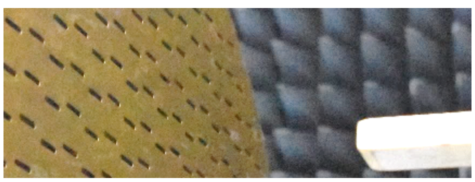

Figure 3. Baseline near-field measurement using WR-90 OEWG with AUT displayed.

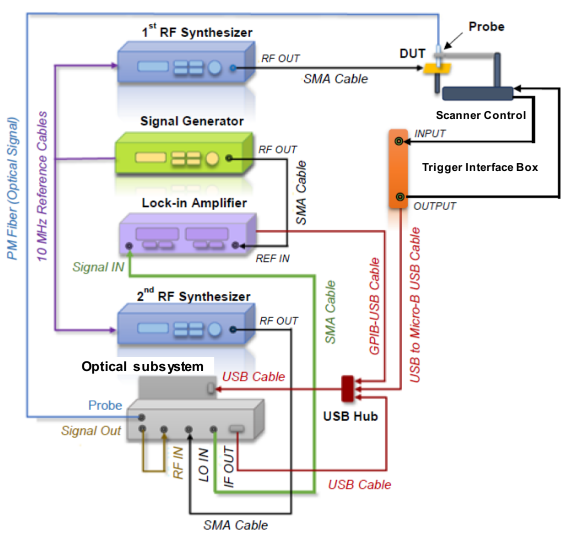

Figure 4. Block diagram of EO probe mounted in conjunction with conventional RF scanner system.

IV. EO Probe Measurement

The measurement process outlined in Section II was repeated using the optical scanning system as shown in Figure 5. This measurement system uses a Bismuth Silicon Oxide, $Bi_{12}SiO_{20}$ (BSO) optical probe and associated optical processing subsystem. The BSO crystal serves as a polarization state modulator which operates based on the Pockels effect [4]. The architecture of the BSO optical probe is illustrated in Figure 6. The characteristics of this type of EO crystal are described in further detail in the literature [5]. While the BSO crystalline structure has reduced E-field detection sensitivity as compared to other crystals, it is more stable over temperature. Other classes of crystals such as Lithium Niobate ($LiNbO_3$) and Lithium Tantalate ($LiTaO_3$), exhibit higher E-field sensitivity, but are not as thermally stable due to the pyroelectric effect that creates interfering electric fields inside the structure.

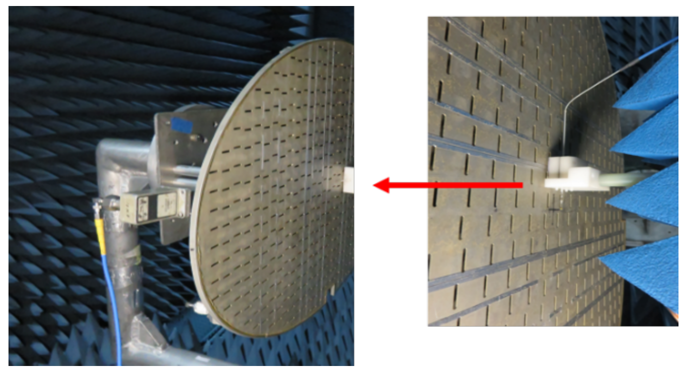

Figure 5. EO probe positioned very close to AUT aperture.

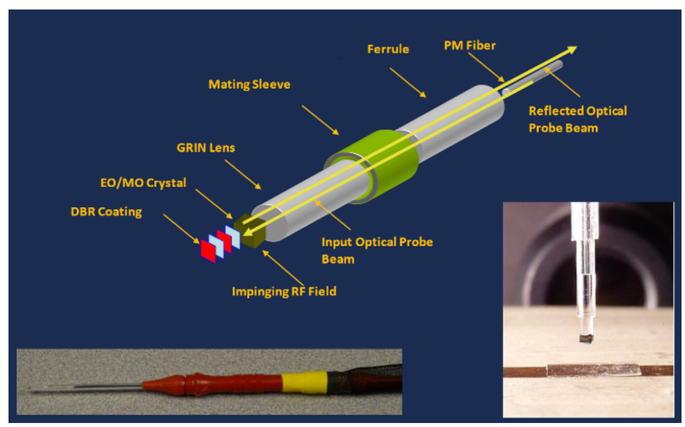

Figure 6. EO probe illustration showing BSO crystal.

For the optical measurement, the Δx and Δy grid spacing was reduced to 0.25λ, and the AUT-to-probe separation distance was significantly reduced from the traditional 3λ to 5λ range to an absolute distance of 7 mm. Such a small separation distance placed the probe in the reactive near-field region of the AUT. After the near-field acquisition was completed, the resultant data was processed using the optical system software utilities and then verified with the same scripts used to process the conventional RF acquisition.

V. Measurement Results and EO/RF Comparison

The far-field amplitude plot generated using the optical probe acquisition data compares reasonably well with that of traditional techniques. A comparison of these results is shown in Figure 7. For reference, plots of the far-field amplitude generated using acquisitions from two separate traditional near-field ranges are included in Figure 8.

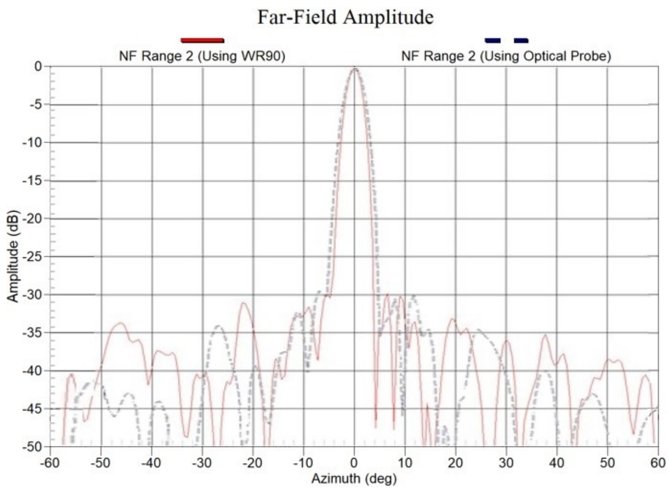

Figure 7. Comparison of far-field amplitude of conventional RF acquisition (WR-90) to optical probe.

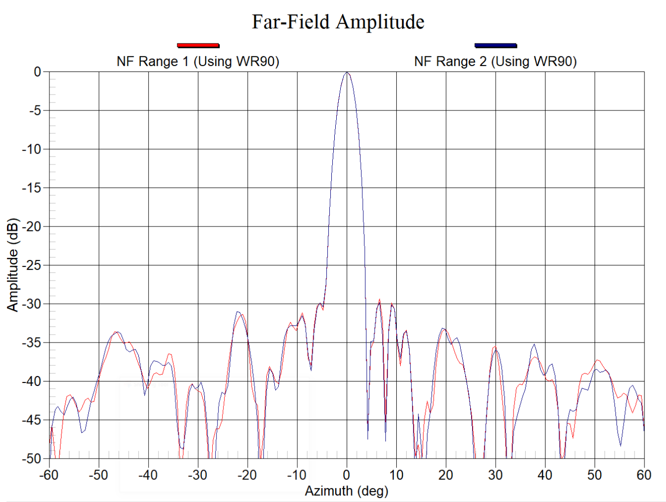

Figure 8. Comparison of far-field amplitude of conventional RF acquisitions from two planar near-field ranges.

Potential sources of measurement error include insufficient grid sampling density for the EO acquisition and polarization mismatch between the EO probe and the AUT due to the non-ideal scanner system configuration. Either potential error may result in the side-lobe level discrepancy between the two measurements. However, the impact of insufficient grid sampling density is of particular interest due to ongoing investigations related to the sampling requirements of reactive near-field measurements.

During analysis of the optical acquisition, the authors observed that a plot of the raw near-field data resembled the holographic image (i.e. back transform) obtained from conventional near-field measurements. Since the optical measurements were conducted with the EO probe positioned extremely close to the antenna aperture (in the reactive near-field region of the AUT), this hologram result is expected.

VI. Conclusions and Future Development

Given the reasonable accuracy of the comparison between data obtained using the WR90 OEWG vs the optical probe, the optical scanning system presented herein would be suitable for performing near-field measurements on high power active array antennas. However, when considering the non-invasive nature of the optical system, the EO measurement methodology may be considered preferable. Of course, due to its non-reciprocal nature, the EO probe system is only capable of performing nearfield measurements when the AUT is in transmit mode.

Furthermore, the significantly reduced AUT-to-probe separation distance of the EO implementation facilitates minimal over-scan to achieve the required valid angle when compared to an OEWG or other similar metallic probe. As a result, the number of acquisition points and the associated scan time could be reduced assuming all other scan parameters remain constant. However, if better resolution is required when acquiring measurements in the reactive nearfield region, the need for smaller Δx and Δy spacing would actually drive the need for more measurement points. This trade-off requires further investigation.

References

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