Modeling and Validation of a mm-Wave Shaped Dielectric Lens Antenna

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Abstract **─** The modeling and validation of a 33 GHz shaped dielectric antenna design is investigated. The electromagnetic modeling was performed in both WIPL-D and FEKO, and was used to validate the antenna design prior to fabrication of the lens. It is shown that both WIPL-D and FEKO yield similarly accurate results as compared to measured far-field gain radiation patterns.

Index Terms **─** Antennas, FEKO, measurement, millimeter wave, shaped dielectric lens, simulations, WIPL-D.

I. INTRODUCTION

A 33 GHz uniquely shaped 50 cm diameter dielectric lens antenna has recently been developed, and it has been modeled in both WIPL-D and FEKO. The electromagnetic modeling effort was undertaken to validate the lens design prior to manufacturing. It will be shown that both models yielded similarly accurate results as compared to the final measured gain radiation patterns. The modeled antenna system shown in Fig. 1 is comprised of a Rexolite dielectric lens illuminated by a corrugated conical horn. The antenna design required dual linear polarization, an azimuth beamwidth of 1.2°, and an elevation beamwidth of 12° with a prescribed elevation beam response as shown in Fig. 2.

II. DIELECTRIC LENS

The dielectric lens shown in Fig. 1 is a composite surface design. First, using the design equations in [1], a conventional rotationally-symmetric convex-plano lens design was used to produce a 1.2º conical beam. The next step was to shape the exiting surface of the lens in the elevation plane to achieve the desired elevation beam shape shown in Fig. 2. The phase perturbation required to achieve the desired elevation beam shape was derived numerically, and this phase perturbation wat then used to the dielectric surface profile.

II. MODELING, SIMULATION, AND MEASUREMENTS

The above antenna design was modeled in both FEKO and WIPL-D. The FEKO simulation used ray launching geometrical optics to solve the full antenna system, using a spherical mode expansion of the moment method modeled corrugated horn as the illumination source of the lens. WIPL-D performed the entire simulation with the method of moments (MoM), using one symmetry plane to reduce the size of the problem. Both simulation tools yielded similar results, thus validating the antenna system design. While the modeling steps are similar in both tools, the following modeling and simulation steps are specific to WIPL-D ProCAD 2017.

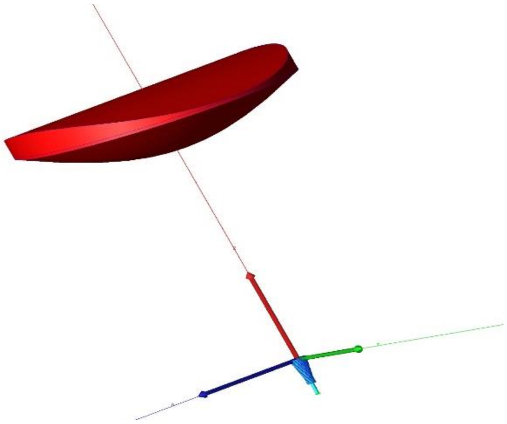

Fig. 1. Ka band corrugated horn and shaped dielectric lens as modeled in WIPL-D ProCAD.

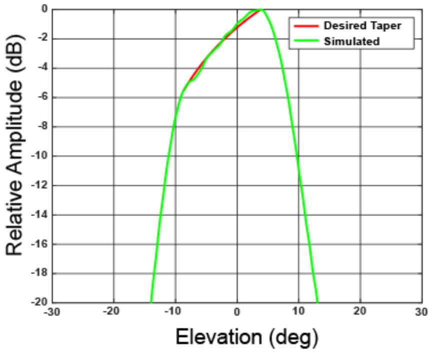

Fig. 2. Prescribed shaped beam elevation pattern.

A. Corrugated horn model & simulation

The profile of the corrugated horn was generated in Matlab, based on designs in [2], and imported into WIPL-D as a polyline. The sweep tool was used to generate the cylindrical horn, and a waveguide port was added as the excitation source. The input impedance and far-field radiation patterns were calculated, and the phase center of the horn was determined. The horn was

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translated to place the phase center at the center of the global coordinate system.

B. Dielectric lens model

Both surface profiles of the dielectric lens were generated in Matlab and imported into WIPL-D ProCAD as polylines. The inner surface is rotationally symmetric about the central axis and was created by sweeping the polynomial about a circle. The outer surface is shaped only in the vertical (elevation) axis, and it is constant along the horizontal axis. The outer surface was created by extruding the polynomial along a horizontal line. To merge the two surfaces and create the solid lens volume, a 50 cm diameter cylinder was generated along the central axis that encapsulated the two surfaces. The three bodies (inner surface, outer surface, and cylinder) were then merged using “Boolean/ Intersect” and the unwanted portions of the structure deleted. The lens was translated along the lens axis by 50 cm to place it at the correct focal position relative to the feed. The final step was to define a dielectric domain with a relative permittivity, $\varepsilon_r = 2.54$, and assign it to the Rexolite dielectric lens structure.

C. Simulating the full antenna system

The WIPL-D and FEKO simulations were performed on different computers so a direct comparison of computational speed is not possible. The computational details of each simulation are as follows.

The WIPL-D simulations were performed on a desktop computer with two Xeon E5-2643V2 3.50 GHz processors, 64 GB RAM, a Tesla K20c GPU and six 2.65 TB solid state hard drives in RAID0 configuration for high speed scratch space. With one symmetry plane enabled, the total number of unknowns in the WIPL-D simulation was 304,240 (156,754 electric currents and 147,486 magnetic currents). Simulation time for one frequency and one polarization took 37 hours with the GPU Solver enabled.

The FEKO simulations were performed on a machine with two E5-2699 V3 2.30 GHz processors and 512 GB RAM. Approximately 91,000 moment method basis functions were used to compute the Ka-band corrugated horn spherical mode expansion functions used to illuminate the shaped lens. 65953 curvilinear triangles were used to mesh the shaped lens, which was solved for the far-field gain patterns using ray-launching geometrical optics. Total CPU time utilizing 36 cores on two CPUs was 21 hours.

The results of the FEKO and WIPL-D gain radiation pattern simulations are shown overlaid in Fig. 3. As can be seen the two simulations yield very similar results, thus validating the antenna design.

D. Comparison of simulations and measurements

Gain and radiation pattern measurements of the shaped lens antenna system were performed in a compact range anechoic chamber. The final validation is given in Fig. 4 where the WIPL-D simulated and measured antenna elevation gain radiation patterns show good agreement.

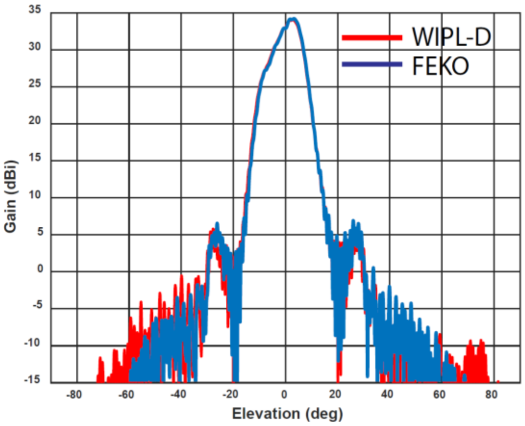

Fig. 3. Comparison of simulated elevation gain patterns for the shaped lens antenna.

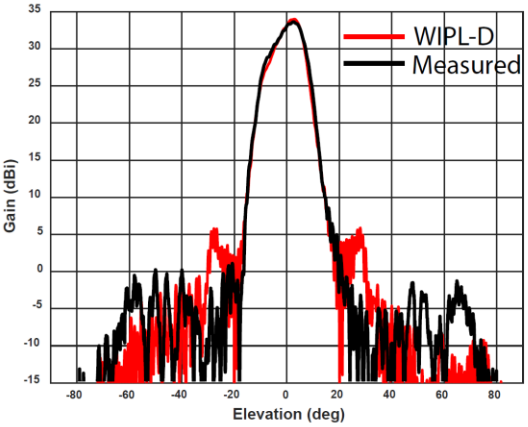

Fig. 4. Comparison of measured and WIPL-D simulated elevation gain patterns for the shaped lens antenna.

IV. CONCLUSION

A 50 cm diameter, 33 GHz, shaped beam dielectric lens antenna design was modeled in WIPL-D and FEKO. The two simulations yielded very similar results, validating design of the antenna prior to manufacturing of the lens. The simulated antenna far-field gain radiation patterns of the shaped lens antenna system also had good agreement with measured data.

REFERENCES

[1] Y. T. Lo and S. W. Lee, Antenna Handbook. Van Nostrand Reinhold Co., New York, Chapter 16, 1988.

[2] T. A. Milligan, Modern Antenna Design. McGraw-Hill, New York, 1985.