Design of Dual-Polarized Pyramidal Log-Periodic Antenna with Integrated Feed for Additive Manufacturing

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***Abstract*—A dual-polarized log-periodic antenna with 5:1 bandwidth is considered for wideband, amplitude only direction-finding applications. The proposed system is comprised of two identical, orthogonal, sets of trapezoidal log-periodic arms. The arms' inclination from planar facilitates reduced back lobe radiation to improve directivity and efficiency once absorber is introduced. One arm of each polarization set contains a variable radius coaxial shell to achieve impedance matching such that the system impedance at the base of the antenna is matched to 50 ohms. Analysis and design for the 3d printed direction-finding antenna system is accomplished using a commercial off the shelf (COTS) finite element method (FEM) solver.**

Keywords— ***3d printing, direction finding, integrated feed, log periodic, wideband.***

I. INTRODUCTION

The relevance of amplitude only (AO) direction finding (DF) was reasserted with the ascension of most recent ultra-wideband spectral power measurement technologies, such as one demonstrated in [1]. This technology facilitates the need for wideband apertures to enable spectrum monitoring and DF without any gaps in frequency. Antennas with frequency independent behavior are desired, ideally with wide field of view and low gain rippling through frequency. These facilitate the decisive power ratios that are needed for meaningful AO-DF. Several antenna classes are feasible for this application inclusive of sinuous antennas projected onto a pyramid [2]. An objectively difficult structure to manufacture, the impedance behavior required matching to 250 Ω, without consideration of a balun. In [3], a balun was demonstrated; however, the increased integration complexity and cost to the manufacturing process, make the entire system cumbersome to produce.

Rectifying these shortcomings yields the proposed antenna system, Fig. 1. The trapezoidal log-periodic antenna in the pyramidal configuration is drastically simpler to manufacture, support, and feed. The addition of an integrated coaxial feed housed within the boom eliminates the need for a balun, effectively reducing the additional space, time, and cost resources a balun demands. The structure also lends itself to 3d printing technology, which can then be complemented with a metal plating process. Overall, this drastically reduces cost, duration, and complexity of manufacturing for the entire system.

The system is designed for operation from 1.67 GHz to 8.525 GHz using ANSYS HFSS. The patterns in both, the E-, and H-plane need a wide field of view with minimal gain rippling. The reduction of the back lobe is desired to maximize the efficiency payoffs precipitated by the pyramidal structure, and to reduce the impact of surrounding radiators on patterns' smoothness.

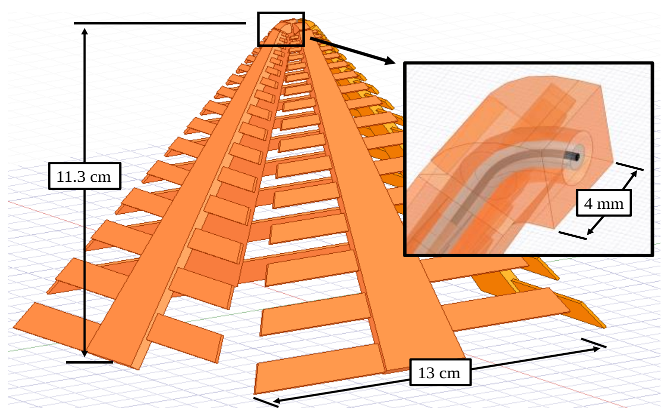

Fig. 1. Proposed dual-polarized log-periodic antenna with integrated impedance transforming feed.

II. DUAL POLARIZED LOG-PERIODIC ANTENNA

The proposed configuration is comprised of two orthogonal two-arm log-periodic structures. In order to reduce the back lobe and minimize the impact the eventual absorber has on efficiency and pattern smoothness; the arms are placed at an incline. The system parameter ψ is the angle between the two arms, such that a planar structure has a ψ of 180°. This, and the other parameters referenced in the design of this structure were summarized by DuHamel and Ore in [4]. The structure's outer angle is the angle prescribed by the tips of the elements on either side of the boom, and the tip of the pyramid. This parameter, α, becomes coupled with ψ in the dual-polarized case; the outer angle of one structure dictates the minimum angle of incline for the other. An increase in α shrinks the height of the structure, but disallows aggressive inclination, increasing the back lobe. The width of the boom is also dictated by an angle, β, which has some pertinence to the stability of the device's impedance. Element widths are described with a growth factor, τ, and selected based on a

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compromise between manufacturability and performance. The feed is a hollowed-out tunnel with a variable radius (to perform an impedance taper) that, after plating, serves as the outer conductor of a coaxial line. A dielectric and conductor from a COTS coax are modelled within the boom tunnel. However, to maximize efficiency of computational resources, the implemented system has a tip-located lumped port with reference impedance of 105 Ω, which represents the output port impedance of the internal transformer. Detailed parametric study resulted in antenna parameters shown in Table I.

Table I. Chosen log-periodic parameters for system implementation

α	β	ψ	τ
50°	10°	65°	0.85

III. Performance

VSWR < 2 was obtained across the band at both the lumped port (with respect to 105 Ω) and at the input of the integrated impedance transformer (with respect to 50 Ω), shown in Fig. 2.

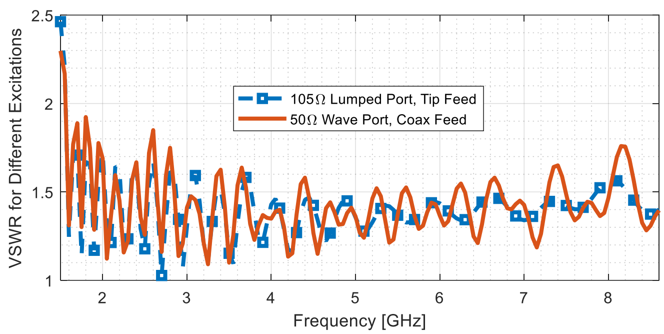

Fig. 2. Simulated VSWR for the proposed antenna system, demonstrating the impact of the integrated, impedance transforming feed.

The gain at boresight and half-power beamwidth (HPBW) of the system are shown in Fig. 3. The gain is stable throughout the band of interest, whereas HPBW changes ±8° across bandwidth. While not demonstrated herein, the addition of an absorber reduces the back lobe, improves pattern stability, but decreases radiation efficiency. This reemphasizes the importance of the pyramidal nature (α-ψ tradeoff) to extract as much radiation efficiency from the system as possible by improving main beam efficiency, while not compromising the performance or overall system size.

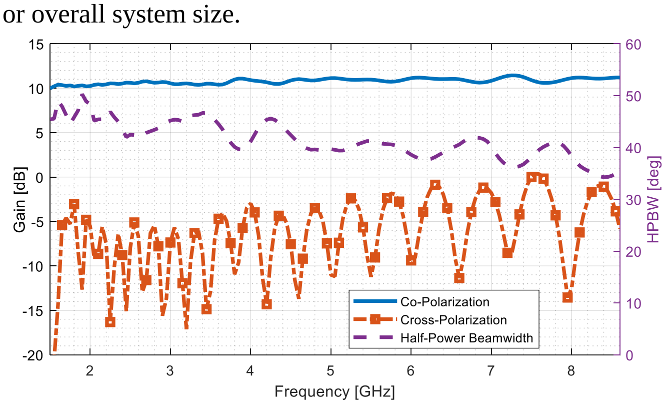

Fig. 3. Simulated boresight gain and HPBW from HFSS model featuring a tip-located lumped port.

To determine the behavior of the system as a direction-finding subsystem, a custom numerical subroutine, implemented in MATLAB, was used. The system function, a combination of two duplicate radiation patterns, squinted at some angle, was generated. The ratio of powers at each angle was obtained, resulting in the direction-finding function. The slope of this function, shown in Fig. 4, demonstrates the system's resolution, and correlates to its robustness to noise. In this case, the field of view is clearly 40° in the H-plane with near 0.5 dB/° slope throughout the band. The practical implications of the additive manufacturing process, including surface roughness and surface impedance is part of the future work.

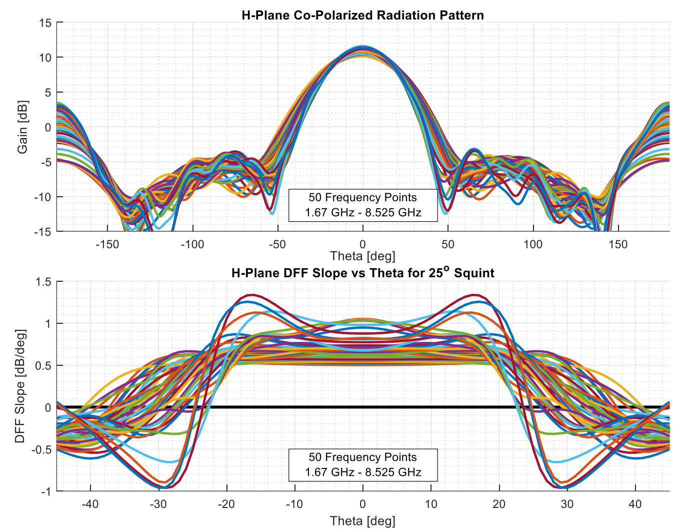

Fig. 4. Radiation pattern (top) in the H-Plane and derivative of the Direction-Finding Function (bottom) for the dual-polarized log-periodic antenna system squinted at 25°.

IV. Conclusion

A dual-polarized, log-periodic antenna in pyramidal configuration is proposed. The approach leveraged an integrated feed to perform impedance matching, improve integration ease with COTS components, and remove the need for a balun. Good performance over 5:1 bandwidth is obtained from simulations in ANSYS HFSS, while maintaining a structure that lends itself to additive manufacturing processes. The demonstrated field of view for the direction-finding function with 0.5 dB/° resolution is 40°.

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