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LOW COST ALL METAL ADDITIVELY MANUFACTURED WIDEBAND ANTENNA ARRAY MODULES (Preprint)

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14. ABSTRACT
This paper introduces a modular, end-fire, dual-polarized ultra-wideband scalable array (MEDUSA) realized exclusively with direct metal laser sintering (DMLS) to achieve a connector-less phased array antenna module. The radiator is based on a variation of conventional tapered slot antennas (i.e. Vivaldi) to achieve an all metal fully-monolithic element consist-ing of RF coaxial interface, balun, and free-space transformer. A very low-cost array module is achieved by adapting the design uniquely to the fabrication process in order to eliminate nearly all post-processing. A finite 8x8 array covering 7-21 GHz has been prototyped and measured to demonstrate agreement in active impedance and element patterns.

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Low Cost All Metal Additively Manufactured Wideband Antenna Array Modules

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***Abstract*—This paper introduces a modular, end-fire, dual-polarized ultra-wideband scalable array (MEDUSA) realized exclusively with direct metal laser sintering (DMLS) to achieve a connector-less phased array antenna module. The radiator is based on a variation of conventional tapered slot antennas (i.e. Vivaldi) to achieve an all metal fully-monolithic element consisting of RF coaxial interface, balun, and free-space transformer. A very low-cost array module is achieved by adapting the design uniquely to the fabrication process in order to eliminate nearly all post-processing. A finite 8x8 array covering 7-21 GHz has been prototyped and measured to demonstrate agreement in active impedance and element patterns.**

I. Introduction

Modern active electronically scanned array (AESA) systems generally support multifunctional, shared-aperture operations such as radar and multiple-input, multiple-out (MIMO) communication systems. These diverse functional requirements lead to AESA systems that must maintain ultra-wideband (UWB) operation over wide-scan angles with polarization agility. High-profile notch or Vivaldi based antenna architectures have remained popular solutions for these sensor applications due to its ability to cover operational bandwidths in excess of 10:1 over wide scan volumes with a simple 50-ohm coaxial feed [1]–[4]. Vivaldi antenna arrays continue to receive interest as researchers seek to improve various performance or fabrication complexities associated with the design [5]–[7]. Recent advances have also demonstrated a low cost UWB array module with connector-less phased array radiating element realized with stereolithography (SLA) [8].

In this paper the metallized SLA MEDUSA antenna architecture is extended to titanium DMLS as an alternative prototyping process to achieve a mechanically robust, low-cost UWB antenna array. This paper will first briefly review the design for the modular, end-fire, dual-polarized ultra-wideband scalable array (MEDUSA). Then, a fully-monolithic all metal titanium element consisting of a 50-ohm coaxial interface, balun, and free-space transformer will be shown which completely eliminates the need for additional RF connectors or alternative interconnects. This titanium DMLS design realizes the advantages of rapid manufacturing and provides substantial cost savings for high power phased array antennas.

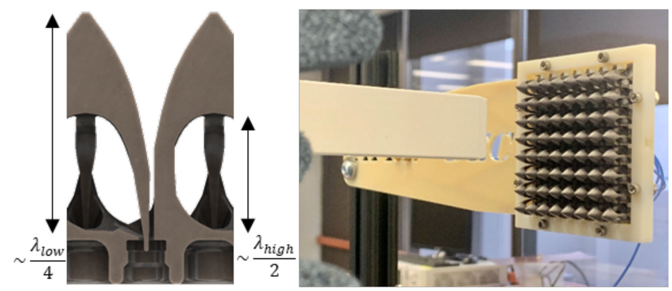

Fig. 1. 3D model of the titanium DMLS MEDUSA element with integrated SMPM connector, balun and impedance transformer.

II. Element Design

The conventional approach to feeding Vivaldi antennas utilizes the Knorr balun for a wideband transition from an unbalanced feed to a balanced slot line radiator. This feed geometry generally consists of the unbalanced feed structure routed out and around the cavity structure to terminate into a 50-ohm coaxial connector at the antenna element base. The standard method unnecessarily increases the transition routing complexity and a modified feed method was introduced in [8]. This new feed method shifts the balun location up and around the parallel line feed arms and allows the impedance transition elements to be concentric with the radiator elements. The approach reduces the DMLS structure complexity and will readily scale into millimeter wave bands.

The presented element realized with titanium DMLS, as shown in Figure 1, accommodates both the printer dimensional tolerances and post-processing requirements (i.e. support structures, build platform removal, etc.) with the inclusion of two 50-ohm embedded SMPM (GIIPO) coaxial connectors. This design eliminates the need for additional RF connectors by printing two modified SPMP connectors directly into the array module. The modified feed geometry attempts to ideally trade-off the geometric requirements for successfully mating to the SMPM connector while also providing a mechanically robust feed pin. This effectively reduces both the materials cost and assembly integration times to achieve a very low cost phased array antenna module.

III. Predicted and Measured Results

Simulations and measurements demonstrate the performance to be comparable to conventional PCB fabricated Vivaldi antenna arrays. The presented titanium DMLS MEDUSA element (8mm x 8mm x 12mm unit cell size) covers 7-21 GHz operation, though may be scaled to other frequency bands and operational bandwidth ratios. A prototype module consisting of 8x8 elements was fabricated and measured to validate the DMLS MEDUSA architecture. This initial prototype was developed with a Concept Laser M2 machine with titanium (Ti 6Al-4V) at 30um layers to achieve the necessary geometric tolerances with a 300 uin Ra surface roughness. Secondary plating may be applied as needed to increase the surface conductivity. Plots of the predicted active-VSW along the E-/H-/D-plane cuts are shown in Figure 2. The design achieves low VSWR for wide scan angles in all planes. This predicted performance is comparable to conventional PCB Vivaldi antennas in terms in operational bandwidth, scan volume, VSWR, and polarization purity.

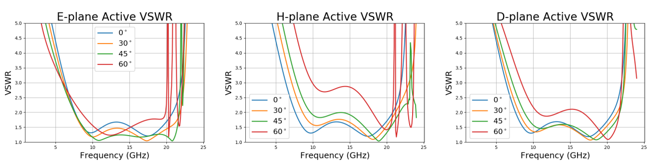

Fig. 2. Predicted infinite array active-VSWR for E/H/D-planes.

Embedded element patterns were measured using a near-field scanner with boresight realized swept gain for the center most element of the array shown alongside predictions for a planar array in Figure 3. At broadside radiation, more than a 3:1 bandwidth is achieved (7-21 GHz). For this operational frequency range the active VSWR is 2.0 or better and the realized embedded element gain correlates to within +/-2 dB the theoretical ideal. Additionally, the measured embedded element patterns along E-/H-/D-plane cuts are shown in Figure 4. The co-polarization and cross-polarization measured patterns are shown for E-plane and H-plane cuts and demonstrate stable patterns across the operational bandwidth. All measurements include some variation due to finite array effects as well general measurement setup and fabrication tolerance errors.

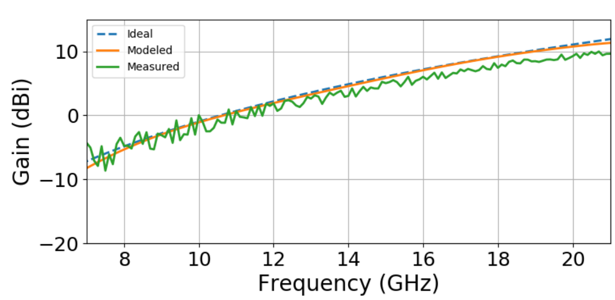

Fig. 3. Modeled vs measured broadside realized embedded element gain for the prototype 8x8 array.

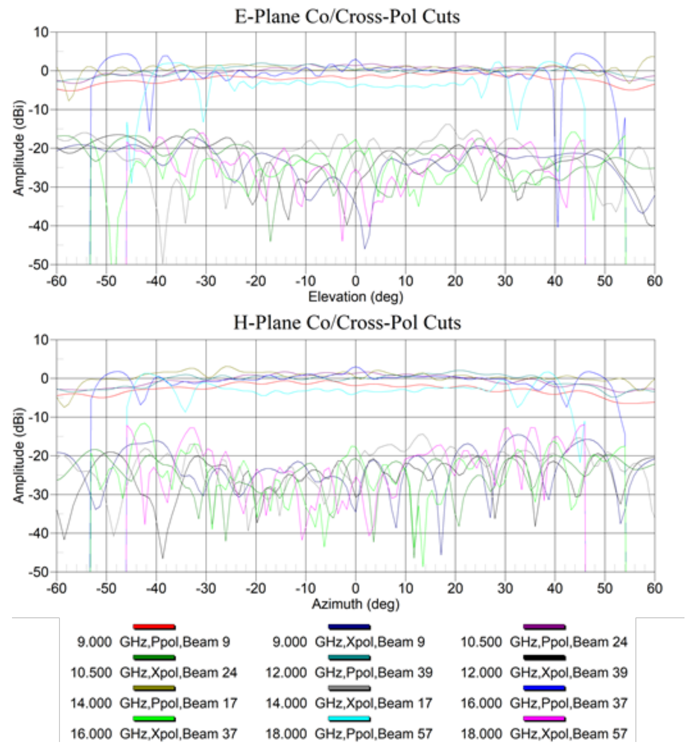

Fig. 4. Measured co-polarized and cross-polarized embedded element radiation patterns for E/H/D-planes.

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