Additive Manufacturing of a Dual Band, Hybrid Substrate, and Dual Polarization Antenna

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Abstract **—** We describe the additive manufacturing results pertaining to a multi-function antenna aperture. The antenna consists of customized high dielectric and low loss feedstocks as the enabling technology. The 3D printed prototype shows agreement with simulation while providing excellent performance.

Index Terms **—** additive manufacturing, 3D printing, dual-band antenna, dual polarization, hybrid dielectric.

I. INTRODUCTION

Additive manufacturing (AM) allows engineers to re-think the RF design space. AM facilitates complex designs that required properties not achievable by current manufacturing methods. The 3D and hybrid-material approaches needed to achieve these designs makes AM critical to the future of radio frequency (RF) systems.

Industry has yet to develop and characterize electromagnetic properties of AM feedstocks for antennas. Recent research into the composition of high dielectric feedstocks for AM opens the design space for printed hybrid material antennas [1],[2]. We propose a dual band antenna utilizing hybrid dielectric substrates to shrink the footprint of the low frequency antenna element. For this investigation, we design the dual-band antenna for S-band and X-band respectively. Each of these elements achieves both vertical and horizontal polarization via a pair of orthogonal pin feeds for each element. We perform all simulations using the finite difference time domain (FDTD) solver of CST Studio Suite 2019.

II. ANTENNA DESIGN

We base the hybrid substrate shared aperture antenna on a previously documented shorted annular ring and concentric patch antenna [3]-[5]. Figure 1 (left) shows the geometry of the dual band antenna on the hybrid substrates, and Fig. 1 (right) shows the layout of the concentric hybrid substrates themselves. Table 1 shows the dimensions of the geometries given in Fig. 1. Using a substrate of ε_{r2}=6.15 instead of ε_{r1}=2.65 under the S-band element allows us to shrink the footprint of the antenna by 32%.

Orthogonal microstrip pin feeds achieve either vertical or horizontal polarization at both S- and X-bands. Figure 2 shows the locations of the orthogonal pin feeds for both the annular ring and the concentric patch. We use a shorting wall, shown in Fig. 2, to short the annular ring at its inner perimeter. This cancels surface waves on the dielectrics by suppressing the dominant mode, and helps increase isolation between both the cross polarization ports in the same frequency band and the isolation between the ports in the S- and X-bands.

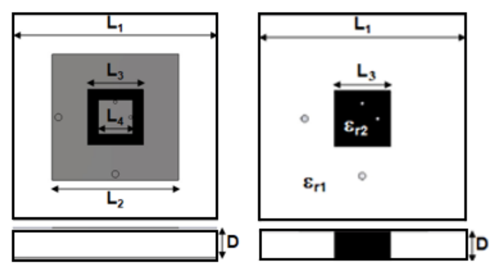

Fig. 1. Top view geometry of the dual band antenna (left) and layout of the hybrid substrates (right).

Table 1: Dimensions of Fig. 1 in millimeters

L_1	L_2	L_3	L_4	D	ε_{r1}	ε_{r2}
36.7	22.57	10.23	7.08	5.05	2.65	6.15

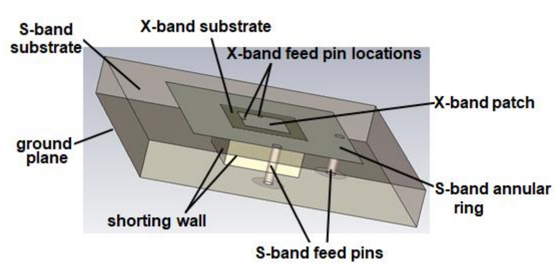

Fig. 2. Transparent schematic view of the dual band antenna and the 50Ω pin feed network.

Figure 3 shows a to-scale 3D printed prototype of the antenna shown in Fig. 2. The antenna shown in Fig. 3 utilizes a microstrip stack of a silver ink layer, hybrid

Submitted On: September 9, 2020
Accepted On: September 9, 2020

https://doi.org/10.47037/2020.ACES.J.351110

custom dielectric layer, and a copper ground layer. All conductive layers are 0.1 mm thick. The hybrid substrate layer is 5.05 mm thick. The total profile of the antenna is 5.25 mm.

III. EXPERIMENTAL RESULTS

We show the measured versus simulated return loss and realized gain of the dual band antenna at S-band in Fig. 4 and Fig. 5 as well as at X-band in Fig. 6 and Fig. 7. We measured all realized gain versus frequency measurements at boresight to the antenna. We see general agreement at both bands for all measurements. One discrepancy is in the S-band realized gain where measurements show a drop out at resonance of 6 dB. We believe this is due to poor isolation between the orthogonal ports at S-band at resonance, but this warrants further investigation. We attribute measured differences in the return loss to manufacturing tolerances since the pin fed patch is an extremely resonant type of feed. This is more apparent at X-band frequencies where tolerances become electrically larger.

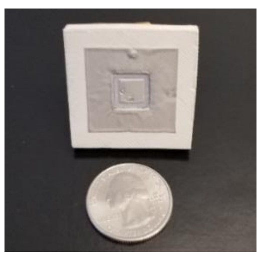

Fig. 3. Prototype dual band antenna of Fig. 1 produced visa additive manufacturing.

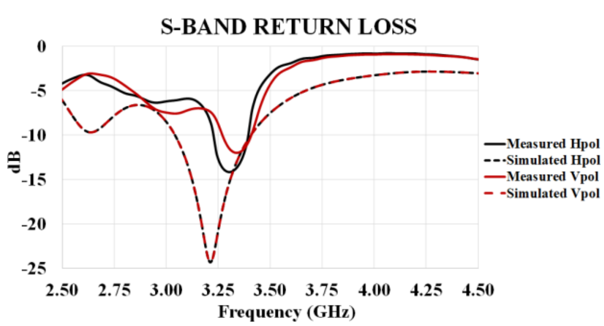

Fig. 4. Return loss comparison at S-band ports.

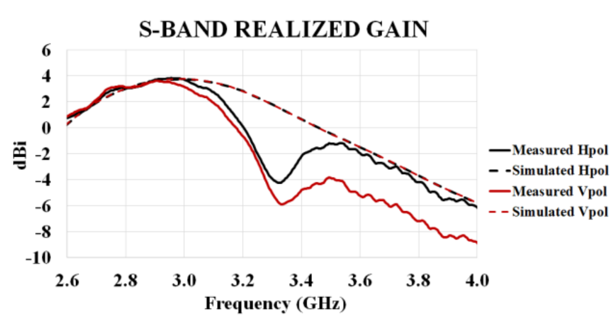

Fig. 5. Realized gain comparison at S-band ports.

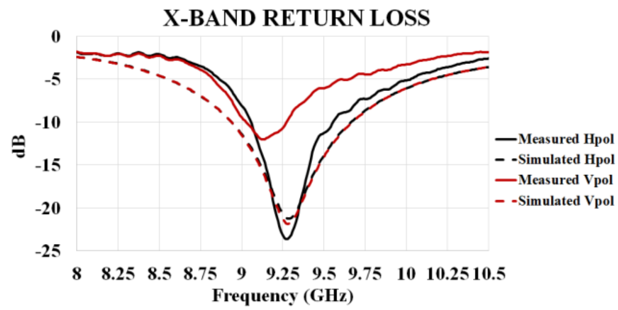

Fig. 6. Return loss comparison at S-band ports.

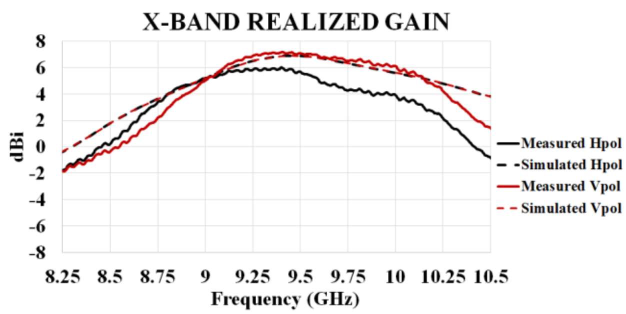

Fig. 7. Realized gain comparison at X-band ports.

IV. CONCLUSIONS

This article shows that AM customizes dielectric properties to optimize antenna designs, and achieves robust measured data compared to simulation. AM enables complex antenna designs combining multi-functionality into a single aperture that would be expensive and cumbersome using traditional methods. Future work includes researching conductivity of AM inks, increasing achievable dielectric constants of AM materials, researching coupling issues, and broad banding the multi-function antenna through future AM advances.

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