Antenna Comparison for Additive Manufacturing versus Traditional Manufacturing Methods

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***Abstract*—We present the comparison of a dual S/X-band antenna manufactured using traditional methods versus a version produced by additive manufacturing. The S-band element is an annular ring antenna with a shorting wall to suppress surface waves and increase isolation between excitation ports. The X-band element is a concentric patch. Both elements use orthogonal feeds to allow horizontal and vertical polarizations. Our results show excellent agreement between the two methods for this antenna design.**

Keywords—additive manufacturing, dual band antenna, dual polarization, hybrid substrate

I. Introduction

Recent interest in multi-function antenna applications necessitates the investigation of multi-band antenna approaches. Currently, a suite of different antennas perform a host of functions making systems challenging to upgrade, costly to maintain, and difficult to network for realizing multi-function capabilities. A single multi-function antenna could replace current disparate antenna technologies. The 3D and hybrid-material approaches needed to achieve these designs makes additive manufacturing (AM) critical to the future of radio frequency (RF) systems. The low profile and light-weight design of references [1],[2] shows great promise for multi-function antenna applications. These multi-function geometries consist of a shorted annular ring for the low frequency element and a concentric patch antenna for the high frequency element.

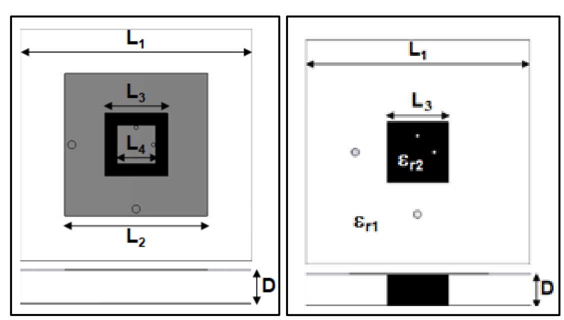
AM allows engineers to re-think the traditional antenna design space. AM facilitates complex designs that require properties not achievable by current manufacturing methods. Strides in AM show robust structural and mechanical parts, but industry has yet to develop and characterize a large suite of AM compatible materials with desirable RF properties. Low dielectric constants of commercial feedstocks limit current AM antenna designs. Recent research into the composition of high dielectric feedstocks for AM opens the design space for 3D printed hybrid material antennas [3],[4].

We compare an established antenna design using both traditional manufacturing and AM materials and techniques. This paper shows the advantages and disadvantages currently associated with replacing common manufacturing practices with AM for RF components, and shows comparative performance of both approaches through return loss measurements. The results show that development of new electromagnetic materials and repeatable techniques for AM are crucial to the future of antenna design and development. New dielectric materials show AM is a viable replacement for traditional manufacturing techniques in terms of performance.

II. Dual Band Antenna Design

We base our dual S/ X-band and dual polarization antenna design on an established geometry [1],[2]. We use a substrate of ε_{r1}=6.15 instead of ε_{r1}=2.33 under the annular ring to shrink the footprint of the antenna by 32%. Fig. 1a shows the geometry of the S/X-band antenna, and Fig. 1b shows the layout of the concentric hybrid substrates. Table I lists the dimensions of the geometry illustrated in Fig. 1. Fig. 2a shows a prototype S/X-band antenna using traditional Rogers Corporation materials and Fig. 2b shows the AM version of the same design.

Orthogonal pin feeds achieve vertical or horizontal polarization at both S/X-band. We short the inner perimeter of the annular ring to ground to cancel surface waves on the dielectrics and help increase isolation between the ports. The microstrip antenna of Fig. 2a utilizes a top copper layer, a hybrid RT6006 and RT5870 substrate layer, and a copper ground layer. All metal layers are 0.1 mm thick. The hybrid substrate layer is 5.05 mm thick. The total profile of the antenna is 5.07 mm. DeLUX Engineering extruded custom high dielectric filaments and achieved substrates mirroring ε_{r1}=6.15 and ε_{r2}=2.33 through proprietary printing techniques using an nScrypt 3D printer. We printed the metallic layers from a high conductivity silver ink formulated by DeLUX Engineering.

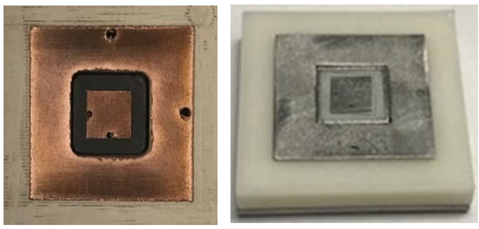


(a) (b)

Fig. 1. a) Layout of the dimensions of the S/X-band antenna and b) layout of the hybrid dielectric substrates.

TABLE I. ANTENNA DIMENSIONS IN MILLIMETERS OF FIG. 1.

L_1	L_2	L_3	L_4	D	ε_{r1}	ε_{r2}
36.7	22.57	10.23	7.08	5.07	6.15	2.33



(a) (b)

Fig. 2. a) Top view of the traditional copper plated antenna and b) top view of the AM version of the same antenna.

III. EXPERIMENTAL RESULTS

This section compares measured results for the prototype antennas in Fig. 2. We show the measured return loss versus frequency curves at S-band resonance in Fig. 3 and X-band resonance in Fig. 4. The solid curves are for the antenna manufactured from standard Rogers Corporation materials in Fig. 2a, and the dashed curves are for the AM antenna manufactured from custom materials provided by DeLUX Engineering in Fig. 2b. We see good agreement at both bands in the return loss curves for both polarizations with an S-band resonance of 3.25 GHz and an X-band resonance of 9.25 GHz. There is a small frequency shift between the horizontal and vertical polarization ports of the AM antenna at X-band. At frequencies of 9.25 GHz, small differences in the locations of the pin feed can have large effects on the quality of the match. However, this difference is only 150 MHz or 1.6% and we attribute this to tolerance errors in the manufacturing process. We can see that there is still better than -10 dB return loss for the AM vertical polarization port at the 9.25 GHz resonance so this 1.6% difference would still be within performance specifications.

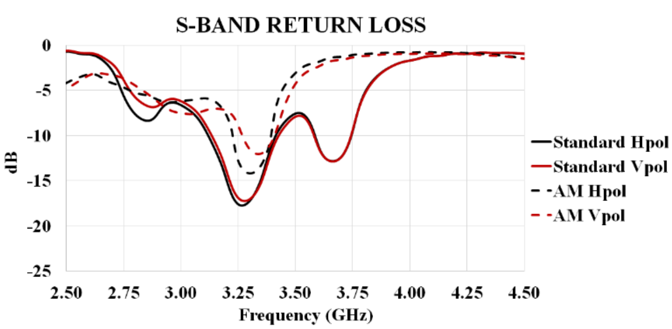


Fig. 3. Comparison of S-band return loss for the antennas shown in Fig. 2 and Fig. 2b.

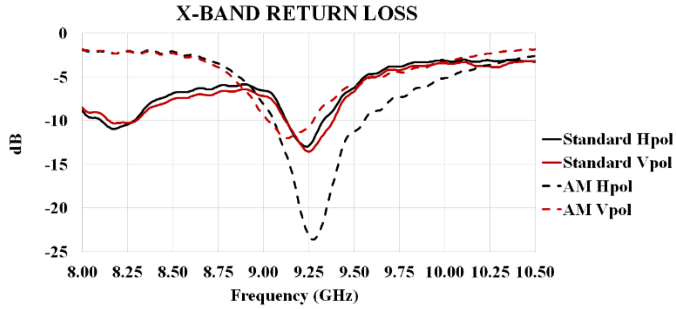


Fig. 4. Comparison of X-band return loss for the antennas shown in Fig. 2a and Fig. 2b.

IV. CONCLUSIONS

We present a comparison of the resonance performance of a S/X-band and dual polarization antenna manufactured using traditional methods versus an AM version. We prototyped the traditional antenna from typical copper clad dielectric substrates from Rogers Corporation and the AM antenna from custom materials developed by DeLUX Engineering. The return loss curves show excellent agreement to within 1.6% at both S- and X-bands. We show that research into methods to produce custom AM compatible filaments for dielectric materials is capable of replicating performance of an antenna made from traditional materials. This is an important step to provide confidence in AM for increasingly complex antenna structures. Future work will highlight performance variations in the radiation patterns and radiation efficiency for the prototype antennas of this paper.

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