National Aeronautics and Space Administration

Submillimeter Antenna Technology Based on Printed Lattice Structures

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Objectives Develop the proof-of-concept for a new class of lightweight, stiff, low cost, and thermally stable submillimeter wavelength antennas through additive manufacturing (AM) that will satisfy the growing need for antennas on cubesats and smallsats. This approach should also result in improved panels for larger antennas.

Background Submillimeter wavelengths are being utilized to an increasing degree in multiple areas of JPL research. The leading state of the art technique for fabricating submillimeter antennas is to form the reflector by electrodepositing a Ni layer over a glass mold and stiffen it by bonding an Al honeycomb. This reliance on molds results in high costs, long lead times, and design inflexibility, while the honeycomb bonding process results in thermomechanical issues due to the use of adhesives and mismatched coefficients of thermal expansion. The proposed solution additively manufactures the complete reflector and back structure, reducing manufacturing lead time and cost, while improving structural stiffness and thermal stability by fully integrating the back structure. The increased design flexibility of additive manufacturing additionally enables the back structure to be highly tuned and optimized, further reducing mass.

Approach and Results A set of representative coupons, including a reflector surface and integrated backing structure, were manufactured from Al 6061 RAM2 using Laser Powder Bed Fusion (LPBF) to evaluate performance. To assess the ability to achieve low areal densities, coupons SN001-SN003 were chemically etched at varying removal rates to hone the geometry (Figure 1). Aluminum-based LPBF is generally limited to printing walls with a thickness of 1 mm; however, through chemical etch post processing, we were able to reliably reduces these thicknesses down to 300 μm and potentially down to 100 μm with further process refinement. To appropriately reflect submillimeter wavelengths (1mm>λ>0.1mm), a surface accuracy of less than λ/20 RMS is required. For reference, a common frequency used on missions such as WISPER and Source is 600 GHz (500 μm wavelength), which requires a 25 μm RMS surface accuracy. SN004 and SN005 had the reflector surface finish machined while SN006 was left in the as-printed state. The machined surfaces were measured with a profilimeter to have 0.56 μm RMS and the as printed surface 2.48 μm RMS (Fgirure 2), both of which are good even for the shortest submillimeter wavelength of 0.1 mm. For the machined coupons, the reflector reflectivity was measured over a frequency range of 220-320 GHz (937-1363 μm) using a custom setup in Prof. Sunil Golwala's laboratory at Caltech. Within the measurement error of the test setup, both coupons demonstrated 98-100% reflectivity over the given frequency range (Figure 3).

Significance/Benefits to JPL and NASA This worked demonstrated the proof of concept for additively manufactured submillimeter reflectors, verifying reflectivity performance and low areal density backing structures. With further development, AM reflectors have the potential to reduce manufacturing lead time and cost, while improving structural stiffness and thermal stability. With a growing interest in submillimeter wavelength antennas within JPL and NASA, AM reflectors have the potential to be a lower cost, higher performance alternative to conventional design architectures, especially for cubesats and smallsats.

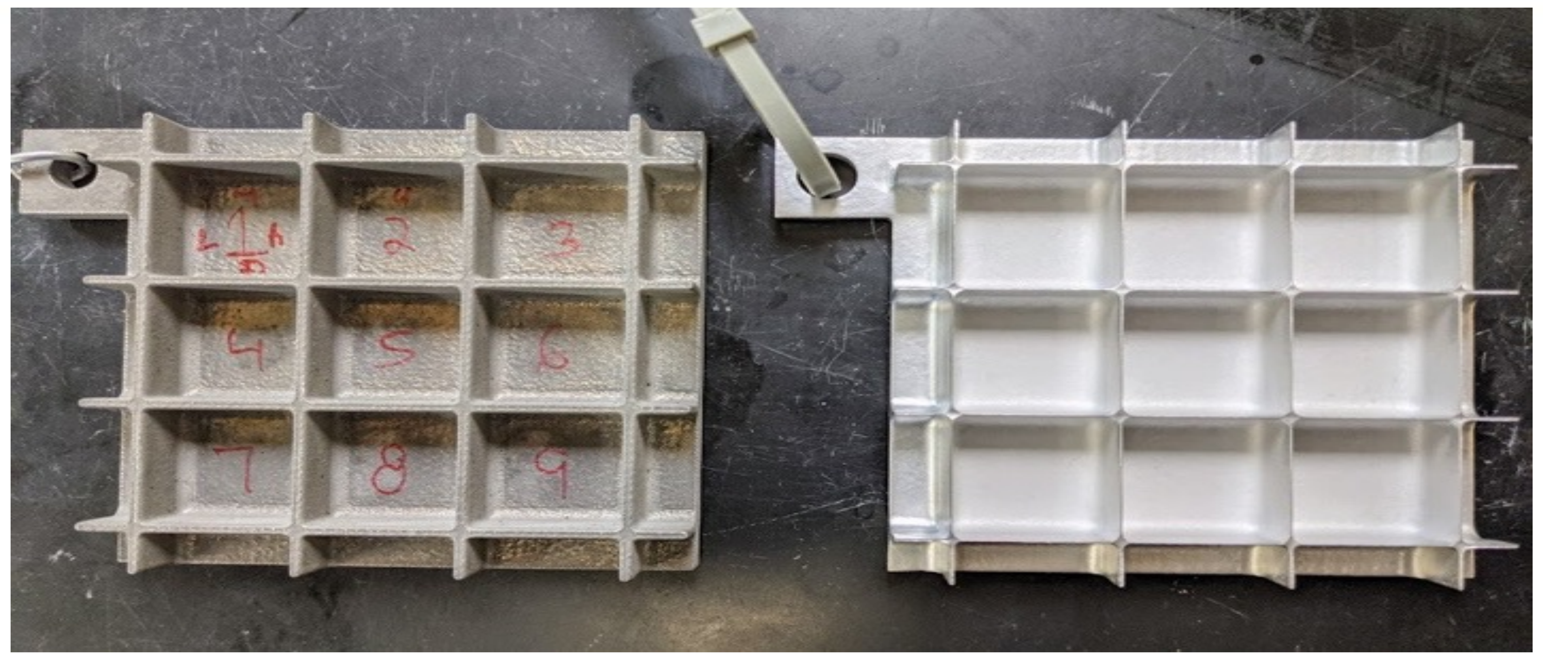

Fig 1. A chemical etching process was used to hone the walls of the as-printed geometry (left) to achieve thinner wall thicknesses than can be printed (right), enabling areal densities comparable to conventional reflectors.

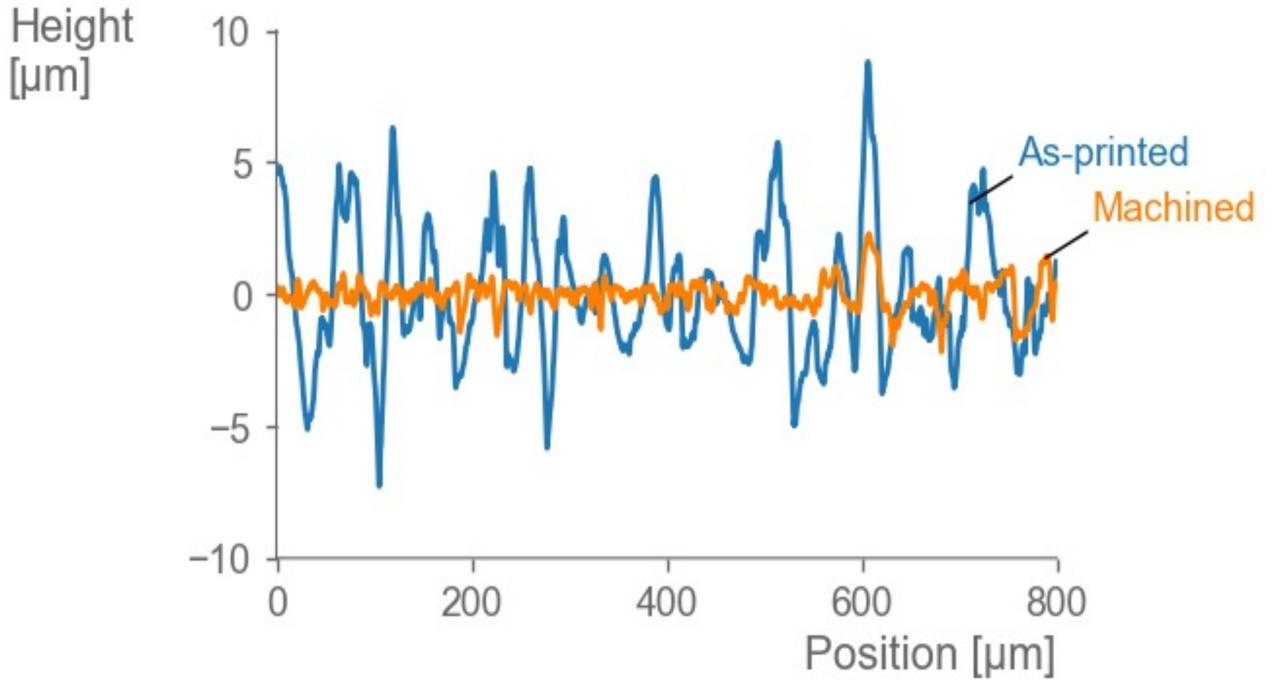

Figure 2. The surface roughness of the as-printed and machined coupons were measured to be 2.54 μm RMS and 0.56 μm RMS, respectively, both sufficiently smooth for high-performance submillimeter reflectors.

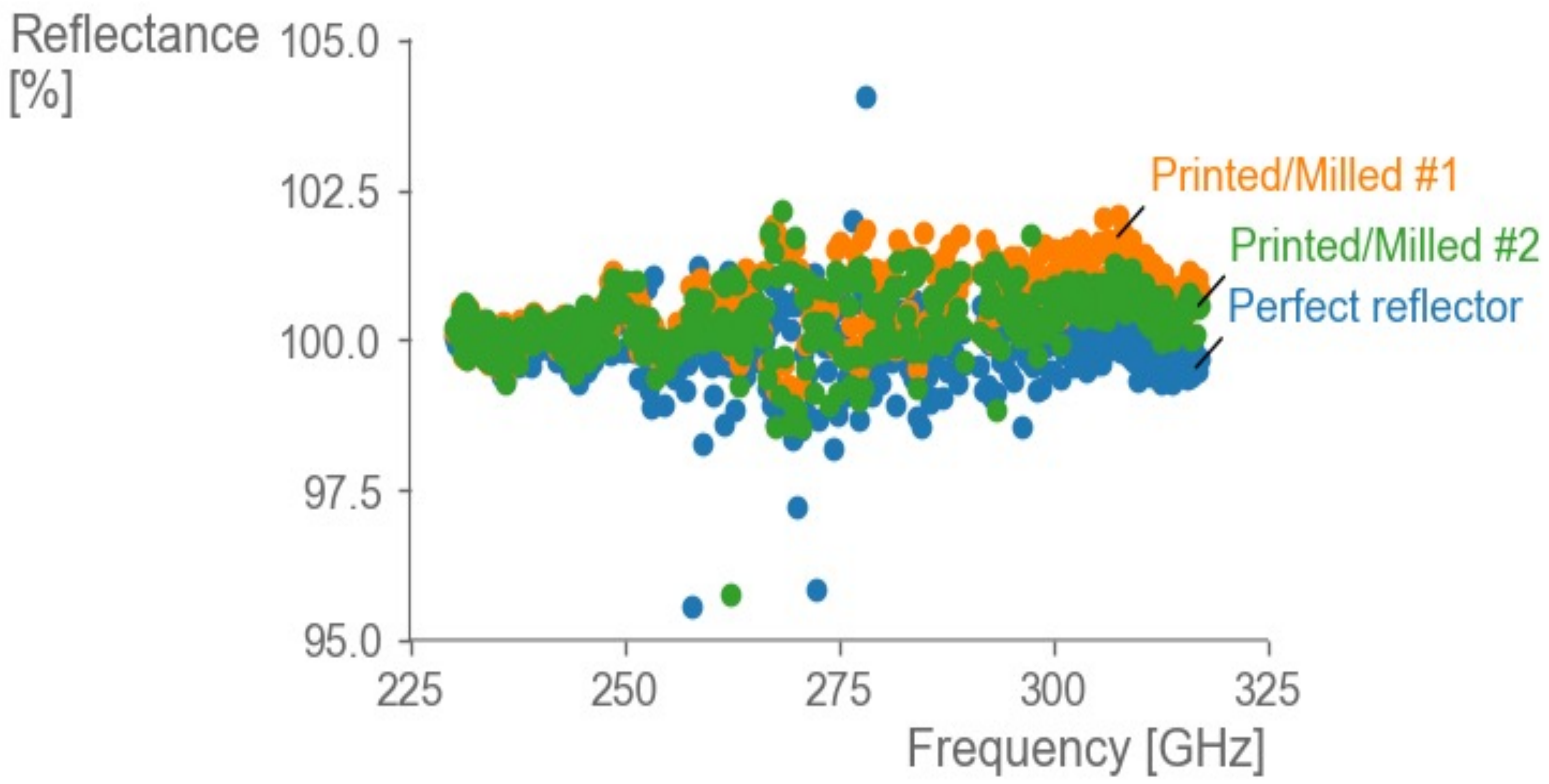

Figure 3. The reflectance of the milled coupons were measured to be equivalent to a perfect reflector within measurement noise.

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