National Aeronautics and Space Administration

Submillimeter Antenna Technology Based on Printed Lattice Structures

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Program: FY22 R&TD Topics
Strategic Focus Area: Additive Manufacturing, Multifunctional Systems

Objectives: Develop 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 panels for large antennas and small antennas on cubesats and smallsats. **Surface accuracy less than λ/20 RMS** for efficient, diffraction-limited operation at wavelength λ: Our initial objective is to develop reflectors for 600 GHz frequency (500 mm wavelength). For this frequency, the primary reflector requires a 25 μm rms surface accuracy. **Antennas must be thermally stable over a temperature range of -250^{o}C to +50^{o}C**: Conventional reflector systems are often constructed from multiple materials with differing Coefficients of Thermal Expansion (CTE), resulting in thermal stability issues. The proposed Additive Manufacturing (AM) methodology consists of a single material configuration, eliminating this issue by design. The proposed methodology includes the design and optimization of a lattice backing structure that is integral to the reflector geometry giving increased performance and lower areal density.

Background: Submillimeter wavelength (1mm > λ > 0.1mm) reflectors are being utilized to an increasing degree in NASA missions. State-of-the-art lightweight antenna designs employ surface panels bonded to a honeycomb core, which can lead to thermal problems for use in space. A new and fast manufacturing technique capable of producing light, monolithic reflectors is therefore highly desirable.

Approach and Results: In initial proof-of-concept development and manufacturing, we produced small scale reflectors with the reflector surface profile accuracy required for submillimeter wavelength performance and low areal density. A set of 4x sub-scale parabolic reflector coupons (Ø8cm) (see Figure 1) were printed out of Al 6061 RAM2 and used to refine the manufacturing process, developing an aggressive chemical etching procedure to light weight the stiffening backing structure and a machining procedure to achieve the desired reflector profile tolerance. The resulting reflectors have a profile tolerance of 14.1 μm RMS (which would be capable of observing efficiently at λ=0.28 μm). This methodology was then scaled to a larger reflector size of Ø20 cm with an off-axis geometry, as shown in Figure 2. Improved designs are in progress as shown in Figure 3.

Significance/Benefits to JPL and NASA: This work has demonstrated the proof of concept for additively manufactured submillimeter reflectors, developing design capabilities and the manufacturing processes required. 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 designs.

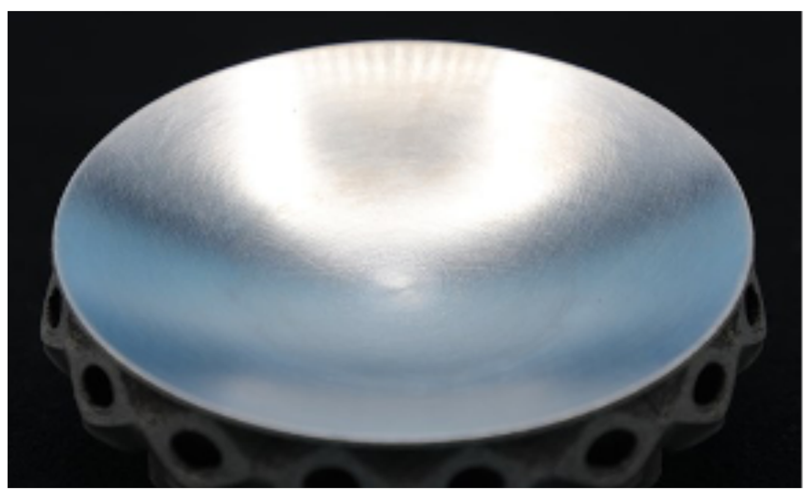

Figure 1: Front side of 8cm diameter parabolic reflector made by Additive Manufacturing with after-machining RMS of 14 μm.

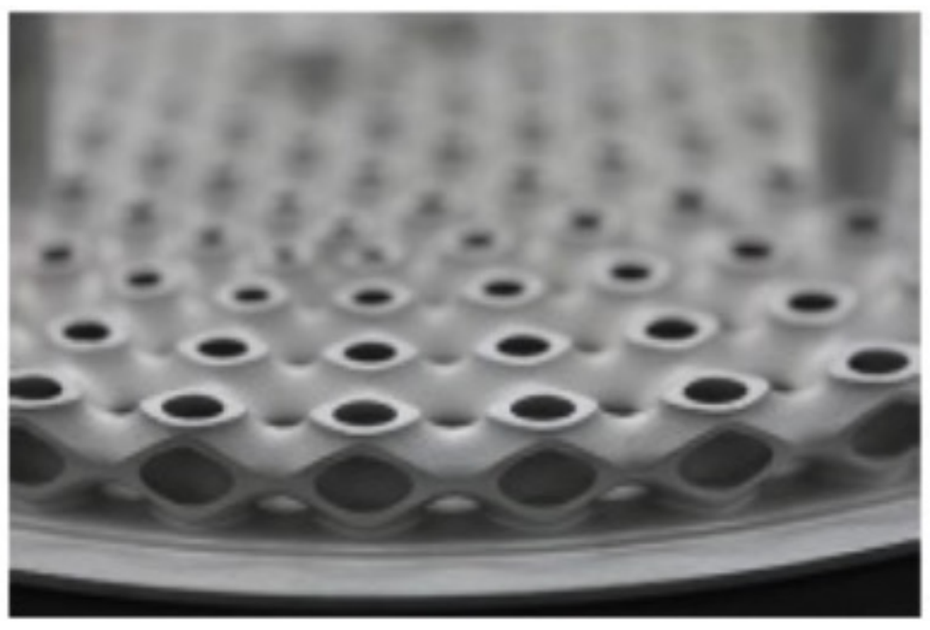

Figure 2: Rear view of 20cm diameter off-axis parabolic reflector designed using JPL's UnitcellApp and a Schwarz unit cell (a Triply Periodic Minimal Surface topology) to obtain high specific stiffness and printability. The antenna is printed in Al 6061 RAM2 and has areal density of 11 kg/m^2.

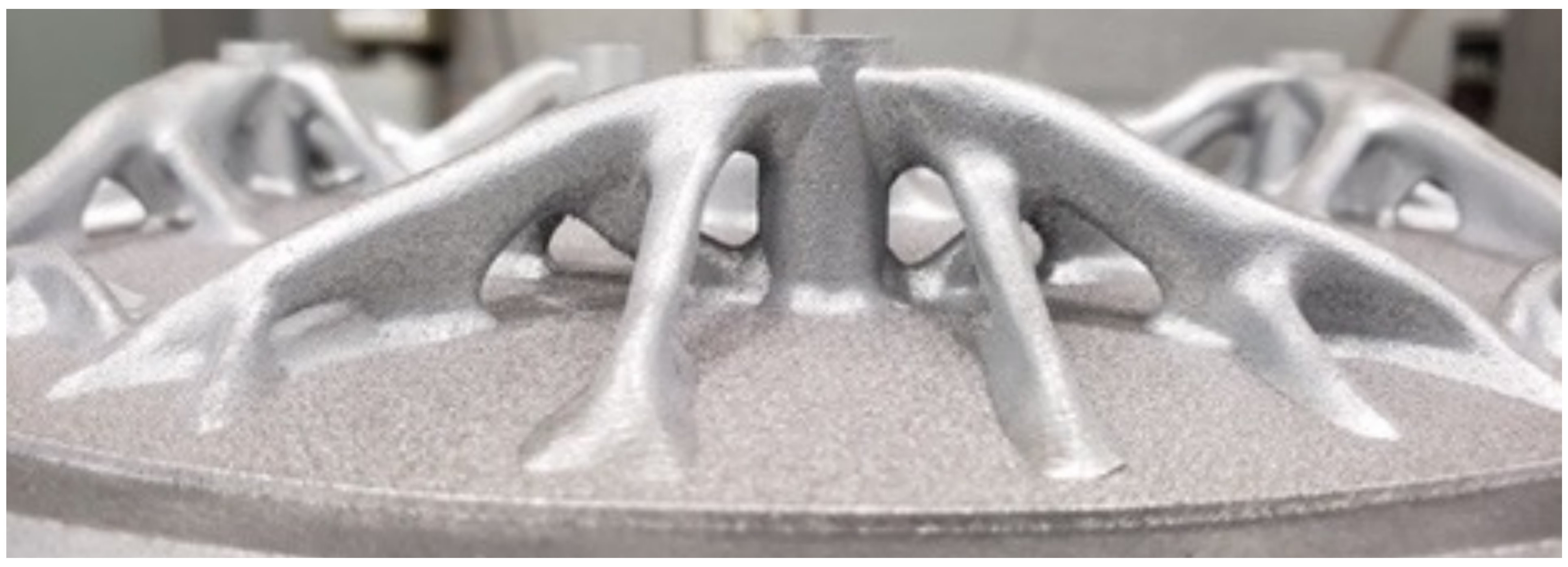

Figure 3: Two views of 20cm diameter AM reflector based on topology-optimized design, printed in Al 6061 RAM2. The areal density is 6 kg/m^2 . The penalty is some anisotropy in the stiffness.

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