National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

Submillimeter Antenna Technology Based on Printed Lattice Structures

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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 small, high-precision antennas on cubesats and smallsats.

- Surface accuracy less than 1/20 wavelength RMS for efficient, diffraction-limited operation: Our initial objective is to develop reflectors for 500 GHz frequency (600 mm wavelength). For this frequency, the primary reflector requires a **<30 μm rms surface accuracy**.
- **Thermally stable** over a temperature range of -250°C to +50°C: Conventional reflector systems are often constructed from multiple materials with differing Coefficients of Thermal Expansion (CTE), resulting in thermal stability issues. The proposed methodology consists of a single material configuration, eliminating this issue by design.
- **Operable in a 1g gravity environment** to allow for balloon-based reflectors and to simplify ground-based qualification of space-based reflectors: The proposed methodology includes the design and optimization of a lattice backing structure that is integral to the reflector geometry.
- **Areal density < 14 kg/m^2**: State-of-the-art commercial submillimeter telescope panels can have an aerial density as low as 14 kg/m^2.

Background: Submillimeter wavelength (1mm>λ>0.1mm) reflectors are being utilized to an increasing degree in NASA missions. In astrophysics, the ASTHROS mission will study how new stars are formed by observing fine structure lines of ionized nitrogen at 0.21 mm and 0.12 mm wavelengths. For many applications, the reflecting surface is electroformed in sections on a glass mold and then bonded to a stiffening backing structure (such as an aluminum honeycomb). The glass molds used in these processes are expensive and long-lead, impacting project budgets, and limiting design flexibility. From a performance standpoint, the mismatched Coefficients of Thermal Expansion (CTE) found in these bonded structures can lead to thermal related performance issues. A new and fast manufacturing technique capable of producing light, monolithic reflectors is therefore highly desirable.

Approach and Results: Due to the complexity associated with predicting outcomes via modeling, reflectors (Figure 1) were manufactured to verify the applicability of AM. Via basic 3-axis post-machining on a mill, surface form accuracies on the order of 10-16 μm RMS were measured as shown in Figures 2a and 2b, meeting the minimum objective for this task of 30 μm RMS. With diamond turning, this could be very significantly improved.

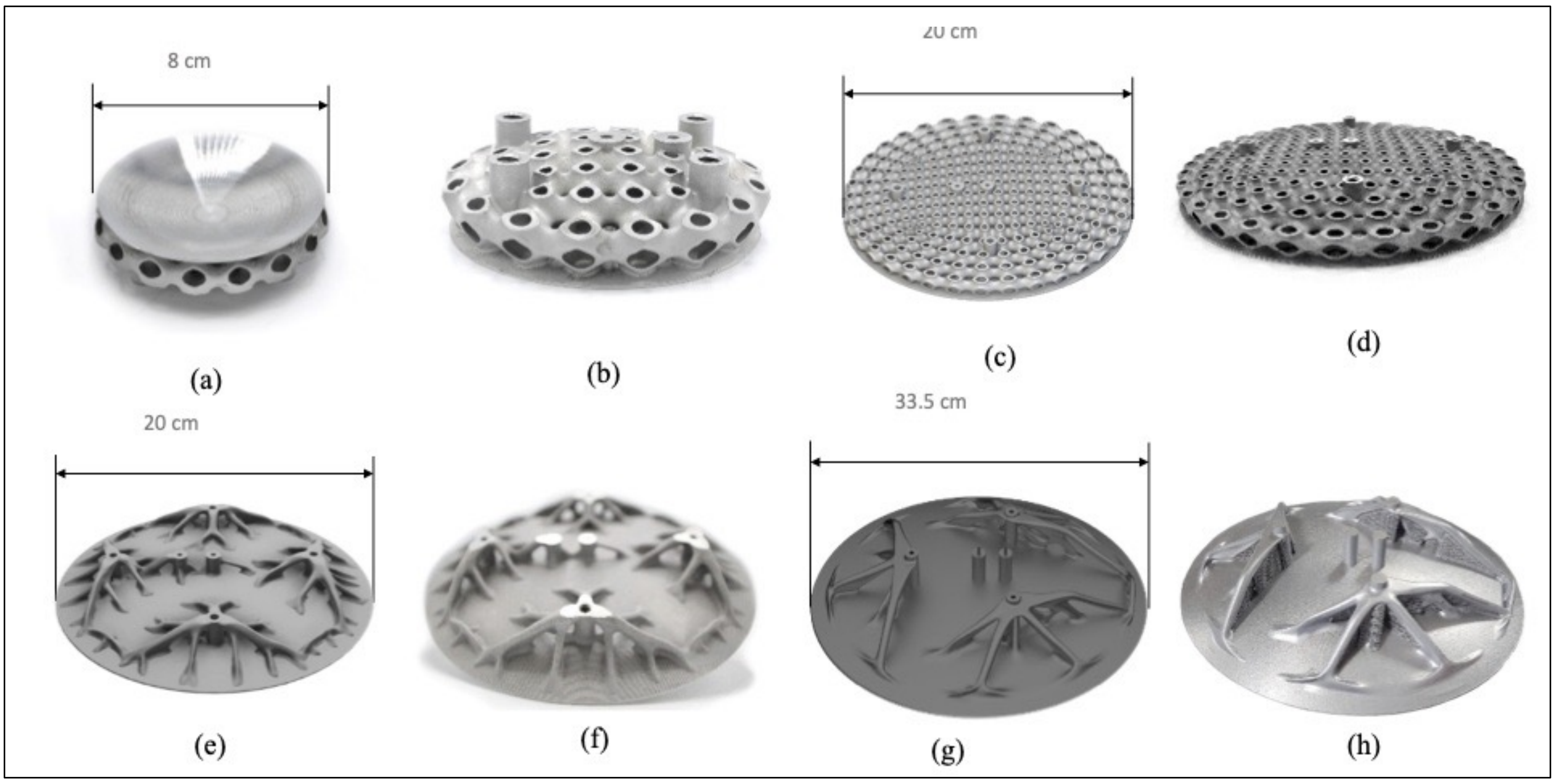

Figure 1: To demonstrate the manufacturing precision requirements for reflectors, four AM reflectors geometries were manufactured: (a, b) on-axis 8 cm diameter subscale geometry used for process development (areal density of 13.4 kg/m^2), (c, d) off-axis 20 cm diameter geometry with a lattice backing structure (areal density of 8.1 kg/m^2), (e, f) off-axis 20 cm diameter geometry with a topology optimized backing structure (areal density of 6.3 kg/m^2), and (g, h) off-axis 33.5 cm diameter geometry with a topology optimized backing structure (areal density of 12.4 kg/m^2). Images (c), (e), and (g) are renderings of the geometries, with the remainder corresponding to the as manufactured parts (noting that (h) shows the geometry prior to the removal of support material and reflector post machining).

Significance/Benefits to JPL and NASA: This worked demonstrated the proof of concept for additively manufactured submillimeter reflectors, the design capabilities, and the manufacturing processes required to create reflector surfaces capable of observing submillimeter wavelengths. 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.

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