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ON-ORBIT ADDITIVE MANUFACTURING OF PARABOLIC REFLECTORS VIA SOLAR PHOTOPOLYMERIZATION

Abstract

In this paper we consider an alternative solution for the conflicting requirements found in designing a spacecraft antenna. High gain and wide bandwidth depend upon large size, while economical orbital deployment dictates lightweight, sturdy, and small structures able to fit (either whole or folded) inside the payload shroud of the launch vehicle. Finally, the antenna must function on orbit; a failed antenna deployment compromises the entire mission. Current solutions are to launch a final-shape unit (compromising on gain, and bandwidth), or to launch a folded antenna (compromising strength and reliability).

There is an alternative: the fabrication of the high-gain spacecraft reflector after the spacecraft is in orbit, outside the atmosphere.

To test this solution we consider a specialized low-power 3D printer that can print a high-gain communication antenna in the space environment. The printer feedstock is a viscous photosensitive resin that crosslinks to a stable heat-resistant solid when exposed to UV. This feedstock is stored in a tank, so it is small, conformable, and immune to launch shock and vibration. Once on orbit, the antenna is printed by extruding the resin onto a motorized base precisely positioned in 3D space as the solar UV polymerizes the resin. By this method we can produce an antenna that may be much larger than the spacecraft itself.

As the antenna is produced on orbit, in microgravity, it does not need to be any more robust than necessary to survive orbit correction maneuvers. Thus, it may be much thinner and lighter than a conventional antenna that must survive the stresses of launch and orbital insertion. The additional motors required for printing then become available for adjusting antenna focus, off-axis aiming, and beam pattern squint control. As the antenna specifics are not determined until actual printing, it would be possible to pre-launch spare space vehicles and print the antenna with a specific (and possibly asymmetric) beam pattern as needed.

To verify that it is possible to produce significant structures with adequate shape control and surface smoothness to be used as spacecraft antennas, we built such a head-and-ram free-form 3D printer extruding one of the candidate resins. While bathing the printer in UV, we successfully printed a 165mm (6.5”) parabolic antenna with an ~f/1 focal ratio and a measured gain of 28 dB in the Ku band (13.5 GHz) with a dipole feed.