National Aeronautics and Space Administration

Ultra-lightweight Deployable Composite RF Apertures

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Program: FY21 R&TD Topics **Strategic Focus Area: Direct/Coherent Detectors and Arrays**

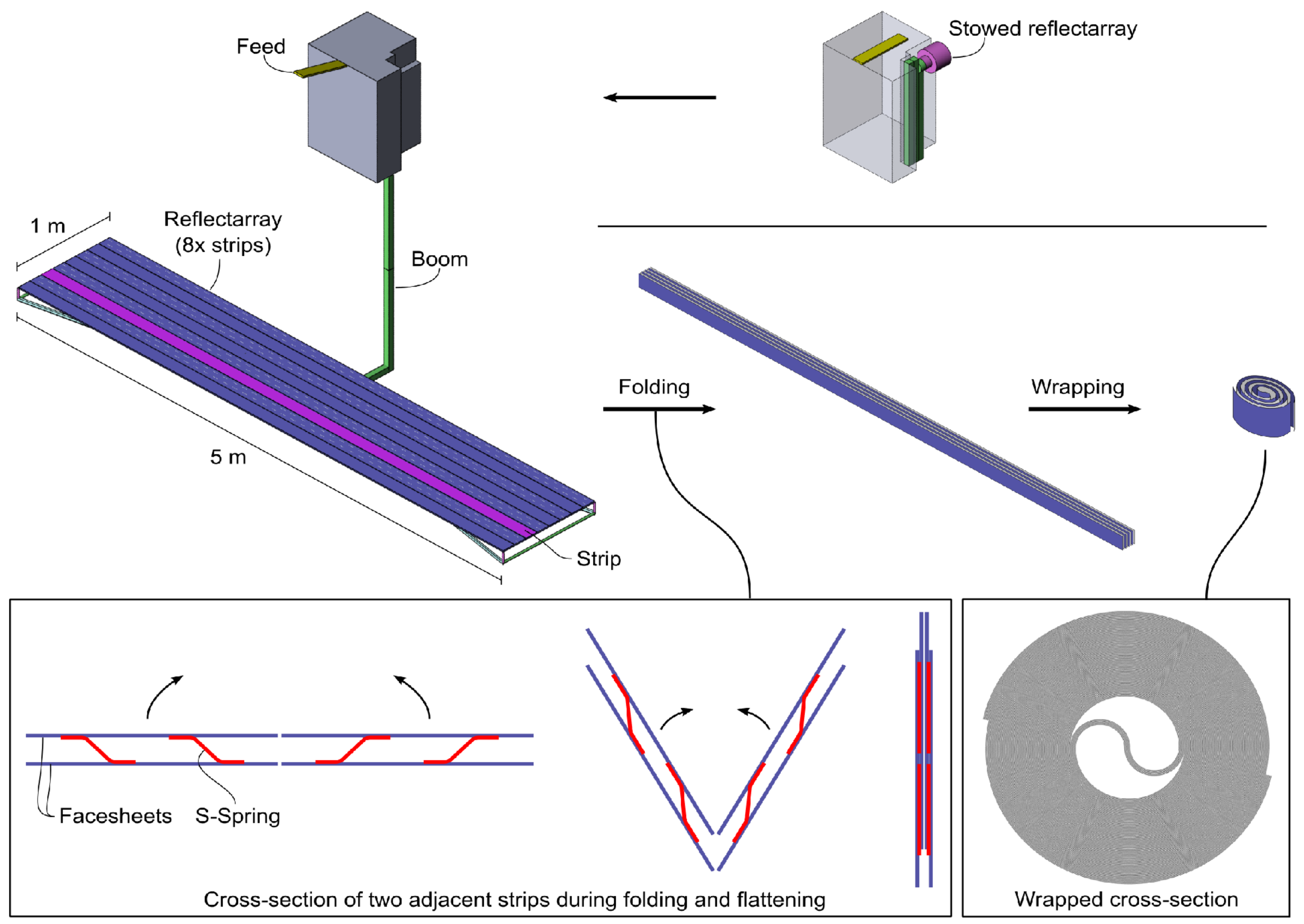

Figure 1: Overview of the antenna deployment and stowage concept, illustrated on a standard ESPA-class bus. The primary 1 m x 5 m reflectarray reflector consists of 8 composite strips, which have cross-section as shown in the left inset. Stowage of the main reflector includes two steps: first the strips are folded and flattened into a long, thin "stack" of strips, and second the strips are wrapped into a compact cylindrical form.

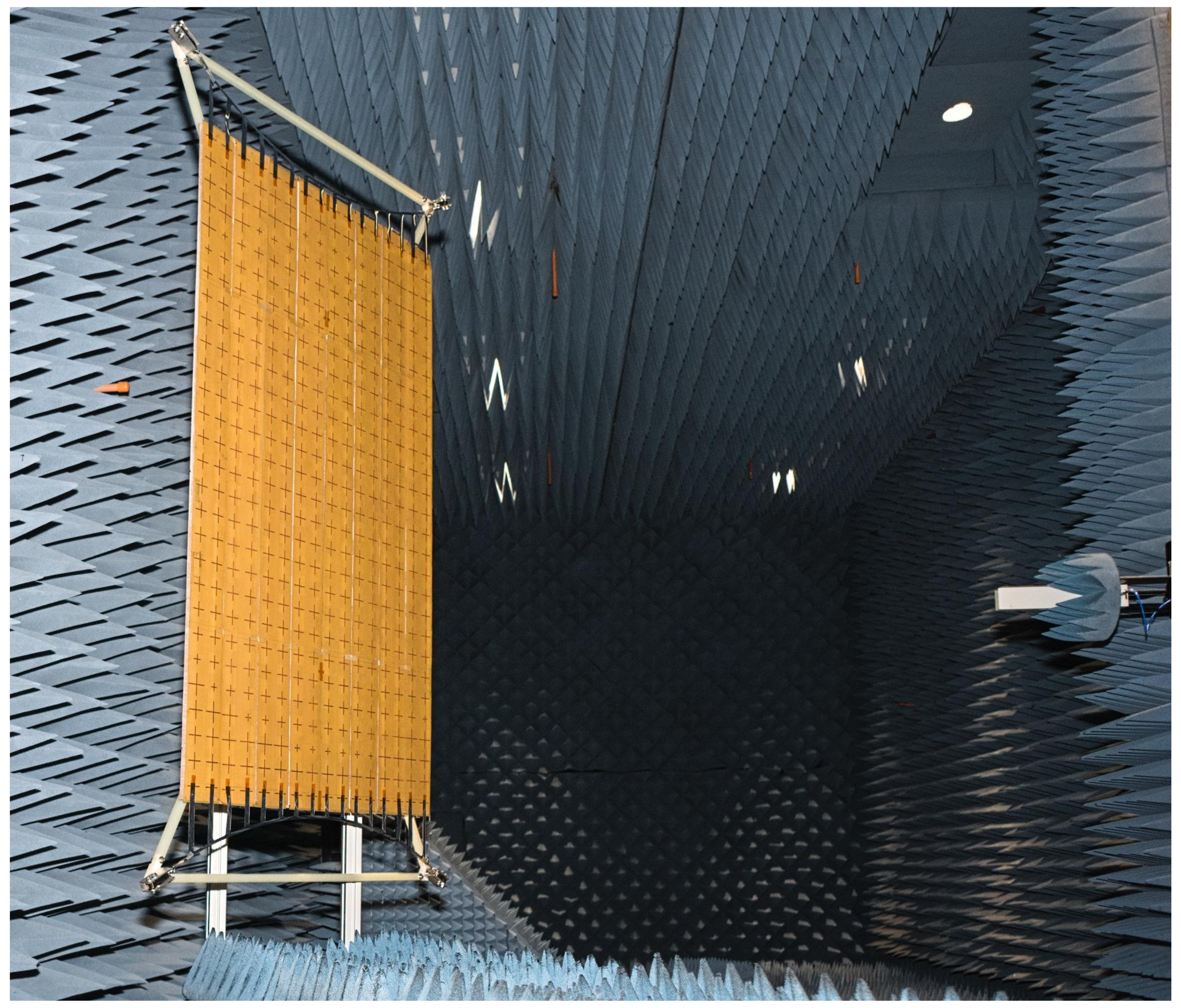

Figure 2: Test article 2 mounted at the 60-ft chamber at the JPL Mesa antenna test range, after having been stowed and deployed.

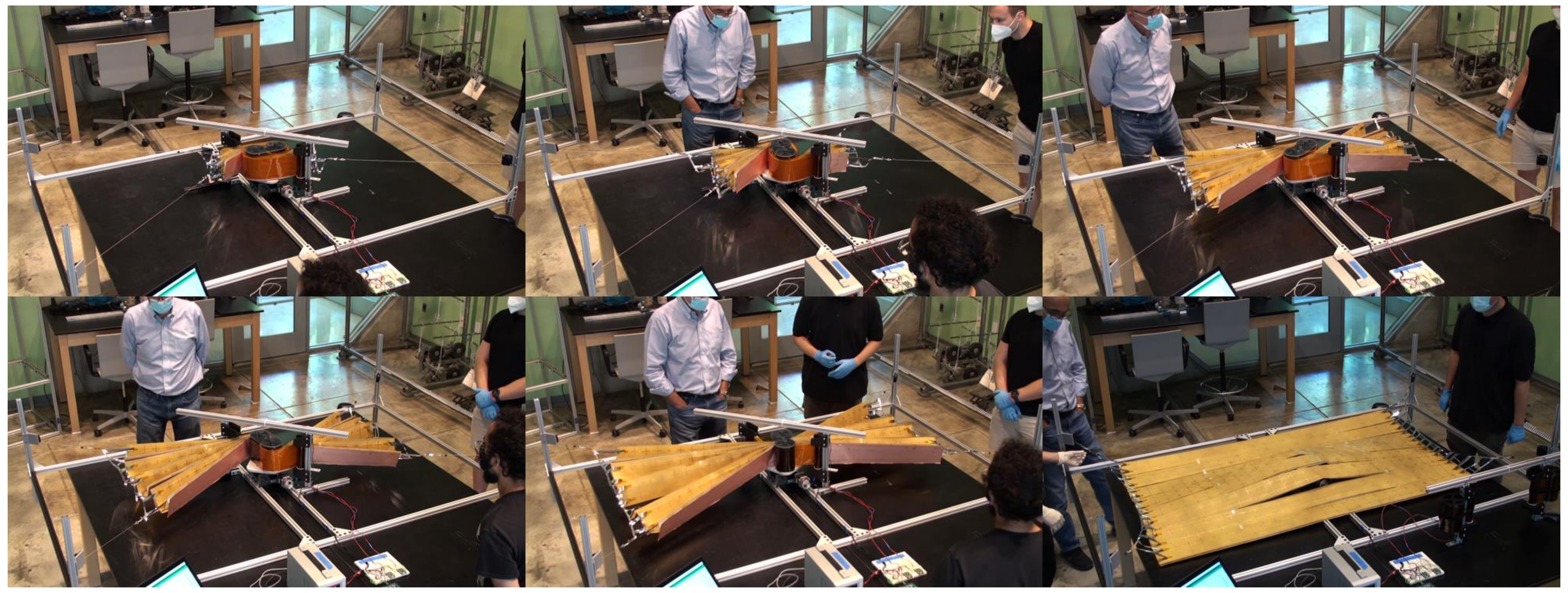

Figure 3: Images showing the sequence of deployment of test article 2. Initially, the reflectarray is folded and coiled in a compact configuration (approximately 250 mm x 200 mm x 120 mm in height). Then, it is quasi-statically uncoiled and unfolded. In the end, the reflectarray lies on the table, given the designed absence of a gravity offload system.

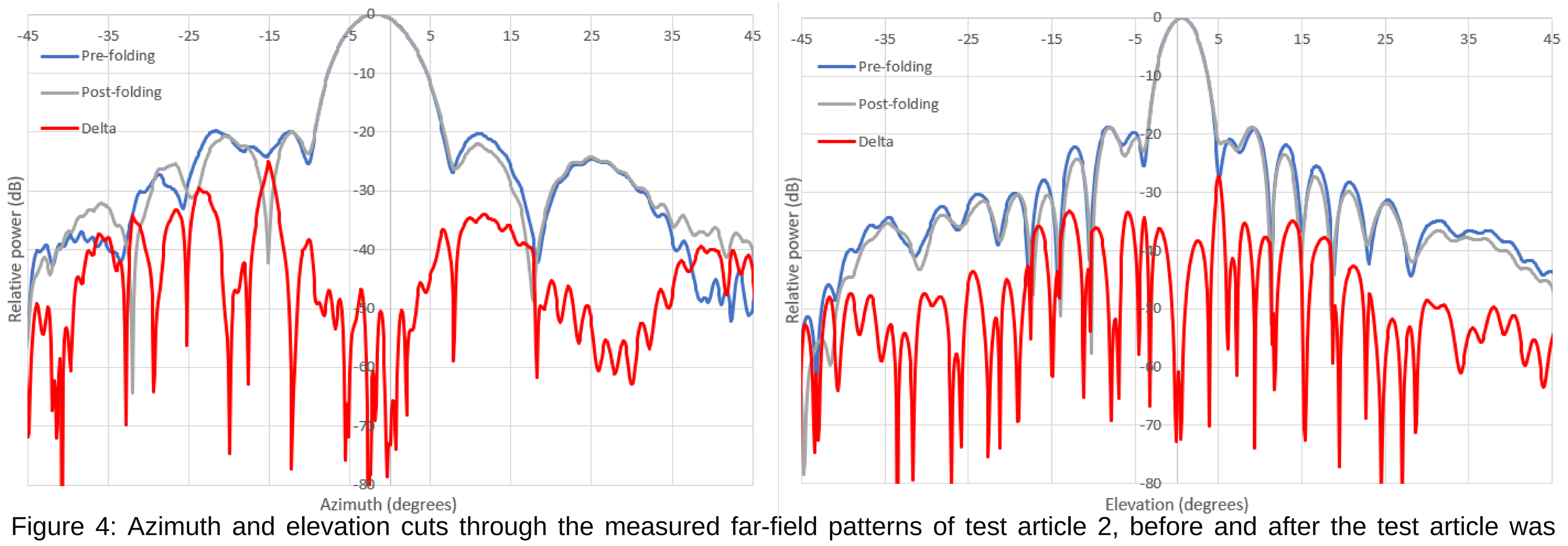

Figure 4: Azimuth and elevation cuts through the measured far-field patterns of test article 2, before and after the test article was stowed and deployed. The patterns match each other to a high degree, showing that folding and deployment had minimal impact on RF performance.

Objective: Our objective was to advance a novel architecture for deployable planar radio frequency (RF) apertures. In FY21, our goals were to (1) demonstrate, through detailed structural finite element analysis (FEA), high stiffness (first fundamental structural frequency > 0.5 HZ) of the deployed aperture and low thermo-elastic deformation (deformed surface RMS < 2 mm rms) when subjected to in-space thermal loading; and (2) design, fabricate, and test a prototype aperture, demonstrating both packaging and deployment, and RF performance (both before and after deployment).

Background: State-of-the-art deployable RF apertures for small spacecraft can be divided into 3 categories based on their structural architectures: solid-panels, mesh reflectors, and tensioned membranes. The proposed concept has key advantages over these: lower areal density than solid-panel apertures; higher stiffness and thermal stability than tensioned membranes; and fewer snag hazards and lower touch labor than mesh reflectors. We target a 5 m x 1 m aperture at S-band that can be deployed from an ESPA-class spacecraft with application to the Surface Deformation and Change (SDC) observable per the 2018 Earth Science Decadal Survey.

Approach: In FY20, we constructed reflector test article 1 (full-scale 1 m width, and 1/3-scale length of 1.67 m). This was critical in verifying fabrication methods and RF performance. Due to a systemic fabrication error, test article 1 could not be fully stowed. In FY21, this fabrication error was corrected, and test article 2 (Figure 2) was constructed. Test article 2 has identical dimensions and materials as test article 1. The facesheets and the S-springs are constructed using state-of-the-art quartz composites ([90/0/90] preforms of spread-tow unidirectional plies of Quartzel fiber in TP402 epoxy matrix, total cured thickness of 120um). The reflectarray pattern was designed to have a focal length of 3.5 m, and consists of an 18 x 84 array of cross-shaped elements (with 59 mm center spacing). The reflectarray element plane is realized as photolithographically etched copper (9 um thickness) on 25 um-thick polyimide film (commercially available Dupont Pyralux). The ground plane is a layer of unetched Pyralux material. Test article 2 has a mass of 1.234 kg and an areal density of 787 g/m^2, which meets the goal of <800 g/m^2 areal density.

Test article 2 was RF tested before and after deployment, see Figure 2. A custom feed was used to illuminate the reflectarray. After an initial pre-stowage RF test, the reflectarray was stowed and deployed. Figure 3 shows the deployment, using a stowage-and-deployment mechanism. This mechanism uses tensioned membrane straps to coil and consolidate the folded-and-flattened strips. After successful stowage and deployment, the reflectarray was re-mounted at the RF test stand and re-measured. As shown in Figure 4, the antenna patterns repeated to a high degree, showing minimal impact of the stowage and deployment process.

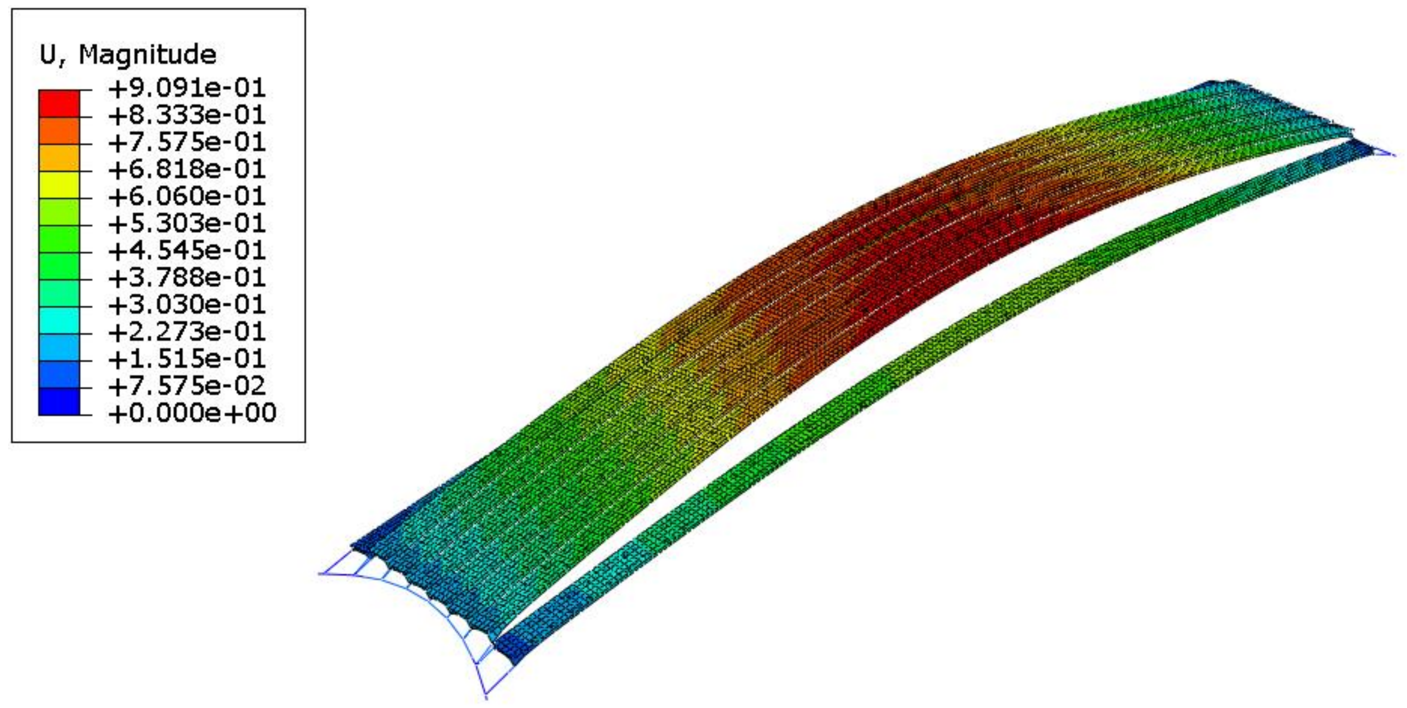

Figure 5: Based on a structural finite element (FE) model of the full-length 5 m x 1 m reflectarray created in Abaqus/Standard, the predicted lowest structural frequency is 1.69 Hz, with a mode shape illustrated.

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