National Aeronautics and Space Administration

# Ka/W-Band Deployable Modularized MetaLens Antennas for SmallSat Applications


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Program: FY22 R&TD Topics

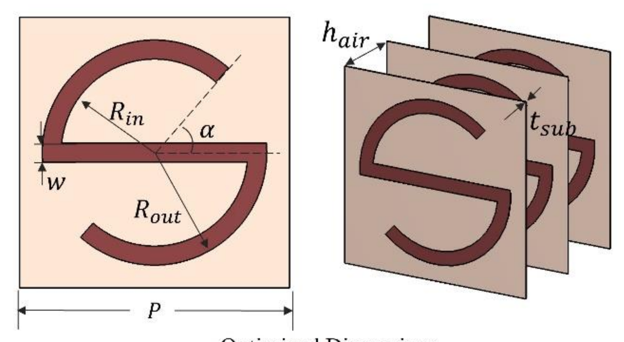
Strategic Focus Area: RF and Optical Communications

## Objectives:

The objective of this research was to develop a tensioned membrane system comprised of multiple layers of Kapton, each of which has a pattern of variable sized copper patches that create an artificial dielectric. Varying the size and geometry of the patches controls the dielectric constant, and provides a practical way to realize an inhomogeneous lens. This flexible MetaLens can be folded and rolled for compact stowage. The precise nature of the copper patterning process provides the unit cell density and high resolution needed to control artificial dielectric permittivity at Ka-band and higher frequencies. The first-year objective is to develop the lens design and fabrication technology. This work included development of a transmitarray design, an alternative to the MetaLens concept. A proof-of-concept transmitarray is being built and will be tested early in year two. In year two we plan to investigate a conical scan Ka-band transmitarray or lens antenna. To realize the conical scanned beam, the feed assembly mechanically rotates to move the feed along the lens focal ring, which permits the lens remains stationary once deployment is completed. Once developed, the transmitarray and lens technology has wide applicability for radar and telecom systems.

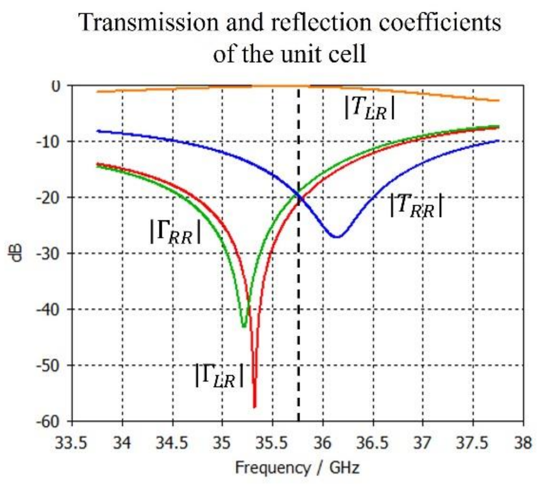
## Background:

Future Earth Science missions are currently being planned that require sensors within the mm-wave regime (35-250 GHz). These missions address Earth Science Decadal Survey science targeted observables related to climate and weather. To support these mission concepts, several radar instruments are currently being developed (e.g. CloudCube, VIPR, PBL), as well as a range of radiometer instruments related to climate and weather. High gain antennas are critically important to meet these science objectives. The only high-TRL antenna option in this frequency regime is the solid composite reflector, a custom designed antenna that is expensive and has a long procurement cycle. The only deployable antenna design at 94 GHz is a hinged composite reflector, which does not support the cost and SmallSat stowage goals of a low-cost Earth Science mission. This research addresses antenna technology that offers that holds promise for construction of large deployable mmWave apertures. Moreover, the conical scan provides a potentially useful way to obtain large coverage area at low cost.

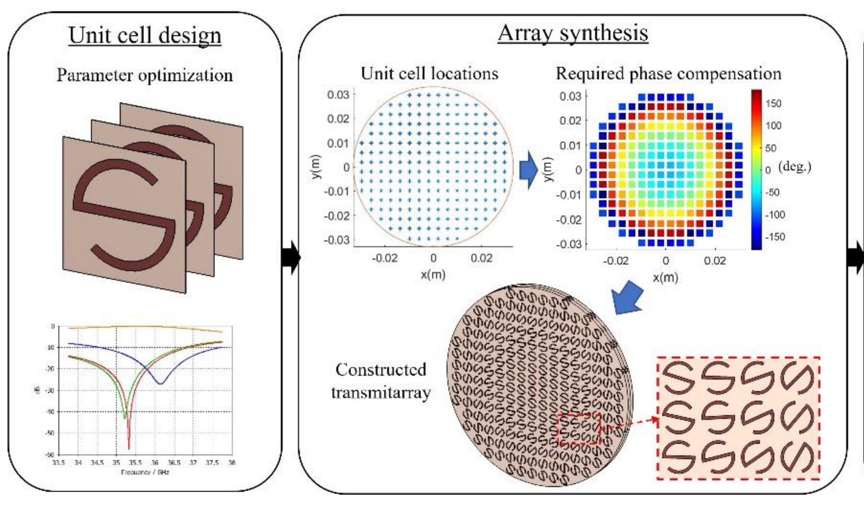



Optimized Dimensions

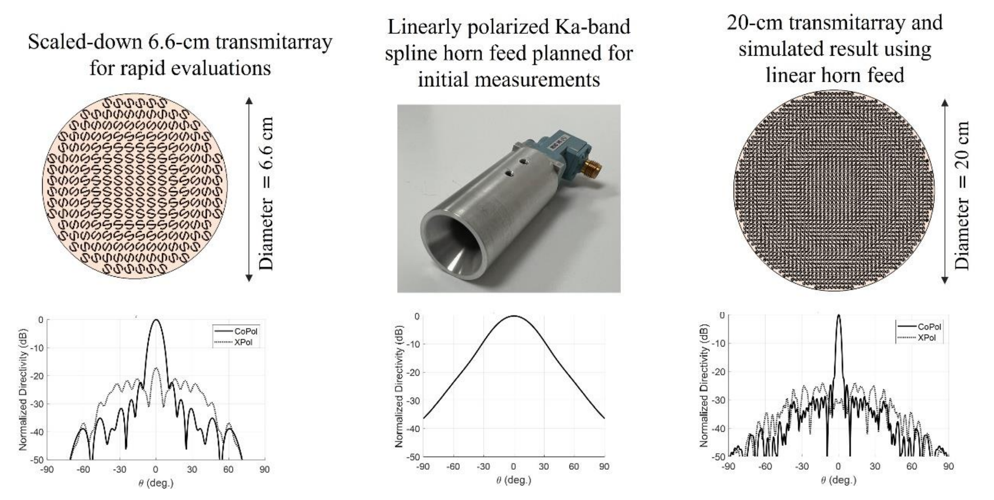
| freq. | $P$ (mm) | $Rout$ (mm) | $Rin$ (mm) | $w$ (mm) | $\alpha$ (deg.) | $t_{sub}$ (mm) | $h_{air}$ (mm) |
|---|---|---|---|---|---|---|---|
| 35.75 GHz | 3.93 (0.47$\lambda$) | 1.64 | 1.36 | 0.28 | 48.8 | 0.0127 | 1.57 |



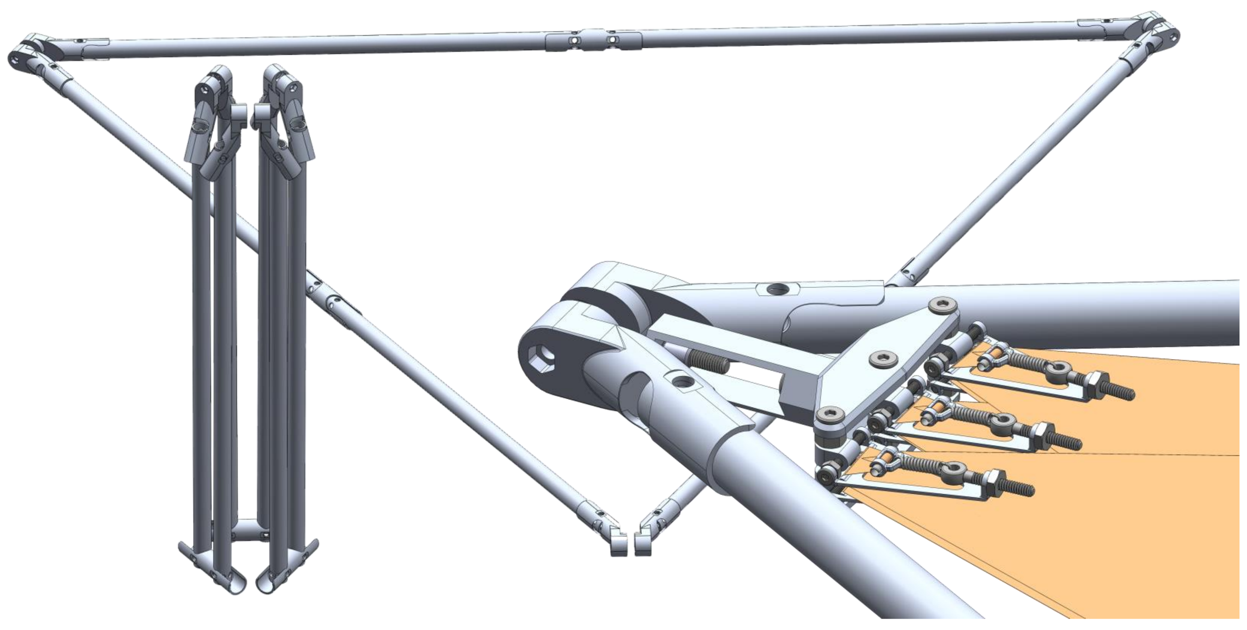

The novel three-layer S-ring transmitarray unit cell for circularly polarized wave designed at the center frequency of 35.75 GHz. The transmission (T_RR,T_LR) and reflection coefficients (Γ_RR,Γ_LR) are shown for the case of right-hand CP (RHCP) incident wave. The transmitted left-hand CP (LHCP) component is maximized at 35.75 GHz




The 20-cm transmitarray system configuration and the corresponding transmitarray designed based on the S-ring unit cell.




Left: The scaled-down version of the transmitarray concept. The simulated far-field pattern is provided. Middle: the previously developed linear polarized Ka-band horn for evaluations of the transmitarray. Right: the 20-cm transmitarray for production and its simulated far-field pattern using the linearly polarized horn as feed.



Design of the triangular frame showing the deployed and stowed configurations. The truss has hinge points at the midsections of the frame. The inset shows the tensioning mechanism that is used to independently adjust the printed sheets of Kapton

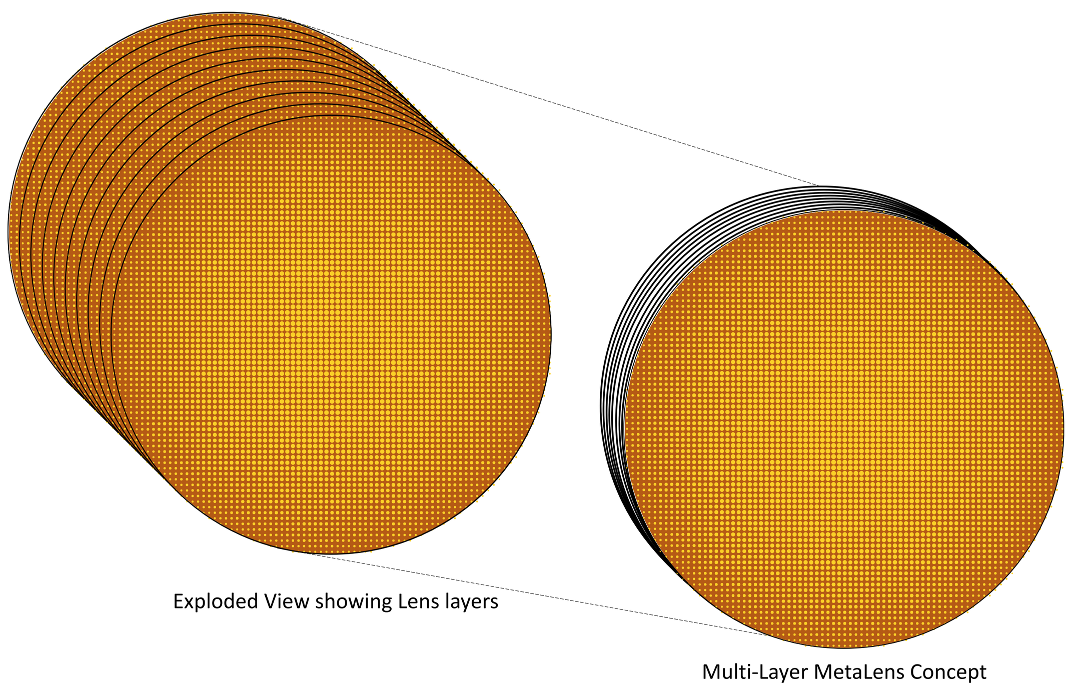
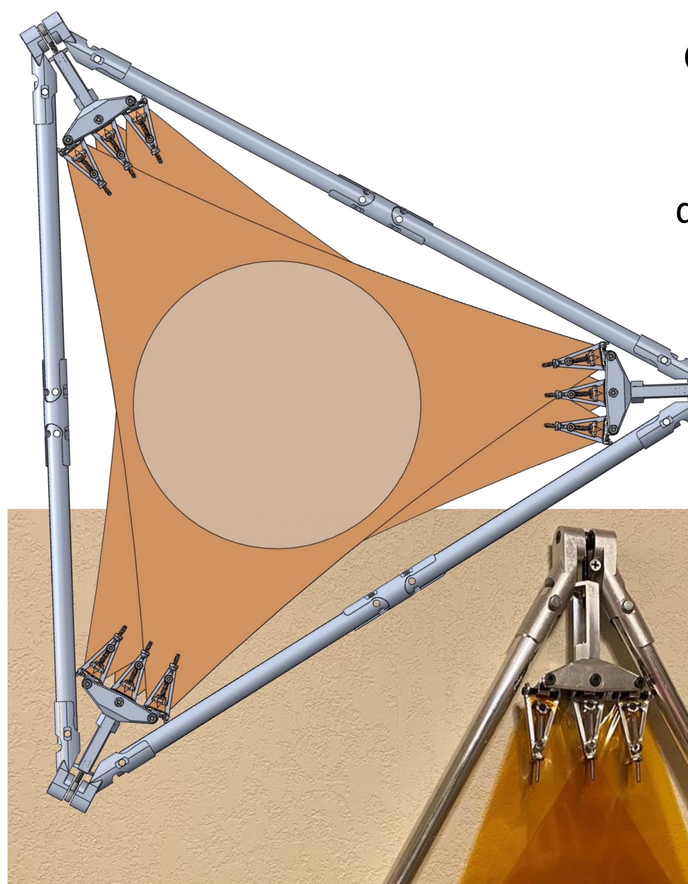



Illustration of multi-layer artificial dielectric MetaLens Concept showing the location where metal traces are printed on Kaption sheets. Each pattern is printed on a different layer and then is tensioned in the deployable frame (shown at right)



CAD model (left) and photograph (below) of a three-layer deployable MetaLens test fixture with an artificial dielectric disk pattern superimposed.

## Significance/Benefits to JPL and NASA:

mmWave antennas are needed to achieve Earth Science goals stated in the Decadal Survey, we devised the tensioned membrane deployable MetaLens operating in mmWave bands as a novel, deployable method for achieving these goals. This can provide very large ground coverage at low cost for Earth Science missions.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## Publications:

none

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