National Aeronautics and Space Administration

TeraCube: A Cubesat Terahertz Spectrometer for Earth and Planetary Remote Sensing

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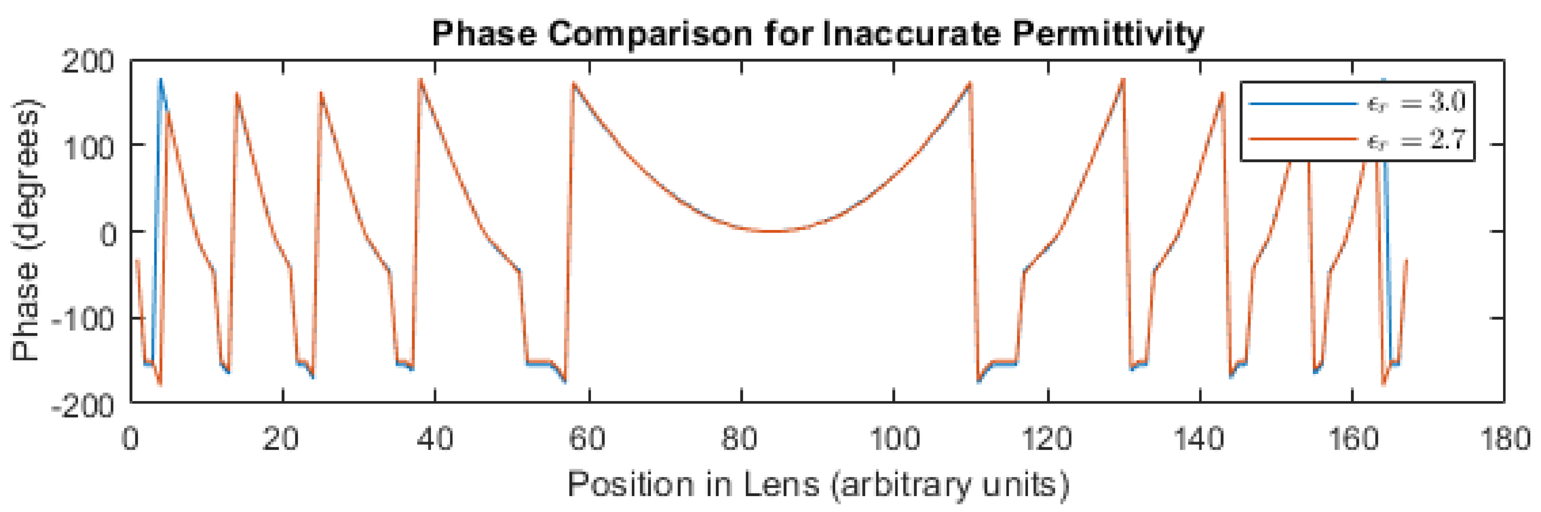
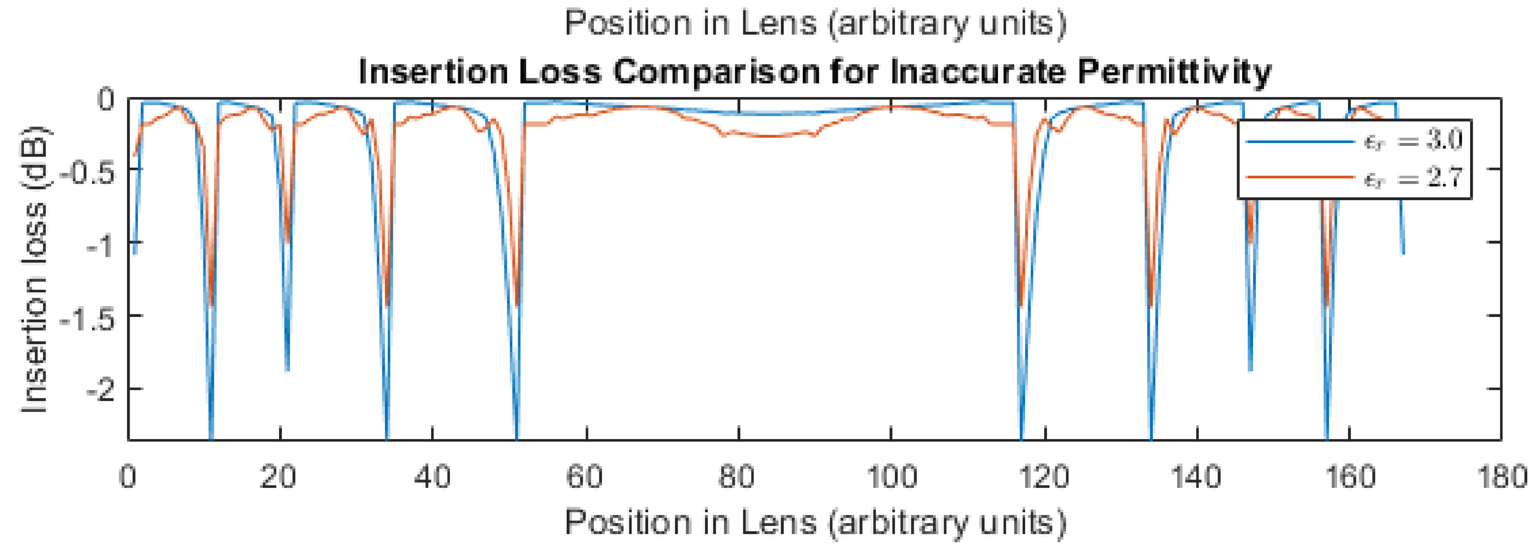
Program: FY21 SURP **Strategic Focus Area: Coherent Detectors and Arrays, Remote Sensing Instruments**

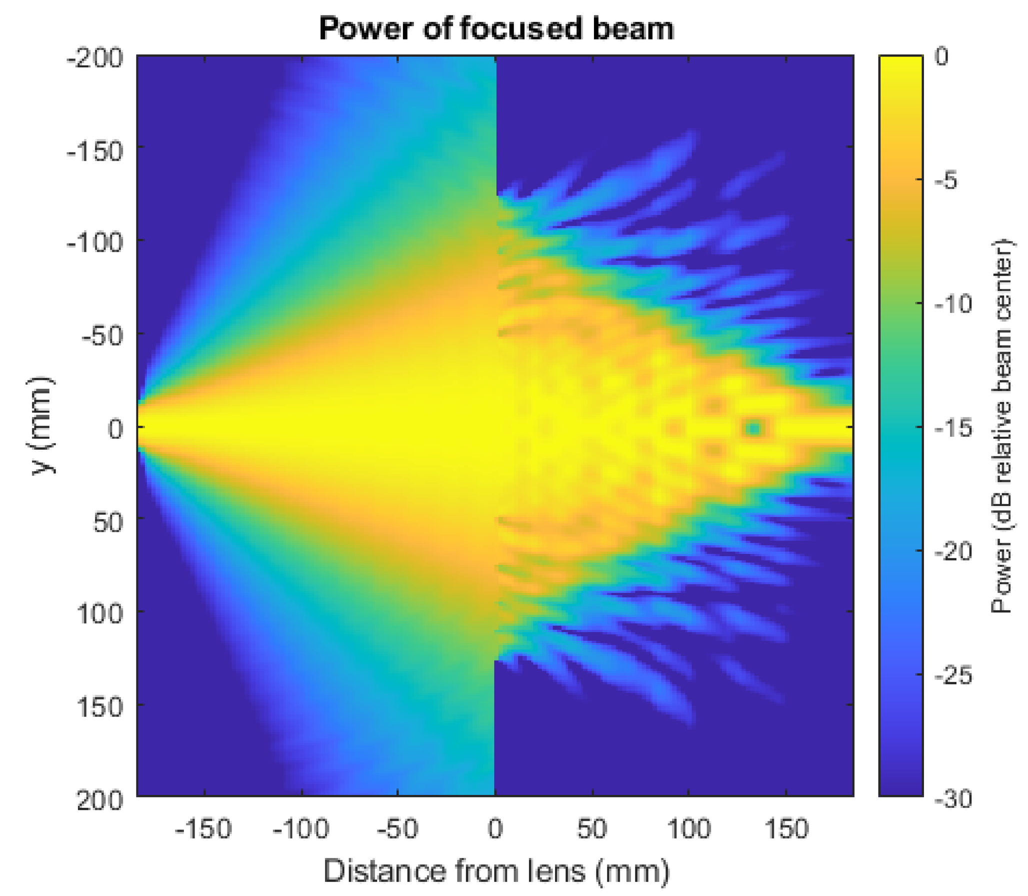
TeraCube is a CubeSat with the goal of observing 557GHz and 1114 GHz water lines. Observations of these water lines are important to astronomy, and planetary sciences, but it is difficult to observe them from the ground. CubeSats offer a cost-effective solution to this problem.

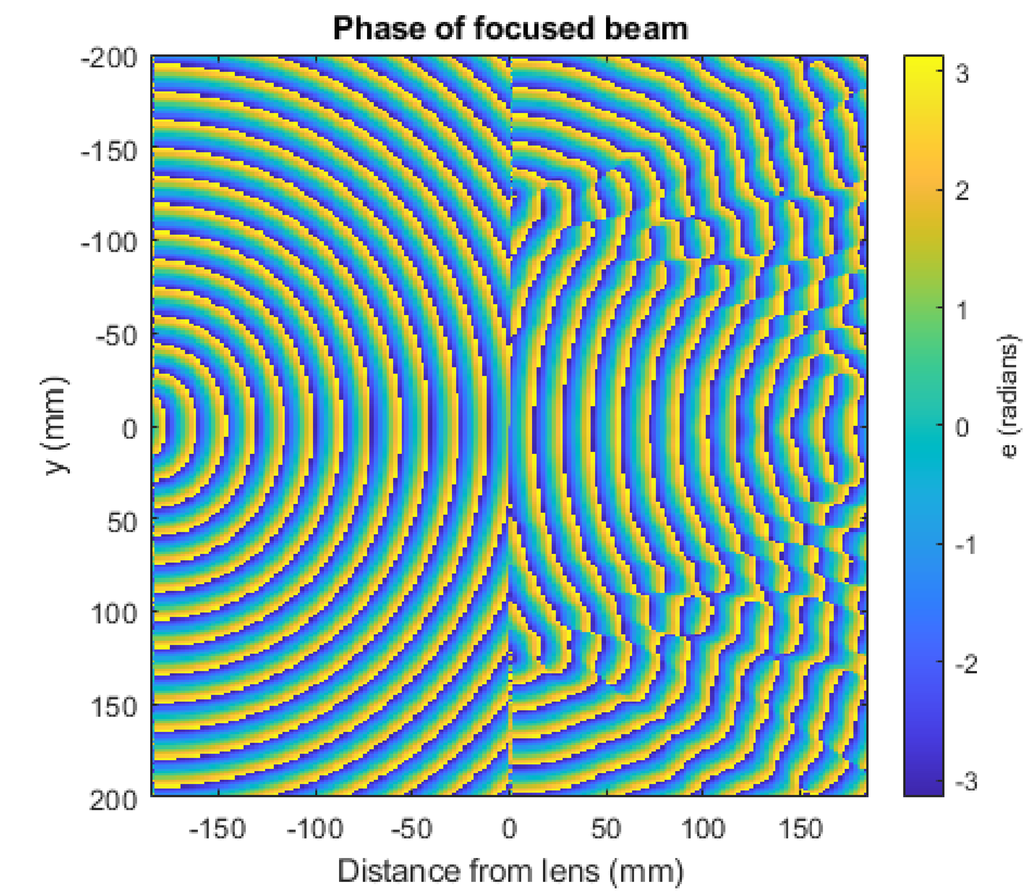
As part of TeraCube, we are designing a lightweight and flat metamaterial lens. Here we present results relating to our design and simulation of our prototype 20 GHz and future 500 GHz flat metamaterial lenses.





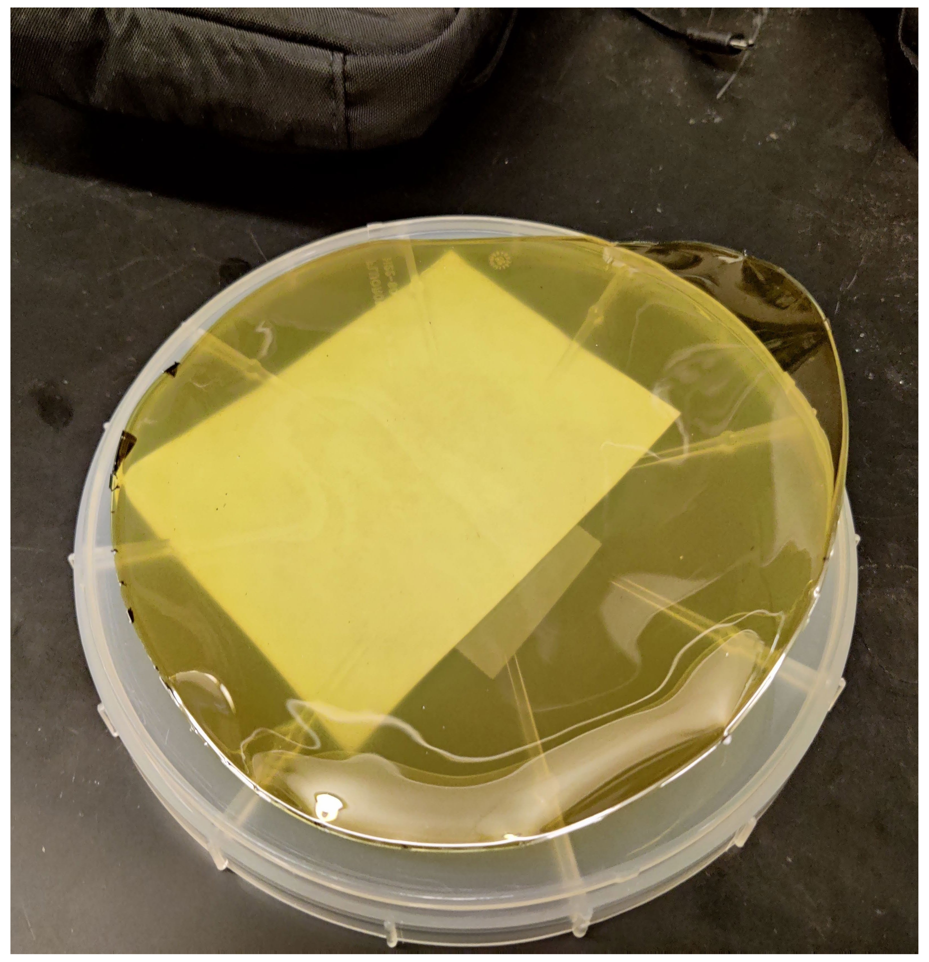
There exists some question about how badly our lens will perform in cases where we mis-estimate the dielectric constant of the substrate. Above, we have used computer simulations to measure the phase and loss of the lens as a function of position, for a Dk of 3.0 (which is what the lens was designed for), and a Dk of 2.7. Though there is slightly increased loss around the lens center, the performance remains largely unchanged. Even with a Dk as low as 2.0, we found that the lens still performs adequately.

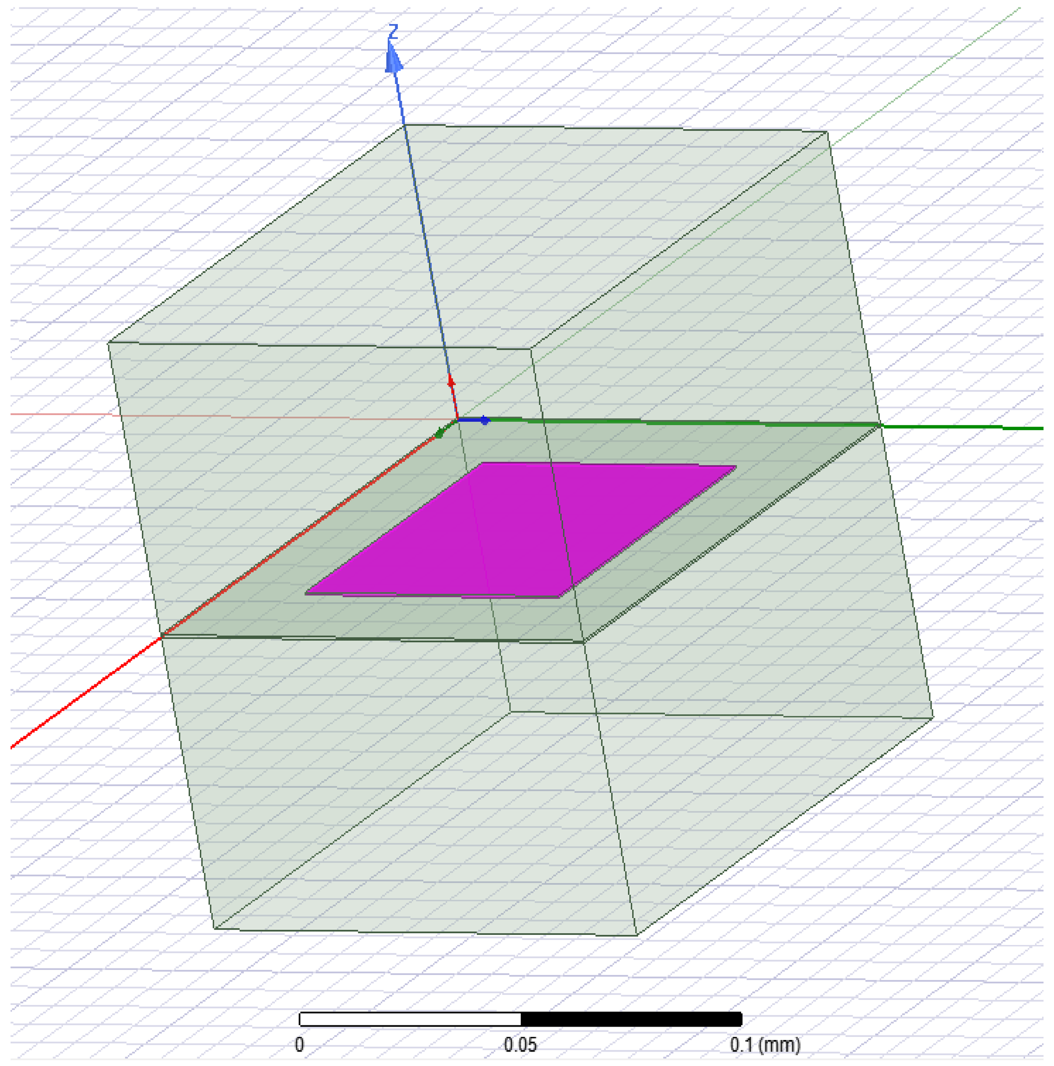




As part of our research, we have developed simulation code that uses Fourier optics to simulate how an arbitrary beam will pass through and be focused by our lens. Above is a depiction of that simulation in use.

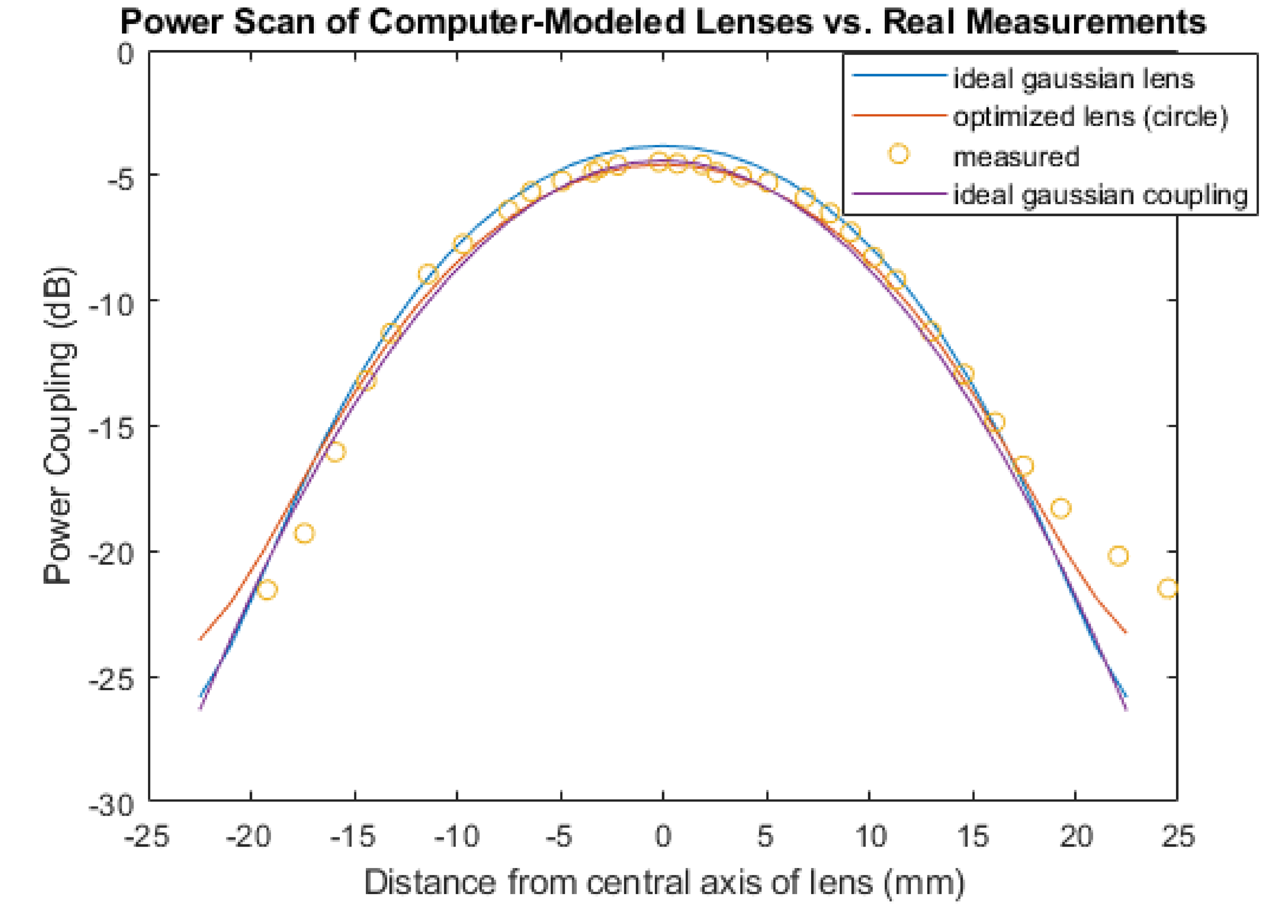
Pictured below, the yellow circle is a sample of the substrate which will be used to create our metamaterial lens. The substrate is 200um thick polyimide. The material is not perfectly flat, but it is flexible, so a mount will be used to hold it flat. We will soon begin characterizing the substrate at the 500 GHz frequencies we intend to use it.





Pictured above is a single cell of our metamaterial mesh lens, simulated in HFSS. In purple is a copper square, 0.5um thick, embedded in polyimide substrate. We have performed simulations of these cells using various sizes of copper at 500 GHz. In the near future, these simulations will enable us to optimize and design our 500 GHz metamaterial flat lens.

Our simulation code was tested against a real-world measurement we performed on a 20 GHz lens which was designed using our software. As pictured below, there is strong agreement between our simulation and the real-world measurement. We see also that, despite phase imperfections in our lens, the coupling performance of the lens is only 0.6 dB less than ideal. We see also ~3.8dB of coupling loss for the ideal lens, but this is explained by over illumination of the lens surface.



CubeSat technology offers a unique opportunity to cost-effectively explore parts of space that were previously only observable by very expensive space telescopes. In this project, we are developing and increasing the TRL of technology that will be useful for a variety of future Cubesat-based observing missions. This should facilitate future missions that seek to observe water both outside and inside the Earth's atmosphere, as well as missions that would benefit from the space- and weight-saving spectrometer and metamaterial lens that we are testing here. The metamaterial lens development works towards solving a critical need for implementing far infrared and submillimeter missions using Smallsats: large aperture, low SWAP-C antennas. The first steps taken here with relatively small aperture planar focusing optics can be extended to larger apertures using segmented optics combined with the larger format fabrication processes (300mm and 370mm x 470mm) to realize meter scale planar optics.

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Clearance Number:
RPC/JPL Task Number: SP20002