Manufacturing Approaches for Experimental Validation of Numerically Designed Conformal Metasurfaces

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Advanced Manufacturing Technology Center

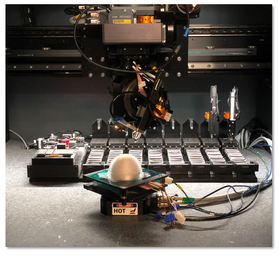
Research to optimally design and develop functional RF devices, systems, and structures that cannot be fully realized using conventional manufacturing but can be using AM technologies such as multi-material and conformal AM

Advanced Manufacturing Technology Center

Conformal Printing

- Enables direct write techniques to be utilized on extreme topologies such as doubly curved surfaces
- Realized using 6-axis machine (nScrypt 3Dx-700)
- Offers the ability to produce electromagnetic devices on arbitrary surfaces which may feature multiple layers

3Dx700 Demonstrating Conformal Printing

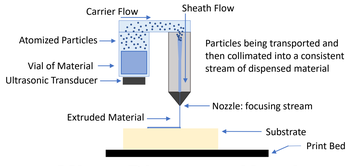


3Dn-300 Hybrid AM Machine

Direct Write Methods Explored

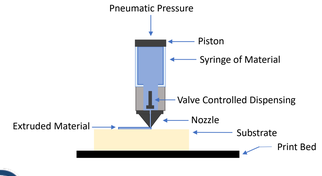
Aerosol Jetting Head

(Integrated Deposition Systems)



Micro Dispense Head

(nScyrpt SmartPump^{TM})



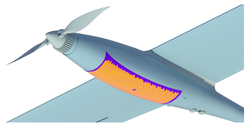
Conformal Holographic Antenna

Goals

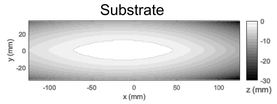
- Develop direct write methods to physically realize a conformal Voronoi Metasurface
- Improve upon current manufacturing methods that are tedious and time consuming
- Demonstrate feasibility of methods developed
- Verify the engineered electromagnetic properties through physical characterization

Antenna Design

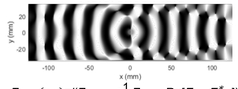
- Leaky wave antenna design at Australia's Defence and Technology(DST) Group
- 30 degrees forward directional pencil beam operating at 10GHz
- Substrate designed to conformally adhere to UAS



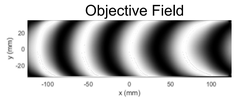
Substrate



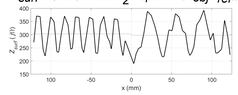
Reference Field



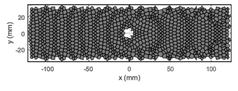
Objective Field



$Z_{surf}(x,y)=j(Z_{mean}+\frac{1}{2}Z_{span}\mathrm{Re}[E_{obj}E^{*}_{ref}])$

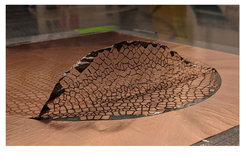


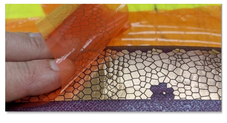
Metasurface Pattern



Current Manufacturing Method

- Laser profile etching of copper foil negative coupled with hand removal, placement and alignment
- Time consuming process
- Two-dimensional plane cannot map to extreme arbitrarily doubly curved surfaces without deformation

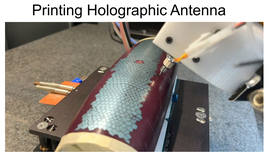




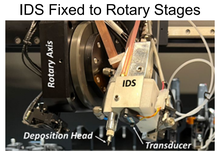
Developed Method of Aerosol Jetting and Electroless Platting

- Aerosol jetting head coupled with 6-Axis Nscyrpt to conformally pattern substrates with nano particle conductive ink (UT DOTS)
- Post processing electroless plating step employed to improve RF conductivity of patches and realize desired RF properties

Printing Holographic Antenna



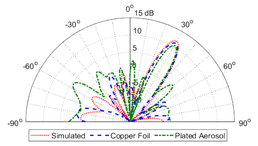
IDS Fixed to Rotary Stages



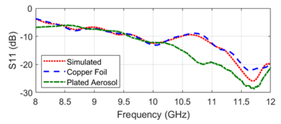
Measurement Results

- Sufficient gain patterns realized using platted aerosol method
- Reduction in manufacturing time realized

Gain at 10GHz



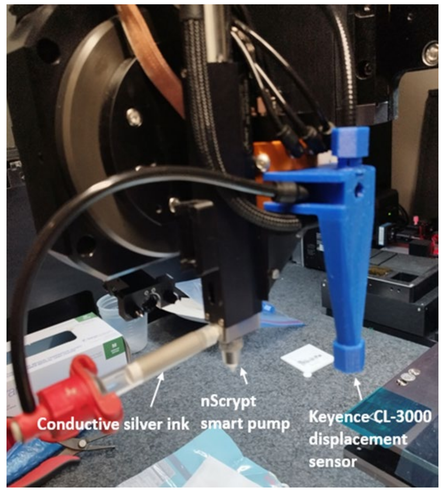
S11 Demonstrating Resonance



Sensor Assisted Conformal Printing of Metasurfaces

Goals

- Develop method that incorporates in-situ sensing and error correction within the print process
- Correct for alignment errors and substrate imperfections to permit for direct write printing with micro dispense
- Demonstrate methods by manufacturing prototypes

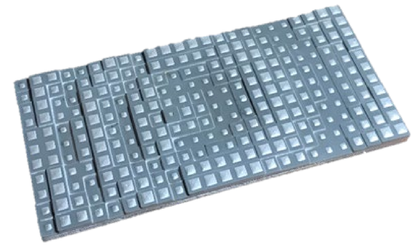


Dynamic G-Code Compiler Process

- Reads predefined sections of G-code
- Scans the surface of that section prior to printing
- Corrects for errors
- Sends section of error corrected G-code to print
- Repeats this process until the part is completed.

Holographic Surface Wave Antenna

Manufactured Antenna



Manufacturing of Antenna

- A multistep substrate was printed using the Fortify Flux Core (DLP) printer
- Individual patches were then printed on each unit cell at various heights using the sensor assisted system
- The sensor was able to properly discern the substrates topology enabling the G-Code to be properly modified

Measurement Results

- Sufficient gain patterns realized using sensor assisted direct write method
- Reduction in manufacturing time realized over aerosol plus electroless platting method

Gain at 12GHz