Submillimeter-Wave Metasurface Antenna Arrays

NF-SYSTERA

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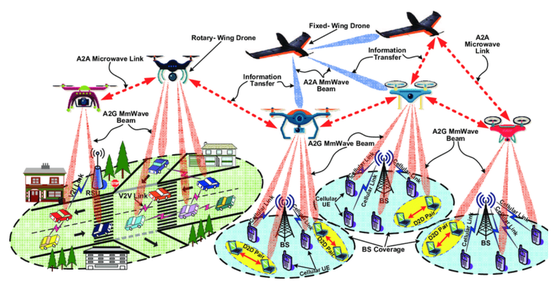
I. Introduction

5G networks demand ultra-high data rates, low latency, and compact hardware [1]. **Sub-terahertz antennas** offer high directivity and small size, making them ideal for next-gen wireless systems.

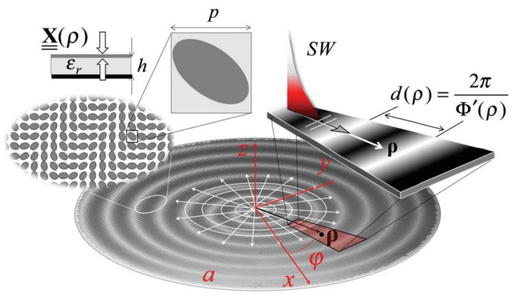
Beyond 5G antenna requirements:

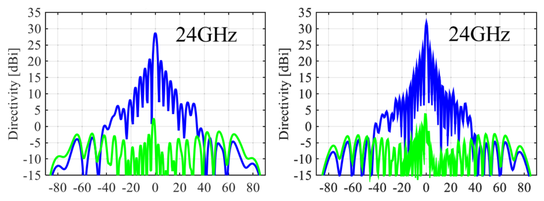
- Beam steering and multibeam capabilities
- Broad bandwidth and high-efficiency
- Wide field of view and low-profile design



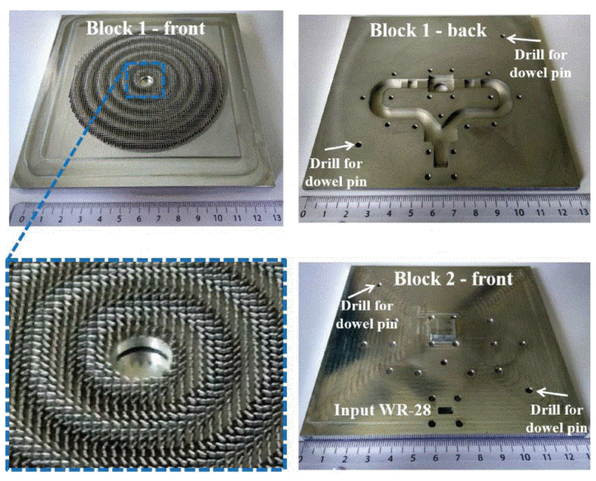
II. Metasurface Antennas

Metasurface (MTS) antennas offer solutions tailored to meet the demanding bandwidth, efficiency, and **beamforming capabilities** required by 5G networks.





Wideband Active Region Metasurface Antennas [2]

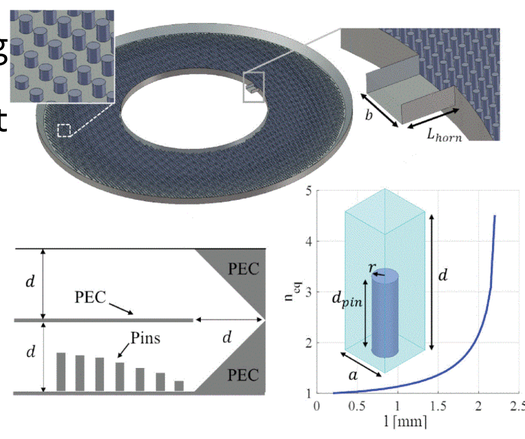


Additive Manufactured Metal-Only Modulated Metasurface Antennas [3]

III. Reflective Luneburg Lens

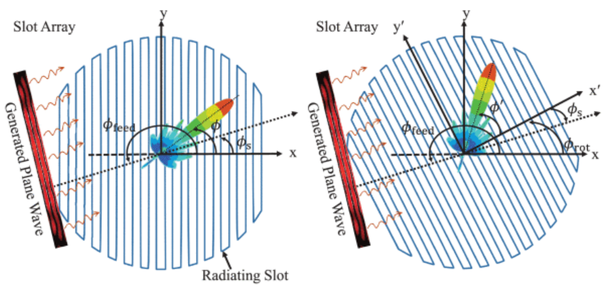
Reflective Luneburg Lens (RLL) [4]

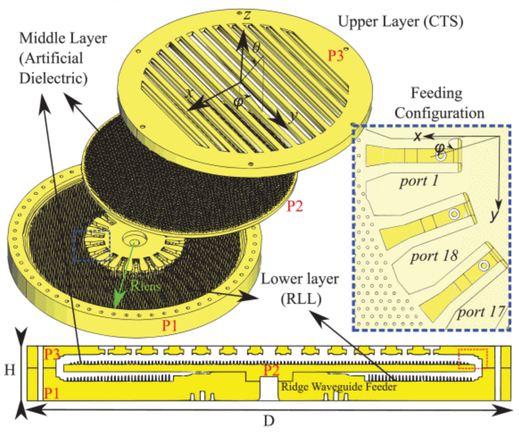
- Double-layer structure
- Full multi-beam azimuthal scanning
- Low-profile and compact design
- Compatible with MTS implementat



Series-fed Continuous Transverse Stub Arrays [5]

- Efficient integration with RLL
- Frequency scanning
- Multiple beam steering





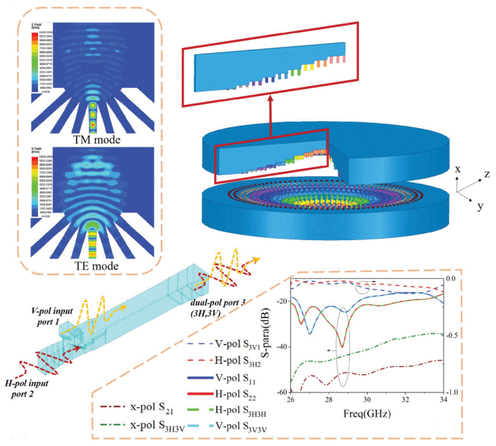
IV. Dual-Polarized Luneburg Lens

Fully Metallic Dual-Polarized Luneburg Lens [6]:

- Bed of Nails
- TM mode modulation: pin height
- TE mode modulation: pin distance

Drawbacks:

- Excitation of unwanted modes
- Bulky feeding scheme

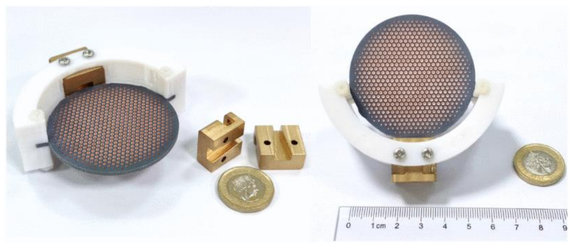


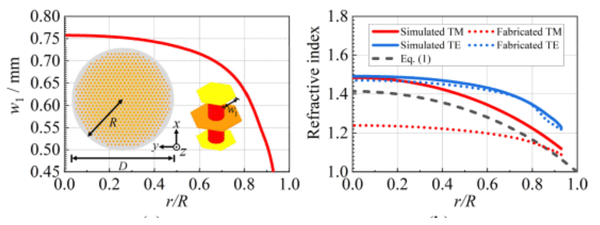
TE/TM Surface Wave Mode-based Luneburg Lens [7]

- Integrated on two-layered substrate

Drawbacks:

- Different refractive index profile for both modes
- Dielectric losses

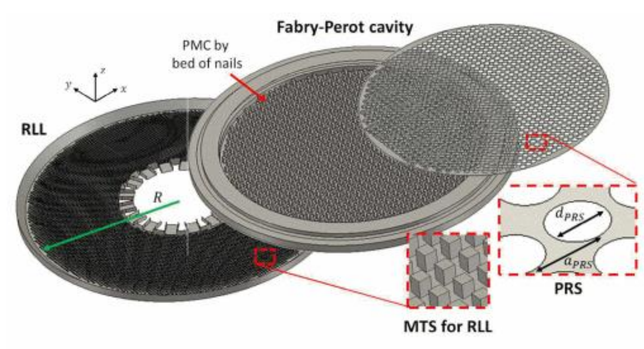


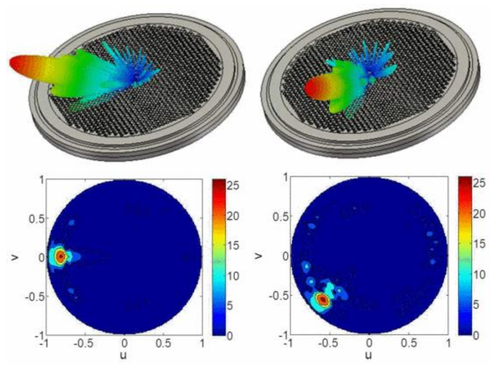


V. Fabry-Perot Antenna Arrays

Metal-only Multi-beam Fabry-Perot Antenna

- Low-profile metal-only structure, ideal for harsh environments
- **Independent 2D beam steering** (azimuth via port switching, elevation via cavity height)
- **High-gain radiation** with azimuthal symmetry





VI. Goals

This PhD thesis pursues multiple goals, including:

- Design a multi-beam dual-polarized Reflective Luneburg lens
- Develop an initial proof of concept at Ka-band
- Scale design to higher frequencies (D-band)
- Integrate the design with a Fabry-Perot antenna and explore reconfigurability

[1] L. Zhang *et al.*, "A Survey on 5G Millimeter Wave Communications for UAV-Assisted Wireless Networks," *IEEE Access*, vol. 7, pp. 117460-117504, 2019.
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[3] D. González-Ovejeroet *al.*, "Additive Manufactured Metal-Only Modulated Metasurface Antennas," *IEEE Trans. Antennas Propag.*, vol. 66, no. 11, pp. 6106-6114, Nov. 2018.
[4] J. Ruiz-García, E. Martini, C. D. Giovampaola, D. González-Ovejero and S. Maci, "Reflecting Luneburg Lenses," *IEEE Trans. Antennas Propag.*, vol. 69, no. 7, pp. 3924-3935, July 2021.
[5] C. Bilitos *et al.*, "Series Dual-Fed Continuous Transverse Stub Array With Enhanced Multibeam Operation Enabled by a Reflective Luneburg Lens," *IEEE Trans. Antennas Propag.*, vol. 72, no. 11, pp. 8420-8432, Nov. 2024.
[6] J. Liu *et al.*, "Fully Metallic Dual-Polarized Luneburg Lens Antenna Based on Gradient Parallel Plate Waveguide Loaded With Nonuniform Nail," *IEEE Trans. Antennas Propag.*, vol. 70, no. 1, pp. 697-701, Jan. 2022.
[7] T. Ao *et al.*, "Low-Profile Dual-Polarized Luneburg Lens Based on TE/TM Surface Wave Modes," *IEEE Antennas Wireless Propag. Lett.*, vol. 21, no. 9, pp. 1862-1866, Sept. 2022.
[8] J. Ruiz-Garcíaet *al.*, "Metal-only Multi-beam Fabry-Perot Antenna," *16th Eur. Conf. Antennas Propag. (EuCAP)*, Madrid, Spain, 2022.