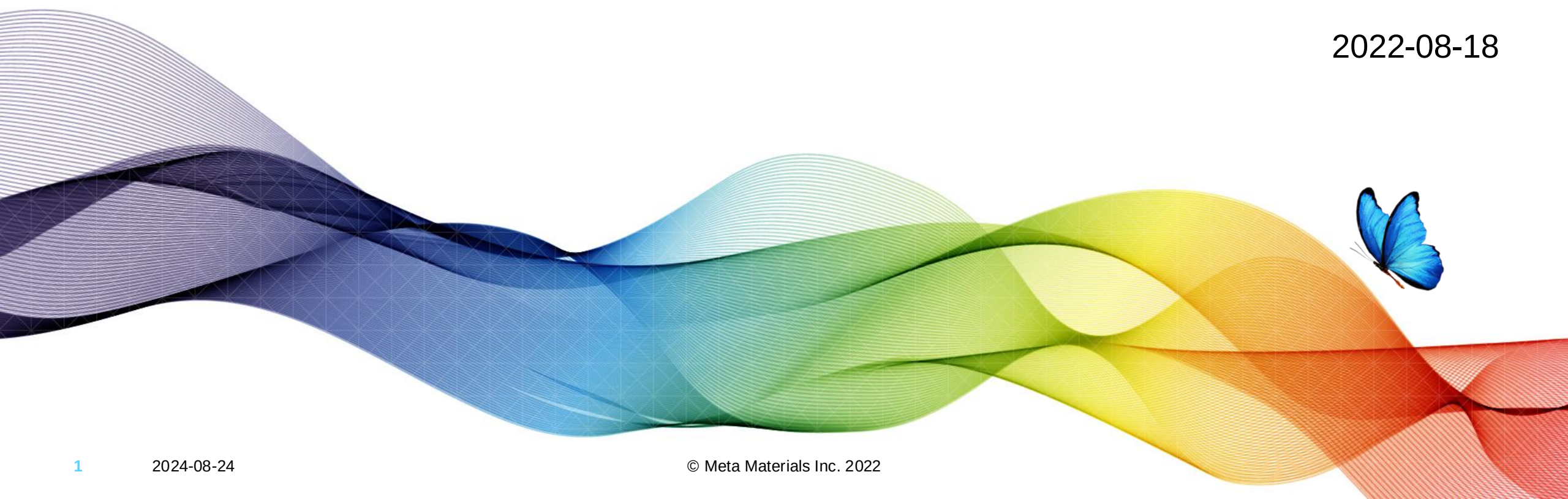
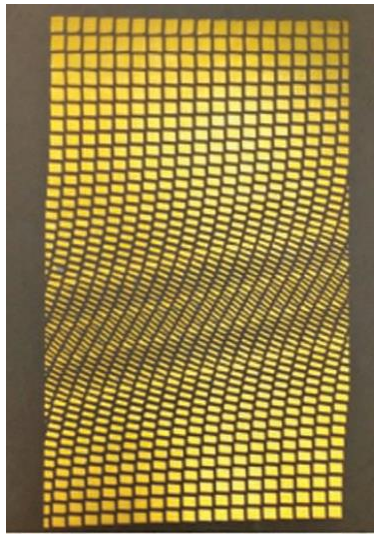
RF Metasurfaces

2022-08-18



What are Metasurfaces?

- Thin structured artificial materials that exhibit abrupt discontinuities in amplitude and phase, used for wavefront manipulation
- Metamaterials
  - Exactingly-designed subwavelength inclusions in a host medium
  - Often characterized by homogenized bulk material parameters
- Metasurfaces
  - Exactingly-designed subwavelength inclusions in a host sheet
  - Often characterized by homogenized boundary conditions



META medical RF metasurface
for impedance matching

J. Lee and D. F. Sievenpiper, *IEEE Trans. Antennas Propag.*, vol. 64, no. 11, pp. 4725–4732, Nov. 2016, doi: 10.1109/TAP.2016.2608935

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Types of Metasurfaces & Applications

Frequency Selective Surfaces (non-homogenizable)	Periodic	Aperiodic	Space-time Modulated
• Frequency-dependent mirrors • Dichroic filters • Transmissive screens • Reflectarrays	• MTS antennas (far field control) • Flat absorbers • Cavity resonators • Near-field plates	• Metalenses • Near-field focusing • Beam deflectors & Splitters • Waveplates • Holographic MTS • Biosensing • Surface/plasmon wave control	• Reflective Intelligent Surfaces (RIS) • Reconfigurable MTS • Active MTS • Programmable MTS

A. Grbic and S. Maci, "EM Metasurfaces [Guest Editorial]," in IEEE Antennas and Propagation Magazine, vol. 64, no. 4, pp. 16-22, Aug. 2022, doi: 10.1109/MAP.2022.3178924.

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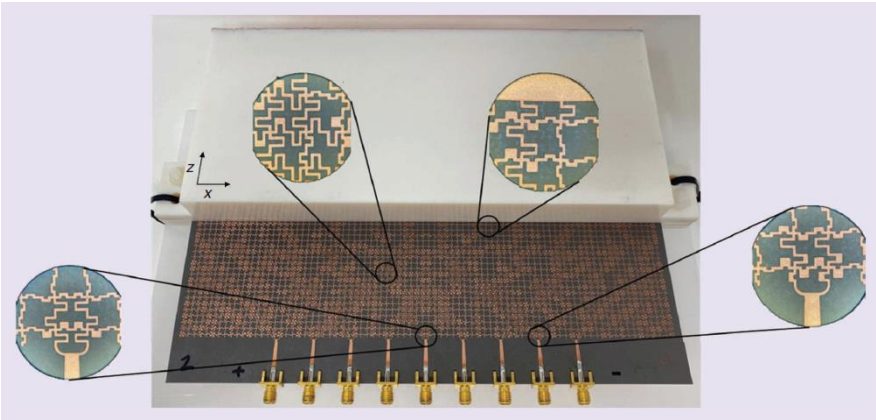
Space-time Modulated Metasurfaces

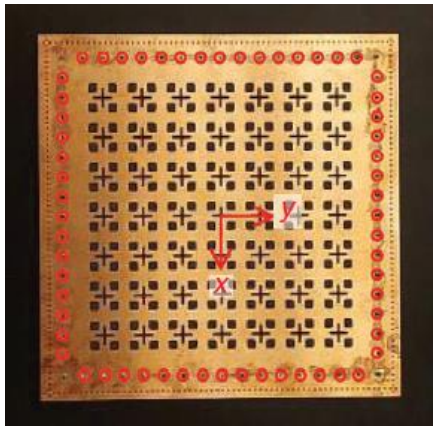
- Controllable and intelligent
- Boundary conditions vary in space or over time
- Reconfigurability is achieved using:
  - Electronic components
  - Time-varying materials
  - Multiple switchable feed points
- Exotic properties can be achieved
  - Nonreciprocity
  - Frequency conversion
  - Parametric amplification

Recent Advances in RF Metasurfaces – 1

- MIMO antenna beamformer using surface wave control



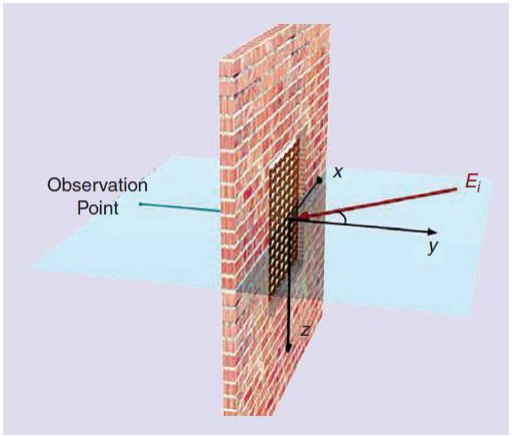
- Beamforming MTS lenses for radomes extending scan range of phased arrays, without feeding networks

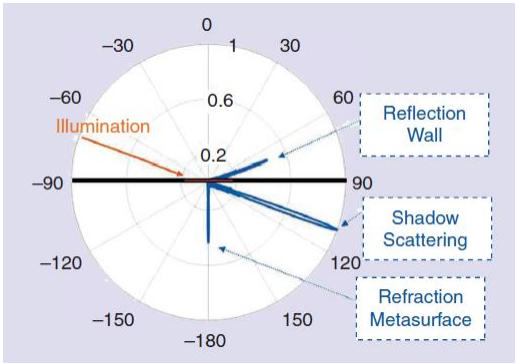


Szymanski et al., (2022) DOI:10.1109/MAP.2022.3169391
Atatoglou et al., (2022) DOI: 10.1109/MAP.2022.3169363

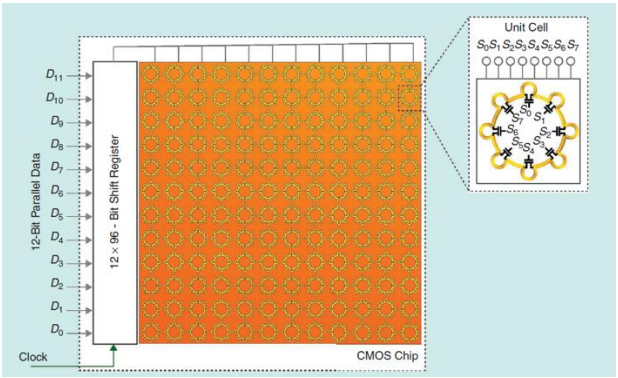
Recent Advances in RF Metasurfaces – 2

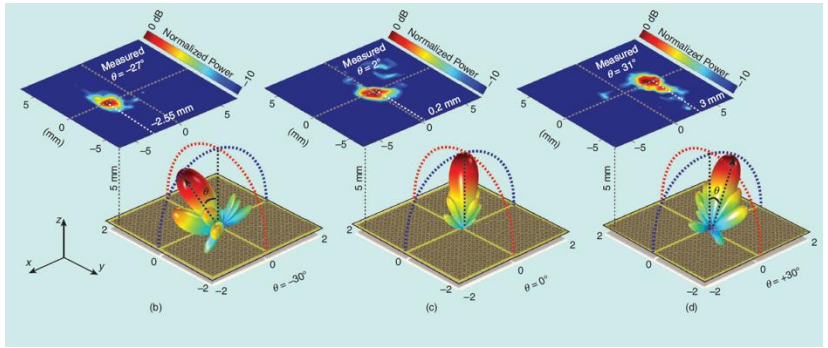
- Far-field anomalous scattering of reflective MTS on walls, for optimization of propagation channels





- THZ beamforming using circuit-coupled programmable elements within tiled silicon chips

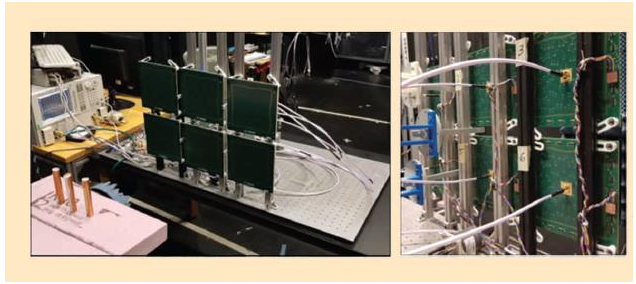


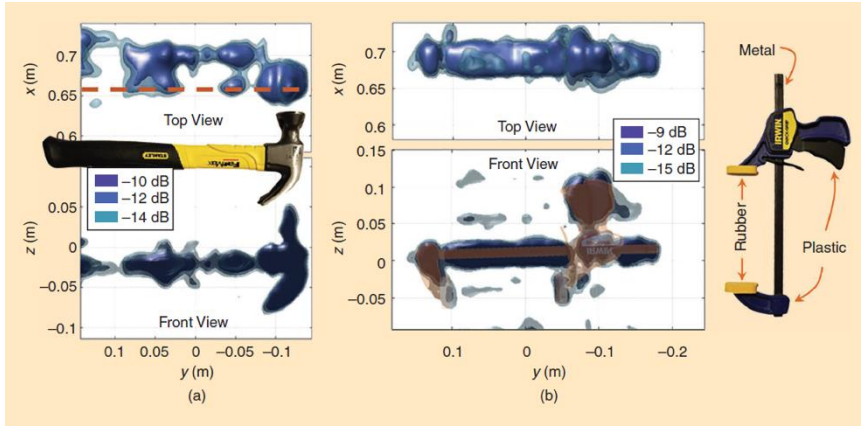


Diaz-Rubio et al., (2022) DOI: 10.1109/MAP.2022.3169396
Venkatesh et al., (2022) DOI: 10.1109/MAP.2022.3176588

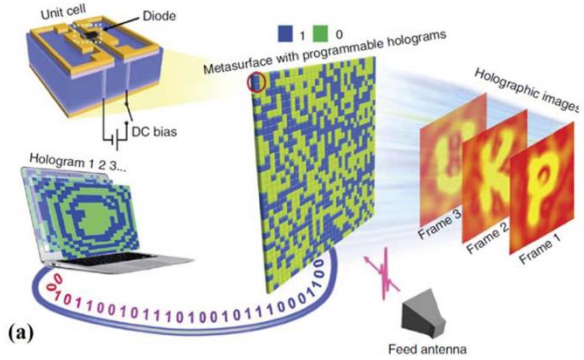
Recent Advances in RF Metasurfaces – 3

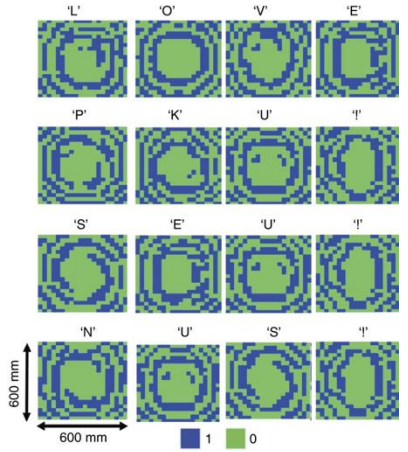
- Microwave imaging using voltage-controlled dynamic metasurface cavities at low bandwidths (RF equivalent of Spatial Light Modulator) to create electrically-large aparture





- Reprogrammable holograms





Sleasman et al., (2022) DOI: 10.1109/MAP.2022.3169395
Li, L., Jun Cui, T., Ji, W. et al. Electromagnetic reprogrammable coding-metasurface holograms. Nat Commun 8, 197 (2017). https://doi.org/10.1038/s41467-017-00164-9

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Issues with Modern Metasurfaces

- Limited bandwidth
- Low efficiency (esp. in transmission modes)
- Coupled amplitude and phase tuning
- Limited phase tuning range
- For optics
  - Limited tuning mechanisms
  - Incompatibility with CMOS technology