Development of Metamaterials for Potential Gain in Detector Performance

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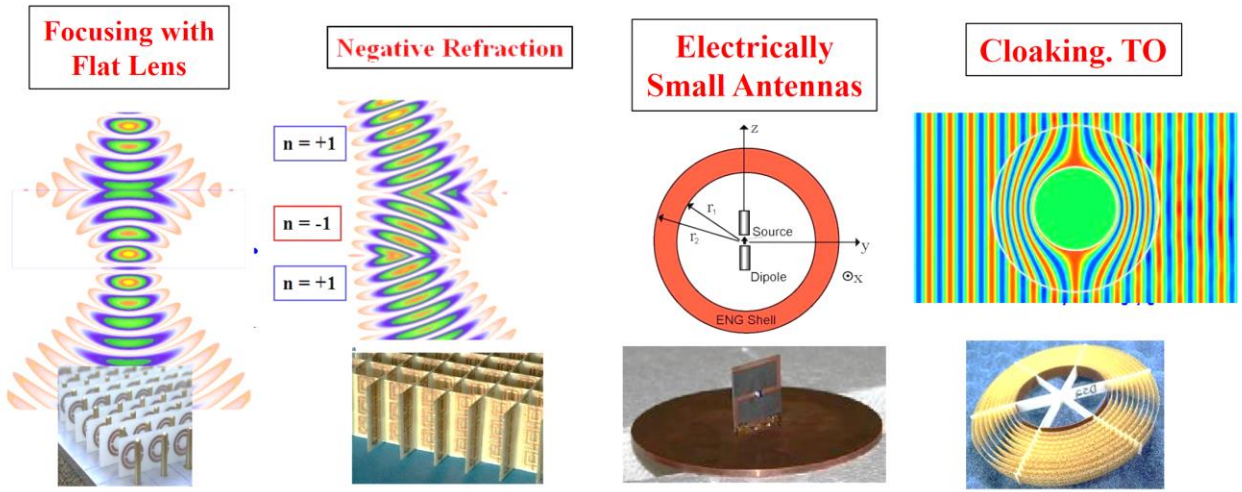
Metamaterial



Engineering Passive and Active Metamaterial-inspired Electrically Small Antenna Systems.
Richard W. Ziolkowski. EM-MTF 2016 Distinguished Lecture (2016)

Meta-materials are artificial materials engineered to provide properties which **may not be readily available in nature** with sub-wavelength structures and/or reactive elements

Ability to engineer:

- Electrical property
  - Permittivity and permeability
  - Electrical size
- Mechanical property
  - Thermal contraction
  - Size availability

Examples from mm-wave optics (CMB inst)

Cardiff U.

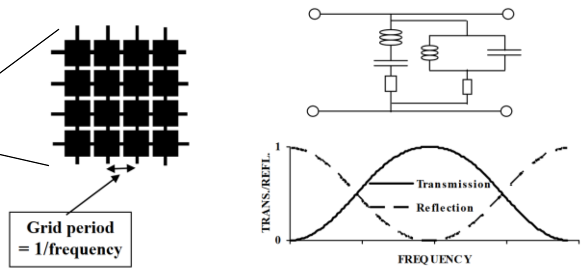
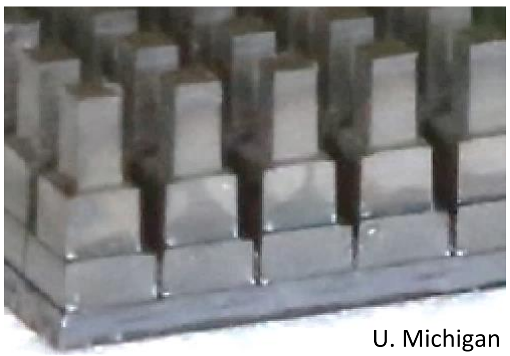


Figure 2: Resonant grid geometry, equivalent circuit and spectral properties

Metal mesh membranes

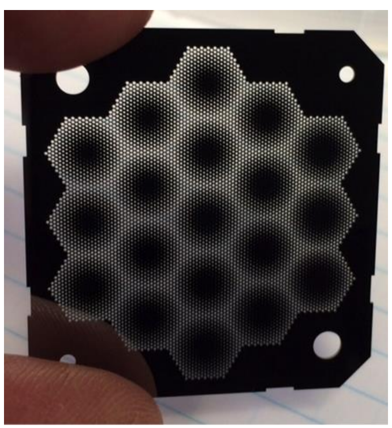
- Base material: Copper film on a plastic film
- RF filter (low/high/band pass)
- Planar lens
- Index matching layer
- Half-wave plate



U. Michigan

Machined sub-wavelength structure

- Base material: Silicon, alumina, plastic, quartz
- Index matching layer
- Half-wave plate
- No thermal contraction mismatch, controlled dielectric constant and size availability



U. Colorado/ NIST

Micro-fabricated subwavelength structure

- Base material: Silicon wafer
- Planar lens array with integrated index matching layer
- Potential to reduce fabrication complexity

Metamaterial Optical Coupling?

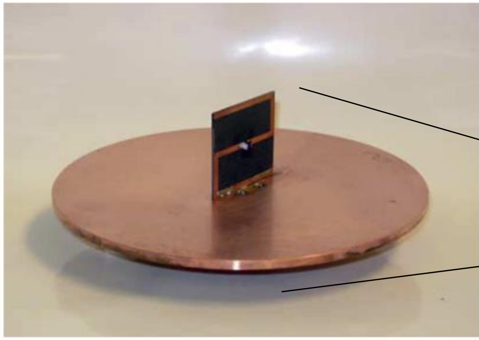
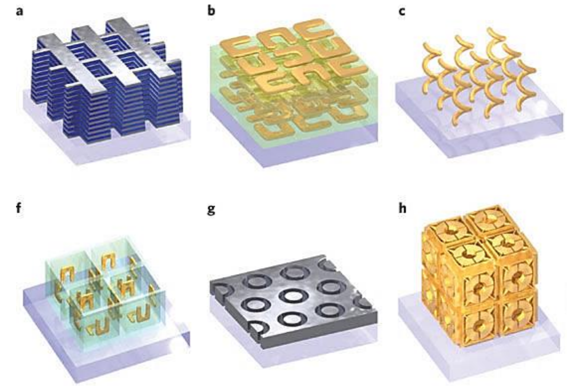


Fig. 2. Fabricated 570-MHz Z antenna on its small circular copper insert.

Fig. 3. Comparison of the 570-MHz small ground plane Z antenna and the dual-ridged reference horn in the NIST–Boulder reverberation chamber.

R.W. Ziolkowski, P. Jin, J.A. Nielsen, M.H. Tanielian and C.L. Holloway. Design and experimental verification of Z antennas at UHF frequencies. *IEEE Antennas Wireless Propag. Lett.*, 2009 vol. 8, pp. 1329-1332.



C.M. Soukoulis and M. Wegener. Past achievements and future challenges in the development of three-dimensional photonic metamaterials. Nature Photonics 5, 523-530 (2011)

- Metamaterial can ***significantly reduced size*** of antenna while maintaining good efficiency
- **Negative index metamaterial** could also be used to beat diffraction limit to increase forward gain

→ Smaller, more efficient detector = Smaller focal plane, less detector

→ Better sensitivity, better cryogenic performance …

- Electrically small antenna demonstrations around 100 MHz ~ 1 GHz
  - R&D to study if ideas are scalable to other frequencies
  - Metal structures may be too lossy at higher frequency → Superconducting metamaterial
- 3-D structures for more capable metamaterial
  - R&D on 3-D micro-fabrication (micro 3-D printing?) could open path to new ideas
  - Computing resource for EM simulation will enable progress