DESIGN OF FLAT LENS USING HUYGENS' METASURFACE

INTRODUCTION

- Transmitarray: a flat array of unit cell elements with spatial periodicity, each producing different phase delays to focus or steer electromagnetic radiation from an antenna
- Achieve same effect as a 3-D dielectric lens, but is planar, lightweight & cheap

AIM

- Design an ultrathin transmitarray using concept of Huygens' metasurface to achieve full 360° phase range with only 2 layers (instead of usual 3-4 layers) to focus EM radiation at 10 GHz with maximum gain & efficiency

TRANSMITARRAY LENS

1. Determine optimum focal length from –10 dB cut of given horn's simulated radiation pattern → 200.2 mm with efficiency of 35%
2. Calculate required phase at each element position of lens

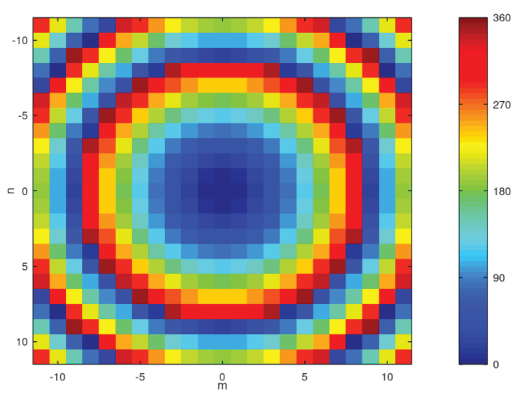

Figure 3. Required phase distribution.

3. Construct metalens by matching required phase to appropriate unit cell

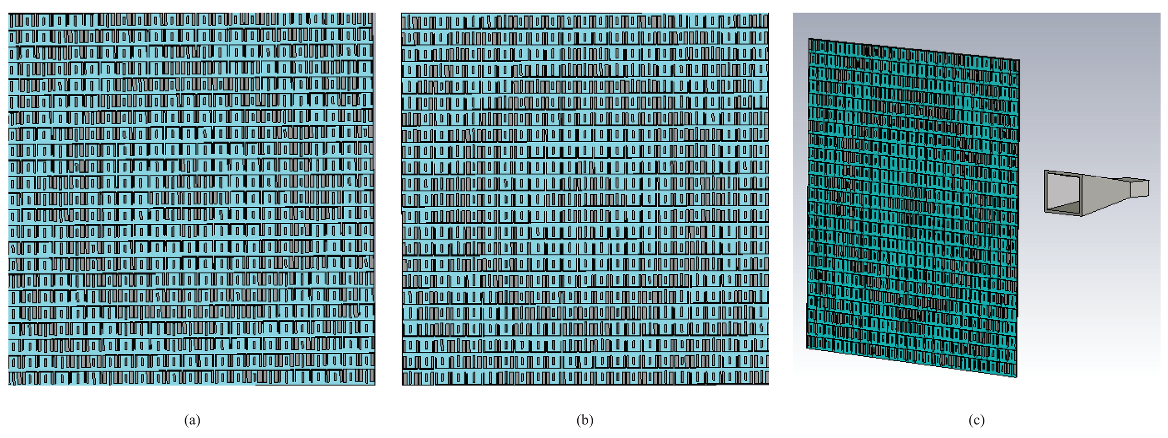

Figure 4. (a) Top view, (b) bottom view of metalens; (c) Simulation model of metalens with horn.

4. Simulate designed metalens: maximum gain for the E-plane and H-plane is 26.49 dB and 26.44 dB respectively

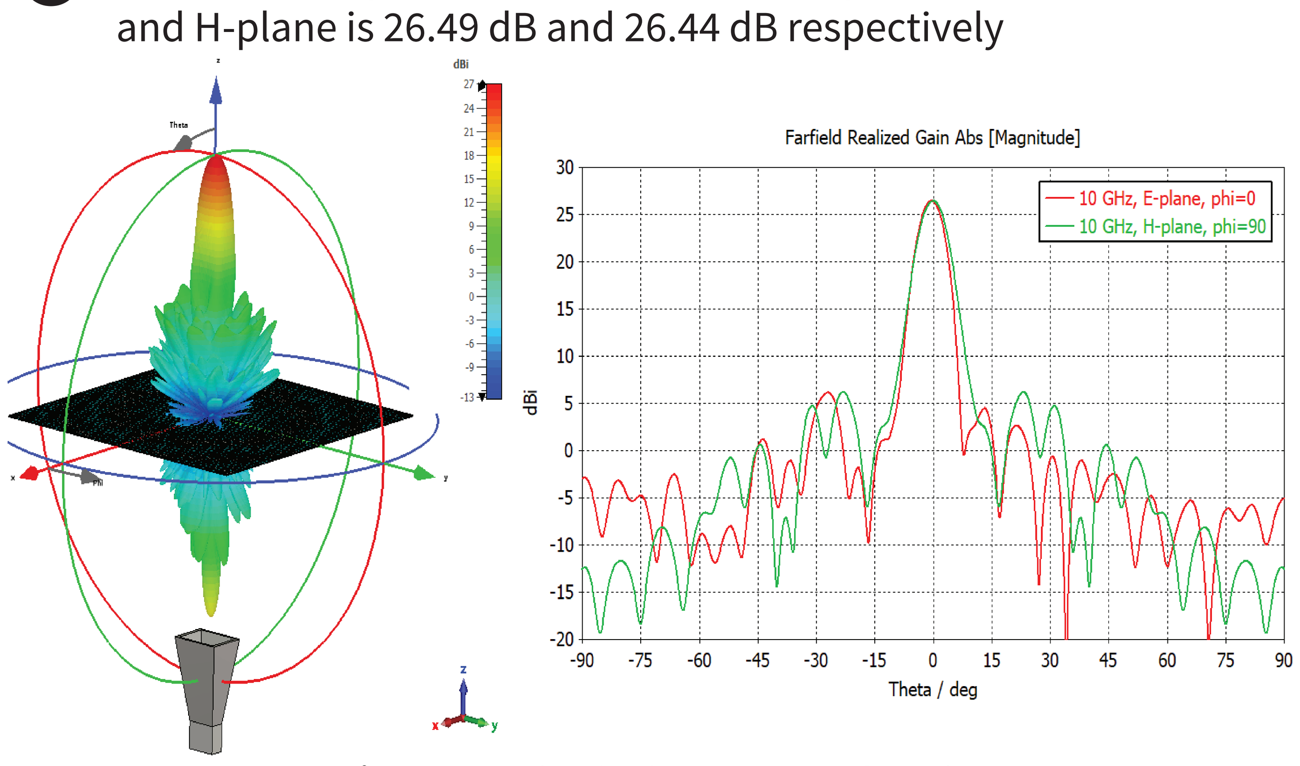

Figure 5. Simulated radiation pattern of metalens.

UNIT CELL DESIGN

- Double layer E-shaped element with 3 variables: $b, h, \& \ l$ (others kept constant)
- Metal strips are etched on 1-mm thick F4B substrate (ε_r = 2.55, tan δ = 0.002)

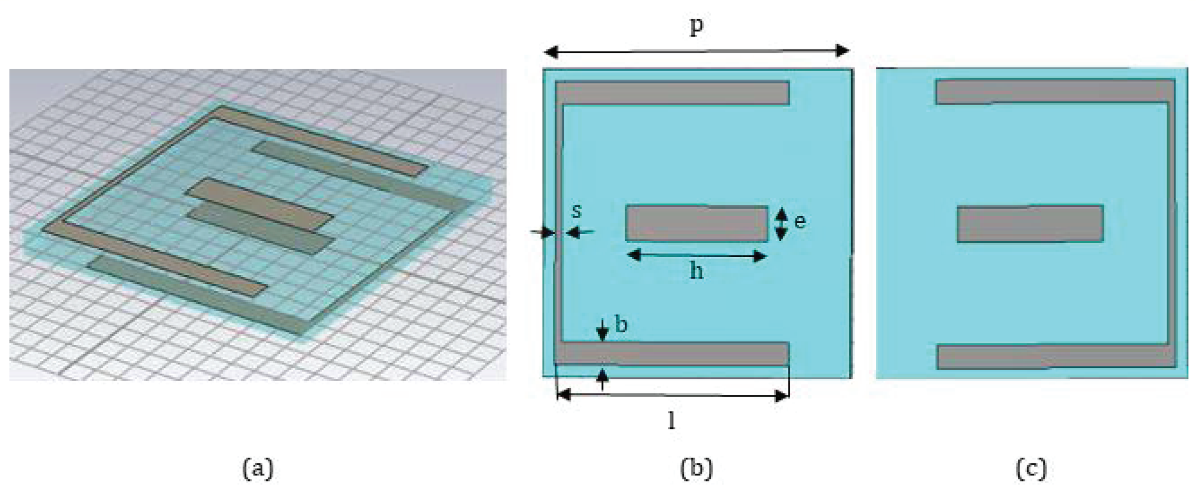

Figure 1. (a) 3D view, (b) top view, and (c) bottom view of unit cell.

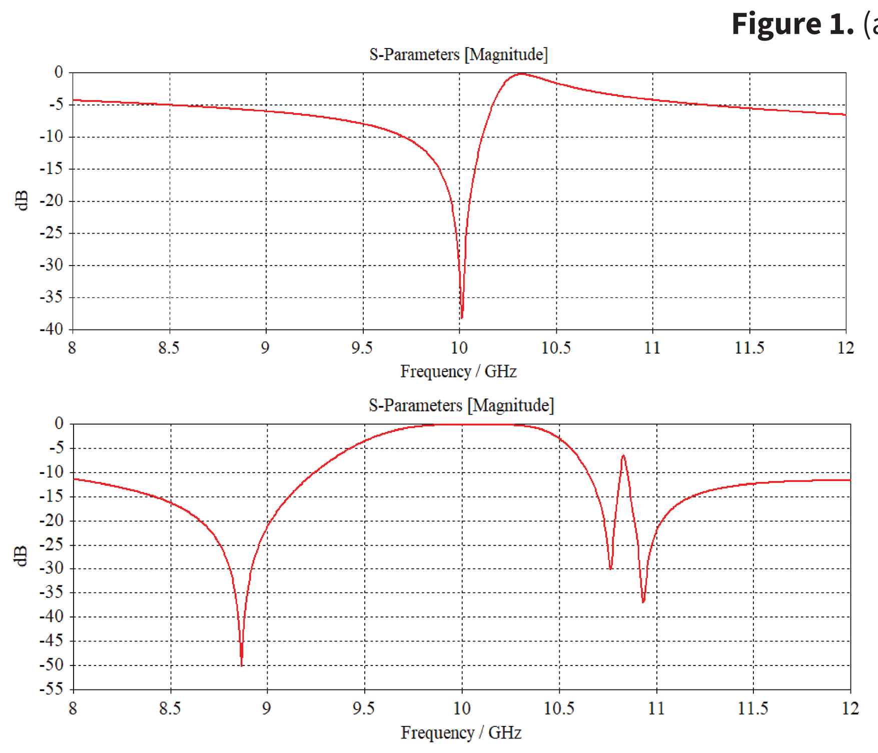

Figure 2. Transmission amplitude of (top) single-layer unit cell & (bottom) 2-layer (entire) unit cell.

- Top plot: transmission dip at 10 GHz when only top or bottom layer is used
- Bottom plot: illustrates Huygens' resonance where there is transmission peak from 9.8-10.3 GHz when both layers are put together on a thin substrate
- Phenomenon is due to impedance matching of electric surface admittance & magnetic surface impedance of unit cell
- Coupling between top & bottom electric dipoles on substrate induces magnetic dipoles such that impedance matching makes surface transparent & reflectionless at 10 GHz

MEASUREMENT RESULTS

- Metalens fabricated using PCB fabrication technology; measured in bistatic chamber

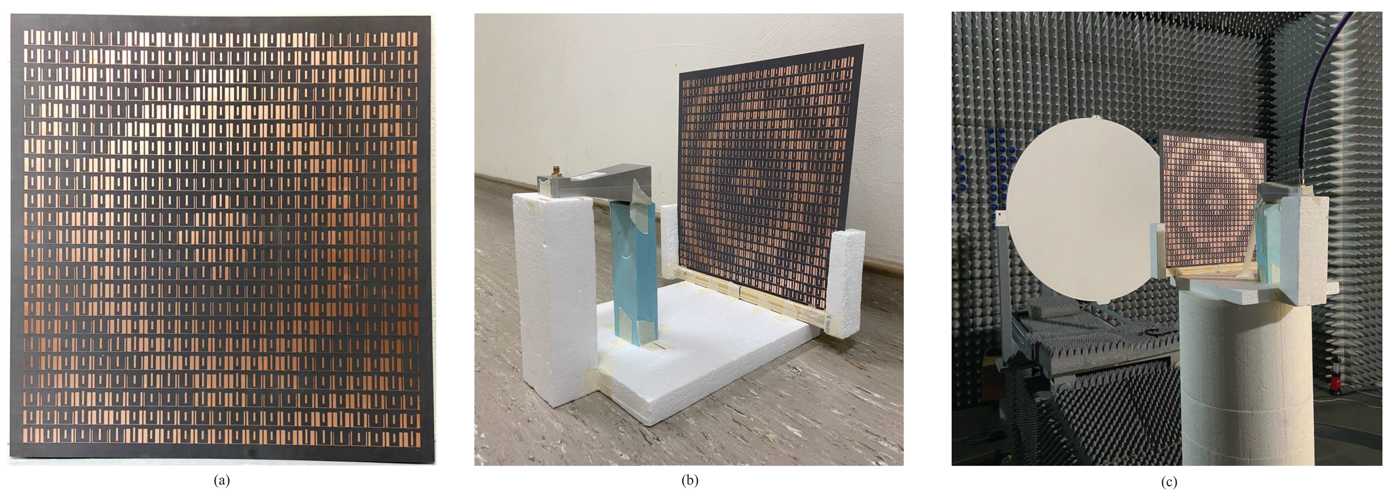

Figure 6. (a) Fabricated metalens, (b) metalen lens with feed horn, & (c) metalens set up in bistatic chamber.

- Metalens gives 9.8 dB ↑ in gain (Fig. 7)
- Main beam of measured & simulated radiation pattern overlaps (Fig. 8)
- Bandwidth of metalens: 0.457 GHz (or 4.57%) for gain of 26.04±1 dB (Fig. 9)

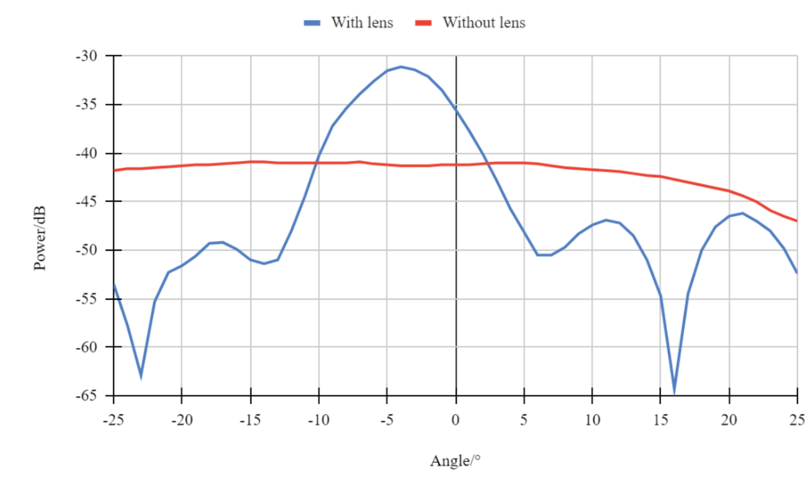

Figure 7. Radiation pattern of horn with & without metalens.

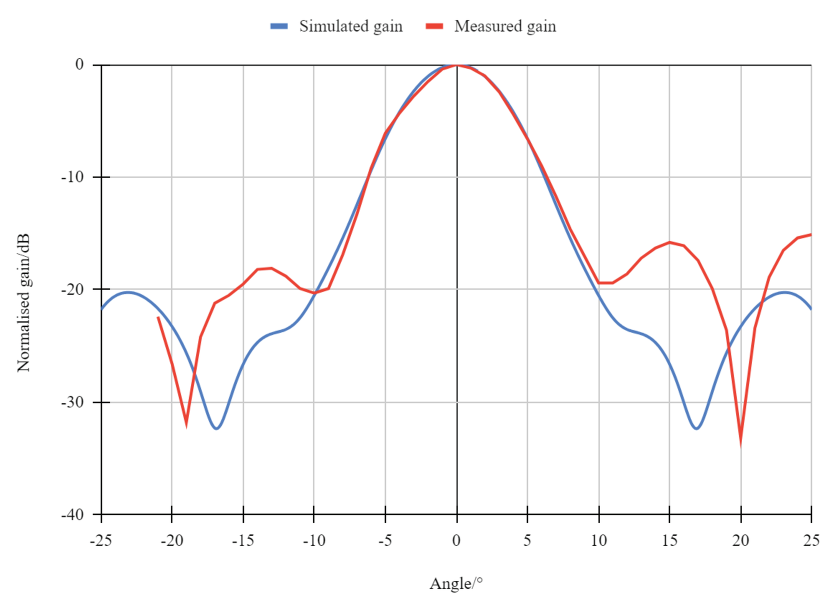

Figure 8. Comparison of normalized measured & simulated radiation patterns.

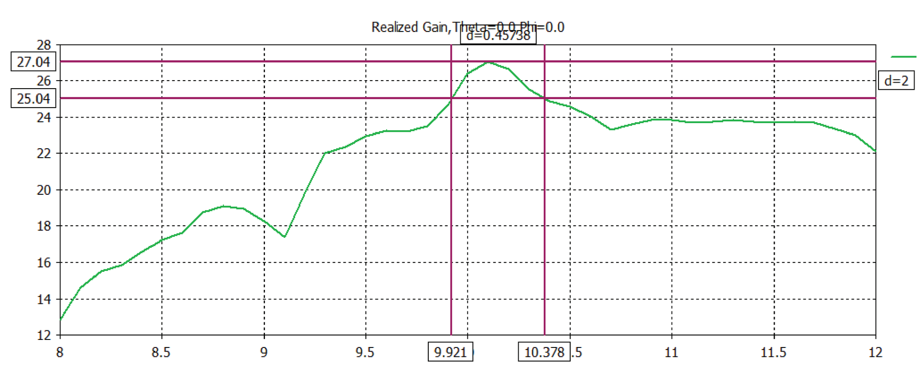

Figure 9. Simulated gain vs. frequency of metalens.

CONCLUSION

- An ultrathin Huygens' transmitarray lens operating at 10 GHz is designed
- Unit cells achieved phase coverage of 360° with transmission amplitude > –0.97 dB
- Simulated results of metalens show maximum gain of 26.5 dBi (aperture efficiency: 35.8%) at 10 GHz, 2 dB gain-bandwidth from 9.9 GHz to 10.4 GHz (4.57%)
- Metalens achieved 9.8 dB increase in gain compared to feed horn
- Bandwidth can be further improved with optimum focal length & dedicated horn design

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