# Single-layer Metasurface and Antenna Arrangement for Wearable Millimeter Wave Radar Applications

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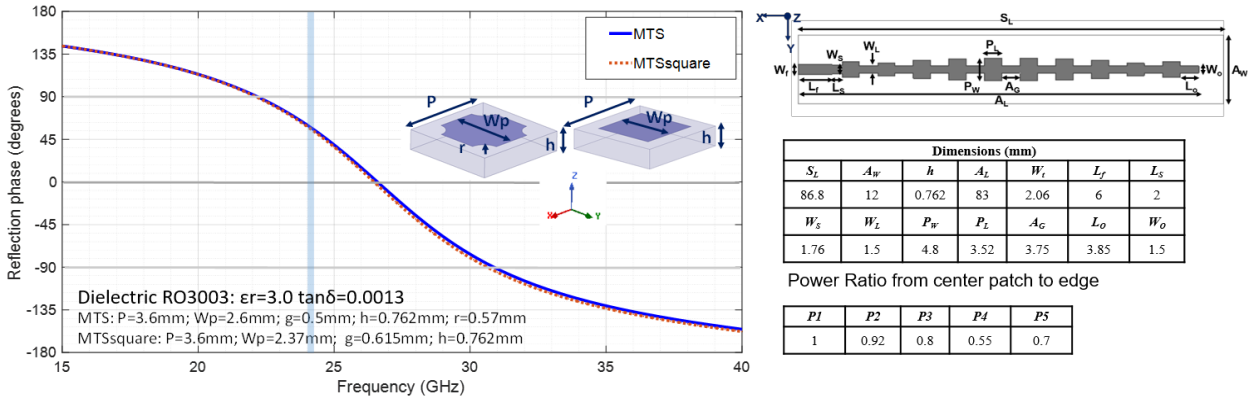
**Abstract:** Two metasurfaces (MTS) and a series end-fed 1x10 array antenna with a modified Dolph-Chebyshev distribution for improved beam-width are designed for imaging applications in 24.05GHz-24.25GHz. Each single-layer MTS-array provides secondary lobes reduction and FTBR increase while preserves Gain, radiation efficiency, SLL and size. Moreover, operation bandwidth is widened, with Gain and radiation efficiency enhancement. The overall devices' size is 86.8 x 12 x 0.762 $mm^3$. The envisioned application is collision avoidance in aid to visually impaired people at medium-long distance.

Two high impedance metasurfaces (MTS) [1] are designed for operation in the ISM 24.05 to 24.25GHz radar band to be arranged around a series end-fed 1x10 array antenna with a modified Dolph-Chebyshev distribution, pursuing a suitable antenna for wearable medium-long distance collision avoidance radar [2]-[3].




| Dimensions (mm) | | | | | | |
|---|---|---|---|---|---|---|
| $S_L$ | $A_W$ | $h$ | $A_L$ | $W_t$ | $L_T$ | $L_S$ |
| 86.8 | 12 | 0.762 | 83 | 2.06 | 6 | 2 |
| $W_S$ | $W_L$ | $P_W$ | $P_L$ | $A_G$ | $L_O$ | $W_O$ |
| 1.76 | 1.5 | 4.8 | 3.52 | 3.75 | 3.85 | 1.5 |

Power Ratio from center patch to edge

| $P1$ | $P2$ | $P3$ | $P4$ | $P5$ |
|---|---|---|---|---|
| 1 | 0.92 | 0.8 | 0.55 | 0.7 |

Figure 1. Metasurfaces reflection coefficient phase and unit cell dimensions. Antenna geometry and dimensions.

| | Freq (GHz) | G (dBi) | D (dB) | η (%) | FTBR (dB) | SLL (dB) φ=0° | HPBW (°) φ=0° | SLL (dB) φ=90° | HPBW (°) φ=90° |
|---|---|---|---|---|---|---|---|---|---|
| Array | 24.05 | 15.1 | 15.4 | 93 | 27 | -16 | 12 | -30 | 62 |
| | 24.15 | 15.2 | 15.3 | 98 | 27 | | | | |
| | 24.25 | 14.7 | 14.9 | 96 | 24 | | | | |
| MTS-Array | 24.05 | 15.2 | 15.4 | 97 | 30 | -16 | 12 | -25 | 58 |
| | 24.15 | 15.0 | 15.1 | 98 | 35 | | | | |
| | 24.25 | 14.6 | 14.8 | 97 | 30 | | | | |
| MTSsquare _scaled-Array | 24.05 | 15.0 | 15.1 | 98 | 42 | -15 | 12 | -30 | 57 |
| | 24.15 | 14.7 | 14.8 | 98 | 30 | | | | |
| | 24.25 | 14.1 | 14.3 | 97 | 26 | | | | |
| Array-parasitic | 24.05 | 11 | 13 | 68 | 14 | -8 | 8 | -34 | 40 |
| | 24.15 | 10 | 12 | 64 | 11 | | | | |
| | 24.25 | 9 | 11 | 63 | 11 | | | | |

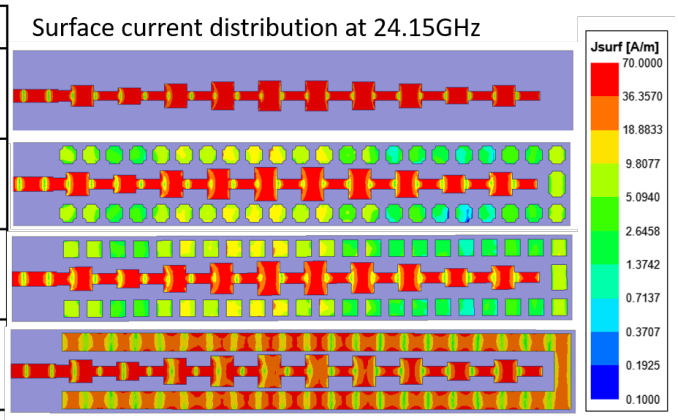



Figure 2. Radiation properties and surface current distribution at 24.15GHz for the antennas under analysis.

As it can be observed in Figure 2 and 3, the metasurfaces arrangement around the array antenna provides Front-to-back-ratio (FTBR) enhancement (key in wearable applications), without degrading radiation parameters

and preserving size. A metallic parasitic does not provide such improvement, but the opposite. Furthermore, the secondary lobes level is reduced by both metasurfaces (see Figure 4), although the square patch worsens the crosspolar level.

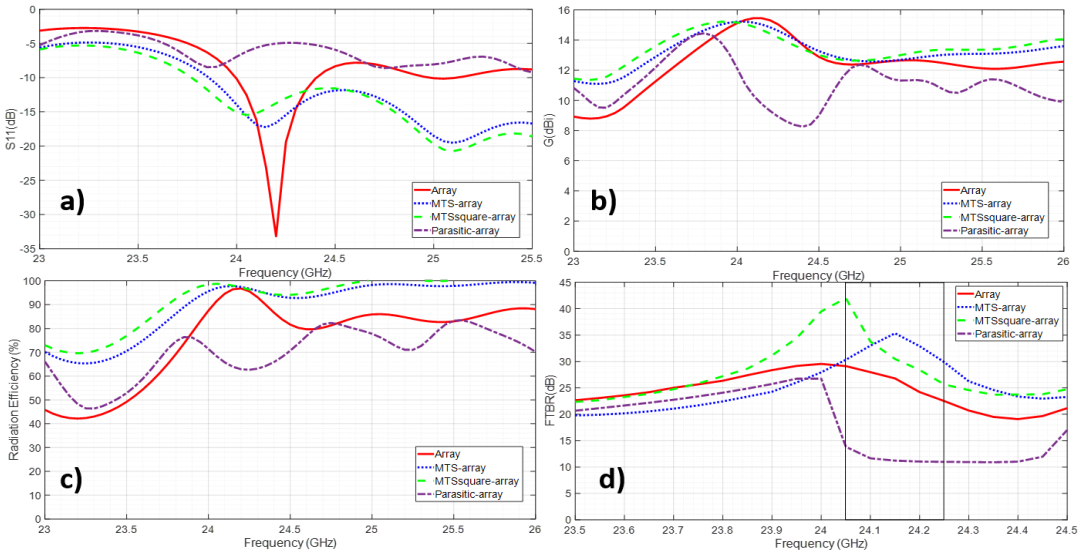



Figure 3. a) S11, b) Gain, c) Radiation efficiency and d) FTBR for the antennas under analysis.

It is very remarkable that metasurfaces widen the operation bandwidth with improved radiation properties preserving the size. For example, the radiation efficiency of the array at 23.75GHz is 65%, whereas the ones of the MTS-array and the MTSsquare-array are 85% and 90% respectively, with reduced secondary-lobes level.

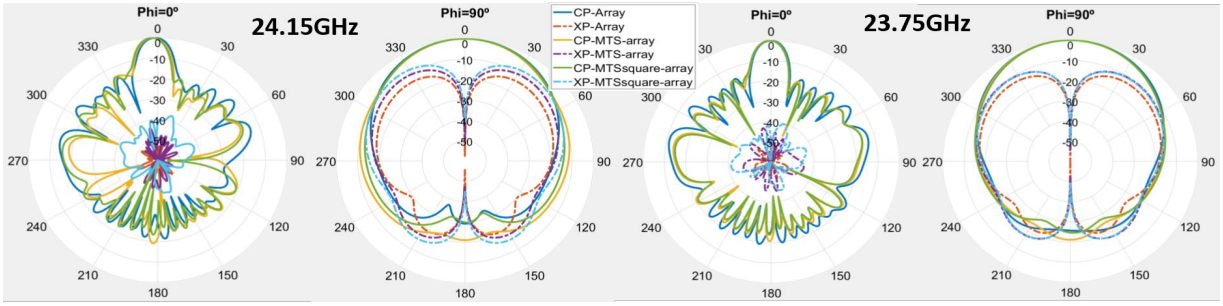



Figure 4. Radiation pattern cuts for Phi=0° and Phi=90° at 24.15GHz and 23.75GHz

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