GENETIC ALGORITHM OPTIMISATION OF SPACE-TIME METASURFACES FOR HARMONIC BEAM STEERING AND BACKSCATTERING REDUCTION

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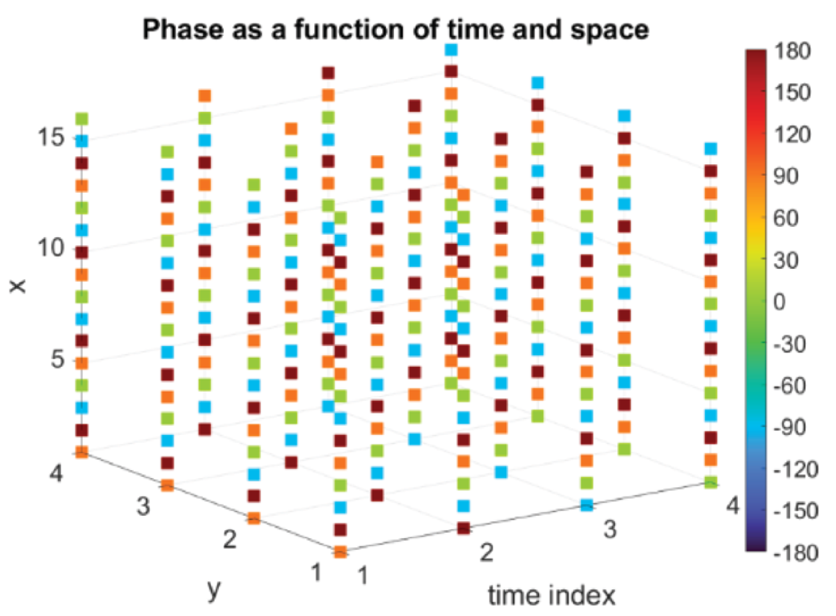
Aim

This project aims to show the potential and versatility of optimised Space-Time Metasurfaces for control of EM waves.

What is a Space-Time Metasurface?

It is a programmable, 2D array of reflectors that reflect EM waves with varying reflection coefficients (Γ) in both **space** and **time.** The **phase and amplitude** of Γ can be changed. For this project, only phase modulation is considered (see example below).



Simulating the far-field pattern

Pattern amplitude at angle θ for reflection coefficients Γ:

$$f(t,\theta) = \sum_{q=1}^{N}\sum_{p=1}^{M} E_{pq}(\theta)\Gamma_{pq}(t)\, e^{jk\mathbf{r}_{pq}\cdot\hat{\mathbf{p}}}$$

Fourier series coefficients of $\Gamma_{pq}(t)$:

$$a_{pq}^{m} = \sum_{n=1}^{L} \frac{\Gamma_{pq}^{n}}{L}\,\mathrm{sinc}\left(\frac{\pi m}{L}\right) e^{-\frac{j\pi m(2n-1)}{L}}$$

Expanding dot product in first equation, the m^{th} harmonic pattern is given by:

$$\sum_{q=1}^{N}\sum_{p=1}^{M} a_{pq}^{m} E_{pq}(\theta)\Gamma_{pq}(t)\, e^{jk\sin\theta[(p-1)d_x\cos\phi+(q-1)d_y\sin\phi]}$$

Optimisation

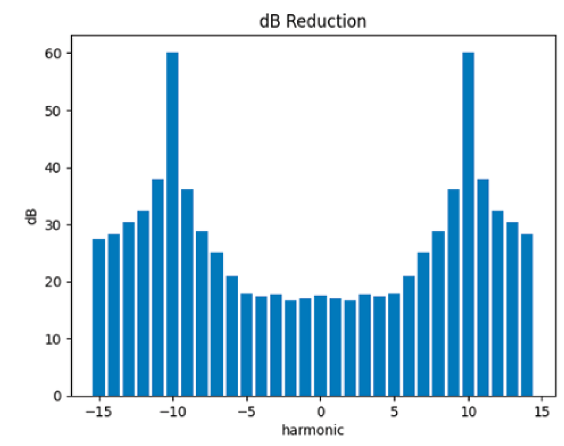
We used genetic algorithms (GA) to optimise the space-time matrices (STMx) for various applications. GA was chosen as its non-linear and random nature can effectively search large search space with numerous variables.

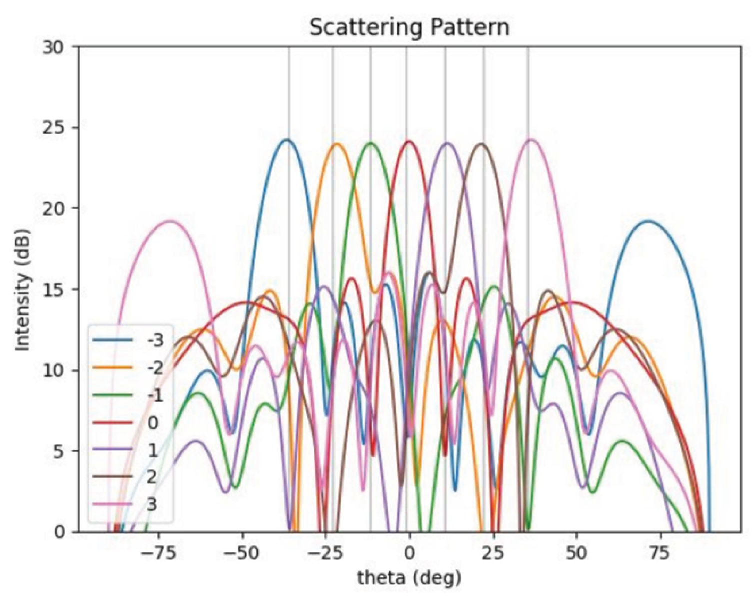
- ## Harmonic beam steering

Harmonic beam steering aims to steer multiple harmonic beams to specified angles, with equal amplitudes and low sidelobes. We consider both symmetric and asymmetric target steering angles. GA was able to optimise for both. ↓

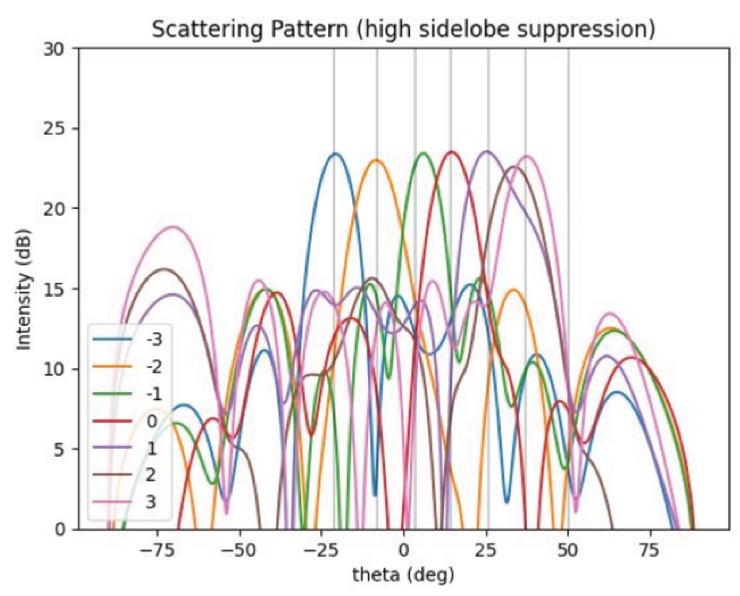
- ## Backscattering reduction

Reduces the maximum amplitude over a range of harmonics. We optimised for a reduction over the -15th to +14th harmonics. →

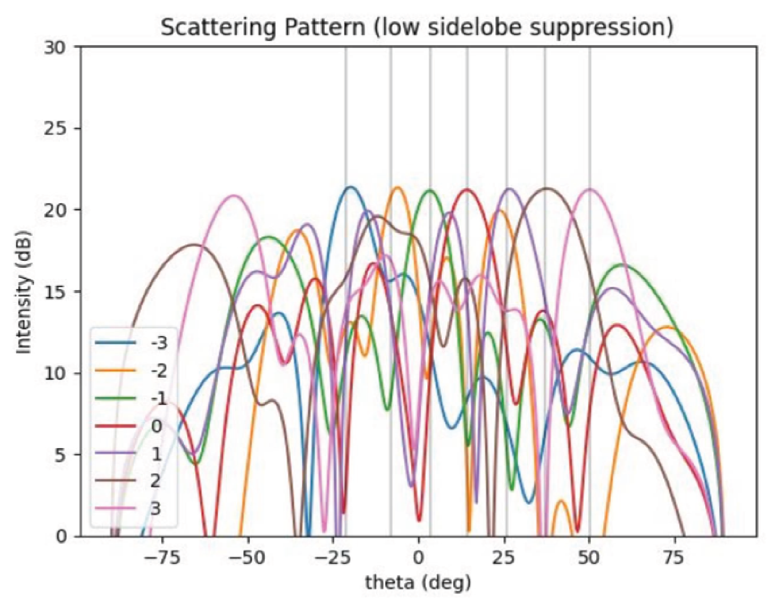




Symmetrical



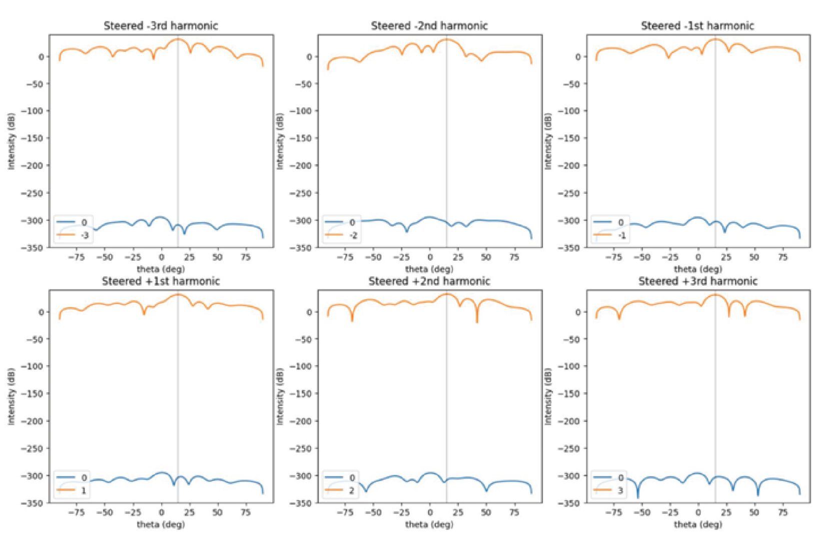
Asymmetrical

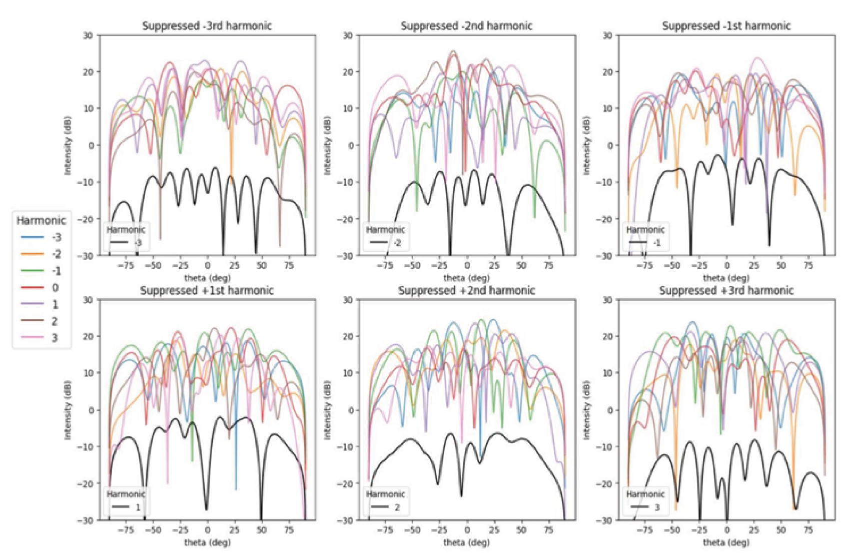


Asymmetrical

- ## Beam Suppression

A GA-optimised STMx could suppress individual harmonic beams. Another GA-optimised STMx could suppress the fundamental while simultaneously steering a harmonic. ↓





Conclusion

Our results demonstrate that GA optimised Space-Time Metasurfaces are versatile and adaptable to many different objectives in EM control. It excels in harmonic beam steering and backscattering reduction, and likely can excel in many other applications. Future work can compare the performance of an STM for an oblique incident versus normal incident plane wave.