NONLINEAR OPTIMISATION FOR VARIOUS APPLICATIONS OF A TIME-DOMAIN DIGITAL CODING METASURFACE

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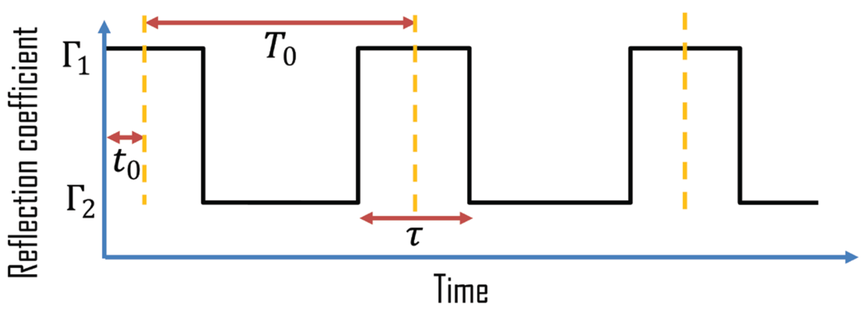
aim

This project investigates the potential of **nonlinear optimisation** methods for a **time-domain coding metasurface**

what is a time-domain coding metasurface?

It is an array of reflectors that can be coded to reflect light at varying reflection coefficients in both **space** and **time**, which can change the **phase and amplitude** of light. Specifically, we vary each component as shown below:



far-field reflection pattern

Amplitude at a certain angle and harmonic:

$$f(\theta,\phi,k) = \sum_{q=0}^{N-1}\sum_{p=0}^{M-1} E_{pq}(\theta)\exp\left(\frac{2\pi i}{\lambda_c}\left(pd_x\sin\theta\cos\phi + qd_y\sin\theta\sin\phi\right)\right)a_{pq}^{k}$$

Fourier series coefficients:

$$a_k = \begin{cases} M\cdot\Gamma_1 + (1-M)\cdot\Gamma_2, & k=0 \\ (\Gamma_1-\Gamma_2)M\,\mathrm{sinc}\,k\pi M\,e^{-ik\omega_0 t_0}, & k\neq 0 \end{cases}$$

Notice that changing $M \equiv \tau/T$ and t_0 allows us to independently change the **amplitude** and **phase** of the coefficients

optimisation

We optimise the array for many applications by changing the time delays t_0 for different rows. We use 3 methods:

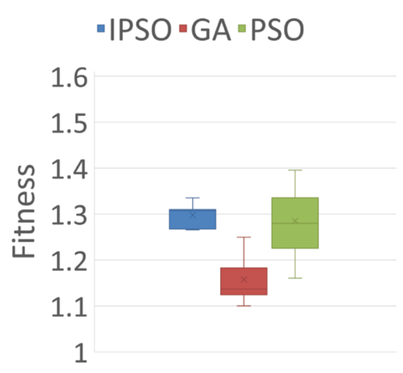
Genetic algorithm (discrete)

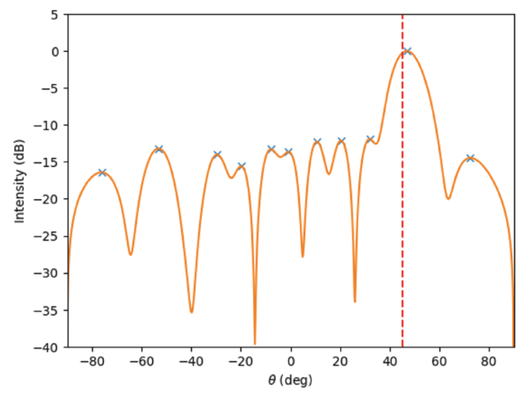
Particle swarm optimisation

Integer particle swarm optimisation

harmonic beam steering

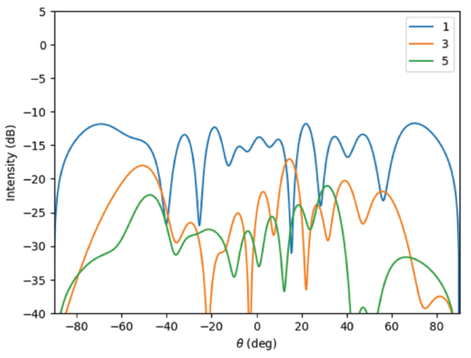
Steers the harmonics produced by the metasurface to a specified angle. We found that the IPSO was able to find the best solution most consistently



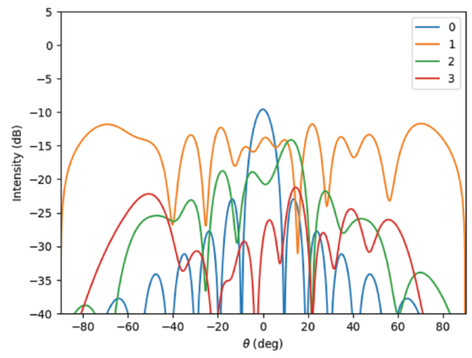


diffusion

Diffuses energy over many angles



M=0.5

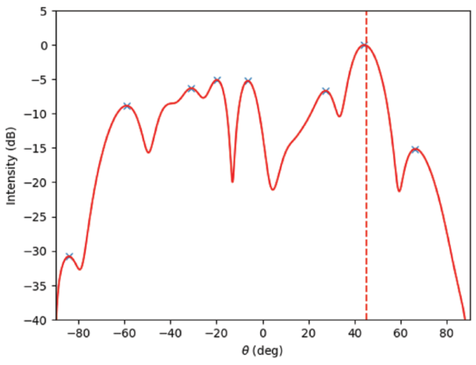


M=0.4

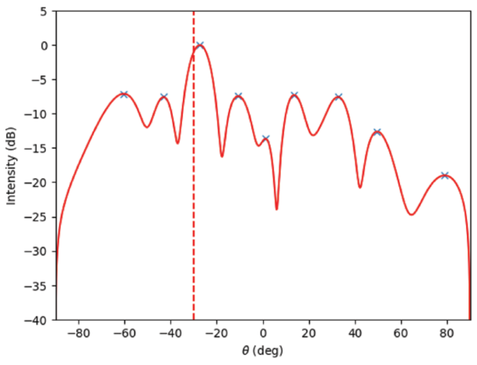
Notice that we can change M to change the ratio of the amplitudes of different harmonics without changing the scattering pattern

dual-harmonic beam steering

Steers two harmonic beams to different angles



1st harmonic



3rd harmonic

conclusion

A metasurface can achieve unusual applications through **nonlinear optimisation**. Its ability to easily modify the amplitude of the Fourier series coefficients also allows for control over the **relative amplitudes** of different harmonics.