0.1 Array antennas

- radiation characteristic for array antenna can be determined from rad characteristic of a singular element and the array factor

$$S_{Array}(\theta, \phi) = S_{Element}(\theta, \phi) \cdot AF(\theta, \phi) \tag{1}$$

- array factor is determined by treating every source of radiation in the array as in isotropic radiator and adding them (superposition for fields holds in linear media, e.g. free space)
- example: uniform linear array of N elements

$$AF(\theta) = \sum_{n=0}^{N-1} \exp(jnkd \cos\theta) \tag{2}$$

- k = wavenumber (explain), d = inter-element distance, no dependence along phi as its only 1D
- inter-element distance is chosen as smaller than wavelength lambda to avoid grating lobes, but has to be large enough to avoid physical overlap and near-field mutual coupling
- from plot, we see that array increases directivity strongly, but high directivity also requires precise alignment between transmitter and receiver
- if moving targets, precise alignment by mechanically orientating antennas bothersome, therefore techniques for beam-forming and beam-steering

0.2 Beam-forming and beam-steering

- explain beam-forming
- e.g. beam-steering is done for a phased array with a progressive phase
- upper element has to be this earlier in time

$$t = \frac{s}{v_{ph}} \tag{3}$$

- this equals a phase shift of

$$\Delta\phi = ktv_{ph} = ks = kd \sin\alpha \tag{4}$$

- illustration for the process in one dimension
- result for array factor in one dimension as plot
- this can be extended to two extensions and NxM elements

$$\phi(m, n) = k \sin\theta(md_x \cos\phi + nd_y \sin\phi) \tag{5}$$

- dx, dy refer to inter-element distances in their respective axes
- plot of result for two dimensions
- add profile for focusing the beam (e.g. bessel-beam, Gaussian beam?)
- how to achieve the phase shifts?

0.3 Implementation

- in the following:
  - before radiation is emitted, electrical phase shifting
  - after radiation is emitted, optics (e.g. lenses / reflectors)
  - combination of both

0.3.1 Electrical

0.3.2 Optical

- lenses, change optical path length by refractive index; quite constant across frequency (non-dispersive), therefore don't limit bandwidth, but introduce losses, also consider matching (easier with silicon lenses) and therefore reflections

$$\phi(l) = knl \tag{6}$$

- refractive index, length through medium of refractive index
  - describe the losses
  - extended hemispherical lens (shape of a bullet) puts antenna at focus, cause almost planar wavefronts and therefore high directivity
  - do the same for a parabolic reflector

0.3.3 Combined

- include this?