0.1 Array antennas

- radiation characteristic for array antenna can be determined from rad characteristic of a singular element and the array factor
    - 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
    - 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
    - illustration for the process in one dimension
    - result for array factor in one dimension as plot
    - this can be extended to two extensions
    - 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 and therefore reflections
    - describe the losses

- extended hemispherical lens (shape of a bullet) puts antenna at focus, cause almost planar wavefronts and therefore high directivity

0.3.3 Combined

- include this?