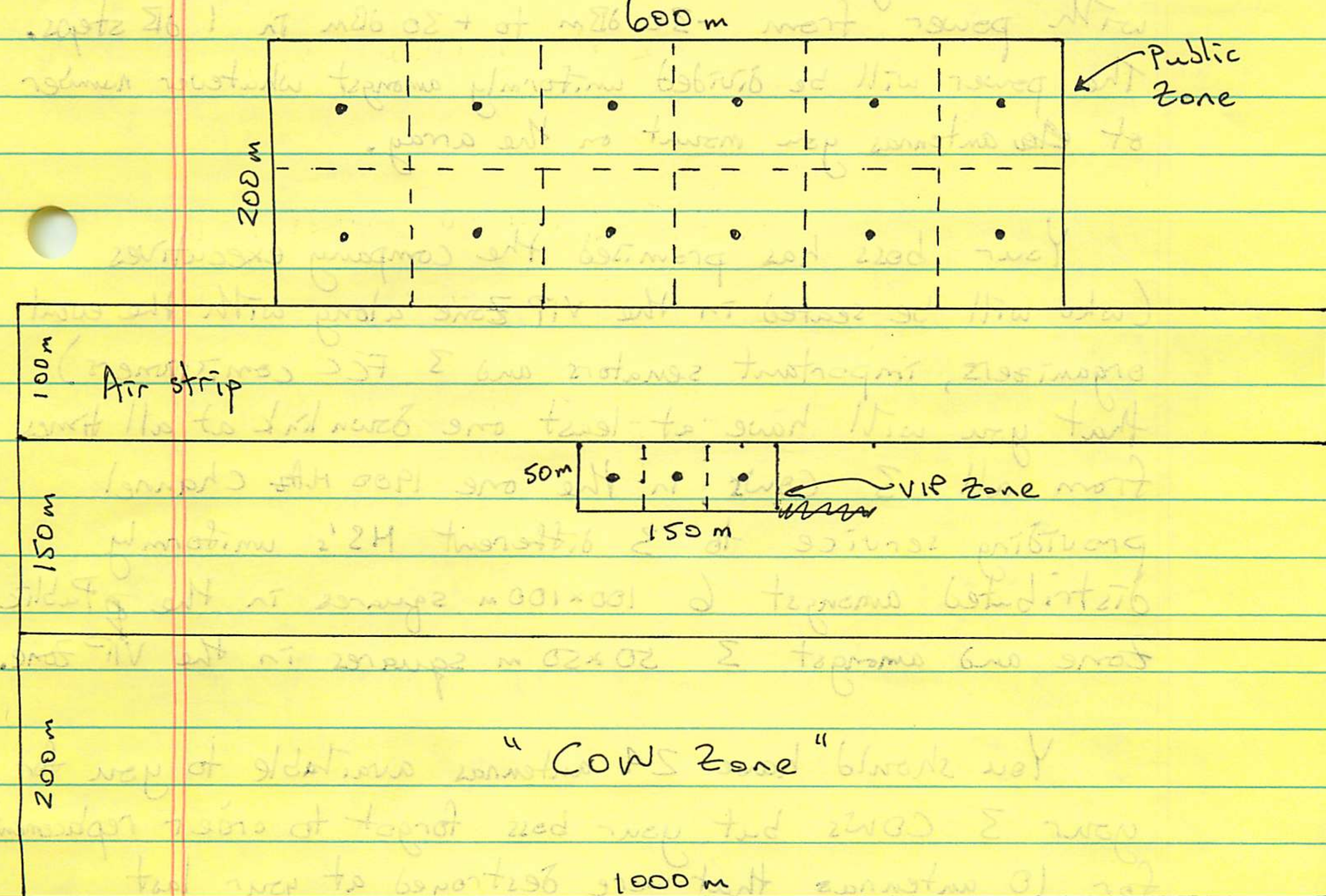
FINAL EXAM EELE 5970

You have 1 week to design an antenna configuration and placement for temporary cellular service at an air show. You are given 3 "cellular on wheels" ("COWS") portable base stations, each of which can drive a linear scan antenna array of up to 8 elements. Here's the layout of the venue:



You are given 1 freq. channel of 20 MHz at $f_c = 1900$ MHz.

Each COW has a mast that can mount and linearly scan up to 8 antennas driven from a common downlink modulated signal. Each antenna ~~[illegible]~~ has $L_x = 20$ cm and $L_y = 40$ cm. You can mount the antennas at any uniform spacing you want but the overall width of the array cannot be more than 240 cm.

Each of your modulated downlink streams can be driven with power from -30 dBm to +30 dBm in 1 dB steps. The power will be divided uniformly amongst whatever number of ~~[illegible]~~ antennas you mount on the array.

Your boss has promised the company executives (who will be seated in the VIP Zone along with the event organizers, important senators and 3 FCC comissioners) that you will have at least one downlink at all times from all 3 COWs in the one 1900 MHz channel providing service to 3 different MS's uniformly distributed amongst 6 100×100 m squares in the Public Zone and amongst 3 50×50 m squares in the VIP Zone.

You should have 24 antennas available to you for your 3 COWs but your boss forgot to order replacements for 10 antennas that were destroyed at your last event (rock concert). So you have 14 antennas to use as you deem fit on the 3 COWs. Your boss also agreed that the 3 COWs must stay in the "COW Zone".

Yes, your boss ~~is~~ an MSU grad.

You are going to assume for design purposes that the MSs can be realistically modeled as a single MS_j where $j=1$ to 15 and MS_1 to MS_{12} are at the centers of each 100x100 m square in the public zone while MS_{13} to MS_{15} are at the centers of each 50x50 m square in the VIP Zone. You assume each MS_j has $G_{RX}=-2$ dBi and NF = 5 dB. Because of the open field plan and short distances, you assume Friis' path loss equation works for all propagation at the venue and fading effects are negligible.

Each of your COWs is one BS_i where $i=1$ to 3, and is characterized by its:

i) (x_i, y_i) location within the COW zone

ii) θ_{Ci} - relative orientation

iii) N_i - number of antennas (min 2, max 8)

iv) d_i - antenna spacing

v) P_{Tx_i} - transmit power for a given time slot

vi) α_i - scan angle for a given time slot

Your boss promised the executives that not only would 3 handsets be downlinked in every time slot but also 24 dB SINR would always be achieved at each MS_j. If you fail to provide this in the Public Zone, you lose your annual bonus. If you fail to provide this in the VIP Zone, you get fired.

Here are your specific tasks:

1) Develop and thoroughly document a design methodology to determine how to distribute and mount your 14 antennas on BS_1, BS_2, BS_3, orient in the azimuthal plane each of BS_1, BS_2, BS_3, and where to park each of BS_1, BS_2, BS_3 within the COW zone. Show your logic for your choices!

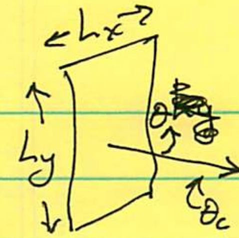
2) Having completed 1), generate sets of polar gain ~~amplitude~~ plots for each antenna array as a function of θ_i at α_i values from $-\pi$ to $+\pi$ in $\pi/4$ steps.

3) Develop a 5 slot round robin scheduler to service each of MS_1 to MS_{15}, 3 MS's at a time each with a modulated stream from 1 of BS_1, BS_2, BS_3, on a uniform time basis. Provide a table that shows at least:

Time Slot #	MS_j served	P_{Tx_i} chosen	α_i chosen	SINR at each MS_j served
1	3 per slot and indicate which BS_i for each MS_j	3 per slot	3 per slot	3 per slot
2				
3				
4				
5				

4) Describe how you plan to i) Spend your annual bonus, ii) Tell your spouse you get no bonus this year, or iii) Find another job.

Linear Scan Antenna Arrays

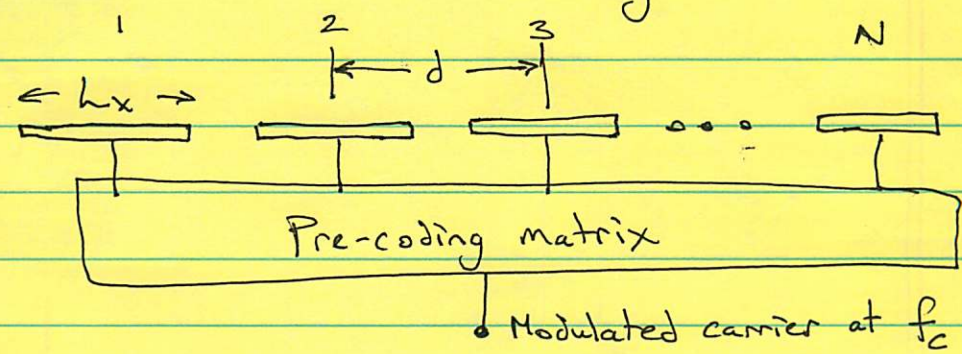


For a single antenna of dimensions L_x, L_y, an approximate formula for "gain" is:

$$G_{ANT} = \frac{10 L_x L_y}{\lambda^2} \left\{ \frac{\sin\left[\frac{\pi L_x}{\lambda}\sin(\theta-\theta_c)\right]}{\frac{\pi L_x}{\lambda}\sin(\theta-\theta_c)} \right\}^2 \left\{ \frac{1+\cos(\theta-\theta_c)}{2} \right\}^2$$

assuming that directivity in the elevation direction is constant within the propagation plane of interest.

In many applications, it is desirable to use multiple such antennas in a linear array:



Ideally the pre-coding matrix permits an arbitrary complex transfer function (amplitude + phase) unique to each of the 1 to N antennas.

A simplified version used in many applications (traditionally radars, but also WiFi and cellular have used this too) sets all the amplitudes the same from 1 to N and then sets the phases relative to the preceding element at α for each of 2 to N.

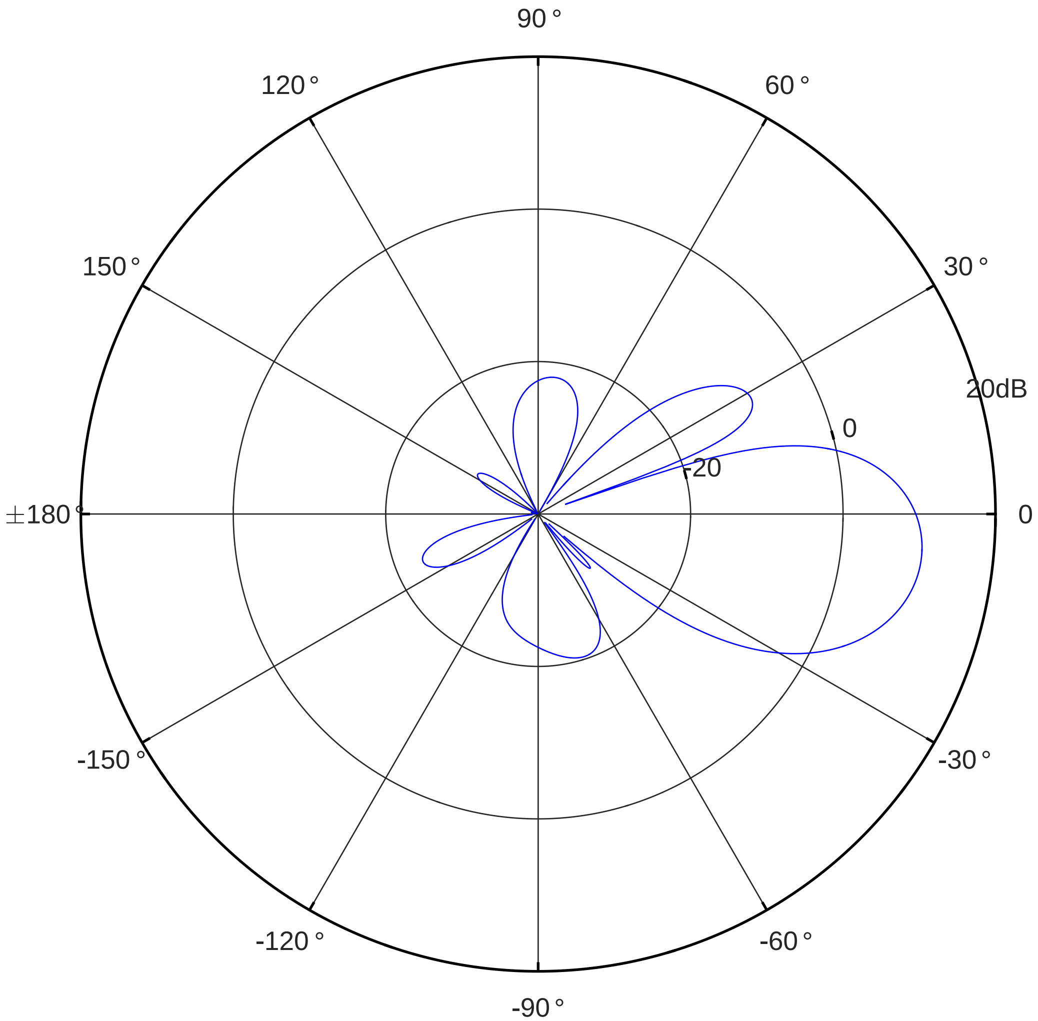
The "gain" of such a linear array is then given approximately by:

$$G_{ARRAY} = G_{ANT} \left\{ \frac{\sin\left(\frac{N\Psi}{2}\right)}{N \sin\left(\frac{\Psi}{2}\right)} \right\}^2 \cdot N$$

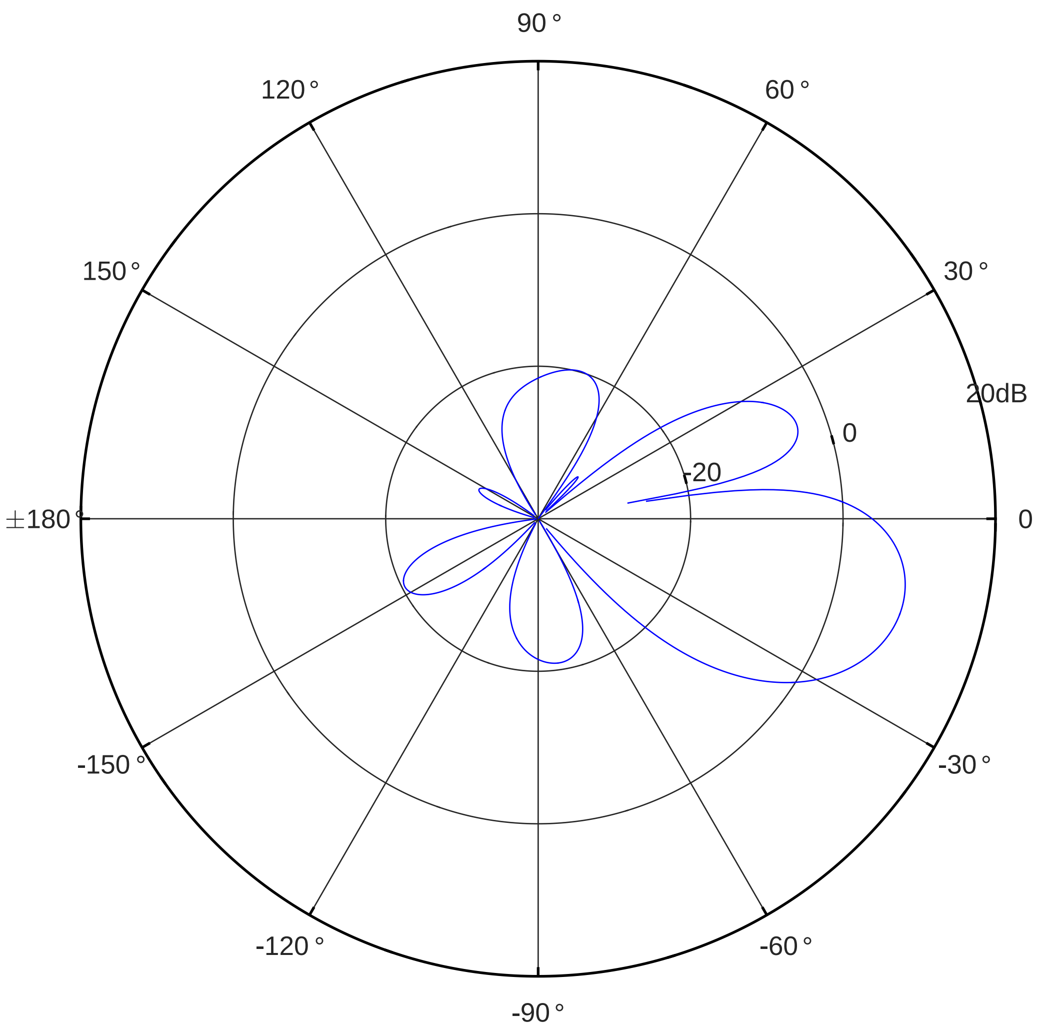
where $\Psi = \frac{2\pi d}{\lambda} \sin(\theta - \theta_c) + \alpha$

and clearly $d > L_x$

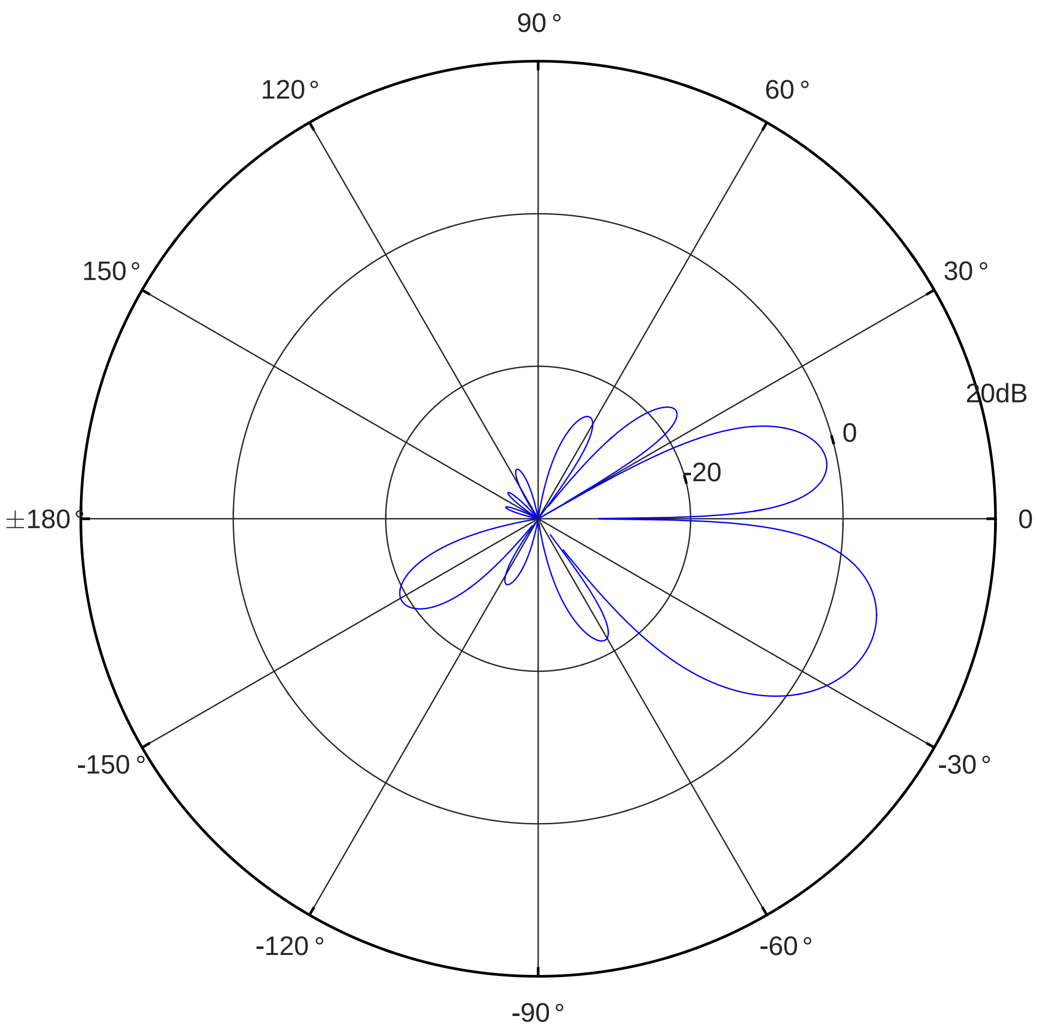
4-element array, 30 degrees



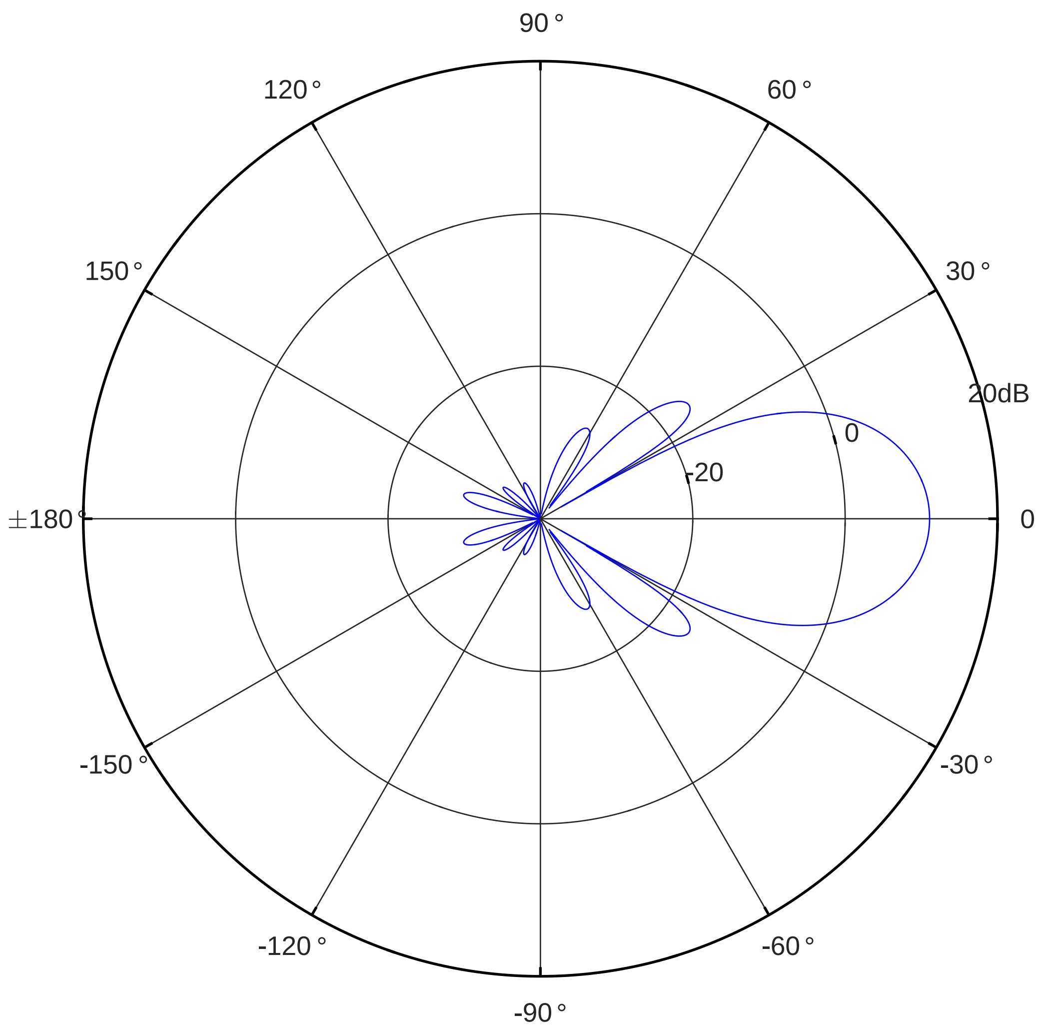
4-element, 60 degrees



4-element array 90 degrees



4-element array no scan



Single element array