ECE 123 **Assignment 2** **Spring 2009**

This problem set is due Tuesday April 14 at 11:00 AM.

Broadcast Antenna Array:

The goal of this project is to design a vertical array antenna for broadcast. It is located in Eastern Colorado where the land is flat. The desired pattern is isotropic in azimuth but narrow in elevation. It has a –3dB beamwidth of $5^0 \pm 1^0$ centered on $\theta = 90^0$. There must be no sidelobes or grating lobes with gain higher than that of the first side-lobe (approx –13.5dB with respect to the main beam). The elements are vertical magnetic dipoles (horizontal loops) with power pattern $\propto \sin^2\theta$. The optimal (cheapest) design will have as few elements as possible.

The design problem is to determine the number of elements N and their spacing d (in wavelengths). The actual wavelength does not matter, but for the sake of concreteness you can assume that it is an FM antenna and the wavelength is 3 m.

(a) Estimate the N and d values you need theoretically from approximate formulas for the beamwidth and grating lobe locations.

(b) Write a Matlab script to calculate the gain $G(\theta)$ for arbitrary N and d. This will require a numerical integration to get the normalizing factor correctly. A template you can use is shown below. Make sure you understand it. Try it with the N and d from your rough estimate and see if they meet the spec.

(c) Optimize the design to meet the spec with the smallest possible N. Plot the final $G(\theta)$ on rectangular axes (dB vs deg). Mark the spec's on this plot.

(d) The FM antenna will be located on the top of an existing AM antenna which is 75 m high. The transmitted power is 1 kw. Use Matlab to calculate the flux (w/m^2) on the ground vs distance from the transmitting tower over a range of 100 m to 100 km. Plot flux vs distance on loglog axes. Overplot the flux vs distance in the center of the beam. The flux in the center of the beam should match the flux on the ground at large distances.

(e) The curvature of the Earth's surface has an important effect at these distances. How far from the antenna can you go and still see the whole antenna from zero elevation? How high would your transmitter have to be, to be visible at a distance of 100 km?

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%matlab script for ps2 Need N=number of elements and d=element spacing in wavelengths
dct=0.0002; ct=-1:dct:1; %define equally spaced cos(theta) vector
ct=ct+eps;          %offset slightly so cos(theta) is never zero
t=acosd(ct);        %get the corresponding theta vector
p=(1-ct.^2).*(sin(pi*N*d*ct)./sin(pi*d*ct)).^2;     %power pattern within unknown constant
intp=dct*sum(p);            %integrate P(cos(theta)) wrt cos(theta)
g=p*2/intp;                 %normalize to get the gain normalizing constant
%get the -3dB width in theta
gmax=max(g); w1=find(g > gmax/2,1,'first'); w2=find(g > gmax/2,1,'last'); width=t(w1)-t(w2)
lg=10*log10(abs(g));                %get log10(gain)
lgmax=max(lg); lgmax=ceil(lgmax/10)*10;
figure(1);          %plot gain vs cos(theta)
plot(ct,lg); grid;
ax=axis; ax(4)=lgmax; ax(3)=ax(4)-40; axis(ax);  %adjust the axis
xlabel('Cos(\theta)'); ylabel('Gain (dB)'); %label the axis
figure(2);          %plot gain vs theta
plot(t,lg); grid;
ax2=axis; ax2(4)=lgmax; ax2(3)=ax2(4)-40; axis(ax2);
xlabel('\theta'); ylabel('Gain (dB)')
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