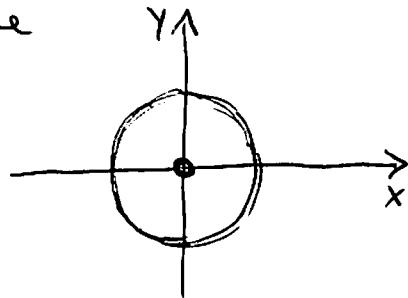


Antenna arrays

○ A practical way to create different radiation patterns is to combine "dipolar" radiation elements. Each one is assumed to be a perfect dipole with the $\sin^2\theta$ pattern. All with the same frequency.

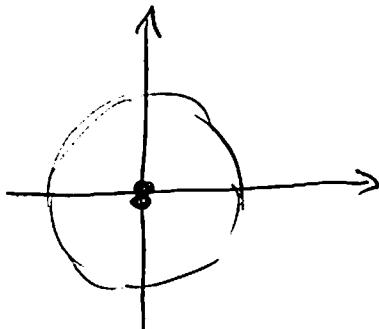
We will assume all dipoles point "out of the plane" (thus the $\sin^2\theta$ pattern becomes a circle). Note that the interference between dipoles will be crucial so we cannot add up squares of contributions but add amplitudes and then square.

○ Seen from above 1 dipole would produce a pattern like



If we would plot the xz or yz pattern we could see the donut shape.

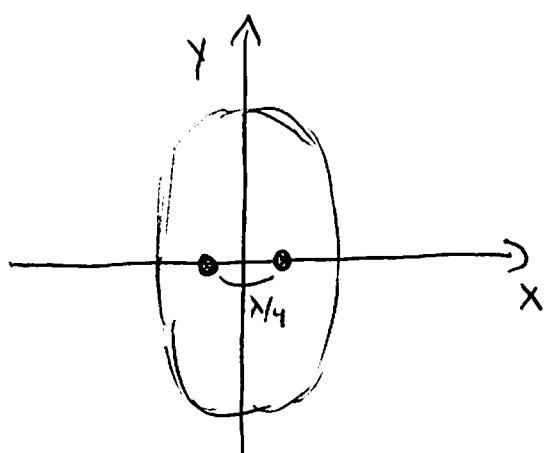
○ If we have 2 of those, one right next to the other, the pattern would be the same (we only care about the angular dependence).



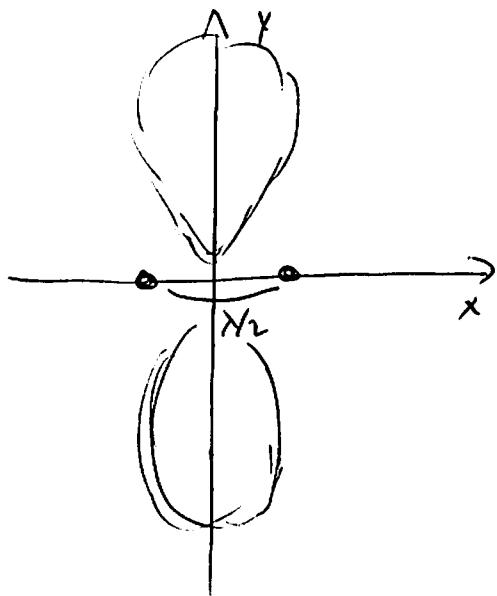
We are assuming the dipoles are in phase.

○ What happens as we start splitting their distance?

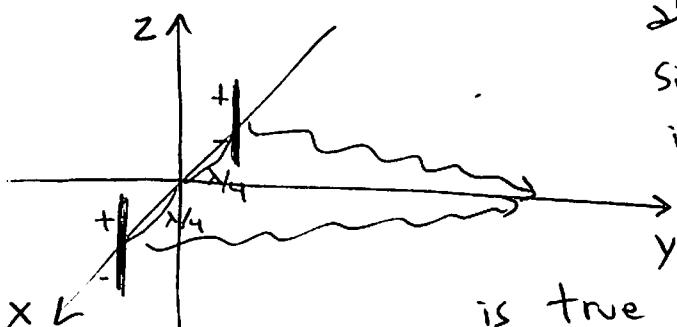
For the case of $\frac{1}{4}\lambda$ apart along the x-axis we get a slight distortion:



For a spacing of $\frac{\lambda}{2}$ we get a very anisotropic result



The maximum along the y axis is easy to understand. Consider a 3D drawing. The dipoles are in phase, thus



along the y axis the signals of both arrive identical at every point of the y axis and they add up. This

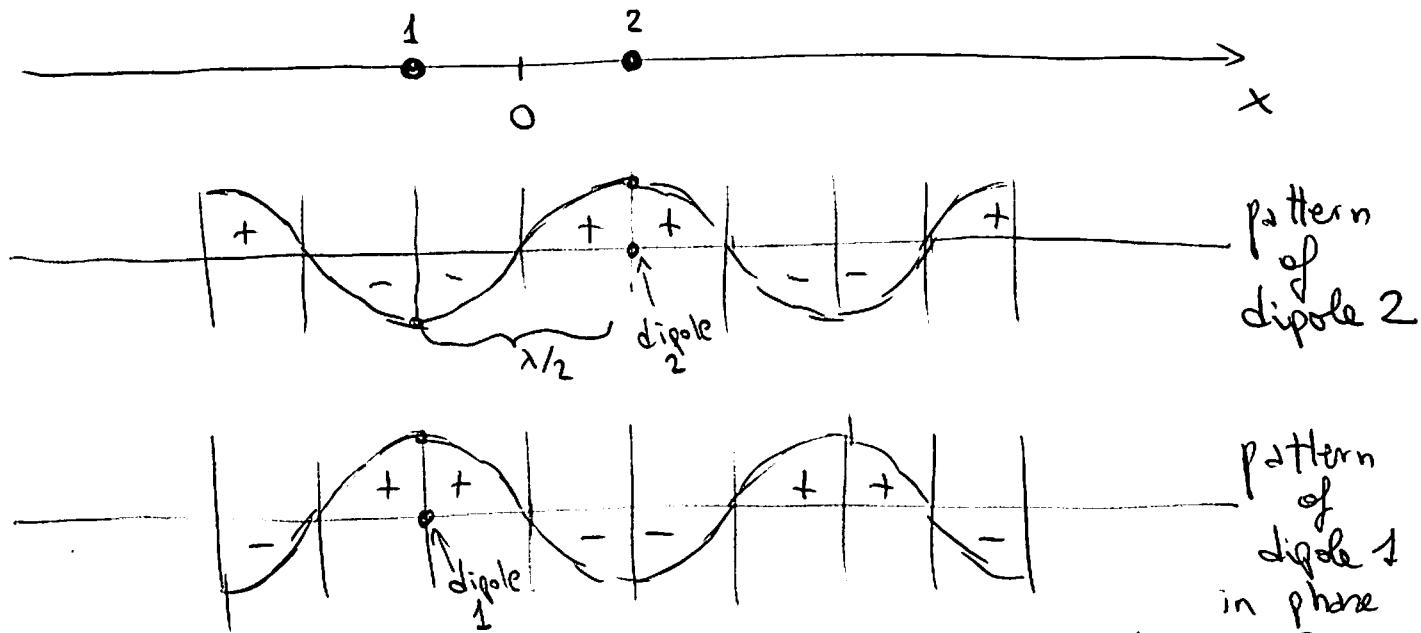
is true for both $\frac{\lambda}{2}$ and $\frac{\lambda}{4}$

(Note: if they were π-shifted then they would cancel along y axis)

distances or any other.

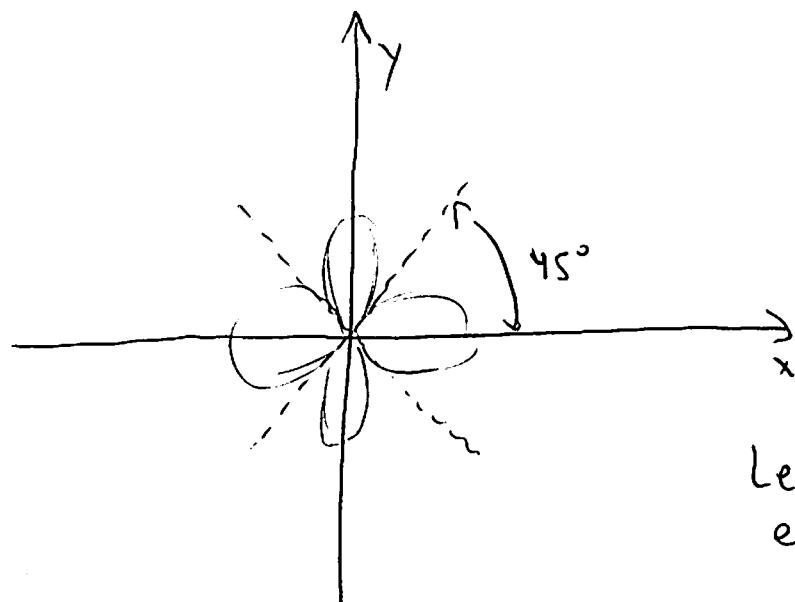
With regards to the cancellation along the

x axis, consider the following sketch:



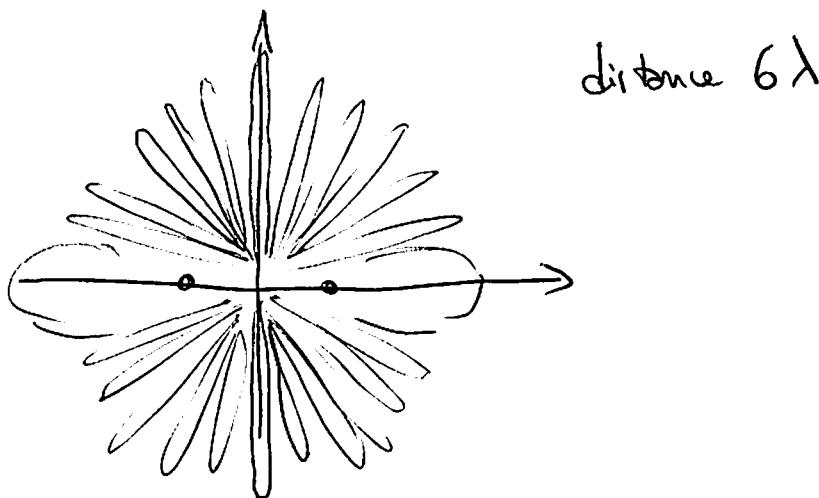
When you add up these two there is a perfect cancellation.

For the case of a distance of 1λ the same reasoning leads to a peak along y and also a peak along x since now the signals add up. However, a complete calculation finds interference at 45° :

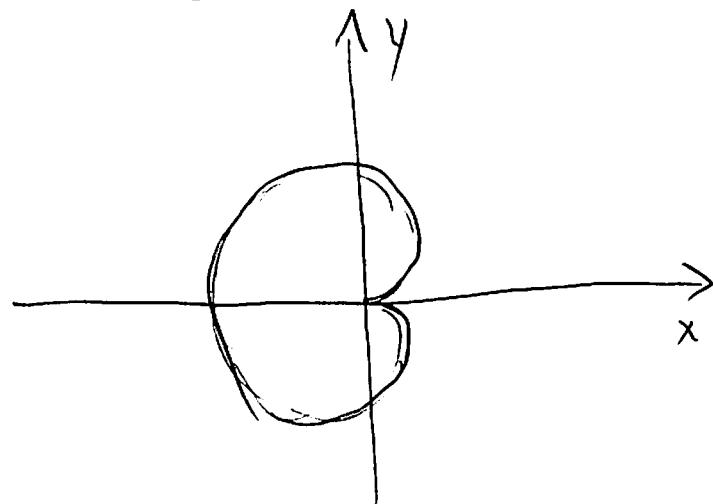


Left as an exercise.

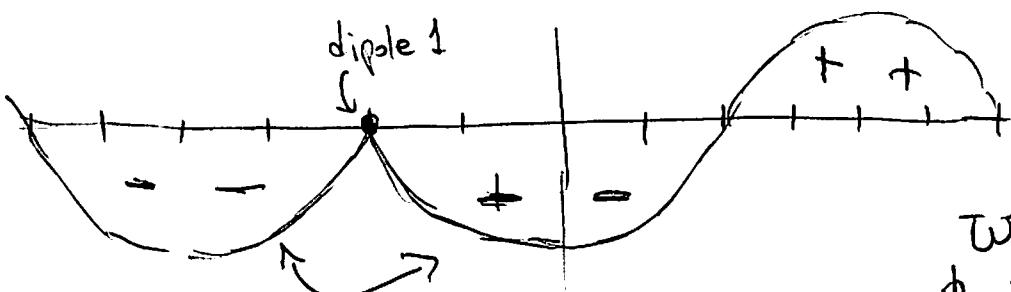
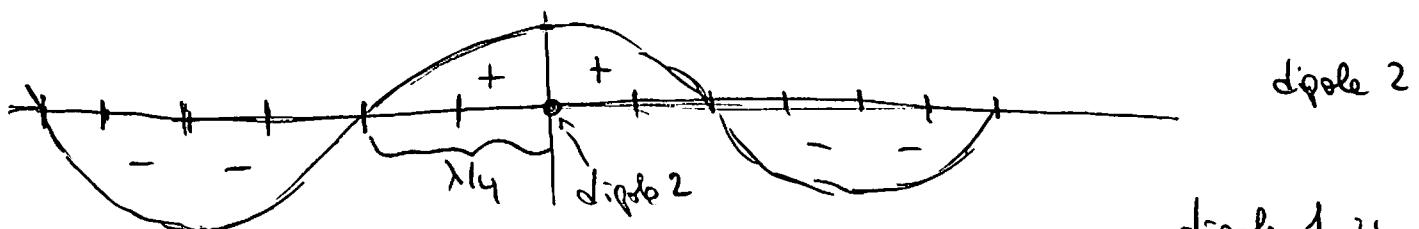
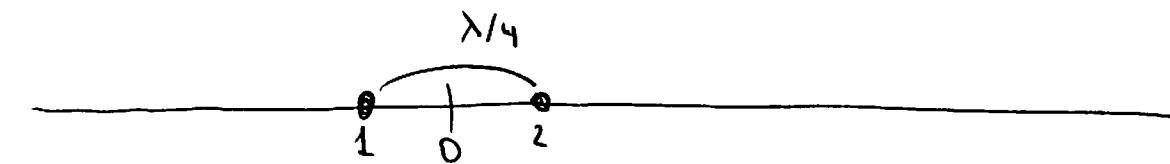
If the distance keeps on increasing, all still in phase, complex patterns are found!



So far we have managed to make a direction "x" or "y" different from the ~~other~~ (the isolated dipole has x and y the same, while the case of $\frac{1}{2}\lambda$ distance has a max at y and a cancellation at x). But what if we wish to prefer not the entire x or y axis but just half of it? That would allow us to direct the radiation as a beam. One easy way to do it is by playing with the phase. Consider the case of two dipoles at distance $1/4\lambda$ but at 90° phase shift.

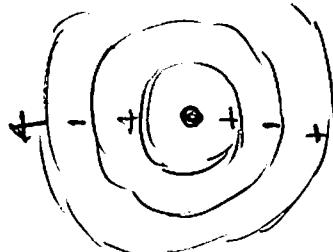


"Cardioid" pattern



note that it
has to be symmetric
with respect to a reflection.

Seen as spheres going out of a
point it is clear:



Then, adding dipole 1 and 2 you get a signal that adds up on the left but cancels on the right!

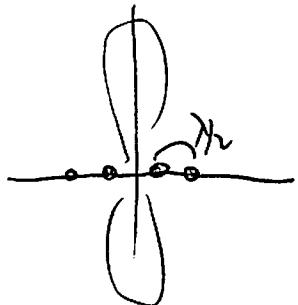
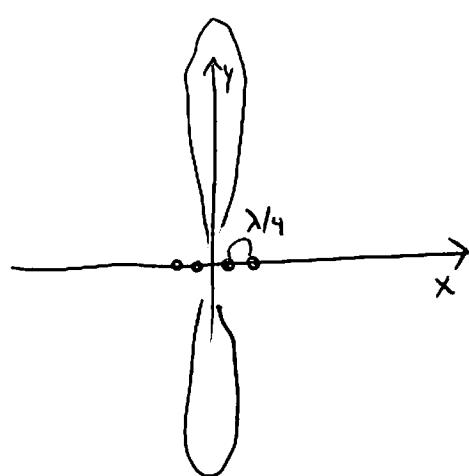
dipole 1 is
shifted 90°

i.e. $\cos \phi$ goes
into $\cos(\phi + \pi/2)$.

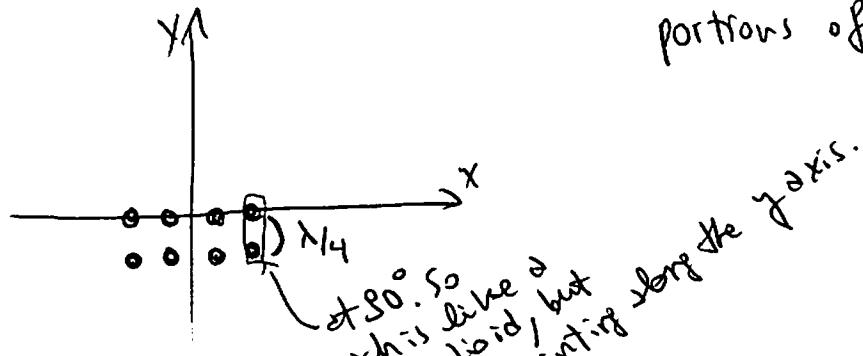
When dipole 2 is at
 $\phi = 0$, i.e. max, then

$\left. \begin{array}{l} \text{dipole 1 is at } \cos(0 + \pi/2) = 0 \\ \text{i.e. min.} \end{array} \right\}$

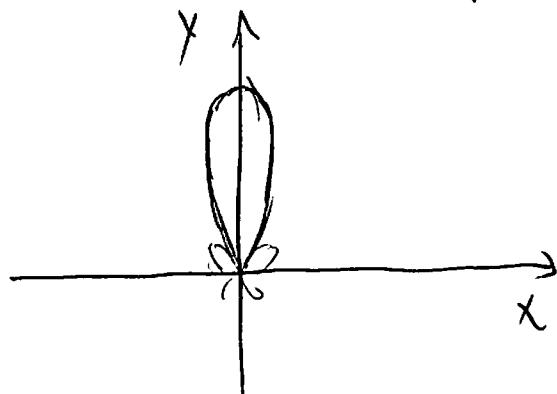
This game can continue. If you consider 4 dipoles spaced $\frac{\lambda}{4}$ all in phase, then the signal along y axis adds up (it is 4 times more intensity i.e. the actual radiation energy is $4^2 = 16$ times more intense). But it can be shown along the x axis it cancels. The same happens for distance $\lambda/2$.



Then we can combine this or other unidirectional patterns with the "cardioid" to "kill" one of the two portions of the x axis!



Result:



This is a true beam! A cardioid alone is not, so first we need to "focus" into a narrow pattern ~~of~~ and then we need to kill one leaf with a cardioid.