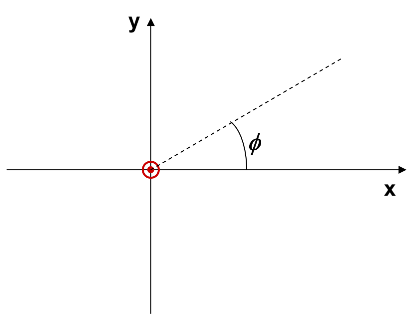
Lecture 36

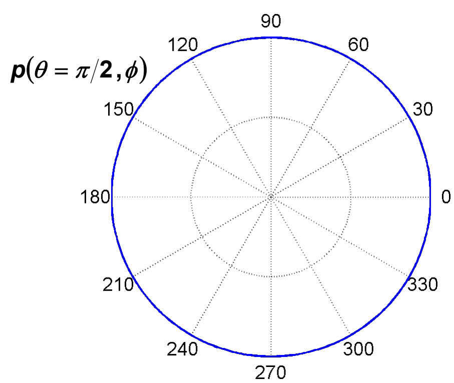
Reflector Antennas

In this lecture you will learn:

- Reflector antennas
- Dish Antennas

A Short Dipole Antenna





Gain:

$$G(\theta,\phi) = \frac{3}{2}\sin^2(\theta)$$

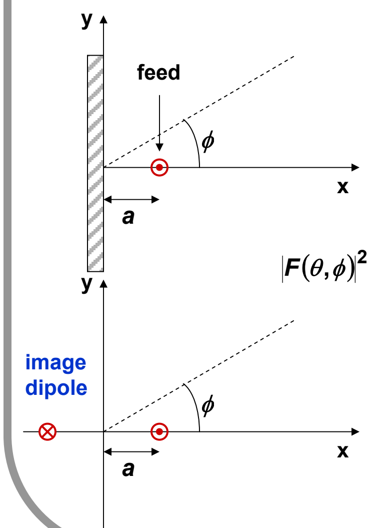
Pattern:

$$p(\theta,\phi) = \sin^2(\theta)$$

In the $\theta = \pi/2$ plane the radiation goes everywhere – not a very efficient antenna

A Plane Reflector with a Short Dipole Feed - I

The basic idea behind reflector antennas is that metal surfaces can be used to direct radiation from antennas in desired directions (or vice versa in reception)



Question: How does one get all the radiation from a Hertzian dipole to go in the +*x* direction?

Answer: Use a reflector

Array Factor:

$$|F(\theta,\phi)|^2 = \begin{cases} 4\sin^2[ka\sin(\theta)\cos(\phi)] & \text{for} \quad -\pi/2 \le \phi \le \pi/2 \\ 0 & \text{for} \quad \pi/2 \le \phi \le 3\pi/2 \end{cases}$$

For maximum gain in the $\theta = \pi/2$, $\phi = 0$ direction, choose:

$$ka = n\frac{\pi}{2} \quad \{n = 1,3,5,.......$$

$$a = n\frac{\lambda}{4} \quad \{n = 1,3,5,.......$$

A Plane Reflector with a Short Dipole Feed - II

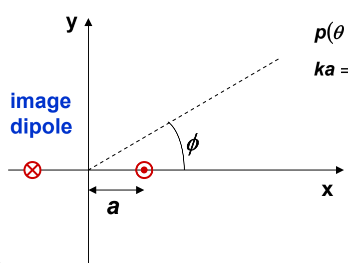
Gain:

$$G(\theta,\phi) = \frac{3}{2}\sin^2(\theta)\,|F(\theta,\phi)|^2$$

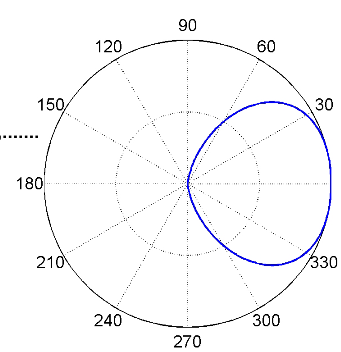
A plain reflector has increased the maximum gain by a factor of 4

Pattern:

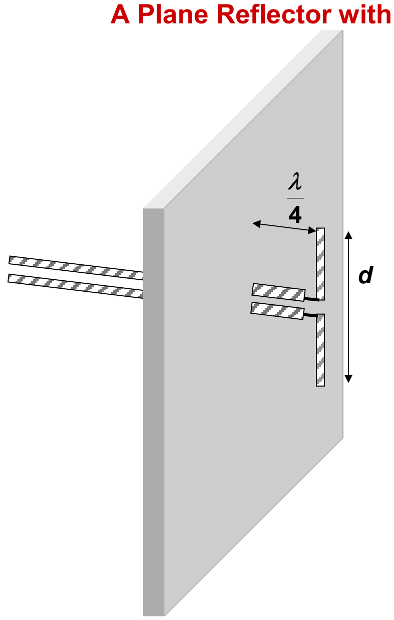
$$p(\theta,\phi) = \frac{1}{4}\sin^2(\theta)\,|F(\theta,\phi)|^2$$



$p(\theta = \pi/2, \phi)$ for $ka = n\frac{\pi}{2}$ $\{n = 1,3,5,.......$

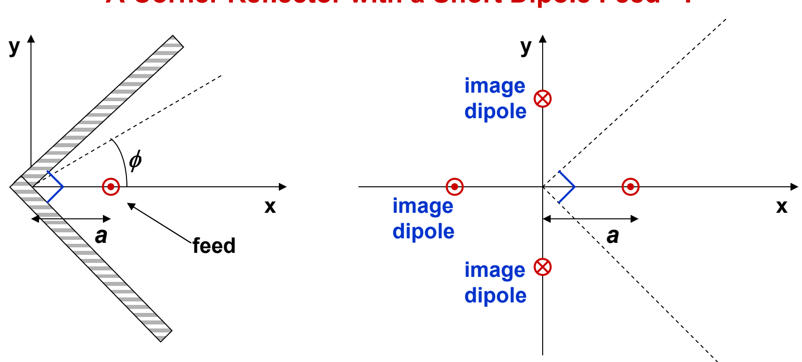


A Plane Reflector with a Short Dipole Feed



A short dipole with a plane reflector

A Corner Reflector with a Short Dipole Feed - I



Array Factor:

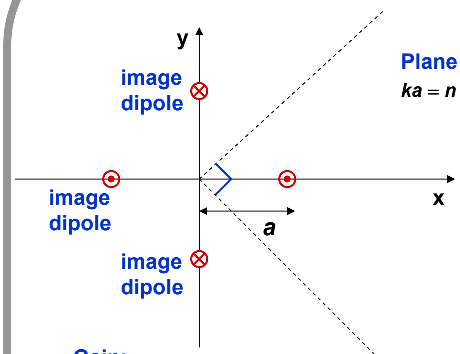
$$|F(\theta,\phi)|^2 = |2\cos[ka\sin(\theta)\cos(\phi)] - 2\cos[ka\sin(\theta)\sin(\phi)]|^2$$

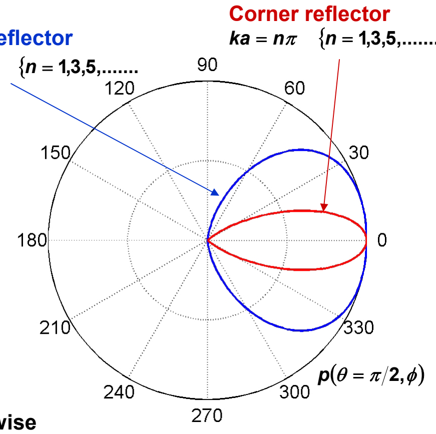
For $-\pi/4 \le \phi \le \pi/4$ and 0 otherwise

For maximum gain in the $\theta = \pi/2$, $\phi = 0$ direction, choose:

$$ka = n\pi \quad \{n = 1,3,5,.......$$

A Corner Reflector with a Short Dipole Feed - II





Gain:

$$G(\theta,\phi) = \frac{3}{2}\sin^2(\theta)\,|F(\theta,\phi)|^2$$

For $-\pi/4 \le \phi \le \pi/4$ and 0 otherwise

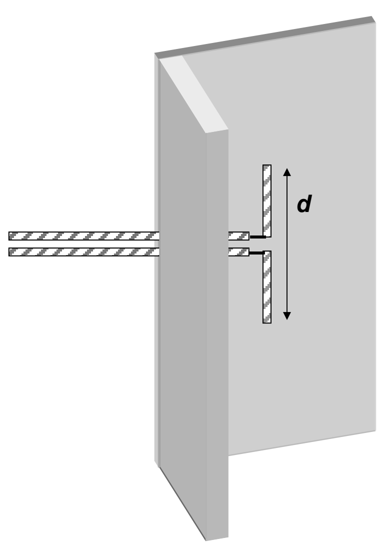
A corner reflector has increased the maximum gain by a factor of 16

Pattern:

$$p(\theta,\phi) = \frac{1}{16}\sin^2(\theta)\,|F(\theta,\phi)|^2$$

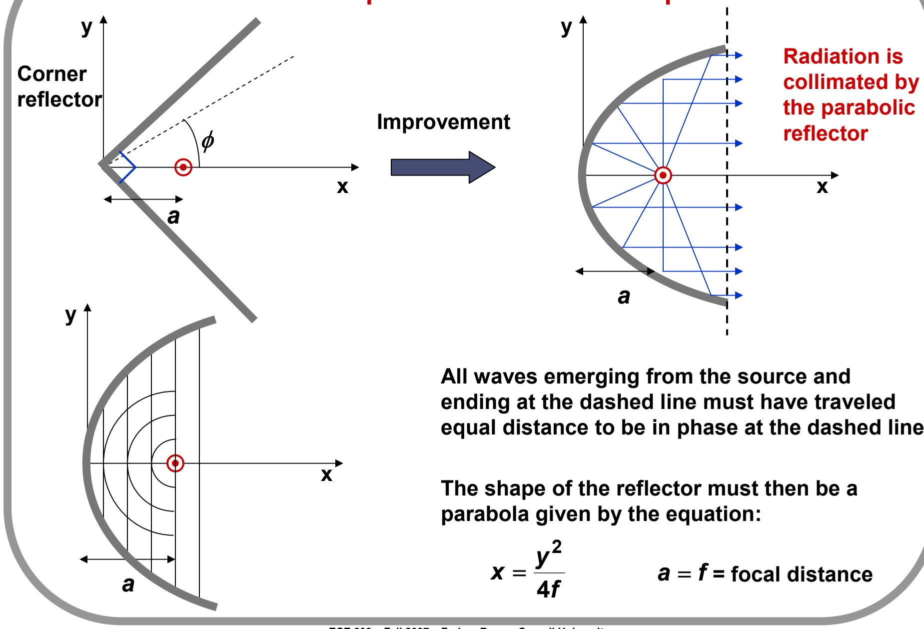
For $-\pi/4 \le \phi \le \pi/4$ and 0 otherwise

A Corner Reflector with a Short Dipole Feed



A short dipole with a corner reflector

How to Improve the Reflector Shape?

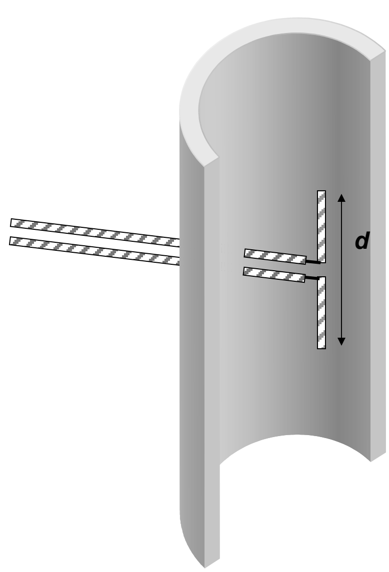


All waves emerging from the source and ending at the dashed line must have traveled equal distance to be in phase at the dashed line

The shape of the reflector must then be a parabola given by the equation:

$$x = \frac{y^2}{4f} \qquad a = f = \text{focal distance}$$

A Parabolic Reflector with a Short Dipole Feed



A short dipole with a parabolic reflector

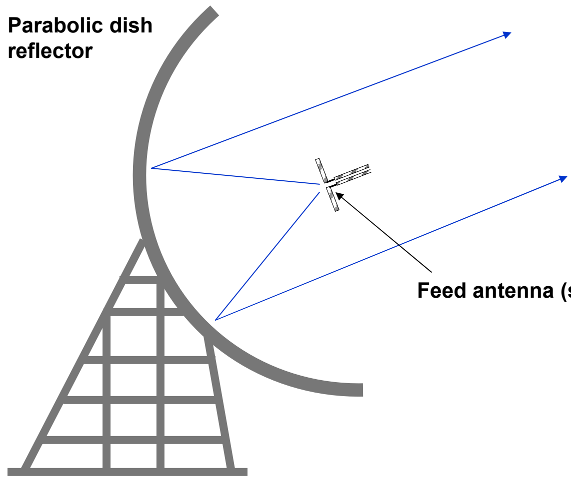
Problem:

Radiation is collimated in only one plane by the reflector

Solution:

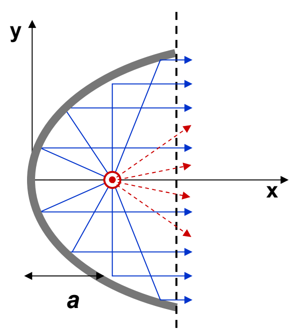
Use a parabolic dish ……..

A Parabolic Dish Reflector with a Short Dipole Feed



Nice design but the feed is problematic ……..

How to Improve the Feed for a Parabolic Reflector?



Problem:

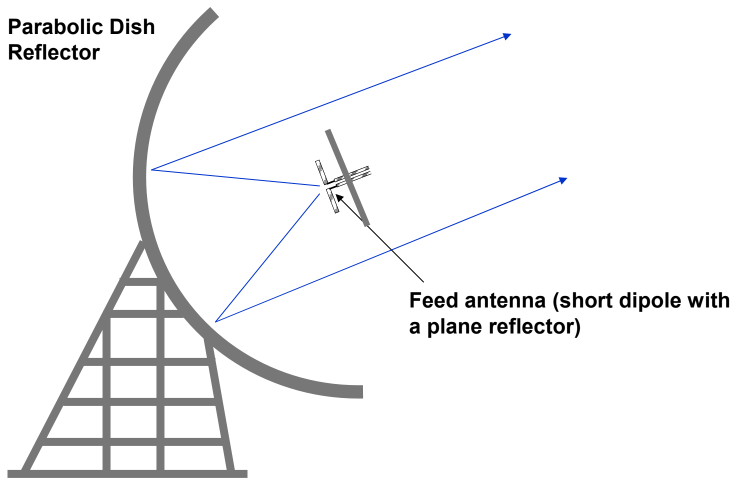
• All waves from the feed that reflect off from the parabolic reflector are in-phase at the aperture (which is marked by the dashed black line)

• But all waves that reach the aperture directly might not be in-phase and in-line with the ones that reflect off from the reflector

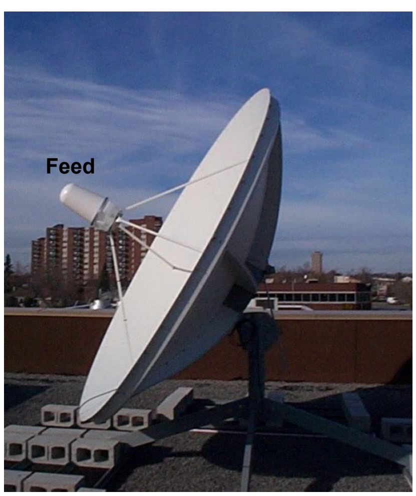
Solution:

The feed must not send out waves directly – all waves must reflect off the reflector

A Parabolic Dish Reflector with a Short Dipole Feed

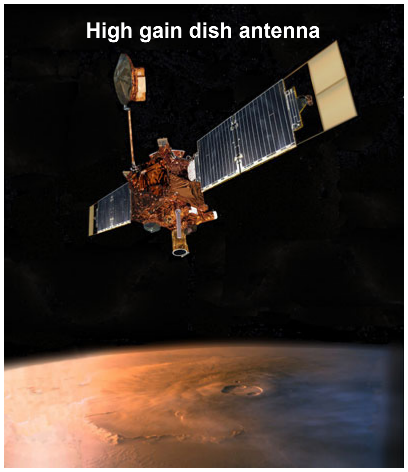


Commercial Dish Antennas for Satellite/TV



A DIRECT-TV dish antenna

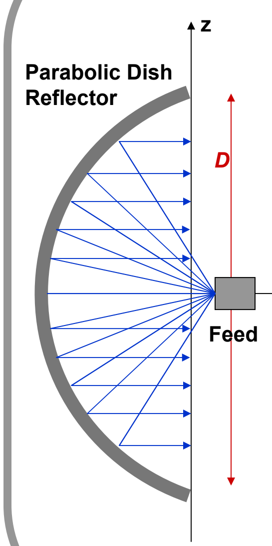
High Gain Dish Antennas for Deep Space



2001 Mars Odyssey

The NASA Deep Space Network (DSN) is an international network of antennas that provide the communication links between Earth and space. DSN consists of three deep-space communications facilities placed approximately 120 degrees apart around the world:

Maximum Gain of a Dish Reflector



Assumption: **The feed antenna "illuminates" the dish uniformly**

Under this assumption the radiation crossing the *y* = 0 plane (at the face of the dish) can be thought of as coming out of an aperture (or hole) of diameter *D*

The radiation pattern of the dish antenna in the far-field can then be determined by diffraction theory

The maximum Gain G(θ,ϕ) will occur in the direction along the y-axis, and from diffraction theory it will be:

$$G(\theta,\phi)\big|_{max} = G\left(\theta = \frac{\pi}{2}, \phi = \frac{\pi}{2}\right)$$

$$= \frac{4\pi}{\lambda^2} A(\theta,\phi)\big|_{max} = \frac{4\pi}{\lambda^2} A\left(\theta = \frac{\pi}{2}, \phi = \frac{\pi}{2}\right)$$

$$= \frac{4\pi}{\lambda^2}\left(\pi\frac{D^2}{4}\right)\eta_{rad} = \pi^2\frac{D^2}{\lambda^2}\eta_{rad}$$

To get larger gain, increase the ratio D/λ