Aperture Antennas

- Aperture antennas (horns and reflectors) have a physical collecting area that can be easily calculated from their dimensions:

$$A_{phy} = \pi r^2 = \pi \frac{D^2}{4}$$

- Therefore, using Eqn. 4.7 and Eqn. 4.5 we can obtain the formula for aperture antenna gain as:

$$Gain = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi A_{phy}}{\lambda^2} \times \eta$$

$$Gain = \left(\frac{\pi D}{\lambda}\right)^2 \times \eta$$

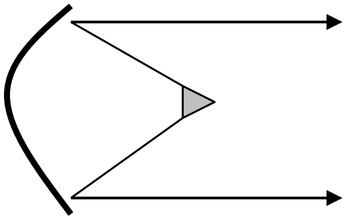
Typical values of η:
-Reflectors: 50-60%
-Horns: 65-80 %

Aperture Antenna Types

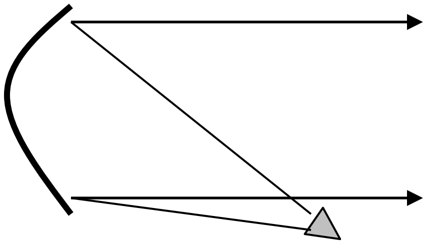
- HORN
  - Efficient, Low Gain, Wide Beam
- REFLECTOR
  - High Gain, Narrow Beam, May have to be deployed in space

Let's concentrate on the ***REFLECTORS*** in the next slides

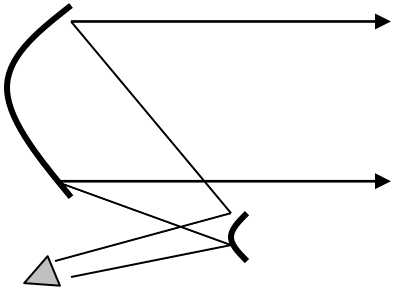
Reflector Types



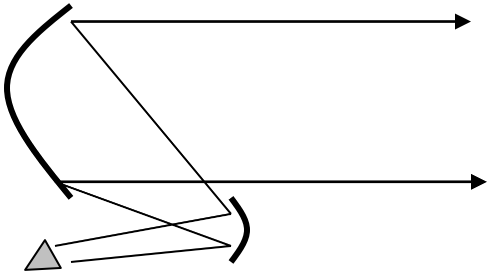
Symmetrical, Front-Fed



Offset, Front-Fed



Offset-Fed, Cassegranian



Offset-Fed, Gregorian

Reflector Antenna -1

- A rule of thumb to calculate a reflector **antenna beamwidth** in a given plane as a function of the antenna dimension in that plane is given by:

$$\theta_{3dB} \cong \frac{75\lambda}{D} \quad \text{degrees} \qquad \text{(Eqn. 3.2)}$$

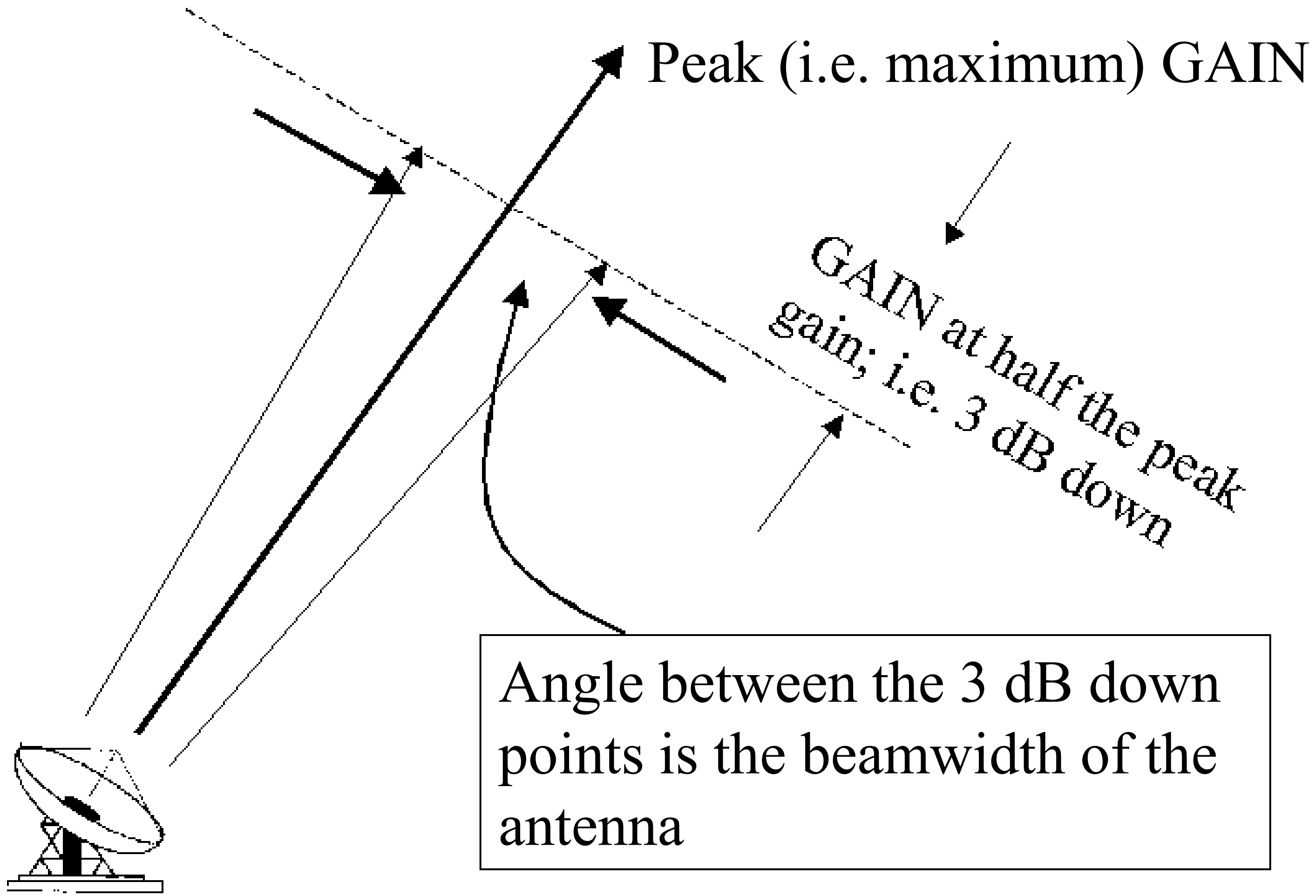
- The approximation above, together with the definition of gain (previous page) allow a gain approximation (for reflectors only):

$$Gain \cong \eta \left(\frac{75\pi}{\theta_{3dB}} \right)^2 = \eta \frac{(75\pi)^2}{\theta_{3dBH}\theta_{3dBE}}$$

- Assuming for instance a typical aperture efficiency of 0.55 gives:

$$Gain \cong \frac{30{,}000}{(\theta_{3dB})^2} = \frac{30{,}000}{\theta_{3dBH}\theta_{3dBE}}$$

Antenna Beamwidth



Angle between the 3 dB down points is the beamwidth of the antenna

Back to Received Power…

- The power available to a receive antenna of effective area $A_r = A_e$ m^2 is:

$$P_r = F \text{ x } A_r = \frac{P_t G_t A_e}{4\pi R^2} \qquad \text{(Eqn. 4.6)}$$

Where A_r = receive antenna effective aperture area = A_e

- Inverting the equation given for gain (Eq. 4.7) gives:

$$G_r = \frac{4\pi A_e}{\lambda^2} \quad \xrightarrow{\text{Inverting…}} \quad A_e = \frac{G_r \lambda^2}{4\pi}$$

Back to Received Power…

- Substituting in Eqn. 4.6 gives:

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2$$

Friis Transmission Formula

(Eqn. 4.8)

- The inverse of the term at the right referred to as "Path Loss", also known as "Free Space Loss" (Lp):

$$L_p = \left(\frac{4\pi R}{\lambda} \right)^2$$

Therefore…

$$P_r = \frac{P_t G_t G_r}{L_p}$$

More complete formulation

- Demonstrated formula assumes idealized case.
- Free Space Loss (L_p) represents spherical spreading only.
- Other effects need to be accounted for in the transmission equation:
  - L_a = Losses due to attenuation in atmosphere
  - L_{ta} = Losses associated with transmitting antenna
  - L_{ra} = Losses associates with receiving antenna
  - L_{pol} = Losses due to polarization mismatch
  - L_{other} = (any other known loss - as much detail as available)
  - Lr = additional Losses at receiver (after receiving antenna)

$$P_r = \frac{P_t G_t G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

Transmission Formula

- Some intermediate variables were also defined before:

$P_t = P_{out} / L_t$ $\qquad$ $EIRP = P_t G_t$

Where:

- P_t = Power into antenna
- L_t = Loss between power source and antenna
- $EIRP$ = effective isotropic radiated power

•Therefore, there are many ways the formula could be rewritten. The user has to pick the one most suitable to each need.

$$P_r = \frac{P_t G_t G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

$$= \frac{EIRP \text{ x } G_r}{L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

$$= \frac{P_{out} G_t G_r}{L_t L_p L_a L_{ta} L_{ra} L_{pol} L_{other} L_r}$$

Link Power Budget

Tx

EIRP

Transmission:
HPA Power
Transmission Losses
(cables & connectors)
Antenna Gain

Antenna Pointing Loss
Free Space Loss
Atmospheric Loss
(gaseous, clouds, rain)
Rx Antenna Pointing Loss

Reception:
Antenna gain
Reception Losses
(cables & connectors)
Noise Temperature
Contribution

Rx

P_r

Review of Decibel

Why dB?

- There is a large dynamic range of parameters in satellite communications
  - A typical satellite antenna has a gain of >500
  - Received power flux is about one part in 100,000,000,000,000,000,000 ← That's a lot of zeros! of the transmitted power
- Wouldn't it be nice to have a better way to write these large numbers?
- dB also lets many calculations be addition or subtraction!

What is a dB?

- Decibel (dB) is the unit for 10 times the base 10 logarithmic ratio of two powers
- For instance: gain is defined as P_{out}/P_{in} (where P_{out} is usually greater than P_{in})
- in dB: $G = 10 \cdot \log\left(\frac{P_{out}}{P_{in}}\right) \text{dB}$
- Similarly loss is: $L = 10 \log\left(\frac{P_{in}}{P_{out}}\right) \text{dB}$

A Dangerous Calculation in dB!

- dB ratios must <u>**NEVER**</u> be calculated as 20 times the base 10 logarithmic ratio of voltages

Unless of course its more convenient, in which case you must be very, <u>very</u> careful. Here's why:

$$P_{in} = \frac{V_{in}^2}{R_{in}} \qquad P_{out} = \frac{V_{out}^2}{R_{out}}$$

If these calculations are performed for say a (passive) transformer with winding ratios of 4 output turns per input turn, $V_{out} = 4$ when $V_{in} = 1$. If the last term is neglected, the gain appears to be $G = 20\log(4) = 12$ dB. This is a curious result for a passive device!
If the last term is used, $R_{out} = 16$ for $R_{in} = 1$, so the last term is -12 dB. This restores the balance at $G = 0$ as expected for an ideal passive device.

$$G = 10\log\left(\frac{P_{out}}{P_{in}}\right) = 10\log\left(\frac{\dfrac{V_{out}^2}{R_{out}}}{\dfrac{V_{in}^2}{R_{in}}}\right)$$

This term is usually forgotten (with tragic results!)

$$G = 10\log\left(\frac{V_{out}^2}{V_{in}^2}\right) + 10\log\left(\frac{R_{in}}{R_{out}}\right) = 20\log\left(\frac{V_{out}}{V_{in}}\right) + 10\log\left(\frac{R_{in}}{R_{out}}\right)$$

Using Decibels - 1

Rules:

- Multiply A x B:

  (Add dB values)

$$10\log_{10}(A \text{ x } B)$$
$$= 10\log_{10}(A) + 10\log_{10}(B)$$
$$= A\text{dB} + B\text{dB}$$
$$= (A + B)\text{dB}$$

- Divide A / B:

  (Subtract dB values)

$$10\log_{10}(A / B)$$
$$= 10\log_{10}(A) - 10\log_{10}(B)$$
$$= A\text{dB} - B\text{dB}$$
$$= (A - B)\text{dB}$$