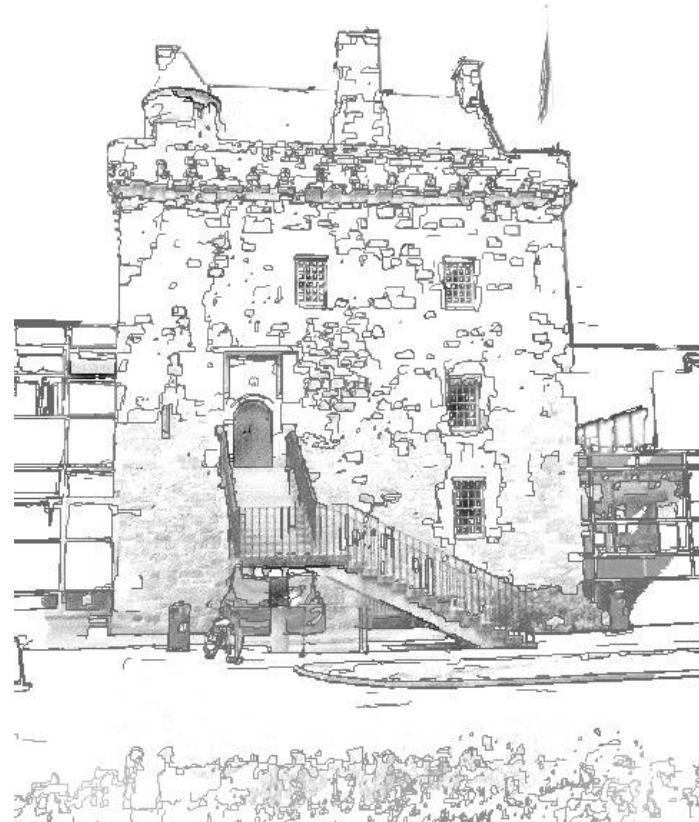


Wireless LAN

Antennas

Areas covered:

**EM fields
Antenna types
Isotropic/dipole
antennas.**

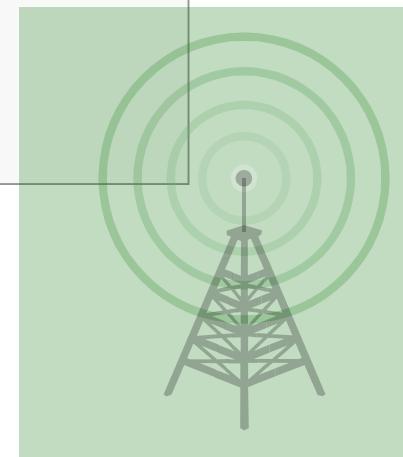


Areas covered:

EM fields

Antenna types

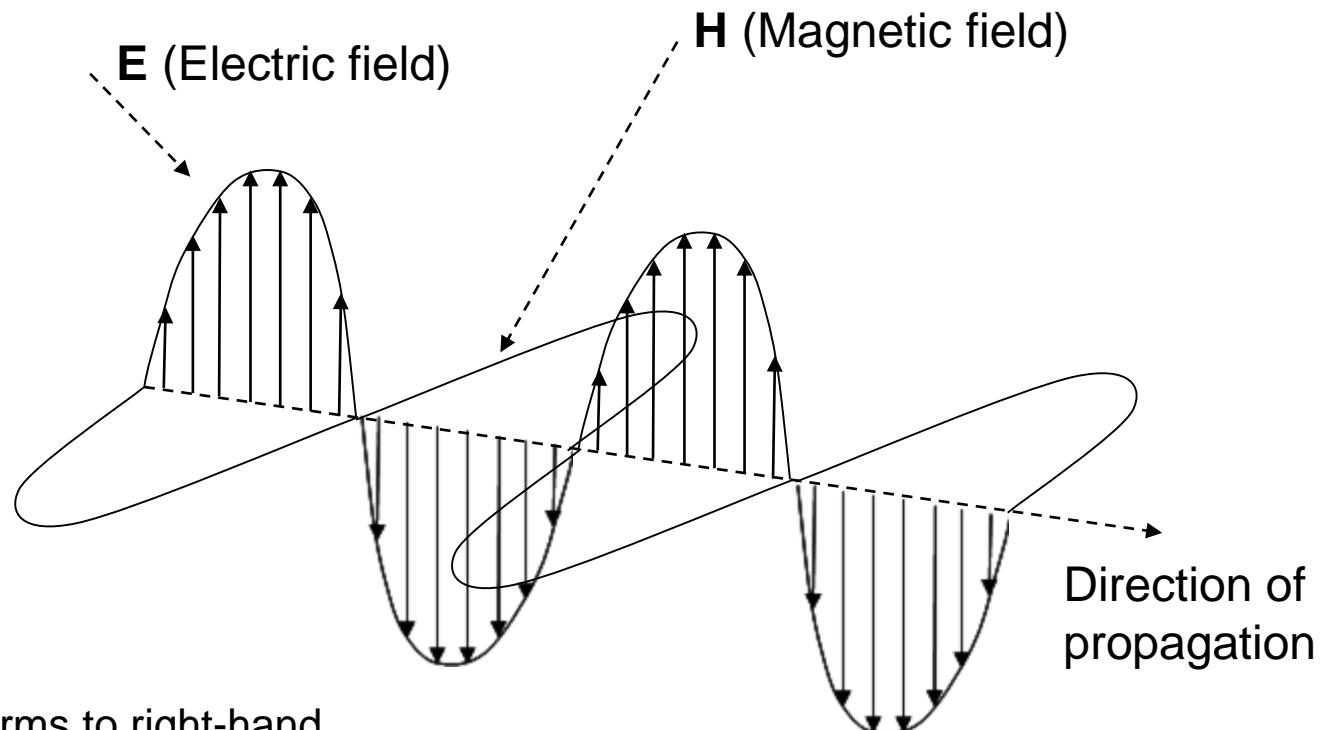
Isotropic/dipole antennas.



EM Fields



Electromagnetic wave propagation



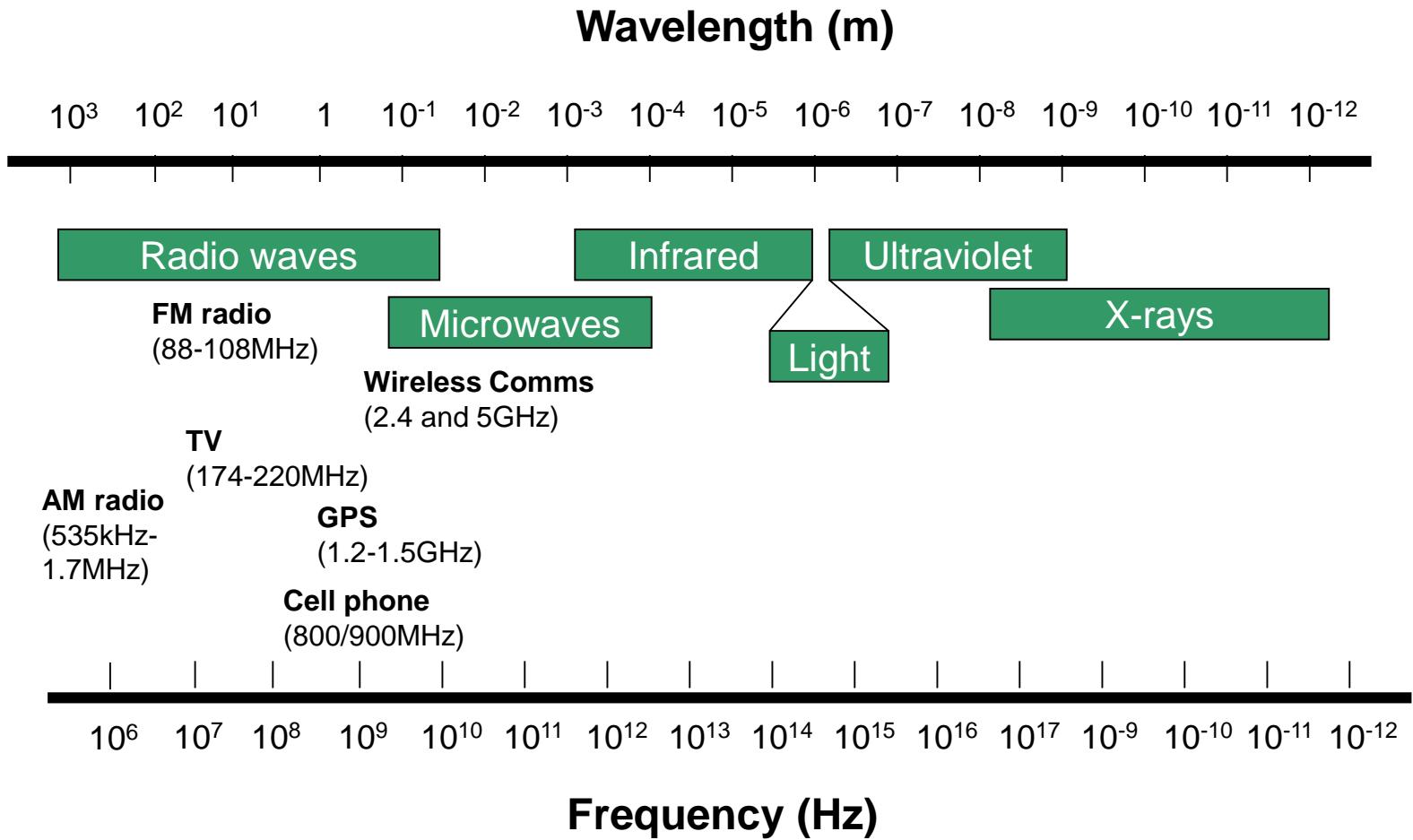
Conforms to right-hand rule:

E – Middle finger

H – Thumb

Propagation – Index finger

EM wave spectrum



Power, Gain and dB's



Power in dB's

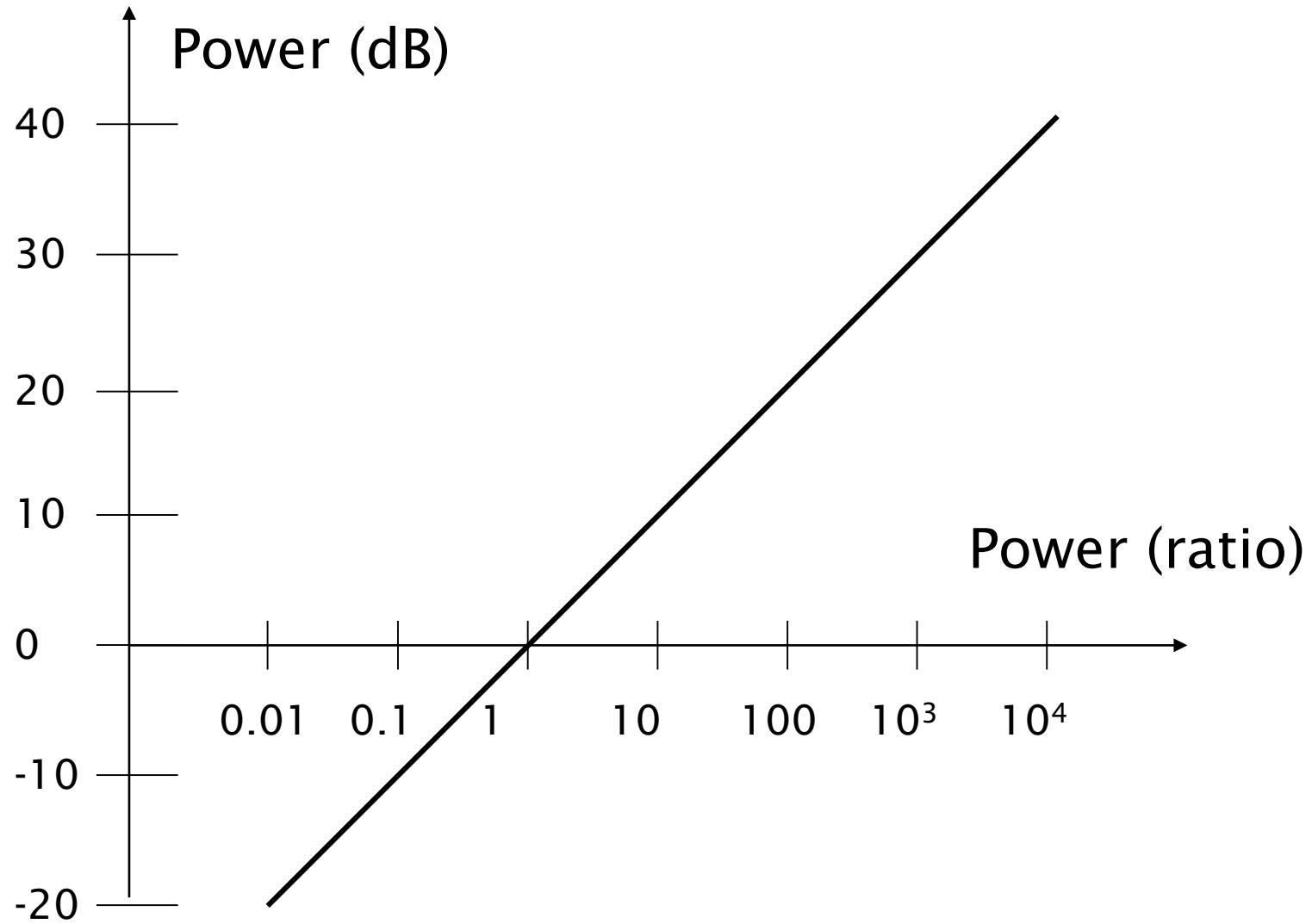
$$\text{Gain} = \frac{P_{\text{output}}}{P_{\text{input}}}$$

$$\text{Gain(dB)} = 10 \log_{10} \left(\frac{P_{\text{output}}}{P_{\text{input}}} \right)$$

$$\text{Gain} = 10 \log_{10} \left(\frac{2 \times P_{\text{input}}}{P_{\text{input}}} \right) = 10 \log_{10} \left(\frac{2}{1} \right) = 3.01 \text{dB}$$

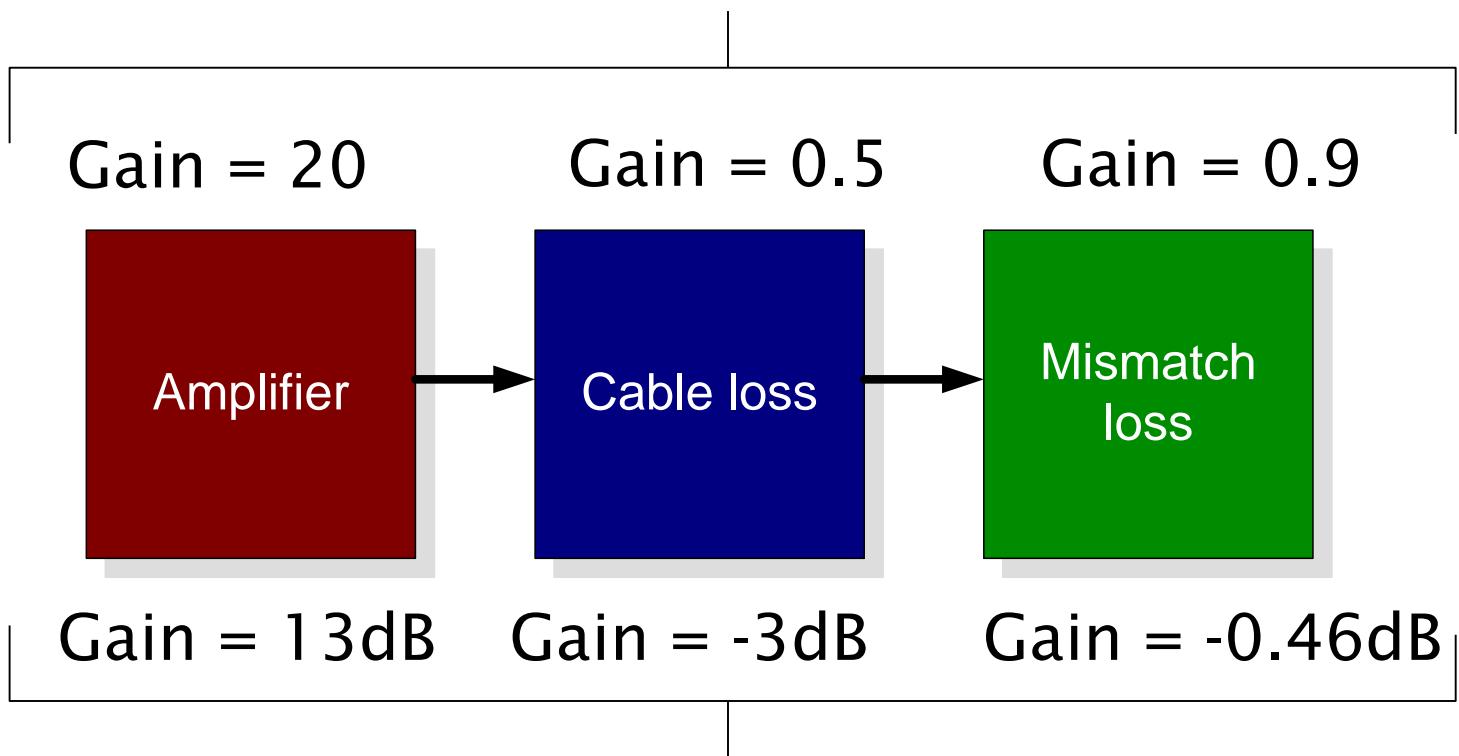
$$\text{Gain} = 10 \log_{10} \left(\frac{0.5 \times P_{\text{input}}}{P_{\text{input}}} \right) = 10 \log_{10} \left(\frac{0.5}{1} \right) = -3.01 \text{dB}$$

dB's against ratio



Calculation of overall gain

$$\text{Overall gain} = 20 \times 0.5 \times 0.9 = 9 \quad [=10 \times \log(9) = 9.54\text{dB}]$$

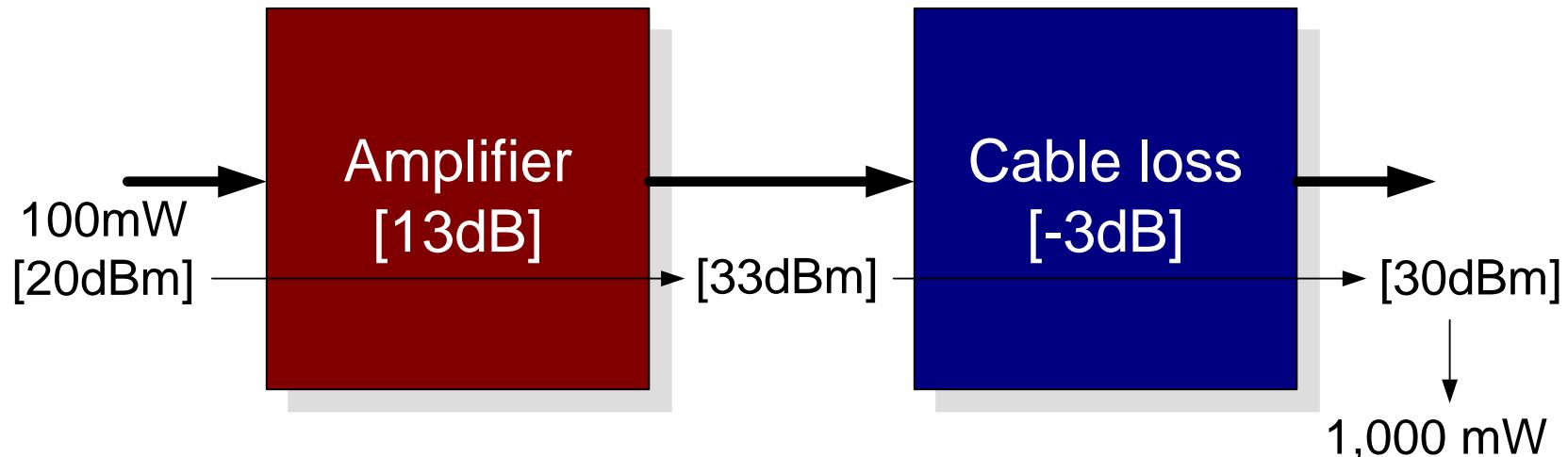


$$\text{Overall gain} = 13 - 3 - 0.46 = 9.54\text{dB}$$

$$\text{Power(dBm)} = 10 \log_{10} \left(\frac{P_{value}}{1 \times 10^{-3}} \right)$$

Thus 1mW is represented as 1dBm,
10mW is 10dBm,
100mW is 20dBm,
and 1W is 30dBm.

It is then possible to easily calculate output power if the input power and the gain elements are defined in dB's.



For example, if the input power is 100mW, and the amplifier gain is 13dB, with a cable loss of 3dB, then the output power is:

$$\text{Pout(dBm)} = \text{Pin(dBm)} + \text{Gain (dB)} - \text{Losses (dB)}$$
$$\text{Pout(dBm)} = 20 + 13 - 3 = 30 \text{ dBm}$$

To convert from dBW to dBm, a value of 30 is added.
30dBm is thus 0dBW (1W).

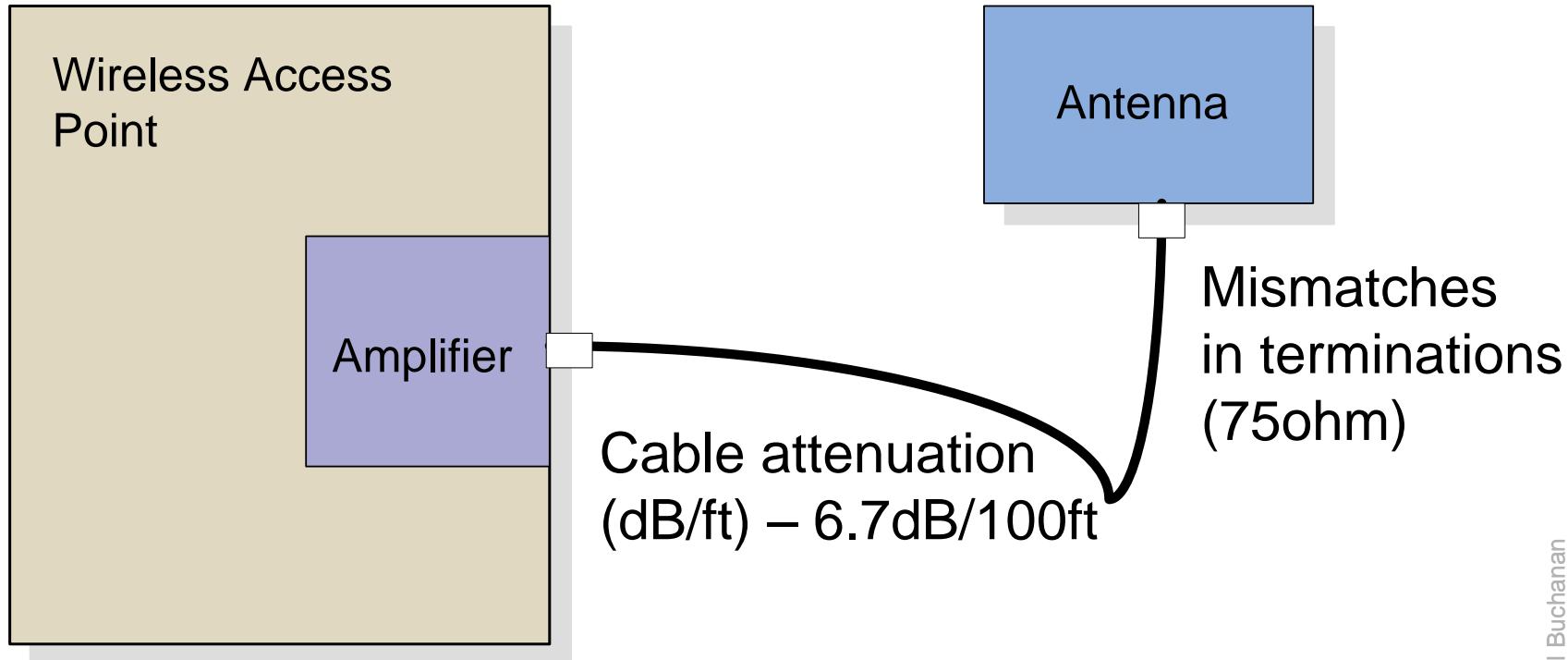
System Losses



System losses (attenuation and mismatches)

A typical low loss cable gives a loss of 6.7 dB per 100 feet (30m). Thus for every 100 feet the signal strength reduces by 23%/100ft.

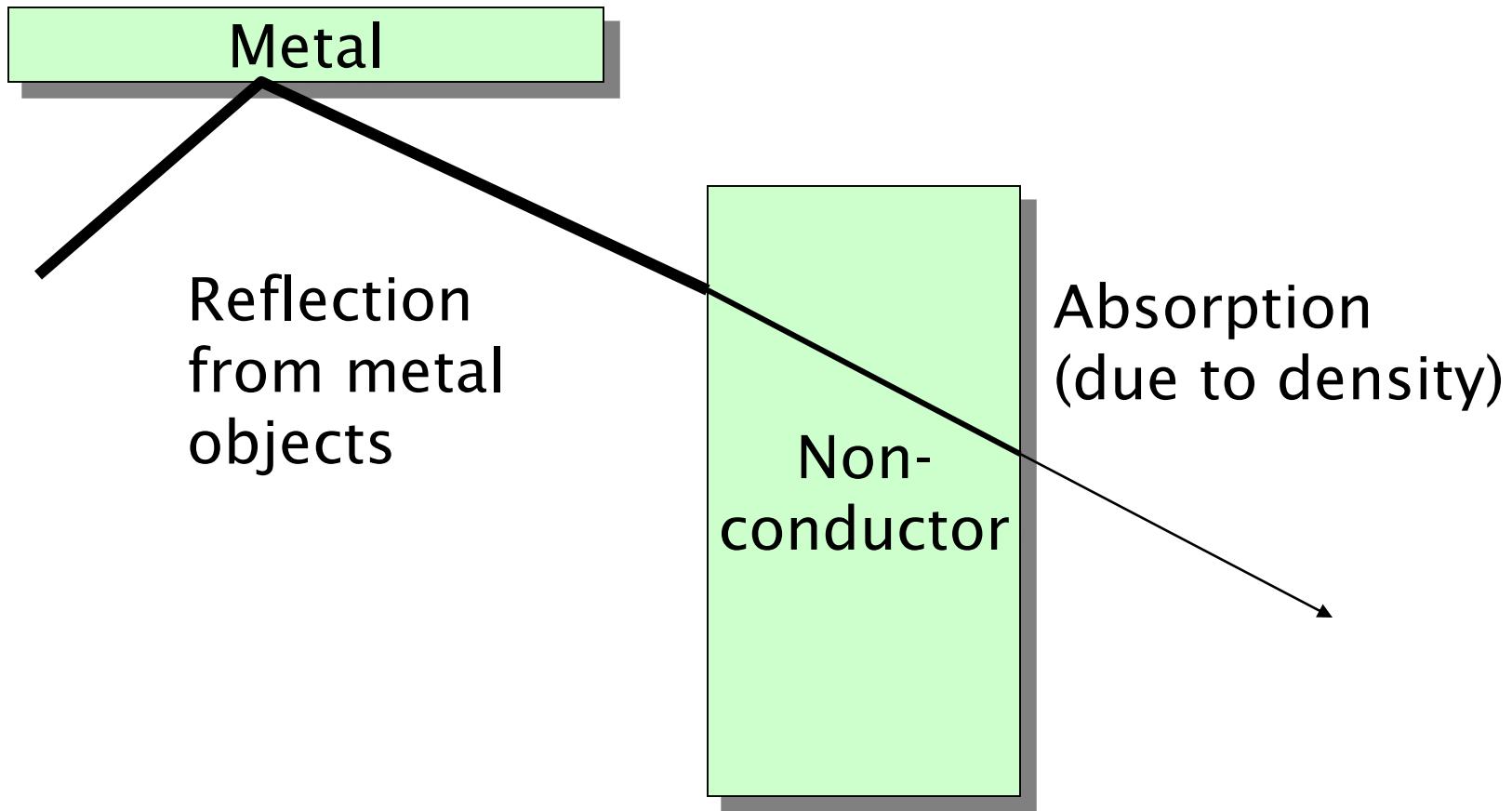
$$\text{Reduction} = \frac{1}{10^{6.7/10}} = 0.213 \text{ per 100 foot (21.3\% / 100ft)}$$



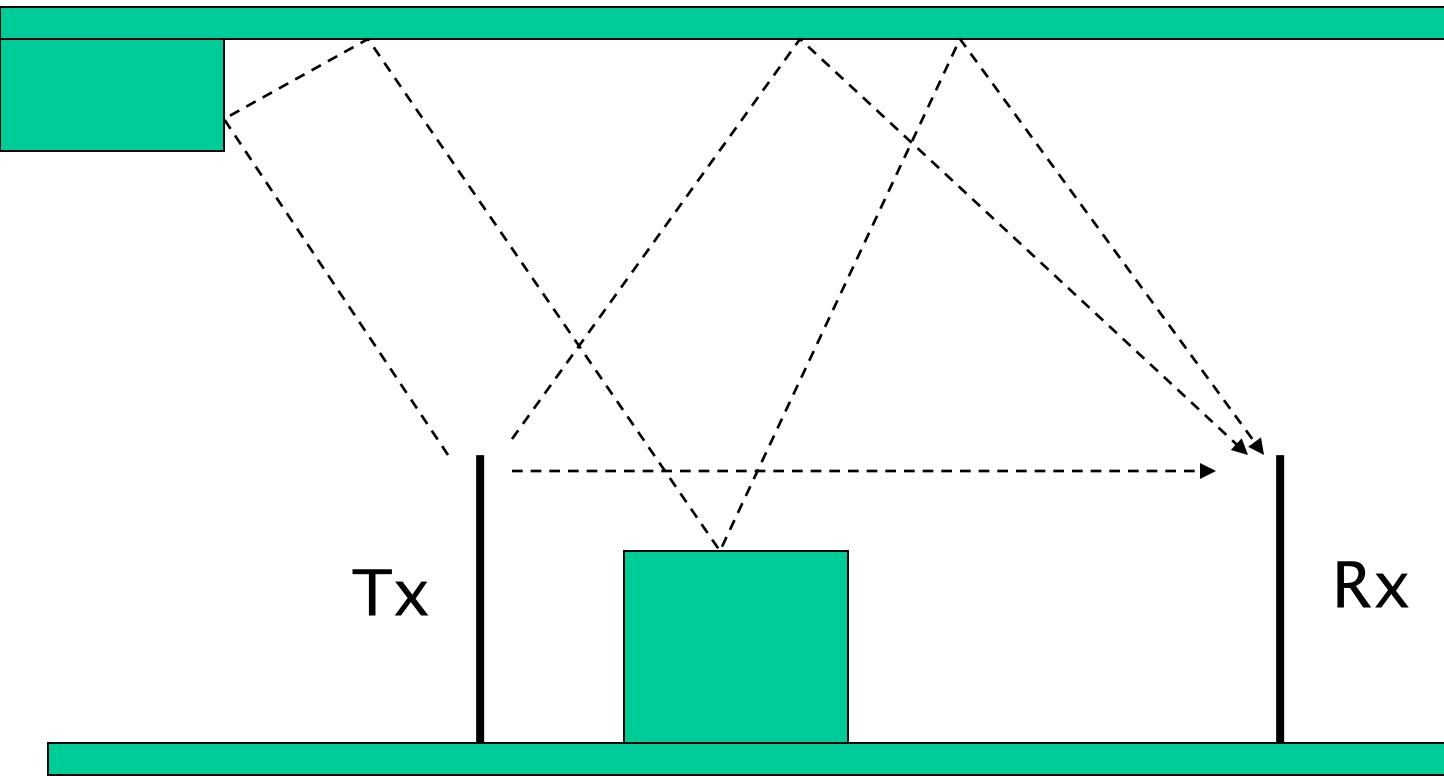
Multipath Problems



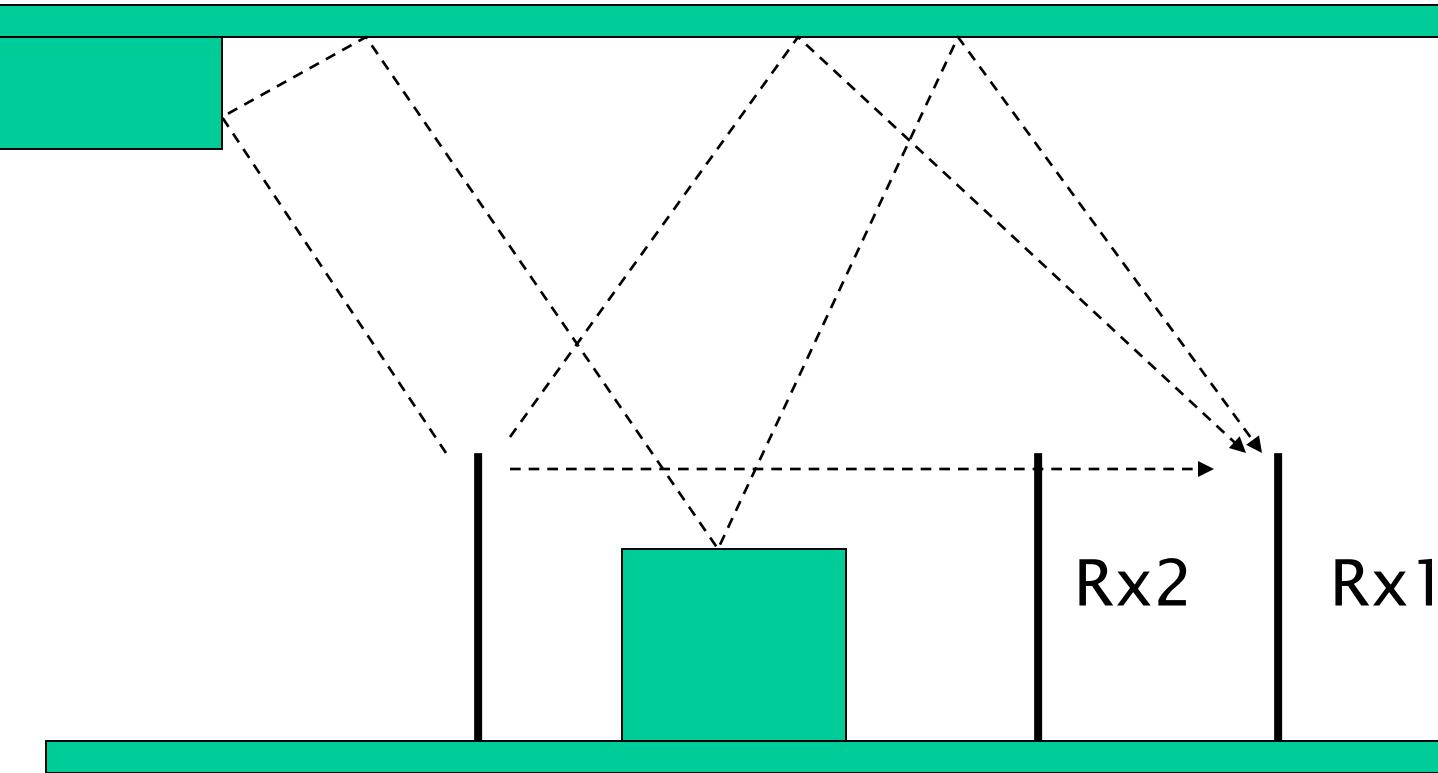
Reflection and absorption



Multipath Problems



Diversity

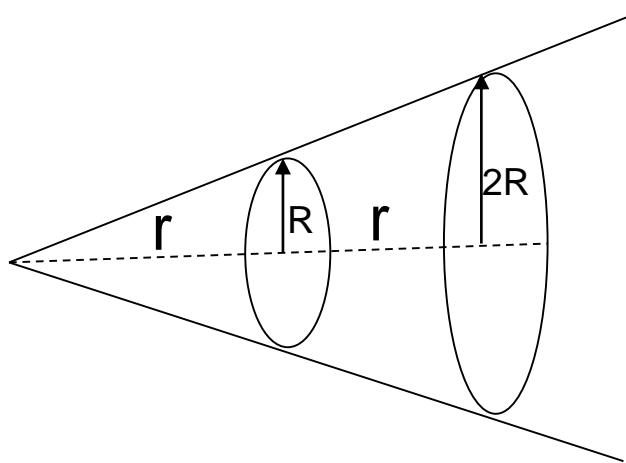


```
# config t
(config) # int dot11radio0
(config-if) # antenna ?
(config-if) # antenna transmit ?
(config-if) # antenna transmit diversity
(config-if) # antenna receive left
(config-if) # exit
(config) # exit
```

Isotropic Radiators



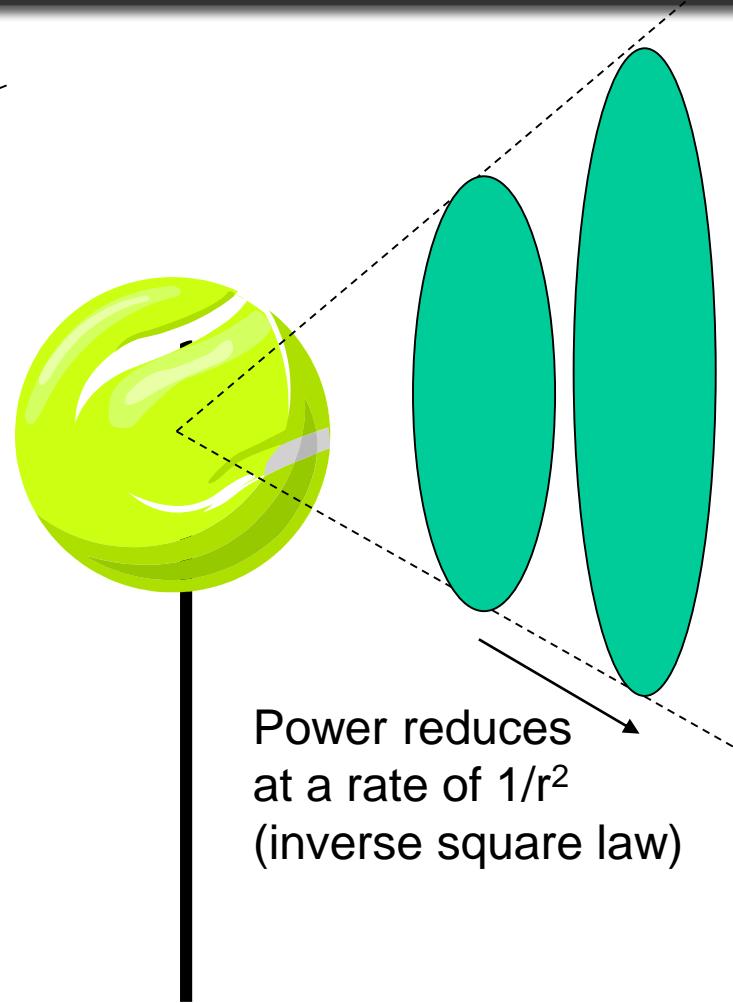
Isotropic radiation



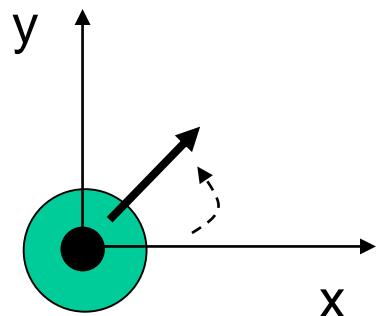
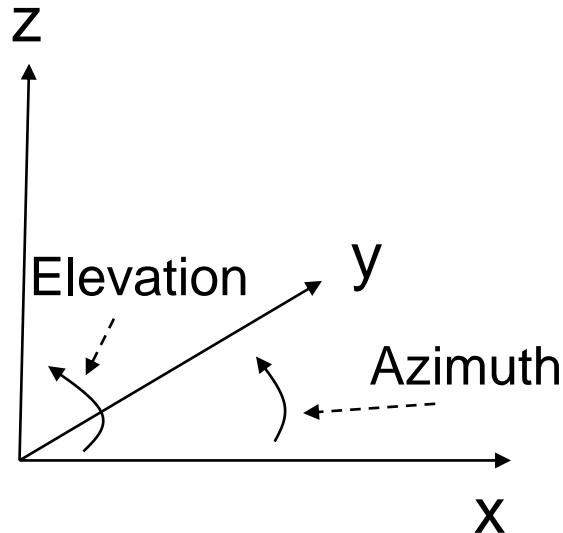
$$P_1(\text{area}) = \pi R^2$$

$$\begin{aligned} P_2(\text{area}) &= \pi(2R)^2 \\ &= 4\pi R^2 \end{aligned}$$

Power is thus spread over 4 times the area thus doubling the distance reduces the power by $\frac{1}{4}$.

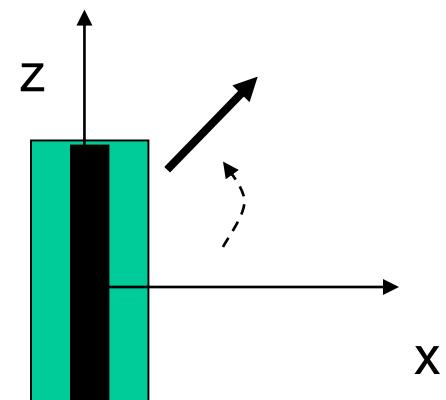


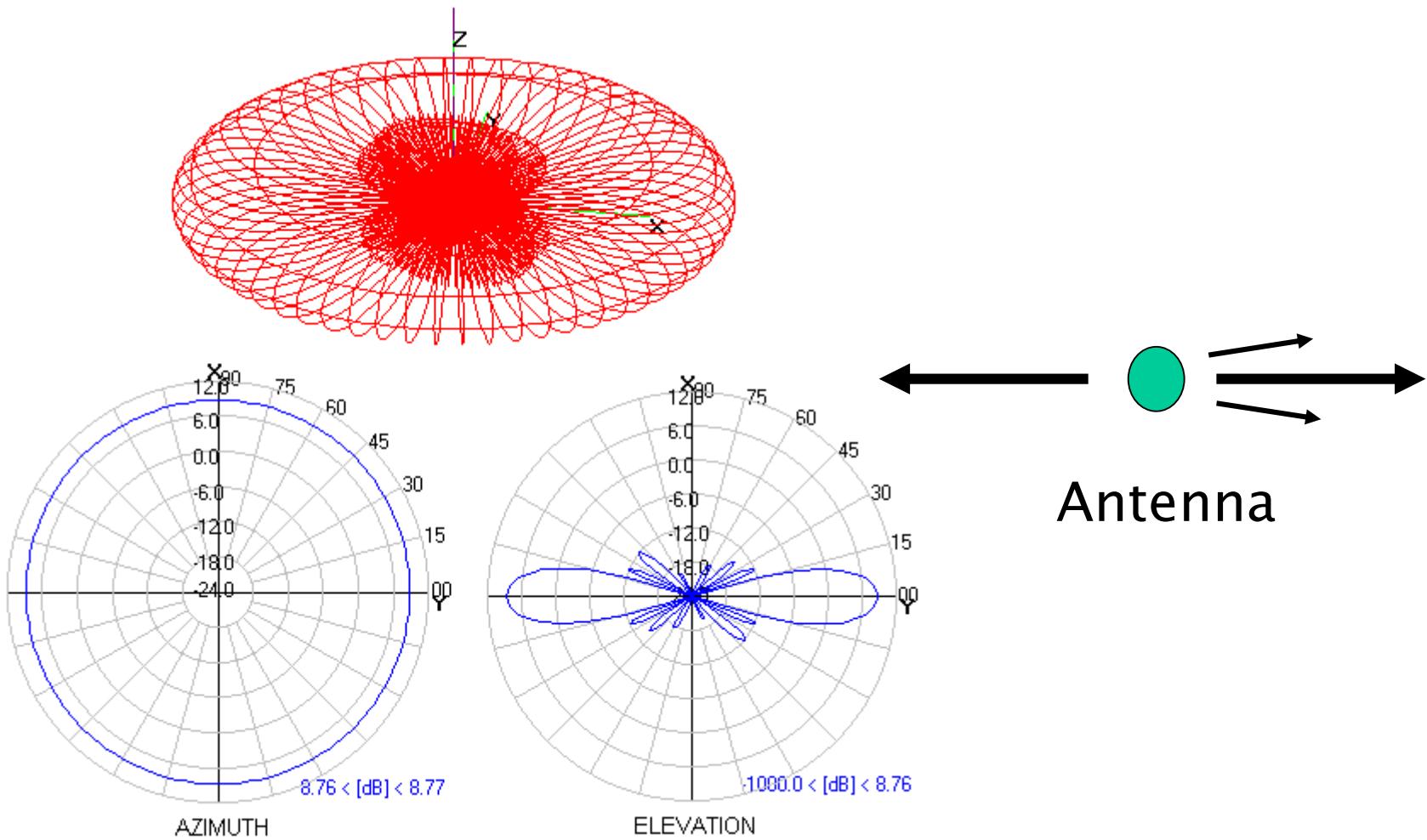
Power reduces at a rate of $1/r^2$ (inverse square law)



Azimuth
(Measure around antenna)

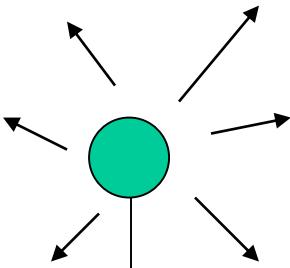
Elevation
(Measure below and above antenna)



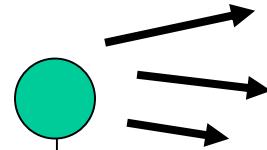


Omnidirectional/Directional



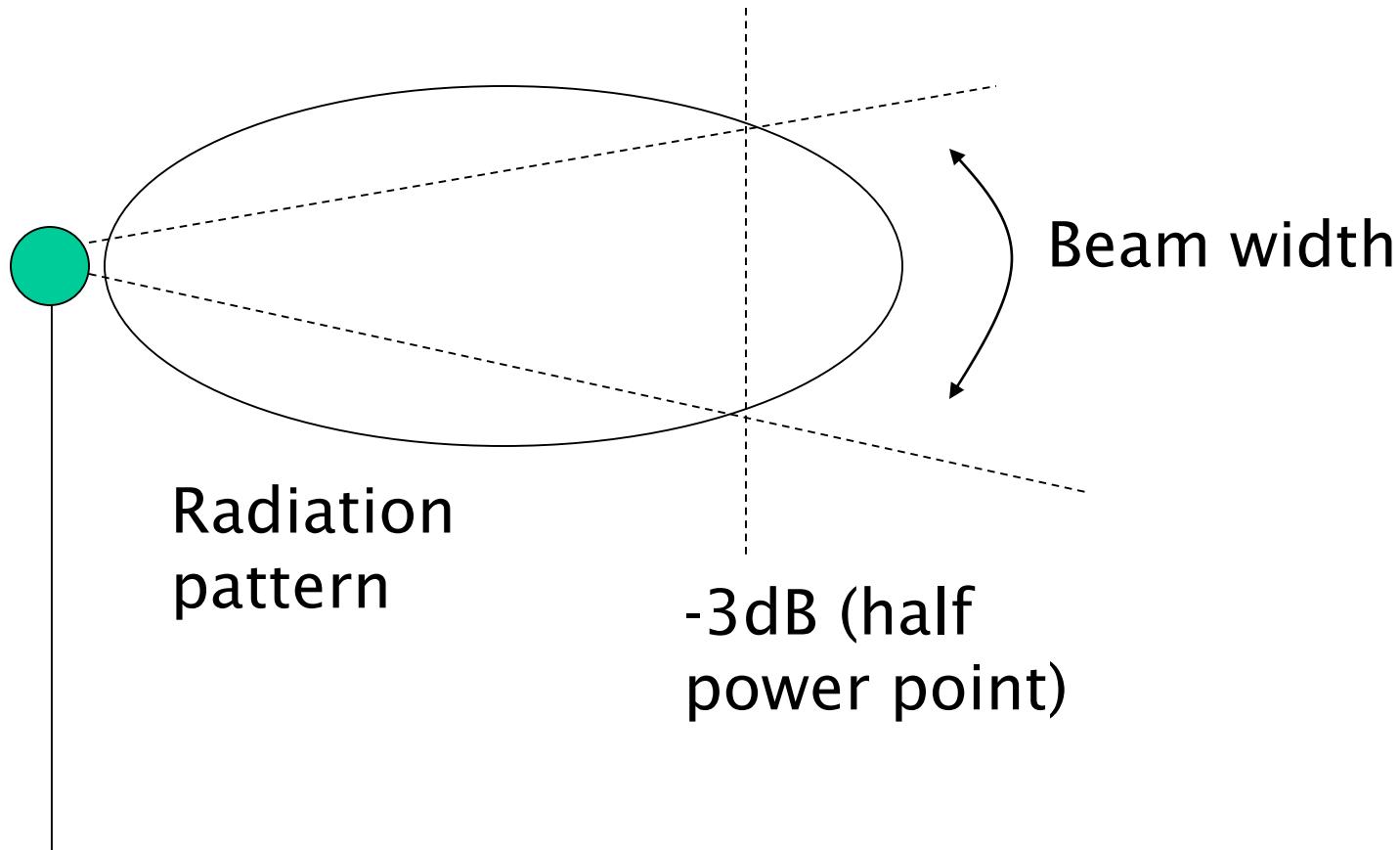


Omni-directional
antennas send
out radiation in
every direction.



Directional
antennas send
out radiation in
a focused pattern
and can thus increase
the power in a given
direction.

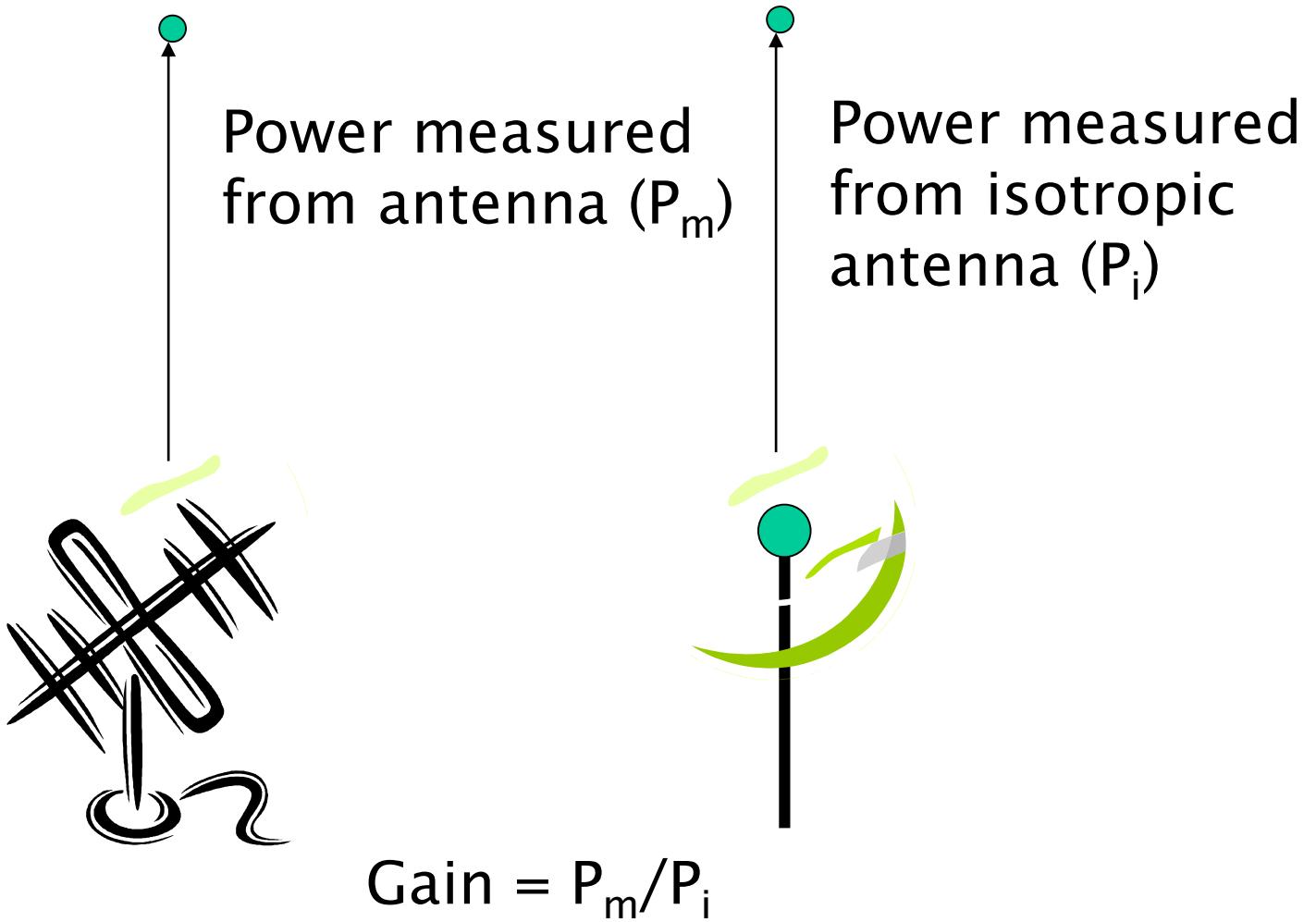
Beamwidth



Antenna Gain



Isotropic gain



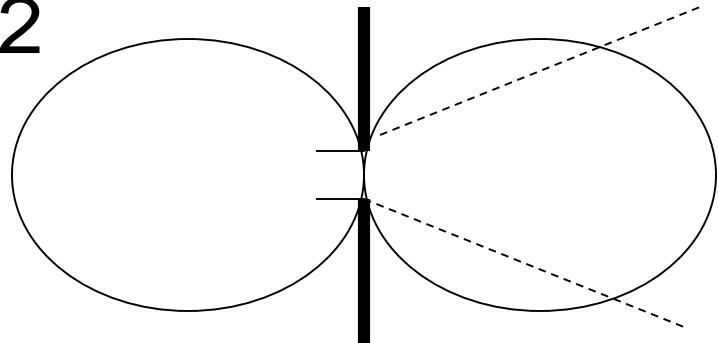
Isotropic gain

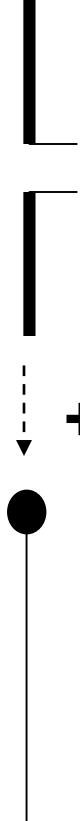
$$\text{Gain(dB)} = 10 \log_{10} \left(\frac{P_m}{P_i} \right)$$

$$\text{Gain(dB)} = 10 \log_{10} \left(\frac{2P_i}{P_i} \right) = \text{Gain(dB)} = 10 \log_{10}(2) = 3\text{dB}$$

$$\text{Gain(dB)} = 10 \log_{10} \left(\frac{4P_i}{P_i} \right) = \text{Gain(dB)} = 10 \log_{10}(4) = 6\text{dB}$$

$$\text{Gain(dBi)} = \text{Gain(dBd)} + 2.2$$





+2.2dB

For example, if an antenna has a gain of 3dB over a dipole it will be defined as:

3dBd

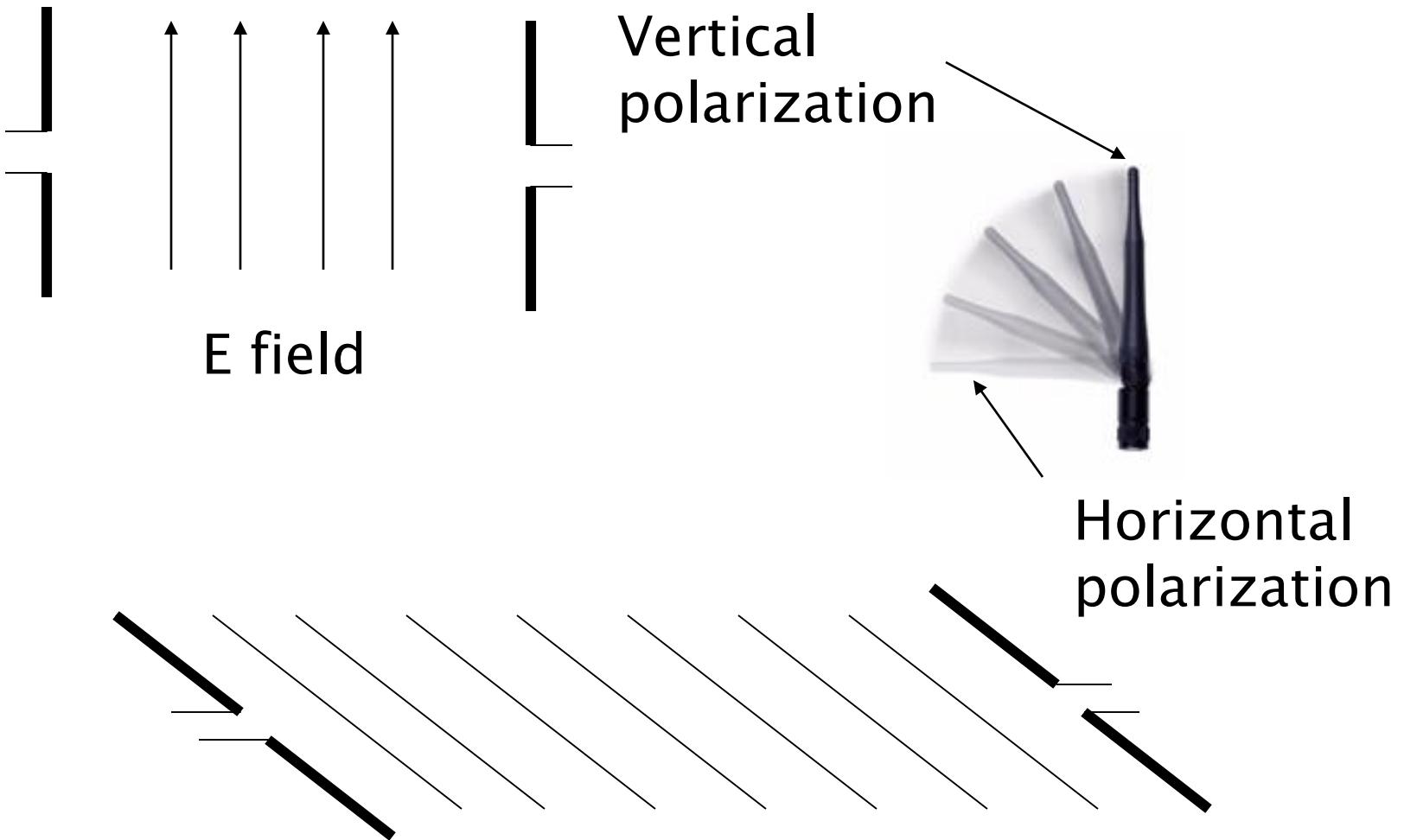
and thus the gain over an isotropic antenna will be:

5.2 dBi

Polarization



Polarization



Antenna Types



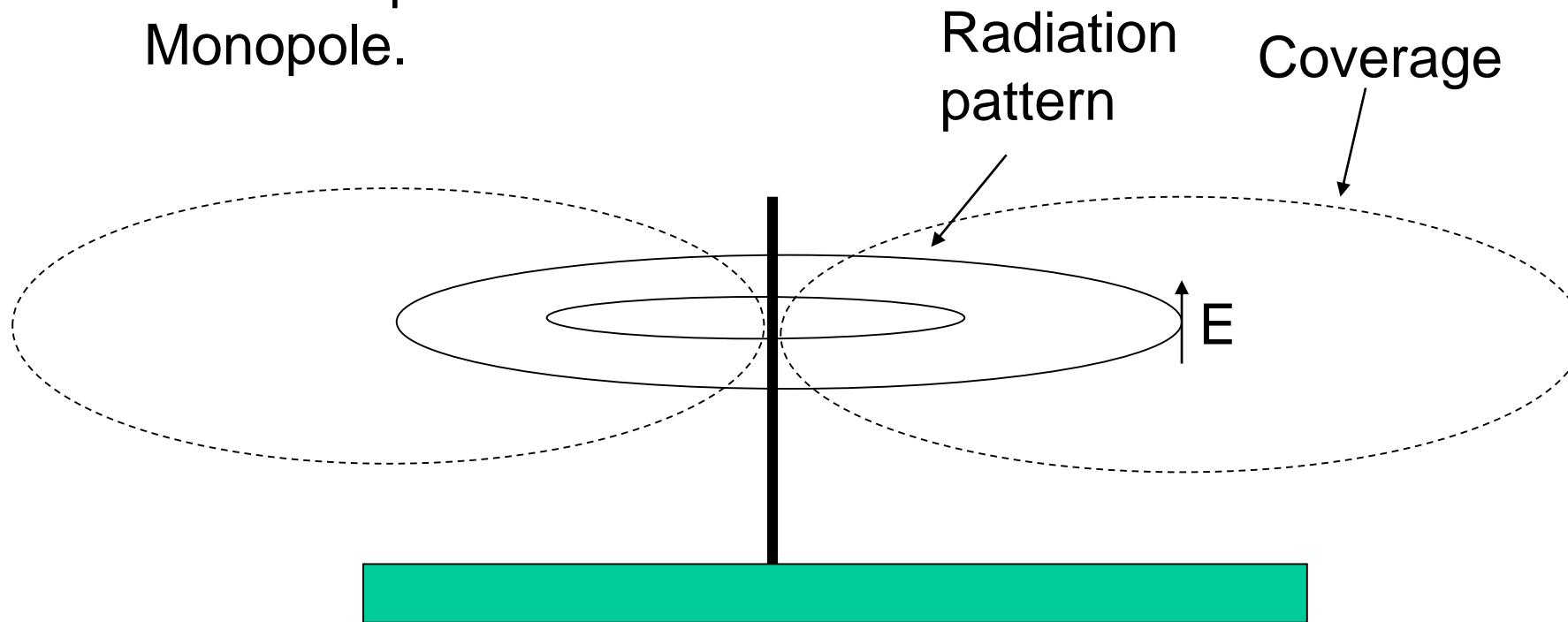
Onmidirectional

Types:

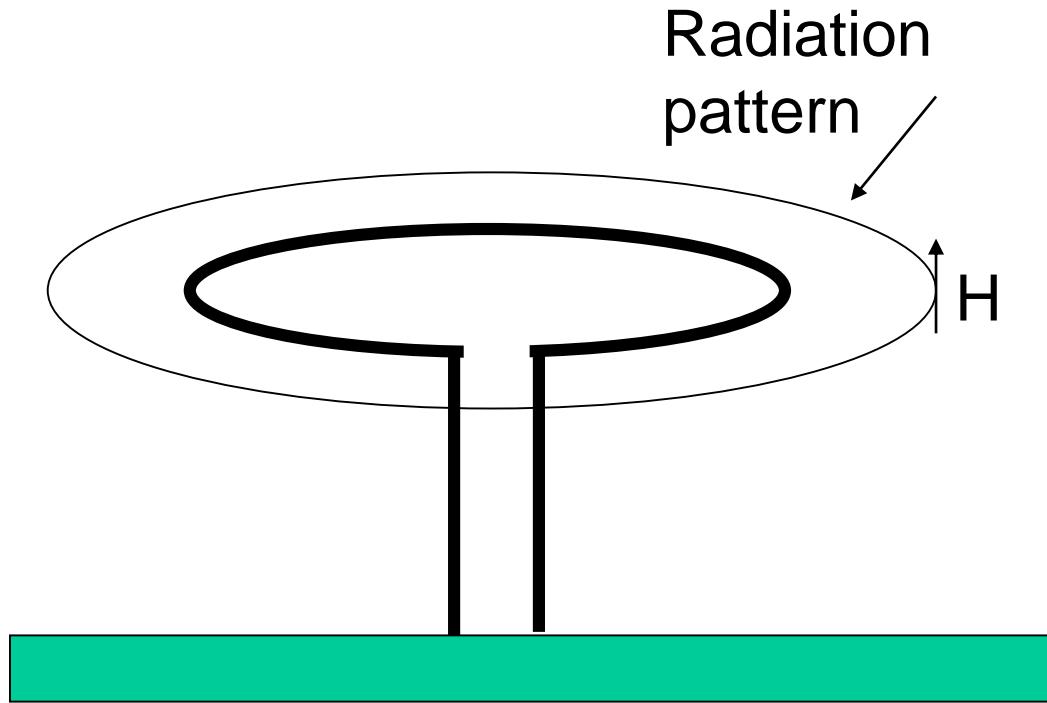
Vertical whip.

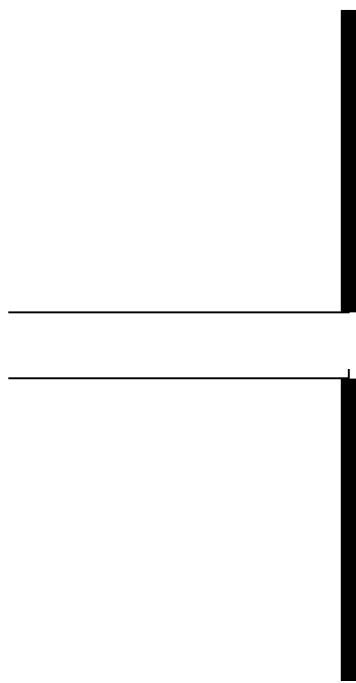
Vertical dipole.

Monopole.



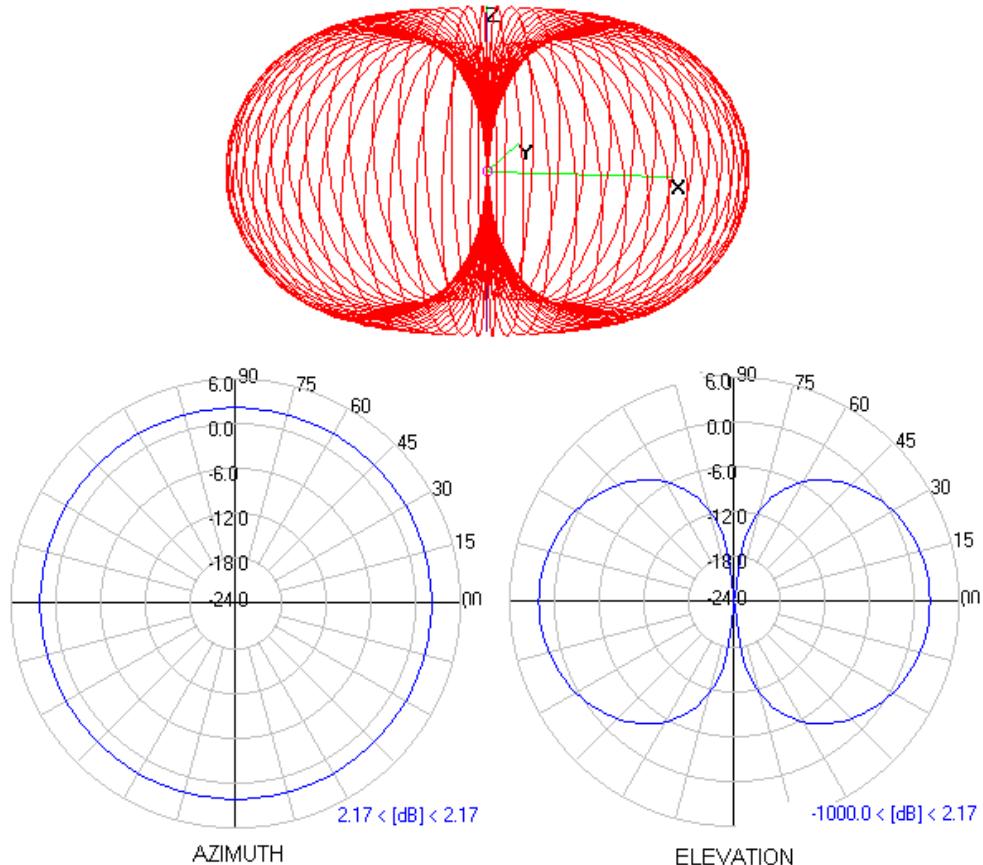
Omnidirectional Horizontal Antenna



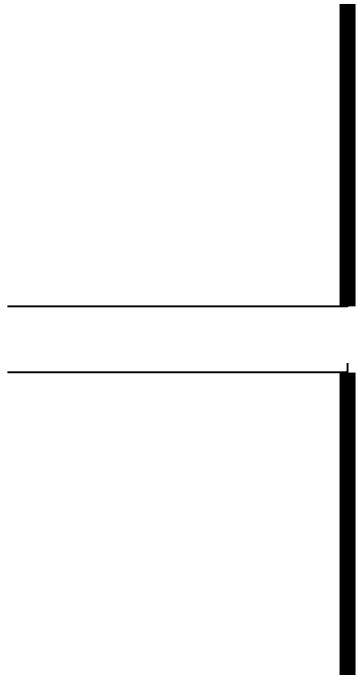


$\lambda/2$

2.4GHz - $\lambda/2$ is 6.25 cm
5GHz - $\lambda/2$ is 3.125 cm



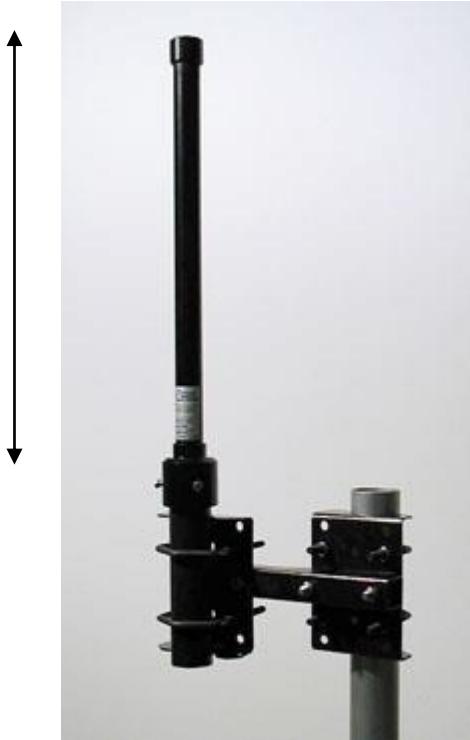
Ref: http://www.trevormarshall.com/byte_articles/byte1.htm



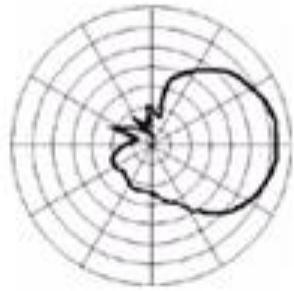
$\lambda/2$

A double-headed vertical arrow is positioned to the right of the dipole, indicating its total length. The text $\lambda/2$ is placed below this arrow, identifying the antenna as a half-wavelength dipole.

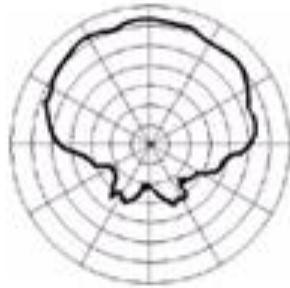
53cm
 $\lambda=1.06\text{m}$
 $f=300\text{MHz}$



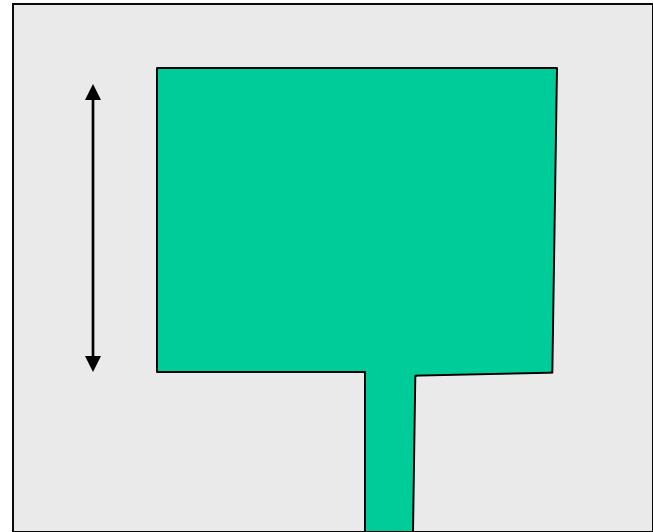
Patch antenna



Horizontal



Vertical



Path antenna

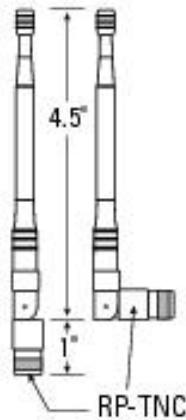


Dielectric

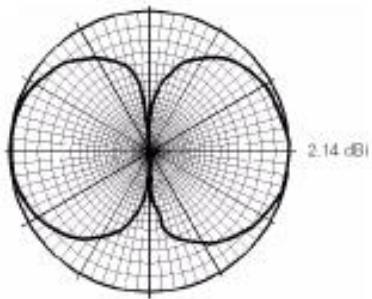
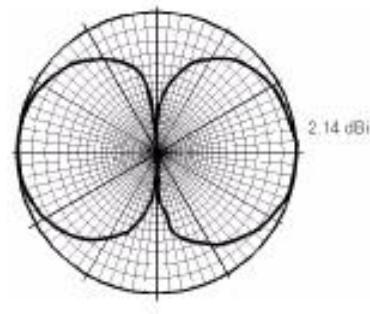
Ground plane (metal)

Practical Antennas

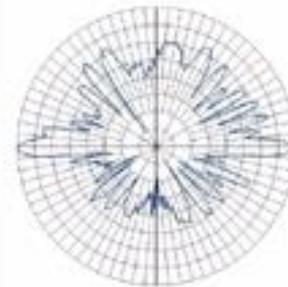
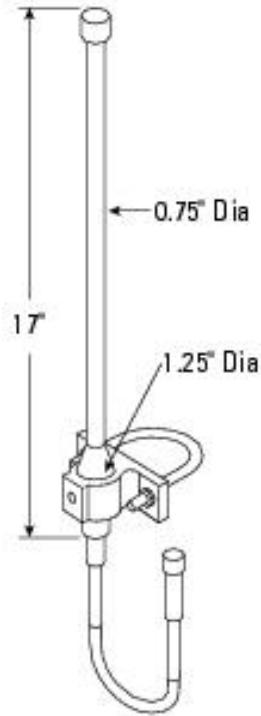




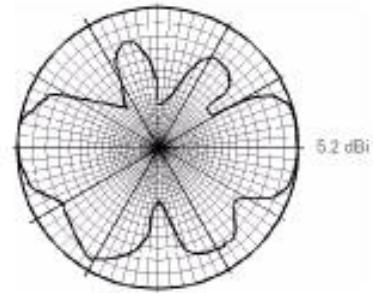
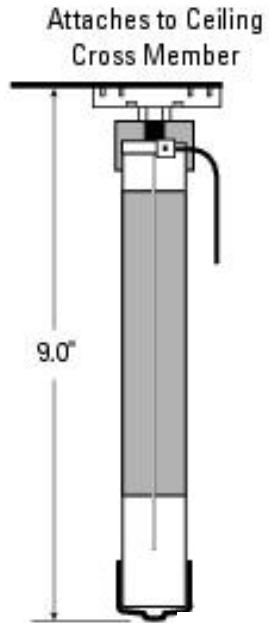
Diversity Dipole
Beamwidth: 70°
Gain: 2dBi



Diversity Dipole
Beamwidth: 80°
Gain: 2.2dBi

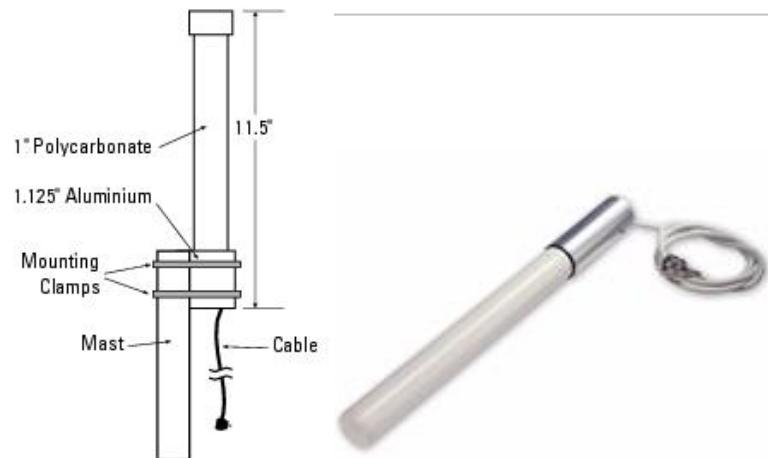
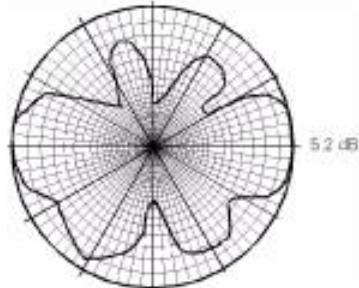


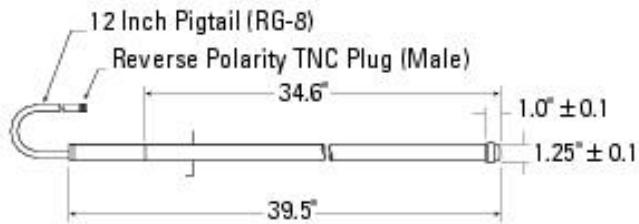
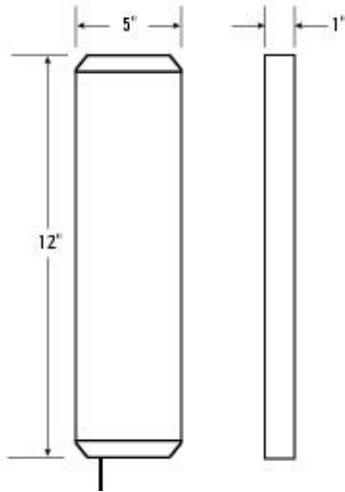
Mast mount (omni)
Beamwidth (Eval): 6°
Gain: 9dBi
Power: 4W



Ceiling mount
Beamwidth: 50°
Gain: 5.2dBi

Mast mount
Beamwidth: 50°
Gain: 5.2dBi



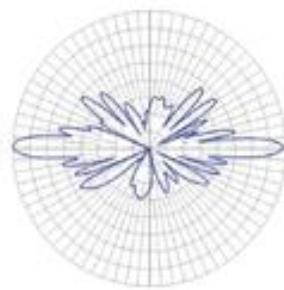


Mast mount (omni)

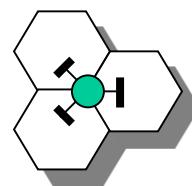
Beamwidth (Eval): 7°

Beamwidth (Az): 360°

Gain: 12dBi

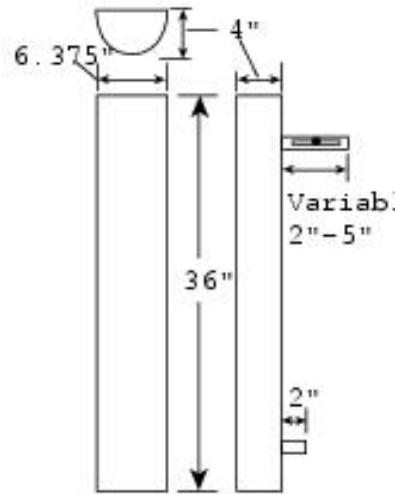
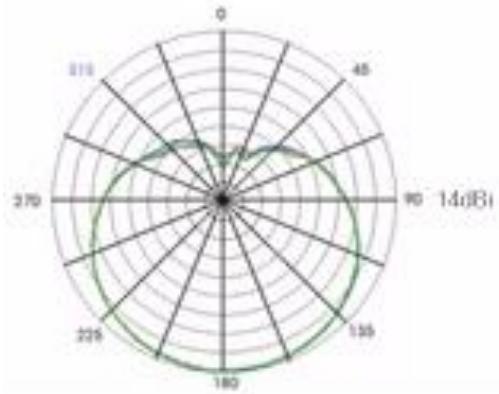
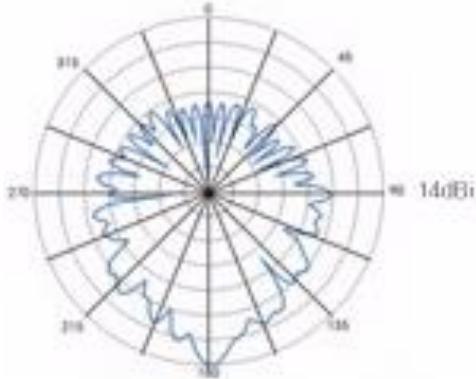


Pillar mount (omni)
Beamwidth: 25°
Gain: 5.2dBi



Tynecastle Stadium offers a local high-point around Gorgie.

Mast mount sectored (directional)



Horizontal

Vertical

Mast mount sector (direct)
Beamwidth (Eval): 8.5°
Beamwidth (Az): 90°
Gain: 14dBi

Wall patch (direct)



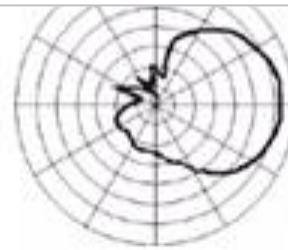
Ceiling mount

Beamwidth (Eval): 80°
Gain: 2dBi

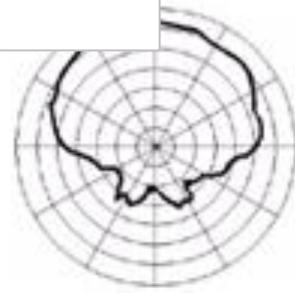


Wall path (direct)

Beamwidth (Eval): 70°
Beamwidth (Az): 65°
Gain: 6dBi



Horizontal

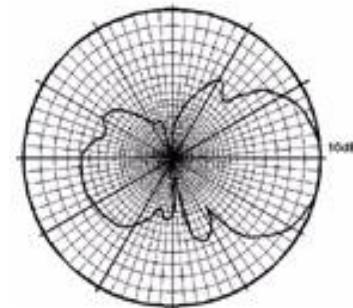
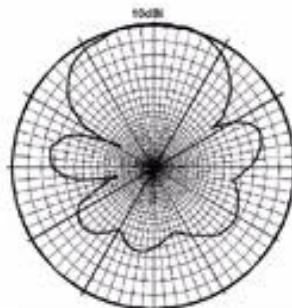


Vertical

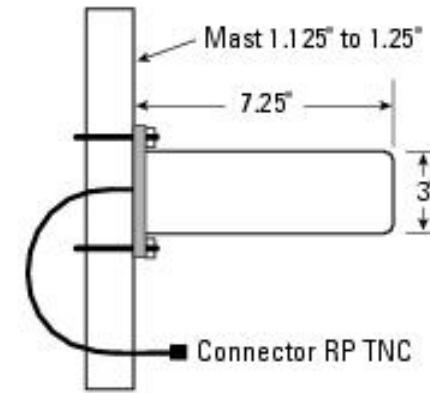
Wall path diversity (direct)

Beamwidth (Eval): 55°
Beamwidth (Az): 80°
Gain: 6dBi

Wall/mast Yagi



Horizontal

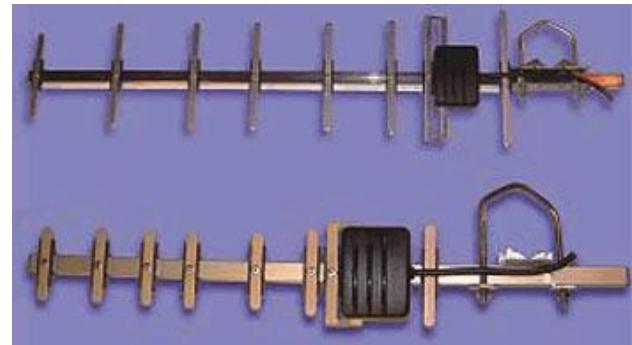


Wall/Mast Yagi (direct)

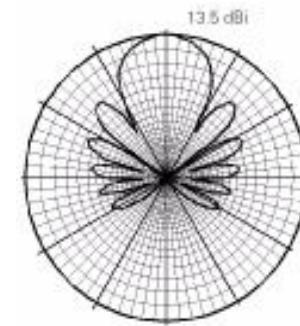
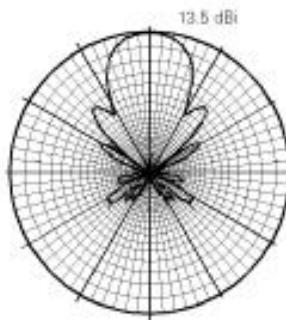
Beamwidth (Eval): 40°

Beamwidth (Az): 55°

Gain: 10dBi



Wall/mast Yagi



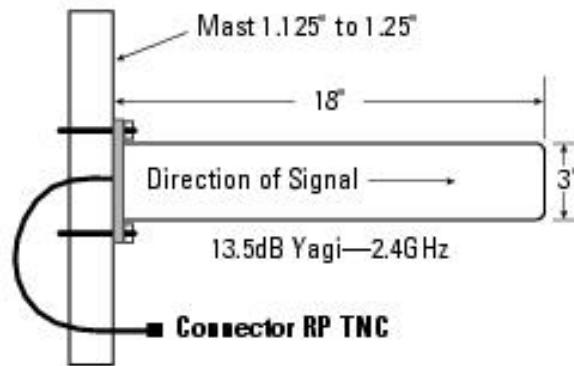
Horizontal

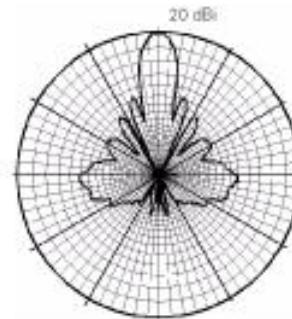
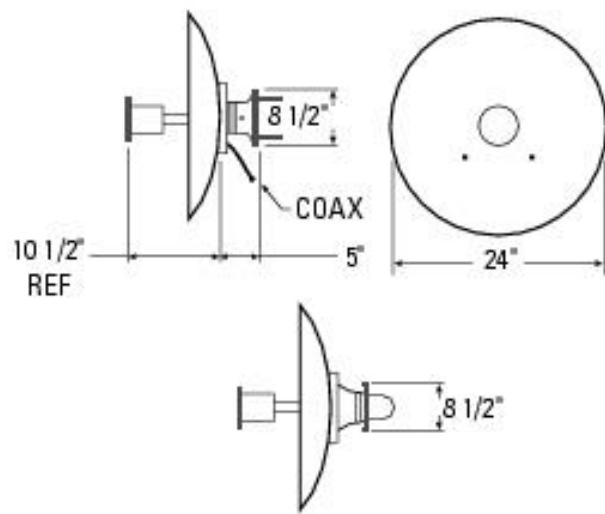
Wall/Mast Yagi (direct)

Beamwidth (Eval): 25°

Beamwidth (Az): 30°

Gain: 13.5dBi





Dish (direct)

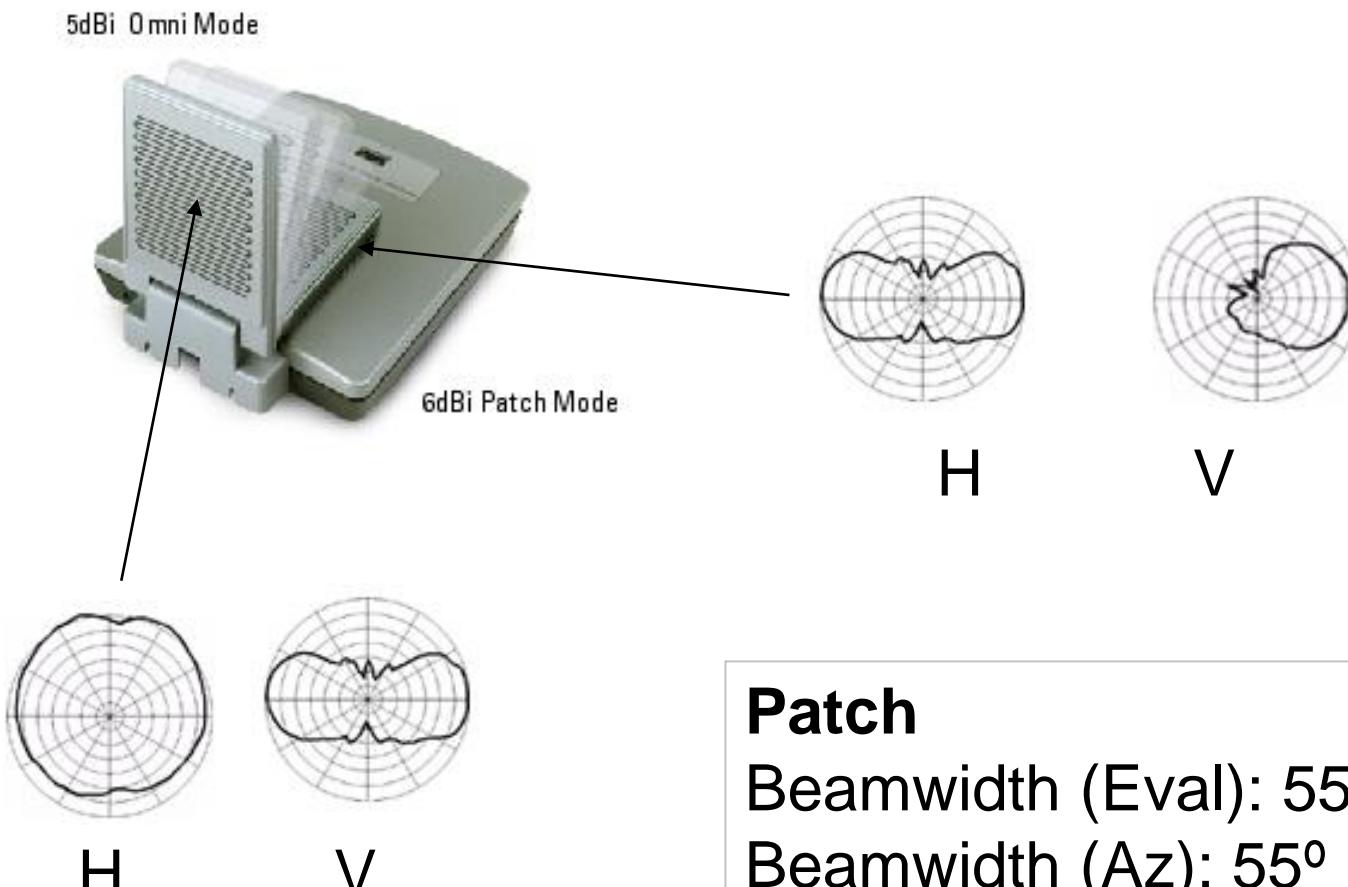
Beamwidth (Eval): 12.4°

Beamwidth (Az): 1.24°

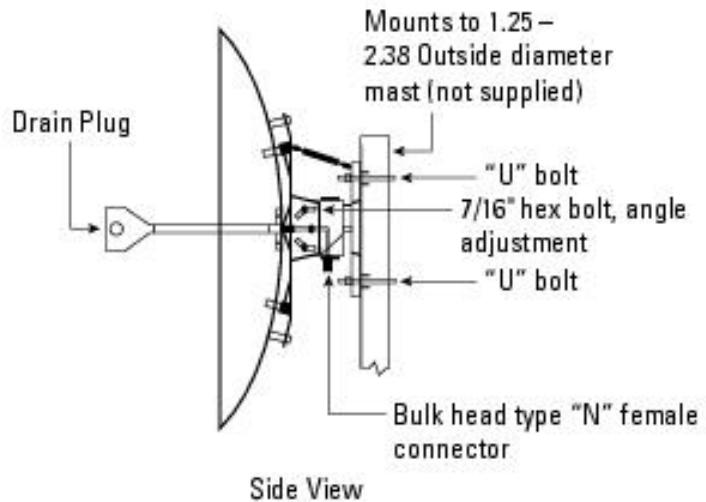
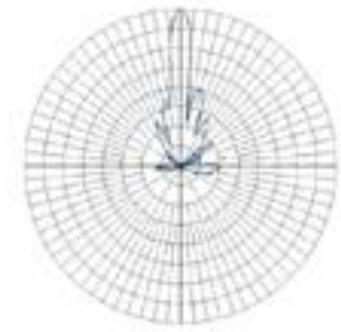
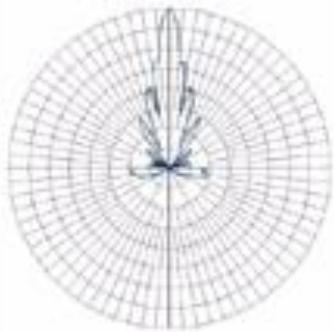
Gain: 21dBi

Power: 5W

Patch/Omni



Patch
Beamwidth (Eval): 55°
Beamwidth (Az): 55°
Gain: 6dBi



Dish (direct)
Beamwidth (Eval): 4.75°
Beamwidth (Az): 4.75°
Gain: 28dBi
Power: 4W

		Outdoor
Short range (<1mile)	Omni Directional mast mount sectored	
		
Omni Directional mast mount	Medium range Directional (6miles)	High range Directional (11miles)
		
	Medium range, P2P (1.4miles)	

Indoor



Ceiling



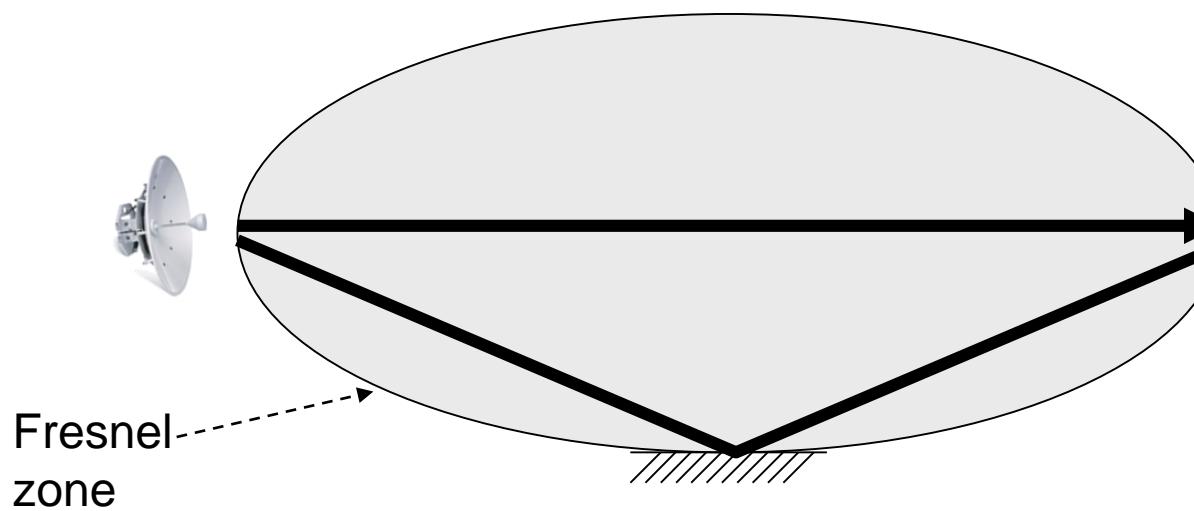
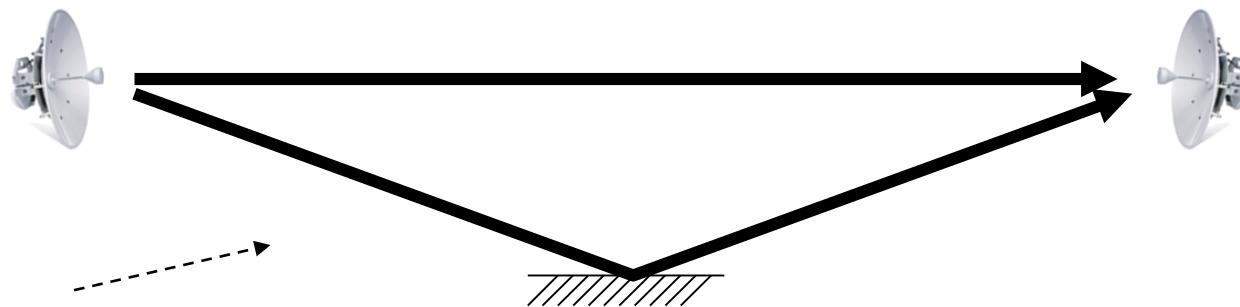
Patch



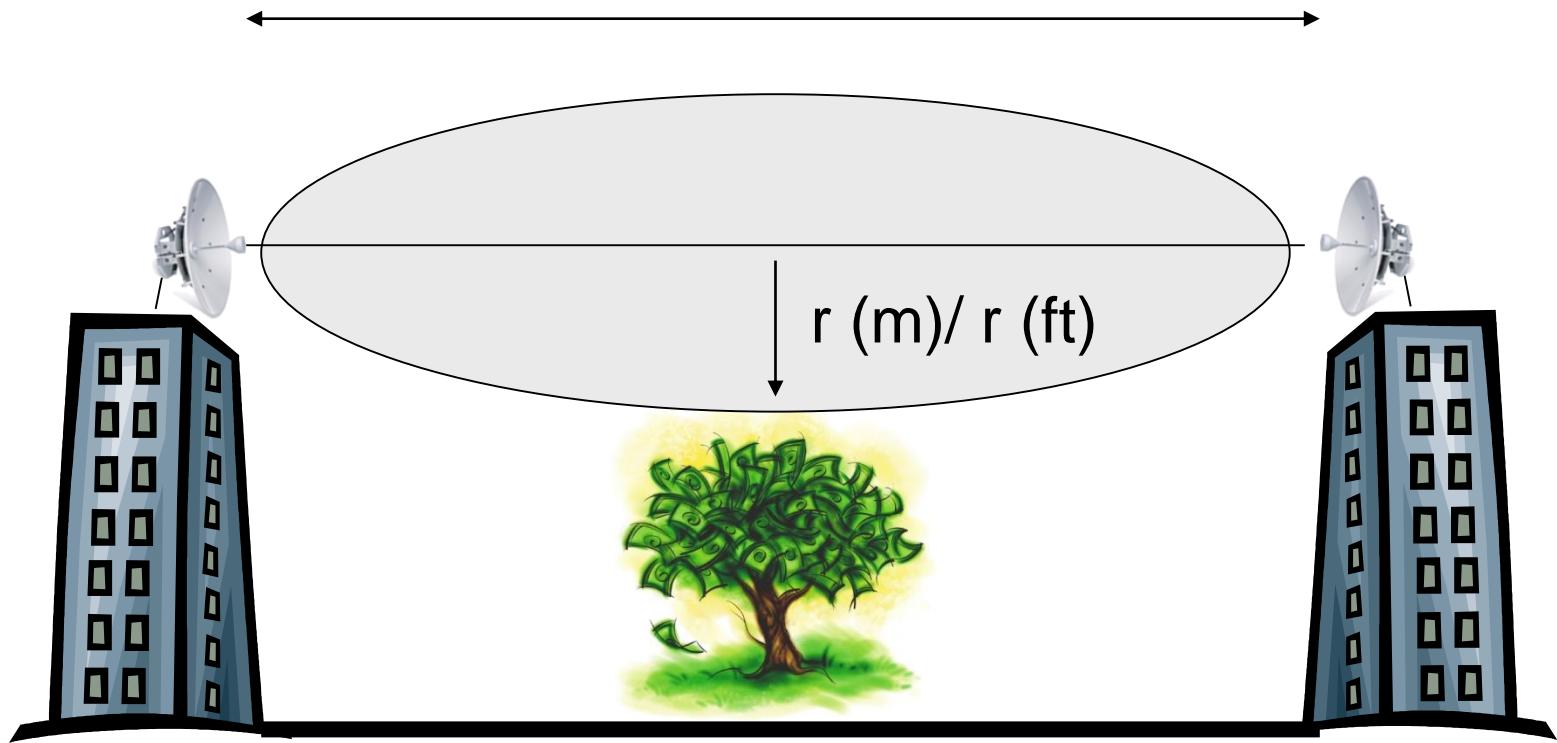
Pillar

Fresnel Zones





d (km)/ D (miles)

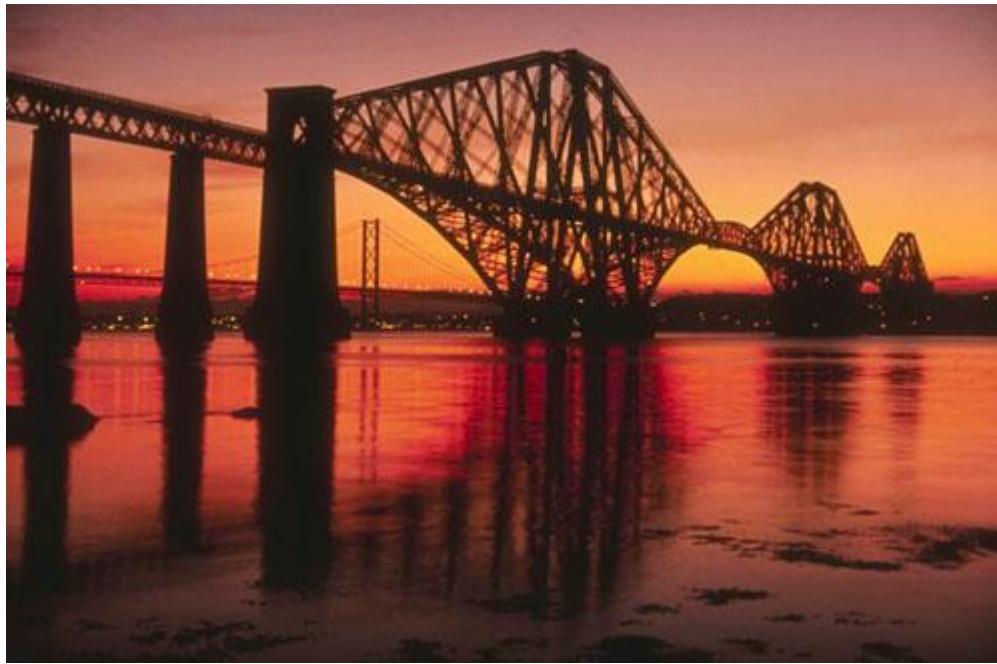


$$r(ft) = 72.05 \sqrt{\frac{D}{4f}}$$

$$r(m) = 17.32 \sqrt{\frac{d}{4f}}$$

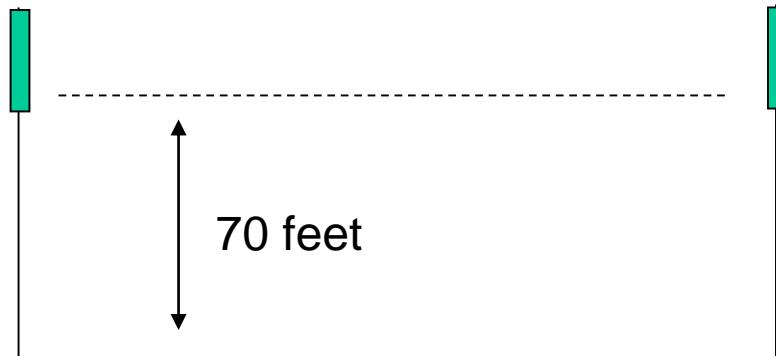
f - GHz

Fresnel Zone



Forth Rail Bridge
8296 ft -> 1.57 miles

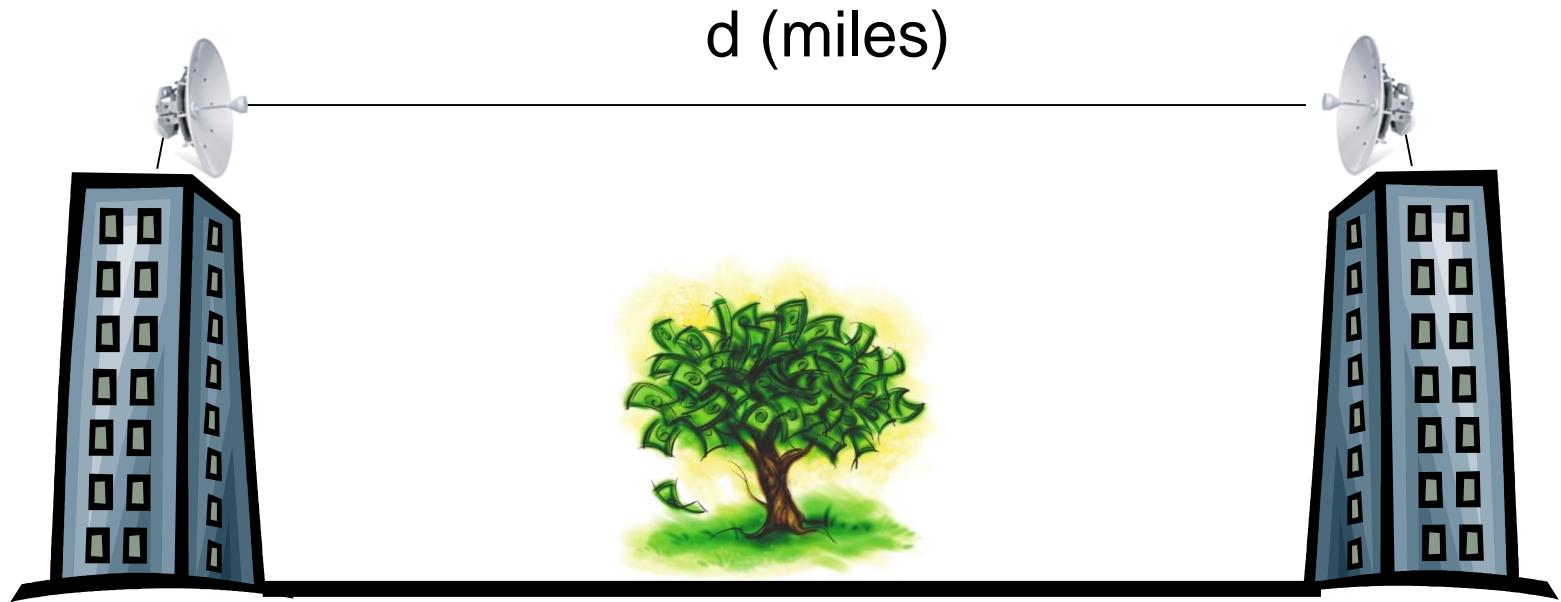
70 feet in the air ... for 1.57 miles apart.



$$r(\text{ft}) = 72.05 \sqrt{\frac{D}{4f}}$$

Firth of the Forth

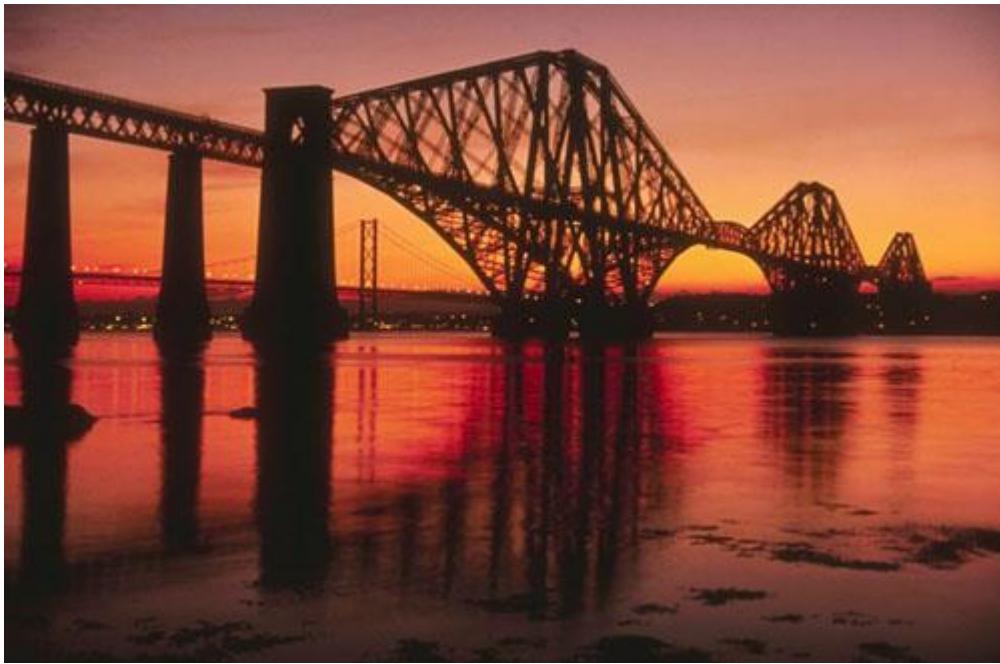
Free space loss



$$\text{Free space Loss(dB)} = 20\log_{10}f + 20\log_{10}d + 36.6 \text{ dB}$$

f (MHz)

Free space loss (across the Forth Rail Bridge)



Forth Rail Bridge
8296 ft -> 1.57 miles
For a 2.4GHz signal...

$$\begin{aligned}\text{Free space Loss(dB)} &= 20\log_{10}f + 20\log_{10}d + 36.6 \text{ dB} \\ &= 20\log_{10}(2400) + 20\log_{10}(1.57) + 36.6 \text{ dB} \\ &= 108.2 \text{ dB}\end{aligned}$$

2 miles

110 dB

[0.000 000 000 01
= 1/100 billion]

4 miles

116 dB

20 miles

130 dB