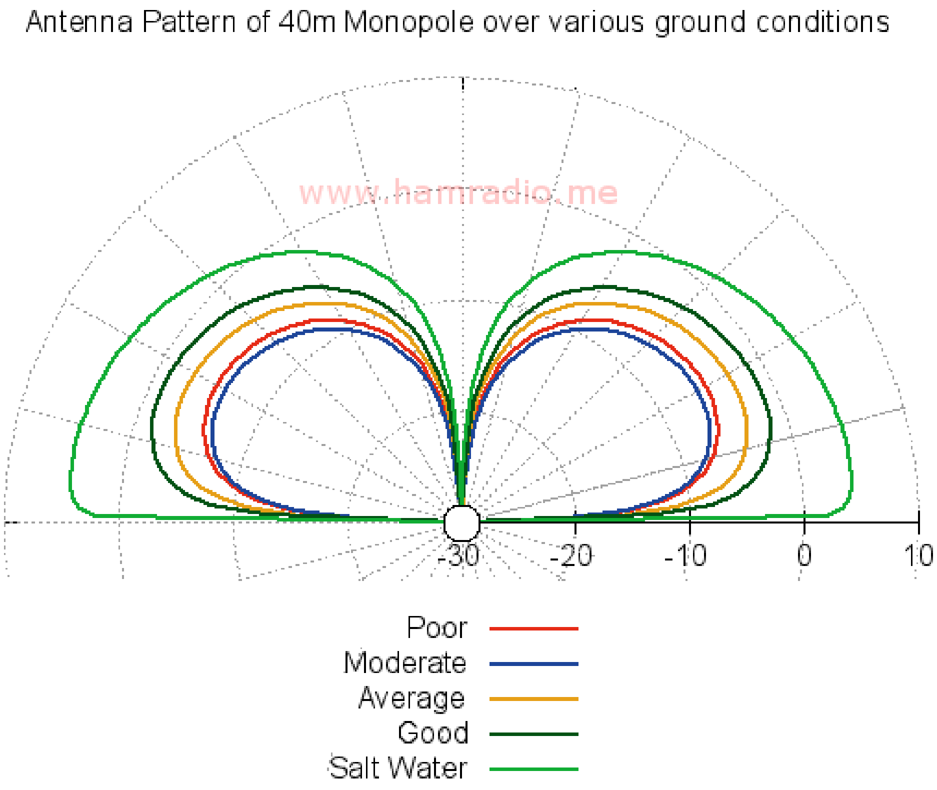
Chapter 9

Antennas
and Feed Lines

Jim Andera K0NK

Section 9.1

Basic of Antennas



Chapter 9

* Basics of Antennas
* Practical Antennas
* Antenna Systems
* Transmission Lines
* Antenna Design

Thanks to:

* Information from:
  * The ARRL Library
  * ARRL Extra Class License Manual
  * Gordon West Extra Class License Class

Near and Far Fields

Technician and General Review

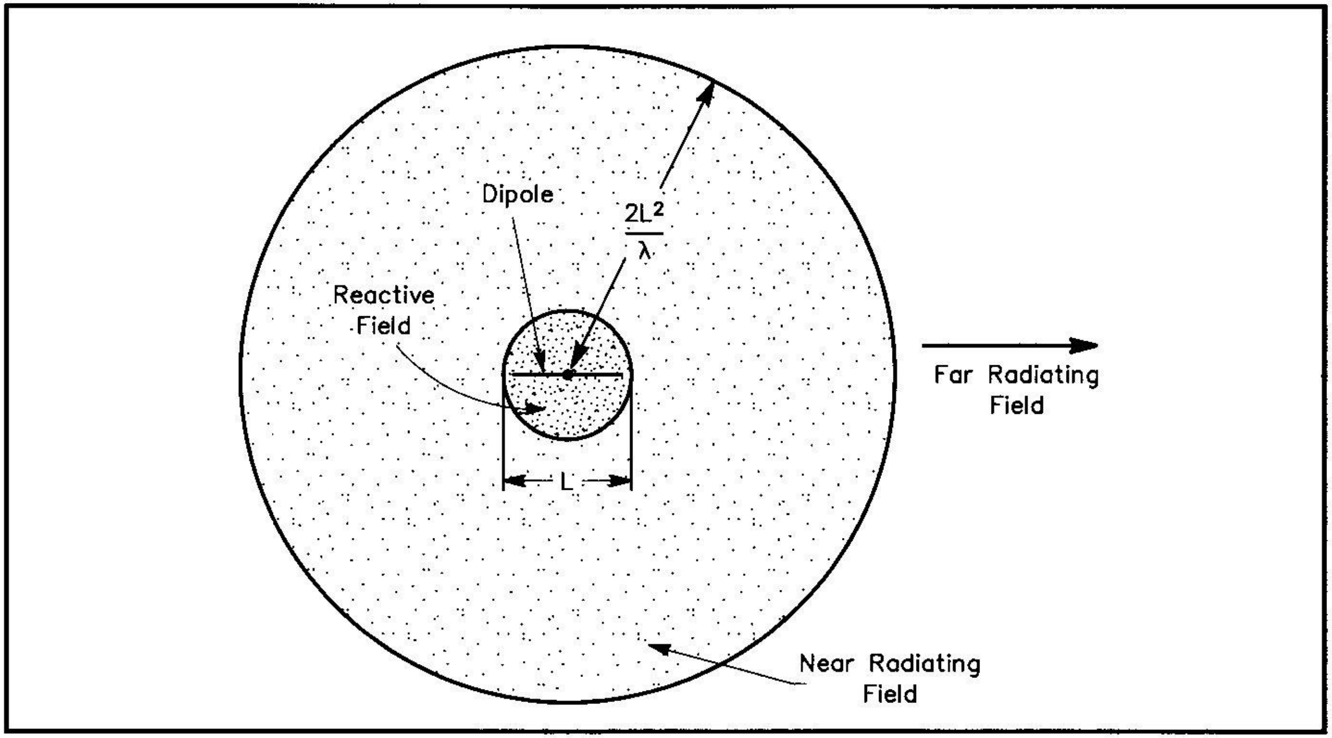


Figure 10-2 — This drawing illustrates the reactive near field, the radiating near field and the far field around a half wavelength dipole antenna.

L is the largest dimension of the physical antenna

* The far field begins at several wavelengths and extends forever!

Dipole Radiation Pattern

Pg. 9-2

* In the far field, the pattern is independent of distance
* The radiation pattern is usually drawn so that it just touches the outer circle at the point of its maximum strength.

Far Field Pattern

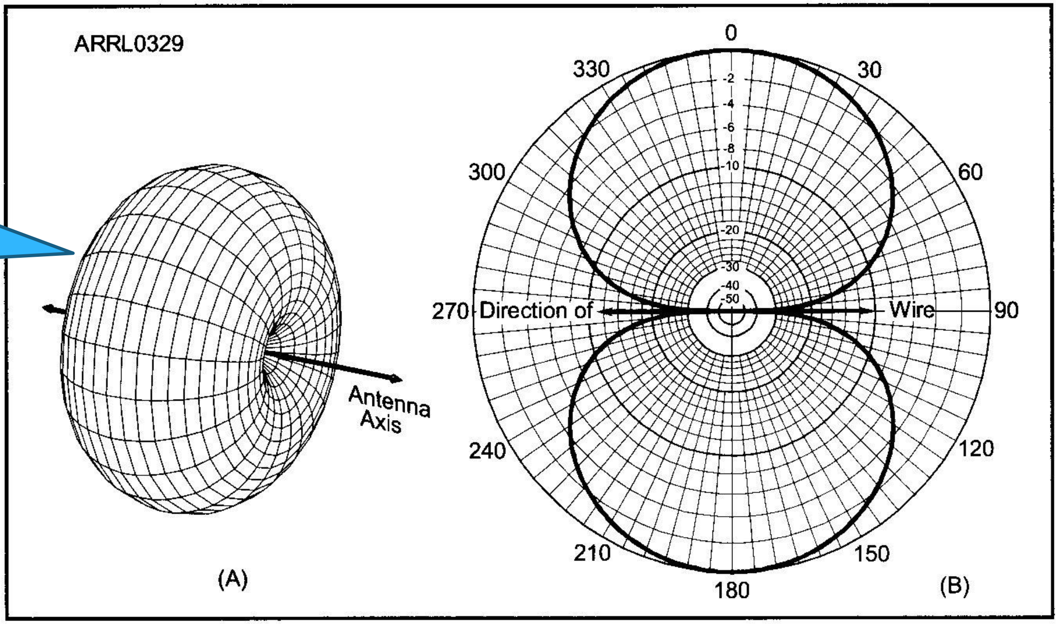
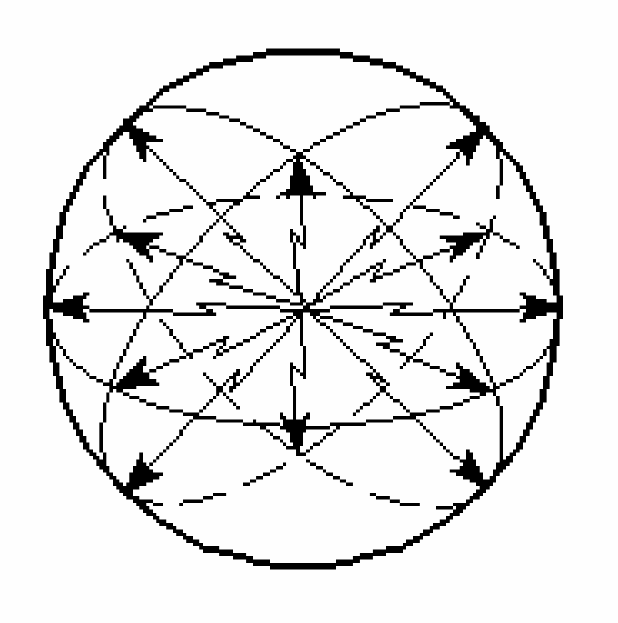


Fig. 9-1

Isotropic Radiator

Pg. 9-2

- *It's is only hypothetical – it does not really exist*
- The Isotropic antenna is a lossless antenna with equal radiation in all directions. It is useful for comparing the differences in gain among real antennas.



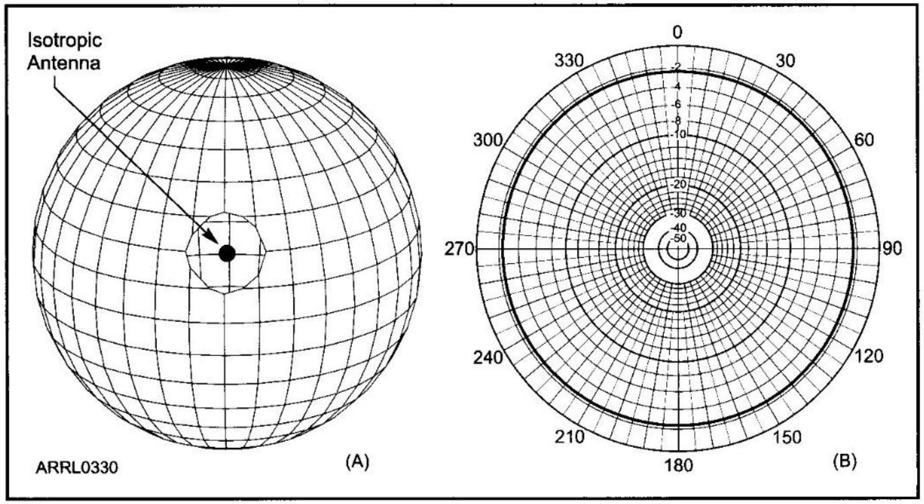


Figure 9-2 — The three-dimensional radiation pattern of an isotropic radiator is shown at A. B shows the radiation pattern of the isotropic antenna in any plane. This plot has been reduced by 2.15 dB so that it can be compared with the radiation pattern of the dipole in Figure 9-1.

Directional Antennas

Pg. 9-3

- The radiation pattern from a practical antenna never has the same intensity in all directions.
- Directional antennas concentrate the energy in one (or more) directions.
  - Major lobe(s)
  - Minor lobe(s)

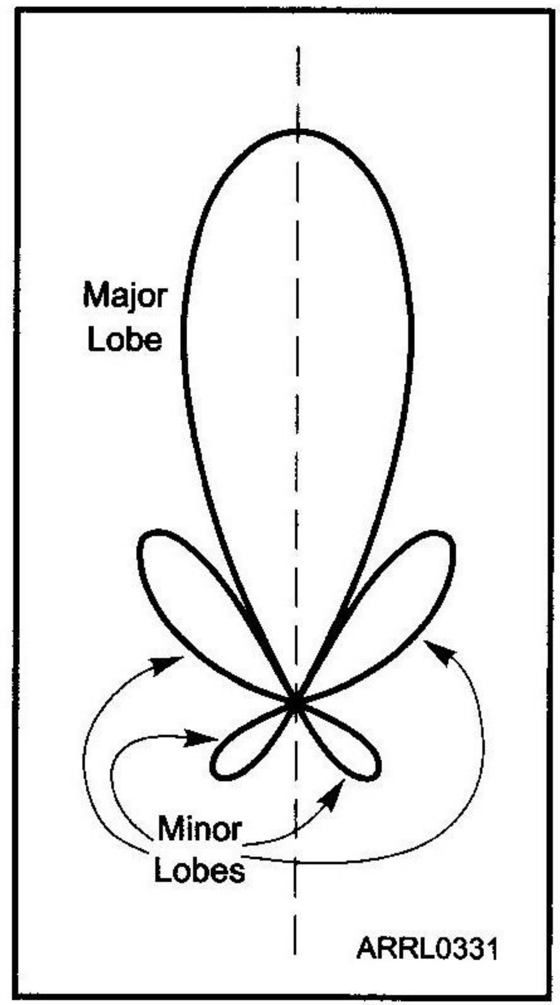


Fig. 9-3

Directional Antennas

Pg. 9-3

- The antenna's gain (expressed in dB) is the signal strength from the antenna in the direction of the main lobe and the signal from a reference antenna.

- Reference antennas:
  - Isotropic
  - Dipole

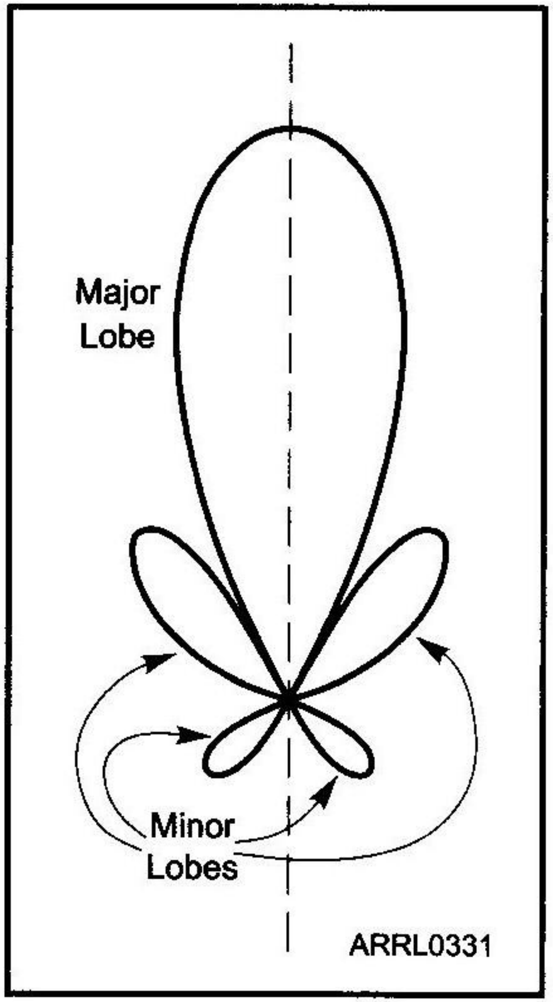
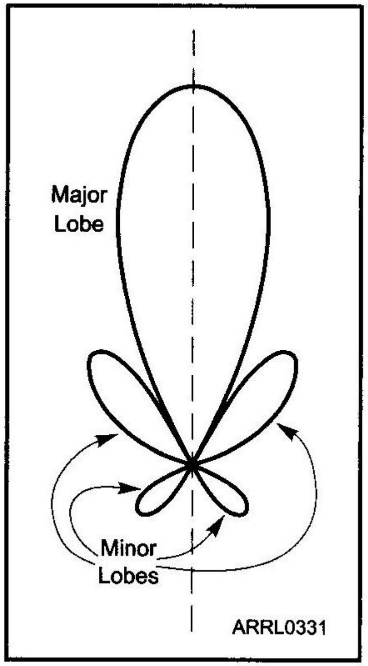


Fig. 9-3

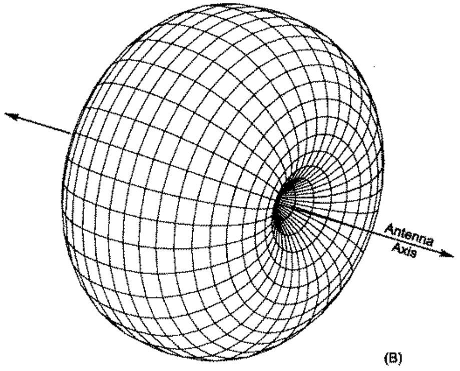
Directional Antennas

Pg. 9-3

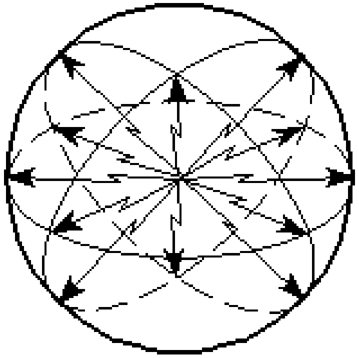
- The gain of the antenna is the result of concentration of the energy in one direction.
- **There is no difference in the total amount of power radiated** between a lossless antenna with gain and an isotropic radiator with the same power.



Gain Antenna
Top View
Fig. 9-3



Dipole Antenna

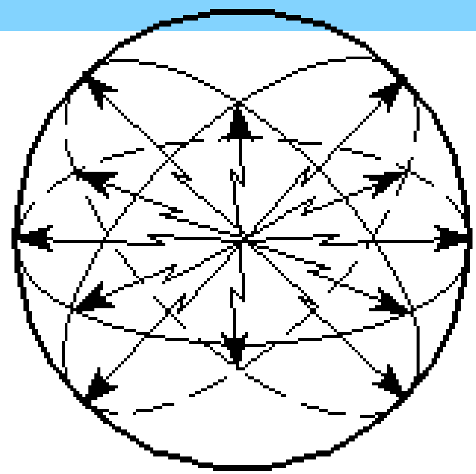


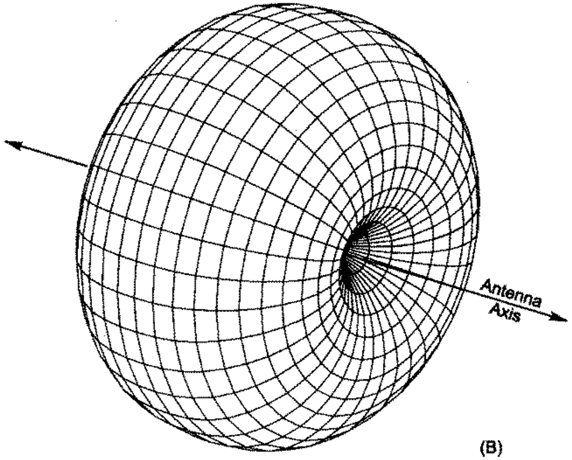
Isotropic Antenna

A Look at Gain

Pg. 9-3

* The Isotropic radiator has no gain in any direction.
* The Radiation of the main lobe of a dipole is 2.15 dB greater than would be expected from an Isotopic antenna.





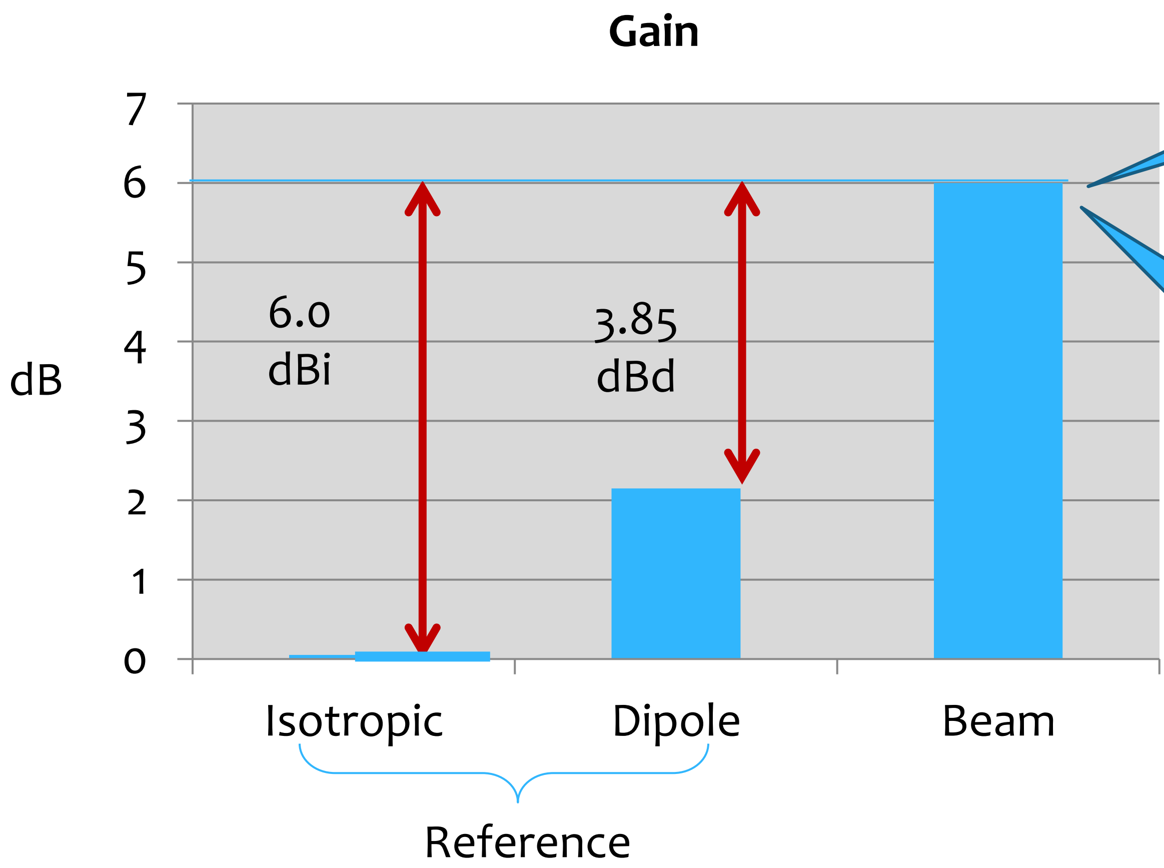
When we talk about the gain of other antennas:

… we can reference the gain to an **isotropic** radiator (**dBi**)

… or we can reference the gain to a **dipole** antenna (**dBd**)

dBi and dBd

Pg. 9-3



The beam antenna we want to buy advertises a gain of **6 dBi**

Or the same antenna could be advertised as having a gain of **3.85 dBd**

Example 9-1

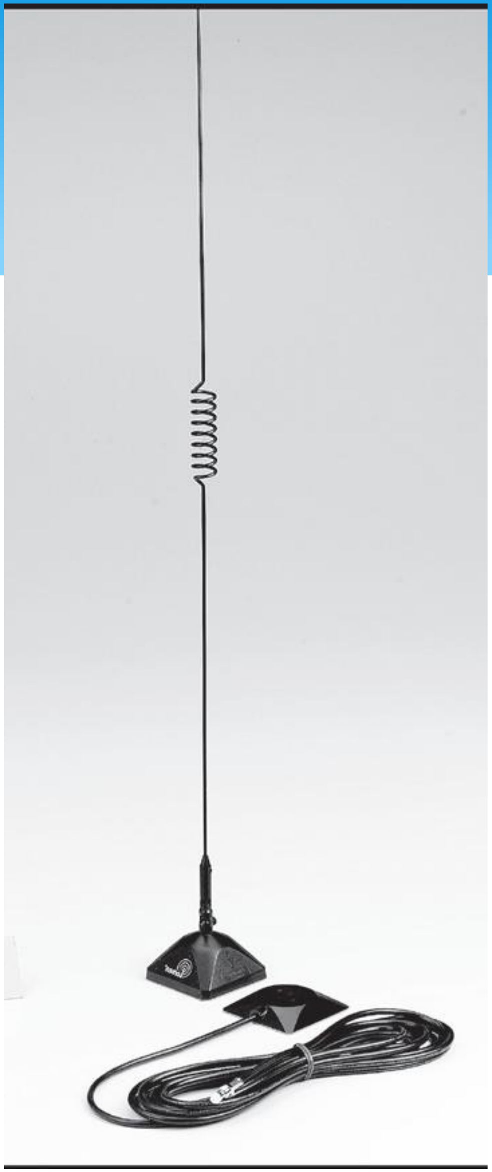
A Look at Advertised Gain

Comet SBB-224/SBB-224NMO

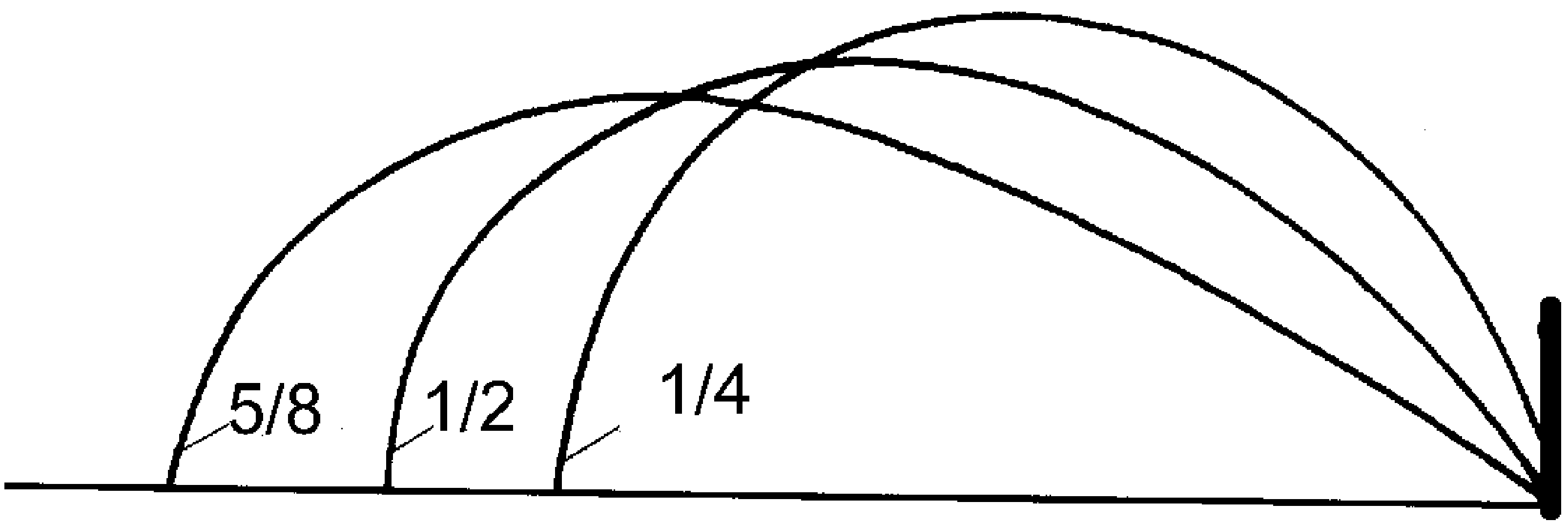
* Tri-Band 146/220/446MHz
  Gain & Wave:
  146MHz 2.15dBi 1⁄4 wave
  220MHz 3.5dBi 5⁄8 wave
  446MHz 6.0dBi 5⁄8 wave x 2
  VSWR: 1.5:1 or less
  Max Power: 100 watts
  Length: 36”
  Connector:
  SBB-224 PL-259
  SBB-224NMO NMO Type

½ λ End-fed Mobile

* **LARSEN MODEL** KG2/70CXPL **FREQUENCY (MHz)** 144 - 148 / 442 - 448
* **SPECIFICATIONS**
  - GAIN VHF: 0 dBd / 2 dBi
  - UHF: 2 dBd / 4.2 dBi



Many Antennas will exhibit **gain.**



Side View

dBi and dBd

Pg. 9-3&4

* Equation 9-1
  * **Gain in dBd = Gain in dBi -2.15 dB**
* Equation 9-2
  * **Gain in dBi = Gain in dBd +2.15 dB**

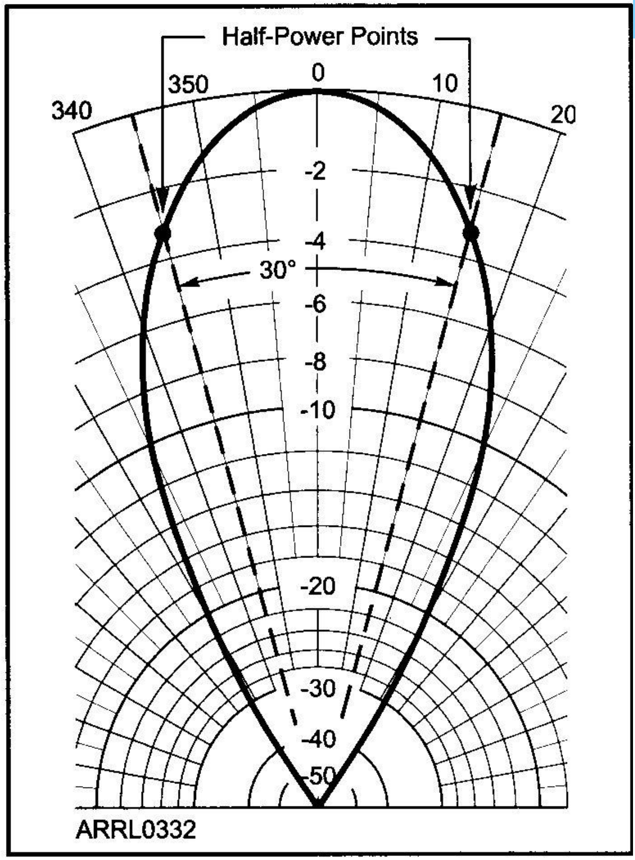
The gain in **dbi** will always be a **larger** number **than dBd** by about **2 dB.**

* Example 9-2
  * If an antenna has 12 dB more gain than an dipole, how much gain does it have compared to an isotropic antenna?
* Gain in dBd = 12 dBi + 2.15 dB = **<u>14.15 dBi</u>**

Beamwidth and Pattern Ratios

Pg. 9-4

- Beamwidth is the angular distance between the point on either side of the major lobe at which the gain is 3 dB below the maximum.
  - Also called the -3 dB beamwidth.
- As gain is increased, the beamwidth **decreases**



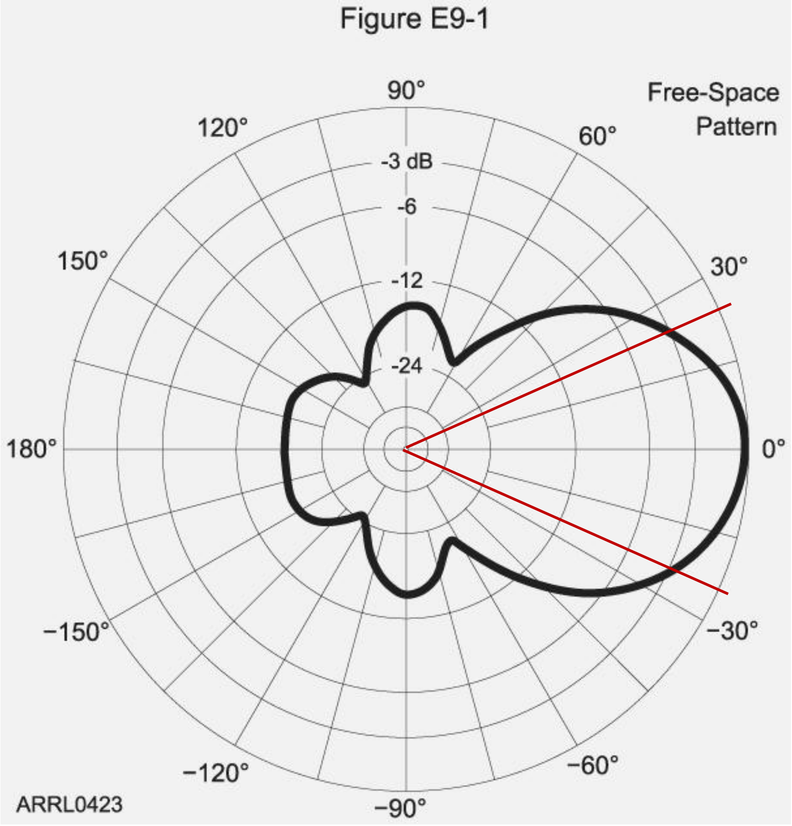
Top View

Figure 9-4 — The beamwidth of an antenna is the angular distance between the directions at which the antenna gain is one-half (–3 dB) its maximum value.

What is the -3dB Beamwidth?

Pgs. 9-4 & 5

Azimuth – Top View



1) Figure out where the –3dB ring is.
2) Observe where the pattern lines cross the – 3dB ring.
3) Estimate the total angular distance.

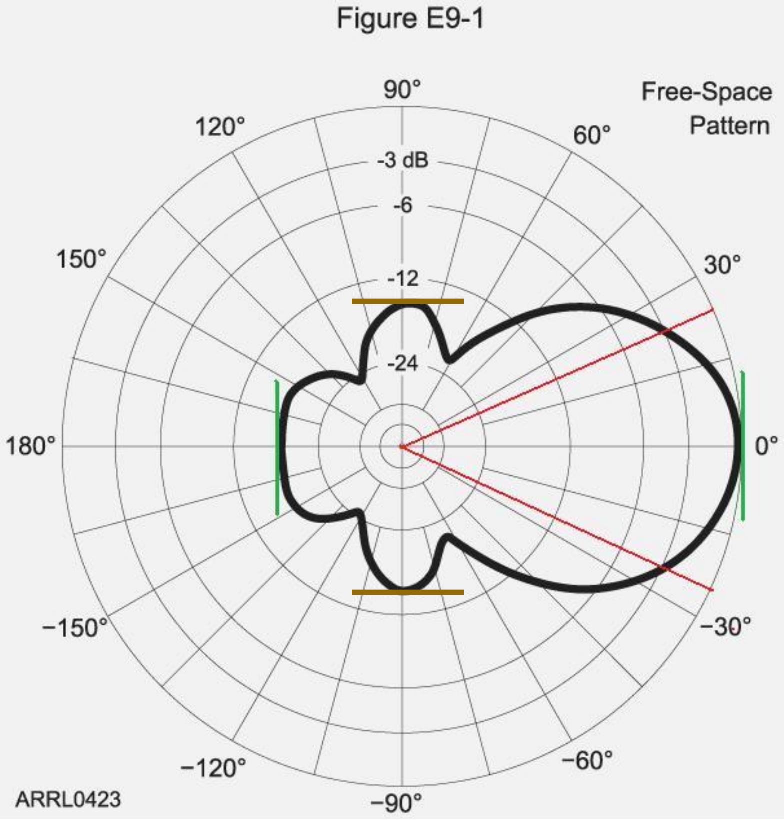
25° + 25° = 50°

Gain Ratios

Pg. 9-5

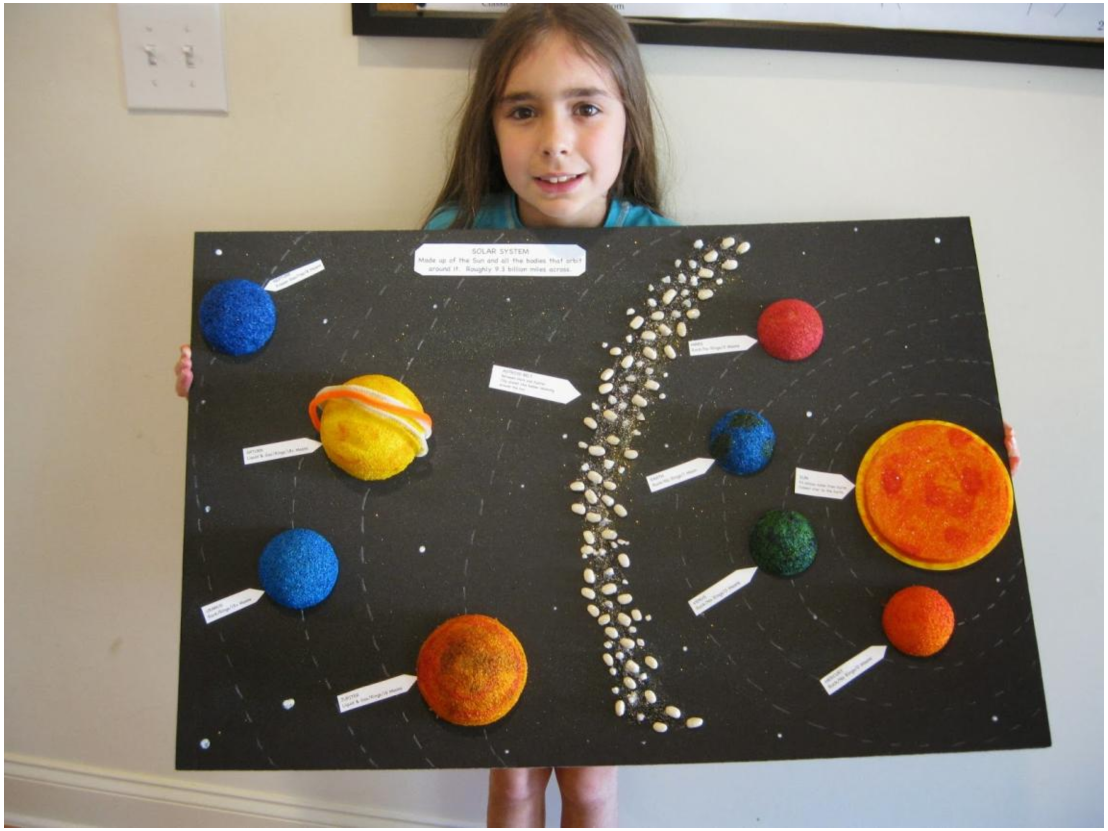
- Beam antennas are also specified by certain **ratios:**
  - Front to Back
  - Front to Side

- F/B = 18 dB
- F/S = 14 dB



Looking at Models

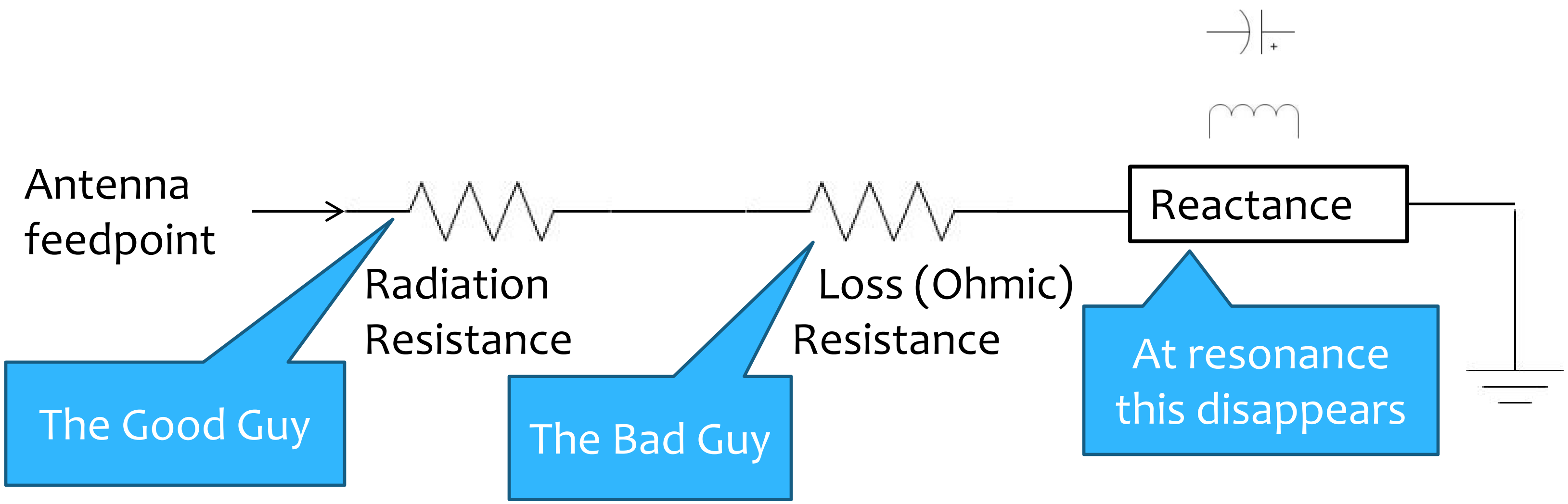
* Model of the Solar System



Radiation and Ohmic Resistance

Pg. 9-5

* RF power supplied to the antenna is dissipated in the form of:
  - **Radio waves**
  - **Heat.**



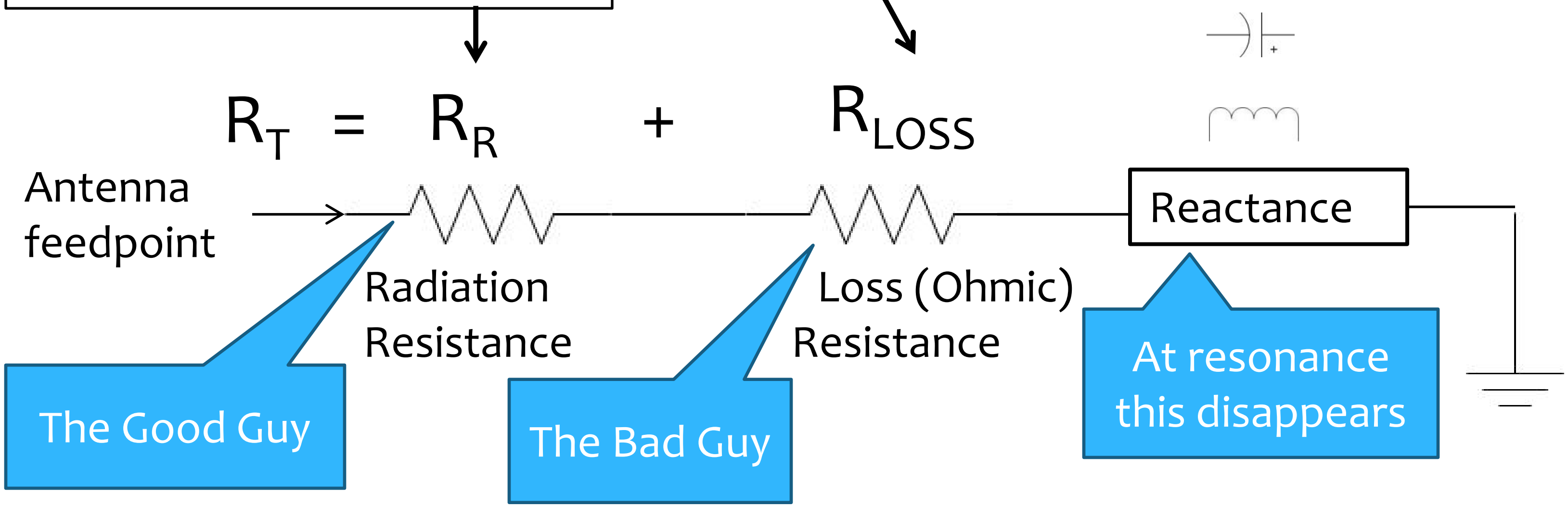
Radiation and Ohmic Resistance

Pg. 9-5

* $R_T = R_R + R_{LOSS}$

The value of resistance that would dissipate the same amount of power as that **radiated from the antenna** as radio waves.

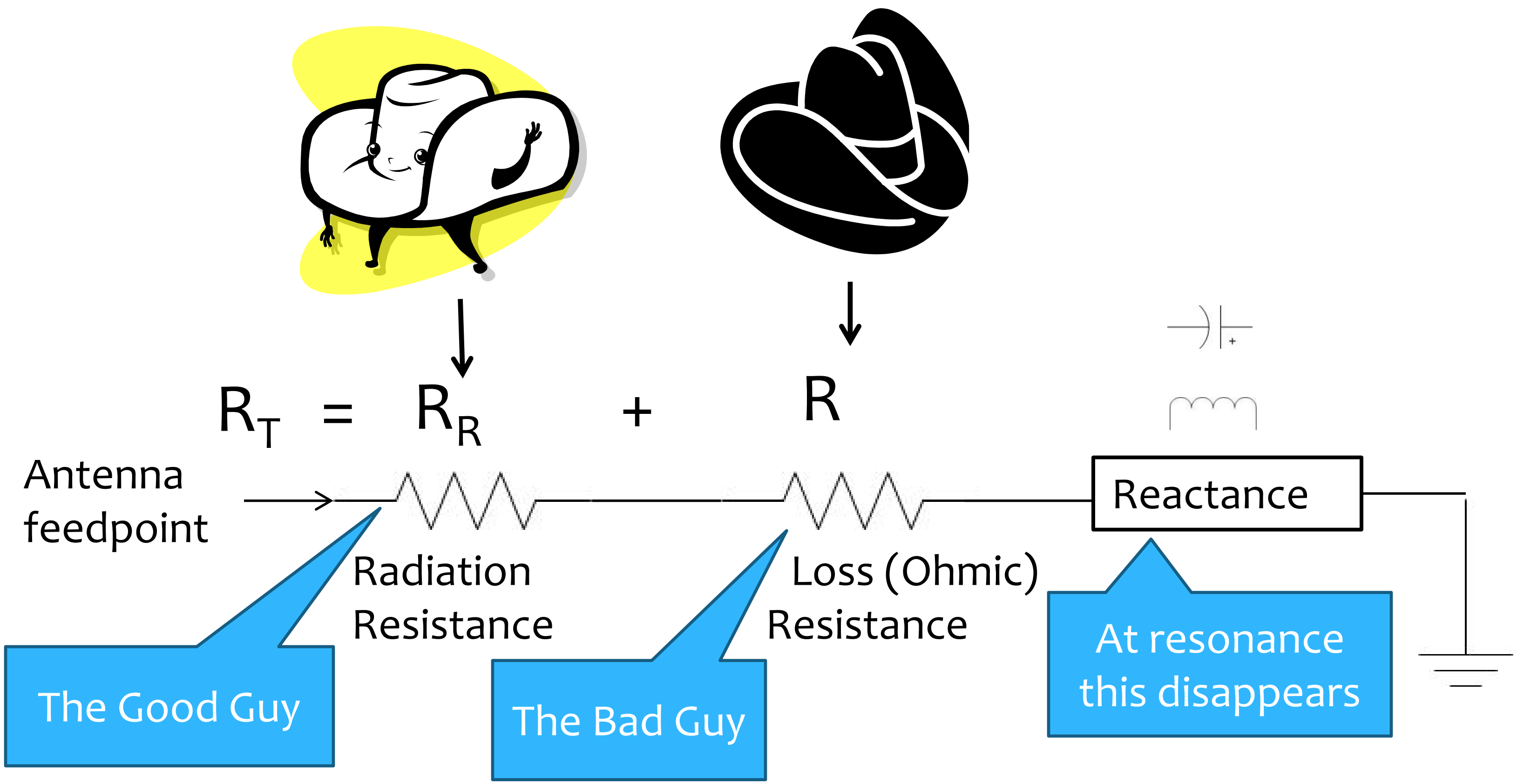
The value of resistance that would dissipate the same amount of power that is **lost to heat.**



Radiation and Ohmic Resistance

Pg. 9-6

* $R_T = R_R + R$



Antenna Efficiency

Pg. 9-6

$$\text{Efficiency} = \frac{R_R}{R_T} \times 100\%$$

where:

R_R = radiation resistance.

R_T = total resistance.

$$R_T = R_R + R_{LOSS}$$

* If a half-wave dipole antenna has a radiation resistance of 70 Ω and a total resistance of 75Ω, what is it's efficiency?
* Efficiency = 70 / 75 x 100% = 93.3%
* What is antenna efficiency? E9A09
  * Radiation resistance divided by total resistance

Feed Point Impedance

Pg. 9-6

The feed point impedance can vary over a wide range:

* The impedance can be resistive only (at resonance)
* Or have a reactive (L or C) component off resonance

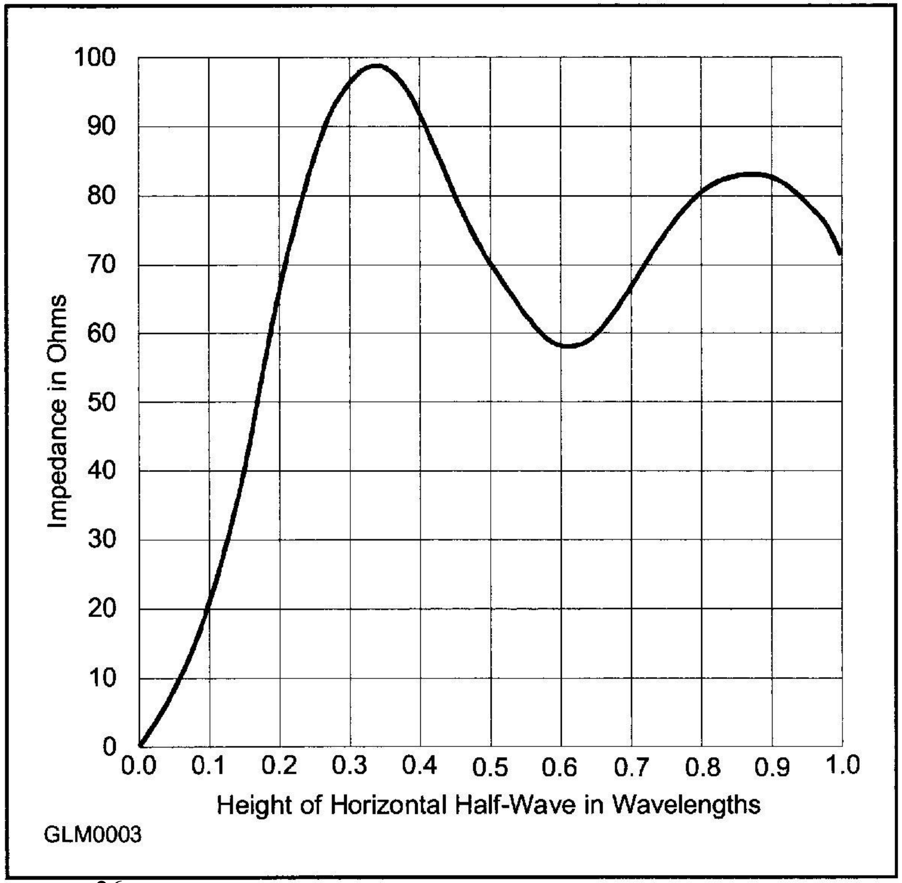
Many factors determine the feed point impedance:

* **The location of the antenna** with respect to other antennas and objects, **especially its location to the earth (height)**
* The Length/Diameter ratio.
* The design of the antenna

Dipole Feedpoint Impedance

General Review

The height of the dipole antenna above the ground affects the impedance of the antenna.

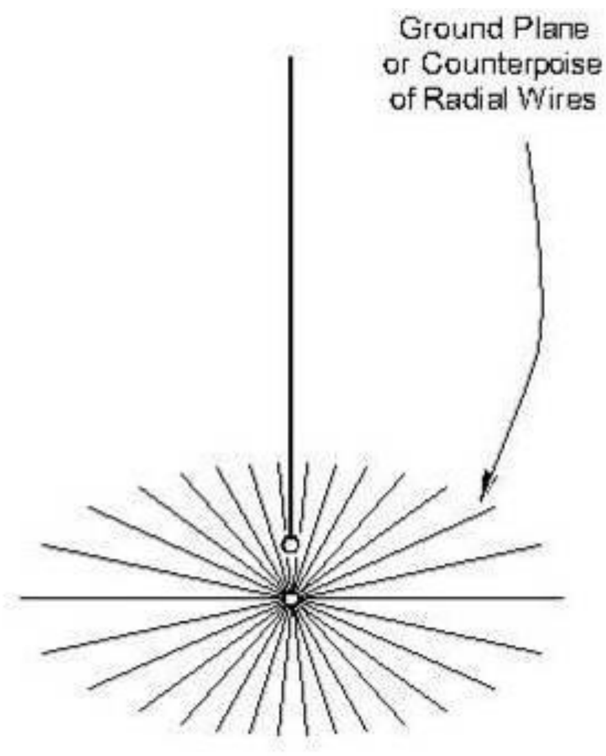


A Practical Look at Antenna Efficiency

Pg. 9-6

- Mobile HF whips may have very low efficiency because the radiation resistance tends to be low due to the short length.
  - Particularly on **80m** and **40m**

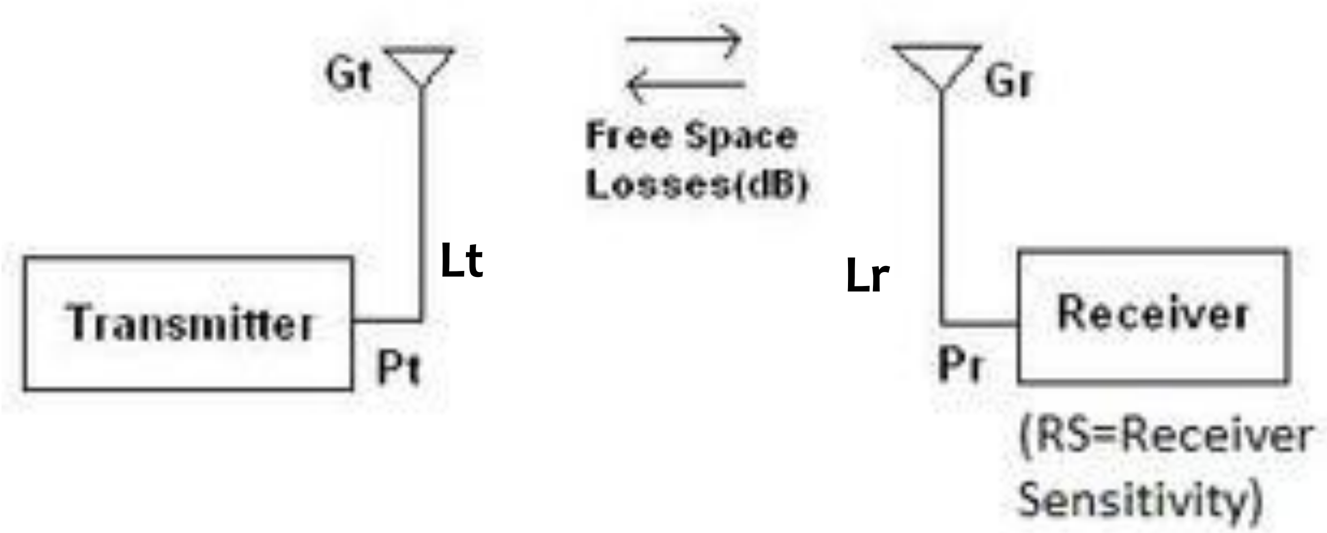
- To be effective, a ¼ wavelength ground mounted vertical antenna requires a ground system of radials.
  - A vehicle's body will be quite **inadequate** at 80 and 40m



Link Budgets

Pg. 9-7

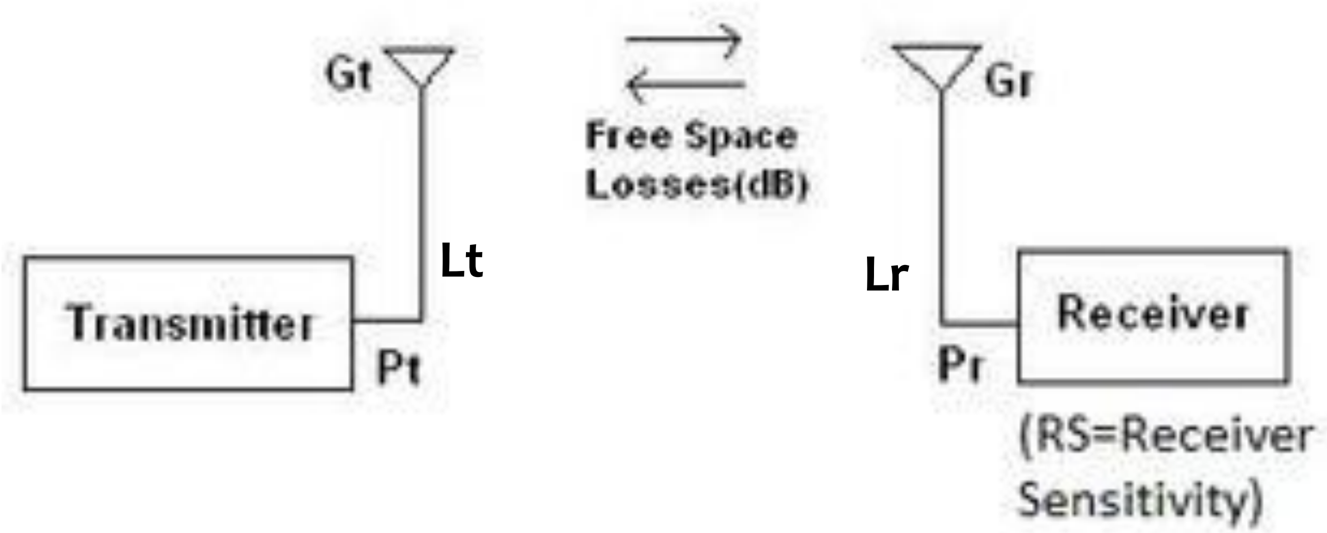
* Link budges accounts for all of the gains and losses a RF signal experience in a system.
* Link Margins is the difference between the minimum power level needed to receive a signal and the actual power level of the received signal.



Link Budgets

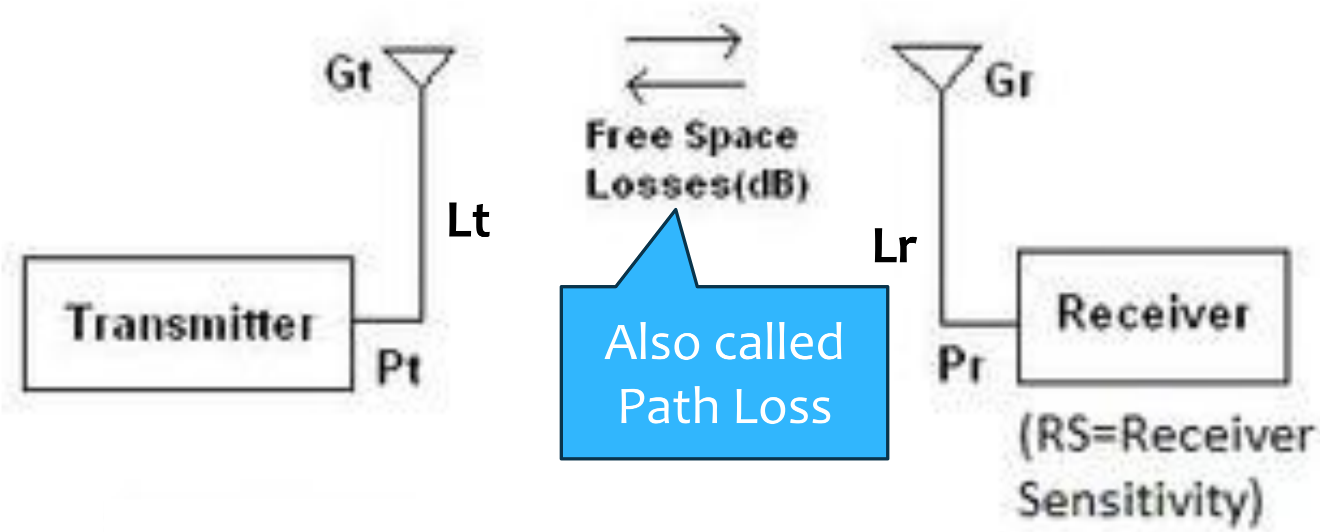
Pg. 9-7

- Link budges accounts for all of the gains and losses a RF signal experience in a system.
- **Link Margin** is the difference between the minimum power level needed to receive a signal and the actual power level of the received signal.



Calculating Link Budgets

Pg. 9-7



- $P_{RX} = P_{TX} + G_{TX} – L_{TX} – L_{FS} + G_{RX} – L_M – L_{RX}$
- Where L_M is miscellaneous losses (i.e.: Connectors, RF switches, duplexers …)
- *Hint: You can Combine gains and losses*: $P_{RX} = P_{TX} + G_{ALL} – L_{ALL}$

Calculating Link Budgets

Pg. 9-7

* $P_{RX} = P_{TX} + G_{TX} – L_{TX} – L_{FS} + G_{RX} – L_{M} – L_{RX}$
* **What is the Link Margin if the Tx = 100W (+40 dBm), a system antenna gain of 10 dBi, total cable loss = 3 dB, Path Loss = 136 dB and a MDS of -103 dBm and we want a S/N ratio of 6 dB** E4D12
* **P_{RX} = +40 dBm +10 dB -3 dB -136 dB = -89 dBm**
* Remember: MDS = -103 dBm and we'd like a 6 dB SNR
* So we need a signal 6 dB stronger than -103 dBm, which is -97 dBm [-103 + 6 = 97] to provide a 6 dB SNR
* A -89 dBm signal is 8 dB stronger than the required -97 dBm, so **we have 8 dB of link margin**

dBm to uV Conversion Charts

* http://wa8lmf.net/miscinfo/dBm-to-Microvolts.pdf

dBm TO MICROVOLTS CONVERSION CHART (For 50 Ω System)

dBm	uV	dBm	uV	dBm	uV
0	224,000	-47	1,000	-94	4.47
-1	200,000	-48	891	-95	3.99
-2	178,000	-49	795	-96	3.55
-3	159,000	-50	709	-97	3.17
-4	141,000	-51	633	-98	2.82
-5	126,000	-52	563	-99	2.52
-6	112,000	-53	501	-100	2.24
-7	100,000	-54	447	-101	2.00
-8	89,100	-55	399	-102	1.78
-9	79,500	-56	355	-103	1.59
-10	70,900	-57	317	-104	1.41

6 dB SNR

6 dB

MDS

Typical Beam Elevation Pattern

Pg. 9-7

What we see in this figure is the **Elevation Pattern**

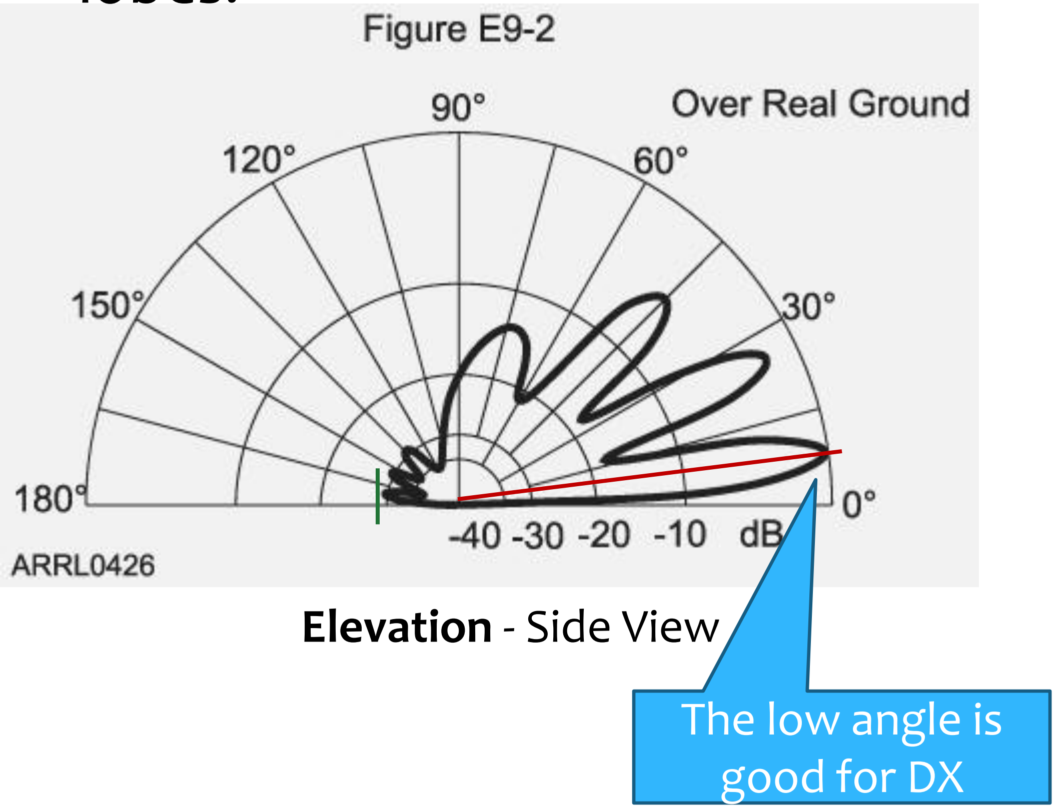
* The peak response is at an **elevation angle of** about 7.5 degrees

  See the red line

* F/B Ratio of ~ 28 dB

  See the green line

This figure shows 4 forward radiation lobes and 3 reverse lobes.



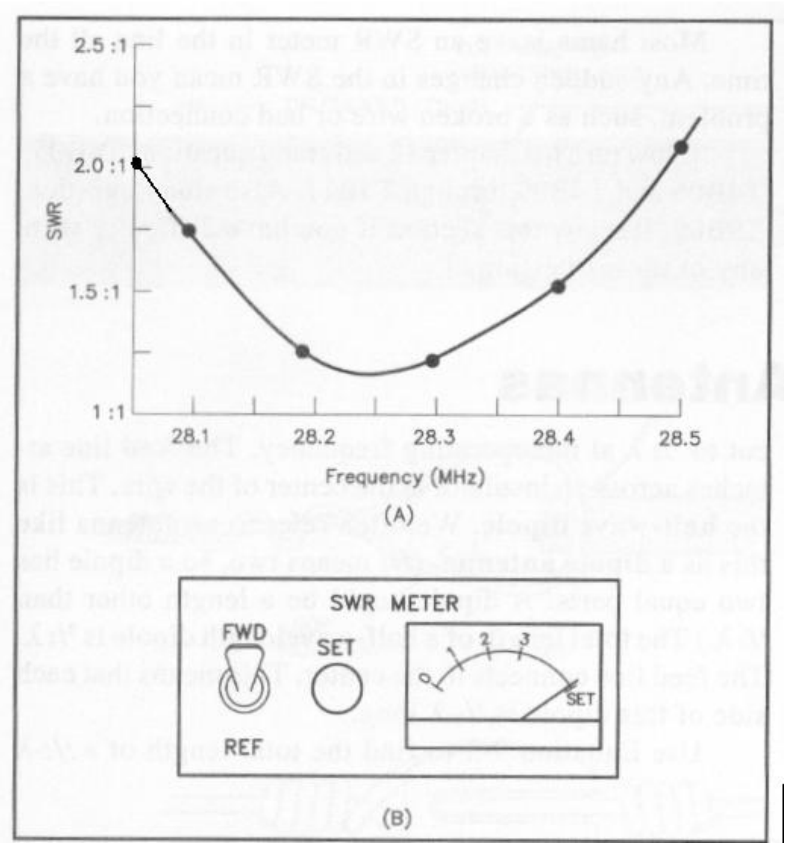
Elevation - Side View

Bandwidth

Pg. 9-8

- The bandwidth of an antenna is the frequency range over which it satisfies a particular performance requirement, often a SWR of 2:1 or less.

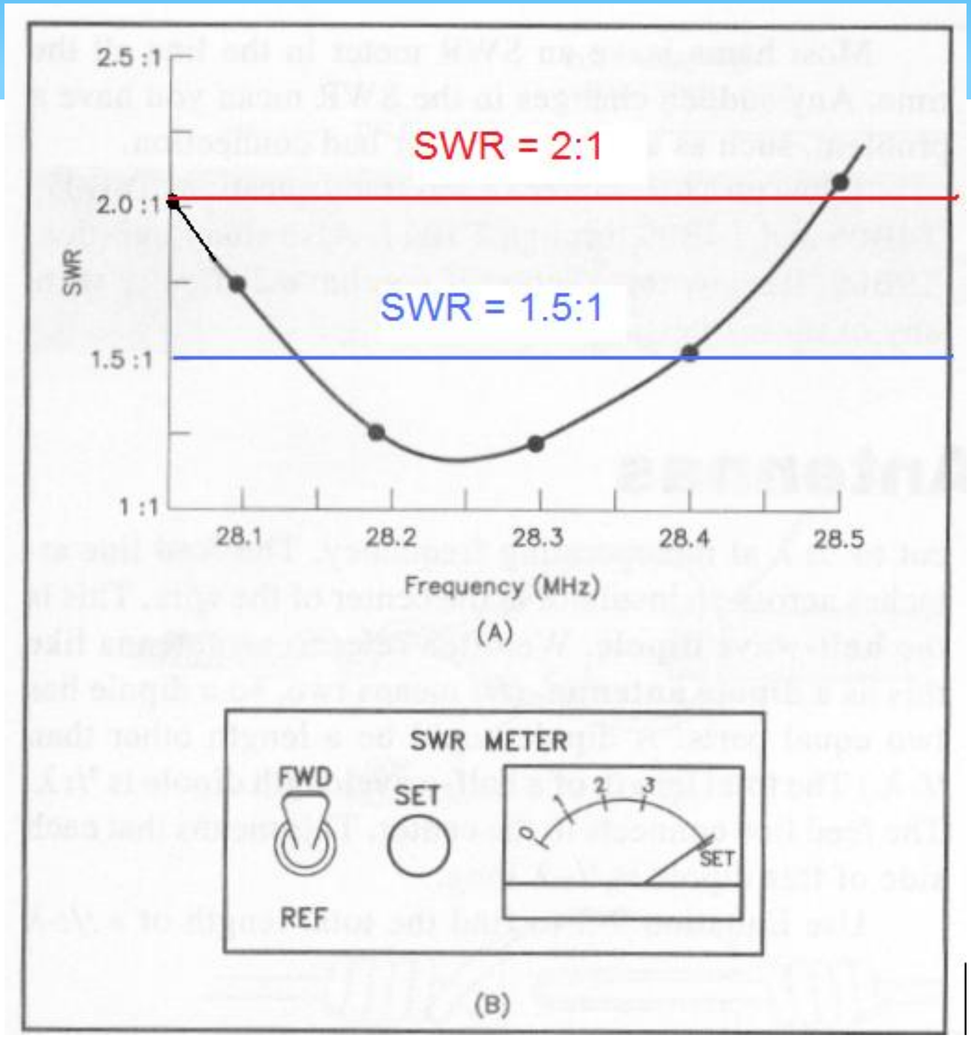
- The higher the antenna's Q, the narrower the SWR bandwidth.

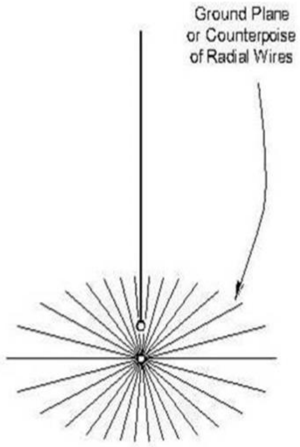


SWR Bandwidth

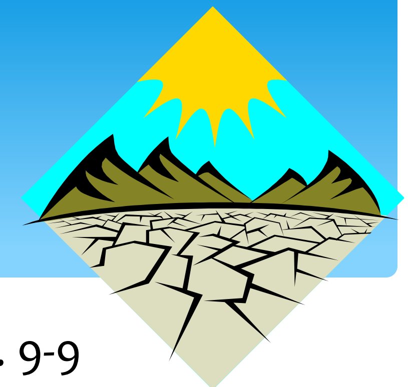
2:1 SWR is the highest SWR that most radios will work into properly. Some reduction in power may be observed

With a 1.5:1 SWR, most radios will deliver full power.



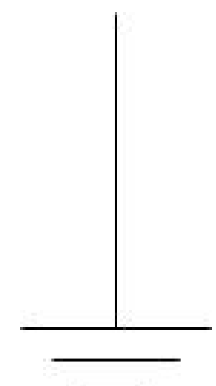


Effects of Ground

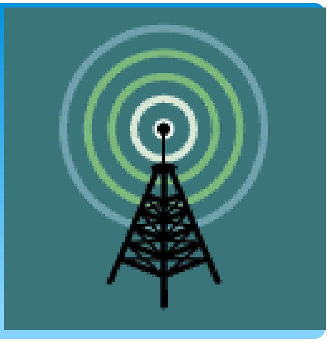


Pg. 9-9

* By far, the biggest effect on antenna systems is the losses in the nearby ground.
* Losses caused by low conductivity in the soil near the antenna dramatically reduce signal strengths at low angles.
* Low angle radiation from a vertically polarized antenna over seawater will be much stronger than over poorly conducting soil.
* Adding a radial system or a wire mesh will help.



Height Above Ground



Pgs. 9-10

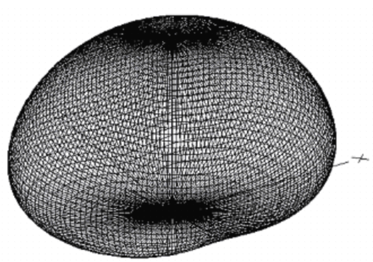
- In general, raising a horizontally polarized antenna off the ground decreases the vertical takeoff angle of lowest-angle lobe.
- Horizontally polarized antennas have less ground loss than ground-mounted vertical antennas.
- As Horizontal antennas are raised, the vertical angle of maximum radiation dips until a height a of ½ wavelength is reached.
- In general, mounting a horizontally polarized antenna as high as possible is a good rule (for long-range com).

Dipole Antennas Pattern

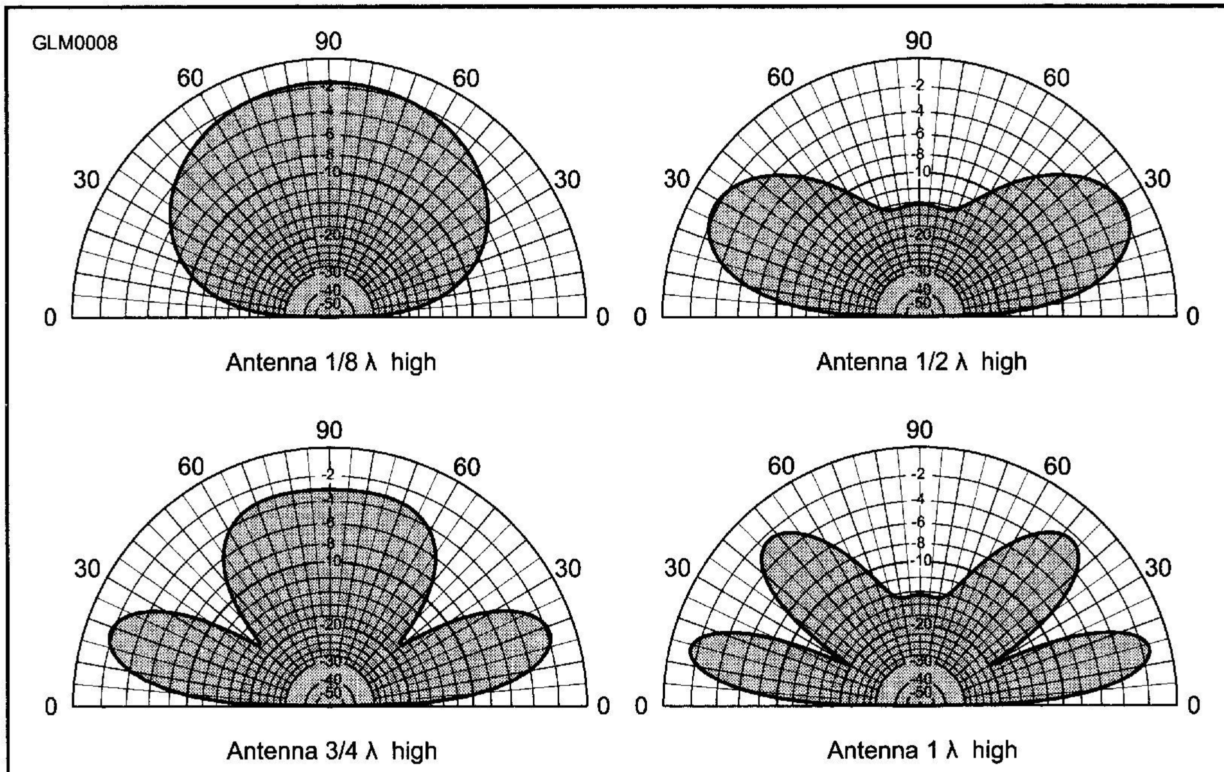
General Review

- **Patterns change as height above ground is varied**

Viewed from the end of the dipole



Omni-directional pattern



The Effects of Dipole Height

General Review

Broadside View | End View

Dashed lines show the pattern with no reflections from the ground

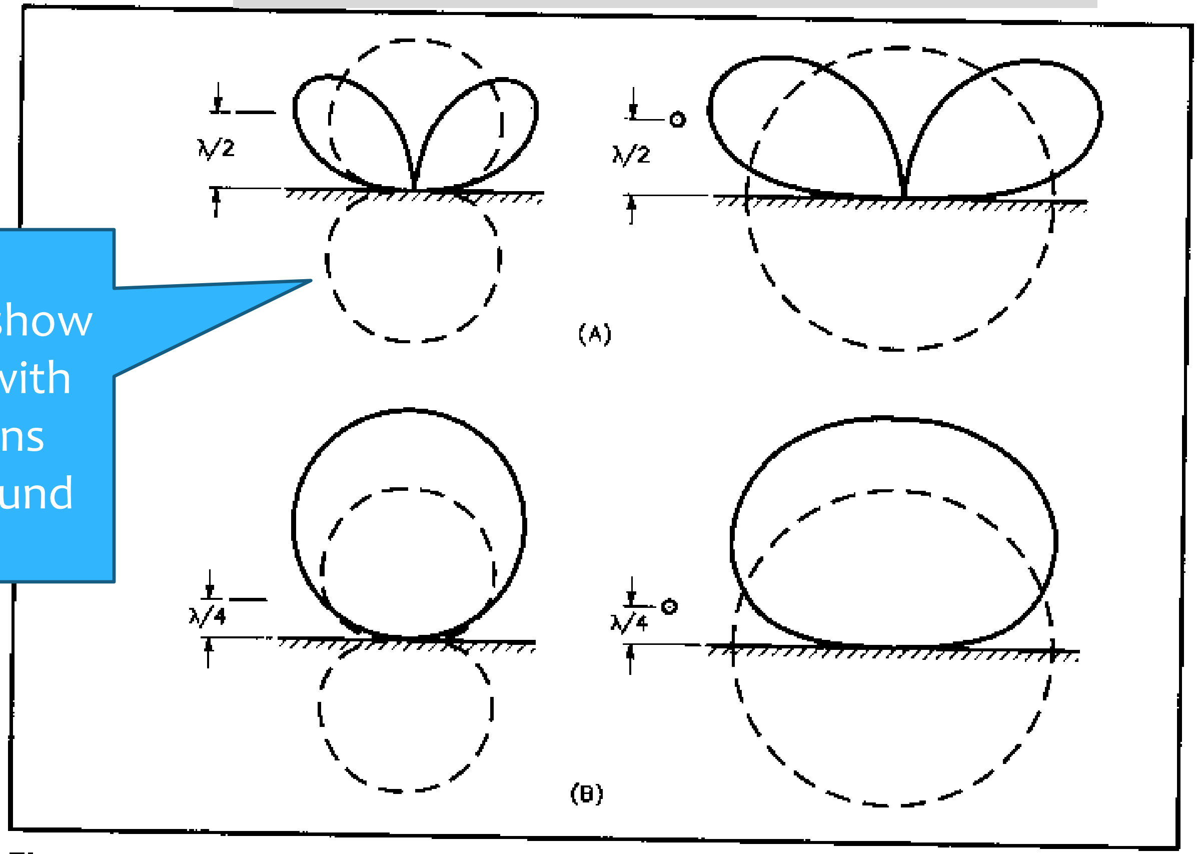
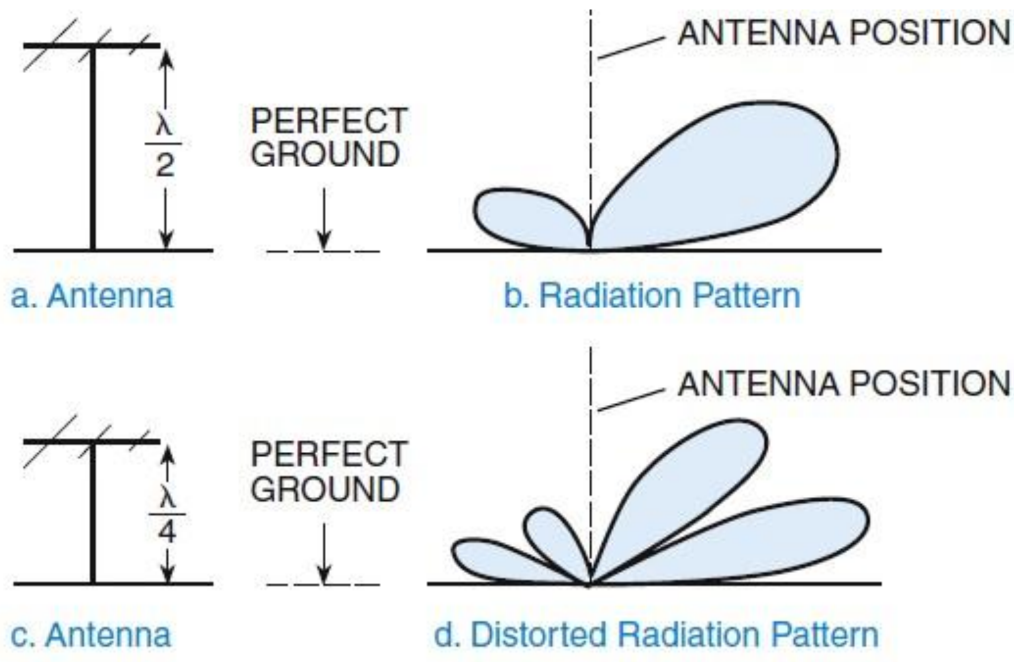


Figure 9-5 — The effect of ground on the radiation from a horizontal half-wavelength antenna, for heights of one-half (A) and one-quarter (B) wavelength is shown. The dashed lines show what the pattern would be if there were no reflection from the ground.

Effects of Height

* Those with a motorized telescopic tower can lower and raise the antenna to control the takeoff angle



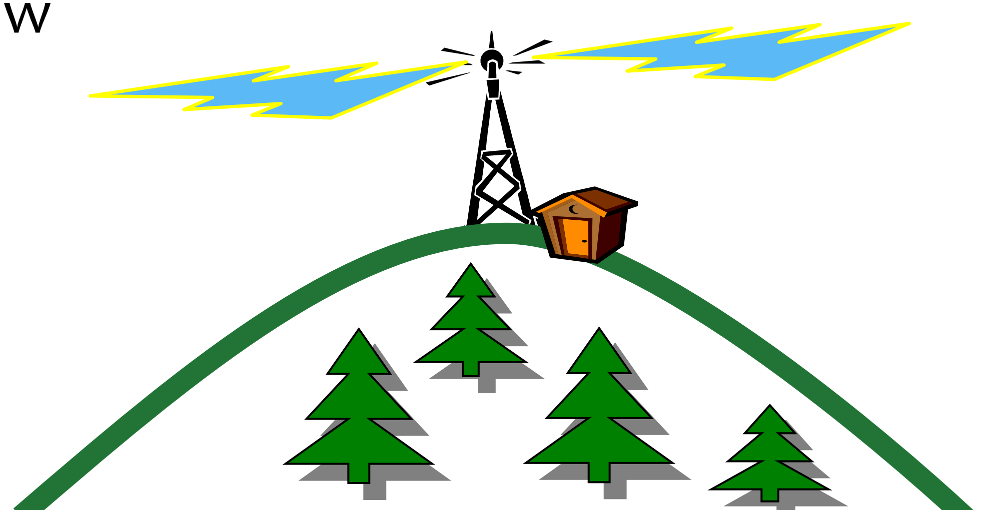
Radiation of 3-Element Yagi for Different Antenna Heights

Gordon West

Effects of Ground

Pg. 9-9

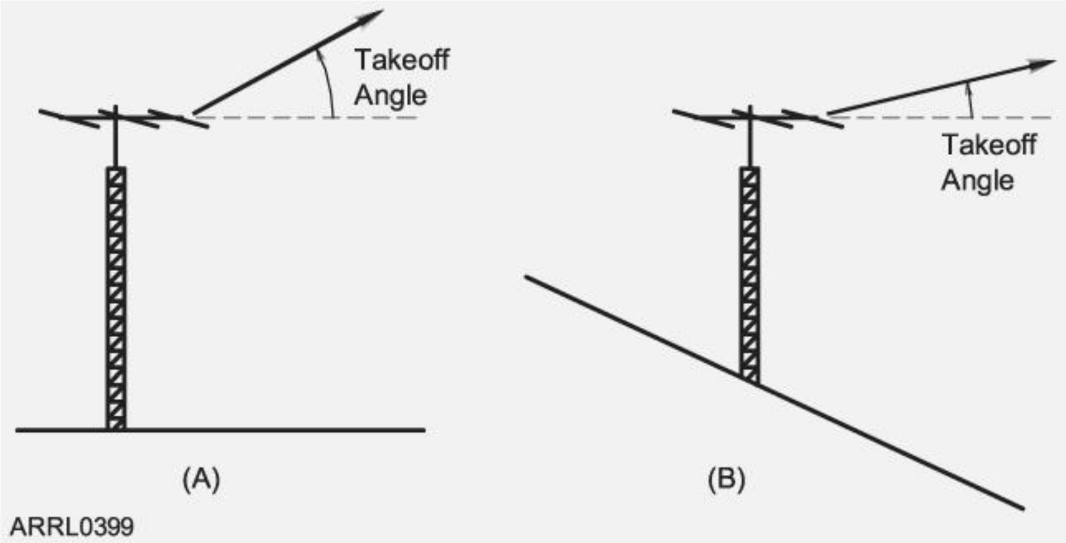
- The terrain on which an antenna is mounted affects both the azimuthal and elevation patterns.
- A hilltop is highly sought after for radio work because the reflections are either reduced or are more likely to reinforce the signal at low takeoff angles.



Living on a Slope

Pg. 9-9

* Hills and slopes have an effect on both the azimuthal and elevation patterns.
* The major takeoff angle will typically be lower in the direction of the slope.

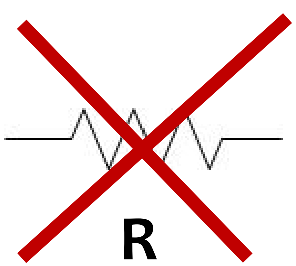


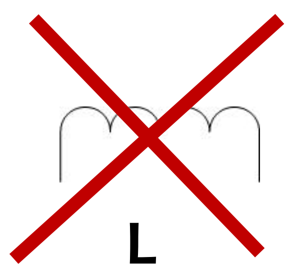
Grounding

Pg. 9-10

- The object is to create a path to ground that has as little impedance as possible.

- Wide flat copper straps are best for minimizing losses and the impedance of the stations RF ground system.

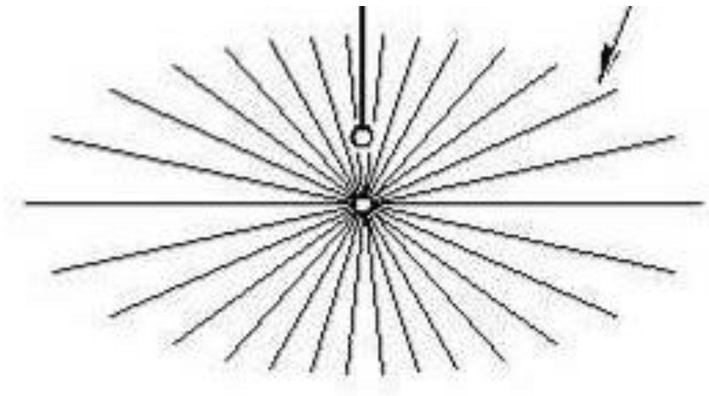




Grounding

Pg. 9-10

* The book says that 3 or 4 interconnected ground rods make a good RF ground for your station.
* K0NK says that you are far better off using radials for the RF ground.
* A ground rod is useful as a lightning ground.



W3yy.com

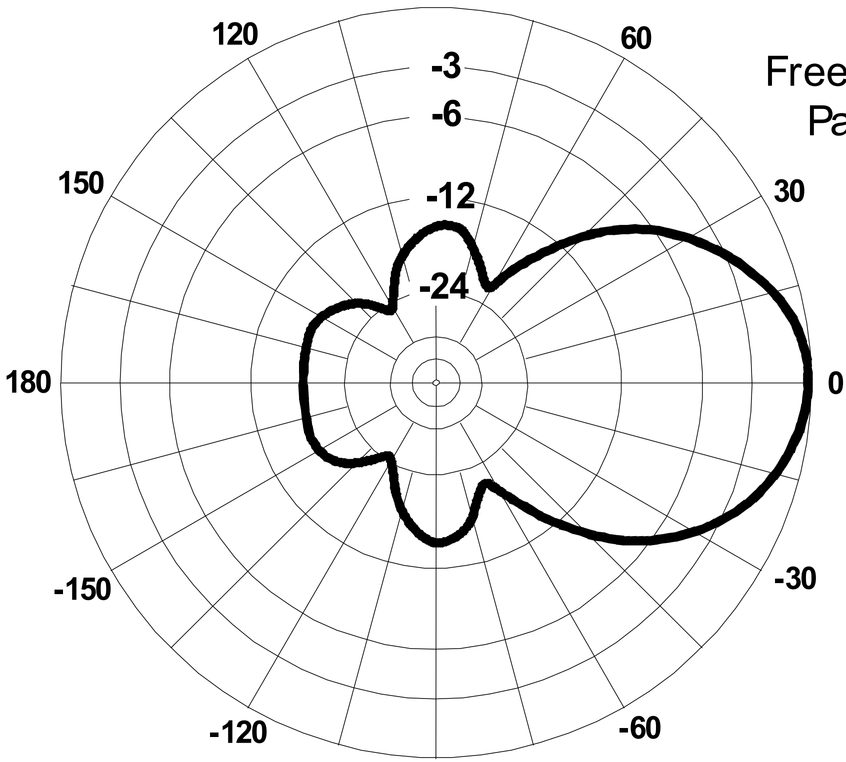
E9A12 How much gain does an antenna have compared to a 1/2-wavelength dipole when it has 6 dB gain over an isotropic antenna?

A. 3.85 dB
B. 6.0 dB
C. 8.15 dB
D. 2.79 dB

E9B02 In the antenna radiation pattern shown in Figure E9-1, what is the front-to-back ratio?

A. 36 dB
B. 18 dB
C. 24 dB
D. 14 dB

Figure E9-1



Next Week:

We finish off Chapter 9

* Practical Antennas
* Antenna Systems
* Transmission Lines
* Antenna Design