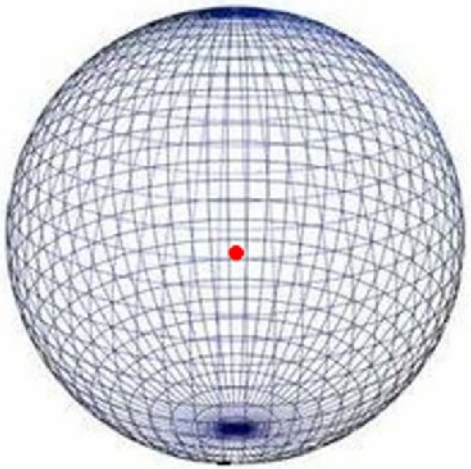
Using EZNEC To Compare Antennas Part 3

Bill Leonard N0CU

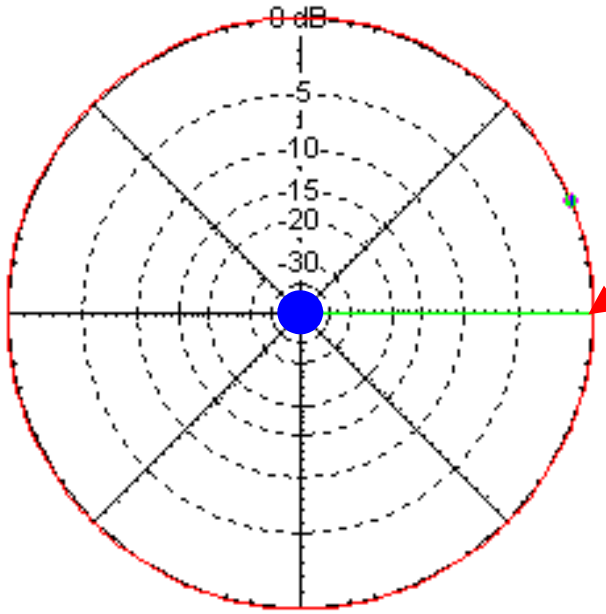
Topics

- **Isotropic radiator and dBi**
- **Reciprocity**
- **Antenna Directivity** vs. **Gain** vs. **Capture Area**
- **1/4λ Vertical (Monopole)**
- **Using EZNEC to calculate Antenna to Antenna Transmission Loss**
  - **Using this method to calculate receive antenna gain**

Isotropic Radiator in *Free Space*

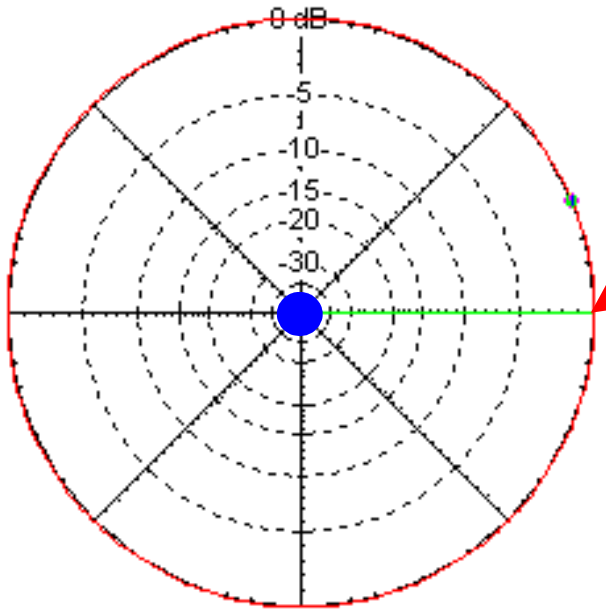


ELEVATION



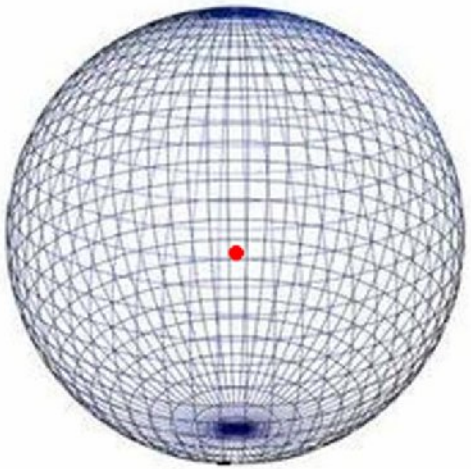
0 dBi

AZIMUTH

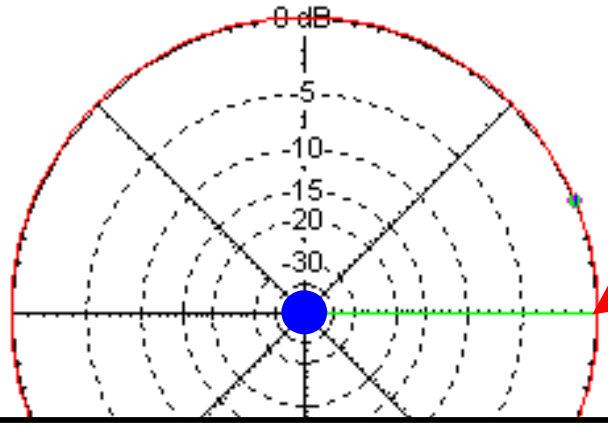


0 dBi

Isotropic Radiator in *Free Space*



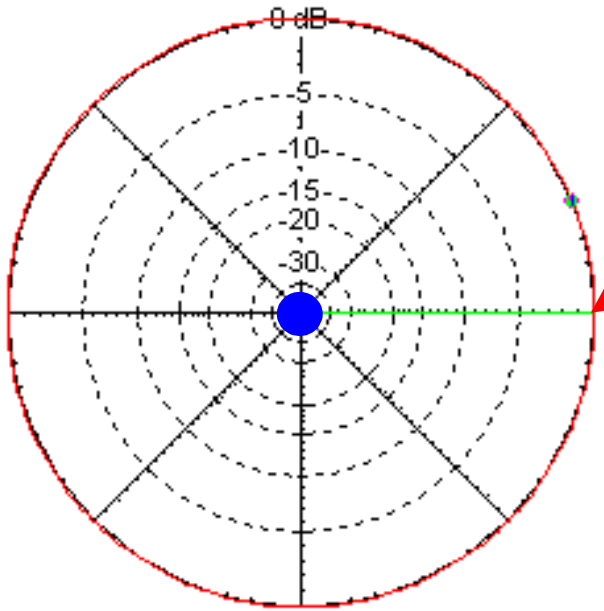
ELEVATION



0 dBi

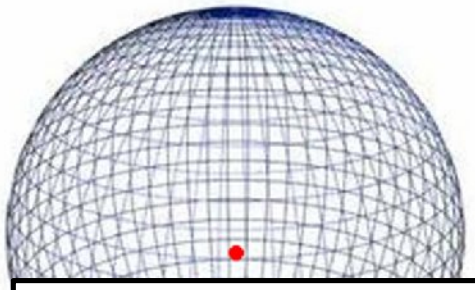
Elevation and Azimuth only having meaning when the x,y,z coordinates are defined!

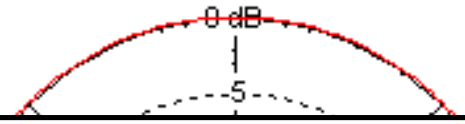
AZIMUTH



0 dBi

Isotropic Radiator in *Free Space*

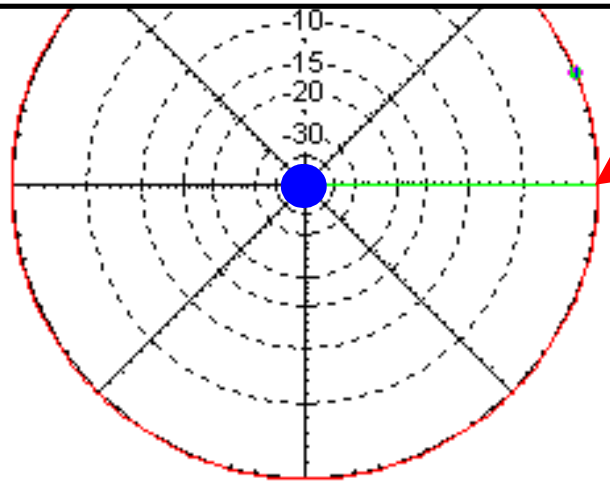




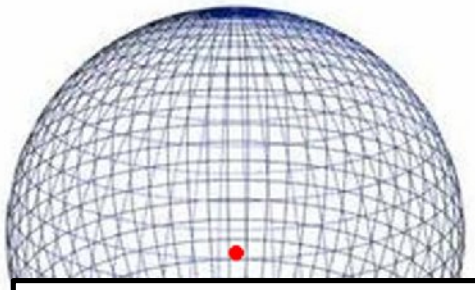
Isotropic Radiators:

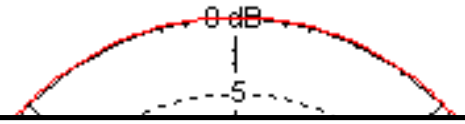
- Radiate **0 dBi** in ***all directions***
  - dBi is independent of source power or distance from source
- Assumes matched ***linear*** polarization
- Are always in ***free space***
  - ***No*** ground reflection gain (**GRG**)
  - This is a necessary condition for a reference antenna
- Only exist in theory

AZIMUTH



Isotropic Radiator in *Free Space*

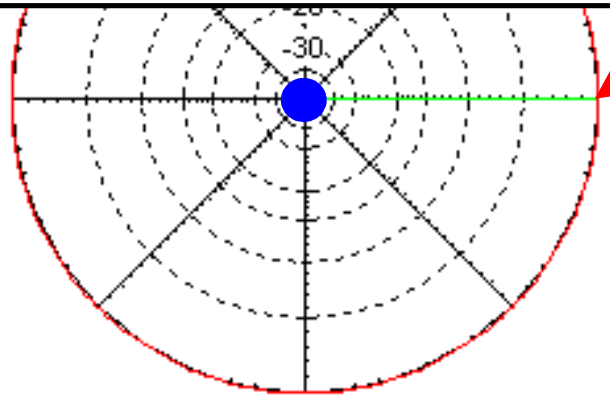




Isotropic Radiators:

- Radiate **0 dBi** in ***all directions***
  - dBi is independent of source power or distance from source
- Assumes matched ***linear*** polarization
- Are always in ***free space***
  - ***No*** ground reflection gain (**GRG**)
  - This is a necessary condition for a reference antenna
- Only exist in theory
  - "Hertzian Dipole" => 1.76 dBi

AZIMUTH



14.15 MHz

Reciprocity

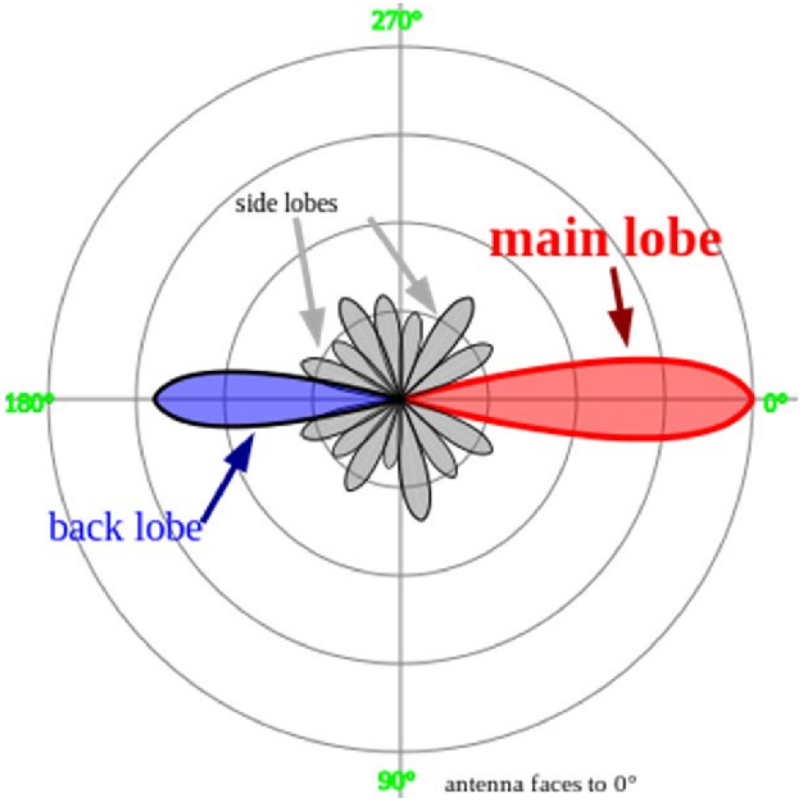
- **"Reciprocity is a fundamental property of *all* antennas."**

Reciprocity

- "Reciprocity is a fundamental property of ***all*** antennas."
- Reciprocity: "the electrical characteristics of an antenna are the same whether the antenna is transmitting or receiving":
  - Gain
  - Radiation Pattern
  - Impedance
  - Bandwidth
  - Resonant Frequency
  - Polarization

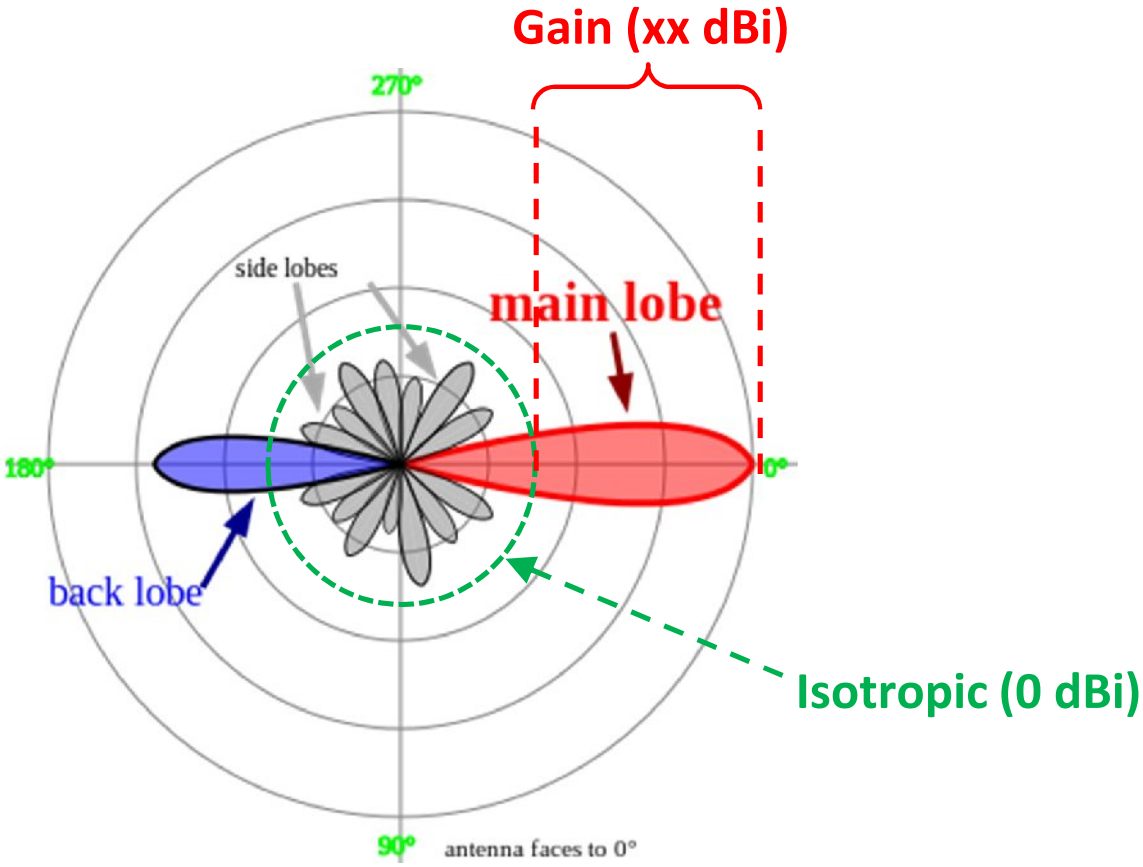
Antenna Directivity vs. **Gain** vs. **Capture Area**

- **Directivity (D)**: how much more power an antenna radiates compared to an isotropic ***radiator*** (*ignoring* any *losses*)
- **Gain (G)**: how much more power an antenna ***radiates*** compared to an isotropic ***radiator*** (*including* any *losses*)



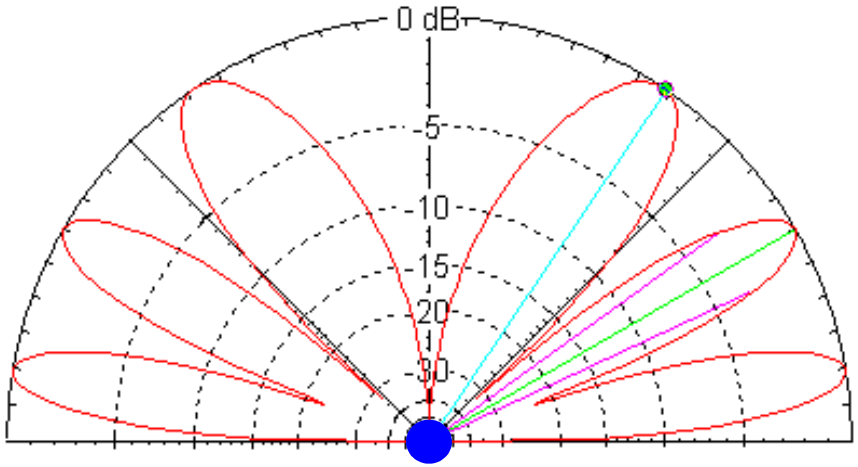
Antenna Directivity vs. **Gain** vs. **Capture Area**

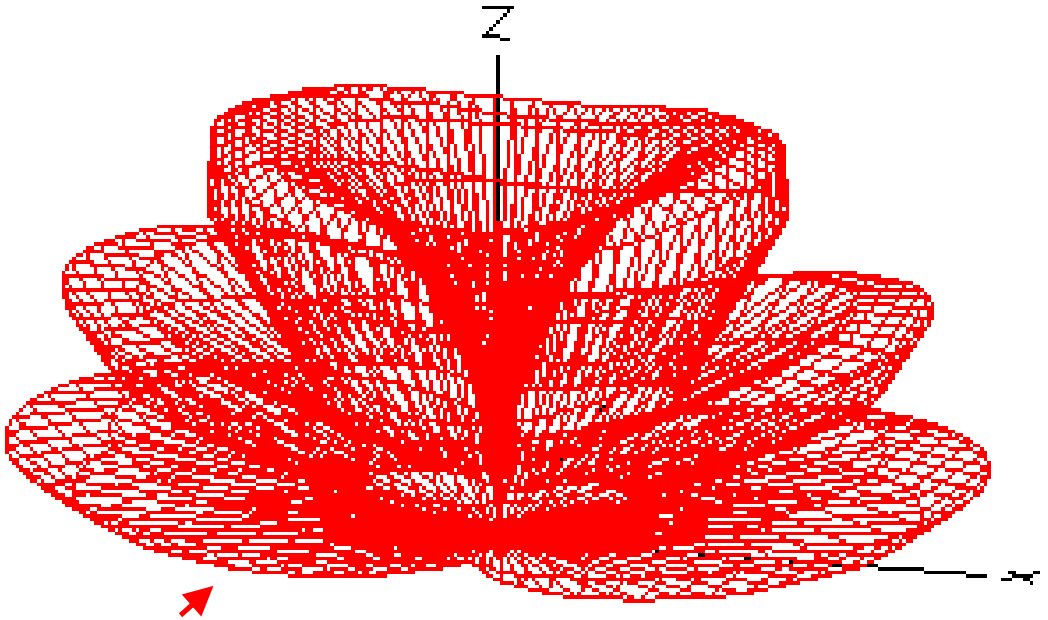
- **Directivity (D)**: how much more power an antenna radiates compared to an isotropic ***radiator*** (*ignoring* any *losses*)
- **Gain (G)**: how much more power an antenna ***radiates*** compared to an isotropic ***radiator*** (*including* any *losses*)



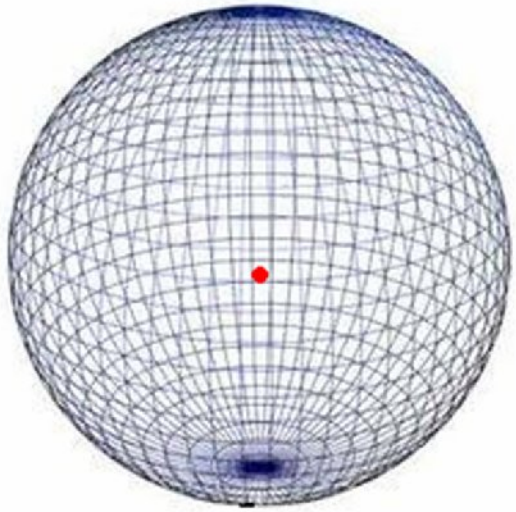
Antenna Patterns Are Three Dimensional

Horizontal Dipole 1.5λ Above Perfect Ground





Equal Volumes



Antenna Directivity vs. **Gain** vs. **Capture Area**

- **Capture Area (A_e)**: the area of an isotropic antenna that would ***receive*** the same power as the real antenna

$$A_e = \frac{G_r \times \lambda^2}{4\pi}$$

λ = Wavelength

G_r = Receive antenna gain

- **Gain** is defined using a **TRANSMIT** antenna
- **Capture Area** is defined using a **RECEIVE** antenna

1/4λ Vertical (Monopole)

- **Transmit Antenna Pattern:**
  - Identical to the top half of a dipole pattern. This means that all of the input power is radiated into half the space of a dipole antenna. Therefore, the monopole antenna will have a gain of twice (3 dB over) the gain of a similar dipole antenna.

    Peak gain =5.16 dBi (2.15 dBi + 3.01 dB)
  - **Shape of pattern is unchanged => no ground reflections**

- **Radiation resistance:**
  - Since the current flows in only half of the antenna, the net radiation resistance the current sees is half that of a dipole.

    Radiation resistance = 36.8 ohms (73.6/2)

1/4λ Vertical (Monopole)

- **Transmit Antenna Pattern:**
  - Identical to the top half of a dipole pattern. This means that all of the input power is radiated into half the space
  - will have a gain of twice (3 dB over) the gain of a similar dipole antenna.

    Peak gain =5.16 dBi (2.15 dBi + 3.01 dB)
  - **Shape of pattern is unchanged => no ground reflections**

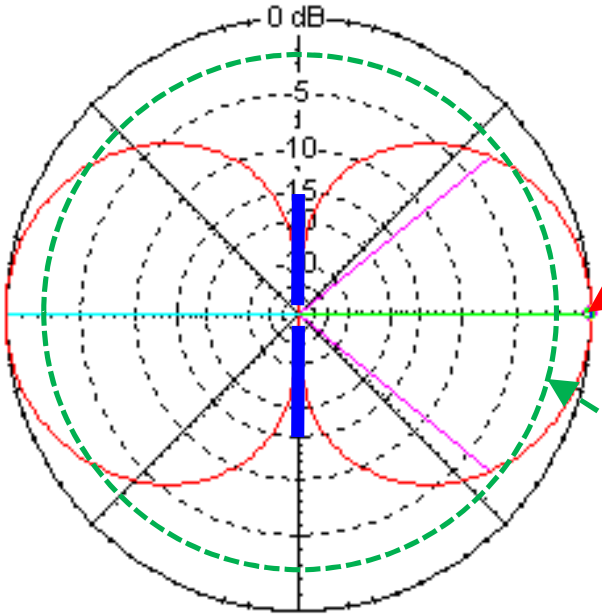
Not a very convincing explanation!

- **Radiation resistance:**
  - Since the current flows in only half of the antenna, the net radiation resistance the current sees is half that of a dipole.

    Radiation resistance = 36.8 ohms (73.6/2)

1/4λ Monople vs. Dipole

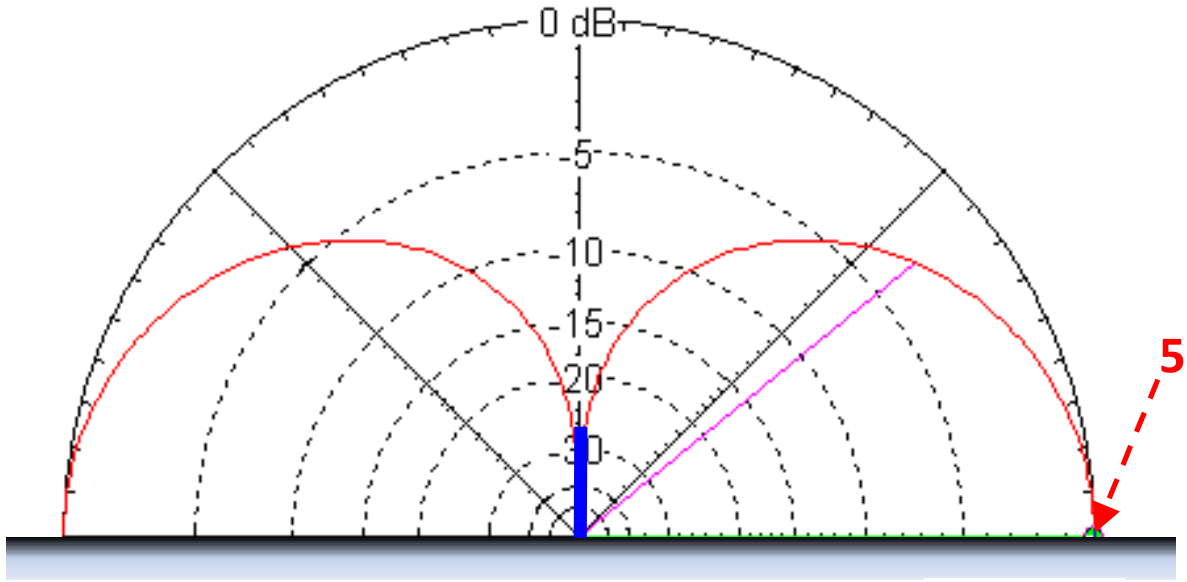
Dipole in Free Space



2.15 dBi

Isotropic (0 dBi)

Monopole over Perfect Ground

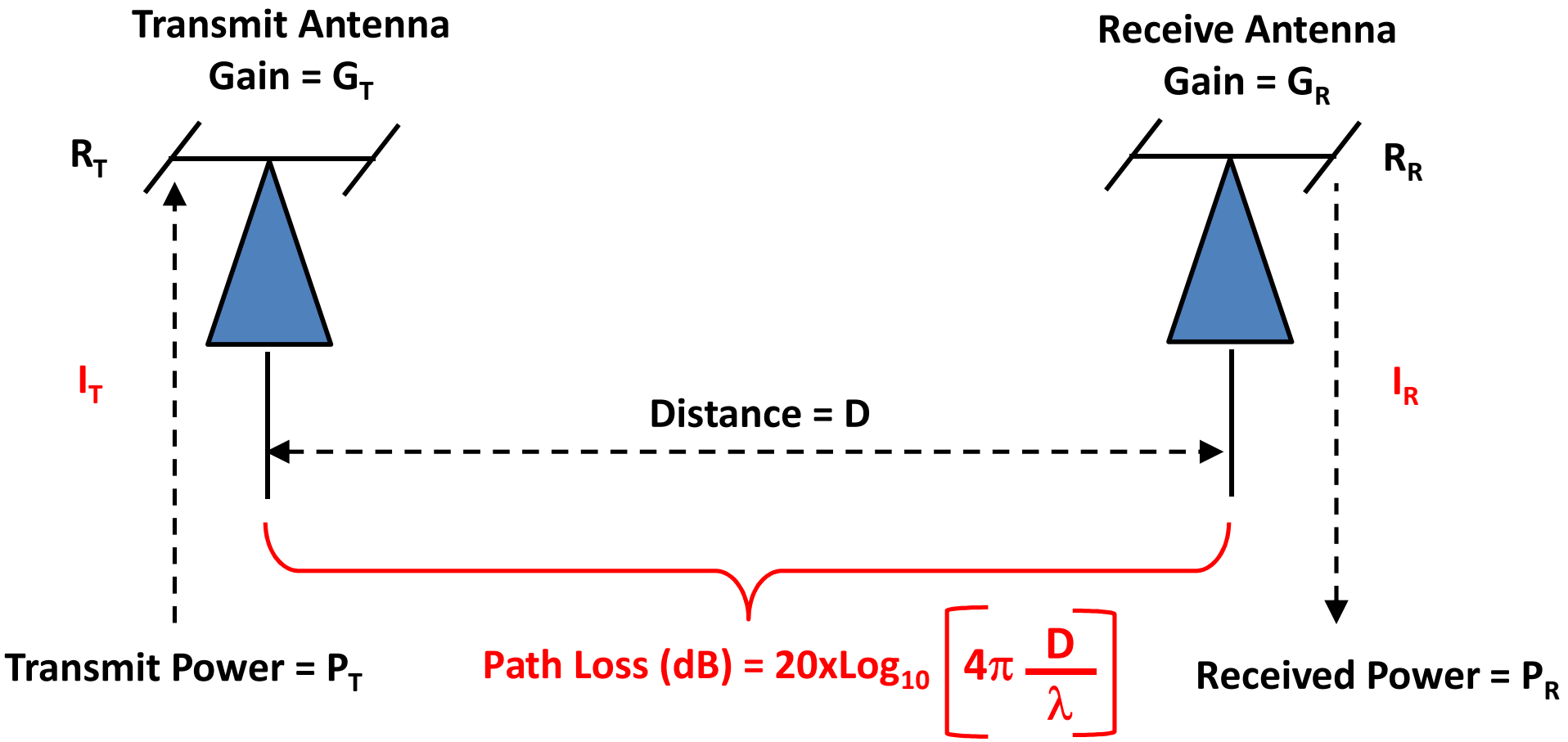


5.16 dBi

Antenna Directivities & Capture Areas

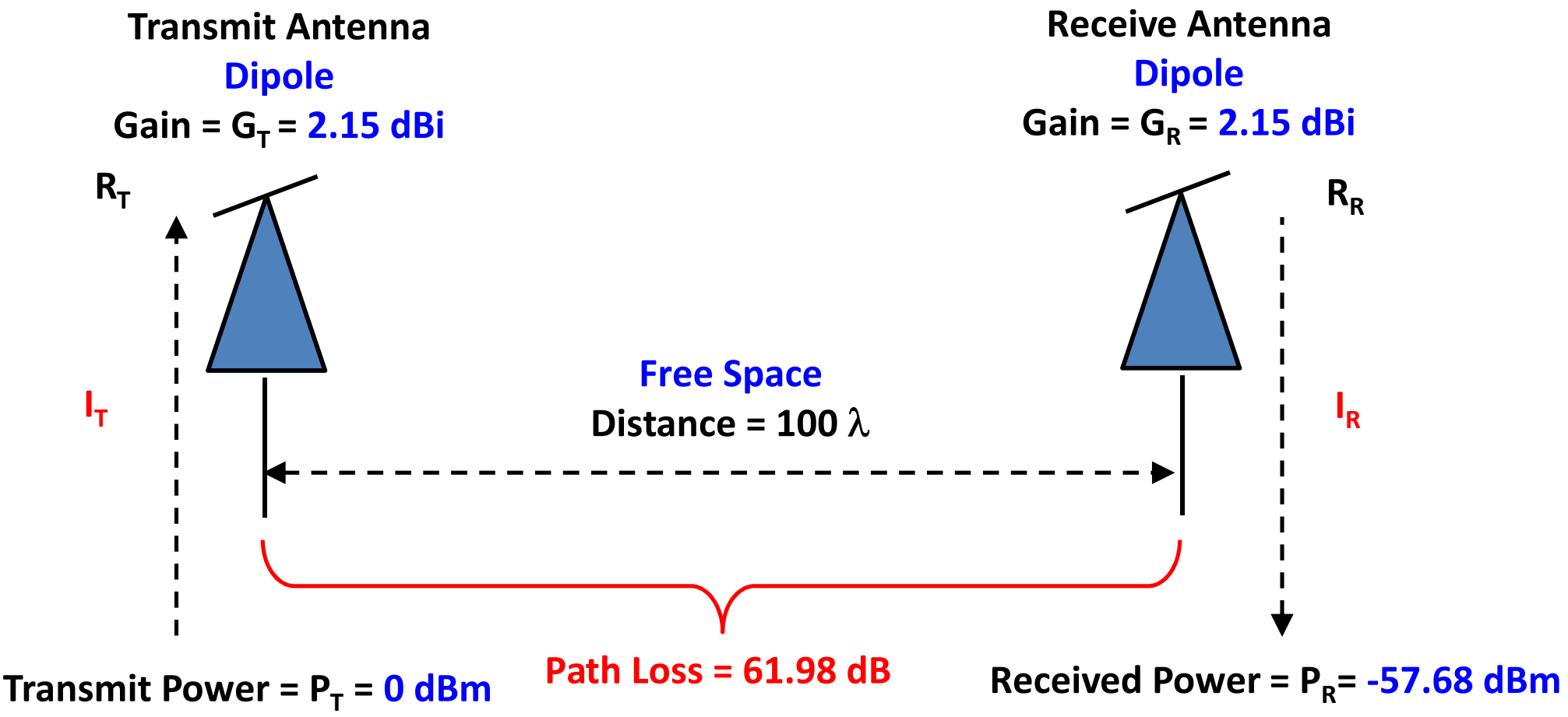
Antenna Type	Medium	Directivity		Capture Area (Ae)
			dBi	
Isotropic	Free Space	1	0	$0.0796\lambda^2$
Dipole	Free Space	1.64	2.15	$0.1305\lambda^2$
Full λ Loop	Free Space	2.14	3.30	$0.1703\lambda^2$
1/4λ Monopole	Perfect Gnd	3.28	5.16	$0.2610\lambda^2$

Antenna to Antenna Transmission Comparison



$$\text{Transmission Loss (dB)} = P_T(\text{dBm}) - P_R(\text{dBm})$$
$$= \text{Path Loss (dB)} - G_T(\text{dBi}) - G_R(\text{dBi})$$

Dipole to Dipole Transmission Comparison



$$\text{Transmission Loss (dB)} = P_T(\text{dBm}) - P_R(\text{dBm})$$
$$= \text{Path Loss (dB)} - G_T(\text{dBi}) - G_R(\text{dBi})$$
$$= 62 \text{ dB} - 2.15 \text{ dBi} - 2.15 \text{ dBi}$$
$$= 57.68 \text{ dB}$$

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68		4.30	**2.15**	**0.00**

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40		6.57	**3.28**	**0.01**

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Perfect Ground

Transmit Antenna		Receive Antenna Type	Height Above Ground**	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
1/4λ Monopole	**5.16**	1/4λ Monopole	0.0λ	-61.98	-51.66		10.32	**5.16**	**0.00**

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Perfect Ground

Transmit Antenna		Receive Antenna Type	Height Above Ground**	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
1/4λ Monopole	**5.16**	1/4λ Monopole	0.0λ	-61.98	-51.66	**-57.69**			

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Perfect Ground

Transmit Antenna		Receive Antenna Type	Height Above Ground**	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
1/4λ Monopole	**5.16**	1/4λ Monopole	0.0λ	-61.98	-51.66	**-57.69**	**4.30**		

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Perfect Ground

Transmit Antenna		Receive Antenna Type	Height Above Ground**	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
1/4λ Monopole	**5.16**	1/4λ Monopole	0.0λ	-61.98	-51.66	**-57.69**	**4.30**	**-0.86**	**6.02**

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Perfect Ground

Transmit Antenna		Receive Antenna Type	Height Above Ground**	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
1/4λ Monopole	**5.16**	1/4λ Monopole	0.0λ	-61.98	-51.66	**-57.69**	**4.30**	**-0.86**	**6.02**

Antenna to Antenna Transmission Comparison

- The gain of a transmitting monopole is twice the gain (+3 dB) of an equivalent transmitting dipole
- The effective capture area of a monopole is one-half (-3 dB) the effective capture area of an equivalent receiving dipole
  - If a monopole and an equivalent dipole are immersed in identical fields, the monopole will deliver *half* as much power to the receiver as the dipole

Antenna to Antenna Transmission Comparison

Free Space

Transmit Antenna		Receive Antenna Type	Height Above Ground	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
Dipole	**2.15**	Dipole	N/A	-61.98	-57.68	-57.69	4.30	**2.15**	**0.00**
Full λ Loop	**3.29**	Full λ Loop	N/A	-61.98	-55.40	-55.42	6.57	**3.28**	**0.01**

Perfect Ground

Transmit Antenna		Receive Antenna Type	Height Above Ground**	Path Loss	Transmission Loss		Net Antenna Gain	Receive Antenna Gain	Tx-Rx Ant Gain Differential
					Predicted	EZNEC			
Type	Gain (dBi)			dB	dB	dB	dBi	dBi	dB
1/4λ Monopole	**5.16**	1/4λ Monopole	0.0λ	-61.98	-51.66	-57.69	4.30	**-0.86**	**6.02**
Dipole (Vert)	**8.41**	Dipole (Vert)	1/2λ	-61.98	-45.16	-51.18	10.80	**2.39**	**6.02**
Dipole (Vert)	**8.20**	Dipole (Vert)	1λ	-61.98	-45.58	-51.60	10.38	**2.18**	**6.02**
Full λ Loop	**9.62**	Full λ Loop	1/2λ	-61.98	-42.74	-48.74	13.24	**3.62**	**6.00**

Articles That Address The 6 dB Discrepency

Reference 1:

"Dipole and Monopole Antenna Gain and Effective Area for Communication Formulas"
by J. C. Logan & J. W. Rockway

NAVAL COMMAND, CONTROL AND OCEAN SURVEILLANCE CENTER RDT&E DIVISION
Technical Report 1756, September 1997
http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA332891

Reference 2:

"**Vertically Polarized Dipoles and Monopoles, Directivity, Effective Height and Antenna Factor**" by Trainotti & Figueroa

IEEE Transactions on Broadcasting Sept 2010

(http://svn2.assembla.com/svn/tesis_gfigueroa/paper_BTS-09-143/paper/paper.pdf)

Reference 2 Conclusions

“…the Received Power in a link between two dipole antennas in free space or between two monopole antennas over a perfect ground is of the same value in the far field region.

For *two monopoles over perfect ground*, the “Transmitting and receiving directivity relationship corresponds to $D_{TM} - D_{RM} = 5.15 - (-0.89) = 6.04 = 6dB$ or *the transmitting antenna directivity is 6dB higher than the receiving antenna directivity*.”

“...only in free space are the transmitting and receiving antenna directivities the same value for physically identical antennas.”

Reference 2 Conclusions

"…the Received Power in a link between two dipole antennas in free space or between two monopole antennas over a perfect ground is of the same value in the far field region.

For *two monopoles over perfect ground*, the "Transmitting and receiving directivity relationship corresponds to $D_{TM} - D_{RM} = 5.15 - (-0.89) = 6.04 = 6dB$ or *the transmitting antenna directivity is 6dB higher than the receiving antenna directivity*."

"...only in free space are the transmitting and receiving antenna directivities the same value for physically identical antennas."

Reference 2 Conclusions

"…the Received Power in a link between two dipole antennas in free space or between two monopole antennas over a perfect ground is of the same value in the far field region.

For *two monopoles over perfect ground*, the "Transmitting and receiving directivity relationship corresponds to $D_{TM} - D_{RM} = 5.15 - (-0.89) = 6.04 = 6dB$ or *the transmitting antenna directivity is 6dB higher than the receiving antenna directivity*."

"...only in free space are the transmitting and receiving antenna directivities the same value for physically identical antennas."

Reference 2 Conclusions

Reciprocity only holds for identical antennas in *Free Space*!

"…the R…tween two mo…d region.

For *two monopoles over perfect ground*, the "Transmitting and receiving directivity relationship corresponds to $D_{TM} - D_{RM} = 5.15 - (-0.89) = 6.04 = 6dB$ or *the transmitting antenna directivity is 6dB higher than the receiving antenna directivity*."

"...only in free space are the transmitting and receiving antenna directivities the same value for physically identical antennas."