Automation Committee

American Water Works Association
Florida Section

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SCADA Radio Telemetry 101

Module 1: Antennas

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SCADA Radio Telemetry 101

Module 1: Antennas

By Rick Nelson & Wayne Wilson

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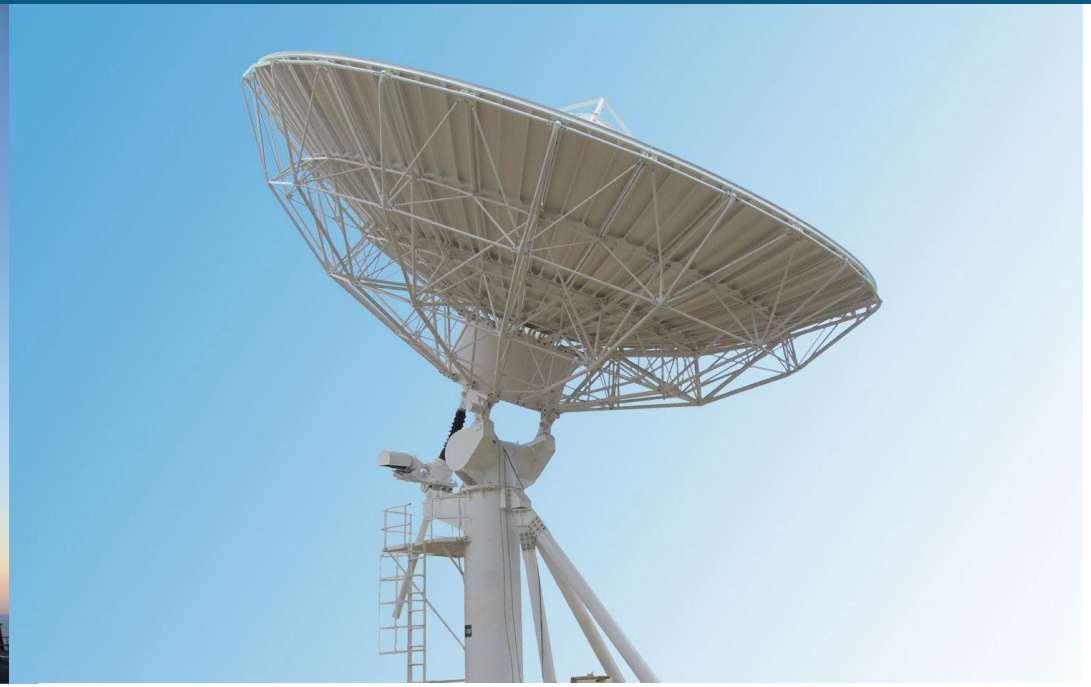
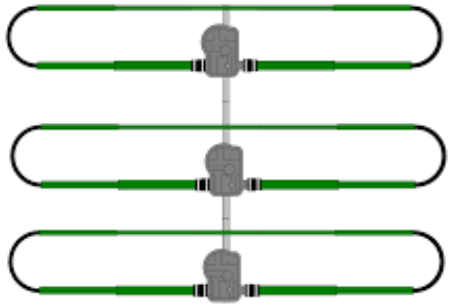
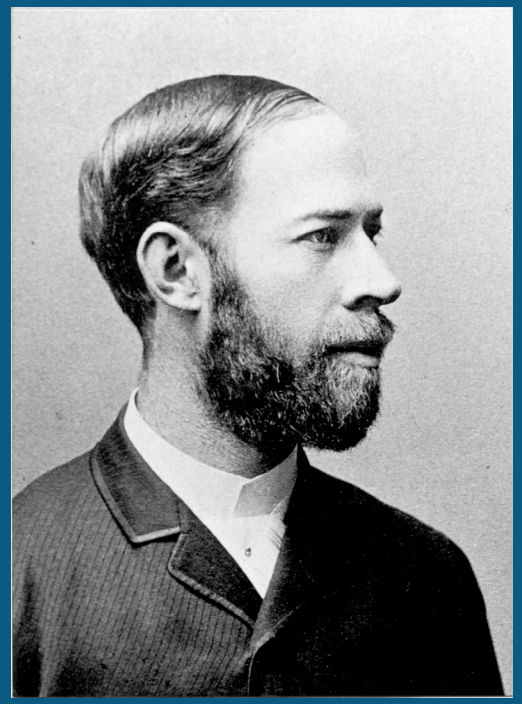
Antennas are essential components of all radio equipment, and are used in radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, satellite communications, and other devices.

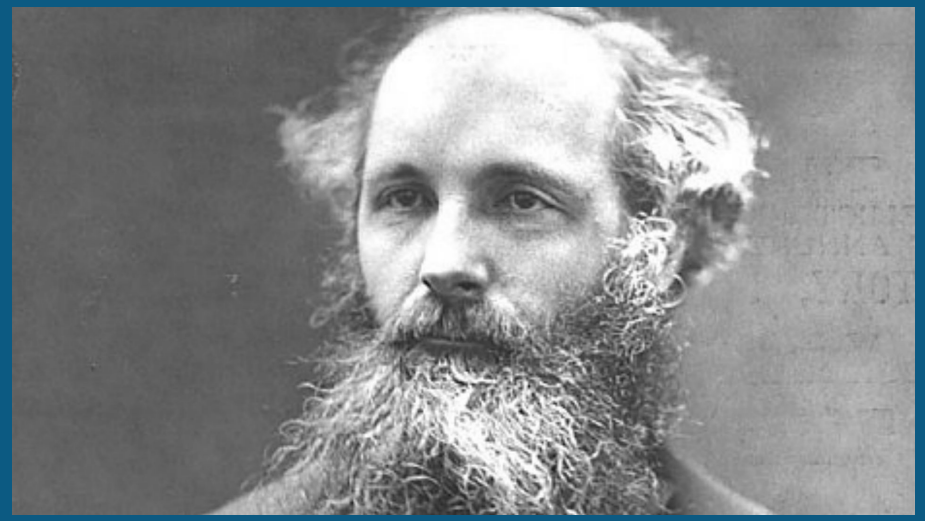




The first antennas were built in 1888 by German physicist Heinrich Hertz in his pioneering experiments to prove the existence of electromagnetic waves predicted by the theory of James Clark Maxwell.



Heinrich Hertz
22 February 1857 – 1 January 1894



James Clark Maxwell
13 June 1831 – 5 November 1879

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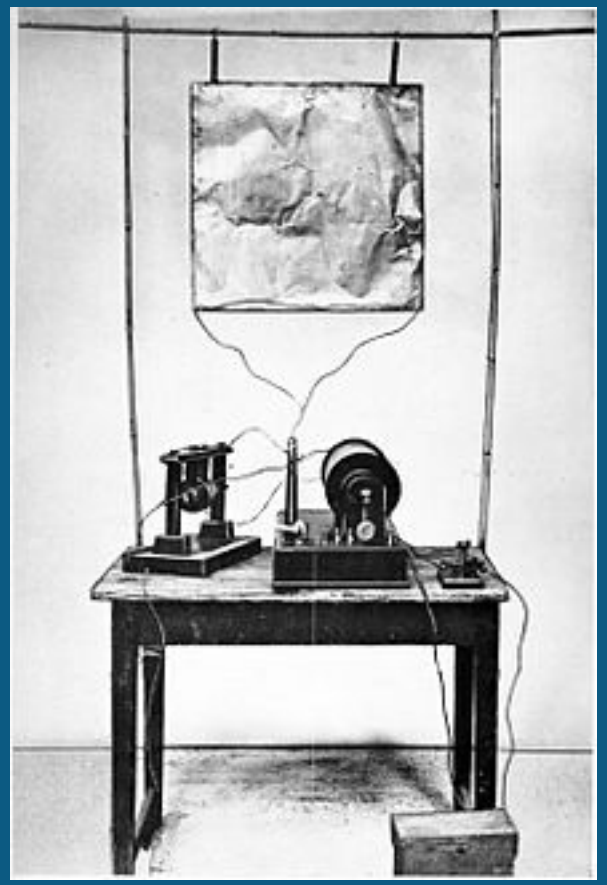
Guglielmo Marconi,
25 April 1874 – 20 July 1937

The monopole antenna reduced the frequency of the waves compared to the dipole antennas used by Hertz, and radiated vertically polarized radio waves which could travel longer distances.

Marconi's experimental apparatus proved to be the first engineering-complete, commercially successful radio transmission system.



Marconi's first transmitter incorporating a monopole antenna. It consisted of an elevated copper sheet

Goals

- To understand the various properties of antennas, so as to be able to choose the proper antenna for a particular application.
- Antennas are the interface between guided waves (from a cable) and unguided waves (in space).
- Realize that not all kinds of cable are appropriate for use with wireless systems.
- Identify different kinds of cable connectors and understand when each kind is needed.

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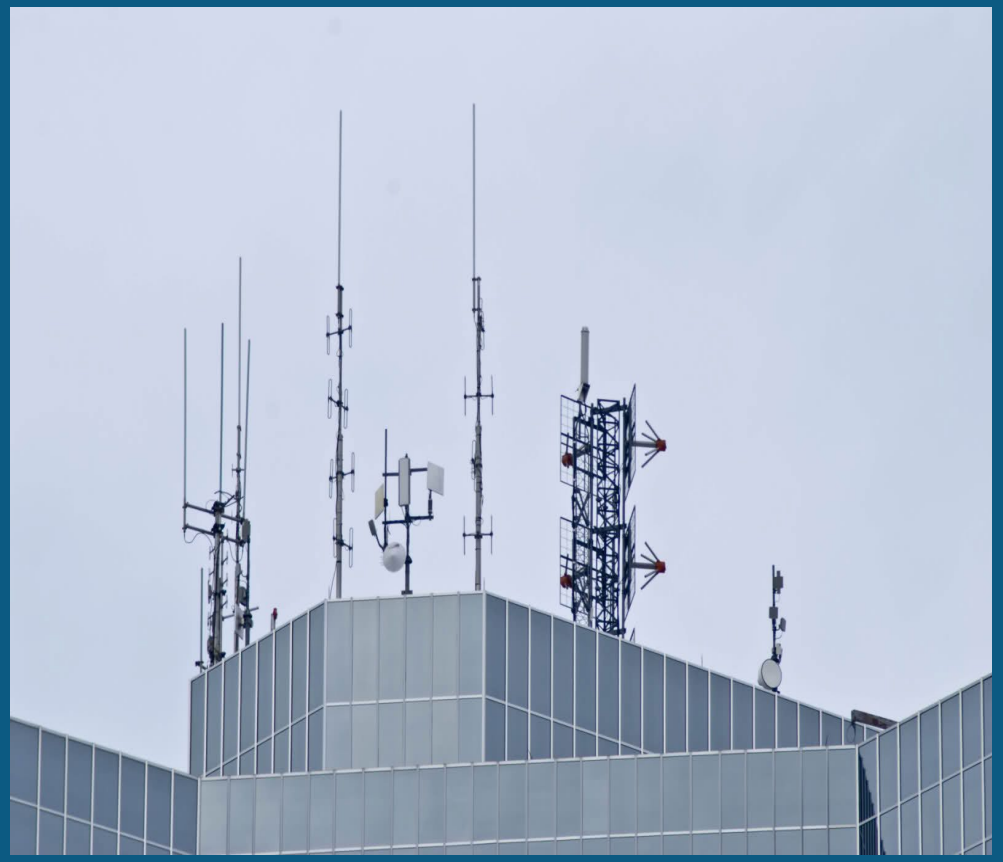
Antennas & Transmission lines

- An antenna is the structure associated with the region of transition from a guided wave to a free space wave, radiating RF energy.

- A transmission line is the device used to guide radio frequency (RF) energy from one point to another (for example a coaxial cable).



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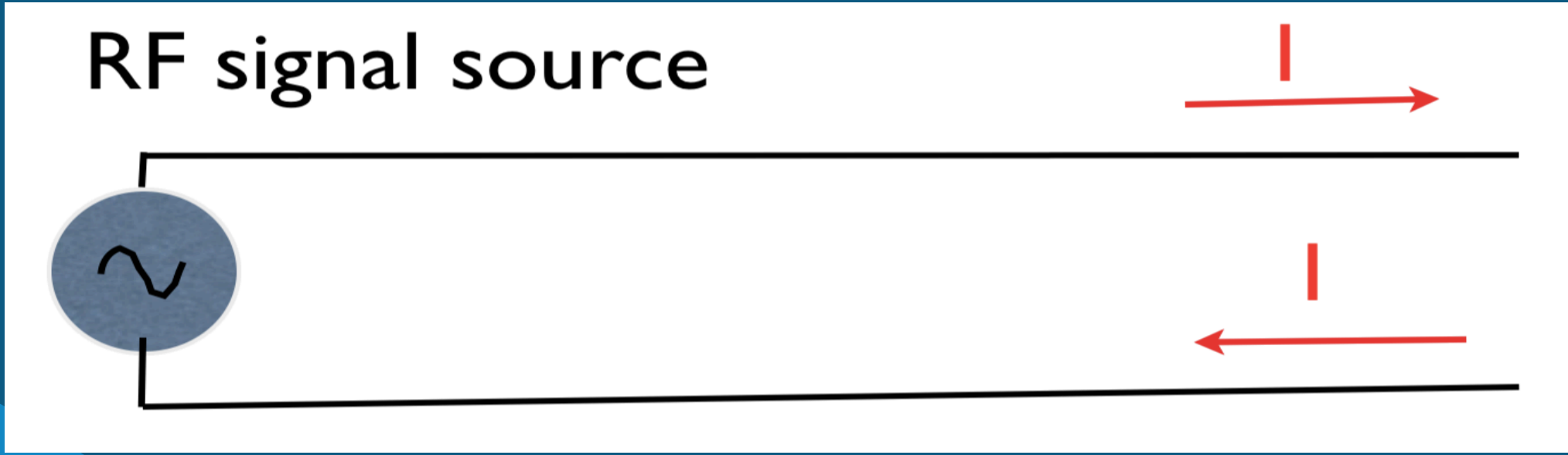
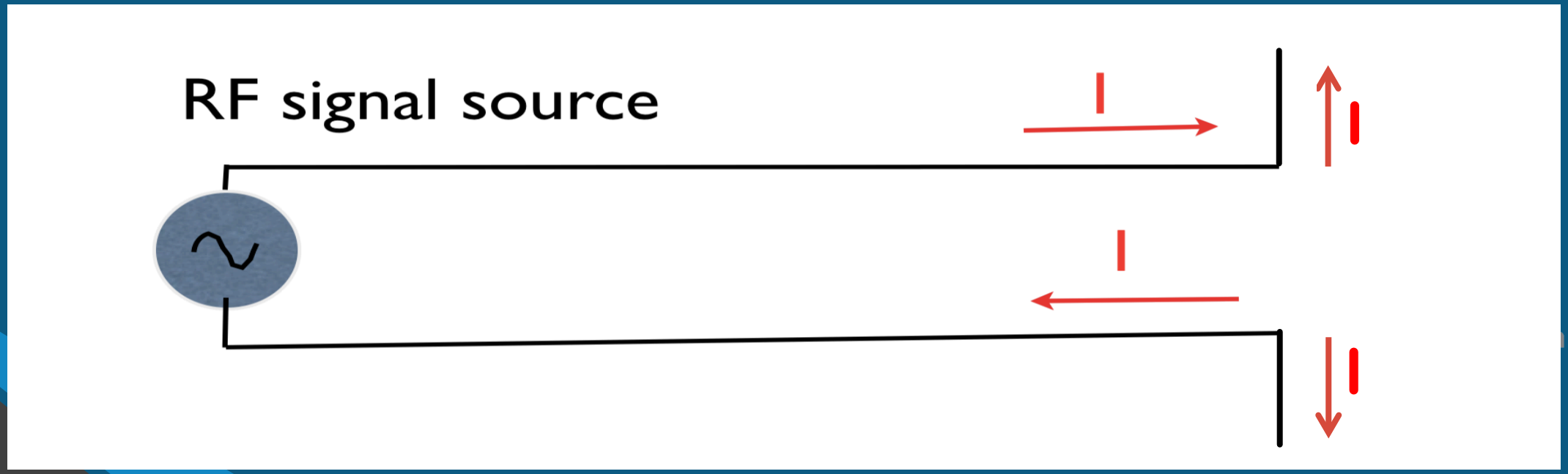
Bifilar transmission lines

Bifilar transmission lines are formed by two conductor wires separated by a dielectric. There can be an alternating current even in an open ended transmission line.

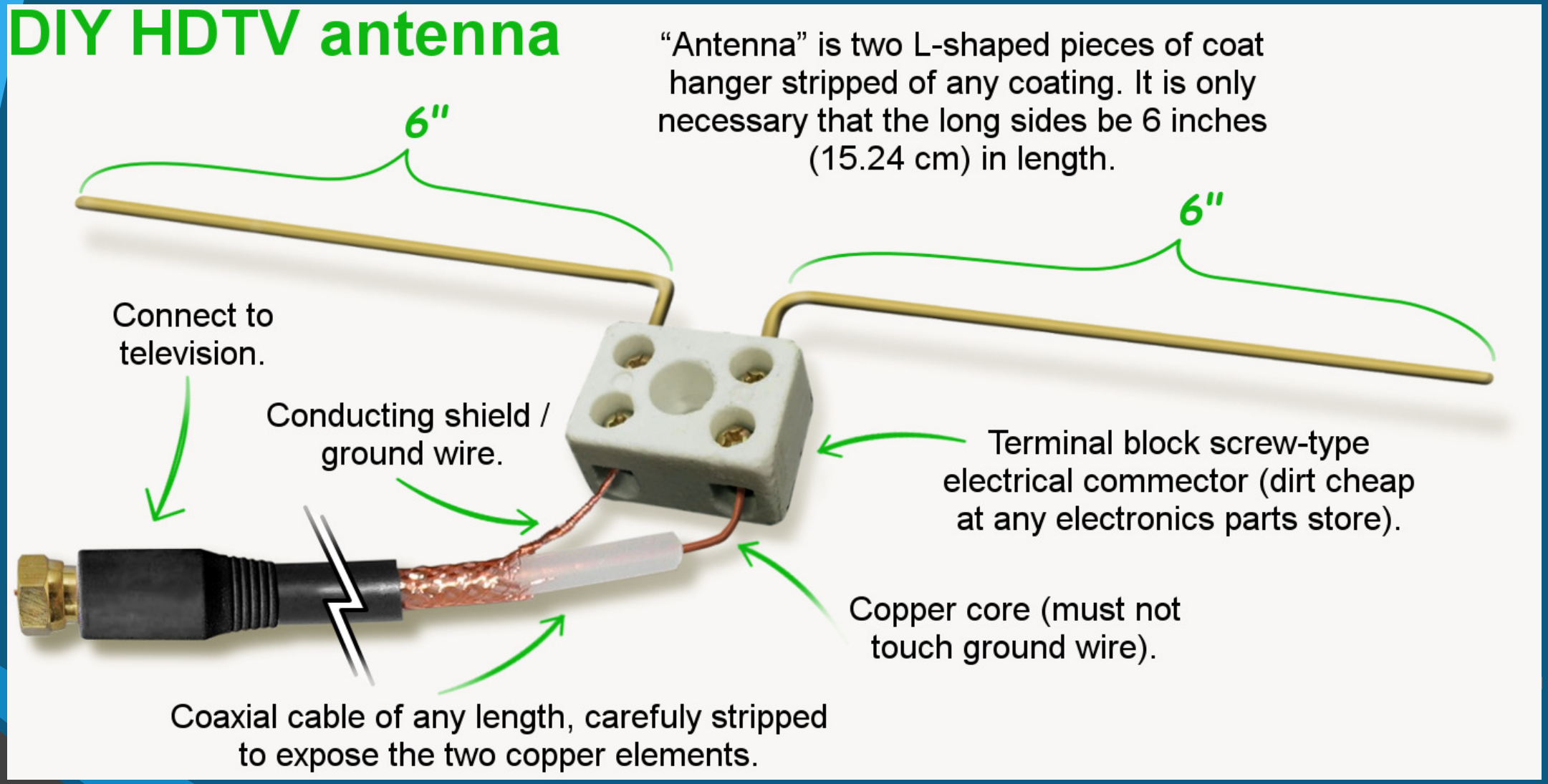


If we now bend the open ends of the transmission line in opposite directions, the currents will now generate electric fields that are in phase and will reinforce each other and also radiate and propagate at a distance.

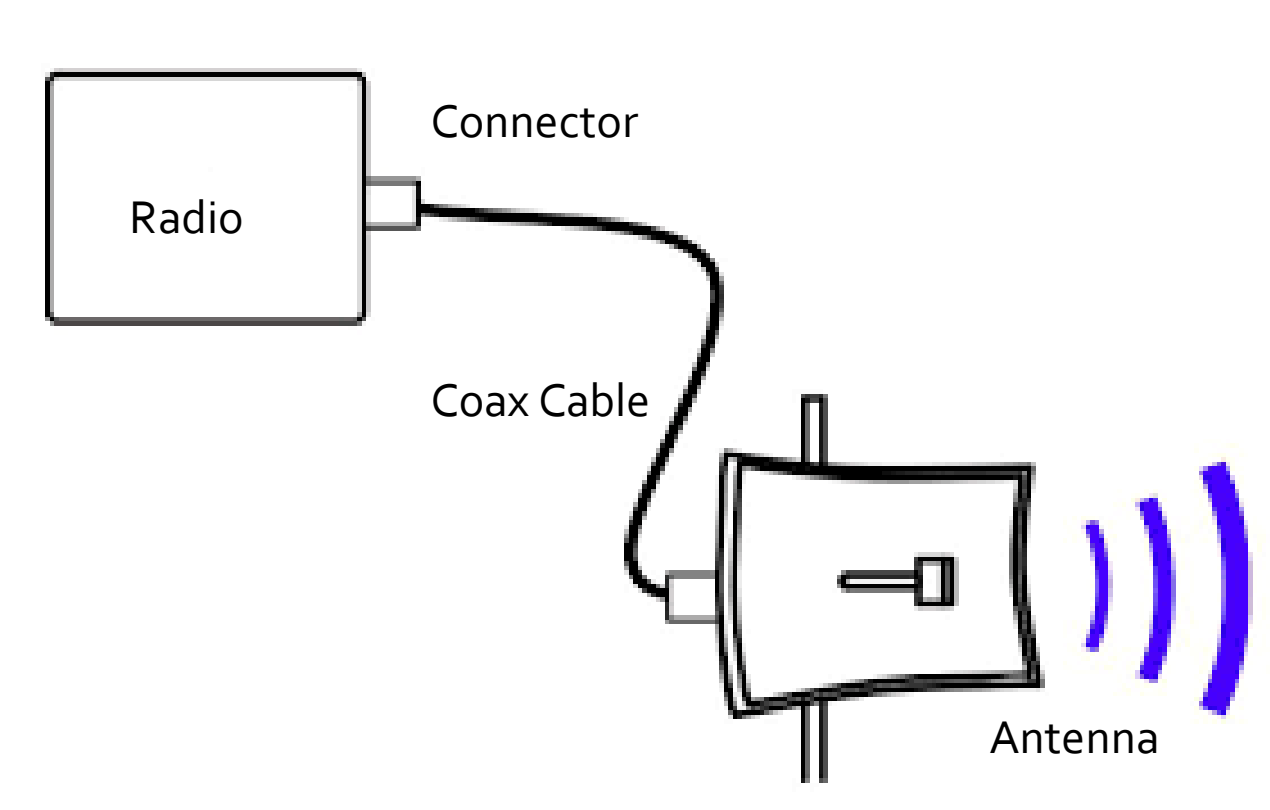
- We now have a an **antenna** at the end of the transmission line.



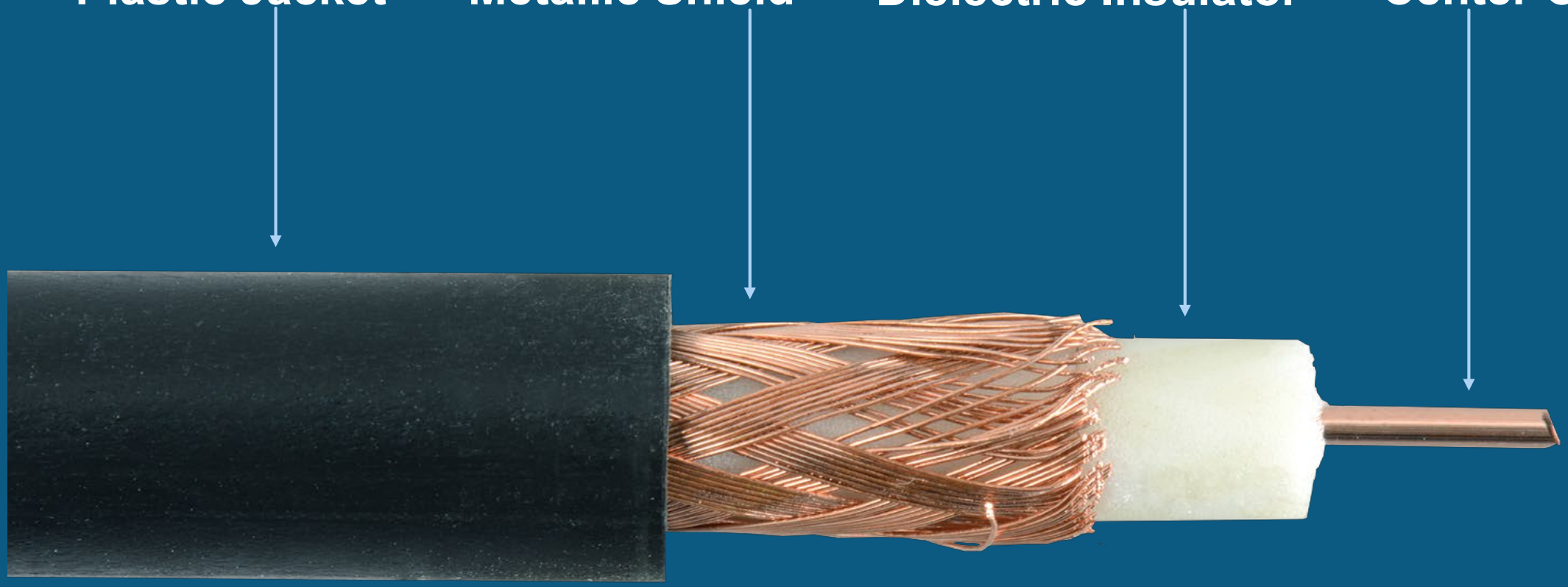
Can be made from simple materials



Basic System Connection



Basic Coaxial Cable



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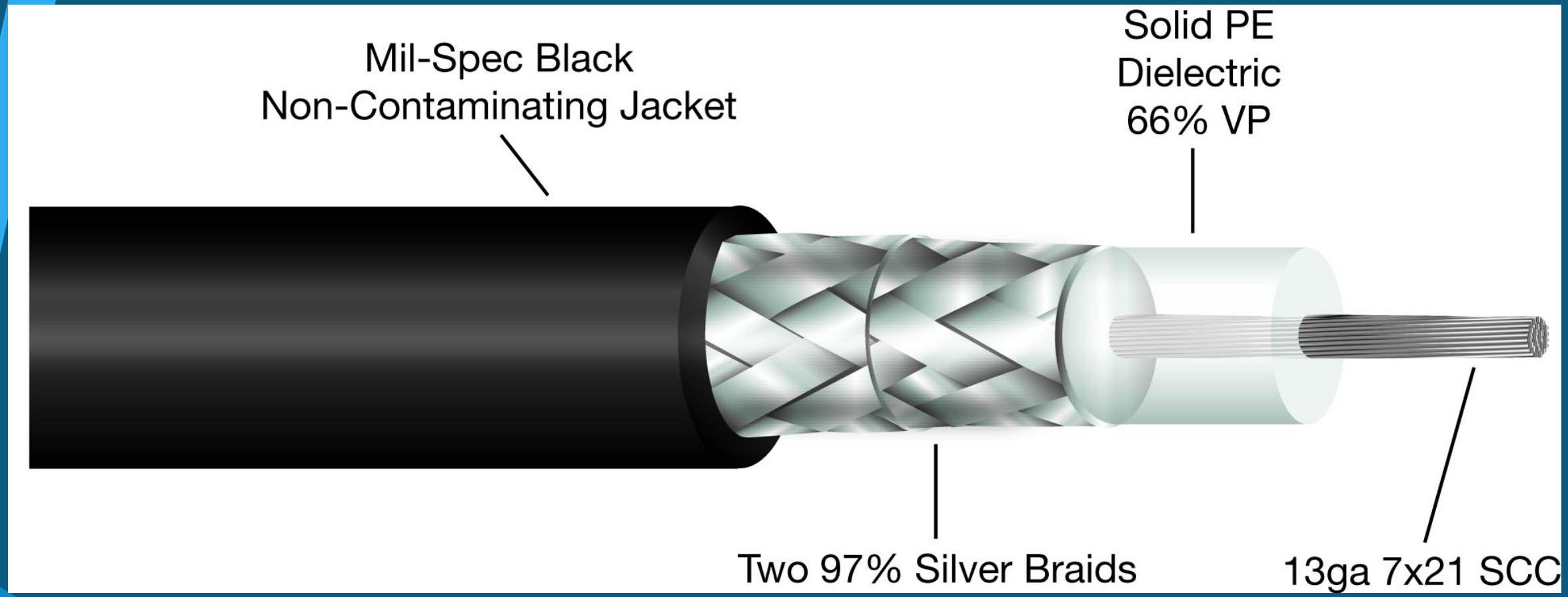

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Coaxial Cable Signal Loss

The loss (or ***attenuation***) of a coaxial cable depends on the construction of the cable and the ***operating frequency.***

The total amount of loss is ***proportional to the length*** of the cable.

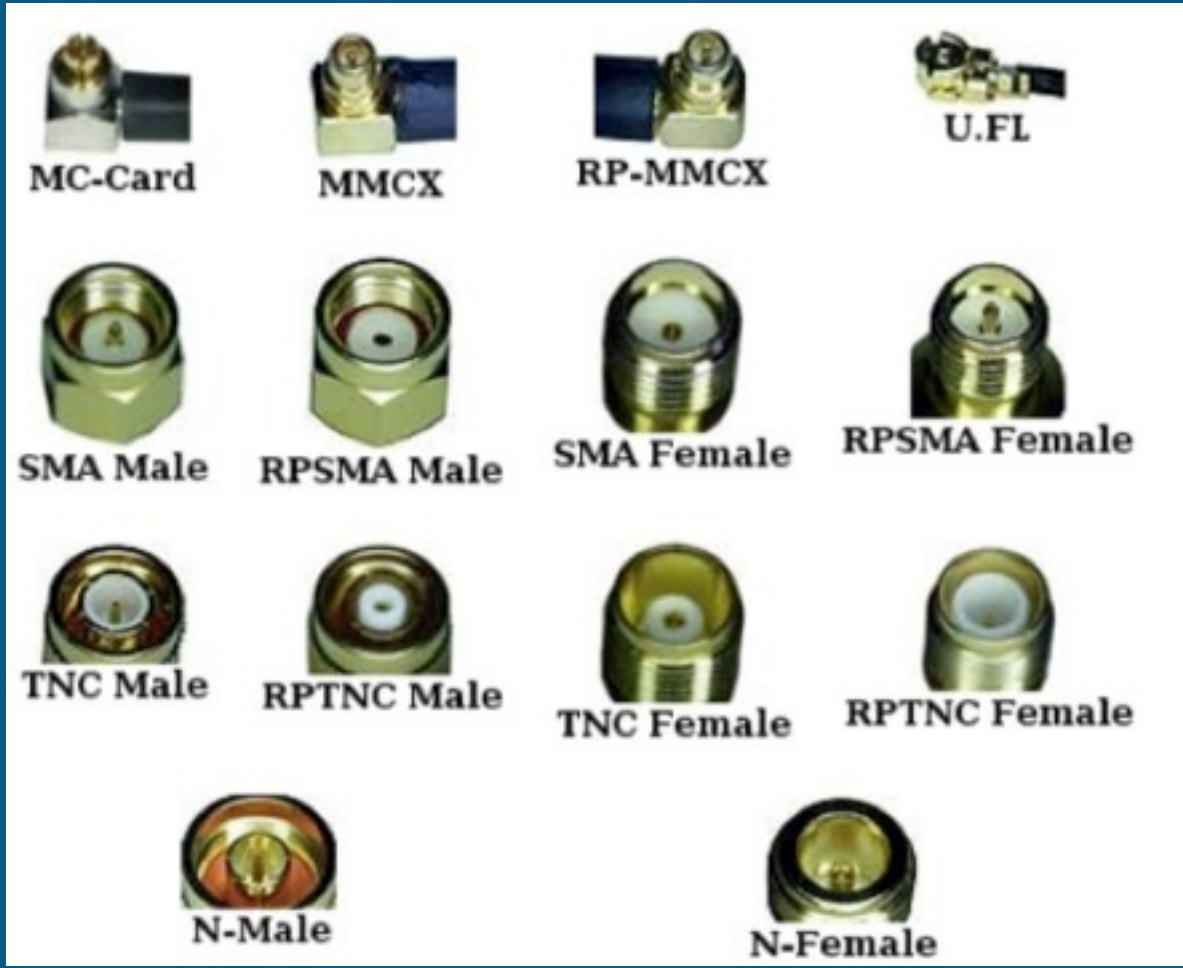
Coax Cable Signal Loss (Attenuation) in dB per 100ft*								
Loss*	RG-174	RG-58	RG-8X	RG-213	RG-6	RG-11	RF-9914	RF-9913
1MHz	1.9dB	0.4dB	0.5dB	0.2dB	0.2dB	0.2dB	0.3dB	0.2dB
10MHz	3.3dB	1.4dB	1.0dB	0.6dB	0.6dB	0.4dB	0.5dB	0.4dB
50MHz	6.6dB	3.3dB	2.5dB	1.6dB	1.4dB	1.0dB	1.1dB	0.9dB
100MHz	8.9dB	4.9dB	3.6dB	2.2dB	2.0dB	1.6dB	1.5dB	1.4dB
200MHz	11.9dB	7.3dB	5.4dB	3.3dB	2.8dB	2.3dB	2.0dB	1.8dB
400MHz	17.3 B	11.2dB	7.9dB	4.8dB	4.3dB	3.5dB	2.9dB	2.6dB
700MHz	26.0dB	16.9dB	11.0dB	6.6dB	5.6dB	4.7dB	3.8dB	3.6dB
900MHz	27.9 B	20.1dB	12.6dB	7.7dB	6.0dB	5.4dB	4.9dB	4.2dB
1GHz	32.0dB	21.5dB	13.5dB	8.3dB	6.1dB	5.6dB	5.3dB	4.5dB
Imped	50ohm	50ohm	50ohm	50ohm	75ohm	75ohm	50ohm	50ohm

*** Note:** Coax losses shown above are for 100 feet lengths. Loss is a length multiplier, so a 200 ft length would have twice the loss shown above and a 50 ft length would have half the loss. This multiplier factor is why you should keep cable installation lengths between radios and antennas as short as practical!

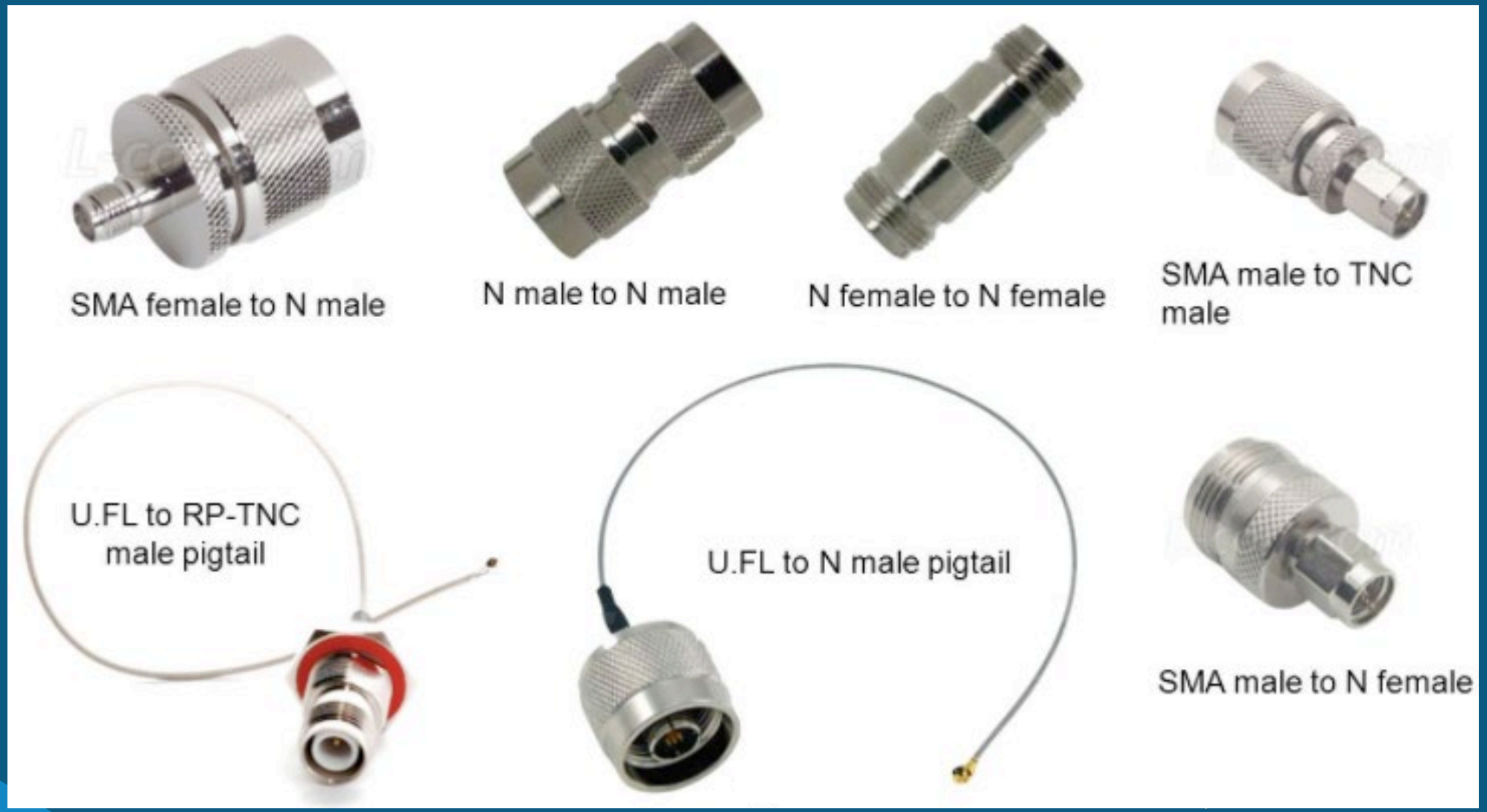
Coaxial Cable Connectors

Connectors come in a huge variety of shapes and sizes.

In addition to standard types, connectors may be reverse polarity (genders swapped) or reverse threaded.



Adapters & Pigtails Adapters and pigtails are used to interconnect different kinds of cable or devices.



Impedance

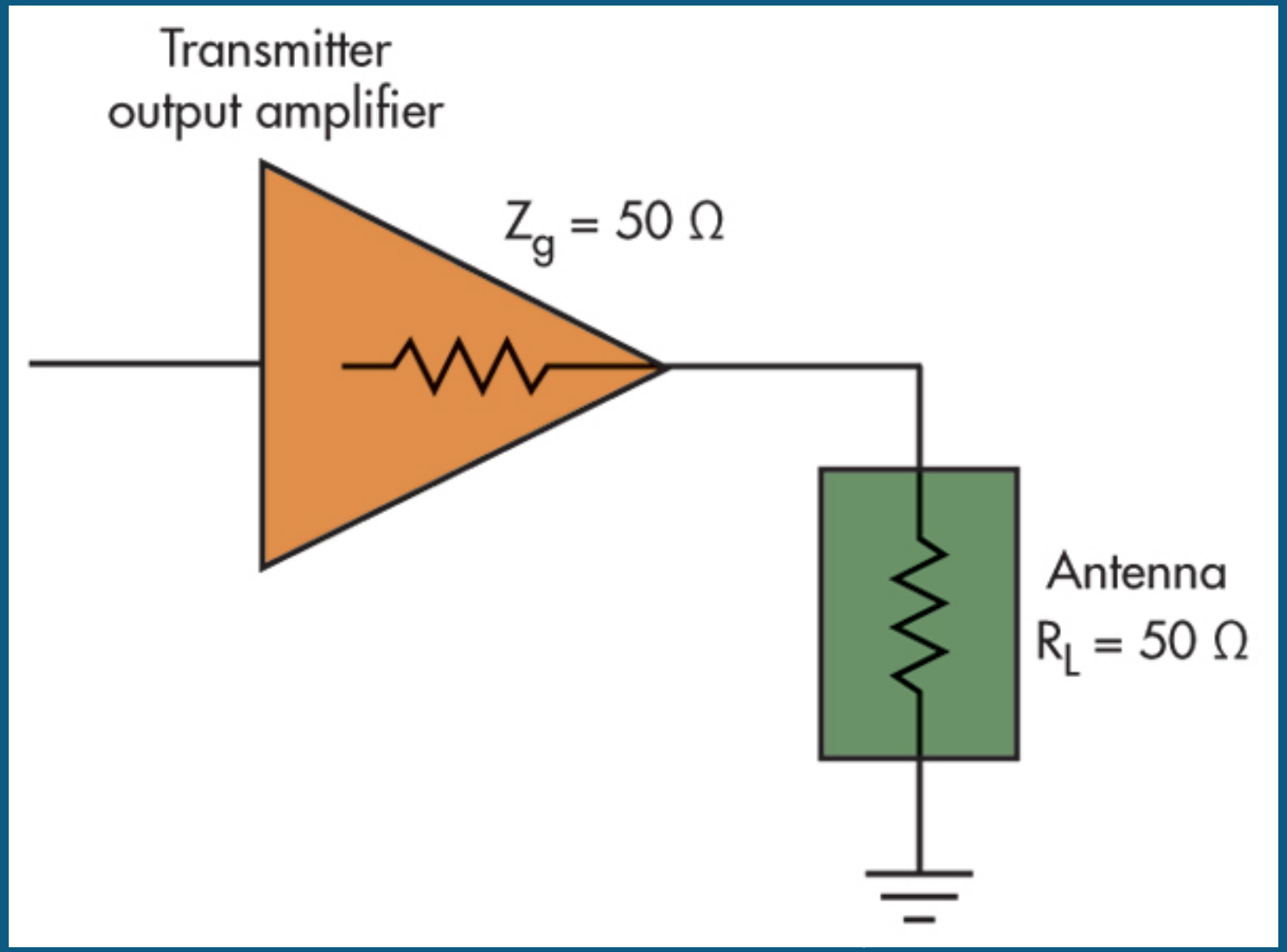
All materials will oppose the flow of an alternating current to some extent. This opposition is called impedance, and is analogous to resistance in DC circuits.

Most commercial communication antennas have an impedance of **50 ohms**, while TV antennas and cables are usually 75 ohms.

Make sure that the characteristic impedance of the cable between the radio and the antenna is **50 ohms**.

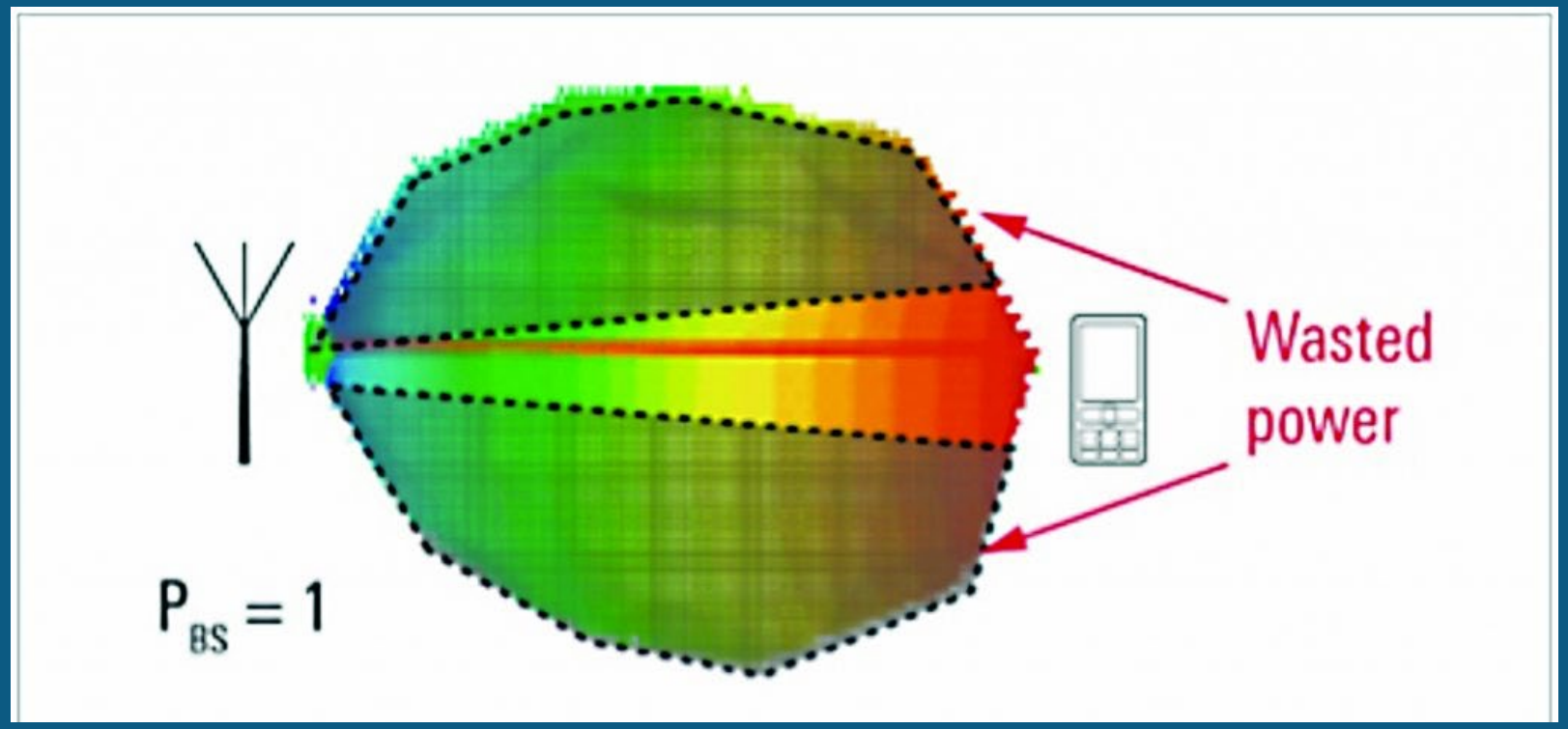
Antenna impedance ***must*** equal the transmitter output impedance to receive maximum power.

Matched Impedance



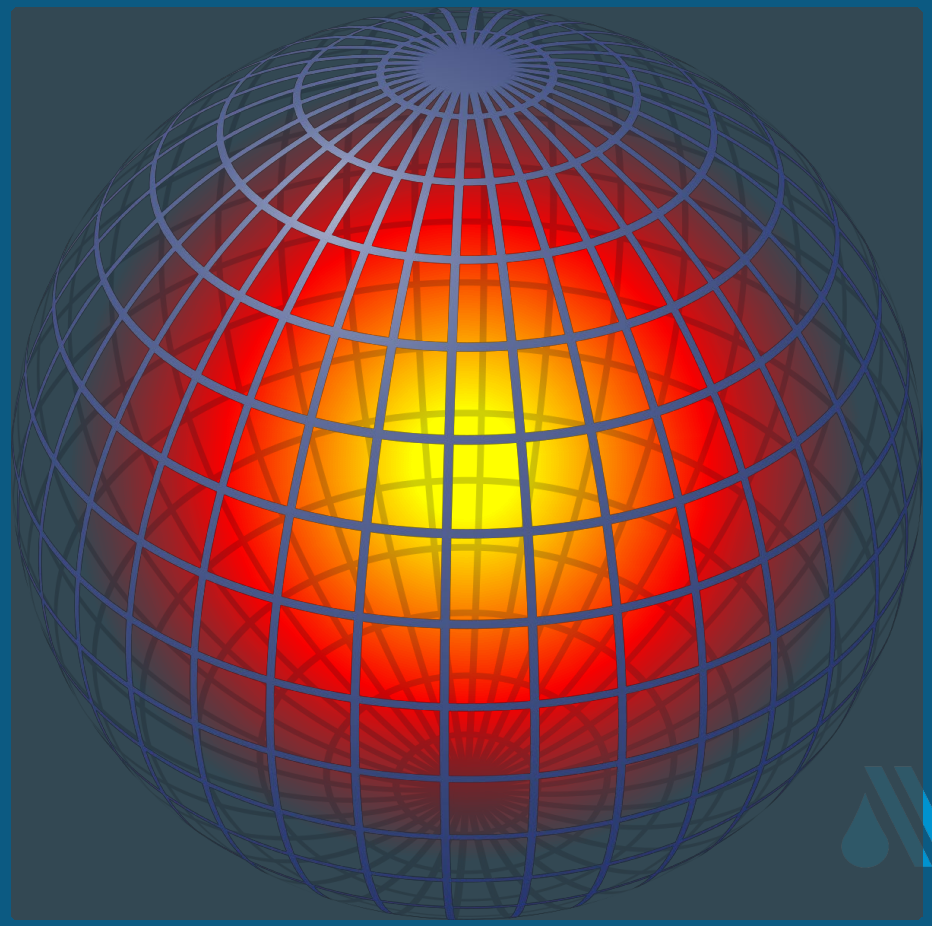
Efficiency

Efficiency of a transmitting antenna is the ratio of power actually radiated (in all directions) to the power absorbed by the antenna terminals.



Isotropic antennas

A theoretical ***isotropic antenna*** radiates the energy fed into it equally in every direction in space. It is only an ideal model and cannot be built.



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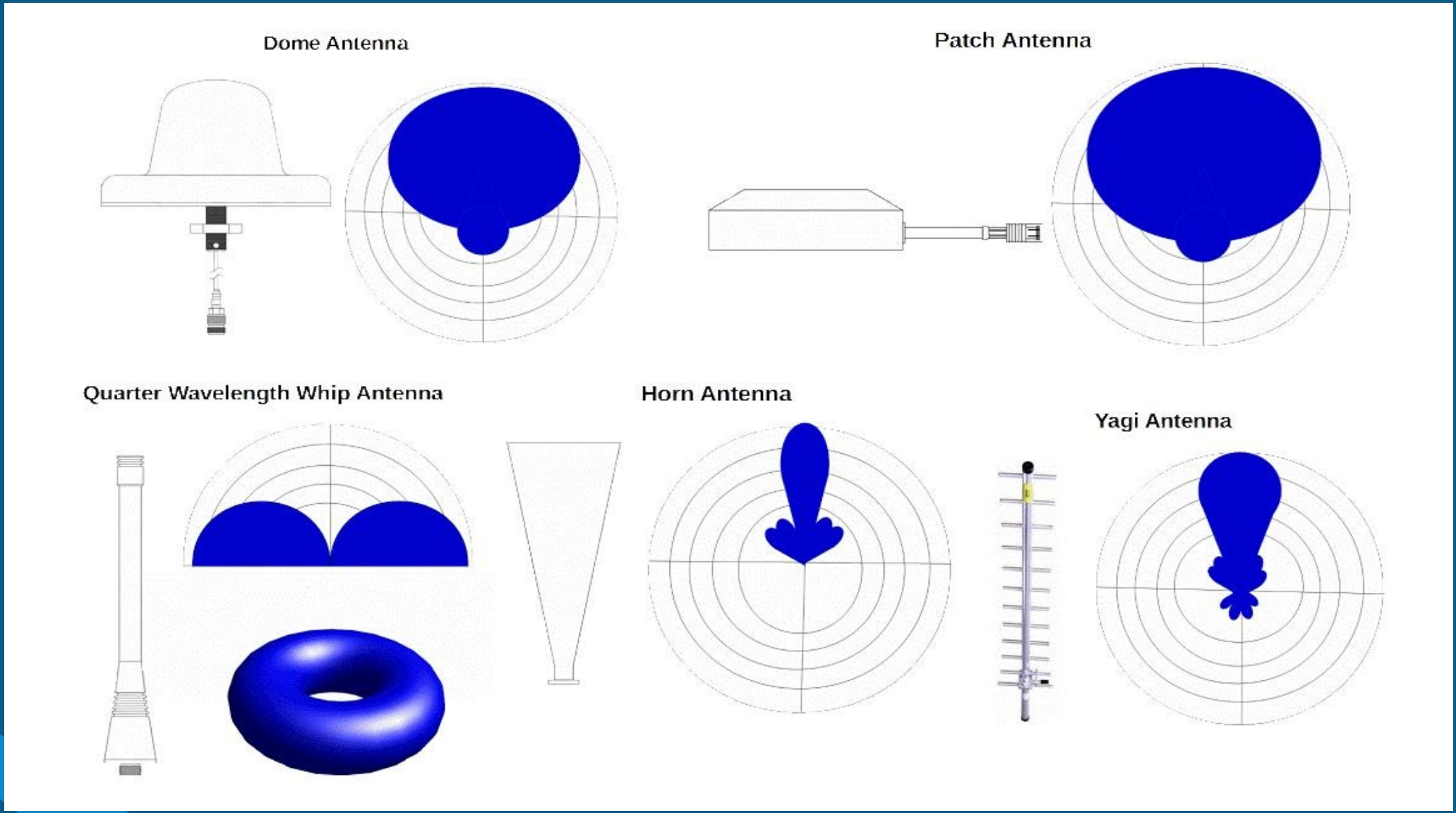
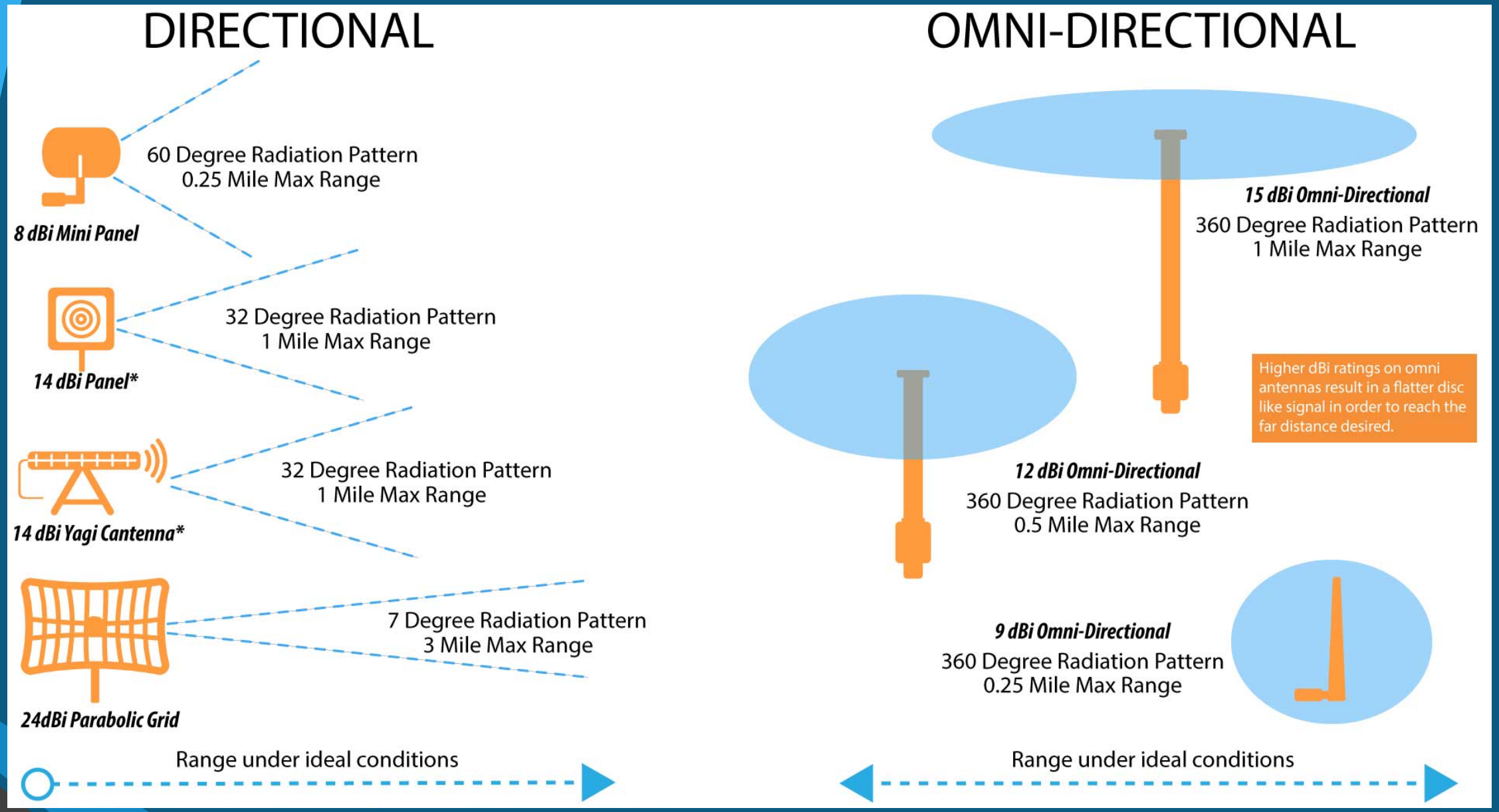
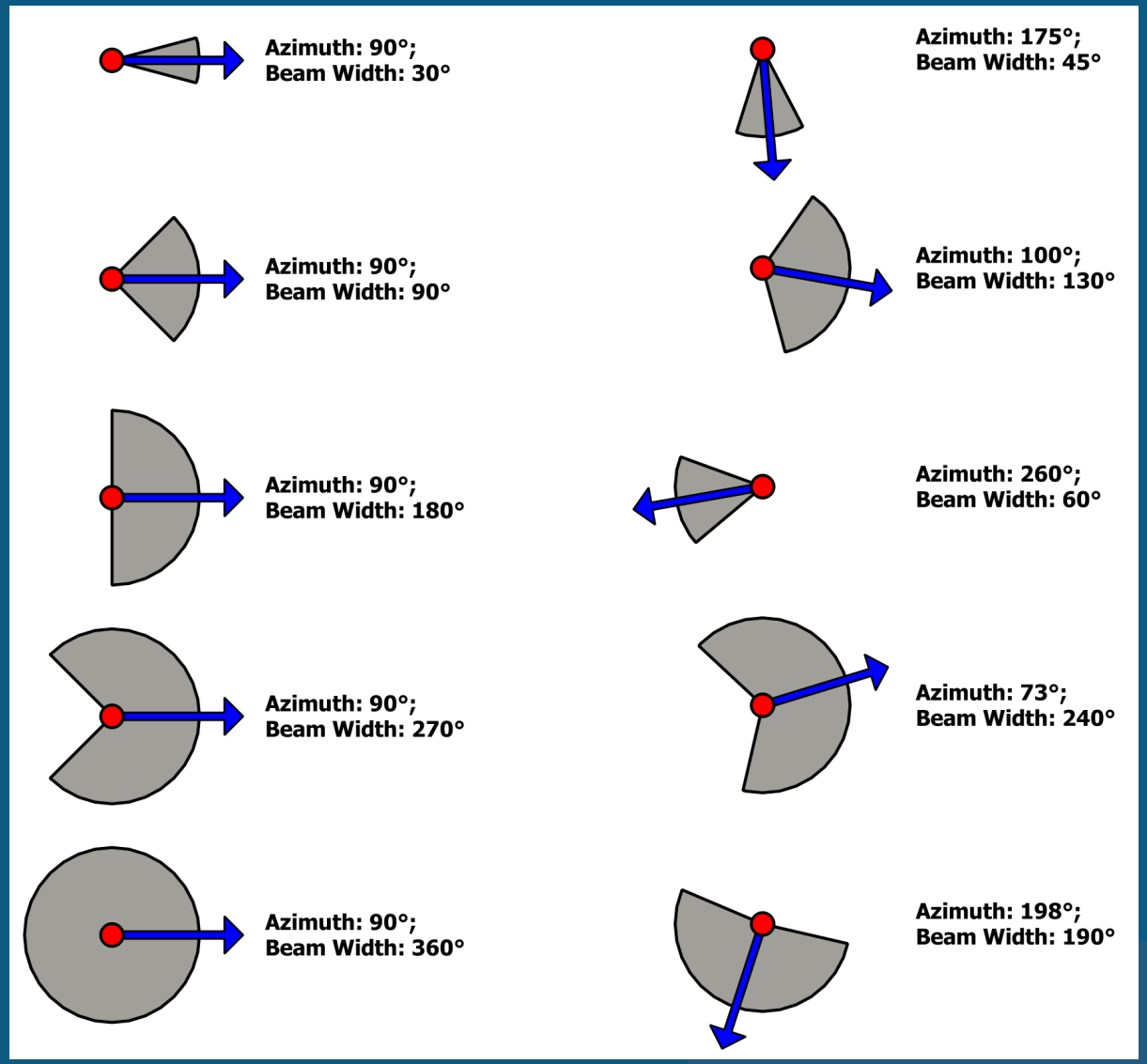
Real-world antennas are characterized by their ability to radiate more strongly in some directions than in others; this is called ***directivity***.



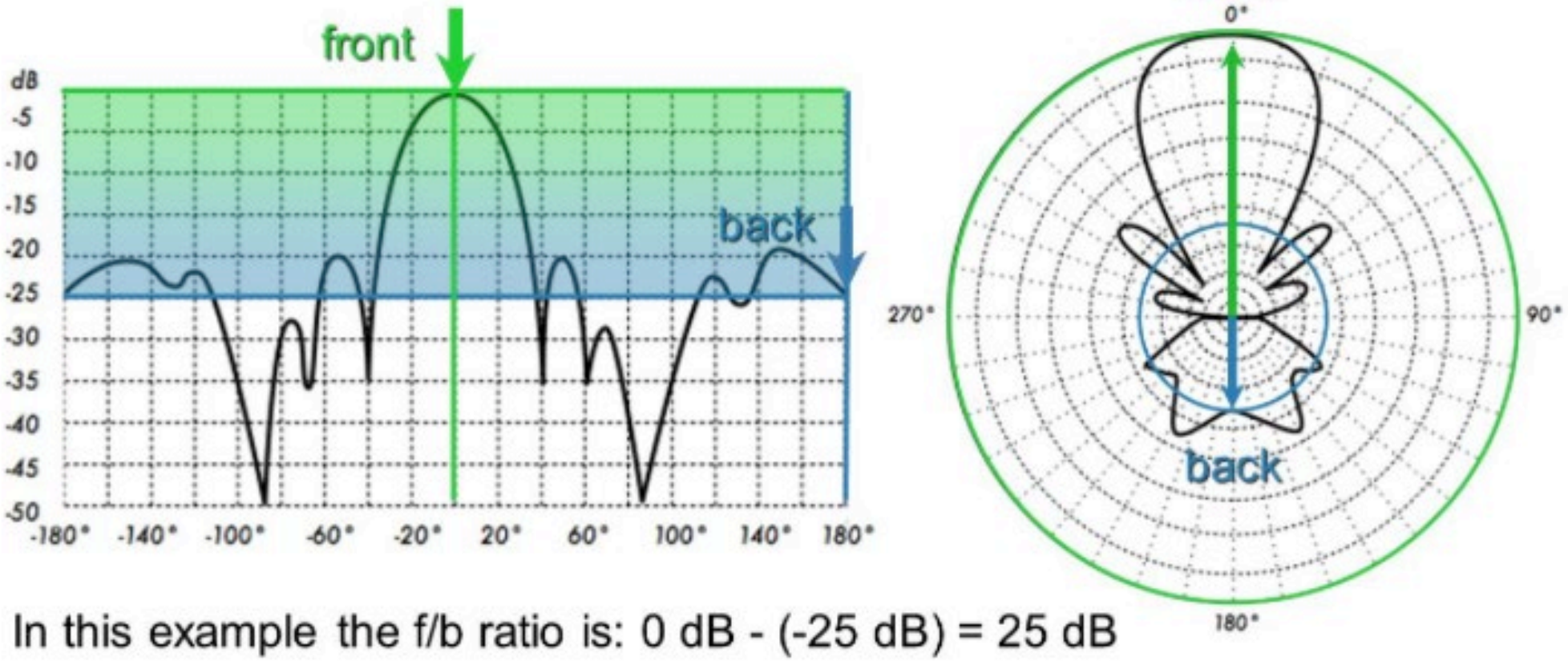

DIRECTIONAL
60 Degree Radiation Pattern
0.25 Mile Max Range
8 dBi Mini Panel
32 Degree Radiation Pattern
1 Mile Max Range
14 dBi Panel*
32 Degree Radiation Pattern
1 Mile Max Range
14 dBi Yagi Cantenna*
7 Degree Radiation Pattern
3 Mile Max Range
24dBi Parabolic Grid
Range under ideal conditions
OMNI-DIRECTIONAL
15 dBi Omni-Directional
360 Degree Radiation Pattern
1 Mile Max Range
Higher dBi ratings on omni antennas result in a flatter disc like signal in order to reach the far distance desired.
12 dBi Omni-Directional
360 Degree Radiation Pattern
0.5 Mile Max Range
9 dBi Omni-Directional
360 Degree Radiation Pattern
0.25 Mile Max Range
Range under ideal conditions

Antenna Beam Width



Front-to-back ratio

The front-to-back ratio of a directional antenna is the ratio of the maximum directivity of the antenna to its directivity in the opposite direction.



In this example the f/b ratio is: 0 dB - (-25 dB) = 25 dB

Polarization

- Electromagnetic waves have electrical and magnetic components.

- The polarization of transmitting and receiving antennas MUST MATCH for optimum communications.

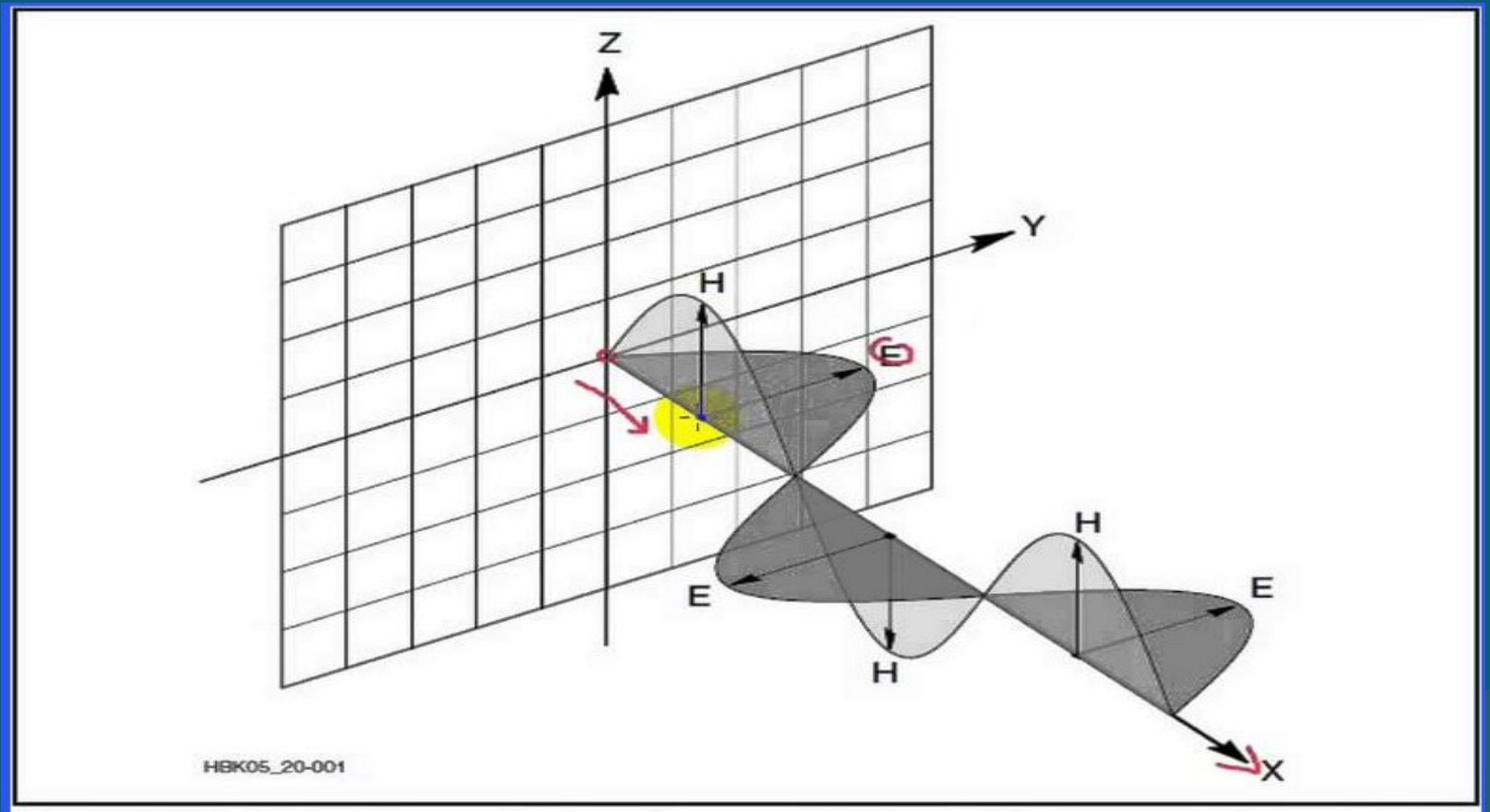
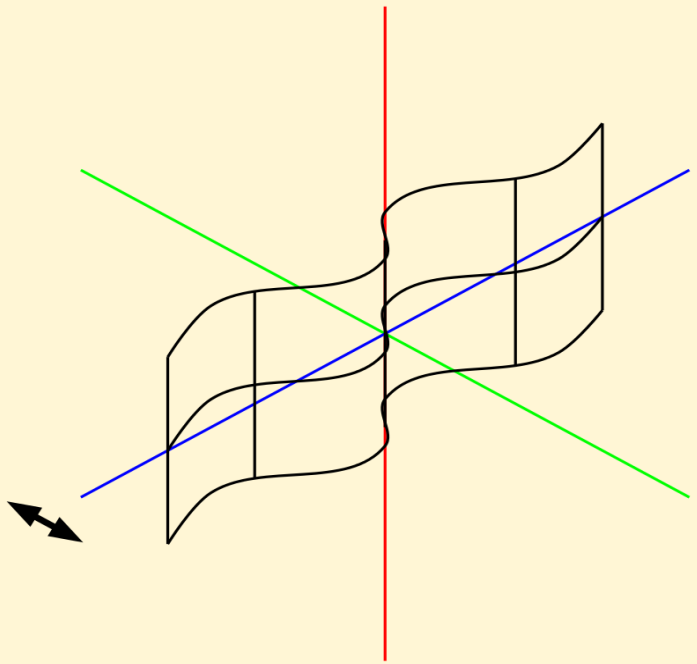


Fig 19.1 — Electric and magnetic field components of the electromagnetic wave. The polarization of a radio wave is the same direction as the plane of its electric field.

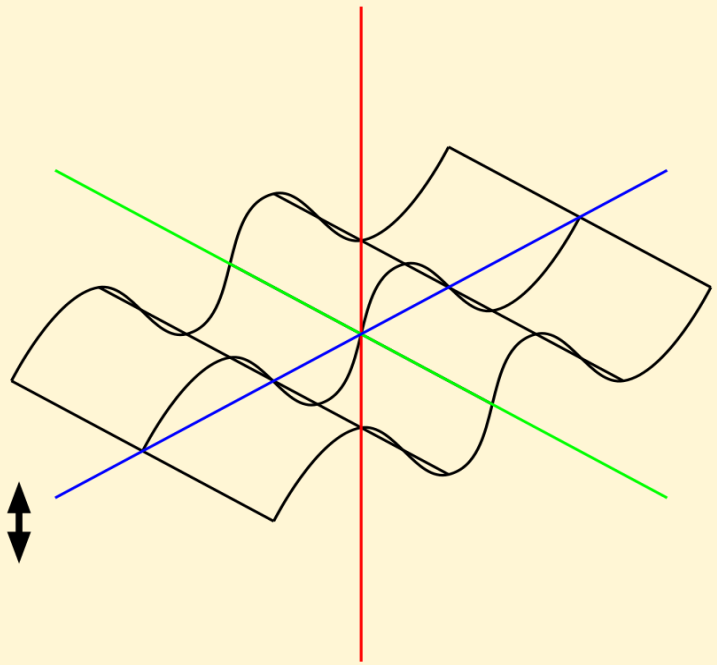
Horizontally polarized (linear) antennas have their electric field parallel to the Earth's surface.

An example of a **vertical** antenna is a broadcast tower for AM radio or the "whip" antenna on an automobile.



Horizontal Polarisation

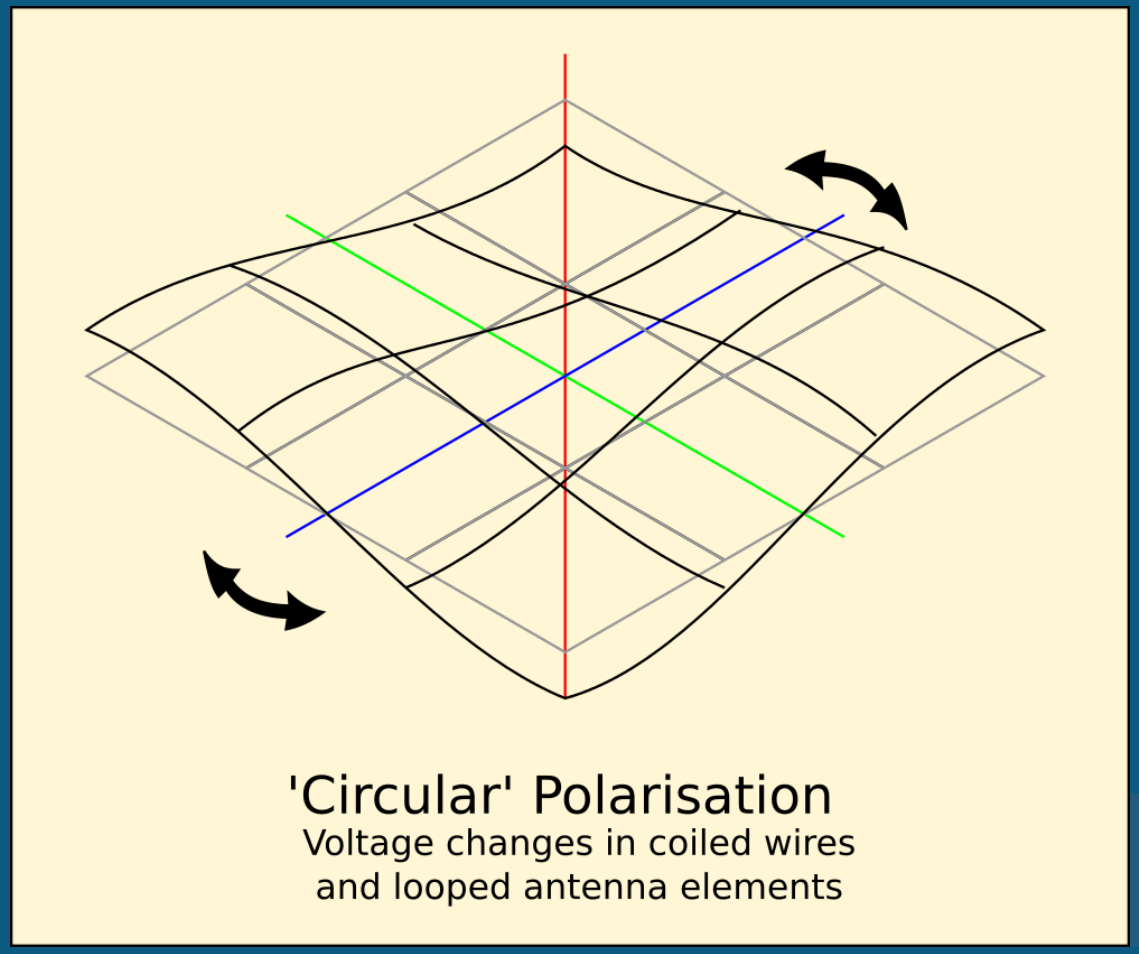
Voltage changes in horizontal wires and antenna elements



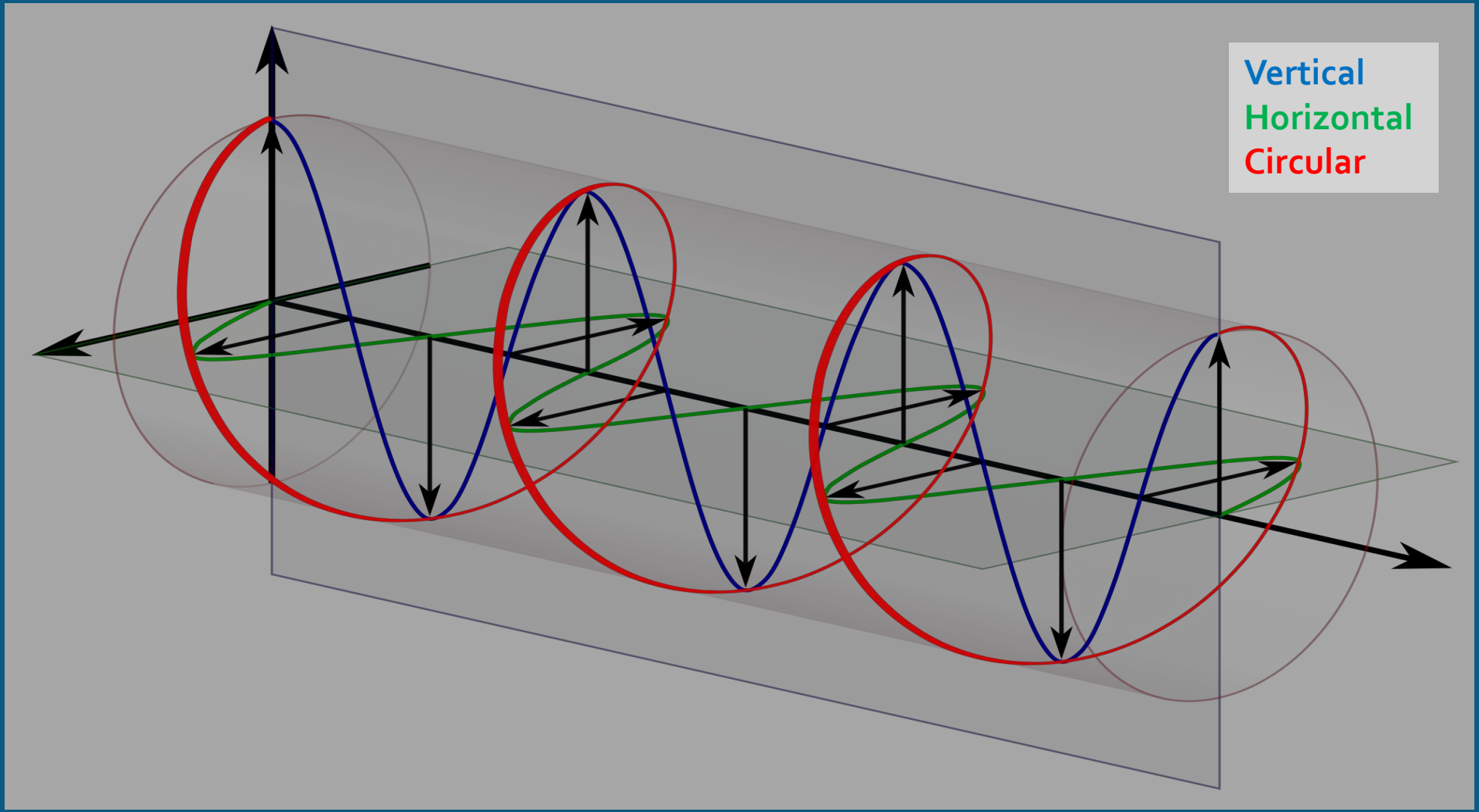
Vertical Polarisation

Voltage changes in vertical wires and antenna elements

A **circular polarized** wave radiates energy in both the **horizontal** and **vertical** planes and all planes in between.



ANTENNA POLARIZATION




V
H


?
TEKO
TELECOM
Vertical


TEKO
TELECOM
Horizontal

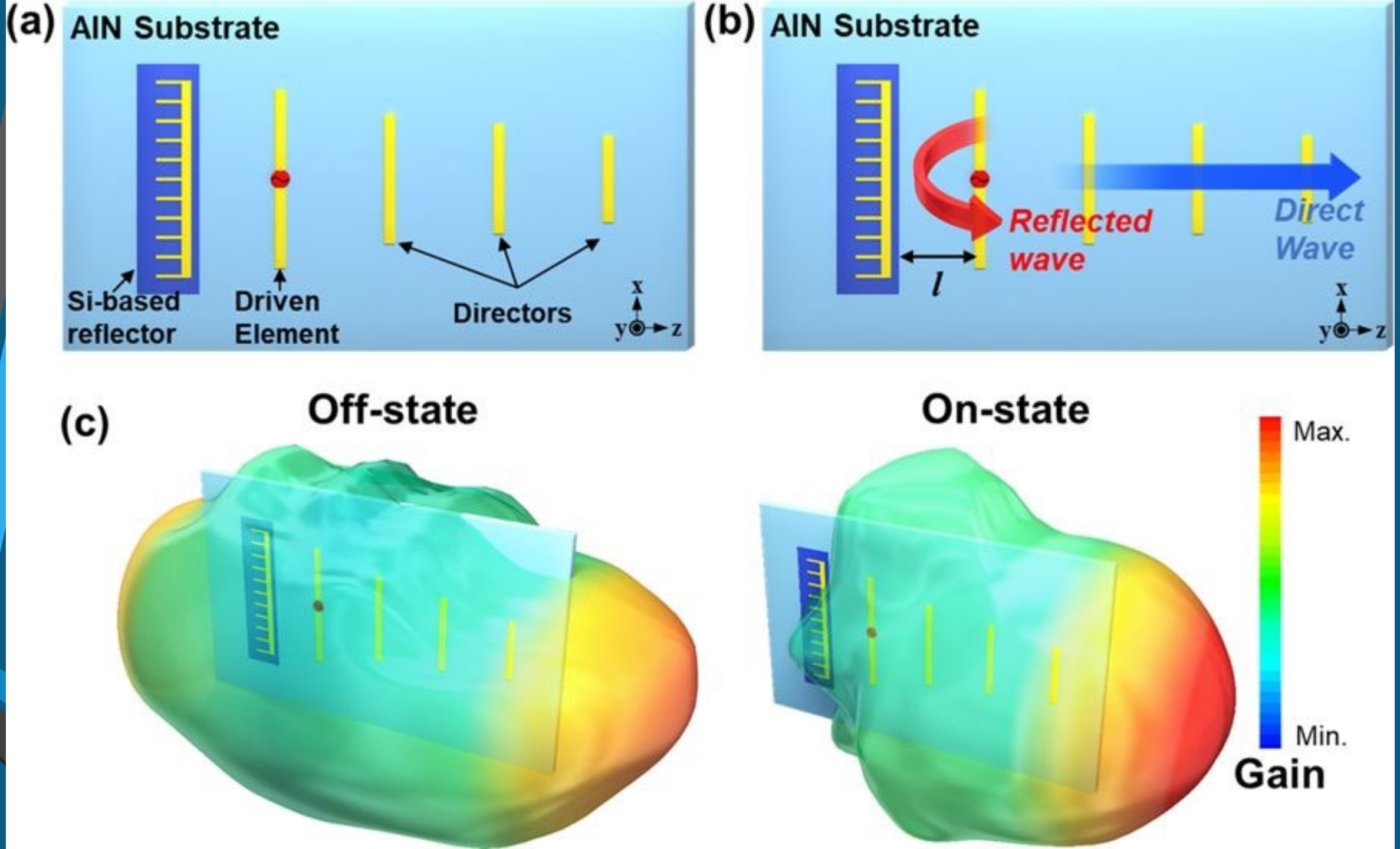
Antenna gain

In electromagnetics, an antenna's **power gain** or simply **gain** is a key performance number which combines the antenna's directivity and electrical efficiency.

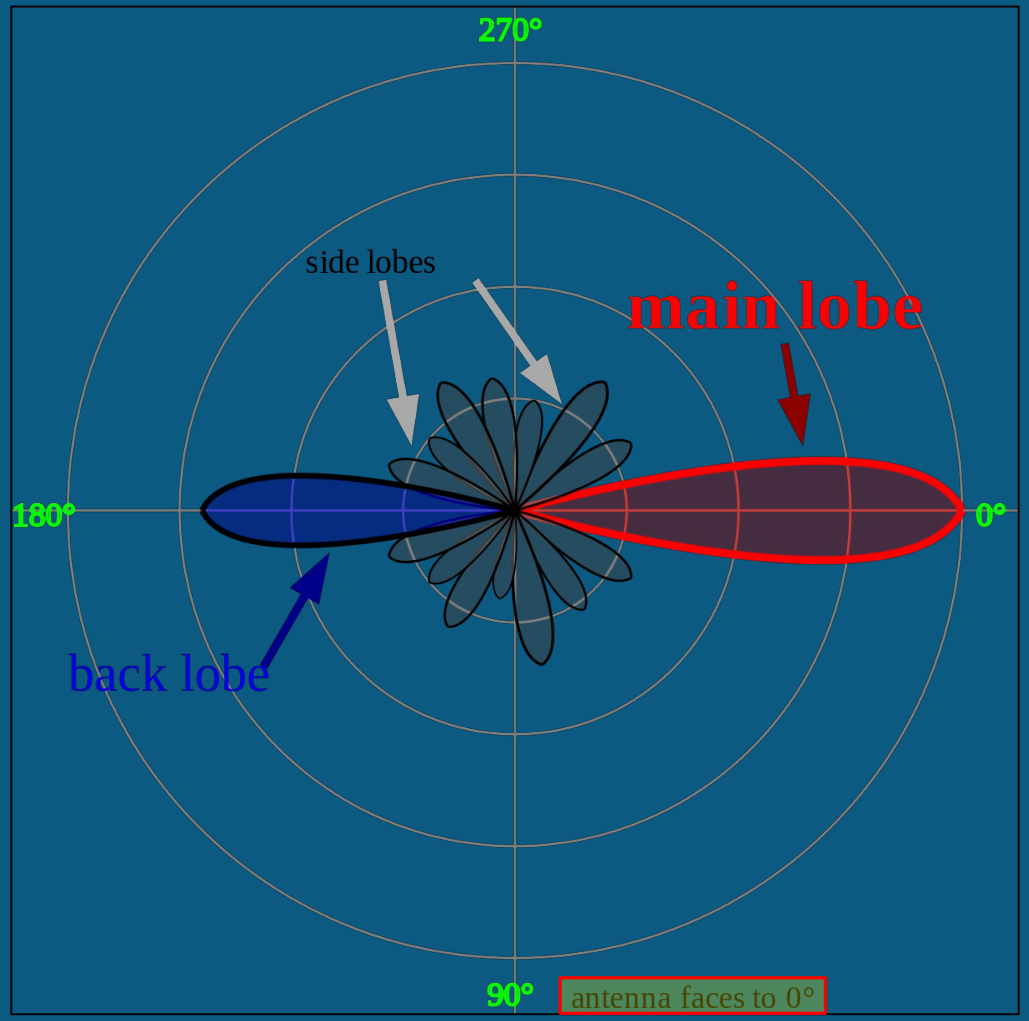
In a transmitting antenna, the gain describes how well the antenna converts input power into radio waves headed in a specified direction.

In a receiving antenna, the gain describes how well the antenna converts radio waves arriving from a specified direction into electrical power.

When no direction is specified, "gain" is understood to refer to the peak value of the gain, the gain in the direction of the antenna's main lobe. A plot of the gain as a function of direction is called the radiation pattern.


(a)
AlN Substrate
Si-based reflector
Driven Element
Directors
x
y
z
(b)
AlN Substrate
Reflected wave
Direct Wave
l
x
y
z
(c)
Off-state
On-state
Max.
Min.
Gain

Antenna Pattern



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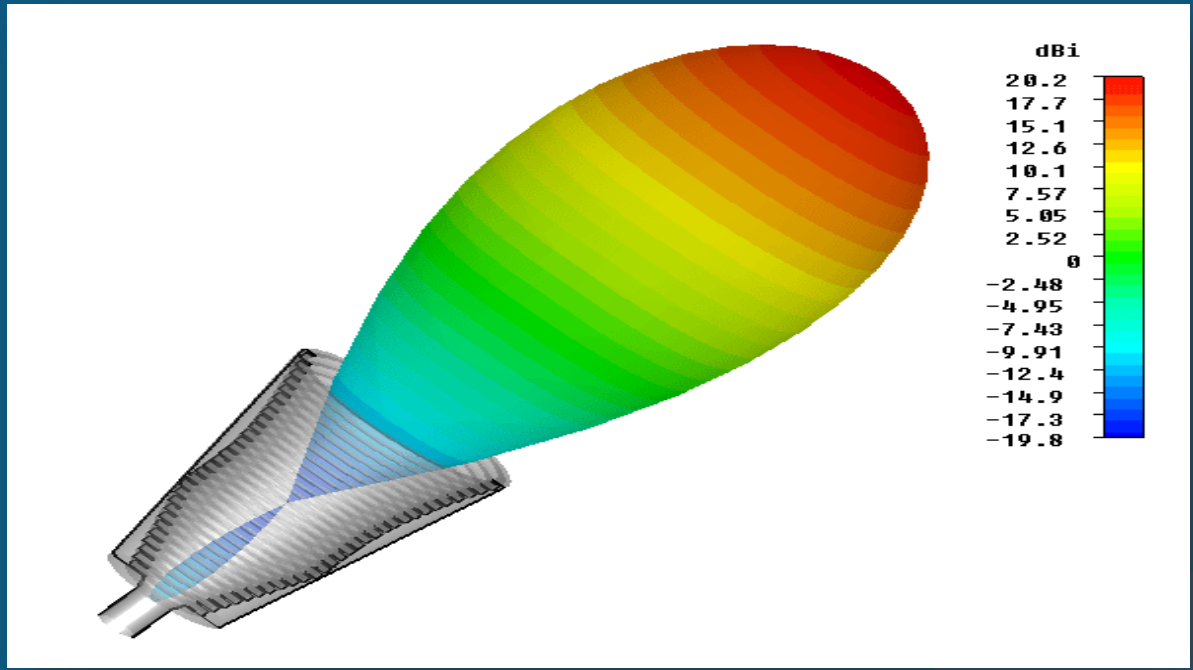
Antennas do not add power. They direct available power in a particular direction.

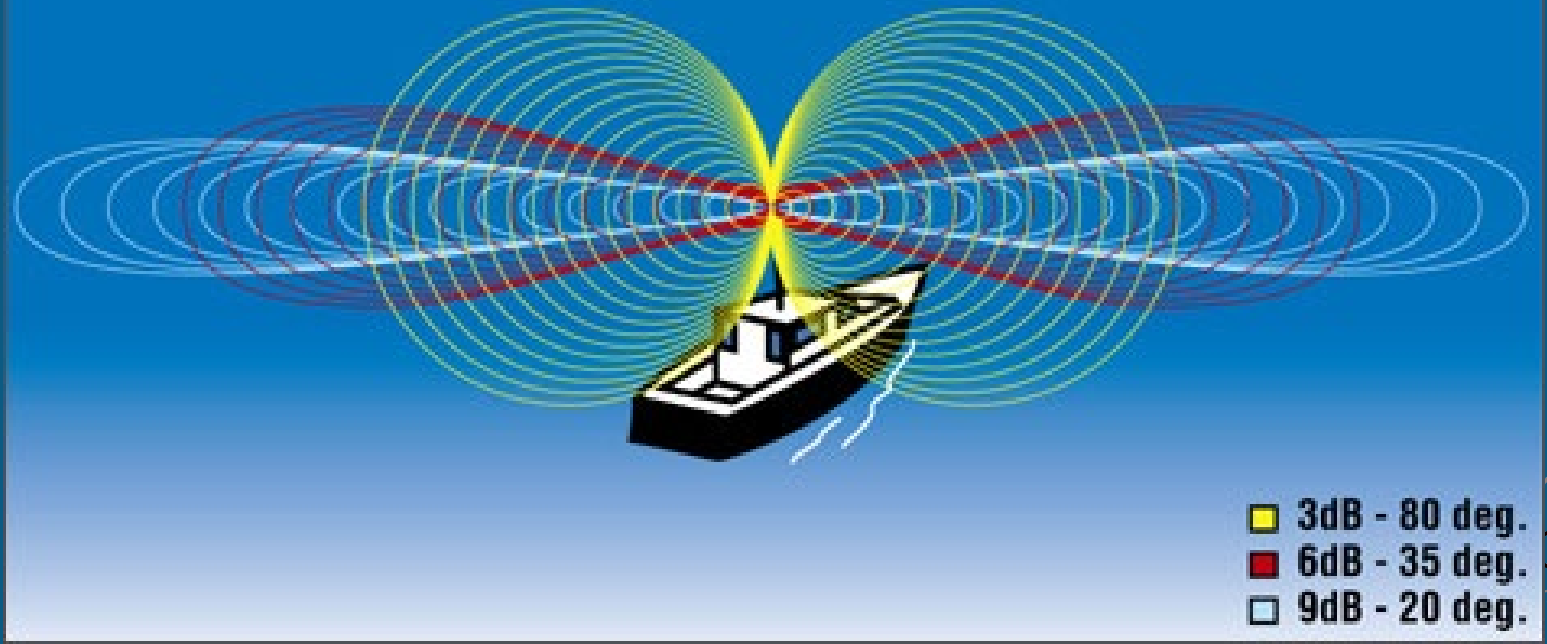
The ***gain*** of an antenna is measured in dBi (decibels relative to an isotropic radiator).

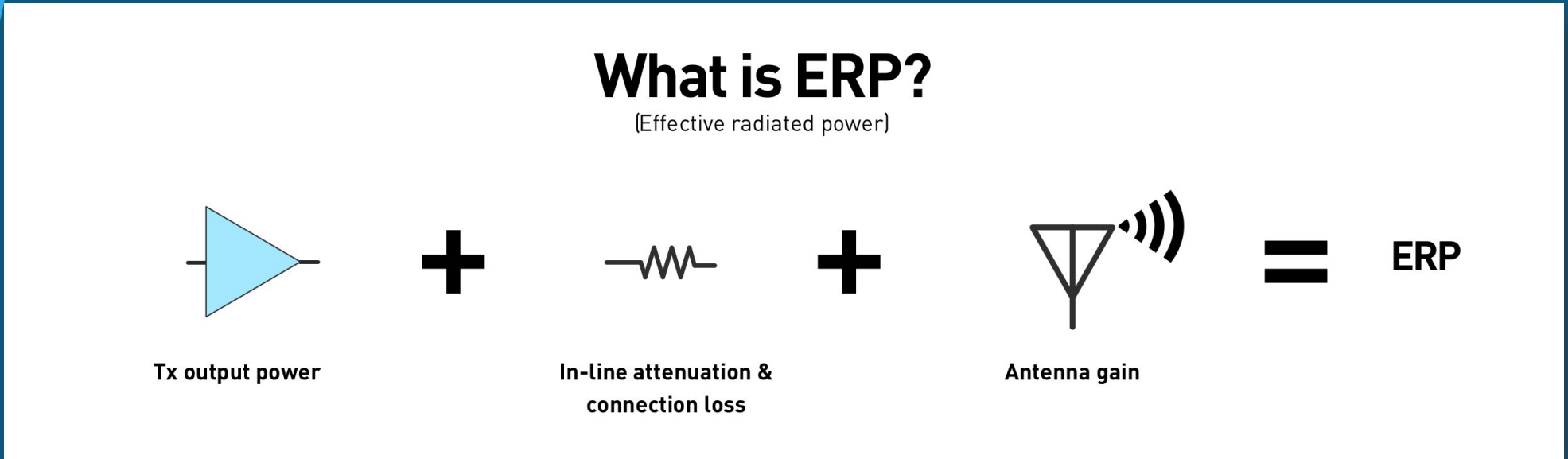


Antenna Gain:

- Each 3 dB gain doubles ERP.

- Example: 2w radio signal thru a 6dB gain antenna would equal 8w of ERP.

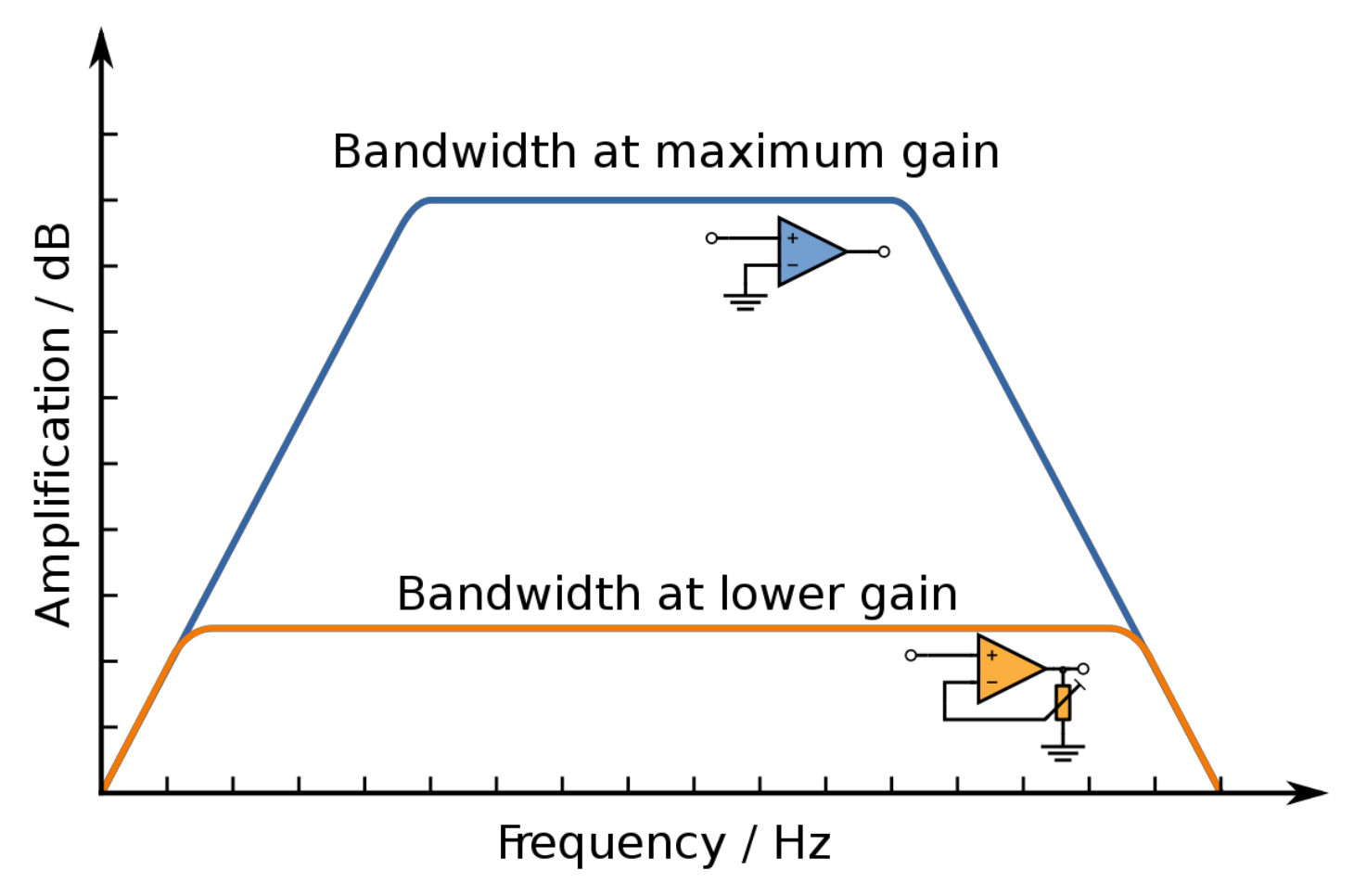




Effective radiated power is the term that describes station output, including the transmitter, antenna and everything in between, when considering transmitter ***power*** and system ***gains*** and ***losses***.
The **effective radiated power**, or ERP, is always given with respect to a certain direction.

Bandwidth

The **bandwidth** of an **antenna** refers to the range of frequencies over which the **antenna** can operate correctly.

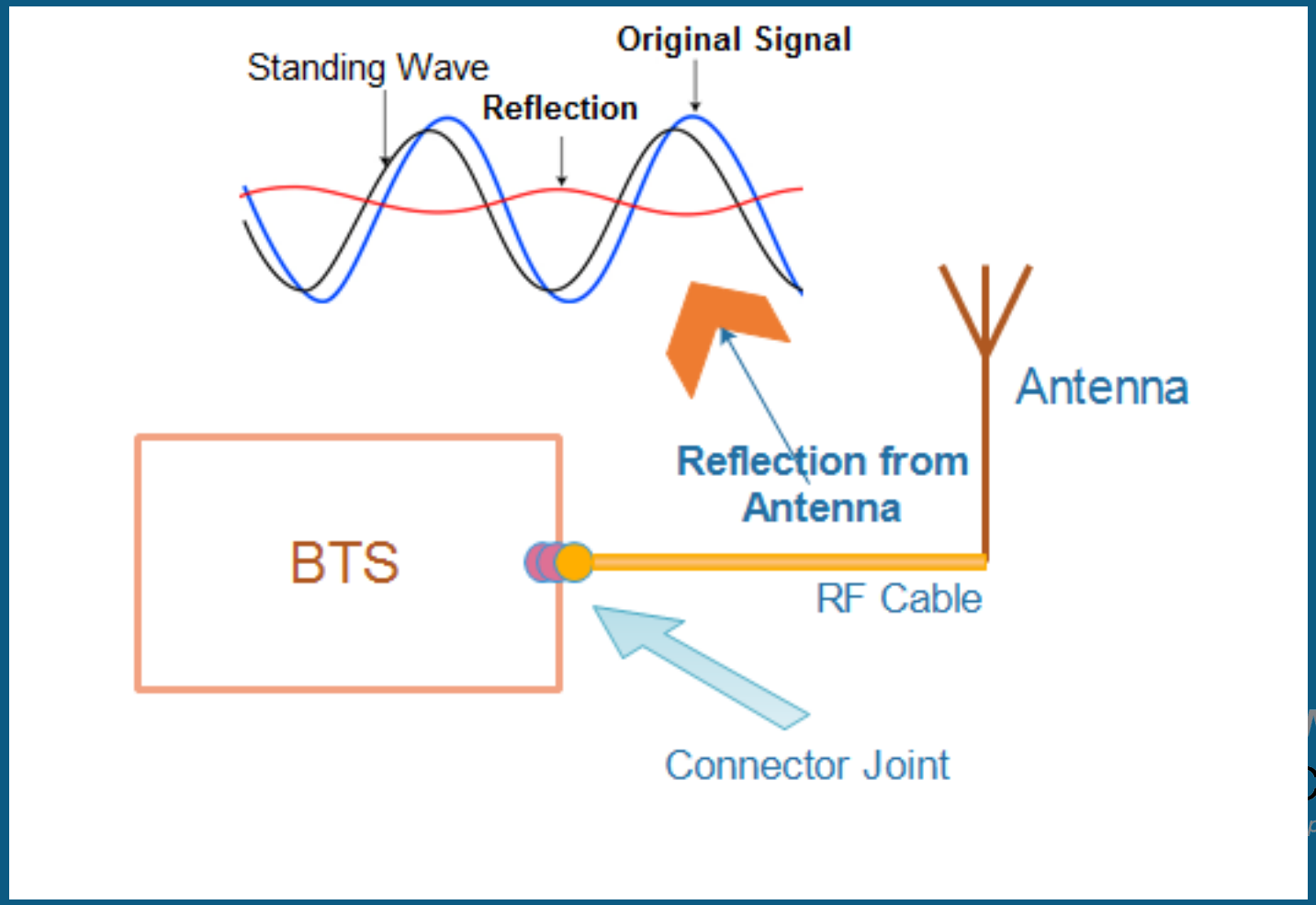


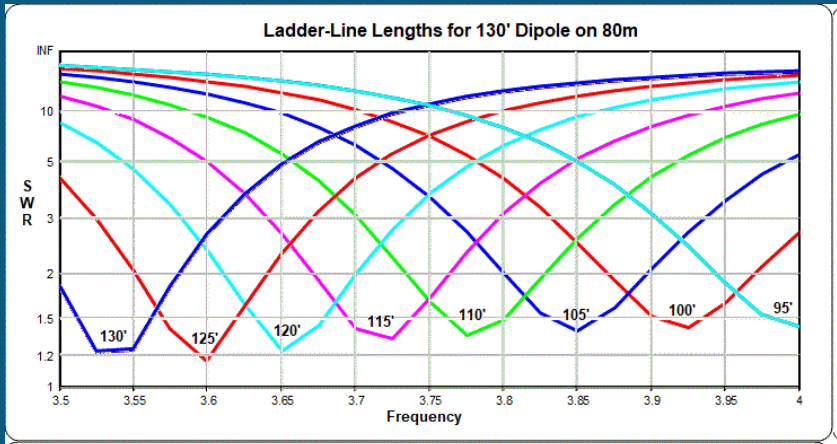
The **antenna's bandwidth** is the number of Hz for which the **antenna** will exhibit an ***SWR*** less than 2:1.

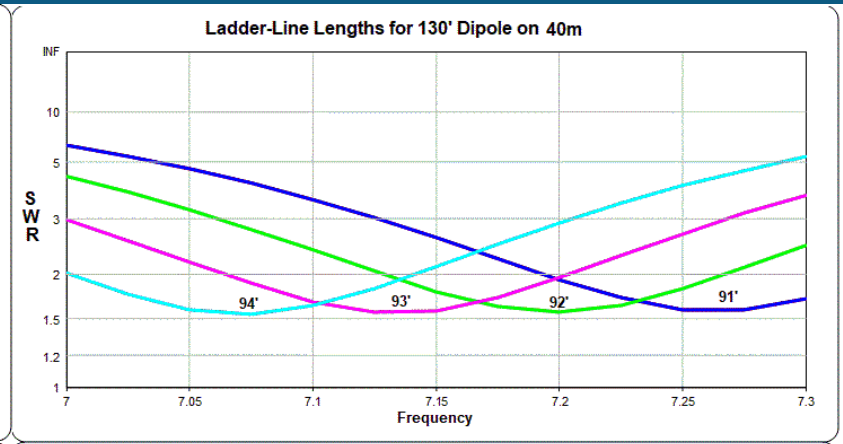
A common example is a power amplifier connected through a transmission line to an antenna. **SWR** is, thus, the ratio between transmitted and reflected waves. ... Since **SWR** commonly refers to the voltage ratio, it is usually known as voltage **standing wave ratio** (**VSWR**).

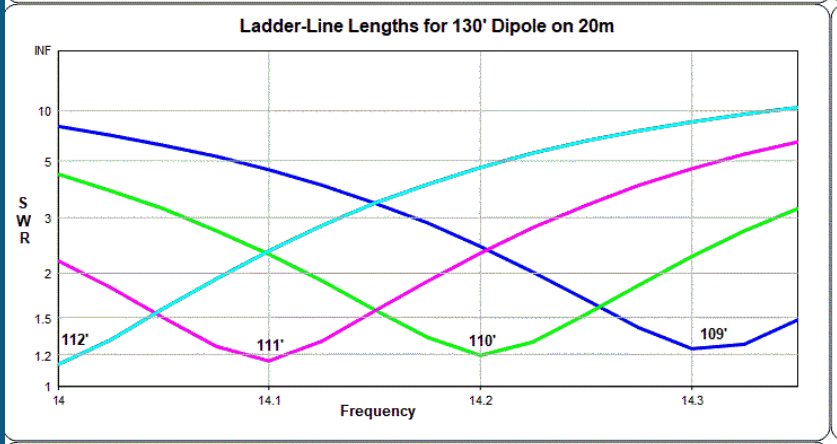
The range of values for **SWR** is from 1 to ∞. A **SWR** value under 2 is considered suitable for most antenna applications. The antenna can be described as having a **good** match.

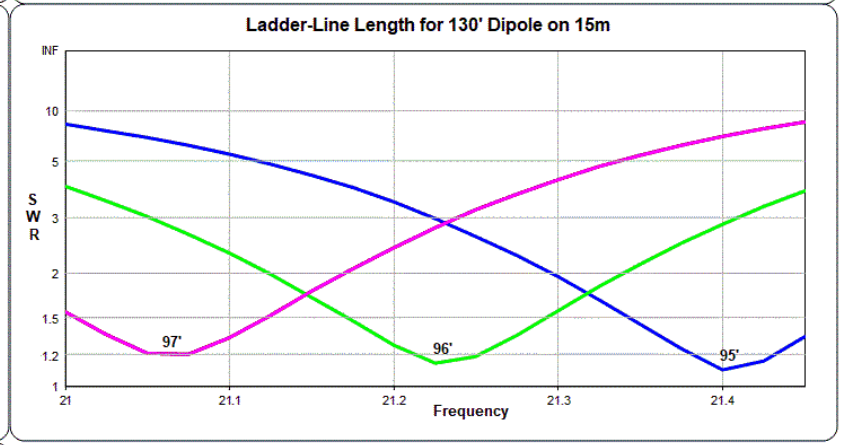
SWR of a ***base transceiver station*** (BTS) Antenna port means that when an Antenna is connected to the BTS output port, then how much power gets reflected back from the Antenna port when BTS is transmitting. If SWR value equals to 1, then there is no reflection and all the power is transmitted through the Antenna.

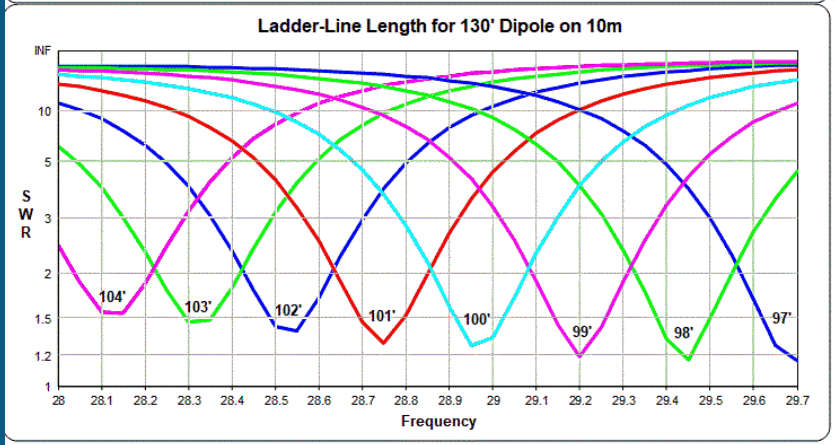






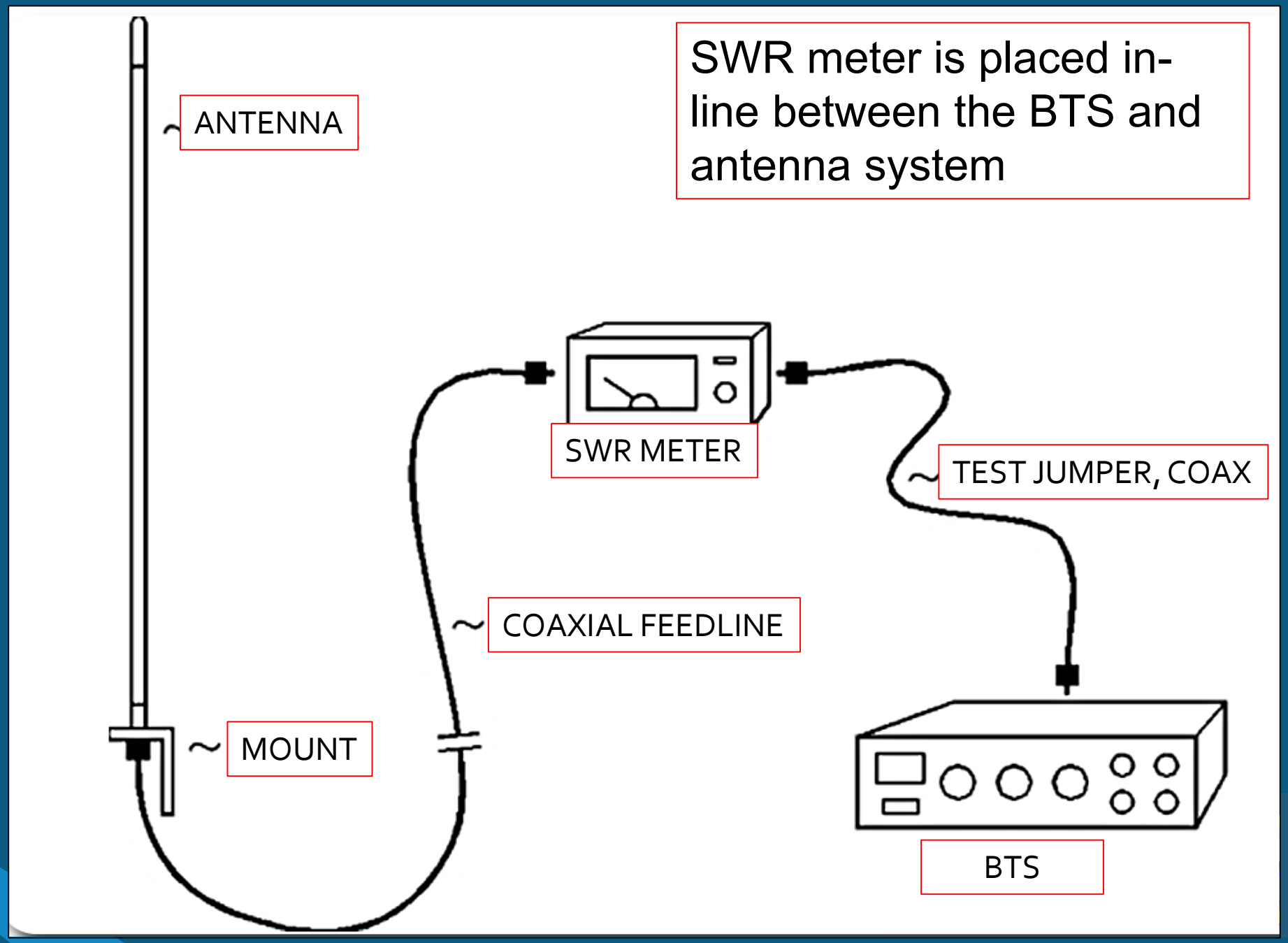






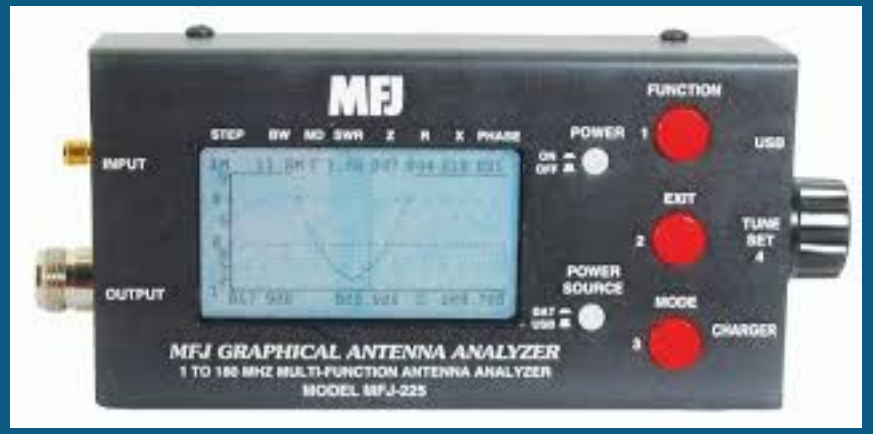
Band	Optimum Ladder-Line Length
60m	135 feet
30m	100 feet
17m	102 feet
12m	94 feet

Optimum Ladder-Line Lengths for All HF Bands


SWR meter is placed in-line between the BTS and antenna system
ANTENNA
SWR METER
TEST JUMPER, COAX
COAXIAL FEEDLINE
MOUNT
BTS

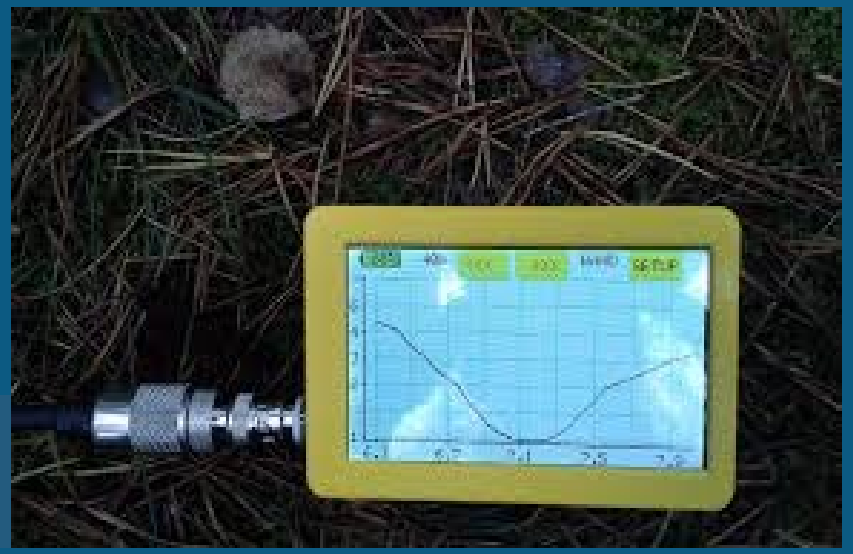
SWR Meters


SWB-2


MFJ
FUNCTION
STEP BW MD SWR Z R X PHASE
POWER
INPUT
USB
EXIT
TUNE SET
OUTPUT
POWER SOURCE
MODE
CHARGER
MFJ GRAPHICAL ANTENNA ANALYZER
1 TO 180 MHZ MULTI-FUNCTION ANTENNA ANALYZER
MODEL MFJ-225


DIGITAL SWR METER
1.64
ANT
TX
ON-OFF


DAIWA
CN-801
FREQUENCY RANGE
1.8~200MHz
HP3 TYPE
FORWARD
REFLECTED
SWR
RANGE
3KW
300W
SELECTOR
PEP
SWR & POWER METER



Ground plane

In antenna theory, a ground plane is a conducting surface large in comparison to the wavelength, such as the Earth, which is connected to the transmitter's ground wire and serves as a reflecting surface for radio waves.

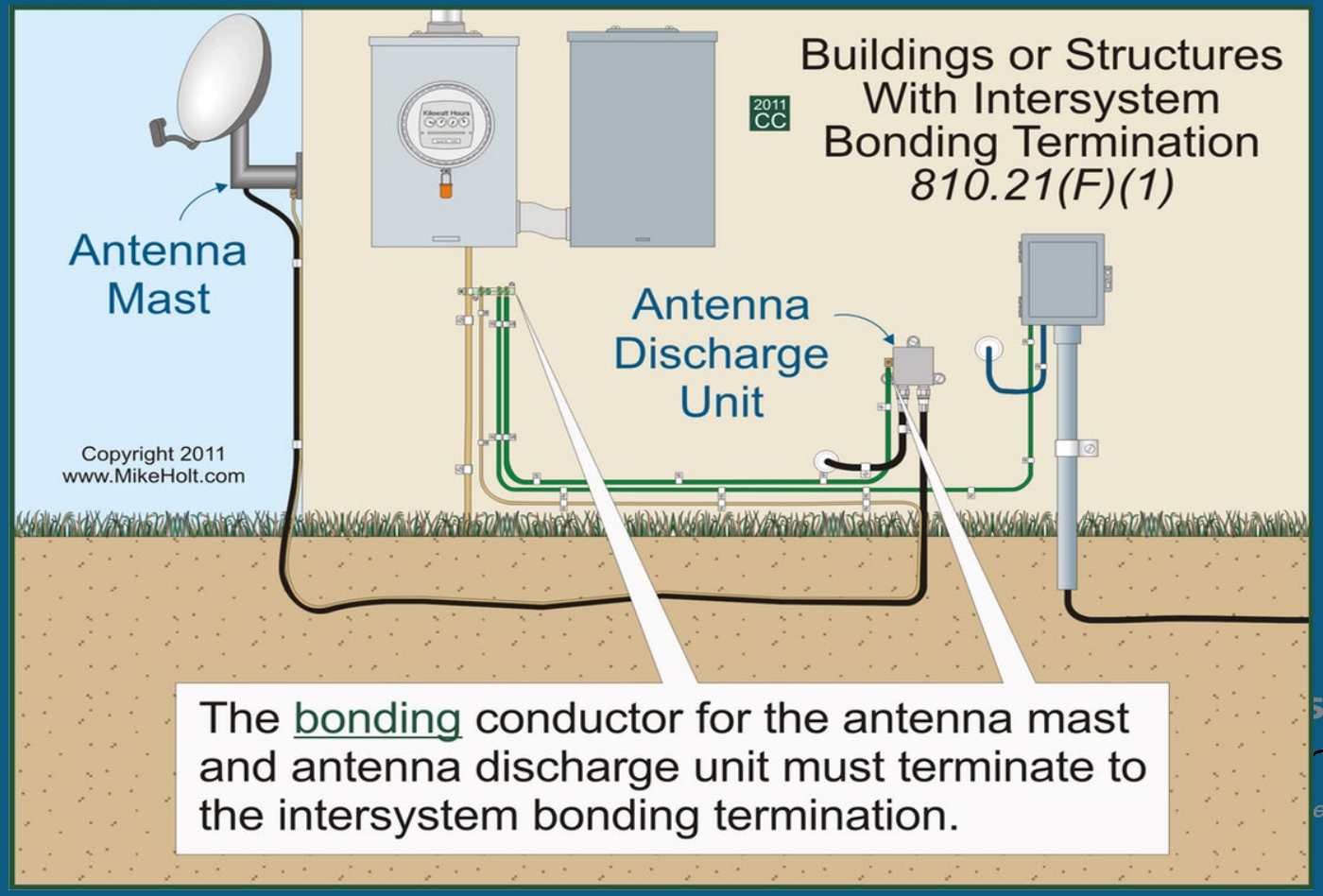
Ground plane

In telecommunication, a *ground plane* is a flat or nearly flat horizontal conducting surface that serves as part of an antenna, to reflect the radio waves from the other antenna elements.

Ground plane

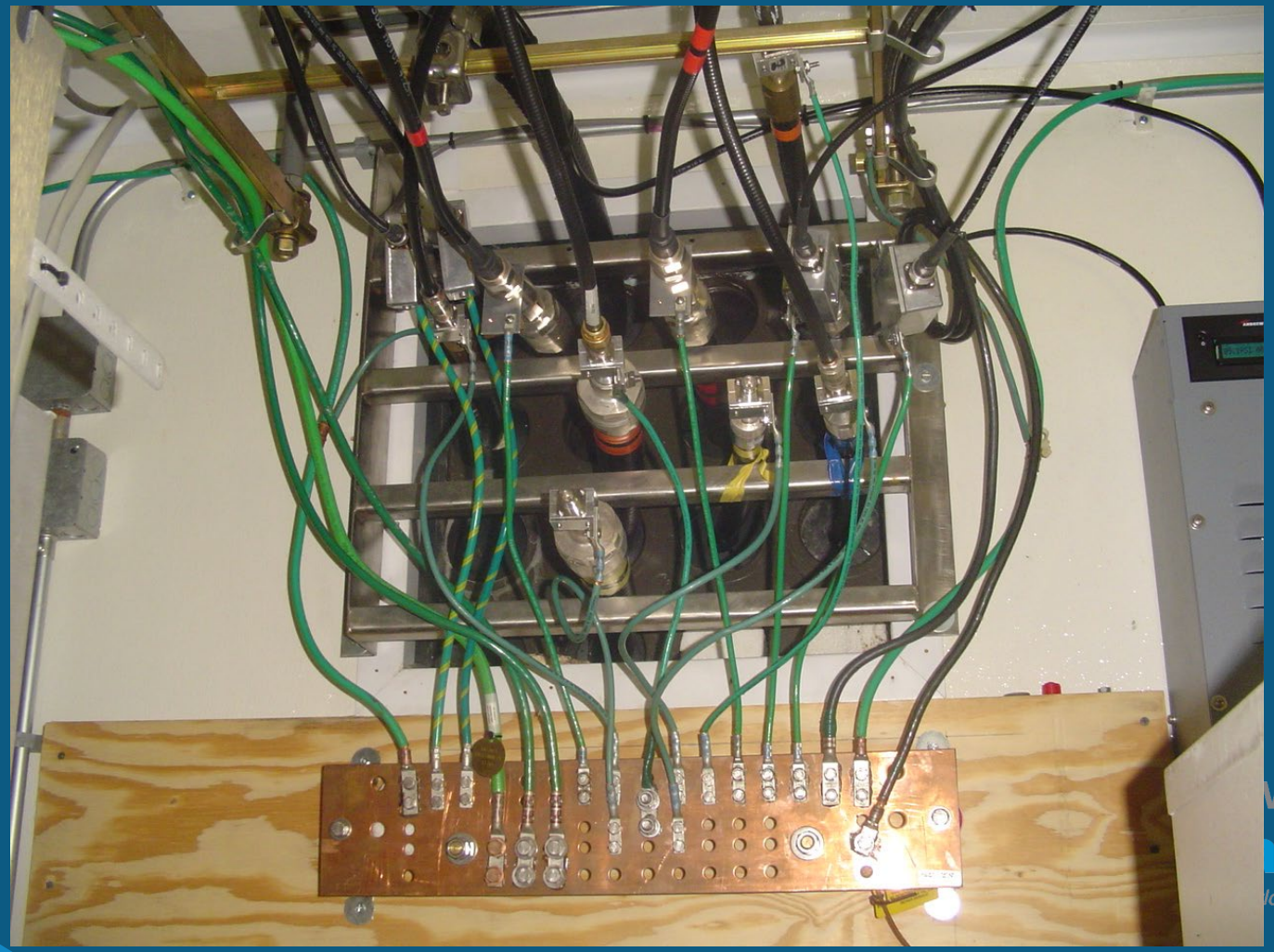
In electrical engineering, a **ground plane** is an electrically conductive surface, usually connected to electrical ground.

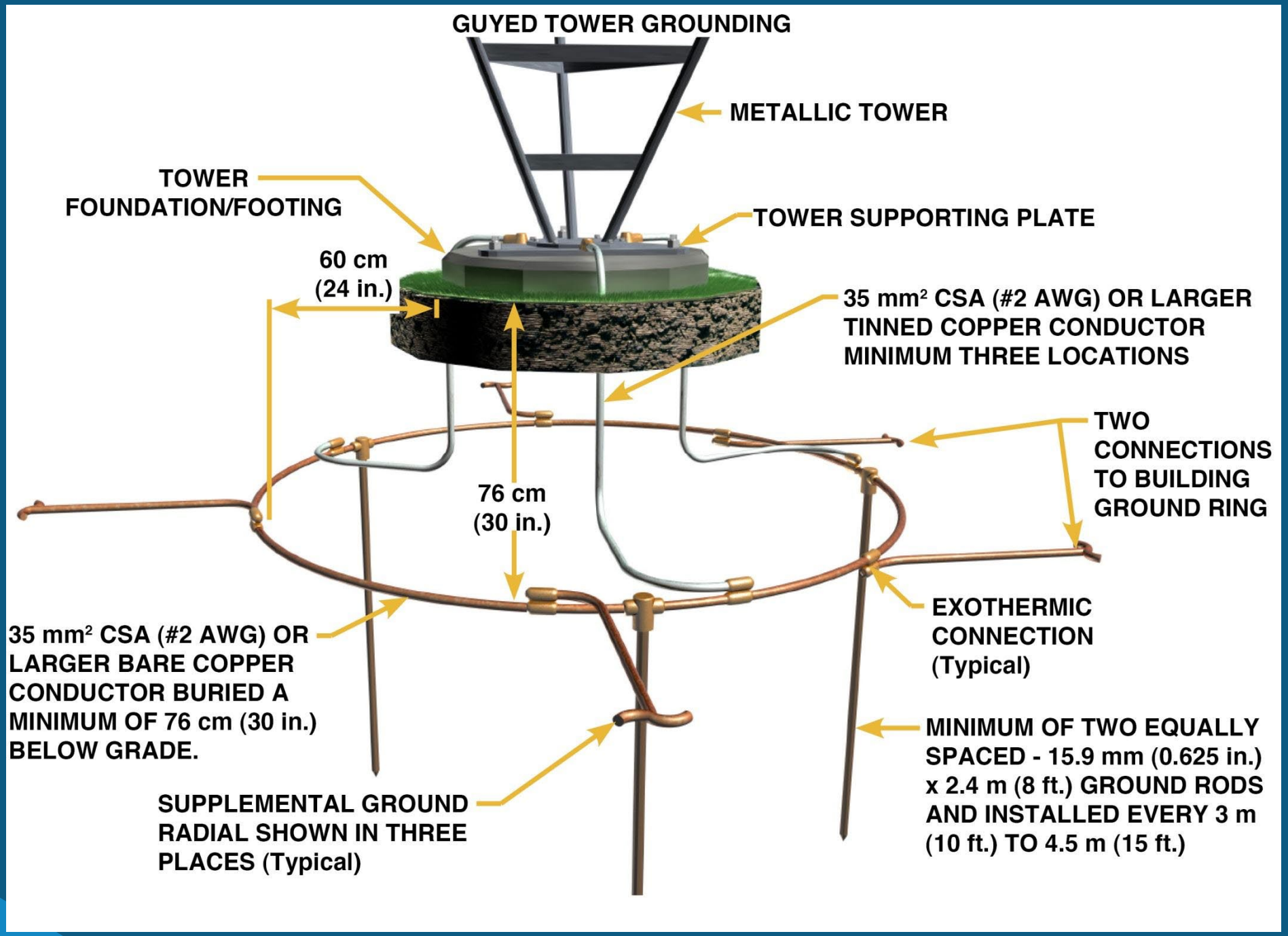
The term has two different meanings in ***separate areas*** of electrical engineering.

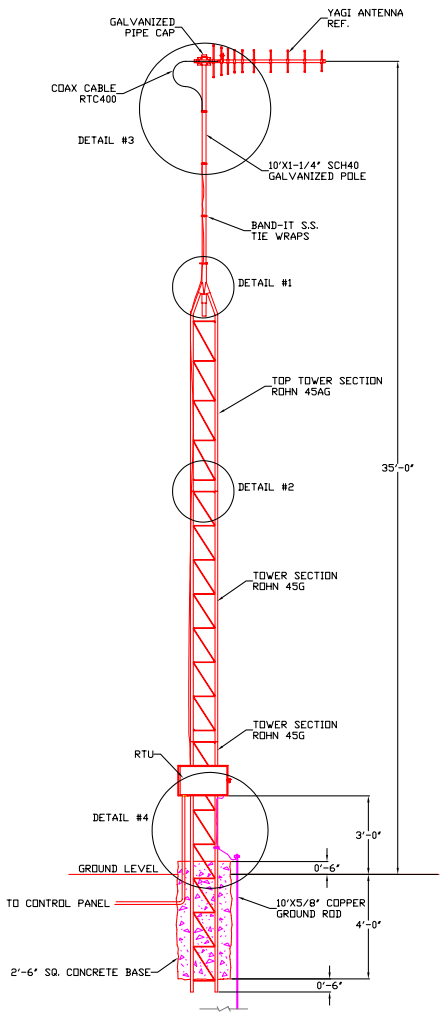


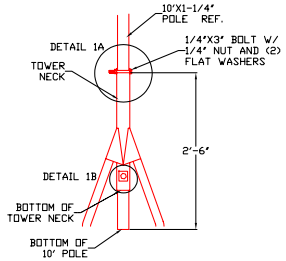
Antenna Ground

Do I need to ground my antenna and coaxial cable?

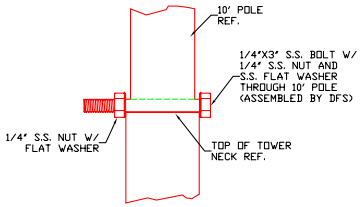



GUYED TOWER GROUNDING
METALLIC TOWER
TOWER FOUNDATION/FOOTING
TOWER SUPPORTING PLATE
60 cm (24 in.)
35 mm² CSA (#2 AWG) OR LARGER TINNED COPPER CONDUCTOR MINIMUM THREE LOCATIONS
TWO CONNECTIONS TO BUILDING GROUND RING
76 cm (30 in.)
EXOTHERMIC CONNECTION (Typical)
35 mm² CSA (#2 AWG) OR LARGER BARE COPPER CONDUCTOR BURIED A MINIMUM OF 76 cm (30 in.) BELOW GRADE.
MINIMUM OF TWO EQUALLY SPACED - 15.9 mm (0.625 in.) x 2.4 m (8 ft.) GROUND RODS AND INSTALLED EVERY 3 m (10 ft.) TO 4.5 m (15 ft.)
SUPPLEMENTAL GROUND RADIAL SHOWN IN THREE PLACES (Typical)

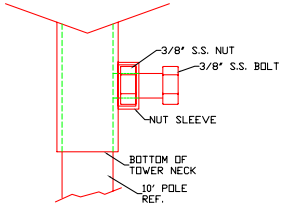




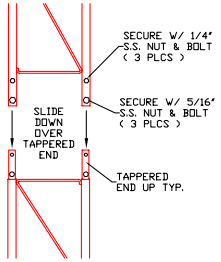
DETAIL #1
ANTENNA MOUNTING POLE



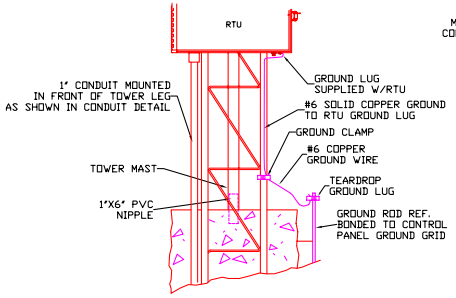
DETAIL 1A
NECK SUPPORT BOLT



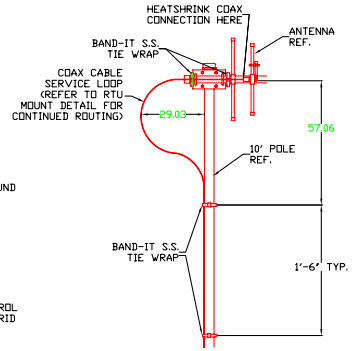
DETAIL 1B
POLE SWIVEL BOLT SIDE VIEW



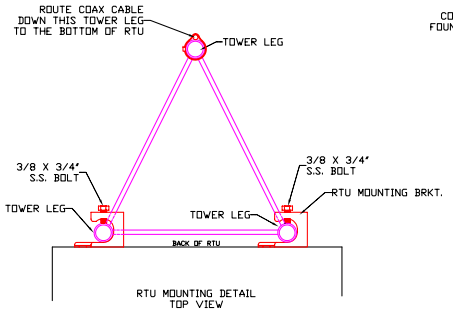
DETAIL #2
TOWER CONNECTING



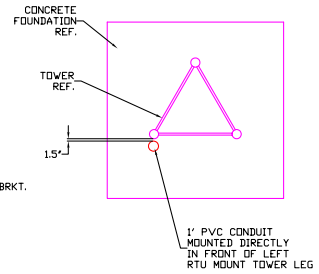
DETAIL #3
GROUNDING DETAIL



DETAIL #3
COAX MOUNTING & ROUTING



RTU MOUNTING DETAIL
TOP VIEW



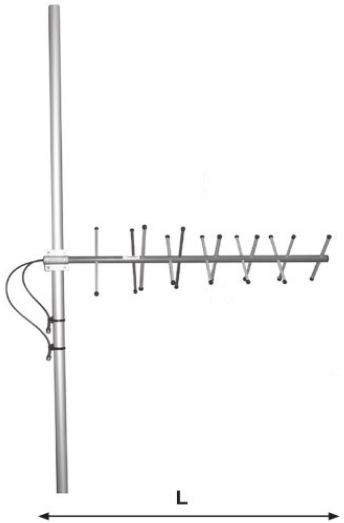
CONDUIT DETAIL
TOP VIEW

JOB NO.		
DFS DATA FLOW SYSTEMS, INC. MELBOURNE, FL		DFS-00353-008-
DRAWN: MCV	TITLE: 45G TOWER ASSEMBLY 35' 1-1/4" POLE 150 MPH WIND RATING (3 SEC GUST)	REV. —
CHK'D:		
ENGR:		
DATE: 12/22/04	SCALE: NTS	SHEET: 1 OF 1

Antenna types

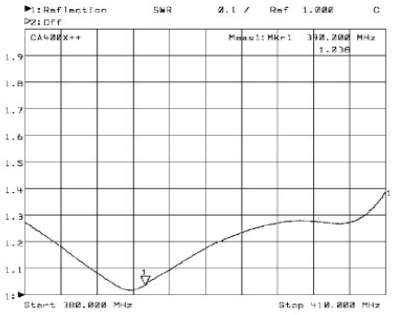
- Omnidirectional
  - Dipole
  - Monopole
  - Collinear
  - Slotted Waveguide
- Directional
  - Sectorial
  - Patch
  - Cantenna
  - Yagi
  - Biquad
  - Dish

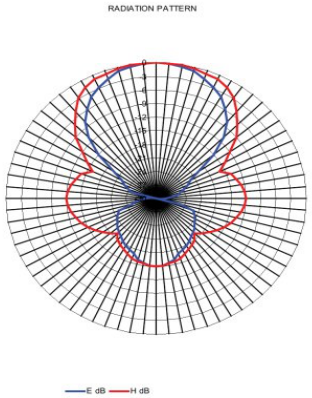
ComAnt® Communications Antennas



FREQUENCY INDEPENDENT DATA

Description:	cross-polarized yagi, dual feed, physically quarter wavelenght along the boom phased,
Frequency:	380-410 MHz, 405-440 MHz, 440-475 MHz, 830-890 MHz, 890-960 MHz
Impedance:	50 ohm
Gain:	10 dBi
Polarization:	dual/circular
Isolation:	30 dB
Connector:	2*N-female/2*TNC-female
VSWR:	< 1.5
Radome:	UV resistant ABS, RAL 7012, PU foam filling
Radiator:	copper
Passive elements:	coated aluminium
Attachment:	Ø 35-60 mm, aluminium alloy bracket, stainless steel V-bolts and self locking nuts
Lightning protection:	DC-short circuited
Temperature:	-40° - +80° C
IP:	67





CompleTech
ComAnt®-antennas by CompleTech, Finland

CAX++ CROSS-POLARIZED YAGI

Antenna features

- Usable frequency range (bandwidth)
- Radiation pattern (beamwidth, sidelobes, backlobe, front-to-back ratio, location of nulls)
- Maximum gain
- Input impedance
- Physical size and wind resistance

Unity or o-gain Antenna:

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Florida Section
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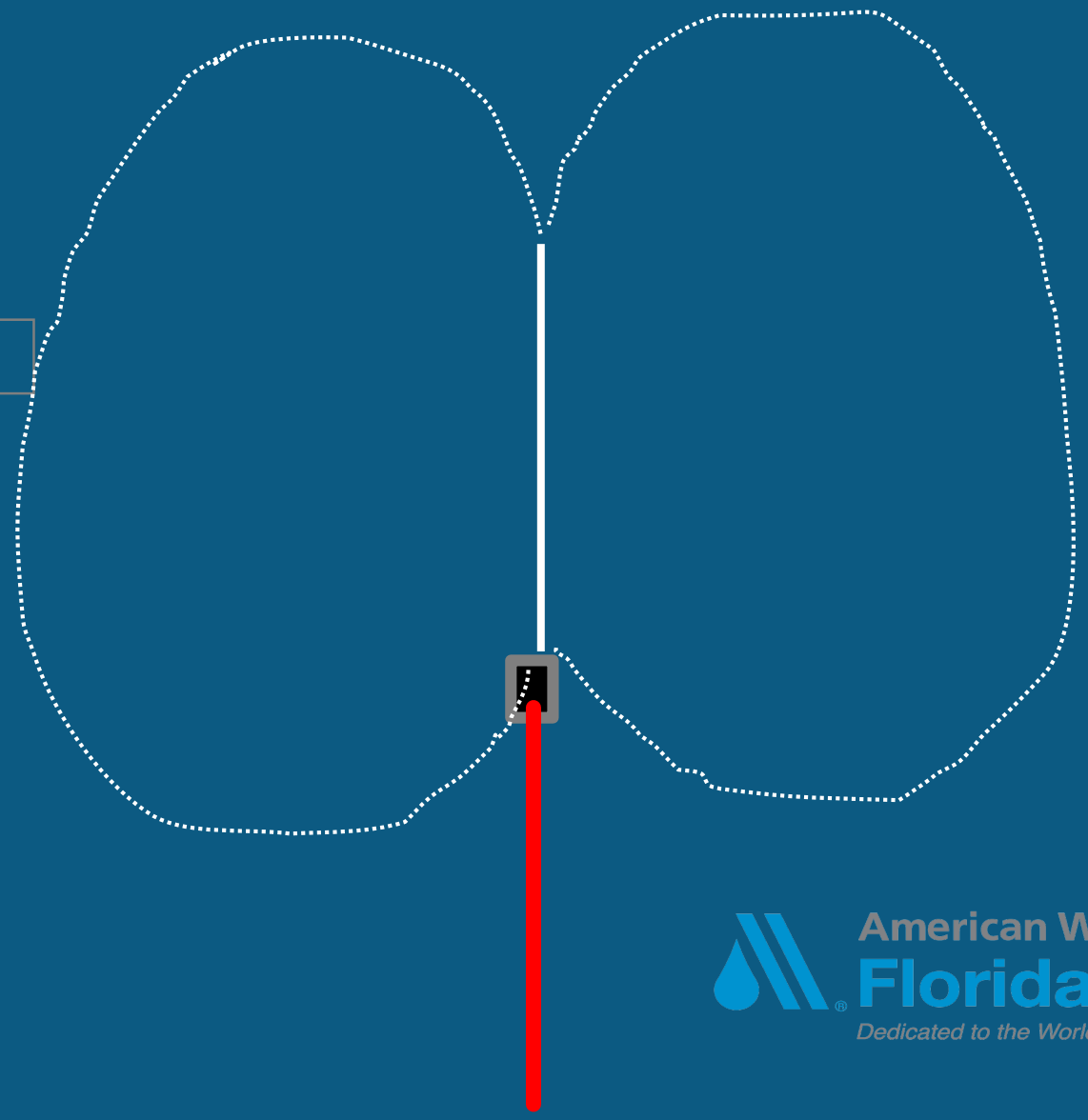
Side View



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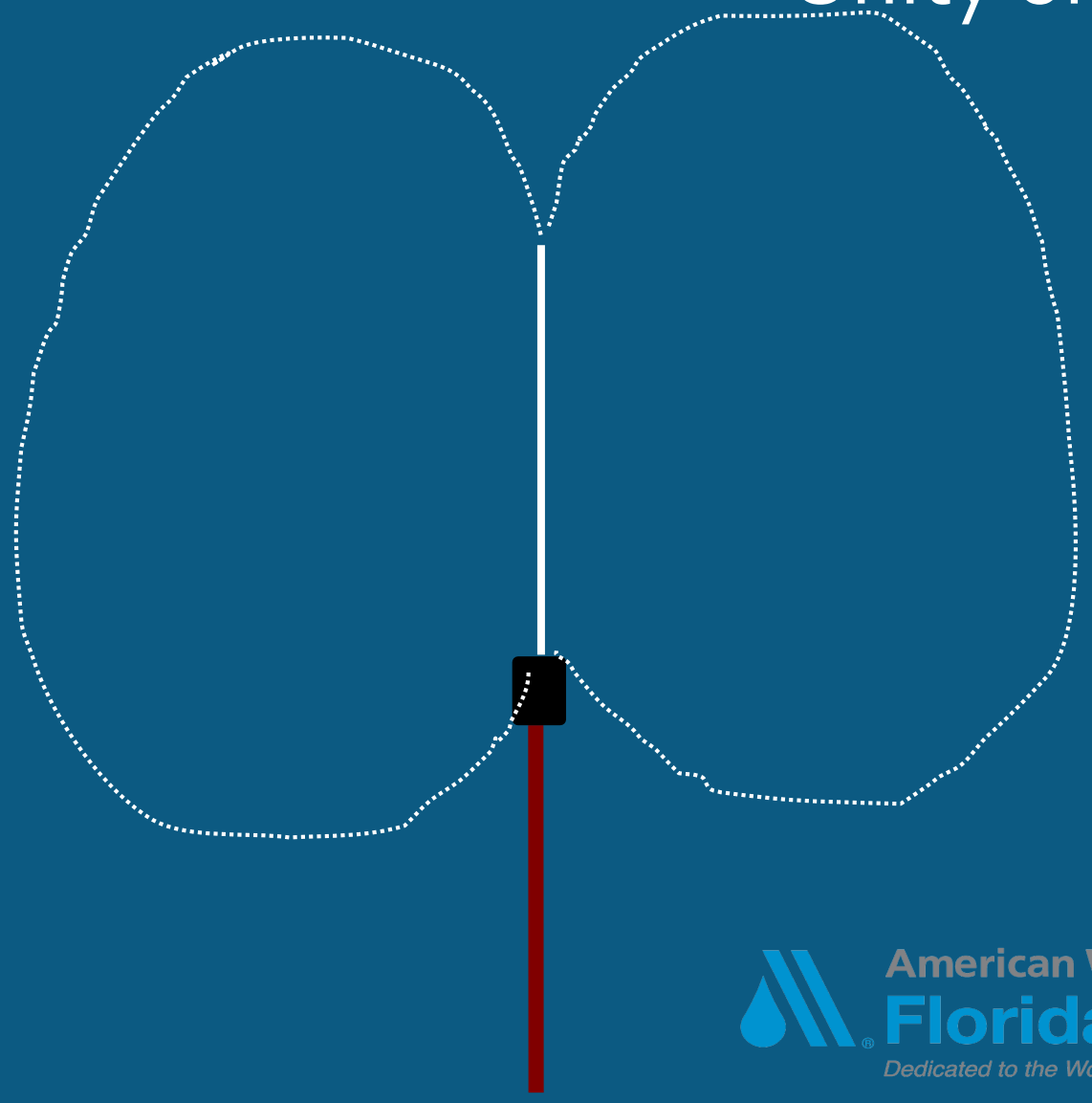
Unity or o-gain Antenna:

Side View



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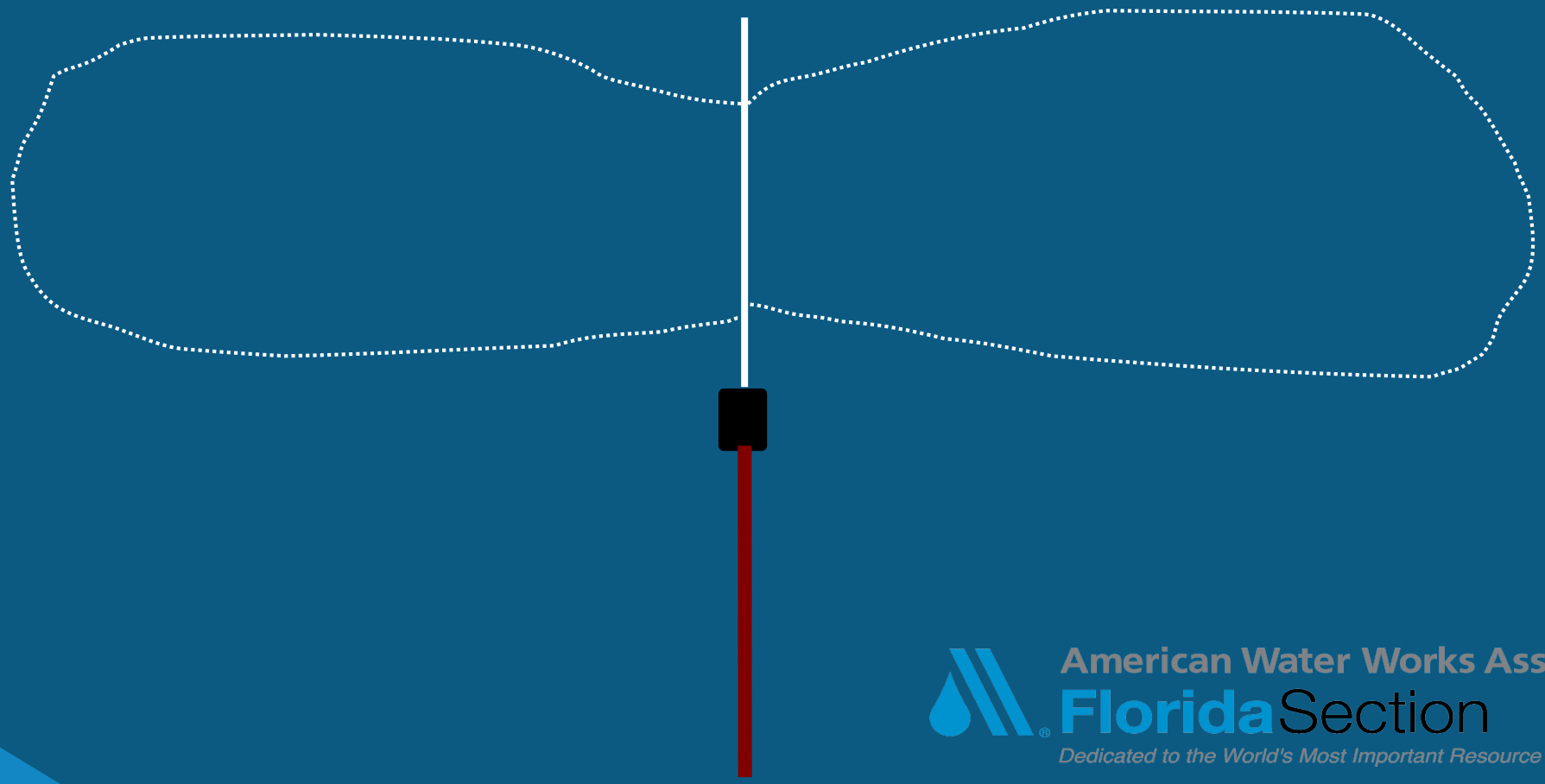
High-gain Antenna:



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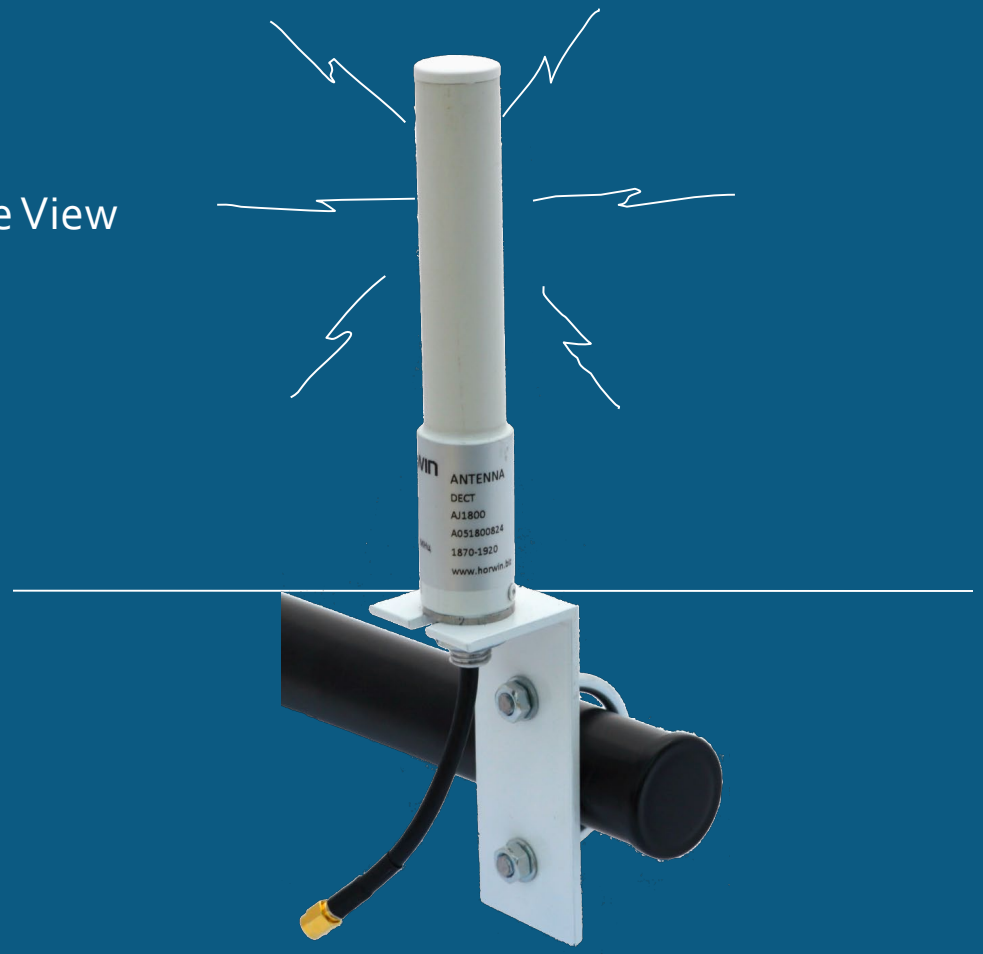
Omni-Directional Antenna:

Side View



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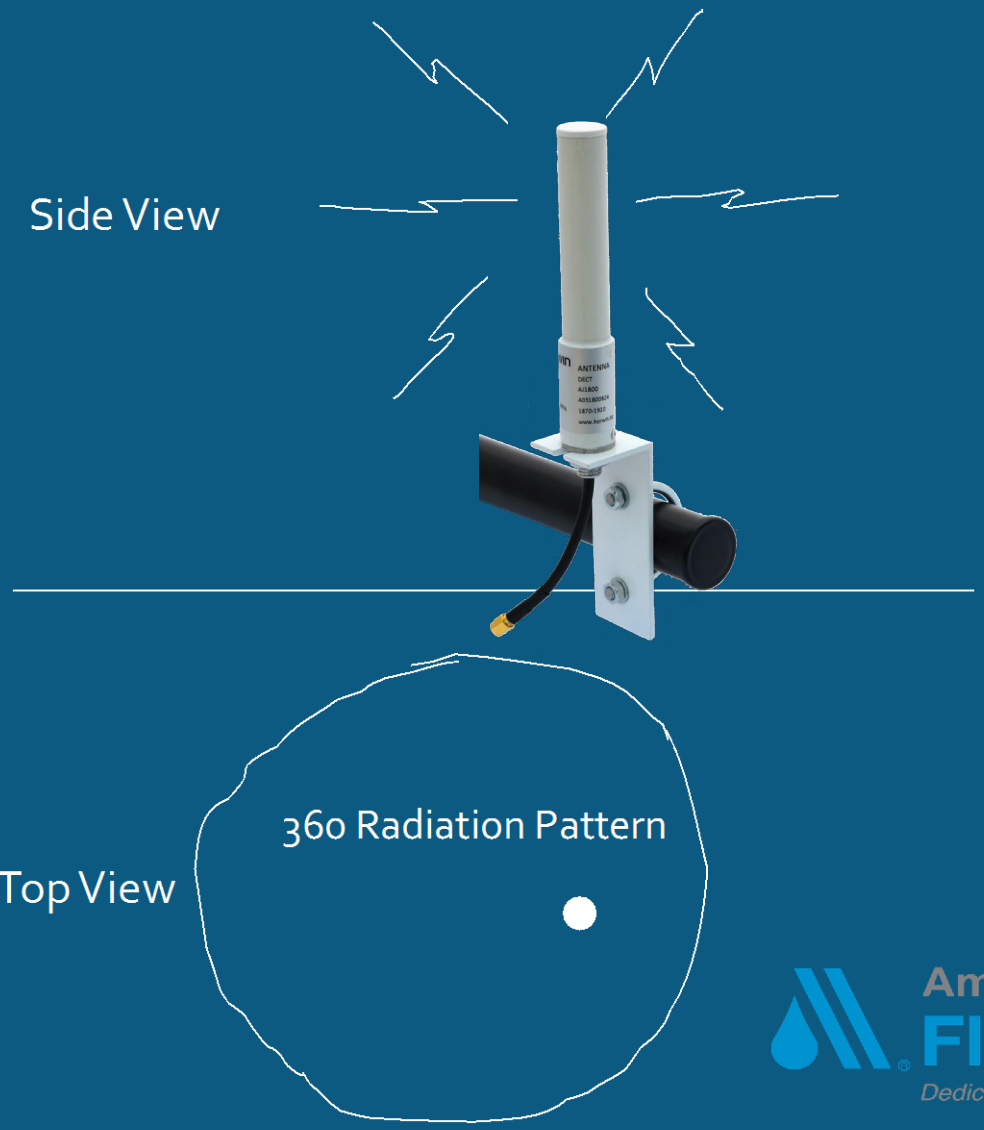
Omni-Directional Antenna:

Side View



Top View

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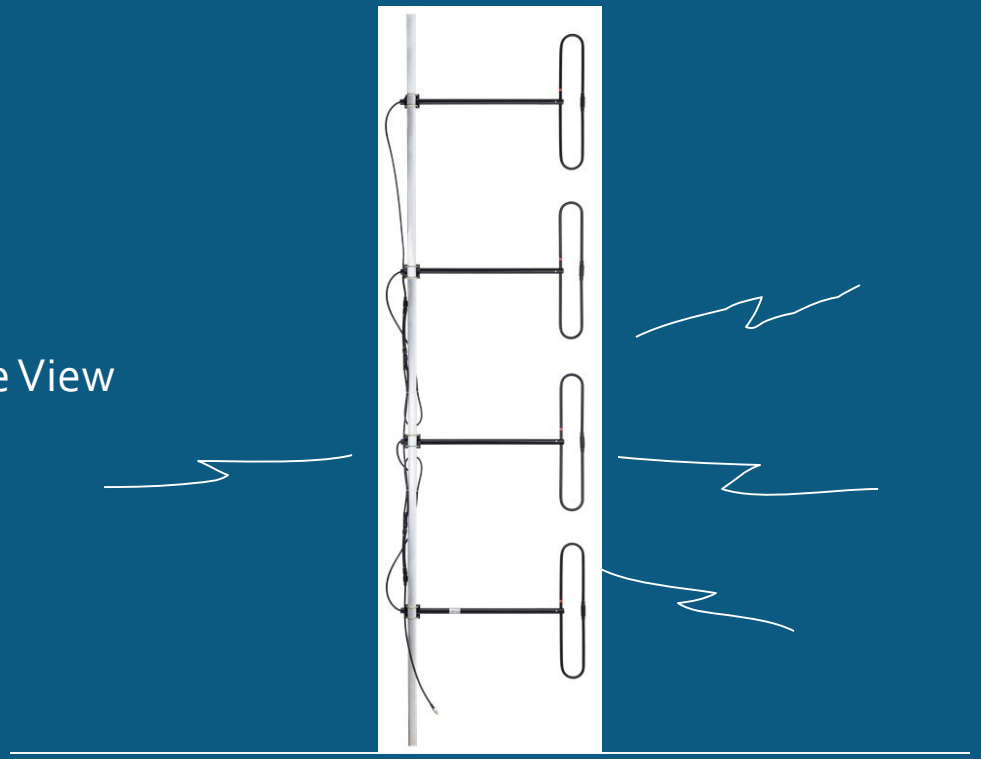
Off-set Antenna:

Side View



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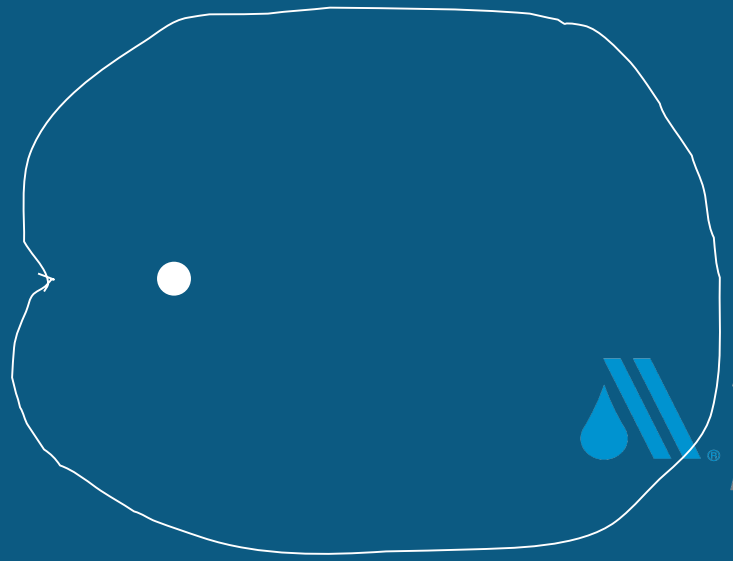
Off-set Antenna:

Side View

Top View



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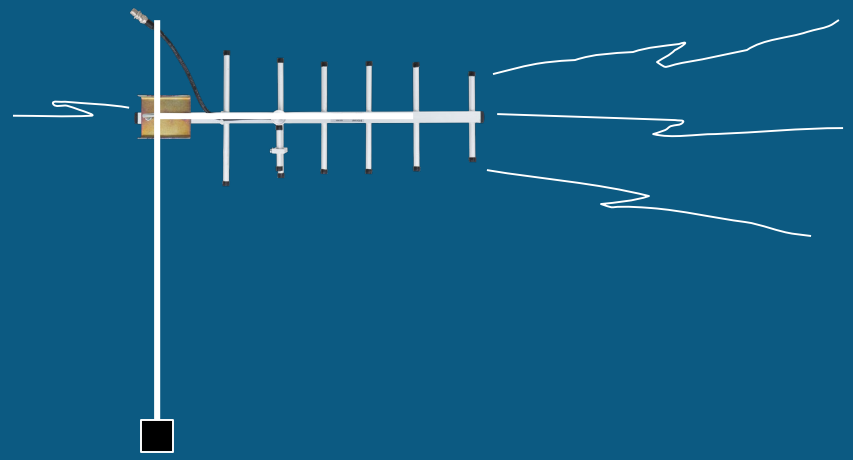
Yagi Antenna:

Side View



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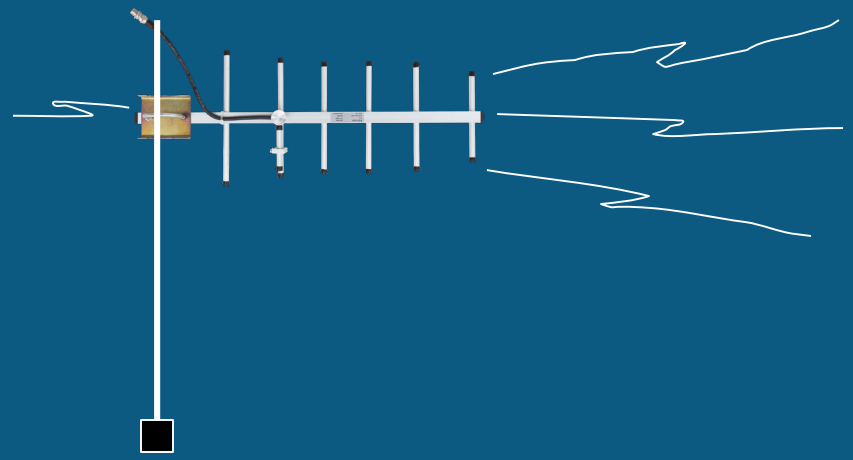
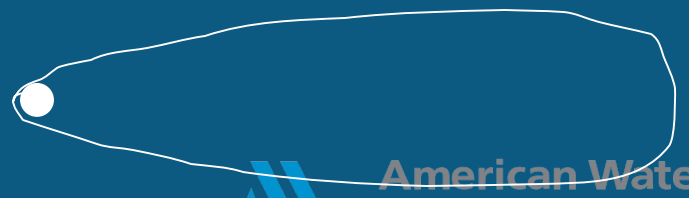
Yagi Antenna:

Side View



Top View



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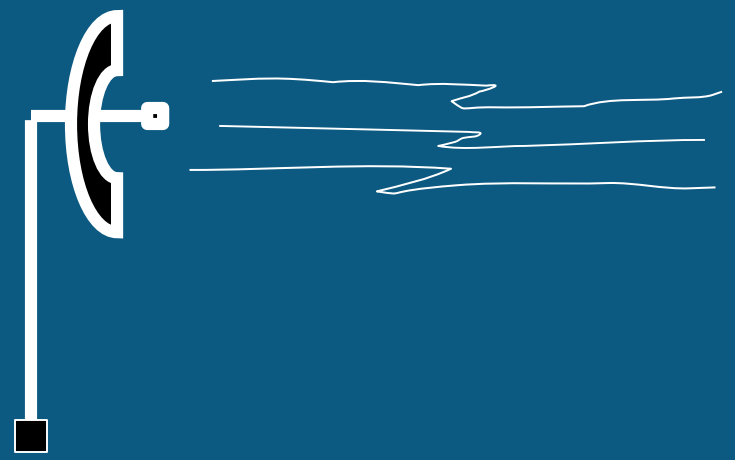
Dish Antenna:

Side View



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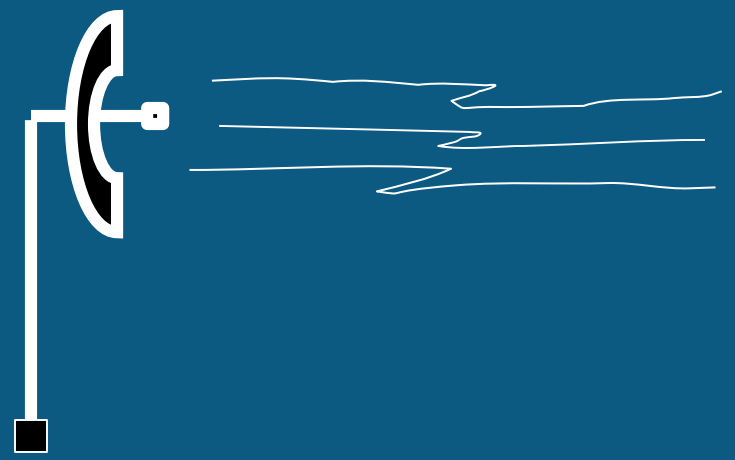
Dish Antenna:

Side View



Top View

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Works Association

ction

portant Resource ®

iation

Questions ?

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Thank You!

The End

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