Antennas and Transmission lines

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Antenna and transmission line irrigation analogy

Irrigation requires:

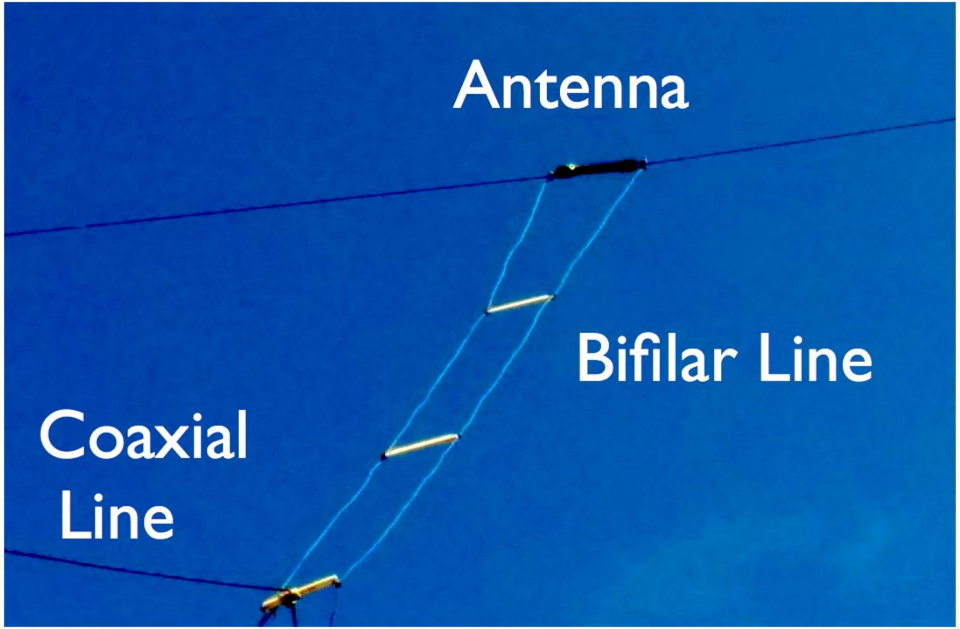
A hose to transport the water to the sprinkler

transmission line

A sprinkler to direct the water to the specific area we want to irrigate

antenna

- 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 a metallic device used to guide radio frequency (RF) energy from one point to another (for example a *coaxial* cable or *bifilar* line).



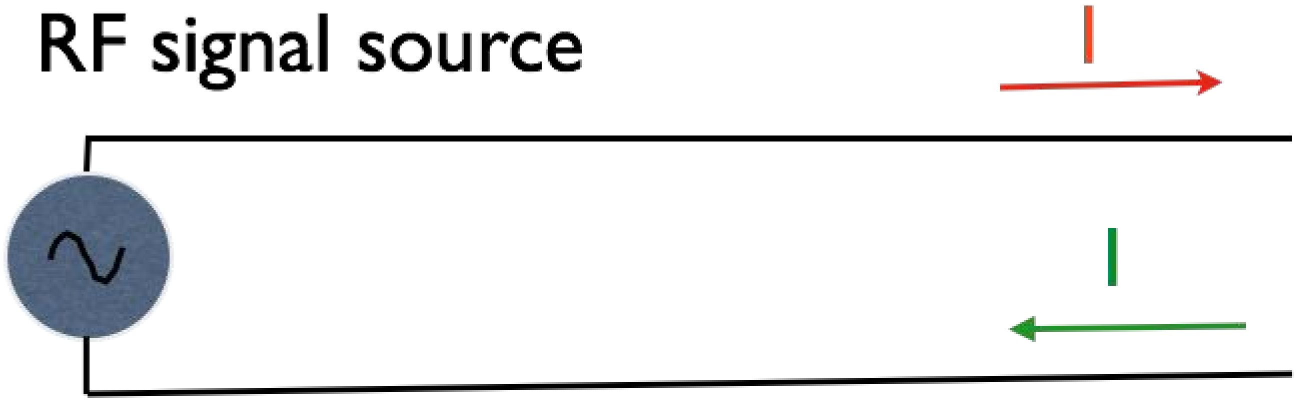
Transmission Line

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

Every transmission line will attenuate the signal.

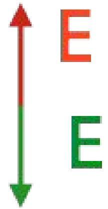
Transmission Line

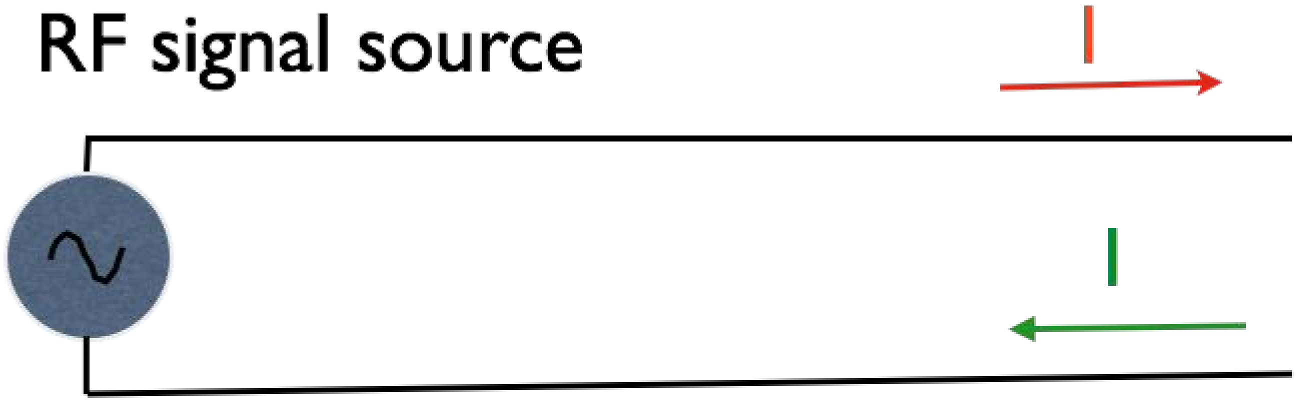
The simplest ***transmission line*** is the bifilar line formed by two parallel conductors separated by air or an insulator. It will carry the RF signal from the source to the other end. There can be an alternating current even in an open ended transmission line, since the electrons will flow back and forth every half cycle



Transmission Line

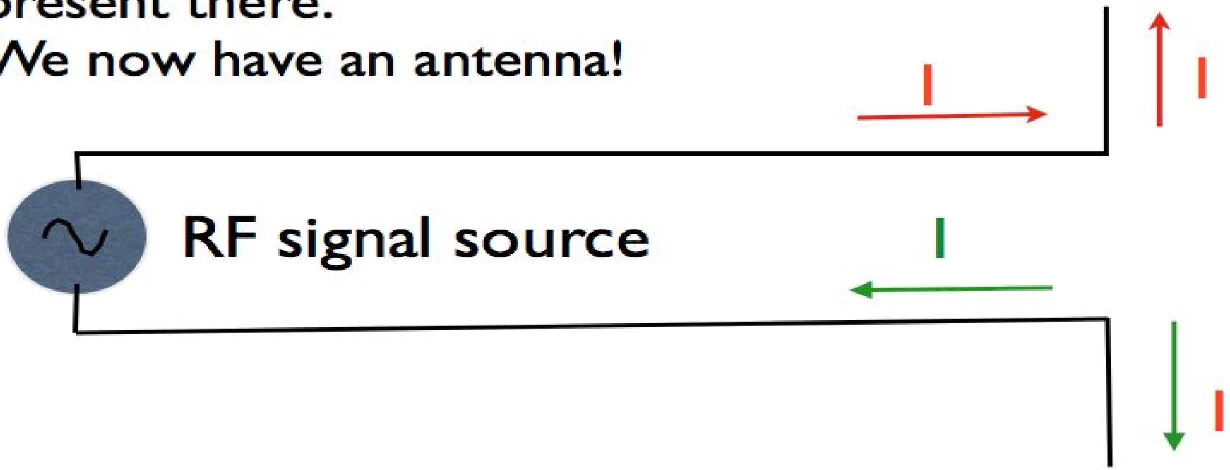
The electric field at a distant point created by the each of the currents will be of the same magnitude but in opposite direction and will therefore cancel.





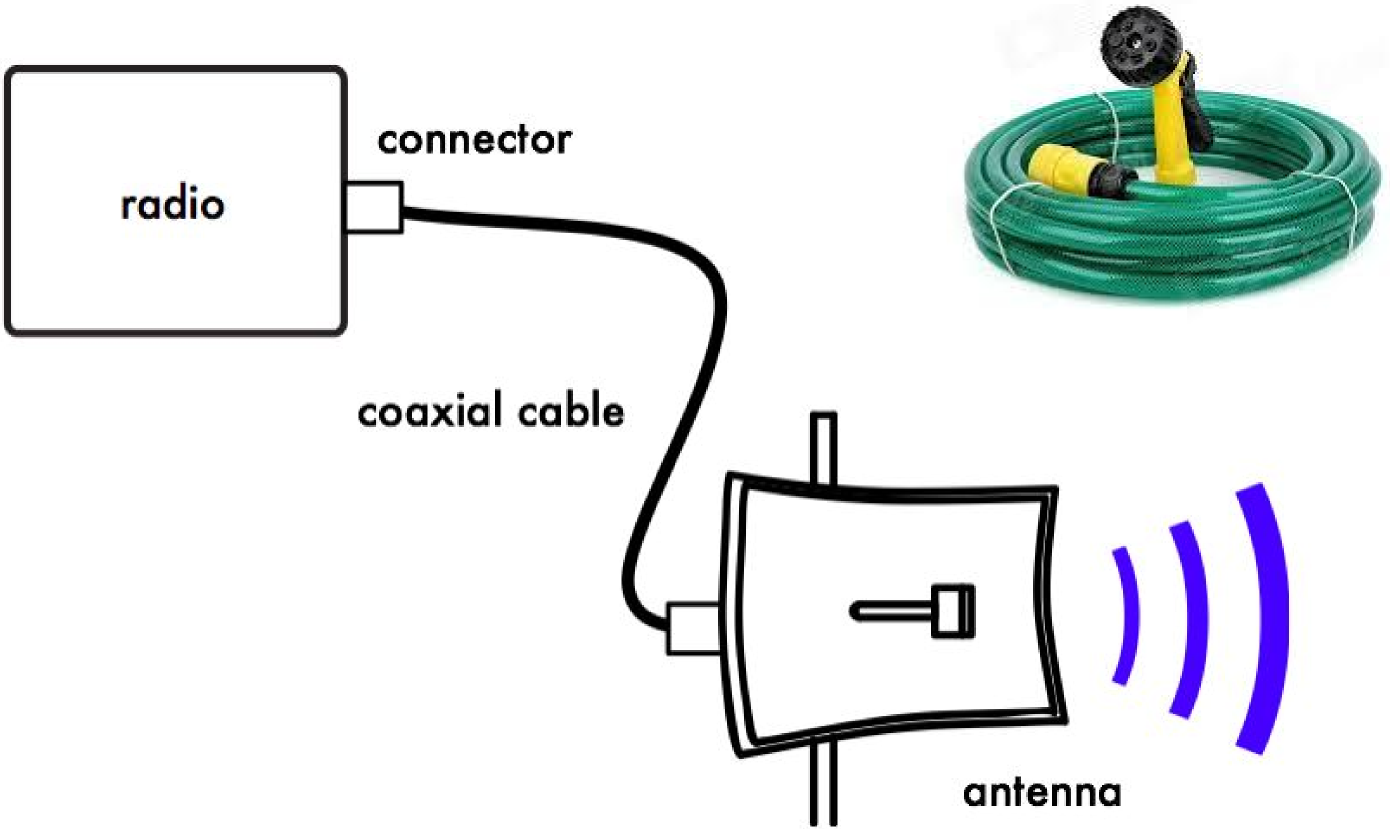
Bent ends transmission line

If we bend one extreme upward and the other downward, the currents will now flow upward in both segments and therefore the electric fields created will reinforce. The resulting electric field will cause a current to flow in any conductor present there.
We now have an antenna!

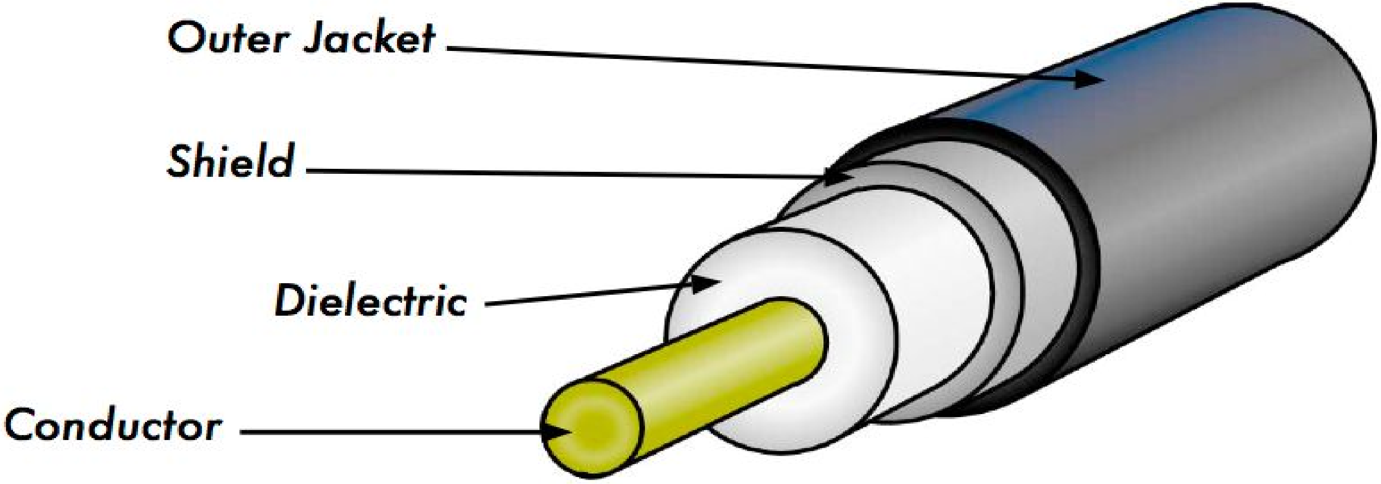


Irrigation system components

Wireless system components



Coaxial transmission lines



Coaxial transmission lines

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.

Cable Type	Diameter	Attenuation @ 2.4 GHz	Attenuation @ 5.3 GHz
RG-58	4.95 mm	0.846 dB/m	1.472 dB/m
RG-213	10.29 mm	0.475 dB/m	0.829 dB/m
LMR-400	10.29 mm	0.217 dB/m	0.341 dB/m
LDF4-50A	16 mm	0.118 dB/m	0.187 dB/m

http://www.ocarc.ca/coax.htm

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Impedance

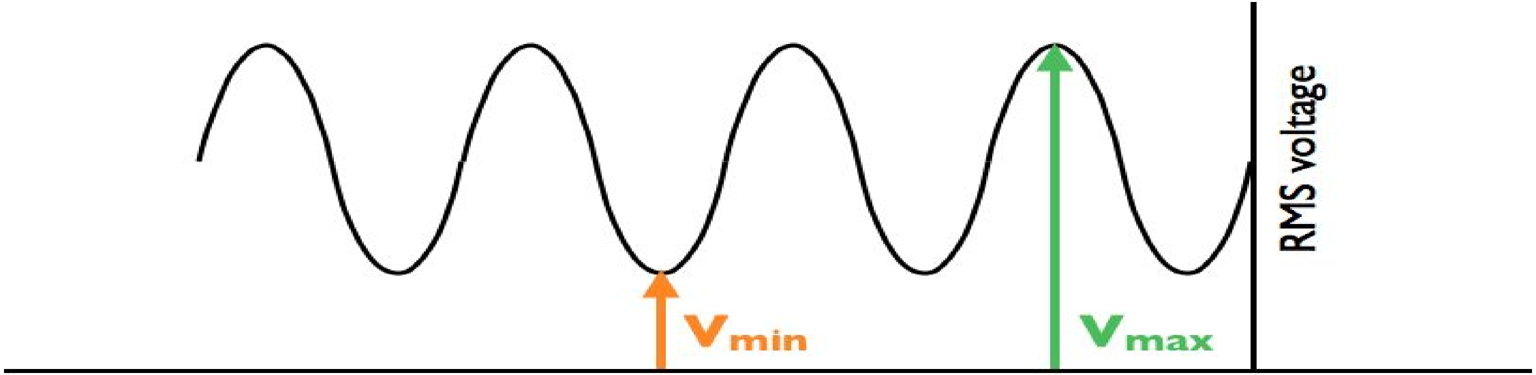
All materials will oppose the flow of an alternating current to some extent. This opposition is called ***impedance***, and is analogous to resistance in DC circuits.

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. Any mismatch will cause undesired reflections and power loss.

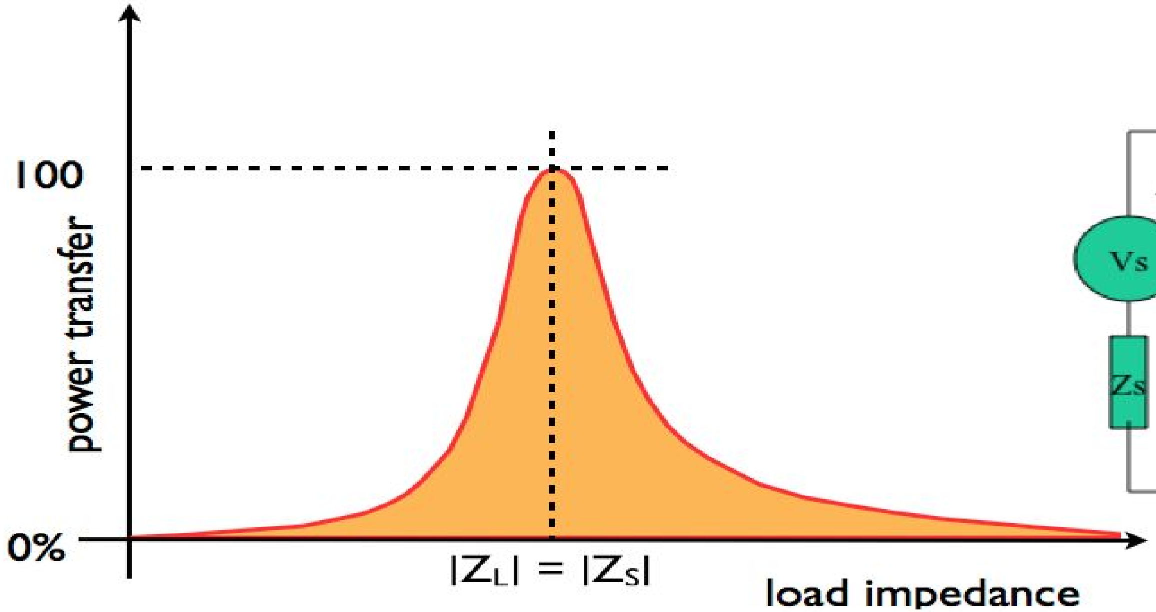
Reflections and VSWR

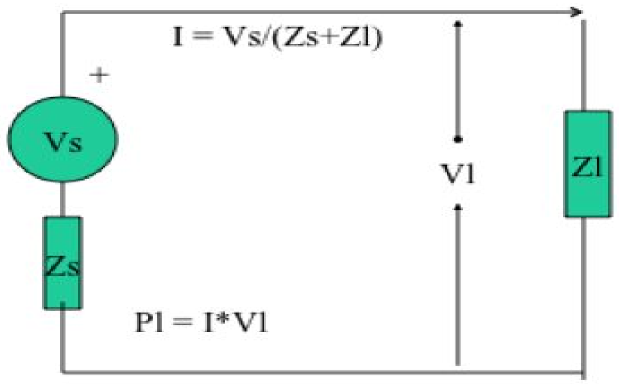
Impedance mismatch causes reflections and increased VSWR.



$$\text{Voltage Standing Wave Ratio VSWR} = \frac{V_{max}}{V_{min}}$$

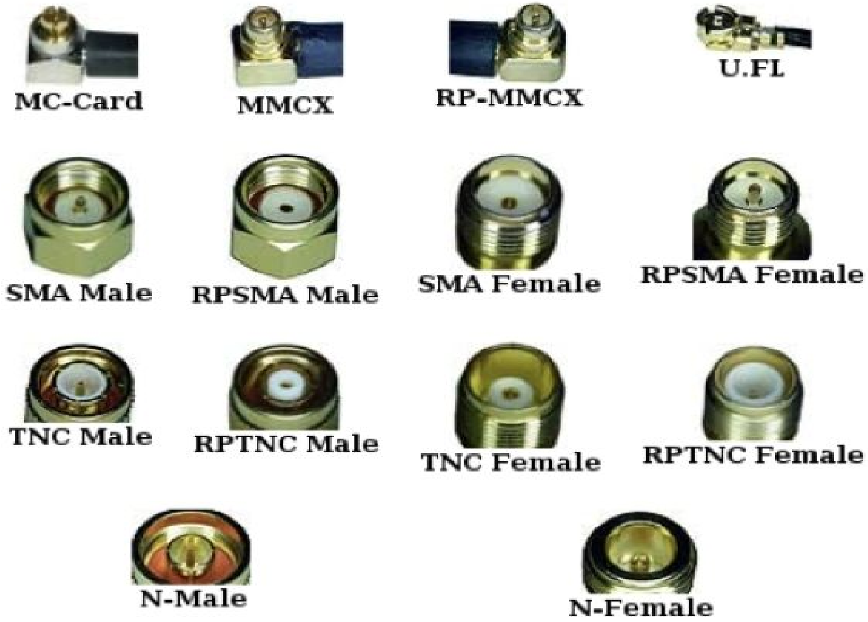
Matched impedance = maximum power transfer





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.

SMA female to N male

N male to N male

N female to N female

SMA male to TNC male

U.FL to RP-TNC male pigtail

U.FL to N male pigtail

SMA male to N female

Theory: isotropic antennas

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

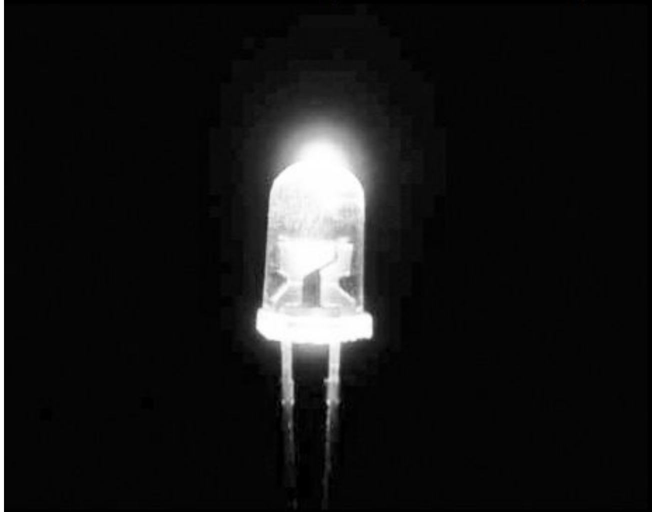
Real-world antennas are characterized by their ability to radiate more strongly in some directions than in others; this is called ***directivity***.

When taking the efficiency of the antenna into account, this preference for a direction of radiation is referred to as ***gain***.

dBi

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).



Omnidirectional antenna

An omnidirectional antenna spreads the signal evenly in every direction of the plane

Directional Antenna

A directional antenna forms a very narrow beam in a specific direction and very little energy is directed elsewhere.

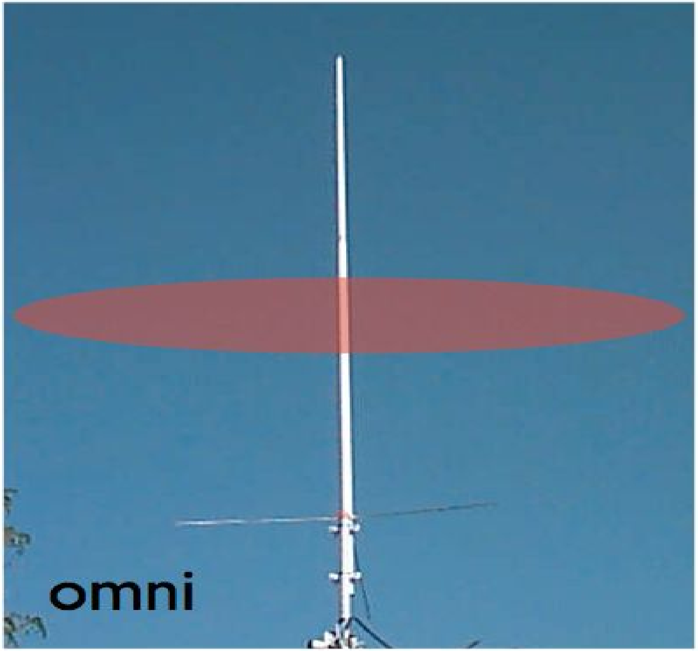
If the beam becomes much wider we will have a sectorial antenna

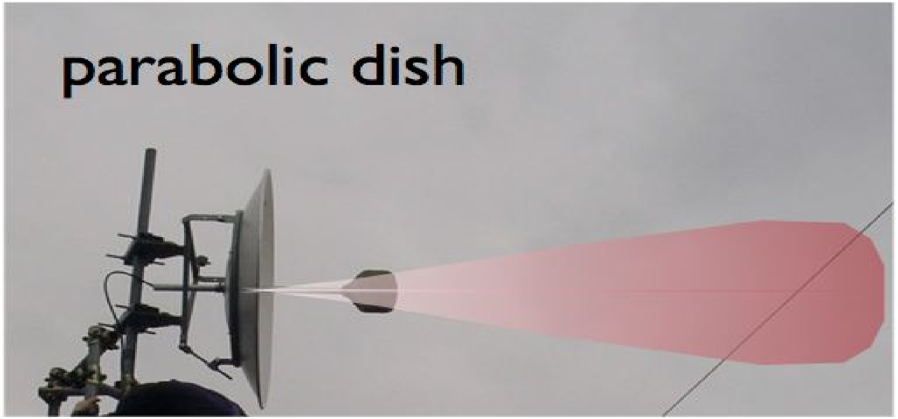
Sectorial Antenna

Spreads the signal in certain angle of the plane, for instance 45 degrees, 60 degrees, etc.

Often combined in a base station to provide 360 degree coverage, for instances 3 sectors of 120 degrees each.

Directional vs. Omnidirectional





Antenna features

When buying an antenna, what features are important to consider?

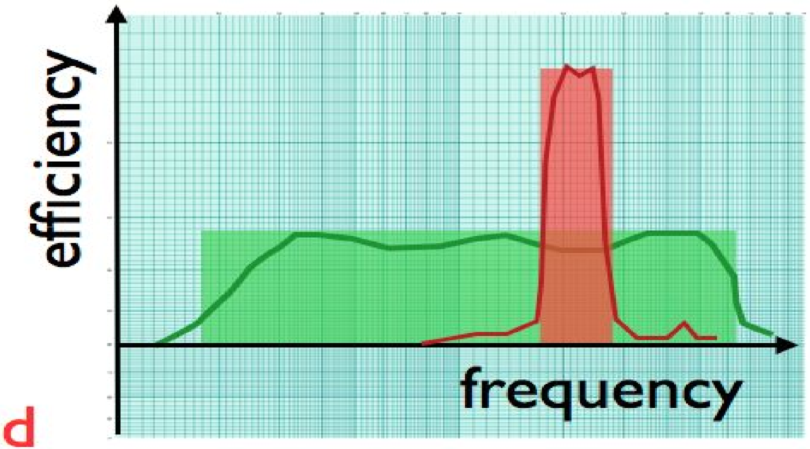
- Usable frequency range (bandwidth)
- Radiation pattern (beamwidth, sidelobes, backlobe, front-to-back ratio, location of nulls)
- Maximum gain
- Input impedance
- Physical size and wind resistance
- Cost

Bandwidth

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

You must choose an antenna that works well for the frequencies you intend to use (for example, use a 2.4 GHz antenna for 802.11 b/g, and a 5 GHz antenna for 802.11a).

narrow band

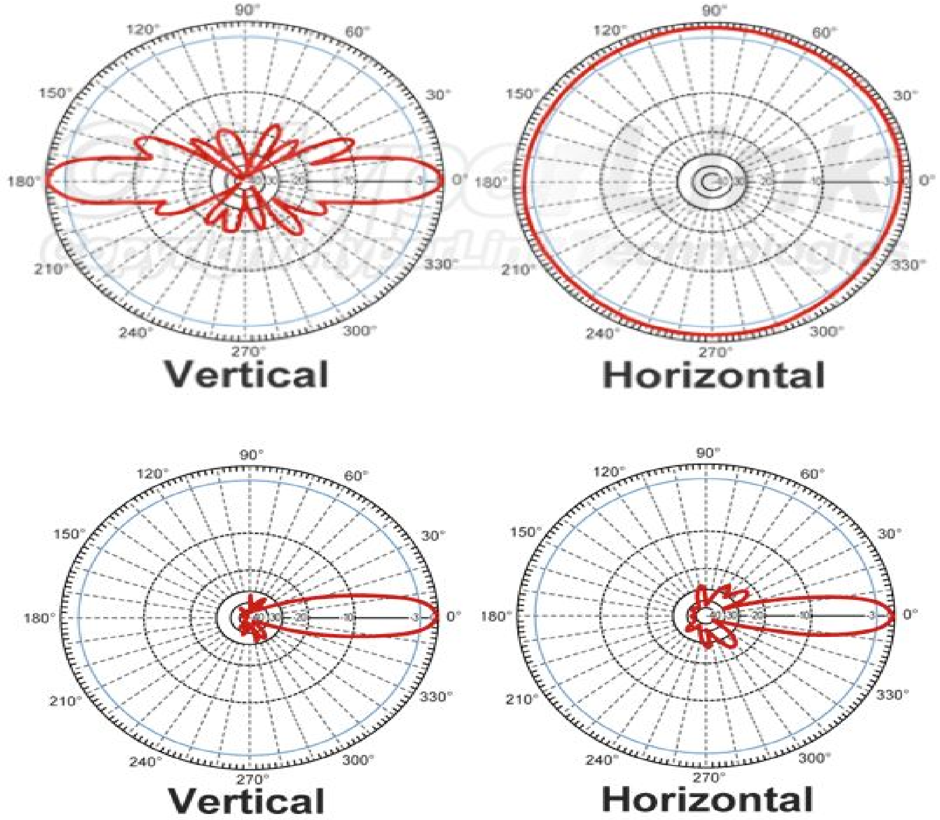


wide band

Radiation pattern

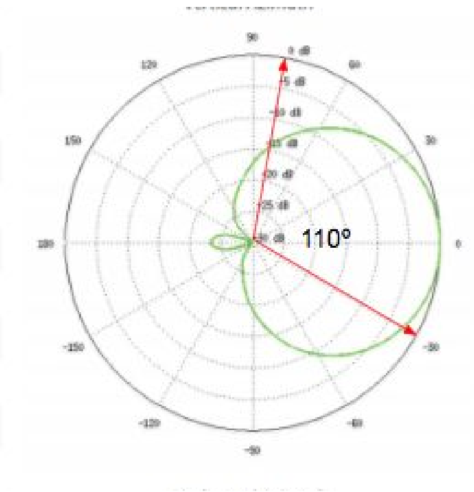
The ***radiation pattern*** of an antenna is a pictorial representation of the distribution of the power radiated from, or received by, the antenna. This is presented as a function of direction angles centered on the antenna.

Radiation patterns usually use a polar projection.



Example of radiation pattern usage

Raila



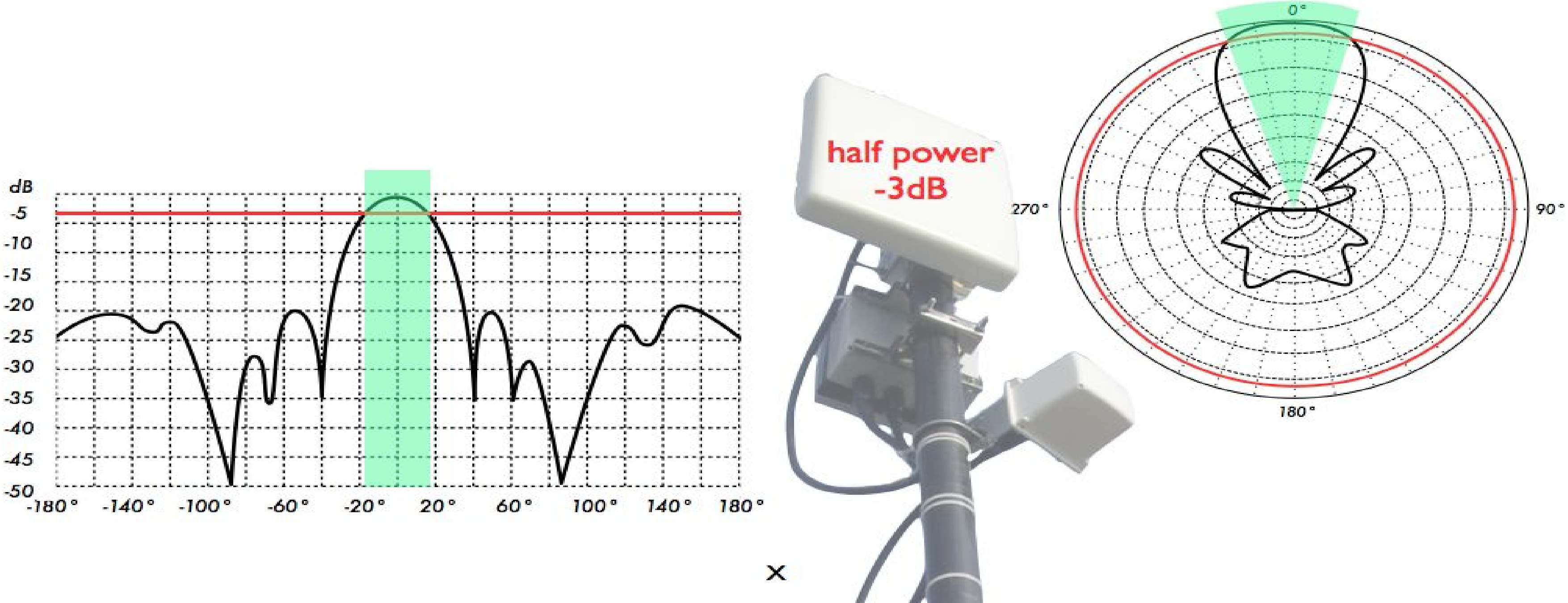
Christine

Gain at -30º is 16-2= 14 dBi, towards Christine

Gain at 10º is 16-15= 1dBi, towards Raila

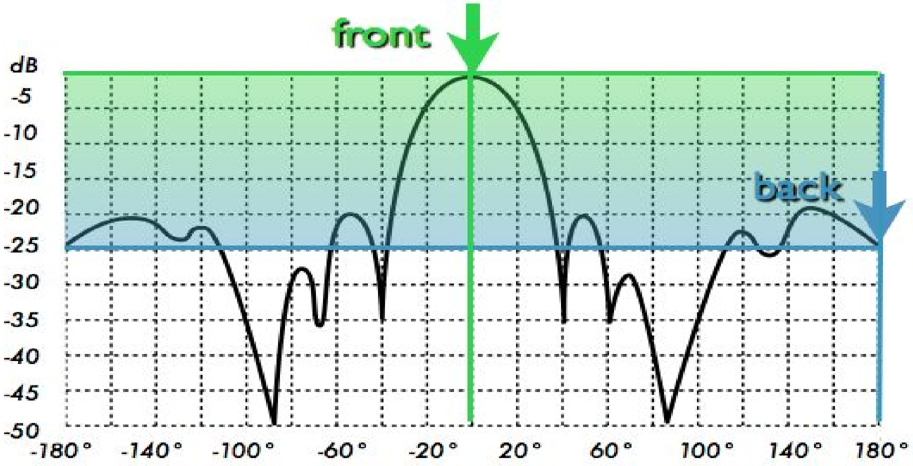
Beamwidth

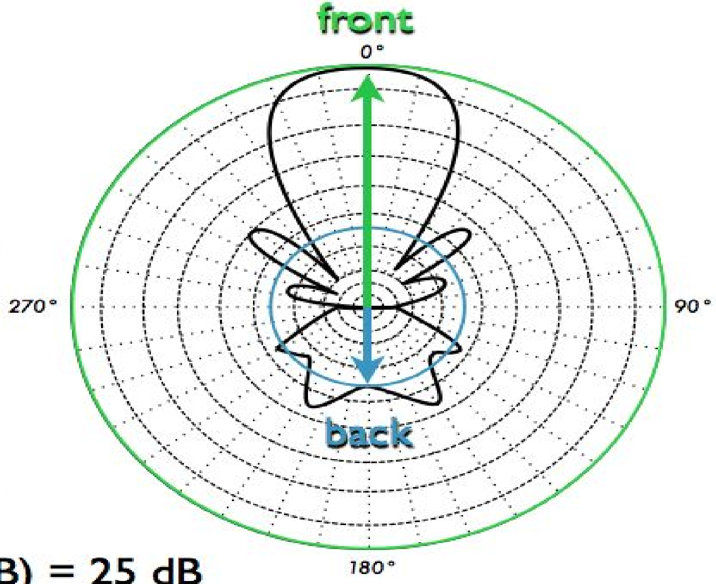
The ***beamwidth*** of an antenna is the angular measure of that part of the space where the radiated power is greater than or equal to the half of its maximum value.



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.

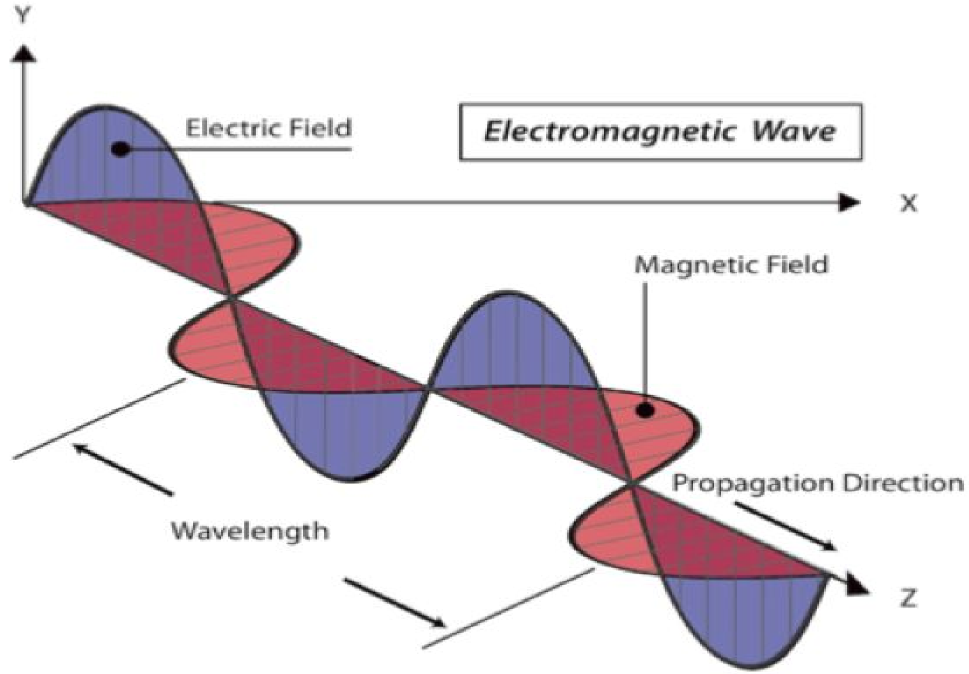




In this example the f/b ratio is: 0 dB - (-25 dB) = 25 dB

Polarization

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



Antenna polarization

Reciprocity

Antenna characteristics like gain, beamwidth, efficiency, polarization, and impedance are independent of the antenna's use for either transmitting or receiving.

Another way to state this is that an antenna's transmitting and receiving characteristics are ***reciprocal***.

Wind load

Parabolic Antenna with Radome

Sector Antenna

Parabolic Grid Antenna

Weather effects

parabolic grid

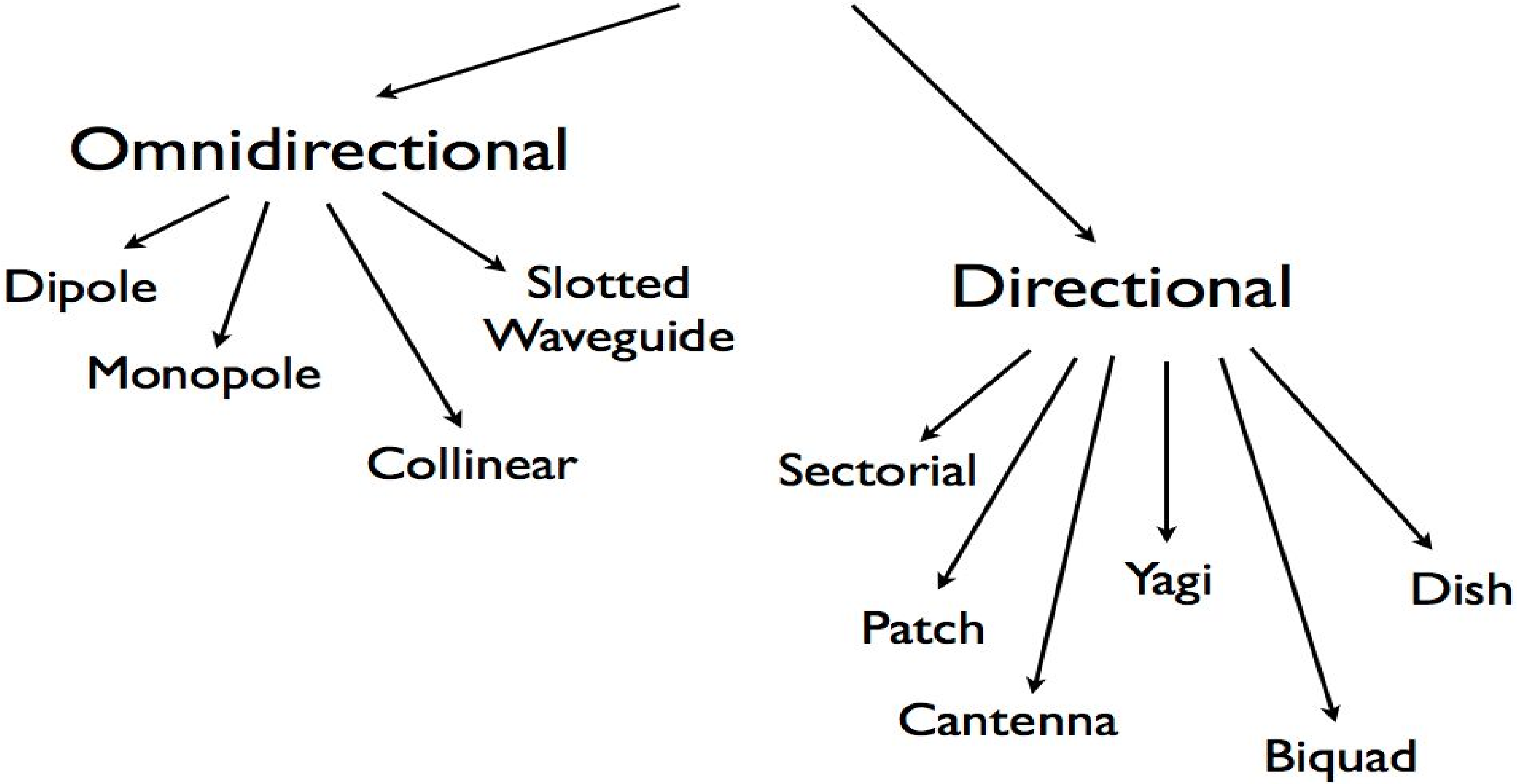
parabolic grid
(covered by snow)

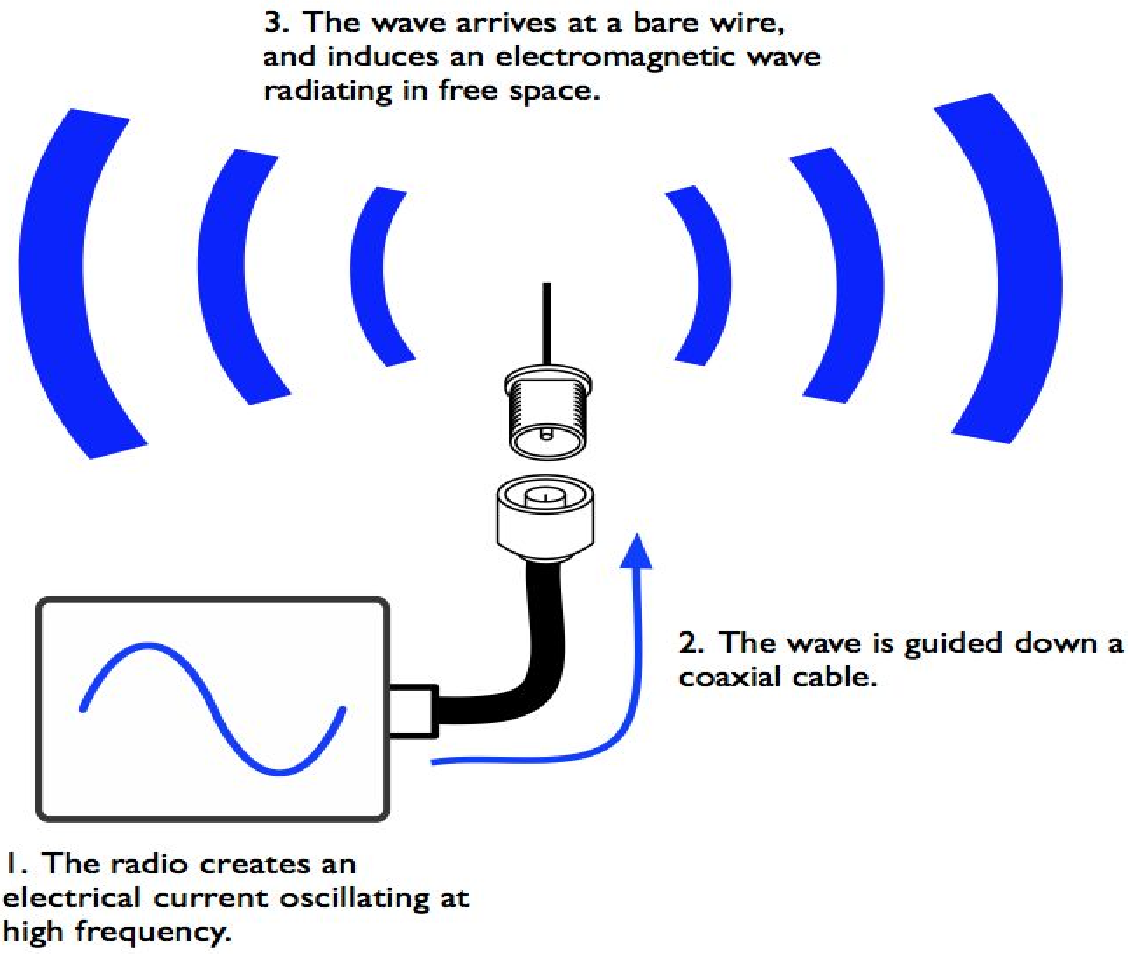
Weatherproofing antennas

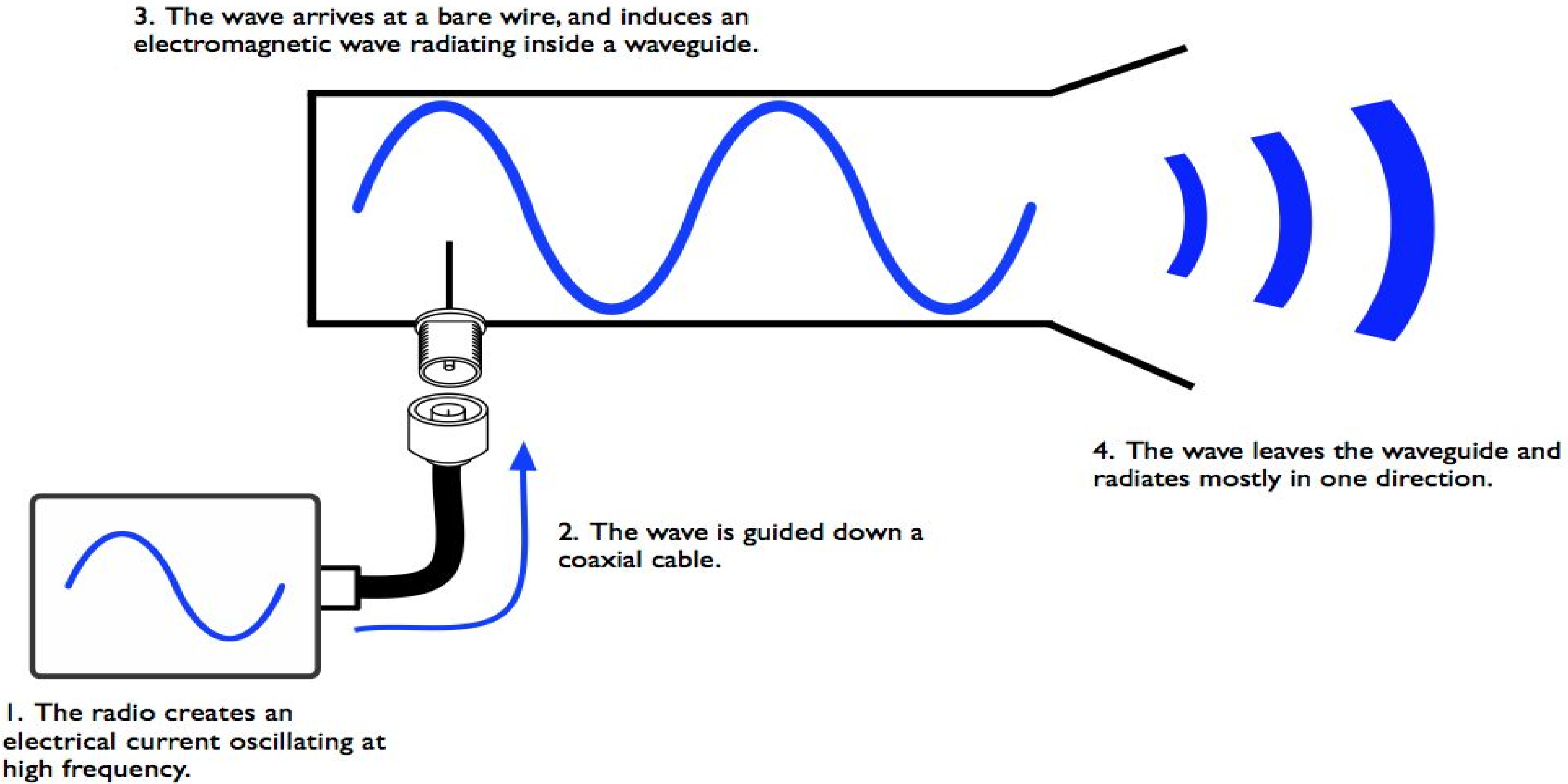
Most antenna problems are caused by coaxial cable connections that loosen due to vibration, allowing moisture to penetrate the connector interface.

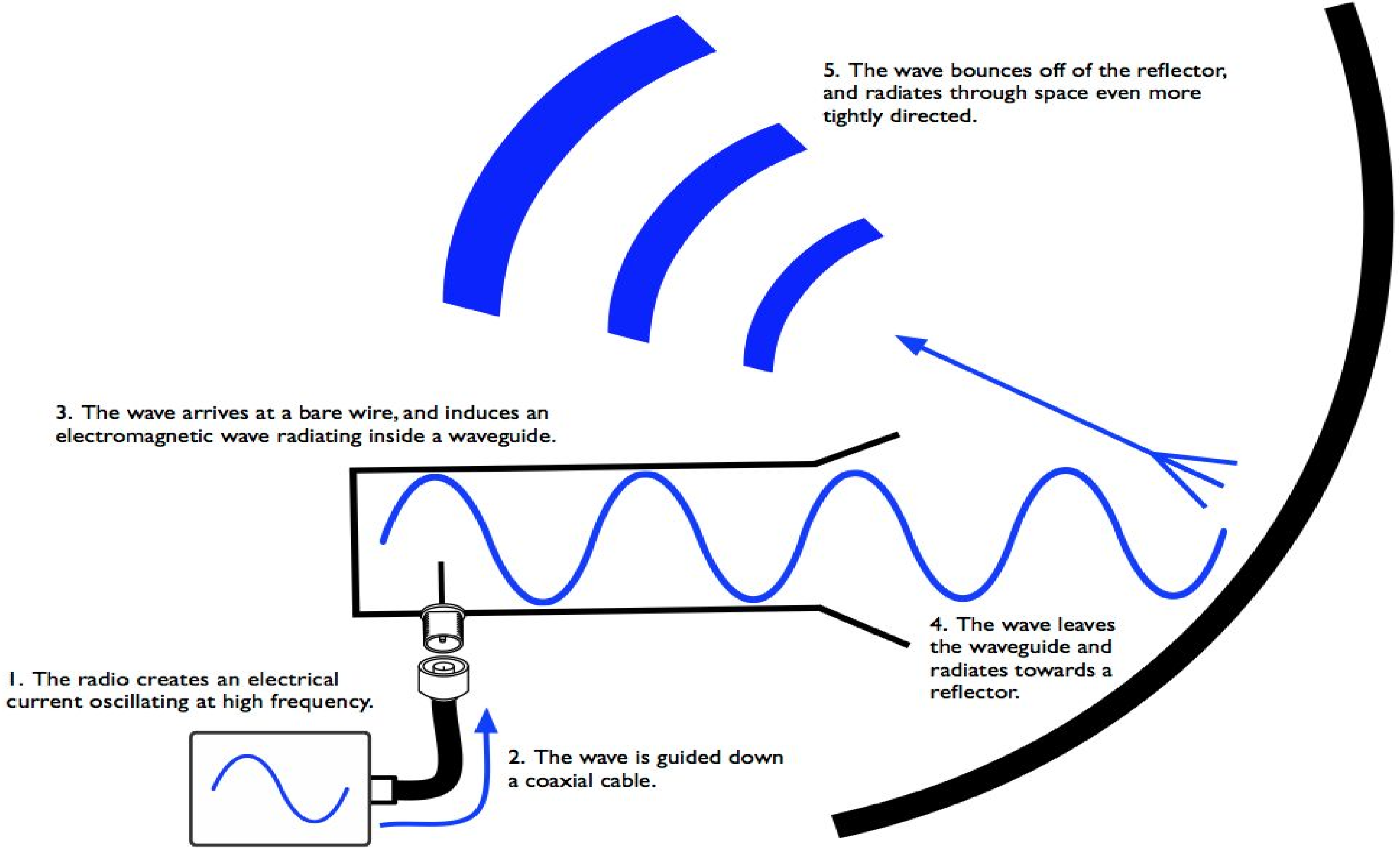
Weatherproof all outdoor connections.

Antenna types




3. The wave arrives at a bare wire, and induces an electromagnetic wave radiating in free space.
2. The wave is guided down a coaxial cable.
1. The radio creates an electrical current oscillating at high frequency.


3. The wave arrives at a bare wire, and induces an electromagnetic wave radiating inside a waveguide.
4. The wave leaves the waveguide and radiates mostly in one direction.
2. The wave is guided down a coaxial cable.
1. The radio creates an electrical current oscillating at high frequency.


5. The wave bounces off of the reflector, and radiates through space even more tightly directed.
3. The wave arrives at a bare wire, and induces an electromagnetic wave radiating inside a waveguide.
4. The wave leaves the waveguide and radiates towards a reflector.
1. The radio creates an electrical current oscillating at high frequency.
2. The wave is guided down a coaxial cable.

Conclusions

- Antennas are the interface between guided and unguided waves.
- Antenna come in all shapes and sizes.
- The size of the antenna must be at least a fraction of the wavelength it handles.
- Antenna impedance must match the transmission line.
- There is no "best antenna" for every application; the choice is always a trade-off between reaching long distances and covering a wide area.
- Use high gain antennas to reach long distances, and omni or sectorial antennas to cover wide areas.

Thank you for your attention

For more details about the topics presented in this lecture, please see the book ***Wireless Networking in the Developing World***, available as free download in many languages at:

http://wndw.net