Multimedia Training Kit

Antennas and Cables

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Goals

- Focus on explaining the losses in the link budget equation
- Introduce a set of types of antennas and cables
- How to make the right choices
  - Optimal Service Area
  - Minimizing Interference
  - Best use of the radio spectrum

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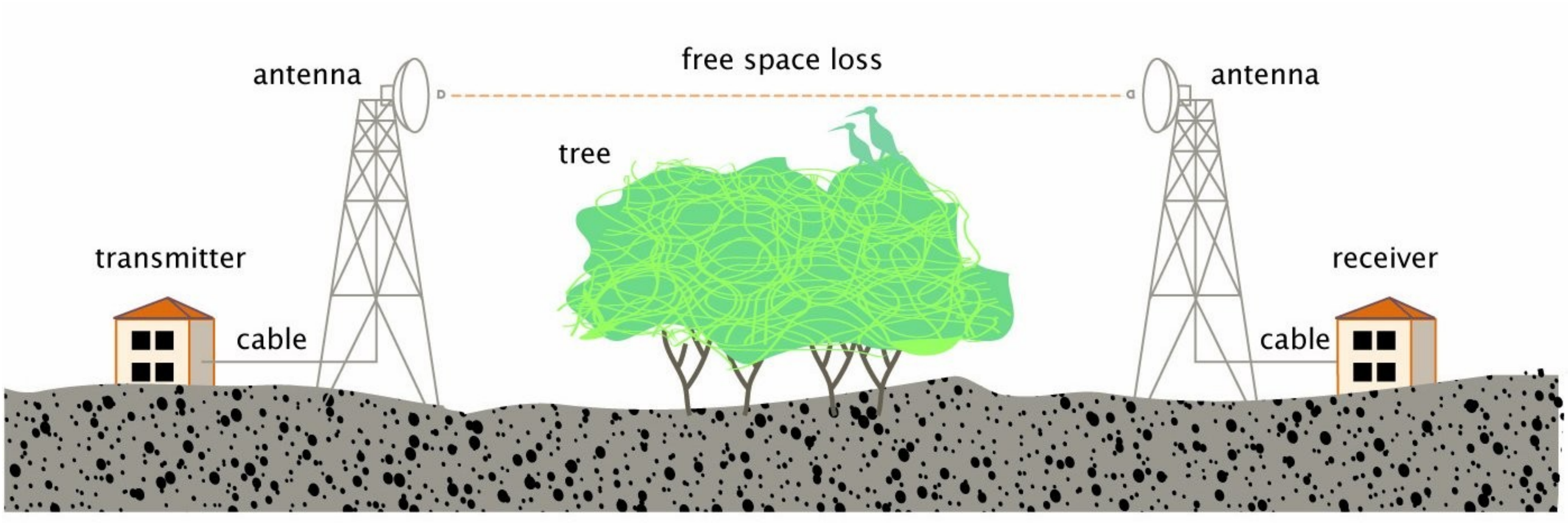
Review of Link Budget



- A radio link has active and passive elements
- Antennas and Cables are passive elements

Review of Link Budget

- Passive elements
  - Absorb energy or focus the electromagnetic energy (beam)
  - Never supply more energy than they absorb
- Link Budget

Margin= P(tx) – Cable loss(tx) + Antenna Gain(tx) – FSPL + Antenna Gain (rx) – Cable Loss (rx) – Sensitivity (rx)

Antenna Definition

- A passive device used to transform an RF signal
- Traveling on a conductor into an EM wave in free space
- A device that passively collect EM waves in free space and turn them into RF signals on a conductor

Antenna Gain

- Antennas are passive elements that do not amplify the radio signal
- Does not just target the signal in certain direction
- The antenna gain is a positive value to the link budget

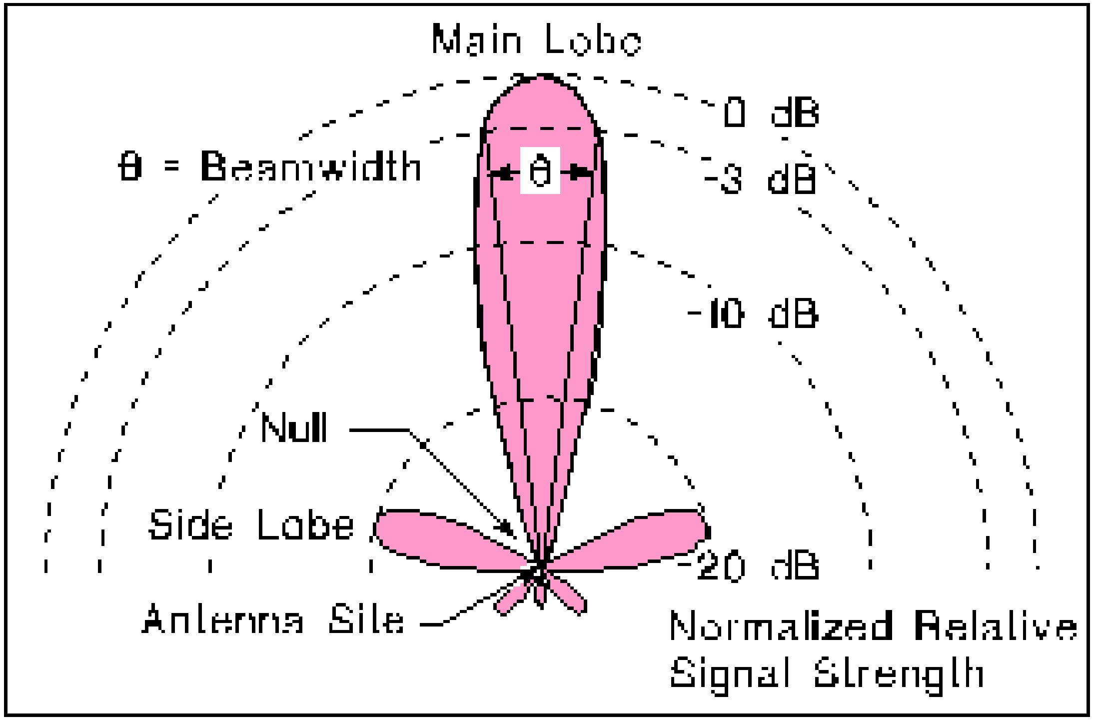
Antenna Gain

- Compares the power sent by the antenna in a certain direction with the “Isotropic Antenna”.
- Given in isotropic decibels [dBi]
- Isotropic antenna
  - a hypothetical antenna that radiates or receives equally in all directions
  - a theoretical reference used as a way to express directional properties of physical antennas.

Radiation Pattern

- A graphical representation of the “shape” of the radio beam.
- Represents which direction the antenna performs better (service area)
- Beam width: The area where 90% of the energy is focused.

Radiation Pattern



beamwidth

Source: http://www.its.bldrdoc.gov/projects/devglossary/images/beamwi4c.gif

Radiation Pattern

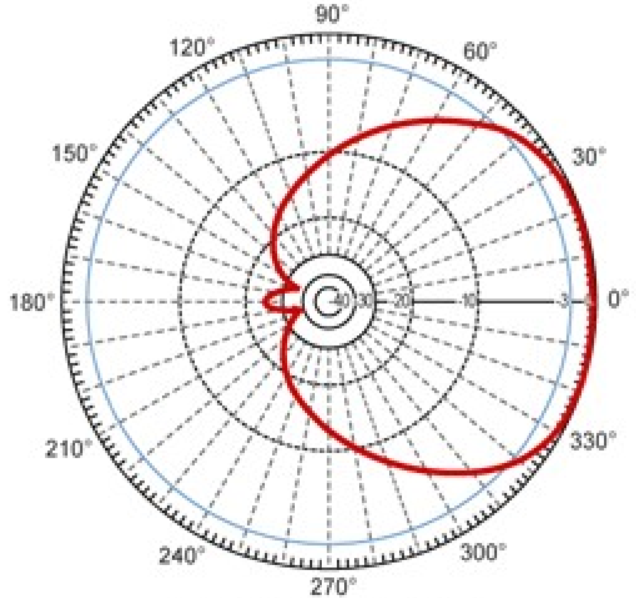
- Radiation patterns should be represented in 3D graphs
- They are normally represented by far more simple 2 x 2D samples: Horizontal and Vertical
- Graph Scale: Angles vs Normalized dB scale

Radiation Pattern

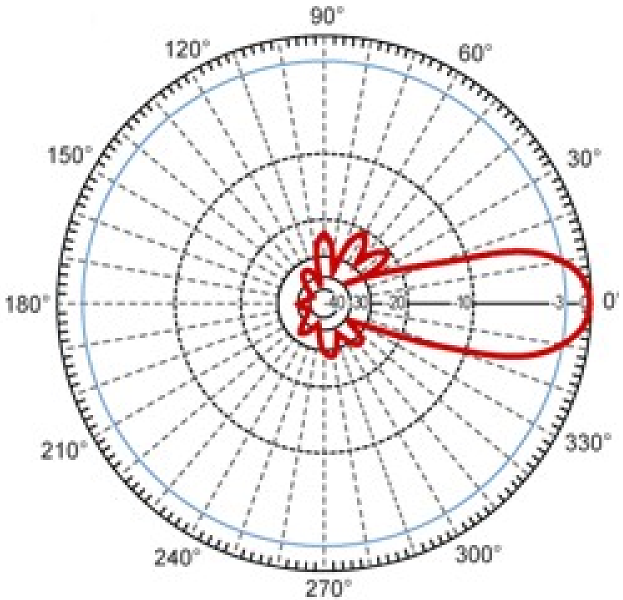
- Normalized dB scale
  - 0 dB: Direction of maximum gain of the antenna.
  - -3 dB: Angle where the antenna performs 50%.
  - The 3 dB beam width is normally known as service area/volume

Radiation Pattern

- Typical Radiation Pattern of Sector Antenna
- 3 dB V-Beamwidth is of 20º and 90º for the H



Horizontal



Vertical

Antenna Types

Classification based on their type of usage:

- **Access Point or Distribution Antennas** (Hub)
  - Wide beamwidth
  - Typically used to connect multiple links that are on different locations on the azimuth

Antenna Types

Classification based on their type of usage:

- **Directional Antennas**
  - Narrow beamwidth
  - Used for client side of multi point links and point to point connections

Antennas: Access Point

- Attached to the Access Point that serves as ”gateway” of several wireless clients
- Service Area
  - 360º Omnidirectional Antenna
  - 30-120º Sectoral Antenna

Omnidirectional Antenna

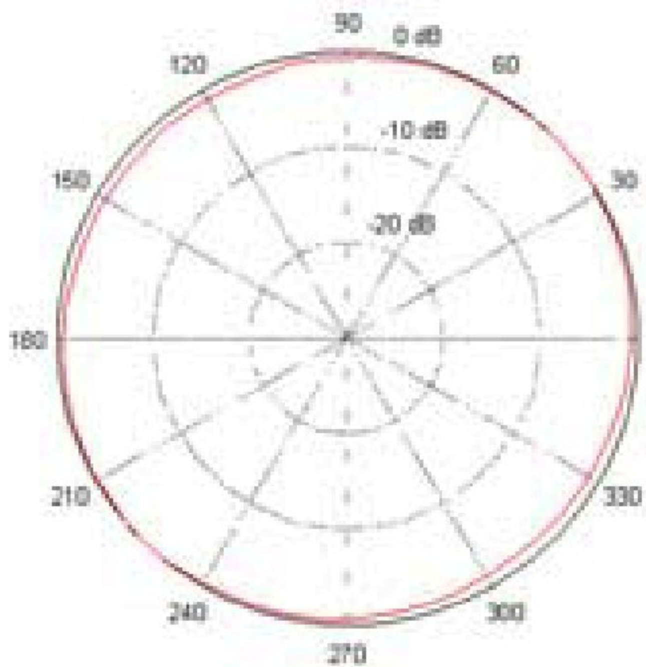
- 360-degree RF radiation pattern.

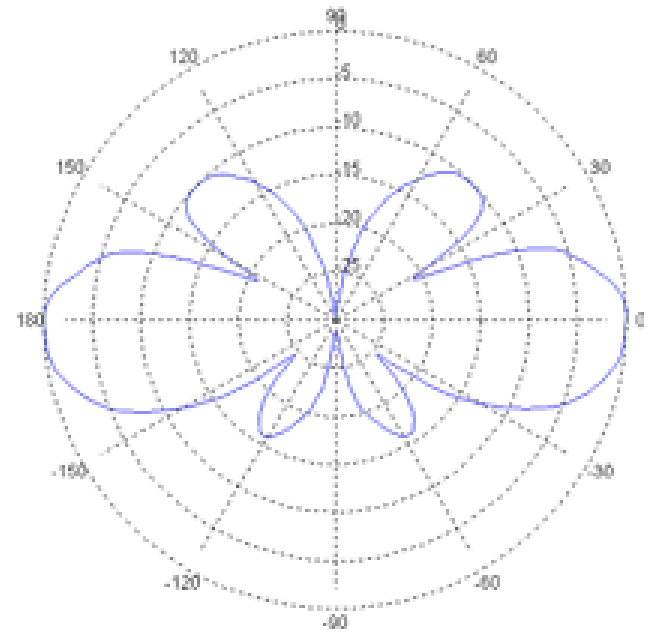
- Normally vertically polarized E-field.
- Normally low gain around 3 - 7 dBi.

Omnidirectional Antenna

- Best suitable for a wide service area with short links, in areas with few connections
- The radio channel is shared and hence its total capacity
- **Be very careful when using Omni antennas**
  - Consider potential problems with hidden nodes
  - Consider potential problems with interference

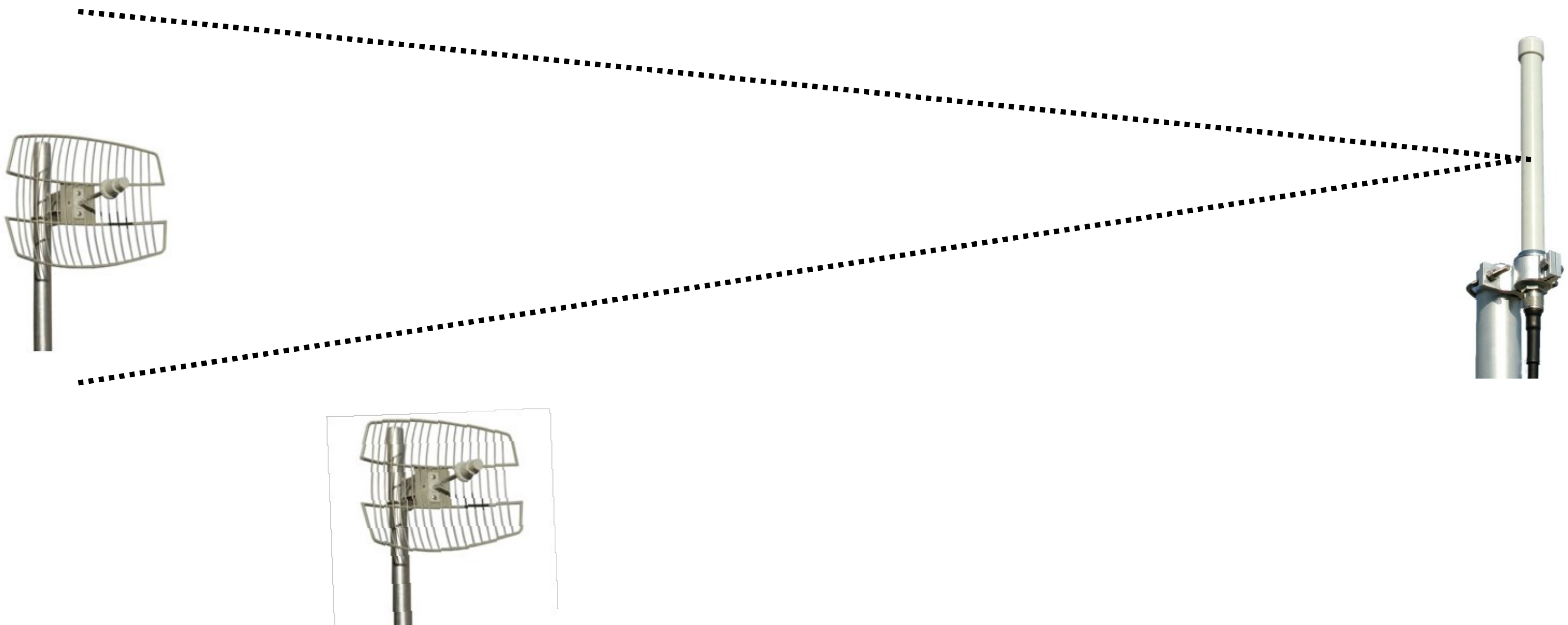
Omnidirectional Antenna





Omnidirectional Antenna

If trying to maximize the service “area”, you might have problems with nodes very close to the antenna

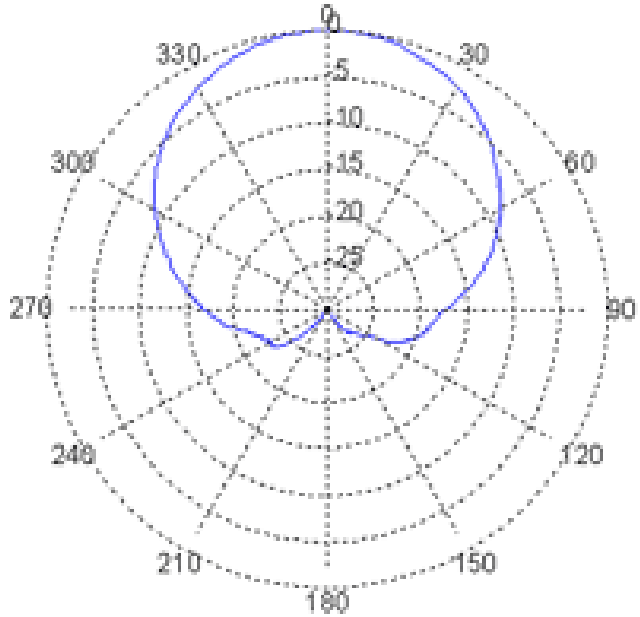


Sectoral Antenna

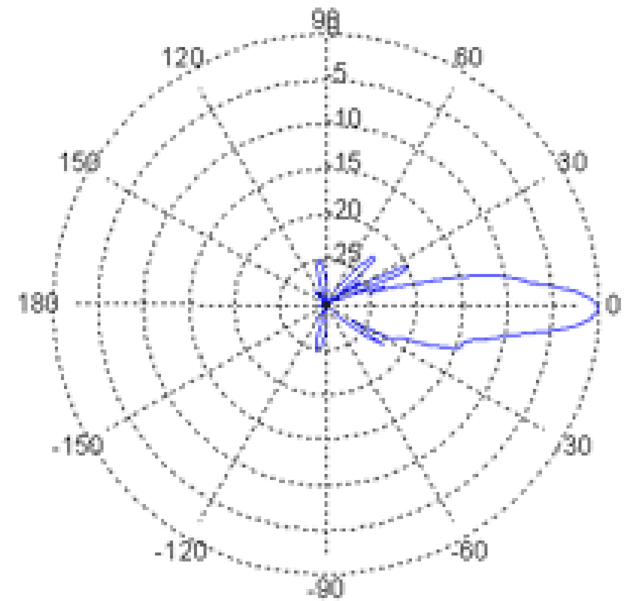
- Used in Access Points (gateways/hubs) to serve Point-to-Multi-Point (PtMP) links.
- Normally vertically polarized but horizontally polarized are also available
- Typical gain of 6-13 dBi

Sectoral Antenna

- Good for serving a large area with a high density of connections
- Horizontal beamwidth to about 30-120º



Azimuth (H-field) radiation pattern



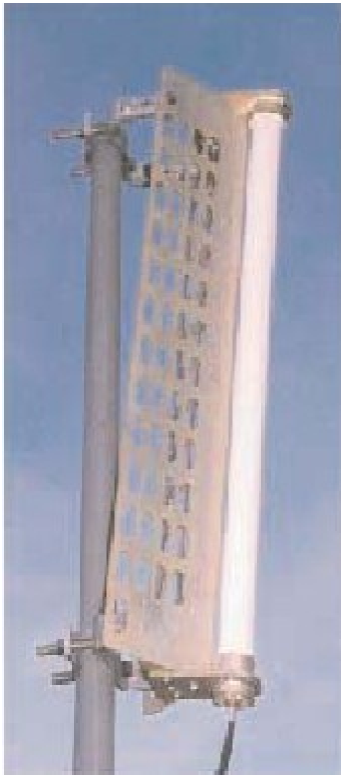
Elevation (E-field) radiation pattern

Sectoral Antenna

- A sectorial antenna with high gain needs careful mounting with respect to down-tilting.

Example: AntennSpecialisten VP870/24 vertical panel antenna, 70°, 16.5 dBi

Sectoral Antenna



- Some sectoral antennas allow to "modify" the radiation pattern by modifying the angle of a V shape reflector

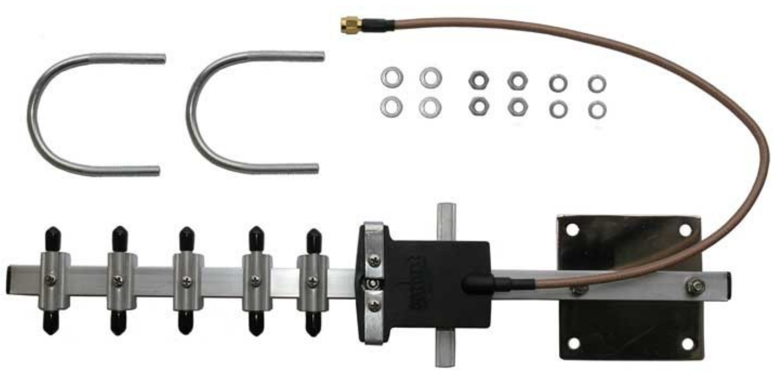
Sectoral Antenna

- Why do we need to sectorize?
  - Allows for multiple access points in one tower. More total bandwidth.
  - Able to isolate areas with higher levels of RF noise
  - Be able to separate short from long distance links (stability)

Directive Antenna

- Client Yagi
  - Yagi
  - Parabolic Antenna
  - Low/High Patch Panels
- Backhaul and PtP Links (narrow beams)
  - Yagi
  - Parabolic Antenna
  - Wave Guide Antenna (Circular: cantenna)

Radome Enclosed Yagi Antenna



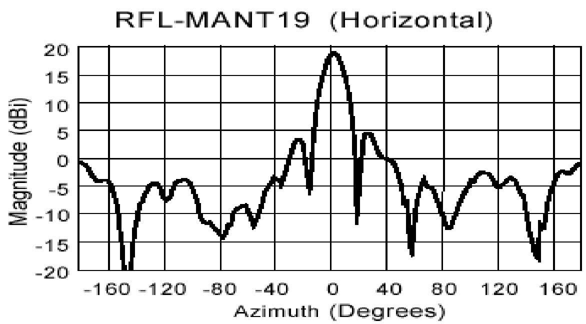
- Radome: radar dome, allows RF signal trough
- Mechanical Protection
- Yagi in a nutshell
  - Driven Element: Dipole
  - Directors: Directivity
  - Reflectors: Optional

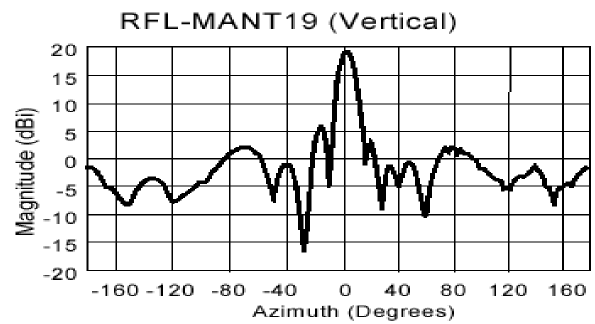
Parabolic Antenna

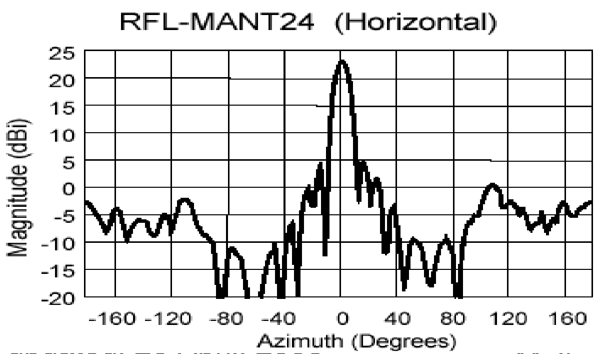
- The bigger the size of reflector the bigger the gain
- Narrow beams
  - Fragile to physical and mechanical disturbance
- Horizontally or Vertically Polarized

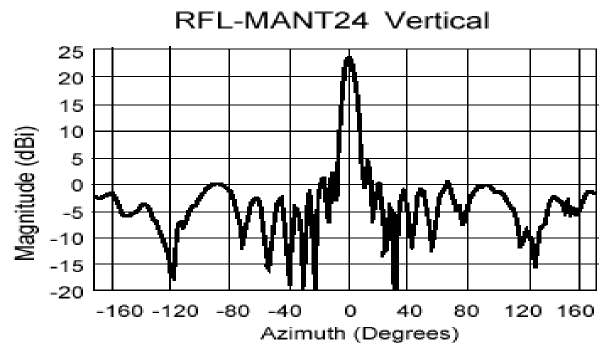
Parabolic Antenna

- Gain vs Beamwidth: 19 dBi vs 24 dBi
- Cartesian Radiation Pattern









Other types of Antennas

- Patch/Microstrip
- Biquad
- Wave Guides

Build Your Own Antenna

- Good quality and low cost antennas can be made mostly using common household goods
  - Yagi antennas made from threaded rod, copper pipe and bumper washers
  - Tin Can Antennas
- Building instructions are available online and in the ICTP Radio Laboratory Handbook on Cables and Antennas (ISBN 92-95003-24-1)

Antenna Polarization

- WiFi Antennas are built to make radio signals propagate vertical and horizontal planes
- Polarization expresses the orientation of the waves electric field
  - If the E-field is horizontal, than the antenna is Horizontally Polarized
  - If the E-field is vertical, than the antenna is Vertically Polarized

Antenna Polarization

- Polarization is used to:
  - Increase isolation of unwanted signals source and hence reduce interference
  - Define different coverage areas by reusing frequencies

Antenna Polarization

- Antennas of the same radio link MUST use the same polarization
- Cross Polarization
  - The extra attenuation when one antenna is H and the other is V can be as big as 25 dB!

Antenna Polarization

- Using Several Parabolic Antennas in the same mast
- Cross Polarization

Source www.radioscanner.ru

Cables and RF Signals

- Low loss coaxial cables connects radio transceiver to antenna
- With RF frequencies, the cable no longer behaves like a regular traditional wire.
- Cables with RF are **transmission line.**
  - Think in another antenna, radiation
- Impedance is a measurement of resistance to a current in a transmission medium

Cables and RF Signals

- Impedance remains constant with independence of the cable length
- Maximum transfer of energy between the transceiver and the antenna only takes place when all the circuit elements match the same impedance

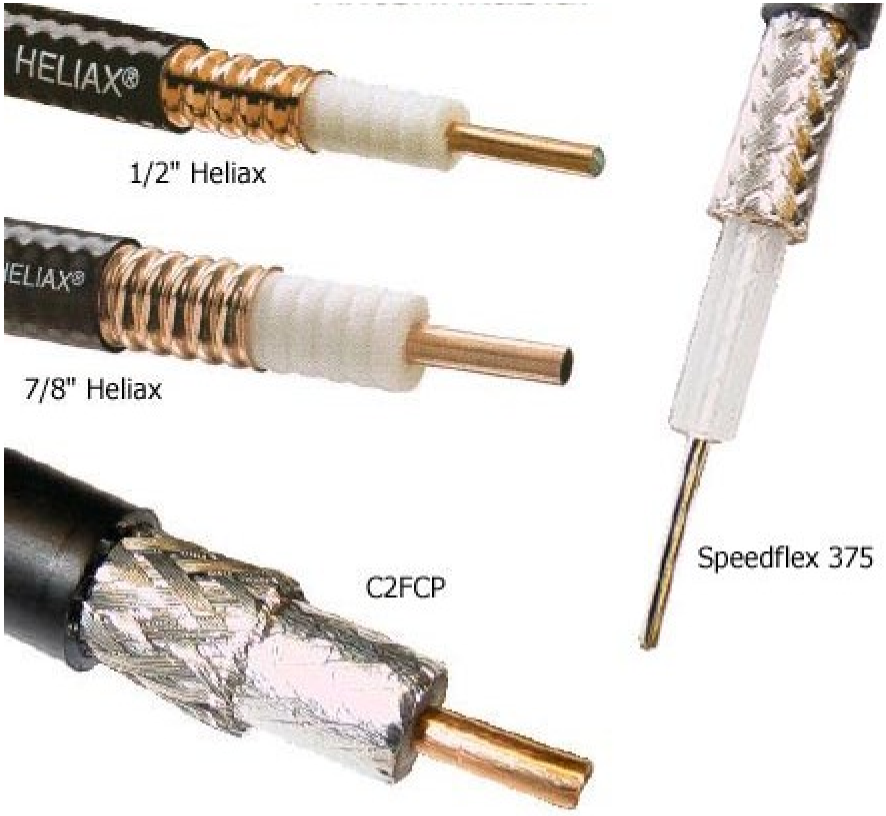
Cables and RF Signals

- In data communication equipment (including WiFi) the impedance is always 50 Ω (Ohm)
- If not, the radio signal (energy) will reflect back into the transmitter rather than into the antenna

Energy Loss in Cables

- The coaxial cable introduces a signal loss between the antenna and the transceiver.
- The signal is attenuated towards the antenna and the signal collected by the antenna is attenuated on its way back to the receiver.
- Typical cable loss for WiFi-friendly cables: 0.07 – 0.22 dB/m

Energy Loss in the cables

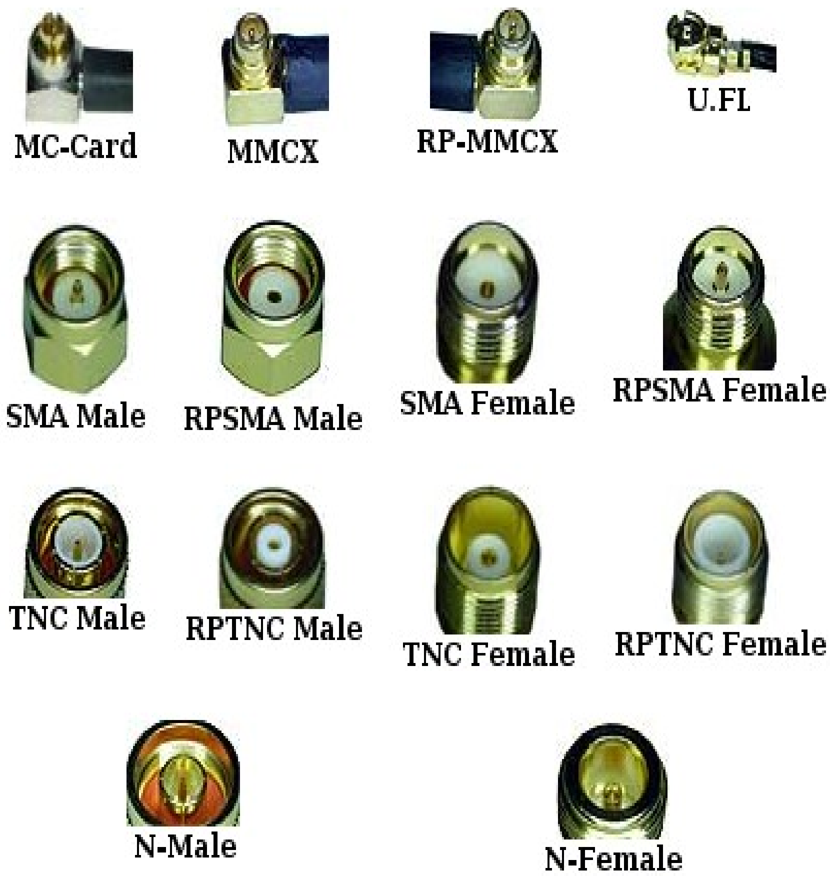


- Typical cables:
  - LRM400/600
  - Heliax
  - Speedflex 375

Energy Loss in the cables

- When you choose a cable you need to consider several factors:
  - How long cable do you need?
  - Do you need to bend the cable in sharp angles?
  - Do you need to transport/bring the cable from overseas?

Connectors



- Endless number of types
- Good connector: 0.1 dB
- Bad connector: several dBs.
- Invest in good connectors

Fig. Source: Connexwireless

Connectors

- Rule of the thumb
  - Antennas and any other active elements, such as radios, normally have female connectors.
  - Cables do normally have male connectors.
  - The most common connector used for long cables are the N-type male or Navy connector

Fig. Source: Solwise

Pigtail/Converter

- Pigtail matches two types of connectors
- Loss of 0.2-0.6 dB
- Small length cable patching
  - A radio with an antenna
  - A radio with a long run cable
- **Converter:** One unit with two types of connectors: 0.1 – 0.2 dB

Pigtail/Converter

Conclusions Antennas

- Antennas:
  - Be spectral efficient and follow the power regulations
  - Match the radios and antennas to give just enough signal, plus a fade margin to make the link work
  - Sectorize the access points, tilt antennas to match your coverage area
  - Have a long perspective, good mechanical properties

Conclusions Cables

- Cables
  - Take care of your cables and connectors as they are always a point of failure.
  - Microwave cables and specially connectors are precision-made parts.
  - Be sure to know how much you can bend your chosen cable and never step over a connector!

Final Conclusions

Good choices in equipment depends on your ability to understand radiation patterns, link budgets and the type of service that you aim for.