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
Table of Contents

• Review of Link Budget
• Introduction to Antennas
• Types of Antennas
• Polarization
• Antenna Isolation and Combiners (handout only)
• Cables and Connectors
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

Source: http://www.its.bldrdoc.gov/projects/devglossary/images/beamwi4c.gif
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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 20° and 90° for the H
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
  – 360° Omnidirectional Antenna
  – 30-120° 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° - 120°

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
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.