Antennas and Cables

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Goals

• Focus on explaining the factors 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
• 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
• Transformation from signal in cable to signal in free space – and back
Antenna Gain

• Antennas are passive elements that do not amplify the radio power.
• Antennas target the signal in certain direction, but make it weaker in others (!).
• 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.
• Beam width: The area where 90% of the energy is focused.
Radiation Pattern

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

- Typical Radiation Pattern of Sector Antenna
- 3 dB V-Beamwidth is 20° vertical and 90° horizontal
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
• **Be very careful when using Omni antennas**
  – Consider potential problems with hidden nodes
  – Consider potential problems with interference
  – Consider narrow vertical pattern!!!
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°
Sectoral Antenna

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

- Parabolic Antenna
- High Gain Patch / Panel Antennas
- Wave Guide Antenna (Circular: The famous Cantenna)
- Biquads
Parabolic Antenna

- Grid or closed surface
- Horizontally or Vertically Polarized
Parabolic Antenna

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

![RFL-MANT19 (Horizontal)](image1)

![RFL-MANT19 (Vertical)](image2)

![RFL-MANT24 (Horizontal)](image3)

![RFL-MANT24 Vertical](image4)
Build Your Own Antenna

• Good quality and low cost antennas can be made mostly using common household goods
• Most suited: Cantennas, Biquads, Omnis (more difficult)
• Guides can be found many places on the net, e.g. at http://wirelessU.org and http://wireless.ictp.it/handbook/download.html
Build Your Own Antenna

• Cantenna
Build Your Own Antenna

- BiQuad

Simple 2.4GHz Antenna

- Short length of 50 ohm miniature coax
- Adjust spacing for best results
- Vertical Polarisation
- Reflector made from any metal or PCB material
- 1.5mm copper wire
- Solder to outer
- Solder to inner

Dimensions:
- 18mm
- 140mm
- 32mm
Build Your Own Antenna

• BiQuad
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 30 dB!
Antenna Polarization

- Using Several Parabolic Antennas on 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 (but can be more!)
# Energy Loss in the cables

<table>
<thead>
<tr>
<th>Cable type</th>
<th>Loss [db/100m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>RG 58</td>
<td>ca 80-100</td>
</tr>
<tr>
<td>RG 213</td>
<td>ca 50</td>
</tr>
<tr>
<td>LMR-200</td>
<td>50</td>
</tr>
<tr>
<td>LMR-400</td>
<td>22</td>
</tr>
<tr>
<td>Aircom plus</td>
<td>22</td>
</tr>
<tr>
<td>LMR-600</td>
<td>14</td>
</tr>
<tr>
<td>1/2” Flexline</td>
<td>12</td>
</tr>
<tr>
<td>7/8” Flexline</td>
<td>6.6</td>
</tr>
<tr>
<td>C2FCP</td>
<td>21</td>
</tr>
<tr>
<td>Heliax ½ “</td>
<td>12</td>
</tr>
<tr>
<td>Heliax 7/8”</td>
<td>7</td>
</tr>
</tbody>
</table>
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 dB
- Invest in good connectors

Fig. Source: Connexwireless
Connectors

• Rule of 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 is the N-type male

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:
  – Start with Link Budget to see what you need in order to get enough margin
  – Be spectral efficient and follow the power regulations
  – Sectorize the access points, tilt antennas to match your coverage area
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.