

# MULTIMEDIA TRAINING KIT

## ANTENNAS AND CABLES HANDOUT

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Based on the original work of: Onno W. Purbo

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### Table of Contents

1. About this document.....	2
1.1 Copyright information.....	2
1.2 Change log.....	2
1.3 TODO.....	2
1.4 Degree of Difficulty.....	2
2. Introduction.....	3
3. Link Budget.....	3
3.1 Radiated Power in antennas .....	4
3.2 Cable and connector losses.....	4
3.3 Antenna Gain.....	5
3.4 Free Space Path Loss.....	5
3.5 Calculating the Link Budget Margin.....	6
4. What is an antenna?.....	7
5. Types of Antennas.....	7
5.1 Omni-directional Antennas.....	7
5.2 Sectoral Antennas.....	10
5.3 Directional Antenna.....	11
5.3.1 Yagi Directional Antenna.....	12
5.3.2 Parabolic Directional Antenna.....	13
6. Antenna Polarization.....	14
7. Power Divider/Combiners.....	17
8. Antenna Isolation.....	18
8.1 Vertical Isolation.....	18
8.2 Horizontal Isolation.....	19
9. Coaxial Cable.....	20
9.1 Cable loss.....	20
10. Antenna Connectors.....	22
10.1 Pigtails.....	22
11. Showcase: Antenna Installation in Indonesia.....	24
12. Conclusions.....	26

# 1. About this document

These materials are part of the Multimedia Training Kit (MMTK). The MMTK provides an integrated set of multimedia training materials and resources to support community media, community multimedia centres, telecentres, and other initiatives using information and communications technologies (ICTs) to empower communities and support development work.

## 1.1 Copyright information

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## 1.2 Change log

- 1.0 Initial Version, Onno Purbo
- 1.1 Added New Introduction and Link Budget, Removed section about towers, 20051227, Alberto Escudero-Pascual
- 1.2 Review of Antenna and Cables, Towers removed in this unit 20051228, Alberto Escudero-Pascual
- 1.3 Added TODO section and rearrange pictures and content 20051230, Alberto Escudero-Pascual
- 1.4 Added Introduction and Conclusions section, Integration with other MMTK units 20060423 Alberto Escudero-Pascual

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## 1.3 TODO

This is a set of areas that will be interested to cover in the unit. If you are want extend the unit, consider addressing the following aspects:

- Add a section about patch and microstrip antennas
- Add a section about VSWR
- Add a section about Power over Ethernet
- Review all sections related to SNR and Isolation.
- Add more concrete scenarios
- Elaborate more about the concept of dB more power calculation. Create some 3D graphs for the radiation patterns
- Include references to some radio patterns softwares and radio planning

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## 1.4 Degree of Difficulty

The degree of difficulty of this unit is "Basic".

## 2. Introduction

This unit covers Antennas and Cables, two passive<sup>1</sup> components that are involved in the design of any wireless data communication network. The unit has been written having the IEEE 802.11 family of standards in mind, but the general Antenna principles can be applied to any other wireless data technology.

Before discussing “Antennas and Cables” in detail, we find necessary to refresh some of the concepts introduced in “Radio Link Budget”. Those who are already familiar with basic radio physics and link budget calculations can start reading in Section 6, Page 7.

## 3. Link Budget

*This section is a summary of the basic concepts learned in “Basic Radio Physics” and “Radio Link Calculations” units.*

A wireless link budget for a point to point radio link is the accounting of all of the gains and losses from the radio transmitter (source of the radio signal), through cables, connectors and free air to the receiver. Estimating the value of the “power” in the different parts of the radio link is necessary to be able to make the best design and the most adequate choice of equipment.

There are two parameters in any radio link budget that deserve special attention: “Maximum Radiated Power” and “Receiver Sensitivity”. Those are the parameters that sets the maximum and minimum boundaries of the link.

The first parameter is known as “Maximum Radiated Power” and specifies the **maximum power that is legally permitted** to be send out to the free air in a specific country/area.

The maximum Radiated Power or Effective Isotropically-Radiated Power (EIRP) is regulated by the national radio regulatory authority. The legal limit in Europe is normally 100 mW. In some very concrete scenarios (point-to-point links) and in some countries the maximum allowed radiated power is 1 to 4 W.

The second parameter is the “Receiver Sensitivity” that tells you what **minimum value of power** is needed in the radio receiver so it can successfully decode/extract “logical bits” of information out of the radio signal.

In simple words, the first parameter tells you how **strong** you are allowed to send your signal in the free air and the second parameter tells you how **weak** the signal can be in the receiver but still provide a functional data link.

These two parameters will be part of any link budget calculation and will help you to determine what kind of antennas and cable to choose for your very concrete scenario.

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<sup>1</sup> When we refer to antennas and cables as passive elements in a radio network we mean that they never supply more energy than they absorb.

### 3.1 Radiated Power in antennas

The Radiated Power is the result of subtracting power losses in the cable and connectors to the Transmitter Power and adding the relative “gain” of the antenna.

$$\text{Radiated Power (dBm)} = \text{Transmitter Power (dBm)} - \text{Losses from cable and connectors (dB)} + \text{Antenna Gain (dBi)}.$$

When measuring radio power, losses and gains are normally expressed in dB (decibels). The unit Decibel is a “logarithmic” relative unit that it is very useful to simplify radio power calculations.

For example, transmitted power is normally expressed in (dBm). A dBm is a decibel relative unit compared to 1 milliwatt (0.001 W). dBm is calculated as following:

$$\text{dBm} = 10 \cdot \log(P/0.001) = 10 \cdot \log(P(W)/1\text{mW})$$

When using dB as a way to calculate the power the following 'guidelines' are useful to remember:

- Duplicating the power is equal to adding 3 dB
- Reducing the power by half is equal to subtracting 3 dB

Notice, that no matter what the power value is, multiplying the power by 2 *always* implies “adding” 3 dB while dividing the power by a factor of two, *always* implies subtracting 3 dB.

The following values are equivalent: 100 mW = 0.1 W = 20 dBm.

If we duplicate the power of the transmitter to 200 mW, we add 3 dB to 20 dBm which gives us 23 dBm. In that way, 400 mW gives us 26 dBm and 800 mW gives us 29dBm.

Following the same reasoning 50 mW is 17 dBm ( 20 dBm - 3 dB).

As a reference, you can consider that a typical value for a PCMCIA IEEE 802.11b card is 30 mW or 14,77 dBm. A good access point will allow you to set the power from 10 to 200 mW and in this way controlling the size of the cell it covers.

### 3.2 Cable and connector losses

Losses in the radio signal will take place in the cable(s) that connects the transmitter and the receiver to the antennas. The losses depend on the type of cable and frequency of operation and are normally measured in dB per meter or foot.

To give you an idea of how large the power loss in a cable can be, consider that you are using a RG58/BNC cable, which has a loss of 1dB/m, to connect a transmitter to an antenna. Using 3 meters of RG58 cable is enough to loose 50% of the power.

If long cables are used, the accounting of the connector losses are normally included in the “cable loss” part of the equation. But to be on the safe side, always assume an average of 0.3 to 0.5 dB loss per connector as a rule of the thumb.

### **3.3 Antenna Gain**

The antenna gain is given in isotropic decibels or dBi. Isotropic decibels is a relative unit that compares the power sent by an antenna in a certain direction with the power sent by a reference antenna (the isotropic antenna). The isotropic antenna is a hypothetical antenna that radiates or receives equally in all directions. Isotropic antennas are a theoretical reference and do not exist physically but are used as a way to express directional properties of physical antennas.

Wireless antennas are not designed to spread the energy in every direction but rather to beam or direct the total radio signal into an area that we aim to provide radio coverage to. The antenna gain is a way to measure how directive an antenna is, in comparison with an antenna that spreads the energy isotropically. The bigger the gain an antenna has, the more directive it is and the more narrow radio beam it has.

It is very important to understand that antennas are passive elements that do not amplify the radio signal. Antennas just target the signal in certain direction. When used as a “sender”, the antenna is responsible of beaming the power of the radio transmitter in certain direction; when acting as a receiver the antenna collects the radio power and send it back to the receiver.

Although antennas are passive elements and do not provide any active amplification, for the point of view of our calculations in the radio link budget, they are considered as a “gain” of the radio signal in certain physical area.

If an antenna has a gain of 3 dBi in certain direction, it means that the transmitted or received power in that direction is equivalent to the power that will be transmitted or received by an isotropic antenna using double of the power in the radio transmitter.

Sometimes, antenna gain is expressed in dBd. In that case the reference antenna is a dipole antenna. A dipole antenna has a gain of 2.14 dBi compared to a isotropic antenna.

$$\text{dBd} = \text{dBi} + 2.14$$

### **3.4 Free Space Path Loss**

The majority of the power of a radio signal will be lost in the air. The Free Space Path Loss (FSPL) measures the power loss in free space without any kind of obstacles. The radio signal weakens in free space due to expansion into a spherical surface. Losses in free space are frequency dependent and respond to this simplified formula:

$$\text{FSPL (2.4 Ghz)} = 100 + 20\text{Log}(R) \quad \text{where } R = \text{distance [km]}$$

As a rule of the thumb in a 2.4 Ghz wireless network, 100 dB are lost in the first kilometer and the signal is reduced by 6 dB every time that the distance doubles. 2 kms link has a loss of 106 dB and a 4 kms link has a loss of 112 dB etc.

As we mentioned in the beginning of this unit, the sensitivity of a receiver is one parameter that deserves special attention as it indicates the minimum power that is needed to achieve a certain bit rate.

The lower the sensitivity is, the better the radio receiver is. A typical value is -82 dBm for a 11 Mbps link and -94 dBm for 1 Mbps (6 mW).

Although the signal received in the receiver is bigger than the sensitivity, it is also needed a certain margin between noise and signal to achieve a certain data bit rate.

The relationship between noise and signal is measured by the signal to noise ratio or SNR. A typical requirement of SNR is 16 dB for a 11 Mbps connection and 4 dB for the lower speed of 1 Mbps.

### 3.5 Calculating the Link Budget Margin

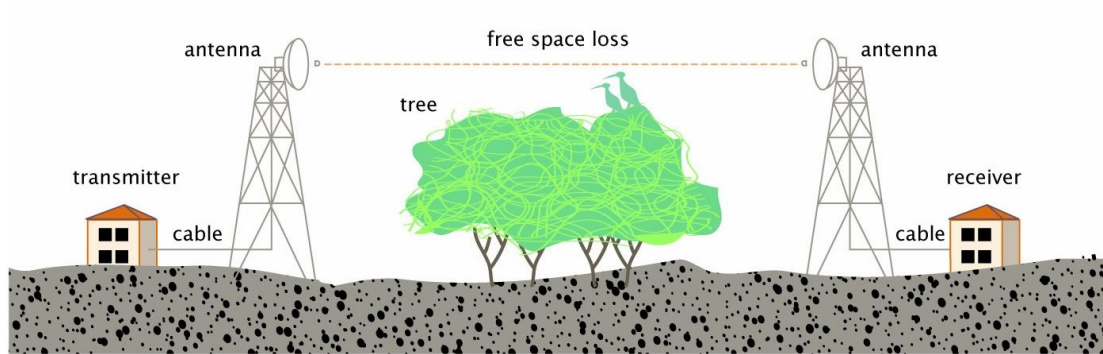


Image 1: Link Budget of a PtP wireless link

The margin of a link budget can be summarized as follows:

$$\text{Margin} = \text{Transmitter power [dBm]} - \text{Cable TX loss [dB]} + \text{Antenna TX gain [dBi]} - \text{Free Space Path Loss [dB]} + \text{Antenna RX gain [dBi]} - \text{Cable RX loss [dB]} - \text{Receiver Sensitivity [dBm]}$$

## 4. What is an antenna?

By definition, an antenna is a passive device used to transform an RF signal, travelling on a conductor, into an electromagnetic wave in free space. Antennas do also operate in the opposite form by passively collecting electromagnetic waves in the free space and turning them into RF signals on a conductor.

## 5. Types of Antennas

We can classify antennas in three different kind of groups according to their type of usage. All of the antennas mentioned below are used in wireless outdoor networks, sometimes known as Metropolitan Area Networks:

- **Omni-directional Antennas:** are usually attached to a WiFi Access Point (AP). They have a 360-degree radiation pattern and normally operate as a central hub or gateway of a network.
- **Sectoral Antennas:** are usually attached to a WiFi Access Point (AP) but are designed to operate with a higher gain than omni-directional antennas. On the contrary to the omni-directional antennas, sectoral antennas cover only a sector area of  $60^{\circ}$  –  $120^{\circ}$  radiation pattern.
- **High Directional Antennas:** are usually used in the client side and are attached to the Customer Premises Equipment (CPE). They have a high gain and are normally aimed towards the Access Point (AP). High Directional Antennas are also used to build point-to-point links and backhaul networks.

### 5.1 *Omni-directional Antennas*

Omni-directional antennas have a 360-degree RF radiation pattern around them. They have a vertically polarized E-field. The gain of an omni-directional antenna is normally low, around 3 to 12 dBi. It is used for implementing Point-to-Multi-Point (PtMP) links. It is quite good for 1-5 km coverage, especially in combination with high gain directional antennas in the client premises.

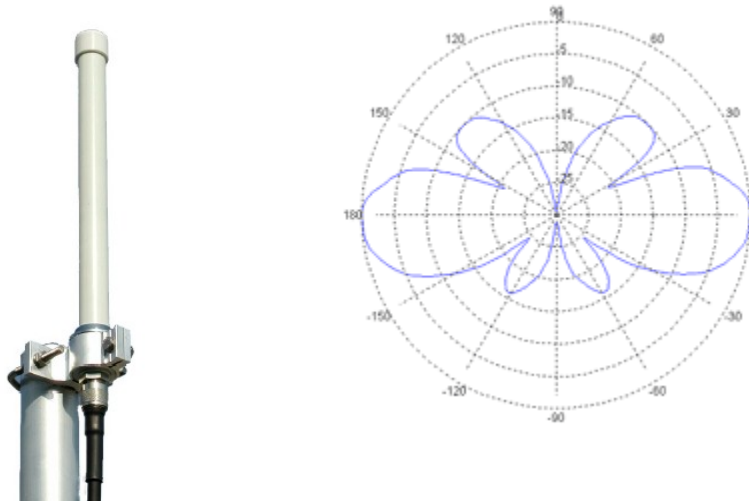


Image 2: A 6 dBi Omni-directional antenna and the corresponding elevation radiation pattern

Image 2 shows a typical Omni-directional antenna ('Svenska Antennspecialisten V06/24'). An interesting feature of this kind of antenna is that although they do radiate in all 360 degrees, they only provide good coverage to clients that there are in the horizontal  $\pm 20^\circ$  range. This means that the antenna, when mounted at the top of a high tower, might not reach clients that is just above or below the tower.

Using the radiation pattern diagram in Image 3, we can calculate the optimal range of angles in the horizontal plane where the antenna operates. The range is known as *Beamwidth* and describes the angular aperture where the greatest part of the power is radiated. The most common value of the beamwidth is 3db which represents the aperture (in degrees) where more than 90% of the energy is radiated.

In our example, the 3dB beamwidth is around  $22^\circ$ , from  $+10^\circ$  to  $-12^\circ$ .

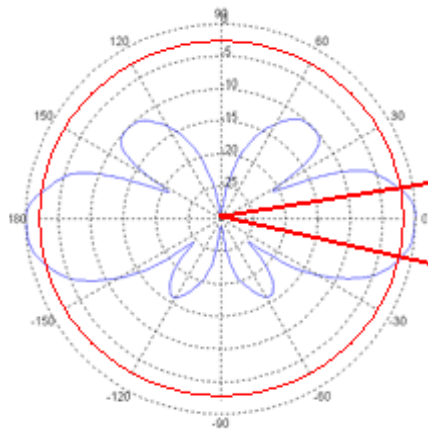


Image 3: Calculation of 3dB beamwidth (+10°, -12°)

In general, the more gain an omni-directional antenna has, the smaller is the beamwidth.

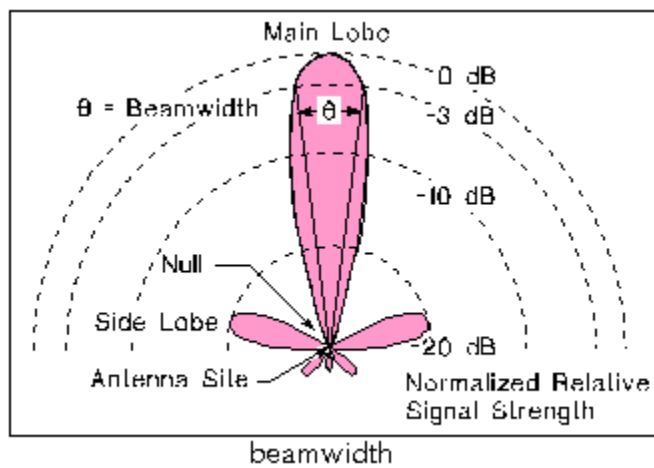


Image 4: The pictures shows the beamwidth of a antenna in comparison to its gain. The more gain, the smaller beamwidth. (Source: <http://www.its.bldrdoc.gov/projects/devglossary/images/beamwi4c.gif>)

## 5.2 Sectoral Antennas

Sectoral Antennas, just like omni-directional antennas, are used in association with Access Points to serve Point-to-Multi-Point (PtMP) links. Sectoral antennas can be found with vertical or horizontal polarization depending on the construction techniques used.

Normally, a sectoral antenna has a higher gain than an omni-directional antenna (in the range of 10-19 dBi) in a reduced sector. It is typically used to serve an area of 6-8 km.

A common value for a sectoral antenna is a 14dBi gain for a 90° horizontal beamwidth and a 20° for vertical beamwidth. Higher gains in antennas are obtained by narrowing the beamwidth of the horizontal radiation.



Image 5: Sectoral Antenna A2.45LP14 180°.

As shown in the Image 5, a Sectoral Antenna can be built using a vertical polarized monopole (omni antenna) and an inverted V-shaped reflector.

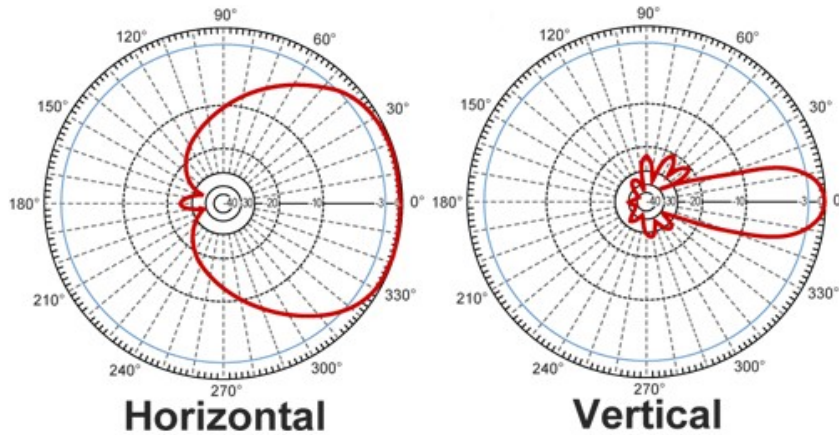


Image 6: Typical Radiation Pattern from a Sectoral Antenna (Source: Hyperlink)

Image 6 shows a typical radiation pattern from a sectoral antenna. The horizontal radiation shows that most of the energy is radiated from the front end of the antenna. A very small part of the energy is expected behind the sectoral antenna. The vertical polarization pattern is very similar to an omni-directional antenna where the beamwidth is very narrow and the service area is normally not bigger than 20°.

Typically, a sectoral antenna is mounted in the top of a high tower, slightly tilted down in order to be able to serve the area just below it.

### 5.3 Directional Antenna

Directional antennas are normally found in the client premises or as part of the network back haul (long distance dedicated Point-to-Point links). Directional antennas in client premises are aimed towards a central (hub) Access Point.

The most common types of directional antennas are:

- Yagi
- Parabolic

### 5.3.1 Yagi Directional Antenna

A Yagi antenna is composed of a dipole (sometimes called a radiator or driven element), a set of director elements in front of it and optionally a reflector. The antenna is normally enclosed in a plastic cylinder for protection.

The protection is normally known as a radome (radar dome) and it is a weatherproof enclosure used to protect the antenna from freezing rain, ice or sand storms.

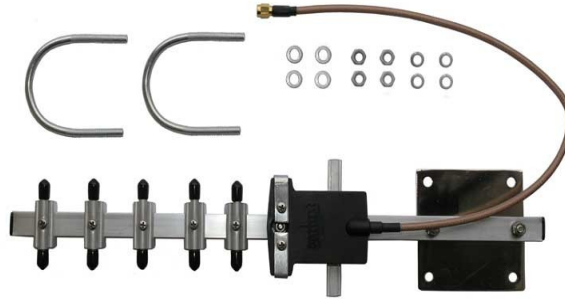


Image 7: Radio-Modules Yagi and P2412 from Terabeam Wireless (enclosed in a radome cylinder).

The greater number of director elements in front of the radiator leads to a higher antenna gain. A Yagi antenna has normally 7 to 19 dBi gain. A 12 dBi gain P-2412 2.4 GHz directional, radome-enclosed, Yagi antenna is shown in the Image 7.

The typical radiation pattern of the Yagi antenna is shown in Image 8. In this kind of antenna, the horizontal radiation pattern is fairly similar to the vertical radiation pattern. Both horizontal and vertical radiations are aiming in the direction of the “directors” and no or little radiation is behind the antenna. As in any other antenna, the wider the radiation angle is the lower the gain of the directional antenna is. In the case of Yagis, the shorter (the less directors) the antenna has, the wider is the service area.

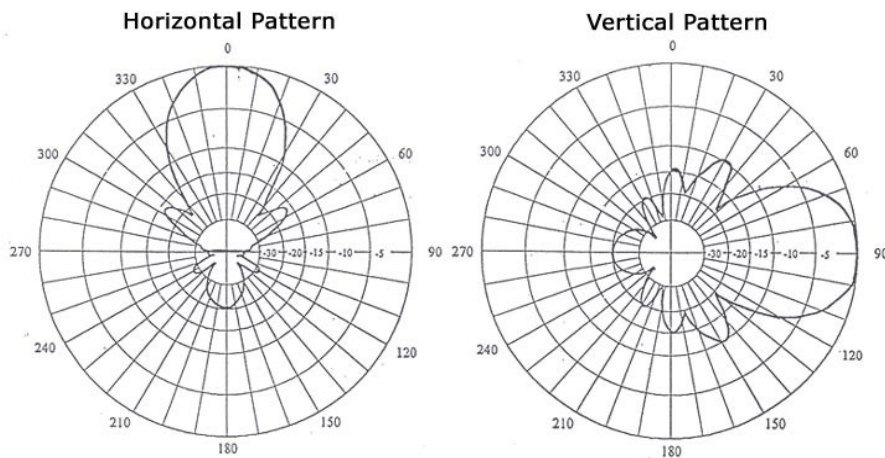


Image 8: Radiation pattern of a Yagi antenna

### 5.3.2 Parabolic Directional Antenna

High gains (greater than 14 dBi ) with good radiation patterns are difficult to achieve with a Yagi design. To increase the antenna gain, it is normal to use a parabolic RF reflector in front of a dipole radiator.

A parabolic antenna has usually 16-28 dBi gain.



Image 9: RFL-MANT 19dBi Parabolic Antenna

The parabolic antenna radiation pattern is fairly similar to a Yagi antenna but with a much narrower service angle. Due to the fact that most of the RF energy aims towards a very small service area, a parabolic antenna is much more difficult to aim. Consequently, the parabolic antenna is more fragile to physical and mechanical disturbance, especially strong wind, than a Yagi antenna.

Due to high gain and the possibility of overpowering the radio link, a parabolic antenna is not a good choice for short distances (< 2 kms).

The image below (Image 10) shows another way to represent antenna radiation patterns. In this example we show the antenna patterns of two antennas of the same model RFL-MANT but with different gains (19 dBi and 24 dBi). We can see that while the horizontal and vertical pattern are fairly similar, the 19 dBi antenna has a wider 3dB beamwidth angle ( $17^\circ$ ) in comparison with the 24 dBi antenna ( $8^\circ$ ).

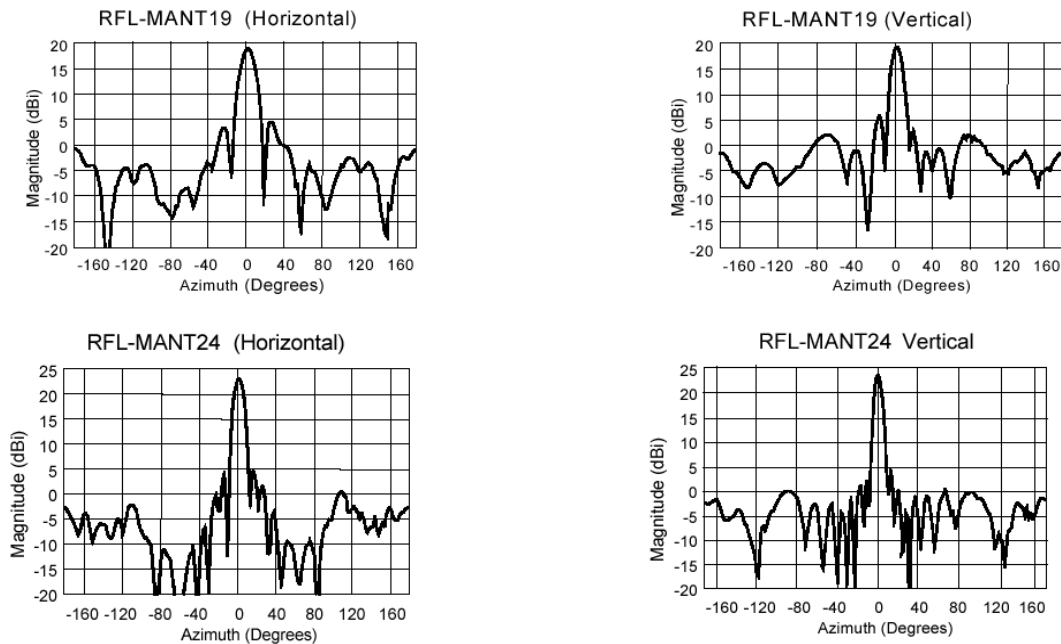


Image 10: RFL-MANT 19dBi and 24 dBi Radiation Patterns

## 6. Antenna Polarization

The magnetic and electric fields are orthogonal to each other when the radio signal propagates through the free air.

An antenna is said to be linear and vertically polarized when its electric field is perpendicular to the Earth's surface. A linear polarized antenna radiates fully in one plane containing the direction of the propagation. In the case of a vertically polarized antenna, the electric field propagates in perpendicular planes to the Earth's Surface.

Similarly, when the E-field is parallel to the Earth's surface (i.e. the magnetic field, the H field, is perpendicular to the Earth's surface), the antenna is said to be Horizontally Polarized.

No matter what polarization you choose, all antennas in the "same" RF network must be polarized identically regardless of the antenna type. Cross polarization takes place when we place two transmitters on the same frequency but with polarizations in the opposite direction. Cross polarization implies a signal loss over 20 dB.

By using a correct polarized antenna we can:

- Increase isolation of unwanted signals source and hence reduce interference
- Define different coverage areas by reusing frequencies

Some examples of vertical polarized antennas:



Image11: AntennSpecialisten Sectoral Antenna V470/24 14 dBi



Image12: HyperGain HG2412Y Antenna 12 dBi 45° 3 dB Beam

Horizontal Polarized Antenna:



Image 13: Parabolic Antenna Horizontally Polarized.  
Ovislink WAE-5822GR 22 dBi 5.8 GHz

For those interested in knowing how 3 dimensional models of E-field patterns look like, check the following link:  
[http://www.odessaoffice.com/wireless/antenna/how\\_to\\_pick\\_the\\_right\\_antenna.htm](http://www.odessaoffice.com/wireless/antenna/how_to_pick_the_right_antenna.htm)

## 7. Power Divider/Combiners

A power divider, sometimes called 'power splitter' or 'combiner', is used to attach several antennas together to one single radio. Combining antennas allow us to create new radiation patterns and to modify the service area of one single access point (radio). You normally see power dividers in scenarios where it is a great need of customizing a service area, for example in the case of repeaters that want to link to non-line-of-sight zones. Imagine the scenario of connecting two villages in separated valleys by placing a repeater at the top of a mountain or a hill.

A power divider will spread the power into equal amount of power to each individual antenna within the antenna system. This type of configuration requires good design skills in order to prevent collisions due to hidden-nodes. If power dividers are used, it normally implies the use of IEEE 802.11 radio access points that include some extension to the basic protocol as "polling extensions".



Image 14: A HyperGain@ SC2402N splitter that can be used to connect two antennas to one wireless bridge or access point. Source: ELIX-Comet

## 8. Antenna Isolation

When we place two antennas in the same tower, we need to ensure that there is no interference between the radio signals. This is done by isolating the antennas, vertically or horizontally.

### 8.1 Vertical Isolation

If we place the antennas in the same vertical plane, we need to take two aspects into consideration:

- Free Space Loss: is directly related to the distance between the antennas in the tower. It is the signal energy loss between the two antennas in free space. As a rule of the thumb, a distance of 3 meters at 2.4GHz will guarantee -49 dB Free Space Loss.
- Pattern Isolation Loss: is related to the shape of each of the antenna beams (beamwidth). If the antennas have a fairly narrow beamwidth (>16 dBi), it will not be significant lobes upward or downward.

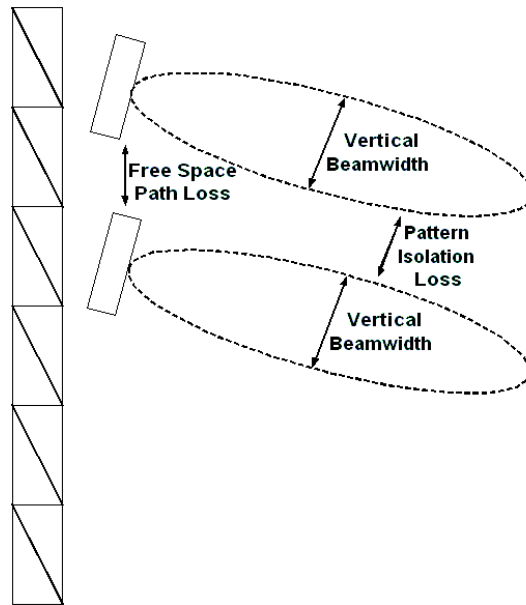


Image 15: Vertical Isolation

## 8.2 Horizontal Isolation

Similar, if we place two antennas in the same horizontal plane, we need to consider:

- Free Space Loss: Similar to Vertical Isolation (3m means -49 dB)
- Pattern isolation Loss: In this scenario we need to know how much energy the antenna radiates in the backlobe. This energy is measure using the Front-to-Back ratio (F/B). The F/B ratio is calculated by taking the energy of the main (front) lobe of an antenna divided by the energy of the back lobe of the antenna.

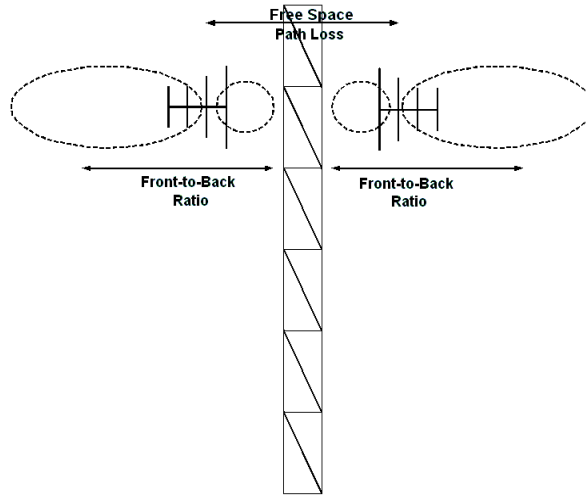


Image 16: Horizontal Isolation

If you are going to place several antennas in the same horizontal plane, consider buying antennas that has a high F/B ratio.



Image 17: Horizontal Isolation in a tower

A good directive antenna has a F/B of 25 dB. In order to have a total isolation of 60 dB, you need to place your antennas at least 50 cm from each other. To achieve that distance when antennas are placed at the top of towers (consider the use of booms and L-brackets) can be challenging but fairly simple when antennas are placed at the top of a roof.

## 9. Coaxial Cable

A low loss coaxial cable is used to connect the radio transceiver to an antenna. When a coaxial cable is used as a conductor of RF frequencies, the cable no longer behaves like a regular traditional wire. The coaxial cable presents an impedance (a measurement of resistance to a current in a transmission medium) that remains constant with independence of the cable length. A coaxial cable, in presence of RF, behaves like a transmission line, and in such circumstances the maximum transfer of energy between the transceiver and the antenna only takes place when all the circuit elements match the same impedance. In data communication equipment including WiFi that impedance is always 50  $\Omega$  (Ohm).

If we place a cable that fails to meet the impedance requirement of 50  $\Omega$  , the radio signal (energy) will reflect back into the transmitter rather than into the antenna.

### 9.1 Cable loss

The coaxial cable introduces a signal loss between the antenna and the transceiver. In transmission, the signal is attenuated towards the antenna and the signal collected by the antenna is attenuated on its way back to the receiver. Notice that only one cable is used for transmission and reception, due to the fact that IEEE 802.11 is a TDM half-duplex protocol. When, the transmitter sends out a radio signal, no signal can be received and vice-versa.

Cable Type	Loss / 10 meters (2.4GHz).
RG 8	3.3 dB
LMR 400	2.2 dB
Helix 3/8"	1.76 dB
LMR 600	1.7 dB
Helix 1/2"	1.2 dB
Helix 5/8"	0.71 dB

Table 1: Cable loss in coaxial cables.

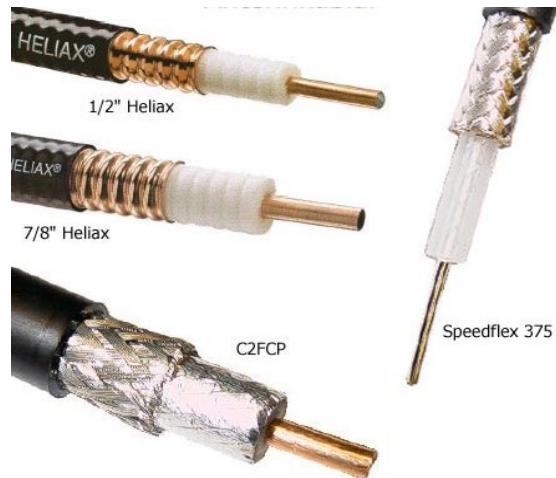


Image 18: Types of Cables (Source: Nowire)

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?

The choice of cable does not only depend on their mechanical properties but also on its availability and cost. As a rule of the thumb, use LMR400 or better cables for installations that require a cable over 10 meters. For less than 10 meters you can use Speedflex 375 or LRM400.

## 10. Antenna Connectors

To connect your radio equipment to the coaxial cable and the coaxial cable to the antenna, you need to choose appropriate connectors. The amount of connectors is endless and make sure that you know what connectors you need before you end up with the wrong connectors in your cables.



Image 19: A set of coaxial cable connectors (Source: connexwireless)

Three basic rules regarding connectors:

- 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

### 10.1 Pigtails

In many cases, connecting the radio equipment to a Helix or LRM400 cable might not be possible. Long run cables (over 10 meters) do normally terminate in N-type connectors while most of the radios use much smaller connectors RPSMA or RPTNC-type.

A pigtail is a short length coaxial cable with a connector in each end to facilitate patching of radios to antennas or radios to long run cables.

In Image 20 we can see a D-link PCI card with a RP-SMA female connector. In order to connect the radio to a Helix N-type male we need a pigtail or a connector converter. The pigtail/converter should be a RPSMA male-N female.



Image 20: A D-link PCI card with a RP-SMA female connector needs a pigtail or a converter in order to connect to a coaxial cable with a Heliax N-type male connector.

Pigtails normally use LMR195 cable and offer a total loss of 0.2-0.4 dB. A good connector converter has a loss of < 0.1 dB.

Finally, take care of your cables, connectors and pigtails 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!

## 11. Showcase: Antenna Installation in Indonesia

The following pictures describe some of the concepts that we have mentioned up to now. In this section, we take the opportunity to provide some comments regarding this specific and concrete implementation.

Image 21 shows a traditional WiFi installation<sup>2</sup> in a client side of the link. The client premise equipment (CPE) is enclosed in a plastic water proof box. A smartBridges indoor unit (Wireless Ethernet Bridge) is placed outdoors inside of a water proof enclosure. Using indoor units as outdoor equipment is a way to save costs as outdoor units are generally more expensive. The client unit is connected by a short cable (SMA connector) to a 24 dBi parabolic antenna (N-type).



Image 21: Installation of a WiFi CPE

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<sup>2</sup> Pictures courtesy of Henry Syarifuddin  
[henry@cgd.co.id](mailto:henry@cgd.co.id).

In our example, the smartBridges client<sup>3</sup> unit has a 100 mW radio with a sensitivity of -94 dBm for 1 Mbps. According to the link budget described earlier in this unit, the radiated power of this installation is:

$$\begin{aligned} \text{Radiated Power} &= 20 \text{ dBm} + 24 \text{ dBi} - \text{Cable/Connector losses} = \\ &= 44 \text{ dBm} - \text{Cable/Connector Losses.} \end{aligned}$$

Assuming that the maximum cable loss is 4 dB, this link is radiating 40 dBm [10 W]. At first hand, we notice that the radiated power seems to be too high.

The whole installation is roof mounted using a L-bracket. Unshielded Twisted Pair (UTP) cable is then run from the CPE to the computers premises in the bottom floor. Power is injected into the CPE through a Power Over Ethernet (PoE) jack prepared for the UTP cable used by the CPE. A special outdoor UTP cable or Shielded Twisted Pair (STP) cable is used in this unit.



Image 22: Access Point installation in the wireless “hub”

In the other side of the link, an Access Point (smartBridges Airpoint Pro) especially designed for outdoor installation links (Point to Point) with the CPE (Client-Bridge mode) is being installed. Similar to the client side, the Access Point is roof mounted in the top of a small tower. Several dedicated links (operating in non-overlapping channels) are collocated in the wireless “hub”.

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3 This unit that acts like a Ethernet bridge has been discontinued

## 12. Conclusions

The choice of antenna will affect your service area, your ability of minimizing interferences with other sources and the durability/stability of your network by ensuring an antenna with good mechanical properties. In many cases, satisfying the requirements of a link budget will be enough and finding an optimal solution for each scenario will make you consider other aspects as: wind load, weather conditions, transport of equipment, availability etc.

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

The five main issues you should remember from this unit can be summarized as:

1. The meaning of radiation pattern, budgets and types of antennas and cables
2. The need of being spectral efficient and follow the power regulations
3. The need of matching the radios and antennas to give just enough signal, plus a fade margin to make the link work
4. How to sectorize access points and tilt antennas to match your coverage area
5. How to take care of your cables and connectors as they are always a point of failure