This paper explains basic parameters and concepts that must be considered when choosing antenna style for use with WLAN radio links. Designs discussed here are both point-to-point and point-to-multipoint. Considerations apply to both 802.11b/g (2.4 GHz) and 802.11a (5.8 GHz). The intent here is to give the reader a conceptual background rather than provide a cook book for actual calculations.

Basic Factors

The range possible with a given wireless setup depends on many factors. The basic factors are relatively easy to quantify and include:

Transmitter power (usually measured in dBm, dB above 1 milliwatt)

Transmitter power is limited by laws which differ from country to country.

Transmitting antenna gain (measured in dBi, relative to an *isotropic* radiator)

Antenna gain is a function of the design of the antenna and is a function of directivity. The more directional an antenna, the higher its gain with respect to a theoretical isotropic radiator

Receiving antenna gain (measured in dBi, relative to an *isotropic* radiator)

Since WLAN systems transmit and receive both ways, the same considerations apply to both antennas. This does not mean the antennas must be of the same design.

Path loss (measured in dB and relates to distance and obstructions)

The longer the path, the greater or higher the path loss. Obstructions also add to the path loss.

Receiver sensitivity (measured in dBm and ranges from -60 dBm to -115 dBm)

The more negative this number is, the more sensitive/better the receiver. The ability of the receiver to operate with weak signals is critical and is directly affected by the *signal to noise ratio*, also expressed in Db. The lower the intrinsic noise level (floor) of the receiver, the *greater the signal to noise ratio* for any given received signal.

Typical Path Budget Calculation

The following table is a basic path budget calculation

Transmitter Power	20	dBm
Transmitting Antenna Gain	18	dBi
Path Loss	-100	dB
Transmitting Antenna Gain	18	dBi
Signal level at Receiver	**-44**	dBm
Receiver noise floor (device specification)	-90	dBm
Signal to noise ratio (SNR) at Receiver	**-46**	**dB**

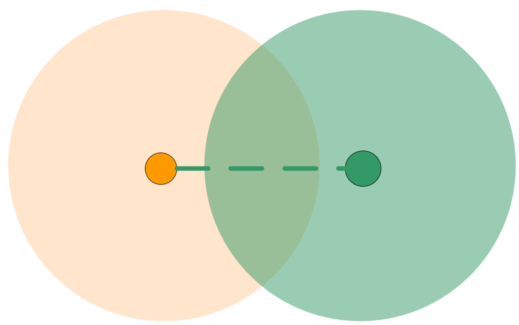
The *signal to noise ratio* is the value that determines the bandwidth or data rate of the link, and even whether it will actually connect at all. Various makes and types of WLAN access points, bridges and backhaul nodes all have data sheets that relate either Signal Level at Receiver or Signal to Noise Ratio (SNR) to available data rate. If a device is rated for instance at 54 Megabits Per Second (Mbps), this data rate will only be available when the signal to noise ratio is quite high. Lower SNR will result in lower available data rates.

Path Loss and Directivity

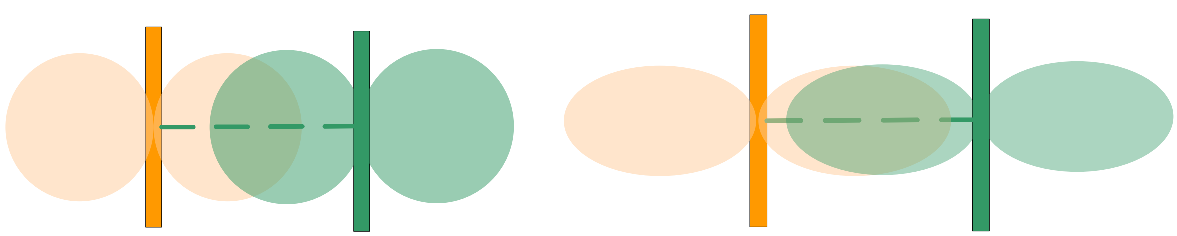
Although exact path loss calculations are beyond the scope of this paper, my intent is to give the reader some ideas why certain antenna configurations may be useful in certain situations.

Omni-Directional Antennas

A basic arrangement for two WLAN nodes using omni-directional antennas is depicted below.



Small vertical (*omni-directional*) antennas typically have gains of between 5 dBi and 9 dBi but exhibit **no directivity in the horizontal plane**. Thus, most of the power of the transmitter is wasted and never reaches the receiver. There must however be some difference between the 5 dBi and 9 dBi models and, it is a function of their **vertical** directivity.

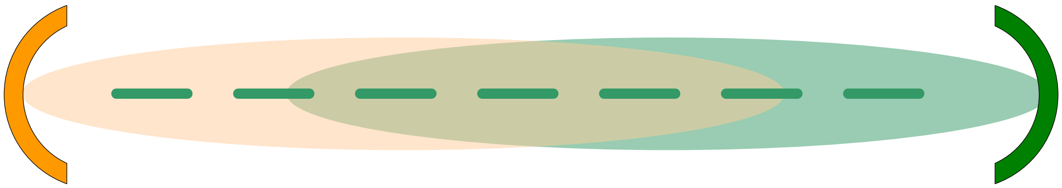


The figures above compares the **vertical** radiation pattern of 5 dBi and 9 dBi *omni directional* antenna pairs. The narrower vertical pattern result in more of the transmitted radiation arriving at the receiver providing a better SNR and higher data rate. The penalty for use of the 9 dBi antenna is usually slightly larger size and cost and the need for somewhat more accurate vertical alignment to avoid “missing” the other antenna.

The important idea here is that using a more directional radiation pattern raises antenna gain and improves the SNR and the data transmission rate.

High Gain Directional Antennas

The foregoing shows that increasing the directivity of the antennas improves the SNR and increases the data rate. This idea can be taken further by using highly directional antennas as shown below.

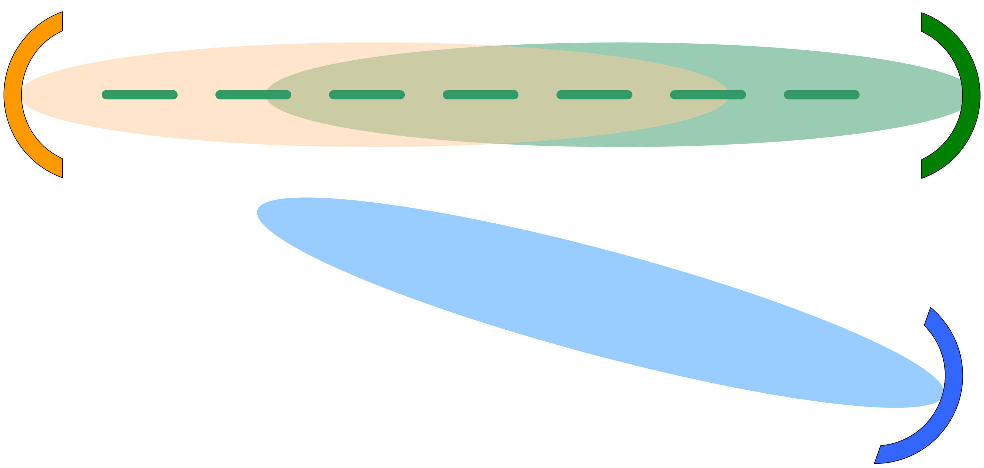


These antennas are often designed in form of flat panels or parabolic reflectors (as illustrated.) These directional antennas may have gains of from 18 dBi to 30 dBi or more. This may represent an improvement of 30 to 50 dB in the total path budget over the simple vertical antennas.

All other things being equal, the transmission range (distance) is **doubled** for each **6 dB** increase in either transmitter power or antenna gain. Thus, a total of **36 dB** of **added** antenna gain increases the range by **32 times**. 500 feet becomes 3 miles. That is a big improvement!

The downside of using highly directional antennas (aside from size and price) is that the narrow radiation pattern (both horizontal and vertical) means the antennas must be accurately aligned.

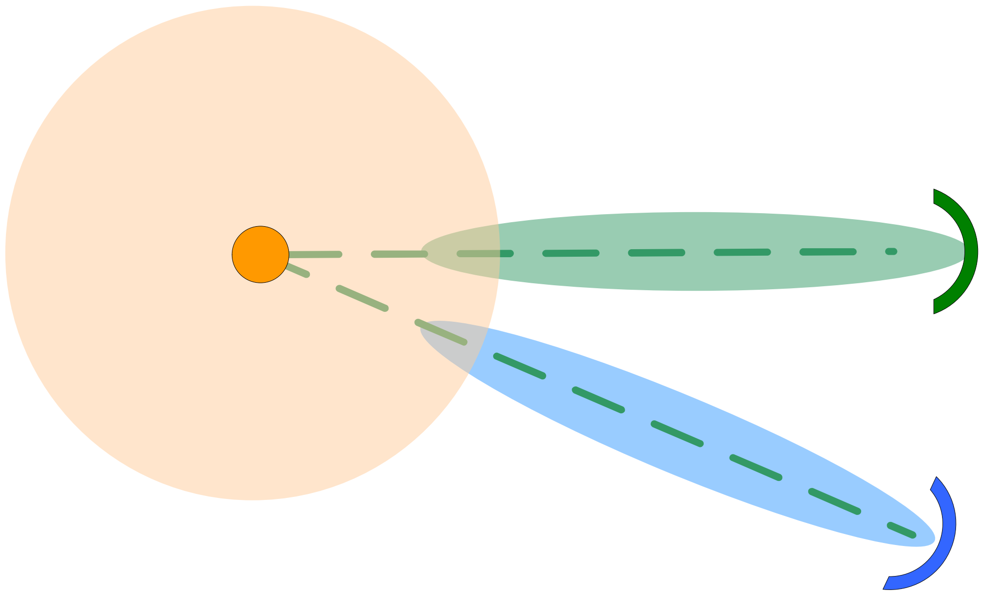
The figure below shows that point-to-multipoint operation with nodes at random locations may not be possible.



The blue antenna is out of alignment and will not receive or transmit effectively with the orange node. An additional antenna and radio could be used at the orange location, turning this into two separate point-to-point links.

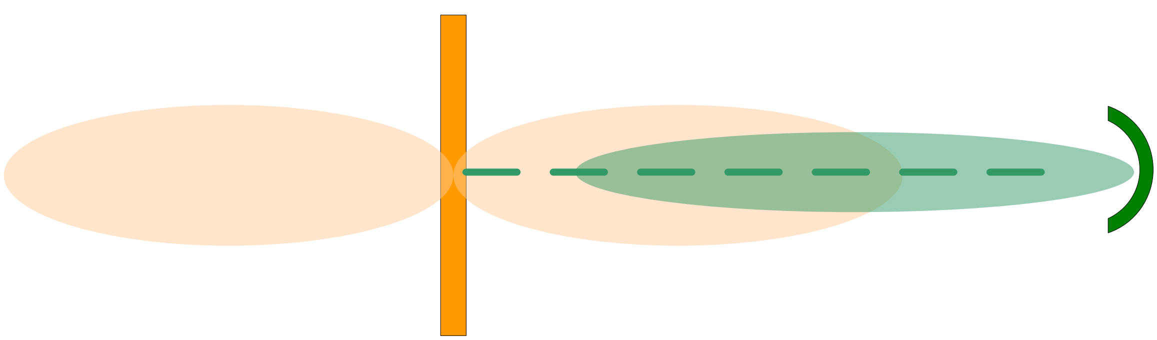
Hybrid Arrangements

The point-to-multipoint problem can be partially overcome by using an arrangement that combines a master node using an omni directional antenna together with remote nodes that use high gain directional antennas. The following figure shows the horizontal radiation patterns of such an arrangement.



Since the path budget includes the sum of the gains of the antennas at both ends of any given path, the full benefit of the high gain at one end will still be applicable. This hybrid arrangement allows multiple remote nodes to be located anywhere within range as long as they point in the direction of the master node. This alignment is much less difficult since the master side requires only vertical adjustment.

The hybrid arrangement can be further improved by using a master omni-directional antenna with a very narrow **vertical** radiation pattern as shown below.



The gain of the special omni might be as much as 15 dBi providing a 2X range improvement over a more standard 9 dBi. The disadvantage is that the narrow vertical radiation pattern of the high gain omni means that vertical alignment is quite critical.