Wireless LAN RF Design Fundamentals

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Sometimes we just have to return to the basics.

This White Paper is just that – a blast back to the past – back to the early days of Wireless LAN design. A time before controllers, before all these new fangled 802.11n technologies, a time where just relied on plain old RF design.

Sure – you can always put back in the high tech bits – but in the end, it still just comes down to delivering RF energy from an Access Point to a Client device.

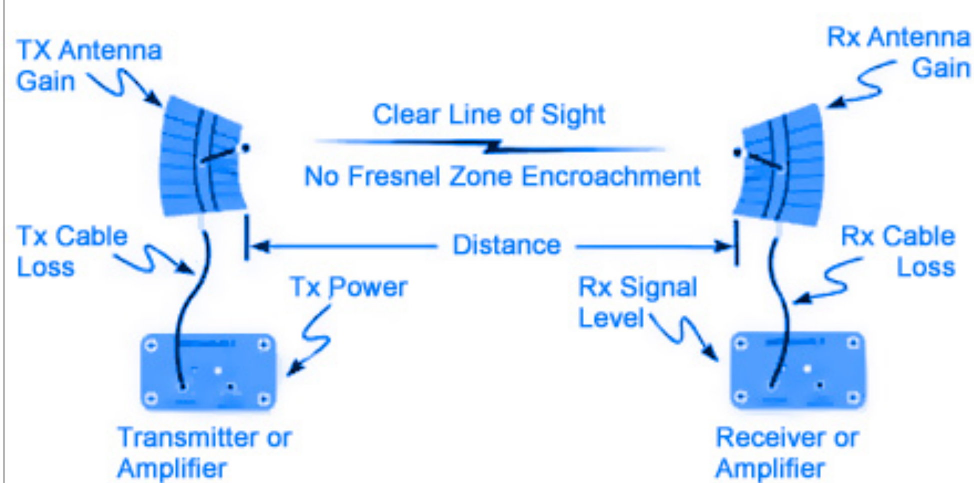
We'll cover a couple fundamental principles:

Link Budget

First – and probably most complex… No, I'm not going to get into all the math and formulas of link budgets.

Just talk for a minute about what it means.

There are two sides to every WLAN communication. The Transmitter and the Receiver. The transmitter sends out a clean series of ones and zeros, modulated in one of the 802.11 approved schemes. The signal travels through the air, through walls, and other materials, then eventually makes it's way – loosing signal strength all the way – to the Receiver device.



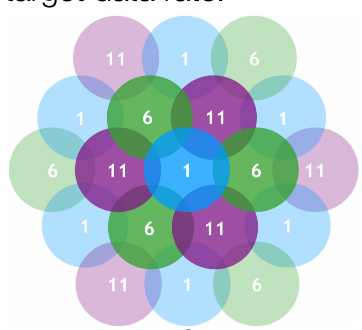
As this signal leaves the Transmitter – it is propagated out using an antenna. This antenna shapes the area of coverage. The Receiver also uses an antenna – this time it is used to amplify the incoming signal to a level where the receiver's chips can discern between a one and a zero.

Transmitters send out signal at a certain power level – usually given in either mw (Milliwatts – one thousandth of a watt) or in dBm – Decibels compared to milliwatts. Depending on your country – different legal limits apply. Most enterprise class access points transmit at 100mw or 20dBm on the high end.

Receivers have something called receive sensitivity – this number is normally rated in dBm – and sets the lower limit of how quiet a signal can be and have the chipsets still be able to discern a one from a zero.

The Link Budget just refers to all the parts, Transmitter, loss over distance, and Receiver sensitivity. In the end, the power coming off the transmitter, boosted by the antenna's gain, less the attenuation loss of the covering distance, boosted by the receivers antenna all must equal at least as much RF energy as the receiving device's Receive Sensitivity at the target data rate.

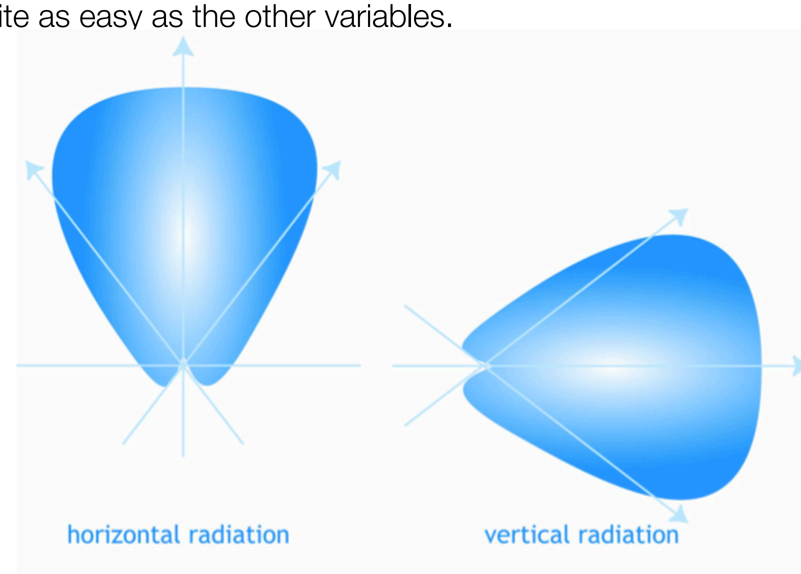
Three Variables of Wireless LAN Design



First Variable – Number of Coverage Zones
Each access point transmits RF energy into a zone of coverage. The more of these 'circles' that you need, means you need more access points. So the first variable is simply the number of access points. More coverage, more access points. Simple.

Second Variable – Size of Coverage Zones
Each access point has a transmit power setting. The higher the transmit power the larger the coverage zone. The second variable is tied to 'size' – more power equals larger sized coverage zones. Also quite simple.

Third Variable – Shape of Coverage Zones
Depending on the antennas used, each access point covers a specific shape of area. Omni-directional antennas cover a circular shape. If you don't want a circular shape, you can purchase antennas with a wide variety of patterns. Funnel-shapes, half-circle shapes, cones, oblong ellipses, etc. Each antenna has a different shape – both in the horizontal plane and in the vertical plane. Since vendors don't always show nice pretty 3D graphics of their antenna patterns, we're left with visualizing the actual three-dimensional patterns in our heads. Not quite as easy as the other variables.



Antenna Options

Why would you choose a different antenna?
The initial and obvious answer is based on coverage patterns. What is the shape of the area you want covered? Many times simple omni-directional antennas fulfill all your design criteria. That is fine.

But sometimes a simple circular shape either isn't what you need for a specific coverage area, or by using circular shapes you'll have too much overlap from access points on the same channel. In this case you can choose other directional antennas.

Another reason to change antennas – isn't only because of the shapes, but because of the passive gain you get from antennas. Antennas amplify the RF energy by focusing it in a specific area. You can increase your link budget results by either focusing the transmitter's beam and/or getting a higher signal. Or increase your link budget by adding a higher-gain antenna on the receiving end.

Either of these options adds to the signal integrity at the receiving end.

Let say you go from a simple 2dBi omni antenna, to a 5dBi antenna – that's a net gain of 3dBm. This equates to twice as strong of RF signal at the receiver. This simple change in antennas will allow much more consistent signal at the same distance, or allow you to go through more space or walls and receive the same signal.

Power and Shape

You can think of the antenna's shape as a custom balloon. Perhaps one of the Thanksgiving-Day parade balloons will come to mind. A unique shape. The antenna will always produce a radiation pattern of that shape.

Power, however, is the amount of air in the balloon. The more power you use at the transmitter – the larger the balloon shape gets.

You could have a balloon (read antenna) with the shape of a bagel. The more power you inject into this antenna, the larger the bagel gets. But it's always the shape of a bagel.

Only Antenna Rule You'll Ever Need

This again is fairly simple and it will be the only rule you'll ever need when choosing between antennas.

"*Pick the antenna that covers the area you need covered, that doesn't cover the area you don't need covered*"

Sounds pretty logical. But I've seen people design crazy networks that continually failed, because they chose the wrong antenna.

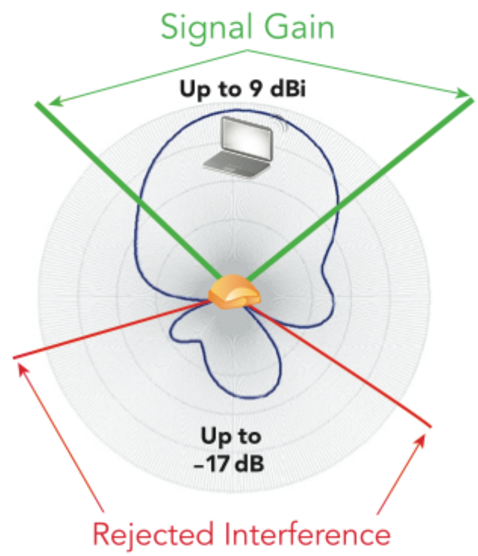
You want the RF energy to go where you need it to go. But if it bleeds over into areas you don't need, then you are causing interference in another area.

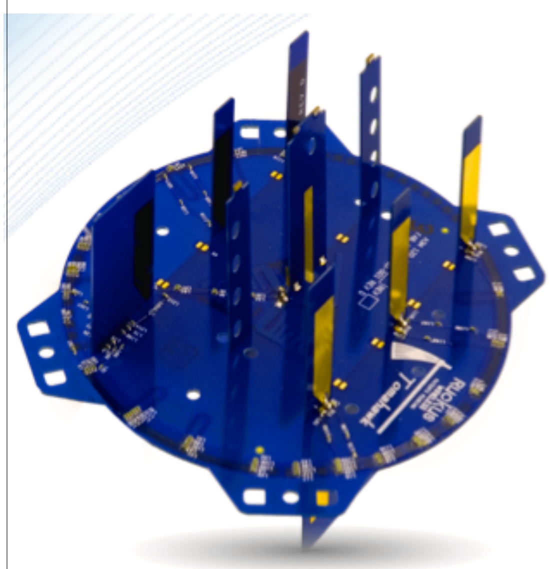
Remember, cover what you want, and don't cover what you don't want.

Dynamic Beamforming Antennas

A company called Ruckus Wireless produces a set of access points that have a unique combination of antenna elements. Each individual element is a directional antenna, but combined they form a full omni-directional coverage pattern.

Dynamically, in between each packet, the custom software compares the signals from the various antenna elements, and chooses the best possible combination for that packet. This results in a 6dBm to 9dBm gain for that one communications combination of access point and client. In regular math terms that's more than quadrupling of RF signals at the receive end!





Additionally, while the unique set of antenna elements is forming a directional signal to one specific client, it also rejects the interfering RF signals coming from most other nearby devices. Allowing for up to 17dBm of noise rejection.

All of this is to focus the RF energy where you want it, and ignore RF energy from where you don't want. All dynamically without any IT administrator's involvement.

Wireless LAN Design Steps

So there you have all the fundamentals – we're ready to design a Wireless LAN.

1. Decide where you need coverage, and where you don't want coverage.

2. Decide how many devices you need coverage for – and divide by your target number of devices per access point. This will tell you how many access points you need at a minimum.

3. Choose the antenna pattern that covers the areas you want covered, and doesn't bleed too much into the areas you don't want covered.

4. Choose the antenna gain that results in the best possible signal at the receiving device.

5. Set the power levels of the access points to have the antenna patterns reach to the edges of the area containing the target number of devices.

6. Don't let access points on the same channel touch each other's coverage areas. This causes collision domains.

Conclusion

Sometimes its alright to stop thinking about all the new-fangled technology with controllers, or not controllers, 802.11n or not 802.11n, 20MHz or 40MHz channels, and just get back to the basics of RF design.

Transmit a strong RF signal, boost it through the appropriate antenna, and receive it at the receiving station with as much Signal to Noise Ratio as possible.

"That's how it's done, old school!"

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