About Mike Fahrion

Mike Fahrion, the director of product management at B&B Electronics, is an expert in data communications with 20 years of design and application experience. He oversees development of the company's rugged M2M connectivity solutions for wireless and wired networks based on serial, Ethernet, wireless and USB communication technologies. Fahrion has particular expertise in reliable connectivity solutions for devices deployed at the "edge" of networks in remote, harsh or uncontrolled environments. His technical expertise combined with a talent for simplifying complex issues allow Fahrion to turn technical babble and marketing speak into practical, useful information for engineers and managers. Fahrion is a speaker and widely-published author, including his politically-incorrect newsletter, eConnections, with over 50,000 monthly subscribers. Fahrion holds a BSEE from Iowa State University.

10 Commandments of Wireless Communications

I. Thou shalt know thy dBm and recall thy high school logarithms.
Radio Frequency (RF) power is measured in milliwatts (mW) or -- more usefully -- in a logarithmic scale of decibels (dB), or decibels referenced to 1 mW of power (dBm). Since RF power attenuates as a logarithmic function, the dBm scale is most useful. Here are some examples of how these scales relate:

1mW = 0dBm	A 2-fold increase in power yields 3dB of signal.
2mW = 3dBm	A 10-fold increase in power yields 10dB of signal.
4mW = 6dBm	A 100-fold increase in power yields 20dB of signal.
10mW = 10dBm	
100mW = 20dBm	
1W = 30dBm	

II. Covet not high frequencies - as the lower the frequency, the more forgiveth the laws of physics and propagation.
Industrial applications typically operate in "license free" frequency bands, also referred to as ISM (Industrial, Scientific and Medical). The frequencies and power of these bands vary from country to country. The most common frequencies encountered are:

- 2.4 GHz – nearly worldwide
- 915 MHz band – North America, South America, some other countries
- 868 MHz band – Europe

As frequency rises, available bandwidth typically rises as well, but range and the ability to overcome obstacles decrease. For any given distance, a 2.4 GHz installation will have roughly 8.5 dB of additional path loss when compared to 900 MHz. Note that lower frequencies require larger antennas to achieve the same gain.

III. Honor thy receive sensitivity - as long-range performance is not a function of transmit power alone.
The more sensitive the radio, the lower the power signal it can successfully receive.

You can often improve your receive sensitivity, and therefore your range, by reducing data rates over the air. Receive sensitivity is a function of the transmission baud rate. As baud rate goes down, the receive sensitivity goes up. Many radios give the user the ability to reduce the baud rate to maximize range.

The receive sensitivity of a radio also improves at lower frequencies, providing another significant range advantage of 900 MHz (vs. 2.4 GHz). It can be as much as six to twelve dB.

IV. Thou shalt be wary of radio noise and recognize situations whereth radio noise may hamper thine installation.
RF background noise can come from sources like solar activity, high frequency digital products or competing forms of radio communications. The background noise establishes a noise floor at which the desired signals are lost in the background ruckus. The noise floor will vary by frequency.

The noise floor will be often be lower than the receive sensitivity of your radio, in which case it wouldn't be a factor in your system design. But if you're in an environment where high degrees of RF noise exist in your frequency band, use the noise floor figures rather than the radio receive sensitivity to make your calculations. Doing a simple site survey to determine the noise floor value can pay off down the road.

Sources of interference aren't always obvious. When in doubt, look about. Antennas are everywhere. They're on the sides of buildings, water towers, billboards and chimneys. Some are even disguised as trees.

V. Thou shalt always know thy fade margin - lest ye have a wireless link that worketh not in rain, snow, or the presence of interference.
Establishing a fade margin of no less than 10dB in good weather conditions will help assure that the system will continue to operate effectively when conditions degrade due to weather, solar, and RF interference. There are some creative ways to estimate the fade margin of a system without investing in specialty gear. Pick one or more of the following and use it to ensure that you've got a robust installation:

1. Some radios have programmable output power. Reduce the power until performance degrades, then dial the power back up to a minimum of 10dB. Remember that doubling output power yields 3 dB, and an increase of 10dB requires a ten-fold increase in transmit power.
2. Invest in a small 10dB attenuator. (Use the correct one for your radio frequency.). You don't have enough fade margin if you lose communications when you install the attenuator in-line with one of your antennas.
3. Antenna cable is lossy, and more so at higher frequencies. Specifications vary by type and manufacturer. So check them yourself. At 900MHz, a coil of RG58 in the range of 50 to 100 feet (15 to 30 m) will be 10dB. At 2.4GHz, a cable length of 20 to 40 feet (6 to 12 m) will yield 10dB. If your system still operates reliably with the test length of cable installed, you've got at least 10dB of fade margin.

VI. Thou shalt use thy given powers of mathematics and logic when specifying wireless equipment.
Predicting the range of a given radio signal isn't a black art. There are some simple rules of thumb. The equation for successful radio reception is:

TX power + TX antenna gain – Path loss – Cabling loss + RX antenna gain – 10dB fade margin > RX Radio sensitivity or (less commonly) RF noise floor
Note that most of the parameters are easily gleaned from the manufacturer's data. That leaves only path loss and -
- in cases of heavy RF interference -- RF noise floor as the two parameters that you must establish for yourself.

VII. Thou shalt not allow leafy greens or mounds of earth between thine antennas; and thou shalt elevate thine antennas towards the heavens; and thou shalt never, ever, attempt a system at the manufacturer's maximum advertised distance.
In a clear path through the air, radio signals attenuate with the square of distance. Doubling range requires a four-fold increase in power, therefore:

- Halving the distance decreases path loss by 6dB.
- Doubling the distance increases path loss by 6dB.

When indoors, paths tend to be more complex, so use a more aggressive calculation:

- Halving the distance decreases path loss by 9dB.
- Doubling the distance increases path loss by 9dB.

Radio manufacturers advertise "line of sight" range figures. Line of sight means that you can see antenna B from antenna A. Just being able to see the building that contains antenna B doesn't count as line of sight. For every obstacle in the path, de-rate the "line of sight" figure specified for each obstacle. The type of obstacle, the location of the obstacle, and the number of obstacles will all play a role in path loss.

Visualize the lines radiating between the antennas as an elliptical path in the shape of a football. The center of the RF path is wide, with many pathways. A single obstacle here will have minimal impact on path loss. But as you approach each antenna the RF field narrows. Obstructions located close to the antennas can cause dramatic path loss.

It's easy to underestimate the distance between antennas. If it's a short-range application, pace it off. If it's a long-range application, establish the actual distance with a GPS or Google Maps.

The most effective way to reduce path loss is to elevate the antennas. At 6 feet (2 m) the line of sight about is only 3 miles (5 km), due to the curvature of the Earth. Anything taller than a well-manicured lawn will be an obstacle.

Weather conditions matter. Increased moisture in the air increases path loss. The higher the frequency, the higher the path loss.

Beware of foliage. A few mid-path saplings are tolerable, but it's very difficult for RF to penetrate significant woodlands. If you're crossing a wooded area your antenna must be higher than the treetops.

Industrial installations often include many reflective obstacles. These will create numerous paths between the antennas. The received signal is the vector sum of each of these paths. Depending upon the phase of each signal, they can be added or subtracted. In multiple-path environments, simply moving the antenna slightly can significantly change the signal strength.

Some obstacles are mobile. More than one wireless application has been stymied by temporary obstacles such as a stack of containers, a parked truck or material handling equipment. Plan for that.

Remember that metal is not your friend. An antenna will not transmit from the inside of a metal box or through the walls of a storage tank.

Path Loss Rules of Thumb:

- N**ever exceed 50% of the manufacturer's rated line of sight distance**. This alone yields a theoretical 6dB fade margin – a big step on the way to the required 10dB.
- De-rate more aggressively if you have obstacles between the two antennas, but not near the antennas.
- **De-rate to 10% of the manufacture's line of site ratings if you have multiple obstacles, obstacles located near the antennas, or if the antennas are located indoors.**

VIII. Thou shalt separate thine antenna from its brethren – for in solitude comes clarity.
Proper antenna choice and location will have a big impact on your wireless connectivity. Antennas can increase their effective power by focusing the radiated energy in a desired direction. Using the correct antenna not only focuses power, it reduces the amount of power broadcast into areas where it is not needed.

But one symptom of the increasing popularity of wireless is the fact that everyone seeks out the highest convenient places to mount their antennas. It's not uncommon to arrive at a job site and find that other antennas are already sprouting all over your installation point. Even if you suspect that these systems are spread spectrum and likely to be using other ISM or licensed frequency bands, you'll still want to maximize the distance between their antennas and your own. Most antennas broadcast in a horizontal pattern, so vertical separation is more meaningful than horizontal separation. Try to separate antennas with like-polarization by a minimum of two wavelengths, which is about 26 inches (0.66 m) at 900 MHz, or 10 inches (0.25 m) at 2.4 GHz.

IX. Thou shalt not be chintzy with the quality of thy cable – only the amount of it.
High frequencies don't propagate well through cable and connectors. Use high quality RF cable between the antenna connector and your antenna. Ensure that all connectors are also high quality and that they are carefully installed. Factor in a 0.2 dB loss per coaxial connector in addition to the cable attenuation itself. Typical attenuation figures for two popular cable types are listed below.

Loss per 10 feet (3 meters) of cable length

Frequency	RG-58U	LMR-400
900 MHz	1.6 dB	0.4 dB
2.4 GHz	2.8 dB	0.7 dB

While long cable runs to an antenna create signal loss, the benefit of elevating the antenna another 25 feet (7.6 m) can more than compensate for it.

X. Thou shalt recognize the issues of latency and packetization before thou issueth purchase orders.
Bit error rates for wireless communications are orders of magnitude higher than those for wired communications. Most radios quietly handle error detection and retries for you, but at the expense of throughput and variable latencies. When using wireless your software must be well designed and your communication protocols must be tolerant of variable latencies. Protocols that are sensitive to inter-byte delays may require special attention or specific protocol support from the radio. Do your homework up front. Confirm that your software won't choke, that the intended radio can get along with your protocol, and that your application software can handle it as well.