How to pre-test your product's antenna

Glenn Robb -June 30, 2017

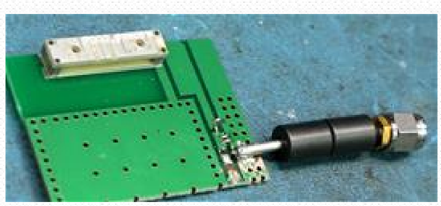
Your wireless product's end-to-end success dictates that your customers will rely on your antennas to perform well in their system. Most hardware and software is thoughtfully tested before sale or deployment, but why are so many antennas ignored? The risks to system functionality and customers' trust hang in the balance if you skip your antenna's verification.

However, there is no reason to defer or ignore your antenna evaluation; help is available. This article will outline some basic antenna pre-testing techniques that can be used in your own desig environment to quantify the basic effectiveness and functionality of your antenna.

Specialty laboratories can do a far more detailed antenna evaluation for you at cost effective rates. The results of an anechoic chamber antenna evaluation will provide insight and confidence throughout your company: from design engineering to parts procurement, right through to field support and customer success. However, there are pre-tests that can and should be done in youı own lab, and they even include preliminary antenna gain measurements.

Return loss pre-check

No antenna can radiate or receive properly unless its impedance is matched to your transceiver. But the feeding and matching of small embedded antennas can be tricky to optimize. Virtually all reference designs will note that their antenna needs to be "matched" or "tuned" for your PCB (actually your PCB size). This article is about radiated gain testing, and will not go into the steps for matching an antenna. There are online resources and tutorials available for this, and often guidance from the antenna manufacturer.



Unless you have a coax connector access to your antenna, you will need to solder on a small semi-rigid coax "probe" in your antenna's path. Do this after disconnecting or cutting the transmitter's feed trace, and locate your coax probe such that it "sees" the matching components in the antenna's feed path. Later, you will need this "port" for antenna testing after matching. Tip: It is a good idea to add ferrite beads to this coax to help stop RF energy from using it as part of the antenna or board radiating structure. Most ferrite beads are useless in 915 MHz and 2.4 GHz We recommend the Steward HFB series of ferrite beads, which do offer some microwave impedance.

After tuning your matching components for a good match over the product's operating frequencies, it is now possible for efficient antenna operation. However, matching networks may appear to offer great broadband return loss to your VNA, while often yielding poor radiation efficiency (under 10%). Some component selections may be lossy, and some antennas may not radiate well, despite a "good match." After all, the "good match" means energy disappears into th antenna port, but it can't be assumed to radiate. Weekly in our lab, we see PCBs with "matched" antennas, that have poor radiation efficiency (under 10% or average gain of less than -10 dBi). Do not skip radiated or "gain testing."

Purchased antennas

Stand-alone antennas that attach to U.FL or SMA connectors are also popular. However, they are typically sourced from very low cost offshore sources. They tend to have misleading data-sheets (sometimes based only on simulations) that overestimate gain and efficiency for the sake of sales Your evaluation of a sample antenna is a prudent (and cost-effective) step.

Antenna gain intro

There are countless online resources and tutorials on antenna gain, but the concept of "average gain" is not well covered. Antenna gain is a function of direction in all antennas, although it is expected to be similar in all directions for omni-directional antennas. Gain is the redirection of energy in some directions at the expense of other directions. The 3D spherical average gain of a antenna cannot exceed unity (or 0 dBi in antenna terms), because the antenna does not create energy. Real antennas are more likely to have average gains of less than 0 dBi, and this is the measure of their efficiency.

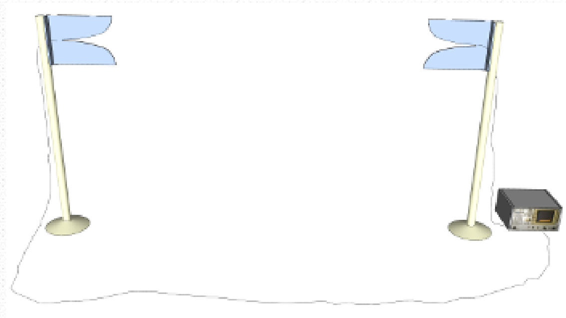
If an antenna has an average gain of −6 dBi, its radiated power is 6 dB down from its input power, or a 25% radiation efficiency. The same antenna may have a peak gain of 4 dBi in some direction, and may be "specified" or "rated" as a 4 dBi gain antenna, but it still has an average gain of −6 dBi. The 4 dBi of gain number is from one peak test direction. In omni-directional antennas, it is average gain (efficiency) that counts! Poor efficiency effects RF link quality by disadvantaging the antenna in all of the "average" directions. Inefficiency's loss of energy may be due to the antenna and/or its matching network components. More **antenna tutorials can be found here**.

Equipment required

To test your antenna's gain, you will need a reasonably open lab space, with distance from any RF reflective objects like metal furniture. You will also need a source and a receiver, which could be a separate signal generator and spectrum analyzer, or a vector network analyzer. Sources such as eBay can be used to locate older used equipment for under $3000. A VNA is a great choice because it can be used for antenna tuning as well. You will also require two antennas and two coax cables to hook everything together. Vendors such as **RFSpace.com** have very broadband Vivaldi antennas (aka "Wideband Tapered Slot Antenna") available for just hundreds c dollars. Such antennas have some gain (directivity) which helps ignore reflections and unwanted effects during your testing.

2-way identical antenna calibration

One of the antennas you use should be calibrated. A NIST traceable calibration is expensive for broadband antennas, and is overkill for bench testing. A simple in-house calibration procedure called the “2 antenna method” is straightforward. Purchase two identical antennas, and assume they will have the same gain as each other.



Then set up your “test range.” Spacing between the antennas can be about a meter for most ISM band frequencies. Both antennas should have the same orientation, vertical is easiest. Try keeping reflective metal objects away from your test space and use plastic drain pipe (from any plumbing source), empty cardboard boxes, or any other dielectric material as supports. Remember, the floor and/or ceiling in your office building is probably metal, and that all of those reflections will ultimately limit accuracy. Qualified antenna testing laboratories would be using an anechoic chamber.

Next, measure the path loss between your two antennas using your VNA or sig-gen/spectrum analyzer combo. This particular path loss does not include the losses of your coax cables, so “normalize” or ignore their loss by first connecting them back-to-back with a coax adapter and measuring their loss. The Friis Transmission Equation (expressed below in dB units) tells us how path loss and antenna gain are related.

$$PL = G_1 + G_2 + 20\log\left(\frac{\lambda}{4\pi R}\right) \ [Equation\ 1]$$

Where: PL is the path loss in dB (express loss as negative dB number, actually “path gain”)
G1 and G2 are the antenna gains in dBi, and it will be assumed that G1=G2
λis the wavelength in meters, calculated as 300/f (frequency in MHz)
R is the antenna spacing in meters

Tip: If you use an Excel spreadsheet to calculate your numbers, it uses natural base logarithms for the “log(x)” function, so make sure to explicitly use the “log10(x)” function.

Since G1 and G2 are the only unknowns, we can rewrite Equation 1 as

$$G_1 + G_2 = PL - 20\log\left(\frac{\lambda}{4\pi R}\right) \ [Equation\ 2]$$

For example, using a 1 meter spacing, and testing at 2450 MHz: Lambda is 0.122 meters; the “20log(Lambda/4 x pi x R)” term is -40.2 dB; and let us say your measured path loss is -27.8 dB.

Then equation 2 becomes:

G1 + G2 = -27.8 dB - (-40.2 dB) = 12.4 dBi

Which is 6.2 dBi gain for each antenna. You now have “calibrated reference antennas,” with known 6.2 dBi gains (at 2450 MHz). These gains are only done in one direction, usually the preferred direction of radiation for directional antennas. This calibration only has to be done once While only one antenna must be calibrated, you will always need two antennas to normalize the test range before any future test session.

Next: 2-way identical antenna calibration

< Previous Page 1 of 2 Next >

MOST RECENT

How to pre-test your product's antenna

ADI helps blaze path from 4G to 5G

IMS: Phased-array antennas and beamforming

Keysight achieves 12Gbps at 28 GHz

IMS: 5G is complicated

Verizon 5GTF comes to life

Want 5G? It’s going to take an IP anyhaul overhaul

Where will 5G appear first?

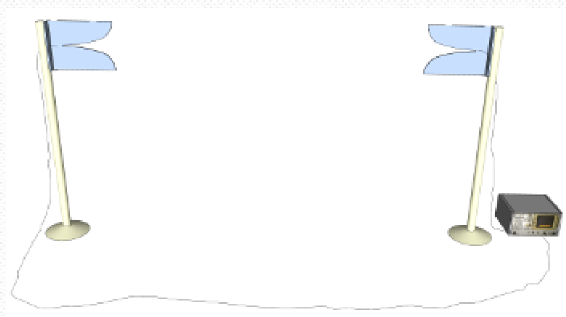
What’s now and what’s next for 5G

How to pre-test your product's antenna

Glenn Robb -June 30, 2017

2-way identical antenna calibration

One of the antennas you use should be calibrated. A NIST traceable calibration is expensive for broadband antennas, and is overkill for bench testing. A simple in-house calibration procedure called the “2 antenna method” is straightforward. Purchase two identical antennas, and assume they will have the same gain as each other.



Then set up your “test range.” Spacing between the antennas can be about a meter for most ISM band frequencies. Both antennas should have the same orientation, vertical is easiest. Try keeping reflective metal objects away from your test space and use plastic drain pipe (from any plumbing source), empty cardboard boxes, or any other dielectric material as supports. Remember, the floor and/or ceiling in your office building is probably metal, and that all of those reflections will ultimately limit accuracy. Qualified antenna testing laboratories would be using an anechoic chamber.

Next, measure the path loss between your two antennas using your VNA or sig-gen/spectrum analyzer combo. This particular path loss does not include the losses of your coax cables, so “normalize” or ignore their loss by first connecting them back-to-back with a coax adapter and measuring their loss. The Friis Transmission Equation (expressed below in dB units) tells us how path loss and antenna gain are related.

$$PL = G_1 + G_2 + 20\log\left(\frac{\lambda}{4\pi R}\right)\ [Equation\ 1]$$

Where: PL is the path loss in dB (express loss as negative dB number, actually “path gain”)
G1 and G2 are the antenna gains in dBi, and it will be assumed that G1=G2
λis the wavelength in meters, calculated as 300/f (frequency in MHz)
R is the antenna spacing in meters

Tip: If you use an Excel spreadsheet to calculate your numbers, it uses natural base logarithms for the “log(x)” function, so make sure to explicitly use the “log10(x)” function.

Since G1 and G2 are the only unknowns, we can rewrite Equation 1 as

$$G_1 + G_2 = PL - 20\log\left(\frac{\lambda}{4\pi R}\right)\ [Equation\ 2]$$

For example, using a 1 meter spacing, and testing at 2450 MHz: Lambda is 0.122 meters; the “20log(Lambda/4 x pi x R)” term is -40.2 dB; and let us say your measured path loss is -27.8 dB.

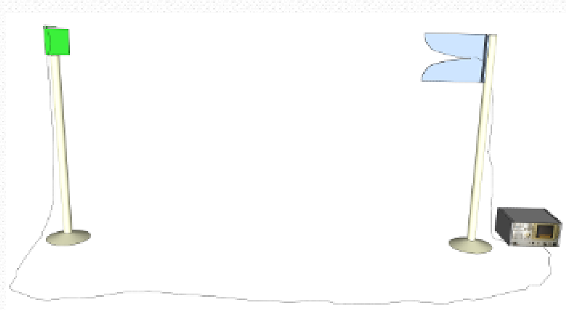
Then equation 2 becomes:

G1 + G2 = -27.8 dB - (-40.2 dB) = 12.4 dBi

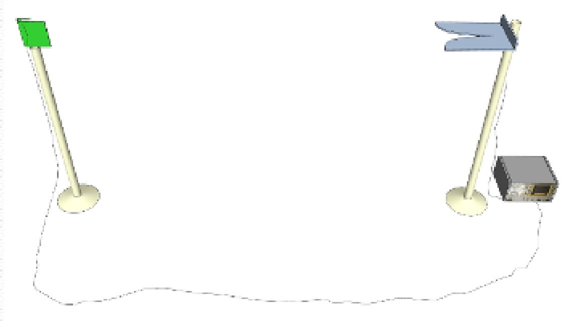
Which is 6.2 dBi gain for each antenna. You now have “calibrated reference antennas,” with known 6.2 dBi gains (at 2450 MHz). These gains are only done in one direction, usually the preferred direction of radiation for directional antennas. This calibration only has to be done once While only one antenna must be calibrated, you will always need two antennas to normalize the test range before any future test session.

Substitution method

The substitution method of antenna testing is just as simple as your calibration. First, setup your test range by facing your two calibrated antennas together. Use a convenient spacing (it no longe needs to be 1 meter), and keep them both vertical. Then normalize the whole range, by “zeroing” or noting the total path loss (both coax cables and spaced reference antennas) as 0 dB. You will only care about changes in the path loss.



Now substitute your antenna under test (AUT) for one of your reference antennas. If the total pat loss increases by 2.5 dB, then your AUT has 2.5 dB less gain than your reference antenna. In this example, the AUT has an absolute gain of +3.7 dBi (at one frequency and in the tested direction). This is the vertical component of the AUT’s gain.



Next, rotate your test antenna to horizontal (while keeping the test distance constant) to measure the horizontal component of its gain. The two gains can be “power sum added” to come up with the AUT’s total gain in the current test direction. Use the following formula:

$$G_t = 10\log \{ [10^{(G_v/10)}] + [10^{(G_h/10)}] \}$$

Where: Gt = Total gain (in dBi), Gv = Vertical gain (in dBi), Gh = Horizontal gain (in dBi)
For example, if the measured vertical gain was +3.7 dBi and the measured horizontal gain was −1.2 dBi, the total gain is +4.9 dBi.

Try to measure your AUT’s gain in multiple directions (by rotating or repositioning it, keeping the path length constant), especially if it is an omni directional antenna. These gains may be averaged to estimate radiation efficiency.

Third-party evaluations

If you send your antenna to an antenna testing service, they will use essentially the same substitution method technique, but with better equipment. The lab will have accurately calibrated reference antennas, fast multi-axis positioners, frequency swept measurements, and a reflectionless environment (anechoic chamber). This 3D far-field antenna evaluation will reveal your complete product’s antenna patterns, gains, radiation efficiency, circularity, axial ratio, and many other quantified performance parameters swept over frequency. Full evaluations are available for $450 at Antenna Test Lab.