Antenna Measuring Notes:

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Since 1987 I have set up my portable antenna range at 26 Conferences measuring well over 1500 antennas, mainly in the 0.9 to 24 GHz range. G4DDK has asked me to list some of my observations.

The Feed is not at the focus of the dish:

First off, I have NEVER been able to calculate the focal point of my dish, mount the feed, and have the antenna optimized. NEVER! It always seems I have to move the feed in towards the dish a bit to tweak things up. But out of the antenna range things are far worse. About half of the dishes have the feed off by as much as 50% in distance!

A chap comes up with a 2 ft. dish and about a 0.35 f/d. The feed is sticking out 3 ft from dish! "But that's where I calculated the focus to be!" is always the answer. I haven't found out what in the $D^2/16c$ equation throws them, but we see it all the time. Another problem is the rounded edge on most dishes. They measure the physical diameter of the dish, not the diameter of the actual parabolic surface. That outer cm or so of many dishes is not usable and should not be used in the F/d calculations. And I won't even start on the complications of calculating the actual phase center of the feed.

I have always been able to pick up a dB or two tweaking the focus and 6 dB or so has been the typical improvement at the conferences when the feed is movable and we can optimize its position. And finally come the 25% or so really bad ones. The "dish" was not parabolic, the feed wasn't resonate in the ham band, the focus was miscalculated by 3 feet (on a 2 ft dish!), using a grid dish on 3cm (and 3cm spacing on the wires), and so on. As I said, typically 25% or so of the dish antennas tested at these conferences are just air cooled dummy loads.

Most of these really bad ones are usually the prime focus dishes. With the offset dishes, you usually have a pretty good idea where the feed was for a starting point if you had saved all the parts. But the ham feeds will usually have a different phase center, so we're back to seeing several dB of improvement moving the feed around a few millimeters.

The antenna range is also a good spot to figure out where the antenna is pointing. Build up some kind of mechanical sight, or mount a telescopic sight on the edge of the offset dish. (Top edge works well too) Peak up the signal, and sight in on the source. An optical sight can be very useful when portable.

On Yagi and Quad loop type antenna, the builder has often used a different diameter boom, or different size elements, or even replaced a round boom with a square boom. In each case there was no attempt to use corrections factors. (50/50 chance they would have gone in the wrong direction anyway!) Again a large percentage of these antennas are not close to what the owners are expecting in the way of performance.

If you tested all the microwave antennas in England, I am sure very few of the antennas would have the dB's you have been optimistically using in your range calculations. Interestingly both the UK and ZL groups left the Microwave Update antenna range saying, "This antenna measuring is not all that hard" and are both looking at setting up antenna ranges back home.

Now we will explain how it is not necessarily complicated to set up an antenna range.

Equipment:

- RF Source
- Source Antenna
- Reference Antenna
- Detector
- Open Space

RF Source 1000Hz vs. CW:

Many of my first antenna range set-ups as just a CW source, a reference horn, and a power meter. Hold up the power sensor and horn, measure power, attach the antenna to be measured, and the difference in dB power is the difference in dB gain.

This works, but you really have some dynamic range problems. The power sensor is not very sensitive, so you have to run a fair amount of power and use a short range. But it does work. Just make sure you have at lease 10 dB more power that the noise floor of the power meter, otherwise you run into (Signal + Noise) / Noise problems. I have been able to make pretty good measurements with 10 to 30 milliwatts sources into 20 dB gain antennas on 6 cm and 3 cm. Horns were measured at about 5 Meters, dish antennas at about 10 Meters from the source.

Generating 1000 Hz:

I have a Wavetek 3001 500 MHz synthesized signal generator I haul to the antenna range. Most RF generators already have a 1000 Hz AM setting. So up to 500 MHz I just set the generator to max output, 1000 Hz AM and drive a source antenna with it.

On 902 MHz, I set the generator to 451 MHz and drive two sides of a mixer, this doubles to 902 MHz which goes through a filter and into a 20 dB gain amp. This gives me about 100 milliwatts to work with.

On 1296 MHz I set the generator to 432 MHz, horribly overdrive a small brick amp, filter the 3rd harmonic, and drive a second brick amp. Again, about 100 milliwatts to work with.

On 2304 MHz, I set the generator to 384 MHz, again horribly overdrive a small brick amp, filter the 6th harmonic, and drive a second brick amp. This gives me about 75 milliwatts to work with, and there is a second similar unit for 2400 MHz.

For 3456 MHz I again use a brick amp (Hand picked this one) driven with 432 MHz and run the 8th harmonic through an interdigital filter. A second brick amp brings this up to 10 milliwatts or so.

On 5.7 GHz, 10.3 GHz, and 24.1, GHz I use Gunn sources driving PIN Diodes.

Sometimes I use a 555 timer circuit AA5C built up for me, other times I just drag along a function generator and directly drive the PIN Diodes. On 47 GHz I have a 23.5 GHz Gunn source driving a doubler out of an old HP 940A. I modulate a PIN diode on the 23.5 GHz source. So a lot of ways to generate a 1000 Hz modulated RF source. Of course if I had a Signal Generator actually on these frequencies, or even a sweeper with an external modulation input, I would use it. On 80 GHz, my Gunn source has a modulator built into its commercial power supply.

Source Antenna

You will need an antenna at the source end. It's nice if the antenna has a fair amount of gain and over the years I have used everything from Coffee Can horns, to 2 ft dish antennas on 3 cm. Over the years I have migrated to multiband antennas at the source, just to speed set-up and less stuff to haul about. Ridged horns work well, some the multiband dish feeds work well too. While it is nice for the source antenna to have gain, it is not necessary and I am a firm believer is using what works. More on the type of antenna to use under Open Area.

Detectors/terminations

At the receiver end we need a simple diode detector to demodulate the 1000Hz AM signal. I normally use a standard Type N Input diode detector. Now, most of these detectors in the US do not contain any kind of terminations. So they don't look like a 50 load, but rather have very complex input impedance. Just put a 6 dB pad on the input of the detector. 10 dB works better, 20 dB has too much loss, and the input is pretty much 50? For the higher bands, the simple diode detector mounted in WG works well.

Receiver:

If you are using CW and a Power Meter, then this is your receiver. If you are using 1000 Hz, then you need an HP-415, HP416, or the Marconi Type 6593A. Many other companies also make these 1000 Hz "SWR Indicators". These are simply an audio meter tuned to 1000 Hz with a high accuracy meter scale. I have also used General Microwave and NARDA versions of the HP415 and they work just as well.

Note: The HP415E needs 9 Volts to run, 16 volts to run in the expanded scale mode. It only pulls about 5 ma, so I will wire in two 9 volt dry cell batteries and can run it for hours and hours on the antenna range.

Reference Antenna:

The most important part of the antenna range is an antenna you know the gain of The hand of God, or someone with a crayon, has written the gain of the antenna on a calibration sticker, or Post-it-Note. We measure how much signal the Reference antenna collected, and if the antenna being tested collects 3.2 dB more signal, then it has 3.2 dB more gain than the Reference. On all bands above 900 MHz, I use horn antennas as the reference. In several cases I was fortunate to acquire Std. Gain Horns, and the gain of a horn antenna can be easily calculated with high accuracy.

But like any ham activity, absolute gain numbers are not as important as optimizing the antenna. We will spend hours tweaking the output of a power amp, or the NF of a Pre-amp, and we know the equipment is not calibrated for the frequency we are using. But Max Power Out is still Max Power Out weather it is 68 Milliwatts, or 92 Milliwatts, it's all we can squeeze out of that circuit. Same for the antennas.

You move the feed around, try several feeds, and so on, even if the range errors are a dB or 2, we have maximized the performance of the antenna and been able to compare the relative performance of different antennas.

Again if the real gain of the antenna is 29.6 dBi or 30.4 dBi is all academic, we have squeezed everything we can out of the antenna. (Or thrown it in the rubbish bin!)

Audio out:

The solid state HP-415's have a "Recorder Out" connector on the back. I usually connect a small audio amp with a speaker to this connector. The raw 1000 Hz can be amplified to drive a speaker.

Several good reasons to listen to the audio signal. It's nice to peak the antenna on a audio signal, especially when you're holding the dish with one hand, moving the feed with another hand, and holding the detector with the third hand .... you know what I mean.

And it is especially good when there might be interference. Some time back I was testing an L-Band Helix for possible use on Phase 3-D. The meter was jumping all over the scale; there were several peaks away from the source, and a constant erratic noise floor on the meter. After some time I connected the audio amp and figured out the problem in nano seconds. Loud video buzz! The long helix was acting like a 1/4 wave whip on TV Channel 4! All further testing included either a 1269 MHz filter or an isolator. I have had similar problems testing Log Periodics that do not have the back ends of the booms terminated. At our Central States VHF Conference we typically have the 50-450 MHz and the 900+ MHz ranges running at the same time. Listening to the tones lets us easily tell when that 1296 MHz rhombic also working as a144 MHz antenna.
(Our 1000 Hz tones are hardly phased locked)

Open Area:

30 to 40 Meters is nice, but I have often set up in more confined areas of 10 to 20 Meters. But I try to avoid areas near walls that might cause reflections. Given a choice, I set up on grass (easier on my feet) but parking lots can also be used.

The whole idea is to find an area where you have a consistent signal about the same size as the capture area of the antenna. i.e. a bit bigger than the biggest antenna you plan to test. Our greatest source of error is having the signal level on one edge of the dish stronger than on the other edge of the dish.

Some of the English lads were looking at me pretty funny while I was waving a horn antenna all over the parking lot at uWave Update. (The US guys had seen me do this before.) Up, Down, Left, Right, and Back up a bit. The antenna range is not pre-planned geometry; I am just looking for an area about 1 meter by 1 meter where the signal level varies less than 1 dB. When I find it, I put some kind of marker on the ground, and then tell everyone how high to hold their antennas.

I gave up on elevated ranges a few years ago. I almost always set up with the source antenna (Usually a horn) sitting right on the ground. Thus the antenna and its reflected image are virtually the same point. Sometimes the horn is sitting on a sheet of metal, sometimes it's sitting on a sheet of absorber. Sheets of the Carbon loaded foam work well if you don't have an Eccosorb. Also the sheet of magnetic material that hold advertising to your fridge work well as Iron loaded absorber. The sheet metal gives me a little more signal; the absorber usually gives me a cleaner test area. Although there is no hard fast rule here, I just use what ever works best. If there is a nice consistent signal area, we start measuring antennas!

Measurement technique:

Substitution: Measuring itself is simple and quick. Hold up the reference antenna, set the meter to a convenient spot, attach the sensor to the antenna to be tested, hold it at the same spot, take a reading, and calculate the difference. I normally carry some kind of marking pen and write the results on the antenna. We usually have someone else standing around with pen and paper making a more complete record, but the guys seem to like having an "Official Result" right on the antenna rather than trying to remembering it, or waiting a month until someone publishes the results.

Dynamic Range: One pitfall is the dynamic range of the SWR Indicator or power meter. You like to keep less than 10 dB difference between the antennas under test. So don't use a dipole as the reference for a 30 dB gain antenna measurement. First of all the meters have errors the farther you stretch them. Second the capture areas of the two antennas will be quite different.

A large number of secondary problems arise when testing antenna with vastly different capture areas. With the 415's or 6593's you want to keep them down in the 30, 40 or 50 dB ranges. Higher than 30 usually means the diode is driven out of the square law region, in the 60's the signal will be pretty noisy. These meters will also work with bolometer mounts. Now you could use all the scales with a bolo, but the bolo is less sensitive than a diode mount and you will need more signal.

The 6593 can be used to directly compare 2 antennas, but this means you will need to find a larger measurement area, bigger than both antennas, to make your measurements. This is easy enough on 50 MHz - 432 MHz, but much more difficult on the microwave bands. I haven't used a 6593, but going over one in G4DDK's garage, it sure looked like a natural for antenna ranges.

Results:

Oh it was fun in the early years deflating egos. "Well, a 5 element Yagi would have 12 dB gain, using quad elements adds 2 dB, and a corner reflector would have 10 dB, so by combing a Yagi, Quad, and corner reflector, my super antenna has 24 dB GAIN!" Yea, sure, here's the detector. (6 dBi if he was lucky!).

Over the years the wild claims have died down, and better, more consistent designs are showing up. And we have developed a bit of a tradition of seeing what kind of strange antennas we can show up with and still get good results. And a sprit of experimentation has developed where guys are not afraid to show up with a dish, 8 feeds, and find out which one works best. Typically at the CSVHFS antenna contests we will measure 100 to 125 different combinations of antennas.

There have been a few fun ones; I particularly remember KB0HH spending several years trying to optimise a scalar feed. With excellent form, his cowboy boot set the feed over 30 meters down the range!

Circular Polarization:

We usually get a few CP antennas to test. Normally I just measure the gain, rotate the antenna 90 degrees, measure the gain, average the numbers add 3 dB, and label the gain dBiC.

Ideally, the gain does not change as the test antenna is rotated. If gain only varies 1 dB I'll congratulate the builder, if it varies 3 dB I'll still call it CP, more than 3 dB and we'll start looking at ways to fix/repair/improve the antenna. This is especially a problem with some of the "Short" Helix dish feeds that have become popular lately. It is very difficult to properly generate a CP wave in only 2 turns of wire.

At an AMSAT Conference we set up the antenna range and only 4 of the 8 Helix antennas had gain along the axis of the antenna! Of the 4 with gain, only 2 were within 3 dB of circularity. And yes, 1 of the 2 had been brought by James Miller G3RUH.

The AMSAT lads have been passing around the idea that Helix antennas are easy to build and fool proof. Test of dozens of Helix antennas says they are WRONG. AMSAT writers perhaps have the worse habit of coping articles. A guy writes an article about a Helix, that is copied from and article, that was copied from and article....... And over the last 5 generations of this design, each writer/builder has substituted materials, slightly changed dimensions, and NEVER tested the antenna.
(Pitfalls in Helix antenna design is another paper I have somewhere.)

Log Periodics:

LP's can also be difficult to test, especially the ones that do not terminate the back of the booms. The antenna picks up fundamental and harmonic frequencies equally well. They also tend to pick up more local interference. A clean source and monitoring the 1000 Hz audio will usually keep you out of trouble. The unterminated LP's tend to act like a big capacitor and pick up noise from the mains and a lot of other garbage. All my current LP designs terminate the back of the booms; it just cleans up so many problems.