Some observations on popular Antenna Lore . . .

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Let's take a look at a piece published at:

(http://www.nancymoon.com/swr_soapbox.htm)

I have had several experiences with aircraft antennas that were purchased as a finished item and just screwed onto an airplane. In most cases an antenna needs to be tuned fit the installed situation. . .

> A bit of a stretch here. Hundreds of thousands of antennas have been installed without particular concerns for "tuning" and have performed quite nicely . . .

. . . . On a certified airplane I dealt with a marker beacon antenna that did not work at all because it was designed for a metal aircraft and installed on a fabric covered one with only a small sheet metal counterpoise.

> . . . an obvious departure from the dictates of antenna physics.

Copper tape antennas that are installed inside the skin of a composite aircraft MUST be tuned to get them to work properly. I read account after account where the fuel gages or engine instruments jump or go off-scale when the COM radio is keyed. That's because an untuned antenna will couple the radio energy back onto the outside of the feedline (the coaxial cable) and then on to the rest of the avionics in the panel.

> A poor sorting of various cause/effect combinations. A poorly tuned antenna does not automatically translated into instrumentation or other interference problems, nor does a properly tuned antenna guarantee that you will not have interference problems. The author doesn't state that achieving proper tuning of the antenna fixed an interference problem.

Tuning an antenna and using a balun lets the antenna radiate the radio energy into space (where is does some good) instead of coupling it into your sensitive engine instrumentation wiring.

OK, what do I mean by tuning???

Just like changing the air path in a trombone changes the tone, changing the length of the arms of an antenna will change the frequency where it resonates. The antenna does the best job of taking the transmit radio energy from the radio and sending it out into the air when it is adjusted to resonate. So, we could just calculate the resonate frequency wavelength and cut the antenna arms to that length, right? If the antenna were suspended in the air that would work fine, however there is a problem when you stick that antenna on the fiberglass skin of your airplane. The fiberglass lowers the resonate frequency by a factor that depends on how thick the fiberglass is and how sloppy you got with too much resin. This effect is big enough that it can move the resonate point completely out of the radio band we use.

So the thing to do is tune the antenna. Fortunately we know that when mounted on fiberglass the antenna has to get shorter to bring it back into resonance. You install the antenna, then cut off short segments from each end of the antenna until the resonate point is in the middle of the frequency band.

The parameter we use is SWR, or Standing Wave Ratio. It's a measure of how well the antenna is taking the radio energy and sending it out into the air instead of back down the feedline. An SWR of 1.0 means all the radio energy from the transmitter is being converted to radio waves out there. This usually can happen with a perfect antenna at only one frequency, which we call the resonant point. As we change the frequency of our radio across the band the SWR will rise up the farther away from the resonant point we go. At the band edges it will probably get up to about 3.0 on a real antenna, which is about as much as the transmitter and our installation should tolerate.

One problem is that you can't make this measurement without special equipment. You can do it with your COM radio and the good old Bird Model 43 Wattmeter for the COM antenna because it has a transmitter, but you can't measure the NAV, glide slope or marker beacon antennas with your radio because it doesn't transmit in those bands. Besides, it's very time consuming and probably illegal to transmit all over the band with your radio. A better way is to use an antenna analyzer.

http://www.mfjenterprises.com/

I used my MFJ-269, though the MFJ-259 would do as well for aircraft applications. It covers 1.8 to 170 Megahertz, so it can tune NAV, COM and marker beacon antennas. It can't handle glide slope (332 MHz), but you usually just use the NAV antenna for this and it can't get up to the transponder band, but you can probably get away without tuning that antenna, as we'll discuss later.

What you can do with this antenna analyzer is use the frequency knob to swing the test signal back and forth across wide frequency bands and watch the SWR meter needle for a dip. As you carefully rock the frequency knob in smaller movements you can zero in on the resonant point and then read the frequency from the LCD screen. By doing this you can see the antenna response over a broad range and do your trimming without getting confused. Without this broad look I would have messed up our NAV antennas when I tried tuning them while the wing was still on metal fixture, which totally detuned the antenna. After getting the antenna trimmed you can then set the frequency in small steps (like 1 MHz) and measure the antenna response across the band, which I then like to plot out as you will see on the antenna pages.

If you choose to use one of these antenna analyzers, I suggest you buy or find a 12 Volt wall wart to run it. It comes with a battery compartment for 8 AA cells, but since I don't use it that much it sits and the battery is always dead. I also worry about the cells leaking and ruining an expensive unit. It's also a lot lighter without all those cells in it.

Enough SWR, what the heck is a balun?

> A fair description of SWR, and the value of adjusting antenna lengths for optimum frequency response . . .

It's short for balanced/unbalanced. The radio signal comes out of your radio in an unbalanced configuration with the center conductor of the coaxial cable carrying the energy and the outside shield holding it in. The currents flow in the center conductor and the inside of the shield. Theoretically there is no current on the outside.

Antennas are by nature balanced. The dipole with two arms is the easiest to understand with equal but opposite currents flowing on the each arm. The arm connected to the shield of the coaxial cable then couples some energy back on to the outside of the shield and then on to places we don't want the energy unless we do something about it. The balun tries to stop this coupling and forces the energy to stay on the antenna. The simplest, smallest, cheapest way to make a balun is to place a few ferrite toroids (tiny donuts of iron bearing material) over the outside of the cable where it joins the antenna. Some folks claim that ferrite toroids introduce loss, but that's exactly what they are supposed to do, keep the radio energy from coming down the outside of the cable. It's not perfect, but good enough for our purposes and better than twitching meter needles.

It's traditional to place three toroids spaced about a quarter inch apart right at the feedpoint. The feedpoint is where the coaxial cable and the antenna join. If the coaxial cable could continue straight away from the antenna perpendicular to the antenna then all would be fine. Since we don't have a whole lot of room inside of an airplane we often have to run the cable near the antenna and parallel to it. You will notice that I added a few more toroids to the outside of the cable further along. I put the first one at the bend where the cable starts parallel, then another about a foot or so farther out.

> I'll object to the term "traditional" as being non-quantified and unsupported by data . . .

I did this toroid trick based on the computer model that shows radio energy being coupled onto the outside of the cable. The plot above on the left shows the currents coupled on to the cable, which is the part that sticks out to the left. The currents are the magenta lines and the higher above the segment the more current there is. The coupled currents are fairly low to start with because the meander line antenna matches the cable impedance so well. The plot on the right shows the effect of the toroid at the bend and then 1 foot farther along. The currents are barely above the segment. The placement of the toroids is not critical and electrically breaking it up into foot long pieces with the toroids drastically reduces this coupling.

> First, I've done the toroid experiment in the lab and found the effects to be very small for a hand-full of toroids. Putting up to a dozen toroids on the feedline had little benefit for eliminating the effects of unbalance coax feedline driving a balanced dipole antenna. Second, if the writer is working to reduce the potential for interference cause/effect cited earlier, then this applies only to transmitting antennas. Most comm antennas are single spike antennas working against a ground-plane. Vertically polarized dipole antennas mounted inside a composite structure should take advantage of the "gamma-match" technique for attaching unbalance feedline (coax) to either balanced (dipole) or unbalanced (vertical rod) antennas. An example of this matching technique is shown in
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> http://www2.arrl.org/qst/2002/12/stroud.pdf (This article describes a "loop" that can be used either horizontally or vertically polarized . . .not unlike a suggestion that appeared here on the List a few weeks ago.)
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> and http://home.hiwaay.net/~sbuc/journal/sportcraft.htm where Sam Buchanan describes our friend Bob Archer's use of this simple matching system to great advantage in his VOR wingtip antenna. Archer's vertical polarized, dipole antennas for mounting inside an composite airplane also uses the gamma-match technology.
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> This is a MUCH superior technique for attaching a feedline to antenna than using toriods. Incidentally, not all toriods are equal. They are made from a variety of magnetic materials with performance ratings optimized for frequency and power levels of interest. Just 'cause it looks like a Life-Saver and fits over your coax feedline doesn't mean it's the right component for the job.
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> Most cases where a dipole is attached to a coax feedline is on VOR antennas. Here, we'll NEVER see an interference problem. Cesnna build several thousands of antennas with some attention to detail like building a proper BALUN assembly for attaching coax to a dipole. After considerable inflight experimentation, they

determined that the BALUN offered no observable benefits and discontinued the practice with much $savings$ over the years.

Unless you’re really into knowing how antennas work and acquiring the knowledge and tools to fabricate them, I recommend you purchase off-the-shelf products or exactly duplicate the work done by a knowledgeable builder. Be cautious of generalized articles like that cited above . . . They can easily mislead you into believing that you’re doing a good thing . . .worse yet, they can misdirect valuable construction time in no-value-added activities.

Bob . . .