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The Ins and Outs of T-Matches

All of our K1FO yagis and the DS50-5 six meter yagi utilize a modified T-Match feed at the driven element. The T-Match provides an impedance matching function, as well as providing a proper de coupling, balun function. The use of a half wave balun keeps the RF energy going to the driven element and nowhere else! The standard T-Match originally had series capacitors going to each side of the driven element. The improved "modified" T-Match does away with the capacitors. In its place, we adjust the length of the driven element to add some capacitive or inductive reactance to cancel out any reactance at the feed point. The antenna feed point consists of the following components:

1. Driven element
2. T-Match sliding bars
3. T-Match wires or rods, (This wire is much smaller in diameter than the driven element.)
4. Half wave balun made from semi rigid Teflon coax cable

The whole assembly, when located on your antenna, generally has the following form.

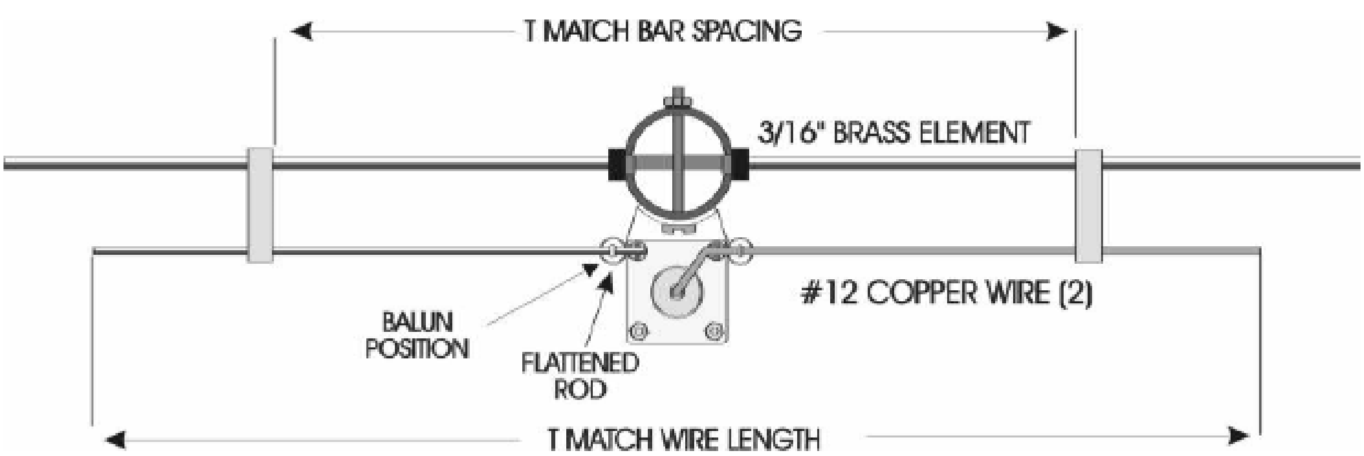

Figure 1

All parts of the T-Match may be varied and include the driven element length, the T-Match wire length, T-Match bar position, as well as the ratio of diameters between the driven element and T-Match wires and the spacing between the two. In our case, with a proven design, most of the adjustments have been determined for you, but we still allow sliding of the T-Match bars and varying the length of the T-Match wires.

So how to get started?

We provide factory dimensions for a good match for most situations. In some cases, you may want to tune the antenna for a specific frequency. The most important fact to understand is that your measurement system should be located right next to the antenna for best results. Tuning the antenna at the end of a long piece of cable may create more problems than not tuning it at all. At 144 MHz and above, most coaxial cable varies enough from a perfect 50 ohm value, to cause errors in measurement through the cable. Be sure your test cable is of high quality, and is as short as possible. Otherwise you may detune the antenna to match it to the non perfect coaxial cable! Your measuring equipment should be capable of measuring accurate amounts of reflected power. Directional couplers or return loss bridges are very sensitive and accurate as a rule. Some antenna analyzers are quite good, but others can get pretty innacurate at the higher VHF frequencies. It is best to be sure of the accuracy levels that you can obtain before you start out.

The position of the T-Match bars, (actually square brass tubing) can be adjusted to increase or decrease the spacing between them. If you increase the dimension, the resonant frequency will go down. If you push the bars in toward the center and decrease that dimension, the resonant frequency will be raised. This is true for all T matches. There will be one point where the match is very good across a wide band. This is the typically the "factory" setting, but by moving the bars in or out, you can move that point of best VSWR either lower or higher in frequency to some extent. Using the DSEFO432-25ATV as an example, here are two settings of the T-Match bars:

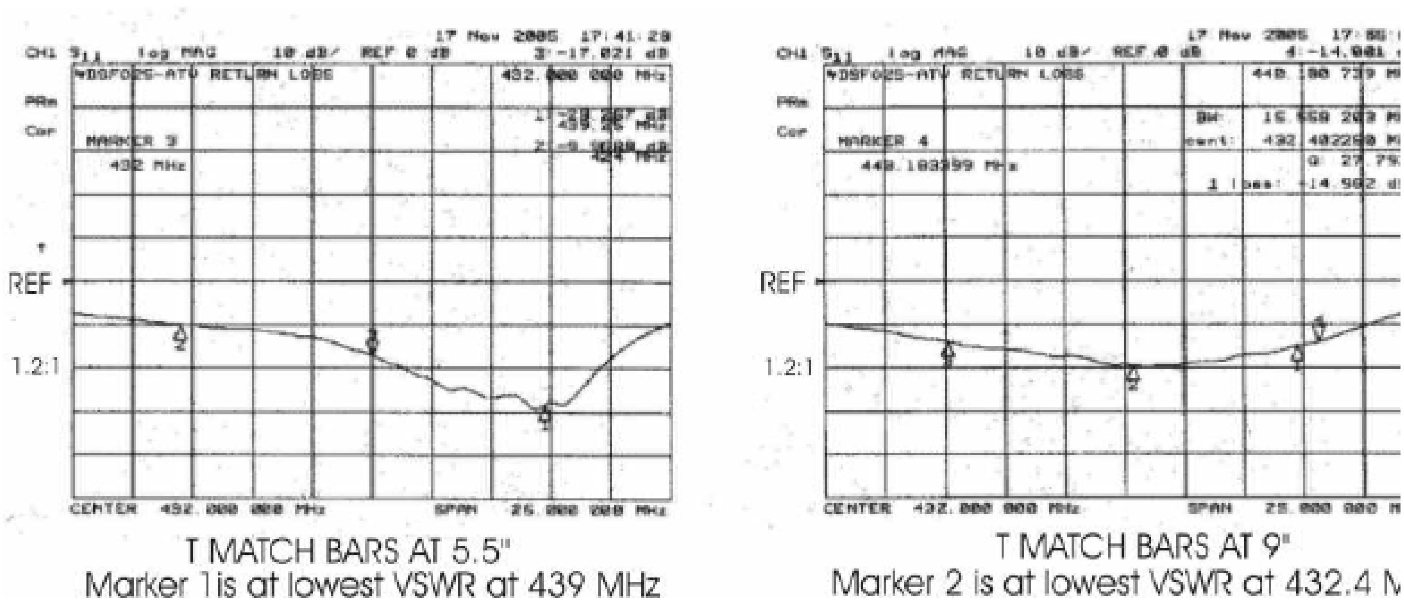

Figure 2a, 2b

Now there is a limit as to how far you can carry this method. Generally, you are limited to the area of the antenna's bandwidth. In other words, if the antenna does not work at some frequency, there is no way you can simply adjust the T-Match to make it work there!

The T-Match wires are usually provided slightly longer than necessary. There are a few hints that can make your tuning faster. The wire length may be adjusted either longer or shorter for best results. The factory settings are a good guide for most users, but should you wish to experiment, this information may help you. Generally, longer T-Match wires will cause an antenna to match up better on the low frequency portion of its band pass. The DSEFO432-25ATV is a case in point. Increasing the T-Match wire from 9.75" to 10.25" overall, will produce the following results. Compare these results with the first curves (Figure 2a) made at T-Match wire length of 9.75", or 4.84" on each side.

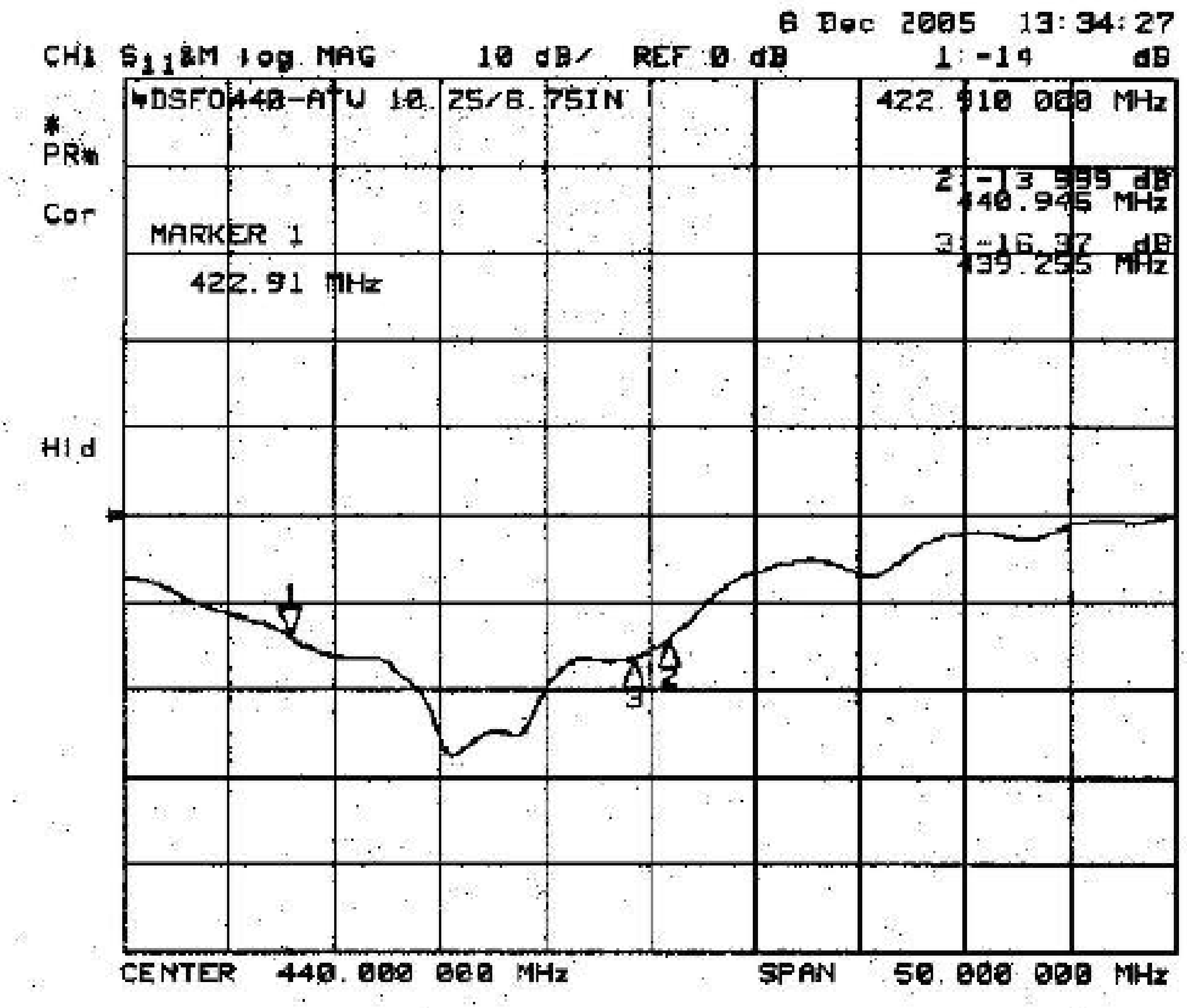

Figure 3

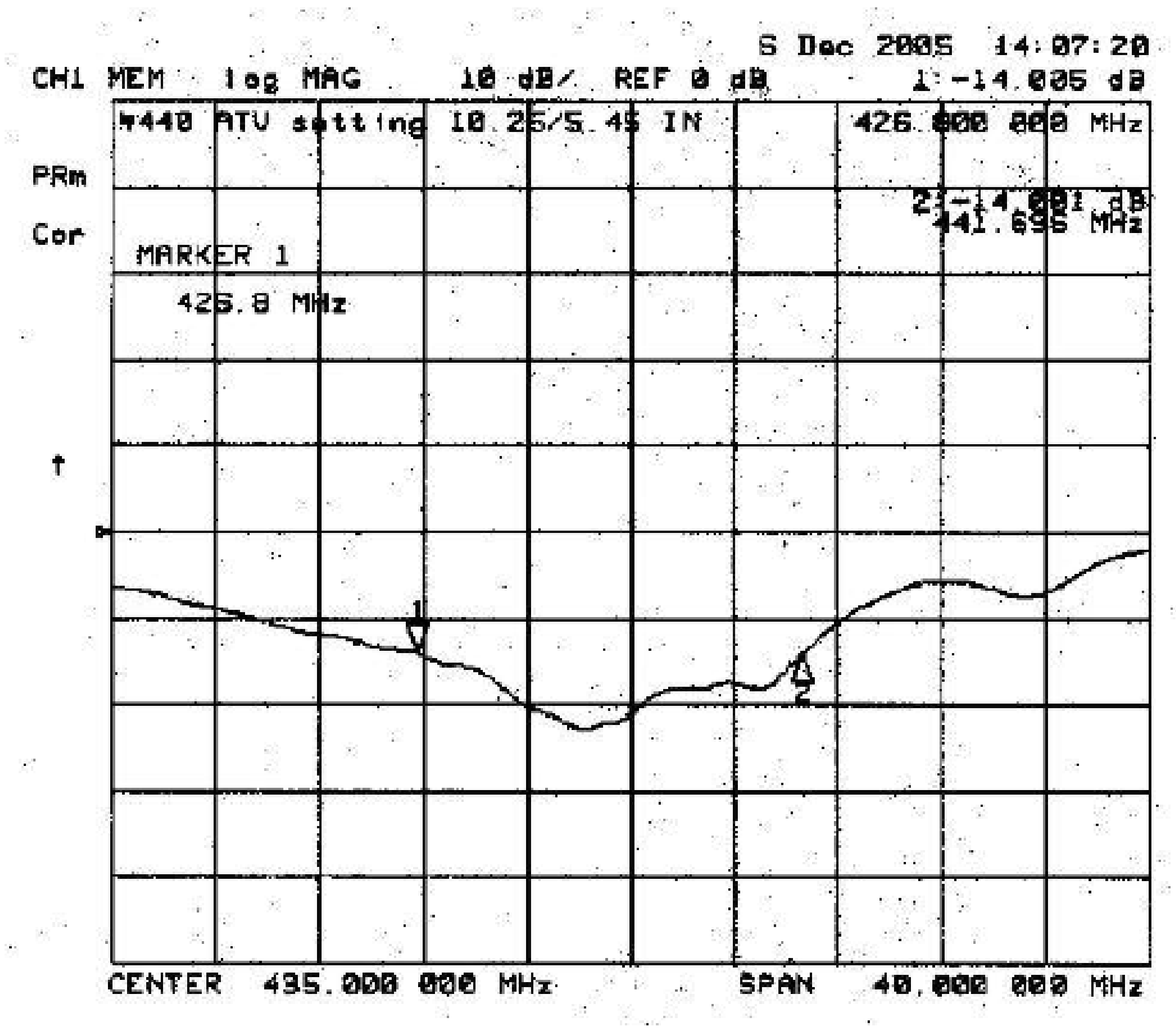

Figure 4

Figure 4 is the same T-Match bar setting as Figure 2a, but with a longer T-Match wire! Note that in figure 4, the best VSWR point has dropped from 439 MHz to about 433 MHz with a best match of 22.5 dB return loss. The resonant point for best match has indeed dropped in frequency with a longer T-Match wire. In figure 3, we see that by moving the bars out a bit, we have enhanced the response and dropped the frequency some more with a wider T-Match bar spacing. Best response is now at 430.5 MHz, or almost 10 MHz lower than the original setting.

So how do you tell if you should lengthen or shorten your T-Match wires? To simulate a shorter T-Match wire, bend the ends of the wires as follows:

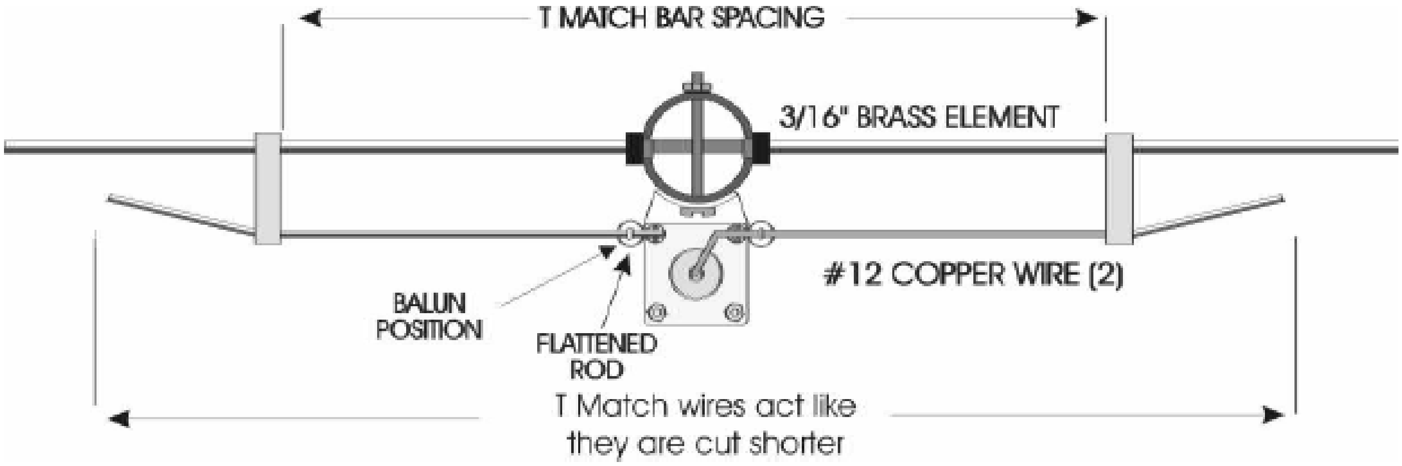

Figure 5

If you want to see what a longer wire will accomplish, bend the wires as shown below. Simple huh?

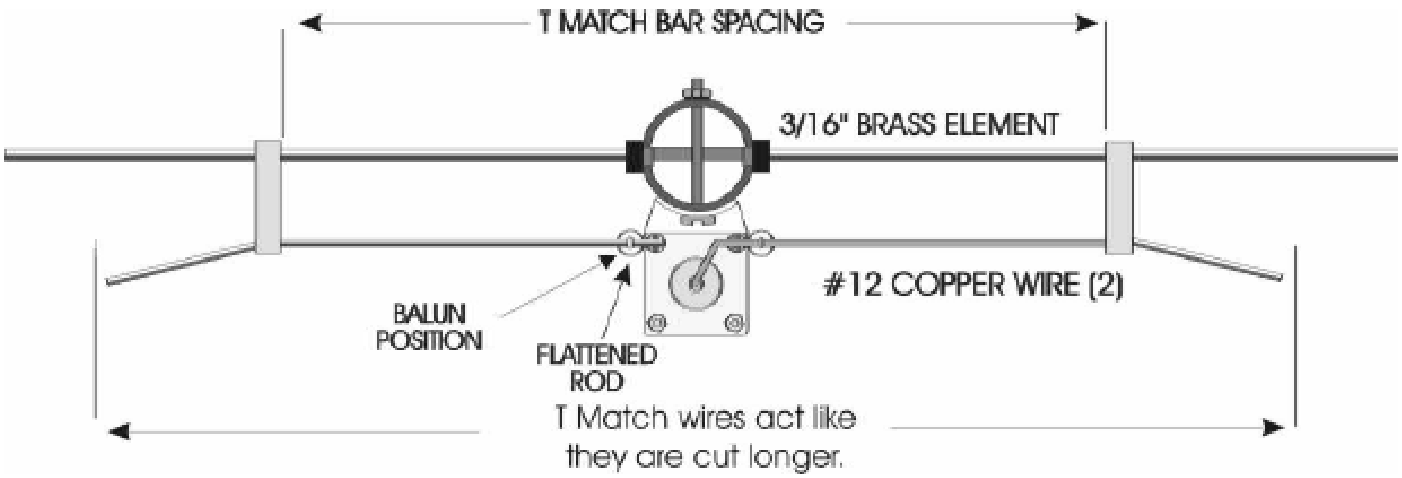

Figure 6

Now this method is generally true and will tell you in which direction to go. Of course, trimming is much easier than stretching, but it is a simple matter to solder a longer length of #12 wire to an existing T match wire. Some models use a telescoping brass rod instead of a wire, (DSEFO144-12), so the length may be adjusted either way. Once you have decided to trim your T-Match wires, proceed slowly. An eighth of an inch at 432 is a big jump.

What is the best method for tuning your antenna? Specifically, what equipment is best for evaluating the match? As we stated earlier, a swept response is always the most informative. The return loss curves above are an example of swept responses. Those plots were made on a network analyzer. What you see with a swept return is the performance at every frequency within the response of the antenna. Any imperfections in your coaxial feedline, coaxial relays, switches, splices etc. will all contribute to introduce a mismatch into your system. On a swept response plot, this mismatch will appear as "ripple" on the basic pass band of the antenna. The more ripple, the worse the mismatch is. If you are using your transmitter and an in line wattmeter, you may be 100 % oblivious to all this. Your operating frequency may look just great, but a change up or down in frequency of 500 kHz may show a very different story. A great match at 144.2 may become a 2:1 problem at 144.7 MHz! If you will look at the above SWR curves, they appear quite smooth over a wide range. There was no cable between the measuring device and the antenna. Had there been 100 ft of good coax cable in between, the response would look much bumpier. Even good coaxial cable will have 25 dB return loss at 432. I have seen brand new coax cable measure out at 10 dB at 144 MHz! This is about a 2:1 VSWR! Any antenna will look horrible when measured through such a cable. You can visualize your coaxial cable as a dirty window through which you must look. The longer it is, the dirtier that window becomes. Semi rigid cables such as the Andrew Heliax and Cablewave products, all routinely show much improved VSWR specs over conventional braided cables. They will generally be less than 30 dB up to 1 GHz or so. This is a 1.06:1 VSWR and makes for a pretty clean window! The idea is to put your measuring device as close to the antenna as possible, then be sure any jumper cable employed has been tested for minimum VSWR at your frequency of interest. It is always good practice to put your VSWR testing equipment as close to the antenna as possible for the best possible results.

So in summary, if you cannot use a swept measurement system, the next best thing is a manual swept system. Measure the VSWR at many frequencies across the band. If you use your transmitter and a wattmeter, this may take some time, but it is well worth it, as it will show the degree of pass band ripple in your system. If you use a signal generator and a homebrew return loss bridge, it is easy to see any ripple just by turning the tuning crank on the signal generator. Watch the bumps go by as you tune!! Some antenna analyzers have built in sources that can be tuned easily as well. If you have a vector analyzer, you need to make only one measurement and read the degree of mismatch / reactance. Some inexpensive analyzers do provide a sort of vector response. It is always a good idea to verify that they are reading correctly. Many suffer from gross inaccuracies at frequencies of 144 MHz and above that caution is in order. A good tipoff is the use of UHF connectors. The ubiquitous PL-259 & SO-239 are notorious above 144 MHz. Typical mismatches for them are about 25 dB return loss at 144, increasing to 20 dB at 222, and about 15 dB return loss at 432. They will cause errors at all VHF frequencies when placed in the transmission line. You will not be able to trust your results with them. Your measurement is only as good as the weakest (read poorest return loss) link in the system.