Accurate Antenna Measurements and the NetTek™ YBA250

Precision vs. Non-Precision Cables and their Effect on Measurements

Reflection measurements are usually made as a comparison of the unknown (device being measured) to a known standard. This standard is assumed to be perfect. The process of comparing is called "calibrating" the measurement equipment.

Any non-precision cable that is placed in between the YBA250 (where the comparison to the standard was made) and the antenna system to be measured can dramatically affect the reflection or VSWR measurement. The higher the frequency of measurement, the worse the degradation will likely be. The measurements made here are done for a sweep of 100 MHz to 2000 MHz. The comparisons are mostly made at the US PCS band at 1900 MHz.

Two distinct types of errors are introduced by a jumper cable.

The first type includes two separate errors: the reflection of the cable itself and loss of the cable. The reflection of the cable usually causes a device being tested to seem to have a worse VSWR or return loss (RL) than it actually has. The loss of a cable will cause the device being tested to seem to have a better VSWR or return loss than it actually has. Any cable loss simply adds directly to the measured return loss, but a reflection due to the cable itself can have a huge effect, and may actually dominate the measurement result.

Interestingly, the two errors have different effects. Loss in the cable has more effect on measurements of a device with small return loss (poor VSWR) and any reflections in the jumper have a much larger effect on measurements of high return loss (good VSWR).

The second type of error is the change in reflection, phase, or loss of the cable as it is flexed or bent. This causes readings to change as the jumper is bent (particularly for measurements of antennas with good VSWR).

▶ *Figure 1. Precision cable, Tektronix Part Number 012-1619-00.*

Jumper Cable Errors Affect Measurements

Cable Reflection and Loss of Cable

Figure 1 is a precision cable that has been made with precision machining of the connection surfaces and the diameters of the component parts. The cable is specially constructed to have an exact 50-ohm impedance and to have very minimal change with bending.

Other cables, such as the one shown in Figure 2 may have lower loss; however, the only real way to identify a precision connector or a cable is to know the VSWR and loss specifications over the frequency range to be measured. While the loss may be important to accurate measurements, the VSWR of the cable is critical. Loss can be subtracted from the result, but reflections usually cannot.

▶ *Figure 2. General-purpose cable, Tektronix Part Number 012-0114-00.*

▶ *Figure 3. Low-loss cable.*

Figure 3 is an example of a low-loss cable that is not precision for VSWR. It is often found connecting a transmitter to the main feeder line that runs up the mast to the antenna.

To demonstrate the effect that such cables can have on return loss measurements, we first calibrated the YBA250 using the YBAC1 calibration kit.

Then we plotted the return loss of a second calibration standard to demonstrate the measurement of a very good load. This standard is specified to have 40 dB return loss. Figure 4 shows the result within 0.3 dB.

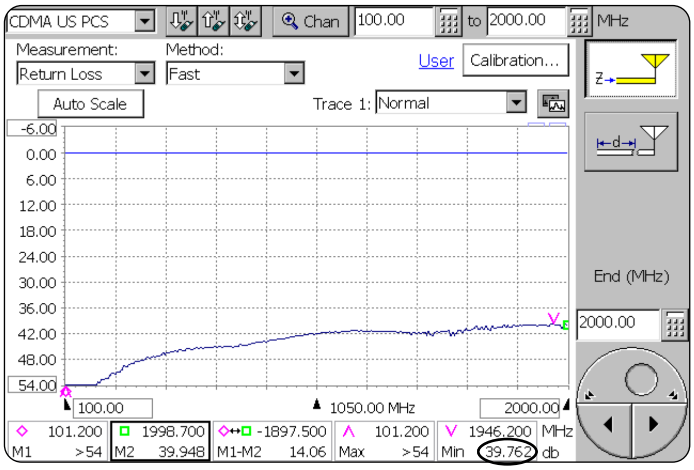


Figure 4.

Now we again connect the load from the calibration kit, this time using the precision cable and a precision type "N" barrel adapter. As you can see in Figure 5, the measurement accuracy has been slightly degraded from 40 to about 33 dB average return loss, which is still pretty good.

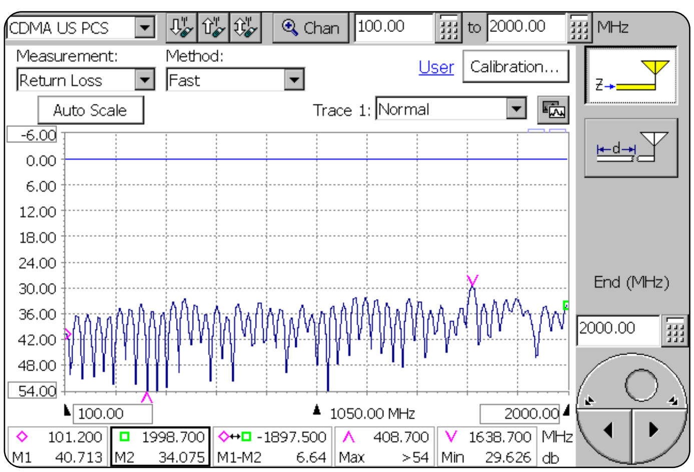


Figure 5.

Now we replace the precision cable with the general purpose cable. Note that the return loss has now degraded to 18 dB average simply from trying to measure through this cable. A very good load now appears to be extremely marginal.

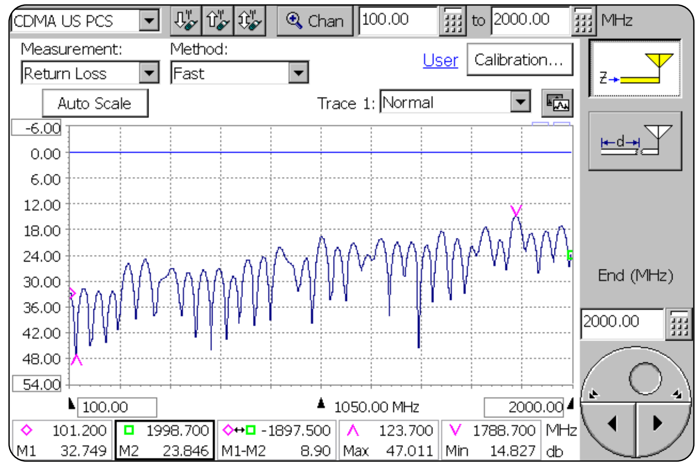


Figure 6.

Next we try a low-loss jumper. It is still worse than the precision cable, but Figure 7 does not show that it varies quite a bit as the cable is flexed, which will be seen later.

Not all such cables work identically and you never know until your measurements come out wrong.

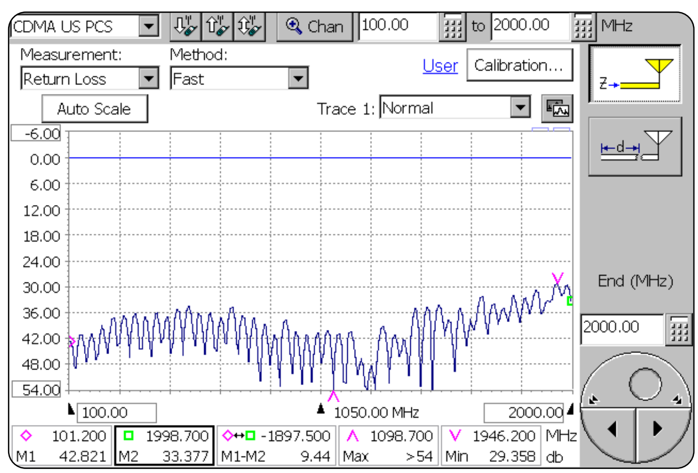


Figure 7.

It is critical to maintain the quality of the precision cable. All the procedures recommended for the YBAC1 also apply to this cable. *Do not twist any adapters onto this cable. Turn ONLY the outside nut.*

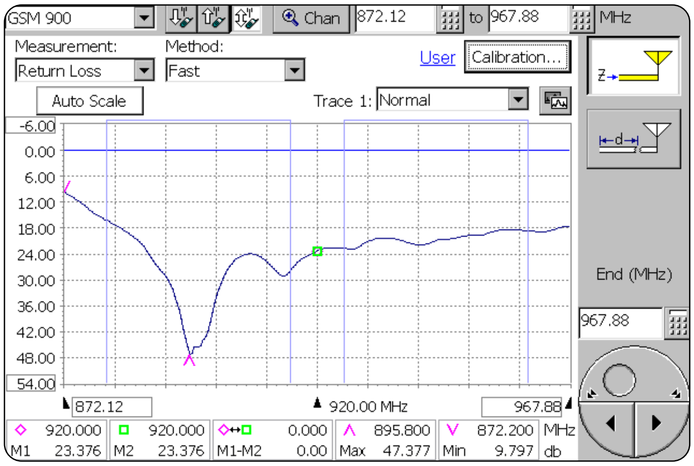


Figure 7a.

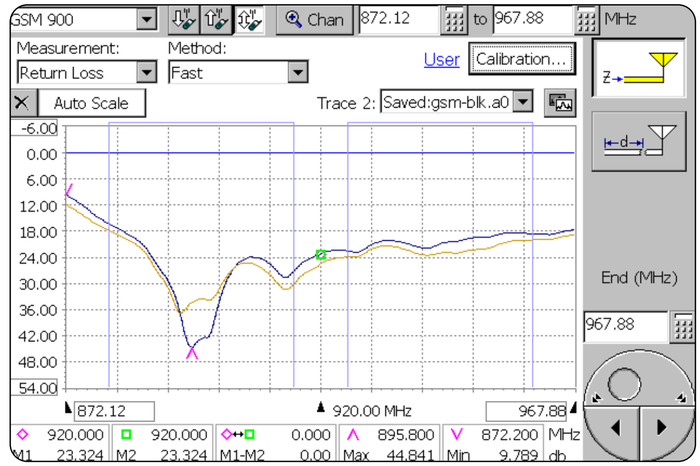


Figure 7b.

How much will this affect my measurements?

To see just how much, we measured a real antenna. Figure 7a is a GSM 900 antenna. It has a reasonable return loss that has a particularly good area in the BTS receive band.

Then we measured again, but with a precision cable connected between the antenna and the test instrument, and we display both traces together in Figure 7b.

We can see that the measurement of really good return loss is limited to about 33 dB (just as we found earlier), and the entire trace shows better return loss by twice the amount of the loss in the coax.

The coax loss comprises most of the error that we see (except for the 33 dB limitation). The random error from the return loss of the cable itself amounts to about 1 dB maximum on this trace. The cable specification allows up to 1.5 dB variation when measuring at 17 dB return loss load. This shows how good a measurement can be made with just the precision cable, not even re-calibrating at its end.

Figure 7c was taken comparing the original antenna with a return loss plot done using a general purpose coax jumper. Now you can see that the trace hardly resembles the original.

There are 10 dB errors that would condemn a perfectly good antenna.

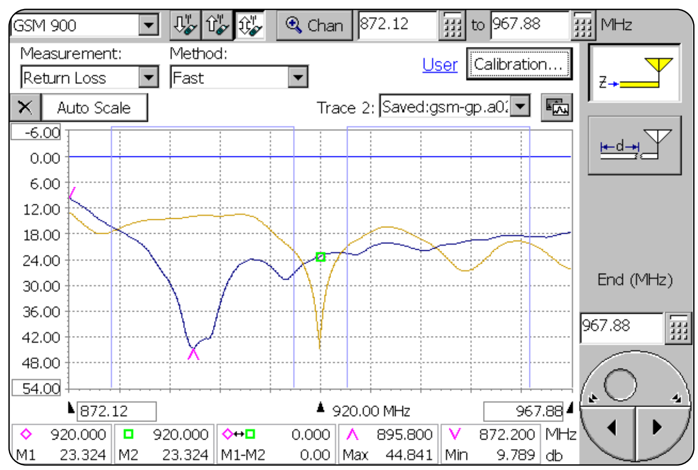


Figure 7c.

This comparison shows why a precision jumper cable should always be used instead of a general purpose one. Good measurements can be made even without re-calibrating at the cable end. Really great measurements can be made if you do re-calibrate at the cable end.

Cable Flex

The second type of error introduced by a non-precision cable is the change of the VSWR, loss or most importantly the phase of signals passing through it as it is flexed. This causes some surprisingly large errors in VSWR measurements that would never be noticeable in simple RF power measurements made through this same cable. Figure 8 demonstrates the almost non-existent changes in the precision cable due to flexing.

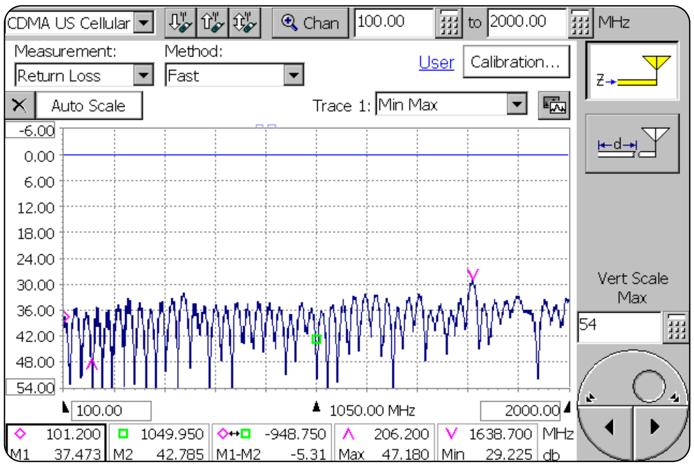


Figure 8.

For these plots of flexing cables, we put the YBA250 into the "min-max" mode. This plots both the maximum and the minimum of the result, and paints a solid between the two plots. The thicker the plot line, the more variation there was as the cable was flexed. These are the dark areas on the plots. Figure 9 is the general purpose cable being flexed. Not only is it a very poor result in general, but it varies as well.

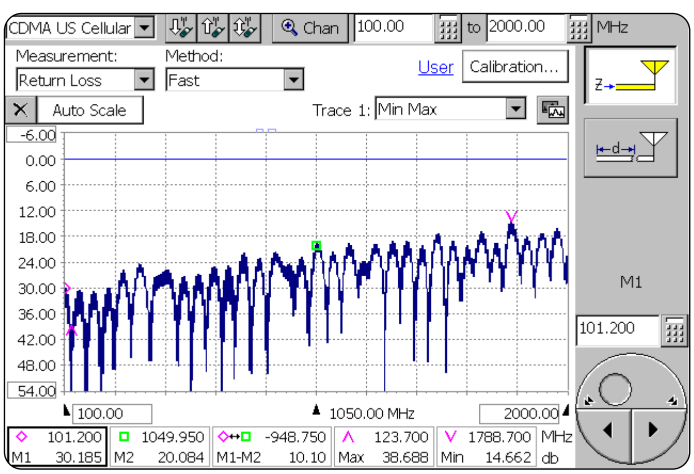


Figure 9.

The low-loss cable varies almost as much as the general purpose one. This is largely due to the cable construction using a foam dielectric. The foam allows the center conductor to move more than other types of materials. See Figure 10.

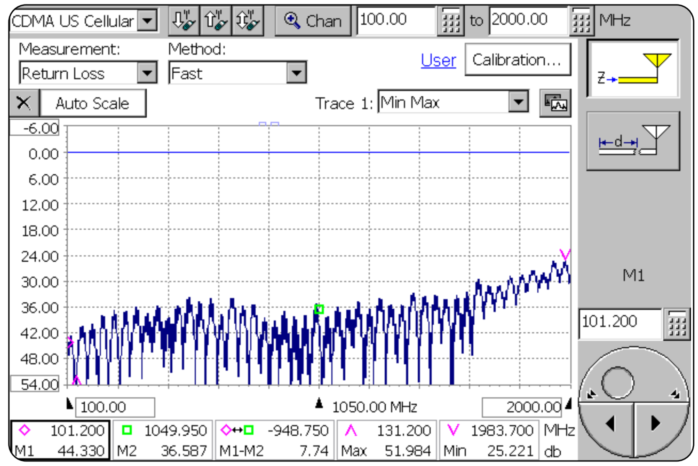


Figure 10.

This same low-loss cable has another disadvantage. It is very stiff and heavy. This may well actually drag a portable test equipment onto the floor.

While flexing this stiff cable, apparently the connector on the end of the cable loosened from the connector on the test equipment or had some other similar difficulty as it was pulled hard to the side. Figure 11 shows the very dramatic changing VSWR at the higher frequencies.

Now we can see the impressive errors that can occur using an ordinary cable.

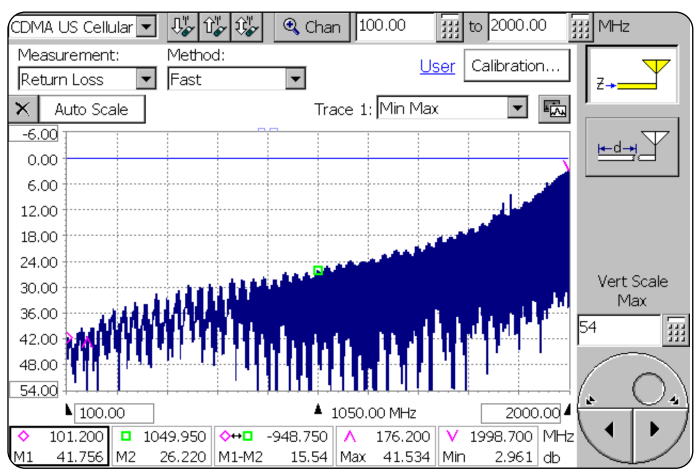


Figure 11.

Solutions to Jumper Cable Errors

Calibrate at the End of the Cable.

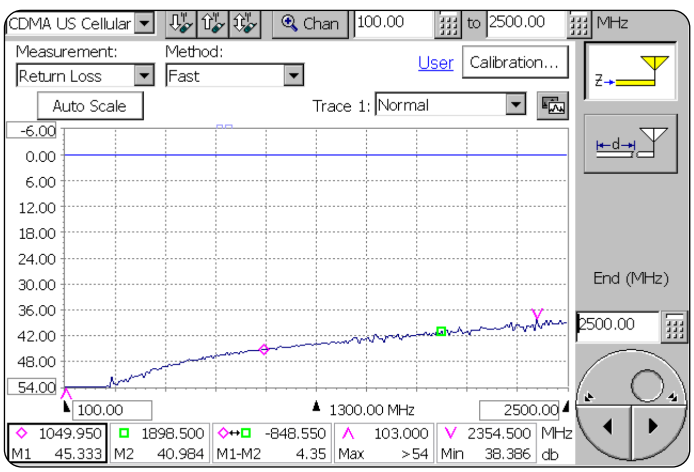
There is a way to work around the first type of error and improve your measurement results when additional accuracy is required. When you are using an extension cable (either precision or non-precision) you should perform the “user cal” with the YBAC1 calibration kit standards connected to the far end of the cable instead of connecting them directly to the VSWR tester.

With the calibration performed this way the calibration itself normalizes out the VSWR errors introduced by the cable. This can be accomplished for jumper cables up to 10 feet (3 meters) in length.

These plots were made from 100 MHz to 2500 MHz.

First we measure the second load directly connected to the instrument. This will allow us to compare results after we cal at the end of the cable. This is plotted in Figure 12.

Next we perform a “User Calibration” at the end of the precision coax. This requires the calibration selection for “end of cable” in the YBA250.

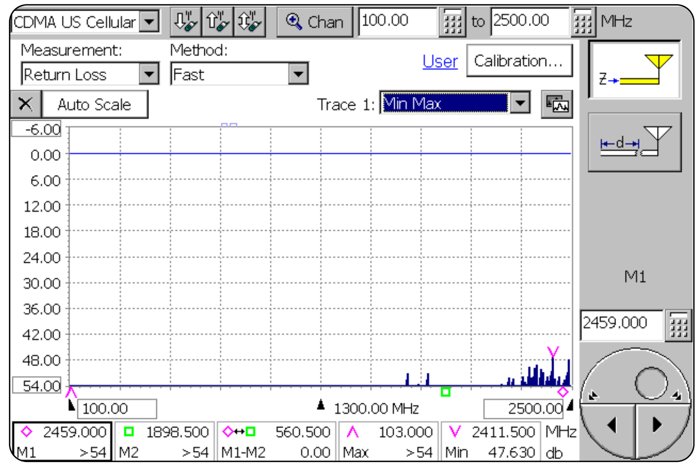


▶ *Figure 12.*

While performing this calibration, the three standards (Open, Short and Load) are all connected to the far end of the jumper cable.

With the calibration performed this way the cal itself normalizes out the VSWR and loss errors introduced by the cable.

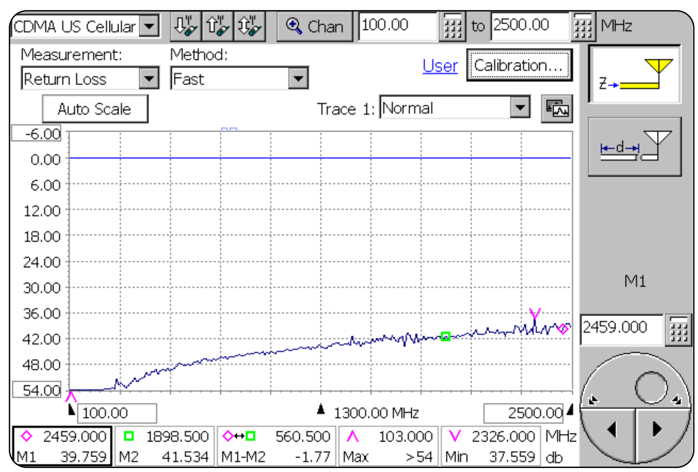
Figure 12a shows the calibration kit load itself being measured. The additional small noise visible at the bottom of the screen is the price you pay for compensating for the losses of the cable.



▶ *Figure 12a.*

Figure 13 is a measurement of the second load (placed at the end of the precision cable). It shows that the precision cable now gives almost exactly the same answers as the YBA250 alone did with the second load.

Compare this to the same load connected directly to the instrument in Figure 12.



▶ *Figure 13.*

Cable Flexing Again

Be aware that only the basic error of the cable can be compensated by calibrating at the end. Any additional error introduced by flexing a non-precision cable will fully degrade your measurements.

Now again using the “Min-Max” mode, we will look at the variations that result as we flex the cable.

In Figure 14 we can see that the precision cable has little effect on measurements while being bent and straightened. It still gives results that average below 42 dB. (Compare this to Figure 12a.)

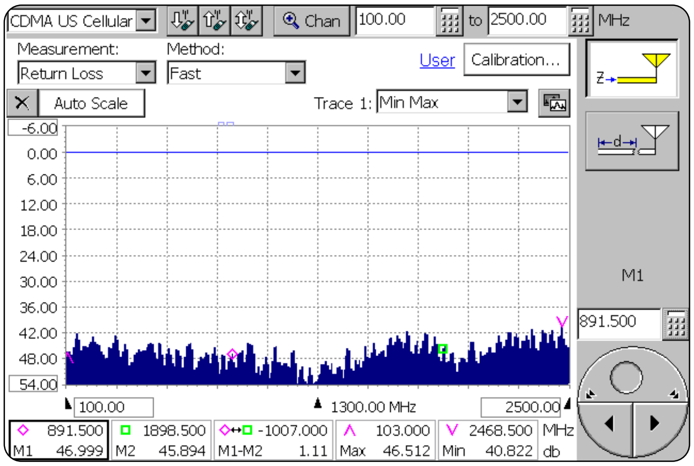


Figure 14.

Figure 15 is the result when measuring the second load and flexing the cable. (Compare this to Figure 13.)

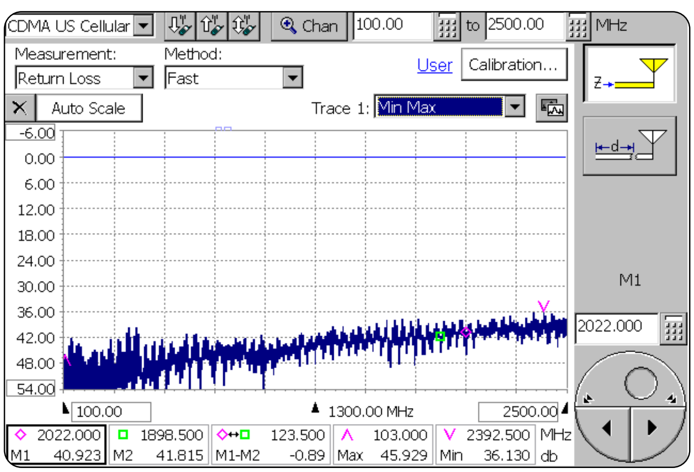


Figure 15.

You might still be tempted to use an ordinary low-loss cable jumper for return-loss measurements. However, even though the loss is low, the connectors are not likely precision, and certainly the cable changes its return loss as it is flexed. To demonstrate this, we performed a calibration at the far end of the low-loss cable.

Figure 16 shows the calibration kit load measured at the end of the low-loss cable.

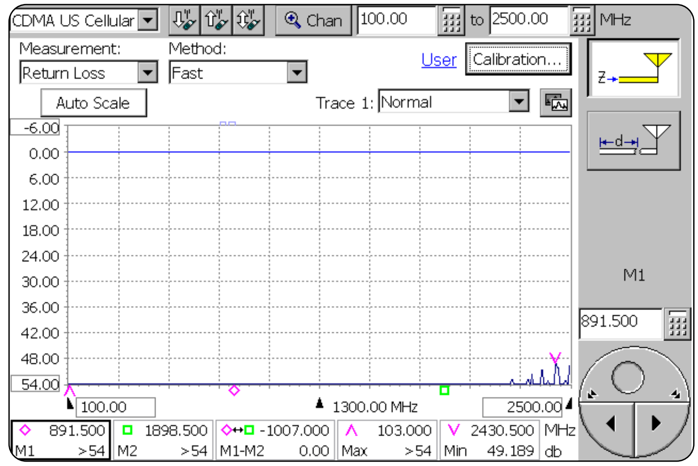


Figure 16.

Now as we flex the "low-loss" cable, we find that the bending of the cable introduces noticeably more error. Figure 17 shows the measurement capability has degraded from 41 dB (possible with the precision coax) to about 35 dB with this low-loss jumper.

This is in spite of the fact that our calibration now includes the (non-flexed) cable losses.

Even though this cable has half the loss (1.2 dB at 2000 MHz) as the precision cable does (2.5 dB), the larger errors that can result from flexing the cable are worse.

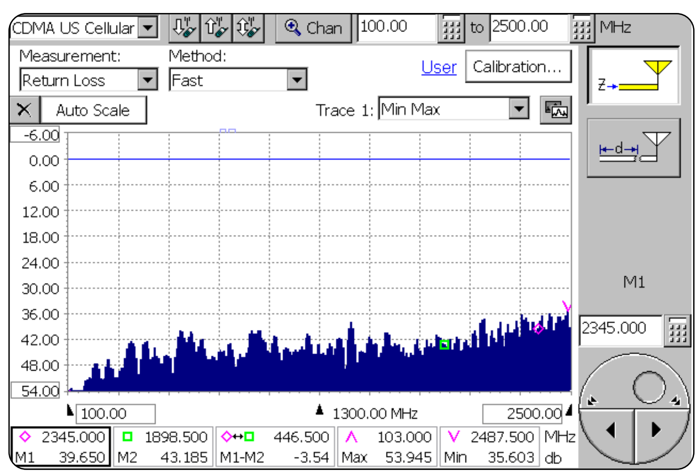
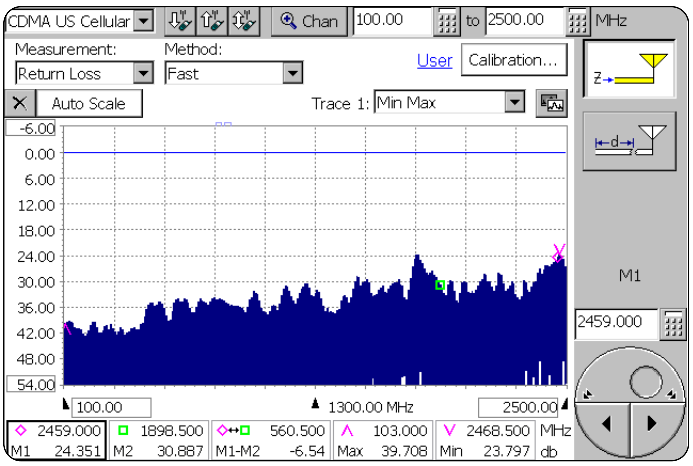


Figure 17.

Just for the sake of completeness, we followed the same procedure and calibrated the general purpose cable. When it is flexed (Figure 18) we see that this degrades the measurement capability to 24 dB return loss at best.

Variations as much as this will surely give wrong results unless the antenna system being measured has had a catastrophic failure, such as the antenna fell off altogether.



▶ *Figure 18.*

Calibration at the end of a jumper cable can enhance accuracy. But the benefit will be lost unless the coax remains stable while being bent.

Precision Components Available

The following optional precision components can facilitate accurate measurements of return loss and VSWR:

Component Description	Part Number	Notes
Precision RF Cable, 10 feet (3 meters) long	012-1619-00	Male Type N both ends
Double female type N adapter	103-0429-00	The “barrel” to use with cable
Double male type N adapter	103-0430-00	
DC Block – Type N	119-6598-00	
7-16 female to N female adapter	103-0431-00	
7-16 male to N female adapter	103-0432-00	

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