At the Repair Bench – MFJ-993B – January 2026

Figure 1 - MFJ-993B IntelliTuner

Not too long ago, one of my fellow GCARC members approached me with a request to repair his Icom IC-7300 transceiver, which had suddenly lost all RF output power. I went to his home armed with my CCT-01 coaxial cable tester and my Rig Expert AA-650 ZOOM antenna system analyzer. The intent was to see if I could identify any possible external causes for the sudden loss of power output, as this seldom happens in a vacuum.

On arrival, we tested the short length of coaxial cable that was in place between the radio and the MFJ-993B IntelliTuner automatic antenna tuner (Figure 1) that was in use with the Icom. That cable tested good, as did a second cable that the owner had on hand there as a back-up in case of any problems with the first cable.

The next test was that of the antenna system, where we found some considerable discrepancy with what should be a desirable VSWR for the bands upon which the owner normally operated. His normal operation was FT-8 using the 40-meter band, with occasional FT-8 operation at 20 meters and also some scattered use of FT-8 at 10 meters. His best match was actually at the 10-meter band, which told me right off that his antenna was longer than it should have been for optimal 40-meter operations. There was quite a bit of wire sag that had occurred since the antenna had been hung, several years earlier. This was nothing that was not fairly easily cured, but also not enough to account for the sudden demise of the radio. I brought the radio *and* the antenna tuner back to the shop for some further investigation, diagnosis, and analysis – and ultimately for repair.

I found the problems in the radio quickly enough, and that is the subject of a future *Repair Bench* article. This article is meant to detail the findings and repair of the antenna tuner.

Some of you may have taken note of an earlier *Repair Bench* article that I wrote a few months back, describing the problems with the mounting of the SO-239 connectors to the rear panel of an MFJ-949E Versa-Tuner. This tuner had the same issue, caused by an identical connector mounting scheme. I see this purely as a cost-cutting move on the part of MFJ, but it is ill-advised and certainly leads to problems for the user. To describe the issue, start out by noting that the common flange-mounted SO-239 connector has a four-bolt mounting pattern, with the holes spaced on 0.750” centers forming a square.

Now… any right-thinking engineer would surely mount the connector using a positive retention method such as machine screws and locking nuts, or at least standard hex nuts and toothed lock washers that would properly “dig into” the aluminum panel material, forming a good and secure mount. However, that is not at all what MFJ chose to do with many of their tuners. Instead, they used aluminum pop rivets to retain the SO-239 connectors in place. Not only did they use pop rivets, but they populated only two diagonally-opposite mounting holes in each connector flange rather than the full complement of four fasteners. With time and use, these pop rivets work their way loose, either through stretching or wear – most likely through stretching. This, of course, leaves the connector loose on the panel and without a secure ground connection. That was the condition in which I found the coaxial connectors on this tuner.

Another issue, though completely trivial in nature and very easy to repair, was the loose grounding (earthing) stud on the rear panel of the tuner. This stud is, in actuality, a Phillips pan head machine screw that is inserted from the inside of the rear panel and extends through the panel, secured in place by a KEPS nut. For those who may be unfamiliar with the term, a KEPS nut is a hex nut that has a captive swiveling externally-toothed lock washer attached to it. If properly tightened upon installation, this nut will not ordinarily work its way loose, which tells me that the nut was most likely not tightened correctly when it was initially installed. Mark this one up as another factory failure.

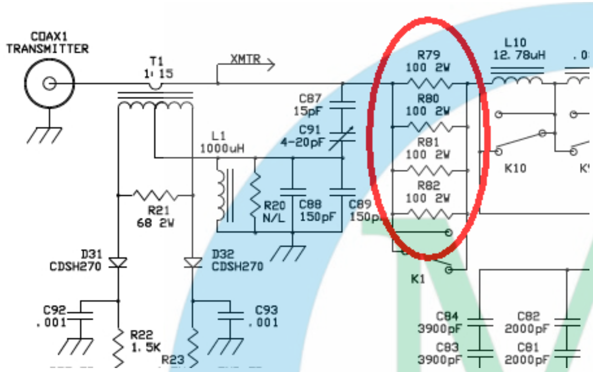

Figure 2 - MFJ-993B schematic excerpt

There were two other problems noted with this unit, one of which is actually tied into the other. The two issues were the failure of a set of parallel resistors on a small daughterboard, and the typical lead-free solder joint failures that we see so often. Let's talk about the resistor failures first.

Directly in line with the input signal path from the transmitter is a set of four parallel resistors. In the schematic (Figure 2), they are indicated as resistors R79, R80, R81, and R82. In reality, the unit mainboard has the location of these resistors identified as R78. What is installed there is a small daughterboard that simply holds the four 2W 100Ω 5% resistors connected in parallel. This connection method yields an 8W 25Ω resistance at that point in the circuit. Once again, some of you may recall another earlier *Repair Bench* article wherein I described the repair of an MFJ-998RT remote automatic antenna tuner unit. That model used a very similar scheme, and it too had failed, though not with the same failure modality as with this unit. In that case, three of the four resistors had gone open and the remaining resistor had suffered a value increase to over a thousand ohms. In this case, the net resistance across the daughterboard was a mere 0.9Ω (see Figure 3). Each of the resistors had failed, with two of them going open, one decreasing its value to ten ohms, and the fourth decreasing its value to about one ohm. The net result was the measured resistance of 0.9Ω – using the product over the sum equation for parallel resistances, we have the following:

$$\frac{1 \times 10}{1 + 10} = \frac{10}{11} = 0.909\overline{09}\Omega.$$

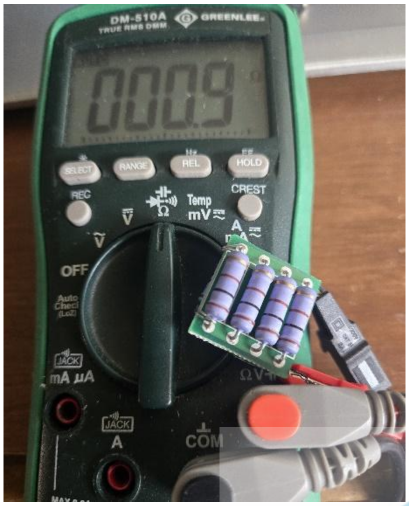

Figure 3 - Resistance through failed resistor set

The fix for this issue was to remove the daughterboard and to replace all four resistors, of course. In removing that board, I discovered that the board's two connecting leads, basically just short wire segments, were loose in the mainboard with cracked solder joints. This effectively presented at least a partial open circuit in the signal path through the tuner. More about that later.

I would have preferred to replace the resistors with 1% tolerance devices, if they had been in stock in my parts inventory. The 1% tolerance would have presented a resistance range from 24.75Ω to 25.25Ω, very close to the schematic value of 25Ω for the parallel set. Instead, I used 5% tolerance 2W resistors as the manufacturer had done in building the unit. This left us with a resistance range of 23.75Ω to 26.25Ω. The actual measured resistance post-replacement was 24.5Ω (see Figure 4).

The MFJ-993B IntelliTuner is an automatic antenna tuner, and as such, it switches the various inductances and capacitances into and out of the circuit by use of a set of relays. There are eight relays for the inductors, and another eight relays for the capacitor banks. The basic circuit (see Figure 5) is an "L", with series inductors and shunt capacitors. This is an important point, as we will see shortly.

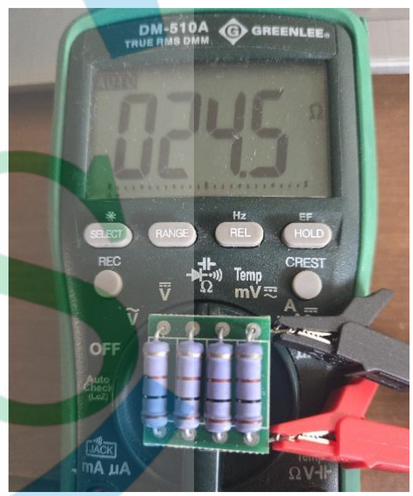

Figure 4 - Resistance after repair

In examining the unit mainboard, I found several locations where there were open or partially open (resistive) solder joints. These were *all* directly in the signal path, in the inductor mountings or in the associated relay connections. This brings us to a discussion of the problems related to lead-free solder joints.

The RoHS rules in Europe and Asia require that all consumer-grade electronic products be assembled with lead-free solder. *"RoHS"* is an acronym for *Restriction of Hazardous Substances,* which is a set of regulations or guidelines designed to limit the use of many hazardous substances (hazardous materials or *hazmat* in the USA), of which lead is just one of the many regulated materials. However, lead is the subject in which we are interested right now.

It is not by accident that the use of lead-free solder is prohibited in mission-critical applications such as aviation or transportation applications, military applications, and medical and life-support applications. This is because lead-free solder joints *will fail with time.* The failure is largely due to shrinking of the alloy over time, causing it to pull away

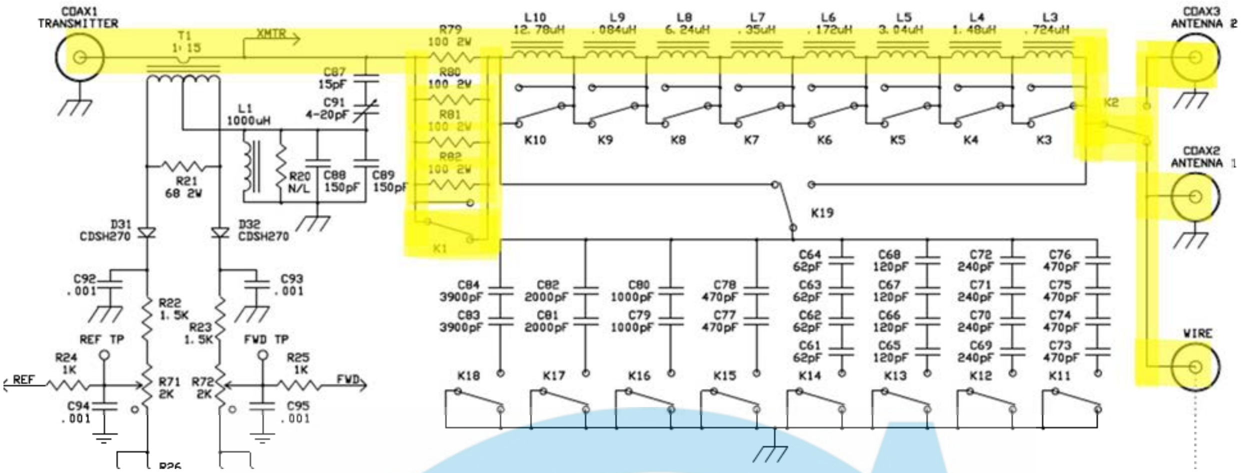

Figure 5 - MFJ-993B signal path (yellow line)

from the points to which it is welded. The larger or more substantial a solder joint is, the more it is affected by this shrinkage problem. Vibration exacerbates the issue, hastening the failure of the joints. Heat – or more correctly repeated thermal changes – also speeds up the process.

While the relay pins are all relatively small by comparison, the leads of the inductors used in this unit are quite substantial, forming rather large solder joints where they are soldered to the printed circuit board (PCB). Several of these inductor joints had failed, two of them (both ends of the same toroidal inductor) having gone completely open, while others were partial failures. The partial failures result in increased resistance in the solder joint. Ideally, the resistance of a proper solder joint will be nil, or as close to nil as to be unmeasurable for all practical purposes.

I use several methods to determine which solder joints, if any, have failed. First of all, I examine the joints visually, under bright light and with a good strong magnifier. Another method is to pour some 99.9% isopropyl alcohol (IPA) on the PCB and look to see where it may seep through the board. I also use the “feel” technique. In this process, I place a fingertip directly on a joint, pressing down on it against the PCB. Then, I gently attempt to wiggle the component on whose solder joint I am pressing. If any movement is felt, the joint has failed. Finally, I measure the resistance through any suspected failure points. For this, a milli-ohmmeter is required, as the resistance will be very low and the resistance of the ohmmeter test leads of a standard ohmmeter can produce erroneous readings. For this job, I use my Æscel 20218 milli-ohmmeter, which uses a Kelvin lead system. The Kelvin lead system is a methodology that uses four wires in the test leads, and effectively removes the test lead resistance from the measured and reported value, resulting in a true “zero ohm” point at the test lead alligator clips. This means that extremely low resistance values can be measured accurately, making it ideal for this task.

In some cases, I may need to remove a bit of solder mask from a trace nearby to the joint under test. I then measure the resistance from the component lead to the exposed trace. Any resistance in excess of a couple of milli-ohms is cause for a reflow of the joint. Lead-free joints have higher resistivity than otherwise equivalent leaded solder joints will have, but should still be no more than a couple of milli-ohms. Bear in mind that this type of measurement cannot be made with any standard ohmmeter. However, if such a measurement is attempted with a standard ohmmeter, and if any resistance *is* indicated, the joint will very obviously be in a failed condition. If solder mask was removed for the test measurement, I will re-coat that area with brush-on solder mask afterwards.

Repair of any failed lead-free solder joints is best done using rosin-core solder of a eutectic 63%/37% tin/lead alloy. I typically start out by adding the leaded solder to the joint to dilute the lead-free solder, and then remove the mix using either some solder braid or my vacuum de-solder tool. Then I re-solder the joint with the lead-alloy solder to finish the joint. This is the process that I used on this PCB. As a preventive measure against future failures, I re-flowed *all* of the inductor joints as well as all of the relay solder points, in both the inductor relay field and the capacitor bank field.

Now… back to the key point of the tuner failures. Remember that I said that the basic circuit (Figure 5) is an “L” circuit? This design places the inductors directly in the signal path, which means that any open circuit in the inductor solder joints creates a break in the signal path. That in turn means that the radio is operating without any load on its output side when the inductor or relay with the open circuit is switched into the circuit. This is, of course, directly responsible for the failure of the radio that was experienced.

While none of these repairs were difficult or were complex, each of them was undoubtedly necessary. Some of the problems could have been prevented with better design and build processes. The greatest problem though, is one that is caused by well-meaning rules and regulations. The conditions created thereby have created a well-known and predictable failure modality that all amateur radio equipment will, at some point in time, experience. The best that any ham can do is to proactively and in a prophylactive manner reflow the larger solder joints in the ancillary equipment through which the radio power output must pass. This means such devices as antenna tuners, SWR meters, RF amplifiers, and so forth. While *any* lead-free solder joints can fail, it is far more common for the larger joints to fail, which occurs quite regularly with high-current circuit paths. Remember that this can, and does, include the incoming DC power supply connections as well as the high-power RF output circuits.

All things considered, this was a basic repair, and one that could have been prevented with a bit of forward-looking preventive activity. Nonetheless, it is the bread-and-butter of what I do. As such, this is one that could easily be undertaken by almost any ham out there, including *you.* All that it takes is some attention to detail.