Troubleshooting Radios

Before you pack it up and ship it off, check it out yourself.

Mal Eiselman, NC4L

I have been repairing the Yaesu FT-102 HF transceiver for the past 19 years and have spent more than 10,000 hours in this endeavor on this one radio model alone. In all, I have worked through problems in several hundred of these radios over the period. As you may be aware the most significant problem with this radio (as well as many others) is intermittent signal path losses. I am trained as a cardiologist and never had any formal training in troubleshooting RF circuitry, except in my pursuit of perfection for the ’102. During this time I have accumulated a wealth of knowledge in how to track down these problems in the ’102, as well as in most other radios and I would like to share these principles with you.

It’s like the old proverb that if you give a man a fish you feed him for a day but if you teach him how to fish you will feed him for the rest of his life. The principles that I am going to share with you are easy to understand and perform by almost any ham. Finding an intermittent and then sledgehammering it into the ground (I am not speaking literally, of course) so that it never, never occurs again is a true joy and an enormous source of satisfaction. Although my examples are for the ’102 they can be applied to other ham radio equipment.

Let’s Get Started — Here’s What You Need

There are three instruments that you must have. The first is the digital multimeter that most hams already possess. The second is an oscilloscope — nothing fancy is required, since it will be mostly used at audio frequencies. It must, however, be an analog type. Digital ’scopes will not always give you the instantaneous information you need because they are not real time instruments. Good ’scopes can be obtained at hamfests or on the internet for $50 to $100. They are all-powerful when used for troubleshooting (see Figure 1). The third instrument is your own intuitive brain. It is the most important of all the troubleshooting instruments. One other possibility is a low tech signal generator (nothing fancy is needed) and this is required only if your radio does not have a marker or calibrator function. Here is how I troubleshoot a ’102.

The First Step — Get a Signal to Work With

Turn on the transceiver and set the frequency to 14,274.0 kHz, the mode to USB and the RF amplifier to ON. If you can disable the transmitter, do so or be careful not to switch to TRANSMIT during this test. Leave the antenna unconnected. Keep the SHIFT and WIDTH controls centered, straight up on the ’102. Turn on the 25 kHz marker signal (at the back chassis on the ’102) or set your signal generator to 14,275.0 kHz.

If your calibration is close, you should receive a tone of about 1 kHz (14,275.0 – 14,274.0 kHz). Peak the preselector for maximum signal on the S-meter. These maneuvers will provide you with a strong IF signal and 1 kHz audio tone from your speaker because of the USB offset.

Adjust the VOLUME control for minimal audible signal as the sound is not important in this part of the test. If the relays and the rest of the receiver are working properly at that moment you should read a signal of +10 to +15 dB over S-9 on a ’102 and something similar on other transceivers. If you do not have a calibrator in your radio, then an inexpensive signal generator should be used to inject enough power to obtain an S-9 + 10 dB signal. Remember your radio must be on USB with the generator’s frequency 1 kHz above the radio’s frequency to receive the audio tone. The actual audio frequency is not important long as you get a good identifiable tone.

Look at Your Output

Hook up a shielded lead from the AUDIO OUT jack of the radio to one VERTICAL INPUT connector of the scope. On the ’102, I use the AUDIO OUT jack of the six socket RCA connector board on the back of the set. In any other radio, just connect a wire to any audio source including the speaker leads and hook that up to the INPUT connector of your ’scope. Adjust the scope VERTICAL GAIN control or the radio’s AF GAIN control until the signal fills six large vertical divisions centered in the cathode ray tube (CRT) display. Adjust the TIME BASE control for 5 ms/division.

Next, turn the automatic gain control (AGC) circuit to OFF. This switch is on the front panel of the ’102 but other radios may vary. Be careful, as the audio may become very loud and distorted and the signal will be off the scope. Adjust the RF gain control so that the signal level on the CRT screen is at the same level as before pushing the AGC to the OFF position. This will decrease the audio output and its distortion to the previous normal level. Follow the same procedure with any other radio.

At this point any signal path loss — no matter how slight — will be reflected by a change in the signal’s amplitude on the CRT. You will be able to see a 0.1 dB change in level. This is because the AGC is defeated and you are not in saturation of the resulting IF or audio signals. A 6 dB power loss anywhere from the antenna input to the final audio amplifier, will halve the voltage amplitude of the CRT trace. This will be reflected by

Figure 1 — An oscilloscope that is typical of those that can be purchased from eBay or at hamfests for $50 to $100. It is a dual channel ’scope with 35 MHz bandwidth — more than is usually needed.

your audio signal's vertical amplitude dropping from six divisions of the scope (total excursion) to three divisions.

Figure 2 — Only hit the chassis hard enough to get the bounce effect (see text) on the scope pattern. In all testing use good common sense.

What's it all Mean?

This degree of RF or IF signal loss would not be heard with usual on-the-air circumstances with the AGC engaged. That is because the AGC's function is to compensate so that the audio voltage and volume stay the same even though the input varies. You would not notice a 6 dB difference on an on-air signal with fading (QSB) and static. It is too small a change unless the signal is very near the noise level. Remember, however, that in reality a 6 dB loss represents losing 75% of the power of your received signal. On the other hand when people lose their S meter deflection or their receiver drops out they are having a 60 to 100 dB loss of signal. That magnitude is equivalent to a million to a billion fold loss of signal.

While troubleshooting with a scope you have the ability to see minuscule changes accurately. The sensitivity of this setup permits you to judge accurately when you are losing even small amounts of signal with certainty and thereby detect, locate and repair the defect.

Give it a Tap

Okay; now you have the radio in the test mode with everything set up to see even the smallest of losses, if any. But you have to stimulate things. I use the plastic handle of my trusty ratcheted screwdriver and I tap the metal chassis fairly hard (it is best to have the upper and lower cases off) and at the same time I look at the sweep of the CRT for changes as shown in Figure 2.

Even if a radio has no intermittents at all, you will notice that at some point of force with your banging you will encounter relay bounce. This will be a very short loss of the signal on the CRT for perhaps 10 or 20 ms, 2 to 4 horizontal divisions at 5 ms per division. This is normal and represents the fact that the contacts are separating because of the vibrations set up by the percussive force of the screwdriver. This then is the amount of force that you should use to check out the rest of the radio. As I mentioned, the 10 or 20 ms disturbance in the CRT display is normal but if it persists any longer, there are intermittent problems.

If you notice that the level changes to a flat line at the middle of the CRT, there is trouble. Remember, I am a cardiologist and flat lines are very bad! This happens in the most severe cases but most of the time the loss is intermediate and you may only lose 5% of the vertical height. If you hit it again, the pattern may settle on a different level or even return to the prior level. No matter how small the level of change *it is not normal* if it persists. After the 20 ms time interval the level should be exactly back to where it started since the relay bounce phenomena is completed by that time and the contacts should have reseated without any added resistance in the circuit.

Figure 3 — Response to a brisk tap. Note that the sweep is at 5 ms per division. The disturbance persists 4 divisions and then resettles to the same level it was before the strike(s).

Poke to Find the Sensitive Spots

The next thing that you should do is to take a non-conductive plastic pen or plastic tuning wand and tap on the top of each relay in the radio while watching the CRT. Don't use the screwdriver inside the radio. This should be done relatively softly as when the relay is bad it will be quite sensitive. I suggest that you tap each relay several times to make sure, using a repetitive motion. (See Figure 4.)

Next, try tapping and flexing the boards as well as moving the wire harnesses and plugs with the tuning wand. There should be no collapsing of the CRT signal. That will occur with poorly crimped interconnect plugs or fracture traces on the boards, as well as bad relays or components.

The Second Step

This is a similar type of test and complements the above procedure, but it uses sound from the speaker as the watch point.

Change the FREQUENCY control of the radio to read 14,275.00 kHz, right on one of your calibrator harmonics, or the signal generator's actual frequency. Tune until you get a zero beat or just have no tone coming through the audio system. This occurs when the carrier signal and receiver signal are exactly the same. Keep your AGC in the OFF position. Next, turn AF GAIN up as far as it will go with the RF GAIN in the minimal or reduced position. Then advance the RF GAIN control until you just start to get self oscillation or feedback and not a received tone. You should still be receiving the zero frequency — if not, readjust your receiver's tuning to zero it. At that point turn the RF GAIN or AF GAIN control down a notch. In this step you have to be very careful to keep the frequency of the radio and generator the same. If the frequency of either were to shift, it would cause a loud commotion.

Watch Your Ears and Full Speed Ahead

At this point the amplification of everything in the receive path to the speaker is near maximum. Tapping on the boards with the plastic wand will cause an echo-like effect known as a *microphonic*. You will clearly recognize this in the speaker and it is a normal effect of vibrating the boards by tapping them. With an intermittent, however, the sound from your speaker will sound like three ball bearings rolling around in a tin can. You should not hear a crackly or clunky distorted sound anywhere in the radio with one exception.

The clunky or crackly sound is okay if you hit a can or adjustment coil that is part of the frequency control circuitry for the voltage controlled oscillator. In the ’102 these circuits are in six cans on the front of the local oscillator board. In Figure 4 the tuning wand is touching one. As you get farther and farther away from those sensitive points, the clunky and crackling sounds should decrease and then disappear. It is normal for the microphonic effect to persist. With a little practice and attention you will quickly know what is normal and what is not.

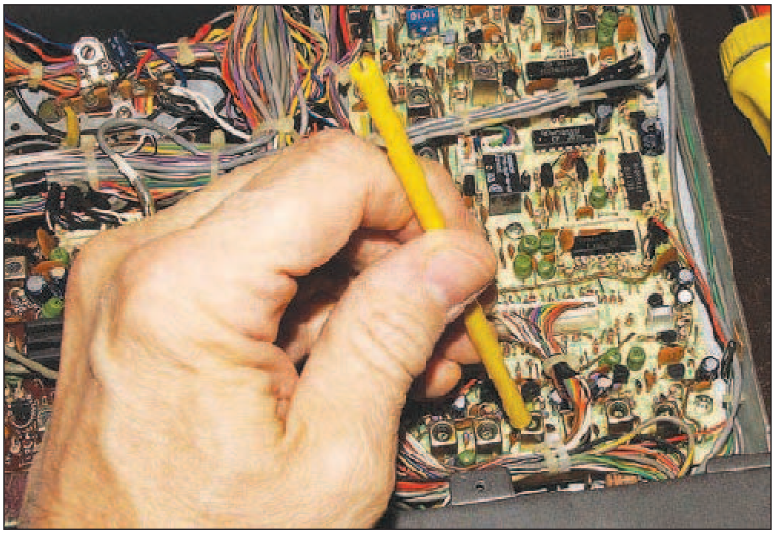

Figure 4 — Flex the boards and tap the components. Be careful if there is high voltage present as fingers sometimes slip.

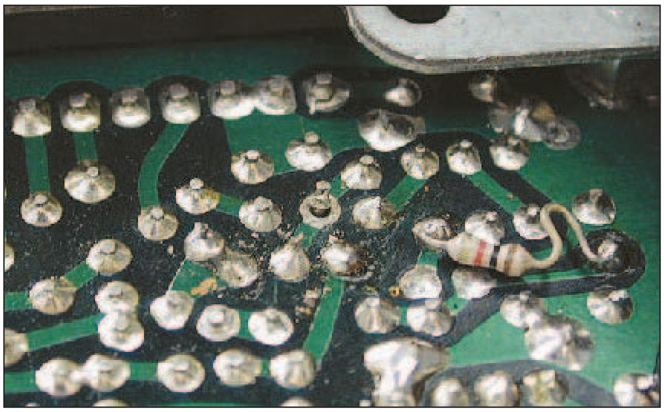

Figure 5 — Note the witch’s hat fracture in the center of the photo. The lead coming from the component side of the board has a circumferential fracture and separation of the solder filet. I have seen these many times. They are usually not as obvious. There are three others in this photo. *Hint — look up*.

Tap and flex all the relays, boards and wires in the radio as you did before with the plastic wand. Tap the bandswitch shaft and anything else you come across with the plastic wand to see if there are signs of a signal intermittent or loud crackly noises. Be careful not to get shocked. You may not know the danger points and places where high voltage resides so be very careful with tube radios. There should be no danger of shock in 12 V radios, but beware of high current shorts that can cause damage.

Any bad component, dirty bandswitch wafer, poor crimp connection, witch’s hat fractures (see Figure 5) or bad relays will, for the most part, be most sensitive at its precise location. If you find a bad spot use lesser and lesser tapping force to narrow the precise area (sort of like playing hot and cold when you were a kid). When you get things localized, check the components and also visually check the trace side of the board after removing it from the radio.

Step Three

Using a signal generator or calibrator, the procedures so far will check all but one signal path in the receiver section of an FT-102. What remains is comprised of the antenna switching relay and the antenna input circuitry. If you are using an external generator you will not need to do this step as that signal runs through those components. But an internal marker signal is inserted following those elements in many radios, including the ’102. The following procedure checks the remaining receive path in the ’102.

With the radio off, connect a digital ohmmeter across the SO-239 antenna jack. I use an alligator clip on the ground post for one lead. You need to make good contact or this test will be invalid. I press the other lead of the ohmmeter into the SO-239 central hole and hold it there with solid pressure.

The ohmmeter should read between 8.5 and 9.5 Ω. That represents the impedance of the fuse bulb in the Yaesu FT-102 — your radio may read differently. Then while watching the ohmmeter, use the back of the screwdriver and bang it against the upper back chassis above the transmit cage until you see the loss of conductivity representing relay bounce. In order to pass this test the digital ohmmeter reading should be back to within 0.1 Ω of where it started within two update periods of the digital display. Remember here that a persisting 0.5 Ω difference after hitting the chassis means there is a resistance blockage on the contacts of the relay or on the relay board or its interconnects. With time and changing temperatures this may blossom to an intermittent and perhaps eventually an open circuit. That can easily happen the next time you use the radio.

The Final Part — The Transmitter Section

We now need to do the same kind of process for the transmit signal path since losses can occur there as well. For this test use a dummy load and apply 20 W of continuous power (key down CW) so that you don’t cook anything including the tubes in the ’102. Use the same power output for other radios as well as full output here will not give an accurate account of things. If you are technically inclined and can connect the scope to the power output, that is the best way to see output changes. If you are not experienced enough to do, then use a power output meter.

Watch the output of the radio by connecting it to the ’scope or meter. Use 5 ms/division as before for the scope trace and make the vertical pattern about 75% of the full CRT screen. A power output meter will be helpful but it will not be quite as sensitive or immediate as an analog ’scope monitoring the events.

Then get your trusty screwdriver and plastic pen/plastic tuning wand and test the transmitter in the same way as you did the receiver. In this step, as you percuss the test radio, listen to its signal on the second receiver as you watch the ’scope. Remember, watch out for high voltage in unfamiliar surroundings and always use an insulated instrument to apply force.

After the visual testing listen to the transmitted CW signal in a second receiver.

Listen on the zero beat frequency with the receiver set to USB or LSB. Turn the volume of the second radio way up and listen for the microphonics and clunking resulting from stressing the boards and wires with the percussive devices in the transmitting radio. This then completes the whole procedure.

And Then What?

If you detect a fault, zero in on it until you locate it or isolate it to two or three components. Then examine those and repair or replace them. In addition, check the solder side of the board for irregularities. Use a good magnifier and light as witch hat fractures can be hard to see.

Finally, I call this quadruple stress testing of the transceiver. Please forgive my use of terms but it does convey the message and ideas properly although it is a difference kind of stress.

I believe I have told you more than you wanted to know. But that is how to troubleshoot the '102 or any other ham radio for intermittents, whether from relays (not always the cause) or anything else. If you are careful and meticulous with this method you will eventually track down every cause of signal loss. One last point before we end and you pull your old radios out for testing: In all my years of doing this I have never found an intermittent in a radio using heat or cold where percussion didn't work.

Becoming conversant with these procedures will help make you a competent technician and enable you to repair and rescue radios that other hams would relegate to the scrap yard. It will also give you a feel for radio design and radio principles. I know it did that for me. Good luck and keep the ionosphere warm.

ARRL member Mal Eiselman, NC4L, has been licensed since 1961 and has been a member of the ARRL for the past 30 years. He currently holds an Amateur Extra class license. He is a trained cardiologist who practiced in Hollywood, Florida for 30 years before retiring in 2003. His love of electronics and ham radio led him to repairing and modifying his Yaesu FT-102 HF transceiver. It is the only radio that he repairs and he has done this for the past 19 years. His Amateur Radio interests include keeping in contact with old friends as well as making new friends on the air on a daily basis. His second interest is making electronic things work better. You can reach the author at 3650 N 55th Ave, Hollywood, FL 33021 or at **NC4LMal@aol.com**. *Visit his Web site at* **www.w8kvk.com/nc4l**.

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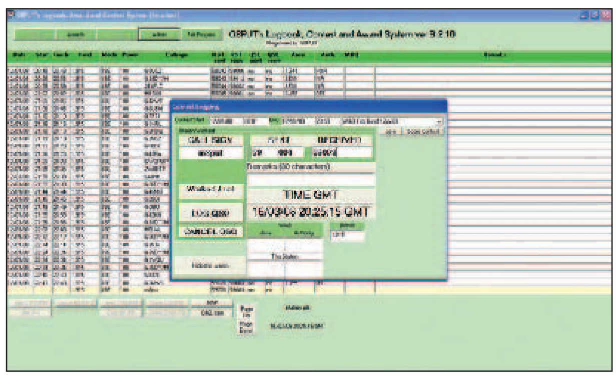

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