The Service Line

Mechanical Filter Test Fixture Simplified

by Don Jackson, W5QN & Paul Christensen, W9AC

The Q2 2015 *Signal* article describing a test fixture for the plug-in "FA" IF filters for the 75S-3B drew some attention, but the design perhaps was not particularly easy to implement, nor did many readers have an instrument similar in function to the Rigol DSA815TG to use for the actual filter measurements. This article is a discussion of a simpler test fixture, and use of more common test equipment.

First, you might ask why the original test fixture is so complicated in the first place. Part of the design complexity relates to measurement of filter ultimate rejection. This measurement requires excellent isolation between the test fixture input and output circuitry, which creates mechanical complexity. Further complexity was created by use of separate circuitry for impedance matching and resonating the 940uH filter inductance.

Since many folks may not have the equipment to measure ultimate rejection, or simply don't find that measurement necessary for basic filter evaluation, I dropped that measurement from my list of requirements.

Although the original article uses shunt capacitors, Bob Jefferis, KF6BC, brought it to my attention that Collins application notes suggest series capacitor networks can also be used in filter circuit designs. Figure 1 shows a test fixture circuit using series capacitors.

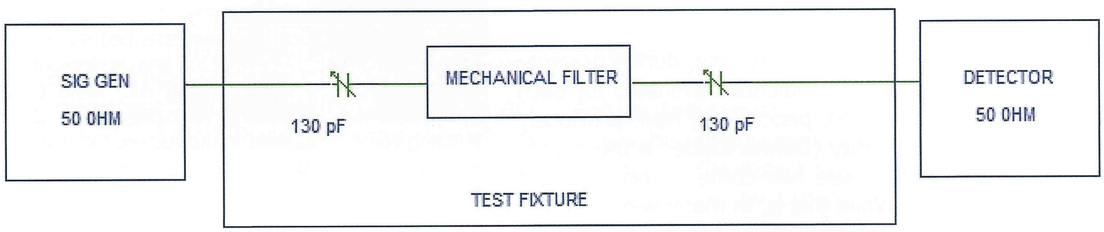


Figure 1 – Test Fixture w/Series Resonating Capacitors

The circuit of Figure 1 uses a single series capacitor for both resonating the 940uH filter input inductance and transforming the 50Ω in/out impedances to a suitable filter terminating impedance. The 130pF series capacitor transforms 50Ω to 145kΩ. One way to think about this impedance conversion is that at 455kHz, 130pF in series with 50Ω is essentially equivalent to 130pF in parallel with 145kΩ. This 130pF is resonant with the filter inductance of 940uH. Thus, the series capacitor provides both the matching and resonating functions. The 145kΩ filter termination impedance is quite acceptable, and actually better represents the impedances in the 75S-3B receiver than the 50kΩ I used in my original test fixture design. A circuit can't get much simpler than this!

The 50Ω output load capability of the series circuit eliminates input/output cable (typically RG58) length issues. The matching networks have low loss, resulting in good measurement dynamic range. This means a filter ultimate rejection measurement is primarily limited by undesired input/output coupling rather than dynamic range of the measurement system.

A disadvantage of the series capacitor approach is that the test fixture input voltage is converted to a much higher voltage at the filter input. The maximum rated input at the filter is 2VRMS. With a filter installed in the fixture, that level is reached when the signal generator level is set to about 0dBm. **If your generator is capable of large output power, it is recommended that you use an attenuator at the test fixture input to avoid potential filter damage.**

Construction of the Test Fixture - Since we have assumed measurement of filter ultimate rejection is not a primary goal, we don't need to worry about attaining a high degree of input/output isolation in the test fixture. Therefore, a PCB design should be adequate. Figure 2 is a schematic diagram of the actual test fixture.

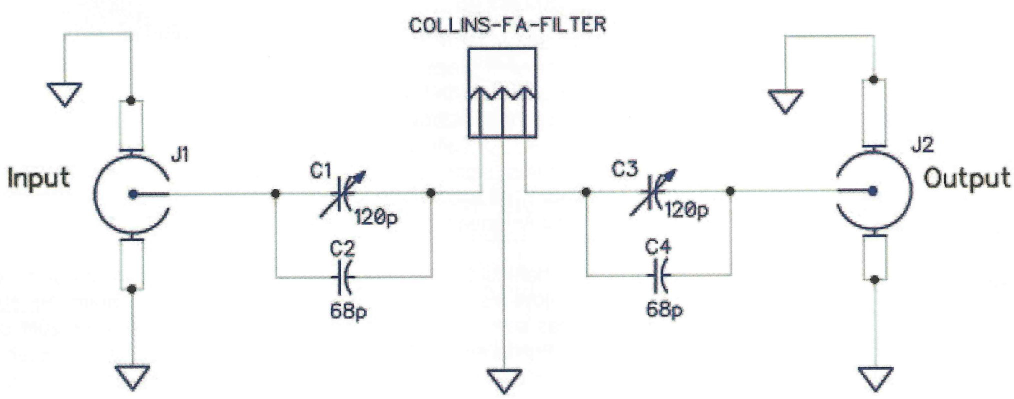


Figure 2 – Test Fixture Schematic Diagram

The test fixture consists of a CAD-designed, dual-sided PC board. Unlike the original test fixture design, the FA filter, surrounding components and traces are not shielded from leakage. However, a reasonable attempt was made in the design to ensure that leakage would be minimized.

This was accomplished through minimum trace distances, component placement, and adequate distance between traces and the ground pour.

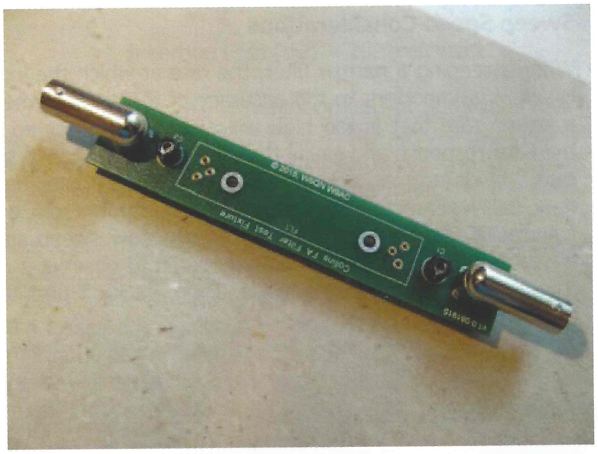


Figure 3 – Test Fixture Assembly (Top)

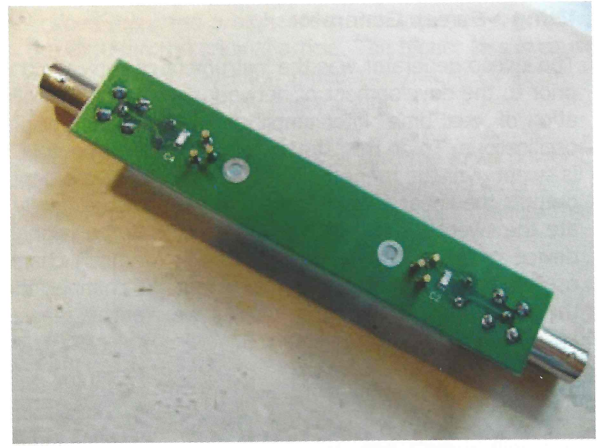


Figure 4 – Test Fixture Assembly (Bottom)

The CAD files were exported into a common .GBR (Gerber) file format and are available for download on the CCA website, along with the component B.O.M. file. The Gerber files are in a single "zip" file titled "FA Filter Gerber Files.zip". The files are free to use for non-commercial purposes. Note that 14 files are used with Gerber definitions and each represents a unique board layer (e.g., top silk, top copper, bottom copper, etc.)

Except for the trimmer caps, all component are available through Mouser – either individually or through the "Mouser Project Manager," a stream-lined ordering process that contains a pre-loaded B.O.M. Please refer to the CCA website for further instructions on accessing the Mouser Project Manager function. Trimmer capacitor information is available on the B.O.M.

Keystone gold-plated micro-sockets were chosen to securely seat the FA filter in place during testing. Optionally, one may secure the FA filter in place with #4 hardware. The micro-sockets offer excellent repeat connectivity and strength. Each hole is plated-through so it's only necessary to apply solder to the bottom portion of the micro-socket.

The BNC connectors, micro-sockets and trimmer caps are leaded components and may be assembled onto the test fixture with a soldering station. However, two components, C2 and C4 are 68 pF C0G 1206 SMD capacitors. For those readers who are not experienced with SMD soldering techniques, I suggest researching the subject online.

Note that Inrad filters are not balanced designs, as are the FA filters. Therefore, when testing an Inrad filter, you must plug it into the test fixture properly. In contrast, a Collins FA filter can be installed in either direction.

Figures 3 and 4 (above) show the completed test fixture assembly.

Test Setups

Using a Signal Generator

Let's assume we do not have a modern Network Analyzer, and must use more basic test equipment. Take a look at the test fixture of Figure 5 which provides a manual method of determining the insertion loss of the filter, its bandwidth and amplitude ripple. Test equipment required consists of a signal generator, oscilloscope and frequency counter. The frequency counter isn't necessary if the signal generator is of a modern synthesized design.

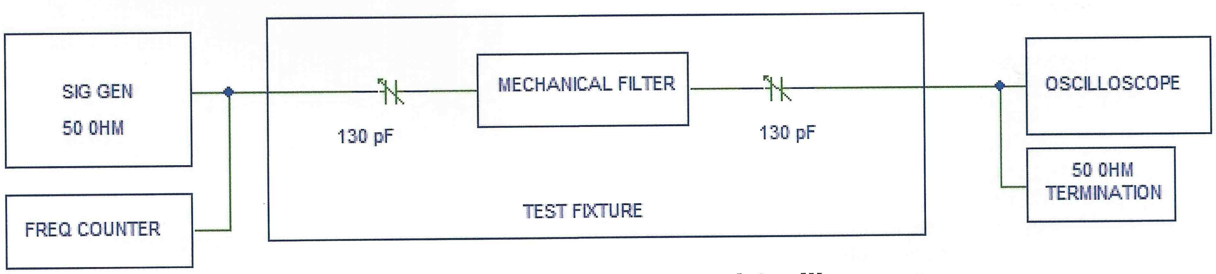


Figure 5 – Signal Generator and Oscilloscope

For a signal generator output of 0dBm, the output at the oscilloscope is typically 20mVRMS (28mV peak), so the scope must have sufficient sensitivity to display this level. With the 50Ω termination attached, the scope input impedance and cable length have no significant affect.

Recall that the maximum rated input voltage for the filter is 2VRMS, and this is typically reached with the signal generator set to 0dBm (224mVRMS). Although the filter isn't likely to suffer damage at somewhat higher levels, it is best to keep the input at 0dBm or lower.

The use of a frequency counter (or a synthesized generator), provides excellent frequency accuracy for determining precise bandwidth and center frequency measurements. The disadvantage of this approach is that the signal generator must be manually tuned while observing the oscilloscope level. Therefore, you do not have the ability to easily see amplitude ripple in "real time".

Using a Sweep Generator

The sweep generator was the instrument of choice in the old days prior to the development of network analyzers. They allowed creation of "real time" filter amplitude vs. frequency displays on an oscilloscope. To do this, the sweep generator RF output frequency is swept over the range of interest. In addition, the generator also outputs the linear voltage ramp that was used internally to generate the swept RF output signal. If the RF output signal from the device under test is applied to the "Y" (vertical) channel of the oscilloscope and the ramp signal to the "X" channel, the result is the amplitude vs. frequency display we want. A diagram of this arrangement is shown in Figure 6.

Sweep Speed Considerations

When sweeping a narrow filter, the rate at which the input signal is swept is important to the accuracy of the measurement. Using a sweep rate that is too high will distort the observed shape of the filter response and cause the amplitude readings to be inaccurate. This is normal, and occurs because every filter has a finite time delay characteristic from input to output. From a practical standpoint, simply start out with a very slow sweep speed, and increase the sweep speed until you begin to observe a change in the displayed frequency response. Then, back off until the distortion goes away.

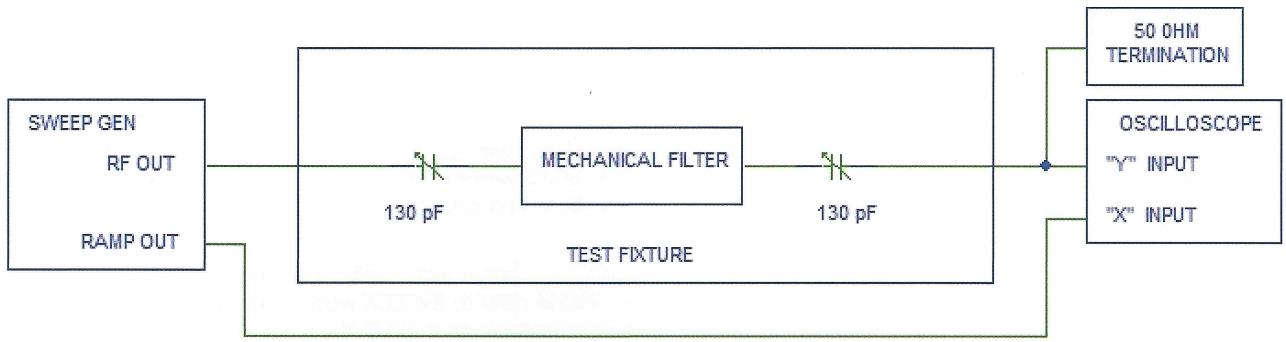


Figure 6 – Sweep Generator and Oscilloscope

Most sweep generator systems use a diode detector at the oscilloscope "Y" input to convert the RF output signal to a detected DC output, resulting in a nice single line trace on the oscilloscope. If you use a detector, be sure it has a good 50Ω input impedance. Also, experiment to be sure you are operating the detector in its typical "square law" range, meaning its output is proportional to power, not voltage. However, if the RF output from the test fixture is simply fed directly into the oscilloscope, the system is very linear, but you will see the entire envelope of the signal on the oscilloscope. It is convenient to adjust the oscilloscope DC offset so that you only see the upper half of the envelope. If you see the filter skirt amplitude drop to one half the mid-band value, you can be sure that is the -6dB down point.

The disadvantages of most vintage analog sweep generators when used to measure narrowband filters are primarily associated with frequency accuracy. For example, FM on the signal can "smear" the resulting sweep, creating frequency measurement inaccuracies. Also, determining frequency points to an accuracy of 50Hz or so represents a real challenge for old sweep generators. Sweep generators often have frequency marker capability but, in my experience, these markers are at frequency spacings too far apart for narrowband applications. One option I've used in the past is to sum an accurate variable frequency CW signal generator signal with the sweep generator RF output. By adjusting this CW signal to a low level, it is possible to observe a small beat note on the oscilloscope display at the CW generator frequency. This technique provides a good variable frequency marker in the passband, but may not be that useful on the steep filter skirts.

Paul Christensen has a Wavetek 144 sweep generator that he attempted to use as a demonstration of this setup. Unfortunately, the results were very unsatisfactory, primarily for the frequency stability and narrow sweep issues mentioned above. In addition, the output ramp voltage did not remain constant as the frequency sweep width was varied, adding to the difficulties. The bottom line is that not all vintage sweep generators are capable of testing narrowband filters.

Figure 7 is a photo of what you might see on the oscilloscope with a good sweep generator. I don't have a good sweeper, so this is just something I rigged up using my Rigol DSA815TG. I apologize for the poor photo quality, but this was a very difficult photo to create without a storage oscilloscope.

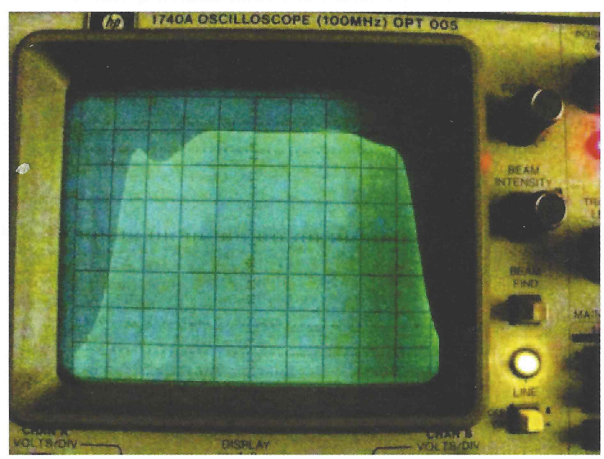


Figure 7 – Typical Display Using Sweep Generator and Oscilloscope

Test Results

Insertion Loss Measurement

Since the test fixture is intended to be used with 50Ω in/out devices, you can perform an insertion loss (I.L.) measurement. Simply remove the test fixture from the circuit and connect the cables together with a BNC female-female adapter. Note the level on the oscilloscope as your reference, Vref. Now insert the test fixture/filter assembly, and note the new voltage reading on the oscilloscope, Vtest. Calculate the insertion loss using the formula:

Insertion Loss (dB) = 20*Vref/Vtest

The I.L. is typically in the neighborhood of 20dB for most FA filters. This doesn't agree with the FA filter spec of 9.5dB maximum. The reason is that the Collins spec is the ratio, in dB, of the voltage at the input pin of the filter and the voltage at the output pin. This ratio is typically in the 5-8dB range, which agrees with the Collins spec. In contrast, the I.L. is a power loss measurement, which includes the loss of the various impedance mismatches in the test fixture, as well as the filter losses. The impedance mismatch losses are significant. Consider that the actual impedance at the input of the filter is typically around 12kΩ-16kΩ, and it is being driven by a "source" impedance of 145kΩ. Each of those mismatches (input and output) contributes a loss of about 4-6dB.

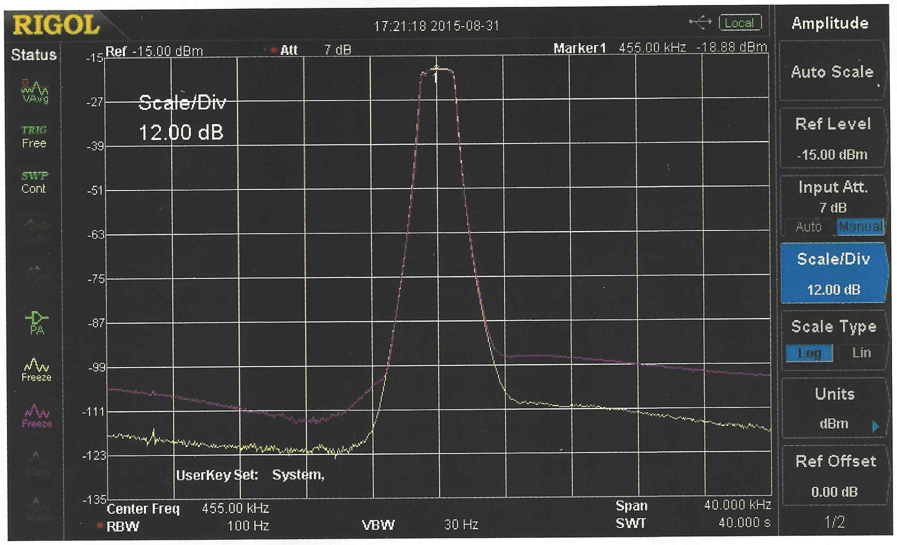


Figure 8 – PCB Fixture vs. Isolated In/Out Fixture

Ultimate Rejection

Although we have said that measurement of filter ultimate rejection isn't the primary goal of the PCB test fixture, it is interesting to compare its performance to the same circuit installed in an enclosure that provides high input/output isolation. Figure 8 shows this comparison using a Rigol DSA815-TG. The yellow trace is the circuit constructed with high isolation, and the purple trace is the PCB version. Clearly, high input/output isolation improves the measurement by about 8-14dB. Nonetheless, I was quite pleased to see how well the PCB version performs in this regard.

Conclusions

If you wish to evaluate Collins "FA" plug-in filters, and are not interested in measuring filter ultimate rejection, the PCB design presented here will do a good job. Basic functions such as bandwidth, center frequency, ripple and insertion loss can be measured using an oscilloscope as the output detector, provided a 50Ω termination is used. Of course, the text fixture will also work with 50Ω test equipment such as spectrum analyzers or network analyzers. However, note that use of an oscilloscope as a detector will limit the useful dynamic range to perhaps 20dB due to its linear (as opposed to logarithmic) Y-channel characteristic.

Although the circuit configuration used in the test fixture in my original article will certainly work, I recommend using the series version described in this article even if you decide to construct a test fixture with high input/output isolation. The series circuit has fewer components and, due to the higher filter termination impedance, produces passband characteristics closer to those seen in an actual S-Line receiver. The only disadvantage is that the series circuit results in a higher insertion loss (maybe 7dB or so) than the circuit in the original article. The higher loss is caused by a greater termination-to-filter impedance mismatch in the series circuit, but this is a relatively minor issue.

Remember, care must be taken to ensure the input power to the test fixture does not exceed approximately 0dBm, as greater input power may create a voltage at the filter input greater than the filter recommended maximum level of 2VRMS.

Cheers,
Don, W5QN
Paul, W9AC

- - - - - - - - - - - - - - - - - - - CCA - - - - - - - - - - - - - - - - - - -

Notes on parts and Gerber files for board construction: By the time that you get this article, our webmaster will have loaded files on the website that will provide an Excel spreadsheet of the parts list and also the Gerber files for the PC board involved.

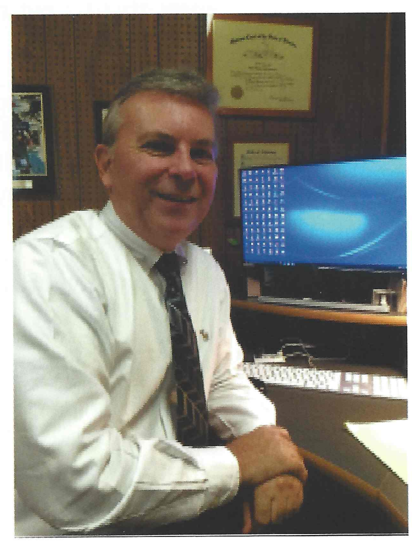
Author Information

You are all well familiar with our *Signal Magazine* Technical Editor, Don Jackson, W5QN. If not please see one of his many bios done in the previous issues. Here, Don writes in concert with a newcomer to our list of authors - Paul Christensen.

Paul, W9AC, has been a ham since 1972 and was initially licensed as WN9JCG while in Joliet, IL. Paul's first rig was a Hallicrafters SX-100 and homebrew transmitter using a 6DQ6A final. His Collins collection began in 1990 with a KWM380, but his favorite is his Collins S-Line, which he operates regularly on the air. One of his prize Collins pieces is a restored very rare 1935 30FX. As well as hardware, Paul also collects Collins literature, particularly pre-WWII vintage.

Check out his QRZ.COM site and you will see a wide variety of professionally executed homebrew projects. Very nice! Also, check out the photos of his remote shack, which is the source of some huge signals, particularly on 40m.

Paul has worked in telecom engineering for 20 years and completed his career as a corporate director of engineering for AT&T Broadband. His areas of expertise also include telecom law and business immigration.



His formal education includes BSEET and BSCS degrees from Northern Illinois University, an MBA from the University of North Florida, and a JD from the Florida Coastal School of Law.

Paul enjoys tennis, and alpine snow skiing when he is not on the air, building projects or visiting with his daughter in Minnesota.