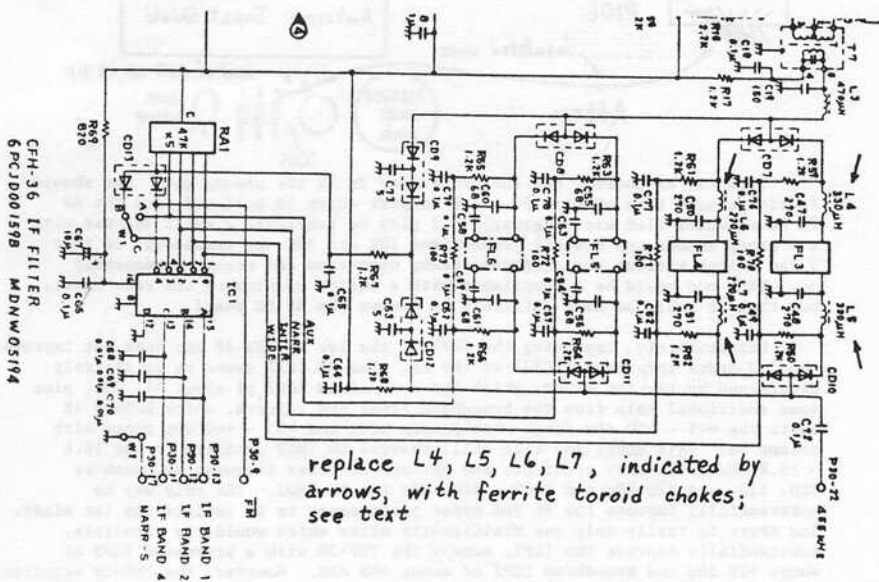


NRD-525: Filter Leakage

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In my recent article, "NRD-525: A Technical Review," I said that no filter leakage was present in the NRD-525s I tested. I was wrong. The method of measurement I used was not accurate below about 65 dB down on the filter skirts, and the "leakage" began about 70 dB down on one skirt of the INTER filter, and about 75 dB down on the other skirt of the INTER filter. The "leakage" is not observed for the WIDE filter when the test signal is injected at the antenna input terminal, as I did, because of the bandwidths of the cascaded filters ahead of the WIDE filter.

Before discussing the technical details of the "leakage" problem, let me describe a cure for the "leakage" problem. Replace L4, L5, L6, and L7 on the CFH-36 IF FILTER PC board with ferrite toroid chokes. For L4 and L5 replacements I used 25 turns of #22 enameled copper wire on Amidon FT-50-43 ferrite toroid cores. For L6 and L7 replacements I used 20 turns of #22 enameled copper wire on Amidon FT-50-43 ferrite toroid cores. You can purchase the FT-50-43 cores and #22 enameled copper wire from Amidon, P.O. Box 956, Torrance, CA 90508, telephone (310) 763-5770. Write for their catalog. By using #22 wire the finished toroid coil is sturdy enough to be self-supporting. However, I tied the ends of the windings with nylon cable lacing. At the output end of the INTER filter I mounted the toroid on its side flat against the PC board. I mounted the other toroids upright. A partial schematic of the NRD-525 filter board with changes indicated is given below.



Magne's RDI white paper review of the NRD-525 (Edition 2.0: 11 June 1987) stated that 525 filter leakage was "due to cross coupling in the matching networks of the IF stage," and that it "can, under extreme conditions, allow for penetration of adjacent interference." Magne's review also stated that "Sherwood has drawn up a tentative solution -- a variant of that used earlier on the '515 -- to improve the ultimate rejection on the '525 to -80 dB or greater." Sherwood's catalog (undated, about 1991) stated "improvement of existing AM and SSB filters can be realized with circuit changes to the i-f filter board. A 20 dB improvement in existing ultimate rejection is typical. Circuit modifications: \$39.00."

To understand the 525 filter leakage problem, you must consider all of the filters in the receiver. A block diagram of the 525 and some typical filter parameters are given below in Figure 1.

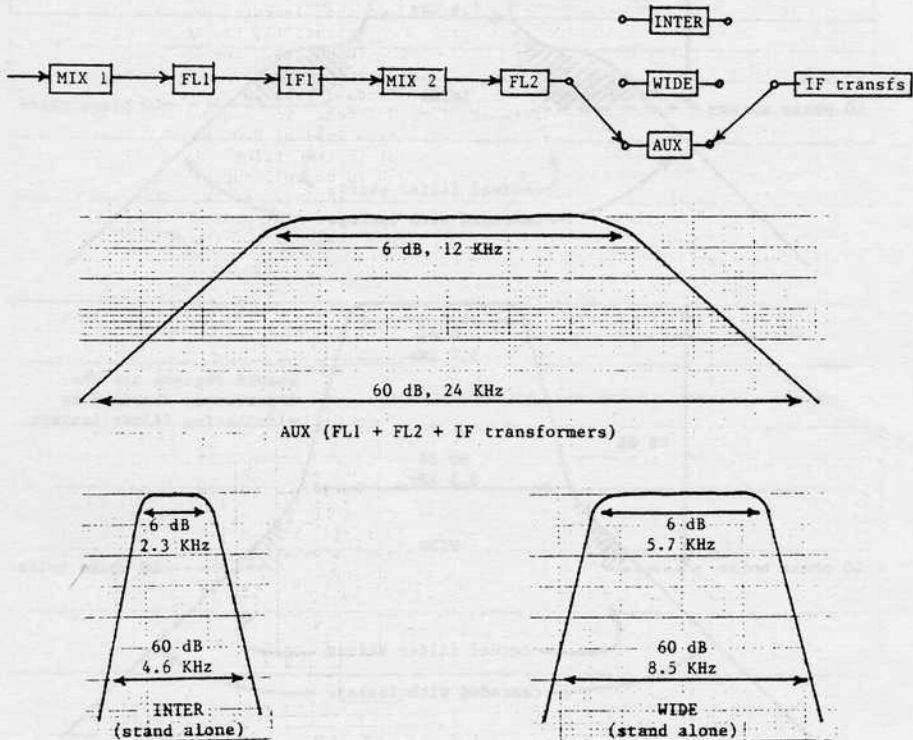


Figure 1

Let us suppose that the ultimate rejection of the WIDE and INTER filters is limited to 65 dB. When either the WIDE or INTER filter is selected, the filter is cascaded with all the other filters in the 525. Attenuation is additive, so the cascaded filter response when measured by injecting a signal at the antenna input and measuring the signal at the audio output should resemble the solid lines in Figure 2 below.

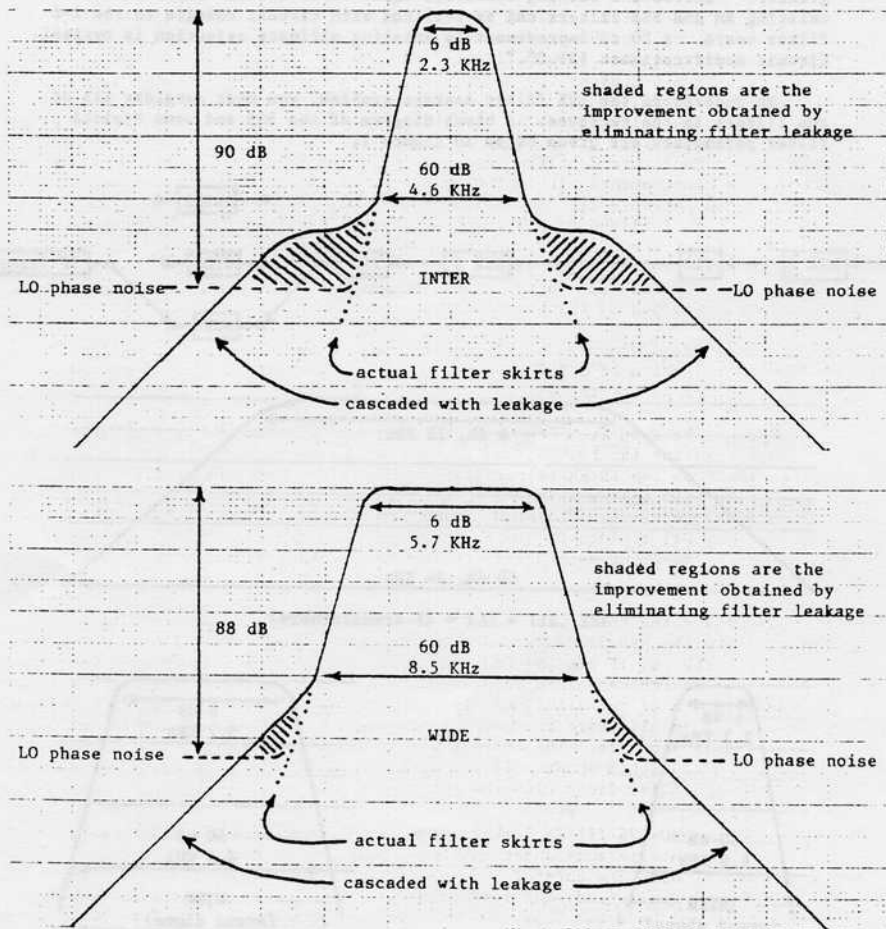


Figure 2

When cascading is included, the ultimate rejection of the WIDE or INTER filter is clearly well in excess of 100 dB. However, the effective ultimate rejection of an NRD-525 within about 50 KHz of a strong signal is determined not by the cascaded filters, but by local oscillator (LO) phase noise for the standard AUX, WIDE, and INTER filters, and for any added filter. In other words, the ultimate rejection of a 525 is LO phase noise limited. For example, at ± 10 KHz from the LO, phase noise is typically 124 dBc/Hz. This means that at ± 10 KHz from a signal injected at the antenna input, noise due to the LO will be about 90 dB down when using the INTER filter, and about 88 dB down when using the WIDE filter. Thus, if you measure the filter shapes by injecting a signal at the antenna input, the ultimate rejection of the WIDE and INTER filters would appear to be 88 and 90 dB respectively at ± 10 KHz. LO phase noise is represented by the dashed lines in Figure 2. LO phase noise begins to fall off slowly beyond ± 10 KHz and may be somewhat higher than shown in Figure 2 at frequencies closer than ± 10 KHz. For example, I have made measurements with a 500 Hz Collins torsion mechanical filter at ± 5 KHz and gotten - 118 dBc/Hz phase noise, or a 92 dB filter bandwidth of 10 KHz. I am inclined to believe that the Collins filter attenuation at ± 5 KHz is in excess of 92 dB, which means that I measured LO phase noise. If that is the case, then the dashed lines should slope upwards as the filter skirts are approached. In any case, the LO phase noise shown in Figure 2 should be regarded as the best one can expect.

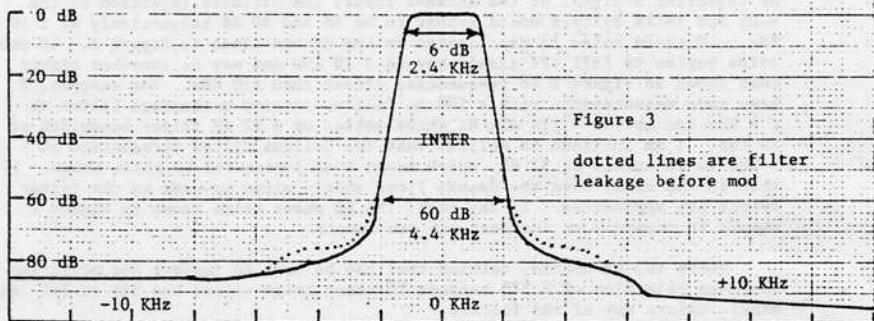
There is, of course, nothing that can be done to improve the effective ultimate rejection of a 525 because LO phase noise enters the 525 at the 1st mixer, before any of the filters.

As can be seen from Figure 2, the mod described at the beginning of these notes, replacing L4, L5, L6, and L7 by toroid chokes, merely eliminates pieces of the hump on the INTER filter skirt below 60 dB, and takes small slices out of the WIDE filter skirt below 60 dB. In fact, it is difficult to measure any difference between "before" and "after" for the WIDE bandwidth. However, you may as well replace L4 and L5 while you have the filter PC board out of your 525 in case you ever decide to replace the WIDE filter with a narrower filter.

I missed the filter leakage previously because I measured the filter skirts with the NRD-525 AGC turned ON, and the signal levels I used were so high that the 1st IF amp and 2nd mixer were driven into gain compression when the signal source was tuned below about 65 dB down on the filter skirt within about ± 10 KHz of the signal source. Beyond ± 10 KHz FL1 apparently has enough attenuation to eliminate the gain compression, and measurements with the AGC on are again accurate. The correct way to measure the deep (below 65 dB) filter skirts within about ± 10 KHz of a signal source is to measure upward from the 525 noise floor with the AGC turned off.

Is the NRD-525 filter leakage substantial enough to allow for penetration of adjacent interference under extreme conditions as suggested by Magne? I doubt it. I did very careful before-after listening under the most extreme conditions I could find, and I could not hear any obvious difference. But then I did not have two 525s, one modified and one unmodified, for simultaneous comparison. So perhaps there are a few DX situations per month where the mod provides slight improvement.

Figure 3 below shows the before-after shape of the INTER filter in my NRD-525. As can be seen, the results are not as dramatic as suggested by Figure 2. The main reason for this difference is that the INTER filter in my 525 did not have as much leakage as suggested by Sherwood. The in-circuit ultimate rejection of my INTER filter was about 75 dB, compared to 65 dB reported by Sherwood. Apparently there may be considerably variation in the amount of leakage from one 525 to another. You can also see that the LO phase noise is not as flat as indicated by Figure 2, and that the LO phase noise for my 525 is not symmetric. The measurements for Figure 3 were made centered at 1880 KHz. I have noticed that at other frequencies the upper and lower LO phase noise sidebands are more symmetric.



One thing is clear as a result of these measurements and observations. Filter cascading by installing add-on filter boards to improve the ultimate rejection of the original 525 filters is unnecessary because the ultimate rejection of the existing 525 filters exceeds LO phase noise when filter leakage is eliminated. Since the amount of phase noise passed by a filter decreases as bandwidth decreases, it is worthwhile to eliminate filter leakage for narrower filters. For example, with a 500 Hz bandwidth Collins CW torsion mechanical filter, the measured noise was 92 dB down at ± 5 KHz. As I said before, it is impossible to determine whether this noise is LO phase noise, ultimate filter attenuation, or signal leakage past the diode switching circuit. But it does establish some upper bounds for each: my 525 LO phase noise at ± 5 KHz is less than -118 dBc/Hz, my CW filter has at least 92 dB ultimate rejection, and the diode switching circuit in my 525 has no more than -92 dB leakage. Some writers have suggested that the 525 diode switching circuit is not capable of such high isolation, but clearly it is.

I would like to express my appreciation to Craig Siegenthaler and Denzil Wright for pointing out that my previous AGC ON method of measurement was not correct in some cases, and to Denzil Wright for many long discussions about LO phase noise and filter leakage.