Experience with the Inrad roofing filter for the TS-940

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Among the roofing filters offered by Inrad (http://www.qth.com/inrad/) there is one with a center frequency of 45.050 MHz, which Inrad designed for the TS-940. I brought this filter back from a recent trip to the USA and now have installed it. As Inrad states on their *'VHF filters for experimenters'* page, the TS-940 transceiver requires some surgery to add this filter. Here are some remarks on the installation procedure I perfomed and a few measurements which show the results.

1. Mechanical installation

I inserted the new roofing filter between the IF and RF boards. It was necessary to very carefully (!) remove about 2 mm from the edge of the IF board next to L3 – L5 in order to get enough space for the Inrad filter. Figure 1 shows where it was installed. The filter was soldered to a small pc board, which also carries two miniature relays. The relays switch from the Inrad filter to the original Kenwood roofing filter (XF1-A, XF1-B, L3-L5), when the TS-940 is set to FM mode. This was necessary because the Inrad filter passband is too narrow for conventional FM.

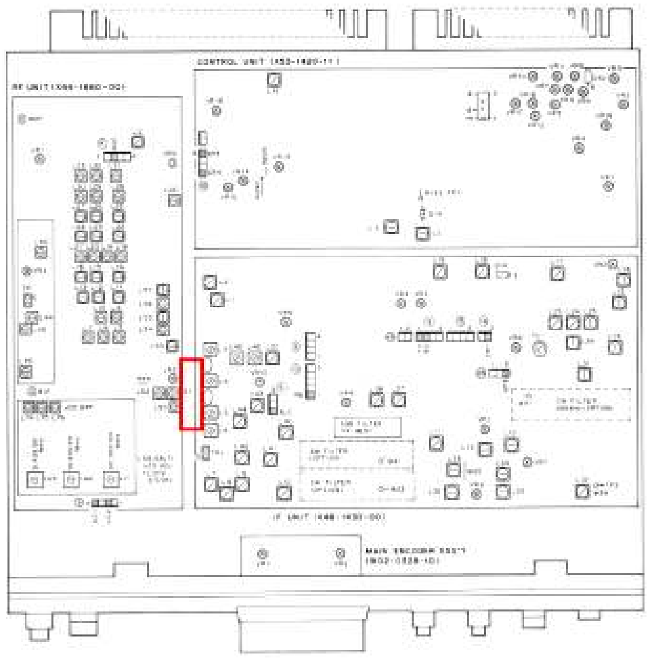

Fig. 1: The red square indicates the position where the new roofing filter was mounted. The vertical position is between the chassis and the bundle of wires travelling along the IF and RF boards.

2. Electrical connections

Inrad designed the filter for input & output impedances of 50 Ohm. Therefore, it appeared possible to feed the RIF signal into the filter input and to connect the filter output to the low impedance primary of L6. The ground connections between the new filter and the IF board had to be as short as possible to obtain good off-band rejection. Figure 2 shows where I derived the signals from the IF board. Two miniature relays (6V types, coils in series) were driven by an NPN transistor in emitter follower configuration. The base was connected via a 2K resistor to the anode of D17 ('K' signal = positive when TRX in FM mode) and the collector fed from the 15V supply (not shown).

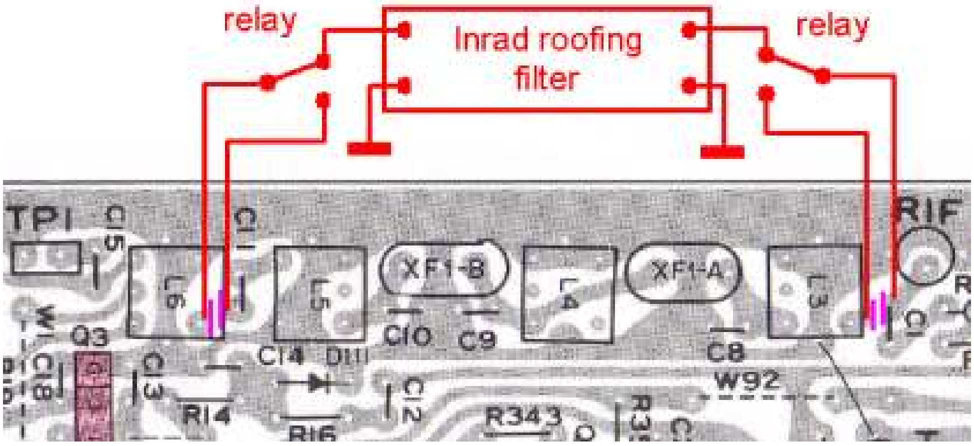

Fig. 2: Insertion of the roofing filter into the first IF circuit of the IF board. Violet lines indicate where the PCB traces were carefully cut.

3. Measurements

As I was not aware of earlier reports about this TS-940 modification, I was curious whether the filter performed as intended. Therefore, I linked a HP8640B signal generator to the TS-940 antenna input and an HP141T spectrum analyser, equipped with a high impedance RF probe, to the drain of Q5 (IF board). The 141T was operated with 100 kHz filter bandwidth, centered to the 2nd IF (8.83 MHz). The sweeping ramp output was connected via appropriate resistors to the FM input (dc) of the 8640B (14.000 MHz center frequency, verified by an external high precision counter). The TS-940 was tuned to 14.000.00 MHz. Similar arrangements proved useful in the past to check the performance of commercial and homemade x-tal filters. I do not have a tracking generator.

Figure 3 shows the passband of the original TS-940 roofing filter, which is active in the modified TS-940 only when switched into FM mode. Coils L3 - L5 were tuned for best filter response before this measurement. The 3 dB bandwidth is approximately 14 kHz.

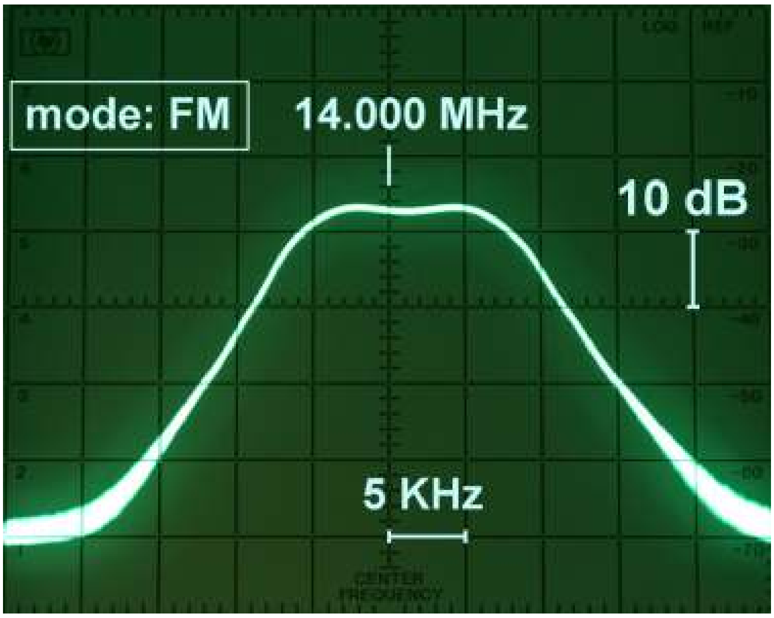

Fig. 3: Passband of the original TS-940 roofing filter (XF1-A, XF1-B, L3, L4, L5). The indicated 14 MHz refers to the frequency of the signal generator at the antenna input. The center frequency of the filter is 45.050 MHz.

Switching the TS-940 to AM activated the new Inrad roofing filter. Figure 4 shows the much smaller 3dB bandwidth of the Inrad filter, which is about 5 KHz. This was exactly what Inrad specified for this filter type. The passband was symmetrically aligned around the center frequency. I observed that the ground connection between the IF board and the filter was very critical. The shorter this connection, the better the off-band rejection that can be achieved.

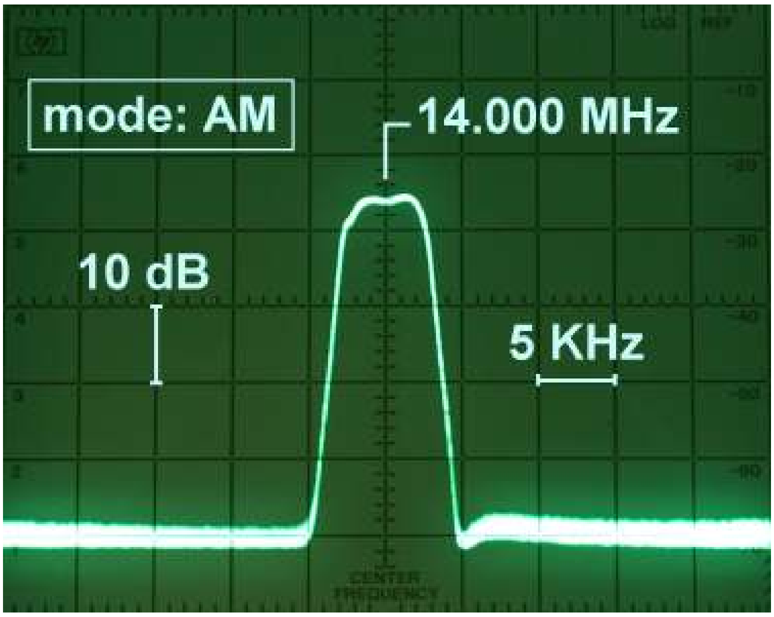

Fig. 4: Passband of the Inrad roofing filter in AM mode. Identical scale as in figure 3. The indicated 14.000 MHz refers to the frequency of the signal generator at the antenna input. The center frequency of the filter is 45.050 MHz.

Next, I found it of interest how the new roofing filter matches with the RX passbands in all possible modes. This is shown in figure 5. The red lines indicate the QRG to which the RX was tuned (14.000 MHz). Not only in AM mode, but also in the CW, USB and LSB the new roofing filter almost perfectly matches the rest of the receiver. FSK is identical with AM and therefore not shown. Obviously, this filter has been manufactured very carefully.

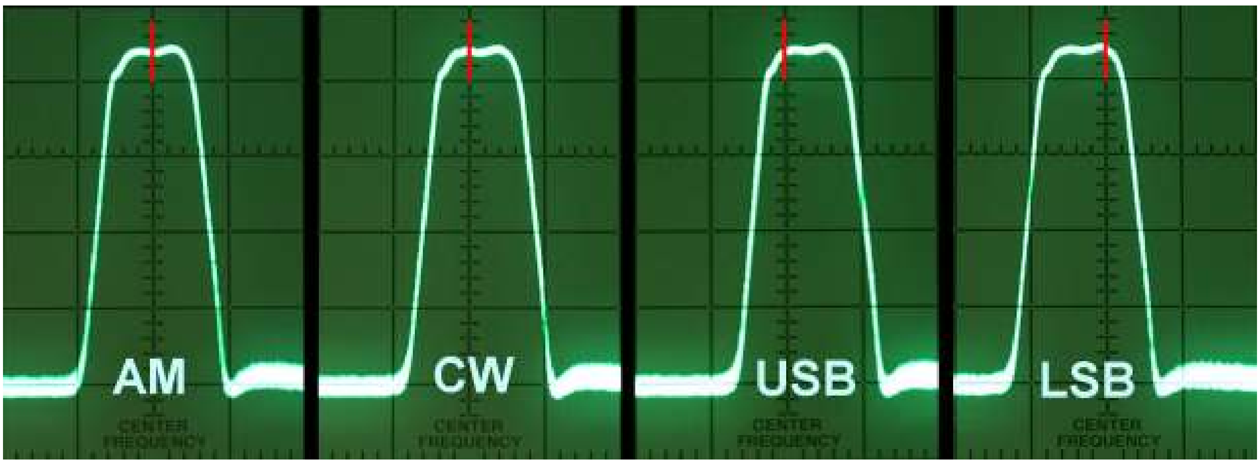

Fig. 5: Passband of the Inrad roofing filter in AM, CW, USB and LSB. Identical scale as in figure 3. The red lines indicate the center of the AM and CW passbands and the zero beat positions in USB and LSB modes. Note that in USB and LSB, the upper and lower sidebands perfectly align with the filter´s flat top.

One would also like to know how the new filter affects RX intermodulation distortion. Therefore, two HP8640B RF generators were connected to a homemade hybrid combiner, which was fed via a variable attenuator into the TS-940 antenna input (RX tuned to 14.1 MHz, mode USB, ATT 0dB, AGC off). The audio output was adjusted to 0.5V on a true RMS voltmeter for a -100dBm reference signal. Then, two-tone measurements were performed with carrier offsets between 3 and 20 kHz. The lower and upper 3rd order IMD products were evaluated on 14.1 MHz and the third order intercept points (IP_3) calculated conventionally (see ARRL handbook). Figure 6 shows the results. As expected from the passband measurements above, the new Inrad filter substantially reduced the 3rd order intermodulation problems of the TS-940 at carrier offsets between 10 and 3 kHz. There was no difference at higher offsets (not shown). Offsets below 3 kHz could not be measured because of noise problems.

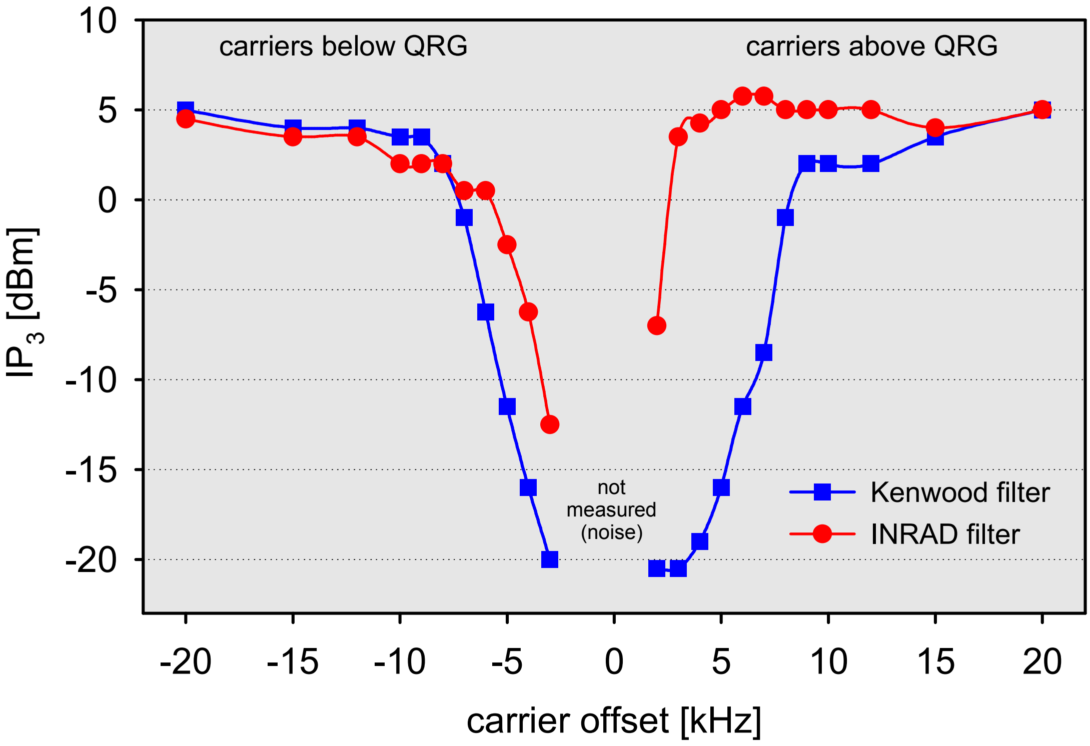

Fig. 6: Third order intermodulation distortion of the TS-940 with the original Kenwood roofing filter (blue) and the new Inrad roofing filter (red). The measurements included upper and lower intermodulation products (indicated by negative and positive carrier offset values in the x-axis).

4. Conclusion

This modification seems to be a real improvement of the TS-940. It is <u>not</u> a beginner´s project, because providing space for the filter and connecting it to the IF board require some effort and experience. The results, however, are excellent. A nice project for the future will be the replacement of the 1st mixer and IF stage (RF board) to further improve the frontend large signal performance.

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I will not be responsible for any damage which may occur in relation to this report. I also can not guarantee that this text is free of mistakes.