Drake R-4C, Filter Leakage Problem.

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This article was originally written in Swedish in 2006 and published in "Resonans", a magazine for ESR, "Experimenterande Svenska Radioamatörer" (www.esr.se). It describes the work and experiments that was carried out to investigate why the Drake R-4C lacks the characteristics expected from a good receiver. This is not intended to be another "modification instruction" but will explain and suggest how to overcome the filter leakage problem and take the R-4C to the next level.

One problem that certainly many observed is that signals are leaking through the narrow crystal filters in the second IF 5695 kHz. This weakness in the R-4C is very clear. If we remove all filters from their sockets, signals can still be heard. This is not acceptable. For decades people have focused on other modifications to improve the R-4C instead of first getting the basics of the receiver to function properly.

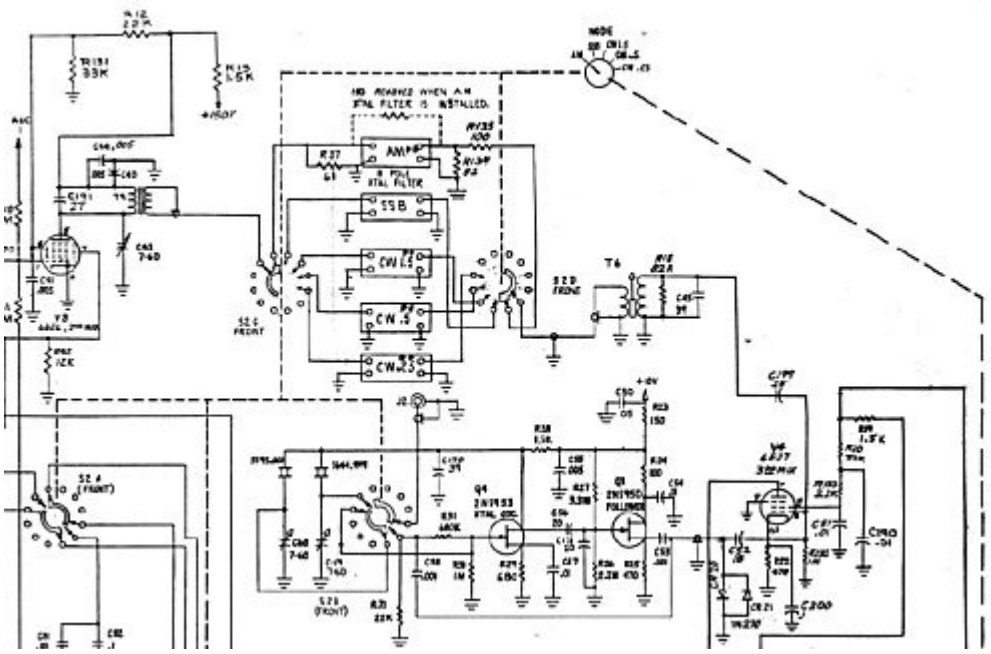

Fig 1. Part of the diagram for R-4C showing how AM, SSB, 1.5kHz, 500Hz and 250Hz filters are switched.

A good receiver should be absolutely quite when filters are removed. This is not the case with the R-4C, it is still alive and many stations can still be heard. A quick fix for many Drake-owners to hide this phenomenon, at least to a certain extend, has been to replace the 8 kHz filter in the first IF to a 600 Hz filter (Sherwood modification). This will satisfy many Drake-owners but the filter leakage problem is still present and should be the first problem to solve before doing other modifications. The weakness in the R-4C which we will take a closer look at will also prove that it is not possible to take fully advantage of the superb narrow 250 Hz filter, this even if you changed the first IF-filter to 600 Hz.

To achieve maximum performance from any receiver it requires an absolute quiet receiver when a filter is removed. In this project we will therefore focus on the 250 Hz filter.

The Drake-engineers was certainly aware of this problem and tried to solve it by adding shield plates in various places. To solve this leakage problem, one must first locate the weak area in the receiver. The intention with this project is to achieve major improvements with minimum efforts.

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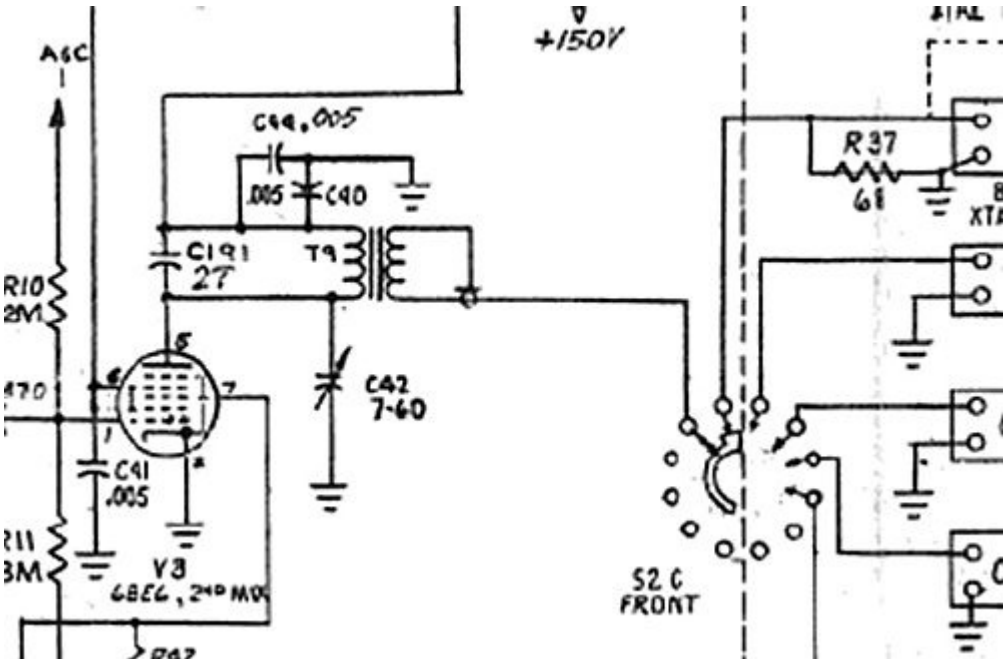

Fig 2. IF transformer T9 with the secondary winding of the filter impedance 50 ohms

Working procedure:
First thing during the test was to disconnect the coaxial cable from the transformer T9 and connect a 50 ohm resistor across the secondary side of T9.

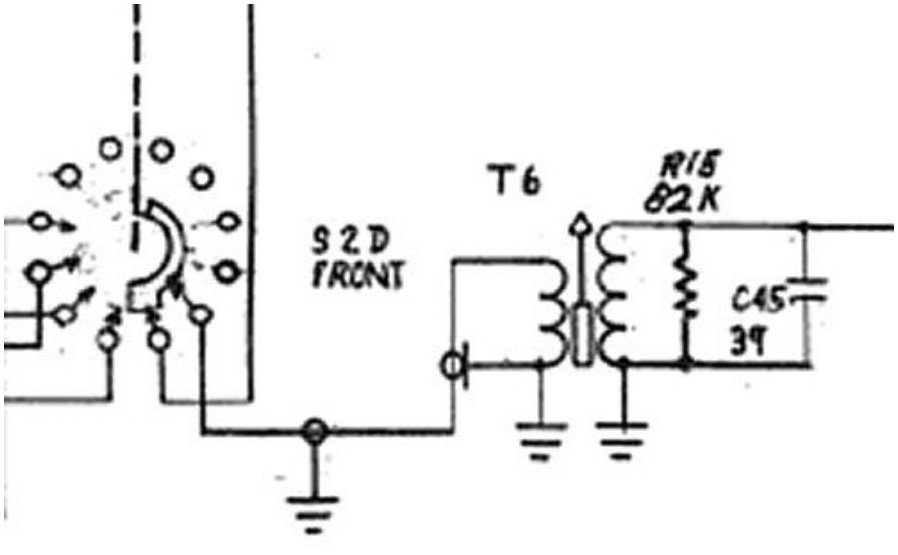

Fig 3. Transformer T6 with the primary winding, the filter impedance is 50 ohms.

The same was done on the primary side of T6. The entire filter assembly with its rotor-switch and cables are now completely disconnected and troubleshooting can begin.
It was quickly found that leakage problems were present and thus one can exclude filter switching package and its coax to be part of the main problem. By using a small plastic isolated screwdriver or probe it is now possible to locate sensitive areas. By approaching components one can quickly locate high impedance points in the structure to find which are sensitive when the noise in the speaker will change.

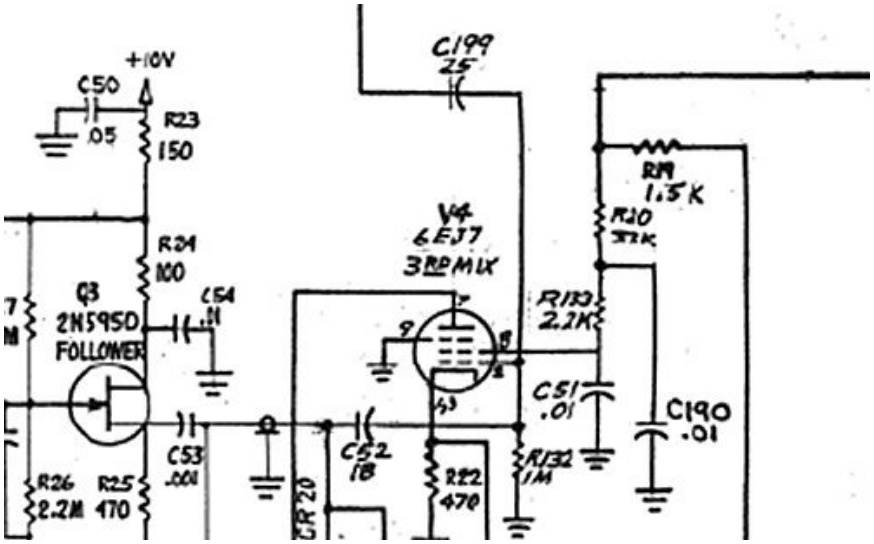

Fig 4. Third mixer

There are already many written articles about problems on the third mixer V4 and various suggestions to improvement including full change of the mixer. This area with its components is hyper-sensitive to external interference. In fact, the area is indeed a fine ”active antenna” in the receiver and effectively picks up all interference signals. This is what we will try to avoid and to solve.

How to trace the problem and find a solution.

The first cure or test was to shorten some wires and move components closer to the chassis. The antenna-effect was reduced but far from enough.

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Fig 5. A closer look at the components at V4.

The probe in Fig 5 pointing at the capacitor C199 (27 pF) which is
connected between T6 high impedance winding (pin at the bottom right of the picture)
to the 3rd mixer (V4) pin 2.



Fig 6. The capacitor C199 is removed

When the capacitor C199 was removed the leakage was reduced by approximately 20 dB.



Fig 7. R 132 1 M moved closer to the chassis to reduce antenna effect.

Next sensitive component found "with antenna effect" was R 132 1 M.
By moving the resistor so the body ended up flat on the edge of the plate on tube holder additional 5 dB was gained. On the same pin is another capacitor C 152, shown in Fig 6. Moving the capacitor to the other side of the shield plate more than 10 dB was gained.
We have now reduced leakage by a total of 35 dB.

In this position, when the filter package is still disconnected, including capacitor C199 between pin 2 (V4) and T6, the receiver was connected to a good antenna and the band was checked. Result. Not a sign of any leakage could be detected.
Now, how good or bad is the 250 Hz filter? This will be measured and the attenuation in the filter will now be our reference for how good isolation is required in the filter-switch.

The filter was connected to an HP 8753D network analyzer. The filter body was grounded to a piece of sheet metal (ground plane 200 x 200 mm) to the board which also included the cable screen. The test set-up without a filter connected showed about 100 dB isolation, which should be enough even for a very good filter.

On visual inspection of the design, we see that the transformer T6 is very unfavorable placed with its terminals (antennas) close to a number of nearby wires. We also see a capacitor with large antenna effect in parallel with T6 high impedance winding.

T6 is now detected to be the weak point in the architecture and will be our target for improvement. Using this method one can step by step continue to find weak point in a receivers design.

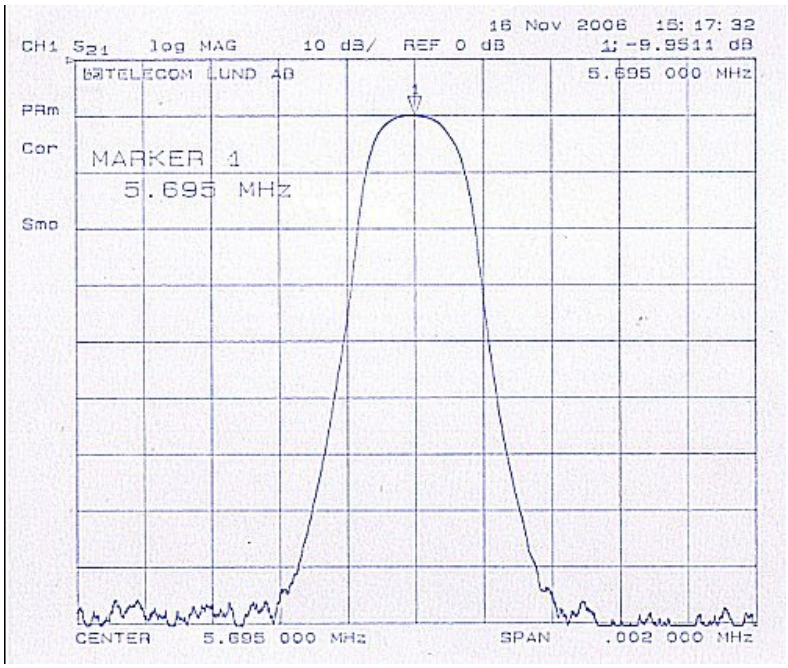


Fig 8: Checking 250 Hz filter in the test jig. Pass Band Attenuation @ 5695 kHz 9.9 dB. Stop Band Attenuation + / - 400 Hz relative to the center frequency of > 87 dB.

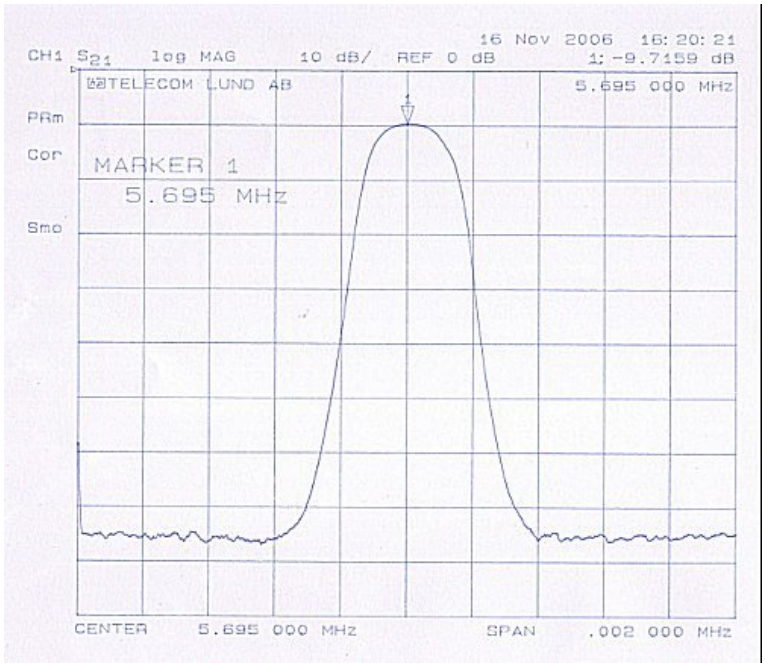


Fig 9. The same filter but now fitted in the receiver together with filter-switch and cables.

Stop band attenuation is now 75 dB or 12 dB lower what the filter can perform under optimal conditions. (See Figure 8)

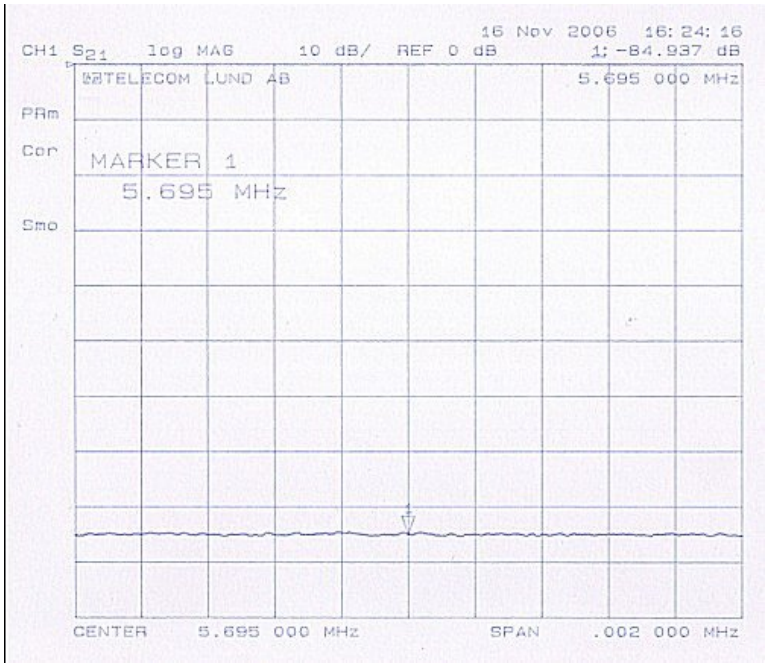


Figure 10. Checking filter switch system. As in Figure 9 above but with the filter removed

These three curves (Figures 8-10) indicate that there is about 12 dB to gain (isolate) by an improved isolation between filter switches inputs and outputs. The existing design consists in total of 20 - 30 mm exposed inner conductors from the coax. The grounding of the cable shields could also have been done in a better way at the Drake factory. We have already achieved 35 dB as mentioned above but in this project we want to investigate how far it is possible to go.

The reason for the very poor result for an unmodified R-4C is probably due to compromises between production time (cost in $) and technical performance achieved in during assembly at the Drake factory.

The question now is if the wiring can be improved sufficiently to gain the 12 dB by a better switch or possibly by RF-relays.

We have already found that T6 and the high impedance winding to the control grid pin 2 (V4) is hyper sensitive. Here we see several possible solutions, and we will now evaluate what solution we find to be the best.

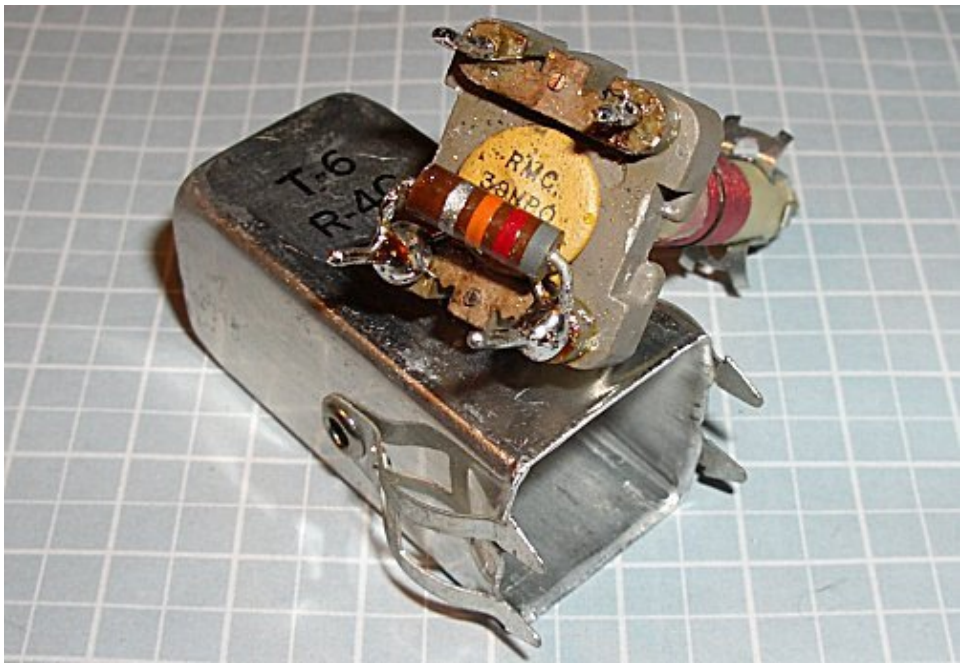


Fig 11. C 45 and R 15 underneath T6 will be moved inside T6 to reduce antenna effect.

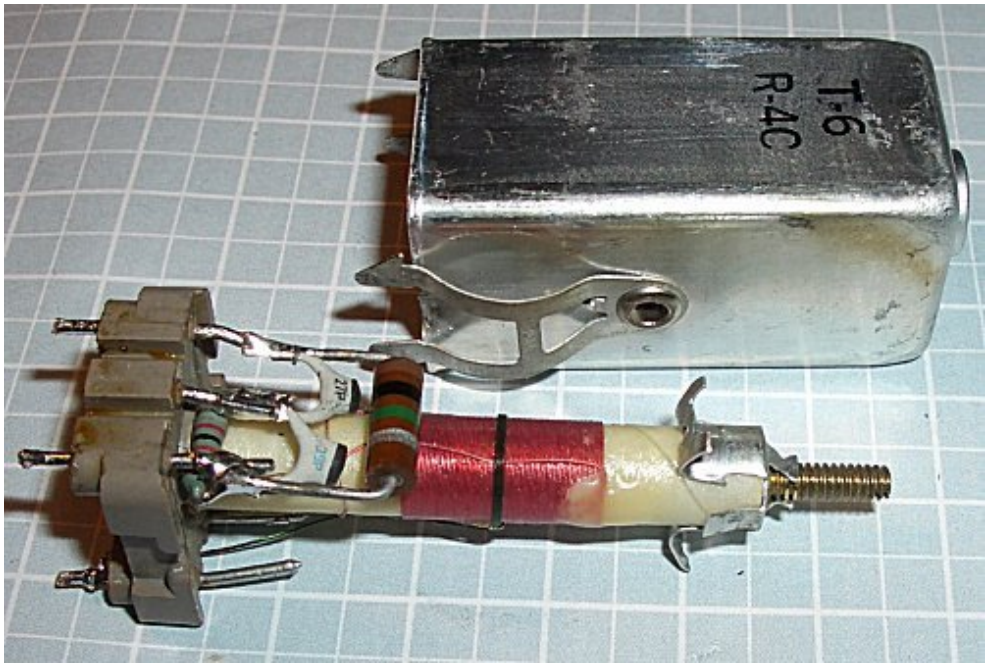


Fig12. There is plenty of space inside T6, we move C199 and R 132 inside T6.

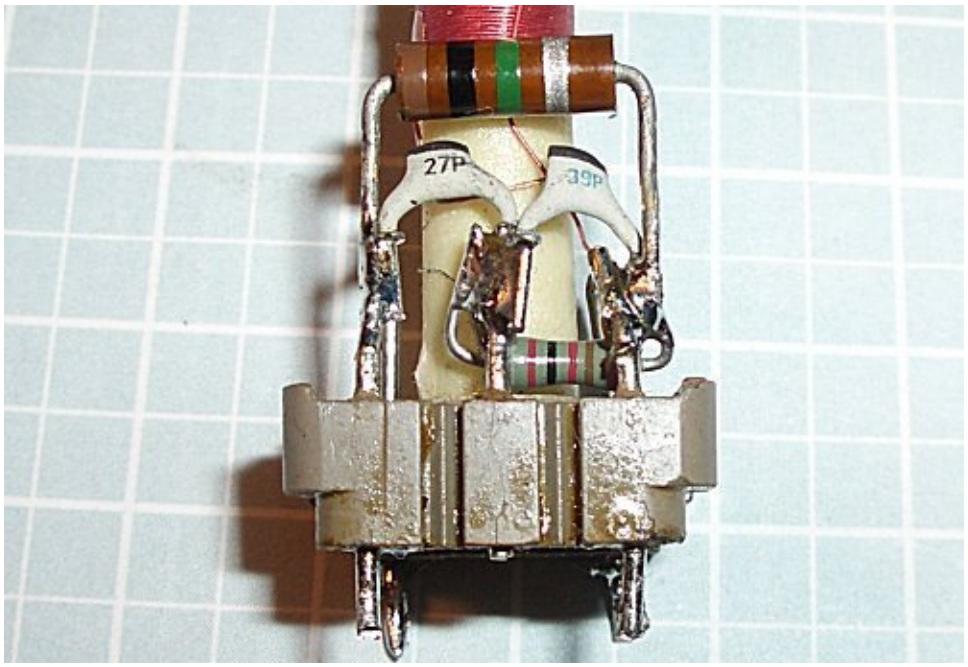


Fig 13. A closer look at the final assembly of T6

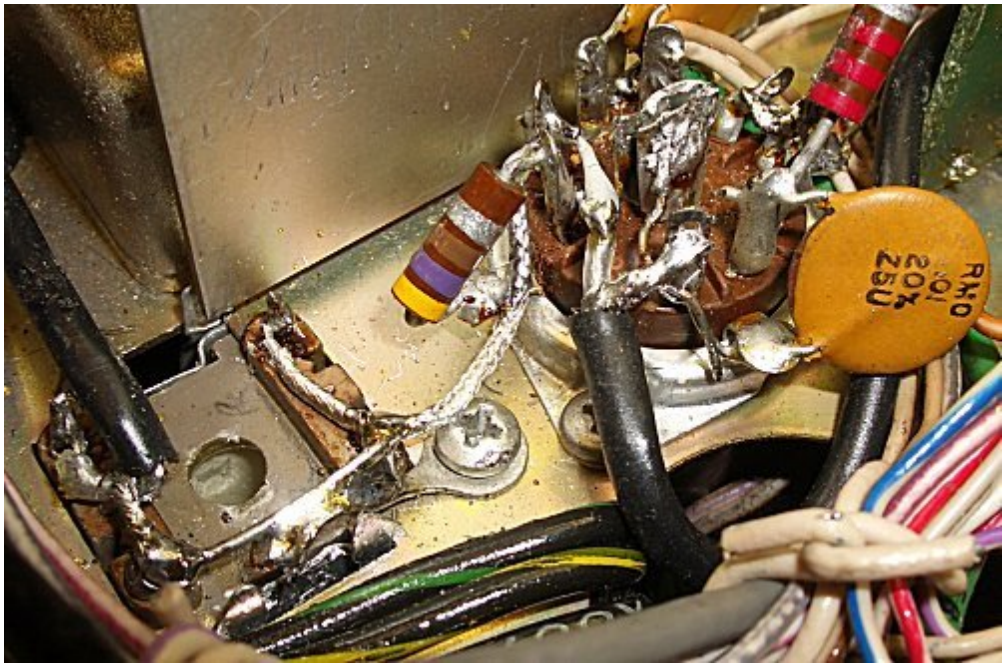


Fig 14. T6 (left in photo) is back in its place. Screen plate that was previously mounted on tube-holder was removed because it is no longer needed.

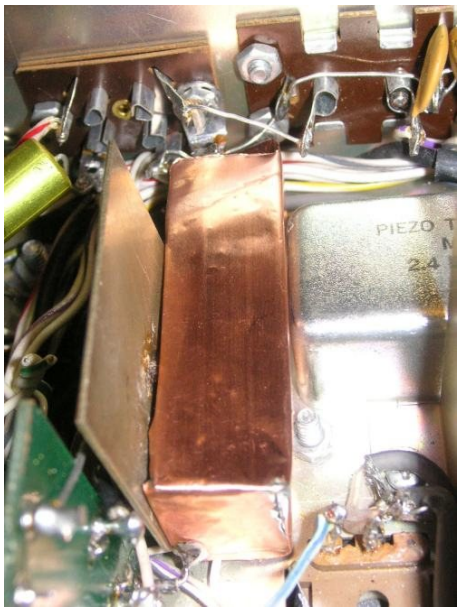
The black coax cable is from the oscillator (on top) for injection signal to the mixer V4. Diodes CR20 and CR21 were also moved to the oscillator board on top side to reduce the "antenna effect". Diodes can be soldered on the back of the PCB without removing the board. The capacitor C52 18 pF was also changed to one with a smaller body.



Fig 15. The high impedance winding of the T6 is connected via a short thin coax to pin 2. The shield is connected to ground.

Now, what have we achieved so far?
The isolation between T9 and T6 without any filter connected was measured to about 85 dB. This is almost the same attenuation as the crystal filter's performance and this limits how good it can be.
Still missing a few dB, either get a shield fitted over T6 and V4 or have T9 and wires around V3 shortened.
To test the Radio "Live" the 250 Hz filter was now moved back into its socket and connected with two 50 ohm coaxial cables directly to the secondary side on T9 respectively primary side on T6.

OOPS! Wow, it’s a new radio. No leakage could be detected and selectivity seems improved.



This figure show how a shield was placed above V4 tube socket in addition to the T6 modification. In this specific R-4C the vertical plate is still in place.

This is really interesting and we can now move on with the experiment.
The next step will be to improve the switching of crystal filters. One idea was to use miniature relays, which can perform 100 to 110 dB isolation.

But, let us give the existing filter-switch a last chance. What is needed is more than 110 dB isolation between the two switch sections. In the original design, we have measured 85 dB. (See Fig 10 above). What is needed is probably to isolate one switch section and hide it into a screened box. Let's see what we can do.

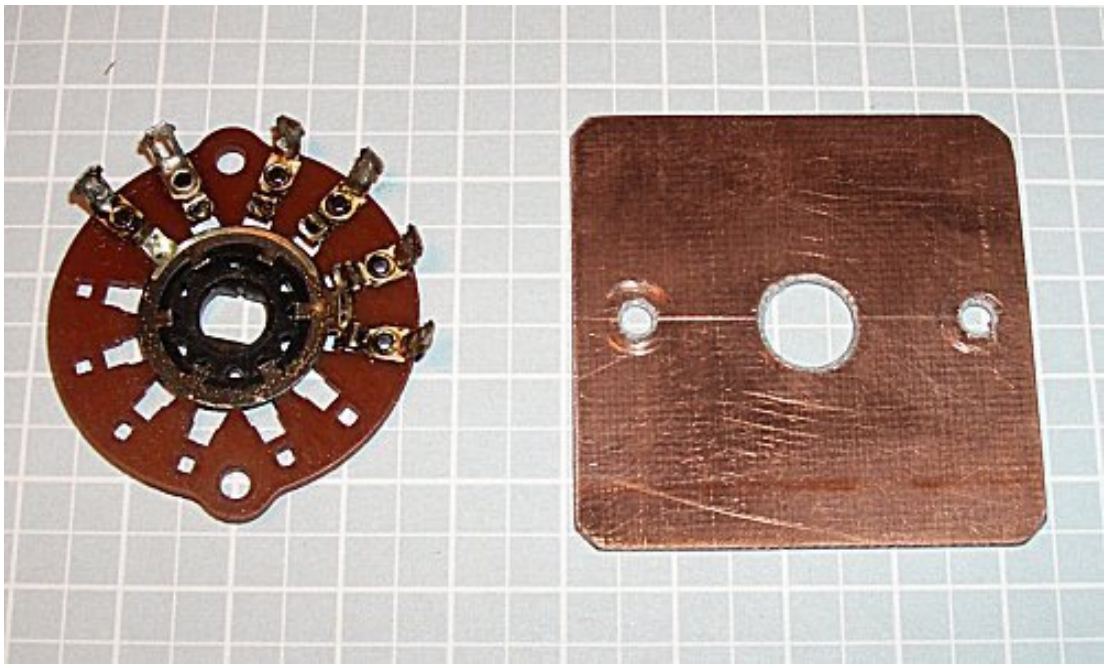


Fig 16. Plain 0.8 mm fiberglass laminate with copper on both sides is easy to use.

To the left we see one switch section and to the right the home-made plate to the screening box which should now be assembled.

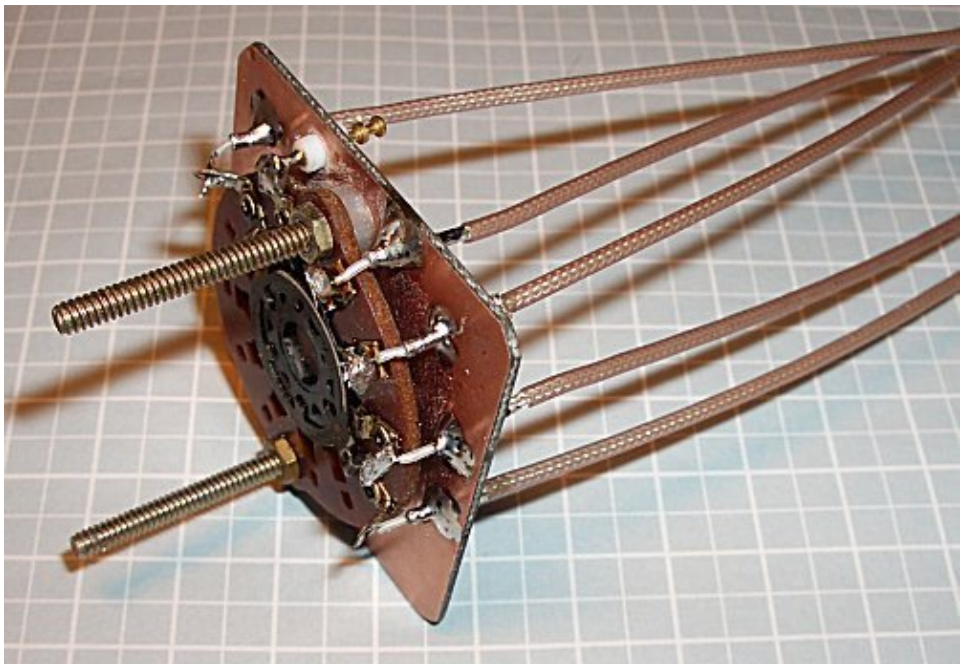


Fig17. Important when handling RF is to arrange a good ground and keep all open wires (inner conductor of the coax) as short as possible.

At frequency 5.6 MHz and attenuation around 100 dB a few millimeter open wire is OK but a few inches will be too long. Note that the coax shield is soldered on both sides of the laminate.

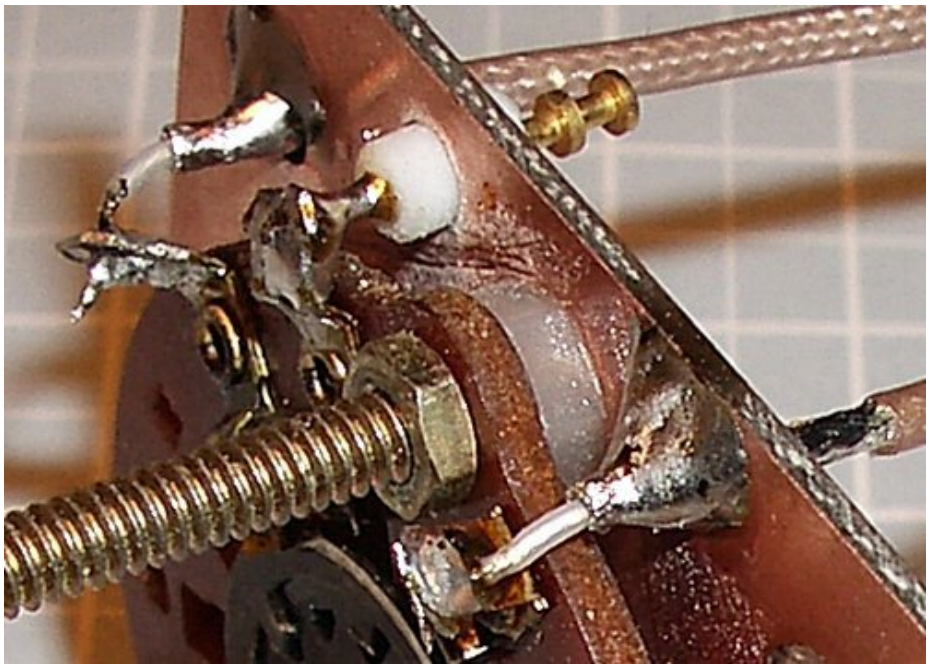


Fig18. The picture shows the connections. Here, the AM filter is connected.

The AM-filter is very close and a possible coaxial cable had only been 5 mm long anyway. A piece of bare wire works fine here.

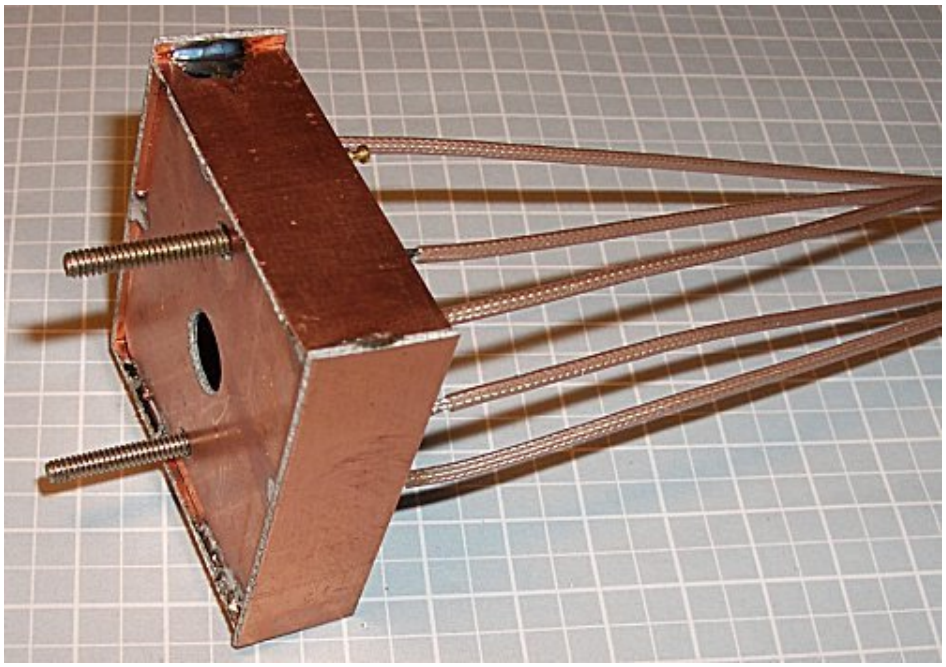


Fig 19. Here is the box-assembly. Coax will go to the filters and to T6.



Fig 20. Switch section to filter inputs. Switch will probably not have to be shielded. We only need one piece of copper laminate. Coaxial cables can be soldered in and that works as both a stabilizing low impedance ground plane and for connecting coax cables.

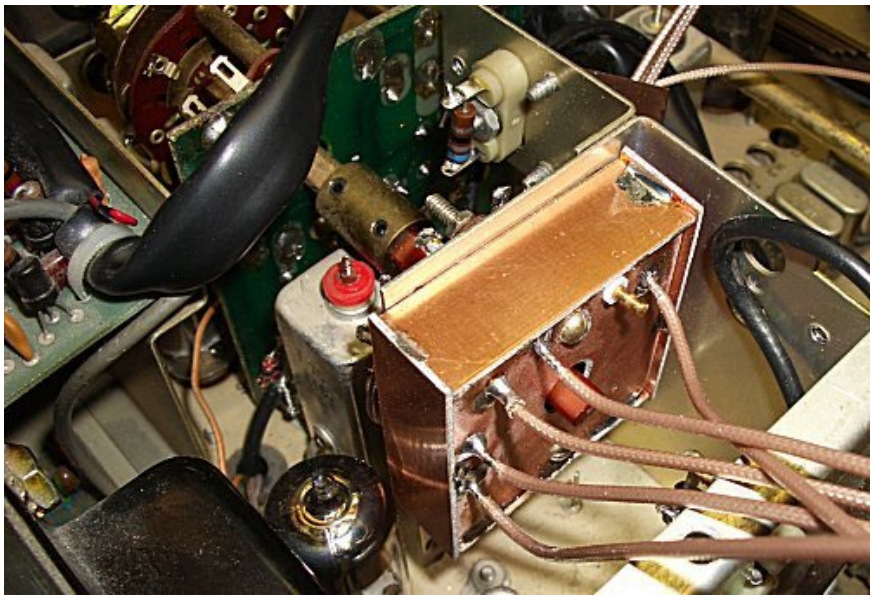


Fig 21. The two switch sections are now in place. Connecting coax takes a few minutes.

What is time consuming with a project like this is to consider and finally determine how to do it and whether to go all the way or only do part of it. .
Will this work? Yeah, we'll see when the network analyzer is connected and tell us the truth. The goal is, as stated > 110 dB, and we end up just around the 100dB that would be enough too, just barely.
But ... the assembly of Fig 21 above gave only 97 dB isolation.

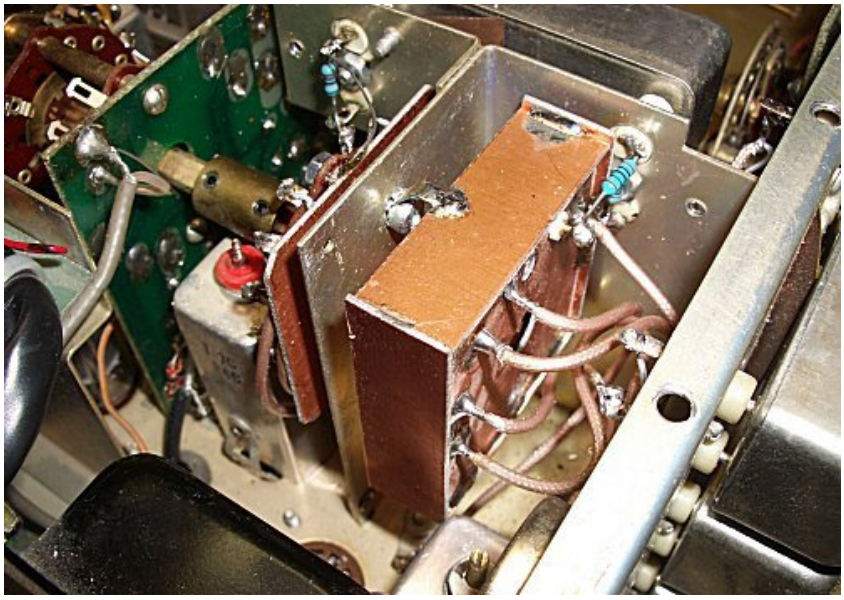


Fig 22. By separating the input and output switches only a few millimeters we increased isolation to 107 dB. Small changes can make a big difference.

The long screws also contributed to the unwanted coupling between the two switch sections and when these was replaced by four separate screw we obtained 117 dB isolation (measured from T9 to T6) which is about 17 dB better than the 250 and 500 Hz filters can perform.

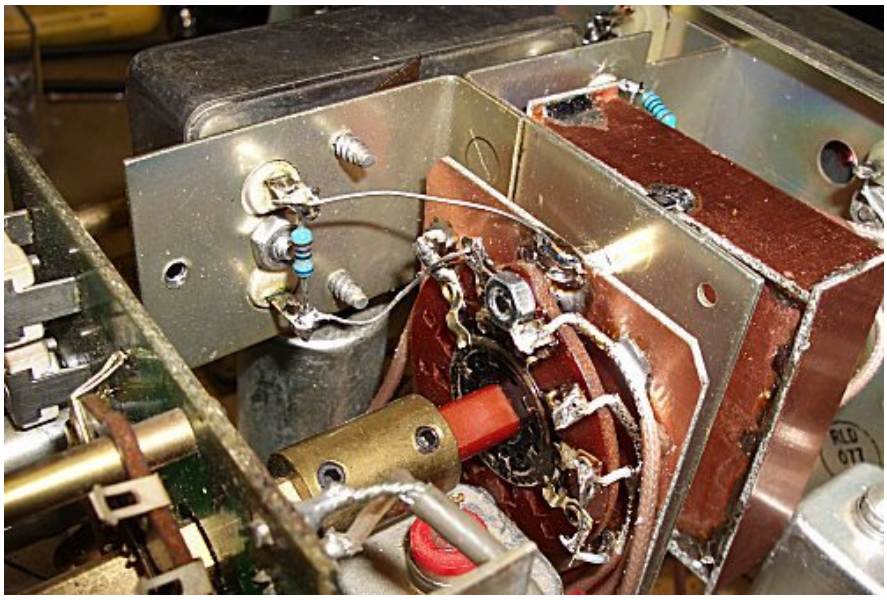


Fig 23. Switch section to the input looks like this.

Now is the time to check the entire switch system with all filters fitted.

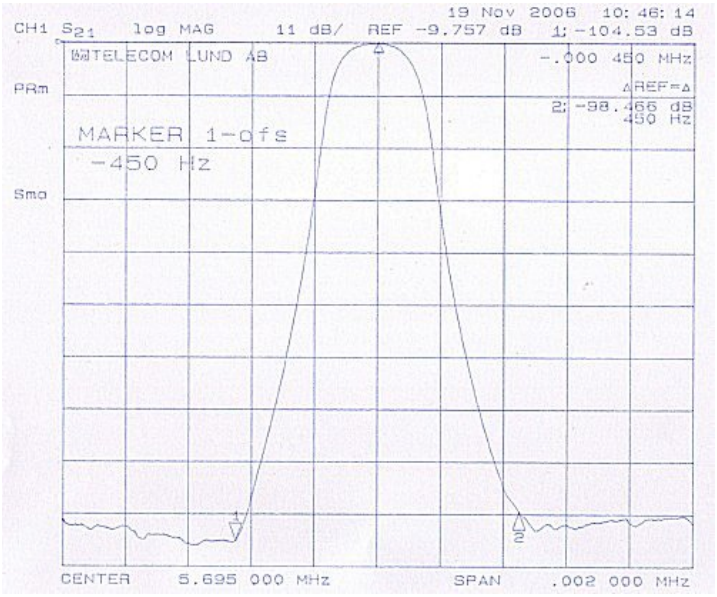


Fig 24. The 250 Hz CW filter. Stop Band Attenuation> 100 dB + / - 450 Hz.

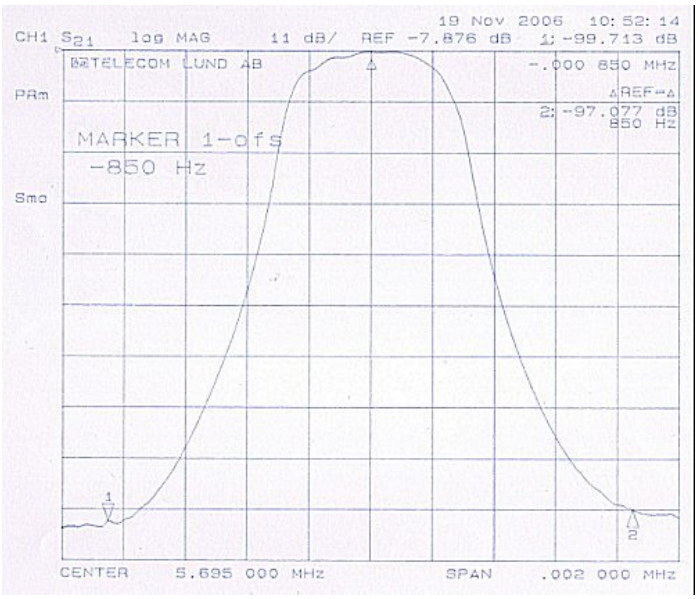


Fig 25. The 500 Hz CW filter. Stop-band attenuation approximately 97 ... 100 dB + / - 850 Hz

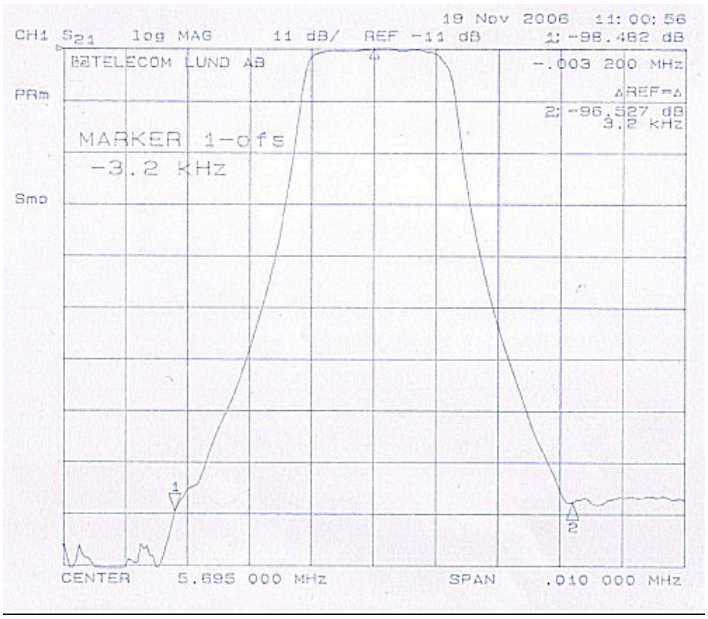


Fig 26. The SSB filter. Stop Band Attenuation about 96 ... 98 dB + / - 3.2 kHz

The experiment is now completed and it is time for evaluation.
Compared to an unmodified original R-4C the result is incredible good. Without any filter installed there is absolutely no signals heard.

Several R-4C have been modified as above. Some have been modified including the switch-system, others with only the changes around T6. It is probably enough to only do changes around T6 to be satisfied and leave the switch-system out. If you still think you need a narrow filter in the first IF, it's for you to decide. A comparison was carried out and yes, there is a difference but it now seems less important.

Check performance of your receiver.

* Remove all crystal filters on the back of the receiver.
* Connect the antenna and listen.

If you now hear any signals your receiver suffers from filter leakage problem. Now,

imagine what you have missed during the past years. Early Drake R-4C can actually see both S5 and S7 signals on the meter without any filter connected. Frankly, a receiver with this problem is totally useless for serious DX-ing especially on 160, 80 and 40 meters. Drake R-4C was made in several versions depending of year of manufacturing. Due to inside wiring the level of “illness” will vary. During this project it was interesting to see how Drakes engineers had tried to overcome the leakage problem by adding shield plates both here and there.

If you want to move another one or two steps further you can do as Tom W8JI, a complete rebuild R-4C where basically only the chassis and knobs retained, or like Phil and Steve VK6APH & VK6VZ wrote in QEX Jan / Feb 2006 - "The Harmanized R4C A High Performance Analog HF Receiver", a very interesting article which is highly recommended.

The above drawings are with reference to Drake schematic 11017421000

August 1st 2013
Drake Forever