Yaesu FT-847 70 MHz band-pass filter simulations

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Being an owner of an FT-847 and also interested in low-VHF propagation, I was fascinated by the technical reports on www.70mhz.org about the 70 MHz capabilities of this radio (and the differences between the UK and other versions). Before doing any filter modification myself I wanted to do simulations for the existing circuit diagrams and if necessary design a new filter.

The first filters that I simulated for this were the **"Original Yaesu FT-847 54-76 MHz RX filter"** and the **"Original Yaesu FT-847 54-76 MHz TX filter"** as found in the service manual circuit diagram. The filter circuits and the simulation results are shown below.

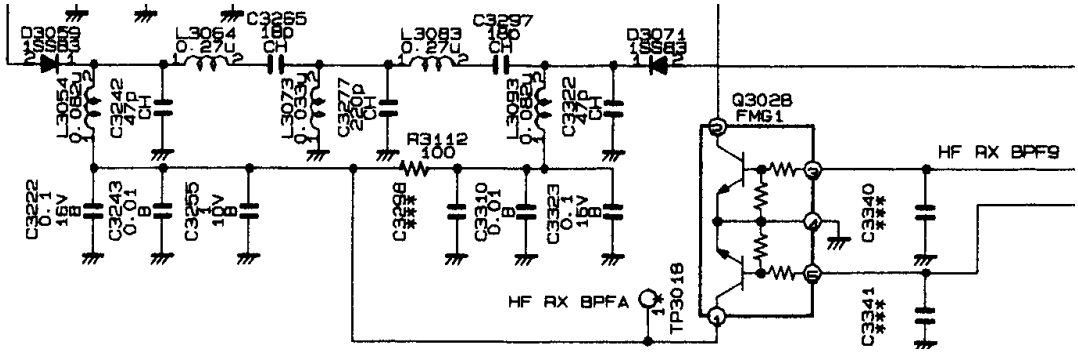

Figure 1: "Original Yaesu FT-847 54-76 MHz RX filter" circuit diagram

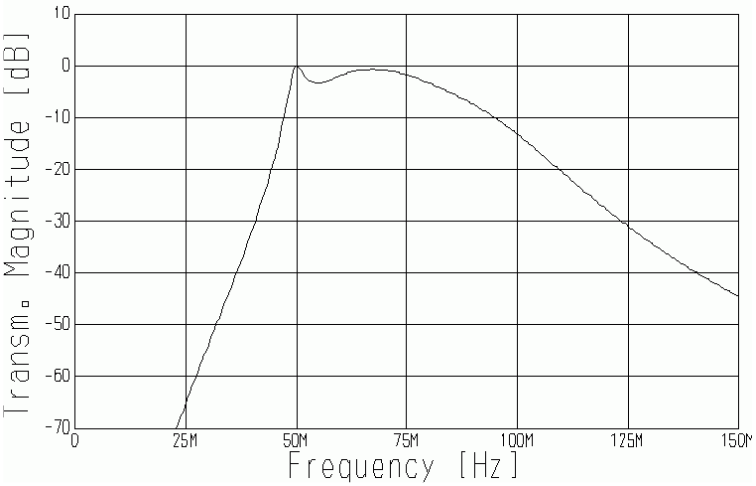

Figure 2: "Original Yaesu FT-847 54-76 MHz RX filter" simulated transfer

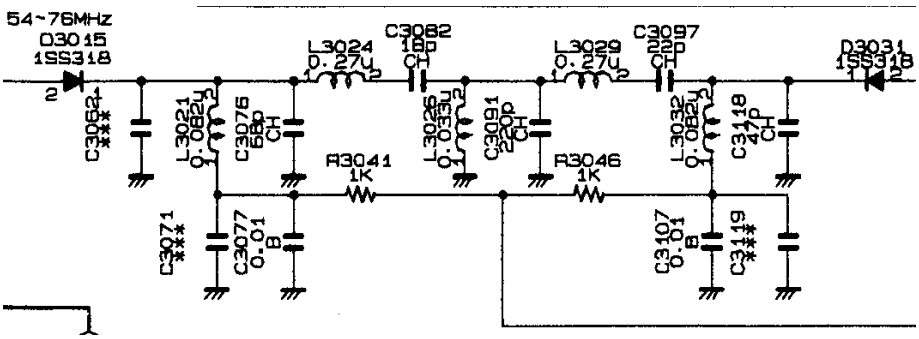

Figure 3: "Original Yaesu FT-847 54-76 MHz TX filter" circuit diagram

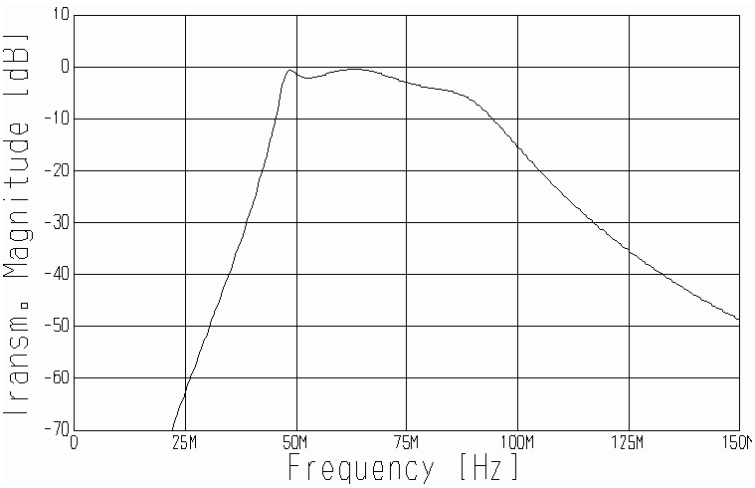

Figure 4: "Original Yaesu FT-847 54-76 MHz TX filter" simulated transfer

These filters have significant ripple in the passband between 54 and 76 MHz, an effect that can be noticed in practice by variations in the receiver's noise level when tuning on different frequencies. This is definitely something to improve because it also affects the noise figure of the receiver. The figures below show pictures of the original RX and TX filters.

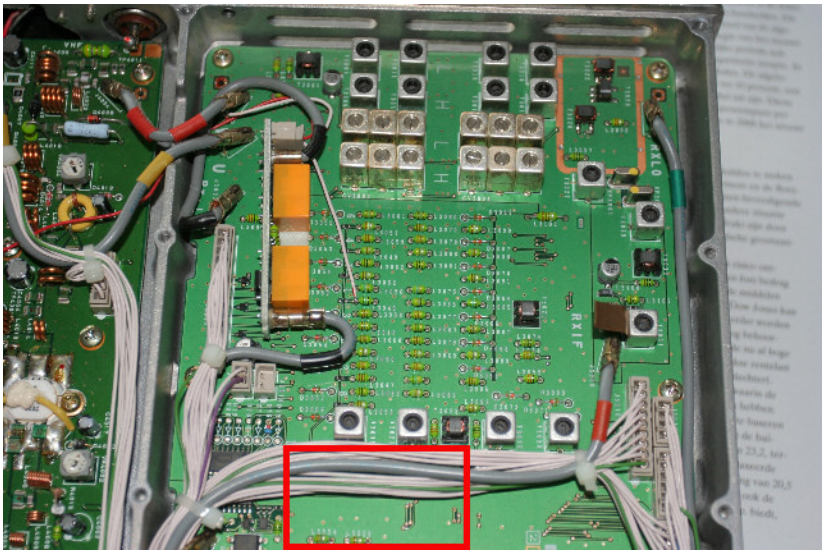

Figure 5: PCB top view of the original 54-76 MHz RX and TX filters

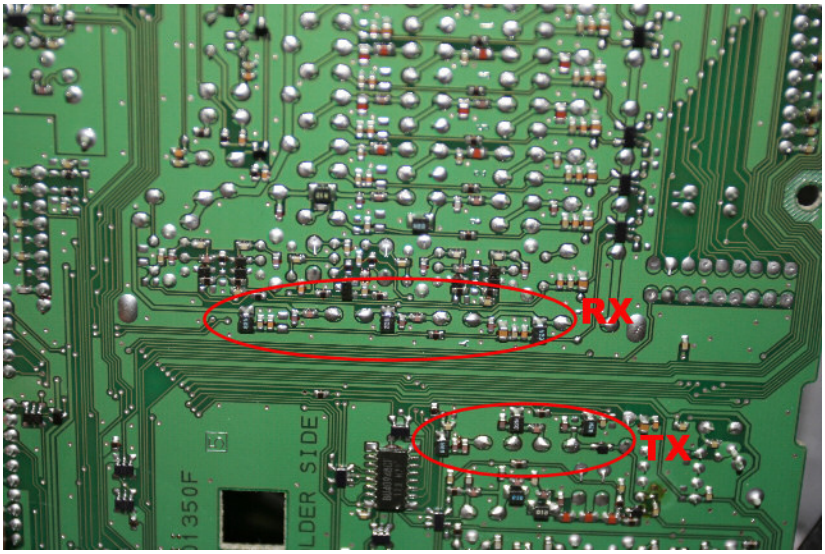

Figure 6: PCB bottom view of the original 54-76 MHz RX and TX filters

The component values in the original Yaesu filters are asymmetrical, and the resonance frequencies of the poles are offset. To me this looks like a result of some tweaking by the Yaesu engineers, so I tried to reconstruct the **"Might have been Yaesu FT-847 54-76 MHz RX filter"**. With symmetrical component values, almost the same values as the filters in the service manual, this resulted in an almost ripple-free passband between 54 and 85 MHz.

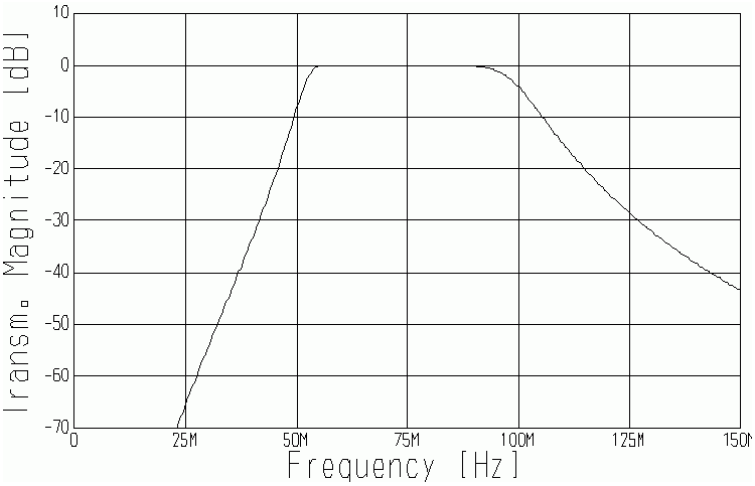

Figure 7: "Might have been Yaesu FT-847 54-76 MHz RX filter" simulated transfer

So why did Yaesu change this? Probably to increase attenuation of FM broadcast band signals between 88 and 108 MHz without changing too many component values. In practice this attenuation is insufficient because I still experience faint broadcast interference.

So what we need is a filter with low ripple between 54 and 76 MHz and more attenuation above 88 MHz (exact requirements depend on your local FM spectrum). If possible a filter that uses standard fixed component values. Using Filtermaster software, a new filter was designed with the same topology as the original filter: the **PA1O 54-76 MHz RX filter** below.

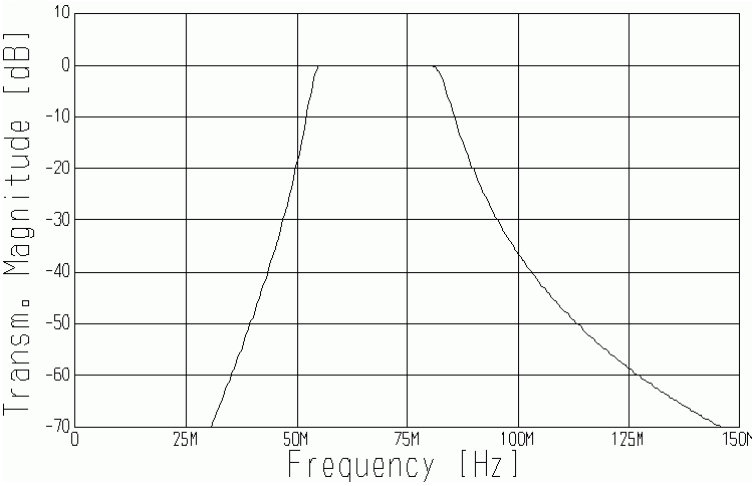

Figure 8: "PA1O 54-76 MHz RX filter" simulated transfer

Ripple between 55 and 76 MHz is less than 0.2 dB (attenuation is 1.8 dB at 54.0 MHz, the lower edge of the filter passband). The attenuation at 70.0 MHz is theoretically 0.034 dB, but in practice this will be higher because of component tolerances and losses of the

components. Attenuation from 88 to 108 MHz is 16 to 45 dB respectively, this means 6 to 26 dB improvement compared to the original filter. This is even 16 to 33 dB improvement compared to what "Might have been Yaesu FT-847 54-76 MHz RX filter". The PA1O filter should be easy to reproduce, with only one critical low-value inductor of 27 nH. I will use an SMD inductor, but you may want to create your own air-inductor. Be careful with parasitic inductance though, compensate about 1 nH/mm for you lead wires!

Now what about the TX filter? The 46 MHz (first LO frequency) attenuation of the PA1O 54-76 MHz RX filter described above is only 32 dB. This will cause spurious signals of the same magnitude within the transmit band. Fortunately the FT-847 uses separate filters for RX and TX, so we can combine wideband RX with narrowband 70 MHz TX. I decided to use the **UK factory mod 70 MHz TX filter on the** internet, but I found out that these filter component values are absolutely incorrect!

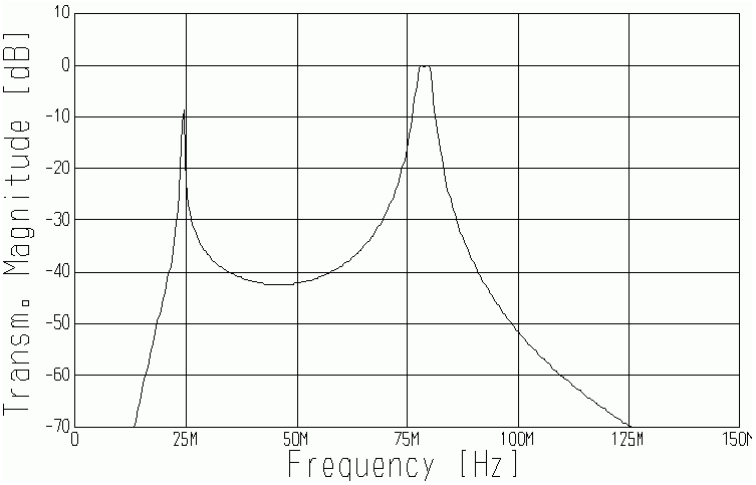

Figure 9: "UK factory mod 70 MHz TX filter on the internet" simulated transfer

This filter would never produce a TX spectrum with spurious 55 dB down as measured by UK amateurs, so Yaesu must have used different values. Two inductor values (330 nH and 150 nH) appear a factor ten too large, probably they were misread from components.

With the right values the **UK factory mod 70 MHz TX filter with correct inductor values** gives the following filter curve:

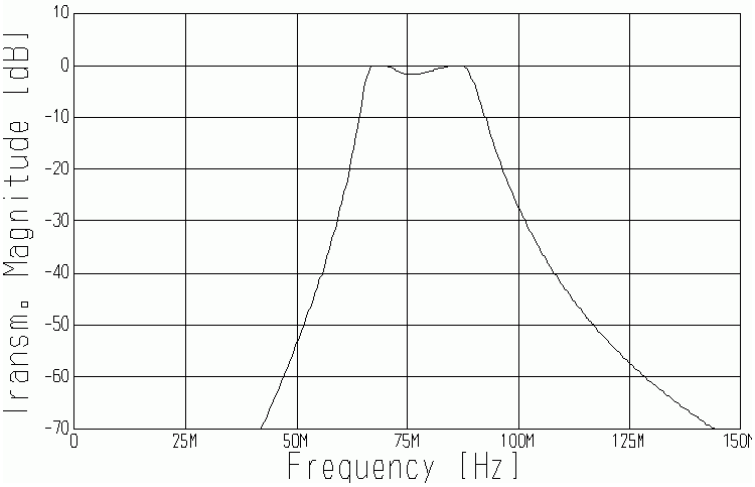

Figure 10: "UK factory mod 70 MHz TX filter with correct inductor values" simulated transfer

This filter delivers a sufficient 62 dB suppression on 46 MHz, and the ripple between 70 and 70.5 MHz is circa 0.1 dB. It looks like the correct component values were found indeed. I did try and get rid of the dip on 75 MHz, but this reduces the suppression on 46 MHz, so I decided not to change the values anymore.

Besides the 15 nH inductor, this filter has two more critical low-value inductors of 33 nH at the input and at the output. Be careful: They are also used to bias the switching diodes and de-coupling capacitors to ground must be placed close to the inductor. (These are indeed the capacitors of 100 nF that Yaesu added in the factory modification).

Below you can find pictures of my filter modifications.

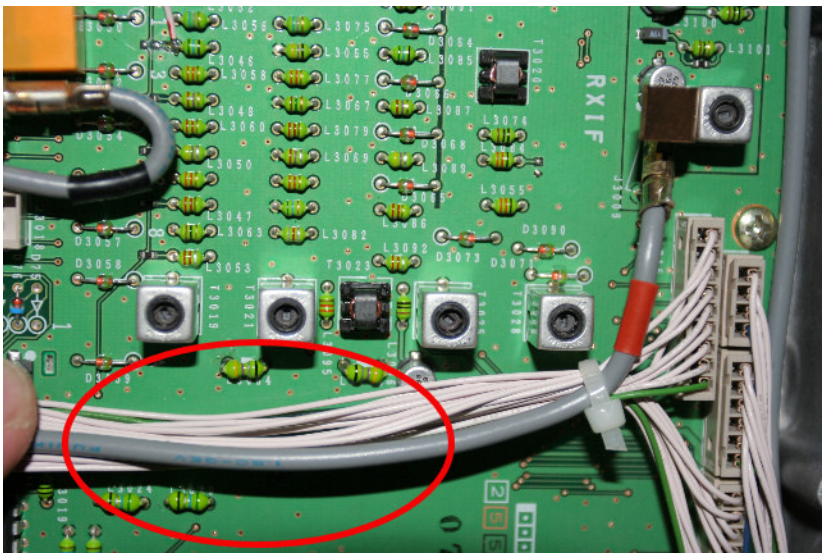

Figure 11: PCB top view of the modified 54-76 MHz RX and TX filters

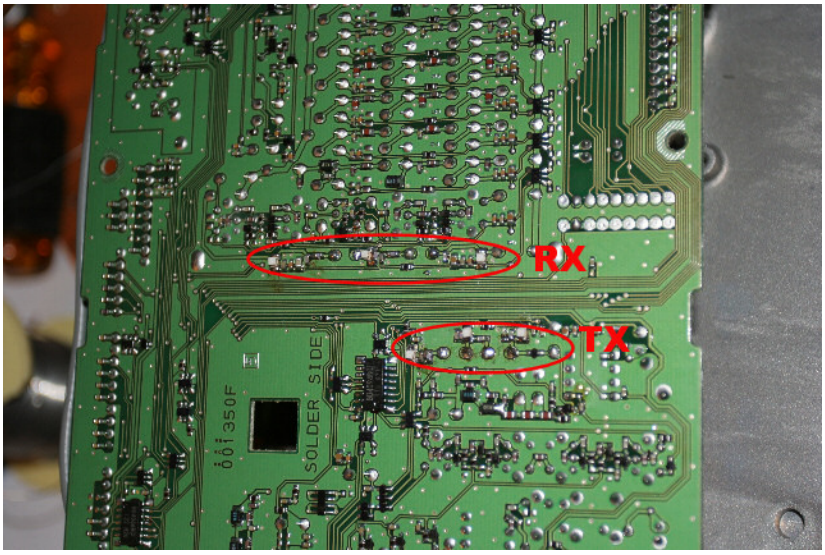

Figure 12: PCB bottom view of the modified 54-76 MHz RX and TX filters

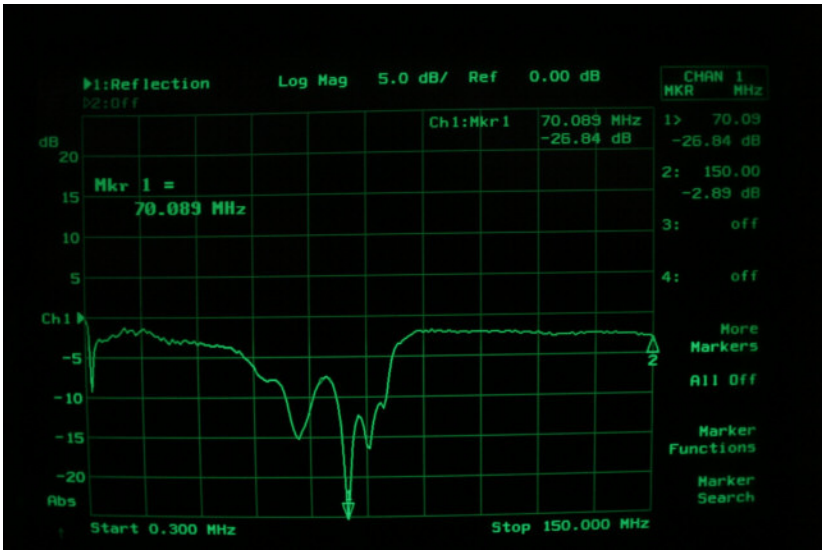

Figure 13: Transceiver input reflection measurement for 54-76 MHz band.

Appendix: Simulated filter component values

Original Yaesu FT-847 54-76 MHz RX filter

C3242 // L3054	47 pF // 82 nH
C3265	18 pF
L3064	270 nH
C3277 // L3073	220 pF // 33 nH
L3083	270 nH

C3297	18 pF
C3322 // L3093	47 pF // 82 nH

Original Yaesu FT-847 54-76 MHz TX filter

C3076 // L3021	68 pF // 82 nH
C3082	18 pF
L3024	270 nH
C3091 // L3026	220 pF // 33 nH
L3029	270 nH
C3097	22 pF
C3118 // L3032	47 pF // 82 nH

"Might have been" Yaesu FT-847 54-76 MHz RX filter

C3242 // L3054	56 pF // 82 nH
C3265	18 pF
L3064	270 nH
C3277 // L3073	150 pF // 33 nH
L3083	270 nH
C3297	18 pF
C3322 // L3093	56 pF // 82 nH

PA1O 54-76 MHz RX filter

C3242 // L3054	120 pF // 47 nH
C3265	12 pF
L3064	470 nH
C3277 // L3073	213 pF // 27 nH (180 pF // 33 pF to get 213 pF)
L3083	470 nH
C3297	12 pF
C3322 // L3093	120 pF // 47 nH

UK factory mod 70 MHz TX filter on the internet

C3076 // L3021	120 pF // 330 nH
C3082	8 pF
L3024	560 nH
C3091 // L3026	270 pF // 150 nH
L3029	560 nH
C3097	8 pF
C3118 // L3032	120 pF // 330 nH

UK factory mod 70 MHz TX filter with correct inductor values

C3076 // L3021	120 pF // 33 nH

C3082	8 pF
L3024	560 nH
C3091 // L3026	270 pF // 15 nH
L3029	560 nH
C3097	8 pF
C3118 // L3032	120 pF // 33 nH