FM Broadcast "Fix" for the Yaesu FT-1802M

26 June 2011

I have two of these 144-148MHz 50 watt mobile transceivers with one normally fitted in the car I drive around. The other has been languishing in my shack unused for a few months since I removed it from the other family car. One of the things I have noticed since I added more channel memories to scan while mobile is that occasionally I would hear what sounded like FM or TV broadcasting sound content (or more commonly called " break-through ") on one or more of the memory channels. Wide-band FM interference on a narrow-band FM receiver is really "chopped up" so it is easy to confirm the style of the interfering source's modulation, even if it hard to understand the audio.

I needed to take the transceiver out of the car to effect another repair, did that one then connected it to the discone antenna that feeds down into my workshop. Once it was powered on, it commenced scanning - as usual. No sooner than it started scanning than it stopped on what was definitely a FM broadcast signal. I quickly tuned another receiver across the FM band and found that the audio content was the same as 103.700 MHz yet the transceiver was displaying 147.100.

I reviewed the original FT-1802M specifications and it said that image response was >70dB so it couldn't be that - could it ? I couldn't think of any other reason so started looking at the frequencies involved. The specs sheet indicates a 21.4MHz "first IF" and a 450KHz "second IF". The textual description indicates low side injection into the mixer. My calculator produced the maths :

147.1000 - 21.400 = 125.700 MHz for the local oscillator

If the problem was a direct mixing image, the receive frequency would be 21.4 lower than the LO.

125.700 - 21.400 = 104.300 MHz for the image when tuned to this frequency (147.100), so while 103.7 was near - but not exactly on frequency - given the wide transmission bandwidth, it was a likely culprit.. Subtractive mixing where additive mixing is the primary mode desired.

Now it was time to check the details of the transmission on 103.7 for a service in the Brisbane area. I accessed the public ACMA register via the web and it showed a 20KW EIRP transmitter at nearby Mt Coot-tha. Yes, that was the problem... but what was the answer ???

I looked at the schematic of the receiver front end in the FT-1802M as it appeared in the Technical Supplement (ie the Service Manual) and the only thing it showed that was at all unusual was the use of several stages of varicap / varactor tuning. Given the wide receiver range, that probably is the only way Yaesu could achieve the sensitivity figures they quote.

My next step was to measure the receiver performance at the two frequencies involved, 147.1 and 103.7. The sig gen was connected, as was a Sinadder, and the sensitivity at 147.1 measured then the generator was shifted to 103.7 and again measured, both for 12dB SINAD. These and all subsequent measurements are at the same standard : 12dB SINAD.

Initial values :

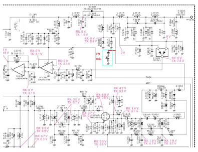
147.100 generator, 147.100 receive : -123dBm

103.700 generator, 147.100 receive : - 46dBm

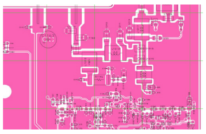
It meets the quoted Yaesu >70 dB image specification.

My thoughts turned to adding a series-tuned resonant trap at 104 MHz at the receiver input, but where could it be added without causing major issues in receive performance. I decided to try across D1020 as it was at a position in the circuit before the varicap-tuned stages but in the receive segment only. My previous experience with series LC-traps was that I could expect a typical "notch-depth" of around 20dB and that might be enough. The actual depth will always depend on the Q of the inductor and the equivalent series resistance (ESR) of the capacitor as well as the impedance at the point across which it is connected..

I looked in my parts box and found that I had both 50nH and 100nH slug-tuned inductors available. My LC calculator indicated that I needed 47pF to resonate the 50nH version and 27pF for the 100nH version in the FM band.



Schematic showing added components as a series-resonant LC filter at about 104MHz.



This is an extract from the PCB layout in the Tech Supplement showing the location of D1020, towards the LHS, just down from the horizontal centre line.

In reality, both were tested and both worked. The sig gen was set to 103.7 and the level adjusted to give a noisy signal in the receiver. The slug tuned coil was adjusted for maximum noise - or if you prefer, minimum signal. I decided to leave the 100nH + 27pF combo in place as it was physically the neatest.

With the trap fitted :

147.100 generator, 147.100 receive : -120dBm

103.700 generator, 147.100 receive : - 29dBm

The addition of the trap had reduced the receiver sensitivity at 147 by around 3dB but had improved the image rejection by 17dB.

To show the difference in real terms, the S-meter on the receiver was used. At 147.1 receive and the generator set to 103.7, it showed S1 at -24dBm with the trap connected and a massive S7 without it.

I left the trap in place in that radio and moved on to the next transceiver.

It was modified in the same way but before and after measurements were taken for comparison.

Initial values :

147.100 generator, 147.100 receive : -123dBm

103.700 generator, 147.100 receive : - 45dBm

With a series-resonant trap fitted across D1020 :

147.100 generator, 147.100 receive : -120dBm

103.700 generator, 147.100 receive : - 23dBm

This shows a drop of 3db in effective sensitivity but a 22dB improvement in image rejection. This is a bit different value to the first one, but is sort-of expected.

A different S1 test was carried out this time. The generator was set to 147.100 and the level raised until the S1 indication just appeared : -114dBm. The generator was moved to 103.700 and the attenuator again adjusted for the same S1 indication : -17dBm.

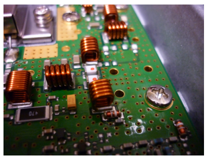
To me, the improvement in image rejection is worth the minor drop in overall receiver sensitivity. I don't normally use these units outside the 146 to 148 range and by having the trap tuned near the middle of that range, it will still provide a measure of extra FM signal rejection.

If you don't have access to a suitable coil, you can wind your own air-wound style with enamelled copper wire. A coil of 7 turns wound on a 4mm diameter tempory former (eg a twist drill stem), about 6mm long will give an inductance of 100nH. The wire diameter needs to be around 0.8mm to achieve the overall length dimension. Once installed in the circuit with a 27pF series capacitor, it needs to be stretched or compressed to a shape which gives the deepest notch on any evident FM-band signal. A "dab/run" of nail polish along the turns afterward will hold it in shape.

The photos below show how and where the traps were fitted. Minor differences exist between the placement of the parts in the two radios but only one had photos taken before any modifications.

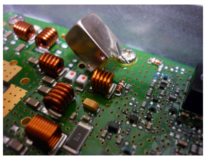
Mouse-over for larger images :

View before any modification

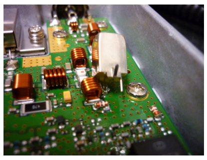


View from around 90 degrees away from the previous image. The 3 large holes are all earthed and the one at bottom left was used to solder the "earthy" end of the 100nH inductor into.

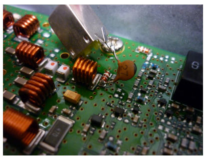
D1020 is the diode at the end of the coil closest to the centre of the photo.



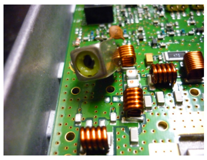
Side view of just the inductor in place. (Second FT-1802M)



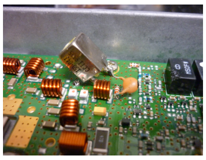
Again, side view of the inductor in place



The 27pF ceramic disc capacitor was added, one leg to the "top" of the inductor and the other to the end of the diode D1020.



A view down into the slug tuned former. It's dark in there but there is a slotted ferrite core in ther somewhere...



This was the first FT-1802M to be modified. The only obvious difference is that the capacitor has it's value underneath and therefore not visible and that it is at a different angle to the other unit.

There is plenty of clearance with the speaker back in place and it is well clear of the top cover.

One of the outcomes of the traps being fitted to these radios : each was tried on the same discone antenna and the FM station on 103.7 was only just noticeable as a variation in the inherent FM noise level.

More and more FM transmitters at high transmitter powers are appearing in the spectrum. If you start to hear one (or more), it could be that the receiver in your transceiver does not have a good enough image rejection figure to allow you to ignore it. The above ideas might be all you need to implement to fix your problems.

You should note that only FM services transmitting between 103.2 and 105.2 will affect the 146 to 148 segment here in Australia (or 101.2 to 105.2 for the full 144-148 band) , and then only if your equipment uses a 21.4MHz "first IF". Any radios with a different "first IF" (eg 10.7 MHz) will not suffer from this effect.

Of course, if you "mobile" into other geographic areas with different FM broadcasting services in place, you could hear outbreaks occur on other frequencies.

Definitely a very worthwhile "fix".