A FM notch filter with 3 quarterwave coaxial cables by ON7EH

Abstract:

In order to use a high gain, low noise receive preamplifier with relatively good intermodulation performance at this QTH on 144MHz, a notch filter of some kind was needed in front of it in order to attenuate, the relatively strong FM broadcast signals, originating from the 88-108MHz band. (see the spectrum plots, hereabove)

All 2m low noise amplifiers (LNA's) available on the market or homebrew (such as the cavity MGF1801's from WD5AGO, I8TDJ, etc) or regular Agilent-based FET's (such as from LNA-Technology or PA3BIY's), don't provide the necessary gain roll-off to attenuate these strong out-of-band FM carriers. The most annoying carriers at this QTH are sited at or about 100MHz

Solution:

To safeguard the system noise figure of the 2m antenna line, a dual-notch filter was tried.
Its requirements to be effective at this QTH are:
-lowest insertion loss, to allow its installation before (in front of) the LNA
-good return loss (impedance match to 50 Ω) and
-at least 20dB of attenuation for the FM-signals.

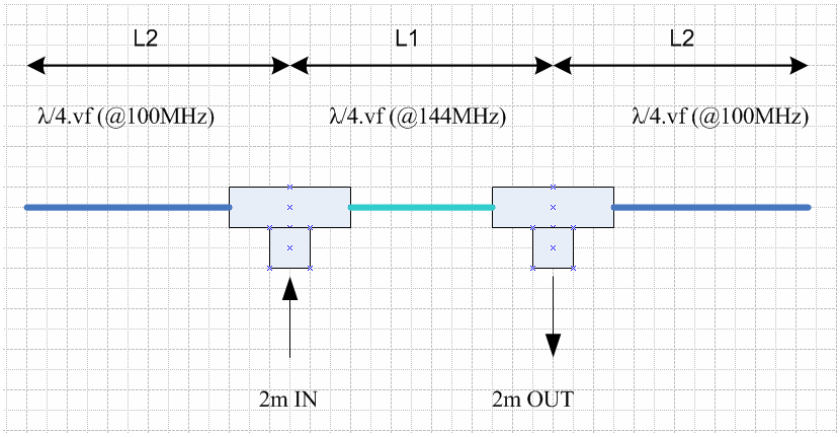
Setup:

The setup shown, hereafter, was proposed by Leif , SM5BSZ on the I-net.
The notch exists of 3 coaxial cables and 2 T-joints.
One electrical quarter wave (the center part) is cut to 144MHz and two electrical quarter waves to 100MHz (open ended on the far side).
N-connectors were always used because they:
-were available, reliable and fine for the application
-were similar in size to the coaxial cables used
-did not require special tools. (hand tools were sufficient)

The cables were cut according to the following (theoretical) table:

Cable type	Frequency (MHz)	λ/4 * vf (m)
1/2" corrugated	100	0.66
	144	0.458
GX 07272B	100	0.495
	144	0.34

The way the different cables are connected can be seen, hereunder:



The 1/2" corrugated L1 and open ended braided cables (L2)

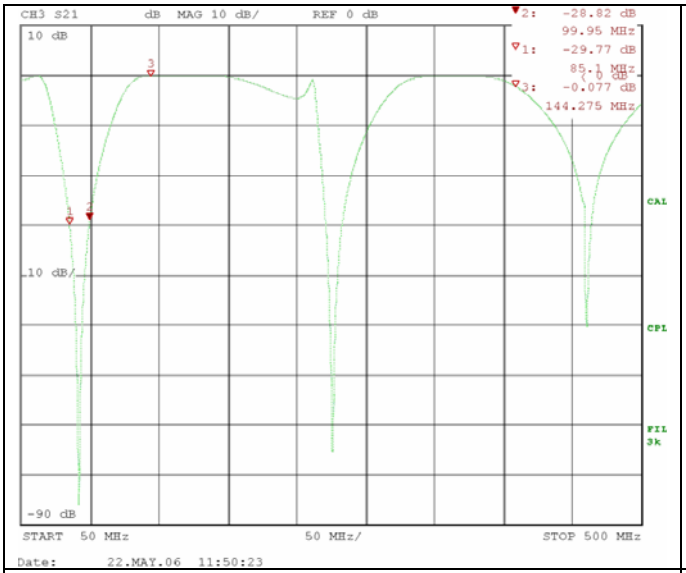
The exclusively 1/2" corrugated cables (L1 and L2)

For L1, ½" corrugated cable was always used with a velocity factor (vf) of 0.88. It is terminated in a 90° angle N-connector .

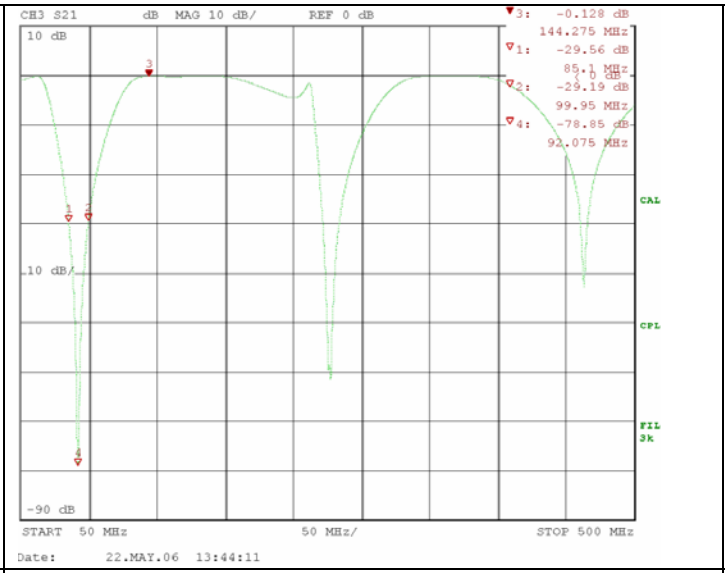
For L2, either the GX 07272D, a low loss 10.8mm diameter braided cable was used (vf=0.66) or another version with 1/2" corrugated cable.

The first prototype was built from the table above with available ½" corrugated cable and in order to obtain acceptable insertion losses, L1 had to be lengthened!
The measurements were performed by observing the insertion losses on the vector network analyzer plot. (R&S VNA ZVRE)
After a first try, the insertion loss IL was measured as **<0.08 dB** between 142 and 145MHz and **<0.1dB** between 141 and 147MHz. ;-)
The return loss RL showed better than **-30dB** in the former frequency range and better than **-23dB** between 140 and 146 MHz.
The attenuation between the broad range of 85 and 100MHz was always better than **30dB** which was better than expected.

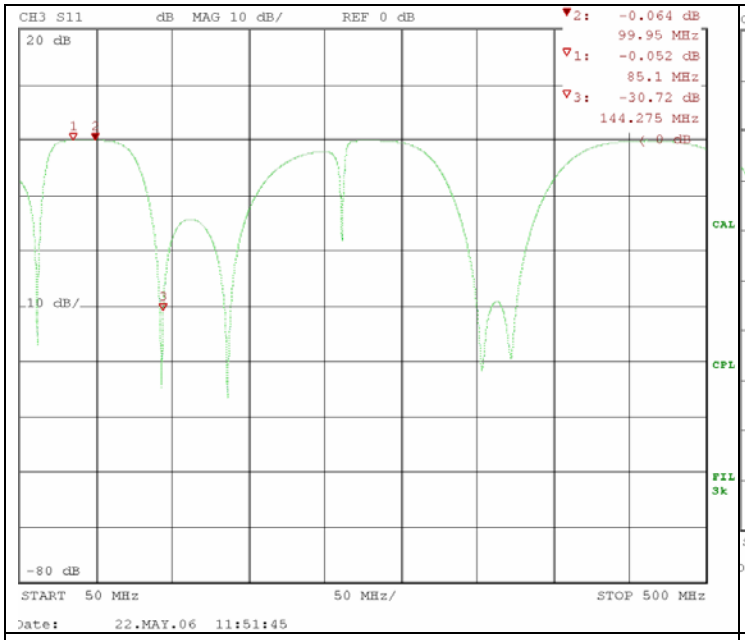
The VNA-plots can be see hereunder:



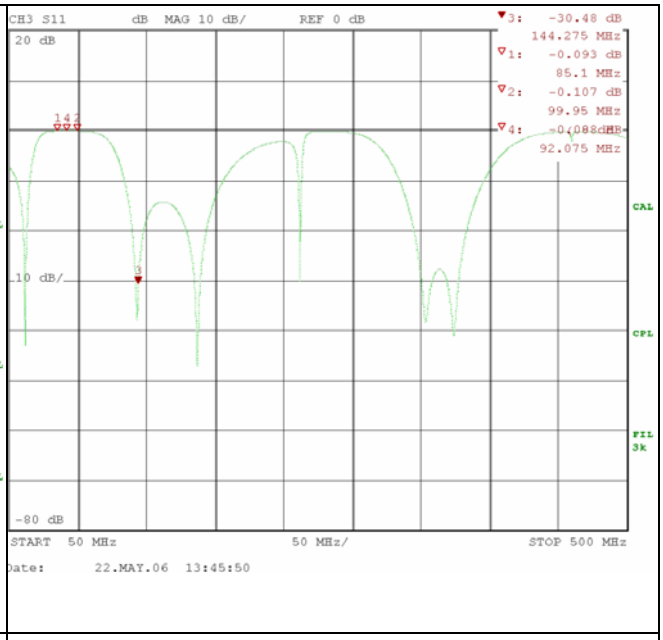
IL with 1/2" corrugated cable



IL with braided cable



RL with 1/2" corrugated cable



RL with braided cable

The final dimensions for both cable options can be found in the table, hereunder:

Final dimensions (cm)	L1 (connector to connector end)	L2
Corrugated 1/2"	54	68,5 and 69
GX 07272BD-braided cable	NA	2 x 49 (to angle connector center)

The following table summarizes the IL/attenuation values when subsequently cutting pieces from the open-ended L2-ends.
(with braided cable and vf = 0.66)

L2 (cm)	IL @ 144MHz (dB)	Attenuation @ 85MHz (dB)	Attenuation @ 100MHz (dB)
72	-0.5	-6	-0.9
52	-0.13	-50	-20
49	-0.13	-29	-29

Observations:

If both L2 electrical lengths differ too much from one another, the notch will show up as a dual notch.
When cutting ends from L2, you'll notice the notch center frequency moving up in frequency.
Cutting too much L2-length will start to eat up 2m insertion loss. (to be avoided)
The 2m center frequency corresponds nicely with the best return loss values.
The full ½" corrugated cable setup beats the more flexible braided setup by 0.05dB in insertion loss.
Surprisingly, the FM-band attenuation of the braided version (for L2) equals the corrugated ½" version.
Playing around (bending) the braided cables L2 away and around the corrugated cable L1did not change the set-up characteristics. (stable behaviour)
The measured in-band insertion loss represents the filter loss which is made up by 2 N-type T, 2 male N-connectors and the short length of 1/2" corrugated cable L1.
The obtained values are much lower than often read in articles, either pointing to:
-measurement errors or
-RF-components of worse or questionable quality. (at least on 144MHz)

Conclusion:

The filters ' performance is better than expected and fulfills the requirements for use in the 2m setup.