Review of two WTMicrowave Chinese Hydrogen Cavity Filter covering hydrogen band and first light results of their performance at Lichfield Radio Observatory (LRO).

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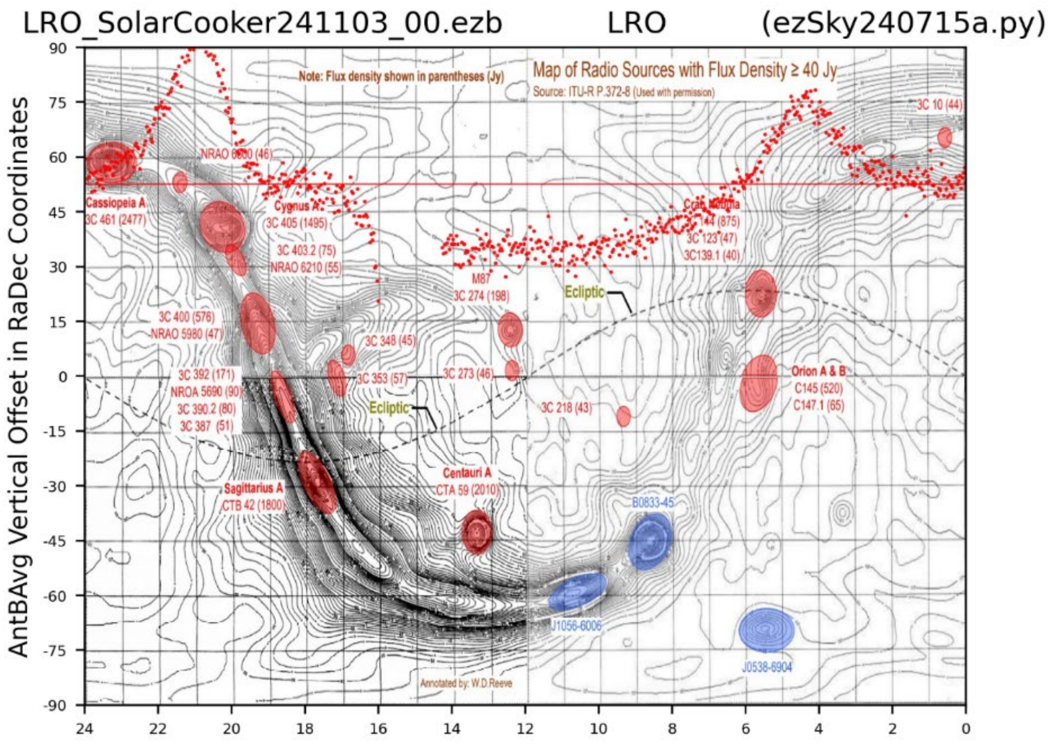
Article for SARA Journal

The need for effective filtering of the hydrogen signal for Milky Way galactic mapping.

The availability of cheap and effective off the shelf antennae from companies such as Nooelec and software defined radios (SDRs) and instructions in the SARA “Scope in the Box” project have led to a need for effective filtering of received radio signals to isolate the hydrogen band, and a small range around it to incorporate Doppler shifted signal, for processing using software such as Easy Radio Astronomy Suite (ezRA).
The Milky Way is composed mostly of hydrogen and, therefore, mapping of galactic arms and Doppler shift calculations are best done using the frequency for hydrogen (1420.405MHz). Unfortunately, this area of the electromagnetic spectrum is subject to quite a lot of radio interference in many of the areas in which we live, a situation made worse as more houses are built and increased use of electronic devices in the modern home.

Data collection on a hydrogen-line radio telescope (1420MHz – Easy Radio Astronomy) (below):



The standard hydrogen line filter and low noise amplifier used in amateur radio astronomy – the Nooelec SAWBird H1.

Many amateur radio astronomers use the Nooelec SAWBird H1 low noise amplifier (LNA) to achieve this filtering (https://www.nooelec.com/store/sdr/sdr-addons/sawbird.html), available for $44.95 at the time of writing of this article on amazon.com (https://www.amazon.com/Nooelec-SAWbird-H1-Applications-Frequency/dp/B07XPV9RX2). The SAW filter in this device provides significant attenuation at +/- 30 MHz either side of 1420 MHz, and also provides a dual cascaded low noise amplifier within a small compact unit.

SAWBird H1 LNA Dongle (below):

Chinese Cavity Filters for the Hydrogen Line.

This current paper looks at a pair of alternative filters using a different design that provides an attenuation over a narrower frequency range, promising to improve signal to noise ratio and give clearer hydrogen signals and improved detail in the maps produced in systems using them.
Cavity Filters are a type of radio frequency (RF) filter used in communication systems to filter out noise and select signals at specific frequencies. They are typically composed of one or more hollow metal cavities containing conductor structures (www.temwell.com/en/pages/what-is-cavity-filter).
Cavity Filters operate using resonance. They contain a resonator with a tuning screw (to fine-tune the frequency) inside a conducting box. An RF or microwave resonator is a closed metallic structure (i.e., waveguides with both ends terminated in a short circuit). The resonator oscillates with higher amplitude at a specific set of frequencies, called resonant frequencies. When an RF signal passes through the cavity filter, a resonator acts as a band-pass filter and passes RF signals at specific resonant frequencies while blocking other nearby non-resonant frequencies. The resonant frequency of the cavity resonator depends on its dimension (length, width, height), mode number, dielectric constant (εr), and magnetic permeability (μr) of the material of construction. In a cavity filter, the resonator is fitted with a screw to tune the frequency range which allows to modify the physical length (inner space length) of the resonator as well as its capacitance to the ground, hence tuning the resonant frequency. Cavity filters are used in the MHz/GHz frequency range. They provide high Q-factor (i.e., high-selectivity/sharply attenuates the unwanted signals), low insertion loss, and robust temperature stability when compared to other forms of filters commonly used in amateur radio astronomy. These advantages make cavity filters ideal for use in microwave and millimetre-wave systems, particularly in professional systems, which need filters with high-Q factor, lower insertion loss, and temperature stability. Advantages of cavity filters: (1) High Q-factor (up to the order of 106), low insertion loss, and robust temperature stability. (2) Superior selectivity and good frequency stability. (3) Reduces the transmitter sideband noise and protects receivers against desensitization. (4) Better performance in microwave range (including 1420MHz that we use for hydrogen detection) when compared to other common forms of filter (https://www.everythingrf.com/community/what-are-cavity-filters).

Traditionally, amateur radio astronomers have had to make their own cavity filters if they wished to use one, a labour-intensive exercise requiring some skill and a lot of fiddling and ideally additional expensive equipment to tune the filter accurately. Commercial versions have been very expensive, limiting their use to professional observatories. However, like most areas of technology, new ranges of these devices have become available from China at much more competitive prices, and these new models provide an opportunity to consider these filters for amateur applications.
I obtained a pair of samples of cavity filters covering the hydrogen band, but will slightly different specifications from WTMicrowave (www.wtmicrowave.com), based in China. The company is also prepared to produce custom-designed filters, should amateurs have a need for them. Prices for the two filters discussed in this article are around $150 each plus carriage.
This article follows on from a previous article published in the November-December 2024 edition of the Journal of the Society of Amateur Radio Astronomy where I discussed the specifications of one of these two filters, the WT-A9940-Q08 cavity filter. which is designed to cover 1400-1427 MHz, and gives up to 69 dB attenuation either side of this. This gives a range of -20 MHz to +7 MHz from 1420 MHz, an improvement over the +/-30 MHz of the Nooelec SAWBird H1 LNA.

WTMicrowave WT-A9940-Q08 cavity filter 1400-1427 MHz.

The WT-A9940-Q08 cavity filter is designed to cover frequencies between 1400-1427 MHz. It provides up to 69 dB attenuation either side of this. This gives a range of -20 MHz to +7 MHz from 1420 MHz, an improvement over the +/-30 MHz of the Nooelec SAWBird H1 LNA.

WTMicrowave WT-A9940-Q08 cavity filter 1400-1427 MHz (below):

This cavity filter has N-type connectors at either end, so adapters are required to use with cables terminated with SMA connectors commonly used in amateur radio astronomy stations where software-defined radios are usually used, or the connector needs to be changed on the cable. Those users who control their systems with an amateur radio transceiver should be able to directly connect to the filter.

Specifications of the WT-A9940-Q08 cavity filter (below):

S/N	Item	Parameters	
1	Center Frequency(F0)	1413.5MHz	
2	Pass Band Frequency	1400 ~ 1427MHz **	
3	Pass Band Insertion Loss	≤1.5dB	
4	Pass Band Ripple	≤0.6dB	
5	Pass Band Return Loss	≥23dB	
6	Stop Band Rejection	≥50dB @ DC ~ 1375MHz	≥50dB @ 1452 ~ 3500MHz
7	Impedance	50 Ohms	
8	Power Handling	200W Max.	
9	Connectors	N-Female	
10	Surface Finish	Painted Black	
11	Temperature Range	-30℃ ~ +70℃	
12	Material	Housing: 6061 Aluminum alloy Cover: LY12 Aluminum alloy Tuning screw: H62 Copper alloy	Resonant column: H59 Copper alloy Connectors: H59 Copper, Plated ternary alloy Other screw: Stainless Steel
13	Dimensions	180*46*25mm	
14	Net weight	0.374 KG	

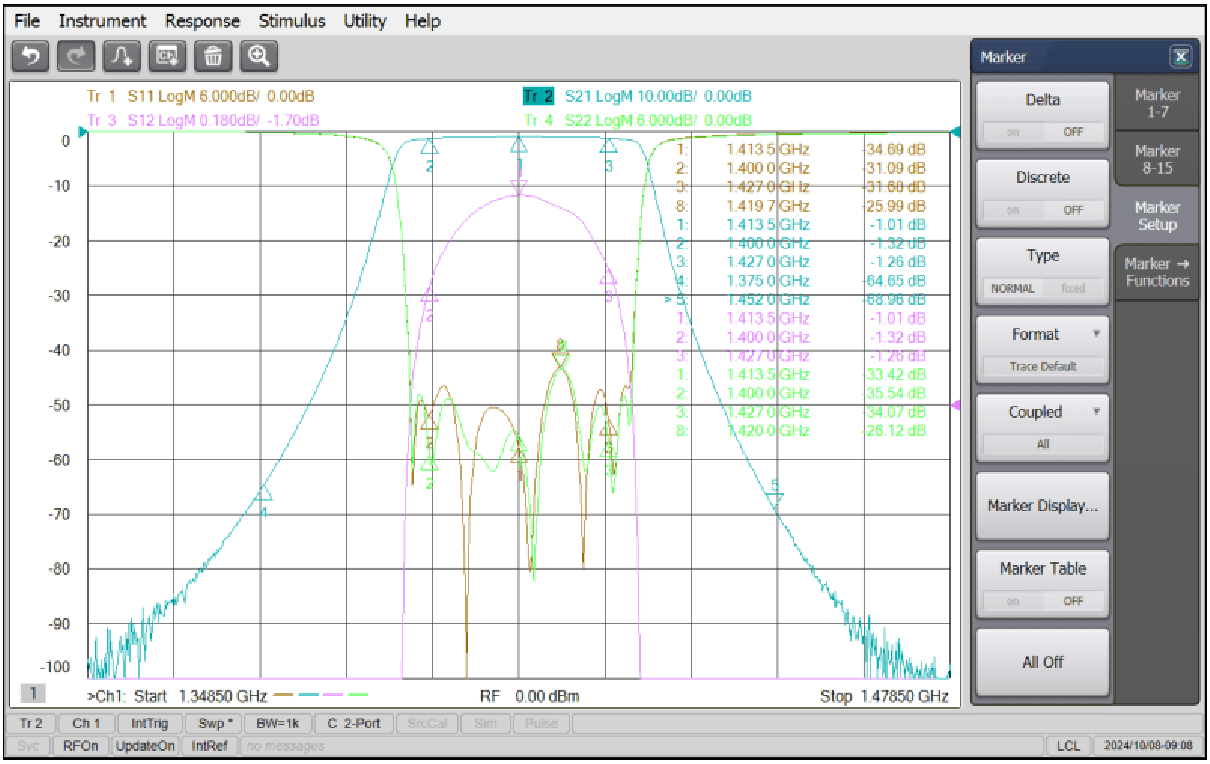
Outline Drawing of the WT-A9940-Q08 Cavity Filter (below, dimensions units: mm, dimension tolerance +/-0.5mm):

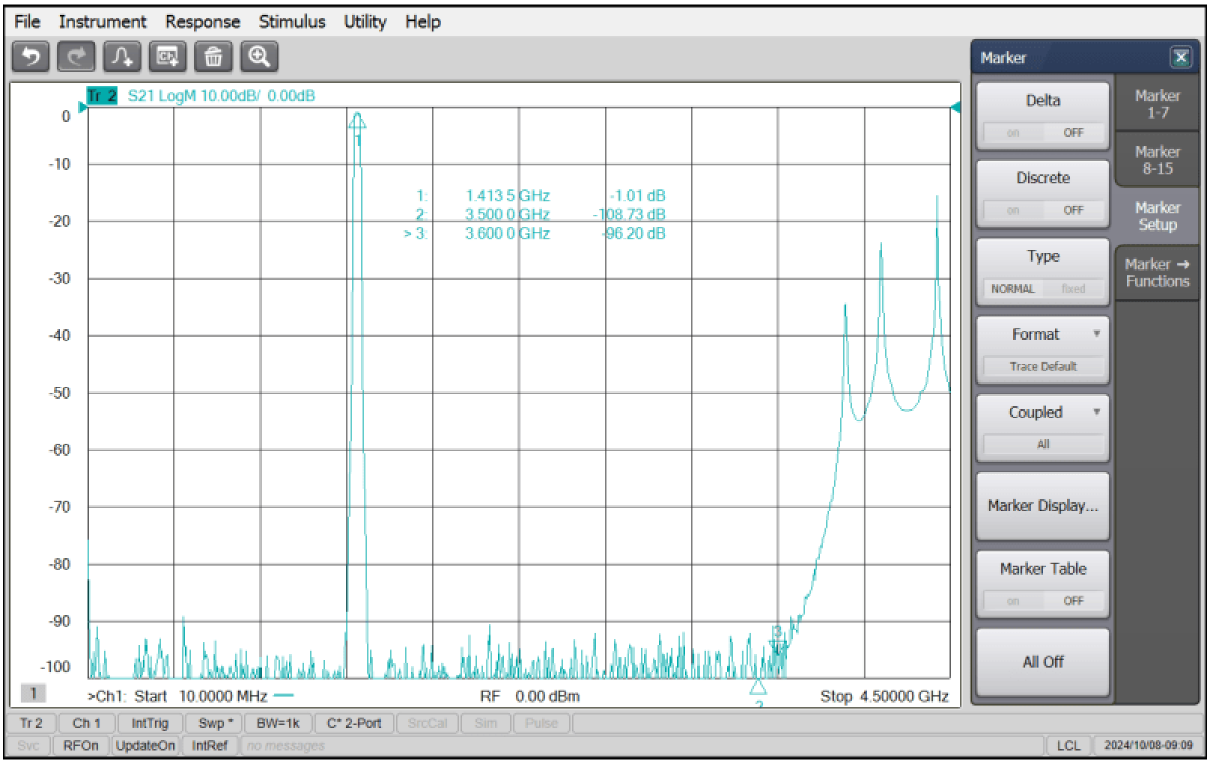
** The actual design bandwidth will be greater than the Pass Band Frequency, and there is no bandwidth limit.

The plots below show test report and curves for an example of these filters that I have been sent by the company (below).

Product Inspection Records

Model	WT-A9940-Q08	Item	Cavity Band Pass Filter	Quantity	3pcs		
Test Data							
Appearance	Major Parameter					Other Parameter	
	Pass Band 1400 ~ 1427MHz F0=1413.5MHz			Stop Band		Connectors	Surface Finish
Reference value / S/N	Insertion Loss	Ripple	Return Loss	DC ~ 1375MHz	1452 ~ 3500MHz	N-Female	Painted Black
	≤1.5dB	≤0.6dB	≥23dB	≥50dB	≥50dB		
1	1.32	0.31	25.9	64	69	N-Female	Painted Black
2	1.29	0.27	27.2	63	69		
3	1.33	0.31	27.1	66	71		
Verdict:		Inspection way: Full inspection				Data recording mode: Full record	
Test Equipment: N5227B		Date: 2024-10-08		Tester: Liqiong Yong		Check: Xiaotao Yang	



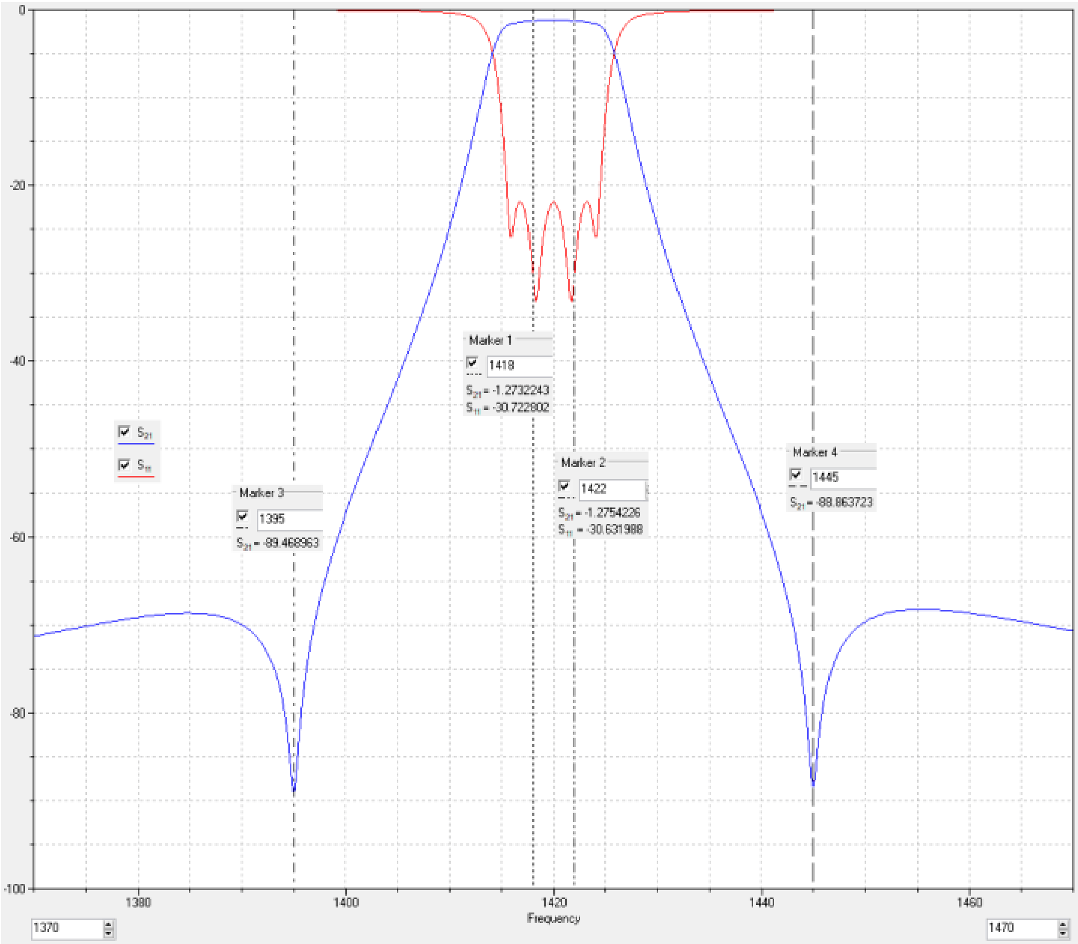


WTMicrowave Cavity Band Pass Filter WT-A11654-Q04 (1418-1422MHz).

The second filter is also from WTMicrowave, but has a narrower bandwidth of only 4MHz, centralised on 1420MHz. It presented an opportunity to provide better attenuation outside the hydrogen band, when high levels of radio frequency interference (RFI) are present, such as at Lichfield Radio Observatory (LRO), which is located in the centre of a moderately large town of 30,000+ inhabitants. Unlike the previous filter, this one has SMA connectors, so does not require adapters for most amateur radio astronomy systems. I received three of this type of filter.

WTMicrowave Cavity Band Pass Filter WT-A11654-Q04 (1418-1422MHz) (below):

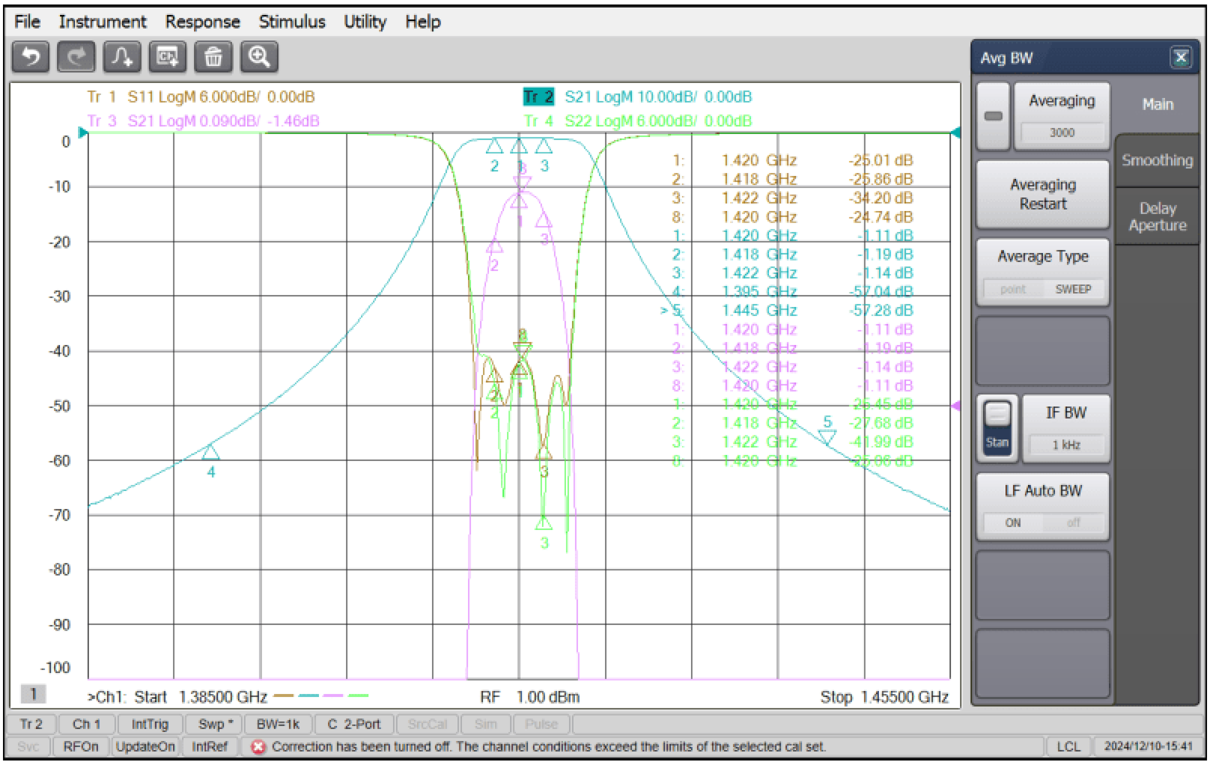
Simulation curve from company (WTMicrowave) below for this filter:

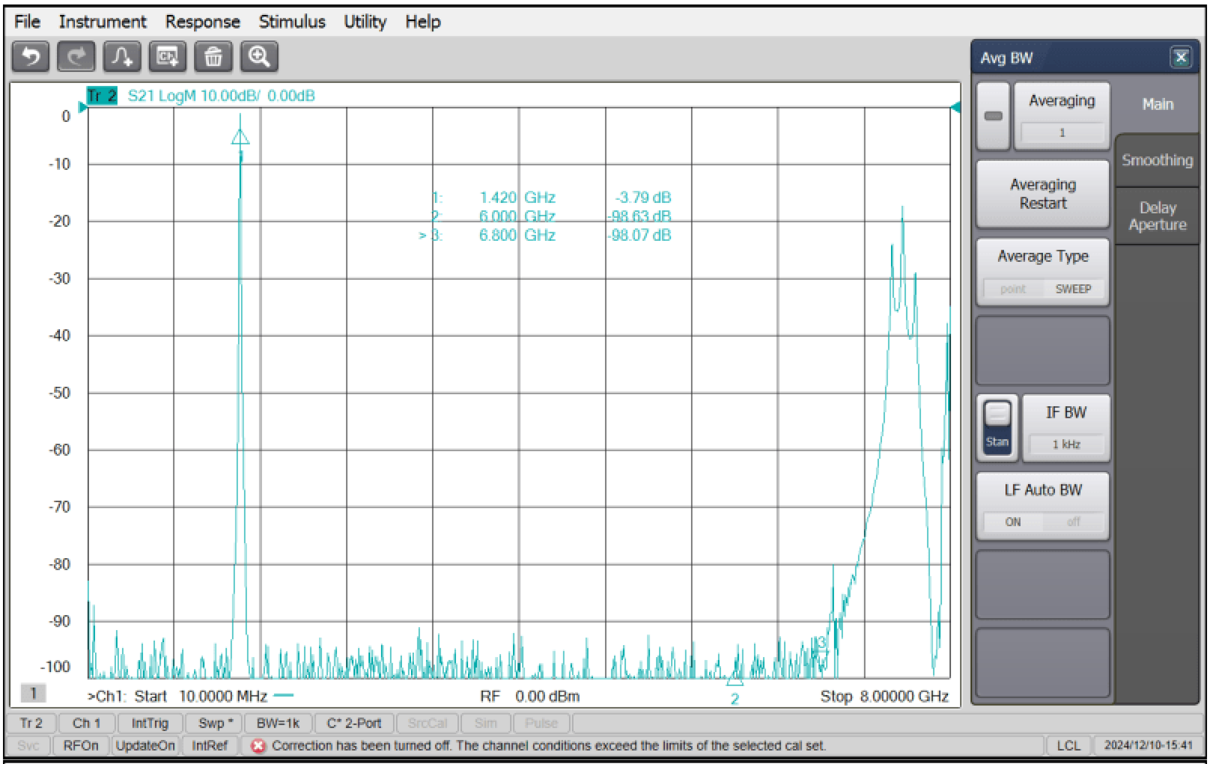


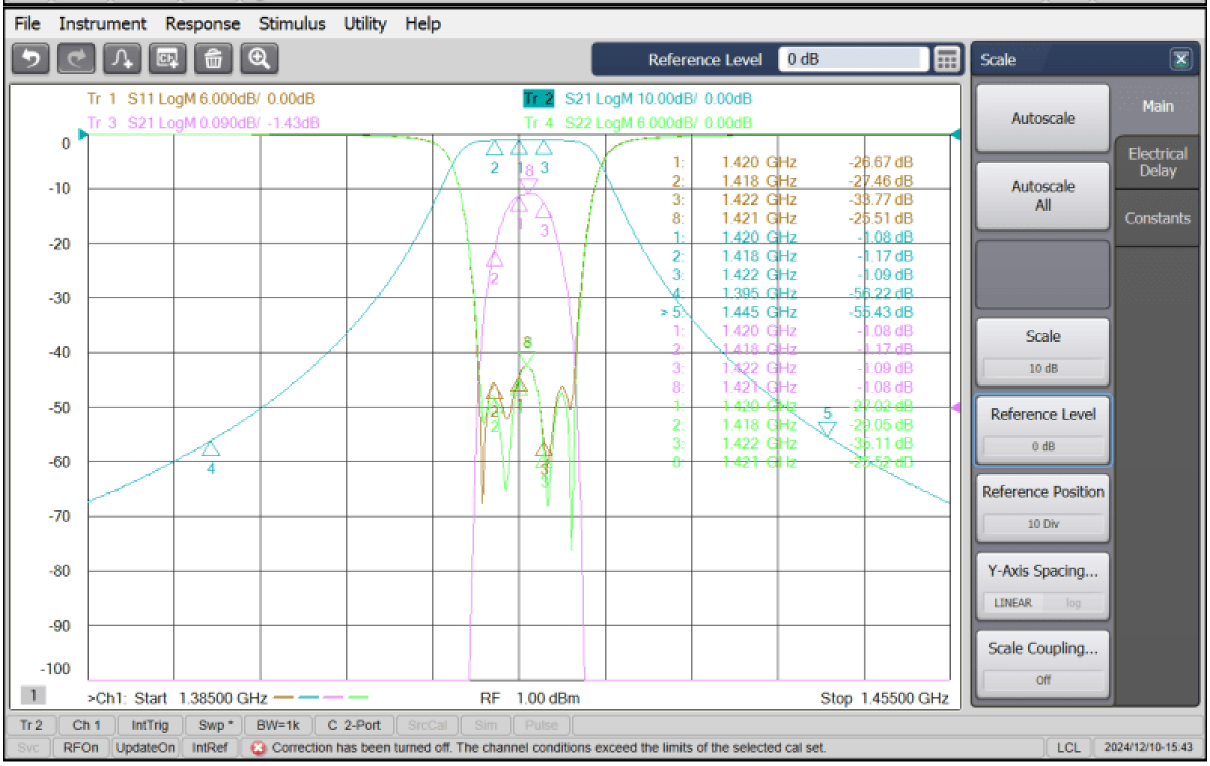
Actual test curves and test data for the three filters of this type I received:

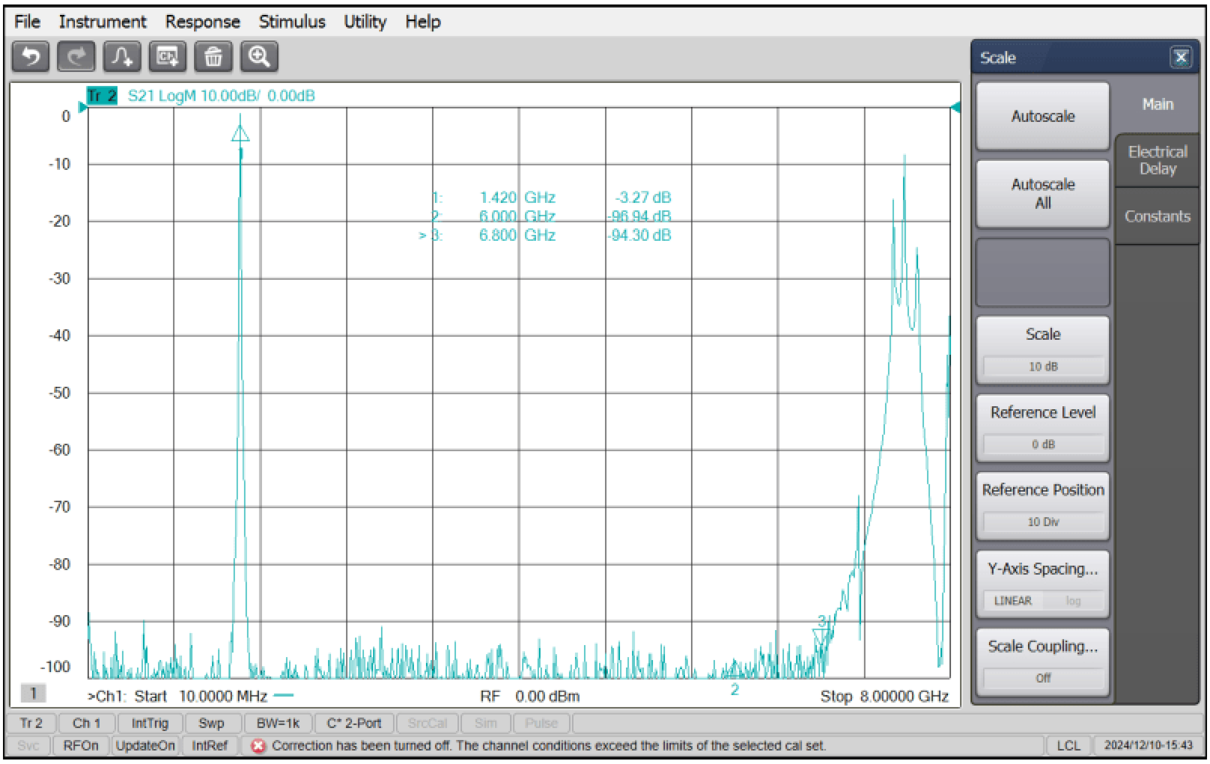
Product Inspection Records

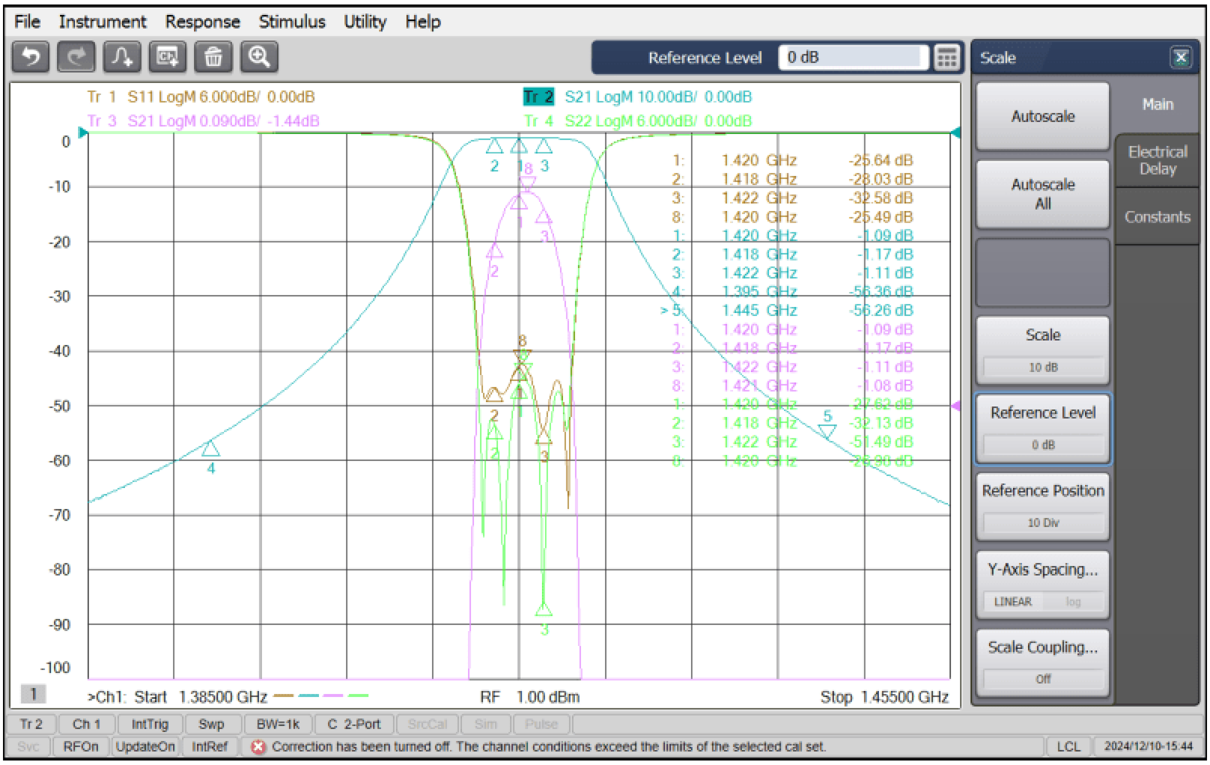
Model	WT-A11654-Q04	Item	Cavity Band Pass Filter		Quantity	3pcs	
Test Data							
Appearance	Major Parameter					Other Parameter	
	Pass Band 1418～1422MHz F0=1420MHz			Stop Band		Connectors	Surface Finish
Reference value / S/N	Insertion Loss	Ripple	Return Loss	DC～1395MHz	1445～6000MHz	SMA-Female	Painted Black
	≤1.5dB	≤0.3dB	≥23dB	≥50dB	≥50dB		
1	1.19	0.08	24.7	57	57	SMA-Female	Painted Black
2	1.17	0.09	25.5	56	55		
3	1.17	0.09	25.5	56	56		
Verdict:		Inspection way：Full inspection				Data recording mode：Full record	
Test Equipment：N5227B		Date：2024-12-10		Tester：Liqiong Yong		Check：Xiaotao Yang	

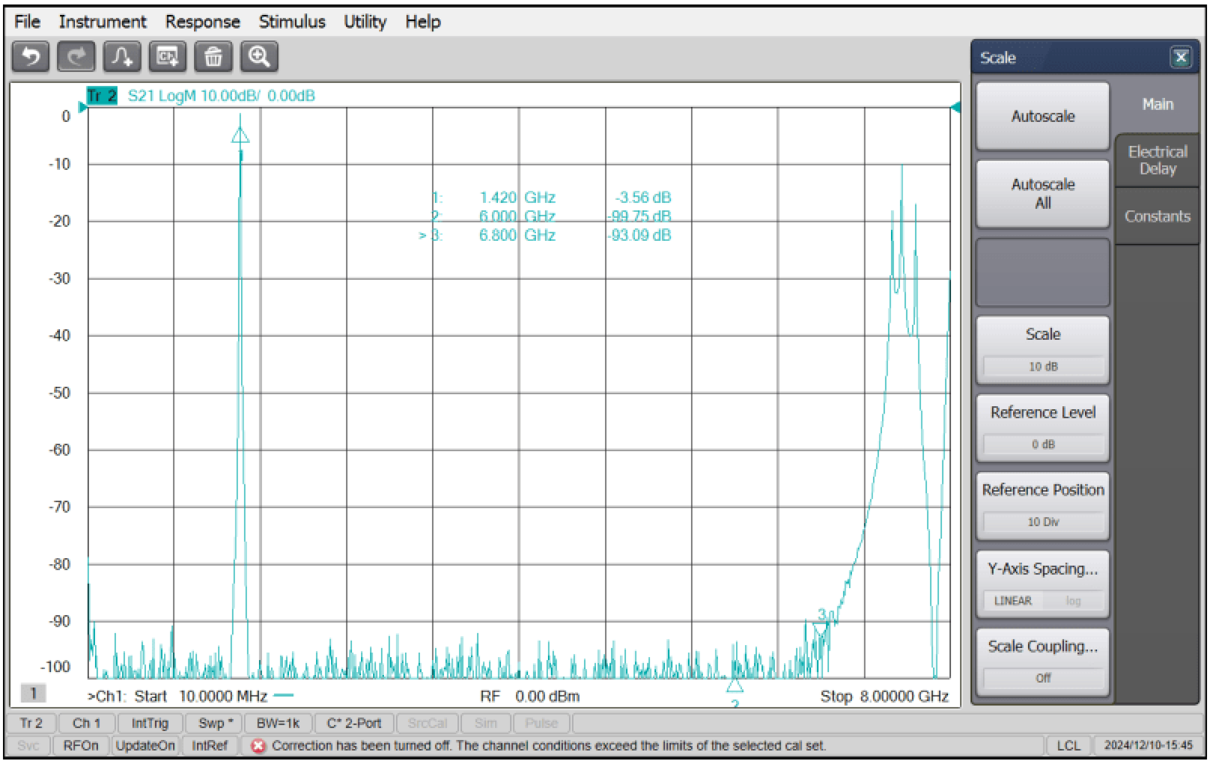



File Instrument Response Stimulus Utility Help
Tr 2 S21 LogM 10.00dB/ 0.00dB
1: 1.420 GHz -3.79 dB
2: 6.000 GHz -98.63 dB
> 3: 6.800 GHz -98.07 dB
>Ch1: Start 10.0000 MHz
RF 0.00 dBm
Stop 8.00000 GHz
Avg BW
Averaging
Averaging Restart
Average Type
IF BW
1 kHz
LF Auto BW
Main
Smoothing
Delay Aperture
Tr 2 Ch 1 IntTrig Swp * BW=1k C* 2-Port SrcCal Sim Pulse
Svc RFOn UpdateOn IntRef Correction has been turned off. The channel conditions exceed the limits of the selected cal set. LCL 2024/12/10-15:41


File Instrument Response Stimulus Utility Help
Reference Level 0 dB
Tr 1 S11 LogM 6.000dB/ 0.00dB
Tr 2 S21 LogM 10.00dB/ 0.00dB
Tr 3 S21 LogM 0.090dB/ -1.43dB
Tr 4 S22 LogM 6.000dB/ 0.00dB
1: 1.420 GHz -26.67 dB
2: 1.418 GHz -27.46 dB
3: 1.422 GHz -33.77 dB
8: 1.421 GHz -25.51 dB
1: 1.420 GHz -1.08 dB
2: 1.418 GHz -1.17 dB
3: 1.422 GHz -1.09 dB
4: 1.395 GHz -56.22 dB
> 5: 1.445 GHz -55.43 dB
1: 1.420 GHz -1.08 dB
2: 1.418 GHz -1.17 dB
3: 1.422 GHz -1.09 dB
8: 1.421 GHz -1.08 dB
1: 1.420 GHz -27.02 dB
2: 1.418 GHz -29.05 dB
3: 1.422 GHz -35.11 dB
8: 1.421 GHz -25.52 dB
>Ch1: Start 1.38500 GHz
RF 1.00 dBm
Stop 1.45500 GHz
Scale
Autoscale
Autoscale All
Scale 10 dB
Reference Level 0 dB
Reference Position 10 Div
Y-Axis Spacing... LINEAR log
Scale Coupling... Off
Main
Electrical Delay
Constants
Tr 2 Ch 1 IntTrig Swp * BW=1k C 2-Port SrcCal Sim Pulse
Svc RFOn UpdateOn IntRef Correction has been turned off. The channel conditions exceed the limits of the selected cal set. LCL 2024/12/10-15:43


File Instrument Response Stimulus Utility Help
Tr 2 S21 LogM 10.00dB/ 0.00dB
1: 1.420 GHz -3.27 dB
2: 6.000 GHz -96.94 dB
> 3: 6.800 GHz -94.30 dB
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
>Ch1: Start 10.0000 MHz
RF 0.00 dBm
Stop 8.00000 GHz
Scale
Autoscale
Autoscale All
Scale
10 dB
Reference Level
0 dB
Reference Position
10 Div
Y-Axis Spacing...
LINEAR log
Scale Coupling...
Off
Main
Electrical Delay
Constants
Tr 2 Ch 1 IntTrig Swp BW=1k C* 2-Port SrcCal Sim Pulse
Svc RFOn UpdateOn IntRef Correction has been turned off. The channel conditions exceed the limits of the selected cal set.
LCL 2024/12/10-15:43


File Instrument Response Stimulus Utility Help
Reference Level 0 dB
Tr 1 S11 LogM 6.000dB/ 0.00dB
Tr 2 S21 LogM 10.00dB/ 0.00dB
Tr 3 S21 LogM 0.090dB/ -1.44dB
Tr 4 S22 LogM 6.000dB/ 0.00dB
1: 1.420 GHz -25.64 dB
2: 1.418 GHz -28.03 dB
3: 1.422 GHz -32.58 dB
8: 1.420 GHz -25.49 dB
1: 1.420 GHz -1.09 dB
2: 1.418 GHz -1.17 dB
3: 1.422 GHz -1.11 dB
4: 1.395 GHz -56.36 dB
> 5: 1.445 GHz -56.26 dB
1: 1.420 GHz -1.09 dB
2: 1.418 GHz -1.17 dB
3: 1.422 GHz -1.11 dB
8: 1.421 GHz -1.08 dB
1: 1.420 GHz -27.62 dB
2: 1.418 GHz -32.13 dB
3: 1.422 GHz -51.49 dB
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
>Ch1: Start 1.38500 GHz
RF 1.00 dBm
Stop 1.45500 GHz
Scale
Autoscale
Autoscale All
Scale
10 dB
Reference Level
0 dB
Reference Position
10 Div
Y-Axis Spacing...
LINEAR log
Scale Coupling...
Off
Main
Electrical Delay
Constants
Tr 2 Ch 1 IntTrig Swp BW=1k C 2-Port SrcCal Sim Pulse
Svc RFOn UpdateOn IntRef Correction has been turned off. The channel conditions exceed the limits of the selected cal set.
LCL 2024/12/10-15:44



Comparison of results from processing LRO-H1(Ptarmigan Array Data) collected by ezCol.py (ezRA software suite) with three filter arrangements 1st to 12th January 2025.

I have installed the cavity filter in line before the SAWBird H1 on both of my hydrogen line radio telescopes (LRO-H1 and LRO-H2) at Lichfield Radio Observatory, UK (www.astronomy.me.uk), and compared results for three filter arrangements. Results are given below for LRO-H1, the Ptarmigan ex-military dipole array.

Filter arrangement 1:

Ptarmigan Dipole Array ==> WT Microwave 1418-1422 MHz Cavity Filter ==> Nooelec SAWBird LNA ==> RTL-SDR Blog V3 Software Defined Radio.

Filter arrangement 2:

Ptarmigan Dipole Array ==> Nooelec SAWBird LNA ==> RTL-SDR Blog V3 Software Defined Radio.

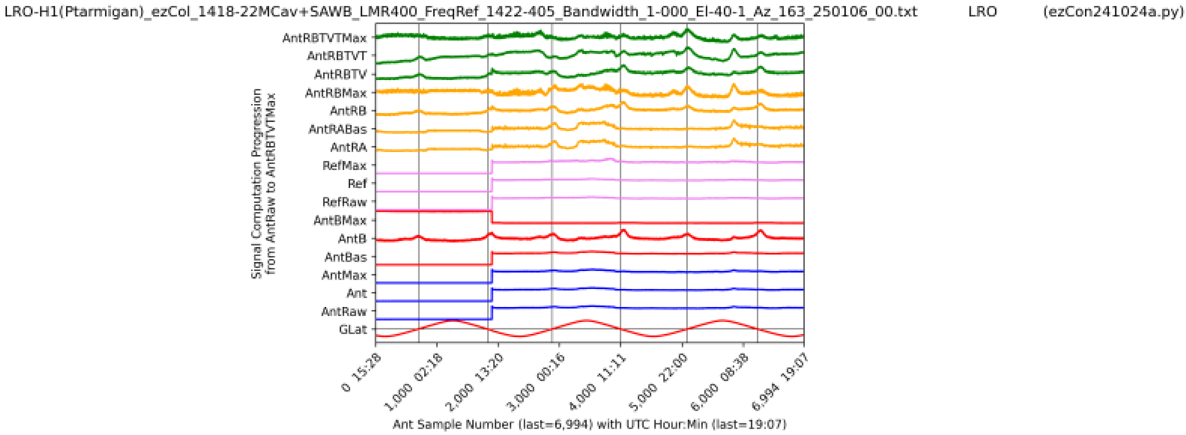
Filter arrangement 3:

Ptarmigan Dipole Array ==> WT Microwave 1400-1427 MHz Cavity Filter ==> Nooelec SAWBird LNA ==> RTL-SDR Blog V3 Software Defined Radio.

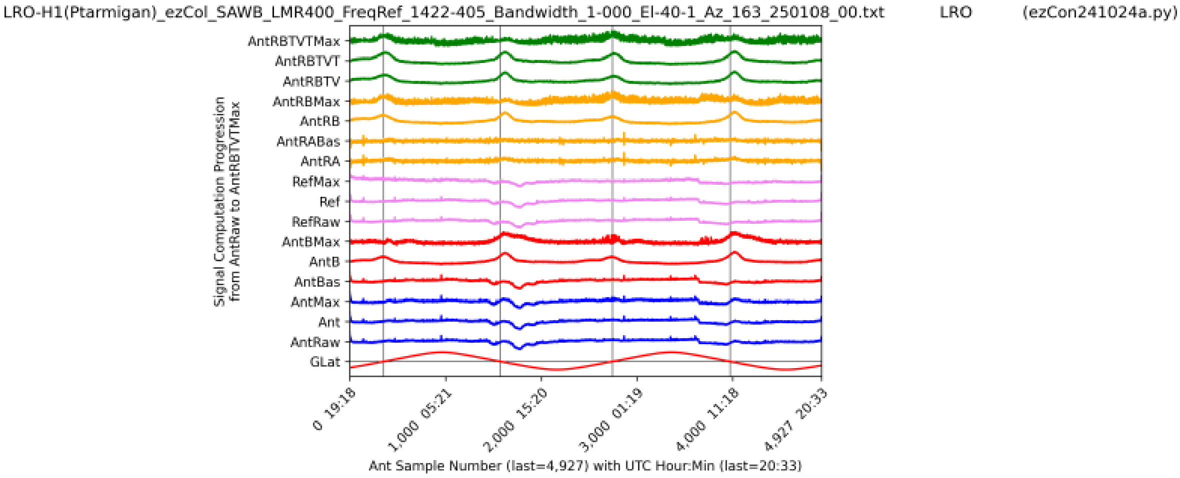
Results:

ezCon Plot 191:

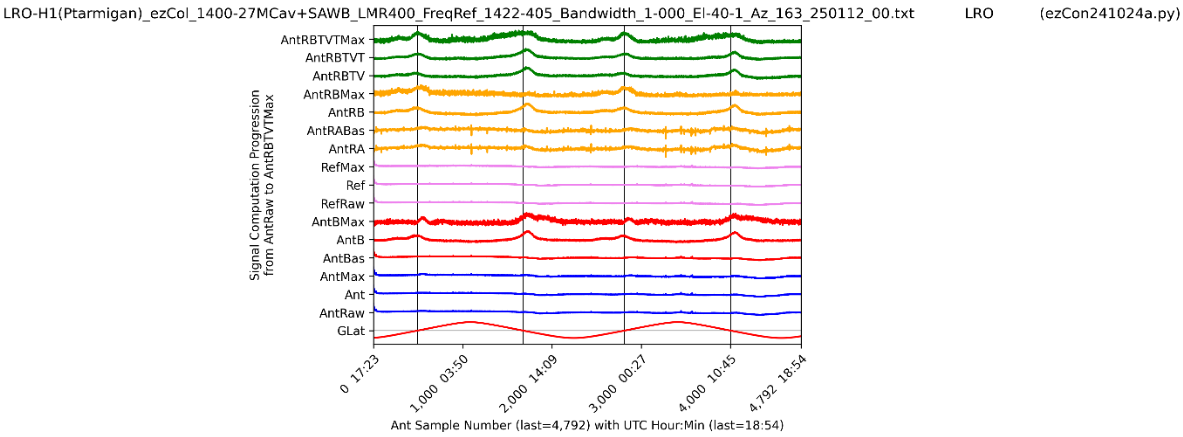
ezCon Plot 191 – Filter arrangement 1:



ezCon Plot 191 – Filter arrangement 2:

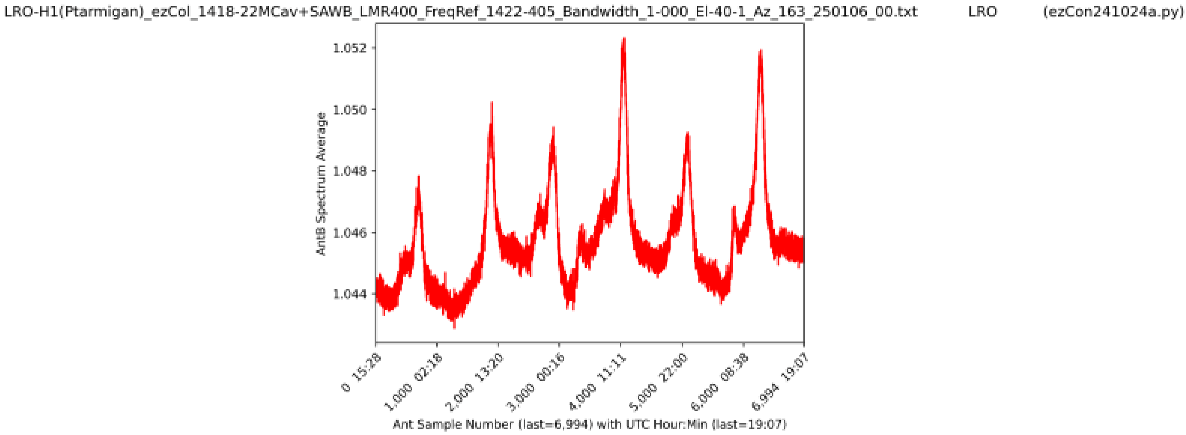


ezCon Plot 191 – Filter arrangement 3:

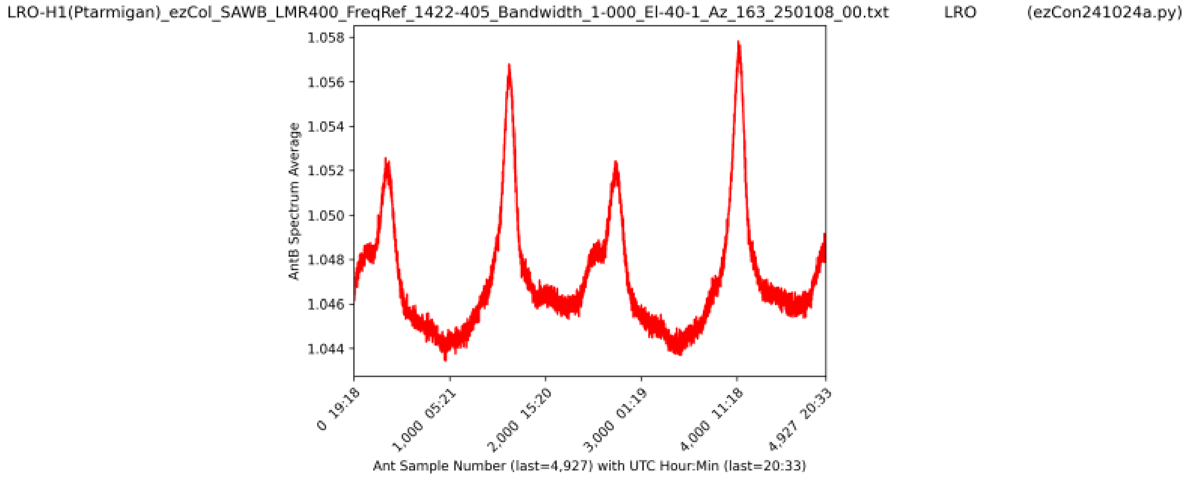


ezCon Plot ezCon114antBAvg:

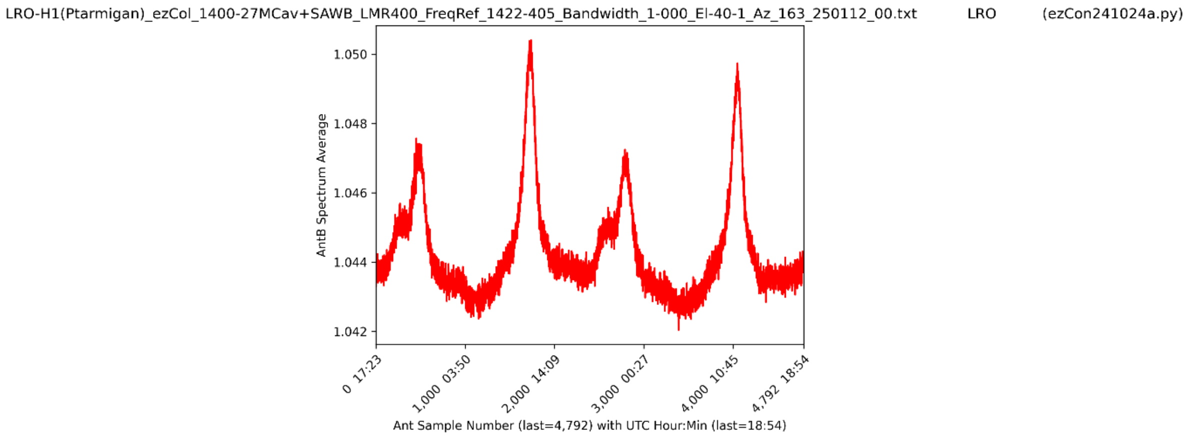
ezCon Plot ezCon114antBAvg – Filter arrangement 1:



ezCon Plot ezCon114antBAvg – Filter arrangement 2:

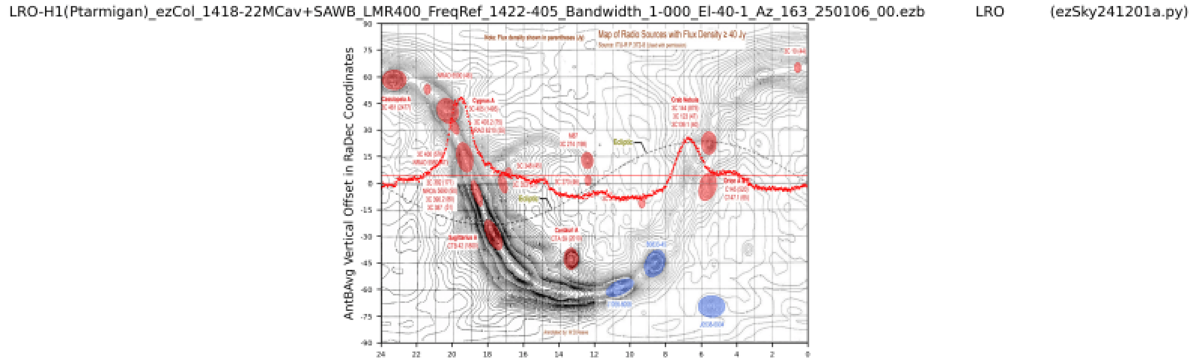


ezCon Plot ezCon114antBAvg – Filter arrangement 3:

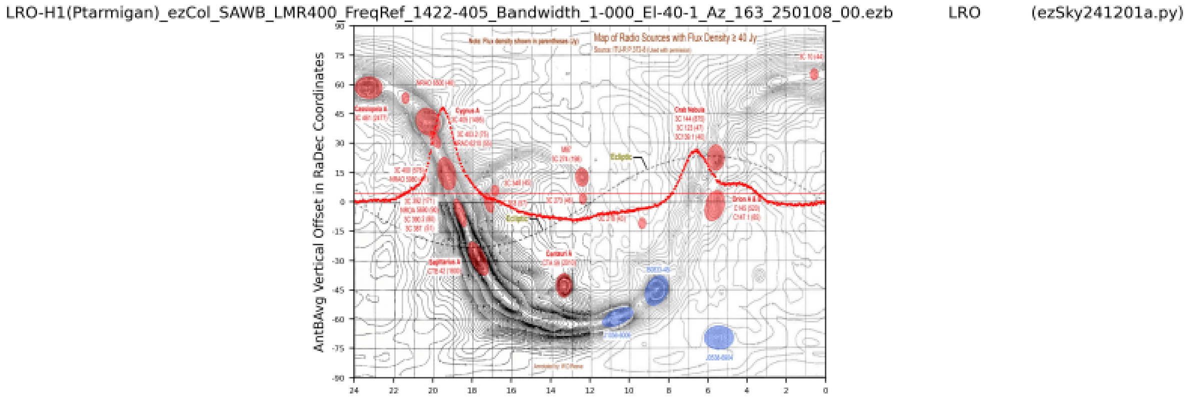


ezCon Plot ezSky200RBVO_14AntBAvg:

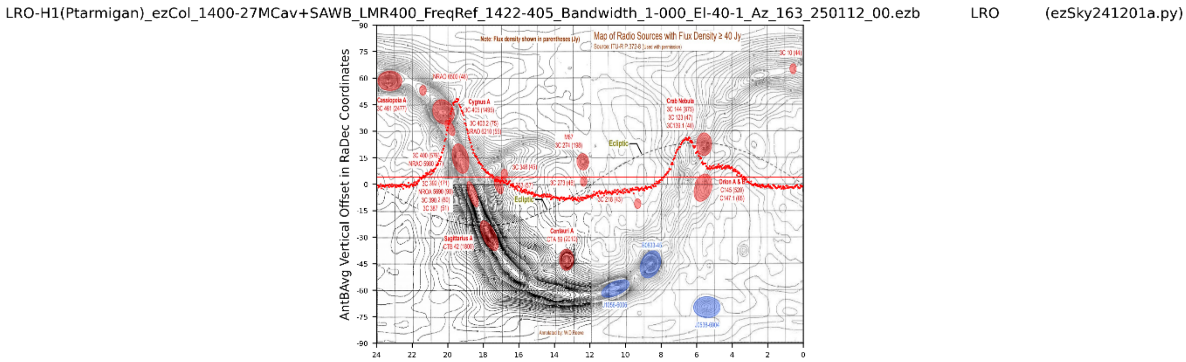
ezCon Plot ezSky200RBVO_14AntBAvg – Filter arrangement 1:



ezCon Plot ezSky200RBVO_14AntBAvg – Filter arrangement 2:



ezCon Plot ezSky200RBVO_14AntBAvg – Filter arrangement 3:



Conclusion.

The differences are subtle but the addition of a cavity filter in front of the Nooelec SAWBird H1 LNA does appear to have improved the signal, and the narrower band 1418-1422MHz cavity filter appears to more slightly effective than the wider band 1400-1427MHz filter.
These filters are considerably cheaper than alternatives manufactured in Europe or America, and the company is prepared to design filters to meet the specific needs of amateur radio astronomers. The units tested in this review were well-made, solid in construction, and performed well during testing.
Delivery from China was within a quick timescale, and the units arrived well-packaged and protected.

Further information.

Further information about this project is available on the www.astronomy.me.uk website or by contacting me using the “contact us” page on that website.