NSD-515 WARC Band option modification

Kohei Fujii, Ph.D.

AK6AB

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1. Brief history and required modifications for adding the WARC band

Japan Radio Company (JRC) NSD-515 was released in 1981 when the WARC bands were not designated as the amateur radio band. Fortunately, the NSD-515 was designed as an upgradable transmitter for the WARC bands that are 10-11MHz, 18-19MHz, and 24-25MHz. After the WARC band was released to amateur radio operators, JRC offered a factory modification service for adding the WARC band functionality. I obtained two NSD-515s from an auction suite in Japan. None of my NSD-515 has been modified for the WARC band option. Therefore, I decided to make the WARC band modification by myself.

Figure 1 shows a block diagram for the NSD-515. For the WARC band modification, four units shown in red need to be modified.

1. Local 1 unit: LO crystal oscillators for 1.8, 3.5, 7, 10, 14, 18, 21, 24, 28, and 29 MHz bands.
2. Local 2 unit: LO pre-mix bord for mixing between the digital VFO (2.455 – 3.455 MHz) and the LO signals from the Local 1 unit.
3. RF amp unit: Frequency up-converter for mixing between the modulated IF frequency (8.7MHz) and the pre-mixed LO signal from the Local 2 unit.
4. Output unit: LPF bank for unwanted harmonics suppression from the final amplifier.

FREQUENCY TABLE				
FT	F1 (MHz)	MULTI	F2(MHz)	FLo (MHz)
1.8 MHz BAND	7.245	×1	7.245	10.5~10.6999
3.5 MHz BAND	9.245	×1	9.245	12.2~12.6999
7 MHz BAND	13.245	×1	13.245	15.7~16.2
※10 MHz BAND	16.245	×1	16.245	18.7~18.9
14 MHz BAND	10.1225	×2	20.245	22.7~23.2
※18 MHz BAND	12.1225	×2	24.245	26.7~26.9
21 MHz BAND	13.6225	×2	27.245	29.7~30.2
※24 MHz BAND	15.1225	×2	30.245	33.5~33.7
28 MHz BAND	17.1225	×2	34.245	36.7~37.6999
	17.6225	×2	35.245	37.7~38.4

※WARC BAND is optional.

For enabling the WARC band operation (10-11MHz, 18-19MHz, and 24-25MHz), additional crystal resonators at the Local 1 unit, BPFs for the pre-mixed LO signals at the Local 2 unit, BPFs for the up converted transmitter frequencies at the RF AMP unit, and LPFs at the output unit must be added.

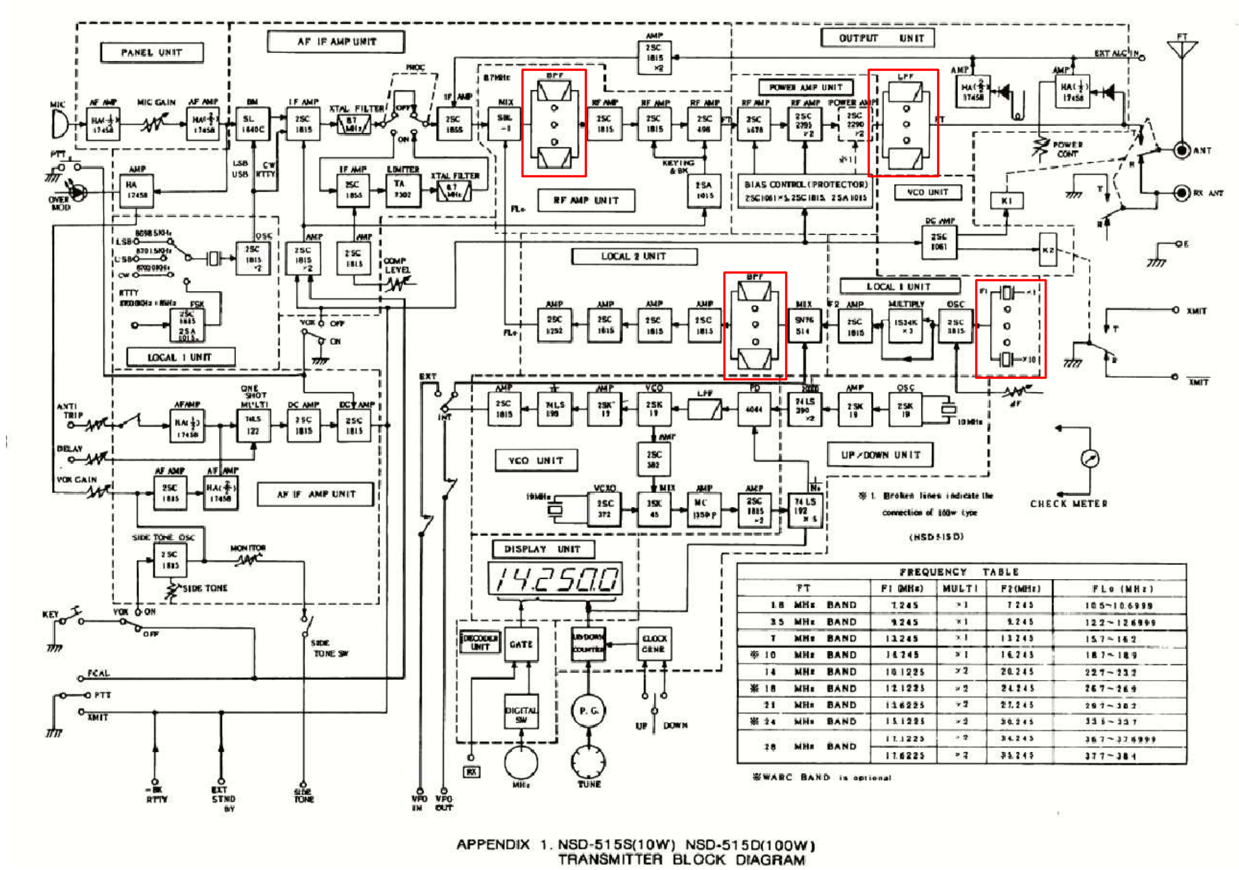

Figure 1. A block diagram for the NSD-515

2. Local 1 unit (CGA-80) modification

For the WARC band options, three crystal resonators shown below must be obtained and installed on the Local 1 unit.

10MHz: 16.245 MHz (Fundamental oscillation)

18MHz: 12.1225 MHz (Fundamental oscillation)

24MHz: 15.1225 MHz (Fundamental oscillation)

Due to technological advancement in the past four decades, manufacturers for the crystal resonator disappeared, and ordering those crystal resonators is very difficult or extremely expensive now a days. I searched all over the world and find a nice company in Czech Republic who can provide the custom crystal resonators at reasonable price and delivery time. Detailed information for the crystal resonator manufacturer is shown below.

Krystaly, Hradec Kralove, a.s.

Okruzin 1144

5003 Hiradec Kralove CR

e-mail: krystaly@krystaly.cz

Mr. Michael Sadovsky

Ordering specs are shown below.

1. 16.245MHz/fundamental with 16pF CL
2. 12.1225MHz/ fundamental with 16pF CL
3. 15.1225MHz/ fundamental with 16pF CL

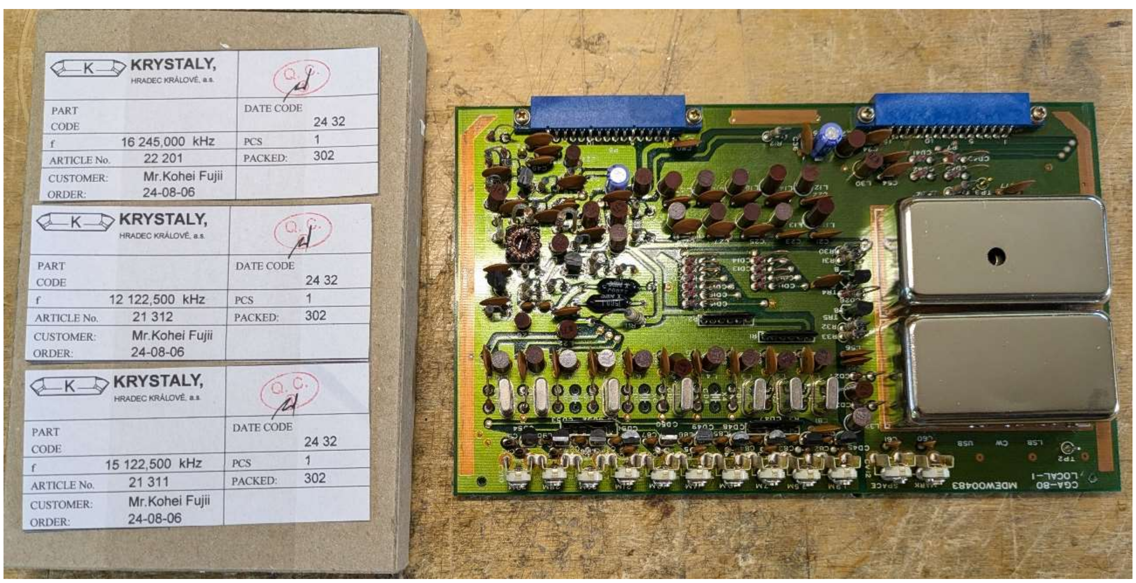

Figure 2. Photo for the custom crystal resonator and the LOCAL-1 Unit (CGA-80) before crystal installing. Three crystals have not been installed.

After installing those crystal resonators, all three optional frequencies were properly oscillated within tolerance with the trimmer capacitor adjustment.

3. Local 2-unit (CGA-81) modification

Desired pre-mixed frequencies for the WARC bands are 18.7-18.9MHz (10MHz band), 26.7-26.9MHz (18MHz band), and 33.5-33.7MHz (24MHz band). Those frequencies are mixed frequency products between the digital VFO (2.455-3.455MHz) and the crystal oscillators in the Local 1 unit (CGA-80). Due to the worst-case frequency proximity of 2.455MHz, the designing BPF requires very steep out of band rejection. To obtain a very high-Q BPF design, I have used three BPF sections for the Local 2-unit modification. I do not know why JRC selected very low VFO frequencies for the NSD-515 design. This BPF design is a really challenging design. Filter center frequency adjustment is also very challenging. Figure 3 shows a schematic for the BPF subassembly. For the BPF, T25-2 toroidal core was selected. This coil requires a tapped terminal for the impedance matching. Detailed design parameters are shown in Figure 3. I also tested a T37-2 toroidal core for higher inductor-Q. However, there is no major difference between T25-2 and T37-2. So, both toroidal cores are applicable for this BPF design. There is 13.5V voltage exist on the IN and OUT signal lines. Therefore, the diode switches are normally off. For activating the desired band, one of band selection terminals must be grounded.

Figure 4. is a photograph for the designed BPF PCB. I have used a free PCB layout editing software KiCAD, and I also ordered this PCB to a low-cost PCB manufacturing hose JLC PCB in China. www.jlcpcb.com. You can find very good YouTube videos for how to use the KiCAD and ordering custom PCB to the JLCPCB. The assembled subassembly (home-made CFL-164) was then installed on the Local-2 unit (CGA-81) as shown in Figure 5.

Measured results for the BPF frequency response are shown in Figure 6 through Figure 8. 2.5MHz out of band rejection is approximately 10dB. This number is similar to other existing bands on the Local 2 Unit (CGA-81). The worst-case insertion loss is 6.2dB. This loss includes the band selection diode switch loss. Due to the very narrow-band design, the measured insertion loss for the BPF is quite high. However, this number is almost identical to the existing non-WARC bands. So, the BPF design looks acceptable.

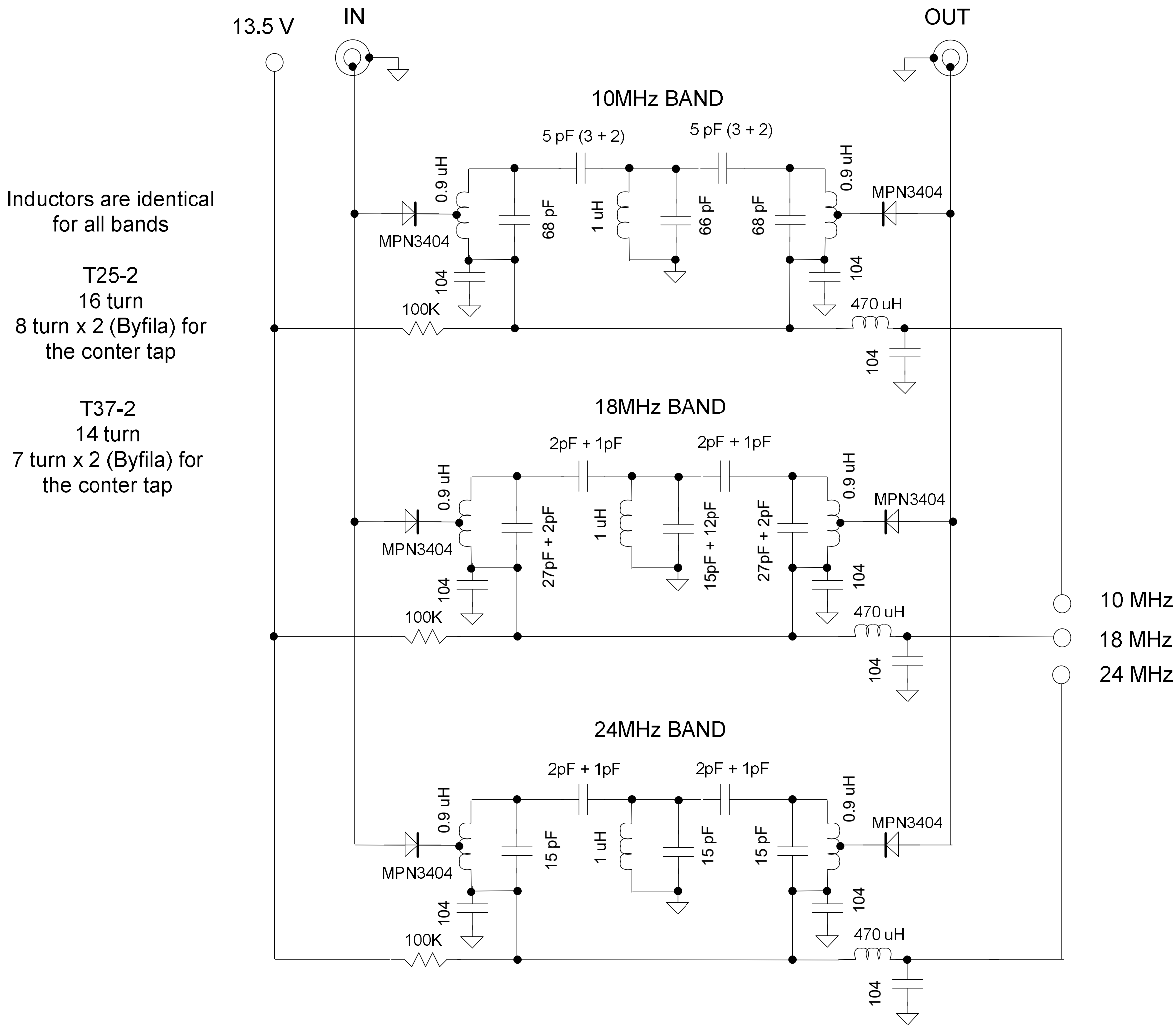

Figure 3. BPF subassembly (Home-made CFL-164) for the Local 2 unit

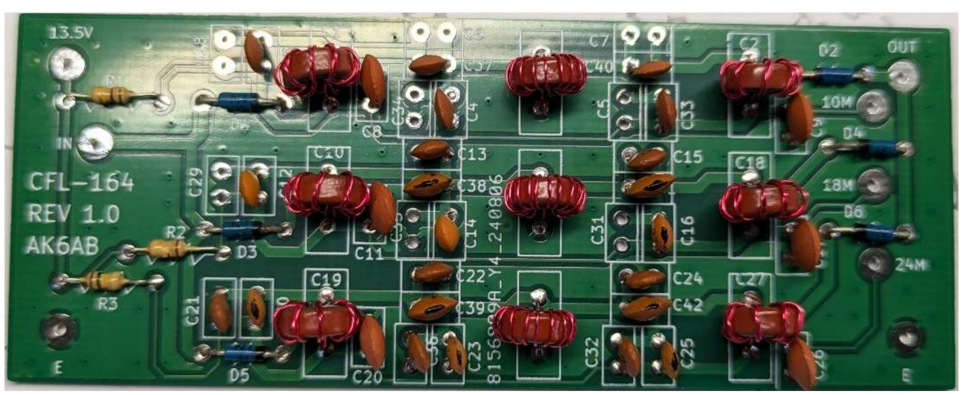

Figure 4. Designed and assembled BPF PCB (Home-made CFL-164).

Figure 5. After installing PCB on the Local-2 unit (CGA-81)

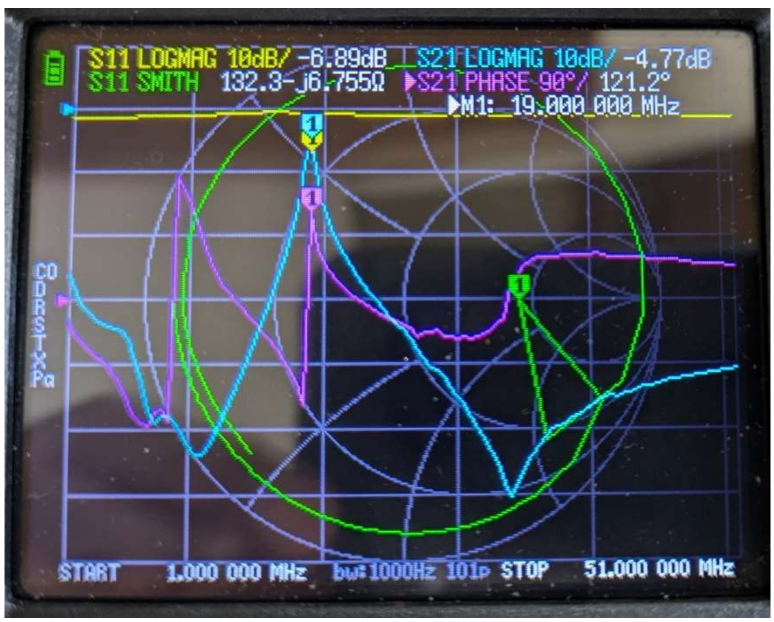

Figure 6. Measured BPF frequency response for the 10MHz band

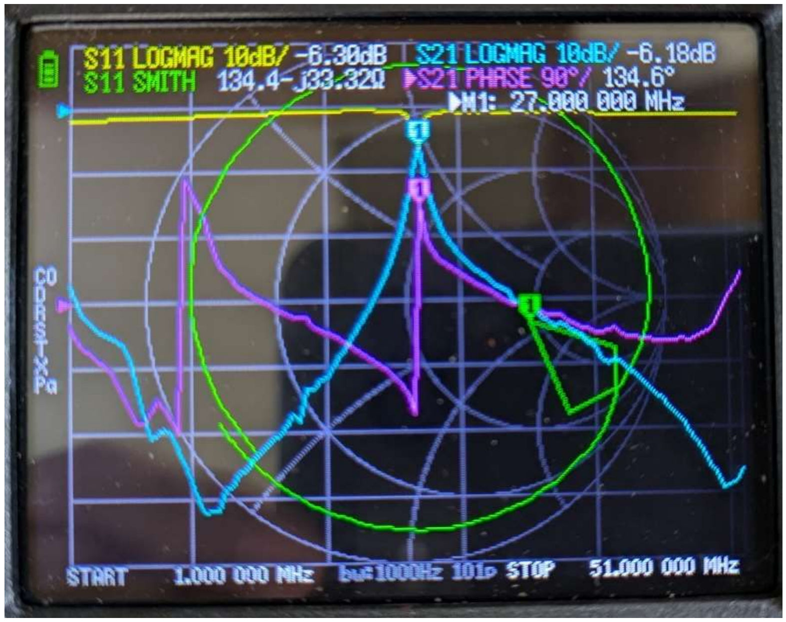

Figure 7. Measured BPF frequency response for the 18MHz band

Figure 8. Measured BPF frequency response for the 24MHz band

4. RF AMP unit (CFA-161) modification

RF AMP Unit (CFA-161) generates the transmitting frequencies from mixing between modulated IF (8.7MHz) signal from the AF IF unit (CAE-117) and the pre-mixed LO signals from the Local 2 unit (CGA-81). The mixing frequencies have 8.7MHz worst case frequency delta; therefore, the BPF design for the RF AMP unit is much easier than the Local 2 Unit. I selected two sections BPF design for all three bands. Figure 9 shows the schematic for the BPF unit, and this sub assembly is called the home-made CFL-163. For the BPF, T37-2 toroidal core was selected. This coil requires a tapped terminal for the impedance matching. Detailed design parameters are shown in Figure 7. CFL-163 also contains band selection diode switches. I used the MPN3404 low loss PIN diodes for the lowest possible insertion loss. Figure 10 shows the home-made CFL-163 board. The CFL-163 was then assembled on the RF AMP unit (CAF-161) as shown in Figure 11.

Measured results for the BPF frequency response are shown in Figure 12 through Figure 14. The worst case 8MHz out of band rejection is approximately 35dB. This number is similar to other existing bands on the RF AMP unit. The worst-case insertion loss is less than 3.2dB. This number includes the PIN diode switch loss. Due to the two sections BPF design, the insertion loss from the BPF is much smaller than the Local 2 unit.

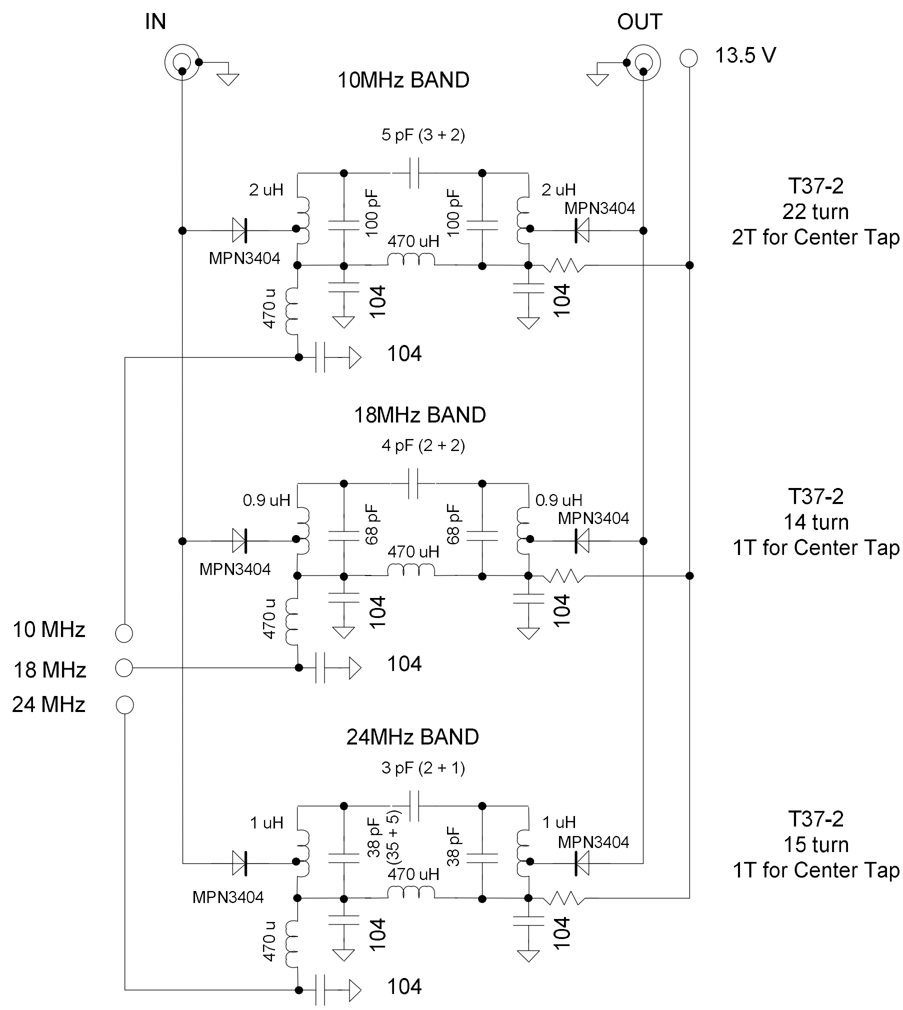

Figure 9. Schematic for the home-made CFL-163

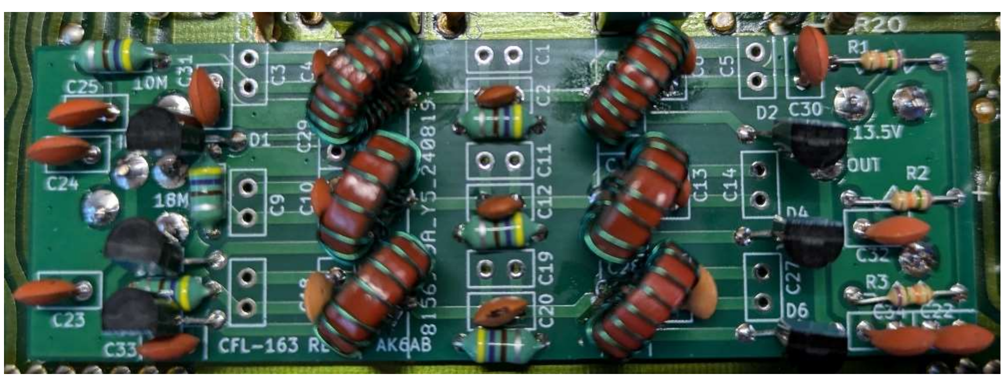

Figure 10. Designed and assembled BPF PCB for the RF AMP unit

(Home-made CFL-163)

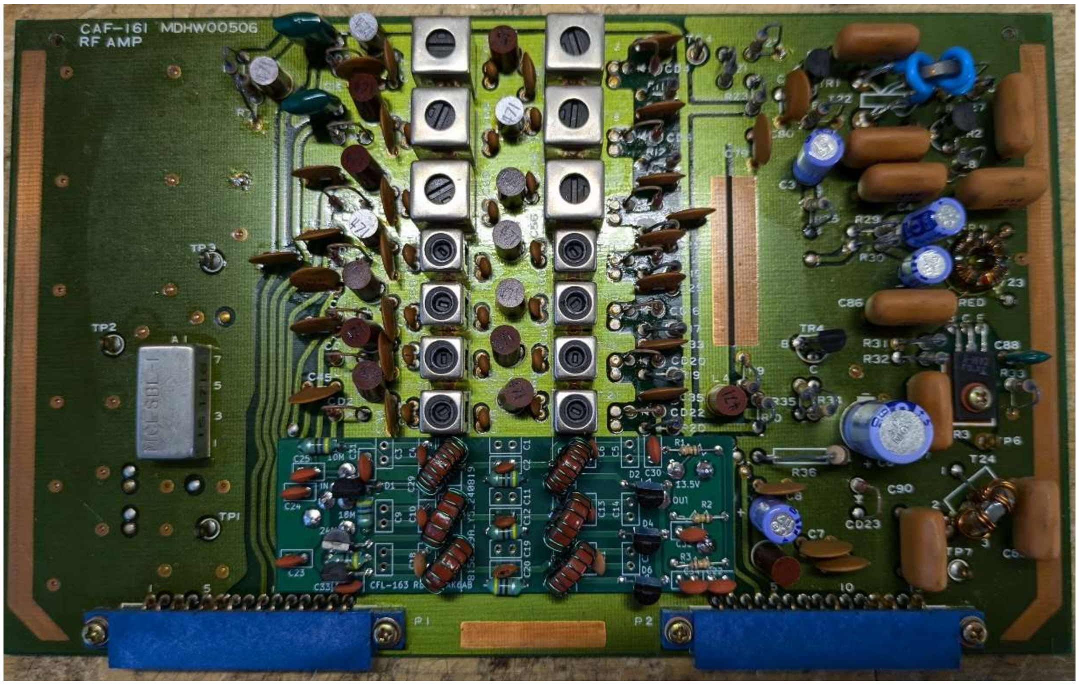

Figure 11. After installing the BPF PCB on the RF AMP unit (CAF-161)

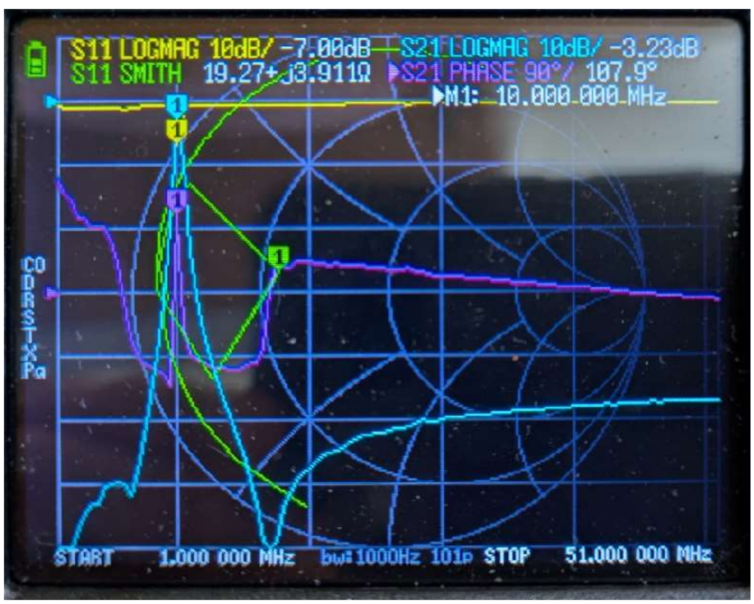

Figure 12. Measured BPF frequency response for the 10MHz band

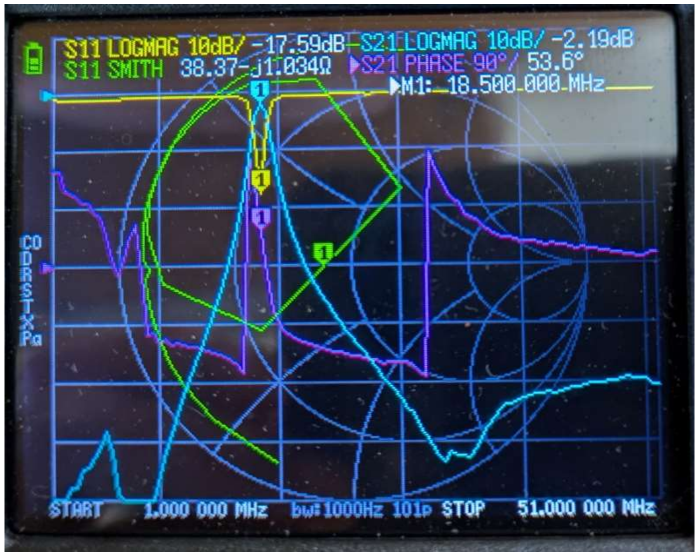

Figure 13. Measured BPF frequency response for the 18MHz band

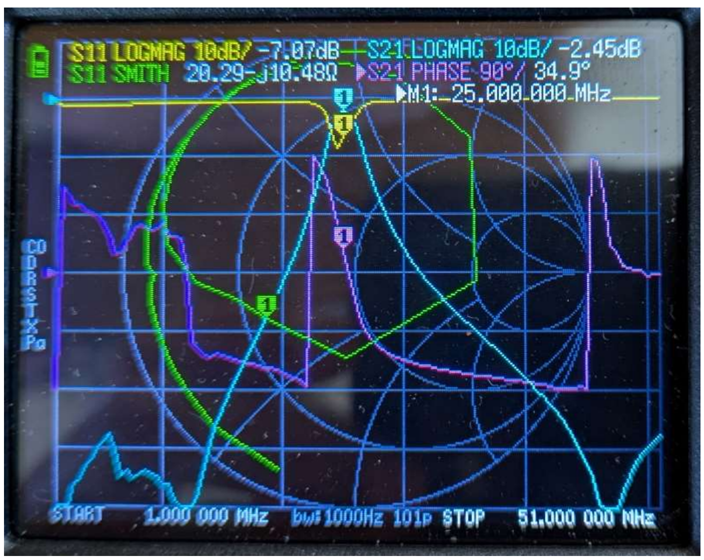

Figure 14. Measured BPF frequency response for the 24MHz band

5. OUTPUT-unit modification

OUTPUT unit contains LPFs for suppressing unwanted higher harmonics from the broad-band final power amplifier. The LPF for the high-power final amplifier requires at least 100W CW power handling. Therefore, I selected T-68-6 toroidal core, and 1mm diameter Cu wire. Also, the LPF requires at least 250V voltage rated silver mica capacitors. Figure 15 shows the designed LPF subassembly board. This board also contains bad selection drivers for controlling the band selecting SPDT relays. Also, this board contains analog switch ICs for selecting output power level control (POW APC) and reflection voltage adjustment (REF APC). A photograph for the home-made CMB-58 subassembly board is shown in Figure 16. The assembled LPF PCB (home-made CMB-58) was then installed over the OUTPUT-unit (CHM-84) as shown in Figure 17.

Measured results for the LPF frequency response are shown in Figure 18 through Figure 20. All LPFs showed better than -15dB return loss in the operational band. For the LPF design for the OUTPUT unit, the 3rd harmonics suppression is the main requirement, because the second harmonics are inherently low due to the push-pull final amplifier design. The measured 3rd harmonic suppression for the 10MHz LPF is 60dB. The worst-case insertion loss from the LPF is 1.42dB. This number includes the SPDT band switching relay loss. There was no overheating issue on the filter components observed from the CW transmitting operation.

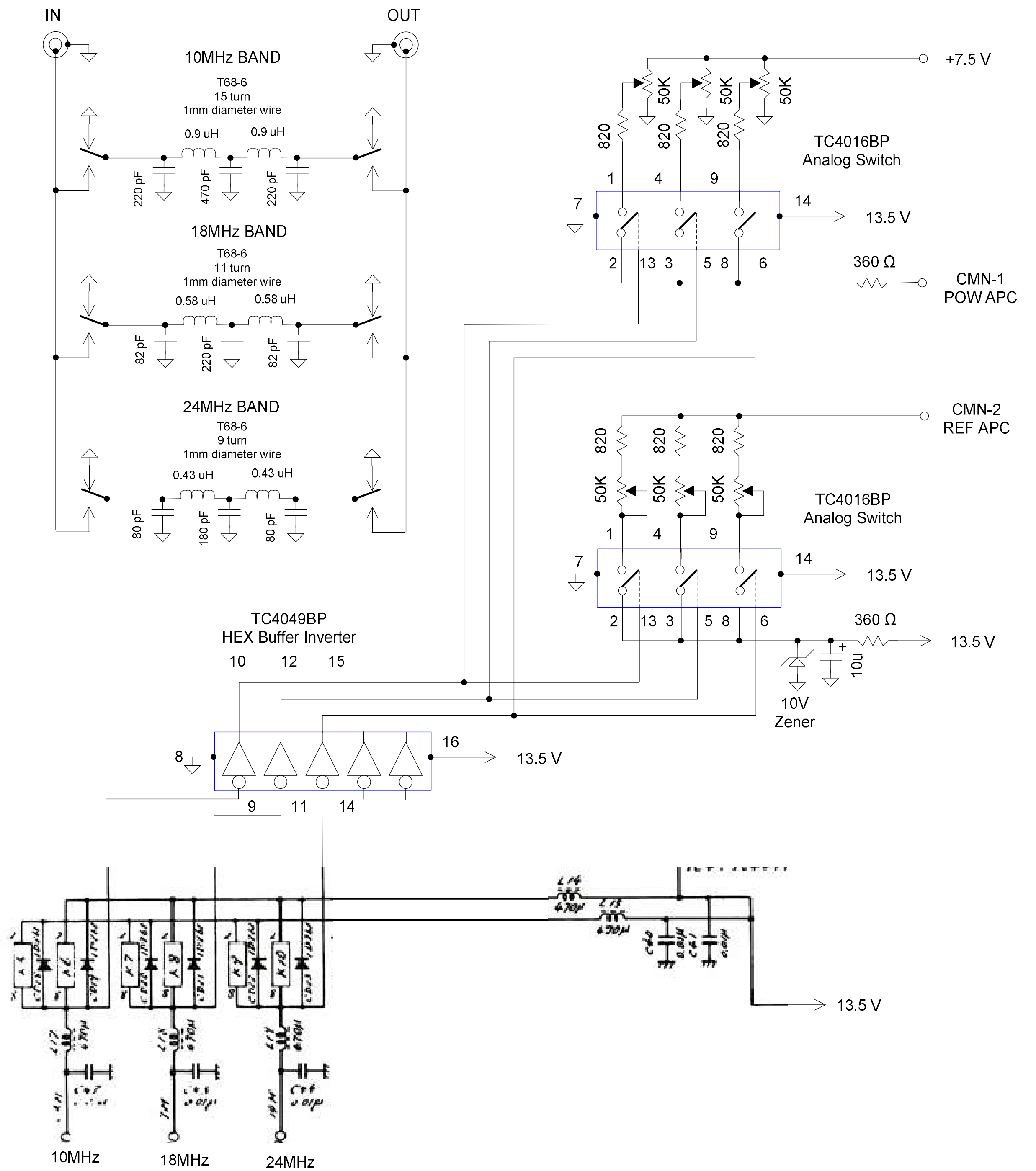

Figure 15. Schematic for the home-made CMB-58

Figure 16. Designed and assembled LPF PCB for the OUTPUT unit

(Home-made CMB-58)

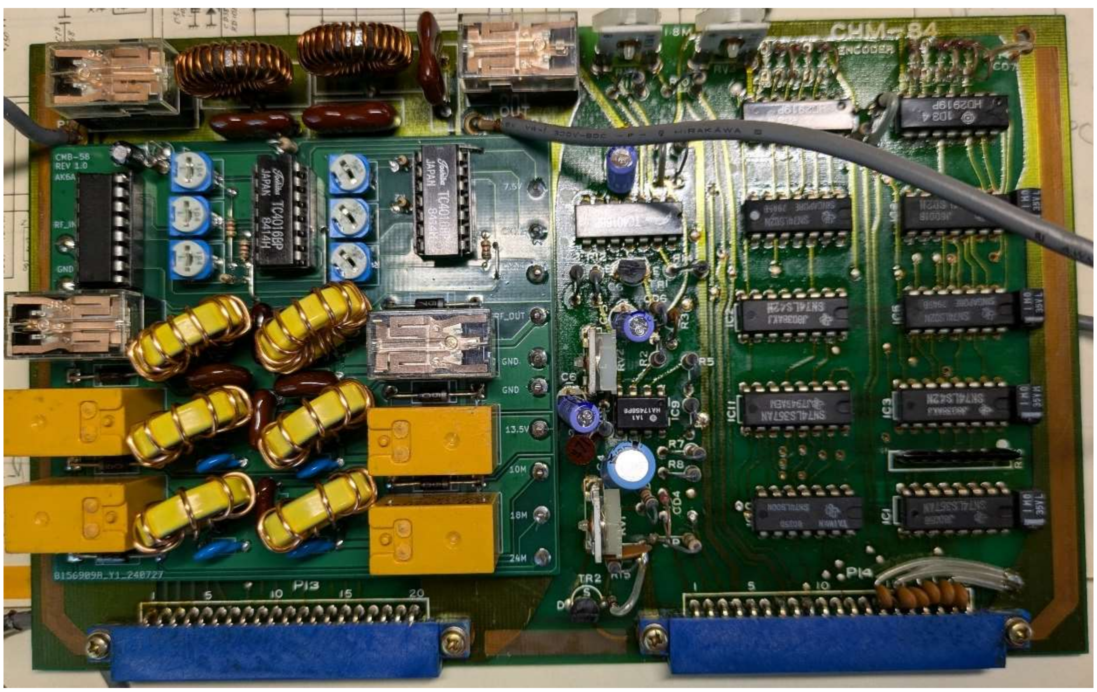

Figure 17. After installing the LPF PCB on the OUTPUT unit (CHM-84)

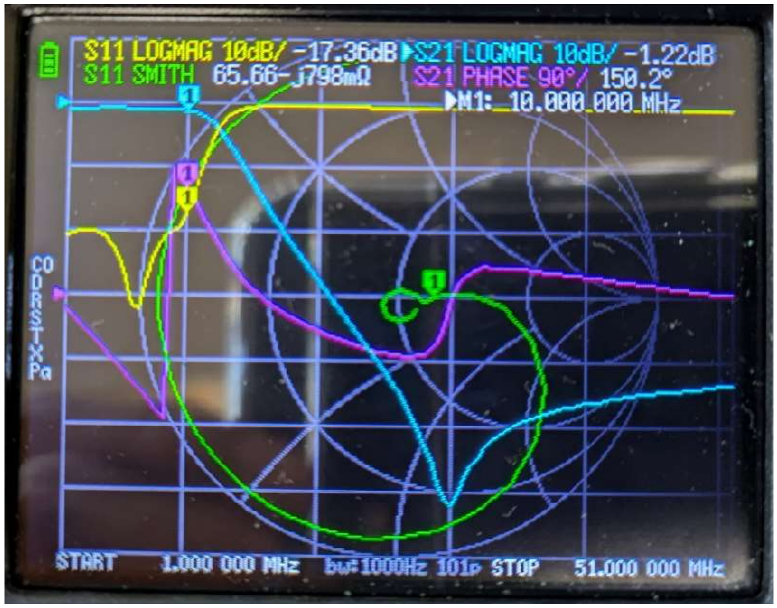

Figure 18. Measured BPF frequency response for the 10MHz band

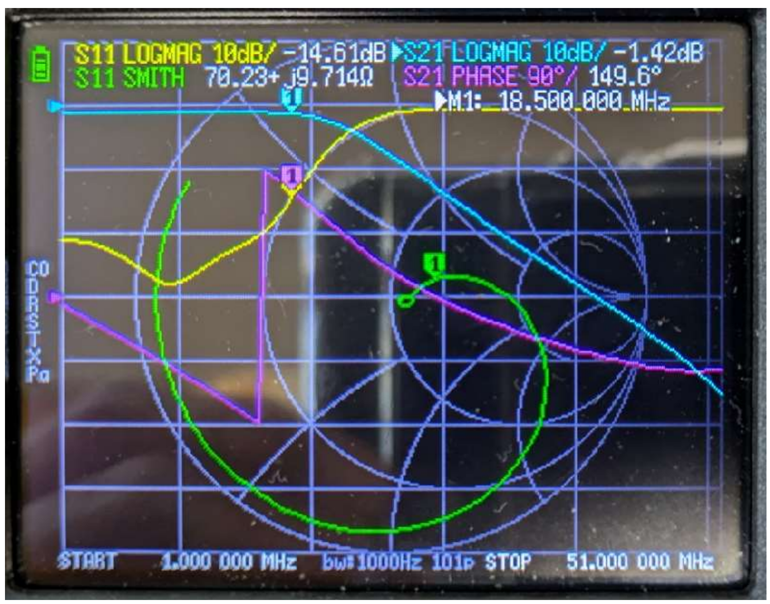

Figure 19. Measured BPF frequency response for the 18MHz band

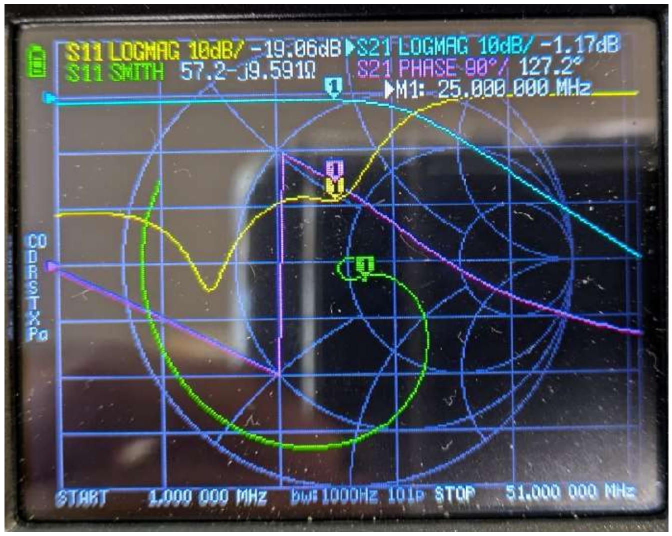

Figure 20. Measured BPF frequency response for the 24MHz band

6. Summary

NSD-515 WARC band modification project is successfully completed. This modification made my emotional bond to the JRC NSD-515 much higher level. Every single QSO using this customized NSD-515 makes me higher satisfactions, and it makes me very happy.