T41 Bandpass Filter Tuning (edited)
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I have built the Bandpass filter two ways; one with toroids and one with 1206 inductors. My testing was done with a NanoVNA. The first plot shows the performance of the bypass function showing a 14.3dB return loss and 1.3dB insertion loss at 50MHz. This is due to PCB layout and the RF switch performance.

When tuning the filters I work on maximizing the return loss (S11), since it is more sensitive than insertion loss (S21). And, I set two markers; one at the low end of the passband and one at the high end to assist in tuning.

I initially put 0402 pull down resistors on all the inverter inputs so that I could choose the filters manually by pulling the control line high. I then switched to using Oliver's (KI3P) BPFTest.ino test sketch which works very well.

Attached are plots with the two configurations; one with toroids and one done with 1206 inductors of every band. I spent a lot of time tuning the toroid version. I spent no time tuning the 1206 inductor version. Some of the 1206 inductor filters have significantly more insertion loss. This might be improved if time were spent adjusting the component values. I don't know if there is enough gain in the design to allow for ~10 dB loss in the bandpass filters.

For the 1206 inductor version, I bought whatever 1206 inductors that Mouser had that were close to what was in the BOM. I did not pay attention to Q, just focused on getting the least expensive inductors.

I changed the number of turns on the toroids and varied capacitance as I was tuning the toroid filters. The chart on the next page indicates calculated values and my final values. The higher frequency filters deviated the most from the calculated values. My assumption is that the PCB inductance/capacitance is not significant at these frequencies, but that the toroidal inductors are affecting the response. I base this on the 6M performance once I switched to air core inductors.

I could not get the 6M filter to work well in either configuration. I had to change the inductors to air core. I calculated the size and turns based on Wheeler's formula for single layer solenoids. I believe that the maximum Q is obtained when the length of the coil equals the width of the coil. I measured 6pF with no C604 (and no coils) installed I made C604 = 200pF + 180pF. Similarly, there is little capacitance from the PCB on C602 and C604 (contrary to my earlier statements). All capacitors in the 6 meter filter were per the BOM. All tuning was done with the air core coils.

I use a tweak stick with a piece of brass glued to one end a piece of ferrite glued to the other when tuning. Brass inserted into a coil lowers inductance. Ferrous material inserted into a coil increases inductance.

T41 K9HZ Bandpass Filter Components

1206 inductor version (micro/nanoHenry), Capacitance per BOM

	Lxx1	Lxx2	Lxx3	Lxx4	Lxx5
160M Calculated	2.0	11.0	1.0	11.0	2.0
160M Installed	2.2	10.0	1.0	10.0	2.2
80M Calculated	1.0	5.6	560	5.6	1.0
80M Installed	1.0	5.6	560	5.6	1.0
60M Calculated	840	5.2	400	5.2	840
60M Installed	840	5.2	400	5.2	840
40M Calculated	560	3.9	330	3.9	560
40M Installed	560	3.9	330	3.9	560
30M Calculated	245	3.6	132	3.6	245
30M Installed	220	3.3	150	3.3	220
20M Calculated	220	2.2	120	2.2	220
20M Installed	220	2.2	100	2.2	220
17/15M Calculated	150	1.2	82	1.2	150
17/15M Installed	150	1.0	82	1.0	150
12/10M Calculated	120	820	82	820	120
12/10M Installed	100	820	82	820	100
6M Calculated	39	680	22	680	39
6M Installed	See Wheeler's formula on right				

Toroid version (turns), Capacitance per BOM except for 17M & 12M

	Lxx1	Lxx2	Lxx3	Lxx4	Lxx5
160M Calculated	26	14	20	14	26
160M Installed	25	15	20	15	25
80M Calculated	20	26	34	26	20
80M Installed	18	26	30	26	18
60M Calculated	18	25	10	25	18
60M Installed	17	25	9	25	17
40M Calculated	34	22	26	22	34
40M Installed	29	21	22	21	29
30M Calculated	22	38	16	38	22
30M Installed	19	37	11	37	19
20M Calculated	21	27	16	27	21
20M Installed	18	26	12	26	18
17/15M Calculated	17	22	13	22	17
17/15M Installed	15	20	12	20	15
12/10M Calculated	16	18	13	18	16
12/10M Installed	14	18	12	18	14
6M Calculated	See Wheeler's formula on right. Toroids didn't work.				
6M Installed					

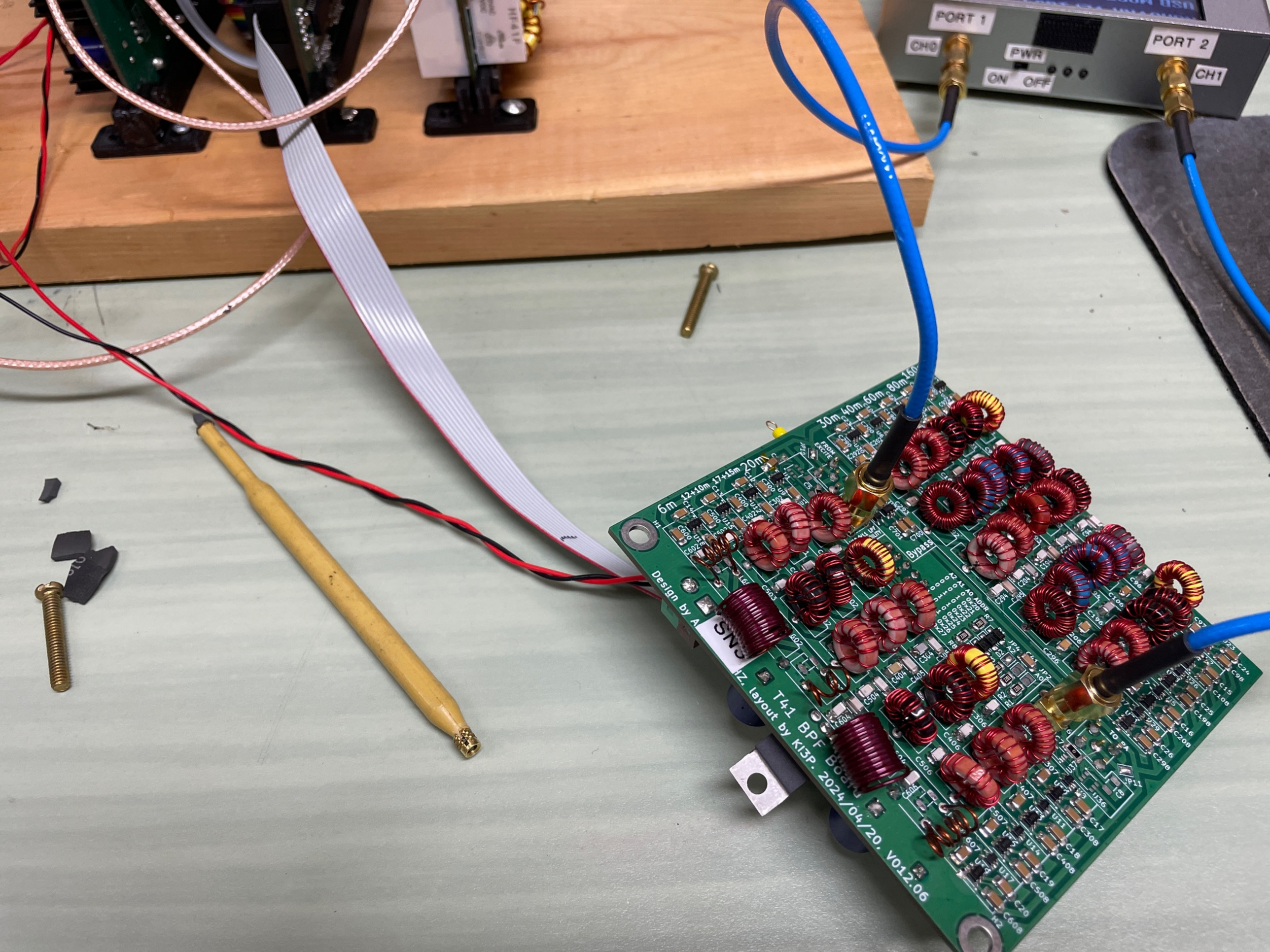
Use Wheeler's formula to calculate inductors for 6 meters

680nH: 13 turns DMandrill=0.313" (5/16) AWG=22

39nH: 5 turns DMandrill=0.125" (1/8) AWG=22

22nH: 3 turns DMandrill=0.125 AWG=22

Capacitor changes pF	**Cxx2**	**Cxx3**	**Cxx4**	**Cxx5**	**Cxx6**
17/15M Calculated	390	51	680	51	680
17/15M Installed	330	51	610	51	610
12/10M Calculated	300	43	510	43	300
12/10M Installed	270	43	470	43	270
6M	**per BOM**				

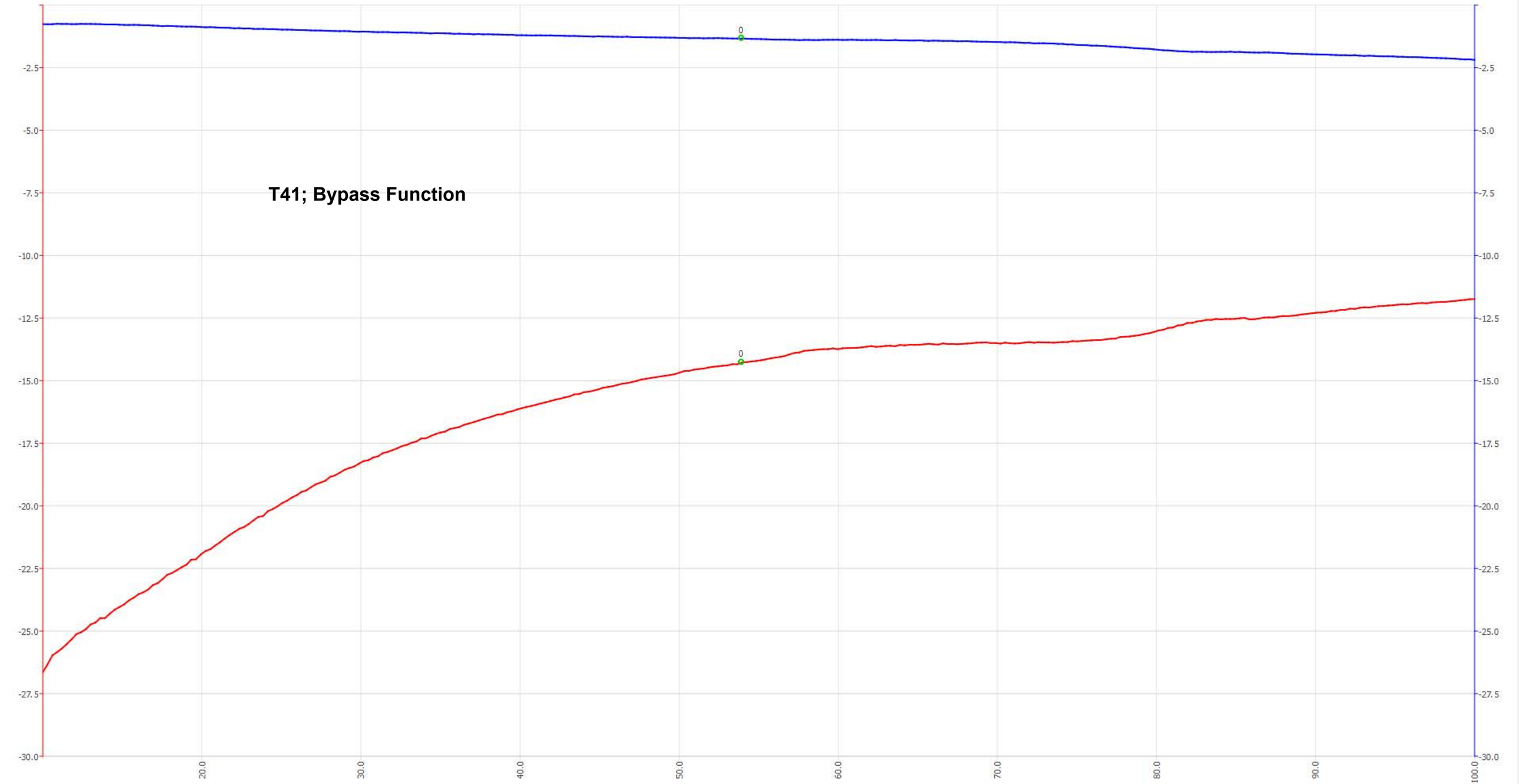

PORT 1
PORT 2
CH0
CH1
PWR
ON OFF
T41 BPF Board
Design by A
SN3
Bypass

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; Bypass Function



\+ 0 53.9465 MHz -14.3 dB -1.3 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 6 Meter Bandpass Filter with Air Core Inductors

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

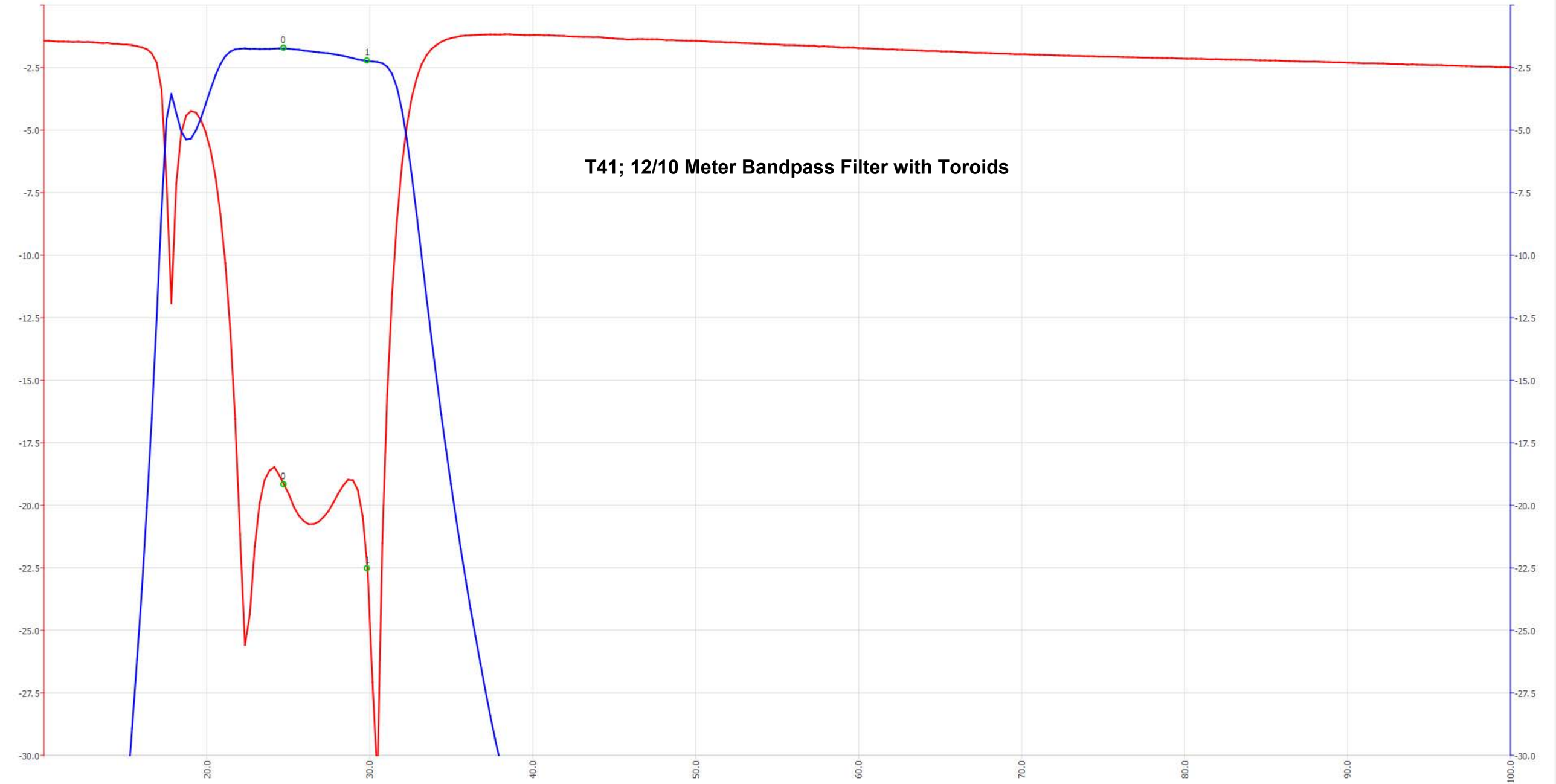
20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0

×	1	53.9465 MHz	-13.9 dB	-3.6 dB
+	0	50.0334 MHz	-11.2 dB	-3.6 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	29.8662 MHz	-22.5 dB	-2.2 dB
+	0	24.7492 MHz	-19.2 dB	-1.7 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 17/15 Meter Bandpass Filter with Toroids

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

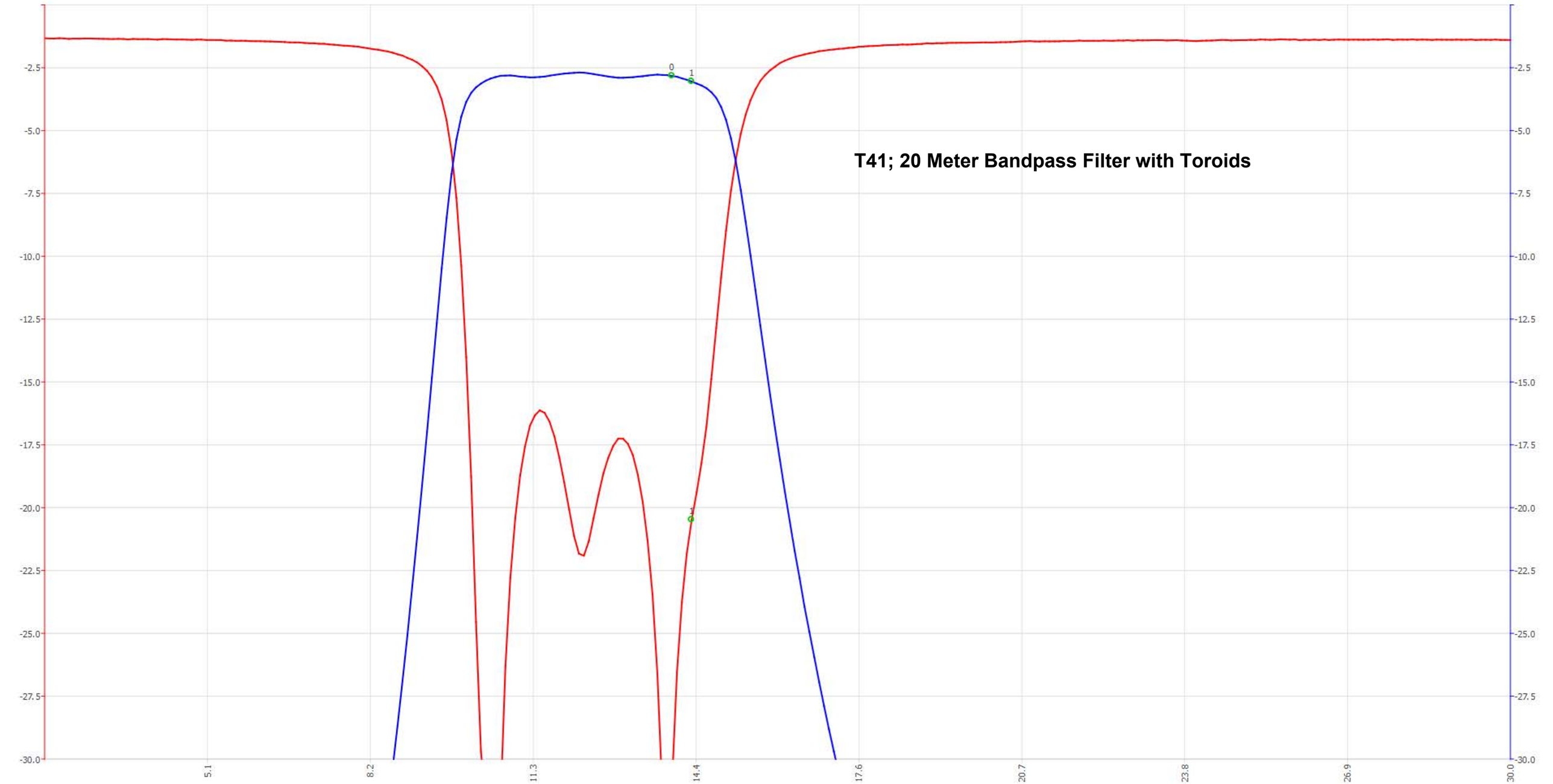
20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0

×	1	21.4381 MHz	-16.1 dB	-2.2 dB
+	0	18.1271 MHz	-17.3 dB	-1.9 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	14.3612 MHz	-20.5 dB	-3.1 dB
+	0	13.9866 MHz	-30.9 dB	-2.8 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 30 Meter Bandpass Filter with Toroids

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

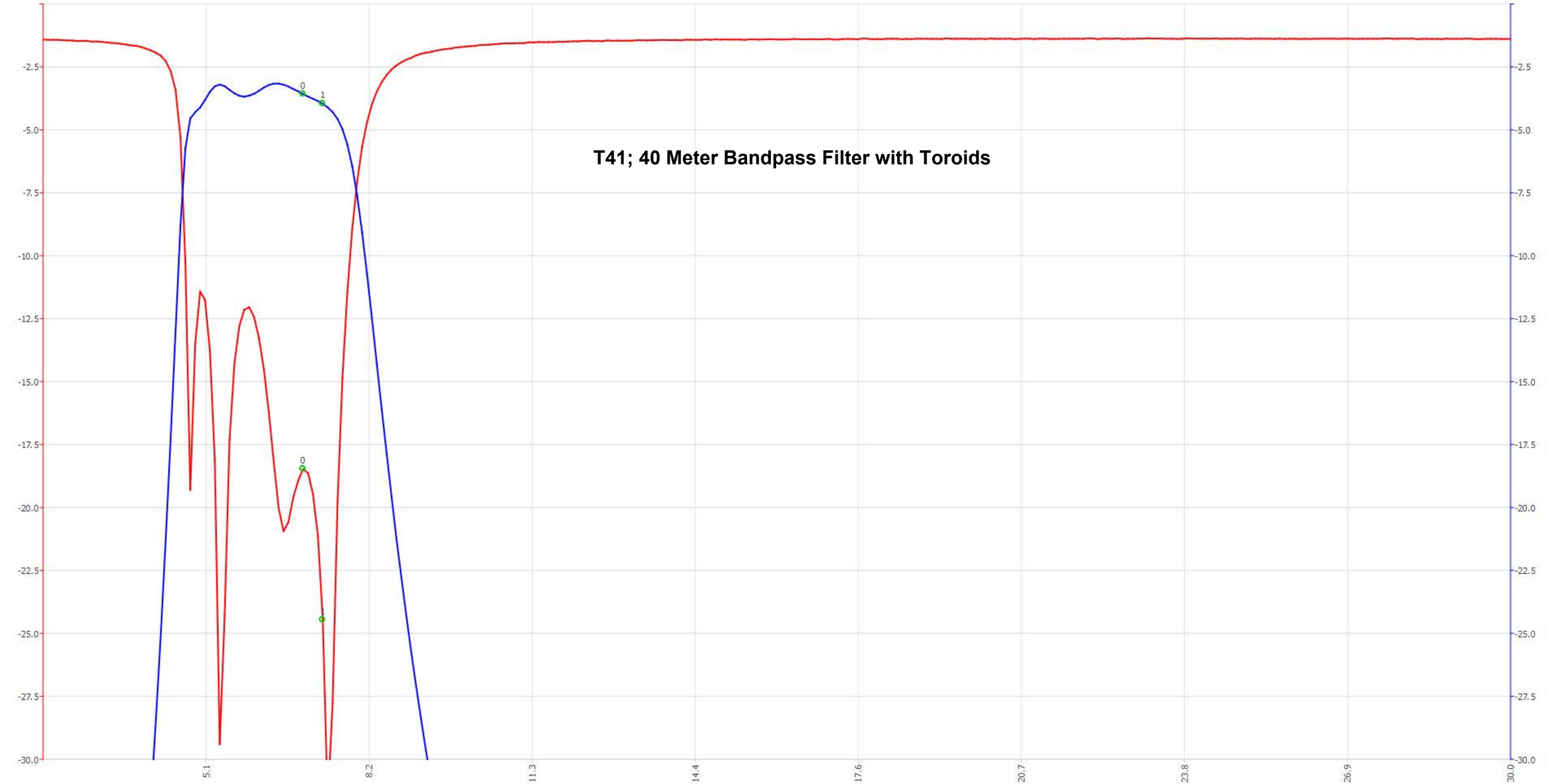
5.1 8.2 11.3 14.4 17.6 20.7 23.8 26.9 30.0

×	1	10.0535 MHz	-17.4 dB	-4.4 dB
+	0	10.1472 MHz	-16.6 dB	-4.3 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	7.33779 MHz	-24.5 dB	-4.0 dB
+	0	6.96321 MHz	-18.5 dB	-3.6 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 60 Meter Bandpass Filter with Toroids

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

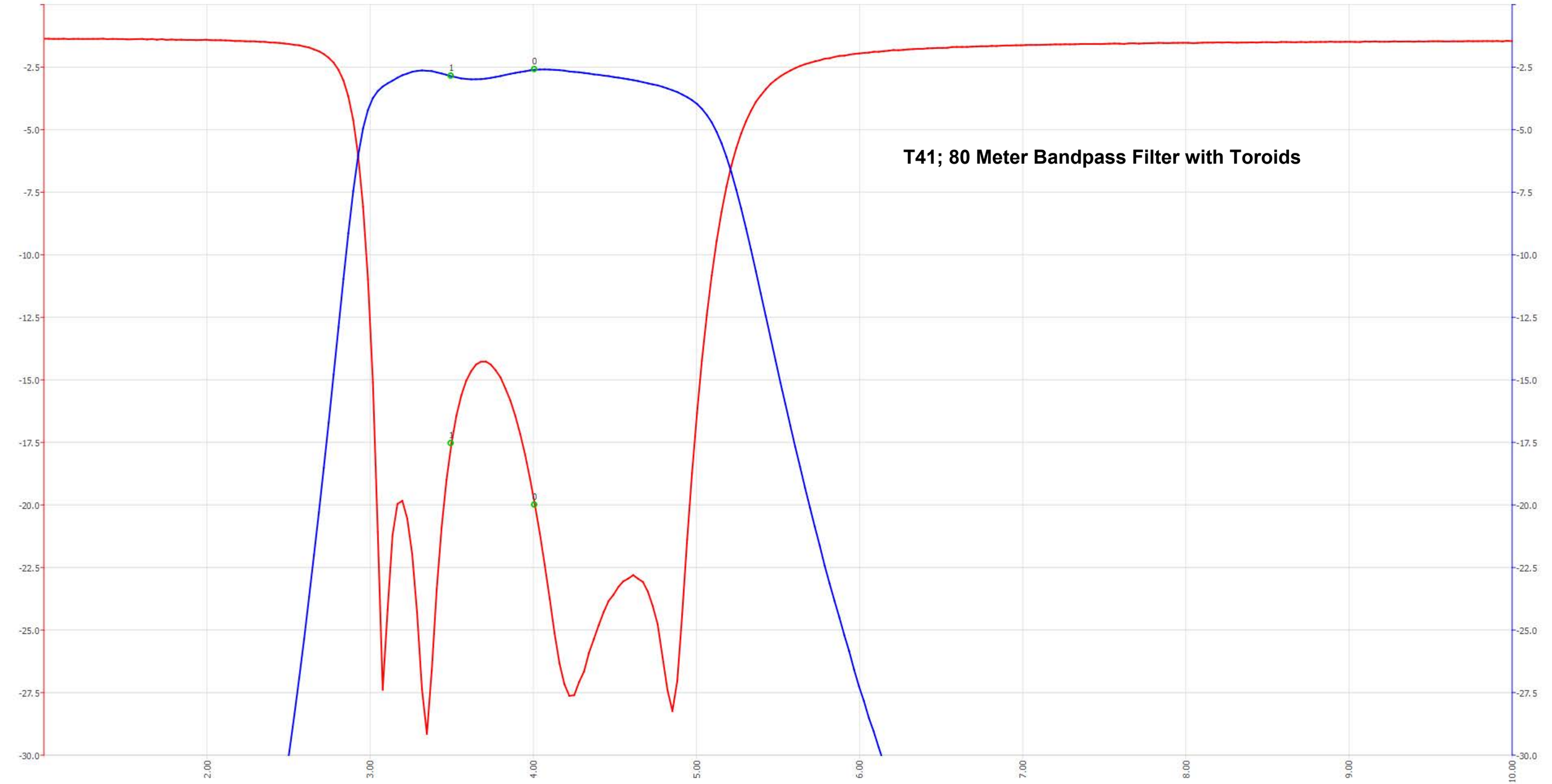
5.1 8.2 11.3 14.4 17.6 20.7 23.8 26.9 30.0

×	1	5.27759 MHz	-14.0 dB	-3.1 dB
+	0	5.46488 MHz	-14.9 dB	-3.1 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	3.49833 MHz	-17.6 dB	-2.9 dB
+	0	4.01003 MHz	-20.0 dB	-2.6 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 160 Meter Bandpass Filter with Toroids

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00

×	1	1.99331 MHz	-25.4 dB	-1.8 dB
+	0	1.81271 MHz	-17.8 dB	-2.1 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 12/10 Meter Bandpass Filter with 1206 Inductors, no tuning

-10.0 -20.0 -30.0 -40.0 -50.0 -60.0

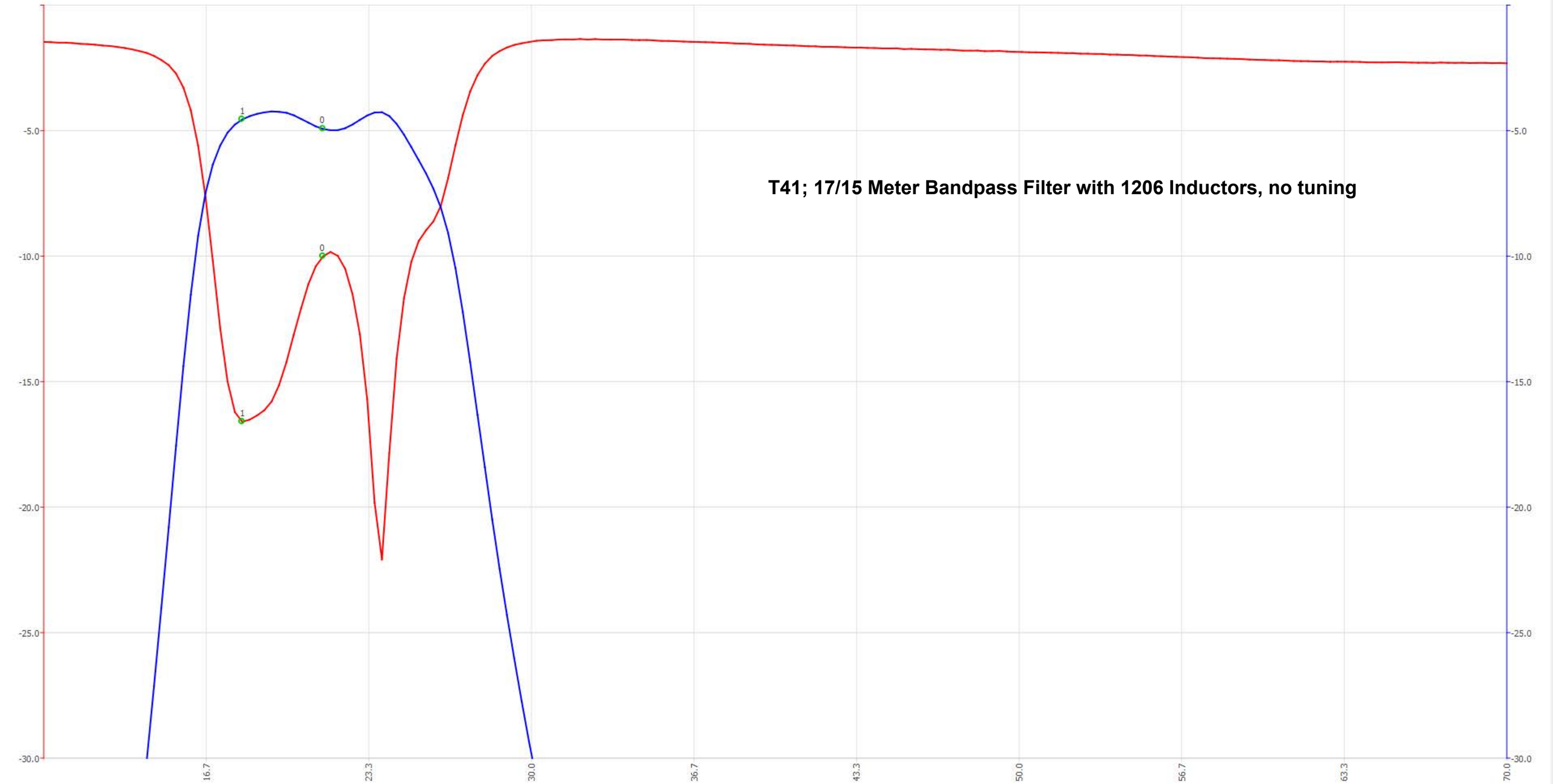
16.7 23.3 30.0 36.7 43.3 50.0 56.7 63.3 70.0

×	1	29.5980 MHz	-13.9 dB	-3.5 dB
+	0	25.0754 MHz	-16.5 dB	-2.9 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

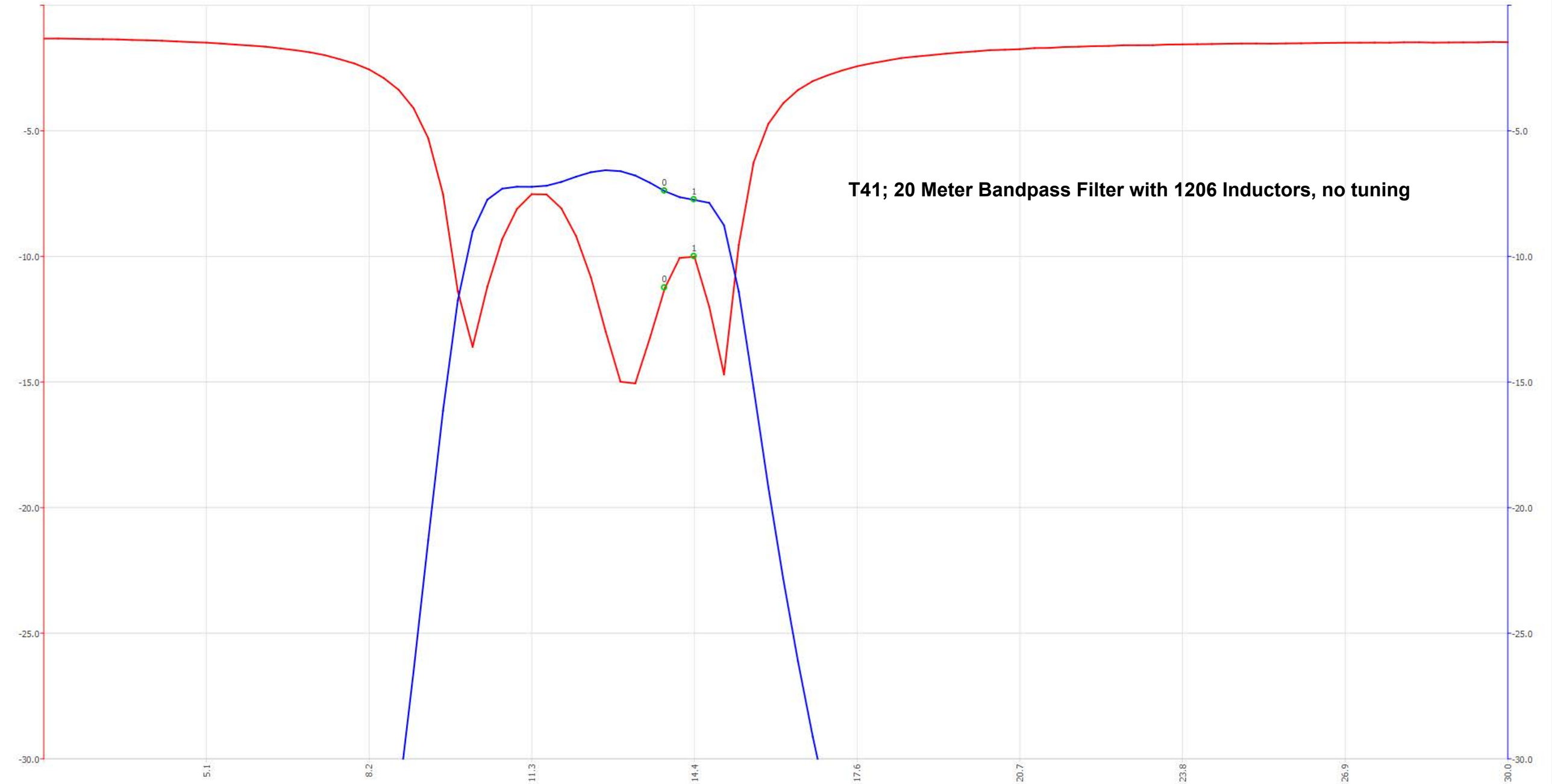


×	1	18.1407 MHz	-16.6 dB	-4.6 dB
+	0	21.4573 MHz	-10.0 dB	-4.9 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



T41; 20 Meter Bandpass Filter with 1206 Inductors, no tuning

×	1	14.4444 MHz	-10.0 dB	-7.8 dB
+	0	13.8788 MHz	-11.3 dB	-7.4 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 30 Meter Bandpass Filter with 1206 Inductors, no tuning

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

01 1 0

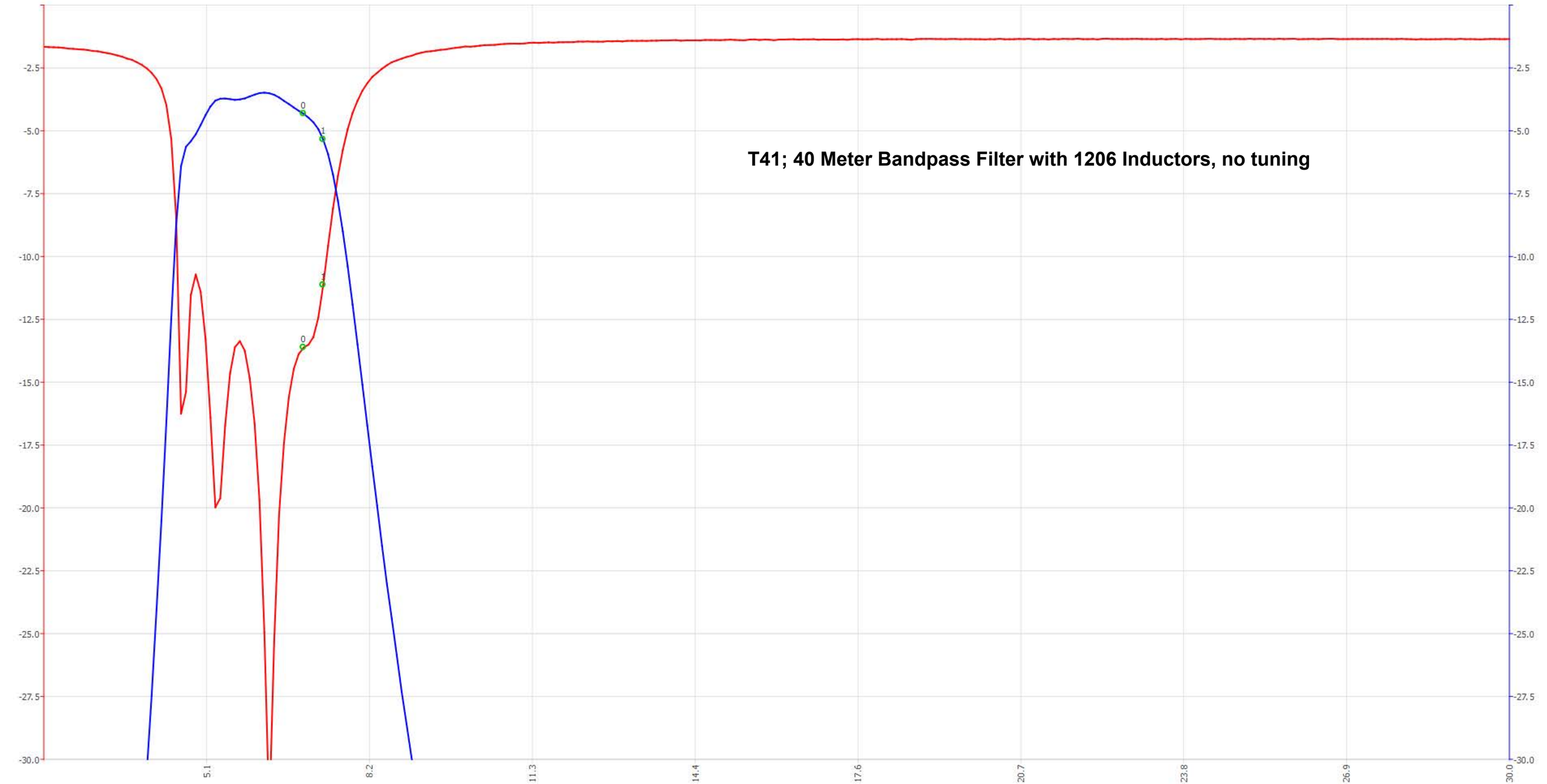
5.1 8.2 11.3 14.4 17.6 20.7 23.8 26.9 30.0

×	1	10.1472 MHz	-12.7 dB	-7.6 dB
+	0	10.0535 MHz	-13.5 dB	-7.6 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	7.33779 MHz	-11.1 dB	-5.4 dB
+	0	6.96321 MHz	-13.6 dB	-4.3 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41; 60 Meter Bandpass Filter with 1206 Inductors, no tuning

-2.5 -5.0 -7.5 -10.0 -12.5 -15.0 -17.5 -20.0 -22.5 -25.0 -27.5 -30.0

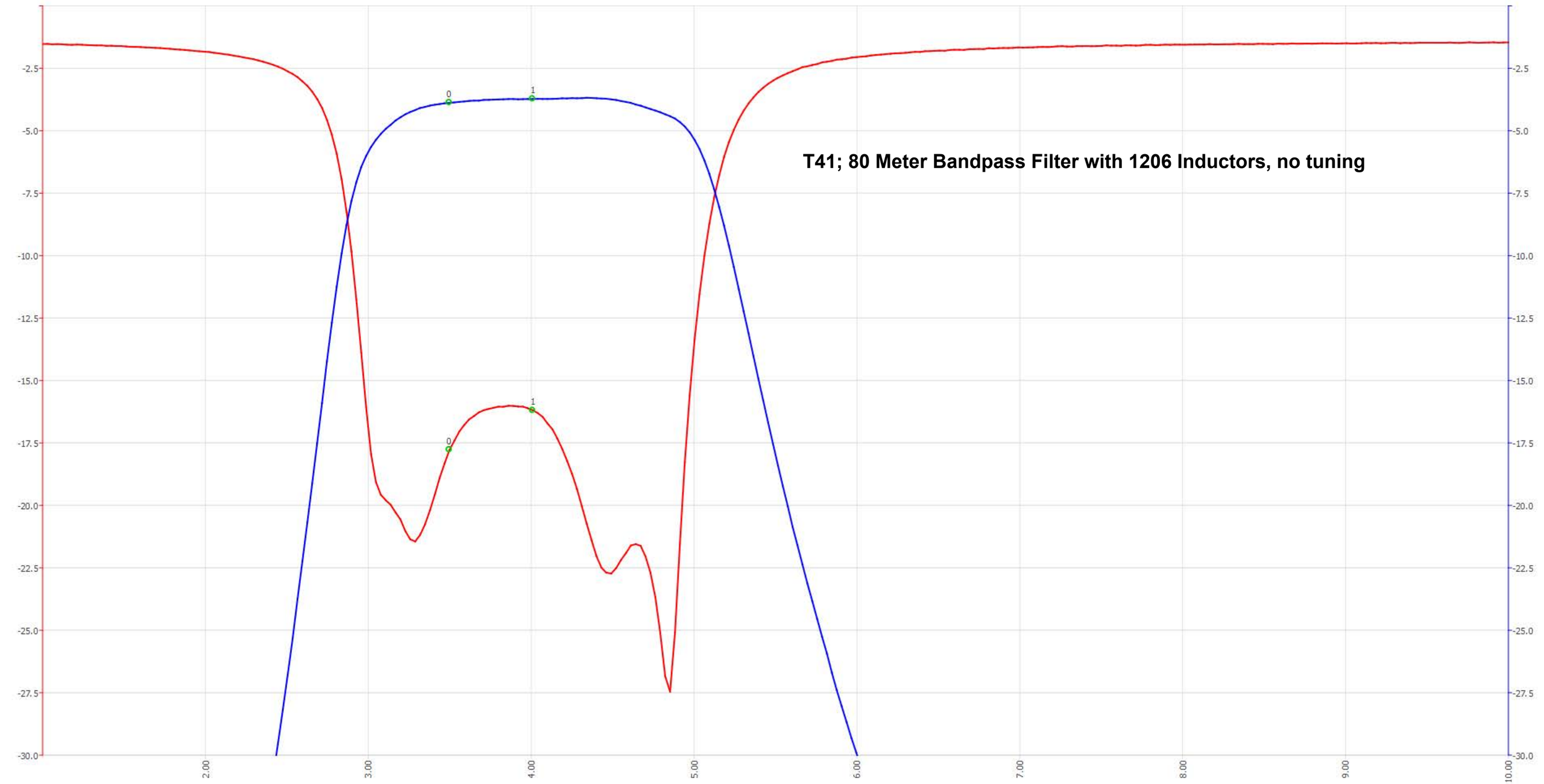
5.1 8.2 11.3 14.4 17.6 20.7 23.8 26.9 30.0

×	1	5.46488 MHz	-9.0 dB	-8.9 dB
+	0	5.27759 MHz	-8.2 dB	-8.8 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

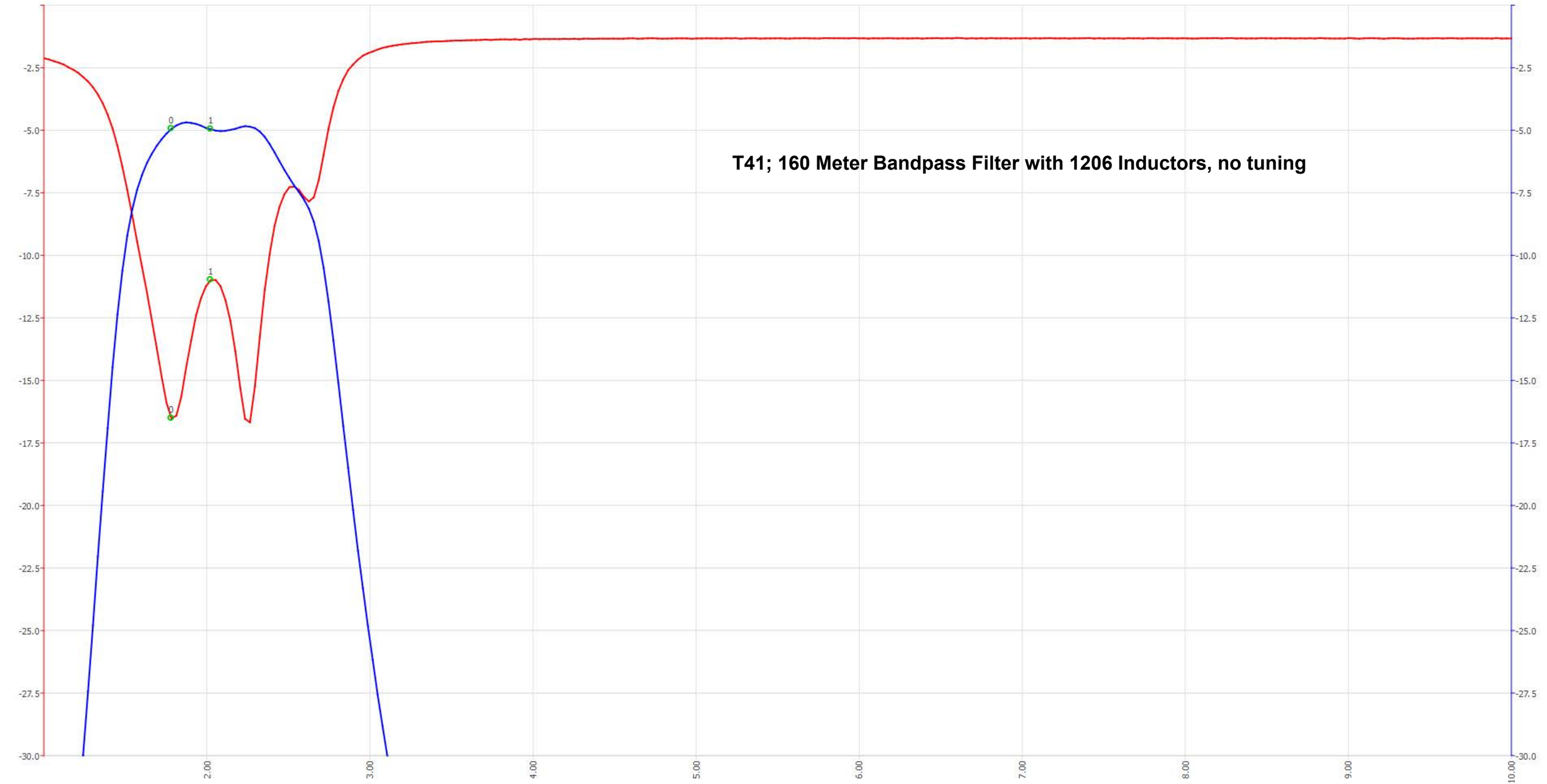


×	1	4.01003 MHz	-16.2 dB	-3.7 dB	
+	0	3.49833 MHz	-17.8 dB	-3.9 dB	

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	2.02341 MHz	-11.0 dB	-5.0 dB
+	0	1.78261 MHz	-16.5 dB	-4.9 dB