T41 Lowpass Filter Tuning
Dave, N3DS; 8-20-24

I have built two K9HZ 100Wt Lowpass Filters Modules and aligned them. My testing was done with a NanoVNA. Attached are a series of plots. The first plot shows the performance of the bypass function showing a >8dB return loss and <2dB insertion loss at 50MHz. This is due to PCB layout and the relay performance.

When aligning 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 selected the filters manually by feeding 12 volts to the LPF board and pulling the control lines low. I tried the K9HZ_LPF_tester.ino sketch, but I don't have the AD7991 populated. This causes the K9HZ_LPF_tester.ino program to crash and I was not able to comment out the required lines.

The three higher frequency filters were difficult to align. I believe that the parasitic capacitance of the PCB and/or the relays skews the frequency response. I measured about 60pF of capacitance on the input and outputs of the filters with no components installed. I reduced the output capacitors by that much on the three higher frequency filters. In the following chart, you can see the capacitor values that I changed. I changed the number of turns on the toroids which is annotated in the chart. I then compressed and stretched the windings as needed to align the filters.

My procedure for building the board was to mount all the SMD components. Then, the relays and other components, followed by the toroids last. I precut all the relay pins so that they were flush and did not protrude into the toroid windings. I soldered all the toroids in from the side that they are mounted on.

If you have to change capacitors, like I did on some filters, you need to be aware that the relays are made with a very low temperature plastic. I used heat shields (1 inch of) copper tape next to the caps when I unsoldered them with the hot air gun with a very small nozzle. Likewise, I used heat shields on the top of the relays so that my soldering iron (with a long slender tip) did not melt the relays when I bumped against them. An alternative would be to remove the relays to get to the capacitors. I also found it difficult to unsolder the toroids without damaging the pads. So, my initial tuning of the filters was done with just tacking the toroids to the board without inserting the leads into the mounting holes

I like to use heavy formvar insulation on magnet wire. The Knipex tool was great for removing formvar – thanks to whoever recommended it. The standard "teeth" works well on 20AWG and up. It did not work will on smaller gages.

T41 K9HZ Lowpass Filter Components

Toroid (T68) turns, Capacitance per BOM except as noted				
	Lin	**Lctr**	**Lout**	
160M design (nH)	5210	4730	5210	
160M Calculated (turns)	30.2	28.8	30.2	-2 red
160M Installed (turns)	30	27	30	-2 red
80M design (nH)	2680	2430	2680	
80M Calculated (turns)	21.7	20.6	21.7	-2 red
80M Installed (turns)	21	20	21	-2 red
60M design (nH)	1760	1600	1760	
60M Calculated (turns)	17.6	16.8	17.6	-2 red
60M Installed (turns)	17	16	17	-2 red
40M design (nH)	1340	1220	1340	
40M Calculated (turns)	16.9	16.1	16.9	-6 yellow
40M Installed (turns)	16	15	16	-6 yellow
30M design (nH)	928	834	928	
30M Calculated (turns)	14.1	13.4	14.1	-6 yellow
30M Installed (turns)	14	13	14	-6 yellow
20M design (nH)	670	608	670	
20M Calculated (turns)	10.8	11.4	10.8	-6 yellow
20M Installed (turns)	11	10	11	-6 yellow
17M design (nH)	519	471	519	
17M Calculated (turns)	10.5	10.0	10.5	-6 yellow
17M Installed (turns)	9	9	9	-6 yellow
15M design (nH)	447	406	447	
15M Calculated (turns)	9.8	9.3	9.8	-6 yellow
15M Installed (turns)	9	9	9	-6 yellow
12M design (nH)	337	342	337	
12M Calculated (turns)	8.5	8.5	8.5	-6 yellow
12M Installed (turns)	7	7	7	-6 yellow
10M design (nH)	335	305	335	
10M Calculated (turns)	8.4	8.1	8.4	-6 yellow
10M Installed (turns)	7	7	7	-6 yellow
6M design (nH)	188	170	188	
6M Calculated (turns)	9.5	9.0	10	-17 blue/yel
6M Installed (turns)	8	7	8	-17 blue/yel

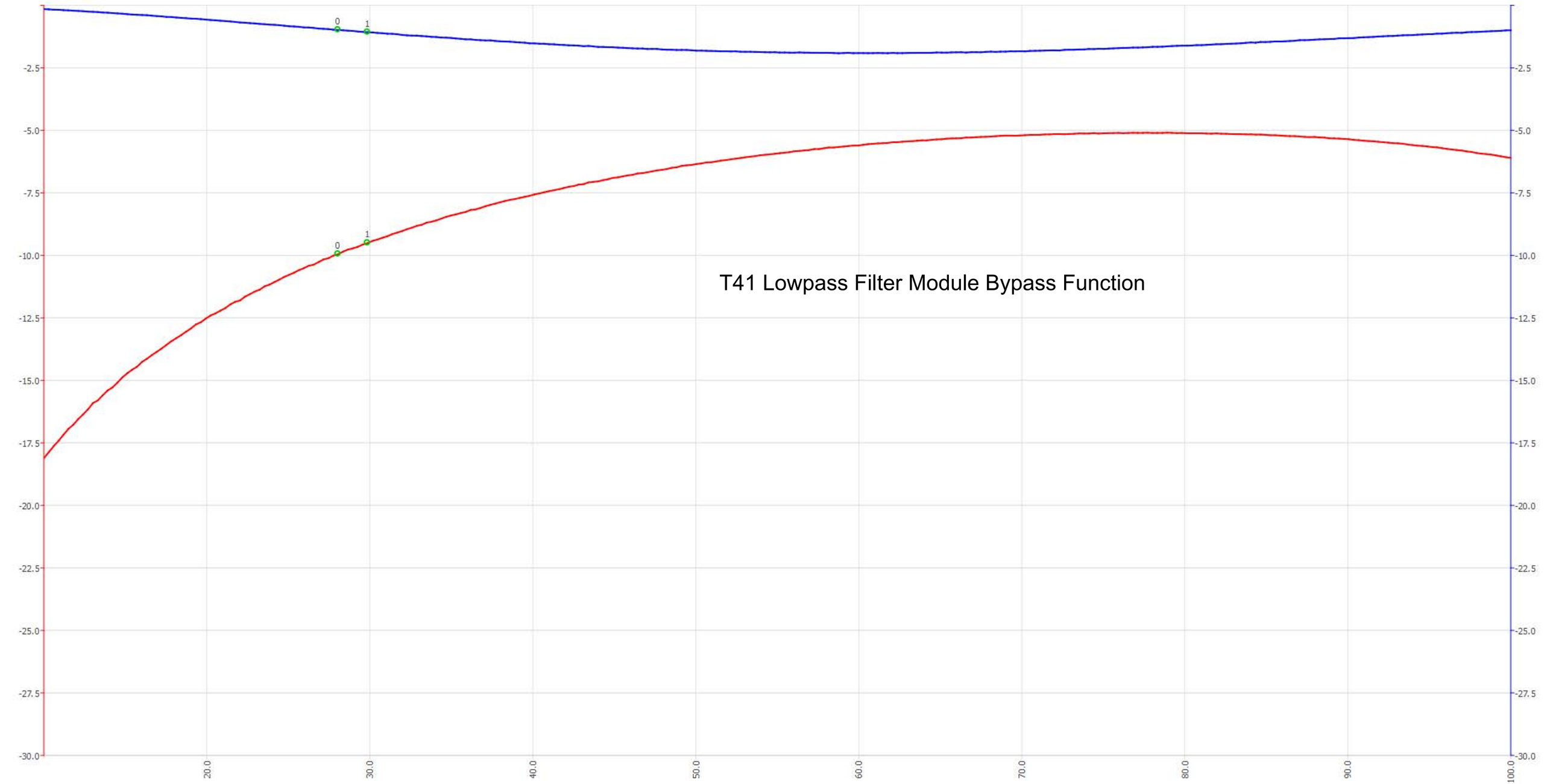
The PCB adds about 60pF to the input and output of the LPF's so reduce the top 3 Bands output caps by ~60pF.

Capacitor changes pF		
	C37/98	C50/81
12M Calculated (pF)	120	180
12M Installed (pF)	56	180
	C38/99	C53/72
10M Calculated (pF)	100	164
10M Installed (pF)	47	164
	C39/100	C51/82
6M Calculated (pF)	60	91
6M Installed (pF)	0	68

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



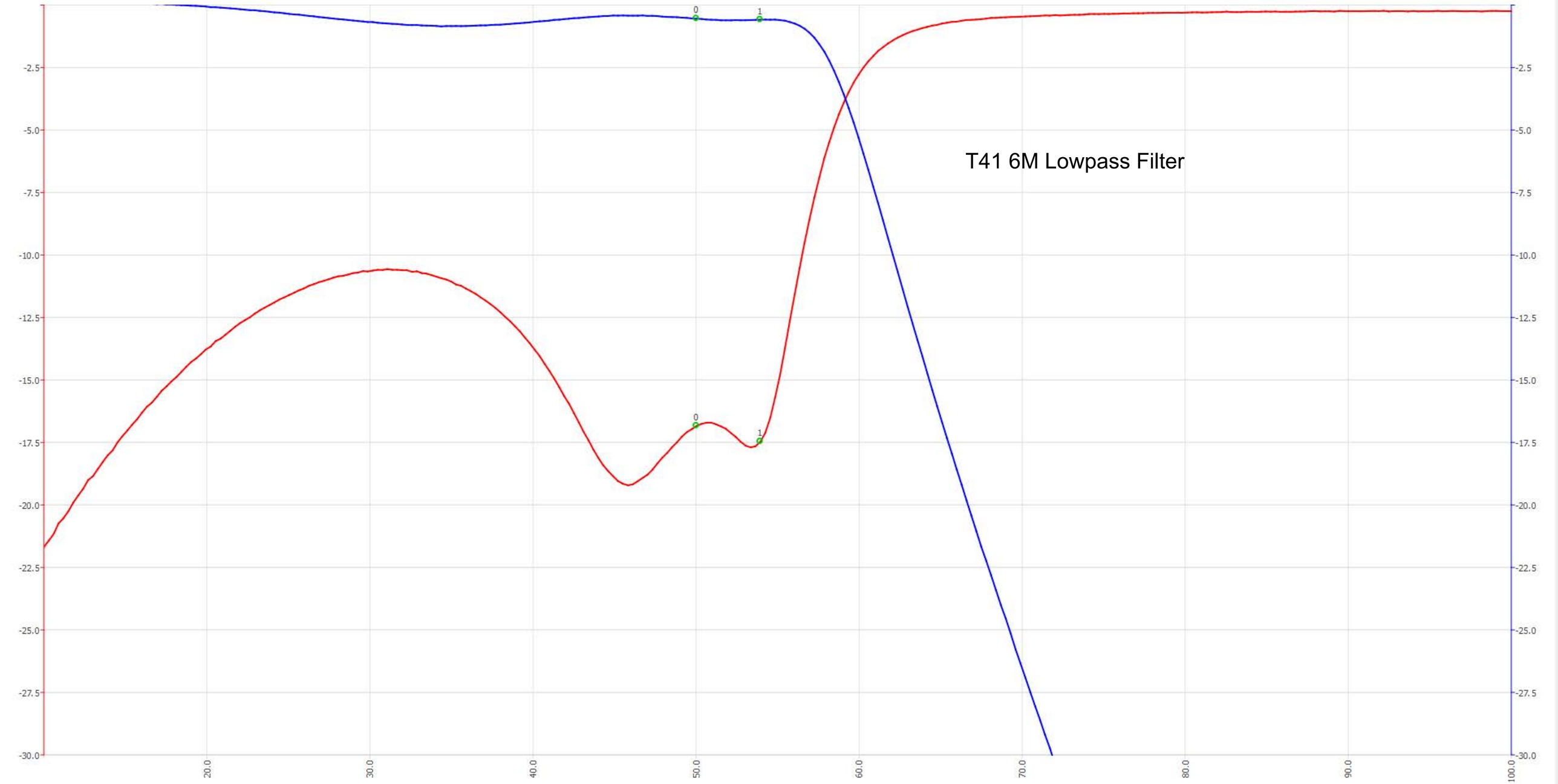
T41 Lowpass Filter Module Bypass Function

×	1	29.8662 MHz	-9.5 dB	-1.1 dB	
+	0	28.0602 MHz	-10.0 dB	-1.0 dB	

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

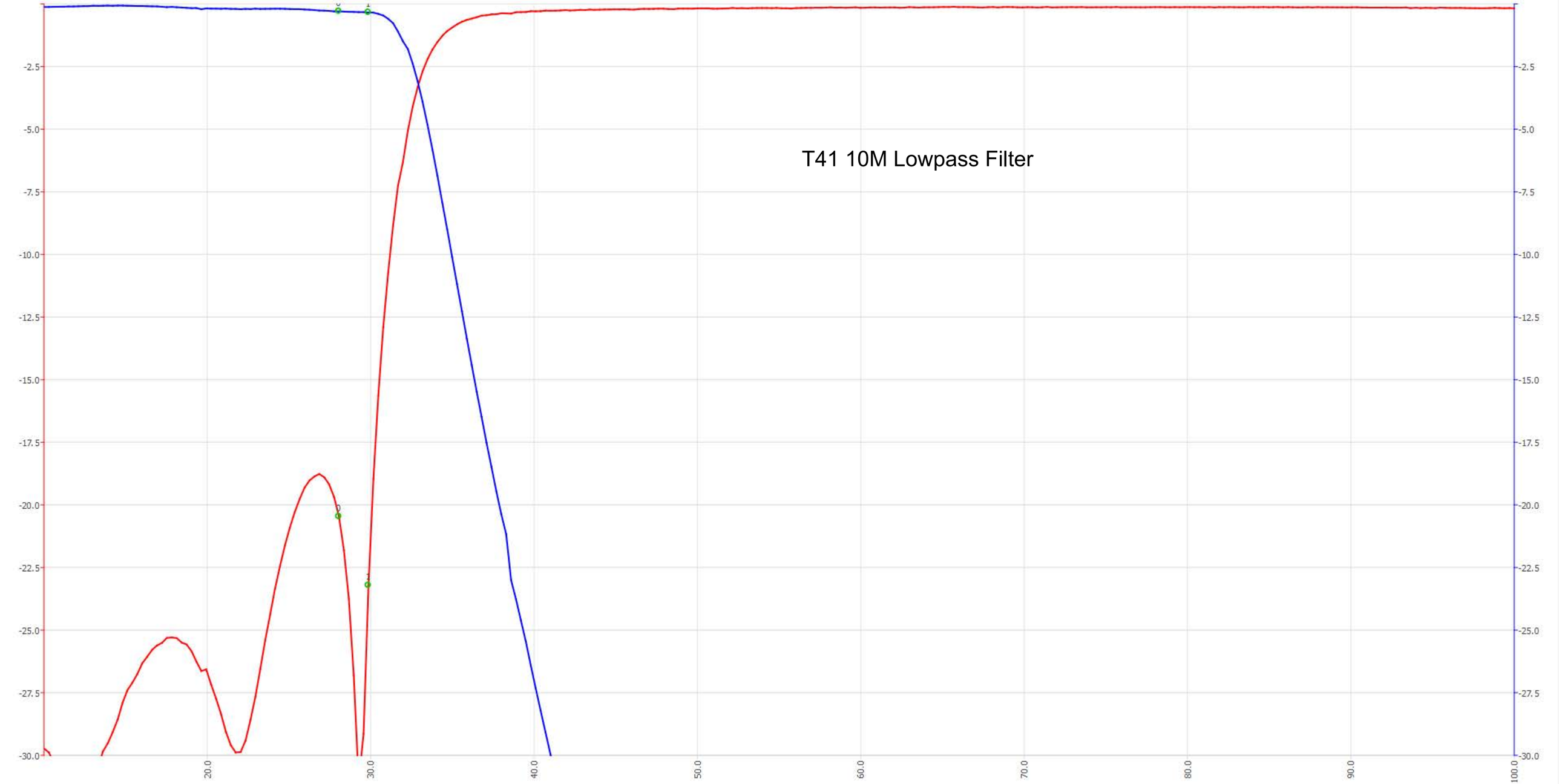


×	1	53.9465 MHz	-17.5 dB	-0.6 dB
+	0	50.0334 MHz	-16.8 dB	-0.5 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

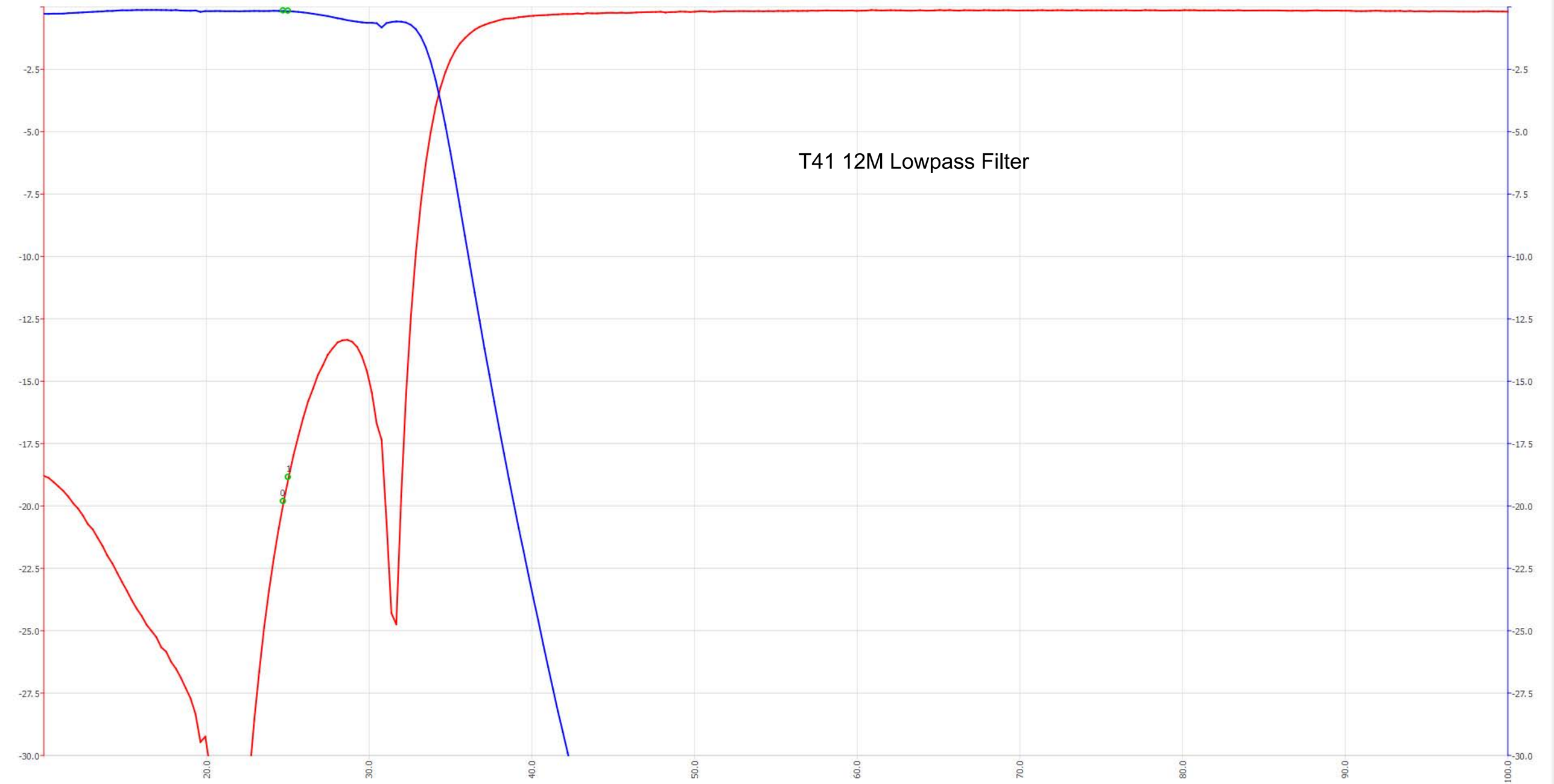


×	1	29.8662 MHz	-23.2 dB	-0.3 dB
+	0	28.0602 MHz	-20.5 dB	-0.3 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

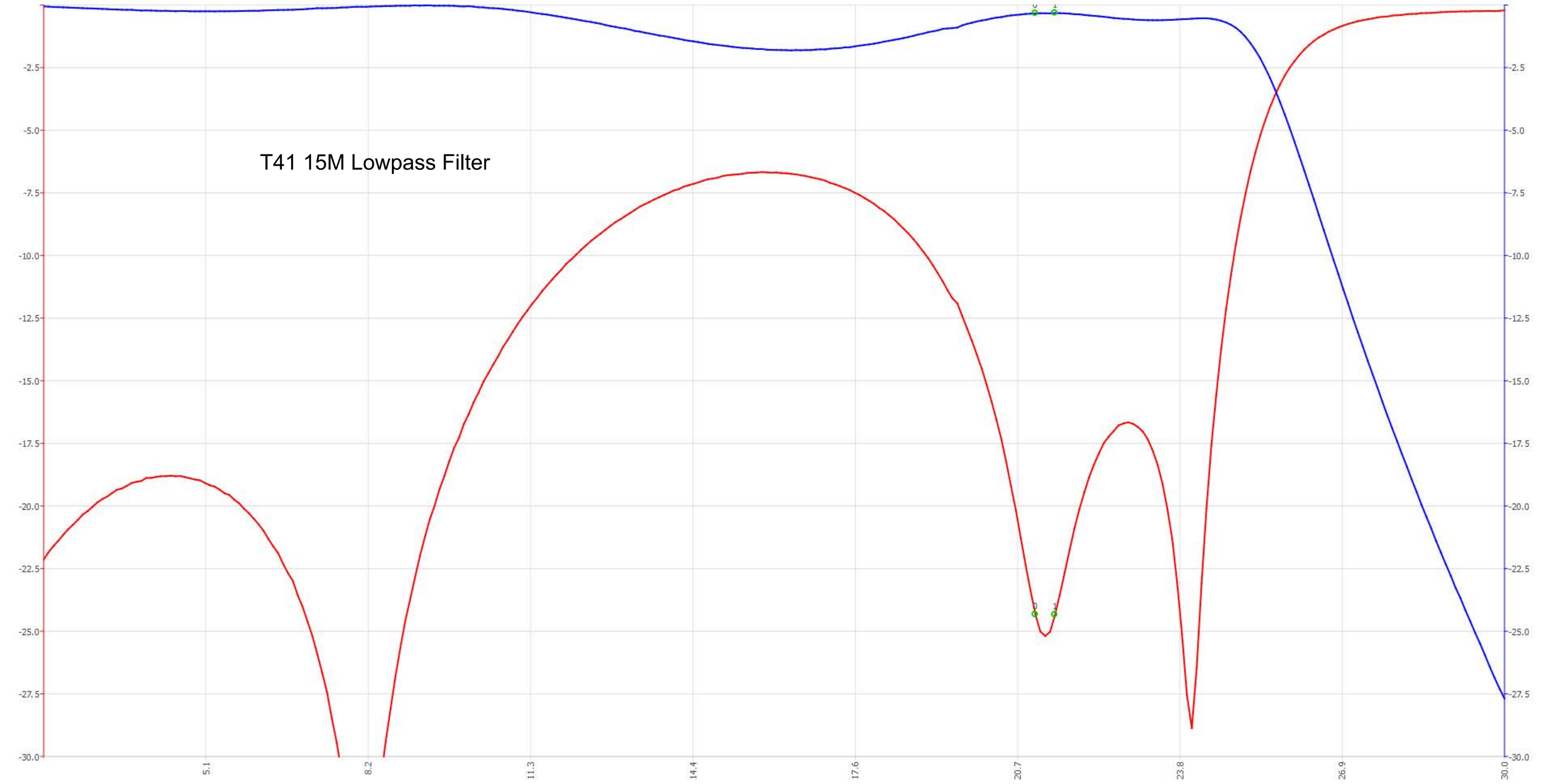


×	1	25.0502 MHz	-18.9 dB	-0.2 dB
+	0	24.7492 MHz	-19.8 dB	-0.2 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

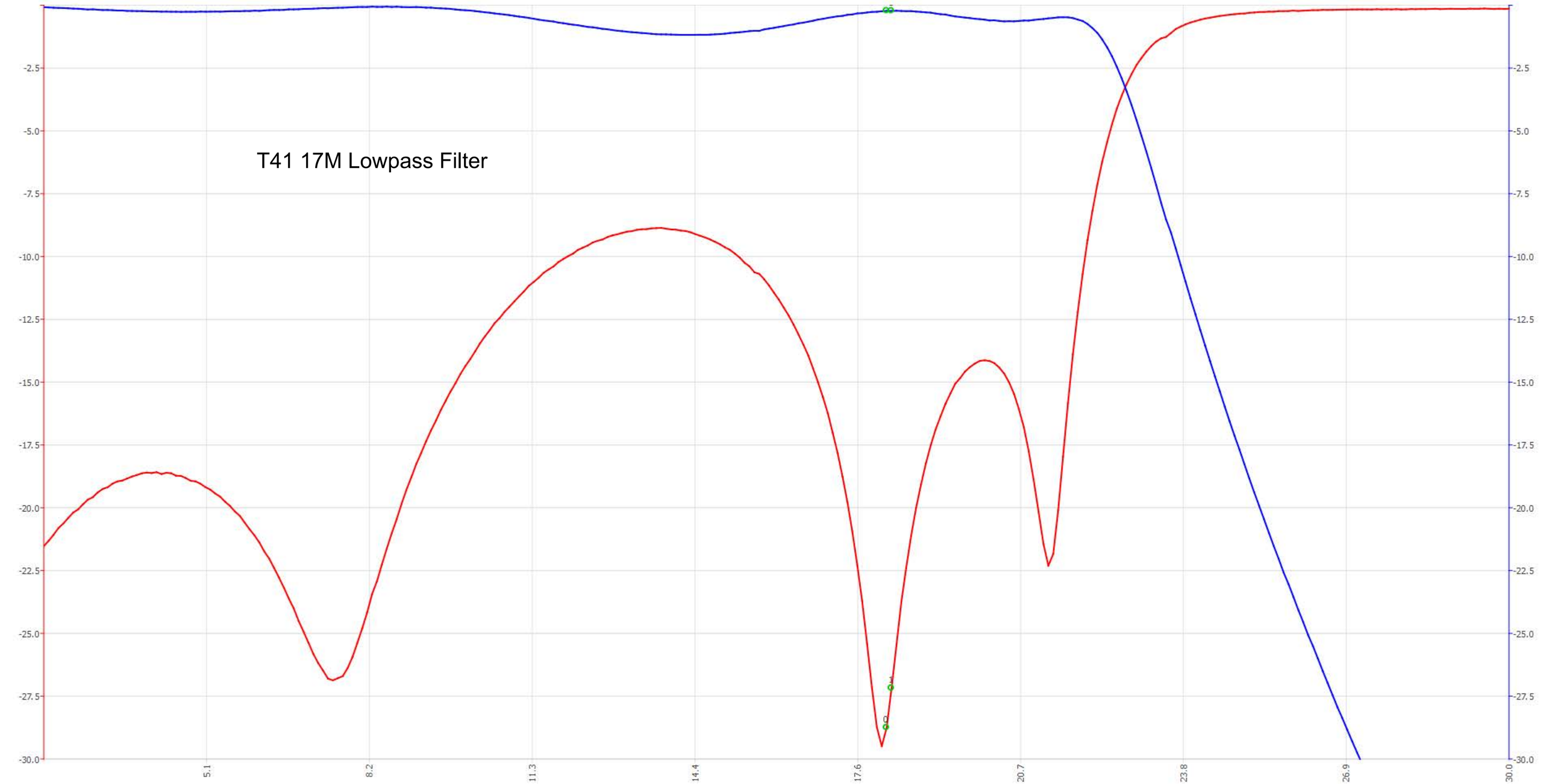


×	1	21.3846 MHz	-24.4 dB	-0.3 dB
+	0	21.0100 MHz	-24.3 dB	-0.3 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	18.2007 MHz	-27.2 dB	-0.2 dB
+	0	18.1070 MHz	-28.8 dB	-0.2 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

T41 20M Lowpass Filter

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

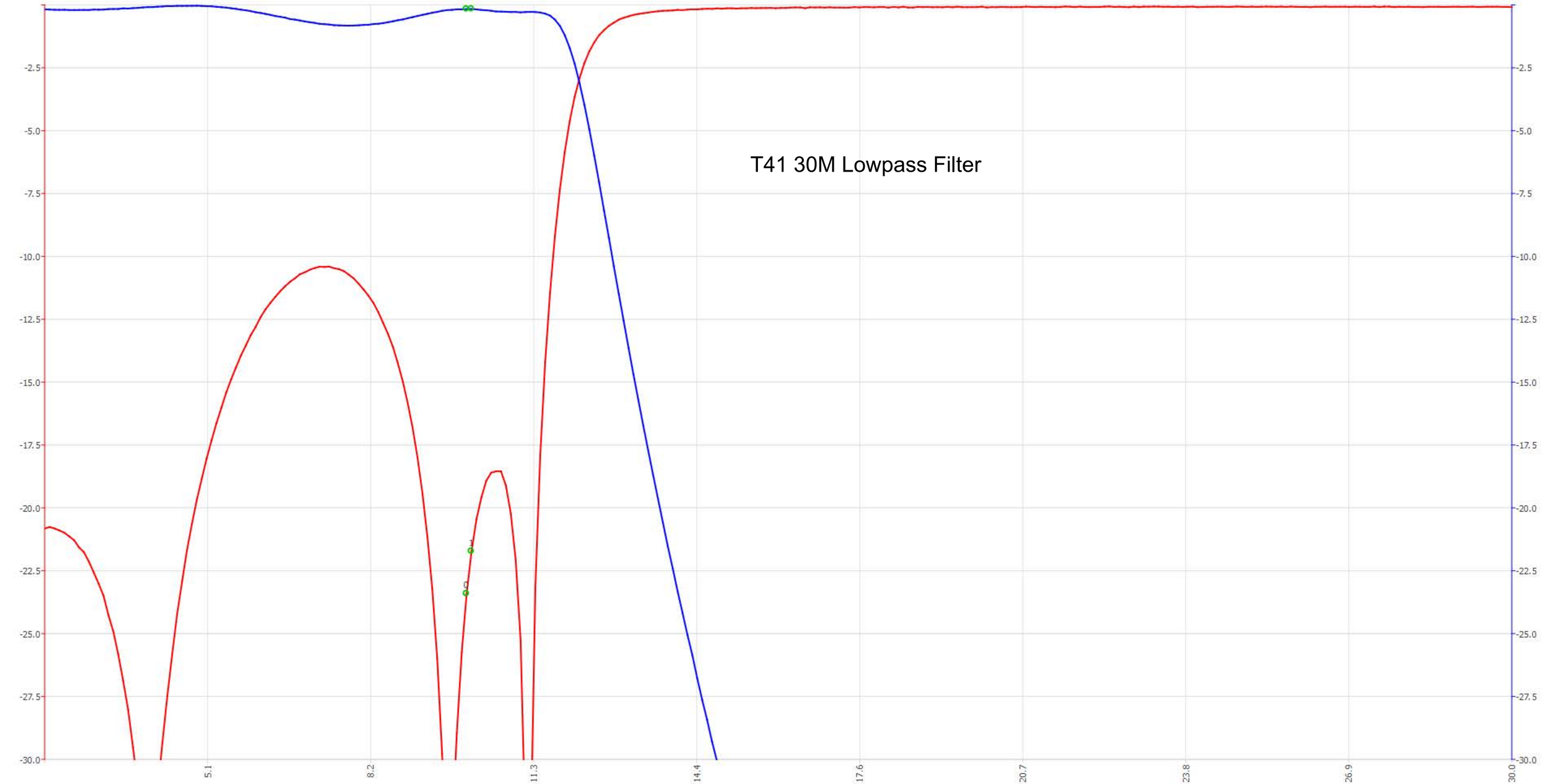
5.1 8.2 11.3 14.4 17.6 20.7 23.8 26.9 30.0

×	1	14.3612 MHz	-16.2 dB	-0.2 dB
+	0	13.9866 MHz	-22.0 dB	-0.2 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

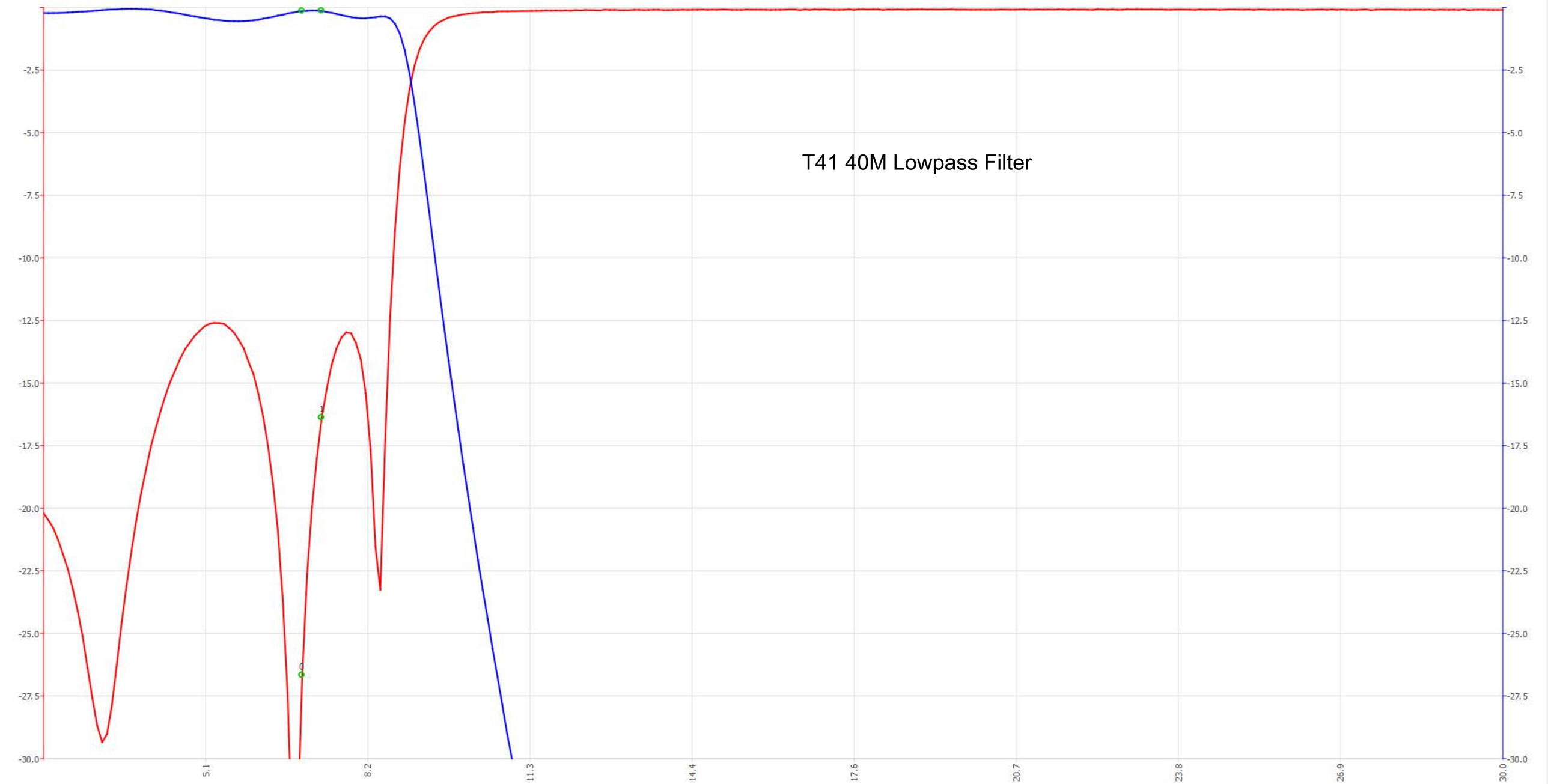


×	1	10.1472 MHz	-21.7 dB	-0.2 dB
+	0	10.0535 MHz	-23.4 dB	-0.2 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)

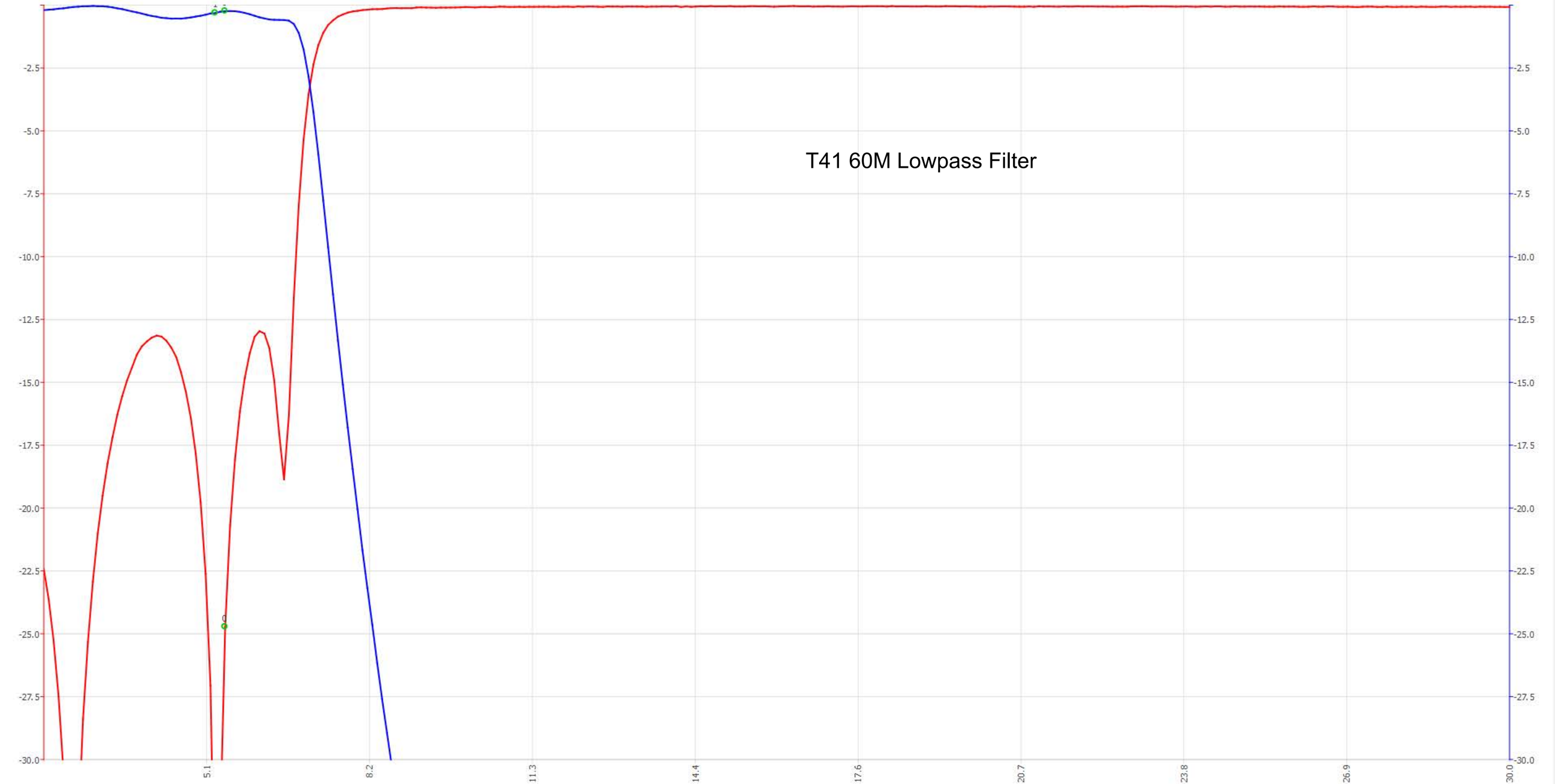


×	1	7.33779 MHz	-16.4 dB	-0.1 dB
+	0	6.96321 MHz	-26.7 dB	-0.1 dB

VNA View

Calibration S parameters View Device Debug Help

mag(S11) mag(S21)



×	1	5.27759 MHz	-37.6 dB	-0.3 dB
+	0	5.46488 MHz	-24.7 dB	-0.2 dB

VNA View

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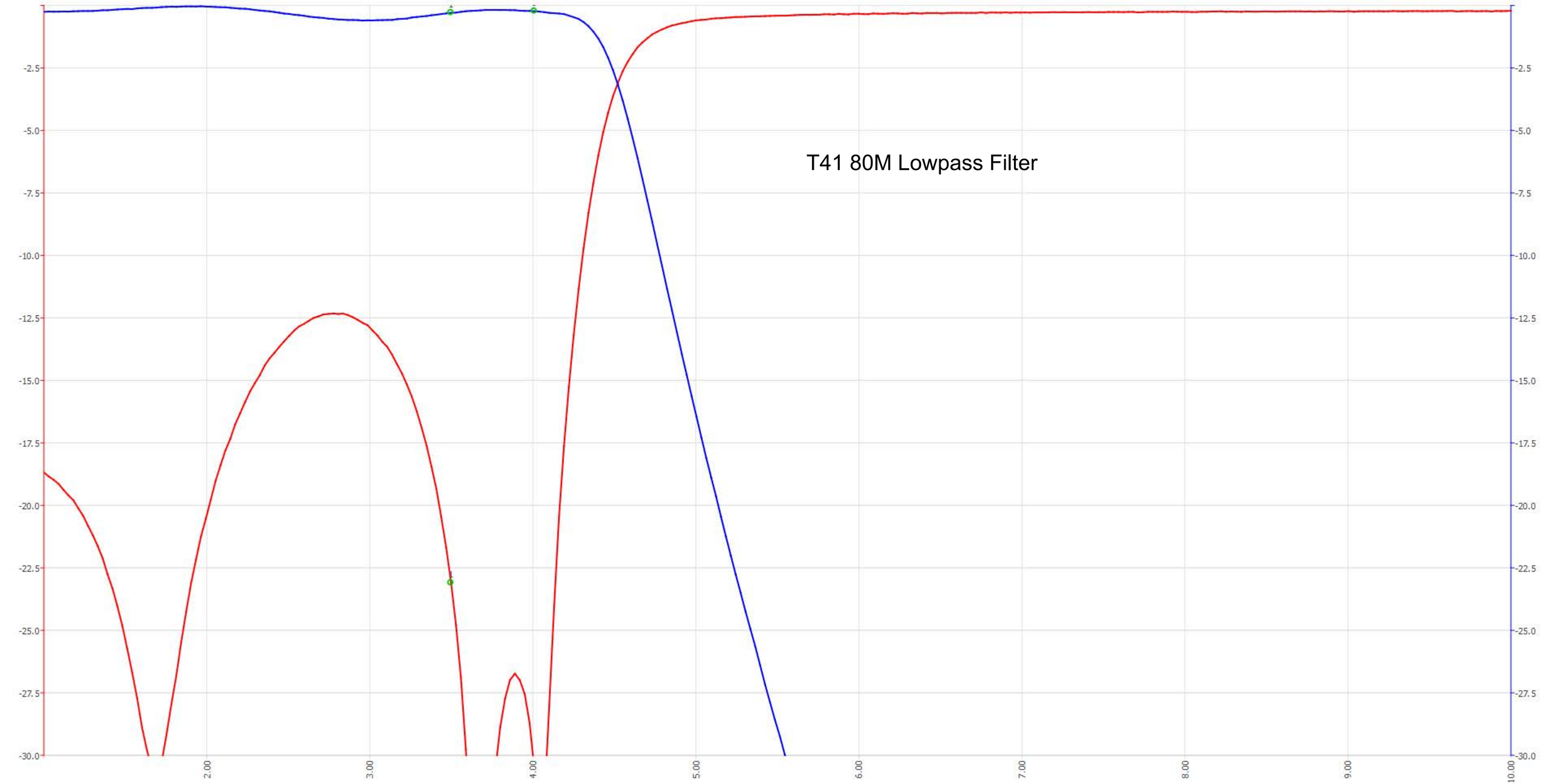
mag(S11) mag(S21)



×	1	3.49833 MHz	-23.1 dB	-0.3 dB
+	0	4.01003 MHz	-30.6 dB	-0.2 dB

VNA View

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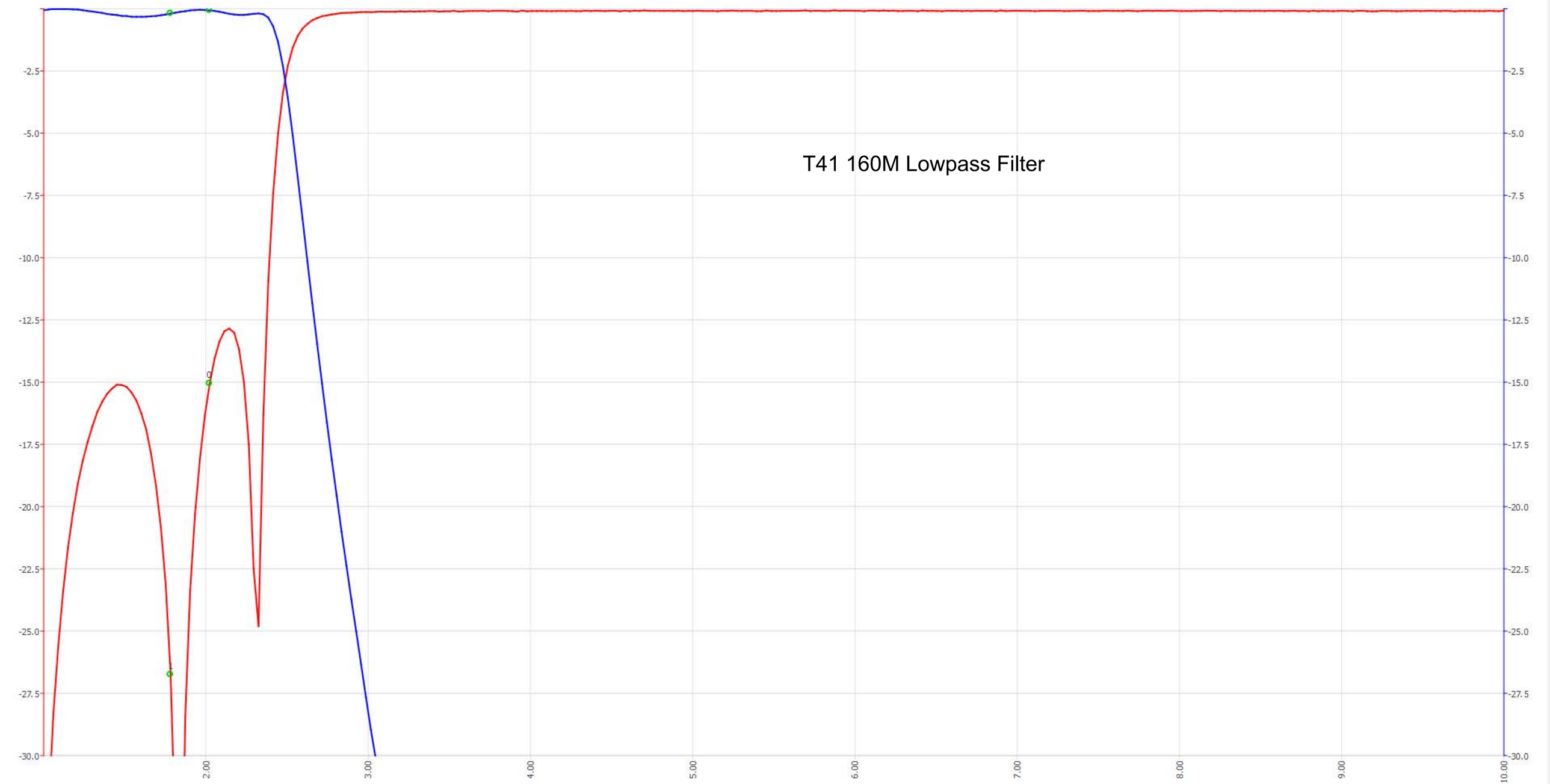
mag(S11) mag(S21)



×	1	1.78261 MHz	-26.8 dB	-0.2 dB
+	0	2.02341 MHz	-15.1 dB	-0.1 dB