Vector network analyzer comparisons

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A number of new instruments capable of measuring impedance and transfer functions have become available to amateurs at reasonable prices. These instruments can greatly improve how amateurs make antenna and laboratory measurements. I obtained several of these instruments and ran some comparison measurements using different loads and an HP3577A vector network analyzer (VNA) as a reference. The following is a summary of what I found.

The instruments I tested were:

1) HP 3577A VNA with the S-parameter test box.

2) An N2PK VNA

3) The AIM4170 by W5BIG

4) TenTec TAPR VNA

5) The IW3HEV miniVNA

6) MFJ 259B

Except for the MFJ259B and the AIM4170, the instruments are capable of two-port measurements but I only performed a one-port (impedance) comparison.

I used two different kinds of loads for the impedance measurements:

1) A set of resistive test loads, see photo 1.

2) An 11' length of RG 400, see photo 2.

The load board includes open-circuit, short-circuit, 50 Ohm, 1, 10, 100, 1k and 10k Ohm loads. Before a run, each instrument was calibrated using the o/c, s/c and 50 Ohm loads. Performance was checked over the range of resistances from 1 Ohm to 1k. However, in the interest of keeping the data tables to something reasonable I have included only those for the extremes, 1 Ohm and 1k Ohm.

The test cable provides an impedance with multiple resonances (alternating series and parallel) over the test range. The cable is a simple test setup but I think it exercises the instruments very well. Providing a wide range of impedances. Instrument calibration before each run was done using HP standards for o/c, s/c and 50 Ohms. The same standards were used for all instruments in a given test.

I ran a number of other test loads beyond what is reported here but that data did not provide any new information so again I've left it out in the interest of providing something short enough to make the point without overwhelming you with data. I have also been using several of these instruments for antenna measurements in the field for some time but again, other than comments on susceptibility to BC signals, there was nothing significant to report there.

Except for the N2PK which is restricted to 60 MHz maximum, the test range for the instruments was from 1 through 100 MHz.

The test data and photos are at the end of this note.

Summary

I leave it to the reader to review the attached data and decide the relative merits but I do have a few comments.

I feel that the N2PK and the AIM4170 are both very nearly as good as the HP VNA. I'm not so sure that the HP is actually better because my instrument has not seen the inside of a calibration laboratory for many years. One thing is clear however, all three instruments provide very accurate measurements, better than anything most amateurs would require.

I made some measurements on a 160 m antenna with about 80 mV of local BC signal on it during the day and then again at night when the signal was off. The HP, N2PK and AIM4170 showed no effect due to the BC signal. The other instruments were effected quite strongly and were not usable for measurements on that antenna while the BC station was on the air. I think this is due to the use of wideband detectors. In the case of MFJ259, this problem is well known.

The miniVNA is very convenient, about half the price of the other options and is powered directly from the USB which is great. But it does not give the sign of the phase measurement (i.e. + or -) and there is no real calibration procedure so it's accuracy suffers as the data shows. Part of the problem is that you can't calibrate for a load at the end of a cable. I mounted the miniVNA directly on the test board but there was still a couple of inches of adapters which I'm sure affected the readings but there is no way to calibrate for fixture parasitics. That's a shame, in many ways this is a neat little instrument.

Besides the problems with signals on the test antenna, the measurements with the TenTec VNA are not as accurate and I think the TenTec is simply not in the same league as the N2PK and AIM4170. I also noticed that for transmission measurements the data had a lot of noise and did not give reliable results for high rejection filters. The N2PK on the other hand does this with ease.

The N2PK VNA is a first class instrument but is not available commercially. You have to brew your own, a fairly advanced project even though you can obtain the boards and other detailed information with little difficulty.

Overall I'm excited by what I see in some of these instruments and things are sure to get better in the future.

Test results

Comparison 1

The first test was to evaluate the return loss capabilities of the instruments. I first ran a full calibration, using the same set of HP standards (open, short, 50 Ohm) for all instruments. I then left the 50 Ohm calibration load on the instrument and measured the return loss with the following results:

Instrument	return loss in dB
H3577A	-90
N2PK	-80
AIM4170	-60
TenTec TAPR	-35
miniVNA	-35

Comparison 2

The second test was to measure the input impedance of the cable over the test frequency range. Impedance magnitude:

	HP3577A	N2PK	AIM4170	Ten-Tec	mniVNA	MFJ259B
Freq MHz	Zmag	Zmag	Zmag	Zmag	Zmag	Zmag
1	490.75	496.63	492.56	632.98		
5	92.35	91.10	90.99	93.32	116.20	149.0309
10	32.14	31.74	31.85	32.202	35.74	48.10436
15	3.56	3.31	3.25	3.2683	2.54	4.140837
20	23.10	23.42	23.57	22.08	21.36	30.71916
25	67.25	67.99	68.05	63.792	69.26	94.16124
30	347.45	358.97	356.55	336.26	334.29	474.1517
35	133.40	131.68	131.84	130.21	141.01	191.9349
40	43.61	43.19	43.21	44.713	43.37	62.29323
45	11.37	11.12	11.03	13.982	7.85	16.03646
50	14.28	14.57	14.61	10.516	15.60	18.80956
55	49.13		49.63	43.414	56.72	71.42656
60	164.15		165.37	148.76	204.96	253.2532
65	233.95		230.62	210.11	194.69	286.4496
70	59.10		58.86	59.438	53.85	80.20531
75	19.86		19.66	23.076	13.65	26.81166
80	6.37		6.61	5.8152	10.16	11.71041
85	35.05		35.71	31.844	46.42	56.29529
90	102.30		102.37	87.257	144.41	168.7219
95	696.50		687.94	647.88	283.47	707.1775
100	82.05		81.96	81.683	67.50	105.9622

Impedance phase:

	HP3577A	N2PK	AIM4170	Ten-Tec	minVNA
Freq MHz	theta	theta	theta	theta	theta
1	-89.8	-89.9	-89.9	-89.01	
5	-89.6	-89.7	-89.8	-83.4	-81.86
10	-88.8	-88.8	-88.6	-81.76	-87.03
15	-75.2	-72.8	-72.8	-66.93	-69.46
20	86.2	86.0	86.4	91.98	83.96
25	86.6	86.5	86.9	92.19	80.95
30	78.4	77.8	78.3	83.65	48.17
35	-84.9	-85.0	-85.0	-78.77	-73.20
40	-86.5	-86.5	-86.3	-80.25	-82.88
45	-81.2	-80.7	-80.3	-75.96	-76.94
50	82.1	82.0	82.4	83.13	80.95
55	85.6		86.0	89.46	80.58
60	81.7		81.9	86.14	60.41
65	-78		-78.3	-75.36	-61.84
70	-84.8		-84.6	-82.13	-80.24
75	-82.4		-81.8	-81.21	-79.10
80	68.5		68.0	65.34	75.76
85	84.4		84.0	83.58	80.24
90	82.9		83.1	82.49	67.79
95	-41.6		-42.6	-43.89	-40.76
100	-82.8		-82.7	-82.86	-77.44

percentage difference of impedance magnitude compared to the HP VNA:

	HP3577A	N2PK	AIM4170	Ten-Tec	mniVNA	MFJ259B
Freq MHz	Zmag	Zmag	Zmag	Zmag	Zmag	Zmag
1	0	-1.1984	-0.3682	-28.982		
5	0	1.3576	1.47285	-1.051	-25.8216	-61.3762
10	0	1.257	0.91159	-0.192	-11.1893	-49.6713
15	0	7.1285	8.67704	8.2453	28.61925	-16.2503
20	0	-1.4061	-2.0369	4.4143	7.54482	-32.9834
25	0	-1.096	-1.189	5.1423	-2.9888	-40.0167
30	0	-3.3146	-2.6199	3.2211	3.787391	-36.4662
35	0	1.286	1.17083	2.3911	-5.7059	-43.8792
40	0	0.9491	0.90872	-2.541	0.532364	-42.858
45	0	2.2059	2.96638	-22.97	30.92965	-41.0419
50	0	-2.0397	-2.3145	26.356	-9.20902	-31.7196
55	0		-1.0134	11.634	-15.4456	-45.3828
60	0		-0.7435	9.376	-24.8603	-54.2816
65	0		1.42191	10.189	16.77982	-22.4405
70	0		0.41435	-0.571	8.879347	-35.7112
75	0		1.0235	-16.19	31.26178	-35.0033
80	0		-3.7037	8.7097	-59.5685	-83.837
85	0		-1.889	9.1469	-32.4487	-60.6142
90	0		-0.0674	14.705	-41.1603	-64.9286
100	0		1.22938	6.9811	59.30064	-1.53303

Comparison 3

The next comparison was to see how well the instruments worked at fairly extreme load resistances, 1 Ohm and 1k Ohm.

	HP3577A	N2PK	AIM4170	TenTec	miniVNA
	1 Ohm	1 Ohm	1 Ohm	1 Ohm	1 Ohm
frequency	Zmag	Zmag	Zmag	Zmag	Zmag
1	0.950	0.969	0.925	2.412	
5	0.980	0.978	0.995	1.009	0.890
10	0.989	0.982	0.977	1.020	0.890
15	0.979	0.983	1.027	1.059	1.059
20	0.999	0.984	0.981	1.047	0.890
25	0.980	0.985	0.986	1.030	1.061
30	0.983	0.989	0.995	1.161	1.064
35	0.996	0.994	0.981	1.051	1.068
40	0.984	0.995	0.993	0.922	1.072
45	0.995	1.000	0.999	0.967	1.078
50	0.995	1.010	0.993	1.050	1.086
55	1.021		0.993	1.080	1.094
60	1.022		0.987	1.029	1.104
65	1.000		0.982	1.088	1.292
70	1.028		1.014	1.022	1.306
75	1.022		0.989	1.016	1.323
80	1.029		0.912	1.101	1.523
85	1.056		0.953	1.021	1.357
90	1.061		0.954	0.953	1.379
95	1.052		0.989	1.163	1.402
100	1.051		0.962	1.154	1.427
	HP3577A	N2PK	AIM4170	TenTec	miniVNA
	1 kOhm	1 kOhm	1 kOhm	1 kOhm	1 kOhm
frequency	Zmag	Zmag	Zmag	Zmag	Zmag
1	1007.15	997.7392	1004.606	837.7749	
5	992.8	987.8504	1001.587	1005.927	455.23
10	998.7	985.7316	1001.144	997.7165	436.57
15	998.25	978.911	999.470	1018.215	402.98
20	989.9	970.3636	990.791	1005.529	362.24
25	990.55	960.1333	987.706	969.7462	328.52
30	978.6	948.7949	956.134	903.5519	291.98
35	969.25	935.835	975.706	913.4344	263.66
40	971.5	921.6791	963.123	938.3183	238.61
45	951.55	907.0224	944.549	980.78	215.12
50	941.25	878.528	957.925	896.4093	197.81
55	937.7		938.629	920.9338	181.32
60	923.95		902.019	953.2789	167.89
65	914.9		921.889	893.118	156.00
70	906.9		890.658	872.0769	144.77
75	889.45		883.816	824.0582	135.39
80	878.7		881.241	890.4102	125.90
85	869.6		866.447	838.8726	118.60
90	848.6		851.702	813.6922	111.58
95	840.3		842.558	745.4389	105.37
100	825.75		914.842	750.6536	99.46

Figure 1A, VNA calibration board front view

Figure 1B, VNA calibration board rear view

Figure 2, VNA test cable.