

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 | minVNA | 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.