TESTING VHF/UHF MOBILE ANTENNAS

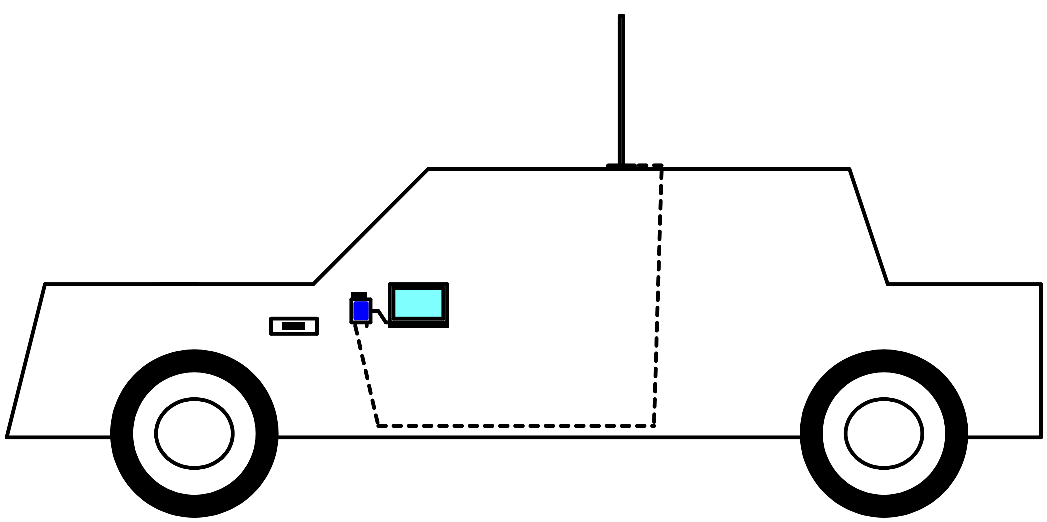
This article is about mobile antennas primarily used by amateur radio operators. Antennas are usually rated by their VSWR performance over a specified frequency range, but with mobile antennas, this specification is missing. The antenna manufacturer has no control over where or how the antenna is going to be installed on the vehicle, so they are reluctant to provide any performance specifications.

For many years, the SWR meter has been the instrument of choice used by amateurs to test and adjust antennas. At HF frequencies, the SWR meter will provide readings that are reasonably accurate, but this is not true for the VHF/UHF frequencies. Mobile antennas designed for the VHF/UHF frequencies are notorious for having "Common-Mode" RF current problems, especially if the antenna uses a magnetic mount. This problem causes the antennas feedline to act as part of the antenna and adding a SWR meter changes feedline length which results in changing the antennas characteristics.

The best instrument for testing and adjusting mobile antennas is any instrument that measures the antennas characteristics at the feedline end that connects directly to the radio. Antenna analyzers will measure the antenna characteristics at the feedline connector end, but there cost usually don't justify the occasional use of such an instrument. Amazingly, an instrument has appeared on the market that cost about the same as a SWR meter (40-60 dollars) and will measure all of the antenna system specifications at the cable end. All of the measurements shown in this article was taken with a new NanoVNA that cost $45.

Test Antennas: Three (3) mobile antennas that are commonly used by amateur radio operators where used as test samples. The first antenna tested is a 1/4 wavelength (λ) attached to a Larsen LM-MM magnetic mount. The second antenna is a 5/8 λ Larsen LM-150 antenna attached to a Larsen LM-MM magnetic mount. The third antenna is a Browning BR-180-B Dual Band 144-148/430-450 MHz antenna attached to a Browning magnetic mount. Each of the antennas were mounted on the vehicles roof at the center and coaxial cable routed thru the rear passenger door.

Test Setup:



Test 1 Antenna: This antenna is 1/4λ vertical antenna which is a resonant antenna. The performance of the antenna was excellent. Resonant frequency occurred at 145.894 MHz's according to the jX resistance level and the worst case SWR level was 1.158:1 @ 144 MHz's.

Measurement data of the 1/4λ antenna

Marker 1

Frequency:	144.000 MHz	VSWR:	1.158
Impedance:	48.13 +j6.95 Ω	Return loss:	-22.710 dB
Series L:	7.6849 nH	Quality factor:	0.144
Series C:	-158.96 pF	S11 Phase:	101.02°
Parallel R:	49.132 Ω	S21 Gain:	-76.042 dB
Parallel X:	375.86 nH	S21 Phase:	161.51°

Marker 3

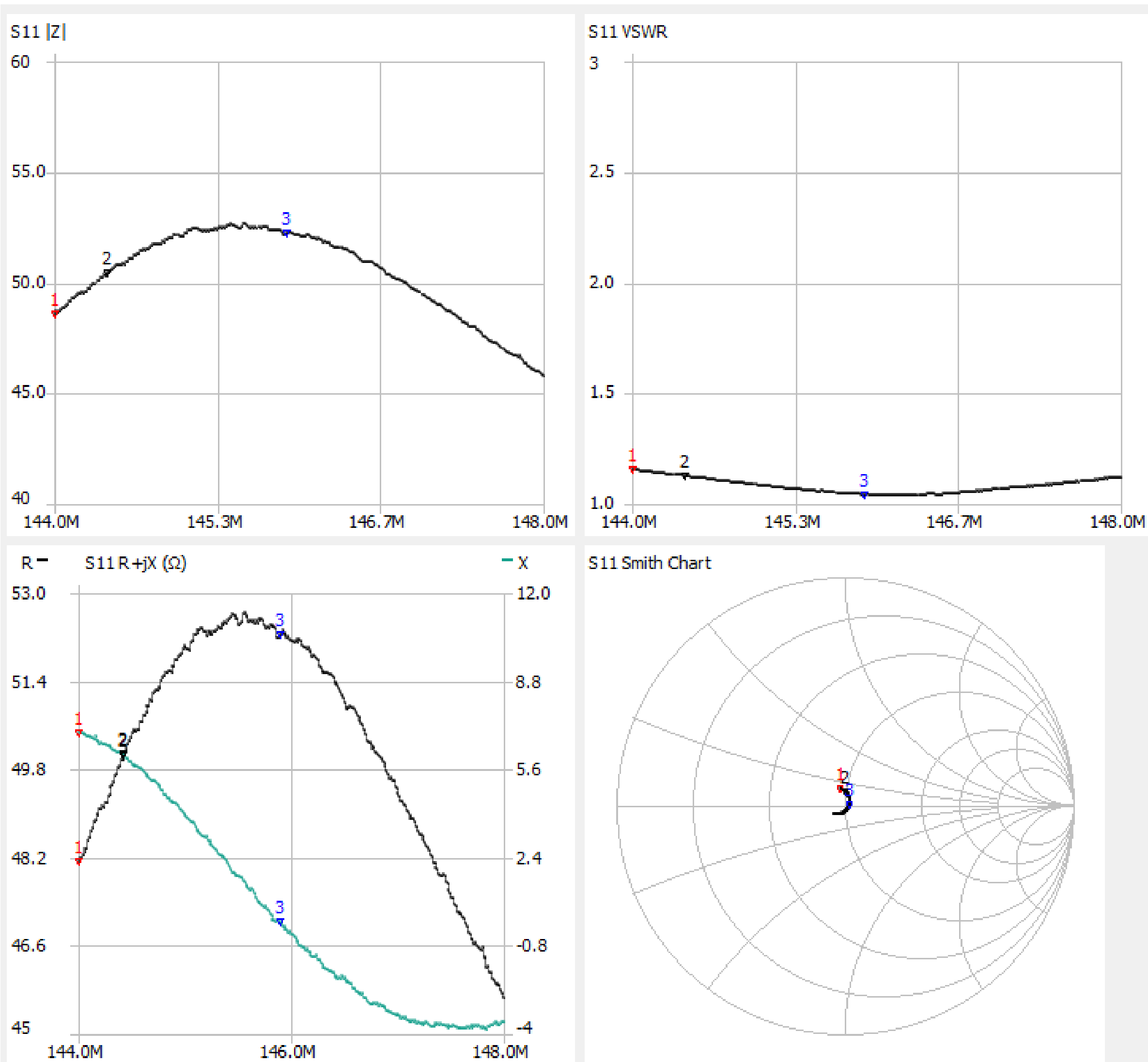
Frequency:	145.894 MHz	VSWR:	1.045
Impedance:	52.25 +j71.4m Ω	Return loss:	-33.147 dB
Series L:	77.893 pH	Quality factor:	0.001
Series C:	-15.278 nF	S11 Phase:	1.78°
Parallel R:	52.25 Ω	S21 Gain:	-74.101 dB
Parallel X:	41.71 µH	S21 Phase:	159.25°

Marker 2

Frequency:	144.424 MHz	VSWR:	1.131
Impedance:	50.06 +j6.16 Ω	Return loss:	-24.230 dB
Series L:	6.7882 nH	Quality factor:	0.123
Series C:	-178.9 pF	S11 Phase:	85.94°
Parallel R:	50.816 Ω	S21 Gain:	-85.857 dB
Parallel X:	455.07 nH	S21 Phase:	45.00°

Marker 4

Frequency:	148.000 MHz	VSWR:	1.124
Impedance:	45.67 -j3.54 Ω	Return loss:	-24.673 dB
Series L:	-3.8025 nH	Quality factor:	0.077
Series C:	304.12 pF	S11 Phase:	-138.65°
Parallel R:	45.944 Ω	S21 Gain:	-66.263 dB
Parallel X:	1.8122 pF	S21 Phase:	-100.85°



Test 2 Antenna: This is a 5/8λ antenna and probably one of the most popular antennas used by amateurs. It's a non-resonant so the reactance never equals zero. This did not equal the performance of the 1/4λ and the maximum Impedance was 65.12 ohms at 144.424 MHz's

Marker 1

Frequency:	144.000 MHz	VSWR:	1.719
Impedance:	61.58 +j28.1 Ω	Return loss:	-11.558 dB
Series L:	31.083 nH	Quality factor:	0.457
Series C:	-39.3 pF	S11 Phase:	53.48°
Parallel R:	74.422 Ω	S21 Gain:	-74.799 dB
Parallel X:	180.1 nH	S21 Phase:	141.57°

Marker 2

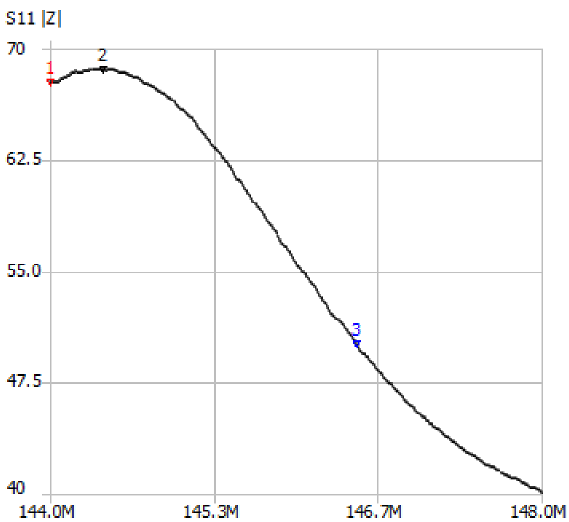
Frequency:	144.424 MHz	VSWR:	1.578
Impedance:	65.12 +j21.5 Ω	Return loss:	-12.985 dB
Series L:	23.659 nH	Quality factor:	0.33
Series C:	-51.329 pF	S11 Phase:	44.28°
Parallel R:	72.201 Ω	S21 Gain:	-77.388 dB
Parallel X:	241.35 nH	S21 Phase:	36.98°

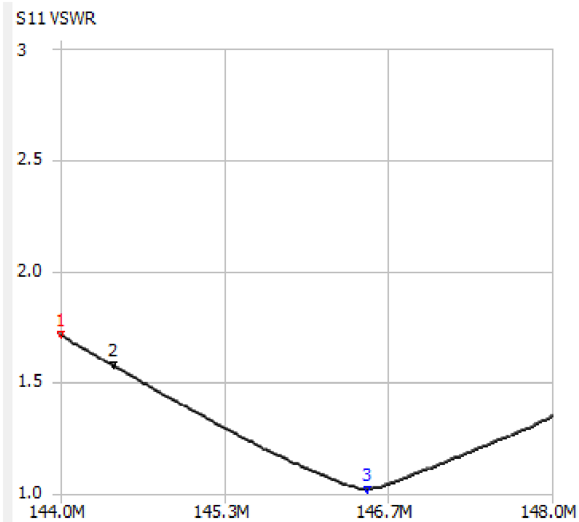
Marker 3

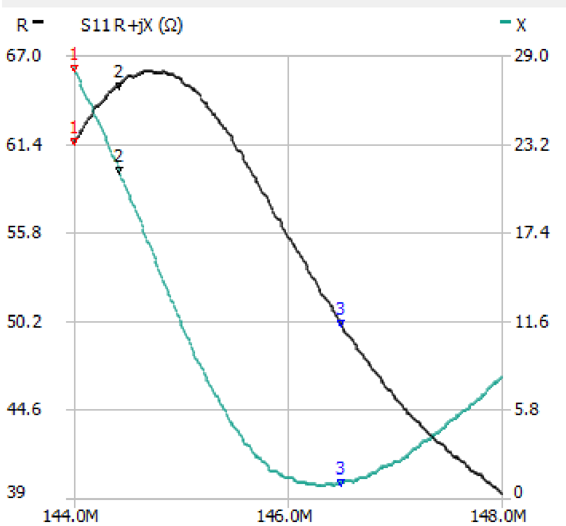
Frequency:	146.490 MHz	VSWR:	1.021
Impedance:	50.1 +j1.06 Ω	Return loss:	-39.481 dB
Series L:	1.1493 nH	Quality factor:	0.021
Series C:	-1.0271 nF	S11 Phase:	83.86°
Parallel R:	50.125 Ω	S21 Gain:	-62.606 dB
Parallel X:	2.5794 µH	S21 Phase:	19.26°

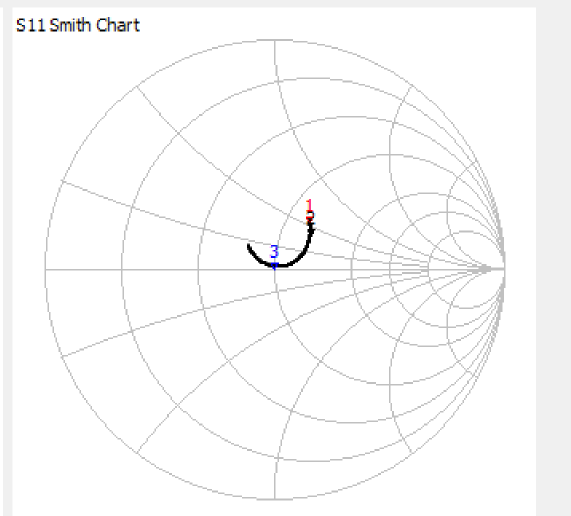
Marker 4

Frequency:	148.000 MHz	VSWR:	1.348
Impedance:	39.34 +j7.94 Ω	Return loss:	-16.586 dB
Series L:	8.5348 nH	Quality factor:	0.202
Series C:	-135.5 pF	S11 Phase:	138.25°
Parallel R:	40.943 Ω	S21 Gain:	-65.889 dB
Parallel X:	218.25 nH	S21 Phase:	-89.51°









Test 3 Antenna: This is the data for the Dual-Band (2M/70CM) antenna manufactured by Browning, the 2M section measured as resonant antenna and the 70CM was non-resonant.

Marker 1

Frequency:	144.185 MHz	VSWR:	1.552
Impedance:	73.93 +j12.3 Ω	Return loss:	-13.302 dB
Series L:	13.63 nH	Quality factor:	0.167
Series C:	-89.392 pF	S11 Phase:	21.60°
Parallel R:	75.996 Ω	S21 Gain:	-84.992 dB
Parallel X:	502.26 nH	S21 Phase:	61.91°

Marker 3

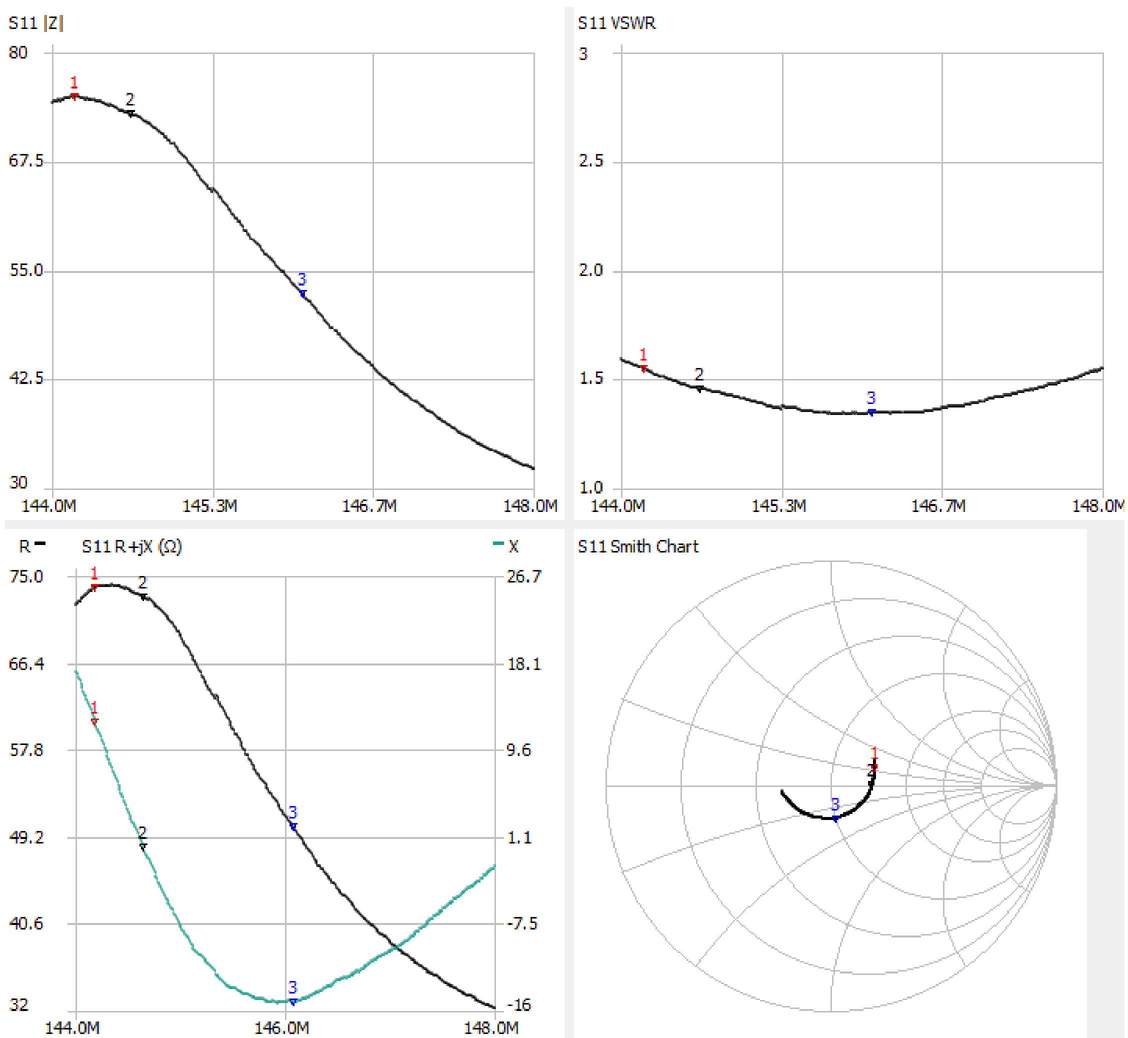
Frequency:	146.079 MHz	VSWR:	1.351
Impedance:	50.19 -j15.1 Ω	Return loss:	-16.521 dB
Series L:	-16.477 nH	Quality factor:	0.301
Series C:	72.041 pF	S11 Phase:	-80.69°
Parallel R:	54.747 Ω	S21 Gain:	-67.527 dB
Parallel X:	5.9965 pF	S21 Phase:	-152.95°

Marker 2

Frequency:	144.649 MHz	VSWR:	1.460
Impedance:	72.98 +j71.7m Ω	Return loss:	-14.571 dB
Series L:	78.929 pH	Quality factor:	0.001
Series C:	-15.338 nF	S11 Phase:	0.15°
Parallel R:	72.976 Ω	S21 Gain:	-74.382 dB
Parallel X:	81.683 µH	S21 Phase:	-103.83°

Marker 4

Frequency:	148.000 MHz	VSWR:	1.551
Impedance:	32.3 -j1.79 Ω	Return loss:	-13.309 dB
Series L:	-1.9213 nH	Quality factor:	0.055
Series C:	601.9 pF	S11 Phase:	-172.99°
Parallel R:	32.402 Ω	S21 Gain:	-65.483 dB
Parallel X:	1.8356 pF	S21 Phase:	-95.92°



Marker 1

Frequency:	430.000 MHz	VSWR:	2.368
Impedance:	30.31 -j28.5 Ω	Return loss:	-7.824 dB
Series L:	-10.536 nH	Quality factor:	0.939
Series C:	13.002 pF	S11 Phase:	-105.16°
Parallel R:	57.045 Ω	S21 Gain:	-58.360 dB
Parallel X:	6.0943 pF	S21 Phase:	-73.95°

Marker 3

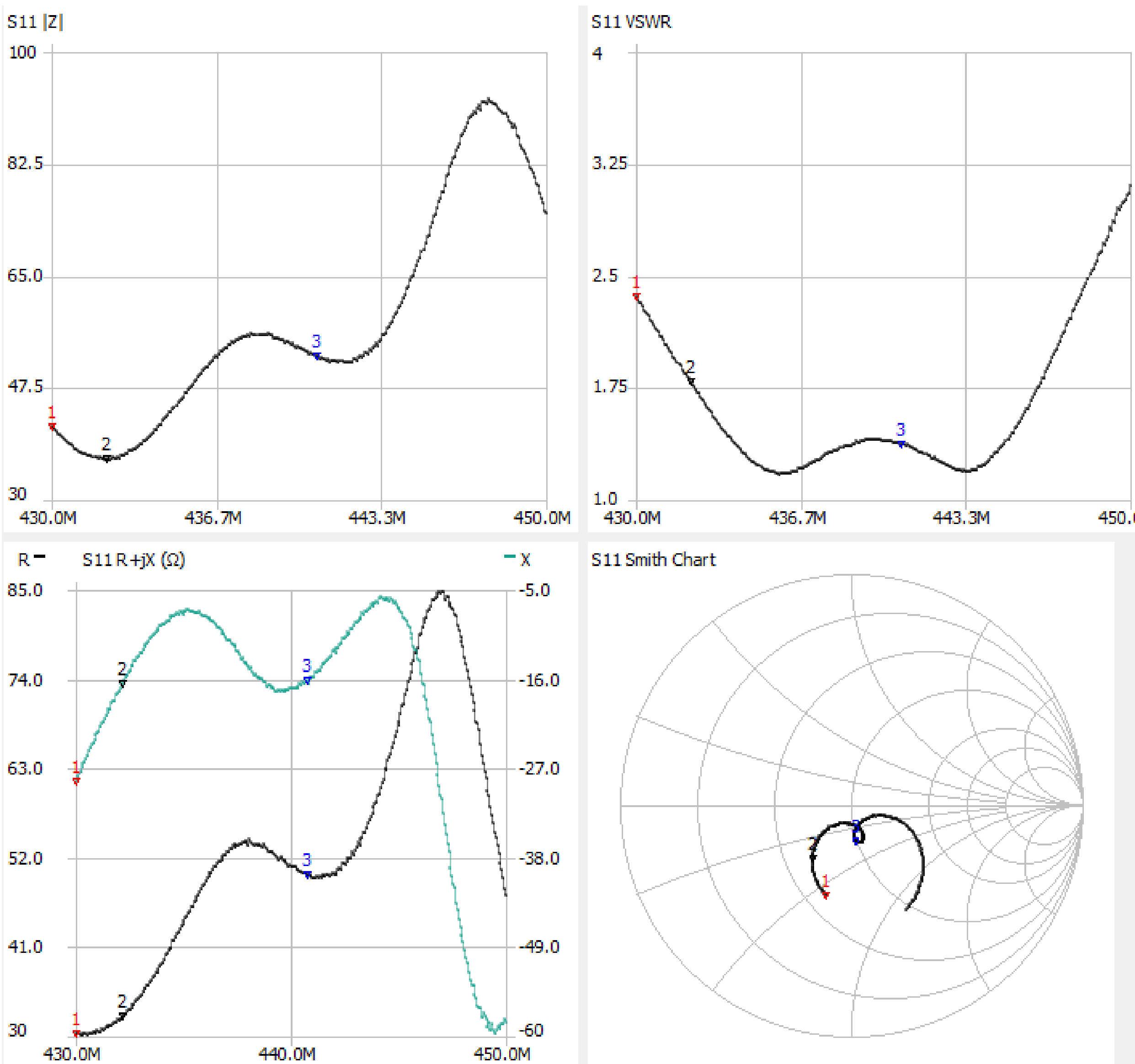
Frequency:	440.728 MHz	VSWR:	1.379
Impedance:	50.02 -j16.2 Ω	Return loss:	-15.950 dB
Series L:	-5.8323 nH	Quality factor:	0.323
Series C:	22.359 pF	S11 Phase:	-80.74°
Parallel R:	55.238 Ω	S21 Gain:	-56.750 dB
Parallel X:	2.1107 pF	S21 Phase:	-67.51°

Marker 2

Frequency:	432.185 MHz	VSWR:	1.795
Impedance:	32.6 -j16.5 Ω	Return loss:	-10.918 dB
Series L:	-6.0659 nH	Quality factor:	0.505
Series C:	22.357 pF	S11 Phase:	-125.30°
Parallel R:	40.92 Ω	S21 Gain:	-57.375 dB
Parallel X:	4.5476 pF	S21 Phase:	-103.82°

Marker 4

Frequency:	447.682 MHz	VSWR:	2.274
Impedance:	81.85 -j43.7 Ω	Return loss:	-8.200 dB
Series L:	-15.519 nH	Quality factor:	0.533
Series C:	8.1441 pF	S11 Phase:	-35.57°
Parallel R:	105.13 Ω	S21 Gain:	-57.955 dB
Parallel X:	1.8036 pF	S21 Phase:	-68.75°



I wasn't very impressed with the Browning antenna, I'm not sure how my dual-band radio would handle an impedance of 73.9Ω (Marker 1) on 2M or the 81.8Ω (Marker 4) on the 70CM antenna section. I purchased the Browning antenna at the Shreveport Ham fest, I'm wondering if they have refunds!!

Antenna Gain: The 5/8λ antenna is very popular with amateur radio mobile operators because tha antenna has more gain. Actually, the 5/8λ antenna has about the same gain as a 1/4λ antenna. Most of the gain difference comes from the antennas lower radiation angle. The radiation angle of a 5/8's antenna is about 16 degrees compared to the 1/4λ antenna which is about 40 degrees.

Summary:

The single band 1/4λ and 5/8λ antennas were adjusted for the best SWR at 146 MHz's. The Browning Dual-Band antenna was not adjustable and was adjusted by the manufacturer.

1/4 λ antennas using "Mag Mounts" are prone to common mode RF current problems and this one was no exception. To rectify that problem, I installed a RF choke at the antenna port.

All measurements were taken at the coax cable end that attaches to the transceiver. As I stated on page 1, at VHF/UHF frequencies, adding a SWR meter to the feedline can affect the impedance values seen by the transceiver. The NanoVNA can make measurements without the use of a computer, but the of measurements are limited to SWR, Smith Chart, Delay, Phase and Log magnitude in the touchscreen mode. The accuracy of this VNA is surprisingly good if properly calibrated and truly better than any SWR meter. The dynamic range in the S21 mode was only 50 dB, which prevents it from being used for repeater duplexer adjustments.

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