Practical Amateur Radio Measurements

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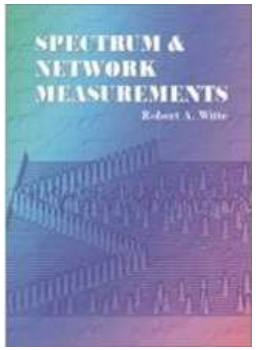
Electronic Test Instruments

Spectrum and Network Measurements



Electronic Test Equipment

- **The Multimeter**

  Measures DC/AC voltage, current and resistance

- **The SWR Meter**
- **The Antenna Analyzer**
- **The Vector Network Analyzer (VNA)**

} Antenna System Measurements

The Multimeter

- Also known as voltmeter, VOM (Volt-Ohm-mA meter),DVM (Digital Voltmeter), or DMM (Digital Multimeter)
- Voltmeter, ammeter and ohmmeter combined into one instrument
- DC and AC measurements
- Some models have diode test, continuity, capacitance, inductance, frequency, temperature
- Bench or handheld form factor
- Mostly digital meters, some analog meters

Safety First

"Digital" is derived from the word "Digit" which means finger.

Be careful where you put your digits when using a Digital Multimeter

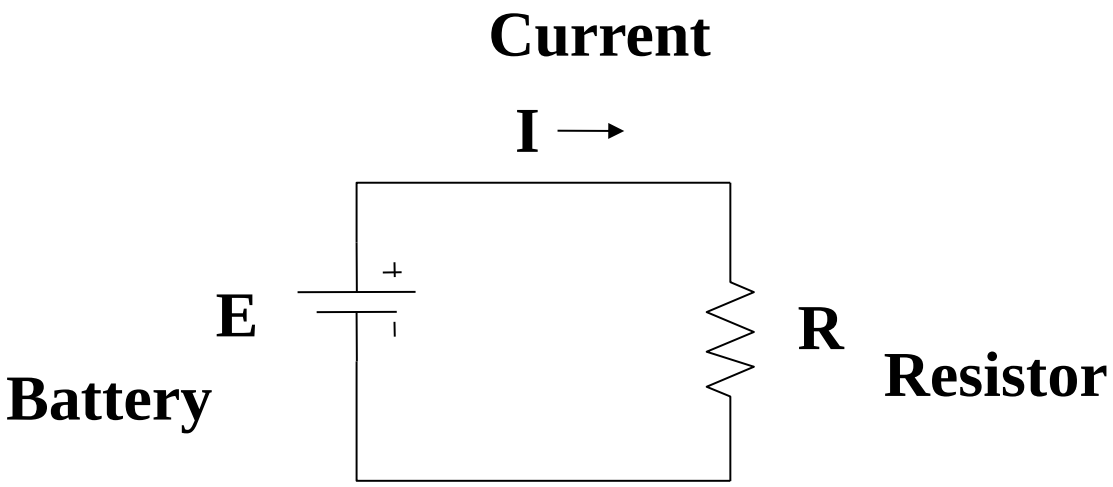
Graphic courtesy of Agilent Technologies

Lots of Meters Out There

A Typical Low Cost DMM

- Velleman DVM850BL
- Price <$25
- 3½ Digits
- 0.5% to 1.5% Accuracy (depends on range)
- Diode test
- Continuity test
- Average reading meter (inferred RMS)
- IEC 1010 Cat II - 600V

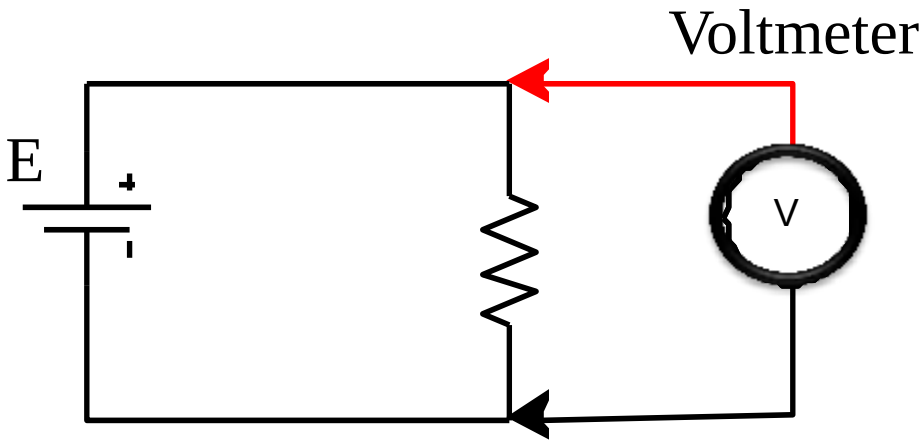
Circuit with Battery and Resistor



Ohm's Law: $I=E/R$

Note: Positive current convention used

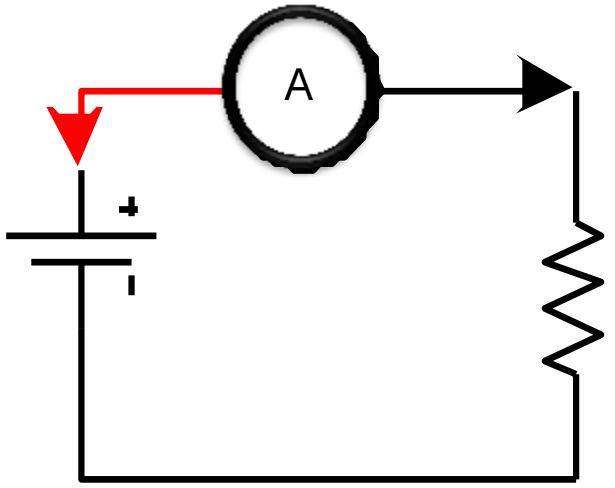
Voltage Measurement



- Configure DMM to DC voltage
- DMM appears as “open circuit”
- Connect DMM in parallel with voltage to be measured

Current Measurement

- Configure DMM to DC Current
- DMM appears as **short circuit**
- Connect DMM in *series* with current to be measured

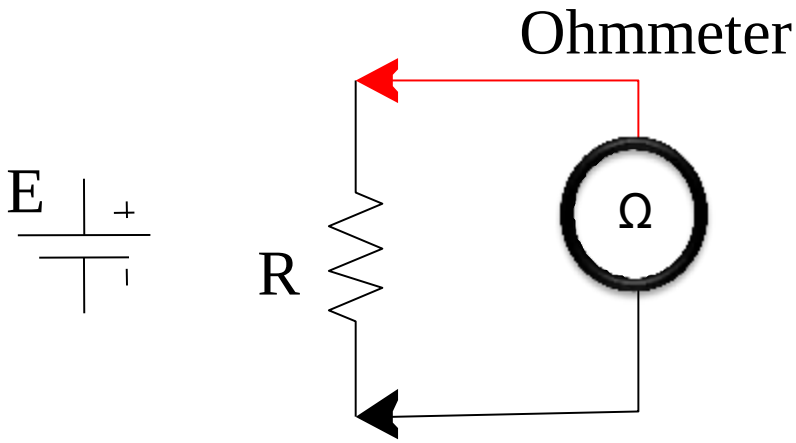


- *Don't select current mode by mistake*
- *Be very careful how you connect when in current mode*
- *Short circuits can cause big problems!*

Be Careful !!!!!!

Resistance Measurement

- Configure DMM to Resistance
- **Remove power** from the circuit
- DMM provides power to the circuit being tested
- Connect DMM in parallel with the resistance to be measured
- Make sure there is nothing else in parallel with the resistor



Ten Amateur Radio Applications of a DMM

1. Check the power supply voltage on the new power supply you just purchased.
2. See if your HT battery pack is fully charged.
3. Measure the current that your transceiver draws to estimate how long your emergency power system will last during a blackout.
4. Sort the bag of resistors you purchased at the swapfest.
5. Check a fuse to see if it is blown.

Ten Amateur Radio Applications of a DMM (2)

6. Troubleshoot your broken rig by checking the bias voltages against the service manual.
7. Figure out if the AA batteries the kids left for you are dead.
8. Verify that your coax is not shorted between the shield and center conductor.
9. Check the level of the power line voltage in the ham shack.
10. Check for good DC continuity between the ends of the cable you just soldered.

Quick Guide to Buying a DMM

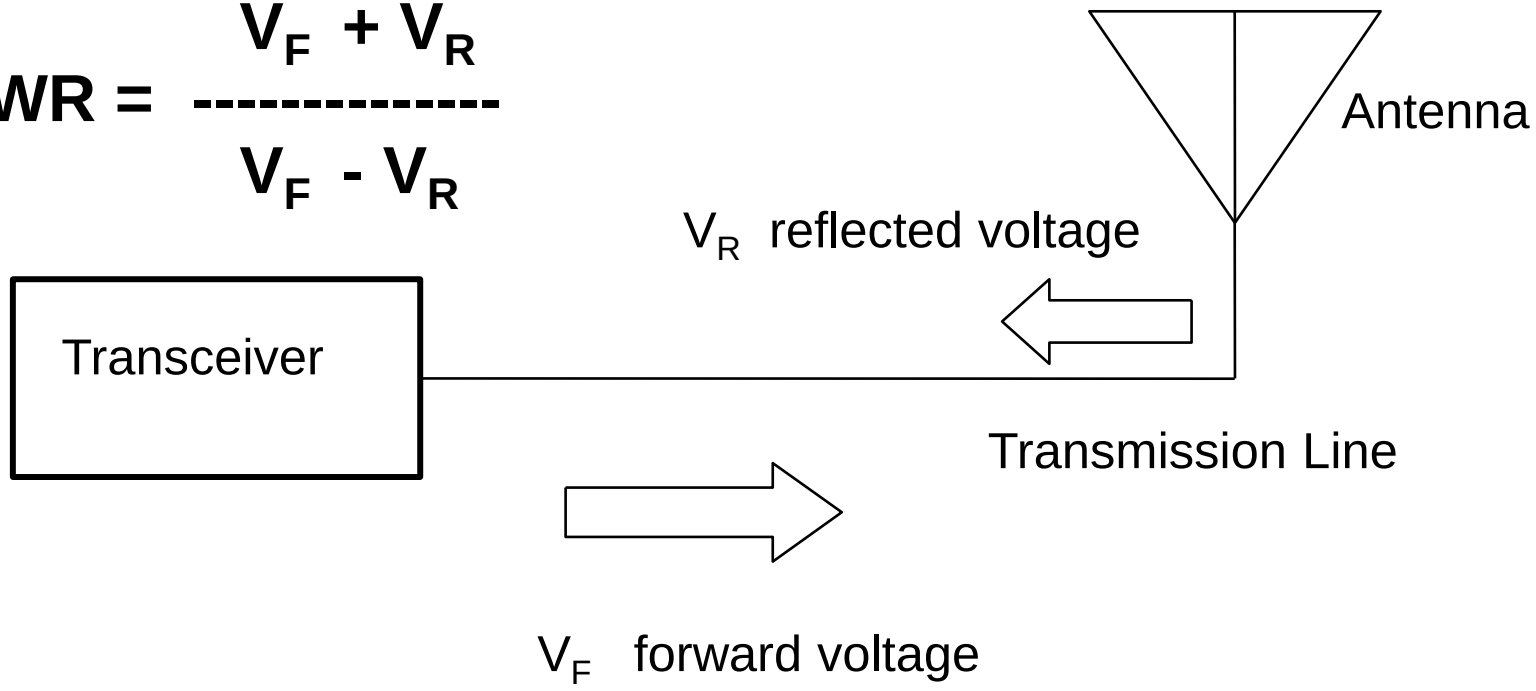
- What? You don't have a Multimeter?
- Buy a digital meter (forget the analog ones)
- Should have a minimum of 600 V Cat II (IEC 1010) rating
- Should have DC volts, AC volts, resistance and DC current
  (might not have *AC current)*
- Other features to consider:
  - Continuity test mode (“beeper”)
  - Diode test mode
  - Autorange
  - “Analog” Bar graph
  - Battery test mode
  - True RMS

Antenna Measurements

- SWR = *Standing Wave Ratio,* more properly called *Voltage Standing Wave Ratio (VSWR)*
- Measures the match between source (transmitter) and load (antenna).
- Perfect match is SWR = 1.0 (1:1)
- Anything greater than 1.0 is less than perfect
- SWR is always $\geq$ 1.0

SWR Measurement

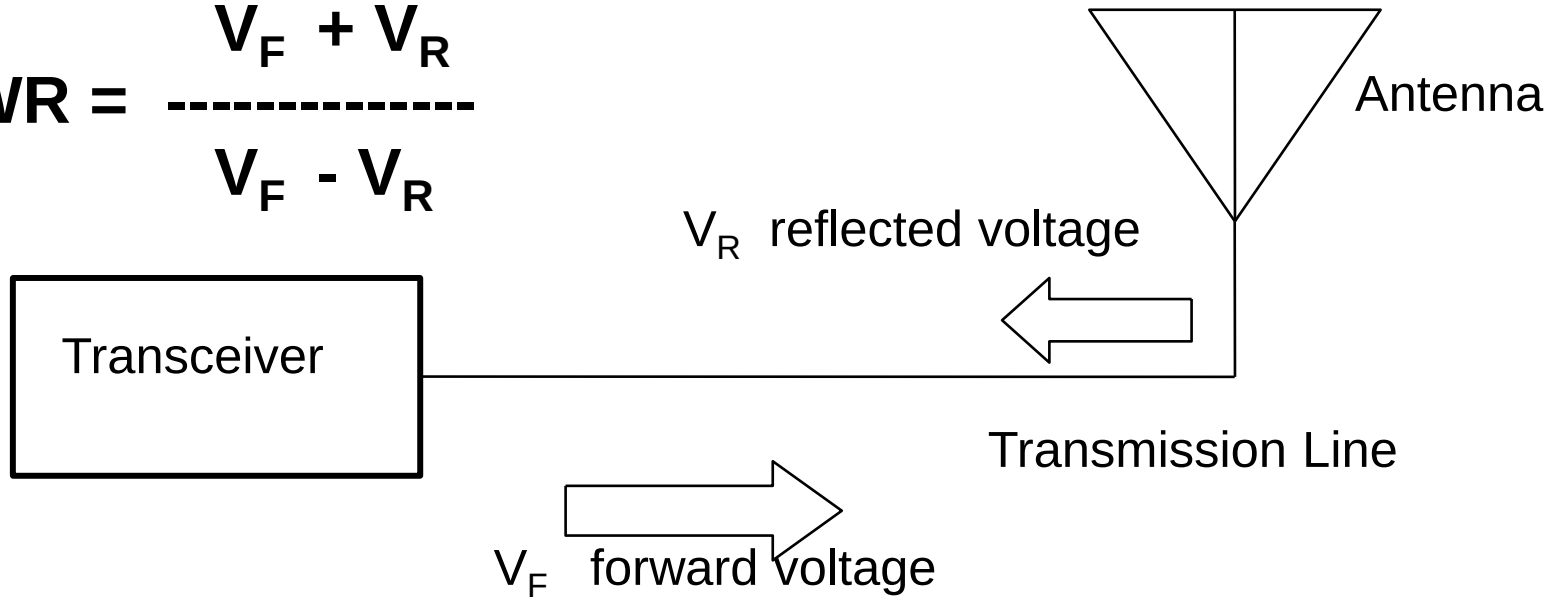
$$SWR = \frac{V_F + V_R}{V_F - V_R}$$



Transceiver, transmission line and antenna are all nominally the same impedance (50 ohms for amateur radio work).

SWR Measurement

$$SWR = \frac{V_F + V_R}{V_F - V_R}$$



Perfect Match: V_R = 0, no reflection, SWR = 1.0
Small reflection: V_R = 20% of V_F , SWR = 1.5
Large reflection: V_R = 80% of V_F , SWR = 9
Open load: V_R = 100% of V_F , SWR = infinite

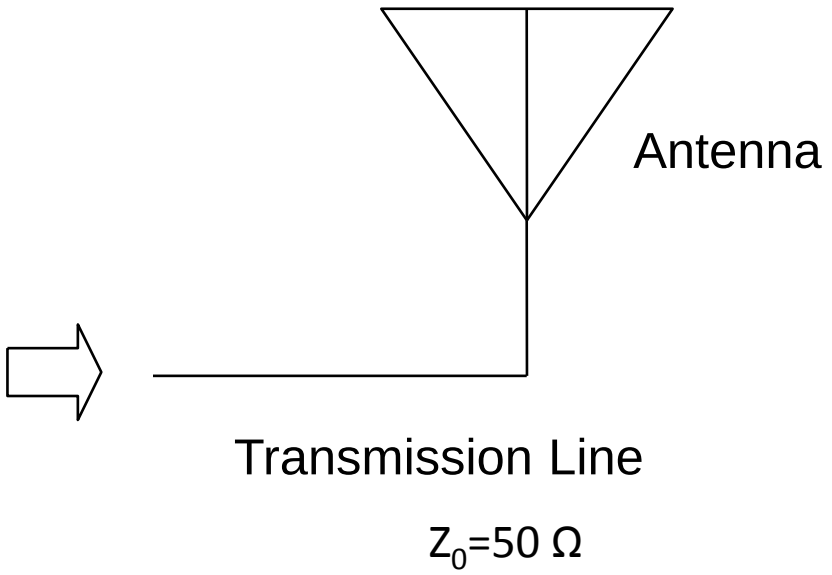
The Fundamental Measurement

What is the impedance looking into this port?

$Z = R + jX$

$SWR = Z_L/Z_0$ or Z_0/Z_L

whichever is ≥ 1, for Z_L real



Example:
What is the SWR with Z_L=100Ω ?
SWR = 100/50 = 2

ρ = reflection coefficient= V_R/V_F

RL = return loss (dB) = -20 log (ρ)

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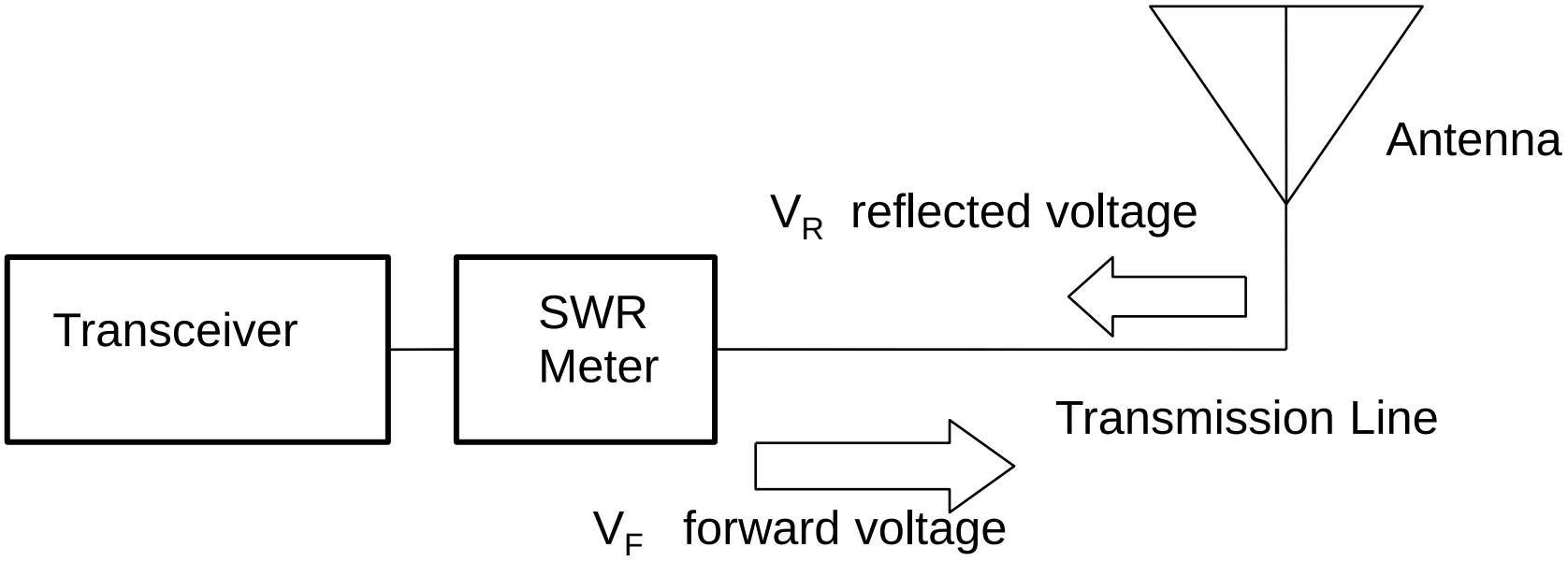
SWR Meter



SWR meter is inserted into the transmission line, which usually requires an additional cable between transceiver and SWR meter.

SWR Meters

Diamond SX-200 SWR/Power Meter

SWR and Power Meter

Freq Range:
1.8-200 MHz

Power Ranges:
5W, 20W and 200 W

Price: ~$100

SWR Meters

MFJ SWR Meter

Note the use of the cross-needle meter to avoid the need to “cal” the measurement

Some comments on SWR measurements

- SWR meters measure the match at the point of insertion.
- SWR does NOT indicate the radiating effectiveness of an antenna
- When measuring/adjusting an antenna, put the SWR meter as close to the antenna as possible.
- Make sure the SWR meter is spec'd for the frequency of interest.
- Long, lossy coax makes the SWR look better.
- How low should the SWR be? Depends on the situation...what can be reasonably expected? It might be OK to run high SWR.

Antenna Analyzers

MFJ-259B Antenna Analyzer

Frequency Range: 1.8 – 170 MHz

Price: ~$250

Measure:

SWR, Return Loss

Impedance, Reactance, Resistance

Default measurement mode is:

- Impedance, Z = R + j X
  (R= resistance, X = reactance)
- SWR

Also:

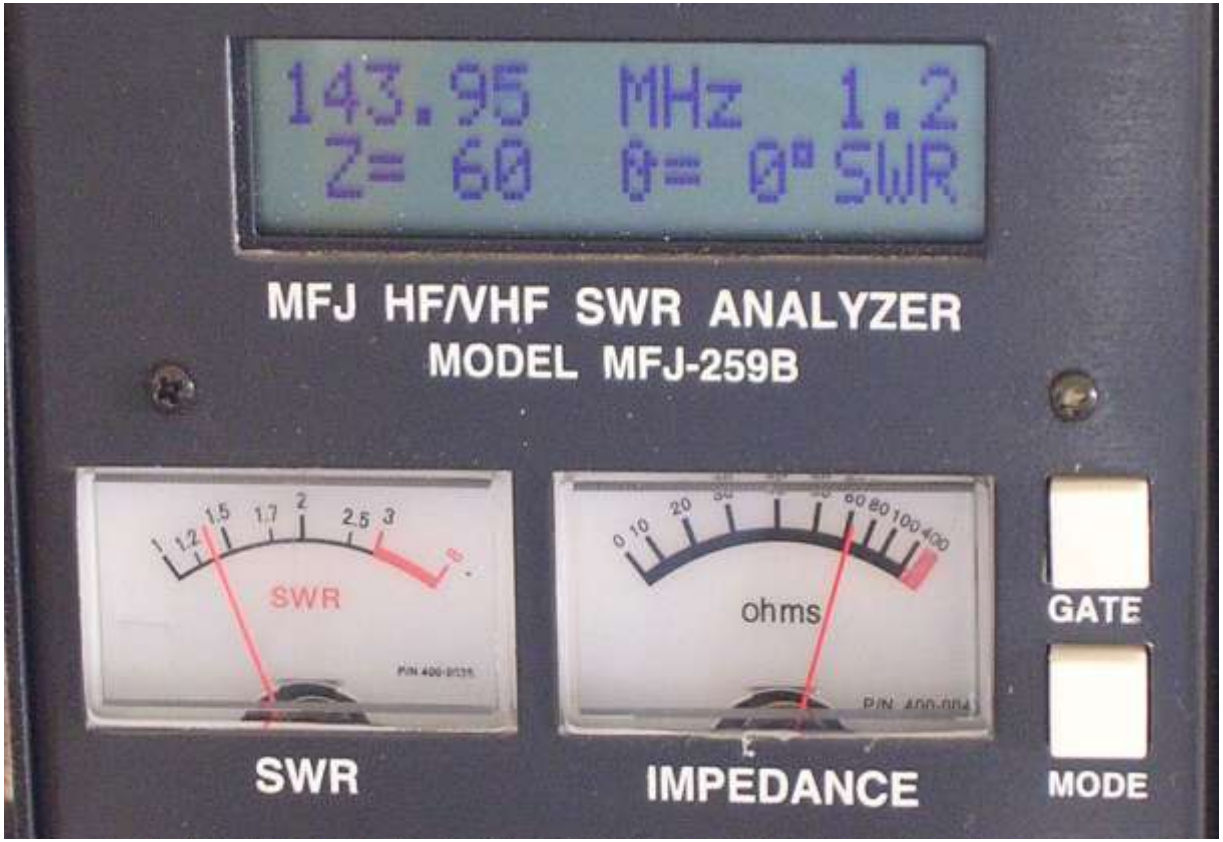
Impedance, Z = $Z_{mag} \angle\theta$

Reflection coefficient

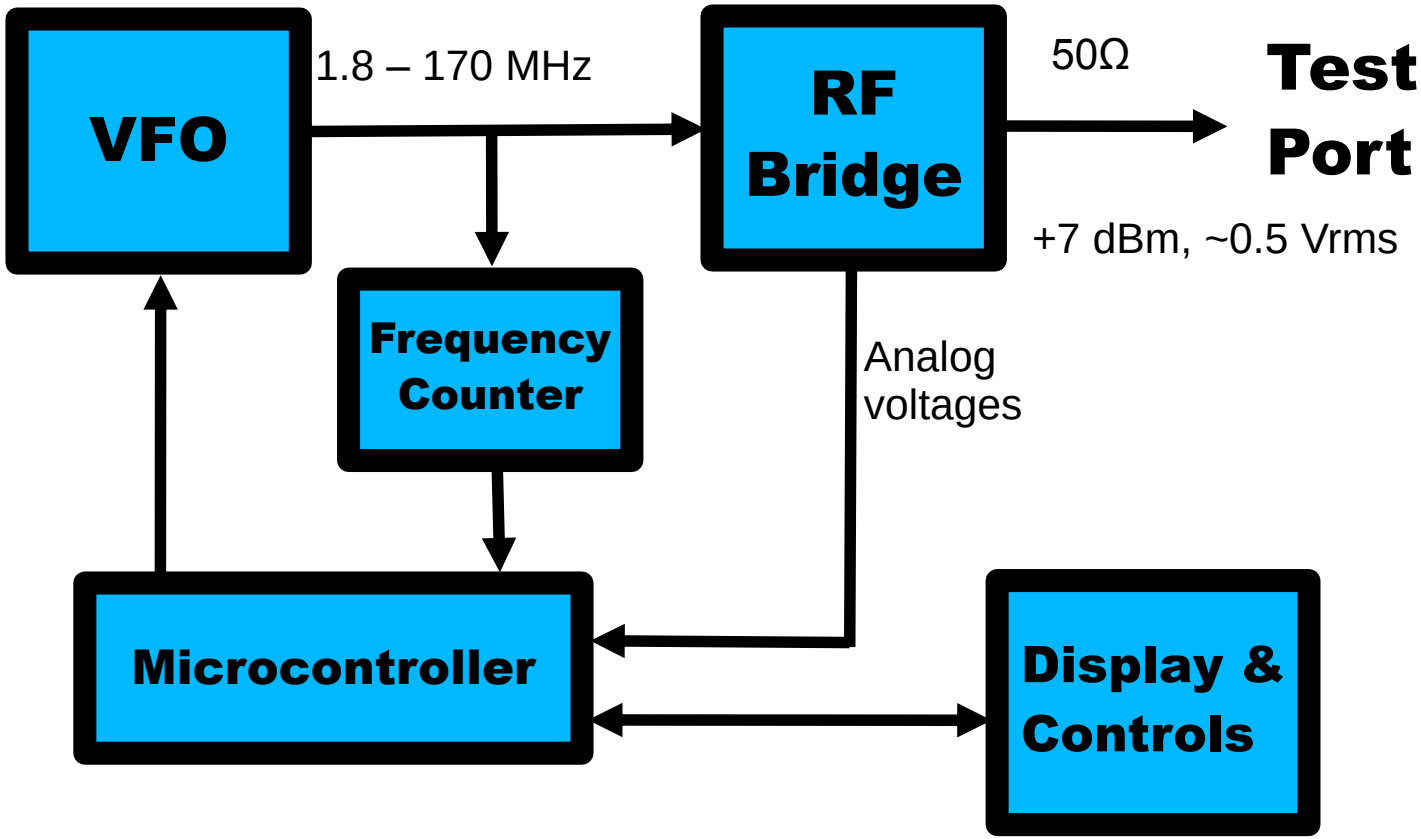
Return Loss

MFJ-259B Antenna Analyzer

MFJ-259B Antenna Analyzer



MFJ-259B Block Diagram



MFJ-259B Antenna Analyzer

Usage Tips

- Best accuracy near 50 ohms (SWR=1)
- Don't use in high RF environment
- Input circuitry is sensitive
- Discharge antennas before connecting
- Do not apply external voltages to test port
- Don't over-interpret the results (the analyzer is just looking at the impedance match against 50Ω)

Comet CAA-500 Antenna Analyzer

Frequency Range:
1.8 to 500 MHz

Price: ~$430

Vector Network Analyzer (VNA)

Freq range:
100 KHz to 200 MHz
Range of Z: 1 to 1000 ohm
Dynamic range:
up to 90 dB in Transmission
& 50 dB in Reflection
Two port VNA with S11 and S21

Price: ~$550

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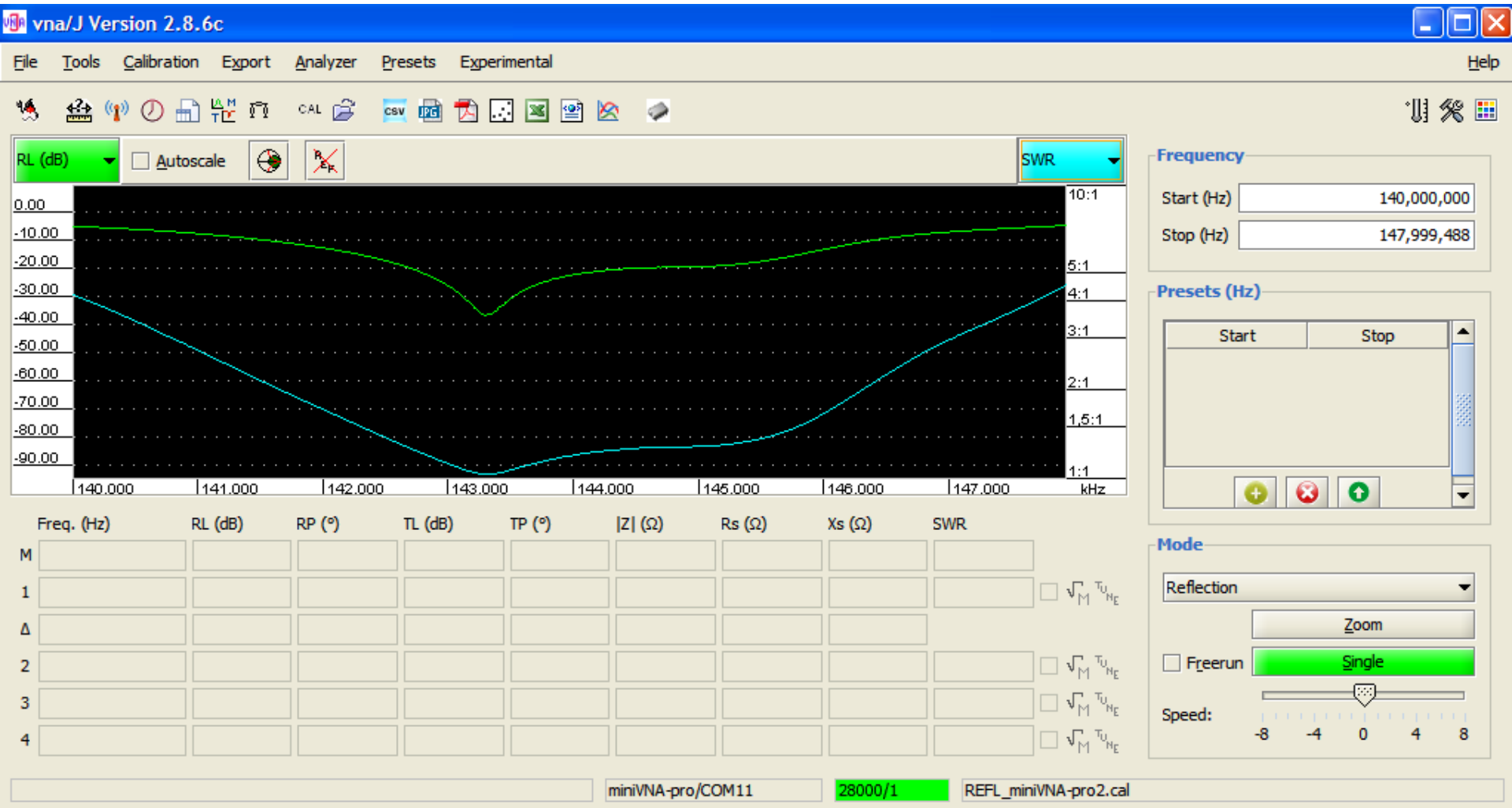
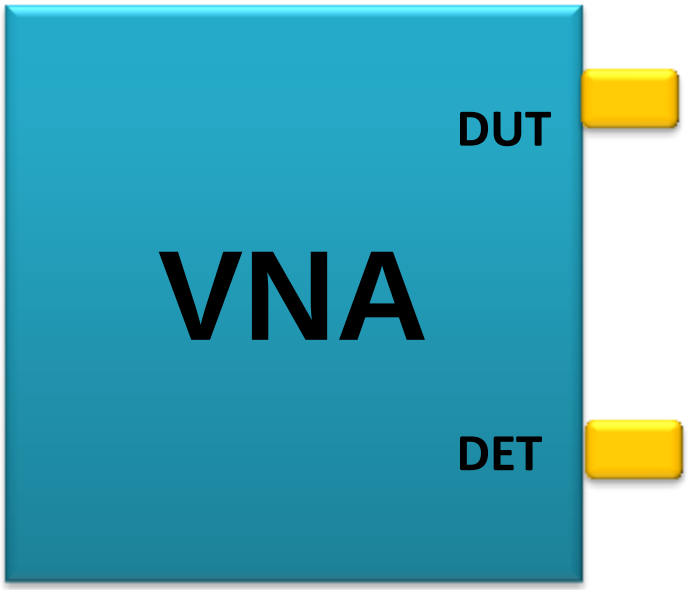
VNA Software



VNA Calibration



Reflection

1) Open
2) Short
3) 50Ω Load

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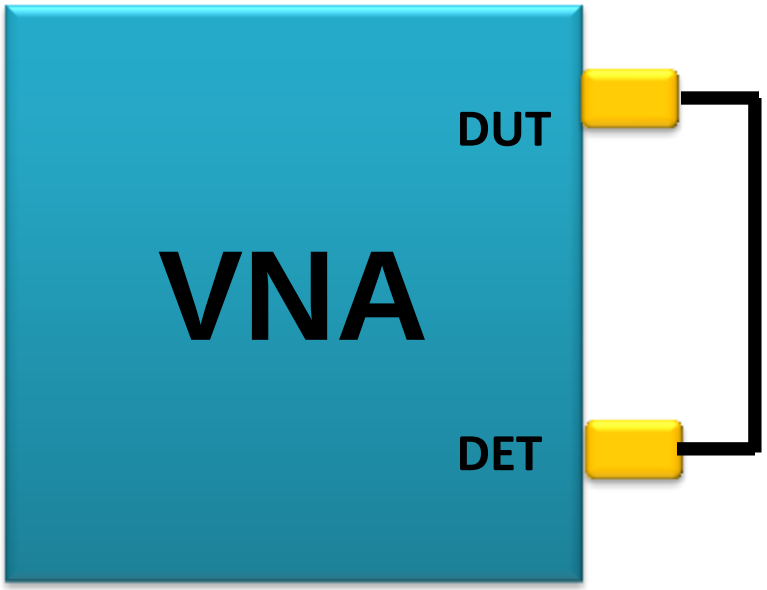
VNA Calibration



Transmission

1) Open

2) Through

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M² 2M9SSB

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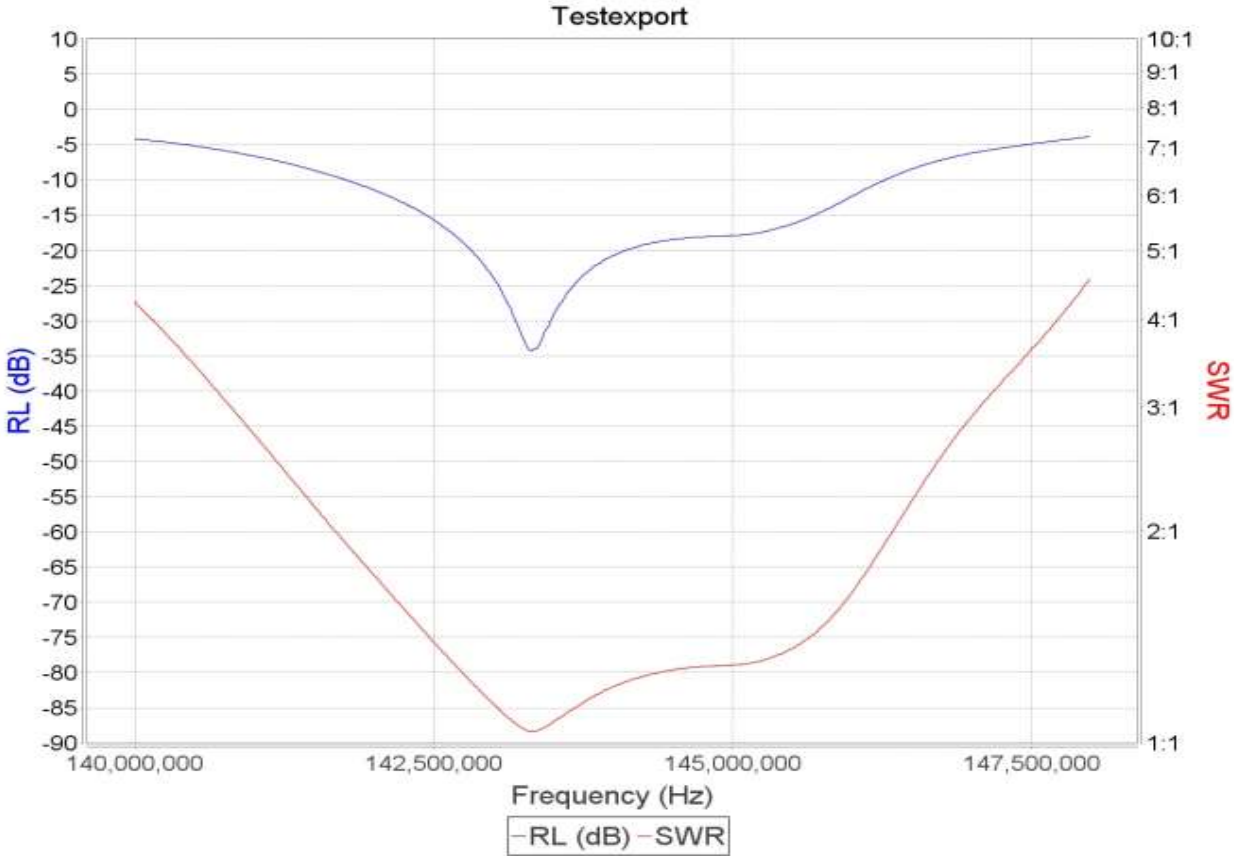
VNA Measurement – 2M Antenna

Measured
SWR
and
Return Loss



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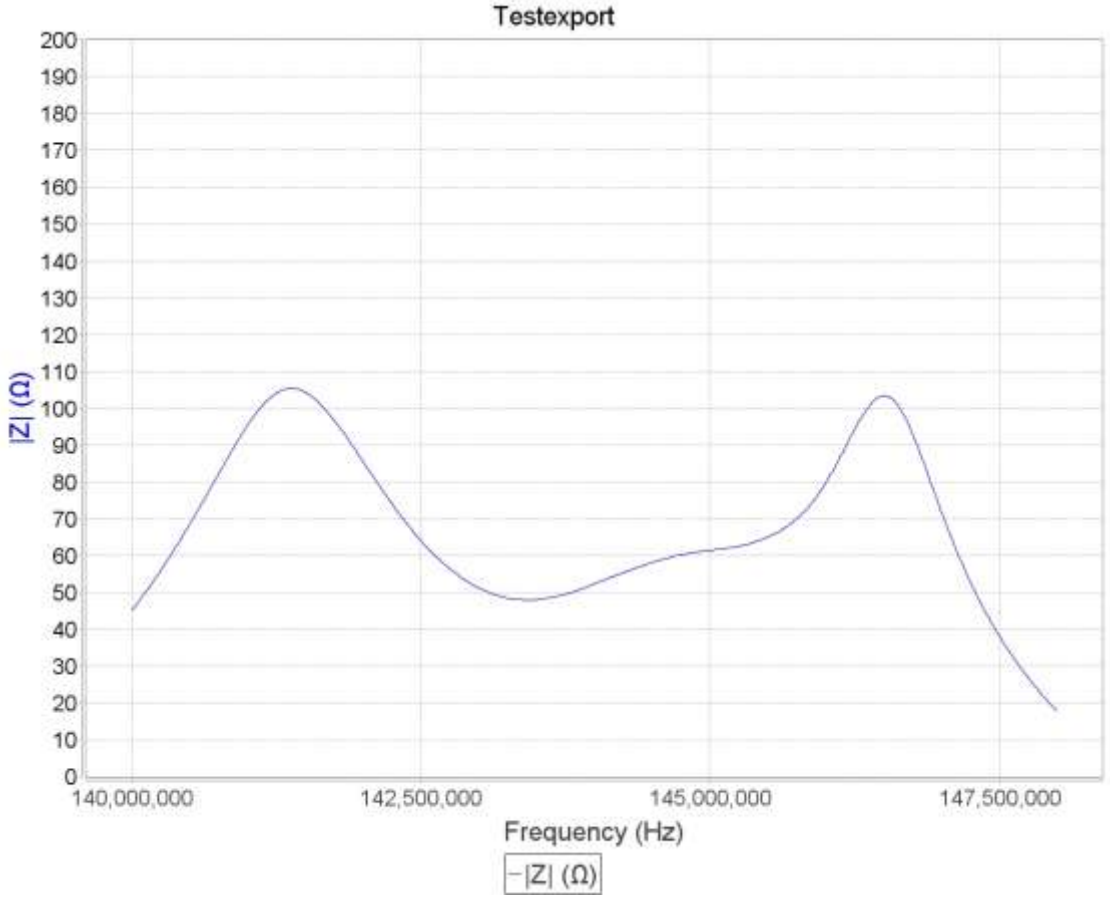
VNA Measurement – 2M Antenna

Measured
|Z|



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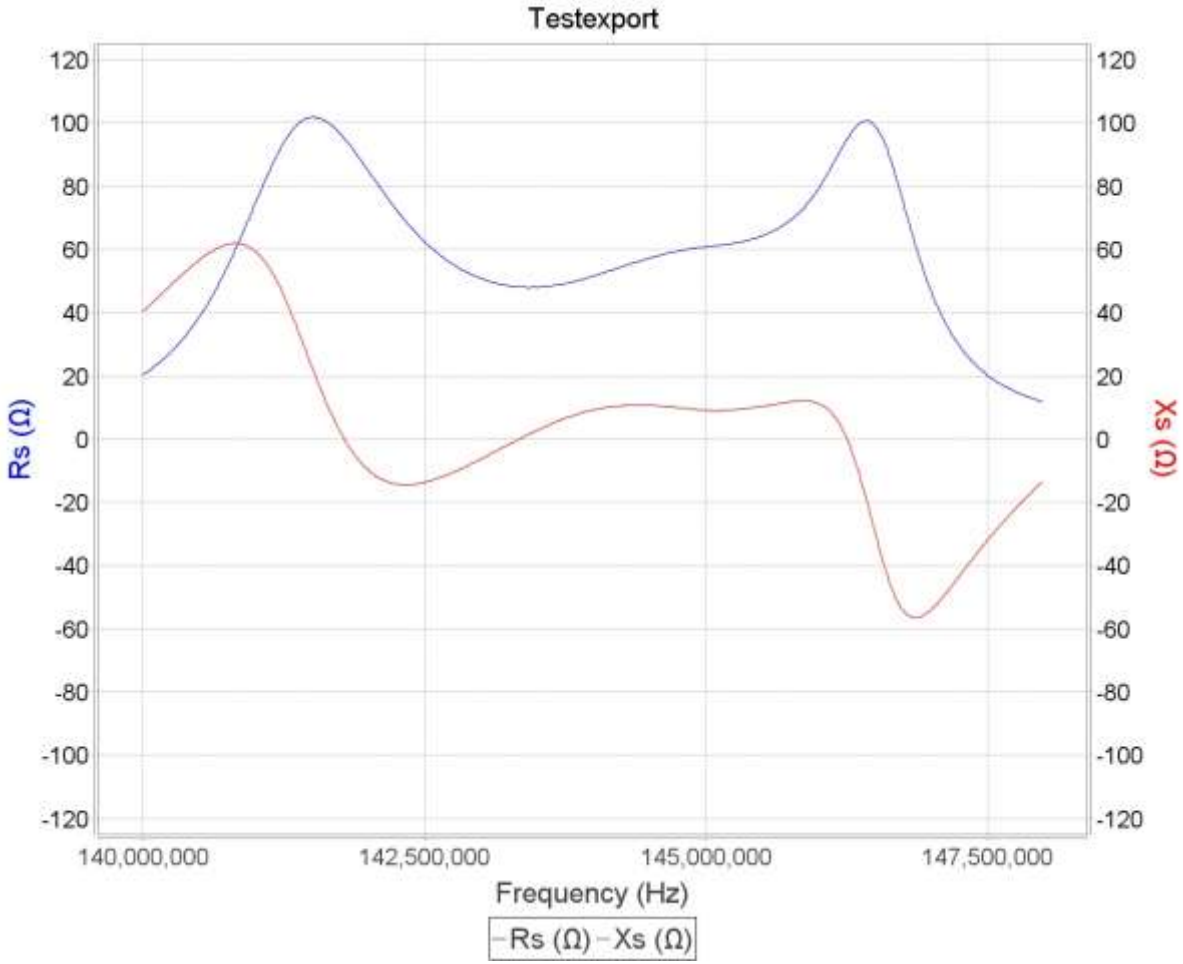
VNA Measurement – 2M Antenna

Measured
R and X



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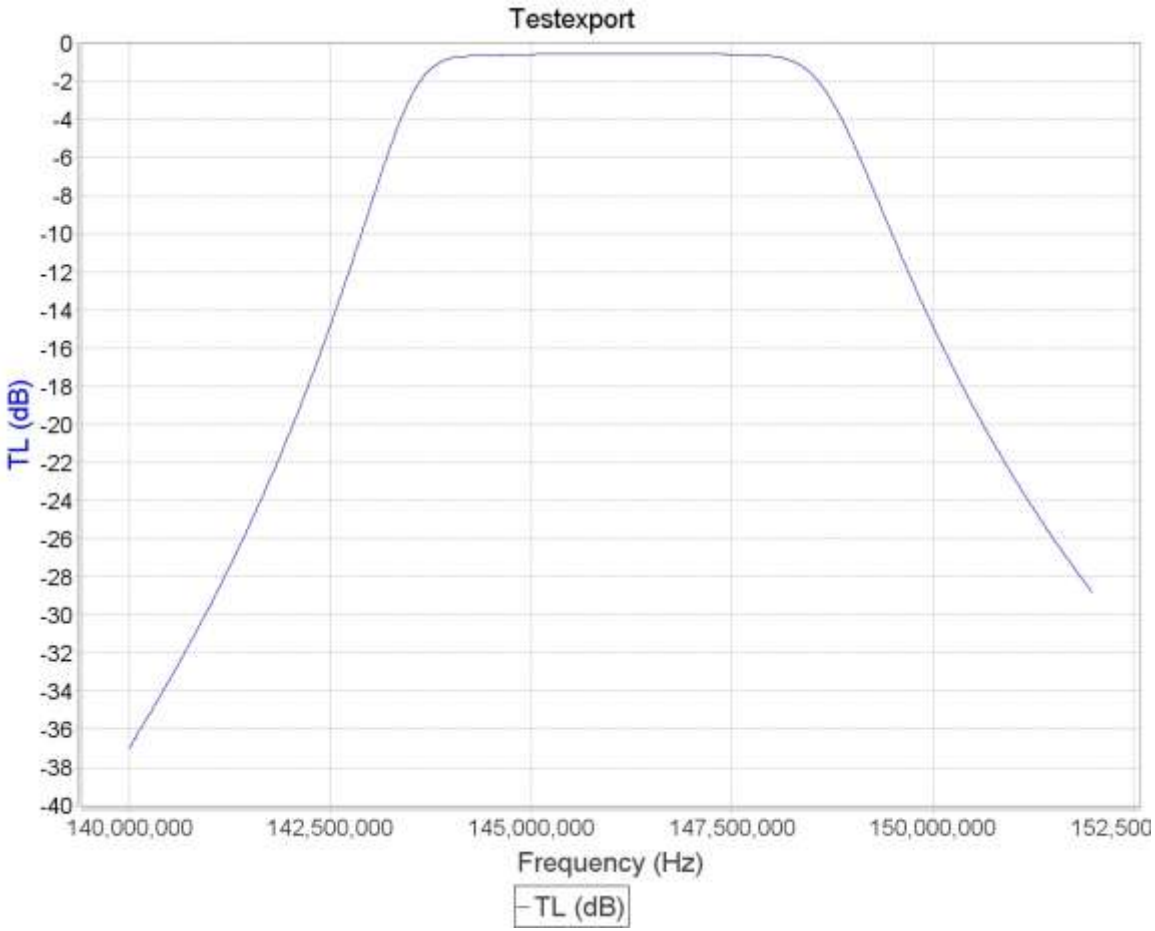
VNA Transmission Measurement

DCI

2 Meter Filter



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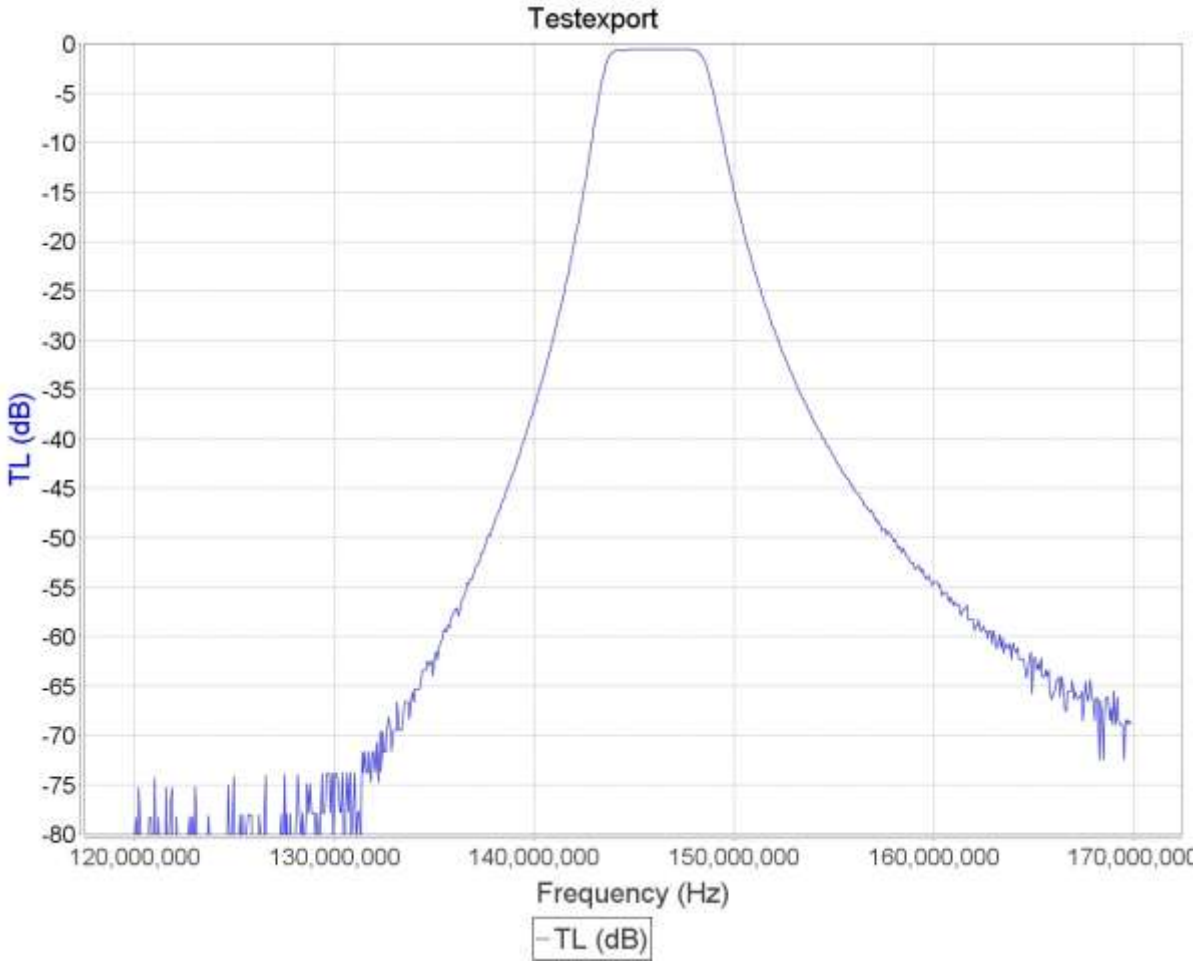
VNA Transmission Measurement

DCI

2 Meter Filter



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Summary

Basic Test Equipment for Ham Use

- Digital Multimeter
- SWR Meter
- Antenna Analyzer
- Vector Network Analyzer

Safety First

- Always be careful with electrical measurements
  (especially high voltage)

This presentation is available for download at k0nr.com