Practical Amateur Radio Measurements

TechFest – Fall 2015

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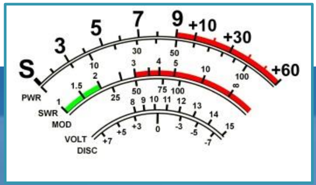


Bob Witte KØNR

Electrical Engineer

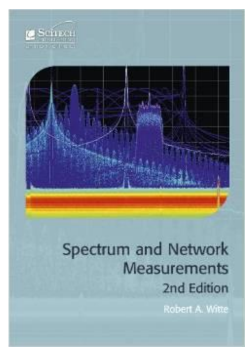
35 years in the Test and Measurement Industry

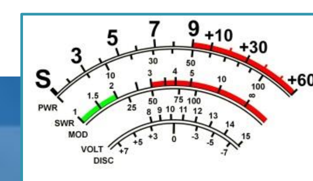
HP, Agilent, Keysight Technologies

Author of

Electronic Test Instruments

Spectrum and Network Measurements





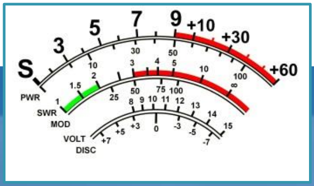
Practical Measurements

The Multimeter

- Measures DC/AC Voltage, Current and Resistance

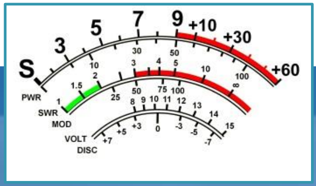
Antenna System Measurements

- The SWR Meter
- The Antenna Analyzer

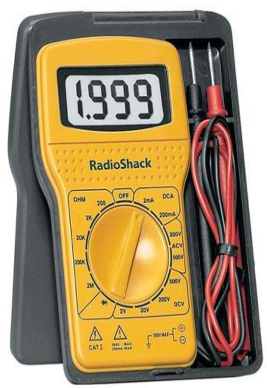


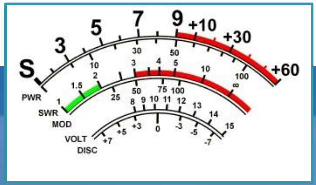
The Multimeter

- 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



Lots of Meters Out There



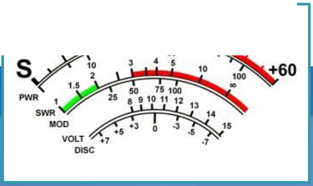


Safety First

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

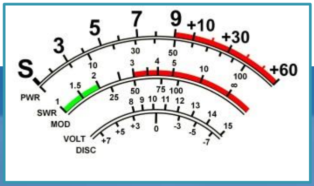
Be careful where you put your digits when using a Digital Multimeter

Graphic courtesy of Agilent Technologies



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

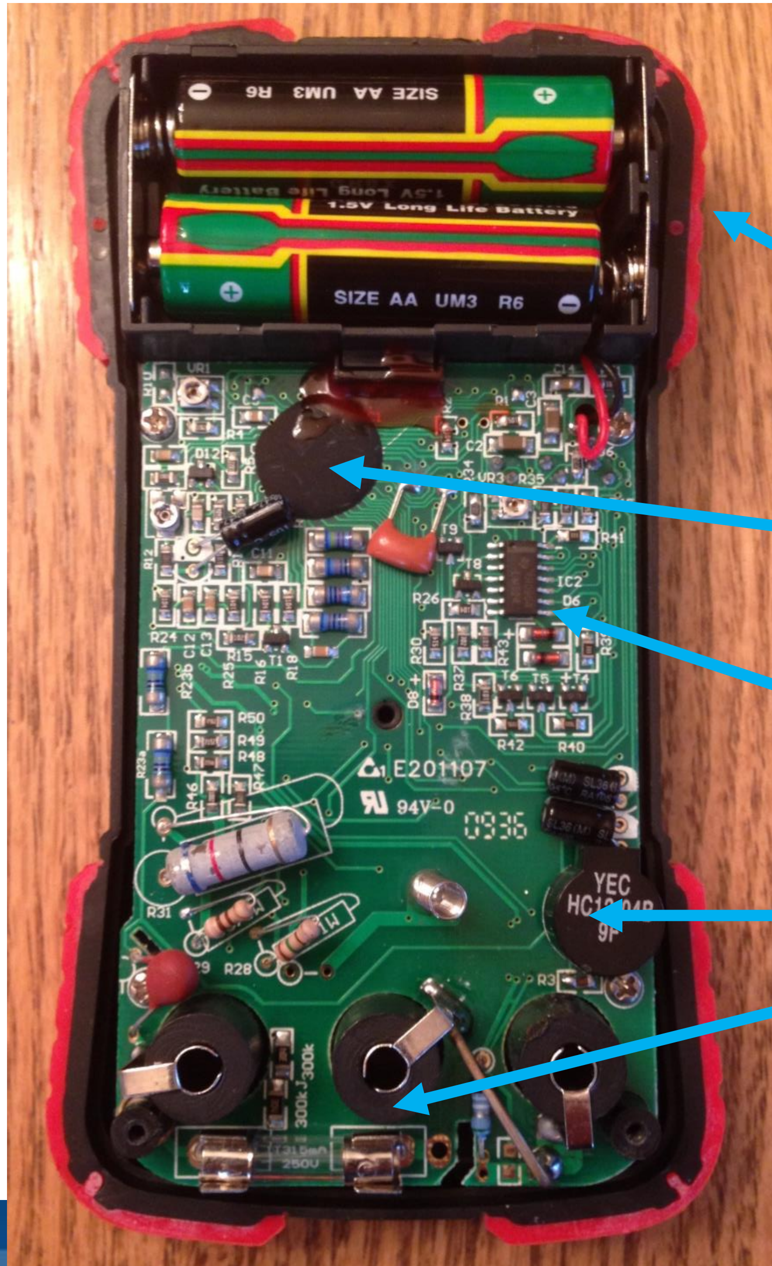


A Typical Low Cost DMM

Innova 3320

- Price ~$20
- 3½ Digits
- 0.8% to 1.5% Accuracy (depends on range)
- Diode test
- Continuity test
- Autorange
- Battery test
- IEC 1010 Cat II - 600V

Inside the meter



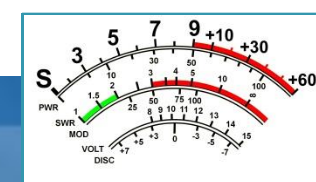
Two AA batteries

DMM IC
(under glop)

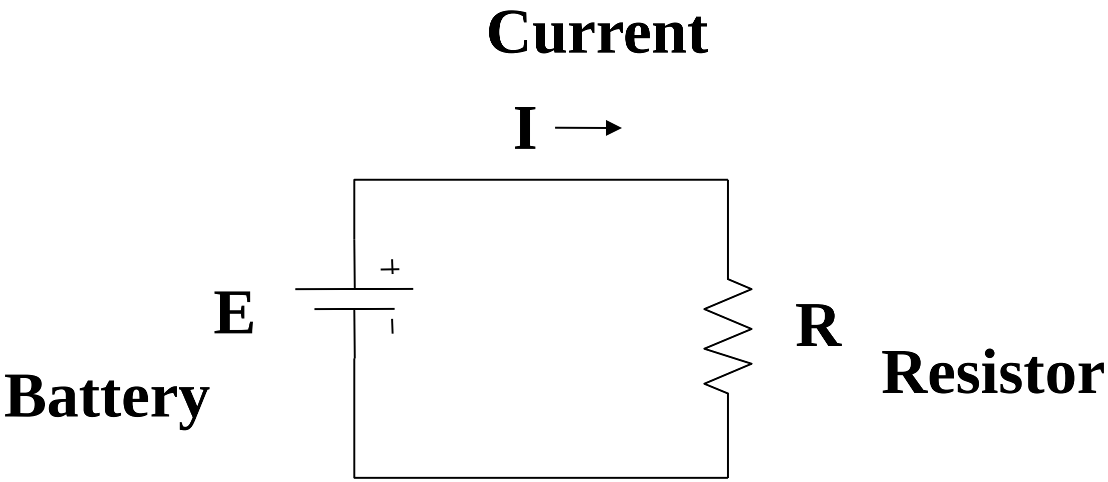
Quad Op Amp
(LM324)

Beeper

Protection Fuse

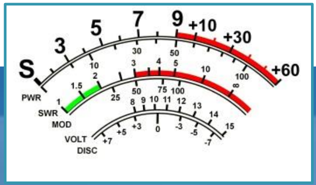


Circuit with Battery and Resistor

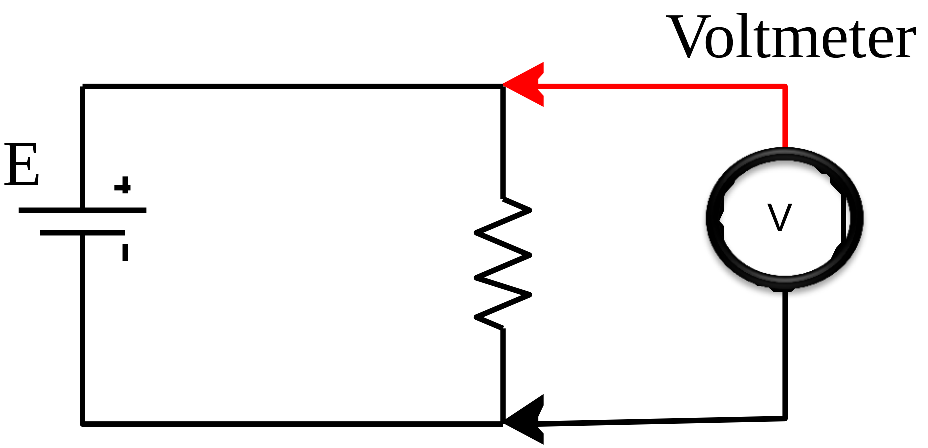


Ohm's Law: $I=E/R$

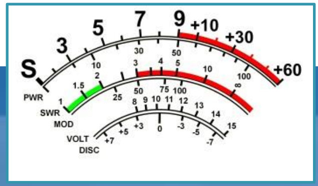
Note: Positive current convention used



Voltage Measurement

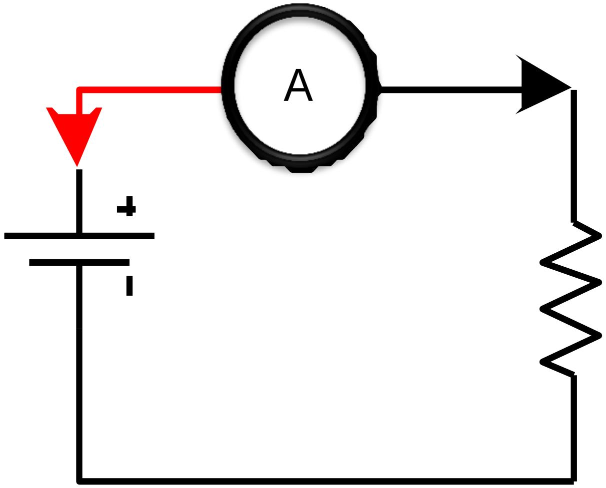


- Configure DMM to DC voltage
- DMM appears as “open circuit”
- Connect DMM in parallel with voltage to be measured



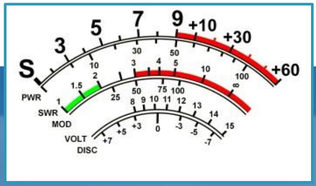
Current Measurement

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



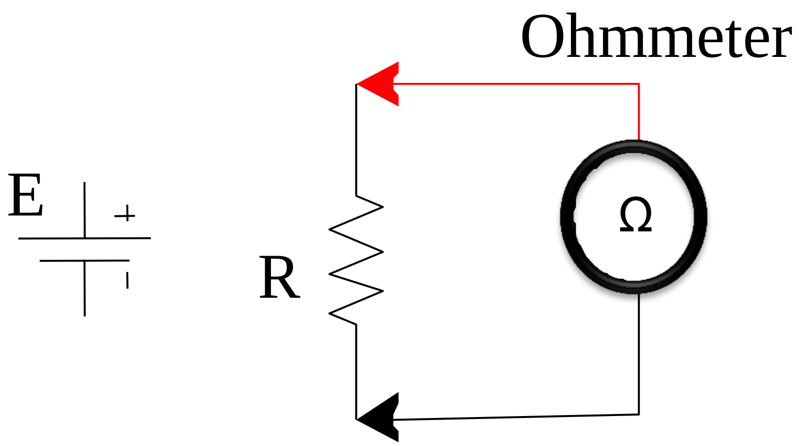
- *Don't select current mode by mistake*
- *Be very careful how you connect when in current mode*
- *Short circuits can cause big problems!*

Be Careful !!!!!!!

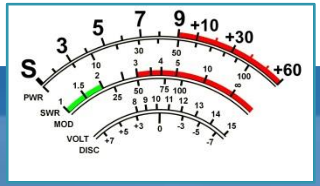


Resistance Measurement

- 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



These principles also apply to diode test, capacitance test, inductance test, continuity test, etc.

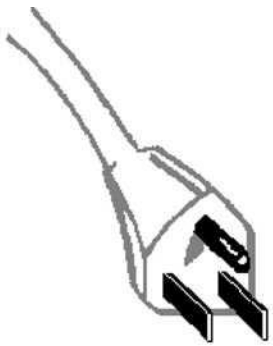
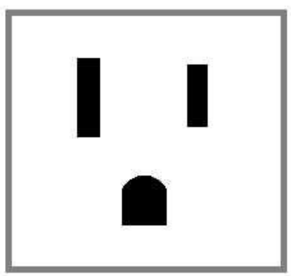


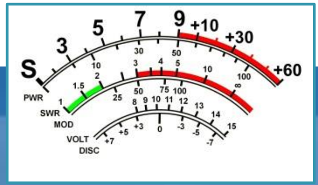
Experiment: What is the AC line voltage in the US?

120 Volts RMS
± 6 V

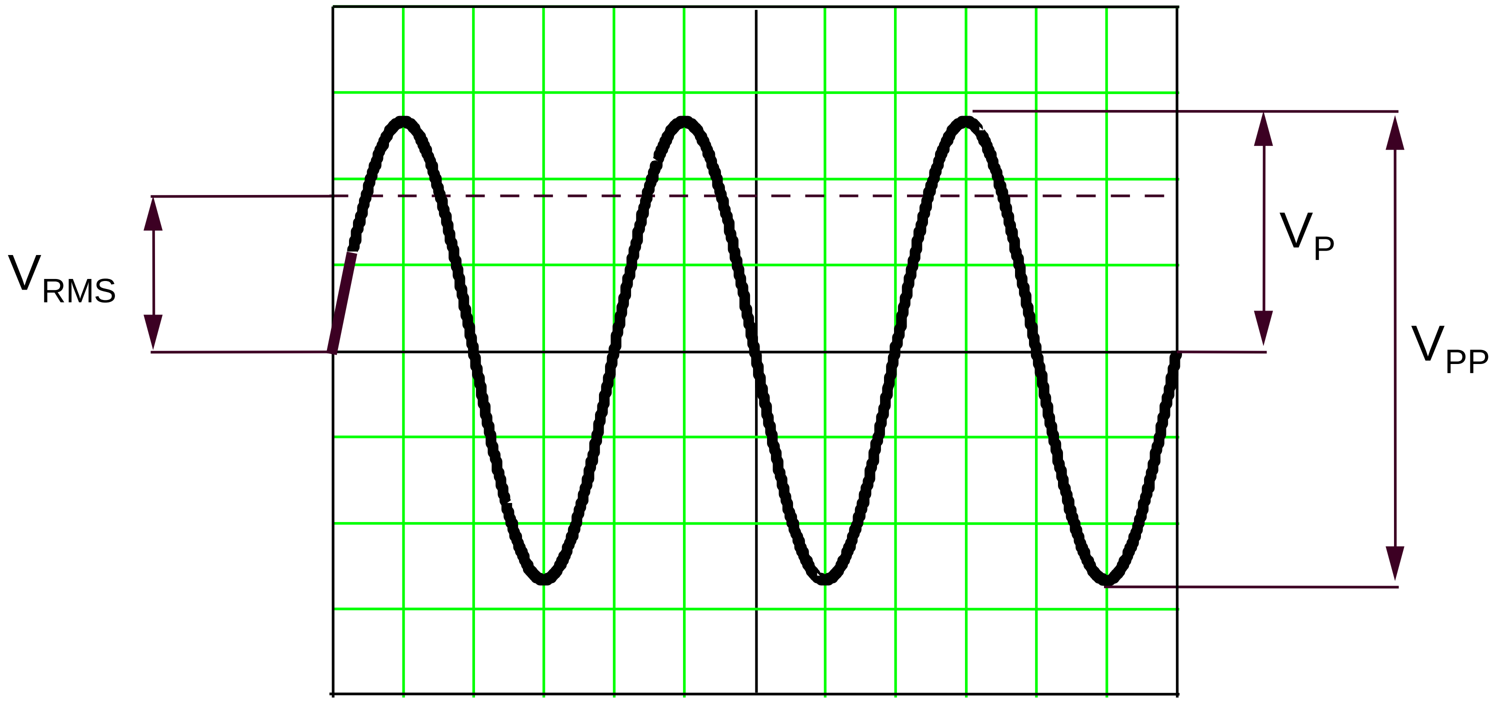
Let’s measure it.

Put DMM in AC Voltage mode and plug ‘er in

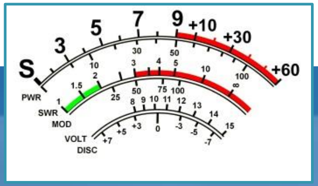





Sine Wave Voltage Measurements



$V_{RMS} = 0.707\ V_P$ $V_P = 1.414\ V_{RMS}$ (sine wave)



Some Superfluous Math Equations

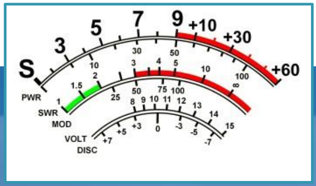
General Equations

$$V_{RMS} = \sqrt{\tfrac{1}{T}\int_0^T v^2(t)\, dt} \qquad V_{AVG} = \frac{1}{T}\int_0^T \left|v(t)\right| dt$$

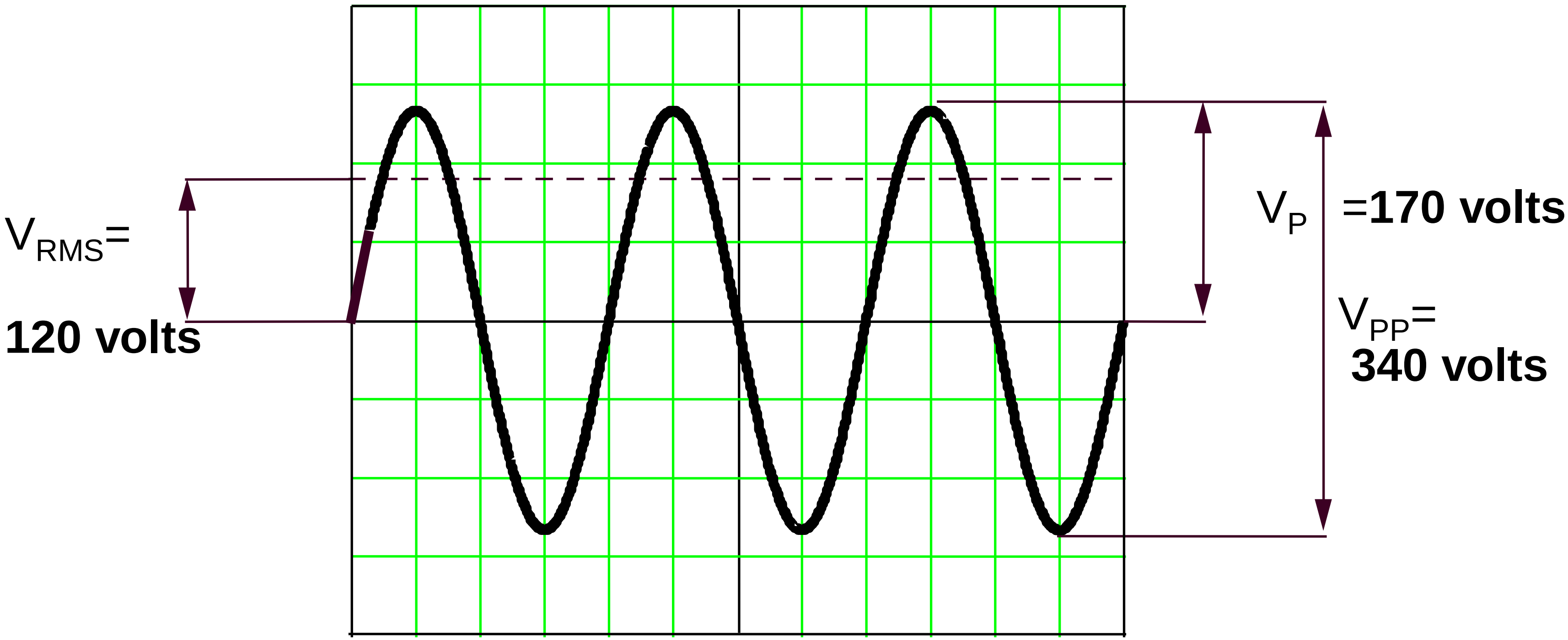
For Sine Wave

$$V_{RMS} = \sqrt{\tfrac{1}{T}\int_0^T V_p \sin^2(2\pi ft)\, dt} = \frac{1}{\sqrt{2}} V_P = 0.707 V_P$$

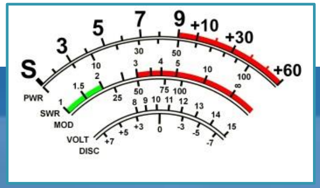
$$V_{AVG} = \frac{1}{T}\int_0^T \left|V_P \sin(2\pi ft)\right| dt = \frac{2}{\pi} V_P = 0.637 V_P$$



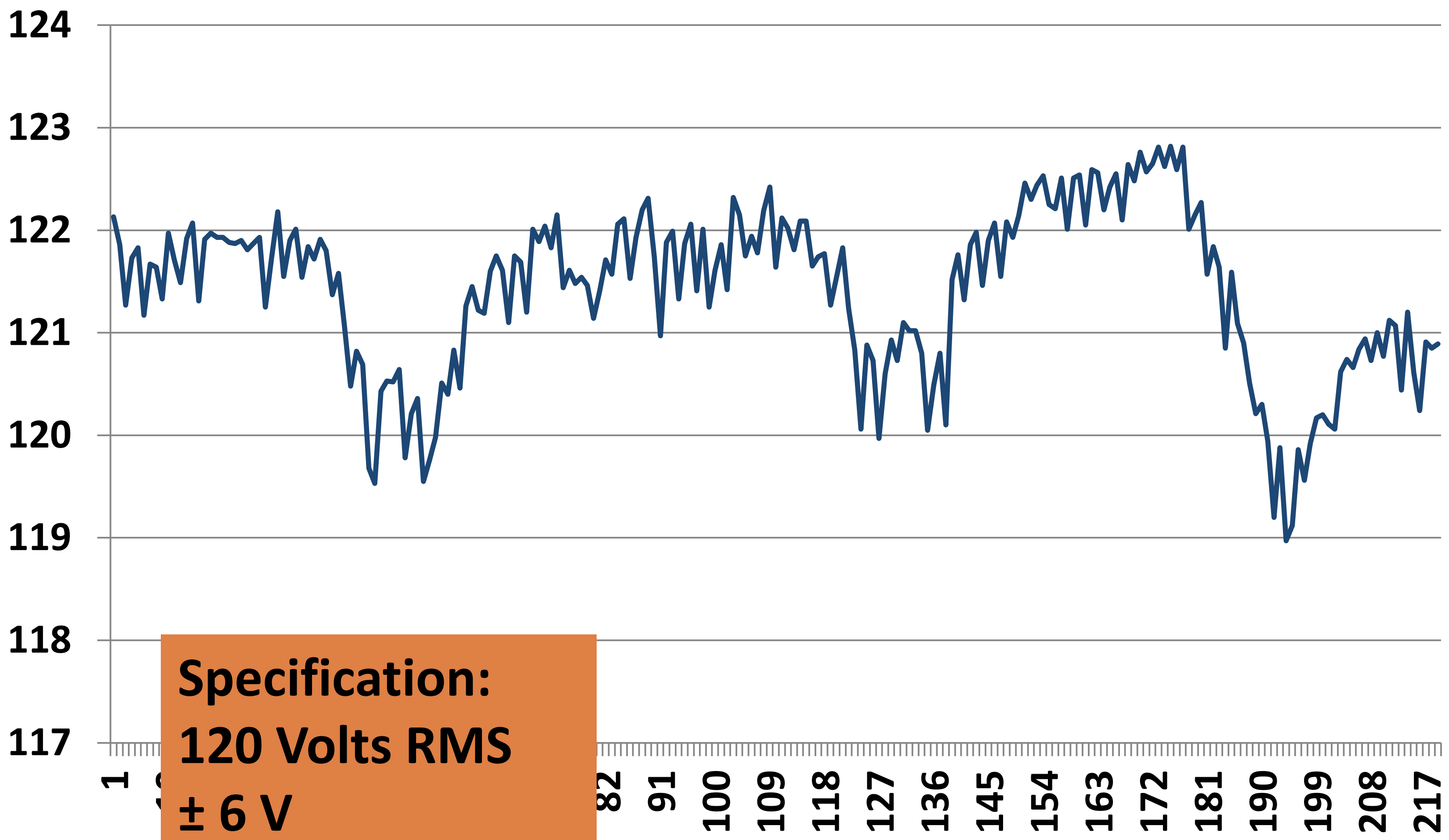
Example: AC Line Voltage



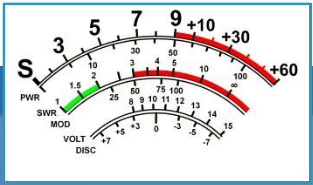
$V_{RMS} = 0.707\ V_P$ $V_P = 1.414\ V_{RMS}$ (sine wave)



AC Line Voltage (40 hours)



Specification:
120 Volts RMS
± 6 V



Multimeter with AC Current Clamp

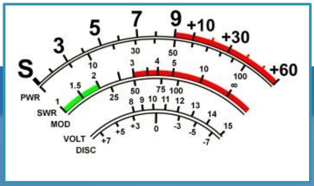
Current measurement is done via clamping the wire

The clamp acts as the core of a transformer

AC-only current measurement

Uni-Trend UT202A $28 on Amazon

Clamp meters are available that measure DC current but are more expensive



AC Line Splitter

Inserted inline with AC power cord

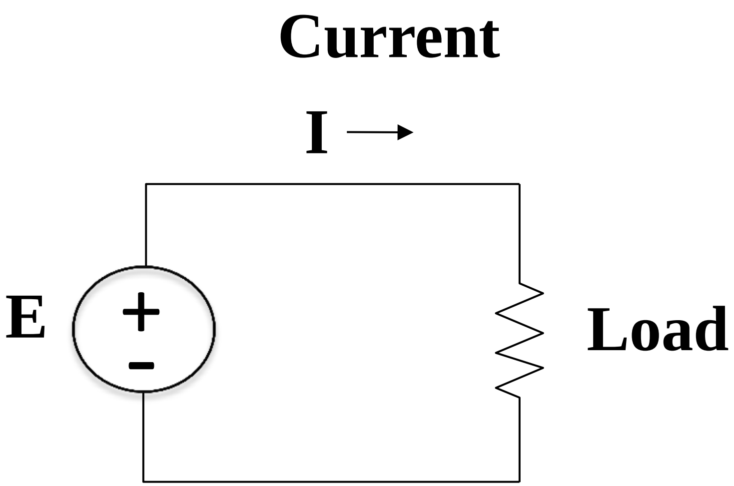
Allows easy attachment of clamp-on ammeter

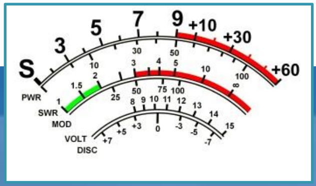
Also has slots for probing voltage

Experiment: Measure Voltage & Current, Calculate Power

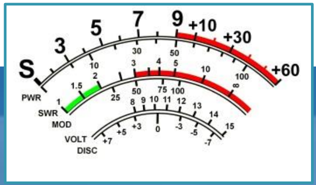
$P = I \cdot E$

- P = power
- E = voltage
- I = current



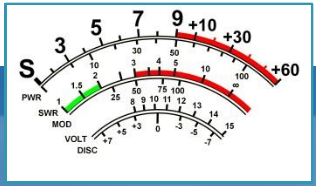


Antenna System Measurements



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 ≥ 1.0



More Superfluous Math Equations

Near Field

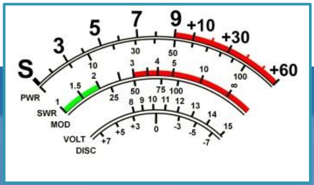
The above formulas are valid for the far field of the antenna ($r \gg \lambda/(2\pi)$), and are the only contribution to the radiated field. The formulas in the near field have additional terms that reduce with r^2 and r^3. These are,

$$E_r = \frac{Z}{2\pi} I_0 \, \delta l \left(\frac{1}{r^2} - i \, \frac{\lambda}{2\pi \, r^3} \right) e^{i(\omega t - k\,r)} \, \cos(\theta)$$

$$E_\theta = i \frac{Z}{2\lambda} I_0 \, \delta l \left(\frac{1}{r} - i \, \frac{\lambda}{2\pi \, r^2} - \frac{\lambda^2}{4\pi^2 \, r^3} \right) e^{i(\omega t - k\,r)} \, \sin(\theta)$$

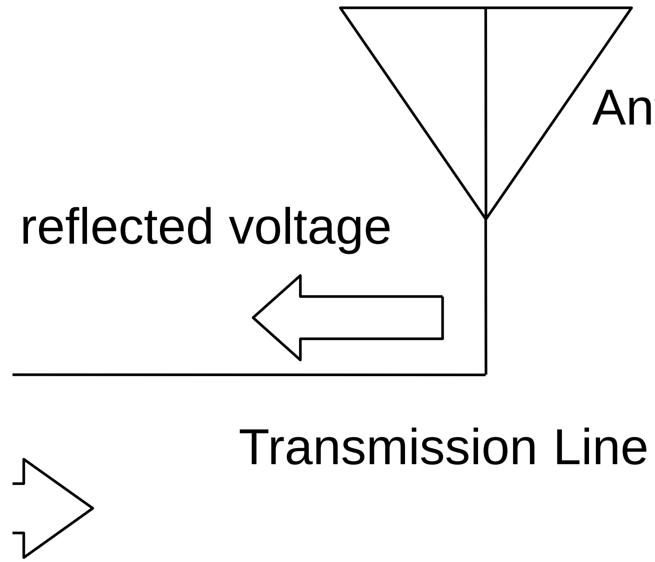
$$H_\phi = i \frac{1}{2\lambda} I_0 \, \delta l \left(\frac{1}{r} - i \, \frac{\lambda}{2\pi \, r^2} \right) e^{i(\omega t - k\,r)} \, \sin(\theta)$$

where $Z = \sqrt{\mu/\varepsilon} = 1/(\varepsilon \, c) = \mu \, c$. The energy associated with the term of the near field flows back and forward out and into the antenna.

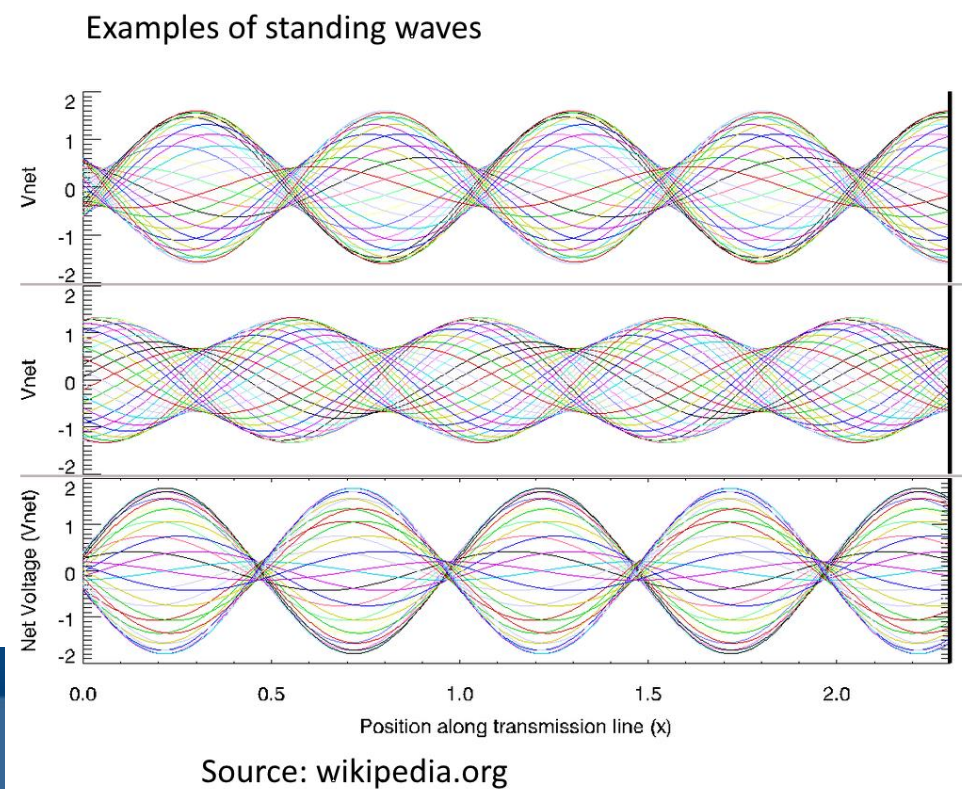


SWR Measurement

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

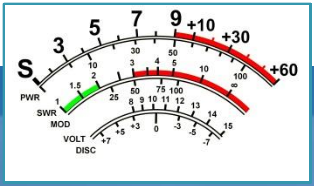


V reflected voltage



rd voltage

itenna are all nominally the
eur radio work).



The Fundamental Measurement

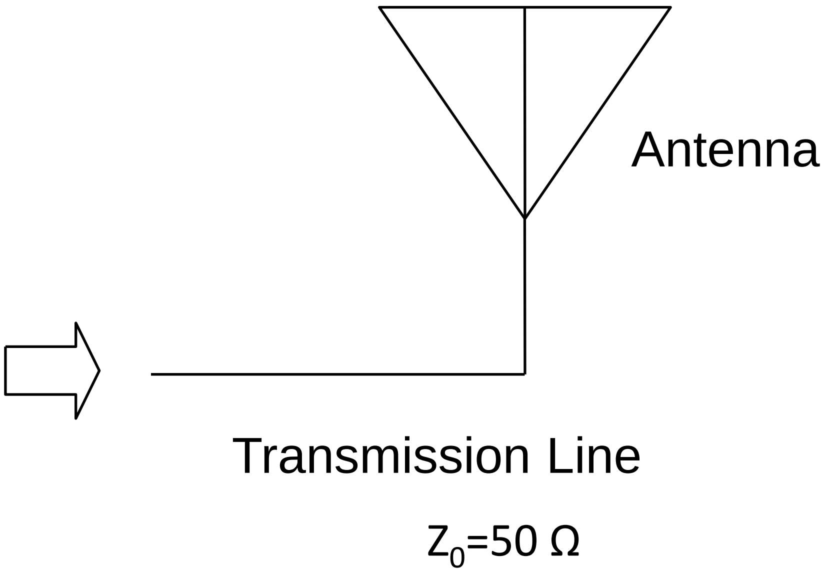
What is the impedance looking into this port?

$Z = R + jX$

$SWR = Z_L/Z_0$ or Z_0/Z_L

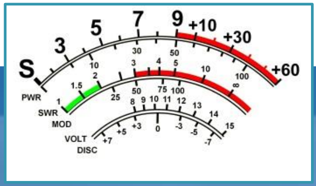
whichever is ≥ 1, for Z_L real

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

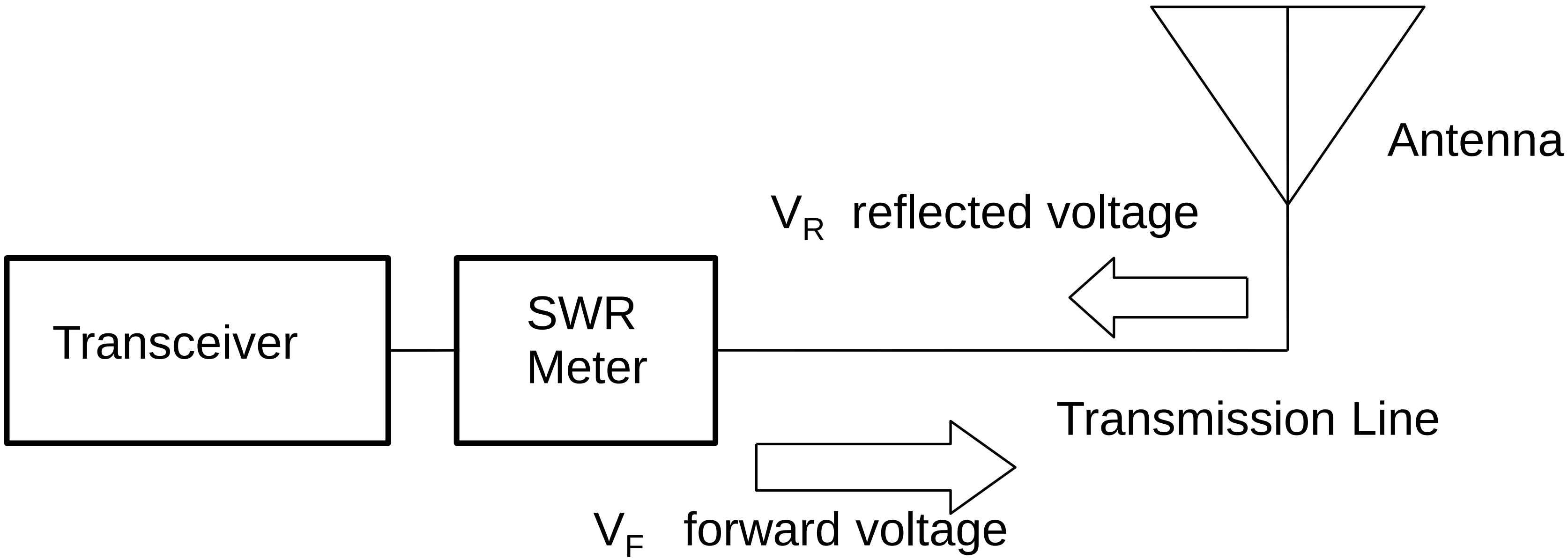


ρ = reflection coefficient= V_R/V_F

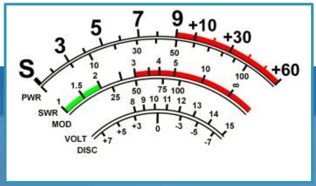
RL = return loss (dB) = -20 log (ρ)



SWR Meter



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



SWR Meters

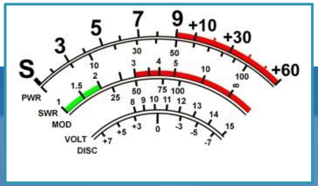
Diamond SX-200 SWR/Power Meter

SWR and Power Meter

Freq Range:
1.8-200 MHz

Power Ranges:
5W, 20W and 200 W

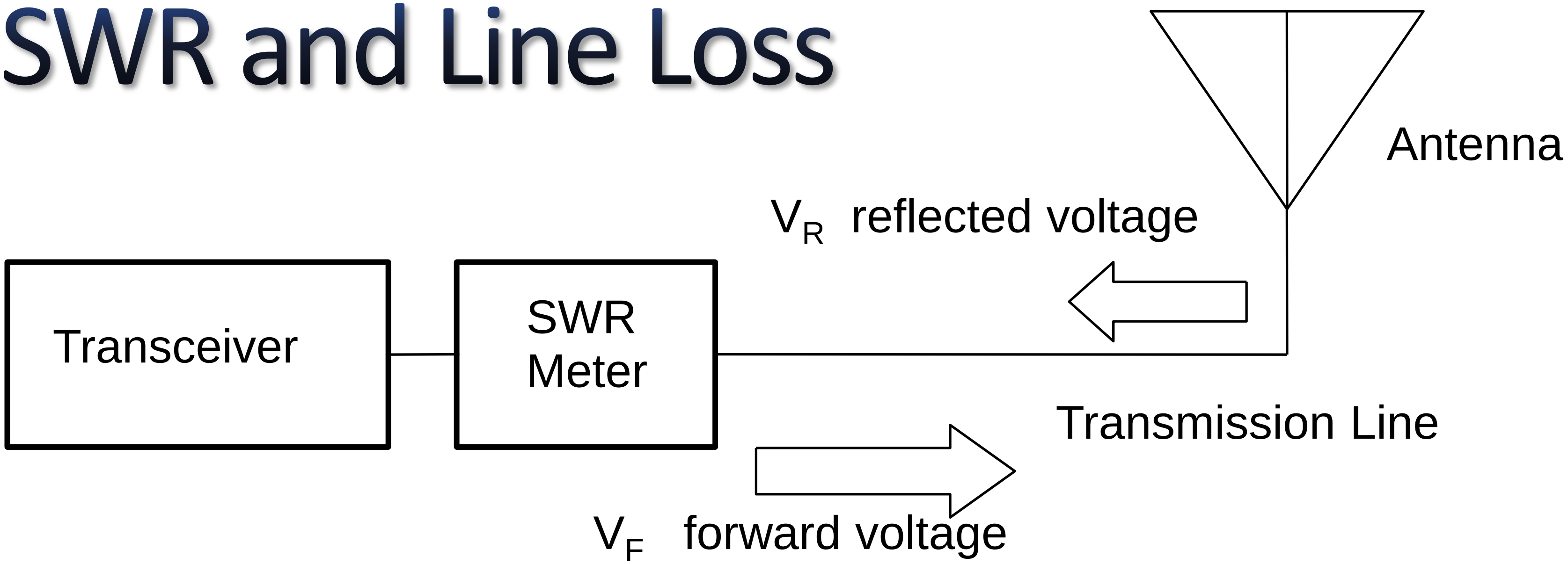
Price: ~$100



Comet CMX-400

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

SWR and Line Loss

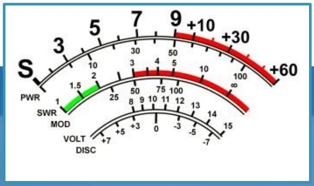


With no transmission line loss, the SWR measurement is the same anywhere on the line (ideal conditions)

With line loss, the reflected voltage may be significantly attenuated, resulting in a lower SWR reading.

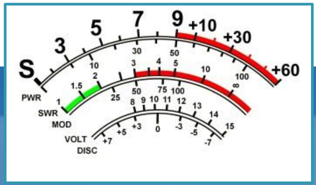
→ High transmission line loss makes your antenna system seem better

→ Move the meter closer to the antenna



Some comments on SWR measurements

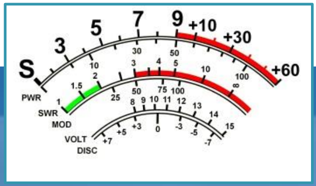
- SWR meters measure the match at the point of insertion.
- When measuring/adjusting an antenna, put the SWR meter as close to the antenna as possible.
- Make sure the SWR meter is spec'd for the frequency of interest.
- Long, lossy coax makes the SWR look better.
- How low should the SWR be? Depends on the situation...what can be reasonably expected? It might be OK to run high SWR.



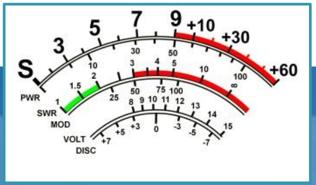
SWR Myths

- SWR does not indicate whether your antenna is resonant
- SWR does not measure the efficiency of your antenna
- SWR does not indicate how well your signal is being radiated

An SWR measurement just tells you the impedance match at the point the meter is inserted into the transmission line



Antenna Analyzers

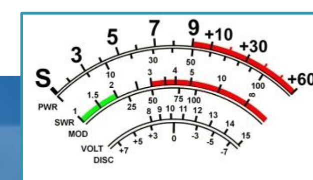


MFJ-259B Antenna Analyzer

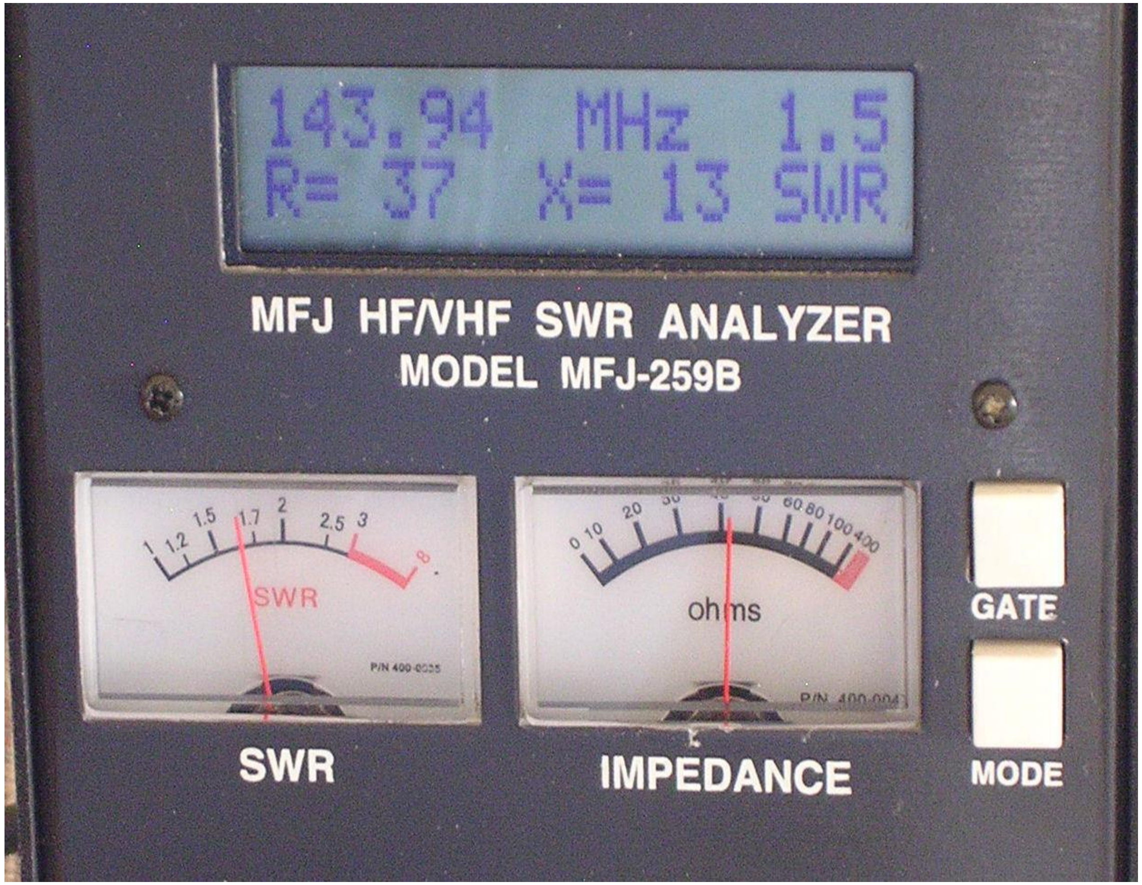
Frequency Range: 1.8 – 170 MHz
Price: ~$250
Measure:
SWR, Return Loss
Impedance, Reactance, Resistance

Default measurement mode is:
- Impedance, $Z = R + j X$
  (R= resistance, X = reactance)
- SWR

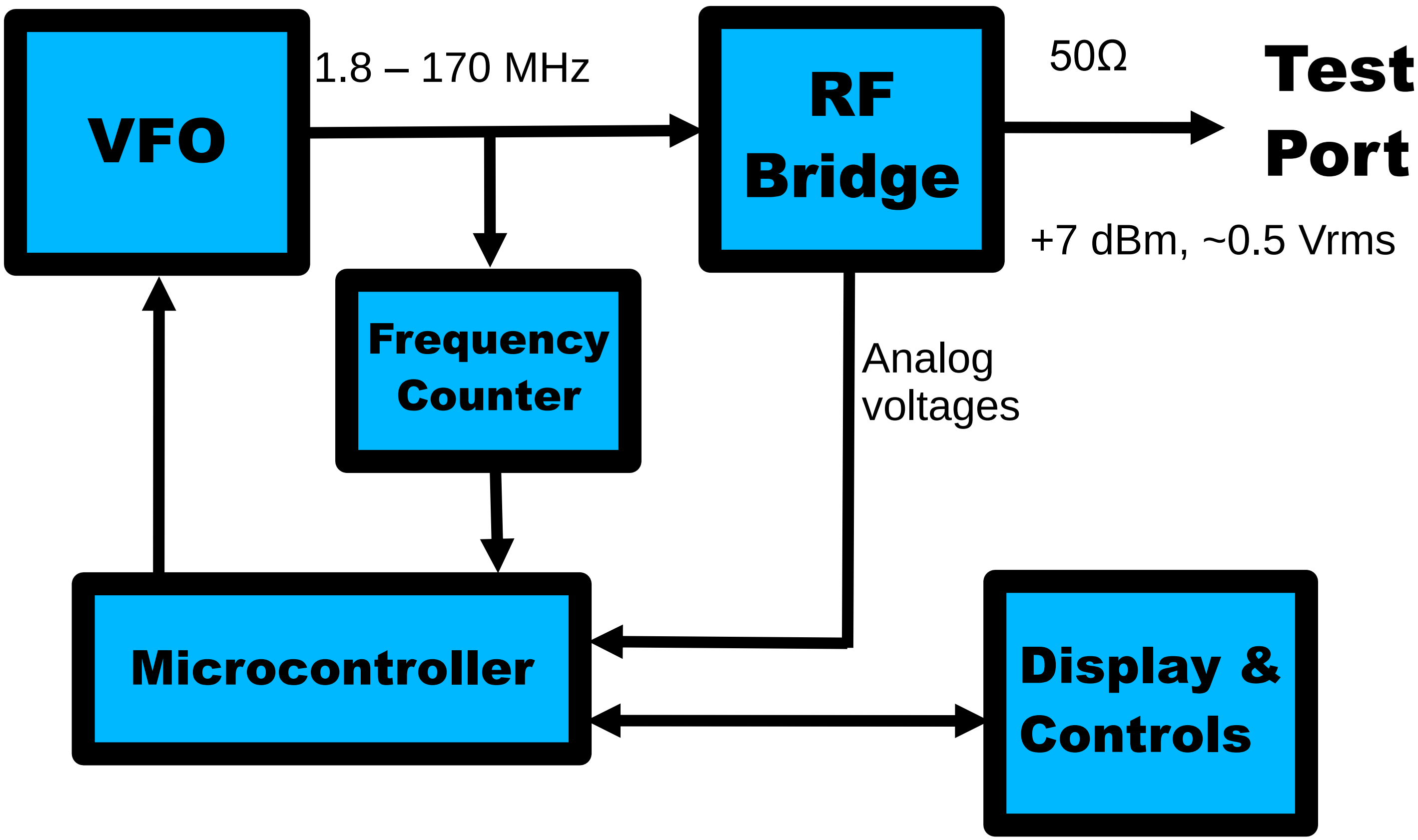
Also:
Impedance, $Z = Z_{mag} \angle\theta$
Reflection coefficient
Return Loss

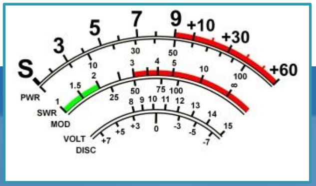


MFJ-259B Antenna Analyzer



MFJ-259B Block Diagram

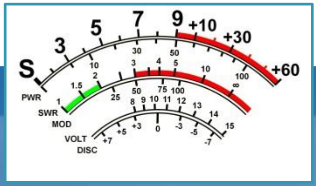




MFJ-259B Antenna Analyzer

Usage Tips

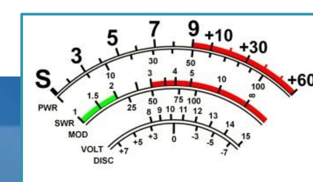
- Best accuracy near 50 ohms (SWR=1)
- Don't use in high RF environment
- Input circuitry is sensitive
- Discharge antennas before connecting
- Do not apply external voltages to test port
- Don't over-interpret the results (the analyzer is just looking at the impedance match against 50Ω)



Comet CAA-500 Antenna Analyzer

Frequency Range: 1.8 to 500 MHz

Price: ~$430



Rig Expert AA-230 Antenna Analyzer

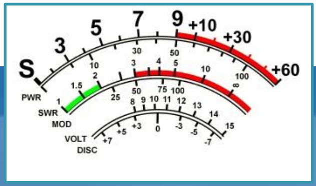
Measure SWR, Return Loss, Cable Loss

100 kHz to 230 MHz.

Graphical display plots SWR versus frequency

Time Domain Reflectometer mode can be used to locate the precise location of a fault within the feedline system.

~$550



Summary

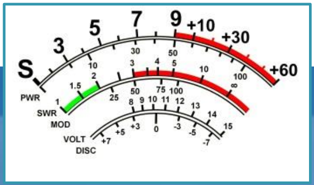
Basic Test Equipment for Ham Use

- Digital Multimeter
- SWR Meter
- Antenna Analyzer

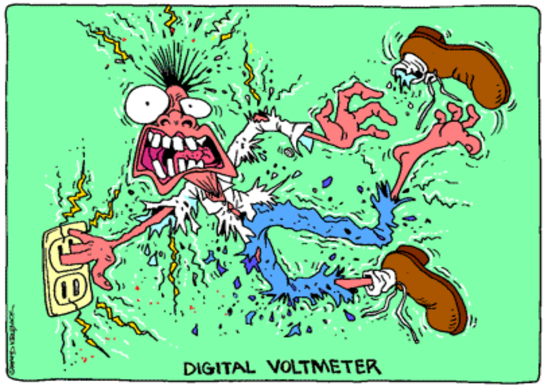
Safety First

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

This presentation is available for download at k0nr.com



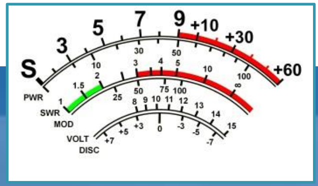

FWD (W)
REF (W)
SWR
ALL TIME MULTI MEDIA MONITOR
30W
60W
200W
AVG
PEP
140 ~ 525MHz
CMX-400
C★MET


DIGITAL VOLTMETER

Questions


Agilent U1273A
3.0000
True RMS OLED Multimeter


INNOVA 3320
AUTO
mV
DC
-35.7
OFF


S 3 5 7 9 +10 +30 +60
PWR
SWR
MOD
VOLT
DISC