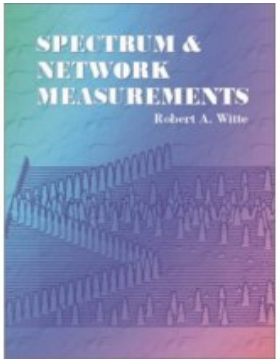
Electronic Test Equipment
for amateur radio use

Bob Witte KØNR
Technical Coordinator
ARRL Colorado Section

Electrical Engineer



Author of
Electronic Test Instruments
and
Spectrum and Network Measurements

Electronic Test Equipment

- The Multimeter
- The SWR Meter
- The Antenna Analyzer

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

The Multimeter

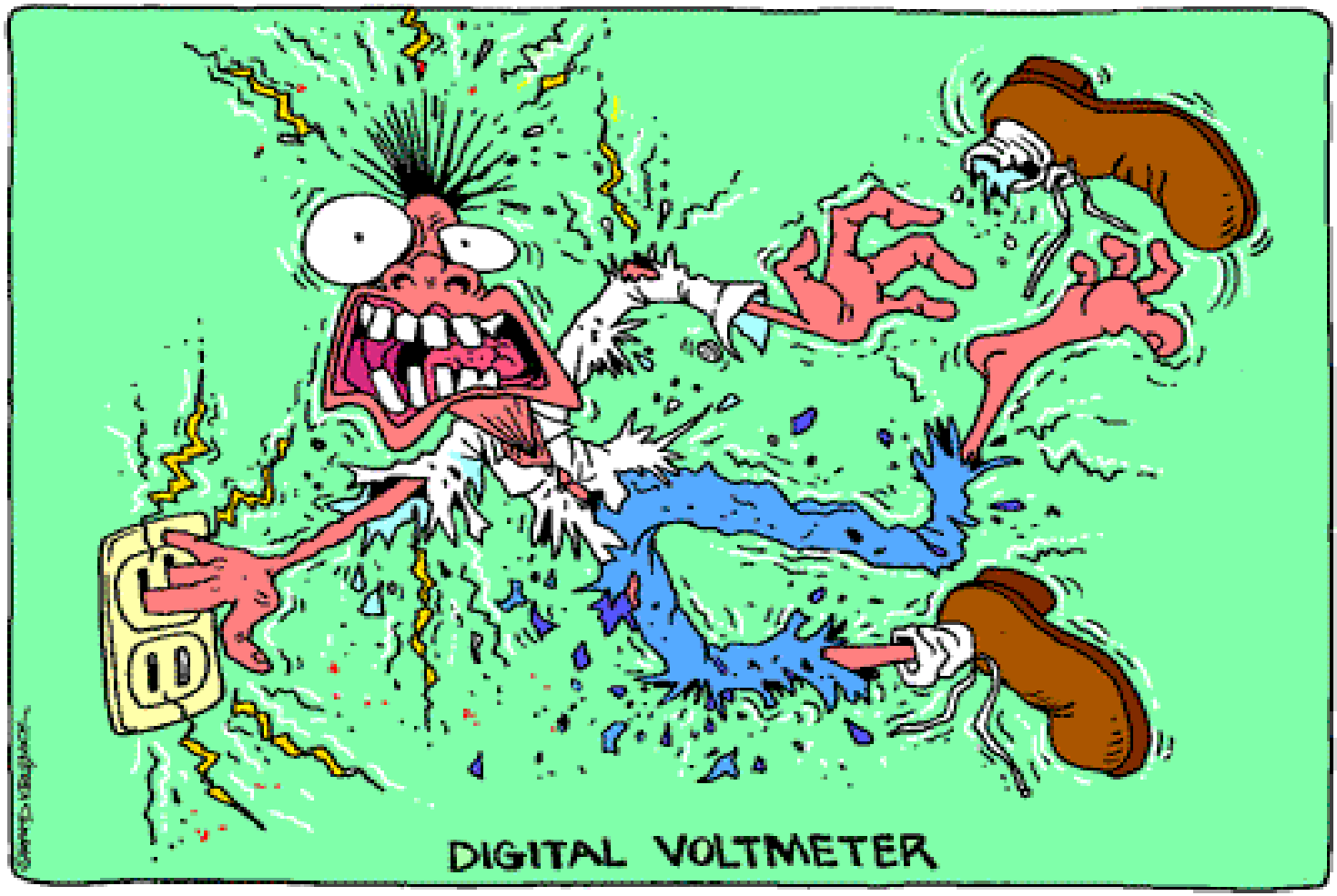
- Also known as voltmeter, VOM (Volt-Ohm-mA meter),DVM (Digital Voltmeter), or DMM (Digital Multimeter)
- Voltmeter, ammeter and ohmmeter combined into one instrument
- DC and AC measurements
- Some models have diode test, continuity, capacitance, inductance, frequency, temperature
- Bench or handheld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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Lots of Meters Out There

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

A Typical Low Cost DMM

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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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.

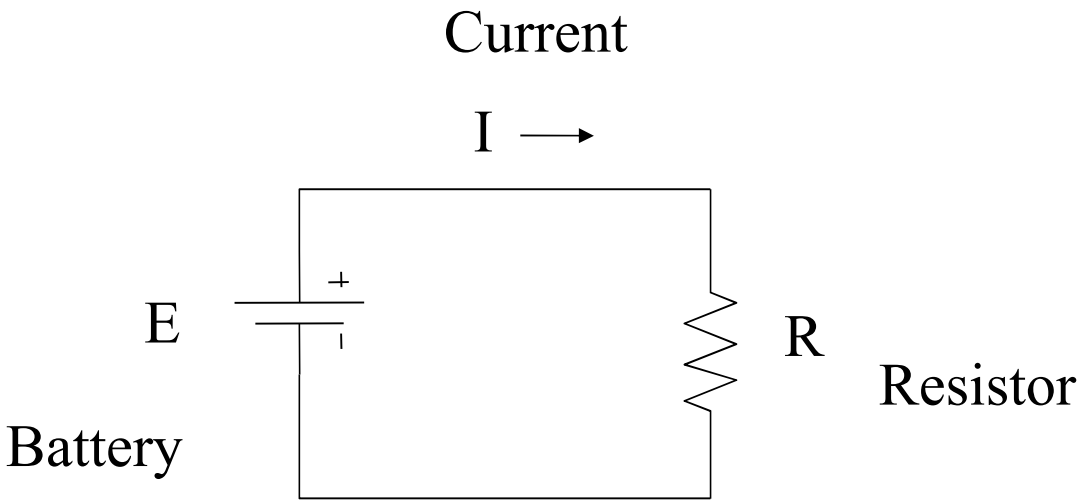
Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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 TNC cable you just soldered.

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Circuit with Battery and Resistor



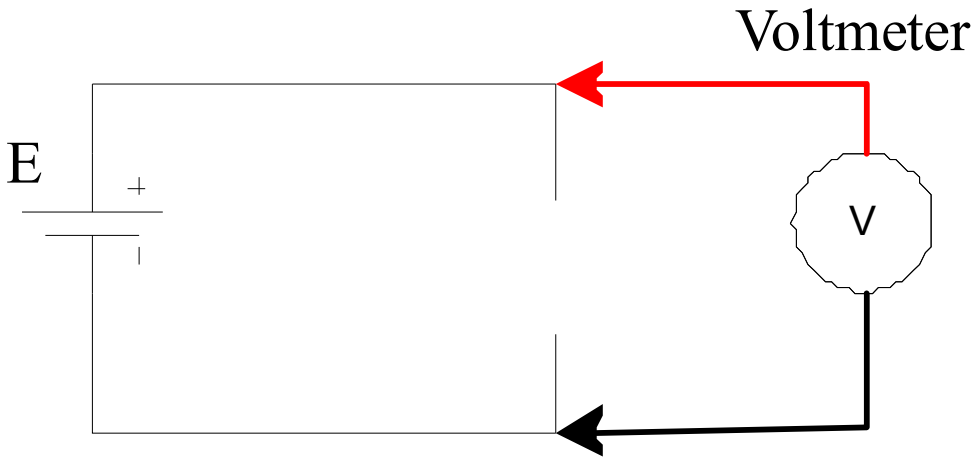
Ohm's Law: I=E/R

Note: Positive current convention used

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Voltage Measurement

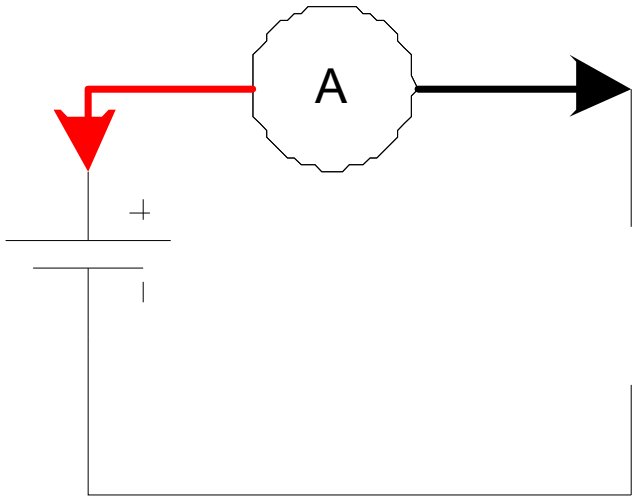
- Configure DMM to DC voltage
- DMM appears as “open circuit”
- Connect DMM in parallel with voltage to be measured



Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Current Measurement

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



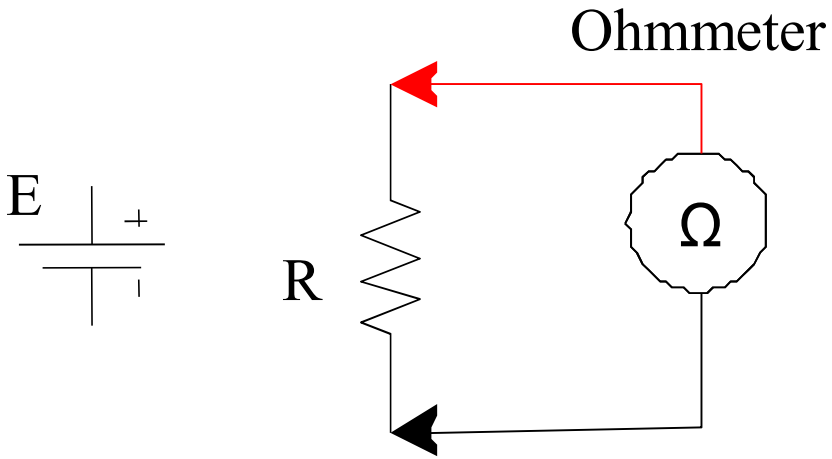
- *Don't select current mode by mistake*
- *Be very careful how you connect when in current mode*
- *Short circuits can cause big problems!*

Be Careful !!!!!!

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

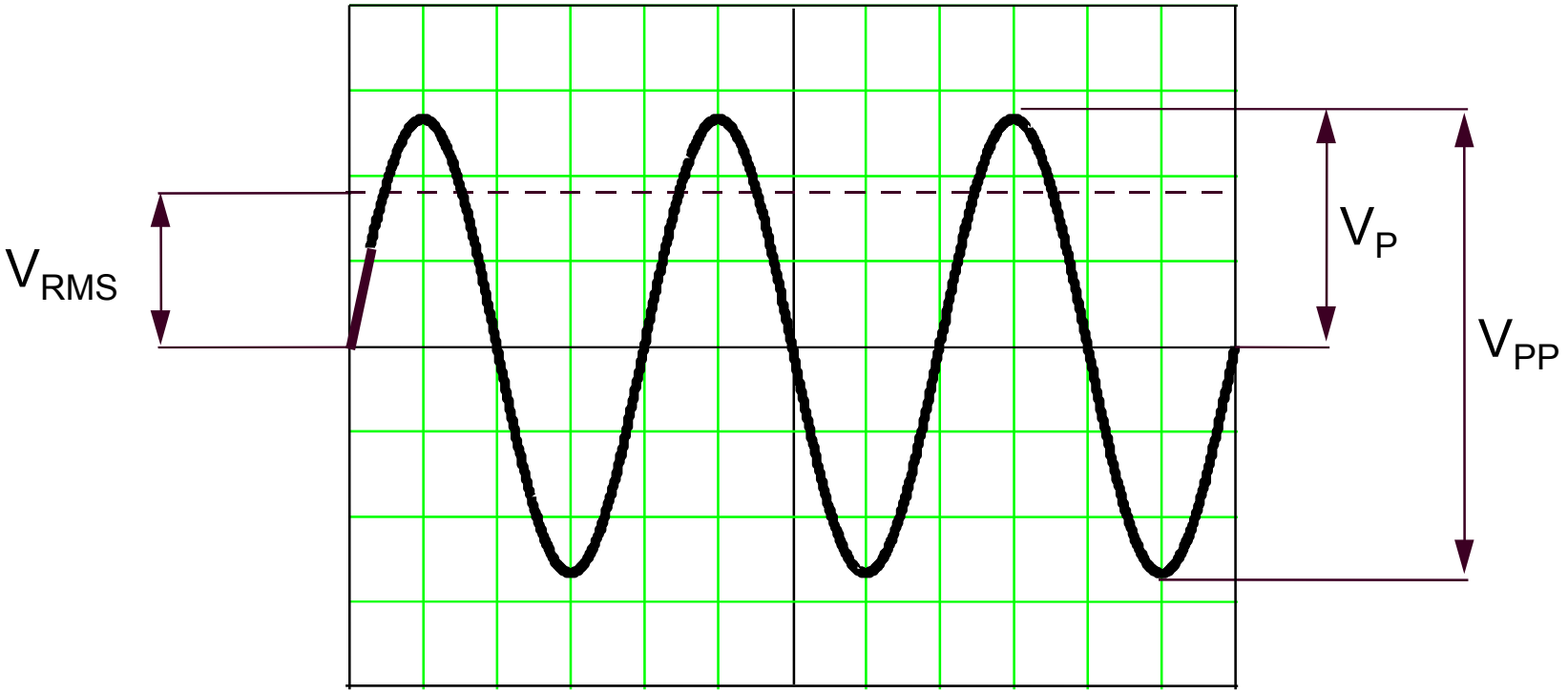
Resistance Measurement

- 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



Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Sine Wave Voltage Measurements



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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Some Superfluous Math Equations

General Equations

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

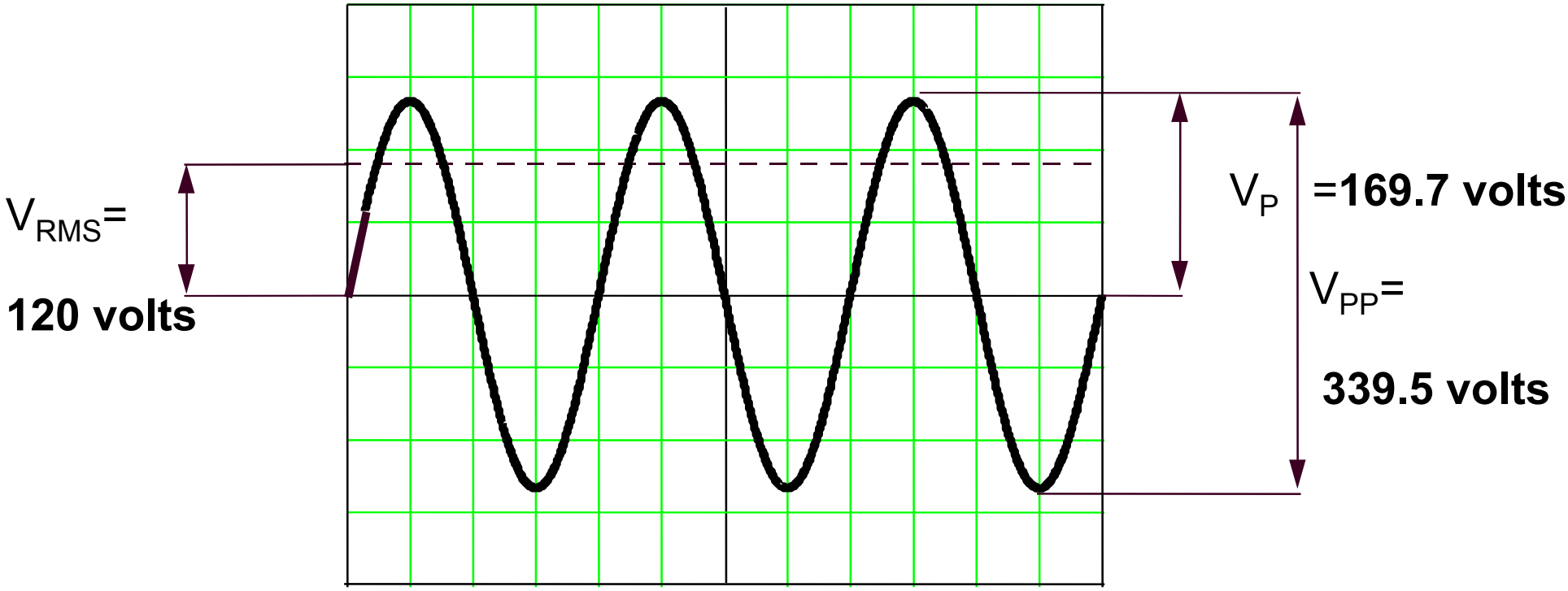
For Sine Wave

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

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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Example: AC Line Voltage



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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

RMS Voltage Measurements

- All DMMs read out in RMS Voltage
- "True RMS" meters read the RMS voltage of all types of waveforms
- Low-cost DMMs are *Average Reading (*not "true RMS") but show RMS voltage accurately for sine waves (only)
- For most ham radio / hobbyist applications, *Average Reading* is just fine.

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

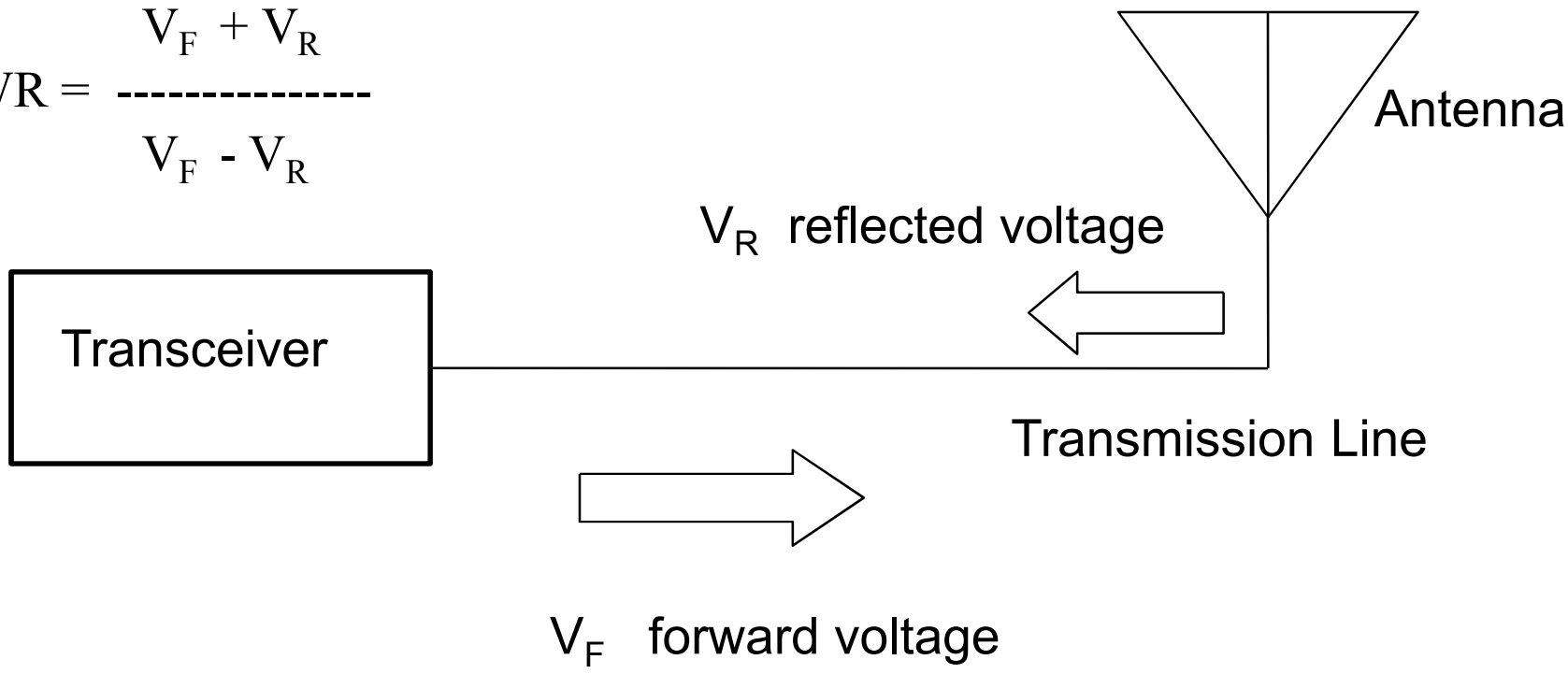
The SWR Meter

- SWR = *Standing Wave Ratio,* more properly called *Voltage Standing Wave Ratio (VSWR)*
- SWR Meter is also called a *Reflectometer*
- Measures the match between source (transmitter) and load (antenna).
- Perfect match is SWR = 1.0
- SWR is always $\geq$ 1.0

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

SWR Measurement

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

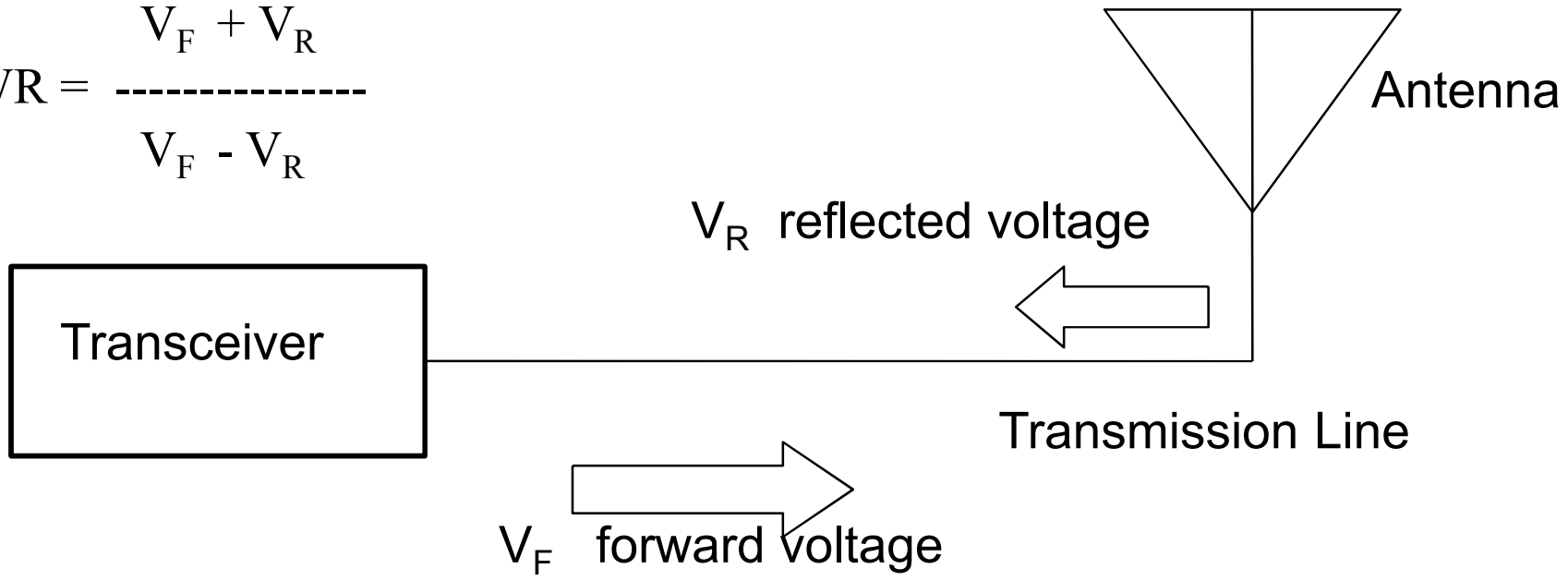


Transceiver, transmission line and antenna are all nominally the same impedance (50 ohms for amateur radio work).

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

SWR Measurement

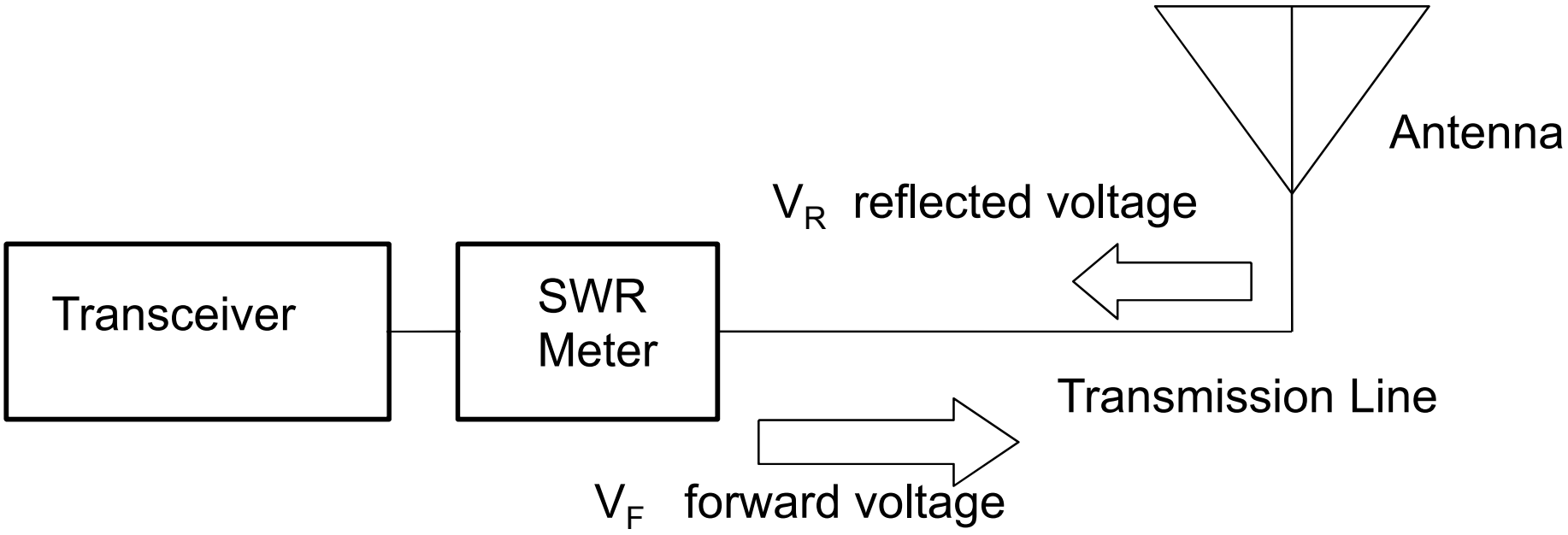
$$SWR = \frac{V_F + V_R}{V_F - V_R}$$



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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

SWR Measurement



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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

SWR Meters

MFJ SWR Meter

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

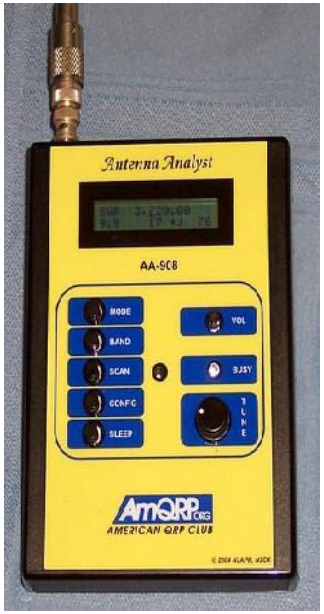
Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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 make 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.

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Antenna Analyzers



Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

MFJ-259B Antenna Analyzer

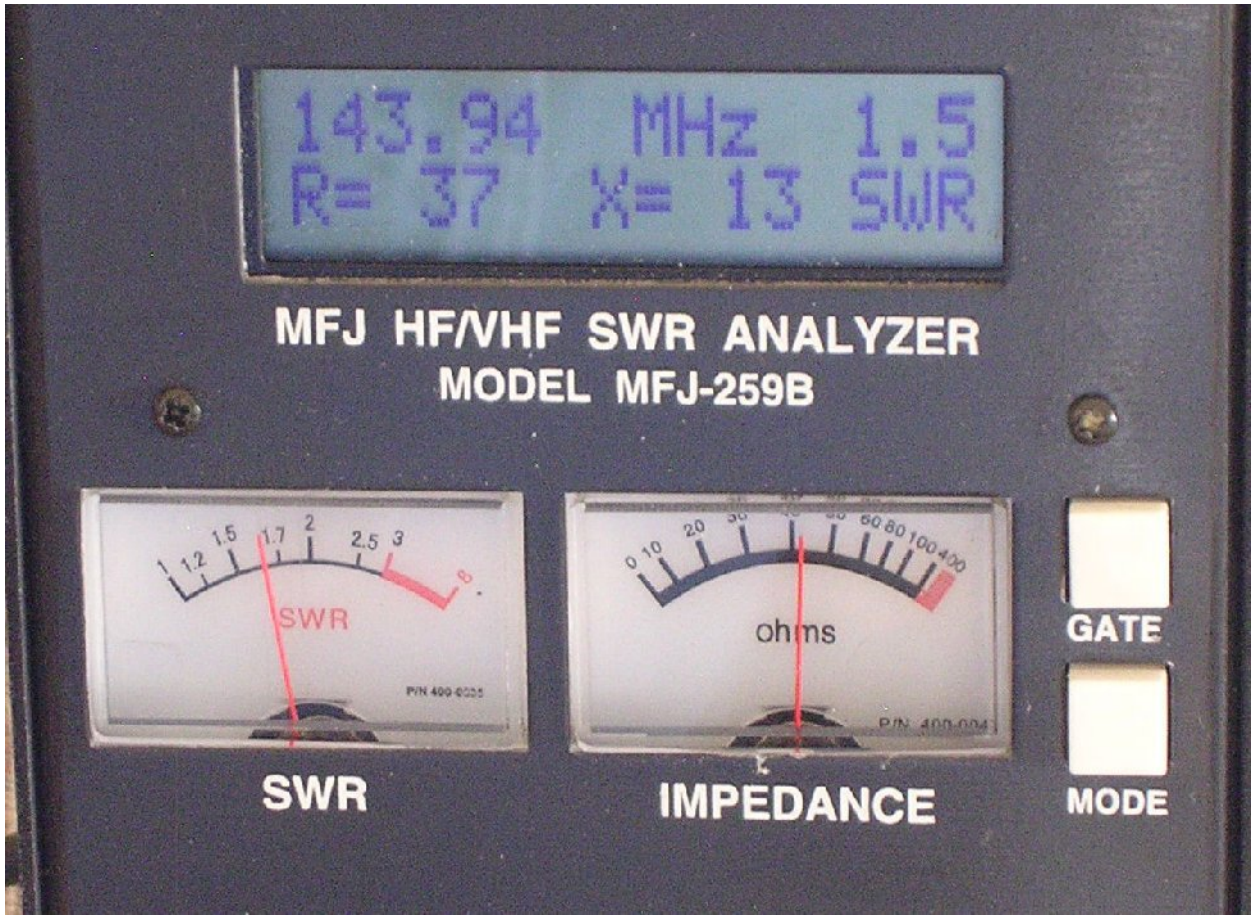
- Frequency Range: 1.8 – 170 MHz
- Price: ~$250
- Measure:
  SWR, Return Loss
  Impedance, Reactance, Resistance

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

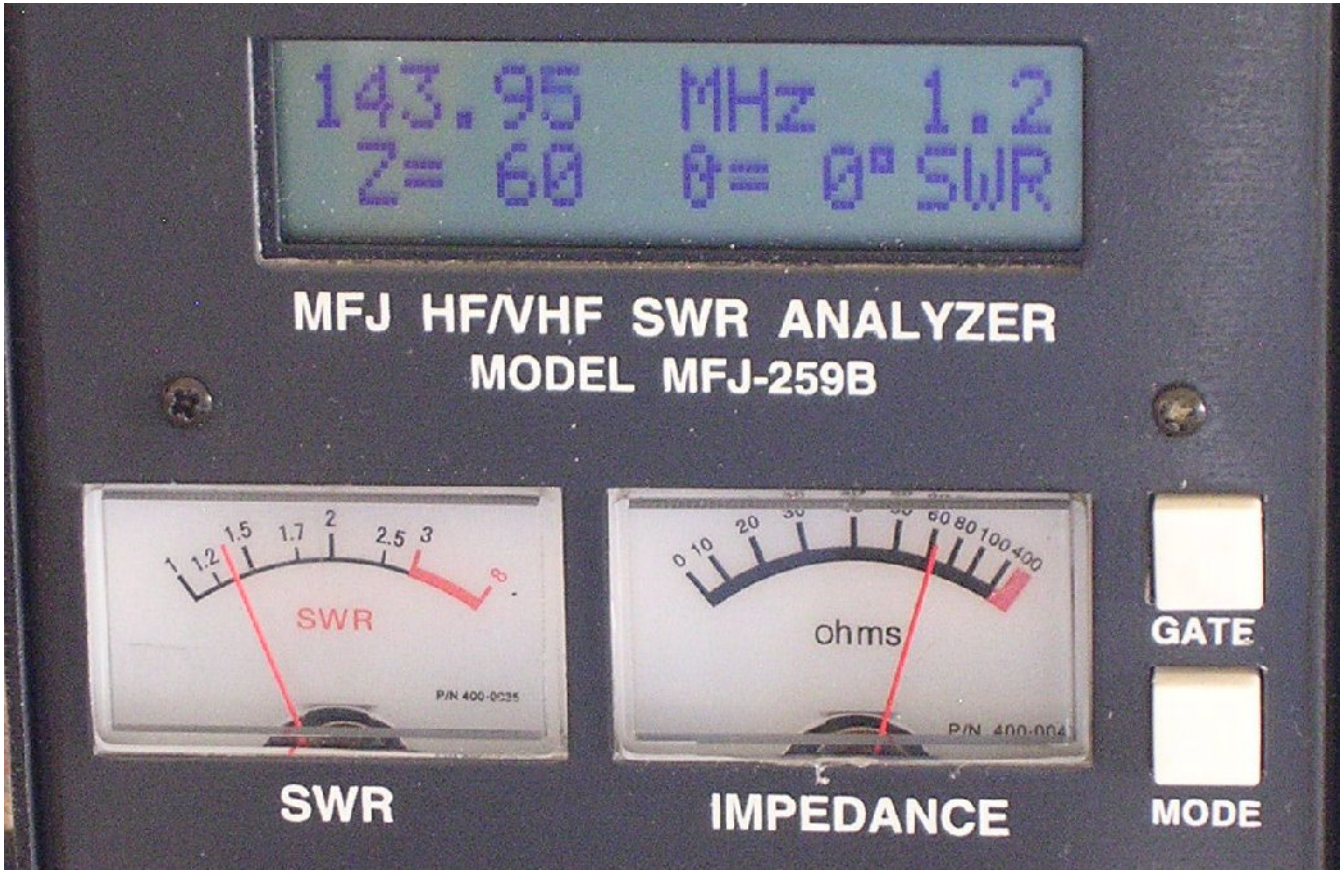
Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

MFJ-259B Antenna Analyzer



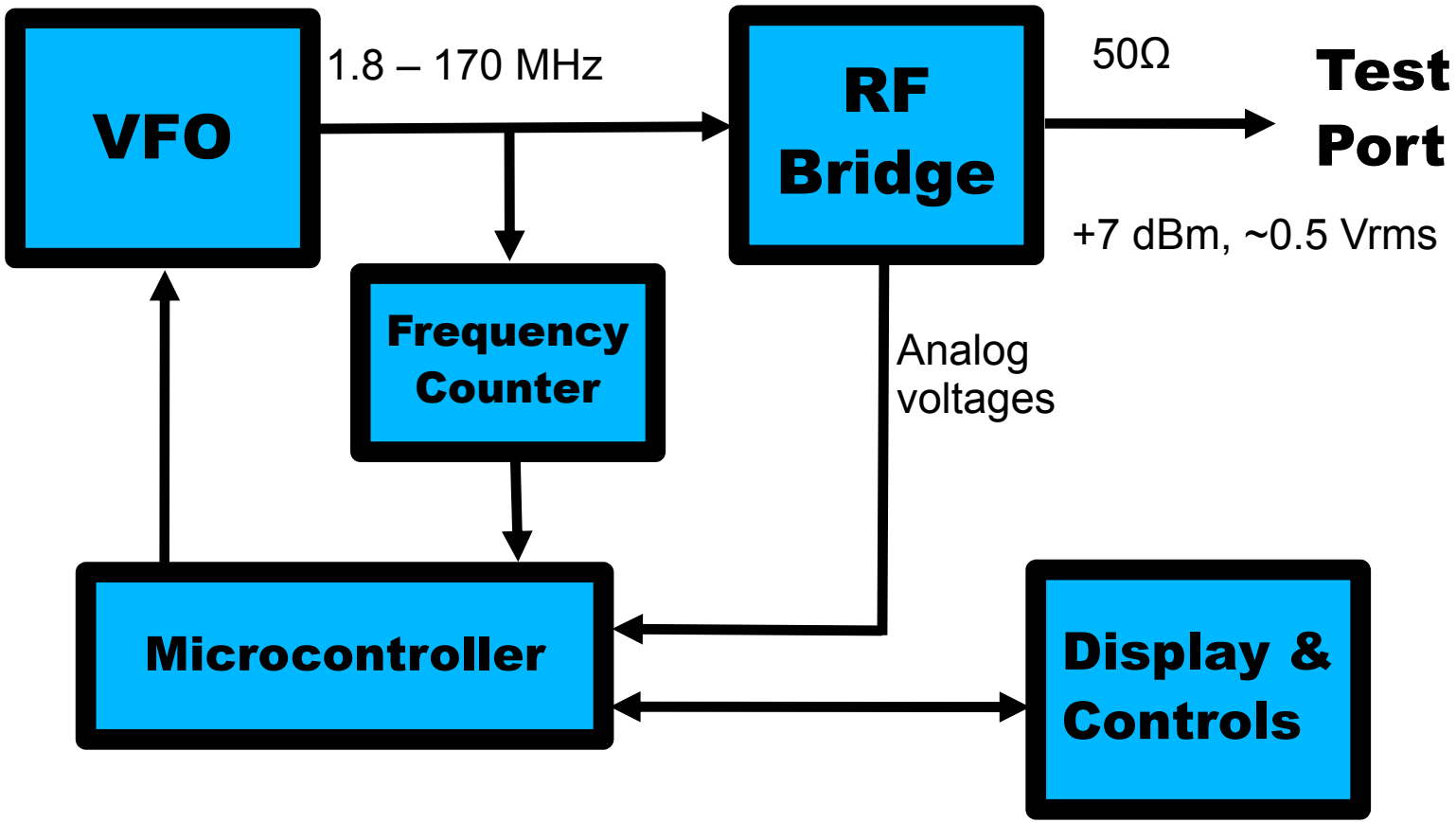
Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

MFJ-259B Antenna Analyzer



Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

MFJ-259B Block Diagram



Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

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)

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com

Summary

- **Basic Test Equipment for Ham Use**
  - Digital Multimeter
  - SWR Meter
  - Antenna Analyzer
- **Safety First**

  Always be careful with electrical measurements (especially high voltage)

Bob Witte KØNR
Technical Coordinator, Colorado Section
bob@k0nr.com