MFJ 259
Operation & Simplified Calibration

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NA0TC 2014 TechFest

What Will Be Covered

- **Part 1: Operation**
  - What is an MFJ 259
  - What Does It Measure
  - Impedance & Admittance
  - How Does It Work
  - How To Interpret The Measurement Results

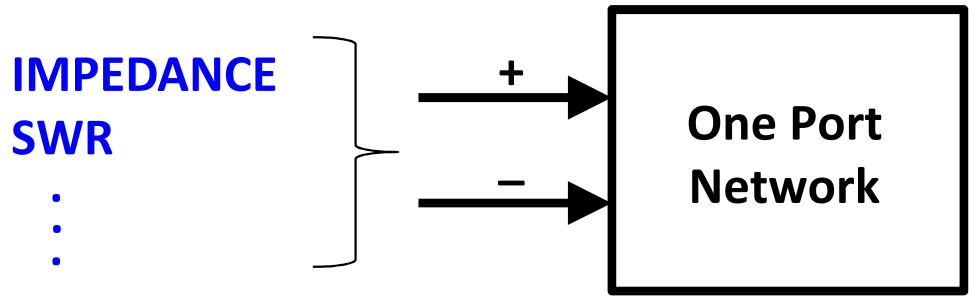
- **Part 2: Calibration**
  - Simplified Calibration Instructions:
    - MFJ 259 (out of production)
    - MFJ 259B (out of production?)
    - MFJ 259C **may, or may not** have the same CAL procedure as the 259B

- **Part 3: Testing (after presentation)**
  - Power out, harmonic levels, calibration & frequency stability
  - Calibration as time permits

Part1: Operation

What Is An MFJ 259?

- MFJ lists the MFJ 259 as a **"HF/VHF SWR Analyzer"**
- AKA: **"ONE PORT VECTOR NETWORK ANALYZER (VNA)"**
  - Measures the electrical parameters of one port of a network
    - Won't measure transmission parameters of a 2 port network
  - Network = Electrical Circuit
  - A port is one complete signal path
  - "Vector" = measures both magnitude and phase



What Does The MFJ 259 Measure?

- **Analog Meters:**
  - Standing Wave Ratio (SWR)
  - Resistance (259) or Impedance (259B/C)
- **Digital Display:**
  - **MFJ 259:** Frequency
  - **MFJ 259B/C:**
    - **Main Modes:**
      - Impedance (resistance & reactance)
        - Impedance of a transmission line
      - Capacitance
      - Inductance
      - Frequency
    - **Advanced Modes:**
      - Impedance (magnitude & phase)
      - Return loss & reflection coefficient
      - Distance to Fault (on transmission line)
        - Velocity Factor of a transmission line
      - Resonance
      - Percentage Transmitted Power

MFJ 259B

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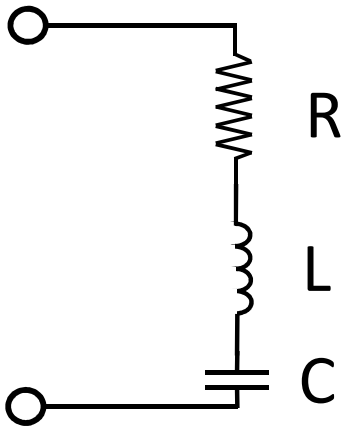
Focus of this presentation

Impedance

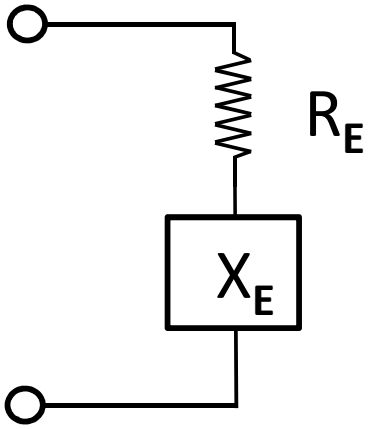
- "The total opposition to **alternating** current by an electric circuit"
  - Impedance = **Z = Resistance + Reactance = R + jX**
  - Measured in **OHMS**
  - Z is a **COMPLEX** number!
    - For most ham applications => ignore the j term
- Equivalent Impedance Circuit:

Physical Circuit



=>

Equivalent Impedance Circuit



$Z_E = R_E + jX_E$

If L & C are lossless: $R_E = R$

X_E = NET reactance = ?

To Calculate the Value of X_E

- To calculate X_E, must specify the **frequency (F)**

$$\mathbf{X_E} = j2\pi FL + 1/(j2\pi FC) = \mathbf{j2\pi FL - j[1/(2\pi FC)]}$$

  - At any specified frequency, if X_E is not zero, it is **EITHER**
    - **Inductive Reactance = $2\pi FL$,**

      OR
    - **Capacitive Reactance = $-1/(2\pi FC)$**

MFJ 259 Analog Meters

- Two Analog Meters:
  - First meter: **SWR**
  - Second meter:
    - MFJ 259: **Resistance**
      - Instruction Manual:
        "Resistance reading is accurate only if reactance equals zero."??
    - MFJ 259B/C: **Impedance**
      - **"Impedance" meter displays Z as <u>one</u> number**
      - "Impedance" is complex number composed of **<u>two</u>** numbers??
- What does the second meter measure?

Magnitude of Impedance

- Using the rules for COMPLEX mathematics:

Magnitude of a complex number Z $= |Z| = \sqrt{R^2 + X^2}$

Example:

If $R_E = 50\ \Omega$ and $X_E = 50\ \Omega$, then,

$$\text{Magnitude of } Z = |Z| = \sqrt{50^2 + 50^2} = \mathbf{75}\ \Omega$$

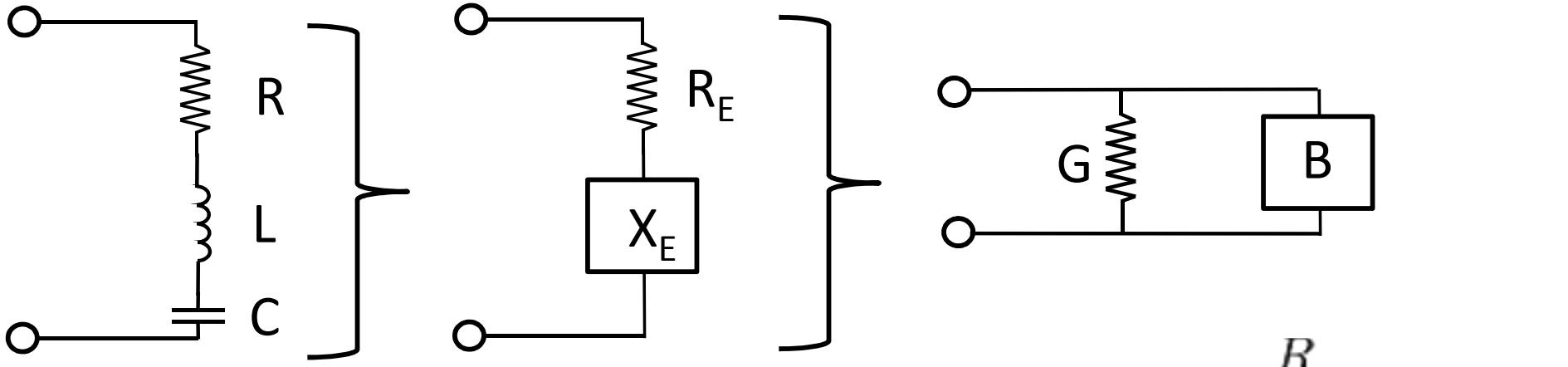
$$\neq 100\ \Omega$$

- The second analog meter displays:
  - 259B: Magnitude of the impedance
    - Reactance does not need to be zero
  - 259: ?

Admittance

- Admittance = **Y** = $\frac{\mathbf{1}}{\mathbf{Z}}$ = Conductance + Susceptance = **G + jB**
  - Measured in **SIEMENS**
    - 1 siemen = 1/(1 ohm) = 1 mho

Physical Circuit **Equivalent Impedance Circuit** **Equivalent Admittance Circuit**



$$G = \Re(Y) = \frac{R}{R^2 + X^2} \quad \textbf{mhos}$$

$$B = \Im(Y) = -\frac{X}{R^2 + X^2} \quad \textbf{mhos}$$

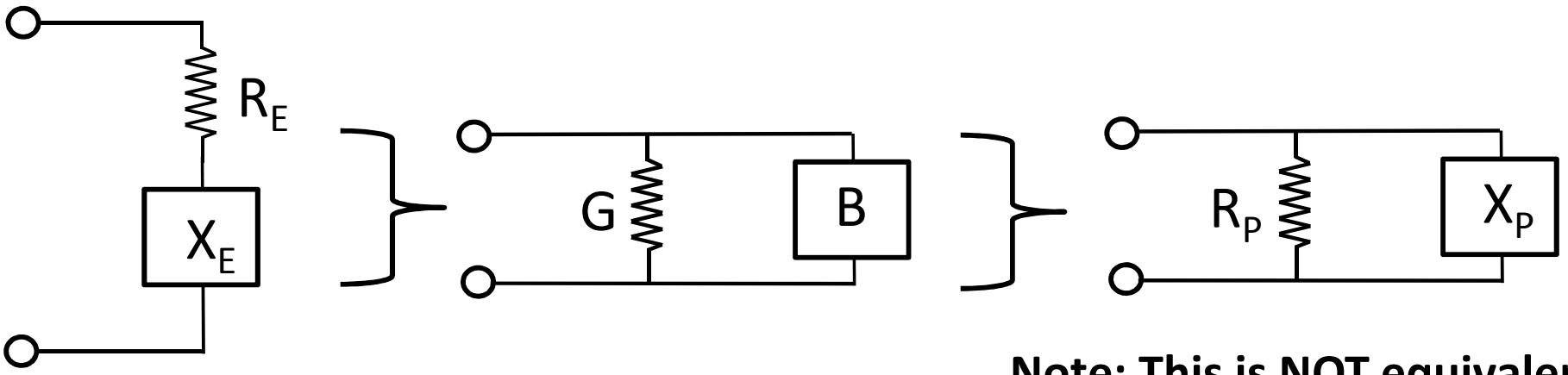
Note: Both G, & B are a function of frequency

Admittance

- To express G & B in ohms, simply invert R_P & X_P :

$R_P = 1/G$ **ohms**

$X_P = 1/B$ **ohms**



Note: This is <u>NOT</u> equivalent to an Impedance Circuit

$R_P \neq R_E$

$X_P \neq X_E$

Admittance

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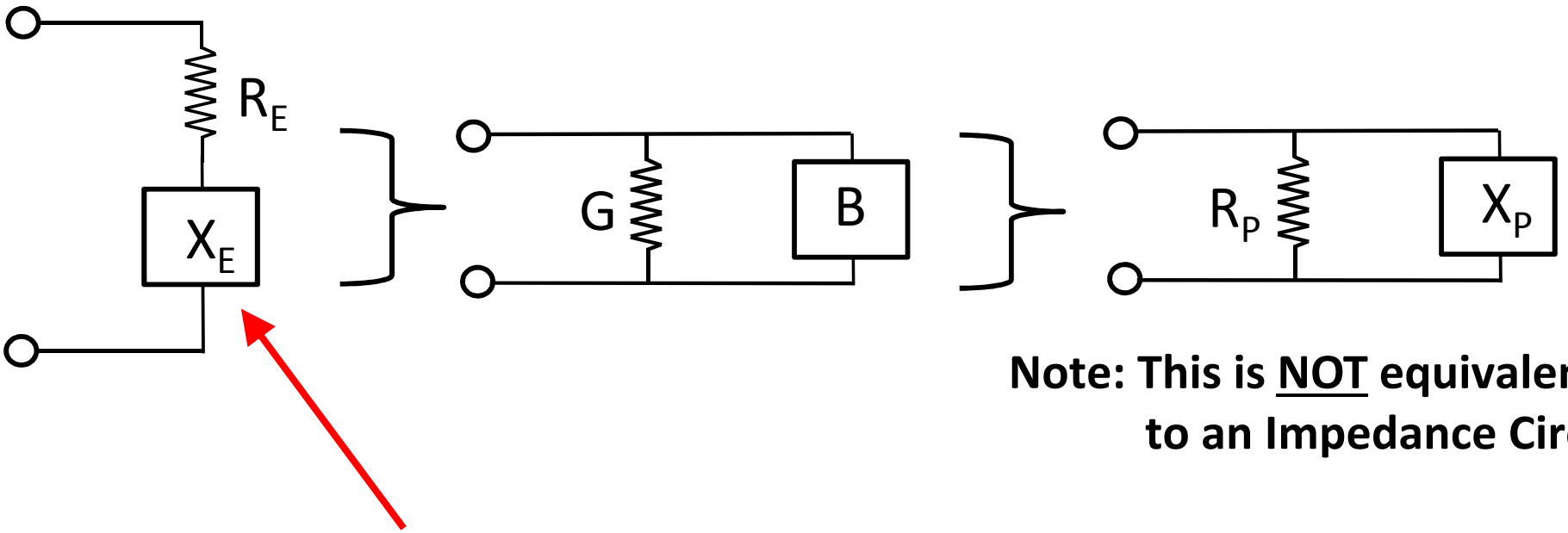


Note: This is <u>NOT</u> equivalent to an Impedance Circuit

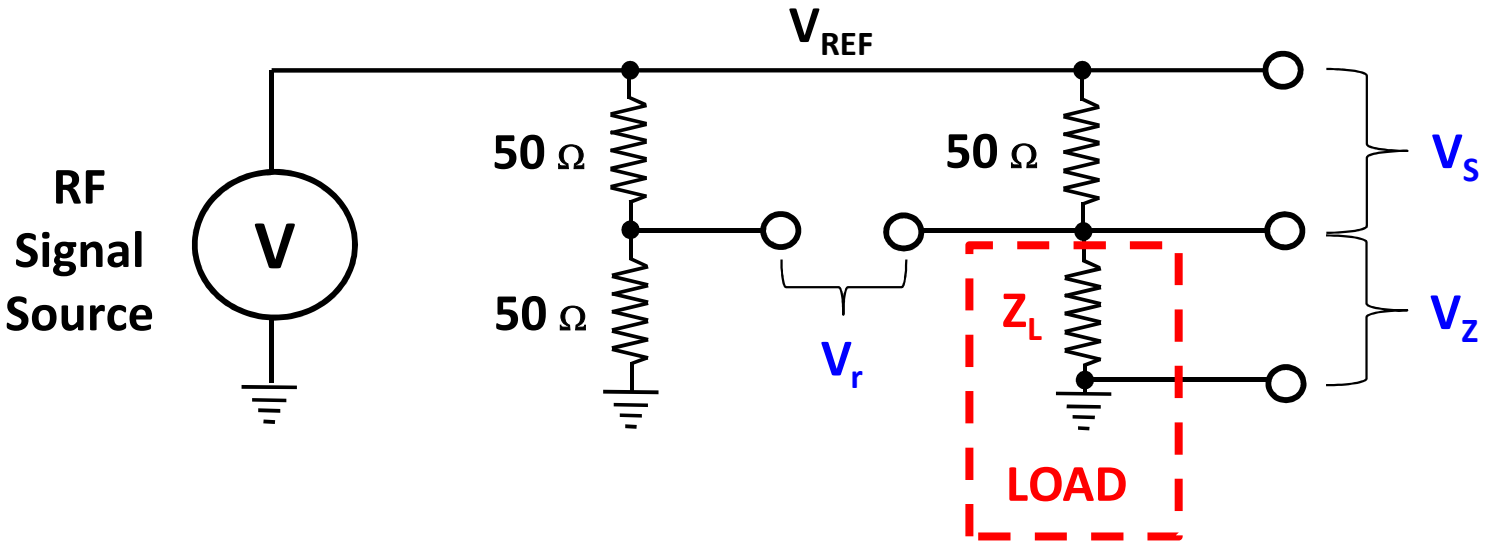
R_E & X_E are what is shown on the MFJ259B digital display

$R_P \neq R_E$

$X_P \neq X_E$

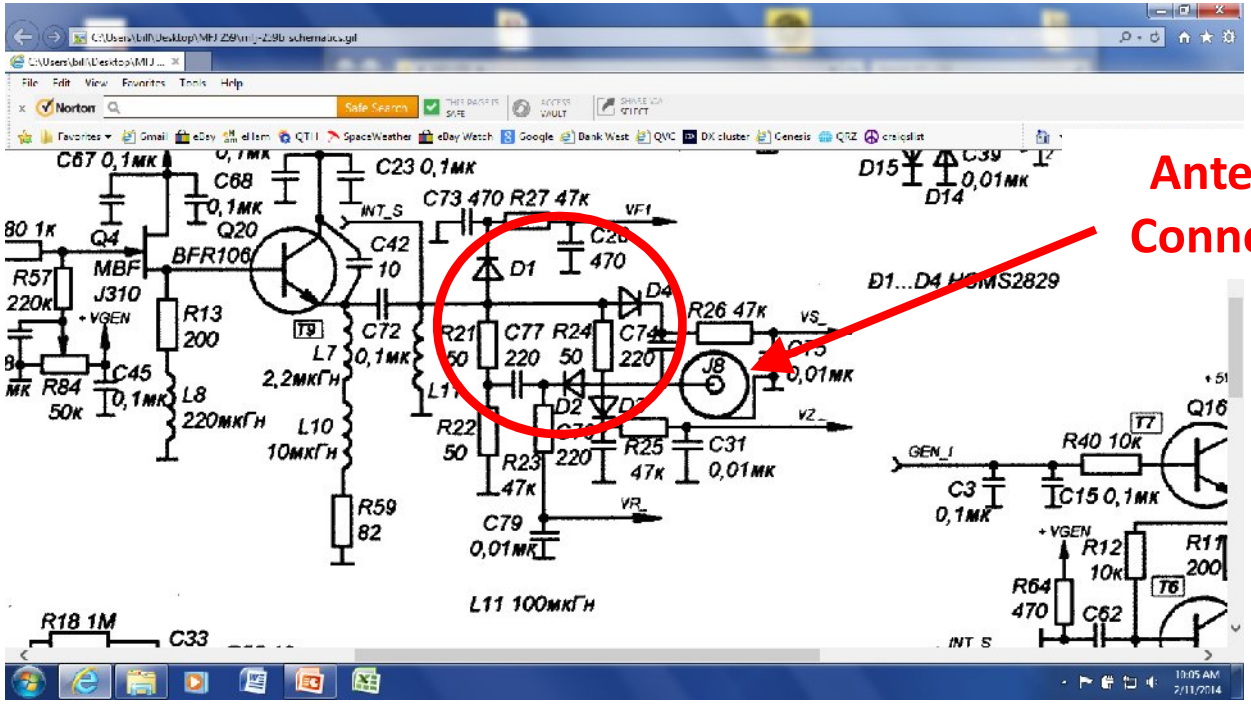
How Does The MFJ 259 Measure Impedance

- Uses a conventional **BRIDGE NETWORK** to compare forward & reflected **RF** signals
  - Generates an RF signal
  - Three **RF** voltages are rectified to generate three **DC** outputs
    - V_Z is the voltage across the load
    - V_r is the voltage indicating bridge balance
    - V_S is the voltage across a series 50Ω resistor between the RF source and the load



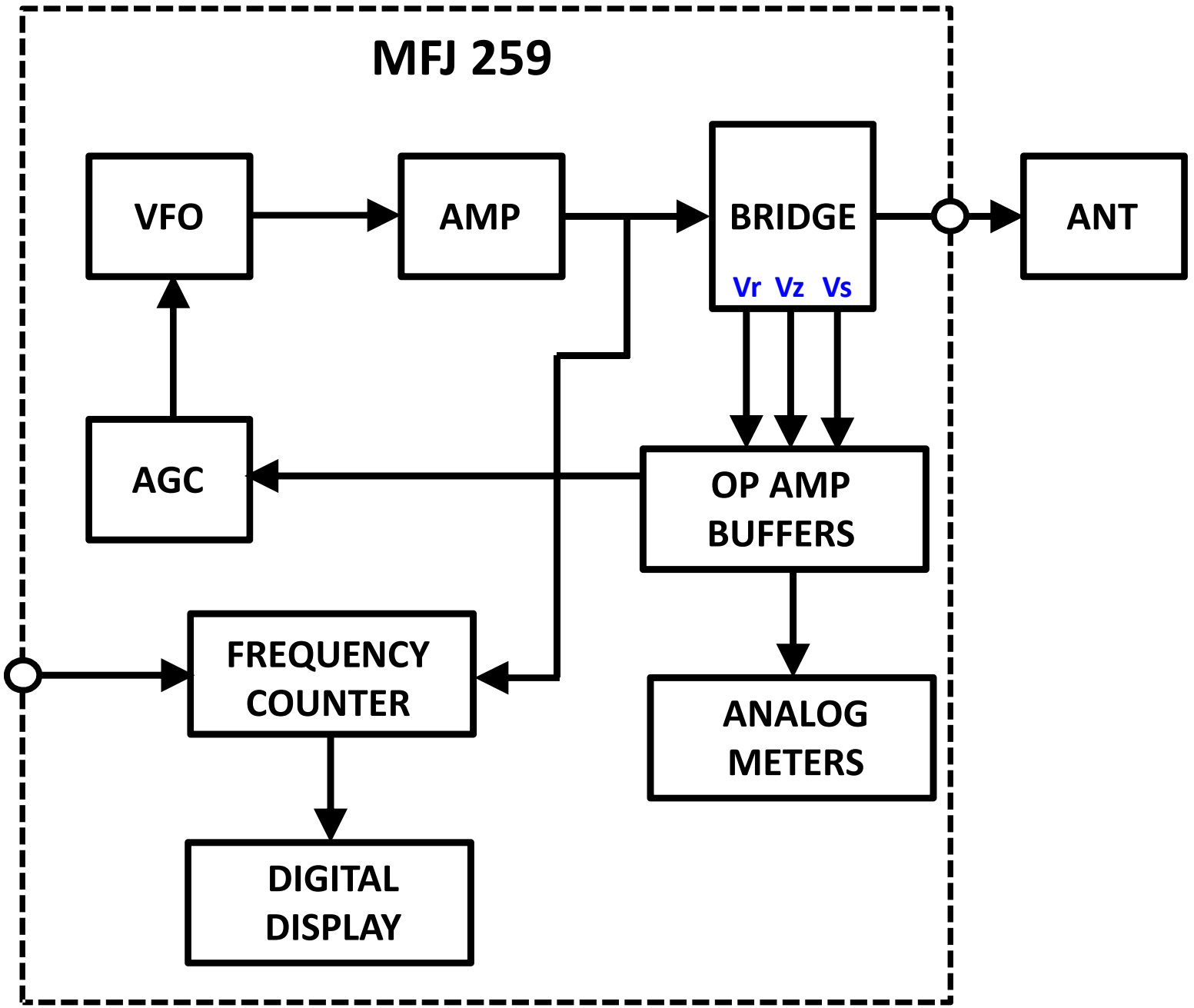
Caution Notes

- Four diodes are used to convert RF voltages to DC voltages



- **Easily burned out** (even when powered OFF)
  - **DC voltage** above **3 volts**
    - **Electrostatic Discharge (ESD):**
      - **Discharge antennas** before connecting to analyzer
      - **Never touch antenna jack** with your hand
  - **RF levels** above ? (not specified)
- Wideband => Strong external signals can cause **erroneous readings**
  - MFJ-731 Tunable Analyzer Filter $100 (for use in HF bands)

Original MFJ 259



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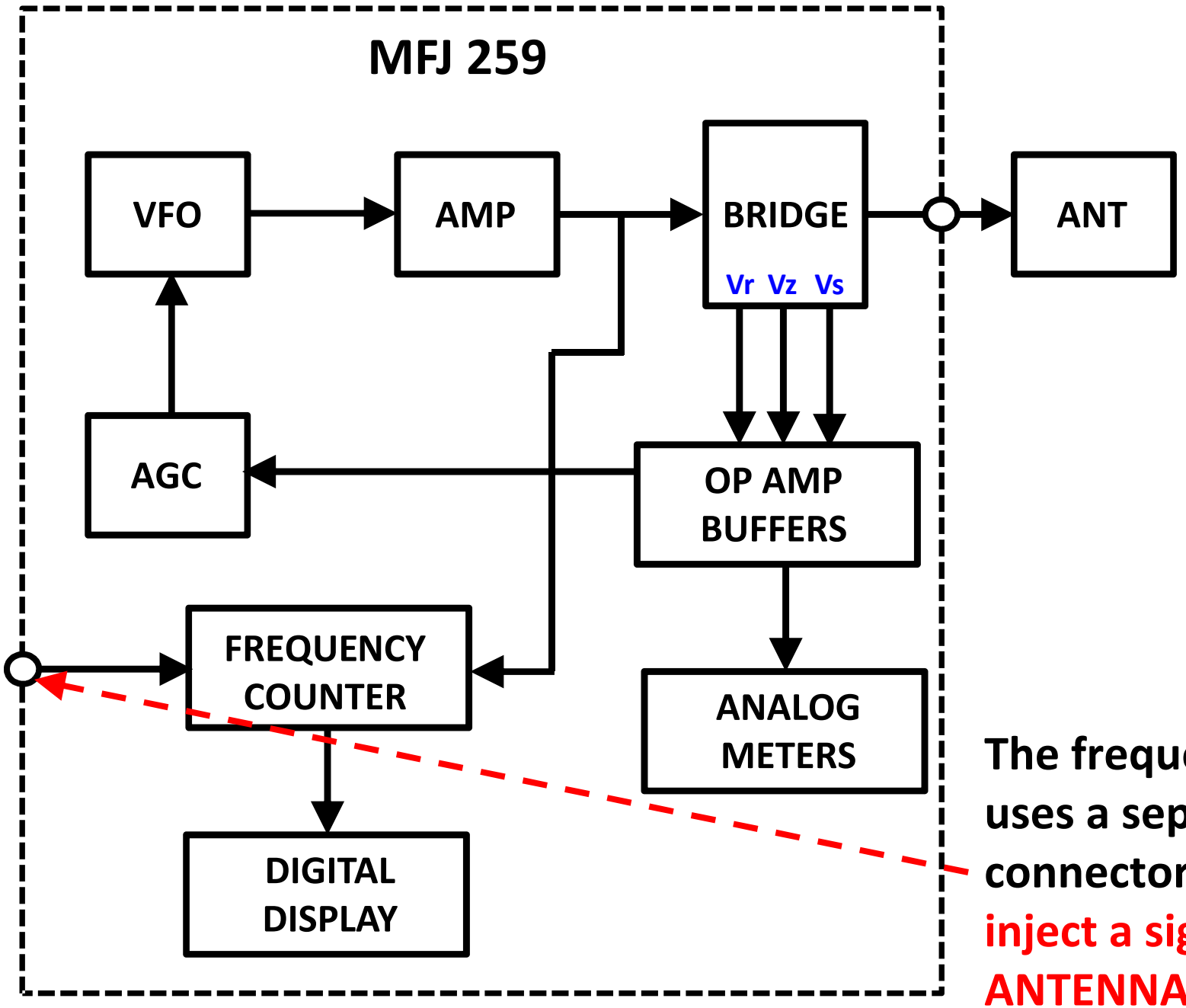
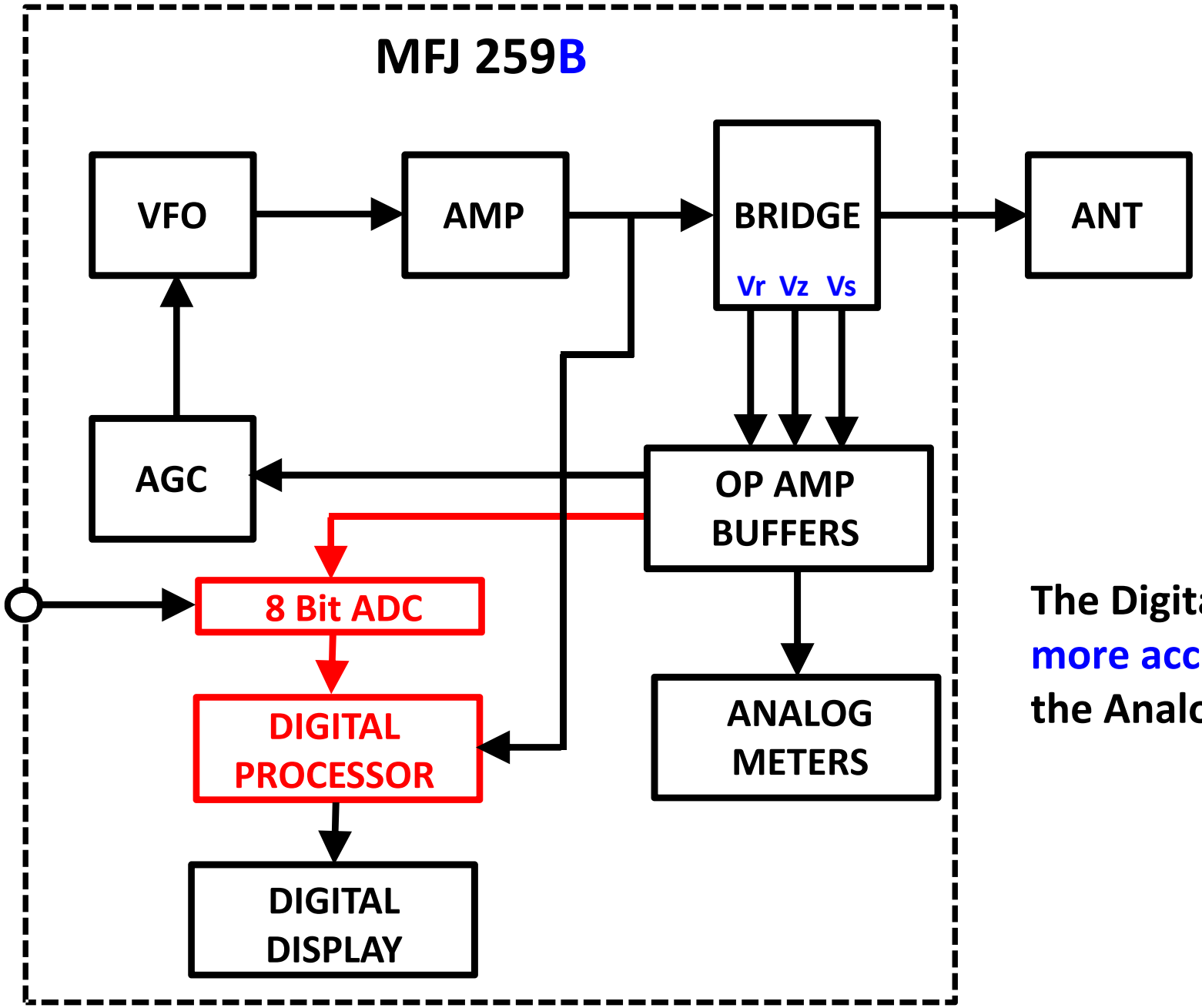


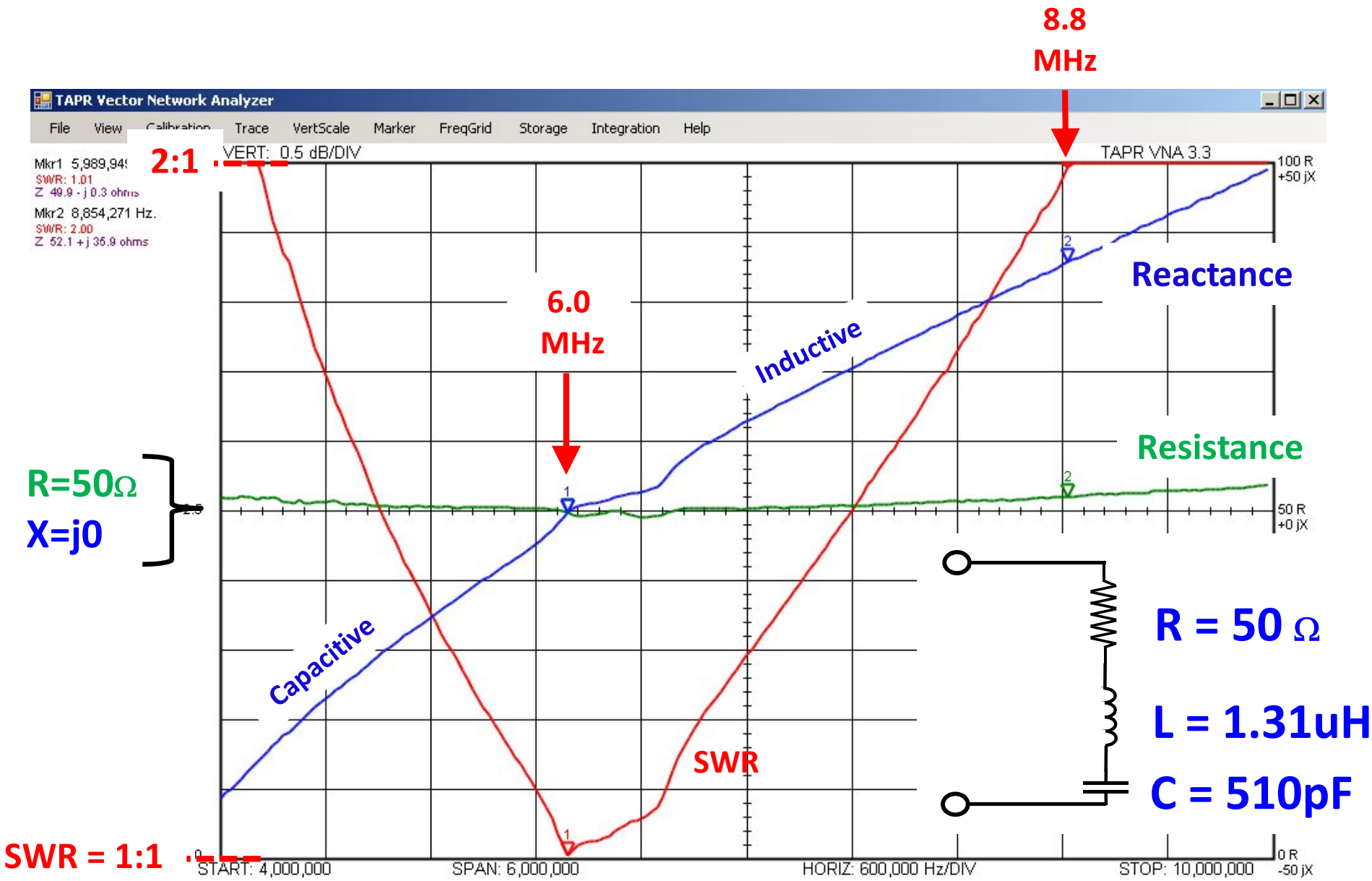
The frequency counter uses a separate (BNC) connector! Never inject a signal into the ANTENNA port!

MFJ 259B/C



The Digital Display is more accurate than the Analog meters

Example 1 – 40M Dipole



What Does The MFJ 259B Measure?

F (SWR=1:1) = 6.0 MHz:

Expected values:

$X = j2\pi FL + 1/(j2\pi FC) = j49.4 + 1/(j19.2x10\text{-}3) = j49.4 - j52.0 \cong \mathbf{j0}$

$Z = R + jX = 50 + j0 = \mathbf{50}\ \Omega$

Magnitude of $Z = |\mathbf{Z}| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 0^2} = \mathbf{50}\ \Omega$

What Does The MFJ 259B Measure? (continued)

F (SWR=1:1) = 6.0 MHz:

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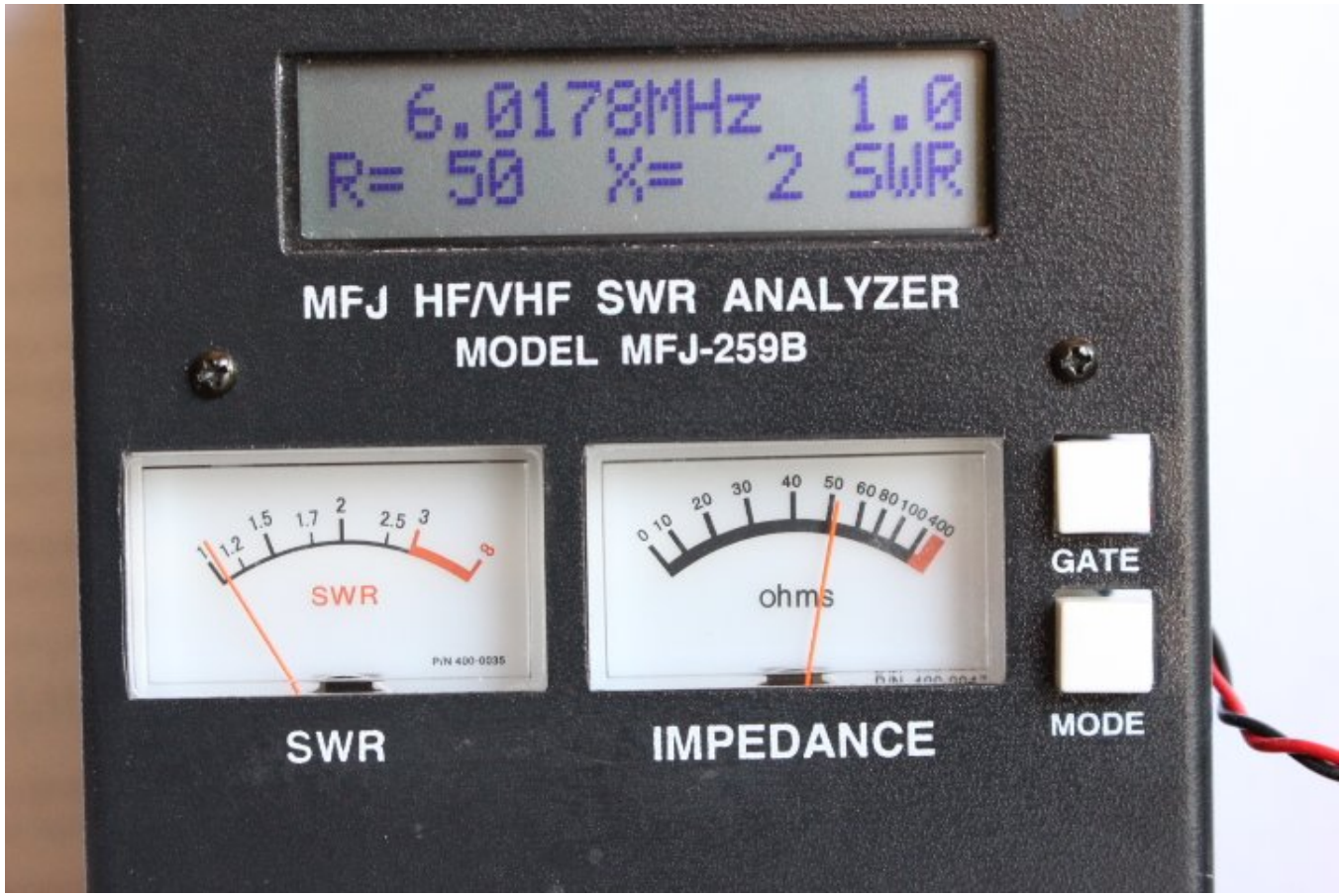

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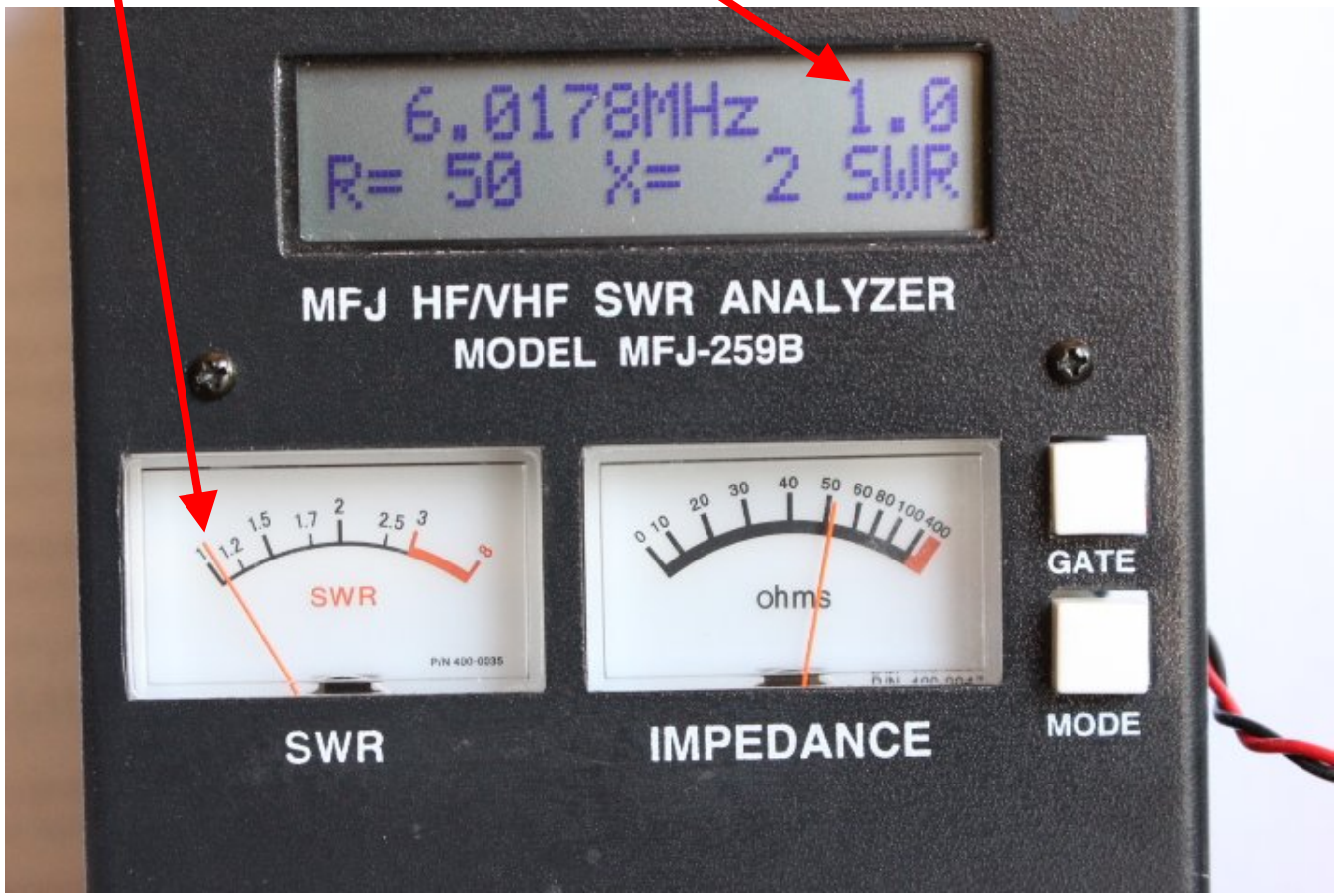

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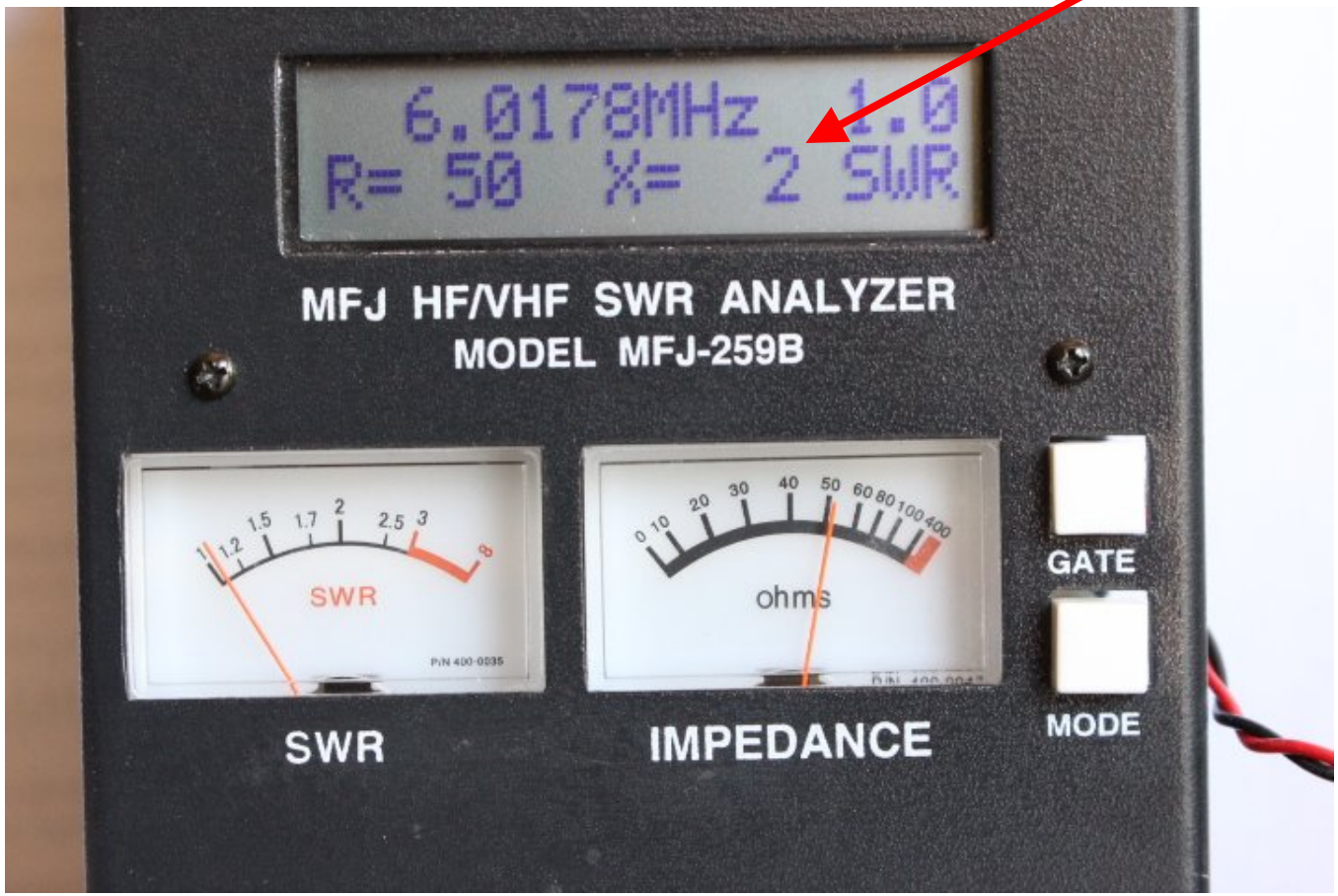

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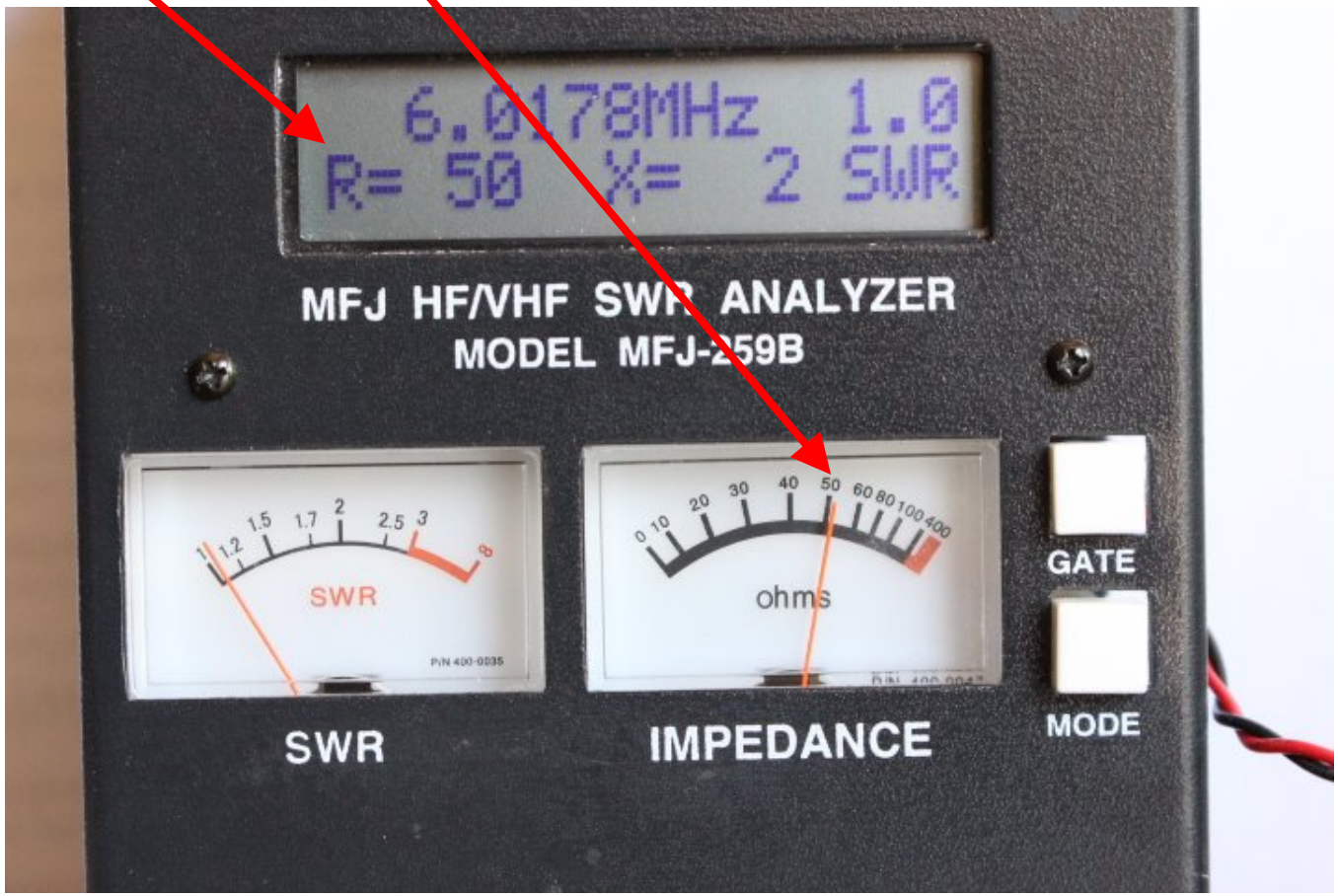

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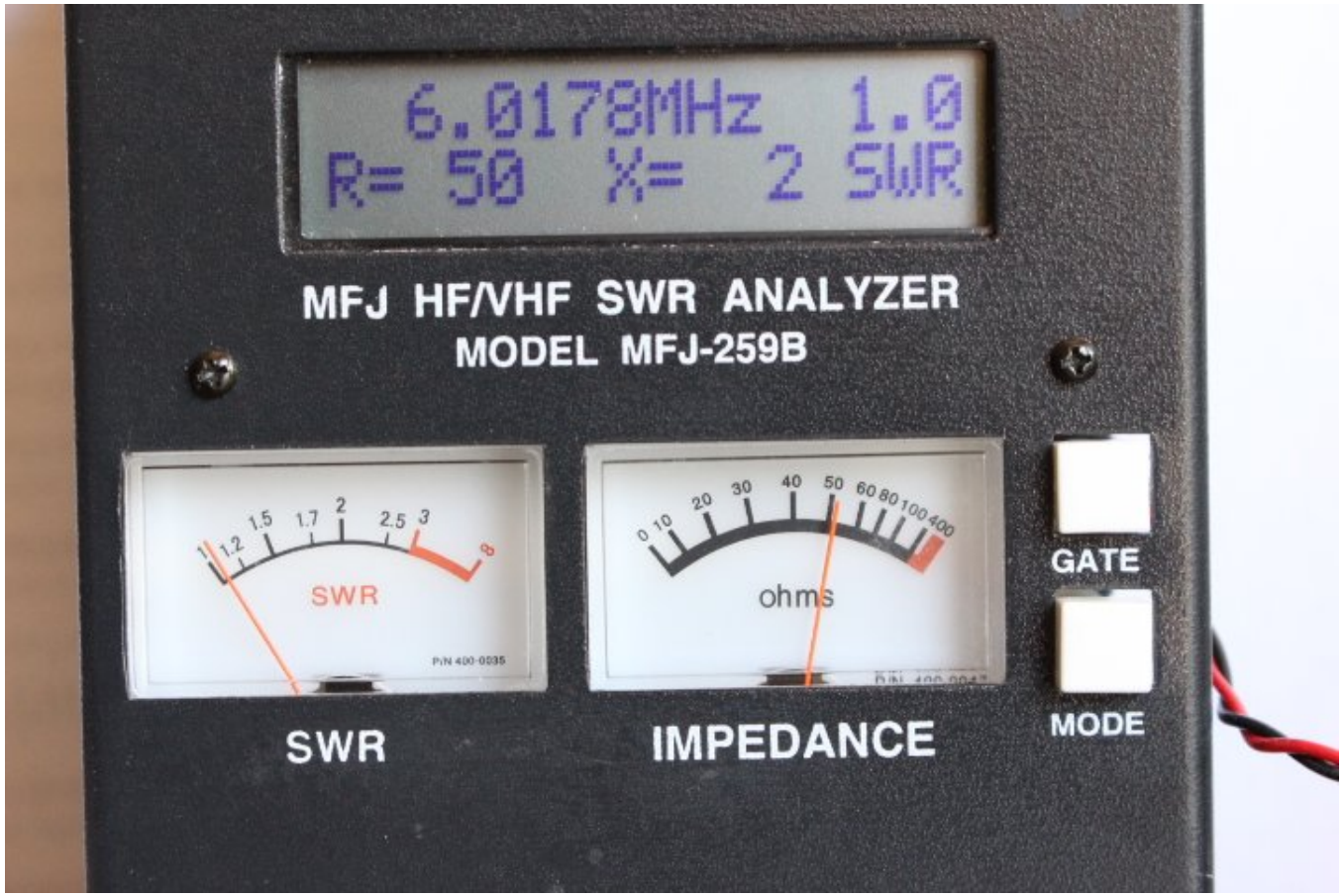
Magnitude of $Z = |\mathbf{Z}| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 0^2} = \mathbf{50}\ \Omega$

VNA Results: SWR = 1.01 & Z = 49.9 – j0.3 ohms



What Does The MFJ 259B Measure? (continued)

F (SWR=2:1) = 8.8 MHz:

Expected values:

X = j2πFL + 1/(j2πFC) = j72.4 +1/(j28.2x10-3) = j72.4 – j35.5 = **j36.9**

Z = 50 + j36.9

Magnitude of Z = $|\mathbf{Z}| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 36.9^2} =$ **62.1**

What Does The MFJ 259B Measure? (continued)

F (SWR=2:1) = 8.8 MHz:

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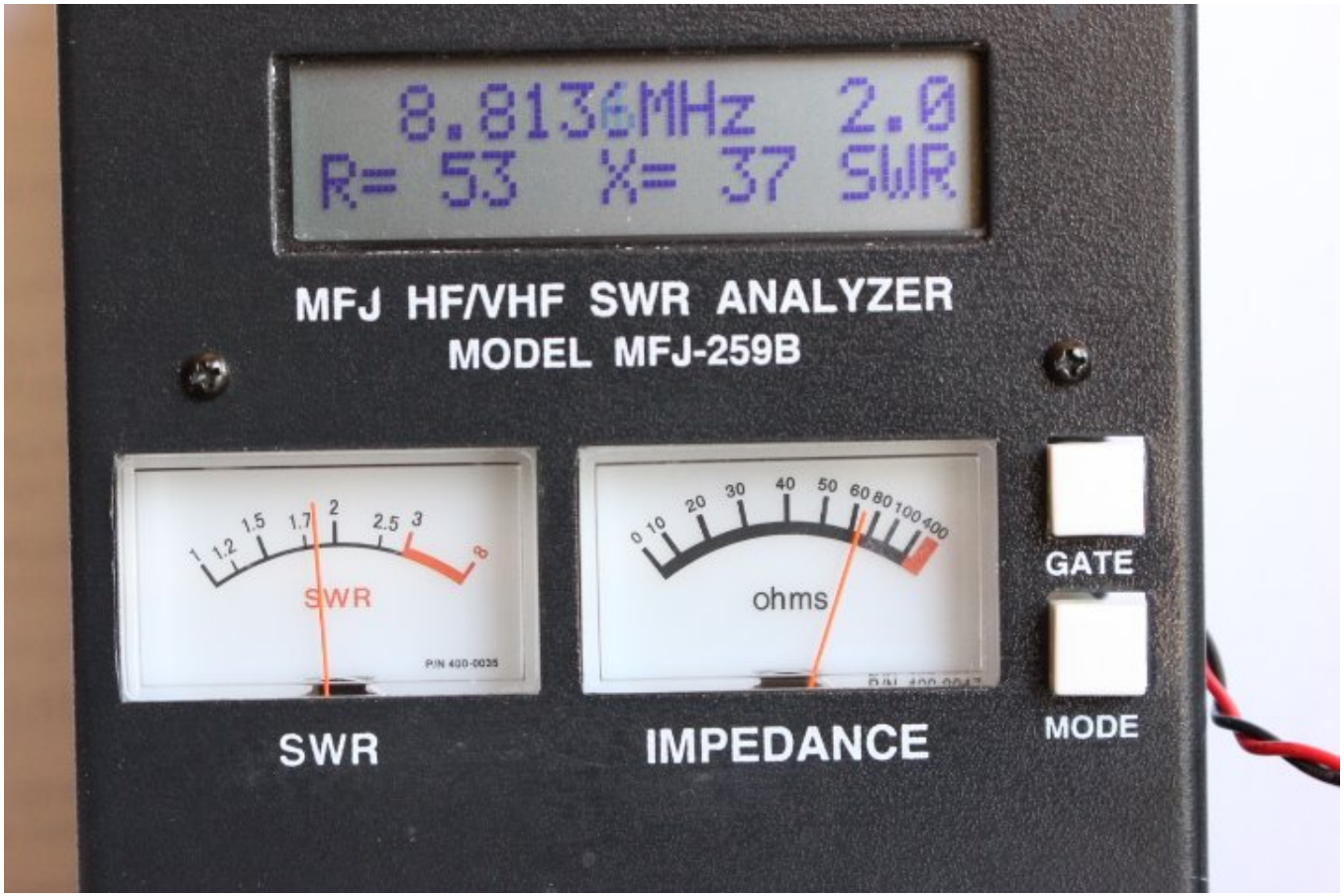

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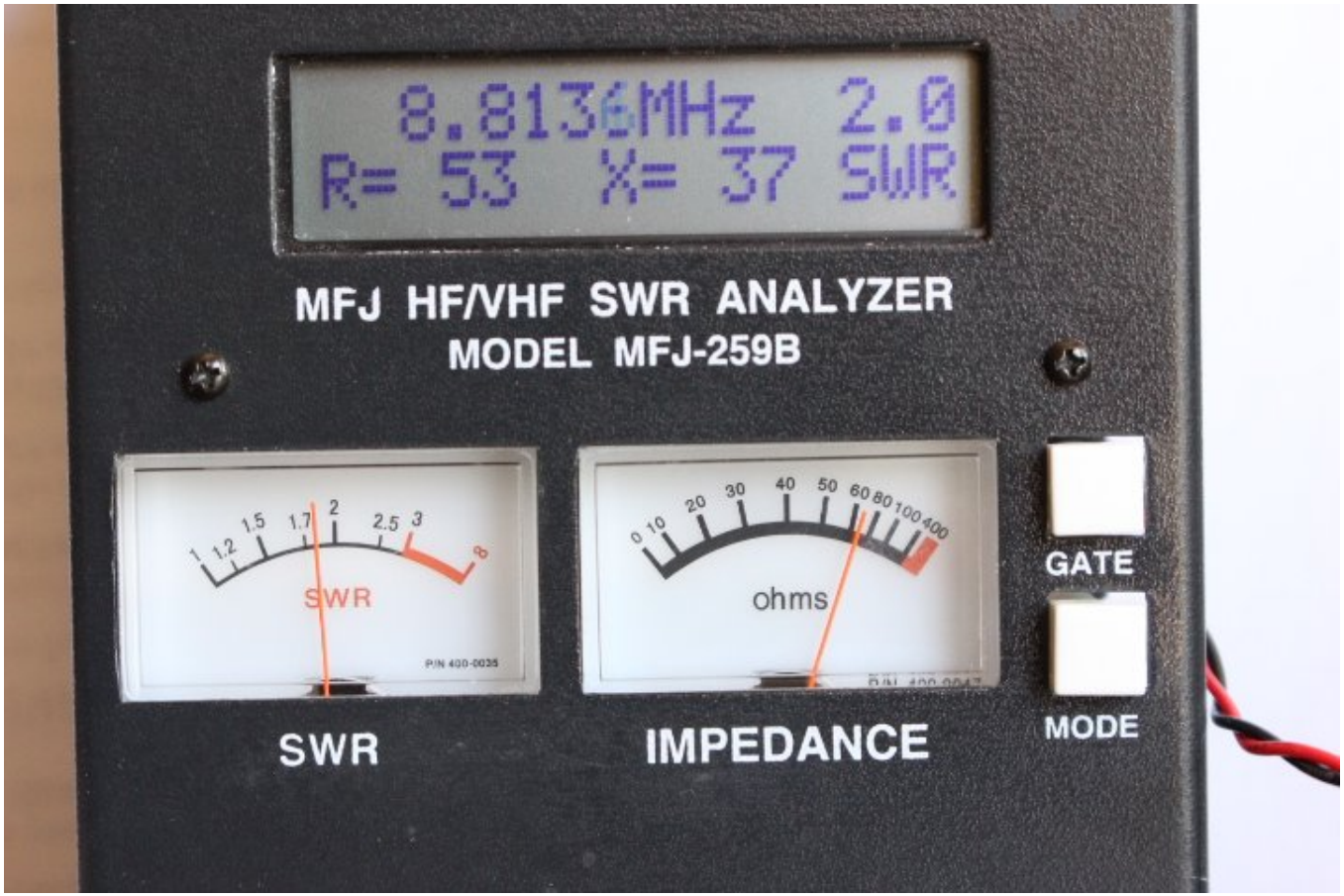
VNA Results: SWR = 2.0 & Z = 52.1 – j35.9 ohms



What Does The MFJ 259B Measure? (continued)

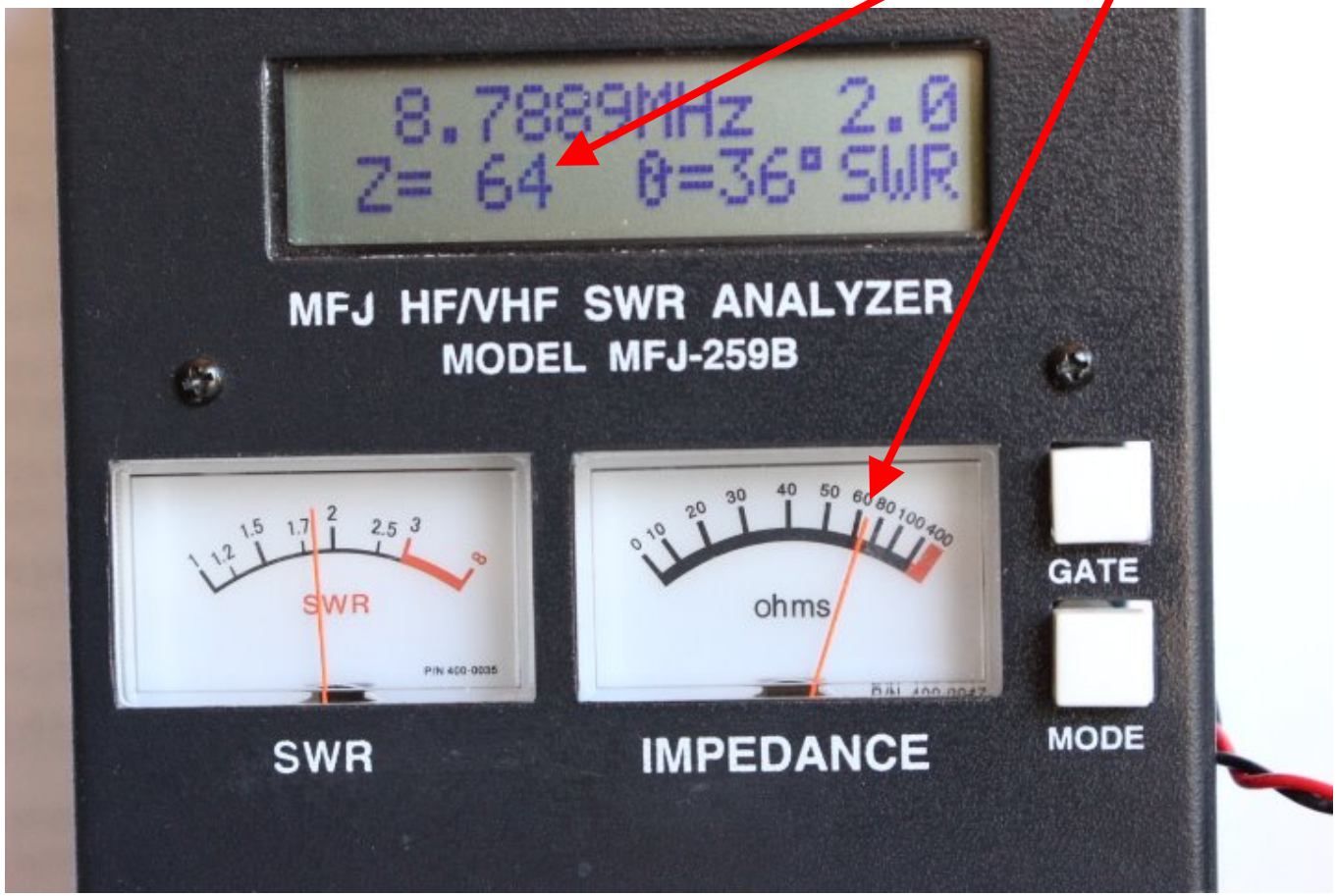
"Magnitude of Impedance" mode

Expected values:

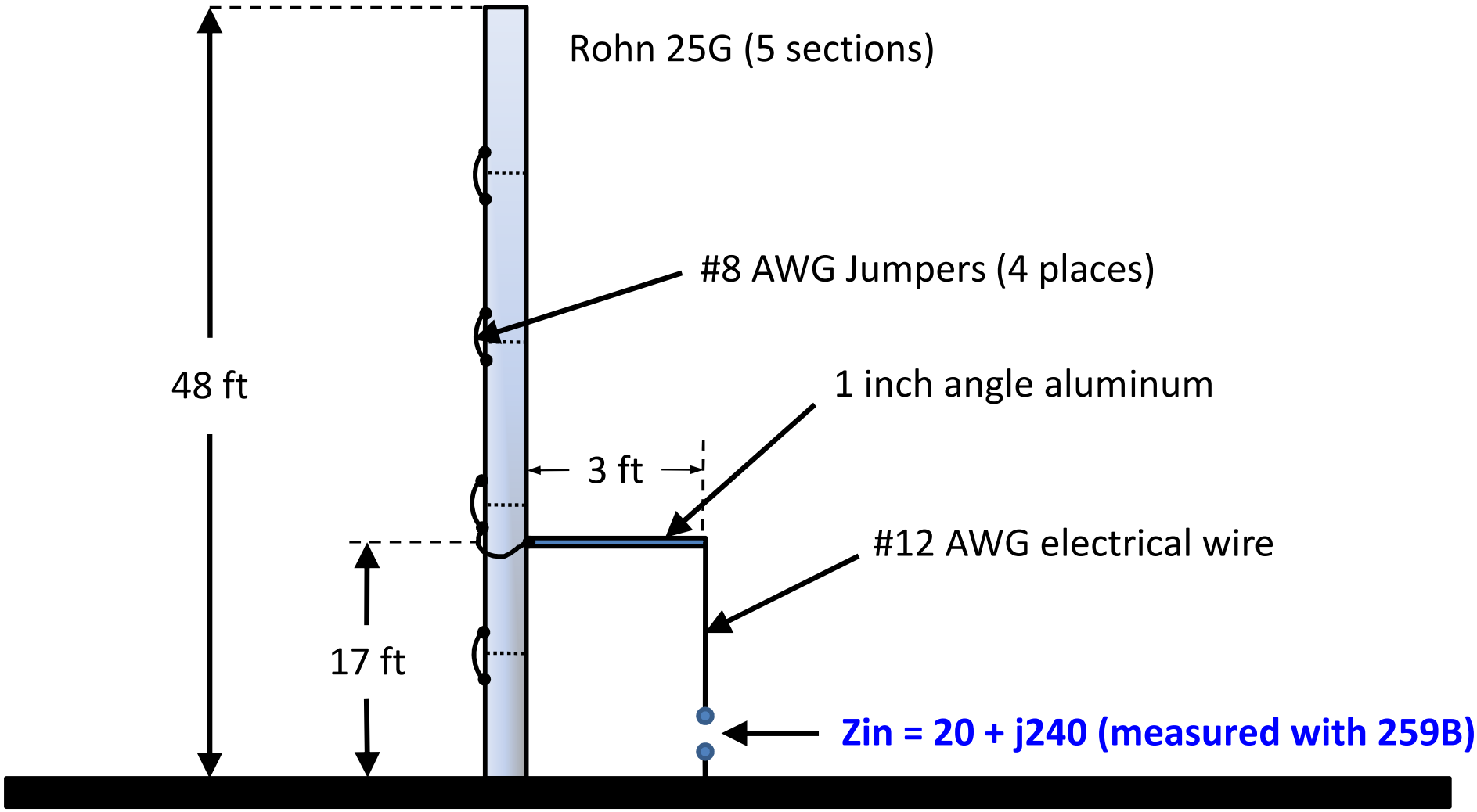
Z = 50 + j36.9

Magnitude of Z = $|Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 36.9^2} =$ **62.1**

Phase of Z = Arctan $\frac{X}{R}$ = **36.4** degrees

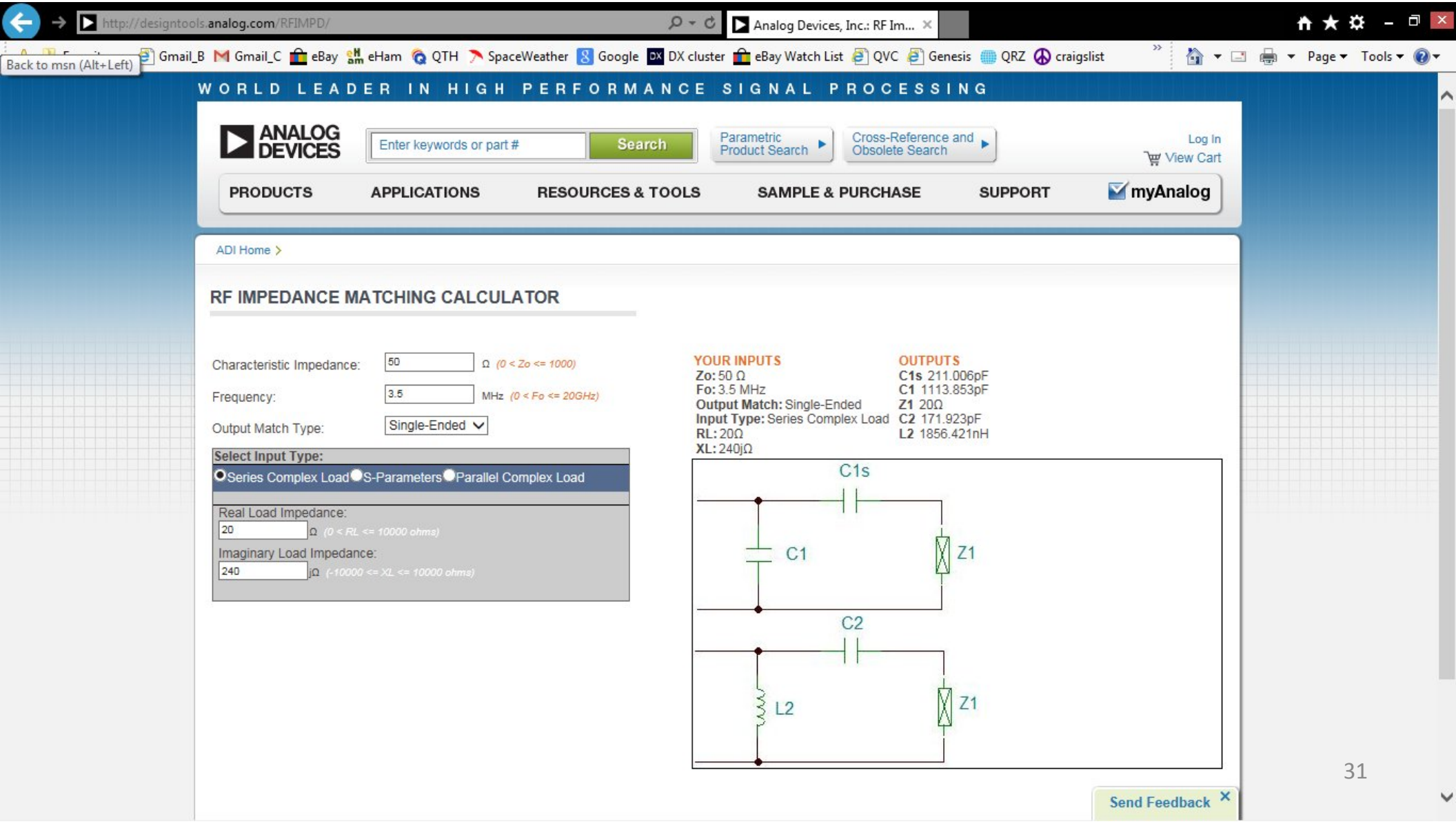


Example 2 – 80M Vertical

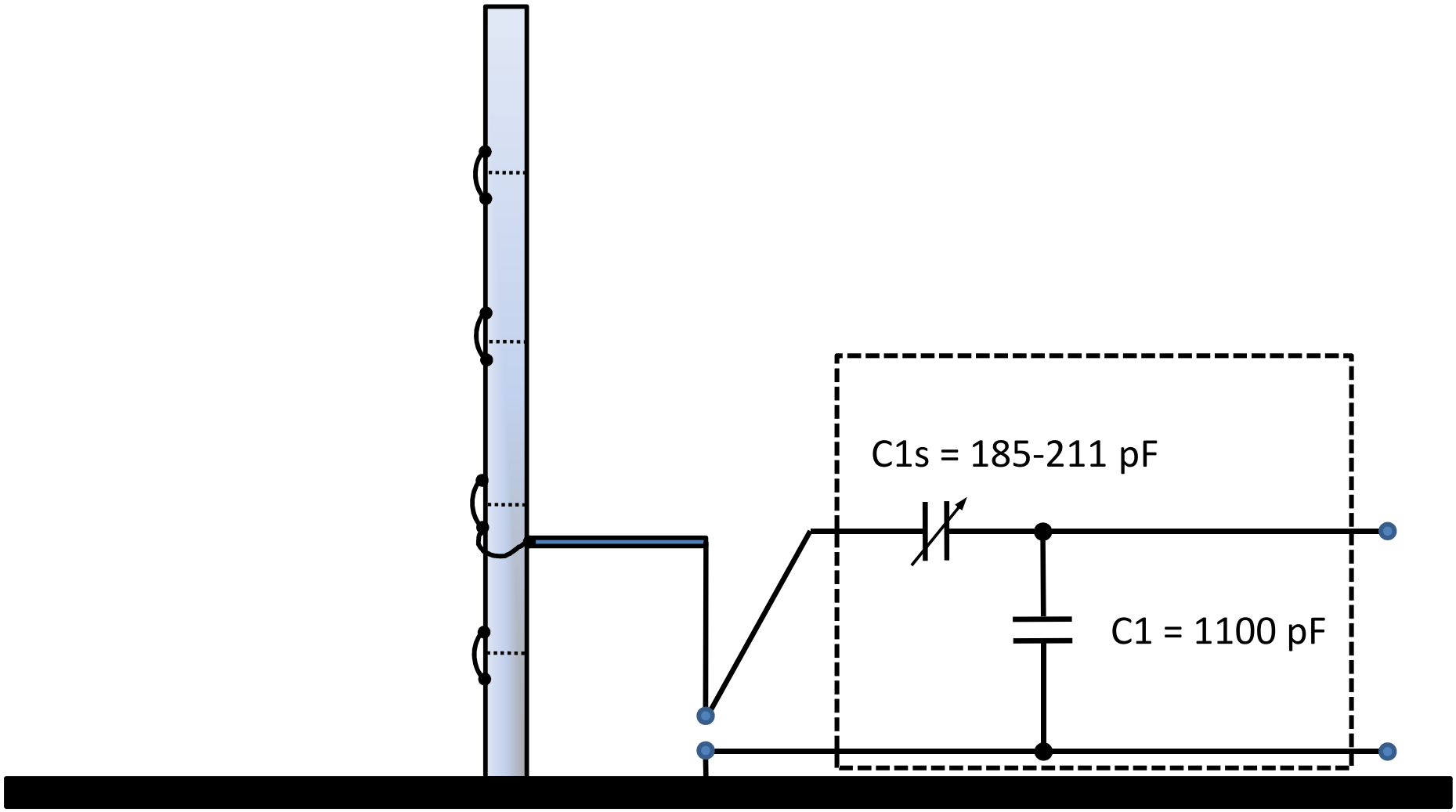


Matching Network Design

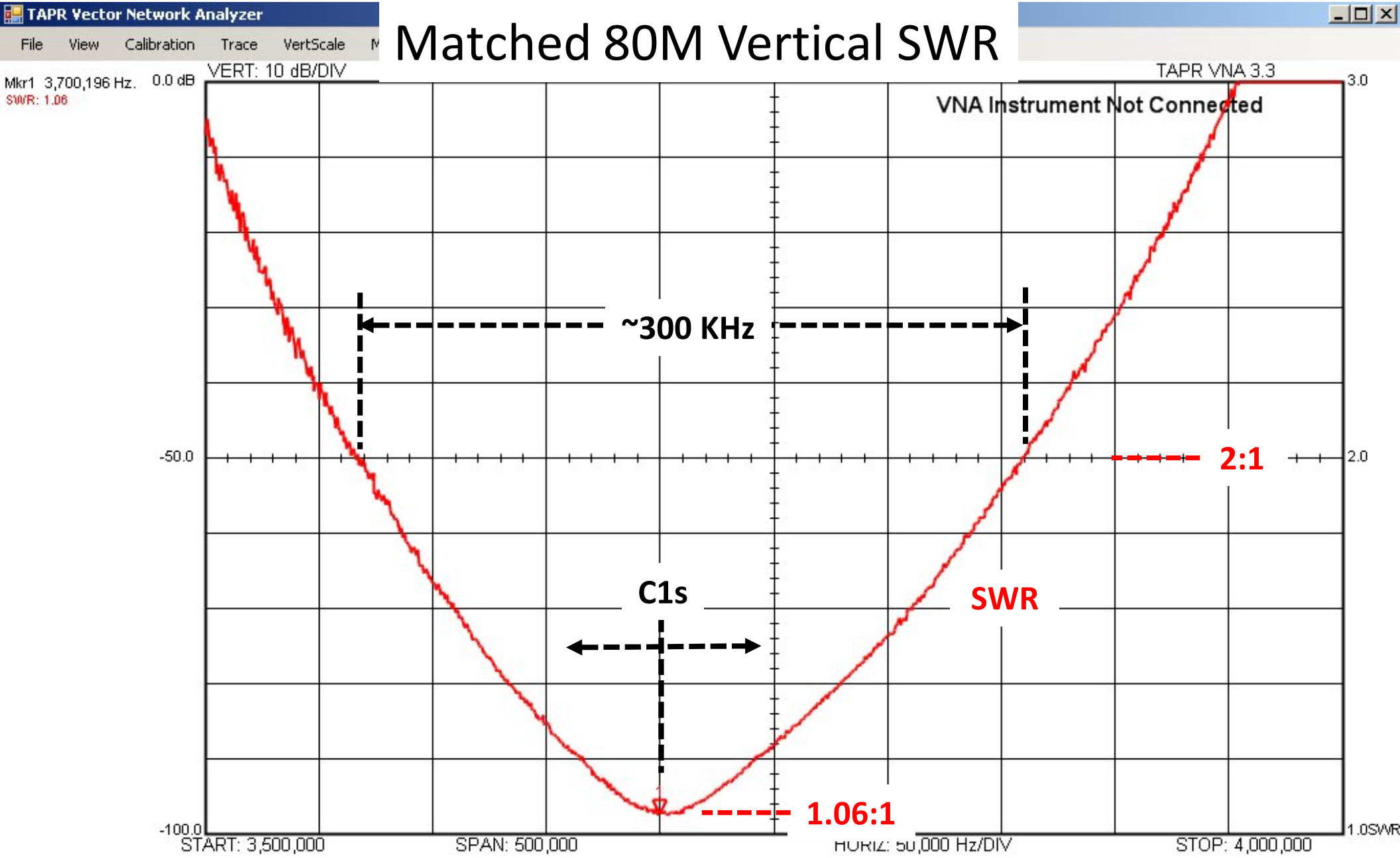
http://designtools.analog.com/RFIMPD/



Matched 80M Vertical



Matched 80M Vertical SWR



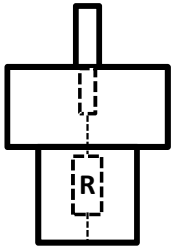
Part2: Calibration

Important Info

- **ESD**: Diode failures due to ESD is a common
  - Do not touch any part of the PC board (or antenna jack)
  - Always discharge antenna before connecting to 259
- Do not stress the wires to the battery holder
- Do not place the 259 on or near metal objects during calibration
- Calibration may be sensitive to battery voltage
- Wall warts:
  - **MFJ 259B:**
    - **With 259B, internal jumper must be set correctly when using wall wart with Alkaline batteries**

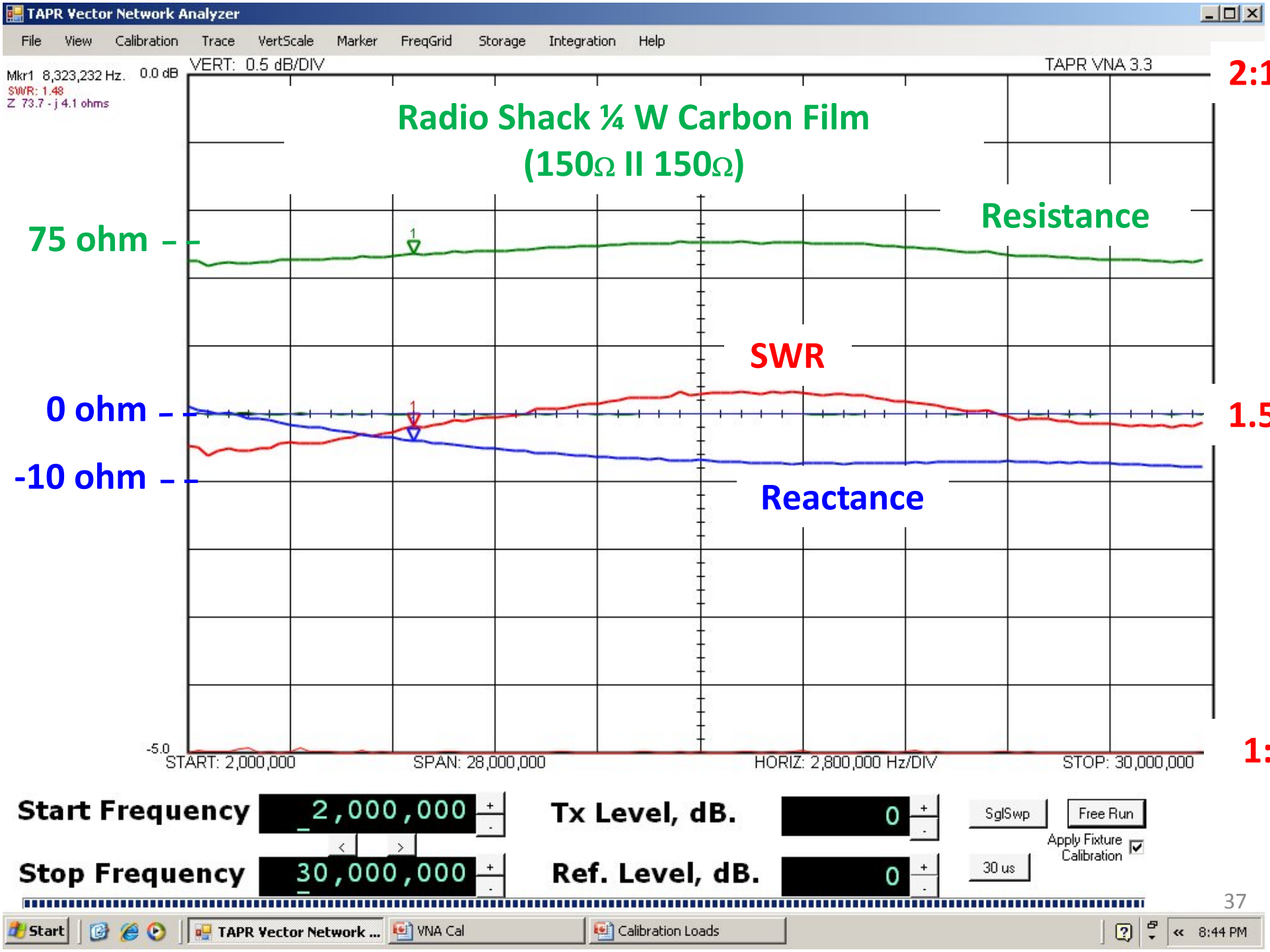
Items Needed for Simplified Calibration

- For checking RF signal output:
  1. Spectrum analyzer or
  2. HF receiver with S meter and **fixed attenuation** (>60 dB)
     - Keep S meter below S9+10 dB
- RF loads:
  - MFJ 259: 50 & 100 ohms
  - MFJ 259B: 12.5, 50, 75, & 200 ohms
  - Easy to make your own load with stock resistors and PL 259s
    - Use the smallest METAL FILM (1%) resistors you can find
      - Radio Shack CARBON FILM resistors worked for me



- Philips screwdriver (#1 or #2)
- Very small screwdriver for alignment tool
  - "Non-metallic" is not necessary for adjusting potentiometers

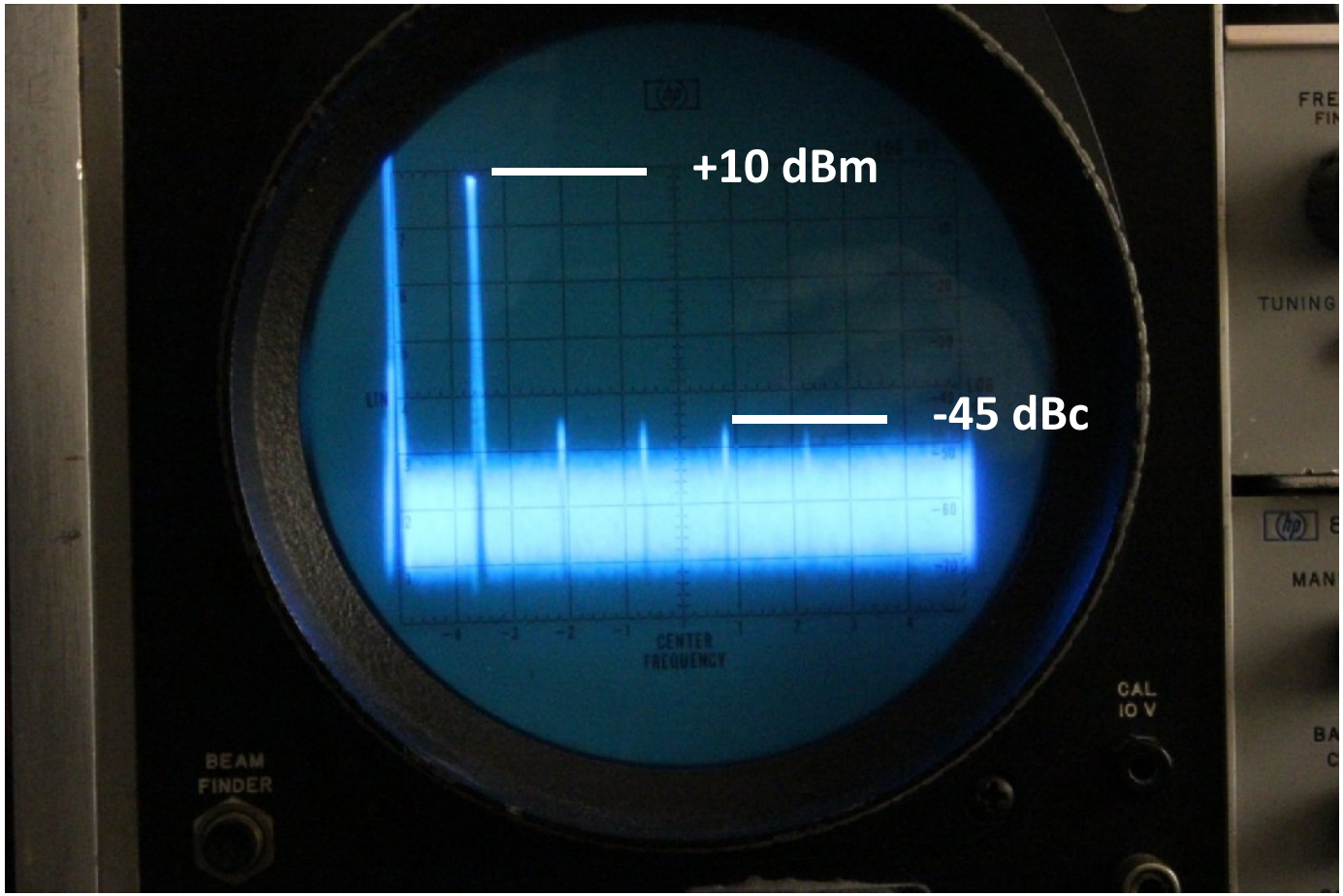
How Good Are PL 259 Loads?



Calibration - First Step

Check RF output level and harmonic content

- Output level should be around 0 to +10 dBm
- Harmonics must be **< -25 dBc** (< -35 dBc desired)
  - Use of 2.7 ohm load recommended
    - I didn't see any difference with or without load



Calibration - Second Step

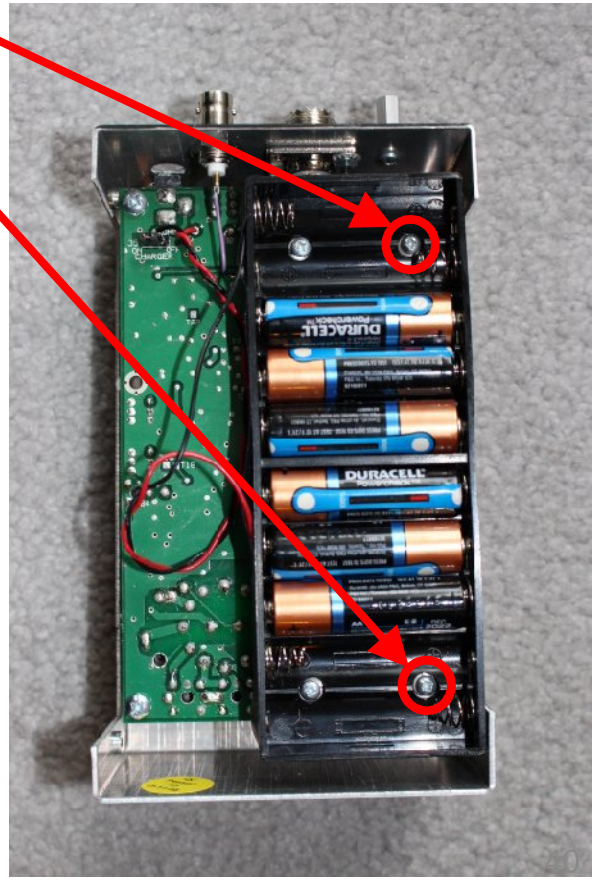
Check CAL accuracy FIRST with 50 & 75/100 ohms

- If it ain’t broke, don’t fix it

Calibration - Third Step

Open case:

- Remove 8 screws on sides of cabinet
- **MFJ 259B:**
  - Remove batteries 1, 2, 9, & 10
  - Remove **only** the **2 screws on right side** of battery tray
  - Remove battery tray
  - Replace batteries
  - **Tape off battery tray contacts**
  - Mark original settings with pen



MFJ 259 Calibration

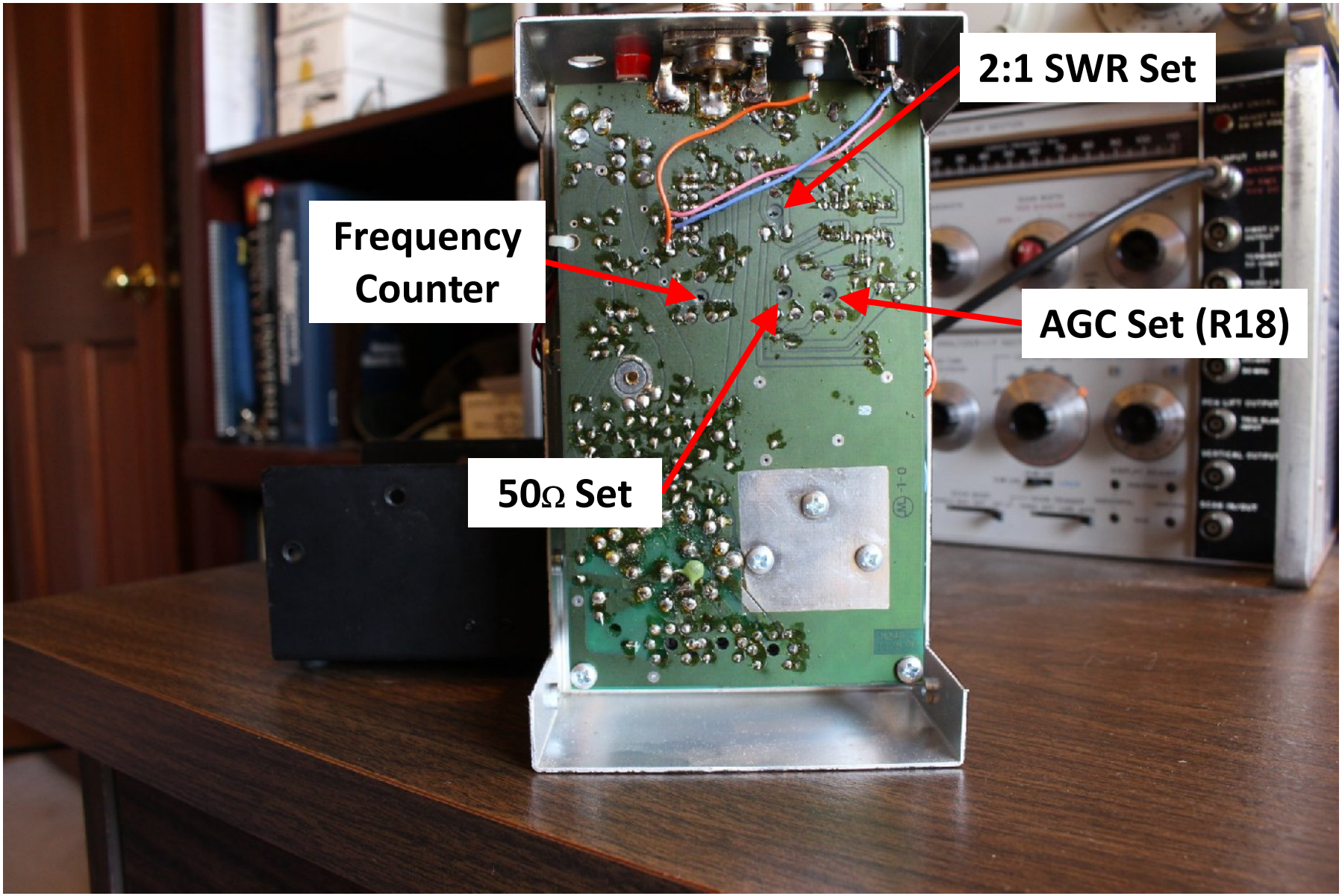
- MFJ 259:
  - Full Calibration Includes:
    - Check output power and harmonic levels
    - Set frequency counter sensitivity (?)
    - Set AGC voltage
    - Set frequency band overlap
    - SWR meter set with 100Ω load
    - Resistance meter set with 50Ω load
  - **Simplified** Calibration:
    - **Check output power, harmonic levels, and stability on all bands**
      - Adjust AGC pot if required
    - **SWR meter set with 100Ω load**
    - **Resistance meter set with 50Ω load**

- References:

1) http://www.radioaficion.com/HamNews/reviews/accesorios/11341-mfj-259-calibrating.html

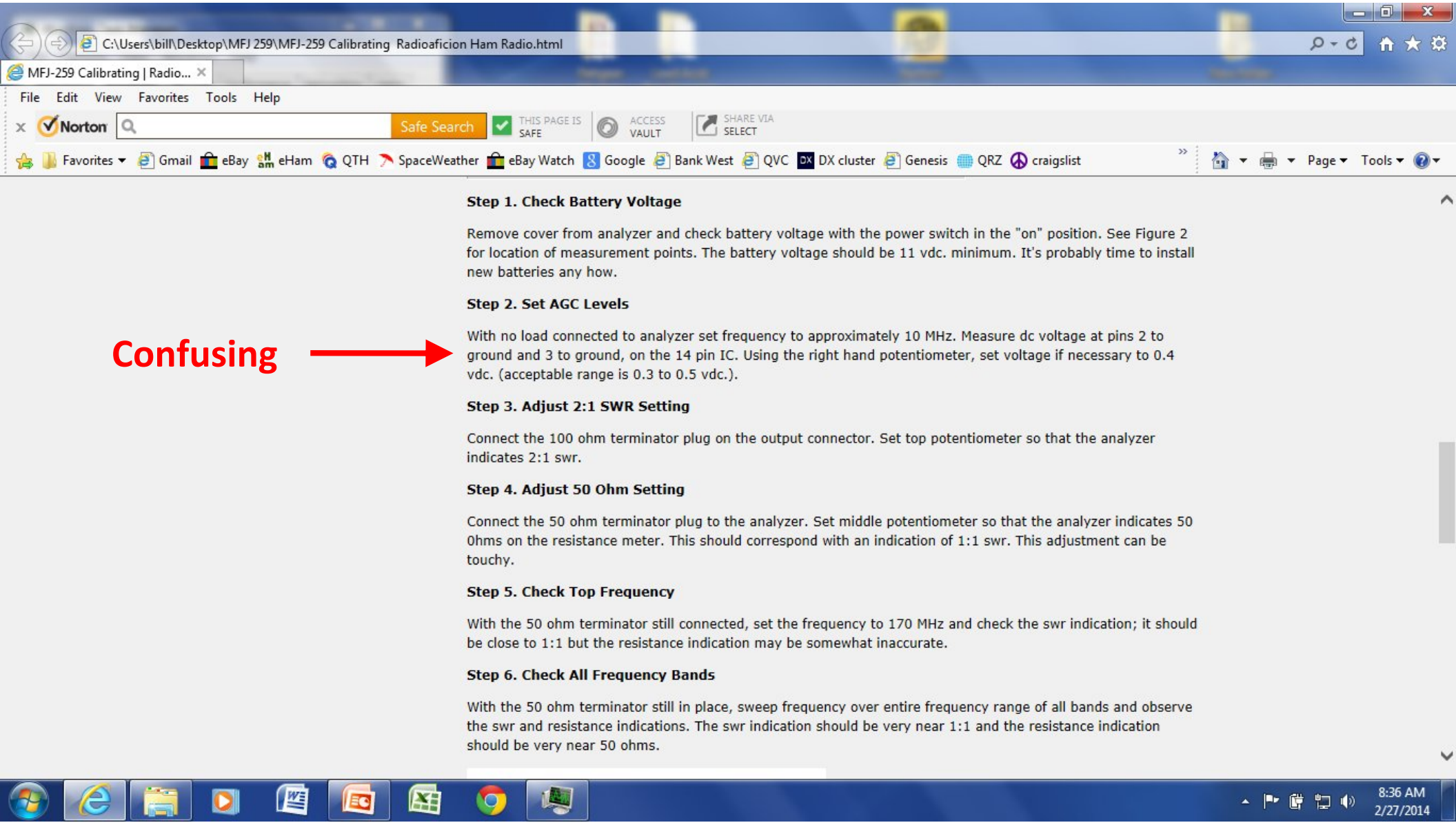
2) http://www.thiecom.de/ftp/mfj/mfj-249_calibration.pdf

MFJ 259 Simplified Calibration



MFJ 259 Simplified Calibration - continued

Reference 1



Confusing →

MFJ 259 Simplified Calibration - continued

Reference 2

Setting the A.G.C. voltage.

1) Range switch should be in the 113 – 17 range.
2) Tune display to read 165 - 166 MHz.
3) On back side of board measure the voltage on pin 2 of ICI. It should be 300 - 400 mV.
4) Check voltage on pin 3 of ICI and adjust R18 till voltage matches pin 2 or is within .003 mV of it Voltage on pin 3 shouldn't drop below that of pin 2 because unit **may become unstable.**

NOTE:

- **Setting the A.G.C. voltage affects:**
  - **Harmonic levels and**
  - **Stability (output frequency may become unstable)**
- **The "Best" A.G.C. setting may be different from the above guidelines**

MFJ 259 Simplified Calibration - continued

http://www.radioaficion.com/HamNews/reviews/accesorios/11341-mfj-259-calibrating.html

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Step 6. Check All Frequency Bands

With the 50 ohm terminator still in place, sweep frequency over entire frequency range of all bands and observe the swr and resistance indications. The swr indication should be very near 1:1 and the resistance indication should be very near 50 ohms.

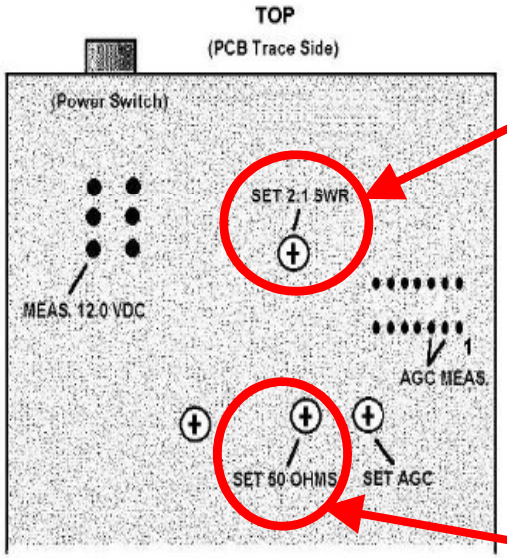


Figure 2. PCB Locator

1) Set SWR meter for 2:1 reading with 100Ω load

2) Set Resistance meter for 50Ω reading with 50Ω load

Summary

This procedure works well assuming that the analyzer is in otherwise good condition. If after carefully performing the preceding procedures, your unit is still not operating properly, consider sending the unit back to MFJ for repairs. It has been my experience that they give good service at reasonable prices.

8:52 AM 2/10/2014

259B Calibration

- MFJ 259B:
  - Full Calibration:
    - Check output power and harmonic levels
    - Adjust amplifier bias for minimum harmonic levels
    - Adjust VFO Ranges for band overlap
    - Calibration of Impedance & SWR at four different load values
  - **Simplified** Calibration:
    - **Check output power and harmonic levels**
    - **Calibration of Impedance & SWR at four different load values**

- Reference:

3) http://www.w8ji.com/mfj-259b_calibration.htm (don't use factory instructions)

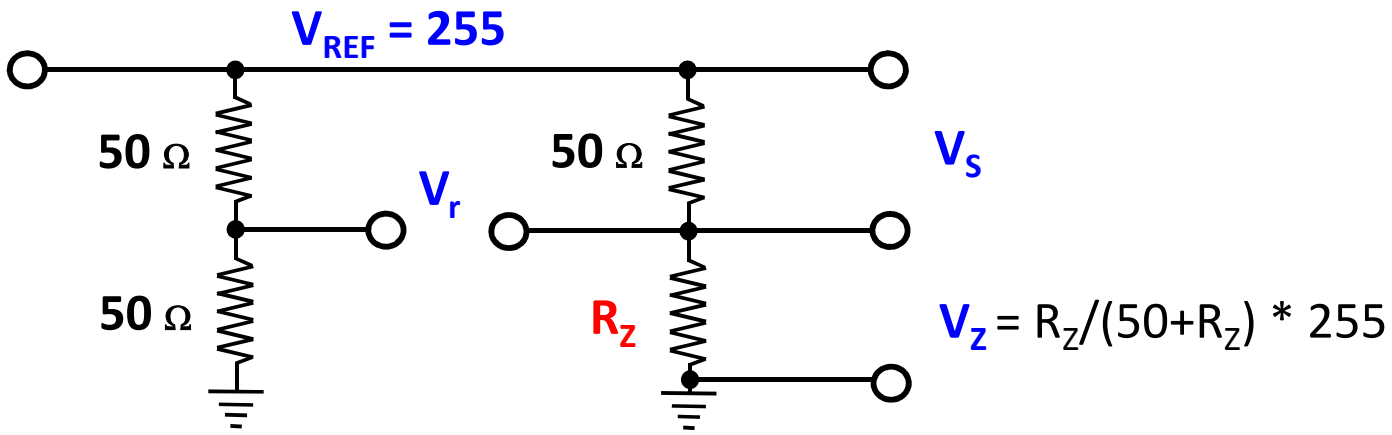
Note: ohms shows up as W in the article (200 W = 200 Ω, not 200 watt)

MFJ 259B Simplified Calibration

- Harmonic level (**Bias**) adjustment:
  - High harmonic levels degrade accuracy
  - Be sure to adjust **R84** (not R89)
  - Harmonic levels vary >30 dB while output level only varies 2-3 dB
  - Using 2.2Ω load or stub didn't make much difference

MFJ 259B Simplified Calibration - continued

- Calibration involves settings based upon a **"number"**
  - 8 bit A/D converts DC voltages to a number between 0 and 255
  - **Ref 3 confuses "digital number" and "bits"**
    - Ex: "voltage Vz in bits = $R_Z/(50+R_Z)$ * 255 bits"



MFJ 259B Simplified Calibration - continued

Simplified calibration procedure:

1. Set digital display impedance readings at 12.5 and 200 ohms
2. Set digital display for SWR = 1.5 with 75 ohms
3. Set analog SWR meter for SWR = 1.5 with 75 ohms
4. Set the analog Impedance meter reading at 50 ohms with 50 ohms

MFJ 259B Simplified Calibration - continued

Set up "TEST MODE" (This can be difficult)

To enter "*Test Mode*":

[ ] Turn power off.
[ ] Hold down ***MODE*** and ***GATE*** buttons while turning power on.
[ ] As display comes up, slowly (about 1 second period) rock between applying finger-pressure on the **MODE** and **GATE** switches. The best method is to use two fingers, rocking your hand from side-to-side to alternate your fingers between the two buttons.
[ ] Confirm analyzer has entered test mode **(it may take more than one try)**.
[ ] Using the **MODE** button, advance display to the **R-S-Z** screen (shown below).

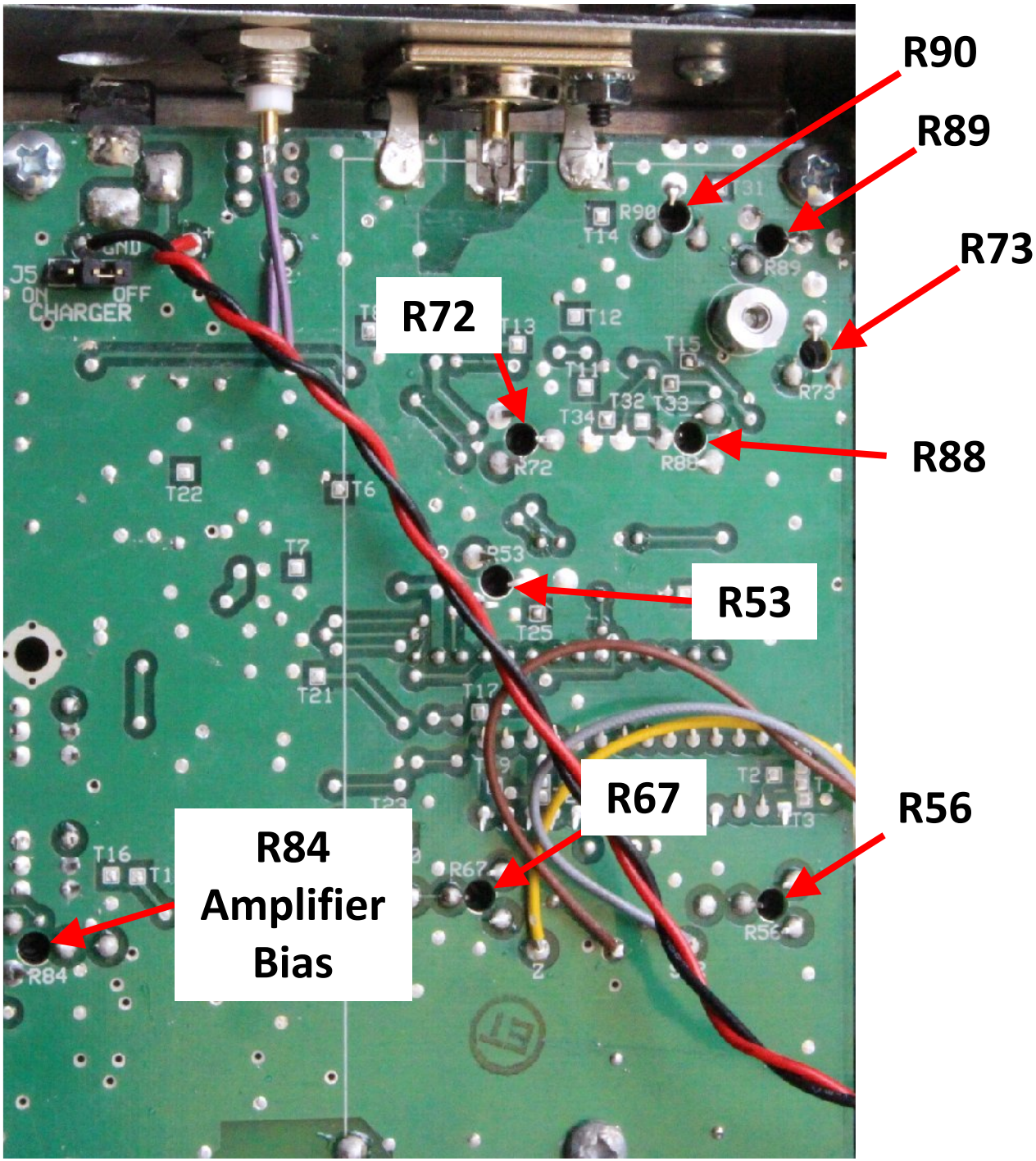
"Note: If you go past the R-S-Z screen, you can still see R-S-Z by pushing and holding the MODE button." } **WRONG (You need to start over)**

R-S-Z Mode Digital Display

xx.xxx MHz

Rxxx Sxxx Zxxx

MFJ 259B Simplified Calibration - continued



MFJ 259B Simplified Calibration - continued

1) Impedance Calibration:

Set Frequency to **14.000 MHz**

Ignore "First Time Adjustments"

1a) [ ] Install **12.5-Ω** load

[ ] Set **R90** for **Z=051**

[ ] Set **R73** for **S=204**

[ ] Set **R53** for **R=153***

***This setting is a compromise between the 12.5 & 200 ohm loads. (ie, you cannot get R=153 for both loads). I set R=160 with 12.5 ohm load, which resulted in R=146 with 200 ohm load.

R-S-Z Mode Digital Display

14.000 MHz

R153 S204 Z051

MFJ 259B Simplified Calibration - continued

1) Impedance Calibration: (continued)

1b) [ ] **Change Load** to **200-Ω**
[ ] Set **R88** for **S=051**
[ ] Set **R72** for **Z=204**
[ ] **R=***

Repeat above steps (I didn't find this necessary)

[ ] **Change Load** to **12.5-Ω**
[ ] Reset **R90** for **Z=051**
[ ] Reset **R73** for **S=204**
[ ] Reset **R53** for **R=153**

[ ] **Change Load** to **200-Ω**
[ ] Verify or reset **R88** for **S=051**
[ ] Verify or set **R72** for **Z=204**
[ ] Verify or set **R53** for **near R=153**

MFJ 259B Simplified Calibration - continued

2) SWR Calibration (Digital):

[ ] **Change Load** to **75-Ω**

[ ] Set **R89** for **R=051**

3) SWR Meter Calibration (Analog):

[ ] Set **R56** for **SWR Meter** reading of **1.5:1**

4) Impedance Meter Calibration (Analog):

Note: Error in W8JI instructions. Analyzer must be in "Impedance" mode to CAL Impedance meter!

[ ] Cycle analyzer power OFF and then ON. Verify that analyzer is in "Impedance" mode.

[ ] **Change Load** to **50-Ω**

[ ] Set **R67** for an **Impedance Meter** reading of **50-Ω**