MFJ 259
Operation & Simplified Calibration

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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

![Diagram](image-url)
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
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      • Percentage Transmitted Power

Focus of this presentation
Impedance

• “The total opposition to **alternating** current by an electric circuit”
  • Impedance = $Z = \text{Resistance} + \text{Reactance} = R + jX$
  • Measured in **OHMS**
  • $Z$ is a **COMPLEX** number!
    • For most ham applications => ignore the $j$ term
• Equivalent Impedance Circuit:

  **Physical Circuit**

  ![Physical Circuit Diagram](image)

  **Equivalent Impedance Circuit**

  ![Equivalent Impedance Circuit Diagram](image)

  $Z_E = R_E + jX_E$

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

  $X_E = \text{NET reactance} = ?$
To Calculate the Value of $X_E$

• To calculate $X_E$, must specify the frequency ($F$)

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

• 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 **one** number
      • “Impedance” is complex number composed of **two** numbers

• What does the second meter measure?
Magnitude of Impedance

• Using the rules for COMPLEX mathematics:

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

Example:
If \( R_E = 50 \, \Omega \) and \( X_E = 50 \, \Omega \), then,

\[
\text{Magnitude of } Z = |Z| = \sqrt{50^2 + 50^2} = 75 \, \Omega
\]
\( \neq 100 \, \Omega \)

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

- Admittance = \( Y = \frac{1}{Z} \) = Conductance + Susceptance = \( G + jB \)

- Measured in **SIEMENS**
  - 1 siemen = 1/(1 ohm) = 1 mho

**Note:** Both \( G \), & \( B \) are a function of frequency
Admittance

• To express G & B in ohms, simply invert $R_p$ & $X_p$:

$$R_p = \frac{1}{G} \text{ ohms}$$
$$X_p = \frac{1}{B} \text{ ohms}$$

Note: This is NOT equivalent to an Impedance Circuit

$R_p \neq R_E$
$X_p \neq X_E$
Admittance

• To express G & B in ohms, simply invert $R_p$ & $X_p$:

\[
R_p = \frac{1}{G} \text{ ohms} \\
X_p = \frac{1}{B} \text{ ohms}
\]

\[R_E \quad X_E\]

\[G \quad B\]

\[R_p \quad X_p\]

Note: This is **NOT** 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 $50\,\Omega$ 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)
The frequency counter uses a separate (BNC) connector! Never inject a signal into the ANTENNA port!
The Digital Display is more accurate than the Analog meters.
Example 1 – 40M Dipole

- $R = 50\, \Omega$
- $X = j0$
- SWR = 1:1
- $L = 1.31\mu\text{H}$
- $C = 510\text{pF}$
- $SWR = 1:1$
- $R = 50\, \Omega$
- $L = 1.31\mu\text{H}$
- $C = 510\text{pF}$
What Does The MFJ 259B Measure?

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

**Expected values:**

\[ X = j2\pi FL + \frac{1}{(j2\pi FC)} = j49.4 + \frac{1}{(j19.2\times10^{-3})} = j49.4 - j52.0 \approx j0 \]

\[ Z = R + jX = 50 + j0 = 50 \Omega \]

Magnitude of \( Z = |Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 0^2} = 50 \Omega \]
What Does The MFJ 259B Measure? (continued)

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

**Expected values:**

\[ X = j2\pi FL + 1/(j2\pi FC) = j49.4 + 1/(j19.2 \times 10^{-3}) = j49.4 - j52.0 \approx j0 \]

\[ Z = R + jX = 50 + j0 = 50 \Omega \]

Magnitude of \( Z = |Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 0^2} = 50 \Omega \]
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\[ Z = R + jX = 50 + j0 = 50 \, \Omega \]

Magnitude of \( Z \):

\[ |Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 0^2} = 50 \, \Omega \]

**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:

\[ X = j2\pi FL + 1/(j2\pi FC) = j72.4 + 1/(j28.2 \times 10^{-3}) = j72.4 - j35.5 = j36.9 \]

\[ Z = 50 + j36.9 \]

Magnitude of \( Z \) = \[ |Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 36.9^2} = 62.1 \]
What Does The MFJ 259B Measure? (continued)

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

**Expected values:**

\[ X = j2\pi FL + \frac{1}{j2\pi FC} = j72.4 + \frac{1}{(j28.2 \times 10^{-3})} = j72.4 - j35.5 = j36.9 \]

\[ Z = 50 + j36.9 \]

Magnitude of \( Z \) = \( |Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 36.9^2} = 62.1 \)
F (SWR=2:1) = 8.8 MHz:

Expected values:

\[ X = j2\pi FL + \frac{1}{j2\pi FC} = j72.4 + \frac{1}{j(28.2\times10^{-3})} = j72.4 - j35.5 = j36.9 \]

\[ Z = 50 + j36.9 \]

Magnitude of \( Z \):

\[ |Z| = \sqrt{R^2 + X^2} = \sqrt{50^2 + 36.9^2} = 62.1 \]

VNA Results: SWR = 2.0 & Z = 52.1 – j35.9 ohms
“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 \( Z = \text{Arctan} \frac{X}{R} = 36.4 \text{ degrees} \)
Example 2 – 80M Vertical

- Rohn 25G (5 sections)
- #8 AWG Jumpers (4 places)
- 1 inch angle aluminum
- #12 AWG electrical wire
- $Z_{in} = 20 + j240$ (measured with 259B)
Matching Network Design

http://designtools.analog.com/RFIMPD/
Matched 80M Vertical

C1s = 185-211 pF
C1 = 1100 pF
Matched 80M Vertical SWR

- SWR: 1.06:1
- C1s: ~300 KHz
- Start Frequency: 3,500,000 Hz
- Stop Frequency: 4,000,000 Hz
- Tx Level, dB: 0
- Ref. Level, dB: 0
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?

Radio Shack ¼ W Carbon Film
(150Ω II 150Ω)

Start Frequency: 2,000,000 Hz
Stop Frequency: 30,000,000 Hz
Tx Level, dB: 0
Ref. Level, dB: 0
Calibration - First Step

Check RF output level and harmonic content

- Output level should be around 0 to +10 dBm
- Harmonics must be $<-25\,\text{dBc}$ ($<-35\,\text{dBc}$ 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
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:
MFJ 259 Simplified Calibration

- 2:1 SWR Set
- AGC Set (R18)
- Frequency Counter
- 50Ω Set
Step 1. Check Battery Voltage
Remove cover from analyzer and check battery voltage with the power switch in the "on" position. See Figure 2 for location of measurement points. The battery voltage should be 11 vdc. minimum. It's probably time to install new batteries any how.

Step 2. Set AGC Levels
With no load connected to analyzer set frequency to approximately 10 MHz. Measure dc voltage at pins 2 to ground and 3 to ground, on the 14 pin IC. Using the right hand potentiometer, set voltage if necessary to 0.4 vdc. (acceptable range is 0.3 to 0.5 vdc.).

Step 3. Adjust 2:1 SWR Setting
Connect the 100 ohm terminator plug on the output connector. Set top potentiometer so that the analyzer indicates 2:1 swr.

Step 4. Adjust 50 Ohm Setting
Connect the 50 ohm terminator plug to the analyzer. Set middle potentiometer so that the analyzer indicates 50 ohms on the resistance meter. This should correspond with an indication of 1:1 swr. This adjustment can be touchy.

Step 5. Check Top Frequency
With the 50 ohm terminator still connected, set the frequency to 170 MHz and check the swr indication; it should be close to 1:1 but the resistance indication may be somewhat inaccurate.

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.
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 ICl. It should be 300 - 400 mV.
4) Check voltage on pin 3 of ICl 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
1) Set SWR meter for 2:1 reading with 100Ω load

2) Set Resistance meter for 50Ω reading with 50Ω load
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](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)
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”

\[ V_{\text{REF}} = 255 \]

\[ V_r \]

\[ 50 \Omega \]

\[ 50 \Omega \]

\[ V_s \]

\[ 50 \Omega \]

\[ R_z \]

\[ V_z = R_z/(50+R_z) * 255 \]
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
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.”

R-S-Z Mode Digital Display

<table>
<thead>
<tr>
<th>xx.xxx MHz</th>
<th>Rxxx</th>
<th>Sxxx</th>
<th>Zxxx</th>
</tr>
</thead>
</table>

WRONG (You need to start over)
MFJ 259B Simplified Calibration - continued

R42
R53
R67
R84
Amplifier
Bias

R90
R89
R73
R88
R56
R72
R53
R67

R84 Bias
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 |
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
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