

MFJ

HF/VHF SWR Analyzer

Model MFJ-259C



INSTRUCTION MANUAL

CAUTION: Read All Instructions Before Operating Equipment

MFJ ENTERPRISES, INC.

300 Industrial Park Road
Starkville, MS 39759 USA
Tel: 662-323-5869 Fax: 662-323-6551

TABLE OF CONTENTS

- 1.0 INTRODUCTION..... 1
 - 1.1 A Quick Word about Accuracy..... 1
 - 1.2 Typical Uses 2
 - 1.3 Frequency Range 2
- 2.0 POWER SOURCES 2
 - 2.1 External Power Supply 3
 - 2.2 Using Internal Batteries 3
 - 2.3 Using Rechargeable “AA” Type Batteries..... 3
 - 2.4 Using Conventional “AA” Drycell Batteries..... 4
 - 2.5 “Power Saving” Mode (sleep mode)..... 4
- 3.0 MAIN MENU AND DISPLAY 4
 - 3.1 General Connection Guidelines 4
 - 3.2 Power-up Display 5
 - 3.3 Main MODE descriptions 5
 - 3.4 Blinking “VOLTAGE LOW” display warning 6
- 4.0 MAIN (OR OPENING) MODE..... 6
 - 4.1 General Connection Guidelines 7
 - 4.2 Antenna SWR 7
 - 4.3 Coax Loss 8
 - 4.4 Capacitance..... 9
 - 4.5 Inductance..... 10
- 5.0 ADVANCED OPERATION 10
 - 5.1 Forward..... 11
 - 5.2 General Connection Guidelines 12
 - 5.3 (Magnitude of) Impedance mode..... 12
 - 5.4 Return Loss and Reflection Coefficient mode..... 12
 - 5.5 Distance to Fault mode 13
 - 5.6 Resonance Mode..... 13
 - 5.7 Percentage Transmitted Power 14
- 6.0 ADJUSTING SIMPLE ANTENNAS 14
 - 6.1 Dipoles 14
 - 6.2 Verticals 15
 - 6.3 Tuning a simple antenna 15
- 7.0 TESTING AND TUNING STUBS AND TRANSMISSION LINES..... 15
 - 7.1 Testing Stubs..... 15
 - 7.2 Velocity Factor of Transmission Lines..... 16
 - 7.3 Impedance of Transmission Lines or Beverage antennas 17
 - 7.4 Adjusting Tuners..... 18
 - 7.5 Adjusting Amplifier Matching Networks 18
 - 7.6 Testing RF Transformers 18
 - 7.7 Testing Baluns 19
 - 7.8 Testing RF Chokes..... 19
- 8.0 TECHNICAL ASSISTANCE 20

1.0 INTRODUCTION

Attention: Read Section-2.0 before attempting to use your analyzer. Incorrect power supply voltages or excessive external voltage applied to the Antenna connector will damage it!

Description

The MFJ-259C is a compact battery powered RF impedance analyzer that combines four basic circuits; a 50-ohm bridge, eight-bit micro-controller, frequency counter, and a 0.53-230 MHz variable-frequency oscillator with switched coverage of nine overlapping bands. These four sub-elements are integrated to provide a wide variety of useful antenna and impedance measurements including coaxial cable loss and distance to an open or short. Although designed primarily for analyzing 50-ohm antennas and transmission line systems, the MFJ-259C also measures RF impedance from a few ohms to several hundred ohms. In addition, it functions as a discrete signal source (RF-Signal Generator) and independent frequency counter.

1.1 A Quick Word about Accuracy

Inexpensive impedance meters have limitations. The main causes of measurement error are:

- (1.) Signal ingress from external RF sources
- (2.) Component limitations
- (3.) Stray reactance from connectors, pc traces, and wires.

1.) Signal Ingress: Virtually all low-cost handhelds use simple broadband diode detectors. Unlike costly lab-grade analyzers using frequency-selective receivers, broadband detectors admit out-of-band signals. Unfortunately, the offending interference can't be filtered out using common low-pass or band-pass circuitry because the L/C elements would act like lengths of transmission line and transform the impedance readings as a function of frequency. Increasing generator power output can, in some instances, overpower interfering signals, but the current needed to deliver the additional RF power greatly reduces battery life. In fact, over 70% of the analyzer's 150-mA current drain is already allocated to the VFO and its amplifier stages for generating a low-harmonic level-amplitude test signal.

Most RF-interference problems occur at lower frequencies and are caused by high-power AM-broadcast stations. These signals couple efficiently into large antenna arrays and are especially problematic for 160-meter verticals. In the event you encounter intense local interference, we recommend using the *MFJ-731 Tunable Analyzer Filter*. It is designed to attenuate off-frequency signals between 1.8 and 30 MHz without introducing significant errors.

2.) Component Limitations: At very low voltage levels, diode detectors become nonlinear, a condition that reduces accuracy. The MFJ-259C minimizes this problem by using special microwave zero-bias Schottky detectors with linearity enhanced by compensating diodes. Using this technique, each analyzer is individually optimized to provide the highest accuracy possible with both high and low impedance loads, making the A/D converter's 8-bit resolution the analyzer's primary accuracy limitation.

3.) Stray Reactance: The length of electrical connections between components within the bridge circuit, and the line between the bridge and antenna connector, may introduce inaccuracy at higher frequencies and when the load impedance is very high or very low. However, the MFJ-259C minimizes this problem with careful pc layout and by using low-capacitance microwave-grade surface-mount components with virtually no lead length.

While some analyzers may display misleading "exact readings" falling outside the reliable measurable range, the MFJ-259C does not. Instead, it is programmed to generate a *display warning* for out-of-range results. For example, if ($Z > 650$) appears on your display, it means the impedance being measured is greater than 650 ohms and outside the reliable measurement range.

1.2 Typical Uses

The MFJ-259C may be used to adjust, test, or measure the following:

- Antennas:**SWR, impedance, reactance, resistance, resonant frequency, and bandwidth
- Antenna tuners:**SWR, bandwidth, frequency
- Amplifiers:**Input and output matching networks, chokes, suppressors, traps, and components
- Coaxial transmission lines:**SWR, length, velocity factor, approximate Q and loss, resonant frequency, and impedance
- Filters:**SWR, attenuation, and frequency range
- Matching or tuning stubs:**SWR, approximate Q, resonant frequency, bandwidth, impedance
- Traps:**Resonant frequency and approximate Q
- Tuned Circuits:**Resonant frequency and approximate Q
- Small capacitors:** Value and self-resonant frequency
- RF chokes and inductors:**Self resonant frequency, series resonance, and value
- Transmitters and oscillators:**Frequency

The MFJ-259C measures and displays the following:

Cable length (feet)	Impedance phase (degrees)	Resonance (MHz)
Cable Loss (dB)	Inductance (uH)	Return loss (dB)
Capacitance (pF)	Reactance or X (ohms)	Signal Frequency (MHz)
Impedance or Z magnitude (ohms)	Resistance or R (ohms)	SWR (referenced to 50 ohms)

The MFJ-259C as a non-precision signal source:

VFO output is leveled at approximately 3-Vpp, or around 20 milliwatts into a 50-ohm load. This signal is relatively pure with harmonics better than -25 dBc (dB below the fundamental-frequency carrier). The internal source impedance (Zo) is 50 ohms.

A more complete description of the MFJ-259C's features along with proper measurement methods can be found by reading sections covering the particular measurement you wish to make. Consult the table of contents for various applications.

1.3 Frequency Range

The MFJ-259C covers 0.53* to 230 MHz without frequency gaps using a precision reduction-drive VFO tuning capacitor and two band switches. Bands of coverage are:

Main Switch:	<u>155-230 MHz</u>	<u>113-155 MHz</u>	<u>67-113 MHz</u>	<u>28-67 MHz</u>	<u>11-28 MHz</u>	<u>Lower Range</u>
Lower Range Switch:	<u>4.7-11 MHz</u>	<u>2.1-4.7 MHz</u>	<u>1.0-2.1 MHz</u>	<u>0.53-1.0 MHz*</u>		

*Note that LF coverage may be shifted from 0.53-1.0 MHz down to 0.47 - 0.94 MHz for 600-Meter and maritime frequency coverage. To retune, remove the cabinet and use a small hex wand (2-mm) to adjust inductor L12 while watching the LCD frequency display.

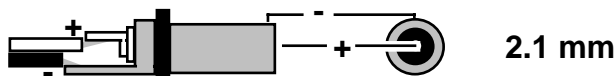
2.0 POWER SOURCES

Please read this entire section before connecting your analyzer to any power source. Improper connections or incorrect voltages may cause permanent damage to your analyzer!

2.1 External Power Supply

MFJ offers an optional power supply, the MFJ-1312D, that satisfies all external supply requirements. We strongly recommend using this supply. If you use a different power source, note that the voltage output must be greater than 11 volts and less than 16 volts when the analyzer is powered on and running (loaded power source). The maximum voltage in Sleep Mode (unloaded power source) should never exceed 18 volts. AC adapters must be well filtered and the plug must have a grounded sleeve and positive center lead. The ideal voltage-source specification is 13.8 VDC at 150 mA. Confirm your supply can deliver this output level safely without overheating or introducing excessive AC ripple.

Please read the battery installation instructions (Section 2.3) if you plan to install batteries. Never connect external DC power if non-rechargeable batteries are installed and the battery charger is enabled. Permanent damage could result!



The MFJ-259C has a recessed 2.1 mm power jack located on the top-right-hand side of the unit. It is labeled Power 13.8 VDC. The jack's outside barrel contact is negative and the center pin is positive. Inserting a power plug into the power jack automatically disables the internal batteries as a power source. However, the batteries will be trickle charged if the charger circuit is enabled.

IMPORTANT WARNING: Reverse Polarity Or Excessive Voltage Can Damage Or Destroy The MFJ-259C. Never Apply More Than 18 Volts, Never Use AC-output or Positive Ground Supplies!

2.2 Using Internal Batteries

Before installing batteries for the first time, check the position of the Charger Jumper. To gain access, remove the eight screws securing the analyzer's back cover and separate it from the unit. Look for a 3-pin header with a small black-plastic shorting plug that fits over two of its pins. It is located at the top of the main pc board near the OFF-ON switch and power connector. The shorting plug must be properly positioned for the type of battery you intend to use (either rechargeable or non-rechargeable). While you have the analyzer's case removed, you may install batteries into their tray -- or install them later by removing the battery-tray door that is attached to the rear of the case with two screws.

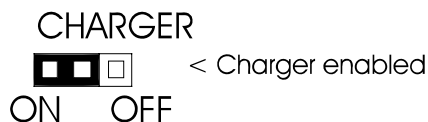
2.3 Using Rechargeable "AA" Type Batteries

IMPORTANT WARNING: Do not use an external power sources that deliver less than 13.8 volts with rechargeable batteries installed. If the external supply voltage is too low, the charger will not work properly and batteries will eventually discharge. We recommend charging batteries with the MFJ-259C power switch off and allowing enough charging time to establish full battery charge. A minimum of ten hours is recommended.

When using rechargeable batteries, your power source must deliver a minimum of 13.8 volts to meet the minimum charge-voltage threshold. Typical charging current is 10-20 mA (trickle-charge rate). The charger circuit functions any time external power is connected, even when the analyzer is turned off. Again, the MFJ-1312D supply fulfills all power supply and charging requirements for the MFJ-259C and is recommended.

When using rechargeable batteries, the internal black plastic jumper must be set to the proper position. If it is not set properly, the batteries will not charge. As described above, the jumper is located inside the analyzer, near the external power jack on the back side of the circuit board.

For rechargeable batteries, set the jumper as shown below:



2.4 Using Conventional “AA” Drycell Batteries

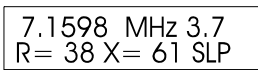
Whenever possible, install a fresh matched set of high-quality alkaline batteries. Conventional zinc cells will work, but alkaline batteries offer a lower risk of damage caused by leakage. Alkaline cells also provide longer running time and superior shelf life. *When using any non-rechargeable dry-cell battery, always remove them immediately when they become weak to avoid damage from leakage. Also, never store your analyzer for extended periods (longer than a month) with non-rechargeable batteries installed.*

IMPORTANT WARNING: When Using Non-Rechargeable Batteries, The Analyzer's Internal Charging System Must Be Defeated! To Defeat The Charger, Set The Internal Jumper To The Charger-Off Position, As Shown Below:



2.5 “Power Saving” Mode (sleep mode)

The analyzer's current drain is normally around 150 mA, which places a moderate demand on the battery pack. You can extend the analyzer's running time significantly by using the internal *Sleep Mode* power-saving function. In *Sleep Mode*, the analyzer's RF-generator shuts down and battery drain drops to under 15 mA. Any time *Sleep Mode* is activated, the analyzer operates with a *two-minute inactivity window*. *During any 2-minute period, you must actuate the Mode switch -- or adjust the frequency by more than 50 kHz -- at least once for the analyzer to remain awake.* Any time a two-minute inactivity period elapses, the power saving circuit automatically switches in. When the analyzer goes to sleep, a blinking *SLP* message will appear in the display's lower right corner, as shown below:



To reawake the unit, momentarily press either the *Mode* or *Gate* button.

To Disable *Sleep mode*:

- (1.) Turn the analyzer off.
- (2.) Press and hold the *Mode* button while reapplying power.
- (3.) Continue holding the *Mode* button until the copyright message appears on the screen.
- (4.) Release *Mode*. If *Sleep Mode* was disabled successfully, the message shown below will appear on-screen. *The Sleep Mode function becomes re-enabled anytime the analyzer is turned Off and On again.*



3.0 MAIN MENU AND DISPLAY

IMPORTANT WARNING: Never Apply RF or any other external voltage to the Antenna port of this unit. The MFJ-259C uses zero bias detector diodes that may be damaged by external voltages. Read Section-2.0 before applying power! Incorrect supply voltages will also damage this unit.

3.1 General Connection Guidelines

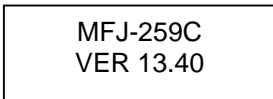
- 1.) **Antenna Jack:** When making RF measurements, connect your *Device Under Test* (DUT) to the SO-239 connector located on the top of the case. You'll use this port for *SWR* and all other RF measurements excluding the *Frequency Counter* function.
- 2.) **Power connector:** (2.1 mm type) is described in Section 2.0. Be sure to read Section-2.0 *before* operating your unit. Using an incorrect power sources can permanently damage the analyzer.

3.) **Frequency Counter Input:** BNC connector used for frequency-counter functions only.

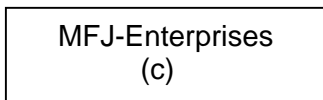
3.2 Power-up Display

After turning on the *Power* switch (or after applying external power with the switch on), a sequence of three message screens appear on the display.

The first screen presents the analyzer's software version (*VER*).



The second message shows the software copyright symbol.



The third message provides a power-source check, displaying the internal battery or external power supply voltage level along with a warning if the source is too low to support reliable operation.



The fourth and final power-up display is the *working screen* for the analyzer's default operating mode, as described in Section 3.2 (*SWR, Impedance R&X*). The two analog panel meters also become active, displaying *SWR* and *Impedance Magnitude (Z)* measurements for the DUT.

The MFJ-259C has five (5) Basic Operating Modes that are used for conducting a variety of measurements. If you tap (momentarily press) the *Mode* button, the analyzer steps to the next *Mode* selection. The five main modes and their opening screens are described in Section-3.3 below:

3.3 Main MODE descriptions

Press the *Mode* switch to scroll through the analyzer's five operating modes. By "scrolling", we mean that each tap of the mode switch will step the analyzer ahead to the next menu selection. Each new selection comes up on the display with an *Identifier Screen*. After 3 seconds, the *Identifier Screen* is replaced by the mode's working screen. The menu is circular, so after sequencing through all five choices, the sequence starts over. The five basic operating modes are described in detail below:

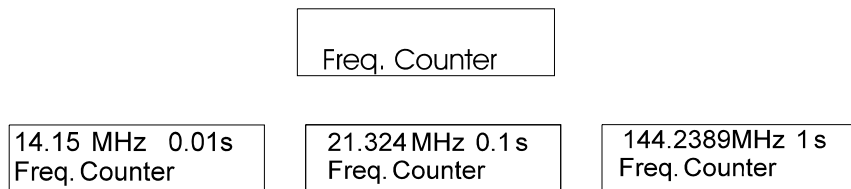
1.) **Impedance R&X (Initial Mode):** Use this mode for measuring SWR and complex impedance. The *Impedance R&X* mode is the analyzer's "default" mode because it is the one most frequently used for routine antenna adjustments. The top line of the working display shows the *VFO Frequency* in MHz and the numerical *SWR* reading. The lower line displays the *Resistive (R)* and *Reactive (X)* impedance components for the attached load. Pressing and holding the *Gate* button in this mode displays the *Impedance Magnitude (Z)* and *Phase Angle (Ø)*. The analog *Impedance* meter also displays *Impedance Magnitude (Z)*, and the *SWR* meter displays *Standing Wave Ratio (SWR)*. The analog meters are especially useful when tuning continuously adjustable circuits such as an ATU or matching networks. The identifier screen for the *Impedance R & X* mode is shown below:



2.) **Coax Loss:** Use the analyzer's second mode to measure loss incurred in random lengths of 50-Ohm cable, 50-Ohm attenuator pads, 50-Ohm transformers, and 50-Ohm baluns. The top working-display line shows the *VFO Frequency* in MHz and the lower line presents the measured *Loss* in dB. *Note that the transmission line or*

device under test must be unterminated at its far end during loss testing. If a load or resistive termination is installed, the measured loss will be significantly higher than the actual loss. Note that this measurement mode only works for lines or devices carrying differential currents.

- 3.) **Capacitance in pF:** Use this mode for checking unknown capacitor values (in pF) and for determining how much reactance a component exhibits at a particular frequency (X_c in ohms). In *Capacitance Mode*, the top line of the working display shows the *VFO Frequency* in MHz and the measured *Capacitive Reactance (X_c) at the VFO frequency* (in ohms). The lower line shows the measured capacitance (C) in picofarads (pF). The analog *Impedance* meter also displays X_c reactance in ohms.
- 4.) **Inductance in uH:** In *Inductance Mode*, the top line of the working display shows the *VFO Frequency* in MHz and the capacitive reactance (X_L) *at the VFO frequency* (in ohms). The lower line shows the measured inductance (L) in microhenries (μH). The *Impedance* meter displays reactance in ohms.
- 5.) **Frequency Counter:** The fifth mode converts the analyzer into a discrete frequency counter. Connect the RF source (DUT) to the BNC connector labeled *Frequency Counter Input*. As with many counters, the sensitivity threshold for a locked-in reading gradually decreases with increasing frequency. The measurement threshold at 0.53 MHz is around 10 millivolts -- and this level gradually increases to around 200 millivolts at 230 MHz. **The "never exceed" limit for safe testing is 2-volts peak-to-peak.** The counter's default gate time is 0.1 second, but you may reset it to either .01 second (very fast) or 1.0 second (very slow) by tapping the *Gate* button. A 1.0-second gate times provide increased frequency resolution (more digits to the right of the decimal point), and the .01 gate provides very fast response with less resolution (see sample screens below):



IMPORTANT WARNING: *Never apply more than two volts of peak voltage -- or any dc voltage -- to the Frequency Counter BNC port.*

3.4 Blinking "VOLTAGE LOW" display warning

If the external dc source or battery voltage drops below 11 volts, a blinking *Voltage Low* warning will come up on the display. Pressing *Mode* during a low-voltage warning will disable it and allow you to continue testing.

Caution: *Measurements made with supply voltages below 11 volts may not be as reliable.*



4.0 MAIN (OR OPENING) MODE

IMPORTANT WARNING: Never apply RF or any other external voltages to the Antenna port of this unit. This unit uses zero bias detector diodes that are easily damaged by external voltages over a few volts. Also, confirm the power supply is correct, as described in Section-2.0, before operating this unit.

A basic understanding of antenna theory and transmission line behavior will be helpful for making the best use of the data provided by your MFJ-259C. The ARRL Handbook and ARRL Antenna Book provide concise peer-reviewed explanations that should suffice for most applications. When it comes to the finer points of antenna design, there is (unfortunately) a fair amount of mis-information circulating on the web and over the airwaves. When it comes to antenna systems, there's no black magic. Stick with the scientific fundamentals as presented by credible professional sources, and everything your analyzer tells you should make sense!

4.1 General Connection Guidelines

When conducting *SWR* and *Impedance* measurements, follow these practical guidelines:

- 1.) If connector transitions (RF adapters) are needed, use only high-quality parts and check them over for wear, oxidation, dirt, and tight pin contact before proceeding.
- 2.) Make all connection electrically secure and keep all leads as short as possible. This precaution is especially important when measuring electrical components that are not part of a 50-ohm coaxial system.
- 3.) Always use good quality 50-ohm cable and connectors when making *SWR* measurements. Contaminated, mismatched, or damaged cable will introduce significant error.
- 4.) When making *Complex Impedance* measurements, ($R+X$) or (Z), remember that **any length of transmission line you install between the load and the analyzer will displace the load from the analyzer's calibration plane**. For simple handheld analyzers like the MFJ-259C, the *calibration plane is always located at the analyzer's RF connector*. This is the point where $Z_0=50$ Ohms and Phase shift = 0 degrees. It is the only test point where the analyzer will be calibrated for complex impedance measurements. Displacing the load away from the analyzer's calibration plane through random lengths of coax will have little or no impact on *SWR* readings, but will introduce enough error through phase shift and transformer action to invalidate virtually any complex impedance measurement you might make! **When measuring Complex Impedance, install the MFJ-259C as close (electrically) to the DUT as possible!**

4.2 Antenna SWR

Use the SO-239 *Antenna* connector located on top of the MFJ-259C for all RF measurements (except those using the *Frequency Counter* mode). Follow the procedure below for measuring *SWR*:

- 1.) **If your antenna doesn't have a dc-grounded feed system, momentarily short the cable's center conductor to the shield immediately before connecting it to the analyzer.** This simple procedure will discharge any static buildup on the antenna and prevent damage to the analyzer's sensitive detector diodes.
- 2.) Connect the antenna lead to the analyzer's SO-239 *Antenna* connector.
- 3.) Set the VFO's two *Frequency* selector band switches to the appropriate range.
- 4.) Turn on the *Power* switch while watching the display. Battery voltage should read *OK* (11-16 volts).
- 5.) Following the boot screens, the default mode will come up with the working screen for *Frequency*, *SWR*, Resistance (R), and Reactance (X). The *SWR* and *Impedance* analog meters will also become active.

7.1598 MHz 3.6
R=153 X= 62 SWR

14.095 MHz Z>25
R(Z>650) SWR

- 6.) Adjust *Tune* (the VFO capacitor) as needed to find your desired test frequency -- or tune until you obtain a minimum *SWR* reading.

Note that the MFJ-259C also has *Advanced* antenna-measurement modes that are described in Section-5.0. However, unless you have a strong working knowledge of RF systems, you may find these added modes of limited value. Most represent more technical ways of expressing the same data offered by the basic modes.

Antenna hints:

- 1.) **Measuring Antenna Impedance:** For complex impedance measurements, you must install the analyzer as close as possible to the element's feed point (within or 1-2 degrees of phase shift) *or* use a precisely cut 1/2-wavelength of cable displace the calibration plane by a controlled amount (360-degree phase rotation).
- 2.) **Electrical Half-Wavelengths of Cable:** Installing a half-wavelength of cable between the load and the analyzer will rotate phase a full 360 degrees so that no apparent transformation takes place in the line. However, the response *will only be transparent on one discrete frequency*. Even a small frequency change will begin to skew your impedance readings and may even shift the antenna's resonant frequency because the cable will begin to introduce its own reactance into the system. Errors will compound with multiple half-wavelengths, so limit cable to one or two phase rotations at most!
- 3.) **SWR, Resonance, and Impedance:** *It's always preferable to measure SWR rather than resonance or impedance magnitude (Z) as the standard for adjusting your antenna.* By definition, minimum SWR (1:1) and maximum power transfer occur when the source, transmission line, and load impedance are all of equal value. Resonance occurs when reactance fully cancels at the antenna's feed point and the load becomes purely resistive ($X_c + X_L = 0$). Although *Minimum SWR* and *Resonance* often coincide closely, they are not directly correlated and rarely occur on exactly the same frequency. If your antenna doesn't happen to present a 50-ohm load at resonance, there will still be resistive mismatch in the system and lower SWR may actually occur on some other frequency. By the same token, if you adjust your antenna for an *Impedance* reading of 50 ohms, the load could have a substantial reactive component (e.g. $R=46$, $X=17$) that elevates SWR *and* shifts the minimum-SWR point to a different frequency. ***SWR is always your best predictor of antenna performance!***
- 4.) **Tuning and Matching:** Unlike simple wire dipoles, many antennas such as Yagis and verticals are adjustable for both *resonant frequency* and *impedance match*. Begin by setting these antennas for the element length prescribed in the instruction sheet -- or the calculated length. Then, adjust the matching network for minimum SWR. The two adjustments (tuning and matching) are separate but often interact, so be prepared to alternately readjust both element length and network setting to achieve minimum SWR at your exact frequency of interest.
- 5.) **Adding and Removing Feedline:** You should be able to add or remove lengths of feedline (or measure SWR at any point along the feedline) without observing a significant change in SWR. It is normal to see SWR *drop slightly* as cable is added, or see it *increase slightly* as cable is removed because of changes in resistive loss. However
 - (a.) if your SWR measurements *change a lot* with relatively small changes in cable length, or
 - (b.) SWR changes as the cable is moved around, or
 - (c.) SWR changes when the coax shield is grounded at some point part way between the antenna and the radio, look for a feed problem!Here are some possibilities to check:
- 6.) **Common Mode Current:** Your coax may be carrying *Common-Mode Current* on its outer shield and radiating RF. To eliminate this problem, install a Guanella current balun at the feed point. It will isolate the shield from the radiating portion of the antenna, stabilize SWR, reduce receiver noise, and suppress "RF in the shack". Installing a balun is good engineering practice -- and always worth doing!
- 7.) **Defective Cable:** Your coax may not really be 50 ohms. Kinks, water ingress, oxidation, corrosion, bad connectors, improper manufacturing, poor quality, or even mislabeling may be the cause. Check SWR with a dummy load installed at the far end of the cable. If the SWR is elevated or the *Impedance (Z)* fluctuates very much as you tune the analyzer's VFO, suspect defective cable.
- 8.) **Excessive Transmission Line Loss:** Your cable may exhibit unusually high losses caused by damage or contamination. Or, it may simply have too much normal attenuation for the frequency range where you're using it (especially true at VHF). To look for unacceptably high loss, unterminate the cable at its far end and use the analyzer's *Coax Loss* mode to check it against specified values.

4.3 Coax Loss

Access the analyzer's *Coax Loss* mode by stepping the *Mode* switch to the *Coax Loss* identification screen. The top line of the working screen displays *Frequency* in MHz and the lower line shows *Coax Loss* in dB. Note that the *Impedance* meter is disabled in this mode. *Coax Loss* was designed to measure losses in 50-ohm cables, but also effectively measures the differential-mode loss in many types of 50-ohm transmission-line transformers, choke baluns, and 50 ohm attenuator pads.

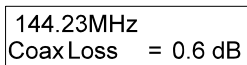
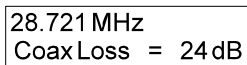
CAUTION: *Do not measure conventional transformers, or attenuators and coaxial cables that are not 50 ohms. When making measurements, the opposite end of the device under test must have an open circuit, a short circuit, or a pure reactance for termination. Any loss resistance will make attenuation appear worse than it actually is.*

To measure loss:

- 1.) Connect the 50-ohm cable, attenuator, transmission line type balun, or transformer under test to the *Antenna* connector. Confirm the distant end of the DUT isn't terminated by a resistance.
- 2.) Turn the analyzer *ON* and toggle the *Mode* switch once to the Coax Loss Screen.

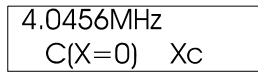
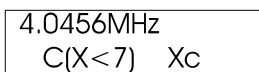
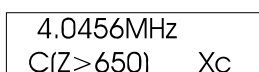
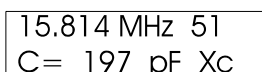


- 3.) Tune the analyzer's *VFO* to the frequency where you wish to measure loss. The loss in dB will be displayed for any specific frequency you select between 0.53 and 230 MHz.



4.4 Capacitance

Access the *Capacitance Mode* by stepping the *Mode* switch to the *Capacitance* identification screen. The top line of the working display shows the *Frequency* in MHz and the Capacitive Reactance (X_c) of the DUT at that specific frequency. The lower line displays the computed *Capacitance* in pF. Normally, the measurement range is from a few pF to a few thousand pF. The MFJ-259C becomes inaccurate when measuring reactance below 7 ohms or above 650 ohms. If reactance falls into the inaccurate range, $C(X<7)$, $C(X=0)$, or $C(Z>650)$ will be displayed. Capacitance values are not displayed when the measurement accuracy is questionable (see examples below):



Finding the Reactance Sign:

The MFJ-259C measures the DUT's reactance (X) and mathematically converts it to a capacitance value. However, the analyzer's processor can't determine if the reactance it measures is actually inductive or capacitive. You can usually determine the type of reactance by adjusting the *VFO* frequency. If you tune *up in frequency* and reactance (X) on the display or meter *decreases*, the load is capacitive ($-j$) at the measurement frequency. If you tune *down in frequency* and reactance *decreases*, the load is inductive ($+j$) at the measurement frequency.

To measure a capacitor:

- 1.) Turn on the analyzer and toggle the *Mode* switch twice to bring up the *Capacitance* identification screen.



- 2.) Connect the capacitor across the *Antenna* connector with the shortest leads possible, or include the lead length normally used in the actual circuit to include stray lead inductance in your measurement.

- 3.) Adjust the *VFO* to your frequency of interest. If a range warning comes up, find the closest frequency where no warning appears. Warnings are $C(Z>650)$, $C(X<7)$, and $C(X=0)$. The $C(X=0)$ warning indicates the capacitor appears as a near-perfect short.

When measuring a capacitor, it's displayed value in pF will typically change with the test frequency. The change occurs because stray inductance inside the capacitor and in the wires leading to the calibration plane are in series with it. The actual value (in pF) for most capacitors does increase with frequency and may reach infinity when the capacitive element and its stray inductance become series-resonant. This frequency is called the device's *Series Resonant Frequency* (where $X=0$). Bypass capacitors are sometimes intentionally operated at or near this frequency, but for most applications, the frequencies will be far below it. In addition to the display, the analyzer's *Impedance* meter displays the reactance (X in ohms) of the capacitor.

4.5 Inductance

Access the *Inductance* mode by stepping the *Mode* switch to the *Inductance* identification screen. The top line of the working display shows the *VFO Frequency* in MHz and the *Inductive Reactance (XL)* of the DUT at that particular frequency. The lower line shows the *Inductance* in uH. Inductance is calculated using the measured Reactance (XL) and the *VFO* frequency. The MFJ-259C will become inaccurate when measuring reactance below 7 ohms or above 650 ohms. If component reactance falls into an inaccurate range, $L(X<7)$ $L(X=0)$ or $L(Z>650)$ will be displayed. No inductance value is displayed if the range is questionable.

15.814 MHz 51 L= 0.513 uH XI	144.04 MHz L(Z>650) XI	3.5456MHz L(X<7) XI	4.0456MHz L(X=0) XI
---------------------------------	---------------------------	------------------------	------------------------

Positive Reactance Sign:

The MFJ-259C measures *Reactance* (X) and mathematically converts it to an *Inductance* value, but its processor can't determine if the reactance is inductive or capacitive. You can usually determine the type (or sign) of the reactance by adjusting the *VFO*. If tuning *up in frequency* cause the reactance to *decrease*, the load is likely capacitive ($-j$) at the measurement frequency. If tuning *down in frequency* causes the reactance to *decrease*, the load is likely inductive ($+j$) at the measurement frequency.

To measure an Inductor:

- 1.) Turn the analyzer on and step the *Mode* switch three times to bring up the *Inductance* identification screen.

Inductance
in uH

- 2.) Connect the inductor (DUT) across the *Antenna* connector using the shortest leads possible, or with the lead length normally used in your working circuit to include stray inductance in the measurement.
- 3.) Adjust the *VFO* to your frequency of interest. If an error sign comes up, choose the nearest frequency where no warning appears. The $L(X=0)$ warning indicates the inductor looks like a near perfect short to the analyzer's bridge and the frequency is too low (or the inductor too small) to measure. The digital display and the analog *Impedance* meter both present the DUT's reactance (X) in ohms.

When measuring an inductor, its displayed value will sometimes change with the test frequency. This happens because of stray capacitance between coil windings and in the leads going to the *Antenna* connector. At RF, the value of an inductor (in uH) may appear substantially different from its "rated" value that was determined at a lower frequency. With increasing frequency, measured inductance usually increases and, at some high frequency, the coil may become self-resonant and appear as an *open circuit* (or a trap) with infinite reactance. At some very low frequency, it may look like a short.

5.0 ADVANCED OPERATION

To access the Advanced Mode, press and hold the Gate and Mode buttons simultaneously for several seconds. When you release, the *Advanced* message appears on-screen. The *Advanced Menu* features the following modes:

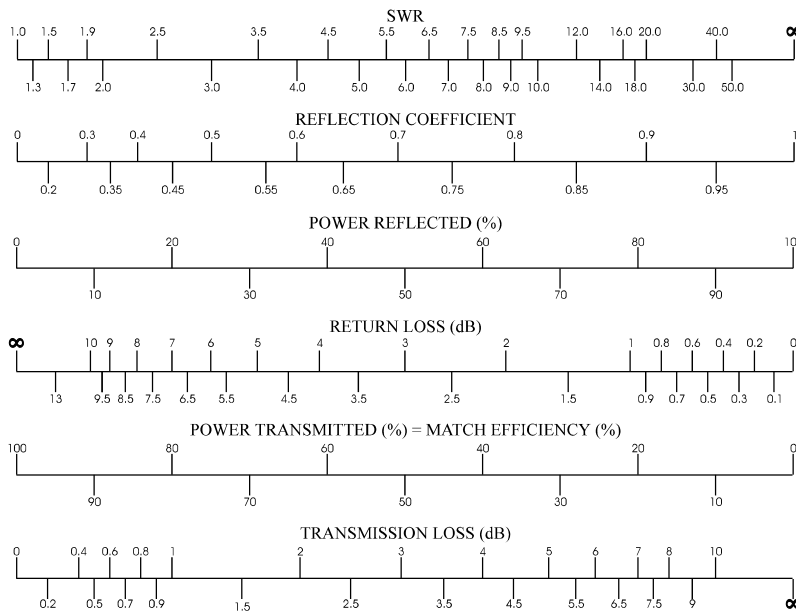
- Impedance. SWR, impedance magnitude, phase angle of impedance
- Return Loss and Reflection Coefficient. SWR, return loss, impedance, reflection coefficient
- Distance to fault SWR, impedance, and distance to fault
- Resonance SWR, resistance and reactance
- Transmit efficiency SWR, Impedance, Forward power as percentage of apparent power

5.1 Forward

In Advanced Mode, the MFJ-259C measures:

- (1.) *Distance to Fault,*
- (2.) *Impedance Magnitude,*
- (3.) *Reactance,*
- (4.) *Resistance,*
- (5.) *Standing Wave Ratio (SWR).*

It also converts basic *SWR* data into alternative parameters such as *Return Loss, Reflection Coefficient, Match Efficiency, Transmission Loss, and Percentage of Apparent Power in the system* (see equivalency chart below). All of these terms have a corresponding *SWR* value attached to them, so if they seem unfamiliar and you have no specific need to apply them, sticking with basic *SWR* measurements will serve you just as well!



MFJ-259C Limitations for Advanced Measurements:

The analyzer's coupler uses a 50-ohm bridge with voltage detectors across each leg. An eight-bit microcontroller processes these voltages and applies formulas to derive useful information from them. The basic calculations are *Resistance, Reactance, SWR, and Complex Impedance*. In accuracy challenged modes, the system crosschecks itself and presents a weighted average of the most reliable information. The overall resolution of the system is limited by eight-bit A/D conversion while some of the formulas contain square-law and higher-order functions. As a result, some data jumping may occur at the edges of a least-significant-bit. The resolution of the analyzer's compensated detector is accurate to about 0.5 %, and to minimize the opportunity for error, we use the most direct calculations possible.

Technical Resources:

As suggested previously, if you wish to delve in and acquire a deeper understanding of electromagnetics and transmission line theory or the associated vocabulary, it's always best to choose sources that have been peer-reviewed and edited by professional RF-design engineers. Not all of the casually posted information you'll read online or hear over the airwaves meets high standards of technical reliability!

5.2 General Connection Guidelines

As before, use the *Antenna* connector for all RF-measurement except those in *Frequency Counter* mode. During testing, the analyzer's VFO (or "stimulus generator") delivers about +7 dBm of RF output (around 0.5 V-RMS), and appears like a 50 ohm source resistance. The unterminated (open circuit) voltage increases to approximately 1 volt RMS. Harmonics are better than -25 dBc over the VFO operating range. While the VFO is not frequency stabilized, it is useful as a discrete signal source for many applications. Also, note that the *Antenna* connector is not dc-isolated from the load, so any external bias voltage will couple directly to the internal detectors diodes and potentially damage them.

IMPORTANT WARNING: *Never apply external voltages or RF signals to the antenna connector. Protect this port from ESD.*

Again, use secure RF connections, and keep leads short as possible when measuring components or systems other than $Z_0=50$ ohms. Also, assume that installing a random-length transmission line between the DUT and the analyzer's calibration plane can and *usually will* substantially alter *Impedance* measurements. When measuring SWR, use properly constructed 50-ohm coaxial cables of known quality and check connector condition.

5.3 (Magnitude of) Impedance mode

Impedance Magnitude is the first measurement mode in the advanced menu. The MFJ-259C also allows you to view *Impedance Magnitude* from the basic-menu *SWR/Impedance R&X* mode by simply pressing the *Gate* key. In Advanced Mode, the identification screen for *Impedance Magnitude* is shown below:

IMPEDANCE
Z=mag. θ =phase

The working display presents the *VFO* frequency, *Impedance Magnitude* in ohms, and the *Phase Angle* (θ) in degrees. The analog meters also indicate SWR and Impedance. The maximum impedance limit for this mode is set at 650 ohms, as indicated by the ($Z<650$) message:

28.814 MHz 3.6
Z=87 Ω θ =53 $^\circ$ SWR

4.0456MHz >25
(Z>650) SWR

Stray Connector Capacitance: The 4.4-pF stray capacitance contributed by the analyzer's SO-259 connector will not affect HF measurements and produce only minor errors for Impedances readings at VHF. Error will be most pronounced at 230 MHz.

5.4 Return Loss and Reflection Coefficient mode

From *Advance Mode*, open the *Return Loss* and *Reflection Coefficient* display by tapping *Mode* one time. The identification screen is shown below:

Return Loss &
Reflection Coeff

On the working screen, the *VFO* frequency and *SWR* are displayed on the top line, while the bottom line presents the equivalent *Return Loss* (in dB) and the *Voltage Reflection Coefficient* (ρ). The analog meters display SWR and impedance.

14.159 MHz	1.0	144.23MHz	1.9
RL=48 dB	$\rho_{\approx}0$ SWR	RL=9.6 dB	$\rho_{\approx}32$ SWR

5.5 Distance to Fault mode

From *Advance Mode*, enter *Distance to Fault* by tapping *Mode* twice. The identification screen is shown below:

Distance to
fault in feet

This mode is useful for finding the physical or electrical length of a random piece of cable, or for finding the distance to a transmission line fault. *Unbalanced lines* need not be isolated during testing and may be coiled on the floor. For *balanced lines* (ladder line, open-wire feeders, etc), run the MFJ-259C on internal batteries and keep it at least a few feet away from earth and other conductors. Attach only the DUT (no other wires) -- one lead to the center pin of the *Antenna* connector and the other to the case via the grounding stud. Suspend two-wire balanced feeder in a straight line so it remains clear of metallic objects and ground by at least a few feet.

The *Distance to Fault* test measures the *electrical distance* to the transmission line's abnormality. To obtain the *physical distance*, multiply *electrical distance* times the feed line's specified *Velocity Factor* (Vf). For example, if the analyzer display reads DTF = 75 feet and the transmission line is typical RG-8 with a specified velocity factor of 0.66, the physical distance to the fault will be: **75 x .66 = 49.5 feet**.

An open or a short-circuit at the fault yields best accuracy -- some resistive and reactive loads or L/C terminations may skew the results or simply not work. To conduct the test, follow the specific sequence of steps outlined below.

To measure fault distance:

- 1.) Connect the DUT to the analyzer's *Antenna* connector. From *Advanced* mode, tap the *Mode* switch twice to bring up the *Distance to Fault* ID screen. The top line of the working screen will display the *VFO* frequency in MHz followed by 1st blinking at a rapid rate. The 1st indicates the analyzer is waiting for entry of the first $X=0$ frequency. The lower line displays *DTF* (no data showing) and X with the *Reactance* reading in ohms.
- 2.) Begin by searching for the lowest *VFO* frequency where the *Impedance* meter shows a sharp null and where the reactance value on the screen approaches zero ($X=0$). If possible, find an *exact frequency* where $X=0$:

21.324 MHz 1st
DTF X=0

- 3.) When you've found the first $X=0$ null, tap the *Gate* button once to enter it. The blinking 1st will change to a blinking 2nd. Now, tune to the next higher $X=0$ null. A minimum reading of a few ohms is acceptable if the X display won't zero.

42.648 MHz 2nd
DTF X=1

- 4.) Press *Gate* again, and the display will indicate *DTF* times the velocity factor of the cable (*Vf*) to get the *physical DTF* (distance in feet).

Dist. to fault
11.3 ft x Vf

5.6 Resonance Mode

From the *Advanced* menu, tap the *Mode* switch three times to bring up the *Resonance Mode* ID screen. The top line of the working screen displays the *VFO* frequency in MHz followed by *SWR*. The lower line displays *Resistance* (*R*) and *Reactance* (*X*). *Resonance Mode* functions exactly the same as in the analyzer's basic *SWR* mode, except the

analog impedance meter measures Reactance rather than impedance magnitude. This feature allows the operator to more easily observe frequencies where system reactance crosses zero. When *Reactance* equals zero ($X=0$), all capacitive and inductive components at the load are cancelled out ($X_L+X_c=0$) and the circuit is said to be *Resonant*.

Resonance mode
tune for $X=0$

Accuracy Note:

As previously discussed in Section 4.2, when measured thro feedline, readings indicating zero reactance (or resonance) may appear at frequencies where the antenna itself isn't actually resonant. Conversely, the antenna may appear to exhibit some reactance even at its true resonant frequency. To ensure measurement accuracy, the analyzer's calibration plane should always be located as close to the DUT (or as close to 0-degrees of phase rotation) as possible.

5.7 Percentage Transmitted Power

From the *Advanced* screen, toggle the *Mode* button four times to open *Percentage of Transmitted Power*. This parameter is yet another way of representing the basic SWR measurement (see chart at 5.1). Mathematically, it is an inverse presentation of the Percentage of Reflected Power scale. If your load measures 3.1:1 SWR, the *Percentage of Reflected Power* in the system will be 26%. By subtracting 26% from 100%, the *Percentage of Transmitted Power* is 74% (see examples below).

1.8963 MHz 3.1 Power = 74 % SWR	50.097 MHz 1.3 Power =98% SWR	29.538 MHz >25 Power < 15% SWR
------------------------------------	----------------------------------	-----------------------------------

Note that the *Percentage of Transmitted Power* may be open to misinterpretation because the power ultimately absorbed into the load may be significantly different than the raw *Percentage of Transmitted Power* parameter might suggest.

6.0 ADJUSTING SIMPLE ANTENNAS

Most antennas are tuned for operating frequency by varying the element length -- and most homemade verticals and dipoles are very simple to adjust.

6.1 Dipoles

Because the dipole is a balanced antenna, it's always a good idea (and good engineering practice) to install a balun at the feed point. A balun could be as simple as several turns of coax wrapped several inches in diameter or it could be a complicated affair with many windings on a ferromagnetic core. A 1:1 Guanella "current" balun wound on a toroid core made from material with the appropriate permeability is usually the most effective choice.

The height of a dipole above ground, as well as any surrounding objects, will influence the feed point impedance and SWR. Typical residential heights usually result in minimum SWR readings below 1.5:1 when using 50-ohm coaxial cable. In general, the only adjustment available for tuning a simple wire dipole is its length. If too long, it resonates too low in the band. If too short, it resonates high. You may be able to improve the match (SWR) by raising or lowering the element in relationship to ground. However, doing so may impact other parameters such as the best take-off angle for distant or local contacts (TOA).

Anytime the antenna impedance and feedline impedance do not precisely match each other (as is usually the case), the feedline will act like a transformer and modify the *Impedance* of the load placed at the opposite end. However, if you use good-quality 50-ohm cable, the *SWR* should remain constant except for a small reduction caused by resistive loss as the line is made longer. If changing the coax length by a relatively small amount changes *SWR* at your test frequency, the feedline either has common-mode current flowing on the outer surface of the shield that is detuning the antenna, or the feedline itself is not really 50-ohm cable. Common-mode current caused by conduction typically occurs when no balun has been installed at the feed point to choke it off. Common-mode induction

currents may also result from other installation errors such as running the feedline parallel rather than perpendicular to the radiating element. Repositioning the feedline may reduce unwanted inductive coupling.

6.2 Verticals

Verticals in the "monopole" class require a ground plane. To simplify installation and cut costs, manufacturers sometimes (incorrectly) downplay the importance of an effective radial system. When installed over a good ground, the impedance of a quarter-wave radiator may be quite low, with SWR running nearly 2:1. Ironically, over a poor ground, minimum SWR for the same antenna could improve to 1:1. However, if the ground system is poor, antenna performance will be compromised despite favorable SWR readings. Far better to install the best ground system possible and configure a matching network at the base of the vertical element to match into a 50-ohm feed system. Verticals tune the same as dipoles -- add length to lower the operating frequency and shorten to raise it.

Another class of verticals are considered "ground-independent" because they come with a counterpoise or rigid radial system built into the design. These antennas are usually configured as multiband OCFDs (off-center fed dipoles) with the longer leg being the dominant vertical radiator. Ground independent verticals tend to work more efficiently when elevated well above ground rather than when installed in close proximity to it because of reduced ground losses. Many use multiple resonators or traps and have a matching network at the feed point. Most ground-independent vertical elements are asymmetrical and require a highly effective baluns to prevent the feedline from becoming part of the antenna system.

6.3 Tuning a simple antenna

To tune a basic dipole fed with 50-ohm coax, follow the steps outlined below:

- 1.) Momentarily short the center conductor and shield to bleed off static, then connect to the *Antenna* jack.
- 2.) Set the analyzer's band switches and *VFO* tuning for the desired band.
- 3.) Select any analyzer operating mode that will display *SWR*.
- 4.) Read the *SWR* and adjust the *VFO* tuning for minimum *SWR*. Write down the frequency.
- 5.) To re-tune your antenna accurately without a lot of cut-and-try, calculate a *Scaling Factor*.
- 6.) First, determine if the antenna needs to be shorter (higher in frequency) or longer (lower in frequency).
- 7.) To make it *shorter* (*higher*), divide the *present frequency* by the *desired frequency* (scaling factor <1).
- 8.) To make it *longer* (*lower*), divide the *desired frequency* by the *present frequency* (scaling factor >1).
- 9.) Multiply the *scaling factor* by the *present length* to calculate the new length.

For example, suppose your 132-foot dipole has low SWR on 3.750 MHz and you want to move it to 3.900 MHz. It needs to be shorter to tune higher, so you calculate the scaling factor: $3.750/3.900 = 0.96$. Next calculate the new length: $132 \text{ feet} \times .96 = 126.7 \text{ feet}$. Note that scaling only applies to full-size verticals and dipoles that don't use loading coils, traps, stubs, resistors, capacitors, or capacitance hats. Antennas with these features should be adjusted according to the manufacturer's instructions.

7.0 TESTING AND TUNING STUBS AND TRANSMISSION LINES

7.1 Testing Stubs

To measure *Resonant Frequency* for a matching stub or transmission line, select the *SWR/Impedance* mode in the *Basic Menu* (opening mode). Note that DUTs measuring $1/4\lambda$ and odd multiples ($1/4\lambda$, $3/4\lambda$, $5/4\lambda$, etc) are terminated with an open circuit at the far end. DUTs measuring $1/2\lambda$ and even multiples (1λ , $1-1/2\lambda$, 2λ) are terminated with a short circuit.

Coaxial lines may be piled or coiled on the floor and the analyzer operated on external power. Coax lines are connected to the analyzer's SO-239 connector with the shield grounded. For *balanced line*, run the analyzer on its internal batteries, keep it a few feet away from other conductors and earth, and do not attach any stray wires (other than the feedline itself). Connect the DUT with one lead to the analyzer's ground stud and the other lead to the *Antenna* connector center pin. The DUT *must* be suspended and kept away from metallic objects and ground. When tuning frequency-critical stubs, trim them *gradually* using the method outlined below:

- 1.) Determine the DUT's target frequency and calculate the length to formula.
- 2.) Cut the DUT 20% longer than your calculated length.
- 3.) At the far end, install a short for $1/2\lambda$ and even multiples -- or leave it open for $1/4\lambda$ and odd multiples.
- 4.) Tune *VFO* to find the frequency of the lowest *Impedance* null. To fine-tune the null, watch the *Reactance (X)* digital display and adjust as close to zero as possible. If your calculations were correct and the feedline *Vf* accurate, the null frequency should be about 20% below your target frequency -- reflecting the 20% in added length.

Continuing:

- 5.) Divide the *present frequency* by the *desired frequency* to calculate a *Scaling Factor*.
- 6.) Multiply the *Scaling Factor* by the feed line's *present* physical length to find the *desired* physical length.
- 7.) Cut the stub and confirm that the reactance null ($X=0$) is on the desired frequency.

7.2 Velocity Factor of Transmission Lines

To determine the *Velocity Factor (Vf)* of a transmission line, select the *Distance to Fault* mode by entering the *Advanced* menu and pressing *Mode* twice. The opening screen is shown below:

Distance to
fault in feet

Coaxial lines may be piled or coiled on the floor and the analyzer can be operated on external power. Coax lines are connect to the analyzer's SO-239 connector with the shield grounded. For *balanced line*, run the analyzer on its internal batteries, keep it a few feet away from other conductors and earth, and do not attach any stray wires (other than the feedline). Connect the DUT with one lead to the analyzer's ground stud and the other to the *Antenna* center pin. The DUT *must* be suspended and kept away from metallic objects and ground.

Note that the *far end of the line may be terminated with an open circuit or a short circuit, but should not be terminated by any other impedance or resistance value.*

To compute *Velocity Factor*, you must measure both the *electrical length (DTF)* and the *physical length* of the line. Velocity factor is calculated by dividing the *physical length* by the *electrical length*. For example, if the analyzer displays an *electrical length* of 75 feet and the physical length measures 49.5 feet, the velocity factor will be: **$Vf = 49.5 / 75 = 0.66$** .

To check reliability, make two or more groups of measurements using different starting frequencies spaced at least one octave apart. If measured distances agree, your result is confirmed. The more frequencies you use for confirmation, the greater your assurance that the results are correct.

To measure velocity factor:

- 1.) Connect the DUT and tune the analyzer *VFO* to a frequency where the analog *Impedance* meter nulls and where reactance displayed on the screen approaches or crosses zero ($X=0$).

21.324 MHz 1st
DTF X= 0

- 2.) Tap *Gate* once to enter your first $X=0$ frequency. The blinking *1st* will change to a blinking *2nd*.

21.324 MHz 2nd
DTF X= 0

39.756 MHz 2nd
DTF X=202

- 3.) Tune the analyzer higher (or lower) in frequency until the *Impedance* meter reads the *next* null and the display again crosses zero. If you can't obtain $X=0$, then a minimum of a few ohms is acceptable.

68.511 MHz 2nd
DTF X=1

4.) Tap *Gate* again, and the display will show electrical distance in feet.

Dist. to fault 10 ft x Vf

5.) Using a tape measure, find the physical length of the DUT in feet.

6.) Divide your *physical length* measurement by the *electrical length* to calculate Vf.

For example, if you measure 27 feet of cable and the *DTF* mode displays 33.7 feet, divide *physical length* (27) by *electrical length* 33.7 feet: $Vf = 27/33.7 = 0.80$. Note that *Velocity Factor* (Vf) may also be expressed as *Velocity of Propagation* (Vp). Velocity of Propagation is an equivalent term expressed as a percentage ($Vp = 80\%$).

7.3 Impedance of Transmission Lines or Beverage antennas

This procedure will show you how to measure the impedance of transmission line ranging from a few ohms to 650 ohms directly -- and also how to measure even higher-impedance lines using a broadband transformer or resistance to extend the analyzer's range. To measure the necessary parameters, use the analyzer's default SWR -- *Resistance (R) and Reactance (X) Mode* augmented by the *Impedance Magnitude* function (access by pressing and holding the *Gate* switch).

Methodology:

When random-length transmission line is terminated by a load of the same impedance, no transformation occurs between the cable's near end and far end. However, as soon as a mismatch is introduced at one end, the impedance transforms to a value higher or lower than the line's *characteristic impedance* at the opposite end. If viewed on a Smith Chart, the transformed impedance would literally trace a circle around the characteristic impedance of the transmission line with every 360-degree phase shift. The greater the mismatch in ohms, the greater the amplitude (or diameter) of the circle. We can use this behavior to determine the impedance of an unknown line. Taking one approach, we intentionally introduce a resistive mismatch at the far end of the line, measure the impedance transformation over a 360 phase rotation at the near end, and calculate the impedance at the center. Or, we introduce different trial loads of known resistance at the far end until we find a value where the cable becomes "flat" across a wide range of frequencies. In essence, we create a circle and then shrink it down until only the center remains.

As recommended for other transmission line tests, *coaxial cable* may be piled or coiled on the floor and the analyzer operated on internal or external power. For *balanced line*, run the analyzer on internal batteries, keep it away from other conductors or earth, and don't attach stray wires other than the DUT. Connect the balanced DUT with one lead to the analyzer's ground stud and the other to the *Antenna* center pin. The DUT *must* be suspended and kept a few feet away from metallic objects and ground. Beverage antennas must be connected directly to the analyzer.

Line Impedance Using an Intentional Mismatch:

The test resistance should be somewhere near (but different from) the line's anticipated impedance. When choosing a resistance value, consider the limits of the analyzer's measurement range (7 - 650 ohms) and stay well within it.

- 1.) Connect the DUT to the *Antenna* connector.
- 2.) Terminate the far end of the DUT with a non-inductive test resistance.
- 3.) Tune *VFO* to the *lowest frequency* where the *Impedance* and *Resistance* indicators both null.
- 4.) Fine tune to find where *X* is closest to 0 and *R* is at its minimum value (null).
- 5.) Press *Gate* to confirm $\theta = 0^\circ$. Write down the *Resistance (R)* value as R1.
- 6.) Tune up in frequency to find a distinct *Impedance peak*. Once again, *X* should approach or equal 0.
- 7.) Fine tune for the *highest Resistance (R)* value and confirm $\theta = 0^\circ$. Record *Resistance (R)* as R2.
- 8.) Multiply R1 x R2 and find the square root of the product. The result is the line's characteristic impedance.

Example: R1 = 37 ohms. R2 = 66 ohms. $37 \times 66 = 2442$. The square root = **49.42 ohms**.

Line Impedance Using a Potentiometer or Resistor Decade Box:

Limit these measurements to the HF region because stray reactance from a potentiometer or decade box could become a significant source of error at VHF frequencies. Also, use only non-inductive resistances (no wire-wound resistors). If needed, you may install a broadband transformer of known performance accuracy to extend the measurement range.

- 1.) Connect the DUT to the *Antenna* connector.
- 2.) Terminate the far end with a potentiometer or resistance decade box.
- 3.) Adjust the analyzer's *VFO* frequency and note *only* the SWR change (SWR need not be low).
- 4.) Adjust termination resistance until SWR remains constant over the widest possible range.
- 5.) The resistance of the termination resistor is the line impedance (or surge impedance of the system).

7.4 Adjusting Tuners

Use a short patch cable to connect the analyzer's *Antenna* jack to the tuner's 50-ohm input. This connection may also be made with a manual RF switch to facilitate rapid changeover, *provided the switch has >50-dB port isolation*. When using any in-line switch, make sure there is no possible way for the transmitter and the analyzer to become inadvertently connected!

Important Warning: Always connect the common (rotary contact) of the external RF switch to the tuner. The switch must connect either the MFJ-259C or the station transceiver to the tuner. Transmitting equipment must never be configured in a manner where it could accidentally become connected to the MFJ-259C.

- 1.) Patch the analyzer *Antenna* jack to the tuner input connector.
- 2.) Connect the desired antenna at the tuner output connector.
- 3.) Tune the analyzer *VFO* to the desired frequency and leave it there.
- 4.) Select the analyzer's basic *SWR*, *Resistance (R)*, *Reactance (X) Mode*.
- 5.) Adjust the tuner's controls until the analyzer's *SWR* indicators show unity (1:1).
- 6.) Turn off and disconnect the MFJ-259C. Re-connect the tuner to the transmitter.

7.5 Adjusting Amplifier Matching Networks

To use the MFJ-259C for testing and adjusting RF amplifiers or other matching networks *without applying operating voltages*, see the instructions below. Note that all tubes and other components should be left in position and connected so that all sources of stray capacitance will remain unchanged.

To measure input circuits: Install a non-inductive resistor equaling the approximate driving impedance of each individual tube between the cathode of each tube and the chassis.

To measure tank circuits: Install a resistor equal to the tube's calculated operating impedance from the anode to the chassis using *short leads*.

The antenna relay (if internal) may be engaged using a small external power supply. Closing the relay will connect the amplifier's external RF input and output connectors to the amplifier's internal RF-matching networks. The appropriate network may now be adjusted. When the analyzer reads 50 ohms and 1:1 SWR at the operating frequency with the proper amounts of capacitance to set the system Q, the networks are functioning properly.

Caution: The driving impedance of most amplifiers will change as the input drive level is varied. Do not attempt to adjust the input network with the tube in an operating condition using the low level of RF generated by the MFJ-259C stimulus generator!

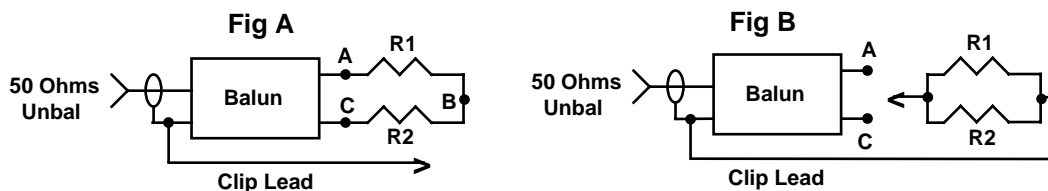
7.6 Testing RF Transformers

The MFJ-259C can test any RF transformer presenting a 25-100 ohm termination on one of its windings. Connect the 25-100 ohm winding to the analyzer's *Antenna* jack using a *very short* 50-ohm pigtail (<1° phase shift). The

other winding (or windings) should be terminated with a low-inductance resistor equal to the desired load impedance. Sweep the analyzer's *VFO* across the DUT's intended operating range. Use the basic *SWR*, *Resistance (R)* *Reactance (X)* Mode (plus the Impedance Magnitude [Z] option) to evaluate the DUT's impedance and useable bandwidth. You may also measure the transformer's efficiency by comparing the source voltage generated by the MFJ-259C to the load voltage using standard power-level conversions.

7.7 Testing Baluns

To test balun performance, connect the analyzer *Antenna* jack to the balun's 50-ohm unbalanced input. Terminate the balanced side with two equal-value load resistors connected in series to make up the required load impedance. For example, to test a 200-ohm (4:1) secondary, use a pair of 100-ohm carbon (non-inductive) resistors in series, as shown below in Fig A:



A properly designed current balun works best for maintaining current balance. It also has the highest power capability and lowest loss for given materials. To evaluate the balun (DUT), measure *SWR* while connecting the grounded clip lead to point A, B, and C. When functioning properly, a current balun will exhibit low *SWR* over its entire operating range with the clip lead installed at any of those three positions.

A well designed voltage balun should show low *SWR* over its operating range with the clip lead installed at position B, but show poor *SWR* with the clip lead is installed at A or C (note, however, that the *SWR* readings should measure about the same whether connected to A or C). A voltage balun should also be tested using the configuration shown in Fig B, with the resistors in parallel. If it is operating properly, *SWR* will remain low with the resistors connected from either output terminal to ground.

7.8 Testing RF Chokes

For testing self-resonance in chokes, use the analyzer in basic *SWR*, *Resistance (R)* + *Reactance (X)* Mode. Large RF chokes often have frequencies where distributed capacitance and inductance form a low impedance *series-resonance*. *Series resonance* occurs because the choke winding acts like a succession of back-to-back L networks. This condition can potentially result in three problems:

- 1.) The end-to-end Impedance of the choke becomes very low.
- 2.) The voltage at the center of the resonant point becomes very high, often causing severe arcing.
- 3.) The current in the winding becomes very high, often resulting in severe heating.

To detect troublesome series resonance, install the choke in its designated operating location and connect the analyzer in an end-to-end configuration through a short 50-ohm jumper cable (with no other connections). Slowly sweep the choke's operating range looking for impedance dips that identify low-impedance series-resonant frequencies. When detected, move a small insulated screwdriver blade along the choke to find a point where the series-resonate impedance changes suddenly. This is the region that has the highest voltage present, and the area where adding or subtracting even a tiny amount of capacitance had the greatest effect. To shift the resonance out of the desired frequency range, try removing turns to reduce capacitance -- or adding a capacitive stub. A small change in capacitance has a much more impact than making a small change in inductance because the ratio of L to C is so high.

8.0 TECHNICAL ASSISTANCE

If you have any problem with your MFJ-259C, first check the appropriate section of this manual. If the manual does not reference your problem and the problem isn't solved by reading the manual, you may call *MFJ Technical Service* at **662-323-0549** or the *MFJ Factory* at **622-323-5869**. We can serve you best if you have your unit, manual, and all pertinent information about your difficulty handy so you can answer questions the technicians may ask.

You can also send questions by mail to:

MFJ Enterprises, Inc.,
300 Industrial Park Road,
Starkville, MS 39759;

by FAX to 662-323-6551; or by e-mail to techinfo@mfjenterprises.com. Send a complete description of your problem, an explanation of exactly how you are using your unit, and a complete description of your station.

FULL 12-MONTH WARRANTY

MFJ Enterprises, Inc. warrants to the original owner of this product, if manufactured by MFJ Enterprises, Inc. and purchased from an authorized dealer or directly from MFJ Enterprises, Inc. to be free from defects in material and workmanship for a period of 12 months from date of purchase provided the following terms of this warranty are satisfied.

1. The purchaser must retain the dated proof-of-purchase (bill of sale, canceled check, credit card or money order receipt, etc.) describing the product to establish the validity of the warranty claim and submit the original or machine reproduction of such proof of purchase to MFJ Enterprises, Inc. at the time of warranty service. MFJ Enterprises, Inc. shall have the discretion to deny warranty without dated proof-of-purchase. Any evidence of alteration, erasure, or forgery shall be cause to void any and all warranty terms immediately.
2. MFJ Enterprises, Inc. agrees to repair or replace at MFJ's option without charge to the original owner any defective product provided the product is returned postage prepaid to MFJ Enterprises, Inc. with a personal check, cashiers check, or money order for **\$12.00** covering postage and handling.
3. MFJ Enterprises, Inc. will supply replacement parts free of charge for any MFJ product under warranty upon request. A dated proof of purchase and a **\$8.00** personal check, cashiers check, or money order must be provided to cover postage and handling.
4. This warranty is **NOT** void for owners who attempt to repair defective units. Technical consultation is available by calling (662) 323-5869.
5. This warranty does not apply to kits sold by or manufactured by MFJ Enterprises, Inc.
6. Wired and tested PC board products are covered by this warranty provided **only the wired and tested PC board product is returned**. Wired and tested PC boards installed in the owner's cabinet or connected to switches, jacks, or cables, etc. sent to MFJ Enterprises, Inc. will be returned at the owner's expense un-repaired.
7. Under no circumstances is MFJ Enterprises, Inc. liable for consequential damages to person or property by the use of any MFJ products.
8. **Out-of-Warranty Service:** MFJ Enterprises, Inc. will repair any out-of-warranty product provided the unit is shipped prepaid. All repaired units will be shipped COD to the owner. Repair charges will be added to the COD fee unless other arrangements are made.
9. This warranty is given in lieu of any other warranty expressed or implied.
10. MFJ Enterprises, Inc. reserves the right to make changes or improvements in design or manufacture without incurring any obligation to install such changes upon any of the products previously manufactured.
11. All MFJ products to be serviced in-warranty or out-of-warranty should be addressed to **MFJ Enterprises, Inc., 300 Industrial Park Rd, Starkville, Mississippi 39759, USA** and must be accompanied by a letter describing the problem in detail along with a copy of your dated proof-of-purchase and a telephone number.
12. This warranty gives you specific rights, and you may also have other rights, which vary from state to state.



MFJ ENTERPRISES, INC.
300 Industrial Park Road
Starkville, MS 39759

MFJ-259C Manual
Version C1
Printed In U.S.A.