MFJ-219/219N 440 MHz UHF SWR Analyzer

TABLE OF CONTENTS

INTRODUCTION

The MFJ-219/219N SWR Analyzer is an easy to operate, versatile test instrument for analyzing nearly any 50Ω RF system on frequencies between 420 and 450 MHz. In addition the MFJ-219/219N can be used as a UHF signal source.

The MFJ-219/219N combines three basic circuits; a UHF oscillator, a 50Ω RF bridge, and a calibrated bridge unbalance indicator. This combination of circuits allows measurement of the SWR (referenced to 50Ω) of any load connected to the ANTENNA connector.

The MFJ-219/219N covers the entire 70 cm amateur band. The dial calibration is approximate and for reference only. The actual frequency may vary from what is marked on the front panel.

The MFJ-219 has a SO-239 socket for the antenna connector. The MFJ-219N has an N type plug for the antenna connector. The only difference between the MFJ-219 and MFJ-219N are the connectors.

A frequency counter, such as the MFJ-346, can be connected to the "FREQUENCY OUT" jack (RCA phono) for a more accurate reading of the frequency. As an alternative to a frequency counter, you can tune in the output with a broad bandwidth UHF receiver. See the section on locating the MFJ-219/219N frequency with a receiver.

The MFJ-219/219N can be used to adjust or measure the following:

- Antennas: SWR, resonant frequency, bandwidth
- Amplifiers: Input and output networks
- Coaxial transmission lines: SWR, velocity factor, losses, resonance
- Networks: SWR, resonant frequency, bandwidth
- Stubs: Resonant frequency

WARNING: Please read this manual thoroughly before using this instrument. Failure to follow the operating instructions may cause false readings or cause damage to this unit.

POWERING THE MFJ-219/219N

The MFJ-219/219N requires between 7 and 18 volts for proper operation. Any power supply used with the MFJ-219/219N must be capable of supplying 100 mA of current. An optional power supply, the MFJ-1312B, is available from MFJ.

The MFJ-219/219N has a standard 2.1 mm female receptacle at the bottom of the case. This jack is labeled "12VDC" and has the word "POWER" near it. A pictorial polarity marking appears on the case near the power jack. The outside conductor of the plug must connect to the negative supply voltage and the center conductor of the plug must connect to the positive voltage. If a 9 volt battery is connected, it will be automatically disconnected when an external power plug is inserted in this jack.

SWR measurement will be inaccurate when the supply voltage falls below 7 volts. To avoid false readings maintain fresh batteries and *always* use the correct power supply.

WARNING: Never apply AC, unfiltered or incorrectly polarized DC to this jack. Peak voltage must never exceed 18 volts.

BATTERY INSTALLATION

To install a battery first turn the unit **OFF**. Remove the 8 phillips head screws on each side of the case. There is a plastic tube on the battery clips that insulates them from the inside of the unit. Slide the insulator down on the wire before installing a battery so that it will not be lost. The insulator *must be* on the battery clips when there is not a battery in the unit. Insert the battery securely into the battery holder.

+ Carefully check to ensure the following:

- The battery leads are positioned so that they do not interfere with the variable capacitor.
- The wires are not pinched between the cover and the chassis.

After the battery is installed, reinstall the 8 cover screws.

MFJ recommends the use of 2 9V ALKALINE (or rechargeable nicad) batteries to reduce the risk of equipment damage from battery leakage. Avoid leaving any batteries in this unit during periods of extended storage. *Remove weak batteries immediately!*

When using a battery with this unit, quickly make a measurement and turn the unit off. If the unit is left on for long periods of time, battery life may be short.

OPERATION OF THE MFJ-219/219N

After the MFJ-219/219N is connected to a proper power source the red ON/OFF button can be depressed to apply power. When pressed, the red button should lock into position.

The "ANTENNA" connector (SO-239 or N-type) on the top of the MFJ-219/219N provides the SWR bridge output connection. To measure SWR, this connector must be connected to the load or device under test.

WARNING: Never apply power to the "ANTENNA" connector.

SWR and the MFJ-219/219N

Some understanding of transmission lines and antenna behavior is necessary to use the MFJ-219/219N properly. For a thorough explanation the ARRL Handbooks or other detailed textbooks can be used for reference.

SWR is the ratio of a load impedance to source impedance. Since nearly all feedlines and radio equipment used in amateur service are 50Ω, this instrument is designed to measure the system SWR normalized to 50Ω. For example a 150Ω load placed across the "ANTENNA" connector will give an SWR reading of 3:1 .

The MFJ-219/219N measures the actual SWR. The load must be 50Ω of pure resistance for a meter reading of 1:1 . The common misconception that 25Ω of reactance and 25Ω of resistance in a load will give a 1:1 SWR is absolutely not true. The actual SWR in this condition will be measured as 2.6:1 . The MFJ-219/219N is not "fooled" by mixtures of reactive and resistive loads.

Another common misconception is that changing a feedline's length will change the SWR. A feedline impedance of 50Ω and a load impedance of 25Ω produces an SWR of 2:1. The SWR will remain 2:1 even if the feedline length is changed. ***If line loss is low*** it is perfectly acceptable to make SWR measurements at the transmitter end of the feedline. The feedline does not have to be any particular length. As line loss increases, and as SWR increases, error is introduced into the SWR reading. The error causes the measured SWR reading to appear ***better*** than the actual SWR at the antenna. Refer to the section on estimating the line loss on page 9.

If changing feedline length changes the SWR reading, one or more of the following must be true:

- The feedline is not 50Ω.
- The bridge is not set to measure 50Ω.
- The line losses are significant.
- The feedline is acting like part of the antenna system and radiating RF.

Feedlines with very low losses, such as air insulated transmission lines, will not have much loss even when operating with a high SWR. High loss cables, such as small polyethylene dielectric cables like RG-58, rapidly lose efficiency as the SWR is increased. With high loss or long feedlines it is very important to maintain a low SWR over the entire length of the feedline.

SWR adjustments have to be made at the antenna, since any adjustments at the transmitter end of the feedline can not affect the losses, nor the efficiency, of the antenna system.

Measuring SWR

The MFJ-219/219N will measure the impedance ratio (SWR) of any load referenced to 50Ω. The SWR can be measured on any frequency from 420 to 450 MHz. No other devices are required.

To measure the SWR on a predetermined frequency adjust the "TUNE" control to the desired frequency. To measure the MFJ-219/219N's frequency connect a counter to the "FREQUENCY OUT" jack or tune the MFJ-219/219N while listening for the signal with a broad band UHF receiver. Read the SWR from the "SWR" meter.

To find the lowest SWR, adjust the frequency until the SWR meter reaches the lowest reading. Read the approximate frequency of the lowest SWR from the "TUNE" scale or measure the exact frequency with a counter or a UHF receiver.

ADJUSTING SIMPLE ANTENNAS

Most antennas are adjusted by varying the length of the elements. Most home made antennas are simple verticals or use a dipole or quad for the driven element. Most types of elements can be easily adjusted.

Dipoles

Dipole elements are balanced radiators. It is a good idea to install a balun at the feedpoint of any balanced dipole element fed directly with coaxial line. The balun can be as simple as a string of very low permeability beads, a low permeability ferrite sleeve, a 1/4 wave sleeve balun, or several turns of miniature coax in a small (less than one inch) diameter coil.

Metallic objects or lossy dielectrics in the immediate vicinity of a dipole and the diameter of the element influences the feedpoint impedance of a dipole and the feedline's SWR. Typically, dipoles have an SWR below 1.5:1.

In general, length is the only adjustment of a dipole antenna. If the antenna is too long it will resonate too low in frequency, and if it is too short it will resonate too high in frequency.

Quad Elements

Quad elements are also balanced radiators. It is a good idea to put a balun at the feedpoint of any quad element that is fed with coaxial line. The balun can be as simple as a string of very low permeability beads, a low permeability ferrite sleeve, a 1/4 wave sleeve balun, or several turns of miniature coax in a small (less than one inch) diameter coil.

Metallic objects or lossy dielectrics in the immediate vicinity of a quad element and the diameter of the material used to construct the element will influence the feedpoint impedance of the quad and the feedline's SWR. Typically unmatched quad elements have an SWR below 2:1.

The only matching adjustment of a quad is the length of the loop. If the antenna circumference is too long it will resonate too low in frequency, and if it is too short it will resonate too high in frequency. The impedance can be modified with stubs or "Q" sections.

Verticals

Verticals for UHF are generally unbalanced ground plane types. They usually have a main vertical element and at least three radials or counterpoises. Verticals are tuned in a manner similar to dipoles, lengthening the element moves the frequency lower, and shortening the element moves the frequency higher.

Tuning an Antenna

Tuning basic antennas fed with 50Ω coaxial cable can be accomplished with the following steps:

1. Connect the feedline to the MFJ-219/219N.
2. Adjust the MFJ-219/219N until the SWR reaches the lowest reading.
3. Read or measure (with a counter) the MFJ-219/219N's frequency.
4. Divide the measured frequency by the desired frequency.
5. Multiply the present antenna length by the result of step 4. This is the new length needed.

Note: *This method may not work on loaded or electrically shortened antennas. They must be tuned by adjusting and re-testing until the proper frequency is obtained.*

Measuring the Feedpoint Resistance of Antennas

The approximate feedpoint resistance of a low impedance (10-100 ohm) resonant UHF antenna or load can be measured with the MFJ-219/219N. An assortment of low value non-inductive resistors can be used to make these measurements.

Note: *Remember that all lead lengths must be extremely short on UHF !*

1. Connect the MFJ-219/219N directly across the terminals of the unknown impedance. If the load is unbalanced be sure that the ground is connected to the SO-239 "ANTENNA" connector's ground.
2. Adjust the MFJ-219/219N until the SWR reads the lowest value.
3. If the SWR is not unity (1:1), place different resistors in parallel with the load. Adjust the potentiometer until the SWR is as good as possible.
4. If the SWR only becomes worse go to step 7.
5. If the SWR reached unity, note the value of the resistor.
6. The resistance of the load is found by using the formula below.

$$R_A = \frac{50\ R}{R - 50}$$

R_A = Antenna resistance

R = Resistor

7. If the earlier steps did not work put the resistor in series with the center pin (ungrounded terminal) of the "ANTENNA" connector.
8. Adjust the value of the resistor until the SWR is unity (1:1).
9. Subtract the value of the resistor used in step 8 from 50 to determine the load resistance.

TESTING AND TUNING STUBS AND TRANSMISSION LINES

The proper length of quarter and half wave stubs or transmission lines can be found with this unit and a 50Ω non-inductive resistor. Accurate measurements can be made with any type of coaxial or two wire line. The line does ***not*** have to be 50Ω.

Note: *Remember that all lead lengths must be extremely short on UHF !*

The stub to be tested should be attached through a series 50Ω non inductive resistor to the center conductor of the "ANTENNA" connector with a coaxial line. The shield should be grounded to the connector shell. For two wire lines the 50Ω resistor is connected in series with the ground shell of the PL-259 and one feedline conductor. The other conductor of the balanced line connects directly to the center pin of the connector.

Coaxial lines can lie in a pile or coil on the floor, two wire balanced lines ***must*** be suspended in a straight line a few feet away from metallic objects or ground. The lines must be ***open circuited*** at the far end ***for odd multiples*** of 1/4 wave stubs (i.e., 1/4, 3/4, 1-1/4, etc.) and ***short circuited for half wave stub multiples*** (like 1, 1-1/2, etc.)

Connect the PL-259 to the "ANTENNA" connector of the MFJ-219/219N and adjust the line or stub by the following method. For critical stubs you may want to **gradually** trim the stub to frequency.

1. Determine the desired frequency and theoretical length of the line or stub.
2. Cut the stub slightly longer than necessary.

3. Measure the frequency of the lowest SWR. It should be just below the desired frequency.
4. Divide the measured frequency by the desired frequency.
5. Multiply the result by the length of the stub. This is the necessary stub length.
6. Cut the stub to the calculated length and confirm that it has the lowest SWR near the desired frequency.

Velocity Factor of Transmission Lines

The MFJ-219/219N can accurately determine the velocity factor of any transmission line. Measure the velocity factor with the following procedure:

Note: *Remember that all lead lengths must be extremely short on UHF !*

1. Cut a sample of the transmission line to a length of seven inches.
2. Set up the line to measure a 1/4 wavelength stub (as in the section on Testing and Tuning Stubs, page 7).
3. Cut off pieces of the open end of the stub until the lowest SWR occurs within the range of the "TUNE" control. This dip will occur slightly below the 1/4 wavelength resonant frequency.
4. Determine the frequency of the MFJ-219/219N. This is the 1/4 resonant wavelength frequency of your transmission line.

example: On a four inch line the measured frequency was 433 MHz.

5. Divide 2950 by the measured frequency. This gives you the free space 1/4 wavelength in inches.

example: 2950 divided by a dip frequency of 433 MHz is 6.81 inches. This is the length of a free space 1/4 wave.

6. Divide the physical measured length of the feedline in feet by the free space 1/4 wavelength calculated in step 5.

example: 4 inches (physical length) divided by 6.81 inches (calculated free space length) equals .587 . The velocity factor is approximately .6 or 60%.

$$\text{Free space } 1/4 \text{ wavelength} = \frac{2950}{\text{Low SWR frequency}}$$

$$\text{Velocity Factor} = \frac{\text{Actual feedline length}}{\text{Free space } 1/4 \text{ wavelength}}$$

Impedance of Transmission Lines

The impedance of transmission lines between 15Ω and 150Ω can be measured with the MFJ-219/219N and an assortment of non-inductive resistor.

Note: *Remember that all lead lengths must be extremely short on UHF !*

1. Measure the 1/4 wavelength frequency of a small sample of the transmission line to be tested as in Testing and Tuning Stubs on page 7.
2. Terminate the far end of the transmission line with a non-inductive resistor.
3. Connect the transmission line to the MFJ-219/219N "ANTENNA" connector and set the analyzer to the 1/4 wave frequency.
4. Observe the SWR as you vary the "TUNE" from end to end of the "frequency" range selected.
5. Select a resistor that produces the smallest SWR reading change over the entire "TUNE" range. Note that the ***value*** of the SWR is not important. Only the ***change*** in SWR as the frequency is varied is important.
6. The value of the resistor will correspond closely to the line impedance.

Estimating transmission line loss

The loss of 50Ω feedlines (between 3 and 10 dB) can be measured with the MFJ-219/219N. It is a simple matter to find the loss at a known frequency and then estimate the loss at a lower frequency.

To measure feedline loss:

1. Connect the feedline to the MFJ-219/219N "ANTENNA" connector.
2. The far end of the feedline is either left unconnected or terminated with a direct short.
3. Adjust the MFJ-219/219N frequency to the frequency desired and observe the "SWR" meter.
4. If the SWR is in the red area of the scale the loss is less than 3 dB.
5. If the SWR on the operating frequency is in the black area of the "SWR" meter, pick the closest SWR point and estimate the loss from the chart below.

SWR	LOSS
3.0 : 1	3.0 dB
2.5 : 1	3.6 dB
2.0 : 1	4.7 dB
1.7 : 1	5.8 dB
1.5 : 1	6.9 dB
1.2 : 1	10.3 dB

ADJUSTING MATCHING NETWORKS

The MFJ-219/219N can be used to adjust matching networks. Connect the MFJ-219/219N "ANTENNA" connector to the network's 50Ω input and the desired load to the network output.

WARNING: RF Power Must Never Be Applied To The MFJ-219/219N.

1. Connect the MFJ-219/219N to the matching network input.
2. Turn on the MFJ-219/219N and adjust it to the desired frequency.
3. Adjust the matching network until the SWR becomes unity (1:1).
4. Turn off the MFJ-219/219N and re-connect the transmitter.

Adjusting Amplifier Networks

The MFJ-219/219N can be used to test and adjust RF amplifiers or other matching networks without applying operating voltages.

The tubes or transistors and the other components should be left in the same physical position. They should remain connected so the circuit's stray capacitance is not changed. A non-inductive resistor with a value equal to the approximate driving impedance of the tube or transistor is installed at the input of the amplifying device. This resistor should have very short leads and be connected between the device input and the chassis. To align the output circuit connect a resistor with a value equal to the anode (or output) impedance of the amplifying device between the anode (or output) of the device and the chassis. The appropriate network can now be adjusted for lowest SWR on the MFJ-219/219N.

The antenna relay (if internal) can be engaged with a small power supply so that the coax input and output connectors are tied to the networks.

Caution: The driving impedance of most amplifiers changes as the drive level is varied. Do not attempt to adjust the input network with the amplifier in an operating condition. The RF level from the MFJ-219/219N is too low.

FINDING THE FREQUENCY OF THE MFJ-219/219N

The "FREQUENCY OUT" jack of the MFJ-219/219N supplies enough signal to drive a frequency counter or a receiver. The signal from this jack is strong enough to drive all but the poorest counters.

To measure the frequency with a receiver you should first connect a short wire to the input of the receiver or to the center conductor of coax feeding the receiver. This wire can normally just be placed near the MFJ-219/219N to provide ample signal strength for the receiver. In rare cases a second wire can be inserted into the FREQUENCY OUT jack and placed near the receiver lead.

To determine the operating frequency of the MFJ-219/219N the receiver should be set to the widest bandwidth position and tuned to the frequency setting of the MFJ-219/219N dial. Slowly tune the receiver dial up and down until a clear signal is heard in the receiver speaker.

Zero in on the signal. The receiver will be approximately on the same frequency as the receiver.

USING THE MFJ-219/219N AS A SIGNAL SOURCE

The MFJ-219/219N can provide a crude signal source for testing and alignment. Signal is produced by the internal oscillator and can be taken either the "FREQUENCY OUT" or the "ANTENNA" jack. Taking the signal from the "ANTENNA" jack will allow a frequency counter (such as the MFJ-346) to be attached to the "FREQUENCY OUT" jack to measure the frequency of the output signal.

An attenuator pad or variable resistor can be used to reduce the output level of the MFJ-219/219N.

TECHNICAL ASSISTANCE

If you have any problem with this unit first check the appropriate section of this manual. If the manual does not reference your problem or your problem is not solved by reading the manual, you may call *MFJ Technical Service* at 601-323-0549 or the *MFJ Factory* at 601-323-5869. You will be best helped if you have your unit, manual and all information on your station handy so you can answer any questions the technicians may ask.

You can also send questions by mail to MFJ Enterprises, Inc., 300 Industrial Park Road, Starkville, MS 39759; by Facsimile to 601-323-6551; or by email to mfj@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.