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MFJ-249B HF/VHF SWR ANALYZER

INTRODUCTION

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MFJ-249B
 Rev. 1.00
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The MFJ-249B SWR analyzer is an easy to operate, versatile test instrument for analyzing nearly any 50 ohm RF system on frequencies between 1.8 and 170 MHz. In addition the MFJ-249B can be used as a signal source and as an accurate frequency counter.

The MFJ-249B combines four basic circuits; a wide range oscillator, a frequency counter, a 50 ohm RF bridge, and a microcontroller. This combination of circuits allows measurement of the SWR (referenced to 50 ohms), magnitude of the impedance, components of the impedance (resistance and reactance), of any load connected to the **ANTENNA** connector. By connecting a signal to the BNC jack labeled **FREQUENCY COUNTER INPUT** it is possible to determine its frequency

The MFJ-249B provide a sinewave signal of approximately 3 Vpp to any load in series with a 50 ohm internal resistance. The unit **FREQUENCY** switch selects the following frequency ranges:

1.8 - 4 MHz
4 - 10 MHz
10 - 27 MHz
27 - 70 MHz
70 - 114 MHz
114 - 170 MHz

The MFJ-249B can be used to adjust or measure the following:

Antennas:	SWR, impedance, resistance, resonant frequency, bandwidth, efficiency
Antenna tuners:	SWR, frequency
Amplifiers:	Input and output networks
Coaxial transmission lines:	SWR, velocity factor, losses, resonance
Matching or tuning stubs:	SWR, resonance frequency, bandwidth
Traps:	Resonant frequency
Tuned Circuits:	Resonant frequency
Small capacitors:	Value
RF chokes and inductors:	Self resonance, series resonance, value
Transmitters and oscillators:	Frequency

The MFJ-249B is also portable. It can be used with either an external low voltage supply, such as the MFJ-1315 AC adapter or with internal AA battery packs.

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

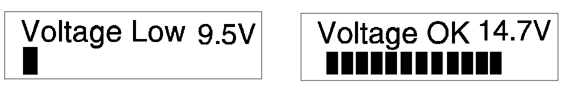
POWERING THE MFJ-249B

The MFJ-249B requires between 11 and 18 volts for proper operation. Any power supply used with the MFJ-249B must be capable of supplying 180mA of current. An optional power supply, the MFJ-1315, is available from MFJ.

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

The MFJ-249B has a standard 2.1 mm female receptacle on the top right of the case. This jack is labeled **POWER 12VDC**. 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.

After turning ON the **POWER** switch, the program code version is displayed. A higher number may indicate later software. The MFJ-249B also checks the voltage applied, then displays the amount of volts received. If the power supply is less than 11Vdc a "Voltage LOW" blinking message will be displayed. By pressing the **MODE** or the **GATE** time button on the unit, it will try to continue working with the low voltage.



WARNING: The measurements will be inaccurate when the supply voltage falls below 11 volts !

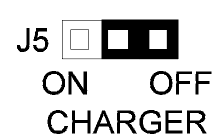
BATTERY INSTALLATION

MFJ recommends the use of ten AA Alkalines or rechargeable NiCd cells 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 !***

If batteries are used, they must be installed by removing the battery cover on the back of the unit. This cover is secured by 2 Phillips head screws. **The MFJ-249B *must be setup* for the type of battery used (Alkaline or NiCd).** There is a header located inside the unit for this purpose. The header is located at the top of the PCB and is accessible by removing the back cover's eight screws (four on each side).

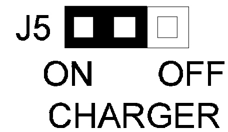
Alkaline Batteries

If Alkaline AA batteries are used, the jumper for the J5 header labeled **CHARGER** must be placed from the center pin to the pin labeled **OFF.** The **CHARGER OFF** mode is the factory default.



WARNING: Never use an alkaline battery pack without setting the **CHARGER** jumper to the **OFF** position !

NiCd Batteries



If NiCd AA batteries are used, the jumper for the J5 header labeled **CHARGER** must be placed from the center pin to the pin labeled **ON.** The **CHARGER OFF** mode is the factory default.

The internal battery pack is not automatically disconnected, considering the possibility of using 10 AA rechargeable NiCd batteries.

The MFJ-249B has a NiCd battery's charger. The unit uses a 20 - 30 mA continuous trickle charging current supply. This rate is enough to maintain a fully charged battery and low enough to permit continuous charging while keeping cell temperature and internal cell pressure at a safe level. The minimum supply voltage necessary to charge 1.25V AA NiCd batteries with that current rate is 15V. The MFJ-1315 is able to provide that voltage when the power is OFF. With power ON it is able to supply more than 13V at the maximum power required. The charger, if enabled, is active while the power of the unit is ON or OFF.

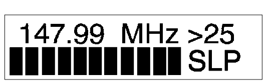
WARNING: Do not use external power supplies with less than 13V, if NiCds are already installed in the unit. This could discharge the batteries to the voltage supplied.

It is recommended to charge the batteries with the power OFF, establishing periods according to the hour capacity of the battery (C). NiCds, like all batteries, self-discharge. They have a relatively high self discharge rate of about 1% per day at room temperature. The purpose of trickle charging is to replace the charge that is draining off.

Power Saving Mode

The unit has a battery saving mode set up by default. This mode can be disabled by pressing the **MODE** push button before the initial messages are displayed. If the battery saving mode is disabled the message "Power Saving OFF" will be displayed while holding the **MODE** push button.

The battery saving mode is to extend the life of the batteries. If there is not any **MODE** operation or any 50 kHz frequency variation during 180 seconds, the unit will go into the power saving mode. This mode will be indicated with a blinking **SLP** text over the display right corner.



By pressing either the **MODE** or **GATE** button the unit will be back to regular operation.

OPERATION OF THE MFJ-249B

Some understanding of transmission line and antenna behavior is necessary in order to use the MFJ-249B properly. For a thorough explanation the ARRL Handbooks or other detailed books can be used for reference.

The **ANTENNA** connector (SO-239 type) on the top of the MFJ-249B provides the measurement bridge output connection. To measure SWR or any impedance, this connector must be connected to the load or device under test.

WARNING: Never apply power to the antenna connector !

To measure the SWR or any impedance, on a predetermined frequency adjust the **TUNE** and **FREQUENCY** knobs until the counter displays the desired frequency.

By pressing the **MODE** push button seven different operation modes are selected. The unit can measure on any frequency from 1.8 to 170 MHz.

The frequency counter will display a maximum of five digits. This will produce an entirely stable reading of the internal oscillator short term drifted signal.

SWR mode

```
SWR
Bargraph
```

The unit enters the **SWR** mode when it is turned ON. The MFJ-249B will measure the standing wave ratio (SWR) of any load referenced to 50 ohms. To measure the SWR of a 50 ohm coaxial line simply connects the line to the **ANTENNA** connector. The display will show the selected frequency and the actual SWR in a numerical and a bar graph format. The maximum numerical SWR displayed is 25.

```
147.99  MHz >25
███████████ SWR
```

```
14.016   MHz 3.0
████████    SWR
```

Any 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.

The bar graph scale is as follows:

SWR:	1	1.1	1.2	1.3	1.4	1.5	2	3	4	5	6	7	8
Bar graph:	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]

Magnitude of the Impedance Mode

IMPEDANCE
Magnitude

This **mode** will provide **magnitude of the impedance** readings for the load connected to the **ANTENNA** jack. The readings are the combination of the resistive and reactive parts of the load. The **magnitude of the impedance** (**Z**) is the square root of the addition of square of the **resistance** (R) and the **reactance** (X).

By considering the definition of **Z** and by adjusting the **TUNE** knob until the lowest SWR reading is obtained, it is possible to read the antenna's pure reactance. The point of the lowest SWR is generally the point of lowest reactance.

For the SWR to be 1:1, the load must be an impedance of 50 ohms of pure resistance (R=50) , with no reactance (X=0).

Pressing the **MODE** push button, from the **SWR** mode selection, the Magnitude of the Impedance (Z) mode is enabled. It will display Z in a range from 0 to 650 ohms. If the impedance is greater than about 650 ohms the message "(Z>650)" is displayed.

28.814 MHz 3.6 Z= 183 ohms SWR	4.0456MHz >25 (Z>650) SWR

The **SWR** value for the connected load will be displayed in the LCD.

The stray output capacitance (around 3pF) will be lower than 650 ohms at frequencies higher than 60 MHz. This stray capacitance does not affect high frequency measurements considering the connection of a transmission line.

Frequency Counter Mode

To use the frequency counter press the **MODE** push button until "Freq. Counter" is displayed. The BNC jack labeled **FREQUENCY COUNTER INPUT** is now selected for the input to the counter. Connect the cable form the BNC jack to the signal to be counted.

The frequency counter in the MFJ-249B will typically measure frequencies between a few kHz and 170 MHz. At frequencies above 1 MHz, the frequency counter is sensitive to 300 mVpp. The sample period selected will be displayed at the right of the frequency. The counter displays the average frequency over the sample time period. At power up, the **AUTO** sample period is set up.

The MFJ-249B **Frequency Counter** has a 100 Hz measurement resolution.

14.15 MHz 0.01s Freq. Counter	21.324 MHz 0.1 s Freq. Counter	144.2389MHz 1 s Freq. Counter

Gate time selection *(only used in frequency counter mode)*

The unit has 1 s, 0.1 s and 0.01 s gate time options.
The gate time can be selected with the **GATE** push button. The selected gate time will be displayed.

ADJUSTING SIMPLE ANTENNAS

Most antennas are adjusted by varying the length of the elements. Most home made antennas are simple verticals or dipoles that are easily adjusted.

Dipoles

Since a dipole is a balanced antenna, it is a good idea to put a balun at the feedpoint. The balun can be as simple as several turns of coax several inches in diameter, or a complicated affair with many windings on a ferromagnetic core.

The height of the dipole, as well as it's surroundings, influence the feedpoint impedance and the line SWR. Typical heights result in SWRs below 1.5 to one on most dipoles.

In general, the only adjustment on a dipole is the length of the 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.

Verticals

Verticals are usually unbalanced antennas. Most antenna manufacturers down play the importance of good radial systems with grounded verticals. If you have a good ground system the SWR of a quarter wave vertical can be nearly 2 to one. The SWR generally gets BETTER as the ground system, and performance, get worse.

Verticals are tuned like dipoles, lengthening the element moves the frequency lower, and shortening the element moves the frequency higher.

Tuning an Antenna

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

1. Connect the feedline to the MFJ-249B.
2. Adjust the MFJ-249B until the SWR reaches the lowest reading.
3. Read the frequency display.
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 of tuning will only work on full size vertical or dipole antennas that do not employ loading coils, traps, stubs, resistors, capacitors or capacitance hats. These antennas must be tuned according to the manufacturers instructions and re-tested with the MFJ-249B until the desired frequency is obtained.

Measuring the Feedpoint Resistance of Antennas

The approximate feedpoint resistance of a low impedance (0-500 ohms) resonant HF or VHF antenna or load can be measured with the MFJ-249B.

1. Connect the MFJ-249B directly across the terminals of the unknown resistance. If the load is unbalanced be sure that the ground is connected to the SO-239 "ANTENNA" connectors outer shell. If the load is balanced it may be necessary to operate the MFJ-249B using internal battery power to allow the case of the unit to float above ground.
2. Set the band switch for the desired frequency measurement range.
3. Adjust the TUNE control until the SWR reads the lowest value.
4. The SWR ratio should be approximately equal to the ratio between the measured resistance and 50 ohms.

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 carbon resistor. Accurate measurements can be made with any type of coaxial or two wire line. The line does ***not*** have to be 50 ohms.

The stub to be tested should be attached with a 50Ω noninductive resistor in series 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 connects in series between the ground shell of the PL-259 and one conductor. The other conductor of the balanced line connects directly to the center pin of the connector.

Coaxial lines can lay in a pile or coil on the floor, two wire 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-249B 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-249B can accurately determine the velocity factor of any impedance transmission line. Measure the velocity factor with the following procedure:

1. Disconnect both ends of the transmission line and measure the physical length of the line in feet.
2. Set up the line to measure 1/4 stubs as in the section on Testing and Tuning Stubs.
3. Find the ***lowest*** frequency across all the bands at which the lowest SWR occurs. The dip should occur slightly below the 1/4 wavelength frequency.
4. Read the frequency from the frequency counter display. This is the 1/4 resonant wavelength frequency of your transmission line. Note that you will get low SWR reading at all odd multiples of 1/4 wavelength.
Example: On a 27 foot line the measured frequency was 7.3MHz.
5. Divide 246 by the measured frequency. This gives you the free space 1/4 wavelength in feet.
Example: 246 divided by a dip frequency of 7.3 MHz is 33.7 feet, the free space 1/4 wavelength
6. Divide the physical measured length of the feedline in feet by the free space 1/4 wavelength calculated in number 5.
Example: 27 feet (physical length) divided by 33.7 feet (calculated length) equals .80 . The velocity factor is .80 or 80%.

$$\text{Free space } 1/4 \text{ wavelength} = \frac{246}{\text{Low SWR frequency}}$$

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

Impedance of Transmission Lines

The impedance of transmission lines between 15 and 150 ohms can be measured with the MFJ-249B, a 250 ohm potentiometer, and an ohm meter. Lines of higher impedance can be measured with a higher resistance potentiometer if a broad band transformer is used (see the section on testing transformers) to transform the line impedance to approximately 50 ohms.

1. Measure the 1/4 wavelength frequency of the transmission line to be tested as in Testing and Tuning Stubs section.
2. Terminate the far end of the transmission line with a non-inductive 250 ohm potentiometer.
3. Connect the transmission line to the MFJ-249B "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. Adjust the potentiometer until the SWR reading varies as little as possible, over the "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 potentiometer will correspond closely to the line impedance.

ADJUSTING TUNERS

The MFJ-249B can be used to adjust tuners. Connect the MFJ-249B "ANTENNA" connector to the tuner's 50 ohm input and the desired antenna to the normal tuner output. This connection can be made with a manual RF switch to facilitate rapid changeover.

WARNING: Always connect the common (rotary contact) of the switch to the tuner. The switch must connect either the MFJ-249B or the station equipment to the tuner. ***The Station Equipment Must Never Be Connected To The MFJ-249B.***

1. Connect the MFJ-249B to the tuner input.
2. Turn on the MFJ-249B and adjust it to the desired frequency.
3. Adjust the tuner until the SWR becomes unity (1:1).
4. Turn off the MFJ-249B and re-connect the transmitter.

ADJUSTING AMPLIFIER MATCHING NETWORKS

The MFJ-249B can be used to test and adjust RF amplifiers or other matching networks without applying operating voltages.

The tubes and other components should be left in position and connected so that stray capacitance is unchanged. A non-inductive resistor that equals the approximate driving impedance of the tube is installed between the cathode of the tube and the chassis, or a resistor should be connected between the anode and the chassis that equals the calculated plate impedance of the tube. The appropriate network can now be adjusted.

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 tube in an operating condition with the low level of RF from the MFJ-249B.**

TESTING RF TRANSFORMERS

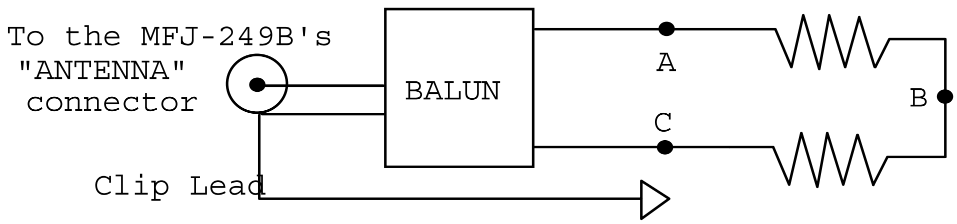
RF transformers that are designed with a 50 ohm winding can be easily and accurately tested with the MFJ-249B.

The 50 ohm winding is connected through a short 50 ohm cable to the "ANTENNA" connector on the MFJ-249B. The other winding(s) of the transformer is then terminated with a low inductance resistor that is equal to the windings impedance. The MFJ-249B can then be swept through the desired transformer frequency range. The SWR and bandwidth of the RF transformer can be measured.

Testing Baluns

Baluns can be tested by connecting the 50 ohm unbalanced side to the MFJ-249B "ANTENNA" connector. The balun must be terminated with two equal value load resistors in series. The resistor combination must have resistance total that is equal to the balun impedance. A pair of 100 ohm carbon resistors must be used to test the 200 ohm secondary of a 4:1 balun (50 ohm input).

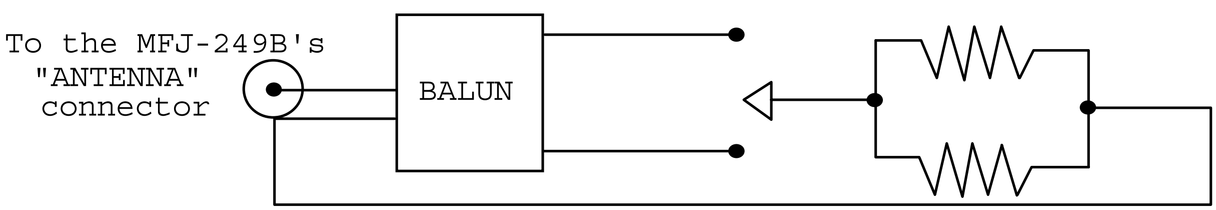
The SWR is measured by moving a jumper wire from point "A" through point "C".



A properly designed current balun, the type that is the most effective and usually handles the most power, should show a low SWR over the entire operating range of the balun with the clip lead in any of the three positions.

A well designed voltage balun should show a low SWR over the entire operating range when the clip lead is in position "B". It will show a poor SWR when the clip lead is in position "A" and "C".

A voltage balun should also be tested by disconnecting the outer connections of the two resistors and connecting each resistor in parallel. If the balun is operating properly the SWR will be very low with the resistors connected from either output terminal to ground.



MEASURING INDUCTANCE AND CAPACITANCE

To measure capacitance or inductance you will need some standard value capacitors and inductors. These should be collected and tested for accuracy. MFJ suggests the following sets of values:
Inductors: 330µH, 56 µH, 5.6 µH, .47 µH
Capacitors: 10 pF, 150 pF, 1000 pF, 3300 pF
Readings will be the most accurate if the standard test values used are between 0.5 µH to 500 µH to measure capacitance or 10 pF and 5000 pF to measure inductance.

Take a component of unknown value and connect it in series with a standard component to make a series LC circuit. Attach the series LC circuit to the "ANTENNA" connector in series with a 50 Ω resistor.

Measure Capacitance

1. Connect an unknown capacitor in series with the highest value standard inductor.
2. Connect the LC circuit to ANTENNA connector with a 50 Ω resistor in series.
3. Adjust the tune knob through the bands until you get the lowest SWR. If you do not get a low SWR, change to the next inductor with a lower value and try again. Continue the process until you obtain low SWR.
4. Solve this equation using F as the resonant frequency and L as the inductance of the standard inductor,

$$C(\text{pF}) = \frac{1}{.00003948F^2L}$$

$$F = \text{MHz} \quad L = \mu\text{H}$$

Measure Inductance

1. Connect an unknown inductor with the highest value standard capacitor in series.
2. Connect the series LC circuit to "ANTENNA" connector with a 50 Ω resistor in series.
3. Adjust the tune knob through the bands until you get the lowest SWR. If you do not get a low SWR, change to the next smaller value standard capacitor and try again. Repeat the process until you get low SWR.
4. Solve this equation using F as the resonant frequency and C as the capacitance of the standard capacitor.

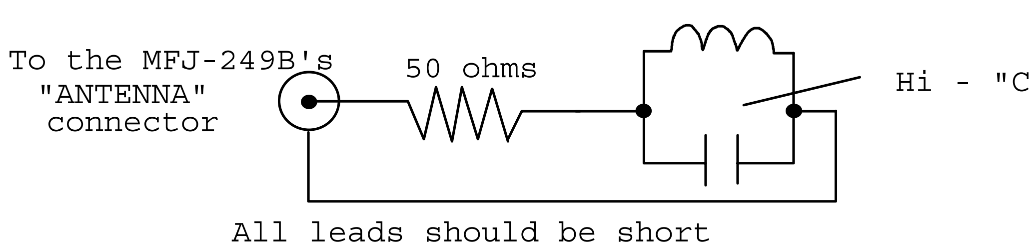
$$L(\mu\text{H}) = \frac{1}{.00003948F^2C}$$

$$F = \text{MHz} \quad C = \text{pF}$$

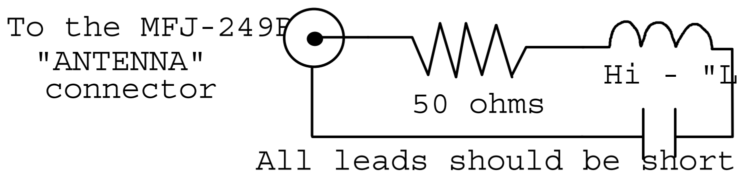
RESONANT FREQUENCY OF TUNED CIRCUITS

The MFJ-249B can be used to measure the resonant frequency of tuned circuits by two methods. The first method involves placing a 50 ohm resistor in series with the MFJ-249B "ANTENNA" connector. The MFJ-249B connects through the resistor to the parallel tuned circuit. This circuit is for high capacitance values.

Tune the MFJ-249B's frequency until the highest SWR is reached. This is the resonant frequency of the load.

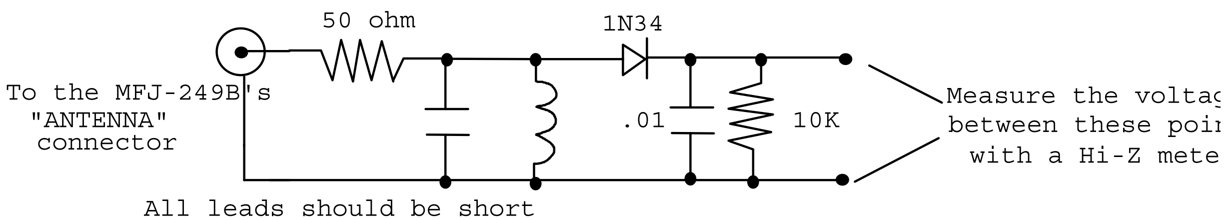


For high inductance values a series LC circuit should be used to measure resonant frequency. The inductor and capacitor should be connected in series through a 50Ω low inductance carbon resistor across the "ANTENNA" connector on the MFJ-249B.



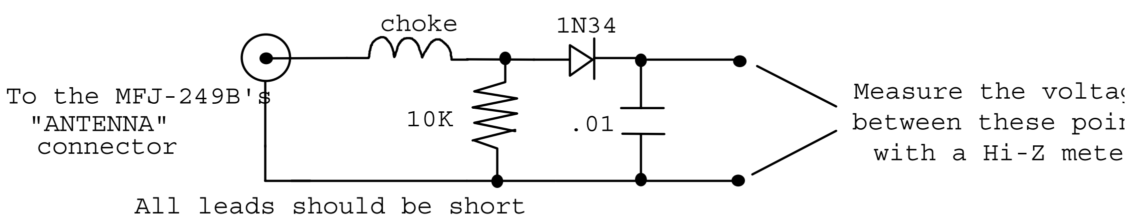
Tune the MFJ-249B's frequency until the lowest SWR is reached. This is the resonant frequency of the load.

An external diode detector and volt meter can also be used to measure the resonant frequency of circuits. The maximum meter reading occurs at the resonant frequency.



Testing RF Chokes

Large RF chokes usually have frequencies where the distributed capacitance and inductance form a low impedance series resonance. The troublesome series resonance can be detected by slowly sweeping the frequency of the MFJ-249B over the operating range of the choke. Peaks in the voltage measured by the RF voltmeter will identify the low impedance series-resonant frequencies.



Refer to the section on measuring the inductance of RF chokes.

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 (FAX) to 601-323-6551; or by email 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.