

MFJ Legal Limit Balanced Line Tuner

Introduction

The MFJ-976 balanced line antenna tuner is a fully balanced true, balanced line antenna tuner, providing superb current balance throughout a very wide matching range – 12 to 2000 ohms – and frequency range of 1.8 through 30 MHz, continuous. It is rated at 1500 watts PEP SSB and CW.

The MFJ-976 is designed to match 50 ohm output transmitters or transceivers to virtually any antenna. Peak and average forward power, reflected power, and SWR are displayed on the MFJ-976's illuminated cross-needle meter.

The MFJ-976 is a fully balanced wide range T-Network using four 500pF air variable capacitors for efficient operation on 160 meters. The MFJ-976 also provides excellent performance on 10 meters using MFJ's exclusive *Self-Resonance Killer™* and low minimum capacitance. The tuning components are mounted symmetrically to ensure electrical balance and are centrally located in the cabinet for better isolation.

A 1:1 current balun is placed on the low impedance 50 ohm input (transmitter) side to convert the balanced T-Network to unbalanced operation. The balun is made of 50 ferrite beads on RG-303 Teflon™ coax to give exceptional and efficient isolation. It stays cool even at the tuner's maximum rated power.

The MFJ-976 will match virtually any balanced-line-fed antenna: dipoles, inverted-vees, verticals, mobile whips, yagis, quad loops, horizontal loops, sterba curtain arrays, random wires, and many other antennas. The MFJ-976 has rear panel connectors for coaxial and single or two wire feedlines. The built-in balun works with balanced open wire, twinlead, or twin-axial feedlines.

Understanding Power Ratings

There are no standardized power rating systems for tuners. The names used (i.e. 3 kW Tuner) carry over from the time when amplifiers were rated by peak power input, and not the true RF power output. For example, the one thousand watt Johnson Matchbox was rated to handle a 1000 watt plate modulated AM transmitter (four kilowatts PEP transmitter input and 3000 watts PEP RF output).

The Heathkit SB-220 was called a two kilowatt amplifier, and the rated CW output was approximately 600 watts. Matching tuners were called 2 kilowatt tuners, and these tuners safely handled 600 watts of CW power and 1200 watts PEP SSB.

The FCC has changed the power rating system of amplifiers, and tuners no longer follow amplifier power ratings. Most typical 1500 watt tuners remain able to safely handle 400 to 600 watts CW, and 600 to 900 watts PEP SSB.

Load conditions and control settings also greatly affect the power handling capability of tuners. T-networks typically handle more power on higher frequency bands into higher load impedances. The worst operating condition for T-network tuners are low-impedance capacitive reactance loads. T-network tuners always handle the least power when operated on 160 meters into low impedance capacitive reactive loads.

Follow the guidelines in this manual to avoid exceeding the ratings of this tuner.

Peak Reading SWR/Wattmeter

The cross-needle meter measures the peak or average FORWARD power, REFLECTED power, and SWR, and is always operating since the tuner is always in line.

The meter's full scale forward and reflected power range is controlled by the **POWER** switch that selects **HI** (1500 watts) or **LO** (300 watts). If your transmitter or amplifier runs more than 300 watts of output power, set this switch to the 300 watt **HI** (in) position. If your transmitter or amplifier has less than 300 watts of output, set this switch to the 300 watt **LO** (out) switch position.

Peak envelope power (PEP) is measured when the **PEAK** or **AVG** power push button is placed in the **PEAK** (in) position. Peak power and average power values are equal with steady un-modulated carriers, FSK, or FM. The meter reading on these modes will be the same whether the **PEAK/AVG** button is in or out. On SSB, the PEP meter reading should be twice the average power with two tone test modulation.

On SSB, the ratio of PEP to average power varies with voice characteristics. With most voices, the PEP reading is three to five times higher than the average voice power reading. The most accurate peak envelope power readings are obtained only with sustained carrier, voice or two tone test modulation. During normal voice modulation the wattmeter will typically indicate only 70% of the true peak envelope power.

Forward power is displayed on the left-hand FORWARD meter scale. This scale is calibrated from 0 to 300 watts. In the **HI** position, each picket (scale mark) represents 5 watts below 10 watts, 10 watts between 10 and 100 watts, and 25 watts between 100 and 300 watts. In the **LO** power position, full-scale meter reading is 30 watts; divide the meter reading by 10 for the correct value.

Reflected power is read on the right-hand REFLECTED meter scale. This scale indicates 60 watts full scale when the **300W** power sensitivity is selected, and 6 watts full scale when the **30W** power scale is selected. This scale has a picket every watt below 10 watts and every 5 watts above 10 watts.

The most accurate power readings occur in the upper half of the meter scales. When trying to measure power with a less than perfect match, the reflected power should be subtracted from the forward power reading.

The SWR is read directly from eleven red SWR curves that range from 1:1 to infinity. SWR is measured by observing the point where the forward and reflected power needles cross. The SWR is indicated by the red curve closest to the needle crossing point. No cumbersome or time consuming SWR sensitivity adjustments are required with this meter.

The wattmeter has an internal lamp that backlights the meter scale. The lamp circuit requires power from an external 12 volt DC source, such as the optional **MFJ-1312D** power supply. The rear panel jack accepts a 2.1 mm coaxial plug with the center conductor positive (+) and the sleeve negative (-). The negative lead is grounded inside the tuner. The **LAMP ON/OFF** switch turns the meter lamp off and on.

Installation

CAUTION

Locate the tuner so the rear is not accessible during operation.

1. Place the tuner in a convenient location at the operating position. With random wire or balanced feedlines, the feed through insulators may have high RF voltages. These voltages can cause serious RF burns if the terminals are touched when transmitting. **Be sure to locate the tuner so these terminals cannot accidentally be contacted during operation.**
2. Install the tuner between the transmitter and the antenna. Use a 50-ohm coaxial cable (such as RG-8/U) to connect the transmitter to the connector marked **TRANSMITTER** on the rear of the tuner.
3. Connect the antenna feedline to the tuner as follows:
 - A. Balanced feedline (open wire, twinlead, or twin-axial line) is connected to the ceramic **BALANCED LINE** terminals.

Note: Route all single and random wire antennas safely to prevent RF burn hazard.

 - B. Coaxial feedlines connect to the coax connector labeled **ANTENNA**.
4. A ground post is provided for an RF ground connection.

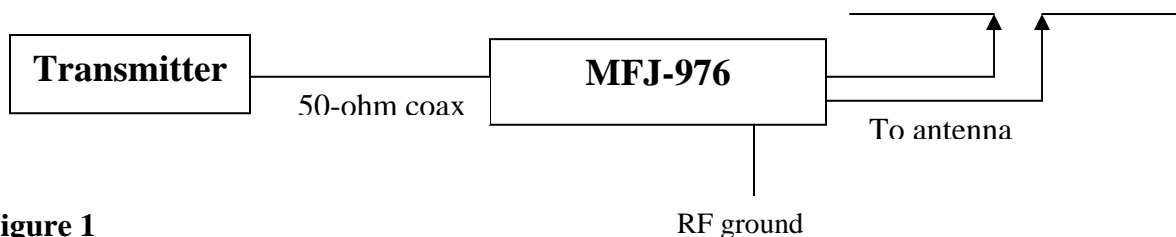


Figure 1
Block Diagram

Operation

The roller inductor has *maximum inductance* at about 000 and *minimum inductance* at 122 on the reference counter. The capacitors have *maximum capacitance* at 0 and *minimum capacitance* at 10. In simple language, as the frequency is increased, the normal control positions rotate clockwise just like on other equipment.

Note: Always use the most capacitance (settings closest to 0) for the most power handling and the least loss. Use the smallest possible inductance (the lowest number possible) also.

Note: The MFJ *Air Core*TM Roller Inductor is designed with an exclusive *Self-Resonance Killer*TM that keeps potentially damaging self-resonances away from your operating frequency. This feature is switched in and out of the circuit with a built-in switch in the roller. Therefore, as you turn the roller up and down, you may feel a bump. This is normal and you should not be alarmed.

Increase the number the controls are set at (on a given frequency) to INCREASE the matching range. Remember, this LOWERS the efficiency and power handling capability of the tuner.

1. Tune the exciter into a dummy load (most solid state transmitters are "pre-tuned" to 50 ohms and do not require adjusting with the dummy load).
2. Position the **ANTENNA** and **TRANSMITTER** controls at the following settings:

The **ANTENNA** and **TRANSMITTER** capacitors have *maximum capacitance* at setting 0 and *minimum capacitance* at setting 10.

Maximum tuner efficiency is achieved with the most capacitance (settings closest to 0) and the least possible inductance (higher letters of the alphabet). This efficiency translates into best power handling, broadest bandwidth, and least power loss. The goal is always to operate the tuner at the lowest Q for the LC (inductance/capacitance) circuit.

When necessary to increase the tuner's matching range, set the **ANTENNA** or **TRANSMITTER** control to a higher number, or dial in a higher number on the **INDUCTOR** counter, but remember that this lowers the efficiency and power handling capability of the tuner.

Adjustment Procedure

1. If the exciter or transmitter must be tuned, do it into a 50-ohm dummy load.
2. Set the **ANTENNA**, **INDUCTANCE**, and **TRANSMITTER** controls at the settings in the Suggested Tuning Chart on Page 9. At these settings signals (or at least some noise) should be audible in your receiver.
3. Place the **POWER** switch in the **LO** position.
4. Transmit at low power (20 or 25 watts should suffice).
5. Rotate the **ANTENNA** and **TRANSMITTER** controls for maximum forward power and minimum reflected power (ideal). If full forward power and zero reflected power cannot be obtained, turn the **INDUCTOR** one letter lower in the alphabet and try again. If this does not achieve a match, turn the **INDUCTOR** control *two* letters lower and try.

Note: *Never* change the **INDUCTOR** setting while power is applied to the tuner!

6. Once full forward power and zero reflected power are achieved, *always* try advancing the **INDUCTOR** setting by one letter (higher) and tune for a match. If a match can be achieved at two different **INDUCTOR** settings, the "higher letter" (lower inductance) setting is better.
7. Adjust transmitter to full output and touch up the tuner settings if needed.
8. For quick retuning of the tuner, record the **INDUCTOR** and **CAPACITOR** settings for each band (see the Logged Tuning Chart, Page 10).

Note: Maximum power handling is achieved when both the **ANTENNA** and **TRANSMITTER** controls are set at the lowest possible number, and the **INDUCTOR** control is set at the highest possible letter that permits matching the antenna. Following this guideline will ensure maximum power handling capability and efficiency, and the smoothest tuning.

WARNING:

- ***Never* operate the tuner with the top removed. Contact with the components inside the tuner while transmitting will result in painful RF burns.**
- ***Never* rotate the INDUCTANCE switch while transmitting. Doing so may permanently damage the switch.**
- **Locate the tuner so that the rear terminals are *not accessible* during operation. The balanced line connectors may have high voltage on them while transmitting.**
- ***Disconnect* all antennas from the tuner during lightning storms.**
- ***Always* tune with low power (i.e. less than 100 watts). Apply maximum power only after tuning up.**
- **Be sure to adjust the SWR before transmitting at full power. Do *not* transmit with a high SWR for extended periods.**

Operating Notes

While this tuner is designed to have as large a tuning range as possible, there are limits to the tuning range of the capacitors. Some antennas may require more or less capacitance than is available. In these cases, the SWR may not be reduced to 1:1. If the SWR is higher than the limits of your rig, try changing the length of the antenna or feedline to bring the impedance within the tuning range of the tuner.

When adjusting the tuner, use the lowest number on the **ANTENNA** and **TRANSMITTER** controls and the highest letter on the **INDUCTOR** control that produces a good SWR. This will reduce tuner losses and increase the power rating of the tuner.

In Case Of Difficulty

If the tuner fails to tune, please **double check** all connections and follow the tuning procedures again.

Be sure you are using *enough inductance* (low enough inductance letter) and have the *capacitors open far enough* (higher front panel numbers).

If the tuner arcs at the rated power levels, please **double check** all connections and follow the tuning procedures again. The power rating of this tuner is 300 watts PEP RF power. Be sure you are using the *least amount of inductance* (highest number) and the *greatest capacitance* (lowest number) possible that still allows matching the load on the operating frequency.

Note: If this tuner arcs when operating on the 160 meter band, it may be necessary to reduce transmitter output power.

If you are still unsuccessful, but the tuner does adjust and operate when used with a dummy load or another antenna, please read the **Antenna System Hints** section.

Grounding Hints

To minimize RFI, single wire feedlines (such as used with Windom or longwire antennas) should be kept away from other wiring. Radiation will be minimized if the single wire feeder runs parallel and reasonably close to the wire that connects the tuner to the outdoor ground. The antenna feed wire should be adequately insulated to prevent arcing or accidental contact.

For safety, please use good DC and RF grounds. It is particularly important to have a good RF ground when using a single wire feeder. When using a single wire feeder, the tuner needs something to "push" against in order to force current into the single wire feedline. If a good RF ground is not available, RF will usually find its way back into the power line (RFI), transmitter audio circuits (RF feedback), or the operator (RF burns).

Caution

For operator safety a good outside earth ground or water pipe ground should always be installed and connected to the case of the MFJ-974H/974. Make certain the safety ground also connects to the transmitter and other station accessories. A wing nut post marked GROUND is provided for ground connections.

Water pipes and ground rods provide good DC and AC safety grounds, but they are often inadequate for RF grounding because they are single conductors. Ground rods by themselves are almost useless for dependable RF grounding.

RF grounds work much better when "spread out" over a large area, especially when they employ multiple connections directly to the equipment ground point. Water pipes, heating ducts, and fences may work (especially if they are connected together with multiple wires), but the best RF grounds are radial systems or multi-wire counterpoises. Radials and counterpoises provide large, low resistance surfaces for RF energy.

RF and lightning travel on the surface of conductors. Braided or woven conductors have high surface resistance to lightning and RF. Ground leads for RF and lightning should have wide smooth surfaces. Avoid the use of woven or braided conductors in RF and lightning grounds unless the lead needs to be flexible.

Antenna System Hints

Location

For the best performance, an end-fed longwire wire antenna should be at least one quarter-wavelength long at the operating frequency. Horizontal center-fed antennas should be at least a half-wavelength long and located as high and clear as possible. While good RF grounds help the signal in almost any transmitting installation, it is extremely important to have good RF grounds with long wire or other Marconi style antennas.

Matching Problems

Most matching problems occur when the antenna system presents an extremely high impedance to the tuner. When the antenna impedance is much lower than the feedline impedance, an *odd quarter-wavelength* feedline converts the low antenna impedance to a very high impedance at the tuner. A similar problem occurs if the antenna has an extremely high impedance and the transmission line is a multiple of a half-wavelength. The half-wavelength line *repeats* the very high antenna impedance at the tuner. Incorrect feedline and antenna lengths can make an otherwise perfect antenna system very difficult or impossible to tune.

One example where this problem occurs is on 80 meters when an odd quarter-wave length (60 to 70 feet) of open wire line is used to feed a half-wave (100 to 140 foot) dipole. The odd quarter-wave line transforms the dipole's low impedance to over three thousand ohms at the tuner. This is because the mismatched feedline is an *odd multiple* of 1/4 wavelength long. The line *inverts* (or teeter-totters) the antenna impedance.

A problem also occurs on 40 meters with this same antenna example. The feedline is now a multiple of a half-wave (60 to 70 foot) and connects to a full-wave high impedance antenna (100 to 140 feet). The half-wave line repeats the high antenna impedance at the tuner. The antenna system looks like several thousand ohms at the tuner on 40 meters.

This places enormous strain on the balun and the insulation in the tuner, since voltages can reach several thousand volts. This can cause component arcing and heating.

The following suggestions will reduce the difficulty in matching an antenna with a tuner:

- Never center feed a half-wave multi-band antenna with a high impedance feedline that is close to an odd multiple of a quarter-wave long.
- Never center feed a full-wave antenna with any feedline close to a multiple of a half-wave long.
- If this tuner will not "tune" a multi-band antenna, add or subtract 1/8 wave of feedline (for the band that won't tune) and try again.
- Never try to load a G5RV or center fed dipole on a band below the half-wave design frequency. If you want to operate an 80 meter antenna on 160 meters, feed either or both conductors as a longwire against the station ground.

- To avoid problems matching or feeding any dipole antenna with high impedance open wire lines, keep the lines around these lengths. [The *worst possible* line lengths are shown in brackets]:

160 meters; dipole	35-60, 170-195 or 210-235 feet	[Avoid 130, 260 ft]
80 meters; dipole:	34-40, 90-102 or 160-172 feet	[Avoid 66, 135, 190 ft]
40 meters; dipole:	42-52, 73-83, 112-123 or 145-155 feet	[Avoid 32, 64, 96, 128 ft]

Some slight trimming or adding of feedline may be necessary to accommodate the higher bands.

WARNING!

To avoid problems, a dipole antenna should be a full half-wavelength on the lowest band. On 160 Meters, an 80- or 40-Meter antenna fed the normal way will be extremely reactive, with only a few ohms of feedpoint resistance. Trying to load an 80-Meter halfwave dipole (or shorter) antenna on 160 Meters can be a disaster for both your signal and the tuner. The best way to operate 160 Meters with an 80- or 40-Meter antenna is to load either or both feedline wires (in parallel) as a longwire. The antenna will act like a "T" antenna worked against station ground.

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 **662-323-0549** or the *MFJ Factory* at **662-323-5869**. 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 662-323-6551; 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.

Suggested Tuning Chart

Frequency (MHz)	Antenna	Inductance	Transmitter	Load(Ω)
1.8	1	46	2	25
1.8	1	48	0	50
1.8	6.5	17	0	800
2.0	0	58	2.5	25
2.0	0	63	0	50
2.0	6	35	0	800
3.5	0	95	2	25
3.5	1	95	0	50
3.5	0	79	1.5	800
3.75	0	97	1	25
3.75	1	97	0	50
3.75	0	80	2	800
4.0	1	100	0	25
4.0	2	99	0	25
4.0	0	84	2	50
5.34	2	105	0	800
7.15	2	112	0	25
7.15	3	110	0	50
7.15	0	97	6	800
10.1	4.5	116	0	25
10.1	4.5	114	0	50
10.1	8	103	7	800
14.2	6.5	117	0	25
14.2	6	114	0	50
14.2	7	113	0	800
18.1	7.5	117	0	25
18.1	7	109	0	50
18.1	9	111	0	800
21.2	8	114	0	25
21.2	8	116	6	50
21.2	0	114	9	800
24.9	8.5	119	6	25
24.9	8	117	7.5	50
24.9	0	115	9	800
28.5	9	121	8	25
28.5	8	119	9	50
28.5	4	117	9	800

Logged Tuning Chart

Use the chart below to log values for your station. You may want to copy this chart and post it by your tuner.

Frequency (MHz)	ANTENNA	INDUCTOR	TRANSMITTER
1.8			
3.5			
7			
10.1			
14			
18			
21			
24			
28			
50			

