# MFJ

# *RF Design Box*

*Model MFJ-5904*


## 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


VERSION 1A

# MFJ-5904 RF Design Box

**Introduction:** MFJ's *RF Design Box* is a "must-have" accessory for antenna designers and experimenters, and the perfect compliment for your handheld antenna analyzer. Inductors and capacitors are the fundamental building blocks for RF design and the MFJ-5904 places both at your fingertips. With them, you'll build and test virtually any popular HF tuning and matching network in minutes without ever plugging in a soldering iron. Your MFJ-5904 is built for portability with a compact molded case and high-quality components Best of all, each component is 300-watt ATU rated so you can put your designs to the test under actual operating conditions using a 100-Watt station transceiver.

The MFJ-5904 provides two capacitor banks with variable and switched components to provide a seamless adjustment range from 12 pF to 912 pF. You also get a switched toroid inductor assembly that is step-adjustable from 0.1 to 11.2 uH in 12 steps. All components are RF-isolated from the aluminum front panel to ensure your safety. Simply connect patch leads to configure the circuit and tune in the optimize values for absolute peak performance. It's so convenient, you can try different network configurations to see which one works best. Here are a few test circuits the MFJ-5904 will help you construct:

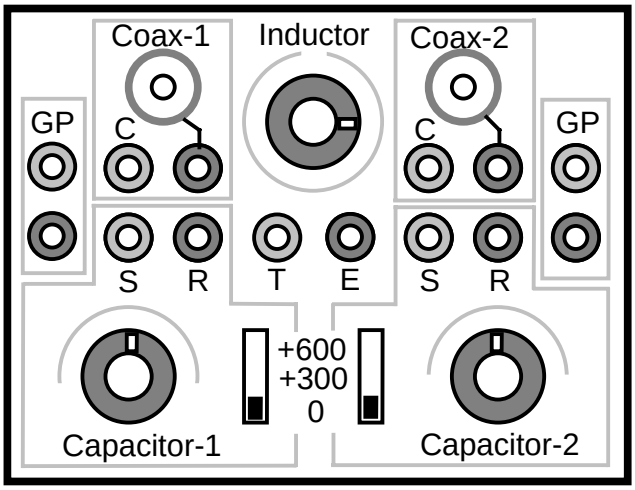
[ ] L-networks (low-Z to high or high-Z to Low)
[ ] T-networks (identical to popular HF antenna tuners)
[ ] Pi-networks
[ ] Band-pass filters
[ ] Band-stop filters
[ ] Traps and reject Filters
[ ] Loading inductors
[ ] Shunt-L and C shunt-matching elements
[ ] Load Converters
[ ] Power Reducers
[ ] Q meter
[ ] Antenna-analyzer pre-selector
[ ] Selective field-strength meter
[ ] Portable antenna tuners

Once you start using your MFJ-5904, you'll quickly discover there is no "black magic" associated with RF design. Every network is predictable and true to its theoretical basis. In fact, the RF Deign Box is a tremendous training tool that can help you to develop a true "hands-on" feel for how each type of RF tuned-circuit works.

Before launching into your first project, take a few minutes to look through the manual in order to gain familiarity with your unit's functions and features. A few minutes spent now will get you up and running more quickly.

**MFJ-5904 Panel Layout:**

The Network Box is configured left-to-right across the front panel to facilitate logical "input-to-output" setups. Color-coded black and red 5-way binding posts help identify junction points (or "nodes") you'll set up during wiring. To make connections, you may use wire jumpers terminated with banana plugs, spade lugs, or stripped ends. Each binding post handles multiple connections and locks them down securely. See the panel layout below:




***1). GP Posts:*** "General purpose" binding posts located on each side of the panel are disconnected from the internal tuning elements and may be used for supporting and connecting external (add-on) components.

***2.) Coax Connectors:*** Coax-1, Coax-2 shields are grounded in common with the front panel. The connector center conductors are terminated to the red "C" (for center) binding posts. Use these SO-239s for coaxial input and output lines.

***3.) Capacitor Bank Assembly:*** Capacitor-1 and Capacitor-2 are 312 pF variable capacitors with a calibrated scale in pF. Their range may be extended to 612 or 912 pF by adding 300 pF or 600 pF in parallel via the switch. Fixed capacitors are precision silver-mica. Note that the variable capacitor binding posts are labeled "S" for stator and "R" for rotor.

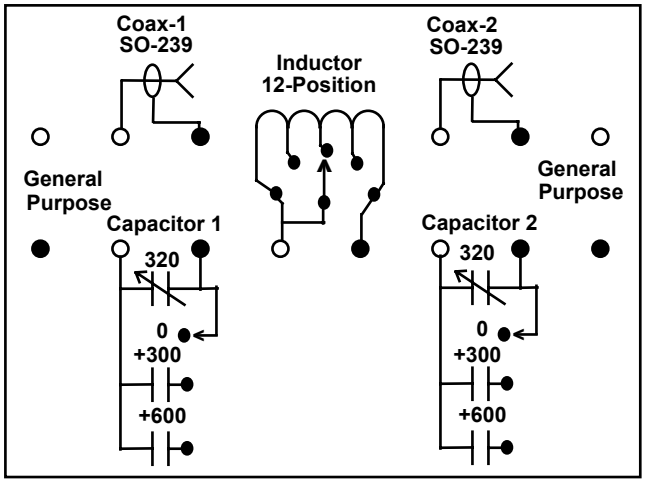
***4.) Inductor Assembly:*** The 11.2-uH toroid-core inductor is tapped with a 12-position selector switch in a shorted-turn configuration. Note that the center-contact terminal is labeled "Center".

***Important Warning:*** *When wiring network configurations, always confirm all external connections are secured with no exposed conductor surfaces before applying RF power. Inadvertent contact with energized wiring can cause severe RF burns and poses an acute injury threat.*

**Schematic Diagram:**

Internal wiring for the MFJ-5904 is shown in the schematic below. Use this diagram as a guide to help you identify individual terminal posts when configuring jumper leads:

**Schematic for MFJ-5904 Network Box**



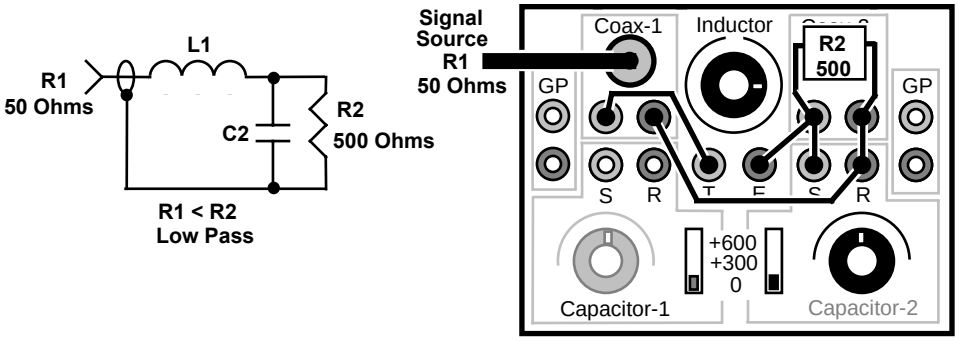

**Antenna Analyzers:** Your hand-held antenna analyzer provides instant feedback for verifying correct network wiring. It also helps you find the optimum component values for your particular circuit configuration. Simply connect it to the analyzer's input antenna port (*Coax-1*) and attach the antenna or device under test to Coax-2 (or its associated binding posts). Use the shortest patch cord practical between the analyzer and the RF Box to minimize impedance measurement errors caused by phase rotation in the test cable. Analyzers with swept-frequency graphic capability such as the MFJ-223 or MFJ-225 provide the added advantage of visualizing the network's performance over a broad frequency span. This feature is especially useful for analyzing filters, traps, and antenna bandwidth. Once your network is configured and adjusted for optimum match, you can remove the analyzer and safely test the network using a 100-Watt station transceiver.

Note that series-L networks (like the pi-network) will form a DC path through the design box to your analyzer. When testing, remember to momentarily short the feedline leads to bleed off static before connecting to the RF Box.

***Important Warning:*** *When testing, never allow your antenna analyzer to become connected to an RF source (such as a transmitter or high-level signal source) or to be exposed to a dc-bias or static discharge. When connecting large antenna arrays to the Design Box, always discharge the conductors first to protect your analyzer at the opposite end.*

**Building a Practical Test Circuit:**

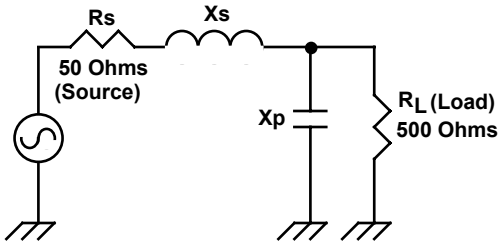
The test circuit shown below is a simple "L" network. In this case, the network's "job" is to transform the 500-Ohm load (R2) connected at the output posts to 50-Ohms at the opposite end. Connect your handheld antenna analyzer to Coax-1, set it up for 10 MHz, and monitor your results.




When configuring an N network of this type, note that the shunt capacitor (C2) is always installed at the high impedance end (R2). To facilitate this configuration, Capacitor-2 is wired in for the test. To find functional L/C values, use the same procedure you would for tuning with an antenna tuner. Step through the inductance settings and rotate the capacitor's tuning range at each stop. Find the value combination that delivers the lowest SWR.

**Calculating a Sample L-Network:** If you wish to calculate the theoretical values for the network shown above, use the procedure outlined below:

**Problem:** Design a shunt-C type L-network to match a 50-Ohm source into a 500-Ohm load at 10 MHz. Note that the shunt component (the capacitor) will go on the high-impedance side of the network.




The solution for this type of network has three steps. First, calculate *network Q*, which is determined by the size (or magnitude) of the impedance transformation. The larger the impedance transformation ratio, the higher the Q requirement.

$$Q = \sqrt{\frac{R_L}{Rs} - 1} = \sqrt{\frac{500}{50} - 1} = \sqrt{9} = 3$$

Next, use the calculated "Q" to determine how much *reactance* the series inductor and parallel capacitor must contribute to the circuit in order to make the 500 Ohm load “look like” 50 Ohms at the network's input end. Note that Qs (series-Q) and Qp (parallel-Q) are of equal value.

$$Xs = Qs \cdot Rs = 3x50 = 150 \text{ (or j+150)}$$

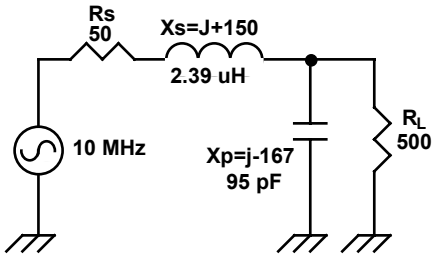
$$Xp = \frac{Rs}{Qp} = \frac{500}{3} = 167 \text{ (or j-167)}$$

Finally, calculate the actual *component values* it will take to develop the required amount of reactance *at the 10-MHz operating frequency*.

$$\text{Note: } \omega = 2\pi \cdot f \text{ (Hz) or } 6.283 \cdot (10x10^6)$$

$$L = \frac{Xs}{\omega} = \frac{150}{\omega} = 2.39 \text{ uH}$$

$$C = \frac{1}{\omega \cdot Xp} = \frac{1}{\omega \cdot 167} = 95 \text{ pF}$$




**Tip:** If your math is a little rusty, converting between Hz, Henries, and Farads to MHz, pF, and uH can sometimes lead to a misplaced decimal point. To reality-check your answer, use a Reactance Nomograph (widely available on line, in the ARRL Handbook, and in other publications) to make a quick L and C approximation for the required amount of reactance. The Nomograph is a very handy tool when used in conjunction with the RF Box. In fact, you could skip the L and C reactance calculations altogether and obtain "ballpark" values for your network setup using only the Nomograph. Note, also, that reactance vs frequency calculators are available online. Simply plug in the data and let your computer do the math.

**Next Steps:** These preliminary instructions provide a basic introduction to help you put the MFJ-5904 Design Box to work. For deeper understanding, many good design primers are available for RF networks, including the ARRL Handbook, ARRL Antenna Book, and RF-Circuit Design, a SAMS publication authored by Chris Bowick. Also, we recommend Experimental Methods in RF Design by Hayward, Campbell, and Larkin (ARRL Publications). Also, the next portion of the MFJ-5904 Manual will describe a variety of simple LC network configurations along with their strengths and weaknesses.

## 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 reading the manual does not solve your problem, 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.

## NOTES

# LIMITED 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 under warrantee provided the product is returned postage prepaid to MFJ Enterprises, Inc. with a personal check, cashiers check, or money order for **$7.00** covering postage and handling.

**3.** This warranty is **NOT** void for owners who attempt to repair defective units. Technical consultation is available by calling the Service Department at 662-323-0549 or the MFJ Factory at 662-323-5869.

**4.** This warranty does not apply to kits sold by or manufactured by MFJ Enterprises, Inc.

**5.** 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 unrepaired.

**6.** Under no circumstances is MFJ Enterprises, Inc. liable for consequential damages to person or property by the use of any MFJ products.

**7.** **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.

**8.** This warranty is given in lieu of any other warranty expressed or implied.

**9.** 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.

**10.** All MFJ products to be serviced in-warranty or out-of-warranty should be addressed to:

**MFJ Enterprises, Inc.,**
**300 Industrial Park Road**
**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.

**11.** This warranty gives you specific rights, and you may also have other rights which vary from state to state.