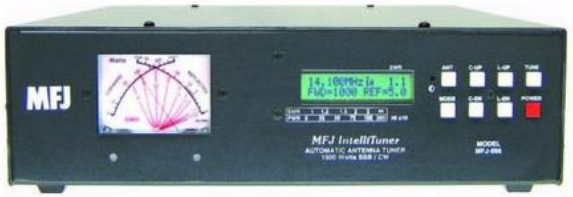


HF Antenna Tuners (New Hams Presentation)

Lewis Thompson, W5IFQ

2 May 2023

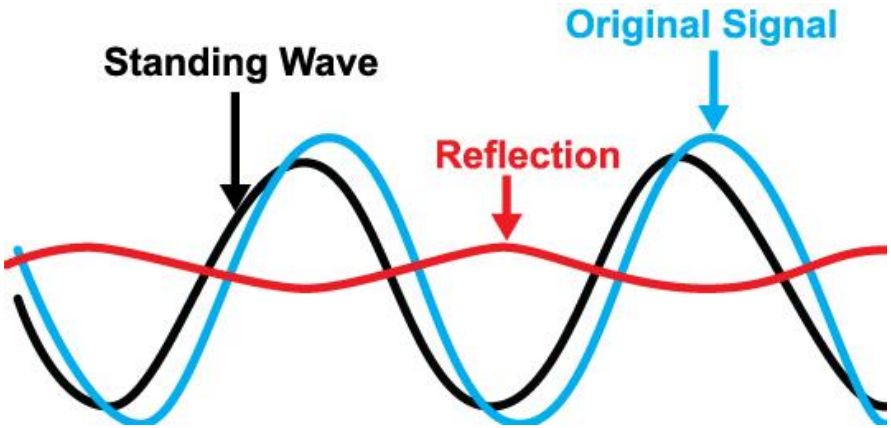
Objectives

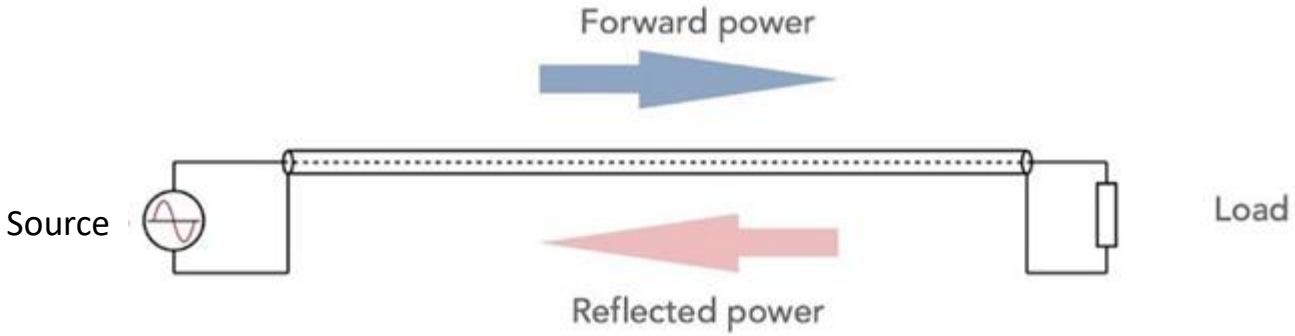
- Understand how VSWR (Voltage Standing Wave Ratio) affects HF (High Frequency) station operation.
- Discuss the contributions that antenna tuners can play in improving the effectiveness of HF station operations.

Outline

- Definition of VSWR
- How VSWR affects station operational efficiency
- Ways to deal with high VSWR
- Typical antenna tuner configurations
- Auto-tuners
- Auto-tuner location

Definition of VSWR





$$VSWR = \frac{1 + \sqrt{P_{ref} / P_{fwd}}}{1 - \sqrt{P_{ref} / P_{fwd}}}$$

What's Bad about High VSWR (> 3:1)

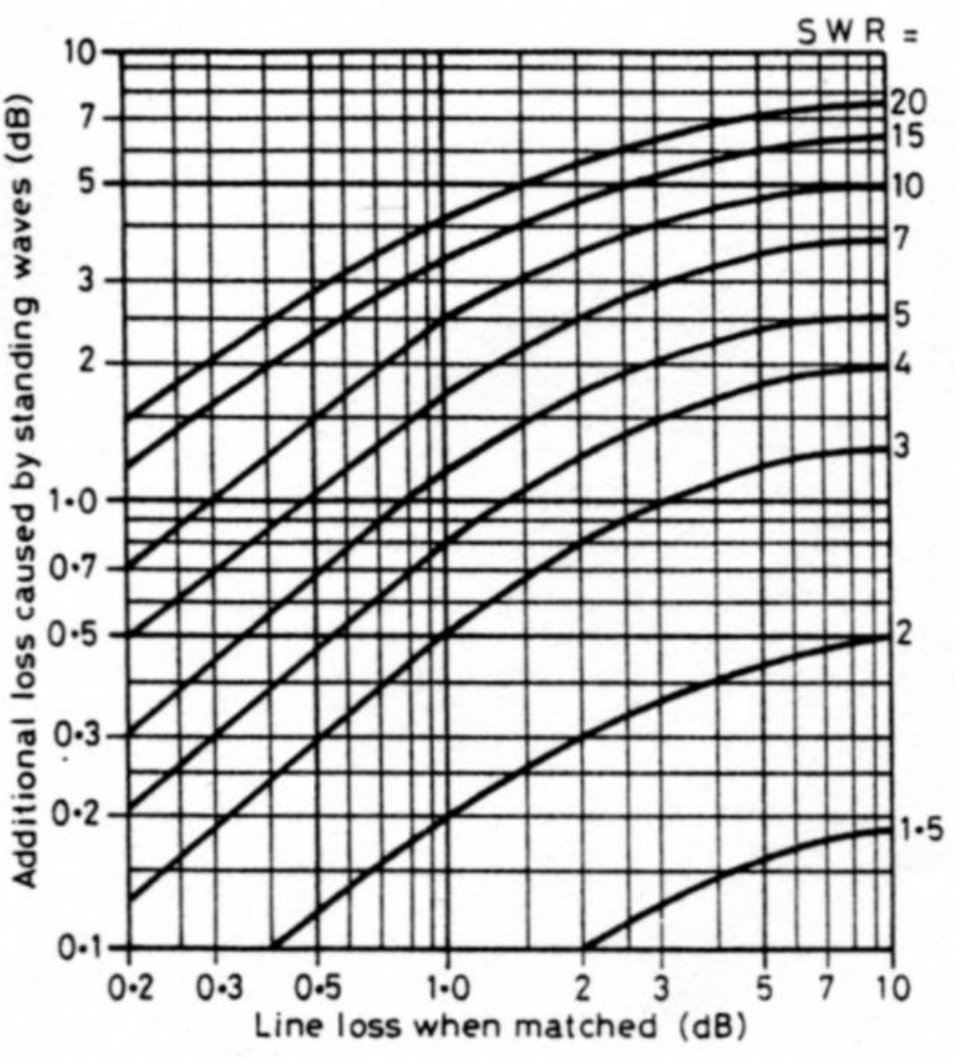
- Transmitter power amplifiers can be damaged
- PA protection circuit will reduce output power
- High voltage and current levels can damage the feedline
- Coaxial Cable – dissipation (loss) of power in cable
- Delay caused by reflection can lead to distortion

When is VSWR A Concern?

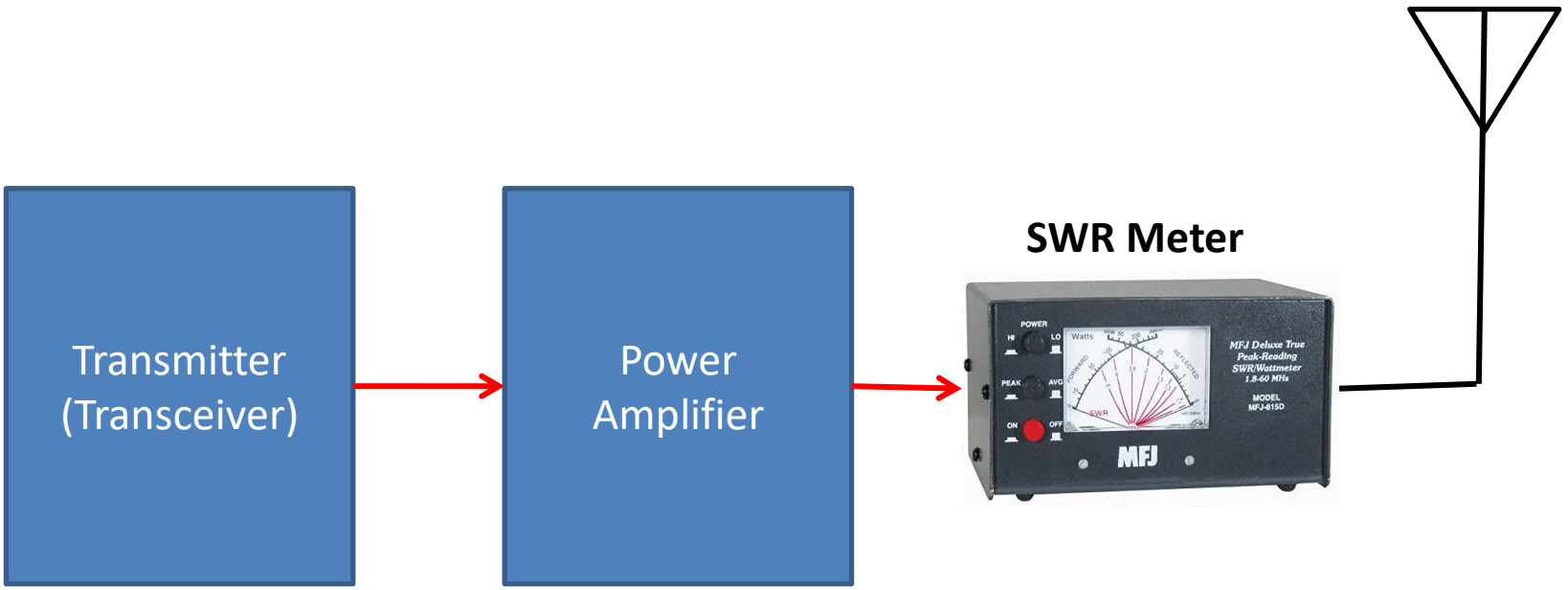
- **When using Coaxial Cable at high VSWR.**
- **Air has no dielectric loss at HF frequencies. This is why ladder is very low loss even at very high VSWR's.**

Coaxial Cable Loss

- Additional coaxial cable lose is caused by dielectric losses in the center insulator when cable is operated at high VSWR's.
- Example – If normal line loss is 1 dB and SWR is 20:1, the additional loss is 5 dB for a total loss of 5 dB. 100 watts in = 32 watts out!
- Ladder Line has an air dielectric so has very low losses even at high SWR.



Measuring VSWR



Note: If using the Transceiver's internal VSWR meter, place the Power Amplifier In standby (pass-through) mode.

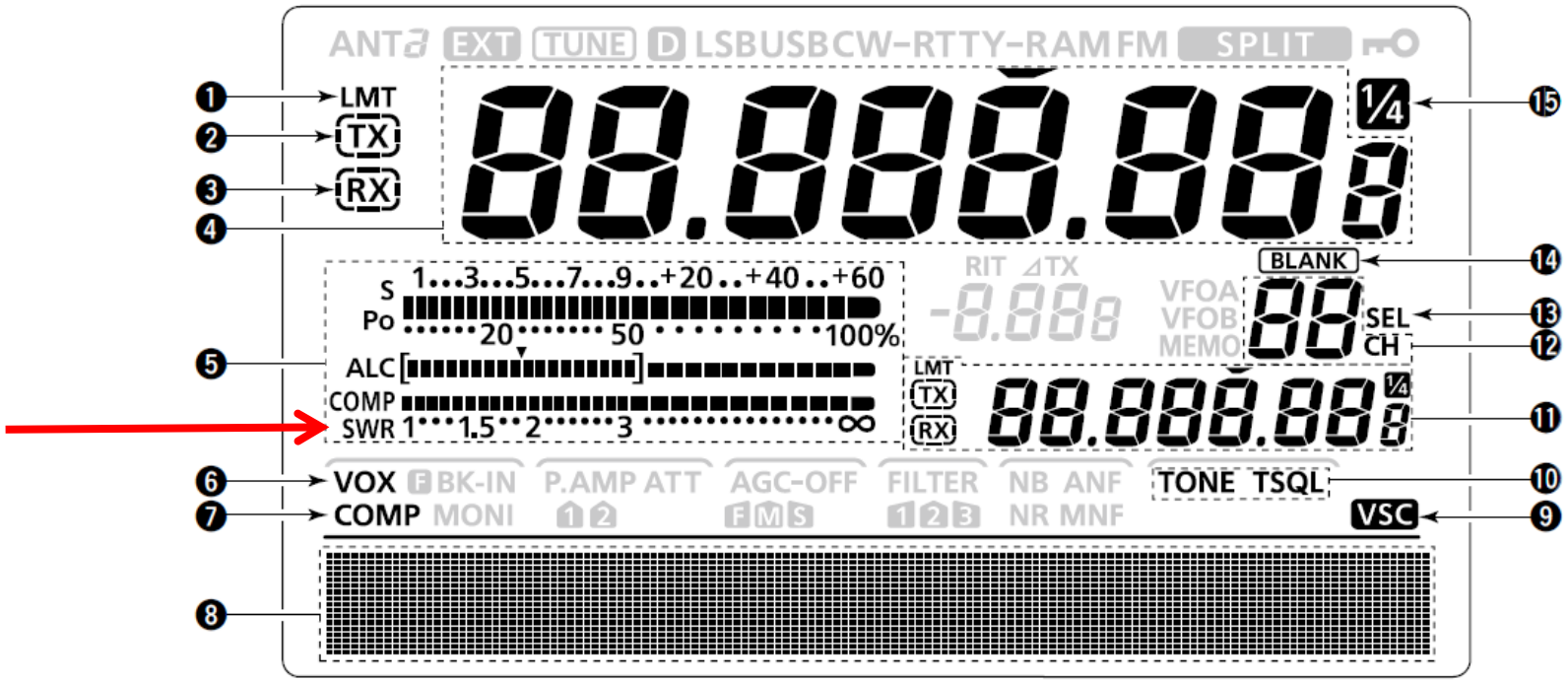
Dedicated VSWR Meter

Dual meters show both forward and reflected power. The crossing point of the two meters is the VSWR on the red scale. Note that all SWR Meters have an operational frequency range. Typically HF or VHF.

Measuring VSWR Using A RF Power Meter

Bird 43 Thuline ® Wattmeter that provides forward and reverse power

Measuring VSWR Using Rig
ICOM IC-7610



❺ MULTI-FUNCTION METER INDICATION

- Displays the signal strength while receiving.
- Displays the relative output power, ALC and SWR or compression levels while transmitting. (p. 33)

Measuring VSWR Using A Vector Impedance Meter (Nano VNA)

Ways To Minimize VSWR

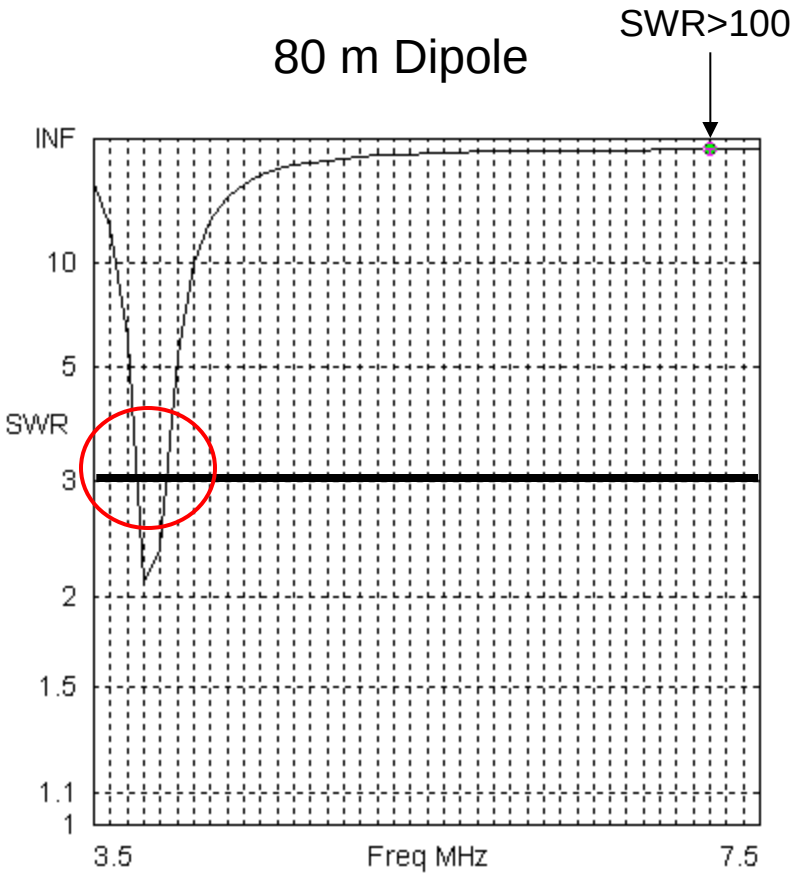
- Resonant Antennas
- Specially tuned Antennas
- Manual Tuner
- Auto-Tuner
  - Internal in some rigs (3:1 maximum)
  - External (at rig or remote)

Low VSWR Antennas

- One-half wave-length Dipoles
- Terminated or loosely coupled Antennas
- Special dimensioned wire antennas (for example - G5RV)
- Commercial antennas

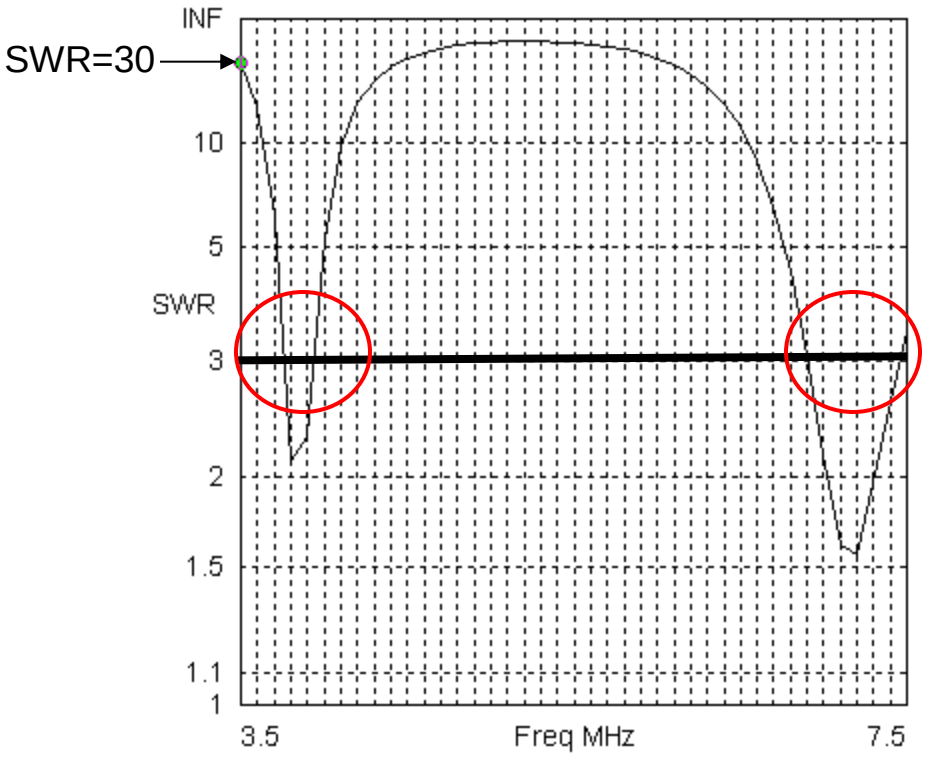
Resonant dipoles

80 m Dipole



Freq	7.2 MHz	Source #	1
SWR	> 100	Z0	50 ohms
Z	4589 + j 2444 ohms		
Refl Coeff	0.9832 at 0.52 deg.		

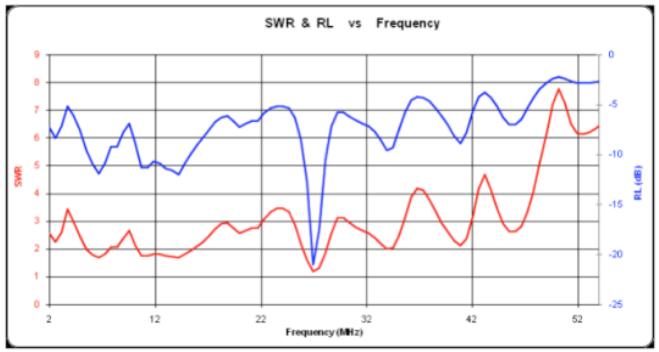
80/40 m Cross-Dipoles



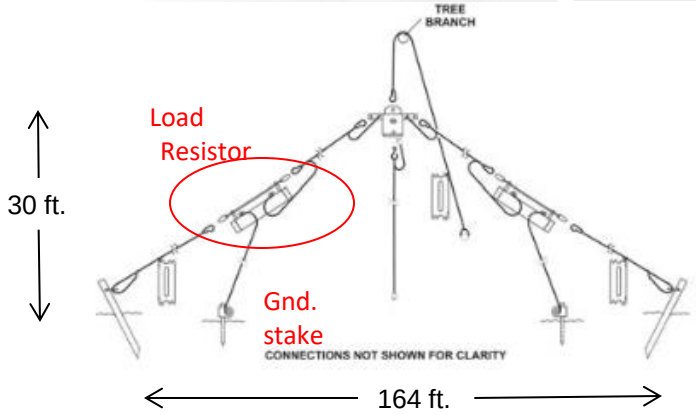
Freq	3.5 MHz	Source #	1
SWR	30.3	Z0	50 ohms
Z	15.27 - j 143 ohms		
Refl Coeff	0.9362 at -38.18 deg.		

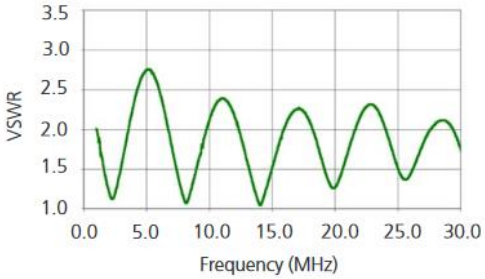
"Junk" Antennas at NVIS Frequencies (2-6 MHz)

Chameleon EMCOMMII
3.5 – 30 MHz
<2.5:1 SWR
$149.00



Harris RF-1944
1.6 – 30 MHz
<2.5:1 SWR
-15 dBi at 2 MHz
(20W in – 0.1 W out)
-2 dBi at 30 MHz
$2530.00





Any long-wire, vertical, or dipole claiming VSWR of <3:1 over the complete HF band has a very high-loss matching network and will have a low transmit efficiency. Receiving requires only gain so will appear to work as a receiving antenna.

Terminated Folded Dipole (TFD) (B&W 90)

From: http://on5au.be/content/a10/wire/wbfd.html

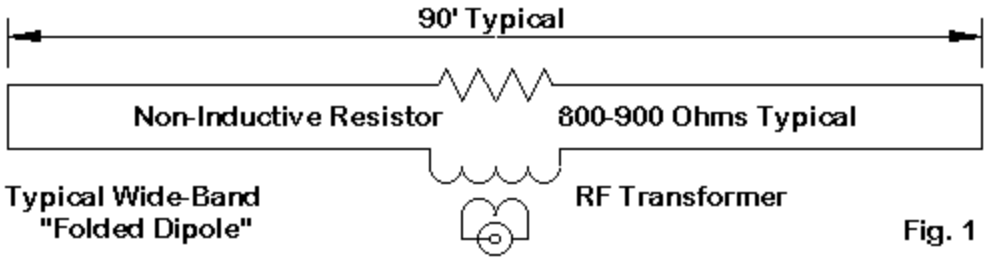


Fig. 1

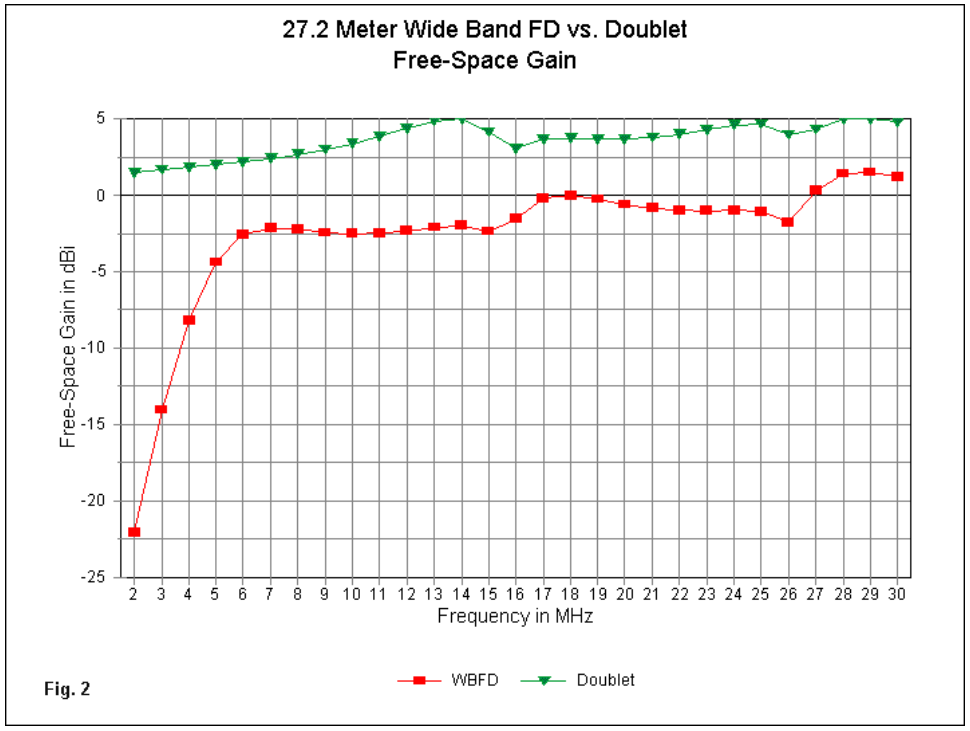
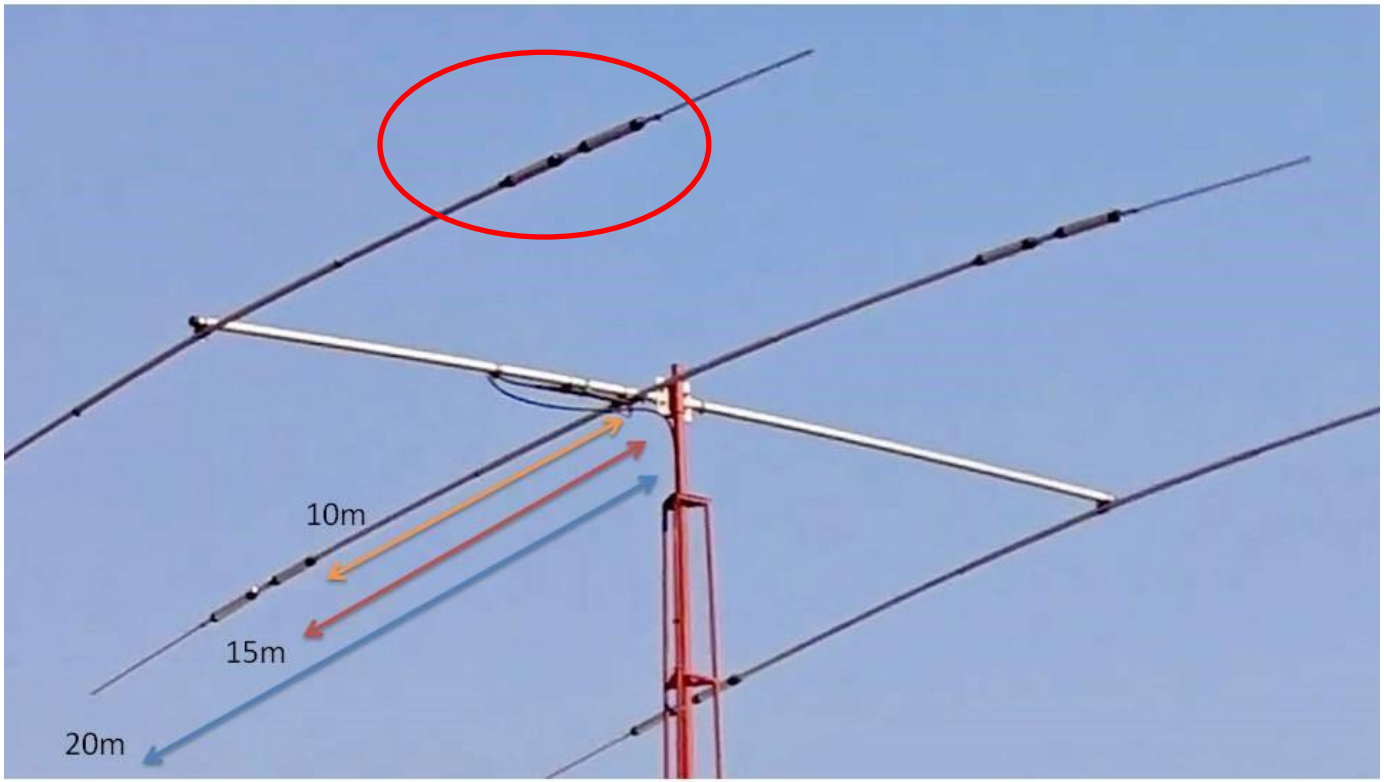


Fig. 2

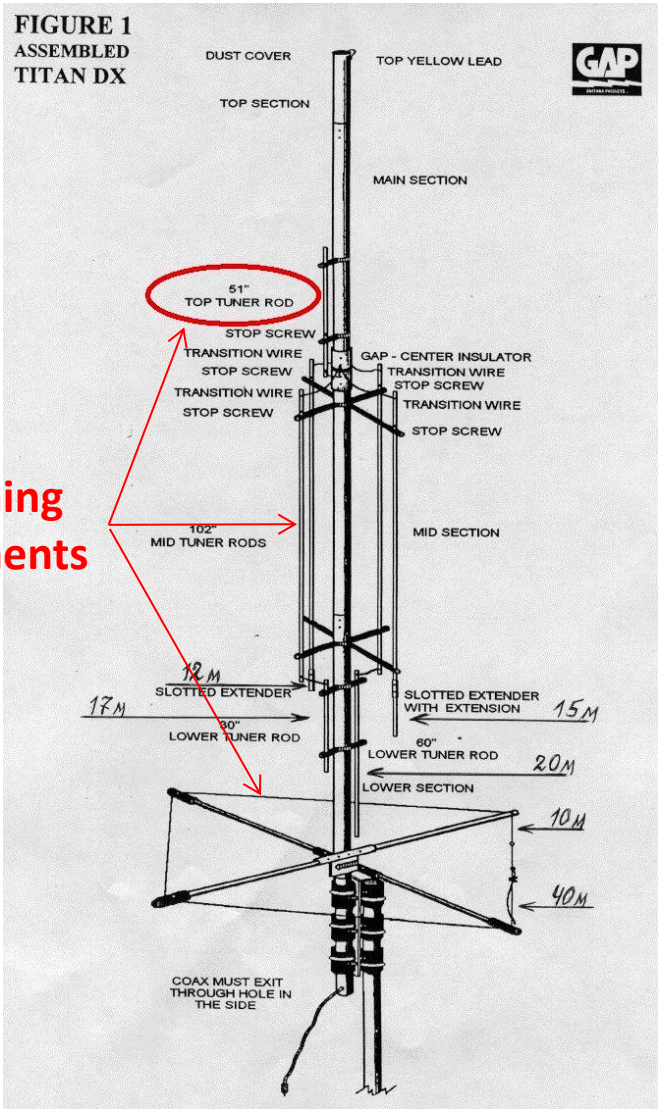
Rules:

1. Length – ½ wavelength at lowest operating frequency
   B&W 90 > 5 MHz
   B&W 180 > 3 MHz
2. Accept losing ¾ of your transmit power, i.e., 100 watts in, 25 watts out!
3. Solution for ALE

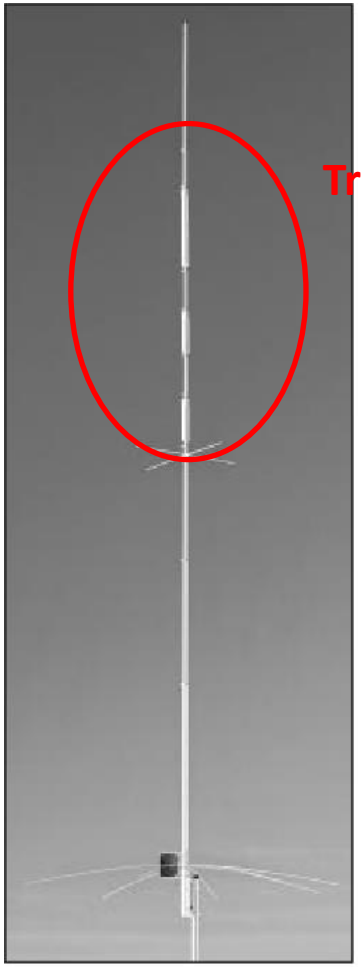
Commercial Antennas (Trap Yagi)



Commercial Vertical Antennas



Tuning Elements



Traps

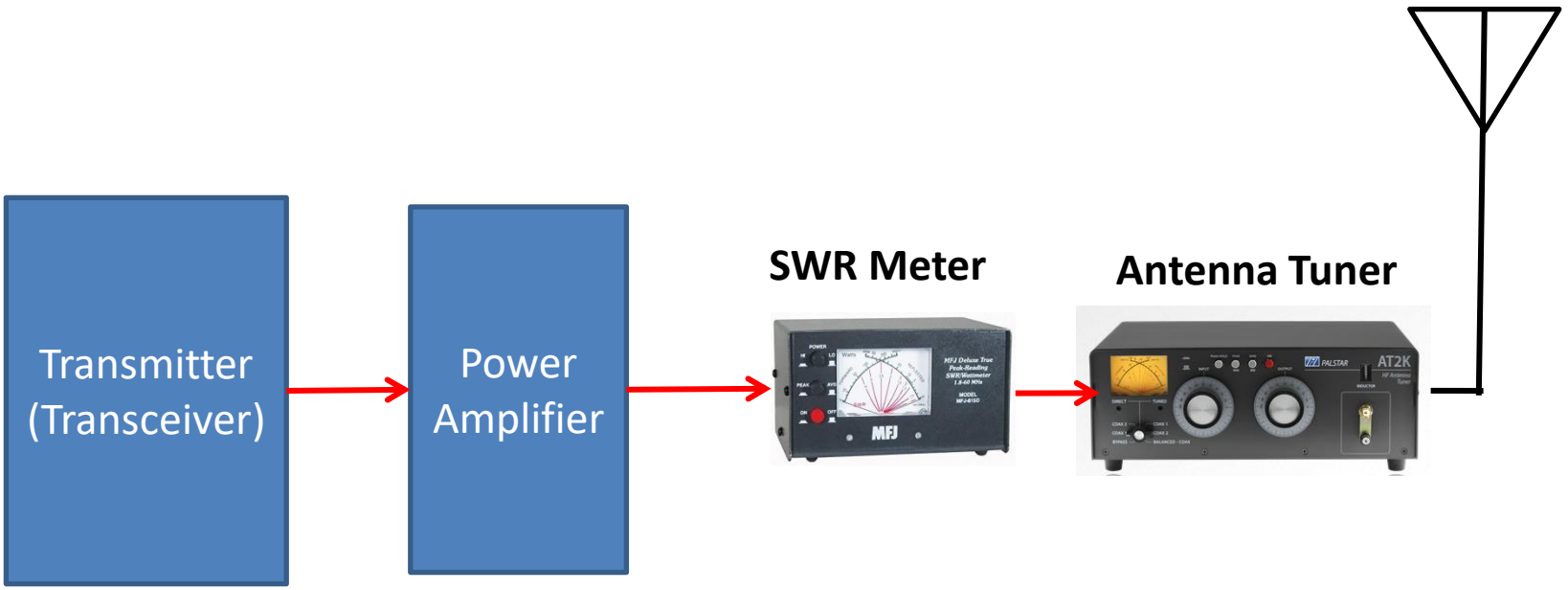
R7000

Diamond X-30
2m/70cm

Antenna Tuners

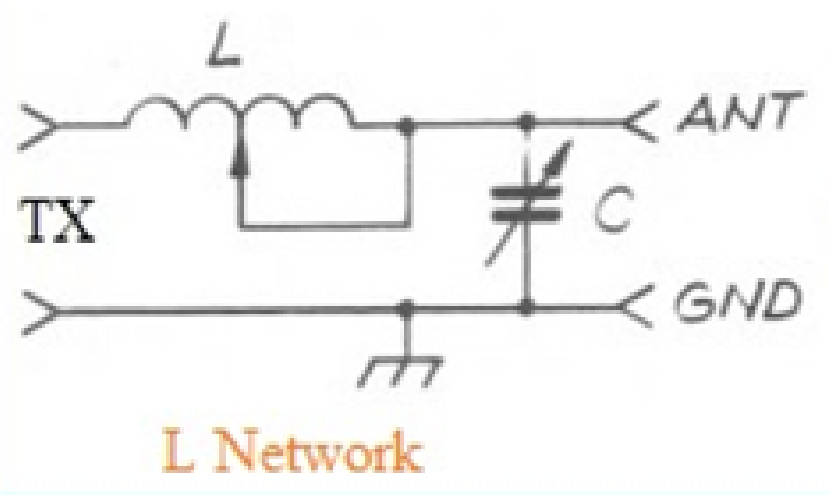
- Manual
- Automatic
  - Rig located
  - Remote located

Tuner Location

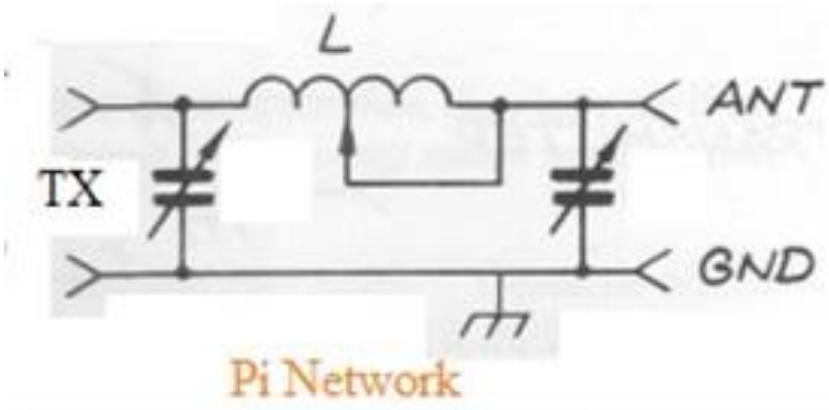


Note: If using the Transceiver's internal VSWR meter for tuner adjustment, place the Power Amplifier in standby (pass-through) mode.

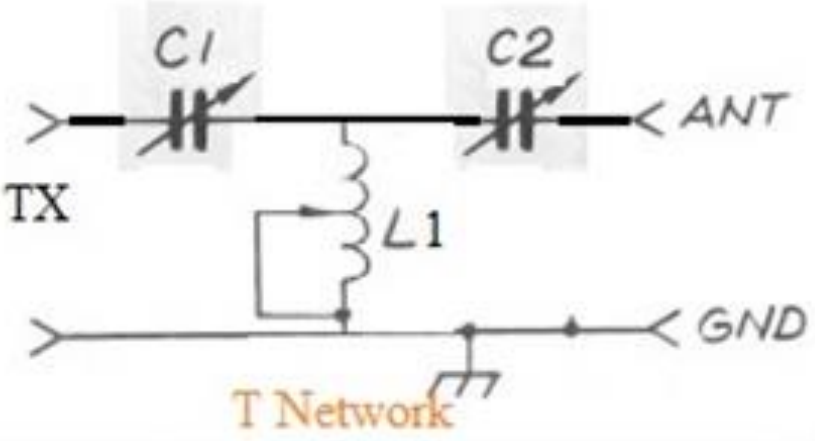
Popular Tuner Configurations



L Network

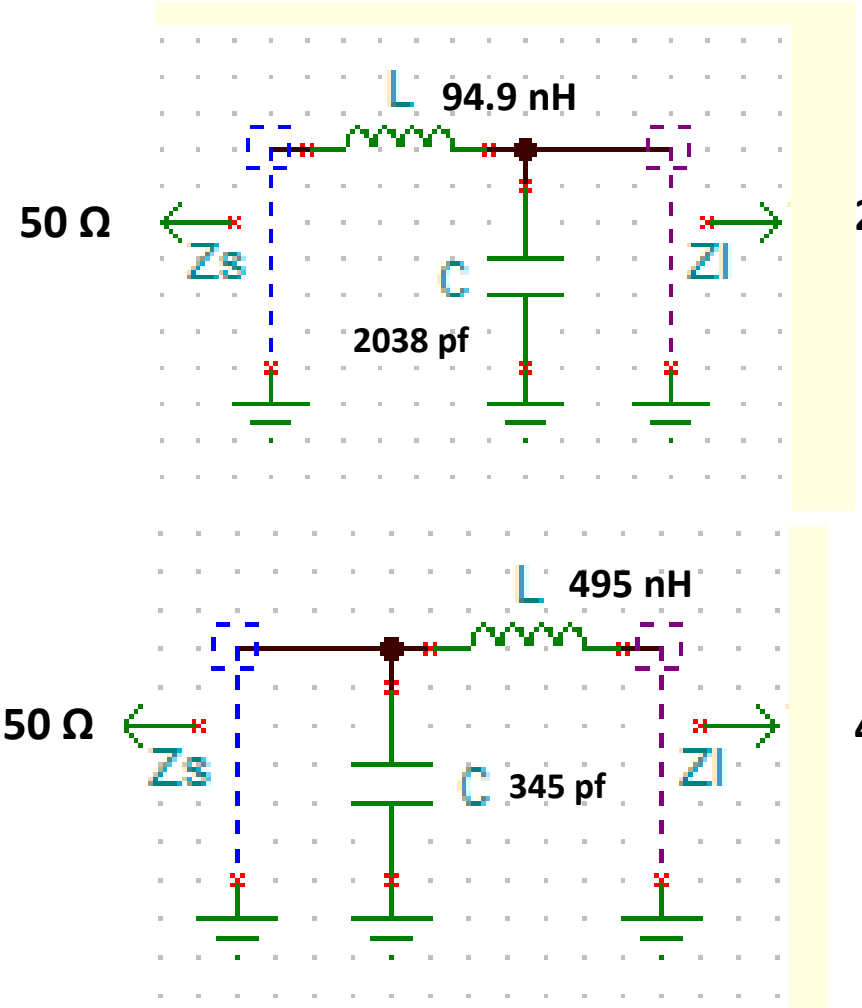


Pi Network



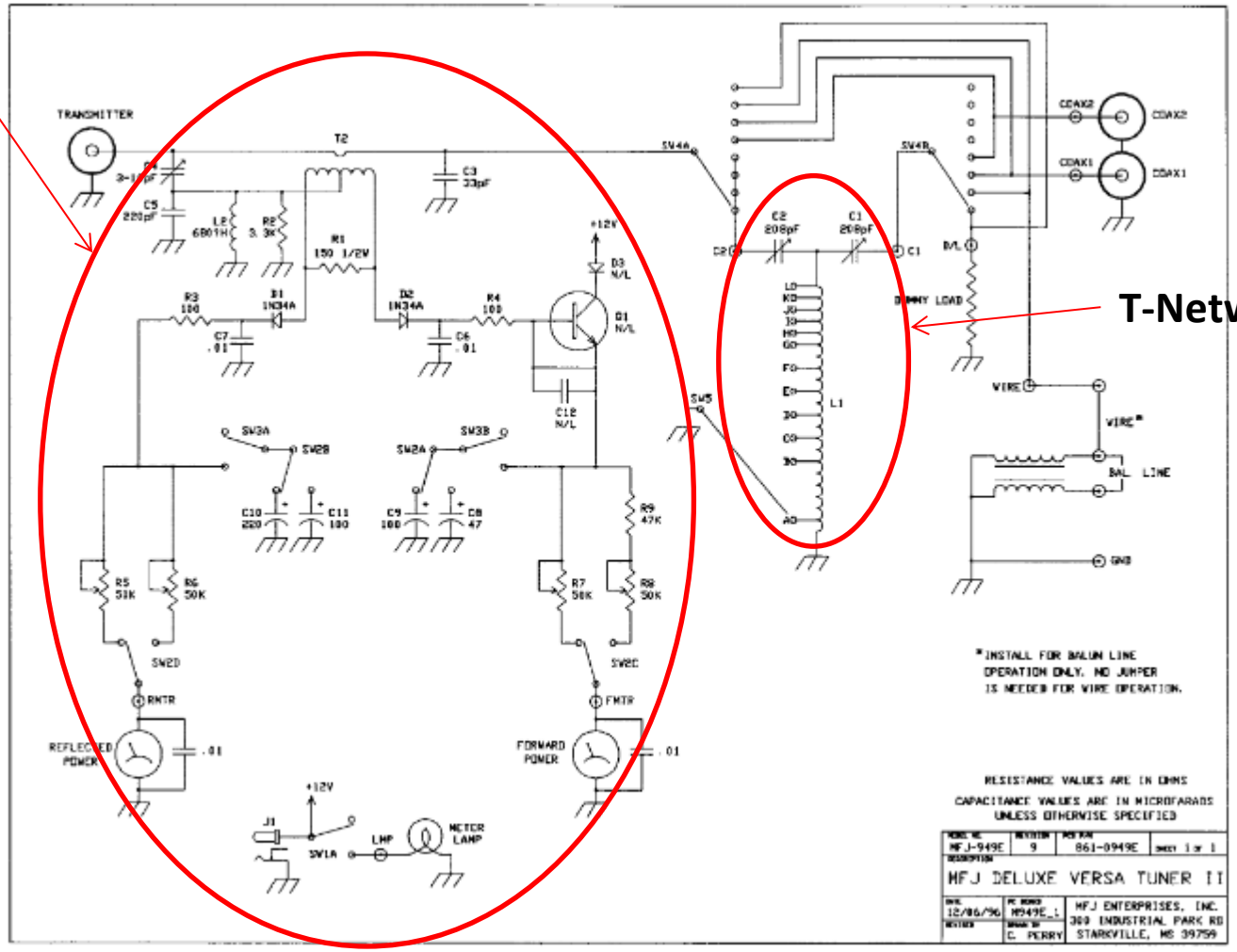
T Network

Example: L Antenna Tuner



Manual Tuner Example: MFJ – 949EB

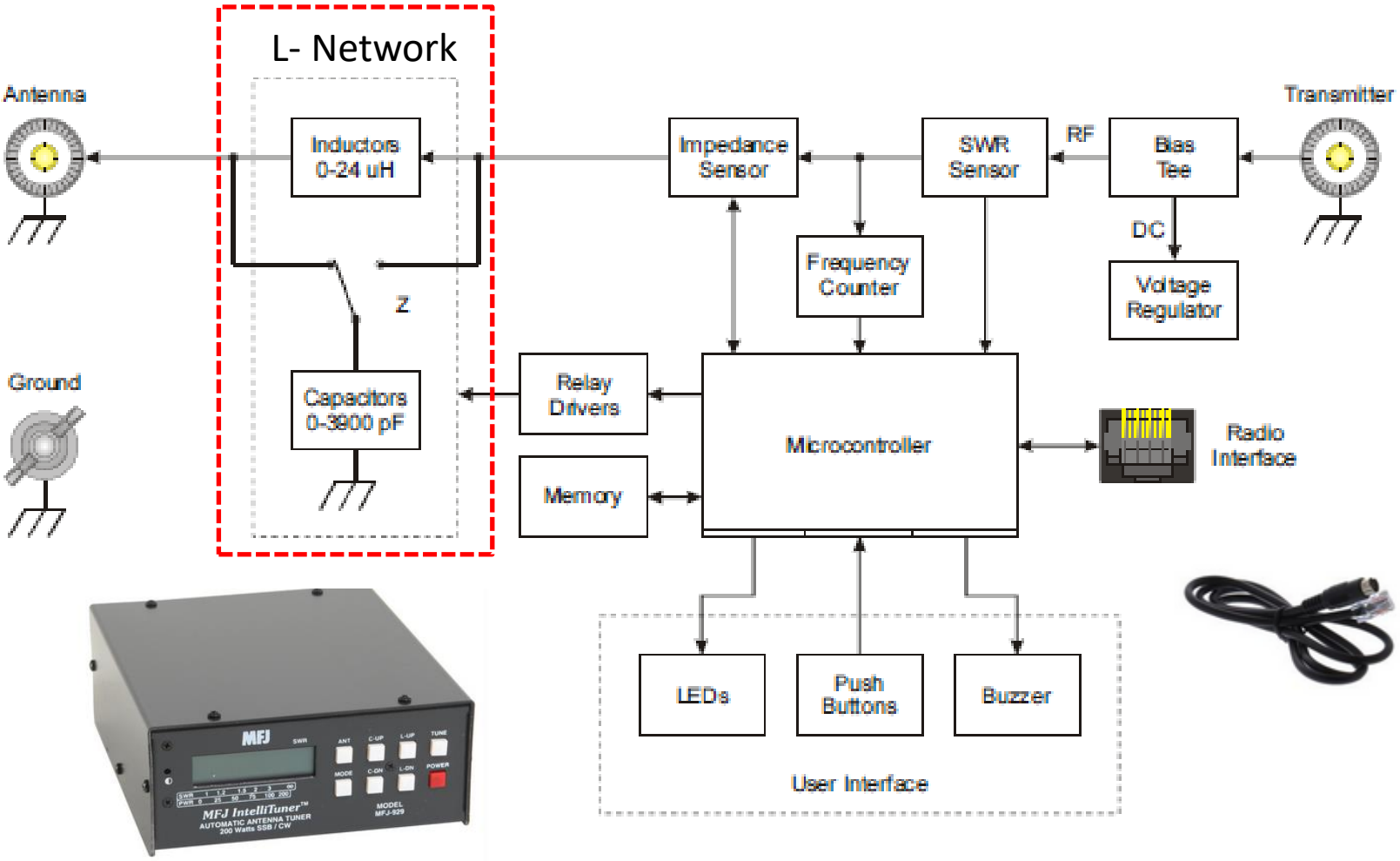
SWR meter



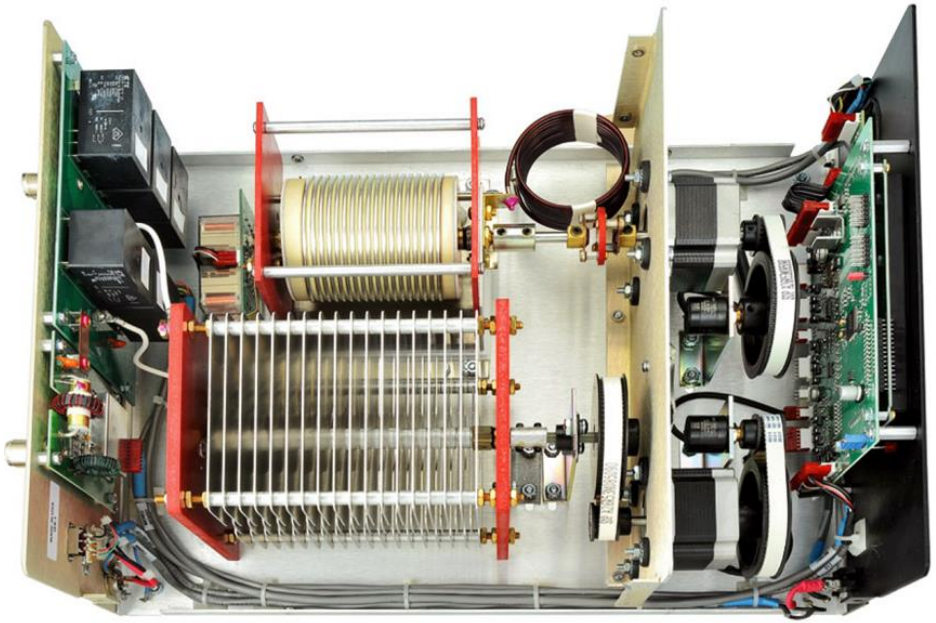
Auto-Tuners

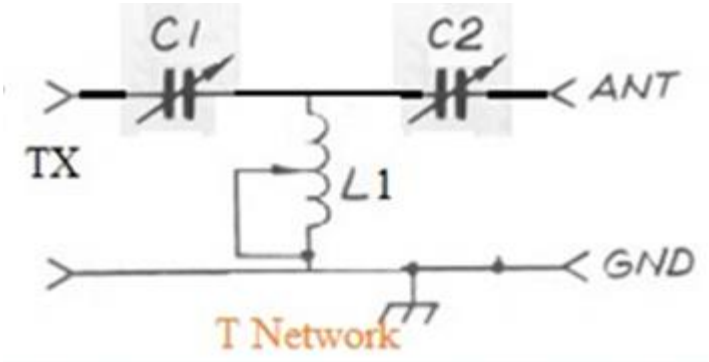
- Both independent and built-in (rig) auto tuners use one of the three configurations previously shown.
- Relays or motors, under computer control, are use to vary the values of inductors and capacitors.
- The auto-tuner's micro-controller uses software to both measure the transmit frequency, antenna impedance and SWR and to adjust the component values to minimize the SWR at 50 ohms input.
- Auto-tuners will "remember" the frequency and component values used at a specific frequency so as to minimize the time required for tuning on a previously used frequency.
- Auto-tuners shut down their computer clock after tuning to prevent RF interference. Tuning will either be automatically initiated on high SWR, or on command.
- Remotely located auto-tuners either used a CW signal to automatically initiate tuning on high SWR, or have hand-shake command lines controlled by the transceiver or a special control box.
- Remote location can be made more convenient by the use of Bias-T units at each end of the transmission line, allowing both DC power and RF to be sent through the transmission line.

Typical Auto-Tuner Block Diagram (MFJ-929)

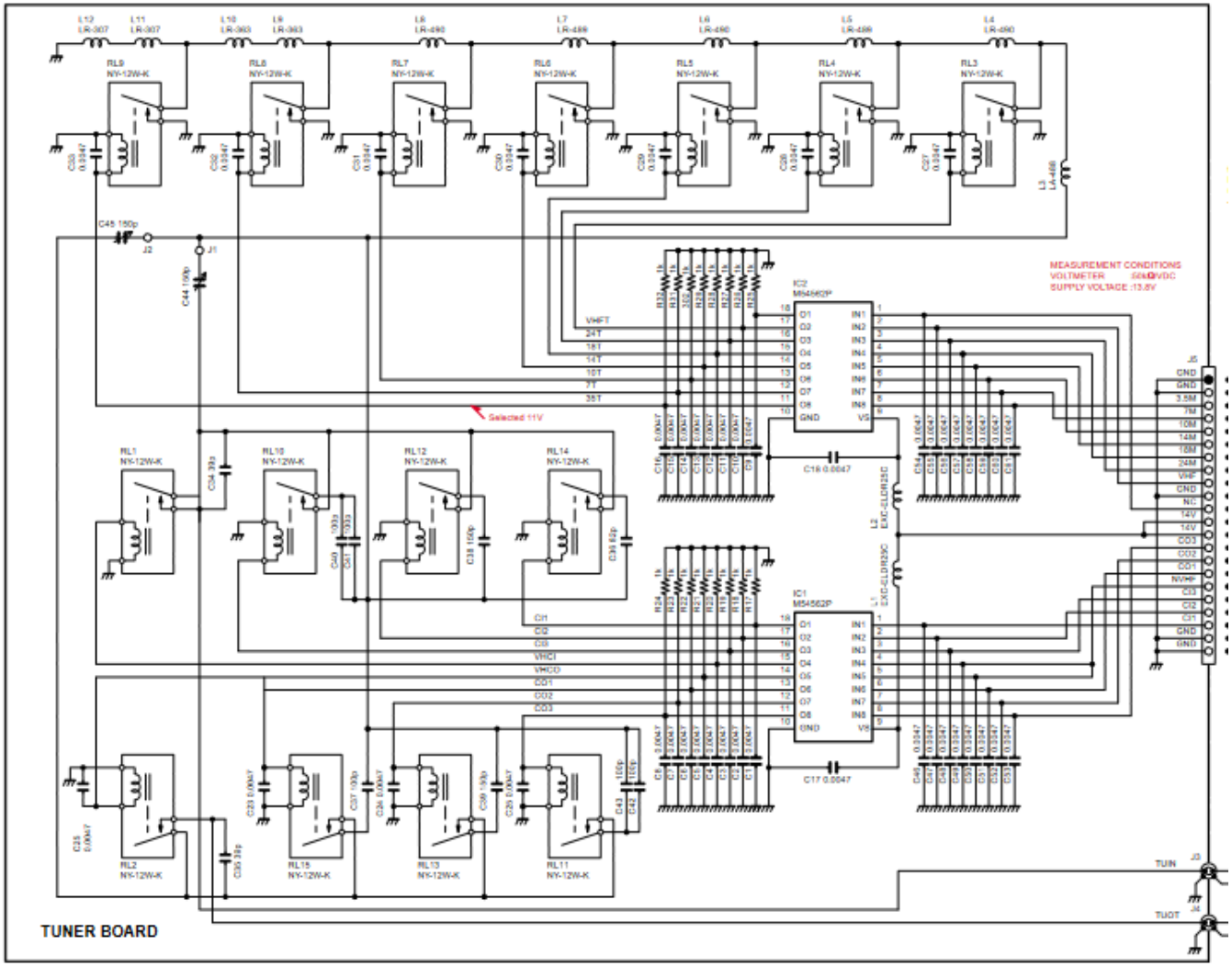


Palstar HF-AUTO (1800 watts)



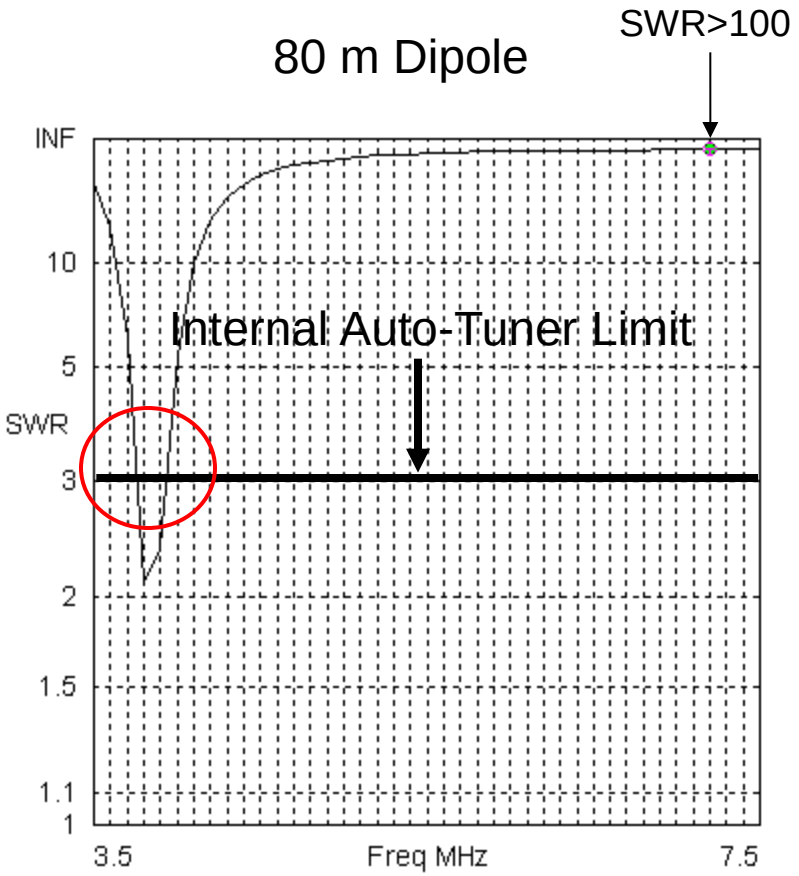


Rig Tuner: ICOM IC-756Pro3 (L type)



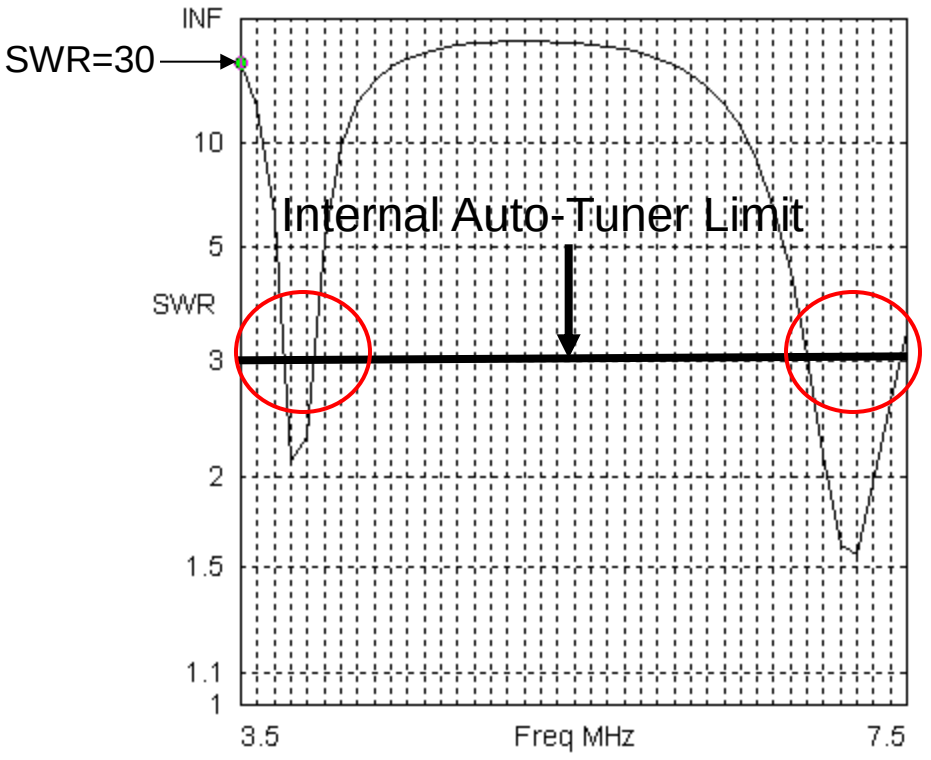
Internal (Rig) Auto-Tuner Limitations (≤3:1 SWR)

80 m Dipole



Freq	7.2 MHz	Source #	1
SWR	> 100	Z0	50 ohms
Z	4589 + j 2444 ohms		
Refl Coeff	0.9832 at 0.52 deg.		

80/40 m Cross-Dipoles

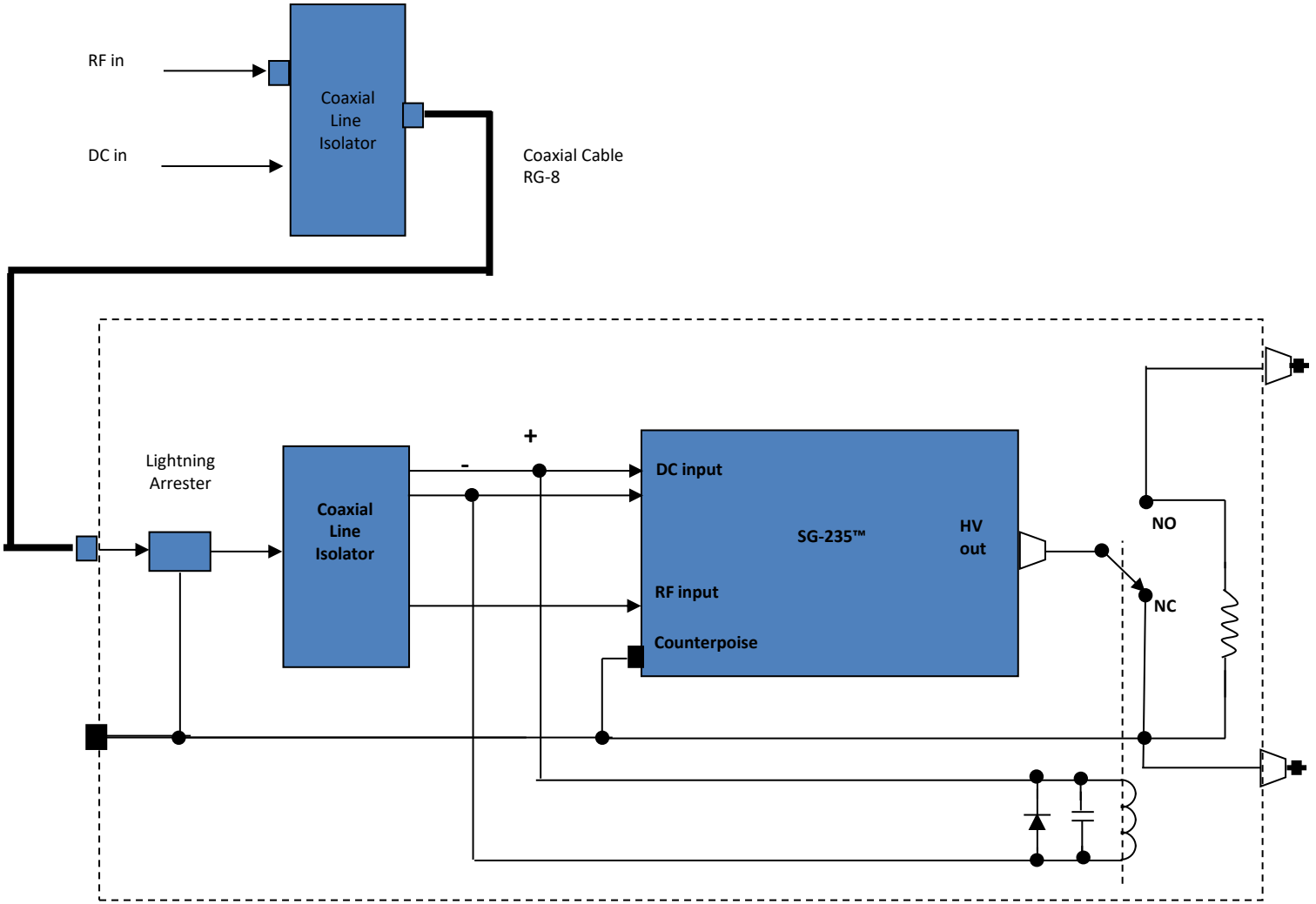


Freq	3.5 MHz	Source #	1
SWR	30.3	Z0	50 ohms
Z	15.27 - j 143 ohms		
Refl Coeff	0.9362 at -38.18 deg.		

Remote Auto-Tuners

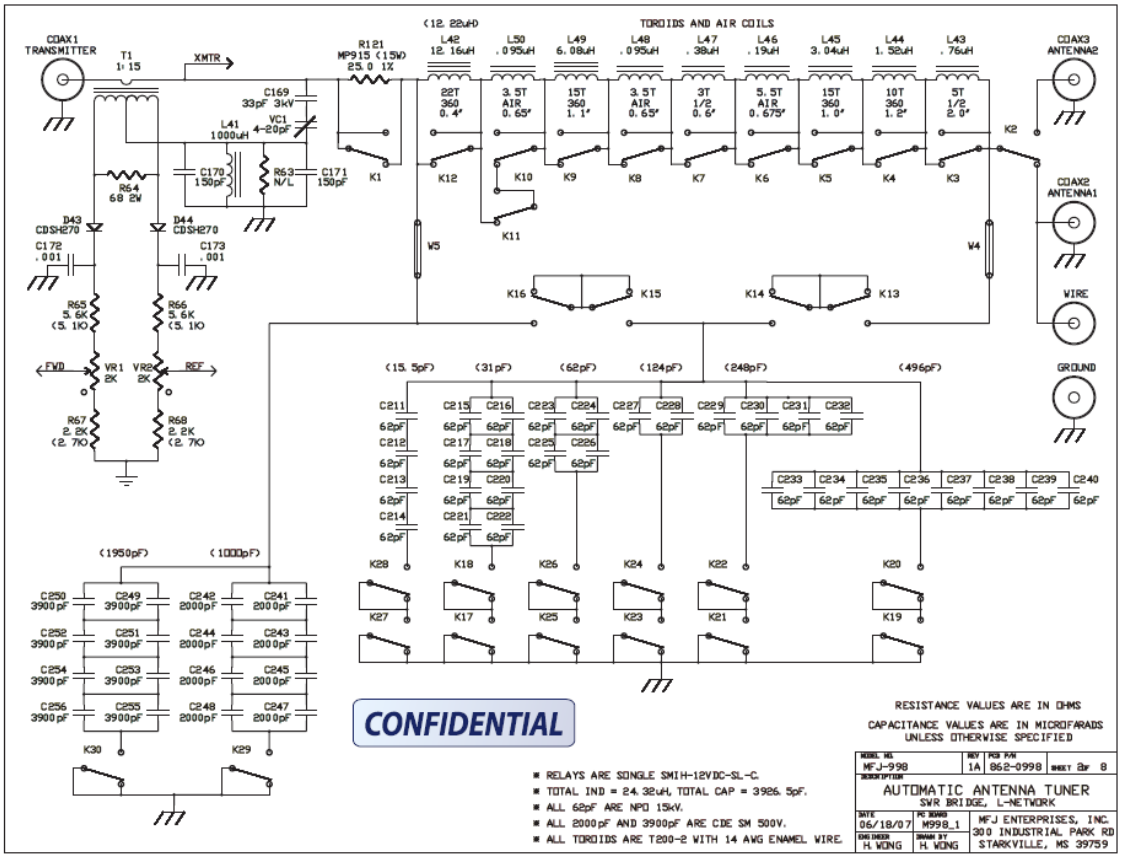
- **Used to eliminated high SWR transmission line loses.**
- **Requires weather tight housing.**
- **Requires lightning protection.**
- **The use of Bias-T's (Coaxial Line Isolators) at each end of the transmission line allows both remote power and RF to be sent to the remote tuner through the coaxial transmission line.**

Bias-T Use in Remote Auto-Tuners



MFJ-998: Desktop and Remote (RT)

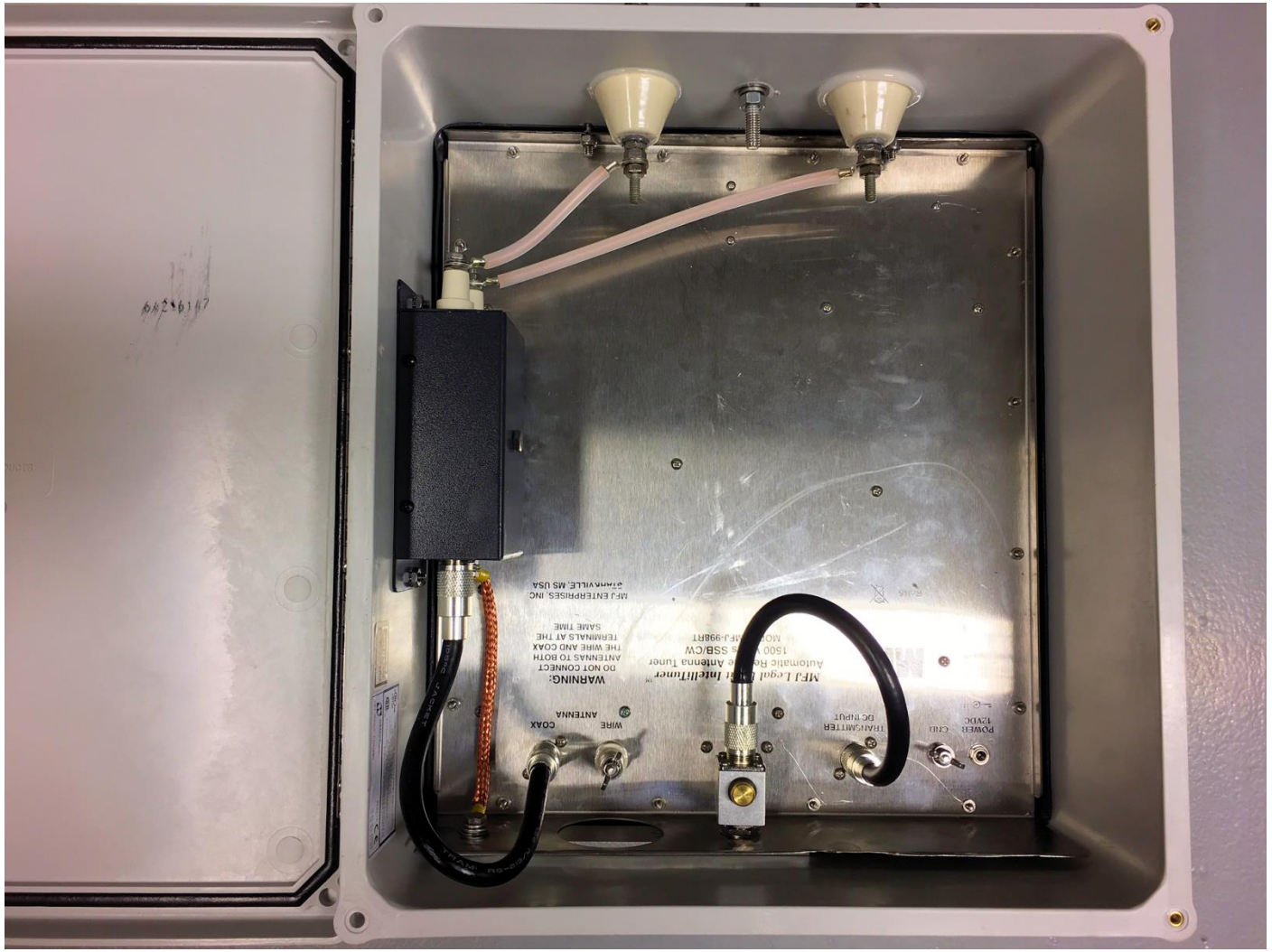
(1000 watts)



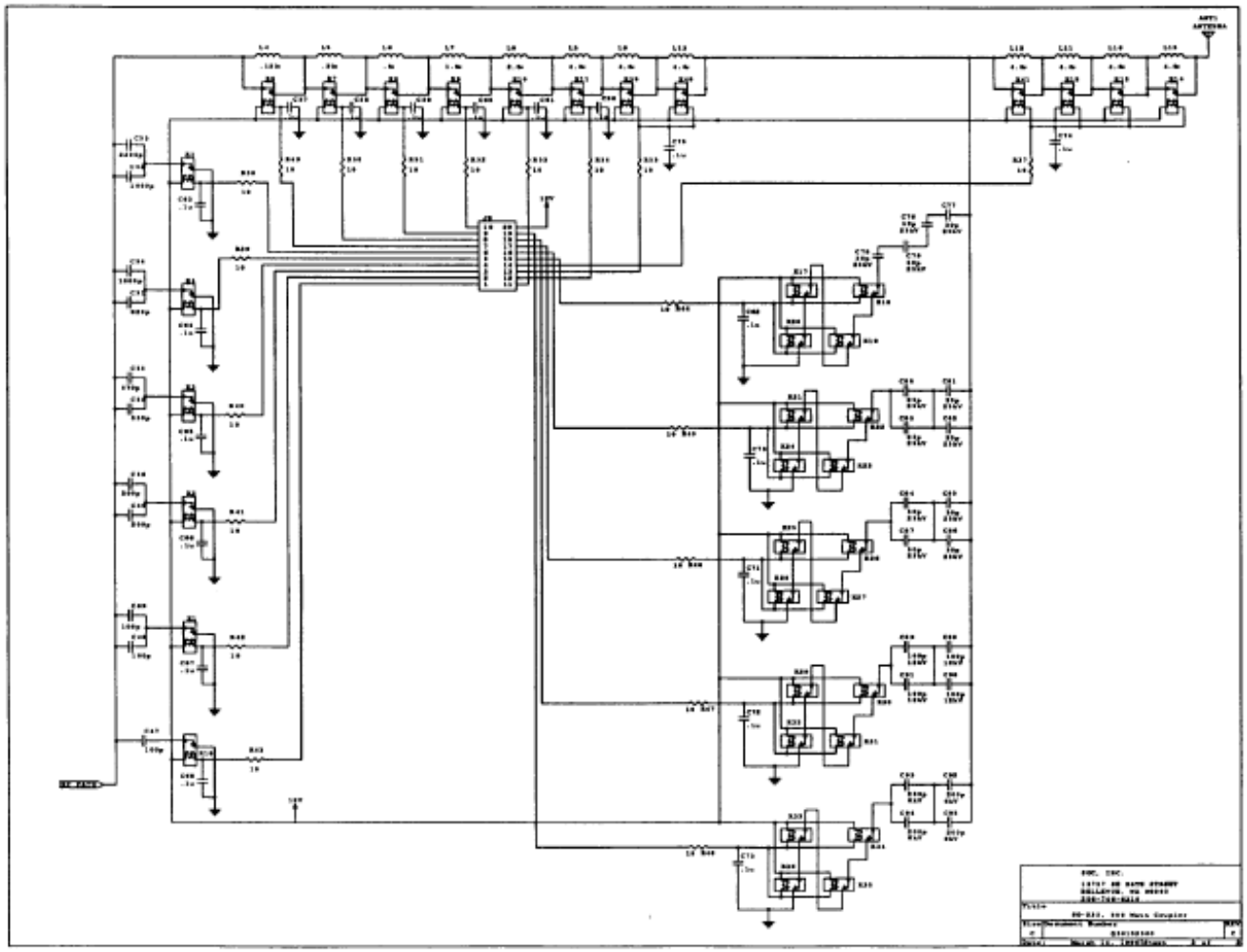
Note: Not weather proof. Must be placed in housing.

Contains a Bias-T so that Both DC power and RF can be sent to the remote tuner.

MFJ – 998RT in NMEA Housing



External Tuners: SGC-SG-230 and 235 (L and Pi Configurations)



Modified SG-235
(Similar modifications for SG-230)

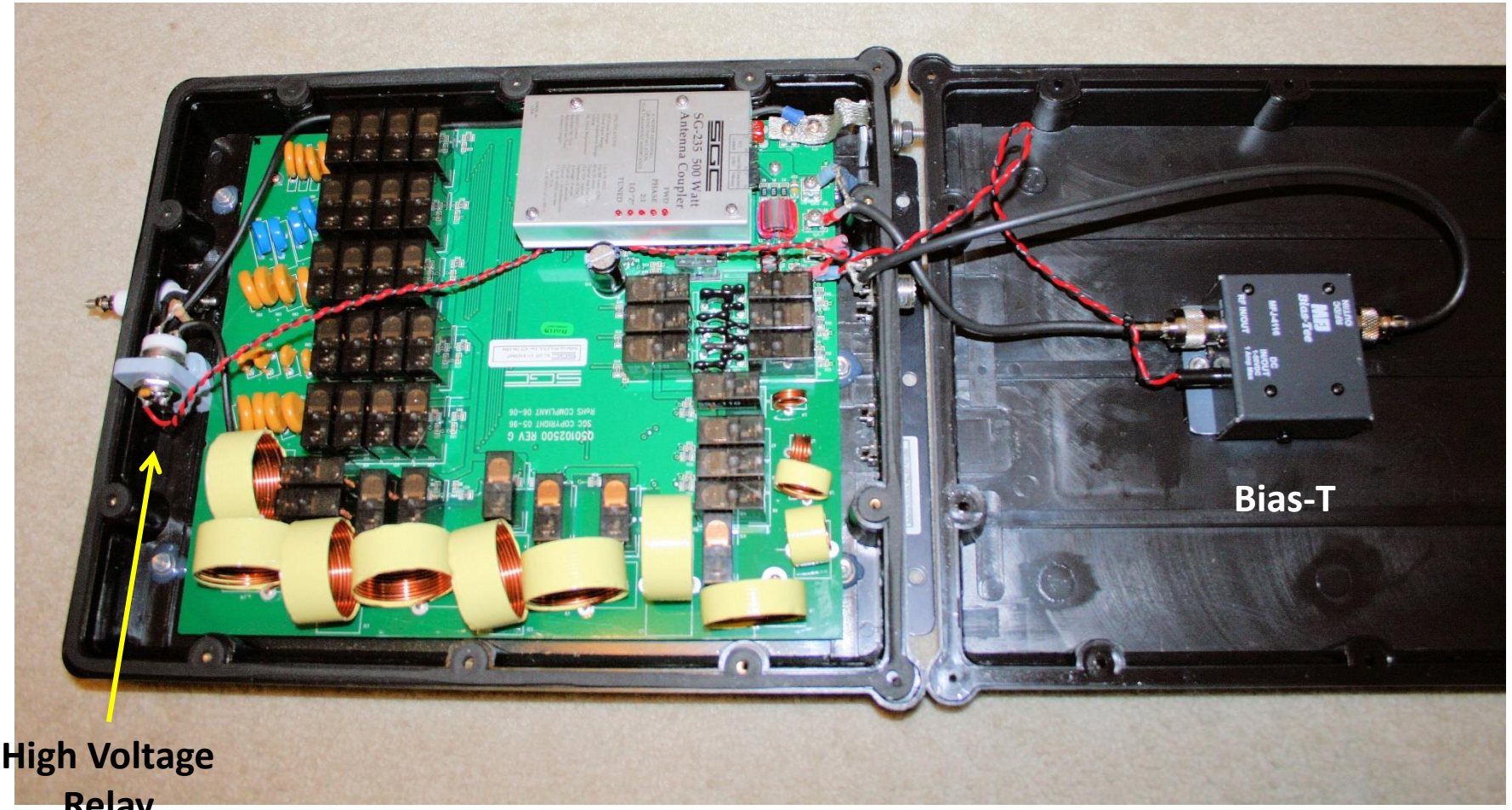
- **SG-230: 200 watts**
- **SG-235: 500 watts**

- **Very good tuning range**

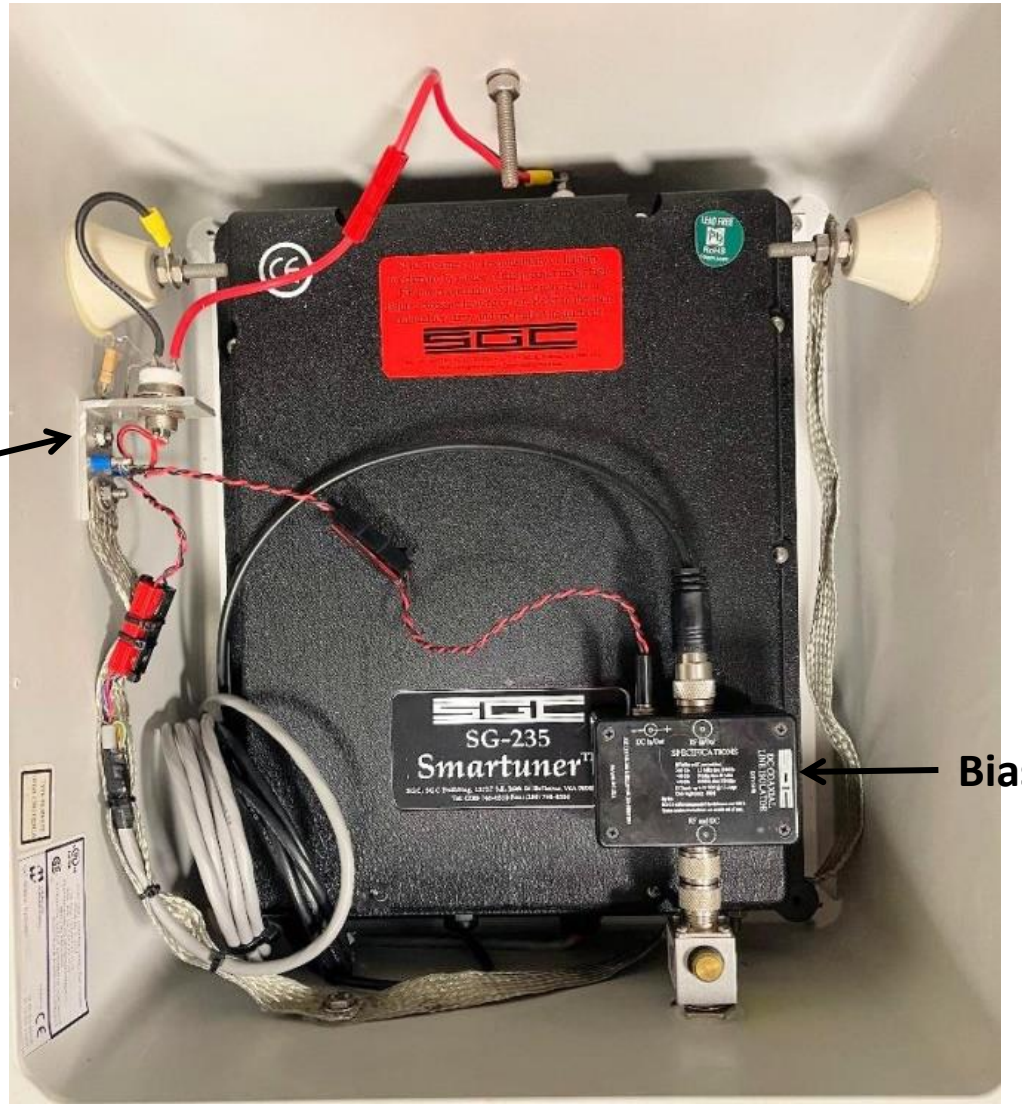
- **SG-230 needs protection from EMP lightning damage.**

- **Both units are weather tight but need to be protected from sun (UV) damage.**

Bias-T and High Voltage Relay Inside SGC Case



Bias-T and HV Relay In NMEA Case



Auto-tuner Maximum Component Values (L-networks)

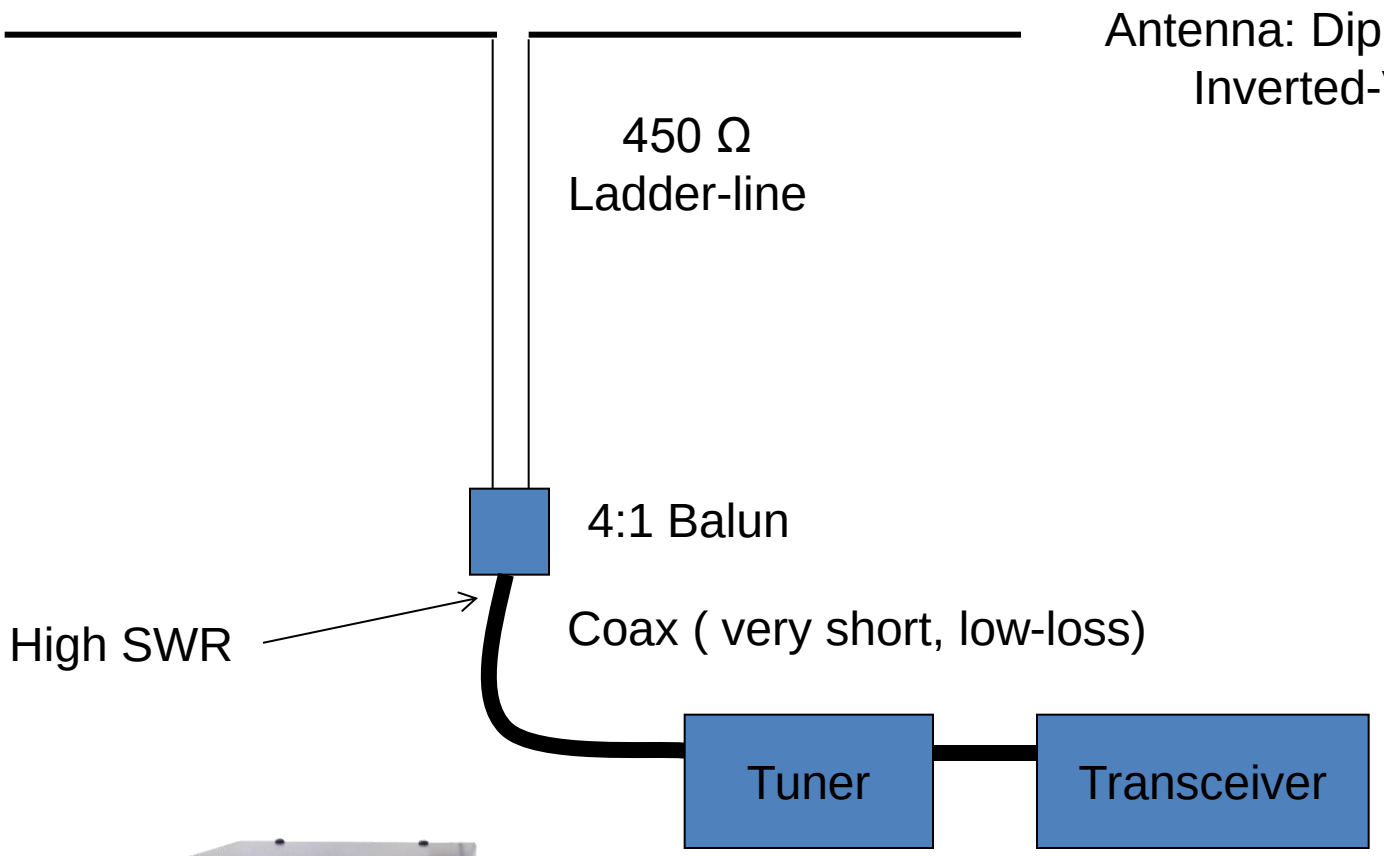
LDG-AT 600Pro	**- 10.07 uH, 1270 pF (600 watts)**
MFJ-998	**- 24.25 uH, 3922 pF (1000 watts)**
MFJ-929	**- 24.87 uH, 3961 pF (200 watts)**
MFJ-939	**- 24 uH, 3900 pF (200 watts)**
MFJ-926	**- 24.866 uH, 3961 (200 watts)**
SG-230	**- 63.75 uH, 7095 pF (200 watts)**
SG-235	**- 31.82 uH, 6696 pF (500 watts)**
MFJ-994	**- 24.85 uH, 3907 pF (600 watts)**
ICOM-AH4	**- 19 uH, 2400 pF (120 watts, ICOM only)**
Palstar HF-AUTO	**- 26 uH, 2 X 470 pF (T-Network)**

Note: Larger total component values allows wider tuning range. LDG tuners have difficulty achieving tuning solutions on some lower frequency (3, 4 and sometimes 5 MHz) MARS antennas. The Palstar tuned low frequency MARS antennas as well as the MFJ-998 due to its T-Network configuration.

Auto-Tuner Location

- Achieving low SWR at the rig only solves one of the power loss issues.
- If coax is run from an inside (rig located) tuner to the high SWR antenna, there will be loss in the cable run from the tuner to the antenna.
- This loss can be eliminated by locating the tuner remotely at the antenna and/or using very low loss ladder line from the antenna to the tuner.

Tuner at Rig



MFJ-929

MFJ – 949E

Remote Tuner at Mast Base

SG-230

MFJ-998RT

Remote Tuner at Antenna (Dipole or Long-Wire)

SGC-SG-230

Conclusions

- **The use of antenna tuners can greatly enhance the effectiveness of your antenna system.**
- **A larger variety of antennas (non-resonant) can be used.**
- **Auto-tuners makes the antenna tuning process very easy.**
- **Manual and auto-tuners can be used to make stealth antennas more capable.**

Questions?

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