SWR and Antenna Tuners

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Four Required Elements of an Amateur Radio System

- A Radio Operator
- A Radio
- An Antenna
- A Transmission Line

Transmission Line Includes Everything between Radio and Antenna

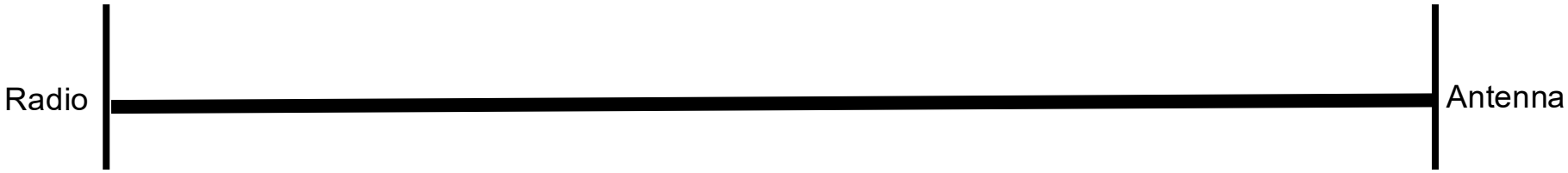
- Amplifiers
- Antenna Tuners
- SWR Meters
- RF Chokes
- Cable Connectors

Transmission Line Includes Everything between Radio and Antenna

To Simplify

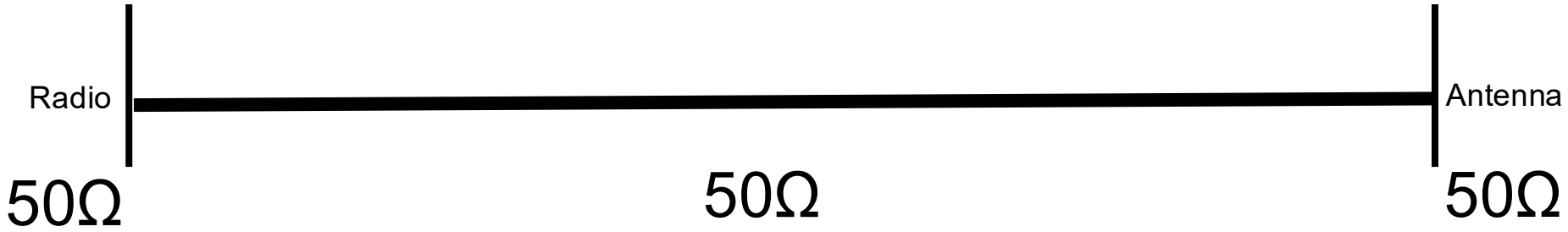
- Amplifiers
- Antenna Tuners
- SWR Meters
- RF Chokes
- Cable Connectors

Transmission Line between Radio and Antenna



Simplified

Transmission Line between Radio and Antenna



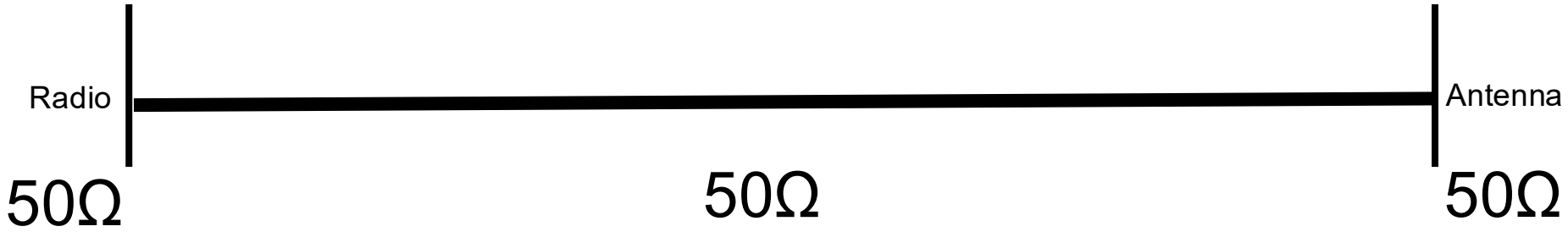
All components

- **Radio**
- **RF Cable**
- **Antenna**

Are designed to match each other at 50 Ohms

When they do, the transfer of energy from the radio to the radio air waves is 100%.

Transmission Line between Radio and Antenna

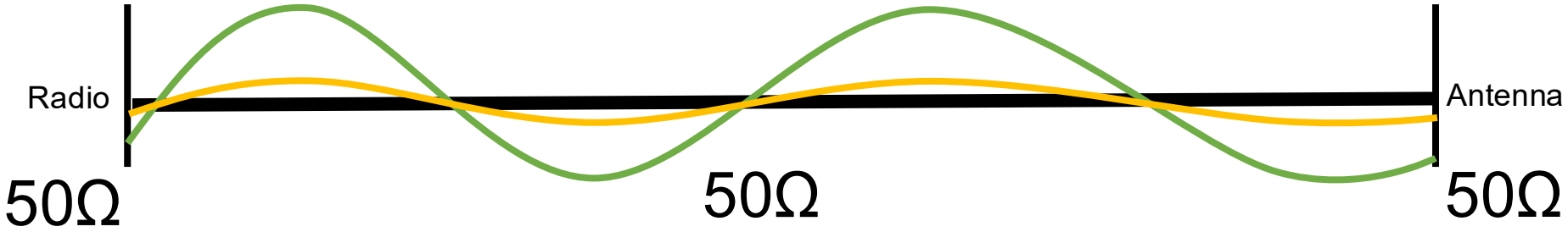


However, there are always losses and never a perfect match.

There is also interaction with the ground and surrounding buildings and trees.

Standing Wave Ratio (SWR) is a useful measurement of the severity of theses losses.

So What is SWR?



SWR is the ratio of the forward power to reflected power.

The mathematics are complicated and involve imaginary numbers because of the three parts of impedance:

- **Resistance**
- **Inductance**
- **Capacitance**

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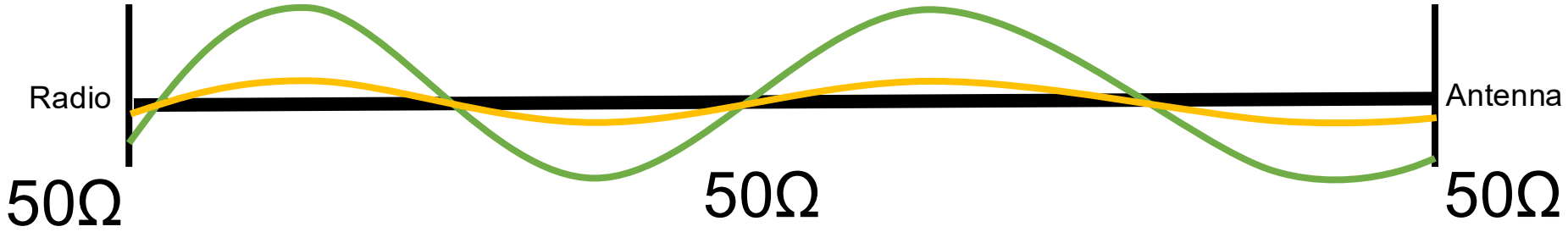

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- **Resistance**
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Fortunately, they make meters to measure SWR and related parameters.

So What is a Good SWR?

- **A perfect SWR is 1:1.**
  - **A 1:1 SWR means the impedance is all resistance**
  - **You have a resistance design end to end**
  - **Part of this is a resistance design antenna**
  - **It also assumes a perfect environment**

- **A good enough SWR is anything below 2:1.**
  - **It means there is some inductance or capacitance that is making it less than 1:1.**
  - **However, the loss of power transmission from the antenna is small such that it is acceptable to transmit.**

So What is a Bad SWR?

- **Bad SWR is anything over 2:1.**
  - **Less power is transmitted out**
  - **More power is reflected back to the radio**

- **High SWR**
  - **Less and less power is transmitted out**
  - **More and more power is reflected back to the radio:**
    - **May cause the radio to automatically throttle back on power output to protect itself.**
    - **May cause radio to shut down to protect itself**
    - **May damage radio such that repair is needed.**

SWR Solutions

- Use a resistance design antenna for the band or sub-band of interest
- Use an antenna tuner

So What is a Resistance Design Antenna

- Every frequency has a wavelength
- Frequencies next to each other have wavelengths close to each other
- A ½ wavelength antenna is a resistance design
  - A dipole antenna is a ½ wavelength antenna
  - A vertical antenna with counterpoise is a ½ wavelength antenna
  - A beam antenna has a driven element that is a ½ wavelength antenna
- There are other antennas incorporating electronics to make it look like ½ wavelength antenna

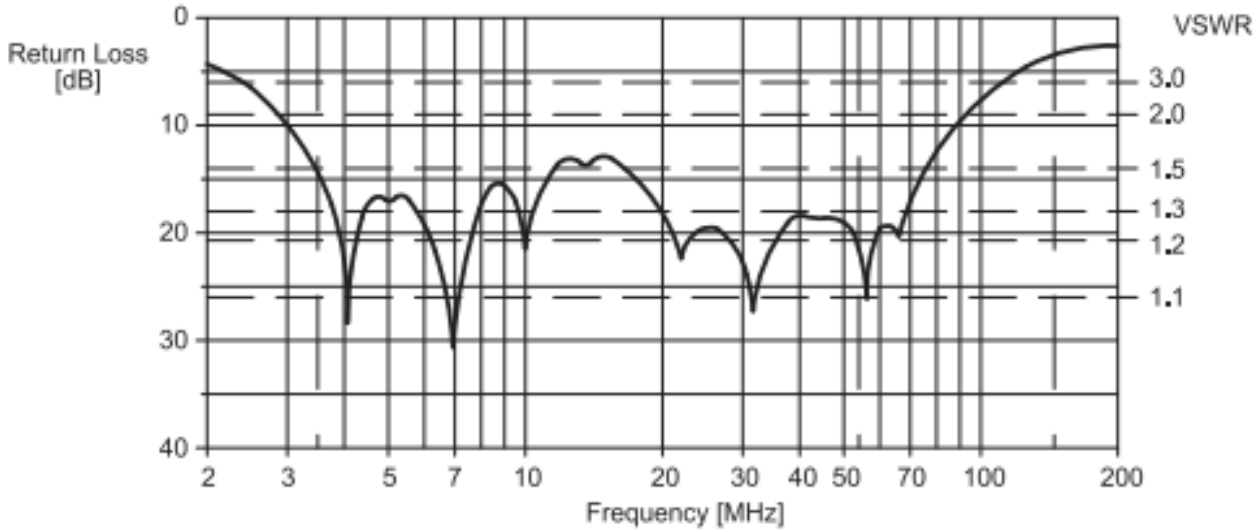
- If you must use an end fed antenna straight from the transceiver, it is not a resistance design. An antenna tuner will be required.

Example Antenna Incorporating Electronics

MODEL **CHA-250HD** HF Broadband Ground Plane Antenna

Broadband:
TX 3.5 – 57MHz
RX 2.0 – 90MHz
VSWR: 1.6:1 or less

Return Loss and VSWR Data



Dipole Measurements

Formula is 468/Freq in MHz
gives wavelength in feet

Dipoles			Begin		Mid		End	
	MHz	MHz	Tot (1/2 wl) in	1/4 wl in	Tot (1/2 wl) in	1/4 wl in	Tot (1/2 wl) in	1/4 wl in
70CM	420	450	13.37143	6.685714	12.91034	6.455172	12.48	6.24
1.25M	222	225	25.2973	12.64865	25.12752	12.56376	24.96	12.48
2M	144	148	39	19.5	38.46575	19.23288	37.94595	18.97297
6M	50	54	112.32	56.16	108	54	104	52
10M	28	29.7	200.5714	100.2857	194.662	97.33102	189.0909	94.54545
12M	24.89	24.99	225.6328	112.8164	225.1804	112.5902	224.7299	112.3649
15M	21	21.45	267.4286	133.7143	264.5936	132.2968	261.8182	130.9091
17M	18.068	18.168	310.8258	155.4129	309.968	154.984	309.1149	154.5575
20M	14	14.35	401.1429	200.5714	396.1905	198.0952	391.3589	195.6794
30M	10.1	10.14	556.0396	278.0198	554.9407	277.4704	553.8462	276.9231
40M	7	7.3	802.2857	401.1429	785.4545	392.7273	769.3151	384.6575
60M	5.332, 5.348, 5.358f, 5.373, 5.405 MHz		1053.263	526.6317	1046.102	523.0511	1039.038	519.519
80M	3.5	4	1604.571	802.2857	1497.6	748.8	1404	702
160M	1.8	2	3120	1560	2955.789	1477.895	2808	1404

Recommend dipoles be built for the mid-point of the band.

A Good Antenna Practice

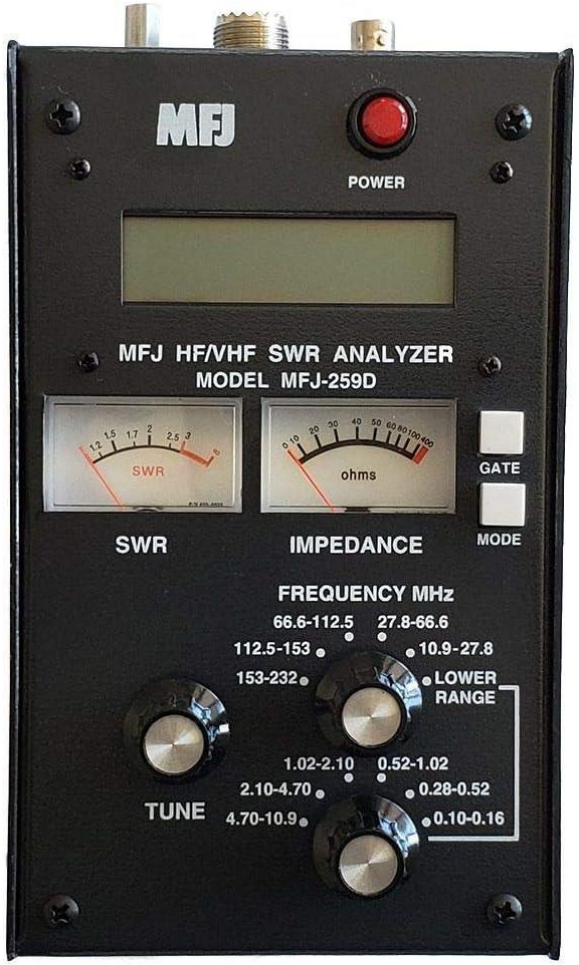
After constructing or erecting an antenna, measure the SWR.

- **From time to time, something is not connected correctly, and infinite SWR is a clear indicator that everything needs to be rechecked.**
- **If a resistance design, you will be able to tell the SWR over the band and adjust as necessary.**
- **If SWR is 1.9 or so, you may want to use a built-in Antenna Tuner, if your transceiver has one.**

How Measure SWR?

- **Use Antenna Analyzer**
  - **MFJ 259 is the classic**
  - **MFJ 259D is latest version**
  - **MFJ has others**

or



How Measure SWR?

- Use Antenna Analyzer

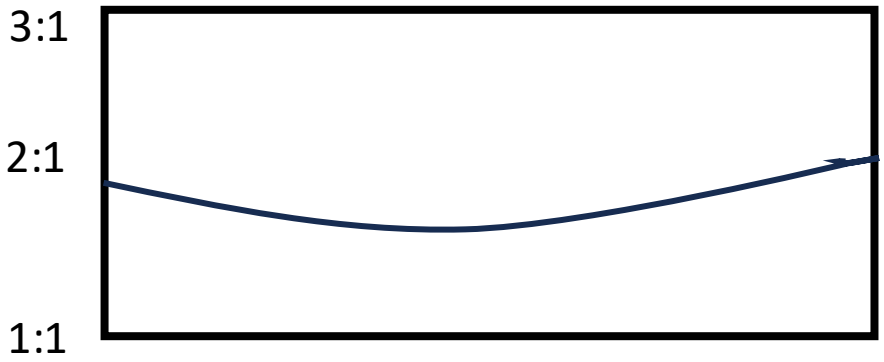
- Use Vector Network Analyzer, e. g
  - MFJ 226
  - NanoVNA

  - There are other VNAs

How Do VNAs Work?

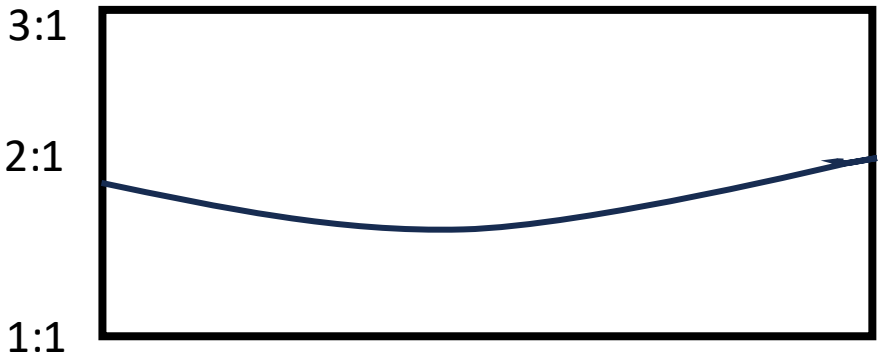
Typically

- **Connect to antenna and RF cable at the radio end**
- **Turn On**
- **Select Measurement – SWR over band**
- **Input Band**
- **Adjust Scale**
- **Analyze results**

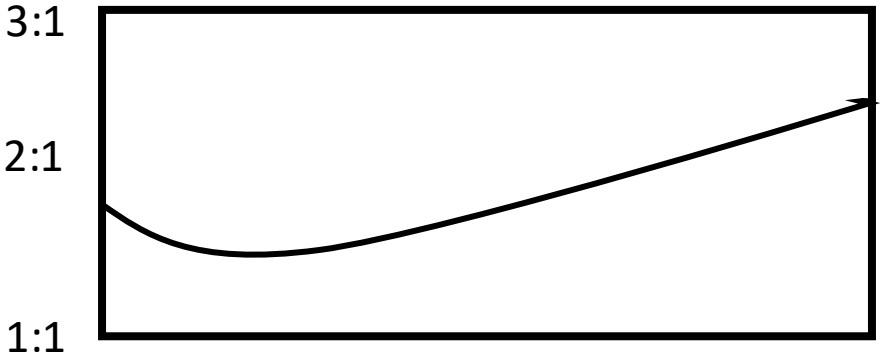


Good!

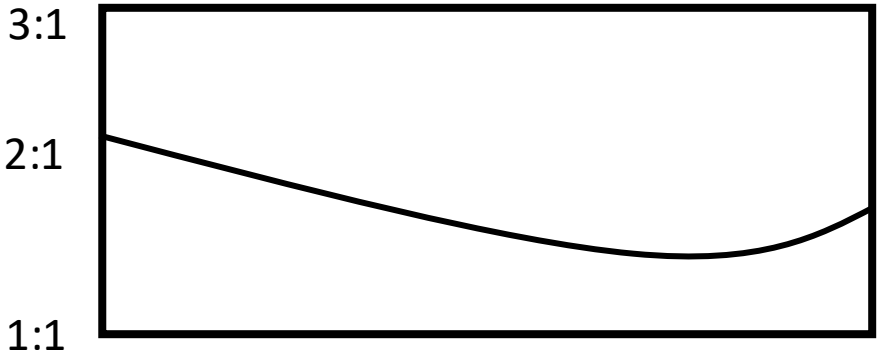
VNA Results



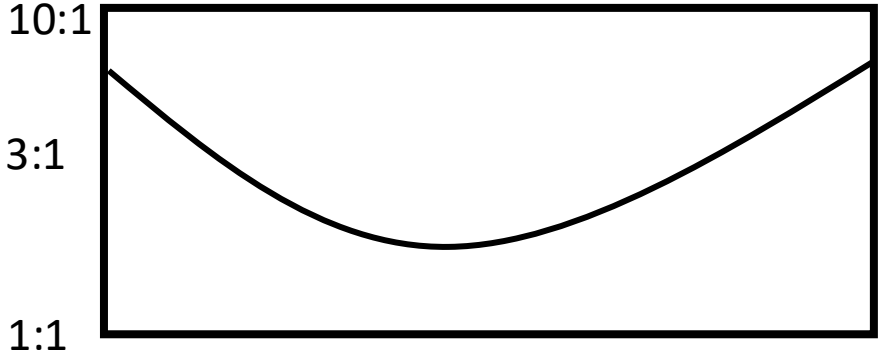
Good!



Lengthen Antenna



Shorten Antenna



Change Antenna Based on Portion of Band to be Used

SWR Solutions

- Use a resistance design antenna for the band or sub-band of interest
- **Use an antenna tuner**

What is an Antenna Tuner?

An Antenna Tuner is a device designed to match the inductance and capacitance in the transmission line so as minimize reflected power back to the transceiver thereby achieving a SWR of 1:1.

Typically, it uses L networks of inductance and capacitance to match the inductance and capacitance that is reflecting the power. In polar coordinate terms, inductance and capacitance existing on the transmission line is pulling the impedance off of 0 degrees. The inductance and capacitance added by the antenna tuner pulls the impedance back to 0 degrees.

Types of Antenna Tuners

- **Internal to the Transceiver**
  - Usually, in later model HF transceivers
  - Usually, automatic (push a button)
  - Usually, the transmission line must be 3:1 and lower to work. (Some transceivers can handle 10:1.)

- **External to the Transceiver**
  - May be manual or automatic (check your radio for interface to automatic)
  - Usually, the transmission line must be 10:1 and lower to work
  - Must be after any amplifier (radio->amp->ant tuner)
  - Must be for highest transmission power
  - Must be for the correct frequency band
  - Many manufacturers, e. g., MFJ, LDG, Flex Radio

Some Available Antenna Tuners

So do I need an Antenna Tuner?

- **What type of antenna are you going to use?**
  - **Resistance Design – Ext Antenna Tuner not needed**
  - **End Fed Random Wire – Ext Antenna Tuner needed**
- **Are you able to check SWR with an Antenna Analyzer or Vector Network Analyzer(VNA)?**
  - **Yes: Antenna Tuner not needed if you adjust it to below 2:1**
  - **No: Antenna Tuner with SWR meter a good idea**
- **Does your transceiver have a built-in antenna tuner?**
  - **Yes: Resistance Design and Antenna Analyzer/VNA, then no Ext Antenna Tuner needed**
  - **No: Antenna Tuner with a SWR meter a good idea**

Summary

- SWR is an important measurement when it comes to radiated transmission power
- SWR below 2:1 is generally acceptable
- Resistance Design generally will get a 2:1 result
- A VNA will let you measure and adjust to be a 2:1 or better result
- A transceiver with a built-in antenna tuner will lower the SWR closer to 1:1
- An External Antenna Tuner is needed for some other antenna designs, especially high power

References

- **ARRL Handbook, Chapter 20 and Table 22.65, 91st Edition, 2014.**
- **Hallas, Joel R., W1ZR. 2012. *The Care and Feeding of Transmission Lines.* Newington, CT: ARRL.**
- **Hallas, Joel R., W1ZR. 2013. *Understanding Your Antenna Analyzer.* Newington, CT: ARRL.**
- **Hallas, Joel R., W1ZR. 2010. *The ARRL Guide to Antenna Tuners.* Newington, CT: ARRL.**