ACCURATE
SWR MEASUREMENTS

The “Standing Wave Ratio” (SWR) is a ratio between the forward RF energy to reflected energy. SWR can be determined by measuring forward to reflected power voltage (VSWR), measuring forward to reflected power current (ISWR) or measuring forward to reflected power watts (PSWR).

Antenna manufacturers always include the antenna’s SWR specifications. So it’s not unusual that amateur radio operators rely on SWR measurements to adjust their antennas for maximum efficiency. The availability of antenna measuring instruments has grown in past years and most of these devices measure SWR and power (watts). Some of the new antenna measuring instruments can flatten your pocket book, so the inexpensive portable in-line SWR meter is still a very popular instrument.

SWR Myth – High SWR can destroy your transmitter’s output stage. The true information is hidden in the “Transmission Line” section of the ARRL handbook. (2001 Handbook, page 19.4) [Now, what actually happens to the energy reflected back down the line? This energy will encounter another impedance discontinuity, this time at the generator. Reflected energy flows back and forth between the mismatches at the source and load. After a few such journeys, the reflected wave diminishes to nothing, partly as a result of finite loses in the line and by absorption at the load.] The transmitter’s output stage is never subjected to reflected energy.

Directional Coupler – Resistive Bridges and current transformers can be used to measure forward and reflected RF energy, but the most common method used is the “Directional Coupler”. See Figure 1. The directional coupler is basically a section of transmission line with additional elements located in close proximity to the main line. The RF energy picked up by the sensing elements is rectified to provide a DC voltage that represents forward and reflected. Figure 2 is a directional coupler electrical diagram.

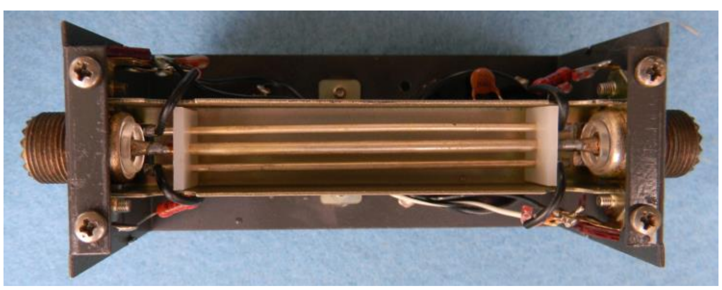


Figure 1

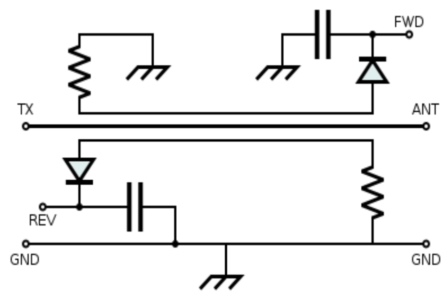
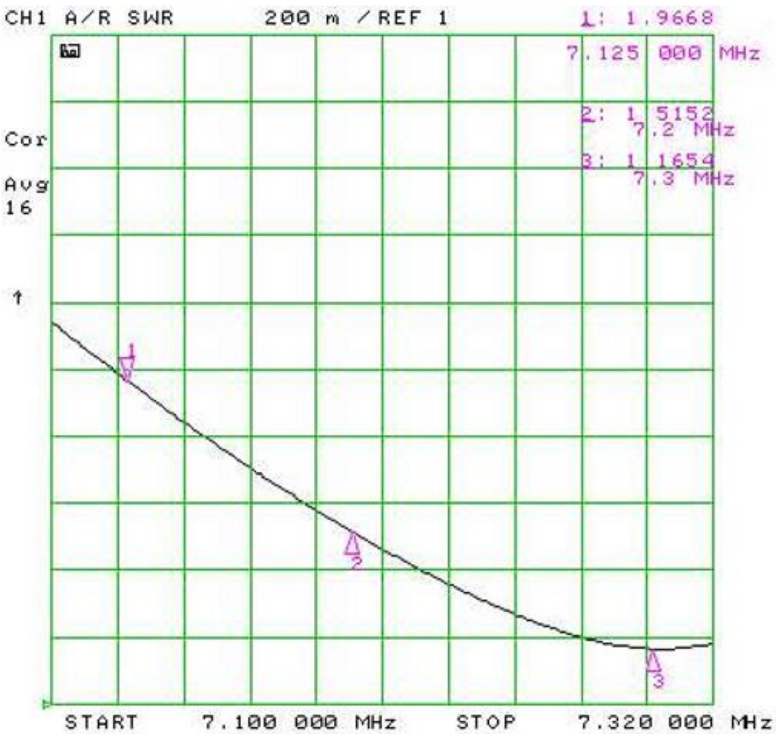


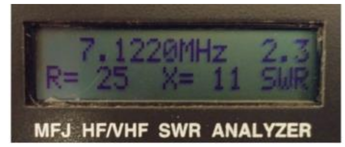
Figure 2

SWR Measurement Accuracy – Making accurate SWR measurements can be challenging because there’s a multitude things that can affect accuracy.

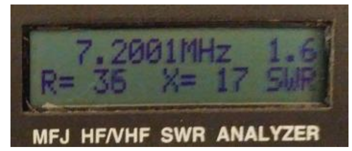
- I have found that the manufactures accuracy specifications are not very reliable. If you have more than one instrument that can be used to check SWR, don’t be surprised if they provide different reading. Phil Salas (AD5X) wrote an article that shows how to construct precision non-inductive resistors that can be used to check SWR meters. http://www.ad5x.com/images/Articles/PrecisionMismatches.pdf Phil was an electrical engineer for Alcatel who retired before I did.

- To demonstrate how different instruments can provide different reading, I measured my 40m inverted V at 7.125, 7.2 and 7.3 MHz's with a VNA, MFJ-259B and SWR meter shown by Figure 1.

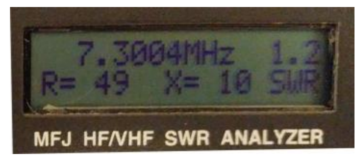




7.12 MHz SWR 2.3:1



7.2 MHz SWR 1.6:1



7.3 MHz SWR 1.2:1

MFJ-259B


2.5:1 @ 7.12 MHz

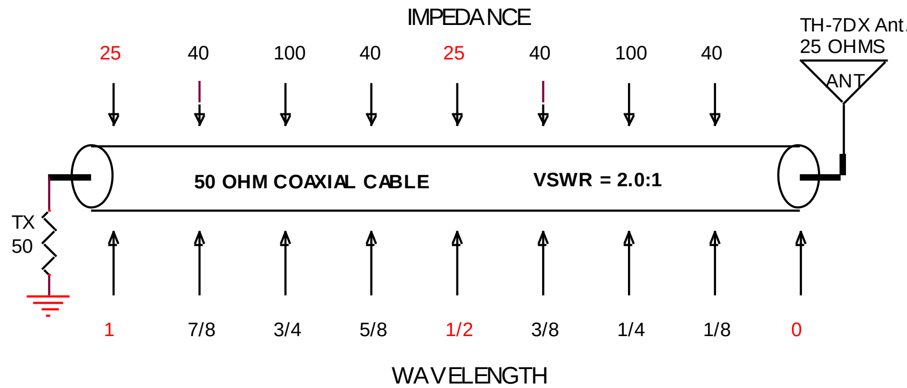

1.45:1 @ 7.2 MHz


1.3:1 @ 7.3 MHz

The HP-8753C Network Analyzer was used because it can be calibrated to establish very accurate (5 digit) SWR measurements. VNA SWR results: 1.9668:1 @ 7.125 MHz, 1.5152:1 @ 7.2 MHz and 1.1654:1 @ 7.3 MHz's. The basic SWR meter has an accuracy spec of ± 10%, but my MFJ-259B SWR analyzer manual does not provide any accuracy specifications.

- Manufacturers never provide the instruments "Directivity" specification. This specification is the dB level of isolation between forward sensing element energy and reflected element. When this isolation level is exceeded, the forward power will influence the reflected power reading.

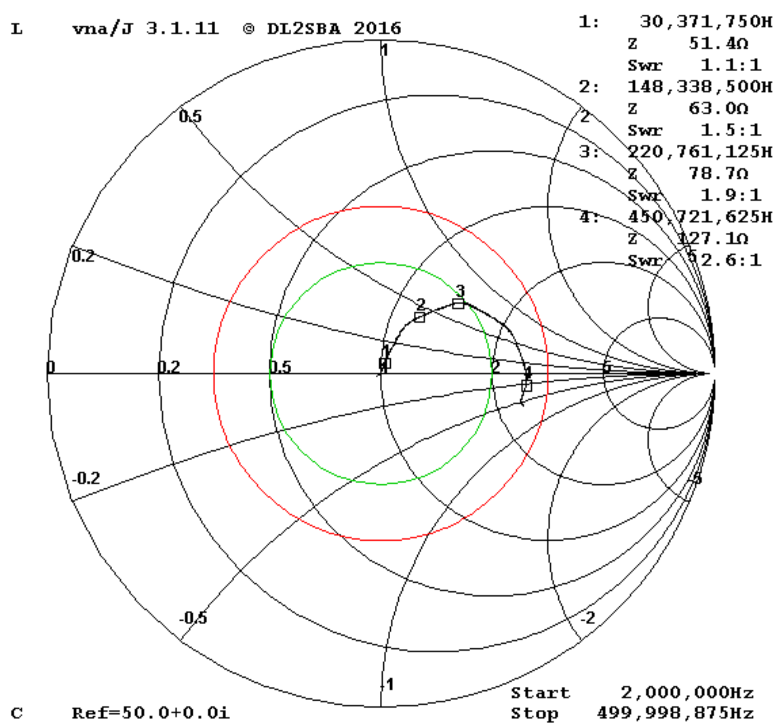
- If the SWR instrument is one that is inserted into the feedline, its accuracy depends how well it handles impedance mismatches. The Hy-Gain TH-7DX Tri-band beam has a maximum SWR specification of 2.0:1. A SWR of 2.0:1 calculates to a maximum impedance of 100 ohms (50X2=100) and minimum is 25 ohms (50÷2=25). See diagram on the next page. This diagram is good example of how the antenna can change the feedline impedance characteristics. If the SWR meter was inserted into this coax feedline it could see one of these impedance extremes.



- If you are using an inline SWR meter, the meter must duplicate coaxial cable 50 ohm impedance. If the meter is using standard SO-239 connectors, it will not accurately cover VHF/UHF frequency range. MFJ is using a special SO-239 connector on their VHF/UHF SWR meters which they advertise as being an "Air Dielectric" connector. See photos. The MFJ connector center conductor is supported by Teflon, unlike the standard air dielectric connector. I have tested air dielectric connectors and most have an impedance of 46 ohms at 400 MHz's. I would be surprised if the MFJ connector would provide the performance of a true air dielectric connector. The VNA Smith Chart screen plot shows the impedance (Z) of my SWR meter across the HF band. This meter uses SO-239 connectors.


MFJ


Amphenol



- Checking the SWR level of a balanced antenna that is connected to an unbalanced coax cable can result in false reading if a balun was not used. Not using a balun can cause the feedline to act like part of the antenna. To check for this condition, add a few feet of additional coax between the SWR meter and transmitter. If the SWR reading changes, the feedline is acting as part of your antenna.

- I'm sure you have read that SWR measurements should be taken at the antenna. This would eliminate the inaccuracies caused by the feedline attenuation. At HF frequencies the cable attenuation is usually minimal, but at VHF/UHF the attenuation might be 3 dB. In this case, your SWR reading would be only half of the true value.

Antenna Tuners - Today you can buy a radio with a built-in antenna tuner or one that connects externally to your rig. Antenna tuners **do not** tune your antenna. They match the feedline impedance to the 50 ohm radio antenna port. Transceivers that incorporate automatic tuners or external units are really an extension of the transmitter's fixed matching circuit. My Kenwood TS-590SG is rated for a SWR of 1.5:1 (33.3 to 75 ohms) without the tuner and 3.0:1 (16.6 to 150 ohms) with the tuner turned on. Some of the external tuners will handle a SWR level of 8:1. Tuners that are not connected directly to the antenna **do not** eliminate the reflected power caused by antennas impedance mismatch. The reflected power still travels back and forth until the reflected power is radiated by the antenna.

Summary – The in-line SWR must be popular, I counted 12 meters in the Ham Radio Outlet catalog and 18 in the MFJ catalog. 12 different antenna analyzers were also available. Measuring SWR is a good way to determine the health of your antenna system. It is important that the readings are accurate. I prefer an instrument that measures SWR at the cable end that attaches to the radio. Most of these instruments also measure impedance and the impedance mismatch is what detunes the amplifiers matching circuit. If adding 2 or 3 feet of coax to my feedline moves the impedance closer to 50 ohms, it's a good move. The majority of in-line SWR meters use analog meters, while the antenna analyzers have digital displays. Digital displays play no part in the accuracy of these instruments. It's obvious that I need to do a little work on my 40m antenna!

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