Standing Wave Ratio Primer

Fully Decoded
Everything you Need to Know


Agenda
•What is Standing Wave Ratio (SWR)
•How SWR Affects Station Performance
•How Much is Too Much
•What We Can Do About it

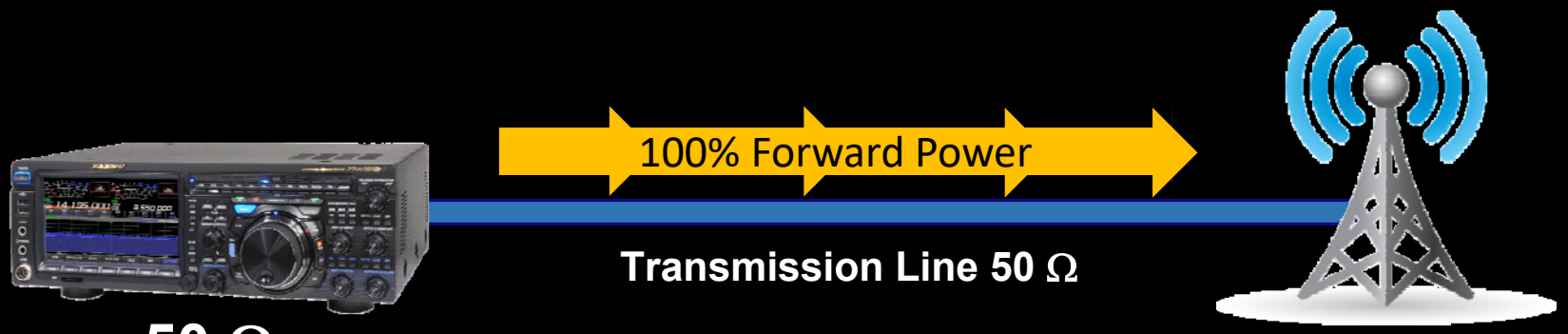
Fully Understand SWR & Improve Station Performance

One of the most mysterious creatures in the world of Amateur Radio is standing wave ratio (SWR)

Darrin Walraven, K5DVW

Ideal RF Power Transfer

Impedance Match

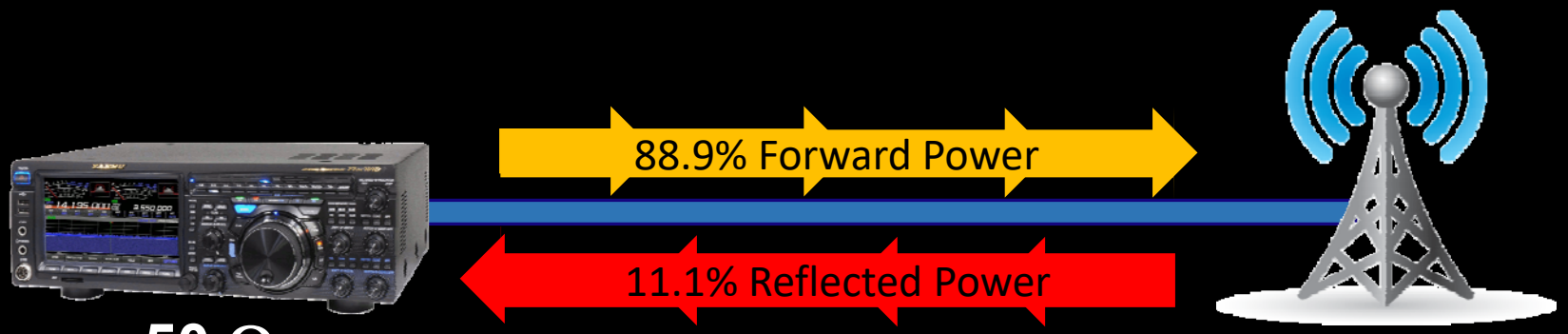


Maximum power is delivered to the antenna when transmitter, feedline, and antenna impedances are matched

SWR: 1:1

Non-Ideal RF Power Transfer

Impedance Mismatch



Power is reflected when there is an impedance mismatch

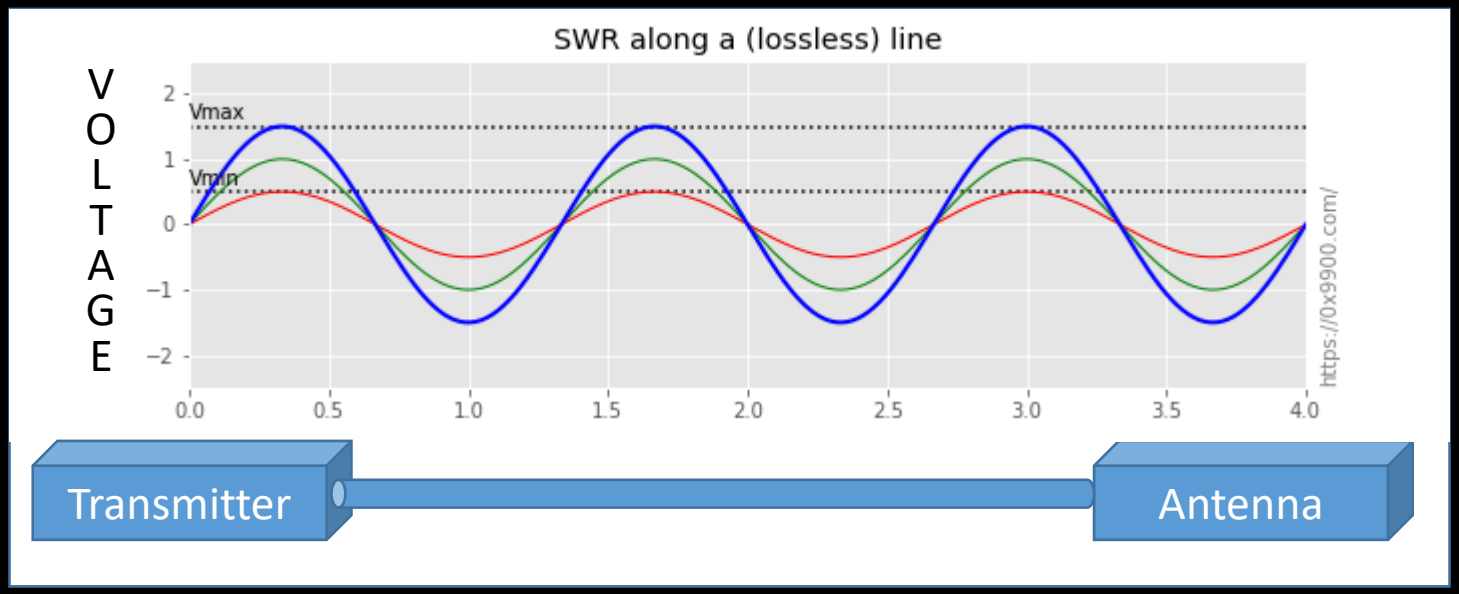
Impedance Mismatch
SWR: 2:1

What Happens to the Reflections?
Where do they Go?
Is Reflected Power Lost?

Incident Wave

Reflected Wave

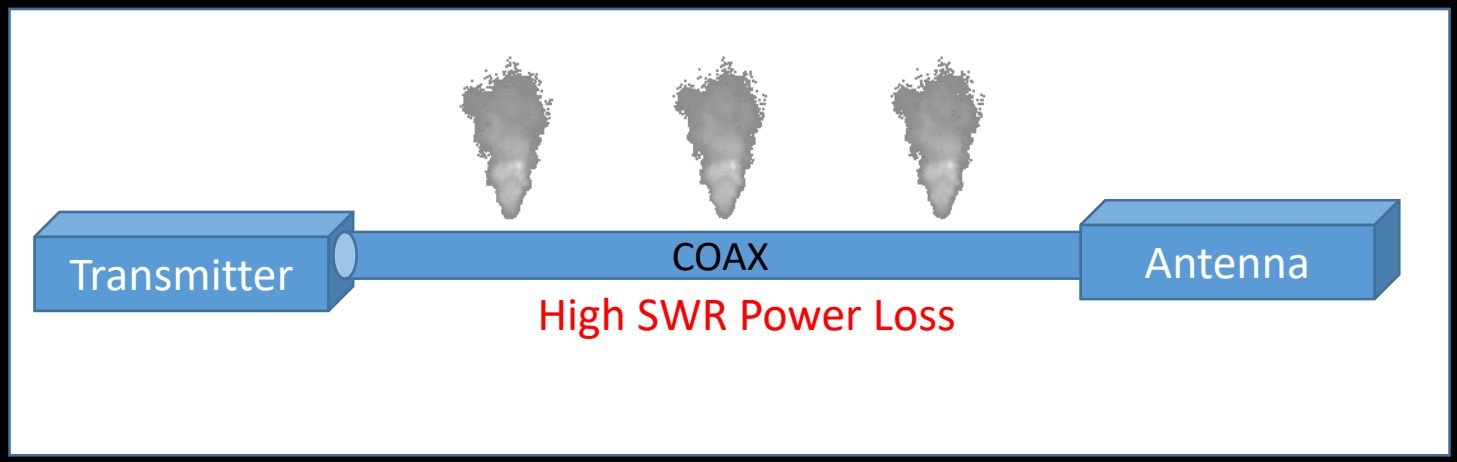
Standing Wave



*The energy bounces back and forth inside the cable until **it's all radiated** by the antenna with lossless transmission line*

This assumes nothing has blown up in the process

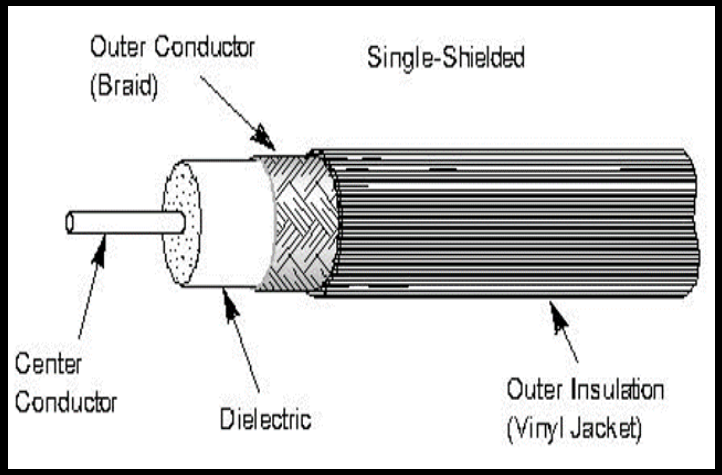
Coax Cable Attenuation



*Coax cable **RESISTIVE LOSS** and **DIELECTRIC LOSS** results in **HEAT** being dissipated*

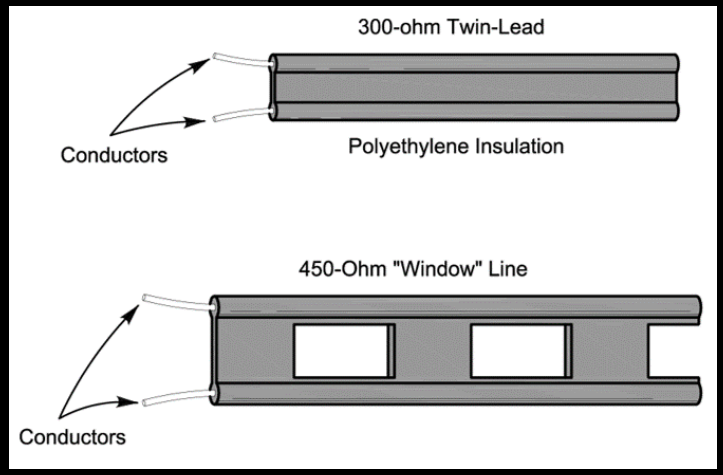
Feedline can Make a Difference

Works OK with limited SWR



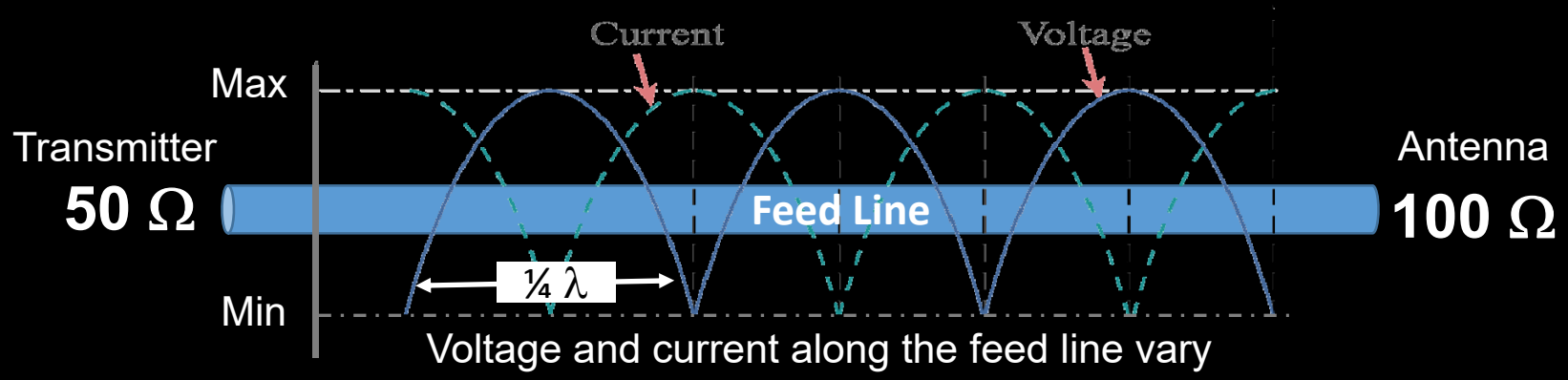
- Higher loss than open-wire line at most frequencies
- Most common feed line
- Easy to use
- Not affected by nearby materials

Recommended for High SWR Applications



- Lower loss than coax at most frequencies
- Affected by nearby materials
- Requires impedance matching equipment to use with most transceivers

Voltage Standing Wave Ratio



$$SWR = \frac{V_{max}}{V_{min}}$$

$$SWR = \frac{Z_0}{Z_{load}} \text{ or } \frac{Z_{load}}{Z_0}$$

whichever is greater

If Antenna Zload = 100 Ω and transmitter Zo = 50 Ω

SWR = 100/50

SWR = 2:1

How SWR can Affect Station Performance

Effects of Excess SWR

- Can damage transmitter, tuner or power amp
- Reduces output power
- Can damage feedline & lightning protection
- Distorts transmitted audio
- Can melt your antenna balun
- Might affect noise, EMI, RFI

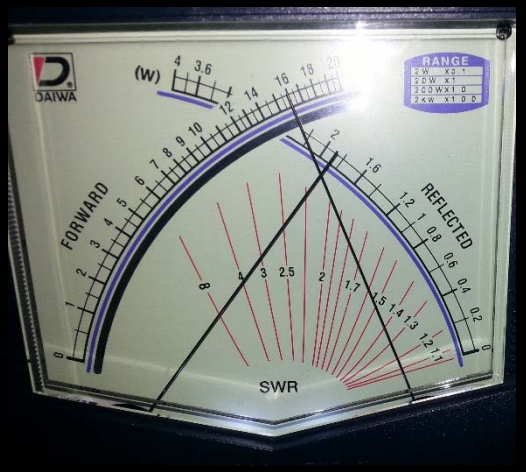
Rule of Thumb:
ALWAYS tune up while running low power before switching to high power

What Causes High SWR

What Causes High SWR?

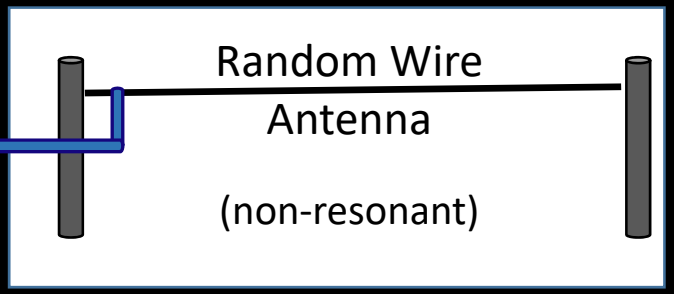
Impedance mismatch due to:

- **Non-resonant antenna**
- **Non-optimal antenna configuration**
- **Defective feedline or connectors**
- **Defective transceiver, amplifier, or tuner**



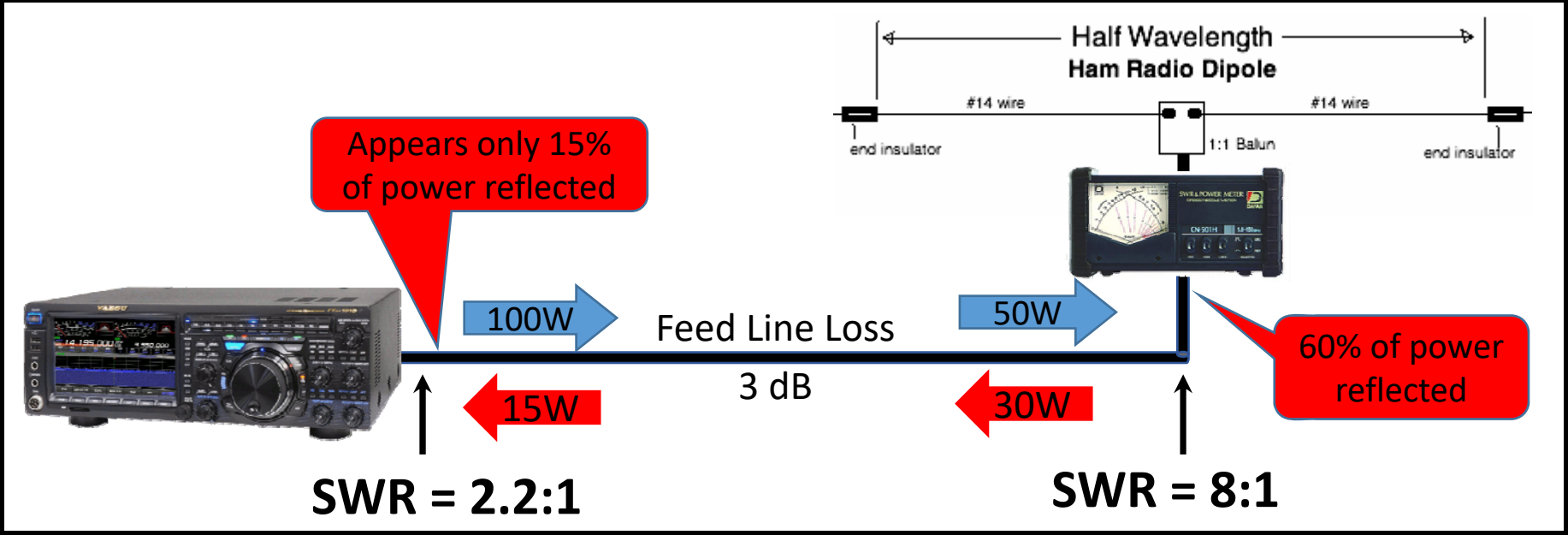
SWR Meter

No Tuner



How to Measure SWR

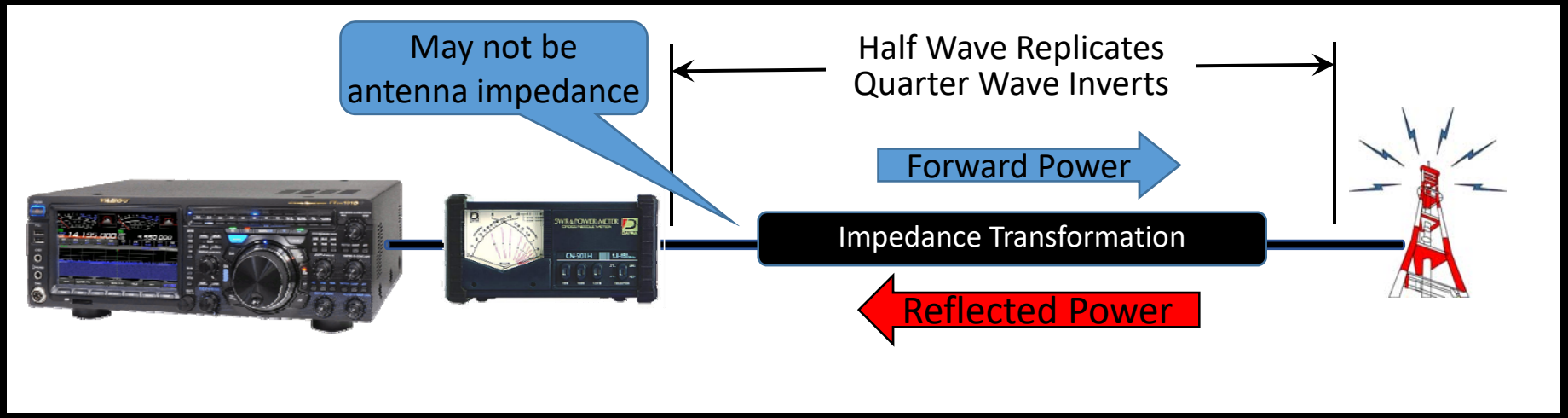
Measuring Antenna SWR



*Accurate antenna SWR readings can **ONLY** be performed at the antenna*

Otherwise feedline attenuation or impedance transformation may be involved

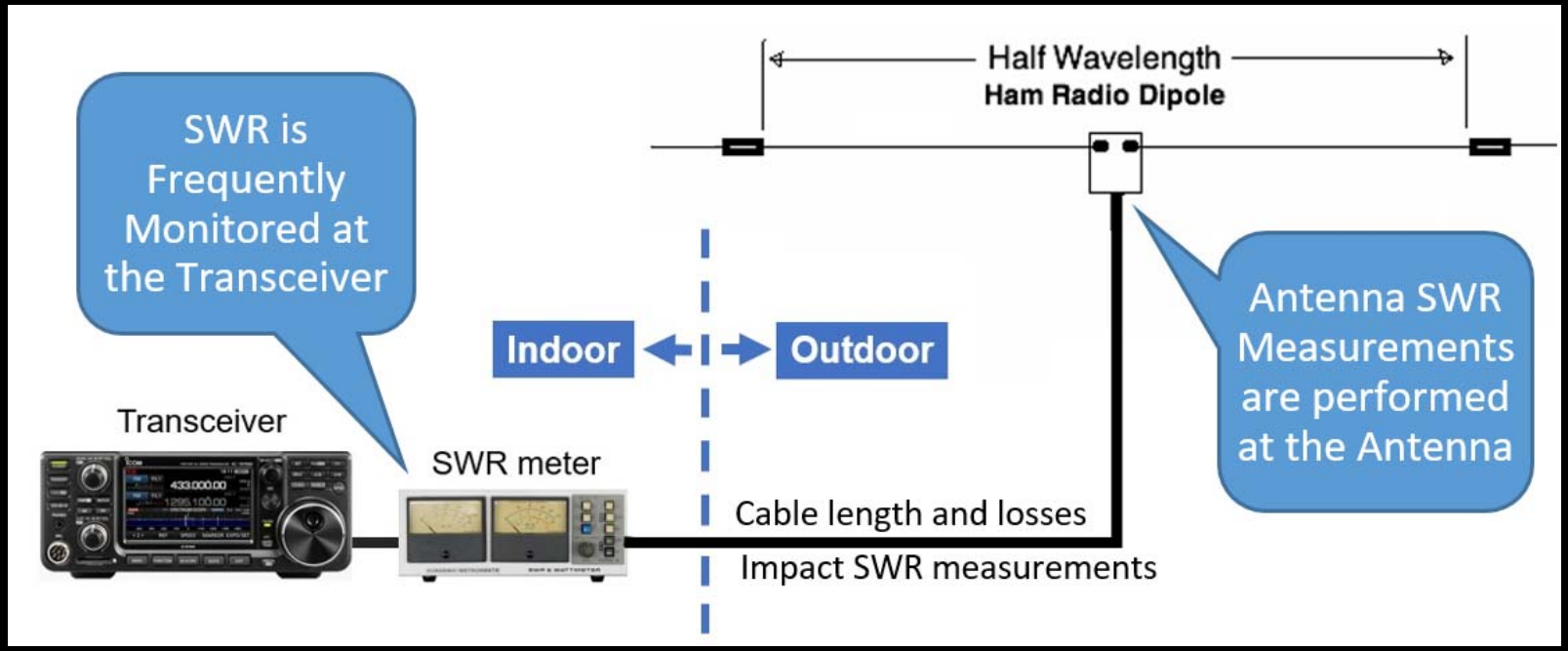
Measuring SWR at the Radio



In this case you are measuring (tuning) your

Feedline & Antenna unless feedline is a multiple of ½ wavelength

Measuring SWR at the Radio



To be practical, most people DO measure SWR at the transceiver. Applications notes are available to help out……

Understanding SWR by Example

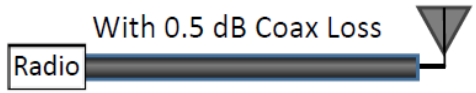
By Darrin Walraven, K5DVW

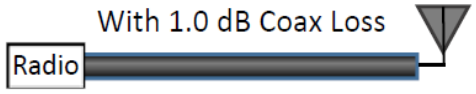
Understanding SWR
The ENTIRE Story Explained

By Gary Fritz, WB9LIB

Posted on the PVARC Web Site

Table 1
SWR & Radiated Power (Includes Effects of Coax Loss on Reflections)





*Meter SWR	*Antenna SWR	Power (%) Radiated	Loss (dB)	*Antenna SWR	Power (%) Radiated	Loss (dB)
1.00	1.00	89.1	0.500	1.00	79.4	1.000
1.10	1.11	89.1	0.502	1.13	79.3	1.006
1.20	1.22	88.9	0.507	1.26	79.0	1.021
1.30	1.34	88.7	0.519	1.39	78.6	1.043
1.40	1.46	88.5	0.532	1.53	78.1	1.073
1.50	1.58	88.2	0.547	1.67	77.5	1.106
1.60	1.70	87.8	0.564	1.89	76.5	1.164
1.70	1.82	87.5	0.581	1.97	76.1	1.187
1.80	1.94	87.1	0.600	2.12	75.3	1.230
1.90	2.07	86.7	0.622	2.28	74.5	1.278
2.00	2.20	86.2	0.644	2.45	73.6	1.330
2.50	2.85	83.9	0.760	3.43	68.5	1.640
3.00	3.56	81.4	0.892	4.40	63.9	1.942

*Meter [illegible] transceiver. Antenna SWR is at the antenna. Assumes coax length is ½ wavelength.

When SWR meter reads 3:1 and coax loss is 1 dB, actual SWR at antenna is 4.4:1

How to Resolve SWR:
The Antenna Tuner!

How to Resolve SWR

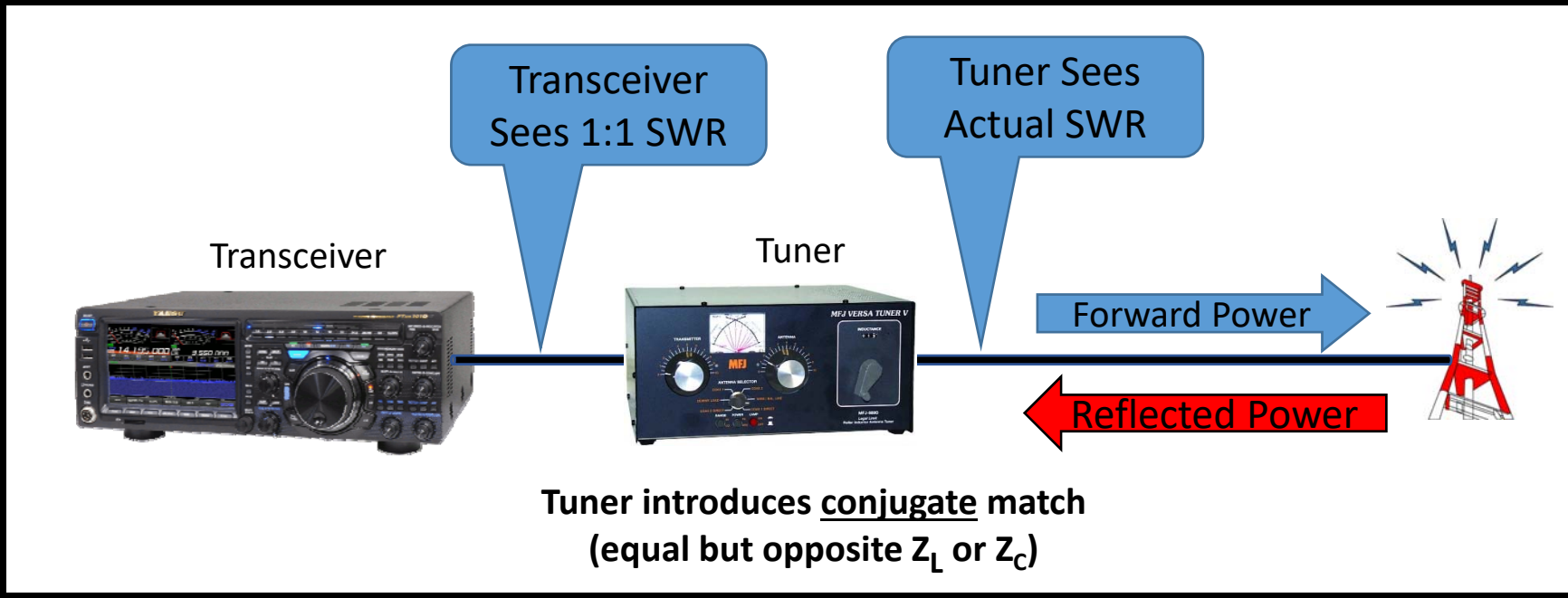
Integrated Tuner:

- Typically cleans us SWR up to 3:1
- Very easy to use

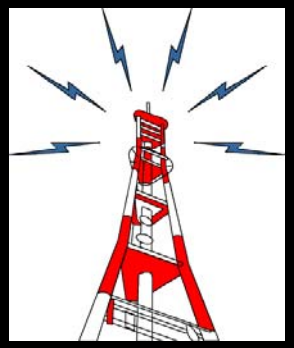
External Tuner:

- Handles a wider range of SWR
- Typically needed when using non-resonant antennas

How Antenna Tuners Work

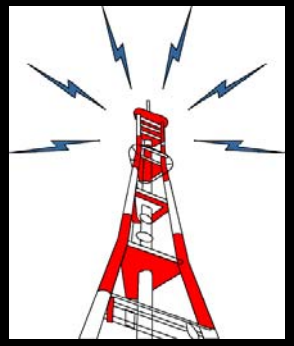


The conjugate match compensates for the mismatch and presents a 50 Ω load to the transceiver



ANTENNA SWR **BEFORE** TUNING:

8:1



ANTENNA SWR **AFTER** TUNING:

8:1

The tuner does NOT change antenna SWR!

ANTENNA TUNERS DO ALLOW YOU TO DELIVER FULL POWER TO THE ANTENNA!

How much SWR is too Much?

How Much SWR is Too Much?

In general:

- **At HF, SWR's up to 2:1 are considerable acceptable**
- **SWR exceeding 3:1 are considered high**

So ……what happens above 2:1 SWR?

SWR above 2:1 causes modern transceivers to cut back power (fold-back protection circuit).

OK ….. I got a tuner ….. It can handle a WIDE range of SWR

How much SWR would cause a noticeable reduction in signal strength?

With a typical setup noted below

An SWR of 24:1

is required for 1 S-unit reduction

100 feet RG-8X

SWR 24:1

Coax Type: RG-8X
Coax Length: 100 Feet
Frequency: 14 MHz
Power In: 100W
Power Out: 25W
Loss With SWR: 6 dB (One – S-Unit)
Loss Without SWR: 1 dB (Negligible)

Set Parameters as Desired		
Line Type:	Belden 9258 (RG-8X)	
Line Length:	100	Feet / Meters
Frequency:	14	MHz
Load SWR:	24	: 1
Power In:	100	W
Calculate		

Results		
Matched Loss:	1.087	dB
SWR Loss:	5.01	dB
Total Loss:	6.097	dB
Power Out:	24.564	W

https://www.qsl.net/co8tw/Coax_Calculator.htm

IN CLOSING

It takes a **LOT** of antenna SWR to degrade your signal

It takes a **LOT LESS** SWR to cause your equipment to reduce output power

Per the ARRL:

With extremely low loss transmission line, *no matter what the SWR*, most of the power can get delivered to the antenna.

** From Understanding SWR by Example, Darren Walraven, November 2006 QST*


Thanks