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Antenna Analyzers, SWR and Complex Impedance

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Antenna Analyzers

- Come in all shapes an sizes, as well as home brew, like what Matt showed today.
- Some are available as kits you can build
- Do two fundamental measurements
  - SWR (really VSWR)
  - Complex Impedance (R+jX)
- Some have additional features for testing coax velocity factor and shorts.
- The high end models have display screens and connect to a computer
- Most only cover HF and VHF frequencies, but there are ones available that cover UHF

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WHY do we use them?

- Is my antenna really an antenna?
- Tuning an antenna for resonance at a particular frequency
- Checking the “working bandwidth” of an antenna, ie. <1.5:1 VSWR
- Comparing readings after an event, like a storm
- Cable testing coax for faults and velocity factor
- Measuring Complex Impedance

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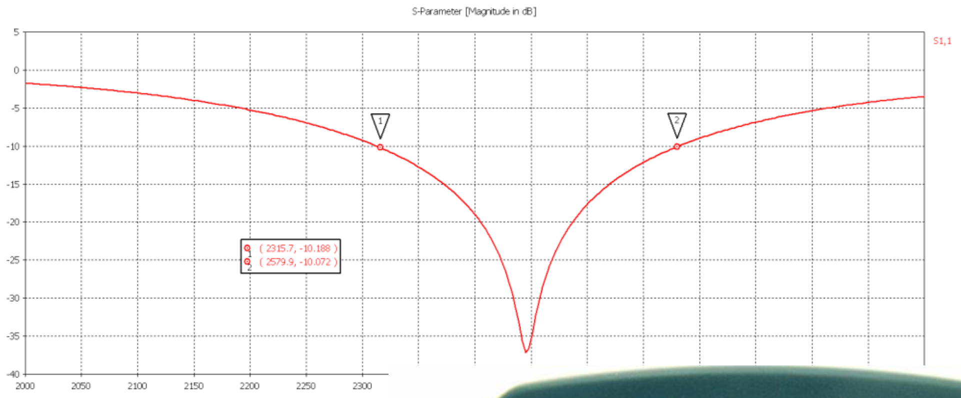
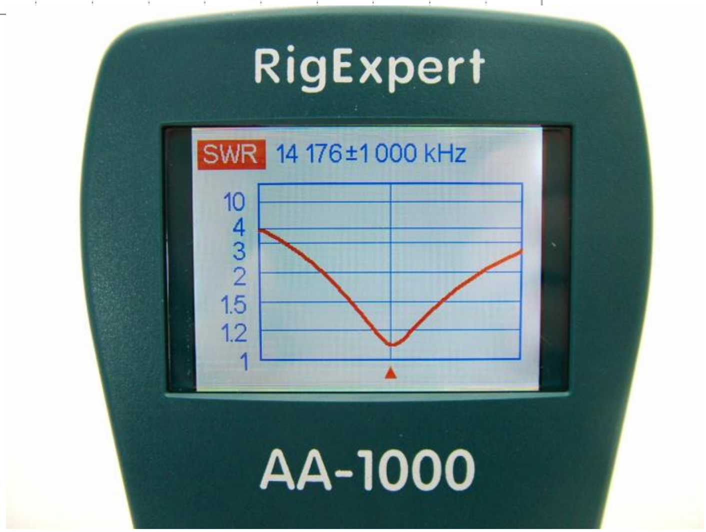
Using an Analyzer





- Using an analyzer requires some understanding of what it does
- Interrupting the results helps us improve the antenna and thus our ability to communicate with other amateur radio stations
- This is a good follow-on to the session we had on antenna modeling. This helps validate our assumptions
- Necessary piece of gear if you are building antennas

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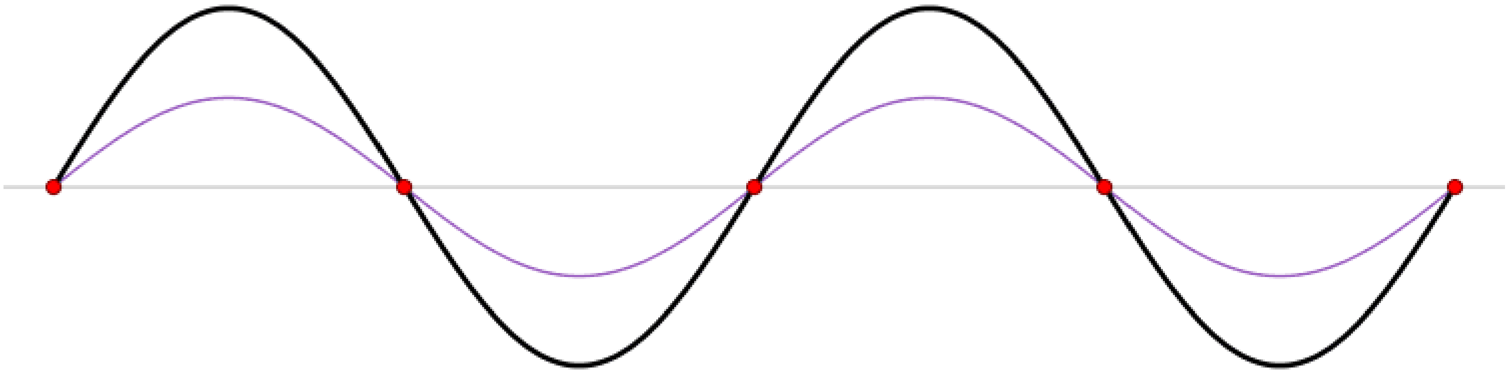
VSWR =
Voltage Standing Wave Ratio

What is a standing wave?



Blue = Forward Wave
Red = Reflected Wave
Black = Net standing Wave

- Standing Waves are reflections of the Forward Wave due to a mismatch in impedance
- A perfectly matched antenna has an impedance of 50 + j0 ohms (what is this?)
- How does it affect me if I don’t have a perfect match?

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Is High SWR bad? What if my VSWR is not 1.0:1?

- NO antenna will ever be 1.0:1, so get over it.
- Up to 2:1 ratios are consider an acceptable operating range.
- What about my antenna tuner? Does it make it perfect?
  - No. It just makes the transmitter "think" it is perfect.
  - Losses are in the tuner and all the RF never reaches the antenna

VSWR	Reflected %	Power Loss %
1.0.1	0	0
1.3:1	13	0.8
1.5:1	20	4
2.0:1	33	11
4.0:1	56	36
5.0:1	67	44.4
10.0:1	82	67

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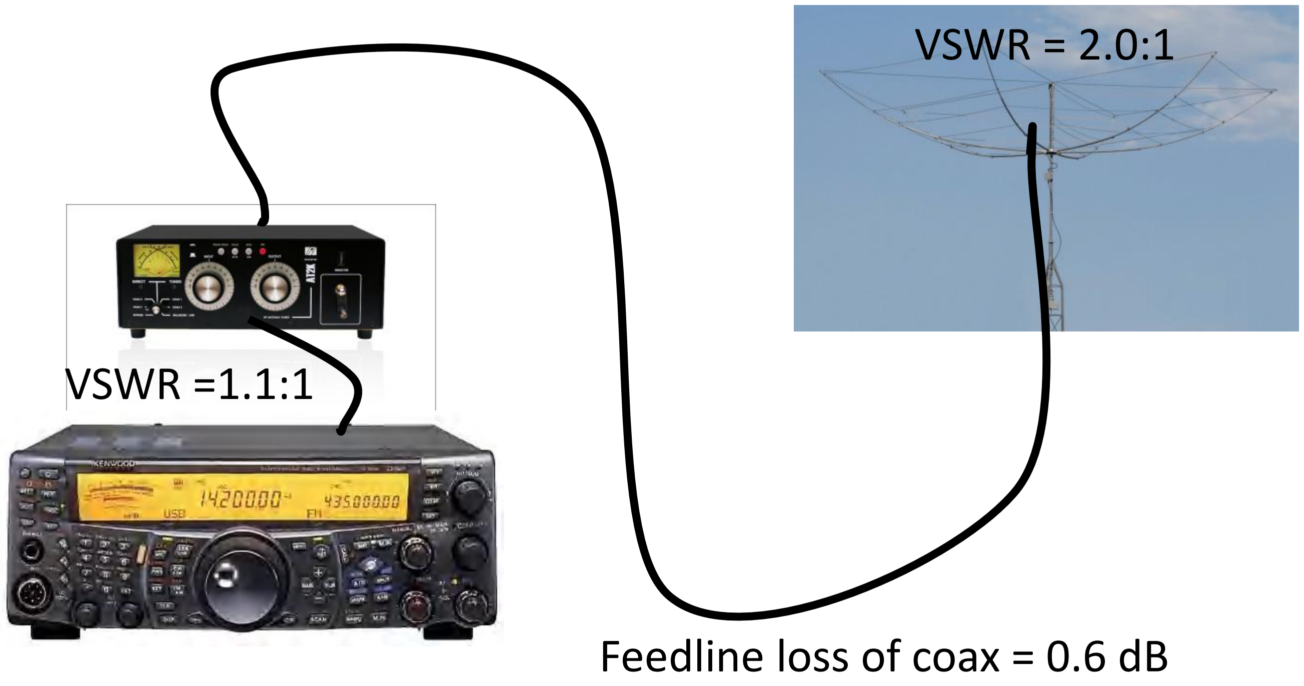
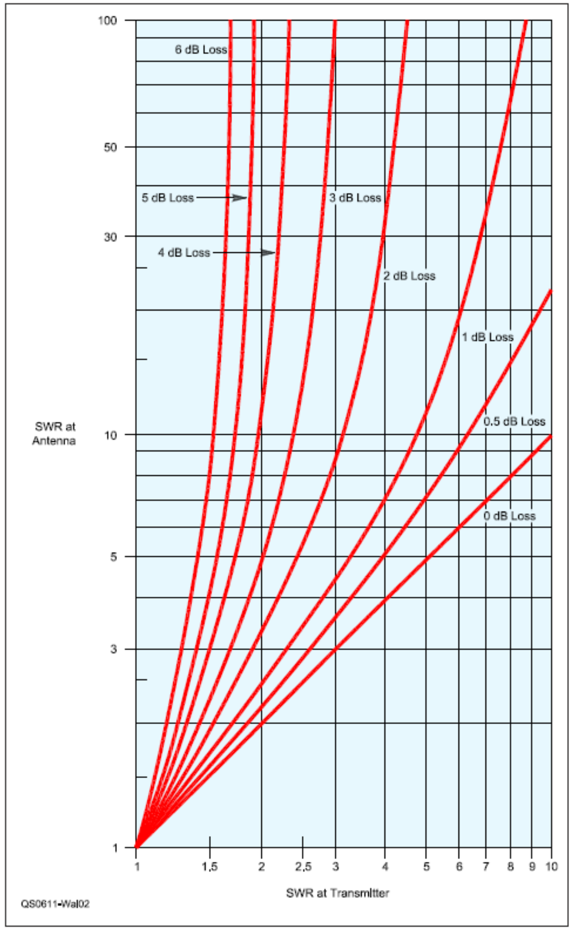
Is that the whole story? Well, no…



Losses can add up, but in most systems these are acceptable

SWR – How can it go wrong?



Setup

- 2 meter antenna
- 120’ of RG-8X Coax feedline
- @ 144mHz loss = 4.5dB

Measurement

- At transmitter: SWR is 2:1 (11%loss) not great, ok
- At antenna – using the graph here
- SWR at the antenna is 20:1 ! Not good at all
- Cost another 7dB in mismatch loss

Result 1/10 of your power is being radiated

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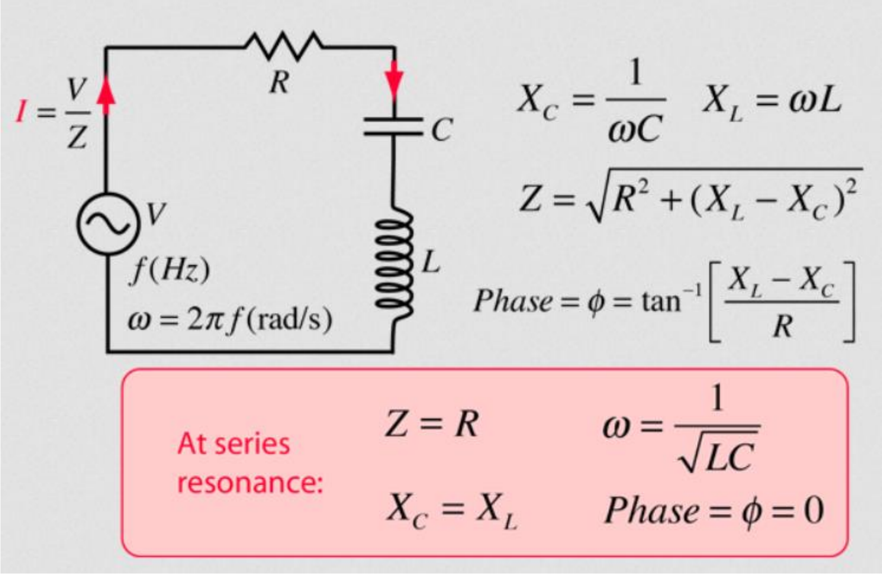
Complex Impedance

A BASIC INTRODUCTION

What is complex impedance



ω is called the angular frequency

- Mathematical representation of the “resistance” in a circuit to AC voltage and current.
- Consists of a Real and Imaginary components R and jX
- The real part consists of a resistor which dissipates active power (heat) , whereas the imaginary part consists of inductive reactance or capacitive reactance or both which is frequency dependent and is responsible for the reactive power in the circuit.

What is the R + jX stuff anyway?

Example: Solve $x^2 = -1$

Using Real Numbers there is no solution, but now we **can** solve it!

Take the square root of both sides:

$x = \pm\sqrt{(-1)}$

$x = \pm \mathbf{i}$

Answer: $x = -i$ or $+i$

Check:

- $(-i)^2 = (-i)(-i) = +i^2 = -1$
- $(+i)^2 = (+i)(+i) = +i^2 = -1$

i j

Unit Imaginary Number

The "unit" Imaginary Number (the equivalent of **1** for Real Numbers) is $\sqrt{(-1)}$ (the square root of minus one).

In mathematics we use i (for imaginary) but in electronics they use j (because "i" already means current, and the next letter after i is j).

Complex Impedance is represented as a complex number.

There is no negative R values

Positive j numbers are inductive reactance.

Negative j numbers are capacitive.

Example: 45 + j9

45 ohms resistance and 9 ohms of inductive reactance.

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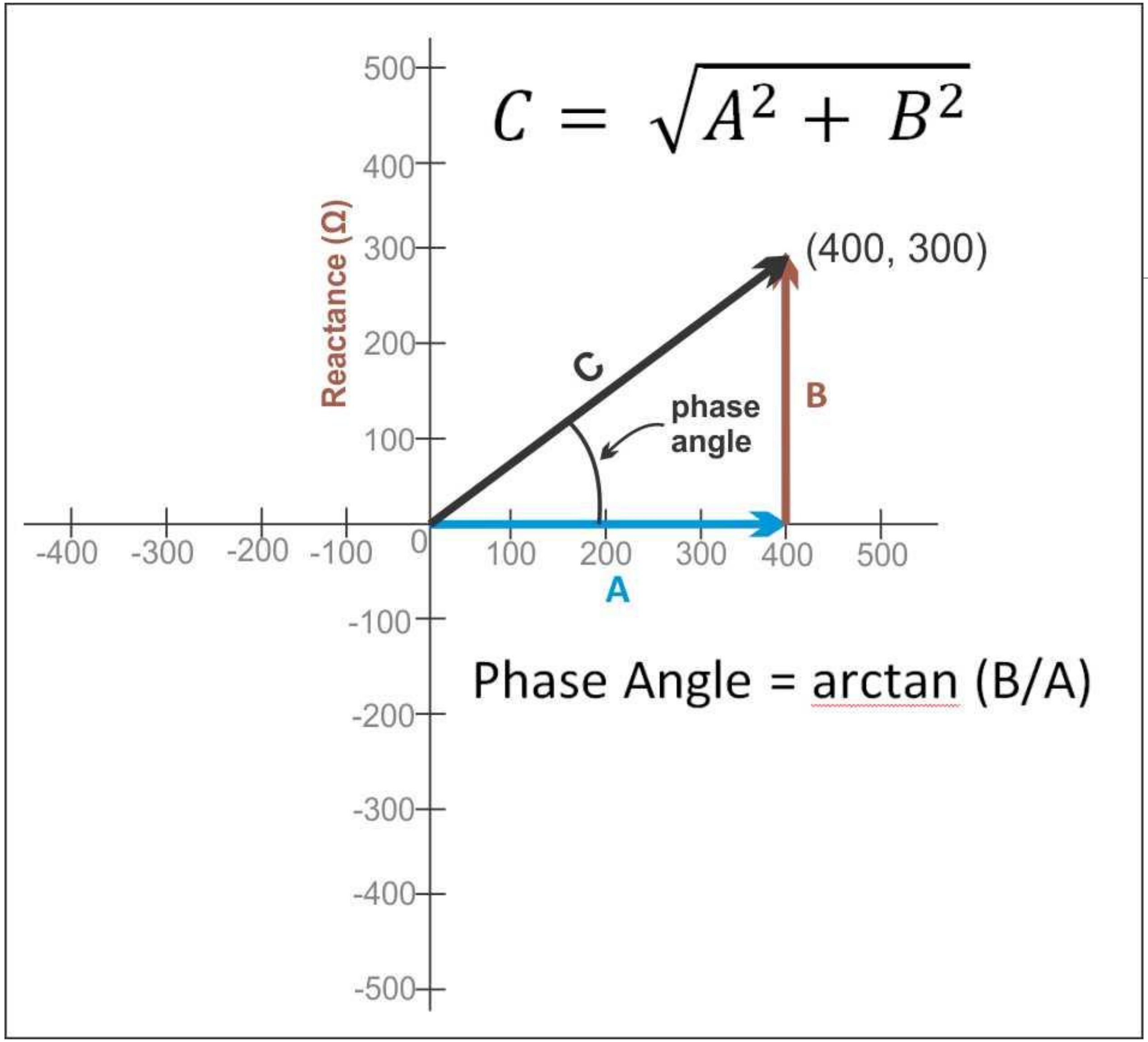
Graphical View of complex impedance



Rectangular Format   400 +j300

Solve the triangle to get vector

Vector Format   500 ∟36°

Vector is sometimes called polar format

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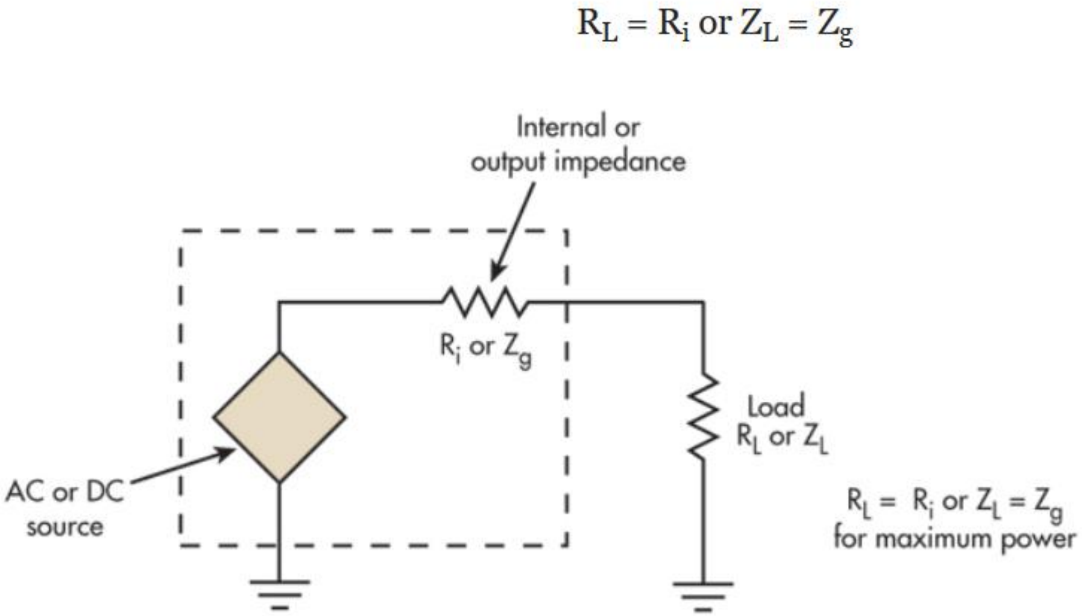
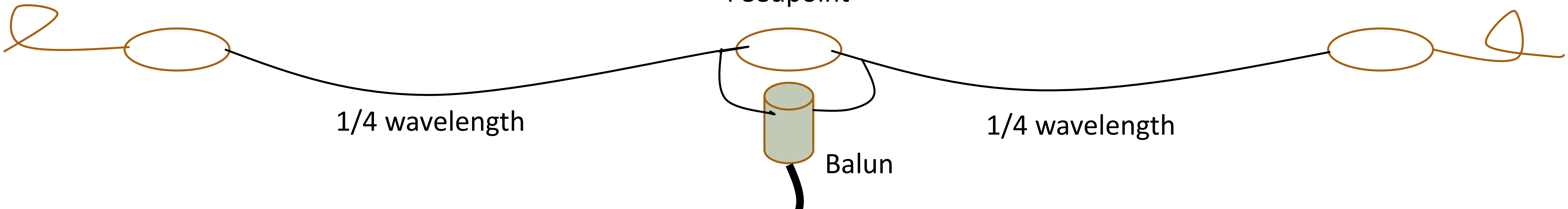
Why do we care?



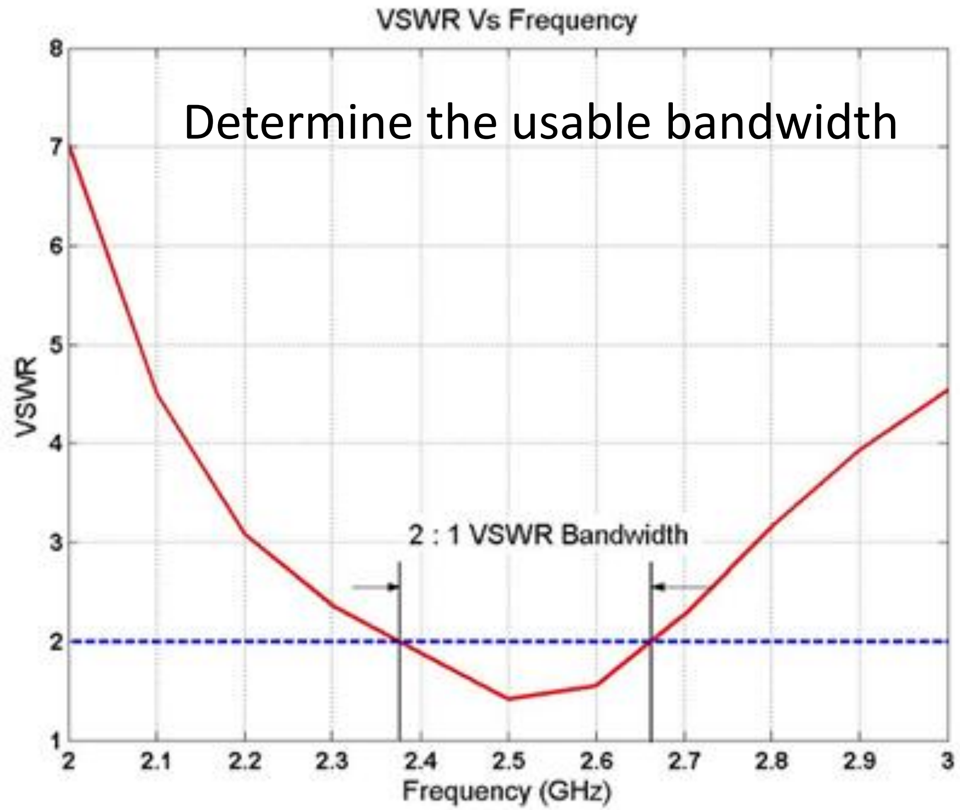
- Impedance match transfers the maximum power
- Our internal impedance in the transmitter is 50 ohms
- Coax feedlines are 50 ohms
- Antenna vary, based on multiple factors, but are ~50 ohms when properly tuned and at proper height.
- Impedance match to the antenna transfers maximum power to be radiated.
- Matched AC loads = no reflections= 1:1 SWR



100 + j77

72 + j44

49 + j16



Values are for example only and will
Vary based on your situation

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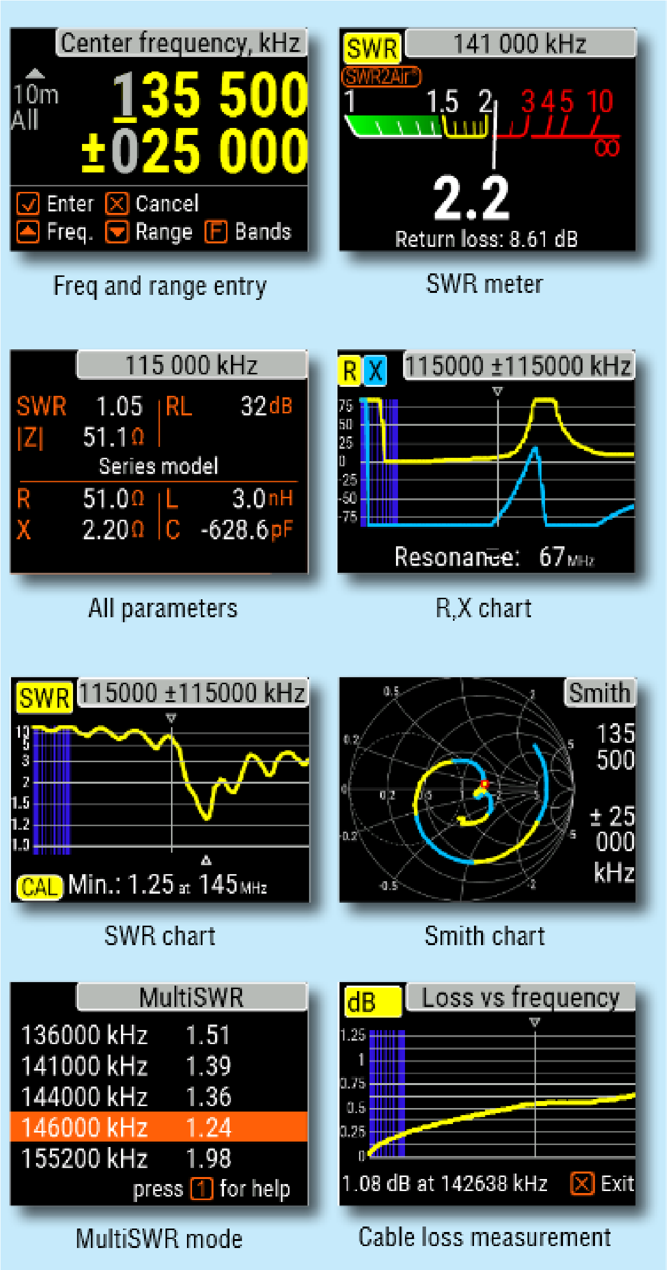


RigExpert AA-230 Zoom

- SWR measurement
- Sweep a band for SWR
- Sweep multiple bands for SWR
- Complex Impedance measurements
- Smith Chart
- Cable loss measurement
- Time domain reflectometer – cable length of fault location

Why use analyzers?

Antenna Building

- Avoid costly pruning mistakes
- Tune to the part of the band you will use it
- Experimentation – configurations and affects on SWR and impedance
- Troubleshoot problems

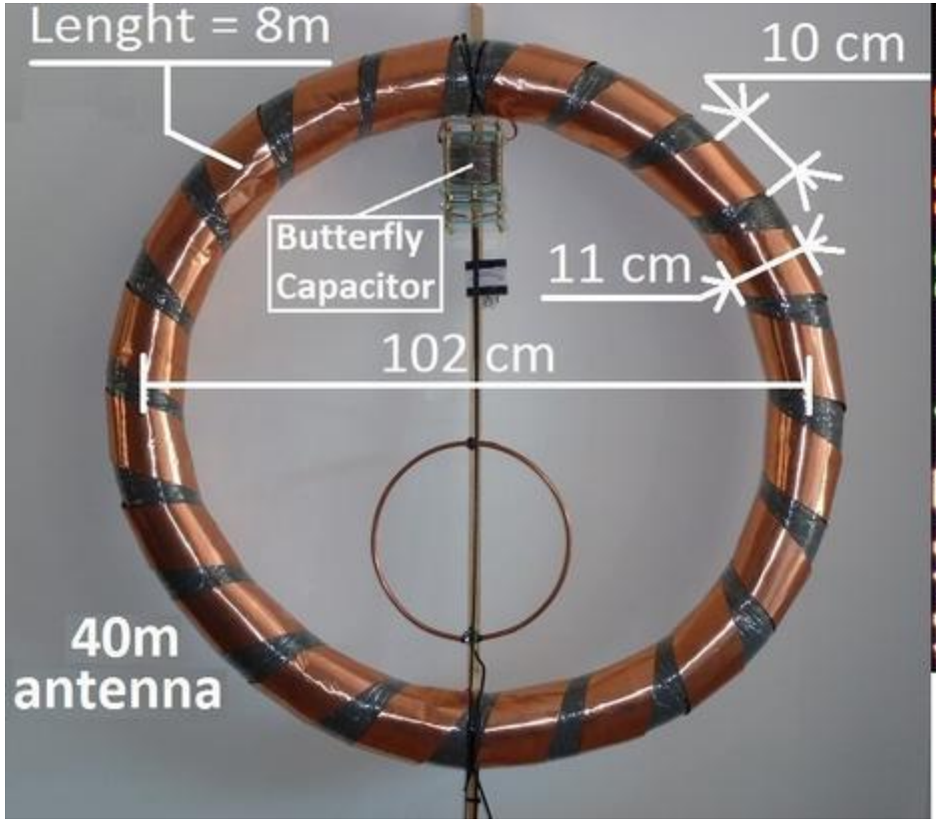
Education

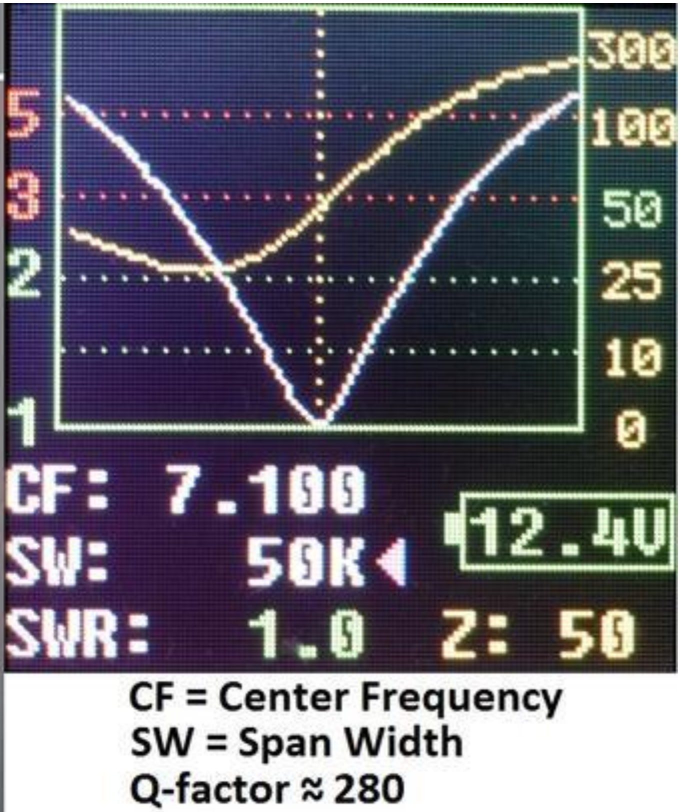
- Demystify your antenna system
- Real world understanding of complex impedance and how it matters
- Understand losses in your system

Operating

- Is my antenna in the range my tuner can correct for?
- Am I expecting too much from antenna? Do I need a new strategy?

See it work on Matt’s loop antenna





Thanks for listening
Questions?

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