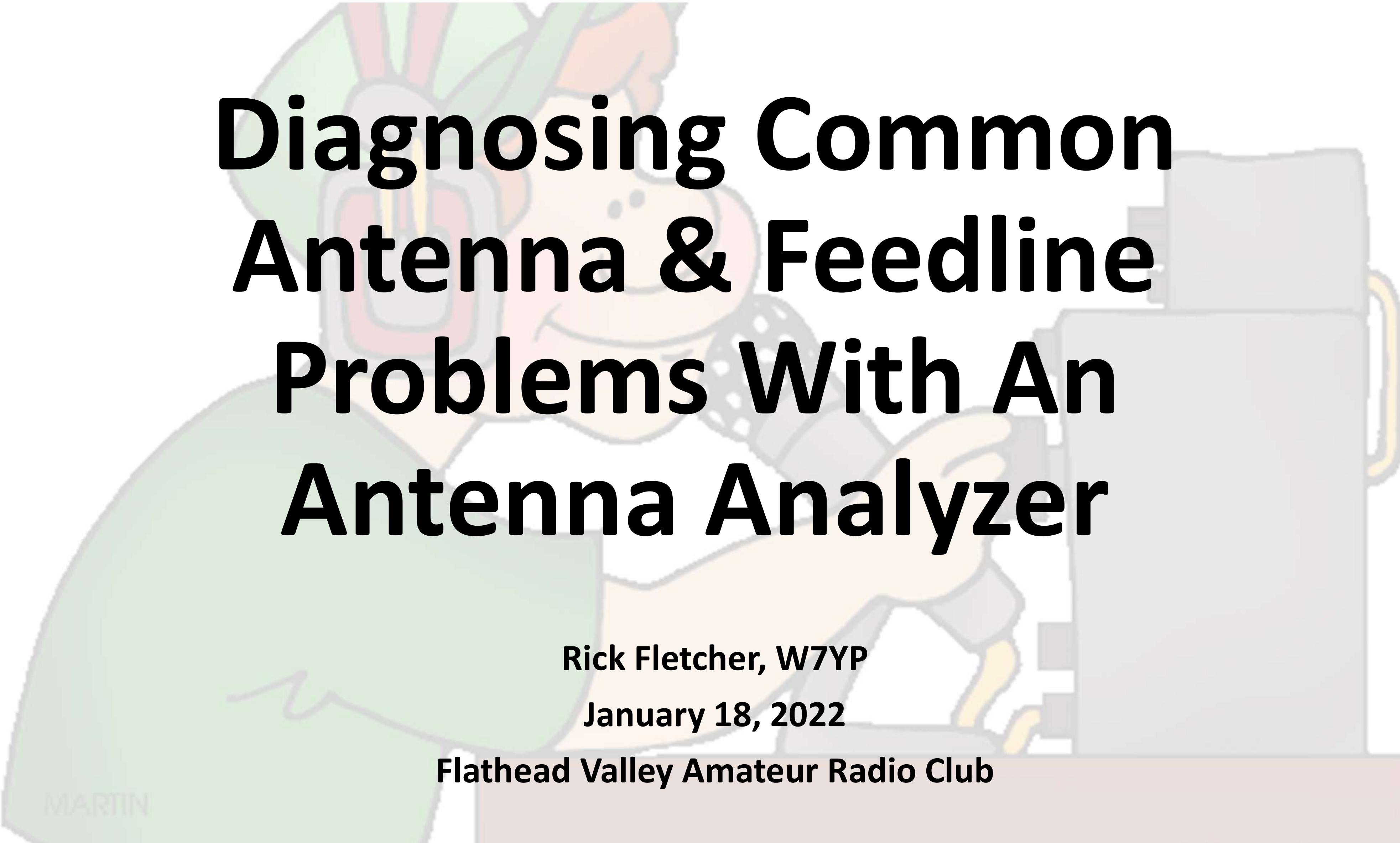

Diagnosing Common Antenna & Feedline Problems With An Antenna Analyzer

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Preface

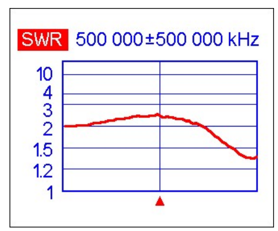
- In the interest of time, we'll only talk about coaxial transmission line
  - It's the most widely used
  - Most antenna analyzers are geared towards coaxial transmission line
- Transmit (high SWR) problems will be our focus in this presentation
  - Generally if you're system is transmitting without problems, it will receive just as well
- Starting assumptions:
  - The transceiver is known to be functioning properly
  - There is no obvious physical damage to the antenna
  - There is no obvious physical damage to the transmission line
  - The transceiver, tuner (if used), antenna switch (if used), amplifier (if used), interconnecting jumpers, transmission line and antenna have already been verified to be connected correctly and connections are tight
    - This is the amateur radio version of the customer support question, "Is it plugged in?"

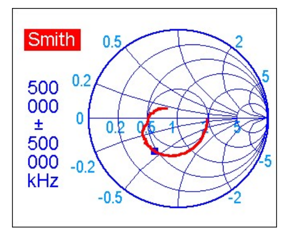
Antenna Analyzers

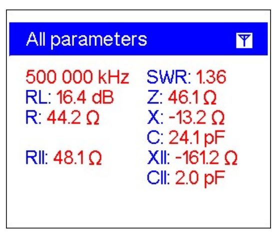
- MUCH more than an SWR meter
  - Contain their own low power variable frequency transmit power source
- Most analyzers can measure impedance and reactance in a transmission line-antenna system
  - Some analyzers can't tell if the reactance is capacitive or inductive
    - HINT:
      - If you increase frequency and the reactance decreases, the load is capacitive
      - If you reduce the frequency and the reactance decreases, the load is inductive
- This is pretty much the extent of features in low cost analyzers (e.g., MFJ, Diamond, Comet, etc.)

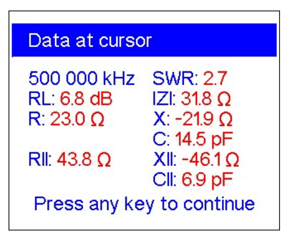
Reference Antenna Analyzer:

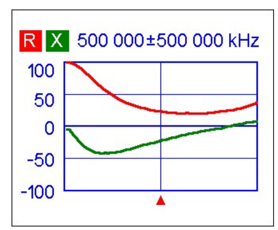
- RigExpert AA-1400
  - 0.1 to 1,000 MHz
    - 1 kHz resolution
  - Designed for 25/50/75/100 Ω systems
  - Benchmarks well against lab grade network analyzer
  - SWR measurement range1 to 100 in numerical mode; 1 to 10 in graphing mode
  - 320 x 240 color TFT display
  - USB connection to PC
    - AntScope software
  - Weight: 23 oz.
  - 'N' connector
  - Output: -10 dBm
  - TDR
  - 2-year warranty
  - $499 (Gigaparts)











What Can You Do With an AA-1400?

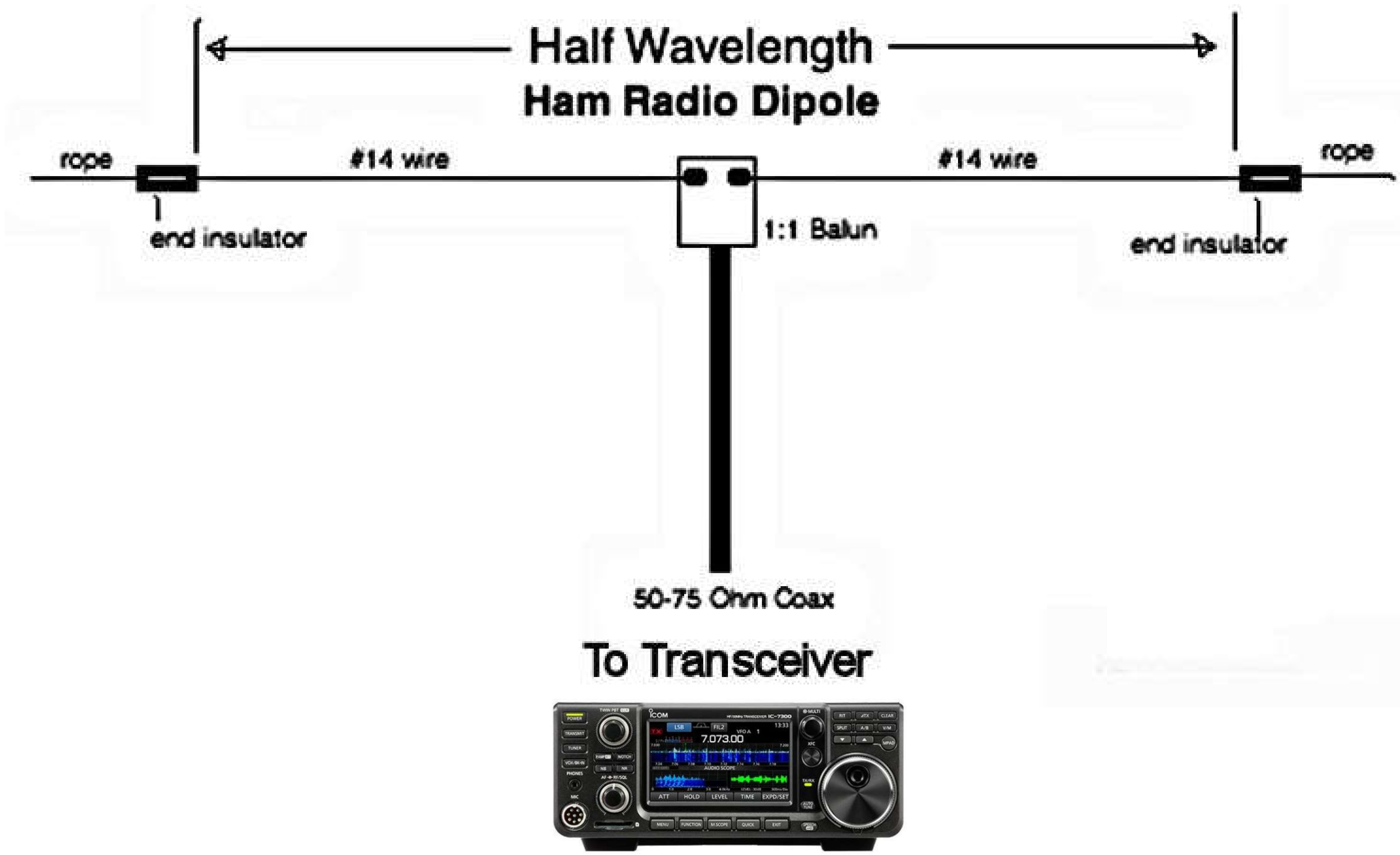
- Measure SWR vs. Frequency
  - Perform specified “sweep” within a frequency range and chart the results
    - SWR, impedance and Smith/polar charts
  - Verify antenna manufacturer’s specs
    - Data can be saved and compared to periodic sweeps to detect variations/declines in performance over time
- Calculate coax length
- Measure Distance-To-Fault (DTF) with Time-Domain Reflectometer
- Measure coax loss
- Reactance in capacitance/inductance
- Test and tune antenna stubs and phasing cables

“I’m not hearing anything and I seem to have a really high SWR. I wonder what’s wrong.”

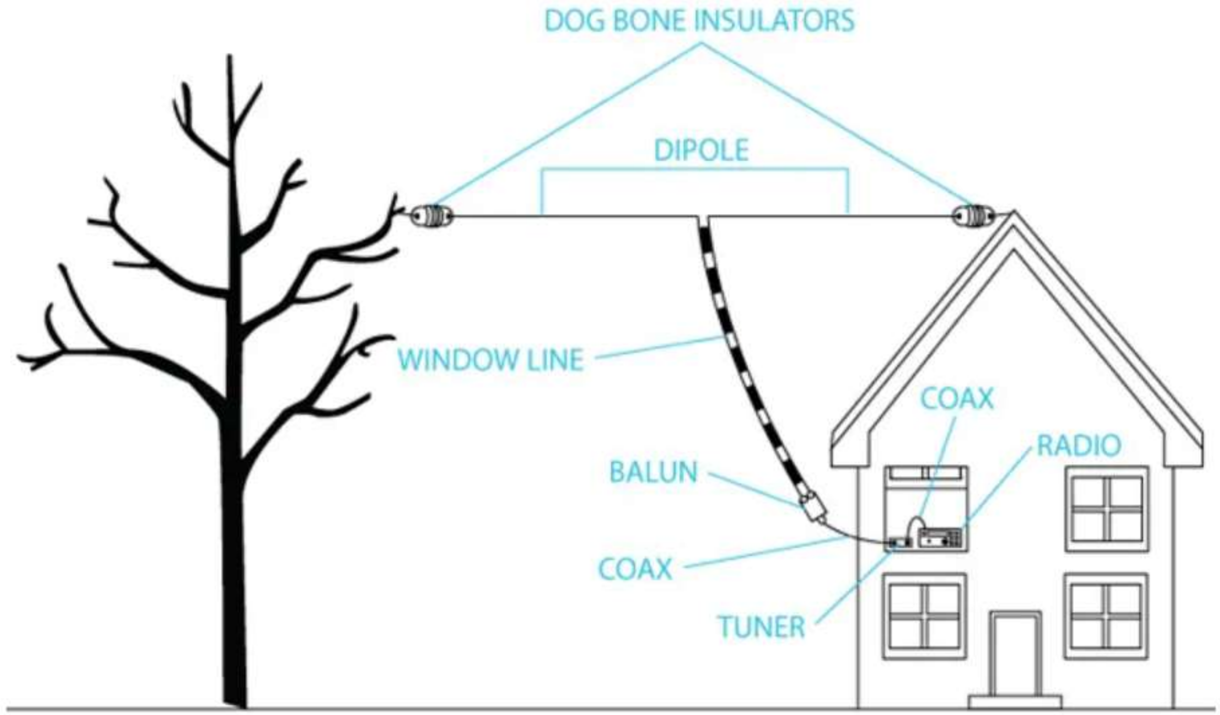
Reference Station Setup

- This discussion will use a simple ‘reference’ station consisting of a transceiver, a 50 Ω coaxial line and the ubiquitous resonant dipole antenna with a feedpoint impedance close to 75 Ω
  - Tuners, antenna switches, amplifiers and other inline devices inserted in the transmission path can have problems of their own
    - They can present issues beyond the scope of this presentation
    - When these items are present and one or more of them are suspected as possibly causing a high SWR when analyzed from the transceiver’s point of view, testing with an analyzer should be done in this order:
      - Feedline to antenna; if that checks out, reconnect the feedline to the next item in the chain (e.g., tuner, amplifier, antenna switch, etc.)
      - Back up towards the transceiver one device at a time until the analyzer shows a problem
      - At that point, the problem is either the device the analyzer is connected to or one or both of the jumpers going into and out of it

Reference Station:



Reference Station With Ladder (Window) Line:

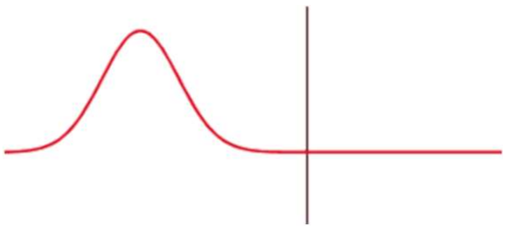


Diagnosing a High SWR at the Transceiver, Part 1

- What you'll need:
  - An antenna analyzer
  - A known good coax jumper cable
  - Possibly PL-259 and 'N' adapters
- Start at the antenna and test it at its feedpoint with the analyzer
  - This might be challenging if the antenna is mounted on a tower
  - In our reference case, we have a dipole which can be lowered so that the feedpoint is within reach (but generally not much can fail in a dipole)
    - Many quality commercial dipole offerings include a 1:1 current balun
    - Since we're using a 50 Ω setting in the analyzer, a good SWR will be at least 1.5:1
    - Use the analyzer to sweep the full bandwidth of the dipole and save the results
      - Is the SWR sweep acceptable across the bandwidth you're using?
        - If not, you may need to shorten or lengthen the dipole to 'center' it appropriately
    - If the sweep tests normally and a transmission line test is also good, you may have a bad balun
      - Balun issues often only show up in transmit mode with more power being applied to them

Diagnosing a High SWR at the Transceiver, Part 2

- Assuming the antenna measurements were acceptable, we next need to test the transmission line
  - Use SWR/Impedance measurements:
    - Connect a known good 50 Ω dummy load at one end of the coax
    - With the analyzer, sweep the frequencies of operation looking for any impedance 'bumps' in the chart produced
      - These will appear at increases in SWR due to an impedance discontinuity
  - Using TDR function:
    - Make sure the coax is disconnected at the end opposite the analyzer
    - Set length to be tested to be longer than the coax's actual length
    - Run the TDR scan
    - If the measured length to the 'fault' (other connector) matches the actual length, the coax is likely good
    - This is a handy test if you're up on the tower doing the coax test



- These tests only confirm that the coax's impedance is 50 Ω
  - There may be other coax losses or problems these simple tests will not detect
    - Use the analyzer to measure loss to confirm that the coax is up to specs

TDR

- Since the invention of direct-burial coax, it has become very popular with amateur radio operators
  - Much cheaper then burying a long run of PVC, then pulling the coax through
  - Sometimes movement within the earth may compress the coax or damage its integrity, negatively impacting its performance
    - In the “old days”, the options were to dig up the coax a few feet at a time, looking for the damaged section, or to bury a whole new run of coax
- An analyzer’s TDR function can measure the Distance-To-Fault within a few feet
  - A new section can be spliced in and sealed, and the coax reburied

Testing a Dummy Load

- A good dummy load will show zero reactance and a 50 Ω resistive load over the specified bandwidth
- SWR of 1.0:1
  - Often the measured SWR will be a bit higher, up to 1.2:1 and that's OK
    - Just remember to factor in the load's performance when testing coax connected to it
  - Use a very short length of coax between the analyzer and the dummy load
  - This procedure can also be used to validate analyzer performance

How to Test a Balun

- For a 1:1 balun, add a 50 Ω resistor across its output
- For a 4:1 balun, use a 200 Ω resistor across its output
- SWR scan should show a low SWR over its entire designed frequency range
- Zero or nearly zero reactance
- If the SWR scan is not flat across its frequency range, the balun is questionable
- If the balun passes these low power tests but presents a high SWR when transmitting, it is questionable

Tips and Tricks

- Always temporarily short out the feedline connector or antenna input to discharge any static buildup BEFORE connecting the analyzer to it
- If the coax seems to be bad, back off the shell on the connectors to expose the soldered braid and ensure the solder joints look good
  - Using a DVM, check for end-to-end continuity on the center conductor and also for the outer braid
    - Also verify there's no short between the braid and the inner conductor
- If the SWR changes with coax length, placement or grounding:
  - Coax is carrying common mode currents and radiating
  - Coax is not 50 Ω
  - Coax has significant loss
- Intermittent problems are often due to defective mechanical connections
  - Flex those points while testing with the analyzer
  - Rotor loops are another frequent cause of intermittent problems
- Problems that show up only after you've been transmitting for a while are usually a burned or oxidized contact in a connector, switch, or relay
  - Can also be water in a connector or the coax or an overheated/cracked balun

Tips and Tricks (cont.)

- Measuring feed-line loss without disconnecting it from the antenna:
  - Most antennas will reflect nearly all power at some out-of-band frequency
    - Increase frequency of measurement until you get a really high SWR (or low RL)
  - If all/most of the power is reflected, the difference between forward power and reflected power (Return Loss or RL) is due to power lost in the feed-line
  - Since the signal has traveled twice through the feed-line, the actual loss is one half of RL

How Can I Use Impedance Values?

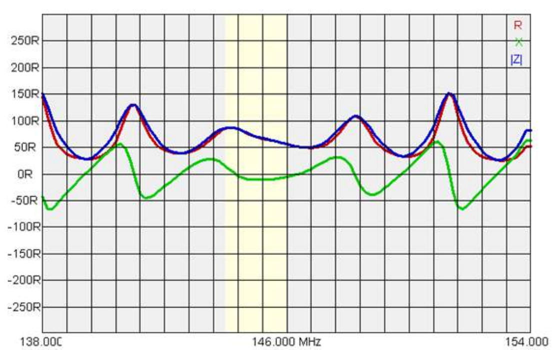
- Complex impedance (Z) = R + jX
  - R = Resistance (real)
  - X = Reactance (imaginary)
    - AC ‘resistance’ caused by capacitance (C) and/or Inductance (L)
      - X_L is always positive reactance
      - X_C is always negative reactance
- Reactance can be used to electrically lengthen or shorten an antenna
  - Add inductance to lengthen an antenna
  - Add capacitance to shorten an antenna
- Inductive reactance can be used to cancel capacitive reactance and vice versa

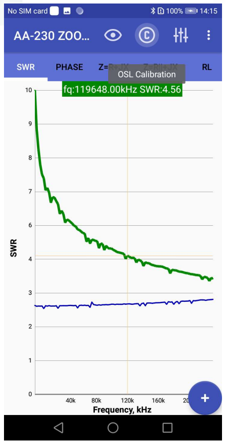
When is an Antenna Resonant?

- When X (reactance) is zero
  - Reactance is likely part of an apparent 50 Ω impedance if the SWR is not 1.0:1
    - Is it inductive or capacitive reactance?
    - To cancel reactance, add reactance of the opposite type and the same value
    - EXAMPLE:
      - $Z = R + jX$, where $R = 35$ and $X = 36$
      - The absolute impedance used to measure AC current flow = square root of ($R^2 + X^2$)
        - In this case, the absolute impedance is 50.2 Ω
        - You'll have an acceptable SWR, but with losses due to the reactive component present
  - **Reactance is non-productive resistance**
- Feedline can affect reactance
  - If the SWR changes significantly with change in feedline length, the antenna is not resonant
- Knowing all of this and with an analyzer to expose these values, the ham antenna experimenter can optimize antenna designs

Other RigExpert Offerings

- StickPro ($350)
  - 0.1 to 600 MHz
  - 25/50/75/100/150/200/300/450/600 Ω systems
  - No TDR (Time-Domain Reflectometer)
- AA-650 ZOOM ($599)
  - New high contrast display easily readable in full sunlight
  - TDR
  - Bluetooth 4.2
    - AntScope Android/iOS app
- AA-2000 ZOOM ($1085)
  - 800 x 480 color Blanview display
  - TDR
  - Adds additional features for antenna developers/testers
    - Complex impedance measurements
  - Additional cable testing features
    - e.g., measuring velocity factor and cable impedance
  - Bluetooth 4.2
    - AntScope Android/iOS app
- ZOOM models have ham-specific features by ham bands and a "zoom" function to drill down in a chart
- Other offerings starting at just over $200





Q & A