HOW DOES AN ANTENNA TUNER WORK?

Inspired by the work of IZ2UUF

https://www.iz2uuf.net/wp/index.php/2019/03/22/how-does-a-tuner-tune/

https://www.youtube.com/watch?v=mmVMQbXmaHA

Why use an antenna tuner?

How does an antenna tuner…tune

Does an antenna tuner ‘fool’ the radio?

Will an antenna tuner waste power?

Can an antenna tuner help get more power to the antenna?

Other Credits:

Wikipedia ‘Antenna Tuner’

About Impedance-Matching Circuits by Ward Silver, N0AX, QST October 2019

‘Portable WIRE Antennas’ by John Hill, KF7SQQ]

Back to Basics: Impedance Matching (Part 2) Electronic Design Lou Frenzel, March 2012

WHY USE AN ANTENNA TUNER?

- To MATCH a transmitter output to an antenna. Even with today's Software Defined Radios which eliminate many of the analog tuned circuits within a radio, antennas still require analog tuning circuits in most cases.
- Antenna tuners are particularly important for use with transmitters. Transmitters are typically designed to feed power into a reactance-free, resistive load of a specific value, very often 50 ohms. However the antenna and feedline impedance can vary depending on frequency and other factors.
- To improve power transfer between the transmitter and antenna by matching the specified load impedance of the radio to the combined input impedance of the feedline and the antenna.

The antenna tuner DOES NOT change the SWR on a transmission line.

The antenna tuner DOES increase the power transferred from the transmitter to the transmission line and therefore increases the power radiated from the antenna.

The antenna tuner does not reduce the portion of signal lost in the transmission line.

The antenna tuner DOES NOT improve the radiation efficiency of an antenna.
Compromise antennas are still compromises, and
poor antennas are still poor antennas.

(from 'Portable WIRE Antennas' by John Hill, KF7SQQ]

HOW DOES AN ANTENNA TUNER…TUNE?

- The antenna tuner should more properly be called an ‘impedance matching network rather than an antenna tuner since it does not actually tune the antenna. Tuning an antenna would actually require adjusting the antenna dimensions. (SteppIR)

- Other names used since radio art and science began:
  - “Match Box”
  - “Antenna Coupler”
  - “Feedline Coupler”
  - “Antenna Tuning Unit”

- An antenna tuner matches the complex impedance of the transmitter to that of the input end of the feedline.
- The input impedance of the transmission line will be different than the characteristic impedance of the feedline if the impedance of the antenna on the other end of the line does not match the line's characteristic impedance.
- The consequence of the mismatch is standing waves on the feedline that alter the line's impedance at every point along the line.

- **REACTANCE CONCEPTS**

- Depending upon the AC Frequency, Inductors and Capacitors resist the flow of electricity in a manner similar to resistors in a DC circuit.

- ***The Inductors and Capacitors thus 'Impede' the flow of current in an AC circuit, and this is called IMPEDANCE*****.** (The symbol for Impedance is 'Z'.)

- ***This form of Impedance in an AC circuit caused by an Inductor or Capacitor is called REACTANCE***. (The symbol for Reactance is 'X'.)

- ***Both Reactance and Impedance are measured in OHMS.***

  For example an Inductor may have a reactance (X_L) of 100 Ohms at a particular frequency.

  In the same fashion, a Capacitor may have a reactance (X_C) of 100 ohms at a particular frequency.

- With lossy, low-impedance feedlines like the commonly used 50 Ohm coaxial cable, maximum power transfer only occurs if matching is done at the antenna in conjunction with a matched transmitter and feedline, producing a match at both ends of the line.

- To make this impedance match, combinations of inductors and capacitors in various configurations are used to add or subtract inductive and capacitive reactance to balance out the reactive components of the feedline and antenna system.

> *"Any method of changing the combination of V and I converts one value of impedance to another."*

(Ward Silver N0AX)

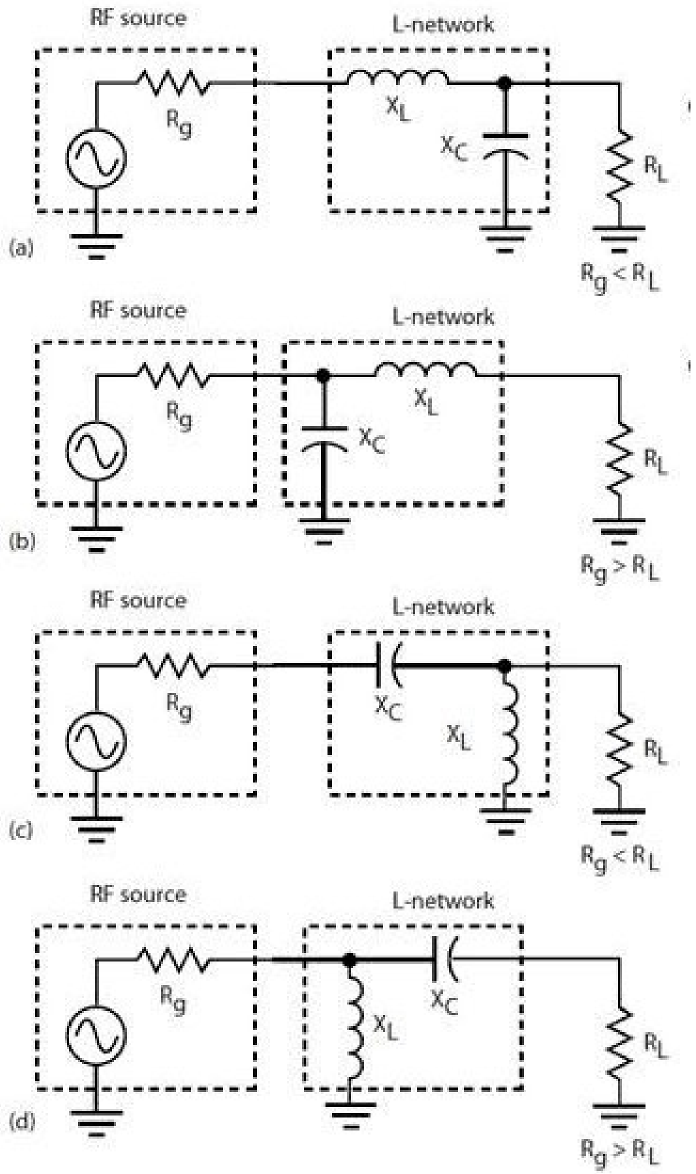
Reactive Matching

What we usually think of as impedance matching is *reactive matching* that uses L and C components. These create phase shifts in ac voltages and currents, which combine to create a new combination of voltage and current. Reactance changes with frequency so the circuit has to be tuned to perform the impedance conversion at each different frequency.

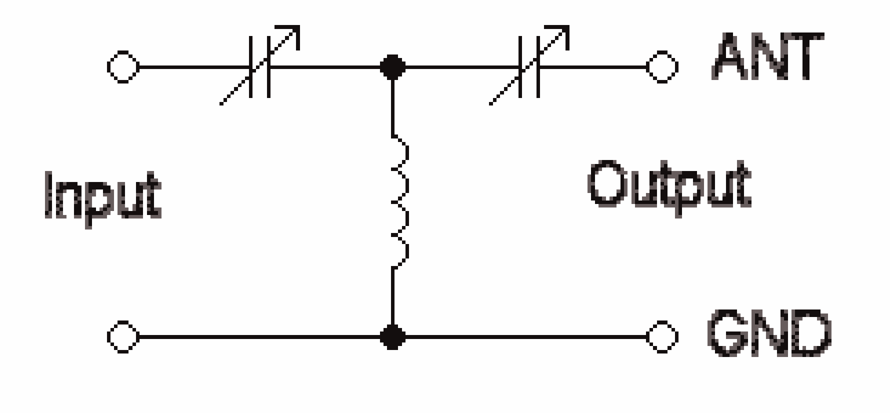
There are a number of different circuits commonly used for reactive impedance matching; **L**-, **Pi**-, and **T**-networks. "Network" is just a fancy name for "circuit." All three of these networks are covered in detail, including design equations, in *The ARRL Handbook* and in an excellent three-part series of *QST* articles by George Grammer, W1DF, in 1957.[4, 5]

The L-network is a simple inductor-capacitor (LC) circuit that can be used to match a wide range of impedances in RF circuits.

Most auto-tuners use this design.

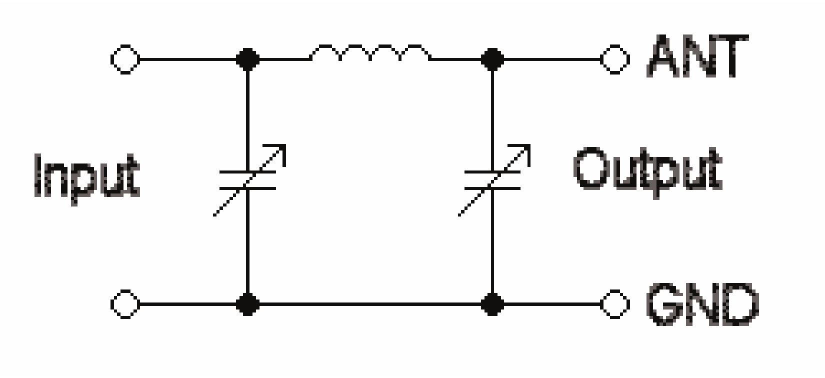


T-network transmatch
This configuration is currently popular because it is capable of matching a large impedance range with capacitors in commonly available sizes.

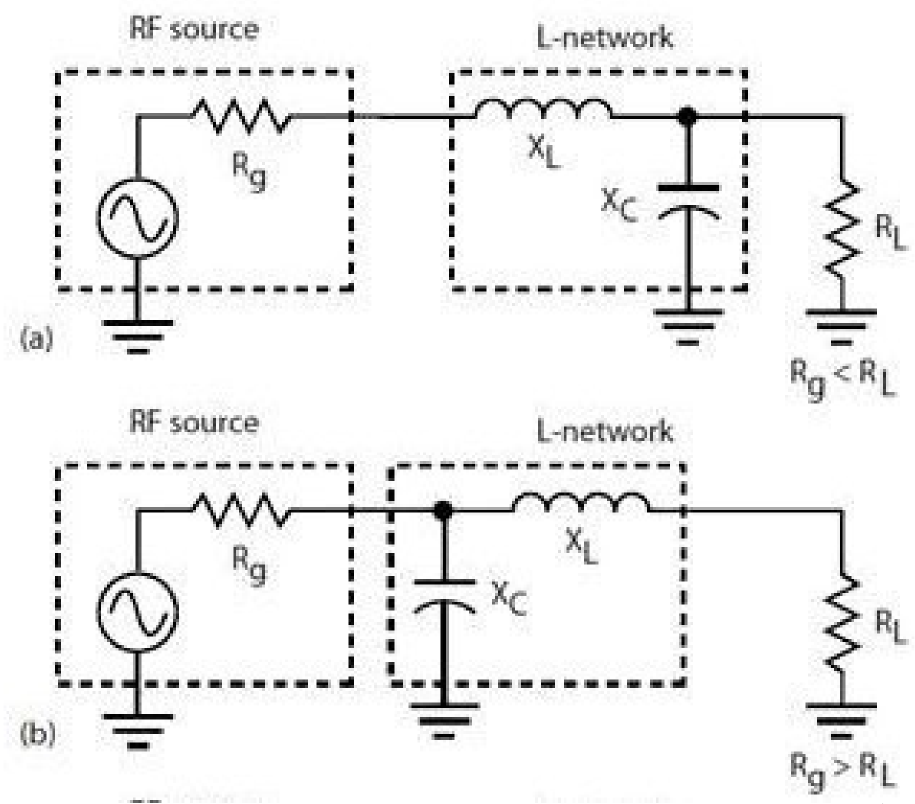


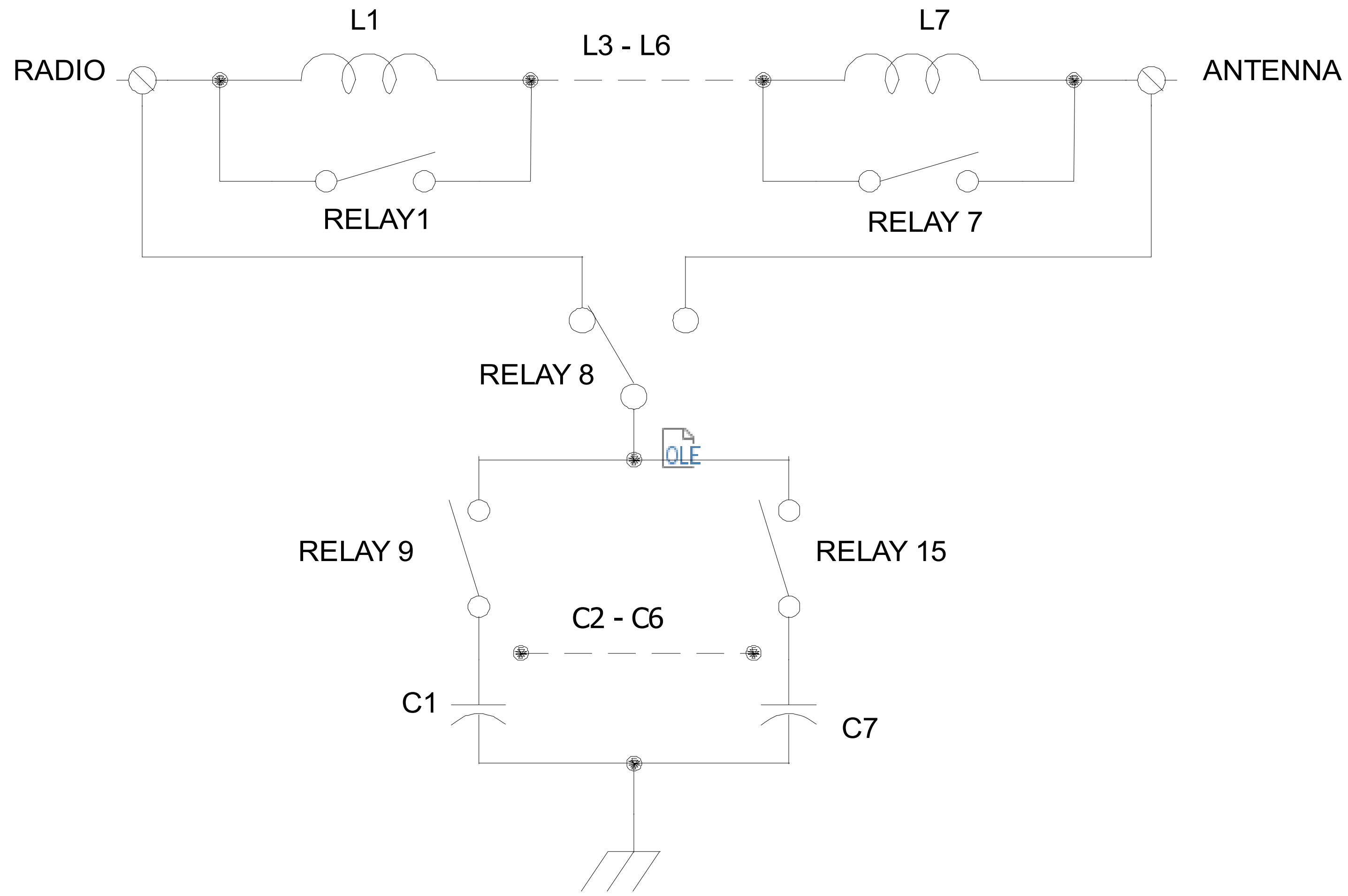
W4DML Built one of these and it woks great!

A π (*pi*) network can also be used. This ATU has very good attenuation of harmonics and was incorporated into the output stage of tube-based ‘vintage’ transmitters and many modern tube-based RF amplifiers.

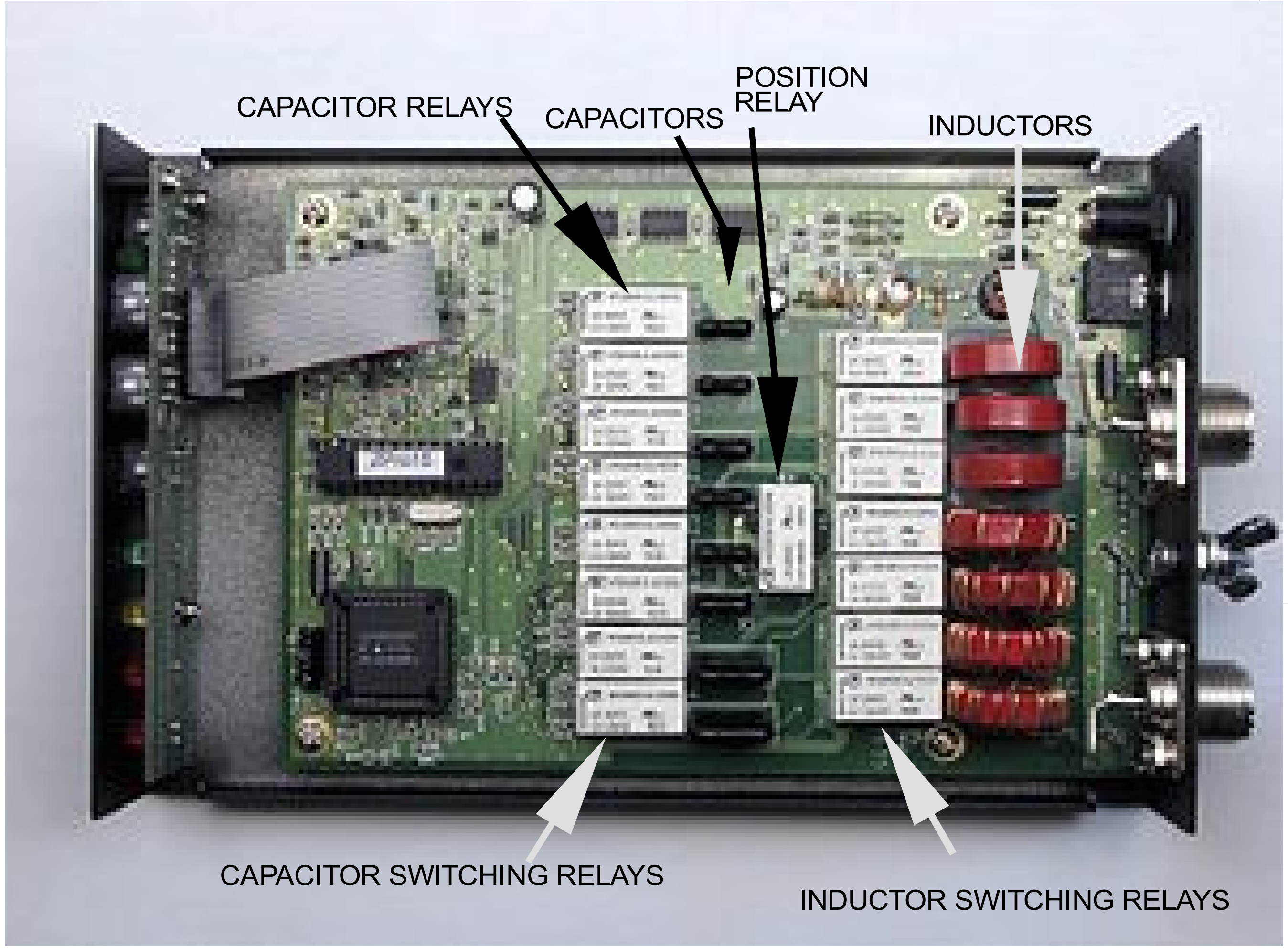


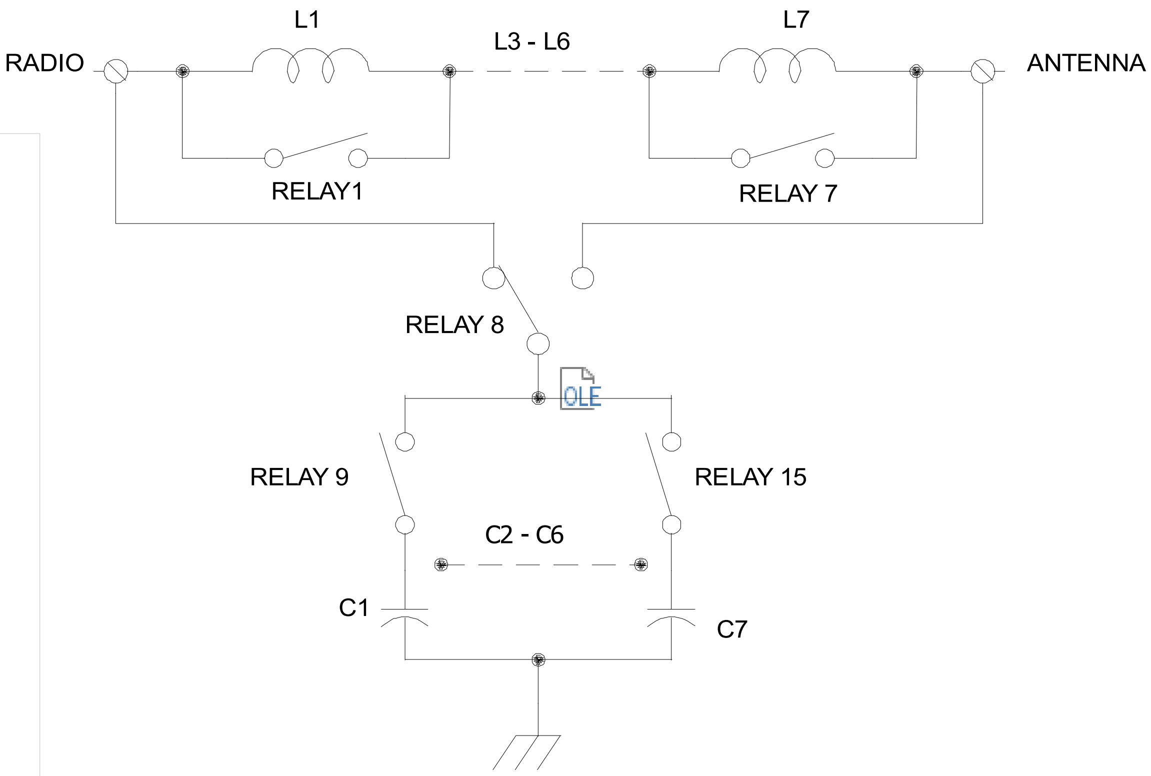
AUTO TUNER CONFIGURATION





AUTO TUNER CONFIGURATION





Does an antenna tuner ‘fool’ the radio?

Not any more than a shack power supply fools the radio to think that 120V AC is 13.8V DC

Will an antenna tuner waste power?

How much power is actually "lost" in the tuner? Power can only be dissipated by the **resistive part of the impedance**. If we could make a tuner with <u>ideal</u> capacitors and inductors (i.e. purely reactive), the power dissipated by the tuner would be none.

A tuner is able to transform the impedance of the load into the impedance required by the generator by creating a circuit that, combined in series/parallel with the load, adds up to the required impedance. Since the components added by the tuner are **reactive**, no power is dissipated by an ideal tuner and all power is transferred to the load. Real (large components)tuners are designed to have very low loss components, so usually almost 100% of the power actually reaches the load.

A tuner dissipates some power due to the internal resistance of its non-ideal components.

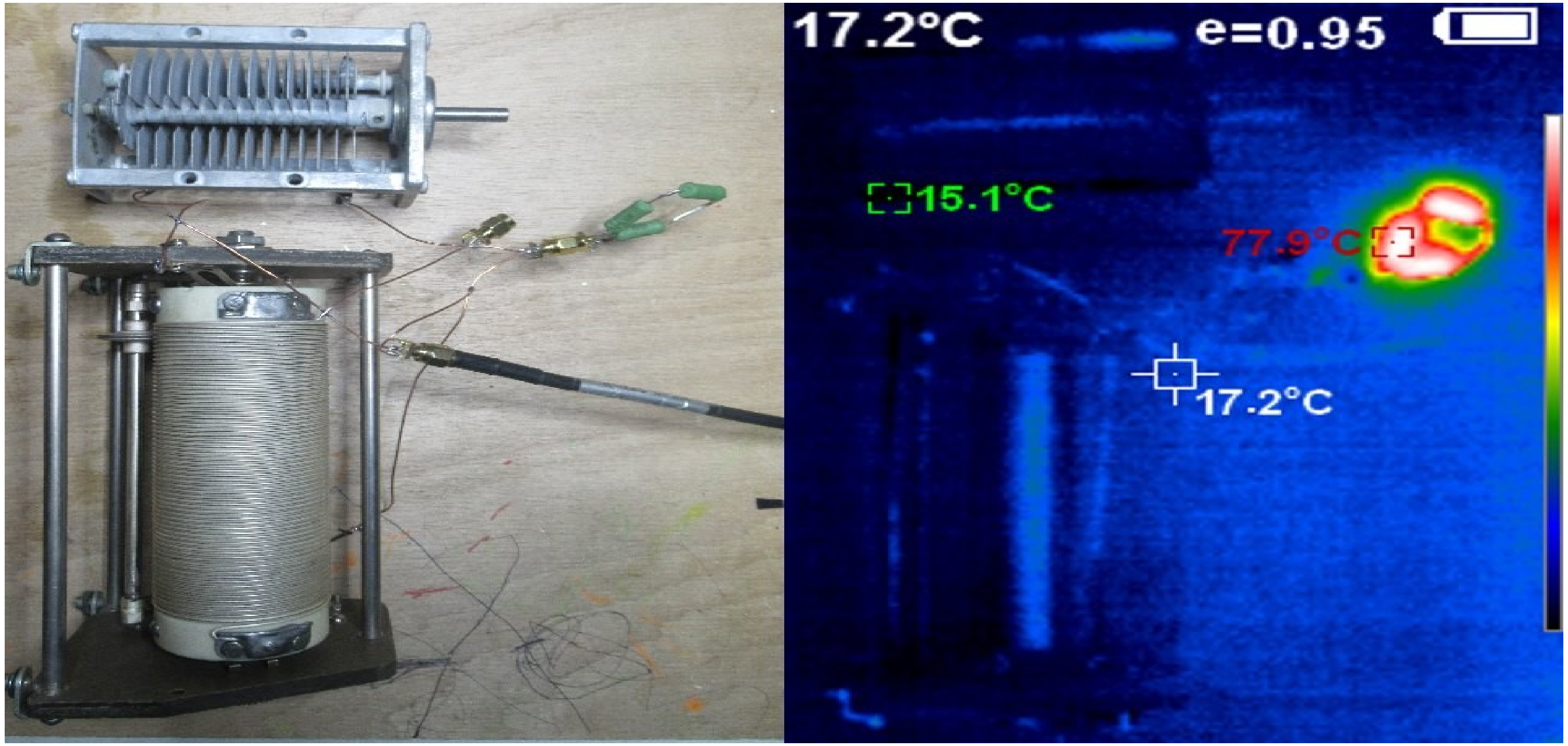
In a real tuner the amount of power dissipated depends on the rules of series and parallel circuits in the AC circuit that includes the load.

If the load resistance R is **high** or the reactance |X| is **low**, the losses can be very low.
(antennas => ½ wavelength).

If the load resistance R is **low** and reactance |X| is **high** (short antennas), losses can become **<u>catastrophic</u>**.

Comments on this slide by IZ2UUF from 'How Does a Tuner … Tune?'

This fact is clearly shown by this tuner in action under a thermal camera: as we can see, only the load resistors are hot while the tuner components are not dissipating any relevant heat. (IZ2UUF)



Notice

This is an article about **how a tuner does the tuning process** and it efficiency,
not about what a load does of the energy it received.
If you connect a transmission line between your tuner and a mismatched antenna, the transmission line will dissipate more power than usual, sometimes a lot of power: in this case, blame the transmission line, not the tuner.

Can an antenna tuner help get more power to the antenna?

Eliminates transmitter fold back.

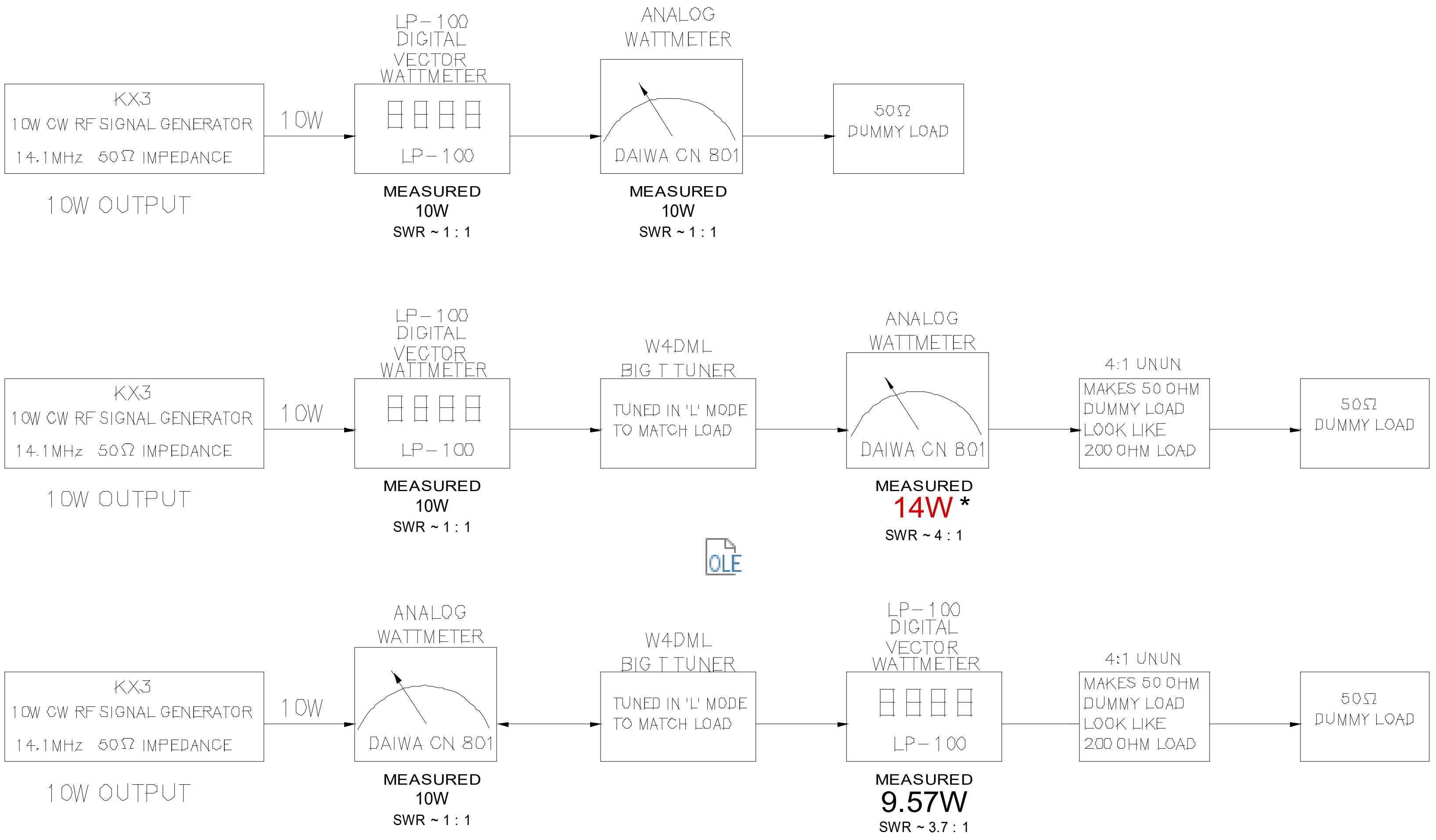
Since the tuner output is ideally purely reactive, no power is lost upon reflection.

What actually happens to the energy reflected back down the line? This energy will encounter another impedance discontinuity, this time at the source.

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 losses in the line, but mainly because of partial absorption at the load each time it reaches the load.

In fact, if the load is an antenna, such absorption at the load is desirable, since the energy is actually radiated by the antenna.

(ARRL Handbook 2015 page 20.4)



IN A STANDING WAVE AT EVERY VOLTAGE ANTI-NODE (MAX V) POINT THERE IS A CURRENT NODE (MIN I).

THE VECTOR WATTMETER MEASURES BOTH CURRENT AND VOLTAGE TO DETERMINE POWER: $P = I * V$

THE DAIWA METER USES DIODE DETECTORS SENSITIVE ONLY TO VOLTAGE, AND ASSUMES 50 OHM LOAD.
TO DETERMINE POWER: $P = V^2 / R$

* THE DAIWA METER READING IS WRONG IN THIS SITUATION.