REFLECTIONS 2.0
"what happens in between the 1/4 wavelengths??"

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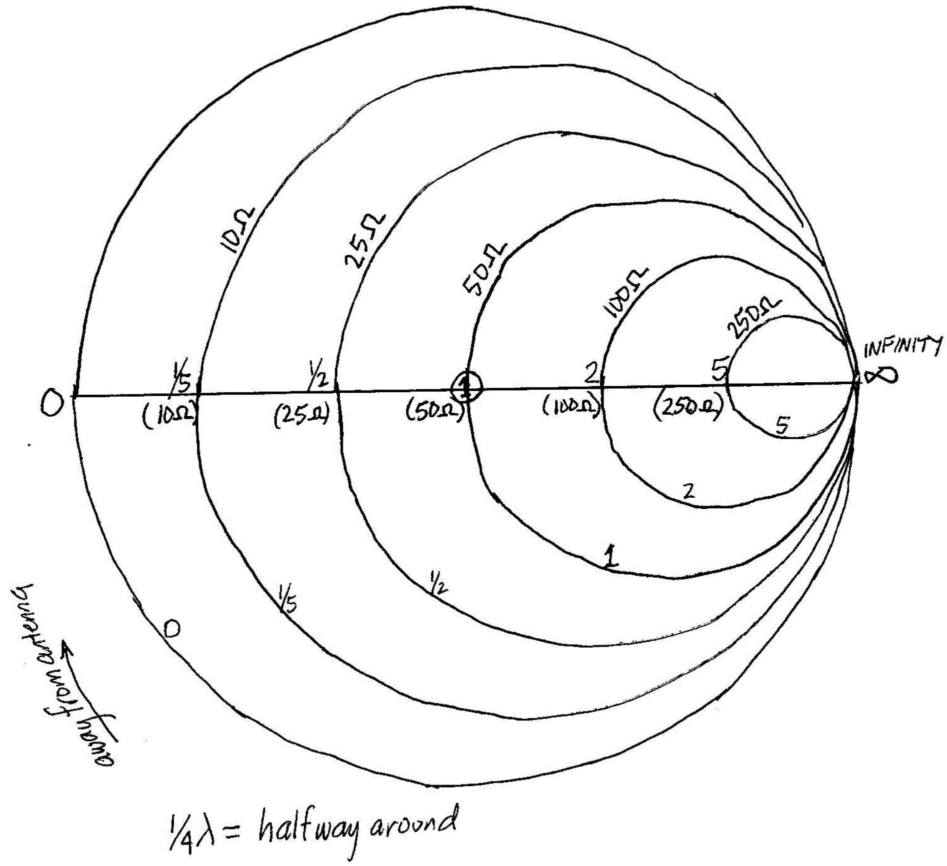
In the first section, we saw that every quarter wavelength along a transmission line, a pure resistive load INVERTS about the characteristic impedance of the line. So a resistance 250 ohms (5 times the 50 ohms -- so a "normalized" "5") become 1/5 the Zo of the line (or 10 ohms) 1/4 wavelength back from the mismatched load. So whereas the voltage was HIGH at the mismatched 250 ohm load and the current LOW (in a 250:1 ratio) -- 1/4 wave back, the CURRENT is high and the VOLTAGE is low because the impedance is now only 10 ohms (so voltage:current is 10:1 instead of 50:1)

A short circuit becomes an open circuit; an open circuit becomes a short circuit --- pure resistances. A pure resistive mismatched load (0, 10, 100, 250, 500 ohms, and so on) INVERTS about the Zo of the line, every 1/4 wavelength -- and causes STANDING WAVES of voltage of current that stay that way as long as the transmitter is one, at those fixed points --- and all of this is caused by the REFLECTED waves. The POWER on the line (except for losses) is the same everywhere, but it has different ratios of voltage: current everywhere (because the impedance is constantly changing) -- all because of the REFLECTIONS.

This session we look at what happens in between the 1/4 wavelength points. As you might expect, the resistance continuously varies. BUT THE REFLECTED WAVE IS NO LONGER IN A PERFECT IN PHASE OR OUT OF PHASE SITUATION -- it ends up at all different phases relative to the forward wave, because the forward and reverse waves differ in the distance they have traveled, and the difference is changing every inch. So how they combine is no longer a simple "addition" or "subtraction" but instead it is an OUT OF PHASE ADDITION that can be solved either by using graphical addition at every point along the sine wave -- or by using some fancy math.

Luckily for us, we don't have to do EITHER of those painful techniques --- many years ago the solutions were put in a circular graphical format for us! All we have to do is read the answer off the graph. Here is a circular plot that can be used to figure out what we'll see at say, 1/8 wavelength (known as 1/8 * 360 or 45 degrees)

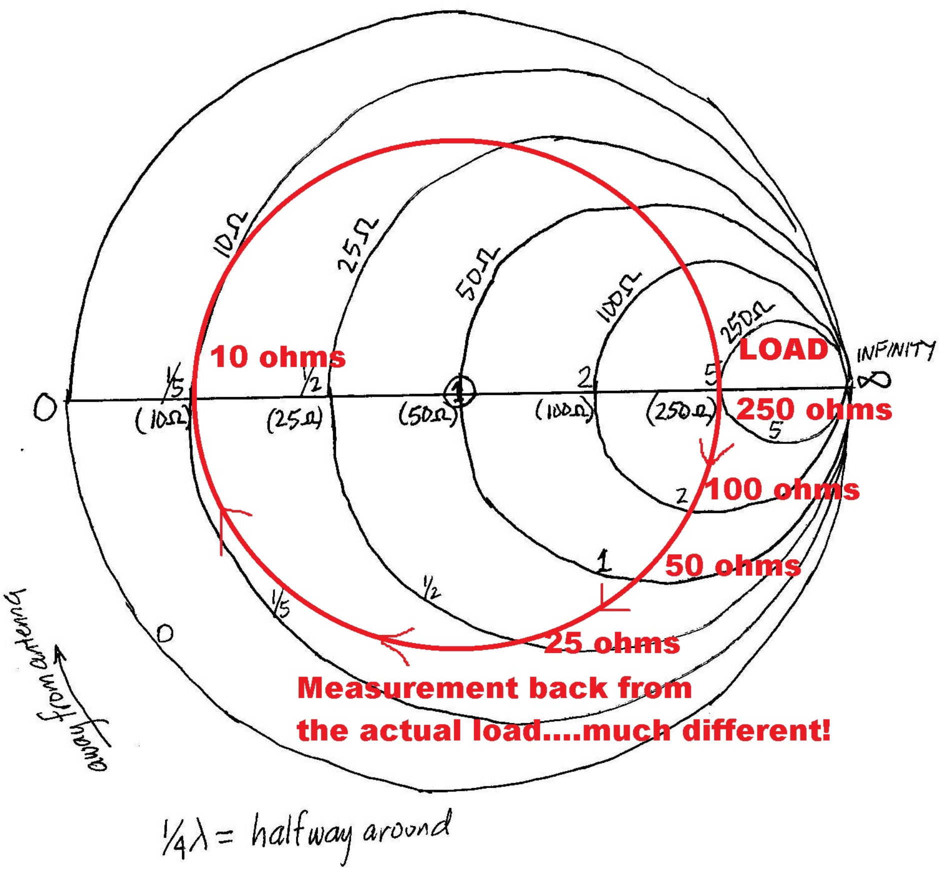


Notice all the 'rings' of resistances -- the 5X ring is for 5 times the Zo of the line (or 250 for coax -- 5 x 50) -- and so on.

How do we use this curve, for example to figure out what a 250 ohm resistive load would actually look like as we back down the coax away from the mismatched 250 ohm load?

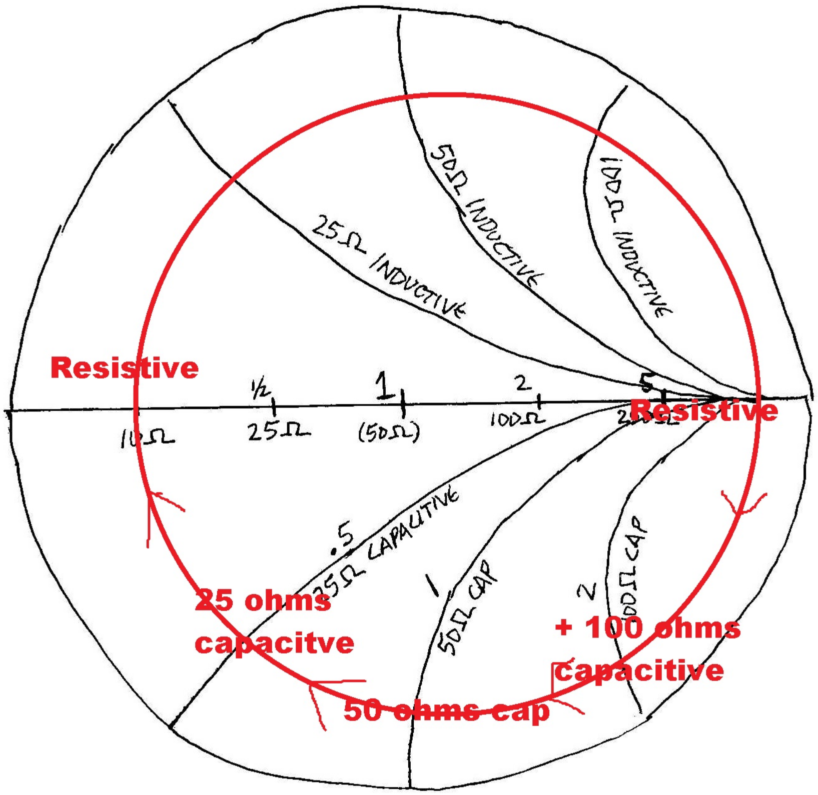
WE FOLLOW A CIRCLE, clockwise, centered on the Zo of the transmission line, and of radius exactly equal to the distance from "1" (50 ohms) to the "5" (250 ohms) where the resistor sits.

The following graph shows the circle and our clockwise traversal from there -- and shows what the resistance will be TRANSFORMED into at every point:



So at 1/8 wavelength ("45 degrees") it will be just past the 25 ohm line, on the way to the 10 ohms, so likely it will be 20 ohms of resistance. at half that distance, 1/16 wavelength it woud have been around 50 ohms!

BUT WAIT -- just like the midnight TV commercial, "There's More!" --- the 250 ohm (5:1 SWR) mismatched load not only changes its resistance along the transmission line (all the way to 10 ohms at 1/4 wavelength away, 3/4 wavelenghts away, 5/4 wavelngths away) --- it adds a REACTIVE component as well, which can be visualized as an additional impedance in SERIES with the transformed resistance -- And the curve shows you which value that reacance will have:



So now at the 1/8 wavelength (45 degree) point (bottom of the SWR circle) the series reactance is now 50 ohms capacitive -- in addition to the 20 ohms resistance that we calculated above ---

We use a NEGATIVE sign for reactance in series that comes from a capacitor (and a positive sign for reactance in series that comes from an inductor) -- negative probably because the current is LAGGING the voltage in a capacitive series circuit.

So at the 1/8 wavelength part it is about 20 ohm resistive - 50 ohms capacitive reactance

and we write that in fancy electrical engineering terms as:

20 - j50 OHMS of impedance.

So at the 1/8 wavelength point backwards from the load, the current is lagging the voltage, the SWR is still 5:1, and the phase between the voltage and current is weird

If you move past 1/4 wavelenght back from the 250 ohm mismatch, the reactance will become INDUCTIVE and the current will LEAD the voltage in phase. at 3/8 wavelngth the mirror image of the impedance at the bottom of the circle will result:

20 + j 50   OHMS of impedance

(Note the Plus sign).

So now the answer to the TEASER -- how to make a capacitor by using only one, unbroken wire --- ***simply make it into a shorted-end transmission line***. The shorted end is 0 ohms. Feeding it with an ac signal, if the length is between 0 and 1/4 wavelength, it wil appear inductive -- but between 1/4 and 1/2 wavelength, **it will be a capacitor!** (Looking at the resistance plot above, the series resistance is ALWAYS 0 ohms, so whatever reactance component it becomes, it is always simple 0 ohms in series with that reactance.)

So, for example, if we pick a frequency or a length such that the shorted balanced transmission line that we make with the wire is 3/8 of a wavelength long --- it will be the same ohms of capacitive reactance (no resistive component --- no loss!) as the characteristic impedance (Zo) of our balanced line. (If we were using 50 ohm coax, 3/8 wavelength long,, it would be 50 ohms reactive). This is one potential way to measure the Zo of a balanced line.