# Let Us Try To Demystify Some Things About Antennas

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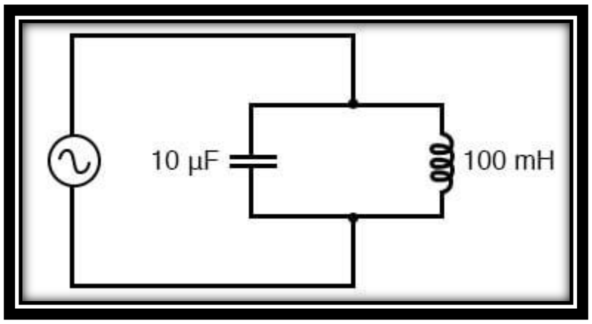
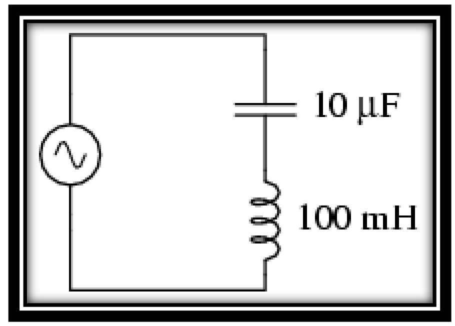
We will start with a dipole antenna. We all learned that most dipole antennas are ½ wave length long. We also learned that it is resonate at one frequency. So what does this resonate thing mean? Well, we have two types of resonate frequency circuits, series and parallel.

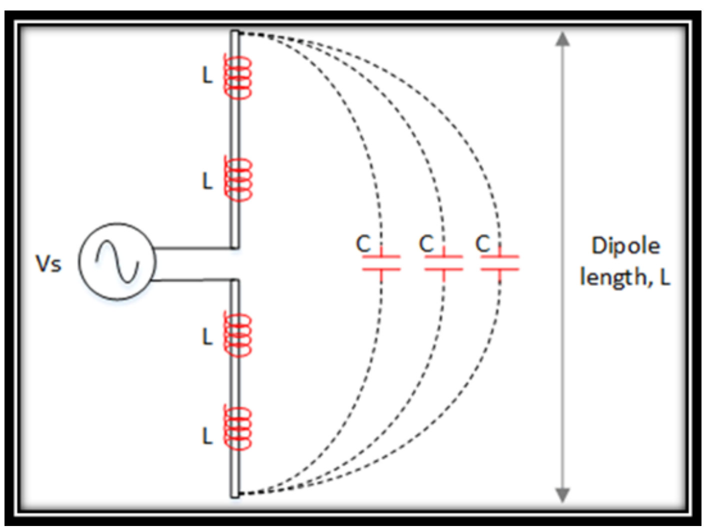



**Parallel**

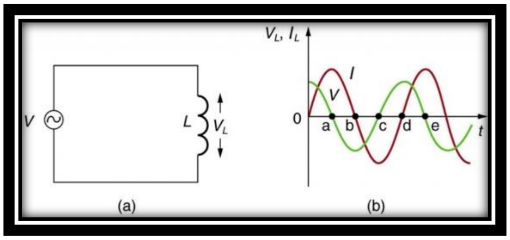


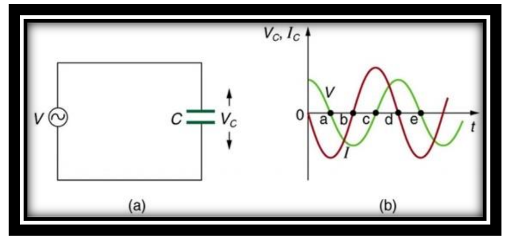

**Series**

Now a couple of interesting facts about these two circuits: the <u>parallel</u> circuit will act like an <u>open circuit</u> at the resonance frequency; the <u>series</u> circuit will like a <u>short circuit</u> at resonance. In other words the parallel circuit will have a very high impedance, very little, if any, current will pass through. The series circuit will look like a piece of wire, with very little, if any, impedance, so current will pass through unimpeded. This characteristic is very useful in electronics. So back to the antenna again: What kind of circuit is an antenna? It is a series resonate circuit. The **picture below** shows the inductance and capacitance. And yes that piece of wire you have hanging up in the air has inductance and the two parts of the dipole have capacitance between the two wires.




So what does resonance mean? Let's back up to what happens to AC, Alternating Current, in an inductor and in a capacitor. An inductor, a coil of wire for example, stores energy in a magnetic field. When the current stops flowing, when the sine wave passes through zero, the magnetic field around the coil collapses and this allows current to continue to flow. Also the inductor allows voltage to go through the wire as the current causes the magnetic field to develop; this causes the current to be 90 degrees behind the voltage. In a capacitor the opposite happens. The current flows immediately and the voltage takes time to build up (charge) the capacitor. When the voltage is removed from the capacitor, the buildup (charge) of the capacitor forces current to continue to flow. But here the Voltage is 90 degrees behind the current. This is where the **ELI the ICE man** comes from.  ELI, E (voltage) comes first in an L (inductive) then I (current).  ICE, I (current) comes first in a C (capacitive) then E (voltage).

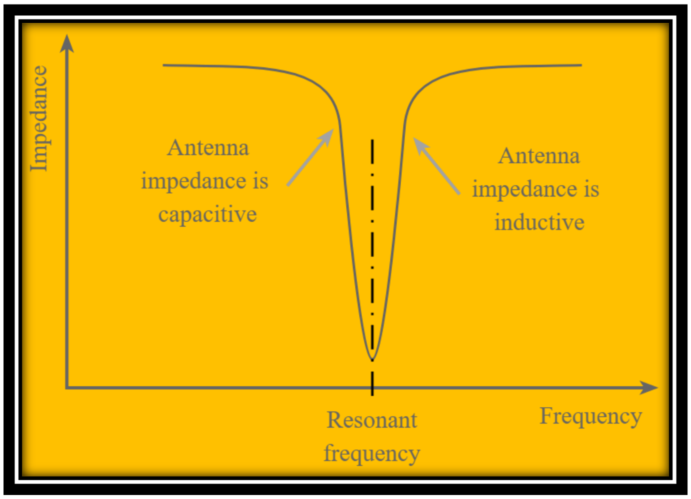



**<u>Notice voltage is ahead of the current in the inductor.</u>**  **<u>Current is ahead of voltage in the capacitor.</u>**

**Calculating Reactance:** First what is reactance, it is the opposition presented to alternating current by inductance or capacitance. The formulas look like this, for an inductor $X_L = 2 \pi F L$
For a capacitor it is $X_C = 1 / 2 \pi F C$. Where F equals the frequency applied, L is the inductance in Henry's, and C is capacitance in Farads.

Notice that the capacitive reactance is a number divided into 1. So at resonance $X_C = X_L$. So as one component is causing the current to lag behind the other component is causing the current to lead ahead. So at resonance we get the lowest Impedance. What's impedance? It is the combination of Reactance and Resistance. There are 3 things that will make up the impedance of the antenna. 1, $X_c$. 2. $X_L$. 3 Resistance. The resistance comes mainly from Radiation Resistance. Radiation Resistance is what causes the antenna to radiate an electric and magnetic field into the space around the antenna. This is a loss of energy, **BUT** it is a good loss as it allows us to send a signal. What is good loss of energy? Well your toaster for one thing. You apply 120 VAC to it, it loses energy in the form of heat and in a minute or two you have toast! That's a good thing.  There is also some ground loss, depending on how high the antenna is, and some loss in the wire itself.
Notice in the picture below, the impedance is high then drops to very low at the resonant frequency. Then it goes back high again as the frequency continues to increase.




I hope everyone is following along okay. So we build and antenna for say 20 meters, 14 MHz. We check it with our antenna analyzer or SWR meter and we see it is not resonate where wanted it to be. It is resonate at a frequency higher than 14 MHz. In fact we determine the antenna is inductive, (look at the above picture) where we want it to have the lowest impedance. So it is resonate at a higher frequency then we wanted it to be. Or another way to look at this is the antenna is too short.

**Example**: $F_r$ or the resonate frequency formula. (this is an example for the math, and not our antenna)

$$F_r = \frac{1}{2\pi\sqrt{LC}}$$

So if L = 1.0 milli henry and C = 0.1 pico farads then $F_r$ = 15.92 MHz.
Looking at the formula if L or C increase in value, go up, then $F_r$ must go down.
So if L = 1.29 Milli Henry and C = 0.1 Pico farads then $F_r$ = 14.013 MHz.
Or If L = 1.0 Milli henry and C = 0.112 Pico Farads then $F_r$ = 14.067 MHz.

Adding wire is the easiest thing to do but we could also add a capacitor in series.

Enough math already ☹

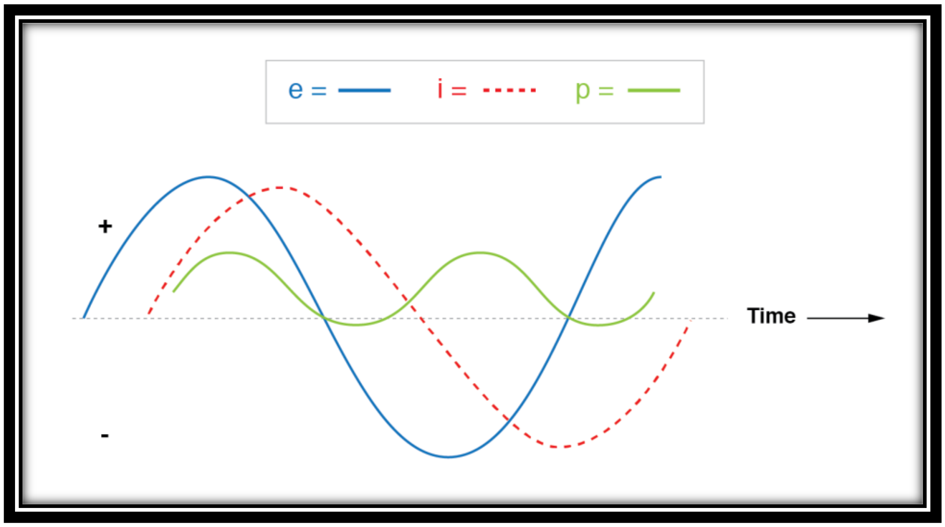
So the inductive reactance is higher than the capacitive reactance. Our fancy antenna analyzer says the antenna has a resistance of 50 Ohms and a reactance of j100 Ohms. *(Note: Dipole antennas have an impedance of 73 Ohms j42.5 Ohms, and ¼ wave verticals have an impedance of 36 Ohms j21 Ohms, but for this example we are stating our antenna has 50 Ohms of impedance)* Wait a minute, what is this "j" thing? It is the way electronic folks talk about imaginary numbers. Math folks use "I" but we electronic folks use "I" for Current. So we use "j" for imaginary numbers. Even though it is an "imaginary number" it does affect what we do. "j" signifies either a capacitive or inductive reactance. "j" for inductive and a "-j" for capacitive reactance. (Notice the negative sign)

So what can we do? Well the obvious answer is to add some wire to each end and check it again. In fact, this is the way most Amateurs make an antenna: we cut our antenna wire too long and trim each end to get the impedance at close to zero. But we will do something else. We will add a capacitor in series with the antenna and bring the $X_C$ up to match up with the $X_L$. Remember when $X_L = X_C$ then the antenna is resonate.

Okay so why is a non-resonate antenna a bad thing? Because some of the energy will not be radiated and it will be sent back the feed line to the generator, or transmitter.

So where is this j100 Ohm coming from? Well it is coming from the inductive reactance of our new antenna.

**Whew, Lets catch our breath.** So why is my nice new antenna not working to maximum potential? After all I know there is a DXPedition to Crozet, FT/W, coming soon and I want to be sure every fraction of a watt I can get transmitted is transmitted! Well, let's look at what is happening at the antenna when it comes to power.



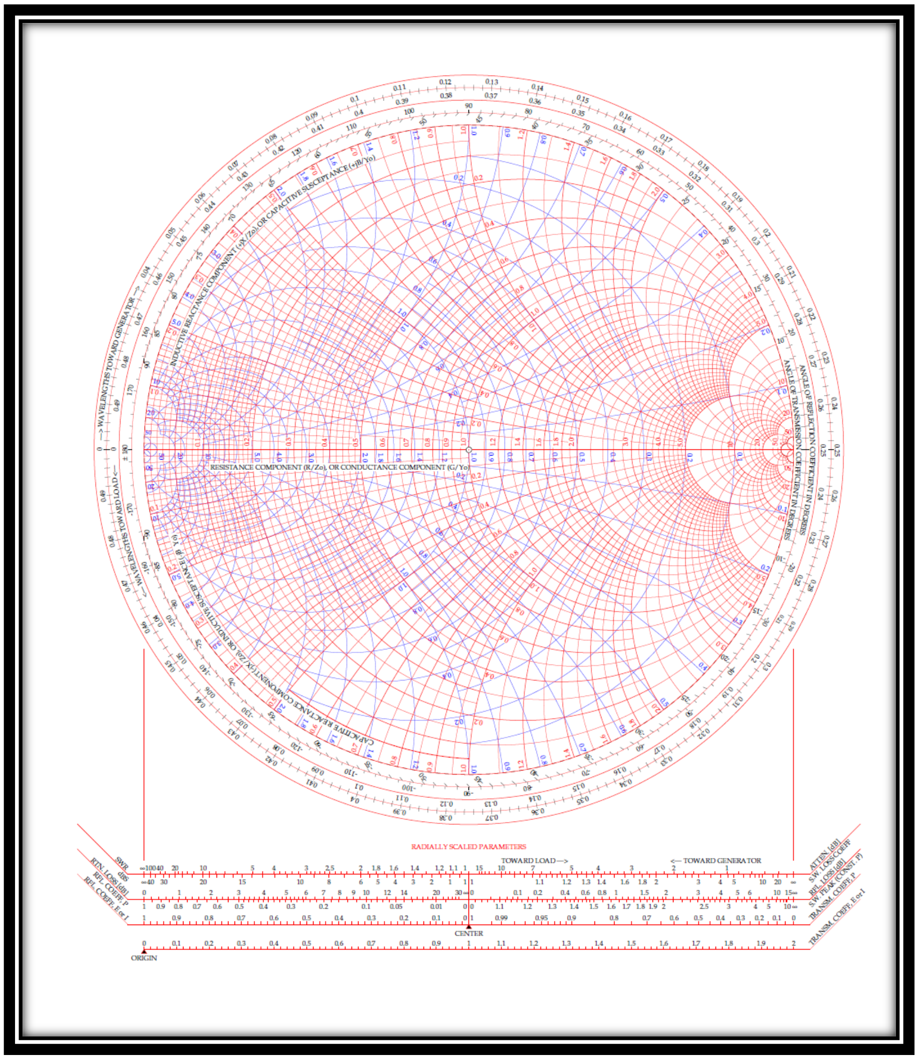

(Although this picture is not what happens with an antenna showing R=50 j100, it does show some power being sent back to the source.)
Look closely at this diagram, See the Blue, (voltage), trace is ahead of the Red, (current), trace. We have an inductive circuit. Now look at the power, (green), trace. See most of it is above the center line, but ever so slightly some is below the center line, and that is energy, power, that is headed back to the source, generator, or transmitter. You have all heard of reflected power, well here is where is comes from, a reactive circuit. In fact if you **just** have a capacitor **OR** an inductor for a load **ALL** the power would be reflected back. Except for a little lost in the feed line.

**MATH TIME!! NO NOT AGAIN!!** I'll try to make it painless. With 100 watts getting to the antenna, we have 70.71 volts getting there and 1.414 amps. Remember P = IE P = 70.71 X 1.414 = 99.98 watts. This is with a 50 ohm load, BUT we don't have a 50 Ohm load. We have R = 50 Ohm and j100 Ohm. If we calculate the Impedance of this circuit we get
$Z = \sqrt{50^2 + 100^2}$
$= \sqrt{2500} = 10000$
$= \sqrt{12500}$
$= 111.8$ Ohms
Now I = E/R or 70.71/111.8 or 0.632 amps. We had 1.414 amps with the 50 ohm load BUT with the j100 calculated in we have 0.632 amps. So P = IE = P = 70.71 X 0.632 = 44.3 watts. We are sending back to the transmitter 55.7 watts. (This is a significant amount!) So the current being out of phase with the voltage is causing a problem. The SWR is 4.89:1. A lot higher then we like. But we want every watt for the QSO with Crozet Island. Here is this formula for SWR (Standing Wave Ratio). Where Pr is reverse power and Pf is forward power.

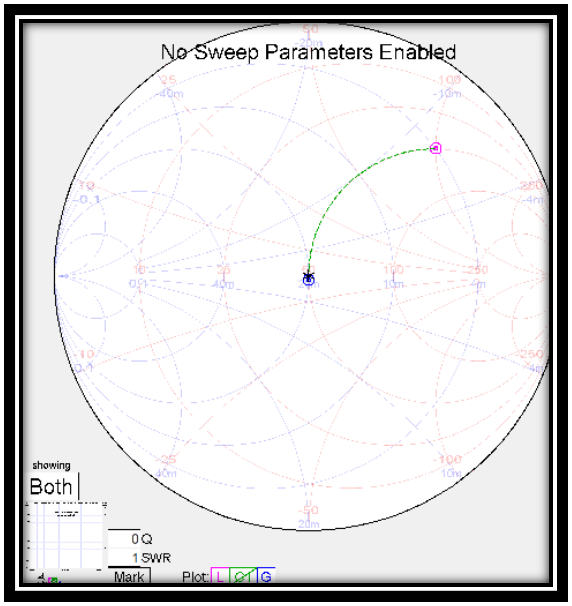
$$VSWR = \frac{1 + \sqrt{\frac{Pr}{Pf}}}{1 - \sqrt{\frac{Pr}{Pf}}}$$

Okay I'll spare you the math on this one, but you can grab your calculator and push the buttons yourself.

Okay so of you probably figured this one is coming, what is it? Our old friend the Smith Chart!!!!!!!




**Okay I will not inflect too much of this on you, but it is a very nice piece of technology to work with.** I feel the best way to learn how to work with a Smith Chart is the old fashioned way, paper, compass, straight edge and a calculator, (I have moved away from the slide rule ☺). Then you can use one of the Smith Chart apps.




See the little pink circle within the bigger pink circle? That is where R50 j100 plots at. We need to move that to the center. Where the blue circle is located. And without going through all the math we just need something to get rid of that pesky j100. Remember how $X_L = X_C$ at resonance? Well we need a –j100 to get rid of the j100.

$L = \frac{X_L}{2 \pi F_r}$ $\quad L = \frac{100\ \Omega}{2 \pi 14^6}$ $\quad = 1.13\ \mu H$

$C = \frac{1}{4 \pi^2 F^2 L}$ = 114pf and 114pf has a reactance of $X_C = \frac{1}{2 \pi F C}$ Wait for it…….99.72 ohms!

This will move the blue circles to the center and now we set back and listen for Crozet Island, FT/W, and I will be one step closer to the DXCC Honor Roll!

**See that wasn't painful at all!!** ☺

**Summary:** Antennas are not some complicated, mysterious, and magical things. There is no need to get out the rubber chicken and shake it at your antenna to get it to work. They are, for the most part, a simple series resonate circuit. Working with them is pretty easy too. I have always said a simple dipole is the best bang for the buck you can get. Get it as high as you can and be sure to stay away from power lines. Cut it too long to begin with and trim it back to get the resonance where you want it. The math for working with antennas, and feed lines for that matter, is pretty simple too. Stuff you learned back in high school. If an antenna has reactance and it is not resonate where you need it to be, and the SWR is way too high. We can figure out how to make it better, and it all makes sense. I will admit there is a lot more to a Smith Chart then what I covered here, but that is for another day. I did simplify a few things but my intent was to show how the reactance affects an antenna. Remember you can always ask for help too.