Newcomers and Elmers Net: What is Resonance?
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If you are an amateur radio operator you are at least somewhat familiar with the term *resonance*.
-- The non-technical description of resonance is that the feedline/antenna system impedance needs to match closely with the transmitter's impedance for the signal to make it out of the antenna system.
-- (While I will approach this from an amateur radio perspective, the science applies to all aspects of RF transmission.)

An analogy from radio itself might be useful here. If you have a transmitter sending out a signal for 700 kHz, but another radio set to receive 550 kHz, you will not hear the signal you want to hear.
-- The same thing is true for a transmitter and an antenna system: if you are sending out a signal for 3.8 MHz but your antenna system is tuned to 14.3 MHz, the signal won't make it out.
-- Another analogy might make things even clearer. Since a transmitter and an antenna system are in effect a *circuit* (or path) for the flow of electricity, it is important that the flow of electricity not be blocked by a short or an open part of the circuit path, or by too much opposition to the current (*reactance*).
-- When your transmitter and antenna system are at resonance, it means the most amount of your signal is getting out of the antenna and (hopefully!) to your intended recipient. Notice I said "antenna system."

Antenna System
Your antenna system includes everything from the coax (or feedline) from the back of your rig to the tips of your radials or antenna wire, and all elements in between.
-- If you have an amplifier there is an influence upon the signal coming out of your radio.
-- If you have an antenna tuner, a low/high pass filter, a pre-amp, a coax switch or switching relay, all of these things can/will affect your signal.
-- Add to this baluns, transition points such as loading coils, capacitance hats, gamma matches or stubs, and a number of other possibilities, and you have things which can and will affect the signal you put out, and are all part of the antenna system.
-- Oh, and of course there is the issue of the actual antenna design and the local ground/inductance/capacitance of near-field influences.
-- I mention all of this not to cause you to go running around in circles trying to keep your head from exploding, but rather to get you thinking of your antenna system as one large electrical circuit. By doing so, and

understanding some basic electrical theory (some of which you probably know already), you can begin to predict in advance how parts of your antenna system work together to affect the whole.

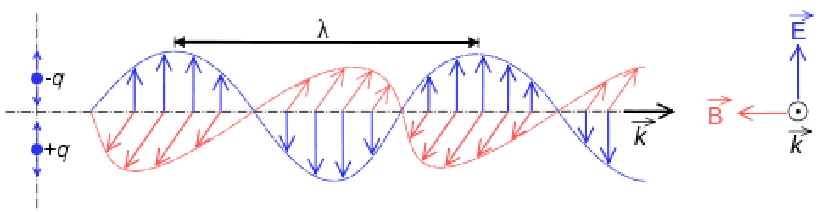
Starting at the Beginning

RF energy is electrical and therefore based on electrons, protons, and neutrons.

-- Specifically it is AC (or *Alternating Current*) in nature, meaning it travels or alternates in two directions as opposed to DC (or *Direct Current)* which travels in only one direction.

-- There is both a magnetic field and an electrical field being generated. Both are very small, but they are there.

-- When you increase the frequency of the electrical field you also increase the magnetic field which, as you will recall, runs 90° perpendicular to the electrical field. As you increase the frequency radiation occurs, and eventually frequencies become strong enough that they can be received.



The blue lines represent the electrical field (vertical plane)
while the red lines represent the magnetic field (horizontal plane).
Image courtesy Wikipedia Commons

-- The alternating current is just that—current (or energy) which builds up and then subsides with each cycle. Of course when we are talking about radio waves we are talking about a minimum of 15 kHz (low frequency band) to 900 MHz and higher, or 15,000 cycles to well over 900,000,000 cycles per second!

-- A cordless phone often operates above 5 GHz, or 5,000,000,000 cycles per second, and we still haven't reached the top end.

While I will not go through electric theory as it relates to electric circuits, say in a radio, what is interesting is how the same principles apply in terms of measuring resistance and capacitance and voltage and current in an antenna system.

-- In a radio capacitance is measured in terms of capacitors, coils provide inductance, and resistors provide resistance. This is sometimes referred to as *lumped constants*.

In an antenna capacitance, inductance, and resistance are measured along the wire, sometimes referred to as *distributed constants*.

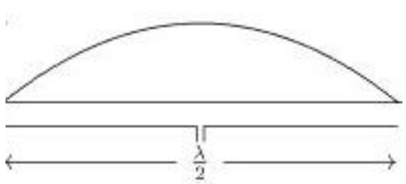
-- Current and voltage work together, as do resistance and capacitance and inductance in electronic circuits, to determine the amount of power output of the circuit.
-- Since your antenna is an electronic circuit, power will be maximized when impedance is zeroed out. What follows is a discussion of some of these factors used to maximize power and minimize impedance.

Wavelengths
One of the most significant aspects of alternating current for our purposes here is the wavelength of various signals. A wavelength is the measurement of one complete cycle of current at a given frequency.
-- You no doubt already know that the wavelength of an 80 meter signal is quite different than a 2 meter signal.
-- The frequency is the clue, of course: a signal of 3.6 MHz has "only" 3,600,000 cycles per second (traveling roughly at the speed of light), whereas a signal at 146 MHz has 146,000,000 cycles per second, a difference of 142.4 million cycles or Hertz in that same one second!
-- If that is not hard enough to wrap your mind around, I have an HT which will transmit and receive on the 1.2 GHz band, or 1,200,000,000 cycles, again in that same one second.
-- In determining the size of an antenna we need to know the wavelength of the signal, and as you may have seen before, this is a relatively easy calculation.

The formula is $\lambda = c/f$, where the wavelength (in meters) equals speed of light (in meters) divided by frequency (in MHz).

Using 300,000,000 m/s as a constant for the speed of light, and a frequency of 144 MHz, we come up with a wavelength of 300/144, or 2.08 meters.
-- I was able to simplify the equation by removing a lot of zeros: the 6 zeros of the MHz frequency (144,000,000) cancels out 6 of the zeros in the speed of light constant, to allow 300/144; just remember that whatever frequency you are using must be stated in terms of MHz for this to work.
-- Another example: using 300 million m/s as the speed of light constant and a frequency of 3.6 MHz (3600 kHz), the wavelength is 300/3.6 or 83.3 meters.
-- Now, how does all of this tie into alternating current and antennas?

Dipole Antenna
You are likely very familiar with the dipole antenna as the basic standard antenna, often recommended for a starting antenna. A true center-fed dipole is two wires of equal length connected by a feedline. These antennas are usually measured in terms of 1/2 λ – that is, the total length of the antenna is equal to one-half of a given frequency's wavelength.



One-half wavelength is considered optimal because it means one full cycle of an electrical wave can travel down the antenna and back again.
-- Adding the distance of the two half-waves totals one whole wavelength. (Not trying to just state the obvious—stick with me here!)

When an antenna can produce one compete wavelength over and over again with no losses, we say that antenna is *resonant*, meaning it is in proper balance.
-- Now here's the rub: a length of wire/antenna can only be resonant at one frequency. In theory, you could build a resonant antenna, for say 14.250 MHz, and it would function perfectly at that frequency, given that the other variables are properly designed.
-- Where it starts getting tricky is when we want to work across a range of frequencies, whether on the same band, or on multiple bands.

Remember the full cycle of the wavelength? As soon as that perfect half-wavelength is changed, say shortened or lengthen a bit, the waves start bunching up on themselves. This is where we get the idea of VSWR, or *Voltage Standing Wave Ratio*.
-- For example, if you would see a reading on a VSWR meter of 1.2:1, this would mean that there is a maximum standing wave amplitude that is 1.2 times greater than the minimum standing wave value of 1:1 if it was perfectly balanced.

When this ratio gets too large, more power is reflected back down the transmission line than is good for efficient operation. Too much reflected power and your radio will likely back down the power it sends out to protect the circuits.

But length of the antenna is not the only element in antenna efficiency. The material/design you use for the antenna itself is important, as it the material/design of your feedline.
-- For example, wires work well for antennas at lower frequencies, but at higher frequencies metal tubes are used as their larger surface area is a better conductor for those higher frequencies.

Another example involves your feedline. On bands such as 80 and 40 meters smaller diameter coax can be used for longer runs since the wavelengths for these bands are much greater. That same coax, say 150 feet, used for 2 meters will cause a rather significant drop in the amount of power reaching the antenna. This all has to do with something called *impedance*.

Impedance

Impedance is the measure of the resistance to the flow of current in a circuit. Remember earlier I mentioned that the flow of electrons produces both an electrical field and a magnetic field.

-- Raise the current (the number of electrons passing through a point in the circuit) and you increase the electrical field and the magnetic field.

-- If electricity operated in a perfect world there would never be any impedance to that flow. However, all materials present some level of impedance to the flow of electricity, and in terms of antennas, this affects how much of our signal makes it into the air.

-- Coax cable has an inner conducting wire, an insulation material called a shield (or a dielectric), an outer conductive material, and a shield over that, usually the rubber skin of the coax.

-- The larger the inner conductor the better the current will flow and the less impact the dielectric material will have on it. The better the outer conductor likewise the better the current flow as well, and any breaks in the inner conductor or problems with the outer conductor, and the signal either shorts or is reflected back down the line in an unwanted manner.

-- At resonance, the current at input and the voltage are in phase; if the frequency falls below the resonant point, the phase of the current leads the voltage, meaning the circuit has capacitive reactance. If the frequency is above resonance, the voltage leads the current, and the circuit shows inductive reactance. (Remember that reactance, whether capacitive or inductive, opposes current in a circuit, thus reducing power.)

Efficiency

The goal for efficient antenna design is to zero out these impedances, and various antenna designs are working to balance these impedances in the most efficient way possible, all the while seeking to maintain the desired bandwidth.

-- For multi-band antennas tuners are generally used to overcome impedance issues which might cause a radio to reduce power or to protect sensitive circuits from overloading.

-- It is important to remember that tuners do not balance the actual circuit – they merely match the 50 Ohm impedance of the transmitter to the incoming impedance of the feedline.

-- Non-resonant portions of an antenna’s bandwidth represent compromises to the signal, some of which is a necessary evil, if you will, to being able to operate on a range of frequencies.

-- An antenna always works best at resonance – and the closer to resonance you can be the better. Still, VSWRs of under 2:1 and even 3:1 are usually acceptable, and this means most of your power will be going where you need it to go assuming proper feedline and antenna design.

-- Keep in mind frequency and conductor length are the variables most important in designing a resonant circuit (since the speed of light is constant), and any variation from resonance means either capacitive reactance or inductive reactance will need to be factored into the design.
-- For example, , coils are sometimes used to electrically lengthen a shortened antenna for 160 meters; the coil is providing inductance. The added inductance helps to cancel out the effects of capacitive impedance, allowing a physically shorter antenna to act like a longer antenna.

Similarly capacitive hats near the top (or end) of an antenna boosts capacitive impedance where it is lowest (and voltage is highest), which in turn lowers inductive impedance.

All of this to say antenna circuits, like electrical circuits in radios, are a balance of current and voltage and impedance. With an antenna, ultimately the more power you can put out the better your signal will radiate. The more you understand about how that power is generated, the better your antenna system will function

Making Sense of it All
While you do not need to understand all the electrical workings behind an antenna system to use it, I hope this brief discussion will encourage further exploration into the electrical theory behind antennas. For me, my interest in antennas led me to (re)learn some basic electronics theory to better understand what was going on behind the scenes. This in turn has rekindled my interest in building/troubleshooting electronic circuits in old radios. Who knows where things may go from there?!