

Ham 68 – License, Impedance
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1. Amateur radio knowledge is electrical in nature. As we discussed in the Tech introduction, Only three electrical items can be measured.
 - a. *Voltage* is the forcing function that pushes electrical energy. Sometimes called electromotive force (EMF), the symbol normally is ‘V’, but in special circumstances is ‘E’. The units are Volts, named for Alessandro Volta. Voltage measures ‘across’ two points. The analog is pressure on a waterline.
 - b. *Current* is the flow rate of charge or number of electrons running ‘through’ an electrical circuit. The symbol is ‘I’. The units are Amps, named for Andre Ampere. The analog is gallons/minute on a waterline.
 - c. *Time* is the third item. Time measures in seconds and has the symbol ‘t’.
 - i. *Rate* is time in denominator with the movement parameter in the numerator.
 - ii. *Frequency* is the time reciprocal. It is the rate of cycles per second and the units are Hertz, ‘Hz’. $f = 1/t$
 - iii. *Phase* is the difference in time between when voltage is maximum and current is maximum. The difference is a delay. It measures in degrees (or radians) and the symbol is a Greek letter, usually ‘ θ ’ or ‘ ϕ ’
2. Impedance is the ratio of voltage to current or voltage divided by current. The symbol is ‘Z’ and the units are Ohms ‘ Ω ’ for Georg Ohm. Impedance is the opposition to current flow. Impedance defines a generalized Ohm’s Law. $Z = V/I$.
3. Impedance derives from three components.
 - a. *Resistor* ‘R’ is the natural opposition to flow in any electrical conductor, whether wire or air.
 - b. *Inductor* ‘L’ results from bending or making a coil of wire. The units are Henry ‘Hy’.
 - c. *Capacitor* ‘C’ results from two conductors near each other. The units are Farad ‘Fd’.
4. Ground or earth is an electrical conductor. It is the reference from which we measure.
 - a. Inductor and capacitor are simply characteristics of location and how conductors are shaped.
 - b. Change the impedance values for a conductor by the cross-section area ‘A’, length ‘ ℓ ’, and height.
5. Since radio operates at a frequency ‘f’. What is that effect on impedance?
 - a. Resistance is mostly unchanged by frequency.
 - b. Reactance ‘X’ is combining inductor or capacitor with frequency. 2π represents going around a complete circle.
 - c. Inductive reactance is a simple product: $X_L = 2\pi fL$.
 - d. Capacitive reactance is inverted: $X_C = 1 / (2\pi fC)$
6. A rectangular coordinate system is normally used to plot Impedance. $Z = R + jX_L - jX_C$.
 - a. Resistance is real or exists naturally in nature. Draw on the horizontal x-axis.
 - b. Reactance is imaginary or exists because of configuration. Draw on the vertical y-axis. Use ‘j’ to designate vertical.
 - c. Inductive reactance is positive, so it goes up. Capacitive is a reciprocal, so it is negative and goes down.
7. The rectangular diagram is an excerpt from the Study Questions. Since R exists in nature, there can be no negative. So left side of the plot is unused. Be careful, the x-axis is named for the plot, not the impedance.
8. A *vector* is a quantity with both magnitude (length) and angle. A *phasor* is an arrow or vector that shows *amplitude* (magnitude) and *phase angle*. Polar Coordinate System shows the amplitude and phase between impedance, such as the blue plot.

Polar coordinate has exactly the same information but measures differently.
9. Phase angle ‘ ϕ ’ measures from the resistance to the reactance.

The answer to the 3 questions on 2024 version is 14° . $\tan \phi = (X_L - X_C) / R$
10. Series circuits work best with impedance. But, parallel can work easier with the reciprocal values. Be very cautious when converting to the reciprocals. *Admittance* ‘Y’ is the reciprocal of impedance ‘Z’. *Susceptance* ‘B’ (susceptible) is the reciprocal or inverse of reactance ‘X’.
 - a. The unit symbol is an upside-down Ohm symbol and now called siemens.
 - b. The magnitude of the reciprocal is reciprocal, but the sign changes.
11. Life is good. Enjoy!

