E5D AC and RF energy in real circuits: skin effect; electrostatic and electromagnetic fields; reactive power; power factor

Skin effect

As frequency increases, RF current flows in a thinner layer of the conductor, closer to the surface. (E5D01). This is known as the skin effect.

The resistance of a conductor is different for RF currents than for direct currents because of the skin effect. (E5D02)

Energy storage in reactive elements

As we've seen, inductors and capacitors can store energy for brief periods of time.
A capacitor stores electrical energy in an electrostatic field. (E5D03)

From physics, the unit used to measure electrical energy stored in an electrostatic field is the *joule*. (E5D04)

An inductor stores energy in a magnetic field. A magnetic field is the region surrounding a magnet or inductance through which a magnetic force acts.(E5D05)

The magnetic field oriented about a conductor is in a direction determined by the left-hand rule, (E5D06) which states that if the fingers of one's left hand are curled and the left thumb is extended in the direction of the current, the magnetic field is circularly oriented in the direction indicated by the fingers.

The strength of the magnetic field around a conductor is determined by the amount of current. (E5D07) The term for energy stored in a magnetic or electrostatic field is potential energy (E5D08) (It's not kinetic energy, which is the energy contained in a moving mass.)

Reactive power

As we have seen, reactance is like resistance in that it limits current, but unlike resistance in that it does not consume power.

The term for out-of-phase, nonproductive power associated with inductors and capacitors is reactive power. (E5D09).

Reactive power may be referred to as wattless, nonproductive power. (E5D15)

In a circuit with both inductors and capacitors, reactive power is repeatedly exchanged between the associated magnetic and electric field, but is not dissipated. (E5D10)

Power factor

In a DC circuit, the power is determined by:
$P_{watts} = E_{volts} * I_{amperes}$

But in an AC reactive circuit, E*I will calculate the *apparent* power, which is greater than the true power because the reactive elements do not consume power. The ratio of true power to apparent power is called the *power factor*. The apparent power is not specified in watts but in *volt-amperes*. The true power is specified in watts.

So the true power can be determined by multiplying the apparent power times the power factor. (E5D11)

If a circuit has an input of 100 volts at 4 amperes, and a power factor of 0.2, the power CONSUMED is 100*4*0.2 = 80 watts. (E5D13)

If a circuit has a 100-ohm resistance in series with a 100-ohm inductive reactance and is drawing 1 ampere, the resistor consumes power of E*I = 100*1, and the inductive reactance consumes no power, so the consumed power is 100 watts. (E5D14)

If a circuit has an input of 200 v at 5 amperes, the apparent power is 200*5 = 1000 watts. If the power factor is 0.6, the true (consumed) power is 1000*.6 = 600 watts. (E5D18)

If the apparent power in a circuit is 500 watts and the power factor is 0.71, the true power is 500*0.71 = 355 watts. (E5D19)

Power factor = cosine of phase angle

(If you haven't been trained in trigonometry, rely on the COS button of your calculator.)

In Section E5A we saw how to calculate the phase angle between Z and R, between E and I. The power factor is equal to the cosine of that phase angle.

If a circuit has a 60-degree phase angle, the power factor is cos(60) = 0.5.(E5D12)

If a circuit has a 45-degree phase angle, the power factor is cos(45) = 0.707.(E5D16)

If a circuit has a 30-degree phase angle, the power factor is cos(30) = 0.866.(E5D17)