Tech Note - Theory - 03 Skin Effect (As Applied to Inductance)

Let us consider the expanding and collapsing magnetic field around an electrical conductor in an AC circuit. There will be more changes in the flux linkage at the centre of the conductor than at the surface. Therefore there is more opposition to the flow of AC in the centre of the conductor than there is at the surface. As the frequency of the AC is increased the rate of change of flux increases, which in turn increases the counter EMF at the centre of the conductor. This effect is so pronounced that at radio frequencies almost all of the current flows along the surface of the conductor. This is called "skin effect". Since there is practically no current in the centre of the conductor at radio frequencies the effective cross sectional area is greatly reduced and therefore the effective resistance of the conductor is much higher than its DC ohmic resistance. Due to the above phenomenon in addition to thinking of resistance as the property of an electric circuit that opposes the flow of electric current, we must now think of resistance as the property of an electric circuit that dissipates electric energy.

Similarly, a capacitor, when measured in a DC circuit has an infinitely high resistance, but can cause an appreciable wattmeter reading in an AC circuit.This produces the effect of a resistance in parallel with the capacitor. The wattmeter in this case is indicating the transfer of energy into heat as the dielectric of the capacitor is stressed first in one direction and then in the other many times a second.Since this loss of energy by conversion to heat is similar to the hysteresis loss in a magnetic circuit, it is called dielectric hysteresis. Because magnetic and dielectric hysteresis loss and eddy current losses all tend to raise the temperature of an AC circuit, additional ohmic losses will increase if the circuit has an appreciable positive temperature co-efficient!

Skin effect is responsible for losses in conductors at EMR frequencies. This resistance is not to be confused with the DC or ohmic resistance or the XL of the conductor. This is a very real resistance because it will convert some of the RFE to heat and at some transmitter power levels damage the conductors or conducting surfaces. The effective resistance of the coil or conductor is raised by skin effect and can be also attributed to counter EMF's in the interior of the conductor along with eddy currents. Increasing the size of the conductor reduces this effect.

AC resistance is the combination of skin effect plus resistance from distributed capacity between the turns of a coil.

An increase in frequency to the point where the distributed capacity and the natural inductance of the coil produces a condition where self resonance takes place, the impedance across the coil terminals is very high and now all that we have is a pure resistance. The natural inductive reactance (XL) disappears at this frequency and the coil no longer supplies any inductive reactance to cancel the capacitive reactance of the circuit. Instead the coil simply introduces high resistance in series with the antenna terminals.

Because this distributed capacity appears in parallel with the inductance of the coil, the profound effect of self resonance is manifested. This can be avoided by improving the Q of the coil, space winding the turns and using optimum sized wire for the job. This would place the self resonant point of the coil well removed from the operating frequency thus preventing the degrading effect self resonance would have on the coil or circuit.

The use of optimum sized wire and turns spacing reduces what is known as proximity effect, which is directly related to wire size. The varying magnetic field set up by the RFE does not induce the same voltage throughout the conductor. When the conductor is wound into a coil this loss by proximity of the turns to each other causes the current to concentrate in those areas of the conductor turns that are closest together (in proximity) which causes a further reduction in the overall cross sectional area of the conducting surface .

It can now be seen that the construction of an inductor to handle even modest amounts of RFE is no simple matter, many factors must be taken into account and when this is done properly a coil can be made to be 99% efficient.