What do I mean by electrical length ?

By way of an explanation of what is meant by the term “Electrical Length” you should all know that the phase of an electrical signal is often discussed in terms of degrees or radians and it is straightforward to translate between phase and wavelengths. Ie one wavelength is equal to 360 degrees or 2 PI radians, half a wavelength equates to 180 degrees or PI radians and two wavelengths equate to 720 degrees or 4 PI radians etc. What is simple, but perhaps not so obvious, is how to translate a wavelength into a physical distance. Representing the wavelength as a physical distance is helpful in appreciating when a circuit (or interconnect between two components) becomes too large to be treated as a discrete entity and more importantly where conventional circuit theory is no longer appropriate.

In other words, the circuit is said to be distributed, or that there is no longer a negligible distance between components, for signals at such high frequencies. Expressed in another way, there can be a significant number (or fractions) of a wavelength between components (at the operating frequency), and this has profound effects on the electrical behaviour of the circuit. To work at such a limit is typically the preserve of Radio Frequency (RF) Engineers and requires a quite different way of looking at circuits and components.

Returning to the matter of electrical length, if you were asked for the period of an electrical signal at a given frequency then this a simple calculation (ie 1/f). So also would be the answer to the question, how far did this signal travel (if it travelled at the speed of light ie. 2.9999E8 m/s) in one period (ie. the distance is given by the product of the velocity and the time). Hence, in one period the wave will have travelled some physical distance (mm) or 2PI radians or 360 degrees. Hence if we know the frequency and the velocity, we can translate a physical length into an electrical length, expressed in degrees or radians.

The only further complication arises when the wave is propagating in a dielectric medium. In this case the propagation velocity is significantly slower than the free-space or vacuum value. The speed is reduced by the inverse of the square root of the permittivity. Hence for this new speed in the dielectric the electrical length can again be calculated. As a consequence of this decrease in propagation speed the wavelength in the dielectric is much reduced also, and this has important consequences as far as the electrical length is concerned.