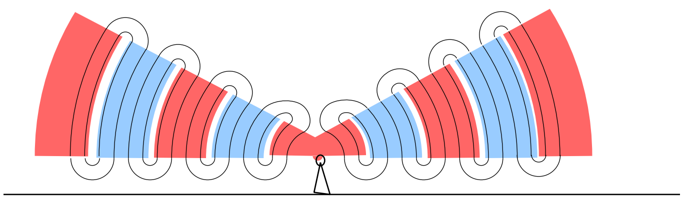
Circular polarisation

HOME: [The Physics of Bruce Harvey]

We understand circular polarisation of radio waves as the superposition of two radio waves with their fields perpendicular to each other and out of phase with each other. Text books usually only explain this in very simplistic terms relying on the concept of plane parallel waves and the superposition of solutions to the wave equation. However, it is a rather weak understanding to say that $Div\,\vec{B} = 0$ is satisfied because the the flux goes off to infinity in one direction and returns from infinity from the opposite direction. Any satisfactory solution must be able to describe the real geometry of the magnetic flux at any instance in time.

Classical theory does not try to describe the geometry of the magnetic fields of photons. If we are convinced that Maxwell's law $Div\,\vec{B} = 0$ is correct, then we should hope to be able to draw the flux lines of the photon's $\vec{B}$ field. The essential element of the geometry of circular polarisation is that part of each flux loop lags behind the rest of it in phase. This means that $\vec{B}$ is not everywhere perpendicular to the path of the photon. But $\vec{H} = \vec{v} \wedge \vec{D}$ must be perpendicular to the path, so the reationship $\vec{B} = \mu_0 \vec{H}$ is broken.

We can better understand how this is possible if we consider an examples from the application of the science. Radio waves from an antenna are often only able to maintain continuity of their magnetic flux by looping it back through consecutive half phases. This clearly breaks the condition that $\vec{B} = \mu_0 \vec{H}$.



This requires a major rethink of the laws of electromagnetism!

We assert that we can replace the equation $\vec{B} = \mu_0 \vec{H}$ with the more general equation:

$$\vec{B} \cdot \hat{h} = \mu_0 H \qquad : \hat{h} \text{ unit vector } \parallel \vec{H}$$

This allows the flux density vector to have a component $\vec{B}_{\perp h}$ perpendicular to $\vec{H}$ as well as a component $\vec{B}_{\parallel h}$ parallel to $\vec{H}$. Thus:

$$\vec{B} = \vec{B}_{\perp h} + \vec{B}_{\parallel h} \qquad \text{and} \qquad \vec{B} \cdot \vec{H} = \vec{B}_{\parallel h} \cdot \vec{H}$$

The only restriction on a loop of flux $\delta\Phi$ is that its energy content is unaltered. If the cross sectional area is δA and $\delta\vec{l}$ is an element of its length, then its energy content is:

$$\delta\mathcal{E} = \int \frac{1}{2}\vec{B} \cdot \vec{H}\,\delta A\,\delta l = \int \frac{1}{2}\frac{\delta\Phi}{\delta A}\delta A\,\vec{H} \cdot \delta\vec{l} = \frac{1}{2}\delta\Phi \int \vec{H} \cdot \delta\vec{l}$$

So the condition that the energy content is equal to half of the product of the flux and the *mmf* is preserved. For a flux loop travelling at the speed of light, $\vec{E} = \vec{v} \wedge \vec{B}$ and $\vec{D} = \varepsilon_0 \vec{E}$. If we now resolve $\vec{B}$ into two components $\vec{B}_{\perp v}$ perpendicular to $\vec{v}$ and $\vec{B}_{\parallel h}$ parallel to $\vec{v}$. We have:

$$\vec{E} = \vec{v} \wedge \vec{B} = \vec{v} \wedge \vec{B}_{\perp v}$$

Therefore $\vec{D}$ must be perpendicular to $\vec{v}$ and $\vec{B}_{\perp v}$. Now $\vec{H} = \vec{v} \wedge \vec{D}$ so $\vec{H}$ is parallel to $\vec{B}_{\perp v}$ implying that:

$$\vec{B}_{\perp v} = \vec{B}_{\parallel h} \qquad \vec{B}_{\parallel v} = \vec{B}_{\perp h}$$

The reader will at this point either be totally confused, or else complaining that this was obvious. Never the less, it is an important result which required proving because we now know that $\vec{B}$ can have components in the three directions radial, circumferential and parallel to its path without affecting the basic relationship that the motion of the magnetic flux generates the electric field which sustains the electric flux and the motion of the electric flux generates the magnetic intensity which sustains the magnetic flux. If the flux loop were circular and perpendicular to the path, $\vec{B}$ would only have a circumferential component and $\vec{D}$ would only have a radial component. The loop may however be of any shape. $\vec{D}$ and $\vec{H}$ will be perpendicular to the each other and the path, but $\vec{B}$ may also have components parallel to the path which affect neither its energy content or the generation of an electric field by its motion.

The magnetic fields we encounter in electro-mechanical engineering contain billions of quanta of magnetic flux and Faraday's concept of tubes of flux is readily applicable except for the fact that the real quantum flux tubes are trillions of times smaller than Faraday imagined. When we come to dealing with fields containing a very few or even just one quanta of magnetic flux, Faraday's concepts are still valid and can divide each quanta into as many flux tubes as we like. The motion of each tube will contain $\delta\Phi \lll \Phi_0$ of flux and be permeated by $\delta\Psi \lll e$ of electric flux. The restriction is that for each phase of a photon, the $\sum_i \delta\Phi_i = n\,\Phi_0$ where n is an integer, usually 1. A similar restriction applies to the electric flux which permeates the phase. The electric flux density D of the electric flux within a phase is inversely proportional to its width. (i.e. measured in the direction of $\vec{v}$) The smaller the wavelength, the greater the electric flux density and the greater the *mmf* generated by its motion.

The photon remains difficult to visualise, but not impossible. Its energy content controls its wavelength and the energy, magent flux content and electric flux content of each phase is preserved regardless of how the flux constituting each phase is distorted by polarisation or diffraction.