Tentative Theory for the "Kick" Phenomenon

Cyril Smith, June 2009

1. Introduction

The production of anomalous voltage spikes or "kicks" has been reported as part of investigations into Steven Mark's Toroidal power unit (TPU). This paper puts forward a theory for why those kicks are produced which demonstrates their anomalous energy as coming from the quantum domain.

2. The Basic Theory

It is known that in the presence of a magnetic field electrons will behave like tiny magnets and align themselves with the field. Quantum rules do not allow complete alignment, the electrons are constrained so that the projection of their spin angular momentum onto the field direction is numerically equal to ½ and can be either parallel or anti-parallel to the field. If we define the parallel case as *spin-up* and the anti-parallel case as *spin-down*, then within a non-ferromagnetic conductor such as copper the conduction electrons will appear in equal numbers as spin-up and spin-down. Thus there is usually no net magnetization available from these conduction electrons, the magnetic susceptibility χ is zero and the relative permeability $\mu_R = (1+\chi)$ is unity. However it is possible that there exists a transient condition where χ takes on a non-zero value for a short period of time, making copper appear to be temporarily ferromagnetic.

An anomalous transient magnetization for *ferromagnetic* materials was postulated in the author's paper "Non-coherent access to precession energy"[1]. It is now suggested that the same argument can be applied to *non-ferromagnetic* conductors. The argument goes like this, normally the conduction electrons have random spins as shown in Figure 1.

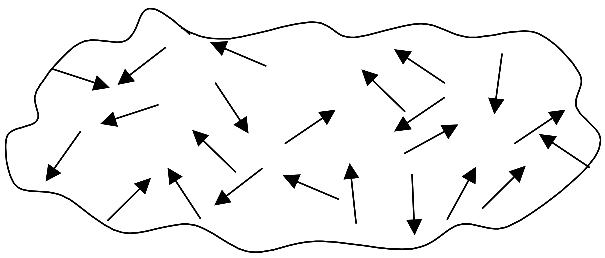

Figure 1. Random spins for conduction electrons

In the presence of a magnetic field the electrons align as spin-up and spin-down in equal numbers, see Figure 2.

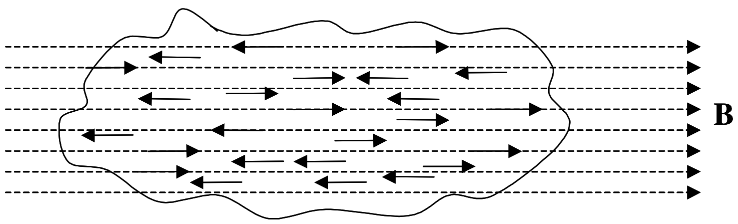

Figure 2. Aligned spins

However they don't fully align as shown. Because their spin projection onto the field direction must be equal to ½, they are tilted to an angle of 54.7°, and because they have angular momentum they precess about the field direction at Larmor frequency, like tiny gyroscopes as illustrated in Figure 3.

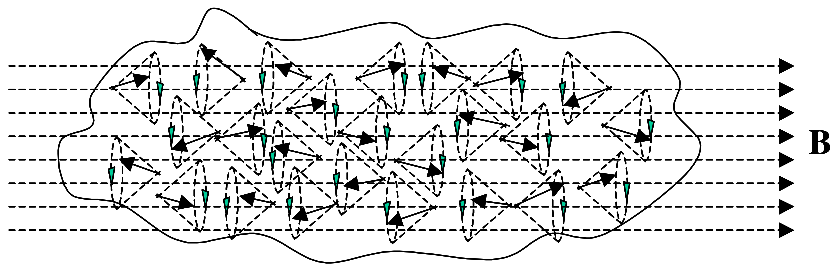

Figure 3. Precessing electrons

The suggestion is now made that a rapid change of applied **B** field will cause those precessions to take on a temporary alignment at an angle that is *not* 54.7°. Figure 4 shows a single spin-up precessing electron that normally supplies a component of longitudinal magnetization given by $\mu_B \cos\theta$ where μ_B is the Bohr magneton and θ is the quantum constrained angle of 54.7°. Note this quantity is normally exactly balanced by a reverse magnetization from the spin-down electrons. For slowly

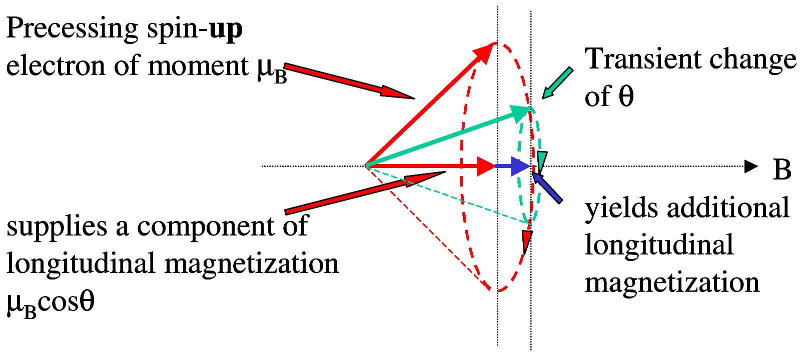

Figure 4. Spin-up electron

changing **B** the precession angle remains at 54.7° while the Larmor precession frequency changes value to maintain gyroscopic torque balance, and the magnetization component remains constant. However for rapid change of **B** this may not be the case, it is possible that the Larmor frequency cannot change value instantaneously, hence there is a momentary torque imbalance which alters the precession angle. In Figure 4 a sudden increase in **B** is shown to reduce θ, hence temporarily increasing the magnetization contribution. θ will then relax back to its proper quantum state over a period of several Larmor cycles.

Figure 5 illustrates the same effect on a spin-down electron. Here a sudden increase in **B** causes the electron to supply a *reduced* component of reverse magnetization, which then adds to the temporary overall magnetization. Note that the change in magnetization is not dependent on the Larmor frequency or phase, and the transient does not wobble at the Larmor frequency. What is seen from the enormous number of electrons contributing to the longitudinal magnetization is a magnetization impulse like a step function with an exponential tail.

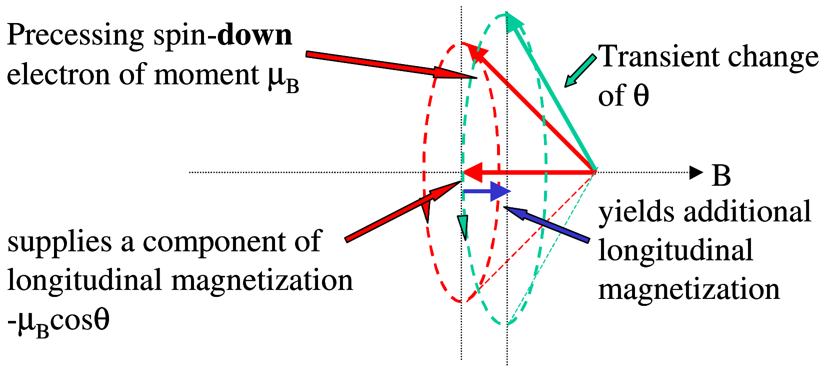

Figure 5. Spin-down electron

3. Material BH Curve

If the magnetization impulse effect is real (and the measured kicks seem to support this) then we can introduce it as a material property where the magnetic susceptibility χ (which can be considered as a magnetization coefficient since $\mathbf{M} = \chi\mathbf{H}$) is not zero but has a transient nature. It is clear that for χ to be non-zero there must be (a) a magnetic field already present and (b) a rapid change to that field. Thus χ and hence μ_R are non-linear functions of **B** (or **H**), $\partial B / \partial t$ (or $\partial H / \partial t$) and time.

Figure 6 illustrates the BH curve for this effect. Normally a non-ferrous conductor like copper exhibits a slope of μ_0 as shown by the broken line where $B=\mu_0 H$.

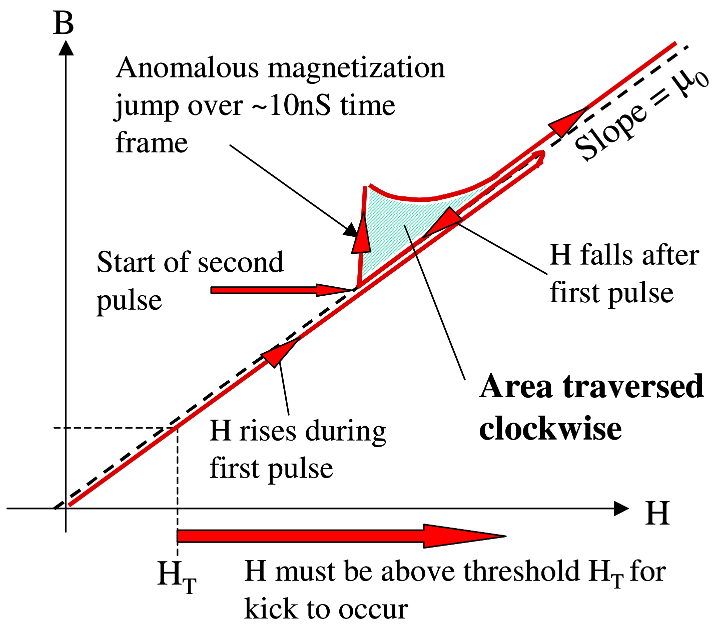

Figure 6. BH Curve for Fast Transients

However under fast pulse conditions we can expect the first pulse to supply the internal *B* field that is required for the kick effect. There could be some threshold of supplied *H* that must be exceeded before the kick effect can appear, which is why there is no kick on the first pulse of a pulse pair. If the second pulse occurs while that threshold is exceeded then the spin alignment condition is met and the rapid rise time of the second pulse drives the anomalous magnetization, resulting in increased B since $B = \mu_0(H + M)$. This jump in B is shown on Figure 6 and would appear as a voltage spike on the leading edge of the second pulse. *Note that over a full cycle the triangular area under the magnetization anomaly is traversed clockwise, indicating a gain in energy. That energy comes from the quantum domain energy that forces the disturbed precessions to return to the 54.7° angle.*

Figure 7 shows voltage pulses and the rise and fall of current (or H field). This makes it clear that at the first pulse the current is zero, hence below the threshold for spin alignment. If the second pulse occurs while the current is above threshold then the kick appears. At large delays the current has fallen below threshold, hence there is then no kick. This could explain the experimental results where kicks appear over a limited range of delay times.

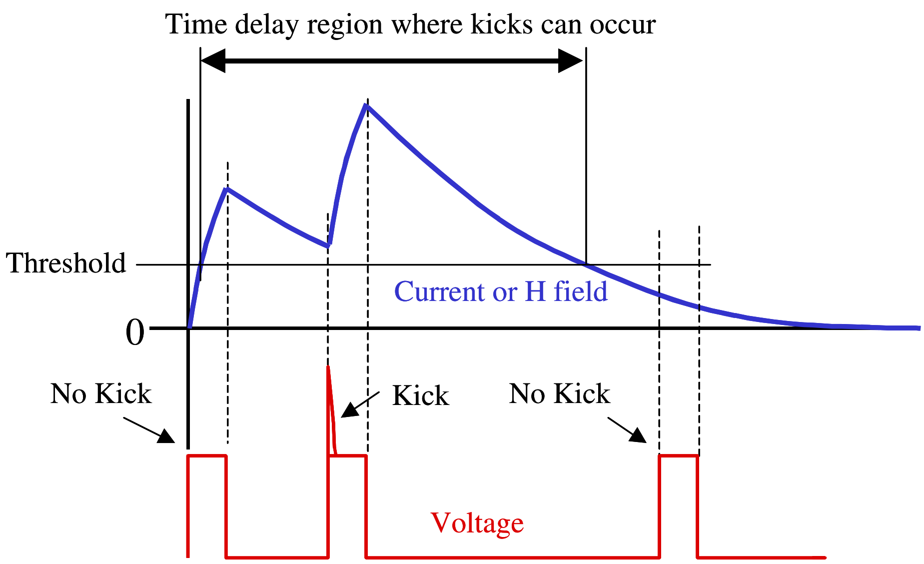

Figure 7. Voltage and current waveforms

4. The Kick Effect in a conductor of cylindrical cross section.

The inductance L of a length of wire carrying a current i is defined by $L = d\Phi / di$ where Φ is the total flux surrounding the current. For a thin wire the current is usually assumed to flow in a line, hence all the flux is external to the current. However when the wire diameter becomes a significant part of the geometry, this is no longer true and for a proportion of the current some flux is internal to the wire. Thus the conductor can be considered to have inductance consisting of two inductors in series, an *external* inductance L_{EXT} for flux external to the wire, and an *internal* inductance L_{INT} for the internal flux. Hallen[1] gives the formula for the internal inductance of a wire that is not too strongly curved or wound into a coil as

$$L_{INT} = \frac{\mu_R \mu_0}{8\pi} \text{ Henry per meter length} \qquad (1)$$

that is independent of the thickness of the wire. The external inductance on the other hand depends on the thickness and curvature of the wire. Thus a 1 meter length of copper wire having μ_R=1 gives an internal inductance contribution to its total inductance of 50nH, which is normally subsumed into its total inductance. However if μ_R obtains a transient value then L_{INT} must be considered separately as also having a transient value that could be a considerable increase on that 50nH value. Figure 8 gives a cross section of a conductor showing the flux lines and the spin alignments that contribute to this transient L_{INT} effect.

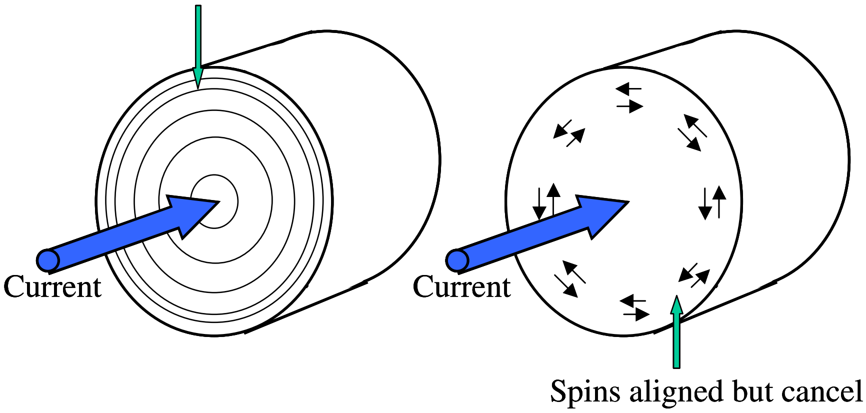

Figure 8. Spin alignments for current carrying conductor

A sudden change in current causes the spins to create circular magnetization which gives L_{INT} a sudden increase in value as shown in Figure 9.

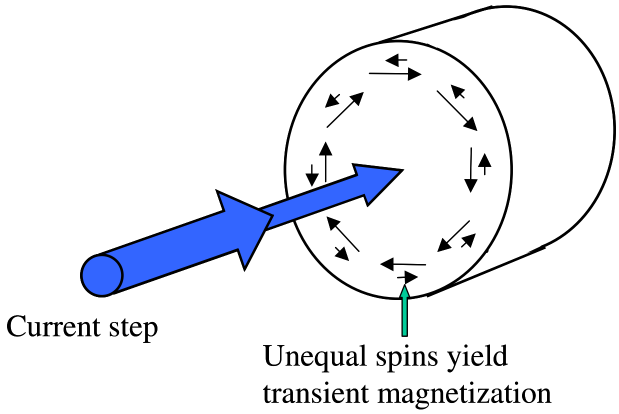

Figure 9. Transient Magnetization due to current step

5. A single loop

Hallen[2] gives the formulae for both L_{INT} and L_{EXT} for a wire of radius b in a single loop of radius a.

$$L_{INT} = \frac{\mu_R \mu_0 a}{4} \tag{2}$$

$$L_{EXT} = \mu_0 a \left(\log\left[\frac{8a}{b}\right] - 2 \right) \tag{3}$$

Thus for a typical experiment using a 0.5mm copper wire as a single loop of diameter 11.78cm, L_{INT} = 18.5nH and L_{EXT}=410nH. It may be noted that it requires the μ_R of the copper to take on a transient value of only 22 to yield $L_{INT} = L_{EXT}$ where anomalous voltage would then be very noticeable. If we look at some typical measured results a 20 V first pulse of 60nS width yields a total flux rise Φ of 1.2μWeber. Since Φ=Li we can use the total inductance value of say 430nH to get the current at the end of the pulse as 2.8A. Now the second pulse gets an anomalous kick of say 30V over 10nS which from $V = i\frac{dL}{dt}$ at a current of 2.8A corresponds to a change in L of 107nH. Hence we can assume that L_{INT} changed momentarily from 18.5nH to 125.5H which corresponds to a transient μ_R of 6.8.

6. New Experiments

It should be possible to validate this theory by providing a DC bias current above the threshold value so that the kick can then occur on the leading edge of the first pulse. Alternatively consideration could be given to using a small diameter copper tube as the conductor. Then an insulated wire could be threaded through the tube, and that wire could carry the bias current, as shown in Figure 10.

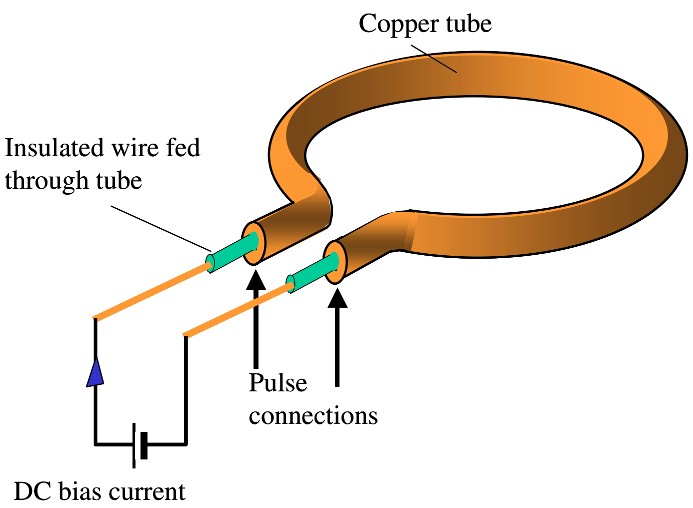

Figure 10. Copper tube experiment

Semi rigid coaxial cable is available which already contains the inner wire, and that might be an expedient route to this experiment.

7. References

1. "Non-coherent access to precession energy" by Cyril Smith. Private paper sent to MPI.
2. "Electromagnetic Theory" by Erik Hallen, published by Chapman Hall 1962