Accessing Hidden magnetic Energy

©Cyril Smith, November 2017

1. **What is this hidden magnetic field energy?**

This magnetic field is hidden within the inter-atomic space of ferromagnetic materials, that relatively huge space that exists between the atoms that we can't see with the naked eye. To discover why this field energy is not known to science we have to look at the historical manner in which magnetism developed. This has created a science which has some serious disconnects in its formulation, never more so than in the physics of ferromagnetic materials. Even though modern scientists know that the magnetization comes from arrays of discrete atomic dipoles, where in that micro-universe the separation between atoms is huge compared to their size, that inter-atomic space and the magnetic fields therein are generally ignored. Scientists use a term called *magnetization* (usually denoted **M**), which is a volume-density of a "substance" called *dipole-moment*, and proceed as though that "substance" is smoothly spread through all space within the material. They know that dipole-moment is a characteristic of a discrete dipole, and that **M** should really be a discrete number-density, but because that number-density is so very high (e.g. like 10^{28} atomic dipoles per cubic meter) it has been found more convenient to imagine **M** as a volume-density smooth function. That inconsistency, the filling of inter-atomic space with that imaginary "substance", prohibits the calculation of the actual magnetic fields there and so continues to hide the magnetic energy stored in that space and its vital connection to the atomic dipoles. For permanent magnets those inter-atomic fields are not trivial, and the stored energy has a density significantly greater than the magnet's maximum BH energy product.

Again for permanent magnets that inconsistency has lead to the nonsense of a negative **H** residing within the magnet, i.e. **H** opposing the **B** field. And it has hidden the true meaning of the reluctance of the *air space* occupied by the magnet, something that is used when calculating the load line. This calculation is usually performed by rote with little thought as to why it works, yet the answer is very simple. The magnetic domain equivalent circuit for a permanent magnet is an mmf source (i.e. the combined effect of all the aligned atomic dipoles) in series with that air-space reluctance, and the load-line procedure is simply a graphical method of calculating the mmf drop across it. Another clue to the inconsistency is the known feature of permanent magnets having an incremental permeability of unity, i.e. they act like air to alternating fields (eddy currents excluded).

The same arguments apply to soft ferromagnetic material, when magnetized there is within the inter-atomic space magnetic energy that is far in excess of that used to create the magnetization. That excess energy is supplied by Nature, it comes from the quantum domain, from the quantum forces driving each atomic dipole. If each atomic dipole were modelled as a small loop driven by a constant current generator, each current generator would supply that excess energy during the magnetic field build-up (and retrieve that excess energy during magnetic field decay). This comes about because the time-changing field induces voltage into each loop so as to oppose or enhance the currents, and it is easily shown that this energy exchange with the generators exactly accounts for the excess energy within that inter-atomic space. In the case of alternating excitation this store of hidden energy is cyclic, which opens the door to methods of extracting a portion on each cycle, with that "loss" (which is our gain) being replenished from the quantum forces driving each dipole.

We are taught that the material stores the quantity of energy we input as given by $\frac{1}{2}Li^2$, where L is the inductance of the coil wound around the material and *i* is supplied current. Assuming no demagnetization, i.e. the magnetic core is closed with no air gaps, that input energy value translates into an *apparent* magnetic energy density of value $\frac{1}{2}B^2/\mu$ within the core material where the material obeys $B=\mu H$ having a permeability $\mu=\mu_r\mu_0$. But that discounts the vast inter-atomic space where the magnetic energy is really stored. In reality the energy density stored there is $\frac{1}{2}B^2/\mu_0$, which is μ_r time greater than we are led to believe, and this comes about because the H within that inter atomic space is increased from that just supplied by the coil current. The increase in H comes from the aligned atomic dipoles, which create an H value of χ times the coil's H where χ is the magnetic susceptibility. The sum of the coil's H and the H from all the dipoles is then $(1+\chi)$ times the coil's H, where $(1+\chi)=\mu_r$.

So instead of imagining a *material* that has the property of increasing B for a given H input value, we should imagine *an air space of the material dimensions* where the supplied H is increased by the addition of χH. The presence of the applied H "conjures up" the additional χH. The "conjuring up" is not a magical process, it comes from an array of atomic dipoles (imagine them as tiny bar magnets) within that air space that rotate or flip in response to the applied field. At zero applied H field they have random orientations so their net effect seen from outside the material is zero. But when an externally applied H field is present they tend to align themselves with the field, hence increasing the internal H field value, and the relative permeability is simply our method of accounting for that increase. Of course that additional χH increases the B field within that *air space of the material dimensions* so that $B=\mu_0(H+\chi H)$ and it is that field that the coil sees as its flux linkage. Giving χH the attribute of magnetization M and imagining that M fills all space within the material gives a false indication of the actual fields there.

2. On BH and Φ*i* hysteresis loops

If, after charging an inductor with current, we could suddenly turn off the magnetization while temporarily retaining the magnetic flux (e.g. by having a shorted coil around the core) we would be able to retrieve the energy hidden in that inter-atomic space (e.g. by switching the current held in the shorted coil onto a load). One way to do this is by heating the core to above its Curie temperature. Perhaps this is best illustrated by considering the BH loop for this situation. It is well known that the area inside a BH hysteresis loop represents an energy-density, to obtain the actual energy it is necessary to multiply by the volume of the core material. The Flux Φ v. current *i* loop has the same shape but now has the advantage that its area represents energy directly. As in BH loops a CCW traverse represents energy loss. (So if in a transformer the flux Φ is plotted against primary current *i* the obtained loop is traversed CCW. The loop area is the energy per cycle consumed by the transformer and its load. Now plot the flux Φ against secondary current *i* and the loop is traversed CW representing an energy output or gain.) The following figure shows the Φi loop for a charged inductor where the coil is then shorted so as to temporarily hold the flux while the core is suddenly taken above its Curie point. The loss of magnetization now makes the core equivalent to an air gap so to maintain the flux the current in the coil increases. Now all the hidden energy is available to be released when the coil is switched onto a load. The loop is traversed CW, the yellow area representing energy gained, i.e. energy discharged into the load after the initial input energy has been subtracted. The green area represents the input energy needed to charge the inductor

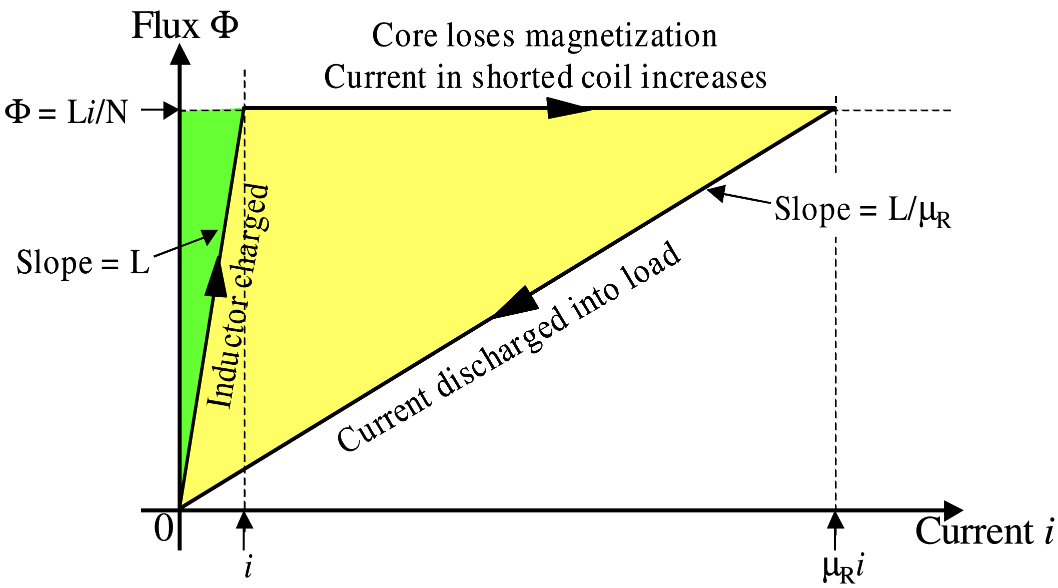

Figure 1. Φi loop for core heated above Curie point

Coil ohmic losses are not considered in figure 1 and for the slow cycling of a ferromagnetic core about its Curie point this is not a very practical method for converting hidden energy into useable electrical energy. It could however form the basis of an over-unity heater where the coil is also the heating element. This is depicted in figure 2 where in this example the heat is extracted by blown air, and the coil is pulsed at a rate to synchronize with the temperature cycling about the Curie point.

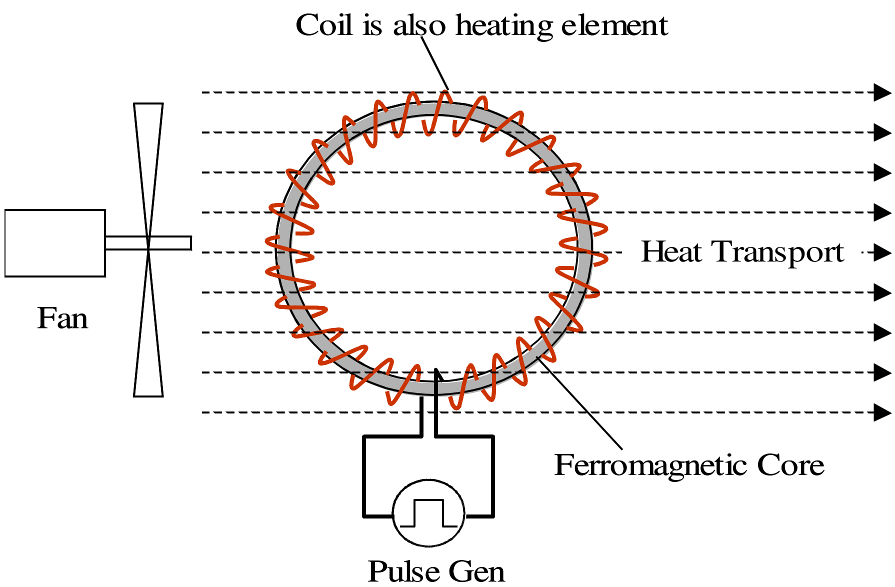

Figure 2. Over-unity Heater

The proposed method is quite simple, we supply current to a toroidal coil wound onto a high permeability ferro-magnetic core. The coil is also a heating element that then heats the core to above its Curie temperature. As the material passes through its Curie point the phase change from magnetic to non-magnetic releases energy in the form of increased coil current to cause the coil and the core to rapidly heat further. The input voltage is switched off, the blown air extracts that heat, cools down the material to below the Curie point, then the cycle is repeated. With the Curie point of most material's being well above ambient, this could find use in efficient heating systems.

Putting aside the heater idea, there exists a method for extracting electrical energy that is worthy of experimentation and that will be described next.

3. **Mutual Inductance Coupling with Time Delay**

We now consider a special case of two coils in close proximity to each other connected in series and operated at a frequency low enough for the electrical time delays along the connecting conductors, as determined by light velocity, to be negligible. However the propagation velocity of the magnetic coupling between the coils is much slower than light velocity hence introducing a small but significant time delay in that coupling path. It appears that this configuration has not been looked at seriously in electromagnetic theory texts, and this omission has kept hidden its remarkable properties. Here we show by classical analysis supported by vector phase diagrams that such delayed magnetic coupling can give rise to either an anomalous power loss or an anomalous power gain. This is followed by a discussion on where the energy sink or source might reside concluding that it is likely to be the active dynamical vacuum. Finally a simple experiment is suggested that would demonstrate that the anomaly is real and worthy of development into something useful.

a) Theory

The inductance for two coils in series is given by the well-known formula

$$L = L_1 + L_2 \pm 2M \qquad (1)$$

where L_1 and L_2 are the inductances of the two coils when isolated from each other and M is the mutual inductance between the coils. For bucking coils the negative sign applies. Now to a first approximation we can say that there are no time delays affecting the values of L_1 and L_2. However there could be a significant time delay concerning the coupling between the coils hence affecting voltage induced into the M term. Taking the current through the two coils to be of value $i \sin(\omega t)$ and using the classical voltage across an inductor as

$V = j\omega L i$ where j is the imaginary operator $j = \sqrt{-1}$ that produces a 90º vector rotation we get from (1) the voltage across the series combination as

$$V = \omega i [L_1 \cos(\omega t) + L_2 \cos(\omega t) \pm 2M \cos(\omega t - \phi)] \qquad (2)$$

where we have introduced a phase delay ϕ for the mutual coupling. Expanding the third term yields

$$V = \omega i [L_1 \cos(\omega t) + L_2 \cos(\omega t) \pm 2M \cos(\omega t)\cos(\phi) \pm 2M \sin(\omega t)\sin(\phi)] \qquad (3)$$

Rearranging (3) to gather the $\cos(\omega t)$ and $\sin(\omega t)$ terms gives

$$V = \omega i [\{L_1 + L_2 \pm 2M \cos(\phi)\}\cos(\omega t) \pm \{2M \sin(\phi)\}\sin(\omega t)] \qquad (4)$$

The phase angle θ between voltage and current is then

$$\theta = \pm \tan^{-1}\left(\frac{2M\sin(\phi)}{L_1 + L_2 \pm 2M\cos(\phi)}\right) \tag{5}$$

This phase is perhaps more readily understood by dividing (4) by the current $i\sin(\omega t)$ to get the impedance of the series-connected coils as

$$Z = \frac{V}{i\sin(\omega t)} = j\omega[L_1 + L_2 \pm 2M\cos(\phi)] \pm 2\omega M\sin(\phi) \tag{6}$$

It is seen that the equivalent circuit of the series connected coils is an inductance

$$L = L_1 + L_2 \pm 2M\cos(\phi) \tag{7}$$

in series with a resistance

$$R = \pm 2\omega M\sin(\phi) \tag{8}$$

Note that the presence of a time delay in the mutual inductance coupling path alters the overall inductance value from that given in (1) and at the same time introduces an additional resistance term. The plus signs represent the case where the mutual inductance adds to the total inductance (coils aiding) where the series resistance is seen to be positive. The minus sign represents the case of interest here where the coils oppose and the series resistance is seen to be negative. Note that value of the negative resistor increases with frequency. Unfortunately positive real losses associated with the core and the conductor also increase with frequency, so the presence of the negative resistance is not always readily discernible. Note also that this only applies to coils wound onto ferromagnetic cores where the magnetic wave propagation is much slower than light velocity c. For coils spaced apart in air the magnetic wave propagation speed through the air is equivalent to the electric wave propagation speed along the wire connecting the two coils, so the currents in each coil can not be assumed to be in phase with each other, hence invalidating (2) and subsequent equations.

b) Vector Phase Diagrams.

Perhaps the above theory is more readily understandable using phase diagrams where multiplication by the imaginary operator j produces a CCW rotation of 90°. For an inductor where the voltage leads the current by 90° the vectors appear as shown in Figure 3.

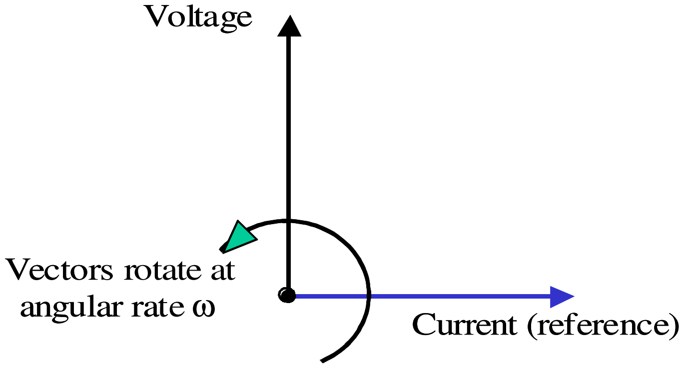

Figure 3. Phase diagram for inductance

The next Figure 4 shows the voltage vectors from (4) for the case where the mutual coupling has zero delay showing the voltage vector summation for the two cases, coils aiding and coils opposing.

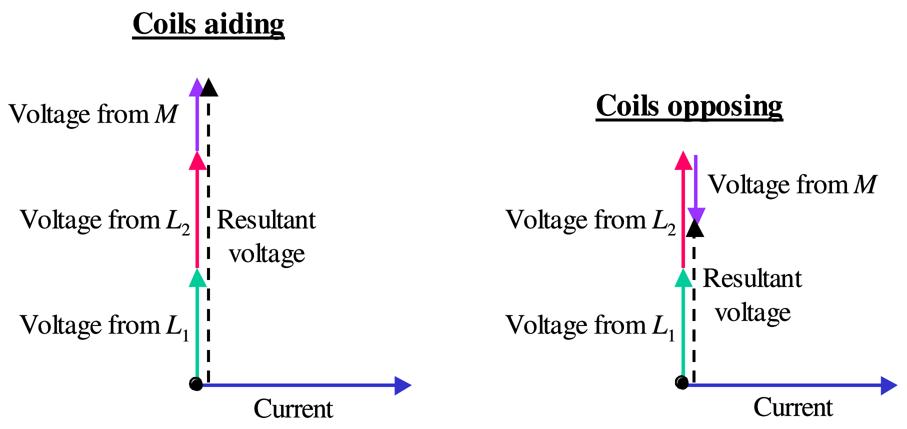

Figure 4. Phase diagram for coupled coils

Compare that to Figure 5 which shows the time (phase) delayed voltages. It is quite clear that the magnetic time delay introduces an in-phase or an anti-phase voltage component, the in-phase component representing a positive (lossy) induced resistance while the anti-phase component represents a negative resistance. A negative resistance is a source of energy, so how can a simple pair of passive components create energy? That dilemma is discussed in the next section.

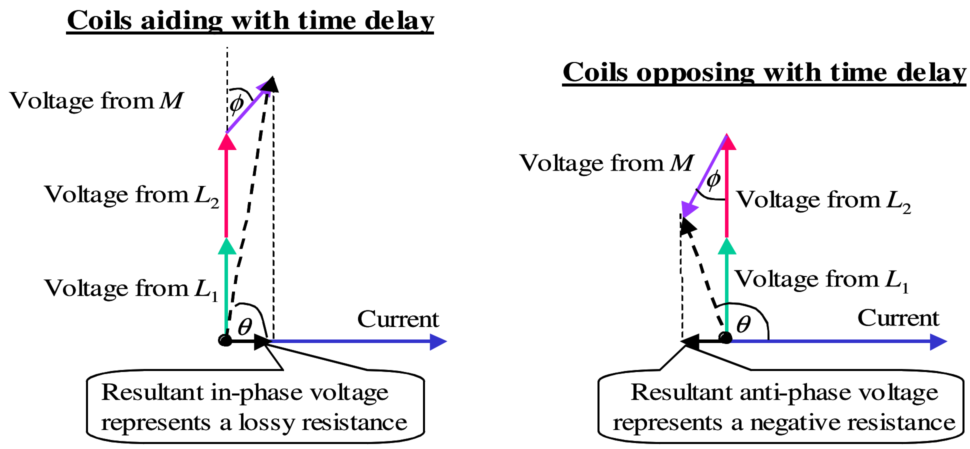

Figure 5. Phase diagrams for coils coupled with a time delay

(c) Discussion

If the coils are in series-aiding the induced resistance is positive representing an energy loss. It is well known that the magnetic propagation delay through ferromagnetic cores does generally result in a loss as seen by a single coil, and the delay has been given the name *magnetic viscosity* invoking the perception that friction causes the loss. The above theoretical analysis could be extended to the coupling between adjacent turns of a single coil to show that with a magnetic propagation delay *between turns* the mutual coupling between turns will produce a loss, and perhaps that could explain the known effect. Where does that energy go? It is generally assumed that it must go to heat the core, but has that been verified by experiment? However that only applies to the situation where the mutual coupling is aiding and not opposing. *When the opposing case is considered there is an energy gain*. The fact that series-aiding turns produce a loss but series-opposing turns produce a gain should tell us that there is more to magnetic propagation than the name *viscosity* implies, and the question must be asked, *where does the energy go to or come from?*

The thing that makes this different from some interconnected passive components is the magnetic field interconnection, and its delayed effect can be seen via the Φi hysteresis loop. If a very fast pulse is applied to the series coils, initially the flux linkage seen is just that of the two inductors because the canceling field has not had time to travel the mutual coupling path. After the delay time the flux reduces due to that cancellation, and the inductance is reduced. Then the current can be switched off slowly at this reduced inductance value. The Φi plot is shown in figure 6.

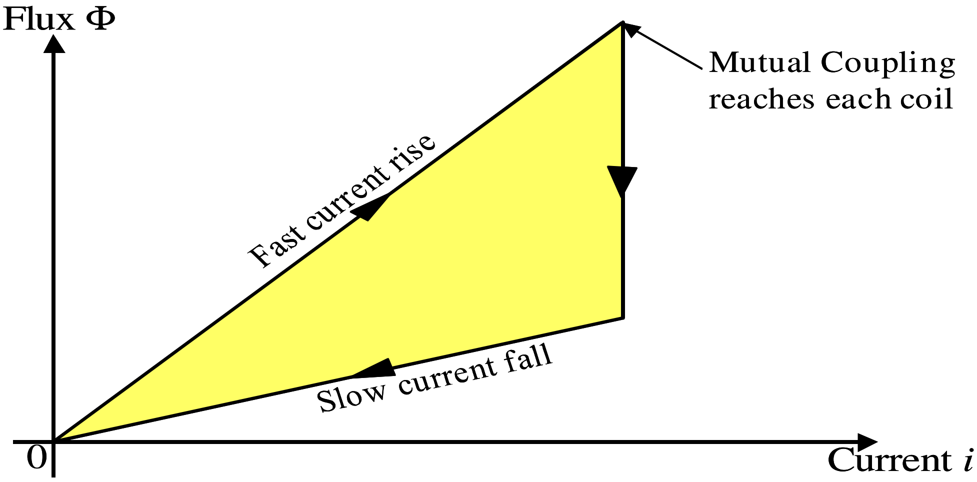

Figure 6. Φi loop for bucking coils

Just like figure 1 this Φi loop is traversed CW representing an energy gain, and it can be expected that the source of that energy is the same, the quantum domain that drives the atomic dipoles.

(d) Suggested Experiments

The first experiment proposed here is designed to look for evidence that the anomalous negative resistance really exists. A large ferrite ring core, Ferroxcube T107/65/18 with grade 3F4 ferrite, is chosen as this has been extensively measured by Chava LLC over a wide range of frequencies for another application, and the author of this paper has access to those measurements.

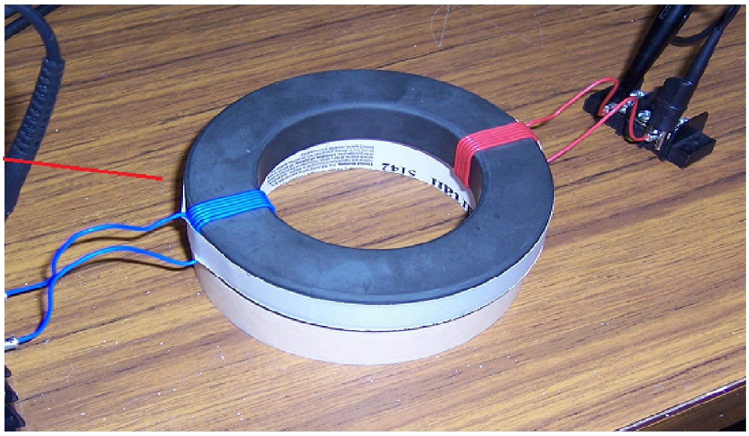

Figure 7. Ferrite ring core as previously measured

Figure 7 shows the configuration that was measured where it can be seen that coils were placed diametrically opposite to each other, thus maximising the time delay in magnetic propagation from one coil to the other. Each coil was 6 turns of Litz wire.

The proposed experiment introduces additional delay along the arms of the core and one way of doing this is to immerse the core in a high dielectric medium. However there is another method that uses coils along the top and bottom arms with tappings at which capacitors can be connected so as to form LC transmission lines. This is depicted in the next figure.

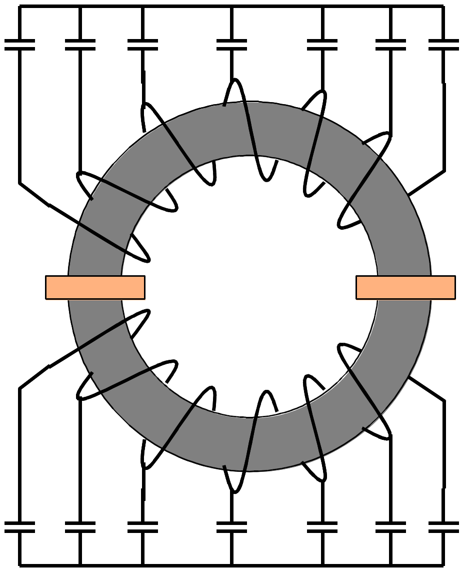

Figure 8 LC transmission lines along top and bottom of core

Initially the two separated coils are connected in series opposing and shunted by a capacitor thus producing an LC resonant circuit where the L is the value for zero magnetic delay. The delay line capacitors are not connected at this time, figure 9.

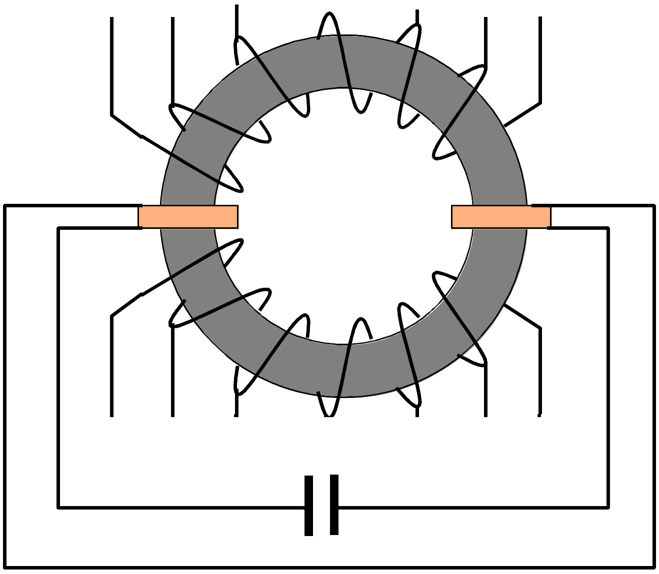

Figure 9. Initial connection without delay-line capacitors

The Q of this resonant circuit is measured taking care that the Q is not significantly reduced by connection to the signal source. The delay-line capacitors are then connected using low values for minimum delay time, then the Q is remeasured to see whether it has increased. An increase in Q indicates a reduction in circuit losses, so if this happens the experiment can be repeated using ever larger values of delay-line capacitors. It will be expected that the losses in the delay line will increase so there could be an optimum where the Q is a maximum. The increase in Q from its original value will enable the value of the induced negative resistance to be determined.

For the second experiment what is now proposed is a pair of coils each with its own closed magnetic path where the coupling between them is done by a separate electrical delay line, in effect two interconnected transformers as shown in figure 10.

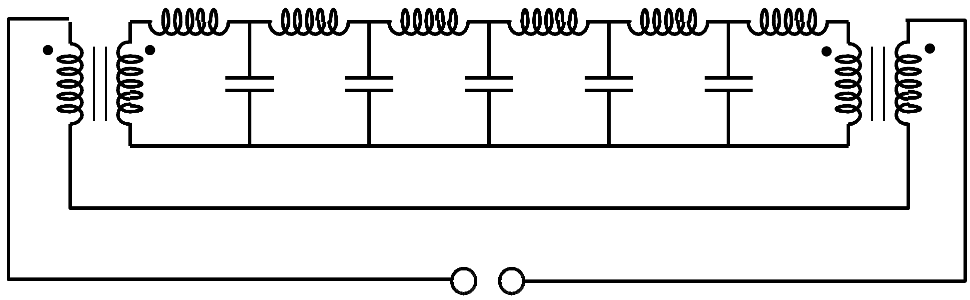

Figure 10. Interconnected transformers

At low frequencies where the delay is negligible this configuration provides current driven round the inner loop as shown in figure 11.

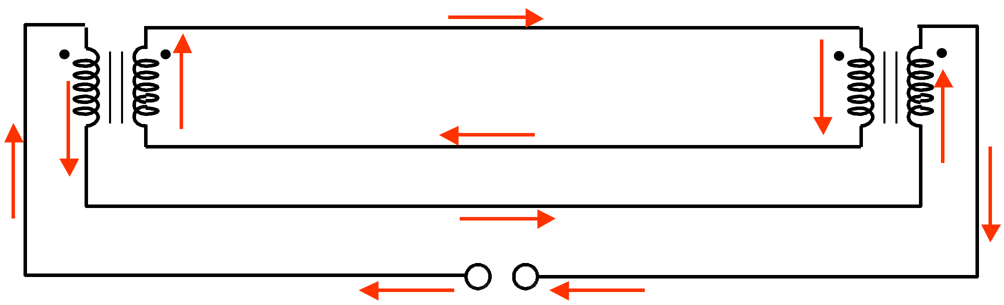

Figure 11. Interconnection provides flux cancellation

The currents within the two coils on each transformer flow in opposite directions so the flux in both transformers is almost cancelled, which is the same situation as for bucking coils wound on the same core. Inductance at the input will be very low. Introduction of a delay in that interconnection results in similar properties to that derived in section 3a , but now derived more accurately for this particular configuration.

Figure 12 shows the current and voltage standing waves along the delay line where by symmetry we know that the current maximum is at the centre where the voltage is zero.

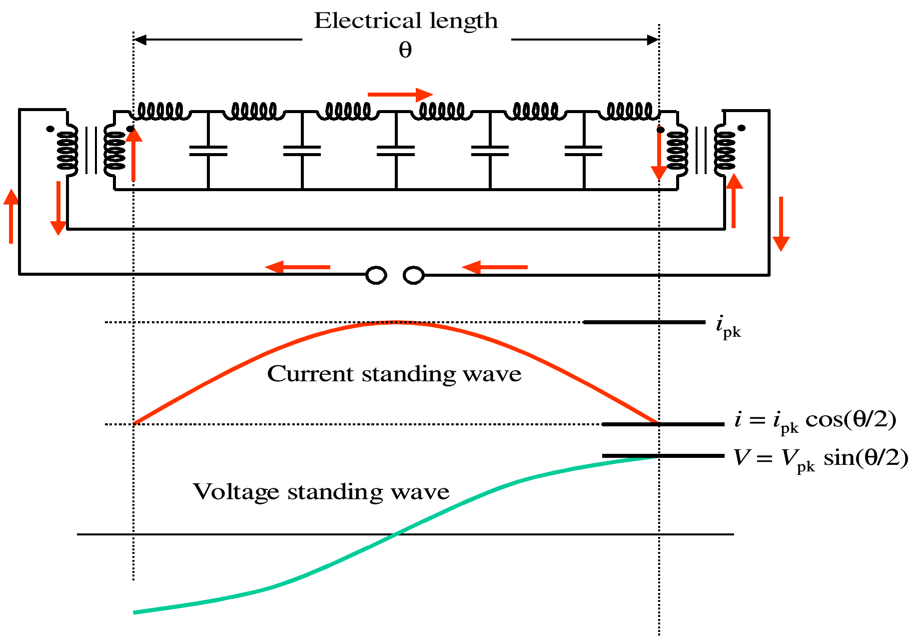

Figure 12. Standing waves along transmission line

With the one way length of the transmission line expressed as an electrical phase θ and its characteristic impedance as Z_0 we know that for 100% standing waves the ratio of voltage maximum V_{pk} to current maximum i_{pk} is Z_0 It is also clear that the current at each end of the line is $i=i_{pk}\cos\left(\frac{\theta}{2}\right)$ and the voltage magnitude at each end of the line is $V=V_{pk}\sin\left(\frac{\theta}{2}\right)$. Then the ratio $\frac{V}{i}$ that yields the input impedance Z as seen through each transformer is given by

$$Z=\frac{V}{i}=-Z_0\tan\left(\frac{\theta}{2}\right) \qquad (9)$$

which is purely resistive. To this must be added the leakage inductance L_L of each transformer hence the two transformers in series gives

$$Z=2\omega L_L-2Z_0\tan\left(\frac{\theta}{2}\right) \qquad (10)$$

It is now possible to proceed in a manner similar to that of the first experiment. With the transformers connected without the delay-line as in figure 11 the input inductance $2L_L$ can be resonated with a capacitor and the Q of the circuit determined. Then with the delay line inserted any increase in Q will indicate the presence of induced negative resistance.