Magnetic Delay Transformer (MDT)

Within magnetic material a time delay is known to exist between the application of an H field and the resulting change in magnetization. In permanent magnets this is known as magnetic viscosity and it has various sources. In magnetically soft material it is linked to the movement of domain walls. The delay is seen to broaden the hysteresis loop and therefore is recognized as a loss mechanism, the loss increasing with frequency. Thus the inductor shown in figure 1 that has negligible loss at low frequencies would, if resonated with a capacitor, exhibit a broadening of the resonance curve as seen in figure 2 which shows the resonance both with and without the wall movement time delay. Here the resonance is plotted as real and imaginary parts of the input impedance. Note that in figure 1 we show the input coupling as a separate winding wound close to the inductor coil so as to minimise any flux leakage, a common feature of transformers. Indeed we can consider this system to be a capacitively loaded transformer as shown in the circuit diagram of figure 1.

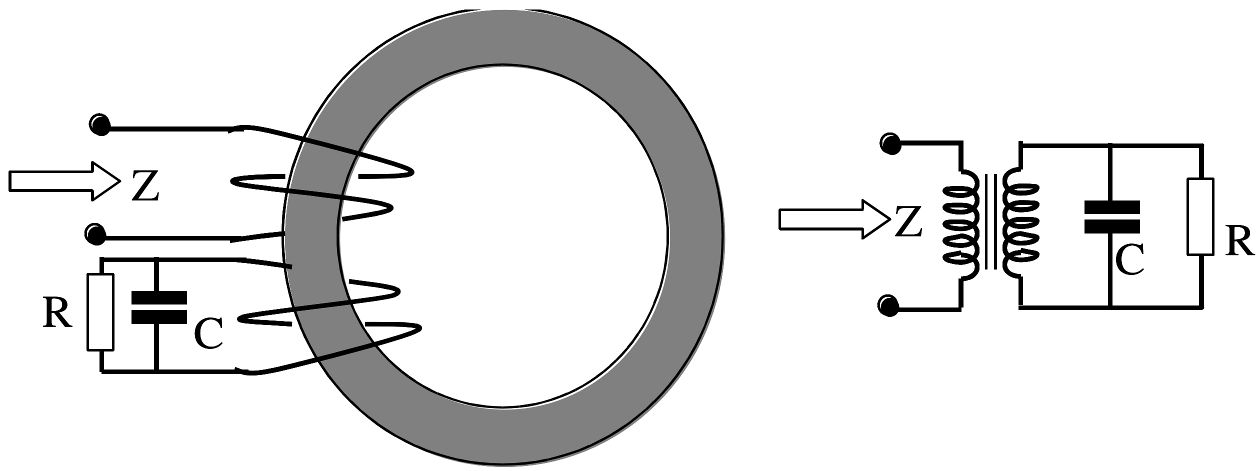
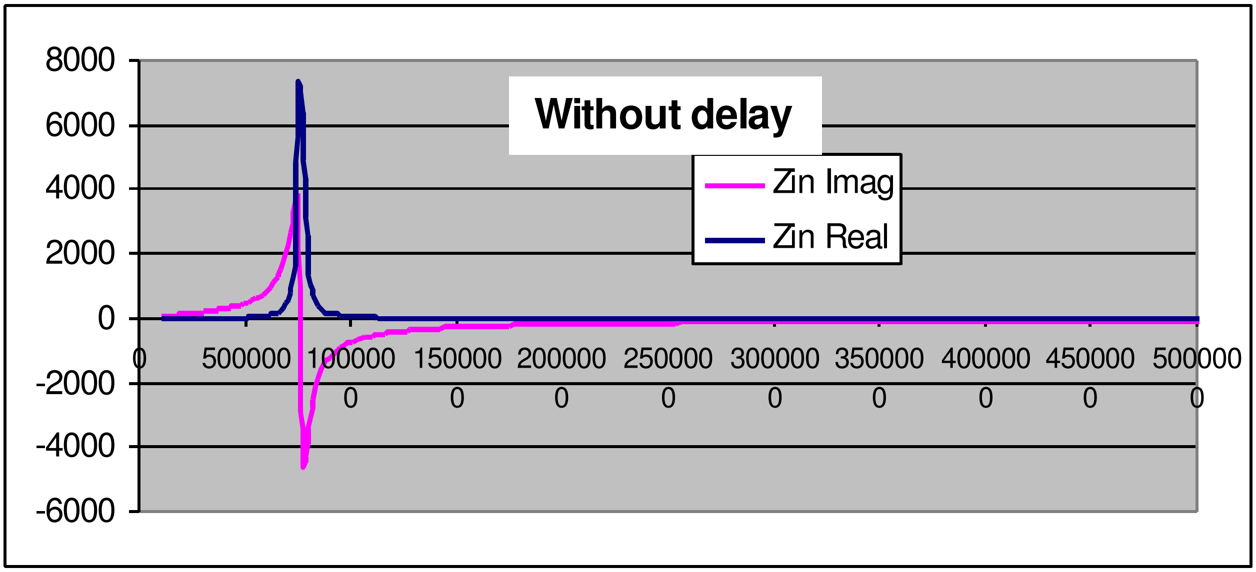


Figure 1. Capacitively Loaded Transformer



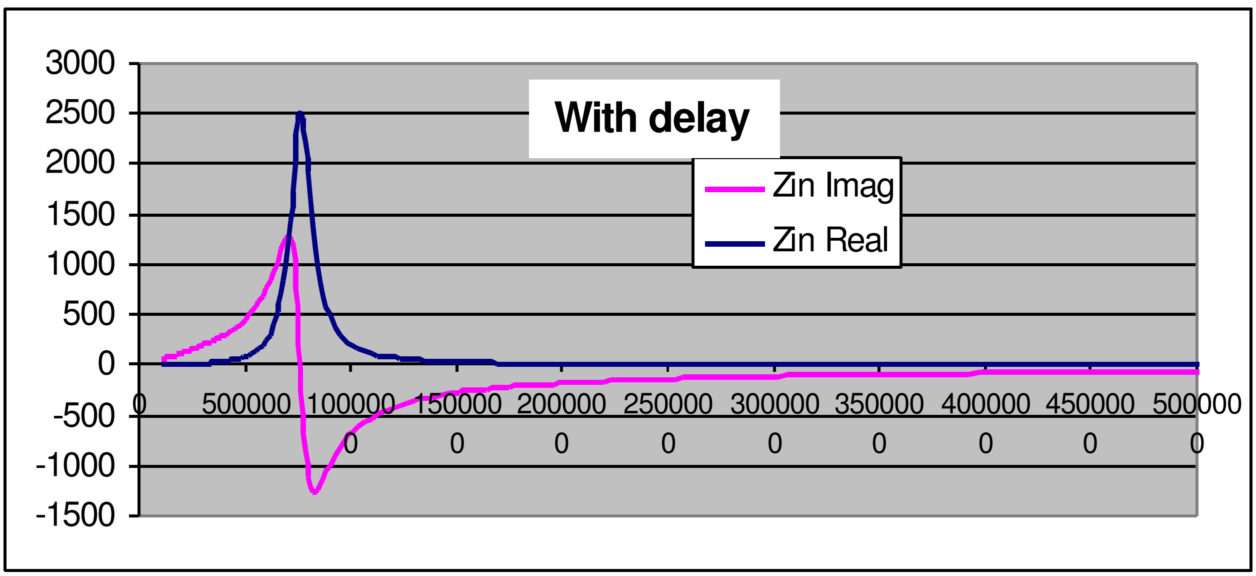


Figure 2. The Input Impedance of Figure 1 With and Without Magnetic Delay.

Now consider the system shown in figure 3 which is the same transformer but with the secondary wound at its furthest position from the primary. At first sight it might be thought this would behave in an identical manner, but there is a subtle difference. Whereas the transformer in figure 1 has a zero time delay between primary and secondary, any magnetic delay within the core affecting both coils equally, in figure 3 the separation distance presents a time delay between primary and secondary. This has a profound effect on the system response at high frequencies where that delay is significant.

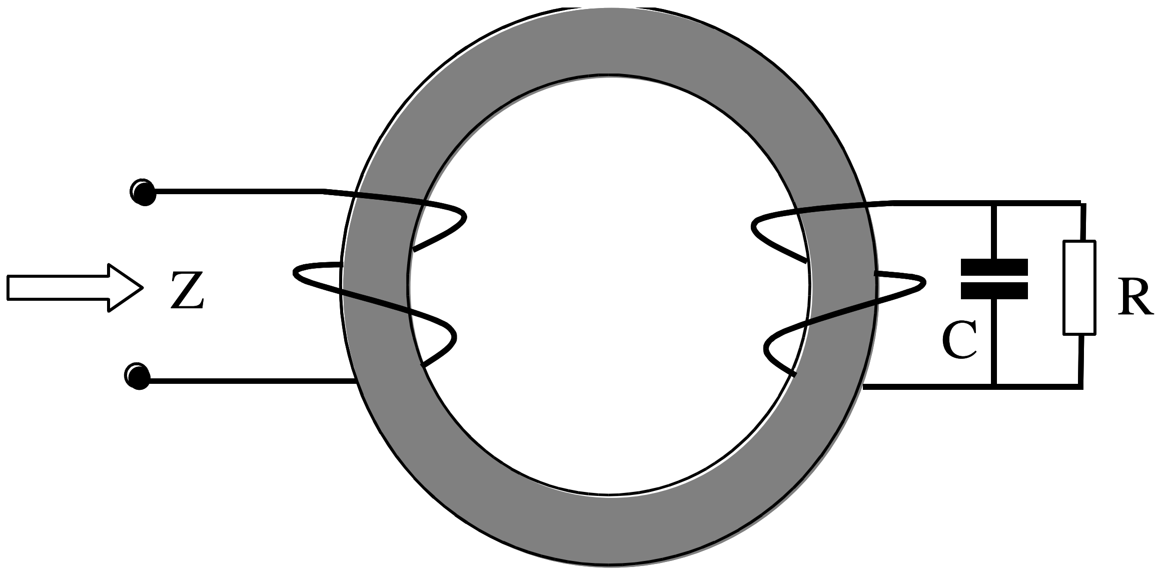
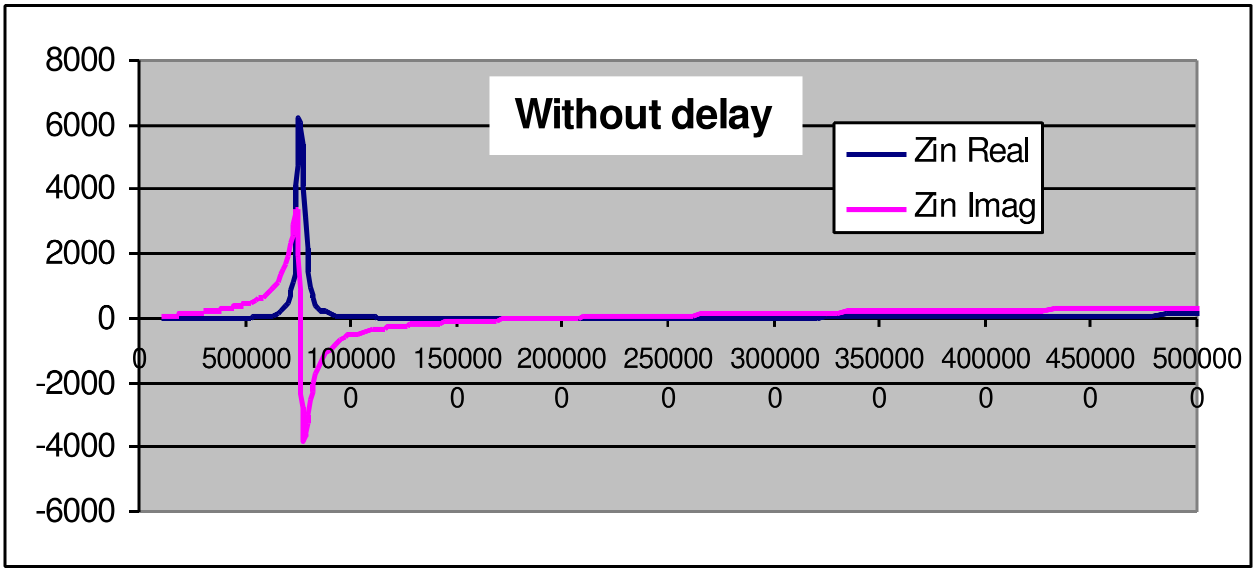


Figure 3. Transformer with Coils Separated.

Now when we examine the response both with and without delay being present we obtain the results shown in figure 4.



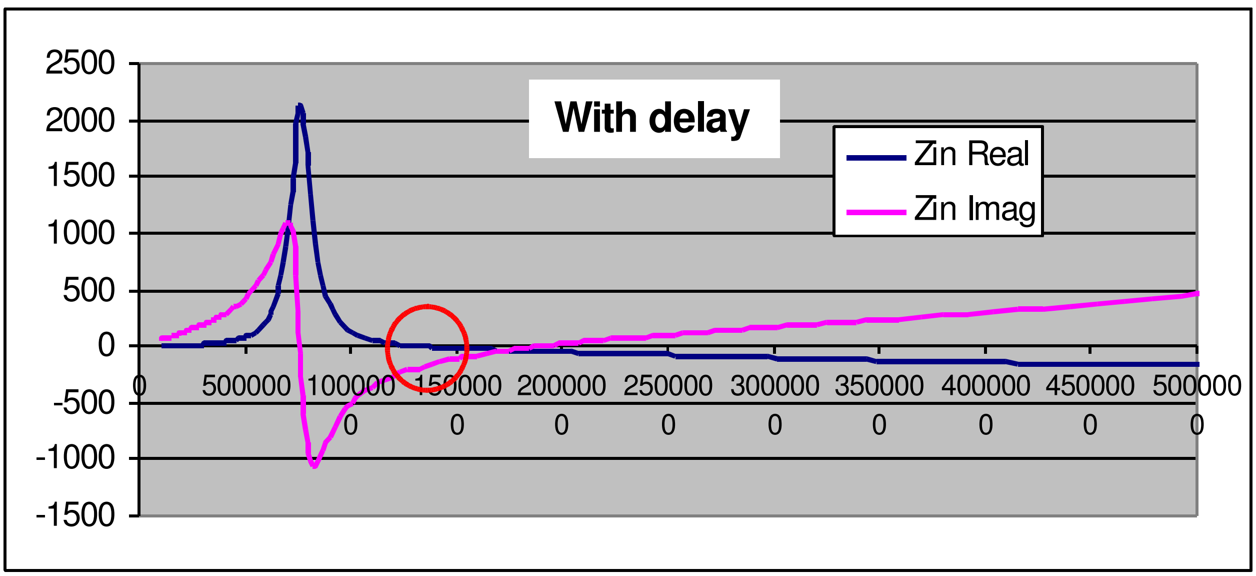


Figure 4. The Input Impedance of Figure 3 With and Without Magnetic Delay.

Again we see the broadening of the frequency response curves but of more interest is the shape of the curves above resonance. Surprisingly we find that the real component of input impedance goes negative (circled). A negative value of resistance represents an energy source, the system can freely oscillate and deliver power to a load. As this revelation seems too good to be true it deserves more investigation, but before doing so it is worth asking the question why has this not been discovered before?

One answer could be that power transformer designers avoid flux leakage which is considered to increase loss, while RF transformer designers avoid flux leakage so as to minimise unwanted feeds to other parts of the circuit, hence they do not use separated coils. Another answer might be that few engineers or scientists are skilled in performing dynamic analysis in the magnetic domain, which is the method used to produce the results above. A third answer could be that there is an additional loss associated with the separation of the coils, and that loss appearing as a positive resistor counteracts the negative value, so the effect is unlikely to show up except in unusual circumstances. There is some lore that Floyd Sweet became interested in magnetic oscillations when he worked for General Electric and discovered anomalous features in ferroresonant transformers. These transformer-like devices were in use in the 1960's as mains AC voltage regulators, and their design required a separate winding that was resonated at mains frequency by shunting with a large capacitor. So it is possible that Sweet discovered this effect, but could not understand its source and his investigations then led him along a different path.

Recently Prof. Turtur has put forward his theories on the zpe derived as a result of his success in creating a motor that operates in an anomalous manner in the presence of a high voltage electrostatic field. The anomalous mechanical power of his electrostatic motor is tiny, but according to Prof. Turtur it could be extracted from the zpe and he puts forward the suggestion that field delay techniques might release this energy. Prof. Turtur has suggested the use of a magnetic field to offer greater power and he put forward a design for a magnetic motor which he thought would do just that, based on his magnetic analysis using finite element techniques. He claims the time delay occurs within the copper used for the coils. Unfortunately that analysis was flawed, but magnetic-domain dynamic analysis has shown that the presence of a time delay due to *magnetic* propagation velocity (which was not included in Prof. Turturs's analysis) *would* create anomalous power. The time delays are far too small for the effect to show up in magnetic motors which can only operate at relatively low rotation frequencies, but when applied to transformers the anomalous effect is strongly predicted to occur. Hence the term "Magnetic Delay Transformer" (MDT).

Magnetic Domain Analysis

As some may know I have strong views on the limitations of the classical equivalent circuit for a transformer which is widely taught and used to this day. It has at its heart an *impossible* "perfect transformer", something that magically, without involving any magnetism, transforms voltage (or current) by the turns ratio (or the inverse of the turns ratio). Attached to this *impossible* device are various resistors and inductors which then account for the imperfections in a real transformer, such as resistive and core losses and the need for a magnetic field. Although the values for some of these add-ons can be derived from first principles, others have to be obtained by performing measurements on a real transformer. The problem with this approach is that it completely hides the real role played by the magnetic field and it is impossible to use the circuit to correctly predict performance outside the narrow envelope around the frequency of the actual measurements. I have adopted a different approach that involves solving the transformer problem in the magnetic domain. This allows the true dynamics of the magnetic field to be included, and offers a model that can predict performance over a wide range.

Magnetic-domain analysis involves the use of well known formula relating voltage and current in the electric domain, but apply them to mmf and flux in the magnetic domain, hence the introduction of "magnetic resistance" (actually reluctance), "magnetic conductance" (actually permeance) and other reactive magnetic impedances obeying electric-like formula (for which there are at present no recognized names). The magnetic circuit of figure 3 coupling the primary coil to the secondary coil has been modelled as a magnetic transmission-line. This transmission-line has distributed series reluctance (derived from core data), distributed series "magnetic reactance" (derived from the core complex permeability data, hence modelling core losses), distributed shunt permeance (hence modelling leakage flux) and distributed shunt "magnetic susceptance (inverse magnetic reactance)" (modelling losses associated with leakage flux). [Note there is now some confusion because of duplication of terms, *susceptibility* χ is commonly used in magnetic materials and *susceptance B* is commonly used as the inverse of reactance in electric circuits. Here we are referring to the circuit value but applied in the magnetic, not the electric domain.] Classical transmission-line formula have then been applied to this circuit to produce the magnetic dynamic performance, which is converted to electrical input and output via the coils, coil current being related to mmf while coil voltage is related to the rate-of-change of flux.

Classical Transmission-line Analysis

Prof. Turtur's description of electric field propagation from a charged sphere as evidence of zpe was really a description of a near-field, which is known to have a reactive impedance (whereas the far-field has a resistive impedance of 377 ohms). The magnetic field in a transformer is also a reactive near-field, albeit not radiative but constrained to travel within a core. Thus we have two methods for modelling the MDT, (a) as an electrical delay-line that has a reactive characteristic impedance or (b) as a magnetic domain delay-line. Classical transmission-line formula have been applied to both methods, with identical results, they both predict an input resistance that goes negative at a frequency above the LC resonance.

Theory v. Measurements

Measurements have been made by Graham Gunderson using a large toroidal core 107mm (4 inches) diameter. It must be said that these did not show the predicted negative input resistance, but nevertheless provided useful data for comparison with the theoretical model. The first significant feature of this comparison concerned the ratio of output voltage to input voltage. It would be expected that this would peak at the LC resonance, but it did not do so. It actually peaked at the frequency where the theoretical model predicted the zero crossing of input resistance. At this frequency the model predicted infinite COP, and this was also the position of maximum (albeit sub-unity) COP in the measurements. The second significant feature concerned the bandwidth of the LC resonance. Although the model included all known core and coil losses, in order to match the measured results it was necessary to also include the magnetic propagation delay. Thus propagation effects were present in the measurements, so there had to be a reason why the model did not match up at frequencies above resonance.

The next step was to explore what additional losses could be incorporated into the theoretical model to make it match the measurements. It was discovered that applying losses to the leakage flux (which being through air was originally considered as loss-less) produced the wanted effect. By trial and error the parameters of this leakage-flux loss were adjusted to the point that the model reproduced results over the frequency range 100KHz to 6MHz. Interestingly these loss parameters did not relate to the core properties, they represented a hitherto ignored phenomenon. It is thought these might be radiation losses, since leakage flux has been seen to affect circuits at a distance.

Conclusions

When magnetic propagation delay is taken into account, theory predicts that a capacitively loaded transformer can produce anomalous over-unity effects at a frequency above the LC resonance. Practical measurements have not yet reproduced this anomaly, but there are clear indications that the anomaly is present but obscured by losses associated with leakage flux. Current investigations are aimed at reducing those losses.