On the Toroidal Coils in the Manelas Device

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1. Introduction

Manelas and Sweet used hard ferrite permanent magnets in the form of one-inch thick billets, six inches by four inches in the other dimensions. When de-magnetized by successive reversals of a diminishing applied field they exhibit a random domain pattern on their surface that has been described as *like foam* or as *similar to the zinc pattern on galvanized steel*. Another form of de-magnetization is to deliberately create a non-random pattern of regular shaped reversed polarity domains, and it appears that is what Manelas tried to achieve. A reversed polarity circular domain is easily impressed onto the ferrite magnet by bringing a stronger NdFeB magnet to its surface. Figure 1 shows such a domain as seen on magnetic viewing film, courtesy of Bran Ahern. (Note:- an obtrusive reflection from a light source has been crudely airbrushed out of the original image)

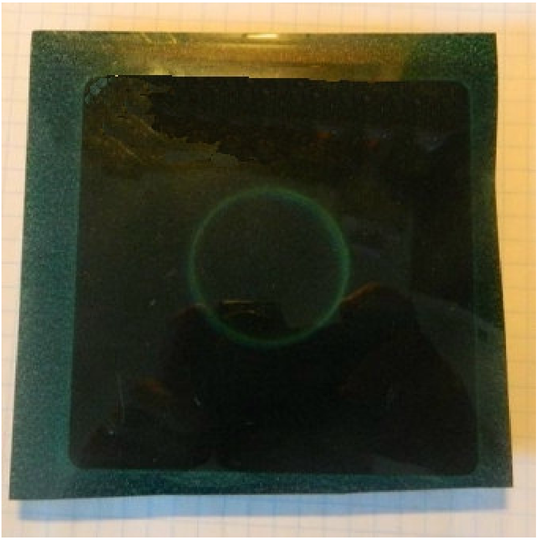

Figure 1. Circular domain induced by NdFeB magnet

Manelas essentially induced five domains, one in the centre and one at each corner. Figure 2 shows his billet as seen by viewing film.

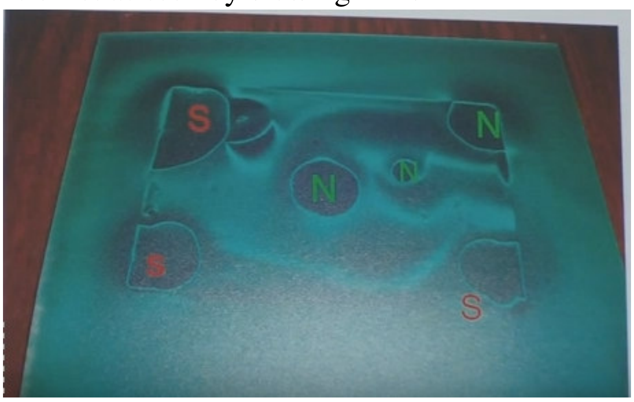

Figure 2. Manelas billet

Manelas had five toroidal coils wound onto ring cores placed close to the surface of his ferrite billet. The coils were pulsed. These toroids were placed over the magnetic domains that had been induced into the surface of the billet, figure3.

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Figure 3. Manelas toroids

2. Control of magnetism in hard ferrite

Like Sweet, Manelas had triaxial coils wound over the billet, the Z coil being wound around the one-inch surface like a picture frame and the X Y coils wound around the other axes (in the Manelas device these are wound over the billet plus toroids). We consider the Z coil to be an output coil sensing changes in the bulk magnetization that is induced by current into the X Y coils, and we offer a new paradigm in the control of magnetism in hard ferrite.

(a) The previously magnetized ferrite is effectively demagnetised (zero flux in a coil wound around the magnetization axis) not by conventional demagnetisation but by a number of reversed polarity circular domains induced in the manner described above.
(b) Each domain is made to expand or contract by application of a crossed field normal to the magnetization axis.
(c) The crossed field is targeted at the dipoles within the domain walls.
(d) Targeting is spatial, the applied field is maximised within the domain walls which for maximum effect requires circular fields coincident with the walls.
(e) Targeting also occurs in the frequency domain as the applied fields are pulsed to obtain dipole flips by precessional reversion [1], the pulse rise or fall times are matched to the Larmor frequency of the dipoles within the domain walls.
(f) Dipole flips within the domain walls initiate a chain reaction in each wall whereby the wall moves an increment in the form of a Barkhausen jump.
(g) A series of Barkhausen jumps create a change of flux in the output coil where induced voltage drives current through a load.
(h) Because of the targeted approach output load energy from each Barkhausen jump exceeds the input energy needed to initiate each jump.

3. Creating a targeted circular field.

A circular field can be created near the surface of a dielectric material by means of a displacement current. Figure 4 shows a circular electrode deposited on the surface with a second concentric electrode of annular form around it. A high voltage pulse applied between the two electrodes charges then discharges the capacitance between them. During the charge and discharge Maxwell's displacement current flows within the material as shown. Just as conduction current creates a magnetic field around it so does displacement current. The magnetic field from this current is shown, it is circular running parallel to the surface and is maximized below the gap between the two electrodes.

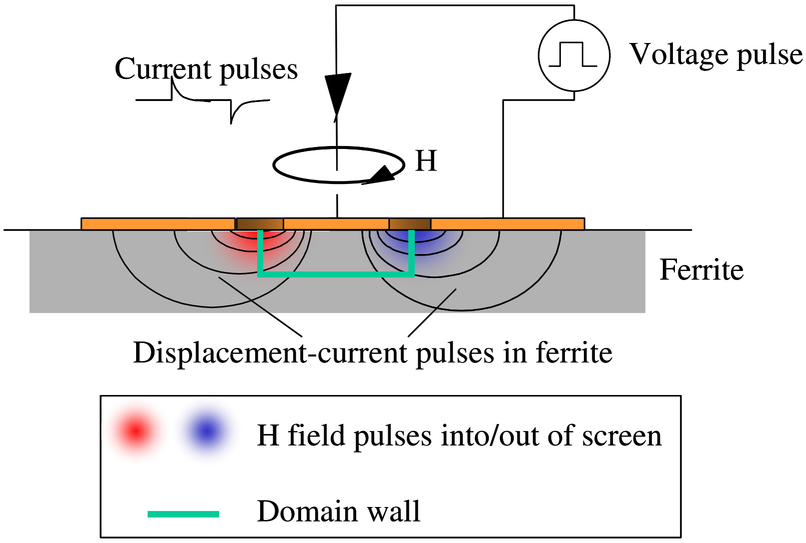

Figure 4. Displacement current inducing an H field.

Also shown is the circular H field around the connecting wire. That field obeys

$$H = \frac{i}{2\pi R} \quad (1)$$

where i is the current and R is the distance from the wire. Equation (1) comes from the more general form equating the closed line integral of H to the surface integral of current density J passing through the H closed line

$$\oint H.dl = \oint J.ds \quad (2)$$

where J can be either a conduction or a displacement current density. For the wire the surface area **s** carrying the current is the cross section area of the wire where $\oint J.ds$ is the current i in the wire. Equation (2) also applies to the displacement current density in the ferrite just below the central circular electrode, where by continuity the RH side is also equal to the current i Thus (1) also applies to the circular H field at the surface of the ferrite running around the electrode but R is now the radius of the electrode. We can obtain the current i from the capacitance C between the electrodes, the pulse voltage V and the rise or fall time τ as $i = \frac{CV}{\tau}$ hence the field H in the ferrite is

$$H = \frac{CV}{2\pi R \tau} \quad (3)$$

Taking some arbitrary (but practical) values if C = 100pF, V = 1KV, R = 12mm and τ = 10 nS we obtain H = 133A/m. That is a significant value for dipole flips in the domain wall.

The current pulses hence also H field pulses can be tailored by using resonant charging and discharging, yielding half sine waves that can be matched to the dipole precession frequency. This also minimises losses. By having different resonance between charge and discharge such as a short charge and long discharge (or vice versa) only one will create the dipole flip. Thus a series of voltage pulses can drive the domain wall in a given direction in a series of Barkhausen jumps, followed by another series of reversed polarity pulses to drive the domain wall back to its starting position. As the domain expands and contracts in this manner the output voltage into the load is thus an alternating voltage at the frequency of the polarity inversions.

An alternative to using high voltage pulses is to supply a time varying magnetic vector potential from a toroidal coil as the electric field source, as described in the next sections.

4. Field external to a toroid.

An energized toroidal coil wound onto a ring core creates a magnetic vector potential field (the **A** field) external to the core. This is shown in figure 5 where the ring core is shown in cross section. Not shown is the toroidal coil on the ring core.

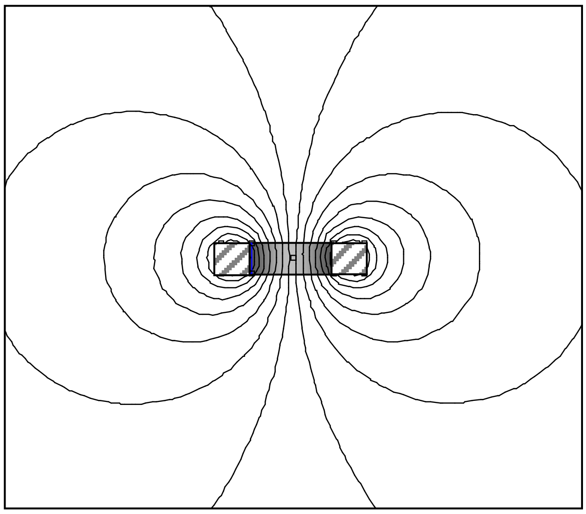

Figure 5 Magnetic vector potential field from ring core

With the toroid placed close to the surface of the ferrite any time variations of the **A** field will induce a displacement current density within the ferrite, as shown in figure 6.

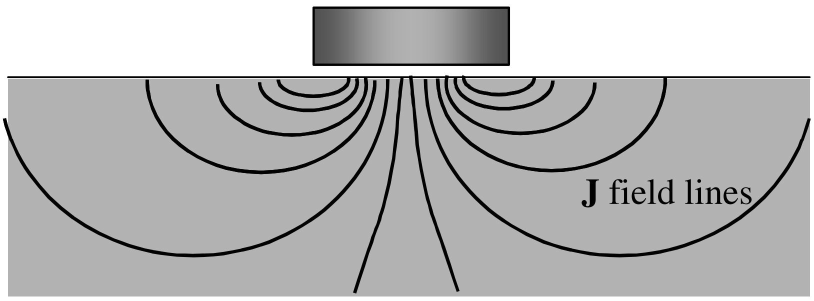

Figure 6. Displacement Current within ferrite

Note the similarity to the displacement current from the surface electrodes in figure 4 where an H field is induced into the domain wall. We should take note that there is a double differentiation taking place for that H field dependency on the current in the toroidal coil. The A field creates an electric field via dA/dt, then the E field creates the J field via dE/dt. Thus a current pulse creates two E field pulses at the leading and trailing edges, then each of those E field pulses creates two J field pulses that in turn produce two H field pulses. Figure 7 shows this situation more clearly for linear rise and fall times of the current pulse.

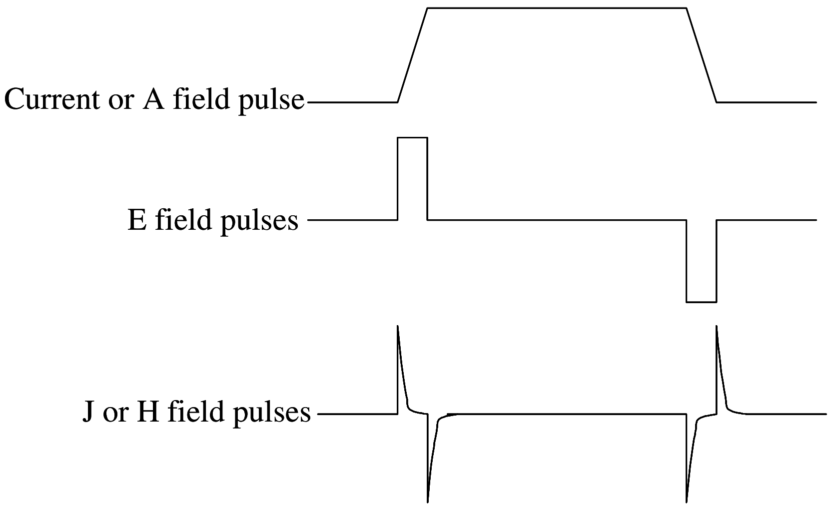

Figure 7. Showing double differentiation

If the current rise and fall is made resonant then the waveforms become as depicted in figure 8, where emphasis is placed on the back edge of the current pulse where it is practical to obtain the fastest fall time.

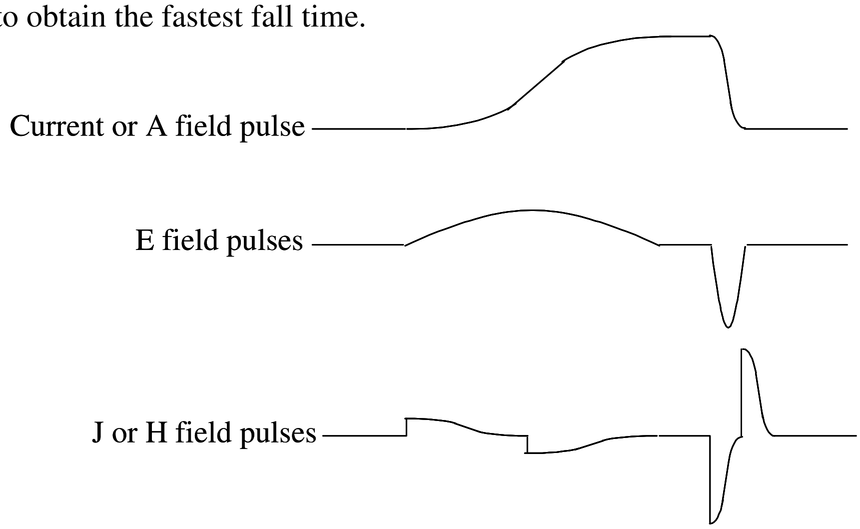

Figure 8. Resonant pulses

It will be appreciated that for sine waves a double differentiation brings in the factor ω^2 where ω is the radian frequency $2\pi f$.

5. Calculations for Manelas toroid.

We don't know the details for the ring core used by Manelas but we can make a reasoned guess of its dimensions as scaled from the images, knowing that the ferrite billet is 6 inches by 4 inches. Taking the OD as 24mm, the ID as 16mm and the height as 4mm, assuming a relative permeability of 1000 and a Bsat of 1T, knowing there are 16 turns we find that only 13mA is required to take the core to saturation. The flux in the ring core is 16 micro-Webers, and that produces an **A** field at the centre of 2 milli-Webers/m. The inductance of the toroid is 82µH,and with that value a pulse fall time of 100nS is feasible. Calculating displacement current in the ferrite requires a knowledge of the relative permittivity of the strontium ferrite, and that varies with frequency from extremely high values at low frequency to a value of about 2 at microwaves. A figure of 20 has been used as a reasoned guess at 10MHz, and unfortunately that yields a circular H field in the billet of only 0.1A/m that is considered too low to cause a dipole flip. Thus it appears that Manelas used his toroids to aid the fields from his X Y coils around the billet, and like Sweet those coils were the main driving force.

The toroidal coils could be used as the main driving force if the number of turns is reduced and the pulse fall time is reduced. Using just 2 turns and a fall time of 10nS, a pulse current of 0.1A produces an H field of 11A/m, and it is believed that could flip a dipole. The toroid inductance is 12µH and the capacitance needed for the pulse fall to be resonant is 8pF, which is practicable. Of course it needs some detailed investigations to see whether this is true.

6. Conclusion

In the Manelas device the X and Y coils will create H fields within the ferrite billet that are normal to the magnetization axis. The X Y coils if pulsed in the correct manner could induce dipole flips within domain walls via precessional reversion. Local coupling to neighbouring dipoles could initiate a chain reaction whereby the domain wall moves an increment in the form of a Barkhausen jump. It is contended that output energy from the voltage pulse induced into the Z coil could be less than the energy needed to flip the dipoles that initiate the Barkausen jump. That this is not generally observed is due to the pulsed H field being applied (via the X Y coils) to the bulk material, and not targeted at the domain wall dipoles, hence energy is lost to the bulk material outside the domain walls. The Manelas toroids have been shown to induce circular H fields within the ferrite billet surface that do not apply to the bulk material, but are targeted towards the domain walls and would support the fields from the X and Y coils, hence raising the efficiency of the system. With improvements to the toroidal system where the toroids are emplaced concentric to circular domain and are designed to handle faster rise or fall time pulses, their induced H fields can be made to flip dipoles directly, hence the x and y coils can be dispensed with. This should raise the efficiency still further and possibly to over-unity. However an even better system creates the targeted H field around circular disc electrodes deposited on the surface of the billet, geometrically aligned with the circular domains. Fast rise/fall time voltage pulses are applied to these electrodes.

7. Reference

[1] "Magnetization Dynamics in Magnetic Nanostructures" Thesis presented by Dana Elena Sorea Stanescu, May 2004