Domain Walls in Anisotropic Ferrite

1. Introduction

This paper looks at the domain walls in modern ferrite material leading to a possible understanding for the anomalous characteristics of the Floyd Sweet and Arthur Manelas devices.

2. Ferrite Manufacture

To obtain maximum permeability of soft ferrites or maximum remanent field of hard ferrites they are produced in a special way. The bulk material is ground down to a particle size that is small enough to preclude the formation of multiple magnetic domains, thus each particle is a single domain. The powder is then put into moulds and sintered so as to reform bulk material; during the sintering process a strong magnetic field is applied so that the magnetic moment of all the single-particle domains align. The final product thus has that alignment permanently frozen in, then variations of the overall magnetization can only occur by 180º dipole flips, the dipoles cannot rotate to intermediate angular positions. This has profound influence on the structure and the dynamics of domain walls.

3. Domain Walls

Domain walls are either Bloch walls or Neel walls, that currently are visualised as in figure 1.

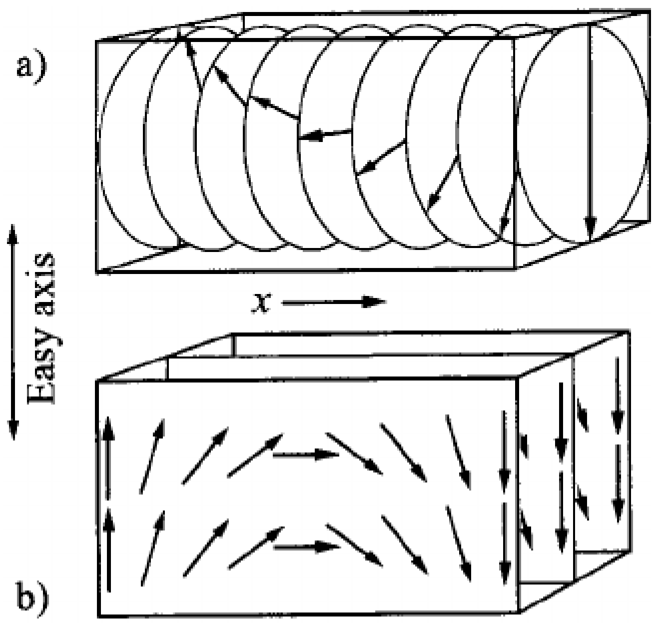

Figure1. Magnetic vector across Bloch wall (a) and Neel wall (b)

In both cases the magnetization vector takes on different angular positions across the wall. The Bloch wall applies to bulk material but here the vectors are seen on thin discs in order to show their variations in 3 dimensions. The Neel wall only applies to surfaces or thin materials, the rotation of the vector lies within the film. Note that in both versions the dipoles take on alignment normal to the easy axis. It is contended that these images are incorrect for anisotropic ferrites, those intermediate angular dispositions of the vectors away from the easy axis are not possible.

Figure 2 shows a domain wall where the vectors of all the grains are parallel, pointing upwards at the left and downwards at the right. At intermediate positions some of the vectors are flipped 180º, with a gradual transition of density from up to down across the wall.

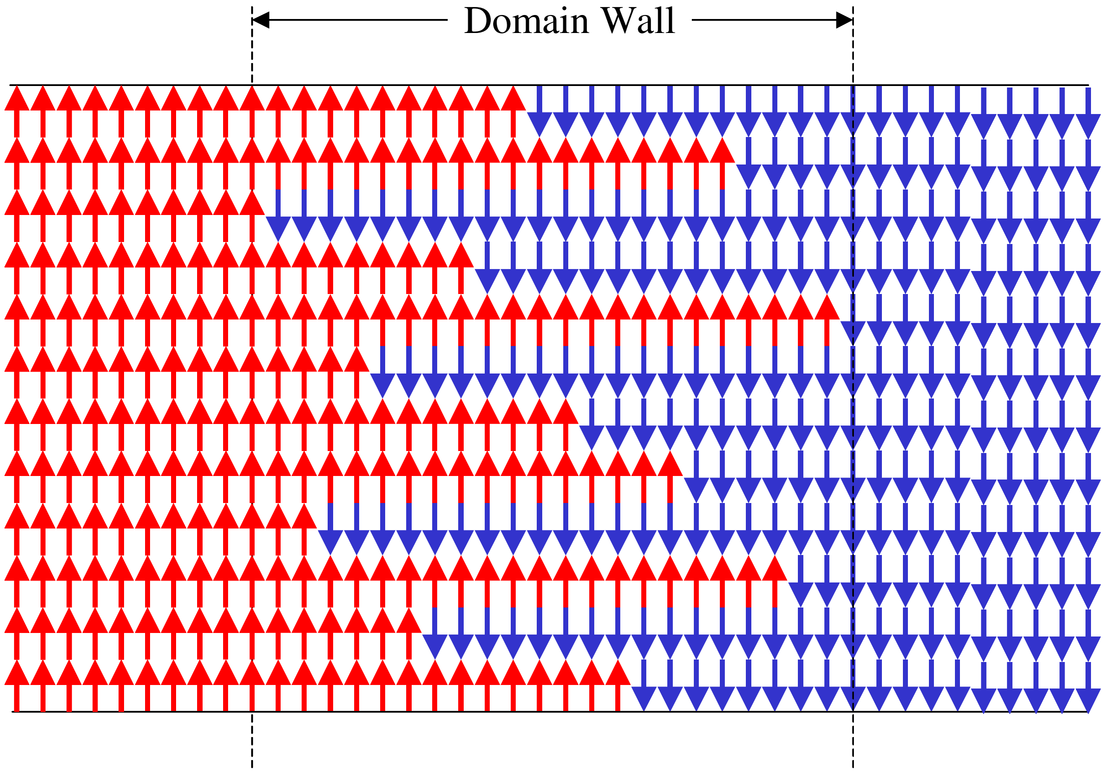

Figure 2. Ferrite Domain Wall

Although the vectors are shown here to be static, they are in fact precessing about their local magnetic field at the Larmor frequency, figure 3.

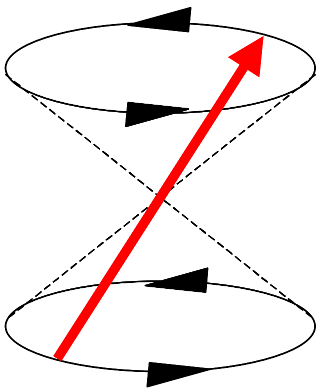

Figure 3. Precessing vector

Figure 4 shows a domain wall with the vectors precessing. Because this shows the vectors in 3 dimensions they appear to have different lengths, but this is just an illusion.

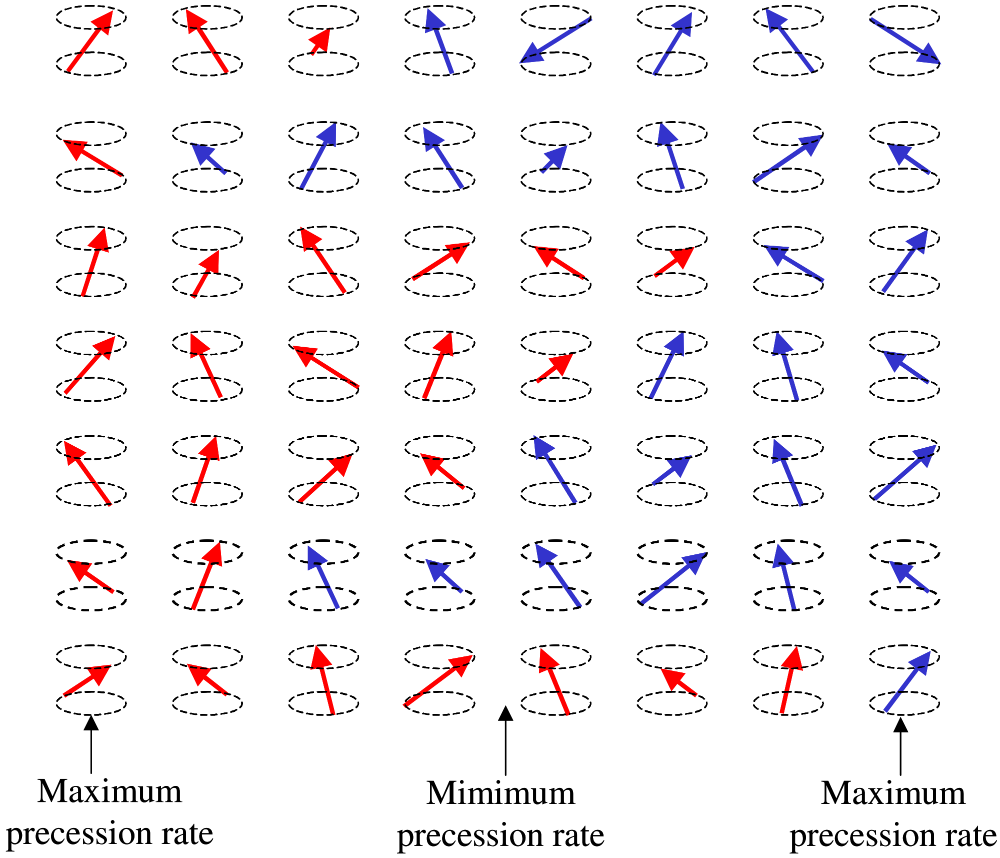

Figure 4. Domain wall showing precessions

The time-average (static) magnetic field across the domain wall is everywhere vertical, upwards at the left and downwards at the right. At the centre it is zero. The vectors precess about this field at a rate (Larmor frequency) determined by the field magnitude. For a domain wall in a hard ferrite the Larmor frequency either side of the wall could be microwave, but within the domain wall it will be much lower. Thus if the ferrite is within an externally applied magnetic field transverse to the magnetization axis (easy axis) and that field is rotating at a sub-microwave frequency it will coherently couple to some of the dipoles that are rotating in the same direction and at the same frequency. Those dipoles will absorb energy from the rotating field and that can cause them to flip. That in turn could affect nearby dipoles creating an avalanche effect (Barkhausen jump) causing the domain wall to move position. The direction in which the domain wall moves would be determined by the rotation direction of the rotating field. This method of driving domain walls is unknown to the author, and is offered as an explanation for the anomalous over-unity feature of the Floyd Sweet and Arthur Manelas devices.

4. Device

The starting point for the device is an anisotropic ferrite slab that is magnetized across its smallest dimension. This slab is then conditioned so as to have a plurality of reversed domains, Figure 5. In the Sweet device this is thought to be stripes, while in the Manelas device it appears to be circular domains. Note that the circular domains are easily achieved by bringing a stronger magnet such as NdFeB into contact with the ferrite.

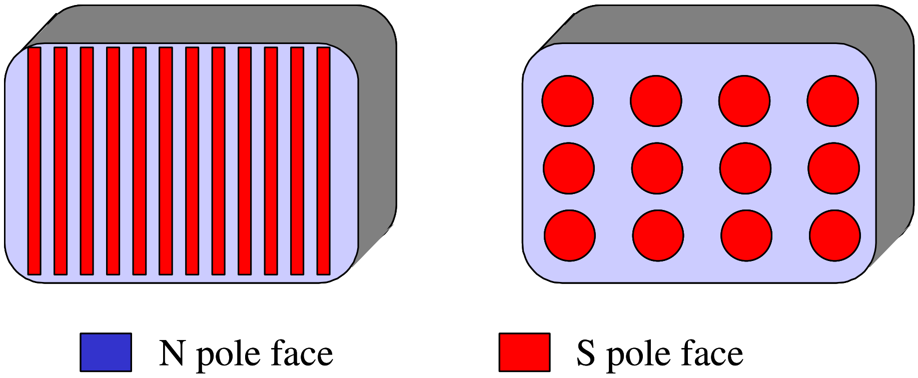

Figure 5. Conditioned magnets

The billet has a coil wound around the thin edges like a picture frame, this is the output coil Figure 6.. It is clear that the total static flux through that coil will be less than that for an un-conditioned ferrite, it could be near zero if the area of the reversed pole faces total that of the non-reversed pole faces. If we now apply a rotating field pulse that causes the reversed domains to expand followed by another pulse that causes them to contract it is clear that the frame coil will endure an alternating flux to produce an induced voltage that can drive current into a load. This rotating field can be produced by two more coils wound around the other two axes of the billet as drive coils.

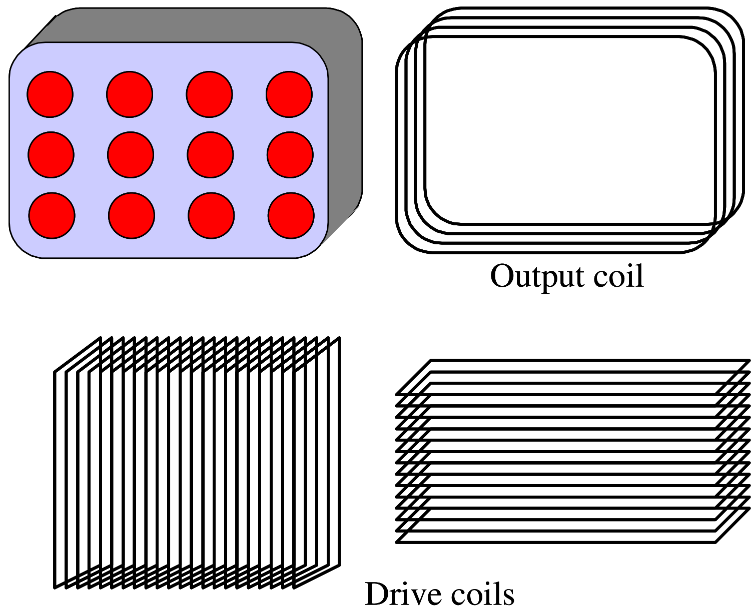

Figure 6. Showing the three coils

The rotating field is produced by having alternating current in the two drive coils but with a 90º phase difference. Since we need to have a set number of cycles with say phase advance followed by the same number with phase retard the easiest way to achieve this is to have one coil permanently fed with AC while the other coil has its phase alternately switched from +90º to -90º, see Figure 7.

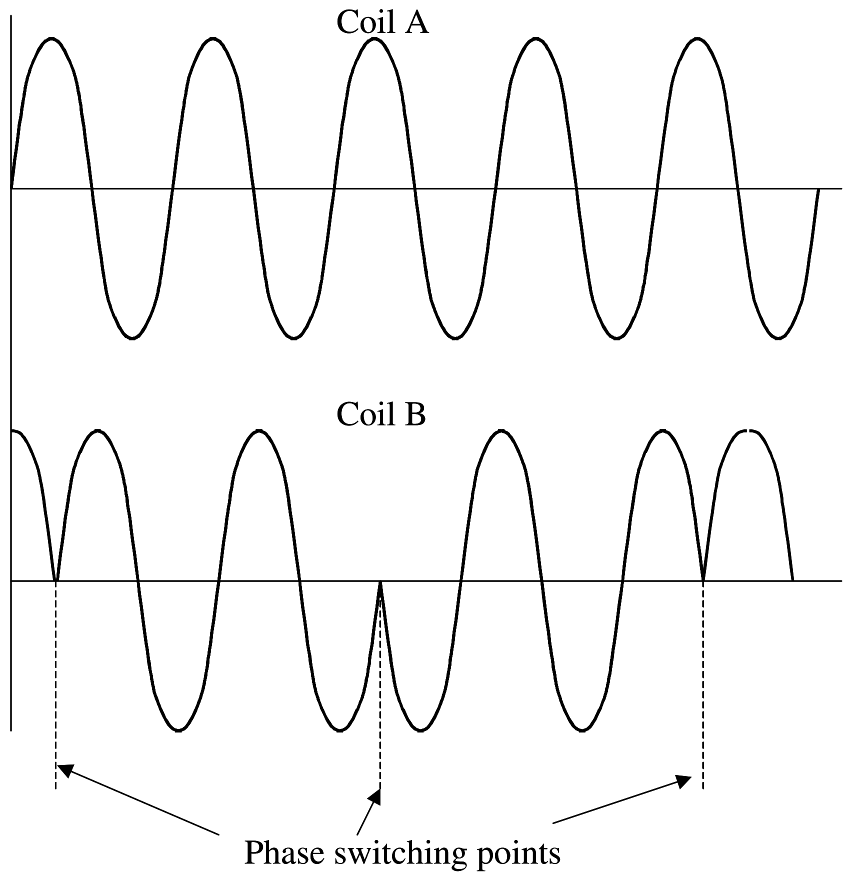

Figure 7. Drive coil waveforms

Shown here as sine waves, the waveforms could also be pulses with appropriate timings, which may explain the complex waveform patterns known for the Floyd Sweet device.

5. Conclusion

A possible explanation for the anomalous performance of the Sweet and Manelas devices has been given. The basis for this is the movement of domain walls in the form of Barkhausen jumps initiated by applying rotating magnetic fields to the precessing magnetic dipoles within the domain walls. Until this explanation is verified by experiment this must be considered as speculative, but it is based on known scientific principles.