UC Davis Counter-Wound Coil Design

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V.3.1

The purpose of this report is to describe some of the subtleties of the UC Davis counter-wound coil design. Throughout the progress made to reproduce the results by Gruber *et al.,* it was clear that one could learn a lot from the simulations in CST. This report aims to further explore the counter wound coil design beyond what was shown in the original paper by Gruber.

The design consists of two coils, separated by 1.5 cm. Each coil has dimensions of 1.8 cm in length, 3.5 cm in width, and 0.63 cm in thickness. One coil is wound clockwise, and the other is wound counter-clockwise. The coil design aims to reduce surface currents due to the oscillating B1 field on the surface of the conducting copper sheet. As nature abhors a change in flux, one can view the magnetic field due to surface currents, as a secondary field, which will oppose the magnetic field lines due to B1, which intersecting with the conducing surface.

A regular surface coil that is wound clockwise will have a magnetic field that points upwards in the center of the coil. If the coil is mounted on the surface of the conducting sheet, the magnetic field lines due to the coil will point upwards on the surface of the sheet. With an oscillating current, the flux on the surface of the conducting sheet is always changing. This change in flux, causes surface currents in the conducting sheet that create an opposing, secondary magnetic field that superimposes itself on the ideal B1 field, to attenuate the experienced B1 field. This attenuated field is unwanted, as a reduction in B1 field intensity will cause a reduction in signal intensity.

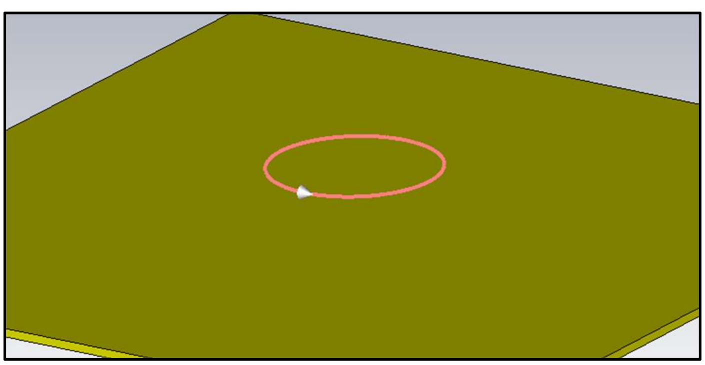

Figure 1: Simple single loop coil wound clockwise.

Below, is an image showing an overview of the coil. Paired with this, is a very useful image of the direction of the magnetic field lines due to the coil.

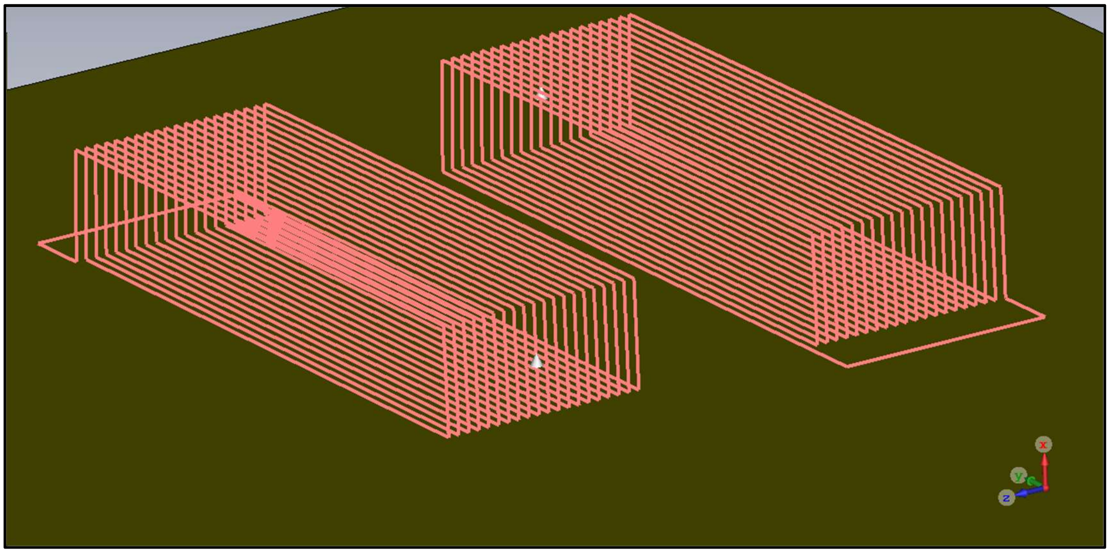

Figure 2: Overview of the coil design.

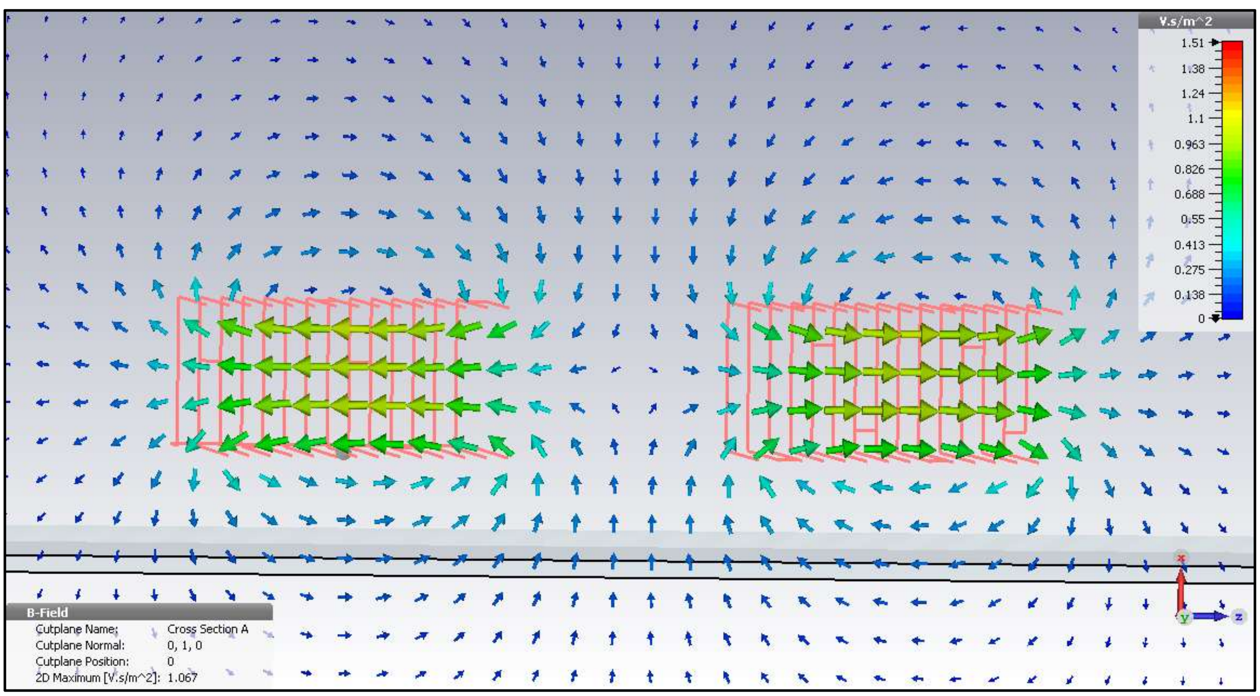

Figure 3: Arrow plot of the magnitude of magnetic field in the XZ plane. This figure is useful for determining the direction of surface currents and how they superimpose themselves on the sensitive spot region.

Figure 3 is a very useful plot which can be used to help one understand the direction of the magnetic field B1 about the coil. This is helpful when trying to understand why this coil design is so useful. As mentioned before, with a B1 field that points upwards on the conducting surface, surface currents in the conducting sheet will create a secondary magnetic field that points downwards. We can see that in the middle of the two coils, at the conducting surface there is a magnetic field that points upwards. This causes surface currents that generate a secondary magnetic field that points downwards. The wonderful part of this design is that we are utilizing the B1 field above the coil, which points downwards. The B1 field above the coil superimposes with the "secondary" field due to surface currents, causing an overall increase in the magnitude of magnetic field B1. Likewise, when the current passes in the other direction, we use the same reasoning to deduce that the magnetic field B1 at the surface of the conductor will be moving downwards, and the B1 field above the coil moves upwards. Since the B1 field is downwards on the conducting surface, this causes surface currents that oppose that field and points upwards. This secondary upwards field superimposes itself on the B1 field above which adds to the magnitude of magnetic field B1. We can now see that with an oscillating field B1, this coil design adds to the magnitude of B1 field, rather than opposing it.

A benefit of this design is the increase in signal due to an increase in B1 field. The signal is proportional to B1 squared, so we may observe the B1 field within the sensitive region to get a perspective on the signal gain due to this design. Below is a plot of the magnitude of magnetic field as a function of h2 (the line that is perpendicular to the surface of the conducting sheet, in the middle of the two coils).

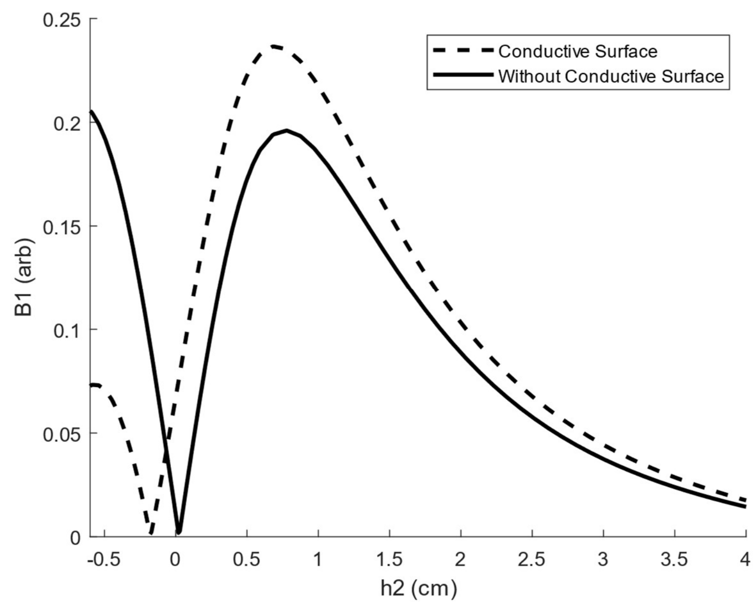

Figure 4: Magnitude of magnetic field as a function of h2 (the line that is perpendicular to the surface of the conducting sheet, in the middle of the two coils). The copper sheet is displaced 6 mm from the bottom of the coil. The bottom of the coil is at h2=0.

The plot in figure 4 was gathered using CST. The magnitude of magnetic field can be seen to be larger with the conducting surface than without. Generating an idea for how much of an improvement the conducting surface makes can be a bit challenging if one considers this coil design to be used with a homogeneous spot unilateral magnet. In this case, we must consider the improvement over a range of h2. For this example, we use the 3-magnet array containing 3, 50x25x18 mm block magnets, with a sensitive spot from 0.52 – 1.45 cm above the surface. By taking the integral of each curve over the 0.52 – 1.45 cm range, we can use those areas to compare the overall improvement to signal within the sensitive region by looking at the percent change in area. By doing this, we see that the percent change is 19.1%. As signal scales with B1 squared, we would expect an approximate increase to signal by a factor of 1.42.

The improvement to signal comes for free, by utilizing the shape of the magnetic field B1 produced by the coil. This design could be a very useful tool in applications where surface currents present a problem.