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Magnetic Field Characteristics of a Magneto-Biosensor Detection coil.

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Abstract.
This study describes numerical modelling of a magneto-biosensor detection coil using a Boundary Element Method (BEM). The Z and X axis magnetic profiles of the coil have been analysed. The model was extended to incorporate paramagnetic particles to evaluate coils Z and X axis detection sensitivity. We obtained a relationship between detection sensitivity and coil geometry specific flux density profiles. A rule was derived to estimate the optimum distance of the sample from the coil and the size of the sample. It has been demonstrated that the simulation tool is a reliable method for fast, accurate modelling of a resonant coil biosensor detecting paramagnetic particles. Results from this study will be used to develop an optimised resonant coil magneto-biosensor.

Introduction.
Novel magneto-immunoassays (MIA) using micron sized paramagnetic particles (PMPs) as the label have been developed at the University of the West of England [1-4] (figure 1) for quantitative analysis of protein or other antigens present in a clinical sample. This paper describes the detection coil, which employs a planar spiral resonant detection coil (figure 2). The system integrates a tuned parallel capacitive, inductive coil circuit with a Phase-Lock-Loop (PLL) detection circuit (figure 3).

Figure 1: Cross section diagram of a sandwich magneto-immunoassay (MIA).

Magnetic Field Characterisation & Detection Sensitivity.
Since flux density, reluctance and coil inductance are related, detection sensitivity to paramagnetic particles will depend on the geometry specific flux density profile of the coil (figure 4). In order to simulate the magnetic flux density distribution, a 2.5 modelling software tool was utilised (supplied by Integrated Engineering Software). This method of modelling allows rapid cost effective analysis, designed to perform cross section simulations of both magneto-static and time-harmonic physical systems. For modelling purposes each coil turn is defined as a concentric track. The coil model was constructed, having 6 copper coil turns, a diameter of 2.5 mm and inductance value of 52 nH. Modelled PMPs had a diameter of 4.5 µm and relative permeability µ of 1.0001. X and Z axis flux density profiles are shown in figures 5 & 6 respectively. Axial detection sensitivity is reported in figures 5, 6 and 7. Figure 8 and 9 show experimental results of PMP Z axial detection and X axis flux density profiles.

Figure 4: Simulated 2-D Contour plot of the flux density distribution of the coil. Figure 5: X axis flux density profile/plots at 5 different distances away from the surface of the coil. Figure 6: Z axis flux density profile from the centre of the coil. Also shown is coil’s inductance response to PMP displacement is Z axis direction.

Conclusion.
A planar spiral inductive coil designed for the detection of PMPs in magneto-immunoassay has been fabricated using thick film technology since it offers the possibility when integrated with a Phase-Lock-Loop control system a low cost, portable magneto-biosensor. A 2.5 model has been constructed using “Oersted” simulation software. Coil’s flux density distribution and axial PMP detection sensitivity has been analysed and experimentally evaluated.

Flux density decays rapidly with 2-axis distance away from the coil’s surface. Maximum sensitivity to PMPs is at the surface of the coil. Highest concentration of magnetic flux is at the coil’s inner turn; in this region PMP detection sensitivity is greatest.

It is evident where detection sensitivity can be enhanced through further investigation of system parameters, such as coil design, sample positioning and spot size. Experiments performed on the bench showed close correlation to simulated results. Results demonstrate that “Oersted” simulation tool could be used to predict coil performance as a magneto-biosensor and aid development of coil configuration and choice of PMP type to optimise detection sensitivity.

References.

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