FINDING THE SENTINEL LYMPH NODE WITH A HANDHELD DIFFERENTIAL MAGNETOMETER

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In cancer staging, the Sentinel Lymph Node (SLN) procedure is a common method to assess the stage to which a cancer has progressed[1]. Currently, the SLN procedure is performed by injecting both a blue dye and a radionuclide tracer near or into the tumor area, and the first lymph node(s) draining the tumor area are located by means of visual inspection and a gamma probe which detects the radiation emitted by the radionuclide tracer. This combined procedure has proven to be very reliable and is used frequently, but suffers from some serious drawbacks that limit its applicability in general practice. These problems are mostly caused by the usage of ionizing radiation, which poses occupational hazards to medical staff and requires extensive logistics, which not all hospitals can offer.

A promising alternative method has been developed[2] which takes a magnetic approach to the SLN problem. This method applies a SPIO tracer which is injected into the tumor area, similar to the combined method. This tracer is then detected with a sensitive magnetometer. However, because of the diamagnetism from the human body, this detection is nontrivial and limited by this background noise. By exploiting the nonlinear magnetic properties of SPIO nanoparticles, we devised a measurement scheme and setup which eliminates these (linear) background signals, allowing for much higher sensitivity and selectivity. By doing this, we combine the attractive features of both methods; the sensitivity and selectivity of the radionuclide tracer are combined with the inherent safety and cost-effectiveness of the magnetic approach.

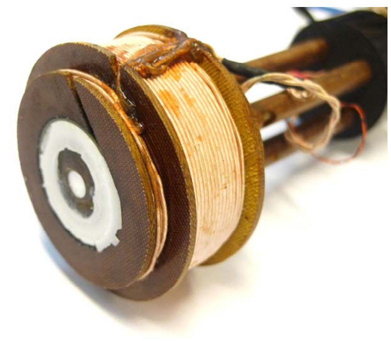

Figure 1. Detail photograph of the *Arthur* prototype handheld differential magnetometer.

Our setup consists of a handheld set of search and excitation coils (Fig. 1) that periodically drive the SPIO nanoparticles towards saturation. By comparing the measured magnetization response for both the saturated and non-saturated signals we get an accurate measure of the amount of tracer material under the probe, a measurement scheme we coined *differential magnetometry* (Fig. 2). Because the magnetic susceptibility of linear media is independent of the applied magnetic field, these signals fall out of the equation and we are left with simply the signal from the SPIO nanoparticles.

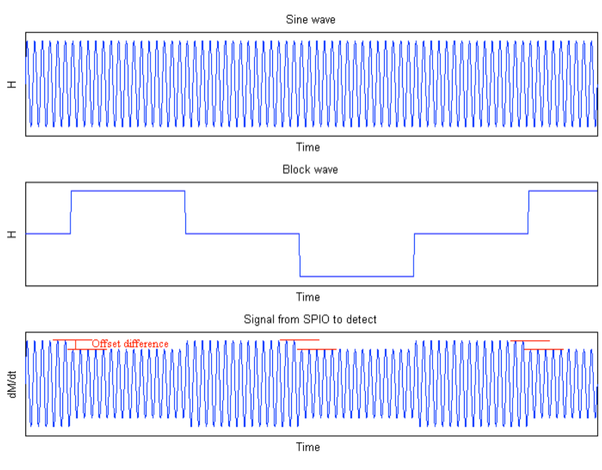

Figure 2. Excitation sequences used in the differential magnetometry protocol. Top: AC excitation signal middle: quasi-DC signal, bottom: resultant induction voltage in the detection coil.

The prototype sensor consists of a concentric set of excitation coils wound around a support structure which houses the detection coil systems. Excitation signals are provided by a set of operational amplifiers controlled by LabVIEW software. The measured induction signal from the detection coils is fed back into the data acquisition system and processed. The periodical nature of our measurement scheme allows us to continuously compensate for any environmental influences like thermal drifts, which improves measurement accuracy.

Using this detection approach we reach sub-microgram sensitivities in phantom studies, whilst being completely insensitive to linear background noise and drifting issues due to temperature fluctuations caused by heating of the coils, which causes problems in normal susceptometry. Studies are currently underway to increase the detection limit to the nanogram level, and focus strongly on the distribution of particle sizes and magnetic moments present in the tracer material, which strongly influences the shape of the derivative of the Langevin curve, which describes the magnetic behavior of the tracer material.

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