nanoTherics

Coil Considerations for Nanoparticle Heating in Magnetic Hyperthermia Applications

Low-cost induction heaters are widely available, typically offering 1 to 3 different frequencies. These frequencies are usually achieved using different coils with varying diameters, and only a few turns. This article comments on the suitability of such systems for nanoparticle heating experiments from the point of view of coil design and magnetic nanoparticle hyperthermia applications.

The simplest issue that seems to be neglected in the use of induction systems for the heating of nanoparticles is the criticality of the positioning of the sample – it is vital that the sample is located at the absolute centre of the coil (both vertically and horizontally) in order for the sample to receive as uniform a field as possible.

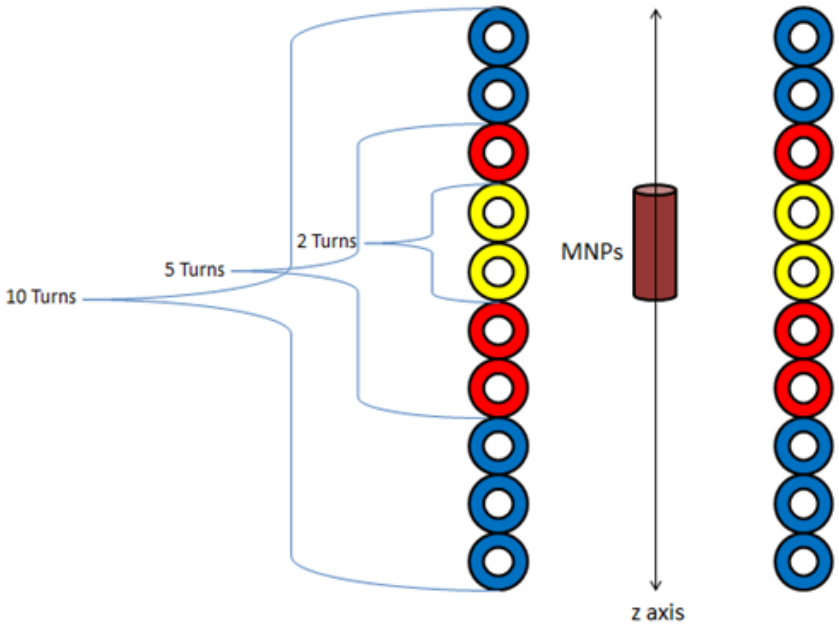

Fig 1. *Sample position in z axis with different number of turns*

Variation in Magnetic Flux Density

As can be seen in figure 2, the magnetic flux density will vary significantly with the vertical z positioning height of the sample within the coil. Unless the positioning is identical each time a coil is used, the data obtained will be far from ideal.

Another very pertinent observation from the data below is that the actual field strength and flux density will change significantly when using coils of different turns and lengths.

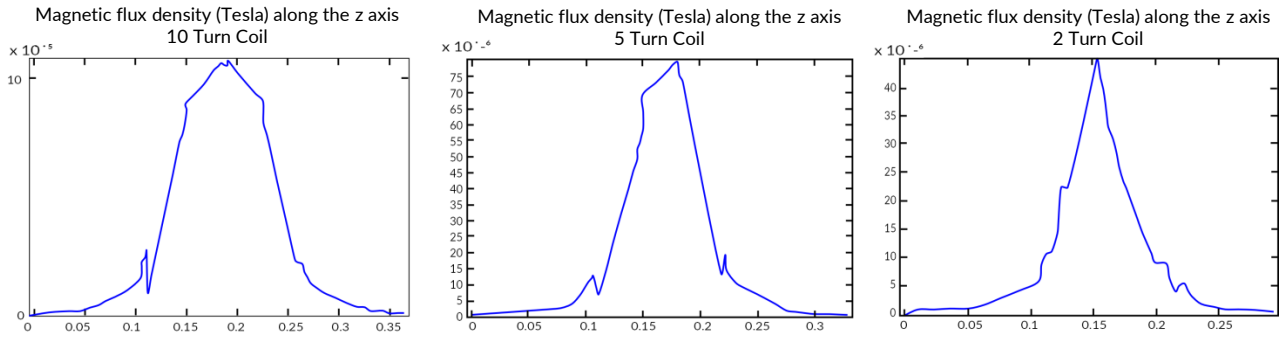

Fig 2. *Calculated magnetic field strength along the z axis with differing number of coil turns*

When a basic induction system is used to measure SAR/SLP/ILP, different coils (with different diameters, lengths and number of turns) are used to offer a selection of different frequencies.

This will have an effect on the magnetic field, in terms of strength, density, and particularly homogeneity, which will vary significantly between different coils and coil geometries. This will obviously impact the values obtained and calculated for SAR/SLP/IP.

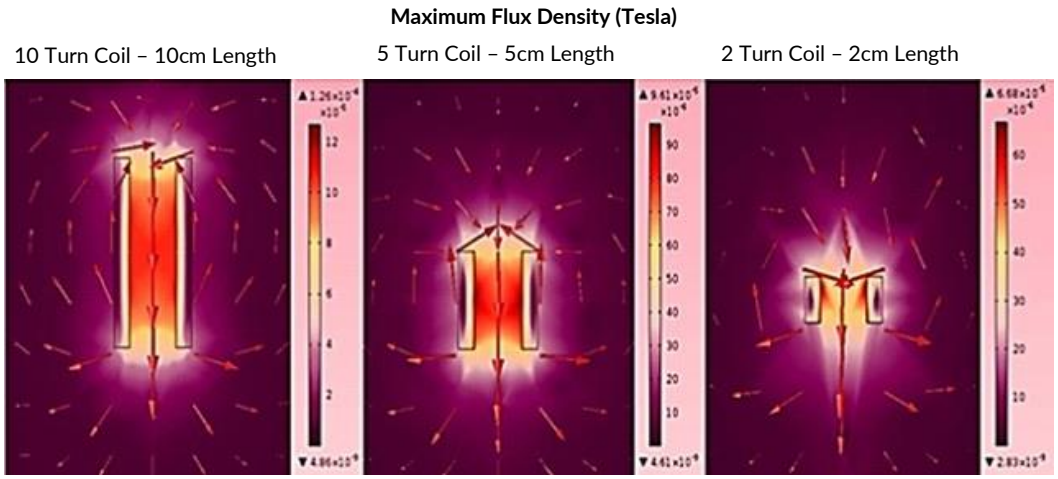

Fig 3. *Finite element method analysis for magnetic field intensity within excitation coils of different number of turns - Left - 10 turns, Centre - 5 turns, Right – 2 turns*

The simulations illustrated in figure 3 clearly show that the homogeneous magnetic field strength experienced by a sample is very narrow for a shorter coil with fewer turns, compared to a longer coil with a higher number of turns.

Based on the homogeneity of the magnetic field for different turns of coil, it is evident that a sample exposed to the centre of a coil with a low number of turns and a larger diameter, wound compactly, will experience different magnitudes of field intensity than with a coil having a higher number of turns at the same diameter where the homogeneity would be better.
This becomes a major issue when comparing the SAR values obtained with different coils with different geometries (number of turns, length, coil spacing etc.), even though the frequency and magnetic field may seem the same.

This is particularly true with induction heat treatment type systems that provide several different frequencies via “interchangeable” coils with different numbers of turns and different geometries. Even a single, compactly-wound coil that is “stretched” so that the winding is not so compact, would result in a different inductance value, a shift in resonant frequency, and also changes in field strength and homogeneity.

The importance of maintaining consistency with coils when making comparative experiments cannot be overstated, as there are already significant issues when comparing frequencies, field strengths and SAR values.

Solenoid Coils in magneTherm Systems

In order to overcome this hurdle and allow researchers to perform calorimetric, in vitro or in vivo experiments appropriately, the magneTherm system from nanoTherics comes with just two custom designed coils that each achieve 5 discrete frequencies each ranging from 100 kHz to 1 MHz.

A 9 turn coil that can achieve	A 17 turn coil that can achieve
175 kHz	110 kHz
260 kHz	165 kHz
520 kHz	330 kHz
740 kHz	470 kHz
990 kHz	625 kHz
at up to 25 mT	at up to 23 mT

This feature of the magneTherm system differentiates it from basic induction heaters, and makes it fit for purpose when performing nanoparticle heating experiments. The coil geometry used allows the user to perform calorimetric, in vitro and in vivo experiments with a single system, and directly compare the results obtained at different frequencies with confidence.

This is especially true when researchers want to perform proof of principle experiments as shown in figure 4.

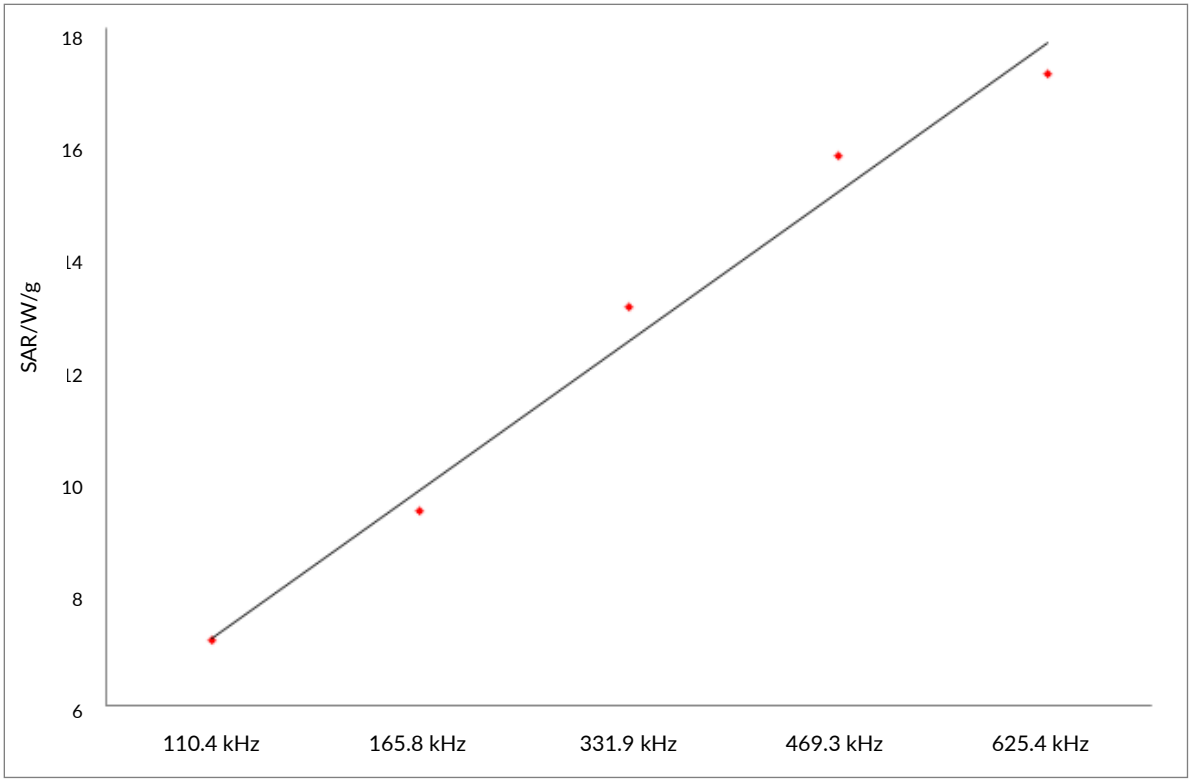

Fig 4. *Increase in SAR value over increase in frequency at 6.4mT in a 17 Turn Coil for 15nm magnetite stabilised in DMSA at a set field strength*

Commercially available induction heating systems utilising different coils to achieve different frequencies should not be used by scientists to perform comparison experiments like the one shown above. The differences between their coils render them unsuitable for such calorimetric experiments,