A Hemispherical 8 Independent Element Probe suitable for Transmit SENSE at 7T

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Introduction A novel head coil is proposed for imaging the head at 7T. This coil's hemispherical geometry and strip lines short-circuited at the open end are chosen in order to reduce SAR in the shoulders while maintaining image quality in the head, and simulations are presented which demonstrate this. The coil consists of eight independent strip-line transmission elements; each tuned to 300MHz and matched to 50Ω. Decoupling of these elements is achieved through the combined use of an electrical and magnetic screen placed between the elements and a discrete component decoupling circuit. Current hemispherical head coils utilise four elements, and thus do not require decoupling [1].

Methods The geometry of this coil is shown in figure 1. Eight curved transmission strip-line elements are arranged radially to create a hemispherical shape. The radius of curvature of the elements is 155mm, ensuring that the resulting hemisphere has sufficient volume to accommodate a human head. A hemispherical screen (radius 175mm) is placed behind the transmission elements. Ceramic variable capacitors placed near the apex of the coil tune the individual elements to 300MHz. A second set of ceramic variable capacitors move the maximum current position of each element so that it lies close to the element's top (the end furthest from the apex). Each element is approximately ¼ wavelengths long with the electric field null 4cm from the top. The 50Ω impedance point is 1 cm away from the null point and this is where each element is driven.

SAR simulations were performed for both the hemispherical coil and an eight-element birdcage coil using XFDTD (Remcom). The elements were all driven by 300MHz sinusoidal currents, with each of the elements being 45^0 out of phase with its neighbours. In each simulation the maximum SAR from the entire model, the average SAR, and the maximum 10g averaged SAR in both the head and the shoulders were measured. Both simulations were scaled so that each coil was creating a 0.7μT B_1 field in the centre of the head, in order to make their results directly comparable. The geometry of these simulations are shown in figure 2.

A prototype was constructed and a network analyzer (Hewlett Packard 8751A) was used to tune and match the elements individually (while all other elements were left open-circuited). The network analyzer was used to measure the strength of the different coupling interactions, referred to as coupling cases A, B, C and D, where A is nearest-neighbour coupling, B is next nearest-neighbour, etc. It was determined, as expected, that the case A coupling was the strongest and therefore had to be eliminated first. Two nearest-neighbour elements were tuned and matched while the rest were left open-circuited. Resonance splitting could be observed in the reflected power spectra of both tuned elements. Case A coupling was reduced with an earthed electrical and magnetic screen, approximately 2cm tall, placed in between the two elements. The introduction of this screen eliminated the resonance splitting from the reflected power spectra of both elements. Sufficient decoupling had not been achieved however, as driving one line with a radio-frequency (RF) signal still caused both elements to transmit RF signals. Case A coupling was significantly reduced by driving the elements through a decoupling interface, as detailed by R.F. Lee et al.[2], with the screen in place. Total decoupling of up to -35dB between nearest-neighbour elements was achieved.

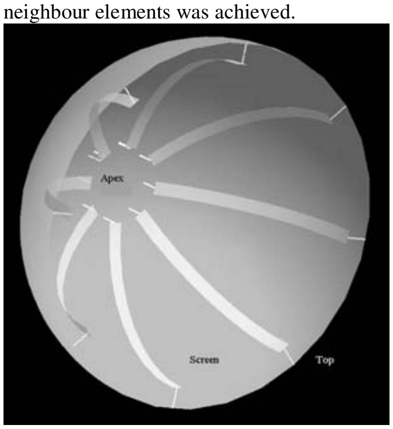

Figure 1 – Coil geometry

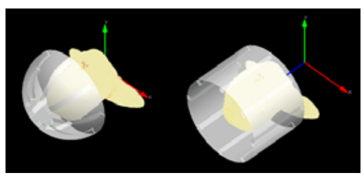

Figure 2 – SAR Simulation Geometries

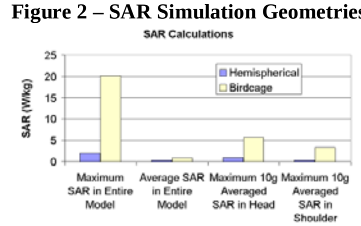

Figure 3 – SAR Simulation Results

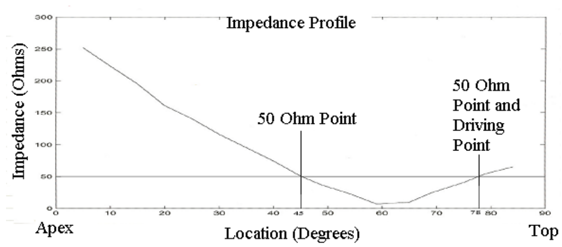

Figure 4 – Impedance Profile of an Element

Results From the SAR simulations (see figure 3) it can be seen that the SAR produced by the hemispherical coil are significantly smaller than the SAR produced by the birdcage coil. Maximum SAR is around nine times smaller in the hemispherical coil, the average SAR is three times smaller, the 10g averaged SAR in the head is four times smaller and the 10g averaged SAR in the shoulders is eleven times smaller. The frequency splitting has been measured between different pairs of tuned elements. From this splitting the coupling constants for the different coupling cases have been calculated. In all cases the coupling was strong, i.e. each split resonance peak moved a different amount from the tuned frequency of 300MHz. This resulted in two different coupling constants for each case. When comparing the relative coupling of each case, the average coupling constant was taken. Figure 4 shows the measured impedance profile of a single element. The 50Ω points are clearly indicated, as is the location where the element is driven. The strong electric fields from each element near the apex of the coil cancel out, while the fields near the top (i.e. near the shoulders) are sufficiently low to produce a relatively low SAR in the shoulders.

Case	K_1	K_2	K_{AV}
A	6.7×10^{-3}	5.1×10^{-2}	2.9×10^{-2}
B	2.0×10^{-2}	6.6×10^{-3}	1.3×10^{-2}
C	0	3.4×10^{-2}	1.7×10^{-2}
D	3.4×10^{-2}	6.6×10^{-3}	2.0×10^{-2}

Table 1 - Coupling Measurements

Conclusions Simulations have shown that the SAR produced by the hemispherical coil are significantly smaller then the SAR produced by a birdcage coil (which is as similar to the hemispherical coil as possible). It has been found that the strongest coupling is that of case A (nearest-neighbour). It has also been demonstrated that it is possible to reduce this coupling considerably (-35dB) through the use of a screen and decoupling interface. Now that decoupling has been achieved, a second prototype shall be built using high-power components, thus making it suitable for imaging.

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References [1] Wolfgang Driesel, Toralf Mildner, Harald E. Moller *A Microstrip Helmet Coil for Human Brain Imaging at High Magnetic Fields* Concepts Magn Reson Part B (Magn Reson Engineering) 33B:94-108 (2008)
[2] Ray F. Lee, Randy O. Giaquinto, and Christopher J. Hardy *Coupling and Decoupling Theory and Its Application to the MRI Phased Array* Magnetic Resonance in Medicine 48:203-213 (2002)