V-Cage and V-Array: Novel coil structures for higher field strengths

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Introduction:

A novel design for coils at high and ultra high field strengths is presented. Simulations done with a full-wave solver for cylindrical problems suggested, that with increasing field strength the well known bird cage antenna design becomes a less suited antenna to maximize SNR at the center of the sample. This can be attributed to phase delay effects in the object under investigation which increase with frequency. A simple modification in the antenna structure can in part compensate for this phase delay: Instead of using straight B0 directed rods for bird cage and array designs, we suggest the use of V-shaped rods.

Methods:

Fig. 1a and 1b show simulated real parts of optimum magnetization densities for a cylindrical structure with 30cm diameter and a conductive cylindrical load with 28cm (εr=58, σ=0.3), calculated for 1.5T (63.6MHz – Fig. 1a) and 3T (123.7MHz – Fig. 2b).
In Fig. 1a and b, z direction (B0) is left-right and azimuthal direction is up-down. The calculations were done using an analytical full-wave solver for homogeneous cylindrical structures [1-4]. As can be seen, at 1.5T the optimum magnetization density appears oval shaped and can be approximated by a bird cage type magnetization density (pulse shaped in z direction and sinusoidal in azimuthal direction). Which is to confirm that a bird cage is a close to optimum structure for imaging cylindrical objects at 1.5T. At 3T however, the optimum magnetization density is "V" shaped. This can be explained by a significant electrical phase delay in the object which has to be compensated by adding an equivalent and inverse directed geometrical phase to the surface magnetization density.

In conclusion, higher SNR at the center of a cylindrical coil or array can be achieved by twisting the z directed antenna legs in a V shaped fashion. The optimum twist angle is a function of object geometry, conductivity and susceptibility as well as the field strength. Figs. 2a and b show well known bird cage and rectangular loop array geometries, while Figs. 2c and d show the modified V-cage and V-array geometries for improved SNR at higher field strengths. Note that the optimum twist angle for lowest SAR at the center in the transmit case will have same magnitude but opposite sign compared to the optimum twist angle for highest SNR at the center in the receive case. Further optimization in SNR could be done by also tapering the z directed current in order to get closer to the optimum magnetization density. Also, in TX case, a different twisting scheme could be used to improve B1 homogeneity at the cost of increasing the global SAR to some degree.

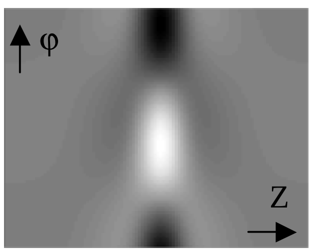

Fig. 1a Optimum surface magnetization density at 63MHz

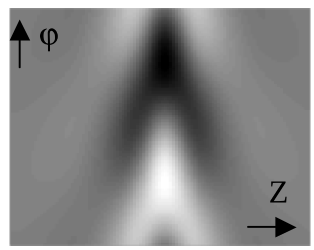

Fig. 1b Optimum surface magnetization density at 123MHz

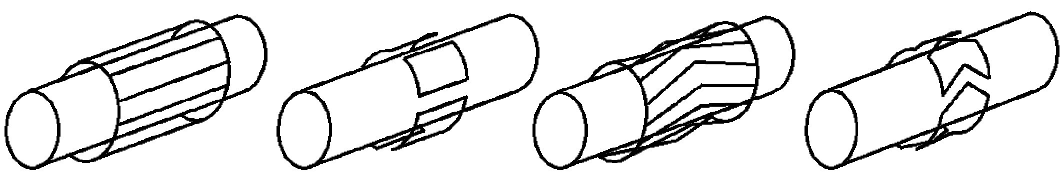

Fig. 2a Bird Cage **Fig. 2b** Rectangular Loop Array **Fig. 2c** V-Cage **Fig. 2d** V-Array

Results and Conclusions:

In order to prove the feasibility, two cylindrical 8 channel arrays for 3T (123.2MHz) were build: Both arrays have same diameter (30cm) and length in z (25cm). The first array consists of 8 rectangular elements and the second of 8 V-shaped elements with a twist angle of 45° between center and ends of the legs. Both arrays were build with geometrically decoupled neighboring elements, as well as isolating preamplifiers.

The simulation predicted a possible increase of 8% in SNR for the V-array over the square loop array. First measurements done with both prototype coils on a 3T Siemens Trio scanner with Total imaging matrix technology confirm feasibility of the V-cage and V-array approach for higher field strengths. However, more results have yet to be obtained with even higher twist angle (90° or more). In addition to that, simulations indicate that at 7T SNR improvements of over 20% can be achieved. The V-cage or derivatives may also be useful in improving B1 homogeneity in the central transverse plane at the cost of somewhat higher global SAR.

References:

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