Comparison of Coil Realisations for Applications Employing Parallel Excitation

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Introduction Various coil geometries have been proposed as transceiver elements in volume coil arrays for parallel excitation (PEX) and reception. Among them are TEM resonators [1], shielded surface coils [2], current sheet antennas (CSA) [3] and ReCav [4] structures. We compare these well known geometries with a printed bow-tie structure which is frequently used in antenna engineering because of its beneficial properties such as low cross polarization, high gain, high bandwidth and compact dimensions [5]. Figure 1 shows the bow-tie structure without the backing RF shield and the surface current on the structure. Because of the triangularly extending legs, the current and hence the magnetic field spread further out in space compared to the TEM resonator. The third leg of the triangular structure serves as distributed capacitance with the ground plane. However, to achieve resonance and the highest possible sensitivity, lumped capacitors may have to be added on both sides.

Methods The comparison is carried out by first optimising and evaluating the single element and then analysing array performance. Because of the similar field distribution of TEM, CSA and ReCav structures, only the former is considered in the comparison. As explained in [6] optimising a single element requires a constrained approach. In this case the desired magnetic excitation field strength ($|\mathbf{H}_1^+|$) on the coil axis is first set to 1 A/m at a penetration depth of 50 mm (roughly ¼ of the head diameter) for a unit current. The structures are then optimised for SNR while maintaining the defined sensitivity. Once the geometry of the single elements is determined, two equiplanar elements are arranged in an array (centre to centre distance 150 mm) to evaluate coupling and array performance.

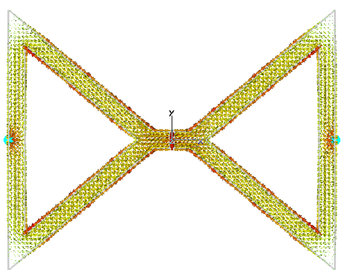

Figure 1 Bow-tie structure and surface current distribution for centre feeding and resonance.

Results To achieve the desired field strength, a spacing of just 5 mm between ground plane and structure was required. For optimal shielding of the electric fields from the load the strip width was adjusted to 7.5 mm. Figure 2 shows the simulated transmit sensitivity $|\mathbf{H}_1^+/I|$ and electrical field strength $|\mathbf{E}|$ in a plane parallel to the coil surface. Geometry factor maps in the same plane for twofold acceleration are also shown in Fig. 2. Finally, coupling between the coil elements is shown in Fig. 3.

Discussion Compared with the TEM resonator, the bow-tie structure shows a broader field-of-view whilst maintaining the desired property of constraining the electrical field between shield and active structure. At the same time coupling between array elements is significantly lower than when using non-overlapping surface coil arrangements. Although it has been speculated that coil coupling for transmit elements is not of importance since it is accounted for by acquiring $\mathbf{B}_1^+$ maps [7], it prevents the designer from optimising array performance. Especially designing the array for low SAR becomes very tedious in the presence of strong inter-element coupling. In addition, optimal arrays require spatially-selective individual elements in transmit and receive operation - to avoid the system matrix used for pulse design or image reconstruction to be badly conditioned. The bow-tie structure known from antenna engineering also shows some beneficial properties in its near field properties and may be employed in (high field) MR arrays.

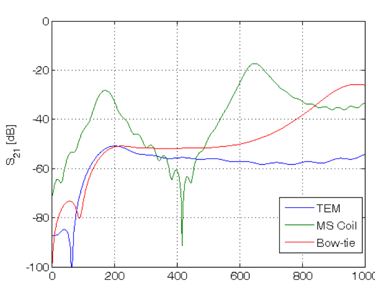

Figure 3 Coupling between neighbouring elements.

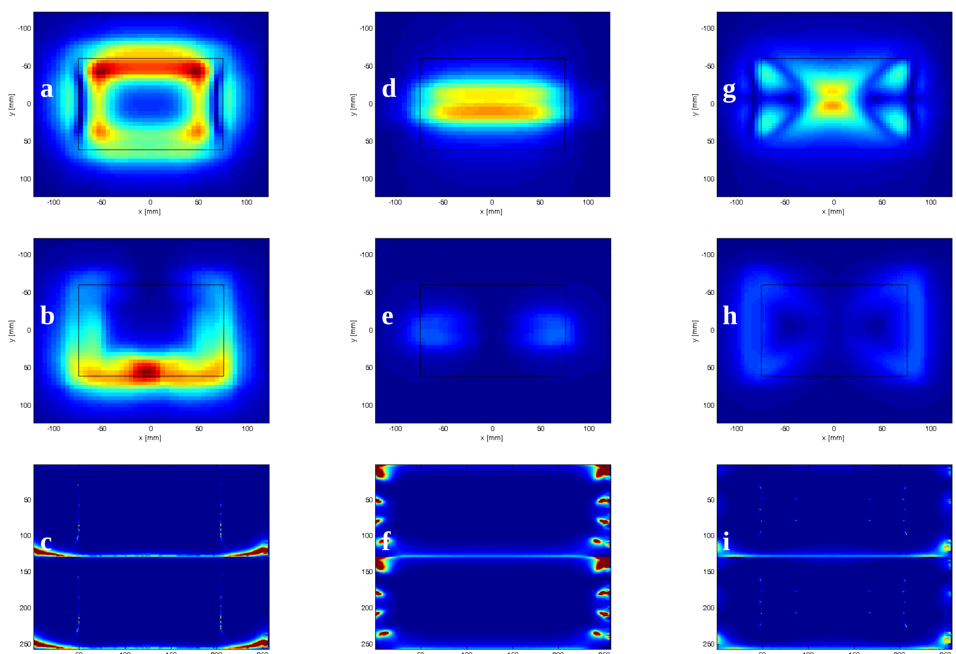

Figure 2 Sensitivity (*top row*), electrical field strength (*middle row*) and geometry factor for twofold acceleration (*bottom row*) of the shielded microstrip coil (**a-c**), the TEM resonator (**d-f**) and the bow-tie structure (**g-i**).

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References [1] G.Adriany et. al. MRM 2005;53:434-445 [2] T. Vaughan et. al. Proc ISMRM 2008:37-39, [3] Junge et. al. Proc ISMRM 2004:41 [4] F. Liu et. al. Concepts in Magn. Reson. 2005;24B:28-38 [5] A. A. Edelek et. al. Microw. and Optical Technol. Letters 204;43:123-126 [6] O. Ocali, E. Atalar, MRM 1998;39:462-473 [7] P. O. Brunner, K. P. Pruessmann, Proc. ISMRM 2008:354