B1+ distortion by residual currents in decoupled Receive arrays

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Target Audience: RF engineers, designers of RF body coil and receive coil arrays.

Purpose: The purpose of this investigation is to examine the B1+ uniformity distortion due to the presence of complex decoupled receive arrays inside the body transmit coil at 127 MHz. The B1+ distortion will result in a non-uniform flip angle distribution, changes in contrast over the slice, and possible inability to do accurate water/fat separated images.

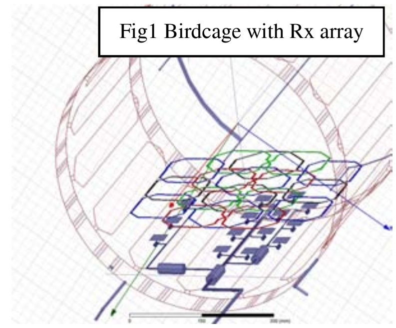
Fig1 Birdcage with Rx array

Method: A full size (60 cm bore, 60 cm long) 3T whole body high pass RF birdcage coil was modeled in a FEM analysis tool (HFSS, Ansys). Inside the body coil was a 14 channel receive array 15 cm below isocenter, consisting of 4 butterfly coils (260 by 120 mm), 6 single loops (125 by 125 mm) and 4 single loops (150 by 150 mm) as shown in fig1. Where traces overlapped in the array, there was a 2 mm gap. Each element was decoupled by 2 parallel resonant 3 Kohm blocking networks. (orange dots in fig 4). Ground planes on preamp feed boards as well as preamp output baluns were accurately modeled. Coaxial cable bundles and cable baluns (1) were also integrated in the model. Baluns were accurately tuned to the frequency of the transmit field. The body coil model came with drive cables for the RF as well as DC. S parameter analysis was performed on the body coil to check for detuning due to coupling with the receive array. The body coil was then tuned back to the larmor frequency. B1+ and E field component plots were generated in all 3 cardinal planes, as well as a high resolution plane 5 mm above the receive array. The RF current density in the receive array and cables / baluns was also investigated. The birdcage and receive array modeled were built and tested. B1+ uniformity was studied as a function of number and location of blocking networks, as well as the vertical distance between traces of elements in overlap regions to understand the variation as a function of parasitic capacitance.

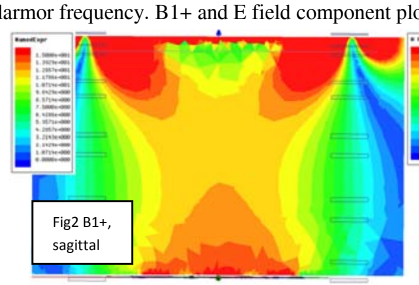
Fig2 B1+, sagittal

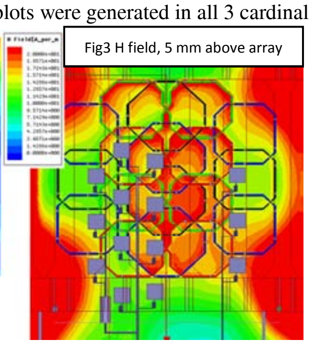
Fig3 H field, 5 mm above array

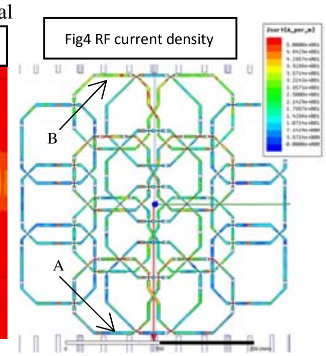

Fig4 RF current density

Results: Simulation: the resonant frequency of the body coil's uniform mode shifts 400 KHz down when inserting the receive array, cables and baluns. The IQ isolation in the body coil remains <-20dB. The Body coil is retuned to compensate for the 400 KHz frequency shift. Fig 2 shows B1+ in a sagittal plane. The asymmetry due to the receive array is clearly visible. Figs 3 shows the H field magnitude in a coronal plane 5 mm above the receive array. Fig 4 shows the RF current density in the array. It is clear from the figures that there is significant current flowing through the array even though there are 2 3 Kohm blocking networks per element. Measurements: The model was validated experimentally through E-field measurements and B1+-field mapping in a physical model. Fig 5 shows a comparison between E-field measurements with a homebuilt probe (a 2 inch long dipole) and the HFSS model, for points along an axially oriented line near the top of the birdcage. The agreement is good. Agreement is less for the radial E field measurements since close to the endrings the field varies exponentially along the length of the probe. Fig 6 shows B1+ map results obtained through MRI of a non-loading (silicon-oil) phantom. A spin echo sequence was run at five different transmitter gain values, and the received signal values were fit to a $\sin^3$ curve on a pixel-by-pixel basis. Again, qualitatively, the agreement with the HFSS model is good. Experiments were run where the vertical distance between traces in overlapped array elements was varied to vary the capacitive coupling, but there was no measurable effect of the B1+ distortion. In other experiments all components were removed from the array, then added back in one by one to identify the biggest contributors to the coupling. A gradual increase in coupling with the number of components was found. No single component stood out as the main contributor.

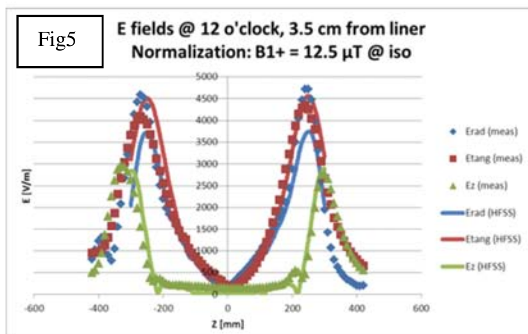

Fig5

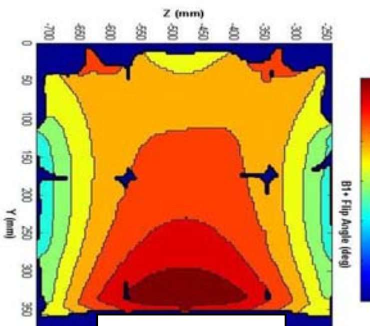

Fig6 Flip angle sagittal

Discussion: It is evident that there is current in the array despite the blocking circuits. The main mechanism is that the array gets turned into a number of copper traces upon decoupling. None of these form a loop, but E field components tangential to the direction of the traces still induces voltages and currents. The magnitude depends on the magnitude of the tangential E field and the length of the trace. Local E and B field coupling will share the energy among traces in close proximity. To prevent most of the coupling, one can increase the number of blocking networks, but it is better to determine the proper location. In fig4 the location of the networks in the bottom butterfly coil is properly chosen (A), since it is the location that sees the most tangential E field close to the birdcage endring plane. Less current is induced here than in the top butterfly, where the E field induces a large current in the top LR conductors (B).

Conclusion: A body coil / B field decoupled receive array system was accurately modeled and measured to identify causes of coupling. Proper location of blocking networks is a must to prevent most coupling effects.

References: (1) B.L. Beck et al. ISMRM Proc 2000, #641