Balancing noise sources and coupling in phased array coils

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Introduction
The rapid expansion of parallel imaging is supported by the development of phased-array surface coils, which allow achieving an optimised signal to noise ratio (SNR) over a large field of view (FOV). In parallel with the development of phased array coils with an increasing number of elements [1], new methods for element decoupling have been introduced [2, 3]. In this paper, we focus on the effect of the combination of electronic losses and inductive coupling on the SNR of a multielement array.

Methods and Materials
In order to study the effect of coupling, we built an array of 12 elements (Fig.1). All elements are equivalent in terms of geometry and electronics. For each element, the optimum impedance required by the preamplifier is transformed into the loaded coil impedance by using a π- matching network. Nearest neighbours in columns and rows are inductively decoupled by overlap, whereas diagonal elements have a mutual coupling of 3.4%. The coupling between not direct neighbours is low (between 0.1% and 1%). This array allows to study different coupling conditions: element 1 has only one diagonal direct neighbour element (el.6) which couples to it, element 2 couples with two diagonal elements (el.5 and 7), and element 6 inductively couples with four diagonal direct neighbours. The coupling between the elements can be selectively switched off in the experiment by disabling elements and in the simulations by making zero the coupling coefficient.

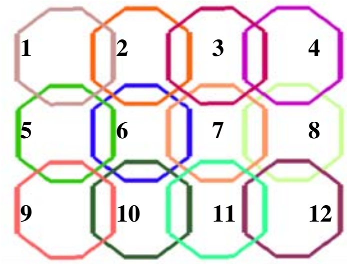
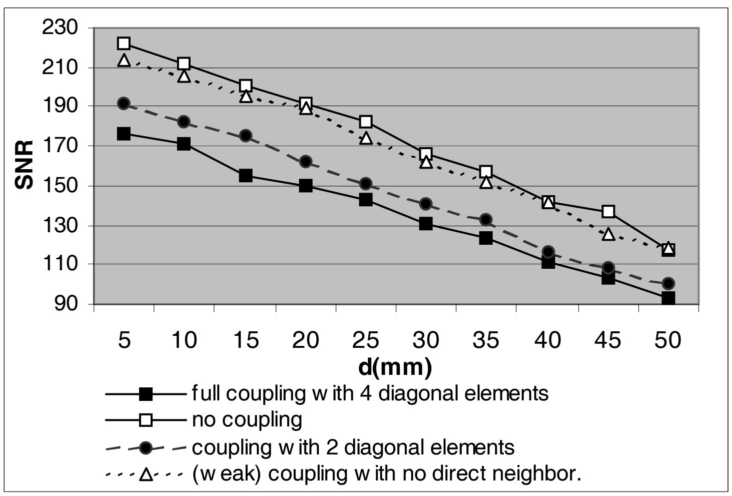


Fig.1: Element array used in the experiment

Results and discussion
We measured the SNR of a single element in the array for different coupling (fig.2a) and we compared it with the results obtained by simulating all noise sources in the chain: i.e. body, coil, matching and preamplifier. The SNR decreases by increasing the coupling (fig. 2a) and the degradation of SNR for different coupling is in agreement with our simulations. However, simulations give the possibility of distinguishing or even switching off different contribution to the noise figure (NF). Fig.2b shows the contribution of each noise source to the NF of one element for different matching losses (Qm=65 and Qm=500) and for different coupling conditions: full coupling (coupling of element 6 with four diagonal elements), no coupling and weak coupling (coupling with not direct neighbour, which is less than 1%).



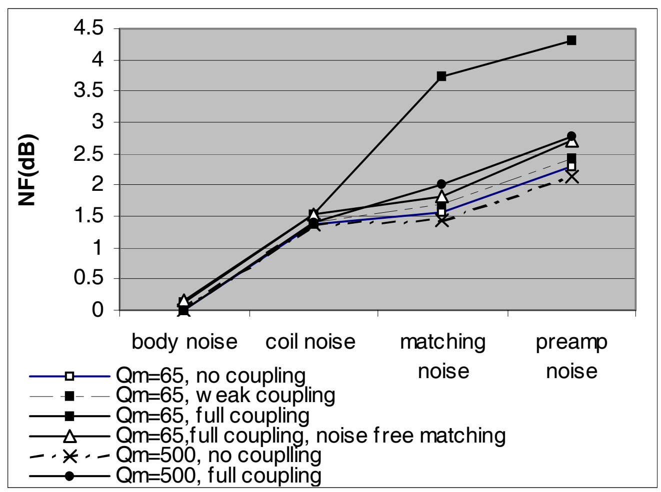


Fig.2: (a) SNR measurements of el 6 versus distance to the coil in loaded condition for different coupling at 1.5T. (b) Simulation of the contribution of the different noise sources for the setup in Fig.1. The reference for NF is body noise, the cumulative NF is shown in the picture.

Conclusions
Simulations in Fig 2b show that, in the presence of full coupling (with four diagonal elements), the increase of NF with respect to the reference level (matching and preamplifier noise) is 100% for matching with low losses (Q=500) and 200% for matching with high losses (Q=65). For weak coupling or no coupling, the increase of NF due to matching and preamplifier losses is less significant even when using a matching circuit with high losses. The increasing of coupling by decreasing matching losses is not merely due to a change in the input impedance: the comparison between the curve with "full coupling" and "full coupling with noise free matching" in fig.2b shows that the contribution to the NF is mainly due to thermal noise, which couples into the coil. The combination between coupling and electronic noise has a major impact on the degradation of NF, whereas the presence of only coupling or only electronic noise has minor consequences. In conclusion, designing of a multi-element coil requires an effort in balancing coupling and electronic noise rather than in minimizing both these contributions.

References
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