A novel inter-resonant coil decoupling technique for parallel imaging

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Introduction
The increasing importance of parallel imaging poses further challenges for RF-coil design [1]. One of the challenges of designing coil arrays is to obtain sufficient decoupling among closely placed resonant elements [2]. Among the techniques available for RF coil decoupling are coil overlap and pre-amplifier decoupling, as well as capacitive decoupling in either series or shunt form [3]. However, it has become evident that overlapping nearest neighbor coils to minimize mutual inductance does not result in optimal parallel reconstructions. Capacitive decoupling is limited to coils which are immediate neighbor and capacitor values becoming impractically small, in particular at ultrahigh magnetic fields [4]**.** In this work, a **new technique** for **decoupling phased-array coils** without overlapping the nearest coil pairs is presented base on the addition of a third resonant element.

Materials and methods
Two planar receiver coils have been constructed from two circular loop coils with 3cm (Di) diameter and 5 mm (L) distance between them, and 1mm width. Figure 1 shows layout of the two coils with the proposed structure underneath them with 0.5 mm width. The characteristics of coils were simulated first numerically by using Aglient©ADS Momentum. The designed coils were simulated for 9.4 T (400 MHz), and achieved good tuning and matching as well as -30 dB decoupling. A prototype of the simulated design has been built. All elements were realized on 1.5mm thick FR4 board with 35 µm copper layers. Fixed nonmagnetic capacitors were used. Each coil was parallel resonated with two capacitors and matched to 50 ohm with one. The decoupling was achieved using one decoupling capacitor (C_Dec) in the middle of the proposed decoupling structure (Figure 1).The prototype was tested with a network analyzer (Aglient 5071C). To test the operation of the prototype in the MRI machine, a cylindrical phantom containing silicon oil, 6 cm diameter and 14 cm long was used. Simulation for the B_1 field generated from the two coils has been done with Ansoft HFSS11 simulation program to show the effect of inserting the proposed structure in the field distribution between the two coils and to show the strength of the field linkage due to the mutual inductance between them.

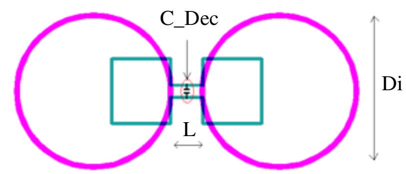

Fig 1: Two coil layout showing decoupler.

Results and discussion
The electrical measurement shows that the reflection coefficient S11 and S22 measured at the input ports of the two coils were better than -25 dB, indicating a good impedance matching. The decoupling between the two coils (S12) was **better than -35 dB** and this show that the mutual inductances between the coils are well minimized. No resonant peak split is observed for both elements. The measured profiles are in good agreement with the simulated one, how as it was being seen in figure 2-a, b. The MR experiments were preformed on a 9.4 T MR system (Brucker Biospec 94-21), with the array orthogonal to B_0 field, acting in all experiments as a receiver device. Fig 3-a and 3-b shows sum of square reconstruction of a flash coronal MR images acquired with a single coil, while the second is terminated, no signal is observed from the other coil, indicating the effectiveness of the proposed decoupling technique. Finally the two coils are used to acquire coronal image with the same phantom (Figure 3-c), the images indicate the great decoupling performance of the proposed decoupling technique with no black spots. Figure 4-a and 4-b shows the B_1 field simulation result along the coils plane compared with the intensity profiles from the MR image at distance of 0.7 cm from the conductors. As shown from the results, weak signals are seen in the region where the coils are terminated and also good agreement between the simulated and measured curves.

Conclusion and outlook
The proposed design provides a **robust approach** to design of parallel imaging arrays at ultrahigh fields. The future work will be focused on investigation of the proposed decoupling technique with more resonant elements and to minimizing the distance between the two coils to get more uniform magnetic field. The proposed two coil design provides good imaging performance due to low mutual coupling. The MR experiments showed that this coil setup can be used for parallel imaging.

Acknowledgement
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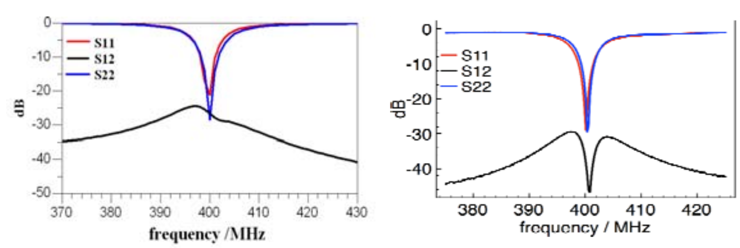

(a) (b)

Fig 2: S-parameters, ADS simulation (a), electrical measurement (b).

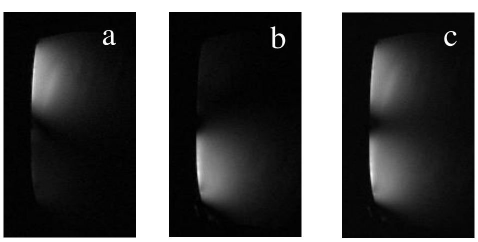

Fig 3: The 9.4T MR Flash imaging results of a silicon oil phantom, coil1 (a), coil2 (b), two coils (c).

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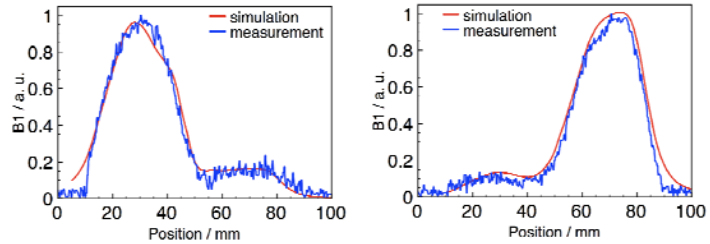

(a) (b)

Fig 4:B_1 field simulation and Image intensity profile, coil 2 terminated (a), coil 1 terminated (b)