Self-selecting, Cable-free MRI RF Coils

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Target audience: RF engineers, MRI operators

Purpose

Handling of RF local coils is a complex and time consuming part in any MRI exam: Usually a large number of RF coils is placed on the patient, but only the subset of coils positioned within the magnet field of view (FoV) can receive meaningful RF signals at any time point. The coil selection procedure, e.g. programming an RF receiver crossbar switch by a GUI and/or adjustment scans is clumsy at best, and becomes a serious issue e.g. for real time interactive scanning.

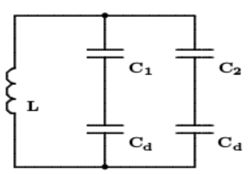
We propose a technical solution that automatically activates any RF pickup loop within the FoV and leaves all other coils safely deactivated. The method is more straightforward than e.g. wireless microwave links [1,2,3].

Methods

A conventional RF coil consists of a MR signal pickup wire loop fixed to the patient on a table which can move relative to the MRI scanner. Flexible cables convey the electrical signal to the receiver(s) within the scanner. These cables pose a danger due to induced voltages during RF transmit. Our solution utilizes RF pickup loops connected to short straight cables to conduct the signal loops laterally to a pair of capacitive coupling plates near the side edge(s) of the patient table at approximately the same axial table position (or a constant axial offset) [3]. The scanner bore has a set of opposing coupler plate pairs which are connected to a corresponding number of RF receivers. The scanner side coupler plate spacing and number of RF receivers is constrained by the requirement of at most a single RF coil coupling to any single RF receiver – otherwise RF coils would get connected in parallel, and become detuned.

This arrangement guarantees that any coil pickup loop within the FoV can convey its signal to either one or two RF receivers, and that any coil outside the FoV is safely disconnected and detuned. RF tuning is achieved across the coupler capacitance by active transmit-receive switches in front of the RF receivers as usual. The RF coils are unpowered with very few passive and no active components. The signal split into two receivers is recoverable during image reconstruction at the array combination stage without SNR penalty.

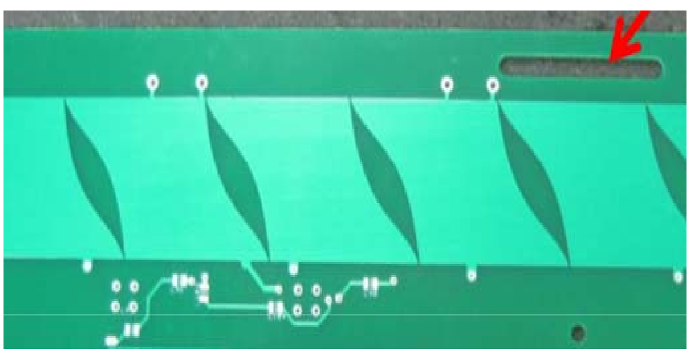
Depending on table position the coil and receiver side coupler plates have arbitrary axial alignment. The remaining technical challenge is to maintain coil tuning in the presence of an RF coil coupling to one or two receiver channels.

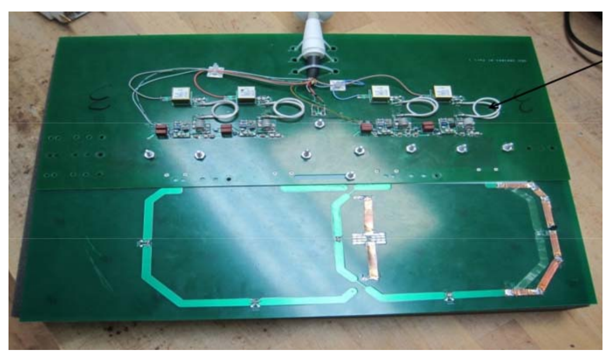


The electrical equivalent circuit is a coil inductor L in resonance with two capacitive couplers C_1, C_2 in series with two RF receiver input capacitances C_d. The total capacitance has to be constant in the presence of blending over from receiver 1 to receiver 2 by C_1 and C_2. To maintain coil tuning during blending (s,1-s), 1>s>0 the single receive channel coupler capacitance C_c splits into partial capacitances

$$C_1(s) = \frac{sC_cC_d}{(1-s)C_c+C_d} \qquad C_2(s) = \frac{(1-s)C_cC_d}{sC_c+C_d}$$

Receiver blending is a function s(z) of the axial table position z. The required capacitance variation can e.g. be implemented by variable coupler plate heights. Rectangular coil coupler plates require scanner side plate shapes as shown on the left.





We built and tested a sliding coupler system for connecting one or two magnetically decoupled octagonal 4" coils to two QED preamps, which fed two receive channels of a 1.5T Siemens Magnetom Espree MRI scanner. The vendor supplied standard image reconstruction software was used.

Results

The test setup is shown above. The dielectric material on the coupler plates turned out to have a significant influence on the coil Q factor. Kapton proved unacceptably lossy, but a 5 mil PTFE film gave essentially identical Q~90 compared to a similar sized conventional, cable connected coil. The signal-to-noise ratio in oil and water phantoms were equal to cable coupled coils within statistical error. Frequency tune shift during blending between channels was less than 300kHz.

Discussion and Conclusion

A passive, non-wireless coil connection method is described which relieves the MRI operator from coil identification and selection tasks. This is an especially important feature for interactive real time MRI, e.g. interventional MRI, where the relative patient position is subject to change between and during scans. The usual RF coil cable loop safety hazard is absent.

References

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