An Orthogonality based RF Decoupling Method

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Introduction: A conformal RF coil array design for use in a MRI system is proposed. In particular, the coil array is designed without the use of any cumbersome mutual decoupling schemes. Coil elements are designed based on orthogonality, which will naturally minimise the problematic mutual coupling effects that inherently exist in most MRI phased-array systems [1]. A prototype of a knee coil constructed with the proposed orthogonality design is shown to have consistent imaging quality invariant to coil orientation with respect to B_0 and application for "magic angle" imaging of soft-tissues.

Method: Regardless of many advantages that can be gained from using multi-element RF coil arrays, one common criterion in designing RF coil arrays is that some form of mutual decoupling scheme has to be incorporated to decouple coil elements. A multi-element RF coil array usually displays strong mutual coupling between individual coil elements and some of the undesirable effects of this include difficulty in tuning, reduced SNR, RF field distortion causing image artefacts and limitations in partial parallel imaging performance. In this work, as shown in Fig. 1, a prototype orthogonal 3-element knee coil array is designed and constructed. The knee coil is based on a cylindrical coil geometry which corresponds to the typical shape of a coil support. The coil element layout was generated by intersecting the cylinder with an orthogonality basis. The coils thus have elliptical shapes and conform to the geometry of interest. In this case, the three elliptical coil elements are arranged 120° apart azimuthally and tilted to an angle of 54.7° with respect to the transverse plane of the cylindrical coil geometry. Arranging the coils orthogonally minimizes mutual coupling between the coils to a degree that no additional mutual decoupling schemes need to be employed to decouple the RF coils. This simplifies the overall construction and is particularly useful in MRI systems where strong space constraints exist. MoM/FEM simulation was employed to accurately predict and verify the performance of the new orthogonal RF coil.

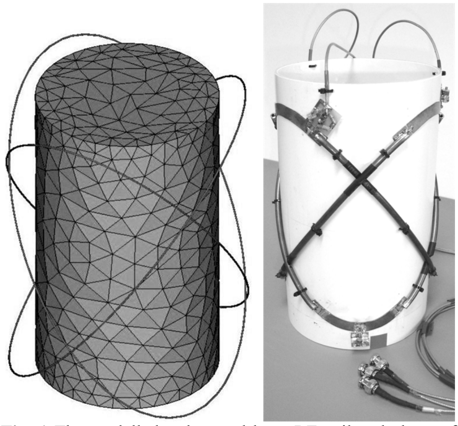

Fig. 1 The modelled orthogonal knee RF coil and photo of the constructed prototype. Coil elements are positioned to be orthogonal to each other and conform to the cylinder structure.

Fig. 3 The acquired coronal and saggittal slice MR images of a male volunteer's left knee. (a, b) are using the orthogonal knee coil (c, d) are using the conventional knee coil array.

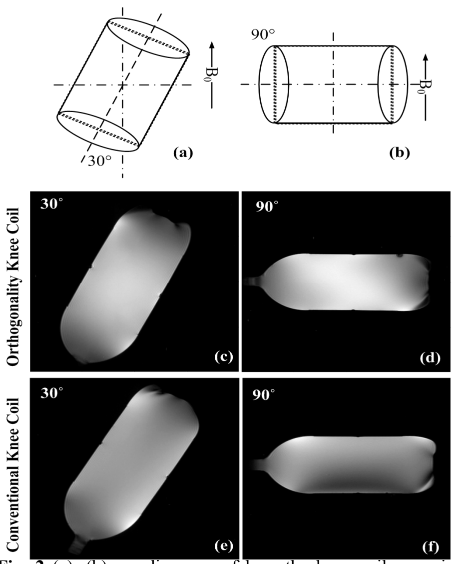

Fig. 2 (a), (b) are diagrams of how the knee coil array is positioned relative to B_0 field; (c), (d) are coronal images of the homogenous bottle sample acquired using the prototype orthogonal knee coil; (e), (f) are with conventional knee coil.

Results and Discussion:

Comparison studies between the new orthogonal design and a conventional 3-element knee coil array, designed with a counter wound inductor method [2], were performed with MRI experiments on a Bruker 2T whole-body system. Shown in Fig. 2 are the images of a homogenous phantom acquired with a Fast Low Angle Shot (FLASH) imaging pulse sequence with TR = 100 msec, TE = 9.1 msec and NEX =1. In contrast to the conventional knee coil, the prototype orthogonal knee coil array provided consistent B_1 homogeneity regardless of its orientation with respect to the B_0 field. Hence, the orthogonality knee coil array is invariant to the direction of B_0 and can be arbitrarily orientated in a MRI system without losing any functionality. Fig. 3 shows knee images of a healthy male volunteer. Higher imaging quality can be observed with the orthogonal coil, especially for cartilage and blood vessels. In MRI, it is well recognized that the "magic angle" phenomenon can increase the signal intensity of the collagen fibres in soft tissues when they are orientated at about 55° to the B_0 field. In practice, to perform magic angle MRI experiments, both the sample under imaging and the RF coil are orientated at the magic angle. With the earlier MRI experiment on the cylindrical phantom, it is shown that when using a conventional RF coil, loss of SNR is inevitable if the coil-sample setup is orientated away from the direction of the B_0 field. However, this is not the case for the orthogonality knee coil array, as illustrated in Fig. 4. To further demonstrate this, magic angle MRI experiments on an adult pig knee were undertaken using both knee coil arrays. The signal intensity was measured with the coil array orientated at different angles relative to the B_0 field. Overall, a 20% higher signal intensity was observed, compared with the conventional coil.

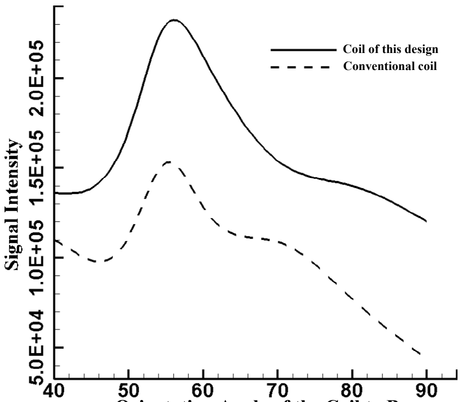

Fig. 4 The measured signal intensity of the patellar ligament versus the knee coil positions relative to B0 field, with orthogonal coil and conventional knee coil.

Conclusion: RF coil arrays designed using the proposed orthogonality method have the flexibility that they can be orientated arbitrarily relative to the B_0 field and still maintain normal operation without any loss of functionalities, like B_1 homogeneity, SNR and coil efficiency. Hence, the proposed coil design is suitable for use in any horizontal or vertical bore and open MRI systems, providing opportunities, particularly in clinical musculoskeletal investigations, for direct anatomical imaging of structures and tissues not easily or comfortably aligned with the B_0 field or in the cases body movements are required during imaging.

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References: [1] H. Wang et al. "Orthogonal RF Coil". Australia PCT, filed. Feb 2009. [2] Weber, Australia Patent, PCT2007901587 (2007)