A modelling study of a Hybrid Loop-Strip coil structure for multichannel Transceive Breast Array Coil

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Introduction Magnetic Resonance Imaging (MRI) has become a very important technique for the diagnosis of breast diseases. A dedicated radio frequency (RF) coil, capable of inducing a homogeneous magnetic field within a defined region of interest as well as receiving MRI signals with a high signal to noise ratio (SNR), is essential for high spatial resolution breast imaging. Close-fitting phased array (surface) breast coils were proposed and developed to improve the SNR and enhance the image quality [1-2]. However, because of the specific position of a patients' breast related to the B_0 field of a horizontal clinical MRI scanner, it is challenging to use conventional equal structured loop coils to induce a desired homogenous B_1 field. More importantly, in the anterior-posterior area of the breast, little or no signal can be received by a loop coil. In this work, we present a novel structure which can improve both the quality of the transmitting B_1 field and the efficiency of RF signal reception.

Methods Shown in Fig.1 is the coil element diagram of the hybrid 8-element phased array breast coil. Loop coils are used at positions 2, 3, 6 and 7 in close proximity to the targeted sample. These loop coils are placed along the *x*-direction to produce homogenous H_x-field in the desired FOV because the primary magnetic field direction of a loop coil, as shown in Fig 1b and in cylindrical coordinate system, is in *r-direction*. This means that if placed at locations 1, 4, 5 and 8 (that is along the B_0 field), the efficiency of the loop coil will drop drastically. Compared to the loop coil, a strip coil-element has obvious advantages in performance at these positions because its principle magnetic field component is in the *phi-direction* (see Fig.1c) [3]; hence this type of coil element is used at these positions instead. Based on these design considerations, Fig 2 shows the designed hybrid 8-element phased array breast coil. Apart from providing full coverage over the FOV, this hybrid coil design has an extra degree of freedom for optimizing the coil element's position because, as the size of the strip coil is much smaller than that of the loop coil, there is more space to search for the optimum position of each coil element. Hence, a further optimization was implemented when designing the hybrid breast array coil in which B_1 homogeneity the g-factor for parallel MRI application we included.

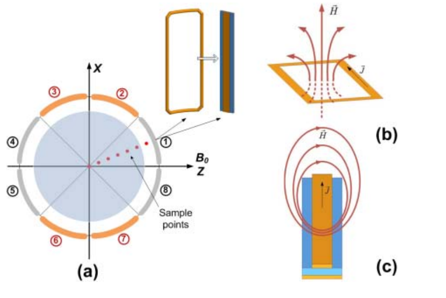

Fig. 1(a)Top view of the eight-element breast phased array coil; (b), (c)Illustration of the *H* field patterns of a loop coil and a strip coil.

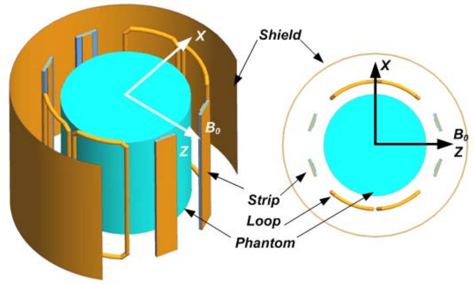

Fig.2. The structure of the hybrid breast array

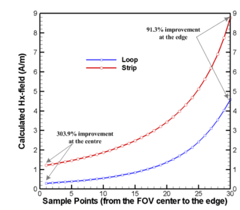

Fig. 3 The H_x-field comparison at sampling points (see in Fig.1a) of the loop coil and strip coil.

Results and Discussion To demonstrate that a strip coil-element is more advantageous over a loop coil at locations along the B_0 field, a comparison of the H_x –field at the sample points (shown as dotted red line in Fig1a) induced by a loop coil, and strip coil respectively, is calculated. A plot of the calculated H_x –field is shown in Fig 3. For a fair comparison, both loop coil and strip coil are excited with the same current source. In comparing the plotted data, it can be observed that the strip coil has much higher field strength than the loop coil; more than double. This means, according to the Principle of Reciprocity, the capability of a strip coil in acquiring NMR signal is twice as efficient as that of a loop coil at these specific locations.

As mentioned, the positioning of coil elements was optimized to produce the most homogenous B_1 field. Fig.4 shows the H_x –field pattern on a coronal plane at the centre of the phantom produced by the optimized hybrid coil. Compared to a conventional 8-loop breast coil, which was also designed but not shown here, the B_1 homogeneity (peak to peak) of the coronal slice located at the centre of the breast coil is improved by 58.28% with the hybrid design, while a 57.14% improvement is achieved over the entire cylindrical space. In addition, the designed hybrid breast coil was also optimized for SENSE parallel imaging. A reduction factor of 2 and 3 were simulated and the simulated g-map in all directions (transverse, sagittal and coronal plane) for a conventional 8-loop structured breast coil and the optimized hybrid design are shown in Fig.5. The mean g-factor and the maximum g-factor inside the ROI for the conventional coil array and hybrid design were also calculated and listed in Table 1.

From the results presented here, during the optimization process of the hybrid coil structure, it is noted that there is a trade off between B_1 field homogeneity and the g factor. One could degrade the field homogeneity by placing the strip coil closer to the loop coil in return for reduction in g-factor and vice versa. Hence, the best configuration of this hybrid 8-element breast array was selected as a compromise between the g-factor and the B_1 homogeneity.

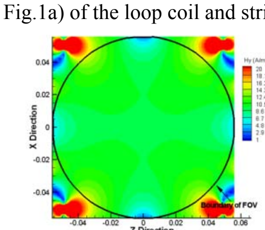

Fig. 4 H_x field induced by the loop-strip hybrid phased array coil

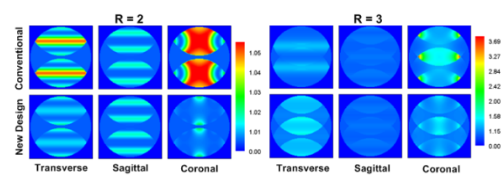

Fig.5 Simulated g-map of the conventional array and the optimized hybrid array

Plane	Arrays	R=2 Mean g	R=2 Max g	R=3 Mean g	R=3 Max g
Transverse	Conventional	1.012	1.044	1.135	1.357
	New Design	1.003	1.016	1.238	1.631
Sagittal	Conventional	1.004	1.012	1.046	1.110
	New Design	1.003	1.012	1.043	1.105
Coronal	Conventional	1.025	1.055	1.326	3.887
	New Design	1.001	1.021	1.184	1.745

Table 1 Comparison of g-factor of the coil arrays.

Conclusion This work presented a loop-strip hybrid transceive phased array breast coil design. The new design can offer improvement to the B_1 field in the anterior-posterior area of the breast, which is difficult to achieve by using a loop-only breast coil. The simulated results demonstrate the potential of this novel hybrid design. A prototype is currently being built to test the practical feasibilities of the hybrid design concept.

References

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[3] R.F.Lee. et al. *Mag. Reson. Med., 45*:673-683, 2001