A novel method in ameliorating signal voids for 11T brain imaging using transmission phase cycled, transceive array coils

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Introduction

MRI is moving inexorably toward higher field strength in search of improved signal-to-noise ratio and spectral resolution. There are several technical difficulties, however, that arise due to strong tissue/field interactions at high magnetic field strengths. At 11T, it has been experimentally demonstrated that image intensity distributions are subject to significant distortions [1] attributable to these interactions [2,3]. Several methods such as optimizing the current distribution on the rungs of a multi-element volume coil [4], transmitting field of time varying spatial characteristics using two separate pulses [5] and the use of parallel imaging at high field strength [6] have been suggested to reduce the distortions. In this work a new method has been proposed to mitigate the problematic signal voids for brain imaging at 11T (470Mhz). The proposed method uses 4 focusing transcieve phased array coils and involves performing 2 separate scans of the same slice (Scan_A and Scan_B) with each scan using different excitations during transmission. That is, parallel, transmission phase cycling. Thereafter, the received B_1 fields from the 2 separate scans are used for calculating the signal intensity (*SI*) maps, which are combined together in the image domain. By optimizing the phases of the transmission systems, signal distortion may be significantly reduced.

Methods

A hybrid Finite Difference Time Domain (FDTD) / Method of Moments (MOM) approach is adopted in this work to accurately calculate B_1 fields inside the brain. Firstly, 4 square surface coils resonating at 470MHz, loaded with a 4 layered spherical phantom with each layer having different dielectric constants and conductivities that approximately resemble a human head [7] is simulated using FEKO (www.feko.co.za), a MOM based *RF* simulation program to calculate the current distribution on each coil. With the coils loaded with the spherical phantom, coil-sample coupling is considered. The dimension of each coil is 120X120mm, positioned orthogonally and separated from its opposite coil neighbor with a distant of 246mm as depicted in Fig 1. At this distance, minimum mutual coupling existed between coils. Tabulated in Table 1 are the various excitations on each coil for Scan_A and Scan_B during MOM simulation. Once the current density distribution on each coil is calculated for Scan_A and Scan_B, an in-house FDTD package [8] is then employed to evaluate the EMF fields in the human head. A voxel-based human head is used during FDTD simulation as shown in Fig 2 to accurately predict the transmit B_1 field in the human head, the reciprocity theorem is used to calculate received B_1 fields, from which signal intensity (*SI*) maps are simulated.

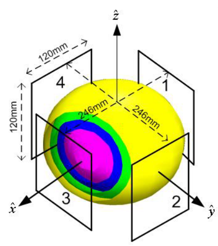

Fig 1

Table 1

	Scan_A		Scan_B	
	Amplitude (V)	Phase	Amplitude (V)	Phase
Coil 1	5	45°	5	180°
Coil 2	5	135°	5	10°
Coil 3	5	225°	5	0°
Coil 4	5	315°	5	190°

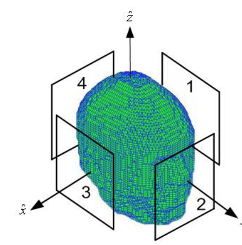

Fig 2

Results and Discussion

Fig 3(a-b) shows the *SI* maps calculated for Scan_A and Scan_B while 3(c) shows the *SI* map when Scan_A and Scan_B are combined together using a sum-of-squares. Fig 4(a-c) shows a corresponding plot of *SI* taken from the mid section of the head along the lateral direction Using the set of excitations for Scan_A, which is a quadrature drive scheme, signal voids are apparent and obvious as shown in Fig 3(a). Bright spots marked by high *SI* and dark rings which appear as low *SI* can be clearly seen in Fig 4(a). However by performing field focusing through changing the phases as for the set of excitations used in Scan_B, a different form of signal voids results as is shown in Fig 3(b) and Fig 4(b). The phases in Scan B are optimized to generate the reverse distortion pattern generated by those in Scan A. Therefore, through pixel by pixel combining *SI* maps of Fig 3(a) and Fig 3(b) using a sum-of-squares method, a relatively uniform *SI* map is attained as is shown in Figs 3(c) and 4(c).

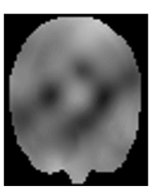

Fig 3(a)

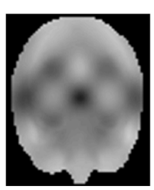

Fig 3(b)

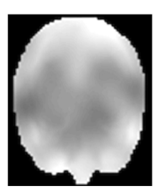

Fig 3(c)

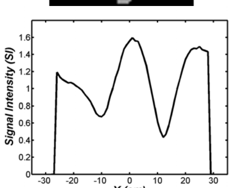

Fig 4(a)

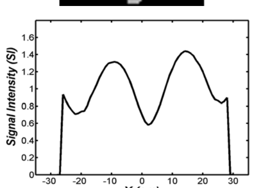

Fig 4(b)

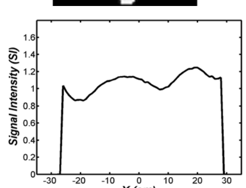

Fig 4(c)

Acknowledgment

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Conclusion

The new method proposed in this work significantly reduces the signal voids in 11T brain images by transmission phase cycling of parallel imaging elements. We assume in this work that motion induced artifacts during the phase-cycling are minimal. B_1 field focusing using transceive phased array coils for MRI applications is an area of active research and development.

By performing optimal field focusing, it is possible to control, to an extent, the location and magnitude of image distortions.

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