An Efficient Multiple Field of View Gradient Coil Set

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Introduction The requirements of modern MRI techniques on the gradient coil system include high gradient strength, fast slew rate and good linearity. These requirements are not usually met by a gradient coil with a single, fixed field of view (FOV). A gradient coil with a large FOV or good linearity requires more power to produce a given gradient strength than a gradient coil with a small FOV. Since the coil's self-inductance increases with the FOV, the slew rate of a gradient coil with a large FOV is reduced for a given power supply. Also, high dB/dt associated with the large FOV would be more likely to cause peripheral nerve stimulation. To meet these requirements, the gradient coil system with multiple FOVs was proposed (1), and MRI systems equipped with a dual FOV gradient coil system (Signa Twinspeed; GE Healthcare, Waukesha, WI, USA) have been commercially available. However, Twinspeed consists of two separate sets of gradient coils, each responsible for a different FOV. One drawback of such a system is that the performance of at least one set of coils has to be compromised. Here, we present a multiple FOV gradient coil set, which can efficiently use a single gradient power supply in all its operating modes.

Method The design was carried out using the recently proposed sum-and-difference method (2). With this method, the multiple FOV gradient coil system consists of separate main and corrector coils for each axis. However, instead of designing for the main and corrector coils directly, the current densities of two hypothetical gradient coils that would produce two targeted FOVs were designed using the method normally adopted for a single FOV gradient coil. Of the hypothetical coils, one would have a smaller FOV and produce higher gradient strength and slew rate, and the other would have a larger FOV and produce lower strength and slew rate. The current densities, and hence the designs, of the main and corrector coils were then obtained by summing and subtracting the two current densities for the targeted FOVs, respectively. The larger FOV with lower gradient strength and slew rate (body mode) is achieved by connecting the main and corrector coils in series such that the gradients produced by the two coils will be in opposite directions. By reversing the connection of the corrector coil to the main coil, the smaller FOV with higher gradient strength and slew rate (brain mode) is achieved. This technique also results in a useful main coil that will produce an intermediate FOV and gradient strength (cardiac mode). Furthermore, if the main and corrector coils are driven by two separate gradient power supplies, the FOV and gradient strength can be varied continuously between body and brain performances.

Results In designing our self-shielded gradient coil system, the body mode was chosen to produce a 50cm diametrically spherical volume (DSV) with 10% spatial error and 50mT/m gradient strength, and the brain mode to produce a 22cm DSV with the same spatial error and 80mT/m gradient strength using a gradient power supply of 550A and 1400V. The designed performance values are listed in Table 1. Note that the cardiac mode has the highest slew rate with an intermediate FOV and gradient strength. A quadrant of the primary y main and corrector coil winding patterns is shown in Fig. 1. Pre-production prototypes have been built using this design; see Fig. 2. The measured resistance and inductance of the main and corrector coils, together with the combined resistance and inductance values of the two coils when in the body and brain modes, are listed in Table 2. The gradient set produced the designed performance in all three modes.

Conclusion We present the design method and measured results of a powerful gradient coil set with three FOVs. The gradient coil set uses the full power of a single gradient power supply in all three operating modes.

References

1. Harvey PR, Katznelson E. Modular gradient coil: a new design concept in high performance whole-body gradient coil design, Magn Reson Med 1999;42:561-570.
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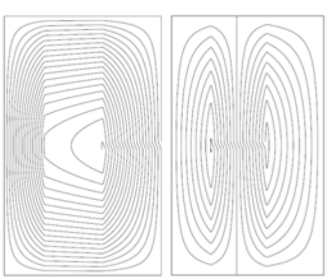

Fig. 1: A quadrant of the primary y main (left) and corrector (right) coils

Fig. 2: Pre-production prototype coil set

Table 1: Designed performance of multiple FOV gradient coils

Axis	Mode	Gradient (mT/m)	Slew Rate (T/m/s)	FOV (cm DSV)
X	Brain	80	260	22
	Cardiac	65	265	27
	Body	50	151	50
Y	Brain	80	265	22
	Cardiac	65	279	27
	Body	50	155	50
Z	Brain	80	259	27
	Cardiac	65	302	32
	Body	50	178	50

Table 2: Measured resistance and inductance for main & corrector coils and brain & body modes

		Main	Corrector	Brain Mode	Body Mode
X	Resistance (mΩ)	87	42	131	131
	Inductance @100Hz (mH)	0.620	0.183	0.772	0.835
Y	Resistance (mΩ)	82	45	129	129
	Inductance @100Hz (mH)	0.589	0.196	0.758	0.814
Z	Resistance (mΩ)	108	85	195	195
	Inductance @100Hz (mH)	0.546	0.203	0.776	0.722