Rapid B1 Mapping Method for Multi-channel RF Transmit Coil Using Phase-difference

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Introduction

Multi channel RF transmit coil is used in high field MRI systems and recently the number of transmit channel is increasing [1]. By using multi channel RF transmit coil, some applications in high field MRI like RF shimming [2] and Transmit SENSE [3] are available. These applications require B1 map for each channel transmit. Bi map for each transmit channel can be measured repeatedly for each transmit channel. However, increasing the number of transmit channels, scan time is multiplied by the number of transmit channels in the case of single transmit channel. By using Bloch-Siegert method [4] that is one of fast B1 mapping method, scan time is 128 sec for 20-channel transmit coil. Or by using method proposed in [5], that repeat B1 mapping for transmit channels with using only 21 images for 20-channel transmit coil, scan time is 278 sec.

In this study, we developed a new fast method to acquire Bi map for each channel transmit. In this method, only one time acquisition with using all transmit channels is used for calculation, and the acquired Bi map is decomposed to Bi map for each transmit channel by using the information of phase difference between transmit channels. Without repeating Bi map acquisition, short scan time is achieved, for 20-channel transmit coil, scan time is only 4 sec.

Theory

For simplicity we discuss 2-channel case here, but extension to general number of transmit channel is straightforward. Fig. 1 is pulse sequence of this method. Short TR, small flip angle Gradient Echo (GrE) sequence is used for fast imaging. Scan parameters of all GrE sequences are quite same, but only different on transmit channel. Before pre-pulse is applied, 2 images are acquired by using only single channel of transmit RF pulse. First image (Ia1) is acquired by using only channel-1, and second image (Ia2) is acquired by using only channel-2 of transmission. The pre-pulse is transmitted with using all channels. After pre-pulse is applied, two images are acquired by using all channels to transmit RF pulse at two different delay time (Td1 and Td2). Signals were received by all channels of same coil as transmission, and QD combined to image reconstruction. From these four images, Bi maps for each transmit channel are calculated as follows: 1) Calculate Bi map using all channels (\[Ia1, Ia2\]) using multi Td method [6], 2) Calculate phase difference between Bi for channel-1 and Bi for channel-2 (\(\phi\)). 3) Calculate phase difference between Bi for all channel transmission and Bi for channel-1 transmission (\(\phi\)). 4) Calculate resulting Bi maps by using \(\theta = a \tan \left( \frac{L_{a1}}{L_{a2}} \right)\), \(\phi = a \tan \left( \frac{L_{a1} + L_{a2}}{L_{a1}} \right)\). Fig. 2 shows Bi of 2-channel RF transmit coil at one spatial point. Bi of channel-1 and 2 are denoted as \(B_{1,1}\) and \(B_{1,2}\). Since Bi is vector quantity, \(\bar{B}_{1,1}\) and \(\bar{B}_{1,2}\) make a parallelogram, and \(\bar{B}_{1,1}\) is diagonal line of this parallelogram. As \(\bar{B}_{1,1}\) and \(\bar{B}_{1,2}\) can be calculated as eq. 1, \(B_{1,1}\) and \(B_{1,2}\) can be calculated as:

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\begin{align*}
\bar{B}_{1,1} &= \frac{\sin(\theta-\phi)}{\sin \theta} |\bar{B}_{1,1}|, \\
\bar{B}_{1,2} &= \frac{\sin \phi}{\sin \theta} |\bar{B}_{1,1}|.
\end{align*}
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Materials and Methods

3T whole body MRI system and 4-channel RF transmit/receive coil (Fig. 3) was used for imaging of a torso phantom (300 [mm]*200 [mm]*300 [mm], T1=200 [ms]). Scan parameters of imaging sequence are as follows, FOV=500 [mm], TR/TE/FA=2.5 [ms]/1 [ms]/3 [deg], slice thickness=10 [mm], and measurement matrix=64*64*1. FA of pre-pulse was 90 [deg] and Td1/Td2=20 [ms]/50 [ms]. Scan time was 1 sec for 4-channel RF transmit coil. The images acquired before pre-pulse were also used to make mask of B1 maps for signal threshold. No smoothing or filtering was used to Bi maps.

Results and Discussion

Fig. 4(a) shows Bi maps for each channel of 4-channel coil and Bi map for all channel transmission. Fig. 4(b) is phase difference between each channel and all channel transmission. To extent this method for n-channel transmit coil case, n-images should be acquired by changing transmit channels before pre-pulse is applied and 2 images using all channels of transmit coil after pre-pulse is applied. So (n+2) images are needed to calculate Bi maps of n-channel RF transmit coil. Then scan time is only \((n+1)\times160+Td\) ms. The Bi map calculation is same as 2-channel case. Another advantage of this method is the required accuracy of Bi map is relaxed by using Bi map for all channel transmission.

Conclusion

Simple relation between Bi map for each and all channel was discovered. By using phase information, Bi map acquired by using all channels to transmit RF pulse can be decomposed to Bi map for each channel of multi channel RF transmit coil. Because fast Bi mapping for each transmit channel is achieved, this method improve workflow of clinical routine practice using RF shimming or Transmit SENSE.

Reference