Transmit Coil Array for Very High Field Head Imaging

Y. Li[1], C. Saylor[1], G. R. Duensing[1]

[1]Research and PreDevelopment, Invivo Diagnostic Imaging, Gainesville, FL, United States

Introduction: The recent expansion of magnetic resonance imaging (MRI) to very high fields (above 3T) has significantly driven the development of new radiofrequency (RF) excitation strategies using transmit coil arrays [1-8]. There are several reasons why a transmit coil array is superior to a conventional volume coil in very high field imaging. First, a transmit coil array allows a better control of RF pulse transmission. It is possible to suppress those dielectric resonance modes that are destructive to B_1 field homogeneity [9, 10]. It is also possible to use B_1 shimming method to finely improve the homogeneity [6, 7]. Secondly, parallel or serial excitation is permitted using a transmit coil array. This can be used to reduce the RF pulse length or specific absorption rate (SAR) [7]. Finally, multiple-channel transmission allows the application of transmit-SENSE methods, which may further increase the imaging speed [8]. Due to these reasons, there has been substantial research effort on the transmit coil array design. However, a number of challenges have been encountered and the most significant one is the decoupling. In this study, a new decoupling technique for very high field transmit coil array design is proposed. It is shown that the coil coupling can be well suppressed when eight surface coils are used for transmission in head imaging at 7T field. With the aid of a power splitter, head images can be acquired using an eight-channel transmit surface coil array on a SIEMENS 7T whole-body scanner.

Methods: A concentric double loop surface coil will generate two resonance modes: co-rotating current mode and counter-rotating current (CRC) mode. In CRC mode, the magnetic field produced by the coil will be reduced due to the opposing currents of the inner and outer coil loops. The degree of this field reduction depends on the current ratio between the inner loop and the outer coil, which can be easily adjusted by tuning two coil loops. Therefore, if a double loop surface coil is used as the basic element to make up a transmit array and the CRC mode is tuned on frequency, the inductive coupling between coil elements can be controlled by capacitance tuning. Using this strategy, an eight-element transmit array was developed for head imaging on a SIEMENS 7T MRI scanner. As shown in Figure 1 and 2, eight coil elements were positioned on a clear acrylic tube of 27cm in diameter. Each element is a concentric double rectangular loop. The size of the inner loop is 8x13cm and that of the outer loop is 9.5x17cm. The inner and outer loops were tuned differently such that the coupling between next nearest neighbors can be suppressed to a satisfactory level. Between nearest neighbors, a shared inductor was used for decoupling. An RF balun was used at the excitation port of every element to remove the coupling through cables. The array is placed in an RF shield with a distance of about 16mm to the coil. To test the coil, an eight-way power splitter/combiner with phase difference by 45° between every two adjacent channels were used to excite the coil array and receive the signal. Because the coil matching is extremely sensitive to loading condition at this field, which dramatically affects the phase control in the RF transmission to every coil, the coils were over-coupled to a certain degree such that the phase of the current in every coil is insensitive to the loading change. This configuration was used to perform both phantom and human subject imaging studies on a SIEMENS 7T whole body MRI scanner.

Figure 1. Eight-channel transmit coil array

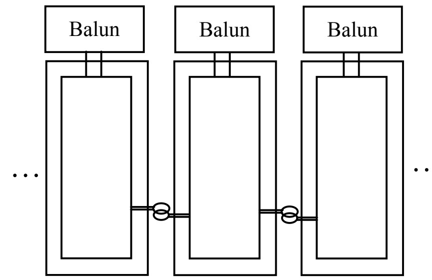

Figure 2. Schematic of transmit coil array

Results and Discussion: The mode structure of the eight-channel 7T head coil array is shown in Figure 3. It can be seen that the co-rotating current mode is about 90MHz away from the CRC mode, which is tuned to 298.17MHz. This gives excellent mode stability even though there exists strong coupling from the co-rotating current mode. At the resonance frequency of interest, the S_{21} parameters between coil elements are all below -23dB. The Q_u/Q_L of every coil element is around 248/30 if fully loaded with a solution of 2g/l $CuSO_4$ and 0.77g/l NaCl. Table 1 shows a bench test result of the coil connected to the power splitter and loaded with a phantom of head dimensions. The S_{21} parameters were measured on the acrylic tube at the center of each coil using a probe. It can be seen that a birdcage-like mode is generated and this mode pattern shows excellent stability even when moving the phantom inside the coil. Figure 4 gives the 720° B_1 field mapping of this coil using a spherical oil phantom at 7T field. Figure 5 gives a saggital brain image of a human subject using this coil at 7T field. These images demonstrate the capabilities of this transmit coil array in generating a homogeneous B_1 field in head imaging at very high field.

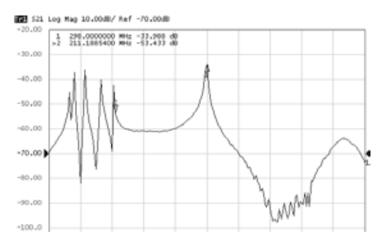

Figure 3. Mode structure of the coil array

Channel	|S21| (dB)	∠S21(Degree)
1	-33.566	-37.663
2	-33.702	-82.706
3	-33.281	-127.46
4	-33.246	-168.45
5	-33.459	143.71
6	-33.816	98.077
7	-33.823	52.570
8	-33.814	5.4559

Table 1. Bench test of the transmit coil array.

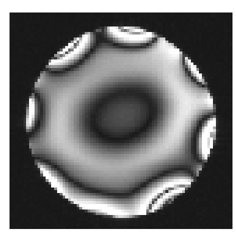

Figure 4. 720° B_1 field map.

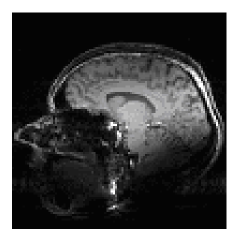

Figure 5. 7T brain image.

Conclusions: This study shows that the use of CRC mode of a concentric double loop coil is capable of giving satisfactory decoupling with sacrifice of some power efficiency in high field transmit coil array design. Head imaging studies were performed using a transmit coil array based on this decoupling technique with an eight-way power splitter/combiner on a SIEMENS 7T whole body scanner. This transmit coil array offers the capability of multiple-channel transmission and can also be used as a receive coil array.

Reference: 1). Duensing, G.R., et. al. Proc. 6th ISMRM, 1998. 2). Boskamp, E. B. et. al., Proc. ISMRM, 2002. 3). Lee, R.F. et.al, MRM, 2004. 51(1):p 172-183. 4). Adriany, G., et. al., MRM, 2005. 53(2): p 172-183. 5). 5). Wichmann, T., et. al., Proc. 13th ISMRM, 2005. 6). Seisert. F., et. al., Proc. 12th ISMRM, 2004. 7). Zhu, Y., MRM, 2004. 51(4): p. 775-784. 8). Katscher, U., et. al., MRM, 2003. 49(1): p144-150. 9). Collins, C.M., et. al., JMRI, 2005. 21:p. 192-196. 10). Kangarlu, A., et. al., JCAST, 1999, 23: p821-831.