Investigation Non-magnetic Amplifiers Applied in an MRI System

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INTRODUCTION: In our previous work on passive current source RF power amplifiers, it was noted that additional inter-element isolation in a parallel transmit coil array was possible when the lengths of the coaxial cables that connected the amplifiers to the coils were reduced [1,2]. In addition, shorter cable lengths also lead to reduced power loss and cost. This can be achieved by placing the RF amplifiers near the magnet (e.g., on front panel or side of the bore) and requires that the amplifiers are compatible within a high magnetic field environment. To accomplish this, the B_0 field should have no adverse impact on MOSFET and amplifier behavior, and, the amplifier should also have no notable impact on image quality. In this study, a 1 kW (peak power) non-magnetic amplifier module was designed and constructed. The impact of the B_0 field on the non-magnetic amplifier and the effect of non-magnetic amplifier on the performance of the system were investigated on a GE 3T MR750 system (GE Healthcare, Waukesha, WI). The experimental results indicated that, at 3T, the magnetic field had no notable impact on the AC and DC characteristic of the power MOSFET. Similarly, the non-magnetic amplifier had no appreciable impact on B_0 and B_1 homogeneity, and, image SNR.

METHOD: Fig.1 illustrates a prototype of the non-magnetic amplifier. Instead of ferrite components, air-core inductors and non-magnetic capacitors were used for input and output impedance matching, and, for the DC feed circuit. A plastic package MOSFET ARF475 was chosen to provide high power RF amplification, and, a thick (~3mm) copper slab was used to dissipate heat from the PCB and MOSFET. Inexpensive, smaller gauge coaxial cables from the equipment room to the non-magnetic amplifier were used to feed DC power from an external power supply and low-power RF signals from the systems cabinet.

The impact of the B_0 field on the DC and AC characteristics (gain and phase) of the ARF475 were evaluated in several bench tests. In the first baseline experiment, the non-magnetic amplifier performance characteristics were evaluated when the amplifier was placed outside the scanner room. The link between static currents and V_{gs} (gate-source voltage), and, the relationships between I_{ds} (drain-source current), gain, phase and RF input power were measured. The same test procedures were repeated when the non-magnetic amplifier was placed at different positions (A, B, C and D) in and around the 3T magnet, as shown in Fig.2. Positions C and D refer to two orthogonal orientations of the amplifier to account for Hall effects. The final results were then compared with that of the baseline experiments.

The impact of the non-magnetic amplifier on B_0, B_1^+, and, image quality were also investigated. The output of the non-magnetic amplifier was connected to a 50-ohm terminator that was placed outside of the scanner room. The RF input of the amplifier was triggered by the exciter unblank signal. Imaging was performed with the body coil on a standard GE quality assurance phantom located at the coil isocenter. When the body coil transmitted an RF pulse, the unblank trigger signal to the non-magnetic amplifier caused a 128 MHz CW signal to flow through the non-magnetic amplifier into the 50 Ω load. During the receive phase, the unblank signal shuts off both the body coil and non-magnetic amplifiers. Any interference caused by the non-magnetic amplifier during this simulated functional test was evaluated in terms of their impact on B_0 and B_1 homogeneity, and image SNR. The experiments were done with the non-magnetic amplifier placed outside the scanner room, and, on the front panel and side of the magnet bore (positions A and B in Fig.2). B_0 maps were acquired with the same GRE sequence at two different echo times [3], while, flip angle maps (proportional to B_1^+) were obtained using a GRE sequence at two different flip angles with a long TR [4]

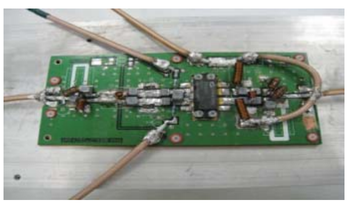

Fig. 1. Prototype of the non-magnetic amplifier

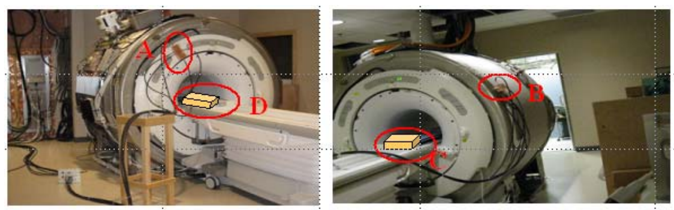

Fig. 2. The non-magnetic amplifier in or near magnet

RESULTS AND DISCUSSIONS: Based on power efficiency and linearity considerations, the ARF475 operated in a class AB mode with the bias current set to 200 mA. The bias voltage was applied in pulse mode, as triggered by an external gating signal. The duty cycle was 1% and continuous on-time was 3 ms .The drain voltage was set to 165 V. Peak 1 kW power output was achieved at 128 MHz.

The results of magnetic field B_0 impact on the DC characteristic and AC characteristic of ARF475 are summarized in Fig.3. Compared with results with the amplifier outside of magnetic room, the AC and DC characteristics were minimally affected by the different positions of the non-magnetic amplifier in the magnet room. The magnetic field B_0 does not have any notable impact to MOSFET behavior at 3T at the four amplifier positions in Fig. 2.

The statistics of the deviation in B_0 and flip angle maps when the amplifier is located in the magnet room, compared to the baseline maps (amplifier outside magnet room), are shown in Table 1. The mean of the absolute change in B_0 field homogeneity was about 1.78 Hz±3.07Hz or 0.01±0.02 ppm at 3T when the non-magnetic amplifier was located on the front panel. Also, the mean error was as low as 1.79 Hz/0.01 ppm with the non-magnetic amplifier at the side of the bore. The mean of the absolute flip angle (~B_1 field) change was 0.10±0.3 deg when the amplifier was positioned at the front panel and side of the magnet bore. The image SNR changes were less than 3.5%. From the above results, the non-magnetic amplifier had no appreciable impact to overall field homogeneity and system.

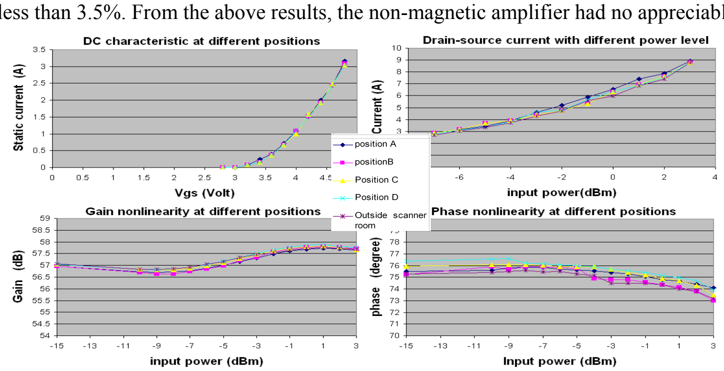

Fig. 3. DC characteristic and AC characteristics of ARF475 at different positions

Table.1. B_0 and flip angle (~B_1^+) changes introduced by non-magnetic amplifier.

	Amp position	mean|change|	std_dev|change|	max|change|
B_0 change	front panel	1.78Hz/ 0.01ppm	3.07Hz/ 0.02ppm	28.3Hz/ 0.22ppm
	side of bore	1.79Hz/ 0.01ppm	3.10Hz/ 0.02ppm	25.3Hz/ 0.20ppm
Flip angle (~B_1^+) change	front panel	0.1 degree	0.3 degree	
	side of bore	0.1 degree	0.32 degree	

REFERENCES: [1] X. Chu, et al., Proc. ISMRM 2007, p. 172. [2] X. Chu, et al., MRM61: 952-961, 2009. [3] Schneider E, et al., MRM 18: 335– 47, 1991. [4] Insko E, et al., JMR Ser A 103: 82–85, 1993.