An improved design of multi-channel switching circuit for matrix gradient coil

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Introduction: Matrix coils were originally developed for shimming to improve the magnetic homogeneity[1-3]. Recently, these coils were adapted for encoding showing their potential to offer high flexibility in generating customized spatial encoding magnetic fields[4,5]. In conventional approaches, each coil element is driven by its own amplifier. Harris introduced a dynamically controlled adaptive shimming method and the current path could be altered to control a high number of coil elements by a single amplifier[6]. Last year, a multi-channel switching system for matrix gradient coil was introduced to reduce the total number of gradient amplifiers required to drive a matrix gradient coil[7]. This work presents an updated multi-channel switching circuit to provide more flexibility to generate customized current patterns.

Methods: The switching circuit consists of a bridge switch array, an interconnection switch array and an amplifier selection switch array. Each coil element is connected to its own bridge switch and can be configured such that current flows in either positive or negative direction or is bypassed. Fig. 1 shows a topology to connect in series and in parallel *n*m* coil elements, *j* gradient power amplifiers, *n*m* analog bridge switches, *(n-1)*(m+1)* interconnection switches and *4*n*j* amplifier selection switches. The bridge switches and interconnection switches are used to dynamically configure the current path of coil elements during the pulse sequence to generate the specific current pattern. The amplifier selection switches are used for dynamically defining different channels of the current path during the experiment (the number of channels of current path is equal to the number of gradient power amplifiers used). The bridge switches and interconnection switches are placed in the immediate vicinity of the coil elements inside or close to the magnet. Thus the length of connection wires between the respective coil element and the switching element can be reduced, which diminishes power losses. The amplifier selection switches are placed in the immediate vicinity of gradient power amplifiers thus also reducing the length of connecting wires. Fig. 2 presents the gradient system including the multi-channel switching circuit. The number of gradient power amplifiers and corresponding power filters is reduced in this method. The current waveform generator and switch controller is based on the commercial high speed digital IO board (PCIe-6536, National Instruments), and a CPLD (Complex Programmable Logic Device) is used to decode digital switching commands.

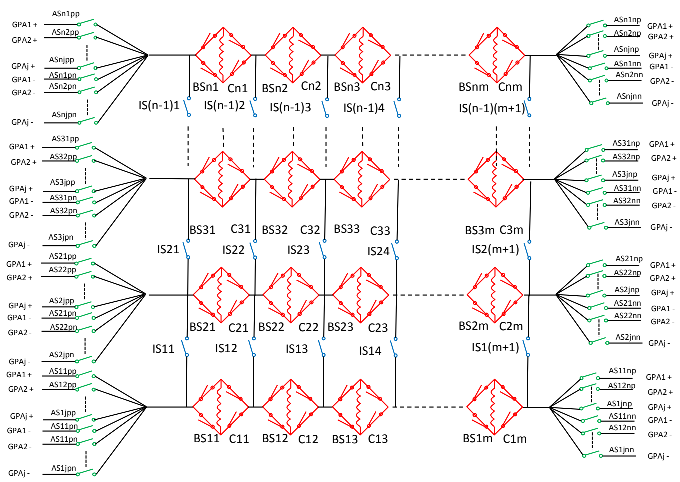

Fig.1 Block diagram of multi-channel switching circuit containing arrays of bridge switches (red), interconnection switches (blue) and amplifier selection switches (green)

Discussion: In this work, the dynamically adapted magnetic encoding field is implemented by the switching circuit to generate different combinations of matrix gradient coil elements and available gradient power amplifiers during pulse sequences. Many coil elements are driven by a single gradient power amplifier; therefore, the total number of gradient power amplifiers can be reduced. A gradient power amplifier with the function of an on-line tunable load is required to drive different combinations of coil elements. Consequently, the amplifiers XPA-150-350 (IECO, Finland) will be used to drive the matrix gradient coil. Each amplifier channel can support 15 different coil loads during one experiment. The metal-oxide-semiconductor field-effect transistor (MOSFET) is used as the switch element. The number of coil elements driven by single gradient amplifier is limited because of the on-state resistance of the MOSFET. The on-state resistance of single switch is approximately 30 mΩ, the resistance of single coil element is approximately 10 mΩ, and the load resistance range of the amplifier is 0 Ω to 1 Ω; therefore, the combinations of coil elements and switches is constrained by these parameters.

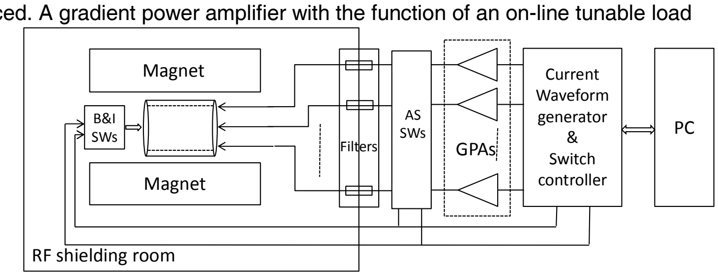

Fig.2 Gradient system including the multi-channel switching circuit
(B&I SWs=bridge and interconnection switches, AS SWs=amplifier selection switches)

To achieve high flexibility of the current pattern, a huge number of switches would be required. For example, for a 12×9 matrix gradient coil with 12 gradient power amplifiers, 108 bridge switches, 110 interconnection switches and 576 amplifier selection switches would be required. This degree of complexity is probably not practical. Therefore an optimization method to find suitable combinations of coil elements and amplifiers is being developed to reduce the number of switches required while maintain the flexibility of the matrix gradient coil. A prototype of switching system will be tested after the construction of the matrix gradient coil.

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