

Multichannel High Power Single-Pole Double-Throw (SPDT) Microstrip T/R Switch for 470 MHz Arrays

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Introduction

The promise of increase in signal to noise ratio has driven the development of MR towards stronger magnetic field strengths. However, these higher magnetic fields and resonant frequencies present unique challenges to the coil designer. The design of large volume coils must take into account field focusing and wave behavior within the sample (1). Many of these designs involve generating different amplitudes and phases of current for each element of an array (2,3,4,5). In order to successfully perform such experiments, the currents sent to the elements of the array need to be easily controlled and measured. The system T/R switch is an element in line with the transmit signal where unwanted deviations in current amplitudes and phases could be introduced. System T/R switches are difficult to test due to the inability of locating test equipment near the magnet and the difficulty in isolating the switch from other front end components. To facilitate the design of large volume arrays on our 11.1T MRI animal imaging system we have built a Multichannel High-Power T/R switch based on a SPDT PIN diode switch design. This switch is easily interfaced with the system through BNC connectors and can be removed for verification of performance.

Methods

A 4-channel T/R switch was designed and constructed to be used on a 11.1 Tesla, 40 cm Magnex clear bore magnet interfaced with a Bruker Biospec imaging/spectroscopy console; with a proton resonant frequency of 470 MHz. The switch is based on a single-pole double-throw PIN diode design (6). A schematic of a single channel is shown in figure 1. The transmit and receive paths each contain two 50 ohm quarter waves transmission lines with shunt diodes (MA4P7461F). The diodes are oriented in opposing directions for the two paths. The system provided control pulse is negative during transmission, which reverse biases the shunt diodes in the transmission path allowing the high power signal to pass through the 50 ohm microstrip transmission lines to the coil port. At the same time, the diodes in the reception path are forward biased, shorting the ends of the quarter wave transmission lines and providing a high impedance to the coil port. During reception, the gated control pulse is positive and the actions just described are reversed. Series and shunt capacitors are added on either end of the circuits for slight adjustments to the impedance match. Passive diodes are added at the receive port in case of active control failure. The circuit was built on 0.030 inch GML 1000 (dielectric constant of 3.2). The 50 ohm microstrip transmission line had a width of 0.070 inches. This circuit was repeated four times and then installed into a box for system interfacing through BNC connectors. The gated control pulse was fed into a separate circuit to provide current limiting and voltage conditioning before being distributed to the T/R switch boards. A photograph of the completed switch is shown in figure 2.

A large 4-element transceive array was built and simulated with full-wave electromagnetic hybrid model using a combined MoM/FEM method (2). Each loop was 13.5cm x 13.5 cm and the 4 loops were positioned around the sample in an orthogonal manner (figure 4). The coil was loaded with a large cylindrical phantom (dia 12.5 cm, height 14 cm) having the same electrical properties as the average brain at 470 MHz ($\epsilon = 48.6$, $\sigma = 0.6$ S/m) (7). The technique of Transmission Phase Cycling (2) was applied whereby differing phases and amplitudes are sent to each element of the array. A spin echo image was acquired using the same transmission phases and amplitudes as the simulation. These were generated by splitting the single channel transmitter output with a quad hybrid-splitter combination and then inputting into channels 1-4 of the T/R switch.

Results

Insertion loss for the transmit (or receive) path when the diodes are reversed biased is 0.5 dB with a phase shift of 102 degrees (for all channels). The return loss under this condition was less than -25 dB for the transmit (or receive) port and the coil port (for all channels). The isolation between the transmit (or receive) port and the coil port when the diodes were forward biased was -40 dB. At all times, the isolation between the transmit and receive ports was -40dB. The acquired image of figure 4 confirms the expected image based on simulation indicating that the proper amplitudes and phases of current were transmitted to the coil and were not disturbed by the 4-channel T/R switch.

Conclusion

We have successfully constructed a multichannel T/R switch based on a SPDT PIN diode design that can be easily removed from the transmit-receive chain for verification of performance. This ability is important to the implementation of high frequency engineering techniques as is currently applied to large volume coils in overcoming B1 field inhomogeneities.

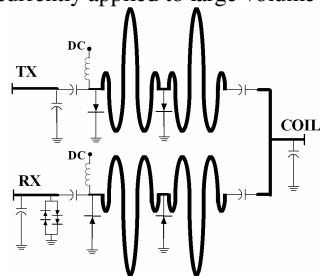


Fig. 1 T/R switch schematic

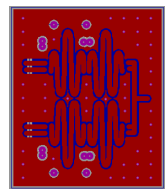


Fig. 2 Microstrip layout

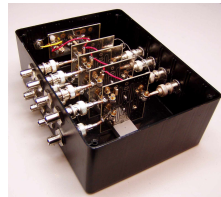


Fig. 3 4-channel switch

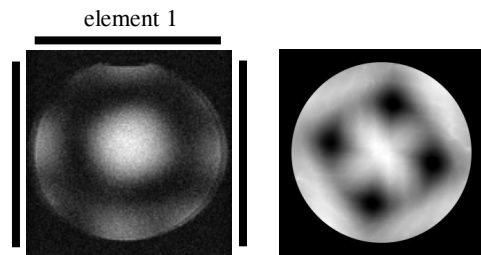


Fig. 4 Acquired (left) and simulated (right) images

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