RF transparent array for testing multi-channel transmit systems

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Introduction

The use of high channel count transmit arrays in the clinical setting has yet to receive widespread adoption, and the integration of prototype hardware with a clinical scanner for testing adds complexity. A simple 8-channel transmit array capable of operating in series or parallel resonance was implemented to facilitate testing of multiple parallel transmit platforms, in particular comparing voltage and current source excitations schemes. The transmit array has been successfully implemented on a 3T GE clinical scanner and can simply be inserted into the body coil (used as the receive coil) without the need for a decoupling network.

Materials and Methods

Operation in both current and voltage (the conventional method) excitation modes requires changing the element from series to parallel resonance, respectively. Changing resonance from series to parallel complicates the design of any transmit/receive switch and/or detuning network required to use the coil as a transmit/receive coil or in conjunction with a separate receive coil. Therefore, it was desired to use a coil configuration for the transmit coil that would work inside the body coil without requiring a detuning network or transmit/receive switch. Without any t/r switch, the conversion between operating modes becomes extremely simple. We implemented a conversion module to achieve parallel resonance. Each contains a tunable Voltronics capacitor with a SMA input from the amplifier stage and a BNC output to the coil. The conversion boxes are connected $n\lambda/2$ wavelengths down from the coil. The integration of the transmit array with a clinical system poses an integration problem. An array coil of loops would couple to the body coil, and rungs over ground planes, used before by our group, would not allow for an outside receive coil. Previously, we have used planar pair coils with raised legs to avoid coupling with volume coils. A variation of the 'raised leg' planar pair coil [3] was used for this array coil. A single element is shown in Figure 1. It consists of a 24.5 cm copper tube held 3 cm over a loop with outer dimensions 25.5 x 9 cm. One end of the rung is connected to the midpoint of the loop through an 18 pF capacitor. The rung is excited against the midpoint of the loop on the opposite side, forming a planar pair. In current source configuration, the element is series resonated with a single series Voltronics variable capacitor at the feedpoint. An SMA connector at the feedpoint allows a $n\lambda/2$ cable with an integrated balun to be connected. The loop, which provides the return path for the rung, is broken with four 15 pF capacitors to avoid self-resonance, and it is not resonant at the 128 MHz Larmor frequency. Figure 2 shows this loop mode alone, showing a resonance at 116.7 MHz, sufficiently far from 128 MHz to not couple significantly to the body coil during receive. The rung only operates in one mode, the planar pair mode, which shows no apparent coupling to the uniform field produced by the body coil. The coil is based around a PCB design and built in-house, with a copper tubing rung acting as the raised leg. Nonmagnetic fixed value capacitors (American Technical Ceramics) and variable capacitors (Voltronics) are used to resonate the elements. In initial stages of coil construction, we placed the balun on the coil body for structural stability, and the element was series-resonated using an S_{11} measurement at the input of the balun. The balun added some small electrical length to the coil element causing the actual resonance of the coil to shift slightly when measured with a double pickup loop. Tuning inside a clinical scanner with a pickup loop would be impractical. To eliminate this issue, we modified the design and placed the baluns on the cables themselves, and an S_{11} measurement effectively tuned the coil element with negligible resonance shift as compared to pickup loop measurements. Since the primary use of the coil is for testing, the assembly and construction needed to be modular in design and relatively easy to disassemble if small modifications became necessary. Thus, we created an acrylic former using a laser table to precisely cut the acrylic pieces in a tab and slot design. The elements fit into the cut acrylic pieces securely, and the use of nylon screws secured the acrylic pieces together.

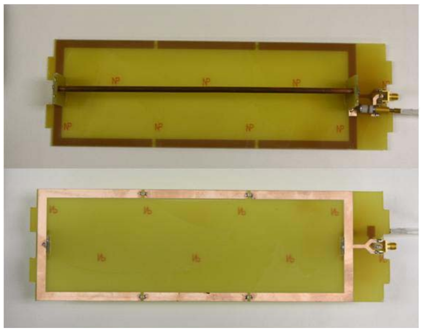
Figure 1: Single element showing the variation on the 'raised leg' planar pair coil. The top and bottom views of the element are shown.

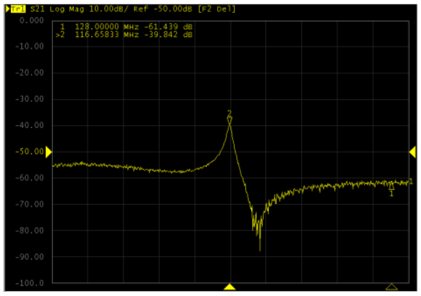

Figure 2: S21 measurement of the loop mode of a single element at 116.7 MHz

Preliminary Results and Discussion

At this stage, we have successfully implemented the 8-channel RF test coil on a 3 Tesla GE clinical scanner. Figure 3 shows the completed eight element transmit array. To verify the lack of coupling to the body coil, eight gradient echo images (TR=250 ms) were obtained successively, each one using a different element for excitation. The images were acquired using commercial power amplifiers to excite the coil and the conversion modules to achieve parallel resonance. Unused coils were open-circuited, as would be the case (ideally) when using current sources. The results are shown in Figure 4. No coupling to the body coil is evident. The coil appears to be ideal for testing parallel excitation with voltage and current sources inside a clinical system, allowing fast setup (body coil is used as receive, transmit is rerouted to the multichannel transmitter), simple coil design (no T/R switches or decoupling) and simple switching between current and voltage source modes. Integration with a clinical scanner poses additional obstacles, and the design of a generic test coil that operates in many modes presents the advantages of being able to use existing hardware with prototype coils and verify next generation transmit chain functionality. The test coil provides a platform for which comparison studies of voltage and current sources are well suited since in both transmit excitation schemes, the same coil element is used allowing information to be accurately quantified and relative measurements to be obtained.

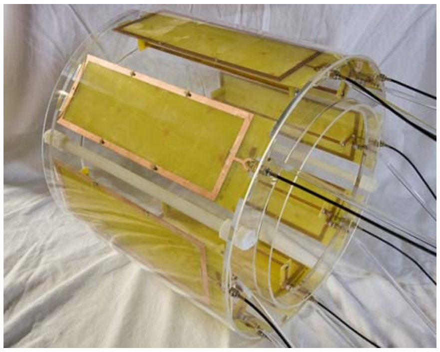
Figure 3: Complete 8-channel transmit array in acrylic former

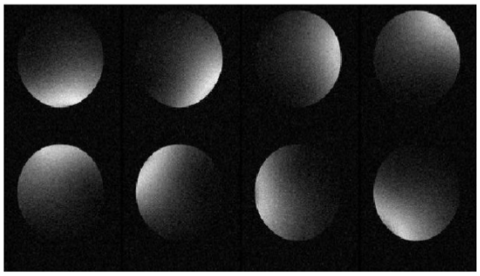
Figure 4: Gradient echo images (TR=250 ms) of the individual coil elements shown in successive order, starting with the bottom element and working counter clockwise. There is no evidence of coupling with the body coil. The images were acquired using commercial power amplifiers and the conversion modules.

Acknowledgement

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References

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