An Improved Constellation Coil

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Introduction:
Parallel transmit multi-port volume coils are becoming important due to increased field strengths in order to improve B1+ homogeneity and to minimize Specific Absorption Rate (SAR). However, it is a challenging task to manufacture such coils, and design a transmit chain to support the functionality of such coils. Zhu et. al. [1] introduced a design, "constellation coil" that simplifies the manufacturability of the parallel transmit coils. Also Zhu's design is easily scalable to other field strengths, since it does not require tuning. In this work, we have analyzed the performance of the constellation coil using numerical simulations and developed a modified version of the constellation coil for better performance. This updated design improves B1+ homogeneity and makes the B1+ profile similar to the birdcage structure.

Materials and Methods:
A coil similar to the one presented in [1] (shown in Figure 1) was modeled using HFSS (Ansys corporation) for 127.72 MHz. The coil had a diameter to 20cm and it was 20cm high. Each stripe of the copper conductor was 4.5mm wide, and the thickness of the FR4 board was approximately 4mm. Instead of putting ports in the center of the structure, eight ports were modeled at one end of the coil to better understand the current propagation inside the coil. The ports were equally spaced around the coil. Original design had a continuous FR4 board between two layers of the conductor stripes. The modified constellation coil, designed in this work, has FR4 material only between the copper patterns and the coil has holes in the areas where there is no copper to force the current along the copper stripes. Simulation had to be stopped early for the new modified design due to limited computing power and memory available. The analysis of the simulation data suggested that while we can expect small numerical errors in s-parameters, it is less likely to have a noticeable impact on the field patterns. Therefore, the data can be used for this work.

Results and Discussions:
A closer look at the surface current density, shown in Figure 2, indicated that current distribution in the x-y plane for the original design has areas of low and high current densities resulting in a square shaped H1+ profile (H1+ is directly related to B1+ field, therefore, it can be used instead of B1+). This profile is different than a typical birdcage profile. However, the modified design showed more uniform current density profile in any x-y plane. However, it was noticed that the current density was not perfectly uniform along z-axis away from the ports. Re-arranging the location of the ports such that they are equally distributed on both ends of the coil can solve this problem. The new H1+ profile looks similar to the birdcage coil. Figure 3 shows the H1+ profiles for both scenarios in x-y plane at isocenter. Both Figure 2, and Figure 3 are normalized to the input power of the original design of the constellation coil.

Figure 1: Original Constellation Coil Design

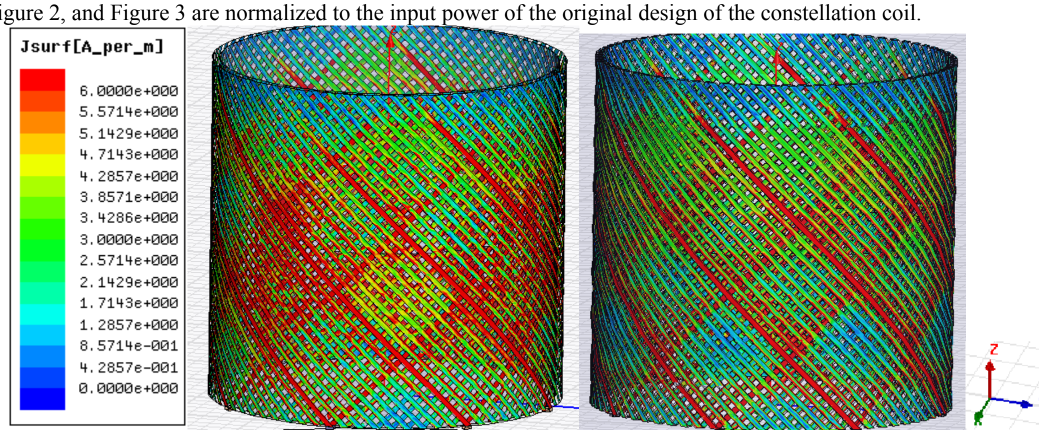

Figure 2: Magnitude of the surface current density on the original design (left), and on the modified design (right) of the constellation coil. All eight ports are located at the bottom of both structures

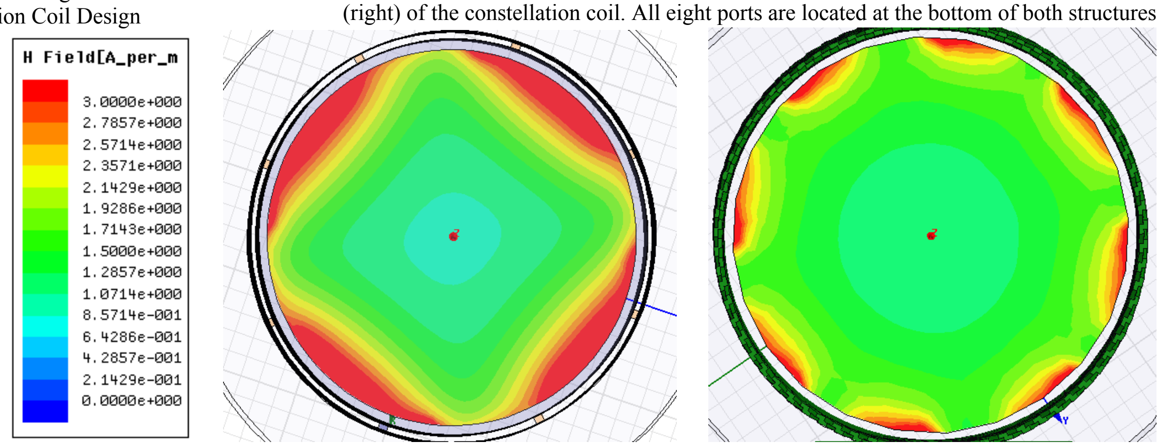

Figure 3: Magnitude of the H1+ field inside the original design (left), and the modified design (right) in x-y plane at isocenter

Conclusion:
This work shows that the new design improves the B1+ homogeneity significantly as compared to the original design. Fewer ports can be used with the new design as compared to multiple ports with the original design to acquire similar homogenous B1+ fields due to poor current propagation in the original design.

Reference:
[1] Y. Zhu et. al., "Constellation coil", ISMRM 2010