A Loop Coil Design Based on the Broadside-Coupled Split Ring Resonator at 7T

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Introduction

In the design of loop coils, a uniform current distribution is required to generate a homogeneous magnetic field. This requirement becomes more critical as the wavelength decreases with increasing frequency. In most of the designs, the common solution is to split the loop and to place capacitors in the gaps [1, 2], the number of gaps depends on the wavelength and the size of the loop, so that the distance between gaps is smaller than the wavelength. Loop designs, where the lumped capacitors are replaced by a distributed capacitance along the loop have been proposed for high field strengths [3, 4]. The distributed capacitance is given by the overlapping of two copper rings which are photo-etched at both sides of a microwave circuit board. In the reported designs [4], the number of gaps in the rings is chosen to be the same as in the conventional design with lumped capacitors. In the area of microwave metamaterials [5], a design similar to the distributed capacitance loop is termed as broad-side coupled split ring resonator (BC-SRR) and is used for the fabrication of microwave devices as filters and delay lines. In [5] it is shown a detailed theoretical analysis of the electromagnetic behaviour of such a resonator. Thus, in [5] it is explained that the sum of the currents flowing in the two rings is a constant (see Fig. 1), so that the field produced by both currents is homogeneous. This happens even if the length of the rings is comparable to the wavelength. Therefore, in distributed capacitance loops, it would not be necessary to cut the rings so many times as in the conventional design with lumped capacitors, since even if the distance between gaps along the rings is comparable to the wavelength, the current as well as the field are uniform. In this work, we propose a loop design based on the BC-SRR to illustrate this. For designing purposes, the authors developed an accurate computational tool which is available at [6].

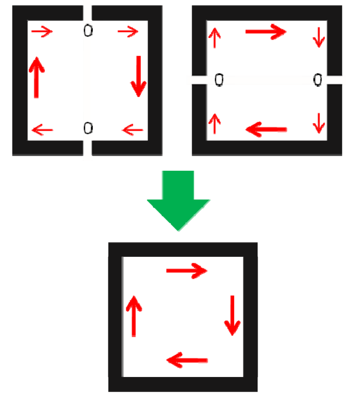

Figure 1 Top: Views of the BC-SRR and, **bottom:** its equivalent loop which results in a uniform current distribution.

Methods

A BC-SRR and two different conventional loops, with one and two capacitors, were simulated and built at 7Tesla. All the loops are 33mm in length and 33mm in width, with a conductor width of 3.5mm, and were built on FR4 substrate of 0.2 mm in thickness. The magnetic fields were simulated with CST and were compared with each other. Each element was tuned to 300.3MHz and matched to 50 Ω. The elements were aligned on a cylindrical surface along the x-y plane which was 29mm in diameter. As a phantom, a plastic tube filled with a physiological NaCl solution (4.7 g/mol) which is 28 in diameter was used. The experiments were performed in a 7 Tesla small animal system (Bruker Biospin, Ettlingen, Germany).

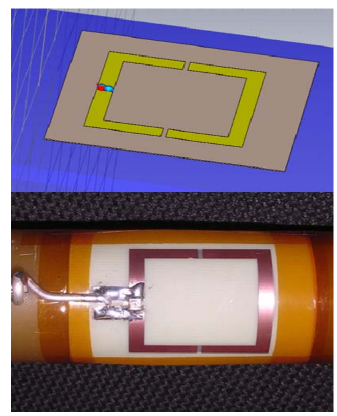

Figure 2 Broadside loop, **top:** simulated, **bottom:** constructed.

Results

In Figure 3, calculated SNR-maps from the simulation and their profiles are shown. For the constructed loops, the quality factor Q of the BC-SRR dropped by a factor of 2 and for the conventional loops design dropped by a factor of 1.6 (one capacitor) and 1.8 (two capacitors) from unloaded to loaded case. Phantom images were also acquired and the calculated SNR maps were compared.

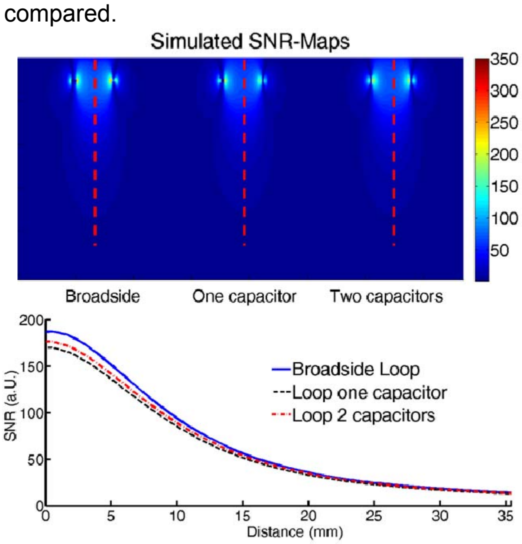

Figure 3 Top: Simulated SNR maps, **bottom:** corresponding transversal SNR-profiles for the three different loops.

Discussion/Conclusion

At 7 Tesla, the BC-SRR design with two gaps has shown a homogeneous magnetic field and a slight improvement in the SNR as compared with conventional designs. This proves that in the design of a loop with distributed capacitance, it is not necessary to split the ring in several parts as referred in [5]. This due to the fact that the total current flowing in the two loops of any distributed-capacitance design is constant independently of the number of gaps which cut the rings.

References

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