A local coil design with CR-LOOP for low field MRI

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Introduction

Nowadays, the general way to enlarge FOV in extremity coil is to add a SADDLE element to the LOOP element. By combining the signal of the LOOP element and the 90^o phase shifted signal of the SADDLE element to make a circular polarized signal, the SNR can be increased by approximately 30%. However, because of the low SNR of the SADDLE element, the FOV is still limited. Especially, the SNR at the two endings is decreased very strongly compared to the SNR at the center of the coil.

Methods

Our new design is adding a CR-LOOP (Counter Rotating Loop) element into the conventional LOOP and SADDLE element design. The CR-LOOP element is two parallel loops that are located at the two sides of the original LOOP element. They are placed parallel to the end-ring structure composed by the SADDLE element. The current in both of the end-rings of the CR-LOOP has a different direction and therefore the signal sensitivity at the center of the coil should be zero. Since the CR-LOOP has the same size as the SADDLE element, we can increase the SNR and FOV without increasing the size of the coil. Because of the CR-LOOP element's symmetry structure, it is geometrically decoupled to the LOOP and the SADDLE elements, which is very important for easy manufacturing.

To make an estimation of the improvement of SNR and FOV, we use Biot-Savart law:

$$\boldsymbol{B} = \frac{\mu_0}{4\pi}\int_C \frac{\mathrm{I}\,\boldsymbol{dl}\times\boldsymbol{R}}{\mathrm{R}^3}$$

to calculate signal profile of the three elements (LOOP, SADDLE and CR-LOOP). Experiment shows that the SADDLE element has approximately 83% SNR of the LOOP element at the center of the coil. We also assumed the end-rings of the CR-LOOP has the coupling coefficient of about 16%. With these parameters, we can plot the SNR of the LOOP, the SADDLE and the CR-LOOP together. In addition, because all these three elements are not coupled to each other, we can use the root-of-the-sum-of-squares to calculate the combined SNR of LOOP + SADDLE and LOOP + SADDLE + (CR-LOOP).

Results

According to the hardware coil's size, we assumed that the diameter of each loop is 19cm, the distance of the two parallel loops of CR-LOOP is 18cm, the SADDLE element's length is 18cm and its opening angle is 60^o. Using Biot-Savart law, we get the result that is plotted in Figure 1. From this result, we can see that the LOOP element has a much better SNR than the SADDLE element. Using the SNR's -3dB FOV definition, we can see that, adding the CR-LOOP, the FOV will extend in z-direction, about 4.2cm. Since the whole length is 18cm, FOV has increased by about 25%. Simultaneously, the SNR in FOV is obviously improved, more than 3dB in the end-rings.

Based on our new design, we built a test coil with the same size discussed above. After testing the coil using NWA, we see that the symmetrical wire structure can achieve very good decoupling. The rest decoupling is achieved by using decoupling capacitors. In the circuit, we use an active PIN-diode to detune the circuit. The coil has been tested in the NOVUS 0.35T MRI system using a Gradient Echo Sequence with a matrix size of 256x256. The phantom used is a 2000ml bottle. The sequence has been run twice, one with RF signal and the other without RF signal to evaluate both signal and noise. The evaluated SNR of the LOOP, SADDLE and CR-LOOP have been plotted in Figure 2. According to the tested result, we can see that with the CR-LOOP element, the FOV extends about 5.5cm and the SNR increases about 4dB in the end-rings, which is very close to the expected value according to the calculation.

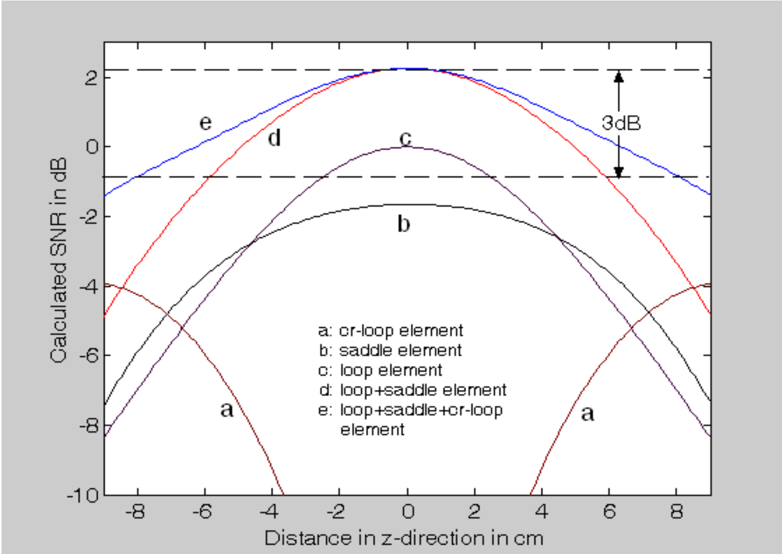

Figure 1 The calculated results of SNR of each element

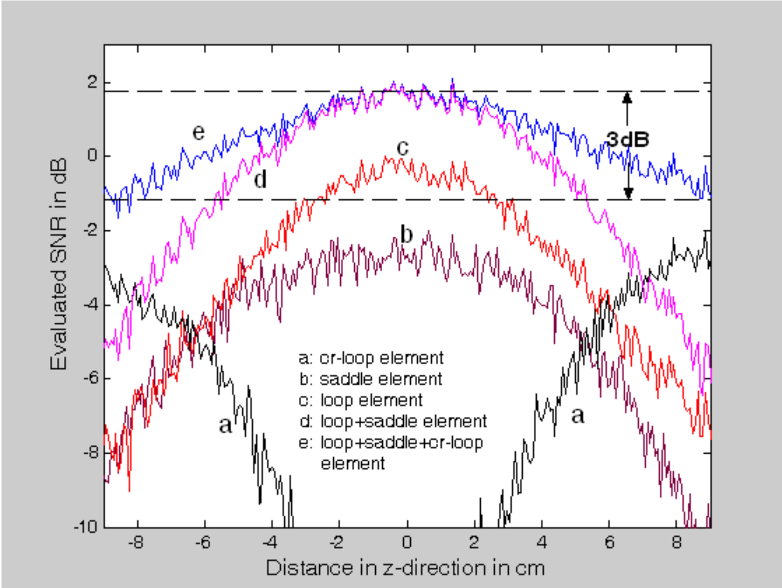

Figure 2 The evaluated results of SNR of each element

Conclusions

We showed a new design of our local coil in theory and experiment in order to increase FOV and improve the imaging quality. From what we have discussed, we can see that, with the new design we increase both SNR and FOV for about 30%, without increase the coil size.

References

[1] PB. Roemer et al, Magn Reson Med 1990;16:192–225.