Opencage: RF coil with an adjusted current distribution

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Introduction: The main volume RF coil used in MRI is the birdcage one which provides a homogeneous signal in the whole volume under study [1]. A birdcage is a circular metallic ladder closed on itself, the magnetic field being generated by the current circulating in the legs. In certain applications the birdcage coil is inconvenient due to a short distance between neighbor legs. Here it is proposed to solve this issue by breaking the periodicity of ladder distribution in order to open a wide access to sample under study. The proposed design is called opencage [2], it has been tested numerically and experimentally for proton imaging of small animals at 7T.

Methods: The design of an opencage coil is based on the metacage analysis. In general, a metacage is made of a metasurface composed of transmission line unit cells. Consequently, a birdcage can be interpreted as a particular metacage where all the unit cells are identical. By adjusting the properties of each unit cell, an original field distribution can be obtained. Here, this approach is used to increase the distance between two neighbor legs on the top of a metacage. The opencage is composed of six legs where four legs are separated by 45° and the two other ones by 90°. The unit cells are designed in order to induce phase shifts that corresponds to the geometrical angle. Beside the phase shift, the Bloch impedance of all the unit cells are identical to avoid reflections due to unmatched impedance.

Results and discussion: The results of calculations have been verified using commercial software CST Studio Suite 2018. Since the coil has been optimized, the prototype has been assembled and tested both with phantom and in-vivo in the preclinical MRI scanner Bruker PharmaScan 7T. An original sequence is used to map the B_1^+ field [3]. The results of phantom and in-vivo imaging have been compared with the conventional birdcage coil of the same size (radius = 35 mm; length = 40mm). The opencage demonstrates suitable homogeneity of signal in the bottom half of the phantom. The relative standard deviation is 8.8% for the opencage versus 8.3% for the birdcage. SNR is comparable for both images 1865 for the opencage versus 1752 for the birdcage coil.

Conclusion: The metacage approach has been used to design an original opencage coil that provides a wide access to the ROI. The coil has been tested for a preclinical imaging of small animals at 7T. It is shown analytically and numerically that the proposed coil achieves suitable homogeneity and SNR. The experimental demonstration of the opencage in the preclinical MRI scanner has validated our approach. Furthermore, the tests of the opencage coil in clinical MRI at 7T are ongoing.

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 736937. This work is supported by LABEX WIFI (Laboratory of Excellence within the French Program "Investments for the Future") under references ANR-10-LABX-24 and ANR-10-IDEX-0001-02 PSL.

References: [1] Cecil E. Hayes, William A. Edelstein, John F. Schenck, Otward M. Mueller, Matthew Eash, An Efficient, Highly Homogeneous Radiofrequency Coil for Whole-Body NMR Imaging at 1.5 T, Journal of Magnetic Resonance, vol. 63 (3), p. 622-628, 1985.
[2] A. Nikulin, J. de Rosny, K. Haliot, B. Larrat, and A. Ourir, Opencage Radio Frequency Coil for Magnetic Resonance Imaging, Applied Physics Letters, vol 114 (5), 053503, 2019.
[3] Kay Nehrke, On the steady‐state properties of actual flip angle imaging (AFI), Magnetic Resonance in Medicine, vol. 61, pp. 84–92, 2009.