A PIN-Diode-controlled double-tuned Birdcage Coil for 1H-Imaging and 31P-Spectroscopy on Mice

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Purpose:

A volume coil which is focused on proton-imaging and spectroscopy and capable of 31P-spectroscopy had to be developed. The coil should be homogeneous for the size of a mouse and easy to integrate to our 7T small animal imaging system.
We decided to develop an 8-leg high-pass Birdcage (BC) coil which is switched by PIN-diodes between the proton and phosphor resonance. The PIN-diode-controlled double-tuned Birdcage has a superior signal-to-noise-ratio (SNR) for proton- imaging and is capable of 31P-single voxel spectroscopy.

Methods:

The coil conductors were etched from copper foil (DuPont Pyralux) and form an 8 cm long and 3.6 cm wide cylindrical high-pass BC coil. The end ring capacitors were split into two parallel lines. The inner line was tuned with 13 pF capacitors to proton lamor frequency. In parallel to this proton capacity is a second current line consisting of two capacitors in series split by a PIN-diode (MACOM, MA4P7446F-1091T). On proton resonance mode the PIN-diodes are supplied with negative voltage and block the current in the outer end ring line. On phosphorus resonance mode the PIN-diodes are biased by DC-current and open the parallel line for radiofrequency current, which tunes the coil to phosphorous lamor frequency. A 6 cm-diameter RF-shield has been mounted to isolate and protect the coil from the gradients. The coil is driven in quadrature mode and capacitive-coupled to the scanner. The interface consists of matching capacitors, cable traps and blocking circuits for the other nucleus resonance frequency. A hybrid board with preamp was mounted outside the bore of the magnet for each of the frequencies. The 16 switching PIN-Diodes are in series and driven via two lines for each of the end ring. The bias current is brought via the center conductors of 1H-BNC connectors to the coil and guided via RF chokes to the PIN-Diodes.
Q-values were measured unloaded and loaded with a 60 ml cupric sulfate measurement phantom. The SNR of the coil was measured with TSE-sequences in the proton mode and GRE-sequences in the phosphorus mode on a 30 ml KH_2PO_4-Phantom consisting of 0.5 Mol phosphorus. The SNR of the BC-coil is compared to a shielded double-tuned 4-Ring-BC-coil [1, 2] (length: 12 cm, inner rings: 6 cm) and an unshielded single tuned P31-BC-coil (length: 6 cm) of the same diameter.

Results:

The Q-value (unloaded/loaded: 170/40) for the PIN-Diode BC is comparable on proton resonance, but lower than on 4-Ring-BC (Q: 210/67). On phosphor resonance Q-values drop to Q: 72/46, and are much lower than for the 4-Ring-BC (Q: 285/90). The SNR of the coil on proton resonance is about 3 times higher than the 4-Ring-BC, but about factor 2 smaller on phosphor resonance (Fig.1+2). The homogeneity is very high (about 6 cm in z direction are within 10% SNR variation). Proton images and P31-spectra were measured on mice (Fig.3).

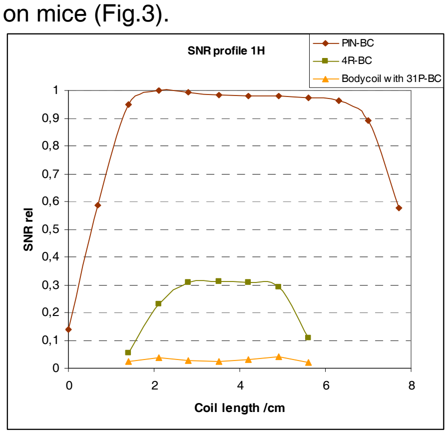

Fig.1: 1H- SNR profile of the selected coils along the coil axis.

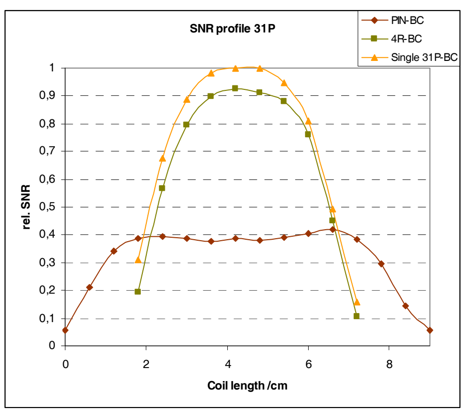

Fig.2: 31P- SNR profile of the selected coils along the coil axis.

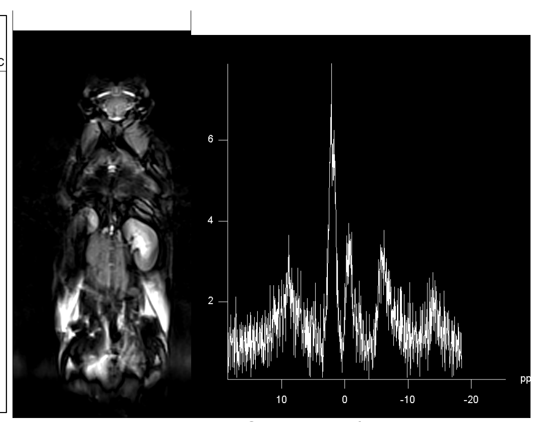

Fig.3: T2- weighted TSE image of a living mouse and 31P-spectrum measured with PIN-Diode -BC

Discussion:

The developed PIN-diode switched Birdcage coil shows superior SNR to a 4-Ring-BC of similar size in proton imaging, but lower SNR on phosphor resonance mode. Thus the intended usage should be proton imaging and spectroscopy with phosphor spectroscopy as an Add-on. One should mention that PIN-diode-switched transmit coils are not capable of transmitting X-nucleus and proton signals at the same time which can be used to gain additional signal boost on X-nucleus frequency by the nuclear Overhauser effect. This makes other coil designs like the 4-Ring-BC favourable where small voxel sizes have to be resolved in 31P-spectra.

References:
[1] Murphy-Boesch J. (1994) Two Configurations of the Four-Ring Birdcage Coil for 1H Imaging and 1H-Decoupled 31P Spectroscopy of the Human Head; J Magn. Res. B. 1994.103-114.
[2] Lanz T. (1997) Double-tuned four-ring birdcage resonators for in vivo 31P- nuclear magnetic resonance spectroscopy ar 11,75T; MAGMA 1997, 5, 243-246.