A 3 channel ^{31}P and 2 channel ^{1}H coil array for ^{31}P NMR in the visual cortex at 7 T

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Target Audience: Researchers who are interested in RF coil array design for X-nuclei applications or ^{31}P brain MRS

Purpose: Phosphorous spectroscopy in the occipital lobe may be used to investigate the ^{31}P metabolism in the visual cortex and its changes during various conditions. Due to the inherently low relative sensitivity of ^{31}P and its low abundance in the brain, the hardware for the application has to be optimized for detection sensitivity. Increasing the field strength to 7 T already results in higher sensitivity, increased spectral resolution and shorter T_1-relexation times [1] for ^{31}P spectroscopy in general [2]. Employing RF surface coil arrays further increases the achievable SNR, enabling increase in temporal and/or spatial resolution. Here, a dedicated 3 channel ^{31}P array combined with a 2 channel ^{1}H array conformed to the back of the head for ^{31}P NMR studies in the human occipital lobe is presented together with preliminary results achieved with the proposed setup.

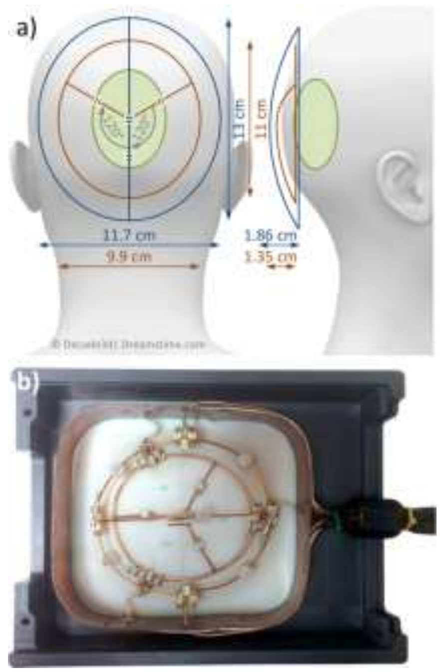

Fig. 1 (a) Frontal and lateral view of the proposed coil setup. The ^{31}P array is depicted in red and the ^{1}H part in blue. The green ellipsoid is the region of interest located in the visual cortex. **(b)** A picture of the built coil setup with its housing.

Methods: The coil was previously simulated and optimized by FDTD 3D electromagnetic simulation (XFdtd 7.4, Remcom, State College, PA, USA) together with a circuit co-simulation (ADS, Agilent, Santa Clara, USA), and an in-house developed post-processing software package (SimOpTx, RSA, MedUni Vienna, Austria) for SAR evaluation [3]. The resulting optimal coil size was used as a starting point for the current work. Additionally it was modified to incorporate a circumferential copper shielding to reduce radiation losses and cable shield currents. Static B_1^+ shimming for the coil setup was determined in terms of a combination of transmit efficiency $(\overline{B_1^+}/\sqrt{SAR_{10g}})$ and relative inhomogeneity $(\overline{B_1^+}/std(B_1^+))$ by 3D EM simulation. Coil performance was evaluated with bench and MRI measurements. The coil setup seen in Fig. 1 consists of a three channel shared-capacitor decoupled, elliptical ^{31}P array, with major/minor axis dimensions of 11 cm/9.9 cm. The ^{1}H array consists of 2 shared-capacitor decoupled channels for scout imaging and major/minor axis dimensions of 13 cm/11.7 cm. Both arrays were bent to conform to the shape of the human head yielding a coil height of 1.4 cm/1.9 cm for the ^{31}P and ^{1}H array, respectively. The scattering parameters were measured on a network analyzer (E5061B, Agilent, Santa Clara, USA). MR measurements were performed on a 7 T MR scanner (Siemens Magnetom, Erlangen, Germany) using the proposed coil. The measurements were performed on a 20 cm spherical phantom filled with a phosphorous containing gel [4] and on a papaya fruit. Tuning, matching and decoupling capacitors were kept fixed for all experiments.

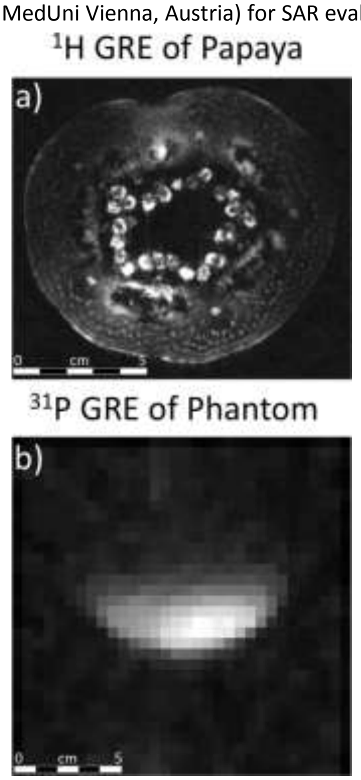

Fig. 2 (a) A transverse slice of the 3D GRE image of a papaya is depicted, showing good coverage of the whole sample. **(b)** A transverse slice of the ^{31}P 3D GRE image of the spherical ^{31}P gel phantom.

	Reflection [dB]		Transmission [dB]	
	ω_{31P}	ω_{1H}	ω_{31P}	ω_{1H}
^{31}P	<-25.9 dB	>-11.6 dB	<-13.5 dB	<28.7 dB
^{1}H	>-9 dB	<-22.4 dB	-32.89 dB	-17.2 dB
	Cross-coupling [dB]			
^{31}P↔^{1}H	ω_{31P}: <-31		ω_{1H}: <-19.5	

Tab. 1 Scattering parameter matrix measured at both Larmor frequencies while the coil was loaded with a spherical gel phantom.

Images were acquired with a 3D gradient echo sequence for both nuclei. Parameters for ^{1}H and ^{31}P scans were T_R/T_E=20/5 ms, FOV=160x160x128 mm^3, matrix=128x128x30, and T_R/T_E=80/6 ms, FOV=281x281x281 mm^3, matrix=32x32x32, 8 averages, respectively.

Results: Reflection and transmission and cross coupling coefficients for the ^{31}P and ^{1}H arrays at both Larmor frequencies (120.3 MHz for ^{31}P, and 297.2 MHz for ^{1}H) can be seen in Tab. 1. The Q ratio ($Q_{unloaded}/Q_{loaded}$) was 3.1 and 16.2 for the ^{31}P and ^{1}H array, respectively, i.e. showing sample noise dominance in both arrays. The optimal phase shift for a high transmit efficiency and low relative inhomogeneity in the ROI (green ellipsoid in Fig.1a) was [0°/-70°/20°] for the ^{31}P channels 1, 2, and 3, respectively. MR images of the papaya and the spherical phantom are shown in Fig. 2.

Discussion: A ^{31}P/^{1}H coil array was developed to improve ^{31}P sensitivity in the visual cortex. Preliminary results show good performance of the setup. The feasibility of in vivo ^{31}P measurements in the brain will have to be evaluated in future experiments.

References: [1] Bogner, MRM 62, 574-82, 2009. [2] Moser, World J Radiology 2, 2010. [3] Kuehne, ISMRM, 2013, 5119. [4] Goluch, MRM 2014, doi: 0.1002/mrm.25339.