

# Uniform prostate imaging and spectroscopy at 7T: comparison between a stripline array and an endorectal coil

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## Introduction

Over the past couple of years, high field imaging is slowly expanding from the head to extremities and the body. A target of particular interest is the prostate, because of the high incidence of prostate cancer and the expected increase in diagnostic capabilities. One of the problems in imaging the prostate is the limited penetration depth of the RF signal, resulting in high power demand and subsequently high SAR deposition. Several concepts for RF coil designs have been proposed and realized. In this study, we evaluate two designs with the most potential: an 8-element stripline array and an endorectal coil. After simulating the SAR levels of both coils, we compare the suitability of both coils for three MR scanning sequences that are commonly used for prostate cancer diagnostics: A T1w FFE sequence, a T2w TSE sequence and a spectroscopy exam.

## Materials and methods

For the comparison we used an in-house developed 8-element stripline coil array [1] and an in-house developed endorectal coil [2]. Both coils were simulated on a human adult model (Virtual Family Duke). Resulting  $B_1^+$  and SAR distributions were used to determine the suitability of the coils for the three imaging protocols. Coil suitability was limited by SAR restriction guidelines, for which we used the ICNIRP threshold [3]. Using the stripline array, conventional RF pulses could be used for T1 and T2 weighted sequences; i.e. a Fast Field Echo (FFE) sequence with short TR for T1 weighted acquisition and a multi-slice Turbo Spin Echo (TSE) sequence for T2 weighted acquisition. For spectroscopic imaging of the prostate with the stripline array conventional pulses are not suitable since the array fails to deliver sufficient  $B_1^+$  amplitude for the required bandwidth. Adiabatic slice selective refocusing pulses that have a much larger bandwidth were therefore considered for volume selective spin manipulation [2]. With the endorectal coil (inhomogeneous excitation field) the use of adiabatic pulses is compulsory for uniform image contrast. Adiabatic pulses based on a second order hyperbolic secant pulse (HS2) [4] require a minimum  $B_1^+$  of 14.1  $\mu\text{T}$  to obtain an acceptably small pulse length of 8 ms for an adiabatic full passage pulse (inversion pulse) or 16 ms for a BIR4 plane rotation pulse [5]. Therefore, a BIR4 pulse was used in an FFE sequence to calculate the minimum TR allowed while remaining within SAR guidelines. For the TSE sequence we used an adiabatic method consisting of slice selective dual adiabatic full passage pulses and a turbo train of BIR4 pulses [6]. For spectroscopic imaging, the same sequence was considered as for the stripline array including the adiabatic RF pulses. MR exams that were found suitable for a particular coil were tested on a volunteer and/or patient in a Philips Achieva 7T scanner (Best, The Netherlands) using home-built TxRx-switches. SAR safety settings were derived from the simulations.

## Results

Figure 1 shows the  $B_1^+$  and SAR distribution for the stripline array and the rectum coil. Table 1 gives an overview of the average  $B_1^+$  level in the prostate at maximum power gain, the maximum SAR (10g average) normalized to 1 W and the largest duty cycle at which the coil can operate without violating the SAR guidelines. The resulting consequences are presented in table 2. Images obtained with both coils are presented in figure 2, 3 and 4.

## Conclusion

The  $B_1^+$  homogeneity of the stripline array is needed for T1w and T2w images. The high  $B_1^+$  amplitude of the endorectal coil is needed for MR spectroscopy. A combination of RF coils (multi-element surface array and detunable endorectal coil) would enable a complete MR examination of a prostate cancer patient, while remaining within SAR constraints.

## References:

- [1] Raaijmakers et al. "Prostate Imaging at 7T..." ISMRM 2009 proceedings [4] Garwood et al. "The return of the frequency sweep..." J. Magn. Reson. Imag. 2001  
 [2] Klomp et al. "Proton spectroscopic imaging..." NMR Biomed. 2009 [5] Scheenen et al. "Towards 1H-MRSI..." Magn. Reson. Mater. Phy. 2008  
 [3] International Commission on Non-Ionizing Radiation Protection [6] De Graaf et al. "Adiabatic rare imaging" NMR Biomed 2003

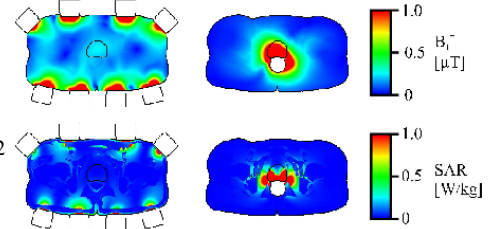


Figure 1: Simulated  $B_1^+$  and SAR distribution for stripline array and endorectal coil. Normalized to 1 W power.

	endorectal coil	stripline array
$B_1^+$ ( $\mu\text{T}$ ) @ 1 W	2.5 ( $\pm$ 73%)	0.23 ( $\pm$ 6%)
$B_1^+$ ( $\mu\text{T}$ ) @ Pmax	110	10.3
SARmax @ 1 W, 100% duty cycle	6.7	1
Duty cycle @ 10 $\mu\text{T}$ , SAR within guidelines	9.3%	0.53%

Table 1: Simulation results summary

	Endorectal coil	Stripline coil array
T1w FFE	Inhomogeneous $B_1^+$ field requires adiabatic pulses $\rightarrow$ SAR level increases $\rightarrow$ safety requires TR > 2.3 s $\rightarrow$ no more T1 contrast.	Sequence with 10° flip angle and TR = 17 ms reaches only 50% of allowed SAR level. (Figure 2)
T2w TSE	Inhomogen. $B_1^+$ field requires adiabatic pulses $\rightarrow$ high SAR $\rightarrow$ safety requires TR > 45 s $\rightarrow$ violation of 10 seconds rule	High flip angles $\rightarrow$ SAR level medium: 3D scan, 5 slices, Nav. = 2, 0.8x0.8x3 mm <sup>3</sup> $\rightarrow$ TR > 5.5 s (Figure 3)
Spectroscopy	$B_1^+$ field is high enough for a semi LASER sequence with MEGA water and lipid suppression (Figure 4)	$B_1^+$ level too low $\rightarrow$ use adiabatic pulse $\rightarrow$ high SAR $\rightarrow$ violation of 10 seconds rule.

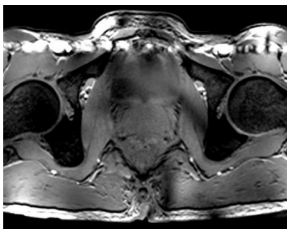


Figure 2: T1w FFE image of healthy volunteer with stripline array. FA=10°, TR/TE= 17/2.2 ms, 1x1x2 mm<sup>3</sup> voxel size

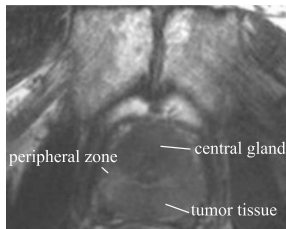


Figure 3: T2w TSE image of a prostate cancer patient with stripline array. Refocusing angle = 100°, TR/TE=5485/100 ms, 0.8x0.8x3 mm<sup>3</sup> voxel size

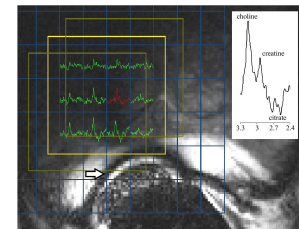


Figure 4: Spectroscopic image of a prostate cancer patient with the endorectal coil using a semi-LASER sequence. TR/TE= 1.6/56 ms. In background: T2w SE image with endorectal coil