# INVESTIGATIONS OF A DTI-PHANTOM WITH PROPERTIES SIMILAR TO *IN VIVO* NEURONAL TISSUE

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## Introduction

A diffusion tensor imaging (DTI) phantom should have diffusion and relaxation properties as they are found in white matter tissue. Typical values for the apparent diffusion coefficient (ADC) and fractional anisotropy (FA) in white matter tissue are ADC=0.7×10µm²/ms and FA=0.7. Up to now, several DTI phantoms have been proposed [e.g.1-4], most of them were built with parallel running fibres. To our knowledge, $B_0$-dependent relaxation properties [5] and high b-value measurements up to 50000s/mm² have not been reported so far. Here we present phantom data illustrating these properties.

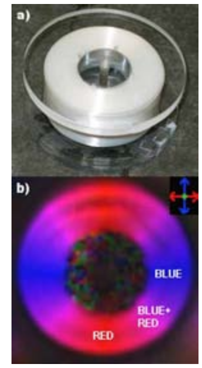


**Fig.1: a)** Picture and **b)** colourmap of the phantom. The Colour represents the direction of the principal eigen-vector and matches well to the fibre orientation.

## Methods

The DTI phantoms consist of polyamid fibres which are wound around an acrylic glass roller (see Fig.1a). Four monofil polyamide fibres (diameter 230µm, 190µm, 140µm, 90µm, G.Krahmer GmbH, Buchholz, Germany) and two polyfil polyamide fibres (50µm, Trevira GmbH, Bobingen, Germany; 14µm, TWD Fibres, Deggendorf, Germany) were used. The phantom was put into a water bath and the remaining air between the fibres was evacuated using a vacuum pump. Diffusion properties of all phantoms were investigated with a SS-SE-EPI diffusion sequence on a 1.5T clinical scanner (Avanto, Siemens, Erlangen). Parameters: b=0,500s/mm², 6 diffusion directions, TE=125, 250ms, TR=2s, 10 averages, voxel size=1.2·1.2·10mm³. FA values were calculated within a region of interest (ROI; NeuroQlab, MeVis, Bremen, Germany).

The signal decay at very large b-values was investigated by evaluating the signal $S_\perp$ of the 14µm and 50µm phantoms in a ROI. The ROI was chosen such that the fibres were parallel to the applied diffusion gradient. Parameters: b=0,...,50000s/mm², TE=253ms, TR=5s, 3 averages, voxel size=4·4·10mm³. The $T_2$ time of the 50µm phantom was determined by means of a SE sequence. Parameters: TE=7.5,…,500ms, TR=1.5s, 1 average, voxel size=1.5·1.5·8mm³. All measurements were performed at room temperature.

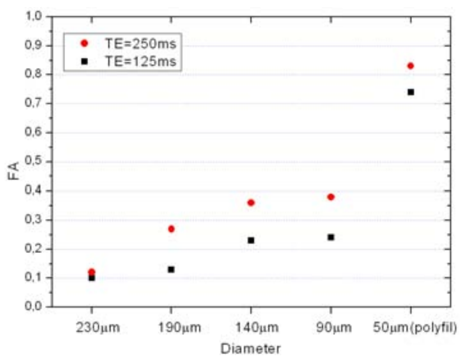


**Fig.2:** FA of the phantoms increases with increasing TE and decreasing fibre diameter.

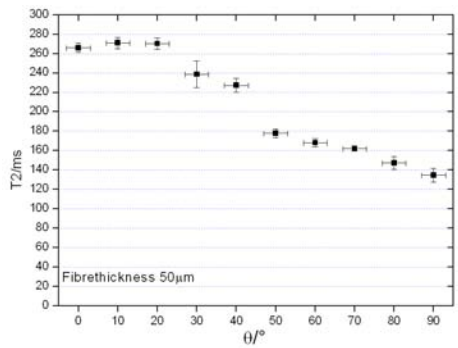


**Fig.3:** $T_2$ depends on the angle Θ between the fibre direction and $B_0$. This influences the SNR in $T_2$ weighted DTI sequences.

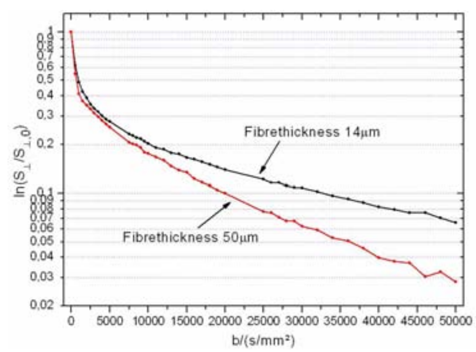


**Fig.4:** The signal decays non-exponentially with increasing b-value.

## Results

Fig.1b shows a colormap of the 50µm phantom. The colour encodes the direction of the principal eigenvector and matches well to the known fibre orientation. The plot in Fig.2 shows that the FA of the phantoms increases with increasing TE and with decreasing fibre diameter. This can be explained by the increasing influence of the fibres on the spins when the ratio of diffusion length to fibre diameter increases. The FA of the 50µm phantom is about 0.75 and similar to the FA of white matter tissue. Fig.3 demonstrates that the $T_2$ time of the 50µm phantom is depending on the angle Θ between the fibre direction and the $B_0$ field. $T_2$ is about 280ms when the fibres run parallel to $B_0$ and decreases to about 140ms when the fibres run perpendicular to $B_0$. In Fig.4, the measured signal $S_\perp$ of the 14µm and 50µm phantom is plotted logarithmically versus b. $S_\perp$ decays non-exponentially. At a b-value of 50000s/mm², $S_\perp$ of the 14µm phantom is decreased to 7% of the unweighted signal, whereas the signal of free water (D≈2.2µm²/ms) would have decreased to about $1.7 \cdot 10^{-46}$% of its unweigthed signal.

## Discussion

The presented phantoms show diffusion properties and relaxation times which are close to those of *in vivo* neuronal tissue and are therefore well suited for optimizing DTI sequences. The 8µm and the 50µm phantom show non-exponential signal decay. This urges caution when trying to relate high b-value measurements to fast and slow diffusion compartments. Because $T_2$ depends on the orientation of the fibres to $B_0$, the SNR varies with the fibre orientation. We expect this effect to be present for a wide range of fibre materials and that care has to be taken in this regard when evaluating and interpreting DTI phantom data. Future versions of the DTI phantom are intended to be shaped like fibre bundles in order to investigate arbitrary geometries, fibre crossing and kissing.

## References

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[5] RM Henkelmann et al. MRM **32**:592-601 1994