# Efficient Detection of Bound Potassium and Sodium *in vivo* Using TQTPPI Pulse Sequence

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## Introduction

A novel way to detect bound potassium and sodium *in vivo* was explored using triple quantum (TQ) signals without filtration. The method is based on time proportional phase increments (TPPI). It allows detection of signals from bound ions that appear as separate peaks on the triple frequency relative to single quantum MR signals. Signals from bound ions are acquired in the same way and, most importantly, with the same efficiency for a wide range of binding strengths. This is advantageous compared to filtration TQ methods, especially during diseases or interventions when the level of binding can be variable.

## Experimental

The experiments were performed on a 21.1T magnet using Bruker MRI Avance III console (PV 5.1). A commonly used TQ filtering pulse sequence 90º(α) - t - 90º(α+β) - 90º (0) was modified so that the phase "α" was incremented by 45º simultaneously with the time delay "t". Phase "β" was alternated each scan (± 90º) to suppress in our case the double quantum (DQ) signal. The time increment in this TQTPPI pulse sequence was 100 µs. The SQ signal in TQTPPI spectrum was normalized to 100 %. The pulse sequence was *in vivo* tested in three male Fisher 344 rats (weight ~ 150 g) to compare the difference between the potassium and sodium TQ signals. All animal experiments were conducted according to the protocols approved by The Florida State University ACUC.

## Results and Discussion

The TQ and SQ signals for potassium in a rat head are presented in Fig. 1. The integral of the TQ signal for potassium was 40.9 ± 1.4 % relative to the SQ signal, while for sodium it was only 20 ± 0.5 %. The observed two times difference in the TQ signals suggests that *in vivo* there is two times more probability of each potassium ion being bound rather than a sodium ion. As potassium is mainly intracellular, this result also indicates that ion binding in intracellular space is more efficient than in extracellular space. For comparison, in the 0.9 % saline solution there are no bound potassium and sodium ions and the TQ signal is equal to zero. In polycrystalline KCl the TQTPPI spectrum gives TQ signal of 58.1 ± 1.7 %. If polycrystalline KCl can be regarded as a model for 100 % bound potassium, we can conclude that in a rat head 70 % of potassium is bound, while the bound sodium is only 34.3 % of the total sodium ion content.

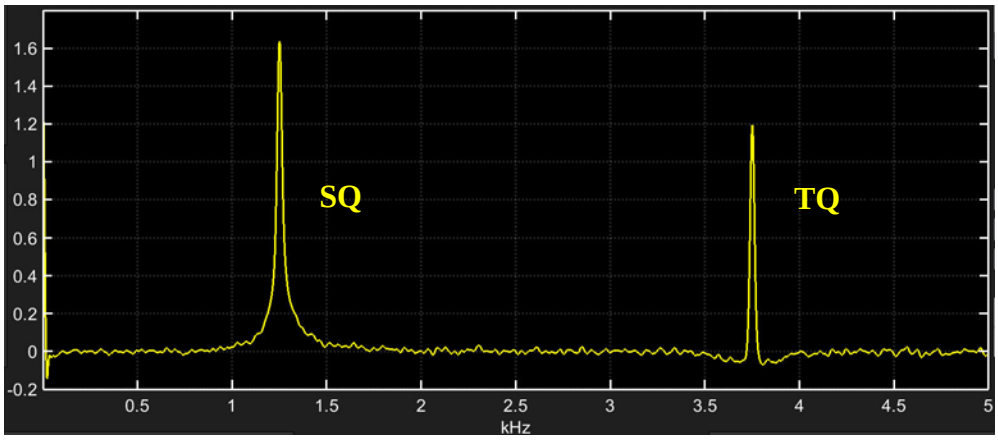


Fig.1. *In vivo* potassium ($^{39}$K) TQTPPI signals from rat head. The left peak at 1.25 kHz represents SQ signal while peak at 3.75 kHz corresponds to TQ signal from bound potassium.

## Conclusions

The first *in vivo* potassium MR signals at 21.1 T are presented. The TQTPPI method allows vividly separate MR signals from bound and unbound ions. These signals in a rat head revealed two times more effective binding of potassium relative to sodium, while ~ 30% of potassium remains unbound.

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