Magn. Reson. Discuss.,
https://doi.org/10.5194/mr-2020-8-AC2, 2020

MAGNETIC RESONANCE
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Discussions

Interactive comment on "ArduiTaM: accurate and inexpensive NMR auto tune and match system" *by* Mazin Jouda et al.

Mazin Jouda et al.

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Received and published: 23 May 2020

Authors: First of all, we would like to thank the reviewer very much for investing time and effort to review our manuscript.

Reviewer: General comments: The authors claim an automatic system for RF tuning and matching through a micro- controller (Arduino) and variable capacitors by mechanical step-motors. This reviewer acknowledges the need to develop automatic system to replace time-consuming man- ual adjustment. However, some points are not clear and mislead the readers so a minor revision is necessary to improve the quality of this manuscript to be published. Major and minor concerns are listed below.

Reviewer: Major concerns 1. This study is limited in receive coil only. As the authors

state in part 2 (why tune and match?), the tuned and matched condition is matter even at receiving side. However, the effect of impedance matching at the transmit side is more important in SNR. There is no any comments about the transmit side, tuning and matching condition with sample.

Authors: In fact, the study is general and was applied to transceive (transmit/receive) coils. We are sorry if the relevant paragraph was not completely clear to convey that message. But in lines 50-55 we mention that the impedance of the coil and the spectrometer electronics (this implicitly includes transmitter and receiver) should match the characteristic impedance of the coaxial cables. Moreover, in that paragraph we stated that matching the coil to 50 Ohm maximizes the power transfer and thus guarantees efficient excitation field B1. We definitely meant here the excitation phase of the NMR experiment. Furthermore, the experiments reported in this paper were all performed on transceive coils.

Reviewer: How can the authors verify the condition of the transmit is always same during all experiments for this work. Perhaps, dose it relate to #5 in minor con- cerns? Even very small difference at transmit side (distance between a sample and coil or between transmit and receive coil. . ...) make a huge different results in S-parameters (S11 and S21) that ultimately make different SNR. The authors should explain how to keep the same condition to conduct the comparison of receive only coil among manual, before and after auto tune and match.

Authors: We think that this point was based on the assumption that we used different coils for Tx and Rx. If this were the case, then this concern would have been very valid and then careful attention must be paid to ensure that the transmitter conditions do not change. But as we mentioned in the first comment, in our experiments we used a single transceive coil. As such and as long as the sample does not change the transmit conditions will not change.

Reviewer: 2. Tuning and matching, in general, are performed after a sample is loaded.

If the shift by loading a sample s negligible, this work has less scientific impact. Also, RF coils that have a little bit wide bandwidth may resolve the loading problems. In this respect, the authors are required supplement ad- dition experiments to prove the necessity of this work. For example, bench test results with a universal tuning and matching before and after a sample loads to show loading effect that should be compensated. Also, the authors can add an image and SNR com- parison with a universal tuned and matched coil using a sample without manual and auto correction in figure 9.

Authors: As detailed in Hoult's paper (Hoult, D. I. (1979). Journal of Magnetic Resonance, 34, 425–433.) the sample-loading effect depends on many parameters including the coil geometry, coil parameters (R, L, C, Q), sample parameters, and the frequency of operation. To elaborate how large this effect can be, we did a couple of experiments and added two figures to the supplementary materials, which we also attach here as Fig 1 and Fig 2.

Figure 1: shows the unloaded/loaded S11 of a commercial 5 mm saddle coil designed to operate in a 11.7 T NMR magnet at 500 MHz. The sample we used was 0.5 M NaPO3, 0.5 M Phosphoric Buffer Solution (PBS), 50 mM TSP, and 0.5 MSucrose. Loading the sample showed a dramatic change (6 MHz frequency shift and 28 dB increase in the reflection) in the tuning and matching condition.

Figure 2: shows the NMR spectrum of the sample before and after readjusting the T&M condition. Readjusting the T&M condition showed a significant enhancement (6.4 times) of the SNR.

Reviewer: 3. (Line 7, page2) and (Line 94, page 4): it misleads the readers because VCO may cover the frequency range for 1T to 23T but it is almost im- possible to adjust resonating frequency (i.e., Larmor frequency) with capacitors and RF coil element. Otherwise, the authors should provide additional description with practi- cal values (e.g., capacitor values and/or size of resonating structure) that can over the wide range of NMR system.

Authors: Sorry for this confusion! What we wanted to say is that ArduiTaM can be used to automatically T&M almost every commercial probe. This is because it utilizes a programmable frequency synthesizer (ADF4351) capable of generating any frequency in the range from 35MHz to 4.4 GHz. So for example, ArduiTaM can T&M any of the following: a 300 MHz 1H probe in a 7T magnet, a 125 MHz 13C probe in a 11.7T magnet, a 600 MHz 1H probe in a 14.1T magnet, and so on. In all these examples, the T&M ranges are limited mainly by the trimmers of the probe (maximum tuining range is in the order of few MHz).

Reviewer: Minor concerns 1. Is stepper motor okay for MRI study even if it has strong magnetic property? It may bring safety issues or magnetic field disturbance.

Authors: If the magent is well shielded and if the motor is placed far enough then this shouldn't be a problem. In our experiment we used a 1T MRI permanent magnet and we placed the stepper motor outside the magnet where the average stray field is 500 uT. We didn't observe any forces or malfunction of the motor. Indeed, the Bruker sample changer system also uses similar stepper motors.

Reviewer: 2. (Line 24, page 2): Please add a reference in the bibliography about the commercial system.

Authors: Done.

Reviewer: 3. How can the NMR console receive a signal from ArduiTaM system? Is there an open port in the console or the homebuilt system need an interface module? The details should be described in the manuscript to better understanding because the minimized interface between automatic system and NMR console is important in this application.

Authors: From our experience of working with different NMR spectrometers, almost all systems provide a number of general purpose TTL inputs and outputs that can be easily programmed by the user to do various contol and triggering tasks. For example, the

Bruker preclinical MRI machine (ICON) has one TTL output trigger port and one TTL input trigger port. For imaging experiments using ParaVision, the TTL output trigger can be set in the pulse program using the commands "TTL1_HIGH" and "TTL1_LOW", while the TTL input can be used (by ticking a Checkbox in the GUI) to allow an external signal to trigger the signal acquisition.

Reviewer: 4. There are some typo (e.g., line 28, page2) and improper English grammar/expression. The authors need to carefully check it.

Authors: Checking done.

Reviewer: 5. This reviewer would like to ask to the authors to add the mathematical analysis to explain SNR comparison in Line 158, page 13.

Authors: The formula we used to calculate the SNR loss due to ArduiTaM is SNR_loss = (SNR(without ArduiTaM)-SNR(with ArduiTaM))/SNR(without ArduiTaM)*100

Reviewer: How only 0.8 dB insertion loss results in lowering 6 dB in SNR in figure 9.

Authors: The SNR values mentioned in this figure are in linear scale. Thus, the loss in SNR is around 1.13 dB.

Reviewer: 6. Figure 5 missed the unit for the Y-axis.

Authors: We have changed this figure.

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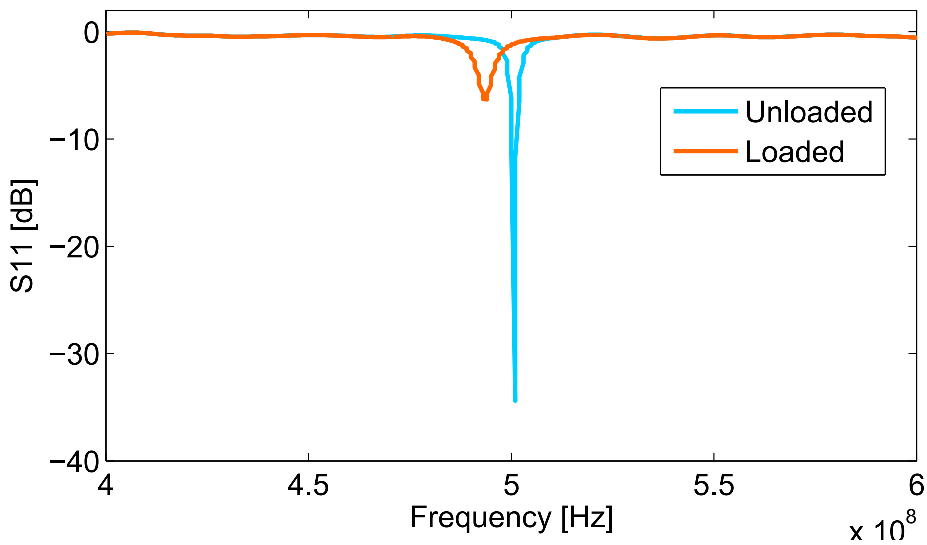

Fig. 1. Sample loading effect

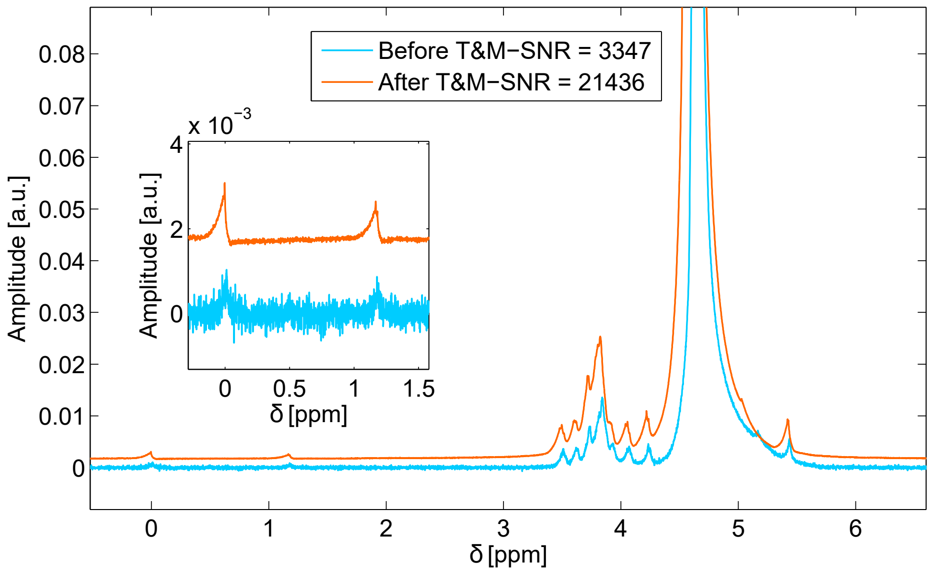

Fig. 2. Before and after effect