MAGNETIC RESONANCE Discussions

Magn. Reson. Discuss., community comment CC5
https://doi.org/10.5194/mr-2022-4-CC5, 2022

Reply on EC1

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Community comment on "A portable NMR platform with arbitrary phase control and temperature compensation" by Qing Yang et al., Magn. Reson. Discuss., https://doi.org/10.5194/mr-2022-4-CC5, 2022

Dear Dr. Bodenhausen,

Thank you very much for taking the time to provide your detailed comments.

We fully agree with your assessment that parts of the paper might be a bit hard to read for spectroscopists without a background in engineering and we will do our best to improve this in the revised version of the manuscript.

Below you can find details answers to your specific comments:

<<It seems that the abbreviation “CMOS” could be removed from the title, since it is clearly defined in the abstract (“complementary metal-oxide-<<semiconductor (CMOS)”)

We are happy to remove the abbreviation CMOS from the title to avoid confusion.

<<The abbreviations TX and RX could be replaced without inconvenience by “transmitter” and “receiver”.

Agreed. We will change that.

<<While the expression "frequency reference and temperature compensation scheme” is clear, I do not understand what is meant by "phase-<<coherent detection” and “phase-synchronous detection". Surely nobody wants to have a detector that does not give any information about the <<phase of the signals? What are the alternatives? A diode-based detector? An absolute-value representation after Fourier transformation?

Thank you for bringing up this important point. You are absolutely right that a pure detection of the magnitude is suboptimal. And all that I will say next is clear to many readers of the journal, but I will use it to define the terms “phase-sensitive” vs. “phase-synchronous”.

All commercial NMR spectrometers allow for phase-sensitive detection, i.e., detection of the amplitude and the phase of the NMR signal (typically used to display the real part of the spectrum). Achieving such a “phase-sensitive” detection is trivial since the Fourier transform of the detector output provides this kind of information. This being said, “phase-coherent” and “phase-synchronous detection” are more than just extracting the phase of the output signal since they are referring to extracting the actual phase of the NMR signal (i. e. the sample magnetization in the rotating frame of reference). In a simple pulse acquire experiment, the phase of the B1 field during the pulse defines the rotating frame of reference and, thereby, also the “phase” of the NMR signal. For simplicity, we also assume a very boring sample with a single resonance line. If you use the same (continuously running) oscillator to produce the B1 field and the local oscillator to frequency downconvert the NMR signal, you are effectively extracting the magnetization in the correct rotating frame, i.e. the correct phase of the NMR signal. If you are using a different frequency to frequency downconvert the NMR signal (we do this for technical reasons to avoid the so-called 1/f noise and other low-frequency noise sources), you are “observing” the magnetization in a rotating frame of reference that rotates at an offset frequency with respect to the rotating frame of reference of the spins. Naturally, you can still extract “a phase” from the output of the frequency downconverter but if you were to repeat the measurement with an arbitrary dwell time in between, you will find out that the phase you are extracting will randomly vary from pulse to pulse because your rotating frame of reference (i.e. the one defined by the mixer/frequency downconverter) is not phase-coherent or phase-synchronous with the spin magnetization (defined by the phase of the B1 field during the excitation pulse). One way that is generally applicable (there are other ways with more or less general applicability described in our manuscript) and that is used in our work (as correctly pointed out by one of the reviewers, we did not invent this approach since it used – to the best of my knowledge – in all Bruker spectrometers) is to make sure that the signal you are using to downconvert (in engineering, we call this the local oscillator signal) the NMR signal always starts with the same phase after the pulse and derive this phase from the phase of the excitation pulse. We refer to the latter two properties of the local oscillator signal as “phase synchronicity” or “phase coherence” (with the rotating frame of reference of the spins).

If you are using a more complicated pulse sequence, you have to establish phase synchronicity of the LO signal after every “observation pulse”, i.e. every pulse after which you read out the transversal spin magnetization.

<<It seems that “non-zero IF” is a somewhat unfortunate expression. If the intermediate frequency (IF) is zero, the very concept loses its meaning. <<How about simply writing "intermediate frequency (IF)”?

We would not say that the concept becomes useless. For a zero-IF scenario (i.e. a local oscillator frequency equalling the frequency of the B1 field) the situation simply becomes trivial as explained above, because you are observing the spin magnetization in the correct rotating frame of reference. By explicitly referring to a non-zero IF and a zero-IF, we wanted to distinguish between the non-trivial and the trivial case. We will try to make this point clearer in the revised version of the manuscript.

<< It is not very clear how you define the difference between the “software TX signal from the pulse controller” and "the actual TX pulse”.

We will explain this in more detail in the revised version. The software TX is essentially the trigger signal from the console and the actual TX is a signal realigned by hardware means. It is a technical detail but we wanted to include it in case somebody wants to rebuild the system.

Best wishes,

Jens Anders