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Publication Date:
2002

Permanent Link:
https://doi.org/10.3929/ethz-a-004387783

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Pulse Programmer for EPR: HYSCORE IN REAL TIME

I. Gromov* B. Glass†, J. Shane*, R. Tschaggelar*, J. Forrer*, J. Keller*, N. Felber* and A. Schweiger*

Overview

We present first results obtained with a new pulse programmer developed at ETH1. The programmer is based on an application-specific integrated circuit (ASIC) specially designed to fit pulse EPR requirements. The pulse EPR ASIC provides high time resolution (2 ns) and high channel density (8 channels per chip). The main unit of the programmer is a pulse forming board which carries two ASICs leading to 16 outputs. The pulse sequences are managed by a digital signal processor (DSP). The sequence programming is solved in a general way - the pulse program written in a high level Pulse Programming Language (PPL)2 is interpreted by the DSP which then calculates a bit image, loads it to the ASICs and runs and controls the sequence flow and the signal measurement. The approach used allows any sequence to be easily programmed and the most frequently used pulse EPR experiments to run on the EPR time scale. The new pulse programmer provides the same or even higher time resolution and channel density than general purpose commercial programmers which are still in use in EPR spectrometers (DDGs or RS690). At the same time, it is faster than these programmers and can compete, in particular for 2D experiments, with the existing pulse EPR-oriented commercial system (PatternJet, Bruker). In comparison with the PatternJet the developed software gives the user more flexible control over the sequence programming. The pulse programmer is tested on a recently upgraded home-built X-band pulse EPR spectrometer.

Hardware setup

1. User terminal
2. SBC62 controller (Innovative Integration) with TMS20C6201 DSP(TI), 180 MHz clock, 1600 MIPS
3. Pulse forming board with two pulse EPR chips
4. Four channels ADC/DAC converter (A4D4, Innovative Integration)
5. ECL to TTL converter
6. Test program
7. Reloading Times
8. HYSCORE spectrum

Testing program

Correct hardware delays. Connect or split pulses if necessary.

Reloading Times

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Used memory (lines)</th>
<th>T1 (µs)</th>
<th>Tp (µs)</th>
<th>TL (µs)</th>
<th>Trel (µs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-pulse ESEEM</td>
<td>29</td>
<td>138</td>
<td>332</td>
<td>237</td>
<td>607</td>
</tr>
<tr>
<td>HYSCORE</td>
<td>34</td>
<td>172</td>
<td>418</td>
<td>164</td>
<td>756</td>
</tr>
</tbody>
</table>

The test demonstrates that standard experiments can be repeated at a rate of about 1.5 kHz. The rearm time does not depend on the sweep direction, the next point or the next phase cycle and depends only slightly on the dwell time. Roughly, half of the rearm time is used for the bit pattern calculation.

Natural abundant (4.7%) Si modulation in irradiated quartz glass

3-pulse ESEEM

time domain

4000 traces are accumulated (10³ sweeps x 4 phases) at 1.25 kHz. 200 points per trace are measured. The total measuring time is 640047 ms. The overhead time 47 ms appears because of a few loading errors. The observed extremely weak modulation (< 0.5%) due to matrix 29Si nuclei and the absence of artificial peaks in the spectrum demonstrate the good quality of the programmer. Other conditions are: \(v_{ms} = 9.62\ \text{GHz}, B_0 = 343.7 \text{ mT}; \text{ dwell time 48 ns; single shot measurement.}\)

HYSCORE spectrum

325x4 sets of (128x128) data blocks are accumulated at 1 kHz. The total measuring time is about 6 hrs. 25 averagings take typically 1638520 ms with a 120 ms overhead. The observation of the correlation peaks due to 29Si nuclei in an E' center demonstrates the good time stability of the programmer. The conditions are the same as for 3-pulse ESEEM except \(v_{ms} = 9.20\ \text{GHz} \) and \(B_0 = 328.8 \text{ mT}.\)

Conclusion

The pulse EPR-specific integrated circuit, together with the DSP and the pulse programming language allow one to program pulse sequences in an easy way and to perform EPR experiments in a time which is limited only by the properties of the sample.

1. I. Gromov et al., ISMAR 2001, Rhodes
2. J. Shane et al., RSI, 69, 3357 (1998)