# Typical Pulses for the Inverse 5 mm CryoProbe[TM]

# 850 MHz, 900MHz and 950 MHz

**Valid from the date of shipment: January first 2008. For older CryoProbe please contact your Bruker office.**

History:

| Index | Date | Changes | Initials |
|---|---|---|---|
| 00 | 30.06.2009 | document created out of ZACP 0508 | KKE |

# 1. Purpose

Safe operation of a NMR probe requires that the power and the durations of RF pulses do not exceed specified values. This document provides values for safe operation of the 5 mm TXI/TCI CryoProbe™ at 850 MHz, 900 MHz and 950 MHz.

# 2. Scope

All 5 mm TXI/TCI CryoProbe™ at 850 MHz, 900 MHz and 950 MHz

# 3. Reference to Documents

None.

# 4. Implementation

## 4.1 Introduction

The following table shows values for pulses, which provide safe operation[1)] with a Bruker 5 mm CryoProbe™.
The given values are related to the power handling of a 5 mm CryoProbe™. The effect of possible heating of the sample is not taken into account.
Please note that the given values provide safe operation only, when standard pulse programs from the Bruker pulse program library are used, and the repetition rate, which is about $d1 + aq$ has a minimum period of 1 s.

Certain segments in a pulse sequence, like a spin lock or a decoupling sequence are applied at a given RF power level. The maximum allowed power for those segments is expressed by the corresponding pulse length. Example:

$^{1}$H *TOCSY* spin lock: 200 ms @ 25 s. This means that the maximum length of the spin lock sequence is 200 ms, and the allowed 1H power level corresponds to a 90° pulse width of 25 s. A power level corresponding to a 90° pulse which is shorter than 25 s is not allowed.

## 4.2 Pulse and power recommendations

| | 5mm 850MHz TXI/TCI CryoProbe™ | 5mm 900MHz TXI/TCI CryoProbe™ | 5mm 950MHz TXI/TCI CryoProbe™ |
|---|---|---|---|
| $^{1}H$ | | | |
| hard pulse[3] (max. length 360°) | 8.0 s | 8.0 s | 8.0 s |
| hard pulse for lossy samples | Power level corresponding to 8.0 s pulse for non-lossy sample | Power level corresponding to 8.0 s pulse for non-lossy sample | Power level corresponding to 8.0 s pulse for non-lossy sample |
| trim pulse p28[4] | 2 ms @ 11 s | 2 ms @ 11 s | 2 ms @ 11 s |
| TOCSY spin lock[5] | 120 ms @ 20 s<br>400 ms @ 35 s | 120 ms@ 20 s<br>400 ms@ 35 s | 120 ms @ 20 s<br>400 ms@ 35 s |
| ROESY spin lock | Up to CW for power level corresponding to a 80 s pulse | Up to CW for power level corresponding to a 80 s pulse | Up to CW for power level corresponding to a 80 s pulse |
| WALTZ65 decoupling during $^{13}C$-detection | Up to CW for power level corresponding to a 80 s pulse | Up to CW for power level corresponding to a 80 s pulse | Up to CW for power level corresponding to a 80 s pulse |
| DIPSI2-decoupling in triple resonance | 400 ms @ 35 s | 400 ms@ 35 s | 400 ms @ 35 s |
| $^{13}C$ | | | |
| hard pulse [6] | 12.0 s | 12.0 s | 12.0 s |
| trim pulse [5] | 2ms @ 22 s | 2ms @ 22 s | 2ms @ 22 s |
| CC spin lock [5] | 20ms @ 22 s | 20ms@ 22 s | 20ms @ 22 s |
| GARP-4 decoupling [7] | 140ms @ 55 s<br>[117 ppm bandwidth] | 140ms @ 55 s<br>[110 ppm bandwidth] | 140ms @ 55 s<br>[104 ppm bandwidth] |
| Adiabatic Decoupling | 140ms @ 55 s<br>Crp48,1.5,25.2 [>169 ppm bandwidth] | 140ms@ 55 s<br>Crp48,1.5,25.2 [>160 ppm bandwidth] | 140ms @ 55 s<br>Crp48,1.5,25.2 [>150 ppm bandwidth] |
| Band selective pulses [8] | G4: 290 s<br>Q3: 180 s<br>CHIRP: 2ms @ 22.2 s | G4: 274 s<br>Q3: 172 s<br>CHIRP: 2ms @ 22.2 s | G4: 260 s<br>Q3: 162 s<br>CHIRP: 2ms @ 22.2 s |
| $^{15}N$ | | | |
| hard pulse [6] | 32.0 s | 32.0 s | 32.0 s |
| GARP4 decoupling [7] | 140 ms @ 170 s | 140 ms @ 170 s | 140 ms @ 170 s |
| CPMG T2 [9] | 250 ms@ 40 s (see warning [9] ) | 250 ms @ 40 s (see warning [9] ) | 250 ms @ 40 s (see warning [9] ) |
| $^{2}H$ | | | |
| hard pulse (max. length 360°) | 150 s | 150 s | 150 s |
| WALTZ64 decoupling | 100 ms @ 250 s | 100 ms@ 250 s | 100 ms @ 250 s |
| Z-Gradient | | | |
| Absolute max. current [10] | 10A | 10A | 10A |
| Max. overall length [11] | 10ms @ 10A | 10ms @ 10A | 10ms @ 10A |

Table 1

**Note: all values require a minimum repetition period $d1 + aq$ of 1s[2]).**
**Important: observe the separate notes on the following pages!**

## 4.3 Notes

1) Although the values given do not necessarily define the actual limits, these conditions have been determined to provide safe operation and are valid unless superseded in whole or in part by (1) a more recent version of this document, (2) a factory document pertaining to the specific probe, or (3) written approval by BRUKER BioSpin AG. Operation in excess of the conditions given is not permitted and will void the warranty as it may result in damage to the CryoProbe.

2) Repetition period related issues:
a) In any case, the power level for a given pulse length (which must be equal or shorter than the specified pulse length value) must never exceed the power maximum given in Table 1.
b) The pulse length values given in Table 1 are based on a repetition period of approximately 1 s. This defines and limits the average power to which the probe may be exposed. Operation with longer repetition periods is allowed without additional restrictions, provided the pulse lengths are still limited according to the values given in Table 1.

3) Non-lossy samples are assumed, such as organic solvents or water without salt.

4) A number of inverse correlation experiments use the proton trim pulse *p28*, like the pulse program *invietgpsi* (XWINNMR up to version 3.1) or *hsqcetgpsi* (XWINNMR version 3.5 or Topspin). According to our experience this trim pulse is only rarely required. Verify if any improvement is necessary or obtained using this pulse.

5) An experiment might contain a spin lock followed by a trim pulse. Note that the total length of spin lock and trim pulse must not exceed the value which is allowed for the spin lock only.

6) Maximum length is 360°. When hard pulses are applied simultaneously on the $^{13}C$ and $^{15}N$ channel, the power on both, the $^{13}C$ and the $^{15}N$ channel, has to be reduced by 3 dB each.

7) Simultaneous decoupling of $^{13}C$ and $^{15}N$ requires that reduced power is used on both channels. 3 dB less power should be used for both $^{13}C$ and $^{15}N$. For simultaneous decoupling it is recommended to use optimized conditions for adiabatic decoupling on $^{13}C$.

8) Pulses G4 and Q3 are used in triple resonance experiments. The 2 ms CHIRP pulse is used in *HSQC* experiments for refocusing. For shaped selective pulses there are

usually no restrictions, as long as the peak power of the shape does not exceed the power limit of a hard pulse. When using non-standard pulses, in addition to the peak power, it should be also verified that the averaged power over the pulse length does not exceed any of the power limits (compare to the listed limits for pulses with a comparable duration). Simultaneous application of a hard pulse on the $^{15}N$ channel is possible up to the full specified strength with a maximum duration corresponding to a 180° pulse.

9) $^{15}N$ $T_2$ pulse sequence *invit2etf3gpsi* (XWINNMR up to version 3.1) or *hsqct2etf3gpsi* (XWINNMR version 3.5 and Topspin): The length of the *CPMG* element is *d20* and should not exceed 250 ms. The 180° pulse is *p30* at a power level *pl23*, the pulse *p30* should not be shorter than 80  s (180° pulse, applied at a power level corresponding to a 90° pulse of 40  s). Increase the recycle delay to > 2.5 s. The given value is true only, when the pulse *p30* is part of a *CPMG* sequence with an inter-pulse delay of 900  s (expressed by $d21 \cdot 2$ in the pulse sequence *hsqct2etf3gpsi*).
**Warning: Never apply the above power level and full uninterrupted duration in a spin lock sequence.**

10) The absolute maximum gradient current $I_{\max}$ is listed in Table 1.

11) It is permissible to apply $I_{\max}$ for the listed maximum overall length $T_{\max}$. The overall length of the gradients is the sum of all gradients applied during a repetition period.

A gradient sequence which has, within a repetition period, an overall length $T_G$ which is longer than $T_{\max}$x, is still permissible if the maximum gradient current is reduced to $I_G$, according to the following equation:

$$I_G = I_{\max} \cdot \sqrt{T_{\max} / T_G}$$

In a more general formulation (using the values of $I_{\max} = 10\ A$ and $T_{\max} = 10\ ms$ for clarity), for $N$ pulses within any repetition (1 s) period, the following condition must hold ($I_{Gi}$, $T_{Gi}$ denote the current and duration of the $i$-th gradient pulse):

$$\sum_{i=1}^{N} T_{Gi} I_{Gi}^{\ 2} \leq T_{\max} \cdot (I_{\max})^2 = 10ms \cdot (10A)^2 = 1000 \cdot msA^2$$

Examples:

1. For an overall gradient length of $T_G = 20\,ms$ within any one second period, the maximum gradient current is $I_G = 7.07\,A$ .
2. A pair of gradient pulses, consisting of a first pulse with a current of 10 A and a length of 5 ms, and a second pulse with a current of 5 A and a length of 20 ms is just permissible.
3. A DC current of 1 A is just permissible.