BRUKER

GREAT 40/60 AV III

Gradient Amplifier
User & Installation Manual

Version   001

think forward

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This manual describes the units as they are at the date of printing. On request, the manufacturer shall supply circuit diagrams, lists of components, descriptions, calibrating instructions and any other information for use by qualified personnel of the user, in charge of repairing the parts of the unit which have been stated by the manufacturer to be "repairable". Such supply shall in no event constitute permission to modify or repair the units or approval of the same.

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This unit is not designed for any type of use which is not specifically described in this manual. Such use may be hazardous.

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Hardware installation and description

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The Master Unit (BGMUI 1, P/N:W1522086) is needed for GREAT 1/40 and GREAT 1/60 amplifiers if one ore three amplifiers are used.

The 60 A gradient system may be delivered in two different versions. One version for High resolution and Diffusion NMR experiments in which only one GREAT 60 A (W1209612) amplifier and one Master Unit (W1522086) is needed. When the system is dedicated to micro imaging experiments, a complete cabinet containing 3 GREAT 60 (W1209612) amplifiers, one Master Unit (W1522086) and one B0 Compensation Unit (W1214106) is delivered.

The Master Unit (Figure 1.1.) contains an interface board between the DPP board located in the IPSO rack and the amplifiers. The interface changes the numerical 48 bits LVDS data coming from the DPP board into 16 bits parallel numerical data needed to drive the GREAT 1/40 and GREAT 1/60 amplifiers. A CPU board is found in the Master Unit for Internet connection to the computer. All the GREAT amplifier commands are sent to/received from the gradient amplifier through an I²C bus. The GREAT amplifier blanking is routed to the amplifier through a BNC connection. The voltage and current detection is done via a connection between the GREAT 1/60 I/U Monitor and the BGMUI 1 Master Unit.

Figure 1.1.   The BGMUI 1 Master Unit (W1522086) front panel below in its ECL 01 version. The firmware version must be higher then 20070924.
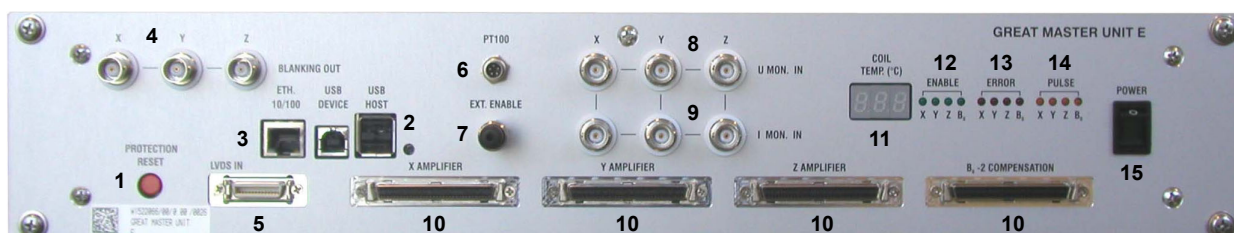
1. General Master Unit RESET button. May be activated on the "Web" page and in the "*SetPre*" interface by using the **Reset protection** function.

2. Reset of the CPU-A board : this button make a **Reset** of the Internet SOAP protocol.

3. Internet female connector : Has to be connected on the Hub.

4. X, Y, Z blanking output BNC connectors : Have to be connected on the individual GREAT blanking BNC connectors. The blanking may be driven with the external TCU orders coming from the IPSO controller or the ctrlgrad orders coming from the GCON board and activated inside of the DPP board (routed through the 48 bits LVDS cable).

5. 48 bits LVDS female connector : Has to be connected on the DPP output 48 bits LVDS connector. The LVDS date coming from the DPP board are routed through the Master Unit Interface with this cable.

6. Four pins PT 100 connector : Has to be connected to the PT100 built in the probe head to measure the gradient coil temperature ➜ coil protection function.

7. External Enable connector : The coil temperature may be managed through the BCU20 water bath temperature used for Gradient coil cooling ➜ coil protection function. Has to be connected on the BCU20 Unit.

8. X, Y, Z I Monitor BNC input connector : The I Monitor input BNC connectors are respectively connected to the I Monitor BNC output connector found on each GREAT Amplifier. The I Monitor is found on all GREAT versions ➜ current and power protection functions.

9. X, Y, Z U Monitor BNC input connector : The U Monitor input BNC connectors are respectively connected to the U Monitor BNC output connector found on each GREAT Amplifier. The U Monitor is only found on GREAT versions whose ECL is higher then 07.

10. 16 bits parallel female connector : Each of the X, Y, Z and B0 Unit has to be connected on the Master Unit through this cable. The 20 bits LVDS data is changed into 16 bits data (the four last bits coming from the DPP board are up rounded), changed into parallel data and sent as 16 bits data to the GREAT amplifiers and to the B0 compensation Unit if there is one.

11. Display : Is used for Gradient coil temperature display in normal working mode. Is also used for error message display if the Master Unit detects an Error (see Error Message Table in section 3).

12. X, Y, Z and B0 Enable Led's : This Led's show the presence/missing of individual GREAT amplifiers and the B0 compensation Unit.

13. X, Y, Z and B0 Error Led's : This Led's shows if an Error has occurred on one or each of the GREAT and B0 Compensation Unit. The errors are related to current, voltage, power overloads as well as if a data buffer shows an error. The errors which may occur are listed on the "Web" page (see section 3).

14. X, Y, Z and B0 Pulse Led's : This Led's show if a channel is pulsing or not. The firmware allows to use the Monitor output for pulse presence/missing detection as default display. It is also possible to observe on this Led's the presence/missing of non zero digital data on the Master Unit. The choice is done inside of the "Web" page (see section 3).

15. Master Unit (BGMUI 1) Power supply On/Off button.

B0 Compensation Unit *1.2*

The B0 compensation Unit (P/N:W1214106) is used to compensate frequency, amplitude and phase effects induced on the Z0 Homospoil coil located in the shim tube (used for B0 Magnet field fine corrections) when PFG gradients are used. The effects are generated by the pulses itself and by resulting Eddy currents induced in the Z0 Homospoil coil by PFG gradient pulsing. These effects are stronger on narrow board systems as on wide board systems as a consequence of a nearer vicinity of gradient/Homospoil coils in narrow board systems. As far as coil shielding can never be perfect, PFG gradients may induce amplitude, phase and frequency distortions on the observed NMR signal. The front panel of the B0 compensation unit is shown below in Figure 1.2.

Figure 1.2. B0 Compensation Unit (W1214106) front panel below in its ECL 01 version.
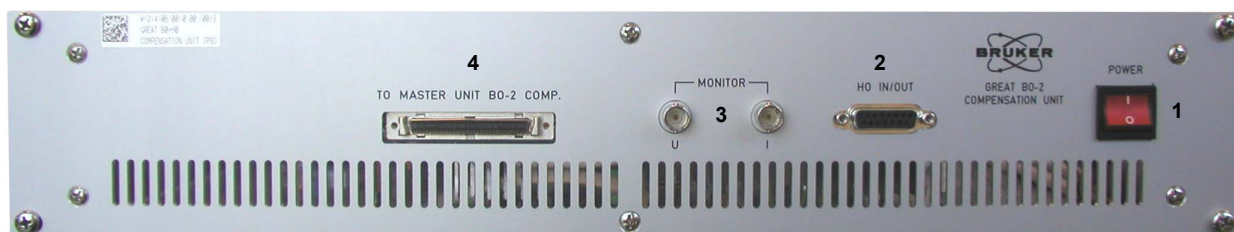

1. B0 Compensation Unit On/Off Power Supply button.

2. BSMS analogical cable connection : SLCB20 Homospoil current is driven to the B0 compensation Unit and sent back to the Homospoil Z0 coil located in the shim tube. This connection allows to sent B0 compensation currents on the Homospoil coil added on the B0 field current. Addition and filtering is performed inside of the B0 compensation Unit. The maximal current which may be added on the Z0 coil is equal to ±200 mA.

3. B0 compensation Unit I and U Monitor BNC output connector : Used for tests only. Can be connected on an oscilloscope to check if the unit properly works. Not used in normal way of working.

4. B0 16 bits parallel female input connector ; Has to be connected on the Master Unit B0 16 bits parallel female output connector to drive the numerical data from the Master Unit to B0 compensation Unit.

Additional Hardware needed for B0 Compensation Unit interfacing *1.3*

If older shim systems are used, (1 connector coming from an older SLCB 7 board and 1 connector coming from an older SLCB 13 board) an additional interface board has to be used in order to be able to connect the B0 compensation analogical cable on the Z0 Homospoil coil.

Hardware installation and description

Interface board needed to connect older shim systems on the SLCB 20 board. On the bottom of the board can be found the connector for the B0 compensation unit analogical input.
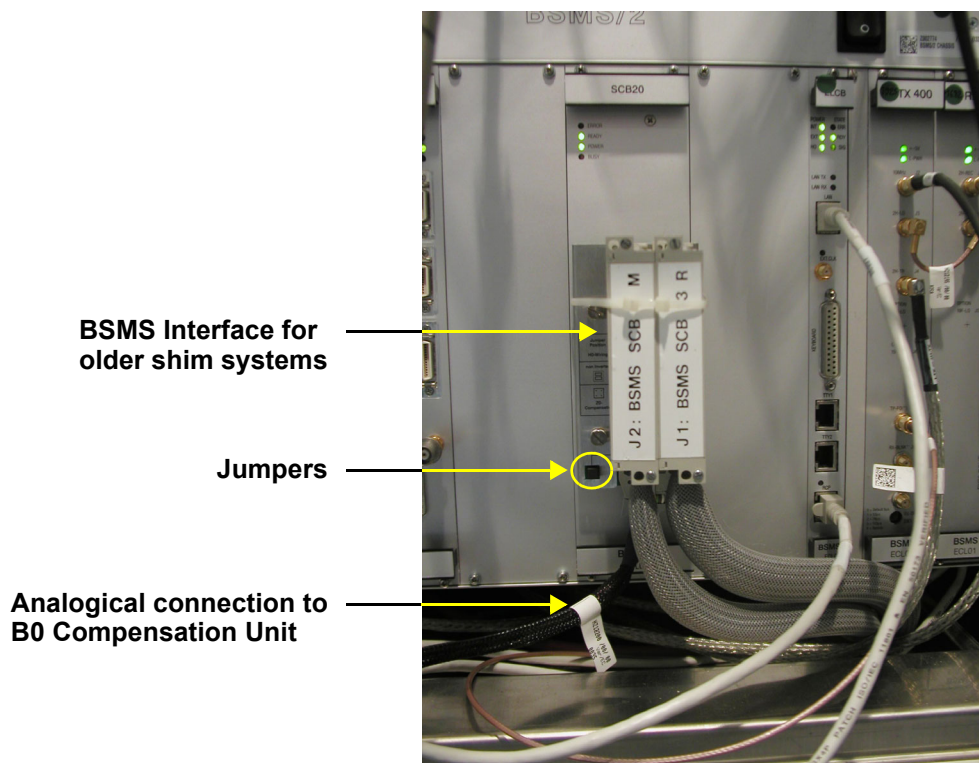
For older shim systems, an additional interface board (Hxxxx) is needed to connect the magnet shim system to the SCB20 board. On this interface can be found an output connector used to drive the analogical Z0 current (to and from) the B0 compensation unit. To allow the current to be sent to and from the B0 compensation Unit, two jumpers have to be removed from the interface board. In the absence of the B0 compensation unit, these jumpers have to be set back on there location. The same interface exists for BOSS II (32 shim currents) shim systems (Hyyyy). The interface shown in Figure 1.3. is the interface requested by BOSS I (20 shim currents) systems.
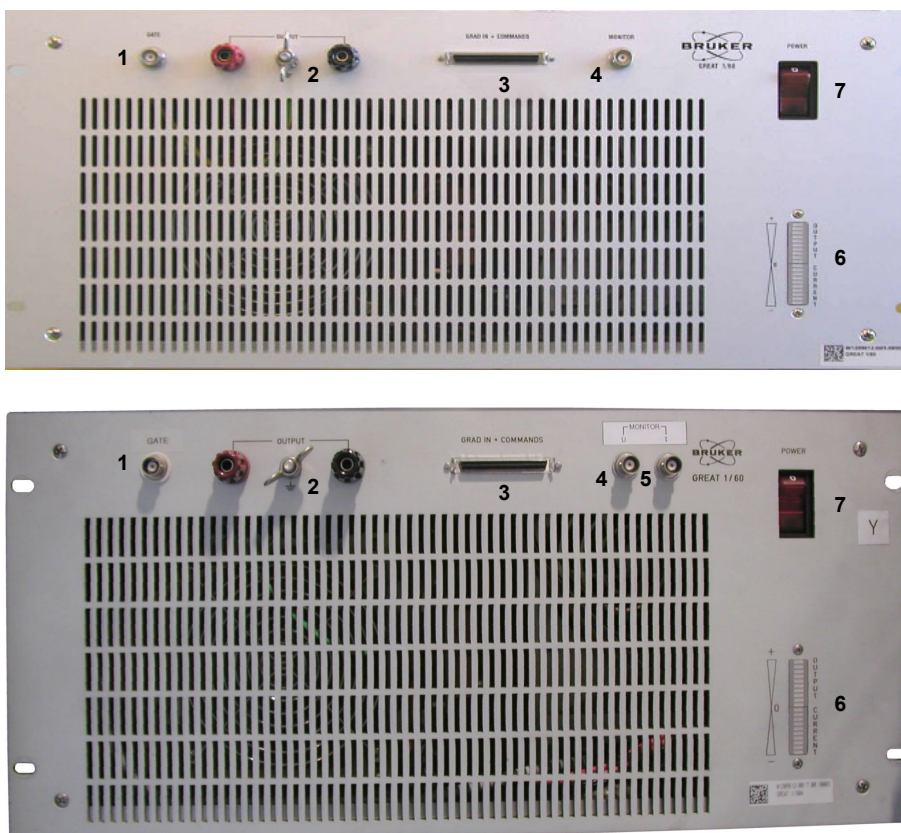
GREAT 1/60 Gradient Amplifiers   *1.4*

The GREAT 1/60 amplifier (P/N:W1209612) has the same characteristics as the gradient amplifiers manufactured by BRUKER since the last five years. The amplifier deliver 60 A pulses on micro imaging and DIFF 30 Gradient Coils. The maximal PFG current is 50 A if Gradient Coils with higher Inductance are used. The amplifier has a 10 % Duty Cycle and is able to deliver 6 A DC. The maximal voltage available is ±110 V leading to Rise/Fall times smaller then 160 ms depending on the Gradient Coil. Two GREAT amplifier versions are existing : the version delivered prior to August 2007 with ECL smaller then 9 and a newer version with ECL 09 delivered after August 2007.

The pictures shown in Figure 1.4. show the difference between both versions.

Figure 1.4.   Front panels of the GREAT 1/60 below in its ECL 07 and ECL 09 version.

The GREAT 1/60 or GREAT 1/40 amplifier has a 16 bits parallel digital input. The digital/analogical conversion is done inside of the gradient amplifier with a 16 bits DAC. This DAC can work with a normal 16 bits amplitude resolution or an improved 19 bits amplitude resolution. The 19 bits amplitude resolution mode is very interesting in the case where the maximum current on the amplifier available current (60 A) is used. The major difference between the GREAT ECL 07 and the GREAT ECL 09 is the use of an older 16 bits LT DAC for the older version and the use of a newer and faster (1 ms) 16 bits DAC from TI in the case of the ECL 09.

1. Blanking (Gate) BNC connector. The blanking can be externally driven (from the TCU à A connector on the 19' IPSO controller) and internally driven (from the GCON through the DPP board).

2. Gradient amplifier cable connector. There is a red/black cable for each of the amplifier. The polarity is dependent of the cable connection. An gradient pulse polarity is obtained if the red cable is connected to the black connecter whereas the black cable is connected to the red connector.

3. 16 bits parallel digital input connector coming from the Master Unit output ➜ One cable for each channel.

4. I Monitor output which has to be connected to the BNC I Monitor Input of the BGMUI 1 Master Unit.

5. U Monitor output which has to be connected to the BNC U Monitor Input of the BGMUI 1 Master Unit.

6. Current output level Led. Only current levels higher then 20 A may be observed on this Led.

7. GREAT amplifier Power Supply On/Off.

Needed cables for Gradient Amplifier systems   1.5

The cables delivered with a Micro Imaging system are shown on Figure 1.5. (1 Master Unit, 1 B0 compensation Unit and 3 GREAT 1/60 or 1/40 gradient amplifiers).

Figure 1.5. Micro Imaging rack back panel showing the different cables.
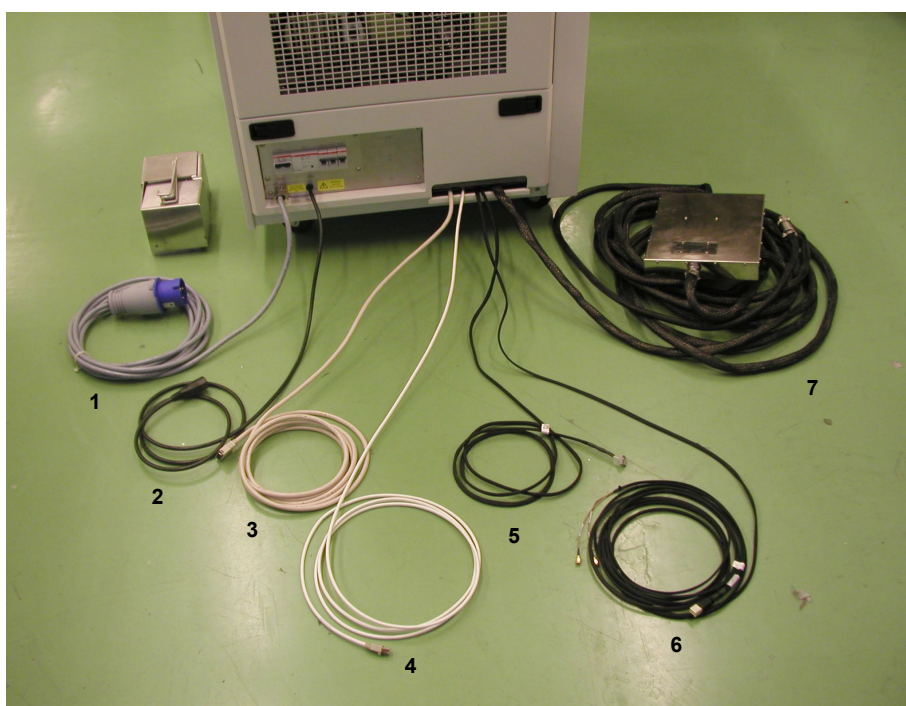
1. Main 230 V single phase 50/60 Hz cable.

2. Auxiliary 230 V Main cable.

3. RD 26 48 bits LVDS cable (5 m) PN:87940.

4. Ethernet cable (RJ 45) PN:86056.

5. BSMS B0 Compensation Unit cable (only present if a B0 Compensation Unit is delivered) PN:HZ12200.

6. Blanking (Gate) cable connected to the TCU A connector on the 19' IPSO front panel PN:W1214403.

7. Gradient cable (X,Y,Z amplifier and PT 100) with filter box PN :W1212109.

The other cables are not shown but also needed :

8. 3 x 16 bits parallel cables (68 pins SCSI) PN:HZ10202 to connect on the master unit outputs and on each gradient amplifier input. If a B0 compensation unit is delivered a fourth cable is needed.

9. BNC/BNC cable PN:Wzzzzzz to connect the U/I Monitor gradient amplifier outputs on the U/I Master Unit inputs.

10. Internal BNC/BNC PN:Wzzzzz cable for internal gating. The cables are connected on the Master Unit X,Y,Z blanking female connectors and on each gating female connector of each GREAT gradient amplifier.

Micro Imaging Rack (HMIMAG) *1.6*

The Micro Imaging Rack in his complete version contains 1 BGMUI Master Unit, 3 Gradient Amplifiers GREAT 1/40 or GREAT 1/60 (depending on the used probe heads) and 1 optional B0 Compensation Unit (needed for standard bore Magnet systems). The HMIMAG rack in it's complete version is shown on Figure 1.6.

Figure 1.6.   Front and back view of a complete HMIMAG rack.
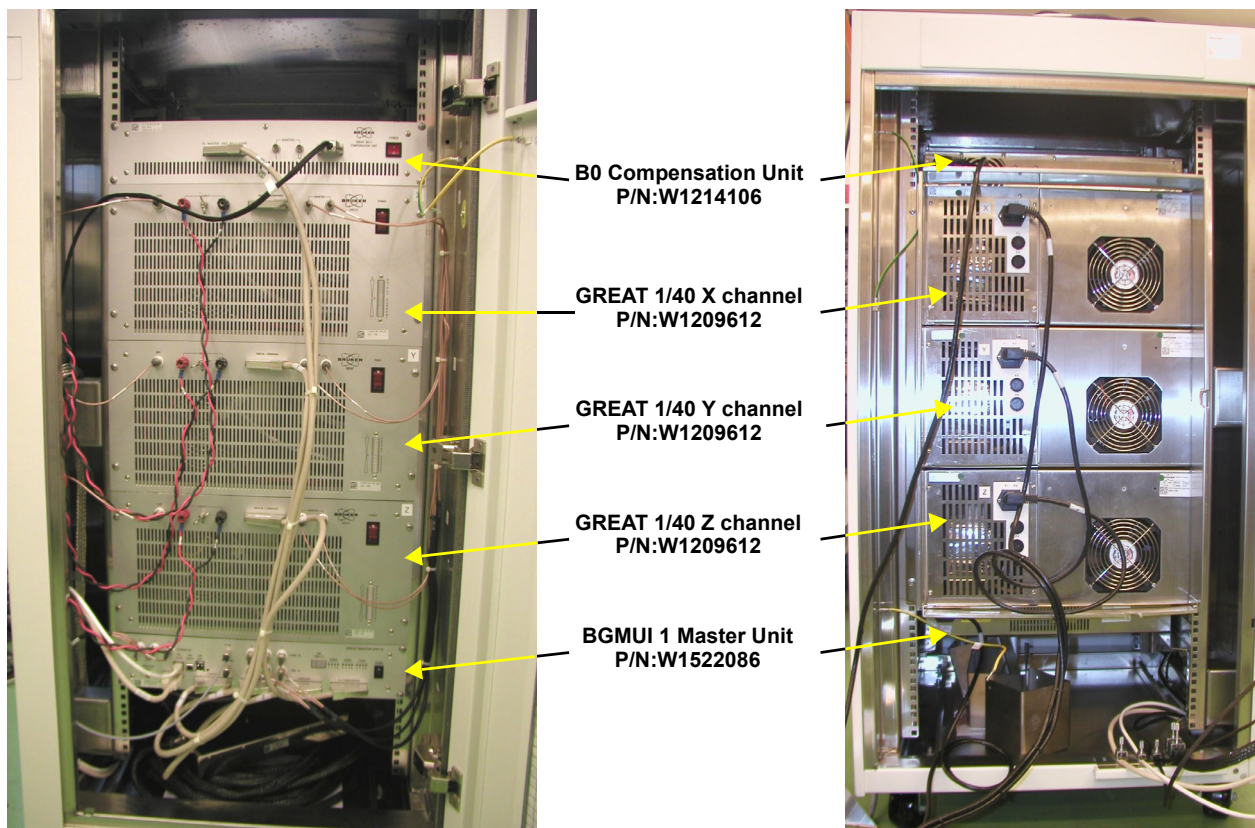
The following pictures in Figure 1.7. show how to connect the Master Unit to the Gradient amplifiers and the Master Unit to the B0 compensation Unit.

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Figure 1.7. *The pictures show how to connect the Master Unit to the Gradient amplifiers abd the B0 Compensation Unit.*
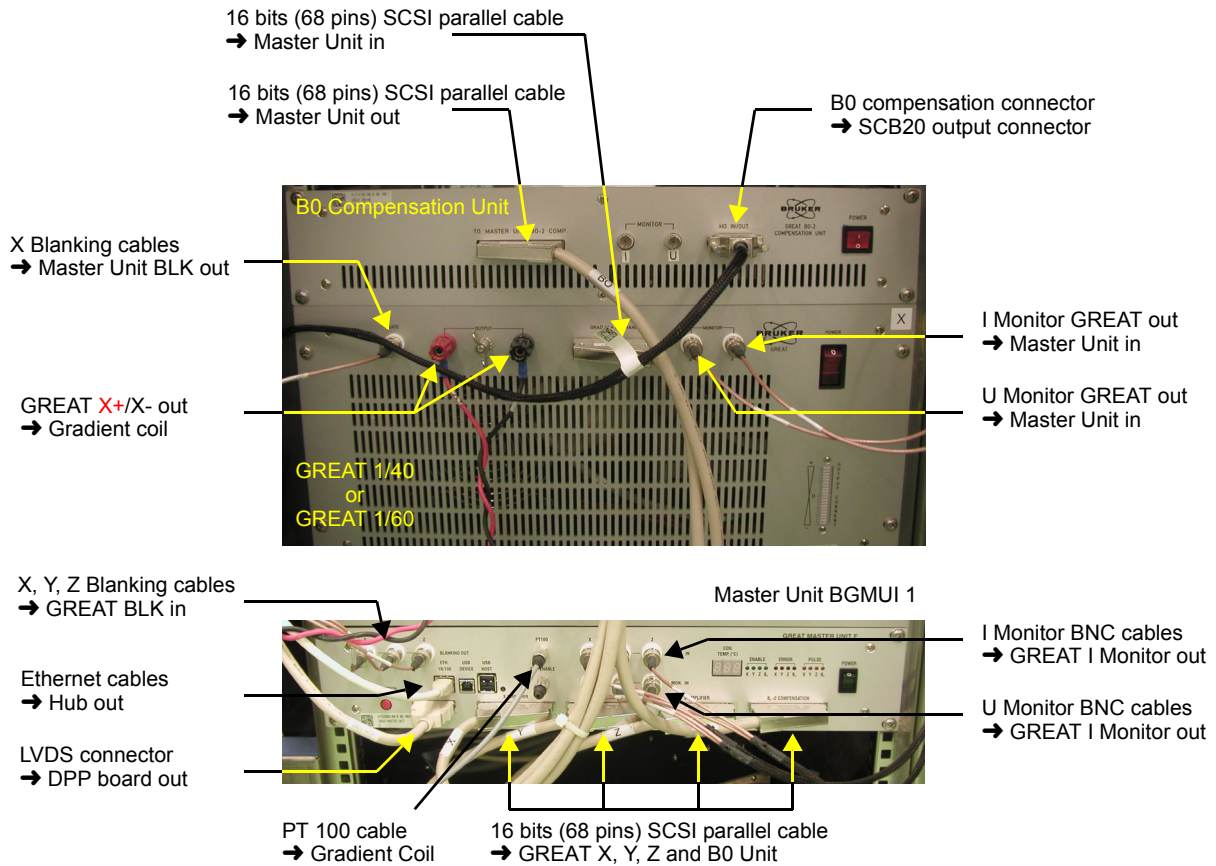
16 bits (68 pins) SCSI parallel cable
➜ Master Unit in

16 bits (68 pins) SCSI parallel cable
➜ Master Unit out

B0 compensation connector
➜ SCB20 output connector

X Blanking cables
➜ Master Unit BLK out

I Monitor GREAT out
➜ Master Unit in

GREAT X+/X- out
➜ Gradient coil

U Monitor GREAT out
➜ Master Unit in

B0 Compensation Unit

GREAT 1/40
or
GREAT 1/60

X, Y, Z Blanking cables
➜ GREAT BLK in

Master Unit BGMUI 1

I Monitor BNC cables
➜ GREAT I Monitor out

Ethernet cables
➜ Hub out

U Monitor BNC cables
➜ GREAT I Monitor out

LVDS connector
➜ DPP board out

PT 100 cable
➜ Gradient Coil

16 bits (68 pins) SCSI parallel cable
➜ GREAT X, Y, Z and B0 Unit

Figure 1.8. *The pictures show the filter box and the fuses used for Gradient Coil safety.*
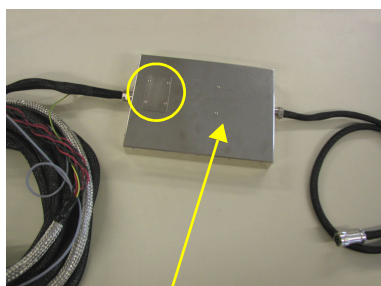
Gradient Filter Box
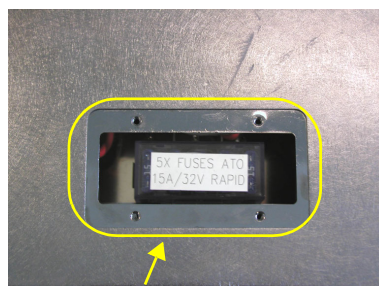
Fuse Box Cover

15A Fuses used for
Gradient Coil Safety

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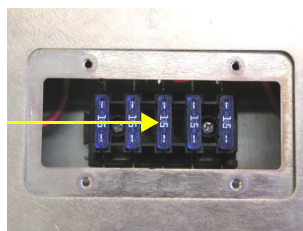
GREAT calibration operations

2

GREAT 1/40 or 1/60 ECL09 (Systems installed after 08/2007)   2.1

Open the BGA Web page by means of the "ha" order of the TopSpin interface or by opening a Web browser page. In the last case you have to know the BGA IP address. Enter the http://IP.address order into the Web browser to access to the BGA Web page.

- On the home page select BGA Service Tools.

- On the BGA Service Tools page, select Channel X, Channel Y, Channel Z.

- The GREAT 1/40 and GREAT 1/60 gradient amplifiers are calibrated during the manufacturing test procedure by BRUKER. Nevertheless, the gradient amplifier offset may change with temperature. **It is strongly recommended each time you switch the GREAT power On/Off** to run an auto offset calibration using the facility in the BGA Web page (see **_"GREAT service Web page" on page 17_**). You have to push the auto offset button and wait until the procedure is finished.

- Two other parameters (the regulation current R and C parameters) may be different if the GREAT is used with X,Y,Z HR gradient coils or Z HRMAS gradient coils. The default values (R = 74,9 % - C = 13,9 %) have to be used with HR probe heads having a Z gradient coil. The R and C loop current adjustment is done by using the **_preempgp2_** pulse program (Standard ^{1}H acquisition parameters with GRD_LENGTH (p16) = 2 ms, GRD_WAVE_FORM (GPNAM 1) = RECT.1, GRD_STRENGTH (gpz1) = 50 %, GRD_RECOVERY (d16) = 100 ms). All pre-emphasis parameters have to be set to 0. Before starting the acquisition with "zg", you have to connect the GREAT I Monitor Output on an external electronic device like an oscilloscope. **If the test is done when the GREAT is used together with the Digital Pre-emphasis Processor (DPP) board, be sure that all the pre-emphasis Gain values are set to 0** (see **_"The SetPre interface" on page 25_**). The test can be done using the **_preempgp.dru_** experiment used for pre-emphasis adjustment. A water sample has to be used and the R and C parameters are optimised by checking the 8 FID obtained FID evolution (with recovery delays equal to 0.1, 0.3, 1, 3, 10, 30, 100 and 500 ms). The R and C values are the good ones if the allure of the 2 first FID's are as close as possible to the last one.

GREAT calibration operations

Figure 2.1. Regulation current loop parameter settings - Pulse with an overshot
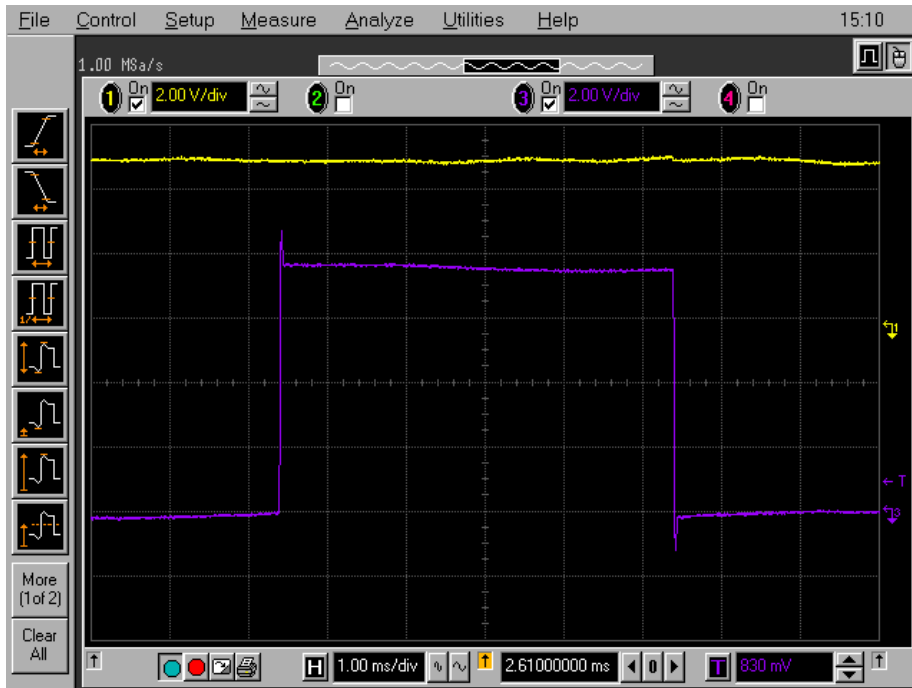(R = 95 % and C = 13.7 %).

Figure 2.2. Regulation current loop parameter settings - Pulse with an undershot
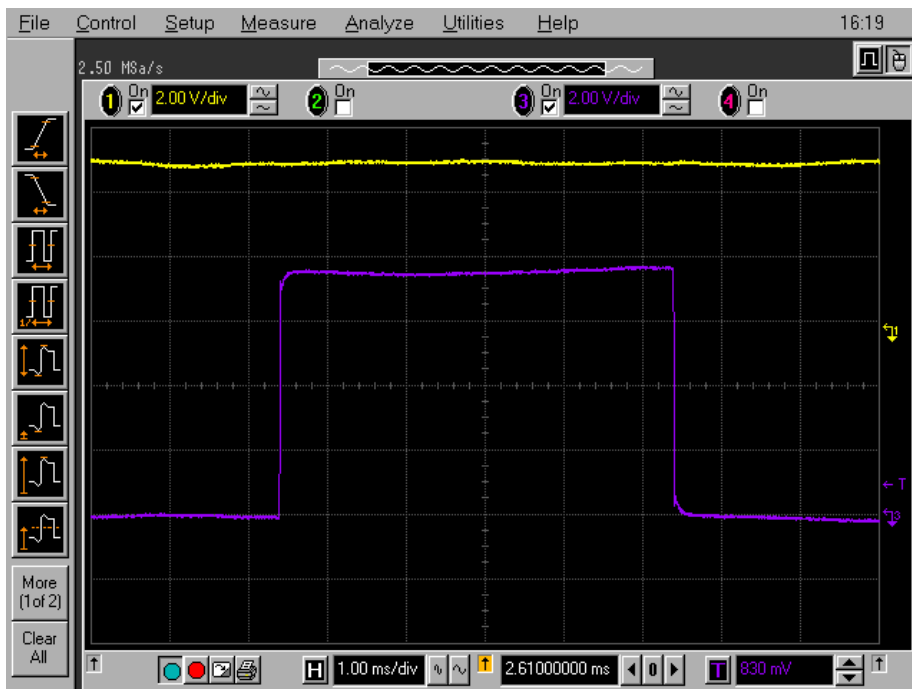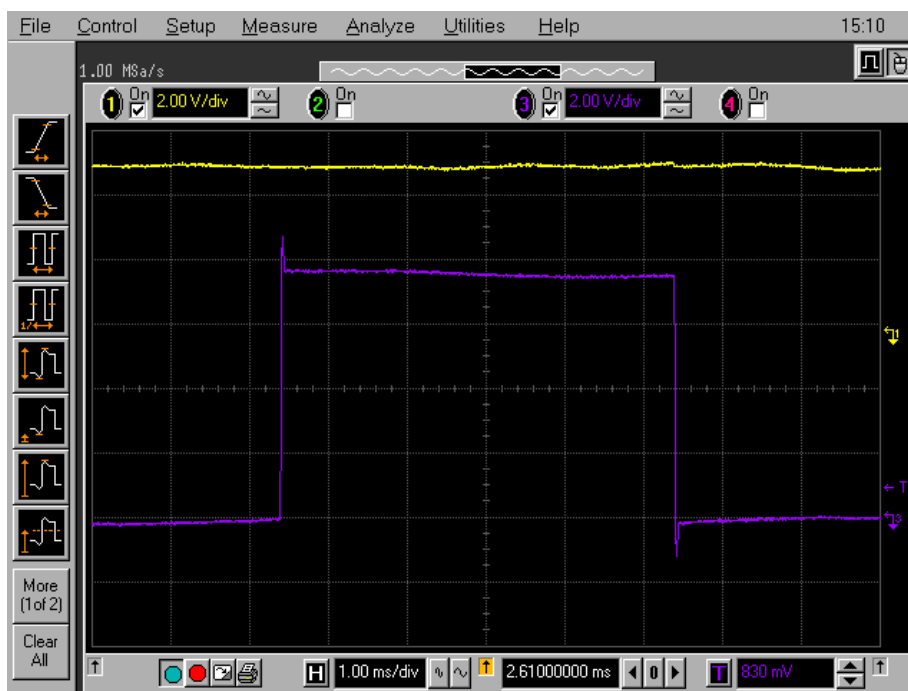(R = 43,1 % & C = 29,4 %).

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Figure 2.3. *Regulation current loop parameter settings - The pulse shape edges are rectangular.* Correct values are R = 81,5 % & C = 14,1 %. For Z gradient coils of standard High Resolution probe heads.

If NMR is used to do this test, the doped water sample is usually used. A 2 ms square gradient pulse is used, the gradient strength is set to 50 % (the used step depend on the gradient coil current limitation) of the maximal current set. The recovery delay is defined in the *preemp* list. In "edasp", you have to connect SGU 1 and SGU 2 on the 1H amplifier box. For the receiver, analogical mode is requested. This means that the **DIGMOD** has to be *qsim* and **DIGTYPE** must be *analog*. The acquisition can be started in *gs* or *zg* mode. The experiment is done in the same manner as the pre-emphasis adjustment. For further details see *"Pre-emphasis adjustment" on page 35*.

GREAT 1/40 or 1/60 ECL07 (Systems installed before 08/2007) 2.2

In the case of GREAT 1/40 and GREAT 1/60 amplifiers delivered with AVANCE II systems, it is possible to use these amplifiers together with the AVANCE III electronics. Nevertheless the Master Unit has to be exchanged with the newer model. The amplifier can be used in normal 16 bits amplitude resolution and in improved 19 bits resolution mode. By starting the Master Unit, the 19 bits amplitude resolution is set as default working mode. In this case, the resulting extra offset generated by the high resolution mode choice on GREAT 1/40 and GREAT 1/60 gradient amplifiers manufactured prior to August 2007 has to be corrected by means of the following procedure. The fine offset is corrected in both modes in the same way as described before. The coarse offset can be set in the "SetPre" window using TopSpin or Paravision and on the "Web" page. In all cases, the offset is corrected in one bit steps (1 LSB = 600 mA on the 60 A step, 200 mA on the 20 A step and so on).

GREAT calibration operations

Figure 2.4.   SetPre software main window display.
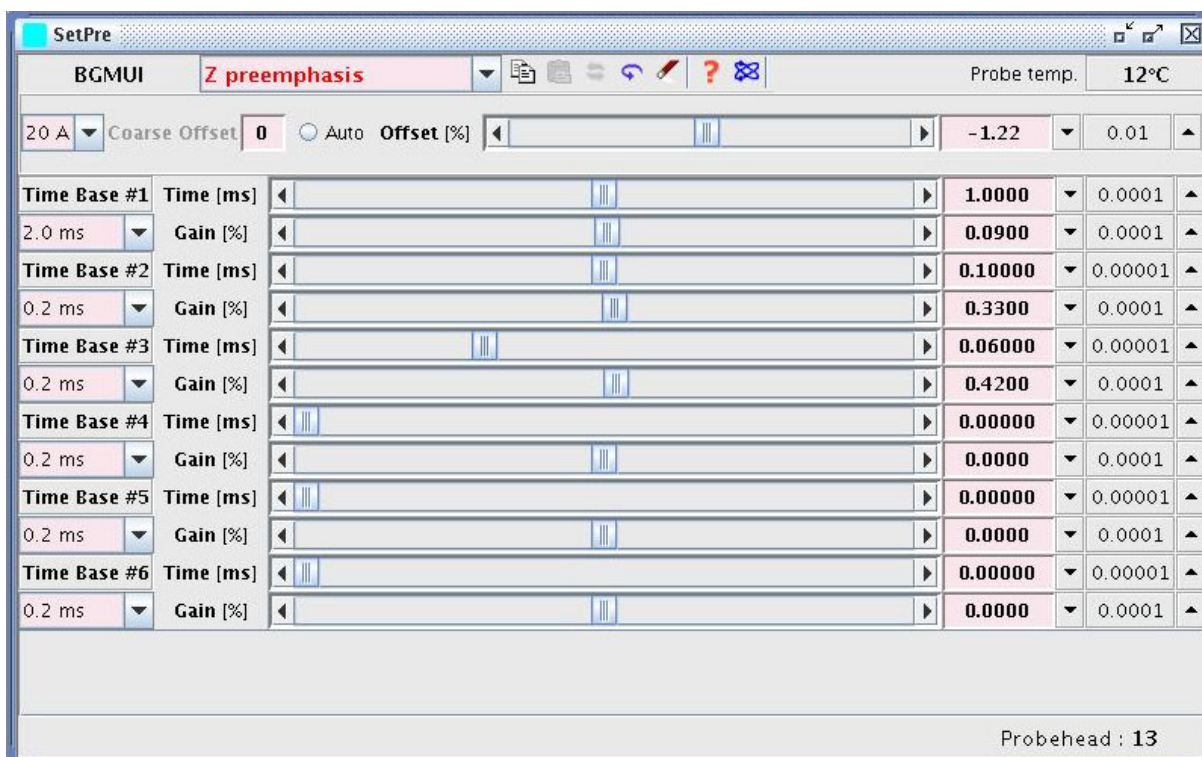
The coarse offset can be adjusted on the lock level if the probe head has a lock channel. Otherwise a single pulse acquisition (**zg**) experiment can be used and the coarse offset is changed until the FID area reaches a maximum. If the value is set, the fine offset is adjusted on the "Web" page as described below or by using the auto-offset button found on the "**SetPre**" window display as seen on Figure 2.4.

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GREAT service Web page

3

The GREAT amplifiers have now a dedicated Web page. You can open this page either in the TopSpin interface using the "*ha*" order after selection of the BGA push button or via a Web browser via the BGA IP address attributed to the GREAT amplifier during the "*cf*" configuration procedure.

BGA Service Web page   3.1

The first BGA Web page which is displayed is the BGA Sevice "Web" page shown in Figure 3.1.

Figure 3.1.   Display of the BGA Service Web page. There is one service Web page for each channel (X, Y, Z). The same page exists for the B0 Compensation Unit.

GREAT service Web page

The BGA reset "Web" page allows to reset the GREAT amplifier CPU in the same manner as an On/Off power switch without cut the amplifier boards.

The Event Log "Web" page is dedicated to service people. In this page are summarized the last events resulting from orders coming from GREAT interface handling like offset changes, loop parameter changes, configuration operation etc...

The BGA service report Web page is dedicated to service people. It shows the status of the device. This Web page may be used for trouble shouting only.

The BIS content Web page shows all the parameters stored in the GREAT amplifier BIS like loop parameters, amplifier address, amplifier type etc...

The BGA configuration "Web" page allows the setting of some GREAT parameters like the amplitude resolution. To enter in this page, the administrator password is required.

The firmware update "Web" page is much more important as far as these page has to be used for GREAT amplifier firmware update. The actual CPU firmware Boot and Application version are displayed on the BGA Service "Web" page. As it is the case for all other spectrometer devices, if a new firmware is needed, he would be delivered with appropriate TopSpin version and can be downloaded using the firmware Update "Web" page.

The BGA codes page gives the table where the Master Unit (BGMUI 1) Errors are summarized.

The following functions are available on the Service "Web" page :

1. Current regulation loop resistors and capacitors setting as indicated in section ***"GREAT calibration operations" on page 13***. These parameters are probe head dependent.

2. Manual Fine Offset setting by looking at the lock level (if the probe has one) or on the FID amplitude as indicated in section ***"GREAT calibration operations" on page 13***.

3. Fine Auto Offset function. The Offset is first calibrated and then adjusted against the reference built in the GREAT amplifier.

4. Amplifier Gain setting. Six gain ranges are available in the pull down menu : 10 A, 20 A, 30 A, 40 A, 50 A and 60 A. If the amplifier is a GREAT 1/40, the number is reduced to four gain ranges.

5. Amplifier Enable/disable pulldown menu.

6. High/Low Impedance choice in a pull down menu. The most of the cases the work in High impedance mode is recommended.

7. Refresh Data button : Allows to refresh the "Web" page if some parameters are changed in the "SetPre" window.

BGA Configuration Web page 3.2

Three Master Unit (BGMUI 1) major configuration parameters can be set on this "Web" page.

The way of working of the internal blanking may be chosen. This blanking is driven by the ***ctrlgrad*** orders included in the Grad.incl file and set inside the BLK/ UNBLKGRAD and BLK/UNBLKGRAM orders found in all the pulse programs where gradient pulses are involved. If the blanking threshold is set to 0, then the GREAT is blanked $20 \times 8 = 160$ μs after the numerical data put in the DAC reaches 0. The amplifier is blanked d16 + 160 μs after the ctrlgrad 7 order is found in the pulse program. The d16 delay correspond to the time used for the DAC digital data to become 0. If the threshold is set to an other value (in mA), the GREAT amplifier may be blanked before the numerical DAC input data reaches 0. In this way, the blanking cuts into the pre-emphasis current. The default value of 0 for positive/negative threshold is strongly recommended.

An other important parameter can be set. The user has the choice to work in normal (16 bits) or enhanced resolution mode (19 bits). The default value is set to enhanced resolution (19 bits) which is recommended especially for higher currents like 60 A. The super User password is needed to change the amplitude resolution.

It is possible to chose if the pulse Led's on the master Unit front panel display the real amplifier output pulses or the potential pulses received on the LVDS interface from the DPP board. The default values displayed are the output pulses measured on the GREAT Monitor output.

Figure 3.2.   Display of the BGA Configuration "Web" page. This is a Master Unit configuration meaning that all connected channels are working with the here set configuration parameters.
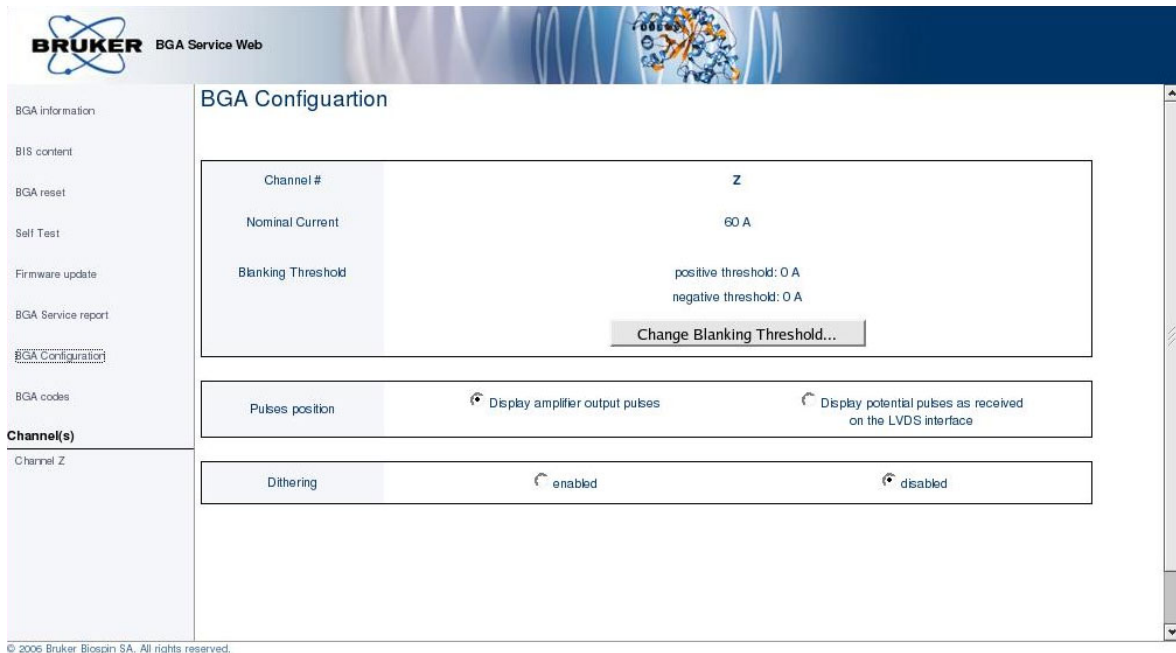
GREAT service Web page

The blanking threshold values are defined in A as shown on the slight below.
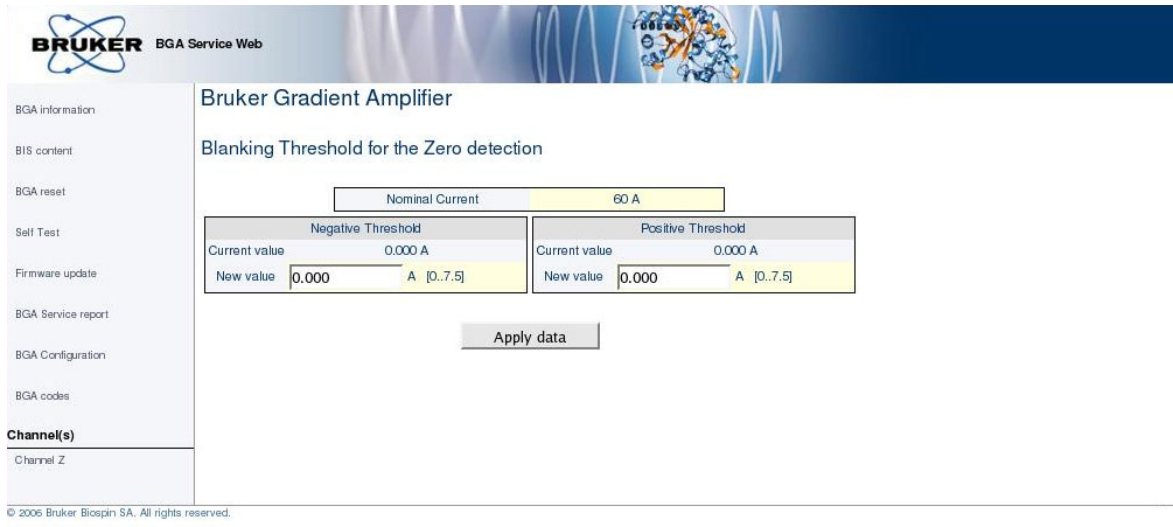

BGA Current Loop parameter Web page   3.3

On this "Web" page it is possible for each of the Gradient channels X, Y and Z to set the current regulation loop resistor and capacitor values. This parameters are probe head dependent. The values are defined in % of the maximum available resistor (in Ohm) and in % of the maximum available capacitor (in μF). A table which summarizes commonly used values for different types of probe heads are given in the table below.

Figure 3.3.   Display of the Web page on which the loop current parameters can be changed for each of the gradient channel's X, Y and Z. Note that there are no R and C parameters to change for the B0 compensation Unit. These parameters may also be changed in the SetPre window.
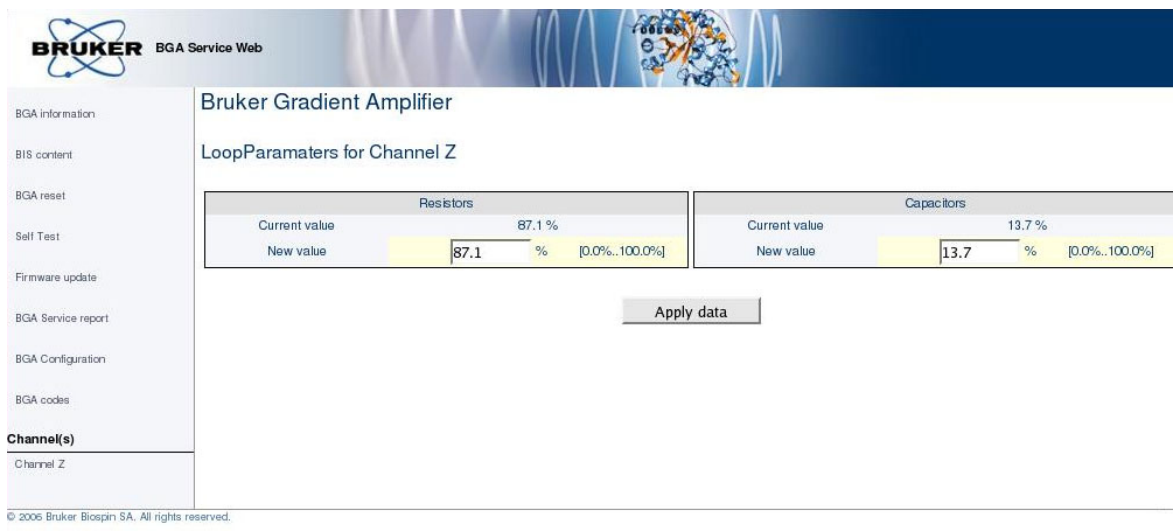
The values given in this table are indications. If the user wants to adjust this parameters to his coil, it is necessary to do it in the way mentioned in section **_"GREAT calibration operations" on page 13_**.

Table 3.1.   Coil parameters values indications.

Probehead	Resistor R in %	Capacitor C in %
High resolution Z gradient coil	80.0	14.3
HR X,Y,Z gradient coil	85.3	13.7
HRMAS Z gradient coil	74.0	14.0
Micro Imaging X,Y,Z gradient coil		
Diff 30 /60 Z gradient coil	32.0	9.8

This "Web" page is used only for firmware updating. This is necessary only if some new features haven been added in the software or if newer Topspin versions require BGMUI 1 Master Unit firmware upgrading. The firmware may be downloaded from every kind of electronic data storage device. If a new TopSpin version is loaded on the computer, the BGA software should be found in the <TopSpin inst.>/conf/instr/servtool/gradient directory.

The firmware pathway is searched with the Browse... button and loaded with the update button.

Figure 3.4.   Display of the BGA firmware update Web page.
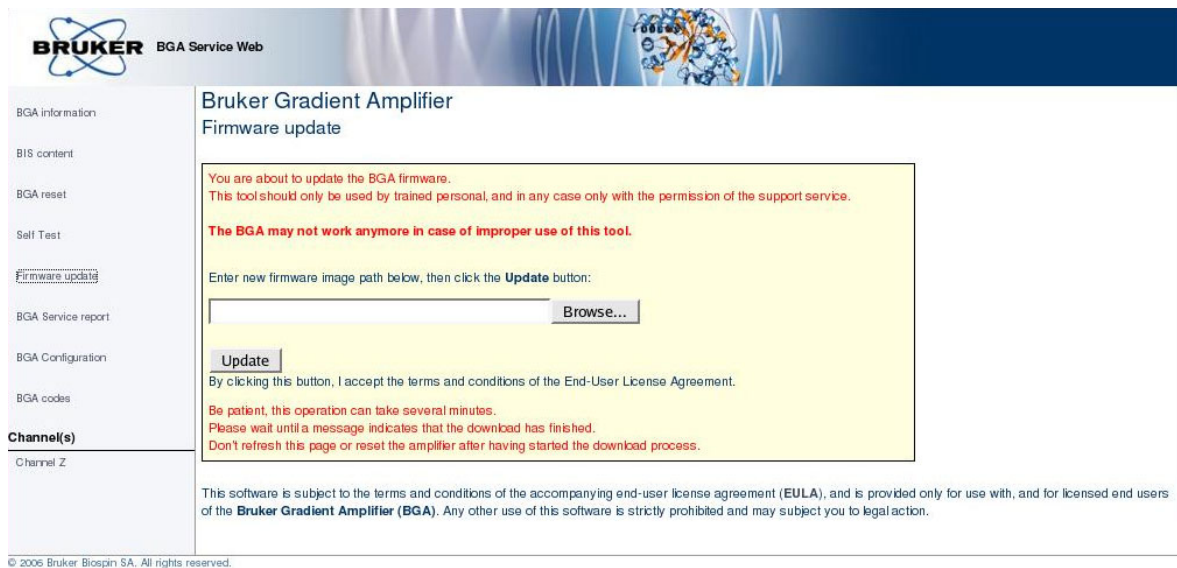
BGA Codes Definition Web page   3.4

The codes given on this "Web" page allows to understand the error messages given on the master Unit front panel display. If one of the following messages is displayed instead of the gradient coil temperature, please have a look on the following list.

Figure 3.5.   Display of the BGA Codes definition Web page.

BGA Service Report Web page   3.5

The service report "Web" page is used if there are one or more red Error Led's on which indicate one or more errors. In this case it is necessary to reset the Master Unit and know which kind of error occurred. These information's are given on the service report page shown in Figure 3.6. The Individual actions which have to be done are given below depending on the error displayed (red box in the corresponding error line of the "Web" page.

Figure 3.6.   Display of the BGA Service Report Web page.

A status register exists for each of the channels X, Y, Z and B0 compensation unit. The last status register is related to the Master Unit (BGUMI 1).

Amplifier X, Y, Z or B0 Compensation Unit :

1. Power Supply error : Check if the amplifier power supply is connected. If it is the case have a look on the fuse located on the GREAT amplifier back panel. If the fuse is OK, the power supply may be damaged ➜ contact your BRUKER office.

2. Board temperature too high : Check if the fan are working properly. If it is not the case call your BRUKER office.

3. Integrator Error : Call your BRUKER office.

4. Output Power fault : There is probably a gradient amplifier parameter (maximal current/voltage, mean power etc…) which is set to low in the gradsafe interface. Have a look on section ***"GREAT amplifier safety parameters" on page 31*** of these manual. Click on the Reset Protection button to remove this error. If the error remain, push on the CPU-A reset button (2 on the Master Unit front panel) and do a "***cf***". If the amplifier remain in protection do a power supply On/Off on the master unit and on the concerned gradient amplifier.

5. If the is an auto-offset fault, be sure that the coarse offset (see section ***"GREAT calibration operations" on page 13***) is properly set. If this is the case and the failure remain ➜ call your BRUKER office.

6. Communication error : Please check if the cable which connect the GREAT digital input to the Master Unit digital output is properly connected or if the cable is not damaged. If the connection is OK, please do a power supply On/Off on the master unit and on the concerned gradient amplifier. If this doesn't help ➜ call your BRUKER office.

Master Unit :

1. DSP fault or Board temperature too high : Do a power supply On/off on the Master Unit and set the gradient safety parameters. If the error remain, please call your BRUKER office

2. LVDS buffer fault : It is necessary to reboot the IPSO computer and sometimes to do a Master Unit power supply On/off. Set the safety parameters in the "SetPre" interface.

3. LVDS parity error : It is necessary to reboot the IPSO computer and sometimes to do a Master Unit power supply On/off. Set the safety parameters in the "SetPre" interface.

4. LVDS bus disconnected : It is necessary to reboot the IPSO computer and sometimes to do a Master Unit power supply On/off. Set the safety parameters in the "SetPre" interface. If does not help, check the LVDS cable connections and the LVDS cable itself.

5. Error parameter from BCU20 : Check if there is a connector on the BCU20 female connector (7 connector on the Master Unit front panel). If it is the case, check if the BCU20 unit is working properly.

6. Temperature from PT100 to high : Be sure that the gradient coil is properly cooled with water. Be sure that there is no problem with the cooling circuit. (This failure occurs when the Master Unit measures a coil temperature higher then 60 °C).

7. FPGA fault : Do a Master Unit power supply On/off. Set the safety parameters in the "SetPre" interface. If this doesn't help, please call your BRUKER office.

The SetPre interface

4

The "SetPre" interface is the major software used to manage gradient amplifiers and the B0 compensation unit with the High resolution TopSpin and the Imaging Paravision software packages. This software is used to manage high resolution gradient systems (GREAT 1/10 and GREAT 3/10) as well as higher current gradient amplifiers like the GREAT 1/40 and GREAT 1/60. The time constants and the gain factors of the real time pre-emphasis functions (up to 6 functions) can be set inside this interface as can be seen on the "SetPre" Main Window shown in Figure 4.1.

Figure 4.1.   The SetPre software Main Window.
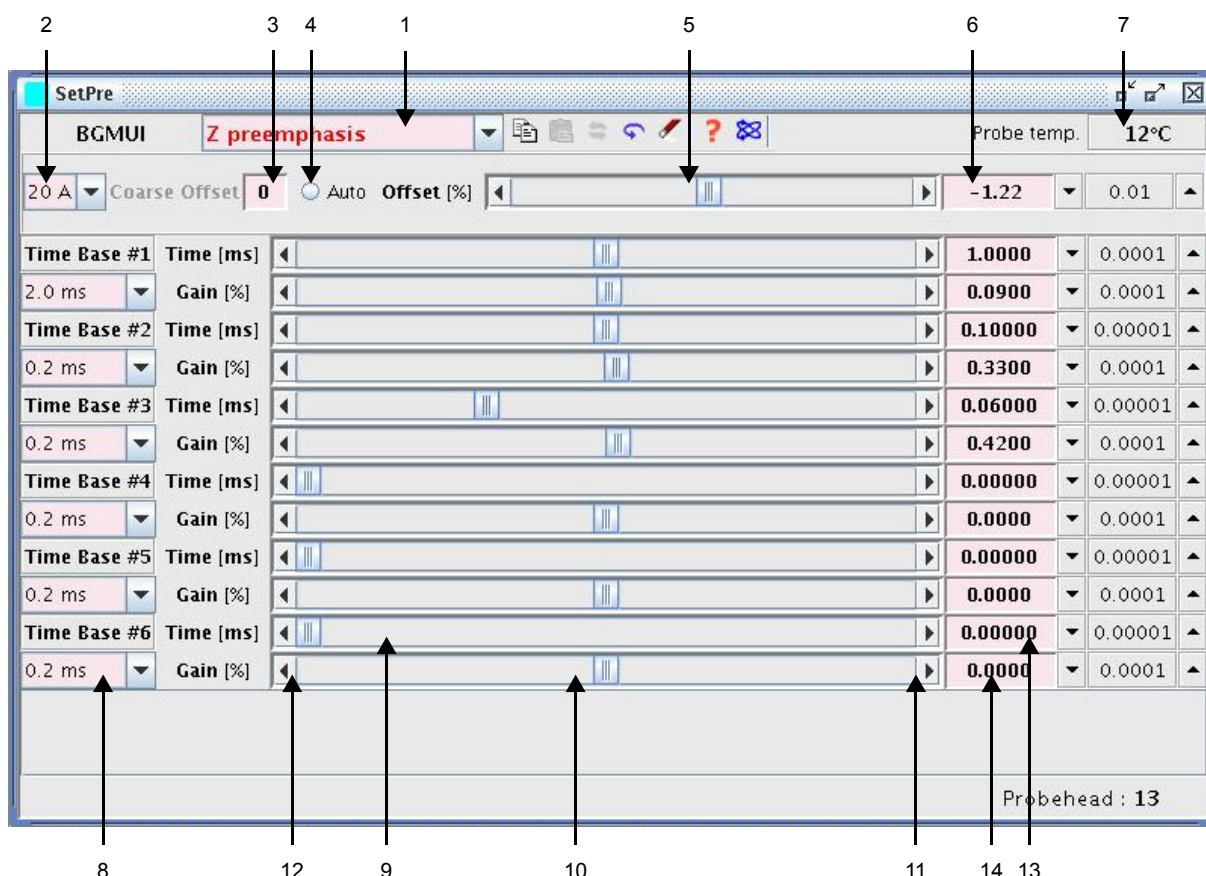
1. Gradient Amplifier Channel selection. Note that if a B0 Compensation Unit is used the Z ➜ B0 compensation, Y ➜ B0 compensation, X ➜ B0 compensation functions have to be choosen in the pull down menu .

2. Gradient Amplifier Gain selection **(available on "Web" page)**.

3. Coarse Offset setting (Different from 0 only if GREAT amplifiers with other ECL then 09 are used in 19 bits improved resolution). A value between -4 and -8 LSB is generally needed.

4. Fine Auto offset toggle On/Off button applied only to the displayed channel **(available on "Web" page)**.

5. Manual Fine Offset adjustment slider. The range is $-100 \leq$ Offset ≤ 100 % where 100 % correspond to 0.6 mA.

6. Fine Offset value. The value can also be set by end by enter the value from the keyboard **(available on "Web" page)**.

7. Gradient Coil real temperature display in °C. A temperature value higher then 60 °C cut the gradient for protection purpose **(available on "Web" page)**.

8. Digital Pre-emphasis time basis pull down menu. The menu gives the choice between no time basis (DC), 0.2 ms, 2 ms, 20 ms and 200 ms.

9. One of the 6 Digital Pre-emphasis time constant slider. The range is $0 \leq \tau \leq$ Time Basis.

10. One of the 6 Digital Pre-emphasis Amplitude Gain slider. The range is $-100 \leq$ Gain ≤ 100 % with the restriction that $\Sigma\ G_n \leq 10$ % of the PFG current.

11. Digital Pre-emphasis step by step value increasing. The step amplitude is defined in the pull down menu of the right side of the interface.

12. Digital Pre-emphasis step by step value decreasing. The step amplitude is defined in the pull down menu of the right side of the interface.

13. One of the 6 Digital Pre-emphasis Time Constant value which may be put in with keyboard.

14. One of the 6 Digital Pre-emphasis Amplitude Gain value which may be put in with the keyboard.

The next "pull down" menu is used for pre-emphasis parameter file handling as shown in Figure 4.2.

Figure 4.2. SetPre pre-emphasis file handling pull down menu.
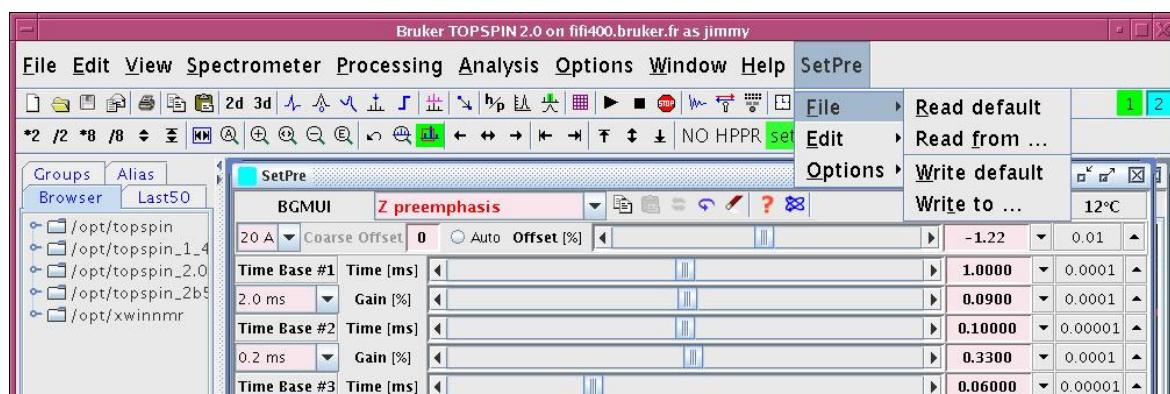

- The default file is stored into the <disk>/exp/stan/nmr/lists/preemp/<probe ID>/ directory with default as filename.

- The file may be written in the same directory with a user choosen filename.

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The <probe ID> is the probe number given for the current probe head in the "edhead" window. In the case shown in Figure 4.1., the <probe ID> is equal to 13.

The next "pull down" menu is used for GREAT amplifier configuration. Some of the functions contained is this menu are available on the service function and the configuration "Web" pages. The available functions are shown on the slight of Figure 4.3.

Figure 4.3.   SetPre gradient amplifier options pull down menu.
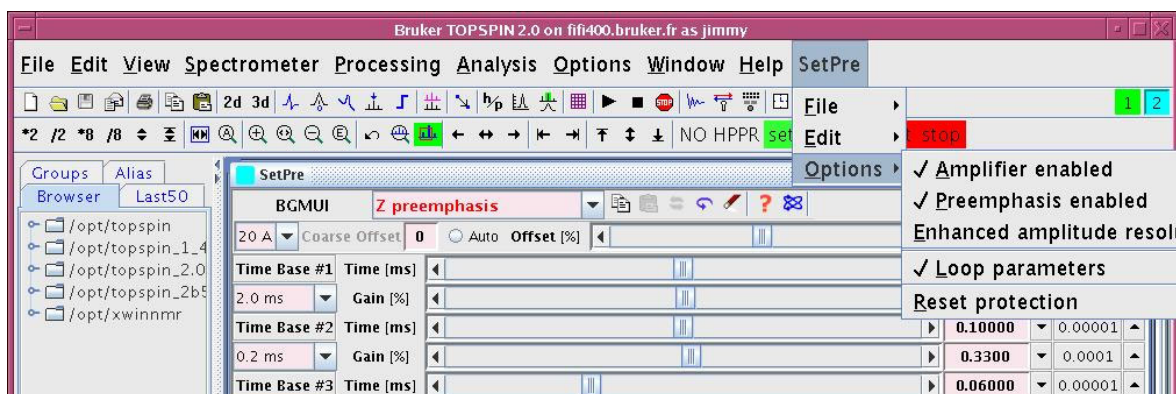
- Amplifier enabled **(on web page)** : Allows to enable/disable the GREAT 1/40 and 1/60 amplifier board power supply.

- Pre-emphasis enable : Allows to use the pre-emphasis or not. If the pre-emphasis is enabled, the first order filters calculated data points (using the time constant and the amplitude Gain factors) are added on the real time scale (every 8 μs when GRADRES = 8 μs) on the pulses. If the pre-emphasis is disabled, digital data coming from the GCON are only routed through the DPP without any modification.

- Enhanced amplitude resolution **(on web page)** : Allows to chose between the 16 bits normal and the improved 19 bits amplitude resolution. The default setting is the improved amplitude resolution.

- Loop parameters **(on web page)** : Allows the settings of the current regulation loop resistor R and capacitor C. Acts as a filter at the amplifier board output. There values are depending on the load (see ***"BGA Current Loop parameter Web page" on page 20***).

- Reset protection **(on web page)** : Software BGMUI1 Master Unit reset button (see ***"BGA Service Report Web page" on page 22***).

The next "pull down" menu is used for GREAT amplifier parameter editing and status control. Some of the functions contained is this menu are available on the service function and the configuration "Web" pages. The available functions are shown on the slight of Figure 4.4.

The SetPre interface

*Figure 4.4. SetPre gradient amplifier parameter status/editing pull down menu.*
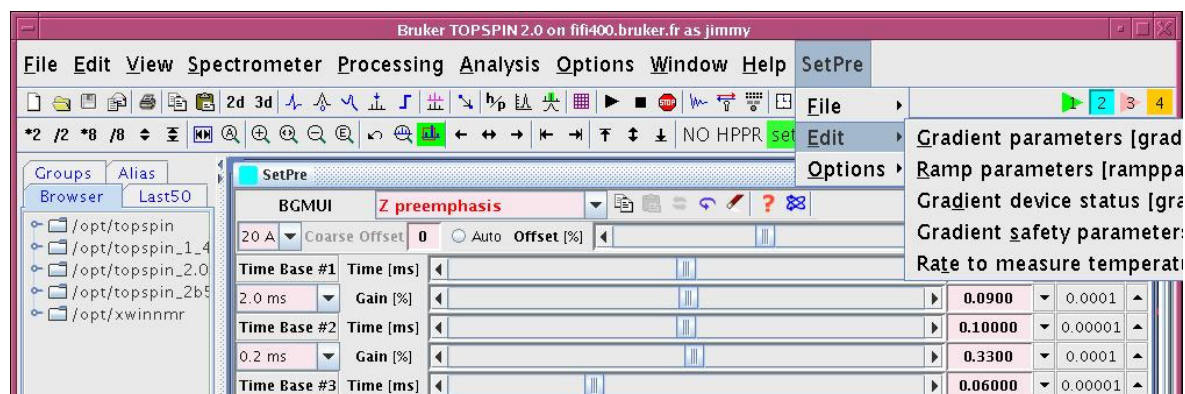
- Gradient parameters [*gradpar*] : Allows to set the expected or measured gradient strength of a gradient coil in G.cm^{-1}.A^{-1}. More details are given on Figure 4.5.

- Gradient Ramp parameters [*ramppar*] : Gradient pulse ramp definition parameters. Finds his use in MRI experiments if the gradient frequency refocusing pulse used during the acquisition time has another wave form then a square. More details are given on Figure 4.6.

- Gradient device status **(on web page)** [*gradstat*] : Allows to control the gradient amplifier status. The same function is available on the "web" page. More may be found details on Figure 4.7. and **"BGA Service Report Web page" on page 22**.

- Gradient safety parameters [*gradsafe*] : This parameter table allows to set Gradient coil protection parameters. These parameters have to be set before to start working with the gradient system. After each BGMUI Master Unit power supply On/Off, the "error message" **C01** appears. To allow the gradient system to work, it is necessary to put in the safety parameters. More details are found in section **"GREAT amplifier safety parameters" on page 31**.

- Rate to measure the temperature : Allows the rate for gradient coil temperature measurements in s. If the gradient coil temperature mean value calculated over 20 points is higher then 60 °C, the gradient amplifier run into protection. The rate to measure the coil temperature defines the time between gradient coil overheating detection and gradient amplifier protection mode setting.

The gradient parameter window (which may also be displayed if the *gradpar* order is entered on the keyboard) is shown in Figure 4.5. The individual X, Y and Z calibration is given by :

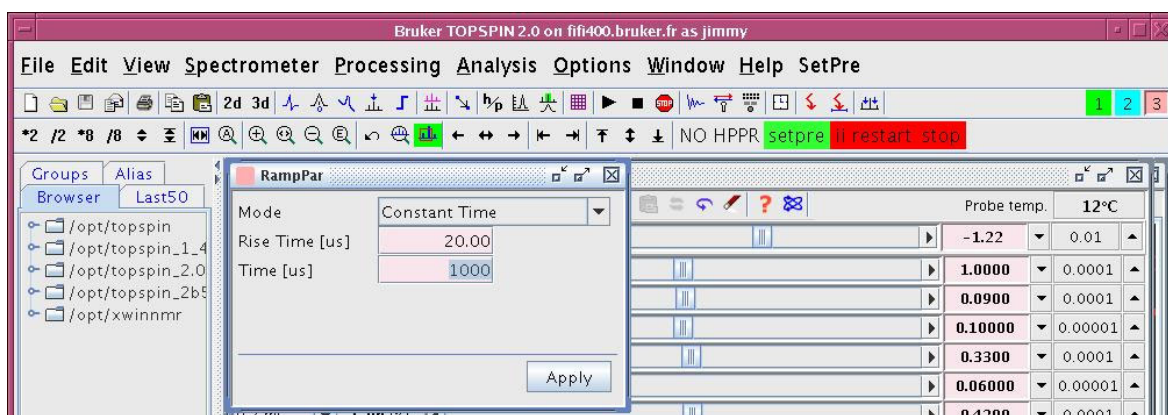$$G_{X,Y,Z} = f_{X,Y,Z} \times G \text{ calib.}$$

Figure 4.5.   Gradient parameter window display.
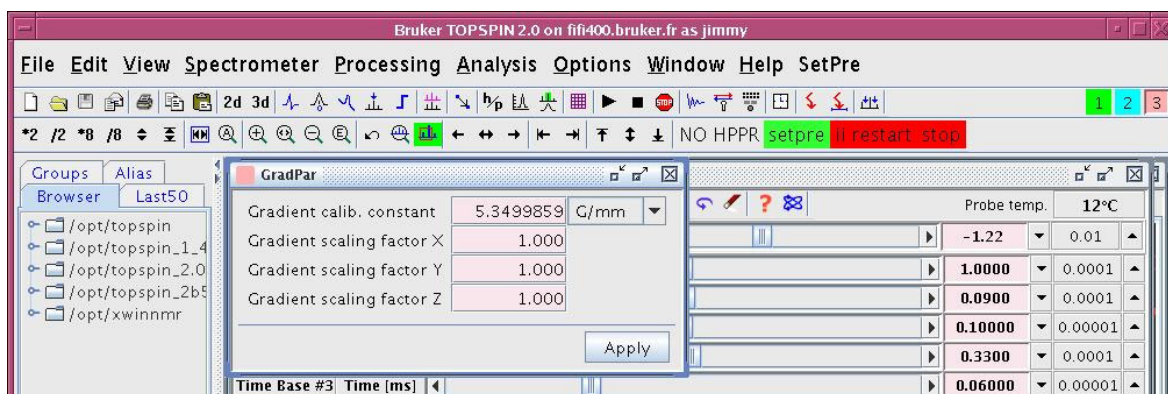
The gradient parameter window (which may also be displayed if the ***ramppar*** order is entered on the keyboard) is shown in Figure 4.6. The following parameters can be modified :

- Ramp parameter : Constant mode, sine or trapezoïdal wave form.

- Ramp rise time : Ramp Rise/fall time duration.

- Ramp time : Gradient pulse time duration including the rise/fall time.

Figure 4.6.   Gradient Ramp parameter window display.

The gradient parameter window (which may also be displayed if the ***gradstat*** order is entered on the keyboard) is shown in Figure 4.6. The same gradient amplifier and BGMUI 1 master unit parameters are displayed on the "web" page. The status parameters are defined in ***"BGA Current Loop parameter Web page" on page 20***.

Figure 4.7.   Gradient amplifier status parameter window display.

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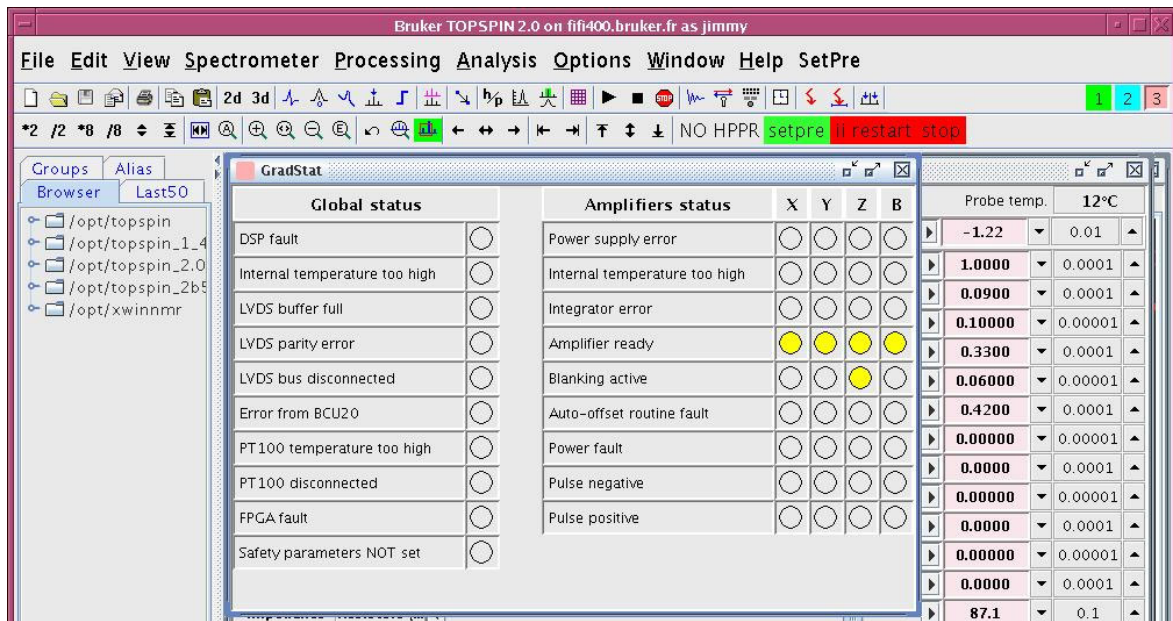
GREAT amplifier safety parameters

<div style="text-align:right">**5**</div>

The gradient amplifiers can only be used if the gradient safety parameters are set according to the gradient coil used for a given experiment. If the power supply of the BGMUI 1 Master Unit is put On, an error message **C01** is displayed on the Master Unit front panel. The only way to remove the error message is to enter in the "*SetPre*" gradsafe "*Edit*" window or to enter the gradsafe order with the keyboard. After accurate gradient safety parameter setting, the temperature measured on the Gradient coil is displayed : **23°C** for example. The gradient safety parameter setting window display is shown in Figure 5.1.

Figure 5.1. Gradient amplifier Safety parameter setting window display.
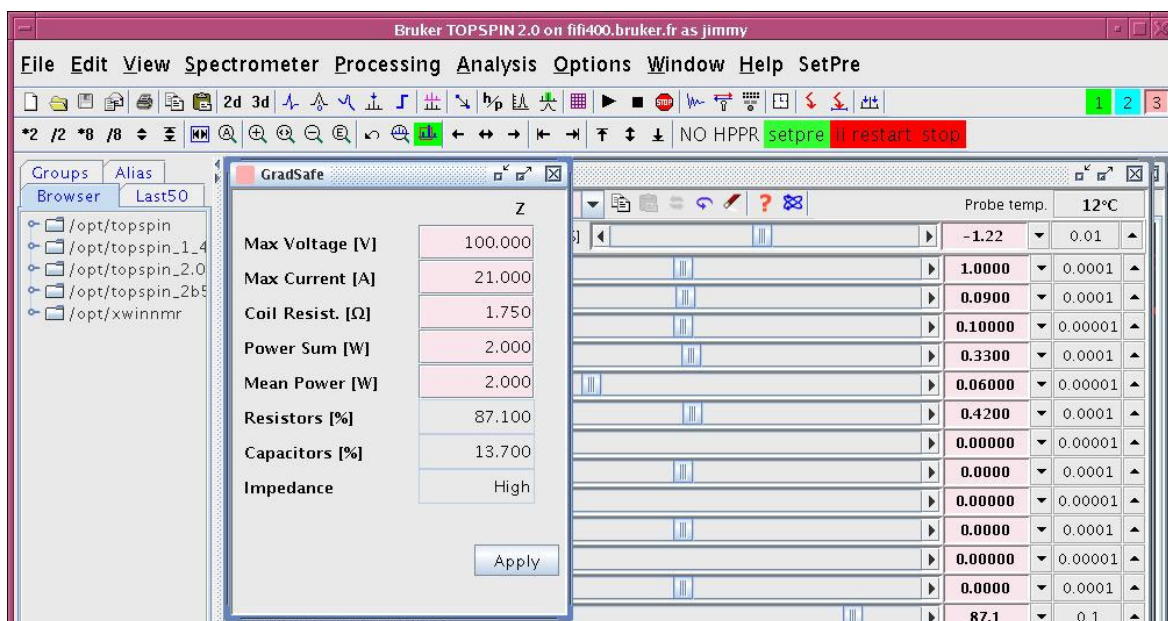
The following safety parameters have to be set in order to protect gradient coils against gradient amplifier mishandling. The safety parameters have to be defined for each used channel. If more then one gradient amplifier is used, the safety parameters have to be defined individually for each channel. The B0 Compensation Unit has no safety parameters.

- Max. Voltage in V : The gradient voltage is measured inside the GREAT amplifier an can be measured at the gradient amplifier U Monitor output (only available on GREAT 1/40 & 1/60 ECL 09 versions). The voltage limitation protect the gradient coil against arching during pulse rise/fall time.

GREAT amplifier safety parameters

- Max. current in A : The gradient current inside the GREAT amplifier an can be measured at the gradient amplifier I Monitor output (available on all GREAT 1/40 & GREAT 1/60 versions). The maximal current which may be applied to a gradient coil is probe head dependent. The gradient coil maximal current which may be used on a gradient coil is given in the documentation delivered with the probe head.

- Coil resistor in Ω : The resistor value is gradient coil dependent and is found in a $0.5 < Rcoil < 2\ \Omega$. The real value of the load may be affected by the cable resistance and skin effects during PFG experiments.

- Gradient Mean Power in W : The safety software record every 25 μs I and U monitor data outputs for each channel. As far as only 240000 data points may be stored in the Master Unit buffer, 40000 data points can be stored for each of the I and U Monitor output data on each of the three X, Y and Z channels. Thus the buffer values are changed in a dynamic way in order to store only the last 40000 points. We can deduce from this hardware way of working that the time constant T used for the mean power calculation is 40000 x 25 μs = 1 s. Thus the mean power (dissipated by Joule effect) is calculated with the following formula :

$$P_{mean} = (1/T)\ \Sigma\ R_{coil}\ i_{mean}(t)^2\ \Delta t \qquad \text{(Eq. 5.1)}$$

where T=1 s, DT = 25 ms. The sum is calculated over 40000 points which is the buffer range memory allocated for the calculation. If the gradient pulse is a square pulse we have $i_{mean} = i_{max}$ If the gradient wave form is a time function f(t), we have $i_{mean} = i_{max} \times f(t)$.

If the gradient maximal current is set to i_{max} in the gradient safety window, it is possible to calculate the maximal mean power and the allowed duty cycle DC where DC = δ_{pulse} / (δ_{pulse} + δ_{rest}).

$$P_{mean} = R_{coil}\ i_{mean}^2\ DC \qquad \text{(Eq. 5.2)}$$

If δ_{pulse} (Gradient pulse length duration) $>>$ δ_{rest} (Duration where the gradient amplifier is not pulsing), the maximal pulse length may be calculated for a given current setting using the following formula :

$$\delta_{pulse} = P_{mean} \times \delta_{rest} / (R_{coil} \times i_{mean}^2) \qquad \text{(Eq. 5.3)}$$

$$\text{where } i_{mean} = (1/\delta_{pulse}) \times \Sigma\ i_{max} \times f(t)\ \Delta t \qquad \text{(Eq. 5.4)}$$

Example : If the current limitation is set to 20 A, the maximal mean power which may be accepted by the system is Pmean = DC $\times$ R $\times$ Imean2. Note that the effective instantaneous power P = U $\times$ I may be even higher (P = 110 x 20 = 2.2 kWatts in this case). The maximal duty cycle DC which may be used before the GREAT amplifier run into protection is 10 % (10 ms pulse length every 100 ms). The maximal mean Power, if a 1 Ω impedance gradient coil is used, is equal to Pmean = 1 $\times$ 0.1 $\times$ 202 = 40 Watts. The system only ran in protection if δpulse/(δpulse + δrest) > 10 %.

It is also possible to calculate the maximal current imax allowed in an experiment if the mean power is set in the gradsafe interface for a given gradient pulse wave form by using equations (Eq. 5.3) and (Eq. 5.4)

- Power Sum in W : The power sum parameter P_{sum} is given by :

$$P_{sum} = P^X_{mean} + P^Y_{mean} + P^Z_{mean} \qquad (Eq. 5.5)$$

GREAT amplifier safety parameters

Pre-emphasis adjustment

6

Pre-emphasis are adjusted fro each amplifier X, Y, Z and the B0 compensation Unit in the "*SetPre*" main window. For each channel, it is possible to define 6 different one order exponential functions defined through there time constant and through there gain following the equation below :

$$f(\alpha,t) = A_\alpha \exp(-tk\alpha/\tau\alpha) \qquad \text{(Eq. 6.1)}$$

with $1 \leq a \leq 6$.

The time domain function s(t) resulting from pre-emphasis filter application is the convolution product of the time domain gradient pulse function e(t) multiplied by the reverse Laplace transform of each filter transfer function. If e(t) is a square pulse (step function), the pre-emphased pulse is an addition of all the $f(\alpha,t)$ to e(t). This operation is done on the real time scale (one data point generated every Δt with Δt = GRADRES) :

$$S(\Delta t) = \sum_\alpha A\alpha \exp(-\Delta t\, k\alpha/\tau\alpha) + e(\Delta t) \qquad \text{(Eq. 6.2)}$$

If $\sum A\alpha \exp(-\Delta t\, k\alpha/\tau\alpha)$ > 10% of the maximum digital gradient amplitude and the $e(t) \geq 90\%$ of the maximal digital gradient amplitude, the pre-emphasis signal is subject to cut off.

The X, Y and Z pre-emphasis functions are defined in there respective window (**Z preemphasis** for the Z channel, **Y preemphasis** for the Y channel, **X preemphasis** for the X channel). For the B0 unit pre-emphasis parameter setting, the $B0_Z$ pre-emphasis may be defined in the **Z ➜ B0 preemphasis** window. In the same manner the $B0_Y$ pre-emphasis are defined in the **Y ➜ B0 preemphasis** and the $B0_X$ pre-emphasis are defined in the **X ➜à B0 preemphasis** window.

The experiment is done using the doped water sample (or some other water containing sample) using a pulse sequence like the sequence shown in Figure 6.1.

Figure 6.1.   Gradient pulse sequence used for the pre-emphasis adjustment.
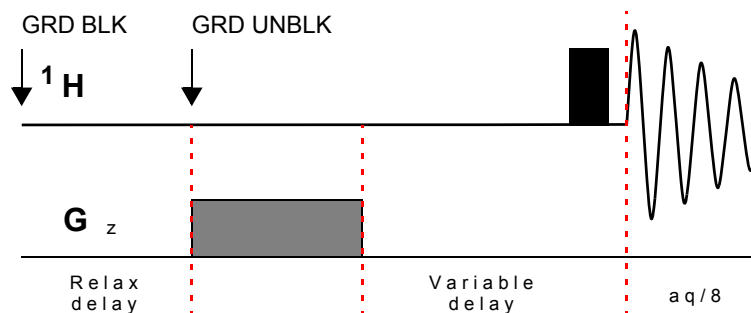
Pre-emphasis adjustment

Before starting with pre-emphasis adjustment, be sure that the current regulation loop resistor and capacitor are accurately set (see section *"GREAT calibration operations" on page 13*). On a square pulse, the regulation circuit has the same effect then the pre-emphasis functions with the difference that pre-emphasis are digitally added to the square pulse and the regulation filter is an analogical current added on the pulse after digital to analogical conversion. ***Thus the obtained pre-emphasis correction values are function of the regulation current loop resistor and capacitor values***.

With the pulse sequence shown on figure 22, 8 FID's are recorded with gradient recovery times respectively equal to 0.1, 0.3, 1, 3, 10, 30, 100 and 500 ms. If Eddy currents are present and/or in the case of a bad current loop parameter adjustment, some of the first FID's recorded with the pulse sequence previously shown show distorted amplitudes/phases as is shown in Figure 6.2.

Figure 6.2.   Display of the 8 FID's obtained with the pulse sequence shown in Figure 6.1. On the top display, the pre-emphasis are not adjusted. On the bottom display, the pre-emphasis are as good adjusted as possible.
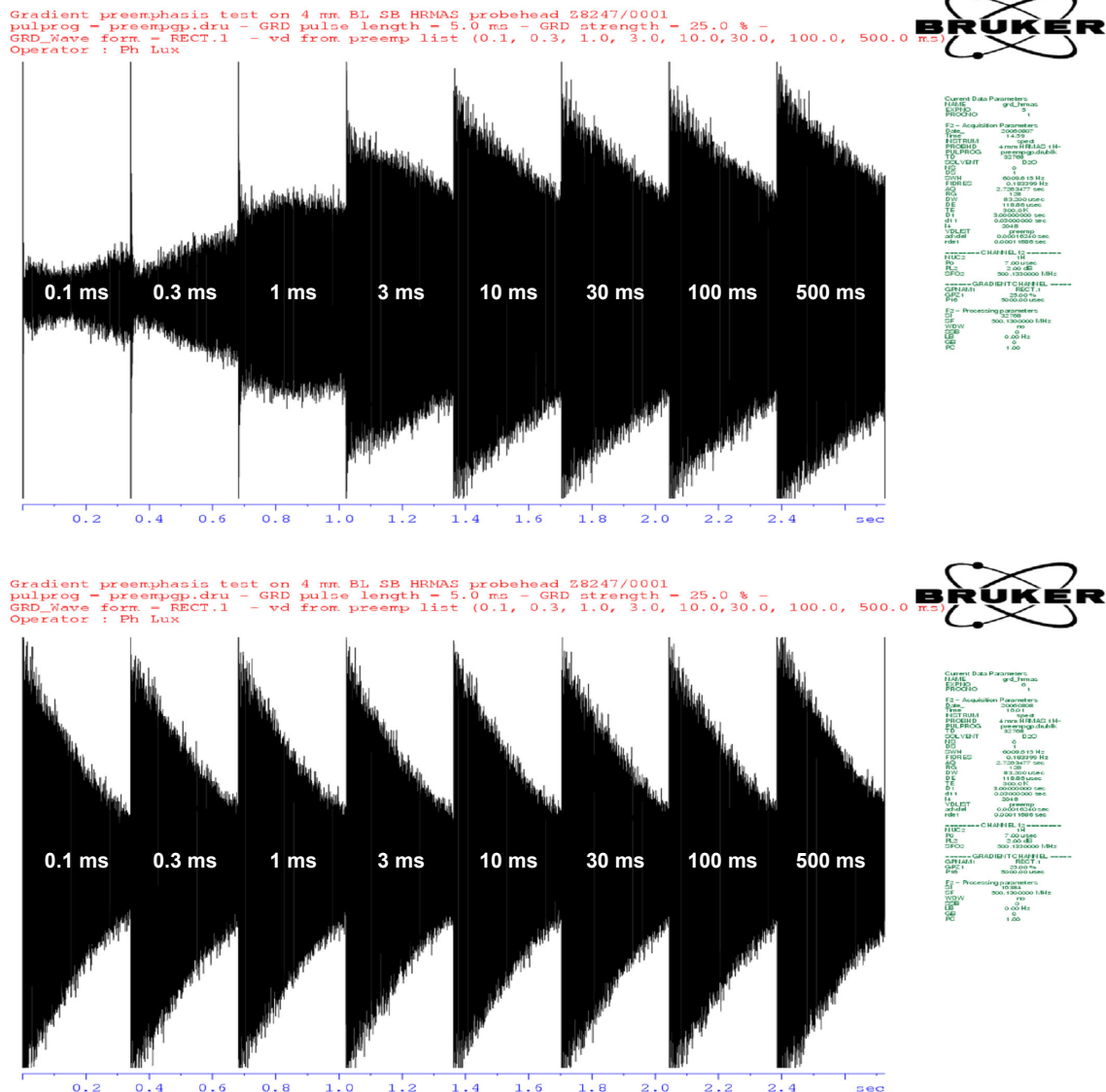
After pre-emphasis parameter adjustment, the amplitude of the eight recorded FID's should be the same. Nevertheless, this test is not sufficient to be sure that the Eddy currents generate by gradient pulses are completely compensated. A second experiment may be necessary to check if the amplitude and the phase of individual water peaks is completely recovered after a gradient in a time range between 50 μs and 1 s. The experiment used for this purpose is nearly the same experiment as shown in Figure 6.1. but only one FID is recorded and the recovery delay changes in logarithmic steps starting at 20 μs up to 1s with a first increment of 10 ms. As far as 64 points are recorded, the logarithmic step factor f is equal to : f = 10^(log(t_{end}/t_{start})/64) = 1.18419. The logarithmic "**paropt**" like spectra shown on Figure 6.3. are obtained with and without Eddy current compensation. The experiments are recorded on a standard bore magnet, a 5 mm TXI Z gradient coil and a GREAT 1/60 amplifier with the Gain set to 20 A.

Figure 6.3. *Gradient Recovery test recorded as mentioned below. Top : All pre-emphasis are set to 0 (Current loop parameters R = 85.3 % and C = 13.7 %). Bottom : The pre-emphasis parameters are set as accurate as possible. In both cases a trapezoidal 5 ms pulse is used (14 points define the rise slope, 100 points at maximal amplitude and 14 points define the fall slope).*

Pre-emphasis adjustment

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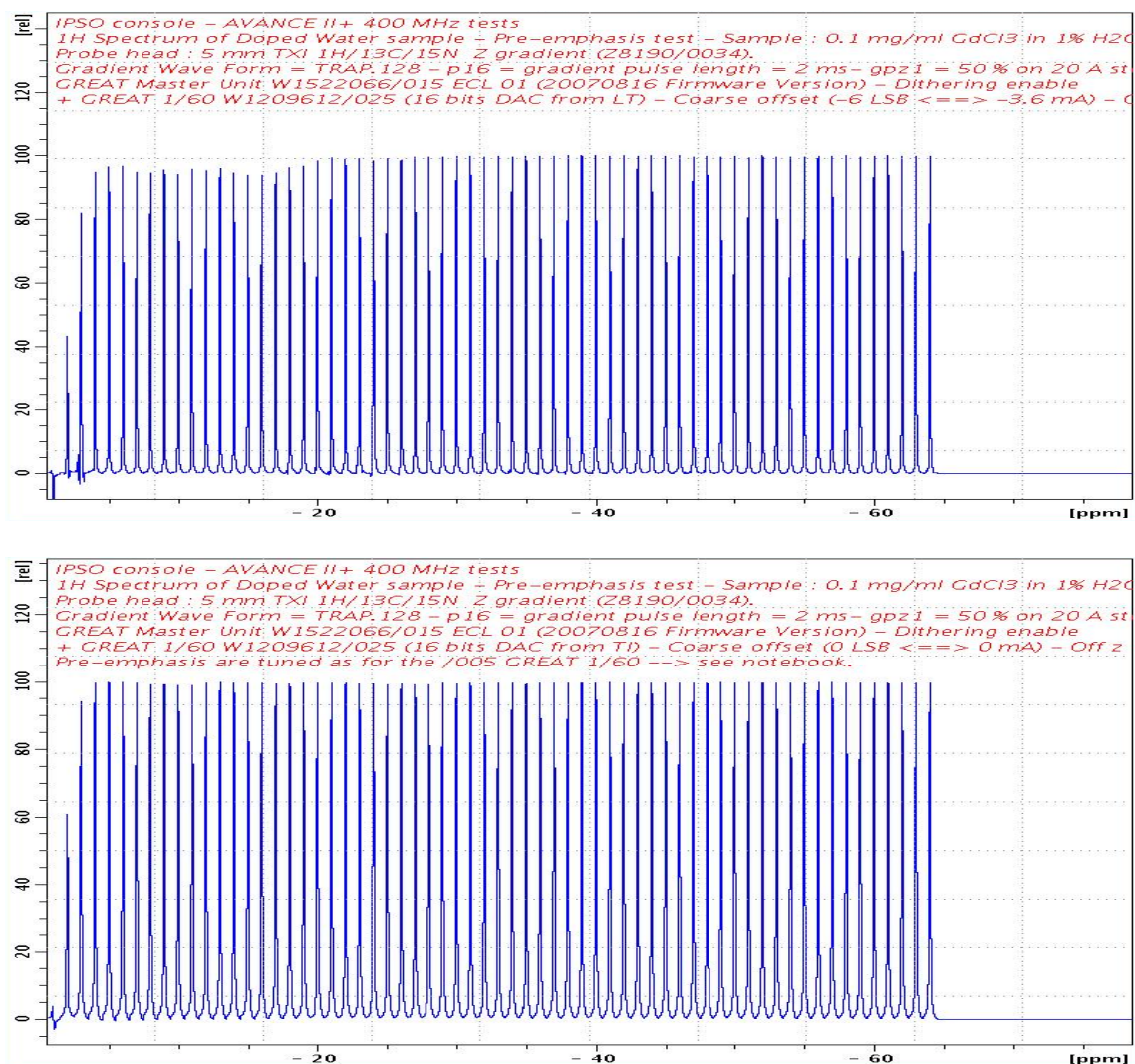
Gradient pulse strength calibration 7

The gradient strength is calibrated by measuring the profile of a phantom of known spatial dimensions in the presence of a gradient and noting the spectral width of the profile. In practice a 5 mm (inner tube diameter = 0.42 mm) doped water sample is adequate for X and Y profiles. The spectral width of the obtained profile gives at a given gradient pulse strength $g_{x,y,z}$ in A, the field gradient $G_{x,y,z} = g_{x,y,z} \times d_{x,y,z}$. The relation ship between the measured profile spectral width and the gradient strength is given by :

$$g_{x,y,z} = \Delta \nu_{x,y,z} / (d_{x,y,z} \times 4.258) \qquad G.cm^{-1} \qquad \text{(Eq. 7.1)}$$

where $\Delta \nu$ is given in kHz and d in cm.

For the Z gradient strength profile a 2.5 mm spherical insert filled with 50 μl water may be used as well as a Shigemi Tube containing 2 mm water height. The insert or the water sample must be put in the middle of the RF coil. Use the sample tube depth gauge. The accurate position of the insert is reached when the gradient profile is perfectly centered in the spectral window. The limitation of the gradient profile measurement method is the spectral width covered with the spectrometer digitizer (2 MHz with RXAD digitizer and 5 MHz with RXAD BB digitizer). If *D_2O is missed* for practical reasons it is possible to work *without lock signal with the lock sweep switched off*.

In both cases, X and Y or Z profile measurements, use the *calibgp* pulse program. Initially use *$g_{x,y,z}$ = 10 %* on 20 A step with an HR probe (e.g. *5 % on 40 A step or 3.33 % on 60 A step*. If DIFF 30 or DIFF 60 probe heads are used, a polymer sample with lower diffusion rates is much more accurate. With such small gradient strength, choose a *50 kHz* spectral width, a time domain *TD = 256 or 512 k*, an *accurate 90° RF pulse*, a correct d1 and a number of scans NS = 4. Put AQMOD to qsim and DIGMOD = analog as far as DQD may not operate at such high spectral width. Acquire the echo signal, Fourier Transform it with *fmc* to obtain a magnitude spectrum. You should obtain the gradient profile shown in Figure 7.1. obtained with a spherical insert of 0.25 cm along the Z Axis of an HR 5 mm TXI Z gradient coil. On each profile it is possible to estimate the Gradient calibration factor in $G.cm^{-1}.A^{-1}$ by dividing the gradient strength (equation (Eq. 7.1)) by the accurate value of the applied current. The gradient calibration factor is also the slope of the straight line obtained on the plot (Figure 7.2.) of $g_{x,y,z} = f (G+)$ if G+ is converted in A (Current = $G+ \times G_z/100$).

The experiment can be done with positive G+ or negative G- gradients. The gradient field strength measured on the gradient coil of a 5 mm TXI probe when using the GREAT 1/60 amplifier on the 20 A step are reported on the plot on Figure 7.2. The gradient strength gz is given in G/cm and calculated using the formula (Eq. 7.1). The Z gradient system linearity (e.g. Z channel of the amplifier and Gradient coil) may be appreciated on the same plot.

Gradient pulse strength calibration

Figure 7.1.   Gradient strength calibration curves obtained with the Z Gradient coil of a 5 mm TXI probe using the GREAT 1/60 amplifier on the 20 A step and a 0.25 cm Spherical Water insert (with 50 μl pure water inside). 1: gp_z1 = 60 %, 2 : gp_z1 = 50 %, 3 : gp_z1 = 40 %, 4 : gp_z1 = 30 %, 5 : gp_z1 = 20 % and 6 : gp_z1 = 10 %.
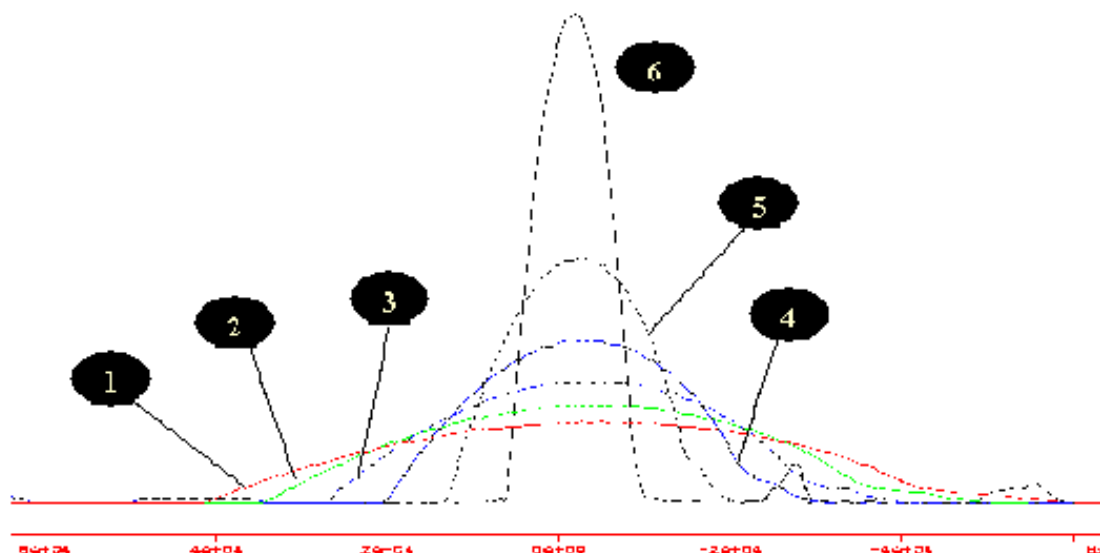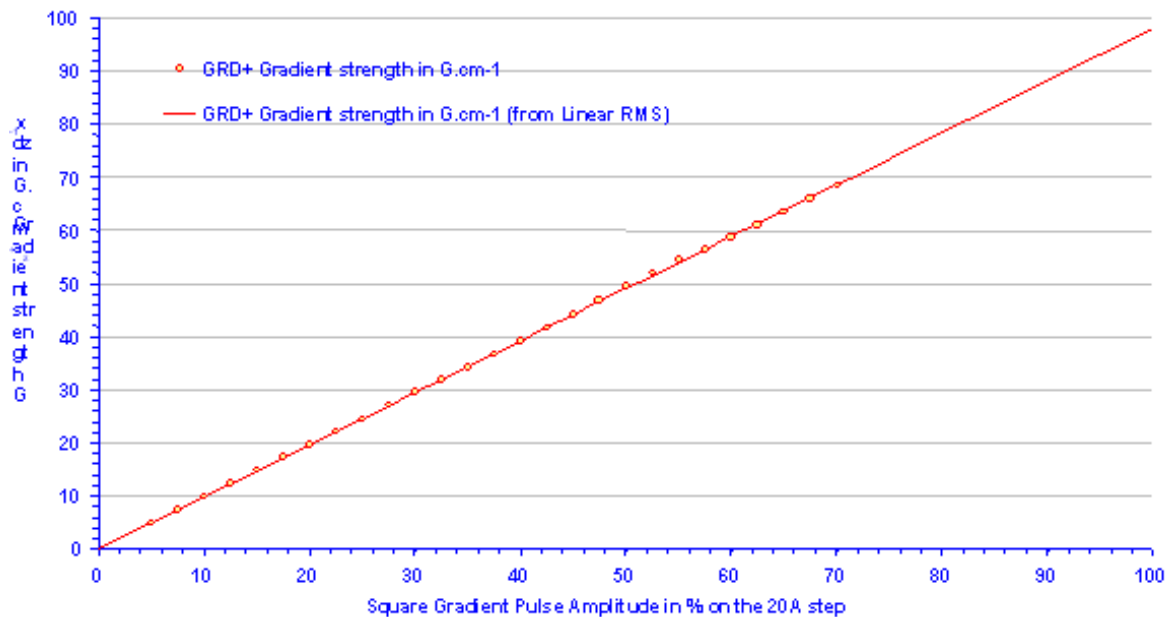

Figure 7.2.   Plot of the Gradient strength $g_z = G_z + \times d_z$ (in $G.cm^{-1}$) against the square pulse gradient amplitude defined by the software (gp_z1 = G+) when using a Z coil of a 5 mm TXI probe. The GREAT 60 amplifier is used on the 20 A step. The sample is a 0.25 cm spherical water plug.

Water diffusion coefficient measurement

8

This last gradient amplifier test is a basic application of diffusion spectroscopy. This test may be done on 5 mm High resolution and diffusion probe heads (DIFF 30 / DIFF 60). The water self diffusion coefficient is measured using an echo experiment using gradients during the echo time as shown in Figure 8.1. The choice of the gradient pulse length δ and of the evolution time Δ is critical and may be done properly. If δ and Δ are too short or too long, the diffusion curve is not properly defined and the water self diffusion coefficient calculated on the basis of the experimental data points (Water peak Intensity = f (gradient strength)) may be not correct. It is also important as for every NMR experiment that the $\pi/2$ is accurately set. In the example shown here, we have used the doped water sample (0.1 mg/ml Gadolinium Chloride + 1 % H_2O + 99 % D_2O) and a 5 mm HR probe head (100 G/cm maximal gradient strength).

Figure 8.1.   Sequence for self diffusion coefficient measurements using the Stekjal/Tanner gradient echo experiment.
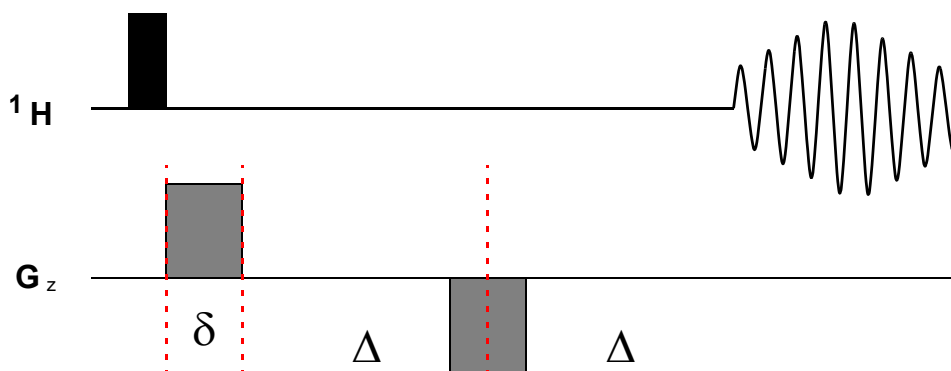
The spectrum shown in Figure 8.2. is obtained by plotting the water peak intensity against the gradient strength. The gradient strength changes in 200 mA steps (Δgp_z1 = 1 %) starting at 0 A up to 20 A. Two square gradient pulses of 800 μs duration are used. The gradient recovery delay is set to 100 μs and the echo time Δ is equal to 30 ms. The experiment shown here is recorded on a 5 mm TXI probe head equipped with a Z gradient coil. When using DIFF 30 or DIFF 60 probe heads, shorter δ and Δ have to be used. It is recommended to work on 10 or 20 A step (Remember that for 10 A gradient pulses the gradients strength is 300 G/cm on a DIFF 30 and 600 G/cm on a DIFF 60 probe head).

Water diffusion coefficient measurement

In the Stejskal & Tanner experiment, the self diffusion coefficient of a molecule can be calculate on the basis of Magnetization changes as a function of the square gradient pulses :

$$M_z = M_0 \times \exp(-D||\ \gamma^2 \delta^2 (\Delta - \delta/3)\ G^2) \qquad \text{(Eq. 8.1)}$$

By plotting the Magnetization (which is proportional to the measured water peak intensity I) against G^2, we obtain a straight line (Figure 8.3.) and the self diffusion coefficient may be calculated from the slope of the straight line. We should obtain for the water self diffusion coefficient at 298 K : 2.30×10^{-9} m^2/s [1]. The plot of the calculated water peak intensity against G using the experimental self diffusion coefficient D|| deduced from the straight line plot should fit properly the experimental points. To obtain good results you may calibrate the gradient strength in G/cm of your gradient coil (see section **_"Gradient pulse strength calibration" on page 39_** of this manual).

Figure 8.2. *Water peak intensity decreasing as function of the gradient pulses strength in the Stejskal & Tanner experiment when δ = 800 μs and Δ = 30 ms. The experiment is recorded at 298 K.*

IPSO console – AVANCE II+ 400 MHz tests
Water Diffusion coefficient measurement – HF : pl1 = 0.0 dB (50.12 Watts) --> p90 = 6.8 us
Sample : 0.1 mg/ml GdCl3 in 1% H2O + D2O – Probe head : 5 mm TXI 1H/13C/15N X,Y,Z gradie
Gradient Wave Form = TRAP.100 – Big Delta d16 = 30 ms – GRD strength in 1% steps from 0 to
p16 = gradient pulse length = 0.880 ms – Gradient Echo on 1% Water 20 A step
BGMU1 Master Unit W1522086/0015 (20070816 firmware) + GREAT 1/60 W1209612/025 (16 bit
GRADRES = 8.0 us – Dithering enabled – Pre-emphasis adjusted and not 0
Coarse offset = 0 LSB – Fine Offset = 3.3 % of 0.6 mA.

Figure 8.3. *Plot of the curve ln(I/I$_0$) = f(G$_z$^{2}) where I$_0$ is the water peak intensity in absence of any gradient pulse and G$_z$ is the gradient strength in G.cm^{-1}.*
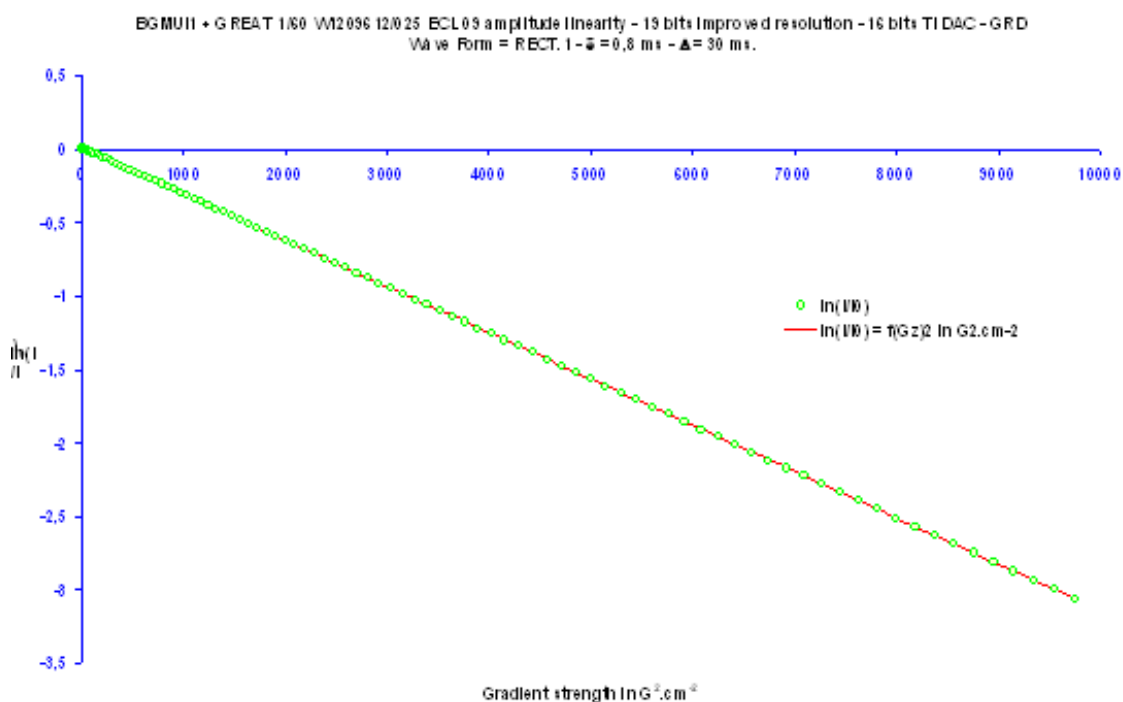
The plot of ln(I/I$_0$) as a function of the square of the gradient strength (G^2) gives us a straight line whose slope is given by :

$$\text{Slope} = D|| \, \gamma^2\delta^2 \, (\Delta-\delta/3) \qquad \text{(Eq. 8.2)}$$

$$\text{leading to} \quad D|| = \text{Slope} / [\, \gamma^2\delta^2 \, (\Delta-\delta/3) \,] \qquad \text{(Eq. 8.3)}$$

Plots obtained when a 0,8 ms square pulse was used are shown below. The calculated values of the slope and the deduced Water Self Diffusion coefficient at 298 K are given in the table below.

Table 8.1. *This values have been obtained with the GREAT 1/60 W1209612/ 005 ECL 09. Water Self Diffusion Coefficient at 298 K : 2.299 × 10^{-9} m^2.s^{-1}.*

	Slope	RMS	D|| in m^2.s^{-1}
19 bits DAC res.	-0.00031526	0.9982	2.291 × 10^{-9}
16 bits DAC res.	-0.00031344	0.9981	2.278 × 10^{-9}

Values extracted from the 1D gradient echo experiment using a 0.8 ms gradient square pulse (δ) - Δ = 30 ms - The Gradient strength changes in 1 % steps starting at 0 up to 95 % (96 points).

Water diffusion coefficient measurement

Gradient Echo stability evaluation

<div align="right">

9

</div>

With the gradient amplifier stability we check the way in which the gradient amplifier is able to sent reproducible pulses to the coil during an NMR experiment. This test allows to check the amplifier DC matching done by the user on the spectrometer (see section ***"BGA Configuration Web page" on page 19*** of this manual) and the efficiency of the amplifier DC offset thermal correction. On the production site the thermal behaviour of a GREAT 1/60 or 1/40 amplifier is matched in a temperature range of 18 < $T_{G\ opt.}$ < 27 C (where $T_{G\ opt.}$ is the optimal room temperature in which high gradient output stability is reached). The principle of this test is to reproduce N times the same pulse sequence (see Figure 9.1.) in proton NMR spectroscopy using the doped Water sample (0.1 mg/ml Gadolinium Chloride in 1 % H_2O + 99 % D_2O). The test may be done in ***paropt*** mode or by using the tests included in the ***BRUKER HWT test procedure***. The results have to be compared with the spectrometer stability test when the gradient amplifier is blanked or the gradient cable un plugged. When N is equal to 64 (using a repetition time of 5 s) we obtain the so called short time stability test which allows to check the amplifier DC offset matching. When N is equal to 256 (using a repetition time of 15 s) we obtain the so called time averaged stability test which allows to check if the temperature gradient output stability is good enough.

Figure 9.1.   G+ / G- Gradient Echo pulse sequence used for gradient amplifier stability tests. The spectra are recorded using 2 ms 20 G/cm gradient square pulses on a 5 mm High resolution probe head.
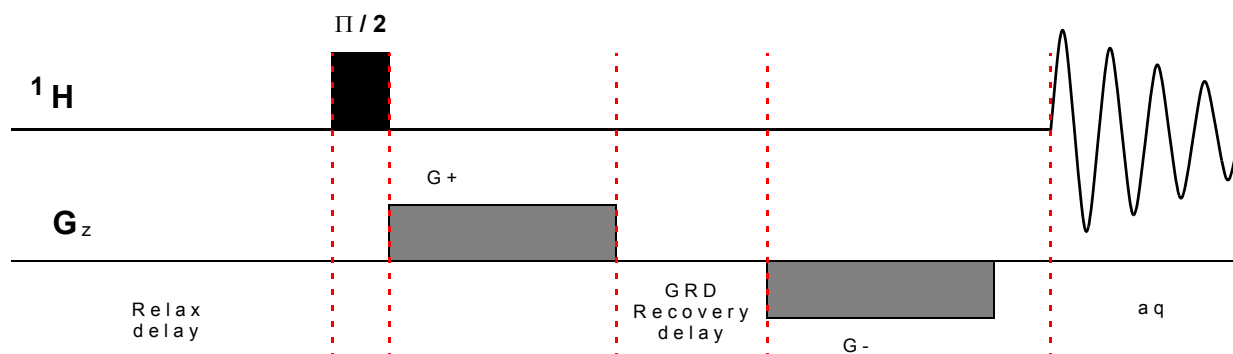
Short time gradient stability test - Number of scans N = 32

In this experiment, the number of scans N is equal to 64, a repetition delay of 5 s (relaxation + acquisition time) is used. The total experiment time is 5 mn 20 s. The experiment is done with the 10 A, 20 A, 30 A and 60 A steps. The gradient strength is maintained unchanged e.g. 40 %, 20 %, 13.222 % and 6.666 % respectively. The spectrum shown on figure 32 is obtained in this conditions using a 2 ms 20 G/cm gradient square pulse echo on the 10 A step.

Gradient Echo stability evaluation

Table 9.1.   *Gradient pulse amplitude stability results obtained on the 10 A, 20 A, 30A and 60 A when using the Gradient echo G+/G- sequence using 2 ms square pulses at 20 G/cm are summarized in the following table.*

	Stability test std Dev. Factor [a]
Gradient echo expt. At 20 G/cm on 10 A	2.1
Gradient echo expt. At 20 G/cm on 20 A	1.8
Gradient echo expt. At 20 G/cm on 30 A	2.3
Gradient echo expt. At 20 G/cm on 60 A	2.9

a. The stability test std Dev. Factor = Water peak Int. Std Dev. (Grad. Echo) / Water peak Int. Std Dev. (without Grad.)

The water peak intensity standard deviation calculated over 64 Gradient echo experiments must be smaller then three times the water peak intensity standard deviation calculated over 64 single pulse experiments (without gradients). Note that on the 60 A step, the stability decreases.

Figure 9.2.   *Figure 32 : Gradient Echo G+/G- short time stability test using the gradient echo sequence recorded on the 1 % Water sample (0.1 mg/ml GdCl3 + 1 % OH2 in 0D2). Gradient Pulse length = 2 ms - Gradient shape = trapezoïdal - Recovery delay = 0.0001s Gradient strength = 20 G/cm.*

BRUKER
BIOSPIN
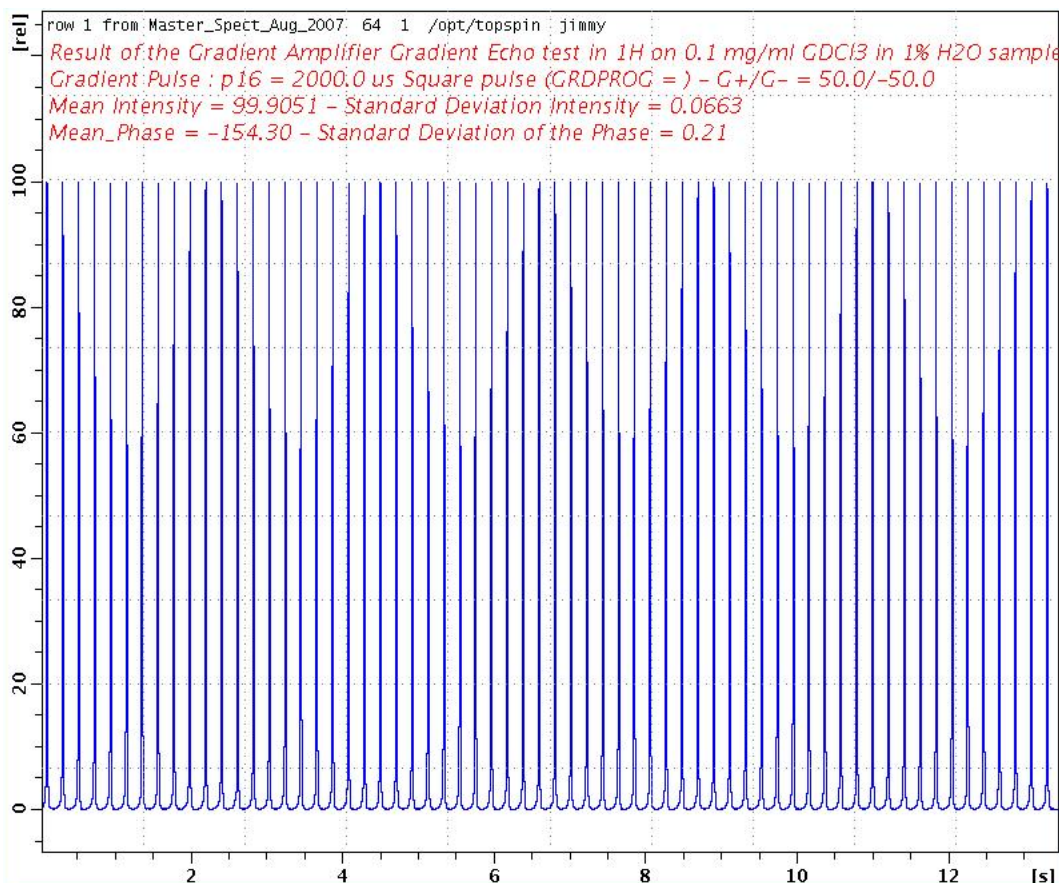
Time averaged gradient stability test - Number of scans N = 256

In this experiment, the number of scans N is equal to 256, a repetition delay of 15 s (relaxation + acquisition time) is used. The total experiment time is 1 hour 4 mn. The experiment is done with the 20 A step (can be done on all the other steps using the same experimental conditions described here). The gradient strength is set to 20 %. The spectrum shown in figure 33 is obtained in this conditions using a 2 ms 20 G/cm gradient square pulse echo on the 20 A step.

Figure 9.3. *Gradient Echo G+/G- time averaged stability test using the gradient echo sequence recorded on the 1 % Water sample (0.1 mg/ml GdCl$_3$ + 1 % OH$_2$ in 0D$_2$). Gradient Pulse length = 2 ms - Gradient shape = square - Recovery delay = 0.0001s Gradient strength = 20 G/cm.*

Result of the Gradient Amplifier Gradient Echo test in 1H on 2 mM CuSO4 sample
Gradient Pulse : p16 = 5000.0 us Square pulse (GPNAM1 = GPNAM2 = RECT.5ms) — G+/G- = 20/20
256 experiments time averaged (e.g. 1 hour) test using 90 degree flip angles
Mean Intensity = 100.3223 — Standard Deviation Intensity = 0.2008
Mean FID Ampl. = 100.1853 — Standard deviation FID Ampl. = 0.1008
Mean FID Phase = 0.0405 — Standard deviation FID Phase = 0.7784

Table 9.2. *Stability test*

	Stability test std Dev. Factor[a]
Gradient echo expt. At 20 G/cm on 20 A step	2.0

a. The stability test std Dev. Factor = Water peak Int. Std Dev. (Grad. Echo) / Water peak Int. Std Dev. (without Grad.)

The water peak intensity standard deviation calculated over 256 Gradient echo experiments must be smaller then three times the water peak intensity standard deviation calculated over 256 single pulse experiments (without gradients) recorded in the same conditions (Room temperature etc...).

Gradient Echo stability evaluation

Figures

Figures

Figures

Tables

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GREAT 40/60 AV III Version 001

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