


AVANCE

- Micro Imaging for AVANCE III Systems
User Guide
Version 001



Copyright © by Bruker Corporation

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form, or by any means without the prior consent of the publisher. Product names used are trademarks or registered trademarks of their respective holders.

This manual was written by

Thomas Oerther

© Thursday, July 12, 2012 Bruker BioSpin GmbH

P/N: Z33075

DWG: Z4D11939

For further technical assistance for this product, please do not hesitate to contact your nearest BRUKER dealer or contact us directly at:

Bruker BioSpin GmbH
am Silberstreifen
76287 Rheinstetten
Germany
Phone: + 49 721 5161 0
FAX: + 49 721 5171 01
E-Mail: nmr-support@bruker.de
Internet: www.bruker.com

Contents

1	About	9
1.1	This Manual	9
1.2	Policy Statement	9
1.3	Symbols and Conventions	9
2	Introduction	11
2.1	Concept	11
2.2	Limitation of Liability	11
2.3	Copyright	11
2.4	Warranty Terms	12
2.5	Customer Service	12
3	Safety	13
3.1	General	13
3.2	Intended Use	13
3.3	Owner's Responsibility	13
3.4	Personnel Requirements	15
3.4.1	Qualifications	15
3.4.2	Unauthorized Persons	15
3.4.3	Instruction	15
3.5	Personal Protective Equipment	16
3.6	Basic Dangers	16
3.6.1	General Workplace Dangers	16
3.6.2	Dangers from Magnetic Fields	17
3.7	Signage	17
4	Imaging Rack (HMIMAG)	19
4.1	Master Unit BGMUI-E (W1522066)	19
4.1.1	Master Unit In/Out Data Connection	19
4.1.2	Security Features	20
4.1.3	Blanking Pulses	22
4.1.4	Control LEDs	22
4.2	Great 1/40 (W1211690 or W1215322) and Great 1/60 (W1209612 or W1215323)	22
4.2.1	Gate Input: Blanking	23
4.2.2	Data Input	23
4.2.3	Signal Output	23
4.2.4	Monitor Output	24
4.2.5	LED Bar	24
4.2.6	Fuses	24
4.3	B0-2 Compensation Unit (W1214106)	25
4.3.1	Digital Data Input	26
4.3.2	Analog Signal Input/Output	26
4.3.3	Monitor Output	26
4.3.4	Link to the BSMS-2	27
4.4	Gradient Filter (W1212109)	28
4.5	Cooling Unit BCU20 (W1210722)	30
4.5.1	Installation of the BCU20	31
4.5.2	Operation of the BCU20	32
4.6	Imaging Accessory Wiring	35

5	Gradient Systems and RF Probes	37
5.1	Micro 5 System	39
5.1.1	Assembly/Disassembly of the Micro 5 System	41
5.2	Micro 2.5 System, Discontinued	45
5.2.1	Assembly/Disassembly of the Micro 2.5 System	49
5.2.2	Installation of the Dewar with Heater in the Micro 2.5 RF Probe	51
5.3	Micro 2.5: MICWB40 System	54
5.3.1	Assembly/Disassembly of the Micro 2.5 System	57
5.3.2	Installation and Usage of the Quadrature Combiner	60
5.3.3	Installation of the MICWB40 VT Kit	62
5.4	Mini 0.5/0.75 System	65
5.4.1	Assembly/Disassembly of the Mini 0.5/0.75 System	68
5.5	Mini SWB90 System	72
5.5.1	Overview	72
5.5.2	Installation and Usage of the Quadrature Combiner	75
5.5.3	Cleaning	76
5.6	Mounting of the SWB Probe	77
6	ParaVision 5 Software Setup	79
6.1	Installation of the ParaVision 5 Software	79
6.1.1	Setup of ParaVision 5	79
6.1.2	Setup of the Gradient Timing Resolution	81
6.1.3	Micro-imaging Add-on CD	81
6.1.3.1	ParaVision Add-ons	81
6.1.3.2	TopSpin Add-ons	83
6.1.4	Installation of RF Inserts Specific Parameters	83
6.1.5	License File Installation and Troubleshooting	84
7	Gradient System and Amplifier Setup	87
7.1	Gradient Safety Parameters	89
7.2	Great Offset Adjustment	91
7.3	Loop Regulation Adaptation	92
7.4	Preemphasis Adjustment	96
7.5	B0 Adjustment	101
7.6	Gradient Calibration	105
7.7	Select an Existing Probe	110
7.8	Setup New Probes	112
7.8.1	Definition of an Individual Value for the Reference Gain Adjustment	113
8	Signal to Noise Ratio and z-B1 Tests for the RF Probes	119
8.1	SNR Imaging Test	119
8.2	The z B1 Test	121
8.3	Processing of the SNR and z-B1 Data Sets	122
8.4	Spectroscopic Test	122
9	Gradient Amplifier Blanking Modes	123
9.1	Hard Blanking	123
9.2	Soft Blanking	124
10	Digital Data Filtering and Analog Sampling	127
10.1	Digital Filtering	127
10.1.1	Handling of the Digitally Filtered FID in TopSpin	129

10.1.2	Handling of the Digital Filtered FID in ParaVision	130
10.2	Analog Sampling	132
11	Animal Triggering Unit	135
11.1	Connection from the Probe to the Triggering Unit	135
11.2	Connection from the Triggering Unit to the Console	136
12	Tips, Tricks and Troubleshooting.....	139
12.1	Creating RF Shapes for ParaVision	139
12.2	Image Display Scaling	141
12.3	Providing Display Memory for Large Data Sets.....	142
12.4	Hardware ON/OFF Procedures	143
12.4.1	Turning the AVANCE III Console ON.....	143
12.4.2	Turning the AVANCE III Console OFF	143
12.4.3	Turning the Imaging Rack ON	143
12.4.4	Turning the Imaging Rack OFF	143
12.5	Different Software (TopSpin) Versions on the System	144
12.6	Disable the HPPR Build-in Power Check	144
12.7	Disabling the 'External Enable' and PT100 Check for the Master Unit	144
12.8	Signal Instabilities.....	144
12.9	External Trigger Doesn't Work.....	146
13	Diffusion Coefficients.....	147
13.1	Diffusion Coefficient D of Various Liquids at 25°C.....	147
13.2	Diffusion Coefficient D of Special Bruker Samples at 25°C.....	147
13.3	Temperature Dependence of the Self Diffusion Coefficient D of Water (H ₂ O)	148
14	Trigger Signals.....	149
14.1	Trigger Signals at the T0 Connector.....	149
15	Quick Introduction to Coil Configurations	151
15.1	Preface: Nomenclature.....	151
15.2	Purpose and Scope of the Present Documentation	152
15.3	Generation of Coil Configuration Files.....	152
15.4	The Coil Configuration Editor	153
15.4.1	The Coil Configuration Management Section.....	153
15.4.2	The Coil Management Section	154
15.4.3	The Spectrometer Management Section	154
15.4.4	The Operation Mode Section.....	154
15.4.5	The Coil Editor Subdialog.....	155
15.5	Identity Section	155
15.5.1	Coil Type Section.....	156
15.5.2	Coil Elements Section	156
15.5.3	Properties Section	156
15.5.4	RF Connections Section.....	157
15.6	Final Remarks	157
15.7	Workflow for Changing Coils	157
15.8	Working with Studies, Scans, and Operation Modes.....	157
15.8.1	Creating a Study	158
15.8.2	Scan and Operation Modes / PVM	158
16	Part Numbers	159
17	RF Probe Parameters and Final Test Information.....	161

17.1	Information Final Test Protocol for RF Probes on Form	161
17.1.1	RF Insert Details and RF Performance Tests	161
17.1.2	Test Sequences and Samples	162
17.1.3	Signal to Noise Ratio for 1H RF-Coil Elements	164
17.1.4	Reference Spectra	165
17.2	Final Test Protocol for RF Probes.....	168
17.2.1	Hardware Components.....	169
17.2.2	Details and Integrity.....	169
17.2.3	RF Insert Details and RF Performance Tests	170
18	Gradient System Parameters and Final Test Information	175
18.1	Information Final Test Protocol Gradient Systems Form	175
18.1.1	Gradient System Adaptation and Strength	175
18.1.2	Gradient Strength and Linearity.....	176
18.1.3	Typical Gradient Coil Parameters	178
18.1.4	Typical Gradient-Setpre Parameters	179
18.2	Final Test Protocol for Gradient Systems	180
18.2.1	Hardware Components.....	181
18.2.2	Gradient Global Check	182
18.2.3	Gradient System Adaptation and Strength	182
18.2.4	Gradient Strength and Linearity.....	185
18.2.5	MAPSHIM (on final system during installation)	185
18.2.6	Miscellaneous and Notes	185
19	Imaging Rack Final Test Information	187
19.1	The Final Test Protocol Imaging Racks Form.....	187
19.1.1	Setpre and Web Interface Functionality	187
19.1.2	ParaVision Tests	188
19.1.3	Enhanced Resolution Tests	189
19.2	Final Test Protocol Imaging Racks	191
19.2.1	Hardware Components.....	192
19.2.2	Master Unit Global Check.....	193
19.2.3	Basic Functionality.....	194
19.2.4	Setpre and Web Interface Functionality	195
19.2.5	ParaVision Tests	196
19.2.6	Enhanced Resolution Tests	197
20	Velocity Imaging and Rheology in Material Science	199
20.1	Introduction.....	199
20.2	Theory of Velocity Imaging	199
20.2.1	Generalized Approach.....	200
20.2.2	Flow Compensation.....	201
20.3	Velocity Imaging Modes.....	202
20.4	Applications	203
20.4.1	Rheology	204
20.4.2	Flow in Complex Geometries	206
20.4.3	Mixing Processes and Chemical Reactions	207
20.5	Methods.....	207
20.5.1	FLOWMAP	207
20.5.2	mic_seflow.....	209
20.6	Hands on: Rheology Experiments	210

20.6.1	Hardware and Setup.....	211
20.6.2	Selection and Filling of the Rheo Cells.....	214
20.6.3	Imaging Experiments.....	216
21	Contact.....	221
	List of Figures	223
	List of Tables	227
	Index	229

1 About

1.1 This Manual

This manual is planned for use by the service engineer in the installation of the device or accessory, and for the user in performing existing experiments and for the setup of new experiments.

This manual is an integral part of the device, and must be kept in close proximity to the device where it is permanently accessible to personnel. In addition, instructions concerning labor protection laws, operator regulations tools and supplies must be available and adhered to.

Before starting any work, personnel must read the manual thoroughly and understood its contents. Compliance with all specified safety and operating instructions, as well as local accident prevention regulations, are vital to ensure safe operation.

The figures shown in this manual are designed to be general and informative and may not represent the specific Bruker model, component or software/firmware version you are working with. Options and accessories may or may not be illustrated in each figure.

1.2 Policy Statement

It is the policy of Bruker to improve products as new techniques and components become available. Bruker reserves the right to change specifications at any time.

Every effort has been made to avoid errors in text and figure presentation in this publication. In order to produce useful and appropriate documentation, we welcome your comments on this publication. Support engineers are advised to regularly check with Bruker for updated information.

Bruker is committed to providing customers with inventive, high quality products and services that are environmentally sound.

1.3 Symbols and Conventions

Safety instructions in this manual are marked with symbols. The safety instructions are introduced using indicative words which express the extent of the hazard.

In order to avoid accidents, personal injury or damage to property, always observe safety instructions and proceed with care.



DANGER

Danger indicates a hazardous situation which, if not avoided, will result in death or serious injury.

This is the consequence of not following the warning.

- ▶ This is the safety condition.
- 1. This is the safety instruction.

 **WARNING**

Warning indicates a hazardous situation, which, if not avoided, could result in death or serious injury.

This is the consequence of not following the warning.

- ▶ This is the safety condition.
- 1. This is the safety instruction.

 **CAUTION**

Warning indicates a hazardous situation, which, if not avoided, may result in minor or moderate injury.

This is the consequence of not following the warning.

- ▶ This is the safety condition.
- 1. This is the safety instruction.

NOTICE

NOTICE indicates a property damage message.

This is the consequence of not following the notice.

- ▶ This is a safety condition.
- 1. This is a safety instruction.



This symbol highlights useful tips and recommendations as well as information designed to ensure efficient and smooth operation.

2 Introduction

2.1 Concept



This manual is a work in progress, and may not reflect the actual stand, as new developments and applications are expanding rapidly.

This manual is planned for use by the engineer in the installation of the imaging accessory, and for the user in performing existing experiments and for the setup of new experiments.

Due to the similarity of the imaging and diffusion hard and software, this manual overlaps the AVANCE diffusion manual in parts. Therefore the reference to “diffusion” will appear, but can be used interchangeably with “imaging”.

2.2 Limitation of Liability

All specifications and instructions in this manual have been compiled taking account of applicable standards and regulations, the current state of technology and the experience and insights we have gained over the years.

The manufacturer accepts no liability for damage due to:

- Failure to observe this manual.
- Improper use.
- Deployment of untrained personnel.
- Unauthorized modifications.
- Technical modifications.
- Use of unauthorized spare parts.

The actual scope of supply may differ from the explanations and depictions in this manual in the case of special designs, take-up of additional ordering options, or as a result of the latest technical modifications.

The undertakings agreed in the supply contract, as well as the manufacturer's Terms and Conditions and Terms of Delivery, and the legal regulations applicable at the time of the conclusion of the contract shall apply.

2.3 Copyright

This manual is protected by copyright and intended solely for internal use.

This manual must not be made available to third parties, duplicated in any manner or form – whether in whole or in part – and the content must not be used and/or communicated, except for internal purposes, without the written consent of the manufacturer.

Violation of the copyright will result in legal action for damages. We reserve the right to assert further claims.

2.4 Warranty Terms

The warranty terms are included in the manufacturer's Terms and Conditions.

2.5 Customer Service

Our customer service division is available to provide technical information. See the chapter Contact for contact information.

In addition, our employees are always interested in acquiring new information and experience gained from practical application; such information and experience may help improve our products.

3 Safety

This section provides an overview of all the main safety aspects involved in ensuring optimal personnel protection and safe and smooth operation.

Non-compliance with the action guidelines and safety instructions contained in this manual may result in serious hazards.

3.1 General

The micro-imaging Accessory for AVANCE III (AV3) systems is made up of a variety of products. Refer to the corresponding product manuals for safety issues concerning the safe use of these products. Where deemed appropriate, additional safety notices have been added within this manual to draw attention to important safety issues.

Note: "Device" is used interchangeable to refer to the micro-imaging accessory as a whole, or to individual components, based on the context of the subjects discussed throughout this manual.

3.2 Intended Use

The imaging accessory should only be used for its intended purpose as described in this manual. Use of the unit for any purpose other than that for which it is intended is taken only at the users own risk and invalidates any and all manufacturer warranties.

Service or maintenance work on the diffusion accessory must be carried out by qualified personnel.

Only those persons schooled in the operation of the diffusion accessory should operate the unit.

Read this manual before operating the unit. Pay particular attention to any safety related information.

3.3 Owner's Responsibility

Owner

The term 'owner' refers to the person who himself operates the device for trade or commercial purposes, or who surrenders the device to a third party for use/application, and who bears the legal product liability for protecting the user, the personnel or third parties during the operation.

Owner's Obligations

The device is used in the industrial sector, universities and research laboratories. The owner of the device must therefore comply with statutory occupational safety requirements.

In addition to the safety instructions in this manual, the safety, accident prevention and environmental protection regulations governing the operating area of the device must be observed.

In this regard, the following requirements should be particularly observed:

- The owner must obtain information about the applicable occupational safety regulations, and - in the context of a risk assessment - must determine any additional dangers resulting from the specific working conditions at the usage location of the device. The owner must then implement this information in a set of operating instructions governing operation of the device.
- During the complete operating time of the device, the owner must assess whether the operating instructions issued comply with the current status of regulations, and must update the operating instructions if necessary.
- The owner must clearly lay down and specify responsibilities with respect to installation, operation, troubleshooting, maintenance and cleaning.
- The owner must ensure that all personnel dealing with the device have read and understood this manual. In addition, the owner must provide personnel with training and hazards information at regular intervals.
- The owner must provide the personnel with the necessary protective equipment.
- The owner must warrant that the device is operated by trained and authorised personnel as well as all other work, such as transportation, mounting, start-up, the installation, maintenance, cleaning, service, repair and shutdown, that is carried out on the device.
- All personnel who work with, or in the close proximity of the device, need to be informed of all safety issues and emergency procedures as outlined in this user manual.
- The owner must document the information about all safety issues and emergency procedures in a laboratory SOP (Standard Operating Procedure). Routine briefings and briefings for new personnel must take place.
- The owner must ensure that new personnel are supervised by experienced personnel. It is highly recommended to implement a company training program for new personnel on all aspects of product safety and operation.
- The owner must ensure that personnel are regularly informed of the potential hazards within the laboratory. This is all personnel that work in the area, but in particular laboratory personnel and external personnel such as cleaning and service personnel.
- The owner is responsible for taking measures to avoid inherent risks in the handling of dangerous substances, preventing industrial disease, and providing medical first aid in emergencies.
- The owner is responsible for providing facilities according to the local regulations for the prevention of industrial accidents and generally accepted safety regulations according to the rules of occupational medicine.
- All substances needed for operating and cleaning the device samples, solvents, cleaning agents, gases, etc. have to be handled with care and disposed of appropriately. All hints and warnings on storage containers must be read and adhered to.
- The owner must ensure that the work area is sufficiently illuminated to avoid reading errors and faulty operation.
- The owner must ensure that the laboratory is equipped with an oxygen warning device, in case the device is operated with nitrogen.

Furthermore, the owner is responsible for ensuring that the device is always in a technically faultless condition. Therefore, the following applies:

- The owner must ensure that the maintenance intervals described in this manual are observed.
- The owner must ensure that all safety devices are regularly checked to ensure full functionality and completeness.

3.4 Personnel Requirements



Only trained Bruker personnel are allowed to mount, retrofit, repair, adjust and dismantle the unit!

3.4.1 Qualifications

This manual specifies the personnel qualifications required for the different areas of work, listed below:

Laboratory Personnel

Laboratory personnel are health care professionals, technicians, and assistants staffing a research or health care facility where specimens are grown, tested, or evaluated and the results of such measures are recorded. Laboratory personnel are able to carry out assigned work and to recognize and prevent possible dangers self-reliant due to their professional training, knowledge and experience as well as profound knowledge of applicable regulations.

The workforce must only consist of persons who can be expected to carry out their work reliably. Persons with impaired reactions due to, for example, the consumption of drugs, alcohol, or medication are prohibited from carrying out work on the device.

When selecting personnel, the age-related and occupation-related regulations governing the usage location must be observed.

3.4.2 Unauthorized Persons



WARNING

Risk to life for unauthorized personnel due to hazards in the danger and working zone!

Unauthorized personnel who do not meet the requirements described in this manual will not be familiar with the dangers in the working zone. Therefore, unauthorized persons face the risk of serious injury or death.

1. Unauthorized persons must be kept away from the danger and working zone.
2. If in doubt, address the persons in question and ask them to leave the danger and working zone.
3. Cease work while unauthorized persons are in the danger and working zone.



3.4.3 Instruction

Personnel must receive regular instruction from the owner. The instruction must be documented to facilitate improved verification.

Date	Name	Type of Instruction	Instruction Provided By	Signature

3.5 Personal Protective Equipment

Personal protective equipment is used to protect the personnel from dangers which could affect their safety or health while working.

Personnel must wear personal protective equipment while carrying out the different operations at and with the device.

This equipment will be defined by the head of the laboratory. Always comply with the instructions governing personal protective equipment posted in the work area.

3.6 Basic Dangers

The following section specifies residual risks which may result from using the device and have been established by means of a risk assessment.

In order to minimize health hazards and avoid dangerous situations, follow the safety instructions specified here as well as in the following chapters of this manual.

3.6.1 General Workplace Dangers

WARNING



Danger to life from nonfunctional safety devices!

If safety devices are not functioning or are disabled, there is a danger of serious injury or death.

1. Check that all safety devices are fully functional and correctly installed before starting work.
2. Never disable or bypass safety devices.
3. Ensure that all safety devices are always accessible.

CAUTION



Danger of injury from tripping over dirt and scattered objects!

Dirt and scattered objects may cause people to slip or trip, resulting in personal injuries.

1. Always keep the work area clean.
2. Remove objects which are no longer required from the work area and particularly from the floor.
3. Indicate unavoidable hazards using marking tape.

3.6.2 Dangers from Magnetic Fields

WARNING

Danger to life from strong magnetic fields!

Strong magnetic fields may cause serious injuries or death and significant damage to property.

1. Persons fitted with heart pacemakers must be kept away from the device. The functionality of the heart pacemaker could be compromised.
2. Persons with metal implants must be kept away from the device. Implants may heat up or be subject to magnetic attraction.
3. Ferromagnetic materials and electromagnets must be kept away from the magnetic source. Such materials could be subject to magnetic attraction and may fly around the room, injuring or killing people. Minimum distance 3 meters.
4. Remove magnetic items (jewelry, watches, pens etc.) before carrying out maintenance work.
5. Keep electronic equipment away from the magnetic source. Such equipment could be damaged.
6. Keep storage media, credit cards etc. away from the magnetic source. Data could be erased.



The magnetic field of the device does not cause any personal injuries or property damage. For further information see the manual of the magnet used.

3.7 Signage

The following symbols and information signs can be found in the work area. They refer to their immediate surroundings.



The identification and placement of warning labels are included in the manual. The laboratory supervisor is responsible for ensuring that all the warning labels are maintained in their proper place any time that the device is used.

Electrical Voltage



Only qualified electricians are permitted to work in a work room marked by this sign. Unauthorized persons must not enter the workplaces thus marked and must not open the marked cabinet.

Danger Spot



Warning indicating a danger spot in work rooms.

The warning label may be ordered using Bruker Part Number 67470.

4 Imaging Rack (HMIMAG)

The AVANCE III compatible micro-imaging system is based on 3 Great gradient amplifiers (Great1/40 or Great1/60), a Master Unit (BGMUI-E), and optionally a B0 compensation unit (B0-2). The components are installed in a single bay stainless steel rack, called an imaging rack.

Additionally, all micro-imaging systems are equipped with a so called DPP board (Digital Pre-emphasis P/N H12513F1 or H12513F2), which modifies the gradient shapes by numerically adding pre-emphasis terms to compensate for eddy currents. The DPP board is located inside the IPSO 19" rack, connected to the systems internal PCI bus and to the gradient controller.

4.1 Master Unit BGMUI-E (W1522066)

The Master Unit BGMUI-E is a dedicated unit to interface the Great1/40 or Great1/60 amplifiers to the AVANCE III system. In addition to the main function of distributing the digital signals to the Great amplifiers, the Master Unit contains a PT100 temperature and an external enable security feature. A DSP based feedback structure is implemented which allows calculating the applied power rate and comparing it with maximum values for coil protection.

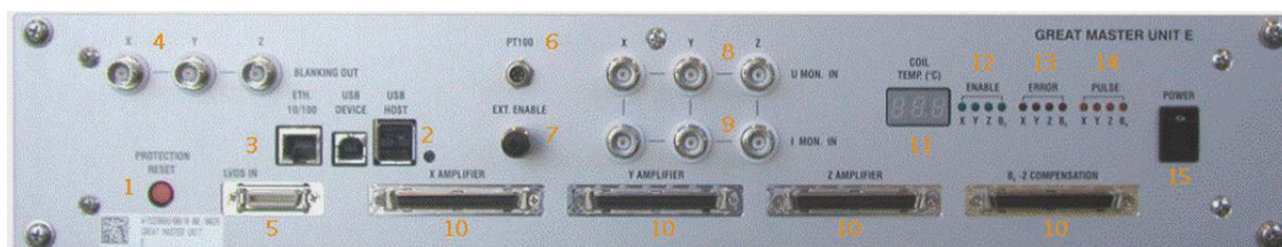


Figure 4.1: Master Unit BGMUI-E Front Panel

The Master Unit must be the last device which is switched on in the imaging rack since it detects the connected amplifiers only during the boot process. During the boot process, the Master Unit will stop and display a 'C01' message in the 7 segment LED display, whereas in normal operation mode the LED's show the coils PT100 temperature (11). The message 'C01' means, that safety parameters for the coil protection need to be loaded, refer to the section Hardware ON/OFF Procedures [▶143] for details about this procedure. This LED display is also used for numerous error messages, which are indicated as 'Exx', where xx is an error code that can be found in the web interface of the unit (accessible by the 'ha' command in TopSpin). If the source for the error message is eliminated, the unit can be reset to normal operation mode by pressing the red reset button (1).

4.1.1 Master Unit In/Out Data Connection

The Master Unit can be connected to either a DPP (Digital Pre-emphasis board), or directly to the GCtrl (gradient controller) of the IPSO board via the LVDS (48 bit wide and 80 MHz bus clock) (5). The maximum allowed cable length for this connection is 5 meters. The internal logic distributes the incoming digital signals to the desired gradient/B0 output connectors (10), where the Great amplifiers or B0-2 compensation unit can be directly connected. The communication between Master Unit and the mentioned amplifiers is via a unidirectional parallel bus for the gradient shape data and a bidirectional I2C bus for the communication between the units.

The Master Unit can be controlled via the Web interface. Therefore, the unit is connected directly to the systems Ethernet switch (3) to allow any browser to access the service pages, e.g. for firmware updates.

4.1.2 Security Features

The Master Unit includes 3 security features:

- A PT100 temperature check,
- a check of the external enable signal e.g. from the gradient cooling water chiller,
- and a DSP based power calculation.

A PT100 can be connected directly to the PT100 connector (6). If the PT100 shows a resistance indicating a temperature below 5 °C (101.95Ω) or above 50°C (119.4Ω), the Master Unit will switch the Great 60 amplifiers off. Temperatures between 5 °C and 50 °C are valid temperatures for the Great operation. The PT100 is measured in 4-wire mode, to eliminate cable resistances. This guarantees an accuracy of ± 1 °C from the actual value.

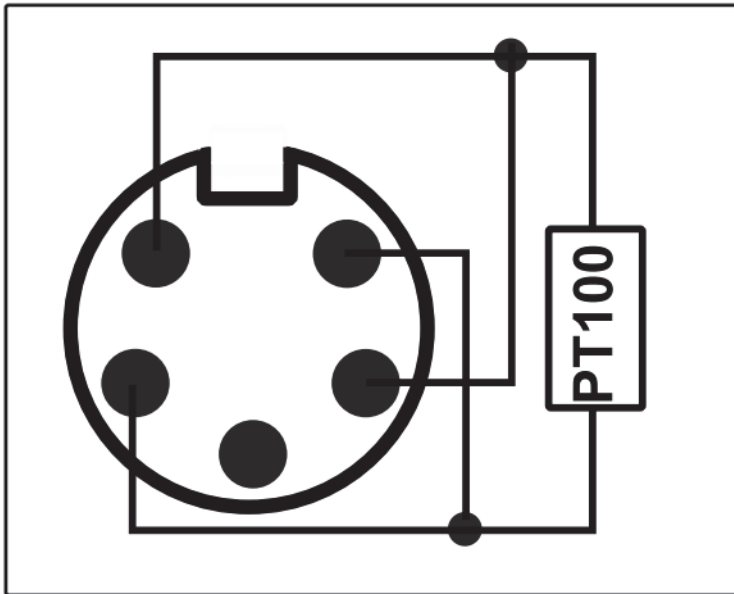


Figure 4.2: Pin Layout of the Pt100 Connector

The external enable connector (7) is used to check the state of the BCU20 cooling unit. In case the BCU20 is switched off, or no water is flowing, the BCU20 opens a short between 2 pins. This is detected at the Master Unit by the external enable connector. If the short is missing, the Master Unit switches the Great amplifiers off.

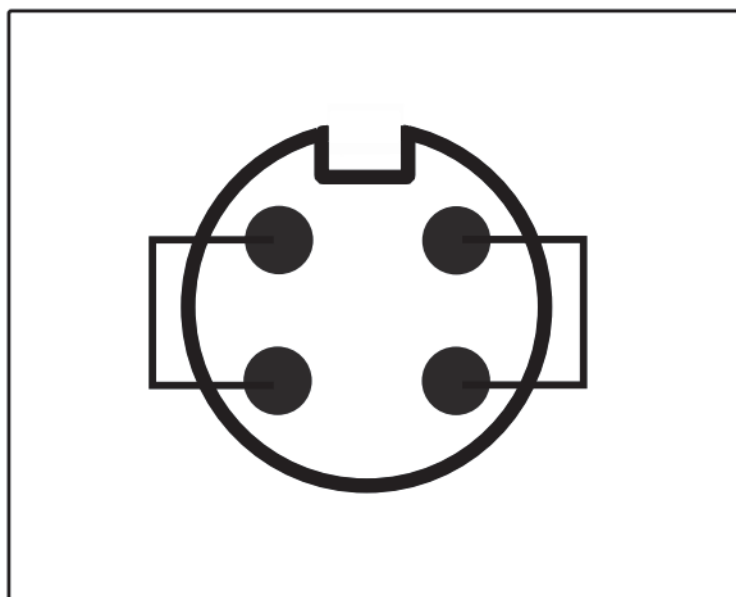


Figure 4.3: Pin Layout of the 'External Enable' Connector

The DSP security feature uses the 6 analog monitor output signals of the Great amplifiers to calculate the power dissipation in the gradient coil on the fly. From each amplifier the current signal and the voltage signal is feed back to the 'U mon' (8) and 'I mon' (9) input connectors of the Master Unit. A 10V U-monitor voltage corresponds to the max. voltage (100V for Great 1/40 and Great 1/60). The I-monitor voltage displays the output current; where 10 V corresponds to 60A (as a result the max. output voltage on a Great 40 is 6.66V at 40A). The analog signal is AD-converted within a 25 μ sec dwell time, and the power applied to each individual gradient coil is calculated by the formula:

$$\frac{1}{T} \int_T R_{ch} \cdot i_{ch}^2(t) dt < P_{lim_{ch}}$$

Figure 4.4: Power Calculation for an Individual Gradient Channel

where R_{ch} is the DC-resistance (stored in the safety parameters in setpre) of the gradient coil, i_{ch} is the current detected by the 'I-mon' input and T is the time in which the energy is integrated. $P_{lim_{ch}}$ is the maximum power value, which is specific for each channel of each gradient system. On triple axis gradient coils, the power sum of all 3 channels must be less than 3 times the max. power for one channel.

$$\frac{1}{T} \sum_{ch=x,y,z} \int_T R_{ch} \cdot i_{ch}^2(t) dt < P_{tot}$$

Figure 4.5: Calculation for the Gradient System (sum of all gradient directions)

The Master Unit checks the power on 2 different time bases. One time base is fixed to 1 second, which checks for the average power applied to the gradient coil. Another time base is configurable between 25 μ sec and 1 second and is mandatory for detecting short (msec range) gradient pulses with high currents, which might burn the coil in less than 1 second. Refer to the section Typical Gradient-Setpre Parameters [▶ 179] for typical values for different coils.

4.1.3 Blanking Pulses

The Master Unit BGMUI-E delivers 3 blanking output signals (4), which can be directly connected to the gating input of the Great 1/40 and Great 1/60 amplifiers. The blanking pulses are TTL level, TTL-low (0V), which forces the amplifiers to switch on (unblank) its output, and TTL-high (5V) which disables (blank) the amplifiers output.

The blanking output of the BGMUI-E is so called 'soft-blanking'. In contrast to the 'hard-blanking' which was used in previous imaging systems, the 'soft-blanking' takes care of residual amplifier output currents. The blanking is switched off by a command in the pulse program (refer to Gradient Amplifier Blanking Modes [▶ 123]), and stays off until a second command is executed in the pulse program and until the digital input signal to the individual Great amplifier is 0. As result, the blanking takes care of pre-emphasis adjustments and keeps the Great output enabled, until the added pre-emphasis terms are fully decayed. The previously used 'hard-blanking' switches off the Great output immediately when the particular command is executed in the pulse program without taking care of any residual currents.

4.1.4 Control LEDs

The Master Unit has 3 LED groups (12, 13, 14), which show the status of the connected amplifiers. If an "Error" LED is illuminated, the connected amplifier is switched off due to an error or because it is not initialized. If the amplifiers are fully operable, the "Enable" LED is switched on. If an amplifier delivers a current, the "Pulse"-LED shows this by flickering. The pulse LED is only switched on for currents >3% of the maximum amplifier current, for lower currents the LED remains off. A second mode can be selected in the Master Units web interface which displays digital input data at the Master Unit LVDS input instead of the amplifier output current. If a B0-2 compensation unit is connected to the Master Unit and the "Field" value of the BSMS-2 is not 0, the B0 "Enable" LED is always on, since the B0-2 unit has to deliver a DC current.

4.2 Great 1/40 (W1211690 or W1215322) and Great 1/60 (W1209612 or W1215323)

The Great 1/40 and Great 1/60 are current regulated amplifiers used to provide the gradient current to the gradient coils at dedicated times. Both amplifiers are basically identical; the only difference is the maximum output current, which is 40A for a Great 1/40 and 60A for a Great 1/60. The signal input of the amplifiers is digital. The digital to analog converter is located inside the amplifiers to avoid ground loops from non-ideal analog cable wiring.

For AVANCE III systems the following ECL's are required:

- W1211690 or W1209612: All ECL are supported. The coarse offset needs to be adjusted in setpre for ECL <= 8; set the coarse offset to 0 for ECL9.
- W1215322 or W1215323: \geq ECL 01 (ECL 0 causes spikes).

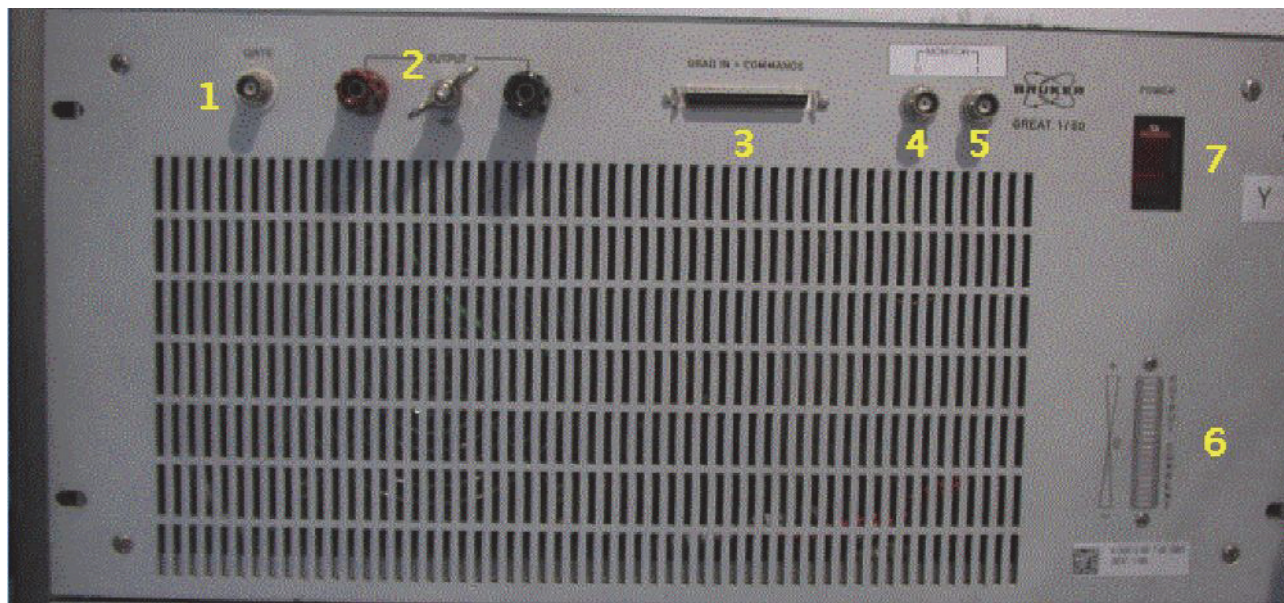


Figure 4.6: Great Amplifier Front View

4.2.1 Gate Input: Blanking

The Gate input (1) of the Great amplifiers enables an external signal to enable or disable the output of the Great amplifier. In case the output is disabled, the amplifier output is disconnected from the gradient coil, so that no amplifier noise is introduced to the sample spin system. The gate pulse must be TTL level, where TTL-LOW enables the amplifier output and TTL-HIGH disables the output. If nothing is connected to this input, the amplifier is always enabled.

The gating pulse is delivered by default from the BGMUI-E Master Unit (output 4 of the Master Unit) or alternatively from the IPSO T0 connector (see Trigger Signals at the T0 Connector [▶149] for the pin numbers).

4.2.2 Data Input

The data input (3) of the Great amplifier is directly connected to the Master Unit. The gradient data are delivered in a parallel way, whereas the bidirectional communication between the Master Unit and the Great amplifier is handled by an I2C bus. Both communication protocols can be found on the data input connector and are distributed via a single cable (P/N HZ10202).

4.2.3 Signal Output

The gradient coil current is provided at the red and black clamps (2). Typically, the gradient filter cable with ring cable lugs is connected to the output clamps, which lead to the gradient filter (see Gradient Filter (W1212109) [▶28]). The output can have a maximum of $\pm 100\text{V}/\pm 40\text{A}$ at the Great 1/40, or $\pm 100\text{V}/\pm 60\text{A}$ at the Great 1/60.

WARNING**Electrical hazard from electrical shock!**

- ▶ A life threatening shock may result when the output clamps or the connected cables are manipulated.
1. Be sure to switch off (7) the amplifier before manipulation the output clamps or the connected cables.

4.2.4 Monitor Output

Both Great amplifiers have a monitor output for the output current, labelled “Monitor I” (5) and a monitor output for the output voltage, labelled “Monitor U”. Both can be used to control the output current on an oscilloscope, e.g. to adapt the amplifiers regulator to the connected load.

The scaling for the outputs is 1V/10V for the voltage monitor of both Great amplifiers, 1V/4A at the current monitor output of the Great 1/40, and 1V/6A at the current monitor output of the Great 1/60. The maximum monitor voltage is 10V at each monitor output. If an externally connected device like an oscilloscope or a voltage meter is not ground free, it can lead to ground loops which disturb the output stability of the amplifier and thus the NMR signal.

During routine work, these monitor outputs have to be connected to the ‘U mon’ and ‘I mon’ inputs of the BGMUI-E Master Unit (see Security Features [▶ 20]). Only when this connection is established, can the Master Unit calculate the power dissipation to the gradient coils and protect them from a power surge.

4.2.5 LED Bar

The LED bar on the bottom right (6) of the Great amplifier is an easy way to control the output current during an experiment. The bar shows the output current of the amplifier in 10% steps, so currents below 10% cannot be seen, but for typical experiments the resolution is sufficient.

4.2.6 Fuses

The Great amplifier itself has 2 different fuses.

- Line fuse.
- Power supply output fuse.

The line fuse is located directly in the housing of the mains adapter. If this fuse is blown, nothing will work on the amplifier anymore, even the illumination of the mains switch will be missing. After removal of the mains connector, an insert can be pulled out of the mains plug (1 in the figure below) with the help of a little screwdriver. The fuses are 20 mm x 5 mm in size and have values of 6.3A (Great 1/40) or 10A (Great 1/60).

If the mains switch illumination is still working but nothing else on the amplifier, the power supply output fuses may be blown. These fuses are located below or to the right of the mains connector (depends on the hardware revision, 2 in the figure below). There are 2 separate fuse housings that can be opened manually or by the help of a screwdriver, which contain 32 mm x 6 mm fuses in size with a value of 20A.

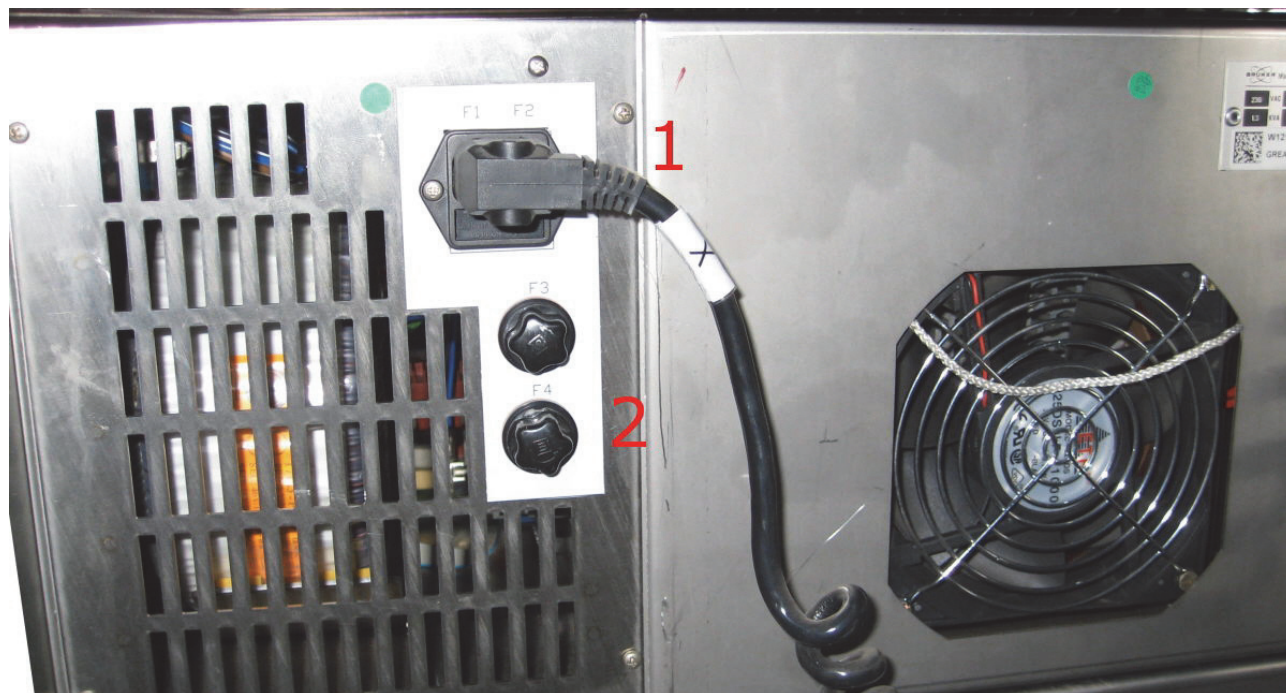


Figure 4.7: Back Side View of the Great Amplifier Showing the Location of the Fuses

4.3 B0-2 Compensation Unit (W1214106)

The B0-2 compensation unit is the fourth amplifier, which can be connected to the Master Unit. A B0-2 compensation unit is required to compensate for zero order field distortions resulting from gradient switching of poorly shielded gradient systems. In this case, a current is introduced in the surrounding conductive material, which leads to a shift in the B0 field and thus in the behavior of the samples spin system. To eliminate these effects, a current which causes an opposite field shift is introduced to the field coil of the shim system. This coil is usually used to control the field stability (Lock), to shift the field by a static value or the automatic drift compensation.

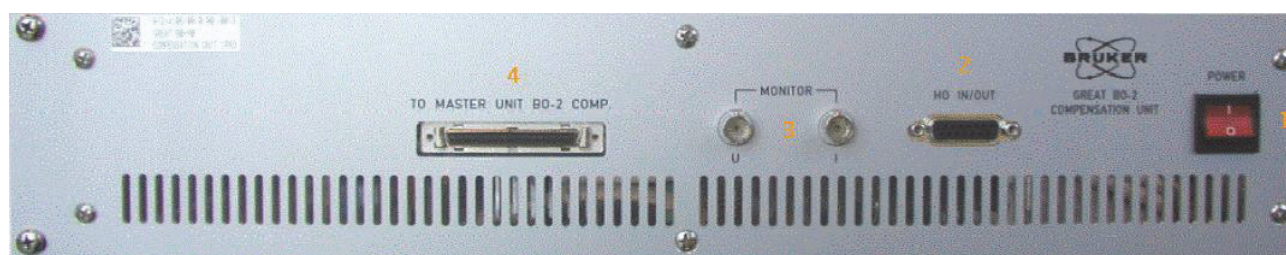


Figure 4.8: Front Plate of the B0-2 Compensation Unit

4.3.1 Digital Data Input

The digital data is handled via the connector “To Master Unit B0-2 Comp” (4). The communication between B0-2 unit and the Master Unit BGMUI-E is via unidirectional parallel bus for the B0 compensation current data and a bidirectional I2C bus for the communication between these units. The digital input data for the B0 current is already fully calculated including all direct and cross terms by the DPP. This means, as opposed to the Great gradient amplifiers, that the B0-2 unit will not work without DPP in the ISPO (if the Master Unit is connected directly to the GCtrl).

4.3.2 Analog Signal Input/Output

The analog B0 current is provided by the connector “H0 Output” (4). Through this connector the B0-2 unit is directly connected to the “Field” coil of the BOSS shim system, which is used by the BSMS to stabilize the magnetic field (Lock), and to shift the field by a static value or for the automatic drift compensation. Since the BSMS-2 functionality must still be operable, the output signal from the BSMS-2 (ELCB board) is fed into the B0-2 compensation unit through connector (4) as well, and added to the B0 compensation terms. The output signal of the B0-2 unit is then the B0 compensation + BSMS-2 output, which includes all the required signals. Since this is an active summation by analog devices, the B0-2 unit might introduce a bit of noise to the BSMS-2 signals.

When the B0-2 compensation unit is switched off, an internal relay is set in a way that the BSMS-2 signals are passively passed through the unit, without any modification and without any additional noise or hum.

The maximum output voltage of the B0-2 compensation unit is $\pm 100V$, the maximum output current is $\pm 200\text{ mA}$.

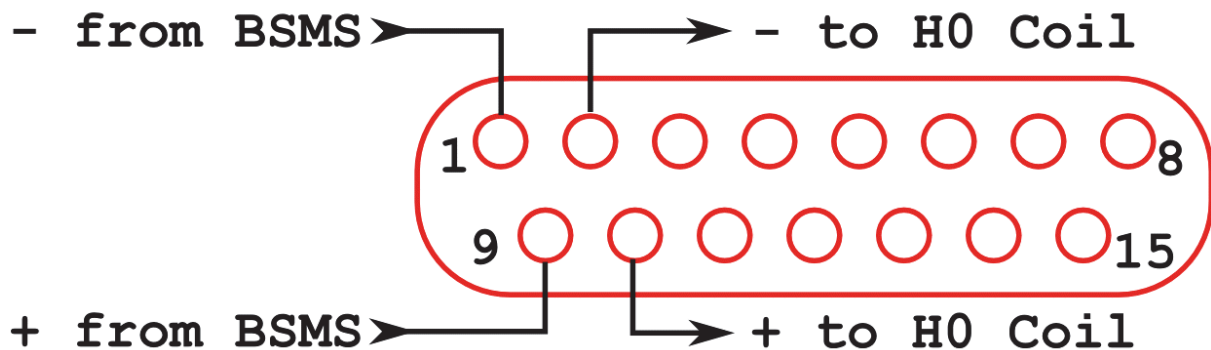


Figure 4.9: Pin Layout of the Analog Input/output Connector at the B0-2 Front Plate

4.3.3 Monitor Output

The analog monitor outputs (3) of the B0-2 unit can be used to check the field coil current since it shows the sum of the BSMS-2 output current plus the B0 compensation terms. The ratio is 1V/10V of the voltage monitor and 1V/20 mA on the current monitor. During routine work, these connectors are not connected and it care has to be taken that no grounded devices are connected to them, since they can create ground loops.

4.3.4 Link to the BSMS-2

To connect the B0-2 unit to an existing BSMS-2/BOSS system, an adaptor board (part number Z108181) is required. This board is mounted on the right most SCB20 board in the BSMS-2 between the output of the board and the cable leading to the shim system (see the figure below). It is basically a 1 to 1 connection of the shim connections, but the connection going to the field coil is cut and wired to the connector on the lower part of the adaptor board.

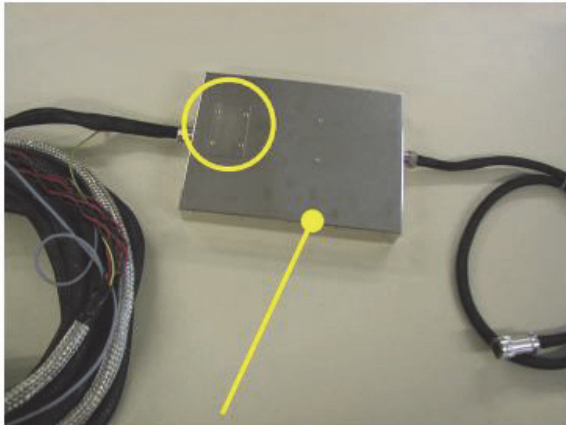
At this connector, a cable (P/N HZ12200) from the analog signal input/output of the B0-2 unit has to be connected. This connector provides the 'Field' output current of the BSMS-2. This field current reaches the B0-2 unit via the cable, is summed up with the B0 current or shifted through, and then returned via the cable to the BSMS-2 adaptor board, where it is directly connected to the field coil of the BOSS shim system. As a result, when the adapter board is installed, but no cable to the B02 unit is connected, the lock, field shift and field drift compensation are in active.



Figure 4.10: BSMS-2 to B0-2 Adaptor Board, Mounted on the Most Right SCB20 Module

4.4 Gradient Filter (W1212109)

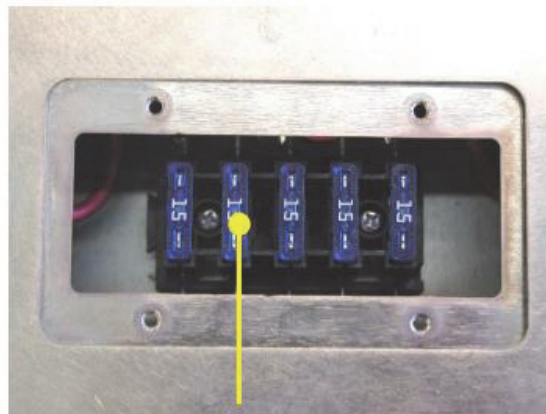
The gradient filter is integrated in the gradient cable, which is connected between the Great outputs and the gradient coil. Its basic function is to eliminate high frequency distortions, which can be introduced to the gradient cable itself. Additionally, the filter has some standard car fuses included, to protect the gradient coil from any gradient amplifier failure or programmer errors. The fuses are accessible after removal of a small metal cover, fixed by 4 screws. There are 5 fuses in the filter box, where only fuse 1, 3, and 5 are in the gradient lines. Fuses 2 and 4 are spare parts. Each fuse has a value of 15A.



Gradient Filter box



Fuse Box Cover



15 A Fuses used for gradient coil safety

Figure 4.11: Gradient Filter and Fuses

Since the gradient filter should remove high frequency noise from the gradient cables, ground conditions are important. The filter must have a good ground connection to the gradient body. This is established on new gradient bodies, but on older bodies the connection might be missing. To check this, the probe body can be controlled. There must be a pin in position G of the Burndy gradient connector, which leads to a ring cable lug checked to the metal of the probe base. If this connection is missing, it has to be established to provide full shielding performance.

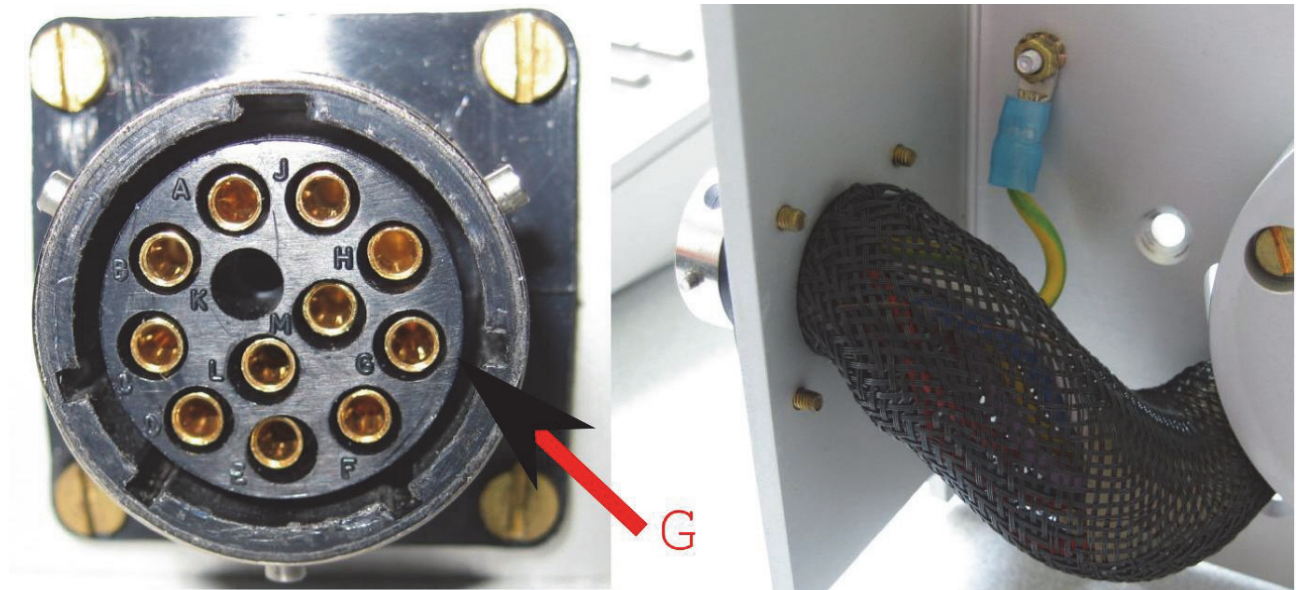


Figure 4.12: Location of Pin G at the Probe Base Connector (left) and Grounding of the Pin (right image)

For AVANCE III systems, filter cables with part number W1212109 and ECL \geq 2 have to be used. If a lower ECL or a different filter cable exists, it needs to be upgraded. With filter cables W1212109/ECL \geq 2 2-wire and 4-wire gradient probe bodies can be driven by the AVANCE III imaging rack.

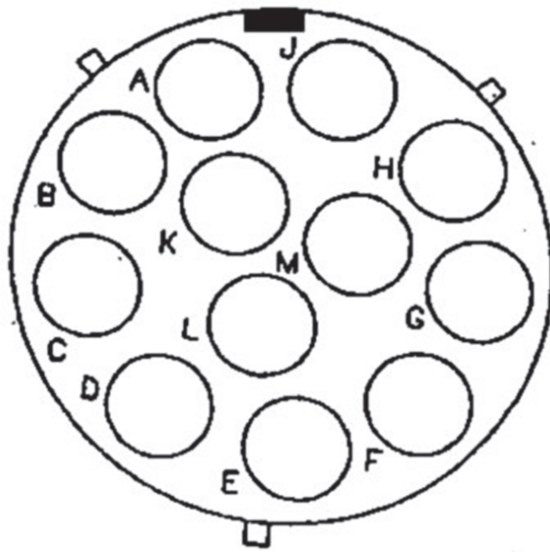


Figure 4.13: Pin Layout of the 12 Pin Burndy Connector (front view of the plug at the probe base)

Burndy Connector	Signal
C	+X Gradient
D	-X Gradient
E	+Y Gradient
F	-Y Gradient
A	+Z Gradient
B	-Z Gradient

L	PT100 Current
M	PT100 Current
H	PT100 Sense
J	PT100 Sense
G	Ground

4.5 Cooling Unit BCU20 (W1210722)

The standard cooling unit for the water cooled micro-imaging and diffusion gradient systems is called BCU20. The BCU20 is a closed loop chiller unit, with a water volume of about 3.5 liters, which can actively heat and cool the water with a power of approximately 250W. Thus the water temperature can be set to values between 5°C and 50°C, at standard flow rates of up to 1 liter/minute at 0.35 bar.

In addition to this basic functionality, the BCU20 provides more features such as a 3 way valve to blow out the water of the gradient before removal, manual and software controlled temperature control, a flow control, a water filter and noise optimized air-bubble free operation. The figure below shows the schematic of the cooler.

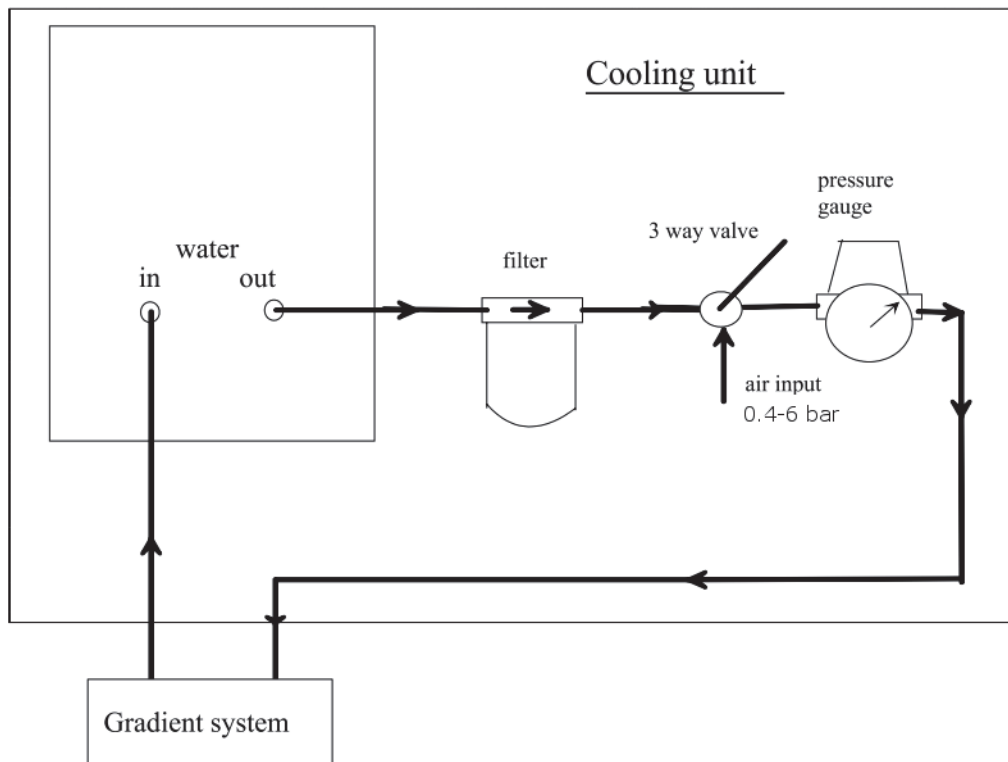


Figure 4.14: BCU20 Schematic Diagram

4.5.1 Installation of the BCU20

During the installation of the BCU20, the flow needs to be adjusted to its maximum. The steps on how to do this are described in this section, refer to the following figure for the location of the connections.

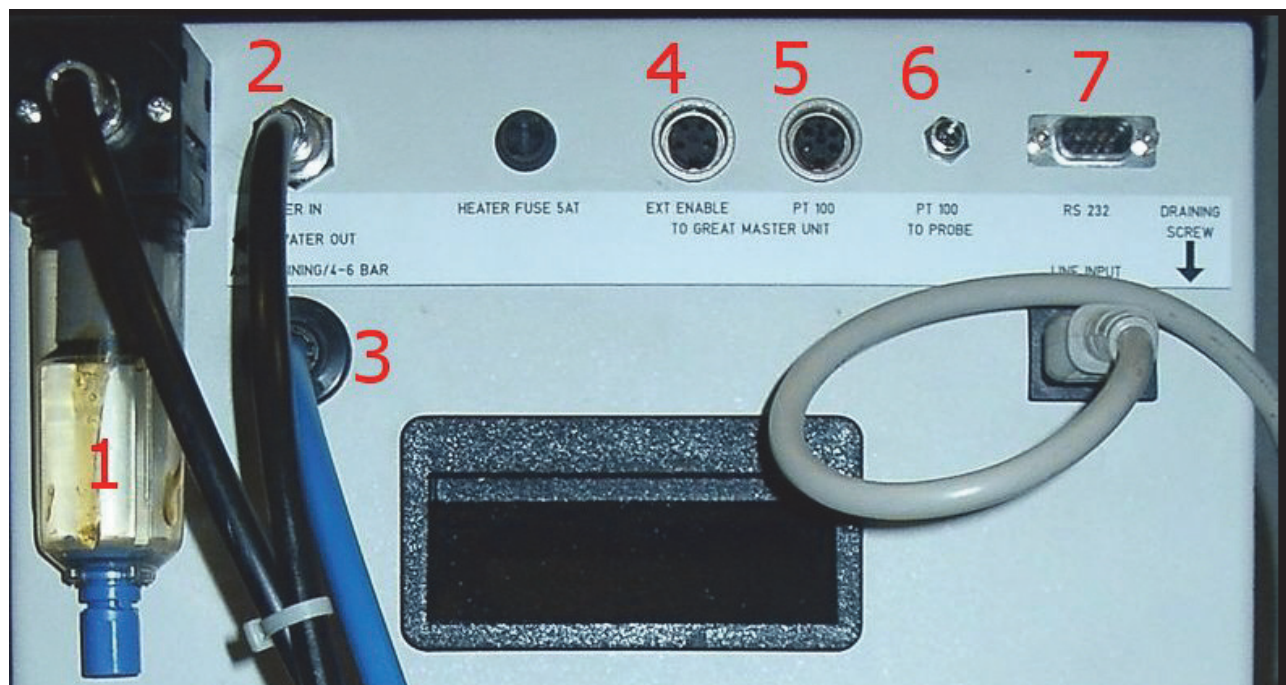


Figure 4.15: Backside View of the BCU20

1. Open the top cover of the BCU20.
2. Turn the flow needle (1) as far down as possible.
3. Fill the water level with distilled water until it reaches the maximum mark. To prevent the growth of algae, use a water conditioner. The recommended concentration is 0.5 ml water conditioner (Art. 9025.1 ROTH) for 3.5 liters of water.
4. Connect the 8 mm water hose and filter to the left most connector (1) of the BCU20 and the other end to the gradient coil. The filter prevents small particles from entering the gradient coil. Since they may block the water flow after a while and thus destroy the gradient coil. The filter element needs to be checked from time to time and if its color of the exchangeable filter element is not white anymore it has to be replaced.
5. Connect the 8 mm return water hose from the gradient coil to the “Water In” (2) connector on the BCU20.
6. Connect one end of the air hose to the “Draining” connector (3) and the other end to the available compressed air or nitrogen supply of the system. This enables to blow out the water from the gradient coil before it has to be disconnected from the chiller unit.
7. Connect the cable from the “Ext. Enable” connector (4) the Master Unit. The cable delivers a signal to the master unit when the BCU20 is operating correctly. When the water level is too low, the BCU20 stops the water flow and gives an alarm. When no water is flowing through the gradient coil, or when the BCU20 is turned off, the enable signal is not delivered to the Master Unit and the unit switches off the amplifiers to protect the gradient coil from overheating.
8. Connect the cable from the “PT100 to Great Master Unit” (5) connector to the connector on the Master Unit. Since the PT100 thermo-resistor of the gradient probe is not directly connected to the Master Unit but to the BCU20, the Master Unit needs a signal which indicates

a temperature between 5...50°C to enable the Great amplifiers. This signal is delivered by this output (5). See also the section Operation of the BCU20 [▶ 32] for the difference in signals in different BCU20 operation modes.

9. Connect the cable from the “PT100 to Probe” connector (6) to the PT100 connector on the gradient coil. Since its cable is in the gradient filter cable, the connection has to be established by an extension cable from the imaging rack to the BCU20. As a consequence, the BCU20 receives the temperature information from the gradient coil and has to remit it to the Master Unit.
10. Connect the serial cable from the “RS232” connector (7) to the IPSO unit. This allows the BCU20 temperature to be set and controlled using the command ‘edtj’ in TopSpin. The command ‘edtj’ behaves identical to the BVT control program ‘edte’ for which a manual can be found under TopSpin help. The configuration to which TTY the unit is connected (default is TTY04) has to be entered during ‘cf’.

4.5.2 Operation of the BCU20

During normal operation the BCU20 is switched on and runs without any user interaction. Only a few settings have to be checked or set.



Figure 4.16: BCU20 Top View with Opened Cover

Most important is that the 3 way valve (2) is set to flow during gradient operation. This position lets the cooling water flow through the gradient coil. In case the gradient coil needs to be disconnected, the water can be blown out of the coil by switching the valve to "Draining". After a few seconds air bubbles in the water reservoir (3) can be observed. This is an indication that the gradient and the water hoses are empty. The 3 way valve can be rotated 90 degrees (pointing downward in the figure above, in this position the output is disabled and the gradient coil can be removed).

The BCU20 can regulate the temperature in 2 different ways:

- The BCU20 uses its internal PT100 to regulate the temperature of the water in the water reservoir. In this case the switch (4) has to be set to "PT100 BCU20". In this operation mode, the water can heat up or cool down during its flow to the gradient coil, so the gradient coil might see a slightly different water temperature. The PT100 of the gradient coil is looped through the BCU20 to the Master Unit in this mode, so the real gradient coil temperature can be read at the Master Unit temperature display. This is the default mode for imaging, since it is often helpful to control the gradients temperature in high duty cycle experiments.
- The BCU20 uses the PT100 of the gradient coil to regulate the temperature of the water. In this case switch (4) has to be set to "PT100 Probe". In this operation mode, the BCU20's regulator regulates the temperature of the gradient coil, so the water itself can have a different temperature. The temperature of the gradient coil is visible in the upper line of the Eurotherm temperature regulator unit (number 1 in the figure below) on the front of the BCU20. The temperature value which is forwarded to the Master Unit is only a dummy value (due to technical reasons). So the Master Unit only shows a temperature value between 5...50 °C which is not related to the real gradient coil temperature. This operation mode is the default mode for diffusion applications, since here the temperature of the gradient coil (and much more important the temperature of the sample) is a critical parameter for precise measurements.



Figure 4.17: Front View of the BCU20

The above mentioned temperatures can be set manually at the Eurotherm (1) with the up and down arrows, or controlled by the 'edtg' program in TopSpin. The set temperature is displayed in the lower line of the Eurotherm, the upper line shows the temperature of the water in the reservoir ("PT100-BCU20"), or the temperature of the gradient coil ("PT100-Probe").

4.6 Imaging Accessory Wiring

The imaging rack is internally wired, so there should be no need to change any wiring. Externally, 7 cables need to be connected, refer to the figures below for details.

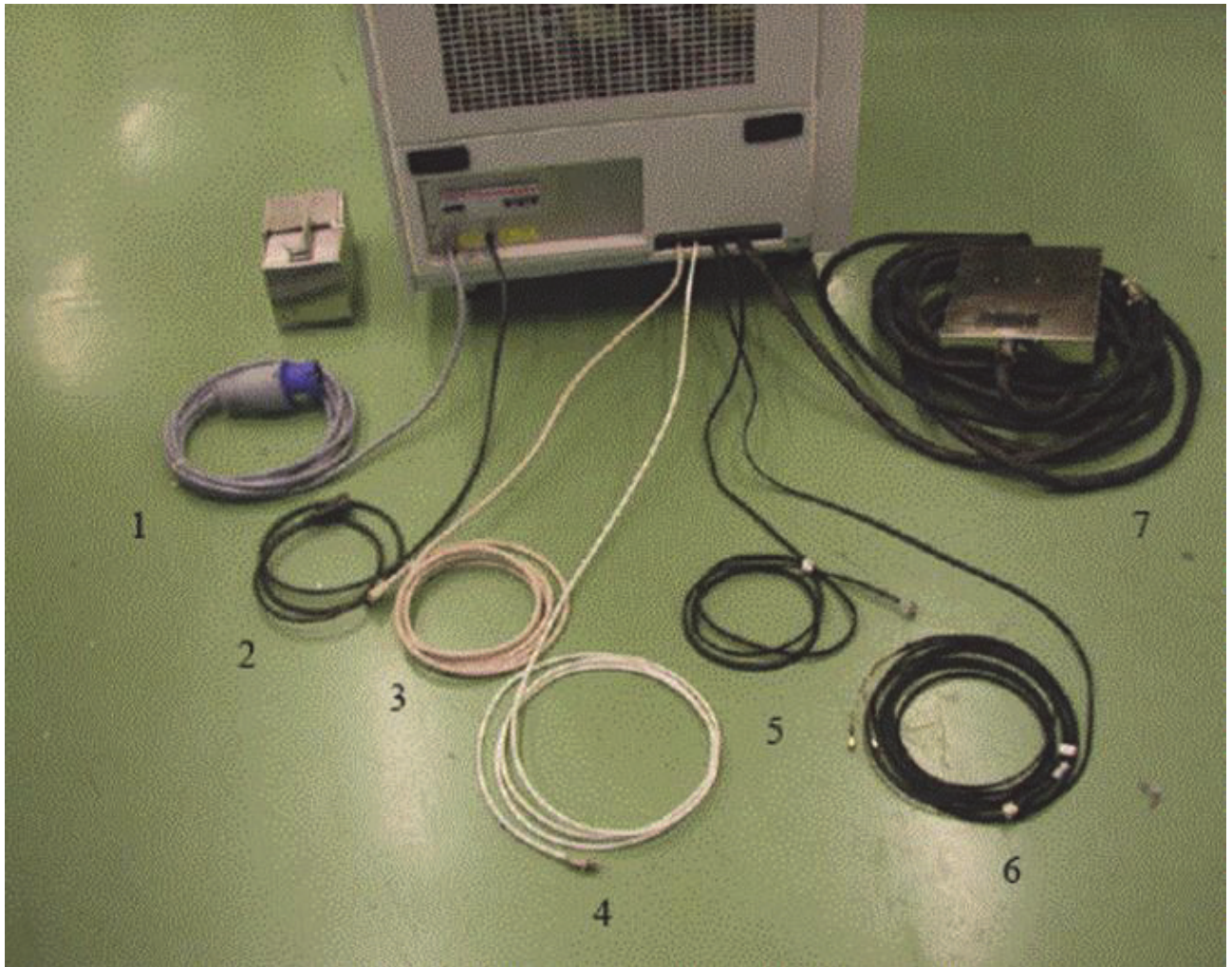


Figure 4.18: External Imaging Rack Cables

1. Connect the mains cable to the mains connector (1) and to 240V/32A socket.
2. Connect the control cable (2) to the connection on the rear of console. This connection switches off the rack in case the console is switched off.
3. Connect the LVDS-in cable (3) to the DPP-Out connector of the DPP board.
4. Connect the Ethernet connection (4) to the switch.
5. If available, connect the B0-Out cable to BSMS-2 adapter board on the right most SCB20 board in the BSMS-2.
6. When required, (typically it is not connected at AVANCE III systems) connect the external blanking cable (6) to the T0 interface of the IPSO board.
7. Connect the gradient filter (7) to the gradient coil.

The following drawing includes the full wiring of the imaging rack, including the BCU20:

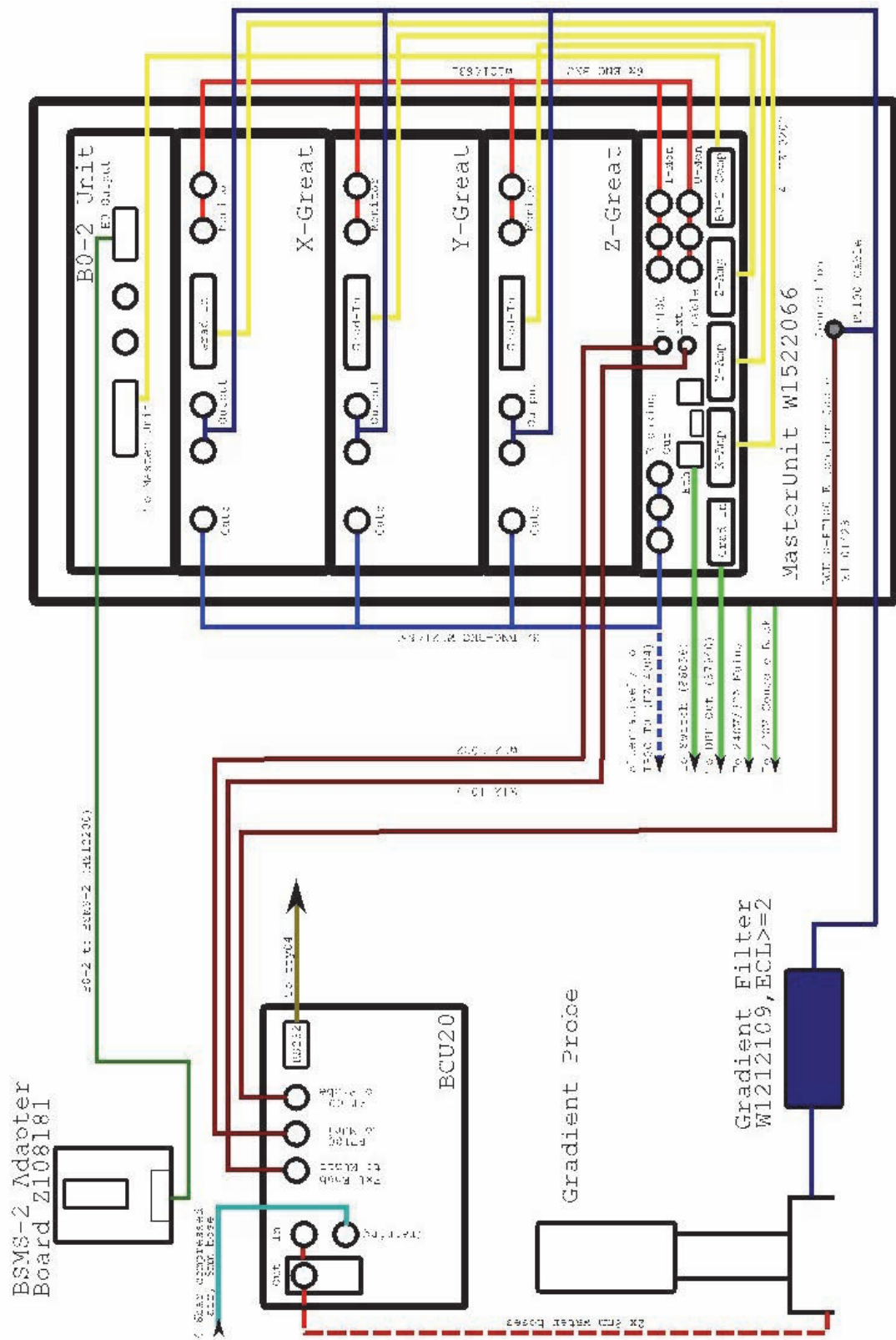


Figure 4.19: Imaging Accessory Wiring

5 Gradient Systems and RF Probes

Different gradient systems and RF probes are available to guarantee an optimum adaptation of the hardware to the application. Gradient coils with narrow inner diameters can have huge gradient strength but a limited sample space. Gradients with larger inner diameter offer more space for the sample but a weaker gradient strength.

There are 3 families of gradient probes and RF components. Within the families the building block principle is applied as far as possible. Parts cannot be interchanged between the families. A list of compatible components is shown in the table below.

The diffusion systems (Diff) are listed for the sake of completeness since they are equipped only with a Z-gradient and cannot be used for imaging.

	Diff 30 Gradient SB-System	Diff 50 Gradient WB-System	Diff 60 Gradient WB-System	Micro 5 Gradient SB-System	Micro 2.5 Gradient WB-System	Mini 0.75 Gradient WB-System	Mini 0.5 Gradient WB-System
RF Diff 30	•	•	•	•			
RF Diff 50	•	•	•	•			
RF Diff 60	•	•	•	•			
RF Micro 5	•	•	•	•			
RF Micro 2.5					•		
MICWB 40					•		
RF Mini 0.75						•	•
RF Mini 0.5						•	•

Table 5.1: Gradient System and RF Coil Compatibility Matrix

The best RF coil for an application is the smallest RF coil where the sample just fits in. Likewise, the best gradient system is the one with the narrowest diameter where the selected RF coil fits in. The table below shows the diameters for the different RF coils and gradient systems.

	Single Tuned Linear Coil	Double Tuned Linear Coil	Single Tuned Quadrature Coil	Single Tuned Solenoid Coil	Single Tuned Surface Coil	
Diff 30 Gradient ID=19 mm OD=40 mm	5-10 mm	5-8 mm		2.5-5 mm		
Diff 50 Gradient ID=19 mm OD=72 mm	5-10 mm	5-8 mm		2.5-5 mm		
Diff 60 Gradient ID=19 mm OD=72 mm	5-10 mm	5-8 mm		2.5-5 mm		Discontinued Type
Micro 5 Gradient ID=19 mm OD=40 mm	5-10 mm	5-8 mm		2.5-5 mm		
Micro 2.5 Gradient ID=40 mm OD=72 mm	5-30 mm	5-30 mm ⁽¹⁾		2-5 mm	10-15 mm	Discontinued Type
Micro 2.5 Gradient ID=40 mm OD=72 mm	1H: 5-15 mm X: 5-30 mm	5-30 mm ⁽²⁾	1H: 20-30 mm	2-5 mm	10-15 mm	New MICWB40 Type
Mini 0.75 Gradient ID=57 mm OD=72 mm	5-38 mm	5-38 mm ⁽³⁾			10-15 mm	
Mini 0.5 Gradient ID=57 mm OD=72 mm	5-38 mm	5-38 mm ⁽³⁾			10-15 mm	

Table 5.2: Gradient Systems and Available RF Coils

- (1) Refer to Micro 2.5 System, Discontinued [▶45] for details
- (2) Refer to Micro 2.5: MICWB40 System [▶54] for details
- (3) Refer to Mini 0.5/0.75 System [▶65] for details

5.1 Micro 5 System

The Micro 5 is the only triple axis imaging gradient system which fits in a standard bore (52 mm) magnet. The Micro 5 probe has one body, where RF coils and gradient coils are mounted which is equipped with a thermocouple (Type T). The body and the RF coils are fully compatible to the diffusion gradient coils (Diff 30, Diff 50, Diff 60), so replacing the Micro 5 gradient coil can turn the system into a spectroscopic diffusion system with a Z-gradient.

The gradient coil is water cooled and the standard RF saddle coils with an inner diameter of 5 to 10 mm can be temperature controlled in a range between -40°C to +80°C. In addition to the saddle coils, small solenoid coils are available, but the temperature control of the solenoids is rather difficult. Where a large temperature range between -100°C to +200°C is required, special single tuned EVT (Enhanced Variable Temperature) RF inserts (5 mm only) can be used with the standard Micro 5, Diff 30, Diff 50 and Diff 60 gradient coils.

For detailed setup parameters for the Micro 5 gradient system refer to chapter “Typical Gradient-Setpre Parameters [▶ 179]”. For maximum duty cycles refer to chapter Typical Gradient Coil Parameters [▶ 178].

ParaVision System Status:	S019
Gradient Inner Diameter.	19 mm
Gradient Outer Diameter.	40 mm
Gradient Cooling.	Water cooled.
RF Shield.	Included in gradient system.
Linearity. (±1.6% peak-peak)	19 mm sphere.
Max. Gradient Current.	60A
Max. Gradient Voltage.	120V
Max. Gradient Strength.	3T/m @ 60 Amp = 300G/cm @ 60 Amp [5G/(cm*A)].
RF Coil.	Version with exchangeable insert: From 2.5 mm (solenoid) to 10 mm single frequency or 8 mm double frequency saddle coil. Planar micro-coils with diameters of 20 to 1000 µm. Micro-solenoid coils with diameters down to 350 µm. Version with non-exchangeable coil: 5 mm or 8 mm double frequency saddle coil with additional 2H Lock.
Temperature Control.	Build in thermo couple type T. Dewar with heater and cable set to BVT available.
Temperature Range.	-20°C to +60°C standard or -100°C to +200°C with EVT insert.
Tuning and Matching.	Tuning and matching trimmers in the probe body.
Typical Applications.	Plants, insects, biopsies, materials, soil/bore/stone samples, flow and diffusion experiments.
Advantages	Sample lift can be used (HR-Sample Lift). EVT Inserts available. High gradient strength. Good temperature control of the sample. Gradient and RF stays in the magnet during sample change. Very good shim performance. Tolerant against high gradient duty cycles.
Drawback	Sample sizes max. 10 mm. Gradient coil needs to be unmounted for RF insert exchange.

Table 5.3: Application Relevant Parameters of the Micro 5 System

5.1.1 Assembly/Disassembly of the Micro 5 System

The assembly of the Micro 5 system is relatively simple, however there are a few points, which require careful consideration and handling.

Saddle Coil

1. Place the system base on a table.
2. Slip the RF insert onto the base. The inserts are very sensitive, especially the ones without a quartz glass tube where the coil wires can be touched. Avoid touching or bending these wires. If the insert is in the right position, it simply slips on the probe base pins.



Figure 5.1: Mounted Mirco5 RF Insert (Saddle Coil)

Solenoid Coil

1. Remove the RF pin shown in the left image of the figure below. The pin has a special collar, which can be screwed out using a small pair of pliers (middle image).
2. Push the solenoid onto the four remaining pins.
3. Fix the solenoid by screwing a RF screw into the thread of the previously removed pin (right image).

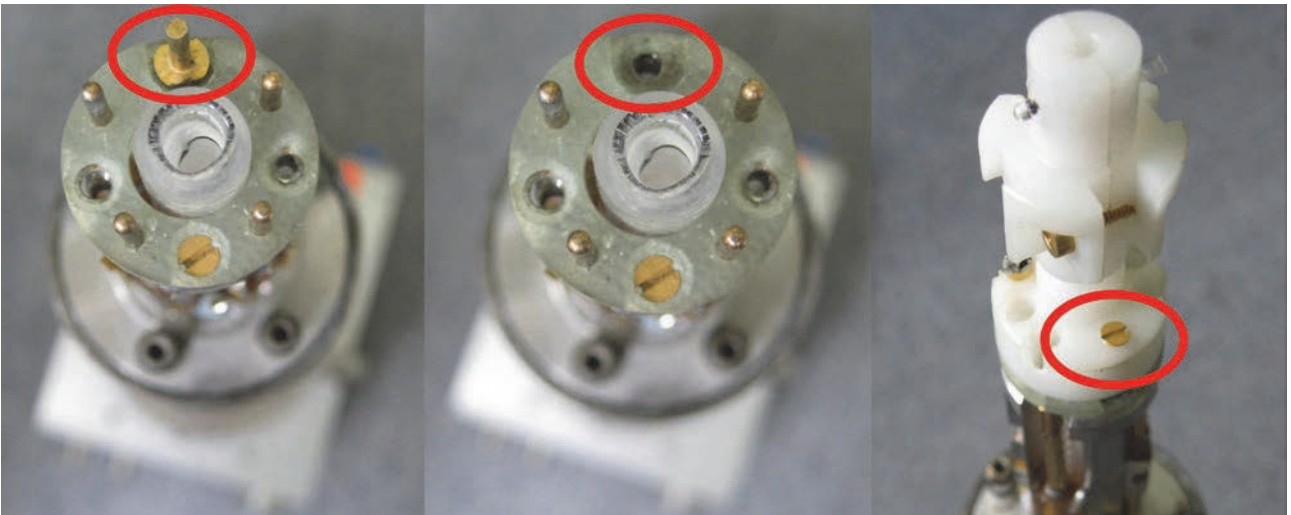


Figure 5.2: Micro 5 RF Insert (Solenoid Coil)

4. Mount the gradient coil by shifting it down over the RF insert until it reaches the gradient current and water pins. Be very careful not to tilt the gradient coil against the RF coil. Since the RF coil is only stabilized by a thin walled quartz tube, it is extremely easy to break.
5. When the gradient coil reaches the probe pins, rotate the gradient coil in order to match the position of the water sockets in the gradient coil to the water connectors on the probe body.
6. Push down the gradient coil using moderate force so that the pins slip into the coils sockets.



Figure 5.3: Mounting of the Micro 5 Gradient

7. Fasten the gradient coil using the lock nut on the probe base. Hold the black gradient coil (not the probe base!) in one hand and fix the gradient coil using the lock nut. The lock nut will pull down the gradient coil. The inner diameter of the gradient coil is reduced about 10 mm down from the top. This edge pushes down the RF insert while the gradient coil is fixed, so that a good RF connection and (if mounted) a good thermal junction to the dewar is guaranteed.

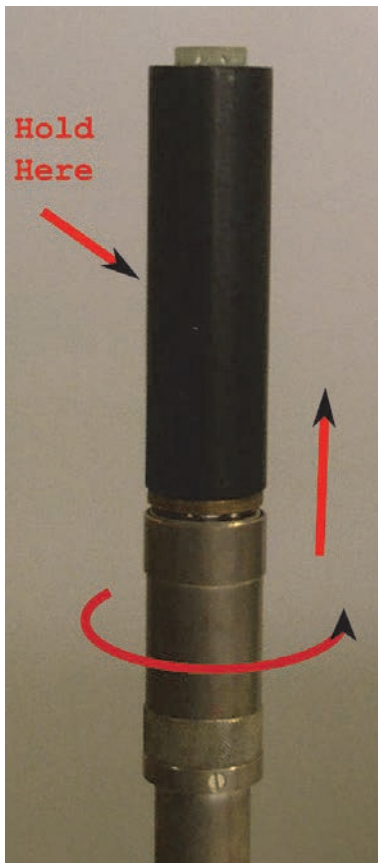


Figure 5.4: Final Assembly of the Micro 5

After all the parts are assembled the complete Micro 5 can be mounted in a standard bore or a wide bore shim system using the gold-colored screws on the bottom plate, or by using the bayonet lock.

Disassembly

To disassemble the system to change the RF insert follow the steps in reverse order. Again, it is extremely important to hold the gradient coil and not the body while unscrewing the lock nut and not to tilt the gradient coil while pulling it over the RF coil. The first few millimeters may be difficult, since the O-rings of the water cooling stick to the gradient coil. A good tip is to push a screw driver into the gap between gradient coil and body and rotate it carefully to shift the gradient coil up (see the figure below).

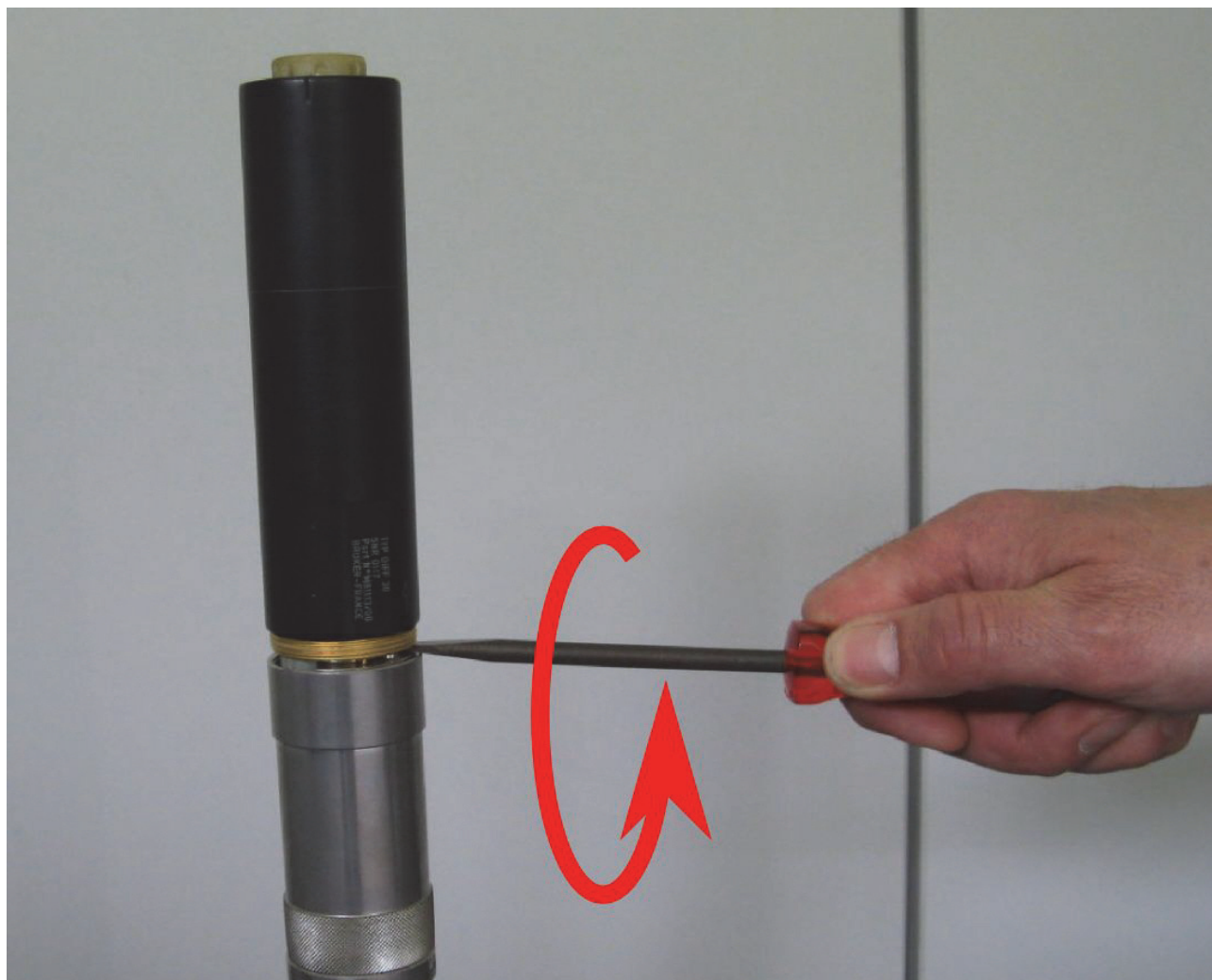


Figure 5.5: Removal of the Gradient Coil from the Probe Base

5.2 Micro 2.5 System, Discontinued

The Micro 2.5 is a water cooled triple axis wide bore imaging system which only fits into wide bore magnets (89 mm) or larger. The gradient coil and the RF part are mounted separately in the magnet, the gradient coil by means of a separate holder adapting it to the individual magnet. The RF part is mounted afterwards inside the gradient system. The Micro 2.5 system is only compatible to Micro 2.5 parts, not to any other micro-imaging probe types. The big advantage of this system is its high flexibility. Three different RF probes can be combined with the same gradient system to adapt the system optimal to the application.

Micro 2.5 Probe

This is the most flexible RF probe for the Micro 2.5 imaging system. It consists of a probe body which is designed for 2 RF channels. The exchangeable RF inserts cover a wide range from 2.5 to 5 mm solenoid coils, 5 to 10 mm saddle coils and 15 to 30 mm birdcage coils, which can be built as single frequency, dual frequency or quadrature (birdcage) inserts. In addition to these insets, an EVT (Enhanced Variable Temperature) insert with an inner diameter of 15 mm is avail-

able which covers temperatures from $-100\text{ }^{\circ}\text{C}$ to $+200\text{ }^{\circ}\text{C}$. The probe is fully compatible to the BVT temperature control unit, has an internal thermocouple (Type T) and an optional dewar with heater.

Micro 2.5 AHS-RF Probe

This probe is dedicated to animal work. The exchangeable inserts are not mounted on top of the 2 channel probe, but a bit further down. This allows installation of exchangeable RF inserts from 2.5 to 5 mm solenoid coils, 5 to 10 mm saddle coils and 15 to 25 mm birdcage coils that can be built as single frequency, and dual frequency or quadrature (15 to 25 mm birdcage) inserts. Additionally, this probe offers the possibility of plugging in surface coils that can be directly attached to the animal to increase the signal to noise of the experiment (currently no cross coil operation is supported). The probe provides the advantage of full animal support with an animal bed to fix and position the animal, anesthesia support (breathing gas), and plug and play support for the SA-Instruments animal monitor system (supporting respiration, ECG and temperature control), see chapter Digital Data Filtering and Analog Sampling [▶127].

MicroMouse (2.5) Probe

This probe is also dedicated to animal work. The big difference to the Micro 2.5 AHS-RF probe is the non-exchangeable 30 mm RF coil which is mounted on top of the 2 channel probe. The 30 mm birdcage RF coil allows full body work with a mouse (30 g) and can be a single frequency coil, dual frequency coil, or a quadrature coil. This probe also offers the possibility of mounting X frequency surface coils that can be directly attached to the animal to increase the signal to noise of the experiment (currently no cross coil operation is supported). The surface coil is mounted as a third channel add on with its own RF cable and tuning unit. The probe has the advantage of full animal support with an animal bed to fix and position the animal, anesthesia support (breathing gas), and plug and play support for the SA-Instruments animal monitor system (supporting respiration, ECG and temperature control), see chapter Digital Data Filtering and Analog Sampling [▶127].

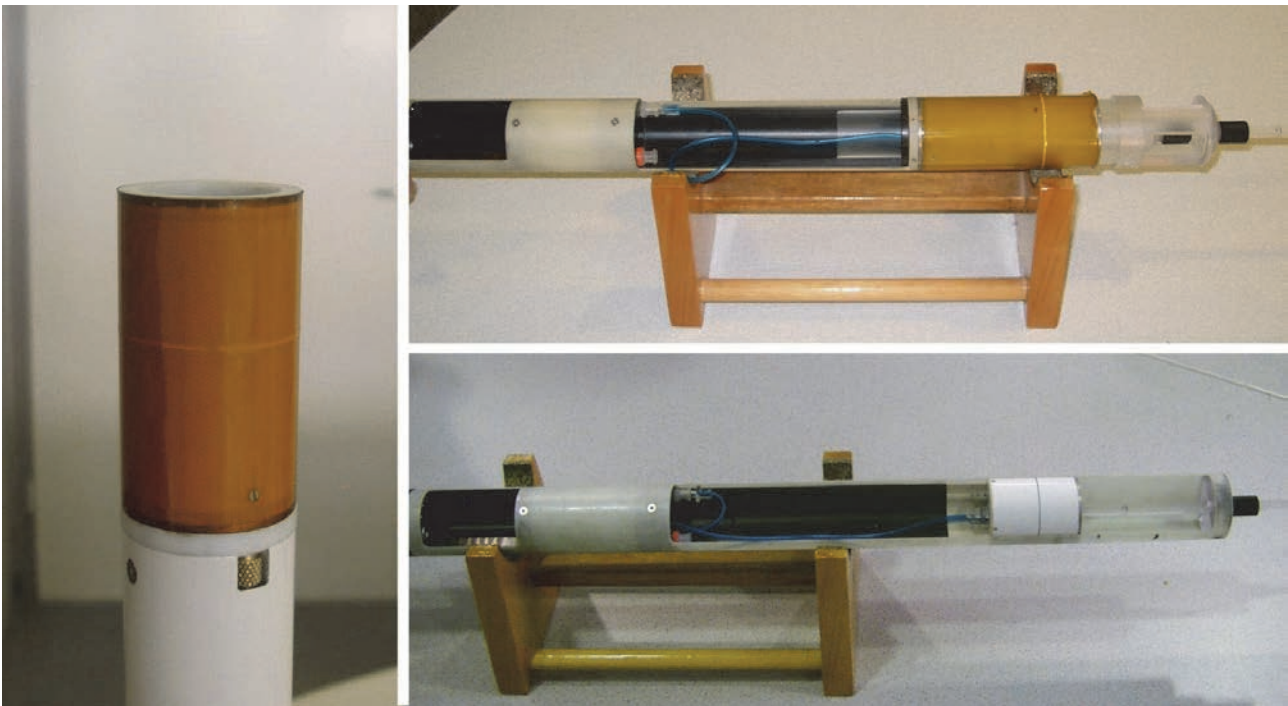


Figure 5.6: Micro 2.5 RF Probes.

The Micro 2.5 probe on the left in the figure above is with a mounted 30 mm insert. The upper right picture shows the MicroMouse probe, the lower right the Micro 2.5 AHS-RF probe, both equipped with an animal bed.

For detailed setup parameters for the Micro 2.5 gradient system refer to chapter “Typical Gradient-Setup Parameters [179]”. For maximum duty cycles refer to chapter Typical Gradient Coil Parameters [178].

Gradient Systems and RF Probes

ParaVision System Status	S040		
Gradient Inner Diameter	40 mm		
Gradient Outer Diameter	72 mm		
Gradient Cooling	Water Cooled		
RF Shield	Each RF Coil is separately shielded.		
Linearity (±1.8% peak-peak)	36 mm sphere.		
Max. Gradient Current	60 A		
Max. Gradient Voltage	120 V		
Max. Gradient Strength	1.5 T/m @ 60Amp = 150 G/cm @ 60Amp [2.5 G/(cm*A)]		
RF Probes			
	Micro 2.5	Micro 2.5 AHS RF	MicroMouse (2.5)
RF Coils	Exchangeable Insert 2.5-5 mm Solenoid 5-10 mm Saddle Coil 15-30 mm Birdcage C All coils can be single or double frequency ⁽¹⁾ tuned, birdcages can be quadrature probes.	Exchangeable Insert 2.5-5 mm Solenoid 5-10 mm Saddle Coil 15-25 mm Birdcage C 5-15 mm Surface Coil All coils can be single or double frequency tuned, birdcages can be quadrature probes.	Fixed Coil 30 mm Birdcage Coil 5-15 mm Surface Coil The 30 mm coil can be a single, double or quadrature probe; the add-on surface coil is single frequency for X only.
Temperature Control	Thermocouple and dewar. Compatible to BVT unit.	Animal temperature control by gradient cooling water.	Animal temperature control by gradient cooling water.
Temperature Range	10°C to +50°C or -100°C to +200°C with EVT Insert		
Typical Applications	Plants, Insects, Biopsies, Materials, Soil/Bore/Stone Samples, Flow Experiments, Rheology.	Mouse Extremities or Head Application Whole Body Mouse Applications up to ~20g.	Whole Body Mouse Applications up to ~30g.
Advantages	<ul style="list-style-type: none"> - High flexibility for all kind of samples. - Temperature Control. - EVT Inserts. - Minimum 15 mm free access inner diameter. 	<ul style="list-style-type: none"> - Flexibility for all kinds of mouse and non in vivo applications. - Animal Support. - Surface Coils. - Easy base for home build coils. 	<ul style="list-style-type: none"> - Full body mouse applications. - Animal Support. - X-Surface Coils.
	The Micro 2.5 gradient system offers a high flexibility and a sufficient gradient strength for almost all micro-imaging applications. The gradient coil remains in the magnet during probe/sample exchange. There is no need to disconnect it.		
Drawback	- No in-vivo applications	- Ex-vivo samples harder to handle.	- Only non exchangeable 30 mm ID RF coil available.
	The RF probe needs to be taken out from the magnet for sample replacement.		

Table 5.4: Application Relevant Parameters of the Micro 2.5 System

(1) 30 mm double tuned exchangeable inserts are not recommended due to their limited performance, caused by restricted space for the coil design. Wherever possible, 25 mm inserts are recommended.

5.2.1 Assembly/Disassembly of the Micro 2.5 System

The assembly of the Micro 2.5 system consists of 2 basic parts, the gradient and the RF probe. The gradient probe is typically assembled only once during the installation. It consists of the gradient coil and the gradient base, which adapts the coil to the correct length for the different magnets. The assembly is very easy and done in a few minutes.

1. Place the gradient coil on the table in such a way, that the brass ring points upwards.
2. Take the gradient base and lubricate the O-rings with some grease.
3. Place the base on the gradient coil and push it down with a moderate force, so that there is no gap between the brass ring and the probe base.
4. Fasten the gradient coil to the probe base using the 3 retaining screws.

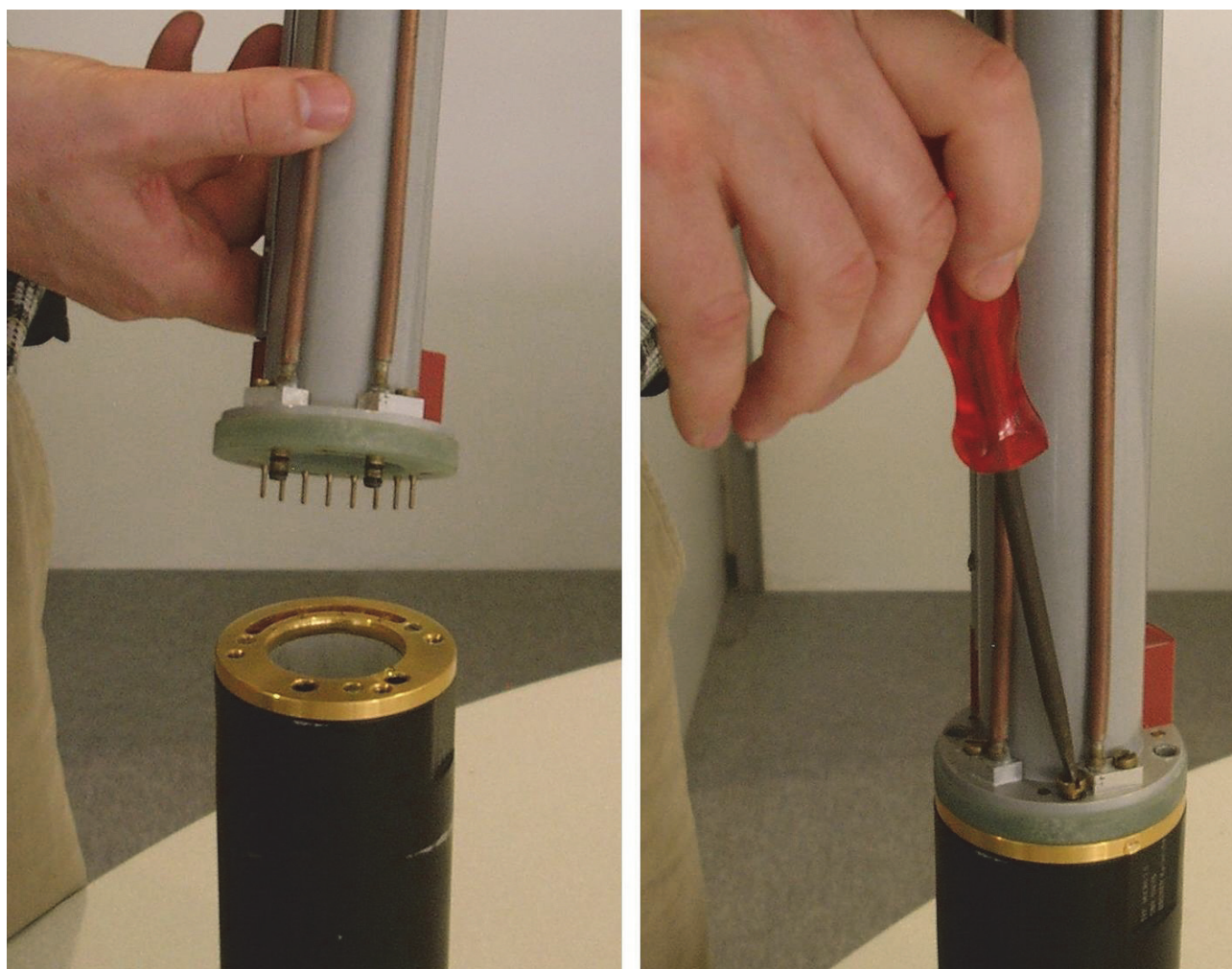


Figure 5.7: Mounting the Micro 2.5 Gradient to its Base

5. Fasten the gradient to the bottom part of the shim system in the magnet using the four special screws. The screws are tightened manually at the outer 4 holes of the gradient probe base.

6. Screw the lock nuts upwards to fix the probe base properly.
7. Connect the water hoses and gradient cable.

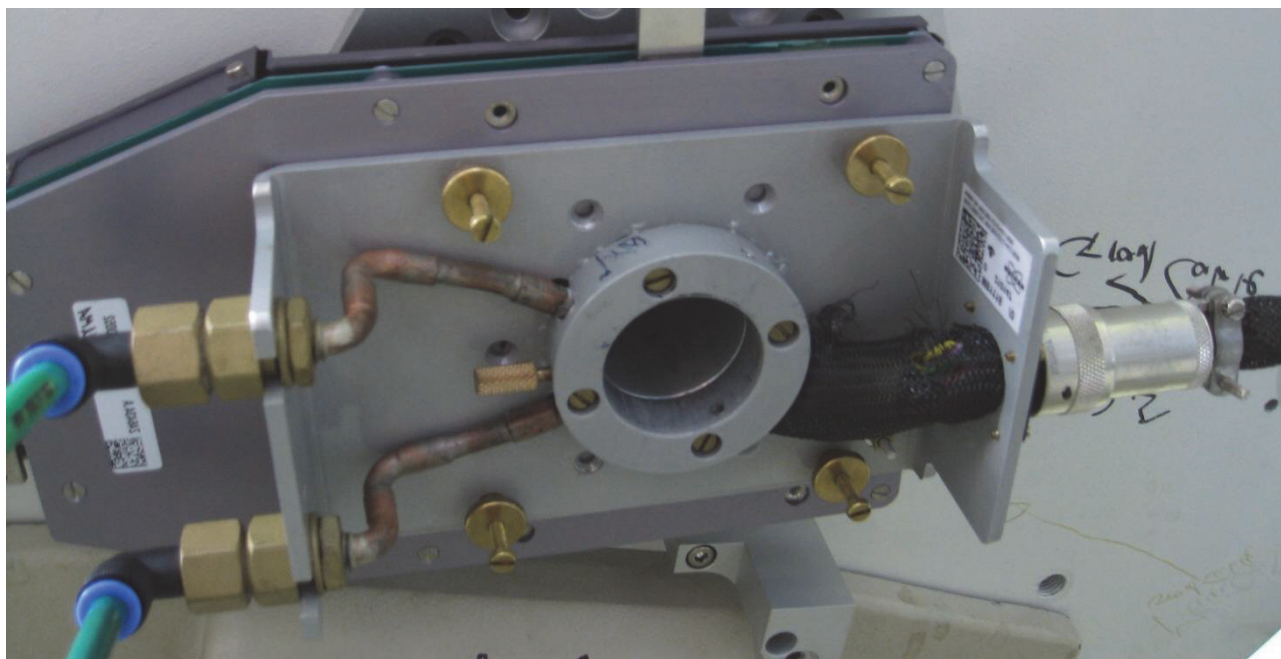


Figure 5.8: Mounted Micro 2.5 Gradient, Fixed with 4 Brass Screws with Lock Nuts

The RF probe needs to be adapted for different sample sizes. The smaller the inner diameter of the RF coil, the higher the signal to noise ratio at a given sample. Saddle coils (5 or 10 mm) improve the signal to noise and the shim performance compared to a birdcage. Solenoid coils (2.5 to 5 mm) improve the signal to noise compared to a birdcage, or saddle coil even more, but with the drawback that they can not be shimmed as good as saddle coils.

The exchangeable inserts of the Micro 2.5 and the Micro 2.5 AHS-RF RF probes need to be installed very carefully, since the tune and match trimmers are very sensitive.



Note: The capacitors for tuning and matching can be rotated only to a certain range. Applying too much force will break the capacitors, if they have reached the end points.

Micro 2.5

1. Place the probe base on a table with the RF connections pointing upward.

There are 2 RF connections (gold-colored connectors) visible and four spring born bushings to adapt the tune and match trimmer rods of the individual insert. The trimmer rods are half cut off and used to align the rods of the insert with the bushings of the probe base.

2. Align the rods of the insert with the busings of the probe base and lightly press the rods into the bushings until a click is heard. If the rods don't slide easily into the bushing, rotate the tuning and matching rods a little forward and backward until the rods slide in.
3. Once the rods are inserted, fix the insert using the thumb wheels.

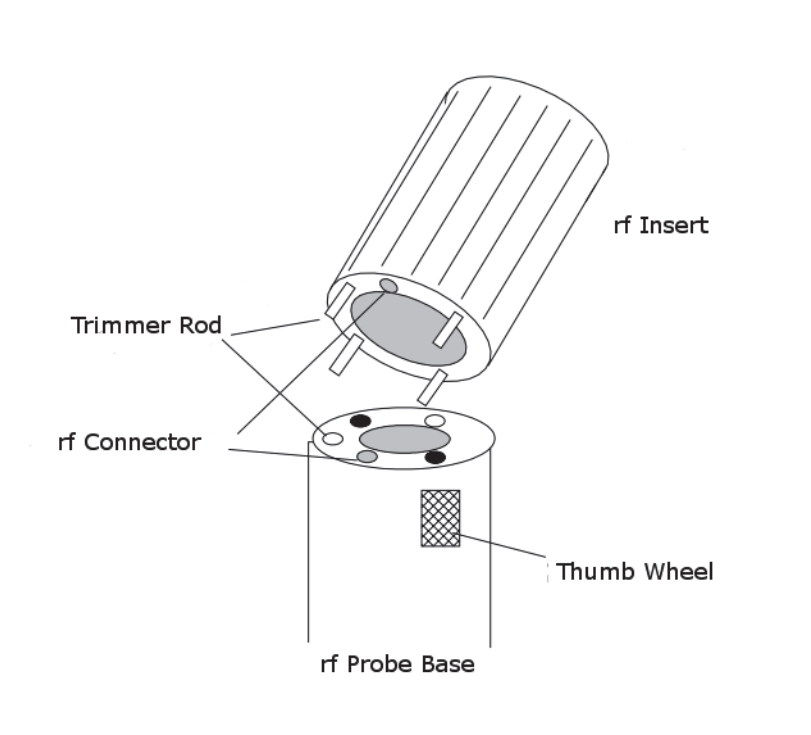


Figure 5.9: Schematic of a Micro 2.5 Probe Base and RF Insert

Micro 2.5 AHS-RF

The mounting of the Micro 2.5 AHS-RF inserts is even simpler compared to the mounting of a Micro 2.5 insert, since there are no thumb wheels to fix the insert.

1. Align the trimmer rods and the bushings as described in the previous section.
2. Lightly press the rods into the bushings until a click is heard. If the rods don't slide easily into the bushing, rotate the tuning and matching rods a little forward and backward until the rods slide in.
3. Once the click is heard, the insert must be pushed down until there is no remaining gap between the flange and the insert.

5.2.2 Installation of the Dewar with Heater in the Micro 2.5 RF Probe

The installation of the dewar including the heater to the Micro 2.5 RF probe is very easy. Unfortunately, there is currently no mechanical support for the fixation of the heater connector.

1. Mount the slotted closure head on top of the Micro 2.5 RF probe base, if not already done.

In the figure below, 2 wires below the head form the thermocouple for the temperature measurement.



Figure 5.10: Closure Head.

2. As soon as the closed head is at its position, shift the glass dewar in from the bottom of the RF probe.

The bottom mount must have a spring to press the glass dewar to closure head and a Teflon ring to protect the glass from the metal spring.

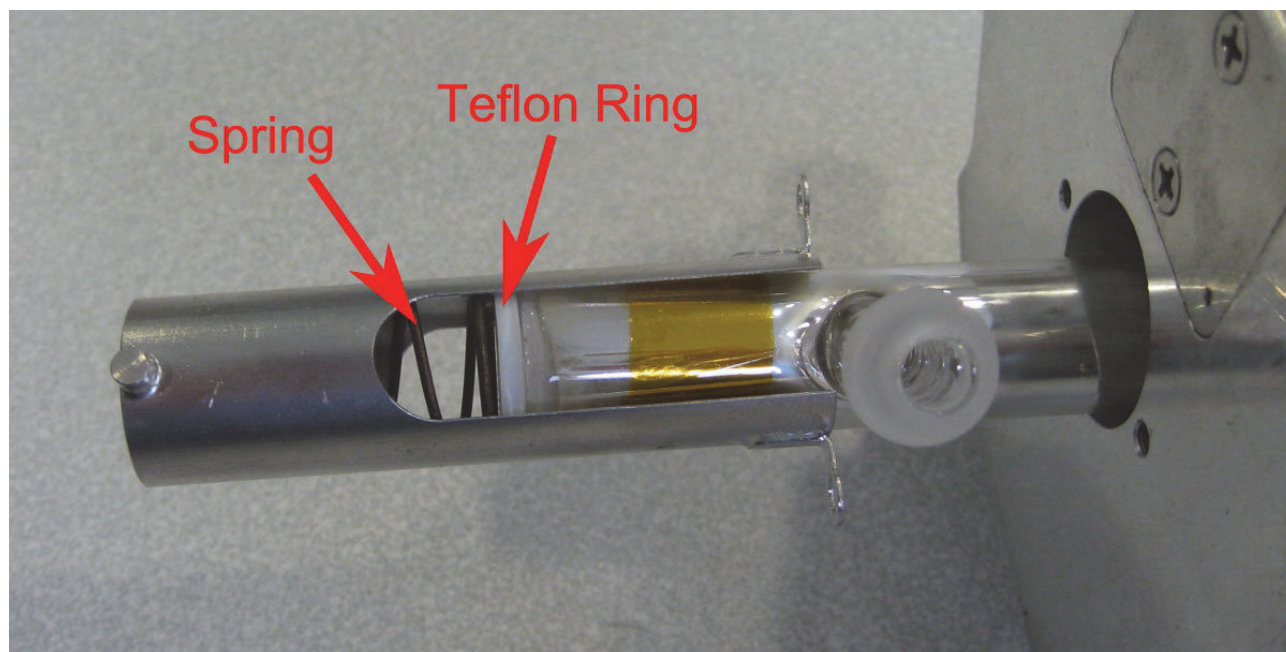


Figure 5.11: Bottom Mount with Spring and Teflon Ring to Protect the Glass Dewar.

3. Fasten the bottom mount with the 2 screws.
4. Shift the dewar in and fasten it with a bayonet lock.

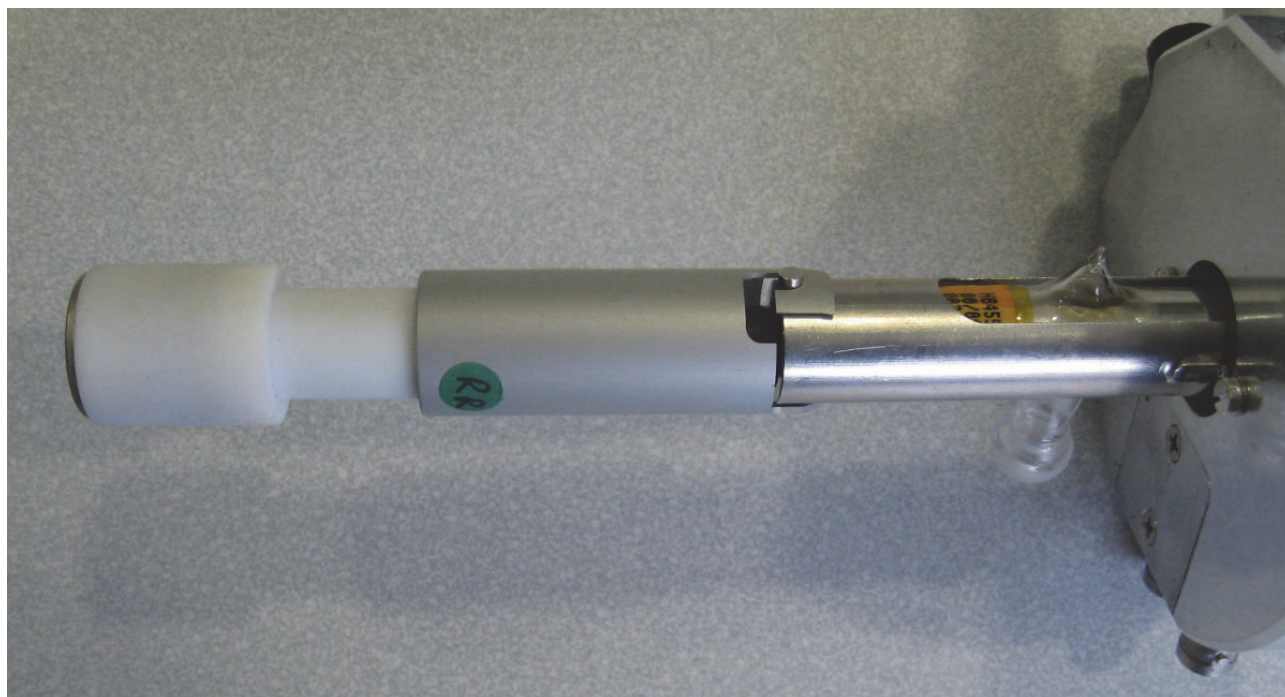


Figure 5.12: Bottom Mount Fastened with 2 Screws.

In the figure above the heater is shifted in and fixed by the bayonet lock.

For the installation of EVT inserts on the Micro 2.5 probe base refer to the “Micro2.5-EVT Manual”.

5.3 Micro 2.5: MICWB40 System

The Micro 2.5 is a water cooled triple axis wide bore imaging system which only fits into wide bore magnets (89 mm) or larger. The gradient coil and the MICWB40 RF part are mounted separately in the magnet, the gradient coil by means of a separate holder adapting it to the individual magnet. The RF part is mounted afterwards inside the gradient system. The Micro 2.5 system is only compatible to the discontinued Micro 2.5 and the MICWB40 parts, not to any other micro-imaging probe types. The big advantage of this system is its high flexibility at a high gradient strength. Two types of RF probes with exchangeable RF inserts adapt the system optimal to the application.

CAUTION

Risk of burn from hot surfaces.

Coming in contact with the inner surface of volume coils may result in serious burns.

- ▶ The application of the maximum allowed CW RF power for long durations increases the temperature of the inner surface of volume coils.
- ▶ The maximum allowed CW RF power is a technical limitation of the coil and can be considerable higher than the maximum dose that can be applied to living samples.
 1. Wait until the RF coil cooled down before removing it from the scanner.
 2. Always monitor the temperature of living samples during the examination to avoid injury or death of the animal.



CAUTION

Risk of personal injury from coming in contact with active coils.

Coming in contact with active coils may result in personal injury or damage to the device.

- ▶ Active coils may contain hot parts or provide other dangers to personal or devices.
 1. Never come in contact with a active MRI coil.
 2. Stop a running experiment before connecting or disconnecting a MRI coil.
 3. Never remove the cover from the coil.
 4. Never connect a damaged coil to the scanner.
 5. Never operate an MRI coil outside the magnet.
 6. When using anesthetic gases ensure correct functioning of the exhaust system for the magnet bore.
 7. Always monitor the body temperature of the animal to avoid a dangerous increase of the temperature of the animal due to increased RF dissipation.
 8. Avoid wire loops inside the transmitter coil.



MICWB40 Probe BASIC

This is the basic probe for non in-vivo applications. It consists of a probe body which is designed for 2 RF channels. The exchangeable RF inserts cover a wide range from 2.5 to 5 mm solenoid coils, 5-30 mm linear coils (5-15 mm for 1H), 5-30 mm double tuned coils, 20-30 mm quadrature coils (1H) and 10-15mm surface coils (fixed housing or flexible wire). In addition to these inserts, an EVT (Enhanced Variable Temperature) insert with an inner diameter of 15 mm is available

which covers temperatures from $-100\text{ }^{\circ}\text{C}$ to $+200\text{ }^{\circ}\text{C}$. The probe is fully compatible with the BVT temperature control unit (with the optional VT Kit that includes heater and thermocouple Type T, Option Number PH2504).

MICWB40 Probe IN-VIVO

In addition to the features of the “MICWB40 Probe BASIC”, this probe also includes animal support. The probe body is equipped with wiring and hoses to control the animal physiology (anesthesia, temperature and respiration measurement, ECG), as well as an animal bed for convenient animal handling (25 mm and 30 mm RF inserts). With experience, whole body experiments of mice up to about 30 grams can be investigated in the 30 mm resonator. The interfacing of the probe directly supports the SA-Instruments animal monitoring system (respiration, ECG and temperature control), see Digital Data Filtering and Analog Sampling [▶ 127].

In combination with the VT Kit, the probe can be temperature controlled as with the MICWB40 Probe BASIC, but only for non in-vivo experiments.

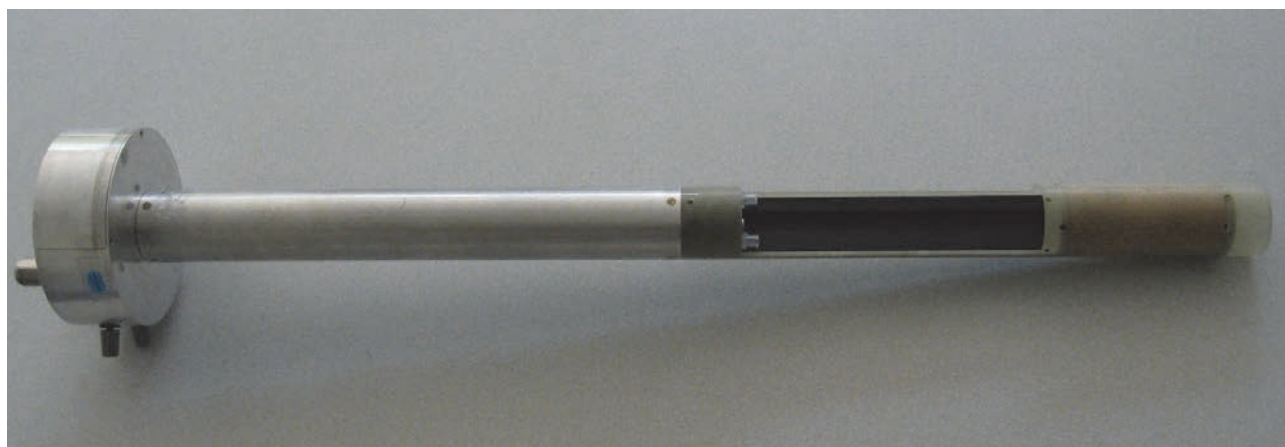


Figure 5.13: MICWB40 Probes.

The left side of the image above shows a MICWB40 configuration with installed VT Kit, the right image shows the IN-VIVO version with animal bed.

For detailed setup parameters for the Micro 2.5 gradient system refer to chapter “Typical Gradient-Setup Parameters [▶ 179]”. For maximum duty cycles refer to chapter Typical Gradient Coil Parameters [▶ 178].

ParaVision System Status:	S040	
Gradient Inner Diameter.	40 mm	
Gradient Outer Diameter.	72 mm	
Gradient Cooling.	Water cooled	
RF Shield.	Each RF coil is separately shielded.	
Linearity. (±1.8% peak-peak)	36 mm sphere	
Max. Gradient Current:	60 A	
Max. Gradient Voltage:	120 V	
Max. Gradient Strength:	1.5 T/m @ 60Amp = 150 G/cm @ 60Amp [2.5 G/(cm*A)]	
RF Probes:		
	MICWB40 BASIC	MICWB40 IN-VIVO
RF Coils:	<ul style="list-style-type: none"> - Exchangeable Insert. - 2.5-5 mm solenoid coils. - 5-15 mm linear coils (1H). - 20-30 mm quadrature coils (1H). - 5-30 mm double tuned coils⁽¹⁾. - 10-15 mm surface coils (fixed housing or flexible wire). 	<ul style="list-style-type: none"> - Exchangeable insert. - 2.5-5 mm solenoid coils. - 5-15 mm linear coils (1H). - 20-30 mm quadrature coils (1H). - 5-30 mm double tuned coils⁽¹⁾. - 10-15 mm surface coils (fixed housing or flexible wire). - Animal beds are only available for 25 mm and 30 mm ID coils.
Temperature Control:	VT kit, thermocouple and dewar. Compatible to BVT unit.	Animal temperature control by gradient cooling water. VT kit, thermocouple and dewar. Compatible to BVT unit (ex-vivo)
Temperature Range:	-10 °C to +50 °C, or, -100 °C to +200 °C with EVT insert and VT-kit.	-10 °C to +50°C, or, -100 °C to +200 °C with EVT Insert and VT-Kit
Typical Applications:	Plants, insects, biopsies, materials, soil/bore/stone samples, flow experiments, rheology	Mouse whole body or head applications plants, insects, biopsies, materials, soil/bore/stone samples, flow experiments, rheology
Advantages:	<ul style="list-style-type: none"> - High flexibility for all kind of ex-vivo samples. - Temperature control. - EVT Inserts. - Minimum 19 mm free access inner diameter. 	<ul style="list-style-type: none"> - Flexibility for all kinds of mouse and non in vivo applications. - High flexibility for all kind of samples - Temperature control. - EVT Inserts. - Minimum 19 mm free access inner diameter
	The Micro 2.5 gradient system offers a high flexibility and a sufficient gradient strength for almost all micro-imaging applications. The gradient coil remains in the magnet during probe/sample exchange. There is no need to disconnect it.	
Drawback:	- No in-vivo applications.	
	The RF probe needs to be taken out from the magnet for sample replacement.	

Table 5.5: Application Relevant Parameters of the Micro2.5 System

(1) 30 mm double tuned exchangeable inserts are not recommended due to their limited performance, caused by restricted space for the coil design. Wherever possible, 25 mm inserts are recommended.

5.3.1 Assembly/Disassembly of the Micro 2.5 System

The assembly of the Micro 2.5 system consists of 2 basic parts, the gradient and the RF probe. The gradient probe is typically assembled only once during the installation. It consists of the gradient coil and the gradient base, which adapts the coil to the correct length for the different magnets. The assembly is very easy and done in a few minutes.

1. Place the gradient coil on the table in such a way, that the brass ring points upwards.
2. Take the gradient base and lubricate the O-rings with some grease.
3. Place the base on the gradient coil and push it down with a moderate force, so that there is no gap between the brass ring and the probe base.
4. Fasten the gradient coil to the probe base using the 3 retaining screws.

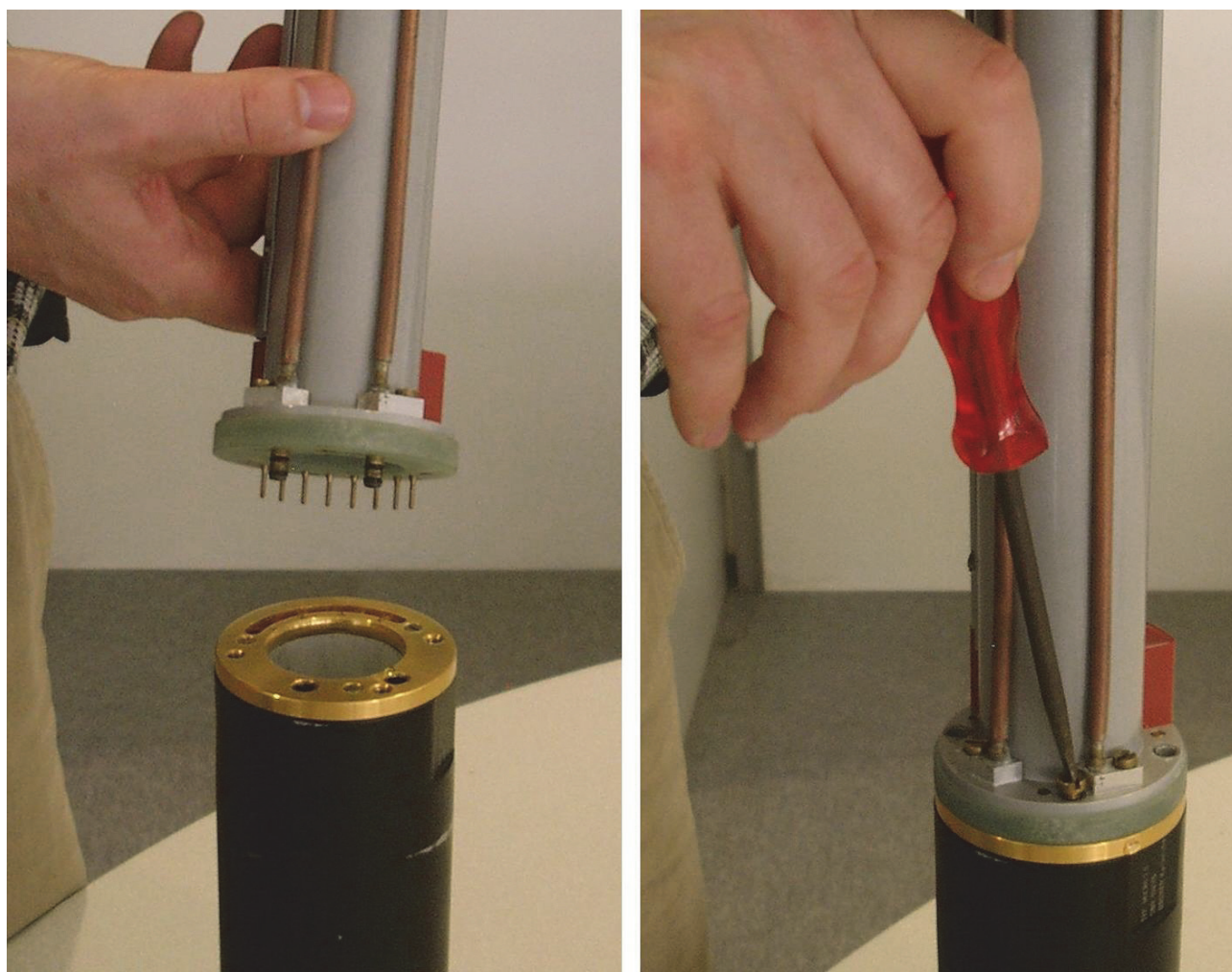


Figure 5.14: Mounting the Micro 2.5 Gradient to its Base

5. Fasten the gradient to the bottom part of the shim system in the magnet using the four special screws. The screws are tightened manually at the outer 4 holes of the gradient probe base.

6. Screw the lock nuts upwards to fix the probe base properly.
7. Connect the water hoses and gradient cable.

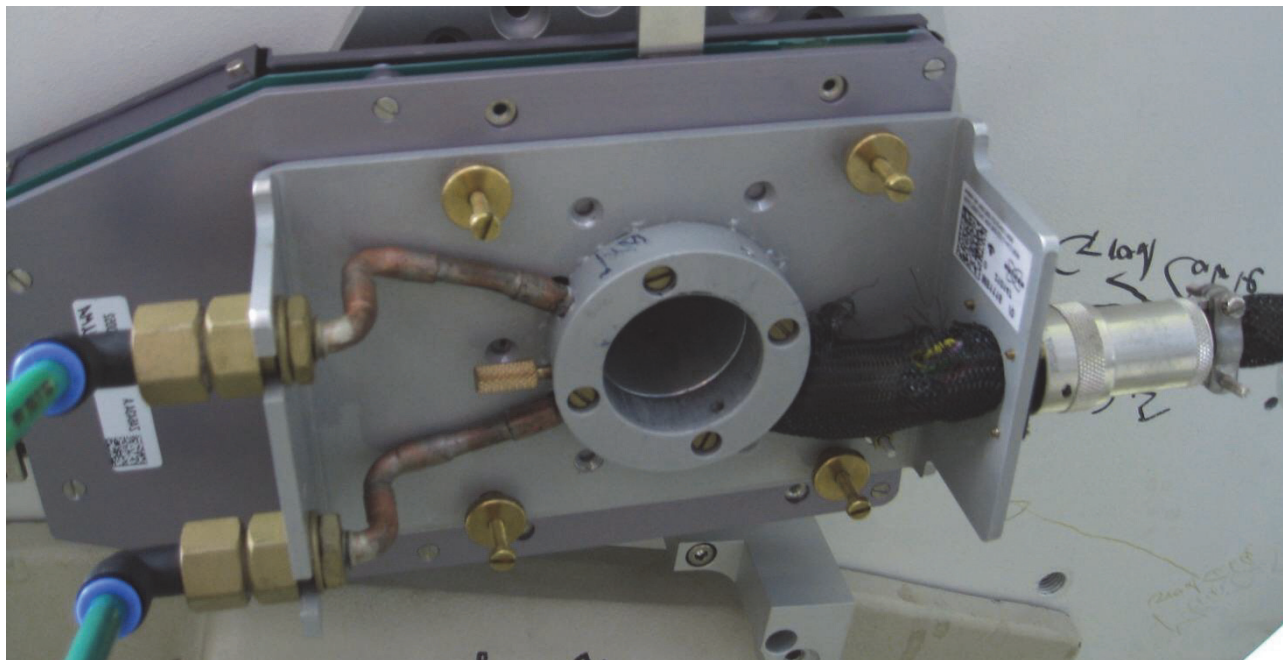


Figure 5.15: Mounted Micro 2.5 Gradient, Fixed with 4 Brass Screws with Lock Nuts

The RF probe needs to be adapted for different sample sizes. The smaller the inner diameter of the RF coil, the higher the signal to noise ratio at a given sample. Saddle coils (5 or 10 mm) improve the signal to noise and the shim performance compared to a birdcage. Solenoid coils (2.5 to 5 mm) improve the signal to noise compared to a birdcage, or saddle coil even more, but with the drawback that they can not be shimmed as good as saddle coils.

The exchangeable inserts of the Micro 2.5 and the Micro 2.5 AHS-RF RF probes need to be installed very carefully, since the tune and match trimmers are very sensitive.



Note: The capacitors for tuning and matching can be rotated only to a certain range. Applying too much force will break the capacitors, if they have reached the end points.

Micro 2.5

1. Place the probe base on a table with the RF connections pointing upward.

There are 2 RF connections (gold-colored connectors) visible and four spring born bushings to adapt the tune and match trimmer rods of the individual insert. The trimmer rods are half cut off and used to align the rods of the insert with the bushings of the probe base.

2. Align the rods of the insert with the busings of the probe base and lightly press the rods into the bushings until a click is heard. If the rods don't slide easily into the bushing, rotate the tuning and matching rods a little forward and backward until the rods slide in.
3. Once the rods are inserted, fix the insert using the thumb wheels.

Since the alignment of probe base and insert is a bit tricky, a small mounting tool was developed. refer to the following figure and follow the instructions below.

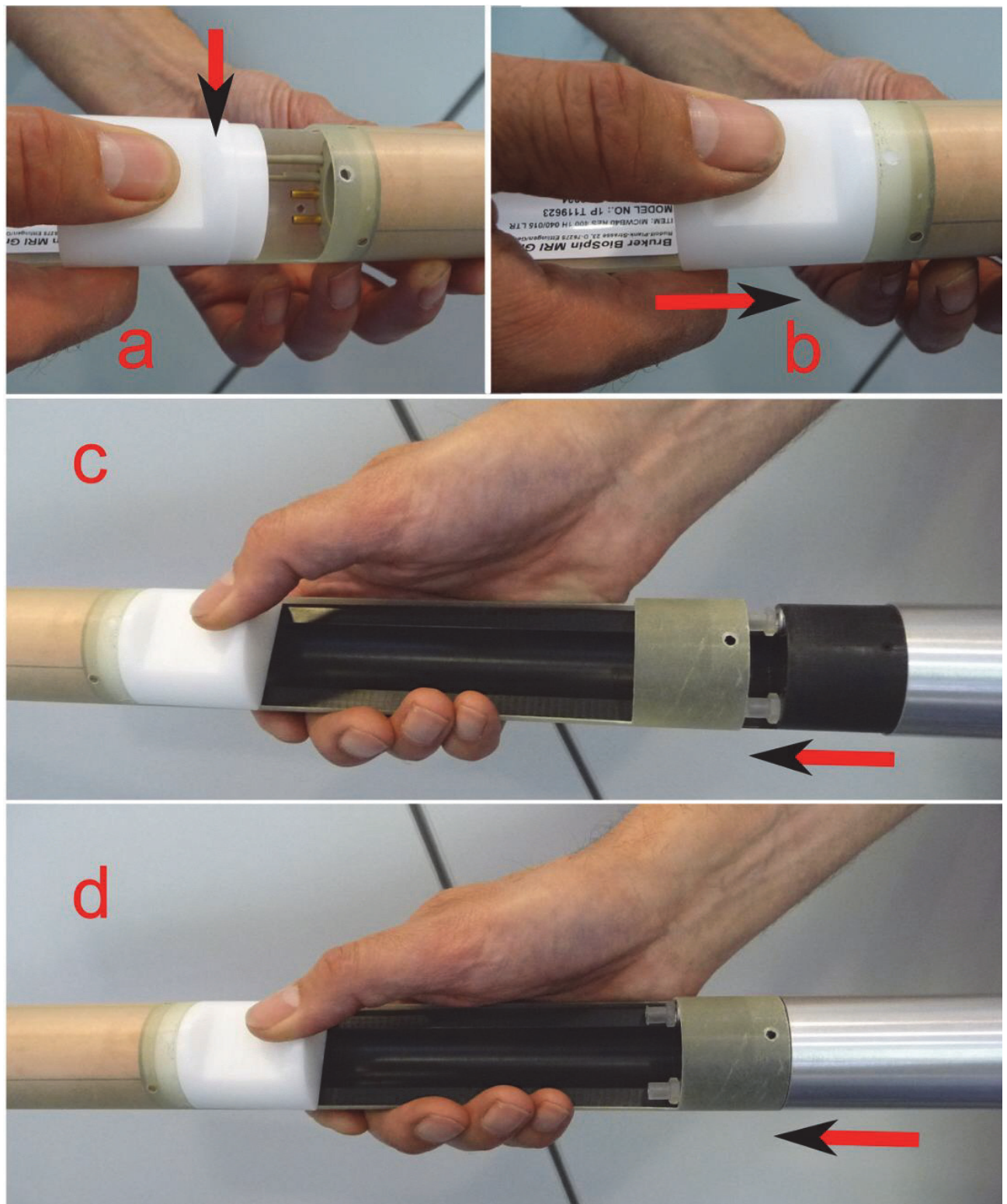


Figure 5.16: Mounting a MICWB40 Insert with the Help of the Small Mounting Tool

1. Place the mounting tool below the RF coil in the half shell of the insert (a).
2. Shift it towards the RF coil into the closed protecting tube (b).

3. Shift the probe base into the insert (or the insert on the base), holding the mounting tool with the thumb (c) until the probe base slips below the mounting tool and connects to the insert (d).
4. Remove the mounting tool and fix the insert to the probe base using the included screws and screwdriver.

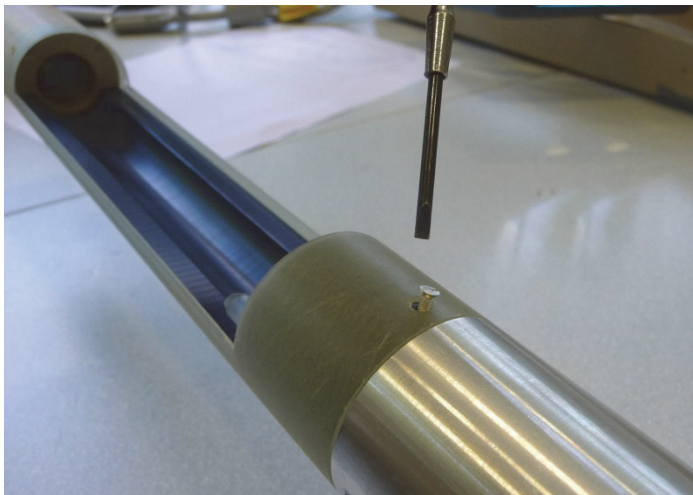


Figure 5.17: Fixing the MICWB40 Insert

5.3.2 Installation and Usage of the Quadrature Combiner

When 20-30 mm 1H quadrature probes should be used, an RF combiner is required to drive the quadrature coil. This combiner is actually a phase shifter which shifts the phase of the transmit signal for one channel of the quadrature probe to $+90^\circ$ and to -90° during the acquisition of the signal from this channel before the signals of both channels are combined. This indicates, that the combiner is a frequency depended device.



Figure 5.18: Combiner for MICWB40 Quadrature Probes

The combiner is controlled by the RGP send and receive signals of the preamplifiers. Thus the combiner needs to be connected to a free connector on the preamplifier flat cable. The combiner receives its power through this cable.

CAUTION



Material Damage Hazard due to Static Electricity

Failure to switch off the preamplifier prior to connecting the combiner to the flat band cable may result in damage to the cover module.

1. Be sure to disconnect the power cable or switch off the rack before connecting the combiner to the flat band cable.



Figure 5.19: Connection of the Combiner to the Preamplifier Flat Band Cable

The RF output of the preamplifier needs to be connected to the combiner input (RF Power IN), not directly to the probe. The probe must be connected to the TX-90°/RX90° and TX/RX 0° connector using two equal length N connector RF cables, whereas the correct wiring is essential. If the signal to noise in the NMR experiment is very low, the two cables between combiner and probe may have been swapped.

To wobble/tune the two RF channels in the quadrature probe, directly connect each channel of the probe to the preamplifier and wobble/tune each channel individually, before reconnecting the combiner.

5.3.3 Installation of the MICWB40 VT Kit

The installation of the VT Kit (Option No. PH2504) including the dewar, heater and thermocouple is easy and can be done within a few minutes.

1. Mount the guide for the dewar to the insert below the coil.

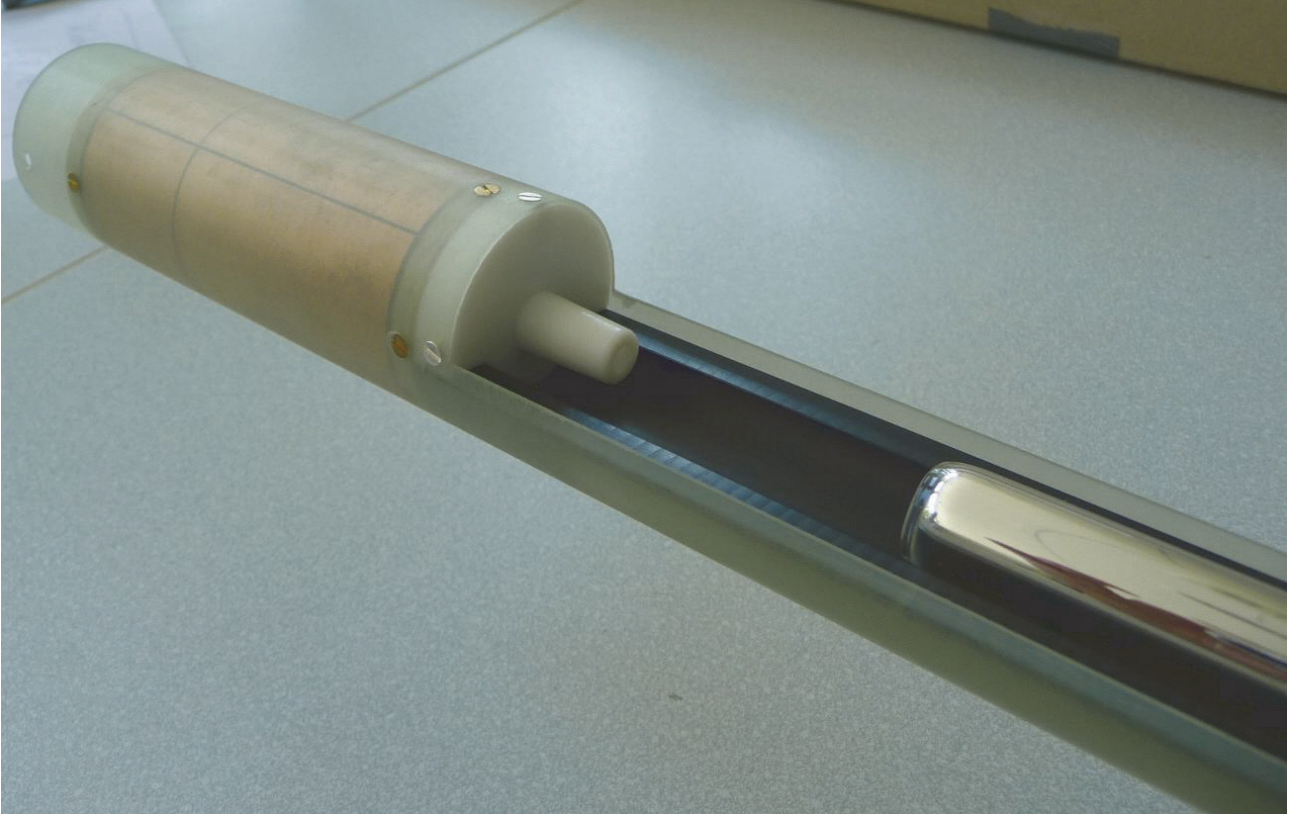


Figure 5.20: Dewar Guide Fixed with 3 Screws below the RF Coil and Dewar Shifted in from Probe Bottom

2. Shift the glass dewar in from the bottom of the RF probe. Do not fasten the dewar to the probe base!

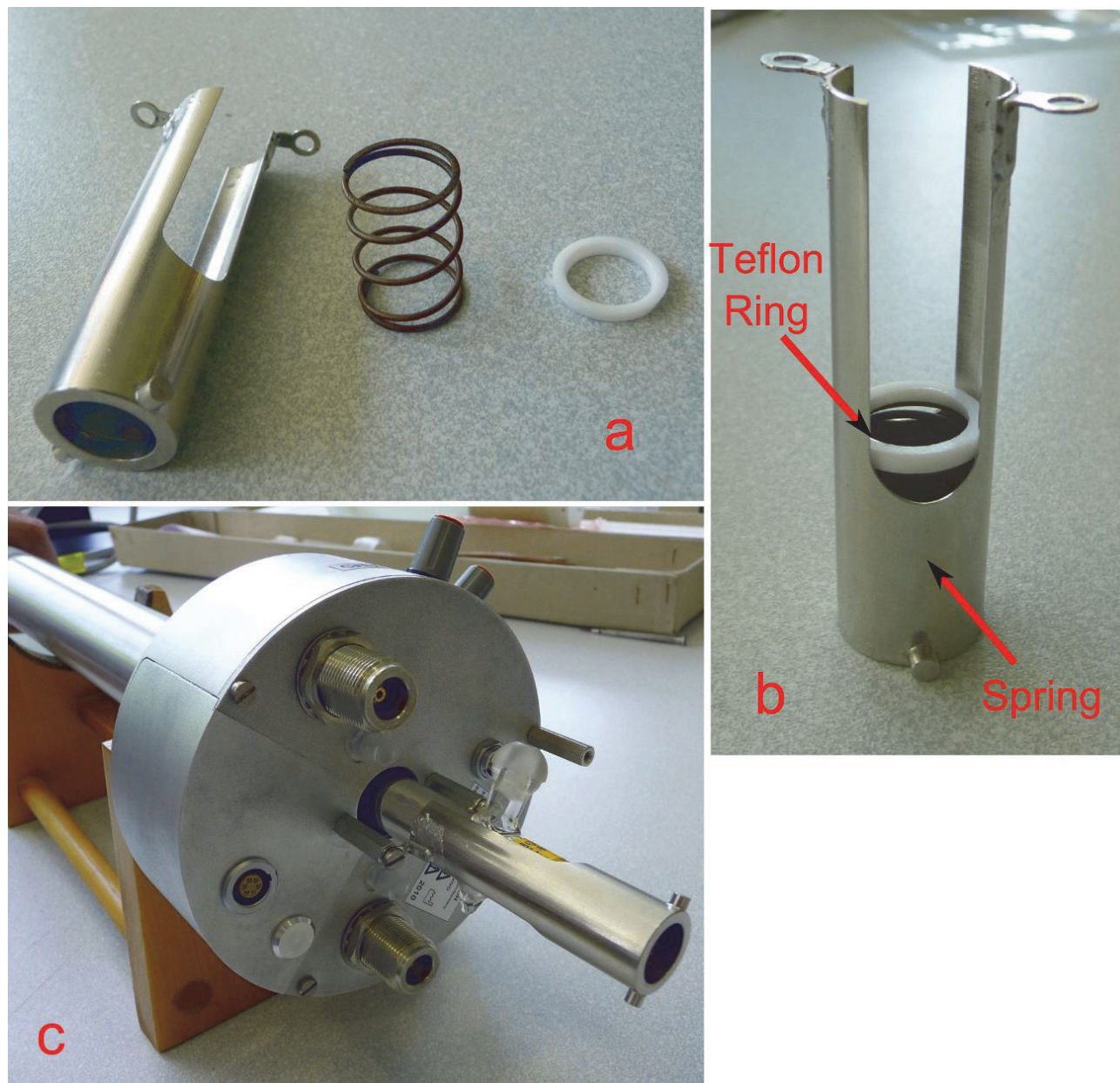


Figure 5.21: Bottom Mount with Spring and Teflon Ring to Protect the Glass Dewar

3. Insert the spring into the fixation, then the teflon ring to protect the glass dewar from the metal spring.
4. Screw the fixation with 2 screws from the bottom of the probe to fix the dewar.
5. Shift the heater/thermocouple in and fasten them using a bayonet lock.

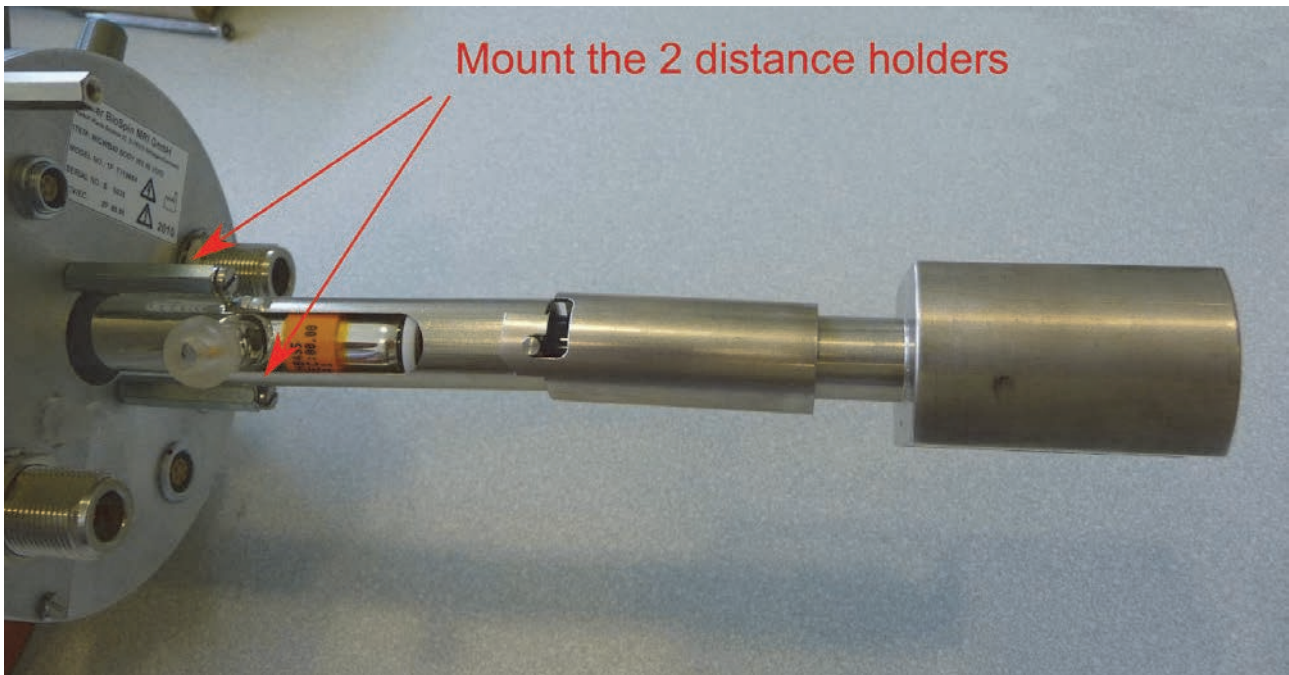


Figure 5.22: The Heater/thermocouple Shifted in and Fixed Using the Bayonet Lock.

6. Depending on the magnets height, the probe may need to be mounted in the magnet before the heater can be plugged in.

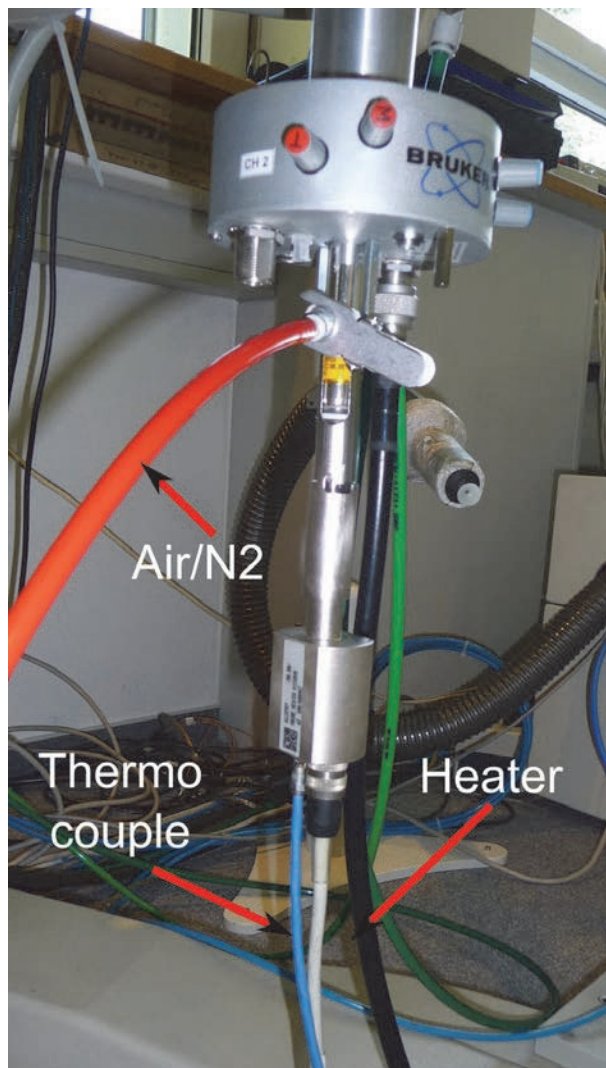


Figure 5.23: Probe with Heater Mounted in the Magnet and Connected to the BVT

For information on the installation of EVT inserts on the MICWB40 probe base, refer to the "MICWB40-EVT Manual".

5.4 Mini 0.5/0.75 System

The Mini 0.5/0.75 is a water cooled triple axis wide bore system which only fits into wide bore magnets (89 mm) or larger. The gradient coil and the RF part are mounted separately in the magnet, the gradient coil by means of a separate holder adapting it to the individual magnet. The RF part is mounted afterwards inside the gradient system. The Mini 0.5 and the Mini 0.75 gradient system have the same dimensions and only differ in the maximum reachable gradient strength. All parts of the Mini 0.5 and Mini 0.75 systems are compatible with each other, but not to any other micro-imaging system. The advantage of this system, compared to the Micro 2.5 and Micro 5 systems, is the larger sample space (up to 38 mm) and the flexibility for in-vivo and ex-vivo work, thus there are 2 different RF probes available to optimally adapt the system to the application.

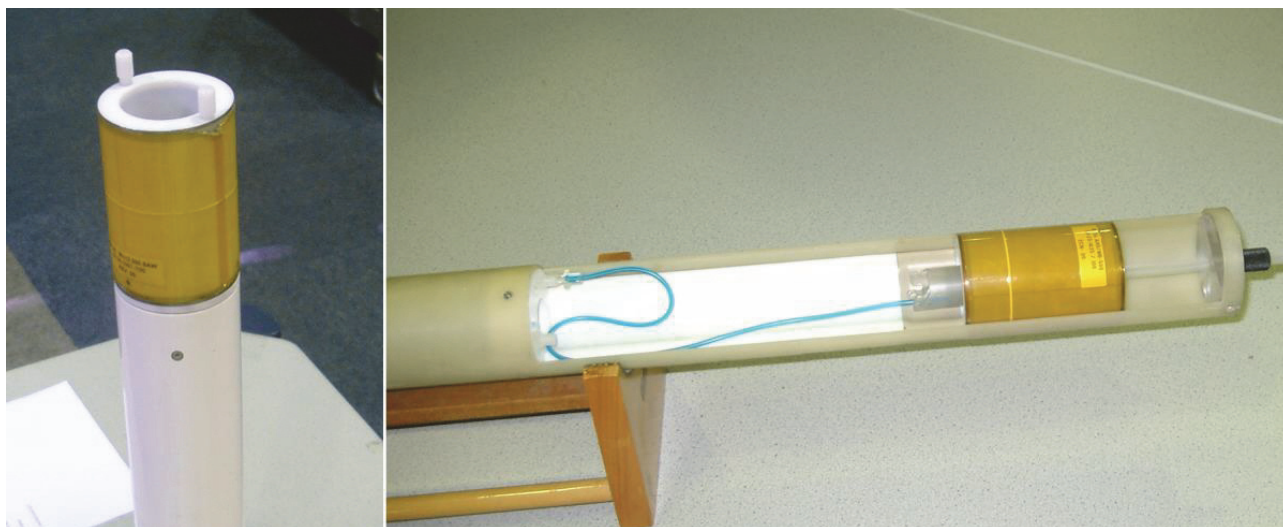


Figure 5.24: Mini 0.5/0.75 RF Probes.

On the left hand side of the figure above, a “Mini 0.5/0.75” is equipped with a 38 mm insert. The right image shows the “Mini 0.5/0.75 AHS-RF” probe equipped with an animal bed.

Micro 0.5/0.75 RF Probe

This is the most flexible RF probe for the Mini imaging system and enables in-vivo and ex-vivo work. It consists of a probe body which is designed for 2 RF channels. The exchangeable RF inserts cover a wide range of up to 38 mm ID double tuned RF inserts, which can be built as single frequency, dual frequency, or quadrature (bird cage) inserts. The Mini 0.5/0.75 RF system is equipped with a separate animal bed (for 38 mm RF inserts only), which can be pulled out of the RF probe from the bottom side. This allows the RF probe to stay in the magnet, while another animal is prepared in the animal bed outside of the magnet. It also allows repositioning of the animal in the RF probe from outside the magnet. The has the advantage of full animal support, with an animal bed to fix and position the animal, anesthesia support (breathing gas), and plug and play support for the SA-Instruments animal monitor system (supporting respiration, ECG and temperature control), see Digital Data Filtering and Analog Sampling [▶ 127].

Mini 0.5/0.75 AHS-RF Probe

This probe is dedicated to animal work. The exchangeable inserts are not mounted on top of the 2 channel probe, rather a bit further down. This allows to install exchangeable birdcage inserts up to 34 mm inner diameter that can be single frequency, dual frequency, or quadrature inserts. Additionally, this probe offers the possibility of plugging in surface coils that can be directly attached to the animal to increase the signal to noise of the experiment (currently no cross coil operation is supported). The probe offers the advantage of full animal support with an animal bed to fix and position the animal, anesthesia support (breathing gas), and plug and play support for the SA-Instruments animal monitor system (supporting respiration, ECG and temperature control), see chapter Digital Data Filtering and Analog Sampling [▶ 127].

For detailed setup parameters for the Mini 0.5/0.75 gradient system refer to chapter “Typical Gradient-Setup Parameters [▶ 179]”. For maximum duty cycles refer to chapter Typical Gradient Coil Parameters [▶ 178].

Gradient Systems and RF Probes

ParaVision System Status:	S057	
Gradient Inner Diameter:	57 mm	
Gradient Outer Diameter:	72 mm	
Gradient Cooling:	Water cooled.	
RF Shield:	Each RF Coil is separately shielded.	
Linearity: (±2% peak-peak)	XY: 43 mm Z: 30 mm sphere.	
Max. Gradient Current:	60 A	
Max. Gradient Voltage:	120 V	
Max. Gradient Strength:	Mini 0.5: 0.3T/m@60A = 30 G/cm@60A [0.5 G/(cm*A)] Mini 0.75: 0.45T/m@60A = 45 G/cm@60A [0.75 G/(cm*A)]	
RF Probes:		
	Mini0.5/0.75	Mini0.5/0.75 AHS-RF
RF Coils:	<ul style="list-style-type: none"> - Exchangeable Inserts. - 2.5-5 mm Solenoid. - 5-10 mm Saddle Coil. - 15-38 mm Birdcage Coil. <p>All coils can be single or double frequency⁽¹⁾ tuned, birdcages can be quadrature probes.</p>	<ul style="list-style-type: none"> - Exchangeable Inserts. - 2.5-5 mm Solenoid. - 5-10 mm Saddle Coil. - 15-34 mm Birdcage Coil. - 5-15 mm Surface Coil. <p>All coils can be single or double frequency tuned, birdcages can be quadrature probes.</p>
Temperature Control:	Animal temperature control by gradient cooling water temperature adjustment.	
Temperature Range:	10 °C to +50 °C by gradient cooling water temperature.	
Typical Applications:	Materials, Soil/Bore/Stone Samples, Flow Experiments, Mouse whole body or rat brain (Rats <190g).	Materials, Soil/Bore/Stone Samples, Flow Experiments, Mouse whole body or rat brain (Rats <190g), Surface coil applications.

Advantages:	<ul style="list-style-type: none"> - High flexibility for all kind of samples with big (38 mm) diameter, in-vivo and ex-vivo. - Sample positioning from outside the magnet. - Minimum 25 mm free access inner diameter. - Plug and play animal support. 	<ul style="list-style-type: none"> -All kind of samples, in-vivo and ex-vivo. -Minimum 25 mm free access inner diameter. -Plug and play animal support. -Surface coils.
	<p>The Micro 0.5/0.75 gradient systems provide a sufficient gradient strength for all applications where not the absolutely highest resolution is required. The advantages are in the possibility to investigate larger samples and the easier animal handling, compared to the smaller systems.</p> <p>The gradient coil remains in the magnet during probe/sample exchange. There is no need to disconnect it.</p>	
Drawback:	<ul style="list-style-type: none"> - Animal bed support only with 38 mm RF insert. 	<ul style="list-style-type: none"> - Non in-vivo samples more difficult to handle. - RF probe needs to be taken out from the magnet for sample exchange.

Table 5.6: Application Relevant Parameters of the Mini0.5/0.75 System

5.4.1 Assembly/Disassembly of the Mini 0.5/0.75 System

The assembly of the Mini 0.5/0.75 system consists of 2 basic parts, the gradient probe and the RF probe.

The gradient probe is typically assembled only once during the installation. The gradient probe consists of the gradient coil and the gradient base, which adapts the coil to the correct length for the systems magnet. The assembly is very easy and done in a few minutes.

1. Place the gradient coil on the table in such a way, that the brass ring points upwards.
2. Take the gradient base and lubricate the o-rings with some grease.
3. Place the base on the gradient coil and push it down with a moderate force, so that there is no gap between the brass ring and the probe base.
4. Fasten the gradient coil to the probe base using the 3 retaining screws.

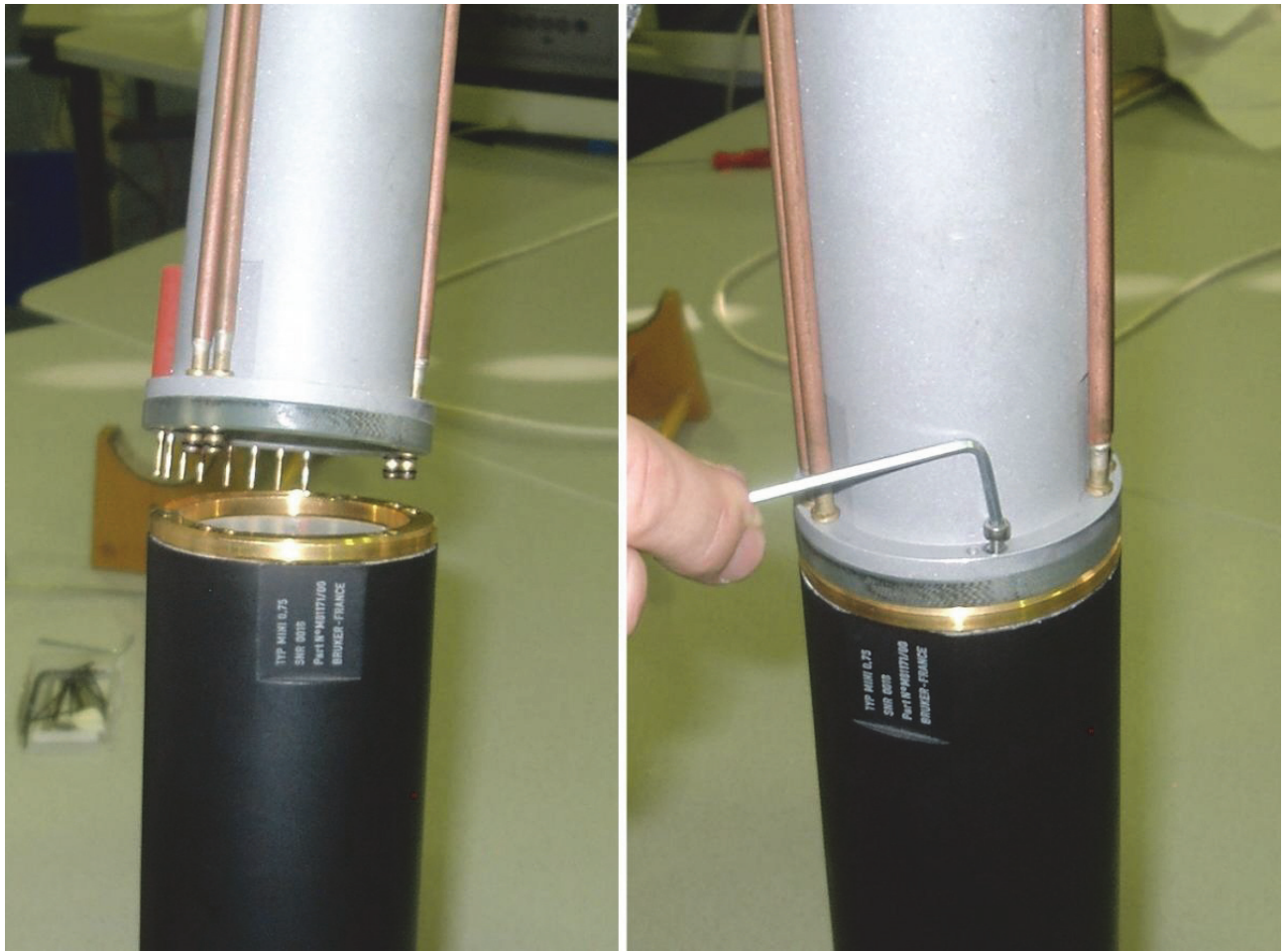


Figure 5.25: Mounting the Mini0.5/0.75 Gradient to the Base

5. Fasten the gradient to the bottom part of the shim system in the magnet using the four special screws. The screws need to be tightened using a non-magnetic screwdriver on the outer holes of the gradient probe base.
6. Connect the water hoses and gradient cable.



Figure 5.26: Mini 05/0.75 Gradient Mounted to a Magnet.

Note: In the figure above the image is the old gradient base. The new base has 4 additional screws arranged in a rectangular shape to fix the base without removing screws from the shim system. The image will be updated as soon as it is available.

The RF probe needs to be adapted, and as a consequence, changed for different sample sizes. The smaller the inner diameter of the RF coil, the higher the signal to noise ratio at a given sample.

The exchangeable inserts of the two Mini 0.5/0.75 probes RF probes need to be installed very carefully, since the tune and match trimmer are very sensitive.

Mini 0.5/0.75

1. Place the probe base on a table with the RF connections pointing upward.

There are 2 RF connections (gold-colored connectors) visible and four spring born bushings to adapt the tune and match trimmer rods of the individual insert. The trimmer rods are half cut off and used to align the rods of the insert with the bushings of the probe base.

2. Align the rods of the insert with the busings of the probe base and lightly press the rods into the bushings until a click is heard. If the rods don't slide easily into the bushing, rotate the tuning and matching rods a little forward and backward until the rods slide in.
3. Once the rods are inserted, fix the insert using the plastic screws.

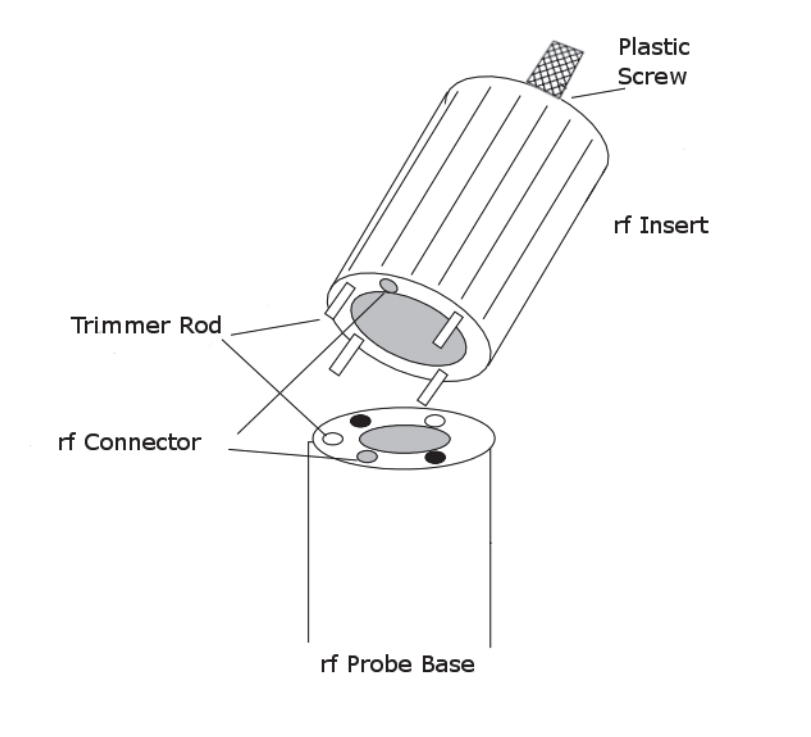


Figure 5.27: Schematic of a Mini 0.5/0.75 Probe Base and RF Insert

Mini 0.5/0.75 AHS-RF

The mounting of the Mini 0.5/0.75 AHS-RF inserts is even simpler compared to the mounting of a Mini 0.5/0.75 insert, since there are no screws to fix the insert.

1. Align the trimmer rods and the bushings as described in the previous section.
2. Lightly press the rods into the bushings until a click is heard. If the rods don't slide easily into the bushing, rotate the tuning and matching rods a little forward and backward until the rods slide in.
3. Once the click is heard, the insert must be pushed down until there is no remaining gap between the flange and the insert.

5.5 Mini SWB90 System

5.5.1 Overview

Several versions of SWB probes are available in combination with the BGA9SHP gradient/shim system.

Nucleus	Type	Inner Diameter
1H	Quadrature	66 mm and 40 mm
X	Linear	66 mm and 40 mm
1H/X	Linear	66 mm and 40 mm
others	On request	On request

Temperature Range:	-20°C to + 80° C
--------------------	------------------

The version of the probe is described on the label at the bottom of the probe.

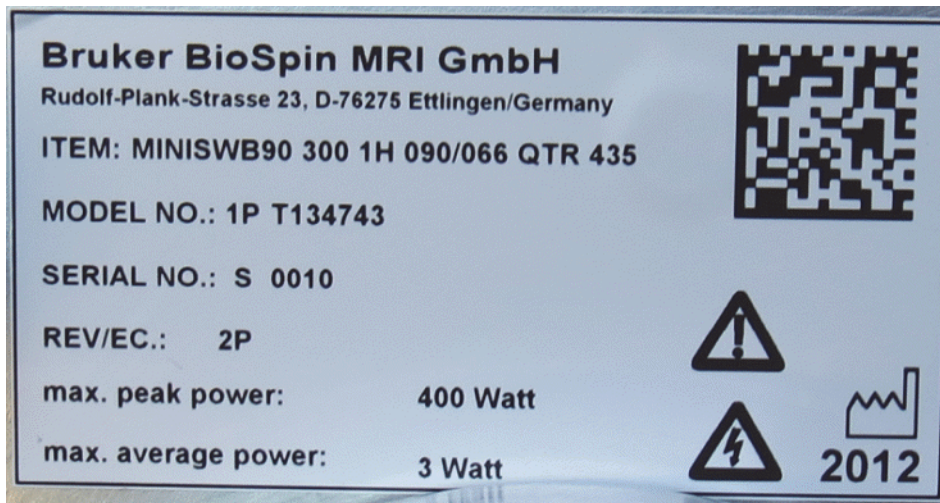


Figure 5.28: Probe Version Information

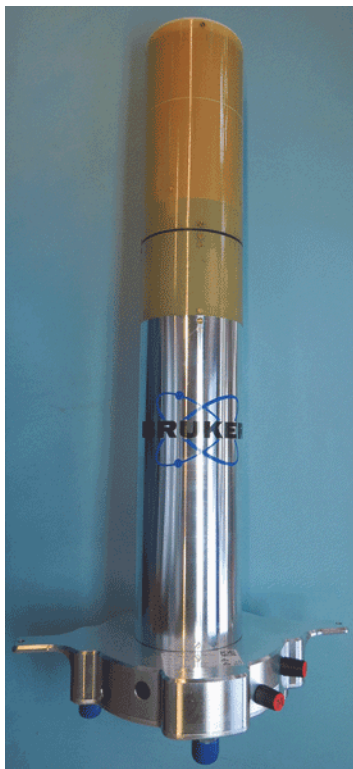


Figure 5.29: The 66 mm 1H Quadrature Probe

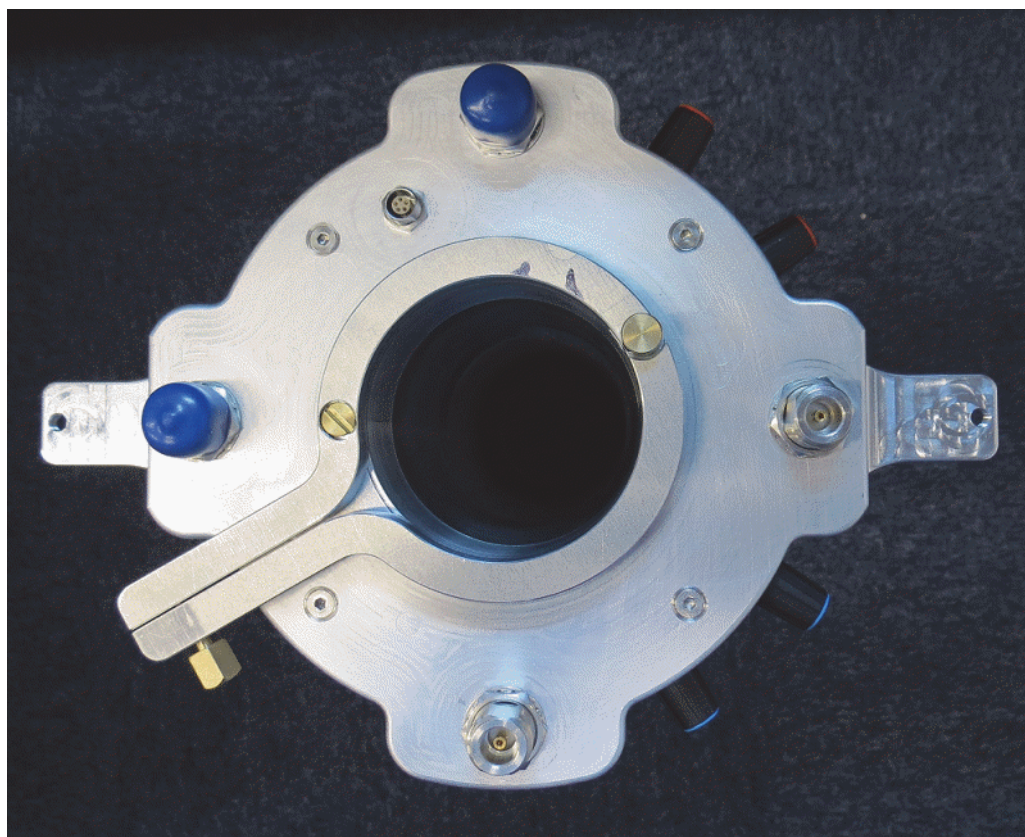


Figure 5.30: Bottom Plate of the SWB90 Probe

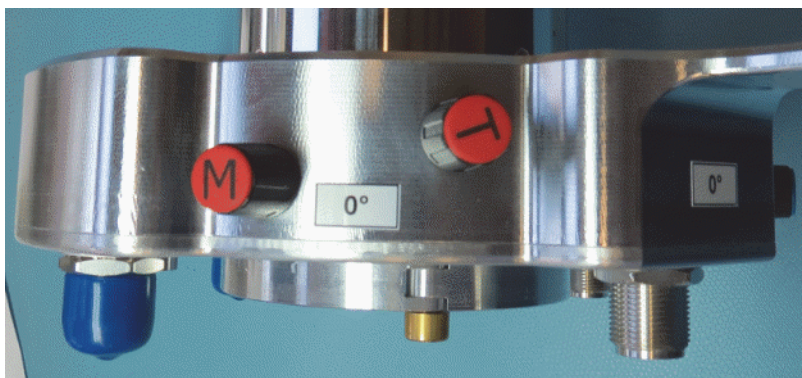


Figure 5.31: Knobs for the Tuning and Matching the two RF Channels

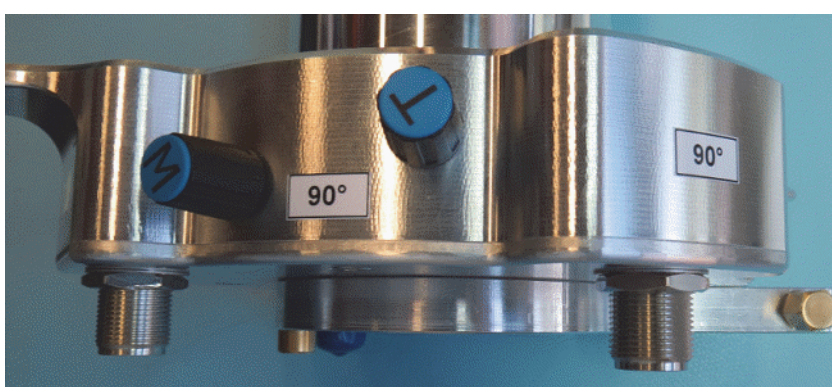


Figure 5.32: Knobs for the Tuning and Matching the two RF Channels

The bottom plate of the probe houses two N-connectors for two RF channels, a Lemo connector for the hardware information chip (HWIDS) and a clamping mechanics for the fixation of tubes and samples holders (not included in the probe delivery). Two other N-connectors are mounted, but not used and not connected.

Single frequency quadrature probes:

The two RF channels are used to connect the 0° and the 90° RF signals to the quadrature combiner/splitter.

Single frequency linear probes

Only the 1H channel is used for the RF connection to the preamplifier.

Double frequency probes

The 1H channel is used for the 1H connection, the X channel is used for the X nucleus.

5.5.2 Installation and Usage of the Quadrature Combiner

When $1H$ quadrature probes are used a frequency dependent RF combiner is required to drive the quadrature coil. This combiner has two different functions during the transmit and receive modes respectively.

In the transmit mode the unit splits the transmitter excitation pulse into two signals of equal intensity and shifts the phase of one signal by 90° . The two signals are connected to the probe to channel 0° and 90° . In the receive mode one of the NMR signals is shifted back by -90° and combined with the NMR signal of 0° phase shift before it is reaching the preamplifier.



Note: Incorrect wiring, e.g. swapping the channels leads to a poor signal to noise ratio.



Figure 5.33: Combiner for MICWB40 Quadrature Probes

The combiner is controlled by the RGP send and receive signals of the preamplifiers. Thus the combiner needs to be connected to a free connector on the preamplifier flat cable. The combiner receives its power through this cable.



Figure 5.34: Connection of the Combiner to the Preamplifiers Flat Band Cable

CAUTION



Material Damage Hazard due to Static Electricity

Failure to switch off the preamplifier prior to connecting the combiner to the flat band cable may result in damage to the cover module.

1. Be sure to disconnect the power cable or switch off the rack before connecting the combiner to the flat band cable.

Wobble Mode

To wobble/tune the two RF channels in the quadrature probe, directly connect each channel of the probe to the preamplifier and wobble/tune each channel individually, before reconnecting the combiner.

Operation Mode

The RF output of the preamplifier needs to be connected to the combiner input (RF Power IN), instead of directly to the probe. The probe must be connected to the 0° and 90° connector using two N connector RF cables of the same length, whereas the correct wiring is essential. Swapped wiring of the two channels leads to a poor signal intensity.

5.5.3 Cleaning

The cover of the probe can be damaged by some cleaning solutions.

Dry clean whenever possible.

Use mild cleaning solution in small quantities (i.e. ethanol).

Do not use aggressive cleaning solutions, e.g., acetone.

5.6 Mounting of the SWB Probe

1. Mount the SWB probe at the flange as shown in the picture below.

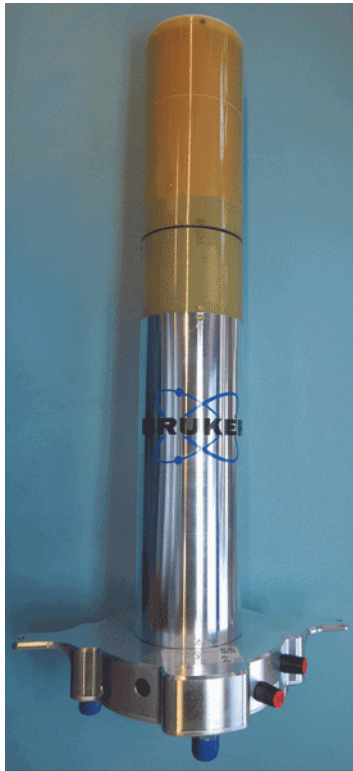


Figure 5.35: The 66 mm 1H Quadrature Probe

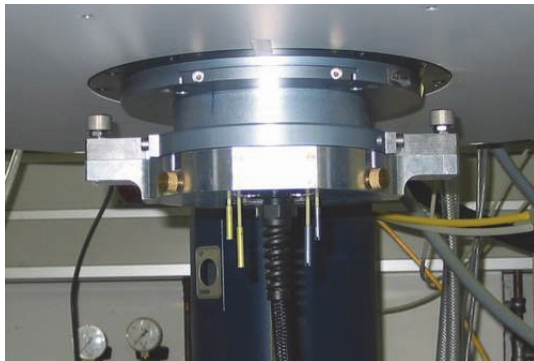


Figure 5.36: Fixation of the SWB Probes (part 1)

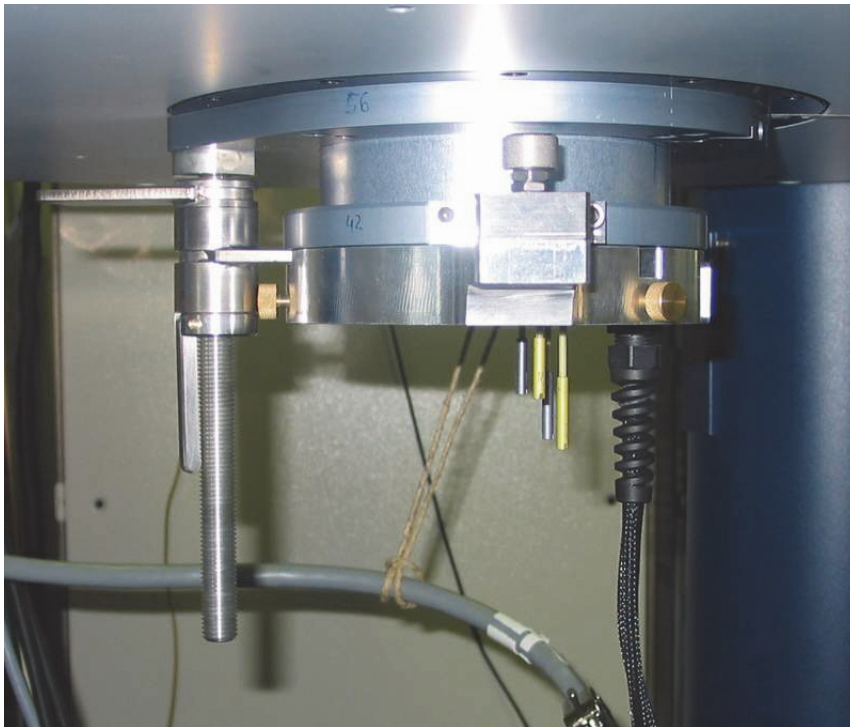


Figure 5.37: Fixation of the SWB Probes (part 2)

2. Mount the sample into the plastic tube and fix it with the brass screws.

6 ParaVision 5 Software Setup

This chapter only focuses on the micro-imaging dedicated points of the ParaVision 5 software installation. For general information refer to the set up document 'PvInstGuide50.pdf' found in the root directory of the ParaVision 5 DVD.

6.1 Installation of the ParaVision 5 Software

After mounting the ParaVision 5 DVD, the software installation can be started using the script 'install'. The standard 'MRI with acquisition, processing and automation' option can be selected for the installation. During the installation only two points need special attention:

- ParaVision 5 should always be installed in a 'ParaVision' directory, never in a 'TopSpin' directory. This allows ParaVision 5 and TopSpin to be installed parallel on a system, without any interferences between both.
- The NMR super user must not be 'root'. Always select 'nmrsu' as NMR Super User.

After the software installation has finished, typically a reboot of the computer is required. It's also a good idea to reboot the console at this time.

6.1.1 Setup of ParaVision 5

ParaVision 5 should be started the first time as NMR super user using the command `<$PvHome>/paravision`, where `<$PvHome>` is the selected installation path.

cf

ParaVision recognizes that it is being started the first time and automatically opens a dialog, whereas 'cf' (the TopSpin configuration) should be started. This 'cf' routine is identical to the original TopSpin routine, the only point which is special for micro-imaging is that the BCU20 should be connected to tty04 in the window, where the serial connections are specified. After 'cf' is finished verify in the protocol created by the 'cf' command that the DPP was found connected to the gradient controller.

expinstall

During 'expinstall' (refer to the next figure) be sure to select in the upcoming window:

- High Resolution Systems.
- Micro-Imaging Systems (installs the TopSpin imaging and diffusion programs).
- Biospec/Pharmascan Systems (these are the ParaVision imaging programs).

Leave everything else unaffected and only select 'OK' or 'Next'.

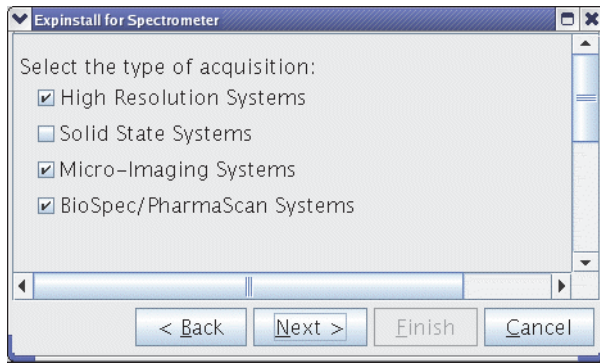


Figure 6.1: The expinstall Selection for Micro-imaging Systems

Creation of standard coil configurations'

In this dialog (accessible after the uxnmr.info window showed up) click 'Create' to generate default coil configurations for single tuned 1H and X probes.

Edit & Save Config

For the ParaVision specific parameters refer to the figure below. On AVANCE III systems typically only the institute name needs to be changed and the system status adapted to the installed gradient system (Micro 5 = S019, Micro 2.5 = S040, Mini 0.5/0.75 = S057).

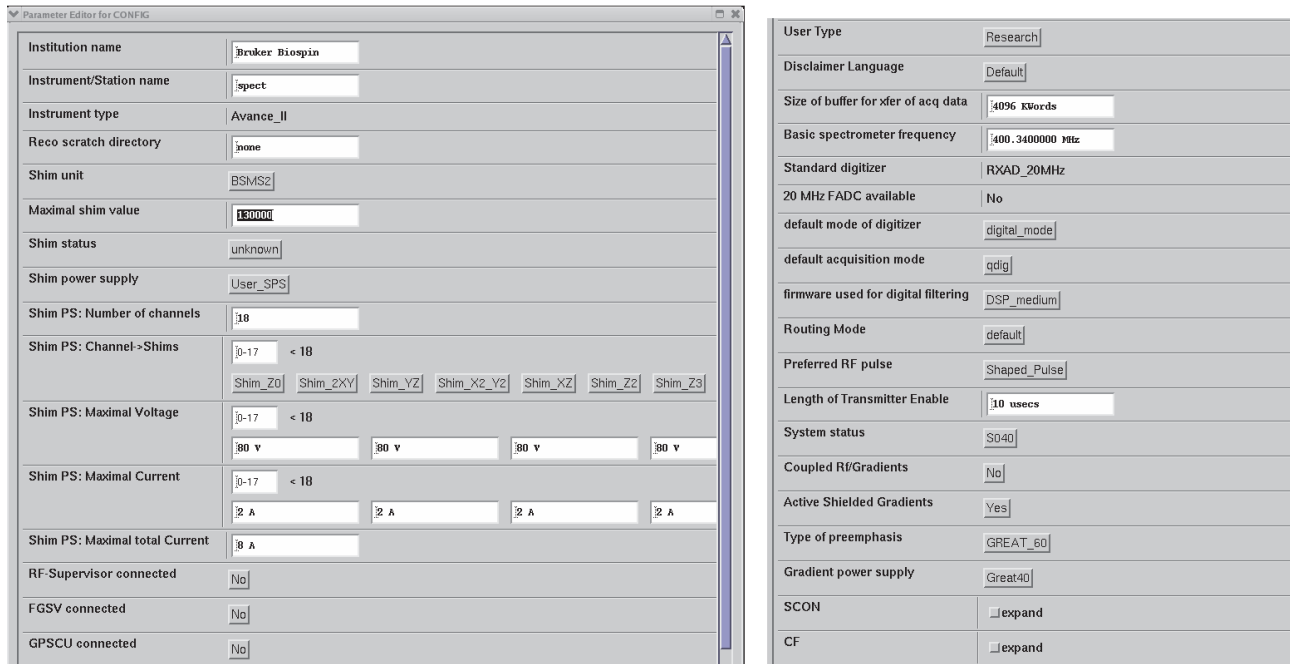


Figure 6.2: Typical 'Edit & Save Config' for Micro-Imaging AVANCE III Systems

6.1.2 Setup of the Gradient Timing Resolution

The gradient timing resolution needs to be set up manually. As default, every 10 μsec a new gradient value is calculated by the DPP and transferred to the Master Unit. This value is used on BioSpec systems, but on micro-imaging systems, 8 μsec are required due to technical reasons. To change the timing resolution edit the file `<$PvHome> /conf /instr /spect /uxnmr.par` as `nmrsu` and set:

```
##$GRADRES=8
```

At the same time the DPPFAC factor in the same file can be set to 1 (not used with the BGMUI-E/Great hardware).

```
##$DPPFAC=1
```

Restart TopSpin/ParaVision and type "ii restart" in the TopSpin command line to restart the DPP.

6.1.3 Micro-imaging Add-on CD

The 'Micro-imaging Add-on CD' contains continuously updated features like gradient default files, additional macros, methods, or au programs. If this CD is not available send an e-mail to `micdiff@bruker.de` to receive the CD or a tar file by e-mail.

To install the add-ons:

1. Shutdown ParaVision 5 and be sure to be logged in as NMR-Super User.
2. Mount the CD.
3. Start the script `<$CDROM>/PV5/m_install` (or unpack the tar file in e.g. `/tmp` by the command `'tar -xvzf pv5adds.tar.gz /tmp'` and start `/tmp/PV5/m_install`).
4. Follow the screen instructions.

This will install the additional methods (all additional method names start with `mic_`), au programs, macros, protocols, gradient coil default files and the newest diffusion scripts.

The Add-on CD contains the following features:

- ParaVision Add-ons [▶81]
- TopSpin Add-ons [▶83]

6.1.3.1 ParaVision Add-ons

ParaVision Updates (for PV5.0 only)

MapShim: Update for MapShim on BSMS systems.

Routing: Update for the routing editor for systems with QNP switch.

iposerver: Fixes a CORBA problem during 'ii restart'.

Extra Manuals:

Fast Map, micro-imaging manual and HWIDS manual.

Firmware:

Recommended BGMUI Master Unit and HWIDS firmware.

Methods:

mic_chess: Chemical shift selective spin echo imaging, based on MSME.

mic_flash: Like the original FLASH but with MinEchoTime mode.

mic_msme: Like the original MSME but with MinEchoTime mode.

mic_rare: Like the original RARE but with MinEchoTime mode.

mic_seflow: Spin Echo velocity imaging (see FLOWMAP manual for details).

mic_gradcalc: Calculation of the gradient calibration.

mic_inverse: Cyclic cross polarization ¹³C imaging/spectroscopy.

mic_jpress: J-resolved 2D localized spectroscopy.

mic_icosy: 2D localized COSY spectroscopy.

mic_preemp: Traditional preemphasis adjustment method.

Protocols:

mic_chess: Chemical shift selective imaging protocol.

mic_flash_3D: 3D gradient echo imaging protocol.

mic_flash_ortho: 3 orthogonal slice, gradient echo.

mic_flash_ortho_multislice: 5 parallel slices from 3 ortho. Planes, gradient echo.

mic_msme_1e_ortho: 3 orthogonal slice, single spin echo.

mic_msme_8e_ortho: 3 orthogonal slice, 8 spin echoes from each slice.

mic_rare_32e_3D: 3D RARE protocol, 32 echoes per scan.

mic_rare_32e_ortho: 3 orthogonal slices, RARE sequence 32 echoes per scan.

mic_spinecho_3D: 3D spin echo protocol.

POSITION_Z_40mm: Positioning protocol, FOV is 40 mm in Z direction.

Shim_SWH_30k_td4k: Shim protocol, bandwidth 30 kHz, 4096 points per FID.

snapshot_FISP_cine_16fr: Cine protocol based on FISP, 16 cine cycles.

snapshot_FISP_T1inv: T1 Inv. Rec. protocol based on FISP in FID mode.

True_FISP_T1inv: T1 Inv. Rec. protocol based on FISP in TRUEFISP mode.

Macros:

mic_CalcRFamp: Calculate the pulse power for shaped pulses from a hard pulse.

mic_convert_2dseq2csv_multi: Convert all slices of a data set to cvs.

mic_convert_2dseq2csv_scale: Convert a parameter image to float csv.

mic_Derive_X: Derivation of an image along X.

mic_Derive_Y: Derivation of an image along Y.

mic_multigop: Start multiple experiments (clone or prepared data sets).

mic_rheo: Control for the Rheo controller.

mic_setpre: Start Setpre in hardware mode, not in cache mode (default in PV).

mic_rfTest: SNR and z B1 calculation for the standard SNR procedure.

AU programs:

CreateScaledCSV: Used by the macro mic_convert_2dseq2csv_scale.

m_teready: Used by the macro mic_multigop.

Lock Up tables:

mic_flow_black: LUT optimized for flow imaging, velocity 0 is black.

mic_flow_white: LUT optimized for flow imaging, velocity 0 is white.

mic_grey_nonLin20: Non linear grey LUT to improve contrast.

mic_grey_nonLin50: Non linear grey LUT to improve contrast.

mic_grey_nonLin80: Non linear grey LUT to improve contrast.

mic_ParameterImg: LUT for parameter images, e.g. T2 maps.

6.1.3.2 TopSpin Add-ons

TopSpin AU Imaging Programs:

lmadd; imcti; imflow; imft3d; imftms; imge3d; imgess; imgrad; impoff; impoff3d; impon; improve; imse3d; imsems; imsesshs; imslice: AU programs for imaging experiments in TopSpin.

6.1.4 Installation of RF Inserts Specific Parameters

For each MicWB40, insert a CD containing routing and power limit information for this individual coil (HWIDS) is delivered. All CD's need to be installed on the system to allow the user, to select the RF insert in use from the software dialog.

The procedure to install the parameters is described in the document 'Microimaging_RFInsert_Installation.pdf', which can be found on every CD.



Figure 6.3: HWIDS Data File CD for Each Individual MicWB40 Insert

6.1.5 License File Installation and Troubleshooting

ParaVision 5 needs a floating license for ParaVision 5 and for TopSpin 2 to run properly. This requires the correct entries in the license file and 2 license daemons running. The installation is described in the ParaVision 5 manual, thus here only the most important issues and a few tips about troubleshooting will be presented.

The license file is installed in `/usr/local/flexlm/Bruker/licenses/license.dat`. The following lines are an example of some lines of a ParaVision 5 license file.

```

1  SERVER image501 001018142992 1700
2  DAEMON bruker_ls /usr/local/flexlm/Bruker
3  DAEMON bbmri_ls /usr/local/flexlm/Bruker
4
5  INCREMENT PVSTARTUP bbmri_ls 5.000 15-oct-2010 1 \
6  ISSUER=00304870aa811e1flllmlCFgjjZlloloHoSPjjF4E6QK5Qw4i \
7  SIGN="00E2 128C 12FB 664E FE52 400A 8C3B F400 13F0 8936 AFB7 \
8  D229 22D4 8D0C B98E"
9  INCREMENT PVDATMAN bbmri_ls 5.000 15-oct-2010 1 \
10 ISSUER=00304870aa811e1flllmlCFgjjZlloloHoSPjjF4ExKQ9K3i \
11 SIGN="0016 3A78 39C8 133F 6E50 77D1 5D73 4500 4384 3942 A58F \
12 AC94 FADE 335D 0BB6"
...

```

1st Line: The entry 'image501' must be the name of the computer, identical to the output of the command 'hostname'. 'hostname -f' must deliver the full qualified domain name, e.g. 'image501.service.bruker.de'. If this behavior is different on the computer, check the network setup. Be sure that the case of the computers name is correct. The best solution is to keep everything in lower case letters, since some Windows based DHCP servers only return the name in lower case.

1st Line: The entry after the computer name must be the eth0 MAC address of the computer. This MAC address is in the output of the command '/sbin/ifconfig eth0' and can be found after the key word 'HWaddr' (i.e. HWaddr 00:10:18:14:29:92). The network port where the license is accessed is 1700.

2nd and 3rd Line: The license daemons and where they can be found. These 2 daemons always need to run, otherwise the licenses are not activated. To check if they are running enter 'ps -ef | grep _ls', and the output should be like:

```
flexlm 2811 2805 0 Mar20 00:00:00 bruker_ls -T image501 9.2 3 -c /usr/local/flexlm/Bruker/licenses/license.dat -p --lmgrd_start 47e23a1a
flexlm 2812 2805 0 Mar20 00:00:00 bbmri_ls -T image501 9.2 3 -c /usr/local/flexlm/Bruker/licenses/license.dat -p --lmgrd_start 47e23a1a
```

If one or both processes are missing, check if the daemon executable's are in the correct directory and have the correct attributes:

```
/usr/local/flexlm/Bruker/bbmri_ls r-xr-xr-x
/usr/local/flexlm/Bruker/bruker_ls r-xr-xr-x
```

If this is the case, try to restart the daemons using the command '/etc/init.d/bruker_lmgr restart', and check the log file /usr/local/flexlm/Bruker/licenses/flexlm.log for possible problems.

5th Line: This is the license part for a feature, in this case 'PVSTARTUP'. The next entry 'bbmri_ls' indicates that this feature needs the 'bbmri_ls' license daemon to run. The following number '5.000' is the ParaVision version, for which this license feature is valid, and hereafter the date of expiry can be found ('15-oct-2010'). The final '1' indicates, that this is a floating license (node locked licenses are no longer generated).

7 Gradient System and Amplifier Setup

The exact setup of the gradient systems and gradient amplifiers are prerequisite for distortion free and geometrically precise images, as well as correct diffusion values. Since the Great gradient amplifier is a current regulated amplifier, its regulation parameters need to be adapted to each individual coil. The gradient coil is assembled extremely precisely, however even the smallest misalignment of individual gradient coil parts causes unwanted distortions in the system, which need to be compensated. Finally, the correct absolute gradient strength at a given current is mandatory for the display of the exact dimensions of an object. Thus the setup of the gradient amplifiers and the gradient coils are split into different parts. Each part must be repeated for every available gradient system/gradient amplifier combination. The complete setup must be performed, even for different maximum current output stages of the Great amplifiers.

The retrieved parameters for a gradient amplifier/coil combination are entered in 'setpre', the gradient parameter program and stored in a gradient coil specific file in <\$PvHome>/exp/stan/nmr/lists/preemp/<SystemStatus>/default. <SystemStatus> is the status, which is selected in "Edit&Save Config", see Setup of ParaVision 5 [] 79]. As a consequence, whenever the gradient coil is changed the 'System Status' in "Edit&Save Config" must be set to the corresponding value, to enable ParaVision to load the correct coil specific gradient amplifier/ coil parameters.

The 'setpre' is the same in ParaVision and TopSpin, however it behaves differently in each mode, which often results in confusion. Here are the main differences between the TopSpin and ParaVision Mode:

	ParaVision Mode	TopSpin Mode
Parameters displayed at 'setpre' Startup:	Always be sure to select File->Read Default' when entering the PV mode.	The parameters which are currently set in the hardware, not the values in the 'default' file.
Displayed System Status:	'System Status' from 'Edit&Save Config'.	The 'edhead' number of the selected probe.
Location for the file storage:	<\$PvHome> /exp /stan /nmr /lists /preemp /<SystemStatus> /default	<\$PvHome> /exp /stan /nmr /lists /preemp /<#edhead> /default
Parameter Upload to the Hardware:	When the arrow 'Upload into Hardware' in the 'setpre' GUI is clicked. If a ParaVision experiment runs and the parameter 'GS_typ' is set to 'Preemphasis', ParaVision automatically loads the 'setpre' values to the hardware whenever necessary.	Immediately when a parameter is changed.
'setpre' Start:	Spectrometer Control Tool->Tools Preemphasis or TopSpin Command Line: 'setpre -cache -system SystemStatus [-debug]' [-debug] option for more info in <\$PvHome>/prog/log/setpre.log	TopSpin Command Line: setpre [-debug] [-debug] option for more info in <\$PvHome>/prog/log/setpre.log

Table 7.1: Different 'setpre' Behavior in ParaVision and TopSpin Mode.

Before the adjustments can be started, the desired current output stage for the Great Amplifiers must be set. The stage defines the max. output current at 100% input signal. Typically in imaging the highest possible stage is set (40 A for the Great 40 or 60 A for the Great 60), but for diffusion probes or to operate HR gradient probes, it might be necessary to lower the maximum output current of the amplifiers.

To set the output stage: Open 'setpre' by selecting 'SpectrometerControlTool → Tools → Adjust Preemphasis Values'. For this procedure, any data set can be selected. Since 'setpre' is the same piece of software in ParaVision and in TopSpin, the 'setpre' window opens in the TopSpin window.

At the current stage drop down selection, select the desired output stage (blue mark in the figure below) and store the setting by 'SetPre->File->Write default' before closing 'setpre'.

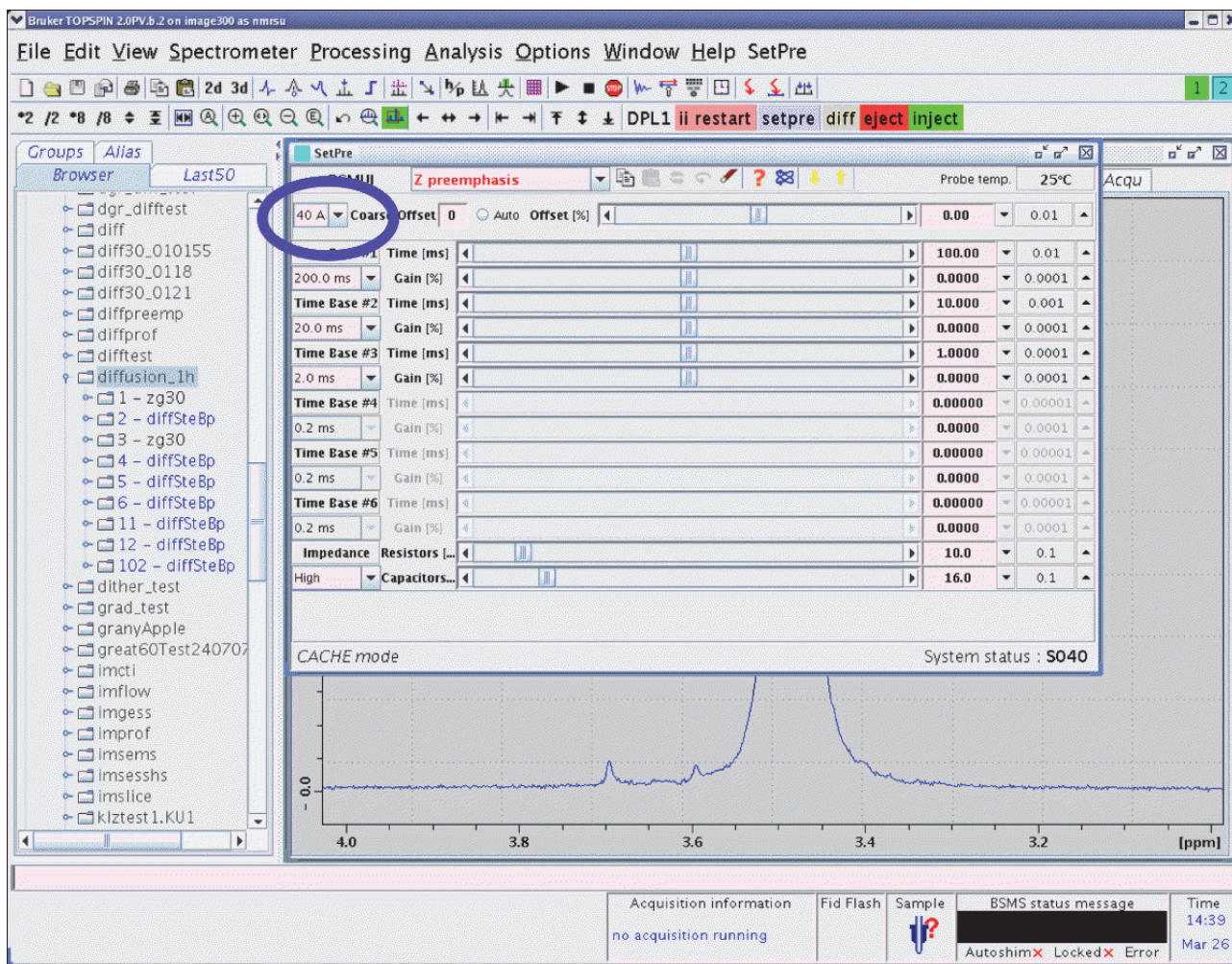


Figure 7.1: Setpre in TopSpin Window, the Output Current Stage Selector Marked in Blue.

7.1 Gradient Safety Parameters

In order to avoid hardware damages to the gradient coil from too much gradient power, the applied electrical energy is monitored and compared with coil specific values. The monitoring is performed by the Master Unit using the current and voltage monitoring signals from the GREAT amplifiers which are AD converted (25 μ sec dwell time) and used by a DSP for the power calculations.

Since this security is essential, the master unit stops its booting process and displays a 'C01' message, while it waits for the power limits for the selected system status.

These parameters have to be entered in the 'setpre' program and downloaded into the Master Unit each time the gradient system is changed or the Master Unit was switched off.

To enter the values open 'setpre' by clicking 'SpectrometerControlTool → Tools → Adjust Preemphasis Values'. The 'setpre' opens in the TopSpin window. Note the additional 'SetPre' menu entry in the TopSpin Window which allows accessing the setpre parameters (red mark in the figure below).

To open the dialog for the safety parameters (gradsafe) select 'SetPre → Edit → Gradient safety parameters'.

The screenshot shows a dialog box titled 'GradSafe' with a table of parameters for X, Y, and Z axes. The parameters include Max Voltage [V], Max Current [A], Coil Resist. [Ω], Power Sum [W], Mean Power [W], Resistors [%], Capacitors [%], Impedance, Adjustable Integ. Time [ms], Integ. Time Power Sum [W], and Integ. Time Mean Power [W]. An 'Apply' button is located at the bottom right.

	X	Y	Z
Max Voltage [V]	100.000	100.000	100.000
Max Current [A]	40.000	40.000	40.000
Coil Resist. [Ω]	0.390	0.480	0.360
Power Sum [W]	172.000	172.000	172.000
Mean Power [W]	82.900	82.900	82.900
Resistors [%]	10.000	10.000	10.000
Capacitors [%]	16.000	16.000	16.000
Impedance	High	High	High
Adjustable Integ. Time [ms]	100.0	100.0	100.0
Integ. Time Power Sum [W]	172.000	172.000	172.000
Integ. Time Mean Power [W]	83.000	83.000	83.000

Figure 7.2: GradSafe Dialog to Enter the Gradient Safety Parameters

Max. Voltage [V]:	Maximum output voltage of the amplifier
Max. Current [I]:	Maximum current for the selected gradient system.
Coil Resist. [Ω]:	DC resistance of the individual gradient coil.
Power Sum [W]:	Maximum power applied to the complete gradient system within 1 second (Eq. 2-1 [▶ 20] on page 2-3 [▶ 20]).
Mean Sum [W]:	Maximum power applied to one gradient direction within 1 second (Eq. 2-2 [▶ 20] on page 2-3 [▶ 20]).
Adj. Integ. Time [ms]:	Time interval for a short term power monitoring.
Integ. Time Power Sum [W]:	Maximum power applied to the complete gradient system within 'Adj. Integ. Time' (Eq. 2-1 [▶ 20] on page 2-3 [▶ 20]).
Integ. Time Mean Pow. [W]:	Maximum power sum applied to one gradient direction within 'Adj. Integ. Time' (Eq. 2-2 [▶ 20] on page 2-3 [▶ 20]).

Note:

The equations for determining these parameters can be found in Security Features [▶ 20].

Table 7.2: Parameters

The parameters for the individual gradient systems can be found in chapter Typical Gradient-Setpre Parameters [▶ 179]. These values must not be exceeded! Typically the same power limits are used on all three gradient channels.

If the "micro-imaging Add-on CD" is installed as described in the section Micro-imaging Add-on CD [▶ 81], the safety parameters already have the default values. If the parameters are changed be sure to save the values with 'SetPre → File → Write default' before closing 'setpre'.

As described above, the master unit stops with the boot process and displays a 'C01' message, until the 'gradsafe' parameters are loaded. There are several possibilities to load these parameters:

- | | |
|----------------|---|
| In ParaVision: | <ul style="list-style-type: none"> a) ParaVision automatically downloads the 'gradsafe' parameters from the default file at each experiment start (GSP/GOP/TrafficLight). b) A manual download is possible when 'setpre' is opened and the 'Upload into Hardware' arrow is clicked, or when 'Apply' in the 'gradsafe' dialog is selected. |
| In TopSpin: | <ul style="list-style-type: none"> a) Only the manual download is possible. Open 'setpre' and select 'Apply' in the 'gradsafe' dialog. |

See also

- 📖 Loop Regulation Adaptation [▶ 92]

7.2 Great Offset Adjustment

Each gradient amplifier has a small DC offset, which should be compensated. This can be done under software control with the Great 1/40 and Great 1/60.

To compensate the offset, open 'setpre' in the TopSpin window, by clicking Spectrometer Control Tool → Tools → Adjust Preemphasis Values. Please recognize the additional 'SetPre' menu entry in the TopSpin menu bar which allows accessing the setpre parameters (red mark in the figure below).

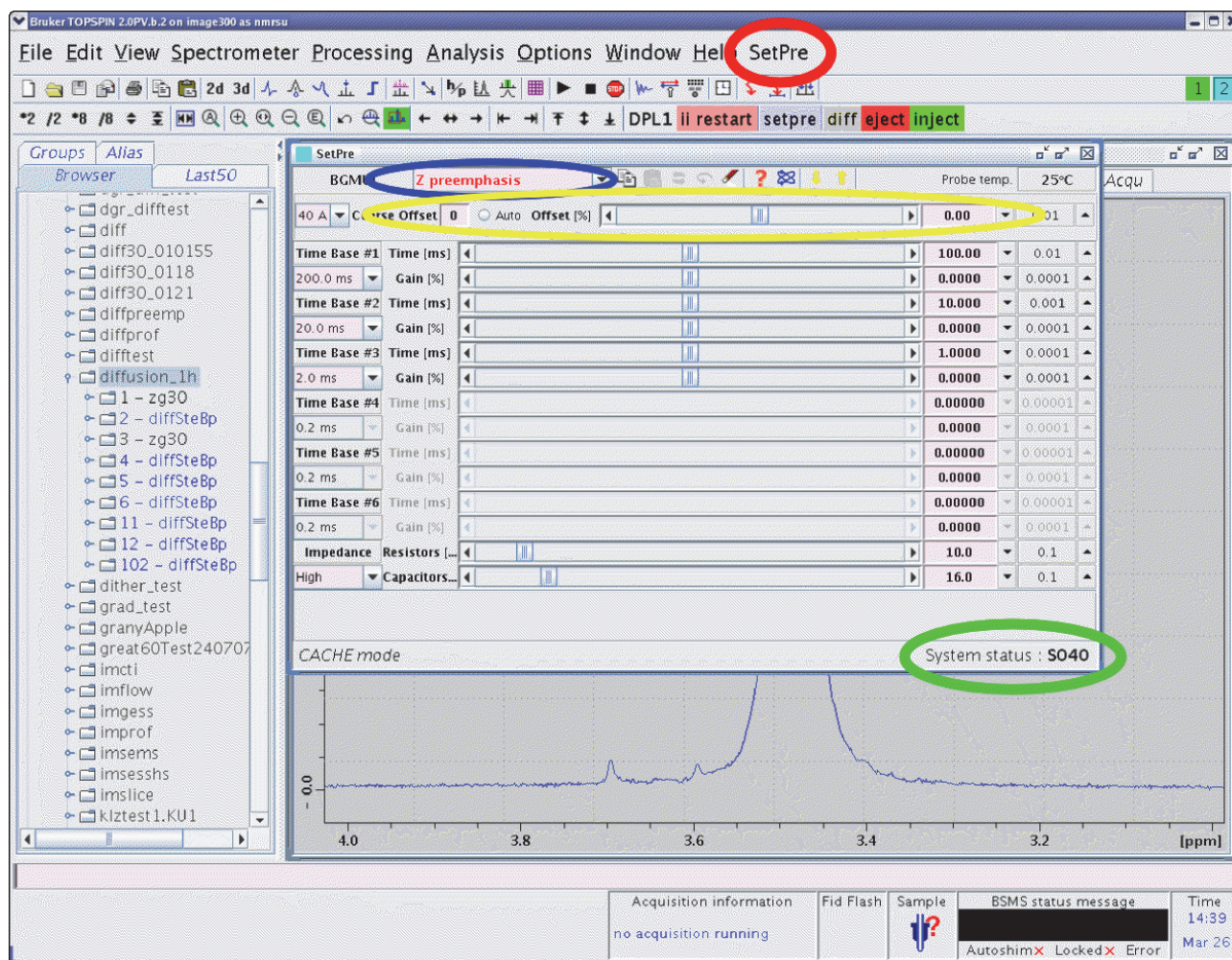


Figure 7.3: Setpre in TopSpin with Marked Offset Adjustment Features.

For Great 1/60 amplifiers W1209612 ECL \geq 9 or W1215323 ECL \geq 0, and for Great 1/40 amplifiers W1211690 ECL \geq 5, or W1215322 ECL \geq 0 the offset adjustment is very simple. If the internal blanking is used (gating for the Greats from the master unit) nothing has to be rewired. When the external blanking is used (gating of the Greats from the IPSO T0 connector), the BNC cables at the Great gating inputs need to be disconnected temporarily. The 'Coarse Offset' for the above mentioned amplifier generation is always 0, so after selecting the desired amplifier by the channel pull down menu (blue mark in figure above) (x/y/z-Preemphasis) the offset can be automatically adjusted by clicking the 'Auto' button. The offset must be adjusted for each gradient direction individually.

If the ECL of the amplifiers is lower than the above mentioned, the 'coarse offset' must be adjusted before the 'Fine Offset' can be adjusted. For this reason, a data set needs to be set up. Refer to the ParaVision Manual 'System Control Tool -> Help -> Getting Started' for details about the data set creation.

NMR Sample:	5 or 10 mm NMR Tube filled with 20% H ₂ O 80% D ₂ O and 1g/l CuSO ₄ or another T1 shortening relaxant. Filling height 40...50 mm.
Data Set Name:	GreatSetup
Protocol Name:	m_installation/mic_ampoffset
Recommended Coil Routing:	"Transceiver 1H 100W"
Frequency BF1:	On resonance.
Shim:	Line width <20 Hz at 50% amplitude, Greats disabled.
RF Gain:	<<90°
Receiver Gain:	---

Table 7.3: Parameters Setup for the Great Offset Adjustment

1. Disable the Great amplifiers by disconnecting the gradient cable from the gradient probe.
2. Shim the sample as good as possible in GSP mode. The easiest way to shim is to observe the integral of the FID and note this value, when the shimming is finished.
3. Reconnect the gradient probe and be sure that the master unit enables the Great amplifiers (Reset button...).
4. Restart the GSP, the FID will decay faster and the integral of the FID will be smaller due to the DC offset of the amplifiers, which acts as linear shims.
5. Adjust the coarse offset of all channels. Select the desired amplifier by the channel pull down menu (blue mark in the previous figure, x/y/z-Preemphasis) and change the coarse offset for the selected amplifier until the FID integral becomes maximal (like shimming).

Typically these 'Coarse Offset' values are between -4 and -6. If the coarse offset adjustment is performed for all amplifiers, the experiment can be stopped.

6. Adjust the fine offset by selecting the desired amplifier by the channel pull down menu (blue mark in the previous figure) (x/y/z-Preemphasis) and automatically adjust the offset by clicking the 'Auto' button for each individual gradient direction.
7. As soon as the adjustment is finished for all directions are sure to save all the values with 'SetPre->File->Write default' before closing 'setpre'.

7.3 Loop Regulation Adaptation

Create a new data set. The recommended setup parameters for the Great loop adaptation are listed in the table below.

NMR Sample:	---
Data Set Name:	GreatSetup
Protocol Name:	m_installation/mic_blankcheck
Recommended Coil Routing:	"Transceiver 1H 100W"
Frequency BF1:	---
Shim:	---
RF Gain:	---
Receiver Gain:	---

Table 7.4: Parameters Setup for the Great Loop Adaptation

Gradient System and Amplifier Setup

Be sure to have the correct system status selected in 'Edit & Save Config'.

The protocol will load a parameter set, which runs a 1 msec gradient with equal polarity on all 3 gradient channels every 450 msec.

It is recommended to check the currently set parameters before the adjustment is started.

1. Open 'setpre' by selecting SpectrometerControlTool → Tools → Preemphasis Adjustment.
2. Verify that the system status in setpre is the same as the select system status in 'Edit&Save Config' (green mark in the figure below).

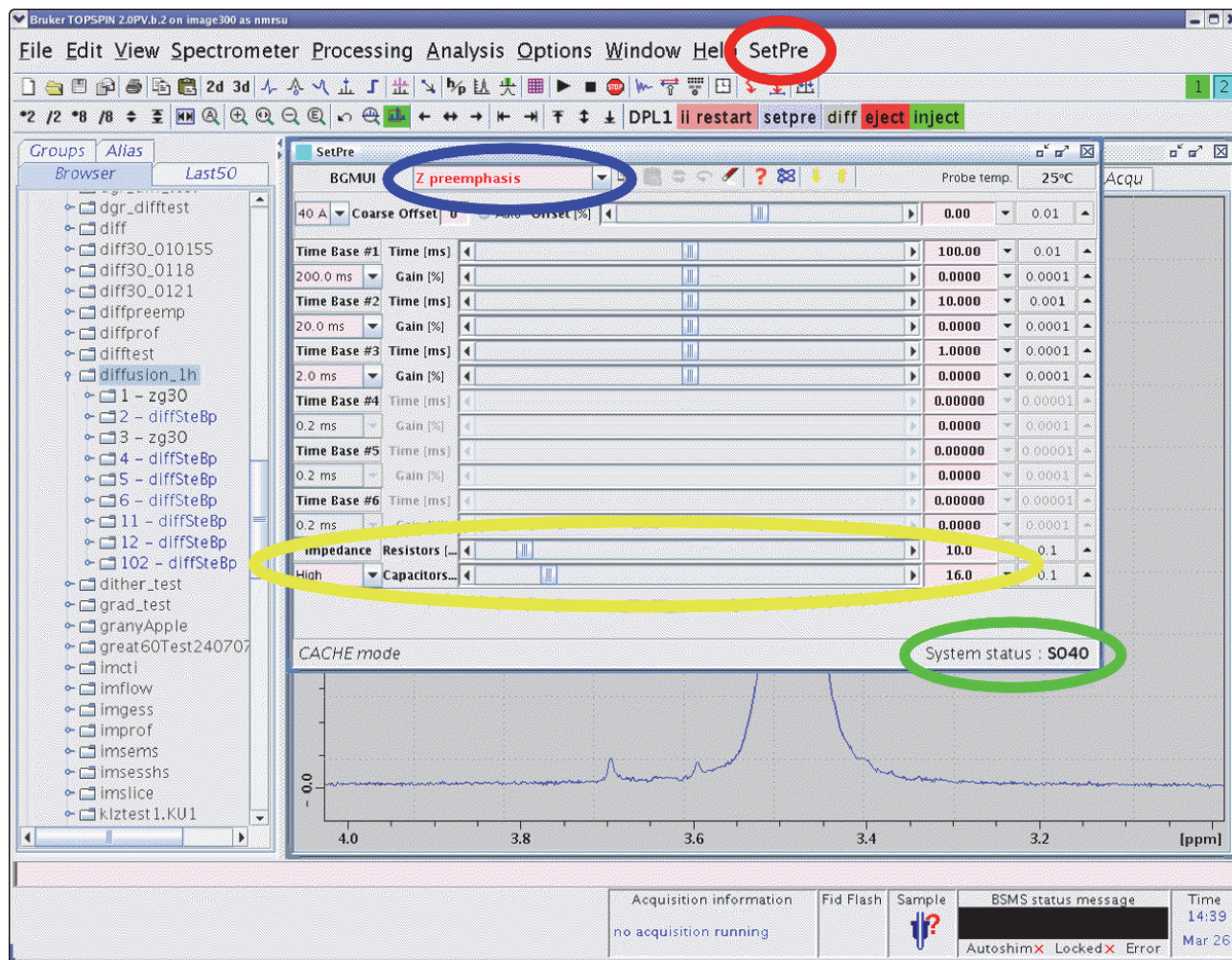


Figure 7.4: The setpre' in TopSpin for the Loop Adaptation

3. Check the ramp time and rise time for the selected gradient coil by opening SetPre → Edit → Ramp parameters. The values should be set to those listed in the table Typical Gradient-Setpre Parameters [179].
4. When the values need to be modified, be sure to select SetPre → File → Write default.



When the "micro-imaging Add-on CD" is installed as described in Micro-imaging Add-on CD [81], the parameters already have their default values.

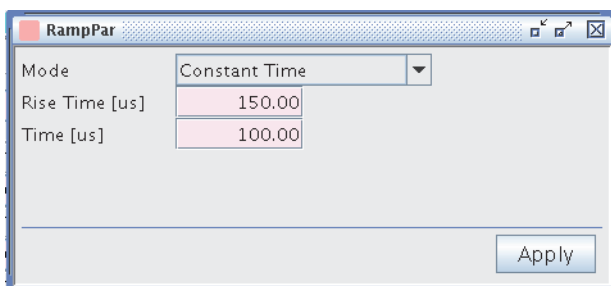


Figure 7.5: Ramp Parameter Dialog. The Parameter 'Time' is the Ramp Time

5. Check the loop values in the last 2 lines of the 'setpre window' (see yellow mark in the setpre figure). These lines are only visible in 'setpre' after they are enabled under 'SetPre →Options →Loop Parameters' when logged-in using the NMR super user password. There are 3 parameters which are responsible for the adaptation, whereas one, the Impedance, is always set to 'HIGH'.
6. Check the 'Resistors' and 'Capacitors' parameters, which are derived from an analog PID regulator. The values, which are displayed for the selected gradient system, should not differ too much from the default values in the table Typical Gradient-Setpre Parameters [179], since they are tested for a long time. Small changes might be necessary for the individual gradient system.

NOTICE

Material Damage Hazard Due to Amplifier Oscillation

Be aware that too small values for the 'Resistors' and 'Capacitors' might cause the amplifier to oscillate, which kills the gradient coil within milliseconds. If you have an unknown gradient system be sure to start from high values for 'Resistors' and 'Capacitors', going down to find the optimum adaptation

7. Find the optimum adaptation by selecting a gradient direction in the blue marked pull down menu (x/y/z Preemphasis) and connect an oscilloscope to the 'I-Mon' current monitor of the selected amplifier (be sure not to connect the scope to the 'U-Mon' voltage monitor), which triggers in 'Norm' mode.
8. As soon as everything is set up as described, the experiment can be started by the 'GSP' button in the spectrometer Control Tool.

The shape of the gradient must be checked on the oscilloscope, while the resistors and capacitors sliders are manipulated. Going to higher values for resistors and capacitors leads to longer current rise times (see the following figure), the desired current might not even be reached.

Gradient System and Amplifier Setup

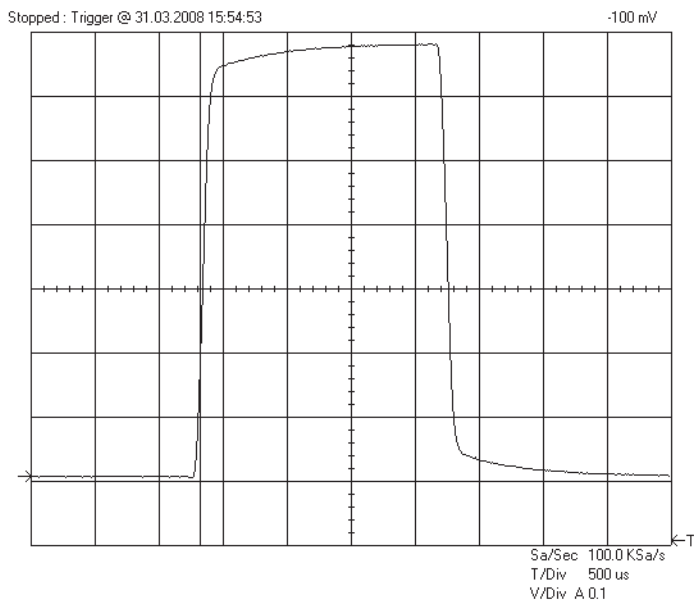


Figure 7.6: Gradient Pulse with High “Resistors/Capacitors” Values, Leading to a Slow Regulation Behavior.

Going to smaller values decreases the rise time of the gradient shape, which may lead to an overshoot of the current (see the next figure). If the values are lowered even more, the amplifier might start to oscillate!

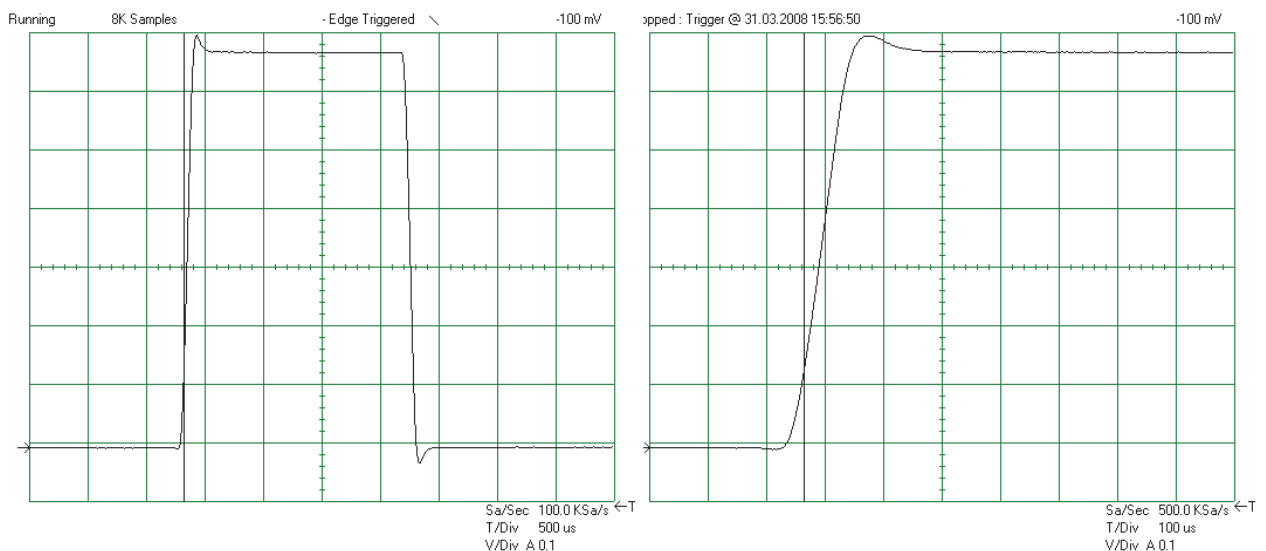


Figure 7.7: Gradient Pulse with low “Resistors/Capacitors” Values, Leading to a Current Overshoot

The best regulation values are those, where the overshoot just begins. With these values, no overshoot appears and on the other hand the values guarantee the fastest possible rise time. Optimal adaptation is shown in the next figure.

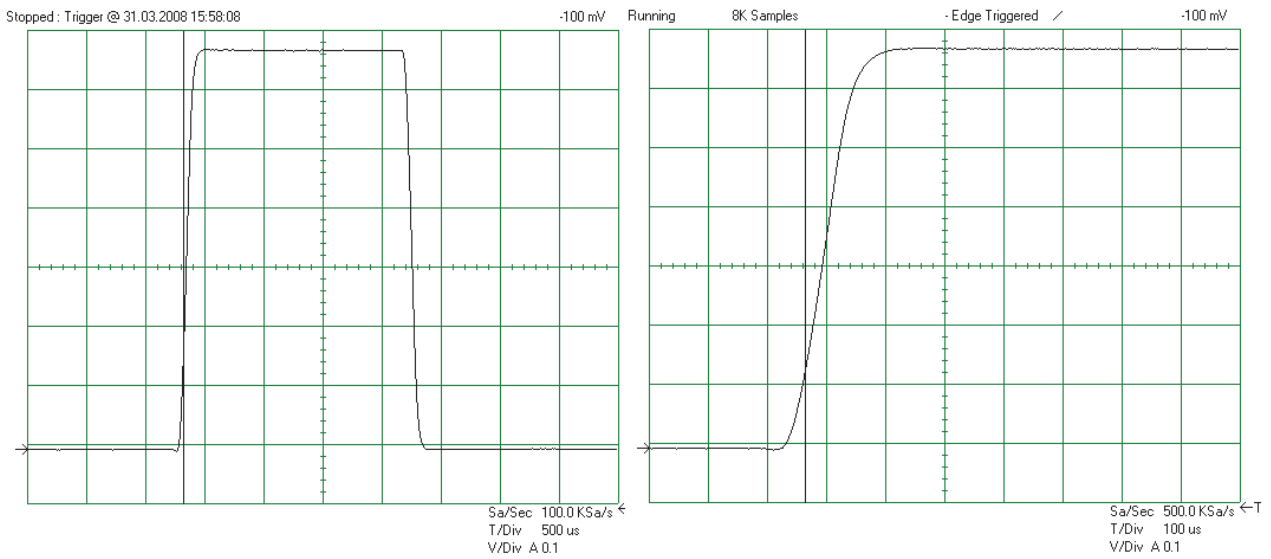


Figure 7.8: Optimal Adjusted Loop Values Leading to the Fastest Raise Time without Current Overshoot

The optimal values have to be adjusted for all gradient amplifiers and all gradient systems. However, for one gradient system the values for x, y, and z will not differ much. If the adaptation is finished for each individual direction of a gradient system, be sure to save all the values with 'SetPre →File →Write default' before closing 'setpre'.

7.4 Preemphasis Adjustment

The preemphasis of each individual direction of a gradient system needs to be setup carefully to acquire distortion free images with the highest possible signal to noise ratio. Preemphasis distortions can result in stripes in multi echo images, ghosts in multi gradient echo images or broad lines in NMR spectra.

To adjust the preemphasis of a gradient system, create a new data set. The recommended setup parameters for the preemphasis adjustment can be found in the table below.



Be sure to have the correct system status selected in 'Edit & Save Config'.

Gradient System and Amplifier Setup

NMR Sample:	5 or 10 mm NMR tube filled with 20% H ₂ O, 80% D ₂ O, and 1g/l CuSO ₄ or another T1 shortening relaxant. Filling height 40...50 mm.
Data Set Name:	Great setup
Protocol Name:	m_installation/ mic_preemp_50msec_33pc_X/Y/Z
Recommended Coil Routing:	Transceiver 1H 100W.
Frequency BF1:	1000 Hz offset from resonance frequency.
Shim:	Line width <20 Hz at 50% amplitude.
RF Gain:	<<90°
Receiver Gain:	---

Table 7.5: Parameters Setup for the Great Preemphasis Adjustment

The protocol will load a parameter set, which runs a 50 msec gradient with 33% of the maximum current on the X/Y/Z gradient channels every 450 msec. The time between the gradient and RF is incremented 8 times from 300 μ sec to 300 msec to visualize the effect of residual magnetic fields by eddy currents on the FID. As a consequence, it takes 8*450 msec to show the result of the measurement.

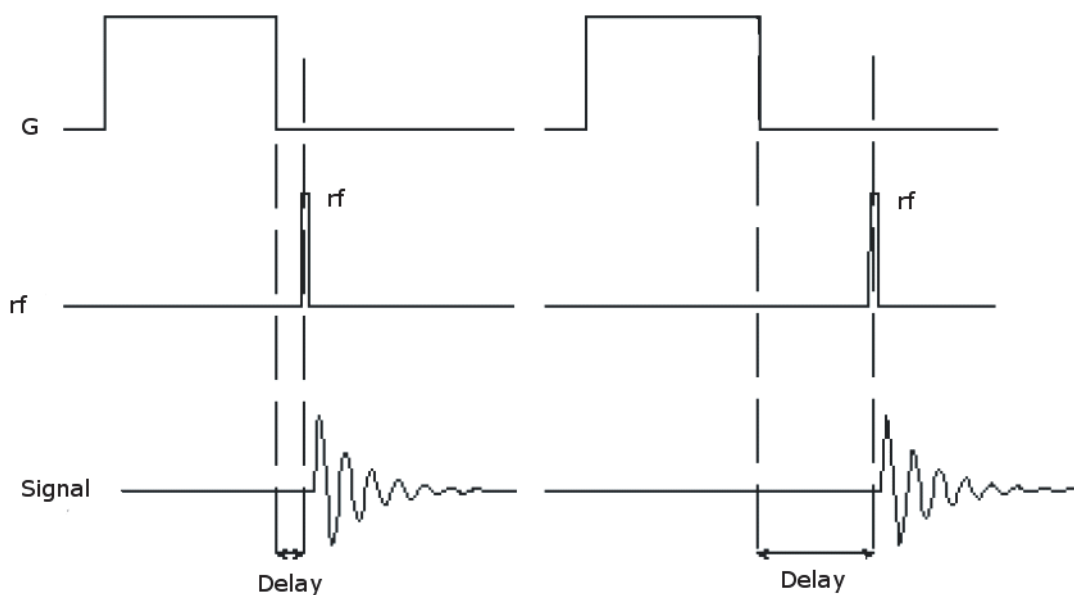


Figure 7.9: Preemphasis Experiment with Varying Delays Between Gradient and RF Detection.

As a prerequisite, the loop parameter of the gradient system/amplifier must be set correctly for the Preemphasis Adjustment [► 96].

1. Open 'setpre' select Spectrometer Control Tool → Tools → Adjust Preemphasis Values'.
2. Check the 'System Status' in 'setpre' to be the same as the select system status in 'Edit & Save Config' (green mark in the figure below).

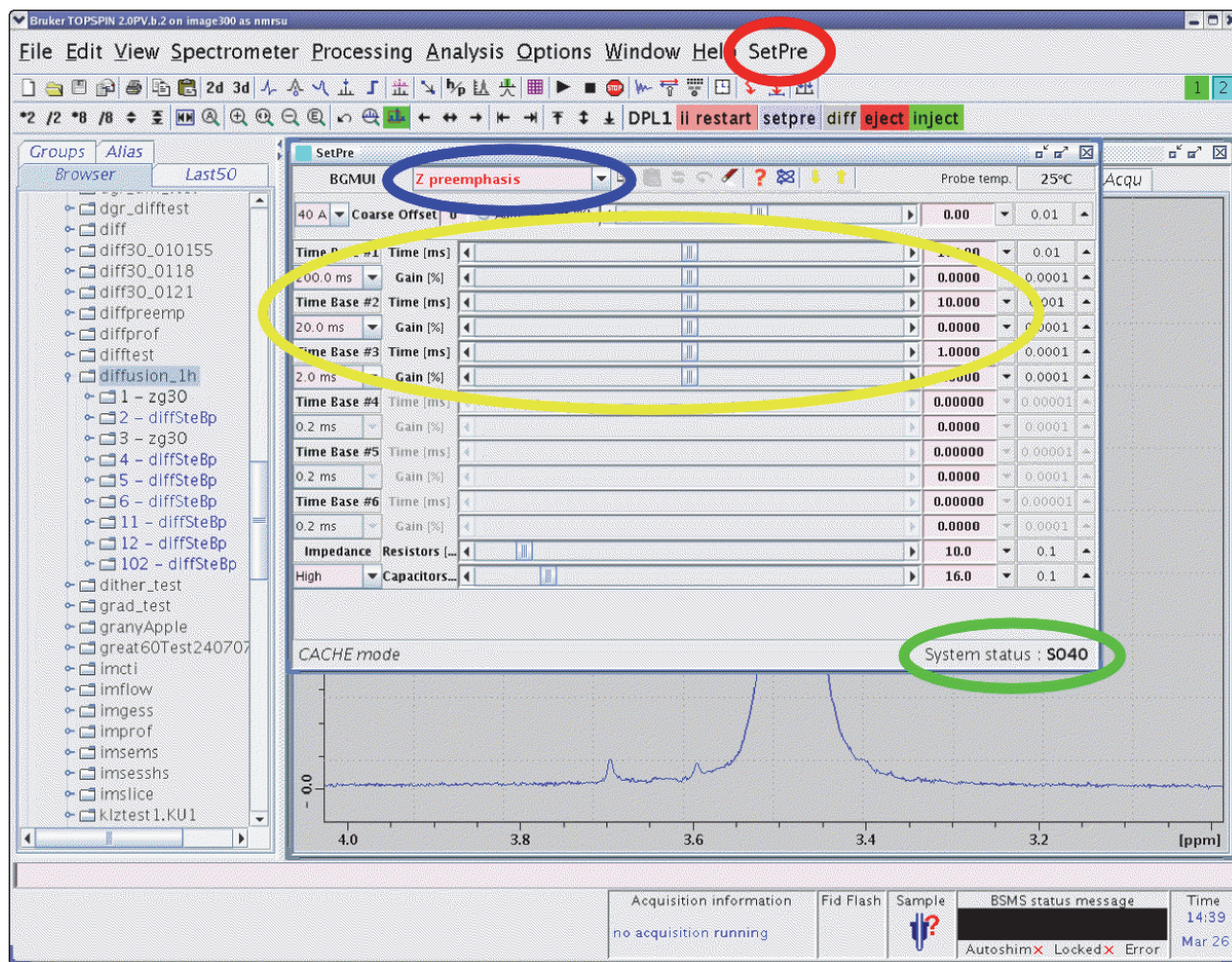


Figure 7.10: The setpre in TopSpin for the Preemphasis Adjustment

3. Check and modify the preemphasis values as necessary in the first 6 lines of the 'setpre window' (see yellow mark in the figure above).

The parameters are always formed from 2 lines that describe an exponential current decay, which is added to the actual gradient shape (see the following figure). In this configuration, three exponentially decaying currents (if GRADRES is ≥ 10.0 μsec (see Setup of the Gradient Timing Resolution [▶ 81]), 6 time constants are available) with individual amplitudes and time constants can be added to the gradient shape, to compensate for eddy currents with different amplitude and decay behavior. The 'Time Base' in front of each amplitude/current slider pair limits the longest possible time constant for this exponential decay. For example, a compensation term with "Time=1msec" and "Gain=10%" adds an exponentially decaying current with an amplitude of 10% of the gradient amplitude. The 10% amplitude is decayed to $1/e$ (approx. 36%) after 1 msec.

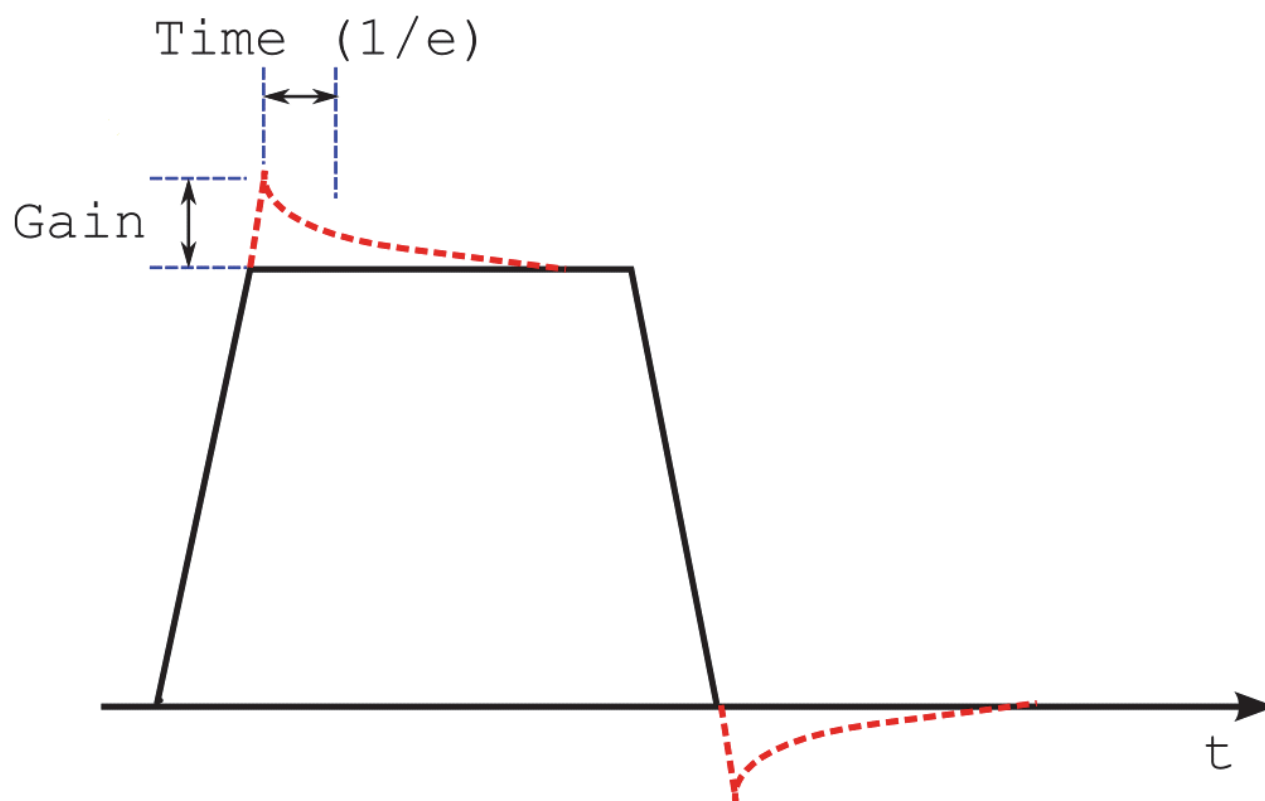


Figure 7.11: A Gradient Shape (black) with 1 Preemphasis Term (red)

The goal of this adjustment is to have all 8 FID's acquired with the above preemphasis protocol look the same, and respectively to have the same FID integral. It can be said, that after 300 msec no eddy current is present any longer. So the most right FID is the reference to which all other FID's need to be adapted.

1. Select a channel to adjust in the blue marked (see the setpre figure) pull down menu (x/y/Z-Preemphasis).
2. Be sure to have the protocol with the same gradient direction loaded and start the setup procedure using the GSP button.

Since all FID's are acquired at different delays after the gradient, the influence of the residual eddy currents on the FID's after different times can be observed. In this protocol, the FID's are acquired after exponentially increasing delays which are 0.3 ms, 0.8 ms, 2.15 ms, 5.8 ms, 15.5 ms, 41.7 ms, 111.8 ms, and 300 ms. So if for example, the first 4 FID's show a different shape/integral compared to the FID acquired after 300 msec, the compensation term might need a 'Time' of about 4-5 msec. To find the correct amplitude of the compensation term, the 'Gain' value is modified in small steps and the influence of the term to the FID's is observed (even small steps can make a huge effect on the signal). Be aware that the new preemphasis values are only uploaded into the hardware, all 8 FID's have been acquired.

One criterion on how good a preemphasis adjustment is, can be the difference of the integrals of the 8 individual FID's. To check the integrals, increase the information area under the acquisition display of ParaVision by dragging & dropping the line between the signal display and the info display. The difference in the integrals should be <15% for a well adjusted gradient system.

At the beginning of the adjustment, the differences in the integral might be much larger (see the next figure), but on very good gradient systems it is already in this range.

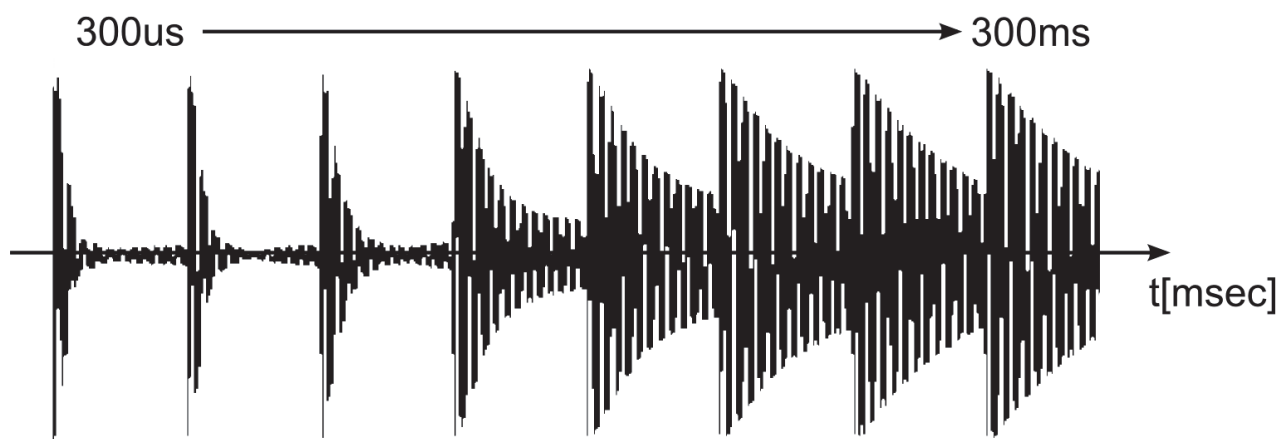


Figure 7.12: Preemphasis Experiment without Preemphasis Compensation

After the adjustment, all FID's should have almost the identical shape and integral. Often it is impossible to adjust the first 2 FID's to perfection, so some compromise has to be accepted. The following figure shows typical FID data after the adjustment.

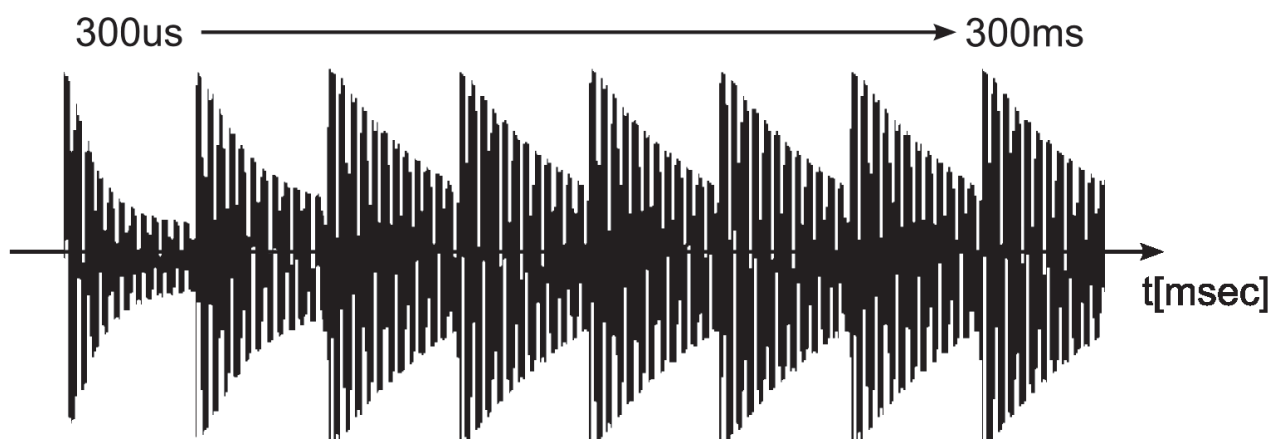


Figure 7.13: Preemphasis Experiment after the Adjustment.

In the figure above the first 2 FID's are still a bit smaller than the others.

However, even this result might not be reachable by adjusting the x/y/z-preemphasis. If this is the case, the gradient system might need cross preemphasis. This means that switching, for example, a gradient along the x-direction causes an eddy current in the y-direction. To compensate for these effects, the cross preemphasis terms need to be adjusted in the same way as the direct preemphasis was done. In the above example, the 'x → y cross preemphasis' would need to be adjusted. This can be done by selecting 'X→Y Cross Preemphasis' in the blue marked (see set-pre figure) pull down menu.

After the adjustment, all parameters must be stored using SetPre →File →Write default.

See also

- Loop Regulation Adaptation [92]

7.5 B0 Adjustment

The B0 and preemphasis adjustments are very similar. As opposed to the preemphasis, where first order field distortions need to be compensated, the B0 adjustment compensates for zero order field distortions, what are identical to a field shift and thus in a shift of the NMR signal phase.

The recommended setup parameters for the preemphasis adjustment are shown in the table below. Be sure to have the correct system status selected in 'Edit & Save Config'.

NMR Sample:	5 or 10 mm NMR tube filled with 20% H ₂ O, 80% D ₂ O, and 1g/l CuSO ₄ or another T1 shortening relaxant. Filling height 40...50 mm.
Data Set Name:	Great Setup
Protocol Name:	m_installation/ mic_preemp_50msec_33pc_X/Y/Z
Recommended Coil Routing:	Transceiver 1H 100W.
Frequency BF1:	On resonance.
Shim:	Line width <20 Hz at 50% amplitude.
RF Gain:	<<90°
Receiver Gain:	---

Table 7.6: Parameter Setup for the Great B0 Adjustment

This protocol will load a parameter set, which runs a 50 msec gradient with 33% of the maximum current on the X/Y/Z gradient channels every 450 msec. The time between gradient and RF is incremented 8 times from 300 μ sec to 300 msec to visualize the effect of shifted magnetic fields by eddy currents on the FID. As a consequence, it takes 8*450 msec to shows the full result of the measurement. The only difference to the preemphasis experiment in the section Preemphasis Adjustment [96] is that the signal is observed on-resonance.

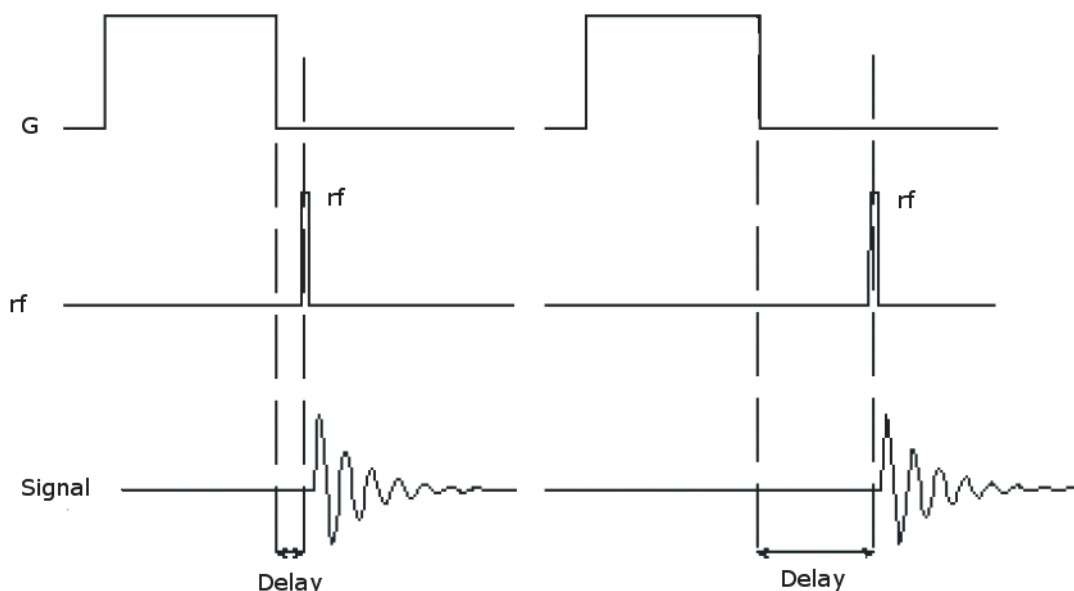


Figure 7.14: B0 Experiment with Varying Delays Between Gradient and RF-Detection.

In the figure above, the difference to the preemphasis experiment is that the signal is observed on-resonance.

Gradient System and Amplifier Setup

As a prerequisite, the loop parameters of the gradient system/amplifier must be set correctly for the B0 adjustment (see Loop Regulation Adaptation [92]).

1. Open 'setpre' by selecting Spectrometer Control Tool → Tools → Adjust Preemphasis Values.
2. Check the system status in setpre to be the same as the select system status in 'Edit & Save Config' (green mark in the figure below).
3. Check the Ramp and Rise Time parameters of the selected gradient coil by opening SetPre → Edit → Ramp parameters and set the values to the value listed in Typical Gradient-Setpre Parameters [179].
4. When the values need to be modified, be sure to save them by SetPre → File → Write default.



When the “micro-imaging Addon CD” is installed as described in the section Micro-imaging Add-on CD [81], the parameters already have their default values.

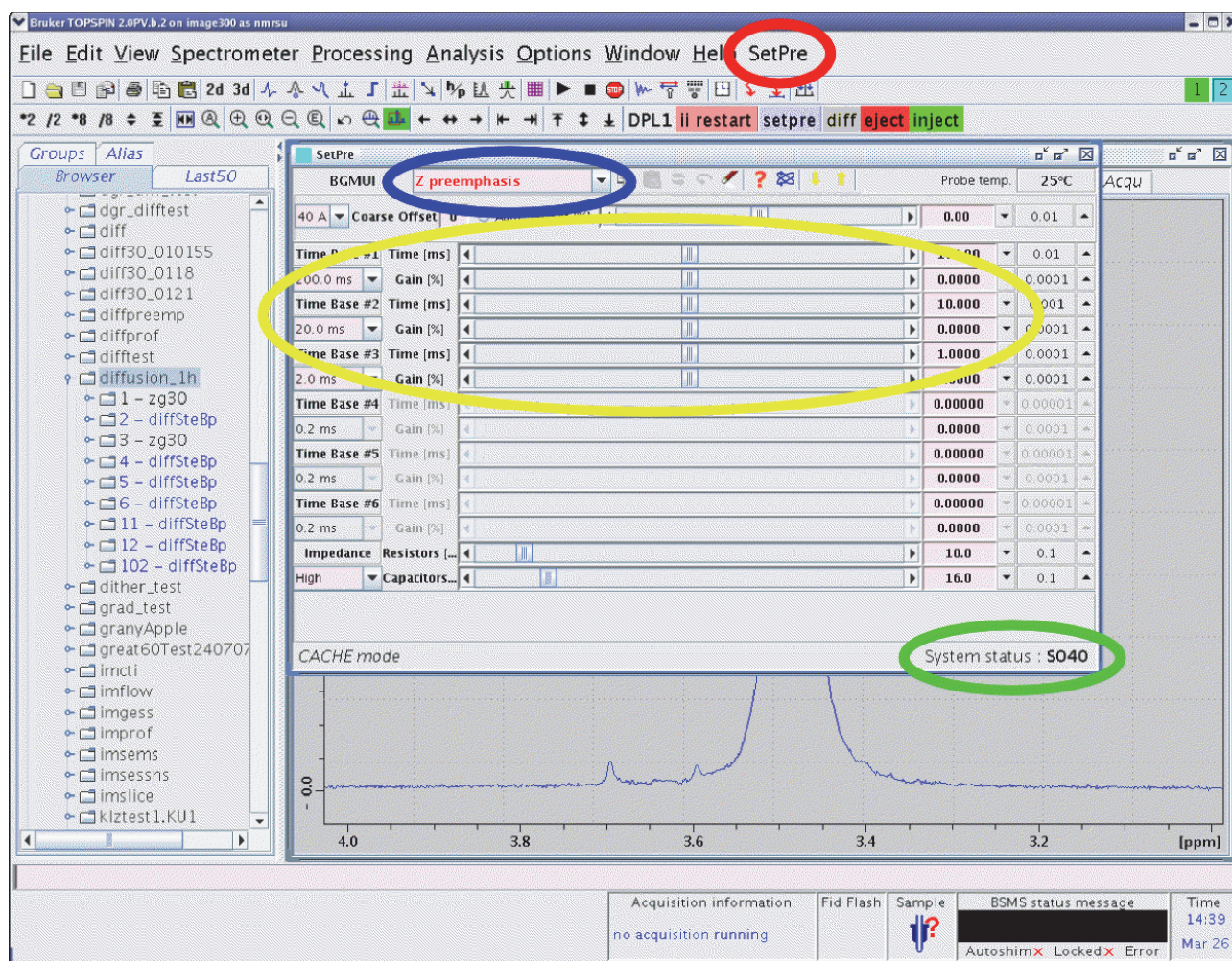


Figure 7.15: The setpre' in TopSpin for the B0 Adjustment

Gradient System and Amplifier Setup

5. Check and modify the B0 values as necessary in the first 6 lines of the 'setpre window', see yellow mark in the figure above, when the B0 is selected in the blue marked (in the figure above) drop down window of 'setpre'. B0 selections are X→B0 (the effect of an x gradient on B0), Y→B0 (the effect of a y gradient on B0), and Z→B0 (the effect of a z gradient on B0) but not B0→X/Y/Z!

Two lines always form the parameters which describe an exponentially decaying current, which is added to the H0 coil current by the B0-2 compensation unit (see the following figure). In this configuration, three exponentially decaying currents (if GRADRES is $\geq 10.0 \mu\text{sec}$ (see Setup of the Gradient Timing Resolution [81]) 6 time constants are available) with individual amplitudes and time constants can be added to the H0 coil, to compensate for eddy currents with different amplitude and decay behavior. The 'Time Base' in front of each amplitude/current slider pair limits the longest possible time constant for this exponential decay. For example, a compensation term with "Time=1msec" and "Gain=10%" adds an exponentially decaying current with an amplitude of 10% of the maximum. The 10% amplitude is decayed to $1/e$ (approx. 36%) after 1 msec.

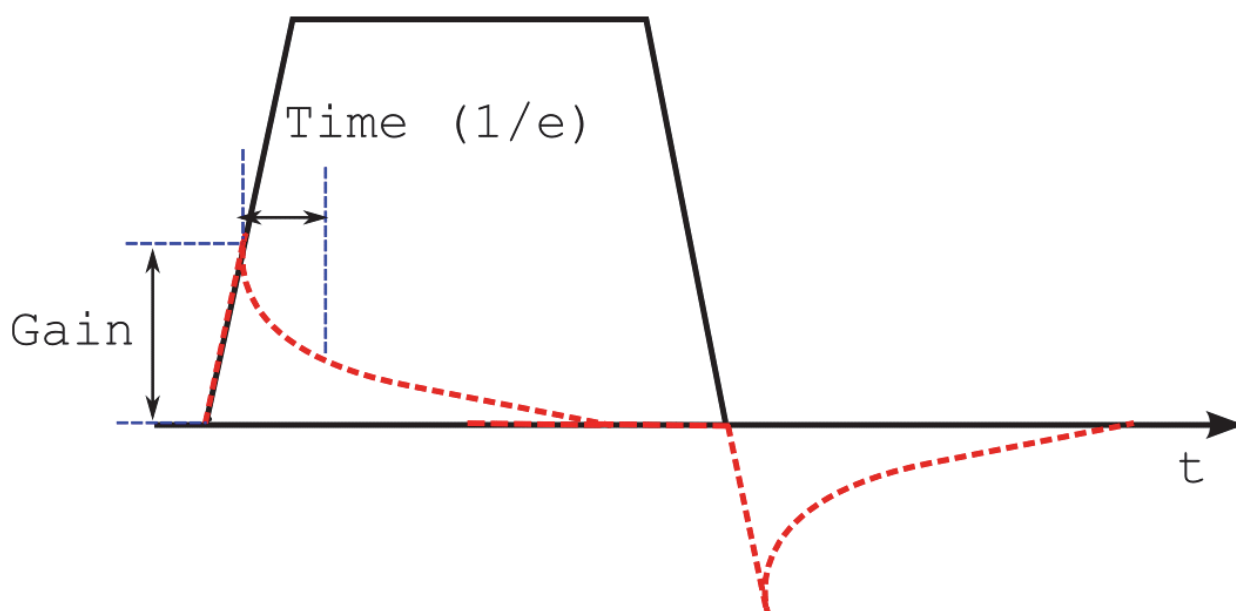


Figure 7.16: A Gradient Shape (black) and the Generated B0 Compensation Terms (red) that are Added to the H0 Coil

The goal of this adjustment is to have the phase of all 8 FID's acquired identical with the above experiment. It can be said, that after 300 msec no eddy current is present any longer. So the far right FID shows the reference phase, to which all other phases need to be adapted. To see the phase difference clearly, the acquisition display should be set to unshuffled.

Select a B0 channel to adjust in the blue marked (see setpre figure) pull down menu (x/y/z→B0), be sure to have the protocol with the same gradient direction loaded and start the setup procedure by the GSP button.

Since all FID's are acquired after different delays behind the gradient, the influence of the residual eddy currents effecting the phases of the FID's after different times can be observed. In this protocol, the FID's are acquired after exponentially increasing delays which are 0.3 ms, 0.8 ms, 2.15 ms, 5.8 ms, 15.5 ms, 41.7 ms, 111.8 ms, and 300 ms. So if, for example, the first 4 FID's show a different phase compared to the FID phase acquired after 300 msec, the compensation term might need a 'Time' of about 4-5 msec. To find the correct amplitude of the compensation

term, the 'Gain' value is modified in small steps and the influence of the term to the phase of the FID is observed (even small steps can make a huge effect on the signal). Be aware that the new B0 values are only uploaded into the hardware, when all 8 FID's have been acquired.

Unfortunately, there is no numerical criterion like the integral in preemphasis adjustment, so the adjustment really has to be done 'by eye'. At the beginning of the adjustment, the differences in the phase might be large (see the following figure), but on very good gradient systems the phases might be already (almost) identical with zero settings.

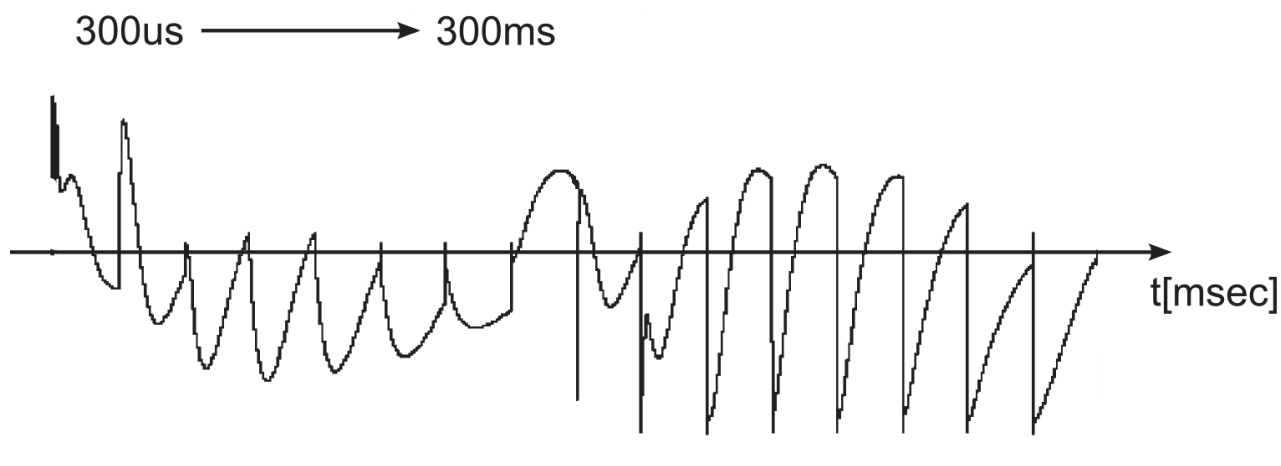


Figure 7.17: B0 Experiment without B0 Compensation (unshuffled display).

After the adjustment, all signals should have almost identical phases. Often it is impossible, to adjust the first 2-3 FID's to perfection, so some compromise has to be accepted. The following figure shows typical data after the adjustment.

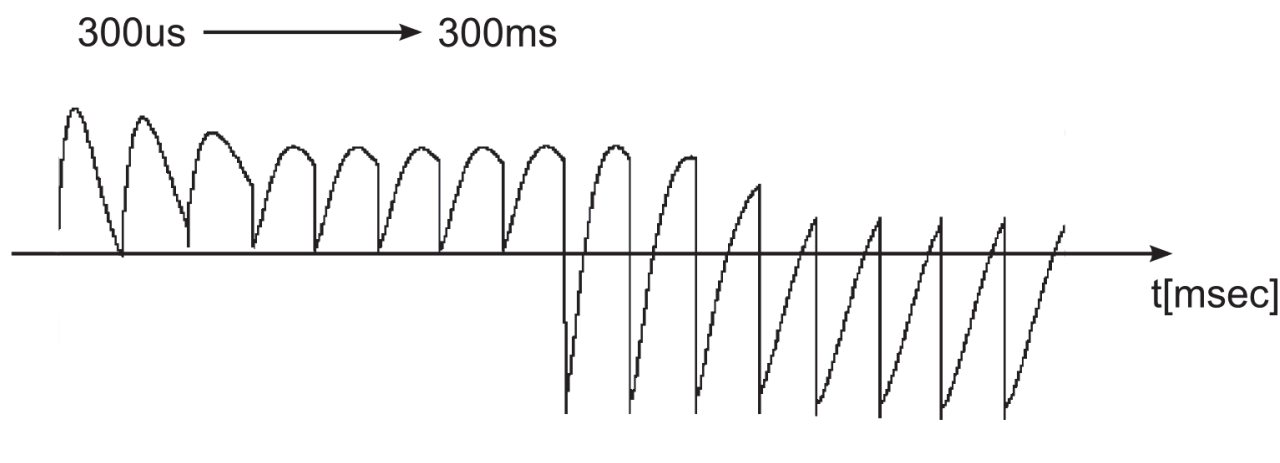


Figure 7.18: Signal after B0 Compensation (unshuffled display).

In the figure above, the first FID's are still show a slightly different phase.

After the adjustment, all parameters must be stored using SetPre →File →Save as Default.

7.6 Gradient Calibration

In order to provide images with correct field of view (FOV), slice thickness (SLTH), slice position and diffusion coefficients, ParaVision needs information about the gradient sensitivity and the maximum current, which are supplied by the gradient amplifiers. Other parameters for correctly scaled images are the relative gradient sensitivities between the X, Y and Z-gradients, caused by differences in design and production of the gradient system and the amplifiers.

The calibration must be performed when:

- the probe and gradient amplifiers are installed the first time,
- when the gradient system or an amplifier is exchanged, or
- when another output gain stage at the Great amplifiers is selected.

Like all other gradient parameters, the calibration parameters are entered in 'setpre' and the system specific status stored in the file <\$PvHome>/exp/stan/nmr/parx/preemp/<SystemStatus>/default. The parameters from this file are loaded automatically every time a new data set is created and/or an acquisition is started in ParaVision.

The calibration values are determined by imaging objects with a well defined geometry, for example a LEGO or nylon screws. These objects are acquired in an axial, sagittal and coronal image. From the acquired images the dimensions in the phase direction are extracted, since this direction doesn't show any image distortions caused by bad shimming.

Two experiments must be setup to acquire the images for the geometry measurement.

1. Create two data sets.
2. Set up the recommended parameters for the imaging experiments in the following table.



Be sure to have the correct system status selected in 'Edit & Save Config'.

3. Adapt the FOV of the protocol to be slightly larger than the object by the help of the 'Geometry Editor'.

NMR Sample:	Geometrically well defined object in an NMR tube filled with 20% H ₂ O, 80% D ₂ O, and 1g/l CuSO ₄ .
Data Set Name:	Great Setup.
Protocol Name:	m_installation/mic_gradcalib_xy m_installation/mic_gradcalib_z
Recommended Coil Routing:	Transceiver 1H 100W.
Frequency BF1:	On resonance.
Shim:	As good as possible.
RF Gain:	Auto Reference Gain must be defined.
Receiver Gain:	Auto Receiver Gain.

Table 7.7: Parameter Setup for Gradient Calibration

After the two data sets are acquired, the images must be transferred into XTip. The 'mic_gradcalib_xy' protocol acquires 2 axial images, where the mic_gradcalib_z acquired one coronal image. From these images, the dimensions have to be measured in XTip by the tool:



Example images of the LEGO are shown in below:

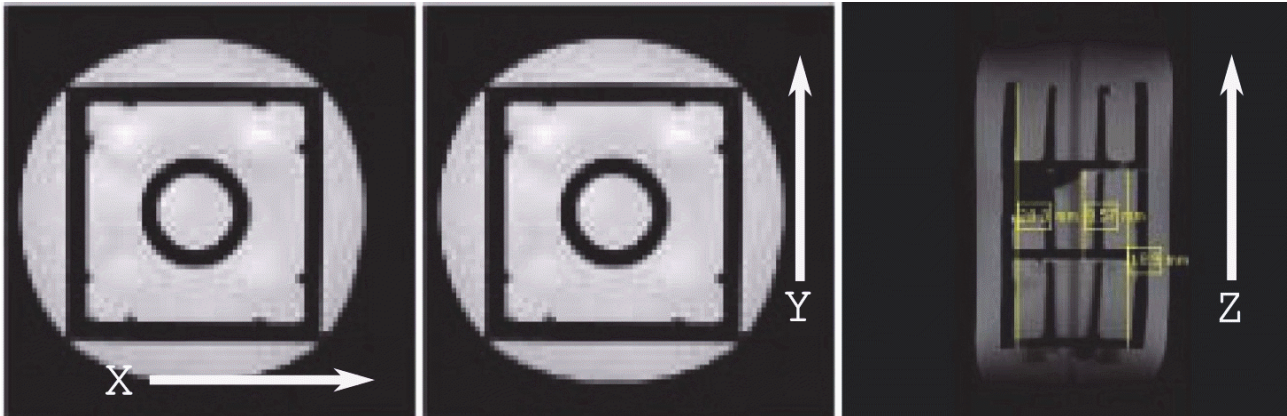


Figure 7.19: Calibration Images of the LEGO.

In the figure above:

Left image: Image 1/2 acquired by mic_gradcalib_xy to measure the x dimension (left-right) .

Middle image: Image 2/2 acquired by mic_gradcalib_xy to measure the y dimension (top-bottom).

Right image: Image 1/1 acquired by mic_gradcalib_z to measure the z dimension (top-bottom).

The sizes of the above 2x2 LEGO is 15.8 mm in x and y direction. The height of each individual LEGO is 9.55 mm.

Another sample for smaller RF coils is a M4 nylon screw in a 5 mm NMR tube where it fits in smoothly. An example of the image series acquired from the M4 nylon screw is shown in the figure below:

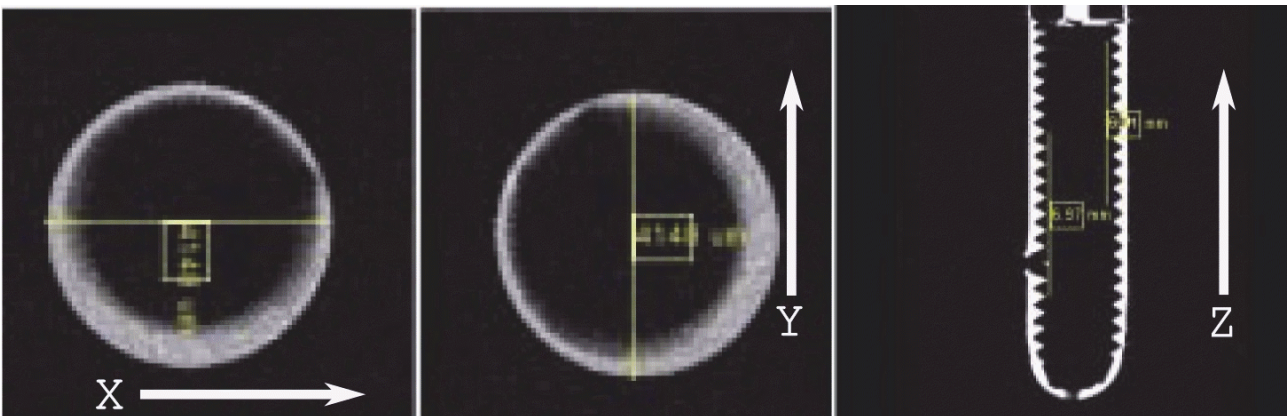


Figure 7.20: Fig. 5-20: Calibration Images of a M4 Screw.

In the figure above:

Left image: Image 1/2 acquired by mic_gradcalib_xy to measure the x dimension (left-right).

Middle image: Image 2/2 acquired by mic_gradcalib_xy to measure the y dimension (top-bottom).

Right image: Image 1/1 acquired by mic_gradcalib_z to measure the z dimension (top-bottom).

The inner diameter of the above selected 5mm NMR tube is 4.1 mm in x and y direction. The distance between the tips of a M4 screw is 0.75 mm, so 10 tips (to increase the accuracy) should have a distance of 7.5 mm.

Gradient System and Amplifier Setup

Of course any other sample with well defined geometry can be used to calibrate the gradients.

When the “micro-imaging Add-on CD” is installed as described in Micro-imaging Add-on CD [▶ 81], the gradient calibration parameters already have their default values, which are typically less than 3% of from the correct values. The default values can be found in Typical Gradient-Setpre Parameters [▶ 179].

When the measured values from the NMR images differ from the real geometry (what they typically do), the calibration constants for the amplifier/gradient system combination need to be calculated. The easiest way to do this is to load the protocol `m_installation/mic_gradcalc` and enter the appropriate values, see the figure below.

REAL:	Enter the physical sizes of the object.
MEASURE:	Enter the sizes of the object measured in the NMR image.
CURRENT:	The current gradient calibration parameters.
CALCULATED:	The new gradient calibration parameters, calculated from the entered REAL and MEASURE parameters.

Measuring Method	mic_gradcalc	
Protocol name	mic_gradcalc	
Measurement Type	GeoMeasurement	
REAL	<input checked="" type="checkbox"/> expand	
	Real Size X	10.000 mm
	Real Size Y	10.000 mm
	Real Size Z	10.000 mm
MEASURE	<input checked="" type="checkbox"/> expand	
	Measured Size X	10.000 mm
	Measured Size Y	10.000 mm
	Measured Size Z	10.000 mm
CURRENT	<input checked="" type="checkbox"/> expand	
	Current CalibFactor X	1.000
	Current CalibFactor Y	1.000
	Current CalibFactor Z	1.000
	Current GradCalibConst	423000.000 Hz/cm
CALCULATED	<input checked="" type="checkbox"/> expand	
	Calculated CalibFactor X	1.000
	Calculated CalibFactor Y	1.000
	Calculated CalibFactor Z	1.000
	Calculated GradCalibConst	423000.000 Hz/cm
Save Calc Data	Not_Saved	
INFO	<input type="checkbox"/> expand	

Figure 7.21: The mic_gradcalc Method Interface

After selecting Save Calc Data → Save Now the values are automatically stored. The file location can be checked in the ParaVision startup console.

The values can also be calculated manually. For a triple axis gradient system a gradient calibration constant (of the weakest gradient) and the scaling values for the stronger gradients must be calculated to equalize the gradient output in all directions.

In order to calculate the values determine the real geometry in x/y/z (real_{x/y/z}) and the measured geometry (meas_{x/y/z}) from the calibration object.

Calculate the ratios by:

$$\text{ratio}_x = \text{meas}_x / \text{real}_x$$

Gradient System and Amplifier Setup

$$\text{ratio}_y = \text{meas}_y / \text{real}_y$$

$$\text{ratio}_z = \text{meas}_z / \text{real}_z$$

From these values calculate the relative scaling using:

$$\text{scale}_x = \text{minimum_of}(\text{ratio}_x, \text{ratio}_y, \text{ratio}_z) / \text{ratio}_x$$

$$\text{scale}_y = \text{minimum_of}(\text{ratio}_x, \text{ratio}_y, \text{ratio}_z) / \text{ratio}_y$$

$$\text{scale}_z = \text{minimum_of}(\text{ratio}_x, \text{ratio}_y, \text{ratio}_z) / \text{ratio}_z$$

Then calculate the new gradient calibration constant:

$$\text{GCC}_{\text{new}} = \text{GCC}_{\text{old}} * \text{minimum_of}(\text{ratio}_x, \text{ratio}_y, \text{ratio}_z)$$

These values have to be entered into setpre:

1. Open 'setpre' by Spectrometer Control Tool →Tools →Adjust Preemphasis Values.
2. Select 'SetPre →Edit →Gradient parameters.
3. Enter the above calculated values.
4. Store the values using 'SetPre →File →Write as default'.

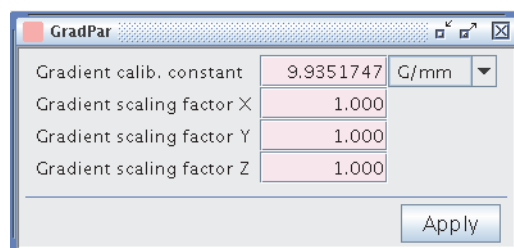


Figure 7.22: Gradient Calibration Parameters Dialog.

After the calculation of the new calibration of the gradients, the calibration should be checked. Perform the same experiments as above, and check if the correct geometry is shown in XTip.



Note: Create new scans to check the calibration. Don't clone the old scans. If 'Clone Scan' is selected, the old values are copied and the new entered values have no effect!

RF Probe Routing Setup

In ParaVision 5 the routing is realized in a different way, as compared to previous ParaVision versions. Each probe has to be specified separately, which causes a bit of work during the installation, but makes it much easier during the experiment setup, since only the connected probe and a valid 'Operation Mode' have to be selected. Valid operation modes are modes that correspond to the set-up routing and allow the transmit and receive chain to handle the selected frequencies. For more detail, refer to Quick Introduction to Coil Configurations [▶151].



Note: The ParaVision method only allows the selection of valid nuclei in the selected operation mode.

7.7 Select an Existing Probe

During 'cf' ParaVision automatically creates a few standard configurations, basically for single tuned 1H and X coils (the corresponding command in the TopSpin command line is "pvdefcoil-confs"). If a coil configuration for a probe is already setup, it is very convenient to load them and have all the routing and power parameters immediately set up. To activate an existing probe configuration:

1. Create a new scan or new study.
2. Select the probe from the 'Probe' pull down menu (red mark in the figure below) in the 'Study Editor'.

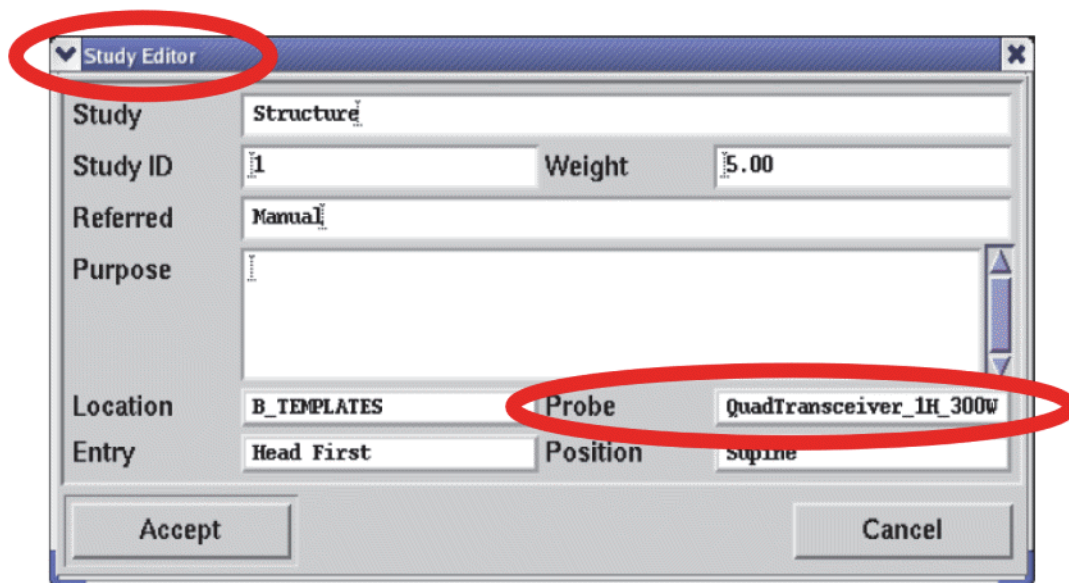


Figure 7.23: Study Editor with Probe Selection Pull Down Menu.

3. Select the desired operation mode for the probe (red mark in the figure above) in the protocol.

For a single tuned 1H volume probe, most likely the only operation mode will be "[1H] Rx/Tx", which indicates a 1H coil for transmit and receive.

For double tuned coils there are typically more operation modes, at least "[1H] Rx/Tx" and e.g. "[13C] Rx/Tx".

When the "[1H] Rx/Tx", the ParaVision method will only allow 1H experiments. When "[13C] Rx/Tx" is selected the method only allows 13C experiments.

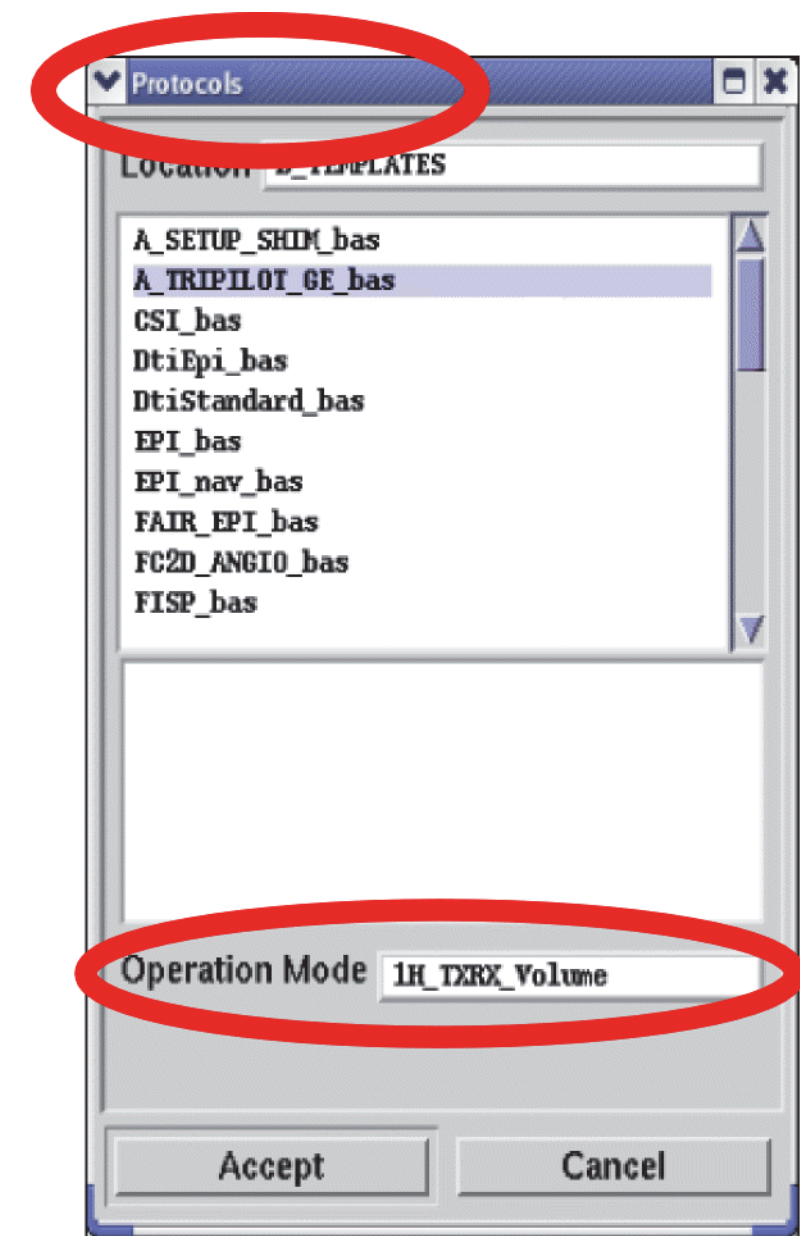


Figure 7.24: Protocols Dialog with 'Operation Mode' Selection

4. Verify that the currently connected coil setup is registered as the connected probe in Para-Vision. Open "ScanControlTool->Set Connected Probes..." and select the connected coil from the list of available probe configurations. It must match the setting for the probe (see the figure above). When the system and the coil are equipped with automatic hardware detection (HWIDS), the selection is made automatically.

7.8 Setup New Probes

For various probes that are not created automatically, the coil configurations have to be set up manually.

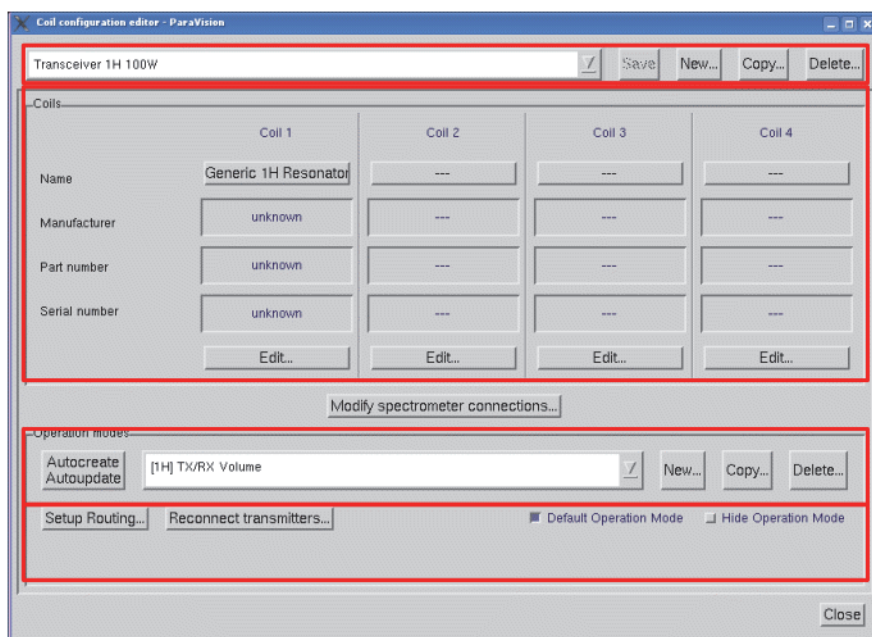


Figure 7.25: Main GUI Window for the Coil Configuration.

1. Login to the system as **nmrsu**.
2. Start ParaVision 5.
3. Open the Macro Manager (Magic Hat icon in the System Control Window) and start the macro 'EditCoilConfs' in the category 'Bruker'.
4. Set up the coil configurations in the upcoming TCL user interface by copying an existing coil configuration or creating a new configuration. It is recommended to create a new configuration rather than copying an existing one.

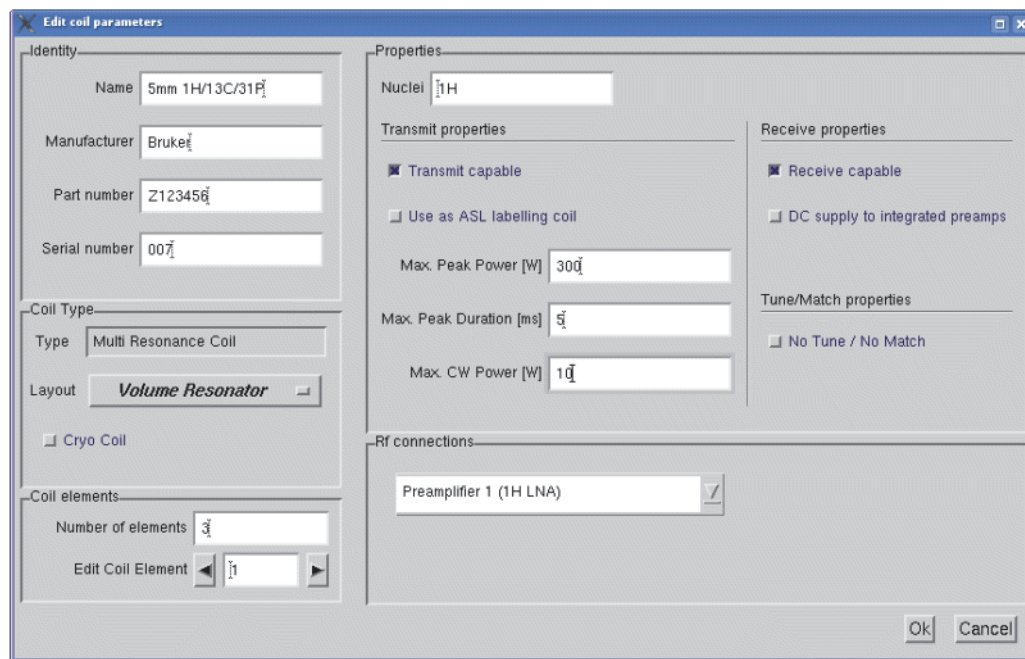


Figure 7.26: Coil Edit Sub Menu For the Coil Configuration (Coil 1→Edit)

7.8.1 Definition of an Individual Value for the Reference Gain Adjustment

The default parameters in the auto adjustment protocols are selected to match the most RF coils. When very small coils are used, for example, the start value for the auto adjustment can be too high to find the best match.

To improve the protocol for the RF amplitude adjustment, the starting point for the RF pulse amplitude (parameter “Initial Attenuation”, which is one of the most critical parameters) can be set manually. P_{ref} is the power in watt of a 90 degree 1 msec block pulse under standard load conditions, P_{max} is the peak power in Watt of the RF amplifier and A_{ref} is the attenuation in dB of the maximum power (note, no attenuation means -6dB). The relation between reference attenuation and reference power is shown by the following equations:

$$A_{ref} = 10 \cdot \log_{10} \left(\frac{P_{max}}{P_{ref}} \right) - 6.0$$

$$P_{ref} = P_{Max} \cdot 10^{-\frac{A_{ref} + 6.0}{10}}$$

Figure 7.27: Equation: Relation Between Reference Attenuation and Reference Power

Gradient System and Amplifier Setup

For systems without hardware detection, the value of P_{ref} can be stored in a coil configuration file using the coil configuration editor (field “Reference Power”).

	Dual Tuned Probe (1H/X)		Dual Tuned Probe (1H/19F), 19F via 1H Amplifier and XBB19F Preamp		Quadrature Coil (1 Coil Tx, 2 Coils Rx; 1H)		Surface Coil (Tx/Rx)
Name	Dual Resonance 1H/X Probe		Dual Resonance 1H/19F Probe		1H Quadrature Probe (1Tx/2Rx)		Surface Probe (Tx/Rx)
Coil1 → Edit →	Multiple Resonance Coil		Multiple Resonance Coil		Array Coil		Linear Coil
Name	1H/X Volume Coil		1H/19F Volume Coil		Quadrature Parallel Coil		Surface Coil
Manufacturer	e.g. Bruker		e.g. Bruker		e.g. Bruker		e.g. Bruker
Part Number	e.g. H9813		e.g. HZ16483		e.g. H9541		e.g. H6737
Serial Number	e.g. 0100		e.g. 0100		e.g. 0103		e.g. 0105
Layout	Volume Coi		Volume Coil		Volume Coil		Surface Coil
Elements	2		2		2		1
	Element 1 1H Receive Cap. Transmit Cap. Tuneable Connected to Preamp LNA[x] 1H	Element 2 e.g. 13C Receive Cap. Transmit Cap. Tuneable Connected to Preamp LNA[x] XBB	Element 1 1H Receive Cap. Transmit Cap. Tuneable Connected to Preamp LNA[x] 1H	Element 2 19F Receive Cap. Transmit Cap. Tuneable Connected to Preamp LNA[x] XBB19F	Element 1 1H Receive Cap. Transmit Cap. Tuneable Connected to Preamp LNA[x] 1H	Element 2 1H Receive Cap. Tuneable Connected to Preamp LNA[x+n] 1H	Element 1 1H Receive Cap. Transmit Cap. Tuneable Connected to Preamp LNA[x] 1H
<p>Tip: Instead of creating an element with one fixed nucleus (frequency), a nucleus (frequency) range for the element can be defined. Element 2 of the ‘Dual Tuned Probe’ for example could be defined from ‘³He-¹⁹⁷Au’ (use this notation without the quotes, always from high to low frequency), so this element covers the full X range the AVANCE III X-channel hardware supports. As a result, this “Dual Tuned Probe” configuration can be used for all 1H-X probes (except for 1H-19F probes), and for single and dual frequency experiments.</p>							

Gradient System and Amplifier Setup

	Dual Tuned Probe (1H/X)	Dual Tuned Probe (1H/19F) 19F via 1H Amp and XBB19F Pre-amp	Quadrature Coil (1 Coil Tx, 2 Coils Rx)	Surface Coil (Tx/Rx)
Routing	<p>AutoCreate/Update or manual setup by selecting 'New'</p> <p>Manual Setup: Create 2 modes.</p> <p>1st mode "1H/[X]": Setup the routing for 1H on F1 and any X nucleus (e.g. 31P) on F2.</p> <p>2nd mode "X/[1H]": Setup the routing for X (e.g. 31P) nucleus on F1 and 1H nucleus on F2.</p> <p>This setup enables single (1H or X) and dual frequency (1H/x and X/1H) experiments with this dual frequency coil</p>	<p>AutoCreate/Autoupdate</p> <p>Select the 19F Operation mode, click 'Reconnect Transmitters' and route the 1H amplifier to the XBB19F preamp and Save.</p> <p>Select the 19F Operation mode, click 'Setup Routing', and route F1 via SGUx to the 1H amplifier (which is routed to the XBB19F). See the figure below.</p> <p>For the 1H operation mode no manual changes need to be performed.</p> <p>For other setups please contact Bruker at micdiff@bruker.de.</p>	<p>AutoCreate/Update or manual setup by selecting 'New'</p> <p>Manual Setup: Create 1 mode.</p> <p>Mode: "1H Quadrature": Setup the routing for 1H on F1 and don't setup any routing for F2. F2 Will be automatically switched to observe during the experiment, so no setup is necessary.</p>	<p>AutoCreate/Update or manual setup by selecting 'New'</p> <p>Manual Setup: Create 1 mode.</p> <p>Mode: "1H Surface": Setup the routing for 1H on F1.</p>

Table 7.8: Parameters for Different Coil Types

For service purposes the routing for one scan can be setup manually, but only for the selected scan.

In the single parameter windows (Spectrometer Control):

1. Set ACQ_routing = RouteAsDefined [3].
2. In ParaVision ScanControl select Advanced -> Command Sender.
3. In the command sender select:
Server = ...pvScan/CmdDispatcher.
Name = pvcreatorout
4. Click on the little arrow in the menu bar to set up the desired routing.

This routing is only valid for the current data set, so it doesn't replace the coil configurations set-up described above.

The following figures show the 1H-19F coil setup with 1H-19F RF amplifier and XBB19F preamplifier:

Gradient System and Amplifier Setup

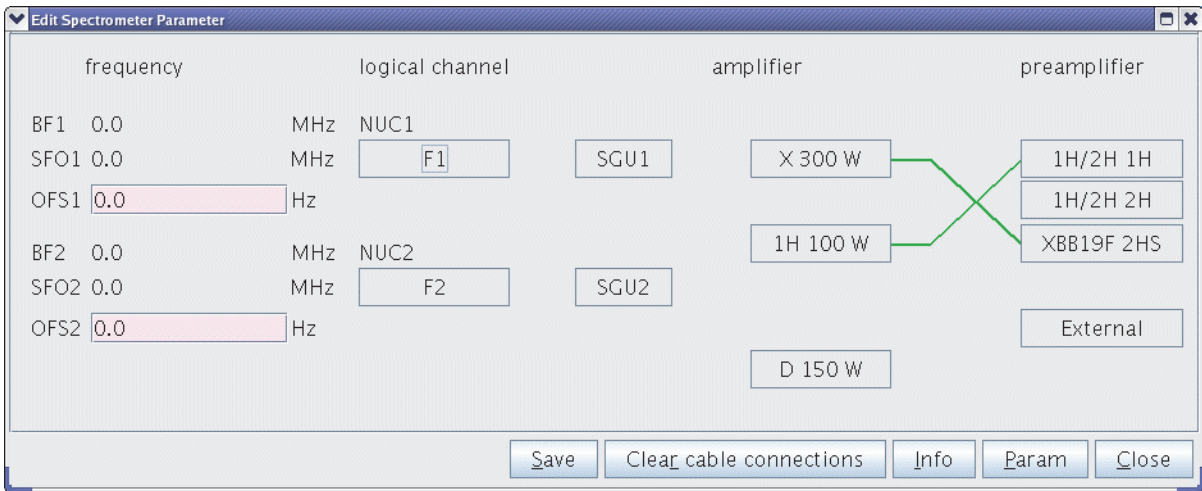


Figure 7.28: Reconnect Transmitters Dialog for 1H.

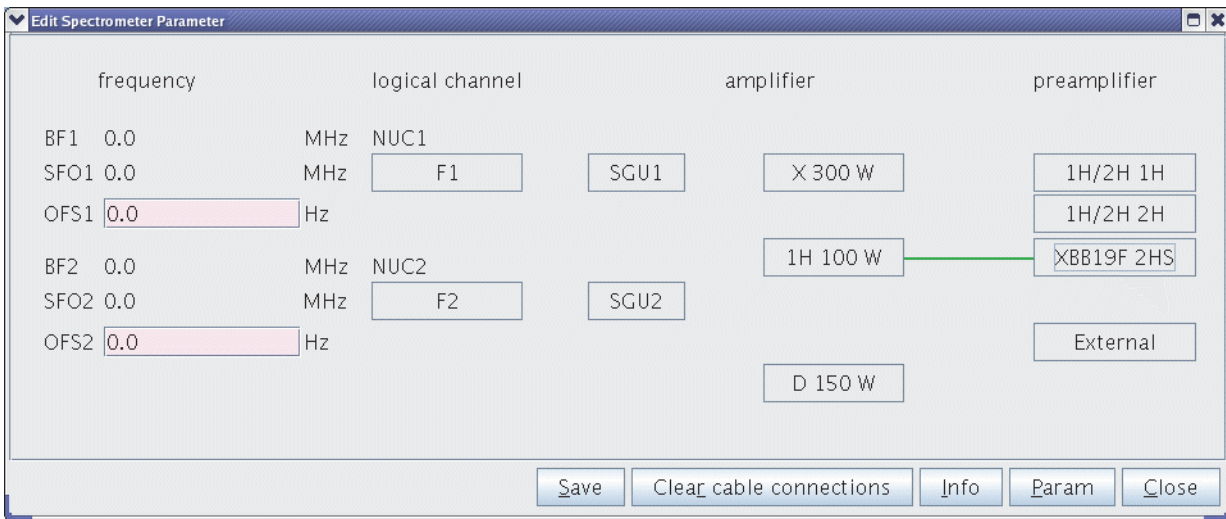


Figure 7.29: Reconnect Transmitters Dialog for 19F.

Gradient System and Amplifier Setup

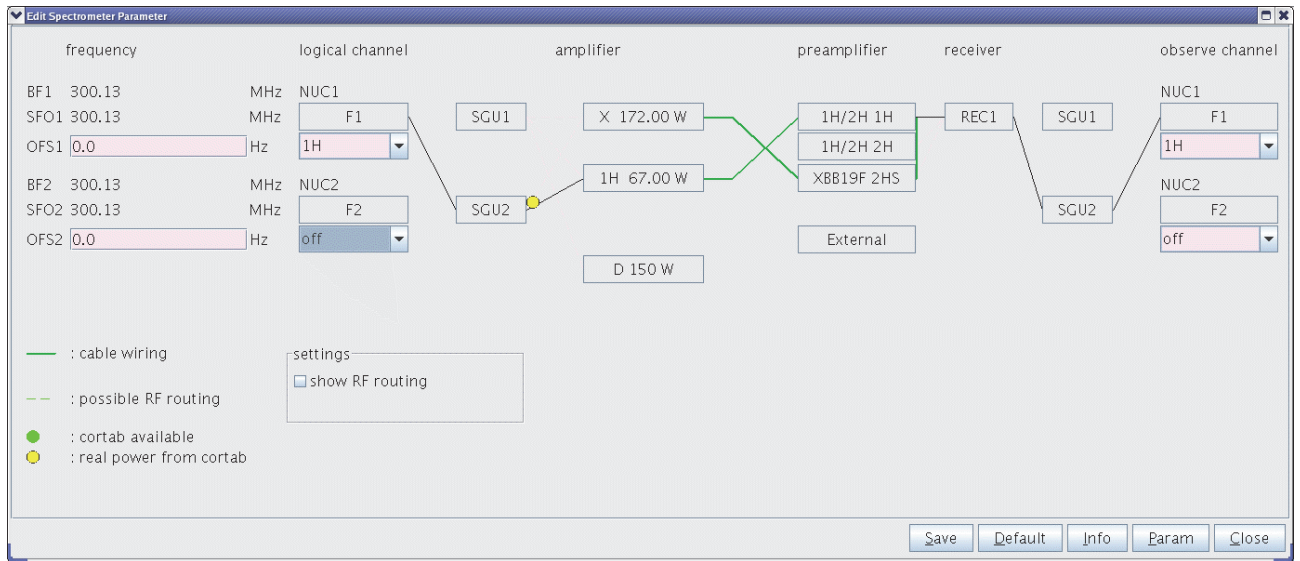


Figure 7.30: Setup Routing Dialog for 1H.

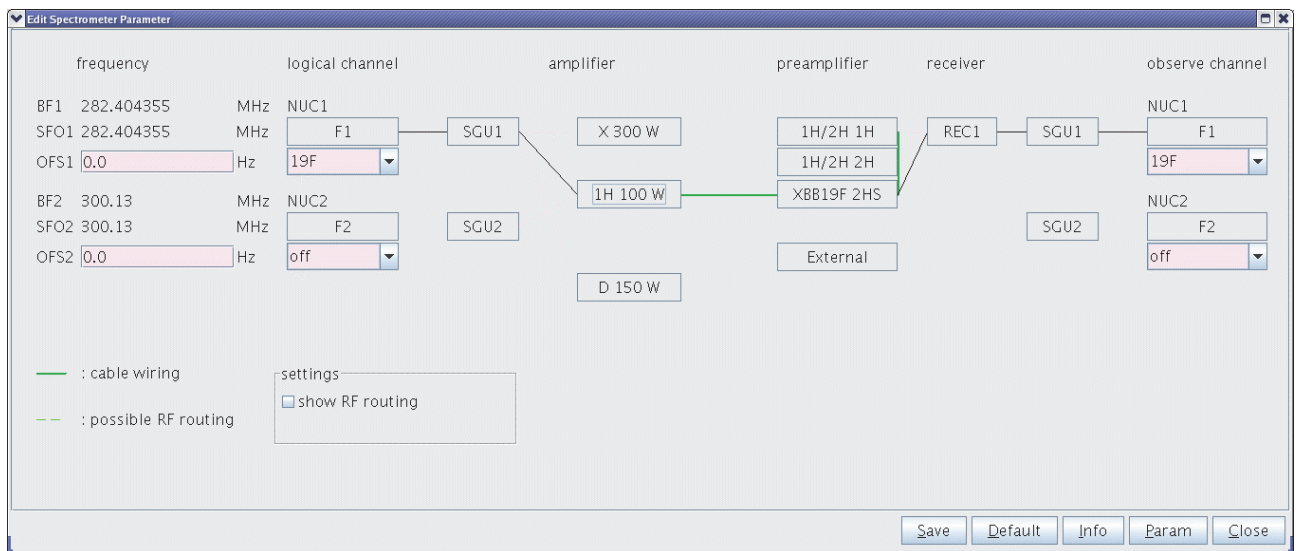


Figure 7.31: Setup Routing Dialog for 19F

8 Signal to Noise Ratio and z-B1 Tests for the RF Probes

The imaging tests have to be performed for all 1H coils and for those X coils, where samples delivering high sensitivity are available. These checks for the probe performance, and dependent on the imaging system and including all components (spectrometer, imaging rack, gradient system), are signal to noise and a B1 homogeneity (z direction) test for the resonator.

8.1 SNR Imaging Test

The Signal to Noise Ratio (SNR) test is based on a multi slice experiment with a standard sample and with standard parameters, which are identical on all systems. The parameters don't take care of varying T1 or T2 of the samples at different frequencies, but if the same experiment is used at the same field strength, the results are comparable. The SNR from the images, acquired with well defined parameters, is automatically calculated and stored by a macro. These values can be used in later tests as a base for comparisons of the system performance.

SNR tests are mostly performed for 1H coils, since the sensitivity of X nuclei for X nuclei imaging tests is typically low. The samples and imaging parameters defined for different nuclei can be found in the table in chapter Information Final Test Protocol for RF Probes on Form [▶161], (for 1H D₂O is added in order to avoid radiation damping effects). The defined liquids are filled in an NMR tube, which fits tightly into the RF coil to investigate and the filling height should at least cover the full coil length.

The protocols for the SNR and test can be found in the protocol location 'm_installation'. In order to acquire SNR test images with the correct parameters, the FOV of the slices must be adapted to 1.2 times the resonator inner diameter. The number of slices can be modified to cover the full z-range of the resonator.



Note: The receiver gain must be set to 101. If the signal is clipped with this receiver gain setting, reduce the slice thickness so that the signal is no longer clipped. If the receiver gain is lower, the SNR values are no longer comparable.

NMR Sample:	See Chapter Information Final Test Protocol for RF Probes on Form [▶161].
Data Set Name:	<\$probe name>
Protocol Name:	m_installation/mic_msme_snr_<\$NUC>
Recommended Coil Routing:	Probe specific coil routing.
Frequency BF1:	On resonance.
Shim:	As good as possible.
RF Gain:	Auto Reference Gain must be defined.
Receiver Gain:	101

Table 8.1: Parameter Setup for SNR tests

The above protocol acquires axial images with defined timing. The calculations for the SNR from these images are performed using the macro BRUKER/mic_rfTest, which needs the z-B1 profile as described in Processing of the SNR and z-B1 Data Sets [122] as additional input. Refer to this chapter for more information. Basically, the macro generates 2 ROIs, one in the signal and the other in the noise, to calculate signal to noise and homogeneity values.

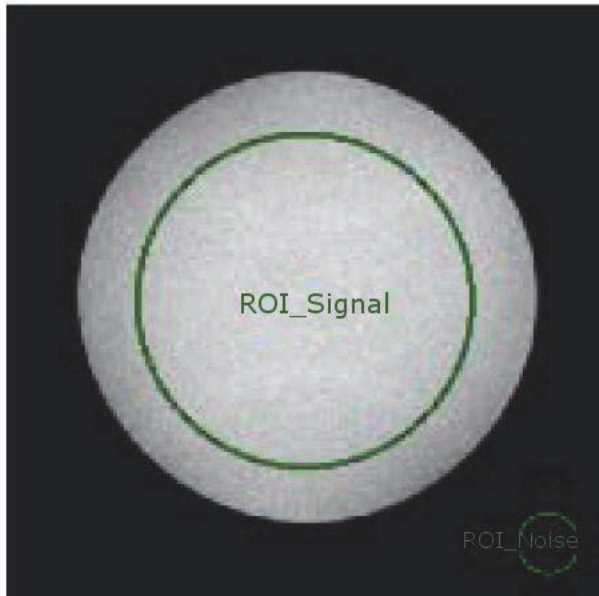


Figure 8.1: Signal and Noise ROIs Created by the mic_rfTest Macro in an Axial 1H SNR Image

From these two ROI's, the macro calculates the SNR of all acquired images out of the mean values and standard deviations, scales it to 1 mm³, and stores the result on disk.

$$SNR / mm^3 = \frac{0.85 * MeanSignal_{Signal}}{StandardDeviation_{Noise} * \frac{FOV_{Read}}{Matrix_{Read}} * \frac{FOV_{Phase}}{Matrix_{Phase}} * SliceThick}$$

Figure 8.2: Equation 7-1: SNR per mm³ Calculation.

The factor 0.85 adapts the results to previous ParaVision versions.

$$Homogeneity = \frac{100 * \left(100 - \sqrt{abs(MeanSignal_{Signal}^2 - StandardDeviation_{Noise}^2)} \right)}{MeanSignal_{Signal}}$$

Figure 8.3: Equation 7-2: Calculation of the Homogeneity.

In some cases, the signal ROI does not fit the sample very well and has to be shifted or modified in size. In this case, modify the ROI with the ROI tool from XTip and uncheck the 'Default ROI' option in the macro BRUKER/mic_rfTest to run the calculation of the SNR values again.

When the execution of the macro is successful, the result is stored in the csv file data/<\$USER>/nmr/<\$dataset>/<\$expno>/pdata/<\$procno>/SNR_homogeneity.txt. An example of such a file is shown below. This data is automatically imported into the test form (see below).

Fra- meNr;	Sig- nal.Mean;	Signal.Std- Dev;	Noise.Me an;	Noise.Std Dev;	Slice.Po- sition;	Homoge- neity;	SN per mm3
1;	20428;	10459;	20428;	10459;	-5.250;	100.0;	7111.55
2;	20756;	10763;	20756;	10763;	-3.750;	100.0;	7021.07
3;	20755;	10808;	20755;	10808;	-2.250;	100.0;	6991.70
4;	20412;	11333;	20412;	11333;	-0.750;	100.0;	6557.52
5;	21110;	10713;	21110;	10713;	0.750;	100.0;	7174.35
6;	20441;	10709;	20441;	10709;	2.250;	100.0;	6949.45
7;	20602;	10898;	20602;	10898;	3.750;	100.0;	6882.81
8;	21844;	11142;	21844;	11142;	5.250;	100.0;	7138.25

The results for 1H coils can be compared to the specification values in the table found in the chapter Signal to Noise Ratio for 1H RF-Coil Elements [▶ 164], to verify that the RF coil matches the specifications. If this is not the case, the spectrometer parameters need to be rechecked (reference pulse, shim, frequency,...), when the SNR values still cannot be reached, the coil may be returned for optimization. The acquired values should be stored safely. If at any time the user has the feeling, that the system has a SNR problem, the tests can be redone and the values compared to the values during the installation.

See also

📖 Test Sequences and Samples [▶ 162]

8.2 The z B1 Test

The B1 homogeneity along z is measured by a single slice msme sequence. Take care that the sample is longer than the RF coil, so that the image length along z is only limited by the coil, e.g. FOV approximately 25 mm for a 10 mm coil or 50 mm for a 30 mm coil. The type of sample does not matter, thus a NMR tube filled with water or 'Sample A' is recommended.

The protocol for the z-B1 test can be found in the protocol location 'm_installation'.

NMR Sample:	A long NMR tube filled with water or doped water. The filling height must be higher than the length of the RF coil.
Data Set Name:	<\$probe name>
Protocol Name:	m_installation/mic_msme_zB1prof
Recommended Coil Routing:	Probe specific coil routing.
Frequency BF1:	On resonance.
Shim:	As good as possible.
RF Gain.	Auto reference gain must be defined.
Receiver Gain:	Does not matter.

Table 8.2: Parameter Setup for SNR tests

The parameter to be noted is the length of the profile, whereas the amplitude is higher than 85% of the maximum profile amplitude. This value can be taken from a 1D profile plot, generated by the macro mic_rfTest, which is described in the following section.

8.3 Processing of the SNR and z-B1 Data Sets

The macro mic_rfTest is a small GUI-macro, which supports the generation of a test report. After starting the macro a small GUI shows up, where expno and procno of the SNR and z-B1 data sets can be entered. The macro contains only minimal checks, so the user has to be sure to provide the correct numbers. As long as the results are not calculated, the 'Calc' buttons are shown in red. When the data is calculated, the color changes to green. As soon as both 'Calc' buttons show green, the test report sheet can be generated by clicking 'Create Test Sheet'.

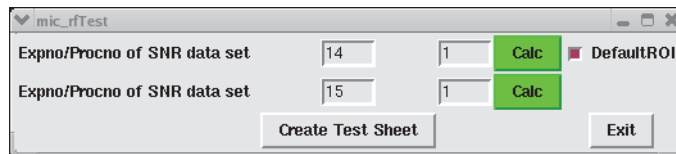


Figure 8.4: The mic_rfTest with Both Data Sets Processed (green color of the 'Calc' buttons)

In case the default ROIs for the SNR calculation do not fit the sample, the ROIs can be rearranged using the ROI tool, 'DefaultROI' must be unchecked and the calculation can be restarted by pressing the 'Calc' button.

8.4 Spectroscopic Test

The sensitivity of X nuclei in imaging experiments is often not sufficient to acquire a 2D image and to perform the imaging test, described in SNR Imaging Test [119]. To test the sensitivity and the shim performance of coils for such nuclei, 5 mm samples are used (see Test Sequences and Samples [162]). For the ease of use, the experiment should be performed in TopSpin. The sample should be shimmed well and the 90 deg pulse needs to be measured first (paropt, popt...). After the acquisition the sensitivity of the coil can be calculated using the formula:

$$SNR = Sino * \Delta f_{(50\%)}$$

Figure 8.5: Equation 7-3: Signal to Noise Calculation from a Spectrum

The 'Sino' (Signal to Noise) is the TopSpin build-in signal to noise calculation result. To perform the calculation, select TopSpin Analysis -> Signal/Noise Calculation and define the signal and noise region as noted in the upper left corner of the spectrum window. The actual calculation can then be started by a right mouse button click -> Start S/N Calculation. This value has to be multiplied by the line width of the selected peak measured at 50% of the maximum amplitude. The width can be measured manually or by the command 'peakw' (it might be necessary to define the plot region where the peak should be searched by the command 'dpl1'). The multiplication of 'Sino' by the line width should compensate for imperfect shimming.

Since some standard samples show multiple peaks, the peak/range to be used for the SNR test is marked in the spectra database in chapter Reference Spectra [165].

9 Gradient Amplifier Blanking Modes

The Great amplifiers can operate in 2 different blanking modes, soft and hard blanking. A low level (TTL) at the 'Gate' input of the Great amplifiers enable their outputs; a high level (TTL) disables the outputs. In imaging experiments the amplifiers are often unblanked during the complete experiment (realized in the include file MRI.include) due to 2 reasons:

- The experiments are quite fast, so there is almost no time to blank the amplifiers.
- The current to gradient ratio is not as high compared to the diffusion gradient systems.

Blanking is essential for experiments with diffusion gradient systems (Diff 30/60), since they have a high current to gradient ratio, so even weak amplifier noise introduces strong effects to the spin system.



Note: The amplifier needs about 10 μsec to enable its output. The blanking command must be executed minimum of 15 μsec before the 'grad' command in the pulse program. Shorter times can lead to unforeseeable effects.

9.1 Hard Blanking

On previous instruments, there was only one blanking mode available which is now called "hard blanking". This blanking mode is controlled by a 'setnmr' command in the pulse program, which enables or disables the amplifier output exactly at that moment, when it is executed, independent from any residual gradient current. This can be well controlled if all preemphasis values are set to zero, but if the preemphasis compensation adds an exponential decaying current to the gradient shape, it can hardly be predicted in the pulse program when the current will be dropped down to zero and blanking can be switched. In this case, the preemphasis compensation current will be cut off and doesn't produce the desired effect. The gating input of the Great amplifiers is directly connected to the IPSO T0 connector for the hard blanking mode. For the T0 pin connections please refer to the table in the section Trigger Signals at the T0 Connector [▶ 149].

To blank all amplifiers in this mode, bit 32, 33 and 34 of nmrword0 have to be set to 1 (5V at the T0 connector) using the command 'setnmr0^32^33^34' in the pulse program. To unblank the amplifiers, the bits have to be set to 0 (0V at the T0 connector) using the command 'setnmr0|32|33|34', where bit32 is for AmpX, bit33 for AmpY, and bit34 for AmpZ.

The following lines show a pulse program example for the hard blanking:

```
...
15μ setnmr0|32|33|34
1m grad { (10) | (t0) | (0) }
200μ groff
2m ; time for the preemphasis current to decay
10μ setnmr0^32^33^34
...
```

setnmr ppg command	AmpX	AmpY	AmpZ
setnmr0^32^33^34	D	D	D
setnmr0^32^33 34	D	D	E
setnmr0^32 33^34	D	E	D
setnmr0^32 33 34	D	E	E
setnmr0 32^33^34	E	D	D
setnmr0^32 33^34	D	E	D
setnmr0 32 33^34	E	E	D
setnmr0 32 33 34	E	E	E

Table 9.1: Hard Blanking Parameters.

D = amplifier disabled (blanked), E = amplifier enabled (unblanked)

The following figure visualizes the behavior of the hard blanking:

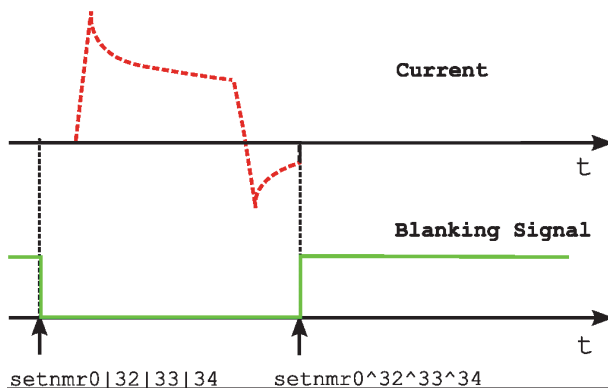


Figure 9.1: Hard Blanking of a Gradient Pulse with Preemphasis Components.

9.2 Soft Blanking

The Master Unit BGMUI-E used on AVANCE III systems can generate so called ‘soft blanking’ pulses. The ‘soft blanking’ is controlled in the pulse program by ‘ctrlgrad’ commands. If a ‘ctrlgrad’ command to blank an amplifier is executed in the pulse program the master unit checks the digital data of the amplifier to be zero. As long as the input data is not zero, the amplifier stays enabled (unblanked). As soon as the input becomes zero, the master unit generates the blanking signal for the amplifier. The big advantage of the ‘soft blanking’ is that residual currents from the preemphasis are not clipped anymore. If e.g. all preemphasis values are zero, the amplifier is blanked immediately when the ‘ctrlgrad’ command is executed. If the preemphasis compensation adds an exponentially decaying current, the amplifier is first blanked when the compensation current is fully decayed. The gating input of the Great amplifiers has to be connected to master unit, refer to the section Blanking Pulses [▶22].

The following is a pulse program example for the soft blanking:

```

...
15µ ctrlgrad 7
1m grad { (10) | (t0) | (0) }
200µ groff
2m ctrlgrad
0 ; blanking stays open for preemphasis decay
...

```

Gradient Amplifier Blanking Modes

The 'soft blanking' of the amplifiers is executed using the keyword 'ctrlgrad <value>' in the pulse program. To unblank the amplifiers, the <value> bits must be set. To blank the amplifiers, the bits must be reset to 0, where bit0 = AmpX, bit1 = AmpY, and bit2 = AmpZ.

Value (bin)	ppg Command	X	Y	Z
000	ctrlgrad 0	D	D	D
001	ctrlgrad 1	D	D	E
010	ctrlgrad 2	D	E	D
011	ctrlgrad 3	D	E	E
100	ctrlgrad 4	E	D	D
101	ctrlgrad 5	D	E	D
110	ctrlgrad 6	E	E	D
111	ctrlgrad 7	E	E	E

Table 9.2: Soft Blanking Parameters.

D = Amplifier disabled (blanked), E = Amplifier enabled (unblanked)



Note: The command ctrlgrad opens the amplifier at the next gradient command in the pulse program. If a 'ctrlgrad 7' isn't followed by a grad{...} command, the amplifiers remain blanked.

The figure below visualizes the behavior of the soft blanking.

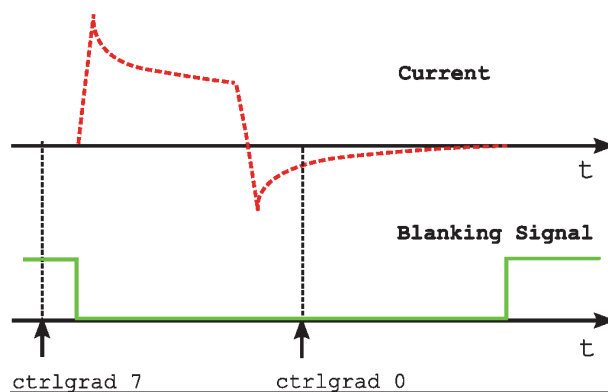


Figure 9.2: Soft Blanking of a Gradient Pulse with Preemphasis Components

Typically all amplifiers are blanked/unblanked at the same time. Therefore, the macros BLKGRAD and UNBLKGRAD are defined in the include file pp/Grad.incl. These macros execute a 'soft' and a 'hard' blanking event, so the behavior of the amplifier depends on where the gating input is connected.

10 Digital Data Filtering and Analog Sampling

10.1 Digital Filtering

The signal received by the RF coil is first amplified by the HPPR preamplifier. A second amplification stage is in the RXAD, the combined receiver and digitizer board. In the RXAD the signal is mixed to the intermediate frequency (720 MHz), in a second step to the so called DQD frequency and then digitized by 2 digitizers running at 20 MHz. During this time, only a smooth analog filter with a bandwidth of 10 MHz is applied to the signal to avoid signal folding. The digitizers run continuously to minimize transient behavior and settling time artifacts after starting the acquisition. The over-sampled signal, with a time resolution of 50 nsec (over-sampling dwell '2*dwov'), is finally filtered and decimated in the DRU (Digital Receiver Unit).

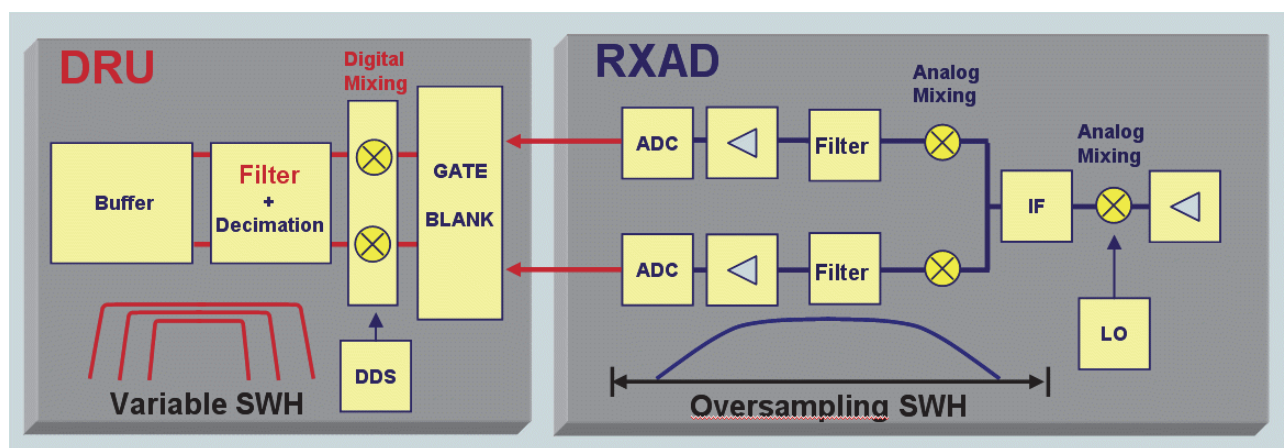


Figure 10.1: The Signal Path in the RXAD and the DRU

Digital filters modify the signal after the analog to digital conversion. They are mathematical operations, which enables the signal to be folded with any function or shape, and increase the signal to noise ratio of the spectrum by reducing the quantisation noise of the ADC.

After the analog signal is digitized with a dwell time 'dwov' in the RXAD, it is digitally filtered in the DRU. First, it is decimated 2 times by a factor of 2 using build-in hardware filters, resulting in a signal with a dwell time of 200 nsec. By adding more filter and decimation stages, which are under software control, the final signal with the desired spectral bandwidth is generated

The influence of the complete filter chain is described by the filter kernel. In frequency domain the filter function would have to be multiplied with the spectrum. Since the digital filter is applied in time domain, it's a convolution with the filter kernel. The over-sampled FID is multiplied by this filter kernel point by point.

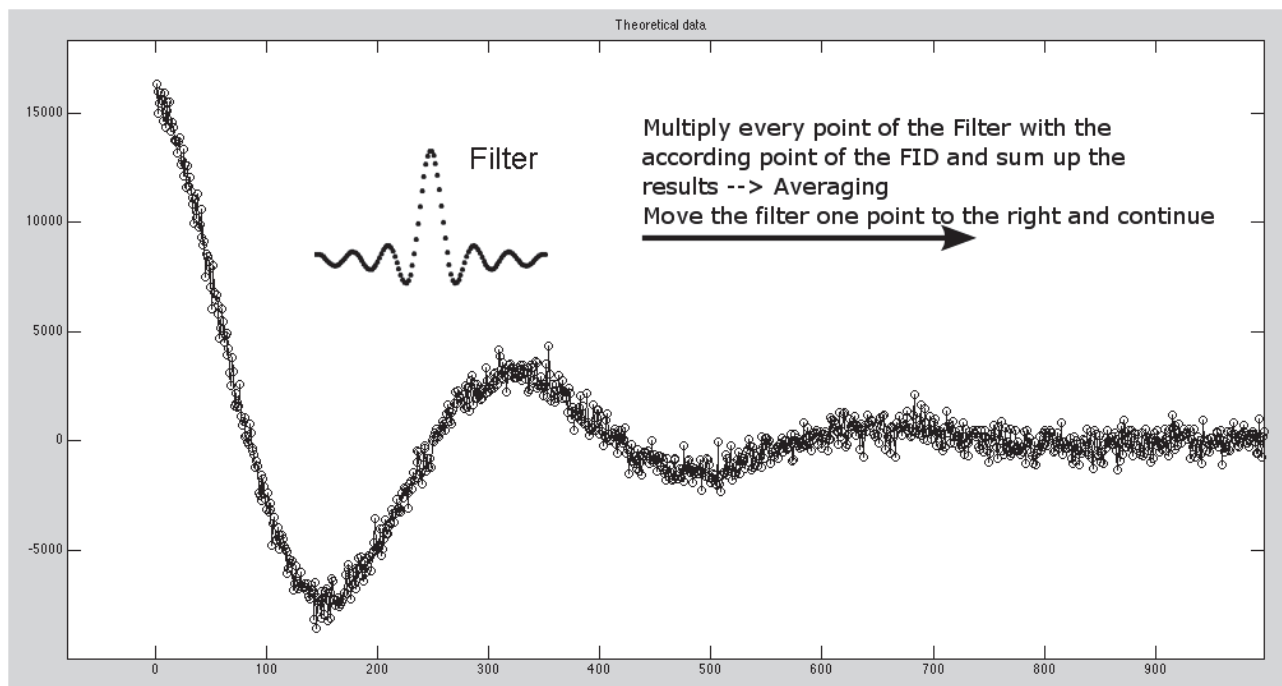


Figure 10.2: Every Individual Point of the Oversampled FID is Multiplied by the Filter Kernel.

When the first digital data point enters the digital filter, all other filter elements are zero. As a result, the first output point is almost 0. When the second data point enters the filter, it already has the previous point to be convolved with, so the second output point already contains the information from 2 input values, the third from 3 input values and so on. As a result, the out signal of a digital filter looks as if it starts with 0. In reality all these points contain signal, which can be seen if the Y-scale of the FID display is increased. The “real” signal “seems to appear” after a time, which is defined by the half width of the filter kernel. This time is called “group delay” in digital filtered signals.

Filter Kernel	f_7	f_6	f_5	f_4	f_3	f_2	f_1	f_0
	0.2	-0.5	1	3	3	1	-0.5	0.2
Sample FID Data	4; 6; -3; 1...							

Each FID data point is multiplied by the filter kernel and summed up									
Input Data Point	i_7	i_6	i_5	i_4	i_3	i_2	i_1	i_0	Output Data Value
1 st	4	0	0	0	0	0	0	0	0.8
2 nd	6	4	0	0	0	0	0	0	-0.8
3 rd	-3	6	4	0	0	0	0	0	0.4
4 th	1	-3	6	4	0	0	0	0	19.7
...									
n^{th}	n	$n-1$	$n-2$	$n-3$	$n-4$	$n-5$	$n-6$	$n-7$	$out = \sum_0^7 f_i i_i$

Table 10.1: Example of a Digital Filter with a Kernel Length of 8

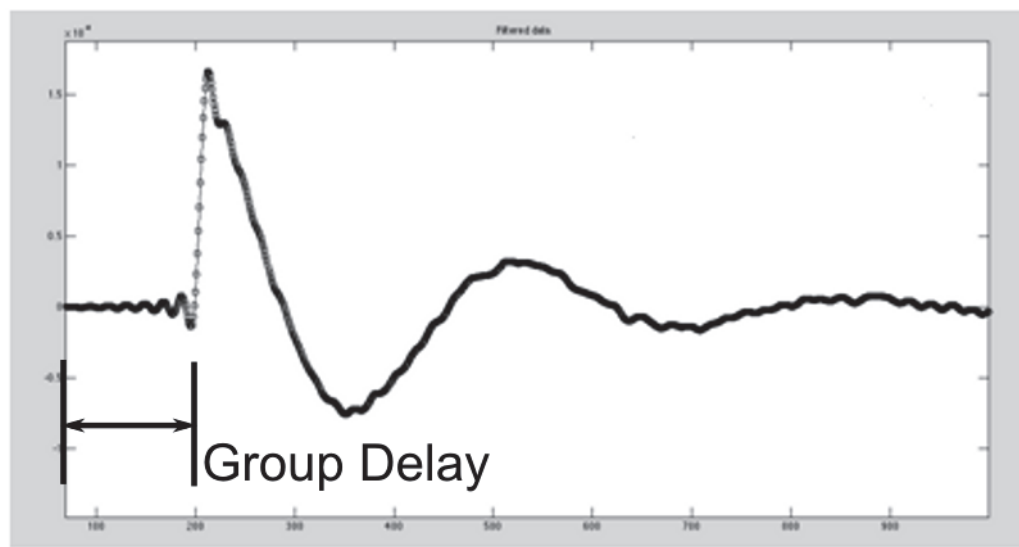


Figure 10.3: Filtered FID with IEss Noise and the Group Delay”

The group delay which is introduced by the digital filter can be checked by entering ‘GRPDLY’ in the single parameter editor of ParaVision, or by entering “1s grpdy” in the TopSpin command line when a TopSpin data set is selected. The result of this input is the shift of the signal in complex points, which means the real signal is shifted by GRPDLY points and the imaginary signal as well. The group delay in seconds is then $GRPDLY/SWH = GRPDLY*2*DW$ (Bruker dwell is half of the real dwell time).

Since the filtered signal in the previous figure now contains many more data points than required to describe the signal, the number of points in the signal can be reduced by eliminating data points that are not required.

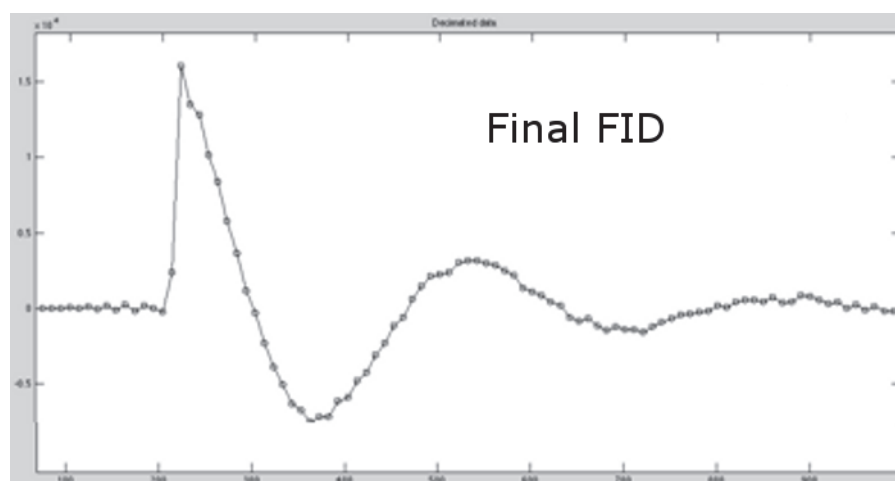


Figure 10.4: Decimated Final FID

10.1.1 Handling of the Digitally Filtered FID in TopSpin

The shift of the FID by the group delay of the digital filter causes a first order phase shift of the data. When the phase correction of the spectrum is started, a first order phase correction calculated from the GRPDLY parameter ($phc1=GRPDLY*360^\circ$) is automatically applied by the software ($pknl = 'true'$).

When the FT should be performed by an external program the 'convdta' command can be used. This command runs an FT followed by an IFT. The result is that the leading points of the original FID can now be found at the end. The end is then cut and added to the beginning of the FID. The result is an FID which looks like an analog one (no group delay at the beginning), but the size of the FID is $td-2*GRPDLY$.

10.1.2 Handling of the Digital Filtered FID in ParaVision

The handling of spectroscopic FID data in ParaVision is identical to the handling of the data in TopSpin. To enable this acquisition mode, the parameter ACQ_scan_shift must be set to 0.



Note: Spectroscopic data must be acquired with ACQ_scan_shift = 0.

Since echo signals are typically much shorter than spectroscopic FID data, they are handled in a different way. The length of an echo can easily be in the same range as the group delay. When the data is handled identically as the FID data, many more data points will need to be acquired than required (causes long acquisition times and an 'apparent' pixel resolution in the image), or the echo may be outside the acquisition window.

When echoes in ParaVision are acquired the leading GRPDLY points are deleted. At the end of the acquisition the filter is flushed to get the remaining data points out of the filter memory. This mechanism is controlled by the parameter ACQ_scan_shift. If ACQ_scan_shift is set to -1 its value is automatically replaced by the number of points to be deleted at the beginning of the echo signal (ACQ_scan_shift is typically $-2*GRPDLY$ because its value is RE+IM).

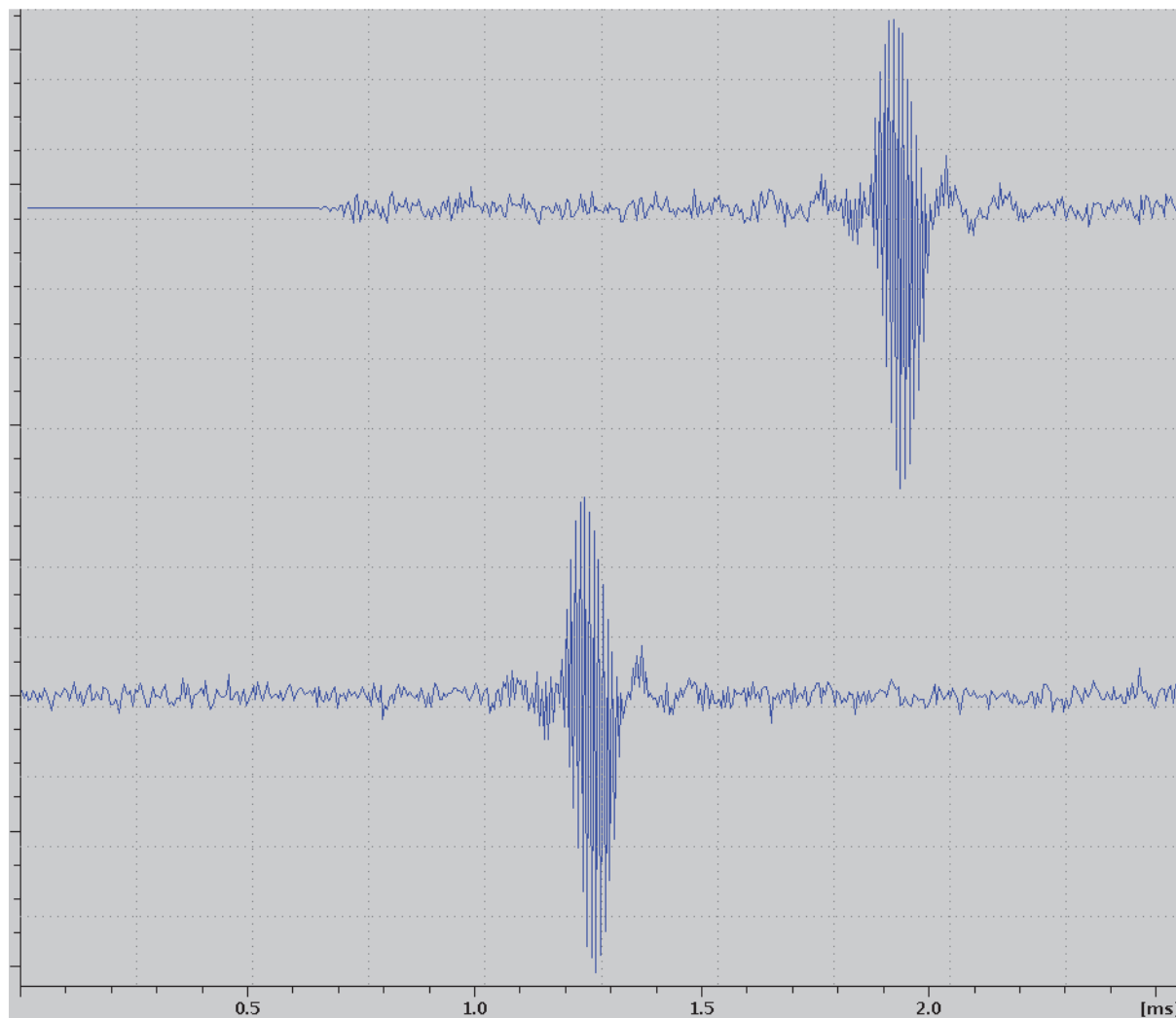


Figure 10.5: Gradient Echo (256 cplx data points)

The gradient echo in the figure above was acquired with `ACQ_scan_shift = 0` (top) and `ACQ_scan_shift = -1` (bottom). The `-1` was automatically replaced with `-136` (`GRPDLY = 67.998`).

As soon as the last point of the echo is acquired, the filter memory is flushed to get the final points out of the queue. The optimum time required to flush the DRU memory can be found in the Digitizer Class of each method in the parameter `PVM_DigEndDelOpt`, refer to the figure below. If this additional time is too long for the sequence to run, the additional time can be reduced to `PVM_DigEndDelMin`. But then the scan shift is reduced to a lower number of points and the echo no longer appears in the center of the acquisition window.

DigitizerPars		
■ expand		
PVM_DigAutSet	Automatic Settings	Yes
PVM_DigQuad	Digital Quadrature	Yes
PVM_DigFilter	Digital Filter	Digital_Sharp
PVM_DigRes	Digital Resolution	22 bit
PVM_DigDw	Sampling Dwelltime	0.0666666666666667 ms
PVM_DigSw	Sampling Bandwidth	15000.000000 Hz
PVM_DigNp	Complex Datapoints	2048
PVM_DigShift	Group Shift of Dig. Filter	68 points
PVM_DigGroupDel	Group Delay of Dig. Filter	4.533 ms
PVM_DigDur	Duration of Acquisition	136.533333333332990 ms
PVM_DigEndDelMin	Min. Delay to End of Scan	0.049999999999983 ms
PVM_DigEndDelOpt	Opt. Delay to End of Scan	0.158799999999985 ms

Figure 10.6: Digitizer Class of a Method

The automatic handling of the scan shift depends on the available time and is controlled by the parameter DEOSC (in μsec) inside ParaVision. The optimum value for DEOSC is equal or longer to $\text{PVM_DigEndDelOpt} + \text{PVM_DigDur}$ ($\text{PVM_DigDur} = \text{aqq}$).

The value for DEOSC is calculated using the time difference between ACD_START and ADC_END in the pulse program. Thus, there should always be a delay between the 'real' acquisition time and the ADC_END command in the pulse program

Example from the FLASH pulse program:

```

...
ADC_INIT_B(NOPH, ph2)
aqq ADC_START
d11 grad{(t6)|r2d(t7)|r3d(t8)} ; 2nd and 3rd dims
d12 grad{(t6)| (0) | (0) }
d3 groff
d0 ADC_END
...

```

In this example $\text{DEOSC} = 1e6 * (\text{aqq} + \text{d11} + \text{d12} + \text{d3})$.

10.2 Analog Sampling

The analog mode on the DRU is no longer realized by selecting a proper dwell time. Instead, the DWL_CLK macro (AVANCE III: $\text{setrtp1}|0 \text{ setrtp1}^{\wedge}0$) is used. The data points are always sampled with 20 MHz (50 nsec). To avoid the increase of noise in this acquisition mode (variable analog filters are no longer available), a predefined number of successive oversampling data points are averaged by a simple box filter to form one "analog" output data point. The number of data points to be averaged is controlled by the value of 'anavpt' (must be 2^n with $9 > n > 0$) in the pulse program.

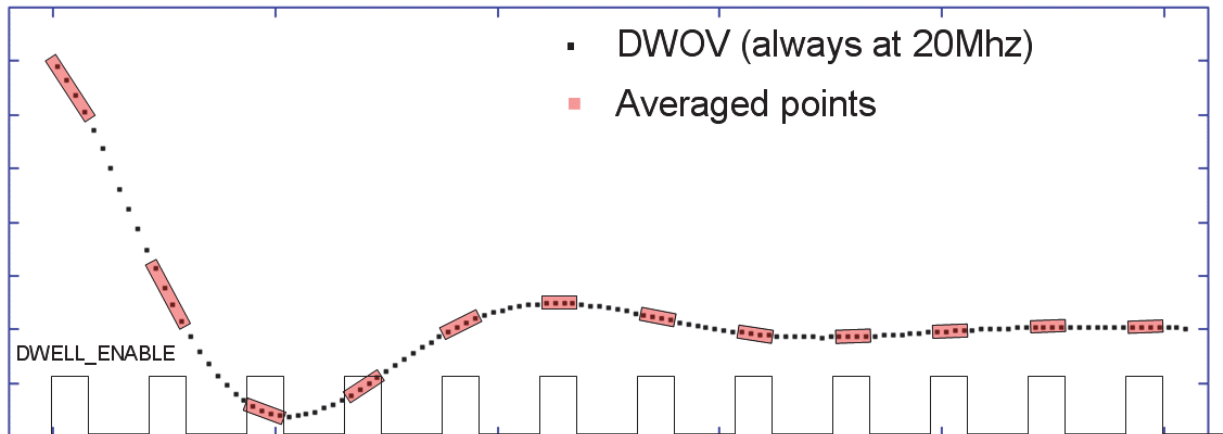


Figure 10.7: Analog Data Sampling with $anavpt=4$

This type of acquisition is a special kind of external address advance. The command “dwell-mode explicit” must be added in the header of the pulse program to allow the analog digitizer setting.



Note: For each group of $anavpt$ points, the DWL_CLK must be switched on and off again before you can acquire the next one.

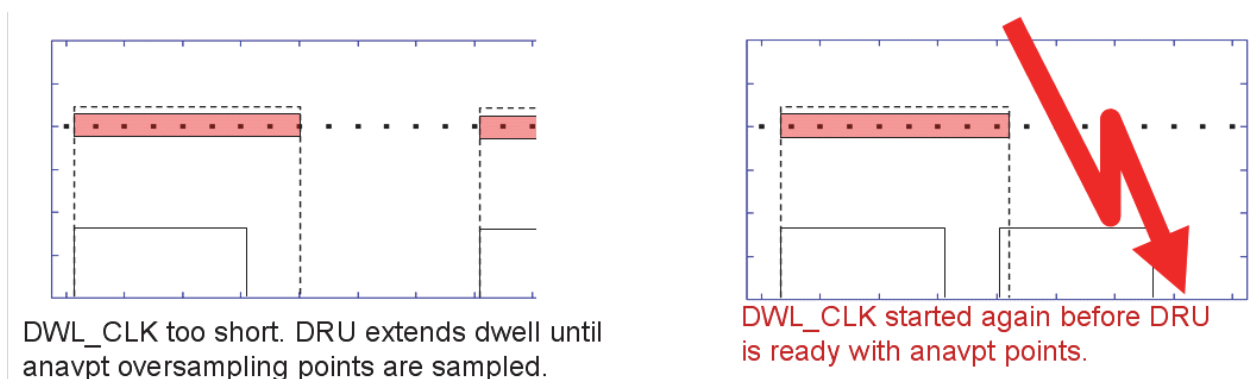
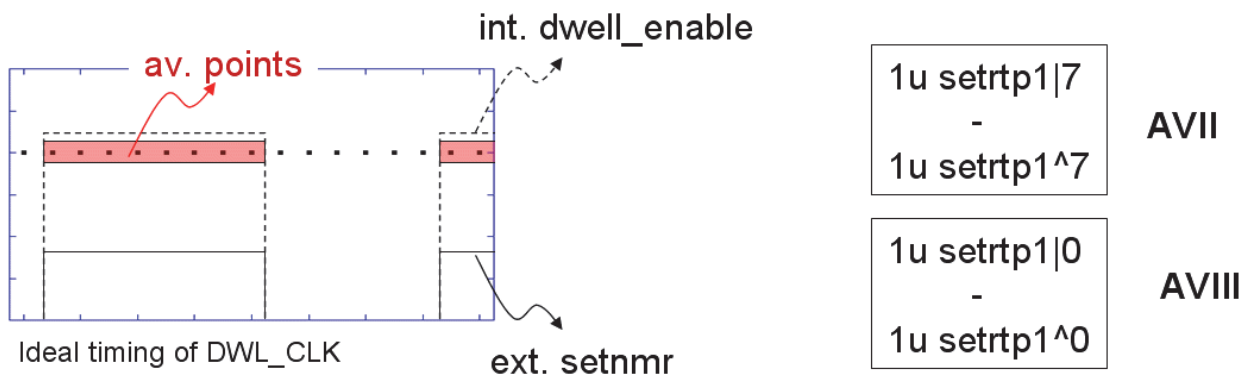


Figure 10.8: DWL_CLK Timing, $anavpt$ is set to 8.

Be sure to watch for any timing problems (lower right drawing in the figure above).



Note: DWL_CLK must be toggled ON/OFF TD times.

Sample pulse program for analog acquisition:

```
;zganav2
;lD sequence
;
;$CLASS=HighRes
;$DIM=1D
;$TYPE=
;$SUBTYPE=
;$COMMENT=

#include <Avancesolids.incl>

;"dwellmode explicit" -> digmod must be set to analog
dwellmode explicit

define loopcounter count
"count=td/2"
define delay acqu
"acqu=0.050u*ll1"
define delay dwrest
"dwrest=dw-(acqu/2)"
define delay rest
"rest=aq-(td*dw)"

;ll : 9>ll>0, number of packages of averaged points
"ll1=pow(2,ll)"
"anavpt=ll1"

1 ze
2 30m
   d1
   (p1 ph1):f1
   STARTADC      ; lu sync lu adc ph31 syrec
   RESETPHASE    ; (lu ph30:r):f1
   de
3  dwrest  setrtp1^0^5      ; REC_BLK and DWL_CLK_OFF
   acqu    setrtp1|0|5     ; REC_UNBLK and DWL_CLK_ON
   dwrest
   lo to 3 times count
   rest setrtp1^0^5      ; REC_BLK and DWL_CLK_OFF
   rcyc=2
   30m mc #0 to 2 F0(zd)
exit

ph1=0 2 3 1
ph30=0
ph31=0 2 3 1
```

11 Animal Triggering Unit

The animal triggering unit (SA Instruments) used for micro-imaging is the same unit used for horizontal bore animal scanners by Bruker. The only differences are the cables for the connections between the probe and the unit, and from the unit to the AVANCE III console.

For general information about the triggering unit and the control software, refer to the manual delivered with the unit.

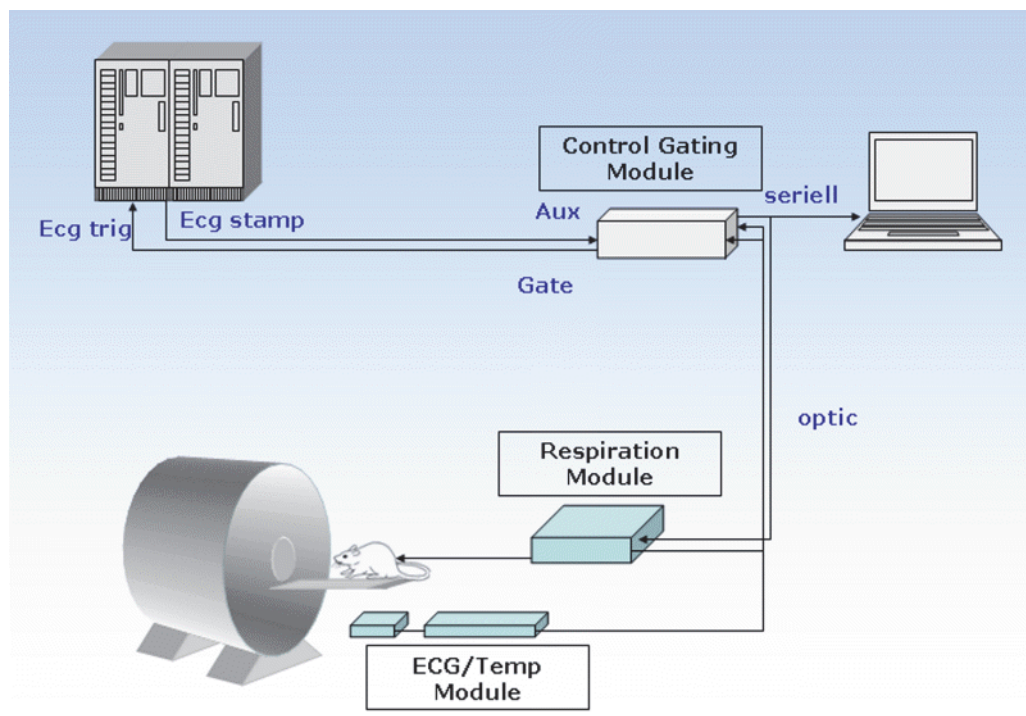


Figure 11.1: Schematic of the Console – Triggering Unit Wiring.

11.1 Connection from the Probe to the Triggering Unit

All current RF probes with animal support offer a connector for direct connection of the probe to the ECG/temperature preamplifier of the triggering unit, including support for ECG and temperature signals. The connection is established by one single cable, leading from the probe base connector ('LEMO' connector labelled BTAM) to the 2 inputs of the preamplifier:



Figure 11.2: Connection of the RF Probe to the ECG/Temperature Preamplifier

In addition to the electrical connections, the probes are equipped with 2 'Luer' connections, leading from the probe base to the upper part of the probe. One of the connections can be used for the anaesthesia gas, the other connection for the respiration balloon that is placed on the animals' belly. For further information about the animal handling refer to the ParaVision 'Applications Manual'.

11.2 Connection from the Triggering Unit to the Console

The 'Gate' output of the 'Control Gating Module' of the triggering unit must be connected to the AVANCE III console via the IPSO T0 connector. This output delivers a configurable TTL signal, which indicates different stages in the animal's physiology to trigger the NMR experiment to these events. For details how to configure trigger events and timings refer to the unit manual.

The connection is established using a BNC-BNC cable, leading from the gate output to the TRIG_IN1 (ECG_TRIG) connector of the IPSO T0 connector ('Coax' Adapter HZ10124 required).

For a jitter free triggering (relative to the gradient switching), the style of the triggering is changed at the AVANCE III. The synchronization is made using an additional trigger command GRAD_SYNC (for details see the pulse programs and include files). This synchronization only works, if an additional connection is made between the Z1 and the E1 pins of the IPSO T0 connector. If the T0-Z connector already has a free BNC connector at Z1, this can be connected to T0-E1 using a HZ10124 coax adapter. If there no free BNC available, an additional coax to BNC cable must be plugged into the T0-Z connector housing. If no coax to BNC is available, the T0-Z connector (Emergency Stop) can be removed and another HZ10124 coax adapter can be plugged in during the time of the workaround.



Note: When the case triggering still doesn't work, open the file `uxnmr.par` in `$PvHome/conf/instr/spect/` and check the value for `SYNCTRIG`. The value for `SYNCTRIG` must be 11.

Animal Triggering Unit

Optionally, the STAMP1 (ECG_STAMP) output of the IPSO T0 connector and the AUX input of the control gating module of the triggering unit can be connected. This enables the triggering unit, to detect and record events in the pulse program, e.g. to synchronize the pulse program timing with physiological parameters of the animal during post processing or to record external events (e.g. fMRI) in the experimental data.

Refer to the section Trigger Signals [▶ 149] for the pin numbers for the IPSO T0 connector.

12 Tips, Tricks and Troubleshooting

12.1 Creating RF Shapes for ParaVision

The ParaVision RF shape files can be stored in the directory `<$PvHome>/exp/stan/nmr/lists/wave` with the TopSpin files. These files can be created using the TopSpin Shape Tool, by entering the command 'stdisp' in the TopSpin command line. Before the files can be used they need to be modified manually to be accepted by ParaVision as correct shape files.

The shape file must first have the extension of the file type it should act as, for example:

.exc for excitation,

.rfc for refocusing,

.inv for inversion, or

.sat for saturation.

The wave files are ASCII files that can be opened and edited by any text editor.

Header of a ParaVision Shape	Header of a TopSpin Shape	Info
##TITLE=nmr/lists/converted/gauss	##TITLE= 90° pulse	Comment
##JCAMP-DX= 5.00 Bruker JCAMP library	##JCAMP-DX= 5.00 Bruker JCAMP library	Comment
##DATA TYPE= Shape Data	##DATA TYPE= Shape Data	Comment
##ORIGIN= Bruker Analytik GmbH	##ORIGIN= Bruker BioSpin GmbH	Comment
##OWNER= <mawi>	##OWNER= <demo>	Comment
##DATE= 101/09/20	##DATE= 2004/09/06	Comment
##TIME= 15:31:06	##TIME= 18:56:10	Comment
	##\$SHAPE_PARAMETERS= Type: Gauss ; Truncation Level [%] 1.0	Comment
##MINX= 1.036651e+00	##MINX= 1.036651e+00	Min Amp Val in [%]
##MAXX= 1.000000e+02	##MAXX= 1.000000e+02	Max Amp Val in [%]
##MINY= 0.000000e+00	##MINY= 0.000000e+00	
##MAXY= 0.000000e+00	##MAXY= 0.000000e+00	
##\$SHAPE_EXMODE= Excitation	##\$SHAPE_EXMODE= Universal	Excitation Mode
##\$SHAPE_TOTROT= 9.000000e+01	##\$SHAPE_TOTROT= 9.000000E01	Pulse Flip Angle
##\$SHAPE_TYPE=conventional	##\$SHAPE_TYPE= Excitation	Shape Typ
	##\$SHAPE_USER_DEF=	
##\$SHAPE_REPHFAC=50	##\$SHAPE_REPHFAC=	Rephase Factor
##\$SHAPE_BWFAC= 2.740000e+00	##\$SHAPE_BWFAC= 2.122000E00	1s Pulse BandWidth
	##\$SHAPE_BWFAC50=	
##\$SHAPE_INTEGFAC= 4.150688e-01	##\$SHAPE_INTEGFAC= 4.115776E-01	Rel. to a rec shape
##\$SHAPE_MODE= 0	##\$SHAPE_MODE= 0	
##NPOINTS= 1000	##NPOINTS= 1000	#Points in shape
##XYPOINTS= (XY..XY)	##XYPOINTS= (XY..XY)	
1.036651e+00, 0.000000e+00	1.000000E00, 0.000000E00	Amplitude, Phase
1.074475e+00, 0.000000e+00	1.018591E00, 0.000000E00	Amplitude, Phase
...	...	
##END	##END=	End of shape file

Table 12.1: Differences in TopSpin and ParaVision Shape Files

As indicated in bold in the table above, four lines in a TopSpin (or 'stdisp' created) shape need to be modified manually to allow ParaVision to recognize the shape.

##\$SHAPE_EXMODE:

In ParaVision this parameter must correspond to the file type indicated by the file extension, e.g. 'Excitation' for an .exc file, or 'Inversion for an .inv file.

##\$SHAPE_TYPE:

Must be 'conventional' or 'adiabatic' in ParaVision.

##\$SHAPE_REPHAC=50:

This parameter defines the length of the pulse in percent to be re-phased in a gradient experiment, e.g. during the slice selection. It cannot be left blank in a ParaVision shape file.

##END=:

A known bug in ParaVision. The '=' needs to be added to the END label.

If all the parameters are set correctly, the wave file only needs to be copied to the wave directory and after a ParaVision restart, the shape will be available in the shape selection drop-down menu of the method GUI.

12.2 Image Display Scaling

The Image Display & Processing routine (Xtip) allows the user to specify the way images are scaled during display.

The default is **automatic** scaling. Each individual frame (e.g. of a T2 sequence) will be displayed with its full dynamic range. Each frame is mapped between its individual minimum and maximum.

The alternative is the **Global User** scaling. All frames will be scaled between the minimum and maximum of the whole series of images.

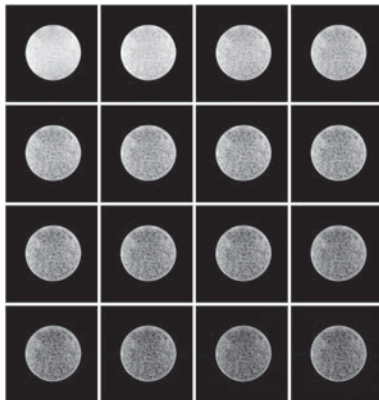


Figure 12.1: T2 Images Series Displayed with Automatic Scaling

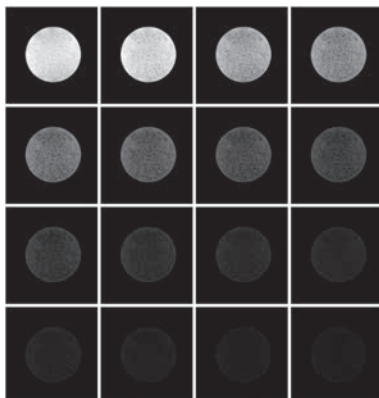


Figure 12.2: T2 Images Series Displayed with Global User Scaling

For automatic scaling add the line to the file <\$PvHome>/exp/stan/nmr/ProcStatPref/xtip.1/lp-Status to specify the mode for all users:

pvcmd tlmRescale a

For global user scaling add the line to the file <\$PvHome>/exp/stan/nmr/ProcStatPref/xtip.1/lp-Status to specify the mode for all users:

pvcmd tlmRescale uGlobal

If the scaling should be set for a particular user only, add the same entries to <\$PvHome>/prog/curdir/<user>/ParaVision/ProcStat/xtip.1/Pref.ips/lpStatus instead of the above file.

12.3 Providing Display Memory for Large Data Sets

In case large 3D data sets should be displayed, e.g. as MIP, the size of the working memory in XTip needs to be set to at least the size of the data set (8 bit/pixel). If the working memory is set too low, the full 3D data set cannot be displayed and the images are cropped. A typical solution, which should cover all applications, is to set the size of working memory in XTip to 256 MByte. To set this value:

1. Select File-> Configure in XTip.
2. Set the value as shown below.

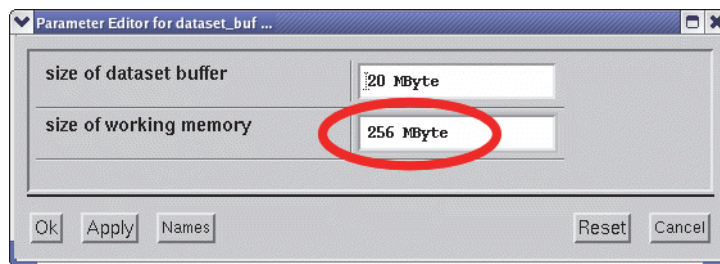


Figure 12.3: Working Memory Setting

3. Restart XTip.



Important: This value should be set as default on all systems.

12.4 Hardware ON/OFF Procedures

This section describe the ways to switch the hardware on or off.

12.4.1 Turning the AVANCE III Console ON

► The console and computer are both off.

1. Power the console up and turn the IPSO unit on.
2. Boot the computer. This is required to start the DHCP server correctly.
3. Once the computer is booted, log in and reset the IPSO unit so that it boots.
4. When the POST code (2 7-segment LEDs on the IPSO front) gets past the stop at 'C0' and starts to load the IPSO operation system, turn the AQS, BSMS, Imaging Rack, and RF amplifiers on. Units without ethernet connections can be turned on any time.

When this procedure is finished, the SYNC LEDs on all SGU/2's should be green.

If not, type 'ii restart' in the TopSpin command line.

If they are still not green, access the DRU service Webpage ('ha' in TopSpin), and reset the DRU (takes ~1 minute).

12.4.2 Turning the AVANCE III Console OFF

1. Enter the service Webpage of the ISPO ('ha' command in TopSpin) unit.
2. Shut down the IPSO ('ha' (TopSpin command line)→ IPSO→ Administration→ Power Off).
3. Switch off all other units in any order.

12.4.3 Turning the Imaging Rack ON

1. Switch on all Great amplifiers.
2. Switch on the B0-2 compensation unit (if available).
3. Switch on the water cooling unit BCU20.
4. Switch on the master unit BGMUI-E.
 - ⇒ The master unit only recognizes the amplifiers connected during the boot process. If an amplifier is switched on after the master unit has booted, the master unit must be restarted to enable the amplifier.
 - ⇒ The master unit will display a 'C01' message in the display until the 'Safety Parameters' for the gradient coil are loaded manually or automatically (refer to Gradient Safety Parameters [89]).

12.4.4 Turning the Imaging Rack OFF

Switch off the devices in any order.

12.5 Different Software (TopSpin) Versions on the System

It is possible to have multiple versions of TopSpin/ParaVision installed on the same system. They are all located in the /opt directory of the system, and each installation has to be in a separate subdirectory, e.g. /opt/TopSpin2.1, /opt/TopSpin2.2, and /opt/ParaVision5.

The only requirement for problem free operation of the different versions is to always have the newest DISKLESS installed.

If one version is stopped and another one started, the first command in the newly started version must be 'ii restart'.

12.6 Disable the HPPR Build-in Power Check

The LNA HPPR modules have a build-in power check, which is sometimes a bit too sensitive for imaging systems. To disable the power check feature open the UniTool ('UniTool' in a shell), and select HPPR, address 80, option P, 1H (option 5) and there disable the emergency stop.



Note: After a HPPR reset (power up) the power check is activated by default.

12.7 Disabling the 'External Enable' and PT100 Check for the Master Unit

The 'External Enable' and 'PT100' security features can be temporarily be disabled in the master unit.

To disable them: open 'ha' (TopSpin command line)→ BGAU→ BGA Configuration→ Bruker Access (scroll down):

Login: BRUKER

Password: BGMUI12215

The security features can be re-enabled in the same menu. They are automatically enabled after a reboot of the master unit.

12.8 Signal Instabilities

Instabilities of the signal can be caused by the magnet itself or any other hardware component. They result in jittering of the echo position in GSP mode or ghost artefacts in images. To find the reason for the instabilities is often a time consuming task. In rare cases it even occur, that the instabilities where caused by movements of the building, causing the magnet to move, which changes the magnetic field. Since the lock cannot be used in imaging, this is a very serious problem. Some other reasons found in the past are listed below.

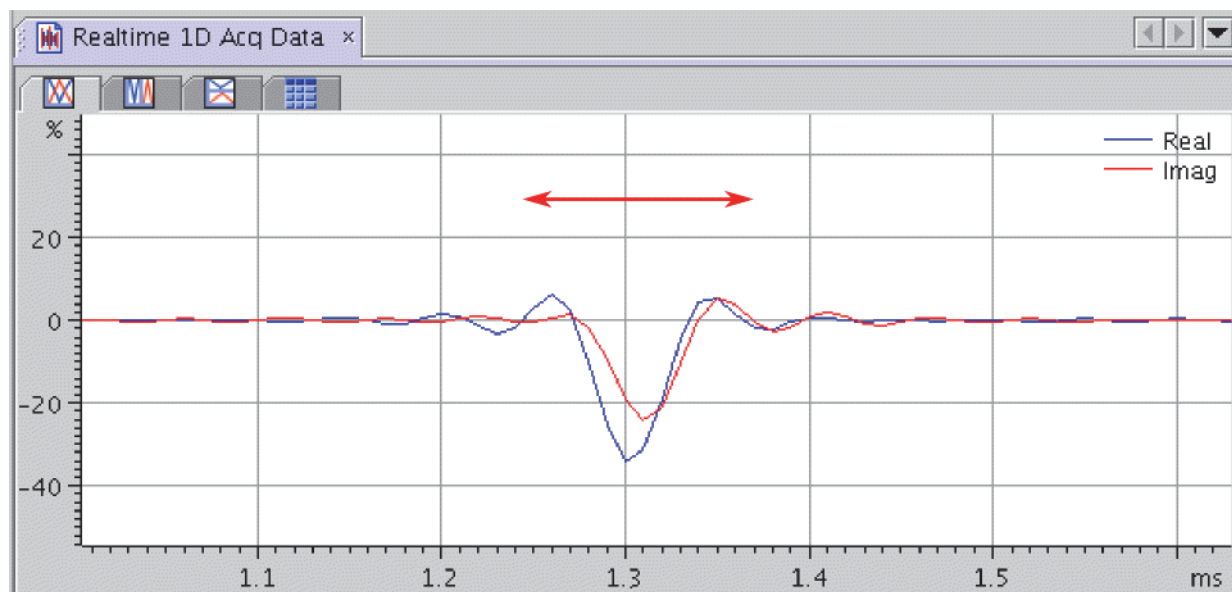


Figure 12.4: Jittering of the Echo Position Due to Instabilities

A very sensitive test for instabilities is a spin echo sequence (MSME) with an echo time of >20 msec. If the system is not stable for any reason, this can often be observed directly at the time signal. As a test, the MSME sequence can be used with a low bandwidth to view the echo position and the phase of the real and imaginary signal. Both the position and the phase should be stable (apart from some noise which is always there).

The MSME sequence can also be acquired using the GOP command. Periodic instabilities result in ghost artifacts, which clearly become visible if the look-up table is modified to show weak intensities.

Here is a list of reasons, which have been found to cause instability in the past:

- 50(60) Hz hum of the gradient amplifier: Ground loops caused a 50(60) Hz hum of the NMR signal. This should be eliminated by the digital signal distribution in the Great imaging rack. To check this, a spectroscopic spin echo sequence can be set up and the amplifiers can be connected/ disconnected during the experiment to see, if the signal behavior changes when the amplifiers are connected.
- Helium valve of the magnet: The helium valve on top of the magnet opens/closes in a periodic way. To check this, simply remove the valve for a short period of time to see, if it affects the signal.
- Vibration dampers: Check if the magnet is on vibration dampers and all dampers are on the air cushion.
- Shim regulator of the BSMS/2: Check the influence of the shim regulator by setting it to a slow mode. 'ha' (TopSpin command line)→ BSMS→ SHIM→ Shim Board Service Functions SCB [1]→ Regulator Settings→ 'Very Slow'.

At the moment is not clear, if this setting affects e.g. the digital lock for HR applications!

- GRADRES Timing: The gradient resolution (GRADRES) must be set to 8 in <\$PvHome>/conf/instr/spect/uxnmr.par.

- DPP ECL: The ECL for a DPP F1 board (H12513F1) must be ≥ 05 , the ECL for a DPP F2 board (H12513F2) must be ≥ 01 . To check this, open 'ha' (TopSpin command line) \rightarrow IPSO \rightarrow Administration \rightarrow Read BIS \rightarrow IPSO DPP \rightarrow DPP1. If the ECL is lower, the board has to be returned to Bruker for upgrading (only in case of ghosting along the phase direction in the images and if all other symptoms can be excluded).
- In case of strong spikes which may even be heard during the experiment (strong non periodic clicks) a hardware modification in the Great amplifiers is required (only valid for W1211690, W1215322ECL0, W1209612, W1215323 ECL0). In this case, a trained person has to open the amplifier and replace the cable shown in the figure below, with a cable with part number W118210. As a work around, the wire #10 of the existing cable can be removed (the red wire marks #1). Replace the flat cable with the modified cable W118210 or remove wire #10 of the existing cable:

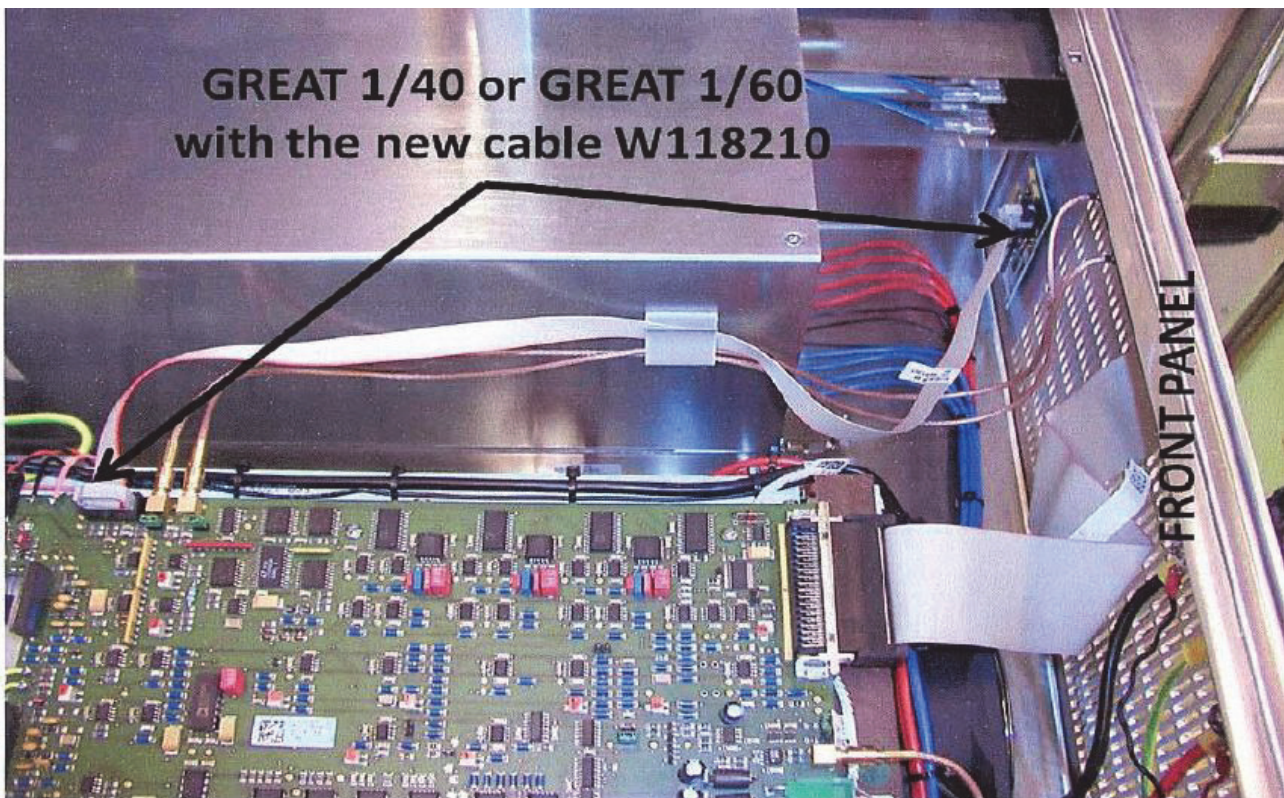


Figure 12.5: GREAT 1/40 or GREAT 1/60 with the New Cable W118210

12.9 External Trigger Doesn't Work

When the external triggering of the console doesn't work as expected, refer to chapter Connection from the Triggering Unit to the Console [▶ 136].

13 Diffusion Coefficients

13.1 Diffusion Coefficient D of Various Liquids at 25°C

Liquid	D	Liquid	D	Liquid	D
Water (H ₂ O)	2.299	Acetonitrile	4.37	Cyclopentane	3.09
Water (H ₂ O)	1.872	Pyridine	1.54	Cyclooctane	0.55
Methanol (CH ₂ OH)	2.415	Nitromethane	2.39	n-Pentane	5.72
Methanol (CH ₂ OD)	2.30	Tetrahydrofuran	2.84	n-Hexane	4.26
Methanol (CH ₂ OH)	2.21	Benzene	2.21	n-Heptane	3.12
Methanol (CH ₂ OD)	2.11	C ₆ H ₅ F	2.39	n-Octane	2.35
Ethanol	1.08	C ₆ F ₆	1.46	n-Nonane	1.77
t-Butanol-d ₁	0.28	Toluene	2.27	N-Decane	1.37
Formamide	0.55	Carbon Disulphide	4.32	n-Undecane	1.07
N, N-Dimethylformamide	1.63	Carbon Tetrachloride	1.30	n-Dodecane	0.81
N, N-Dimethylacetamide	1.35	Chloroform	2.35	n-Tridecane	0.70
Dimethylsulphoxide	0.73	Acetic Acid	1.08	n-Tetradecane	0.52
Dioxane	1.09	Formic Acid	1.08	Pentan-1-ol	0.29
Acetone	4.57	Cyclohexane	1.42	Octan-1-ol	0.14

Table 13.1: Diffusion Coefficients D in $10^{-9}m^2s^{-1}$.

Source: Bruker Almanac 2007.

13.2 Diffusion Coefficient D of Special Bruker Samples at 25°C

Liquid	D	Liquid	D	Liquid	D
"Doped Water" 1% H ₂ O in D ₂ O	1.91	1% PEG 20000 0.1% CuSO ₄ in D ₂ O			

Table 13.2: Diffusion Coefficients D in $10^{-9}m^2s^{-1}$

13.3 Temperature Dependence of the Self Diffusion Coefficient D of Water (H₂O)

T [°C]	D	T [°C]	D	T [°C]	D	T [°C]	D	T [°C]	D
-5	0.913	20	2.023	45	3.588	70	5.615	95	8.111
0	1.099	25	2.299	50	3.956	75	6.078	100	8.667
5	1.303	30	2.594	55	4.344	80	6.557		
10	1.525	35	2.907	60	4.748	85	7.056		
15	1.765	40	3.238	65	5.127	90	7.574		

Table 13.3: Diffusion Coefficients of H₂O at different temperatures. D in 10⁻⁹m²s⁻¹

Source: Bruker Almanac 2007

14 Trigger Signals

14.1 Trigger Signals at the T0 Connector

T0 Name	Description/Label	ppg Command	Connection Point
Signal Outputs			
TTL1	TTL Out 1	TTL1_LOW TTL1_HIGH (nrmword 3#28)	T0 / I1
TTL2	TTL Out 2	TTL2_LOW TTL2_HIGH (nrmword 3#29)	T0 / I2
TTL3	TTL Out 3	TTL3_LOW TTL3_HIGH (nrmword 3#30)	T0 / I3
TTL4	TTL Out 4	TTL4_LOW TTL4_HIGH (nrmword 3#31)	T0 / I4
STAMP1	ECG_STAMP	STAMP1_LOW STAMP1_HIGH (nrmword 3#6)	T0 / C1
NV_CLOCK	DPP NV_CLOCK		T0 / Z1
BlankXAmp		nrmword0#32	T0 / A4
BlankYAmp		nrmword0#33	T0 / A5
BlankZAmp		nrmword0#34	T0 / A6
Signal Inputs			
TRIG_IN1	ECG_TRIG see chapter 10.2 [▶136]	trig[np][le]1	T0 / C5
TRIG_IN2	TTL IN 1	trig[np][le]2	T0 / C6
TRIG_IN3	GRAD_SYNC	trig[np][le]3	T0 / E1
TRIG_IN4	TTL IN 2	trig[np][le]4	T0 / E2

Table 14.1: T0 Trigger Signals

15 Quick Introduction to Coil Configurations

Thanks to Ulrich Heinen for this part of the manual.

15.1 Preface: Nomenclature

The NMR and the MRI community have adopted different naming conventions for RF antennae systems. As a consequence, ParaVision uses a different terminology than the TopSpin software package. Users working with both packages should be aware of these differences.

In ParaVision, the physical unit bearing one or more RF resonant loops is termed a *Coil* (NMR/Topspin terminology: probe or probe head). An individual resonant loop is called *Coil Element* (NMR/Topspin: coil). ParaVision supports the operation of linear and quadrature coils, array coils and multi-resonance coils as well as cryo-cooled variants of these types. Up to four different coils may be connected to the scanner at any time. Such a combination of multiple coils is called a *Coil Configuration*. The connected set of coils is termed the *Active Coil Configuration*.

In ParaVision 5.0, the scope of a coil configuration is tied to a study. In other words: all scans within a study use the same coil configuration that has been specified during study setup. This *Study Coil Configuration* does not need to be identical to the active coil configuration (to allow preparation of scans before the coils are installed), but the scans cannot be executed until the configured coils are installed.

When multiple coils are installed together, they may take up different roles in an experiment. For example, if a transmit/receive resonator is installed together with a receive-only array, the resonator can act both as the transmitting and receiving coil, or it may be used for transmission only while the array is used for signal detection. Such different experiment situations are referred to as (*Coil*) *Operation Modes*. Since they do not require the addition or removal of coils, operation modes can be freely switched for each scan within a study.

The relationships between coils, coil configurations, and operation modes are visualized in the figure below:

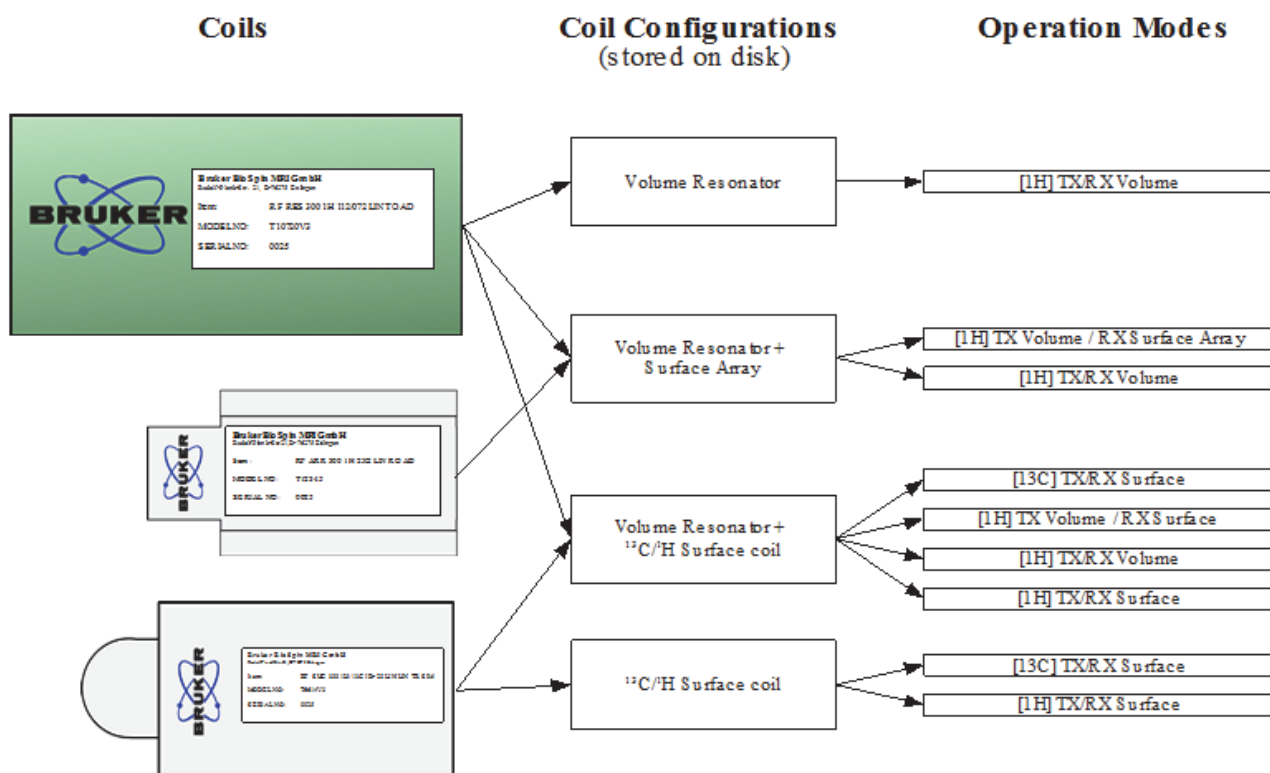


Figure 15.1: Coil Handling and Routing Infrastructure in ParaVision 5.0

15.2 Purpose and Scope of the Present Documentation

The present text is meant to bridge the gap until the corresponding chapter in the ParaVision manual is complemented. It does not document the full capabilities of the coil handling but restricts itself to the typical needs on NMR spectrometers with micro-imaging accessories.

The micro-imaging systems (AVANCE/AVANCE II/AVANCE III) are typically not equipped with an Active Detuning Module (ADM), with the MRI coil interface (ODU sockets and plugs), or with HWIDS. Likewise, systems with parallel receive extensions (RF splitter/pulse splitter) are not discussed (yet).

Furthermore, it is assumed that typically only a single coil is mounted, which is often equipped with multiple coil elements for different frequencies (nuclei). The configuration of multiple coils used together, and the configuration of quadrature and array coils are not discussed.

15.3 Generation of Coil Configuration Files

For each micro-imaging probe used for ParaVision acquisition, an appropriate coil configuration file must exist. Coil configuration files are created:

- During 'cf' (subcommand pvdefcoilconfs). These configuration files only cover very simple cases; they are appropriate for initial.
- Automatically, if HWIDS and (ideally) the MRI socket interface are available and the coils support it.
- Manually using the Coil Configuration Editor. This third option is described more closely in the following notes.

15.4 The Coil Configuration Editor

The coil configuration editor is technically part of pvScan (Scan Control Tool/Spectrometer Control Tool), but is not accessible from its menus as it is only needed for the initial configuration of a new probe/coil but not for daily work afterwards. The editor window contains several distinct sections referring to the different management/editing tasks.

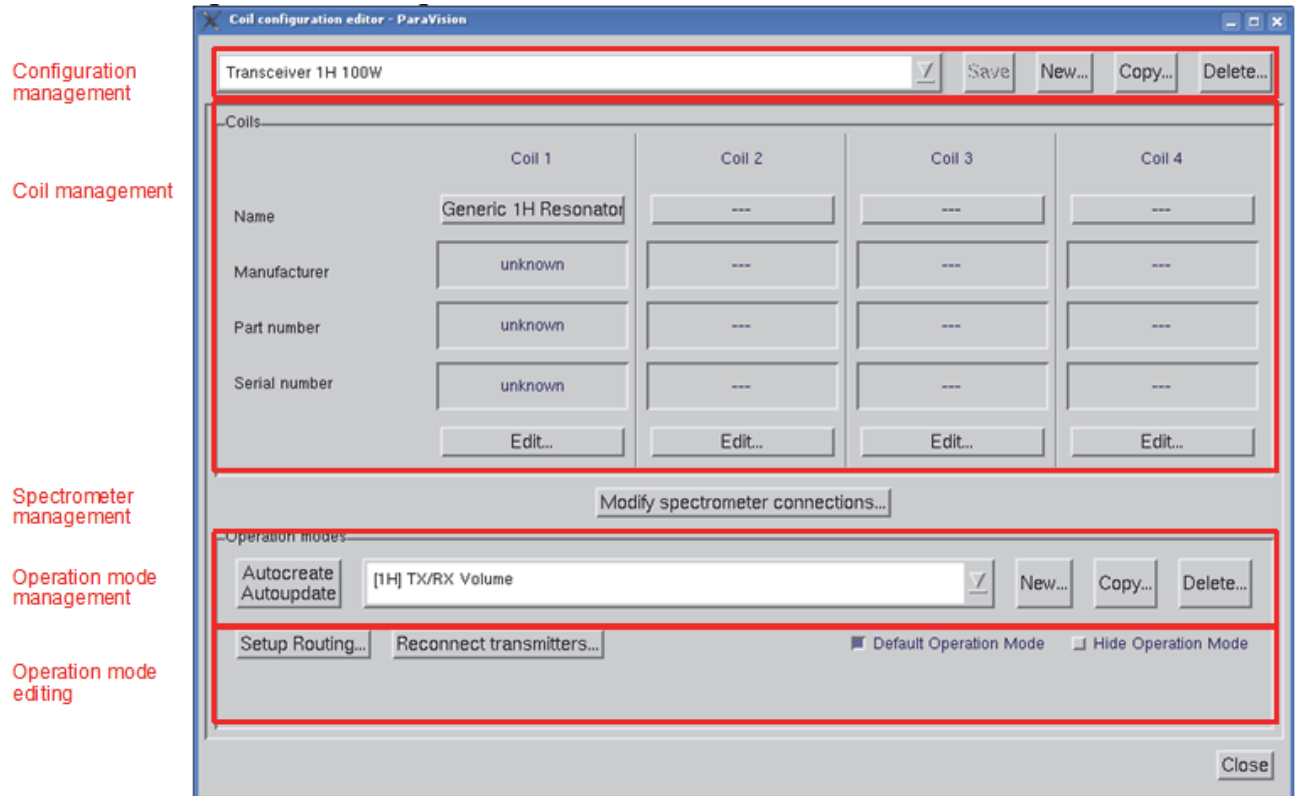


Figure 15.2: The Coil Configuration Editor

15.4.1 The Coil Configuration Management Section

The top most section of the Coil Configuration Editor provides functionality for managing the existing coil configurations. On the left, an existing coil configuration can be selected, the content of which is then displayed in the lower sections of the editor, and to which the command buttons on the right of the configuration management section apply. Buttons exist:

- To save the presently displayed configuration, if it has been changed.
- To create a new, initially empty configuration. ParaVision asks for a name for the new configuration when this button is clicked.
- To copy the selected configuration. This is essentially the same as the “New” button, but the new configuration is initialized with the contents of the copied configuration, which can then be modified (e.g. by adding further coils).
- To delete the presently displayed configuration from the ParaVision installation.

15.4.2 The Coil Management Section

A single coil configuration may consist of up to four coils, although only a single coil (probe) is present in micro-imaging systems. The four panels in the editor are equivalent if no MRI socket interface is present, thus, as a general rule, only the “Coil 1” panel is used to configure micro-imaging probe. The “Name” button can be used to load a coil known from another coil configuration into the panel, below the manufacturers name, the part number and the serial number are shown which together provide an unambiguous characterization of a coil/probe¹. Clicking “Edit...” opens a new editor window where the properties of the coil can be manipulated. This will be discussed later in this chapter.

¹ If the actual probe has exchangeable coils, it is recommended to keep the different setups in separate coil configurations and use the part number of the mounted coil for registration.

15.4.3 The Spectrometer Management Section

The spectrometer management section consists of a single button “Modify spectrometer connections...”. Normally, the spectrometer wiring (transmitter to preamplifier, preamplifier to receivers, LO supply from SGU’s to receivers) is defined once during ‘cf’ (subdialog edasp setpreamp). Nevertheless, for certain coils it may be necessary to rewire the spectrometer to some degree to allow the desired experiments to be carried out. The button “Modify spectrometer connections...” invokes edasp setpreamp and stores the defined connections within the coil configuration file.

15.4.4 The Operation Mode Section

The operation mode section is further divided into a management and an editing area. The management area is similar to the coil configuration management section in so far as the operation mode to be edited can be selected here, and buttons “New”, “Copy”, “Delete” are also provided, performing the obvious tasks.

The button “AutoCreate / AutoUpdate” provides access to ParaVisions automatic routing generator. Based on the given coils, their properties and connectivity, the spectrometer configuration and its wiring, this Autorouter is able to determine all possible routing and create operation modes for them. After changes in the spectrometer electronics (addition/removal/exchange of AQS boards, transmitters, or preamplifiers), the Autorouter tries to update existing operation modes to adapt to a possibly changed routing situation. In standard situations, clicking this button should generate all operation modes needed for acquisition. If this is not the case, you may:

- Modify the generated modes by clicking “Setup routing...” and correct the routing paths.
- Add new modes by clicking first “New...”, then enter a unique name for the new mode and finally by clicking “Setup routing...” to define the routing path.
- Use the button “Reconnect transmitters...” to invoke edasp setpreamp for defining a deviation in the transmitter-preamplifier connections for this particular mode.



Note: The button “Reconnect transmitters...” is not yet available in current Beta versions. On current versions, you may use the “Modify spectrometer connections...” button between setting up the routing for different operation modes. Only the transmitter connections may differ between different operation modes. Note that current Beta versions will display routing errors when operation modes use deviating transmitter connections by this workaround.

One operation mode may be marked as “Default”. If a coil configuration contains multiple operation modes, this is the one preselected initially when the first scan of a study is created.

In some cases, the AutoRouter may create modes, which are technically feasible but nevertheless not useful for practical experiments. Rather than deleting such modes, it is recommended to mark them as “hidden” using the corresponding button. Otherwise, such modes may reappear when the Autorouter is rerun either manually or automatically when ParaVision detects a change in the hardware configuration that potentially invalidates the routing.

Below these buttons, the operation mode section contains a message area which may contain textual information about special properties of an operation mode. Currently, two such special properties may appear:

- If an operation mode contains receive routing for more than one channel, it can only be used in conjunction with ParaVisions Multi Scan Control Tool.
- If an operation mode has been generated manually, or if an automatically generated mode has subsequently been modified, and a spectrometer configuration change is detected later, such modes cannot be updated automatically. Instead, a warning message appears, stating that the mode requires manual inspection. “Setup Routing...” has to be clicked to inspect and potentially correct the routing. After edasp has been completed with “Save”, this warning disappears, and the operation mode will be available again for setting up scans.

15.4.5 The Coil Editor Subdialog

When clicking on the “Edit...” button of one of the coil panels, the Coil Editor dialog appears. As an exception, if the panel previously contained no coil, then ParaVision will first ask what type of coil is to be configured, as the layout of the coil editor depends on this. ParaVision supports four basic types of coils:

- Linear coils with a single element.
- Multiple resonance coils with multiple elements resonant at different frequencies.
- Quadrature coils with an internal or external splitter/combiner.
- Coil arrays.

The first two types are relevant for micro-imaging setups.

Furthermore, the layout of the editor varies depending of the availability of an Automatic Detuning Module (ADM) and the MRI RF socket interface.

The editor contains 4 or 5 sections as shown in Coil Type Section [▶ 156] (the section “Coil Elements” is only shown for array coils and multiple resonance coils).

15.5 Identity Section

The section “Identity” contains the name, manufacturer, part number, and serial number of the coil. This information unambiguously identifies each coil. It is displayed in the main coil configuration editor, and is also used to generate an initial file name for the coil configuration.

The actual file name is not relevant to ParaVision but must not be changed, since the file is referred to from the created scans. However, creating the file name from part and serial number eases identification of the files by an administrator.

15.5.1 Coil Type Section

The section “Coil Type” displays the basic type of the coil being edited. You may further specify the coarse geometry of the coil (Volume/Surface/...), although “Volume” is probably appropriate for typical micro-imaging coils. The information is used by the Autorouter mostly for naming operation modes. Finally, a coil may be marked as a cryo coil. This ensures that the connected HPPR module is forced into cryo mode during acquisition.

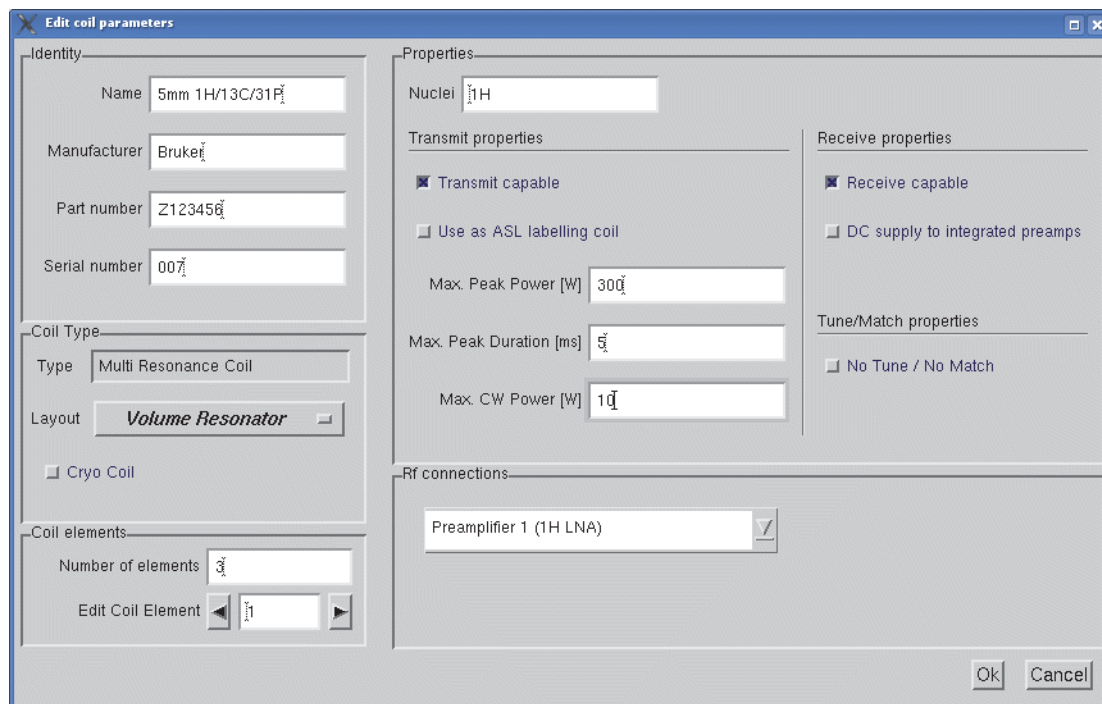


Figure 15.3: The Coil Editor

In the figure above, the system is without ADM and socket interface, editing a multiple resonance coil.

15.5.2 Coil Elements Section

The section “Coil Elements” (available only for array and multiple resonance coils) is used to define the number of individual elements in the coil operating at the same frequency (array) or at possibly different frequencies (multiple resonance coils). Below, the coil element to be edited in the remaining sections can be selected.

15.5.3 Properties Section

This section applies to the entire coil except for multiple resonance coils where it applies to each coil element individually (i.e. its contents change when a different coil element is selected). Most importantly, the nucleus or nuclei supported by the coil element(s) can be specified. You can either enter a single nucleus, or multiple nuclei written as, for example “1H/19F”, or an entire nucleus range like “13C-127I” for broad-band tunable coil elements. Note that nucleus lists or ranges should always be written with the highest-frequency nucleus in the front.

Below the nucleus field, two panels exist for transmit and receive properties of the coil. For micro-imaging purposes, coils are typically both transmit and receive capable. You may specify simple power limits for the pulse and cw case; these are taken into account by ParaVision's PVM method framework during pulse optimization. Certain receive-only coils may require a DC supply via the RF line, e.g. for an integrated preamplifier. It is recommended to leave this feature switched off, unless you are sure that your coil requires it. Finally, if a coil element cannot be tuned or matched, you can activate the corresponding button. The ParaVision wobble function will then not consider this coil element.

15.5.4 RF Connections Section

If no ADM and no MRI socket interface are present, and if the coil being edited is not a quadrature coil, the section "RF connections" consists of a single selection box by which you may specify where the current coil element is connected. While coil elements are normally connected to the "Probe" connector of an HPPR/2 module, ParaVision also supports some unorthodox connection options:

- Probe output of the HPPR/2 module.
- HPPR/2 channel bypass (rf_in socket at side of HPPR/2, possibly available by an adaptor module).
- Directly to an amplifier/switchbox output.
- Directly to a receiver input.

Typically, micro-imaging coil elements are connected to the "probe" connectors in the standard manner, thus you only have to select the correct module here.

15.6 Final Remarks

If a certain coil (probe) appears in multiple configurations, and you edit its properties within one of the configurations, the changed properties will not apply to other configurations, since the editor only modifies the local copy of the coil description contained in the edited coil configuration file.

15.7 Workflow for Changing Coils

When a new coil (probe) has been inserted into the magnet, the first task with ParaVision should be to invoke "Scan Control Tool / Scanner / Change Active Coil Configuration..." to make the currently installed configuration known to the software. On a system with installed hardware detection (HWIDS), this is done automatically. If the coil is being used for the first time, it may be necessary to create the coil configuration manually using the editor as described previously.

15.8 Working with Studies, Scans, and Operation Modes

The study concept of ParaVision relies on the idea that during a study the object of investigation is held fixed within the magnet. This implies that adjustment results remain valid for the entire study. Consequently, coils cannot be changed within a study, and the coil configuration is a property of the study.

15.8.1 Creating a Study

When creating a new study, you can use the field “Coils” to select the coil configuration that will be used for all scans in the study. By default, the active coil configuration is preselected, but you may also choose a different configuration, e.g. if you need to prepare a sequence of scans in advance before the coil/probe is mounted in the magnet. This choice cannot be changed at a later time.

15.8.2 Scan and Operation Modes / PVM

For each scan, you can choose any of the operation modes provided by the study. ParaVision’s method framework PVM will evaluate the routing of this operation mode and select the channel nuclei according to the routed coil elements. Unless the coil element itself supports multiple nuclei (by broad-range tuning capabilities), the nucleus cannot be changed in the method editor. Instead you will typically use the “Edit Scan” button of the spectrometer control tool, the scan editor contains a selection box where you may choose a different operation mode that targets a different coil element, and hence causes other nuclei to be selected.

If an operation mode has more than one channel routed on the transmit side, PVM will allow decoupling to be activated, and the nuclei are correctly predefined for the decoupling channel.

16 Part Numbers

DPP

DPP Board	H12513F1
DPP Board (lead free)	H12513F2

Master Unit

PT100 Master Unit Dummy	W1214954
External Enable Master Unit Dummy	W1500332
Cable Set Upgrade Master Unit -> BGMUI-E	W1214823

Gradient Systems

O-Rings Micro 2.5	W3302019
O-Rings Mini 0.5/0.75	W3302248
O-Rings Diff 60, Micro 5, Diff 30	40178

BCU20

10 Filter Elements for the BCU20 water filter	
- old version with white 'paper' filter	H9531 or 68443
- new version with plastic filter	79671
Water Conditioner (Algae Stop) for BCU20	Art. 9025.1 ROTH

SA Instruments Triggering Unit

ECG Cable for Probe->SA Trig connection	HZ13044
ECG Electrodes	85003
Respiration Sensor Pad	85004

IPSO

'Coaxi' Adapter (Coaxi to 6 BNC)	HZ10124
LVDS Cable 0.5m	88201
LVDS Cable 1m	86868
LVDS Cable 2m	87925
LVDS Cable 5m	87940

HWIDS

Hardware Detection Unit (HDU) in HPPR/2	H14175
Hardware Detection Unit (HDU) in 19"	H14179
Hardware Detection Interface (HDI)	H14176

Cable HDU-Memory Board 1.2m
Cable HDU-Memory Board 2.5m
Cable HDU-HDI:

T12321
T12322
Standard SBS 15P.
Cable ST/BU

17 RF Probe Parameters and Final Test Information

17.1 Information Final Test Protocol for RF Probes on Form

This chapter gives information to some points of the form 'Final Test Protocol for RF Probes on AV3 Systems'. For detailed information about the signal to noise measurement procedures refer to section Signal to Noise Ratio and z-B1 Tests for the RF Probes [▶119].

17.1.1 RF Insert Details and RF Performance Tests

Peak width of selected peak

Shim the sample as good as possible and acquire a single pulse spectrum (e.g. with zg in Top-Spin or SINGLEPULSE in ParaVision). Measure the line width at 5% and 50% of the maximum peak amplitude.

90 degree hard pulse

Run a paropt (or popt) with fixed RF pulse amplitude and vary the RF pulse length until you reach at least a 360° RF pulse angle. Be sure that the peak of interest is on resonance. Calculate the 90 degree pulse from the 360° pulse length (1/4 of the 360 degree pulse length). If possible, add a print out of the paropt to this report. The real power in watt should be noted (i. a.).

SNR from Spectrum

The sensitivity of X nuclei in imaging experiments is often not sufficient to acquire a 2D image. Measure the spectrum with the parameters noted in the table for X nuclei in Test Sequences and Samples [▶162]. Measure the sino value of the peak (area) marked in the spectra in the section Reference Spectra [▶165], and multiply it with the line width at 50% of the maximum peak amplitude. The sample should be shimmed well and the sensitivity is calculated by the formula:

$$SNR = Sino * \Delta f_{(50\%)}$$

Figure 17.1: Equation A-1: Signal to Noise Calculation from a Spectrum

The same spectroscopic test can be performed for the 1H samples as well.

ParaVision Reference Gain

Start ParaVision, execute Auto Reference Gain Adjustments and note the value for PVM_RefAtt (enter PVM_RefAtt in the 'Single Parameter Editor' to get the value). This typically only work for 1H signals and can be skipped for X-nuclei.

S/N per mm³ and B1 Homogeneity in xy Planes, z-Homogeneity

For proton coils (and for X if the test sample delivers a sufficient signal for imaging), run the sequence as described in the table for 1H in Test Sequences and Samples [▶162]. (e.g. mic_msme_snr*).

Create a new scan and load the protocol mic_msme_zB1prof. This is actually a single xz-slice spin echo sequence, where the isotropic FOV should be larger than the length of the RF coil. If this experiment is set up, the correctly adjusted FOV could be checked in the Reco window while GSP is running. Correctly adjusted in this case means, that there is a plateau in the center of the Reco display which goes down toward 0 at the window borders (e.g approx FOV of 25 mm for a 10 mm coil, or 50 mm for a 30 mm coil).

After the axial and the sagittal data sets are acquired, start the macro 'mic_rfTest'. Enter the expno and procno number of the 2 experiments and finally press 'Create Test Form' to generate a test report print out.

From this test report, the S/N and xy-homogeneity values can be extracted. Note the z-B1 interval where the profile doesn't go below 85% of the maximum amplitude. For more details refer to chapter Signal to Noise Ratio and z-B1 Tests for the RF Probes [▶119].

17.1.2 Test Sequences and Samples

Experiments with the parameters and samples from the table below are performed to acquire parameters for signal to noise ratio and if possible homogeneity of an RF coil.

Until now, only a 1H image signal to noise data base is available (see the table in Signal to Noise Ratio for 1H RF-Coil Elements [▶164]) but X data bases will be added when they are available. The 1H coils are tested with an imaging sequence, where the signal to noise is normalized to a volume of 1 mm³ with the help of a post processing macro to be able to compare different coil diameters and coil performances at different field strengths. Additionally, the coil homogeneity is calculated using the same post processing macro. Test samples are containers, filled with the appropriate liquid for the nucleus of interest. The container should tightly fit into the RF coil, e.g. a 10 mm NMR tube for a 10 mm coil, or a 34 mm tube/cylinder for a 34 mm coil.

Signal to noise tests for X coils are performed on 5 or 10 mm test samples. Their size is not adapted to the RF coil. These samples do not provide enough signal for an image test. Imaging tests to check the homogeneity can be performed on different samples with higher concentration but are not part of the acceptance test. However, the homogeneity tests should be performed during the Bruker final test to ensure a good coil quality and the print out should be added to the final test forms.

RF Probe Parameters and Final Test Information

	1H	2H	13C	19F	23Na	31P	129Xe
Sample	20% H2O, 80% D2O, g/l CuSO4	20% H2O, 80% D2O, 1g/l CuSO4	10g 13C 99% en- riched methanol + 17ml D2O	Fomblin y LVAC 06/6 Al- drich 31,792-6 average MW 1800	18g/l NaCl in H2O	85% Phos- phoric Ac- id, doped ca 1g/l GdCl3	
Sample Spectrum							
Imaging Sequence							
Method	mic_msme	mic_msme	mic_msme	mic_chess	mic_msme	mic_msme	
Matrix	256	64	64	256	64	128	
SW_h	100 kHz	100 kHz	50 kHz	100 kHz	100 kHz	100 kHz	
TE	7 msec	7 msec	7 msec	10 msec	7 msec	7 msec	
TR	1000 msec	1000 msec	5000 msec	1000 msec* NSlices	200 msec	500 msec	
Rf pulse	Sinc3	Sinc3	Sinc3	Sinc3	Sinc3	Sinc3	
Pulse BW	3 kHz	3 kHz	3 kHz	Exc: 2.0 kHz Rfc: 3.0 kHz	3 kHz	3 kHz	
NA	1	4	4	1	16	16	
FOV	1.2*CoilID	1.2*CoilID	1.2*CoilID	1.2*CoilID	1.2*CoilID	1.2*CoilID	
SliceOrient	Axial	Axial	Axial	Axial	Axial	Axial	
SIThick	1 mm	2 mm	10 mm	1 mm	5 mm	3 mm	
NSlices	Ca. 15	Ca. 11	Ca. 3	Ca. 10	Ca. 3	Ca. 5	
Protocol	mic_msme _snr_1H	mic_msme _	mic_msme _snr_13C		mic_msme _23Na		

Table 17.1: Standard Parameters for Imaging Signal to Noise Ratio Tests (1H) and Homogeneity Tests

RF Probe Parameters and Final Test Information

	1H	13C	19F	23Na	31P
Sample	20% H2O, 80% D2O, 1g/l CuSO4	"Temp Calibration" 80% Glycol DMSO-d6 5 mm Z10129 10 mm Z10130	1 molar TFT in CHCl3		1 molar TPP in Acetone
Sample T1		1.13 sec at 9.4T	1.63 sec at 11.7T		1.9 sec at 9.4T
Imaging Sequence					
Pulse Program	mic_msme	Zg	Zg		Zg
td	256	16 k	8 k		16k
swh	100 kHz	30 kHz	10 kHz		10 kHz
NS	7 msec	32	4		4
DS	1000 msec	0	0		0
P1 PL1	Sinc3	90°	90°		90°
D1	3 kHz	5s	5s		5s
No lock, no decoupling					
WDW	1.2*CoilID	No	No		No
lb	Axial	0Hz	0 Hz		0 Hz
Si	1 mm	16 k	8 k		16 k

Table 17.2: Standard Parameters for Spectroscopic Signal to Noise Ratio Tests (X nuclei)

17.1.3 Signal to Noise Ratio for 1H RF-Coil Elements

Data base for signal to noise ratio of proton coils at different frequencies. The acquired images are processed by the macro mic_rfTest to normalize the SNR to 1 mm³.

ID (mm)	200 MHz	300 MHz	400 MHz	500 MHz	600 MHz	700 MHz	750 MHz	800 MHz	900 MHz
2.5		10301	38277	61590	64277				
5		5246	15509	24141	27055		30950		45900
8			8405						
10	370	2672	6284	9463	11388				
15		1800	3704	5471	6865		21380		
20		1361	2546	3709	4793		5325		
25		1095	1903	2744	3628				
30		917	1501	2144	2889				
34		812	1275	1811	2471				
38		728	1103	1558	2151				
64	170	439	559	770	1122				

Table 17.3: SN Ratios for 1H Coils, acquired with Sample 20% H₂O, 80% D₂O, and 1g/l CuSO₄

17.1.4 Reference Spectra

13C

The standard sample for 13C SNR tests is the HR standard sample “Temp. Calibration”, which consists of 80% Glycol in DMSO-d6. The 5 mm sample has the part number Z10129, the 10 mm sample part number Z10130.

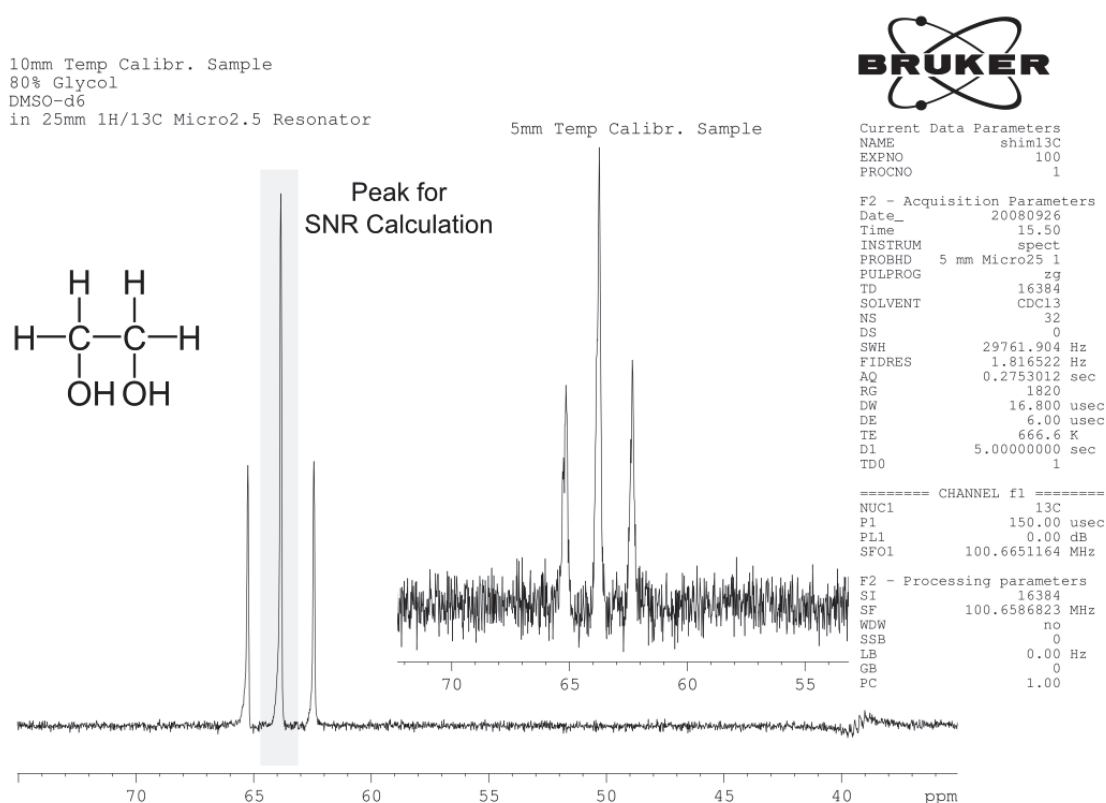


Figure 17.2: 13C Spectrum of the Temp. Calibration Sample.

The spectrum above was acquired at 400 MHz with a 25 mm 1H/13C birdcage resonator. The figure shows the S/N comparison for a 5 mm and 10 mm sample. The acquisition and processing parameters are noted in the X Nuclei table in Test Sequences and Samples [▶ 162].

19F

The standard sample for 19F SNR tests is 1 molar TFT (Trifluorotoluene) in CHCl₃, 5 mm or 10 mm samples.

RF Probe Parameters and Final Test Information

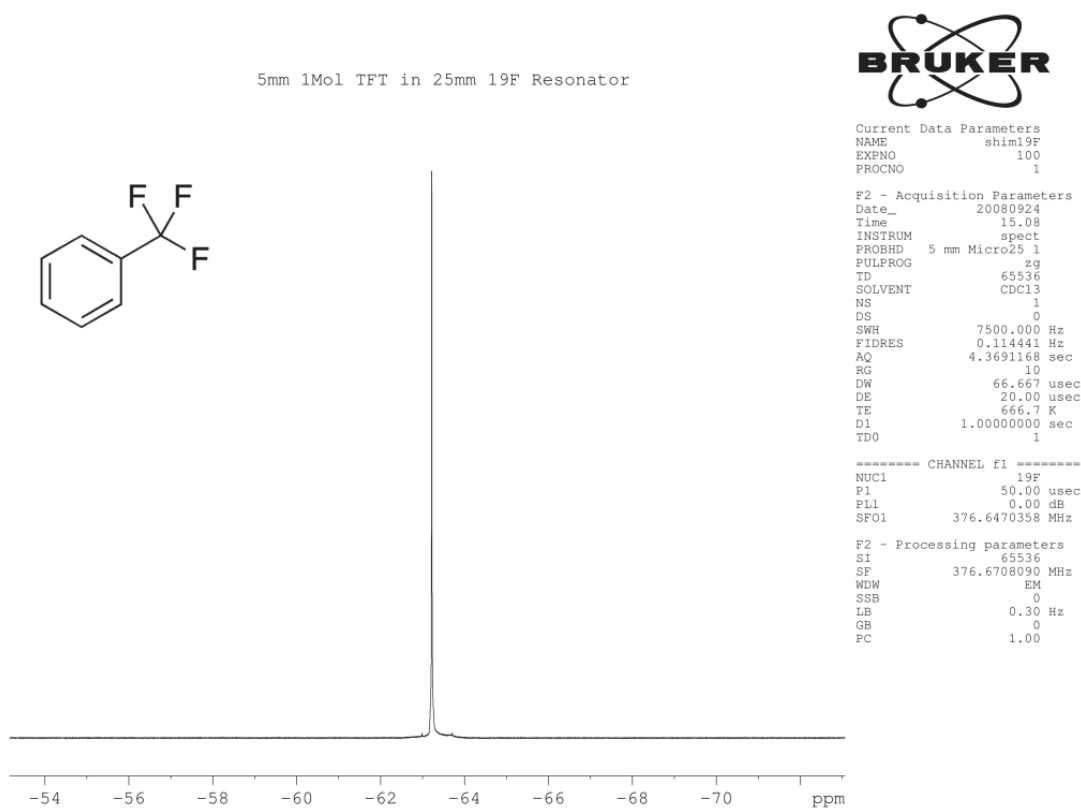


Figure 17.3: ^{19}F Spectrum of the 1 Molar TFT Sample.

The spectrum above was acquired at 400 MHz with a 25 mm $^1\text{H}/^{19}\text{F}$ birdcage resonator. The acquisition and processing parameters are noted in the X Nuclei table in Test Sequences and Samples [▶ 162].

^{23}Na

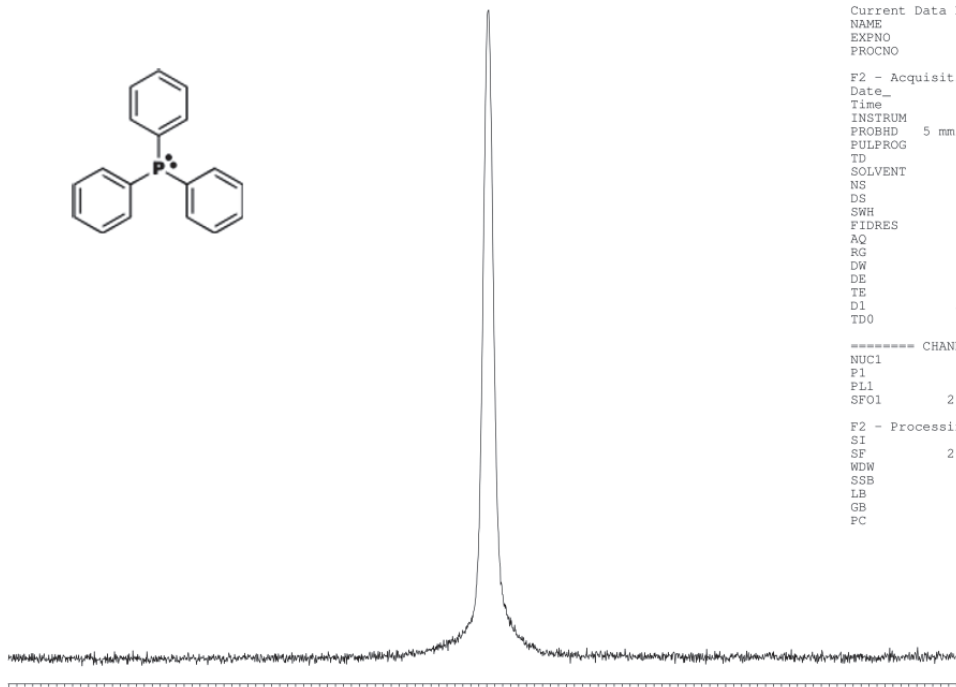
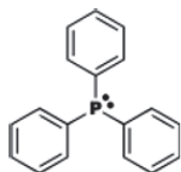
Not available.

^{31}P

The standard sample for ^{31}P SNR tests is 1 molar TPP (Triphenylphosphine) in Acetone, 5 mm or 10 mm samples.

RF Probe Parameters and Final Test Information

1Mol TPP 5mm Sample
measured in a 20mm 1H/31P 500MHz Resonator



```
Current Data Parameters
NAME      shim31P
EXPNO     1
PROCNO    1

F2 - Acquisition Parameters
Date_     20080929
Time      15.18
INSTRUM   spect
PROBHD    5 mm Micro5 1H
PULPROG   zg
TD         8192
SOLVENT   None
NS         4
DS         0
SWH        10000.000 Hz
FIDRES     1.220703 Hz
AQ         0.4097000 sec
RG         128
DW         50.000 usec
DE         6.50 usec
TE         300.0 K
D1         5.00000000 sec
TD0        1

----- CHANNEL f1 -----
NUC1      31P
P1        35.00 usec
PL1       0.00 dB
SFO1      202.455243 MHz

F2 - Processing parameters
SI         8192
SF         202.4592038 MHz
WDW        no
SSB        0
LB         0.00 Hz
GB         0
FC         1.00
```

Figure 17.4: 31P Spectrum of the 1 Molar TPP Sample.

The sample above was acquired at 500 MHz with a 20 mm 1H/31P birdcage resonator. The acquisition and processing parameters are noted in the X Nuclei table in Test Sequences and Samples [▶ 162].

17.2 Final Test Protocol for RF Probes

System Order Number			
Customer Name & Location			
System / 1H Frequency			
Test Engineer / Date			
Test Equipment			
Test Equipment			
TopSpin Software Version			
ParaVision Software Version			
	Passed	Passed with restrictions	Not Passed
Overall Test			
Information:			
<i>Create one copy for each probe type.</i>	Signed:		
Send a copy of the filled in form to micdiff@bruker.de	Name:.....		
	Date:		

RF Probe Parameters and Final Test Information

17.2.1 Hardware Components

Record part numbers, ECL's, serial numbers of the individual components.

Type of Probe (Mini, Micro, AHS...)			
Probe Base			
Part Number/Serial Number			
1H Amplifier of Test System			
1H Preamplifier	LNA	HPLNA	HPHPPR
X-Amplifier of Test System			
X Preamplifier	LNA	HPLNA	HPHPPR
Quad Combiner (i.a.)			
Part Number/Serial Number			
Test System	Final Test System	Customer System	

17.2.2 Details and Integrity

In this part of the test procedure the RF system should be checked for completeness, mechanically correct assembly and proper appearance. Additionally, some details of the probe base are recorded.

Description			OK	Not OK	Not Req.
All components are properly manufactured and assembled					
All parts are labelled correctly (part numbers...)					
Technical manual included?					
RF system contains HWIDS?		Yes	No		
→ if 'Yes'	All cables included?				
Probe base has build-in slip clutches?		Yes	No		
Probe base has animal support?		Yes	No		
→ if 'Yes'	Head holder available and anaesthesia hose fixed?				
	Cable to connect trigger device to probe base?				
	ECG extension leads required and available?				
Rf connectors		BNC-Type	N-Type		
Dewar is delivered and has correct length?					
Heater and heater BVT cable delivered and has correct length?					
Comments on this tests:					

17.2.3 RF Insert Details and RF Performance Tests

In this section, the details and RF performance of the inserts should be tested. Check the details of the insert record the position of the RF centre and determine the RF properties (90° pulse, SNR and homogeneity (1H), pulse power).

To determine the RF properties, a fully functional ParaVision with a *calibrated gradient system* is mandatory.

Test samples are defined in the section Test Sequences and Samples [▶162].

Nomenclature:

- “RF Coil” is the physical resonator, which can be an exchangeable insert or a fixed coil.
- “Coil Element” is the oscillating circuit in an RF-Coil. A double tuned RF coil for example contains 2 coils elements, one for each frequency.

RF Probe Parameters and Final Test Information

Customer and Order Number				
RF Coil - Description				
Part-/ ECL-/ Serial Number				
Comment				
Coil Tuning	<input type="checkbox"/> Single	<input type="checkbox"/> Single, 2 Freq	<input type="checkbox"/> Double	<input type="checkbox"/> Quadrature
Tunable Nucleus/Nuclei				
Inner Diameter of RF Coil				
Coil Centre				
Exchangeable Inserts: Upper End of Insert ↔ centre RF coil				

Test Results for first coil element (fill out one form for each coil element)

Nucleus and Nominal Frequency				
Sample	Type		OD/ID	mm
Peak Width of selected Peak		Hz(50% int.)		Hz(5% int)
90 degree hard pulse (global)		usec @	dB =	W
ParaVision Reference Gain 1msec rectangular 90 deg Pulse		dB =	W	<input type="checkbox"/> paropt <input type="checkbox"/> PvRefGain
SNR per mm3 1H coils only, set RG = 101, adapt FOV to 1.2*Coil-ID		-	over	mm along Z
Homogeneity in XY Plane Images 1H coils, X if poss.		-	over	mm along Z
Z-Homogeneity (1H coils only, X if possible) mic_msme_snr, zx image through centre plane of the coilrange along z, where $B_1 > 85\%$ of B_1^{\max}	$Z_{l(85)}^{\text{top}} - Z_{l(85)}^{\text{bottom}} =$ mm along Z			
Name of S/N Data Set		Expno		

RF Probe Parameters and Final Test Information

Test Results for first coil element (fill out one form for each coil element)

Nucleus and Nominal Frequency	<input type="text"/>	<input type="text"/> MHz
Sample	Type <input type="text"/>	OD/ID <input type="text"/> mm
Peak Width of selected Peak	<input type="text"/> Hz(50% int.)	<input type="text"/> Hz(5% int.)
90 degree hard pulse (global)	<input type="text"/> usec @ <input type="text"/> dB = <input type="text"/> W	
ParaVision Reference Gain 1msec rectangular 90 deg Pulse	<input type="text"/> dB = <input type="text"/> W	<input type="checkbox"/> paropt <input type="checkbox"/> PvRefGain
SNR per mm3 1H coils only, set RG = 101, adapt FOV to 1.2*Coil-ID	<input type="text"/> - <input type="text"/> over <input type="text"/> mm along Z	
Homogeneity in XY Plane Images 1H coils, X if poss.	<input type="text"/> - <input type="text"/> over <input type="text"/> mm along Z	
Z-Homogeneity (1H coils only, X if possible) mic_msme_snr, zx image through centre plane of the coilrange along z, where $B_1 > 85\%$ of B_1^{\max}	$Z_{l(85)}^{\text{top}} - Z_{l(85)}^{\text{bottom}} = \text{ mm along Z}$	
Name of S/N Data Set	<input type="text"/>	Expno
	<input type="text"/>	

Overall Test of the Coil	<input type="checkbox"/> OK <input type="checkbox"/> Not OK, see comment
Comment	<input style="width: 100%; height: 40px;" type="text"/> <input style="width: 100%; height: 40px;" type="text"/> <input style="width: 100%; height: 40px;" type="text"/>

Date	Name	Department	Sign
<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	
<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	
<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	<input style="width: 100%; height: 20px;" type="text"/>	

FormblattSystemtest3.odt

This test form can be found as PDF form on the ulmag-Addon CD or in \$PvHome/prog/docu/english/uimag/FormSystemtest.pdf when the Addon CD (version created after 09.09.2010) is installed. The completed form can only be printed as hardcopy or printed to file as postscript or PDF (if appropriate software is installed).



In case the file can only be printed to file as postscript file, it can be converted to PDF by the console command: `ps2pdf <name>.ps`

- ▶ Two pdf files can be combined by:
`gs -dBATCH -dNOPAUSE -q -sDEVICE=pdfwrite
-sOutputFile=<outfile>.pdf <pdf1>.pdf <pdf2>.pdf ...`
(doesn't work for pdf forms!)
-

18 Gradient System Parameters and Final Test Information

18.1 Information Final Test Protocol Gradient Systems Form

This chapter gives information on some points of the form 'Final Test Protocol Gradient Systems'. For detailed information on the individual adjustments, refer to chapter Gradient System and Amplifier Setup [▶87].

18.1.1 Gradient System Adaptation and Strength

Loop Adaptation

First of all, the loop parameters of the amplifiers need to be adapted to the gradient coil.

1. Run a preemphasis experiment (mic_preemp in ParaVision or 'diff config' in TopSpin) to generate gradient pulses with a length of 1 msec and an amplitude of 33%.
2. Adjust the loop parameters in setpre in that way, that there is no or a minimum ($\ll 5\%$) overshoot of the gradient current.
 - ⇒ There must be no negative dip and no oscillation following the gradient current overshoot.
3. Measure the current at the current monitor output of the gradient amplifier or (better) with a current probe.

For this test, all preemphasis values must be set to 0!

For details refer to the section Loop Regulation Adaptation [▶92].

Preemphasis Adjustment

1. Run a preemphasis experiment with gradient amplitude of 33% and a length of 50 msec.
2. Observe the FID's between 300 μ sec...300 msec, each FID should be at least 50msec long.
3. Adjust the preemphasis in such a way, that the integrals of the FID's are within a 15% peak-peak range.

Pay attention to have a well shimmed sample and avoid radiation damping (low flip angle) or saturation effects (add CuSO₄ or another T1 shortening substance).

For details refer to the section Preemphasis Adjustment [▶96].

B0 Adjustment

1. Adjust the B0 shift compensation (if available) running the same experiment as for the preemphasis adjustment, but be sure to be on resonance.
2. Unshuffle the acquisition display to see the signal phases and adjust all FID's to have the same phase and frequency.

For details refer to the section B0 Adjustment [▶ 101].

Preemphasis adjustments and B0 adjustments can also be automatically adjusted, but should be checked manually.

18.1.2 Gradient Strength and Linearity

Gradient Strength

1. Measure spin echo (MSME) images of the sample and compare the physical geometry of the sample with the geometry displayed in the MRI images.
2. Calculate the gradient strength manually or use the protocol `m_installation/mic_gradcalc` to calculate them.
 - ⇒ Be sure to determine the dimensions in the images only in phase direction, since shim distortions do not affect the geometry in phase direction.
 - ⇒ Use the protocols `m_installation/mic_gradcalib_xy` (measure the values for x in the 1st image from left to right (“B”), the value for y in the second image from top to bottom (“A”)) and `m_installation/mic_gradcalib_z` (z from top to bottom).
3. Adapt the ‘Field of View’ of the protocols to the calibration sample size (Geometry Editor).

For details refer to section Gradient Calibration [▶ 105].

Gradient Linearity

1. Measure the linearity of the gradient.
2. Load the protocol `m_installation/mic_gradlin_xy`.
3. Adapt the ‘Field of View’ of the protocol to the calibration sample size and the number of slices to its length (Geometry Editor).
4. Measure the values for x in the first half of the image series from left to right (“B”), in the second half of the series measure y from top to bottom (“A”) (e.g. if you acquire 24 images measure x in the images 1...12 and y in the images 13...24).

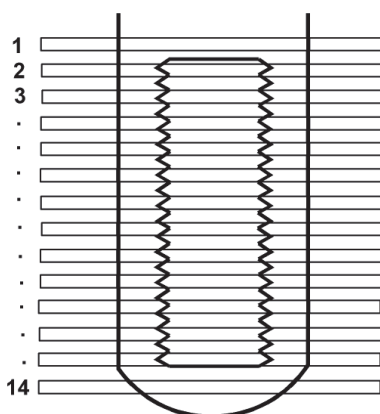


Figure 18.1: Nylon Screw Sample

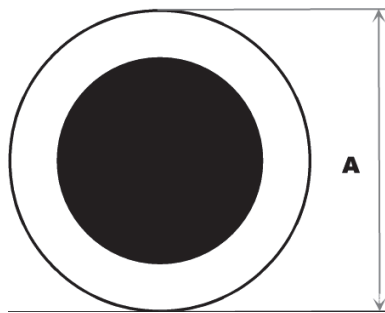


Figure 18.2: XY and YX Images Used to Determine the Linearity of the Gradient System in X and Y of a Nylon Screw Sample

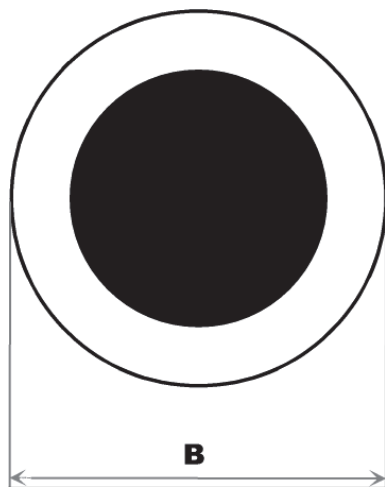


Figure 18.3: XY and YX Images Used to Determine the Linearity of the Gradient System in X and Y of a Nylon Screw Sample

5. Load the protocol `m_installation/mic_gradlin_z`. Adapt the 'Field of View' of the protocol to the calibration sample size (Geometry Editor).
6. Measure the z distance at different positions in the image to get the linearity information.

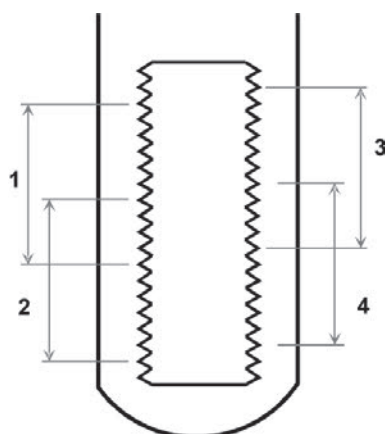


Figure 18.4: XZ Image of a Nylon Screw.

7. Measure the distance between the tips with the help of a caliper and compare it with the distance, measured in the MRI image.

Gradient System Parameters and Final Test Information

In the center is should be precise, the further you move away from the center, the stronger the deviation will be.

The deviation is calculated using:

$$\text{Deviation} = \text{Dimension of Sample} / \text{Dimension in Image}$$

18.1.3 Typical Gradient Coil Parameters

Typical gradient coil parameters and maximum power specifications.

	Micro 5	Micro 2.5	Mini 0.5	Mini 0.75	Diff 30	Diff 50	Diff 60
Part Number	M81111	M81112		M81171	M81113	W1223 05	M81163
PV Status	S019	S040	S057	S057			
Maximum DC Current on 1 Channel (1.2*I _(3 channel))	14.4A	14.4A	14.4A	10.5A	6.2A	6A	5A
Maximum DC Current on all Channels	3*12A	3*12A	3*12A	3*8.8A	6.2A	6A	5A
Typical L[μH]	18	100	45	80	180	540	850
Typical R[Ω]	X:0.11 Y:0.18 Z:0.17	X:0.39 Y:0.48 Z:0.36	X:0.72 Y:0.78 Z:0.53	X:1.24 Y:1.45 Z:1.19	Z:1.04	Z:0.67	Z:1.6
Resistor for HWIDS Encod- ing [Ω]					1k		

Table 18.1: Typical Gradient Coil Parameters

Gradient System Parameters and Final Test Information

18.1.4 Typical Gradient-Setpre Parameters

Typical parameters to set up the gradient systems in the software.

	Amplifier	Micro 5	Micro 2.5	Mini 0.5	Mini 0.75	Diff 30	Diff 50	Diff 60
Safety Parameters in setpre → ,gradsafe'								
Maximum Voltage		100 V	100 V	100 V	100 V	100 V	100 V	100 V
Maximum Current	Great 40 Great 60	40 A 60 A	40 A 60 A	40 A 60 A	40 A 60 A	40 A 60 A	40 A 60 A	40 A 50 A
Coil Resist x/y/z [Ω]		0.11/ 0.18/0.17	0.39/0.48/ 0.36	0.72/ 0.78/ 0.53	1.24/1.45/ 1.19	1.04	0.67	1.6
Power Sum		66 W	177 W	300 W	300 W	40 W	25 W	40 W
Mean Power x/y/z [W]		23/37/35	80/100/75	150/161/ 110	136/160/ 13	40	25	40
Adjustable Int. Time		1 s	1 s	1 s	1 s	1 s	1 s	1 s
Integ. Time Power Sum		66 W	177 W	300 W	300 W	40 W	25 W	40 W
Integ. Time Mean Power		23/37/35	80/100/75	150/161/ 110	136/160/ 131	40	40	40
Loop Parameters in setpre								
Resistors		50	10	75	x:28.2 y:28.2 z:19.3	30	0	10
Capacitors		5	16	13	x:4.3 y:4.3 z:4.2	11.8	27	27
Gradient Parameters in setpre								
Typ. Ramp Time[usec]		80	100	100	100	300	500	900
Typ. Rise Time[usec]		120	150	150	160		600	
Calib.. Constant [Hz/cm]	Great 40 Great 60	808 000 1 212 000	404 000 606 000	80 000 121 000	120 000 180 000	5 023 000 7 535 000	8 000 000 121 00 000	10 133 000 12 660 000

Table 18.2: Setpre Parameters for the Different Gradient Systems

18.2 Final Test Protocol for Gradient Systems

System Order Number			
Customer Name & Location			
System / 1H Frequency			
Test Engineer / Date			
Test Equipment			
Test Equipment			
TopSpin Software Version			
ParaVision Software Version			
	Passed	Passed with restrictions	Not Passed
Overall Test			
Information:			
<i>Create one copy for each individual gradient system.</i>	Signed:		
Send a copy of the filled in form to micdiff@bruker.de	Name:.....		
	Date:		

Gradient System Parameters and Final Test Information

18.2.1 Hardware Components

Record part numbers, ECL's, and serial numbers of the individual components.

Gradient Coil Type		
Part Number/ECL/Serial Number		
Gradient Holding		
Part Number/ECL/Serial Number		
Gradient System Length I	_____ mm	
Bottom of shim system to magnet center		
Gradient System contains HWIDS ?	Yes	No
Imaging Rack	Final Test System	Customer System
Gradient Interface (Master Unit,...)		
Part Number/ECL/Serial Number		
x-Amplifier		
Part Number/ECL/Serial Number		
y-Amplifier		
Part Number/ECL/Serial Number		
z-Amplifier		
Part Number/ECL/Serial Number		
B0-2 Compensation Unit (i.a.)		
Part Number/ECL/Serial Number		

Gradient System Parameters and Final Test Information

18.2.2 Gradient Global Check

In this part of the test procedure the gradient system should be checked for completeness, mechanically correct assembly, proper appearance and the correct spare parts.

Description	OK	Not OK	Not Required
All components are properly manufactured and assembled?			
All parts are labelled correctly (part numbers...)?			
All necessary screws and tools are delivered? Mini Systems: Allen key to mount the gradient coil on the holder and in the magnet Micro 2.5 system: Brass screw/disk combination for tool free fitting.			
Spare o-rings for cooling?			
Manual for the gradient system?			
Assembled gradient system is water tight (connect to chiller)?			
Gradient System can be fixed tightly in the magnet?			
Comments on this tests:			

18.2.3 Gradient System Adaptation and Strength

In this section, the gradient system has to be connected to the imaging rack. ParaVision must be running and at least a default preemphasis file has to be installed on the system. Be sure to run all experiments with **GRADRES=8.0µsec**. ($\$XWINNMRHOME/conf/instr/spect/uxnmr.par$)

Description	OK	Not OK	Not Required
Loop Adaptation Typical values with 'Ramp Time = 100 µsec' (80 µsec for Micro 5): Adjusted loop values for each direction: X: Resistors: _____ Capacitors: _____ Imp: HIGH Y: Resistors: _____ Capacitors: _____ Imp: HIGH Z: Resistors: _____ Capacitors: _____ Imp: HIGH			

Table 18.3: Loop Adaptation

Gradient System Parameters and Final Test Information

Description	OK	Not OK	Not Required
Preemphasis Adjustment: The integrals of the FIDs between 300 μsec and 200 msec are within a 10% peak-peak range?			
X→X	Amplifier Offset	Coarse: _____ Fine: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
Y→Y	Amplifier Offset	Coarse: _____ Fine: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
Z→Z	Amplifier Offset	Coarse: _____ Fine: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____	
Are strong cross preemphasis values necessary to reach the 10% pre-emphasis criteria? If yes, please add values on a separate form.			

Table 18.4: Preemphasis

Gradient System Parameters and Final Test Information

Description		OK	Not OK	Not Required
B0 Adjustment: The FIDs between 300 μsec and 200 msec show (almost) the same and frequency during the experiment?				
X→B0	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
Y→B0	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
Z→B0	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
	Time Base _____ msec	Time [msec]: _____ Gain[%]: _____		
Comments on this tests: 				

Table 18.5: B0 Compensation

Gradient System Parameters and Final Test Information

18.2.4 Gradient Strength and Linearity

During these tests, the calibration of the gradients is performed. Prerequisite for this test is an adapted preemphasis and (i.a.) B0 compensation. All tests run in ParaVision and a geometrically well defined sample (well defined in all 3 dimensions) must be used. The sample can be e.g. a nylon screw, a LEGO, a connector enclosure or something similar.

Description	OK	Not OK	Not Required
Gradient Strength within Specifications? Value: _____ Hz/cm			
Gradient Scaling Factors: Gradient Scaling Factor X: _____ Gradient Scaling Factor Y: _____ Gradient Scaling Factor Z: _____			
Gradient Linearity Test: Specified Value: The deviation should be $0.9 < \text{Deviation} < 1.1$ Max. Deviation along x: _____ Max. Deviation along y: _____ Max. Deviation along z: _____ Range along z: _____ mm			
Comments on this tests:			

18.2.5 MAPSHIM (on final system during installation)

Run the MapShim calibration during the installation of the final system as described in the step to step MapShim manual (available on the micro-imaging add-on or from micdiff@bruker.de). Mark the position (mounting angle) of the gradient system on the magnet bottom.

MapShim calibrated successfully?	
Position marked on magnet:	
Comments on this tests:	

18.2.6 Miscellaneous and Notes

19 Imaging Rack Final Test Information

19.1 The Final Test Protocol Imaging Racks Form

This chapter gives information to some points of the form 'Final Test Protocol Imaging Racks'.

19.1.1 Setpre and Web Interface Functionality

Setpre after 'ii restart'

1. Open setpre (type 'setpre' in the TopSpin command line) and close it.
2. Enter 'ii restart' in the TopSpin command line to restart the ipso server.
3. Open setpre again.
 - ⇒ Does it start properly?

Open Web Interface

Open the Web interface by:

1. Entering the 'ha' command in TopSpin.
2. Selecting 'Open BGAU'.

Internal Blanking:

1. Start the protocol m_installation→mic_blankcheck in GSP mode.
2. Observe the gradient current output (monitor) and the blanking output of the Master Unit on a scope.
 - ⇒ If all preemphasis values for the selected channel are 0, the blanking must be opened (low) at the start of the gradient pulse and stay open for approx. 10 msec after the gradient is switched off.
3. Set a time constant of 2 msec for the selected channel in setpre and increase the gain.
 - ⇒ With increasing gain the low period (open) of the blanking signal must become longer.

Offset

To observe any offset changes:

1. Start the protocol m_installation→mic_ampoffset in GSP mode with a well shimmed sample in the system.
2. See whether the integral (shape) of the FID changes if the offset value is modified.

For details refer to the section Great Offset Adjustment [▶91].

Auto Offset

When the internal blanking is connected simply start the “Auto Offset” procedure by clicking on the button.

When the external blanking is connected disconnect the blanking cables first, then start the ‘Auto Offset’.

The auto offset adjusts only the fine offset. The coarse offset has to be set beforehand. On new systems (Great 1/60 with ECL \geq 9, Great 1/40 with ECL \geq 5) the coarse offset is typically set to 0.

For older Great amplifiers, the coarse offset must be set manually (typical values are between -4 and -6, but certain amplifiers might need different values).

For details refer to the section Great Offset Adjustment [91].



Note: During the auto offset process it might happen, that the I2C communication between the Master Unit and the Great amplifiers break down (error message in setpre and I2C error message in the web interface). The Master Unit has to be restarted to get rid of this error. This problem can show up during the ‘Auto Offset’ process and was never observed in any other situation.

Loop Adaptation:

1. Control the gradient current shape on an oscilloscope, which is connected to the current monitor, using a current probe.
2. Use the protocols `m_installation→mic_preemp_50msec_33pc_X/Y/Z` to generate the gradients.

19.1.2 ParaVision Tests

Automatic Safety Parameter Download

Safety Parameter Setting:

1. Switch Master Unit Off and On. It stops with a C01 in the display.
2. Start ParaVision Experiment with GSP or GOP.
 - ⇒ The safety parameters must be set automatically.
 - ⇒ The experiment must start without any delays or missing scans.

Preemphasis Adjustment

1. Run the protocol `m_installation→ mic_preemp_50msec_33pc_<XYZ>` on a well shimmed sample.
 - ⇒ Be sure that external blanking is disabled in the pulse program, or use internal blanking.
 - ⇒ “GS_yp” must be set to “Preemphasis” (check/set in the Single Parameter Editor) to allow any preemphasis/B0 shift changes.

FLASH sequence

1. Load protocol `ulmag_xmm/mic_flash_ortho` and start it with the traffic light.
2. Scale up the look up table to see the noise.

⇒ There should be no ghost image of the original object visible then.

Multi Slice Multi Echo sequence

1. Load protocol `ulmag_xmm/mic_msme_8e_ortho` and start it with the traffic light.
2. Scale up the look up table to see the noise.
⇒ There should be no ghost image of the original object visible then.

Duty Cycle Tests

1. Load protocol `m_installation/duty_cycle_x` and start it with GOP, so that it runs for 30 seconds.
2. On Great 60 amplifiers, the 15A fuses in the filter box must be replaced with 20A fuses.

This test should only be performed at a Bruker Final Test Site!!!

Field modulation

- ▶ Be sure that the B0 shift compensation unit is switched on in setpre.
1. Put a 20...100% H₂O with 1g/l CuSO₄ sample to the magnet and shim it roughly.
 2. Put the Tx0 slider to 60 dB, set the receiver gain to 64 and run the protocol `m_installation→mic_magtest`.
 3. Enter the experiment data directory of the selected data set and display the file `PhiPlot.ps` (`kghostview PhiPlot.ps`).
⇒ In the upcoming spectrum, the peak amplitude of the 50 Hz resonance must be ≤ 0.15 Hz (or. ≤ 0.75 Hz on a standard bore system).

There are 2 reference lines visible at 5 Hz and 70 Hz with amplitudes of 0.2 Hz. It may be necessary to run the macro `Service/SvMagTestAuto` to process the acquired data manually when the scan has finished.

19.1.3 Enhanced Resolution Tests

These tests are only required if a new DPP software or a new Master Unit firmware is involved in the tests.

Enhanced Current Resolution:

Connect a load of ~1 Ohm/50W to the output of a Great amplifier. Set the loop parameters Resistor/Capacitor to 50% and disconnect the blanking connector. Measure the voltage at the 1 Ohm resistor by a multi meter in ~200 mV range.

`telnet <IPSO IP Adresse>, login root:IPSO and start ./ipsotest`

In `ipsotest` enter 'd' (for DPP1) and change the value and the addresses
`address 3000=x, address 3004=y, address 3008=z.`

`wm <address> 4 <value> <value> = 20 Bit hex value.`

If ,Enhance Resolution = OFF' the voltage value measured by a multimeter should only change, when the fifth lowest bit changes. This means a change from 0x00 → 0x07 does not change the voltage; a change from 0x07 → 0x08 changes the voltage. Then the voltage must be stable from 0x08 → 0x017 and a change appears from 0x17 → 0x18.

If ,Enhance Resolution = ON' the voltage value measured by the multimeter should change every 2 second bit. This means a change from 0x00 → 0x01 does not change the voltage, a change from 0x01 → 0x02 changes the voltage, no change from 0x02 → 0x03, a change from 0x03 → 0x04 and so on...

Amplitude Stability

1. Put a 20 to 100% H₂O with 1g/l CuSO₄ sample in the magnet and shim it roughly.
2. Load the protocol ulmag_xmm/mic_flash_ortho.
3. Enter the parameter 'ACQ_scaling_phase' in the field 'Spectrometer Control Tool → Edit Single Parameter'.
4. Set this value to 0.0.
5. Run this experiment.
6. Clone it.
7. Set "Enhance Resolution==OFF" in the setpre tool.
8. Run the experiment again.

⇒ The images should only show a vertical or horizontal line in the center of the image. The images should not have visible sidebands, and more importantly, no differences in the side band amplitudes between the 2 images when the lookup table is scaled up.

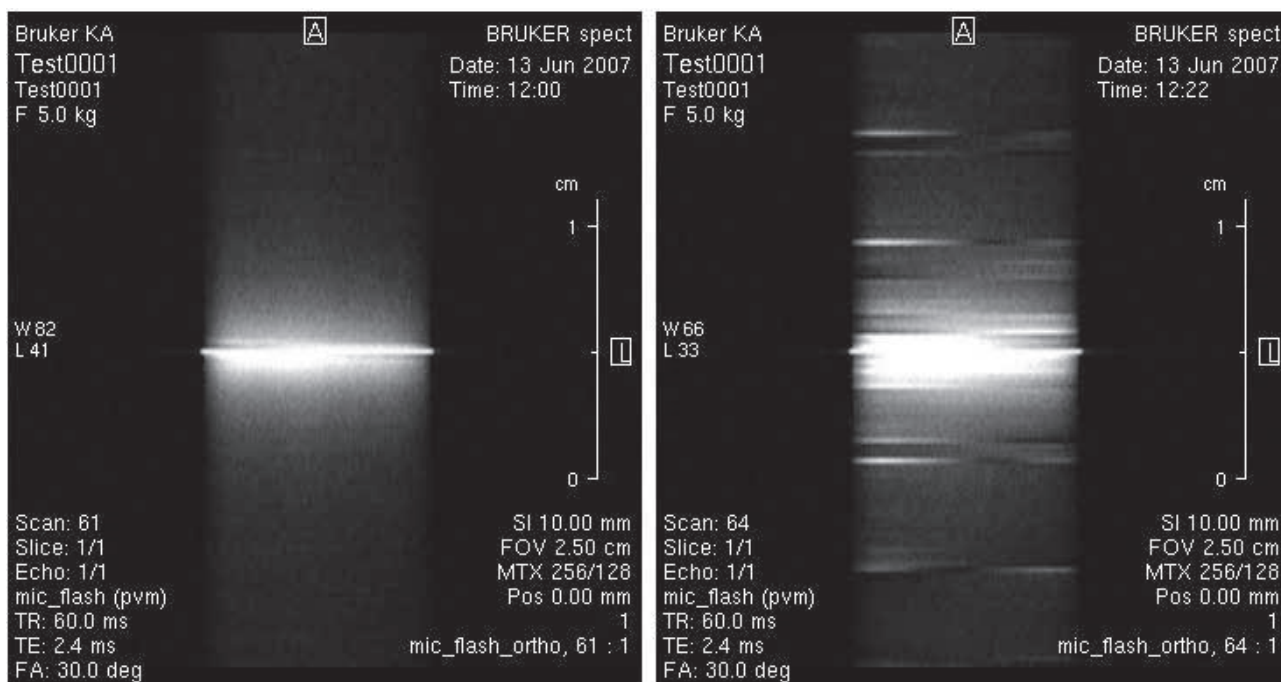


Figure 19.1: Images Acquired as Described in 'Amplitude Stability'.

The left image in the figure above shows a good stability, the right image shows a modulation of the FID signals.

19.2 Final Test Protocol Imaging Racks

System Order Number			
Customer Name & Location			
System / 1H Frequency			
Test Engineer / Date			
Test Equipment			
Test Equipment			
TopSpin Software Version			
ParaVision Software Version			
Diskless Version /tftpboot/version.txt			
	Passed	Passed with restrictions	Not Passed
Overall Test			
Information:			
Send a copy of the filled in form to micdiff@bruker.de	Signed:		
	Name:.....		
	Date:		

19.2.1 Hardware Components

Record part numbers, ECL's, serial numbers of the individual rack components.

Master Unit Version W1522066	BGMUI-E		
Part Number/ECL/Serial Number	W1522066/		
x-Amplifier	Great ____/____		
Part Number/ECL/Serial Number			
y-Amplifier	Great ____/____		
Part Number/ECL/Serial Number			
z-Amplifier	Great ____/____		
Part Number/ECL/Serial Number			
B0-2 Compensation Unit (i.a.) W1214106	B0-2 Compensation Unit		
Part Number/ECL/Serial Number	W1214106/		
Gradient Filter Cable Part Number/ECL/Serial Number W1212109 ECL ≥ 02 W1212172 ECL ≥ 03 W1213554 ECL ≥ 02			
Mains	230V/32A	380V/16A	380V/32A

Imaging Rack Final Test Information

19.2.2 Master Unit Global Check

In this part of the test procedure the global like completeness and mechanically correct assembly should be performed. No software or test hardware is required for this section.

Sequence to switch on the imaging rack:

1. All gradient amplifiers
2. The B0 compensation unit (i.a.)
3. The Master Unit

Description	OK	Not OK	Not Required
All components are labelled with the correct number?			
All cables mounted and fixed properly, cables leaving the rack on the backside are not squeezed?			
Technical manual for the Master Unit (printed or BASH)?			
Technical manual for the Amplifiers (printed or BASH)? The Great manual Z31659 can be found on the BASH			
All components are assembled correctly and fixed tightly?			
A plug is connected at the 220V control cable?			
External Enable Dummy Connector is available?			
External Blanking Cable is available? (HZ14004)			
B0 Compensation Unit Cable is available? (HZ12200) SCB20 adapter Z108181 is required to connect to BSMS/2			
The 6 monitoring coax cables are connected?			
Master Unit boot process stops with a C01 display message?			
Connection for Gradient Synchronization and external Trigger? IPSO T0 Connector E1-Z1 (by 2xHZ10124 or HZ10124 and HZ16260)			
Comments on this tests:			

19.2.3 Basic Functionality

The basic functionality of the imaging rack is tested in TopSpin. A TopSpin version ≥ 2.1 or a TopSpin version coming with ParaVision 5 is required for this test. A standard, or already optimized setpre parameter file including safety parameters, is the precondition for this test. Make sure that the Master Unit BGMUI-E W1522066 GRADRES (\$XWINNMRHOME/conf/instr/spect/uxnmr.par) is set to 8.0.

During the boot process, the Master Unit may stop and display a C01 message. This indicates that the safety parameters are not set, and you will need to use setpre to load the safety parameters to the unit. These parameters are stored in the gradsafe menu in setpre and are loaded automatically to the Master Unit, when 'Read Default' is selected, or alternatively, when 'Apply' is selected in the (password protected) gradsafe menu page.

Description	OK	Not OK	Not Required
Master Unit and DPP are correctly detected by 'cf'?			
Check the Application Firmware Version in the web interface Application Version (Firmware): 20080205?			
Are all amplifiers shown 'enabled' by the Master Unit LED's?			
Master Unit changes status from C01 to temperature display when 'Read Default' is executed in setpre?			
Master Unit shows correct temperature of gradient coil (+/- 1K)?			
Master Unit shows E03 if PT100 connector is disconnected?			
Master Unit shows E02 if ext. enable connector is disconnected?			
Master Unit can be reset by red button?			
Comments on this tests:			

Imaging Rack Final Test Information

19.2.4 Setpre and Web Interface Functionality

Check the functionality of the web-interface and the setpre features. The communication between both programs is checked and the offset for the Great amplifiers is adjusted.

Description	OK	Not OK	Not Required
Master Unit: Ethernet is detected by 'ha' in TopSpin? Ethernet Address: _____			
Does setpre recognize the amplifiers and B0 correctly?			
Does setpre restart correctly after 'ii restart'?			
Is the BIS data in the web-interface correct (BIS content)?			
Are the same amplifier stages displayed in setpre and the web-interface (Channel X, Y, Z → Gain) for x, y, and z?			
Are the same loop parameters displayed in setpre and the web-interface (Channel X, Y, Z → Res, Cap, Load) for x, y, and z?			
Is the internal blanking threshold set to 0 in the web-interface? See "BGA Configuration→Change Blanking Threshold..."			
Is the internal blanking changing when the time constant for the preemphasis is changed?			
Is a change of the 'Enhance Resolution' parameter in setpre detected by the web interface (BGA Configuration→Bruker Access, only if password available) and the opposite way?			
Which gradient system is connected to test the amplifiers? Name: _____ Part Number/Serial Number: _____			

Description	OK	Not OK	Not Required
Can the coarse offset be changed from setpre (x, y, z)?			
Is the same coarse offset value displayed in the web-interface (Channel X, Y, Z → Coarse Offset)?			
Can the offset be changed from setpre (x, y, z)?			
Is the same offset value displayed in the web-interface (Channel X, Y, Z → Fine Offset)?			
Execute AutoOffset in setpre for X, Y, and Z. X-Channel: Coarse Offset _____ (Fine) Offset _____ Y-Channel: Coarse Offset _____ (Fine) Offset _____ Z-Channel: Coarse Offset _____ (Fine) Offset _____			
Can the loop parameters be adjusted for all (x, y, z) directions? X-Channel: Resistor _____ Capacitor _____ Y-Channel: Resistor _____ Capacitor _____ Z-Channel: Resistor _____ Capacitor _____			

Does a change of the preemphasis values in setpre change the integral of the FIDs in a preemphasis experiment (x, y, z)?			
Does a change of the B0 values in setpre change the phase of the FIDs in a preemphasis experiment (x, y, z)?			
Comments on this tests:			

19.2.5 ParaVision Tests

These tests indicate the communication between ParaVision and the imaging racks. It also shows the stability of the gradient current (periodic errors) and the 50 Hz hum behavior of the B0 compensation unit. A standard or already optimized setpre parameter file including safety parameters is the precondition for this test. Be sure, that for the Master Unit BGMUI-E W1522066 GRADRES (\$PvHome/conf/instr/spect/uxnmr.par) must be set to 8.0.

Description	OK	Not OK	Not Required
Does a GSP/GOP in ParaVision load the safety parameters?			
Does ParaVision-Setpre (Spectrometer Control Tool→Tools→ Adjust Preemphasis Values) recognize Greats and B0?			
Can the preemphasis values (x, y, z) and B0 be changed from ParaVision Setpre?			
Does a “flash” sequence run without artefacts?			
Does a “multi slice multi echo” sequence run without artefacts?			
Duty Cycle Test on X (trained personal only)?			
Duty Cycle Test on Y (trained personal only)?			
Duty Cycle Test on Z (trained personal only)?			
Is the ‘FIELD’ current passed through the B0 compensation unit, independent of whether the B0 is enabled or not?			
Is the B0 field distortion strength with a frequency of 50 Hz less than 0.15 Hz (WB shim system, or 0.75 Hz on a SB shim system) when the B0 compensation unit is switched on?			
Field modulation with 50 Hz: _____ Hz			
Comments on this tests:			

19.2.6 Enhanced Resolution Tests

These tests only have to be performed on newer software and/or firmware version as the following:

ParaVision, BGMUI-E Application Firmware: 20100419

Be sure, that for the Master Unit BGMUI-E W1522066 GRADRES in (\$PvHome/conf/instr/spect/uxnmr.par) must be set to 8.0.

Description	OK	Not OK	Not Required
Enhanced current resolution?			
Amplitude Stability?			
Comments on this tests:			

20 Velocity Imaging and Rheology in Material Science

20.1 Introduction

Velocity maps of simple or complex liquids, emulsions, suspensions and other mixtures in various geometries provide valuable information about macroscopic and molecular properties of materials in motion.

The hardware of the experiments for investigating the velocity distributions covers arrangements, where tubes or hoses, a NMR rheology accessory, or containers with motor driven stirrers are mounted in the magnet.

2D and 3D spin echo velocity imaging methods are used, where two dimensions contain spatial information and the third dimension, or the image intensity contains the information of the displacement of the spins during an observation time Δ . This information is used to calculate the velocity vectors and the dispersion at each position in 2D spatially resolved slices. The range of observable velocities depends mainly on the time the spins stay in the RF-coil, the T2 relaxation time and the available gradient strength.

The properties of the methods are explained and demonstrated in the workshop and some applications are shown and discussed.

20.2 Theory of Velocity Imaging

The presence of coherent motion, flow, in an MRI experiment leads to phase changes of the signal. These phase changes cause artefacts in the images, so they can be used to measure the velocity of the flow.

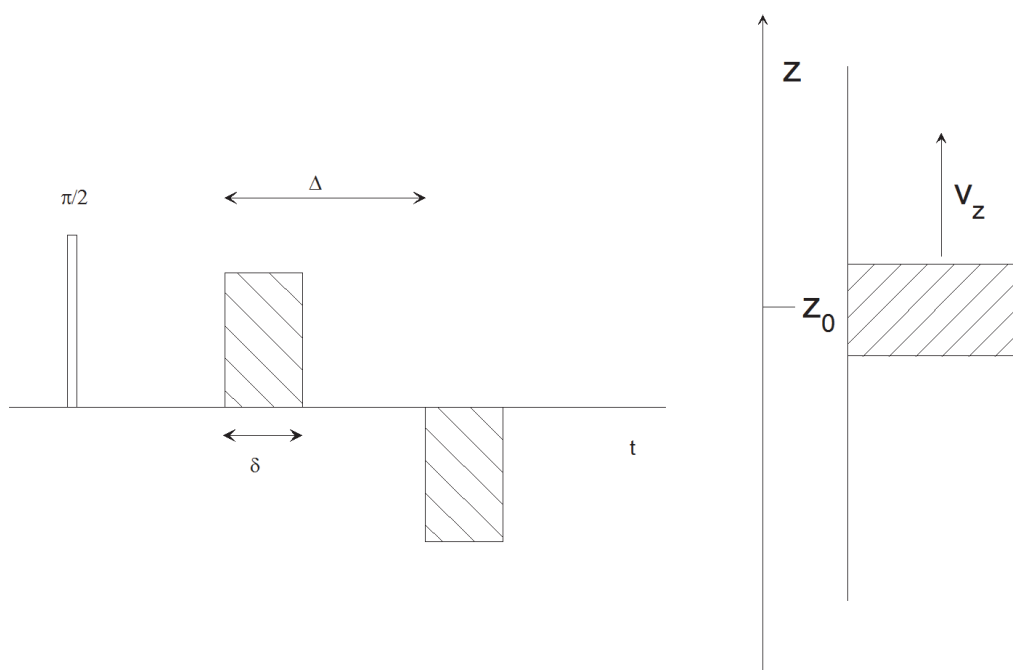


Figure 20.1: Simple Gradient Echo Experiment Applied on a Volume Element in Tube Filled with Water

Let's use a simple experiment, applying a pair of gradient pulses with opposite signs on the FID of a tube filled with water, as shown in the figure above. The gradient direction is the same as the long axis of the tube. If the water does not move, the net phase shift is zero.

$$\begin{aligned}\Phi_1 &= \gamma g_z z_0 \delta & \Phi_2 &= -\gamma g_z z_0 \delta & (1) \\ \Phi &= \Phi_1 + \Phi_2 = 0\end{aligned}$$

In the formula above Φ_1 stands for the phase shift during the first gradient pulse and Φ_2 for the phase shift during the second gradient pulse. The other parameters are used as usual, γ is the gyromagnetic ratio, g_z the gradient strength in z direction, z_0 is the position of the volume of interest, and δ stands for the gradient pulse length.

If the velocity v_z is not equal to zero, there will be a change of the position of the volume of interest during the evolution time Δ . For simplicity the motion during the gradient pulses is neglected, also diffusion effects are not taken into account. Similar treatment as in the static case now leads to a non zero phase shift, proportional to the velocity, the gradient strength, the time between the gradient pulses, and the gradient pulse length.

$$\begin{aligned}\Phi_1 &= \gamma g_z z_0 \delta & \Phi_2 &= -\gamma g_z (z_0 + v_z \Delta) \delta & (2) \\ \Phi &= \Phi_1 + \Phi_2 = -\gamma g_z v_z \Delta \delta\end{aligned}$$

Obviously this behavior allows us to measure the velocity. On the other hand, in a conventional imaging experiment, this motion will lead to artefacts.

20.2.1 Generalized Approach

In a more generalized approach we have to look at the time evolution of the spin phase as a function of the time dependent gradients and the time depended position of the spin.

$$\Phi(t) = \gamma \int \vec{g}(t) \vec{r}(t) dt \quad (3)$$

A standard trick to simplify such a problem is to apply a Taylor expansion on the position vector:

$$\vec{r}(t) = \vec{r}_0 + \frac{\delta \vec{r}}{\delta t} t + \frac{\delta^2 \vec{r}}{\delta t^2} + \dots \quad (4)$$

This can be rewritten:

$$\vec{r}(t) = \vec{r}_0 + \vec{v}t + \dots \quad (5)$$

Assuming we have a constant flow we can simplify equation (3):

$$\begin{aligned}\Phi(t) &= \gamma \int \vec{g}(t) \vec{r}_0 dt + \gamma \int \vec{g}(t) \vec{v}_0 t dt & (6) \\ \Phi(t) &= \gamma M_0 \vec{r}_0 + \gamma M_1 \vec{v}_0\end{aligned}$$

This way we get 2 terms, one describing the position, and the other describing the motion with constant velocities. The time integrals over the gradient have been replaced by the so called moments.

M_0 stands for the zero order gradient integral, i.e. the integral of the gradient itself. This is the most important parameter for imaging: At the echo center M_0 must be equal to zero, except for the phase gradient. M_0 in phase encoding must correspond to the required k-space position.

M_1 stands for the first order gradient integral, i.e. the integral of the gradient times the time. According to equation (6) this is the relevant parameter for flow. For clean images in the presence of flow, M_1 must be equal to zero at the echo position. In order to get a well-defined flow depending phase shift M_1 must be calculated accordingly.

To get undistorted images in the presence of flow one has to fulfil equation (7), except for the phase gradient:

$$M_0 = M_1 = 0 \quad (7)$$

The moment calculations for different orthogonal gradient directions are independent from each other.

Coming back to the example at the beginning, we can see: In the static case the second component of equation (6) vanishes, because $v = 0$. Comparing this to equation (1) leads to the conclusion, that in that experiment $M_0 = 0$.

In the case where v is not equal to zero, we can see, that M_1 is not equal to 0, $M_1 = g_z \delta \Delta$. M_0 stays zero, because it is only a function of the gradient. In order to remove flow artefacts, we have to modify the pulse sequence in order to fulfil equation (7) at the position of the echo.

20.2.2 Flow Compensation

In order to learn how to fulfil equation (7) we have to review the simple experiment shown in the previous figure. In practice we often use spin echo experiments in this context, see the upper part of the figure below. Because the 180 degree pulse reverses all phases, M_0 is still equal to zero.

At least one more gradient pulse is required to fulfil equation (7). Easier to handle is actually to introduce a pair of additional gradients, of duration δ_c , with an amplitude of g_c , and a distance of Δ_c , see the lower part of the figure below. Looking at the symmetry of the pulse sequence, one can see directly, that M_0 is equal to zero. The second condition can then be fulfilled by:

$$g_c = -g \frac{\delta \Delta}{\delta_c \Delta_c} \quad (8)$$

The example described here corresponds to the read gradient of a standard spin echo sequence. The other gradient directions are calculated similarly and will not be discussed in detail.

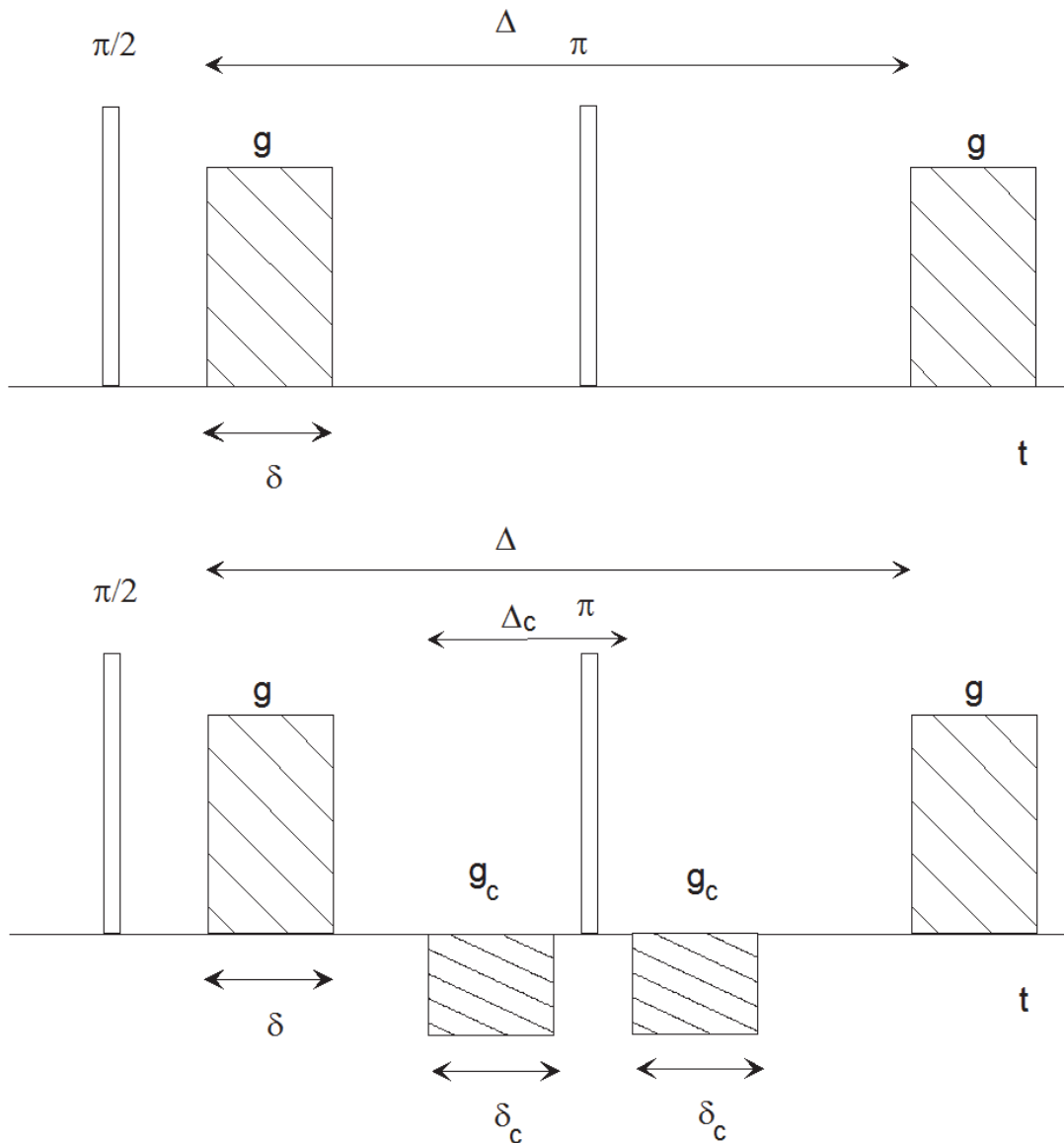


Figure 20.2: Spin Echo Experiment with Velocity Encoding and Flow Compensation Gradients

20.3 Velocity Imaging Modes

To measure the velocity we have to review equation (6). For a practical experiment there is one term missing, there is an additional time constant but position dependent phase shift. This phase shift is due to field inhomogeneity, susceptibility changes. In other words additional, usually unknown field gradients. This phase shift is described in equation (9) as an additional Φ_0 .

$$\Phi(t) = \gamma M_0 \vec{r}_0 + \gamma M_1 \vec{v}_0 + \Phi_0 \quad (9)$$

There are two experimental ways to measure the velocity under such conditions:

- The first is to introduce an additional dimension to the experiment, incrementing the value of M_1 . Fourier transform in this direction will directly give the velocity, independent of the other phase shifts. We call this mode **"Fourier Flow Imaging"**. The advantage of this mode is

the feasibility to measure spatially resolved velocity distributions (propagators). The disadvantage is the relatively long acquisition time since the experiment dimensionality is the spatial dimensionality + one dimension for flow.

In an “Fourier Flow Imaging” experiment there are 1 to 3 spatial dimensions, plus one velocity dimension. In order to measure the whole velocity, vector 3 experiments with the same spatial parameters have to be performed. In the velocity direction the image shows the velocity distribution within one pixel.

In many cases it is useful to derive a so called velocity map out of such a data-set (e.g. by the macro *mic_VelocityFromFourierflow*). This is done by calculating the mean value of the velocity for each pixel and assigning this value to the amplitude of the pixel, see equation (10). The index i runs over all pixels in the velocity direction.

$$v_m = \frac{\sum_i I_i v_i}{\sum_i I_i} \quad (10)$$

Having the velocity map, spatial derivatives needed for the shear rate, can be easily calculated, e.g. by the macro *mic_CalcShearRates*.

- The second way is to measure images, with different M_1 . The phase difference $\Delta\Phi$ between the images can then be used to calculate the average velocity:

$$\Delta\Phi = \gamma M_1 \vec{v}_0 \quad (11)$$

This mode is called “**Velocity Mapping**”. In this mode only the velocity can be calculated, but the experiment time is only defined by the spatial resolution and dimension. Additionally, the Bruker sequences support Hadamard encoding, thus only 4 images have to be acquired to calculate the flow in all 3 dimensions.

Velocity maps can be directly calculated in different directions. In order to get a 3D velocity vector, 4 Hadamard encoded slices have to be acquired, from which the velocity can be calculated from the phase differences:

$$\Phi = \arctan \frac{IM}{RE} \quad (12)$$

IM stands for the imaginary, RE for the real components of the complex image. Depending on the calculated phase differences and the encoding times, the velocity for each individual pixel can be calculated.

20.4 Applications

A wide range of applications exists, where velocity distributions are investigated by NMR methods in material science and in process engineering. Common to these applications are the special arrangements and construction of the samples or sample containers in the magnets. Liquids or pastes are pumped through hoses and tubes in the probe inside the magnet, sometimes flowing through filters or extruders, or they are filled into Couette and Cone & Plate cells for rheology studies.

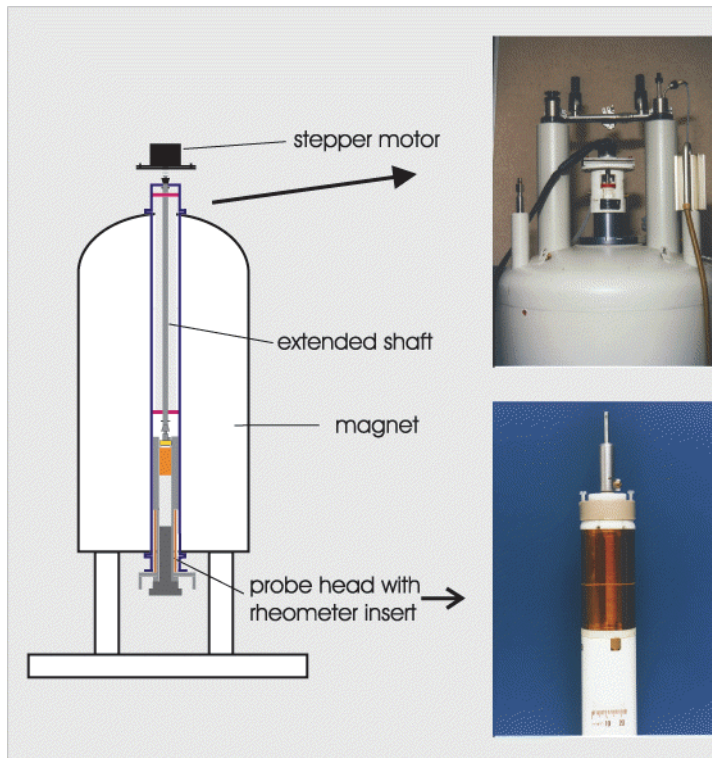


Figure 20.3: Rheo Cell

20.4.1 Rheology

The combination of rheology and NMR spectroscopy exists since several years. But the combination of rheology and NMR imaging is relatively new. The most important advantage and the unique feature of the combination with NMR imaging methods is the possibility to visualize spatially resolved shear rates and spatially resolved strain distributions in the rheometer cells (Couette or Cone & Plate types). Therefore shear banding and material slipping along the cell walls can be visualized, even in cases, where the samples are not optically transparent. These effects are of significant importance for the correct interpretation of the rheology experiments.

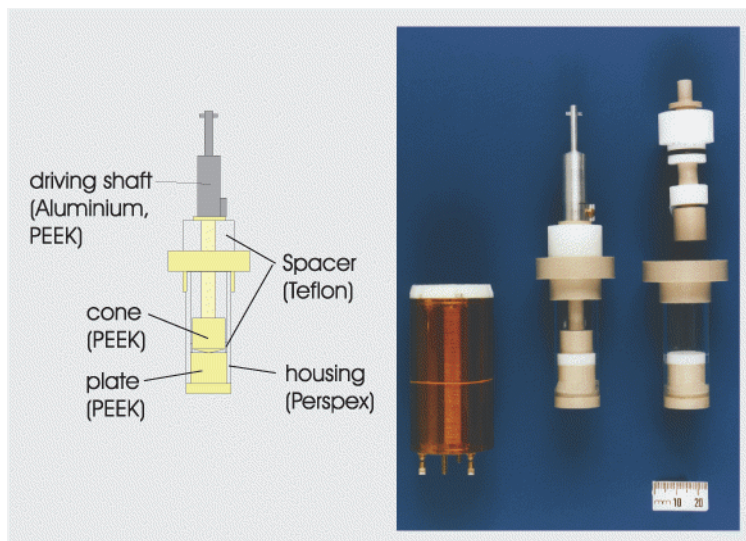


Figure 20.4: Cone & Plate Rheo Cell

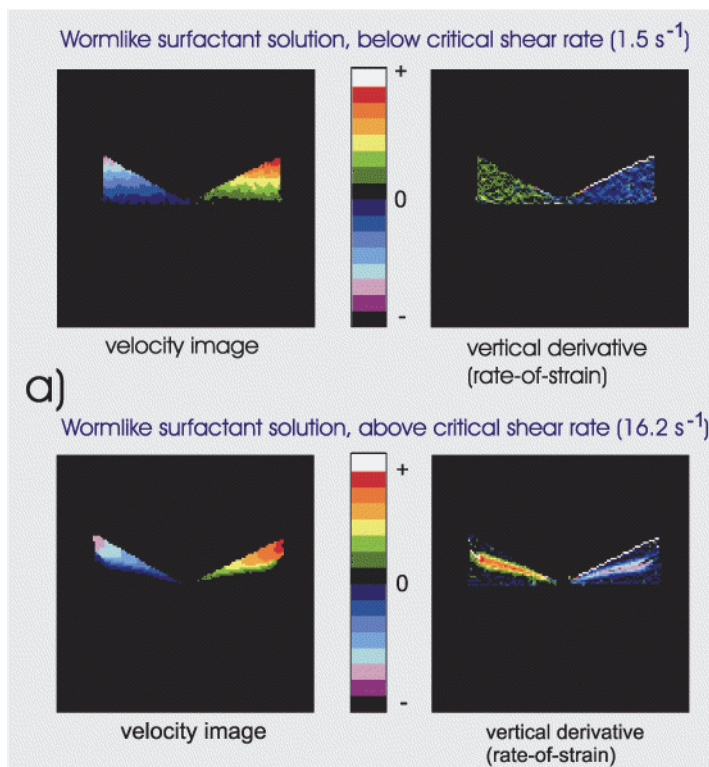


Figure 20.5: Maps of the Velocity and Rate of Strain Distribution on a Cone & Plate Cell with Shear Banding (lower right)

An introduction to rheology and nmr imaging is given in:

“Rheo-NMR: a New Application for NMR Microscopy and NMR Spectroscopy“ from Paul T. Callaghan and Elmar Fischer, Institute of Fundamental Sciences-Physics, Massey University, Palmerston North, New Zealand

More information can be found in:

P. T. Callaghan, Rheo-NMR: Nuclear magnetic resonance and the rheology of complex fluids. Reports on Progress in Physics 62, 599-670 (1999).

A lot of additional information can be found on the Internet. Some useful addresses include:

<http://www.rheo-nmr.com>

http://www.bruker-biospin.de/NMR/microimg/img_rheo.html

<http://www.iop.org/EJ/abstract/0034-4885/62/4/003>

20.4.2 Flow in Complex Geometries

The velocity distributions of simple and complex liquids in almost any type of geometries can be studied by NMR imaging methods using the Rheo NMR accessory with small modifications. The Couette cells, or Cone & Plate cells for rheology, have to be replaced by other cell types. Models of dedicated cells or extruders of even very complicated structures¹ can be connected to the drive shaft of the Rheo motor. Examples that were tried recently are the study of the flow behavior in a stirring design made from a liquid filled tube containing a paddle and from another tube containing a propeller². For such applications the data are acquired in a position triggered style to get undisturbed images, because the paddle or propeller is continuously rotating while the experiment is running.

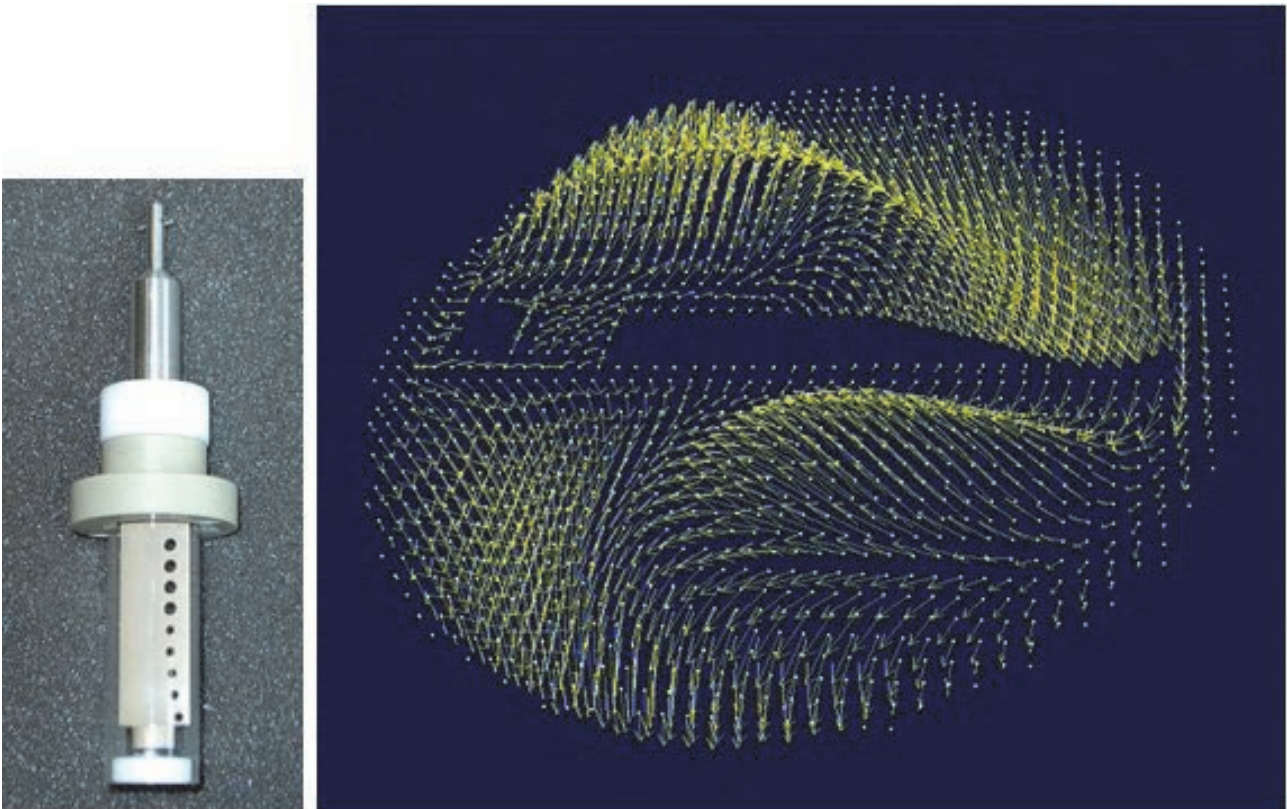


Figure 20.6: Paddle for Rheo Cell and Vector Display of the 3D Velocity Field

¹ S.Laukemper-Ostendorf, K.Rombach, P. Blümmler and B. Blümich, RWTH Aachen, Germany, Bruker Application Note NMR/1200/2/97/8-HA

² Joachim Götz, University of Munich

20.4.3 Mixing Processes and Chemical Reactions

The velocity distribution contains information about mixing and segregate properties in dedicated cells. The velocity vectors indicate, whether the constructions of the mixing cells are supporting a convenient transport of the material. The material should, for example, not undergo a sedimentation process caused by gravitational forces. This means that the velocity distribution must have significant components in the vertical direction within the entire mixing cell. Observing the spatially resolved velocity vectors may help to develop and optimize stirrer types for materials of different properties, e.g. viscosities, particle sizes and particle shapes.

In addition, it may be possible to study the temporal evolution of chemical/physical reactions of mixing materials in process engineering, e. g. mash process or fermentation¹.

Combining chemical shift selective imaging and spectroscopy (separation of different compounds, OH, CH₂, CH₃, ...), multinuclear imaging and spectroscopy (¹H, ²³Na, ¹³C, ⁷Li, ...) or T₂ relaxation measurements (information about changed mobility of molecular groups due to shear motion) with the velocity imaging method may give further insight into the mixing processes and reaction of materials.

¹ Joachim Götz, University of Munich, private communication.

20.5 Methods

In this section, the method specific parameters for the two velocity measurement methods in ParaVision 5.1 are described. The official method FLOWMAP, delivered with ParaVision 5.1 is a gradient echo based sequence, where mic_seflow is a spin echo based sequence (derived from FLOWMAP) which is available from the Microlmaging add-on CD (micdiff@bruker.de).

20.5.1 FLOWMAP

The official FLOWMAP method has the same parameter layout as all other Bruker sequences. Therefore, only the special flow parameters will be described here. Also refer to the methods manual in the Spectrometer Control Tool -> Help. The sequence is calculated in a way, that gradients compensate each other, so there are no special timing parameters that define the maximum or minimum flow velocity. If the velocity constraints don't fit the desired values, then the echo time or the spectral bandwidth may need to be changed.

Measuring Method	FLOWMAP
Echo Time	4.520 ms
Repetition Time	60.000 ms
Flow Encoding Mode	VelocityMapping
Flow Encoding	<input checked="" type="checkbox"/> expand
Flow Encoding Direction	SliceDirection
Flow Encoding Steps	2
No. of Flow Encoding Directions	1
Maximum Velocity (Venc)	12.00 cm/sec
Min Venc	0.76 cm/sec
Twister Gradient	Off
Signal Mask Threshold	2.00 %

Figure 20.7: FLOWMAP Velocity Parameter

The above figure shows the special parameters of the sequence FLOWMAP. Echo time and repetition time are common to (almost) all sequences, so the first “special” parameter is the “**Flow Encoding Mode**”. This mode can be “Phase Contrast Angiography”, “Velocity Mapping” or “Fourier Flow Imaging” as described in the previous chapter. Phase Contrast Angiography doesn’t deliver quantitative results; it only generates high image intensities in areas of high flow.

“**Flow Encoding Direction**”, “Flow Encoding Steps” and “No. of Flow Encoding Directions” are related parameters. The flow encoding direction defines the direction, in which the velocity will be measured (in RPS coordinates). It can be a single direction (Flow Encoding Steps = 2) or all three directions in space (Flow Encoding Steps = 4).

The “**Maximum Velocity (Venc)**” defines the maximum detectable velocity in the object and must be selected very carefully. If the value is too high, the resolution in flow direction is not optimal. If the value is too low (lower than the velocity in the object) the final data set will show phase wraps which result in signal folding in the flow direction (Fourier Flow Imaging) or in steps from positive to negative values (Velocity Mapping). The velocity is defined as absolute number, e.g. a parameter value of 10 cm/sec. defines a range from -10cm/sec..+10 cm/sec.

“**Min Venc**” shows the minimal velocity that can be resolved.

“**Twister Gradient**” ###

During the post processing, all velocities in pixels with an intensity below a certain level will be set to zero. This level can be set by “**Signal Mask Threshold**” in percentage of the maximum pixel intensity.



Note: If you find the threshold to be misadjusted after the experiment clone reco, enter ‘Signal-Mask’ in the “Single Parameter Window”, modify the value and select Reco.

20.5.2 mic_seflow

The velocity parameter mic_seflow is based on the official FLOWMAP method, but it is a spin echo sequence which is advantageous for inhomogeneous samples. Since it's based on FLOWMAP, some parameters are identical, but it also has some additional parameters.

Flow Encoding Mode	FourierFlowImaging
Flow Encoding	<input checked="" type="checkbox"/> expand
FlowEnc Grad Time (d)	1.000 msec
FlowEnc Grad Separation (D)	10.000 msec
Flow Encoding Direction	SliceDirection
FlowEncGradMatrix	<input type="checkbox"/> expand
Flow Encoding Steps	128
No. of Flow Encoding Directions	1
Maximum Velocity (Venc)	12.00 cm/sec (+/-)
Min Venc	8.34 cm/sec
Velocity Resolution	0.19 cm/sec
Flow Encoding Steps	128
Flow Encoding Gradient	69.50 %
Flow Compensation	<input type="checkbox"/> expand

Figure 20.8: The mic_seflow Velocity Parameter

The “FlowEnc Grad Time (d)” and the “FlowEnc Grad Separation (D)” are the parameters δ and Δ as shown in Flow Compensation [▶ 201]. They are independent parameters to adjust the minimal resolvable flow velocity. They will of course affect the echo time. The longer the δ or Δ , the slower the velocity can be measured.

All the other parameters shown in the figure above are identical to the FLOWMAP parameters. A new sub menu is the “Flow Compensation”. Since δ and Δ can be set independently, there are no constrains for other gradient amplitudes. Since the calculation of the flow compensation parameters is quite complicated, it cannot be guaranteed through the method, that no gradient amplitude exceeds 100%.

If a gradient amplitude exceeds 100%, it will generate an error at the experiment start. In this case the “**Flow Compensation**” parameters need to be checked. If the gradient that exceeds the 100% is identified, parameters like e.g. δ , Δ , or “**Read FC Grad Time**” need to be modified to get all gradient amplitudes below 100%.

Flow Compensation	
<input checked="" type="checkbox"/> expand	
Read FC Grad Time	2.000 msec
Read Dephase Gradient	92.1083 %
1st FlowComp Read Grad	-75.2488 %
Phase 2D FC Grad Time	2.000 msec
2D Phase Gradient	8.75681 %
1st FlowComp 2dPhase Grad	2.49777 %
Slice FC Grad Time	2.000 msec
Slice Rephase Gradient	-2.03653 %
1st FlowComp Slice Grad	-1.09899 %
1st 2D Slice Comp. Grad	0.00 %
2nd 2D Slice Comp. Grad	0.00 %

Figure 20.9: The mic_seflow Flow Compensation Parameter



Note: Take care that the magnetized spins do not leave the RF-coil before the magnetization is acquired.



Note: Take care that the magnetized spins did not leave the excited slice before the refocusing pulse is applied. It's often a good idea to use a rectangular shaped 90 degree pulse and a shaped (slice selective) refocusing pulse.

20.6 Hands on: Rheology Experiments

This section explains the setup of a rheology study since it differs a bit from 'typical' micro-imaging experiments. For more details about the hardware and programming for the components please refer to the dedicated Rheo manual.

The Rheo controller has a serial connection that is controlled by the spectrometer hardware. In ParaVision 5 there is no possibility of defining the serial port during cf, so the Rheo controller needs to be set up manually. To do so, create the file `$PvHome/conf/instr/spect/rs232_device/rheo` as shown in the example below and set the correct values for host (IP address of the IPSO) and device (selected TTY connection).

unit = Rheo unit

host = 149.236.99.250

device = /dev/tty05

type = RS232

stty = 9600 time 5 cs8 cread clocal istrip

Example of the file `$PvHome/conf/instr/spect/rs232_device/rheo`

After ParaVision is restarted, the Rheo controller, and thus the speed of the Rheo motor can be controlled by the macro 'mic_rheo' in ParaVision, or the command 'rheo' on the TopSpin command line.

20.6.1 Hardware and Setup

The Rheo kit consists of various parts, which can be divided into 2 groups:

- Drive group.
- Cell group.

The **drive group** consist of all parts which remain in/at the magnet during the complete rheo experiment.

The **cell group** consists of the different cell types, that have to be selected properly depending on the desired sample and shear rate.

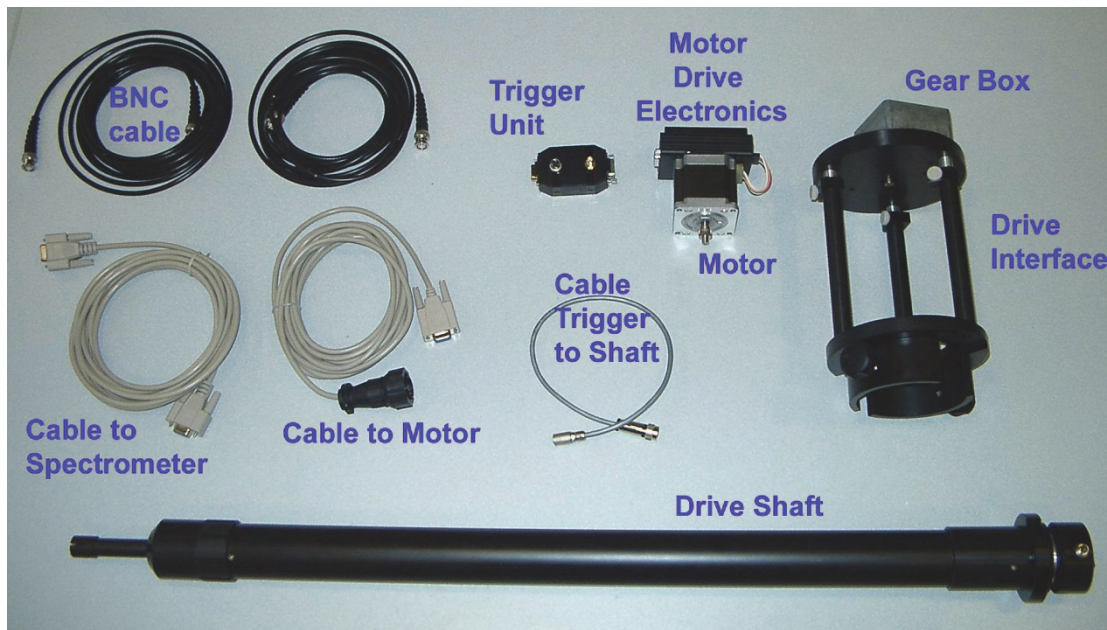


Figure 20.10: Cables, Motor, Gear Box, Drive Shaft and Interface

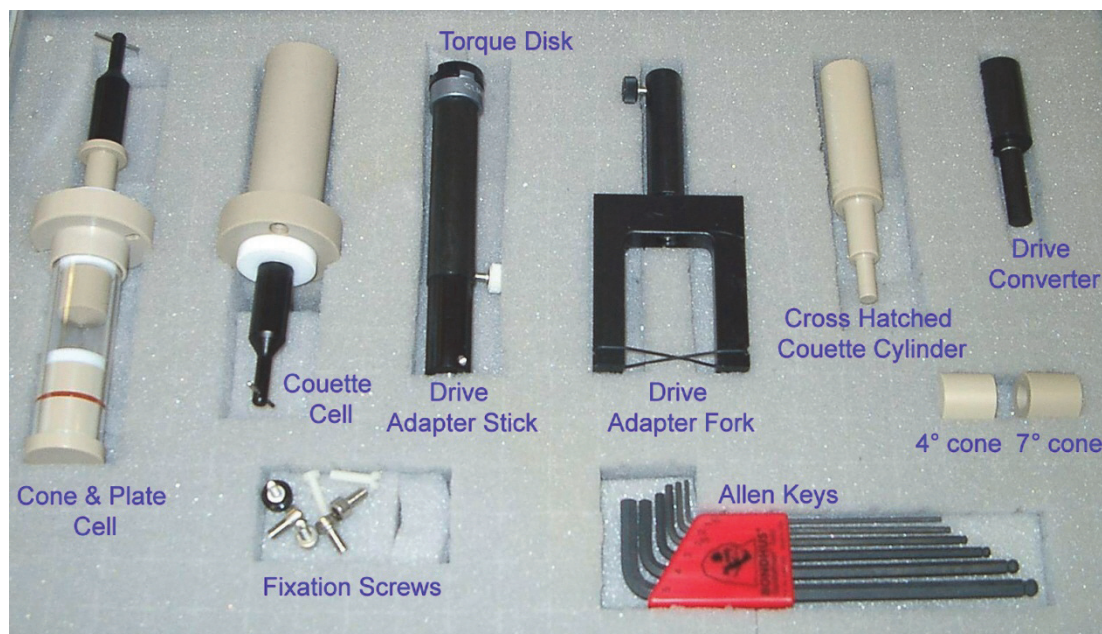


Figure 20.11: Cells and Drive Adaptation

The rheo drive hardware must first be mounted at the magnet. This will not be described in detail here, refer to the rheo manual for detailed information.



Important: To mount the rheo drive hardware you must have a wide bore upper shim stack with a short turbine, since the Micro 2.5 gradient system is longer than a standard wide bore RF probe.

When the modified shim upper part is mounted in the magnet, all rheo drive accessories can be mounted from the top of the magnet.



Figure 20.12: Rheo Drive Hardware, Fixed with 2 Screws (blue arrow) on Top of a Magnet

20.6.2 Selection and Filling of the Rheo Cells

The rheo kit offers 2 different cell choices, **Cone & Plate** and the **Couette** cell.

There is no rule, as to which cell is the better one for a dedicated application. Basically, the desired shear rate for the experiment has to be known in advance, and then the cell and the rotation speed can be determined from that value. The table below shows some typical values for the shear rates.

Rheometer Type	Dimensions ^a (mm)	Material	Shear Rate (s ⁻¹) at 4.74 Hz rotation rate
Cone-and-plate	cone diam.: 24 or 16 angle: 4° or 7°	machinable glass (smooth)	426
PEEK Couette cell	ID: 19 OD: 17	PEEK (smooth or hatched)	253
PEEK Couette cell	ID: 19 OD: 18	PEEK (smooth or hatched)	536
Glass Couette cell	ID: 7.0 OD: 4.0	smooth glass cylinder, Teflon bushes	40
Glass Couette cell	ID: 9.0 OD: 7.5 or 5.0	smooth glass cylinder, Teflon bushes	149 or 37

^aID: inner diam. of chamber; OD: outer diam. of rotor.

Figure 20.13: Typical Shear Rates (P. Callaghan, E. Fischer)

For small angles in the Cone & Plate cell, the shear rate γ can be calculated using

$$\gamma = \omega / \tan \alpha = 2\pi f / \tan \alpha$$

Where ω is the rotation speed and α is the angle of the Cone & Plate.

In the Couette cell, the shear rate can be calculated using:

$$\gamma = \omega r / s = 2\pi f r / s$$

Where r is the radius of the rotor cylinder and s is the gap between rotor and chamber.

If it turns out that the system requires a very low rotation speed, a gear box should be used. This allows the motor to run at higher speed, since slow stepper motor speeds might introduce vibrations to the sample.

It is very important to fill the cells without air bubbles. Unfortunately, there is no simple rule how to do this. It's easier with samples with low viscosity, but the higher the viscosity the higher the chance of having air bubbles in the cells. During the imaging experiment, the bubbles will move and create image artifacts.

After filling the cell, it has to be mounted to a 25 mm MicWB40 (Micro 2.5) resonator and (depending how tight the cell already is) needs to be fixed by screws.

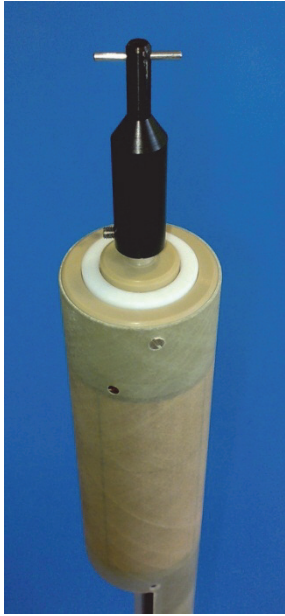


Figure 20.14: Rheo Cell Mounted in a 25 mm MicWB40 Probe

When the probe is shifted into the magnet, it may happen that it cannot be shifted in to its standard position. The reason is that the horizontal carrier pin at the cell doesn't slip into the gap of the drive shaft. The probe has to be rotated until it can be moved to its standard position. Now the probe can be fixed as usual.

20.6.3 Imaging Experiments

For the first experiments, switch the rheo motor off. After tuning, setting the frequency, shimming and detection of the auto reference gain, a gradient echo experiment with three orthogonal planes should be acquired to check for the correct position, geometry and for air bubbles.

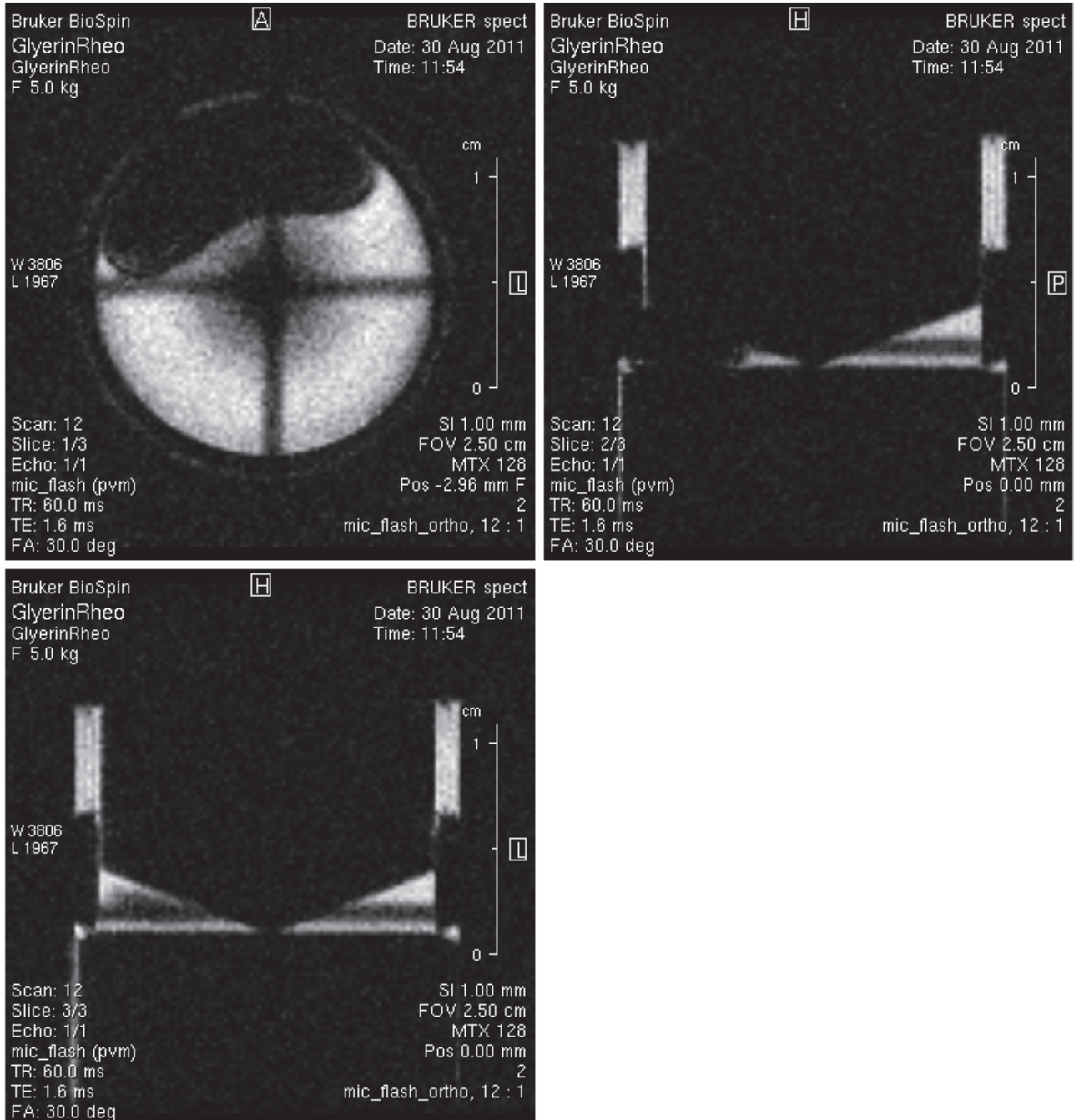


Figure 20.15: Three Orthogonal FLASH Planes Showing Air Bubble

If the cell contains air bubbles, for example as shown in the figure above, the cell has to be taken out of the magnet and refilled.

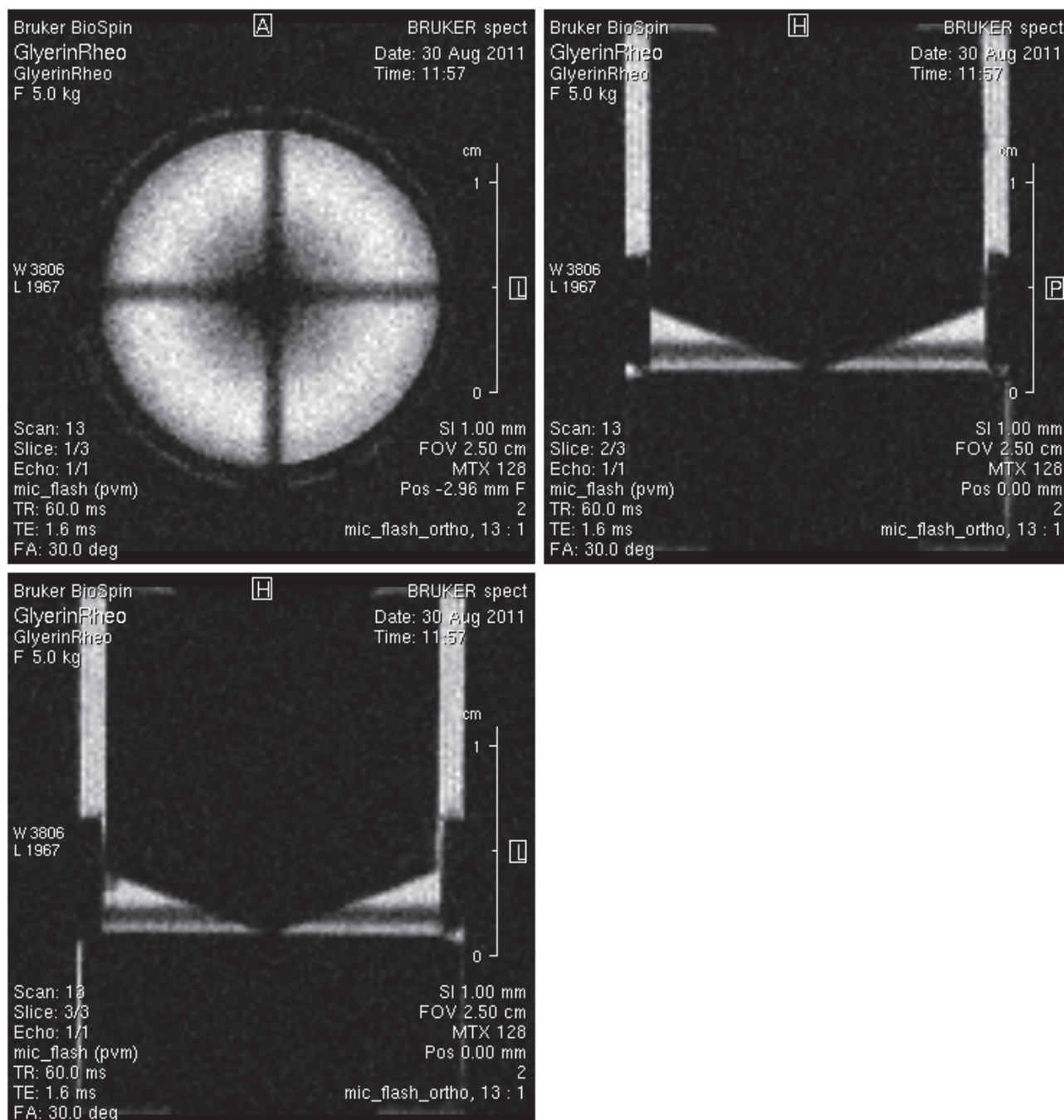


Figure 20.16: Three Orthogonal FLASH Planes Without Bubbles

Once all the preparation is finished, it is time to start with some real velocity experiments. One should start with a standard FLOWMAP sequence. Since it's based on a gradient echo sequence, it is a much faster experiment than a mic_seflow experiment that is based on spin echo.

A good starting point for the Cone & Plane experiments is the protocol FlowMap_ConePlate from the rheo location in S040 (Micro 2.5). It defines one velocity map image in slice direction with 4 averages. In Cone & Plate experiments we are interested in the velocity orthogonal to the sagittal (or coronal) plane. If we look at the sagittal image (upper right) in the figure above, we assume, that nothing is flowing from left to right and nothing is flowing from top to bottom. But

we know, that the inner cylinder is rotation and the outer chamber is static. In an ideal Newtonian fluid we would expect, that on the surface of the cylinder the fluid has the same velocity and flow directions as the cylinder, and on the static chamber wall the velocity should be 0.

So the only flow direction we are interested in is the slice direction. In the two other directions there should be no flow.

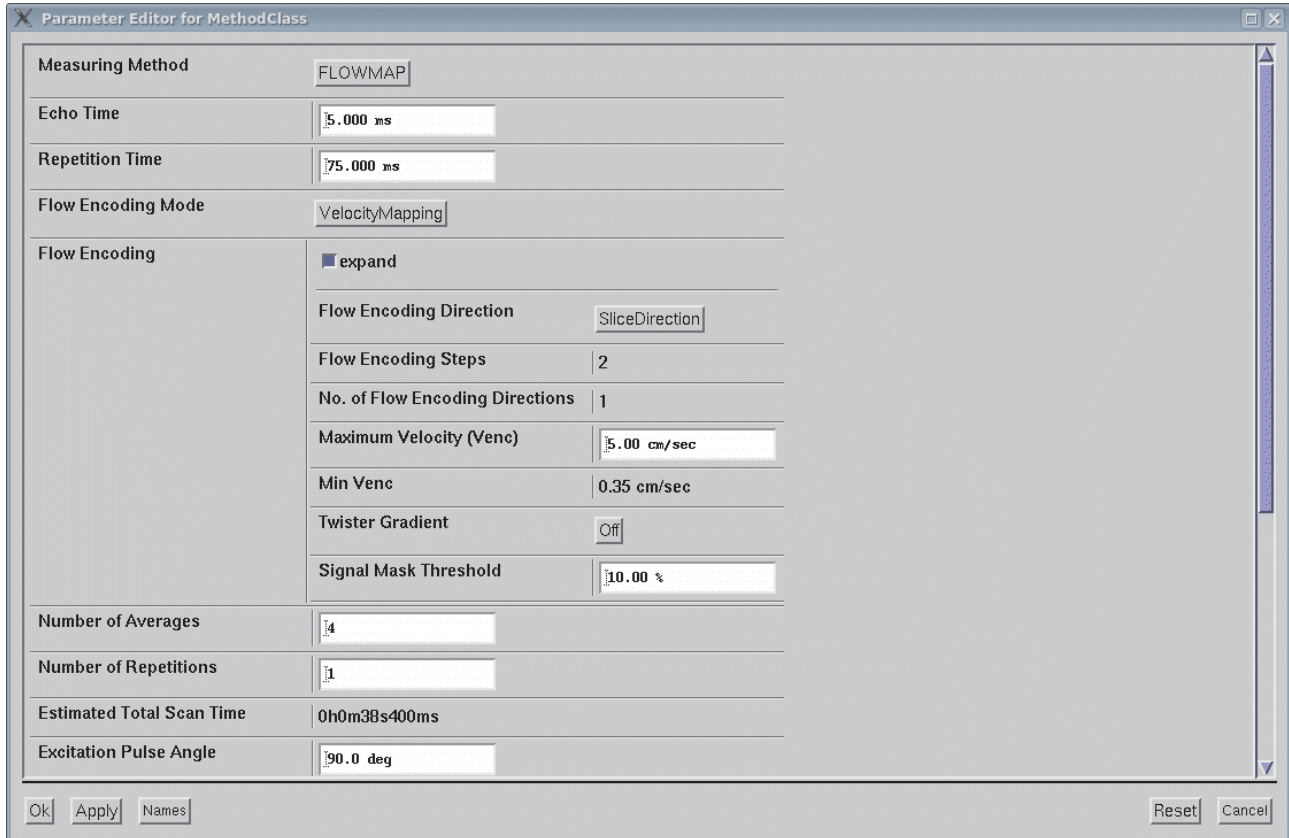


Figure 20.17: Typical FLOWMAP Data for a Cone & Plate Experiment

Since FLOWMAP is a pretty fast experiment, it is recommended to acquire a few averages to improve the signal to noise ratio and to cancel remaining flow artefacts. There might still be some remaining flow artefacts since we only compensate for the first momentum, the laminar flow, but not for turbulent flow which we might have in the circular Cone & Plate cell.

As a result of the experiment, 2 images are obtained, one shows the velocity image, the other should show the magnitude image. However, due to ParaVision 5 scaling problems, the magnitude image always appears with an incorrect scaling. This problem should be fixed in the next ParaVision version.

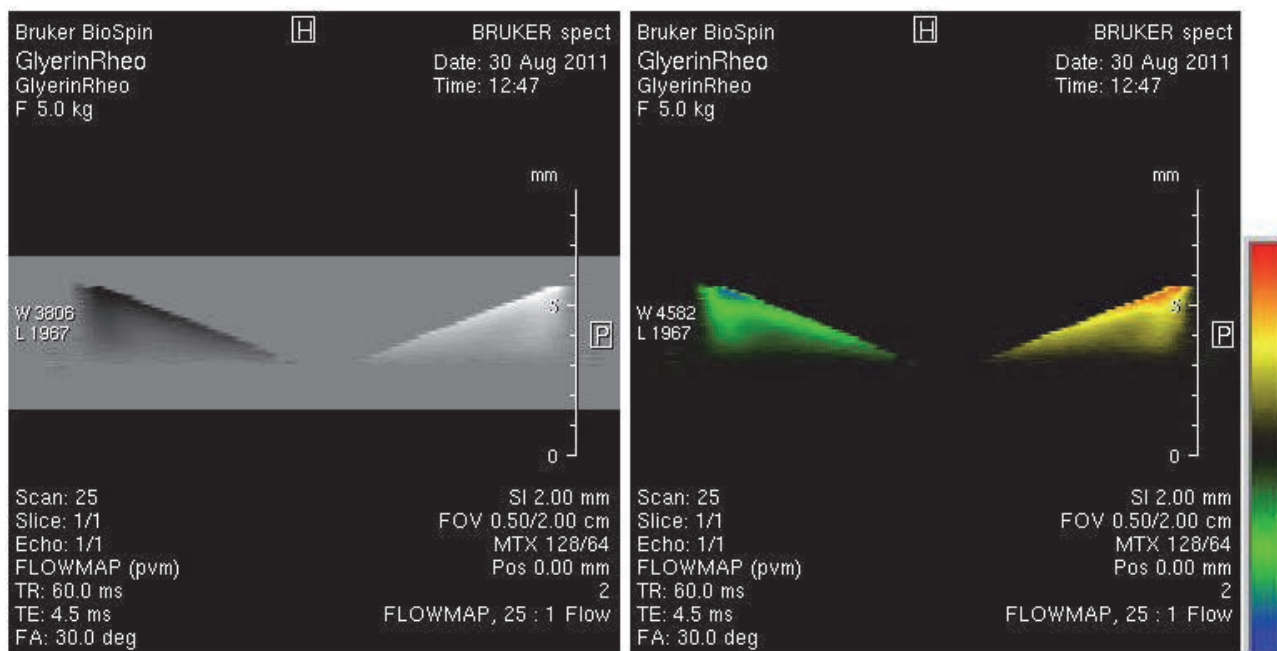


Figure 20.18: Velocity Data with Different Lockup Tables

The figure above shows the result of the Cone & Plate FLOWMAP experiment. Both images show the same data, the left one in standard black and white, the right in colour coded with the lockup table *mic_flow_black*, showing high positive velocities in red, high negative velocities in blue and no flow in black.

The velocity values can be checked by the Cross Hair Tool in the Image Display Tool of ParaVision, or the 2D image data can be exported as scaled ASCII file by the help of the macro *mic_convert_2dseq2csv_scale*.

The shear rate of the acquired data can be calculated by the macro *mic_CalcShearRates*. It will calculate the shear rate along x (left to right in the velocity image) and along y (top-bottom) and store these data in new processing numbers.

It is often required, to adapt the image intensities of the shear rate data to a reasonable range. This can be done in the Image Display Tool -> View -> Window Image Intensity. Set this to user defined and enter a symmetrical interval e.g. -900 to +900 for the range.

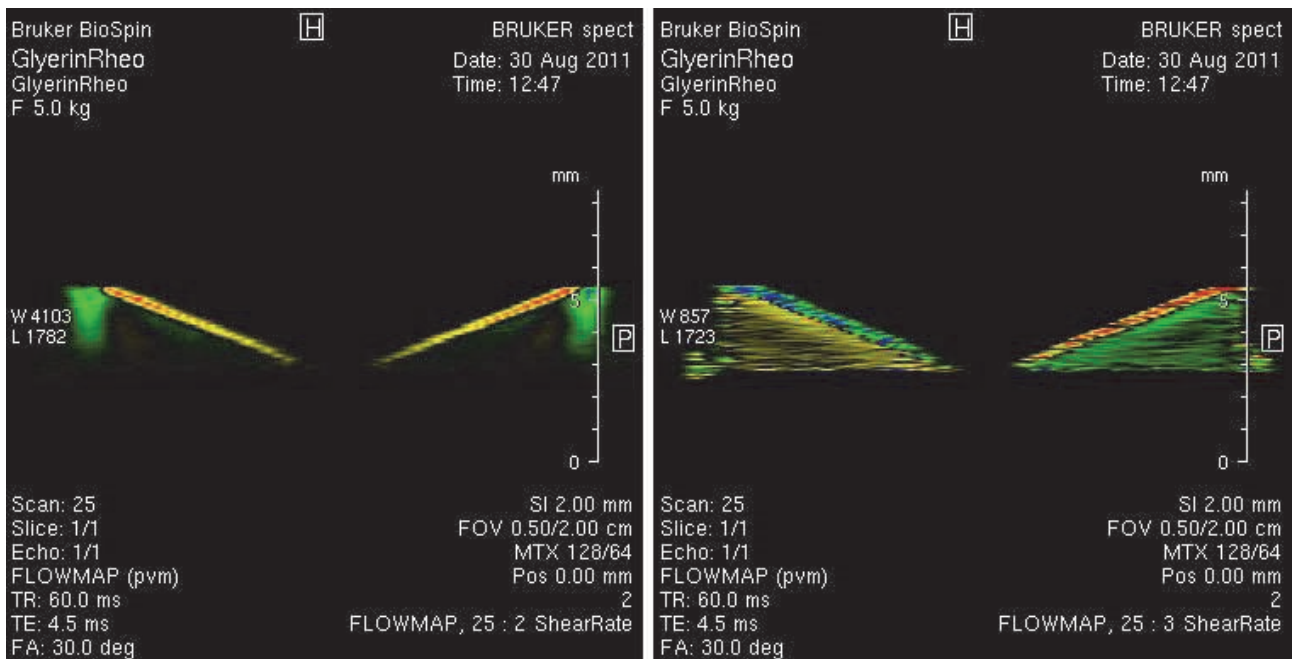


Figure 20.19: Shear Rate Data Along x (left) and y (right) with Different Image Intensities

The setup of a fourier flow imaging experiment is identical to the previously described procedure, the only difference is 1 additional parameter in the method GUI, which defines the number of flow encoding steps in the flow dimension. The result of the experiment is a data set that contains typically 2 spatial dimensions and additionally a flow dimension. The only post processing offered for this type of data set currently is to calculate the velocity images, to get results like in the previous Velocity Map FLOWMAP experiments. This calculation can be done by the macro *mic_VelocityFromFourierflow*.

The mic_seflow experiments are similar, but are based on a spin echo sequence, which requires longer acquisition time with the advantage, that it is less sensitive to sample and magnetic field in homogeneities.



Note: Take care that the magnetized spins did not leave the excited slice (or even the sample) before the refocusing pulse is applied. It's often a good idea to use a rectangular shaped 90 degrees pulse and a shaped (slice selective) refocusing pulse.

21 Contact

Manufacturer:

Bruker BioSpin NMR
am Silberstreifen
D-76287 Rheinstetten
Germany
Phone: +49 721-5161-0
<http://www.bruker-biospin.com>

NMR Hotlines

Contact our NMR service centers.

Bruker BioSpin NMR provide dedicated hotlines and service centers, so that our specialists can respond as quickly as possible to all your service requests, applications questions, software or technical needs.

Please select the NMR service center or hotline you wish to contact from our list available at:

http://www.bruker-biospin.com/hotlines_nmr.html

Figures

Figure 4.1:	Master Unit BGMUI-E Front Panel	19
Figure 4.2:	Pin Layout of the Pt100 Connector	20
Figure 4.3:	Pin Layout of the 'External Enable' Connector	21
Figure 4.4:	Power Calculation for an Individual Gradient Channel	21
Figure 4.5:	Calculation for the Gradient System (sum of all gradient directions).....	21
Figure 4.6:	Great Amplifier Front View	23
Figure 4.7:	Back Side View of the Great Amplifier Showing the Location of the Fuses	25
Figure 4.8:	Front Plate of the B0-2 Compensation Unit.....	25
Figure 4.9:	Pin Layout of the Analog Input/output Connector at the B0-2 Front Plate	26
Figure 4.10:	BSMS-2 to B0-2 Adaptor Board, Mounted on the Most Right SCB20 Module	27
Figure 4.11:	Gradient Filter and Fuses	28
Figure 4.12:	Location of Pin G at the Probe Base Connector (left) and Grounding of the Pin (right image) 29	29
Figure 4.13:	Pin Layout of the 12 Pin Burndy Connector (front view of the plug at the probe base).....	29
Figure 4.14:	BCU20 Schematic Diagram	30
Figure 4.15:	Backside View of the BCU20.....	31
Figure 4.16:	BCU20 Top View with Opened Cover.....	32
Figure 4.17:	Front View of the BCU20.....	34
Figure 4.18:	External Imaging Rack Cables	35
Figure 4.19:	Imaging Accessory Wiring	36
Figure 5.1:	Mounted Mirco5 RF Insert (Saddle Coil)	41
Figure 5.2:	Micro 5 RF Insert (Solenoid Coil)	42
Figure 5.3:	Mounting of the Micro 5 Gradient	43
Figure 5.4:	Final Assembly of the Micro 5	44
Figure 5.5:	Removal of the Gradient Coil from the Probe Base	45
Figure 5.6:	Micro 2.5 RF Probes.	46
Figure 5.7:	Mounting the Micro 2.5 Gradient to its Base	49
Figure 5.8:	Mounted Micro 2.5 Gradient, Fixed with 4 Brass Screws with Lock Nuts	50
Figure 5.9:	Schematic of a Micro 2.5 Probe Base and RF Insert	51
Figure 5.10:	Closure Head.	52
Figure 5.11:	Bottom Mount with Spring and Teflon Ring to Protect the Glass Dewar.....	53
Figure 5.12:	Bottom Mount Fastened with 2 Screws.	53
Figure 5.13:	MICWB40 Probes.....	55
Figure 5.14:	Mounting the Micro 2.5 Gradient to its Base	57
Figure 5.15:	Mounted Micro 2.5 Gradient, Fixed with 4 Brass Screws with Lock Nuts	58
Figure 5.16:	Mounting a MICWB40 Insert with the Help of the Small Mounting Tool	59
Figure 5.17:	Fixing the MICWB40 Insert	60
Figure 5.18:	Combiner for MICWB40 Quadrature Probes.....	60
Figure 5.19:	Connection of the Combiner to the Preamplifier Flat Band Cable.....	61
Figure 5.20:	Dewar Guide Fixed with 3 Screws below the RF Coil and Dewar Shifted in from Probe Bottom 62	62
Figure 5.21:	Bottom Mount with Spring and Teflon Ring to Protect the Glass Dewar	63
Figure 5.22:	The Heater/thermocouple Shifted in and Fixed Using the Bayonet Lock.....	64
Figure 5.23:	Probe with Heater Mounted in the Magnet and Connected to the BVT	65
Figure 5.24:	Mini 0.5/0.75 RF Probes.....	66

List of Figures

Figure 5.25:	Mounting the Mini0.5/0.75 Gradient to the Base	69
Figure 5.26:	Mini 05/0.75 Gradient Mounted to a Magnet.	70
Figure 5.27:	Schematic of a Mini 0.5/0.75 Probe Base and RF Insert.....	71
Figure 5.28:	Probe Version Information	72
Figure 5.29:	The 66 mm 1H Quadrature Probe	73
Figure 5.30:	Bottom Plate of the SWB90 Probe	73
Figure 5.31:	Knobs for the Tuning and Matching the two RF Channels	74
Figure 5.32:	Knobs for the Tuning and Matching the two RF Channels	74
Figure 5.33:	Combiner for MICWB40 Quadrature Probes.....	75
Figure 5.34:	Connection of the Combiner to the Preamplifiers Flat Band Cable	76
Figure 5.35:	The 66 mm 1H Quadrature Probe	77
Figure 5.36:	Fixation of the SWB Probes (part 1).....	77
Figure 5.37:	Fixation of the SWB Probes (part 2).....	78
Figure 6.1:	The expinstall Selection for Micro-imaging Systems	80
Figure 6.2:	Typical 'Edit & Save Config' for Micro-Imaging AVANCE III Systems.....	80
Figure 6.3:	HWIDS Data File CD for Each Individual MicWB40 Insert	84
Figure 7.1:	Setpre in TopSpin Window, the Output Current Stage Selector Marked in Blue.....	88
Figure 7.2:	GradSafe Dialog to Enter the Gradient Safety Parameters.....	89
Figure 7.3:	Setpre in TopSpin with Marked Offset Adjustment Features.	91
Figure 7.4:	The setpre' in TopSpin for the Loop Adaptation.....	93
Figure 7.5:	Ramp Parameter Dialog. The Parameter 'Time' is the Ramp Time	94
Figure 7.6:	Gradient Pulse with High "Resistors/Capacitors" Values, Leading to a Slow Regulation Behavior.....	95
Figure 7.7:	Gradient Pulse with low "Resistors/Capacitors" Values, Leading to a Current Overshoot ..	95
Figure 7.8:	Optimal Adjusted Loop Values Leading to the Fastest Raise Time without Current Overshoot	96
Figure 7.9:	Preemphasis Experiment with Varying Delays Between Gradient and RF Detection.	97
Figure 7.10:	The setpre in TopSpin for the Preemphasis Adjustment.....	98
Figure 7.11:	A Gradient Shape (black) with 1 Preemphasis Term (red)	99
Figure 7.12:	Preemphasis Experiment without Preemphasis Compensation.....	100
Figure 7.13:	Preemphasis Experiment after the Adjustment.	100
Figure 7.14:	B0 Experiment with Varying Delays Between Gradient and RF-Detection.....	101
Figure 7.15:	The setpre' in TopSpin for the B0 Adjustment	102
Figure 7.16:	A Gradient Shape (black) and the Generated B0 Compensation Terms (red) that are Added to the H0 Coil	103
Figure 7.17:	B0 Experiment without B0 Compensation (unshuffled display).....	104
Figure 7.18:	Signal after B0 Compensation (unshuffled display).....	104
Figure 7.19:	Calibration Images of the LEGO.	106
Figure 7.20:	Fig. 5?20: Calibration Images of a M4 Screw.	106
Figure 7.21:	The mic_gradcalc Method Interface	108
Figure 7.22:	Gradient Calibration Parameters Dialog.....	109
Figure 7.23:	Study Editor with Probe Selection Pull Down Menu.	110
Figure 7.24:	Protocols Dialog with 'Operation Mode' Selection.....	111
Figure 7.25:	Main GUI Window for the Coil Configuration.....	112
Figure 7.26:	Coil Edit Sub Menu For the Coil Configuration (Coil 1→Edit)	113
Figure 7.27:	Equation: Relation Between Reference Attenuation and Reference Power.....	113
Figure 7.28:	Reconnect Transmitters Dialog for 1H.....	116
Figure 7.29:	Reconnect Transmitters Dialog for 19F.	116

Figure 7.30:	Setup Routing Dialog for 1H.....	117
Figure 7.31:	Setup Routing Dialog for 19F	117
Figure 8.1:	Signal and Noise ROIs Created by the mic_rfTest Macro in an Axial 1H SNR Image	120
Figure 8.2:	Equation 7?1: SNR per mm ³ Calculation.	120
Figure 8.3:	Equation 7?2: Calculation of the Homogeneity.....	120
Figure 8.4:	The mic_rfTest with Both Data Sets Processed (green color of the 'Calc' buttons)	122
Figure 8.5:	Equation 7?3: Signal to Noise Calculation from a Spectrum	122
Figure 9.1:	Hard Blanking of a Gradient Pulse with Preemphasis Components.	124
Figure 9.2:	Soft Blanking of a Gradient Pulse with Preemphasis Components.....	125
Figure 10.1:	The Signal Path in the RXAD and the DRU	127
Figure 10.2:	Every Individual Point of the Oversampled FID is Multiplied by the Filter Kernel.....	128
Figure 10.3:	Filtered FID with IEss Noise and the Group Delay”	129
Figure 10.4:	Decimated Final FID.....	129
Figure 10.5:	Gradient Echo (256 cplx data points)	131
Figure 10.6:	Digitizer Class of a Method	132
Figure 10.7:	Analog Data Sampling with anavpt=4	133
Figure 10.8:	DWL_CLK Timing, anavpt is set to 8.....	133
Figure 11.1:	Schematic of the Console – Triggering Unit Wiring.....	135
Figure 11.2:	Connection of the RF Probe to the ECG/Temperature Preamplifier.....	136
Figure 12.1:	T2 Images Series Displayed with Automatic Scaling	141
Figure 12.2:	T2 Images Series Displayed with Global User Scaling	141
Figure 12.3:	Working Memory Setting	142
Figure 12.4:	Jittering of the Echo Position Due to Instabilities.....	145
Figure 12.5:	GREAT 1/40 or GREAT 1/60 with the New Cable W118210.....	146
Figure 15.1:	Coil Handling and Routing Infrastructure in ParaVision 5.0	152
Figure 15.2:	The Coil Configuration Editor	153
Figure 15.3:	The Coil Editor	156
Figure 17.1:	Equation A?1: Signal to Noise Calculation from a Spectrum	161
Figure 17.2:	13C Spectrum of the Temp. Calibration Sample.	165
Figure 17.3:	19F Spectrum of the 1 Molar TFT Sample.	166
Figure 17.4:	31P Spectrum of the 1 Molar TPP Sample.....	167
Figure 18.1:	Nylon Screw Sample	176
Figure 18.2:	XY and YX Images Used to Determine the Linearity of the Gradient System in X and Y of a Nylon Screw Sample	177
Figure 18.3:	XY and YX Images Used to Determine the Linearity of the Gradient System in X and Y of a Nylon Screw Sample	177
Figure 18.4:	XZ Image of a Nylon Screw.....	177
Figure 19.1:	Images Acquired as Described in 'Amplitude Stability'.....	190
Figure 20.1:	Simple Gradient Echo Experiment Applied on a Volume Element in Tube Filled with Water... 199	
Figure 20.2:	Spin Echo Experiment with Velocity Encoding and Flow Compensation Gradients.....	202
Figure 20.3:	Rheo Cell.....	204
Figure 20.4:	Cone & Plate Rheo Cell	205
Figure 20.5:	Maps of the Velocity and Rate of Strain Distribution on a Cone & Plate Cell with Shear Banding (lower right)	205
Figure 20.6:	Paddle for Rheo Cell and Vector Display of the 3D Velocity Field.....	206
Figure 20.7:	FLOWMAP Velocity Parameter	208
Figure 20.8:	The mic_seflow Velocity Parameter	209

List of Figures

Figure 20.9:	The mic_seflow Flow Compensation Parameter	210
Figure 20.10:	Cables, Motor, Gear Box, Drive Shaft and Interface	211
Figure 20.11:	Cells and Drive Adaptation	212
Figure 20.12:	Rheo Drive Hardware, Fixed with 2 Screws (blue arrow) on Top of a Magnet	213
Figure 20.13:	Typical Shear Rates (P. Callaghan, E. Fischer).....	214
Figure 20.14:	Rheo Cell Mounted in a 25 mm MicWB40 Probe	215
Figure 20.15:	Three Orthogonal FLASH Planes Showing Air Bubble	216
Figure 20.16:	Three Orthogonal FLASH Planes Without Bubbles.....	217
Figure 20.17:	Typical FLOWMAP Data for a Cone & Plate Experiment	218
Figure 20.18:	Velocity Data with Different Lockup Tables.....	219
Figure 20.19:	Shear Rate Data Along x (left) and y (right) with Different Image Intensities	220

Tables

Table 5.1:	Gradient System and RF Coil Compatibility Matrix	37
Table 5.2:	Gradient Systems and Available RF Coils.....	38
Table 5.3:	Application Relevant Parameters of the Micro 5 System	40
Table 5.4:	Application Relevant Parameters of the Micro 2.5 System	48
Table 5.5:	Application Relevant Parameters of the Micro2.5 System	56
Table 5.6:	Application Relevant Parameters of the Mini0.5/0.75 System.....	67
Table 7.1:	Different 'setpre' Behavior in ParaVision and TopSpin Mode.	87
Table 7.2:	Parameters	90
Table 7.3:	Parameters Setup for the Great Offset Adjustment.....	92
Table 7.4:	Parameters Setup for the Great Loop Adaptation	92
Table 7.5:	Parameters Setup for the Great Preemphasis Adjustment	97
Table 7.6:	Parameter Setup for the Great B0 Adjustment.....	101
Table 7.7:	Parameter Setup for Gradient Calibration	105
Table 7.8:	Parameters for Different Coil Types	115
Table 8.1:	Parameter Setup for SNR tests	119
Table 8.2:	Parameter Setup for SNR tests	121
Table 9.1:	Hard Blanking Parameters.	124
Table 9.2:	Soft Blanking Parameters.....	125
Table 10.1:	Example of a Digital Filter with a Kernel Length of 8.....	128
Table 12.1:	Differences in TopSpin and ParaVision Shape Files	140
Table 13.1:	Diffusion Coefficients D in 10-9m ² s ⁻¹	147
Table 13.2:	Diffusion Coefficients D in 10-9m ² s ⁻¹	147
Table 13.3:	Diffusion Coefficients of H ₂ O at different temperatures. D in 10-9m ² s ⁻¹	148
Table 14.1:	T0 Trigger Signals	149
Table 17.1:	Standard Parameters for Imaging Signal to Noise Ratio Tests (1H) and Homogeneity Tests	163
Table 17.2:	Standard Parameters for Spectroscopic Signal to Noise Ratio Tests (X nuclei).....	164
Table 17.3:	SN Ratios for 1H Coils, acquired with Sample 20% H ₂ O, 80% D ₂ O, and 1g/l CuSO ₄	164
Table 18.1:	Typical Gradient Coil Parameters.....	178
Table 18.2:	Setpre Parameters for the Different Gradient Systems	179
Table 18.3:	Loop Adaptation	182
Table 18.4:	Preemphasis.....	183
Table 18.5:	B0 Compensation	184

Index

Numerics

1H coils	162
1H/19F birdcage resonator	166
31P SNR tests	166

A

Active Coil Configuration.....	151
Active Detuning Module	152
ADM	152
analog B0 current.....	26
analog mode on the DRU	132
animal monitor system	66
animal triggering unit.....	135
Autorouter	154

B

B0 shift compensation.....	175
B0-2 unit.....	27
B1 homogeneity	121
BCU20	30, 79
Installation.....	31
Operation	32
Temperature regulation.....	33
BCU20 cooling unit.	20
BGMUI-E.....	19
BGMUI-E Master Unit	24
BioSpec systems.....	81
blanking modes.....	123
BOSS shim system	27
BSMS-2.....	26, 27
BSMS-2 adaptor board	27
Burdy gradient connector.....	28
BVT control program.....	32

C

cf	79
Coil.....	151
Coil Configuration	151
Coil Configuration Editor	152, 153
Coil Element.....	151

Coil Operation Modes	151
Copyright	11
Cross Hair Tool	219

D

DEOSC	132
diffusion probes	88
diffusion systems	37
Digital filters	127
DPP	19, 26
DPP board	19
DPP software.....	189
DQD frequency	127
DRU	127
DSP	89
DSP security feature.....	21
dwel time.....	127

E

ECG	66, 135
edte.....	32
edtg.....	32
EVT.....	39
EVT inserts	
Installation	53
Exchangeable Inserts	67
exchangeable RF inserts	66

F

FID	127
filter cables.....	29
FLOWMAP method.....	207
Fourier Flow Imaging.....	203, 208
Fourier transform	202

G

gating pulse	23
Geometry Editor.....	105
GRAD_SYNC	136
Gradient calibration.....	105

gradsafe menu	194	preemphasis adjustment.....	99
Great 1/40	22	preemphasis compensation.....	123
Great 1/60	22	Preemphasis distortions	96
Great amplifier	24	Product liability.....	13
GREAT amplifiers	89	proton coils	162, 164
Great gradient amplifiers.....	19	PT100	20
group delay	129	PT100 connections.....	31
H		pulse program for analog acquisition.....	134
Hadamard encoded slices	203	Q	
HPPR/2 module	157	quadrature coil.....	75
HR gradient probes.....	88	quadrature probes	75
HWIDS.....	83, 152	R	
I		receiver gain	119
in-vivo experiments	55	RF amplitude adjustment.....	113
IPSO 19" rac	19	RF coil.....	37
L		RF insert	41
Laboratory personnel	15	RF pulse amplitude.....	113
loop parameters	175	RF shape files.....	139
M		Rheo NMR accessory.....	206
Macro Manager.....	112	Risk assessment.....	14
MapShim.....	185	RXAD.....	127
Master Unit BGMUI-E	19, 124	S	
Master Unit. A B0-2 compensation unit	25	Saddle Coil	41
maximum detectable velocity	208	saddle coils	39
Measure spin echo.....	176	Scan Control Tool	153
MSME sequence.....	145	security features	20
multiple coils	151	sensitivity of X nuclei	161
N		Signal to Noise Ratio (SNR) test	119
NMR rheology	199	SNR tests.....	119
O		soft blanking.....	124
offset changes.....	187	SOP	14
P		Spectrometer Control Tool	153
ParaVision 5.....	79	Standard Operating Procedure	14
Peak width	161	T	
Personal protective equipment	16	Terms and Conditions.....	11
Personnel qualifications	15	Terms of Delivery	11
Phase Contrast Angiography	208	thermocouple.....	39
		TopSpin Shape Tool.....	139
		trigger command GRAD_SYNC	136

triple axis imaging gradient system	39
TTL.....	123

U

UniTool	144
Untrained personnel.....	11

V

velocity distributions	206
Velocity Mapping.....	208
Velocity maps	199
VT Kit	62

X

X nuclei imaging tests	119
xy-homogeneity values	162

End of Document

 **Bruker Corporation**

info@bruker.com
www.bruker.com