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RF-chain procedures

The purpose of this document is to provide the FSE with several procedures to test, troubleshoot and adjust the RF-chain of the Gyroscan NT and Intera systems equipped with a BDAS data acquisition system. It also includes general background information (e.g. theory of operation) about several System Tuning Tools.

Although for most FSE's this document gives too much detail, it may prove to be a valuable source of information for regional MR specialists dealing with the RF-chain and all associated problems.

Several chapters in this document are still under construction. This document does not contain information about former Marconi MR scanners. If you have any remark, question or suggestion about this document, please contact me: Rob.Hurkmans@philips.com

It is my intention to frequently update this document for corrections, additional information and new material. Feel free to send me any material of which you think it should be in this document.

NOTE

For Achieva systems, the 50 Ohm dummyload (also called 50 Ohm/50 dB attenuator, 12nc: 452213042452) is not a part of the measuring accessory set. ***Be aware that this tool is not suitable for 3.0T systems!***
This tool is essential in troubleshooting the RF-chain.
It can be ordered as a tool via the PMS tool catalogue.

RF-chain procedures

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1 INTRODUCTION

This document describes several RF-chain measurements, tests and adjustments for the NT and Intera systems (3.0T included). Chapter 2, 3, 4 and 5 describe in more detail which tests should be executed in a specific fault situation.

2 SYSTEM TUNING TOOLS FAULTS

2.1 MAX KW ADJUSTMENT FAILURES RF-AMPLIFIER

2.1.1 RF-DRIVE SCALE(S) TOO HIGH

RF-drive scale(s) being out of specification (too high) can be caused by the following reasons (in order of probability):

1. Gain of the RF-amplifier is too low.
2. Transmit output of the transceiver or transceiver converter (3.0T only) is too low.
3. Actual attenuation of the calibrated cable does not correspond with the value on the sticker.
4. Wrong attenuation values for directional coupler, calibrated cable or 50 Ohm dummy load (0.5T systems only) entered in the software.
5. The VSWR of the system is out of specification.
6. For 0.5T systems: The actual attenuation of the 50 Ohm dummy load does not correspond with the value written on the sticker.
7. Receiver gain of the transceiver or transceiver converter (3.0T) board is too low.
8. Actual attenuation of the RF-amplifier directional coupler does not correspond with the value written on the sticker.

Perform the following tests to find the root cause:

- Perform the automatic gain and linearity check according paragraph 7.13. When this measurement does not function, the gain of the RF-amplifier may be out of specification. Use the manual method according paragraph 7.14 or 7.15. For S21, S22 and MR500x amplifiers, it is sometimes possible to adjust the gain within specifications. Refer to paragraph 9.4 for further instructions.
- Perform the RF-amplifier selftest (Sx-y types only), refer to paragraph 7.18 or 7.19. The IPA tube may also be defective (S23 only), refer to FAQ 492 for more details.
- Execute the Max kW adjustment with the 50 Ohm QBC load (or 50 Ohm dummyload, **not for 3.0T systems**) directly connected to the output of the RF-amplifier. At this point it is assumed that the impedance of the 50 Ohm QBC load or 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).
- For 0.5T systems: Perform the measurement with the calibrated cable connected to FRX5 of the RF-amplifier. Fill in the value of the sticker at FRX5 in the software at position "50E-load ATT [dB]".
- For 0.5T systems: Measure the actual attenuation of the 50 Ohm dummy load and compare it with the value written on the sticker. Refer to paragraph 7.8 for this procedure.
- Maximum output 1H transceiver/transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Perform the external wrap gain test according paragraph 6.5 or 6.6.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Use another calibrated cable for the measurement.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.

- Replace the 50 Ohm QBC load on the magnet by the 50 Ohm dummy load (**not for 3.0T systems**) and repeat the measurement.

2.1.2 RF-DRIVE SCALE(S) TOO LOW

RF-drive scale(s) being out of specification (too low) can be caused by the following reasons (in order of probability):

1. Gain of the RF-amplifier is too high.
2. Transmit output of the transceiver/transceiver converter (3.0T) is too high.
3. Actual attenuation of the calibrated cable does not correspond with the value on the sticker.
4. Wrong attenuation values for directional coupler, calibrated cable or 50 Ohm dummy load (0.5T systems only) entered in the software.
5. The VSWR of the system is out of specification.
6. For 0.5T systems: The actual attenuation of the 50 Ohm dummy load does not correspond with the value written on the sticker.
7. Receiver gain of the transceiver/transceiver converter (3.0T) board is too high.
8. Actual attenuation of the RF-amplifier directional coupler does not correspond with the value written on the sticker.

Perform the following tests to find the root cause:

- Perform the automatic gain and linearity check according paragraph 7.13. When this measurement does not function, the gain of the RF-amplifier may be out of specification. Use the manual method according paragraph 7.14 or 7.15. For S21, S22 and MR500x amplifiers, it is sometimes possible to adjust the gain within specifications. Refer to paragraph 9.4 for further instructions.
- Perform the RF-amplifier selftest (Sx-y types only), refer to paragraph 7.18 or 7.19. The IPA tube may also be defective (S23 only), refer to FAQ 492 for more details.
- Execute the Max kW adjustment with the 50 Ohm (QBC) load connected to the output of the RF-amplifier. At this point it is assumed that the impedance of the 50 Ohm QBC load or 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).
- For 0.5T systems: Perform the measurement with the calibrated cable connected to FRX5 of the RF-amplifier. Fill in the value of the sticker at FRX5 in the software at position "50E-load ATT [dB]".
- For 0.5T systems: Measure the actual attenuation of the 50 Ohm dummy load and compare it with the value written on the sticker. Refer to paragraph 7.8 for this procedure.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Maximum output 1H transceiver/transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Use another calibrated cable for the measurement.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10
- Perform the external wrap gain test according paragraph 6.5 or 6.6.
- Replace the 50 Ohm QBC load on the magnet by the 50 Ohm dummy load (not for 3.0T systems) and repeat the measurement.

2.1.3 FAULT 95

The RF-amplifier switches off on a "Forward Power High" when not expected.

NOTE

This error message is only applicable for S21 up to and including S26 amplifier types.

NOTE

During the max kW adjustment, the transceiver as well as the PMU of the RF-amplifier is used.
*During the part where the PMU is used, it is part of the calibration that **a fault 95 is deliberately generated**.*
With a successful max kW adjustment, this error message (because it is expected) is suppressed in the central logging as well as on the screen.
The fault (which is not a real fault in this phase) is however always logged in the NVRAM of the RF-amplifier.
Therefore during the TSW, TBDAS, RFAMP, LOGGING test, it is normal that fault 95 (and 97) are present.
Refer to paragraph 9.2.1 for more details

Perform the following tests to find the root cause:

- Execute the Testsoftware, TBDAS tests.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Execute under installation procedures: "Run automatic BDAS procedures", inspect if the measured vale "Internal wrap gain" of the level test is around nominal. There are known cases that fault 95 was caused by a transceiver board of which this value was just within spec (on the low side).
- Use another calibrated cable for the measurement.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Check the gain of the RF-amplifier manually according paragraph 7.14 or 7.15.
- Check parallel interface cable. Pin2 on connector X3 at the RF-amp should switch to high TTL-level to reset RF-amp faults.

2.1.4 PEAK POWER NOT REACHED YET

This message is displayed if the measured RF-input signal is unstable or if there is a large non-linearity behavior between the RF-output signal from the transceiver (converter) and the RF-input. The reason for this error may be:

1. Transmit attenuator(s) of linear modulator transceiver instable or defective.
2. RF-amplifier has a very high non-linearity (e.g. reduced gain with higher power levels).
3. RF-amplifier's output signal is unstable.
4. The load on the RF-amplifier (QBC, T/R-headcoil (3.0T) or 50 Ohm dummy load) is unstable.

Perform the following tests to find the root cause:

- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures"
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.

- Execute the test with the 50 Ohm (QBC) load connected to the output of the RF-amplifier.
- Check the gain of the RF-amplifier manually according paragraph 7.14 or 7.15.

2.1.5 RF-DRIVE SCALE EXCEEDS 100%

The required RF-output signal from the BDAS (based on the results of the max kW adjustment) is much higher than expected by the software.

Perform the following tests to find the root cause:

- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".
- Execute the external wrap around test according paragraph 6.5 or 6.6.
- Maximum output 1H transceiver/transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Check the gain of the RF-amplifier manually according paragraph 7.14 or 7.15.
- For 0.5T systems only: Check the attenuation of the 50 ohm dummy load according paragraph 7.8.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Use another calibrated cable.
- Check the attenuation of the coaxial cable FCH-X57 (FJA-B-X4 for 3.0T systems) and FR-X1 using the method according paragraph 7.11 (without 50 Ohm load). Typical attenuation < 0.2 dB.

2.1.6 OVERFLOW OCCURED

This message is displayed if an ADC overflow occurred. The reason for this error may be:

1. The attenuation of the calibrated cable and/or directional coupler or 50E dummy load is such that the signal is too large.
2. The calibrated cable is not connected, while the normal RF-cable is connected to the 1H/MN transceiver RF-input.

Perform the following tests to find the root cause:

- Check if the made connections are correct.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- 0.5T systems only: Check the attenuation of the 50 Ohm dummy load, refer to paragraph 7.8.
- Use another calibrated cable for the measurement (very unlikely that this is the cause).

2.1.7 SIGNAL TOO LOW

This message is displayed if the measured RF-in signal is less than 70% of the expected input signal. The reason for this error may be:

1. No calibrated cable connected while the 1H/MN-transceiver RF-in connector is left open.
2. Wrong attenuation values entered.
3. Gain RF-amplifier much too low.
4. Directional coupler defective/out of spec.
5. No or not enough RF-input signal present on FR-X1 of RF-amplifier
6. No gating signal present on RF-amplifier.

Perform the following tests to find the root cause:

- Check if the made connections are correct.
- Check if the correct attenuation values are entered.
- Check the gain of the RF-amplifier manually according paragraph 7.14 or 7.15.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- External wrap gain test according paragraph 6.5 or 6.6.
- Check the presence of a RF-signal on coax-cable FR-X1/FT-X1.
- Check the presence of a gating signal on coax-cable FR-X4/FT-X4.

2.1.8 SIGNAL TOO HIGH

This message is displayed if the measured RF-in signal is more than 130% of the expected input signal. The reason for this error may be:

1. Wrong connections.
2. Wrong attenuation values entered.
3. Directional coupler out of spec.
4. Gain of the RF-amplifier is much too high (which is very unlikely).

Perform the following tests to find the root cause:

- Check if the made connections are correct.
- Check if the correct attenuation values are entered.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Check the gain of the RF-amplifier manually according paragraph 7.14 or 7.15.

2.1.9 HARDWARE ERROR DETECTED, CHECK RF-PATH

The system detects a hardware error in the RF-path during this adjustment. Examine the central logfile for more details and fault codes. Sometimes the details in the central logfile may contain a fault description that already is described in chapter 2 of this document (e.g. RF drive scale exceeds 100%). In these cases, please refer to the applicable paragraph.
On other cases, take the appropriate actions (e.g. run Testsoftware, consult technical documentation) to find the cause and solve the problem.

2.2 MAX KW ADJUSTMENT WARNINGS RF-AMPLIFIER (3.0T SYSTEMS ONLY)

Because the tolerances on gain and attenuation in the 3.0T RF-chain compared to other field strengths are higher, can result in possible situations where the Max kW scales are within specifications but one or more of the components in the RF-chain are out of specification.
Warning levels are implemented in the Max kW adjustment for 3.0T systems, in order to detect suspected components and draw attention to the service engineer that the found drive scales are out of the typical 3σ range.

For systems where these warning levels are exceeded, it could results in problems with Power optimization, IQ or PMU trip level failures during scanning (refer to paragraph 4.1 and 4.2).

Also problems can be expected with the sensitivity of the pickup coils. If e.g. the receiver gain of the transceiver converter boards is too low, the PU-coil sensitivity seems to be low, while the actual offered B1 to the trip-level-circuit is correct. Due to the measured low sensitivity the engineer will remove 1 or more of the extra attenuators to the pickup coil signal, which might lead to a "Trip level error occurred when not expected". Or when the receiver gain is too high, to a "No switch off occurred during max allowed B1-field"

Even in a worst case situation, due to the fact that the transceiver gain is too low, the found RF drive cal scale will be too high (probably a warning should be generated), which means that more than 5 kW is generated when expected 5 kW.

2.2.1 RF-DRIVE SCALE(S) WARNING LEVEL EXCEEDED (TOO HIGH)

Warning level for RF-drive scale(s) exceeded (too high) can be caused by the following reasons (in order of probability):

1. Gain of the RF-amplifier is too low.
2. Transmit output of the transceiver or transceiver converter (3.0T only) is too low.
3. Actual attenuation of the calibrated cable does not correspond with the value on the sticker.
4. Wrong attenuation values for directional coupler, calibrated cable or 50 Ohm dummy load (0.5T systems only) entered in the software.
5. The VSWR of the system is out of specification.
6. Receiver gain of the transceiver or transceiver converter (3.0T) board is too low.
7. Actual attenuation of the RF-amplifier directional coupler does not correspond with the value written on the sticker.

Perform the following tests to find the root cause:

- Perform the automatic gain and linearity check according paragraph 7.13. When this measurement does not function, the gain of the RF-amplifier may be out of specification. Use the manual method according paragraph 7.14 or 7.15.
- Perform the RF-amplifier selftest, refer to paragraph 7.19.
- Execute the Max kW adjustment with the 50 Ohm QBC load (or 50 Ohm dummyload, **not for 3.0T systems**) directly connected to the output of the RF-amplifier. At this point it is assumed that the impedance of the 50 Ohm QBC load or 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).
- Maximum output 1H transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Perform the external wrap gain test according paragraph 6.5 or 6.6.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Use another calibrated cable for the measurement.
- Replace the 50 Ohm QBC load on the magnet by the 50 Ohm dummy load (**not for 3.0T systems**) and repeat the measurement.

2.2.2 RF-DRIVE SCALE(S) WARNING LEVEL EXCEEDED (TOO LOW)

Warning level for RF-drive scale(s) exceeded (too low) can be caused by the following reasons (in order of probability):

1. Gain of the RF-amplifier is too high.
2. Transmit output of the transceiver converter (3.0T) is too high.
3. Actual attenuation of the calibrated cable does not correspond with the value on the sticker.
4. Wrong attenuation values for directional coupler or calibrated cable entered in the software.
5. The VSWR of the system is out of specification.
6. Receiver gain of the transceiver converter (3.0T) board is too high.
7. Actual attenuation of the RF-amplifier directional coupler does not correspond with the value written on the sticker.

Perform the following tests to find the root cause:

- Perform the automatic gain and linearity check according paragraph 7.13. When this measurement does not function, the gain of the RF-amplifier may be out of specification. Use the manual method according paragraph 7.14 or 7.15.
- Perform the RF-amplifier selftest, refer to paragraph 7.19.
- Execute the Max kW adjustment with the 50 Ohm (QBC) load connected to the output of the RF-amplifier. At this point it is assumed that the impedance of the 50 Ohm QBC load or 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Maximum output 1H transceiver/transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Use another calibrated cable for the measurement.
- Perform the external wrap gain test according paragraph 6.5 or 6.6.
- Replace the 50 Ohm QBC load on the magnet by the 50 Ohm dummy load (**not for 3.0T systems**) and repeat the measurement.

2.3 PMU TRIPLEVEL FAILURES RF-AMPLIFIER

2.3.1 PMU TRIP POINT(S) TOO LOW

PMU trip point(s) being out of specification (too low) can be caused by the following reasons (in order of probability):

1. Actual attenuation of the calibrated cable does not correspond with the value on the sticker.
2. Wrong attenuation values for directional coupler, calibrated cable or 50 Ohm dummy load (0.5T systems only) entered in the software.
3. The VSWR of the system is out of specification.
4. For 0.5T systems: The actual attenuation of the 50 Ohm dummy load does not correspond with the value written on the sticker.
5. Receiver gain of the transceiver/transceiver converter (3.0T) board is too low.
6. Actual attenuation of the RF-amplifier directional coupler does not correspond with the value written on the sticker.
7. PMU of the RF-amplifier is defective or out of specification.

Perform the following test to find the root cause:

- Execute the PMU triplevel test with the 50 Ohm (QBC) load connected to the output of the RF-amplifier. At this point it is assumed that the impedance of the 50 Ohm QBC load or 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).
- For 0.5T systems: Perform the measurement with the calibrated cable connected to FRX5 of the RF-amplifier. Fill in the value of the sticker at FRX5 in the software at position "50E-load ATT [dB]".
- For 0.5T systems: Measure the actual attenuation of the 50 Ohm dummy load and compare it with the value written on the sticker. Refer to paragraph 7.8 for this procedure.
- Maximum output 1H transceiver/transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Perform the external wrap gain test according paragraph 6.5 or 6.6.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Use another calibrated cable for the measurement
- Check the directional coupler value of the RF-amplifier according paragraph 7.10
- Replace the 50 Ohm QBC load by the 50 Ohm dummy load (**not for 3.0T systems**) and repeat the measurement.

2.3.2 PMU TRIP POINT(S) TOO HIGH

PMU trip point(s) being out of specification (too high) can be caused by the following reasons (in order of probability):

1. Actual attenuation of the calibrated cable does not correspond with the value on the sticker.
2. Wrong attenuation values for directional coupler, calibrated cable or 50 Ohm dummy load (0.5T systems only) entered in the software.
3. The VSWR of the system is out of specification.
4. For 0.5T systems: The actual attenuation of the 50 Ohm dummy load does not correspond with the value written on the sticker.
5. Receiver gain of the transceiver/transceiver converter (3.0T) board is too high.
6. Actual attenuation of the RF-amplifier directional coupler does not correspond with the value written on the sticker.

7. PMU of the RF-amplifier is defective or out of specification.

Perform the following test to find the root cause:

- Execute the PMU triplevel test with the 50 Ohm (QBC) load connected to the output of the RF-amplifier. At this point it is assumed that the impedance of the 50 Ohm QBC load or 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).
- For 0.5T systems: Perform the measurement with the calibrated cable connected to FRX5 of the RF-amplifier. Fill in the value of the sticker at FRX5 in the software at position "50E-load ATT [dB]".
- For 0.5T systems: Measure the actual attenuation of the 50 Ohm dummy load and compare it with the value written on the sticker. Refer to paragraph 7.8 for this procedure.
- Maximum output 1H transceiver/transceiver converter (3.0T), refer to paragraph 7.1 or 7.2.
- Perform the external wrap gain test according paragraph 6.5 or 6.6.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Use another calibrated cable for the measurement
- Check the directional coupler value of the RF-amplifier according paragraph 7.10
- Replace the 50 Ohm QBC load by the 50 Ohm dummy load (**not for 3.0T systems**) and repeat the measurement

2.3.3 FAULT 95

The RF-amplifier switches off on a "Forward Power High" when not expected.

NOTE

This error message is only applicable for S21 upto and including S26 amplifier types.

NOTE

During the PMU triplevel test, the transceiver as well as the PMU of the RF-amplifier is used.
During the part where the PMU is used, it is part of the calibration that a fault 95 and 97 deliberately are generated.
With a successful PMU triplevel test, this error message (because it is expected) is suppressed in the central logging as well as on the screen.
The fault (which is not a real fault in this phase) is however always logged in the NVRAM of the RF-amplifier.
Therefore during the TSW, TBDAS, RFAMP, LOGGING test, it is normal that fault 97 (and 95) are present.
Refer to paragraph 9.2.1 for more details

Perform the following tests to find the root cause:

- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures "Run automatic BDAS procedures", inspect if the measured vale of the level is around nominal. There are known cases that fault 95 and/or 97 were caused by a transceiver board of which this value was just within spec (on the low side).
- Use another calibrated cable for the measurement.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Check parallel interface cable. Pin2 on connector X3 at the RF-amp should switch to high TTL-level to reset RF-amp faults.

2.3.4 FAULT 97

The RF-amplifier switches off on a "Average Power Trip" when not expected.

NOTE

This error message is only applicable for S21 up to and including S26 amplifier types.

NOTE

*During the PMU triplevel test, the transceiver as well as the PMU of the RF-amplifier are used.
During the part where the PMU is used, it is part of the calibration that a fault 97 deliberately is generated.
With a successful PMU triplevel test, this error message (because it is expected) is suppressed in the central logging as well as on the screen.
The fault (which is not a real fault in this phase) is however always logged in the NVRAM of the RF-amplifier.
Therefore during the TSW, TBDAS, RFAMP, LOGGING test, it is normal that fault 97 (and 95) are present.
Refer to paragraph 9.2.1 for more details*

Perform the following tests to find the root cause:

- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures "Run automatic BDAS procedures", inspect if the measured vale of the level is around nominal. There are known cases that fault 95 and/or 97 were caused by a transceiver board of which this value was just within spec (on the low side).
- Use another calibrated cable for the measurement.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Check parallel interface cable. Pin2 on connector X3 at the RF-amp should switch to high TTL-level to reset RF-amp faults.

2.3.5 RF-DRIVE SCALE EXCEEDS 100%

The required RF-output signal from the BDAS (based on the results of the max kW adjustment) is much higher than expected by the software.

Perform the following tests to find the root cause:

- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures "Run automatic BDAS procedures".
- Execute the external wrap around test according paragraph 6.5 or 6.6.
- For 0.5T systems only: Check the attenuation of the 50 ohm dummy load according paragraph 7.8
- Directional coupler defective/out of spec. Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Use another calibrated cable.
- Check the attenuation of the coaxial cable FCH-X57 (FJA-B-X4 for 3.0T systems) - FR-X1 using the method according paragraph 7.11 (without 50 Ohm load). Typical attenuation < 0.2 dB.

2.3.6 OVERFLOW OCCURED

This message is displayed if an ADC overflow occurred. The reason for this error may be:

1. The attenuation of the calibrated cable and/or directional coupler or 50 Ohm dummy load is such that the signal is too large.
2. The calibrated cable is not connected while the normal RF-cable is connected to the 1H/MN transceiver RF-input.

Perform the following tests to find the root cause:

- Check if the made connections are correct.
- Use another calibrated cable for the measurement.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- For 0.5T systems only: Check the attenuation of the 50 Ohm dummy load, refer to paragraph 7.8.

2.3.7 SIGNAL TOO LOW

This message is displayed if the measured RF-in signal is less than 70% of the expected input signal. The reason for this error may be:

1. No calibrated cable connected while the 1H/MN-transceiver RF-in connector is left open.
2. Wrong attenuation values entered.
3. Gain RF-amplifier much too low.
4. Directional coupler defective/out of spec.
5. No RF-input signal present on FR-X1 of RF-amplifier.
6. No gating signal present on RF-amplifier.

Perform the following tests to find the root cause:

- Check if the made connections are correct.
- Check if the correct attenuation values are entered.
- Check the gain of the RF-amplifier manually according paragraph 7.14 or 7.15.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Check the presence of an RF-signal on cable FR-X1.
- Check the presence of a gating signal on cable FR-X4.

2.3.8 SIGNAL TOO HIGH

This message is displayed if the measured RF-in signal is more than 130% of the expected input signal. The reason for this error may be:

1. Wrong connections.
2. Wrong attenuation values entered.
3. Directional coupler out of spec.
4. Gain of the RF-amplifier is much too high (which is very unlikely)

Perform the following tests to find the root cause:

- Check if the made connections are correct.
- Check if the correct attenuation values are entered.

- Check the directional coupler value of the RF-amplifier according paragraph 7.10.
- Check the gain manually according paragraph 7.14 or 7.15.

2.3.9 HARDWARE ERROR DETECTED, CHECK RF-PATH

The system detects a hardware error in the RF-path during this adjustment. Examine the central logfile for more details and fault codes. Sometimes the details in the central logfile may contain a fault description that already is described in chapter 2 of this document (e.g. RF drive scale exceeds 100%). In these cases, please refer to the applicable paragraph.
On other cases, take the appropriate actions (e.g. run Testsoftware, consult technical documentation) to find the cause and solve the problem.

2.4 PU TRIPLEVEL FAILURES

2.4.1 MAX. ALLOWED B1-FIELD CANNOT BE GENERATED

This may be caused by one ore more of the following reasons (in order of probability):

1. Insertion loss transmit path too high.
2. VSWR transmit path too high.
3. QBC incorrectly adjusted.
4. Max kW adjustment not successfully executed.

Perform the following test to find the root cause:

- Insertion loss measurement, refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Max kW adjustment, refer to paragraph 9.2.2
- Check the adjustments of the QBC, refer to the SMI or Service Procedure Documents for the procedures.

2.4.2 TRIP LEVEL ERROR OCCURRED WHEN NOT EXPECTED

The PU-coil signal amplitude at the input of the coilint is too high and is not within the allowed coilint range for this signal.

This may be caused by one ore more of the following reasons (in order of probability):

1. PU-coil(s) positioned too close to the QBC.
2. Coilint gain out of spec for the PU-coil path.
3. Coilint defective.

Perform the following tests to find the root cause:

- Mechanically check/reposition the PU-coils according Table 1. For 3.0T TR-headcoil only systems, check the attenuators in the PU-coil path.
- Coilint gain test, refer to paragraph 6.1
- Check, using a DVM, the impedance of both PU-coils (measure it on the cable). The impedance should be 50 ± 1 Ohm.
- Check the coaxial cable, used for the PU-coil signal, between the hybrid box and the coilint.

- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures"

Table 1 PU-coil distances to QBC

System type	***Distance to QBC (mm)***
0.5T	14 +/- 2mm
1.0T PT1000, PT2000 and Omni	14 +/- 2mm
1.0T PT3000 and Power	14 +/- 2mm
1.5T PT1000, PT2000 and Omni	6 +/- 1mm
1.5T PT3000, PT6000, Power, Master and Explorer	12 +/- 2mm
3.0T Master	n.a. (integrated in QBC)

2.4.3 NO SWITCH OFF OCCURRED DURING MAX. ALLOWED B1-FIELD

The PU-coil signal amplitude at the input of the coilint is too low and is not within the allowed coilint range for this signal.

Perform the following tests to find the root cause:

- Mechanically check/reposition the PU-coils according Table 1. For 3.0T TR-headcoil only systems, check the attenuators in the PU-coil path.
- Coilint gain test, refer to paragraph 6.1.
- Check, using a DVM, the impedance of both PU-coils (measure it on the cable). The impedance should be 50 ± 1 Ohm.
- Check the coaxial cable, used for the PU-coil signal, between the hybrid box and the coilint.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.4.4 FAULT 95

The RF-amplifier switches off on a "Forward Power High" when not expected. In this fault situation, more RF-power has to be delivered for the required maximum B1 field than the software allows.

NOTE

This error message is only applicable for S21 up to and including S26 amplifier types.

This may be caused by one ore more of the following reasons (in order of probability):

1. Insertion loss transmit path too high.
2. VSWR transmit path too high (too much reflected power in this path).
3. QBC incorrectly adjusted.
4. PMU of RF-amplifier defective/out of specification.
5. Max kW adjustment not successfully executed.

Perform the following test to find the root cause:

- Insertion loss measurement, refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- PMU test, refer to paragraph 7.12.
- Max kW adjustment, refer to paragraph 9.2.2

- Check the adjustments of the QBC, refer to the SMI or Service Procedure Documents for the procedures.
- Bypass the TR-switch (using a HN-HN I-piece) and repeat the measurement.
- Replace the 50 Ohm QBC load by the 50 Ohm dummyload (**not for 3.0T systems**) and repeat the measurement. At this point it is assumed that the impedance of the 50 Ohm dummyload and short coax cable is ok (to be verified with a DVM).

2.5 POWER REFERENCE MEASUREMENTS FAILURES QBC

2.5.1 REFERENCE RF DRIVE SCALE TOO HIGH

This may be caused by one ore more of the following reasons (in order of probability):

1. Insertion loss transmit path too high.
2. VSWR transmit path too high.
3. QBC incorrectly adjusted.
4. Max kW adjustment not successfully executed.

Perform the following tests to find the root cause:

- Insertion loss measurement, refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Max kW adjustment, refer to paragraph 9.2.2
- Check the adjustments of the QBC, refer to the SMI or Service Procedure Documents for the procedures.

2.5.2 PICKUP CAL B1 VALUE TOO HIGH / PICKUP COIL SENSITIVITY TOO LOW

NOTE

With software release R10.1 and higher, the name “Pickup cal B1” changed into “Pickup coil sensitivity”.

The measured amplitude in the PU-coil path is lower than expected.

Perform the following tests to find the root cause:

- Mechanically check/reposition the PU-coils according Table 1.
- Coilint gain test, refer to paragraph 6.1
- Check, using a DVM, the impedance of both PU-coils (measure it on the cable). The impedance should be 50 ± 1 Ohm.
- Check the coaxial cable, used for the PU-coil signal, between the hybrid box and the coilint.
- Execute the QBC receive path test, refer to paragraph 6.9.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.5.3 PICKUP CAL B1 VALUE TOO LOW / PICKUP COIL SENSITIVITY TOO HIGH

NOTE

With software release R10.1 and higher, the name “Pickup cal B1” changed into “Pickup coil sensitivity”.

The measured amplitude in the PU-coil path is higher than expected.

Perform the following tests to find the root cause:

- Mechanically check/reposition the PU-coils according Table 1.
- Coilint gain test, refer to paragraph 6.1.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.5.4 MAX RF-FIELD EXCEEDED, DETECTED BY PU-COIL

The PU-coil signal amplitude at the input of the coilint is too high and is not within the allowed coilint range for this signal.

This may be caused by one ore more of the following reasons (in order of probability):

1. PU-coil(s) positioned too close to the QBC.
2. Coilint gain out of spec for the PU-coil path.
3. Coilint defective.
4. 20 dB external attenuator not installed at coilint input MME-X8 (3.0T systems only)

Perform the following tests to find the root cause:

- Mechanically check/reposition the PU-coils according Table 1.
- Coilint gain test, refer to paragraph 6.1
- Check, using a DVM, the impedance of both PU-coils (measure it on the cable). The impedance should be 50 ± 1 Ohm.
- For 3.0T systems: check the presence of the external 20dB attenuator at coilint input MME-X8.
- Check the coaxial cable, used for the PU-coil signal, between the hybrid box and the coilint.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.5.5 NO MR RESPONSE SIGNAL FOUND AT ALL

This may be caused by one ore more of the following reasons (in order of probability):

1. Required transmit B1 field could not be generated in the transmit coil.
2. Used transmit coil does not receive the MR response signal.
3. No 3 ltr bottle present in the transmit coil.
4. Magnet not on field.
5. Magnet field polarity incorrect.
6. Magnet shimming far out of specification.

Perform the following tests to find the root cause:

- Check the adjustments of the QBC; refer to the SMI or Service Procedure Documents for the procedures.
- Check the QBC receive path, refer to paragraph 6.9.
- Insertion loss measurement TX-path, refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Check magnet field presence and polarity.
- Required phantom present in the bore?
- Fid shimming successfully executed?

2.6 POWER REFERENCE MEASUREMENTS FAILURES H-HEAD COIL (1.5T SYSTEMS ONLY)

2.6.1 REFERENCE RF DRIVE SCALE TOO HIGH

This may be caused by one ore more of the following reasons (in order of probability):

1. Insertion loss transmit path too high.
2. VSWR transmit path too high.
3. H-Headcoil incorrectly adjusted.
4. Max kW adjustment not successfully executed.

Perform the following tests to find the root cause:

- Insertion loss measurement TX-path from RF-amp to input TR-switch. Refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Max kW adjustment H-headcoil, refer to paragraph 9.2.2

2.6.2 NO MR RESPONSE SIGNAL FOUND AT ALL

This may be caused by one ore more of the following reasons (in order of probability):

1. Required transmit B1 field could not be generated in the transmit coil.
2. Used transmit coil does not receive the MR response signal.
3. No 3 ltr bottle present in the transmit coil.
4. Magnet not on field.
5. Magnet field polarity incorrect.
6. Magnet shimming far out of specification.

Perform the following tests to find the root cause:

- Insertion loss measurement TX-path from RF-amp to input TR-switch. Refer to paragraph 7.11.
- Bridge (using a HN-HN I-piece) TR-switch connections MSEX2 – MSEX3 (NT systems) or MMFX7 – MMFX6 (Intera systems) and repeat the measurement.
- Check the presence of the short coaxial cable MSEX4 – MSFX34 (NT systems) or MMFX5 – MME-X6 (Intera systems).
- Check all coaxial cables (using a DVM) from PFEI to H-headcoil connection in the PICU.
- VSWR measurement, refer to paragraph 7.7.
- Check magnet field presence and polarity.

- Required phantom present in the bore?
- Fid shimming successfully executed?

2.7 POWER REFERENCE MEASUREMENTS FAILURES TR-HEAD COIL (3.0T SYSTEMS ONLY)

2.7.1 REFERENCE RF DRIVE SCALE TOO HIGH

This may be caused by one ore more of the following reasons (in order of probability):

1. Insertion loss transmit path too high.
2. VSWR transmit path too high.
3. TR-Headcoil incorrectly adjusted.
4. Max kW adjustment not successfully executed.

Perform the following tests to find the root cause:

- Insertion loss measurement TX-path from RF-amp to input TR-switch. Refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.Max kW adjustment TR-headcoil, refer to paragraph 9.2.2

2.7.2 PICKUP CAL B1 VALUE TOO HIGH / PICKUP COIL SENSITIVITY TOO LOW

NOTE

With software release R10.1 and higher, the name “Pickup cal B1” changed into “Pickup coil sensitivity”.

The measured amplitude in the PU-coil path is lower than expected.

Perform the following tests to find the root cause:

- Check the external attenuators in the PU-coil path for the TR-headcoil.
- Coilint gain test, refer to paragraph 6.1
- Check, using a DVM, the impedance of both PU-coils in the coil. The impedance should be 50 ± 1 Ohm.
- Check the coaxial cable, used for the PU-coil signal, between the TR-headcoil and the Synco plug.
- Check the coaxial cable between the PICU and the coilint.
- Execute the TR-headcoil receive path test, refer to paragraph 6.11.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.7.3 PICKUP CAL B1 VALUE TOO LOW / PICKUP COIL SENSITIVITY TOO HIGH

NOTE

With software release R10.1 and higher, the name “Pickup cal B1” changed into “Pickup coil sensitivity”.

The measured amplitude in the PU-coil path is higher than expected.

Perform the following tests to find the root cause:

- Check the external attenuators in the PU-coil path for the TR-headcoil.

- Coilint gain test, refer to paragraph 6.1.
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.7.4 MAX RF-FIELD EXCEEDED, DETECTED BY PU-COIL

The PU-coil signal amplitude at the input of the coilint is too high and is not within the allowed coilint range for this signal.

This may be caused by one ore more of the following reasons (in order of probability):

1. No external attenuators installed on the PU-coils path for the TR-headcoil.
2. Coilint gain out of spec for the PU-coil path.
3. Coilint defective.

Perform the following tests to find the root cause:

- Check the external attenuators in the PU-coil path for the TR-headcoil.
- Coilint gain test, refer to paragraph 6.1
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures".

2.7.5 NO MR RESPONSE SIGNAL FOUND AT ALL

This may be caused by one ore more of the following reasons (in order of probability):

1. Required transmit B1 field could not be generated in the transmit coil.
2. Used transmit coil does not receive the MR response signal.
3. No 3 ltr bottle present in the transmit coil.
4. Magnet not on field.
5. Magnet field polarity incorrect.
6. Magnet shimming far out of specification.

Perform the following tests to find the root cause:

- Insertion loss measurement TX-path from RF-amp to input TR-switch. Refer to paragraph 7.11.
- Bridge (using a HN-HN I-piece) TR-switch connections MSEX2 – MSEX3 (NT systems) or MMFX7 – MMFX5 (Intera systems) and repeat the measurement.
- Check if the thin coaxial cable from PICU connector SC2 (MC1-X22) used for the receive signal for this coil, is connected to MME-X6.
- Check all coaxial cables (using a DVM) from PFEI to TR-headcoil connection in the PICU.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Check magnet field presence and polarity.
- Required phantom present in the bore?
- Fid shimming successfully executed?

3 PREPARATION PHASE (ERROR) MESSAGES

3.1 PU-COIL OPTIMISATION

3.1.1 THEORY OF OPERATION

Purpose:

The PU preparation phase determines:

- an estimate of the optimal drive scale (to be improved by the Power Optimisation phase).
- an estimate of the load factor (to be improved by the Power Optimisation phase).
- an upper limit to the drive scale (to prevent a high-B1 trip).

It uses the pickup coil device (PU-coil circuit) to determine these values.

The pickup coil device:

The pickup coil device produces a signal which is a direct representation of the B1 field strength in the transmit (body) coil. Once it is calibrated, this can be taken as a measure of the average B1 field in the system. The device can therefore be used to obtain a drive scale.
The pickup coil device measures:

1. absolute B1: this is used to determine drive scale and load factor as described above. It requires accurate calibration and reproducible RF conditions. This used to be a problem, so that the best that could be obtained was a reasonable *initial estimate.* This is now much improved. The main reason to improve on the PU result (by the subsequent PO phase) is the difference between the average B1 (detected by the pickup coil) and the local B1 in the patient, possibly influenced by the presence of receive coils (which is determined by the Power Optimization phase).

2. relative B1: this is far less dependent on reproducible RF conditions. The measurement of relative B1 values can be used to estimate amplitude-dependent RF pulse amplification. Such a function indeed exists, but is (rather confusingly) part of the Power Optimization phase, not of the PU phase.

Determination of drive scale:

The PU sequence transmits a block pulse with nominal amplitude B1_ref. It measures the B1 actually produced (B1_meas). The optimum drive scale is derived from B1_meas and B1_ref.
The PU sequence is performed twice. During its first execution, the drive scale is set to “ref drive scale”, and the optimum drive scale is given by

$$\text{opt drive scale}_1 = \frac{\text{B1\_ref}}{\text{B1\_meas}_1} \cdot \text{ref drive scale}$$

(Both B1_ref and “ref drive scale” are taken from the coil archive. B1_ref is the transmit coil attribute “Ref. B1”. “ref drive scale” is the transmit coil attribute “Ref. scale”. The B1 during the center of the pulse is determined based upon the calibrated sensitivity of the pickup coil and the calibrated receive gain value.)
During the second execution, the drive scale is set to the optimum drive scale as derived from the first execution. The final optimized drive scale is

$$\text{opt drive scale} = \frac{\text{B1\_ref}}{\text{B1\_meas}_2} \cdot \text{opt drive scale}_1$$

Although in a loaded system B1_meas1 is much smaller than B1_meas2, an entirely linear RF system yields the same 'opt. drive scale' for the two executions. In a nonlinear system this is not the case. The second execution, because of the larger B1_meas, gives a much better estimate of the drive scale at which a B1 trip occurs.

Determination of the Load Factor:

The load factor is given by

Reduction of drive scale:

The strongest RF pulse that occurs in either a preparation phase or in the scan itself should not exceed the maximum power limit. If its amplitude is B1_max, and its power exceeds the limit, the PU code lowers the value of "opt drive scale" to

"max scale" is the MP parameter 'MP_hw_max_scale.

Also the drive scale should not exceed the value:

and also not generate a too high B1 for the high-B1 circuit to stop the scan.

CPR_PU_b1_trip_margin = 0.92: a safety margin

B1_trip: the B1 value at which the protection circuit generates an interlock.

Given by the hardware parameter 'HW_trip_b1_level, and equal to 26μT or 33μT.
Without this protection, the PO phase might generate an interlock if the local transmit coil sensitivity is much lower than its average sensitivity (in this case a correct B1 value in the local volume coexists with a much-too-high value detected by the pickup coil).

3.1.2 ADC OVERFLOW IN PU PHASE, DECREASE HW_PICKUP_CAL.

Even in lowest gain the signal from the pickup coil is too strong. Perform the tests described in paragraph 2.5.3.

3.1.3 NO SIGNAL FROM PU-COIL, OR PU-COIL IMPROPERLY CALIBRATED.

Either the pickup coil hardware is defect (no signal) or its sensitivity was never calibrated (Power reference measurement). Perform the tests described in paragraph 2.5.2.

3.1.4 NEW SCALE EXCEEDS THE MAXIMUM FOR THIS AMPLIFIER-MODE

This is a hardware problem or a calibration problem, unless the patient poses a most exceptional load (High SAR scans). Repeat the RF-amplifier and Power reference and PU coil procedures.

3.1.5 REQUIRED RF DRIVE SCALE X.YYY NOT ALLOWED (TOO MUCH POWER)

RF pulses with amplitude B1_max would exceed the maximum power limit at drive scale x.yyy. The drive scale is automatically reduced to a lower value that does not exceed this limit.

3.1.6 REQUIRED RF DRIVE SCALE A.BBB NOT ALLOWED (B1 TOO HIGH)

RF pulses with amplitude B1_max would exceed the maximum B1 limit at drive scale a.bbb. The drive scale is automatically reduced to a lower value.

3.2 RF-POWER OPTIMISATION

3.2.1 CANNOT SET THE GAIN IN PO PHASE, INCREASE HW_PICKUP_CAL

Pickup coil device or receive attenuators not calibrated. Perform/repeat the applicable STT installation procedures (automatic BDAS procedures and Power reference measurement).

3.2.2 CANNOT DETERMINE OPTIMUM RF POWER

Not enough signal for SE (**S**pin **E**cho) or STE (**ST**imulated **E**cho) in time or frequency domain. If a higher gain is possible that may remove this condition, it will be tried. If not, Power Optimization has a problem. Perform the tests described in paragraph 2.5.1 and 2.5.5.

3.2.3 PICKUP COIL SIGNAL TOO LOW

Not enough signal from pickup coil device to use it. Perform the tests described in paragraph 2.5.2.

3.2.4 FATAL (MR SIGNAL) ADC OVERFLOW IN PO PHASE

Even in lowest gain, lowest excitation angle there is overflow.

3.2.5 FATAL (PU SIGNAL) ADC OVERFLOW IN PO PHASE

Even in lowest gain, there is pickup coil overflow. Perform the tests described in paragraph 2.5.3.

3.2.6 RF DRIVE SCALE LIMITED BY MAX POWER

The optimal drive scale is not allowed because the resulting average power would be too high. Can occur with patients that pose a heavy RF load. Perform the measurements described in paragraph 2.5.1

3.2.7 RF DRIVE SCALE LIMITED BY MAX B1

The optimal drive scale is not allowed because the resulting B1 field (as detected by the pickup coil) would be too high. Can occur when the scan is at a large offcentre, presence of receive coils disturbs the RF field or the VSWR or insertion loss in the TX-chain is too high. Perform the tests described in paragraph 2.5.1

3.2.8 PMU_POWER / AVG_RF_POWER LESS THAN 2. AVG_RF_POWER: XXX

High average power in spectro scan. Adjust protocol.

3.2.9 TOO MUCH AVERAGE POWER. AVG_RF_POWER: XXX

Average power too high in spectro scan. Adjust protocol.

3.2.10 THE H-HEAD-COIL NEEDS XXXX WATTS WHERE 4000 WATTS IS ALLOWED

Too much power on aux port (imaging or spectro). Check the H-Head coil connection cables to PICU and repeat the STT installation procedures (RF-amplifier and power reference H-Head).

3.2.11 THE H-HEAD-COIL NEEDS XXXX WATTS AVERAGE WHERE 5000 WATTS IS ALLOWED

Too much power on aux port in spectro scan. Check the H-Head coil connection cables to PICU and repeat the STT installation procedures (RF-amplifier and power reference H-Head).

3.2.12 TOO MUCH AVERAGE POWER. AVG_RF_POWER: XXX, MARGIN: 0.XX

Too much power required in imaging scan. Reduce SAR level.

4 RF-AMPLIFIER ERROR MESSAGES DURING SCANNING

4.1 FAULT 95

More forward RF-power is used than the system allows. The peak power triplevel of the PMU of the amplifier is set to this level by the software. Therefore the amplifier generates this fault.

NOTE

This error message is only applicable for S21 up to and including S26 amplifier types.

This can be caused by the following reasons (in order of probability):

- Insertion loss in the transmit chain too high.
- VSWR transmit path too high (too much reflected power in this path).
- Incorrectly adjusted max kW adjustment.
- PMU in the RF-amplifier does not work correctly.
- Very heavy patients.

Perform the following test to find the root cause:

- Insertion loss measurement, refer to paragraph 7.11.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- PMU test, refer to paragraph 7.12.
- Max kW adjustment, refer to paragraph 9.2.2.
- Check the adjustments of the QBC, refer to the SMI or Service Procedure Documents for the procedures.
- Bypass the TR-switch (using a HN-HN I-piece) and repeat the failing scan.
- Replace the 50 Ohm QBC load by the 50 Ohm dummy load **(not for 3.0T systems)** and repeat the failing scan.

4.2 FAULT 97

More average forward RF-power is used than the system allows. The average power triplevel of the PMU of the amplifier is set to this level by the software. Therefore the amplifier generates this fault.

NOTE

This error message is only applicable for S21 up to and including S26 amplifier types.

This can be caused by the following reasons (in order of probability):

- Too much average RF-power generated in protocol.
- PMU in the RF-amplifier does not work correctly.
- VSWR transmit path too high (too much reflected power in this path).
- Insertion loss in the transmit chain too high.

Perform the following tests to find the root cause:

- PMU test, refer to paragraph 7.12.
- Max kW adjustment, refer to paragraph 9.2.2.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Insertion loss measurement, refer to paragraph 7.11.
- Check the adjustments of the QBC; refer to the SMI or Service Procedure Documents for the procedures.
- Bypass the TR-switch (using a HN-HN I-piece) and repeat the measurement.
- Replace the 50 Ohm QBC load by the 50 Ohm dummy load **(not for 3.0T systems)** and repeat the measurement.

4.3 BIT 7, MAXIMUM PATIENT DOSE EXCEEDED

NOTE

This error message is only applicable for MR5001 and MR5002 amplifier types.

A "Maximum Patient Dose Exceeded" fault should only occur if the average forward RF power level (DSP-integrated over the most recent 30 second window of history) rises above the protection threshold set by the system. In this event, the µP records a Maximum Patient Dose Exceeded fault.

Possible causes:

- Excessive RF output power level.
- Excessive RF duty cycle (not allowed protocol) .
- Directional coupler calibration incorrect.
- Directional coupler circuitry malfunctioning/inoperative.
- Software bug (MR5002 only).

First perform the following tests to find the root cause:

- PMU test, refer to paragraph 7.12.
- Max kW adjustment, refer to paragraph 9.2.2
- Automatic gain and linearity check according paragraph 7.13. When this measurement does not function, the gain of the RF-amplifier may be out of specification. Use the manual method according paragraph 7.14 or 7.15 to determine the gain and linearity.
- Check the directional coupler value of the RF-amplifier according paragraph 7.10

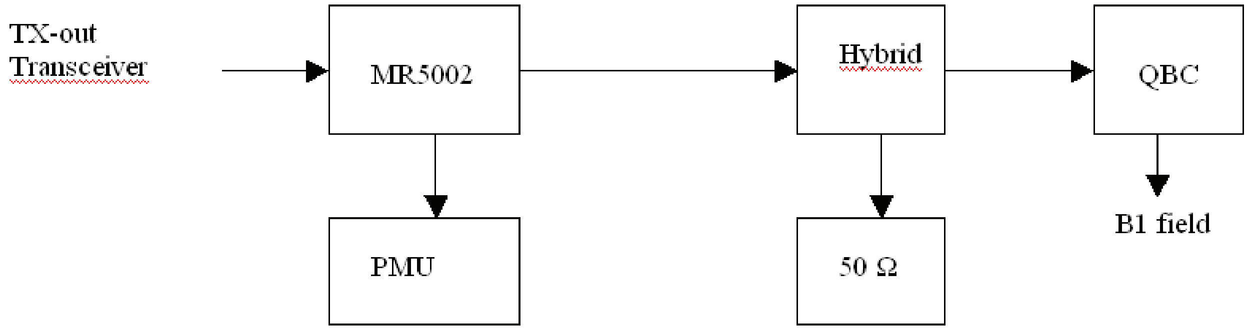
For MR5002 only:

It is possible that all tests described above are within spec. Even sometimes a complete RF-amplifier replacement doesn't solve the problem. Recently it is discovered that with some specific protocols, this error is caused by a software bug (problem is registered under PMSmr40116 and PMSmr40044)

Final status with respect to this problem given by development:

In 0.5T systems where the MR5002 RF-amp is used, in some experiments a “Patient Overdose” error may occur while in fact there is no real danger for the patient. However this failure may result in a complex faultfinding procedure.

Figure 1



In Figure 1 one can see that the RF demand signal, generated by the transceiver board is converted in RF power which is routed via coax cables towards the Hybrid box (T/R switch not shown here). With a typical patient present, the hybrid box matches the combination of the QBC and the 50 Ω QBC load so that that combination equals a resistive load of 50 Ω as close as possible to keep reflected power to a minimum.
The wanted effect is a generated B1 field, which is measured by pick-up coils inside the QBC and transferred through the Coil interface to the Transceiver.
The complete chain contains some non-linear ties in converting the demand signal into B1 field. The biggest source for non-linearity is however the RF-amp.
In our modeling in the acquisition software the complete chain from demand to B1 is measured at a full dynamic range and the deviations are saved in a table. The values in this table are used during scanning to linearize the deviations at a lower level of the system software, enabling the higher levels of software to act as if the RF chain was completely linear. So far so good, but unfortunately there is no linear relation between the power needed at a certain B1. The relation between demand signal and RF Power is only measured at 1 point of the dynamic range and that is done by the so-called "5kW-callibration". During that calibration the trip values for the Power Monitoring Unit (PMU) inside the RF-amp is determined. In the calculation a total deviation between actual RF Power and the calculated Power of 3.5 dB is foreseen. This must be enough to avoid such "Bit 7" errors.
However in extreme situation, depending on the site conditions and of special load conditions in some MR examinations it turned out to be not enough.
The only right way of modeling would be a calibration of the relation between demand signal and RF power, i.s.o. only at the 5kW point. This problem however showed up some 2 years ago and the real solution as I stated is cumbersome.
While this problem is due to a lot of factors, which affects the linearity of the chain in a few known cases, it is possible to solve the problem by changing the Transceiver board. (No guarantee).
We advise therefore to perform that change first to avoid unnecessary change of the RF-amp.

4.4 OTHER RF-AMPLIFIER RELATED ERROR MESSAGES

Refer to the technical manual of the applicable RF-amplifier for further instructions.

5 INTERLOCKS

5.1 MAX RF-FIELD EXCEEDED, DETECTED BY PU-COIL

More RF-field is detected by the PU-coils than the hardware allows.

This can be caused by the following reasons (in order of probability):

- Triplevel adjustment not correct or changed.
- PU-coil positions moved.
- Coilint defective.
- 50 ohm QBC load defective.
- QBC and/or hybrid box misadjusted or defective (e.g. bad contact).
- Bad connection in the transmit path.

Perform the following tests to find the root cause:

- Mechanically check/reposition the PU-coils according Table 1. For 3.0T TR-Headcoil only systems, check the attenuators in the T/R-headcoil PU-coil path.
- For 3.0T systems only, check the 20dB attenuator in the QBC PU-coil path.
- Perform the trip level adjustment again according paragraph 9.6.1
- Coilint gain test, refer to paragraph 6.1.
- Determination VSWR, refer to paragraph 7.7. Also refer to the applicable sub-paragraph (QBC, TR-Headcoil (3.0T) or H-Headcoil (1.5T) measurements) for further instructions.
- Check the adjustments of the QBC; refer to the SMI or Service Procedure Documents for the procedures.
- Check all (screw) connections in the transmit chain (incl. QBC).
- Execute the Testsoftware, TBDAS tests.
- Execute under installation procedures: "Run automatic BDAS procedures"
- Perform test described in FAQ472. When necessary, replace it with a level 2 (or higher)

6 TEST PROCEDURES RECEIVE CHAIN

6.1 COILINT GAIN

For NT systems:

The gain between the Coilint+ inputs and its output is measured. At first the RF input signal is measured. Afterwards the RF input signal will be led to the RF inputs of the Coilint+.
The measured gain and the gain differences between the various input channels are reported within the MRL and are checked against specification.
The input channels checked are QBC-in, SC1-in, SC2-in, TRC-in, Aux-in and PU-in.

For Intera systems:

The Coilint gain test tests the gain and the differences between the various signals received for each input channel from a reference (built-in) noise source. In case the measured noise level for a specific input channel is too low, this will be reported to the operator.
In case the measured noise level for all input channels is too low, the scan will be aborted.
The measured gain and the gain differences between the various input channels are reported within the MRL and are checked against specification.
The input channels checked are QBC-in, SC1-in, SC2-in, TRC-in, Aux-in and PU-in.

6.1.1 MEASUREMENT

Tools needed (only for NT systems):

Several adapters and cables from the measuring acc. set

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: Coilint gaintest
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

6.1.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When one ore more values do not meet their specification, the coilint must be replaced.

6.2 MN-COILINT GAIN (MULTI NUCLEI (31P) SYSTEMS ONLY)

The principle of the gain and noise-figure measurement is that a (built-in) noise source with a specified ENR (Excess Noise Ratio) is used as input for the MN-Coilint receive chain. The sequence of the measurement is:

1. The ENR of the built-in noise source is measured.
2. The output of the MN-Coilint receive chain is measured while the input of the MN-Coilint is terminated with 50 Ohm.
3. The output of the MN-Coilint is measured while the built-in noise source is used as input.
4. The temperature of the MN-Coilint is measured to determine the thermal noise floor. From these four measurements the gain and the noise-figure of the MN-Coilint are calculated.

6.2.1 MEASUREMENT

No additional tools are needed to perform this measurement.

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: MN-Coilint gaintest
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

6.2.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When one ore more values do not meet their specification, the MN-coilint must be replaced.

6.3 SYNCOINT GAIN (INTERA SYSTEMS ONLY)

The Syncoint gain test measures the differences between the various signals received for all input channels of a specific synco connector from one (built-in) noise source. In case the measured noise level for a specific input channel is too low, this will be reported to the operator.
In case the measured noise level for each input channels is too low, the scan will be aborted.
The measured gain differences between the input channels on the synco 1 resp. the synco 2 connector are written into an MRL and they are checked against specification.

6.3.1 MEASUREMENT

No additional tools are needed to perform this measurement.

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: Syncoint gaintest
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

6.3.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When one ore more values do not meet their specification, the synco-int must be replaced.

6.4 PICU-NTDAC GAIN

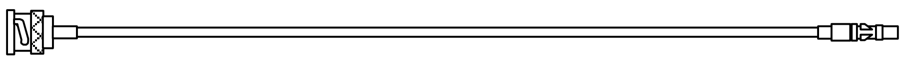
The gain between the PICU RF inputs and the NTDAC RF-input is measured. At first the used RF input signal is measured. Afterwards this RF input signal will be connected to the RF inputs at the PICU.

6.4.1 MEASUREMENT

Tools needed:

- Coax BNC-male to Mini-BNC female (Figure 2)
- I-piece BNC
- 15 mtr Calibrated cable (2x)

Figure 2



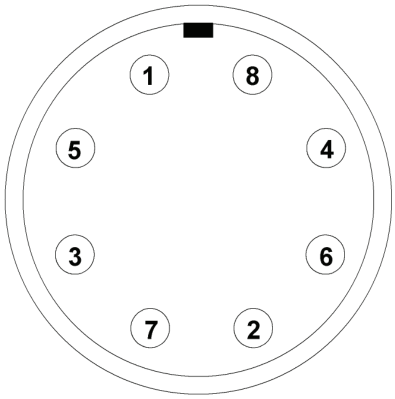
4522 131 3270.
COAX PICU

HS41.DRW

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools

5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: PICU-NTDAC gain test
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen. Also refer to Figure 3 for synergy channels in the PICU.
10. All measured values (in the displayed MRL) should meet the specifications.

Figure 3 Synco channels PICU connector



6.4.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

At this point it is assumed that the separate coilint or synco-int tests succeeded. Find out which cable (channel) is out of specification and replace the appropriate FRU.

6.5 EXT. WRAP AROUND GAIN 1H TRANSCEIVER TX -> RX PATH

With this procedure it is possible to check if the RF-output and the receive input of the 1H transceiver board operate correctly within the typical value range. RF-output and RF-input are checked.

6.5.1 MEASUREMENT

Precondition: Automatic STT BDAS measurement "level test" passed.

Tools needed:

- Short (< 1mtr) 50 Ohm coaxial cable
- N-male to BNC-female adapter

1. Disconnect cable FCH-X51 and cable FCH-X57 on the transceiver.
2. Connect RF-output FCH-X57 with a short coax (<1 mtr) to RF-input FCH-X51.
3. Select: Scan utilities
4. Select: Enter service mode
5. Select: System tuning
6. Select: System tuning tools
7. Select: Expert tools
8. Select: Analysis tools

9. Select: RF chain analysis
10. Change the following parameters:

	0.5T/1.0T/1.5T	3.0T
Pulse shape	SG_100_100_0	SG_100_100_0
Transm. Atten. [dB]	25	40
LM scale [%]	100	100
Rec. Att setting	3	3

11. Press <PROCEED> to start the measurement.
12. Write down the maximum value (of the sinc gauss curve) on the screen.

The typical value for this maximum value is between 22% and 37%.

13. When finished, restore the system to the original configuration.

6.5.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

Replace the transceiver board.

6.6 EXT. WRAP AROUND GAIN 1H TRANSCEIVER CONVERTORS TX -> RX PATH

NOTE

This measurement is only applicable for 3.0T systems.

With this procedure it is possible to check if the RF-output and the receive input of the 1H transceiver converter boards operate correctly within the typical range. RF-output and RF-input are checked.
At this point it is assumed that the measurement according paragraph 6.5 is within the typical value range.

6.6.1 MEASUREMENT

Precondition: Automatic STT BDAS measurement "level test" passed.
Tools needed:

- Short (< 1mtr) 50 Ohm coaxial cable
- N-male to BNC-female adapter

1. Disconnect cable FJA-A-X1 and cable FJA-B-X4 on both transceiver converters.
2. Connect RF-output FJA-B-X4 with a short coax (< 1mtr) to RF-input FJA-A-X1.
3. Select: Scan utilities
4. Select: Enter service mode
5. Select: System tuning
6. Select: System tuning tools
7. Select: Expert tools
8. Select: Analysis tools
9. Select: RF chain analysis
10. Change the following parameters:

Pulse shape	SG_100_100_0
Transm. Atten. [dB]	25
LM scale [%]	100

Rec. Att setting	3

11. Press <PROCEED> to start the measurement.
12. Write down the maximum value (of the sinc gauss curve) on the screen.

The typical value for this maximum value is between 22% and 37%.

13. When finished, restore the system to the original configuration.

6.6.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

Replace the applicable transceiver convertor board.

6.7 EXTERNAL WRAP AROUND GAIN 1H SYNERGY RECEIVER BOARDS

With this procedure it is possible to check if the receive inputs of both synergy receiver boards operate correctly within the typical range. At this point it is assumed that the tune output of the transceiver functions correctly.

6.7.1 MEASUREMENT

Precondition: Automatic STT BDAS measurements and measurement according paragraph 6.5 passed.

Tools needed:

- Short (< 1mtr) 50 Ohm coaxial cable
- N-male to BNC-female adapter

1. Disconnect cable FCH-X56 on the transceiver.
2. Disconnect all three (3) receive cables (but not the thin coaxial cables (clock signals)) on both synergy receiver boards.
3. Connect RF-output FCH-X56 with a short coax (<1 mtr) to synergy board1 input FCD-X51.
4. Select: Scan utilities
5. Select: Enter service mode
6. Select: System tuning
7. Select: System tuning tools
8. Select: Expert tools
9. Select: Analysis tools
10. Select: RF chain analysis
11. Change the following parameters:

	0.5T/1.0T/1.5T	**3.0T**
Transmit path	Tune	Tune
Pulse shape	SG_100_100_0	SG_100_100_0
Transm. Atten. [dB]	0	15
LM scale [%]	100	70
Rec. Att setting	6	6
Rec. Coil conn.	Synco-1	Synco-1
Receive channel	1	1

12. Press <PROCEED> to start the measurement.

13. Write down the maximum value (of the sinc gauss curve) on the screen. (= value A).
14. Disconnect the cable on FCD-X51 and connect it to FCD-X52.
15. Enter: RCHAN in the scan control window and press <RETURN>.
16. Enter: 2 and press <RETURN>.
17. Write down the maximum value (of the sinc gauss curve) on the screen. (= value B).
18. Disconnect the cable on FCD-X52 and connect it to FCD-X53.
19. Enter: RCHAN in the scan control window and press <RETURN>.
20. Enter: 3 and press <RETURN>.
21. Write down the maximum value (of the sinc gauss curve) on the screen. (= value C).
22. Disconnect the cable on FCD-X53 and connect it to FCE-X51.
23. Enter: RCHAN in the scan control window and press <RETURN>.
24. Enter: 4 and press <RETURN>.
25. Write down the maximum value (of the sinc gauss curve) on the screen. (= value D).
26. Disconnect the cable on FCE-X51 and connect it to FCE-X52.
27. Enter: RCHAN in the scan control window and press <RETURN>.
28. Enter: 5 and press <RETURN>.
29. Write down the maximum value (of the sinc gauss curve) on the screen. (= value E).
30. Disconnect the cable on FCE-X52 and connect it to FCE-X53.
31. Enter: RCHAN in the scan control window and press <RETURN>.
32. Enter: 6 and press <RETURN>.
33. Write down the maximum value (of the sinc gauss curve) on the screen. (= value F).

The typical value for values A-F is between 15% and 25%.

34. When finished, restore the system to the original configuration.

6.7.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the transceiver board is ok. Replace the suspected synergy receiver board.

6.8 EXTERNAL WRAP AROUND GAIN 1H SYNERGY CONVERTER BOARDS

With this procedure it is possible to check if the receive inputs of both synergy converter boards operate correctly within the typical range. At this point it is assumed that the tune output of the transceiver functions correctly.

6.8.1 MEASUREMENT

Precondition: Automatic STT BDAS measurements and measurement according paragraph 6.7 passed.

Tools needed:

- Short (< 1mtr) 50 Ohm coaxial cable
- N-male to BNC-female adapter

1. Disconnect cable FJA-A-X6 on the transceiver converter board.
2. Disconnect all input cables (X1, X2 and X3) on both synergy converter boards.
3. Connect RF-output FJA-A-X6 with a short coax (<1 mtr) to synergy convertor board1 input FJB-B-X1.
4. Select: Scan utilities
5. Select: Enter service mode
6. Select: System tuning
7. Select: System tuning tools

8. Select: Expert tools
9. Select: Analysis tools
10. Select: RF chain analysis
11. Change the following parameters:

Transmit path	Tune
Pulse shape	SG_100_100_0
Transm. Atten. [dB]	0
LM scale [%]	100
Rec. Att setting	6
Rec. Coil conn.	Synco-1
Receive channel	1

12. Press <PROCEED> to start the measurement.
13. Write down the maximum value (of the sinc gauss curve) on the screen. (= value A).
14. Disconnect the cable on FJB-B-X1 and connect it to FJB-B-X2.
15. Enter: RCHAN in the scan control window and press <RETURN>.
16. Enter: 2 and press <RETURN>.
17. Write down the maximum value (of the sinc gauss curve) on the screen. (= value B).
18. Disconnect the cable on FJB-B-X2 and connect it to FJB-B-X3.
19. Enter: RCHAN in the scan control window and press <RETURN>.
20. Enter: 3 and press <RETURN>.
21. Write down the maximum value (of the sinc gauss curve) on the screen. (= value C).
22. Disconnect the cable on FJB-B-X3 and connect it to FJB-A-X1.
23. Enter: RCHAN in the scan control window and press <RETURN>.
24. Enter: 4 and press <RETURN>.
25. Write down the maximum value (of the sinc gauss curve) on the screen. (= value D).
26. Disconnect the cable on FJB-A-X1and connect it to FJB-A-X2.
27. Enter: RCHAN in the scan control window and press <RETURN>.
28. Enter: 5 and press <RETURN>.
29. Write down the maximum value (of the sinc gauss curve) on the screen. (= value E).
30. Disconnect the cable on FJB-A-X2 and connect it to FJB-A-X3.
31. Enter: RCHAN in the scan control window and press <RETURN>.
32. Enter: 6 and press <RETURN>.
33. Write down the maximum value (of the sinc gauss curve) on the screen. (= value F).

The typical value for values A-F is between 15% and 25%.

34. When finished, restore the system to the original configuration.

6.8.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the synergy boards are ok. Replace the suspected synergy converter board or coaxial cable between synergy converter board and synergy board.

6.9 RECEIVE PATH TEST QBC

With this procedure it is possible to check the receive path of the QBC with a signal generated on tunecoil A. At this point it is assumed that the tune circuit functions correctly.

6.9.1 MEASUREMENT

Precondition: Automatic STT BDAS measurement "level test" passed.
No additional tools are needed to perform this measurement.

1. Remove all phantoms and/or (surface) coils from the bore.
2. Select: Scan utilities

3. Select: Enter service mode
4. Select: System tuning
5. Select: System tuning tools
6. Select: Expert tools
7. Select: Analysis tools
8. Select: RF chain analysis
9. Change the following parameters:

	0.5T	1.0T	1.5T	3.0T
Transmit path	Tune	Tune	Tune	Tune
Frequency control	User defined	User defined	User defined	User defined
Frequency [Hz]	21295000	42576000	63870000	127370000
Pulse shape	SG_100_100_0	SG_100_100_0	SG_100_100_0	SG_100_100_0
Transm. Atten. [dB]	15	15	15	25
Tune coil	Tune coil A	Tune coil A	Tune coil A	Tune coil A
Rec. Att setting	6	6	6	6
Rec. Coil conn.	Body	Body	Body	Body

10. Press <PROCEED> to start the measurement.
11. Write down the maximum value (of the sinc gauss curve) on the screen. Compare the measured value with the typical values according Table 2.

Table 2 Typical values receive path test QBC

System type	Typical value (%)
0.5T	7-20
1.0T PT1000, PT2000 and Omni	15-25
1.0T PT3000 and Power	7-17
1.5T PT1000, PT2000 and Omni	20-31
1.5T PT3000, PT6000, Power, Master and Explorer	15-26
3.0T Master	10-30

12. When finished, restore the system to the original configuration.

6.9.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the transceiver board is ok. Because this measurement is not specified, it only implies that tune chain and/or QBC receive chain is suspected. Troubleshoot these chains and replace the applicable FRU.

6.10 RECEIVE PATH TEST QHC (NOT FOR 3.0T SYSTEMS)

With this procedure it is possible to check the receive path of the QHC with a signal generated on tunecoil A. At this point it is assumed that the tune circuit functions correctly.

6.10.1 MEASUREMENT

Precondition: Automatic STT BDAS measurement "level test" passed.

No additional tools are needed to perform this measurement.

1. Remove the head phantom and/or the loadring from the QHC.
2. Plug the QHC connector into the PICU surface coil connector 1.
3. Position the QHC in the isocenter of the magnet.
4. Select: Scan utilities
5. Select: Enter service mode
6. Select: System tuning
7. Select: System tuning tools
8. Select: Expert tools
9. Select: Analysis tools
10. Select: RF chain analysis
11. Change the following parameters:

	0.5T	1.0T	1.5T
Transmit path	Tune	Tune	Tune
Frequency control	User defined	User defined	User defined
Frequency [Hz]	21295000	42576000	63870000
Pulse shape	SG_100_100_0	SG_100_100_0	SG_100_100_0
Transm. Atten. [dB]	15	15	15
Tune coil	Tune coil A	Tune coil A	Tune coil A
Rec. Att setting	4	5	4
Rec. Coil conn.	Sc1	Sc1	Sc1

12. Press <PROCEED> to start the measurement.
13. Write down the maximum value (of the sinc gauss curve) on the screen. Compare the measured value with the typical values according Table 3.

Table 3 Typical values receive path test QHC

System type	Typical value (%)
0.5T	15-25
1.0T PT1000, PT2000 and Omni	13-23
1.0T PT3000 and Power	10-18
1.5T PT1000, PT2000 and Omni	10-17[1]
1.5T PT3000, PT6000, Power, Master and Explorer	9-16[2]

14. When finished, restore the system to the original configuration.

[1] These values are only valid for a headcoil with an electronic load. Typical values for the 1.5T headcoil without electronic load are not available.
[2] These values are only valid for a headcoil with an electronic load. Typical values for the 1.5T headcoil without electronic load are not available.

6.10.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the transceiver board is ok. Because this measurement is not specified, it only implies that tune chain and/or QHC receive chain is suspected. Troubleshoot these chains and replace the applicable FRU.

6.11 RECEIVE PATH TEST T/R QHC (3.0T SYSTEMS ONLY)

NOTE

This measurement is only applicable for 3.0T systems.

With this procedure it is possible to check the receive path of the T/R-headcoil with a signal generated on tunecoil A. At this point it is assumed that the tune circuit functions correctly.

6.11.1 MEASUREMENT

Precondition: Automatic STT BDAS measurement "level test" passed.

Tools needed:

- Fluxprobe with holder (refer to Figure 4)

Figure 4

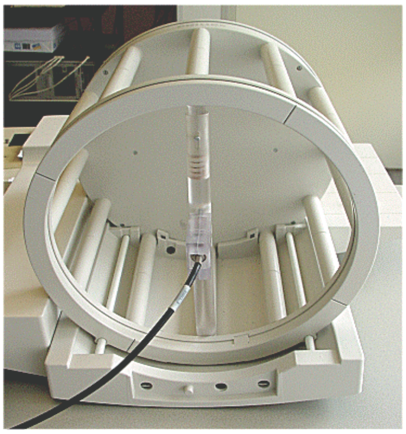
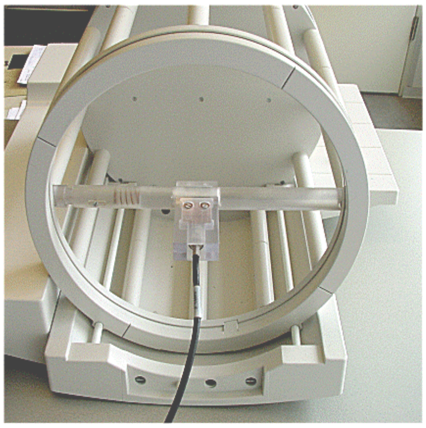


Figure 5



1. Plug the T/R-headcoil connector into the PICU.
2. Position the T/R-headcoil in the isocenter of the magnet.
3. Position the fluxprobe according Figure 4 in the T/R-headcoil and connect it to MMF-X2.
4. Select: Scan utilities
5. Select: Enter service mode
6. Select: System tuning
7. Select: System tuning tools
8. Select: Expert tools
9. Select: Analysis tools
10. Select: RF chain analysis
11. Change the following parameters:

Transmit path	Tune
Xmit coil	T/R-head
Frequency control	User defined
Frequency [Hz]	127782000
Pulse shape	SG_100_100_0
Transm. Atten. [dB]	10
Tune coil	Tune coil A
Rec. Att setting	6
Rec. Coil conn.	aux

12. Press <PROCEED> to start the measurement
13. Write down the maximum value (of the sinc gauss curve) on the screen.
14. Position the fluxprobe according Figure 5 in the T/R-headcoil.
15. Write down the maximum value (of the sinc gauss curve) on the screen.

Typical value for this maximum value (horizontal and vertical fluxprobe position): between 10% and 20%.

15. When finished, restore the system to the original configuration.

6.11.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the transceiver and transceiver convertor board are ok. Because this measurement is not specified, it only implies that the tune chain and/or T/R headcoil receive chain is suspected. Troubleshoot these chains and replace the applicable FRU.

7 TEST PROCEDURES TRANSMIT CHAIN

7.1 MAX. RF-OUTPUT 1H TRANSCEIVER BOARD (0.5T, 1.0T AND 1.5T SYSTEMS)

7.1.1 MEASUREMENT

Tools needed:

- Oscilloscope: 300 MHz for 1.5T, 200 MHz for 1.0T and 100 MHz for 0.5T
- 15 mtr calibrated cable
- Terminator 50 Ohm 3W (when oscilloscope cannot be 50 Ohm terminated internally)

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: RF unit output signals
8. Read the displayed info text carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.

7.1.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When the value do not meet the specification, the transceiver board must be replaced.

7.2 MAX. RF-OUTPUT 1H TRANSCEIVER CONVERTOR BOARD (3.0T SYSTEMS)

Tools needed:

- Oscilloscope 300 MHz
- 15 mtr calibrated cable
- Terminator 50 Ohm 3W (when oscilloscope cannot be 50 Ohm terminated internally)

7.2.1 MEASUREMENT

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurements
6. Select: RF-chain measurements
7. Select: RF unit output signals

The displayed infofile does not yet include specifications for 3.0T systems. The following values must be measured at the output of the transceiver converter FJA-B-X4:

Minimum value	Typical value	Maximum value
1060 mVpp	1230 mVpp	1430 mVpp

8. Start the measurement with <PROCEED> and follow the instructions on the screen.

When the measured value is not within specification, refer to paragraph 7.3.1 to check if the 64 MHz output of the transceiver board is causing the problem.

7.2.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When the value does not meet the specification, the transceiver converter board must be replaced.

7.3 MAX. RF-OUTPUT 1H TRANSCEIVER BOARD (3.0T SYSTEMS)

Tools needed:

- Oscilloscope 300 MHz
- 15 mtr calibrated cable
- Terminator 50 Ohm 3W (when oscilloscope cannot be 50 Ohm terminated internally)

7.3.1 MEASUREMENT

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: RF unit output signals
8. Read the displayed info text carefully.

NOTE

Because output FCHX57 generates a 64 MHz signal, the specification in the info file for 1.5T systems (T15) must be used.

9. Start the measurement with <PROCEED> and follow the instructions on the screen.

7.3.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When the value does not meet their specification, the transceiver board must be replaced.

7.4 MAX. RF-OUTPUT MULTI-NUCLEI TRANSCEIVER BOARD

7.4.1 MEASUREMENT

Tools needed:

- Oscilloscope 100 MHz
- 15 mtr calibrated cable
- Terminator 50 Ohm 3W (when oscilloscope cannot be 50 Ohm terminated internally)

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: MN RF unit output signals
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.

7.4.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When the value does not meet the specification, the MN-transceiver board must be replaced.

7.5 EXT. WRAP AROUND GAIN 1H TRANSCEIVER BOARD TX -> RX PATH

Refer to paragraph 6.5 for this procedure.

7.6 EXT. WRAP AROUND GAIN 1H TRANSCEIVER CONVERTORS TX -> RX PATH

NOTE

This measurement is only applicable for 3.0T systems.

Refer to paragraph 6.6 for this procedure.

7.7 DETERMINATION VSWR

7.7.1 WHAT IS VSWR

VSWR is the abbreviation for voltage standing wave ratio. The VSWR is a measure of impedance mismatch between the transmission line and its load. The higher the VSWR, the greater the mismatch. The minimum VSWR, *i.e.,* that corresponds to perfect impedance match, is unity (1:1).

It is possible to measure the VSWR using the directional coupler of the RF-amplifier.

7.7.2 QBC MEASUREMENT FOR 1.0T AND 1.5T SYSTEMS

For 1.0T and 1.5T systems, a pre-defined parameter set already is present in the software. For 0.5T and 3.0T systems, this parameter set must be created, refer to paragraph 7.7.3

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Disconnect cable FCH-X51 on the transceiver.
2. Use the 15 mtr calibrated cable and adapter to connect FRX5 on the RF-amplifier to FCH-X51
3. Select: Scan utilities
4. Select: Enter service mode
5. Select: System tuning
6. Select: System tuning tools
7. Select: Expert tools
8. Select: Analysis tools
9. Select: RF chain analysis
10. Select: Parset/Info
11. Select: Restore parameter set
12. Select: Determ_vswr
13. Press <PROCEED> to start the measurement
14. Write down the maximum value (of the sinc gauss curve) on the screen (=value A)
15. Leave the measurement running. Change connection of calibrated cable from FRX5 to FRX6 on the RF-amplifier.
16. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
17. Calculate the VSWR with the following formula:

VSWR = (A+B)/(A-B)

The typical value for this parameter is <1.5

18. When finished, restore the system to the original configuration.
19. When the mentioned typical value is not met, refer to paragraph 7.7.6 for further instructions.

7.7.3 QBC MEASUREMENT FOR 0.5T AND 3.0T SYSTEMS

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. For 0.5T systems: Disconnect cable FCH-X51 on the transceiver.
   For 3.0T systems: Disconnect cable FJA-A-X1 on the transceiver converter.
2. Use the 15 mtr calibrated cable and adapter to connect FRX5 on the RF-amplifier to FCH-X51 (for 3.0T systems: FJA-A-X1 on the transceiver converter).
3. Select: Scan utilities
4. Select: Enter service mode
5. Select: System tuning
6. Select: System tuning tools
7. Select: Expert tools
8. Select: Analysis tools

9. Select: RF chain analysis
10. Change the following parameters:

Table 4

	0.5T	3.0T
Pulse shape	SG_100_100_0	SG_100_100_0
Power setting	By Power	By Power
RF Power	250W	250W
Rec. Att setting	4	2

11. Press <PROCEED> to start the measurement
12. Write down the maximum value (of the sinc gauss curve) on the screen (=value A)
13. Change calibrated cable from FRX5 to FRX6 on the RF-amplifier
14. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
15. Calculate the VSWR with the following formula:

VSWR = (A+B)/(A-B)

The typical value for the VSWR is <1.5

16. When finished, restore the system to the original configuration.
17. When the mentioned typical value is not met, refer to paragraph 7.7.6 for further instructions.

7.7.4 T/R-HEADCOIL MEASUREMENT FOR 3.0T SYSTEMS

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Position the empty T/R-Headcoil in the isocenter and connect it to the auxiliary connector of the PICU.
2. Disconnect cable FJA-A-X1 on the transceiver converter.
3. Use the 15 mtr calibrated cable and adapter to connect FRX5 on the RF-amplifier to FJA-A-X1 on the transceiver converter.
4. Select: Scan utilities
5. Select: Enter service mode
6. Select: System tuning
7. Select: System tuning tools
8. Select: Expert tools
9. Select: Analysis tools
10. Select: RF chain analysis
11. Change the following parameters:

Table 5

Xmit-coil	T/R-Head
Pulse shape	SG_100_100_0
Power setting	By Power
RF Power	250W
Rec. Att setting	2

12. Press <PROCEED> to start the measurement
13. Write down the maximum value (of the sinc gauss curve) on the screen (=value A)

14. Change calibrated cable from FRX5 to FRX6 on the RF-amplifier
15. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
16. Calculate the VSWR with the following formula:

VSWR = (A+B)/(A-B)

The typical value for the VSWR is <1.5

17. When finished, restore the system to the original configuration.
18. When the mentioned typical value is not met, refer to paragraph 7.7.7 for further instructions.

7.7.5 H-HEADCOIL MEASUREMENT FOR 1.5T SYSTEMS

Optionally, 1.5T systems can be equipped with a Transmit/Receive Headcoil used for proton spectroscopy. For 1.5T systems, a pre-defined parameter set already is present in the software. For 0.5T and 3.0T systems, this parameter set must be created, refer to paragraph 7.7.3

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Position the empty H-Headcoil in the isocenter and connect it to the auxiliary connector of the PICU.
2. Disconnect cable FCH-X51 on the transceiver.
3. Use the 15 mtr calibrated cable and adapter to connect FRX5 on the RF-amplifier to FCH-X51.
4. Select: Scan utilities
5. Select: Enter service mode
6. Select: System tuning
7. Select: System tuning tools
8. Select: Expert tools
9. Select: Analysis tools
10. Select: RF chain analysis
11. Select: Parset/Info
12. Select: Restore parameter set
13. Select: Determ_vswr
14. Change the following parameters:

Xmit-coil	H-Head

15. Press <PROCEED> to start the measurement
16. Write down the maximum value (of the sinc gauss curve) on the screen (=value A)
17. Leave the measurement running. Change connection of calibrated cable from FRX5 to FRX6 on the RF-amplifier.
18. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
19. Calculate the VSWR with the following formula:

VSWR = (A+B)/(A-B)

The typical value for this parameter is <1.5

20. When finished, restore the system to the original configuration.
21. When the mentioned typical value is not met, refer to paragraph 7.7.7 for further instructions.

7.7.6 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL (QBC MEASUREMENT)?

The reflected transmit power in the QBC transmit path, measured with the RF-amp directional coupler, is higher than expected.

Perform the following test to find the root cause:

- Connect the 50 Ohm QBC load (**assumed that it is OK, to be checked with a DVM**) to the cable MGB-X1 (for 0.5, 1.0 and 1.5T systems with C I-piece 2411 027 07821) and perform the VSWR measurement.
- Connect the 50 Ohm QBC load to the output of the T/R-switch (MSE-X1 for NT systems, MMF-X8 for Intera systems) and perform the VSWR measurement. When still not within spec, perform the VSWR measurement with the 50 Ohm dummy load connected **(not for 3.0T systems)** instead to check if possibly the QBC load is defective.
- Bypass the T/R-switch using a HN-HN I-piece and repeat the VSWR measurement.
- Replace the 50 Ohm QBC load with the 50 Ohm dummy load (it is not possible to use the 50 Ohm dummy load for 3.0T systems because the results are unpredictable) on the magnet and repeat the measurement (in order to check if the cable between 50 Ohm load and hybrid box possibly is defective).
- Connect the 50 Ohm QBC load (assumed that it is OK) to cable MME-X7/MSE-X2 (using the HN-HN I-piece) and repeat the measurement.
- Connect the 50 Ohm QBC load (assumed that it is OK) on ZAX1 (in the SFB) and repeat the measurement.
- Connect the 50 Ohm QBC load directly to FR-X2 and repeat the measurement.
- Perform the insertion loss measurements according paragraph 7.11

7.7.7 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL (TR-HEAD AND H-HEAD MEASUREMENT)?

The reflected transmit power in the auxiliary transmit path, measured with the RF-amp directional coupler, is higher than expected.

Perform the following test to find the root cause:

- Connect the 50 Ohm QBC load (**assumed that it is OK, to be checked with a DVM**) to the output of the T/R-switch (MSE-X3 for NT systems, MMF-X6 for Intera systems) and perform the VSWR measurement. When still not within spec, perform the VSWR measurement with the 50 Ohm dummy load connected **(not for 3.0T systems)** instead to check if possibly the QBC load is defective.
- Check all coaxial cables (using a DVM) from PFEI to H-headcoil/TR-Headcoil connection in the PICU.
- Bridge (using a HN-HN I-piece) TR-switch connections MSEX2 – MSEX3 (NT systems) or MMFX7 – MMFX6 (Intera systems) and repeat the measurement.
- Connect the 50 Ohm QBC load (assumed that it is OK) to cable MME-X7/MSE-X2 (using the HN-HN I-piece) and repeat the measurement.
- Connect the 50 Ohm QBC load (assumed that it is OK) on ZAX1 (in the SFB) and repeat the measurement.
- Connect the 50 Ohm QBC load directly to FR-X2 and repeat the measurement.
- Perform the insertion loss measurements according paragraph 7.11

7.8 DETERMINATION ATT. 50 OHM DUMMYLOAD (NOT FOR 3.0T SYSTEMS)

With the Gyroscan NT and Intera system it is possible to measure/calibrate the actual attenuation value of the 50 Ohm dummy load.

Precondition: The Attenuator and Gain (automatic STT BDAS procedures) calibration must have been done.

CAUTION

The 50 Ohm dummy load is not suitable for 128 MHz (3.0T).
The VSWR for the 50 Ohm dummy load at 128 MHz is out of specification and unpredictable.

Tools needed:

- 2x 15 Mtr calibrated cable
- 2x N-male to BNC-female adapter
- BNC I-piece

Preparation:

1. Disconnect the RF-input FRX1 of the RF-amplifier (Safety!).
2. Disconnect FCH-X51 and FCH-X57 on the transceiver.
3. Remove the cable (when present) on the input of the 50 Ohm dummy load.
4. Connect one side of one calibrated cable to FCH-X57, connect the other side of the cable to the input of the 50 Ohm dummy load.
5. Connect one side of the other calibrated cable to FCH-X51 using the adapter, connect the other side of the cable to the output of the 50 Ohm dummy load.
6. Select the tuned hardware parameters, entry "Rec. Att normal (dB)" and press <RETURN>.
7. Write down the actual value for the receive attenuator marked with * in Table 6 **on your system.** It corresponds with the actual value for rec attenuator step "11" (= value C).
   Ignore the figures 1,4,7 and 10 on the left side of Table 6.

Table 6 Example of receive attenuation values

rec. att. normal [dB]	0.00 - 50.00	
1: 0.00	4.05	7.78
4: 11.83	15.62	19.75
7: 23.66	27.73	31.83
10: 35.92	39.75	43.81*

Measurement:

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Expert tools
6. Select: Analysis tools
7. Select: RF chain analysis
8. Change the following parameters:

Pulse shape	SG_100_100_0
Transmit att.	0
Safety checking	Disabled

9. Press <PROCEED> to start the measurement.
10. Enter **Yes** after the question:
    NO SAFETY CHECKINGS ARE PERFORMED, DO YOU WANT THAT?"
11. Write down the maximum value (of the sinc gauss curve) on the screen (=value A)
12. Enter: ATT in the scan control window and press <RETURN>.
13. Enter: 11 and press <RETURN>.
14. Leave the measurement running. Disconnect both calibrated cables at the 50 Ohm dummy load and connect them together using the BNC I-piece.
15. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
16. Calculate the attenuation of the 50 Ohm dummyload with the following formula:

Attenuation 50 Ohm dummy load (dB) = 20*log (B/A) + C

Compare the calculated value with the value written on the sticker of the 50 Ohm dummy load. The typical difference between the two values is < 0.2 dB.

17. When finished, restore the system to the original configuration.

7.8.1 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the transceiver and transceiver converter board are ok. Order a new 50 Ohm dummyload.

7.9 DETERMINATION ATT. 30 dB ATTENUATOR (MULTI NUCLEI (31P) SYSTEMS ONLY)

NOTE

Because of a software bug, this measurement is not possible with SW-release R4.7.2/5.7.2/6.7.2/R7.1. and R8.1.*. It will abort with the message "remove the coil from surface coil connector 1.*
It is not possible to repair this bug in the field.

At this moment, only the MR5003 RF-amplifiers is used for the 31P TX-channel.

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

Preparation:

1. Disconnect cable FCF-X51and cable FCF-X57 on the MN-transceiver.
2. Install the 30 dB attenuator on FCF-X57 of the MN-transceiver.
3. Connect the calibrated cable between FCF-X51 and the 30 dB attenuator.
4. Connect a 31P coil to the MN-input of the PICU.
5. Put this coil on the tabletop.
6. Position the 31P coil in the isocentre of the bore (without any phantoms).

Measurement:

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Expert tools
6. Select: Analysis tools
7. Select: RF chain analysis
8. Change the following parameters:

Xmit coil	"the connected 31P coil"
Pulse shape	SG_100_100_0
Power setting	By Power
RF Power	250W
Rec. coil connector	mn

9. Press <PROCEED> to start the measurement. Ignore the message "be aware, you are measuring cross-talk" and press return.
10. A sinc_gauss curve should now be visible. Click: display min/max in the monitoring window.
11. Write down the maximum value of the sinc_gauss curve (=value A).
12. Remove the 30dB attenuator from FCF-X57 and connect the calibrated cable directly to FCF-X57.
13. Write down the maximum value of the sinc_gauss curve (=value B).
14. Calculate the attenuation value of the 30dB attenuator with the following formula:

Attenuation 30dB attenuator (dB) : 20*log (B/A)

Compare the calculated value with the value written on the sticker of the 30 dB attenuator. The typical difference between the two values is < 0.2 dB.

15. When finished, restore the system to the original configuration.

7.9.1 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the transceiver and transceiver converter board are ok. Order a new 30 dB attenuator (45221315818).

7.10 DIRECTIONAL COUPLER RF-AMPLIFIER (NOT FOR 3.0T SYSTEMS)

CAUTION

The 50 Ohm dummy load is not suitable for 128 MHz (3.0T).
The VSWR for the 50 Ohm dummy load at 128 MHz is out of specification and unpredictable.

Preconditions:

- First calibrate/check the actual attenuation of the 50 Ohm dummy load according paragraph 7.8.

- Check the VSWR of the 50 Ohm dummy load with connection cable. Connect the 50 Ohm dummy load to the RF-amplifier output FR-X2 and measure the VSWR according paragraph 7.7.1. With the 50 Ohm dummy load connected to the RF-amplifier output FR-X2, the VSWR must be < 1.2.

7.10.1 WHAT IS A DIRECTIONAL COUPLER?

A transmission-coupling device for separately sampling (through a known coupling loss) either the forward (incident) or the backward (reflected) wave in a transmission line.

A directional coupler may be used to sample either a forward or backward wave in a transmission line. A unidirectional coupler has available terminals or connections for sampling only one direction of transmission; a bi-directional coupler has available terminals for sampling both directions. A bi-directional coupler is present on all RF-amplifiers in the NT and Intera systems.
It is possible to measure the forward attenuation value of this directional coupler using the NT/Intera system. Measuring the reflected port of this directional coupler is not possible.

7.10.2 MEASUREMENT (1H RF-AMPLIFIERS)

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter
- 50 Ohm dummy load (4522 130 3810 or 4522 130 4245) with short cable RG214

1. Stop any measurement or scan currently running.
2. Disconnect FRX1, FR-X4 and FR-X2 on the RF-amplifier.
3. Connect the 50 Ohm dummy load on FR-X2 of the RF-amplifier.
4. Write down the att. value written on the sticker of the 50 Ohm dummy load for the corresponding frequency (=value C).
5. Disconnect cable FCH-X51 on the transceiver.
6. Use the 15 mtr calibrated cable and adapter to connect the output of the 50 Ohm dummy load to FCH-X51.
7. Connect FR-X1 and FR-X4 to the RF-amplifier.
8. Select: Scan utilities
9. Select: Enter service mode
10. Select: System tuning
11. Select: System tuning tools
12. Select: Expert tools
13. Select: Analysis tools
14. Select: RF chain analysis
15. Change the following parameters:

Pulse shape	SG_100_100_0
Power setting	By Power
RF Power	250W
Rec. Att setting	8

16. Press <PROCEED> to start the measurement.
17. Change when required, by using the command ATT, the value until the measured curve is as high as possible but lower than 40%. **Don't stop the measurement when finished.**
18. Write down the maximum value (of the sinc gauss curve) on the screen (=value A)
19. Disconnect the calibrated cable on the output of the 50 Ohm dummy load. Connect the calibrated

cable to FR-X5 of the RF-amplifier.

20. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
21. Calculate the attenuation value of the directional coupler forward output with the following formula:

Att. value directional coupler FR-X5 (dB) : 20*log (A/B) + C + 0.1

Compare the calculated value with the value written on the RF-amplifier at FR-X5. The typical difference between the two values is < 0.3 dB.

22. When finished, restore the system to the original configuration.

7.10.3 MEASUREMENT (31P RF-AMPLIFIERS)

NOTE

Because of a software bug, this measurement is not possible with SW-release R4.7.2/5.7.2/6.7.2/R7.1. and R8.1.*.*
It will abort with the message "remove the coil from surface coil connector 1.

At this moment, only the MR5003 RF-amplifiers is used for the 31P TX-channel.

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter
- 50 Ohm dummyload (4522 130 3810 or 4522 130 4245) with short cable RG214
- 30 dB attenuator

Preparation:
1. Disconnect cable FCF-X51 on the MN-transceiver.
2. Disconnect FT-X1 and FT-X4 of the RF-amplifier.
3. Install, using an adapter, the 30 dB attenuator on FCF-X51 of the MN-transceiver.
4. Connect a 31P coil to the MN-input of the PICU.
5. Put this coil on the tabletop.
6. Position the 31P coil in the isocentre of the bore (without any phantoms).
7. Connect the 50 ohm dummy load on the output of the MR5003 connector FT-X2.
8. Write down the att. value written on the sticker of this dummy load @ 21 MHz (= value A).
9. Write down the directional coupler att. value (near connector FT-X5) of the MR5003, this is called value D.
10. Connect the 15 mtr calibrated cable between FCF-X51 (with the 30 dB att. still installed) and the output of the 50 Ohm dummy load.

Measurement:
1. Connect FT-X1 and FT-X4 on the RF-amplifier.
2. Select: Scan utilities
3. Select: Enter service mode
4. Select: System tuning
5. Select: System tuning tools
6. Select: Expert tools
7. Select: Analysis tools
8. Select: RF chain analysis
9. Change the following parameters:

Xmit coil	"the connected 31P coil"
Pulse shape	SG_100_100_0
Power setting	By Power
RF Power	250W

Rec coil connector	mn

10. Press <PROCEED> to start the measurement. Ignore the message "be aware, you are measuring cross-talk" and press return.
11. A sinc_gauss curve should now be visible. Click: display min/max in the monitoring window.
12. Write down the maximum value of the sinc_gauss curve (= value B).
13. Leave the measurement running and disconnect the calibrated cable at the side of the 50 Ohm dummyload.
14. Connect this side of the calibrated cable on FT-X5 of the MR5003 (directional coupler forward out).
15. Write down the maximum value of the sinc_gauss curve (= value C).
16. Calculate the attenuation value of the directional coupler forward output with the following formula:

Att. value directional coupler FT-X5 (dB): 20*log (B/C) + A + 0.1

Compare the calculated value with the value written on the RF-amplifier at FT-X5. The typical difference between the two values is < 0.3 dB.

17. When finished, restore the system to the original configuration.

7.10.4 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

At this point it is assumed that the used tools and measurement setup are ok. When the measured difference is out of typical, it is advised to write down the found new directional coupler att. value on the sticker at FR-X5. Experience learns that in general the directional coupler is a very reliable device. Situations where the directional coupler is not within typical are therefore considered to occur rarely.

7.11 INSERTION LOSS TX-PATH

NOTE

In some NT and Intera measuring accessories sets, the adapter (I-piece C-female/C-female), which is needed to measure at connector MGB-X1, is not yet present.
The 12nc for this adapter is: 2411 027 07821

7.11.1 MEASUREMENT

Tools needed:

- Oscilloscope 300 MHz
- 15 mtr calibrated cable
- Several adapters from the measuring acc. set
- 50 Ohm terminator (when oscilloscope cannot be 50 Ohm terminated internally)

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: Insertion loss measurements
8. Select: Insertion loss measurements (without 50E)
9. Read the displayed infotext carefully.
10. Start the measurement with <PROCEED> and follow the instructions on the screen. Note that one is

asked to write down the value "Uref" during the reference measurement. This however should be read as (%). The NT and Intera systems only measure this value in percentages.

NOTE

In some cases the message "Signal overflow" will appear. In this case increase the receive attenuator using the "ATT" command. Increase the ATT value with 1 step at a time until the "signal overflow" message disappears. It is important to keep the modified ATT value constant during the measurement.

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11. Repeat the measurement "Insertion loss measurements (with 50E)"
12. All measured values (in the displayed MRL) should meet the specifications.

7.12 PMU TRIPLEVEL RF-AMPLIFIER

7.12.1 THEORY OF OPERATION

The PMU Trip Level Test is used to test the functioning of the Power Monitoring Unit (PMU). This test is not available for a MR5000. To test the PMU, the PMU is set to some pre-defined value and it is checked whether the RF-amplifier is shut down when excessive RF-power is generated. This test is done for average power and, in case of a Sx-y RF-amplifier, also for peak power. In case of a Sx-y RF-amplifier, all available power modes are tested. The PMU tests are preceded by a calibration of the required peak power.

Average Power Trip Level test:

For this test, the required average power is 50 W (30W for S26 in low power mode). To determine the PMU trip point, the PMU trip point is varied from 100 W (twice the required average power) down to 25 W (half of the required average power) while RF-pulses of 50 W average are continuously transmitted. Before sweeping the PMU level, RF-power (50 W average) is transmitted during 30 seconds. During the sweep of the PMU trip point from 100 W down to 25 W, the status of the RF-amplifier is read and the sweep stops when the RF-amplifier shuts down. This is done for all applicable power modes. The resulting PMU trip point is saved in the output parameter *Avg. PMU trip pnt* for a MR500x RF-amplifier, and in the output parameter *HIGH Avg. PMU trip pnt, MID Avg. PMU trip pnt* and *LOW Avg. PMU trip pnt* for a Sx-y RF-amplifier.

Peak Power Trip Level test (only for Sx (Tube) RF-amplifiers):

For this test, the required peak power (Ppeak) is 2500 W, 2500 W and 250 W for, respectively, the power modes HIGH, MID and LOW. For a QBC-less 3T system, 500W is used in HIGH mode. To determine the PMU peak trip point, the PMU peak trip point is varied from 1.5*Ppeak to 0.5*Ppeak while RF pulses with the required peak power are continuously transmitted. During the sweep of the PMU peak trip point, the status of the RF-amplifier is read and the sweep stops when the RF-amplifier shuts down. This is done for all applicable power modes. The resulting PMU peak trip points are saved in the output parameters *HIGH Peak PMU trip pnt, MID Peak PMU trip pnt* and *LOW Peak PMU trip pnt*.

7.12.2 MEASUREMENT

Precondition: The 5 kW calibration must have been done.

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Installation procedures
6. Select: RF power amplifier procedures
7. Select: PMU test
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

7.12.3 WHAT TO DO WHEN THE SPEC IS NOT MET?

It is not possible to readjust the PMU in the field. Refer to paragraph 2.3 for more details.

7.13 AUTOMATIC GAIN AND LINEARITY TEST RF-AMPLIFIER

The gain, the gain-linearity and the phase-linearity of the RF-amplifier are measured. For this purpose, a sequence of sinc-gauss RF-pulses is transmitted and the response of the amplifier are measured. The amplitude of the RF-pulse is varied from 5000 W (500W for S26 systems without QBC) down to 1.58 W: this covers a dynamic range of 35 dB (25 dB for S26 systems without QBC). For an ETO RF-amplifier, all applicable power modes are used. To calculate the gain, a reference measurement is performed first to measure the 1H/MN-transceiver signal. For this reference measurement, the RF input cable between transceiver and RF-amplifier + calibrated measurement cable (+ the MN-attenuator in case of MR5003) must be connected between the 1H/MN-transceiver RF in and RF out.

7.13.1 MEASUREMENT

Precondition: The 5 kW calibration must have been done.

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter
- BNC I-piece

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: Gain and linearity checks
8. Start the measurement with <PROCEED> and follow the instructions on the screen.
9. All measured values (in the displayed MRL) should meet the specifications.

7.14 MANUAL DETERM. GAIN 1H RF-AMPLIFIER WITH DIRECTIONAL COUPLER

NOTE

Measuring the gain in mode mid (S21 and S23) and mode low (S21, S23 and S26) is not possible with this manual measurement.

In some situations (e.g. faults), it is not possible to use the automatic gain and linearity tests. However, a coarse determination of the gain is in most cases still possible. When this measurement also does not function or abort, the measurement according paragraph 7.15 could be attempted.

Preconditions:

- The transceiver board Testsoftware, TBDAS and automatic BDAS procedures succeeds.
- RF-amplifier is not in a fault condition.
- First calibrate/check the actual attenuation of the directional coupler according paragraph 7.10.

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter
- BNC I-piece
- HN-HN I-piece

NOTE

At this point it is assumed that the transmit cable between the RF-amplifier and the input of the T/R-switch is not suspected. Also the 50 Ohm QBC load is assumed to be ok.

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1. Disconnect FR-X1 and FR-X4 from the RF-amplifier.
2. Disconnect MSE-X2 (NT systems) or MMF-X7 (Intera systems) of the T/R-switch.
3. Connect **this cable** using a HN I-piece to the 50 Ohm QBC load. When the cable tree prevents this action, the 50 Ohm QBC must temporarily be removed from the magnet first in order to reach the cable.
4. At this point the transmit path is terminated with 50 Ohm.
5. Disconnect cable FCH-X51 on the transceiver (for 3.0T systems: FJA-A-X1 on the transceiver converter).
6. Use the 15 mtr calibrated cable to connect FR-X5 on the RF-amplifier to FCH-X51 (for 3.0T systems: FJA-A-X1 on the transceiver converter). Write down the att. value (written on the sticker) near FR-X5. (= value A).
7. Connect FR-X1 and FR-X4 to the RF-amplifier.
8. Select: Scan utilities
9. Select: Enter service mode
10. Select: System tuning
11. Select: System tuning tools
12. Select: Expert tools
13. Select: Analysis tools
14. Select: RF chain analysis
15. Change the following parameters:

Table 7

	0.5T	**1.0T**	**1.5T and 3.0T**
Pulse shape	SG_100_100_0	SG_100_100_0	SG_100_100_0
Repetition time [ms]	500	500	500
Transm. Atten. [dB]	5	10	15
LM scale [%]	70	70	100

Rec. Att setting	7	6	6

16. Press <PROCEED> to start the measurement
17. Enter **Yes** after the question (when it appears):
    NO SAFETY CHECKINGS ARE PERFORMED, DO YOU WANT THAT?"
18. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)
19. Disconnect cable FR-X1 and FR-X5 on the RF-amplifier.
20. Connect these two cables together using the BNC I-piece.
21. Write down the maximum value (of the sinc gauss curve) on the screen (=value C)
22. Calculate the gain with the following formula:

Gain (dB) = 20*log (B/C) + A

The specification for this gain is:

0.5T	1.0T	1.5T and 3.0T
67 dB +/- 2.0 dB	71.8 dB +/- 2.5 dB	74 dB +/- 2.5 dB

23. When finished, restore the system to the original configuration.

7.15 MANUAL DETERM. GAIN 1H RF-AMPLIFIER WITH 50 OHM DUMMYLOAD

NOTE

This measurement is not possible for 3.0T systems.

NOTE

Measuring the gain in mode mid (S21 and S23) and mode low (S21, S23 and S26) is not possible with this manual measurement.

In some situations (e.g. faults), it is not possible to use the automatic gain and linearity tests. However, a coarse determination of the gain is in most cases still possible. When this measurement also does not function or abort, the measurement according paragraph 7.14 could be attempted.

CAUTION

The 50 Ohm dummy load is not suitable for 128 MHz (3.0T).
The VSWR for the 50 Ohm dummy load at 128 MHz is out of specification and unpredictable.

Preconditions:

- The transceiver board Testsoftware TBDAS and automatic BDAS procedures have been executed without errors.
- RF-amplifier is not in a fault condition.
- First calibrate/check the actual attenuation of the 50 Ohm dummy load according paragraph 7.8

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter
- BNC I-piece

- 50 Ohm dummy load (when required determine the att. value according paragraph 7.8)
- Terminator 50 Ohm 3W (optional)

1. Disconnect FR-X1, FR-X4 and FR-X2 from the RF-amplifier.
2. Connect the 50 Ohm dummy load on FR-X2. Write down the att. value for the corresponding frequency (written on the sticker) on the 50 Ohm dummy load (= value A).
3. Disconnect cable FCH-X51 on the transceiver.
4. Use the 15 mtr calibrated cable to connect the output of the 50 Ohm dummy load to FCH-X51.
5. Connect FR-X1 and FR-X4 to the RF-amplifier.
6. Select: Scan utilities
7. Select: Enter service mode
8. Select: System tuning
9. Select: System tuning tools
10. Select: Expert tools
11. Select: Analysis tools
12. Select: RF chain analysis
13. Change the following parameters:

Table 8

	0.5T	**1.0T**	**1.5T**
Pulse shape	SG_100_100_0	SG_100_100_0	SG_100_100_0
Repetition time [ms]	500	500	500
Transm. Atten. [dB]	5	10	15
LM scale [%]	70	70	100
Rec. Att setting	11	11	11

14. Press <PROCEED> to start the measurement.
15. Enter **Yes** after the question (when it appears):
    NO SAFETY CHECKINGS ARE PERFORMED, DO YOU WANT THAT?"
16. Write down the maximum value (of the sinc gauss curve) on the screen (=value B)

NOTE

In rare cases, the message "signal overflow" will appear. Only if this is the case, the 50 Ohm terminator must be installed in series with the cable at FCH-X51.
Leave this terminator installed during the whole measurement.

---

17. Leave the measurement running. Disconnect cable FR-X1 and the calibrated cable on the 50 Ohm dummy load.
18. Connect these two cables together using the BNC I-piece.
19. Write down the maximum value (of the sinc gauss curve) on the screen (=value C)
20. Stop the measurement.
21. Calculate the gain with the following formula:

Gain (dB) = 20*log (B/C) + A + 0.1

The specification for this gain is:

0.5T	**1.0T**	**1.5T**
67 dB +/- 2.0 dB	71.8 dB +/- 2.5 dB	74 dB +/- 2.5 dB

22. When finished, restore the system to the original configuration.

7.16 DECOUPLING CROSS TALK TEST (MULTI NUCLEI (31P) SYSTEMS ONLY)

This procedure can be used to check the proper decoupling of the proton (1H) frequencies from the 31P frequencies. It transmits one long block pulse of 600 Watt on the proton channel in the acquisition period on the 31P channel.
Two measurements must be done:
One with the "blanking" of the proton RF amplifier disconnected, the other one with the blanking connected. The difference in the received "noise" level is an indication of the RF coupling between the two RF channels. If everything is ok, NO increase will be found. The P_Head coil must be connected to the PICU with this measurement.

7.16.1 MEASUREMENT

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: Decoupling cross talk test
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

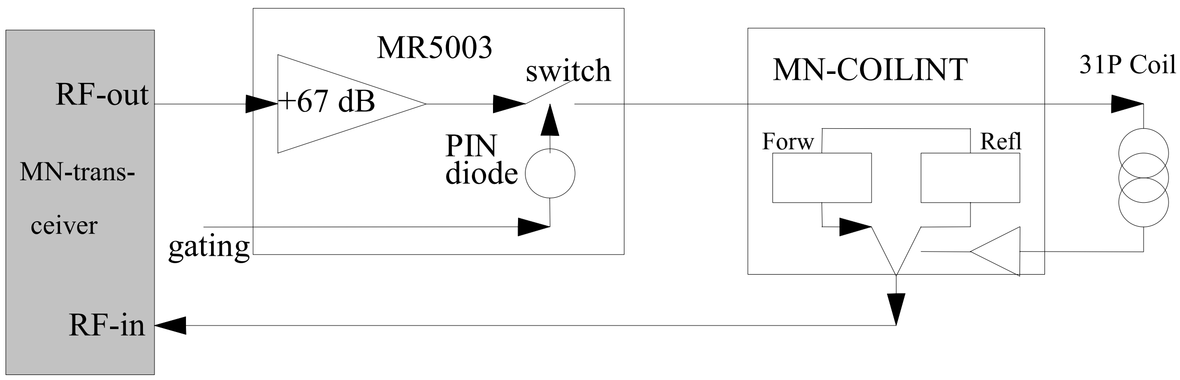
7.16.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

At this point it is assumed that the measurement setup and used tools are ok. The RF-amplifier has to be replaced in this case.

7.17 PIN-DIODE TEST (MR5003 ONLY)

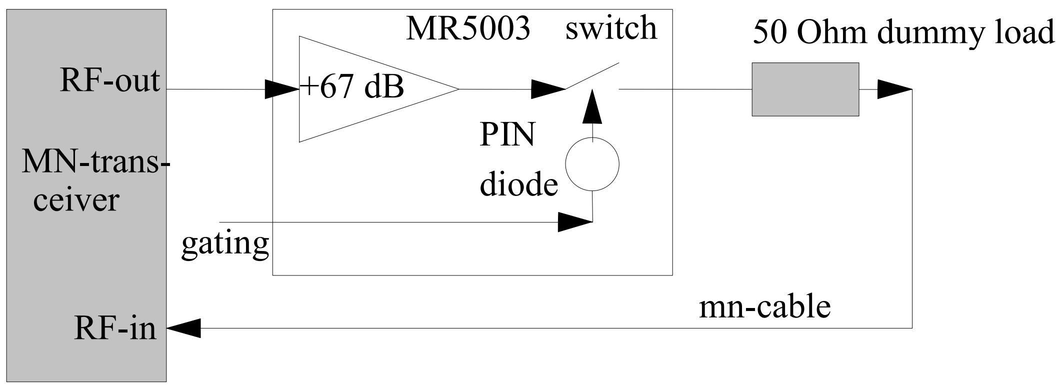
The MR5003 has the possibility to switch ON and OFF the Bias on the PIN diode for the purpose of checking the PIN diode switch integrity (see technical manual MR5003). For this purpose, a signal of less than -40 dBm is applied to the MR5003. The resulting signal after 67 dB amplification is measured, either via the MN-Coilint, or via the 50E dummy load (for factory testing). This measurement is done twice: once with PIN diode ON, and once with PIN diode OFF. From these two measurements, the attenuation of the PIN diode is calculated and is stored in the output parameter *PIN diode att*. The PIN diode ON measurement is preceded by a measurement of the noise.
For the PIN diode test, the operator can choose between the normal RF-path via the MN-Coilint, or the RF-path via the 50 Ohm dummy load. When the normal RF-path is used, a tuned 31P coil must be connected at the PICU (see Figure 6).

Figure 6 Hardware setup for the PIN diode test using the MN-Coilint



When the 50 Ohm dummy load is used, then the 50 Ohm dummy load is connected at the RF-out outlet of the MR5003 and the calibrated measurement cable is connected between the attenuation outlet of the 50 Ohm dummy load and the MN-transceiver (see Figure 7).

Figure 7 Hardware setup for the PIN diode test using the 50 Ohm dummy load.



7.17.1 MEASUREMENT

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: Pin diode test
8. Read the displayed info text carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

7.17.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

At this point it is assumed that the measurement setup and used tools are ok. Replace the RF-amplifier.

7.18 RF-SELFTEST RF-AMPLIFIER (S21 AND S22)

7.18.1 AUTOMATIC MEASUREMENT

Precondition: The 5 kW calibration must have been done.

1. Start the Testsoftware application.
2. Select: TBDAS
3. Enter: RUN FUNCTIONAL RFAMP SELFTEST

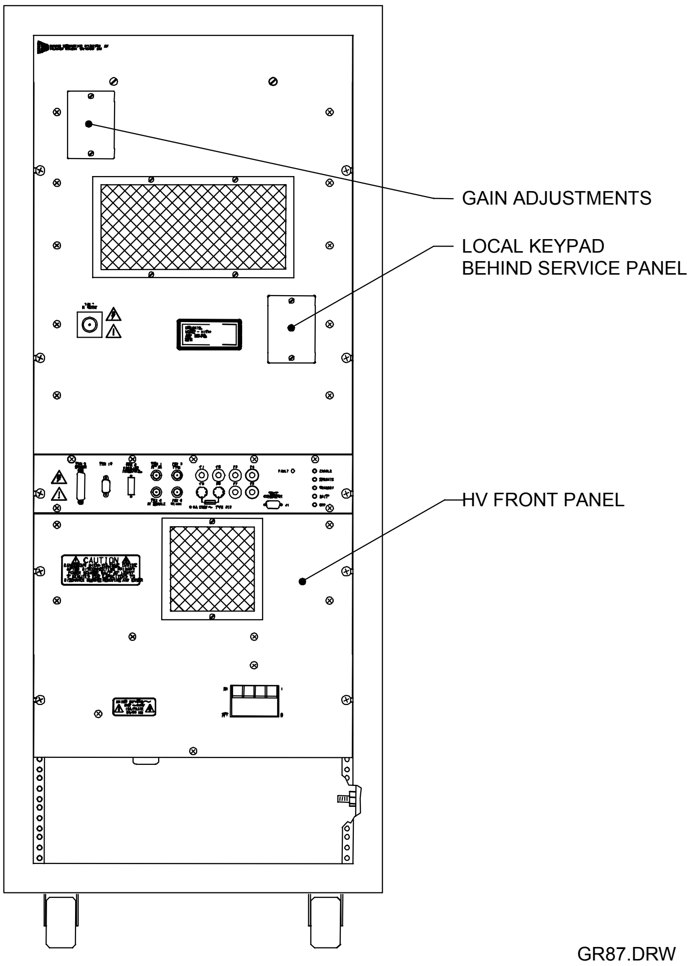
In case the test fails, perform the separate RF-amplifier stage tests according paragraph 7.18.2.

7.18.2 LOCAL MEASUREMENT

There are four RF tests available. These are:

1. TEST=SSARF {Solid State Driver test}
2. TEST=IPARF {Solid State Driver and IPA tube test}
3. TEST=AMPRF {Solid State Driver, IPA tube and PA tube test}
4. TEST=RF {Performs tests 1, 2 and 3}

Figure 8



To run the tests in LOCAL mode, do the following:

1. Remove the small service panel on the front. Behind this panel the local keypad is located. See Figure 8.
2. Press the LOCAL button on the keypad (LED goes on). If the amplifier was in Standby state or Operate state it will go to Off state.
3. Press the OPER button, this will command the amplifier to Operate state. Wait until the amplifier is in OPERATE state (up to 6 minutes). The LED Operate on the front of the panel goes on.
4. Press the MENU button, until the following menu appears:

   RF TEST SSA
   RF TEST SSA, IPA
   RF TEST SSA, IPA, PA
   ----
5. The test to be conducted can be selected with the UP/DOWN keys and the ENT buttons. The selected test will run. If the test passed, a message is displayed and the test menu can be exited by pressing MENU or ENT. If a test failed, the system goes to the default menu and displays a warning message.

Solid State Driver (SSD) test:

During this test the solid state driver has a wattmeter and an internal 50 Ohm load at its output and an internal crystal oscillator at its input. During the test, the relay at the output of the SSD is switched to direct the output to the internal 50 Ohm load. The crystal oscillator is turned on and a single 4 millisecond RF pulse is run through the SSD. The output power is sampled every 333 μs during the pulse.

If the SSD output power is found to be less than approximately 25 Watts, a warning 11 (SSA GAIN LOW) is given. If it is found to be above 100 Watts a warning 10 (SSA GAIN HIGH) is given. The crystal oscillator output is not very stable, so a ± 3 dB window around 50 Watts nominal was chosen.
If the droop across the 4 millisecond pulse is greater than approximately 1 dB, a warning 12 (SSA DROOP HIGH) is given.

The data collected over the pulse is saved in volatile memory. Part of the data is used during the IPA and PA tube tests.

Solid State Driver and IPA tube test:

First, the SSD test is run, as described under "**Solid State Driver (SSD) test"**. The RF relay-path is set so that the PA tube is by-passed and the IPA tube stage is directed to the output amplifier, through the output wattmeter into the 50 Ohm load. The crystal oscillator in the SSD is turned on and a single 4 millisecond RF pulse is run through the amplifier. The forward power output of the amplifier is sampled once every 333 μs and the data is stored in volatile memory.
The gain of the IPA stage is calculated by dividing the forward power at the output wattmeter by the SSD output level. If the gain of this stage is outside a ± 3 dB window from the nominal gain, a warning 20 (IPA GAIN HIGH) or 21 (IPA GAIN LOW) is given. If the droop across the pulse is greater than approximately 1dB, then a warning 22 (IPA DROOP HIGH) is given. High droop across the pulse is an indication that the IPA tube is near end-of-life.

Solid State Driver, IPA tube and PA tube test:

First, the SSD test is run, as described under "**Solid State Driver (SSD) test"** . The RF relay-path is set so that both the IPA and the PA tubes are used. The output of the PA stage is directed into the internal 50 Ohm load. The crystal oscillator in the SSD is turned on and a single 4 millisecond RF pulse is run through the amplifier. The forward power output of the amplifier is sampled once every 333 μs and the data is stored in volatile memory.

The gain of the IPA and PA stages is calculated by dividing the forward power at the output wattmeter by the SSD output level. If the gain of the combined stages is outside a ± 3 dB window from the nominal gain, a warning 30 (IPA/PA GAIN HIGH) or 31 (IPA/PA GAIN LOW) is given. If the droop across the pulse is greater than approximately 1 dB, a warning 32 (IPA/PA DROOP HIGH) is given. High droop across the pulse is an indication that one, or both, of the tubes is near end-of-life. If a warning 22 (IPA DROOP HIGH) does not occur during TEST=IPARF, but does occur during TEST=AMPRF then most likely the PA tube is the problem.

7.19 RF-SELFTEST RF-AMPLIFIER (S23, S24 AND S26)

The RF self-test of the S24-42, S23-64, or S26-128 RF-amplifier is performed. According to the supplier's specification, at least 16 block pulses of at least 7 ms width must be supplied to the RF-amplifier before the amplifier can perform a diagnosis of the amplifiers behavior. The result of this test is a status PASSED or FAILED. In case of failure, all errors indicated by the amplifier are collected in the central log-file and the operator is informed that errors occurred. This test is preceded by a calibration of the required peak power.

For a 3T system without body coil, this is the ‘RF amplifier tool’ test that does not use the T/R-Head coil as load and that does not restrict the peak power used to 500W. In fact, 5kW is used. This is made possible by employing the 50 Ohm QBC load, present on top of the magnet, as load.

The following items are checked and verified for proper operation during the test:

- Tube bias and operating point.
- Input drive level.
- Solid State Amplifier (SSA) output.
- System stage gain and output.
- IPA and PA tube filament voltage.
- IPA and PA tube emission and plate current.
- IPA and PA power supply regulation.

During the test the amplifier retrieves its driving signal from the MR system. The amplifier will collect data samples and, upon test completion, issue a status report message.

If any out-of-bounds condition is found during the test a warning may be issued. Refer to the technical manual of the corresponding RF-amplifier for a list of warnings and possible follow-up actions. Warnings are intended to alert the system operator to a condition that requires attention.

7.19.1 MEASUREMENT

Precondition: The 5 kW calibration must have been done.

Tools needed:

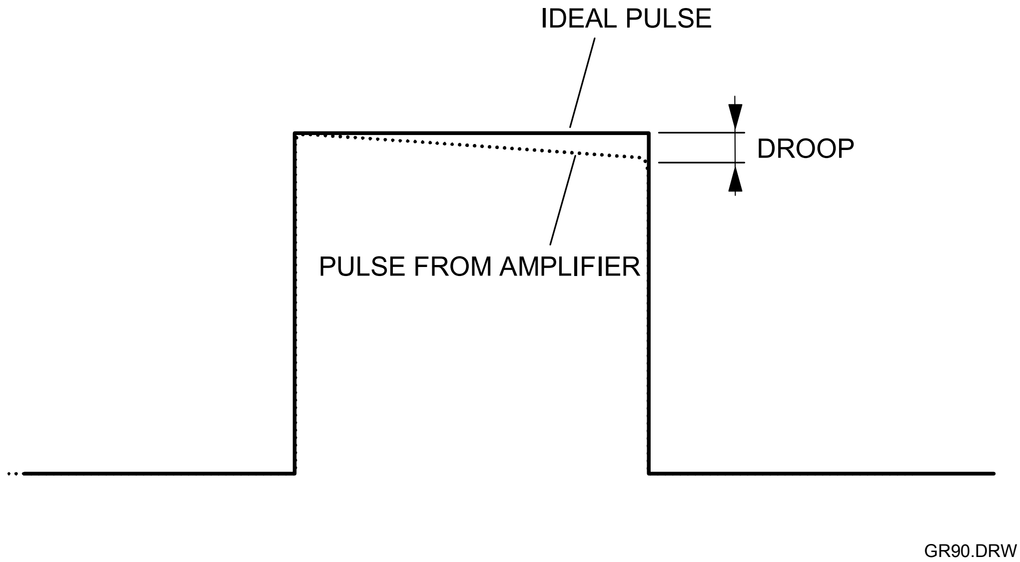
- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: RF-selftest
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

7.20 RF PULSE DROOP TEST

The RF pulse droop of the RF-amplifier is measured. For this purpose, a block pulse is transmitted and the pulse generated by the RF-amplifier is measured. The pulse droop is the relative decrease of the amplitude of this pulse (in dB), also refer to Figure 9.
This test is done in HIGH mode. For Sx-64 RF-amplifiers, it is also done in MID mode and, when applicable, in LOW mode. For the S26-128 amplifier, it is also done in LOW mode. In HIGH or MID mode, a 3ms / 5000W block pulse is used (500W for S26). In LOW mode, a block pulse of 500ms / 500W is used.

Figure 9 RF pulse droop



7.20.1 Measurement

Precondition: The 5 kW calibration must have been done

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: RF pulse droop test
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

7.20.2 What to do when the spec is not met?

At this point it is assumed that the measurement setup and the tools use dare ok. Replace the RF-amplifier.

8 TEST PROCEDURES TUNE CHAIN

8.1 EXT. WRAP AROUND GAIN 1H TRANSCEIVER BOARD (TUNE -> RX PATH)

With this procedure it is possible to check if the tune output and the receive input of the 1H transceiver board operate correctly within the typical range. Tune output and RF-input are checked.

8.1.1 MEASUREMENT

Precondition: Automatic STT BDAS measurement "level test" passed.

Tools needed:

- Short (< 1mtr) 50 Ohm coaxial cable
- N-male to BNC-female adapter

1. Disconnect cable FCH-X56 and cable FCH-X51 on the transceiver.
2. Connect Tune output FCH-X56 with a short coax (<1 mtr) to RF-input FCH-X51.
3. Select: Scan utilities
4. Select: Enter service mode
5. Select: System tuning
6. Select: System tuning tools
7. Select: Expert tools
8. Select: Analysis tools
9. Select: RF chain analysis
10. Change the following parameters:

Transmit path	Tune
Pulse shape	SG_100_100_0
Transm. Atten. [dB]	15
LM scale [%]	100
Rec. Att setting	0

11. Press <PROCEED> to start the measurement
12. Write down the maximum value (of the sinc gauss curve) on the screen.

The typical value for this maximum value is between 23% and 33%.

13. When finished, restore the system to the original configuration.

For 3.0T systems only:

Refer to paragraph 8.2 for the additional measurement for the transceiver converter.

8.1.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

Replace the transceiver board (or transceiver converter board when applicable).

8.2 EXT. WRAP AROUND GAIN 1H TRANSCEIVER CONVERTOR BOARD TUNE -> RX PATH (3.0T SYSTEMS ONLY)

With this procedure it is possible to check if the tune output and the receive input of the 1H transceiver converter board operate correctly within the typical range. Tune output and RF-input are checked.
At this point it is assumed that the measurement according paragraph 8.1 is within the typical value range.

8.2.1 MEASUREMENT

PRECONDITION: Automatic STT BDAS measurement "level test" passed.

Tools needed:

- Short (< 1mtr) 50 Ohm coaxial cable
- N-male to BNC-female adapter

1. Disconnect cable FJA-A-X1 and cable FJA-A-X6 on the right transceiver converter.
2. Connect Tune output FJA-A-X6 with a short coax (<1 mtr) to RF-input FJA-A-X1.
3. Select: Scan utilities
4. Select: Enter service mode
5. Select: System tuning
6. Select: System tuning tools
7. Select: Expert tools
8. Select: Analysis tools
9. Select: RF chain analysis
10. Change the following parameters:

Transmit path	Tune
Pulse shape	SG_100_100_0
Transm. Atten. [dB]	15
LM scale [%]	100
Rec. Att setting	0

11. Press <PROCEED> to start the measurement
12. Write down the maximum value (of the sinc gauss curve) on the screen.

The typical value for this maximum value is between 20% and 30%.

13. When finished, restore the system to the original configuration.

8.2.2 WHAT TO DO WHEN THE VALUE IS NOT TYPICAL?

Replace the right transceiver convertor board.

8.3 TUNE BOX CHECKS ON OSCILLOSCOPE (NT SYSTEMS ONLY)

8.3.1 MEASUREMENT

Tools needed:

- Oscilloscope: 300 MHz for 1.5T, 200 MHz for 1.0T and 100 MHz for 0.5T

- 15 mtr calibrated cable
- Terminator 50 Ohm 3W (when oscilloscope cannot be 50 Ohm terminated internally)

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: Tune box checks on oscilloscope
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.

8.3.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When one or more of the values do not meet their specification, one or more of the following components could be defective:

- Transceiver board
- Coaxial cable FCHX56-ZDX1
- Tune box
- Control signals to tune box

8.4 TUNE SIGNAL OUPUT IMAGE SCREEN

8.4.1 MEASUREMENT

No additional tools are needed to perform this measurement.

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: Tune signal output image screen
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.

8.5 TUNE SWITCH (INTERA SYSTEMS ONLY)

The Tune switch test tests the TRC-switch (isolation) and verifies the Tune A and the Tune B signal (implicitly). For each path (Tune A resp. Tune B) the gain of the (test) tune-path is measured with the specific test HW. The measured signal levels for both paths are compared with each other. In case the tune signal level varies too much the scan will be aborted. The scan is also aborted in case the measured tune level is too low.
During the isolation measurement the TRC-switch is not set. The measured signal level should be reduced. The difference in signal level in case the TRC-switch is set or not is the measured isolation.

8.5.1 MEASUREMENT

No additional tools are needed to perform this measurement.

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-chain measurements
7. Select: Tune switch test
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

8.5.2 WHAT TO DO WHEN THE SPEC IS NOT MET?

When one ore more values do not meet their specification, the TR-switch must be replaced.

9 ADJUSTMENT PROCEDURES

9.1 RX AND TX ATTENUATION CALIBRATION

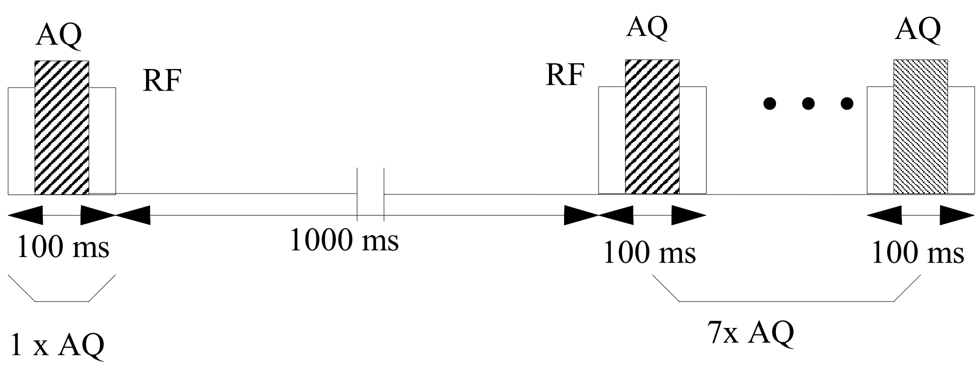
9.1.1 INTRODUCTION

The Attenuator and Gain Calibration tool (AGC) is used to calibrate all attenuators (1H/MN-Transceiver, Synco-receivers) and to calibrate the ADC non-linearity of all receive channels (Transceiver, MN-transceiver, Synco-receivers). A calibration of the attenuators is necessary for e.g. 5 kW adjustment (and so for the preparation phase Power Optimization) and for Profile Dependent Attenuation (PDA). Furthermore, the calibration of the ADC non-linearity is necessary to allow correction of images for the ADC-characteristic. Both calibrations have to be done at initial system installation and after replacement of the 1H/MN-transceiver and/or Synco receivers.

9.1.2 THEORY OF OPERATION

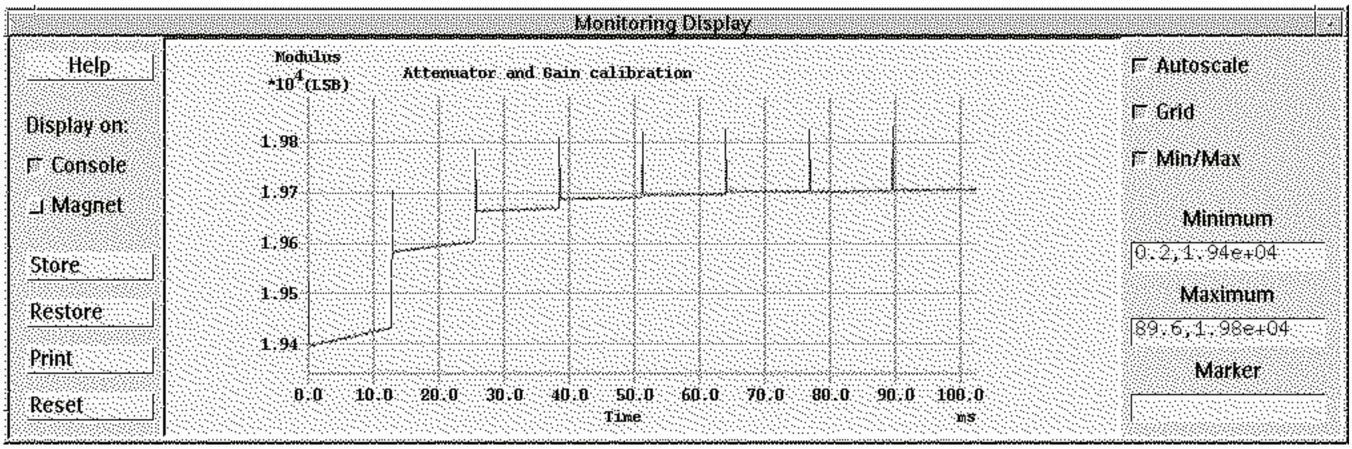
The absolute values of the attenuators can not be measured. All values will be related to a reference value, namely 0 dB. This means, that the 0 dB attenuator setting gives, by definition, 0 dB attenuation. All other attenuator settings should have a higher attenuation, and, consequently, the measured signal should be lower than the reference signal.
To make sure that the hardware has settled after switching the attenuator, a delay of 1000 ms is built in into the measurement sequence before acquiring data which is used for the calibration. The following sequence is used:

Figure 10 Calibration sequence



The attenuator setting to calibrate is switched just before the first RF-pulse. The first acquisition is not used. Then, 1000 ms later, a train of 7 identical RF-pulses is transmitted and the resulting ADC samples (7x128) are acquired for processing. The average amplitude and phase are calculated using the maximum signal in the frequency-domain. To minimize DC effects, an offset acquisition frequency of 1250 Hz is used. An example of the measured response is given in Figure 11.

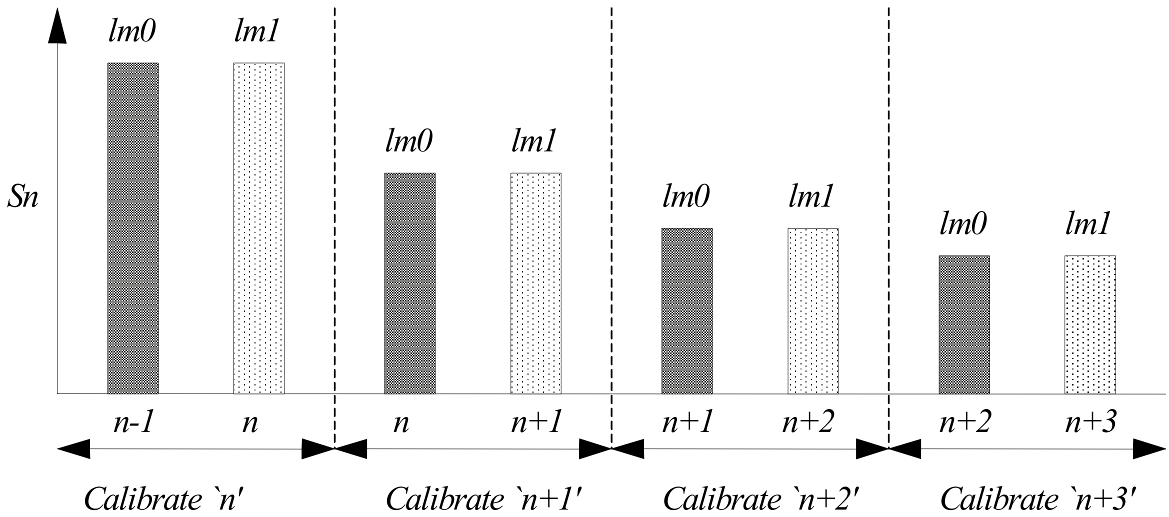
Figure 11 Example of one calibration sequence



Attenuator calibration:

To measure the attenuation value ATT_n at attenuator position *n*, two measurements are performed: one measurement with attenuator position *n* and LM-scale lm_1 (which yields signal S_n^1) and one measurement with attenuator position *n-1* (which is already calibrated) and LM-scale lm_0 (which yields signal S_{n-1}^0). The LM-scales lm_0 and lm_1 are chosen such that the ADC input signals S_{n-1}^0 and S_n^1 are almost equal in both measurements (note that $lm_0 < lm_1$). In this way, ADC non-linearity effects are minimized. This is shown schematically in Figure 12.

Figure 12 Schematic depiction of calibration cycle



The resulting attenuation ATT_n is given by the following recursive relation:

$ATT_0 = 0$ dB

$ATT_n = ATT_{n-1} + 20.0 * \log10[(S_{n-1}^0 / lm_0) / (S_n^1 / lm_1)]$

The nominal value of the ratio lm_0/lm_1 depends on the nominal attenuation step. For the calibration of the power attenuator of the 1H- and MN-transceiver, the nominal attenuation step is 5dB (lm_0/lm_1 is taken $10^{-5/20}$= 0.56). For the calibration of the receiver of the 1H-transceiver, the nominal attenuation step is 4 dB (lm_0/lm_1 is taken $10^{-4/20}$= 0.63). For the calibration of the receivers of the synco-receivers, the nominal attenuation step is either 3 dB or 6 dB, depending on the attenuator position which is calibrated.

The ratio lm_0/lm_1 is calibrated by performing the first (n=1) measurement twice: once with LM-scale lm_0 and once with LM-scale lm_1. Assuming that ADC non-linearity effects have no significant contribution at high input signal levels (n=1), the ratio lm_0/lm_1 is given by the S_n^0 / S_n^1.

The absolute value of the LM-scales lm_0 and lm_1 depend on the selected RF-path and, in case of an external RF-path, also on the used cable and (optional) extra attenuators. To be flexible in this respect, an automatic LM-scale adjustment procedure precedes the actual calibration. This automatic LM-scale adjustment reduces the LM-scale lm_1 (since $lm_0 < lm_1$) until no overflow occurs. As initial value, lm_1 = 40%.

ADC integral non-linearity:

The values obtained so far can be used to calculate the ADC integral non-linearity INL_n. The INL_n is given by the following relation:

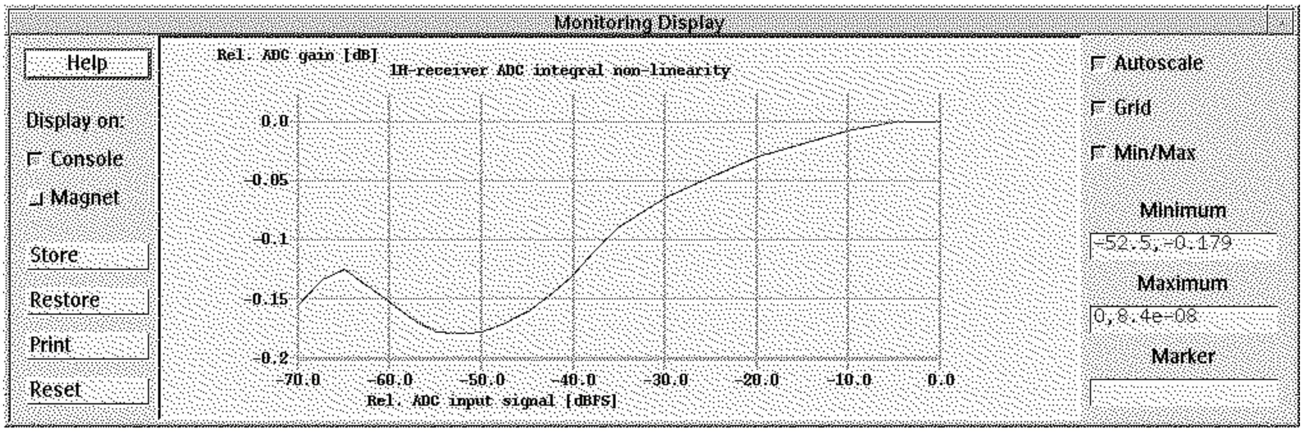
INL_0 = 0 dB

$INL_n = ATT_n - 20.0 * \log10[(S_0^0 / lm_0) / (S_n^1 / lm_1)]$

The ADC input signal levels are measured on a base (ATT_0, ATT_1, ... , ATT_m), relative to S_0^0(m is the last measured attenuator position). An extrapolation is required to map the INL-values on the required base (0,5,...,70 dB) with respect to Full-Scale (=0.7*32767).

An example of a resulting INL-curve is given in Figure 13.

Figure 13 Example of an INL-curve of a 1H-transceiver



In case of the 1H- and MN-transceiver, the dynamic range of the power attenuator is equal to the specified dynamic range of the INL-curve. Therefore, the INL-curve can be derived directly from the calibrated attenuation values. However in case of synco, the dynamic range of the synco receiver attenuator is limited to 45 dB. Therefore, the measurement of the synco INL-curve is separated from the synco attenuator calibration. The synco INL-curve is measured (via external wrap-around) by varying the power attenuator from 0 dB to 70 dB at a fixed synco receiver attenuator position. Below, an overview is given of the used attenuation values.

```
1H-TX:   TX=0,5,...,65,70 dB
MN-TX: TX=0,5,...,65,70 dB
Synco: SRX=0,3,6,...,45 dB for attenuator calibration
     TX=0,5,...,65,70 dB for ADC integral non-linearity calibration
```

The effect of the ADC integral non-linearity on IQ can be expressed in an IQ-figure, called the clinical INL. The larger this value, the more impact the ADC integral non-linearity may have on IQ. When the clinical INL value exceeds a certain value, the non-linearity of the ADC is corrected during reconstruction.

9.1.3 PROCEDURE

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Installation procedures
6. Select: Run Automatic BDAS procedures
7. Select: Attenuator and Gain calibration / All Automatic BDAS tests
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

9.2 MAX KW ADJUSTMENT

After installing a MR system, a calibration of the RF power amplifier(s) on system-level is done to get an equivalent behavior of all systems. In case of a MR system, which includes the Multi-Nuclei (31P) option, there are 2 RF-amplifiers: the 1H RF-amplifier and the MN RF-amplifier. In that case, both RF-amplifiers must be calibrated and tested.

The so-called KWA-tool offers several calibrations (5 kW calibration, amplifier calibration) and several tests (PMU trip level test, linearity and gain test). These calibrations and tests use either a 50 Ohm dummy load, a 50 Ohm internal load, the body coil or transmit coil as load, dependent on the system type.

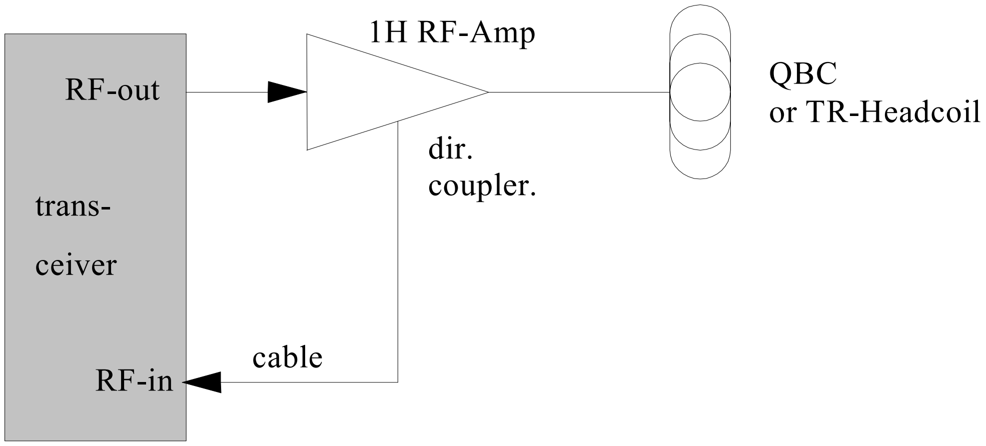
The service engineer uses the KWA-tool during installation, diagnostic measurement tools and planned maintenance.

9.2.1 THEORY OF OPERATION

1H RF-amplifier:

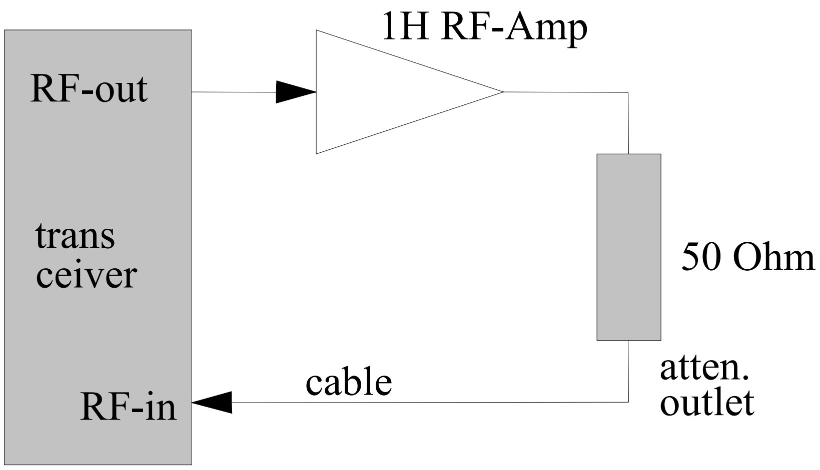
For the 1H RF-amplifier, the calibrations/tests offered by the KWA tool load the Sx RF-amplifier by the body coil, the transmit head coil, or a 50E dummy load. For the MR500x RF-amplifier, only the 50E dummy load is used.
When the body coil or the transmit head coil is used, the calibrated measurement cable is connected between the forward output of the directional coupler on the RF-amplifier and the 1H-transceiver (transceiver converter for 3.0T) RF-in (see Figure 14).

Figure 14 Hardware setup for calibrations/tests using the body coil.



When the 50 Ohm dummy load is used, the calibrated measurement cable is connected between the attenuation outlet of the 50 Ohm load and the 1H-transceiver RF-in (see Figure 15)

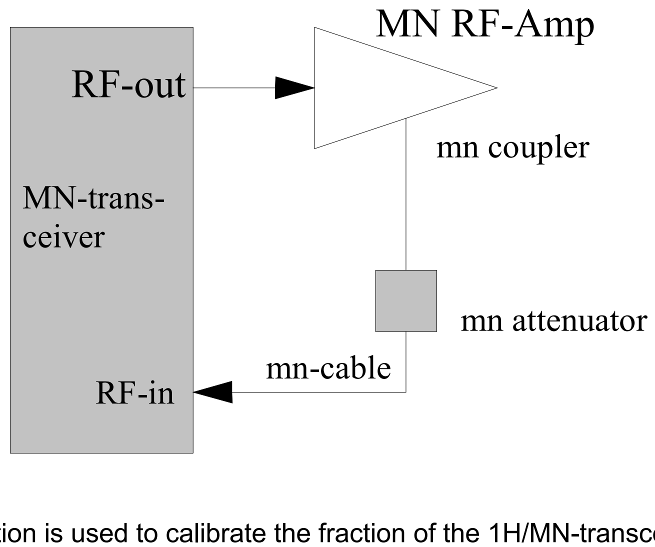
Figure 15 Hardware setup for calibrations/tests using the 50 Ohm dummy load



MN RF-amplifier:

For the MN RF-amplifier, the 5 kW calibration, the Amplifier Calibration, the PMU test and the Linearity and gain test use the 50 Ohm internal load. The calibrated MN attenuator and the calibrated measurement cable are connected between the forward output of the directional coupler on the MN RF-amplifier and the MN-transceiver RF-in (see Figure 16).

Figure 16 Hardware setup for calibrations/tests for the MN RF-amplifier using the 50E internal load



The 5 kW calibration is used to calibrate the fraction of the 1H/MN-transceiver full scale output signal (8/3 dBm) which yields an RF power of 5 kW. The fraction is derived from a 5 kW calibration. In case of a MR5000/1/2 RF-amplifier, this fraction is stored in the output parameter *RF drive cal scale*. In case of a MR5003 RF-amplifier, the fraction is stored in the output parameter *MN RF drive cal scale*. In case of an Sx RF-amplifier, the calibration is done in HIGH mode and, when applicable, also in MID and LOW mode. Also in case of an Sx RF-amplifier, separate calibrations are done for the BC path and for the auxiliary path. The resulting fractions for the BC path are stored in the output parameters *HIGH RF drive cal scale*, *MID RF drive cal scale* and *LOW RF drive cal scale*; the resulting fractions for the auxiliary path in *HIGH RF aux. drive cal scale*, *MID RF aux. drive cal scale* and *LOW RF aux. drive cal scale*.

Sx RF-amplifiers:

Before the measurement starts, the operator is asked to remove patients, phantoms and coils from the magnet (safety). Furthermore, the operator is asked to connect the calibrated measurement cable between the forward power directional coupler of the RF-amplifier and the 1H-transceiver. When the body coil (BC) is used as load, the 5 kW level is calibrated automatically for the HIGH mode and, when applicable, also the MID and LOW mode. The 50E dummy load can also be used. When the H-Head coil or the T/R-Head coil is used as a load, 500W is used in stead of 5kW. The calibration algorithm tries to minimize the difference between the actual measured ADC voltage and the expected ADC voltage by adapting the 1H/MN-transceiver output signal. To avoid scan aborts due to max pick-up trip level exceeded, the max. pick-up trip level is set to 100 before the calibration starts.

From R6.1.2 on, an extra, so called fine 5 kW calibration is performed after the before mentioned 5 kW calibration. The fine peak power calibration sets the PMU peak trip level of the RF-amplifier to 5000 [W] and slowly increases (step: 0.05 dB) the drive scale. The drive scale which causes the RF-amplifier to stop is called the fine drive scale. When the difference between the fine drive scale and the drive scale as determined before is less than 1.2 dB, then the fine drive scale will be used; otherwise, the previously determined drive scale is used. The difference in drive scales between the two calibrations is assumed to be caused by a receiver gain that differs from its nominal value (34.0 dB). The nominal receiver gain value is adjusted accordingly for the measurements that follow the 5 kW calibration (although this value is not stored!).

In case of an S21-64 RF-amplifier in combination with Powertrak 3000 or 6000, the operator is asked whether a cable length tuning measurement is required (default: ‘YES'). If the operator answers ‘YES', then the 5 kW calibration is performed twice: once without the 1/4 Lambda RF-cable, and once with the 1/4 Lambda RF-cable. The cable length which yields the optimal match, i.e. the cable length that yields the minimum *HIGH RF drive cal scale*, is the optimal length and is stored in the output parameter *Cable length*. If the difference in HIGH RF-drive cal scales with and without 1/4 Lambda RF-cable is less than 2%, then the current cable length is stored in the output parameter *Cable length*. If the cable length is not tuned, the output parameter *Cable length* has the value *Not tuned*.

MR5000/1/2:
The operator is asked to connect the calibrated 50 Ohm dummy load and to connect the calibrated measurement cable between the 50 Ohm attenuation outlet and the 1H-transceiver. Then, the 5 kW and 20 W levels are calibrated. The calibration algorithm tries to minimize the difference between the actual measured ADC voltage and the expected ADC voltage by adapting the 1H-transceiver output signal.

MR5003:
The 50 Ohm internal load of the MR5003 is used. The operator is asked to connect the calibrated MN-attenuator and the calibrated measurement cable between the amplifier's directional coupler and the MN-transceiver. The 5 kW level[3] is calibrated automatically. The calibration algorithm tries to minimize the difference between the actual measured ADC voltage and the expected ADC voltage by adapting the MN-transceiver output signal.

NOTE

When the scanner hardware configuration item 'MN-transcv. Board' is set to 'Available' (e.g. Multi Nuclei present) in GYROTOOL, it is assumed that an extra 3 dB Band Pass Filter is connected on the RF-in of the 1H RF-amplifier. This implies that the RF-drive-cal-scales are about a factor 1.41 larger compared to systems without Multi Nuclei. The specs are scaled accordingly.

9.2.2 PROCEDURE

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Installation procedures
6. Select: RF power amplifier procedures
7. Select: Max kW adjustment (select the appropriate channel and coil)
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

9.3 POWER REFERENCE MEASUREMENT

The Power Reference Determination (REF) tool is used to estimate initial values for the coil-parameters, such as B1 field, Q-factor and required RF-drive-scale, based on the coil information in the coil archive. The estimated values will be used as input for the power optimization preparation phase.

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3 To minimize the non-linearity of the gain in the working region (2.0 - 2.5 kW), it was decided to calibrate the 2.5 kW power level and to extrapolate the resulting drive-scale to 5 kW. As a consequence, the gain-difference (estimate: between 0.0 and 2.0 dB) between 2.5 kW and 5 kW must be taken into account for the spec-values.

9.3.1 THEORY OF OPERATION

The power reference measurement is used to estimate initial values for coil-parameters, which are used in the power optimization preparation phase. This power optimization precedes each scan. The power reference measurement is done using either a 3 L bottle (in case of the body coil), or a 1 L bottle (in case of the 1H head-coil or the T/R-head coil). In these latter cases, the 1 L bottle should be positioned inside the head-coil. The thus estimated reference power is used to calculate the patient's load factor. Besides the power-reference measurement, also the Q-factor is determined (in case of the body coil) and the pick-up coil calibration is done provided the coil is equipped with a pick-up coil (which is the case for the body-coil and the T/R-head coil).

NOTE

In case the mechanical position of the pick-up coil is changed, the pickup cal. B1/pickup coil sensitivity value will be unreliable and should be measured again. If the T/R-head coil is exchanged, the pickup cal. B1 value/pickup coil sensitivity should likewise be redetermined.

9.3.2 MEASUREMENT

Precondition: The Attenuator and Gain calibration, the 5 kW adjustment and the F0-determination must have been done.

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Installation procedures
6. Select: RF power ref and pu coil measurements
7. Select: RF power reference measurement "QBC/H-HEAD/T/R-HEAD"
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.

9.4 GAIN ADJUSTMENT RF-AMPLIFIER (MR5002, MR5003, S21 AND S22 ONLY)

CAUTION

Gain adjustment of the S23, S24 and S26 RF-amplifiers is not possible.
Don't touch any potentiometers inside the unit, it will disorder factory-only adjustments.

To adjust the gain of the RF-amplifier to the nominal value(s) (67.0 dB and/or 71.8 dB and/or 74.0 dB), the following procedure is used: first, a reference measurement will be done to calibrate the external BDAS gain. For this purpose, the calibrated measurement cable and the RF-input cable between transceiver and RF-amplifier must be connected between the transceiver output and the transceiver input. After this reference measurement, the measurement cable must be connected between the RF-amplifier's directional coupler (S21/S22) or the outlet of the 50 Ohm dummy load (MR500x). In case of a MR500x, S21-42 or S21-64 RF-amplifier, a continuous measurement is started and the measured gain at 5 kW is displayed continuously. The operator can adjust the potentiometers on the RF-amplifier to adjust the gain. The nominal gain values are maintained in the STT fixed archive.

9.4.1 PROCEDURE

PRECONDITION: the receiver- and transmit-attenuators of the 1H/MN-transceiver must have been calibrated.

Tools needed:

- 15 Mtr calibrated cable
- N-male to BNC-female adapter
- BNC I-piece

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: Gain adjustment
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.

9.5 RF-AMPLIFIER CALIBRATION (MR5002 AND MR5003 ONLY)

The MR5001, MR5002 and MR5003 RF-amplifiers have the possibility of an automatic output module calibration to calibrate the forward power at a fixed output level. For this calibration, a 50 Ohm dummy load (MR5002) or the internal load (MR5001, MR5003) is used. In case of a MR5002 or MR5003, the forward power calibration is preceded by a calibration of the peak power.

Forward power calibration:

RF pulses of either 200 W average power (MR5001, MR5003) or 80 W average power (MR5002) are generated and the RF-amplifier is put in forward calibration mode. After a few seconds, the RF-amplifier has finished the calibration and the RF pulse generation is stopped. The calibrated forward power is read back from the RF-amplifier and is saved in the output parameter *Ref. forw. power*.

9.5.1 MEASUREMENT

PRECONDITION: The 5 kW calibration must have been done

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Diagnostic measurement tools
6. Select: RF-amplifier measurements
7. Select: RF-amplifier calibration
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.

9.6 PICKUP COIL TRIPLEVEL ADJUSTMENT

The Pickup-Coil Trip Level Adjustment (PUA) tool is used to adjust the pickup-coil trip level and to check whether the determined trip level actually occurs and whether the trip level is not too critical.

The Pickup-coil trip level adjustment consists of three phases. Firstly, the power-scale factor, which yields the maximum allowed B1 field (33 uT for 0.5T and 1.0T, 26 (1.5T Omni) or 33 uT (Power/Master/Explorer) for 1.5T and 32 uT for 3.0T) is determined. Secondly, the Coilint trip level is decreased while the maximum B1 field is generated until a pickup-coil error is detected. The trip level, which yields this error, is uploaded from the BDAS and is saved in the output parameter *PU trip level setting*. Finally, the thus obtained trip level is used in combination with a B1-field, which is 2% less than the maximum B1-field. In this case, no pickup error should occur; otherwise the pickup-coil trip level setting is too critical. This is checked.
In this test there are only transmit coils allowed, in case of another coil the program displays an error and the measurement should stop.

9.6.1 MEASUREMENT

1. Select: Scan utilities
2. Select: Enter service mode
3. Select: System tuning
4. Select: System tuning tools
5. Select: Installation procedures
6. Select: RF power ref and pu coil measurements
7. Select: Pickup coil triplevel adjustment
8. Read the displayed infotext carefully.
9. Start the measurement with <PROCEED> and follow the instructions on the screen.
10. All measured values (in the displayed MRL) should meet the specifications.