Welcome at MR Achieva 3.0T TX
Welcome to the Introduction of and e-learning module for the Achieva 3 Tesla TX-system. This CBT is setup for those engineers who will soon receive a Achieva 3Tesla TX system. The course is an introduction to this system.

About the system
The Multi transmit system is introducing a new generation in 3 Tesla MR scanners. To address and overcome the challenges of 3T and to encourage the adoption of 3T as a mainstream system for all applications, Philips has undertaken an extensive development program. This has led to the next generation technology, called MultiTransmit parallel RF transmission. This technology is now available with the Achieva 3Tesla TX.

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3. How is the system built and what is the Multi Transmit Architecture?
4. Other new hardware introduced in the Achieva 3T TX system
5. How is the Installation of the Front covers for the Ambient Light Ring done?
6. An overview of the hardware in the System overview drawing
7. What are the new Achieva 3Tesla TX Software items?
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And 14. How is a Multi Transmit scan setup?

1.1 Introduction
The Achieva 3.0T TX is the first generation of multi transmit systems. MultiTransmit parallel RF transmission uses two fully independent RF channels. Both RF sources can be adjusted individually in power, amplitude, phase and waveform.

The New MultiTransmit software R3 has dedicated protocols for key application areas like torso, body, breast and spine imaging. The new software also includes the SmartExam Breast package. The 3T TX system’s appearance includes a patient friendly Ambient light Ring and dual-sided system controls, and also includes wireless physiology.
2.1 Problem
Why is multi transmit introduced? What problems do conventional 3T systems experience?
As MRI has moved to higher field strengths, the RF frequency for proton MRI has also increased. This is partly due to the electrical properties of the human body and partly due to the physical scale.

The RF excitation uniformity that is obtainable using a single channel RF transmit source, as used in conventional 3T systems, is sometimes not adequate for reliable clinical diagnosis in some applications and with some patients.

Sometimes this results in dielectric shading artifacts, depending on the size and shape of the patient. In the image you see 2 kind of patients; a smaller one and a larger one in the transmit body coil.

Dielectric shading artifacts can appear in the images.

Dielectric shading is a result of RF standing waves inside the object. It results in a non-uniform transmitted B1 field inside the object, and also a non-uniform receive sensitivity!

The image shows a patient in the transmit body coil.

The colors in the image indicate a difference in RF field strength; Red is pointing to a higher B1 field, and blue stands for a lower B1 field. You can clearly see that the homogeneity of RF field is not optimal in the patient.

The RF standing waves can interfere in an object destructively; leading to dark regions or constructively; showing up as bright regions.

2.2 Solution 1
Multi-channel RF transmission or MultiTransmit, using multiple RF transmit/receive chains and coil elements in parallel, has demonstrated that it is possible to significantly improve RF or B1 field uniformity in high-field MRI.

MultiTransmit employs multiple RF sources that can be individually adjusted to each patient’s unique anatomy.

This is also called patient adaptive RF shimming.

The results are directly visible; the homogeneity of the RF field is considerably better. The image quality shows that the dielectric shading artifact has been tremendously reduced and that the image uniformity is enhanced.

Furthermore, we also experience that improved RF uniformity using RF shimming is accompanied by reduced whole-body and/or local SAR.
2.3 Solution 2
Destructive or constructive interference of RF standing waves can be influenced by the transmitted RF pulses from multi individually controlled RF sources, and by controlling some demodulation parameters of the received MR signal.

Individually adjusted multiple RF sources (via Body Coil TX channel 1 and 2), adjusted to each patient’s unique anatomy, is called B1 shimming or RF shimming.

In the top drawing you see an example of an unshimmed B1 field.

After adjusting some parameters of the transmitted RF pulses, a shimmed B1 field is the result.

2.4 Solution 3
Patient adaptive RF shimming can be used for both individually controlled RF transmit source’s 4 variables; the RF waveform, phase offset, amplitude scaling and the frequency offset.
In the present Achieva 3Tesla TX system, 2 separate RF sources are available.

Philips, along with numerous researchers, are exploring the benefits of increasing the number of RF sources. Philips’ own development started with a MultiTransmit system being built using 8 RF sources.
Based on the experience gained in-house, and with external research partners, Philips’ researchers established that two sources, when implemented with full flexibility and control, provide the largest proportion of dielectric shading correction that can be obtained.

Due to the reciprocity principle, RF shimming can also be used during MR signal reception. In the demodulation process, 3 variables per receive channel can be used for more in depth RF shimming: Independent scaling, Phase offset and Frequency offset.

To find out more about multi transmit and its background, click on the link, or go to the attached file “2009 White Paper Multitransmit.pdf”.
2.5 Benefits

The clinical benefits for the customer using a multi transmit system are:
1. MultiTransmit parallel RF transmission technology addresses dielectric shading and local SAR at the source
2. Patient-adaptive RF management gives consistent results in every anatomy and for every patient, and
3. Up to 40% faster scanning compared to conventional 3T; due to the lower SAR.

3.1.1 TX chain

How are these functions implemented in the hardware?
Let’s compare a conventional 3 tesla system with a multi transmit, and have a look to the architecture of the transmit chain.

Let’s look first at the transmit chain of a conventional 3 tesla Achieva X system:
The TXR-board in the CDAS gives RF input to an RF amplifier.
The amplified RF pulse is send via the T/R Switch to the hybrid box.
In the hybrid box, the RF signal is equally split in two in amplitude, but with 90° phase shifted RF signals.
Both signals are fed to the QBC respectively to mode 3-11 (TX1) and 7-15 (TX2).
Reflected RF power from the QBC is dumped in the dummy load, and connected to the 90° power splitter.
The QBC, loaded with a patient, creates a circular polarized RF field.
During the Transmit cycle, the pickup coil circuit is continuously monitoring the created RF field.
The sum of the signals of the two pickup coils is compared on the MRX board to a switch off level.

3.1.2 RX chain

The receive chain of a 3 tesla conventional system works in this way:
The two modes of the QBC receive the MR signal.
Both signals are pre-amplified and fed into a 90° Receive combiner.
The sum of the two signals is fed into the QBC receive channel of the MRX board.
3.2.1 TX chain

On the other hand, in the Achieva 3Tesla TX system, a second RF transmit source is added to the system.

The RF transmit chain works as follows:

A first TX channel is using the regular TX path via the T/R Switch to the Quadrature Body Coil Interface Box (QIB).

A second TX channel is feeding the RF TX pulses directly into the QIB.

We have now two individually controlled RF channels:

- TX Channel 1 to Body Coil TX1 mode 7 - 15
- TX Channel 2 to Body Coil TX2 mode 3 - 11

Both TX channels are individually adjustable in amplitude, phase, waveform and frequency.

They create a circular polarized RF field in the transmit body coil.

Two Circulator circuits are used to dump the reflected power of each channel into its own 50 ohm dummy load. Both are located inside the circulator box.

2 PU coil channels monitor each transmit channel separately: One via MRX board 1, the other via MRX board 2.

3.2.2 RX chain

In the 3T TX system body coil receive path, we see that the two body coil modes are treated as 2 separate receive channels.

Each mode of the Body Coil detects the MR signal vector.

Each detected MR signal is pre-amplified and fed into separate receive channels of the MRX boards.

Both MR Receive vectors are demodulated separately.

During demodulating the two receive signals, variables such as scaling, phase and frequency offset are used to minimize dielectric shading artifacts.

At the end, the two signals are added in the reconstruction process.
4.1 Hardware changes

When we look at the hardware changes, we see what we need for the Individually controlled multi-Transmit /Receive channels of the Body Coil:
1. An Additional TXR-board in the CDAS rack
2. A New additional cabinet (ACC-TX) with two solid-state RF-amps and the circulator box AN8133. *(Pronounced “A-N-81-33” or “A-N-8-1-3-3”)*
3. There is a new hybrid box, called QIB *(Pronounced “Quib” or “Kib” or “Q-I-B”)* with Integrated attenuators for the PU-coil signals and separate multi receive and PU-coil outputs to the MRX-boards.

The Body Coil remains unchanged, also for TX upgrades.

From an installation point of view: There are no significant differences between installing an Achieva 3.0T X system or an Achieva 3T TX system.

4.2 Upgrading

Upgrading systems from Achieva 3Tesla X to 3Tesla TX.

Achieva 3T X systems either with a DACC can be upgraded to Achieva 3.0T TX systems.

Please note that the Achieva 3T TX covers that have the Ambient light rings and the new User Interface Modules are not part of the TX upgrade package; only initial delivered TX systems will get this new hardware.

4.3 Hardware configuration DACC

There are different hardware configurations of the technical room cabinets with DACC when upgrading your system. The differences are explained on this slide.

Starting from an initial or field upgraded X system, adding the TX upgrade package will result in this TX upgraded configuration; notice that the RF amp previously located in the DACC is now moved to the ACC TX cabinet with the upgrade.

Starting with an X-series system with the Multi Nuclei option, now an upgraded TX system with the TX upgrade package; notice that the Multi Nuclei amplifier with its PMU, and the RF amp 3T have swapped places. The ACC-MN cabinet can be disposed after the TX upgrade.

Please note, you have the option to upgrade your system with the Multi Nuclei option before or after the TX upgrade.
4.4 Hardware configuration NTDACC
The different hardware configurations of the technical room cabinets with NTDAC when upgrading your system are explained on this slide.
Starting from an initial or field upgraded X system with NTDAC, adding the TX upgrade package will result in this upgraded TX configuration; notice that the RF tube amplifier is not supported in the TX system and has to be returned to Best.
Starting with an X-series system with Multi Nuclei option and NTDAC, now upgraded with the TX upgrade package to an upgraded TX system; notice that here also the RF tube amplifier needs to be returned to Best.
Please note, you have the option to upgrade your system with the Multi Nuclei option before or after the TX upgrade.

4.5 Circulator box 1
The Circulator box is a device from Analogic, the AN8133, and is located in between the two Solid State RF amplifiers in the ACC TX cabinet.
The Circulator is the interface between the two AN8134 amplifiers and the two ports of the body transmit coil.
It is designed to provide isolation for the RF amps that drive the module from the intended load, the Body coil.
The two-channel specially designed circulator circuits inside the box re-direct reflected power from the load to an internal resistive load.
Forward and reflected couplers allow accurate sampling of the RF on the output of the module.

4.6 Circulator box 2
Diving deeper into the circulator box, we find two separate yet completely identical circulator circuits.
At each circulator circuit is connected a 50 Ohm RF dump load, used to dump the Reflected Powers from each port of the body coil.
The Temperatures of the load and the Circulator are monitored; any problems are reported via the parallel link.
These Parallel links are daisy chained from the two TXR boards in the CDAS to the two RF amplifiers. Each circulator circuit has a Forward and Reflected Power connection to a TXR board in the CDAS rack.
4.7 Circulator box 3
The Circulator box is treated as one Field Replaceable Unit.

Its weight is about 39 kilograms.

A Service lifting tool will be available for the RF amps and the circulator box. The tool can be ordered via the Tool Catalog.

All 7/16 DIN RF connections have to be tightened with the delivered 20 Newton meter torque wrench. You will find the wrench at the bottom of ACC-TX cabinet. Take care: the wrench is made of magnetic material and may not be used in the examination room!

For Faultfinding purposes there are LED indicators for Channel 1 and Channel 2.

The LED’s indicate faults. These faults include excessive reflected power via the VSWR LED, the Internal RF load Overheated via the LOAD OH LED’s, and the Internal Circulator Overheated with the CIRC OH LED’s.
More information is available in the AN8133 service manual on InCenter.

4.8 Other new hardware
Newly delivered 3tesla TX systems will have additional new hardware delivered:
Dual sided, on the left and right User Interface Modules, connected to the User Interface Hub on the magnet.
An LED-power sourced Ambient-light ring powered via an Additional Power Supply located in the Patient Support.
New front/rear covers and ring frames.
Modified Physiology Display Bezel/bracket.
Also note that the location of the RF-coil connections is placed on a different position. Now, you can find them on the left side, only.
The RF coil receive connections are also called the Façade connectors.

5.1 Installing front covers
Installing the front covers that include the ambient light ring is done in the following way:
First the cone cover is shifted into the magnet bore.
Then the bottom cover is mounted.
Now the cone and bottom cover can be tightened with 4 nuts to the ring frame by a spanner.
The light ring consists of two parts; an upper ring and a lower ring.
Move the upper light ring to the magnet and click it inside the cone cover; just push with your fingers.
Connect the LED power cable on both sides.
Now the bottom ambient light ring can be mounted and connected on both sides.
Then connect the little connector covers; called the façade bezels.
Now, at the end, connect the cables to the User Interface Modules, mount them and tighten them with one screw one the inside.
6.1 System overview drawing
Please study the system overview drawing carefully.
The differences or additional hardware there now is when compared to the Achieva 3Tesla X system you find in blue.

7.1 Software items
The Achieva 3Tesla TX is build on a new software release, release 3.1.
The software platform is designed for installation, operation and diagnostics of the new Multi transmit system.

This Release 3.introduces the smart breast package to the customer.
It includes also an interactive resonance frequency determination.

The scan parameter interactive f zero is set in the post-processing tab.
It enables a graphical user interface for the operator. so that he or she can select and set the resonance frequency of the water protons.

With the multi transmit system, a new preparation phase is introduced, called RCU check. It is a functional check of the RF circulator unit, checking forward and reflected power.

8.1 Configure the new system
When we set the hardware configuration in the Field Service Framework, we have to take care of some items.

First of all, the only supported amplifier type at this moment is the solid state amp AN8134, tuned at 128 Mega Hertz.
The magnet cover type for initial TX systems is Achieva Ambiring.
The number of receive channels can either be 16 or 32 channels; a 3 Tesla TX system with 8 receive channels is not supported.
The number of Hydrogen Transmit channels is two.
The examination room system control unit needs to be set for new systems to SCU 3.
This indicates that the system control unit used for this system is the User Interface Module.

9.1 Adjusting the new hardware
When we look at the adjustments for the Achieva 3 Tesla TX system, we see that the only new adjustment for this system is the Multi Transmit RF calibration.
This adjustment is found in the menu system of the adjustments - in the Installation procedures - in Test and Tuning procedures - in the Field service framework.
The Calibration is automatic. It is done with the 1 liter bottle phantom filled with mineral oil.
This measures the phases of the two body coil transmit and receive channels, and calculates the receive sensitivity of both body coil channels.
All results are stored in the body coil parameter list.

10.1 RF chain hardware 1
A quick test of the new RF chain hardware - in particular the circulator box - is set in menu quick checks of the installation procedures.
In this general test, each transmit channel of the circulator box is checked on its status for mains power, internal and external faults.

10.2 RF chain hardware 2
The other new, or additional boards and units, are tested in the submenu’s CDAS [pronounce C das], RF-amp and chain of RF in the diagnostic procedures.
Look the next slides for more information.

10.3 RF chain hardware 3
In the CDAS sub menu we find the transmitter boards, TXR1 and TXR2 in the CDAS rack, self tests and properties tests.
All of these tests are automatic.
Further, we can do interactive tests to test the serial and parallel interfaces of the two RF amps.
Finally, there are also interactive output tests of the two TXR boards. An oscilloscope is needed to do these measurements.

10.4 RF chain hardware 4
The two RF amps and the two transmit circuits of the circulator box can be tested individually in the RF-amp menu.
The following tests are available:
Rf amp general tests
Circulator general tests
RF amp info overview tests
PMU tests
Maximum kilowatt tests of the separate transmit circuits to the body coil
RF amp gain and linearity tests
Rf pulse droop tests
And, last but not least, Voltage standing wave ratio tests of both transmit chains to the body coil, or of TX1 and TX2 from the RF amps to the circulator box.

10.5 RF chain hardware 5
Finally, in the new RF chain hardware tests, there are some tests listed in the Chain menu.
The Multi Transmit RF verification test will verify the functions of the circulator box.
There are noise tests for the two body-coil receive channels and stability tests for the TX1 and TX2 RF transmit channels.
With RF insertion losses we can test the RF losses in the two transmit chains. And some generic procedures which need to be used in combination with the RF chain procedure doc.

10.6 Other hardware
Continuing our exploration of the diagnostic procedures, we can test the other new hardware that is introduced with this TX system, namely the User Interface modules and user interface hub. Board tests, button and interface tests are available to the user via the menus of patient support and patient communication.
On the UIM left or UIM right, the same patient and patient support functions are implemented compared to the PICU; only the layout is a little bit different. Roll over the image to see more information.

10.7 Firmware installation
The User Interface Hub board contains firmware that can be updated. New firmware can be downloaded to the UIH board via the function UIH firmware download. Users are advised that with each firmware download, they should follow the process of downloading via the actual logging display function. “Start, Run, LOG D”.

11.1 Replacement procedures 1
You can find a list of all tests and calibrations that have to be performed after the replacement in the replacement procedures for each hardware replacement what you do. Find and select the hardware part that is replaced, and the to-do list appears on the screen. Now you can simply select the test or calibration to be done. For example, on the right you can see the tests and calibrations that are required when the circulator box is replaced.

11.2 Replacement procedures 2
The new FRU’s for the TX system are the circulator box, the QIB, the UIM’s and UIH, the upper and lower ambient light ring, and the power supply for the light ring.

12.1 Planned maintenance actions
The Planned Maintenance procedures for the Achieva 3Tesla TX systems described in Field service framework, Test and Tuning procedures are not different than these of the Achieva 3.0T X-systems.
Automatic calibrations, typical for TX hardware are included in the PM menu; for example “Multi Transmit RF calibration”.
13.1 Multitransmit scan setup

The last item in this CBT we want to look at is what is important for multi transmit scanning.
First of all, there are no new System performance test scans specified to check the image quality of this system.
The Regular SPT scans are used to check whether the image quality of the system is within specifications.
To setup Multi Transmit scans, you first have to enable the multi transmit mode via a scan parameter in the geometry tab.
When Multi Transmit is enabled, the user has the choice to enable RF shims in tab Contrast.
With RF shims enabled, the homogeneity of the B1 field is optimized.
The optimization can only be done when the Multi Transmit scan is preceded by a B1 calibration scan.
In the geometry tab, it is also possible to select which QBC Receive coil elements are used for the scan; coil element 1, or coil element 2, or both.

Finally you can see on the slide how to setup a multi transmit scan procedure in combination with sensitivity encoding:
First you select the survey scan on which you can position the slices of the next scans.
Then you need to select a B1 calibration scan.
These prepared scans are in the protocol list called ‘Calibrations’.
Next you select the sense reference scan.
And finally you select sense scans with the multi transmit scan parameter set to ‘enabled’ to start ‘multi transmit scanning’.
On the right you find an example of an exam card of a multi transmit scan.

Summary

This concludes the “Introduction to Achieva 3 Tesla TX systems” CBT.
In this e-learning module you learned:
Why Multi Transmit was introduced
About Multi Transmit Architecture Hardware and Software
Other new hardware introduced with the Achieva 3.0T TX system
Installing Front covers including the Ambient Light Ring
How to configure the new system
Which new adjustments are needed for the RF chain
How to test the new hardware of the RF chain
How to test the ‘other new’ hardware UIM/UIH
How to load new firmware in the UIH
Where to find the Replacement Procedures
What the FRUs are, typical for TX systems.
Where to find the new actions for Planned maintenance
How to check the Image Quality of the Multi Transmit system, and
How to setup a Multi Transmit scan.