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3T MRI systems

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3T MRI systems
Issue 3

Comparative report on five MRI systems

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Summary

Purpose of this report

CEP has produced a series of comparison reports to aid the selection of MRI equipment. Although most hospitals are purchasing 1.5 tesla (T) MRI systems there is a growing market for 3T systems as they provide an increased signal-to-noise ratio, better spatial resolution and an improved temporal resolution. This report provides updated comparative specifications from RSNA 2005 and technical evaluation of 3T systems.

Comparative specifications

The comparative specification is presented as a side-by-side summary comparison of the specifications of each scanner and related equipment. It is grouped into a series of sub-sections relating to different aspects of the scanner, such as magnet, gradients, coils etc. A dedicated section on parallel imaging coil has been included. The data have not been verified by CEP.

Technical evaluation

The technical evaluation section presents a detailed analysis of the head and body coils available from each manufacturer. Parameters such as signal-to-noise ratio, uniformity and resolution are included in the evaluation. Furthermore dedicated sections on parallel imaging and acoustic noise have also been incorporated. The data are published after consultation with manufacturers. Their comments are included in the Appendix.

Introduction

This report combines system specification, safety and technical evaluation results to provide a comprehensive comparison of 3T MR systems available on the UK market. This report replaces the previous issue (Report 05048). There are other factors, outside the scope of this report, which should be taken into account in purchasing decisions. For information on capital and operating costs, maintenance, safety and peripheral equipment please contact MagNET.

The aim of the technical assessment is to obtain type-test measurements of imaging performance of MR systems. Type-testing is the evaluation of one machine, confirmed by the manufacturer as operating to specification that is taken to be representative of that model. The measurements enable a comparison of different type-tested MRI systems. The technical evaluation is normally carried out at a factory site with the full cooperation of the manufacturer. In special circumstances, where resources are available, the evaluation can be carried out at a clinical site. The results are consequently of a scientific nature and are intended as a guide to image performance.

This report does not attempt to explain MRI. Readers who are unfamiliar with this modality may have difficulty understanding the results presented in this report. In this case, advice should be sought from a suitably qualified MRI specialist.

Structure

The main body of the report is divided into two sections, the first presents system specifications, system information and safety evaluation, and the second gives technical evaluation results. The results contained in this report are published after consultation with the manufacturer. Their comments are included in the Appendix.

Evaluated systems

This report presents system specification and technical evaluation data of the MR systems listed below and shown in Figure 1.

Table 1. 3T MRI systems

Company	GE	Philips	Siemens	Siemens	Siemens
Model	HDx	Achieva	Allegra	Trio	Trio, A Tim system
Gradient system	Twinspeed HDX	Quasar Dual	Allegra	Sonata	TQ engine

Figure 1. Evaluated 3.0T systems

GE HDX

Philips Achieva 3T

Siemens MAGNETOM Allegra

Siemens MAGNETOM Trio

Siemens MAGNETOM Trio, A Tim system

Comparative specifications

Specification data were correct at the time of going to press (subsequent updates or newer versions from the manufacturers are not accounted for). The data provided have not been verified by CEP. An entry of “Not supplied” in the tables indicates that the manufacturer(s) did not supply CEP with the required information in time for publication of this report.

Magnet system

Table 2. Magnet specification

	GE HDx	**Philips Achieva**	**Siemens Allegra**	**Siemens Trio**	**Siemens Trio,A Tim system**
RF frequency *MHz*	127.7	127.7	123.2	123.2	123.2
Shielding	Active	Active	Active	Active	Active
Homogeneity (V-RMS) 40 cm DSV *ppm*	0.25	0.6	Not supplied	0.1	0.1
Number of measurement planes	24	12	18	24	24
Number of points per plane	-	12	24	20	20
Field stability *ppm/hr*	<0.1	<0.1	<0.1	<0.1	<0.1
Cooling system	Liquid helium	Liquid helium	Liquid helium	Liquid helium	Liquid helium
Boil-off rate *l/hr*	<0.03	≤0.15	<0.1	<0.12	<0.12
Helium refill	~4 years	~1 year	7 months	~9 months	~9 months

Table 3. Magnet shimming details

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Passive on installation	Yes	Yes	Yes	Yes	Yes
Number of shim plates	36 trays	36 rails	24 trays, 17 pockets per tray	16 trays, 15 pockets per tray	16 trays, 15 pockets per tray
Active with patient in position	Yes 3D autoshim	Yes	Yes 3D autoshim	Yes 3D autoshim	Yes 3D autoshim
Number of independent channels	3 linear terms with gradient offsets, 5 second order and 14 higher order terms	3 first order, 5 second order	3 linear terms via gradient offsets, Additional 5 second order terms	3 linear terms via gradient offsets, Additional 5 second order terms	3 linear terms via gradient offsets with 20 coils, Additional 5 non linear second order terms with 32 coils*

* Can be used for patient-specific shimming

Table 4. Patient comfort details

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Patient aperture at narrowest:					
Width *cm*	60	60	35	60	60
Length *cm*	105	60	78	150	142
Height (couch to pole) *cm*	46.5	42	35	40	45.5
Patient aperture at maximum:					
Width *cm*	106	154	60	120	Not supplied
Height *cm*	69.5	96	60	80	Not supplied
Length (with covers) *cm*	201	167	142	225	213
Patient couch:					
Min height *cm*	69	52	46	45	57
Max height *cm*	97	89	80	100	100
Table top width *cm*	40	53	55	54	54
Body mass limit *kg* (full movement)	159	150*	200	200	200

* 250 kg with no vertical movement

Table 5. Magnet installation details

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Mass: magnet and He only *t*	9.5	5.5	4.0	10.0	10.0
Mass: assembly *t*	12.0	6.8	5.15	12.0	12.0
Depth (with covers) (z) *cm*	201.6	167	147	225	213
Width (with covers) (x) *cm*	216.6	200	195	238	244
Height (with covers) (y) *cm*	240	206	220	226	221
Radial (x,y) 0.5 mT fringe field *m*	2.8	3.0	2.9	3.4	3.4
Axial (z) 0.5 mT fringe field *m*	5.0	5.2	4.4	5.9	5.9
Minimum installed area m^2*	36	20	28	<33	<33
Minimum ceiling height *cm**	266.7	290	300	273	273

*To include 0.5 mT fringe field

Table 6. Electronics cabinets

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Number of cabinets	5	4	3	3	2 cabinets, additional RF-amplifier
Total width *cm*	287.3	259	225	276	156
Maximum depth *cm*	95.2	98	65	65	65
Maximum height *cm*	217.4	196	189	189	197
Cooling system	Air	Water	Water	Water	Water

RF system

Table 7. RF system specification

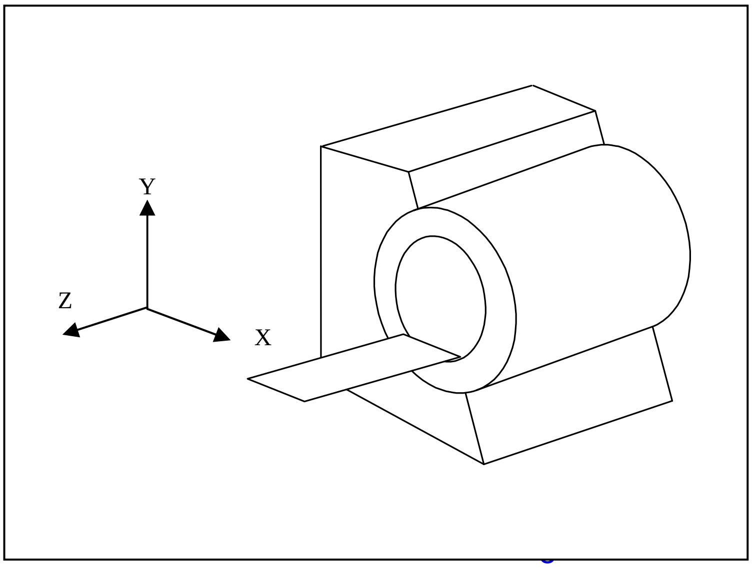
	GE HDx	Philips Achieva	Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
Name/type/ version of the system	HDx	Freewave	iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels (standard/ optional)	8 (std) 16 (opt)/ 32 (opt)	8 (std) 16 (opt)/ 32 (opt)	4	8	8	8	18	32
Bandwidth of each independent RF receiver channel (*MHz*)	0.5	3	1	1	1	1	1	1
Number of Analog-to-Digital Converters for each independent RF channel	1	1	1	1	1	1	1	1
Sampling frequency of each Analog-to-Digital Converter (*MHz*)	Not supplied	80 Direct digital sampling with no intermediate frequency modulation	10	10	10	10	10	10

Gradient system

Table 8. Gradient system specification (x, y, z as defined in Figure 2)

	GE HDx		Philips Achieva		Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
	Zoom mode	Whole body mode	Standard mode	Enhanced mode			
Shielding	Active	Active	Active	Active	Active	Active	Active
Single axis maximum amplitude *mT*/m							
x (horizontal)	50	23	40	80	40	40	40
y (vertical)	50	23	40	80	40	40	40
z (along the bore axis)	50	23	40	80	40	40	45
Single axis slew rate *mT/m/ms*							
x (horizontal)	150	80	200	100	400	200	200
y (vertical)	150	80	200	100	400	200	200
z (along the bore axis)	150	80	200	100	400	200	200
Duty cycle at max amplitude %	100	100	100	100	100	100	100
Amplitude at 100% duty cycle *mT/m*	50	23	40	80	40	40	40; 40; 45

Figure 2. Gradient directions



Sequence information

Quoted values correspond to imaging with no interpolation, no asymmetric echo, no partial Fourier, no parallel imaging, no fat-sat, no rectangular matrix, no rectangular field-of-view.

Table 9. Speed parameters

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Minimum TR *ms* Spin echo*	7	29.6	11	11	6.8
Minimum TR *ms* 2D gradient echo*	2.6	1.1	1.72	1.66	1.5
Minimum TR *ms* 3D gradient echo*	1.3	1.1	1.72	1.66	1.5
Minimum echo spacing *ms* Turbo spin echo*	2.5	2.29	4.12‡	4.26‡	3.86‡
Minimum echo spacing *ms* Echo planar imaging†	0.296	0.34	0.42	0.43	0.41
Minimum TE *ms* Single-shot diffusion imaging with b-value of 1000 mm^2/s†	64.8	37	57	57	53

* For 256x256 matrix with no interpolation
† For 128x128 matrix with no interpolation
‡ with 3T-optimized low-SAR RF pulses

Table 10. Resolution parameters

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Minimum FOV *mm*	10	5	5	5	5
Maximum imaging matrix	1024 x 1024	2048 x 2048	1024x1024	1024x1024	1024x1024
Minimum 2D slice thickness *mm*	0.5	0.5	0.1	0.1	0.1
Minimum 3D slice thickness *mm*	0.1	0.05	0.05	0.05	0.05

Table 11. Sequence packages: standard packages (1)

	Packages
GE HDx	**Scantools (standard package)**: Fast Spin Echo(FSE – Minimises T2 blurring with short echo spacing), Fast Recovery FSE(FRFSE) and FRFSE-XL – high quality, high speed, high contrast T2-weighted imaging, VERSE – improves T1 & T2 contrast whilst reduces SAR, MART, Single Shot, Fast Spin Echo(SSFSE) & Enhanced MRCP – Ultrafast acquisition in a single excitation for excellent T2 weighted brain & abdominal imaging, Gradient Echo (GRE)- 2D & 3D FGRE, 2D&3D SPGR, FSPGR used in vascular and contrast enhanced MRA, Dual Echo GRE – 2 sets of images in a single breath hold, SPECIAL – spectral inversion with optimised fat suppression used with 3DGRE, I-DRIVE Pro – real time interactive imaging, HD LAVA – 3D SPGRE technique giving contrast enhanced breath hold dynamic liver imaging (asset factor up to 3.5), T1 & T2 FLAIR for contrast between gray and white matter in brain and spine imaging, Echoplanar and Flair Echoplanar – rapid neuro imaging, DW Echoplanar imaging – single shot FLAIR & Diffusion Weighted epi , BRAVO- IR prepared 3D GRE technique for isotropic coverage, combined with parallel imaging capabilities giving gray-white matter contrast at high speed, 2D MERGE – for improved gray-white matter contrast in the spinal cord, Black Blood Double and Tripple IR, ECG-Gated FGRE & FSPGR FastCine – for functional analysis, 2D & 3D Gated and Enhanced TOF – non contrast enhanced angiography, 2D & 3D PC, SmartPrep – triggering for optimum MRA, SmartStep – enhances vascular run offs, Interactive Vascular Imaging(IVI) – enhanced background subtraction. ASSET (opt) – reduces scan time to increase spatial or temporal resolution, compatible with phased array coils up to acceleration factors of 3.5 and sequences: 2DFGRE, 2DFSPGR, 3DFGRE, 3DFSPGR, 3DTOFGRE, 3DFSPGR, 2DFSE, 2DFSE-XL, 2DFSE-IR, T1-FLAIR, SSFSE, EPI, DW-EPI, BRAVO, HD LAVA(opt), 3D FLAIR(opt), TRICKS-XV(opt), BrainWave-RT (opt). GEM – accelerated imaging to increase resolution and coverage. Also contains post processing capabilities such as MPVR (Multi projection Volume Recon), MPR and FuncTool Performance for ADC maps, eADC maps, correlation coefficients, NEI, MTE, PEI, Signal enhancement ratio, Max slope increase, Max difference function.

Table 11. Sequence packages: standard packages (2)

	Packages
Philips Achieva	**ScanTools package** (standard on each Achieva system): Spin Echo (SE); Fast Field Echo (FFE) including steady state (Balanced-FFE) and spoiling techniques; Turbo Field Echo (TFE) including pre-pulses and flip angle sweep; Turbo Spin Echo (TSE) with single and dual echoes, DRIVE (Driven Equilibrium), Single Shot (SS) TSE; Echo Planar Imaging (EPI) Multi Shot (MS) and Single Shot (SS) for FFE and SE imaging compatible with pre-pulses; Inversion Recovery (IR, STIR, FLAIR) compatible with SE, TSE and EPI imaging methods; Time of Flight (ToF) with FFE and TFE imaging techniques, including RF Spoiling and MTC, gating acquisitions and dual gated inflow, 3D acquisition with TONE and multi-chunk (MOTSA); Contrast Enhanced (CE) with CENTRA with ultra-short short TE, FFE and TFE, CENTRA (Contrast Enhanced MR Angiography with 3D profiles); Phase Contrast (PC) 2D and 3D with variable VENC values, retrospectively gated 2D multi-phase; Quantitative flow in 3 directions; CLEAR (Constant LEvel AppeaRance); Cardiac gated breath-hold TFE: bright blood or dark blood; Single-slice multi-phase with Balanced FFE with retrospective gating; 3D k-space shutter 25% reduction in scan times. ProSet (provides water- or fat-selective excitation images), SPAIR (fat saturation technique to address RF field inhomogeneities). BLISS (bilateral breast imaging in the sagittal view with SENSE), TRACS, time-resolved MRA, SENSE parallel imaging for all sequences (SENSE factor 2)
Siemens Allegra	**Core package**: Spin Echo (SE), Inversion Recovery (IR), 2D/3D TurboSE, Turbo IR, Dark-Fluid IR, True IR, 2D/3D Multi-Echo Data Image Combination (MEDIC), 2D/3D Gradient Echo (GRE) Fast Low Angle Shot (FLASH), 2D/3D GRE Fast Imaging with Steady Precession (FISP), 2D/3D PSIF (Time-inverted FISP technique), 2D Turbo FLASH, 3D Magnetization Prepared Rapid Gradient Echo imaging (MP-RAGE) (3D TurboFLASH), 2D/3D Time Of Flight (TOF) angiography, Magnetization Transfer Contrast (MTC), Tilted Optimised Non-saturating Excitation (TONE) used with 3D TOF Magnetic Resonance Angiography (MRA), Gradient Motion Rephasing (GMR), Long Term Averaging (LOTA)
Siemens Trio	**Core package**: Spin Echo (SE), Inversion Recovery (IR), 2D/3D TurboSE, Turbo IR, Dark-Fluid IR, True IR, 2D/3D Multi-Echo Data Image Combination (MEDIC), 2D/3D Gradient Echo (GRE) Fast Low Angle Shot (FLASH), 2D/3D GRE Fast Imaging with Steady Precession (FISP), 2D/3D PSIF (Time-inverted FISP technique), 2D Turbo FLASH, 3D Magnetization Prepared Rapid Gradient Echo imaging (MP-RAGE) (3D TurboFLASH), 2D/3D Time Of Flight (TOF) angiography, Magnetization Transfer Contrast (MTC), Tilted Optimised Non-saturating Excitation (TONE) used with 3D TOF Magnetic Resonance Angiography (MRA), Gradient Motion Rephasing (GMR), Long Term Averaging (LOTA)

Table 11. Sequence packages: standard packages

	Packages
Siemens Trio, A Tim system	**Tim application suite includes**: neuro, angio, cardiac suites. See following tables. **Sequences**: Spin Echo (SE): Single, Double and Multi Echo (up to 32 echoes). Inversion Recovery (IR). 2D/3D FLASH (spoiled GRE). 2D/3D FISP. 2D GRE segmented. 2D/3D PSIF. PSIF Diffusion. 2D/3D TrueFISP. TrueFISP segmented Shared Phases Real-time TrueFISP (without ECG). 2D/3D MEDIC (Multi Echo Data Image Combination). 2D/3D TurboFLASH (MPRAGE). 3D VIBE (Volume Interpolated Breath-hold Examination), using interpolation and fat saturation. 2D/3D TSE. Echo Sharing technique for dual-contrast, proton density and T2 images simultaneously. 2D/3D Restore TSE. Single-slab 3D TSE (SPACE) for T2 and dark-fluid applications with isotropic resolution. 2D/3D TurboIR (TrueIR, STIR, DarkFluid T1 and T2). 2D/3D HASTE (Half-Fourier Acquisition with Single Shot Turbo Spin Echo). 2D/3D HASTE IR for fat or fluid suppression. 2D/3D Single Shot TSE for heavy T2 weighting. 2D/3D Time-of-Flight (ToF) Angiography, single and multi slab. 2D/3D ToF, triggered and segmented **Body suite (standard)**: Free breathing 2D PACE applications with 2D/3D HASTE (Restore) and 2D/3D TSE (Restore). Single-shot HASTE. Fat suppression protocols with Quick FatSat, STIR, HASTE and FLASH in-phase/opposed-phase protocols and multi-echo TSE. Dynamic 3D VIBE protocols. Colonography bright lumen with T2-weighted TrueFISP and dark lumen with T1-weighted VIBE. Dynamic volume examinations with 3D VIBE **Onco suite (standard)**: STIR TSE and FLASH in-phase/ opposed-phase protocols. Breast imaging protocols with iPAT. Dynamic imaging protocols for assessment of the kinetic behaviour for lesion detection and characterization. Quantitative evaluation with colorized Wash-in, Washout, Time-To-Peak, Positive- Enhancement-Integral, MIPtime, and combination maps with Inline Technology or for offline calculation. Display and analysis of the temporal behavior in selected regions of interest with the included MeanCurve postprocessing application. This includes the capability of using additional datasets as a guide for defining regions of interest even faster and easier than before **Ortho suite (standard)**: 2D TSE protocols for PD, T1, and T2-weighted contrast. 3D MEDIC, 3D TrueFISP protocols with water excitation for T2-weighted imaging. 3D VIBE protocols for MR arthrography (knee, shoulder and hip). 3D MEDIC, 3D TrueFISP, 3D VIBE protocols with water excitation. 3D TSE with variable flip angle. Whole-spine single-step or multi-step protocols. Fat suppression in off-centre positions. Dynamic TMJ and ilio-sacral joint protocol. Susceptibility-insensitive protocols **Paediatric suite (standard)**: Head and spine protocols divided according to age groups. Cardiac morphology protocols according to age groups, optimised for a small FoV and faster heart rates in congenital heart diseases (CHD). Imaging protocols for ventricular function as well as valvular and septal defects. CE-MRA as an adjuvant in the assessment of CHD and vasculature

Table 12. Sequence packages: angiography and cardiac imaging (1)

	Packages
GE HDx	**Angiography**: TRICKS-XV – Time resolved imaging of contrast kinetics – dynamic vascular imaging. Asset compatible technique enabling repeated scanning of large high resolution volume. Fast Gradient Echo Train (FGRET) allowing multi slice/phase imaging , Fluoro triggering MRA. **Cardiac**: ECG-Gated 2D Fiesta Cine Cardiac Imaging, Cardiac Tagging, 3D Fat Sat FIESTA Coronary Artery Imaging, Navigators for 3D coronary imaging, Report Card – cardiac reporting tool, I-Drive Pro Plus.
Philips Achieva	**Angiography**: BolusTrak (provides 2D-real time fluoroscopic display of contrast bolus arrival for synchronization of contrast-enhanced angio acquisitions), MobiTrak (provides automatic table movement between successive angiographic image acquisitions for visualization of the abdominal aorta and peripheral vasculature), MobiFlex (enhances the MobiTrak peripheral vascular angiography technique by providing the flexibility to individually specify contrast timing and image resolution for each station. MobiFlex enables use in combination with SENSE and BolusTrak), MobiView (automatically presents multi-station data as one image), Qflow analysis (provides quantitative flow results from Regions of Interest (ROI) in velocity encoded Phase Contrast (PC) datasets) **Cardiac**: Cardiac performance package (includes VCG triggering capabilities, multi-slice multi-phase imaging and quantitative flow analysis), Cardiac perfusion package (enables multi-slice first-pass perfusion studies with full heart coverage), Viability (tissue viability characteristics are revealed via late hyper enhancement of the tissue signal in T1-weighted images. Package provides single breath-hold or free breathing examinations with full heart coverage. MotionTrak provides real-time interactive motion correction for free breathing protocols), Cardiac tagging (provides the visualization of myocardial wall motion, allowing visualization of both contractual and torsional motions throughout the cardiac cycle), Coronary artery imaging (enables fast, free breathing coronary imaging)
Siemens Allegra	**Angiography**: 2D/3D Phase Contrast (PC), 2DTOF segmentation and ECG triggering, Contrast Enhanced (CE) MRA, Turbo MRA, 2D FLASH segmented, 2D PC ECG triggered, Evaluation for flow velocity (cm/s), flow volume (ml/s)
Siemens Trio	**Angiography**: 2D/3D Phase Contrast (PC), 2DTOF segmentation and ECG triggering, Contrast Enhanced (CE) MRA, Turbo MRA, 2D FLASH segmented, 2D PC ECG triggered, Evaluation for flow velocity (cm/s), flow volume (ml/s) **Cardiac imaging**: Cardiac post-processing

Table 12. Sequence packages: angiography and cardiac imaging (2)

	Packages
Siemens Trio, A Tim system	**Angio suite (standard)**: 3D contrast-enhanced MRA protocols with or without iPAT for head, neck, thorax, abdomen, peripheral regions. CareBolus functionality: determination of the bolus arrival time. Peripheral CE-MRA. 2D/3D time of flight. Triggered 2D/3D ToF sequences for non-contrast MRA. 2D/3D phase-contrast. MR venography with 2D/3D ToF and phase-constrast. Tilted optimised non-saturating excitation (TONE) and MTC techniques. Water-excitation 3D ToF protocol. MIP, MinIP, 3D SSD. Inline MIP. Inline subtraction of pre-post contrast measurements. Inline standard deviation maps of phase-contrast measurements for delineation of arteries and veins. Software-controlled table movements. **Cardiac suite (standard)**: Various breath-hold techniques (dark-blood TSE, HASTE, cine techniques: FLASH). Acquisition of a stack of shortaxis slices (standard segmented FLASH, or advanced segmented TrueFISP). Use of the Inline ECG for graphical ECG triggering set-up. Prospective gating with cine sequences (TrueFISP, FLASH). iPAT. Turbo FLASH **Advanced cardiac package**: Dark-blood sequences. Ventricular Function and Wall Motion. Dynamic CINE TrueFISP imaging of cardiac function with prospective and retrospective ECG triggering, with or without breath-hold technique. Cine imaging with echo sharing. Triggered retrogated cine imaging with arrhythmia rejection for automatic adjustment of the number of phases to the heart rate. Real-time cine TrueFISP imaging without need for ECG triggering or breath-hold commands. Real-time radial imaging. TrueFISP iPAT and Half Fourier techniques. Protocols for pediatrics, plaque imaging and stress imaging. Dedicated sequences for coronary imaging and angiography providing free breathing navigator (1D PACE) and breath-hold techniques (2D and 3D Flash and TrueFISP, requires PMU Wireless Physio Control option)

Table 13. Sequence packages: diffusion, perfusion imaging (1)

	Packages
GE HDx	**Neuro Options :** Propeller – T2FSE & T2 FLAIR & DW Propeller, DTI – up to 150 directions, FiberTrak – tractography, 3D FIESTA – Fast Imaging Employing Steady State Acquisition – short TR and gives high T2 contrast, FIESTA-C , 3D FLAIR, 3D COSMIS – 3D imaging designed for C-spine, PROBE-PRESS – Spectroscopy, PROBE-PRESS and PROBE STEAM - advanced spectroscopy, Brain Wave Real Tim – functional brain mapping package, Brainwave Post Acquisition – post processing of fmri data, BrainWave Fusion – fusion package for fMRI, DTI & Structure, BrainWave Hardware Lite – paradigm generation system, Multi Nuclear Spectroscopy and Sage MNS post processing software.
Philips Achieva	**Neurological**: Advanced EPI package (features temporal and spatial resolution for EPI imaging), GRASE package (combines characteristics of TSE with EPI into a single imaging sequence), Perfusion imaging package (features hemodynamic maps with dynamic multi-slice T2*-weighted sequences), SameScan package (enables repetition of Neuro studies. Exact scanning parameters, slice positioning and geometry of previous studies can be easily repeated) **Diffusion imaging**: Diffusion imaging performance package (includes Single-Shot (SS) EPI diffusion imaging sequences for motion free imaging, plus the automatic calculation of isotropic Diffusion Weighted (DW) images and Apparent Diffusion Coefficient (ADC) maps), High-resolution diffusion package (enables high-resolution diffusion imaging of the brain and brain stem), Diffusion Tensor Imaging package (DTI) (measures the directional dependence of the diffusion coefficient in tissue. Enables visualization of white matter tracts in Fractional Anisotropy (FA) maps) **Functional imaging**: PRESTO package (ultra-fast imaging sequence provides a combination of whole brain coverage using high temporal-resolution T2*-weighted images), BOLD imaging package (provides acquisition sequences for performing BOLD (Blood Oxygen Level Dependent) studies in order to localize T2* task-related signal changes in the brain), IView BOLD analysis package (provides real-time processing of functional BOLD MR data sets into functional activation maps), Total spine imaging (Multi-station spine imaging in a single scan) **Perfusion imaging** package (features hemodynamic maps, Negative Index (NI), Time-to-peak (TTP), Time-of-arrival (T0), Mean Transit Time (MTT) and flow index (index)) using dynamic multi-slice T2* weighted sequences.
Siemens Allegra	**Functional imaging**: Single shot EPI (FID), Online processing/dynamic evaluation, Single shot EPI SE, Diffusion – ADC/Trace, Perfusion – global bolus plot, Time To Peak map (TTP), percentage signal image
Siemens Trio	**Functional imaging**: Single shot EPI (FID), Online processing/dynamic evaluation, Single shot EPI SE, Diffusion – ADC/Trace, Perfusion – global bolus plot, Time To Peak map (TTP), percentage signal image

Table 13. Sequence packages: diffusion, perfusion imaging (2)

	Packages
Siemens Trio, A system	**Neuro suite (standard)**: 3D isotropic resolution volume imaging using T1 3D MPRAGE/3D FLASH and T2 DarkFluid SPACE. Whole-spine protocols in multiple steps with software-controlled table movement. T2-weighted 3D Restore protocols optimised for inner ear examinations. 2D and 3D MEDIC protocols for T2-weighted imaging, particularly for C-spine examinations in axial orientation. 3D Myelo with 3D HASTE and 3D TrueFISP for anatomical details. Dynamic sacro-iliac joint imaging using T1-weighted FLASH 2D sequence. Spine diffusion protocols to differentiate osteoporosis versus tumour infiltration and post radiotherapy changes versus residual tumour with PSIF sequence **Neuro advanced package (optional)**: Automatic real-time calculation of Global Bolus Plot (GBP), Percentage of Baseline at Peak map (PBP) and Time-to-Peak map (TTP) with Inline Technology. Automatic real-time calculation of trace-weighted images and ADC maps with Inline Technology. Integral part of single-shot diffusion weighted EPI. **Inline BOLD Imaging (optional)**: Automatic real-time calculation of z-score (t-test) maps with Inline technology, for variable paradigms. Compatible to single-shot EPI for multi-slice imaging. ART (Advanced Retrospective Technique) for fully automatic 3D retrospective motion correction, for 6 degrees of freedom (3 translations and 3 rotations); 3D spatial filtering; Overlay of Inline calculated t-test results on the EPI images. **Advanced Functional Neuro: 3D PACE (optional)**: Fully automatic 3D prospective motion correction during data acquisition, for 6 degrees of freedom (3 translations and 3 rotations); Motion correction covering the complete 3D volume. **Diffusion Tensor Imaging and Diffusion Tensor Evaluation for advanced DTI analysis (with SW MR B13):** Diffusion Tensor Imaging uses a Single Shot EPI sequence for measuring diffusion-weighted data sets with diffusion weighting in up to 256 directions. Based on these data sets, the diffusion tensor and parameter cards derived from it are calculated automatically and in real-time (fractional anisotropy). The DTI Evaluation package is a dedicated application card for advanced post-processing and visualization of Diffusion Tensor Imaging (DTI) data.

Table 14. Sequence packages: fast imaging techniques

	Packages
GE HDx	**Fast imaging**: EPI, FSE, SSFSE **Parallel acquisition imaging**: ASSET, GEM
Philips Achieva	**Fast Imaging**: single-shot TSE, Balanced FFE, Balanced TFE, single- and multi-shot EPI **Parallel acquisition imaging**: SENSE (Sensitivity Encoding) parallel imaging techniques. SENSE acceleration factors up to 8.
Siemens Allegra	**Fast imaging**: True FISP, Half-Fourier Acquisition Single-Shot Turbo SE (HASTE), HASTE IR, Single shot TSE (SS TSE) **Parallel acquisition imaging**: GRAPPA and mSENSE parallel imaging techniques
Siemens Trio	**Fast imaging**: True FISP, Half-Fourier Acquisition Single-Shot Turbo SE (HASTE), HASTE IR, Single shot TSE (SS TSE), Hybrid sequence for high resolution in orthopaedics, interactive realtime option **Parallel acquisition imaging**: GRAPPA and mSENSE parallel imaging techniques
Siemens Trio, A system	**Fast imaging techniques:** provided in the Tim Application Suite (See sequence list above). **Parallel acquisition imaging**: GRAPPA and mSENSE parallel imaging techniques. iPAT Extensions (integrated Parallel Acquisition Techniques). iPAT2 allows iPAT in 2 directions simultaneously (phase-encoding direction and 3D direction for 3D sequences)

Table 15. Sequence packages: spectroscopy

	Packages
GE HDx	**Spectroscopy**: Single voxel, Multi voxel.
Philips Achieva	**Spectroscopy**: 1H Spectro package includes single voxel, multi-voxel and multi-slice proton spectroscopy acquisition methods. The package includes SpectroView data processing and display. Multi-nuclear option
Siemens Allegra	**Spectroscopy**: FID, Stimulated Echo Acquisition Method (STEAM), PRESS, Postprocessing SW including algorithms working on time-domain data, algorithms working on spectra, and display of results, STEAM-CSI, PRESS-CSI, multinuclear option
Siemens Trio	**Spectroscopy**: FID, Stimulated Echo Acquisition Method (STEAM), PRESS, Postprocessing SW including algorithms working on time-domain data, algorithms working on spectra, and display of results, STEAM-CSI, PRESS-CSI, multinuclear option
Siemens Trio, A system	**Single Voxel Spectroscopy**: integrated software package with sequences and protocols for proton spectroscopy. **SVS techniques SE and STEAM**: automated adjustments including localized shimming and adjustment of water suppression pulses. Interactive adjustments and control of adjustments. Optimised protocols for brain applications. **Chemical Shift Imaging**: Matrix Spectroscopy – phase-coherent signal combination. 2D and 3D Chemical Shift Imaging. Hybrid CSI with combined Volume selection and Field of View (FoV) encoding. Outer Volume Suppression. Spectral Suppression **Multinuclear Support and Multinuclear Spectroscopy packages available for studying nuclei other than 1H (with SW MR B13).**

Table 16. Sequence packages: others

	Packages
GE HDx	**Body**: LAVA-XV – Extends Lava functionality incorporating GEM allowing phase acceleration as well as slice accelerations. VIBRANT-XV – Breast Imaging incorporating GEM allowing acceleration factors for bilateral breast imaging in sagital and axial planes. BREASE – Breast Spectroscopy **MSK:** Cartigram – T2 cartilage mapping.
Philips Achieva	**Body**: Keyhole (allows fast imaging with high temporal and spatial resolution), Thrive (enables isotropic high-resolution T1-weighted body images with large slice coverage and uniform fat suppression in short breath-hold times), MobiScan whole-body imaging package (enables rapid, automated whole-body imaging with an effective field of view of over 2 meters (7 feet). MobiScan combines MobiTrak, MobiFlex, and MobiView imaging and viewing techniques with ExamCards to deliver multi-station head-to-toe coverage) **Others**: Real-time interactive imaging (provides the imaging techniques and user interface elements for fluoroscopic MR imaging.)
Siemens Allegra	**Others**: 3D Constructive Interference in the Steady State (CISS), 3D Dual Echo Steady State (DESS) with/without water excitation, Online visualisation of contrast enhancement as centre of k-space is filled as quickly as possible for exact timing of CE MRA, Fast switch from 2D to 3D, Centric, elliptical k-space filling
Siemens Trio	**Others**: 3D Constructive Interference in the Steady State (CISS), 3D Dual Echo Steady State (DESS) with/without water excitation, Online visualisation of contrast enhancement as centre of k-space is filled as quickly as possible for exact timing of CE MRA, Fast switch from 2D to 3D, Centric, elliptical k-space filling
Siemens Trio, A system	**CISS & DESS (Double Echo Steady State)**: T2/T1-weighted. Fluid-cartilage differentiation in orthopedic imaging 3D CISS (Constructive Interference in Steady State). **Flow Quantification**: quantitative flow determination studies: measuring blood/CSF flow non-invasively Requires Physiological Measurement Unit (PMU) option. **RetroGated Flow**: Dynamic representation of temporally changing flow **Interactive Realtime**: Real-time cardiac examinations. Real-time interactive slice positioning and slice angulation. 3D Magellan SpaceMouse included **TGSE (Turbo Gradient Spin Echo)**: Hybrid Turbo Spin Echo/Gradient echo used primarily for T2- weighted imaging **SWI (with SW MR B13):** Susceptibility Weighted Imaging is a high-resolution 3D imaging technique for the brain with ultra-high sensitivity for microscopic magnetic field inhomogeneities caused by deoxygenated blood, products of blood decomposition and microscopic iron deposits. Among other things, the method allows for sensitive proof of cerebral hemorrhages and display of venous cerebral blood vessels. **BLADE (with SW MR B13):** Motion insensitive multi-shot Turbo Spin Echo (TSE) sequence with inter-shot motion correction for in-plane head motion. BLADE supports T2-weighted, dark fluid and STIR contrast imaging as well as inversion recovery T1-weighted imaging.

Computer system

Table 17. Main computer system - architecture

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Type	Dual AMD® Opteron™ 250 (2.4 GHz) processors	Dual Pentium IV Xeon processors	2 x Pentium IV/Intel Xeon	Pentium IV/Intel Xeon	Pentium IV Xeon
Operating system	Linux	Windows XP	Windows XP	Windows XP Professional, *sygno* speaking	Windows XP Professional, *sygno* speaking
CPU speed *GHz*	Dual 2.4GHz	> 2x3.2	2x3	2x3.06	2x3.6
Word length bit	64	32	32	32	32
Memory size *GB*	4	2	2	2	2
Hard disk:					
Software *GB*	1 x 32	36	36	36 (+ 36 database)	73 (+ 73 database)
Images *GB*	2 x 32	36	73	73	73
Image capacity 256^2 images*	> 490 000	250 000	110 000	110 000†	110 000†
Archive drive:					
Drive	MOD, DVD RW	DVD RW	CDR, MOD (read only)	CDR, MOD (read only)	CDR
Size	1.3GB or 2.6GB for MOD 4.7GB for DVD	4.7GB	640MB	640MB	640MB
Image capacity 256^2 images*	15 000 for 1.3GB MOD 30 000 for 2.3GB MOD >35 000 for DVD	40 000	4 300	4 300	4 300

* Image capacity for uncompressed 256^2 images
† Image capacity for uncompressed 512^2 images

Table 18. Main computer system – image processor

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Manufacturer and type	8 x 2.6 GHz AMD Opteron 252 CPUs	Dual Pentium IV Xeon processors	Pentium IV/Intel Xeon	Pentium IV/Intel Xeon	2 x AMD Opteron 248 CPU
Processing speed *GHz*	12.8GB/sec	> 2x3.2	3	2 x 3.06	2 x ≥2.2
Word length *bit*	64	32	32	32	64
Memory size bulk array *GB*	4	4	1 opt 2 GB RAM for iPAT plus with four 36 GB hard disks	2 GB RAM†	≥8†
Number of 256^2 images* reconstructed per sec	5400	>256	239 with full FOV 1773 with 25% recFOV	355	1002
Transfer rate from host *MB*/s	No Transfer Time common bus	1000 BaseT	No transfer time common bus	No transfer time common bus	No transfer time common bus

* Reconstruction time for a true 256x256 matrix with no interpolation, no asymmetric echo, no partial Fourier, no parallel imaging, no fat-sat, no rectangular matrix, no rectangular field-of-view.
† Siemens offers four additional 36GB hard disks for largest multiple data sets.

Table 19. Main computer image display monitor

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Screen size *in*	23	23	18	19	19
Type (BW/colour)	LCD flat panel	LCD colour	LCD colour	LCD colour	LCD colour
Matrix size	1920 x 1200	1900x1200	1280×1024	1280×1024	1280×1024
Bit depth *bit*	24	3×8	16	16	16

Radio-frequency (RF) coils

The following definitions are provided to clarify the RF coils' design and components:

- # output channels: number of independent RF receiver channels the RF coil plugs into.
- # elements for QD/CP: number of elements used for quadrature (QD)/circularly polarised (CP) detection.
- # elements for LP: number of elements used for linearly polarised (LP) detection.

Manufacturers have been asked to adopt the above definitions in the description of their coils.

Table 20. Head coils

	GE HDx	**Philips Achieva**	**Siemens Allegra**	**Siemens Trio**	**Siemens Trio, A Tim system**		
Name	Quadrature Head	Quadrature Head	CP Head	CP Head	CP Head		
Type*	T/R	T/R Q	T/R Q	T/R Q	T/R Q		
Dimensions *cm*	28 x 38 (dia x l)	28 × 30 (dia × l)	27 x 35 (dia x l)	27 x 35 (dia x l)	27 x 35 (dia x l)		
# output channels	1	1	1 CP	1 CP	1 CP		
# elements for QD/CP	2	12	2 elements (= 1 CP)	2 elements (=1 CP)	2 elements (=1 CP)		
# elements for LP	0	0	0	0	0		
Name	8 channel head	SENSE head coil	4-channel head array (iPAT compatible)	8-channel head array (iPAT compatible)	Head Matrix CP mode	Dual mode	Triple mode
Type*	R PA	R PA	R PA L	R PA L	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	24x24 (dia x l)	23x22 (dia x l)	Not supplied	Not supplied	30 x 30 x 33 (l x w x h)		
# output channels	8	8	4	8	4 CP	8 CP	12
# elements for QD/CP	0	0	0	0	12 (=4 CP)	12 (=8 CP)	12 (=12)
# elements for LP	8	8	4	8	See above	See above	See above

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 21. Neck coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system		
Name	Open neuro-vascular	16 channel SENSE neuro-vascular	No such coil	Neuro-vascular array (iPAT compatible)	Neck Matrix CP mode	Dual mode	Triple mode
Type*	R PA	R PA	-	R PA L	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	20x25x48 (w x h x l)	43×35 (dia × l)	-	Not supplied	19 x 33 x 33.2 (l x w x h)		
# output channels	4	16	-	8	2 CP	4	4
# elements for QD/CP	6	16	-	0	4 (=2CP)	4 (=4)	4 (=4)
# elements for LP	1	18	-	13	See above	See above	See above
Name	No other coil	8 channel SENSE neuro-vascular	No other coil	No other coil	Head/neck coverage[†] CP mode	Dual mode	Triple mode
Type*	-	R PA	-	-	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	-	43×35 (dia × l)	-	-	See individual coils		
# output channels	-	8	-	-	In total 6 CP	In total 12 (=8CP +4)	In total 16
# elements for QD/CP	-	8	-	-	In total 16 (=6CP)	In total 16 (=12CP)	In total 16 (=16)
# elements for LP	-	18	-	-	See above	See above	See above

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

[†] Head/neck & neuro-vascular applications: Head Matrix and Neck Matrix can be combined and used simultaneously (Matrix technology) to provide head-neck coverage.

Table 22. Body coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system		
In-built body coil							
Name	Quadrature T/R body	Quadrature Body	No such coil	CP Integrated Body	CP Integrated Body		
Type*	T/R	T/R Q	-	T/R Q	T/R Q		
Dimensions cm	60x60 (dia x l)	Aperture 60 cm	-	60 × 60 (dia × l)	60 × 60 (dia × l)		
# output channels	1	1	-	1 CP	1 CP		
# elements for QD/CP	2	16	-	2 (= 1 CP)	2 (= 1 CP)		
# elements for LP	-	-	-	-	-		
Body coils							
Name	Torso phased array	Sense Torso	No such coil	Body/pelvic array (iPAT compatible)	Body Matrix CP mode	Dual mode	Triple mode
Type*	R PA	R PA	-	R PA L	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	34x30 (l x w)	45×35 (l x w)	-	Not supplied	52 x 32.2 (w x l)		
# output channels	8	6	-	8	2CP	4CP	6
# elements for QD/CP	0	0	-	0	6 (=2CP)	6 (=4CP)	6 (=6)
# elements for LP	8	6	-	8	See above	See above	See above

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 22. Body coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system		
Name	No other coil	No other coil	No other coil	No other coil	Body/spine coverage†		
					CP mode	Dual mode	Triple mode
Type*	-	-	-	-	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	-	-	-	-	See individual coils		
# output channels	-	-	-	-	4CP	8CP	12
# elements for QD/CP	-	-	-	-	In total 12 (=4CP)	In total 12 (=8CP)	In total 12 (=12)
# elements for LP	-	-	-	-	See above	See above	See above
Name	No other coil	No other coil	No other coil	No other coil	Body/spine: 50cm coverage‡		
					CP mode	Dual mode	Triple mode
Type*	-	-	-	-	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	-	-	-	-	See individual coils		
# output channels	-	-	-	-	8CP	16CP	24
# elements for QD/CP	-	-	-	-	In total 24 (=8CP)	In total 24 (=16CP)	In total 24 (=24)
# elements for LP	-	-	-	-	See above	See above	See above

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

† Body Matrix and Spine Matrix can be combined (Matrix technology) to provide body and spine coverage.

‡ Two Body Matrix and Spine Matrix can be combined (Matrix technology) to provide 50 cm coverage in the z-direction.

Table 22. Body coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Name	No other coil	No other coil	No other coil	No other coil	Whole body coverage†
Type*	-	-	-	-	See individual coils
Dimensions *cm*	-	-	-	-	See individual coils
# output channels	-	-	-	-	Up to 32 channels
# elements for QD/CP	-	-	-	-	Up to 102 seamlessly integrated coil elements in total
# elements for LP	-	-	-	-	-

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference
† Whole body applications: combination of Head Matrix + Neck Matrix + Spine matrix + up to 3 Body Matrix +PA Matrix.

Table 23. Spine coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system		
Name	CTL spine	SENSE spine	No such coil	Spine array (iPAT compatible)	Spine Matrix		
					CP mode	Dual mode	Triple mode
Type*	R PA	R Q PA	-	R PA L	R PA Q/L	R PA Q/L	R PA Q/L
Dimensions *cm*	Not supplied	82 (l)	-	Not supplied	48.4 x 118.5 (w x l)		
# output channels	8	6	-	8	8 CP (up to 4CP sim.)	16 CP (up to 8CP sim.)	24 (up to 12CPsim.)
# elements for QD/CP	0	12	-	0	24 (=8CP)	24 (=16CP)	24 (=24)
# elements for LP	8	12	-	16	See above	See above	See above

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 24. Cardiovascular coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system	
Name	Cardiac coil	SENSE Cardiac	No such coil	Cardiac array (iPAT compatible)	PA Matrix CP mode	Dual mode
Type*	R PA	R PA	-	R PA L	R Q PA	R Q PA
Dimensions *cm*	Not supplied	32×23 (w x l)	-	Not supplied	86 x 30 - 64 x 28 (l x w x h)	
# output channels	8	6	-	8	12 CP	24 CP
# elements for QD/CP	0	0	-	0	36 (=12CP)	36 (=24CP)
# elements for LP	8	6	-	8	36	36

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 25. Breast imaging coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Name	8 Ch HDx Breast Coil	SENSE Breast	13C/1H double resonant surface coil	Bilateral breast array (iPAT compatible)	Breast array (iPAT compatible)
Type*	R PA	R PA	T/R Q	R PA L	R PA L
Dimensions *cm*	Not supplied	16 (dia) 12 (depth)	Not supplied	Not supplied	Not supplied
# output channels	8	4	1	4	4
# elements for QD/CP	0	0	1	0	0
# elements for LP	8	4	0	4	4

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 26. Extremity coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Knee coils					
Name	Quad Extremity	SENSE knee	No such coil	8-channel knee array (iPAT compatible) (accessory coil)	8-channel knee array (iPAT compatible) (accessory coil)
Type*	T/R	R PA	-	R PA L	R PA L
Dimensions *cm*	18x22 (dia x l)	37 x 28 x 32 (l x h x w)	-	Not supplied	Not supplied
# output channels	1	8	-	8	8
# elements for QD/CP	1	8	-	0	0
# elements for LP	0	8	-	8	8
Wrist coils					
Name	Wrist coil	SENSE Wrist	No such coil	CP Wrist	CP Wrist
Type*	T/R	R PA	-	T/R Q	T/R Q
Dimensions *cm*	Not supplied	7 x 13 x 15 (w x l x d)	-	Not supplied	Not supplied
# output channels	1	4	-	1	1
# elements for QD/CP	1	0	-	1	1
# elements for LP	0	4	-	0	0
Shoulder coils					
Name	Shoulder coil	SENSE Shoulder	No such coil	Shoulder array (iPAT compatible)	Shoulder array (iPAT compatible)
Type*	R PA	R PA	-	R PA L	R PA L
Dimensions *cm*	Not supplied	13 x 18 x 20 (l x h x w)	-	Not supplied	Not supplied
# output channels	3	4	-	4	4
# elements for QD/CP	0	0	-	0	0
# elements for LP	3	4	-	4	4

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 26. Extremity coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Others					
Name	General purpose flex	SENSE Flex M	No other coil	CP Extremity	CP Extremity
Type*	R PA	R PA	-	T/R Q	T/R Q
Dimensions *cm*	21x45 (l x w)	14 x 17 per element	-	Not supplied	Not supplied
# output channels	1	2	-	1	1
# elements for QD/CP	0	0	-	1	1
# elements for LP	1	2	-	0	0
Name	No other coil	SENSE Flex L	No other coil	No other coil	No other coil
Type*	-	R PA	-	-	-
Dimensions *cm*	-	20 (dia) per element	-	-	-
# output channels	-	2	-	-	-
# elements for QD/CP	-	0	-	-	-
# elements for LP	-	2	-	-	-

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Table 27. General purpose/other coils

	GE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Name	General purpose flex	SENSE Flex M	31P/1H double-resonant head coil	CP Extremity	CP Extremity
Type*	R PA	R PA	T/R Q	T/R Q	T/R Q
Dimensions *cm*	21x45 (l x w)	14 x 17 per element	Not supplied	Not supplied	Not supplied
# output channels	1	2	1	1	1
# elements for QD/CP	0	0	1	1	1
# elements for LP	1	2	0	0	0
Name	No other coil	SENSE Flex L	No other coil	Endorectal coil (accessory coil)	No other coil
Type*	-	R PA	-	R Q	-
Dimensions *cm*	-	20 (dia) per element	-	Not supplied	-
# output channels	-	2	-	1	-
# elements for QD/CP	-	0	-	1	-
# elements for LP	-	2	-	0	-
Name	No other coil	31-P T/R surface coil	No other coil	No other coil	No other coil
Type*	-	T/R L	-	-	-
Dimensions *cm*	-	14 (dia)	-	-	-
# output channels	-	1	-	-	-
# elements for QD/CP	-	0	-	-	-
# elements for LP	-	1	-	-	-

*R=receive, T/R=transmit/receive, PA=phased array, Q=quadrature, L=linear, w=width, h=height, d=depth, l=length, dia=diameter, circ=circumference

Parallel imaging product information

Table 28: Parallel imaging product information

	GE Signa EXCITE HDx	Philips Achieva	Siemens Allegra	Siemens Trio	Siemens Trio, A Tim system
Parallel imaging product name	ASSET / GEM	SENSE	iPAT (standard) iPAT plus (with Whole Body Array)	iPAT (standard) iPAT plus (with Whole Body Array)	iPAT (standard) iPAT Extensions (optional)
k-space based reconstruction method	no	no	GRAPPA GeneRalised Autocalibrating Partially Parallel Acquisition)	GRAPPA GeneRalised Autocalibrating Partially Parallel Acquisition)	GRAPPA (GeneRalised Autocalibrating Partially Parallel Acquisition)
Image-space based reconstruction method	ASSET/GEM	SENSE (SENSitivity Encoding)	mSENSE (Modified SENSE)	mSENSE (Modified SENSE)	mSENSE (Modified SENSE)
Comments	**Asset:** Used for reducing scan time, for increasing spatial or temporal resolution, or for acquiring more slices in a given scan time. ASSET is also an effective way to manage SAR at 3.0T. **GEM:** Highly accelerated imaging to increase resolution and coverage in a fraction of the scan time. Uses Self Calibration with artifact reduction.	Features a short reference scan which is done in parallel with scan planning. As a result no time-consuming auto-calibration is needed and the speed gain always equals the SENSE factor selected See manufacturers' comments	Featuring Auto-Calibration without the need of an additional, time-consuming calibration scan; compatible with all IPA/Matrix coils and all array coils and coil combinations.	Featuring Auto-Calibration without the need of an additional, time-consuming calibration scan; compatible with all IPA/Matrix coils and all array coils and coil combinations.	Featuring Auto-Calibration without the need of an additional, time-consuming calibration scan; compatible with all IPA/Matrix coils and all array coils and coil combinations.

Table 29: Parallel imaging factors for head imaging coils

	GE HDx			Philips Achieva		Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			Sense Head coil (8-channel)		No such coil		8-channel Head array	Head matrix		
Parallel imaging factors				Max 8.0	Max 8.0			HF*: 1 AP*: 4 LR*: 4	HF*: 1/4 ‡ AP*: 4 LR*: 4 max†: 16	HF*: 1/4 ‡ AP*: 4 LR*: 4 max†: 16	HF*: 1/4 ‡ AP*: 4 LR*: 4 max†: 16

* HF/AP/LR: max. Parallel Imaging factors in head-feet/anterior-posterior/left-right directions
† max: max. Parallel Imaging factor for 3D scans with iPAT^2 functionality.
‡ x/y: Parallel Imaging factors for the respective coil alone / for typical clinical coil combinations (utilizing IPA technology resp. Matrix technology)

Table 30: Parallel imaging factors for neck imaging coils

	GE HDx			**Philips Achieva**		**Siemens Allegra**		**Siemens Trio**	**Siemens Trio, A Tim system**		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			Sense 8-channel Neurovascular coil		No such coil		Not supplied by manufacturer	Neck matrix		
Parallel imaging factors				Max 8.0	Max 8.0				HF: 1/4 AP: 2/2 LR: 2/2-3 max: 8	HF: 1/4 AP: 2/2 LR: 2/2-3 max: 8-12	HF: 1/4 AP: 2/2 LR: 2/2-3 max: 8-12
Name	Not supplied by manufacturer			Sense 16-channel Neurovascular coil		No such coil		Not supplied by manufacturer	Head matrix + Neck matrix (Matrix technology)		
Parallel imaging factors				Max 16	Max 16				HF: 2 AP: 2 LR: 2-3 max: 6	HF: 2 AP: 2 LR: 2-3 max: 6	HF: 2 AP: 2 LR: 2-3 max: 6

Table 31: Parallel imaging factors for neurovascular imaging coils

	GE HDx			Philips Achieva		Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			Sense 8-channel Neurovascular coil		No such coil		Not supplied by manufacturer	Head matrix + Neck matrix (Matrix technology)		
Parallel imaging factors				Max 8	Max 8				HF: 2 AP: 2 LR: 2-3 max: 6	HF: 2 AP: 2 LR: 2-3 max: 6	HF: 2 AP: 2 LR: 2-3 max: 6
Name	Not supplied by manufacturer			Sense 16-channel Neurovascular coil		No such coil		Not supplied by manufacturer	Head matrix + Neck matrix + Body matrix + Spine matrix (Matrix technology)		
Parallel imaging factors				Max 16	Max 16				HF: 3 AP: 2 LR: 2 max: 6	HF: 4 AP: 2 LR: 2-3 max: 8	HF: 4 AP: 2 LR: 3 max: 12

Table 32: Parallel imaging factors for spine imaging coils

	GE HDx			Philips Achieva		Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE spine coil		No such coil		Not supplied by manufacturer	Spine matrix		
Parallel imaging factors				Max 4	Max 4				HF: 4 AP: 1/2-3 LR: 3 max: 9	HF: 4 AP: 1/2-3 LR: 3 max: 12	HF: 4 AP: 1/2-3 LR: 3 max: 12

Table 33: Parallel imaging factors for body imaging coils

	GE HDx			Philips Achieva		Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE Torso coil		No such coil		Not supplied by manufacturer	Body matrix + Spine matrix (Matrix technology)		
Parallel imaging factors				Max 6	Max 6				HF: 2 AP: 2-3 LR: 3 max: 9	HF: 2 AP: 2-3 LR: 3 max: 12	HF: 2 AP: 2-3 LR: 3 max: 12
Name	Not supplied by manufacturer			No other coil		No such coil		Not supplied by manufacturer	2 x Body matrix + Spine matrix (Matrix technology)		
Parallel imaging factors									HF: 4 AP: 2-3 LR: 3 max: 9	HF: 4 AP: 2-3 LR: 3 max: 12	HF: 4 AP: 2-3 LR: 3 max: 12

Table 34: Parallel imaging factors for knee imaging coils

	GE HDx			Philips Achieva		Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE knee		No such coil		Not supplied by manufacturer	CP extremity		
Parallel imaging factors				Max 8	Max 8				1	1	1
Name	Not supplied by manufacturer			SENSE flex M coil		No such coil		Not supplied by manufacturer	8-channel knee coil		
Parallel imaging factors				Max 2	Max 2				HF: 1 AP: 4 LR: 4	HF: 1 AP: 4 LR: 4	HF: 1 AP: 4 LR: 4

Table 35: Parallel imaging factors for shoulder imaging coils

	GE HDx			**Philips Achieva**		**Siemens Allegra**		**Siemens Trio**	**Siemens Trio, A Tim system**		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE Shoulder coil		No such coil		Not supplied by manufacturer	Shoulder array (large/small)		
Parallel imaging factors				Max 4	Max 4				HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2
Name	Not supplied by manufacturer			SENSE flex M coil		No such coil		Not supplied by manufacturer	No other coil		
Parallel imaging factors				Max 2	Max 2						

Table 36: Parallel imaging factors for breast imaging coils

	GE HDx			Philips Achieva		Siemens Allegra		Siemens Trio	Siemens Trio, A Tim system		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE Breast coil		No such coil		Not supplied by manufacturer	Breast matrix		
Parallel imaging factors				Max 4	Max 4				HF: 1 AP: 1 LR: 2	HF: 1 AP: 1 LR: 2	HF: 1 AP: 1 LR: 2

Table 37: Parallel imaging factors for wrist imaging coils

	GE HDx			**Philips Achieva**		**Siemens Allegra**		**Siemens Trio**	**Siemens Trio, A Tim system**		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE wrist coil		No such coil		Not supplied by manufacturer	CP wrist coil		
Parallel imaging factors				Max 4	Max 4				1	1	1
Name	Not supplied by manufacturer			Sense flex-M		No such coil		Not supplied by manufacturer	No other coil		
Parallel imaging factors				Max 2	Max 2						

Table 38: Parallel imaging factors for other/general purpose imaging coils (1)

	GE HDx			**Philips Achieva**		**Siemens Allegra**		**Siemens Trio**	**Siemens Trio, A Tim system**		
RF system	EXCITE HDx			Freewave		iPAT	iPAT plus	iPAT plus	Tim [102x8]	Tim [102x18]	Tim [102x32]
Number of independent RF receiver channels	4	16	32	8	16	4	8	8	8	18	32
Name	Not supplied by manufacturer			SENSE flex-L coil		No other coil		No other coil	No other coil		
Applications				Hip / head / shoulder/ paediatric							
Parallel imaging factors				Max 2	Max 2						

Introduction to evaluation

The technical performance of the 3.0 T systems included in this evaluation is provided in this section of the report. Table 39 provides information on these systems and Table 40 shows our standard quality assurance protocol.

We require all images to be acquired without any pre-reconstruction or post-processing filters.

Table 39. MR model abbreviation codes for evaluated 3.0T systems.

	GE	Philips	Siemens	Siemens
Model	HD	ACHIEVA 3T	MAGNETOM ALLEGRA	MAGNETOM TRIO
Gradient evaluated	Twinspeed HD Head coils: Zoom mode Body coils: Whole mode	Quasar dual	Allegra	Sonata
Code	GE-EXC	PH-ACH	SI-ALL	SI-TRI
Report	Not applicable	Not applicable	MHRA 03026	MHRA 04102
Assessment date	29/11/04	27/09/04	07/11/02	26/02/04

Table 40. Type-test sequence parameters

	Standard protocol
Sequence	SE
TE (ms)	30
TR (ms)	1000
NSA	1
FOV (mm)	250
Matrix (PE x FE)	256 x 256
Bandwidth (kHz)	Manufacturer's choice
Slice width (mm)	5
Scan time (min:sec)	4:18
Image plane	TRA, SAG, COR

Quadrature head coil evaluation

Quadrature head coil: signal to noise ratio (SNR)

Scan parameters
The standard quadrature head coil SNR test is carried out using our standard type-test protocol in Table 40. MagNET's flood field oil test object (MAGFF-OIL or MAGFF3TOIL+MAGANN3T) is placed at the centre of the coil and is imaged at the iso-centre in all three planes. Two sequential images are taken for each plane and used to form a subtracted image. Experimental conditions are presented in Table 41.

Analysis
The SNR was calculated using a subtraction method; two identical scans were acquired and a difference image obtained. The mean signal was measured from five regions of interest within the test object area in one of the acquired images and the noise was measured from the standard deviation from these regions in the difference image (Lerski 1998). The values obtained for SNR were normalised for voxel size (including measured slice width), scan time, and sampling bandwidth (no normalisation for coil loading).

Interpretation of results
The image SNR value obtained on a system is influenced by many factors. For example, system factors such as the main magnetic field strength B_o and the design of the radiofrequency receive and transmit systems can affect the SNR. Other factors are the choice of sequence and imaging parameters.

The SNR could not be normalised for loading since some manufacturers were unable to provide Q measurements. Readers should take this into account when reading the report.

The normalised SNR measurements are presented in Table 42. The comparison made in Graph 1 shows the mean NSNR for 3T systems.

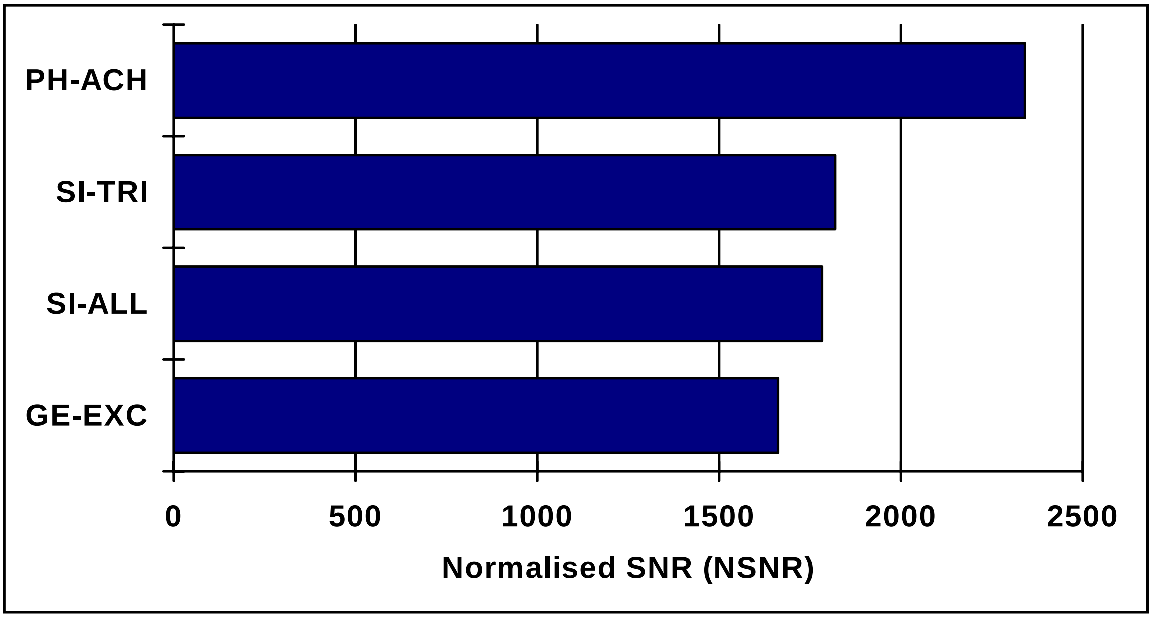
Table 41. Experimental conditions for quadrature head coil SNR test

	GE-EXC	PH-ACH	SI-ALL	SI-TRI
Temperature (°C)	24	23	21	20
Bandwidth (kHz)	11.90	46.54	16.64	16.64
Test object	MAGFF3T-OIL	MAGFF3T-OIL	MAGFF-OIL	MAGFF-OIL
Loading	MAGANN-3T	MAGANN-3T	None	None

Table 42. Quadrature head coil normalised SNR

	Transverse	Sagittal	Coronal	Mean
GE-EXC	1777	1512	1697	1662
PH-ACH	2393	2410	2220	2341
SI-ALL	1795	1810	1743	1783
SI-TRI	1884	1801	1772	1819

Graph 1: Comparison of normalised SNR (mean of three planes)*



* no normalisation for coil loading

Quadrature head coil: uniformity

Scan parameters
The standard quadrature head coil uniformity test is carried out using our standard type-test protocol in Table 40. MagNET's flood field oil test object (MAGFF-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The average of several intensity profiles is calculated in all three gradient directions. The fractional uniformity is calculated for each gradient direction from the fraction of the profile that lies within 10% of the mean value of a central ROI (Lerski 1998). The optimum value is unity, indicating 100% of the signal is considered uniform over the measured distance.

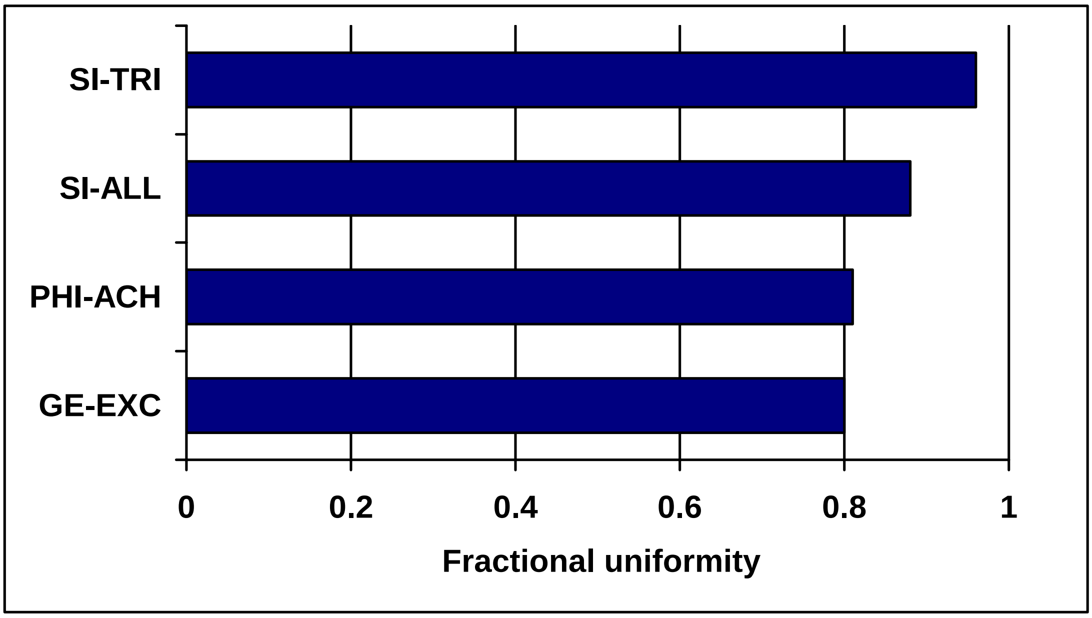
Interpretation of results
A key factor affecting uniformity is the design of the radiofrequency coil, in this case, the head coil. Most head coils are optimised to give a high value for the transverse orientation. Poor uniformity often occurs in the bore direction (z-gradient direction). This can be seen in the vertical values for the sagittal and coronal plane. These values often lower the average for the three planes.

The fractional uniformity measurements in the two directions for each plane are presented in Table 43. The comparison made in Graph 2 shows the mean fractional uniformity for 3T systems.

Table 43. Fractional uniformity for the head coil (unfiltered)

	x-direction	y-direction	z-direction	Mean±SD
GE-EXC	0.98	0.99	0.43	0.80±0.29
PH-ACH	1.00	1.00	0.42	0.81±0.30
SI-ALL	0.92	1.00	0.71	0.88±0.15
SI-TRI	0.96	0.95	0.98	0.96±0.04

Graph 2. Comparison of fractional uniformity (mean of three planes)



Quadrature head coil: spatial resolution

Scan parameters
The standard quadrature head coil resolution test is carried out using our standard type-test protocol in Table 40. MagNET's resolution test object (MAGRES-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The resolution is evaluated by calculating the 50% point on the modulation transfer function (MTF) plot (Lerski 1998). This frequency is converted into pixel resolution.

Interpretation of results
The resolution measurements are presented in Table 44. The measured resolution should be equal to the nominal pixel dimension of 0.98mm.

Graph 3 shows a comparison of the average pixel dimension for both the PE and FE directions (256 x 256 matrix) for 3 T systems.

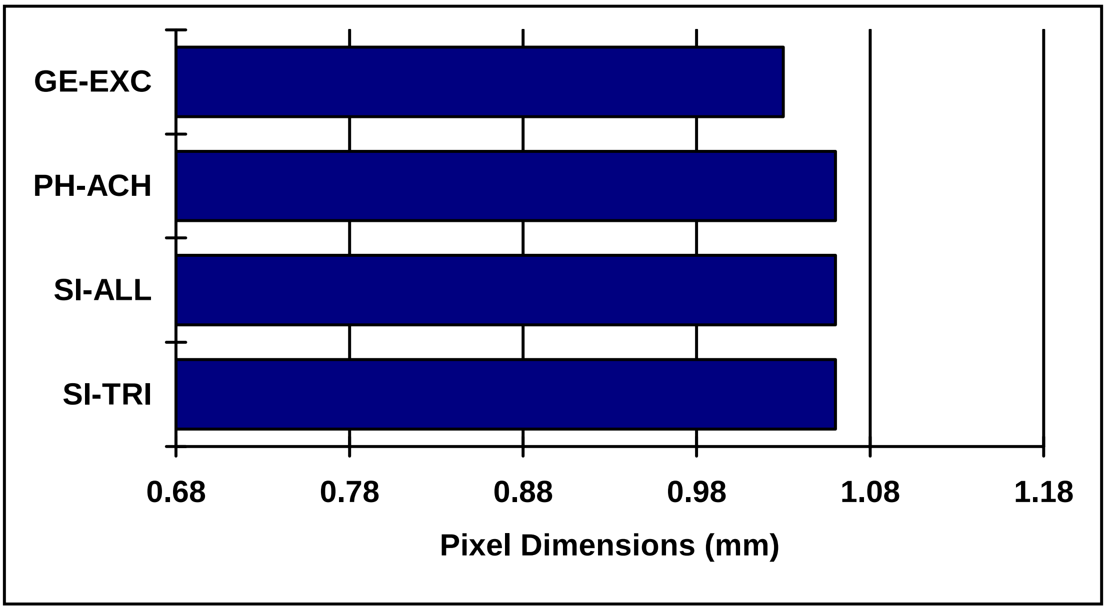
CEP comment

Measurements of MTF are considered to be within experimental error if they are within ±10% of the nominal pixel size.

Table 44. Pixel dimension measurements (mm) for 256 x 256 matrix (nominal 0.98 mm)

	Mean (in PE direction)	Mean (in FE direction)	Mean ± SD
GE-EXC	1.03	1.03	1.03±0.05
PH-ACH	1.05	1.06	1.06±0.01
SI-ALL	1.06	1.07	1.06±0.04
SI-TRI	1.03	1.08	1.06±0.03

Graph 3: Mean pixel dimension - 256 x 256 matrix (mean of three planes)* †



* Optimum value = 0.98mm
† Errors ± 10% of the nominal value

Quadrature head coil: geometric linearity

Scan parameters
The standard quadrature head coil geometric linearity test is carried out using our standard type-test protocol in Table 40 with FOV=256 mm. MagNET's geometry test object (MAGGEOM-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The geometric linearity results are obtained from a set of horizontal and vertical distance measurements in the acquired images (Lerski 1998).

Interpretation of results
These measurements are converted from pixels to millimetres and compared to the actual separation distance of 120mm.

Table 45 shows a comparison of the mean geometric linearity for the three planes.

Graph 4 compares the mean geometric linearity for 3T systems.

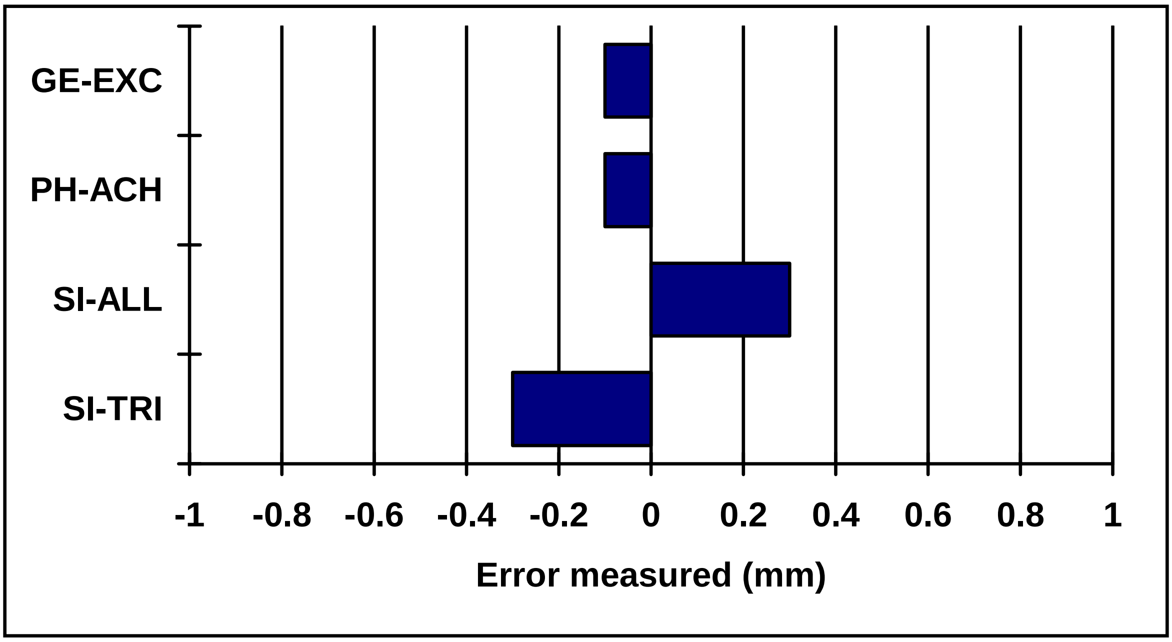
CEP comment

Measurements of geometric linearity are considered to be within experimental error if they are within ±1mm of the actual dimension.

Table 45. Linearity for three planes direction (mm)

	x-direction	y-direction	z-direction	Mean ± SD
GE-EXC	120.0	119.7	120.0	119.9±0.32
PH-ACH	120.0	119.8	120.0	119.9±0.24
SI-ALL	119.5	120.7	120.8	120.3±1.03
SI-TRI	120.5	119.8	118.8	119.7±1.41

Graph 4. Comparison of mean error in geometric linearity for 3.0 T systems (mean of three planes)*.



*The optimum value is 0 ± 1 mm. Systems are ranked in order of the absolute deviation from optimum.

Quadrature head coil: geometric distortion

Scan parameters
The standard quadrature head coil geometric linearity test is carried out using our standard type-test protocol in Table 40 with FOV=256 mm. MagNET's geometry test object (MAGGEOM-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The coefficient of variation (CV) indicates the degree of variation of the distance measurements from one another. The coefficient of variation is defined as (Lerski 1998):

$$CV = \frac{standard\ deviation}{mean}\ x\ 100\%$$

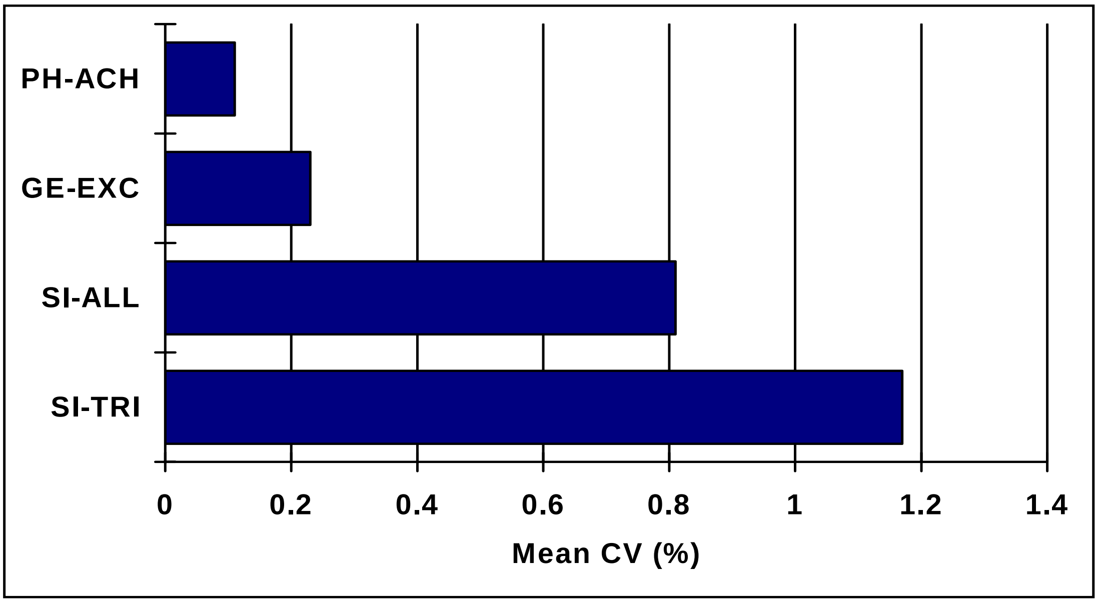
Interpretation of results
The lower the coefficient of variation, the lower the in-plane distortion and the better the performance.

Graph 5 shows a comparison of the mean geometric distortion for the three gradient directions.

Table 46. Distortion measurements for three gradient directions

	x-direction	y-direction	z-direction	Mean
GE-EXC	0.00	0.34	0.34	0.23
PH-ACH	0.00	0.34	0.00	0.11
SI-ALL	0.84	0.63	0.96	0.81
SI-TRI	1.54	1.05	0.91	1.17

Graph 5. Comparison of geometric distortion (mean of three gradients)*



*The optimum value is zero.

Quadrature head coil: slice profile and slice width

Scan parameters
The standard quadrature head coil slice width test is carried out using our standard type-test protocol in Table 40 with SW=3 and 5 mm. MagNET's geometry test object (MAGGEOM-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The slice width is measured from the full width at half maximum (FWHM) of the slice intensity profile (Lerski 1998).

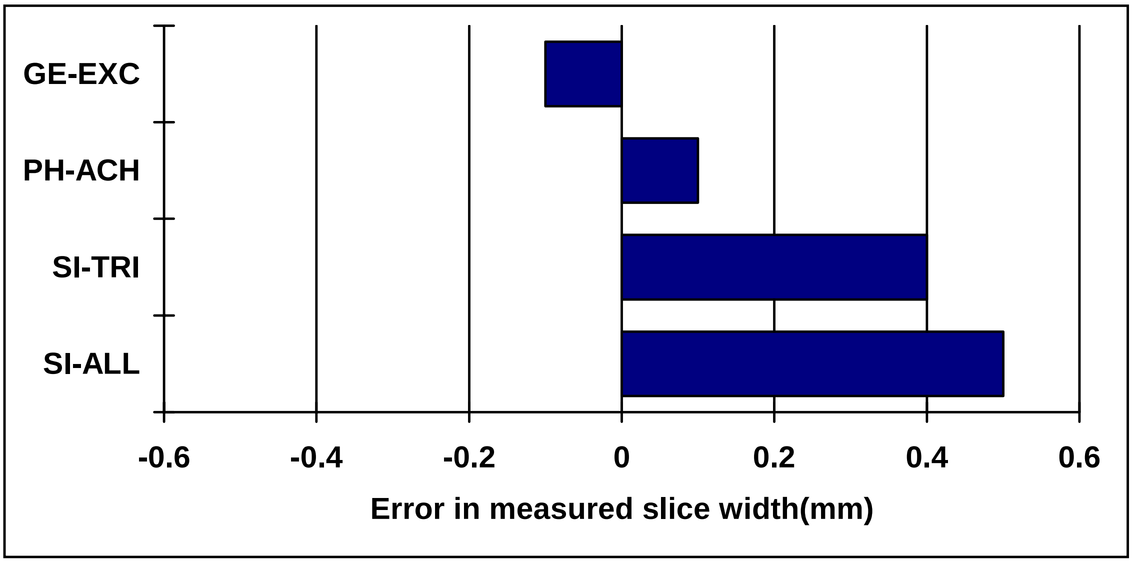
Interpretation of results
The slice profiles should have minimum side lobes, no ringing, and no central drop-out. The measured slice widths for the three imaging planes presented in Table 47 should lie within 10% of the nominal slice width.

Graph 6 and Graph 7 show comparisons of the mean 3 mm and 5 mm slice width measurements for 3T systems tested by MagNET.

Table 47. Slice widths (mm) measured as FWHM of derived profiles

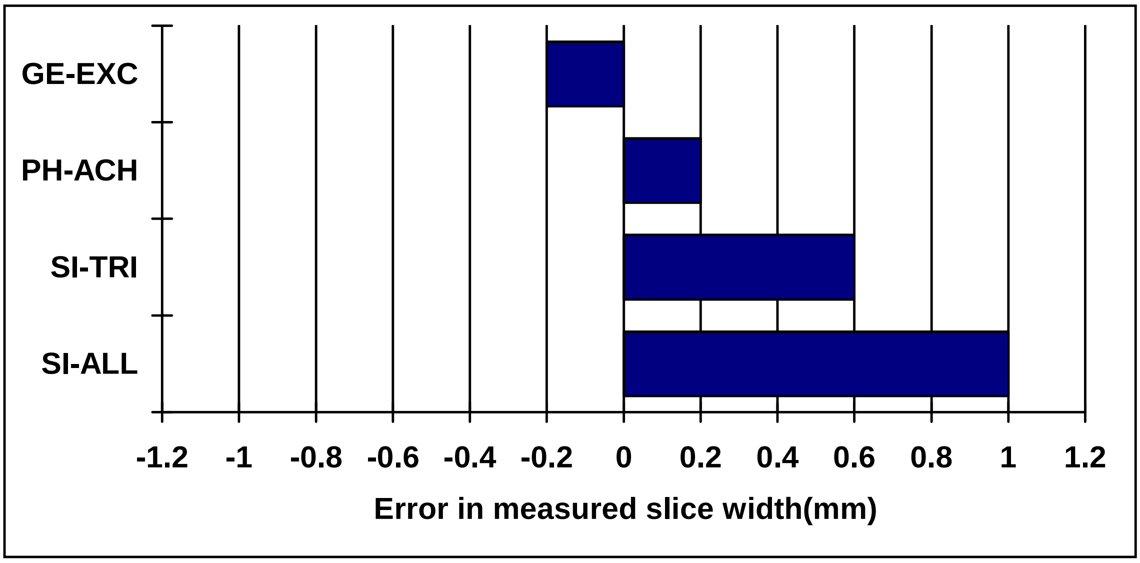
	Transverse	Sagittal	Coronal	Mean ± SD
3 mm test				
GE-EXC	2.9	3.2	2.7	2.9±0.25
PH-ACH	3.1	3.1	3.1	3.1±0.04
SI-ALL	3.9	3.3	3.5	3.5±0.29
SI-TRI	3.3	3.5	3.4	3.4±0.09
5 mm test				
GE-EXC	4.9	5.1	4.5	4.8±0.31
PH-ACH	5.2	5.2	5.3	5.2±0.07
SI-ALL	6.6	5.5	5.9	6.0±0.57
SI-TRI	5.4	5.5	5.7	5.6±0.13

Graph 6. Comparison of measured slice widths for a nominal slice width of 3 mm (mean of three planes)*



* The optimum value is 0 ± 0.3 mm. Systems are ranked in order of the absolute deviation from optimum.

Graph 7. Comparison of measured slice widths for a nominal slice width of 5 mm (mean of three planes)*



* The optimum value is 0 ± 0.5 mm. Systems are ranked in order of the absolute deviation from optimum.

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Quadrature head coil: ghosting

Scan parameters
The standard quadrature head coil ghosting test is carried out using our standard type-test protocol in Table 40 with a four echo sequence TE=30 ms, and NSA=1,2. MagNET's ghosting test object (MAGGHO-OIL) is placed offset from the centre of the coil and is imaged in the transverse planes.

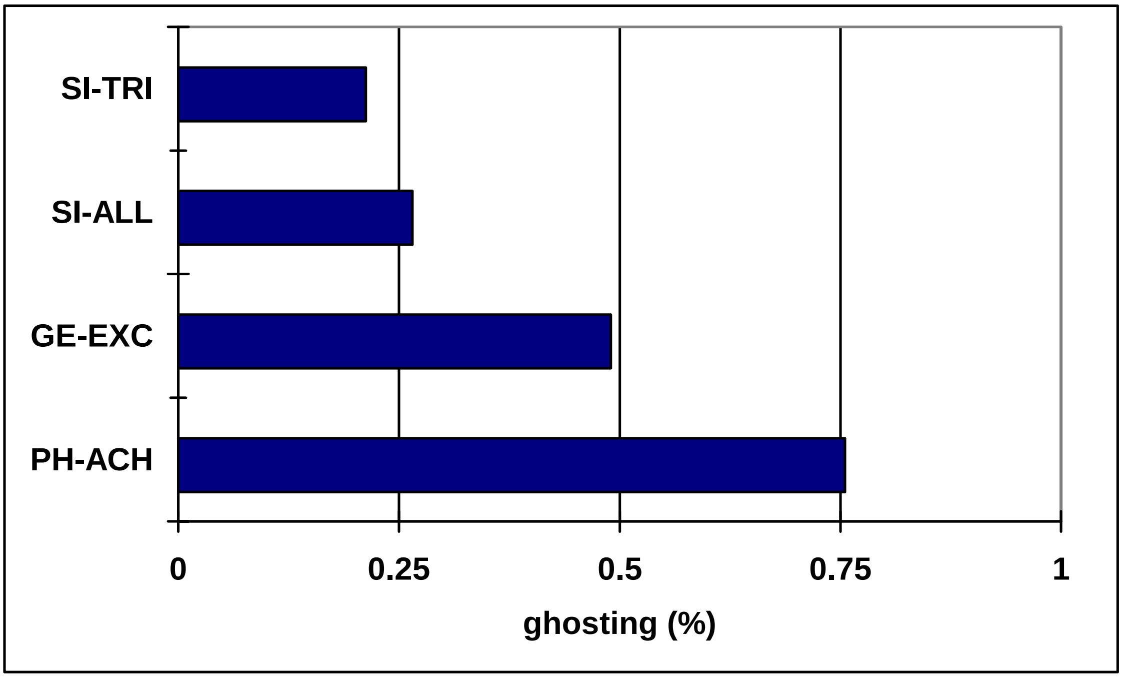
Analysis
Ghosting is calculated as the ratio of the maximum image ghost, minus the background noise, to the image signal (Lerski 1998).

Interpretation of results
The lower the ghosting, the better the performance. Table 48 presents the ghosting results for each echo. Graph 8 and Graph 9 present results for these 3T systems for 1 and 2 NSA respectively.

Table 48. Maximum ghosting ratio for 1 and 2 signal averages

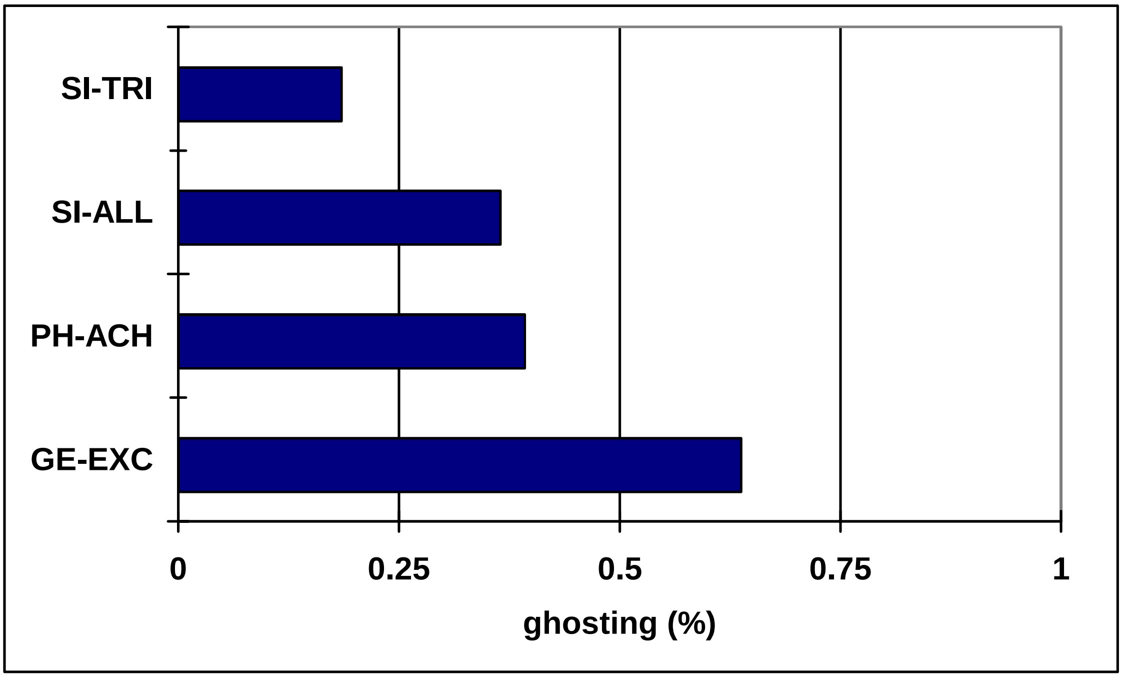
	Echo 1 30 ms	Echo 2 60 ms	Echo 3 90 ms	Echo 4 120 ms	Mean
NSA = 1					
GE-EXC	0.63	0.53	0.37	0.43	0.49
PH-ACH	0.78	0.45	1.04	0.75	0.75
SI-ALL	0.26	0.28	0.27	0.25	0.27
SI-TRI	0.19	0.23	0.23	0.20	0.21
NSA = 2					
GE-EXC	0.73	0.80	0.41	0.61	0.64
PH-ACH	0.28	0.45	0.27	0.57	0.39
SI-ALL	0.39	0.41	0.31	0.35	0.36
SI-TRI	0.15	0.16	0.16	0.27	0.19

Graph 8. Comparison of maximum ghosting (NSA=1)*



*The optimal value is zero.

Graph 9. Comparison of maximum ghosting (NSA=2)*



*The optimal value is zero.

In-built body coil evaluation

In-built body coil: signal to noise ratio (SNR)

Scan parameters
The in-built body coil SNR test is carried out using our standard type-test protocol in Table 40. MagNET's flood field oil test object (MAGFF-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes. Two sequential images are taken for each plane and used to form a subtracted image. Experimental conditions are presented in Table 49.

Analysis
The SNR was calculated using a subtraction method; two identical scans were acquired and a difference image obtained. The mean signal was measured from five regions of interest within the test object area in one of the acquired images and the noise was measured from the standard deviation from these regions in the difference image (Lerski 1998). The values obtained for SNR were normalised for voxel size (including measured slice width), scan time and sampling bandwidth (no normalisation for coil loading).

Interpretation of results
The image SNR value obtained on a system is influenced by many factors. Example system factors are the main magnetic field strength B_0 and the design of the radiofrequency receive and transmit systems. Other factors are the choice of sequence and imaging parameters.

The SNR could not be normalised for loading since some manufacturers were unable to provide Q measurements. Readers should take this into account when reading the report.

The image normalised SNR results for the in-built body coil are presented in Table 50. The comparison made in Graph 10 shows the image SNR normalised for voxel size, scan time and sampling bandwidth for 3T systems.

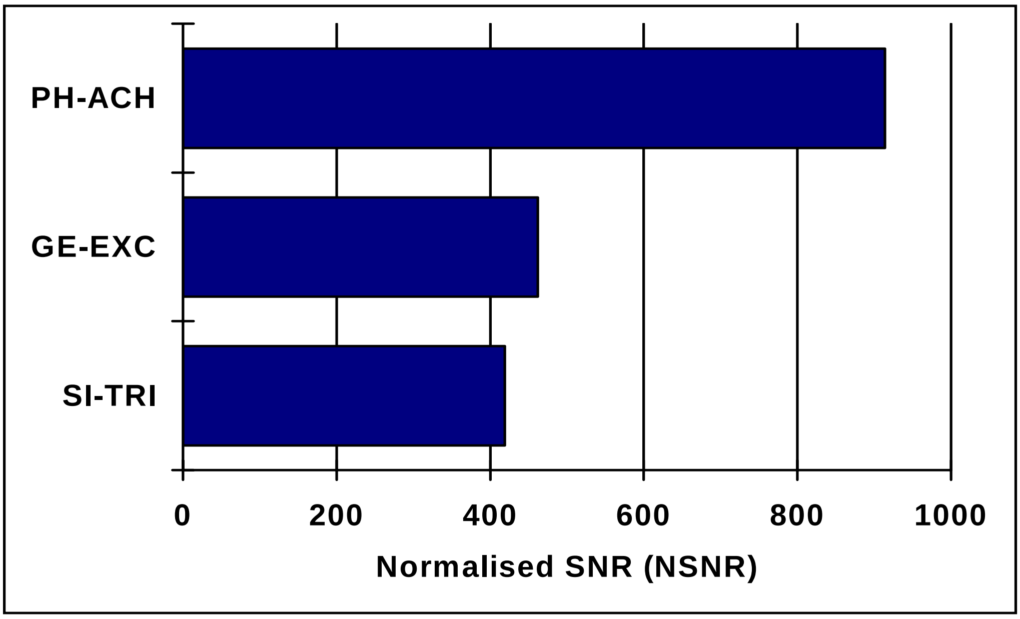
Table 49. Experimental conditions for in-built body coil SNR test

	GE-EXC	PH-ACH	SI-TRI
Temperature (°C)	24	23	20
Bandwidth (kHz)	11.90	46.54	16.64
Test object	MAGFF-OIL	MAGFF3T-OIL	MAGFF-OIL
Loading	None	MAGANN3T	Siemens body loader

Table 50. Signal to noise ratio for the in-built body coil

	Transverse	Sagittal	Coronal	Mean
GE-EXC	437	449	499	462
PH-ACH	933	910	900	914
SI-TRI	417	427	414	419

Graph 10. Comparison of normalised SNR for in-built body coils (mean of three planes)*



* no normalisation for coil loading

In-built body coil: uniformity

Scan parameters
The in-built body coil uniformity test is carried out using our standard type-test protocol in Table 40. MagNET's flood field oil test object (MAGFF-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The average of several intensity profiles is calculated in all three gradient directions. The fractional uniformity is calculated for each gradient direction from the fraction of the profile that lies within 10% of the mean value of a central ROI (Lerski 1998). The optimum value is unity, indicating 100% of the signal is considered uniform over the measured distance.

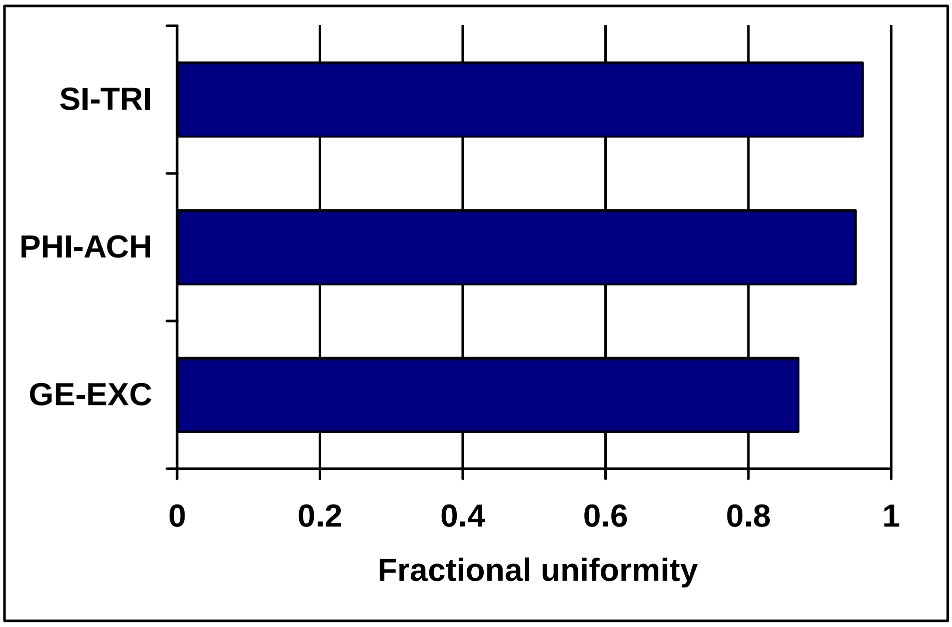
Interpretation of results
A key factor affecting uniformity is the design of the radiofrequency coil. Most body coils are optimised to give a high value for the transverse orientation. Poor uniformity often occurs in the bore direction (z-direction for this system). This can be seen in the vertical values for the sagittal and coronal planes. These values often lower the average for the three planes.

The fractional uniformity measurements in the two directions for each plane are presented in Table 51. The comparison made in Graph 11 shows the mean fractional uniformity for 3T systems.

Table 51. Fractional uniformity for the in-built body coil (unfiltered)

	x-direction	y-direction	z-direction	Mean±SD
GE-EXC	0.97	0.88	0.75	0.87±0.10
PH-ACH	1.00	1.00	0.85	0.95±0.08
SI-TRI	0.95	1.00	1.00	0.96±0.04

Graph 11. Comparison of fractional uniformity (mean of three planes)*



*The optimum value is unity.

Multi-channel head coil evaluation

Multi-channel head coil: signal to noise ratio (SNR)

Scan parameters

The multi-channel head coil SNR test is carried out using our standard type-test protocol in Table 40, using a selection of parallel imaging factors. MagNET's flood field oil test object (MAGFF-OIL or MAGFF3TOIL +MAGANN3T) is placed at the centre of the coil and is imaged at the iso-centre in all three planes. Two sequential images are taken for each plane and used to form a subtracted image. Experimental conditions are presented in Table 52.

Analysis

The SNR was calculated using a subtraction method; two identical scans were acquired and a difference image obtained. The mean signal was measured from five regions of interest within the test object area in one of the acquired images and the noise was measured from the standard deviation from these regions in the difference image (Dietrich 2005). The values obtained for SNR were normalised for voxel size (including measured slice width), scan time and sampling bandwidth (no normalisation for coil loading).

Interpretation of results

The image SNR value obtained on a system is influenced by many factors. For example, system factors such as the main magnetic field strength B_o and the design of the radiofrequency receive and transmit systems can affect the SNR. Other factors are the choice of sequence and imaging parameters.

Table 53 shows the measured SNR values. The comparison made in Graph 12 shows the image SNR normalised for voxel size, scan time, and sampling bandwidth for high-field systems.

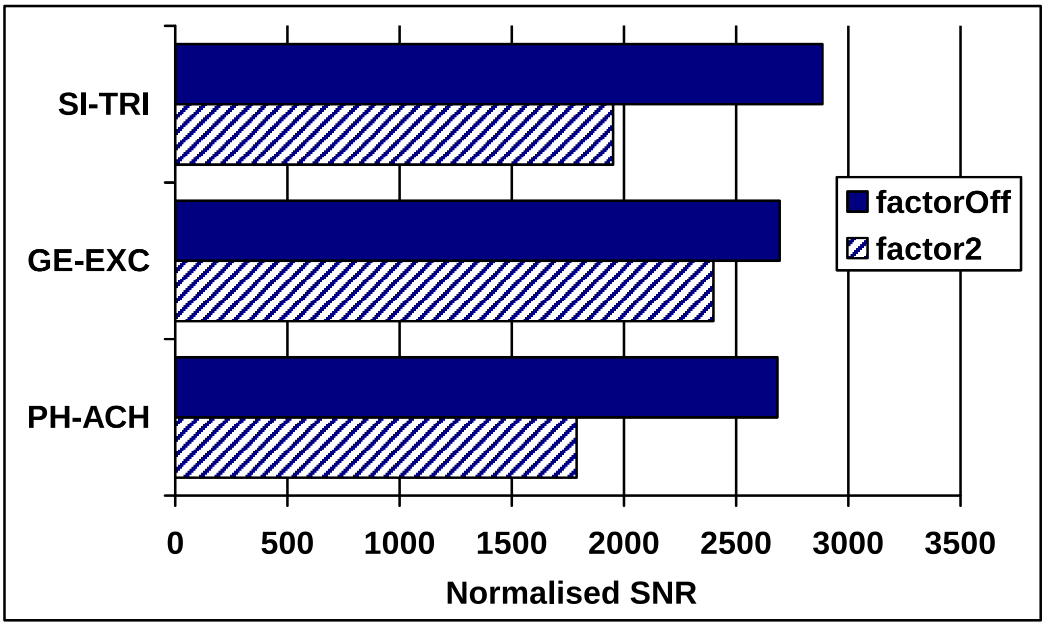
Table 52. Experimental conditions for multi-channel head coil SNR test

	GE-EXC	PH-ACH	SI-TRI
Coil tested	8 channel high resolution brain coil	SENSE head	8 channel head array
Temperature (°C)	24	23	21.5
Bandwidth (kHz)	11.90	46.54	16.64
Sequence	SE for factor off TSE for other factors Turbo factor = 2	SE for factor off TSE for other factors Turbo factor = 2	SE for factor off TSE for other factors Turbo factor = 2
Test object	MAGFF3T-OIL	MAGFF3T-OIL	MAGFF-OIL
Loading	MAGANN-3T	MAGANN-3T	None

Table 53. Multi-channel head coil SNR

	Parallel imaging factor	Transverse	Sagittal	Coronal	Average
GE-EXC	Off	3069	2372	2639	2694
	2	2661	2254	2279	2398
PH-ACH	Off	3240	2568	2244	2684
	2	2278	1568	1520	1789
	3	1715	1333	1195	1415
SI-TRI	Off	3468	3002	2186	2885
	2	2455	1861	1539	1951
	3	1366	2295	1206	1622
	4	1653	1613	1532	1600

Graph 12. Multi-channel head coil normalised SNR (NSNR) (mean of three planes, parallel imaging factors = off, 2)*



* no normalisation for coil loading

Multi-channel head coil: uniformity

Scan parameters
The multi-channel head coil uniformity test is carried out using our standard type-test protocol in Table 40, using a selection of parallel imaging factors. MagNET's flood field oil test object (MAGFF-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis
The average of several intensity profiles is calculated in all three gradient directions. The fractional uniformity is calculated for each gradient direction from the fraction of the profile that lies within 10% of the mean value of a central ROI (Lerski 1998). The optimum value is unity, indicating 100% of the signal is considered uniform over the measured distance.

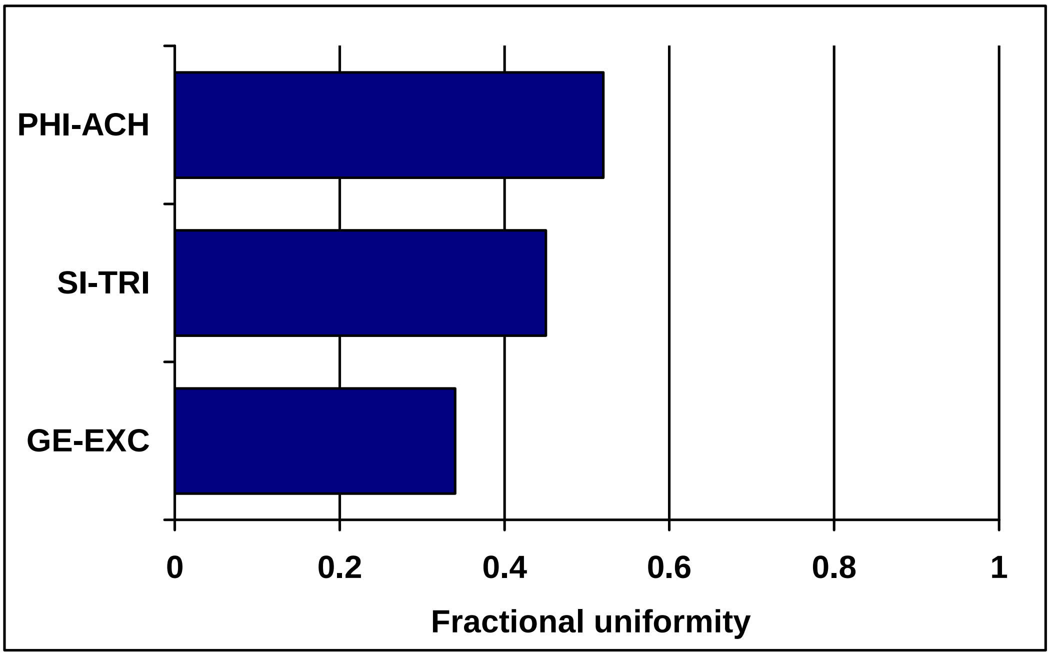
The results for each gradient direction are presented in Table 54. The mean of the gradient directions for each system is indicated in Graph 13.

Table 54. Multi-channel head coil fractional uniformity

	Parallel imaging factor	X-direction	Y-direction	Z-direction	Mean ± SD*
GE-EXC	Off	0.39	0.47	0.17	0.34±0.14
	2	0.39	0.55	0.17	0.37±0.17
PH-ACH	Off	0.60	0.63	0.33	0.52±0.15
	1	1.00	0.96	0.69	0.89±0.15
SI-TRI	Off	0.45	0.56	0.33	0.45±0.10

*Standard deviation (SD) of six measurements (2 measurements per gradient direction)

Graph 13. Multi-channel head coil uniformity (parallel imaging factor off)*



*The optimum value for fractional uniformity is unity.

Multi-channel body coil evaluation

Multi-channel body coil: signal to noise ratio (SNR)

Scan parameters

The multi-channel body coil SNR test is carried out using our standard type-test protocol in Table 40, using a selection of parallel imaging factors. MagNET's flood field oil test object (MAGFF-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes. Two sequential images are taken for each plane and used to form a subtracted image. Experimental conditions are presented in Table 55.

Analysis

The SNR was calculated using a subtraction method; two identical scans were acquired and a difference image obtained. The mean signal was measured from five regions of interest within the test object area in one of the acquired images and the noise was measured from the standard deviation from these regions in the difference image (Dietrich 2005). The values obtained for SNR were normalised for voxel size (including measured slice width), scan time and sampling bandwidth (no normalisation for coil loading).

Interpretation of results

The image SNR value obtained on a system is influenced by many factors. Example system factors are the main magnetic field strength B_0 and the design of the radiofrequency receive and transmit systems. Other factors are the choice of sequence and imaging parameters.

The normalised SNR results for multi-channel body coils are presented in Table 56. The comparison made in Graph 14 shows the image SNR normalised for voxel size, scan time, and sampling bandwidth for systems with equivalent field strength.

Table 55. Experimental conditions for multi-channel body coil SNR test

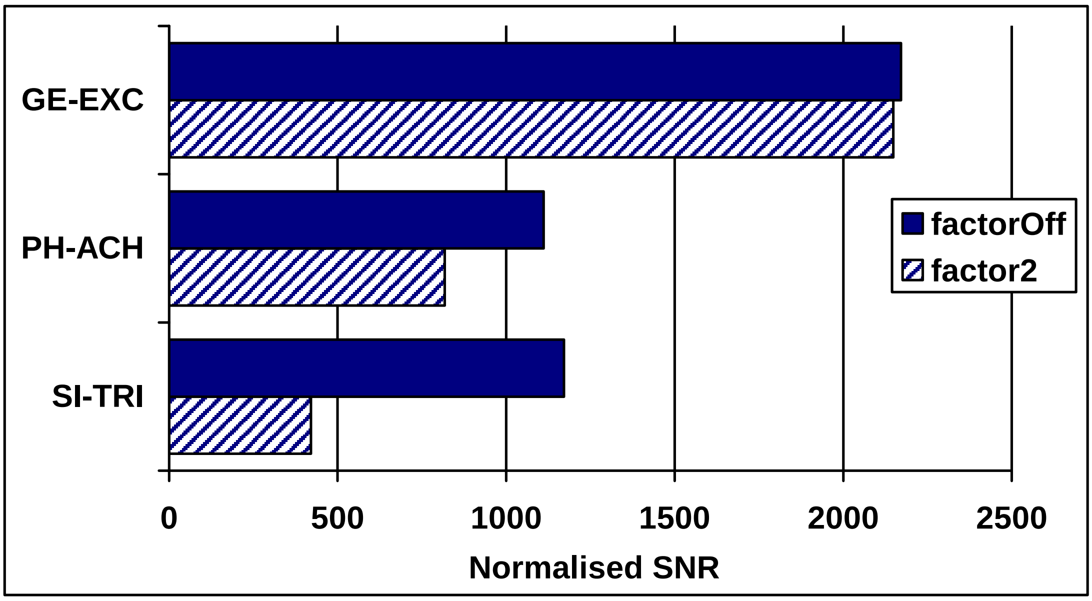
	GE-EXC	PH-ACH	SI-TRI
Coil tested	8 channel high definition cardiac array	SENSE body (x2)	CP body array flex and CP body array extender
Temperature (°C)	24	23	20
Bandwidth (kHz)	11.9	46.54	16.64
Sequence	SE for factor off TSE for other factors Turbo factor = 2	SE for factor off TSE for other factors Turbo factor = 2	SE for factor off TSE for other factors Turbo factor = 2
Test object	MAGFF-OIL	MAGFF-OIL	MAGFF-OIL
Loading	None	None	None

Table 56. Signal to noise ratio for the multi-channel body coil

	Parallel imaging factor	Transverse	Sagittal	Coronal	Mean
GE-EXC	Off	2000	2323	2191	2171
	2	2269	2178	2000	2149
PH-ACH	Off	1179	1193	962	1111
	1	1274	1247	1041	1187
	2	823	872	757	818
	3	462	472	417	450
	4	244	303	233	260
	6	51	45	39	45
SI-TRI	Off	1181	1300	1033	1171
	2	743	291	230	421

Data for further parallel imaging factors are not available due to time constraints at the time of system technical assessment.

Graph 14. Comparison of normalised SNR for multi-channel body coils (mean of three planes, parallel imaging = off, 2)*



* no normalisation for coil loading

Multi-channel body coil: uniformity

Scan parameters

The multi-channel body coil uniformity test is carried out using our standard type-test protocol in Table 40. MagNET's flood field oil test object (MAGFF-OIL) is placed at the centre of the coil and is imaged at the iso-centre in all three planes.

Analysis

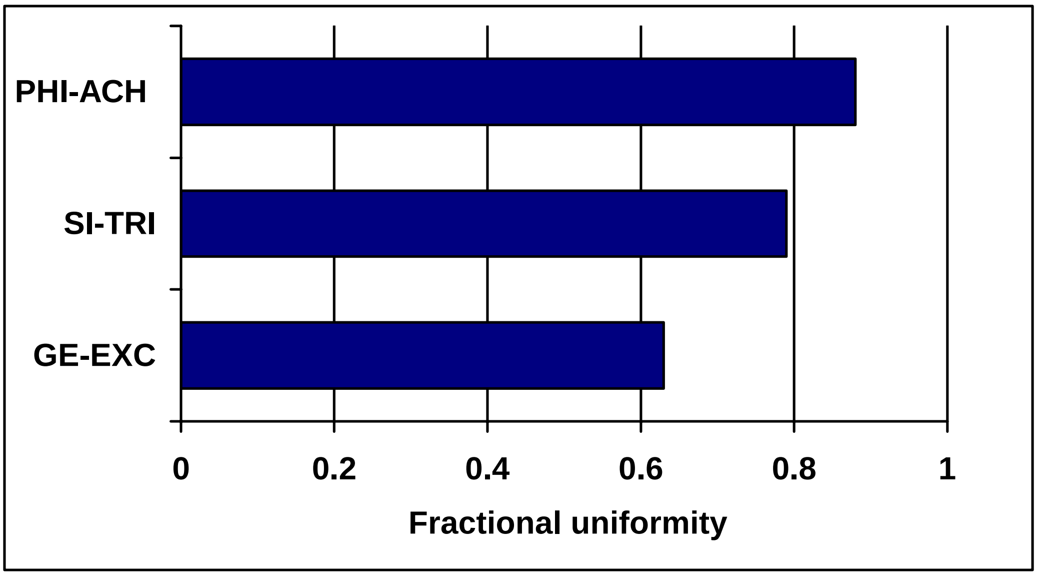
The average of several intensity profiles is calculated in all three gradient directions. The fractional uniformity is calculated for each gradient direction from the fraction of the profile that lies within 10% of the mean value of a central ROI (Lerski 1998). The optimum value is unity, indicating 100% of the signal is considered uniform over the measured distance.

The results for each gradient direction are presented in Table 57. The mean of the gradient directions for each system is indicated in Graph 15.

Table 57. Multi-channel body coil fractional uniformity

	Parallel imaging factor	Transverse	Sagittal	Coronal	Mean ± SD
GE-EXC	Off	0.96	0.39	0.53	0.63±0.28
	2	0.93	0.39	0.50	0.61±0.27
PH-ACH	Off	0.94	0.88	0.81	0.88±0.06
	1	1.00	1.00	0.87	0.96±0.07
SI-TRI	Off	0.93	0.46	0.98	0.79±0.05

Graph 15. Comparison of fractional uniformity for multi-channel body coils (mean of three planes, parallel imaging factor = off)*



*The optimum value is unity.

2D and 3D imaging speed

Scan parameters
The sequences and parameters used for evaluating 2D and 3D imaging speed are presented in the Appendix (p.77)

Interpretation of results
Both the 2D and 3D imaging speed tests require a fixed volume to be acquired using 2D and 3D fast imaging sequences. The aim of these tests is to measure data acquisition speed in voxels/second. The voxel size is defined by the image matrix and the number of slices in the fixed range. Both the 2D and 3D imaging speed tests allow for the use of parallel imaging techniques.

CEP comment

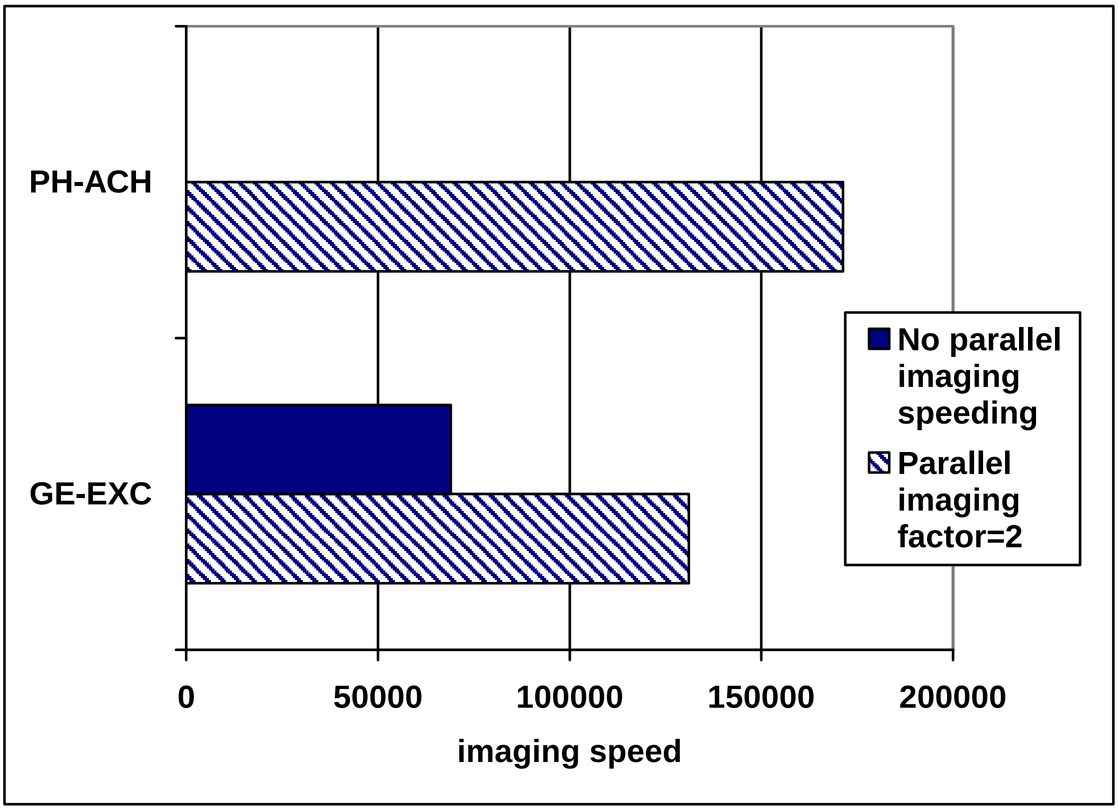
Imaging speed has been calculated as the ratio of imaged voxels to total scan time. The total scan time is the time displayed by the scanner, rather than the number of phase-encoding steps × repetition time (TR).

In the case of parallel imaging, pre-scanning (sensitivity encoding) is a pre-requirement for image reconstruction. GE and Philips systems perform the pre-scan before a parallel imaging scan study hence the pre-scan time is not included in the total scan time when calculating imaging speed. Siemens systems perform the pre-scan as part of each parallel imaging scan; hence the pre-scan is included in the total scan time when calculating imaging speed.

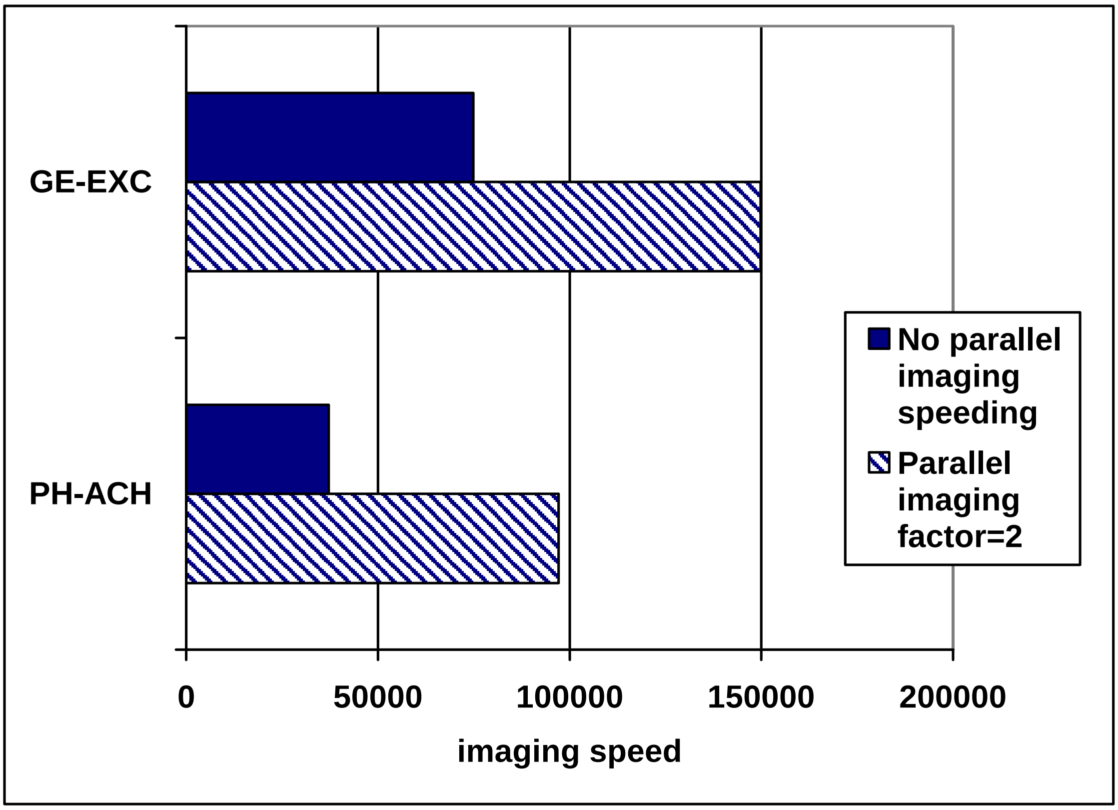
Therefore the imaging speed results, where applicable, are presented in separate graphs.

The numerical results of the 2D and 3D imaging speed tests are presented in the Appendix.

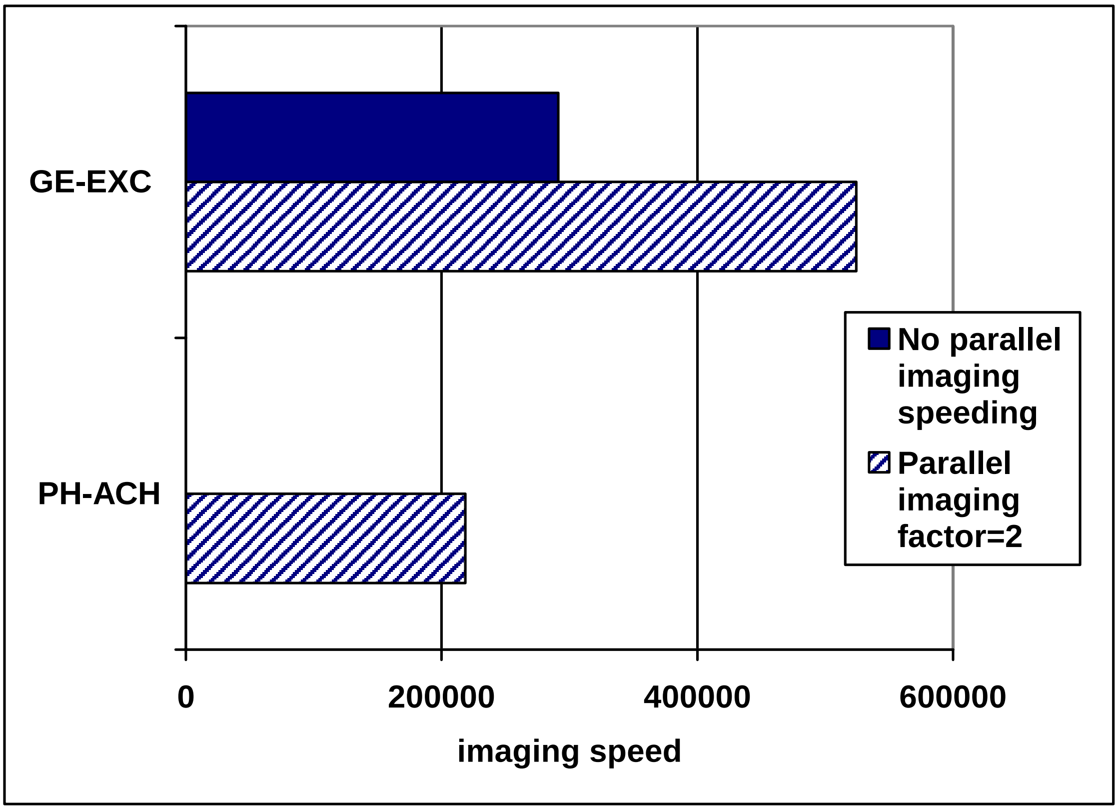
Graph 16. Comparison of 2D imaging speed with GRE-type sequences



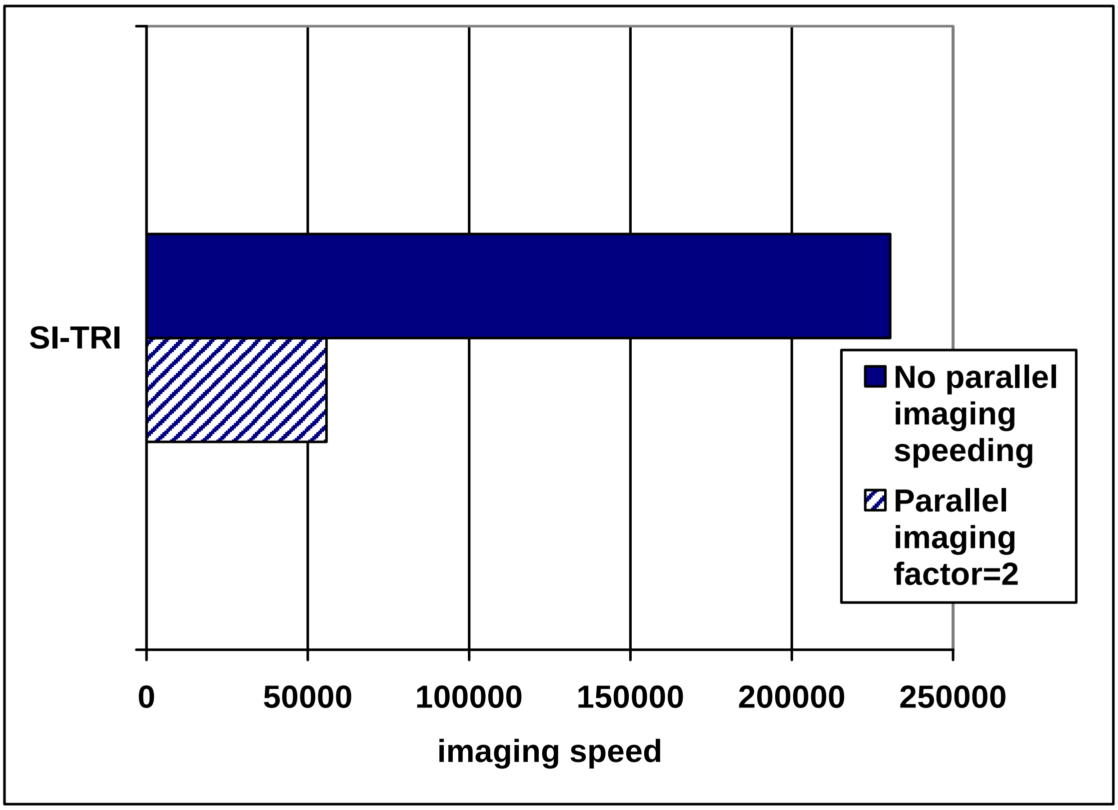
Graph 17. Comparison of 2D imaging speed with FSE-type sequences



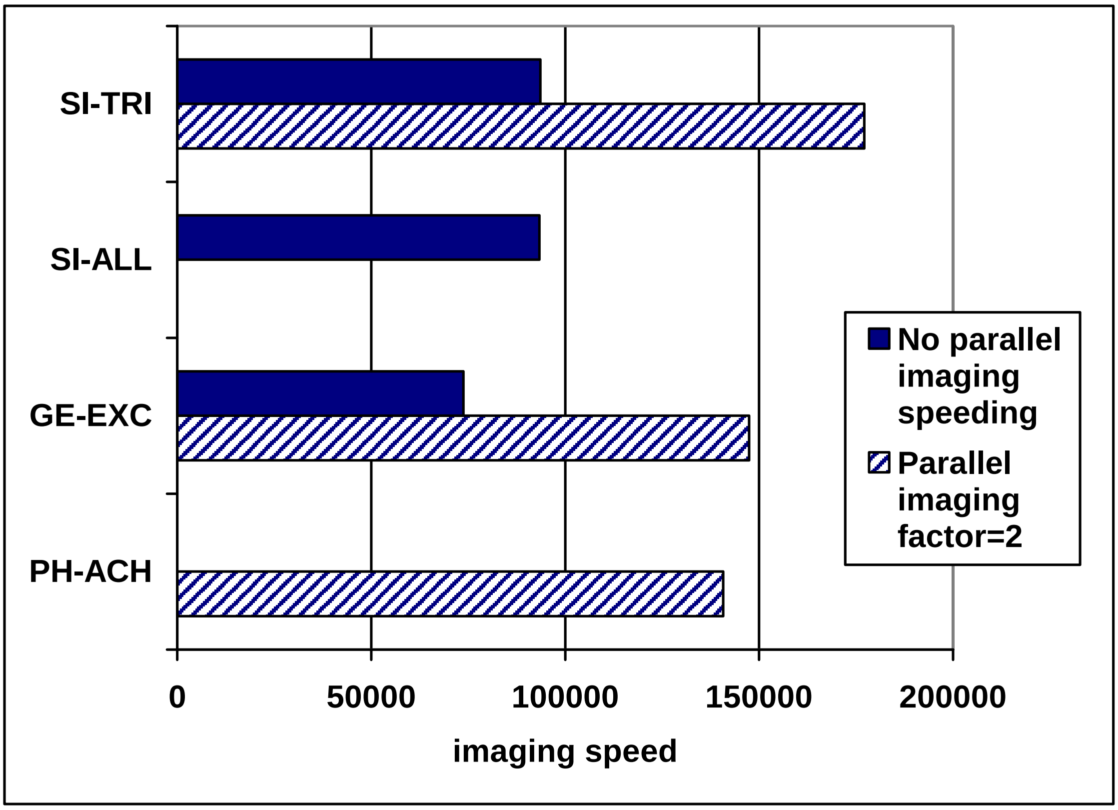
Graph 18. Comparison of 2D imaging speed with EPI-type sequences (pre-scan separate from main scan)



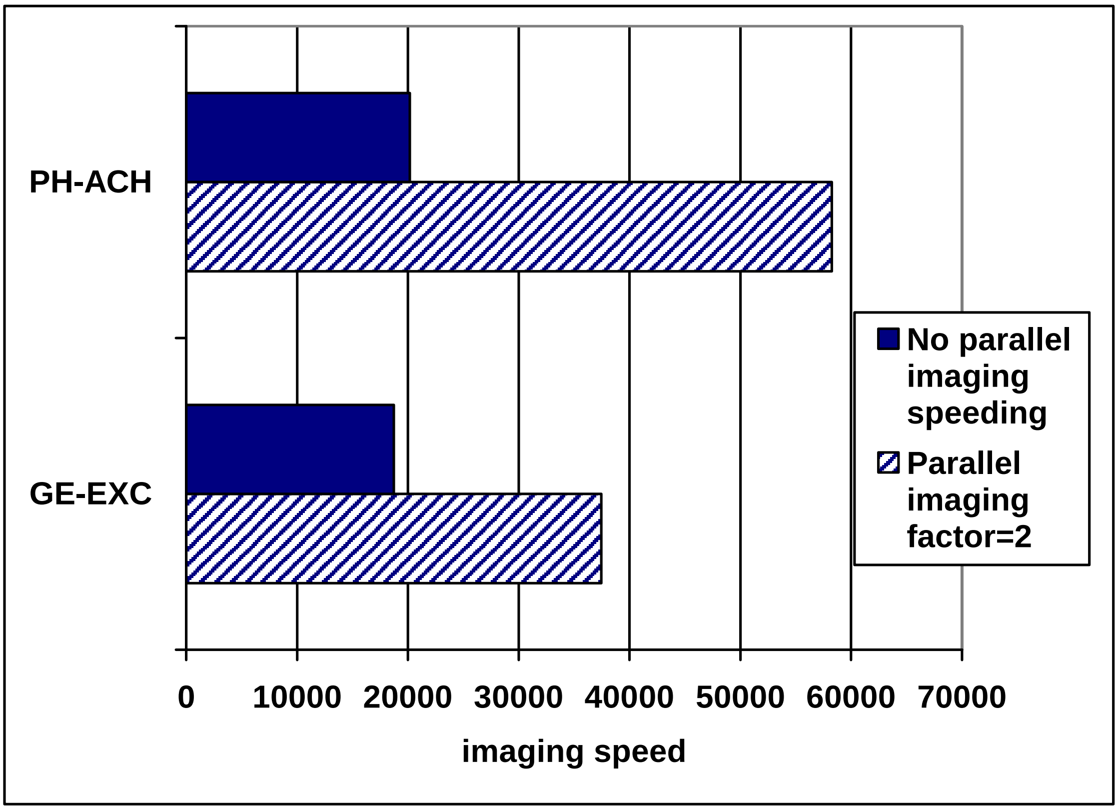
Graph 19. Comparison of 2D imaging speed with EPI-type sequences (pre-scan included in main scan)



Graph 20. Comparison of 3D imaging speed using parallel imaging, with FGE-type sequences



Graph 21. Comparison of 3D imaging speed using parallel imaging, with FSE-type sequences



Acoustic noise

Acoustic noise levels are given in terms of the continuous equivalent level, L_{AEQ}, which is A-weighted root-mean-square sound pressure level (SPL) averaged over the measurement period of 1 minute. The relevant safety levels follow.

Patients and volunteers

IEC-60601-2-33
If the scanner can exceed 99 dB(A) then an instruction for the use of hearing protection must be included in the manufacturer's instructions for use.

MHRA
Hearing protection is recommended for all patients even when exposure is less than 99 dB(A). Where sites can demonstrate noise levels significantly below 85 dB(A) then this requirement may be relaxed. Please refer to Guidelines for Magnetic Resonance Diagnostic Equipment in Clinical Use: Medical Devices Agency 2002.

Staff

The UK legislation is to meet the requirements of the EU DIRECTIVE 2003/10/EC and The Control of Noise at Work Regulations 2005 (effective from 6 April 2006)
Employers have legal duty to protect the hearing of their employees. Hearing protection must be available for workers exposed to 80 dB(A) and must be worn if levels exceed 85 dB(A). Employers are responsible for performing risk assessments for employees exposed to noise. This would include staff present in the MR scan room during imaging.

Table 58 displays clinical pulse sequences designed to be run on all tested systems to provide comparative information about acoustic noise. The acoustic noise levels for these sequences are displayed in Table 59. Graph 22 displays comparatively the L_{AEQ} levels for the 3DGE sequence. Acoustic noise levels are given in terms of the continuous equivalent level, L_{AEQ}. All values are on the A-weighted scale.

Table 58 displays clinical pulse sequences designed to be run on all tested systems to provide comparative information about acoustic noise. The acoustic noise levels for these sequences are displayed in Table 59 and in Graph 22. Acoustic noise levels are given in terms of the continuous equivalent level, L_{Aeq} and the peak noise L_{peak}. All values are on the A-weighted scale.

Table 58. Clinical pulse sequences for comparative acoustic noise

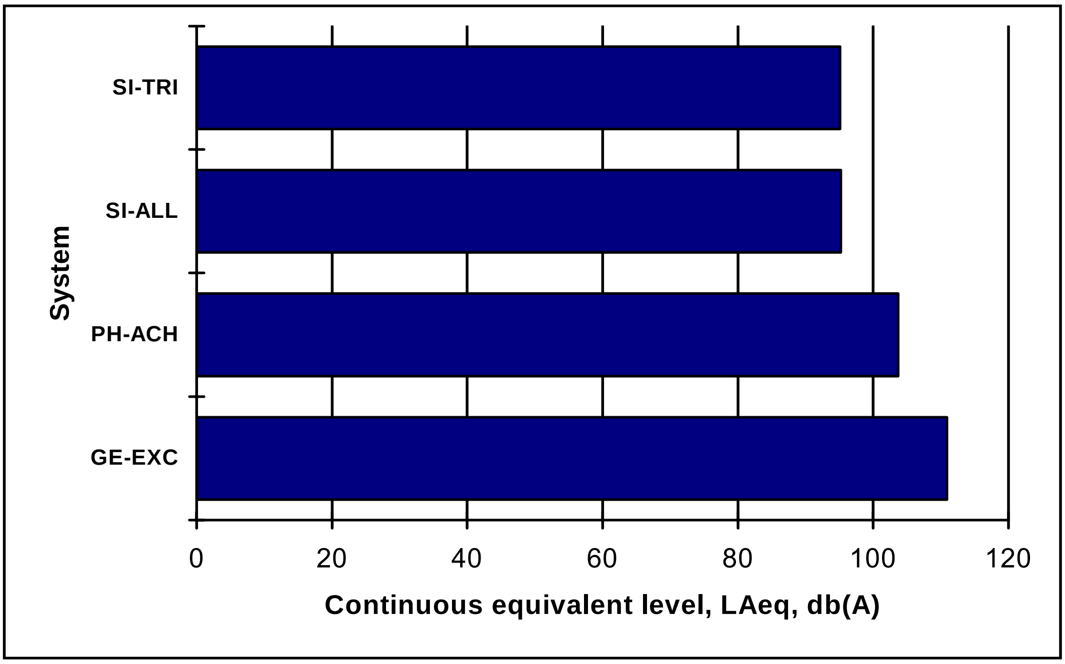
Pulse Sequence	TE	TR	Matrix	NSA	FOV	Flip angle	SW	Slices
SE	15	450	256×256	1	320	1	4	10
FSE (ETL = 4)	15	4000	256×256	1	320	1	4	10
GE (3D)	9	23	160×256	1	170	1	1	10
Single shot EPI	24	2000	128×128	32	230	1	5	10

Table 59. Acoustic noise levels for comparative pulse sequences

	Pulse sequence with acoustic noise level dB(A)							
System	SE		FSE		3DGE		EPI	
	L_{Aeq}	L_{peak}	L_{Aeq}	L_{peak}	L_{Aeq}	L_{peak}	L_{Aeq}	L_{peak}
GE-EXC*	101.9	115.1	98.8	116.8	110.9	123.0	102.7	119.1
PH-ACH†	83.9	96.7	83.3	101.4	103.7	112.4	108.6	119.2
SI-ALL	72.0	86.4	81.8	85.2	95.2	95.9	94.1	103.7
SI-TRI‡	88.5	95.5	87.4	92.2	95.1	95.9	95.2	99.0

*For 3DGE sequence: TE=2.1ms; For single shot EPI sequence: NSA=30
†For 3DGE: NSA=2; For EPI sequence: matrix=80x80.
‡For FSE sequence: slice width=5; For 3DGE: slices=16; For EPI: TE=35ms, FOV=395

Graph 22. Acoustic noise levels for 3DGE sequences



List of safety information

3 Tesla safety

MRI at 3 T falls into the controlled mode of operation (Guidelines for Magnetic Resonance Diagnostic Equipment in Clinical Use: Medical Devices Agency 2002). This is because the clinically monitored upper level as defined by the Health Protection Agency (NRPB, Volume 2 Number 1) is between 2.5 T and 4 T. Pregnant women should not be scanned above 2.5 T. Care should also be taken to ensure the safety of implants, monitoring equipment and other devices since use at a lower field strength cannot be taken as evidence of safety at 3 T.

General

Reference Manual for Magnetic Resonance Safety: F Shellock. Amirsys Inc, Salt Lake City, 2003.

Magnetic Resonance Procedures Health Effects and Safety: F Shellock Ed.CRC Press, Boca Raton, 2001.

UPMC MR Safety Web Site at www.radiology.upmc.edu/MRsafety

Institute of Magnetic Resonance Safety, Education and Research Web Site at www.mrisafety.com.

Medicines and Healthcare products Regulatory Agency

Guidelines for Magnetic Resonance Diagnostic Equipment in Clinical Use: Medical Devices Agency 2002.

MDA/2003/014 - Static MRI scanners with quench vent pipes.

MDA Safety Warning SN 2001 (27) – Programmable Hydrocephalus Shunts: Risks of Reprogramming during MRI Procedures

Safety notice MDA SN 9517. Risk of burns to patients, with attached monitoring leads, undergoing MRI scan: Medical Devices Agency. July 1995.

Medicines and Healthcare products Regulatory Agency Adverse Incident Reporting at www.mhra.gov.uk.

Health Protection Agency

NRPB: Advice on limiting exposure to electromagnetic fields (0-300 GHz) Volume 15 Number 2 2004. http://www.hpa.org.uk/radiation

NRPB Board Statement on “Principles for the protection of patients and volunteers during clinical magnetic resonance diagnostic procedures” Volume 2 Number 1 1991.

ICNIRP: Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz), Health Physics Vol. 74, No 4, pp 494-522, 1998. www.icnirp.de.

ICNIRP: Exposure to Static and Low Frequency Electromagnetic Fields, Biological Effects and Health Consequences (0-100 kHz)- Review of the Scientific Evidence and Health Consequences. J.H. Bernhardt, R. Matthes, A. McKinlay, P. Vecchia, B. Veyret (eds.) International Commission on Non-Ionizing Radiation Protection 2003, ISBN 3-934994-03-2. www.icnirp.de.

Other bodies

IEC 60601-2-33:2002 (Medical Electrical Equipment. Part 2. Particular Requirements for Safety. Section 2.33 Specifications for Magnetic Resonance Equipment for Medical Diagnosis). www.iec.ch

FDA Center for Devices and Radiological Health www.fda.gov/cdrh

NHS advice

Health Building Note (HBN) 6, supplement 1:Accommodation for Magnetic Resonance Imaging. 1994. Produced by NHS Estates, published by HMSO PO Box 276, London SW8 5DT. ISBN 0113217307.

Health Guidance Note: Magnetic Resonance Imaging. 1997. Produced by NHS Estates, published by HMSO PO Box 276, London SW8 5DT. ISBN 0113220510.

Health Building Note (HBN) 6: Facilities for diagnostic imaging and interventional radiology. 2001. Produced by NHS Estates, published by HMSO PO Box 276, London SW8 5DT. ISBN 0113220000.

Health Building Note (HBN) 6, Volume 3:Extremity and open MRI, magnetic shielding and construction for radiation protection. 2003. Produced by NHS Estates, published by HMSO PO Box 276, London SW8 5DT. ISBN 0113224869.

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References

Lerski R, De Wilde J, Boyce D, Ridgway J. (1998). "Quality-control in magnetic resonance imaging" (IPEM report No. 80). York, UK, ISBN 0 904181 901

Dietrich O, Reeder SB, Reiser MF, Schoenberg SO, Proceedings of ISMRM, 7-13 May 2005, Florida USA, Abstract No 158 "Influence of Parallel Imaging and Other Reconstruction Techniques on the Measurement of Signal-To-Noise Ratios"

Appendix

Manufacturers' comments

GE
The manufacturer had no additional comments
Philips
The manufacturer had no additional comments
Siemens

Comparative specifications
Key technical data (e.g. gradient strength and slew rate, image reconstruction speed) are based on manufacturer information and are not cross-checked by MagNET applying independent experimental procedures.
The reader of this document should be aware that some manufacturers define these specifications in a different way making direct comparison invalid. Please note that Siemens specifies gradient strength and gradient slew rate for each individual axis (and not as a vector summation).

SNR-evaluation
Comparison of different SNR values acquired with not comparable loads are highly questionable. The reader is advised to ask each manufacturer for SNR values obtained under clinical loading conditions.

Spatial resolution
The MTF of a properly calibrated MRI system with 2D-spin single echo imaging is (in absence of raw data filters) rectangular with a step from one to zero at pi/(nominal pixel size). To see this, the analysis has to be performed on the complex image data prior to the application of the magnitude operator [Steckner et al., Med. Phys. 21 (3), 1994 and examples provided therein]. The presented data are obtained from magnitude images. The differences of the calculated values to the nominal pixel resolution may result from the applied magnitude operator on the evaluated image and therefore probably will not represent a true resolution difference.

Parallel imaging SNR
Evaluation or comparison on images acquired using parallel imaging techniques requires to keep in mind that the noise background is not uniform so the results are dependent on the ROI choice.

CEP comment
CEP recognises that the image noise can be spatially dependent in images acquired using parallel imaging techniques. An average is taken from 5 ROIs placed on the image. The technique used by CEP has been shown to be robust for parallel imaging acquisitions, as shown recently in ISMRM (Influence of Parallel Imaging and Other Reconstruction Techniques on the Measurement of Signal-To-Noise Ratios, Olaf Dietrich, Scott B. Reeder, Maximilian F. Reiser, Stefan O. Schoenberg, Proceedings of ISMRM, 7-13 May 2005, Florida USA, Abstract No 158)

2D and 3D imaging speed
Image reconstruction speed is specified for a true square 256x256 matrix, with 100% matrix and 100% FOV, i.e. for a true 256x256 data set (65,536 data points) without any data reductions. If in doubt a written confirmation of data by the manufacturer may be advisable.
In the presented 2D-epi data within parallel imaging a pre-scan based on the same epi-technique is acquired for all slices. This time is included in the presented measurement times and in the calculated imaging speed values. The speed values are therefore not a measure for imaging speed. For proper interpretation of the imaging speed when using epi-technique the repetition time can be used as a time reference instead of the overall scan time. The latter includes the duration of the epi-specific pre-scan. These pre-scans are not representative for non-epi 2D imaging where the pre-scans are part of the imaging scan.

2D imaging speed: sequence parameters

Table 60. Standard imaging protocol for 2D imaging speed evaluation

Sequence parameter		Standard protocol
2D sequence		Gradient Echo (GRE), Echo Planar Imaging (EPI), Fast Spin Echo (FSE)
TE (ms)		Manufacturer's choice
TR (ms)		Manufacturer's choice
Flip angle (degrees)		Manufacturer's choice
NSA		Manufacturer's choice
Bandwidth (kHz)		Manufacturer's choice
Echo Train Length (where applicable)		Manufacturer's choice
FOV (mm)		250
Matrix (PE x FE)		256 x 256
Slice width (mm)		Less than 5 mm
Parallel imaging factors		Selection (manufacturer's choice)
Range (mm)	I	To equal 200
Contiguous slices	II	Maximise
Scan time (min:sec)	III	Minimise

Table 61. Scan parameters for 2D imaging speed evaluation on the GE MRI system (Twinspeed HD gradients)

Sequence parameter	Sequence parameter values						
Imaging coil	8-channel high resolution brain coil						
2D sequence	2D FGRE			GRE-EPI		FSE-XL	
TE (ms)	1.6			113	57.4	3.3	
TR (ms)	3.5			9300	4800	21000	
Flip angle (degrees)	10			90		Not supplied	
NSA	1			1		1	
Bandwidth (kHz)	200			Not measured		83.3	
Echo Train Length	Not applicable			Not applicable		128	
FOV (mm)	250			250		250	
Matrix (PE x FE)	256 x 256			256 x 256		256 x 256	
Slice width (mm)	5			5		4.2	
Parallel imaging factors	off	1.5	2.0	off	2.0	off	2.0
Range (mm)	200			200		201.6	
Contiguous slices	40			40		48	
Scan time (min:sec)	0:38	0:26	0:20	0:09	0:05	0:42	0:21

Table 62. Scan parameters for 2D imaging speed evaluation on the Philips Achieva MRI system (Quasar Dual gradients)

Sequence parameter	Sequence parameter values		
Imaging coil	8-channel SENSE head coil		
2D sequence	2D-FFE	FE-EPI	2D-TSE
TE (ms)	1.50	9.00	34.90
TR (ms)	119	1000	8100
Flip angle (degrees)	10	10	30
NSA	1	1	1
Bandwidth (kHz)	Not measured	Not measured	Not measured
Echo Train Length	Not applicable	Not applicable	Not measured
FOV (mm)	250	250	250
Matrix (PE x FE)	256 x 256	256 x 256	256 x 256
Slice width (mm)	5	5	2.09
Parallel imaging factors	1 2 4 8	1 2 4 8	1 2 8
Range (mm)	200	200	200
Contiguous slices	40	40	96
Scan time (min:sec)	0:30.8 0:15.3 0:07.6 0:04.0	0:21 0:12 0:08 0:06	2:09.6 1:04.8 0:16.2

Table 63. Scan parameters for 2D imaging speed evaluation on the Siemens MAGNETOM Trio MRI system (Trio gradients)

Sequence parameter	Sequence parameter values		
Imaging coil	8-channel head coil		
2D sequence	2D EPI		
TE (ms)	145	75	40
TR (ms)	11370	5850	3060
Flip angle (degrees)	90		
NSA	1		
Bandwidth (kHz)	Not measured		
Echo Train Length	Not applicable		
FOV (mm)	250		
Matrix (PE x FE)	256 x 256		
Slice width (mm)	5		
Parallel imaging factors	off	2	4
Range (mm)	200		
Contiguous slices	40		
Scan time (min:sec)	0:11.37	0:47	0:31

3D imaging speed: sequence parameters

Table 64. Standard imaging protocol for 3D imaging speed evaluation

Sequence parameter		Standard protocol
3D sequence		Gradient Echo (GRE), Fast Spin Echo (FSE)
TE (ms)		Manufacturer's choice
TR (ms)		Manufacturer's choice
Flip angle (degrees)		Manufacturer's choice
NSA		Manufacturer's choice
Bandwidth (kHz)		Manufacturer's choice
Echo Train Length (where applicable)		Manufacturer's choice
FOV (mm)		250
Matrix (PE x FE)		128 x 128
Slice width (mm)		Manufacturer's choice
Parallel imaging factors		Selection (manufacturer's choice)
Range (mm)	I	To equal 200
Contiguous slices	II	Maximise
Scan time (min:sec)	III	Minimise

Table 65. Scan parameters for 3D imaging speed evaluation on the GE MRI system (Twinspeed HD gradients)

Sequence parameter	Sequence parameter values				
Imaging coil	8-channel high resolution brain coil				
3D sequence	FSPGR			FRFSE-XL	
TE (ms)	0.9			17	
TR (ms)	1.7			217	
Flip angle (degrees)	10			Not measured	
NSA	1			1	
Bandwidth (kHz)	125			125	
Echo Train Length	Not applicable			32	
FOV (mm)	250 x 250 x 201.6			250 x 250 x 200	
Matrix (PE x FE)	128 x 128			128 x 128	
Slice width (mm)	1.6			2.5	
Parallel imaging factors	off	1.5	2.0	off	2
Range (mm)	201.6			200	
Contiguous slices	126			80	
Scan time (min:sec)	0:28	0:19	0:14	1:10	0:35

Table 66. Scan parameters for 3D imaging speed evaluation on the Philips Achieva MRI system (Quasar Dual gradients)

Sequence parameter	Sequence parameter values							
Imaging coil	8-channel SENSE head Coil							
3D sequence	3D FFE				3D TSE			
TE (ms)	0.83				51			
TR (ms)	1.73				268			
Flip angle (degrees)	10				30			
NSA	1				1			
Bandwidth (kHz)	329.97				329.97			
Echo Train Length	Not applicable				34			
FOV (mm)	250 x 250 x 199.68				250 x 250 x 199.68			
Matrix (PE x FE)	128 x 128				128 x 128			
Slice width (mm)	1.56				1.56			
Parallel imaging factors	1	2	4	8	off	2	4	8
Range (mm)	199.68				199.68			
Contiguous slices	128				128			
Scan time (min:sec)	0:28.4	0:14.9	0:07.4	0:03.7	1:44	0:36	0:18.8	0:10.2

Table 67. Scan parameters for 3D imaging speed evaluation on the Siemens MAGNETOM Allegra MRI system (Allegra gradients)

Sequence parameter	Sequence parameter values
Imaging coil	8-channel head coil
3D sequence	3D FLASH
TE (ms)	0.67
TR (ms)	1.70
Flip angle (degrees)	8
NSA	1
Bandwidth (kHz)	Not measured
Echo Train Length	Not applicable
FOV (mm)	250 x 250 x 200
Matrix (PE x FE)	128 x 128
Slice width (mm)	5
Parallel imaging factors	off
Range (mm)	200
Contiguous slices	40
Scan time (min:sec)	0:0.7

Table 68. Scan parameters for 3D imaging speed evaluation on the Siemens MAGNETOM Trio MRI system (Trio gradients)

Sequence parameter	Sequence parameter values		
Imaging coil	8-channel head coil		
3D sequence	3D FLASH-CE		
TE (ms)	0.67		
TR (ms)	1.70		
Flip angle (degrees)	5		
NSA	1		
Bandwidth (kHz)	Not measured		
Echo Train Length	Not applicable		
FOV (mm)	250 x 250 x 200		
Matrix (PE x FE)	128 x 128		
Slice width (mm)	5		
Parallel imaging factors	off	2	4
Range (mm)	200		
Contiguous slices	40		
Scan time (min:sec)	0:0.7	0:03.7	0:02.4

2D and 3D imaging speed results

Table 69. 2D imaging speed results (voxels/sec) for GRE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-EXC	68 985	Not applicable	131 072	Not applicable	Not applicable	Not applicable
PH-ACH	Not measured	85 1112	171 336	344 926	Not measured	655 360
SI-ALL	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable
SI-TRI	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable

Table 70. 2D imaging speed results (voxels/sec) for EPI-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-EXC	291 271	Not applicable	524 288	Not applicable	Not applicable	Not applicable
PH-ACH	Not measured	124 830	218 453	327 680	Not measured	436 907
SI-ALL	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable
SI-TRI	230 558	Not applicable	448 109	856 680	Not measured	Not applicable

Table 71. 2D imaging speed results (voxels/sec) for FSE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-EXC	74 898	Not applicable	149 797	Not applicable	Not applicable	Not applicable
PH-ACH	37 131	48 545	97 090	Not measured	Not measured	388 361
SI-ALL	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable
SI-TRI	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable

Table 72. 3D imaging speed results (voxels/sec) for FSE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-EXC	18 725	Not applicable	37 449	Not applicable	Not applicable	Not applicable
PH-ACH	20 165	Not measured	58 254	111 551	Not measured	205 603
SI-ALL	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable
SI-TRI	Not measured	Not applicable	Not measured	Not measured	Not measured	Not applicable

Table 73. 3D imaging speed results (voxels/sec) for GRE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-EXC	73 728	Not applicable	147 456	Not applicable	Not applicable	Not applicable
PH-ACH	Not measured	73 843	140 748	283 399	Not measured	566 798
SI-ALL	93 356	Not applicable	Not measured	Not measured	Not measured	Not measured
SI-TRI	93 623	Not applicable	177 124	273 069	Not measured	Not applicable