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Report 06005

1.5T MRI systems

Issue 7

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1.5T MRI systems
Issue 7

Comparative report on seven MRI systems

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Contents

Summary

Purpose of this report

CEP has produced a series of comparison reports to aid the selection of MRI equipment in this program. This latest issue of the 1.5 tesla (T) comparison report comprises both specification and technical data to help sites during procurement. This report provides updated comparative specifications from RSNA 2006 and technical evaluation of 1.5T 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 specifications, safety and technical evaluation results to provide a comprehensive comparison of 1.5T MRI systems available on the UK market. It is an update of the previous issue (Report 06005), with the addition of specification information on the GE, Siemens and Toshiba MRI systems. The specification tables describe the Toshiba Excelart Vantage MRI, with additional information for the model with Atlas gradient system, where applicable.

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 MRI 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 may be carried out at a clinical site. The results are 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.

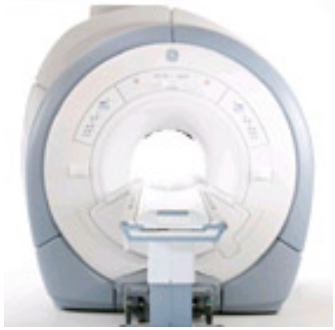
Evaluated systems

The MRI systems included in this report are listed in Table 1 and shown in Figure 1.

Table 1. 1.5T MRI systems included in the report

Company	GE	GE	Philips	Philips	Siemens	Siemens	Toshiba	Toshiba
Model	Signa HDx	Signa HDe	Intera	Achieva	MAGNETOM Symphony	MAGNETOM Avanto, I-class & T-class	Excelart Vantage	Excelart Vantage with Atlas

Figure 1. 1.5T MRI systems included in the report



GE Signa HDx

GE Signa HDe

Philips Intera

Philips Achieva

Siemens MAGNETOM Symphony

Siemens MAGNETOM Avanto I-class

Toshiba Excelart Vantage

Toshiba Excelart Vantage with Atlas

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 Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
RF Frequency *MHz*	63.86	63.86	63.86	63.9	63.6	63.6	63.86
Shielding	Active, standard	Active, standard	Active, standard	Active, standard	Active shielding	Active shielding	Passive and Active standard
Homogeneity (V-RMS) 40 cm DSV ppm	Typ: <0.27	Typ: <0.27	0.35	typ: 0.2	typ. 0.4	typ. 0.2	<1.0 (static measurement)
Measurement planes	13	13	12	12	24	24	24
Points per plane	24	24	32	12	20	20	20
Field Stability *ppm/hr*	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cooling system	Liquid helium only	Liquid helium only	Liquid helium only	Liquid helium only	Liquid helium only	Liquid helium only	Liquid helium only
Boil-off rate *l/hr*	~ 0.03	~ 0.03	0.03	0.03	<0.075	0.0	<0.05
Helium refill	>3 years,	>3 years,	3 years	3 years	~2 years	~10 years (max)	2-3 years

Table 3. Magnet installation details

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Mass: magnet only *tonnes*	3.6	3.6	2.9	2.9	4.05	3.55 ± 0.80 (incl. Helium)	3.8 (4.0 including helium)
Mass: assembly *tonnes*	5.7 5.5 (Twin)	5.1	4.1	4.1	5.5	5.5	5.265
Depth (with covers) (z) *cm*	195	195	167	167	160	160	149.5
Width (with covers) (x) *cm*	221	221	188	188	198	230	215
Height (with covers) (y) *cm*	241	241	240	240	233	230	241
Radial (x,y) 0.5 mT Fringe Field *m*	2.48	2.48	2.4	2.4	2.5	2.5	3.0
Axial (z) 0.5 mT Fringe Field *m*	4.0	4.0	3.8	3.8	4.0	4.0	5.0
Minimum installed area m^2*	<33	<22	30	30	30	≤ 30	28.8
Minimum ceiling height *cm**	250	250	265	265	240	235	240 (scan room) 280 (equipment room)

*To include 0.5 mT fringe field

Table 4. Magnet shimming details

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Passive on installation	With Superconductive coils	With Superconductive coils	Yes	Yes	Yes	Yes	Yes
Number of shim plates	Superconductive coils, no Shim plates	Superconductive coils, no Shim plates	32 trays	32 trays	16 azimuthal φ x 15 axial	16 azimuthal φ x 15 axial	24 trays
Active shimming	3 gradient, 18 superconducting coils Twin: further 5 Higher order resistive Shims	3 gradient, 18 superconducting coils	Standard: 3 first order Dynamic FOV with user-defined shim volume	Standard: 3 first order Dynamic FOV with user-defined shim volume	Standard: 3 linear terms via gradient offsets with 20 coils* Optional: 5 additional non-linear 2nd order terms with 32 coils*	Standard: 3 linear terms via gradient offsets with 20 coils* Optional: 5 additional non-linear 2nd order terms with 32 coils*	Standard: 3 linear Optional: 5 high order

*Can be used for patient-specific shimming

Table 5. Electronics cabinets

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Number of cabinets	2 3 (Twin)	1	3	3 (4 for Nova Dual)	2	2	3
Total width *cm*	120 180 (Twin)	200	188	188 (259 for Nova Dual)	160	156	247.5
Maximum depth *cm*	95.2	80	98	98	65	65	96
Maximum height *cm*	250	290	196	196	189	197	193
Cooling system	Air	Water	Water	Water	Water	Water	Water

Table 6. Patient comfort details

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Patient aperture at narrowest:							
Width *cm*	60	60	60	60	60	60	60 at narrowest
Height (couch to pole) *cm*	46.5	46.5	42	42	45.2	45.5	48.25 45.5 at isocenter
Length *cm*	70 105 (Twin)	70	60	60	90	85	75
Patient aperture at maximum:							
Width *cm*	106	106	154	154	120	Not supplied	65.5
Height *cm*	97	97	60	96	120	Not supplied	48.25
Length (with covers) *cm*	195	195	167	167	160	160	149.5
Patient couch:							
Min height *cm*	69	69	52	52	45	47	42
Max height *cm*	97	97	89	89	100	89	87.5
Table top width *cm*	62.2	62.2	53	53	54	54	57.5
Body mass limit *kg* (full movement)	159*	159*	150†	150†	200	200	200

* 180 kg with no vertical movement,
† 250 kg with no vertical movement

RF system

Table 7. RF system specification

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage			
Name/type/ version	HDx	HDe	Synergy	FREE WAVE	Advanced Array	Whole-Body Array	TIM [32×8]	TIM [76×18]	TIM [76×32]	AGV	XGV	ZGV	ATLAS
Number of independent RF receiver channels (standard/ optional)	8 (std) 16 (opt) 32 (opt)	4 (std) 8 (opt)	4 6	8 (std) 16 (opt) 32 (opt)	4	8	8	18	32	4	4, 8	8	16
Bandwidth of each independent RF receiver channel MHz	1	1	1	3	1	1	1	1	1	0.5	0.5	0.5	0.5
Number of analog-to-digital converters for each independent RF channel	1	1	1	1	1	1	1	1	1	1	1	1	1
Sampling frequency of each analog-to-digital converter MHz	20	20	1	80*	10	10	10	10	10		Not supplied		

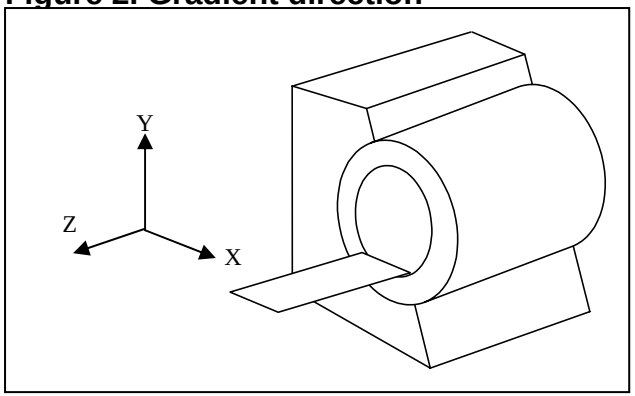
*Direct digital sampling with no intermediate frequency demodulation

Gradient system

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

	GE Signa HDx		GE Signa HDe	Philips Intera	Philips Achieva			Siemens Symphony	Siemens Avanto I-class & T-class		Toshiba Excelart Vantage		
Shielding	Active		Active	Active	Active			Active	Active		Active		
Gradient system	HDx	Twin	HDe	Pulsar	Pulsar HP	Nova HP	Nova Dual HP	Quantum	Q-engine	SQ-engine	AGV	XGV	ZGV
Maximum amplitude mT/m													
x (horizontal)	33	50	23	33	33	33	33/66	30	33	40	30	30	33
y (vertical)	33	50	23	33	33	33	33/66	30	33	40	30	30	33
z (along the bore axis)	33	50	23	33	33	33	33/66	30	33	45	30	30	33
Slew rate mT/m/ms													
x (horizontal)	120	150	50	80	100	180	180/90	125	125	200	50	130	200
y (vertical)	120	150	50	80	100	180	180/90	125	125	200	50	130	200
z (along the bore axis)	120	150	50	80	100	180	180/90	125	125	200	50	130	200
Duty cycle at max amplitude %	100	100	100	100	100	100	100	100	100	100	100	100	100
Amplitude at 100% duty cycle mT/m	33	23/ 50	23	33	33	33	33/66	30	33	40/40/45	30	30	33

Figure 2. Gradient direction



Sequence information

Quoted values should 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 Signa HDx		GE Signa HDe	Philips Intera	Philips Achieva			Siemens Symphony	Siemens Avanto I-class & T-class		Toshiba Excelart Vantage		
Gradient system	HDx	Twin	HDe	Pulsar	Pulsar HD	Nova HD	Nova Dual HD	Quantum	Q-engine	SQ-engine	AGV	XGV	ZGV
Minimum TR *ms* Spin echo*	10	7	11	13.3	11.6	11.4	11.4	11	7.4	6.8	Not supplied	9.0	9.0
Minimum TR *ms* 2D gradient echo*	2.7‡	2.6‡	2.8‡	2.25	1.07	0.83	0.83	1.8	1.8	1.5	Not supplied	5.1	5.1
Minimum TR *ms* 3D gradient echo*	1,2	1,2	1,7	2.25	1.07	0.83	0.83	1.8	1.8	1.5	Not supplied	3.5	3.5
Minimum echo spacing *ms* Turbo spin echo*	2.5	2.5	3.3	3.15	1.93	1.74	1.74	2.9	2.8	2.6	Not supplied	2.6	2.6
Minimum echo spacing *ms* Echo planar imaging†	0.460	0.412	0.712	0.53	0.49	0.393	0.393	0.79	0.48	0.41	1.2	0.5	0.4
Minimum TE *ms* Single-shot diffusion imaging with b-value of 1000 mm^2/s†	Not supplied	Not supplied	Not supplied	66.5	63.4	62.7	44.3	66	58	53	105	80	70

* For 256x256 matrix with no interpolation
† For 128x128 matrix with no interpolation
‡ Maximum EPI factor =12

Table 10. Resolution parameters

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Minimum FOV *mm*	10	10	5	5	5	5	5
Maximum FOV *mm*	480 (isotropic)	480 (isotropic)	530 (isotropic)	530 (isotropic)	500 (isotropic)	500 (isotropic)	500 550 in x and y directions for Atlas ZGV
Maximum imaging matrix	1024x1024	1024x1024	2048x2048	2048x2048	1024x1024	1024x1024	1024x1024
Minimum 2D slice thickness *mm*	0.3	0.9	0.5	0.5	0.1	0.1	0.5 0.4 for Atlas ZGV
Minimum 3D slice thickness *mm*	0.1	0.2	0.05	0.05	0.05	0.05	0.05

Table 10. Sequence packages: standard packages (1)

	Packages
GE Signa HDx	**Multi-Purpose Functionality:** Fast Spin Echo (FSE), Fast Recovery Fast Spin Echo (FRFSE) and FRFSE-XL, Single Shot Fast Spin Echo (SSFSE) and Enhanced MR Cholangio-Pancreatography (MRCP), Gradient Echo (GRE), Dual Echo Gradient Echo, Spectral Inversion at Lipids (SPECIAL), i-Drive Pro Real-time interactive imaging, HD LAVA (Liver Acquisition with Volume Acceleration), T1 and T2 Fluid-Attenuated Inversion Recovery (FLAIR), Echoplanar and FLAIR Echoplanar Imaging, Diffusion-weighted Echo Planar imaging, BRAVO (Brain Volume) Imaging: IR-prepared 3D gradient echo imaging technique, whole-brain coverage, MERGE (Multi-Echo Recombined Gradient Echo): Imaging technique designed to image the C-spine, Black Blood Double and Triple Inversion Recovery, ECG-Gated FGRE and FSPGR FastCine, Gated and Enhanced Time of Flight (TOF) Imaging: for non-contrast enhanced angiography in the body, 2D and 3D Phase Contrast (2D PC, 3D PC): Determines flow velocities and directional properties of blood flow in vessels, SmartPrep: Improves contrast-enhanced MRA by ensuring trigger upon contrast arrival, SmartStep: Enhances peripheral vascular run-offs, Adds table-stepping capabilities to SmartPrep. **Post-Processing Functionality:** Interactive Vascular Imaging (IVI): Produces angiographic and maximum intensity projections (MIPs) in multiple scan planes, Multi-Projection Volume Reconstruction (MPVR): generation of volumetric images for MR angiography, Multi-Planar Reformation (MPR): evaluation of anatomy in off-axis planes, Batch reformations, Interactive Vascular Imaging (IVI), 3D surface rendering, Brainwave Fusion: Enables fusion of Diffusion Tensor tractography data with functional activation areas into a single data set, FuncTool Performance: advanced MRI post-processing: ADC maps, eADC maps, Correlation coefficients for mapping of motor strip and visual/ auditory stimuli, NEI (Negative Enhancement Integral), MTE (Mean Time To Enhance), Positive enhancement integral, Signal enhancement ratio, Maximum slope increase, Maximum difference function, Difference function, Optional single-voxel, 2D and 3D CSI post-processing. **Standard pulse sequence imaging options:** ASSET/GEM, Blood suppression, Cardiac gating/triggering, Cardiac compensation, Classic, DE prepared, Extended dynamic range, Flow compensation, Full echo train, IR prepared, Magnetization transfer, MART, Multi-station, Multi-phase and DynaPlan, No phase wrap, Real time, Respiratory compensation, Respiratory gating/triggering, Sequential, SmartPrep, Spectral spatial RF, Square pixel, T2 prep, Tailored RF, VERSE, ZIP 1024, ZIP 512, Slice Zip x 2 (Z2) and Zip x 4 (Z4)
GE Signa HDe	**Multi-Purpose Functionality:** Fast Spin Echo (FSE), Fast Recovery Fast Spin Echo (FRFSE) and FRFSE-XL, Single Shot Fast Spin Echo (SSFSE) and Enhanced MR Cholangio-Pancreatography (MRCP), Gradient Echo (GRE), Dual Echo Gradient Echo, Spectral Inversion at Lipids (SPECIAL), i-Drive Pro Real-time interactive imaging, HD LAVA (Liver Acquisition with Volume Acceleration), T1 and T2 Fluid-Attenuated Inversion Recovery (FLAIR), IR-prepared FGRE, Black Blood Double and Triple Inversion Recovery, ECG-Gated FGRE and FSPGR FastCine, 2D and 3D Phase Contrast (2D PC, 3D PC): Determines flow velocities and directional properties of blood flow in vessels, SmartPrep: Improves contrast-enhanced MRA by ensuring trigger upon contrast arrival, SmartStep: Enhances peripheral vascular run-offs, Adds table-stepping capabilities to SmartPrep **Post-Processing Functionality:** Interactive Vascular Imaging (IVI): Produces angiographic and maximum intensity projections (MIPs) in multiple scan planes, Multi-Projection Volume Reconstruction (MPVR): generation of volumetric images for MR angiography, Multi-Planar Reformation (MPR): evaluation of anatomy in off-axis planes, , FuncTool Performance: advanced MRI post-processing: ADC maps, eADC maps, Correlation coefficients for mapping of motor strip and visual/auditory stimuli, NEI (Negative Enhancement Integral), MTE (Mean Time To Enhance), Positive enhancement integral, Signal enhancement ratio, Maximum slope increase, Maximum difference function, Difference function, Optional single-voxel, 2D and 3D CSI post-processing

Table 10. Sequence packages: standard packages (2)

	Packages
Philips Intera	**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)
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)

Table 10. Sequence packages: standard packages (3)

	Packages
Siemens Symphony	Core package
Siemens Avanto I-class & T-class	Tim Application Suite includes Neuro Suite, Ortho Suite, Angio Suite, Cardiac Suite, Body Suite, Onco Suite, Paediatric Suite, Breast Suite, Scientific Suite **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**: 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, SPAIR 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, dynaVIBE - Inline motion correction of multi-phase VIBE data sets. **Onco suite**: STIR TSE and FLASH in-phase/ opposed-phase protocols. Colorized Wash-in, Washout, Time-To-Peak, Positive-Enhancement-Integral, MIPtime, and combination maps with Inline Technology or for offline calculation. MeanCurve for display and analysis of the temporal behaviour in selected regions of interest, including the capability of using additional datasets as a guide for defining regions of interest. Precision filter for 3D spatial accuracy e.g. for radiotherapy planning. **Ortho suite**: 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**: Head, spine and cardiac protocols divided according to different age groups. **Breast Suite**: Customized protocols (e.g. with fat saturation or water/silicone excitation) with multiplanar visualization and iPAT. VIEWS (Volume Imaging with Enhanced Water Signal) is included as standard within this suite for 3D isotropic breast MRI. **Scientific Suite**: Phoenix, Camtasia and the facility to offer trial applications licenses, as standard with the system.
Siemens Avanto T class	**Tim Workflow Suite:** Inline and offline composing of images and planning tools for planning, reading and processing with focus on extended Field of View and whole body exams. Automatic real time calculation of trace-weighted images and ADC maps **syngo Chorus MR:** Departmental integration of MR scanner and Siemens RIS, features protocol planning, support of automated follow up studies and billing. Protocols from one scanner can be distributed to other scanners connected to the RIS. **syngo TimCT**: Enables continuous table move scanning. syngo TimCT FastView is based on a gradient echo sequence a complete extended Field of View in isotropic resolution with continuous table move.

Table 10. Sequence packages: standard packages (4)

	Packages
Toshiba Excelart Vantage	**All packages are optional and can be chosen dependent on case mix to build up a specific and tailor-made system.** **Note:** Cardiac package is not available for the AGV system. **Basic sequences**: Spin Echo, Fast Spin Echo ('Turbo Spin Echo'), Field Echo (Gradient Echo), Fast Field Echo ('Turbo Gradient Echo'), Inversion Recovery, Fast Inversion Recovery, STIR, Fast Stir, Fast FLAIR are standard. Hybrid Echo Planar Imaging, with up to 60 echoes. Multi-Shot Echo Planar Imaging. Single Shot Echo Planar Imaging. T1-TrueSSFP. T2-TrueSSFP. FSE T2 **Plus**: fasterT2 weighted imaging, FASE T2 Plus, FISP3D SuperFase. SPEEDER (parallel imaging).

Table 11. Sequence packages: angiography and cardiac imaging (1)

	Packages
GE Signa HDx	**Angiography:** SmartPrep (Improves contrast-enhanced MRA by ensuring trigger upon contrast arrival), SmartStep (Enhances peripheral vascular run-offs, Adds table stepping capabilities to SmartPrep), Gated and Enhanced Time of Flight Imaging (for non-contrast enhanced angiography in the body), Interactive Vascular Imaging (IVI) (produces angiographic and maximum intensity projections (MIPs) in multiple scan planes), TRICKS: Time Resolved Imaging of Contrast KineticS technology (uses temporal sampling to accelerate the temporal resolution of 3D dynamic imaging. Now integrated with Elliptical-Centric data sampling), TRICKS-XV (uses a 3D k-space acquisition and reconstruction strategy. The result is arterial, venous and equilibrium 3D volumes. ASSET compatible. Enables repeated scanning of large volumes.), Fluoro-Triggered MRA (enables the user to manually trigger each angiographic acquisition with the desired level of vessel enhancement), SWIFT: Switch on the Fly Technique (option): combines TRICKS and parallel imaging with the 32-element vascular coil to produce high-resolution images of the vascular tree, 2D and 3D Phase Contrast (2D PC, 3D PC): determines flow velocities and directional properties of blood flow in vessels. **Cardiac:** ECG-Gated FGRE and FSPGR FastCine (functional acquisitions of the heart, Full R-R coverage), Fiesta Cine and FatSat Fiesta (Fast Imaging Employing Steady-State Acquisition: contrast enhancement between the myocardium and the blood pool), Cardiac Tagging (applies spatial SAT pulses over the anatomy of interest to obtain cardiac images sensitive to tissue motion), Black Blood Double and Triple Inversion Recovery, Navigators for 3D Coronary Imaging (Software designed for use in conjunction with 3D IR-prepared FGRE or 3D FatSat FIESTA for coronary imaging. Enables the patient to breathe freely throughout the acquisition while eliminating respiratory motion from the resultant images), IR-Prepared FGRE Sequence (consists of an IR-prepared FGRE sequence that allows the suppression and enhancement of various tissues within the myocardium (available in 2D and 3D)), ReportCARD (cardiac reporting software provides a way to review and analyse cardiac MR images and generate comprehensive reports for referring physicians. Reports tailored specifically to pediatrics and CSF flow), i-Drive Pro Plus (expands i-Drive Pro functionality, permits geometric scan plane changes on the fly).
GE Signa HDe	**Angiography:** SmartPrep (Improves contrast-enhanced MRA by ensuring trigger upon contrast arrival), SmartStep (Enhances peripheral vascular run-offs, Adds table stepping capabilities to SmartPrep), Interactive Vascular Imaging (IVI) (produces angiographic and maximum intensity projections (MIPs) in multiple scan planes), TRICKS: Time Resolved Imaging of Contrast KineticS technology (uses temporal sampling to accelerate the temporal resolution of 3D dynamic imaging. Now integrated with Elliptical-Centric data sampling), Fluoro-Triggered MRA (enables the user to manually trigger each angiographic acquisition with the desired level of vessel enhancement) , 2D and 3D Phase Contrast (2D PC, 3D PC): determines flow velocities and directional properties of blood flow in vessels. **Cardiac:** ECG-Gated FGRE and FSPGR FastCine (functional acquisitions of the heart, Full R-R coverage), FIESTA Cine Cardiac Imaging: (Fast Imaging Employing Steady-State Acquisition: contrast enhancement between the myocardium and the blood pool), Cardiac Tagging (applies spatial SAT pulses over the anatomy of interest to obtain cardiac images sensitive to tissue motion), Black Blood Double and Triple Inversion Recovery, Coronary Artery Imaging (FIESTA 3D FatSat allows acquisition of breath-held 3D datasets of the coronary arteries), Navigators for 3D Coronary Imaging (Software designed for use in conjunction with 3D IR-prepared FGRE or 3D FatSat FIESTA for coronary imaging. Enables the patient to breathe freely throughout the acquisition while eliminating respiratory motion from the resultant images), IR-Prepared FGRE Sequence (consists of an IR-prepared FGRE sequence that allows the suppression and enhancement of various tissues within the myocardium (available in 2D and 3D))

Table 11. Sequence packages: angiography and cardiac imaging (2)

	Packages
Philips Intera	**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).
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).

Table 11. Sequence packages: angiography and cardiac imaging (3)

	Packages
Siemens Symphony	**Angiography**: Advanced Angio Package, Care Bolus Package, Panoramic Table for Integrated Panoramic Positioning (IPPTM), Flow Quantification **Cardiac**: Advanced Cardiac Package, Interactive Real-time Imaging
Siemens Avanto I-class & T-class	**Angio Suite:** Standard package included in Tim Application Suite. 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-contrast. 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. TWIST is also available (optional) for time-resolved 3D MR angiographic imaging with high spatial and temporal resolution. Flow Quantification also available. **syngo TimCT Angiography (optional for T-class only)**: Continuous table move 3D angiographic exams of the peripheral vessels. 3D gradient echo sequence with strong T1 weighting and continuous table movement during imaging with table velocity up to 50 mm/s. **Cardiac Suite:** Standard package included in Tim Application Suite. 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 paediatrics, 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). Interactive Real-time Imaging also available
Toshiba Excelart Vantage	**Angiography**: MRA R6 package - Visual Prep to trigger scan for contrast enhanced MRA, Moving bed for Peripheral Angiography, Centric order K-space filling, 2D TOF (time of flight) MRA or 2D FFE, 3D TOF MRA or 3D FFE, MRV (magnetic resonance venography). WET (water excitation technique) – removes unwanted fat signal, improves visualisation of vessels. STAMD (Sequential Target MIP Display) allows the observation of the relationship between inflowing artery and outflowing vein (e.g. heart). DRKS R6 (different rate k-space sampling). Apply to FFE 3D dynamic imaging. Data is collected around the centre of k-space with higher temporal resolution than in other sections, reducing scan time. **SuperFASE R6 package** - contains FBI (Fresh Blood Imaging) – peripheral angiography without the need for contrast. **Cardiac**: Cardiac R6 package Includes Cardiac function analysis software – cardiac output, ejection fraction, volume curves, percentage wall thickness. FASE BB (black blood imaging). Cine imaging (use FFE technique plus breath hold, prospective and retrospective gating). Real time motion correction (estimates and corrects change of heart position due to respiratory motion) – use with 3D FFE, for imaging heart, coronary arteries.

Table 12. Sequence packages: perfusion imaging

	Packages
GE Signa HDx	T2* EPI sequence is standard FuncTool Performance enables advanced MRI post-processing: NEI (Negative Enhancement Integral), MTE (Mean Time To Enhance), Positive enhancement integral, Signal enhancement ratio, Maximum slope increase, Maximum difference function, Difference function
GE Signa HDe	T2* EPI sequence is standard FuncTool Performance enables advanced MRI post-processing: NEI (Negative Enhancement Integral), MTE (Mean Time To Enhance), Positive enhancement integral, Signal enhancement ratio, Maximum slope increase, Maximum difference function, Difference function
Philips Intera	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.
Philips Achieva	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 Symphony	Echo Planar Imaging and Advanced Turbo Packages
Siemens Avanto I-class & T-class	Perfusion sequences included in standard Tim Application Suite Inline Perfusion: 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. .
Toshiba Excelart Vantage	EPI R6 package – allows diffusion, Perfusion and Functional MR imaging. Perfusion images using “ASL” allows perfusion studies to be performed without the need for contrast.

Table 13. Sequence packages: diffusion imaging (1)

	Packages
GE Signa HDx	**Diffusion-Weighted Echoplanar Imaging:** Single Shot FLAIR EPI and Single Shot, diffusion-weighted EPI with b-values up to 10,000 s/mm2,, Multi-NEX capability, Online image processing, ADC and eADC maps (enabled by FuncTool Performance) **Diffusion with PROPELLER package:** acquires data in radial “blades” that rotate in sequence until the acquisition is complete. Reduces susceptibilities.
GE Signa HDe	**Diffusion-Weighted Echoplanar Imaging:** Single Shot FLAIR EPI and Single Shot, diffusion-weighted EPI with b-values up to 10,000 s/mm2,, Multi-NEX capability, Online image processing, ADC and eADC maps (enabled by FuncTool Performance) **Diffusion with PROPELLER package:** acquires data in radial “blades” that rotate in sequence until the acquisition is complete. Reduces susceptibilities.
Philips Intera	**Diffusion Imaging Performance Package**: includes Single-Shot EPI Diffusion imaging sequences for motion free imaging, plus the automatic calculation of isotropic Diffusion Weighted images and online calculation of Apparent Diffusion Coefficient (ADC) maps. Flexible choice of diffusion sensitivity (b-value), up to 16 b-values in one scan, modulus averaging, selective averaging for increased SNR and higher b-values, three diffusion directions per scan - P (Phase), M (Measurement) and S (Slice), automatic online calculation of isotropic diffusion-weighted images, online calculation of ADC maps. Can be combined with SENSE. **High-Resolution Diffusion Package**: enables high-quality high-resolution diffusion imaging of the brain and brain stem. High Resolution Diffusion uses motion-corrected diffusion-weighted multi-shot sequences. Multi-shot EPI, TSE and GRASE-based diffusion imaging sequences, PhaseTrak provides real-time, interactive phase correction for motion-insensitive images, high-resolution multi-shot TSE and GRASE diffusion imaging, can be combined with SENSE.
Philips Achieva	**Diffusion Imaging Performance Package**: includes Single-Shot EPI Diffusion imaging sequences for motion free imaging, plus the automatic calculation of isotropic Diffusion Weighted images and online calculation of Apparent Diffusion Coefficient (ADC) maps. Flexible choice of diffusion sensitivity (b-value), up to 16 b-values in one scan, modulus averaging, selective averaging for increased SNR and higher b-values, three diffusion directions per scan - P (Phase), M (Measurement) and S (Slice), automatic online calculation of isotropic diffusion-weighted images, online calculation of ADC maps. Can be combined with SENSE. **High-Resolution Diffusion Package**: enables high-quality high-resolution diffusion imaging of the brain and brain stem. High Resolution Diffusion uses motion-corrected diffusion-weighted multi-shot sequences. Multi-shot EPI, TSE and GRASE-based diffusion imaging sequences, PhaseTrak provides real-time, interactive phase correction for motion-insensitive images, high-resolution multi-shot TSE and GRASE diffusion imaging, can be combined with SENSE.

Table 13. Sequence packages: diffusion imaging (2)

	Packages
Siemens Symphony	Echo Planar Imaging and Advanced Turbo Package: Single Shot EPI for Diffusion, Single Shot EPI for Perfusion, 2D/3D HASTE (w. Restore), 2D/3D HASTE IR, 2D/3D True FISP, Shared Phases Realtime TrueFISP, 2D/3D TrueFISP with Fat Sat, PSIF Diffusion, 2D/3D segmented EPI (SE and FID), Multi Directional Diffusion Imaging
Siemens Avanto I-class & T-class	Diffusion included in **standard Tim Application Suite**. Includes sequences like Single Shot EPI or PSIF Diffusion with a matrix size up to 1024. Up to 16 b-values in one scan with a maximum b-value of 10000. Diffusion with iPAT (parallel imaging) can be used to reduce susceptibility artifacts. **Inline Diffusion**: Automatic real-time calculation of trace-weighted images and ADC maps with Inline technology. Compatible to single-shot diffusion-weighted EPI.
Toshiba Excelart Vantage	EPI R6 package – allows Diffusion, perfusion and Functional MR imaging. Diffusion images with EPI or FASE (Fast Advanced Spin Echo). ADC images produced.

Table 14. Sequence packages: diffusion tensor imaging

	Packages
GE Signa HDx	**Diffusion Tensor Imaging with FiberTrak:** expands EPI capability to include DTI. FuncTool (included with ScanTools) create Fractional Anisotropy Maps (FA Maps) and Volume Ratio Anisotropy Maps (VRA Maps). Optional FiberTrak post-processing utilizes information from DT acquisition and processing. This processing produces maps of diffusion along the white-matter tracts using the principal axes of diffusion.
GE Signa HDe	Not applicable
Philips Intera	**Diffusion Tensor Imaging Package (DTI)**: extends Diffusion Weighted Imaging to measure the directional dependence of the diffusion coefficient in tissue. Enables visualization of white matter tracts in Fractional Anisotropy (FA) maps. Multi-directional DTI imaging sequences using the full range of available diffusion acquisition methods, selectable number of diffusion directions (up to 32), online calculation of Fractional Anisotropy maps. Can be combined with SENSE.scan)
Philips Achieva	**Diffusion Tensor Imaging Package (DTI):** extends Diffusion Weighted Imaging to measure the directional dependence of the diffusion coefficient in tissue. Enables visualization of white matter tracts in Fractional Anisotropy (FA) maps. Multi-directional DTI imaging sequences using the full range of available diffusion acquisition methods, selectable number of diffusion directions (up to 32), online calculation of Fractional Anisotropy maps. Can be combined with SENSE.scan)
Siemens Symphony	MDDW (Multiple-Direction Diffusion Weighting) allows the acquisition of diffusion weighted data sets with diffusion weighting in up to 12 directions. These data sets may be used for the evaluation of diffusion tensors (evaluation software not included).
Siemens Avanto I-class & T-class	**Diffusion Tensor Imaging, Diffusion Tensor Evaluation and Diffusion Tensor Tractography for advanced DTI analysis :** 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. The DTI Tractography package allows the visualization of multiple white matter tracts of the human brain and is optimized to support the presurgical planning and to allow for neuro physiological research with respect to connectivity and white matter pathology.
Toshiba Excelart Vantage	**DTI R6 package** – visualisation of white matter fibres running in a specific direction in the brain – based on diffusion anisotropy.

Table 15. Sequence packages: functional imaging (1)

	Packages
GE Signa HDx	EPI sequence for fMRI is standard. **FuncTool Performance** enables advanced MRI post-processing: NEI (Negative Enhancement Integral), MTE (Mean Time To Enhance), Positive enhancement integral, Signal enhancement ratio, Maximum slope increase, Maximum difference function, Difference function. **BrainWave Real-Time Functional Brain Mapping Package:** allows acquisition, processing and display of BOLD fMRI activation images in real time (up to 25 frames/sec) on the scanner operator console. Multiple options for 2D color activation maps display. **BrainWave Post-Acquisition Software:** allows rendering and exploration of of 3D brain images to provide visualization of functional activation from fMRI data acquired with BrainWave Real-Time. **BrainWave Fusion:** enables fusion of Diffusion Tensor tractography data with functional activation areas into a single data set. **BrainWave Hardware Lite Supplemental Paradigm Delivery:** BrainWave Hardware Lite is a supplemental paradigm delivery system for functional MRI, developed for use with BrainWave Real-Time (RT) image acquisition software. It includes a dedicated computer workstation, equipment rack and penetration panel waveguide insert, Cedrus patient response pads, and related cabling and connectors. It is designed to deliver visual and auditory stimuli. The computer includes preset paradigms and software tools to generate custom protocols. The visual and auditory output can be coupled to fMRI delivery systems purchased separately from other vendors (not included with BrainWave Hardware Lite).
GE Signa HDe	EPI sequence for fMRI is standard. **FuncTool Performance** enables advanced MRI post-processing: NEI (Negative Enhancement Integral), MTE (Mean Time To Enhance), Positive enhancement integral, Signal enhancement ratio, Maximum slope increase, Maximum difference function, Difference function
Philips Intera	**PRESTO Package**: ultra-fast imaging sequence provides a combination of whole brain coverage using T2*-weighted images, ideal for examinations including perfusion and BOLD (Blood Oxygen Level Dependent) studies, 3D ultra-short TR sequences, TE longer than TR for enhanced T2* weighting, PhaseTrak real-time interactive phase correction for motion-insensitive images. PRESTO can be combined with SENSE. **BOLD Imaging package**: provides specialized acquisition sequences for performing BOLD studies in order to localize T2* task-related signal changes in the brain. High temporal resolution dynamic Slice Single, Multi Slice FFE or FFE-EPI sequences, protocol-controlled trigger interface for integrated fMRI environment, allows acquisition of up to 16,000 images. BOLD can be combined with SENSE. **IView BOLD Analysis package**: provides real-time processing of functional BOLD MR data sets into functional activation maps, enabling clear visualization of task-related areas of activation. Time Intensity Diagrams (TID), real-time computation of statistical parameter maps to visualize and quantify areas of neural activity, real-time image registration during the study, color-coded image maps, including cross correlation maps (CC) and Z-score, creation of composite reference images by placing derived images on top of high-resolution anatomical MR images, numerical results of functional MR data, color overlay of areas of activation on top of anatomical reference image.

Table 15 Sequence packages: functional imaging (2)

	Packages
Philips Achieva	**PRESTO Package**: ultra-fast imaging sequence provides a combination of whole brain coverage using T2*-weighted images, ideal for examinations including perfusion and BOLD (Blood Oxygen Level Dependent) studies, 3D ultra-short TR sequences, TE longer than TR for enhanced T2* weighting, PhaseTrak real-time interactive phase correction for motion-insensitive images. PRESTO can be combined with SENSE. **BOLD Imaging package**: provides specialized acquisition sequences for performing BOLD studies in order to localize T2* task-related signal changes in the brain. High temporal resolution dynamic Slice Single, Multi Slice FFE or FFE-EPI sequences, protocol-controlled trigger interface for integrated fMRI environment, allows acquisition of up to 16,000 images. BOLD can be combined with SENSE. **IView BOLD Analysis package**: provides real-time processing of functional BOLD MR data sets into functional activation maps, enabling clear visualization of task-related areas of activation. Time Intensity Diagrams (TID), real-time computation of statistical parameter maps to visualize and quantify areas of neural activity, real-time image registration during the study, color-coded image maps, including cross correlation maps (CC) and Z-score, creation of composite reference images by placing derived images on top of high-resolution anatomical MR images, numerical results of functional MR data, color overlay of areas of activation on top of anatomical reference image.
Siemens Symphony	**BOLD Imaging, 3D PACE and BOLD 3D Evaluation** : Single Shot EPI for BOLD Imaging, 3D PACE, and a processing and visualization package for BOLD fMRI, providing a full set of features for clinical fMRI, as well as advanced features for more research oriented applications.
Siemens Avanto I-class & T-class	**Inline BOLD (Blood Oxygen Level Dependent) Imaging:** Automatic real-time calculation of z-score (t-test) maps with Inline technology, for variable paradigms. Compatible to single-shot EPI with high susceptibility contrast for fast multi-slice imaging; ART (Advanced Retrospective Technique) for fully automatic 3D retrospective motion correction, for 6 degrees of freedom (3 translations, 3 rotations); Mosaic images for storage and transfer of large data sets; 3D spatial filtering; Overlay of Inline calculated t-test results on EPI images **3D PACE (Prospective Acquisition CorrEction) Syngo** Prospective motion detection and correction in the volume to eliminate motion artefacts during BOLD measurements; 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; reduces motion-related artefacts in t-test calculations; increases signal changes in the activated neuronal volume; increases functional MRI (fMRI) sensitivity and specificity. In contrast to a retrospective motion correction that corrects previously acquired data, the unique 3D PACE tracks the head of the patient, correcting for motion in real time during the acquisition. **BOLD 3D Evaluation**: Processing and visualization package for BOLD fMRI. It provides a full set of features for clinical fMRI, as well as advanced features for more research oriented applications such as, for example, overlay of functional information on 3D dataset during image acquisition
Toshiba Excelart Vantage	**EPI R6 package** – allows diffusion, perfusion and Functional MR imaging. BOLD (Blood Oxygen Level Dependent) technique. Post processing - Alignment (two- dimensional, motion correction), Filtering (Thresholding, filters) and Analysis. Uses a T2* weighted image acquired with the FE type EPI technique as the original image.

Table 16. Sequence packages: spectroscopy(1)

	Packages
GE Signa HDx	**PROBE-PRESS Single-Voxel**: allows acquisition and display of volume localized, water-suppressed 1H spectra in single-voxel mode. This package includes the PROBE-P (PRESS) pulse sequence as well as automated reconstruction, acquisition set-up and graphic prescription of spectroscopic volumes. **PROBE-PRESS and PROBE-STEAM Single-Voxel**: this enables single-voxel capability with both the PROBE-PRESS and PROBE-STEAMpulse sequences. **PROBE 2DCSI**: enables simultaneous multi-voxel, 2-D in-plane acquisitions. Post-processing, including the creation of metabolite maps, is automatically generated with the FuncTool Performance Package (included in ScanTools). **PROBE 3DCSI**: enables 3-D multi-voxel acquisitions. Post-processing, including the creation of metabolite maps, is automatically generated withthe FuncTool Performance Package (included in ScanTools). **PROSE** Prostate Spectroscopy: 3D CSI with VSS (Very Selective Saturation) to suppress surrounding fat tissues. **BREASE Breast Spectroscopy**: single-voxel breast spectroscopy, allows the detection of choline in the resultant spectrum. **Multi-Nuclear Spectroscopy** : allows non-proton spectroscopy including 31P, 13C, 19F, 23Na, 7Li, 129Xe or 3He. All T/R switches and MNS coils must be purchased separately. **FuncTool Performance**: Enables single-voxel, 2D and 3D CSI post-processing **Sage 7 Software:** allows processing, display, manipulation, analysis, management and printing of in-vivo spectroscopy data via graphical interface using filters, transformations, correction algorithms, segmentations and quantifications to obtain information from your spectroscopic data. Also electronic output format (BMP, EPS and GIF to JPEG, PICT and TIF).
GE Signa HDe	Not applicable
Philips Intera	**Spectroscopy**: 1H Spectro package includes single voxel, multi-voxel and multi-slice proton spectroscopy acquisition methods. The package includes SpectroView data processing and display.
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.

Table 16. Sequence packages: spectroscopy(2)

	Packages
Siemens Symphony	Single Voxel Spectroscopy (SVS), Chemical Shift Imaging (CSI), 31P Spectroscopy, Multi-Nuclear Option
Siemens Avanto I-class & T-class	**Single Voxel Spectroscopy (SVS)**: Integrated software package with sequences and protocols for proton spectroscopy. Matrix Spectroscopy-phase-coherent signal combination for maximum SNR. SVS techniques: SE and STEAM. Short TEs available. Automated adjustments including localized shimming and adjustment of water suppression pulses. Also available: Interactive adjustments and control of adjustments. Optimized protocols for brain applications. **Chemical Shift Imaging**: Integrated software package with sequences and protocols for chemical shift imaging (CSI). Extension of the SVS package. Matrix Spectroscopy: phase-coherent signal combination for maximum SNR with configurable prescan-based normalization for optimal homogeneity. 2D and 3D Chemical Shift Imaging. Hybrid CSI with combined Volume selection and Field of View (FoV) encoding. Short TEs available (30 ms for SE, 20 ms for STEAM). Automized shimming of the higher order shimming channels for optimal homogeneity of larger CSI volumes. Weighted acquisition, leading to a reduced examination time compared to full k-space coverage while keeping SNR and spatial resolution. Outer Volume/ Spectral Suppression. Protocols for prostate spectroscopy. **GRACE Syngo:** Integrated software package including sequences and protocols for proton spectroscopy, optimized for breast studies. **Multinuclear Support and Multinuclear Spectroscopy Packages available for studying nuclei other than 1H.**
Toshiba Excelart Vantage	Spectroscopy package – single voxel acquisition Advanced Proton Spectroscopy Package – multi-voxel acquisition.

Table 17. Sequence packages: other (1)

	Packages
GE Signa HDx	**MRgFUS:** combines MRI and Focused Ultrasound to non-invasively treat tumors inside the body without the need for incisions. Currently commercially approved for treatment of Uterine Fibroids. Research utilization for treatment of various pathologies can be pursued under Collaboration Research Agreement. **PROPELLER:** acquisition technique for transverse imaging with low sensitivity to motion artifacts. Available in T2 FSE , T2 FLAIR and Diffusion-weighted EPI. **3D FIESTA:** 3D FIESTA (Fast Imaging Employing Steady-State Acquisition) delivers short repetition times (TR) between RF pulses, delivering high T2 contrast. Suitable for rapid, high-resolution imaging in areas such as the Internal Auditory Canals (IACs). **3D FIESTA-C:** Phase-cycled FIESTA technique reducing sensitivity to changes in magnetic susceptibility that may be encountered when imaging in the posterior fossa and near air-tissue boundaries. Suitable for the internal Auditory Canals (IACs) as well as for T2 imaging in the cervical spine. **3D COSMIC:** 3D imaging technique is designed specifically for imaging in the C-spine. It provides a unique, fluid-weighted contrast to improve visualization of the cervical nerve roots and the intervertebral disks. **LAVA-XV Imaging:** a selfcalibrated acquisition approach that allows simultaneous acceleration in both the phase encoding and the slice select direction for better slice coverage and higher spatial and temporal resolution. Suitable for single breath-hold imaging of the abdomen and pelvis. **VIBRANT-XV Breast Imaging:** allows acceleration in both the phase encoding as well as the slice select direction, coupled with a fat-saturation technique and automatic subtraction of the images for good contrast and high lesion conspicuity. **CadStream Breast Analysis:** includes hardware and postprocessing software that facilitates analysis and management of breast image data. CADstream includes SureLoc reports needle position in real time and displays images and needle position in the patient's orientation, for MR-guided interventions. **CartiGram:** provides high-resolution maps of the T2 values in cartilage and other tissues. The imaging results are color coded to highlight those structures with increased water-content yielding elevated T2 values.
GE Signa HDe	**PROPELLER:** acquisition technique for transverse imaging with low sensitivity to motion artifacts. Available in T2 FSE , T2 FLAIR and Diffusion-weighted EPI. **3D FIESTA:** 3D FIESTA (Fast Imaging Employing Steady-State Acquisition) delivers short repetition times (TR) between RF pulses, delivering high T2 contrast. Suitable for rapid, high-resolution imaging in areas such as the Internal Auditory Canals (IACs). **3D FIESTA-C:** Phase-cycled FIESTA technique reducing sensitivity to changes in magnetic susceptibility that may be encountered when imaging in the posterior fossa and near air-tissue boundaries. Suitable for the internal Auditory Canals (IACs) as well as for T2 imaging in the cervical spine. **VIBRANT (Volume Imaging for Breast AssessmeNT):** Sagittal VIBRANT scans both breasts simultaneously (in the time it would normally take to do one). Axial VIBRANT scans without in-plane data interpolation (zero-filling) for enhanced data integrity. Both are multi-phase techniques that use dual shimming for optimum image quality and provide the choice of subtraction for enhanced background suppression. ASSET compatible. Fat-suppression technique developed specifically for breast imaging.

Table 17. Sequence packages: other (2)

	Packages
Philips Intera	**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.)
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 Symphony	Advanced 3D Package, TGSE (Turbo Gradient Spin Echo), AutoAlign syngo, syngo Security, MPPS syngo, IDEA (Integrated Development Environment for Applications), BLADE, AutoAlign Syngo, SWI, Composing Syngo.
Siemens Avanto I-class & T-class	Tim Whole Body Suite, iPAT Extensions (integrated Parallel Acquisition Techniques), CISS and DESS, TGSE (Turbo Gradient Spin Echo), AutoAlign Head, AutoAlign Spine, syngo Security, MPPS syngo, IDEA (Integrated Development Environment for Applications), SWI, BLADE, ParametricMap Syngo, Composing Syngo, Inline Composing Syngo, Tim Planning Suite, TWIST.

Table 17. Sequence packages: other (3)

	Packages
Toshiba Excelart Vantage	**SuperFASE R6 Package**: FASE (Fast Advanced Spin Echo): fast T2 Weighted imaging with a turbo-factor of up to 512. Compatible with 2D and 3D. Short ETS FASE - Improves visualisation of tissues with a relatively short T2 (liver, cardiac muscle, blood), moving organs and the vascular system. Useful for imaging the abdominal region and with Single Shot images of soft tissues - motion artefact virtually eliminated. FBI with 3D – fast blood flow is visualised as if stationary. LONG ETS FASE - High T2 weighted images, Myelography, MRCP, IAMS with FASE 3D. Sequential FASE - Multi-slice imaging of the Heart and Great Vessels with FASE BB (images with suppressed blood signal obtained – Black Blood). SPEED - To be able to view vessels running in different directions on a single image e.g. pulmonary, portal, systemic vessels. A 3D sequence. ECG PREP - Scan determines the Optimal delay time for FBI of the heart. FBI - To visualise fresh blood ejected from the heart without contrast. Uses FASE 3D. Vascular Imaging with ECG gating or peripheral pulse gating. FSE/ FASE T2 PLUS - Reduces scanning time for T2 weighted scans e.g MRCP. Like “DRIVE”. FSE 3D REAL –IR - 3D FSE T1 weighted, small FOV, high resolution volume scans. E.g. imaging temporal lobes for TLE. INTERMITTENT BREATHOLD - Use with FSE 3D with SPEED technique. Breath hold scan, will have less misalignment. FASE BB - Is a black blood pre-pulse, suppresses intra-cardiac blood signal. Chest scan with breath hold is fast – decreases flow artefact. Used as a localiser scan also in the chest. FASE DIFFUSION - A motion probing Gradient is attached to a FASE sequence which produces Diffusion weighted images with less distortion. MULTI-SHOT FASE 2D - Decreases scan time, decreases image blurring. Use with intermittent breath hold high resolution BB scan. FASE FLOW COMPENSATION - Decreases artefact for single shot images. Don’t have to set phase encode to flow direction for FBI. TRUE SSFP - For Visualisation of abdominal blood vessels. For depicting tissues and blood vessels with relatively long T2 during breath holding. TIME-SLIP - When used with FBI for Non contrast enhanced lung MRA the pulmonary arteries are selectively visualised. Can use in non-contrast-enhanced MRA with FASE or TRUE SSFP sequences (particularly artery/vein separation in the lung fields.) FLOW SPOILED FBI - Enables Non-contrast enhanced artery/vein separation images, MRA of the lower limbs without the use of contrast. Extended table travel option (for Atlas systems): increases FOV to 205cm to enable whole body imaging studies,

Computer system

Table 18. Main computer system – architecture

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Operating system	Linux	Linux	Windows XP	Windows XP	Windows XP Pro *syngo* speaking	Windows XP Pro *syngo* speaking	MS Windows XP Pro
Processor							
Type	Dual AMD Opteron 250	Dual AMD Opteron	Dual Pentium IV Xeon	Dual Pentium IV Xeon	Dual Pentium IV Xeon	Dual Pentium IV Xeon	Xeon Dual
Speed	2 × 2.4 GHz	2 × 2.4 GHz	> 2 × 3.2 GHz	> 2 × 3.2 GHz	2 × 3.60 GHz	2 × 3.60 GHz	2 × 3.0 GHz
Word length *bit*	64	32	32	64	32	32	64
Memory size *MB*	4000	4000	2048	2048	2000	2000	3000 (4000 for Atlas)
Hard disk							
Software *GB*	400 (total)	254 (total)	36	36	73	73	37 (73 for Atlas)
Images *GB*	See above	See above	36	36	73	73	37 (146 for Atlas)
Image capacity (256^2 images uncompressed)	400,000	400,000	250,000	250,000	110,000*	110,000*	140,000 (560, 000 for Atlas)
Archive drive							
Type and size	MOD:1.3/2.3GB DVD: 4.7 GB	MOD:1.3/2.3GB DVD: 4.7 GB	DVD: 4.7 GB	DVD: 4.7 GB	CDR: 640 MB	CDR: 640 MB	DVD: 9.4 GB
Image capacity 256^2 images	MOD 1.3: 15,000 MOD 2.3: 30,000 DVD: 35000	MOD 1.3: 15,000 MOD 2.3: 30,000 DVD: 35000	40000	40000	4300	4300	48000

* Image capacity for uncompressed 512^2 images

Table 19. Main computer system – image processor

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Processor							
Number/ Type	4 × AMD Opteron 252 CPU	Dual AMD Opteron	Dual Pentium IV Xeon	Dual Pentium IV Xeon	Dual Pentium IV Xeon	Dual AMD Opteron 248 CPU	Dell, Xeon Dual
Speed	4 × 2.6 GHz	2 × 2.4 GHz	> 2 × 3.2 GHz	> 2 × 3.2 GHz	2 × 3.06 GHz	2 × ≥ 2.2 GHz	2 × 3.0 GHz
Word length *bit*	64	64	32	32	32	64	64
RAM	16 GB	4 GB	4 GB	4 GB	1 GB (standard) 2 GB (Whole Body Array interface)	≥ 8 GB	1GB
Hard disk storage	4 × 73 GB	Not supplied	Not supplied	Not supplied	4 × 36 GB	4 × 36 GB	1.9 TB for Atlas
Number of 256×256 images* reconstructed /sec	2700	1350	≥ 256	≥ 256	355	> 1200	820 4000 (max) for Atlas
Transfer rate from host	1.0 Gbps Ethernet image transfer	1.0 Gbps Ethernet image transfer	No transfer time common bus	No transfer time common bus	No transfer time common bus	No transfer time common bus	1000 MB/s

* Reconstruction time for a true 256×256 matrix with no interpolation, no asymmetric echo, no partial Fourier, no parallel imaging, no fat-sat, no rectangular matrix, no rectangular field-of-view.

Table 20. Main computer image display monitor

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Screen size *in*	23 (16 :9)	23 (16 :9)	23	23	19	19	18 23 for Atlas
Type (BW/colour)	LCD colour	LCD colour	LCD colour	LCD colour	LCD colour	LCD colour	LCD colour
Matrix size	1920 x 1200	1920 x 1200	1900x1200	1900x1200	1280×1024	1280×1024	1280x1024 1900x1200 for Atlas
Bit depth *bit*	24	24	3×8	3×8	16	16	32

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.
- # QD/CP elements: number of elements used for quadrature (QD)/circularly polarised (CP) detection.
- # LP elements: 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 21. In-built body coil

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	Body Quadrature	Body Quadrature	Quadrature Body	Quadrature Body	CP Integrated Body	CP Integrated Body	Whole body coil
Type*	T/R Q	T/R Q	T/R Q	T/R Q	T/R Q	T/R Q	T/R Q
Dimensions *cm*	60 x 70 (dia × l) 60 x 105 (twin)	60 x 70 (dia × l)	60×60 (dia × l)	60×60 (dia × l)	60 × 60 (dia × l)	60 × 60 (dia × l)	60 × 50 (dia × l)
# output channels	2	2	1	1	1 CP	1 CP	1
# QD/CP elements	2	2	16	16	2 (= 1 CP)	2 (= 1 CP)	16
# LP elements	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

*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. Head coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	Head Quadrature	Head Quadrature	Quadrature head	Quadrature head	CP Head Array	Head Matrix	Quadrature head
Type*	T/R Q	T/R Q	R Q	R Q	R PA Q	R PA Q/L	T/R Q
Dimensions *cm*	36.8×40.6×30.5 (l × w × h)	36.8×40.6×30.5 (l × w × h)	28×30 (dia × l)	28×30 (dia × l)	48×34 (l × w)	30×30×28 (l × w × h)	55.5×48×40.5 (l ×w × h) Inner dia: 27
# output channels	1	1	1	1	1 CP	CP Mode : 4 CP Dual Mode : 8 CP Triple Mode : 12	1
# QD/CP elements	2	2	12 (birdcage rods)	12 (birdcage rods)	2 elements (= 1 CP)	12 elements, combined to: CP Mode: 4 CP elements Dual Mode: 8 CP elements Triple Mode: 12 elements	4
# LP elements	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Name	HD Brain Array	HD Brain Array	SENSE Head coil	SENSE Head coil	8-channel Head Array	Quadrature Tx/Rx Head Coil	QD Head SPEEDER
Type*	R PA	R PA L	R PA L	R PA L	R PA L	T/R PA Q	R PA Q
Dimensions *cm*	41.8×39.3×40.6 (l × w × h)	41.8 ×39.3 ×40.6 (l × w × h)	23x22 (dia x l)	23x22 (dia x l)	23×22 (dia × l)	40×36×36 (l × w x h)	94.5×36×42.5 (l ×w × h)
# output channels	8	8	8	8	8	1 CP	4 or 8
# QD/CP elements	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	2 elements (= 1 CP)	10
# LP elements	8	8	8	8	8	Not applicable	Not applicable

*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
† CP head array coil as detailed for Symphony system is also compatible with Avanto system

Table 23. Neck coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	HD NV Array	HD NV Array	Synergy Head/Neck	Synergy Head/Neck	CP Neck Array	Neck Matrix	QD Head / NV SPEEDER
Type*	R PA	R PA	R PA	R PA	R PA Q	R PA Q/L	R PA Q
Dimensions *cm*	72 × 46 × 43 (l × w × h)	72 × 46 × 43 (l × w × h)	43×35 dia × l)	43×35 (dia × l)	49 × 31 (l × w)	19 × 33 × 33.2 (l × w × h)	94.5 × 36 × 42.5 (l ×w × h)
# output channels	8	8	3	3	2	CP Mode: 2 CP Dual Mode: 4 Triple Mode: 4	4 or 8
# QD/CP elements	Not applicable	Not applicable	12	12	3 (= 1 CP + 1 LP)	4 elements, combined to: CP Mode: 2 CP Dual &Triple Mode: 4 elements	12
# LP elements	18	18	3	3	(see above)	(see above)	Not applicable

*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. Neurovascular coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	HD NV Array	HD Neurovascular Array / HD NV Array	No such coil	8 channel or 16 channel SENSE Neurovascular	CP Head Array, CP Neck Array and CP Spine Array combined & used simultaneously (IPA technology)	Head Matrix and Neck Matrix combined & used simultaneously (Matrix technology)	QD Neurovascular Array
Type*	R PA	R PA	-	R PA	R PA Q	R PA Q/L	R PA Q
Dimensions *cm*	72 × 46 ×43 (h×w×l)	72 × 46 × 43 (h×w×l)	-	37×45×66 (h×w×l)	(see individual coils)	(see individual coils)	77.5 × 41.5 × 36.5 (l ×w × h)
# output channels	8	4/8	-	8 or 16	In total: 5 (4 CP + 1)	CP Mode : 6 CP Dual Mode : 12 (8 CP + 4) Triple Mode : 16	4
# QD/CP elements	Not applicable	Not applicable	-	8 or 16	In total 9 elements (= 4 CP + 1 LP)	16 elements, combined to: CP Mode: 6 CP elements Dual Mode: 12 (CP) elements Triple Mode: 16 elements	7
# LP elements	18	6/18	-	18	(see above)	(see above)	Not applicable

*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. Spine coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	HD CTL spine Array	HD CTL spine Array	SENSE Spine	SENSE Spine	CP Spine Array	Spine Matrix	Quadrature CTL Spine Array
Type*	R Q PA	R Q PA	R Q PA	R Q PA	R PA Q	R PA Q/L	R Q PA
Dimensions *cm*	110×41×34.5	110×41×34.5	82 (l)	82 (l)	49 × 103.5 (w × l)	48.4 × 118.5 (w × l)	109 x 35 x 34 (l ×w × h)
# output channels	8	4/8	5	5	6 CP (up to 4 CP simultaneously in one FOV)	CP Mode: 8 CP (up to 4 CP simultaneously in one FOV) Dual Mode: 16 CP (up to 8 CP simultaneously in one FOV) Triple Mode: 24 (up to 12 simultaneously in one FOV))	6
# QD/CP elements	24	12/24	10	10	12 (= 6 CP)	24 elements, combined to: 8 CP elements in CP Mode, 16 CP elements in Dual Mode, 24 elements in Triple Mode	12 elements
# LP elements	Not applicable	Not applicable	10	10	(see above)	(see above)	Not applicable

*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. Body coils (1)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	HD Body Array	HD Body Array	SENSE Body	SENSE Body	CP Body Array Flex and CP Spine Array (IPA technology)	1 × Body Matrix and Spine Matrix (Matrix technology)	QD Torso SPEEDER
Type*	R PA	R PA	R PA	R PA	R PA Q	R PA Q/L	R PA Q
Dimensions *cm*	53.5 x 71 (ant) 53.5 x 77 (post)	53.5 x 71 (ant) 53.5 x 77 (post)	45 × 30 (l × w)	45 × 30 (l × w)	(see individual coils)	(see individual coils)	54 × 47 × 5 (l ×w × h)
# output channels	8/12	8	4	4	4 CP	CP Mode : 4 CP Dual Mode : 8 CP Triple Mode : 12	4 or 8
# QD/CP elements	Not applicable	Not applicable	Not applicable	Not applicable	8 (= 4 CP)	12 elements, combined to: 4 CP elements in CP Mode, 8 CP elements in Dual Mode, 12 elements in Triple Mode	16 elements
# LP elements	8/12	8	4	4	Not applicable	(see above)	Not applicable

*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. Body coils (2)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	No other coil	4ch Body Array	SENSE Cardiac (available with 6-channel option)	SENSE Cardiac	CP Body Array Extender, CP Body Array Flex and CP Spine Array (IPA technology) for 50cm coverage in z-direction.	2 × Body Matrix and Spine Matrix (Matrix technology) for 50cm coverage in z-direction	QD Torso Duo SPEEDER (2 parts)
Type*	-	R PA	R PA	R PA	R PA Q	R PA Q/L	R PA Q
Dimensions *cm*	-	40 x 30 (2 parts)	20 × 39 (l × w)	20 × 39 (l × w)	(see individual coils)	(see individual coils)	54 × 47 × 5 per coil (l ×w × h)
# output channels	-	4	5	5	8 CP	CP Mode: 8 CP Dual Mode: 16 CP Triple Mode: 24	8 or 16
# QD/CP elements	-	Not applicable	Not applicable	Not applicable	16 (= 8 CP)	24 elements, combined to: 8 CP elements in CP Mode, 16 CP elements in Dual Mode, 24 elements in Triple Mode	32 elements
# LP elements	-	4	5	5	Not applicable	(see above)	Not applicable

*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. Body coils (3)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	No other coil	No other coil	No other coil	SENSE XL TORSO	2 × 6-channel Body Array (anterior & posterior)	Whole-Body Applications: Combination of Head Matrix + Neck Matrix + Spine Matrix + up to 3 × Body Matrix + PA Matrix	Flex Body Array
Type*			-	RPA	R PA L	(see individual coils)	R PA
Dimensions *cm*			-	45×40	46 × 31.6 (each) (l× w)	(see individual coils)	113×47×30 (l × w × h) (132cm max circ)
# output channels			-	16	8	Up to 32 channels	4
# QD/CP elements			-	Not applicable	12 (2x6), combined to 8 channels	Up to 76 seamlessly integrated coil elements in total	4
# LP elements			-	16	12 (2x6), combined to 8 channels	-	Not applicable
Name	No other coil	No other coil	No other coil	No other coil	CP Body Array Flex (ant. Part)	Body Matrix (ant. Part)	Atlas SPEEDER Body
Type*	-	-	-	-	R PA Q	R PA Q/L	R PA
Dimensions *cm*	-	-	-	-	50 × 43.5 (w × l)	52 × 32.2 (w × l)	56.5 × 56 × 6 (w×d×h)
# output channels	-	-	-	-	2 CP	CP Mode : 2 CP Dual Mode : 4 CP Triple Mode : 6	16
# QD/CP elements	-	-	-	-	4 (= 2 CP)	6 elements, combined to: 2 CP elements in CP Mode, 4 CP elements in Dual Mode, 6 elements in Triple Mode	16
# LP elements	-	-	-	-	(see above)	(see above)	Not applicable

*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. Cardiac coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class &T-class	Toshiba Excelart Vantage
Name	HD Cardiac Array	HD Cardiac Array / 4ch Cardiac Array	SENSE Cardiac (available with 6-ch option)	SENSE Cardiac	Peripheral CP Angio Array, CP Body Array Flex and CP Spine Array (IPA technology)	PA Matrix	QD Torso SPEEDER
Type*	R PA	R PA	R PA	R PA	(see individual coils)	R Q PA	R PA Q
Dimensions *cm*	50 x 42 x 12	50 x 42 x 12 (2 parts) /21 x 19 (2 parts)	39×20 (w × l)	39×20 (w × l)	(see individual coils)	97×30-60×27 (w×l×h)	54 × 47 × 5 (l ×w × h)
# output channels	8	8/4	5	5	(see individual coils)	8 CP	4 or 8
# QD/CP elements	Not applicable	-	Not applicable	Not applicable	(see individual coils)	16 elements (8 CP)	16
# LP elements	8	8/4	5	5	(see individual coils)	(see above)	Not applicable

Table 28. Vascular imaging coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class &T-class	Toshiba Excelart Vantage
Name	HD Lower Leg Array	No other coil	Peripheral Vascular 4D Array	Peripheral Vascular 4D Array	Peripheral CP Angio Array	Phased Array Carotids Coil (Machnet BV)	Atlas SPEEDER Body x 2 or 3
Type*	R PA	-	PA	PA	R Q PA	R PA	PA
Dimensions *cm*	not supplied	-	9×74×173 (h × w × l)	9×74×173 (h × w × l)	105 × 60 (l × w)	105 x 60 (l x w)	56.5 × 56 × 6 (w ×d × h) per coil
# output channels	8/16	-	12	12	8 CP	4	16 per coil
# QD/CP elements	Not supplied	-	Not applicable	Not applicable	16 elements (8 CP)	Not applicable	16 per coil
# LP elements	32	-	Not applicable	Not applicable	See above	Not applicable	Not applicable
Name	No other coil	No other coil	Phased Array Carotids Coil (Machnet BV)	Phased Array Carotids Coil (Machnet BV)	Phased Array Carotids Coil (Machnet BV)	No other coil	No other coil
Type*	-	-	R PA	R PA	R PA	-	-
Dimensions *cm*	-	-	105 x 60 (l x w)	105 x 60 (l x w)	105 x 60 (l x w)	-	-
# output channels	-	-	4	4	4	-	-
# QD/CP elements	-	-	Not applicable	Not applicable	Not applicable	-	-
# LP elements	-	-	Not applicable	Not applicable	Not applicable	-	-

*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 29. Breast imaging coils (1)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	HD Breast Array†	HD Breast Array / 4ch Breast Array†	SENSE Body with Breast support	SENSE Body with Breast support	CP Breast Array	Breast matrix	Breast Coil
Type*	R PA	R PA	R PA	R PA	R Q PA	R PA	R PA L
Dimensions *cm*	52 x 54 x 24	52 x 54 x 24 / Not supplied	45×30 (l x w)	45×30 (l x w)	14.5×53×50 (h × w× l)	14.5×53×50 (h × w× l)	108×48.5×16 (w × d × h)
# output channels	8	8/4	4	4	2 CP	4	Not supplied
# QD/CP elements	Not supplied	Not supplied	Not applicable	Not applicable	4 (=2CP)	Not applicable	Not supplied
# LP elements	8	8/4	4	4	Not applicable	4	Not supplied

*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
†Biopsy kit available as an option

Table 29. Breast imaging coils (2)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class &T-class	Toshiba Excelart Vantage
Name	No other coil	No other coil	4-channel SENSE Breast	4-channel SENSE Breast	Breast Biopsy	Breast Biopsy	Breast SPEEDER (+ biopsy)
Type*			R Q PA	R Q PA	Q L R	Q L R	R Q
Dimensions *cm*			Not supplied	Not supplied	19 (dia)	19	Not supplied
# output channels			4	4	1	1	8
# QD/CP elements			Not applicable	Not applicable	1	1	7
# LP elements			4	4	Not applicable	Not applicable	Not supplied
Name	No other coil	No other coil	No other coil	SENSE Breast (compatible with biopsy device)	No other coil	No other coil	No other coil
Type*	-	-	-	R Q PA	-	-	-
Dimensions *cm*	-	-	-	Not supplied	-	-	-
# output channels	-	-	-	7	-	-	-
# QD/CP elements	-	-	-	Not applicable	-	-	-
# LP elements	-	-	-	7	-	-	-

*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 30. Extremity coils (1)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Knee coils							
Name	Quadrature extremity	Quadrature extremity	Quadrature knee	Quadrature knee	CP Extremity	CP Extremity	Quadrature Knee
Type*	T/R Q	T/R Q	R Q	R Q	T/R Q	T/R Q	R Q
Dimensions *cm*	38×46 (dia × l)	38×46 (dia × l)	16.5×18 (dia × l)	16.5×18 (dia × l)	40.5×27x29 (l × w × h)	40.5×27x29 (l × w × h)	60×45×x28 (w×d×h) 19.5 dia
# output channels	1	1	Not supplied	Not supplied	1	1	4
# QD/CP elements	1	1	Not supplied	Not supplied	1	1	4
# LP elements	2	2	Not supplied	Not supplied	Not applicable	Not applicable	Not applicable
Name	HD Knee Array	HD Knee Array	No other coil	SENSE knee coil	No other coil	8-channel knee coil	Quadrature Knee/ Foot coil
Type*	T/R PA	T/R PA	-	R Q PA	-	R PA Q	R Q
Dimensions *cm*	40 × 42 ×31	40 × 42 × 31	-	Not supplied	-	40 × 42 × 31 (l × w × h)	45×60×38 (w×d×h)
# output channels	8	8	-	8	-	8	4
# QD/CP elements	Not applicable	Not applicable	-	Not applicable	-	Not applicable	4
# LP elements	9	9	-	8	-	8	Not applicable

*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 30. Extremity coils (2)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
TMJ coils							
Name	TMJ Kit	TMJ Kit	Paired TMJ	Paired TMJ	Bilateral TMJ	Bilateral TMJ	TMJ KIT
Type*	PA	PA	R L 2 circular coils	R L 2 circular coils	R L PA	R L PA	R L
Dimensions *cm*	7.5	7.5	8	8	7	7	7
# output channels	2	2	2	2	2	2	2
# QD/CP elements	Not supplied	Not supplied	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
# LP elements	2	2	2	2	2	2	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 30. Extremity coils (3)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Wrist coils							
Name	HD Wrist Array	HD Wrist Array/ 4ch Wrist Array	SENSE Wrist†	SENSE Wrist†	No other coil	8-ch wrist Coil	No other coil
Type*	R PA	R PA	R Q PA	R Q PA	-	R PA L	-
Dimensions *cm*	6.5×15×12.5	6.5×15×12.5/ 21.5×44×36	7×13×15 (w×l×d)	7×13×15 (w×l×d)	-	40 × 30 × 40 (l × h × w)	-
# output channels	8	8/4	4	4	-	8	-
# QD/CP elements	Not supplied	Not supplied	Not applicable	Not applicable	-	Not applicable	-
# LP elements	8	8/4	4	4	-	8	-

*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
†Synergy SENSE S can also be used for wrist imaging (see table for general purpose coils)

Table 30. Extremity coils (4)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Shoulder coils							
Name	HD Shoulder Array	HD Shoulder Array	SENSE Shoulder	SENSE Shoulder	Shoulder Array (small, large)	Shoulder Array (small, large)	Shoulder Array
Type*	R PA	R PA	R Q PA	R Q PA	R PA	R PA	R PA
Dimensions *cm*	22×23× 32	22 ×23 ×32	17 × 20	17 × 20	16.5 (s), 20 (l)	16.5 (s), 20 (l)	24.5 × 21 × 17.5 (w × d × h)
# output channels	3	3	4	4	4	4	4
# QD/CP elements	Not supplied	Not supplied	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
# LP elements	3	3	4	4	4	4	4
Other extremity coils							
Name	See general purpose coils, Table 33	See general purpose coils, Table 33	See general purpose coils, Table 33	See general purpose coils, Table 33	No other coil	8 ch Foot Ankle Coil	See general purpose coils, Table 33
Type	-	-	-	-	-	R PA L	-
Dimensions *cm*	-	-	-	-	-	53 × 33 × 28 (l × h × w)	-
# output channels	-	-	-	-	-	8	-
# QD/CP elements	-	-	-	-	-	Not applicable	-
# LP elements	-	-	-	-	-	8	8

*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 31. Endorectal coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	Endo-Rectal+	No other coil	Endo-cavity (2 sizes)	Endo-cavity (2 sizes)	Endorectal†	Endorectal†	No other coil
Type*	R L	-	R L	R L	R L	R L	-
Dimensions *cm*	Not supplied	-	4.8 / 3 (dia)	4.8 / 3 (dia)	3×8 (dia × l)	3×8 (dia × l)	-
# output channels	Can be combined with up to 8 elements	-	Not supplied	Not supplied	1 (+ 4 CP in combination with CP Body+Spine Array)	1 (+ up to 12 in combination with Body+Spine Matrix)	-
# QD/CP elements	Not supplied	-	Not supplied	Not supplied	Not applicable	Not applicable	-
# LP elements	1	-	Not supplied	Not supplied	1	1	-

+ Combines with HD Body array or 4ch Body array for anatomy coverage.
† Combine with CP Body Array and CP Spine Array for max. image homogeneity

Table 32.Paediatric coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	Paediatric	No other coil	Synergy Paediatric	Synergy Paediatric	No other coil	No other coil	No other coil
Type*	PA	-	R PA,	R PA,	-	-	-
Dimensions *cm*	Not supplied	-	Not supplied	Not supplied	-	-	-
# output channels	8	-	Not supplied	Not supplied	-	-	-
# QD/CP elements	Not supplied	-	5	5	-	-	-
# LP elements	Not supplied	-	10	10	-	-	-

*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 33. General purpose coils (1)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	3”/5” GP coils	3”/5” GP coils	C1/C3/C4 Circular Surface	C1/C3/C4 Circular Surface	Flex (Small/Large)	Flex (Small/Large)	Phi Circular Flex coils × 4
Applications	Orbits, ankle, wrist (3”): CTL spine, shoulder, ankle, foot (5”)	Orbits, ankle, wrist (3”): CTL spine, shoulder, ankle, foot (5”)	Orbits (all), spine, shoulder (C1/C3), knee, kidney (C1), wrist, TMJ (C3/C4), foot (C3)	Orbits (all), spine, shoulder (C1/C3), knee, kidney (C1), wrist, TMJ (C3/C4), foot (C3)	upper/ lower extremities (large), small structures, & joints (small)	upper/ lower extremities (large), small structures, & joints (small)	Orbits, shoulder, knee, kidney , wrist, TMJ, foot
Type*	R L	R L	R L	R L	R Q	R Q	R L
Dimensions *cm*	7.5/12.5	7.5/12.5	27/11/8 (dia)	27/11/8 (dia)	17 × 36 (small) (l × w) 21 × 52 (large) (l × w)	Small:17 × 36 (l × w) Large:21 × 52 (l × w)	7, 10,15 or 20 (dia)
# output channels	2	2	1	1	1 CP	1 CP	Not supplied
# QD/CP elements	Not supplied	Not supplied	Not supplied	Not supplied	2 (=1CP)	2 (=1CP)	Not supplied
# LP elements	2	2	Not supplied	Not supplied	See above	See above	Not supplied

*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 33. General purpose coils (2)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class& T-class	Toshiba Excelart Vantage
Name	GP Flex coil	GP Flex coil	E1 Flexible Extremity Surface	E1 Flexible Extremity Surface	Loop Flex (small/large)	Loop Flex (small/large)	GP FLEX
Applications	Hip, shoulder, ankles, thigh, elbow, large knees, brachial plexus	Hip, shoulder, ankles, thigh, elbow, large knees, brachial plexus	Shoulder, knee, ankle, elbow	Shoulder, knee, ankle, elbow	Wrist, hand, elbow, shoulder, knee, ankle	Wrist, hand, elbow, shoulder, knee, ankle	Shoulder, wrist, hand, elbow, knee, ankle
Type*	R L	R L	R L	R L	R L	R L	R L
Dimensions *cm*	21×45 (l × w)	Not supplied	16×13.5 (dia × l)	16×13.5 (dia × l)	4 (small) (dia) 19 (large) (dia)	4 (small) (dia) 19 (large) (dia)	39×24×10
# output channels	1	1	Not supplied	Not supplied	1	1	Not supplied
# QD/CP elements	Not supplied	Not supplied	Not supplied	Not supplied	Not applicable	Not applicable	Not supplied
# LP elements	1	1	Not supplied	Not supplied	1	1	Not supplied

*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 33. General purpose coils (3)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	No other coil	No other coil	Synergy SENSE Flex S	Synergy SENSE Flex S	No other coil	4 channel Flex Coil large	Rectangular Flex
Applications	-	-	Head, IAC, Wrist, Elbow, eyes, small joints	Head, IAC, Wrist, Elbow, eyes, small joints	-	Hip, Knee, Shoulder, elbow, ankle, wrist	Limbs, spine
Type*	-	-	R Q PA	R Q PA	-	R Q PA	R L
Dimensions *cm*	-	-	8 (dia)	8 (dia)	-	Not supplied	18 × 36 (w × l)
# output channels	-	-	2	2	-	4	Not supplied
# QD/CP elements	-	-	Not applicable	Not applicable	-	Not applicable	Not supplied
# LP elements	-	-	2	2	-	4	Not supplied
Name	No other coil	No other coil	Synergy SENSE Flex M	Synergy SENSE Flex L	No other coil	4 channel Flex Coil small	No other coil
Applications	-	-	Shoulder, Wrist, small joints	Hip, Head, Shoulder, knee, ankle, elbow, paediatric	-	Hip, Knee, Shoulder, elbow, ankle, wrist	-
Type*	-	-	R Q PA	R Q PA	-	R Q PA	-
Dimensions *cm*	-	-	14×17	20 (dia)	-	Not supplied	-
# output channels	-	-	2	2	-	4	-
# QD/CP elements	-	-	Not applicable	Not applicable	-	Not applicable	-
# LP elements	-	-	2	2	-	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 33. General purpose coils (4)

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	No other coil	No other coil	Synergy SENSE Flex L	Synergy SENSE Flex M	No other coil	No other coil	No other coil
Applications	-	-	Hip, Head, Shoulder, knee, ankle, elbow, paediatric	Shoulder, Wrist, small joints	-	-	-
Type*	-	-	R Q PA	R Q PA	-	-	-
Dimensions *cm*	-	-	20 (dia)	14x17	-	-	-
# output channels	-	-	2	2	-	-	-
# QD/CP elements	-	-	Not applicable	Not applicable	-	-	-
# LP elements	-	-	2	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 34. Other coils

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Name	HNS coil	No other coil	No other coil	No other coil	No other coil	No other coil	Atlas SPEEDER Head
Applications	Head, Neurovascular & Spine coil	-	-	-	-	-	Head (Only for Atlas systems)
Type*	R PA	-	-	-	-	-	R PA Q
Dimensions *cm*	90cm SI	-	-	-	-	-	47×52×41.5 (w × d × h)
# output channels	16	-	-	-	-	-	16
# QD/CP elements	Not supplied	-	-	-	-	-	14
# LP elements	29	-	-	-	-	-	(see above)
Name	No other coil	No other coil	No other coil	No other coil	No other coil	No other coil	Atlas SPEEDER Spine
Applications	-	-	-	-	-	-	Spine (Only for Atlas systems)
Type*	-	-	-	-	-	-	R PA
Dimensions cm	-	-	-	-	-	-	105 x 47 x 4.5 (l ×w × h)
# output channels	-	-	-	-	-	-	16
# QD/CP elements	-	-	-	-	-	-	32 elements
# LP elements	-	-	-	-	-	-	(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

Parallel imaging product information

Table 35: Parallel imaging product information

	GE Signa HDx	GE Signa HDe	Philips Intera	Philips Achieva	Siemens Symphony	Siemens Avanto I-class & T-class	Toshiba Excelart Vantage
Parallel imaging product name	ASSET / GEM	ASSET	SENSE	SENSE	iPAT (standard) iPAT plus (with Whole Body Array)	iPAT (standard) iPAT Extensions (optional)	SPEEDER
k-space based reconstruction method	GEM uses auto-calibration signal (ACS) lines	no	no	no	GRAPPA (GeneRalised Autocalibrating Partially Parallel Acquisition)	GRAPPA (GeneRalised Autocalibrating Partially Parallel Acquisition)	no
Image-space based reconstruction method	ASSET / GEM	ASSET	SENSE (SENSitivity Encoding)	SENSE (SENSitivity Encoding)	mSENSE (Modified SENSE)	mSENSE (Modified SENSE)	SENSE (SENSitivity Encoding)
Comments	ASSET/GEM can be used to scan up to 3.5 times faster but can also be used to increase spatial resolution or to acquire more slices per unit time. ASSET/GEM also offers the means to minimize the RF exposure to a patient.	ASSET can be used to scan up to 3.0 times faster but can also be used to increase spatial resolution or to acquire more slices time. ASSET also offers the means to minimize the RF exposure to a patient.	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.		maximum speed up factor is triple and quadruple with 8 channels option. Use to reduce scan times and /or increase image quality for the same time. For Atlas system, speed up factors of up to 16 can be achieved.

Table 36: Parallel imaging factors for head coils with parallel imaging capability

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	32	8	8	18	32	4,8	8,16
Name	HD Brain Array			HD Brain Array		SENSE HEAD		SENSE HEAD		CP Head Array		Head Matrix			Head SPEEDER	Atlas Head SPEEDER
Parallel imaging factors	2	2	2	-	2	Max4	Max6	Max 8	Max 8	HF*: 1/2 ‡ AP*: 1 LR*: 1	HF: 1/2 ‡ AP: 1 LR: 1	HF*:2/4‡ AP*: 3/3 LR*: 3/3 max†: 9	HF*:2/4‡ AP*: 3/3 LR*: 3/3 max†:12	HF*: 2/4‡ AP*: 3/3 LR*: 3/3 max†: 12	2	8
Name	No other coil			No other coil		No other coil		No other coil		8-channel Head Array		No other coil			No other coil	
Parallel imaging factors	-			-		-		-		Not applicable	HF 1 AP 4 LR 4	-			-	

* HF/AP/LR: max. Parallel Imaging factors in head-feet/anterior-posterior/left-right directions
† max: max. Parallel Imaging factor for 3D scans with iPAT² functionality.
‡ x/y: Parallel Imaging factors for the respective coil alone / for typical clinical coil combinations (utilizing IPA technology resp. Matrix technology)

Table 37: Parallel imaging factors for neck/neurovascular coils with parallel imaging capability

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	4	8	8	18	32	4,8	8,16
Name	HD NV Array			HD NV Array		Synergy Head/neck PA		Synergy Head/neck PA		CP Neck array		Neck Matrix			Head SPEEDER with NV attachment	ATLAS SPEEDER Head/Neck
Parallel imaging factors	2	2	2	-	2	Max 3	Max 3	Max 3	Max 3	HF: 1/2 AP: 2/2 LR: 1	HF: 1/4 AP: 2/2 LR: 1	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	2	Up to 16
Name	Head, Neck and Spine (HNS) Array			HD Neurovascular Array		No other coil		8 or 16 channel SENSE Neurovascular		CP Head Array,CP Neck Array and CP Spine Array (IPA technology)		Head Matrix and Neck Matrix (Matrix technology)			No other coil	No other coil
Parallel imaging factors	-	2	2	2	-	-		Max 8	Max 16	HF:4 AP:2 LR:2-3 max:8-12	HF:1/4 AP:1 LR:1	HF: 3 AP: 2 LR: 2-3 max: 6	HF: 3 AP: 2 LR: 2-3 max: 9	HF: 3 AP: 2 LR: 2-3 max: 9	-	-

Table 38: Parallel imaging factors for spine coils with parallel imaging capability

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	4	8	8	18	32	4,8	8,16
Name	HD NV Array/ Head, Neck and Spine (HNS) Array			HD Neurovascular Array / HD NV Array		SENSE Spine		SENSE Spine		CP Spine Array		Spine Matrix			QD CTL Array	ATLAS spine array
Parallel imaging factors	2	2	2	2	2	Max 2	Max 2	Max 2	Max 2	HF: 2 AP: 1/2 LR: 1	HF: 4 AP: 1/2 LR: 1	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	2	Up to 16

Table 39: Parallel imaging factors for body coils with parallel imaging capability

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	4	8	8	18	32	4,8	8,16
Name	HD Body Array			HD Body Array		No such coil		SENSE XL Torso		CP Body Array + CP Spine Array		Body Matrix + Spine Matrix			QD Torso Duo SPEEDER	Atlas SPEEDER Body
Parallel imaging factors	3.5	3.5	3.5	-	3.5	-		Max 8	Max 16	HF: 2 AP: 2 LR: 1	HF: 2 AP: 2 LR: 1	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	4	Up to 16
Name	No other coil			4ch Body Array		No other coil		No other coil		CP Body Array + CP Body Extender + CP Spine Array		2 x Body Matrix + Spine Matrix			No other coil	No other coil
Parallel imaging factors	-	-	-	2	-	-		-		not applicable	HF: 4 AP: 2 LR: 1	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 40: Parallel imaging factors for extremity coils with parallel imaging capability (1)

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	4	8	8	18	32	4,8	8,16
Knee coils																
Name	HD Knee Array			HD Knee Array		No such coil		SENSE knee		No such coil		8-channel knee coil			No such coils	
Parallel imaging factors	2	2	2	2	2	-		Max 8	Max 8	-		HF: 1 AP: 4 LR: 4	HF: 1 AP: 4 LR: 4	HF: 1 AP: 4 LR: 4	-	
Wrist coils																
Name	No such coil			No such coil		SENSE Wrist		SENSE Wrist		Wrist Array		Wrist Array			No such coils	
Parallel imaging factors	-			-		Max 4	Max 4	Max 4	Max 4	HF: 1 AP: 2 LR: 2	HF: 1 AP: 2 LR: 2	HF: 1 AP: 2 LR: 2	HF: 1 AP: 2 LR: 2	HF: 1 AP: 2 LR: 2	-	
Name	No other coil			No other coil		No other coil		No other coil		No other coil		8 ch Wrist Coil			-	
Parallel imaging factors	-			-		-		-		-		HF: 1 AP: 3 LR: 3	HF: 1 AP: 3 LR: 3	HF: 1 AP: 3 LR: 3	-	

Table 40: Parallel imaging factors for extremity coils with parallel imaging capability (2)

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	4	8	8	18	32	4,8	8,16
Shoulder coils																
Name	No such coil			No such coil		SENSE Shoulder		SENSE Shoulder		Shoulder Array (large+small)		Shoulder Array (large+small)			No such coil	
Parallel imaging factors	-			-		Max 4	Max 4	Max 4	Max 4	HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	-	

Table 41: Parallel imaging factors for breast coils with parallel imaging capability

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva		Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE		Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16	4	8	8	18	32	4,8	8,16
Name	HD Breast Array			4ch Breast Array / HD Breast Array		SENSE Breast		SENSE Breast		CP Breast Array		Breast Matrix			Breast SPEEDER	
Parallel imaging factors	3.5	3.5	3.5	2	3.5	Max 4	Max 4	Max 5	Max 5	HF: 1 AP: 1 LR: 2	HF: 1 AP: 1 LR: 2	HF: 1 AP: 1 LR: 2	HF: 1 AP: 1 LR: 2	HF: 1 AP: 1 LR: 2	Max 4	Max 4

Table 42: Parallel imaging factors for other/general purpose coils with parallel imaging capability

	GE Signa HDx			GE Signa HDe		Philips Intera		Philips Achieva			Siemens Symphony		Siemens Avanto I-class & T-class			Toshiba Excelart Vantage	
RF system	HDx			HDe		FREEWAVE		FREEWAVE			Advanced Array	Whole Body Array	Tim [32x8]	Tim [76x18]	Tim [76x32]	Vantage	ATLAS
Number of independent RF receiver channels	8	16	32	4	8	4	6	8	16		4	8	8	18	32	4,8	8,16
Name	3”/5” GP coils			3”/5” GP coils		SENSE Flex L/M/S		SENSE Flex L/M/S			No other coil		4-channel Flex coils, large and small			No other coils	
Parallel imaging factors	2			2		2	2	2	Max 2		-		HF: 2 AP: 1 LR: 2	HF: 2 AP: 1 LR: 2	HF: 2 AP: 1 LR: 2	-	
Name	No other coil			No other coil		No other coil		No other coil			No other coil		8 channel Foot ankle coil			-	
Parallel imaging factors	-			-		-		-			-		HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	HF: 2 AP: 2 LR: 2	-	

Technical evaluation

Introduction to evaluation

The technical performance of the 1.5 T systems included in this evaluation is provided in this section of the report. Table 43 provides information on these systems and Table 44 shows our standard imaging protocol.

CEP requires all images to be acquired without any pre-reconstruction or post-processing filters. Further information on imaging protocols, image analysis (including SNR normalisation) and test objects can be found at the MagNET website at www.magnet-mri.org.

Table 43. MR model abbreviation codes for evaluated 1.5T systems

	GE	GE	Philips	Philips	Siemens	Siemens
Model	Signa EXCITE HD	Signa EXCITE HD	Intera	Achieva	MAGNETOM Symphony	MAGNETOM Avanto
Code	**GE-ES**	**GE-TWS**	**PH-INT**	**PH-ACH**	**SI-SYM**	**SI-AVA**
Gradient evaluated	Echospeed HD	Twinspeed HD -Zoom mode (Head coil) - Whole body mode (Body coils)	-Explorer (Head coil) -Master (Body coil) -Nova Dual (multi-channel coils)	Nova dual	Quantum	SQ
RF System	16 channel	16 channel	6 channel	8 channel	8 channel	32 channel
Report	Not applicable	Not applicable	MDA 02 077	Not applicable	MDA 01 14	MHRA 04036
Assessment date	29/11/2004	29/11/2004	-08/02/02 (Head coil) -25/09/00 (Body coil) -29/01/03 (multi-channel coils) -11/04/03 (imaging speed)	27/09/2004	-23/10/2000 -30/10/2002 (multi-channel coils) -28/04/2004 (imaging speed)	28/04/2004
Notes	-Since this evaluation, the gradient amplifier has been changed to improve performance. -Gradient systems are now called HDx and HDx option Twin.		The Master gradient system is replaced by the Pulsar system: results should be similar or slightly improved		GRAPPA reconstruction applied in parallel imaging.	GRAPPA reconstruction applied in parallel imaging.

Table 44. Standard imaging protocol parameters

parameter	value
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 44. MagNET's loaded flood field test object (MAGFF-Loaded) 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 45.

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, sampling bandwidth and Q-factor.

Interpretation of results

The image SNR value obtained on a system is influenced by system and sequence factors. Example system factors are the main magnetic field strength B_0 and the design of the radiofrequency receive and transmit systems. Example sequence factors are voxel size, scan time and sampling bandwidth.

The normalised signal to noise ratio value is used for comparison as it is independent of sequence parameters and test-object specific system performance. The normalised SNR results for the quadrature head coil are presented in Table 46 and in Graph 1.

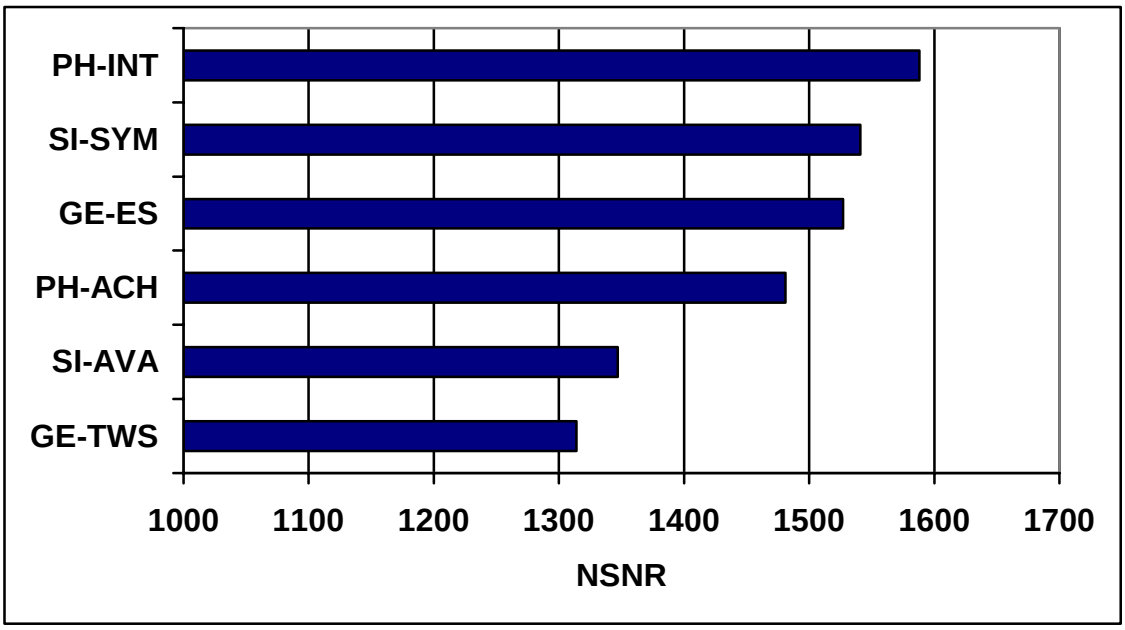
Table 45. Experimental conditions for quadrature head coil SNR test

	GE-ES	GE-TWS	PH-INT	PH-ACH	SI-SYM	SI-AVA
Temperature *°C*	24	25	22	23	21	20
Bandwidth *kHz*	11.90	11.90	28.1	23.26	16.64	16.64
Test object	MAGFF-Loaded	MAGFF-Loaded	MAGFF-Loaded	MAGFF-Loaded	TO1A_S	MAGFF-Loaded
Q factor	1.04	1.12	1.03	1.00	1.00	1.00

Table 46. Quadrature head coil normalised signal to noise ratio

	Transverse	Sagittal	Coronal	Mean
GE-ES	1476	1471	1635	1527
GE-TWS	1177	1458	1306	1314
PH-INT	1683	1562	1520	1588
PH-ACH	1536	1440	1465	1481
SI-SYM	1699	1473	1450	1541
SI-AVA	1456	1306	1277	1347

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



Quadrature head coil: uniformity

Scan parameters

The standard quadrature head coil uniformity test is carried out using our standard type-test protocol in Table 44. 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 directions. The fractional uniformity is calculated for each 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

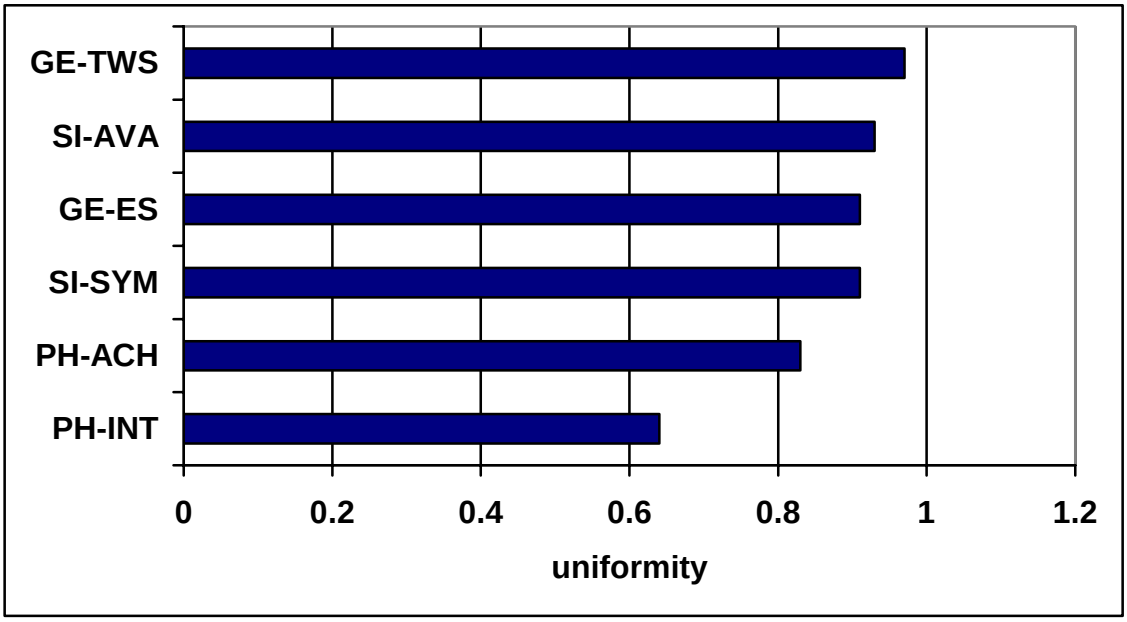
Results describe unfiltered images. Filtering is likely to improve image uniformity usually at the expense of image resolution. The optimum value of fractional uniformity is 1.00. Fractional uniformity results in the x, y and z directions are presented in Table 47. Graph 2 shows the fractional uniformity results averaged over the three directions.

Table 47. Fractional uniformity for the head coil (unfiltered)

	x-direction	y-direction	z-direction	Mean ± SD*
GE-ES	1.00	1.00	0.72	0.91 ± 0.15
GE-TWS	1.00	1.00	0.90	0.97 ± 0.08
PH-INT	1.00	1.00	0.64	0.88 ± 0.19
PH-ACH	1.00	1.00	0.49	0.83 ± 0.26
SI-SYM	1.00	1.00	0.74	0.91 ± 0.15
SI-AVA	1.00	1.00	0.79	0.93 ± 0.11

*Standard Deviation (SD) of 6 measurements (2 measurements per direction)

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



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 44. MagNET's resolution test object (MAGRES) 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 frequency at the 50% point on the modulation transfer function (MTF) plot (Lerski 1998). This frequency is converted into pixel resolution.

Interpretation of results

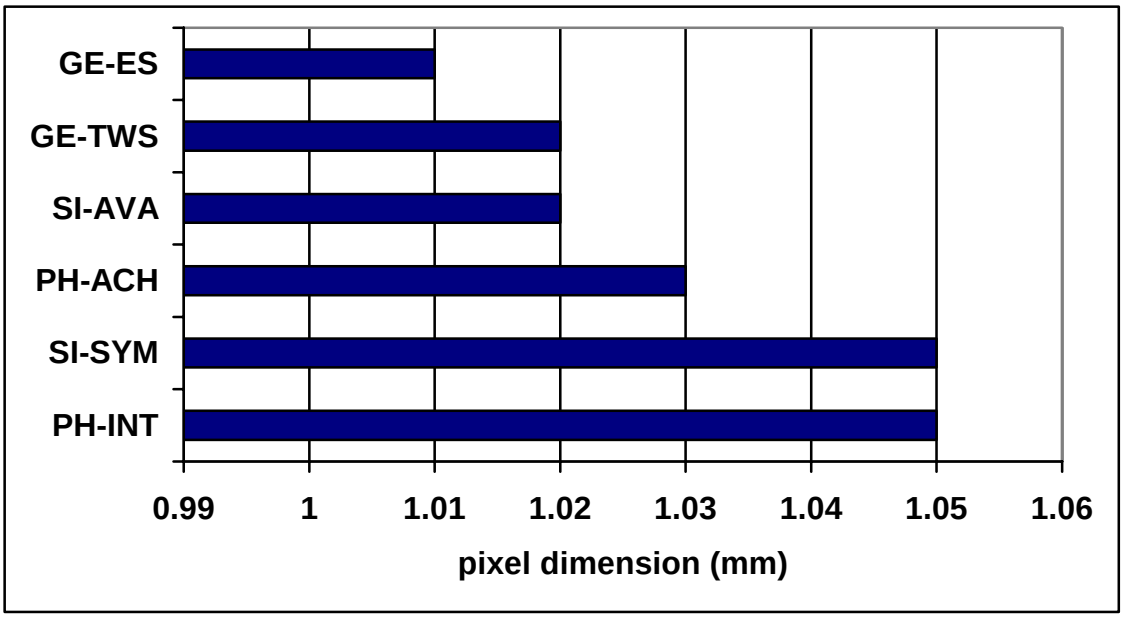
Measurements of MTF are considered to be within experimental error if they are within ±10% of the nominal pixel size. The resolution measurements are presented in Table 48. The measured resolution should be equal to the nominal pixel dimension of 0.98mm. Graph 3 shows a comparison of the average pixel dimension.

Table 48. Pixel dimension measurements (mm) for 256×256 matrix, FOV=25 cm

	Mean (in PE direction)	Mean (in FE direction)	Mean ± SD*
GE-ES	1.01	1.02	1.02 ± 0.01
GE-TWS	1.02	1.02	1.02 ± 0.01
PH-INT	1.04	1.06	1.05 ± 0.01
PH-ACH	1.03	1.03	1.03 ± 0.02
SI-SYM	1.05	1.05	1.05 ± 0.01
SI-AVA	1.02	1.02	1.02 ± 0.02

*SD of 24 measurements (4 measurements per direction per plane)

Graph 3: Comparison of mean pixel dimension for 256×256 matrix, FOV=25 cm*



*Optimum pixel dimension value is 0.98mm

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 44 with FOV=256 mm. MagNET's geometry test object (MAGGEOM) 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. These measurements are converted from pixels to millimetres and compared to the actual separation distance (Lerski 1998).

Interpretation of results

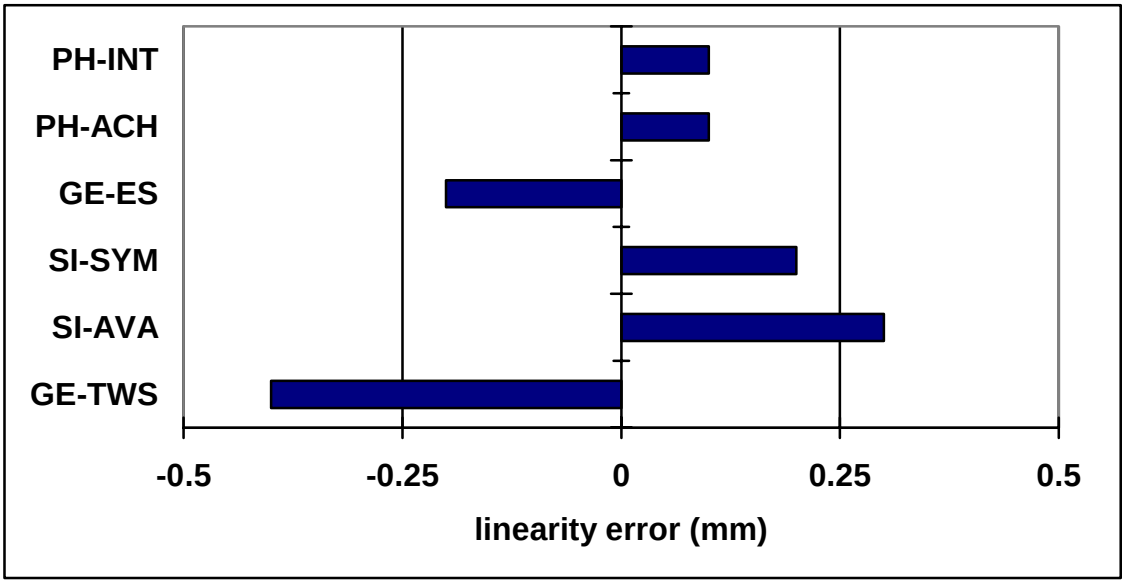
The optimum value for the geometric linearity is 120 mm and for its error it is zero. However, results are considered to be within experimental error if they are within ±1 mm. Table 49 shows the linearity measurements for each gradient direction. Graph 4 compares the mean linearity errors for the systems.

Table 49. Geometric linearity for three directions (mm)

	x-direction	y-direction	z-direction	Mean ± SD*
GE-ES	120.2	119.7	119.7	119.8 ± 0.51
GE-TWS	119.3	119.8	119.7	119.6 ± 0.50
PH-INT	120.3	120.0	120.0	120.1 ± 0.47
PH-ACH	120.2	120.2	120.0	120.1 ± 0.47
SI-SYM	120.0	120.3	120.2	120.2 ± 0.38
SI-AVA	120.0	120.5	120.5	120.3 ± 0.48

*Standard Deviation (SD) from 18 measurements (6 measurements per direction)

Graph 4. Comparison of mean error in geometric linearity systems (mean of three gradient directions).*



*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 44 with FOV=256 mm. MagNET's geometry test object (MAGGEOM) is placed at the centre of the coil and is imaged at the iso-centre in transverse, sagittal and coronal 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):

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

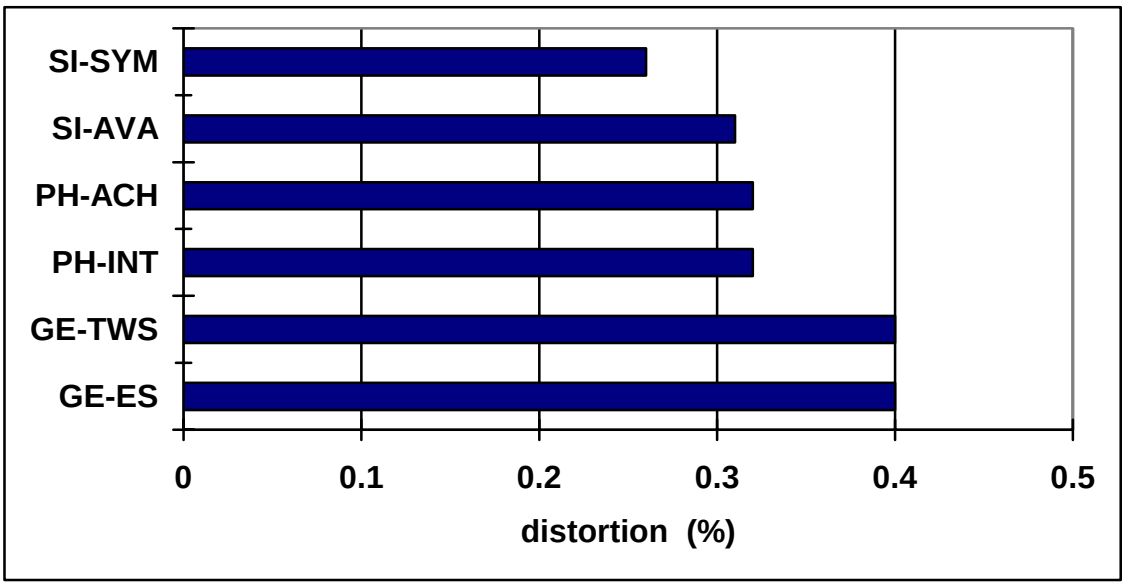
Interpretation of results

The optimum value for the coefficient of variation is zero, hence the lower the coefficient of variation, the lower the in-plane distortion and the better the performance of the system. Table 50 shows the distortion results for the three gradient directions. Graph 5 shows a comparison of the mean geometric distortion for the three gradient directions.

Table 50. Distortion measurements (CV%) for three gradient directions

	x-direction	y-direction	z-direction	Mean
GE-ES	0.34	0.43	0.43	0.40
GE-TWS	0.43	0.34	0.43	0.40
PH-INT	0.43	0.53	0.00	0.32
PH-ACH	0.34	0.63	0.00	0.32
SI-SYM	0.00	0.43	0.34	0.26
SI-AVA	0.01	0.45	0.45	0.31

Graph 5. Comparison of geometric distortion (CV%, mean of three gradient directions)



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 44 with SW=3 and 5 mm. MagNET's geometry test object (MAGGEOM) is placed at the centre of the coil and is imaged at the iso-centre in transverse, sagittal and coronal 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

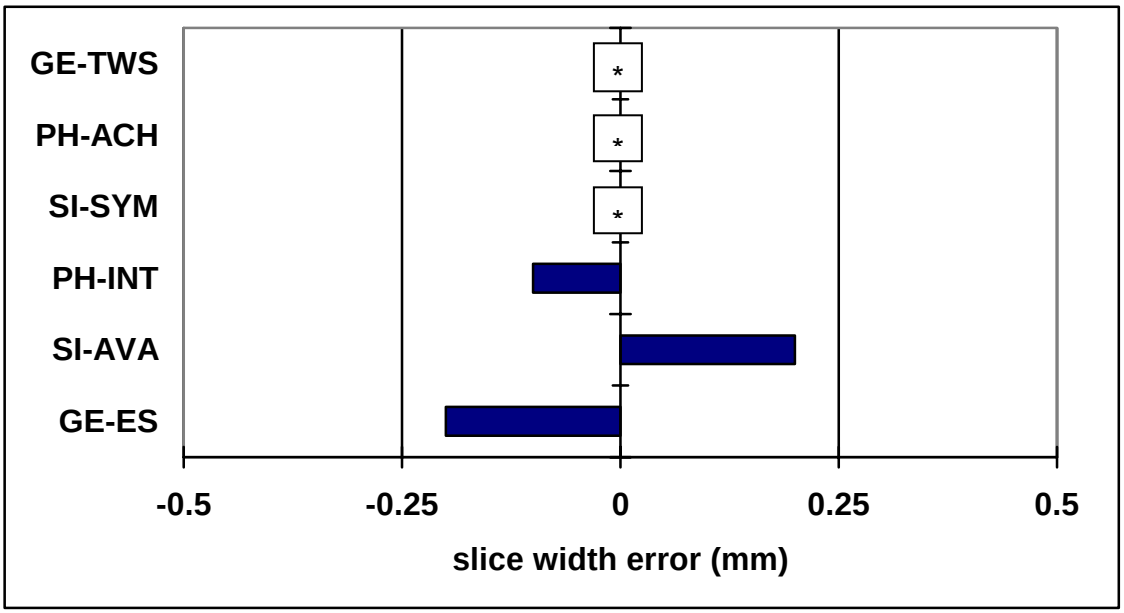
The slice profiles should have minimum side lobes, no ringing, and no central drop-out. The measured slice widths for the three imaging planes presented in Table 51 should lie within 10% of the nominal slice width. Graph 6 and Graph 7 show comparisons of the mean 3 mm and 5 mm slice width measurements.

Table 51. Measured slice widths (mm)

	Transverse	Sagittal	Coronal	Mean ± SD*
3 mm test				
GE-ES	2.9	2.9	2.7	2.8 ± 0.06
GE-TWS	3.0	2.9	3.0	3.0 ± 0.08
PH-INT	2.9	2.9	2.9	2.9 ± 0.08
PH-ACH	3.0	2.9	3.0	3.0 ± 0.05
SI-SYM	2.9	3.0	3.1	3.0 ± 0.12
SI-AVA	3.1	3.2	3.2	3.2 ± 0.09
5 mm test				
GE-ES	4.7	4.7	4.3	4.6 ± 0.20
GE-TWS	5.1	4.7	5.0	4.9 ± 0.21
PH-INT	4.9	4.7	4.9	4.8 ± 0.08
PH-ACH	5.0	5.0	5.0	5.0 ± 0.02
SI-SYM	4.8	4.8	5.1	4.9 ± 0.14
SI-AVA	5.3	5.3	5.5	5.3 ± 0.10

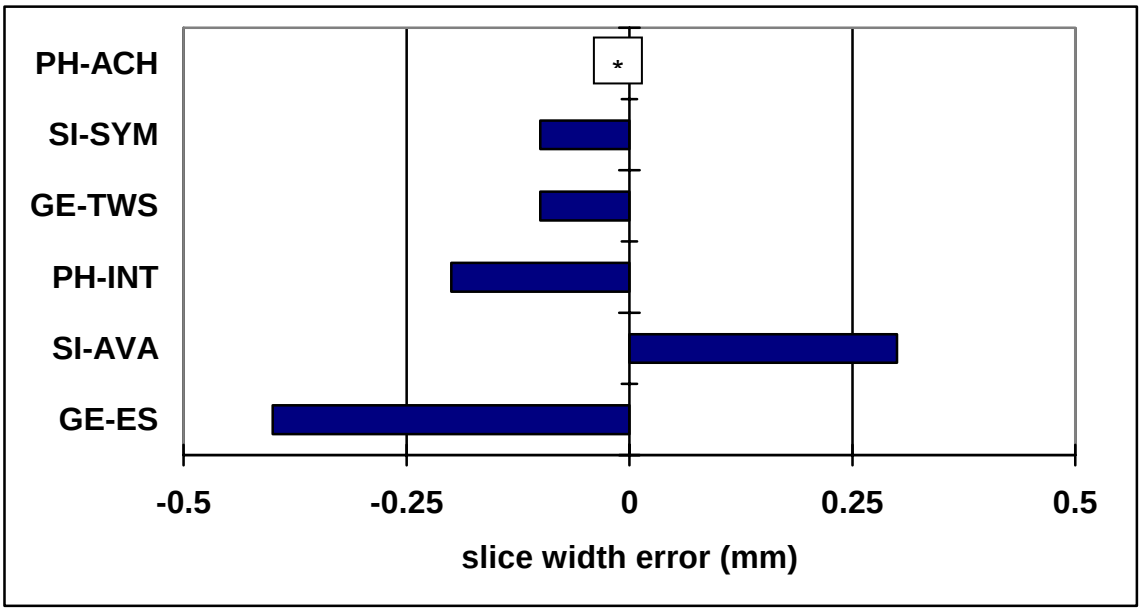
*Standard deviation (SD) of 12 measurements (4 measurements per plane)

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



* The system has the optimum measured error value of 0.0 mm.
† 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 system has the optimum measured error value of 0.0 mm.
† The optimum value is 0 ± 0.5 mm. Systems are ranked in order of the absolute deviation from optimum.

Quadrature head coil: ghosting

Scan parameters

The standard quadrature head coil ghosting test is carried out using our standard type-test protocol in Table 44 with a four echo sequence TE=30 ms, 60 ms, 90 ms, 120 ms and NSA=1,2. MagNET's ghosting test object (MAGGHO) 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).

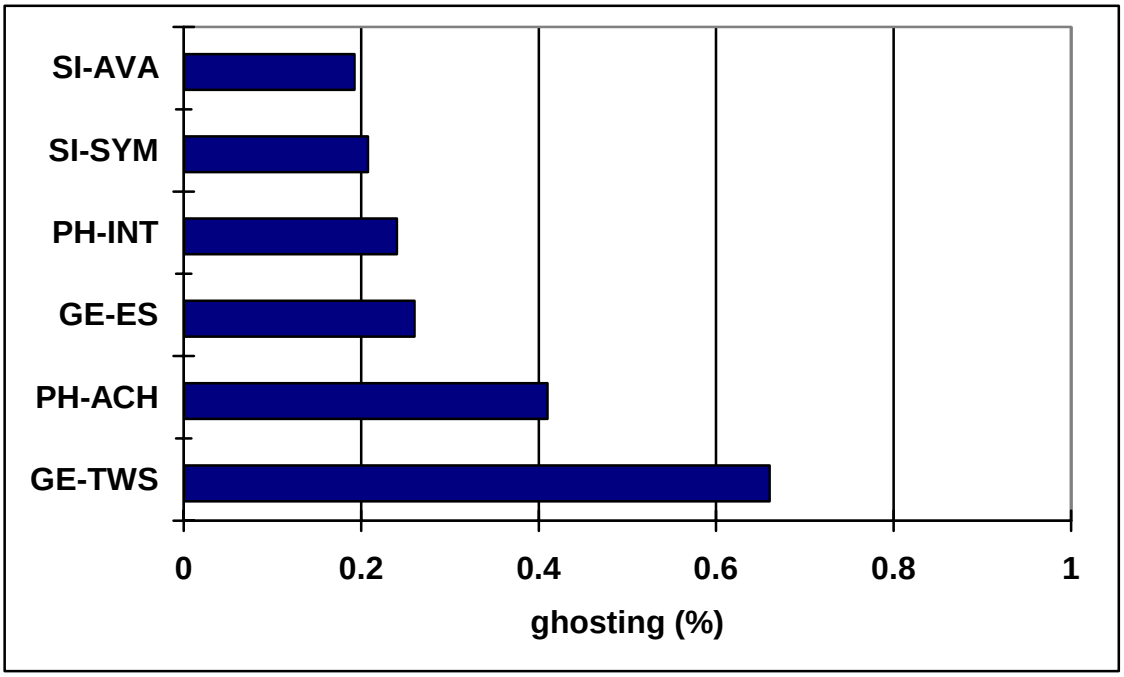
Interpretation of results

The optimum value for ghosting is zero, hence the lower the ghosting, the better the performance of the system. Table 52 presents the ghosting results. Graph 8 and Graph 9 present the results for 1 and 2 NSA respectively.

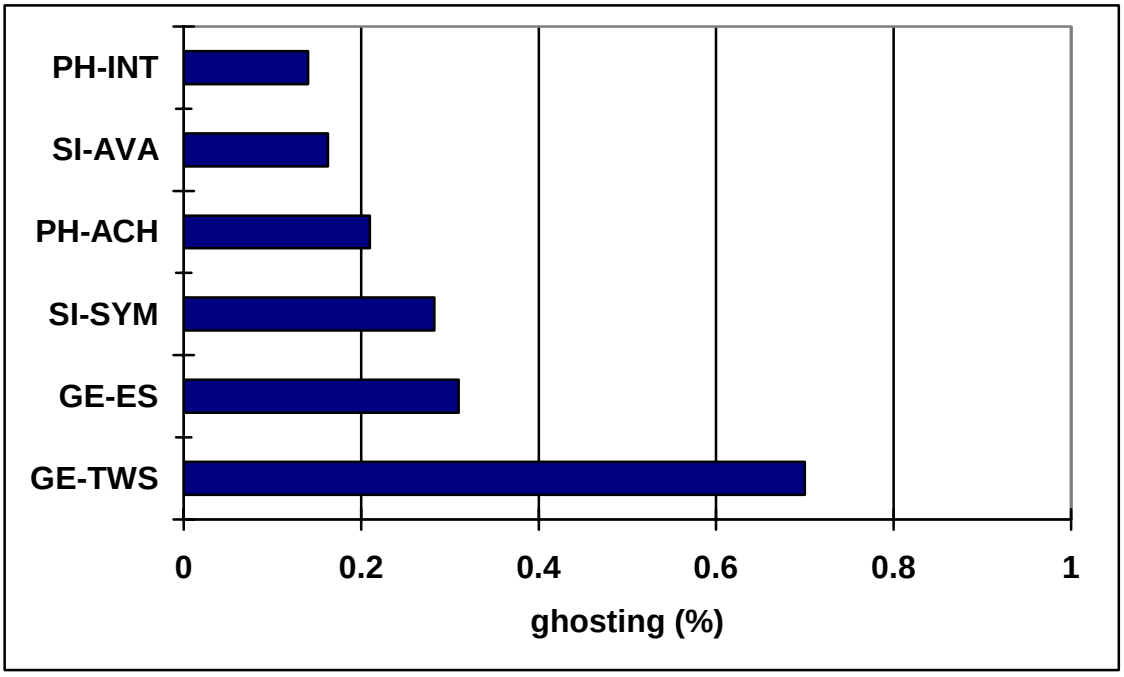
Table 52. Maximum ghosting ratio for 1 and 2 signal averages

	Echo 1 30 ms	Echo 2 60 ms	Echo 3 90 ms	Echo 4 120 ms	Mean
NSA = 1					
GE-ES	0.00	0.20	0.39	0.45	0.26
GE-TWS	0.67	0.43	0.42	1.14	0.66
PH-INT	0.24	0.18	0.25	0.29	0.24
PH-ACH	0.33	0.39	0.54	0.36	0.41
SI-SYM	0.18	0.23	0.22	0.20	0.21
SI-AVA	0.21	0.13	0.21	0.16	0.19
NSA = 2					
GE-ES	0.22	0.24	0.35	0.42	0.31
GE-TWS	0.70	0.51	0.64	0.96	0.70
PH-INT	0.13	0.12	0.19	0.12	0.14
PH-ACH	0.22	0.22	0.21	0.21	0.21
SI-SYM	0.33	0.34	0.26	0.20	0.28
SI-AVA	0.16	0.14	0.17	0.18	0.16

Graph 8. Comparison of average ghosting for NSA=1



Graph 9. Comparison of average ghosting for NSA=2



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 44. MagNET's flood field loaded test object (MAGFF-Loaded) 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 53.

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, sampling bandwidth and coil loading.

Interpretation of results

The image SNR value obtained on a system is influenced by system and sequence factors. Example system factors are the main magnetic field strength B_0 and the design of the radiofrequency receive and transmit systems. Example sequence factors are voxel size, scan time and sampling bandwidth.

The normalised signal to noise ratio value is used for comparison as it is independent of sequence parameters and test-object specific system performance. The normalised SNR results for the in-built body coil are presented in Table 54 and in Graph 10.

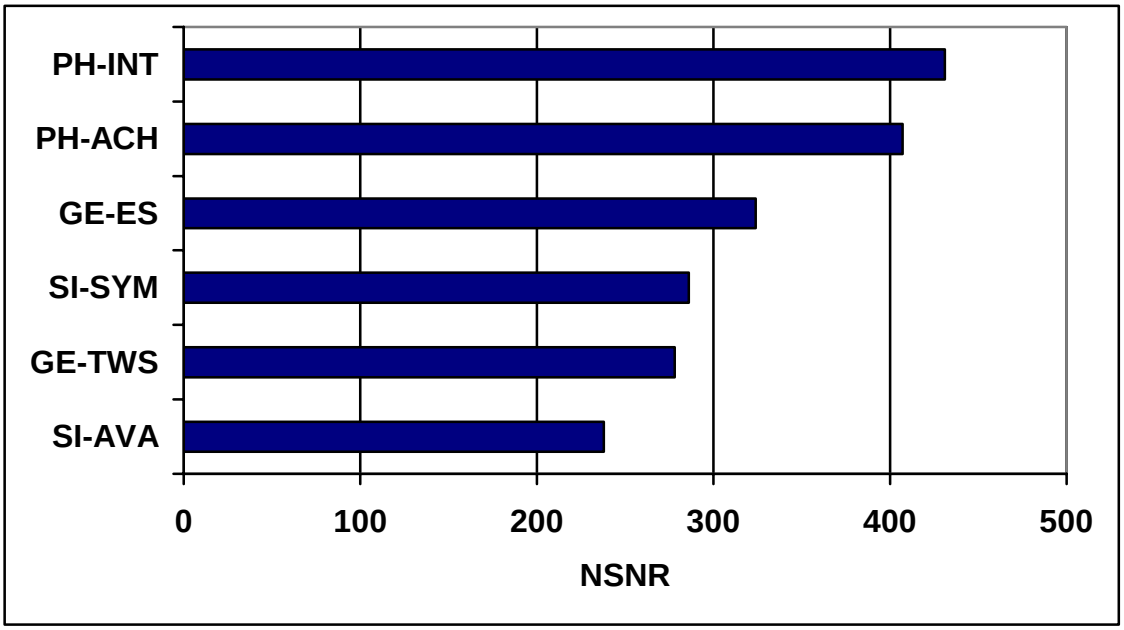
Table 53. In-built body coil signal to noise ratio experimental conditions

	GE-ES	GE-TWS	PH-INT	PH-ACH	SI-SYM	SI-AVA
Temperature *°C*	24	25	22.5	23	21	20
Bandwidth *kHz*	11.90	11.90	28.80	23.26	16.64	16.64
Test object	MAGFF-Loaded	MAGFF-Loaded	TO1A_L	MAGFF-Loaded	MAGFF-Loaded	MAGFF-Loaded
Additional loading	None	None	-	None	Siemens Body Loader	None
Q factor	0.84	0.84	0.79	0.81	1.18	0.43

Table 54. In-built body coil normalised signal to noise ratio

	Transverse	Sagittal	Coronal	Mean
GE-ES	322	311	338	324
GE-TWS	269	295	269	278
PH-INT	442	428	423	431
PH-ACH	426	397	396	407
SI-SYM	298	283	277	286
SI-AVA	249	232	233	238

Graph 10. Comparison of in-built body coil normalised signal to noise ratio (mean of three planes)



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 44. 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 directions. The fractional uniformity is calculated for each 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

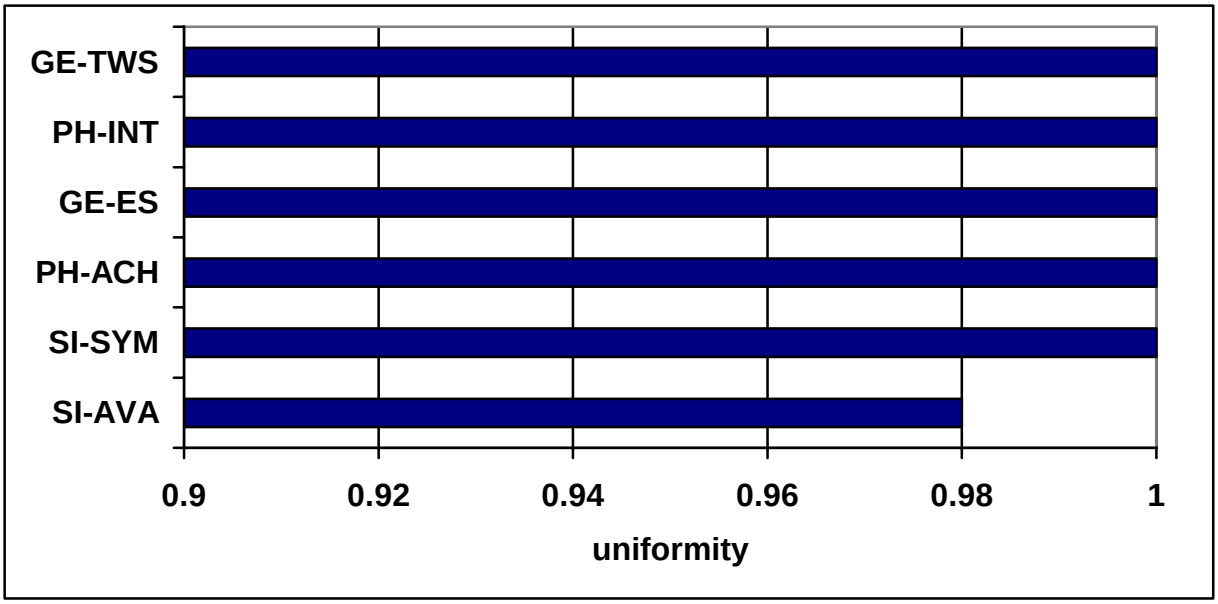
Results describe unfiltered images. Filtering is likely to improve image uniformity usually at the expense of image resolution. The optimum value of fractional uniformity is 1.00. Fractional uniformity results in the x, y and z directions are presented in Table 55 and in Graph 11.

Table 55. In-built body coil fractional uniformity

	x-direction	y-direction	z-direction	Mean±SD*
GE-ES	1.00	1.00	1.00	1.00 ± 0.00
GE-TWS	1.00	1.00	1.00	1.00 ± 0.00
PH-ACH	1.00	1.00	1.00	1.00 ± 0.00
PH-ACH	1.00	1.00	1.00	1.00 ± 0.00
SI-SYM	1.00	1.00	0.99	1.00 ± 0.01
SI-AVA	0.95	1.00	1.00	0.98 ± 0.03

*Standard Deviation (SD) of 6 measurements (2 measurements per direction)

Graph 11. Comparison of in-built body coil fractional uniformity (mean of three directions)



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 44. MagNET's flood field loaded test object (MAGFF-Loaded) 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 56.

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, sampling bandwidth. There was no correction for coil loading.

Interpretation of results

The image SNR value obtained on a system is influenced by system and sequence factors. Example system factors are the main magnetic field strength B_0 and the design of the radiofrequency receive and transmit systems. Example sequence factors are voxel size, scan time and sampling bandwidth.

The normalised signal to noise ratio value is used for comparison as it is independent of sequence parameters and test-object specific system performance. The normalised SNR results for the multi-channel head coil are presented in Table 57 and in Graph 12.

Table 56. Experimental conditions for multi-channel head coil SNR test

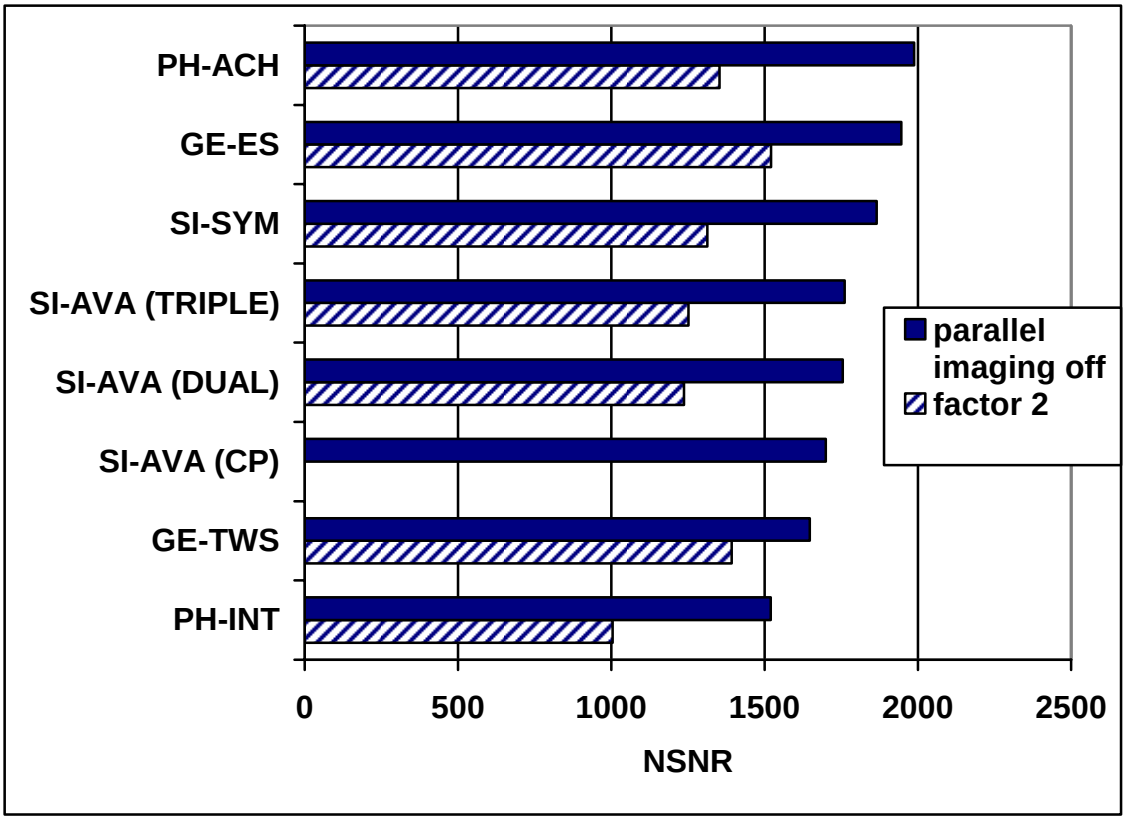
	GE-ES	GE-TWS	PH-INT	PH-ACH	SI-SYM	SI-AVA
Coil tested	8-channel high resolution brain coil	8-channel high resolution brain coil	Sense Head	Sense Head	8-channel head array	Head Matrix
Temperature *°C*	24	25	Not measured	23	23	20
Bandwidth *kHz*	11.90	11.90	14.00	23.26	16.64	16.64
Sequence	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	TSE with ETL=1	TSE with ETL=1

Table 57. Multi-channel head coil normalised signal to noise ratio (NSNR)

	Parallel imaging factor	Transverse	Sagittal	Coronal	Average
GE-ES	None	2054	1834	1952	1946
	2	1695	1302	1567	1521
GE-TWS	None	1806	1617	1518	1647
	2	1464	1394	1322	1393
PH-INT	None	2123	1327	1109	1520
	2	1064	1062	886	1004
	4	621	514	683	606
	6	209	226	228	221
PH-ACH	None	2229	1860	1872	1987
	1	2175	1443	1454	1691
	2	1738	1136	1185	1353
	3	1299	930	945	1058
SI-SYM	None	2004	1561	2030	1865
	2	1374	1153	1410	1313
	4	944	1070	1474	1163
SI-AVA	None (CP)*	1744	1749	1603	1699
	None (DUAL)*	1932	1697	1638	1755
	2 (DUAL)*	1295	1154	1262	1237
	None (TRIPLE)*	1964	1626	1693	1761
	2 (TRIPLE)*	1287	1233	1235	1252
	4 (TRIPLE)*	738	838	876	817

*imaging mode

Graph 12. Comparison of multi-channel head coil normalised signal to noise ratio (NSNR) (mean of three planes, parallel imaging factors = off, 2)



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 44, 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. In the case of the GE systems a 17 cm sphere filled with silicon oil was imaged instead.

Analysis

The average of several intensity profiles is calculated in all three directions. The fractional uniformity is calculated for each 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

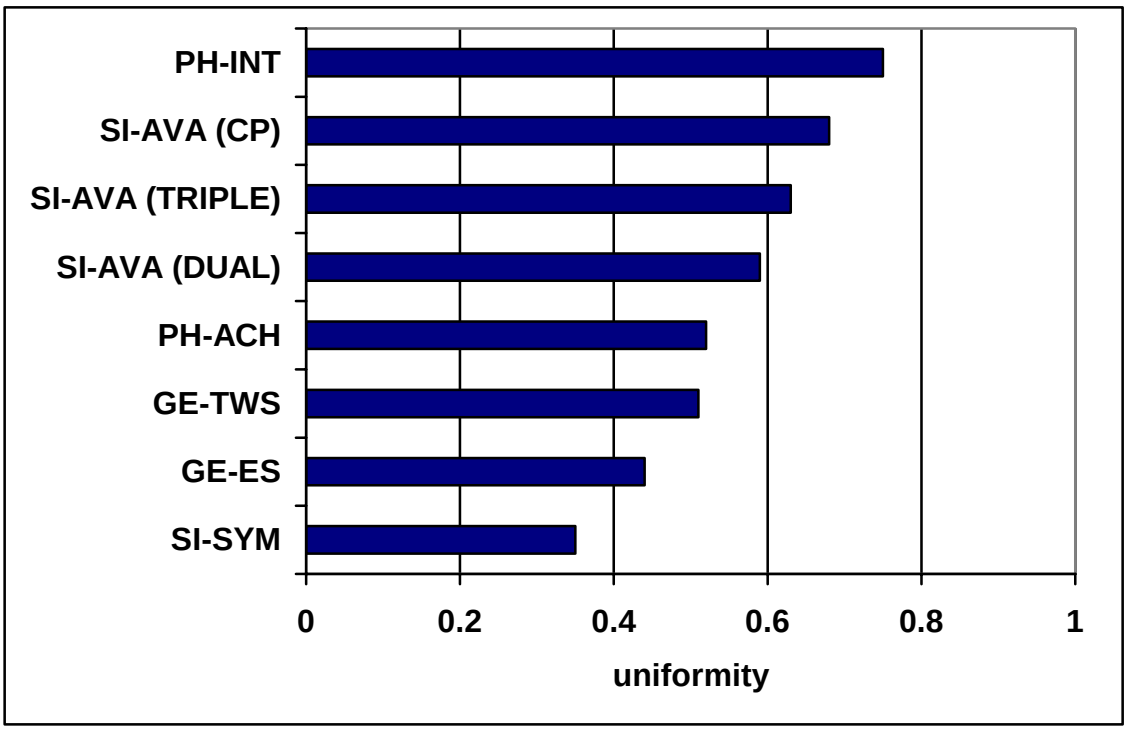
Results describe unfiltered images. Filtering is likely to improve image uniformity usually at the expense of image resolution. The optimum value of fractional uniformity is 1.00. Fractional uniformity results in the x, y and z directions are presented in Table 58 and in Graph 13.

Table 58. Multi-channel head coil fractional uniformity

	Parallel imaging factor	X-direction	Y-direction	Z-direction	Mean ± SD*
GE-ES	None	0.43	0.55	0.35	0.44 ± 0.09
	2	0.46	0.62	0.43	0.50 ± 0.09
GE-TWS	None	0.50	0.58	0.45	0.51 ± 0.07
	2	0.51	0.65	0.62	0.59 ± 0.07
PH-INT	None	1.00	0.84	0.31	0.75 ± 0.38
	1	1.00	1.00	0.97	0.99 ± 0.02
PH-ACH	None	0.58	0.63	0.36	0.52 ± 0.13
	1	1.00	1.00	1.00	1.00 ± 0.00
SI-SYM	None	0.38	0.43	0.23	0.35 ± 0.11
SI-AVA	None (CP)	0.66	0.61	0.76	0.68 ± 0.07
	None (Dual)	0.45	0.62	0.72	0.59 ± 0.13
	None (Triple)	0.45	0.66	0.79	0.63 ± 0.16

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

Graph 13. Comparison of multi-channel head coil fractional uniformity (mean of three directions for parallel imaging turned off)



Multi-channel body coil evaluation

Multi-channel body 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 44. MagNET's flood field loaded test object (MAGFF-Loaded) 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 59.

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, sampling bandwidth. There was no correction for coil loading.

Interpretation of results

The image SNR value obtained on a system is influenced by system and sequence factors. Example system factors are the main magnetic field strength B_0 and the design of the radiofrequency receive and transmit systems. Example sequence factors are voxel size, scan time and sampling bandwidth. The normalised signal to noise ratio value is used for comparison as it is independent of sequence parameters and test-object specific system performance. The normalised SNR results for the multi-channel body coil are presented in Table 60 and in Graph 14.

Table 59. Experimental conditions for multi-channel body coil SNR test

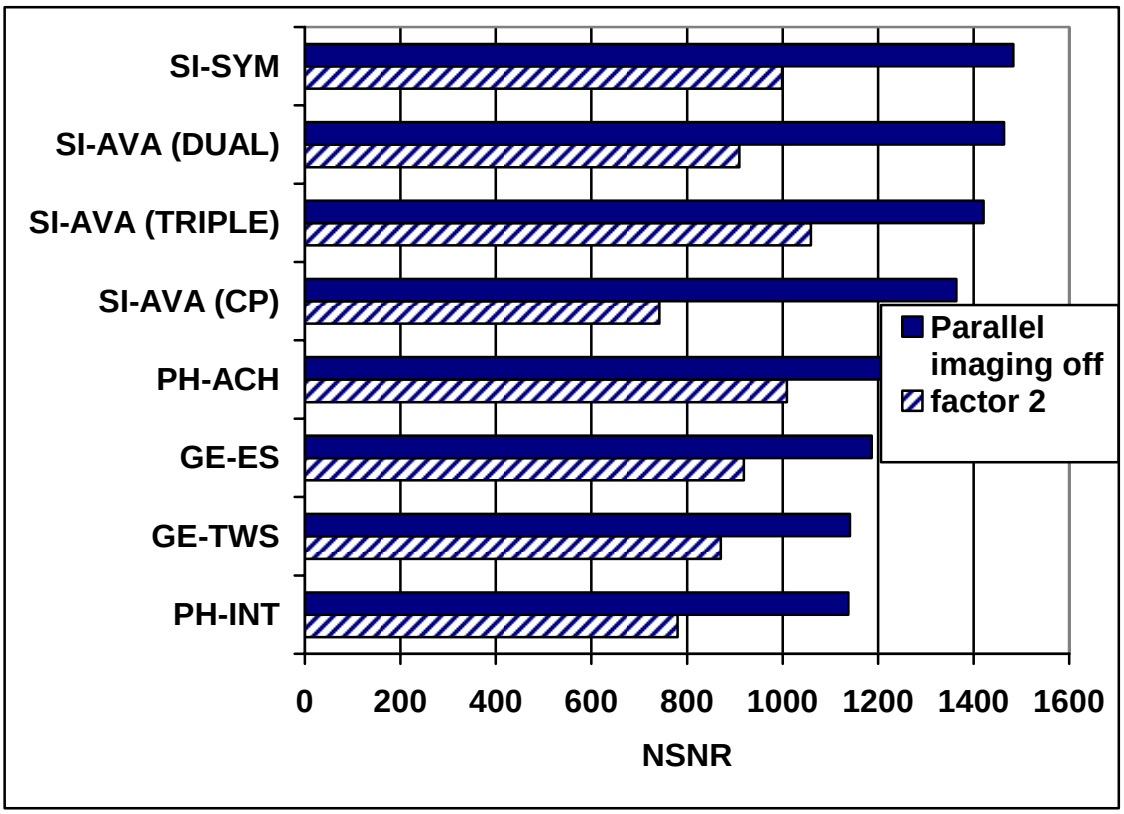
	GE-ES	GE-TWS	PH-INT	PH-ACH	SI-SYM	SI-AVA
Coil tested	8-channel high definition cardiac array	8-channel high definition cardiac array	Sense Body (x2)	Sense Body (x2)	CP Body Array & CP Body Array Extender	Body Matrix & Spine Matrix
Temperature *°C*	24	25	Not measured	23	23	20
Bandwidth *kHz*	11.90	11.90	14.00	23.26	16.64	16.64
Sequence	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	E for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	SE for parallel imaging off TSE (Turbo factor = 2) for parallel imaging	TSE with ETL=1	TSE with ETL=1

Table 60. Multi-channel body coil normalised signal to noise ratio

	Parallel imaging factor	Transverse	Sagittal	Coronal	Mean
GE-ES	None	1275	1254	1033	1187
	2	920	1004	834	919
GE-TWS	None	1149	1333	943	1141
	2	845	1018	750	871
PH-INT	None	1322	1271	822	1138
	2	744	898	697	780
	4	183	212	340	245
PH-ACH	None	1346	1253	1142	1247
	1	1541	1351	1269	1387
	2	1037	1021	968	1009
	3	624	631	543	599
	4	319	330	274	308
Si-SYM	None	1450	1585	1414	1483
	2	838	1140	1018	999
SI-AVA	None (CP)	1421	1497	1176	1364
	2 (CP)	742	Not available*	Not available*	Not available*
	None (DUAL)	1464	Not available*	Not available*	Not available*
	2 (DUAL)	910	Not available*	Not available*	Not available*
	None (TRIPLE)	1421	Not available*	Not available*	Not available*
	2 (TRIPLE)	1059	Not available*	Not available*	Not available*

*Data not available due to time constraints at the time of system technical assessment.

Graph 14. Comparison of multi-channel body coil normalised signal to noise ratio (NSNR) (mean of three planes, parallel imaging = off, 2)



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 44. 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 directions. The fractional uniformity is calculated for each 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

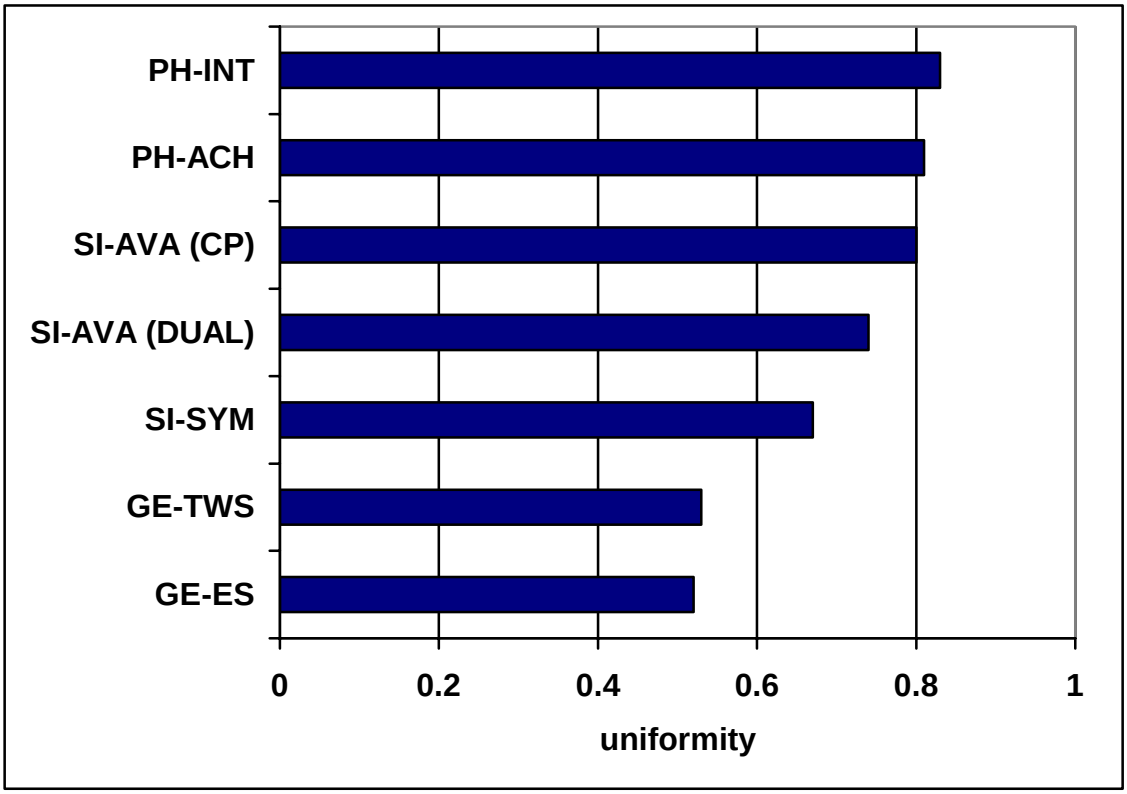
Results describe unfiltered images. Filtering is likely to improve image uniformity usually at the expense of image resolution. The optimum value of fractional uniformity is 1.00. Fractional uniformity results in the x, y and z directions are presented in Table 61 and in Graph 15.

Table 61. Multi-channel body coil fractional uniformity

	Parallel imaging factor	X-direction	Y-direction	Z-direction	Mean ± SD*
GE-ES	None	0.59	0.28	0.70	0.52 ± 0.22
	2	0.42	0.46	0.66	0.51 ± 0.19
GE-TWS	None	0.62	0.25	0.72	0.53 ± 0.22
	2	0.76	0.26	0.98	0.67 ± 0.33
PH-INT	None	0.93	0.81	0.76	0.83 ± 0.09
PH-ACH	None	1.00	0.72	0.71	0.81 ± 0.15
	1	1.00	1.00	1.00	1.00 ± 0.00
SI-SYM	None	0.62	0.40	1.00	0.67 ± 0.30
SI-AVA	None (CP mode)	1.00	0.40	1.00	0.80 ± 0.31
	None (Dual mode)	0.79	0.44	1.00	0.74 ± 0.26

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

Graph 15. Comparison of multi-channel body coil fractional uniformity (mean of three directions for parallel imaging turned off)



2D and 3D imaging speed

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

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

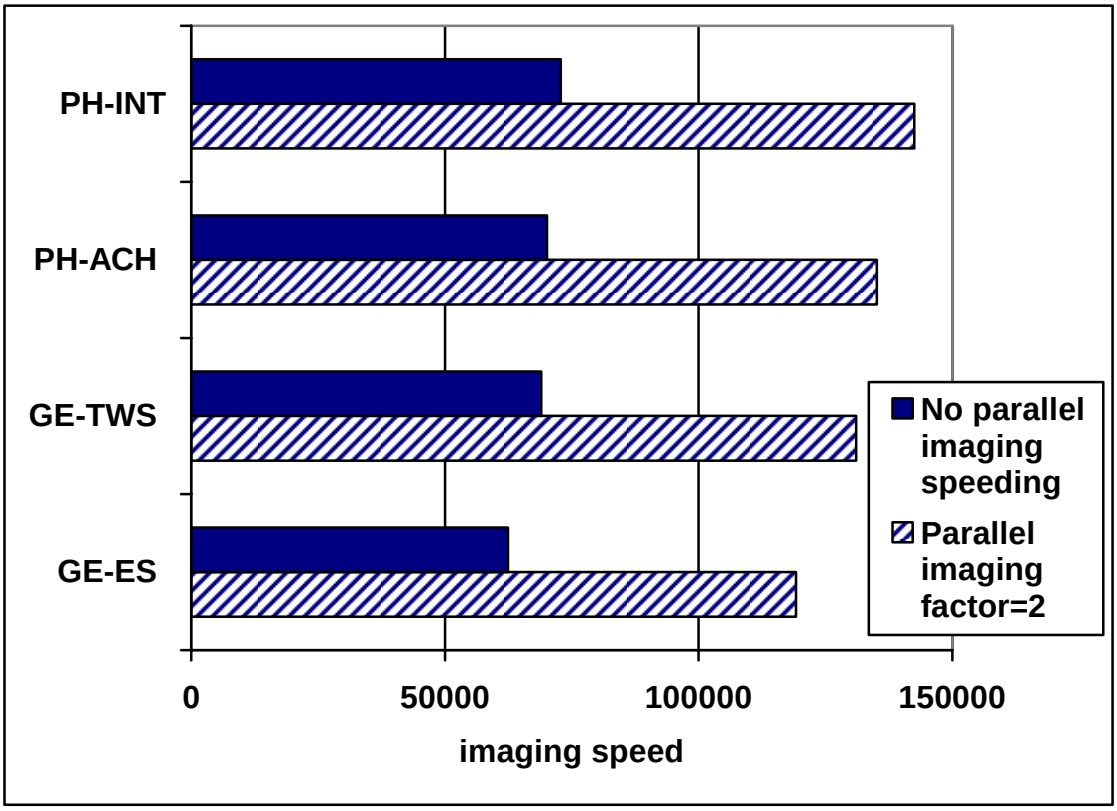
Imaging speed has been calculated as the ratio of imaged voxels to total scan time. The total scan time is the time displayed by the scanner, rather than the number of phase-encoding steps × repetition time (TR).

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 a parallel imaging scan; hence the pre-scan is included in the total scan time when calculating imaging speed.

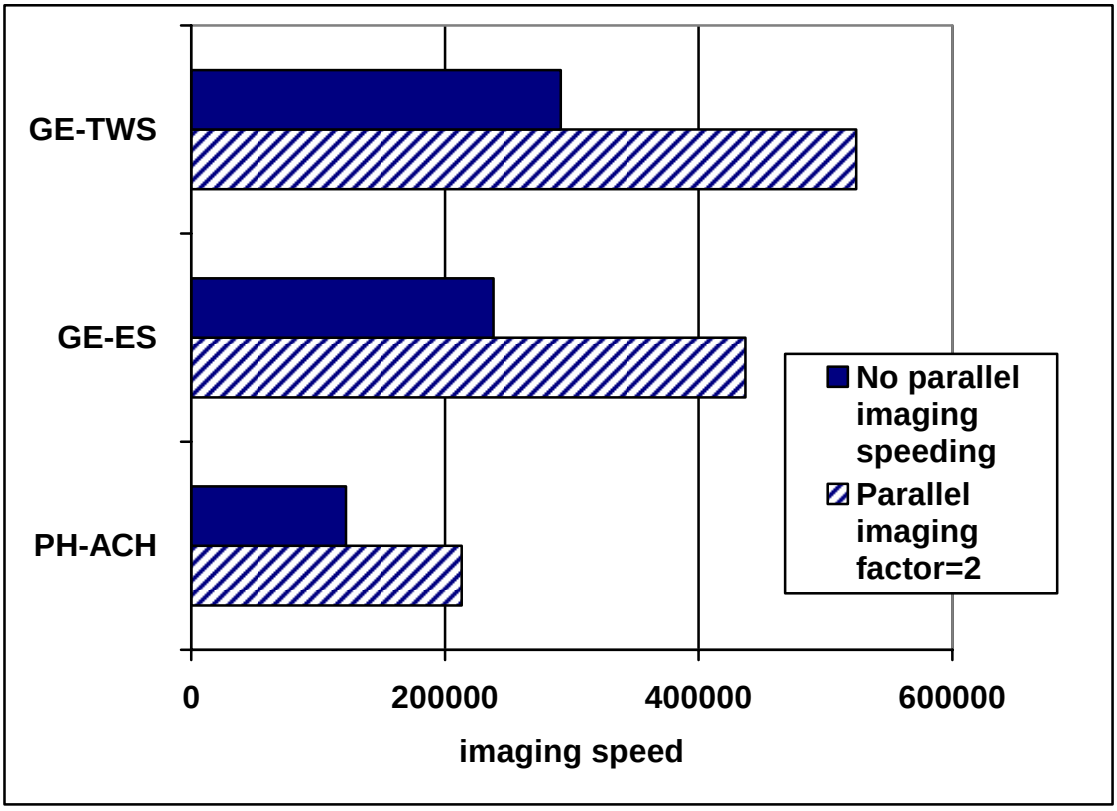
Therefore the imaging speed results, where applicable, are presented in separate graphs.

The numerical results of the 2D and 3D imaging speed tests are presented in the Appendix. The following graphs show the results for no parallel imaging speeding (parallel imaging off or parallel imaging factor=1) and for parallel imaging factor =2.

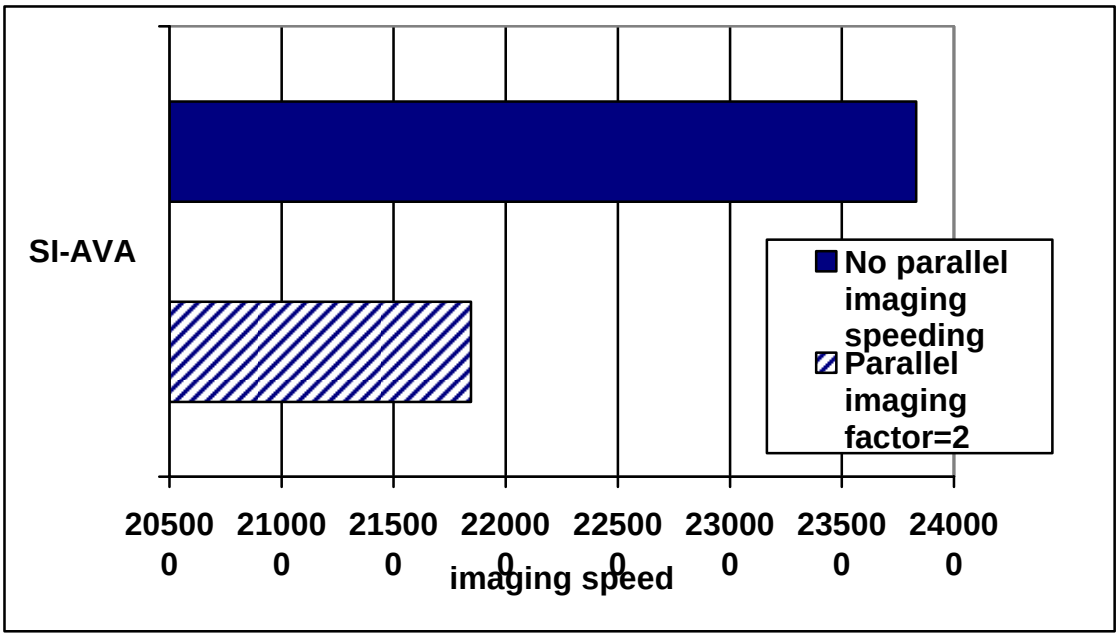
Graph 16. Comparison of 2D imaging speed with GRE-type sequences



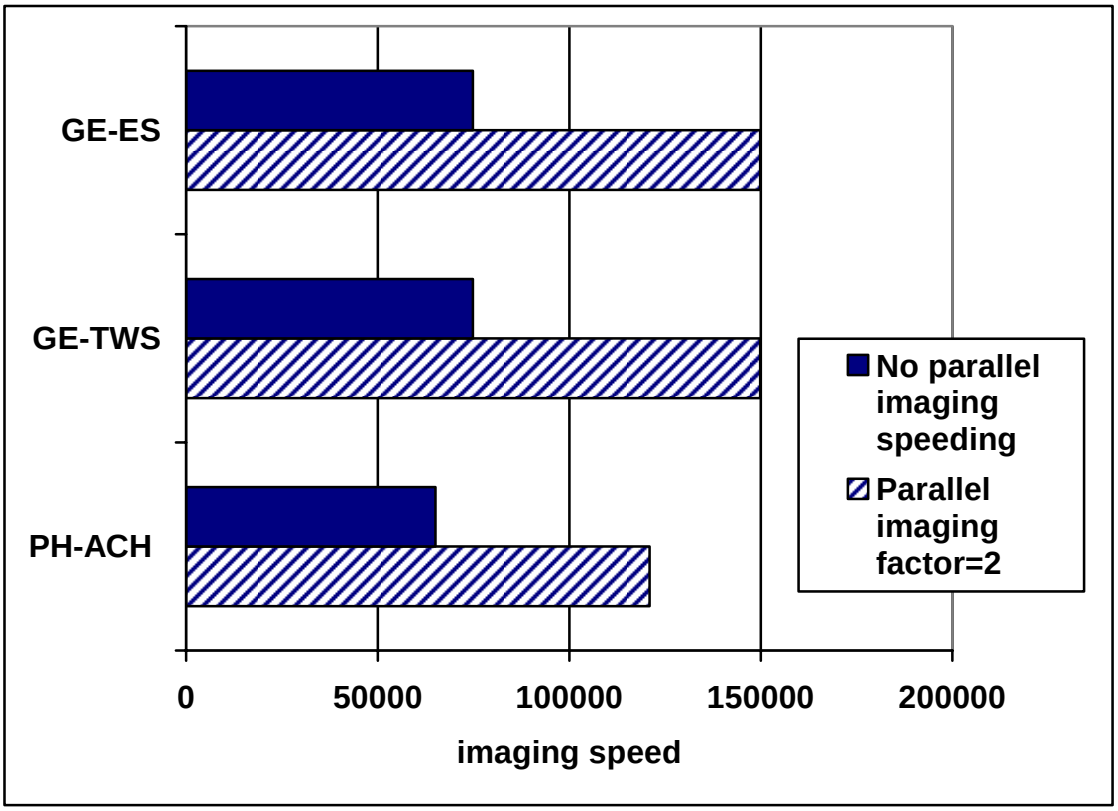
Graph 17. Comparison of 2D imaging speed with EPI-type sequences (pre-scan separate from main scan)



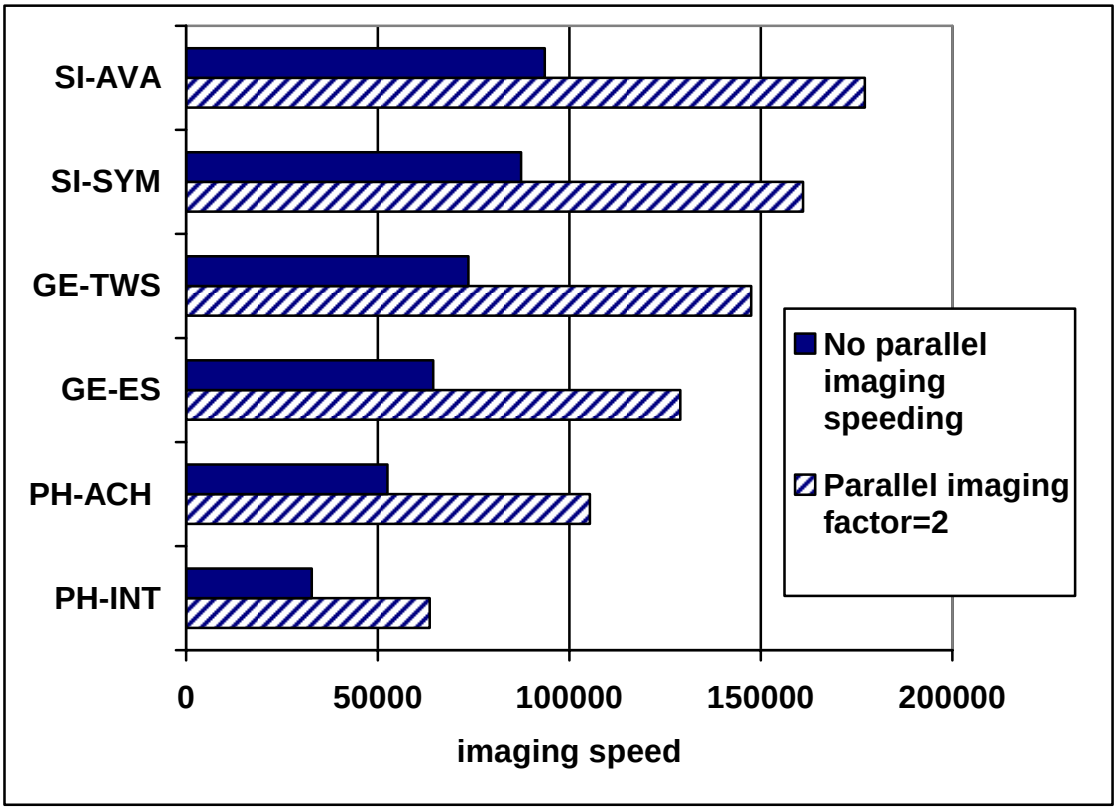
Graph 18. Comparison of 2D imaging speed with EPI-type sequences (pre-scan included in main scan)



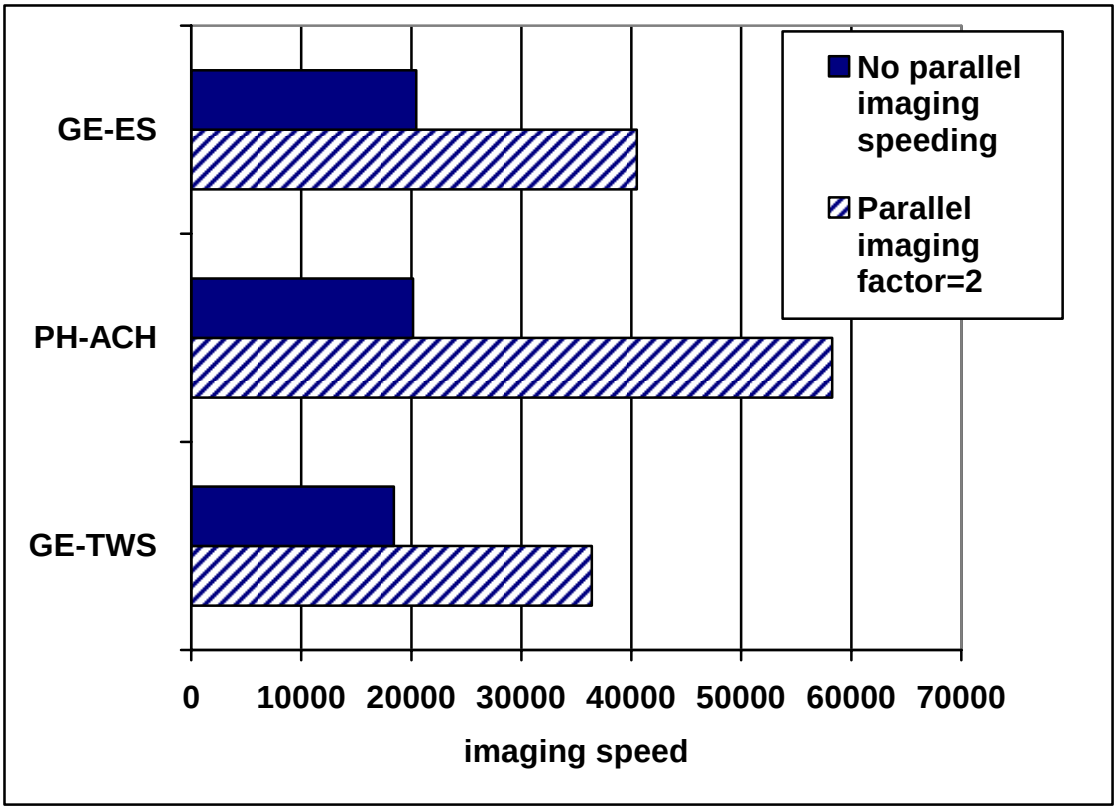
Graph 19. Comparison of 2D imaging speed with FSE-type sequences



Graph 20. Comparison of 3D imaging speed with GRE-type sequences



Graph 21. Comparison of 3D imaging speed 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 62 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 63. 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 62. Clinical pulse sequences for comparative acoustic noise

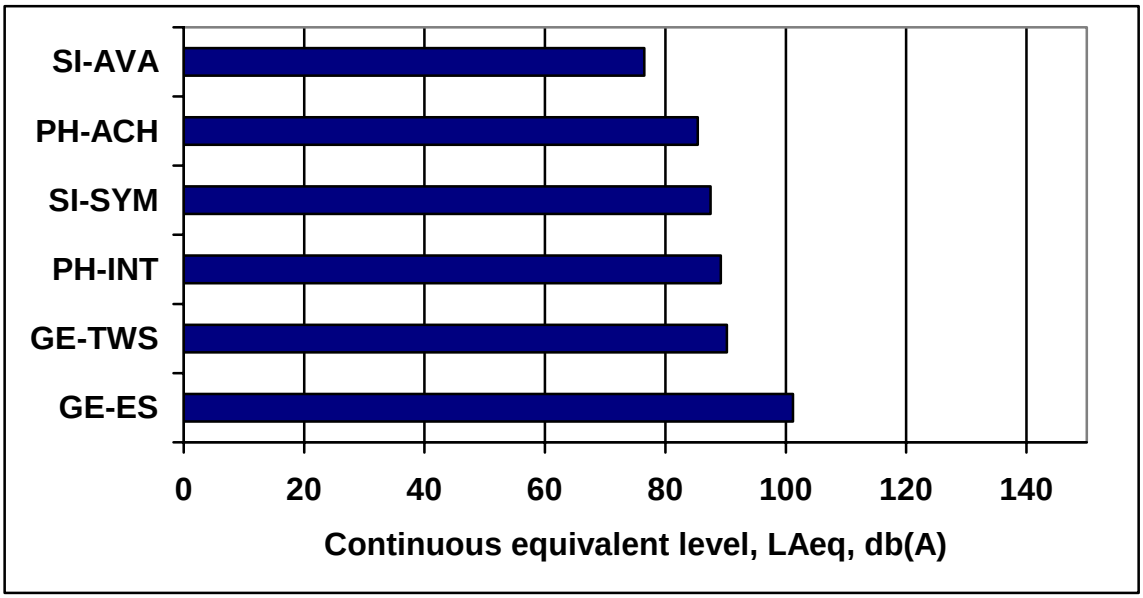
Pulse Sequence	TE	TR	Matrix	NSA	FOV	Flip angle	SW	Slices
SE	15	450	256×256	1	320	1	4	10
FSE (ETL = 4)	15	4000	256×256	1	320	1	4	10
GE (3D)	9	23	160×256	1	170	1	1	10
Single shot EPI	24	2000	128×128	32	230	1	5	10

Table 63. 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-ES*	99.3	111.6	97.2	114.4	101.2	116.9	110.6	120.7
GE-TWS†	89.6	102.8	75.3	104.2	90.2	104.3	102.8	113.6
PH-INT##	77.00	77.7	98.9	101.2	89.2	89.7	94.7	105.7
PH-ACH‡	80.1	96.5	78.4	95.6	85.4	95.1	98.5	111.8
SI-SYM#	87.4	89.9	86.9	87.6	87.5	89.5	89.5	97.8
SI-AVA**	63.7	90.5	71.7	93.1	76.5	99.0	83.4	98.6

*For 3DGE sequence: TE=2.1ms; For single shot EPI sequence: NSA=30
†For 3DGE: TE=2.6ms; For single shot EPI sequence: NSA=30.
##For FSE Turbo factor=64; For EPI, Matrix: 64×64
‡For 3DGE: NSA=2; For Single shot EPI: NSA=32, Matrix: 64×64
#For FSE: TE=12, ETL=3; For 3DGE: No. dlices=16
**For FSE: TE=12ms, ETL=4

Graph 22. Acoustic noise levels for 3DGE sequences



List of safety information

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
Gradient system: Please note that GE specifies gradient strength and gradient slew rate for each individual axis. **Speed parameters** (Table 9): 2D Gradient Echo sequence used allows EPI readout and hence has a higher mimimum TR/TE compared to another manufacturer. Note also that key technical data (e.g.: mimimum TR/TE for various sequences, gradient strength and slew rate, image reconstruction speed) are based on manufacturer information and are not cross-checked by MagNET: one manufacturer did not give his sequence performances for 256 matrix as requested **Sequence information**: In parallel to dedicated High coil element Density (HD) solutions which has proven their outcome, signature applications (like Propeller, etc…) are dedicated sequences specifically optimized for organs. It constitutes today a major improvement of MR in terms of robustness: capacity to reproduce consistent image quality across patients.
Philips
Main computer system- image processor: Philips high linearity does not require additional reconstruction time that is not taken into account with competitive systems. Competitive systems have reconstruction times that are many factors lower when linearity correction is switched on. **Gradient system:** Philips wants to stress that highest amplitude and slew-rate are reach without compromising linearity or field of view. Philips gradients feature a FoV of 53 cm with a linearity of 1.4% for all gradient types and modes (even the dual mode Nova). **Head coil uniformity:** The Philips Head coil uses an RF mirror. This results in a faster signal drop-off in the neck but a better signal in the brain. **Parallel imaging:** Philips uses true scan acceleration factors. E.g. A SENSE factor of 2 truly is twice as fast (Philips does not require reference data within the scan allowing highest possible speeds)

Siemens

SNR evaluations: The normalized SNR is strongly dependent on the measured Q factors obtained from volunteers which are used within normalization procedure. For example the Q body for the in-built body resonator is highly dependent on the weight, physical condition and position of the volunteer within the resonator. All uncertainties concerning reproducibility from system to system of these parameters will result in systematic errors of the obtained normalized SNR values. The reader should be aware of this when comparing normalized SNR values from different systems which can be acquired under non comparable loading conditions.
Additionally, Siemens does not recommend using the in-built body resonator for receive. Tim technology offers a comprehensive set of Matrix coils to cover the whole body. This results in best possible SNR for all clinical applications, including whole body imaging.
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).
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 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)

Toshiba

The manufacturer had no additional comments

2D imaging speed: sequence parameters

Table 64. 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 65. Scan parameters for 2D imaging speed evaluation on the GE MRI system (Echospeed gradients)

Sequence parameter	Sequence parameter values							
Imaging coil	8-channel high resolution brain coil							
2D sequence	2DFGRE			GRE-EPI		FSE-XL		
TE (ms)	1.9			133.7	67.9	3.3		
TR (ms)	3.9			11000	5600	20895		
Flip angle (degrees)	60			90		Not measured		
NSA	1			1		1		
Bandwidth	166.67			250		83.33		
Echo Train Length	Not applicable			Not applicable				
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	1.5	2.0
Range (mm)	200			200		201.6		
Contiguous slices	40			40		48		
Scan time (min:sec)	0:42	0:29	0:22	0:11	0:06	0:42	0:31	0:21

Table 66. Scan parameters for 2D imaging speed evaluation on the GE MRI system (Twinspeed gradients)

Sequence parameter	Sequence parameter values						
Imaging coil	8-channel high resolution brain coil						
2D sequence	2DFGRE			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 measured	
NSA	1			1		1	
Bandwidth	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		5	
Parallel imaging factors	off	1.5	2.0	off	2.0	off	2.0
Range (mm)	200			200		201.6	
Contiguous slices	40			40		4.2	
Scan time (min:sec)	0:48	0:26	0:20	0:09	0:05	0:42	0:21

Table 67. Scan parameters for 2D imaging speed evaluation on the Philips Intera MRI system (Explorer gradients)

Sequence parameter	Sequence parameter values			
Imaging coil	SENSE Head Coil			
2D sequence	FFE			
TE (ms)	2.0			
TR (ms)	177			
Flip angle (degrees)	30			
NSA	1			
Bandwidth	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	6
Range (mm)	200			
Contiguous slices	50			
Scan time (min:sec)	0:45	0:23	0:12	0:07

Table 68. Scan parameters for 2D imaging speed evaluation on the Philips Achieva MRI system (Nova Dual gradients)

Sequence parameter	Sequence parameter values										
Imaging coil	8-channel SENSE head coil										
2D sequence	2D-FFE				FE-EPI				2D-TSE		
TE (ms)	1.95				13				3.92		
TR (ms)	144				1025				6500		
Flip angle (degrees)	10				10				30		
NSA	1				1				1		
Bandwidth	Not measured				Not measured				Not measured		
Echo Train Length	Not applicable				Not applicable				33		
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)	0:37	0:19	0:10	0:05	0:21	0:12	0:08	0:06	1:44	0:52	0:13

Table 69. Scan parameters for 2D imaging speed evaluation on the Siemens MAGNETOM Symphony Maestro Class MRI system

Sequence parameter	Sequence parameter values		
Imaging coil	PAT head		
2D sequence	EPI 2D		
TE (ms)	188	97	52
TR (ms)	14720	11190	5760
Flip angle (degrees)	90		
NSA	1		
Bandwidth	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)	Not measured	Not measured	Not measured

Table 70. Scan parameters for 2D imaging speed evaluation on the Siemens MAGNETOM Avanto MRI system

Sequence parameter	Sequence parameter values			
Imaging coil	Head matrix coil			
2D sequence	2D EPI			
TE (ms)	141	141	141	141
TR (ms)	11060	5760	4020	2100
Flip angle (degrees)	90			
NSA	1			
Bandwidth	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	3	4
Range (mm)	200			
Contiguous slices	40			
Scan time (min:sec)	0:11	0:12	0:20	0:19

3D imaging speed: sequence parameters

Table 71. 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		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 72. Scan parameters for 3D imaging speed evaluation on the GE MRI system (Echospeed gradients)

Sequence parameter	Sequence parameter values				
Imaging coil	8-channel high resolution brain coil				
3D sequence	FSPGR			FRFSE-XL	
TE (ms)	1.1			22.1	
TR (ms)	2.0			200	
Flip angle (degrees)	10			Not measured	
NSA	1			1	
Bandwidth	100			100	
Echo Train Length	Not applicable			32	
FOV (mm)	250 x 250 x 201.6			250 x 250 x 201.6	
Matrix (PE x FE)	128 x 128			128 x 128	
Slice width (mm)	1.6			1.6	
Parallel imaging factors	off	1.5	2.0	off	2
Range (mm)	201.6			201.6	
Contiguous slices	126			126	
Scan time (min:sec)	0:32	0:22	0:16	1:41	0:51

Table 73. Scan parameters for 3D imaging speed evaluation on the GE MRI system (Twinspeed gradients)

Sequence parameter	Sequence parameter values				
Imaging coil	8-channel high resolution brain coil				
3D sequence	FSPGR			FRFSE-XL	
TE (ms)	0.9			35	
TR (ms)	1.7			220	
Flip angle (degrees)	10			Not measured	
NSA	1			1	
Bandwidth	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			2.0	
Parallel imaging factors	off	1.5	2.0	off	2
Range (mm)	201.6			200	
Contiguous slices	126			100	
Scan time (min:sec)	0:28	0:19	0:14	1:29	0:45

Table 74. Scan parameters for 3D imaging speed evaluation on the Philips Intera MRI system (Explorer gradients)

Sequence parameter	Sequence parameter values			
Imaging coil	SENSE Head coil			
2D sequence	3D FFE			
TE (ms)	1.35			
TR (ms)	3.1			
Flip angle (degrees)	30			
NSA	1			
Bandwidth	Not measured			
Echo Train Length	Not applicable			
FOV (mm)	250 x 250 x 199.68			
Matrix (PE x FE)	128 x 128			
Slice width (mm)	1.56			
Parallel imaging factors	off	2	4	6
Range (mm)	199.68			
Contiguous slices	128			
Scan time (min:sec)	1:04	0:33	0:17	0:11

Table 75. Scan parameters for 3D imaging speed evaluation on the Philips Achieva system (Nova Dual gradients)

Sequence parameter	Sequence parameter values							
Imaging coil	8-channel SENSE head coil							
3D sequence	3D-FFE				3D-TSE			
TE (ms)	1.16				5.1			
TR (ms)	2.4				268			
Flip angle (degrees)	10				30			
NSA	1				1			
Bandwidth	Not measured				Not measured			
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	off	2	4	8	off	2	4	8
Range (mm)	199.68				199.68			
Contiguous slices	128				128			
Scan time (min:sec)	0:39	0:19	0:10	0:05	1:44	0:36	0:18	0:10

Table 76. Scan parameters for 3D imaging speed evaluation on the Siemens MAGNETOM Symphony system

Sequence parameter	Sequence parameter values		
Imaging coil	PAT head		
2D sequence	3D-Flash		
TE (ms)	0.96		
TR (ms)	2.13		
Flip angle (degrees)	25		
NSA	1		
Bandwidth	Not measured		
Echo Train Length	Not applicable		
FOV (mm)	250 x 250 x 192		
Matrix (PE x FE)	128 x 128		
Slice width (mm)	2.00		
Parallel imaging factors	off	2	4
Range (mm)	192		
Contiguous slices	96		
Scan time (min:sec)	0:21	0:12	0:08

Table 77. Scan parameters for 2D imaging speed evaluation on the Siemens MAGNETOM Avanto system

Sequence parameter	Sequence parameter values			
Imaging coil	Head matrix			
2D sequence	3D Flash			
TE (ms)	0.67			
TR (ms)	1.7			
Flip angle (degrees)	5			
NSA	1			
Bandwidth	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	3	4
Range (mm)	200			
Contiguous slices	40			
Scan time (min:sec)	0:07	0:03	0:02	0:02

2D and 3D imaging speed results

Table 78. 2D imaging speed results (voxels/sec) for GRE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-ES	62415	Not applicable	119156	Not applicable	Not applicable	Not applicable
GE-TWS	68985	Not applicable	131072	Not applicable	Not applicable	Not applicable
PH-INT	72817	Not measured	142469	273066	468114	Not applicable
PH-ACH	Not measured	70091	135125	259548	Not measured	494611
SI-SYM	Not measured	Not applicable	Not measured	Not measured	Not measured	Not measured
SI-AVA	Not measured	Not applicable	Not measured	Not measured	Not measured	Not measured

Table 79. 2D imaging speed results (voxels/sec) for EPI-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-ES	238312	Not applicable	436906	Not applicable	Not applicable	Not applicable
GE-TWS	291271	Not applicable	524288	Not applicable	Not applicable	Not applicable
PH-ACH	Not measured	121927	213125	319687	Not measured	429744
SI-SYM	Not measured	Not applicable	Not measured	Not measured	Not measured	Not measured
SI-AVA	238313	Not applicable	218453	137971	Not measured	Not measured

Table 80. 2D imaging speed results (voxels/sec) for FSE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-ES	74898	Not applicable	149796	Not applicable	Not applicable	Not applicable
GE-TWS	74898	Not applicable	149796	Not applicable	Not applicable	Not applicable
PH-ACH	65048	60494	120989	Not measured	Not measured	483958
SI-SYM	Not measured	Not applicable	Not measured	Not measured	Not measured	Not measured
SI-AVA	Not measured	Not applicable	Not measured	Not measured	Not measured	Not measured

Table 81. 3D imaging speed results (voxels/sec) for FSE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-ES	20439	Not applicable	40478	Not applicable	Not applicable	Not applicable
GE-TWS	18408	Not applicable	36408	Not applicable	Not applicable	Not applicable
PH-ACH	20164	Not measured	58254	111550	Not measured	616809
SI-SYM	Not applicable	Not measured	Not measured	Not measured	Not measured	Not measured
SI-AVA	Not applicable	Not measured	Not measured	Not measured	Not measured	Not measured

Table 82. 3D imaging speed results (voxels/sec) for GRE-type sequences

System	Parallel imaging factor					
	off	1	2	4	6	8
GE-ES	64512	Not applicable	129024	Not applicable	Not applicable	Not applicable
GE-TWS	73728	Not applicable	147456	Not applicable	Not applicable	Not applicable
PH-INT	32768	Not measured	63550	123361	190650	Not applicable
PH-ACH	52560	Not measured	105384	201649	Not measured	403298
SI-SYM	87400	Not applicable	161000	238000	Not measured	Not measured
SI-AVA	93623	Not applicable	177124	273076	Not measured	Not measured