Siemens MAGNETOM Avanto 1.5T

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Janet De Wilde
Queen Mary, University of London
37 PUBLICATIONS **763** CITATIONS

Ioannis Delakis
UNSW Sydney
62 PUBLICATIONS **178** CITATIONS

Caroline Renaud
Imperial College Healthcare NHS Trust
32 PUBLICATIONS **47** CITATIONS

Medicines and Healthcare products Regulatory Agency

March 2005

EVALUATION

MHRA 04133

Siemens MAGNETOM Avanto 1.5 T

Department of Health

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Siemens MAGNETOM Avanto 1.5 T

MR imaging system

Janet De Wilde, David Price,
James Williams, Ioannis Delakis, Caroline Renaud

MagNET
Bagrit Centre
Department of Bioengineering
Imperial College London
Exhibition Road
London SW7 2AZ

Telephone: 020 7594 6305
Facsimile: 020 7954 6337
E-mail: enquiry@magnet-mri.org
Website: www.magnet-mri.org

Director
Richard I. Kitney OBE

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Summary

In May 2003 the United Kingdom (UK) Government announced a £90 million fund to replace all magnetic resonance imaging (MRI) and computed tomography (CT) scanners installed in National Health Service (NHS) establishments before 1997 as part of the UK National Health Service Cancer Plan. MagNET has produced evaluation reports to aid the selection of MRI equipment as apart of this program. Most NHS hospitals within this program are selecting 1.5 tesla (T) MRI systems. This report provides a detailed evaluation of Siemens MAGNETOM Avanto 1.5 T whole-body MRI, a new system offered by Siemens Medical Solutions, Erlangen, Germany, from 2004.

The MAGNETOM Avanto MRI system incorporates a new magnet, which the manufacturer claims provides improved homogeneity, new gradients with acoustic noise reduction, a new radio-frequency (RF) system with multi-channel options and a new RF coil concept. The MagNET team performed a technical assessment of the system at the manufacturer's headquarters in Erlangen, Germany. This report contains the results of that evaluation along with detailed specifications of the system.

Measured parameters with outstanding performance levels for a 1.5 T system were:

- Head Matrix coil uniformity (CP, Dual and Triple mode)
- Body Matrix coil uniformity (CP and Dual mode)
- CP head coil uniformity
- CP head coil geometric distortion
- CP head coil ghosting
- Head Matrix Coil 3D imaging speed

Measured parameters with performance levels as expected for a 1.5 T system were:

- Head Matrix coil SNR (CP, Dual and Triple mode)
- Body Matrix coil SNR (CP mode)
- CP head coil spatial resolution
- CP head coil geometric linearity
- CP head coil slice width
- CP head coil slice position
- In-built body coil uniformity

Measured parameters with performance levels below average for a 1.5 T systems were:

- CP head coil signal-to-noise ratio
- In-built body coil signal-to-noise ratio

Introduction

This report format combines system specification, user information, safety and technical evaluation results to provide a comprehensive overview of a particular MR system. This report replaces the user and technical evaluation reports that were previously published separately. 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 user information incorporates an assessment of system features and their operation, and system specification. This information is collected from manufacturer’s documentation and MagNET’s observations during the technical assessment.

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

MagNET comment

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 summary section of this report comprises a summary of system features and technical evaluations. This section also includes comparisons of the technical test results with the average values of systems with similar magnetic field strengths evaluated by MagNET, as well as overall comments on the performance of this system.

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

Additional information is obtainable at the MagNET website: www.magnet-mri.org.

The MHRA

The Medicines and Healthcare products Regulatory Agency (MHRA), an executive agency of the Department of Health, was created on 1 April 2003 from the merger of the Medical Devices Agency and the Medicines Control Agency. Further details are available in the Appendix of this report and on the agency's website: www.mhra.gov.uk.

Description

The Siemens MAGNETOM Avanto is a 1.5 T whole-body scanner. It is 1.60 m long (including covers) and has a total mass of 5.5 metric tonnes (operational). The minimum standard installed area is 30 m^2.

The radial 0.5 mT fringe field (xy) is 2.5 m from the isocentre whilst the axial fringe field (z) is at 4 m from the isocentre. The patient aperture at its narrowest measures 88 cm x 60 cm (width x height). The couch height can be varied from 47 to 89 cm. The body mass limit is 200 kg.

The Q-Engine gradient system features a maximum amplitude of 33 mT/m and a slew rate of 125 mT/m/ms. The SQ-Engine gradient system features a maximum amplitude of 40 mT/m in the x- and y-gradient directions (45 mT/m in the z-gradient direction) and a slew rate of 200 mT/m/ms.

The host computer system now features two Pentium IV computers running Microsoft® Windows® XP Professional with a CPU speed of 3.06 GHz and 2 GB main memory. The hard disk comprises 36 GB for software and 73 GB for image storage accommodating 110,000 512^2 images. The dual AMD Opteron image processors have a processing speed of 2.2 GHz, leading to a reconstruction speed of 1002 256^2 images per second (full FOV).

The Tim (Total Imaging Matrix) RF system features 8, 18 or 32 independent RF receiver channels (Tim [32x8], Tim [76x18] or Tim [76x32], respectively), each with a 1 MHz bandwidth. Each channel has an analogue-to-digital convertor with sampling frequency 10 MHz. The RF system supports the iPAT (integrated Parallel Acquisition Techniques) parallel imaging. GRAPPA and mSENSE parallel imaging techniques are supported.

The standard RF coils consist of the multiple-channel Head Matrix, Neck Matrix, Spine Matrix, CP Integrated Body and the CP Flex Coils (Large and Small). Optional coils include the CP Head Array, CP Head Tx/Rx, CP Extremity, Bilateral TMJ, Bilateral Breast, Breast Biopsy Device, Endorectal, Shoulder Array and the Flex Ring coils (Standard and Small). A range of multiple-channel coils are also available as options, including Body Matrix Coil(s), PA Matrix Coil and 8-Channel Knee coil.

The Tim Application Suite including the sub-suites Neuro Suite, Ortho Suite, Angio Suite, Cardio Suite, Body Suite, Onco Suite and Pediatric Suite provides, amongst others, imaging sequences for whole body imaging, iPAT applications, diffusion, perfusion and BOLD imaging as standard. This includes SE, IR, 2D/3D GRE (FLAS, FISP), CE MRA, TrueFISP, TSE, HASTE and EPI.

System specification

Specification data are those from the MHRA reports indicated and were correct at the time of going to press (subsequent updates or newer versions from the manufacturers are not accounted for).

Conformity with standards and EC directives

Table 1. Quality assurance of manufacturing sites.

Standard	Accreditation
ISO 9000 accreditation	Compliance with No Q1Z 04 04 52074 001
ISO EN BS 4600 accreditation	Compliance, see above

Table 2. Equipment conformity with international standards

Standard	Accreditation
IEC-60601-1 conformity (no. & date)	Compliance, see above
CE marked under MDD directive	Compliance, see above

Table 3. System specification summary

Manufacturer and model	Gradient system	Field strength (T)	MHRA report no.
Siemens MAGNETOM Avanto 1.5 T	Q-Engine/ SQ-Engine	1.5	MHRA 04133

Magnet and gradient system

Table 4: Magnet specification

Parameter	Siemens
RF frequency MHz	63.6
Shielding	Passive and active
Homogeneity (VRMS) 40 cm DSV ppm	0.2 (typically)
Field stability ppm/hr	< 0.1
Number of measurement planes	24
Number of measurement points	20
Cooling system	Liquid helium only
Boil-off rate l/hr	0
Helium refill	10 years maximum (approximately)

Table 5: Shimming details

Parameter	Siemens
Passive on installation	Yes
Number of shim plates	16 x 15 (azimuthal x axial)
Active with patient in position	Yes
Number of independent channels	Standard: 3 linear terms via gradient offsets with 20 coils Optional: 5 additional non-linear 2nd order terms with 32 coils

Table 6: Patient comfort details

Parameter		Siemens
Patient aperture at narrowest:	Width cm	60
	Length cm	88
	Height (couch to upper bore) cm	45.5
Patient aperture at maximum:	Width cm	Information not supplied by the manufacturer
	Height cm	Information not supplied by the manufacturer
	Length with covers cm	160
Patient couch:	Min. height cm	47
	Max. height cm	89
	Table top width cm	54
Body mass limit (full movement) kg		200

Table 7: Installation details

Overall scanner dimensions	Siemens
Mass: magnet only tonnes	3.55 ± 8(including helium)
Mass: assembly tonnes	5.5
Depth with covers (z) cm	160
Width with covers (x) cm	230
Height with covers (y) cm	230
Radial (x, y) 0.5 mT fringe field m	2.5
Axial (z) 0.5 mT fringe field m	4.0
Minimum installed area m^2*	<30
Minimum ceiling height cm *	250

*To include 0.5 mT fringe field

Table 8: Electronics cabinets

Cabinets	Siemens
Number	2
Total width cm	156
Maximum depth cm	65
Maximum height cm	197
Cooling system	Water

Table 9: RF system specification

Parameter	Siemens		
Name/type/version of the system	Tim [32x8]	Tim [76x18]	Tim [76x32]
Number of independent RF receiver channels	8	18	32
Bandwidth of each independent RF receiver channel (MHz)	1	1	1
Number of analog-to-digital converters for each independent RF channel	1	1	1
Sampling frequency of each analog-to-digital converter (MHz)	10	10	10

Table 10: Gradient system specification

Parameter	Siemens	
Gradient system	Q-Engine	SQ-Engine
Shielding	Active	Active
Single axis maximum amplitude (x, y, z) mT/m	33, 33, 33	40, 40, 45
Single axis maximum slew rate (x, y, z) mT/m/ms	125, 125, 125	200, 200, 200
Duty cycle at max amplitude %	100	100
Amplitude @100% duty cycle mT/m	33	40, 40, 45

Computer system

Table 11: Main computer system - architecture

Parameter	Siemens
Type	2 x Pentium IV Intel Xeon
Operating system	Microsoft® Windows® XP Professional, *syngo* speaking
CPU MHz	2 x 3.06
Word length bit	32
Memory size GB	2
Hard disk:	
Software GB	36 (+ 36 database)
Hard disk:	
Images GB	73
Image capacity 512^2 images (uncompressed)	110,000
Archive Drive	CDR, MOD (read only access)
Size MB	640, 1700
Image capacity 256^2 images (uncompressed)	4,300, 110,000

Table 12: Main computer system – image processor

Parameter	Siemens
Manufacturer and type	2 x AMD Opteron
Processing speed GHz	2 x ≥ 2.2 GHz
Word length bit	32
Memory size bulk array GB	> 8*
Number of 256^2 image reconstructed per sec (True 256 x 256 matrix, no interpolation, no rectangular matrix, no rectangular FOV)	1002
Transfer rate from host MB/s	No transfer time common bus

* Siemens offers four additional 36 GB hard disks for largest multiple data sets

Table 13: Image display monitor

Parameter	Siemens
Screen size inches	18
Type (BW / colour)	LCD colour
Matrix size	1280×1024
Bit depth bit	16

Table 14: Networking

Parameter		Siemens
Interface standard support		
	for HIS	DICOM3 conformance standard
	for PACS	DICOM3 conformance standard
	for workstation	DICOM (Send/receive/query)
Physical interface standard		Ethernet
All system peripherals networked?		Yes
Video interface availability		Yes

Table 15: Independent console

Parameter	Siemens	
Manufacturer and type	MRSC	Leonardo
Operating system	Microsoft® Windows® XP Professional	Microsoft® Windows® XP Professional
Software	*syngo*	*syngo*
CPU speed GHz	≥ 3.06	≥ 3.06
Word length bit	32	32
Memory size GB	2	2
Hard disk GB	36 (system) 73 (data)	73
Image capacity (512^2 images-uncompressed)	110,000	110,000
Archive GB	0.64 (CD-R)	0.64 (CD-R) 2.3/4.1 (MoD, DICOM format) 5.2 (MOD, non-DICOM format)

Table 16: Resolution parameters

Parameter	Siemens
Minimum FOV mm	5
Maximum imaging matrix	1024x1024
Minimum 2D slice thickness mm	0.1
Minimum 3D slice thickness mm	0.05

Table 17: Speed parameters

Parameter	Sequence	Siemens	
Gradient system		Q-Engine	SQ-Engine
Minimum TR ms	Spin Echo*	7.4	6.8
Minimum TR ms	2D gradient echo*	1.5	1.5
Minimum TR ms	3D gradient echo*	1.8	1.5
Minimum echo spacing ms	Turbo spin echo*	2.8	2.6
Minimum echo spacing ms	Echo planar imaging†	0.48	0.41
Minimum TE ms	Single-shot diffusion imaging with b-value of 1000 mm^2/s†	58	53

*For 256x256 matrix with no interpolation
† For 128x128 matrix with no interpolation

User information

Patient handling

Table 18: Patient comfort

Feature	User information
Magnet design	Ultra-short, wide bore
View of patient from console	Direct view down bore
Patient accessibility during scanning / positioning	Accessibility from two sides / three sides
Bore lighting	Bore illumination from rear, adjustable
Bore ventilation	Adjustable control
Patient intercom	Bi-directional intercom
Music system	Music system provides music through headphones
Panic button	Nurse call pinch ball Audio alarm with steady audio signal
Closed circuit TV	Optional

Table 19: Gantry control panel

Feature	User information
Position of control panel	On both sides of gantry
Controls	Light visor, centre position, home position Start/stop scan ECG Ventilation Bore lighting Stop table Buttons controlling up/down and in/out movement Two music volume knobs controlling volume through loudspeaker and volume through headphone (on one panel only)
Position indicator	Centred above entrance to bore on LCD display panel (also indicates bore light and ventilation levels, light localiser, current table movement, text)
Landmarking lights	Laser positioning with transverse and sagittal lights
Alignment at isocentre	Head coil fixed position: no landmarking using laser light required: Pressing ‘centre position’ button automatically moves centre of coil to isocentre (default position). Head coil with laser light: Use joystick, laser light and ‘centre position’ functions
To recall landmark	Press ‘centre position’ button to return table to isocentre. With buttons: landmark position recalled only if table is not pulled out entirely

Table 20: Cable connectors

Feature	User information
RF coil connectors	10 connectors on table top (6 on head end and 4 on foot end)
Gating connectors	PMU (physiological measuring unit) system is integrated into the system. Wireless sensors for ECG/VCG, peripheral pulse, respiratory belt with no need for ports. External triggering input and output ports integrated into the system. Also: connectors for headphones, vacuum bag, patient squeeze bulb connectors at the end of the table top.
Patient alarm connectors	Positioned at end of table

Table 21: Patient couch specification

Feature	User information
Couch type	Removable table top with trolley supplied as standard. Second table top and trolley supplied as an optional item.
Table top width	54 cm
Body mass limit	200 kg
Horizontal movement	In/out velocity is dependent on “speed button” and status of the laser light Max. horizontal motion range: 263.5 cm. Maximum speed: 20 cm/s
Vertical movement and height range	Up/down, automatically switches to vertical movement after slight pause Vertical motion range: 47 - 89 cm. Maximum speed: 10 cm/s
Table top release	Stop button on control panel and intercom releases table brake to allow manual operation

Table 22: Patient transfer facility

Function	Type*	Description
Removable tabletop and trolley	S	Removable table-top with trolley
Wheelchair	O	Optional items
Patient step	-	Not available

*Type code: S = standard, O = optional

Table 23: Accessories

Function	Type*	Accessory
Immobilisation, support and positioning devices	S	Velcro straps which snap into side of table Sandbags, wedges Foam inserts including head support Vacuum bags (3 sizes) Optical mirror
Coil storage cupboard	S	Trolley cupboard. Stores most commonly used accessories.

*Type code: S = standard, O = optional

Operator console

Table 24: Operator console – configuration

Key components	User information
Console	PC based
Keyboard	Alphanumerical data entry and symbol keypad for frequently used functions
Mouse	Three button mouse
Software	*syngo* MR 2004V

Table 25: Operator console – features

Console features	User information
General features	Menu-driven software architecture with status bar, task cards, image space and workspace. Multi-tasking capabilities
System status information	Remaining scan-time, active patient name and date-of-birth, scan control, SAR level, level of stimulation monitor, scan queue, protocol selection taskcard
Patient details	Pull-down menu or hotkey on symbol keypad for patient registration. DICOM worklist supported
Scan parameters	Program parameter card in Exam task card. All parameters variable
Using set protocols	Siemens tree of Exam Explorer
Changing set protocols	Exam Explorer offers Siemens protocols (cannot be changed) and User protocols (can be changed). Entire sets can be saved in separate User tree.
Conflicts alert	Yes. Conflicts are highlighted and suggestions can be accepted or rejected
Scout/Localisation	Flexible, e.g. 3 orthogonal views from scout survey scan
Positioning slices	Graphical slice positioning with any orientation using mouse and 16-button Position Toolbar
Batch image sequencing	Yes
Advance planning	Yes. Plan in Patient Browser in Scheduler as a pre-registration or automatically from RIS
Pause scan	No, stop scan only
Coil tuning	Coils are no-tune coils
Raw data availability	Raw data can be saved
Image archiving	Automatic to selected hostname or burn onto CD-ROM; possibility to store DICOM Viewer together with the images on CD.
Image retrieval	Select images to retrieve in Patient Browser to retrieve either from CDs or previously archived MODs (read-only MOD drive is optional) or from local database. DICOM Query/Retrieve from remote network node.
Image hard-copy	In Filming tab
Programming language	C, Ansi-C++
Software packages	Standard: Tim Application Suite including Neuro Suite, Ortho Suite, Angio Suite, Body Suite, Cardio Suite, Onco Suite, Pediatric Suite. Optional packages for advanced applications and evaluation packages, e.g. Tim Whole Body Suite for whole-body applications, AutoAlign for automatic slice planning in the brain, Advanced Cardiac Package for advanced cardio application, Spine Composing for combining images from different table positions, or IDEA, the sequence development platform.

Table 26: Operator console – multi-tasking

Image tasks	Run at same time as data acquisition?
Image reconstruction	Yes
Image display	Yes
Image archiving*	Yes
Image retrieval	Yes
Image hardcopying	Yes
Other tasks (specify)	All post-processing on operator console (e.g. image analysis, MRS evaluation)

* Siemens comment: Archive refers to usual long-term device, e.g. PACS. CD ROM is supported as storage media.

Table 27: Image display

Image presentation	User information
General features	Multiple windows
Screen configurations	1 large, 2 x 1, 2 x 2, 3 x 3, 4 x 4, 8 x 8
Image paging/scrolling	Drag scroll bar, use +/- on symbol keypad, click and flick through 'dog ears' document icon on layered images
Simultaneous studies	3 different viewing folders with up to 4 different studies each in viewing screen.
Cine display	Yes
Store window level/width	Select individual series, images, or image sets to window. Two different window levels can be stored
Change default values	Yes. Use middle mouse button to window. Vertical movement for level (brightness) and horizontal movement for width (contrast). Autowindowing also possible by double-clicking middle mouse button or using icon
Scope of windowing	Numeric input possible Window: 0 – 4094 Level: 0 – 4095
Grey level inversion	Yes
Image zoom and pan	Select Zoom and Pan on then zoom and pan using left mouse button: cursor at periphery of image to zoom, and at the centre of the image to pan for single images or whole datasets. Image magnification can be numerically entered using icon
Image rotation and flip	Image rotation in fixed 90° steps. Mirror image about the vertical or horizontal axis

Table 28: Regions of interest (ROI)

ROI types	User information
Circular	Yes
Rectangular	Not available
Free-hand	Yes
Other	Hover for pixel intensity

Table 29: Regions of interest (ROI) functions

ROI functions	User information
Moving ROI	Select ROI on number and drag. Size markers alter size
Copying ROI onto same image	Yes – possible when ROI is active on task card (shape and size retained)
Copying ROI onto new image	Yes
Replicating ROI on new image	Yes
Maximum number of ROI	>30
Crop inside ROI	When using MIP function one can choose to crop inside or outside the selected ROI on the MIP image
Crop outside ROI	When using MIP function one can choose to crop inside or outside the selected ROI on the MIP image

Table 30: Regions of interest (ROI) analysis

ROI analysis	User information
Dimensions and position	Yes. X and y positions in patient coordinates.
Area	Yes. In number of pixels
Volume	Yes (optionally with 3D VRT evaluation package)
Statistics	Yes. mean, standard deviation, minimum value, maximum value, number of pixels, total pixel area Number of statistics displayed on image can be altered
Histograms	No
Other	Intensity/flow: intensity diagram vs. time or position

Table 31: Image distance measurements

Distance measurements	User information
Scaled grid overlay	Yes
Distance and angle values	Distance in cm, angle in degrees (2 lines are drawn) x-y coordinates.
Moveable measurement points	Yes – drag entire line, select line to alter dimensions

Table 32: Image profiles

Image profiles	User information
Multiple profiles	Yes
X and Y values on profile	Yes
Distance measurements	Yes

Table 33: Image functions

Image functions	User information
Image addition	Yes
Image subtraction	Yes
Image multiplication	Yes
Image division	Yes
Image histograms	Yes
Image averaging	Yes
Other	Text annotation on image, arithmetic mean, differentiate, diffusion coefficient, integrate, logarithm, quadratic summation, slope, standard deviation, T1, T2, time to peak, t-Test

Table 34: Image enhancement: SNR

SNR improvement	User information
Enhanced display processing filters	Weights specific lines of data in order to suppress edge oscillation. Select filter strength (intensity) from set list (weak, medium, strong, free). ‘Free’ allows user to define ramp of filter edges with ‘Slope’

Table 35: Image enhancement: resolution

Resolution improvement	User information
Yes	Yes

Table 36: Image enhancement: uniformity

Uniformity correction	User information
Yes	Reduces brightness of areas in vicinity of surface coil and increase brightness away from coil User selects strength (intensity) from set list (weak, medium, strong, free). ‘Free’ allows user to select width (how many rows of data are used in reconstruction) and cut-off (brightness level below which pixels are not used in reconstruction)

Table 37: Image enhancement: geometric distortion

Geometric distortion correction	User information
Automatic	Pin-cushion distortions along the edge of the image can be compensated.

Table 38: Post processing functions

Distance measurements	Console*	User information
MPR	OC/IC	Yes
MIPs	OC/IC	Yes – volumes of interest
Volume measurements	OC/IC	ROI x slice thickness standard; Volume measurements with 3D VRT option
Surface rendering	OC/IC	Yes. SSD (surface shaded display)
Flow analysis	OC/IC	Yes – with Flow Quantification Software Option

*Console Key: OC - operator console IC – independent console O – optional

Radio-frequency (RF) coils

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

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

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

Table 39: Head and neck coils

Name	Type*	Dimensions cm	# output channels	# elements for QD/CP	# elements for LP	S/O[†]
Head Matrix (a Tim coil)	R PA Q L	30 x 30 x 28 (l × w x h)	CP Mode : 4 CP Dual Mode : 8 CP Triple Mode : 12	12 elements, combined to: 4 CP elements in CP Mode, 8 CP elements in Dual Mode, 12 elements in Triple Mode	As for QD/CP	S
CP Head Array Coil	R PA Q	48 x 33 (l x w)	1	1 CP	As for QD/CP	O
CP TX/RX Head Coil	TR Q	40 x 36 x 36 (l × w x h)	1	1 CP	As for QD/CP	O
Neck Matrix (a Tim coil)	R PA Q L	19 x 33 x 33.2 (l × w x h)	CP Mode: 2 CP Dual Mode: 4 Triple Mode: 4	4 elements, combined to: 2 CP elements in CP Mode, 4 elements in Dual and Triple Mode	As for QD/CP	S

*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

[†] S = standard, O = optional (may be offered in tailored package)

Table 40: Body and spine coils

Name	Type*	Dimensions cm	# output channels	# elements for QD/CP	# elements for LP	S/O†
CP Integrated Body	T/R Q	60 × 60 (dia × l)	1 CP	2 (= 1 CP)	-	S
Body Matrix (a Tim coil)	R PA Q	52 x 32.2 (l x w)	CP Mode: 2 Dual Mode: 4 Triple Mode: 6‡	6 elements, combined to: 2 CP elements in CP Mode, 4 CP elements in Dual Mode, 6 elements in Triple Mode‡	As for QD/CP	O
Spine Matrix (a Tim coil)	R PA Q	118.5 x 48.4 x 33	CP Mode : 8 CP Dual Mode : 16 CP Triple Mode : 24	24 elements, combined to: 8 CP elements in CP Mode, 16 CP elements in Dual Mode, 24 elements in Triple Mode	As for QD/CP	S

*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

†S = standard, O = optional (may be offered in tailored package)

‡The Body Matrix coils are combined with elements from the Spine Matrix coil. This means that in clinical applications, the combination of (1 Body Matrix coil + 2 Clusters of Spine Matrix coil) results in 4CP/8CP/12 elements in CP/Dual/Triple Mode. The combination of (2 Body Matrix coils + 4 Clusters of Spine Matrix coil) results in 8CP/16CP/24 elements in CP/Dual/Triple Mode.

Table 41: Extremity coils

Name	Type*	Dimensions cm	# output channels	# elements for QD/CP	# elements for LP	S/O†
CP Extremity	T/R Q	40.5 x 27 x 29 (l x w x h)	1	1	-	O
Flex Large	R Q	21 x 52 (l x w)	1	1	-	S
Flex Small	R Q	17 x 36 (l x w)	1	1	-	S

*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

†S = standard, O = optional (may be offered in tailored package)

Table 42: Breast imaging coils

Name	Type*	Dimensions cm	# output channels	# elements for QD/CP	# elements for LP	S/O†
Bilateral Breast	R PA Q	50 x 53 x 14.5 (l x w x h)	1	1	-	O
Breast Biopsy Device	R L	19	1	1	-	O

*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
†S = standard, O = optional (may be offered in tailored package)

Table 43: Cardiovascular coils

Name	Type*	Dimensions cm	# output channels	# elements for QD/CP	# elements for LP	S/O†
PA Matrix (a Tim coil)	R PA Q	97 x 30-60 x 27 (l x w x h)	8	16 (= 8 CP)	-	O

*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
†S = standard, O = optional (may be offered in tailored package)

Table 44: General purpose/other coils

Name	Type	Dimensions cm	# output channels	# elements for QD/CP	# elements for LP	S/O†
Shoulder Array (Large)	R PA L	20 (opening)	4	-	4	O
Shoulder Array (Small)	R PA L	16.5 (opening)	4	-	4	O
Bilateral TMJ	R PA L	82 x 135 x 145 (l x w x h)	2	-	2	O
Endo-rectal	L R	80 x 30 (l x dia)	1	-	1	O

*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
†S = standard, O = optional (may be offered in tailored package)

Sequences and packages

Table 45: Spin echo (SE) sequences

Sequence name	Description	S/O*
2D/3D SE	2D/3D spin echo	S
2D/3D TSE	2D/3D turbo spin echo	S
2D DSE	2D double echo spin echo	S
2D MSE	2D multi-echo spin echo	S
SS TSE	Steady state turbo spin echo	S
HASTE	Half-Fourier turbo spin echo	S

*S=standard, O= included in an optional package (see packages)

Table 46: Inversion recovery (IR) sequences

Sequence name	Description	S/O*
2D IR	2D inversion recovery	S
TIR	Turbo inversion recovery	S
STIR	Short time inversion recovery	S
DarkFluid T2	Dark fluid T2	S
HASTE IR	Half-Fourier turbo spin echo - inversion recovery	S
True IR	True inversion recovery	S

*S=standard, O= included in an optional package (see packages)

Table 47: Gradient echo (GE) sequences

Sequence name	Description	S/O*
2D/3D GE	2D/3D gradient echo	S
2D/3D FLASH	2D/3D fast low angle shot	S
TurboFLASH	2D/3D fast low angle shot: turbo	S
3D FISP	3D fast imaging with steady state	S
3D PSIF	3D FISP reversed in time	S
True FISP	2D fast imaging with steady state	S
2D/3D TOF	2D/3D time of flight	S
3D DESS	3D dual echo steady state	S
3D CISS	3D constructive interference in steady state	S
2D TGSE	2D gradient spin echo	S

*S=standard, O= included in an optional package (see packages)

Table 48: Echo planar imaging (EPI) sequences

Sequence name	Description	S/O*
EPI	Single-shot EPI (FID)	S
	DWI – ADC map and trace images	O
	Perfusion – global bolus plot, TTP, percentage signal image	O
	Integrated post-processing	O

*S=standard, O= included in an optional package (see packages)

Table 49: Acquisition parameters

Parameter	Specification
Imaging range	Whole body
Slice planes	2D axial, sagittal, coronal, oblique and double oblique (in steps of 1°)
Head FOV (mm)	5 – 500
2D slice thickness (mm)	0.1 – 200.0
3D slice thickness (mm)	0.05 – 20.0
2D slice gap (mm)	-5.0 – 800.0
2D max slices (256^2)	128 per single stack; 65,536 (256^2) / 262,144 (128^2) per series
3D max slices (256^2)	512 per single slab
Flip angle (degrees)	1° to 180°
Number of echoes	512
TSE factor	3 – 512
Signal averages	1 – 32
Max acquisition matrix	1024 x 1024
Dynamic scans	512 (no of repeat scans)

Table 50: Parallel imaging

Package	Manufacturer's name	Description
Parallel acquisition imaging	iPAT	GRAPPA and mSENSE parallel imaging techniques available

Table 51: Packages (optional)

Package	Manufacturer’s name	Description
Standard imaging	Tim Application Suite including Neuro Suite, Ortho Suite, Angio Suite, Cardio Suite, Body Suite, Onco Suite, Pediatric Suite	SE, IR, 2D TurboSE, 3D TurboSE, Turbo IR, Dark-Fluid IR, True IR, 2D/3D MEDIC, 2D/3D GE (FLASH, FISP), 2D/3D PSIF, 2D Turbo FLASH, 3D MP-RAGE (3D TurboFLASH), 2D/3D TOF angiography, MTC, TONE used with 3D TOF MRA, GMR, LOTA 2D/3D PC 2DTOF segmentation and ECG triggering CE MRA, Turbo MRA True FISP 2D/3D HASTE HASTE IR SS TSE TrueFISP segmented, 2D/3D FLASH segmented, Magnetization Preparation TrueFISP (IR, SR, FS), SPACE (3D TSE with variable flip angle), Single Shot EPI (SE, FID)
Angiography	Flow quantification	2D FLASH segmented 2D PC ECG triggered Evaluation for flow velocity (cm/s), flow volume (ml/s)
Fast imaging	TGSE	Hybrid sequence for high resolution in orthopaedics
Cardiac imaging	Advanced Cardiac	Advanced cardiac techniques like retrogating, projection reconstruction, PACE (navigator techniques)
Functional imaging	Inline BOLD imaging	On-the-fly processing/dynamic evaluation, e.g. t-Test
	Inline Diffusion	On-the-fly calculation of ADC-maps, Trace images
	Inline Perfusion	Global bolus plot, TTP, percentage signal image
Spectroscopy	Spectroscopy SVS (Single Voxel)	FID, STEAM, PRESS Postprocessing SW including algorithms working on time-domain data, algorithms working on spectra, and display of results
	Spectroscopy CSI (Chemical Shift Imaging)	FID, STEAM, PRESS Postprocessing SW including algorithms working on time-domain data, algorithms working on spectra, and display of results
	Spectroscopy CSI (Chemical Shift Imaging)	STEAM-CSI, PRESS-CSI Postprocessing SW

Table 52: Packages - other

Package	Manufacturer's name	Description
Other	AutoAlign	Automatic slice positioning for brain examinations. No user interaction for graphical slice positioning is necessary.
	Tim Whole Body Suite	Whole-body examinations up to 205 cm scan range.
	Interactive Realtime	Sequences for interactive realtime applications. Controlled by special 3D Mouse.
	iPAT Extensions	Parallel Acquisition in 3D direction or simultaneously in phase-encoding and 3D direction. Enables max. PAT factors up to 12.
	CISS & DESS	3D CISS 3D DESS with/without water excitation
	Advanced Functional Neuro	Prospective Motion correction with 3D PACE for e.g. BOLD examinations. 3D Inline fMRI for realtime overlay of functional information on a 3D data volume.

Table 53: Artefact reduction techniques

Generic	Package	User information
Anti-aliasing	Swap	Exchange of frequency and phase encoding direction
	Read/phase oversampling	Using extended sampling in frequency (performed automatically) or phase (increasing scan time) encoding direction to avoid aliasing
	Slice oversampling for 3D	Extended phase encoding range on both sides of the slab to avoid aliasing in the slice selection direction
Spectral pre-saturation	FatSat	Additional frequency selective RF pulses to suppress bright signal from fat
	Fat/water excitation	Spectral selective RF pulses for exclusive fat or water excitation
	Water saturation	Special sequences with selective water saturation to suppress the water signal
Spatial pre-saturation	Presaturaton Travelling Saturation Band	Up to six saturation bands located in any orientation using RF saturation pulses to suppress flow and motion artefacts
Flow compensation	Gradient Motion Rephasing (GMR)	Sequences with additional bipolar gradient pulses, permitting effective reduction of flow artefacts to avoid signal loss and smearing by moving spins
Respiratory compensation	PACE	2D PACE techniques for online motion correction
Respiratory gating	Respiratory triggering	Avoids artefacts caused by respiratory motion
Cardiac ECG gating	ECG Gating (standard)	Acquisition of multiple slices of the heart at different phases of the cardiac cycle
Peripheral pulse triggering	Peripheral pulse triggering	Reduction of flow artefact caused by pulsatile blood flow
Other	External triggering	Interface for trigger input from external sources
	LOTA (Long Term Averaging Technique)	Motion and flow artefact reduction with improved SNR without increasing scan time (Short term averaging mode improves SNR with optimum resolution)
	2D Interpolation	Zero filling interpolation for higher resolution
	3D Slice Interpolation	Acquisition of thinner slices in less scan time

Table 54: Imaging options

Generic	Manufacturer’s name	User information
Variable bandwidth	Optimised bandwidth	Sequences with freely adjustable receiver bandwidth to increase signal to noise ratio
Other	TONE	Tilted Optimised Nonsaturating Excitation: variable excitation flip angle to compensate inflow saturation effects in 3D MRA
	Optimised flip angle	Freely adjustable flip angle

Table 55: Time saving options

Generic	Manufacturer’s name	User information
Rectangular FOV	Reduced FOV	5% - 100% in phase encoding direction
K-space reduction	Reduced number of Fourier lines	Range dependent on raw data matrix
	Phase Partial Fourier imaging (including Half-Fourier)	Reduction of acquisition time by approx. 50% - 80% without loss of spatial resolution
Partial Echo	Asymmetric echo	Reduce echo time through asymmetry of echo in frequency encode direction
Other	Elliptical scanning	Reduces scan time for 3D imaging by up to 25% with elliptical k-space scanning
	Echo sharing	Dual contrast TSE technique enhancing speed by using acquired echoes least important for image contrast in T2 and proton density image

1.5 tesla safety

MRI at 1.5 T falls into the normal mode of operation (Guidelines for Magnetic Resonance Diagnostic Equipment in Clinical Use: Medical Devices Agency 2002). The uncontrolled level as defined by the NRPB (1991) is below 2.5 T.

Acoustic noise

The acoustic noise levels measured in this assessment are provided for indication only. Variations in factors such as room acoustics may mean that similar noise levels may not be reproduced at a different site - even with an identical pulse sequence. Acoustic noise levels are given in terms of the A-weighted continuous equivalent level, L_{Aeq}, which is the root-mean-square sound pressure level (SPL) averaged over the measurement period of 1 minute, and the peak sound pressure level, L_{peak}. The relevant safety levels are given below:

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 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

NOISE AT WORK REGULATIONS 1989 (UK)
Employers have legal duty to protect the hearing of their employees. Hearing protection must be available for workers exposed to 85 dB(A) and must be worn if levels exceed 90 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.

EU DIRECTIVE 2003/10/EC

This directive becomes effective in the UK in 2006. Compared to the regulations above action levels will be reduced by 5 dB(A). Substitution and control of noisy equipment must be prioritised above the use of hearing protection. There will be an exposure limit of 87 dB taking into account the noise reduction afforded by protective equipment.

Table 56 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 57. Acoustic noise levels are given in terms of the A-weighted continuous equivalent level, L_{Aeq} and the peak weighted sound pressure level, L_{peak}. All values are on the A-weighted scale.

Table 56: 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	n/a	4	10
FSE (ETL = 4)	15	4000	256×256	1	320	n/a	4	10
GE (3D)	9	23	160×256	1	170	30	1	10
Single shot EPI	24	2000	128×128	32	230	n/a	5	10

Table 57: Acoustic noise levels for comparative pulse sequences

	Pulse sequence with acoustic noise level dB(A)							
System	SE		FSE		GE		EPI	
	L_{Aeq}	L_{peak}	L_{Aeq}	L_{peak}	L_{Aeq}	L_{peak}	L_{Aeq}	L_{peak}
SI-AVA	63.7	90.5	71.7	93.1	76.5	99.0	83.4	98.6

Emergency systems

Table 58: Shutdown buttons

Buttons	User information
Electrical shutdown (on equipment)	On keyboard
Electrical shutdown (on site)	Three positions: on wall in examination room, in console room in alarm box, in equipment room
Magnet shutdown (on site)	Two positions: in console room in alarm box (under Plexiglas cover), in examination room by door

Table 59: Alarm systems

Alarms	User information
Helium monitor	Yes. LED in alarm box. Message displayed on console
Oxygen monitor	Can be supplied if required
Refrigeration system	Yes
Room temperature monitor	Can be supplied if required

Table 60: Specific absorption rate (SAR)

SAR management	User information
Does the system calculate the SAR level when a sequence is selected?	Yes. The status bar shows at all times at which operating mode the current sequence is being performed
Does the calculation purely rely on the patient weight entered by the operator?	No but the patient weight and date-of-birth form the basis for SAR monitoring.
Does the system show the predicted SAR level before the start of a scan?	Yes. It can be displayed at any time in SAR Information dialogue box on console.
Does the system show a message if the sequence exceeds the safety limit?	Yes. ‘SAR limit exceeded’ is displayed with suggestions as to which parameters to change and the option to switch to first-level mode.
Is the limit that set in IEC 601 standard?	Yes.
Can the operator ignore the warning and continue the scan?	Yes. The operator is given three options: to change parameters, to select an alternative scan programme with reduced SAR, or to activate first level mode.
As well as the software monitor is there a hardware monitor?	Yes.

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.medical-devices.gov.uk.

National Radiological Protection Board

NRPB: Advice on limiting exposure to electromagnetic fields (0-300 GHz) Volume 15 Number 2 2004. www.nrpb.org.

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.

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 6, Supplement 1: Accommodation for Magnetic Resonance Imaging. Produced by NHS Estates, published by HMSO PO Box 276, London SW8 5DT. ISBN 0113217307.

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

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

‘Facilities for diagnostic imaging and interventional radiology’ Produced by NHS Estates in 2001, published by HMSO PO Box 276, London SW8 5DT. ISBN 0113220000.

Technical evaluation

Details of assessment

Table 61: Technical assessment

Site	Date of assessment
Siemens Medical Solutions, Erlangen, Germany	28 April 2004

Introduction to evaluation

The technical performance of the Siemens MAGNETOM Avanto 1.5 T is provided in this section of the report. The performance is compared with other systems of similar field strength evaluated by MagNET, as listed in Table 62.

MagNET requires all images to be acquired without any pre-reconstruction or post-processing filters. However, this is not possible for some manufacturers where pre-reconstruction filters are part of the reconstruction process and cannot be switched off. 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 62: MR model abbreviation codes for high-field systems.

Company	Model	Gradient	Code	Assessment date
GE*	SIGNA INFINITY	EchoSpeed Plus	GE-ESP	04/12/01
GE*	SIGNA INFINITY	TwinSpeed	GE-TWS	03/12/01
PHILIPS	INTERA	Master / Nova Dual (parallel imaging)	PH-INT	25/09/00
SIEMENS	MAGNETOM AVANTO	SQ-Engine	SI-AVA	28/04/04
SIEMENS	MAGNETOM SONATA MEASTRO CLASS	Sonata	SI-SON	09/07/01[†]
SIEMENS	MAGNETOM SYMPHONY MAESTRO CLASS	Quantum	SI-SYM	23/10/00
TOSHIBA	EXCELART XG	XG	TO-EXC	27/08/01

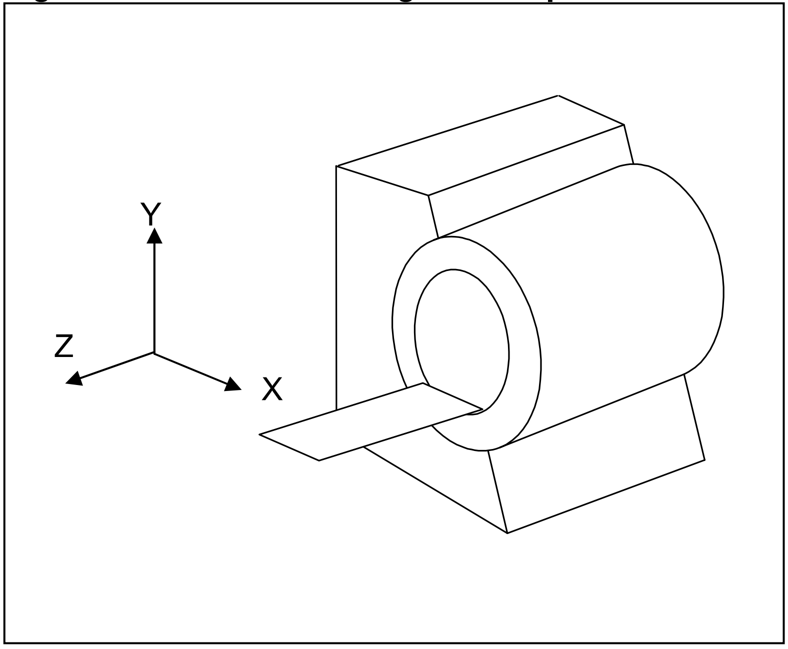
[*] GE systems apply a pre-reconstruction Fermi filter as standard. This cannot be switched off during type-testing

[†] Q-factor, SNR and slice width measurements were made on the 08/02/01. Clinical speed measurements were made on the 17/10/01.

Gradient labelling convention

The Siemens MAGNETOM Avanto 1.5 T is a horizontal field MR scanner and as such it is necessary to explain X-, Y- and Z-directions used in the report. Z-direction is always the direction of the magnetic field B_0, as shown in Figure 1.

Figure 1. Gradient labelling with respect to table and magnet



Quadrature head coil evaluation

MagNET comment

The CP Head Coil is not supplied as standard with the Siemens MAGNETOM Avanto 1.5T system. The head imaging coil supplied with this system is the Head Matrix Coil and the imaging performance tests for this coil are shown on Page 68.

The Avanto maintains, however, backwards compatibility with the CP Head Coil supplied with the Siemens MAGNETOM Symphony and Sonata systems.

Quadrature head coil: signal to noise ratio (SNR)

Scan parameters

Table 63. Standard quadrature head coil signal to noise ratio (SNR) scan parameters.

	Standard protocol	Actual protocol
Test object	MAGFF_LOADED	MAGFF_LOADED
Loading	Internal in test-object	Internal in test-object
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Bandwidth (kHz)	Manufacturer’s choice	± 16.64
Temperature (°C)	Ambient	20
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

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

The comparison made in Table 64 shows the image SNR both un-normalised and normalised for voxel size, scan time, coil quality factor, and sampling bandwidth for high-field systems. Table 65 shows the coil quality (Q) factor measurements.

MagNET Comment

The SNR values obtained for the CP Head Coil were below the average for the 1.5 T systems tested by MagNET.

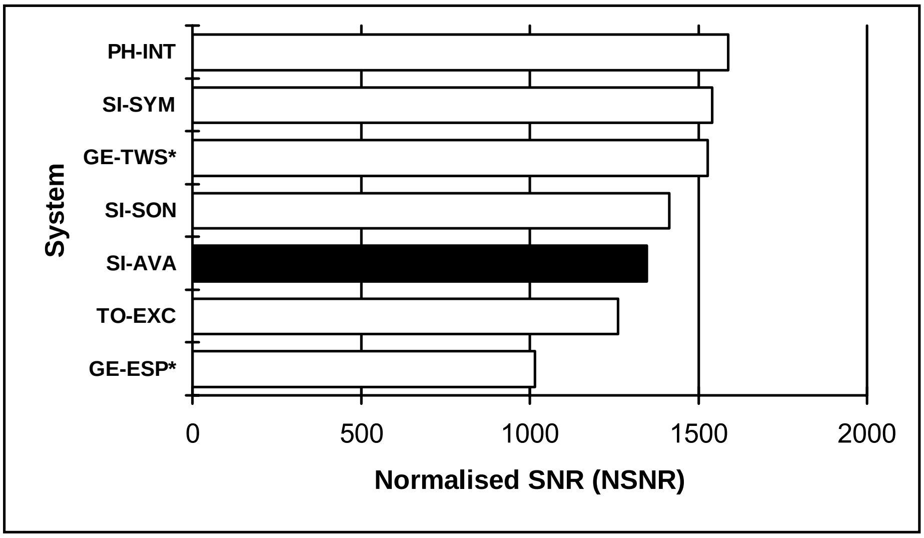
Table 64: Signal to noise ratio for the head coil

	Transverse	Sagittal	Coronal	Mean
Image SNR	157	142	143	147
Normalised SNR	1456	1306	1277	1347

Table 65: Coil quality factor (Q) measurements

Test object	Q_{loaded}	Q_{head}	Q factor
MAGFF_LOADED	1.00	1.00	1.00

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



*GE systems apply a pre-reconstruction Fermi filter as standard. This cannot be switched off during type-testing.

Quadrature head coil: uniformity

Scan parameters

Table 66. Standard quadrature head coil uniformity scan parameters.

	Standard protocol	Actual protocol
Test object	MAGFF_OIL	MAGFF_OIL
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

The fractional uniformity was calculated over a distance of 160 mm, with the midpoint positioned at the centre of the test object. The optimum value is unity, indicating 100% of the signal is considered uniform over the measured distance.

The MagNET protocol specifies that the fractional uniformity should be calculated as the fraction of the profile lying within ± 10% of its mean value.

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

The fractional uniformity measurements in the two directions for each plane are presented in Table 67 and Table 68 (without and with the uniformity filter, respectively). The comparison made in Graph 2 shows the mean fractional uniformity for 1.5T systems tested by MagNET. Unfiltered uniformity profiles in the x-, y-, and z- directions are provided in Graph 3.

MagNET comment

The Siemens normalisation filter is designed to improve image uniformity. Both filtered and unfiltered images were analysed.

The overall uniformity performance of this coil was above the average for the 1.5 T systems tested by MagNET.

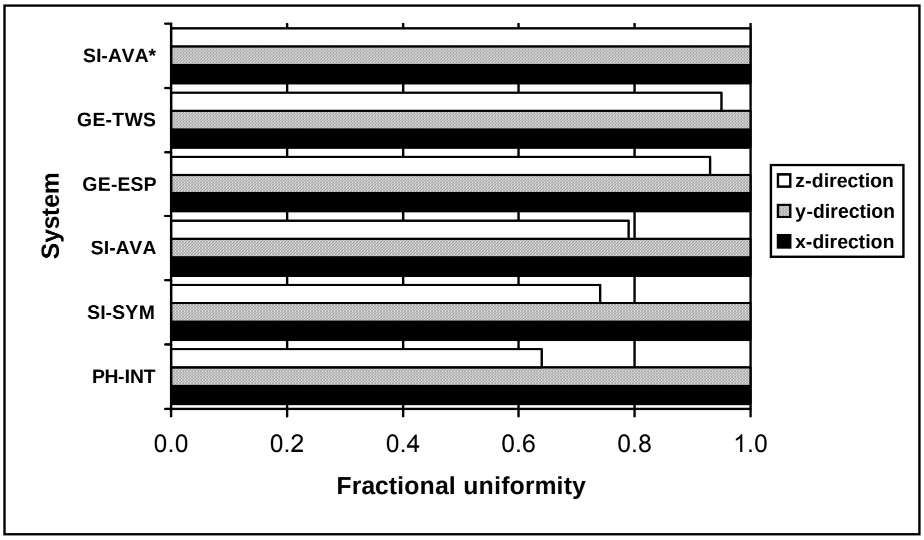
Table 67: Fractional uniformity for the head coil (unfiltered)

	Transverse	Sagittal	Coronal	Mean	Mean±SD
X-direction	1.00	-	1.00	1.00	
Y-direction	1.00	1.00	-	1.00	0.93±0.11
Z-direction	-	0.78	0.80	0.79	

Table 68: Fractional uniformity for the head coil (filtered)

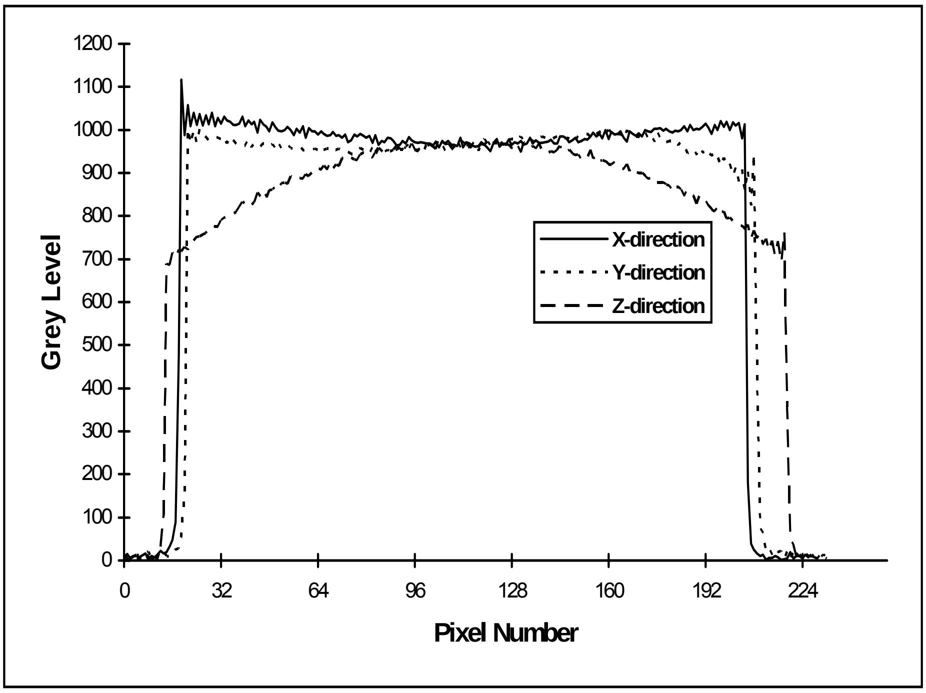
	Transverse	Sagittal	Coronal	Mean	Mean±SD
X-direction	1.00	-	1.00	1.00	
Y-direction	1.00	1.00	-	1.00	1.00±0.00
Z-direction	-	1.00	1.00	1.00	

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



*Uniformity filter applied.
The optimum value is unity.

Graph 3: Uniformity profiles in x-, y-, and z- directions (unfiltered)



Quadrature head coil: spatial resolution

Scan parameters

Table 69. Standard quadrature head coil spatial resolution scan parameters.

	Standard protocol	Actual protocol
Test object	MAG_MTF	MAG_MTF
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

The MAG_MTF test object was used to measure resolution from the modulation transfer function (MTF) blocks. The MTF is measured for a 256 x 256 matrix in the phase- and frequency-encoding directions.

The resulting resolution measurements are presented in Table 70, and summarised in Table 71. The measured resolution should be equal to the nominal pixel dimension. The MAG_MTF test object was imaged in all three imaging planes.

Graph 4 shows a comparison of the average pixel dimension for both the PE and FE directions (256 x 256 matrix) for 1.5 T systems tested by MagNET.

MagNET comment

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

From the MTF measurements, the resolution performance in both the FE and PE direction were within experimental error.

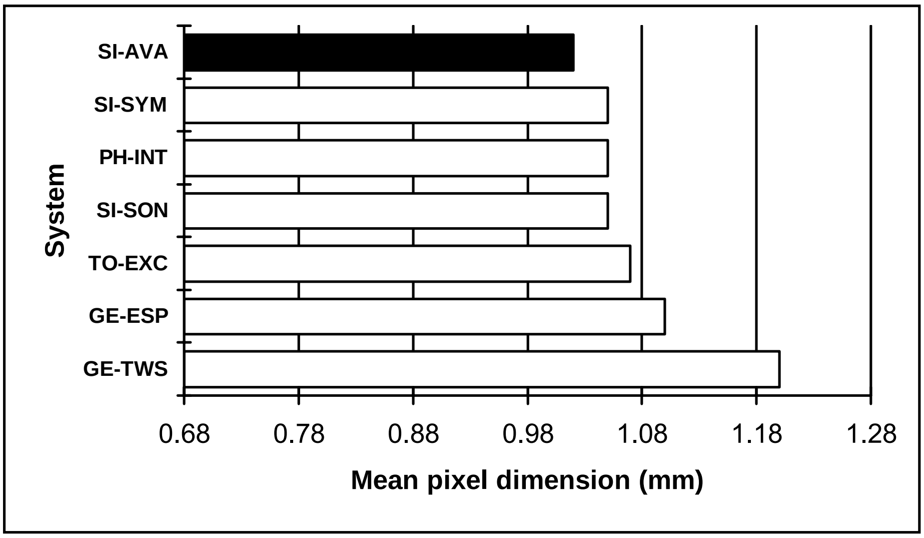
Table 70: Pixel dimension measurements (mm) for 256 x 256 matrix (nominal 0.98 mm)

Encoding direction	Transverse	Sagittal	Coronal	Mean ± SD
PE	1.02 ± 0.01	1.02 ± 0.01	1.02 ± 0.02	1.02 ± 0.01
FE	1.01 ± 0.02	1.03 ± 0.02	1.02 ± 0.01	1.02 ± 0.02

Table 71: Mean pixel dimension measurements (mm)

Matrix size	Nominal pixel dimensions	Mean ± SD
256 x 256	0.98	1.02 ± 0.02

Graph 4: Mean pixel dimension - 256 x 256 matrix (mean of three planes)



Errors ± 10% of the nominal value.

Quadrature head coil: geometric linearity and distortion

Scan parameters

Table 72. Standard quadrature head coil geometric linearity and distortion scan parameters.

	Standard protocol	Actual protocol
Test object	MAG_GEOM	MAG_GEOM
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	256	256
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Coefficient of variation

The Coefficient of Variation (CV) is defined as:

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

Interpretation of results

The geometric linearity results are obtained from a set of horizontal and vertical distance measurements in the acquired images. The closer these values are to the actual separation distance of 120 mm, the better the performance. Table 73 and Table 74 show the values obtained for imaging planes and gradients, respectively. Graph 5 shows a comparison of the mean geometric linearity for three planes for systems of equivalent field strength.

The coefficient of variation indicates the degree of variation of the distance measurements from one another. The lower the coefficient, the lower the in-plane distortion and the better the performance. Graph 5 shows a comparison of the mean coefficient of variation for 1.5 T systems.

MagNET comment

The mean error in geometric linearity is considered to be within experimental error if it measures 0 ± 1 mm.

The geometric linearity performance measured on this system was within experimental error. The geometric distortion performance was better than the average of the 1.5 T systems tested by MagNET.

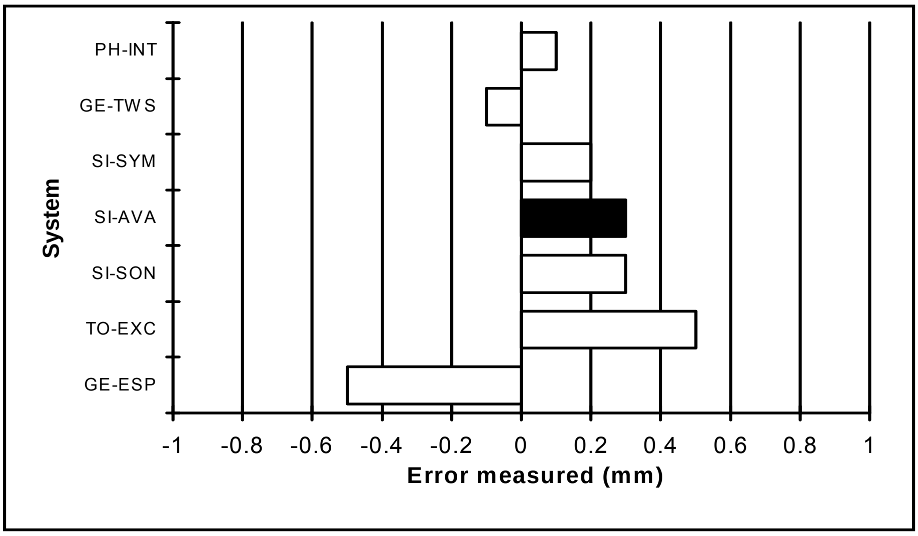
Table 73: Linearity and distortion measurements for three planes

	Transverse	Sagittal	Coronal	Mean ± SD
Mean (mm)	120.3 ± 0.52	120.5 ± 0.55	120.2 ± 0.40	120.3 ± 0.48
CV (%)	0.43	0.45	0.34	0.40

Table 74: Linearity and distortion measurements for three gradients

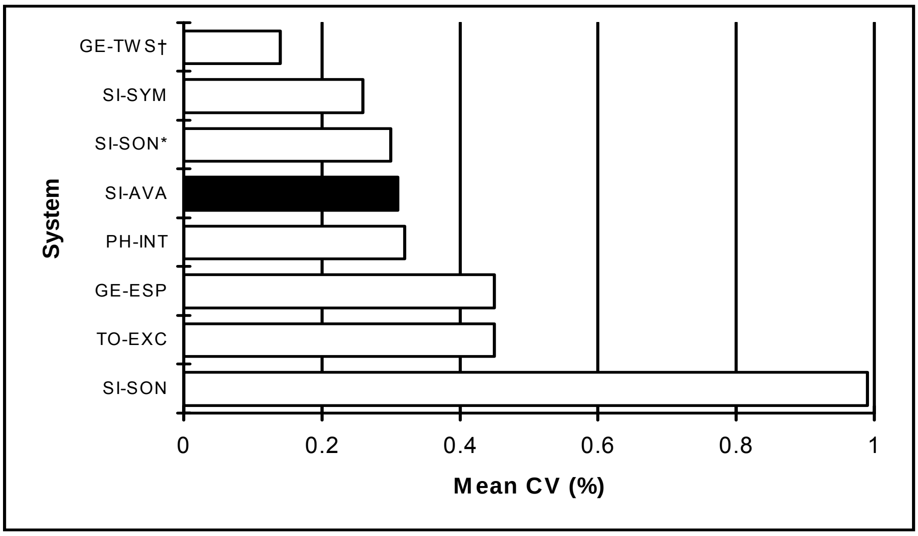
	X-direction	Y-direction	Z-direction	Mean ± SD
Mean (mm)	120.0 ± 0.01	120.5 ± 0.55	120.5 ± 0.55	120.3 ± 0.48
CV (%)	0.01	0.45	0.45	0.31

Graph 5: Comparison of mean error in geometric linearity for 1.5 T systems (mean of three planes).



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

Graph 6: Comparison of geometric distortion (mean of three gradients)



The optimum value is zero.

[*] Results with the distortion correction filter on.

[†] Distortion was evaluated with Zoom Mode and distortion filter.

Quadrature head coil: slice profile and slice width

Scan parameters

Table 75. Standard quadrature head coil slice profile and slice width scan parameters.

	Standard protocol	Actual protocol
Test object	MAG_GEOM	MAG_GEOM
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	256	256
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	3, 5	3, 5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

The slice profiles should have minimum side lobes, no ringing, and no central drop-out. Graph 7 shows the measured profiles in the transverse plane.

The measured slice widths for the three imaging planes presented in Table 76 should lie within 10% of the nominal slice width. Graph 8 and Graph 9 show comparisons of the mean 3 mm and 5 mm slice width measurements for other 1.5 T systems tested by MagNET.

MagNET comment

The measured slice widths are considered to be within experimental error if they are within ±10% of the nominal slice widths.

The values obtained in all three planes for both the 3 mm and 5 mm nominal slice widths were within experimental error.

Graph 7: 3 mm and 5 mm slice profiles in the transverse plane

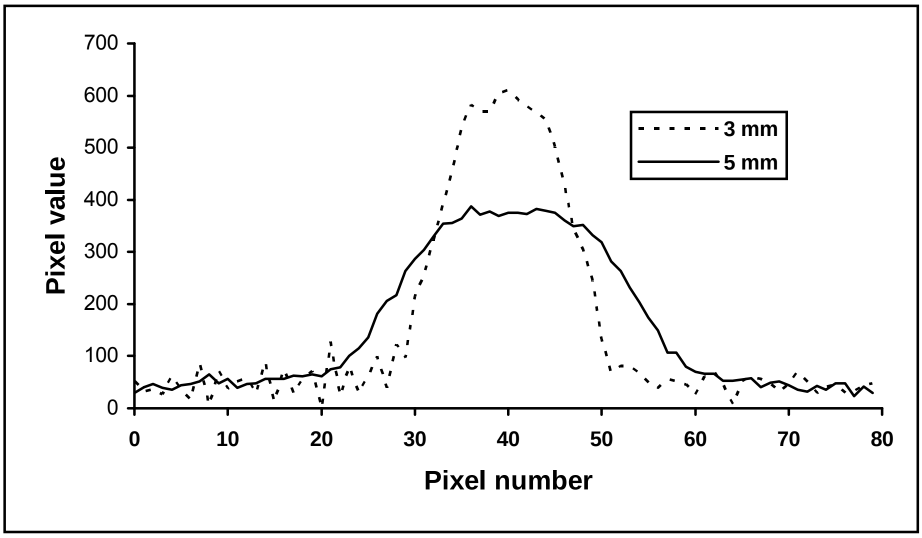
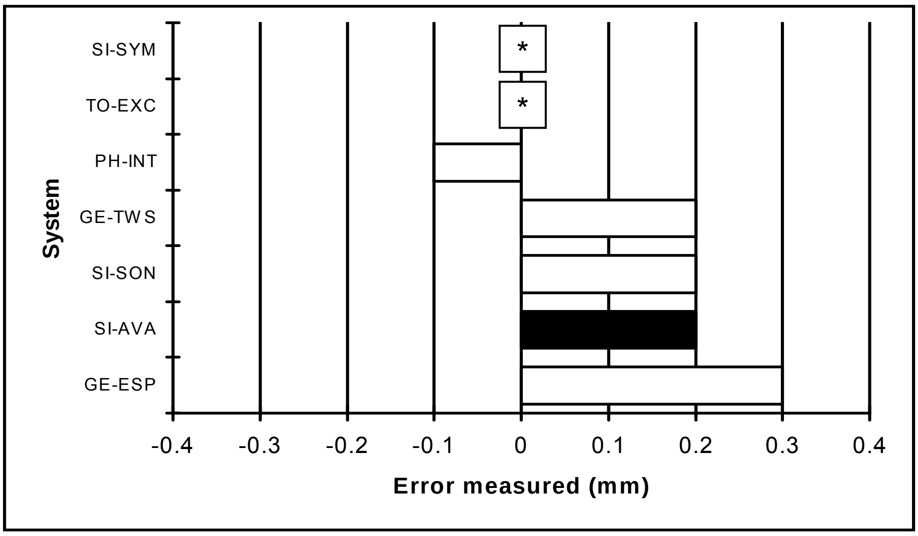


Table 76: Slice widths (mm) measured as FWHM of derived profiles

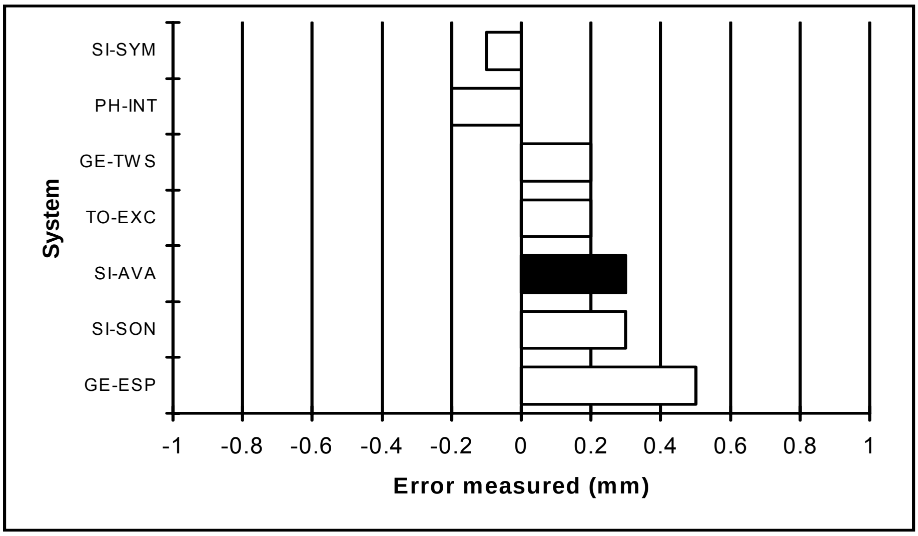
Nominal slice width (mm)	Transverse	Sagittal	Coronal	Mean
3.0	3.1	3.2	3.2	3.2
5.0	5.3	5.3	5.5	5.3

Graph 8: Comparison of measured slice widths for a nominal slice width of 3 mm (mean of three planes)



The optimum value is 0 ± 0.3 mm. Systems are ranked in order of the absolute deviation from optimum.
*The system has the optimum measured error value of 0.0 mm.

Graph 9: Comparison of measured slice widths for a nominal slice width of 5 mm (mean of three planes)



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

Quadrature head coil: slice position

Scan parameters

Table 77. Standard quadrature head coil slice position scan parameters.

	Standard protocol	Actual protocol
Test object	MAG_SLICEPOS	MAG_SLICEPOS
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	Manufacturer's choice	2310
NSA	1	1
FOV (mm)	256	256
Matrix (PE x FE)	256 x 256	256 x 256
Number of slices	Manufacturer's choice	63
Slice width (mm)	2.5	2.5
Slice gap – centre-to-centre (mm)	2.5	2.5
Scan time (min:sec)	Dependent on TR	9:54
Image plane	TRA	TRA

Interpretation of results

The acquisition protocol for this test is chosen by the manufacturer in accordance with the guideline protocol given above, with slice number 33 at the iso-centre.

Measurements of the actual slice positions are made from the analysis of consecutive images in the acquired data set. A separation of 1 pixel in the image plane corresponds to half a pixel in the slice separation axis. Consequently, slice position errors of less than the nominal pixel dimension (1.0 mm) are within experimental uncertainty.

Graph 10 shows the error between the nominal and actual position for each slice. A positive error indicates that the actual position is displaced from the nominal position in the direction of the patient's foot. A negative error indicates that the actual position is displaced from the nominal position in the direction of the patient's head. The slice number indicates the slice order from foot to head.

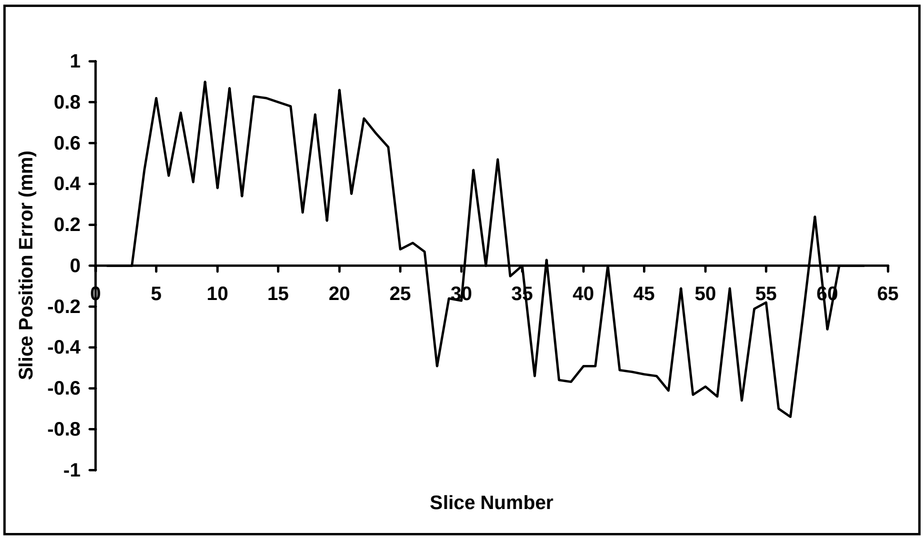
The mean errors for high-field systems are compared in Graph 11. The error bars indicate the variation (standard deviation) of error about the mean in each case.

MagNET comment

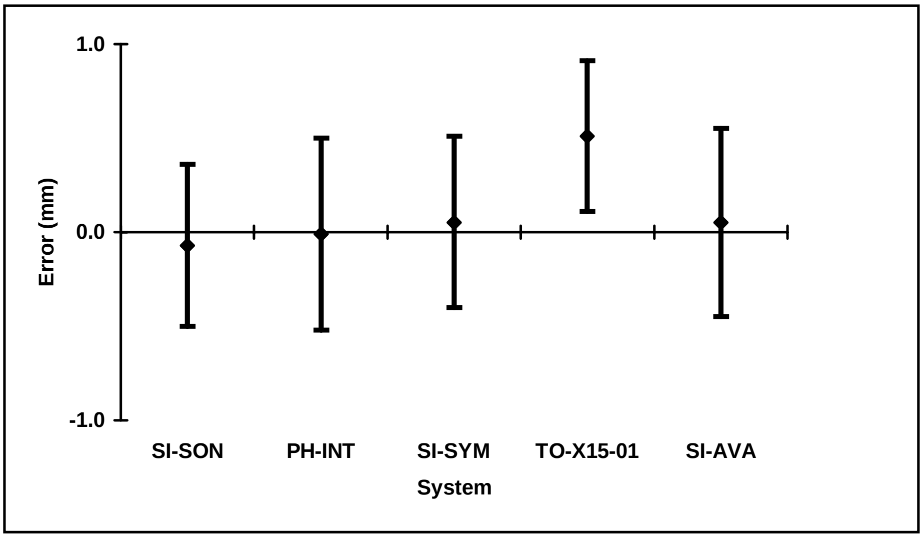
The measured slice position is considered within experimental error if it is within ±1.0 mm of the nominal slice position.

Slice position errors were within experimental error in the clinical range. The mean slice position error is average compared to those obtained for 1.5 T systems tested by MagNET.

Graph 10: Slice position errors



Graph 11: Comparison of mean slice position error



Quadrature head coil: ghosting

Scan parameters

Table 78. Standard quadrature head coil ghosting scan parameters.

	Standard protocol	Actual protocol
Test object	MAG_GHO	MAG_GHO
Loading	None	None
Sequence	SE	SE
TE 1 (ms)	30	30
TE 2 (ms)	60	60
TE 3 (ms)	90	90
TE 4 (ms)	120	120
TR (ms)	1000	1000
NSA	1,2	1,2
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Scan time (min:sec)	4:16, 8:32	4:18, 8.36
Image plane	TRA	TRA

Interpretation of results

Table 79 presents the ghosting results for each echo. Ghosting is calculated by the ratio of the maximum image ghost minus the background noise to the image signal. Graph 12 and Graph 13 present results for this system for 1 and 2 NSA respectively.

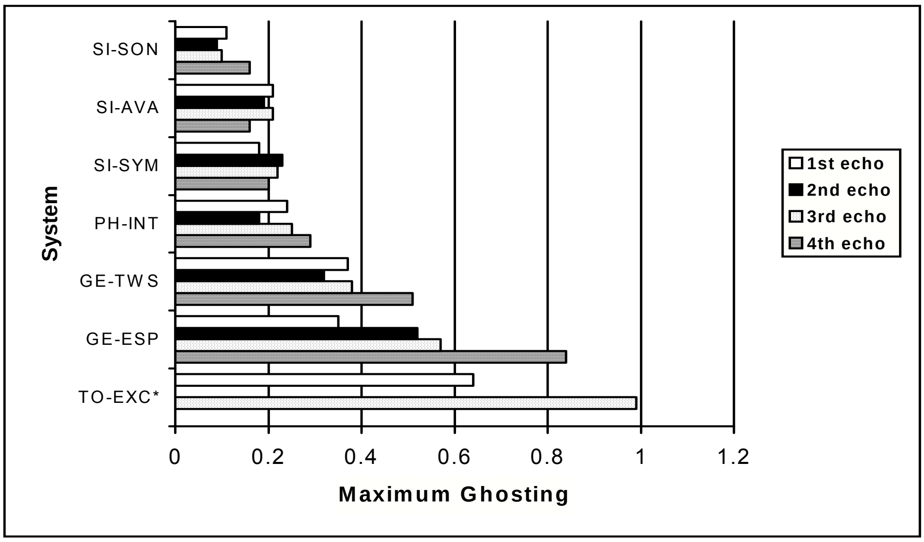
MagNET comment

The maximum measured ghosting was below the average for 1.5 T systems tested by MagNET, indicating a good performance, for both 1 and 2 signal averages.

Table 79: Maximum ghosting ratio for 1 and 2 signal averages

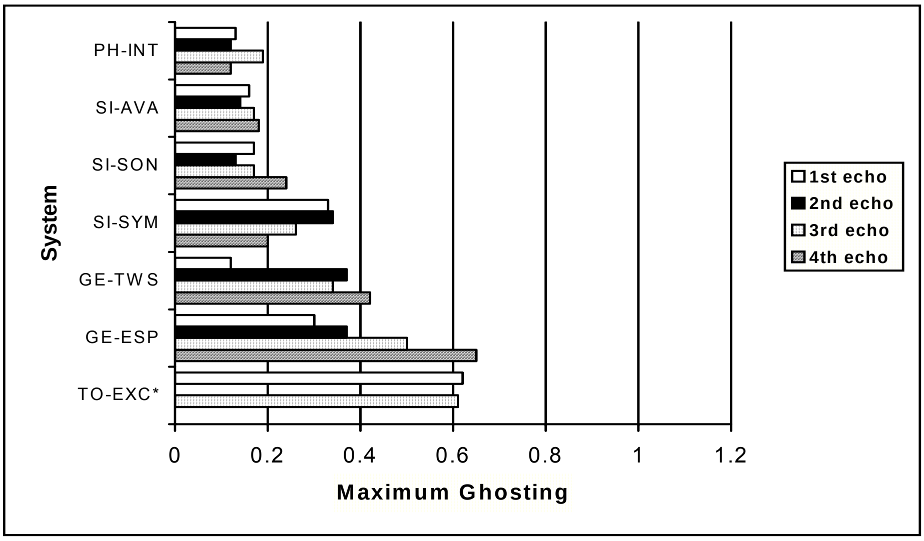
NSA	Echo	Maximum ghosting	NSA	Echo	Maximum ghosting
1	1	0.21	2	1	0.16
1	2	0.19	2	2	0.14
1	3	0.21	2	3	0.17
1	4	0.16	2	4	0.18
Mean		0.19 ± 0.03	Mean		0.16 ± 0.02

Graph 12: Comparison of maximum ghosting (NSA=1)



The optimal value is zero.
*Only two-echo sequences available for this system

Graph 13: Comparison of maximum ghosting (NSA=2)



The optimal value is zero.
*Only two-echo sequences available for this system

In-built body coil evaluation

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

Scan parameters

Table 80. In–built body coil signal to noise ratio (SNR) scan parameters

	Standard protocol	Actual protocol
Test object	MAGFF-LOADED	MAGFF-LOADED
Loading	Internal in the test object but additional loading by the manufacturer can be used.	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Bandwidth (kHz)	Manufacturer's choice	± 16.64
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

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

The image SNR and normalised SNR results for the built-in body coil are presented in Table 81.Table 82 gives the Q factor measurements for the built-in body coil. The comparison made in Graph 14 shows the image SNR normalised for voxel size, scan time, coil quality factor, and sampling bandwidth for systems with equivalent field strength.

MagNET comment

The normalised SNR was below average when compared to those of in-built body coils of 1.5 T systems tested by MagNET.

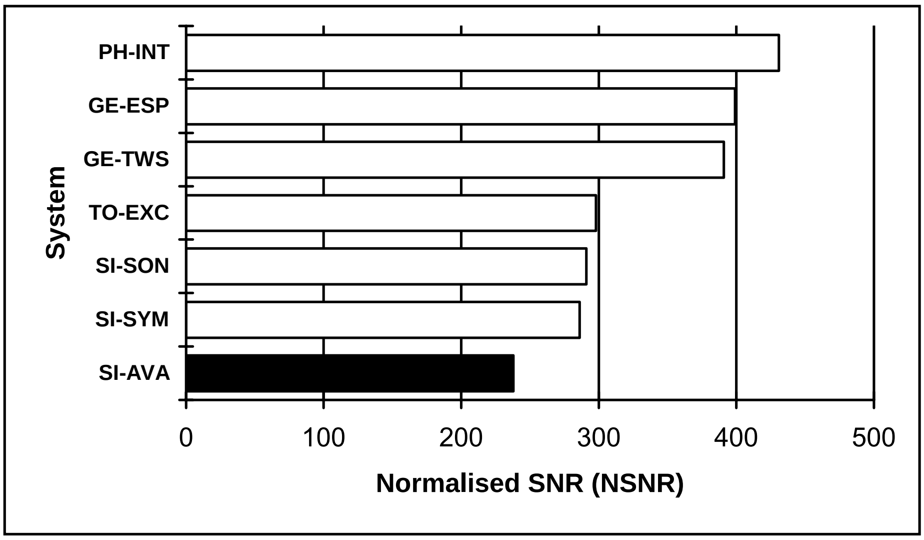
Table 81: Signal to noise ratio for the in-built body coil

	Transverse	Sagittal	Coronal	Mean
Image SNR	59	55	55	56
Normalised SNR	249	232	233	238

Table 82: Coil quality factor (Q) measurements for the in-built body coil

Q loaded	Q body	Q factor
245	46	0.43

Graph 14: Comparison of normalised SNR for in-built body coils (mean of three planes)



In-built body coil: uniformity

Scan parameters

Table 83. In-built body coil uniformity scan parameters

	Standard protocol	Actual protocol
Test object	MAGFF_OIL	MAGFF_OIL
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

The fractional uniformity was calculated over a distance of 160 mm, with the midpoint positioned at the centre of the test object. The optimum value is 1, indicating 100% of the signal is considered uniform over the measured distance.

The MagNET protocol specifies that the fractional uniformity should be calculated as the fraction of the profile lying within ±10% of its mean value.

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

The fractional uniformity measurements in the two directions for each plane are presented in Table 84 and (without and with the uniformity filter, respectively). The comparison made in Graph 15 shows the mean fractional uniformity for 1.5T systems tested by MagNET. Unfiltered uniformity profiles in the x-, y-, and z- directions are provided in Graph 16.

MagNET comment

The uniformity for the built-in body coil was average when compared to 1.5 T systems tested by MagNET.

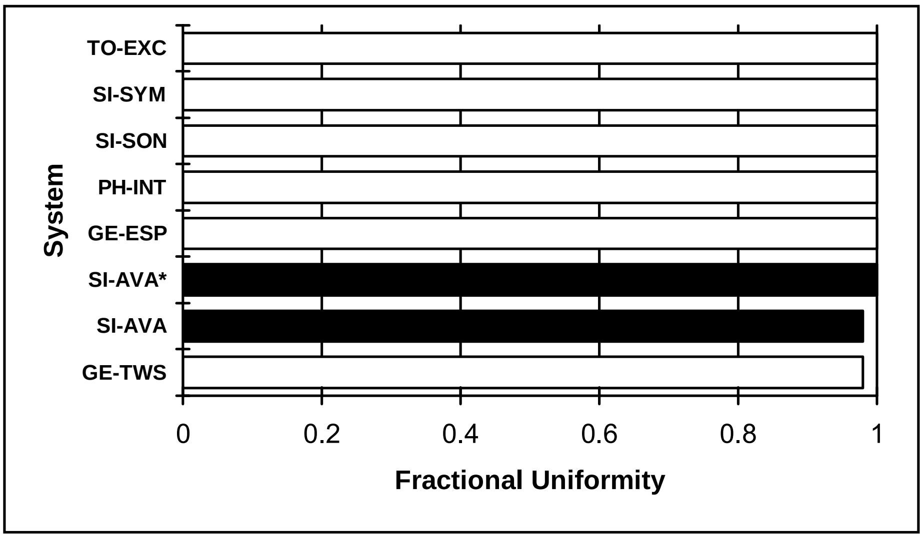
Table 84: Fractional uniformity for the in-built body coil (unfiltered)

Gradient direction	Transverse	Sagittal	Coronal	Mean ± SD
X-direction	0.96	-	0.94	0.95 ± 0.01
Y-direction	1.00	1.00	-	1.00 ± 0.00
Z-direction	-	1.00	1.00	1.00 ± 0.00

Table 85: Fractional uniformity for the in-built body coil (filtered)

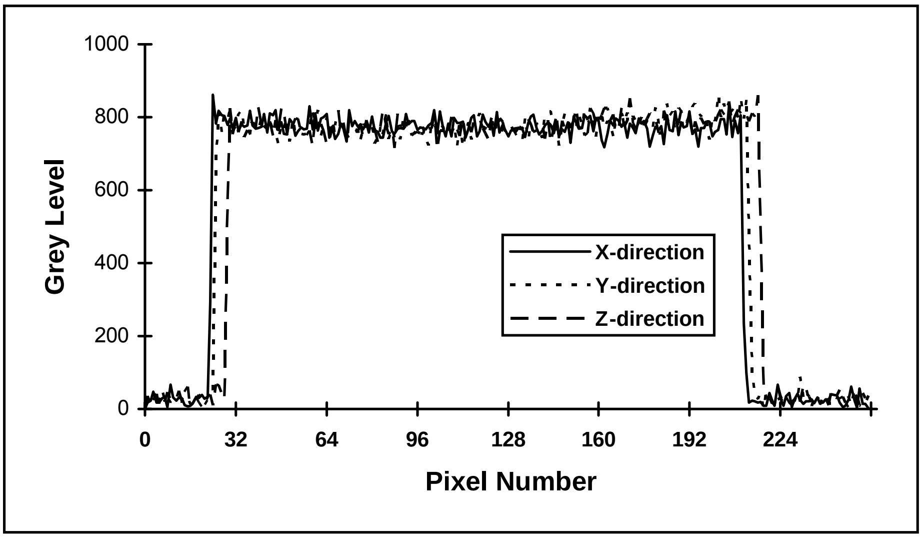
Gradient direction	Transverse	Sagittal	Coronal	Mean ± SD
X-direction	1.00	-	1.00	1.00 ± 0.01
Y-direction	1.00	1.00	-	1.00 ± 0.00
Z-direction	-	1.00	1.00	1.00 ± 0.00

Graph 15. Comparison of fractional uniformity (mean of three planes)



The optimum value is unity.
*Uniformity filter applied.

Graph 16. Signal intensity profiles in x-, y-, and z-directions for built-in body coil (unfiltered).



In-built body coil: geometric distortion over large field of view

Scan parameters

Table 86. In-built body coil geometric distortion over large field of view scan parameters

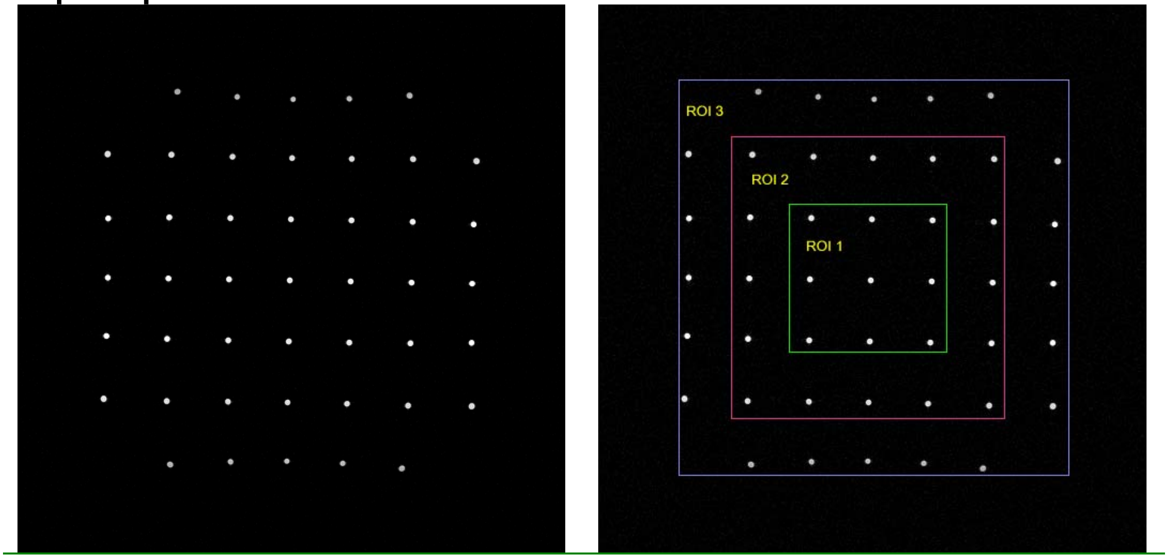
	Standard protocol	Actual protocol
Test object	MAGFF_GEOM_L	Siemens Large Geometry
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	500
NSA	1	1
FOV (mm)	450	450
Matrix (PE x FE)	256 x 256	512 x 512
Slice width (mm)	5	5
Scan time (min:sec)	4:16	4:18
Image plane	COR	COR

Interpretation of results

This test evaluates geometric distortion over a large FOV using the in-built body coil. The geometry phantom, the Siemens' Large Geometry Phantom, was placed in the coronal plane at the isocentre. A cross-sectional image of the phantom, shown in Figure 2, shows an array of 45 disks with a 50 mm horizontal and vertical spacing. Distortion is assumed to be minimal for the nine central disks (ROI 1). Their positions are used to calculate the actual pixel size. The predicted positions of the remaining 36 disks can then be calculated. The distortion is then defined as the difference between the predicted and actual disk positions in both horizontal (x) and vertical directions (y).

Table 87 and Table 88 show the nominal and calculated pixel dimensions obtained from the reference points in ROI1 for images without and with the uniformity filter applied, respectively. Table 89 and Table 90 display the geometric distortion results for images without and with the uniformity filter applied, respectively. ROI 2 consists of the 16 disks around ROI 1 whilst ROI 3 is defined as the 25 disks around the edge of the phantom.

Figure 2. (a) Transverse image of the large field of view geometric distortion test object. (b) Transverse image of the large field of view geometric distortion test objects with the three regions of interest (ROIs) superimposed used in the distortion calculations.



(a) **(b)**

Table 87. Nominal and calculated pixel dimensions over ROI1 of the large field of view for the built-in body coil (unfiltered)

Coordinate point	Measured coordinates		Corrected coordinates		Mean distance (mm)	Calculated pixel dimensions (mm)
	x	y	x	y		
A	255	200	1	-57	57	0.877
B	311	258	57	1		
C	253	314	-1	57		
D	197	256	-57	-1		
E	254	257	0	0		

Table 88. Nominal and calculated pixel dimensions over ROI1 of the large field of view for the built-in body coil (filtered)

Coordinate point	Measured coordinates		Corrected coordinates		Mean distance (mm)	Calculated pixel dimensions (mm)
	x	y	x	y		
A	255	200	1	-57	57	0.877
B	311	258	57	1		
C	253	314	-1	57		
D	197	256	-57	-1		
E	254	257	0	0		

Table 89. Geometric distortion over large field of view for the built-in body coil (unfiltered)

Gradient direction	Region of interest (ROI)	Maximum distortion (mm)	Mean distortion (mm)	Total distortion (mm)
x	2	1.75	0.82	1.21
	3	6.13	2.06	
y	2	0.89	0.39	0.69
	3	2.65	1.23	

Nominal pixel size = 0.877 mm

Table 90. Geometric distortion over large field of view for the built-in body coil (filtered)

Gradient direction	Region of interest (ROI)	Maximum distortion (mm)	Mean distortion (mm)	Total distortion (mm)
x	2	0.87	0.28	0.28
	3	1.75	0.40	
y	2	0.89	0.18	0.24
	3	0.40	0.41	

Nominal pixel size = 0.877 mm

Functionality evaluation

Functionality: multiple-channel head coil signal stability

Scan parameters

Table 91. multiple-channel head coil signal stability scan parameters

	Standard protocol	Actual protocol
Coil evaluated	Head coil	Head
Test object	FDTO	FDTO
Loading	None	None
Image plane	TRA	TRA
Position	Iso-centre/Iso-centre/ 50mm off iso-centre	Iso-centre/Iso-centre/ 50mm off iso-centre
EPI sequence	GRE-EPI	GRE-EPI
TE (ms)	Shortest possible	130
TR (ms)	1500	1500
NSA	1	1
Flip angle (°)	90/45/90	90/45/90
Bandwidth (Hz/pixel)	Manufacturer's choice	1148
Echo spacing (ms)	Manufacturer's choice	0.92
FOV (PE x FE) (mm)	400 x 400	400 x 400
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
Images	100	100
Scan time (min:sec)	Dependent on shots	2:35

Interpretation of results

Eight rectangular regions of interest (ROI) with sizes of 1, 3, 5, 7, 9, 11, 13 and 15 pixels are placed co-centrally in the signal area of the acquired images. The signal intensity fluctuation (SIF) is calculated as the ratio of standard deviation of signal intensity in the ROI across the image series, to signal intensity x 100. The stability quality factor (SQF) is calculated as the ratio of measured to optimal SIF, as calculated by the MRI system's signal to noise ratio (SNR) (Weisskoff 1996)

Table 92 shows the measured SIF and SQF value. Graph 17 and Graph 18 show a comparison of the measured SIF and SQF values with other 1.5 T systems.

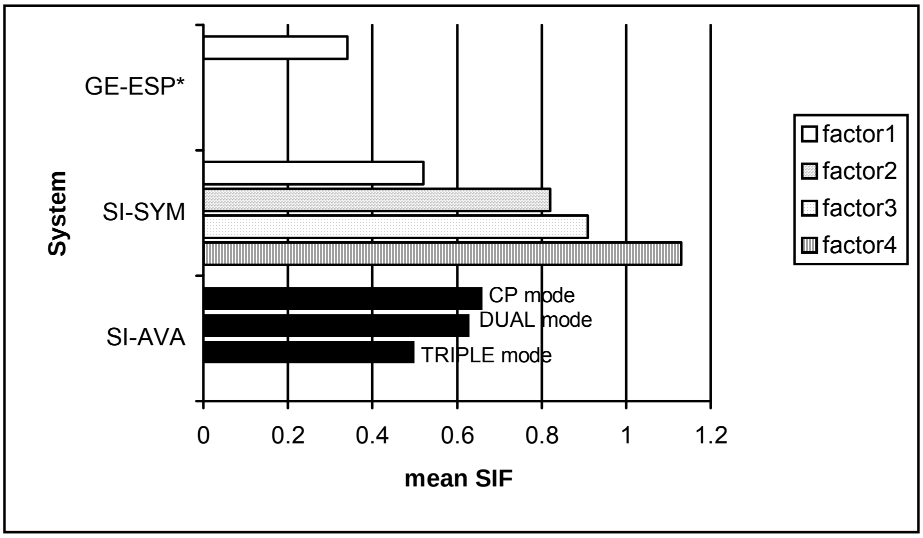
The SIF describes the MRI system's signal stability performance. The SQF compares the measured with the expected-optimal performance of the MRI systems. The optimal value of SQF is unity.

Table 92. Multiple channel head coil signal stability

Imaging mode	Parallel imaging (iPAT) factor	SIF (mean)	SQF (mean)
CP	1	0.40	1.25
Dual	1	0.45	1.64
Triple	1	0.41	1.42

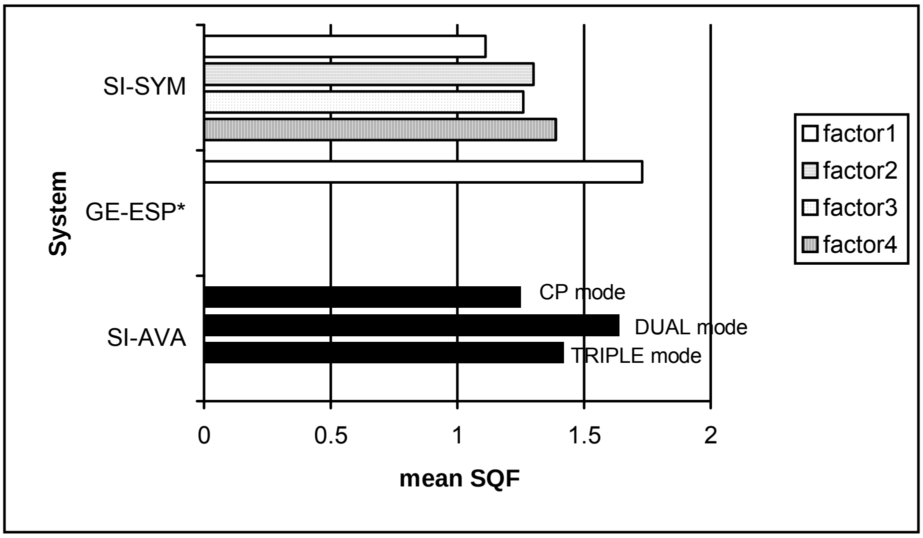
Data for further parallel imaging factors are not available due to time constraints at the time of system technical assessment.

Graph 17: Multi-channel head coil mean signal intensity fluctuation (SIF)



*EPI applicable on the GE system only with parallel imaging factor=1.

Graph 18: Multi-channel head coil mean stability quality factor (SQF)



*EPI applicable on the GE system only with parallel imaging factor=1.
The optimal value of SQF is unity.

Functionality: multiple channel head coil Nyquist ghosting

Scan parameters

Table 93. Quadrature head coil Nyquist ghosting scan parameters

	Standard protocol	Actual protocol
Coil evaluated	Head coil	Head
Test object	FDTO	FDTO
Loading	Internal	Internal
Image plane	TRA	TRA
Position	Iso-centre	Iso-centre
EPI sequence	GRE-EPI	GRE-EPI
TE (ms)	Shortest possible	130
TR (ms)	1500	1500
NSA	1	1
Flip angle (°)	90	90
Bandwidth (Hz/pixel)	Manufacturer's choice	1148
Echo spacing (ms)	Manufacturer's choice	0.92
FOV (PE x FE) (mm)	400 x 400	400 x 400
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
Images	100	100
Scan time (min:sec)	Dependent on shots	2:35

Interpretation of results

Ghosting is calculated as the ratio of maximum Nyquist ghost found in the image background (minus background noise) to image signal x 100. Nyquist ghosting provides the maximum ghosting level in the implemented echo planar imaging (EPI) study.

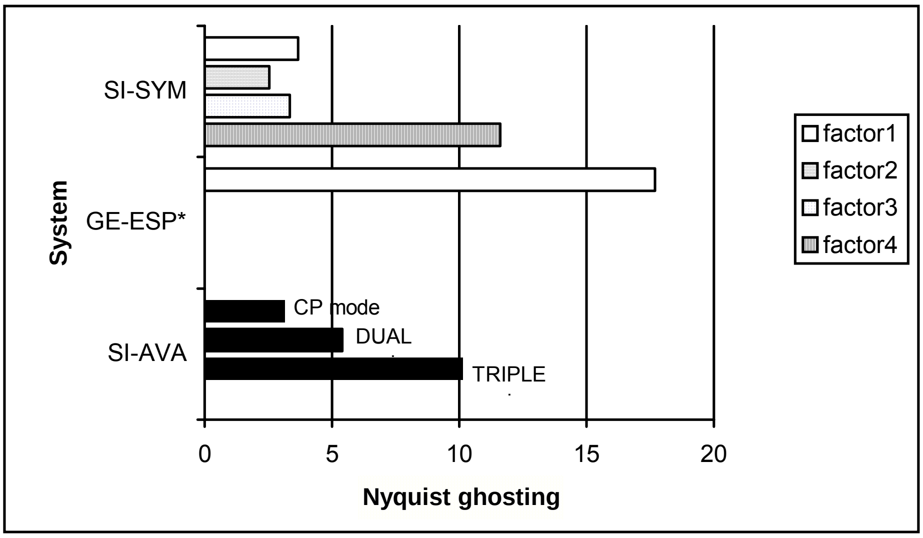
Table 94 shows the measured Nyquist ghosting values. Graph 19 shows a comparison of the measured Nyquist ghosting values with other 1.5 T systems.

Table 94. Multiple channel head coil Nyquist ghosting

Imaging mode	Parallel imaging (iPAT) factor	Nyquist ghosting
CP	1	3.14
Dual	1	5.40
Triple	1	10.14

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

Graph 19: Multi-channel head coil Nyquist ghosting



* EPI applicable on the GE MRI system only with parallel imaging (iPAT) factor =1.
The optimal value is zero.

Functionality: multiple channel head coil ADC measurement

Scan parameters

Table 95. Quadrature head coil ADC measurement scan parameters

	Standard protocol	Actual protocol
Coil evaluated	Head coil	Head
Test object	FDTO	FDTO
Loading	Internal	Internal
Image plane	TRA	TRA
Diffusion gradient direction	x, y, z	x, y, z
EPI sequence	GRE-EPI	Diffusion-weighted EPI
TE (ms)	Shortest possible	100
TR (ms)	1500	1500
NSA	1	1
Flip angle (°)	90	90
Bandwidth (Hz/pixel)	Manufacturer’s choice	1302
Echo spacing (ms)	Manufacturer’s choice	0.81
FOV (PE x FE) (mm)	400 x 400	400 x 400
Matrix (PE x FE)	256 x 256	256 x 256
Slice width (mm)	5	5
k-space sampling	Partial	Partial
b-values	0, 600	0, 600
Images	18	18
Temperature (°C)	Ambient	23
Scan time (min:sec)	Dependent on shots	0:13

Interpretation of results

Results are presented in Table 96. Graph 20, Graph 21 and Graph 22 present a comparison of the ADC measurement for the evaluated MRI systems in the slice encode, frequency encode and phase encode diffusion sensitisation directions, respectively.

The ADC of the solution is equal to that of water: 200×10^{-5} mm^2/s at 20 °C (Mills 1973). A temperature variation of about 5×0 10^{-5} mm^2/s per °C is expected.

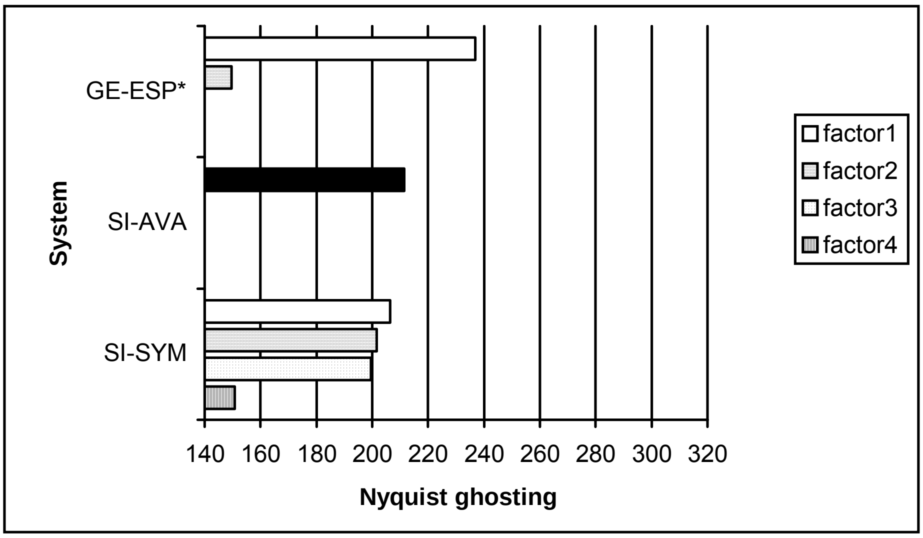
As the diffusion in the test object is isotropic, the measured ADC is expected to be independent of diffusion sensitisation direction and in the region of 200×10^{-5} mm^2/s (allowing for statistical and temperature variations).

Table 96. Multiple channel head coil ADC measurements

Imaging Mode	Parallel imaging (iPAT) factor	ADC x 10^{-5}mm^2/s (slice)	ADC x 10^{-5}mm^2/s (frequencye)	ADC x 10^{-5}mm^2/s (phase)
CP	1	211.35 ± 7.90	202.88 ± 7.69	206.61 ± 7.49

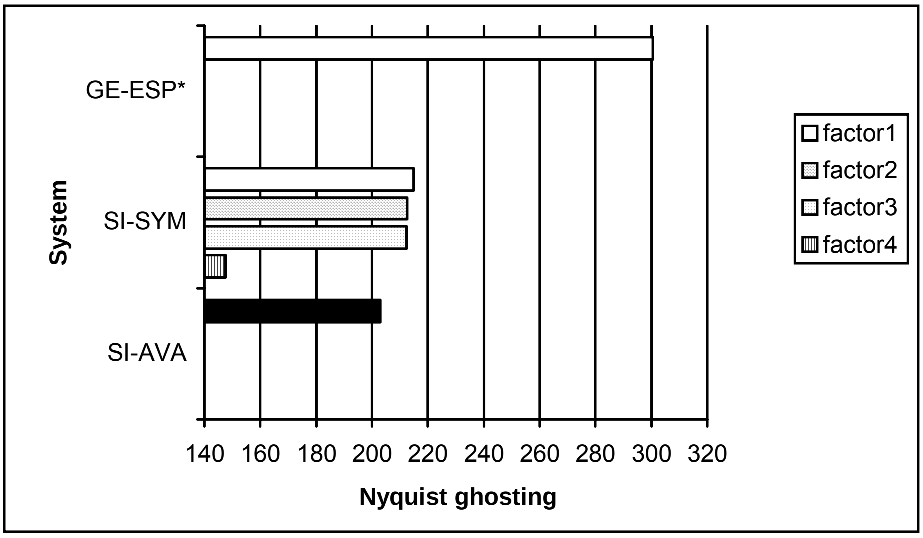
Data for further parallel imaging factors are not available due to time constraints at the time of system technical assessment.

Graph 20. Multiple channel head coil ADC measurements (slice encode diffusion sensitisation direction)



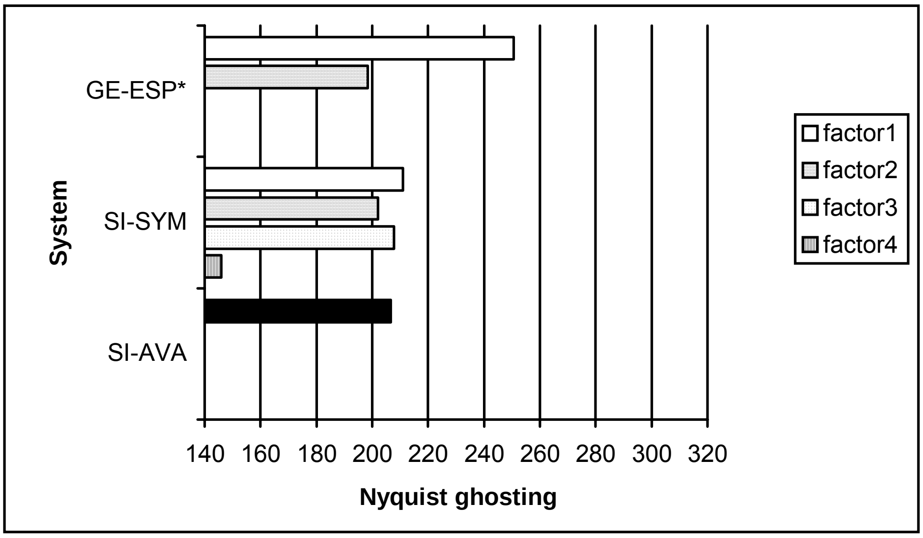
* EPI applicable on the GE MRI system only with parallel imaging factor = 1.

Graph 21. Multiple channel head coil ADC measurements (frequency encode diffusion sensitisation direction)



* EPI applicable on the GE MRI system only with parallel imaging factor = 1.

Graph 22. Multiple channel head coil ADC measurements (phase encode diffusion sensitisation direction)



* EPI applicable on the GE MRI system only with parallel imaging factor = 1.

Parallel imaging evaluation

Parallel imaging head coil: signal to noise ratio (SNR)

Scan parameters

Table 97. Parallel imaging head coil signal to noise ratio (SNR) scan parameters.

	Standard protocol	Actual protocol
Coil	Multiple-channel head coil	Head Matrix
Test object	MAGFF_LOADED	MAGFF_LOADED
Loading	Internal in test-object	Internal in test-object
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Bandwidth (kHz)	Manufacturer’s choice	± 16.64
Temperature (°C)	Ambient	20
Slice width (mm)	5	5
Parallel imaging (iPAT) factors	1, 2, 4, 6	iPAT factors 1, 2, 4
Scan time (min:sec)	4:16, 2:08, 1:04, 0:32	4:18, 2:21, 1:54
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

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

Table 98 shows the measured SNR values. The comparison made in Graph 23 shows the image SNR normalised for voxel size, scan time, coil quality factor, and sampling bandwidth for high-field systems. Details of the normalisation process can be found in the Appendix of this report.

MagNET comment

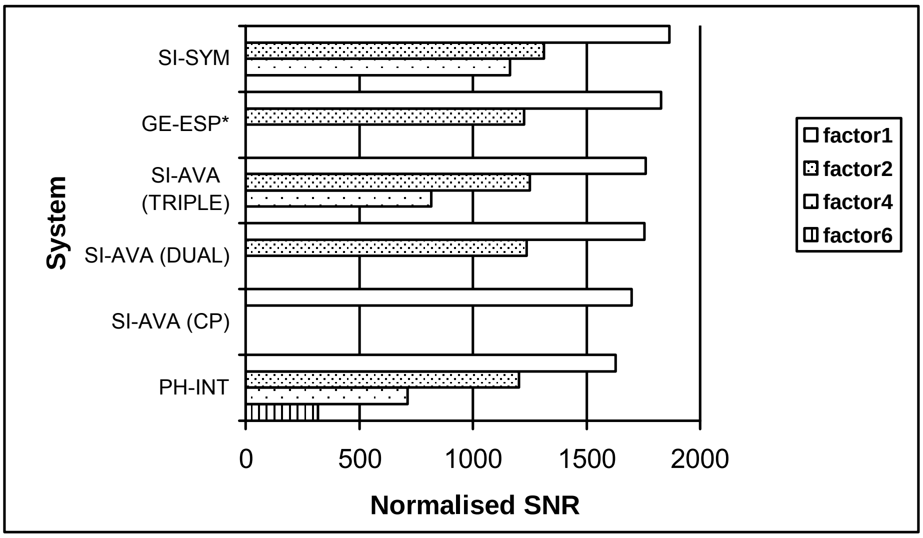
The SNR values for obtained for this coil were average for the 1.5 T systems tested by MagNET in all three imaging modes.

Table 98. Parallel imaging head coil SNR

	Imaging Mode	Parallel imaging (iPAT) factor	Transverse	Sagittal	Coronal	Average
Image SNR	CP	1	158	159	150	156
	Dual	1	175	155	154	161
		2	117	105	118	114
	Triple	1	178	148	159	162
		2	117	112	116	115
		4	67	76	82	75
Normalised SNR	CP	1	1744	1749	1603	1699
	Dual	1	1932	1697	1638	1755
		2	1295	1154	1262	1237
	Triple	1	1964	1626	1693	1761
		2	1287	1233	1235	1252
		4	738	838	876	817

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

Graph 23: Multi-channel head coil normalised SNR (NSNR) (mean of three planes, parallel imaging factors = 1, 2, 4, 6, where applicable)



*GE systems apply a pre-reconstruction Fermi filter as standard. This cannot be switched off during type-testing.

Parallel imaging head coil: uniformity

Scan parameters

Table 99. Parallel imaging head coil: uniformity scan parameters.

	Standard protocol	Actual protocol
Coil	Multiple-channel head coil	Head Matrix
Test object	MAGFF_OIL	MAGGFF_OIL
Loading	Internal in test-object	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Bandwidth (kHz)	Manufacturer's choice	± 16.64
Temperature (°C)	Ambient	20
Slice width (mm)	5	5
Parallel imaging (iPAT) factor	1 (no acceleration)	iPAT factor 1
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

Uniformity measurements are made in all three gradient directions. The fractional uniformity is calculated for each gradient direction from the percentage of pixels that lie within 10% of the mean value of a central ROI.

The results for each gradient direction are presented in Table 100. The mean of the gradient directions for each system is indicated in Graph 24 and Graph 25. Note that the uniformity results for k-space based (GE and Siemens) parallel imaging methods are presented separately from image-based (Philips) parallel imaging methods.

MagNET comment

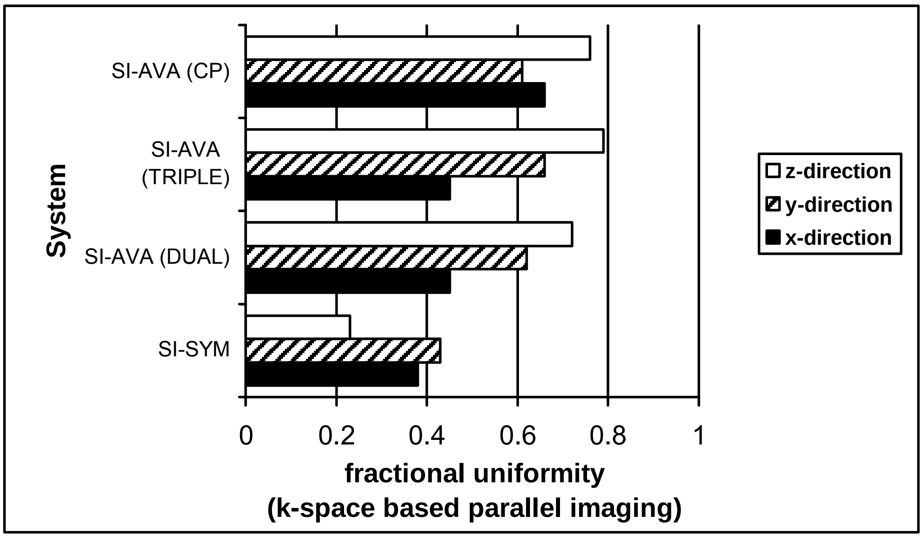
The uniformity values obtained for this coil were above the average for the 1.5 T systems tested by MagNET in all three imaging modes.

Table 100. Multi-channel head coil fractional uniformity (parallel imaging [iPAT] factor = 1) with image-based parallel imaging methods.

Imaging mode	X-direction	Y-direction	Z-direction	Mean ± SD*
CP	0.66	0.61	0.76	0.68 ± 0.07
Dual	0.45	0.62	0.72	0.59 ± 0.13
Triple	0.45	0.66	0.79	0.63 ± 0.16

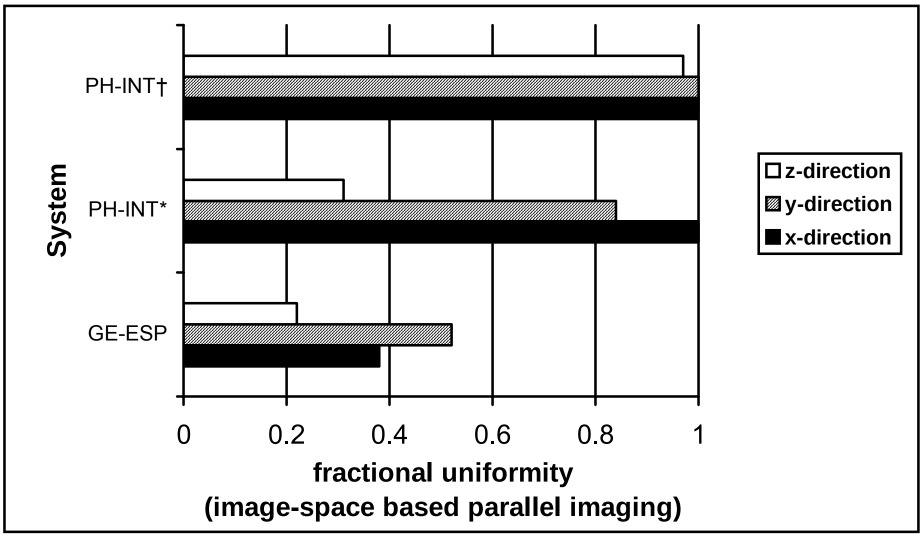
*Standard deviation (SD) of six measurements (2 measurements per gradient direction)

Graph 24: Multi-channel head coil uniformity (parallel imaging [iPAT] factor = 1) with k-space-based parallel imaging methods



The optimum value for fractional uniformity is unity.

Graph 25: Multi-channel head coil uniformity (parallel imaging [iPAT] factor = 1) with image-based parallel imaging methods



*Quadrature mode.
†SENSE mode.
The optimum value for fractional uniformity is unity.

Parallel imaging body coil: signal to noise ratio (SNR)

Scan parameters

Table 101. Parallel imaging body coil signal to noise ratio (SNR) scan parameters.

	Standard protocol	Actual protocol
Coil	Multiple-channel head coil	Body Matrix
Test object	MAGFF_LOADED	MAGFF_LOADED
Loading	Internal in test-object	Internal in test-object
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Bandwidth (kHz)	Manufacturer’s choice	± 16.64
Temperature (°C)	Ambient	20
Slice width (mm)	5	5
Parallel imaging (iPAT) factors	1, 2, 4, 6	iPAT factors 1, 2
Scan time (min:sec)	4:16, 2:08, 1:04, 0:32	4:18, 2:21
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

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

The image SNR and normalised SNR results for the built-in body coil are presented in Table 102. The comparison made in Graph 26 shows the image SNR normalised for voxel size, scan time, coil quality factor, and sampling bandwidth for systems with equivalent field strength.

MagNET comment

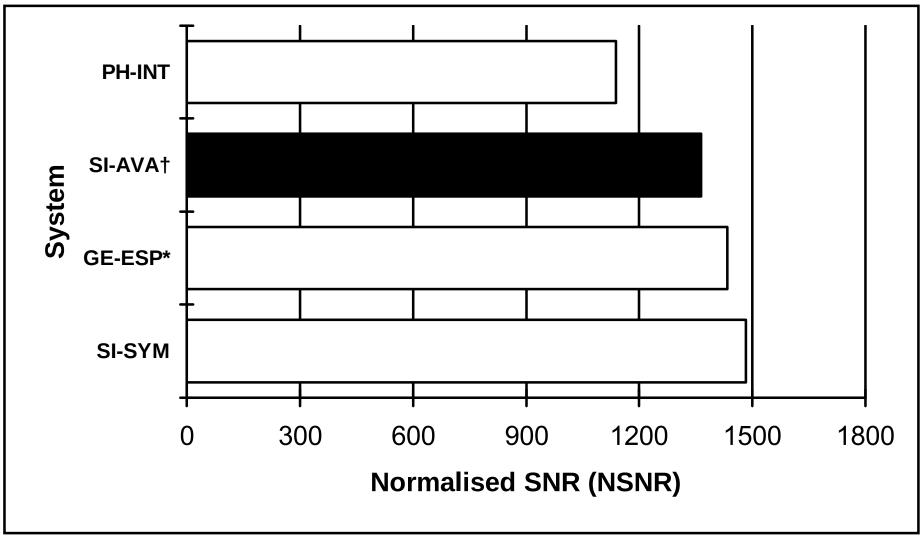
The normalised SNR was average when compared to the multiple-channel body coils of 1.5 T systems tested by MagNET.

Table 102: Signal to noise ratio for the parallel imaging body coil (Body Matrix)

	Imaging mode	Parallel imaging (iPAT) factor	Transverse	Sagittal	Coronal	Mean
Image SNR	CP	1	146	153	120	140
	CP	2	76	Not available	Not available	Not available
	DUAL	1	150	Not available	Not available	Not available
	DUAL	2	93	Not available	Not available	Not available
	TRIPLE	1	146	Not available	Not available	Not available
	TRIPLE	2	109	Not available	Not available	Not available
Normalised SNR	CP	1	1421	1497	1176	1364
	CP	2	742	Not available	Not available	Not available
	DUAL	1	1464	Not available	Not available	Not available
	DUAL	2	910	Not available	Not available	Not available
	TRIPLE	1	1421	Not available	Not available	Not available
	TRIPLE	2	1059	Not available	Not available	Not available

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

Graph 26. Comparison of normalised SNR for multi-channel body coils (mean of three planes, parallel imaging [iPAT] factor = 1)



*GE systems apply a pre-reconstruction Fermi filter as standard, which increases the SNR level. This cannot be switched off during type-testing

† CP mode

Parallel imaging body coil: uniformity

Scan parameters

Table 103. Parallel imaging body coil uniformity scan parameters.

	Standard protocol	Actual protocol
Coil	Multiple-channel body coil	Body Matrix
Test object	MAGFF_OIL	MAGFF_OIL
Loading	None	None
Sequence	SE	SE
TE (ms)	30	30
TR (ms)	1000	1000
NSA	1	1
FOV (mm)	250	250
Matrix (PE x FE)	256 x 256	256 x 256
Bandwidth (kHz)	Manufacturer’s choice	± 16.64
Temperature (°C)	Ambient	20
Slice width (mm)	5	5
Parallel imaging (iPAT) factor	1 (no acceleration)	iPAT factor 1
Scan time (min:sec)	4:16	4:18
Image plane	TRA, SAG, COR	TRA, SAG, COR

Interpretation of results

The fractional uniformity was calculated over a distance of 160 mm, with the midpoint positioned at the centre of the test object. The optimum value is 1, indicating 100% of the signal is considered uniform over the measured distance.

The MagNET protocol specifies that the fractional uniformity should be calculated as the fraction of the profile lying within ±10% of its mean value.

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

The fractional uniformity measurements for each direction and plane for the built-in body coil are presented in Table 104. Graph 27 shows the mean fractional uniformity for systems with equivalent field strength. The signal intensity profiles for each direction are shown in Graph 28 and Graph 29 for CP and DUAL imaging modes, respectively.

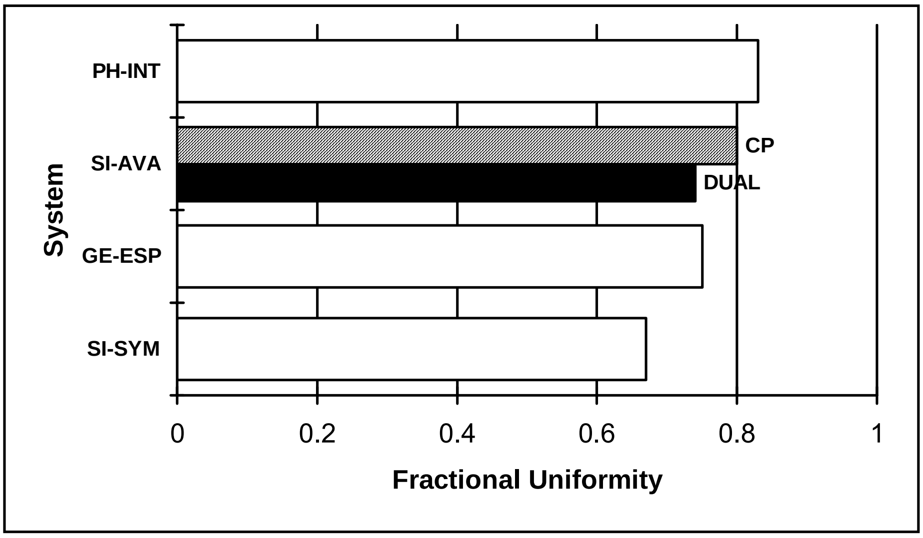
MagNET comment

The uniformity for the parallel imaging body coil was above the average of the 1.5 T systems tested by MagNET in both imaging modes.

Table 104: Fractional uniformity for the multi-channel body coil (Body Matrix)

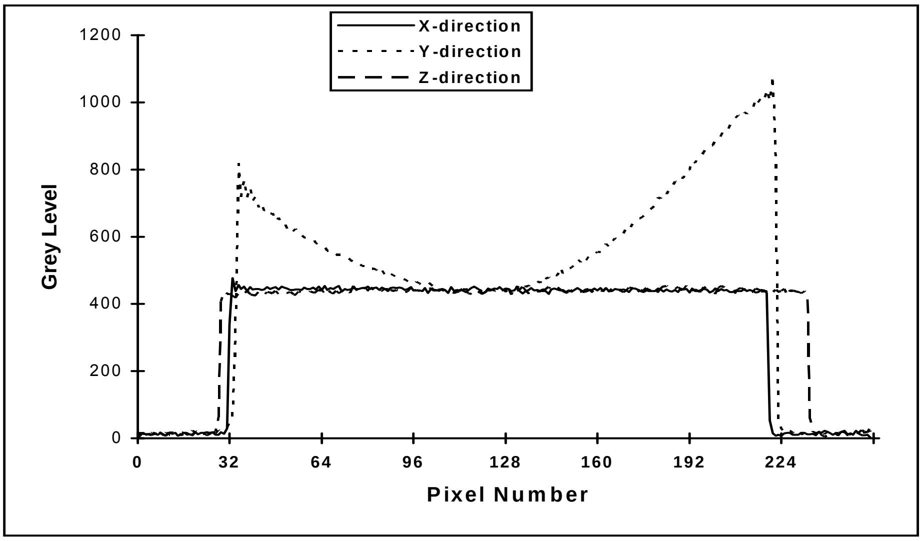
Gradient direction	Imaging mode	Parallel imaging (iPAT) factor	Transverse	Sagittal	Coronal	Mean± SD
X-direction	CP	1	1.00	-	1.00	1.00 ± 0.00
Y-direction	CP	1	0.40	0.39	-	0.40 ± 0.01
Z-direction	CP	1	-	1.00	1.00	1.00 ± 0.00
X-direction	DUAL	1	0.80	-	0.78	0.79 ± 0.01
Y-direction	DUAL	1	0.43	0.44	-	0.44 ± 0.01
Z-direction	DUAL	1	-	1.00	1.00	1.00 ± 0.00

Graph 27: Comparison of fractional uniformity for multi-channel body coils (mean of three planes).

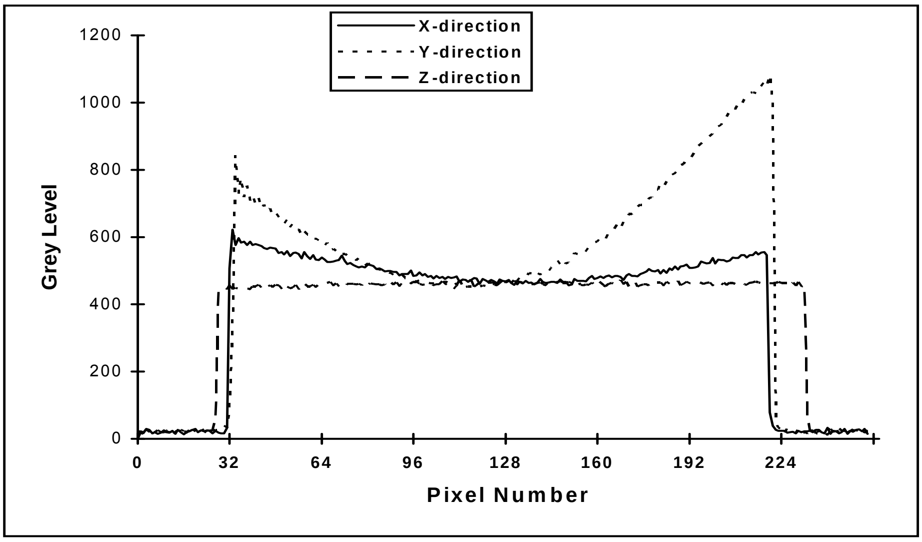


The optimum value is unity.

Graph 28: Signal intensity profiles in x-, y-, and z-directions for multi-channel body coil in CP imaging mode.



Graph 29: Signal intensity profiles in x-, y-, and z-directions for multi-channel body coil in DUAL imaging mode.



Parallel imaging head coil: clinical fast sequences – multiple slice measurements

Scan parameters

Table 105. Multiple slice measurements scan parameters.

		Standard protocol	Actual protocol
Coil(s) evaluated		Head coil	Head Matrix
Test object		TO1 and TO4A	MAG_BARS
Loading		None	None
Sequence		SE	SE
TE (ms)		Manufacturer's choice	15
TR (ms)		Manufacturer's choice	1170
NSA		Manufacturer's choice	1
FOV (mm)		250	250
Image plane		TRA	TRA
Matrix (PE x FE)	I	Maximise	1024 x 1024
Slice width (mm)	II	Minimise	0.5
Contiguous slices	III	Maximise	46
Scan time (min:sec)	IV	Minimise	19:59

Roman numerals I to IV indicate the order in which the scan parameters are prioritised.

Maximum 2D slices

Acquire the maximum number of 2D slices using the actual protocol in Table 105, but with the scan parameter priorities re-ordered to:

I	Contiguous slices
II	Matrix
III	Slice width
IV	Scan time

Single slice acquisition

Repeat the multiple slice protocol in Table 105 twice (once in each test object) but with a single slice.

Interpretation of results

The multiple slice acquisition protocol is chosen with the objective of maximising the coverage with good resolution. Table 106 presents a comparison of multiple slice protocols on systems of equivalent field strength.

Table 107 presents the protocols used for acquiring a maximum number of 2D slices. This test is part of MagNET's new protocol and thus comparative protocols are not available.

Table 108 provides a comparison of SNR, uniformity, and resolution performance between the multiple and single slice acquisitions for this system. The nominal pixel dimension is given in brackets.

Table 106: Results 1 - Multiple slice acquisition protocols for 1.5 T systems

System	Matrix	Slice width (mm)	No. of slices	Scan time (mins)	TE (ms)/TR (ms)/NSA
PH-INT	1024 x 1024	0.5	26	19:55	13/3000/1
SI-AVA	1024 x 1024	0.5	46	19:59	15/1170/1/
SI-SYM	1024 x 1024	1.3	50	19.86	14/1160/1
SI-SON	1024 x 1024	0.8	56	19.86	13/1160/1

Ordered on (I) matrix, (II) slice width, (III) number of slices and (IV) scan time

Table 107: Results 2 - Maximum 2D slices for 1.5 T systems

System	No. of slices	Matrix	Slice width (mm)	Scan time (mins)	TE (ms)/TR (ms)/NSA
PH-INT	256	96 x 96	0.5	13:40	31/5435/1
SI-AVA	128	192 x 192	0.1	16:36	34/5160/1
SI-SYM	90	256 x 256	0.1	21.83	42/4630/1
SI-SON	106	256 x 256	0.1	19:51	36/4630/1

Table 108: Results 3 - Multiple slice and single slice performance comparison for 1.5 T systems

	Comment
SNR	Comparable
Uniformity	Not measured
Resolution (0.24 mm)	Images too noisy to measure resolution because of small voxel size

Parallel imaging head coil: clinical fast sequences – 2D and 3D imaging speed

Scan Parameters

Table 109. Measurements with clinical fast sequences basic scan parameters.

	Standard protocol	Actual protocol
Coil evaluated (standard)	Head coil	Head Matrix coil
Test object	TO1A	MAGFF_LOADED
Loading	MAG_ANN	Internal in test object
Image plane	TRA	TRA

Standard clinical 2D fast sequence

The basic scan parameters used are shown in Table 109. The additional scan parameters used in the 2D fast imaging test are shown in Table 110.

Table 110. Standard clinical 2D fast sequence scan parameters.

		Standard protocol	Actual protocol
2D sequence		Manufacturer’s choice	2D GE EPI
TE (ms)		Manufacturer’s choice	141
TR (ms)		Manufacturer’s choice	11060
Flip angle (degrees)		Manufacturer’s choice	90
NSA		Manufacturer’s choice	1
FOV (mm)		250	250
Matrix (PE x FE)		256 x 256	256 x 256
Slice width (mm)		Less than 5 mm	5.0
Parallel imaging factors		1, 2, 4, 6	iPAT factors 1, 2, 3, 4
Range (mm)	I	To equal 200	200
Contiguous slices	II	Maximise	40
Scan time* (sec)	III	Minimise	11, 12, 20, 19

* This is the predicted scan time displayed on the scanner’s console prior to scanning.
Roman numerals I to III indicate the order in which the scan parameters are prioritised.

Standard clinical 3D fast sequence

The scan parameters used in the 3D fast imaging test are shown in Table 111. These are used in addition to the basic scan parameters shown in Table 109.

Table 111. Standard clinical 3D fast sequence scan parameters.

		Standard protocol	Actual protocol
3D sequence		Manufacturer's choice	3D FLASH
TE (ms)		Manufacturer's choice	0.67
TR (ms)		Manufacturer's choice	1.7
Flip angle (degrees)		Manufacturer's choice	5
NSA		Manufacturer's choice	1
FOV (mm)		250 x 250 x RG	200 x 200 x RG
Matrix (PE x FE)		128 x 128	128 x 128
Slice width (mm)		Manufacturer's choice	5
Parallel imaging factors		1, 2, 4, 6	iPAT factors 1, 2, 3, 4
Range (mm)	I	To equal 200	200
Contiguous slices	II	Maximise	40
Scan time (sec)	III	Minimise	7.0, 3.7, 2.8, 2.4

Roman numerals I to III indicate the order in which the scan parameters are prioritised.

Interpretation of results

Both the 2D and 3D imaging speed tests require a fixed volume to be acquired using standard clinical 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 matrix and the number of slices in the fixed range. Tests 3 and 4 allow for the use of parallel imaging techniques.

Table 112 gives the 2D and 3D imaging speeds measured on this system for parallel imaging techniques. Graph 30 and Graph 31 present comparisons of 2D imaging speed values for systems requiring pre-scanning prior to each acquisition and those not requiring pre-scanning prior to each acquisition, respectively. Graph 32 shows a comparison of 3D imaging speed obtained for systems of 1.5T. Details of the 2D and 3D sequences used for each of these systems are given in the Appendix to this report.

MagNET comment

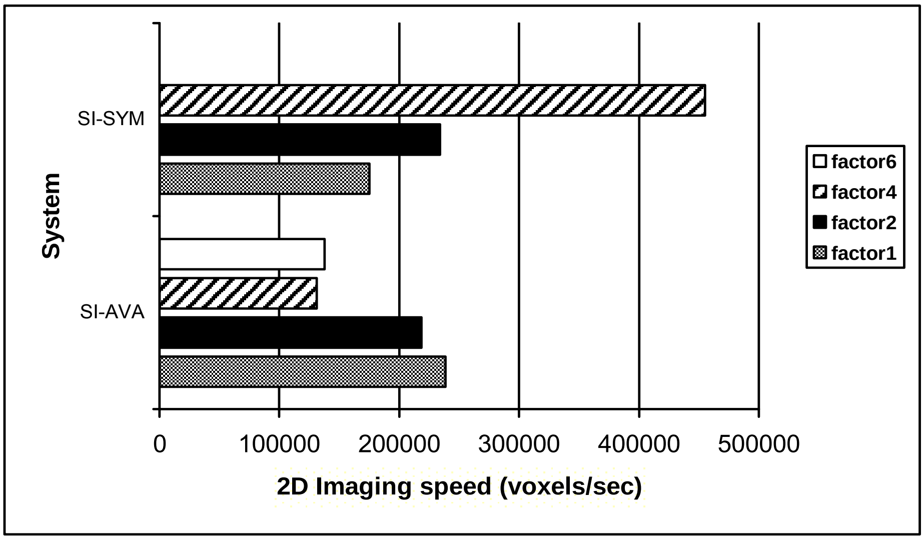
In calculating the 2D imaging speed, scan time displayed by the scanner, rather than the nominal repetition time (TR), has been used. Readers are made aware that pre-scanning (sensitivity scanning) is a pre-requirement for scanning with parallel-imaging coils. Systems utilising k-space based parallel imaging methods, such as the Siemens MAGNETOM Avanto, require this pre-scan to be performed prior to each acquisition and this pre-scan time has been included in the total scan time when calculating the 2D imaging speed. Systems utilising image-based parallel imaging methods require this pre-scan to be performed only once and hence this pre-scan time has not been included when calculating the 2D imaging speed.

The 3D imaging speed was above the average for the 1.5 T systems tested by MagNET for parallel imaging (iPAT) factors 1, 2 and 4.

Table 112. Imaging speed using parallel imaging

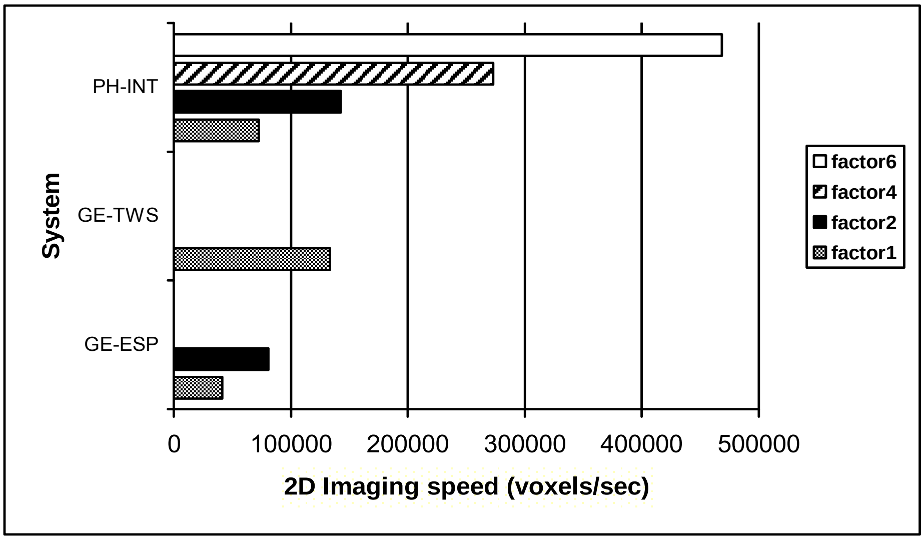
Imaging mode	Parallel imaging (iPAT) factor	2D imaging speed (voxels per second)	3D imaging speed (voxels per second)
Triple	1	238313	93623
	2	218453	177124
	4	131072	234057
	6	137971	273067

Graph 30. Comparison of 2D imaging speed using parallel imaging for systems using k-space based parallel imaging methods.



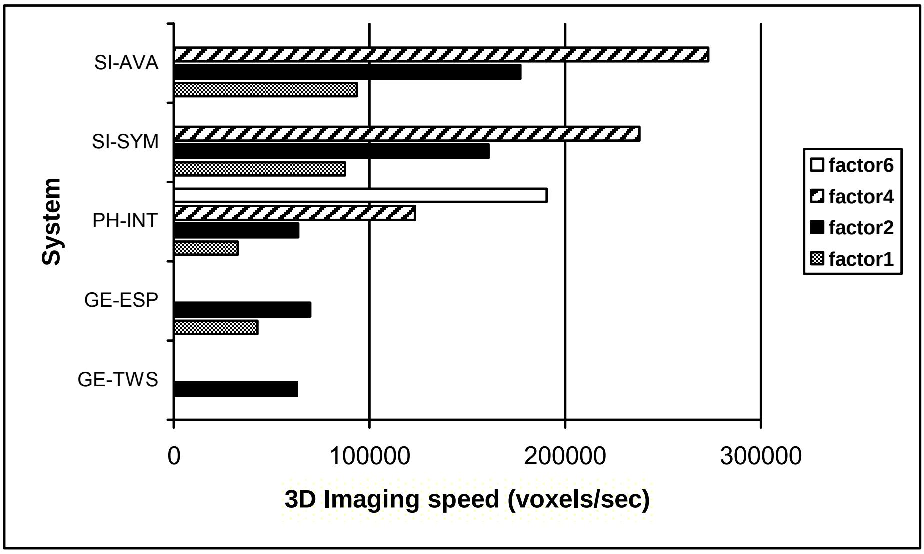
Please interpret the results with sequences in mind

Graph 31. Comparison of 2D imaging speed using parallel imaging for systems using image based parallel imaging methods.



Please interpret the results with sequences in mind

Graph 32. Comparison of 3D imaging speed using parallel imaging



Conclusion

Technical summary tables

MagNET comment

The CP Head Coil is not supplied as standard with the Siemens MAGNETOM Avanto 1.5T system. The head imaging coil supplied with this system is the Head Matrix Coil and the imaging performance tests for this coil are shown on Page 68.

The Avanto maintains, however, backwards compatibility with the CP Head Coil supplied with the Siemens MAGNETOM Symphony and Sonata systems.

Table 113. Comparison of performance of the Siemens MAGNETOM Avanto 1.5 T system with mean of all 1.5 T systems evaluated by MagNET-conventional imaging

Coil	Parameter	Optimum value	Mean ± SD	No. of systems	SI-AVA
CP Head	SNR (normalised)	Maximum	1385 ± 200	7	1347
	Uniformity	1.00	0.94 ± 0.05	7	0.93
	PE pixel size (mm)	0.98	1.09 ± 0.09	7	1.02
	FE pixel size (mm)	0.98	1.07 ± 0.03	7	1.02
	Linearity (mm)	120.0	120.1 ± 0.3	7	120.3
	Distortion	0.00	0.40 ± 0.24	7	0.40
	3 mm slice width (mm)	3.0	3.1 ± 0.1	7	3.2
	5 mm slice width (mm)	5.0	5.2 ± 0.2	7	5.3
	Ghosting (NSA =1)	0	0.36 ± 0.25	7	0.19
	Ghosting (NSA =2)	0	0.31 ± 0.17	7	0.16
	Slice position	0	0.11 ± 0.23	5	0.05
In-Built Body	SNR (normalised)	Maximum	333 ± 73	7	238
	Uniformity	1.00	0.99 ± 0.01	7	0.98
	Geometric distortion over large field of view (x-gradient direction) (mm)	0	-	1	1.21
	Geometric distortion over large field of view (y-gradient direction) (mm)	0	-	1	0.69

Table 114. Comparison of performance of the Siemens MAGNETOM Avanto 1.5 T system with mean of all 1.5 T systems evaluated by MagNET- parallel imaging

Coil	Parameter	Optimum value	Mean ± SD	No. of systems	SI-AVA
Head Matrix	SNR (normalised)				
	Parallel imaging (iPAT) factor 1	Maximum	1733 ± 136[*]	5	1699[†] 1755[‡] 1761[§]
	Parallel imaging (iPAT) factor 2	Maximum	1206 ± 118[*]	5	1237[‡] 1252[§]
	Parallel imaging (iPAT) factor 4	Maximum	862 ± 281	3	817[§]
	Parallel imaging (iPAT) factor 6	Maximum	221	1	-
	Uniformity	1.00	0.62 ± 0.22	7	0.68[†] 0.59[‡] 0.63[§]
	2D imaging speed				
	Parallel imaging (iPAT) factor 1	Maximum	103723 ± 93033	4	237020
	Parallel imaging (iPAT) factor 2	Maximum	124289 ± 52824	6	455111
	Parallel imaging (iPAT) factor 4	Maximum	224394 ± 75044	3	1248305
	3D imaging speed				
	Parallel imaging (iPAT) factor 1	Maximum	61035 ± 28189	4	93623
	Parallel imaging (iPAT) factor 2	Maximum	93588 ± 52148	6	177124
	Parallel imaging (iPAT) factor 4	Maximum	197679 ± 74858	3	273067

[*] Normalised SNR without filtration, however includes results from the GE TwinSpeed system on which the image filters cannot be disabled.

[†] CP Mode

[‡] Dual Mode

[§] Tripe Mode

Overall comments on technical performance

Table 115: Overall comments on technical performance

Evaluation	Parameter	Comment
CP Head coil evaluation	SNR (normalised)	Below average*
	Uniformity	Above average*
	PE pixel dimension	Within experimental error†
	FE pixel dimension	Within experimental error†
	Linearity	Within experimental error‡
	Distortion	Better than average*
	3 mm slice width	Within experimental error§
	5 mm slice width	Within experimental error§
	Ghosting (NSA = 1)	Better than average* performance
	Ghosting (NSA = 2)	Better than average* performance
	Slice position	Within experimental error**
In-built body coil evaluation	SNR (normalised)	Below average*
	Uniformity	Average*
	Geometric distortion over large field of view	No comparison data
Head Matrix coil evaluation	SNR (normalised)	Average*
	Uniformity	Above average*
	2D imaging speed	No comparison data available
	3D imaging speed	Above average*
Body Matrix coil evaluation	SNR (normalised)	Average*
	Uniformity	Above average*

*“Average” is defined as the mean value measured on all 1.5 T systems assessed by MagNET.
†Defined as an error of ±10% of the nominal pixel size.
‡Defined as an error of ± 1mm of the nominal measurement distance of 120 mm.
§Defined as an error of ±10% of the nominal slice width.
**Defined as an error of ± 1mm of the nominal slice position

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References

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Weisskoff RM (1996) Simple measurement of scanner stability for functional NMR imaging of activation in the brain, *Magnetic Resonance in Medicine,* **36**(4), 643-645.

Appendix

Manufacturer’s comments

Quadrature head coil: signal to noise ratio (SNR)

The values provided are measurements from the CP Head Array coil which has been already been tested by MagNET for the Symphony. The Avanto is usually supplied with the new Head Matrix Coil which has a better SNR performance. The customer can use the CP Head Array coil from Symphony/Sonata, if already present at the site, with the Avanto but this coil is not usually supplied with the Avanto. The Tim features are only available if the new Head Matrix Coil is used. Therefore we recommend providing image quality results for the new Head Matrix Coil since these have already been published in MagNET’s Diffusion and Perfusion report, issue 2 (MHRA 4036).

MagNET comment:

The SNR values for the Head Matrix Coil are included in this report (page 68) for a number of imaging modes and parallel imaging factors. The SNR results for the CP Head Coil were included in this report because of this backwards compatibility of the Avanto with other MAGNETOM family coils.

Parallel imaging head coil: signal to noise ratio (SNR)

Evaluation or comparison on images acquired using parallel imaging techniques may be highly questionable because the noise background is not uniform so the results are strongly dependent on the ROI choice.

MagNET comment:

MagNET recognises that the image noise can be spatially dependant in images acquired using parallel imaging techniques. An average is taken from 5 ROIs placed on the image.

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

The normalized SNR is strongly dependent on the measured Q factors. 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 on the obtained normalized SNR values. The reader should be aware of this when comparing different systems. 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.

Clinical imaging speed – 2D

The repetition time (TR) should be used as the time reference instead of scan time in calculating the 2D imaging speed, as done so in MagNET's Diffusion and Perfusion report, issue 2 (MHRA 4036) for the Avanto. The preparation scans - necessary for parallel imaging - are only done once for one setting. The overall measurement time scales with the repetition time:

Scan time = preparation scan time + number of measurements x repetition time

Therefore the imaging speed is characterized by the repetition time.

MagNET comment:

The scan time displayed by the scanner, rather than the nominal repetition time (TR), has been used in calculating the 2D imaging speed. This is to maintain consistency with MagNET's tests in all previously published single-product reports. Readers should be aware that pre-scanning is a requirement for scanning with parallel-imaging coils, and some manufacturers' sequences do not include this pre-scanning time in the displayed scan time.

Manufacturer's QA method

To keep maintenance times short, the standard QA procedures only include those items which are influenced by not very obvious degradation of system components performance. These are signal to noise ratio (SNR) and ghosting, due to instabilities for any reason, and gradient sensitivity (GradSens). GradSens, which determines the image scale (geometric linearity) and slice thickness, is checked using the same image data sampled for SNR evaluation. The above parameters are evaluated using methods that are equivalent, though not identical, to the procedures outlined this report. These QA measurements are accessible to the user and can be performed as frequently as believed necessary.

There are no special procedures for modulation transfer function (MTF), slice profile, and distortion. These performance factors are believed by the company to change little over time. MTF, which is an indicator of resolution, is a matter of dynamic field errors (eddy fields) which are minimal by design because the system has an actively shielded gradient coil. Slice profile is a matter of sequence design and, with respect to scaling (slice thickness), a matter of GradSens. Distortion is governed by gradient coil design, which is invariant. It is also governed by the second and higher order shim status, that is optimised during system installation. Dynamic field errors (of zero and first order including cross eddy fields) as well as shim status up to third order can be checked by special fully automated (local or remotely controlled) phantom measurements, however. In contrary to the standard QA, these procedures require more expertise and are therefore reserved to the service engineer. In case of image quality problems identified in the QA procedure, the service engineer has the facilities to analyse specifically the source of the problem.

For customers asking for direct demonstration of spatial resolution, slice profile, distortion, etc. a multipurpose phantom is optionally available. This phantom has test objects inside that are similar to those used in this assessment report. The evaluation procedures are also equivalent.

Procedures

Table 116. Manufacturer’s QA procedures- SNR

Procedure	Details
Parameter measured	SNR
Coils:	Body coil, head coil, all optional coils
Test objects:	Body loader and 24 cm sphere for the built in body resonator, 7l bottle for the head coil (loading adjusted to mimic a human head by doping with NaCl) and – if necessary - dedicated phantoms for all local coils
Scanning protocol:	Gradient echo sequence, flip angle = 60°, TR = 300 ms, TE = 10 ms, bandwidth = 130 Hz/pixel, slice thickness = 3 mm, matrix = 256 x 256, 1 acquisition, FOV body=300 x 300 mm^2, FOV head = 250 x 250 mm^2

Table 117. Manufacturer’s QA procedures - ghosting level

Procedure	Details
Parameter measured	Ghosting (signal intensity of background after subtraction of averaged noise level)
Coils:	Body coil
Test objects:	Body loader and 24 cm sphere
Scanning protocol	Double spin echo sequence, TR = 600 ms, TE = 35 ms and 105 ms, bandwidth = 130 Hz/pixel, slice thickness = 10 mm, matrix = 256 x 256, 1 acquisition, FOV = 500 x 500 mm^2

Table 118. Manufacturer’s QA procedures - image scale

Procedure	Details
Parameter measured	Image scale (geometric linearity, gradient sensitivity)
Coils:	Body coil
Test objects:	Body loader and 24 cm sphere
Scanning protocol:	Gradient echo sequence, flip angle = 40°, TR = 50 ms, TE = 10 ms, bandwidth = 130 Hz/pixel, slice thickness = 10 mm, matrix = 256 x 256, 1 acquisition, FOV body and head = 350 x 350 mm^2

Results

Table 119. Manufacturer's QA results - head matrix coil SNR

Image Plane	Specification
HE1 (head, anterior)	>75
HE2 (head, posterior)	>80
HE3 (feet, anterior)	>50
HE4 (head, posterior)	>55

Table 120. Manufacturer's QA results - body coil SNR

Image Plane	Specification
Transverse	>26

Table 121. Manufacturer's QA results - ghosting level

Image Plane	Specification	
	1st echo	2nd echo
Transverse	<2%	<3%
Sagittal	<2%	<3%
Coronal	<2%	<3%

Table 122. Manufacturer's QA results - image scale

Image Plane	Specification
Transverse	(240 ± 4) mm
Sagittal	(240 ± 4) mm
Coronal	(240 ± 4) mm

Background information

MagNET

The assessment reported on the preceding pages was carried out by the Magnetic resonance National Evaluation Team (MagNET) based at Imperial College London. The project is supported by the Department of Health to assess the imaging performance of commercially available clinical MR systems. Resources from the National Health Service fund the project.

Medicines and Healthcare products Regulatory Agency (MHRA)

One of the roles of the MHRA, an executive agency of the Department of Health, is to manage evaluation programmes for medical devices and equipment. MHRA's Device Evaluation Service (DES) business unit is responsible for this work. The evaluation of magnetic resonance imaging equipment is part of the diagnostic imaging evaluation programme also covering computed tomography and both general and digital x-ray equipment, including mammography.

MHRA is also the Competent Authority for medical devices in the UK, with responsibilities for negotiating European Directives and implementing and enforcing UK Regulations for medical devices. MHRA's European and Regulatory Affairs section is responsible for this work and regularly issues guidance on the Regulations. MHRA's Device Technology and Safety Group is responsible for investigating adverse incidents associated with medical devices and their use, and helping to prevent further incidents by communicating findings to those who make or use the devices. Further details about MHRA and its activities can be found by visiting the MHRA website (www.mhra.gov.uk)

Manufacturer involvement

The choice of MR system to be evaluated is influenced by both new system releases and customer demand. Both the user and clinical evaluations are performed with the active participation of the manufacturer. The clinical sites are chosen by MagNET from a short-list provided by the manufacturer. The technical evaluation is carried out at a site agreed with the manufacturer, where the performance of the system is within specification and is representative of that model. Acknowledgement is made to the company for arranging and supporting the examination of MR equipment. A copy of each report is sent to the manufacturer of the equipment for comment before publication. These comments are included in the published report.

Availability of other reports

Information on previous and future MR evaluation reports is given on the MagNET website. This evaluation report is one of a series issued regularly by the Department of Health. For information on reports from other modalities contact the MHRA.

Contact details

MagNET

In addition to answering queries on the evaluation reports, MagNET can provide advice on detailed specification, general MR technology, acceptance testing and quality assurance.

Dr J P De Wilde
Manager
MagNET
Department of Bioengineering
Bagrit Centre
Imperial College London
London SW7 2AZ

☎ Tel: 020 7594 6306
Fax: 020 7594 6337

💻 E-mail: j.dewilde@imperial.ac.uk
General: enquiry@magnet-mri.org
Web page: http://www.magnet-mri.org/

MHRA general enquiries

Device Evaluation Service
Medicines and Healthcare products Regulatory Agency
Hannibal House
Elephant and Castle
London SE1 6TQ.

☎ Tel: 020 7972 8155
Fax: 020 7972 8105

💻 E-mail: des@mhra.gsi.gov.uk
Web page: http://www.mhra.gov.uk/