The Challenges of CT Accreditation: Introduction

Thomas G. Ruckdeschel, MS, DABR
Diagnostic Radiological Physicist
Medical Nuclear Physicist
Alliance Medical Physics LLC

Outline

- Acknowledgements
- Resources
- Common Reasons for Failure
- ACR Accreditation: Table I
- GE Scanners
- Siemens Scanners
- Philips Scanners
- Toshiba Scanners
- Electronic Submission
- Panel Discussion

Disclaimer

- ACR CT Accreditation Physics Subcommittee
  - Charter member
  - Reviewer
- Alliance Medical Physics LLC
  - President
  - Medical Physics Consultant

Acknowledgements

- ACR CT Accreditation Physics Subcommittee
  - Dianna Cody, PhD Co-Chair
  - Doug Pfeiffer, MS Co-Chair
  - Cynthia McCollough, PhD
    - Former Chair
  - Michael McNitt-Gray, PhD
  - Thomas Payne, PhD
- ACR Staff
  - Theresa Branham
  - Dina Hernandez
  - Krista Bush
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- Siemens Healthcare
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- Philips Healthcare, N.A.
- Toshiba America Medical Systems
  - Rich Mather, PhD
  - Kirsten L. Boedeker, PhD

Resources

- ACR
  - 1-800-227-5483
    - Staff available to answer questions
    - Technical questions passed onto Physics subcommittee
  - www.acr.org/accreditation
- Medical Physicist
- Vendor
  - Service engineer
  - Applications Support
  - Operators Manual
  - Tips for Accreditation
- ImPACT
  - ImPACTscan.org

ACR

- Phantom Testing Instructions
- Phantom Testing Criteria
  - Take home test with the answers!
- Medical Physics 31(9) September 2004
  - Practical Tips, Artifact Examples, Pitfalls to Avoid
- FAQ’s
  - Detector configurations (GE LS example)
  - Helical to axial conversion
  - Toshiba Dose
  - Toshiba FOV and CT numbers
Resource Personnel

- Qualified Medical Physicist
  - Qualifications submitted to ACR with Entry Application
  - Experience with various scanners
- Service Engineer
  - Familiar with scanner operations and capabilities
  - Should be available to correct deficiencies
  - Service Mode access
- Applications Support
  - Familiar with scanner operations and capabilities
Scanner's Operators Manual

- **Pro's**
  - Detector configurations
  - Available slice reconstructions
  - Parameters are defined

- **Con's**
  - Not always easily accessible
  - Soft copies
  - May be difficult to find what is needed

- **Tips for Accreditation**
  - Supplied by some vendors upon request

Common Reasons for Failure

- **Failure to follow instructions**
- **Phantom Alignment**
  - Major Failure
- **Improper scanning parameters used**
  - Table I protocols do not match Protocols used
  - Helical to Axial conversions
  - mA vs effective mA
  - Medical Physicist vs Technologist
- **Low Contrast Detectability**
  - Cannot visualize at least all four 6 mm rods
- **Dose**
  - Incorrect parameters used
  - Dose Calculator Excel Spreadsheet must be used

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### ACR Phantom Gammex 464

<table>
<thead>
<tr>
<th>Phantom</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACR Phantom</td>
<td>Gammex 464</td>
</tr>
</tbody>
</table>

**Table I: Protocol (No. of slices, slice thickness, & protocol)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Protocol 1</th>
<th>Protocol 2</th>
<th>Protocol 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of slices</td>
<td>100</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>Slice thickness</td>
<td>1mm</td>
<td>2mm</td>
<td>3mm</td>
</tr>
<tr>
<td>Protocol</td>
<td>Helical</td>
<td>Axial</td>
<td>Helical</td>
</tr>
</tbody>
</table>

---

### Tips for Accreditation

- Supplied by some vendors upon request

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<table>
<thead>
<tr>
<th>Protocol</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Axial</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helical</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Dosage Calculator Excel Spreadsheet must be used**
Phantom Alignment
Alignment tip: A/P and Lateral (Scouts)
Table I Parameters

- kVp
  - Must be tested if not disabled. Does not matter if they are used clinically or not.
  - For all scanners, a kVp may not be available for a given time and mA combination. Keep mAs the same and increase the rotation time or keep mA/mAs as close as possible to Table I.
  - Remember available kVp's are entered into page 1 of Site Scanning Data Sheet.

- mA
  - Typically mAs is displayed
    - mAs/time = mA
  - Effective mAs
    - Effective mAs = mAs/Pitch
  - mA modulation?
    - Determine average mA or mAs
      - Enter average value into Table I
mAs

- **GE**
  - mAs = mAs

- **Philips**
  - mAs/slice = effective mAs = mAs/Pitch
  - mAs = effective mAs / Pitch

- **Siemens**
  - Effective mAs = mAs/Pitch

- **Toshiba**
  - mAs = mAs
  - Toshiba 32 and 64
    - Eff mAs

---

**Table I Parameters**

- **Scan Field of View (SFOV)**
  - in cm or name
    - 25 cm, 50 cm, Large, Medium & Small Body, Head
    - Note: Head and Body use different Bowtie filters
    - Siemens 64 has 70 cm SFOV option
    - Toshiba has 18 cm, 24 cm, 32 cm, 40 cm & 50 cm
    - Must use appropriate SFOV for phantom, even though the protocol may be different

- **Display Field of View (DFOV)**
  - 5 cm – 50 cm (70cm)
  - Select appropriate for phantom
  - ACR recommends closest to, but not <21 cm for ACR phantom (20 cm phantom)
  - 24 cm – 25 cm DFOV prevents displayed text obstruction
  - CTDI body
    - 32 cm diameter
    - 35–40 cm DFOV
  - CTDI head
    - 16 cm diameter
    - 20 cm – 35 cm DFOV

- **Time per rotation(s) in sec**
  - Partial scans
    - <0.4 sec/rotation
    - 270° rotation
    - Affects CTDI measurements
  - Overscans
    - 420° rotation
    - Affects CTDI measurements
  - Use Time per 360° rotation for dose measurements

- **Note**: Head and Body use different Bowtie filters

- **Siemens 64 has 70 cm SFOV option**

- **Toshiba has 18 cm, 24 cm, 32 cm, 40 cm & 50 cm**
  - Must use appropriate SFOV for phantom, even though the protocol may be different

- **ACR recommends closest to, but not <21 cm for ACR phantom (20 cm phantom)**

- **Display Field of View (DFOV)**
  - 5 cm – 50 cm (70cm)
  - Select appropriate for phantom
  - ACR recommends closest to, but not <21 cm for ACR phantom (20 cm phantom)
  - 24 cm – 25 cm DFOV prevents displayed text obstruction
  - CTDI body
    - 32 cm diameter
    - 35–40 cm DFOV
  - CTDI head
    - 16 cm diameter
    - 20 cm – 35 cm DFOV
Table I Parameters

- **Reconstruction Algorithm**
  - Equipment manufacturer specific
  - High Resolution Chest algorithm is usually Lung, Detail or Bone (sharp or very sharp)
    - Must use for high resolution image at S120
- **Axial (A) or Helical (H)**
  - Indicate mode used for clinical protocol

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Table I Parameters

- **Detector Configurations**
  - Z axis collimation (in mm)
    - Width of the tomographic section along the z axis imaged by one data channel
    - Note: In MDCT, several detector elements may be grouped together to form one data channel
  - # Data Channels (N) in a single axial scan
  - \( N \times T = \text{detector configuration} = \text{total effective x-ray beam width} \)

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**Detector Arrays**

- **z = 20 mm, 16 vs 8 detectors**
**Equal Width Array**

- 16 detectors x 1.25 mm
- Recon 4i x 5.0 mm
- 4 detectors x 1.25 mm
- Recon 4i x 1.25 mm

**Unequal Width Array**

- 8 detectors recon 4i x 5.0 mm
- 6 detectors recon 4i x 2.5 mm
- 4 detectors recon 4i x 1.0 mm (Note: collimate outer 3rd of outer detectors)
- 2 detectors recon 2i x 0.5 mm (Note: collimate outer half of detectors)

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**Comparison of Early Detector Designs**

<table>
<thead>
<tr>
<th>Vendor</th>
<th># of Detector elements</th>
<th>Type of Array</th>
<th>Detector Widths</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>16</td>
<td>Equal</td>
<td>16 x 1.25</td>
</tr>
<tr>
<td>Marconi</td>
<td>8</td>
<td>Unequal</td>
<td>2 x 1.0, 2 x 1.5, 2 x 2.5, 2 x 5.0</td>
</tr>
<tr>
<td>Siemens</td>
<td>8</td>
<td>Unequal</td>
<td>2 x 1.0, 2 x 1.5, 2 x 2.5, 2 x 5.0</td>
</tr>
<tr>
<td>Toshiba</td>
<td>34</td>
<td>Unequal</td>
<td>4 x 0.9, 40 x 1.8</td>
</tr>
</tbody>
</table>

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**Table I Parameters**

- **Pitch (IEC)**
  - \( P = I / (N \times T) \)
  - \( I = \) Table Speed in mm/rotation
  - \( N = \) # data channels
  - \( T = \) detector width in z axis
  - \( N \times T = \) collimated x-ray beam width

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**Example of Pitch**

- $I = 15 \text{ mm/rotation}$
- $N = 4$ data channels
- $T = 2.5 \text{ mm detector width}$
- $P = \frac{(15.0 \text{ mm/rotation})}{(4 \times 2.5 \text{ mm})}$
- $P = 15.0/10.0 = 1.5$

**Pitch**

- Determines effective mAs
  - $= m\text{As/Pitch}$
- Determines CTDIvol
  - $= \text{CTDIw/Pitch}$
- Used to also derive DLP and effective dose

**Reconstruction Scan Width**

- Image thickness of reconstruction images

**Reconstruction Scan Interval**

- Interval between reconstructed images

**Dose Reduction Techniques**

- mA modulation
  - Auto mA/Smart mA
  - CAREDOSE
  - Doseright
  - Real EC
  - $^\text{3D}$Exposure

**Clinical use recorded in Table I**

- Not used to obtain images
CT Dosimetry

- Must measure CTDI in Axial Mode
- Must use Technique in Table I for Adult Head, Adult Abdomen and Pediatric Abdomen (unless attested)
  - Use mAs vs effective mAs
- Adult Head in Head Holder
- Adult Abdomen and Pediatric Abdomen on Table
- Must fill all Phantom Holes
- Must use Dose Calculator Spreadsheet

CT Dosimetry

- Must use Clinical/Table I Techniques
- Must use Axial scan to measure CTDI
- When Clinical protocol is Helical
  - Convert to Axial
  - Use Axial scan with effective x-ray beam width closest to clinically used
  - Enter detector configuration used to obtain dose measurement
  - Adjust Table Speed to provide appropriate Pitch
- Use mAs not effective mAs
  - Effective mAs will yield CTDIvol instead of CTDIw

CT Dosimetry

- Must meet Dose Criteria
  - Pass/Fail
    - Adult Head: 80 mGy
    - Pediatric Abdomen: 25 mGy
    - Adult Abdomen: 30 mGy
  - Reference Values
    - Adult Head: 75 mGy
    - Pediatric Abdomen: 20 mGy
    - Adult Abdomen: 25 mGy

CT Dosimetry

- Compare CTDIvol with:
  - Displayed
  - Dose Calculator Programs
    - ImPACT
- Caveat:
  - Pediatric
    - Dependent on SFOV used
      - 16 cm vs 32 cm CTDI phantoms
Tips for success

- Follow instructions
- Know your scanner
  - Enlist technologist assistance
- Verify Scanner is calibrated and all previously identified deficiencies are corrected
- Use resources
  - Service engineer should be available
- Be your own reviewer!

The Challenges of CT Accreditation
GE CT Scanners

Thomas G. Ruckdeschel, MS, DABR
Diagnostic Radiological Physicist
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GE Lightspeed (4 Detectors)

ACR FAQ
Provided with accreditation material
GE Lightspeed 16

- Detector Configuration
  - 16 x 0.625 mm = 10.0 mm
  - 8 x 1.25 mm = 10.0 mm
  - Total effective length = 20.0 mm
  - Helical (# simultaneous slices/rotation time)
    - 2, 4, 8 & 16

- Simultaneous slices/rotation
  - 2 x 0.625 mm, 4 x 3.75 mm, 16 x 0.625 mm
  - 8 x 1.25 mm, 16 x 1.25 mm, 8 x 2.5 mm

GE Lightspeed 32

- Detector Configuration
  - 32 x 0.625 mm = 20.0 mm
  - 16 x 1.25 mm = 20.0 mm
  - Total effective length = 40.0 mm
  - Helical (# simultaneous slices/rotation time)
    - 8 & 32

- Simultaneous slices/rotation
  - 8 x 0.625 mm, 32 x 0.625 mm, 32 x 1.25 mm

GE Lightspeed 64 (VCT)

- LS VCT (64)
  - 64 x 0.625 mm = 40.0 mm
  - Helical (# simultaneous slices/rotation time)
    - 8, 32 & 64

- Simultaneous slices/rotation
  - 8 x 0.625 mm, 32 x 0.625 mm, 32 x 1.25 mm
  - 64 x 0.625 mm
GE VCT 64 CT

SMPTE Pattern

- Usually loaded and stored in Browser
- If not, Use Service Browser
  - Image Quality
  - Install SMPTE
Slice Thickness

- All requested slice thicknesses available
- GE VCT (64)
  - CT # vs Slice Thickness
  - > 5.0 mm slice thickness unavailable
Low Contrast

- Verify that low contrast criteria pass with Clinically used Technique
  - Must visualize all four 6.0 mm rods
  - If not, optimize technique, consult with site and adjust protocol
    - Table I

CT Dosimetry

- Convert Helical Technique to Axial Technique
  - 4 slice
    - Helical = 4 x 3.75 mm = 15 mm, I = 10 mm/rot
      - Pitch = 1.5
    - Axial = 4 x 3.75 mm = 15 mm, Table Feed = 0 mm
  - 64 slice
    - Helical = 64 x 0.625 mm = 40 mm, I = 55 mm/rot
      - Pitch = 1.375
    - Axial = 64 x 0.625 mm = 40 mm, Table Feed = 0 mm

The Challenges of CT Accreditation

Siemens Scanners
Siemens Sensation 10

- Detector Elements
  - 16 x 0.75 mm and 8 x 1.5 mm for a total “maximum” effective length of 24 mm @ isocenter

Siemens Sensation 10

- Nominal slice widths (Axial)
  - 0.6 mm, 0.75 mm, 1.0 mm, 1.5 mm, 2.0 mm, 3.0 mm, 4.5 mm, 5.0 mm, 6.0 mm, 9.0 mm & 10.0 mm

- Nominal slice widths and simultaneous slices (Axial)
  - 10 x 0.75 mm, 10 x 1.5 mm, 2 x 0.6 mm, 2 x 1.0 mm, 6 x 3.0 mm and 2 x 12.0 mm

Siemens Sensation 10

- Important Notes:
  - The 0.6 mm detector is available on Head Work & extremities
  - 0.75 mm and 1.5 mm are available in all modes.
  - 1.5 mm Helical can be reconstructed as 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm, 6.0 mm, 7.0 mm, 8.0 mm & 10.0 mm

Siemens Sensation 10

- Head (Axial):
  - 0.75 mm can be reconstructed as 0.75 mm, 1.5 mm, 3.0 mm & 6.0 mm
  - 1.5 mm can be reconstructed as 1.5 mm 3.0 mm & 6.0 mm
  - 0.6 mm can be reconstructed as 0.6 mm, 0.75, 1.0, 1.5
Siemens Sensation 10

**Head (Helical):**
- 10 x 0.75 mm can be reconstructed as 0.75 mm, 1.5 mm, 2.0 mm, 3.0 mm, 4.5 mm, 6.0 mm, 7.0 mm, 8.0 mm & 10.0 mm
- 10 x 1.5 mm can be reconstructed as 1.5 mm, 2.0 mm, 3.0 mm, 4.5 mm, 6.0 mm, 7.0 mm, 8.0 mm & 10.0 mm

**Detailed Head Work:**
- 0.6 mm 2 x 0.6 mm can be reconstructed as 0.6 mm
- 6 x 0.75 mm can be reconstructed as 0.75 mm, 1.0 mm, 1.5 mm, 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm & 6.0 mm
- 6 x 3.0 mm can be reconstructed as 3.0 mm, 5.0 mm, 6.0 mm, 7.0 mm, 8.0 mm & 10.0 mm

Siemens Sensation 10

**Abdomen (Axial):**
- 8 x 0.75 mm can be reconstructed as 0.75 mm, 1.5 mm, 3.0 mm & 6.0 mm
- 8 x 1.5 mm can be reconstructed as 1.5 mm, 3.0 mm & 6.0 mm
- 6 x 3.0 mm can be reconstructed as 3.0 mm, 6.0 mm & 9.0 mm
- 2 x 5.0 mm can be reconstructed as 5.0 mm & 10.0 mm

Siemens Sensation 10

**Abdomen (Helical):**
- 10 x 0.75 mm can be reconstructed as 0.75 mm, 1.0 mm, 1.5 mm, 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm & 6.0 mm
- 10 x 1.5 mm can be reconstructed as 0.75 mm, 1.0 mm, 1.5 mm, 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm & 6.0 mm
- 6 x 3.0 mm can be reconstructed as 3.0 mm & 6.0 mm
**Siemens Sensation 10**

- **Reconstructed slice widths available in Axial Mode:**
  - 0.6 mm, 0.75 mm, 1.0 mm, 1.5 mm, 2.0 mm, 3.0 mm, 4.5 mm, 5.0 mm, 6.0 mm, 7.0 mm, 8.0 mm, 9.0 mm & 10.0 mm

**Helical to Axial Slice Thickness**

- **Sensation 10**
  - Abdomen Helical:
    - 10 x 1.5 mm
    - 5.0 mm slice recon
  - Abdomen Axial:
    - 8 x 1.5 mm
    - 3.5 mm or 6.0 mm slice recon
    - 2 x 5.0 mm
    - 5.0 mm

**Siemens Sensation 16**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Maximum # Detectors/rot</th>
<th>Detector Configurations</th>
<th>Reconstructed image thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial</td>
<td>12</td>
<td>12 x 1.5 mm, 12 x 0.75 mm, 6 x 3.0 mm, 2 x 0.6 mm, 2 x 5.0 mm</td>
<td>4 x 4.5 mm, 3 x 3.0 mm, 2 x 3.0 mm, 1 x 1.25 mm, 3 x 5.0 mm</td>
</tr>
<tr>
<td>Helical</td>
<td>16</td>
<td>16 x 1.5 mm, 16 x 0.75 mm</td>
<td>5.0 mm, 4.0 mm</td>
</tr>
</tbody>
</table>

**Siemens Sensation 64 Detector Configurations**

- 64 x 0.6 mm, 20 x 0.6 mm, 12 x 0.6 mm
- 24 x 1.2 mm, 3 x 1.2 mm
- 6 x 3.0 mm, 3 x 6.0 mm, 2 x 9.0 mm
- 12 x 2.4 mm, 6 x 4.8 mm, 4 x 7.2 mm
- 3 x 9.6, 2 x 14.4 mm
- 1 x 5.0 mm, 1 x 10.0 mm
- 6 x 0.8 mm, 3 x 1.2 mm
- 2 x 1.8 mm, 1 x 3.6 mm

**Note:**
- Effective length of each element @ isocenter
  - 32 x 0.6 mm = 19.2 mm
  - 32 x 1.2 mm = 38.4 mm
  - 32 x 1.5 mm = 57.6 mm
  - 8 x 1.2 mm = 9.6 mm
  - Total effective length = 28.8 mm
Siemens Sensation 64 CT

- Dose Measurements
  - Technique may use 64 detector elements
  - Axial Techniques permit 32 detector elements only
  - Important Note: “Flying focal spot” uses 32 detector elements

-- The ACR instructions state that the CT dosimetry spreadsheet should use the techniques provided in Table I which should also be the techniques that are used clinically. If the technique is 120 kVp, 276 effective mAs, 0.5 seconds per rotation, N = 64 and T = 0.6 mm, Pitch = 0.75 then the Table I should be completed as follows:

```
<table>
<thead>
<tr>
<th>kVp</th>
<th>mA</th>
<th>As</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>414</td>
<td></td>
</tr>
</tbody>
</table>
```

- If effective mAs = 276 mAs, Pitch = 0.75, and mA = mAs x Pitch then,
  mAs = 276 x 0.75 = 207 mAs
- If As = mA x time in sec then,
  mA = As / time
  mA = 207 mAs / 0.5 sec = 414 mA
- Time per rotation: 0.5 sec

Siemens Sensation 64

- kVp: 120
- mA: 414
  - If effective mAs = 276 mAs, Pitch = 0.75, and mA = mAs x Time then,
    mAs = 276 x 0.75 = 207 mAs
  - If mAs = mA x time in sec then,
    mA = mAs / time
    mA = 207 mAs / 0.5 sec = 414 mA
- Time per rotation: 0.5 sec
Siemens Sensation 64

- Scanner Technique
  - T = 0.6 mm and N = 64
  - Flying Focal Spot
  - Pitch: 0.75
- What is the Table Speed?:
  - Pitch = Table Speed x N x T
  - Table Speed = 0.75 x 32 x 0.6 = 14.4 mm/rot

* The table speed is not displayed but is determined from the IEC definition of Pitch, P = Table speed (mm/rot) x N x T

Service Engineer

- Service Mode
  - Permits all technique combinations for all modes
  - (Rotate) Rot Mode
    - Imaging
  - (Stationary) Stat Mode
    - Generator tests
      - kVp
      - HVL

Service Mode

- Problems
  - Need service engineer
  - Difficulty filming from service mode
- QC or Physics Mode?
Anticipated Options for ACR Accreditation

- Potential Change of phantom alignment criteria from Major to Minor deficiency?
- Allow Helical scan with appropriate SFOV for CT accuracy
  - Acrylic (+110 to +135)
- Use Adult Head protocol for CT water and slice thickness
- When Abdomen Protocol kVp is 140 kVp, use 120 kVp for CT accuracy
- Remove conversion of helical protocol to axial except for Dose
- Add to instructions method to determine mAs for mA modulated techniques

Anticipated Options for ACR Accreditation

- New definitions and calculations to instructions:
  - Add mAs & effective mAs to Table I
  - Instructions to include N & T on e submissions
  - \( T = \frac{\text{the width of the tomographic section along the } x \text{-axis}}{\text{imaged by one data channel}} \)
    - In multi detector-row CT, several detector elements may be grouped together to form one data channel. In single detector-row CT, the value of \( T \) is equal to the nominal scan width.
  - \( N = \frac{\text{the number of tomographic sections imaged in a single axial scan}}{\text{(one rotation of the x-ray source)}} \)
    - This is equal to the number of data channels used in a particular scan. The value of \( N \) may be less than or equal to the maximum number of data channels available on the system.

Thank you!