CT Scanner Hardware and Image Quality Assessment

— Slice Sensitivity Profile

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Funding support, disclosures, and conflicts of interest

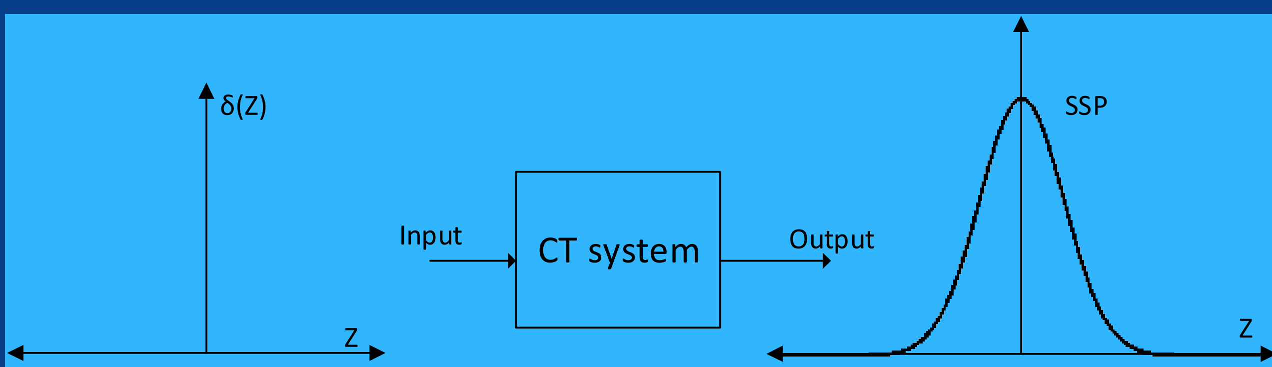
- Employee of GE Healthcare
- No other disclosures

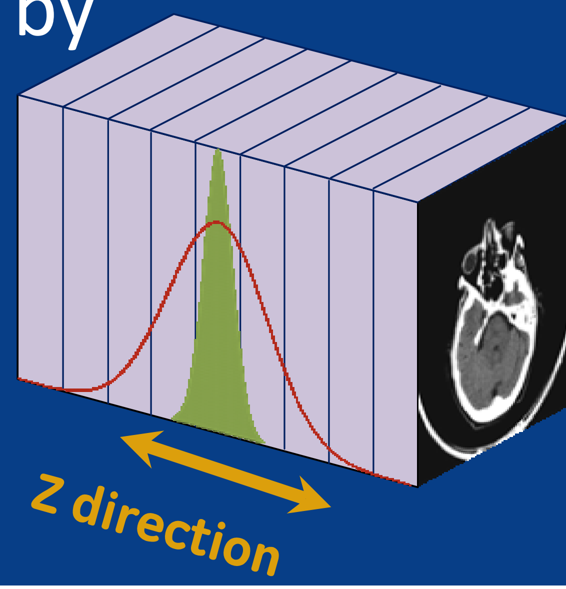
Outline

- Introduction
- How to measure SSP
- Examples
- Questions

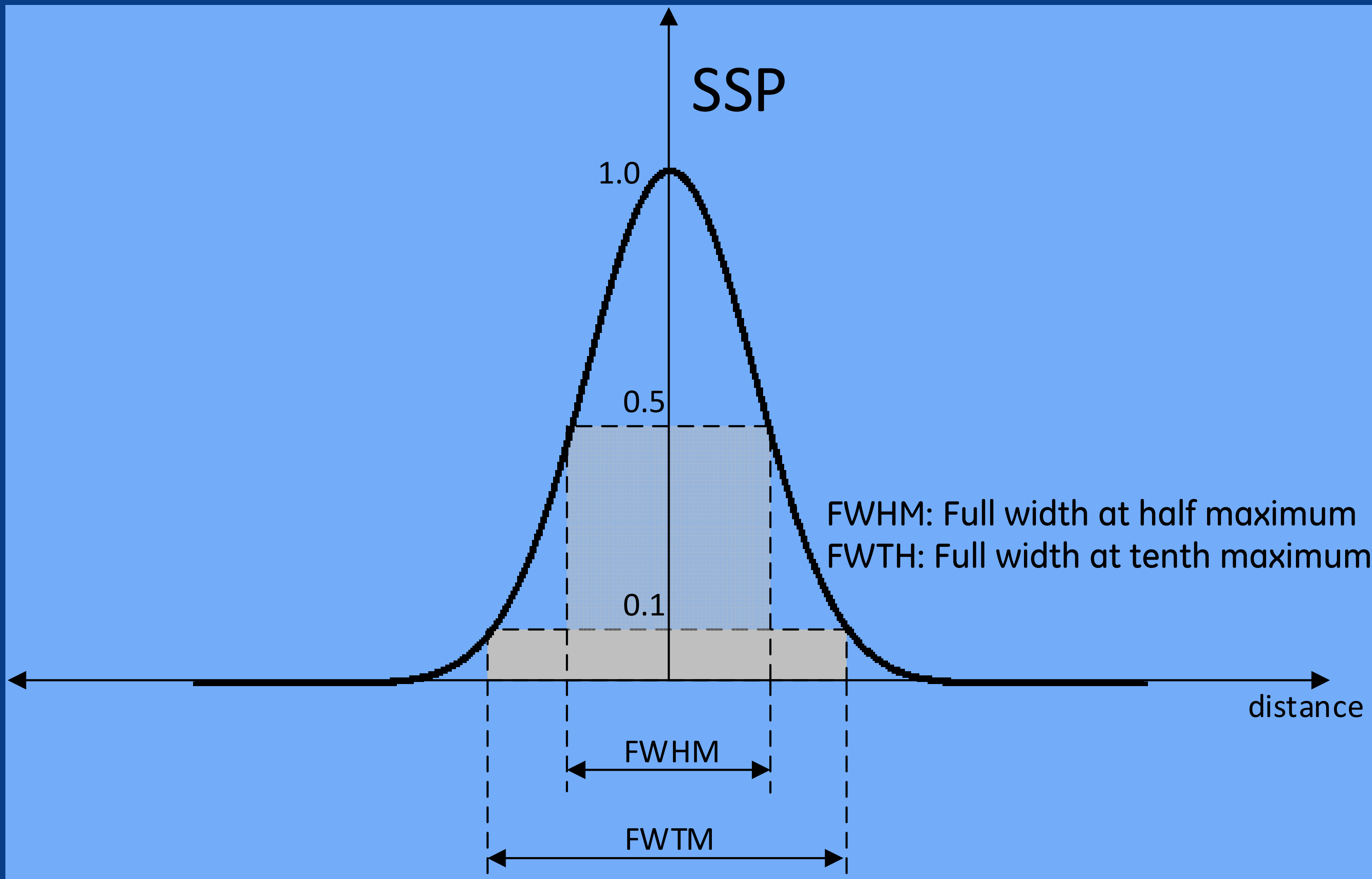
Introduction: Slice Sensitivity Profile

- The cross-plane (or perpendicular to the scan plane, or Z direction, or table direction) spatial resolution is often described by the slice sensitivity profile (SSP).
- SSP: the CT system response function to a Dirac delta function in Z.
- An SSP curve is typically described by FWHM and FWTM.



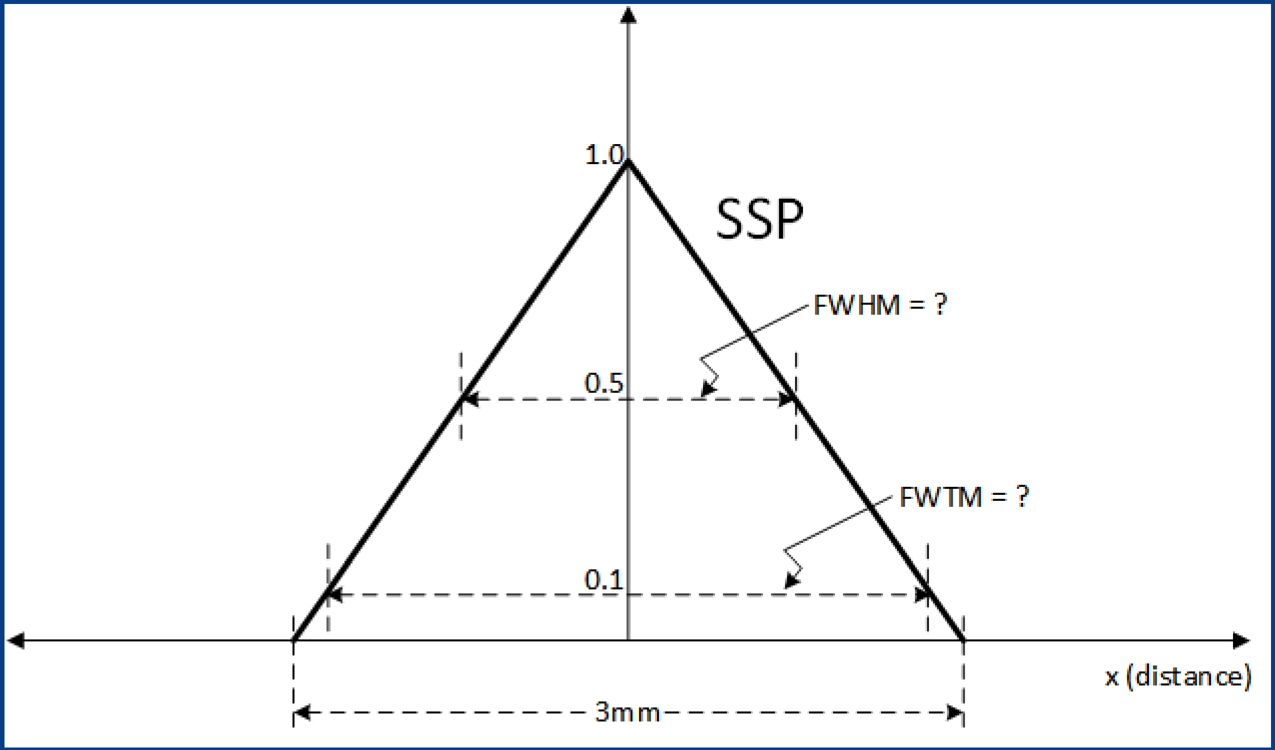


FWHM, FWTM



FWH(T)M: The distance on the abscissa of an SSP between two points whose values are ½ (1/10) of the maximum value.

Example of FWHM, FWTM



FWHM = 3mm * (1 – 0.5) = 1.5mm

FWTM = 3mm * (1 - 0.1) = 2.7mm

How to measure SSP

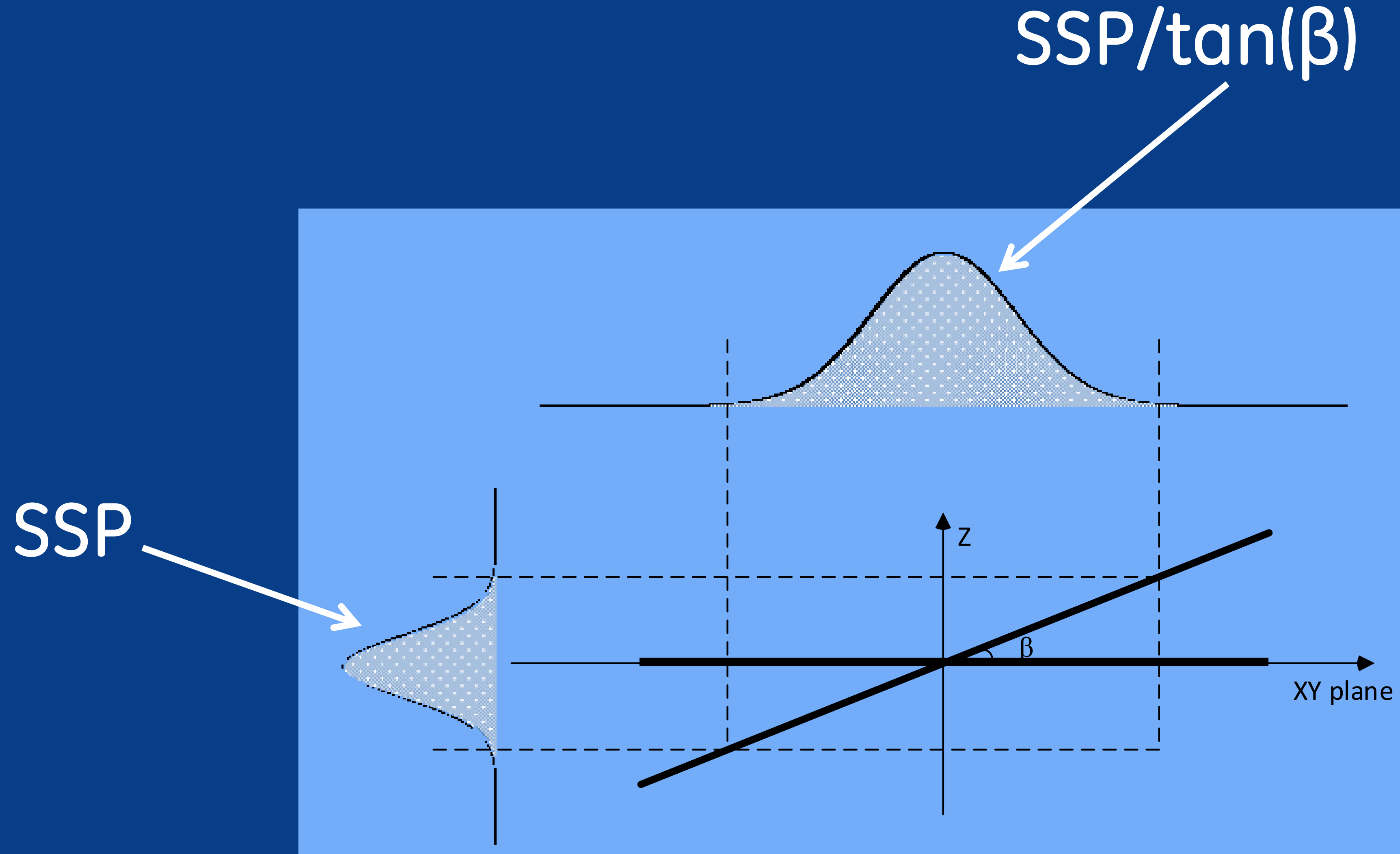
Phantoms to measure SSP:

- Small bead
- Thin disc
- A shallow-angled slice ramp

Practical considerations:

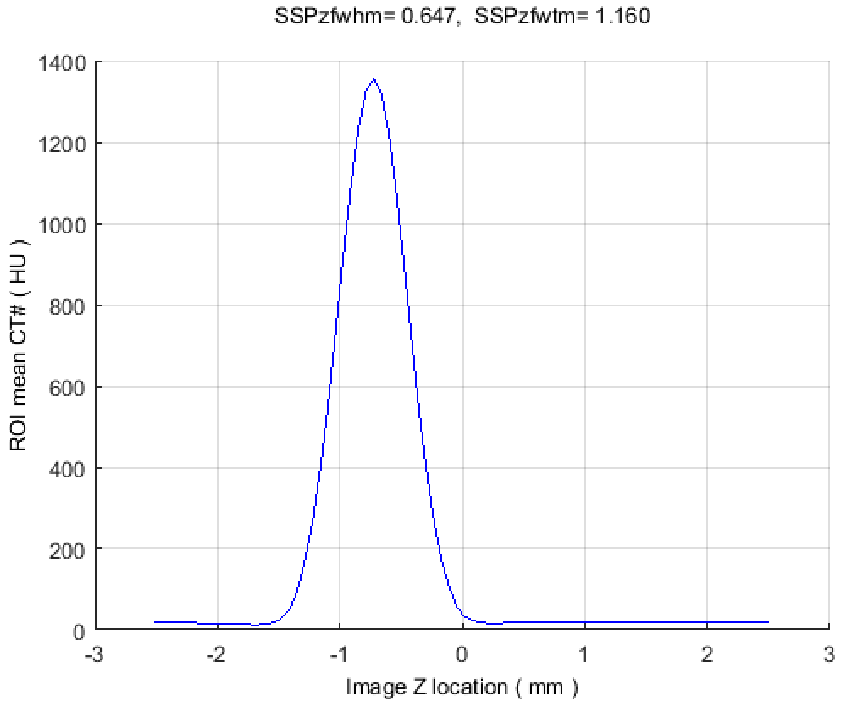
- Sampling required for accuracy
- Alignment of the phantom
- Scan mode

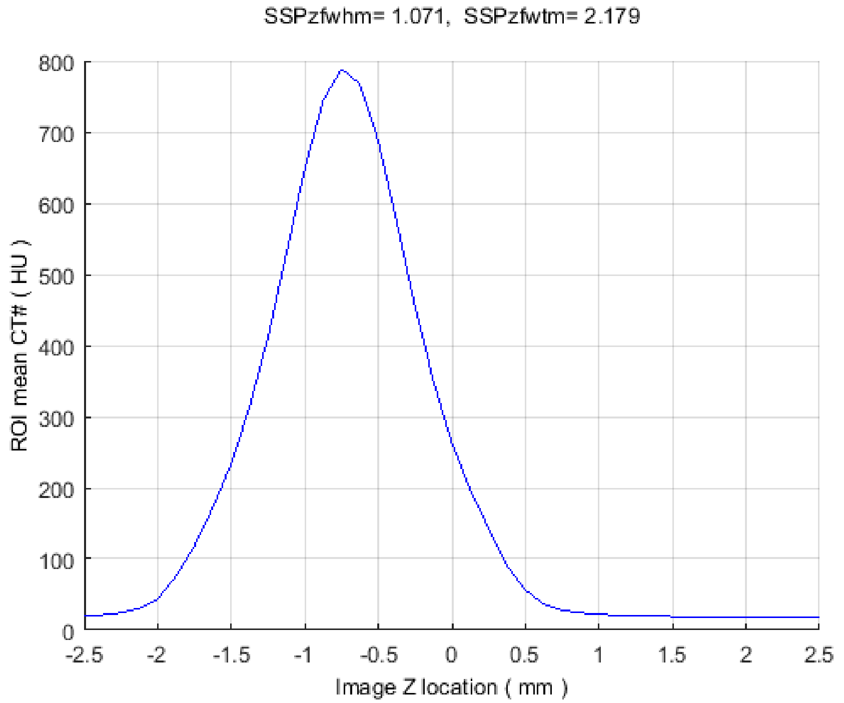
Ramp method



Examples

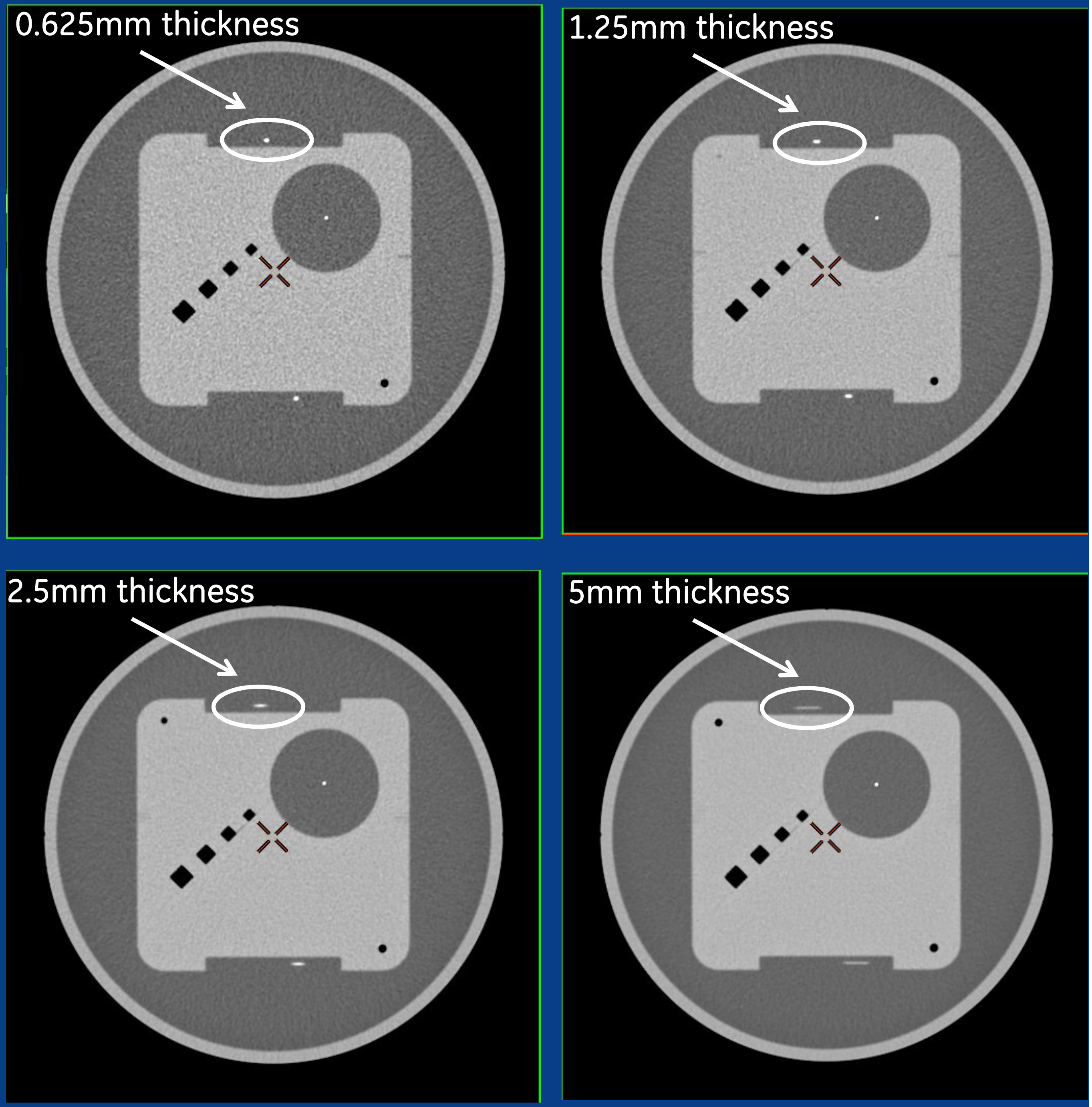
SSP measured using a thin disc:
same scan data but reconstructed using different slice thickness





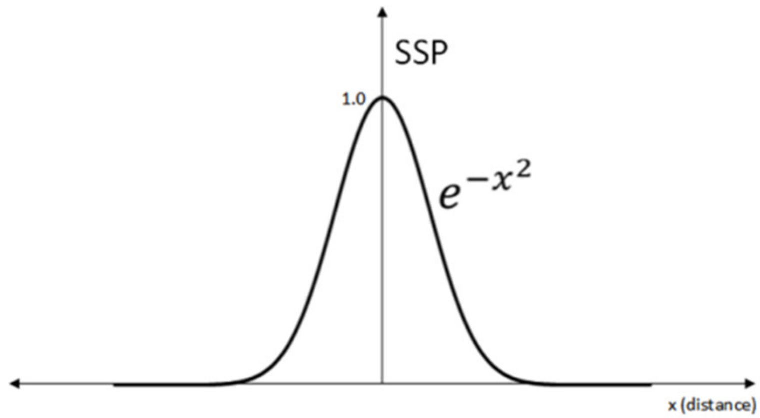
SSP measured using a thin wire placed at a shallow angle

$SSP = SSP_{xy} * \tan(\beta)$



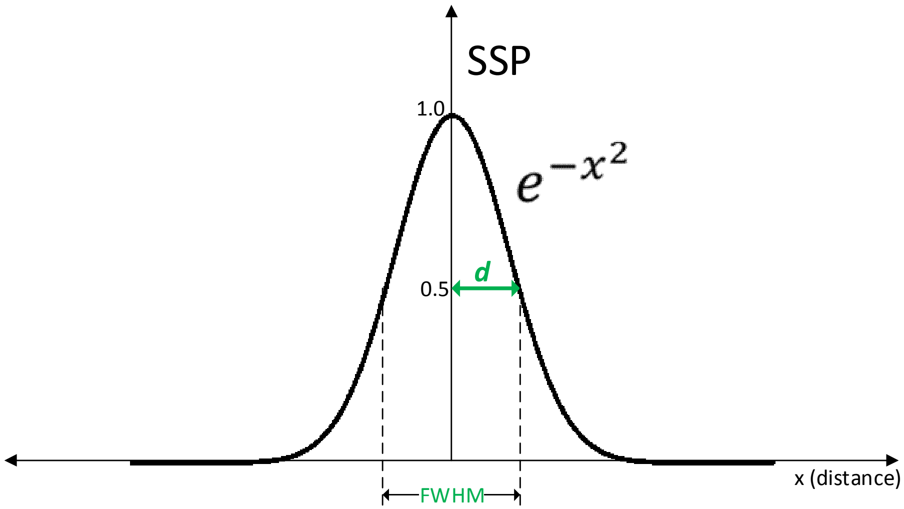
Questions

Q1. The SSP of a CT system can be described using the function of e^{-x^2}. What is its FWHM value?



20%	1. 0.5
20%	2. $\sqrt{-\ln(0.5)}$
20%	3. 1.0
20%	4. 0.1
20%	5. $\sqrt{-\ln(0.5)}$*2

10



$$0.5 = e^{-d^2}$$
$$d^2 = -\ln(0.5)$$
$$d = \sqrt{-\ln(0.5)}$$
$$FWHM = 2 * d = \sqrt{-\ln(0.5)} * 2$$

Answer: 5. $\sqrt{-\ln(0.5)} * 2$.

Ref: Jiang Hsieh, Computed Tomography: principles, design, artifacts, and recent advances, SPIE Press, 2009. Chapter 5, Section 5.1.2.

Q2. Which of the following descriptions about SSP is not correct?

20%	1. Focal spot size could affect the SSP.
20%	2. For a helical scan, the helical pitch used may affect the SSP.
20%	3. Increasing the slice thickness will reduce SSP.
20%	4. SSP describes the cross-plane (Z) spatial resolution.
20%	5. SSP can be measured by using a small bead.

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Answer: 3. Increasing the slice thickness will reduce SSP.

Ref: Jiang Hsieh, Computed Tomography: principles, design, artifacts, and recent advances, SPIE Press, 2009.

CT Scanner Hardware and Image Quality Assessment

— Automatic tube current modulation (ATCM)

Outline

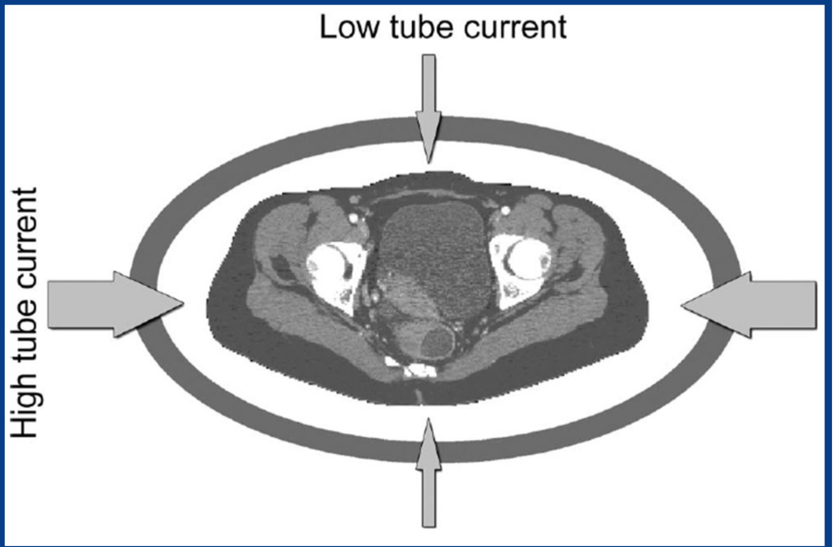
- Introduction
- How to evaluate ATCM
- Examples
- Questions

Introduction: ATCM

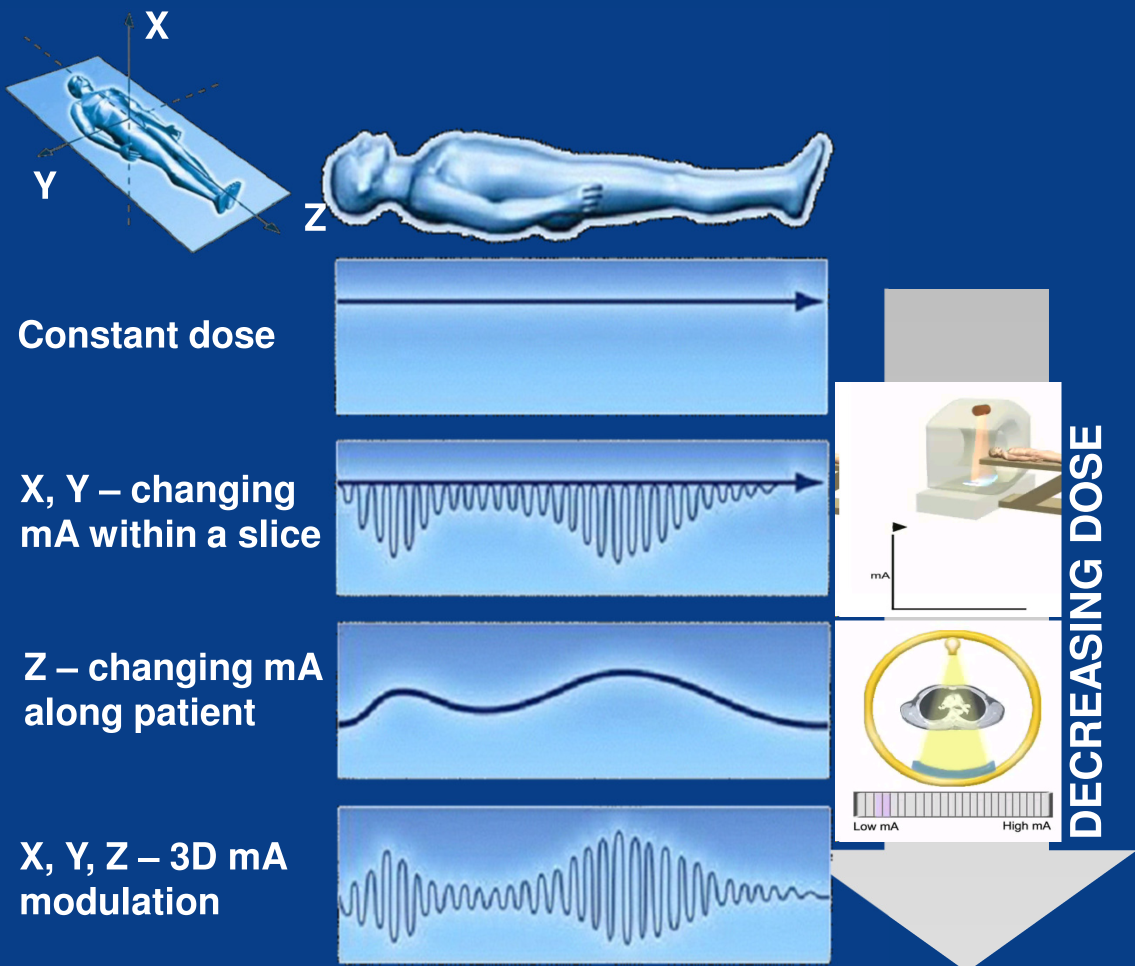
- ATCM: Automatic tube current modulation
- Adjust tube current based on patient attenuation
- Maintain consistent image quality level
- Reduce streak artifact
- Aim in protocol optimization and dose management

ATCM

- Adjust tube current as a function of patient attenuation
  - Increase current when higher attenuation
  - Reduce current when lower attenuation
- Axial and longitudinal modulation



Karla *et al*. Techniques and applications of Automatic tube current modulation for CT; Radiology (2004).



Prospective 3D dose modulation

From single low dose scout

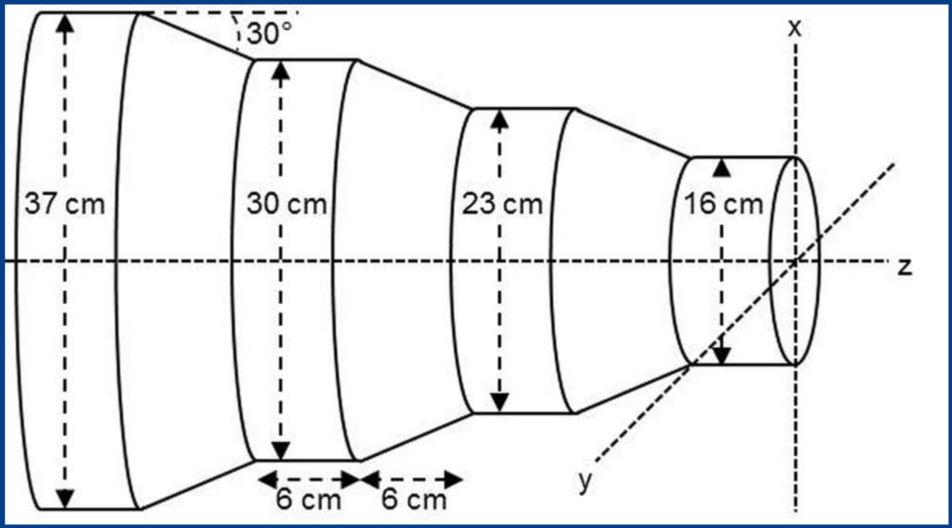
Automatically changes mA

- Along patient
- Within a slice

How to evaluate ATCM system

- Measurement using variable-sized phantoms

The ImPACT AEC phantom
MHRA Report 05016: CT scanner automatic exposure control systems (2005).



The Mercury phantom
Wilson *et al*. A methodology for image quality evaluation of advanced CT systems; Medical Physics (2013).

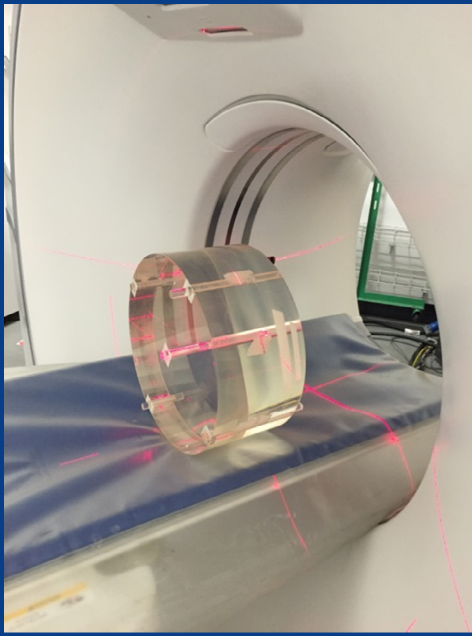
ATCM evaluation using the 32cm and 16cm PMMA CTDI dosimetry phantoms (follows the upcoming IEC standard*)

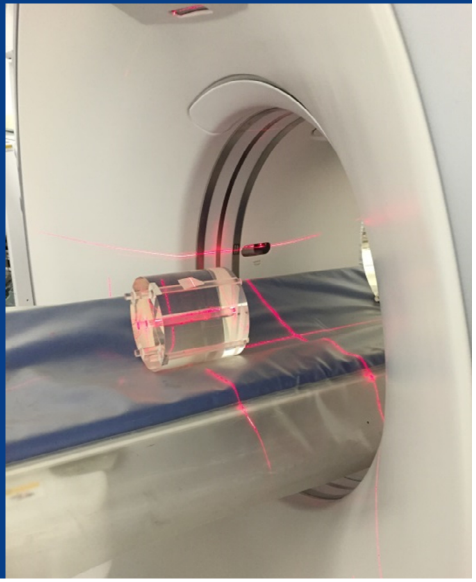
- Test devices:
  - 32 cm diameter PMMA CTDI dosimetry phantoms.
  - 16 cm diameter PMMA CTDI dosimetry phantoms.
  - For pediatrics, a 10 cm diameter PMMA phantom.
- All holes in the phantoms shall be plugged.

* Works in Progress – unpublished - IEC 61223-3-5 Ed. 2: Acceptance and Constancy tests – Imaging performance of computed tomography X-ray equipment.

Size-dependent modulation evaluation

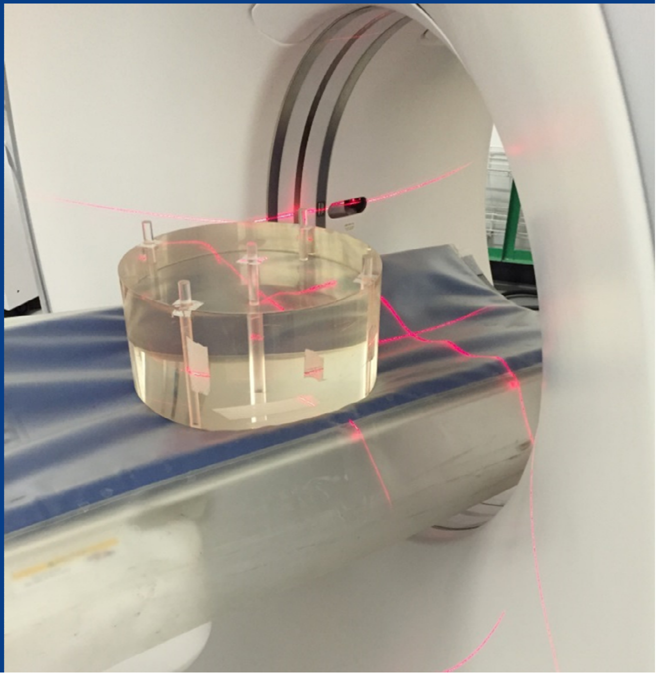
- Place phantoms: the axis of cylindrical symmetry is aligned with z-axis.
- Scan 32cm CTDI phantom using the adult body protocol.
- Scan 16cm CTDI phantom using the same protocol.
- Record the post-scan $CTDI_{vol}$ values reported by the scanner.



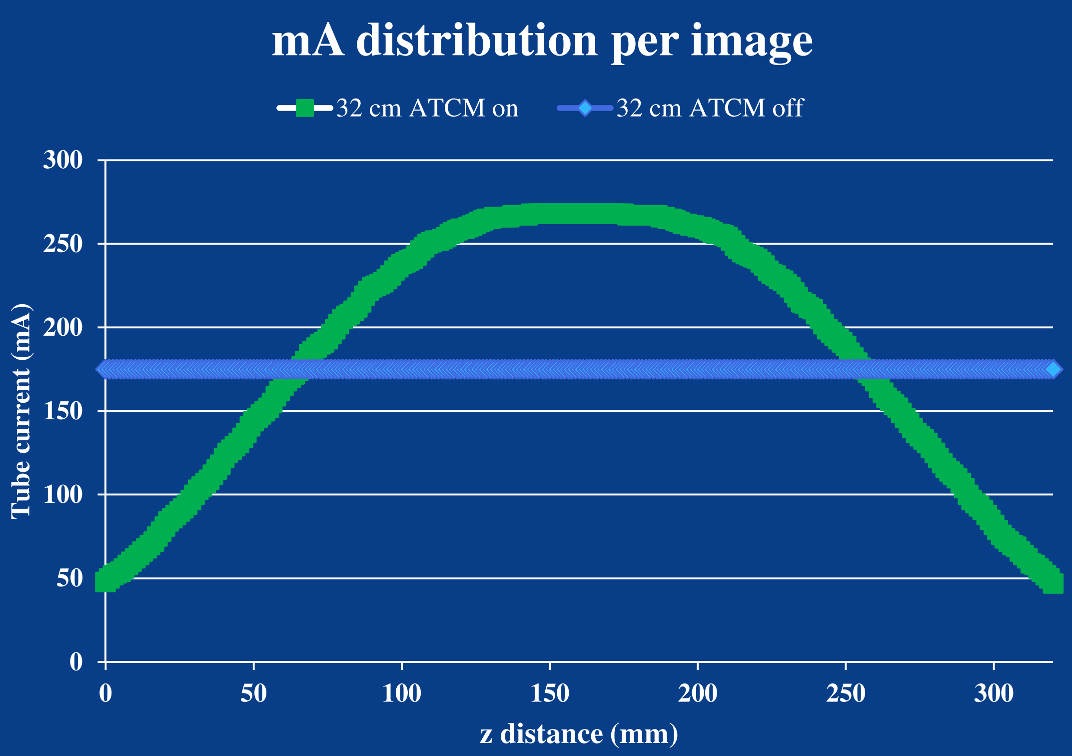


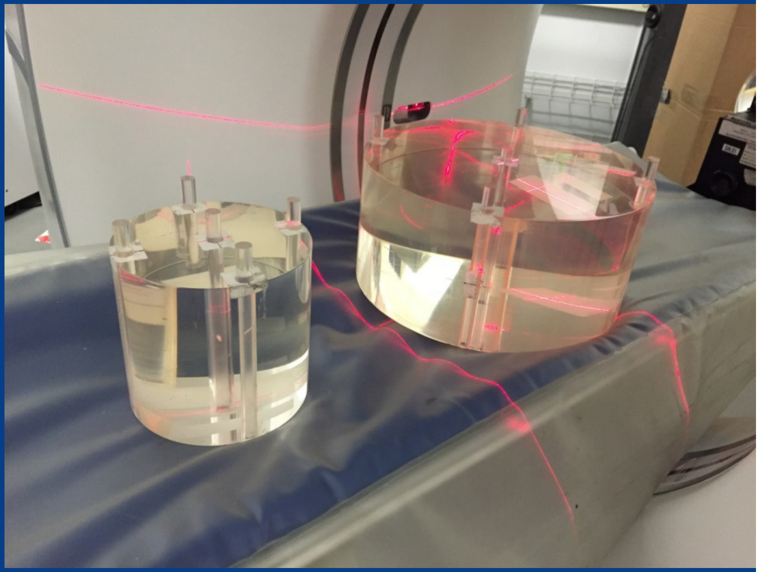
Longitudinal modulation evaluation

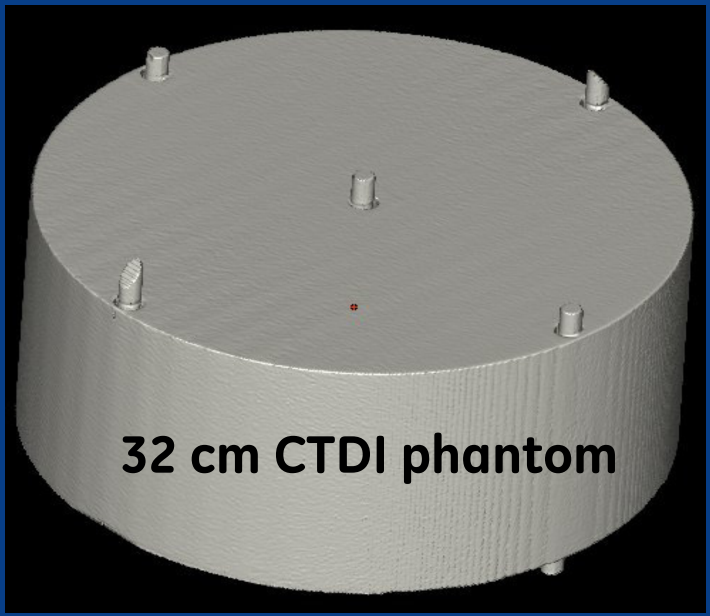
- Place 32cm CTDI phantom: the axis of cylindrical symmetry is aligned with y-axis.
- Scan the whole 32cm CTDI phantom using the Helical ATCM protocol defined for this test.
- Ensure tube current modulation is clearly evident and is not truncated.
- Record the metric used for the tube current as displayed in images at ~ 6.4 cm (20%), 16 cm (50%), and 25.6 cm (80%) from the leading edge of the 32cm CTDI phantom.



Examples


mA distribution per image
32 cm ATCM on
32 cm ATCM off
Tube current (mA)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
z distance (mm)




32 cm CTDI phantom

Questions

Q3. Using ATCM on a CT scanner can help reduce:

20%	1. Beam hardening artifact
20%	2. Scatter artifact
20%	3. Ring artifact
20%	4. Streak artifact
20%	5. Patient motion artifact

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Answer: 4. Streak artifact.

Ref: Jiang Hsieh, Computed Tomography: principles, design, artifacts, and recent advances, SPIE Press, 2009.

Q4. Please select the correct statement about ATCM from the following:

20%	1.	ATCM technique may largely reduce radiation exposure while enabling uniform image quality across different patient body regions.
20%	2.	ATCM is applied based on the geometric size of the scanning object.
20%	3.	ATCM can always reduce dose.
20%	4.	ATCM performance can be completely characterized using the 32cm and 16cm PMMA CTDI dosimetry phantoms.
20%	5.	Using ATCM will always improve image quality.

10

Please select the correct statement about ATCM from the following:

1. ATCM technique may largely reduce radiation exposure while enabling uniform image quality across different patient body regions.
2. ATCM is applied based on the geometric size of the scanning object.
3. ATCM can always reduce dose.
4. ATCM performance can be completely characterized using the 32cm and 16cm PMMA CTDI dosimetry phantoms.
5. Using ATCM will always improve image quality.

Answer: 1. ATCM technique may largely reduce radiation exposure while enabling uniform image quality across different patient body regions.

Ref: Jiang Hsieh, Computed Tomography: principles, design, artifacts, and recent advances, SPIE Press, 2009.

References

- Jiang Hsieh, Computed Tomography: principles, design, artifacts, and recent advances, SPIE Press, 2009.
- IEC 61223-3-5 Ed. 1 (2004): Acceptance tests – Imaging performance of computed tomography X-ray equipment.
- Works in Progress – unpublished - IEC 61223-3-5 Ed. 2: Acceptance and Constancy tests – Imaging performance of computed tomography X-ray equipment.

Thank you!