Medical Physics
Course on Nuclear Physics
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Outline

- Definition of the field
- Medical Physics as a course in UTM
- Example of research in medical imaging

Definiton of the field

AAPM - Public & Media

Medical Physics

Medical Physics is an applied branch of physics concerned with the application of the concepts and methods of physics to the diagnosis and treatment of human disease. It is allied with medical electronics, bioengineering, and health physics.

What Is a Medical Physicist?

Medical physicists contribute to the effectiveness of radiological imaging procedures by assuring radiation safety and helping to develop improved imaging techniques (e.g., mammography CT, MR, ultrasound). They contribute to development of therapeutic techniques (e.g., prostate implants, stereotactic radiosurgery), collaborate with radiation oncologists to design treatment plans, and monitor equipment and procedures to ensure that cancer patients receive the prescribed dose of radiation to the correct location.

What do Medical Physicists Do?

Medical physicists are concerned with three areas of activity: clinical service and consultation, research and development, and teaching. On the average their time is distributed equally among these three areas.

Definition of a Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields of medical physics.

- Therapeutic Medical Physics
- Imaging Medical Physics
- Nuclear Medical Physics
- Medical Health Physics

Medical Physics as a course at UTM

Synopsis	:	This course introduces Medical Physics to physics majors as an elective in their program. Three main areas of medical physics namely medical imaging, nuclear medicine and radiotherapy are surveyed. The emphasis is in the physics that govern the field. At the end of the course students are expected to have an idea of the subject matter, its usefulness and applications in modern medicine.

No.	Course Learning Outcomes	Programme Learning Outcome(s) Addressed	Assessment Methods
CO1	Outline the physical principle of image formation of imaging modalities – radiography, fluoroscopy, tomography, ultrasound, .and by referring the recommended reading materials, elaborate further the advancement of the technology.	PO1(C2,P2,A2) PO2(C3,P3,A3) PO8(LS2)	Assignment 1 (group), Test 1, Final exam
CO2	Outline factors affecting image quality, resolution, contrast and noise.	PO1(C2,P2,A2) PO2(C3,P3,A3)	Test 1 Final exam

CO3	Describe and compare various methods of production of radionuclides and radiopharmaceuticals that are used in nuclear medicine and work in group to explain the localization mechanisms of radiopharmaceuticals.	PO1(C2,P2,A2) PO2(C4,P3,A2) PO8(LS1,2)	Assignment 1 (group), Test 1 Final exam
CO4	Outline the working principle of detectors used in nuclear medicine, the design and principle of image formation of an Anger camera and work in group to describe in detail the design, principle of operation and performance of SPECT and PET.	PO1(C2,P2,A2) PO2(C4,P3,A2) PO3(C5,P3,A2) PO8(LS1,2)	Assignment 2 (group), Test 2 Final exam
CO5	Outline the principles of radiotherapy , its applications and radiotherapic treatment planning work in group to elaborate further characteristic of radiotraphic radiation.	PO1(C2,P2,A2) PO2(C4,P3,A2) PO8(LS1,2)	Assignment 3 (group), Test2 Final exam

PO1: Fundamental Physics knowledge PO2: Application of physics knowledge and skills PO3: Analyzing and experimental skills PO8: Leadership

Example of research in medical imaging

Medical Imaging

- Medical image: a representation of the distribution of some property of the human body which shows the structure and/or function of organs and tissues under investigation

Medical imaging modalities (ICRU 1995)

1. X-ray
   1.1 Planar projection imaging
   1.2 Digital x-ray imaging
   1.3 Computed tomographic imaging (CT)

Medical imaging modalities (cont.)

2. Nuclear medicine
   2.1 Planar projection imaging
   2.2 Single photon emission computed tomography (SPECT)
   2.3 Positron emission tomography (PET)

Medical imaging modalities (cont.)

3. Magnetic resonance imaging (MRI)
4. Ultrasonography
5. Thermography
6. Impedence imaging
7. Biomagnetc imaging
8. Light transmission imaging

Diagnostic imaging

- Ultimate aim is a correct diagnosis based on medical images

Diagnostic accuracy

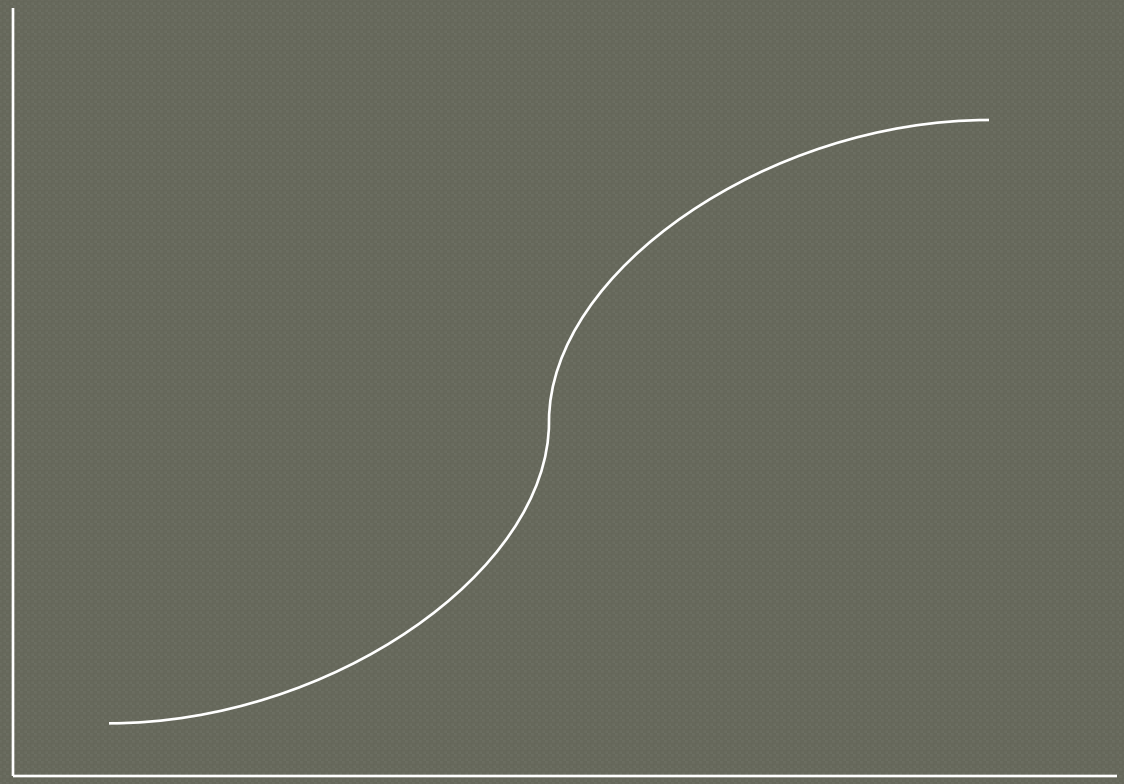
- High percentage of true positive and true negative from image reading

		Patient's state	
		Abnormal	Normal
Result of diagnosis via image reading	Positive	True positive	False positive (false alarm)
	Negative	False negative	True negative

Image quality

- A measure of the effectiveness with which an image can be used for its intended task (Sharp, 1990).

Hypothetical relationship between image quality and diagnostic accuracy (Doi et al 1986)



Physical quality (objective measure) and psycophysical quality (subjective measure)

- ICRU (1995) recommends both objective and subjective measures for assessment of quality

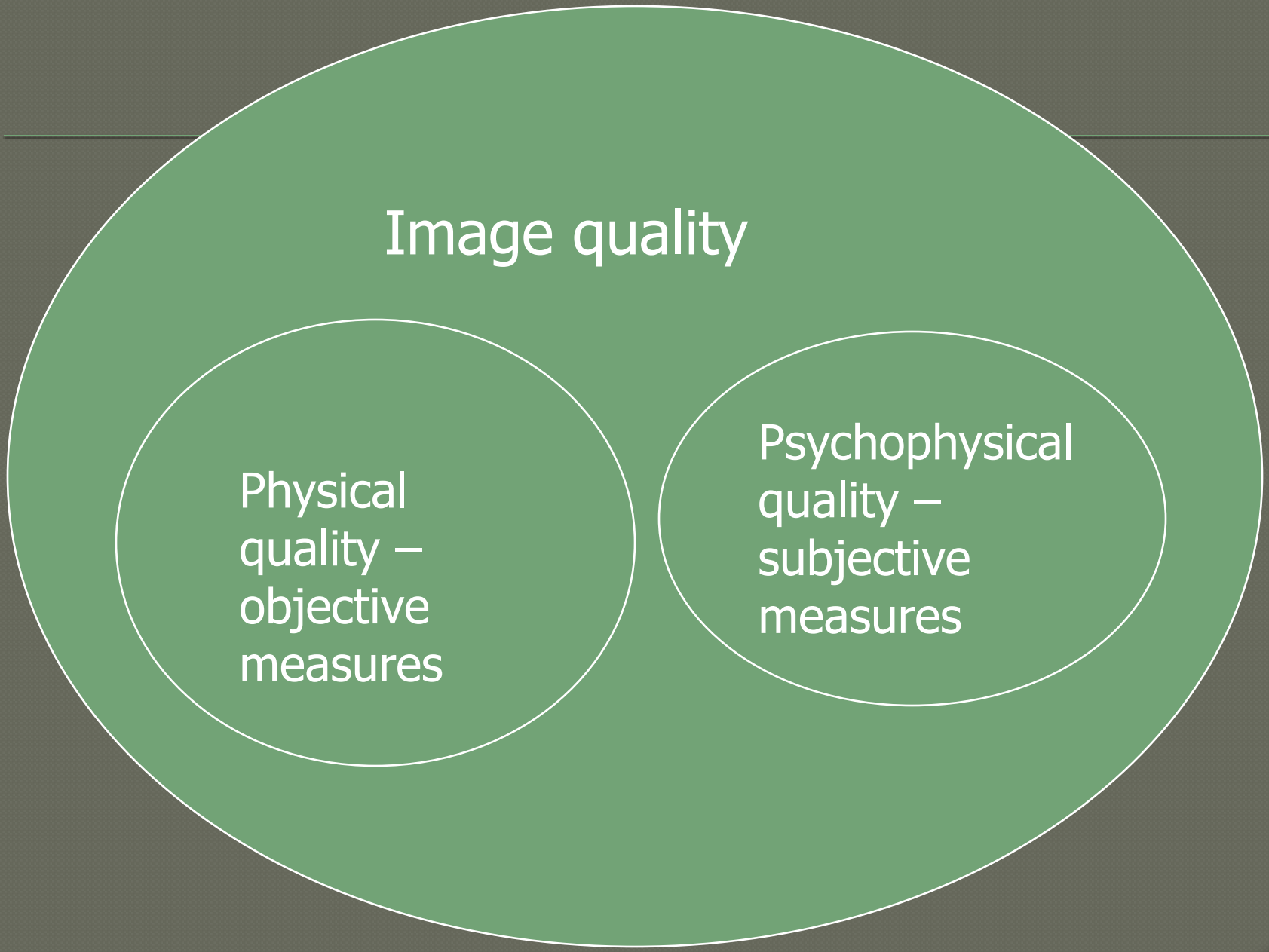


Image quality
Physical quality – objective measures
Psychophysical quality – subjective measures

3 physical measures incorporated in NEQ

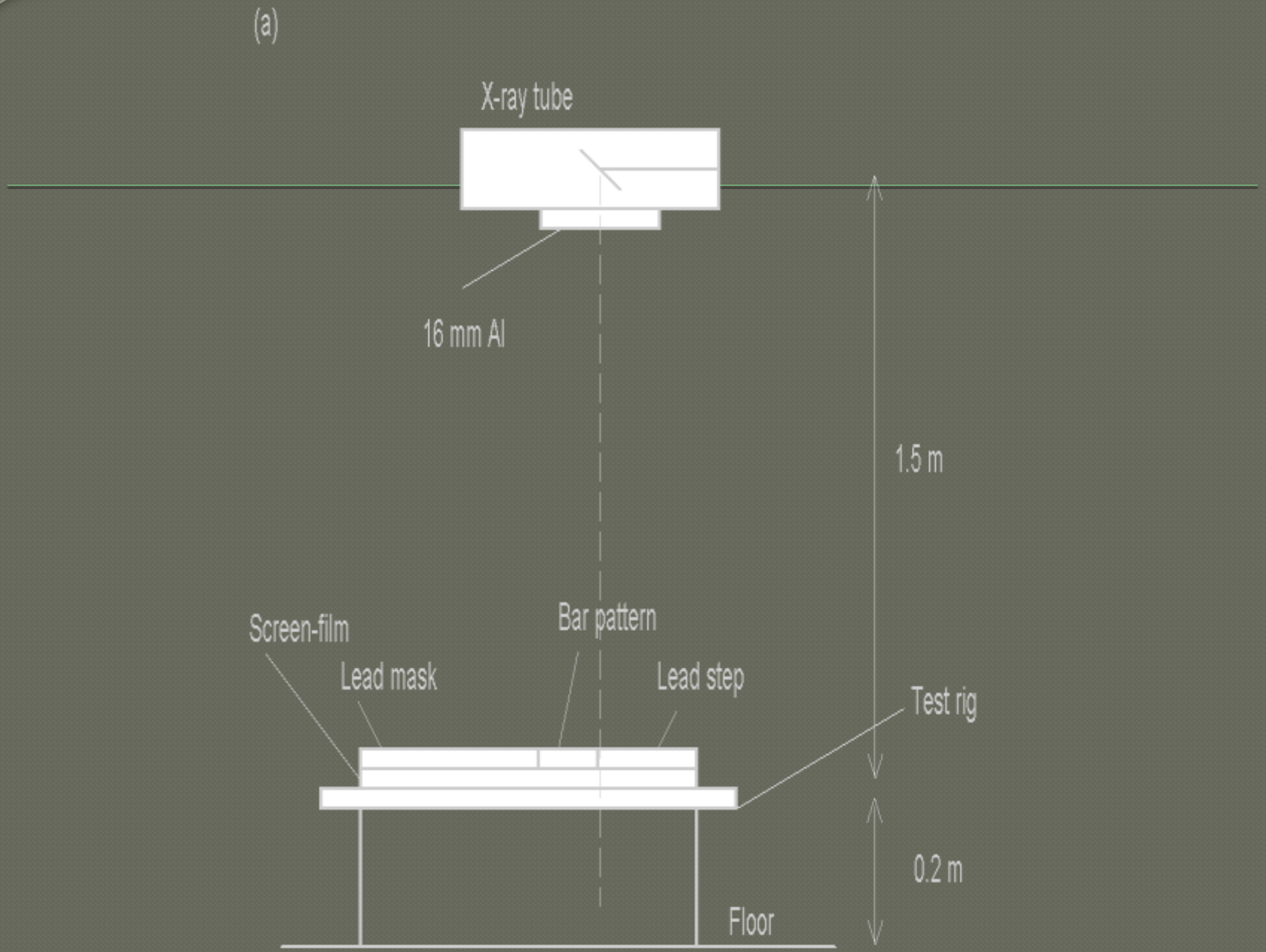
- Large area transfer characteristics - the gamma
- Spatial resolution characteristics - the modulation transfer function (MTF)
- Noise properties - the noise power spectrum (NPS) or the Wiener spectrum

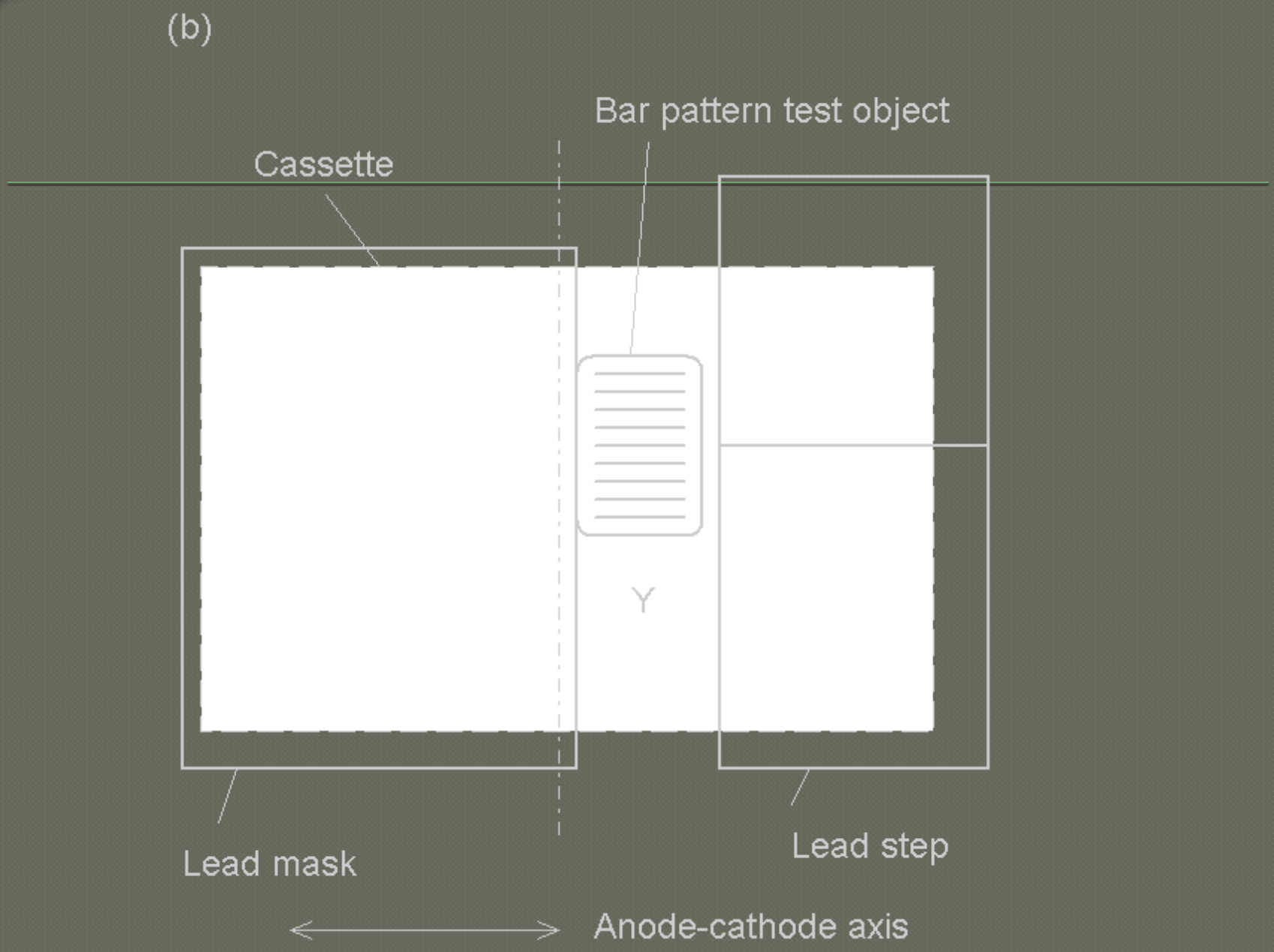
MTF measurement methods

- Slit method
- Square wave response function method
- Edge spread function method

NPS measurement methods

- Digital fast Fourier method
- Autocorrelation function method

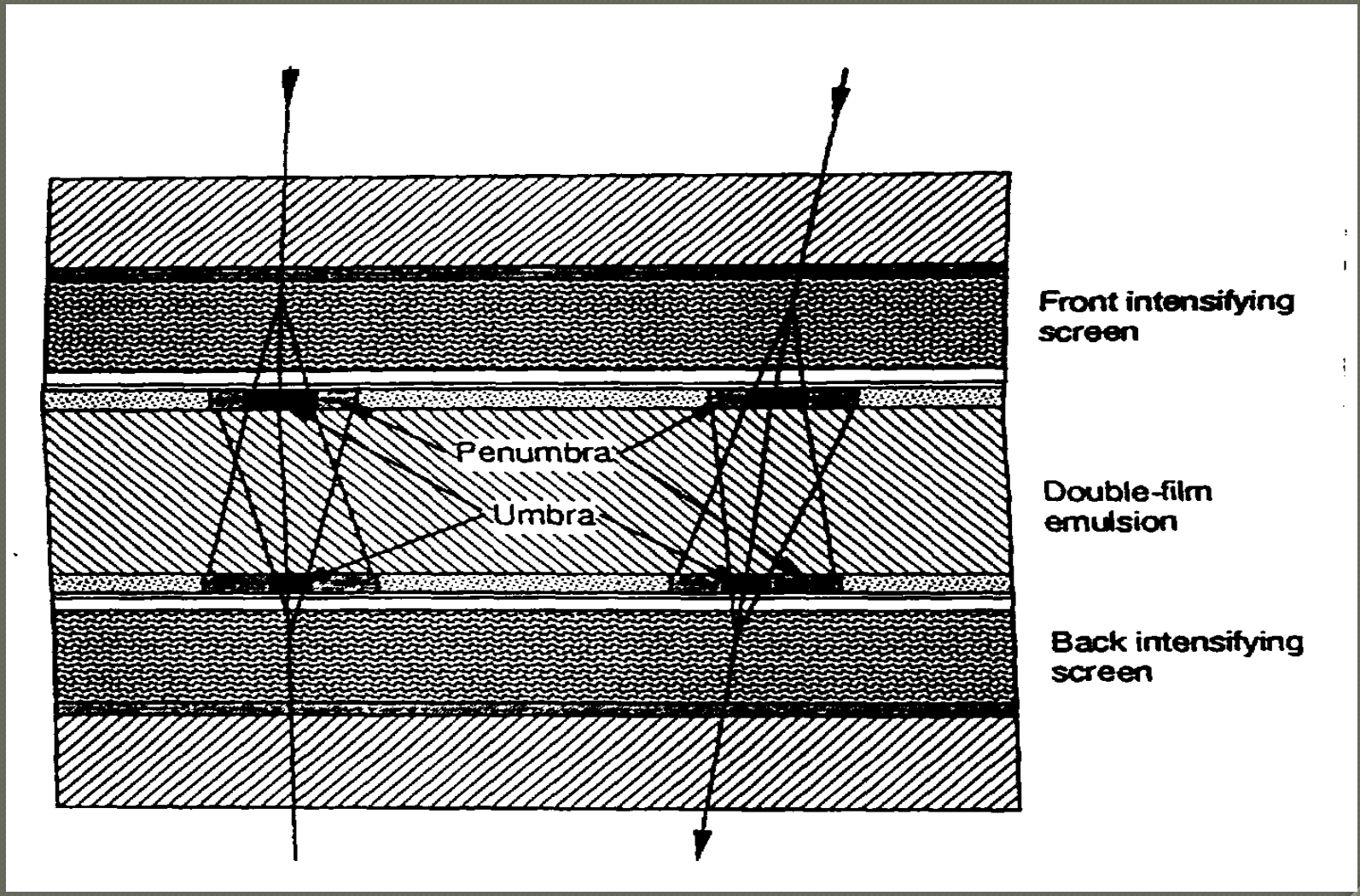

(a)
X-ray tube
16 mm Al
1.5 m
Screen-film
Lead mask
Bar pattern
Lead step
Test rig
0.2 m
Floor


(b)
Bar pattern test object
Cassette
Y
Lead mask
Lead step
Anode-cathode axis

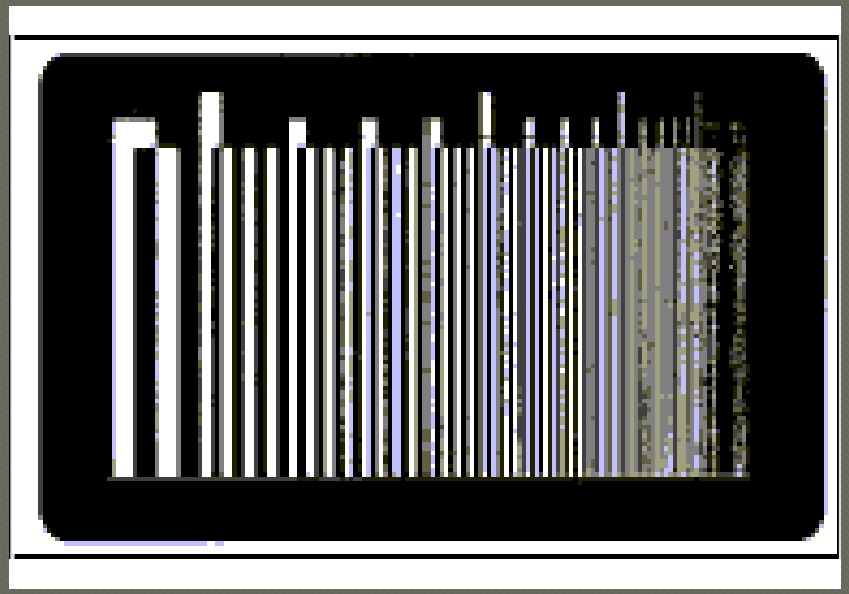
Screen-film

Screen-film

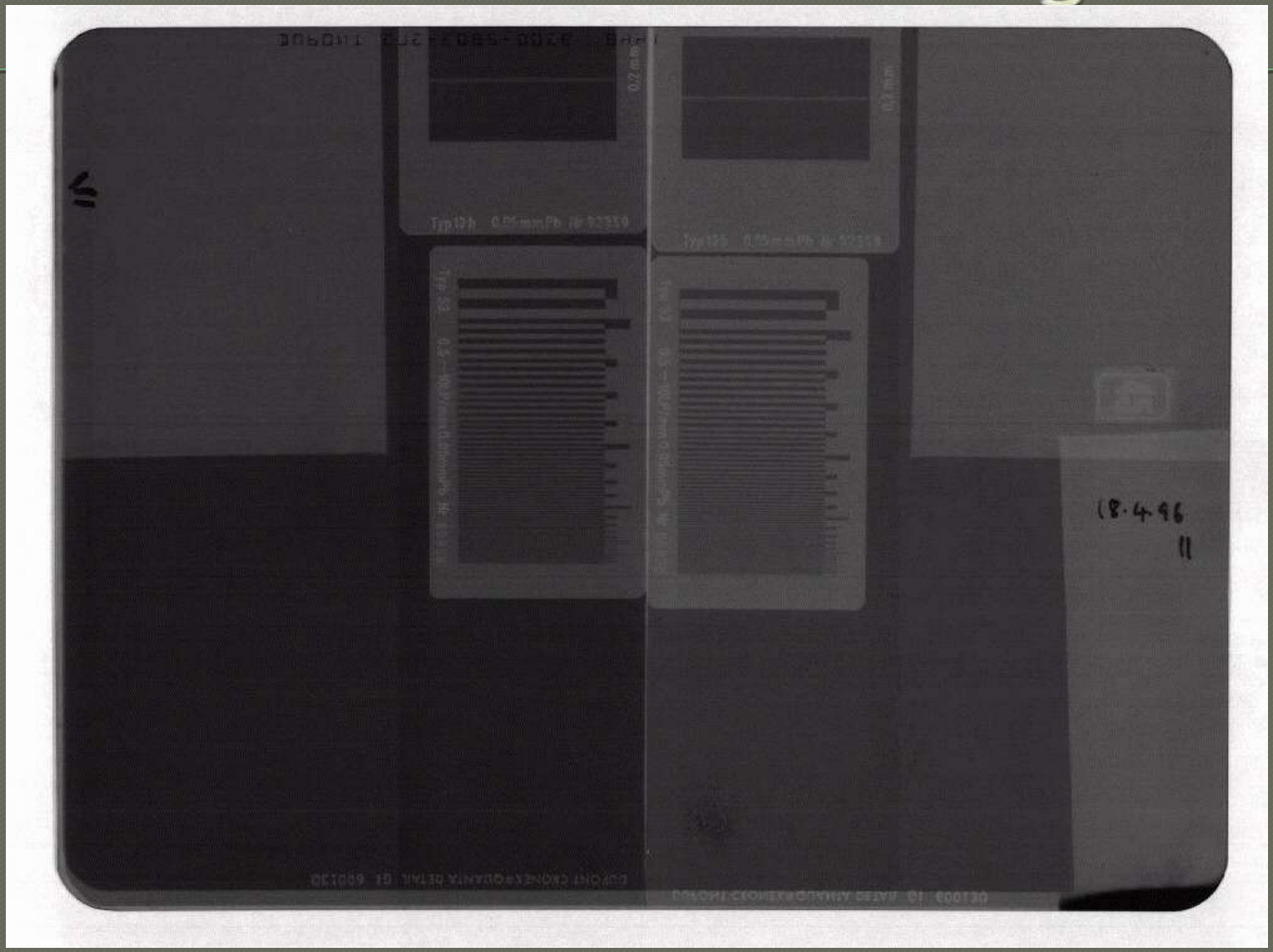
Cross section of a screen-film



Bar pattern test object ...

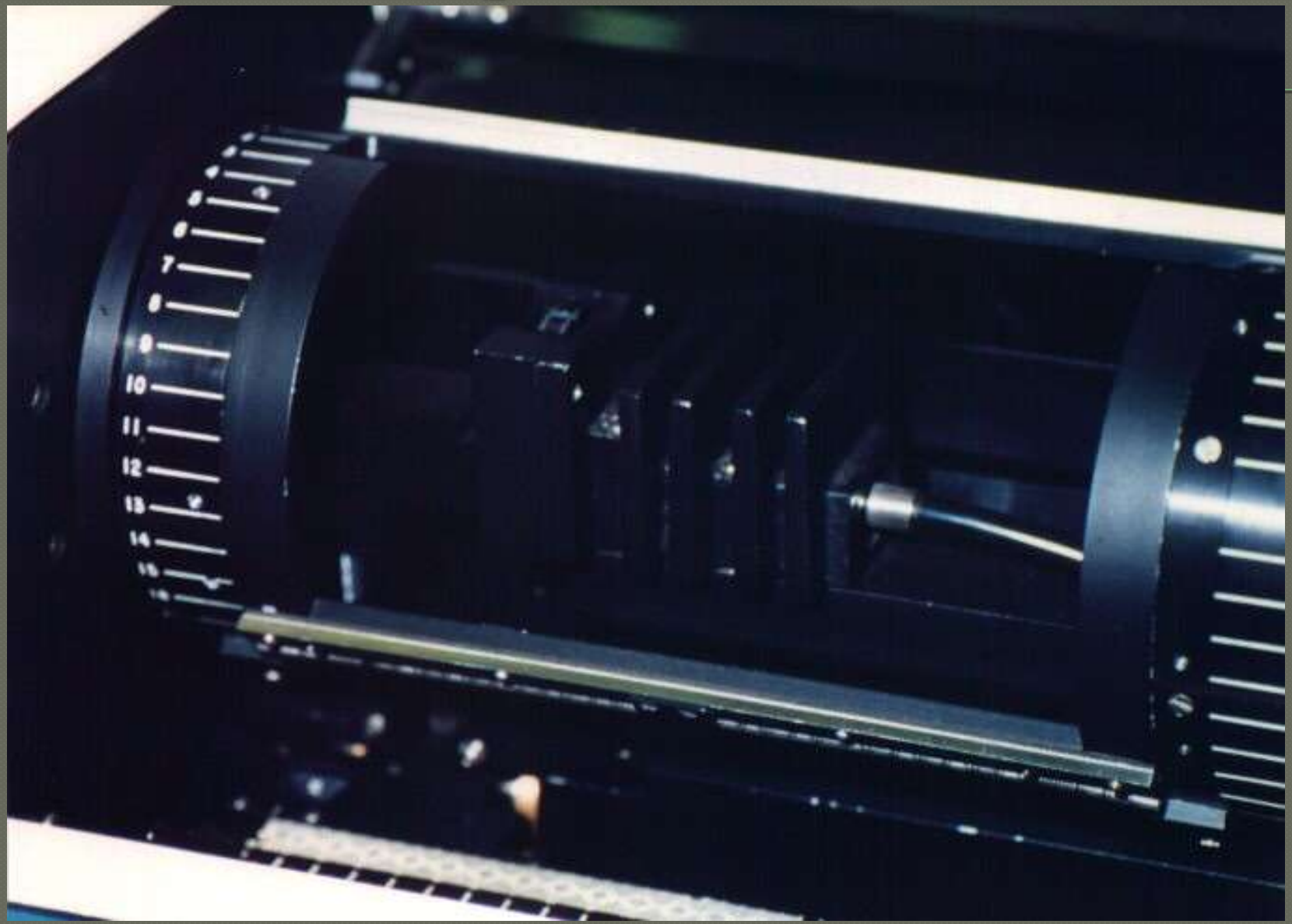


Image

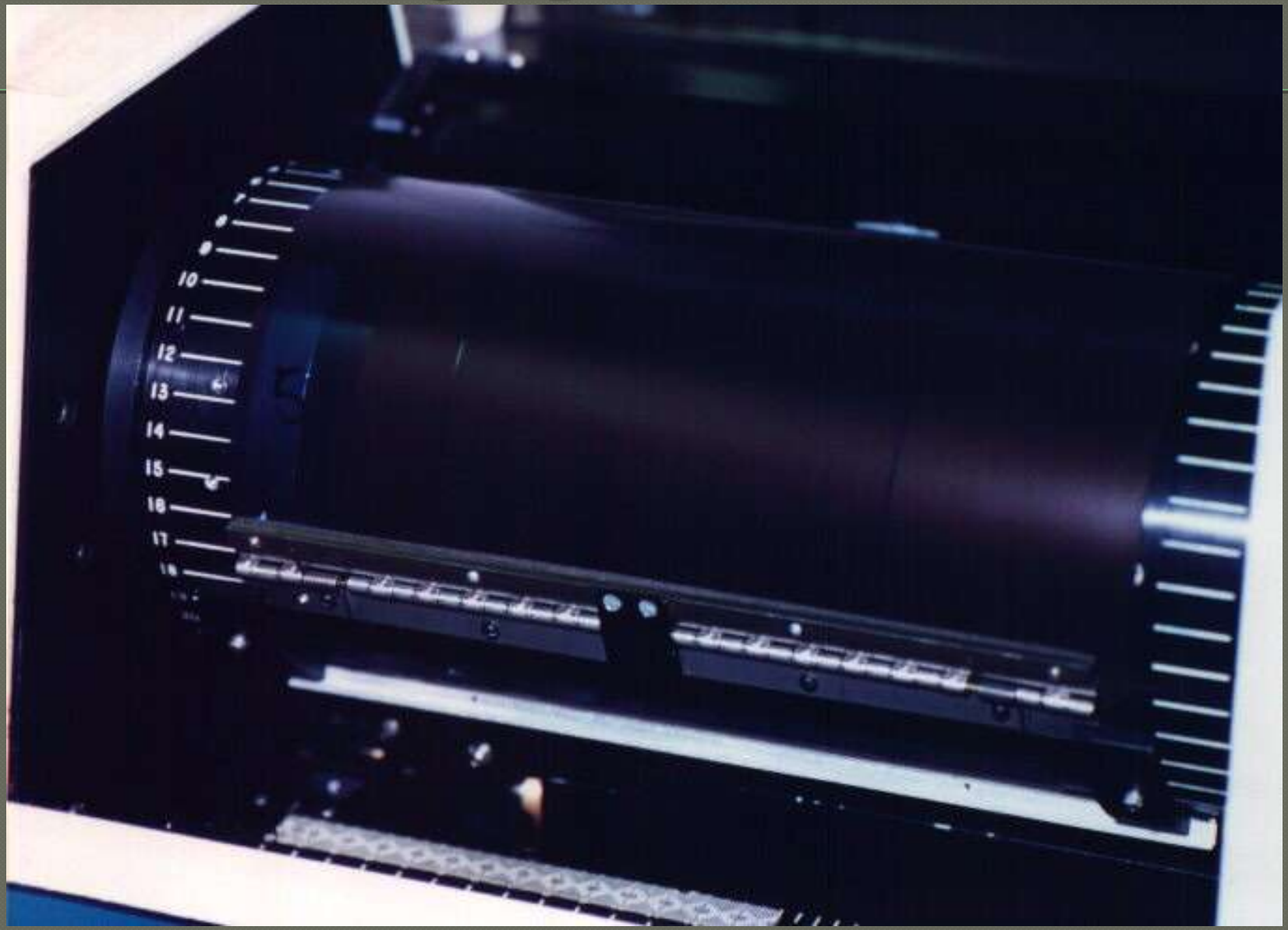


Microdensitometer

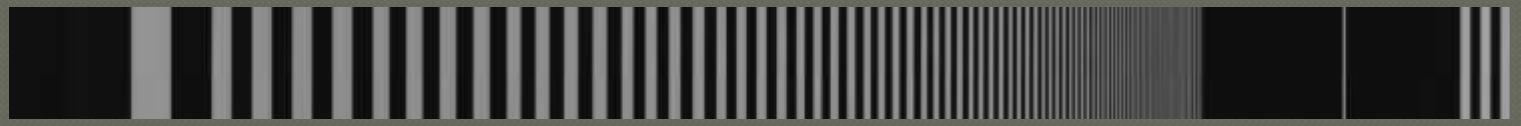
Close up of microdensitometer



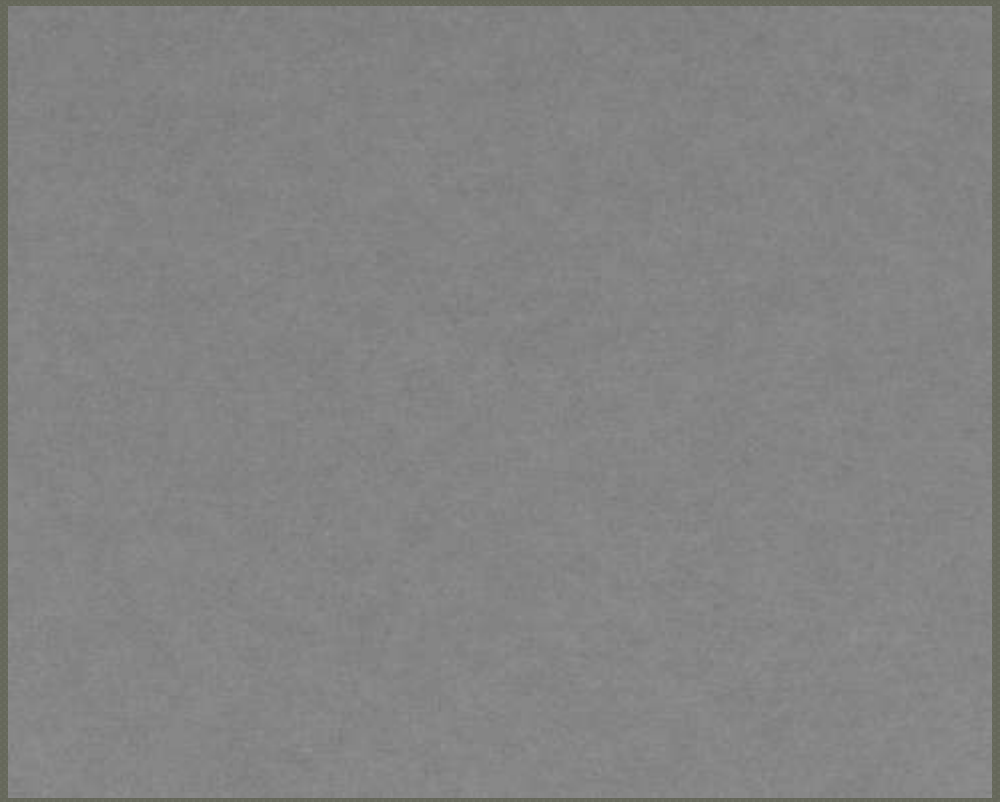
Radiograph/film mounted



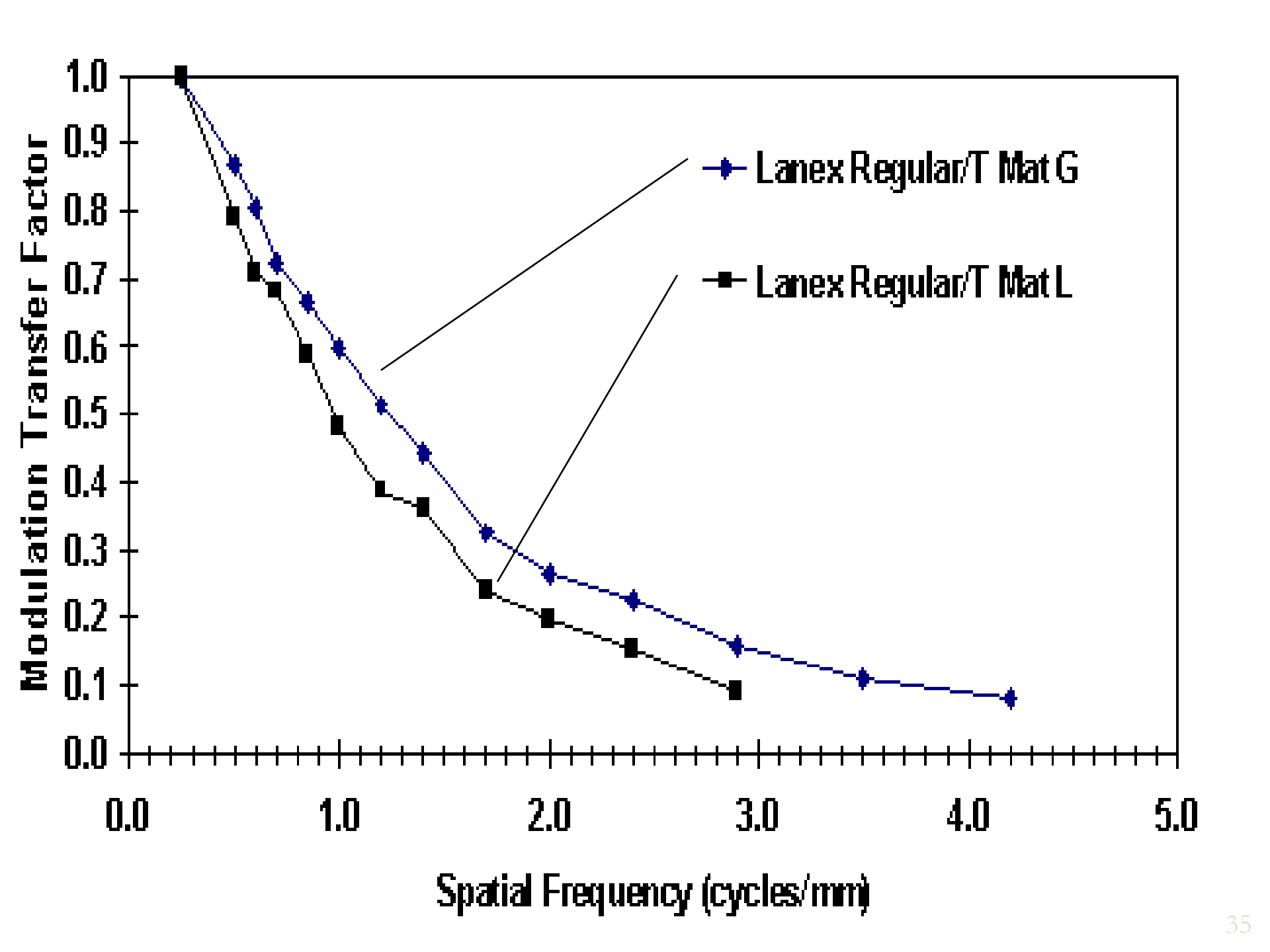
Scanned images

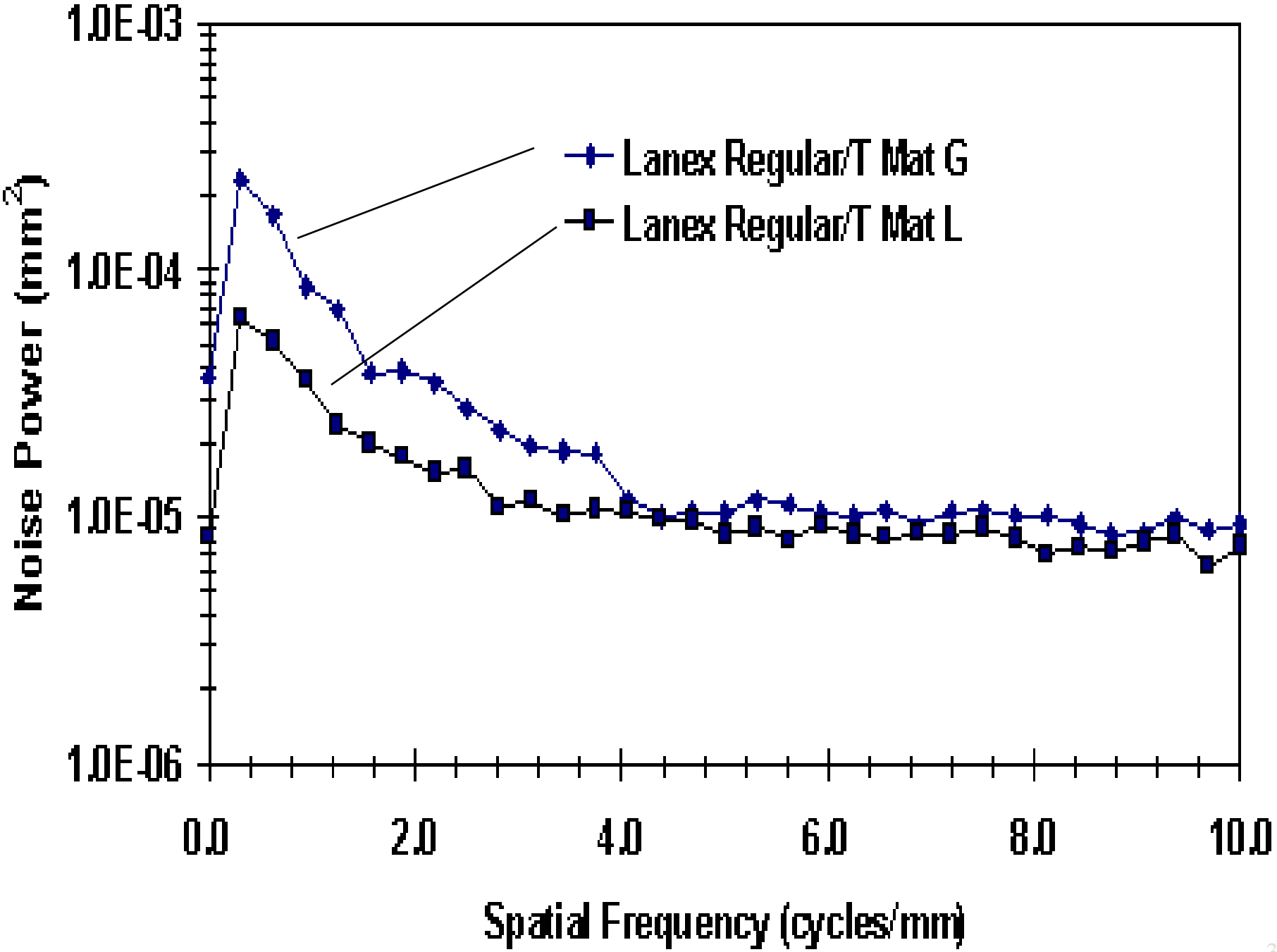


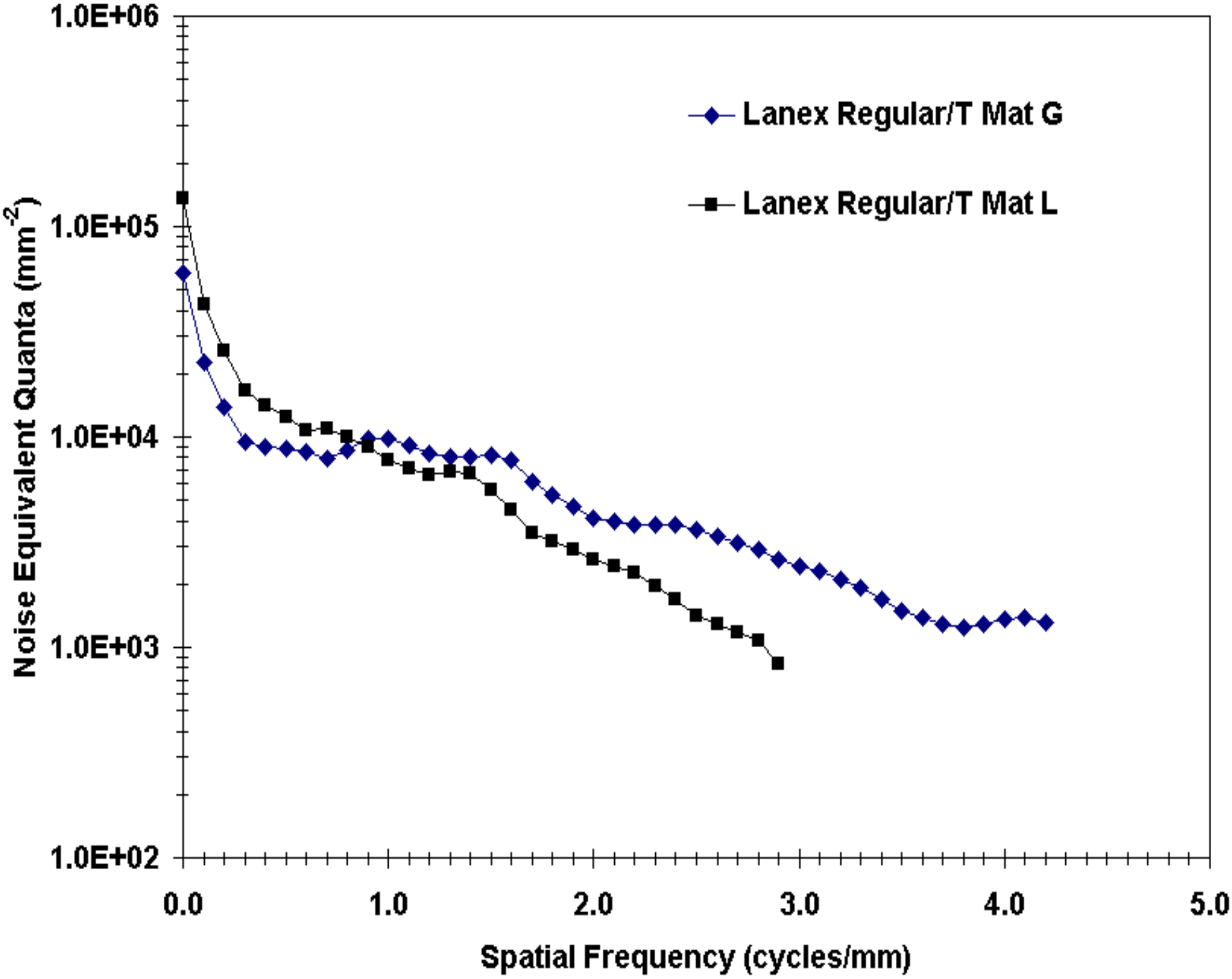
MTF



NPS


Modulation Transfer Factor
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
1.0
2.0
3.0
4.0
5.0
Spatial Frequency (cycles/mm)
Lanex Regular/T Mat G
Lanex Regular/T Mat L

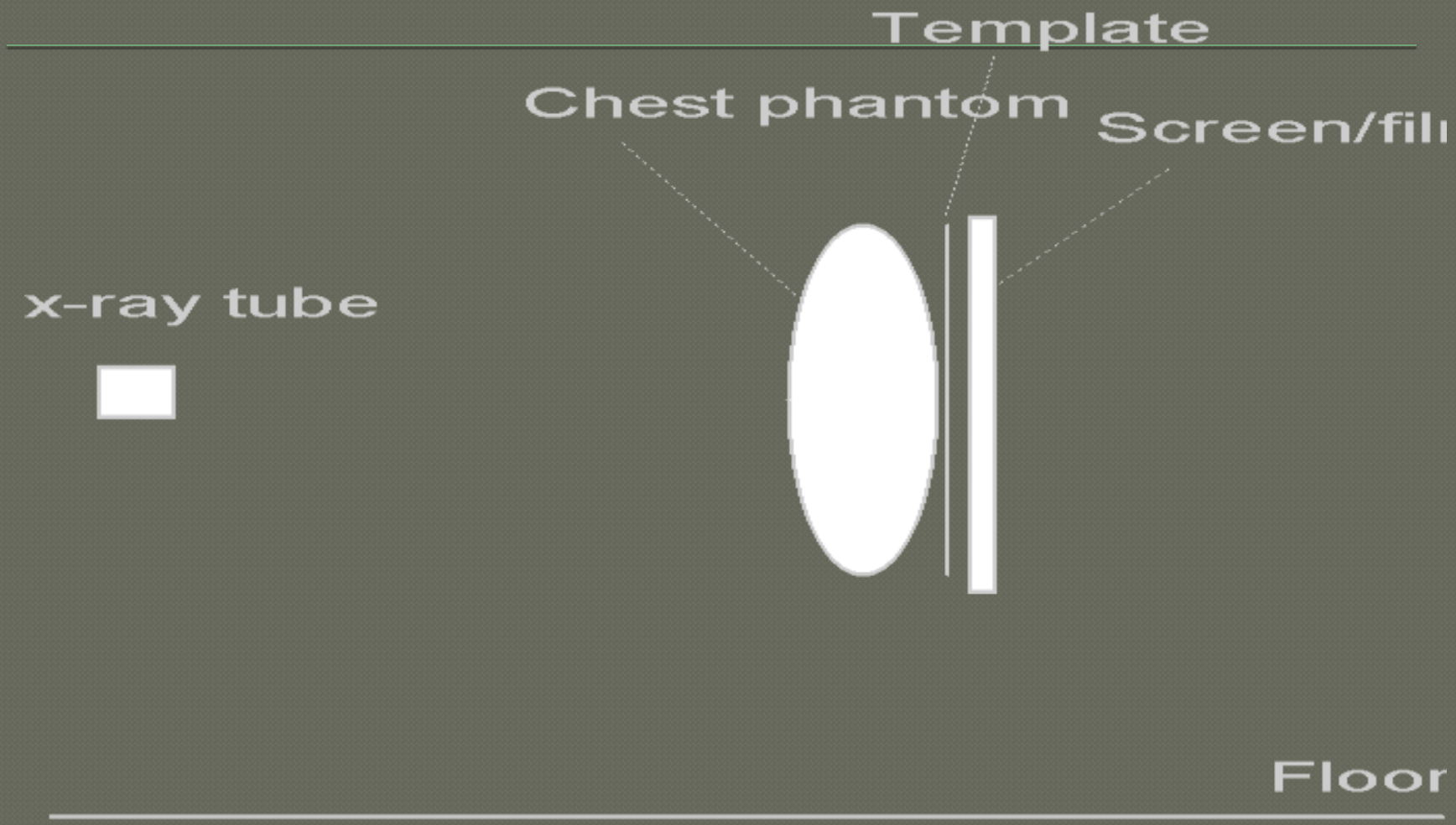

1.0E-03
1.0E-04
1.0E-05
1.0E-06
Noise Power (mm2)
Lanex Regular/T Mat G
Lanex Regular/T Mat L
0.0
2.0
4.0
6.0
8.0
10.0
Spatial Frequency (cycles/mm)


1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
Noise Equivalent Quanta (mm-2)
0.0
1.0
2.0
3.0
4.0
5.0
Spatial Frequency (cycles/mm)
Lanex Regular/T Mat G
Lanex Regular/T Mat L

NEQ computation

- Compute average gamma
- Interpolate MTF
- Interpolate NPS
- Compute NEQ

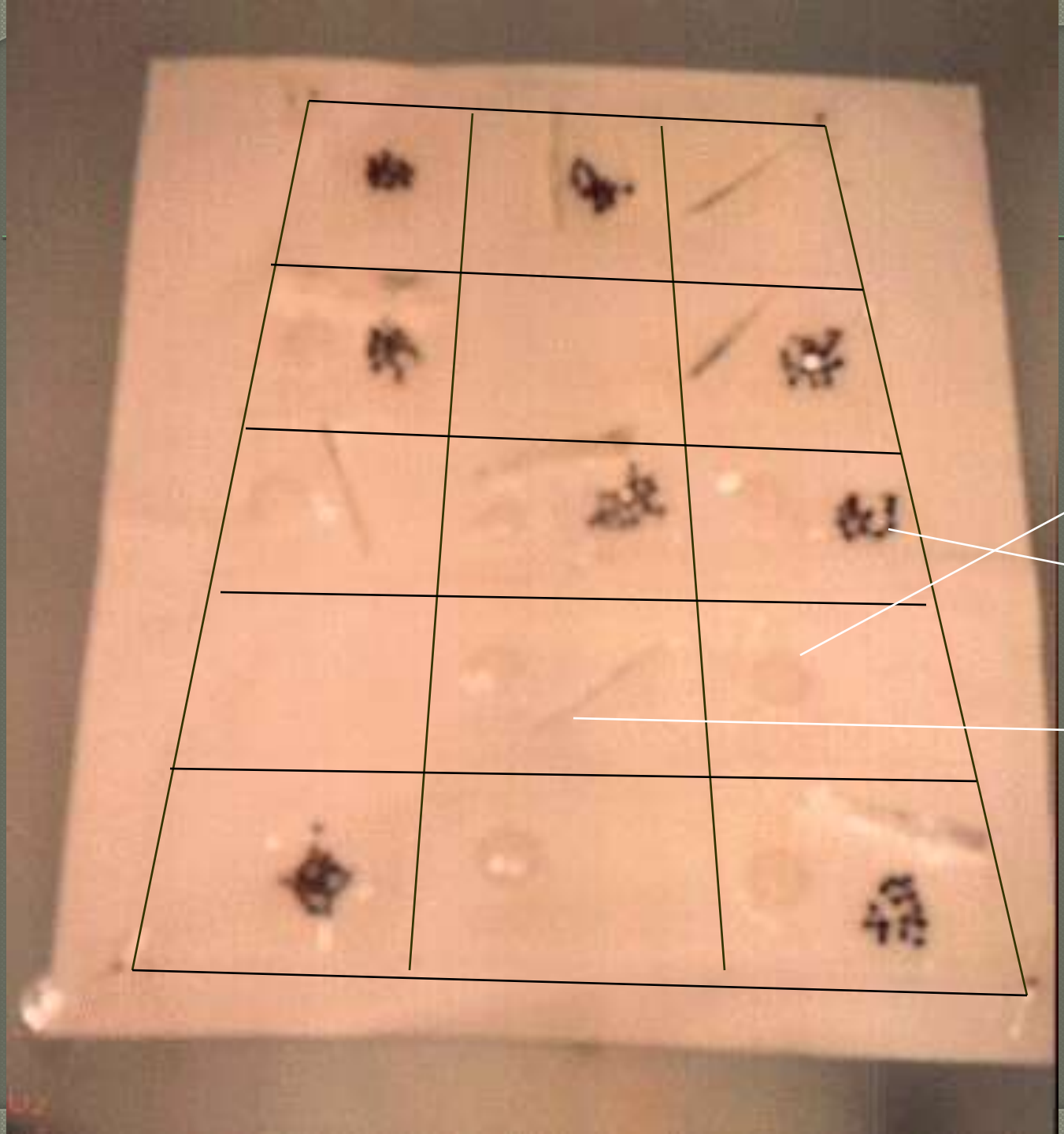
Subjective measure – receiver operating characteristic (ROC) analysis



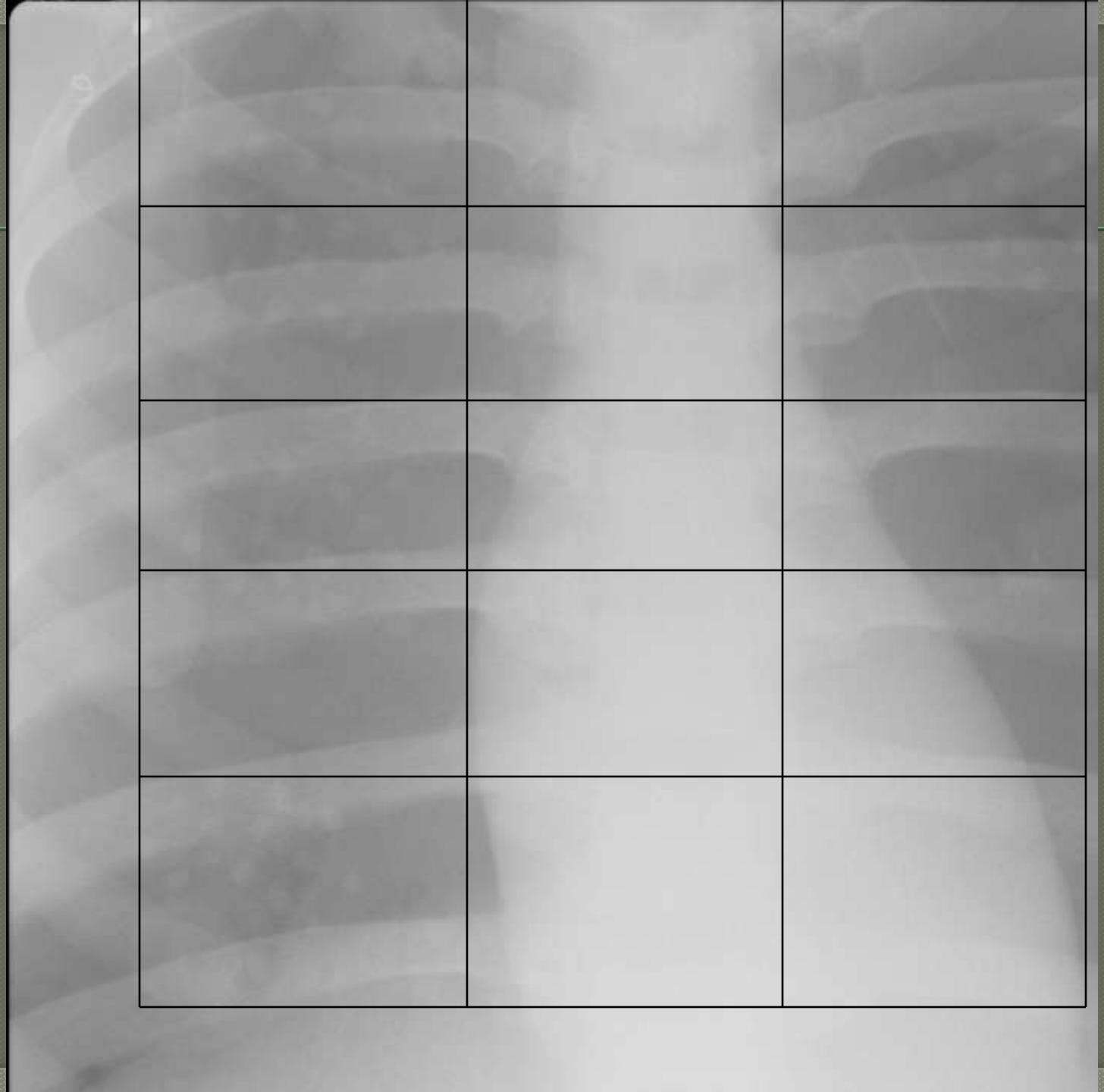
Experimental setup

Anthropomorphic chest phantom

Template



- Candle wax
- Green beans
- Aluminum foil



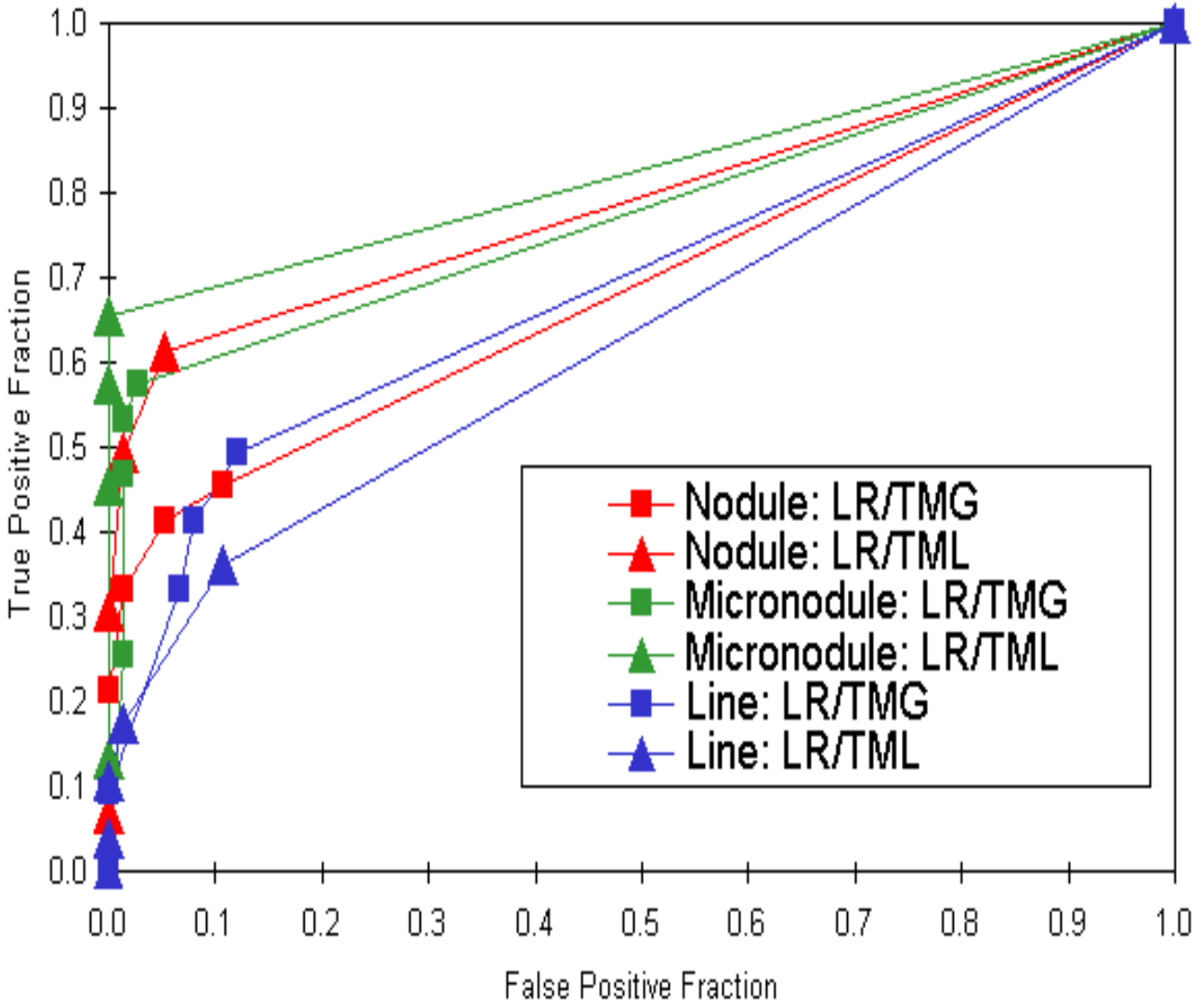
ROC Study Score Form

Use the following confidence categories:
=1= Definitely not present
=2= Probably not present
=3= No decision possible
=4= Probably present
=5= Definitely present
Circle your decision.

Film No:
(top left)

Reader:

Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5= in this field.	Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5= in this field.	Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5= in this field.
Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5= in this field.	Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5= in this field.	Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5= in this field.
Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5=	Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5=	Decide your confidence in seeing a nodule: =1=2=3=4=5= a line: =1=2=3=4=5= micronodules: =1=2=3=4=5=



ROC curves for detecting the nodules, lines, and micronodules using Lanex Regular/T Mat G (LR/TMG) and Lanex Regular/T Mat L (LR/TML) systems.

Areas under the ROC curves

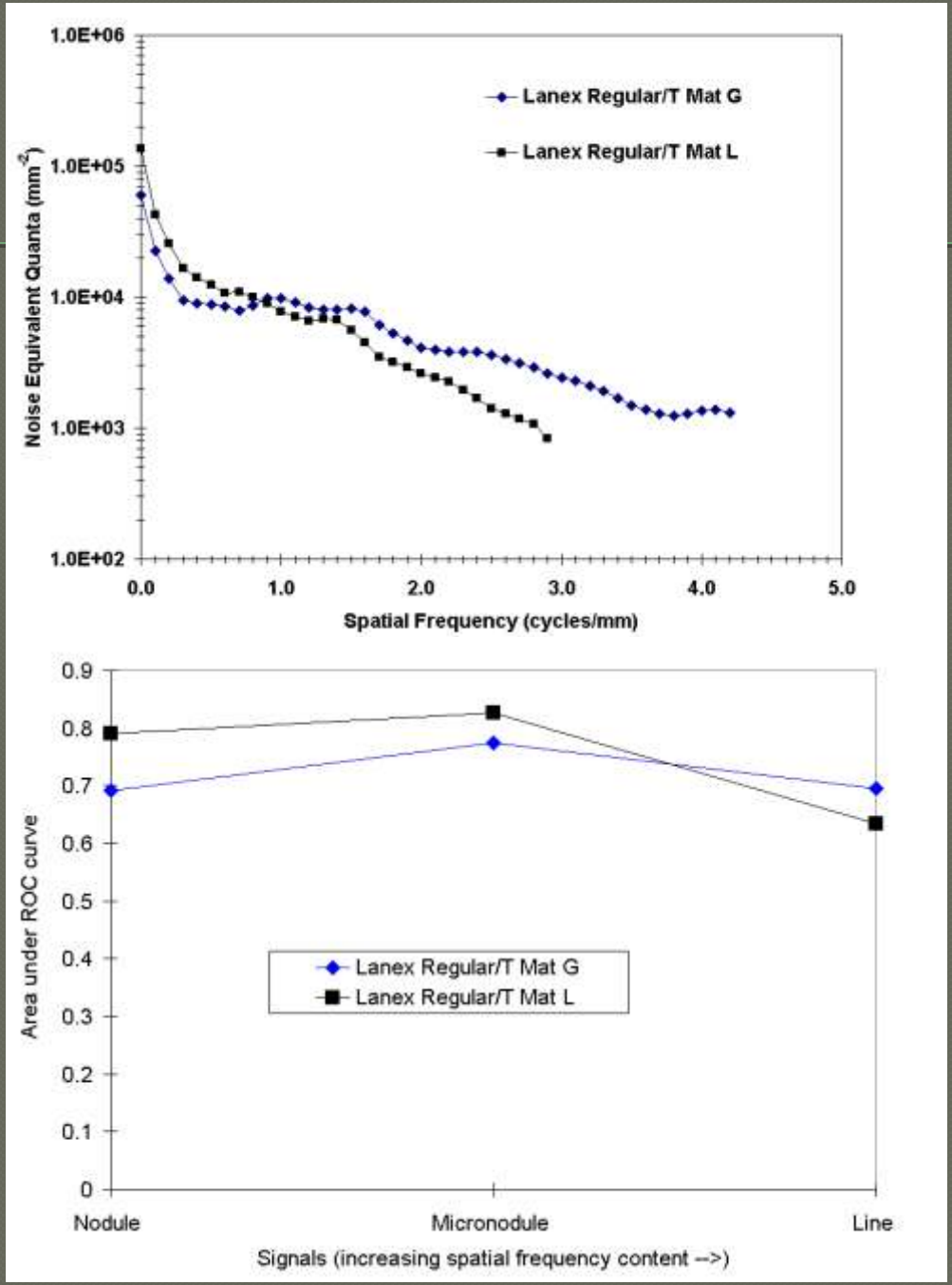
Simulated lesion	Lanex Regular/T Mat G	Lanex Regular/T Mat L
Nodule	0.6908	0.7911
Micronodule	0.7748	0.8267
Line	0.6944	0.6342

Using area as a measure of detection, i.e. the area under the ROC curve corresponds to the probability of correctly identifying which of the two stimuli is ‘noise’ and which is ‘signal plus noise’ [10], the curves show that modules and micronodules show better on LR/TML whilst lines show better on LR/TMG.

The spatial frequency content of the lesion signals are: 1/10 mm = 0.1 cycle/mm for nodules, 1/3 mm = 0.3 cycles/mm for micronodules, and 1/1 mm = 1.0 cycle/mm for lines.

For nodules and micronodules the objective measure indicates that the NEQ of LR/TML is higher than that of LR/TMG (Figure 2). This agrees with the subjective measure which says that better detection of the lesions using LR/TML than LR/TMG (Figure 3).

For lines, the NEQ of LR/TMG is higher than that of LR/TML (Figure 2) and this agrees with the observer performance exhibiting better detection of the lesions using LR/TMG than LR/TML (Figure 3).


1.0E+06
1.0E+05
1.0E+04
1.0E+03
1.0E+02
Noise Equivalent Quanta (mm-2)
Lanex Regular/T Mat G
Lanex Regular/T Mat L
0.0
1.0
2.0
3.0
4.0
5.0
Spatial Frequency (cycles/mm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Area under ROC curve
Lanex Regular/T Mat G
Lanex Regular/T Mat L
Nodule
Micronodule
Line
Signals (increasing spatial frequency content -->)

Medical imaging research

- Detector development
- Signal/data processing
- Image processing
- Image quality evaluation
- Patient dose
- Digital imaging
- PAC, teleradiology

Thank you