

Principles of Digital Radiography

Principles of Digital Radiography (DR)

Designed for quick reference and deeper study

1. Overview of Digital Radiography

Aspect	Traditional Film-Based X-ray	Digital Radiography (DR)
Image Capture	Photographic film + intensifying screen	Direct conversion of X-ray photons to electrical signals
Processing Time	5–10 min (development, fixing)	Seconds (real-time acquisition)
Dynamic Range	~10 dB	12–15 dB (up to 100 dB in some systems)
Radiation Dose	Higher (due to limited detector efficiency)	30–60% lower dose on average
Storage	Physical archives, limited reuse	PACS, cloud, virtually unlimited copies
Image Manipulation	Limited (darkroom techniques)	Wide range (window/level, filters, measurements)

2. Core Physical Concepts

Concept	Definition	Relevance to DR
X-ray Attenuation	Exponential loss of photon intensity as it passes through matter ($I = I_0 e^{-\mu x}$).	Determines contrast; detector material must have appropriate attenuation coefficients.
Photoelectron Conversion	Interaction that liberates charge carriers (electrons/holes).	Basis of detector operation (direct vs. indirect conversion).
Signal-to-Noise Ratio (SNR)	Ratio of useful signal to random noise. Higher SNR = clearer images.	Detector design, readout electronics, and post-processing aim to maximize SNR.
Dynamic Range	Ratio between the largest and smallest detectable signal.	Determines ability to display both high- and low-density structures in one image.

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Concept	Definition	Relevance to DR
Modulation	Frequency response of the imaging	Higher MTF = sharper edges;
Transfer Function (MTF)	system; measures spatial resolution.	influenced by pixel size, scintillator thickness, and readout method.

3. Detector Technologies

Type	Direct vs. Indirect	Typical Materials	Advantages	Limitations
Flat-Panel Detectors (FPDs)	Both	Direct: Amorphous Selenium ($\alpha\text{-Se}$) Indirect: CsI(Tl) scintillator + Amorphous Silicon ($\alpha\text{-Si}$) photodiodes	Large active area, fast readout, high DQE (detective quantum efficiency)	Cost, potential for image lag (indirect), pixel size limits resolution
Charge-Coupled Devices (CCDs)	Indirect (scintillator + fiber optic plate)	CsI or $\text{Gd}_2\text{O}_3\text{S}$ scintillator + CCD sensor	High spatial resolution (small pixel pitch)	Smaller field of view, slower readout, more fragile
Complementary Metal-Oxide-Semiconductor (CMOS) Sensors	Direct & Indirect variants	$\alpha\text{-Si}$ or $\alpha\text{-Se}$ photodiodes, sometimes with scintillator	Low power, fast frame rates, on-chip processing	Historically lower DQE, but improving rapidly
Photon-Counting Detectors (PCDs)	Direct (semiconductor)	CdTe, CZT, or Si	Excellent contrast, energy discrimination, very high DQE	Expensive, limited to smaller detector sizes, count-rate saturation

Key Performance Metrics

Metric	Symbol	Typical DR Values
Detective Quantum Efficiency (DQE)	$\text{DQE}(f)$	0.1 - 0.5