Deep Learning in Biomedical Image Analysis

Seminar 3: Tomography

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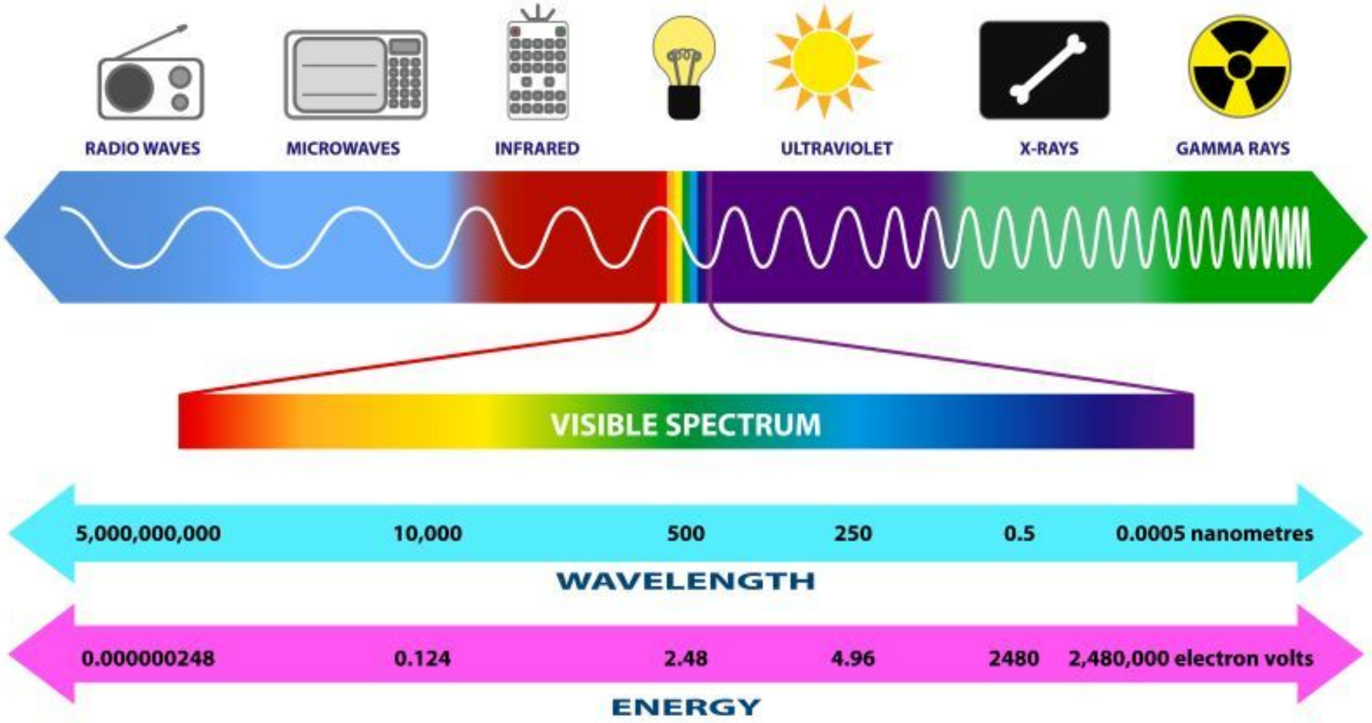
Electromagnetic spectrum



Source: https://www.nibib.nih.gov/science-education/science-topics/x-rays

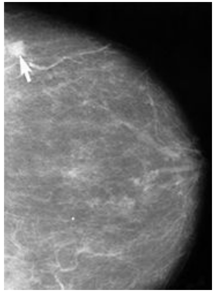
A brief history of X-ray

Source: wikimedia

- Prior to 1985: partially evacuated glass tubes produced X-rays when voltage was applied. This produced glow, darkened photoplates etc.
- 1985 Röntgen "On a new kind of ray: A preliminary communication"
- John Hall-Edwards in Birmingham, England on 11 January 1896, when he radiographed a needle stuck in the hand of an associate

Wilhelm Röntgen

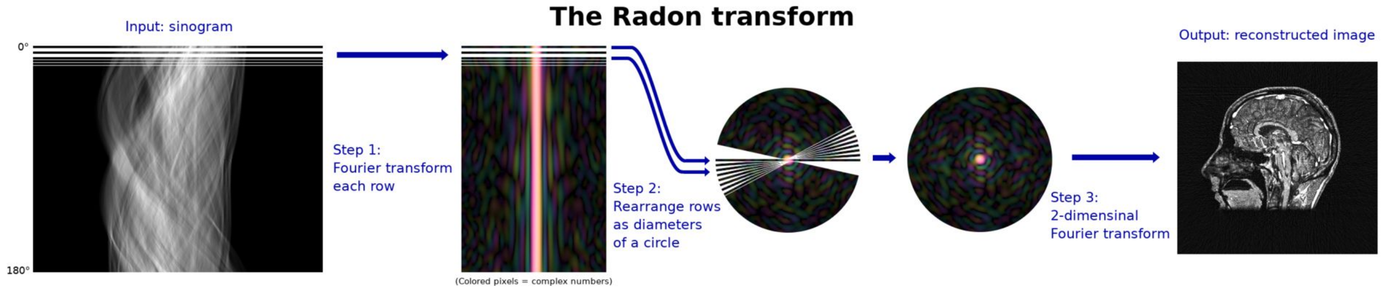
Chest X-ray showing COVID-19 pneumonia, source wikipedia



A mammogram showing a small cancerous lesion, source nibib.hih.gov

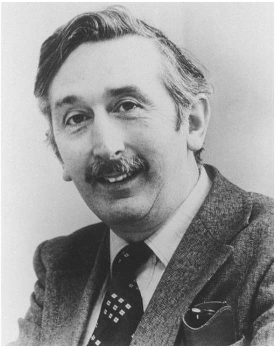
Source: https://www.nibib.nih.gov/science-education/science-topics/x-rays

Computed tomography (CT): brief history



Source: wikipedia

Sir Godfrey Hounsfield



- 1917 Johan Radon proposes a Radon transform: *a function could be reconstructed from an infinite set of its projections.*
- Ca. 1967 Sir Godfrey Hounsfield in Hayes, United Kingdom, at **EMI** Central Research Laboratories using X-rays.
- First brain scan on 1 October 1971 in Atkinson Morley Hospital in Wimbledon, England

First commercial EMI CT scanner (wikipedia)

Computed tomography (CT)

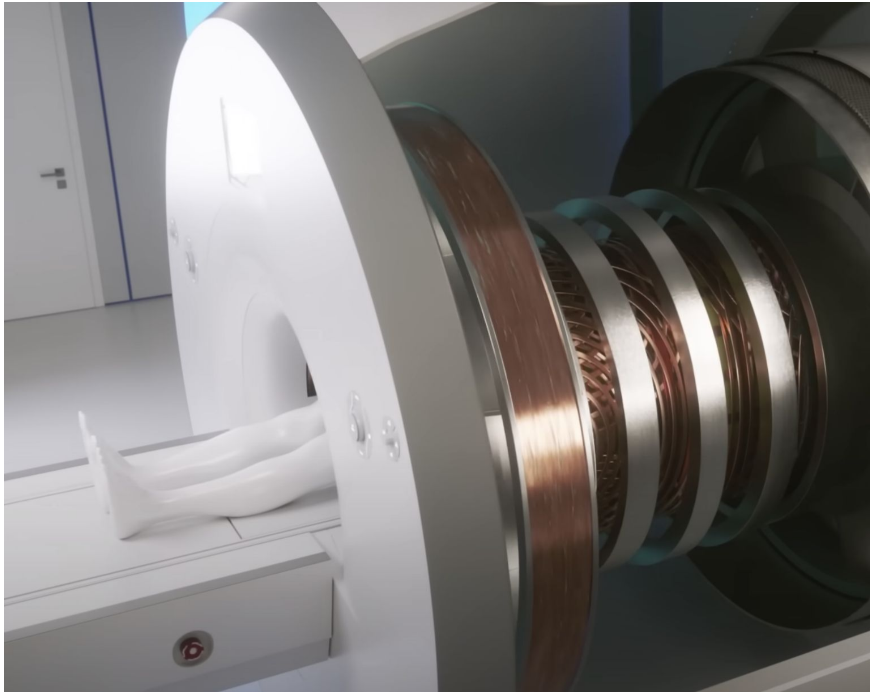
- Sequential CT (increased time of scanning)
- Spiral CT (most common)
- Electron beam tomography (high temporal resolution)
- CT perfusion imaging (blood vessels)
- PET CT (positron emission CT)

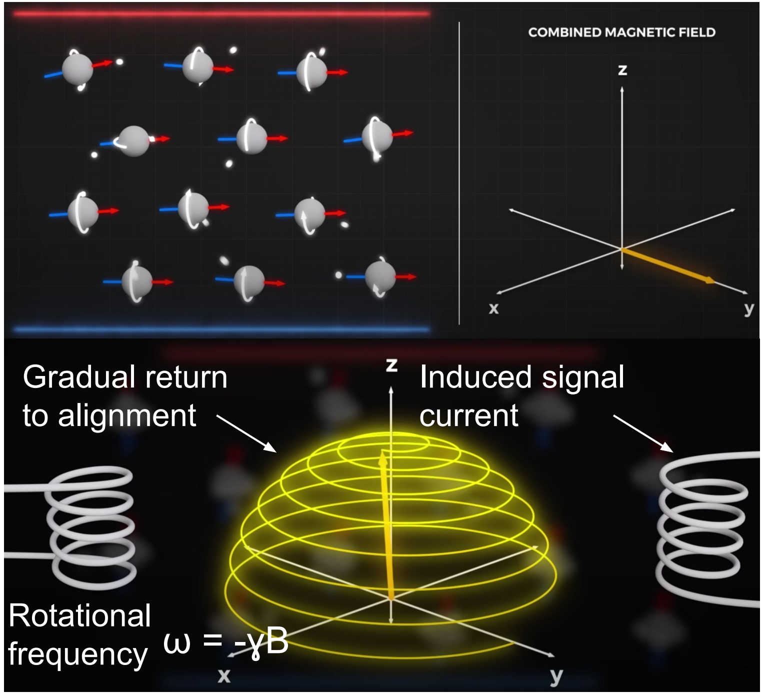
*CT scans can have 100 to 1,000 times higher dose than conventional X-rays (Redberg et al. 2017)

Modern CT scanner (wikipedia)

Magnetic resonance imaging (MRI)

- All water magnetic molecules are aligned in a strong magnetic field
- Next a magnetic radio frequency pulse is applied to shift the alignment





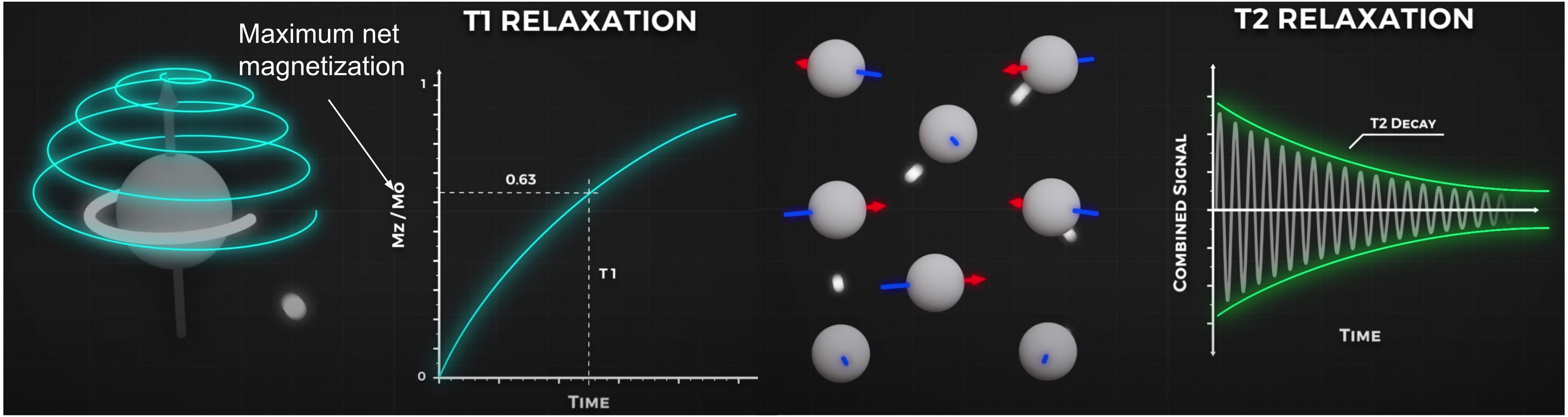
Source: Real Engineering

Magnetic resonance imaging (MRI)

- There are two major sources of signal T1 and T2 relaxation

How quickly atoms realign?

How uniformly atoms realign?



Fat rich tissue

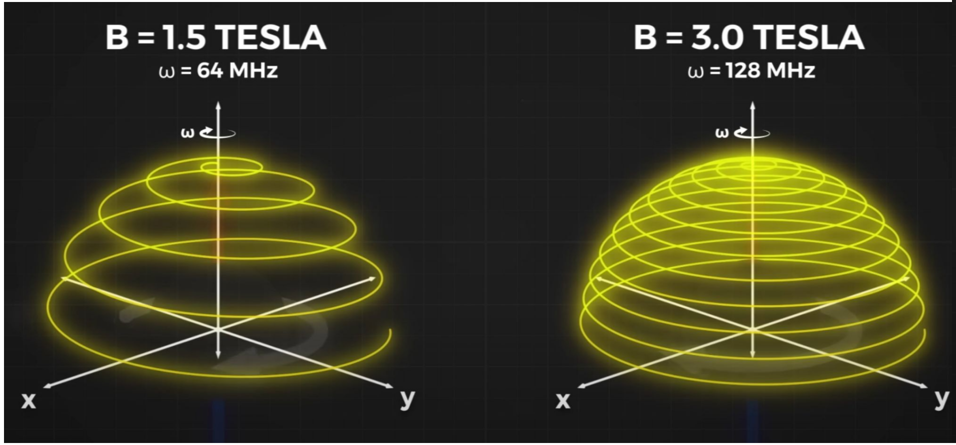
Water rich tissue

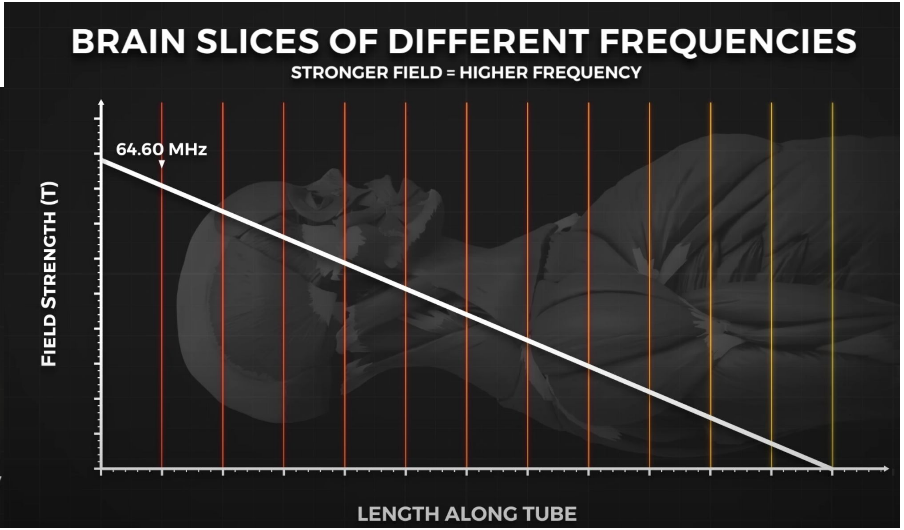
Source: Real Engineering

Magnetic resonance imaging (MRI)

- Slices of tissue can be selected by altering Magnetic Field Strength (B)

H atom relaxation under different B

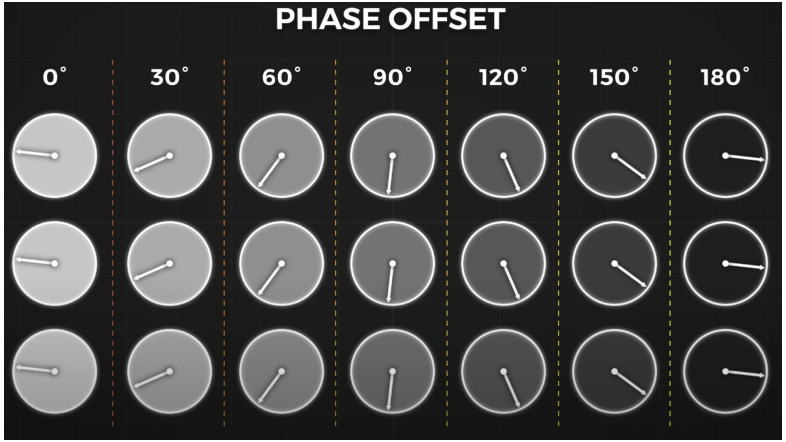


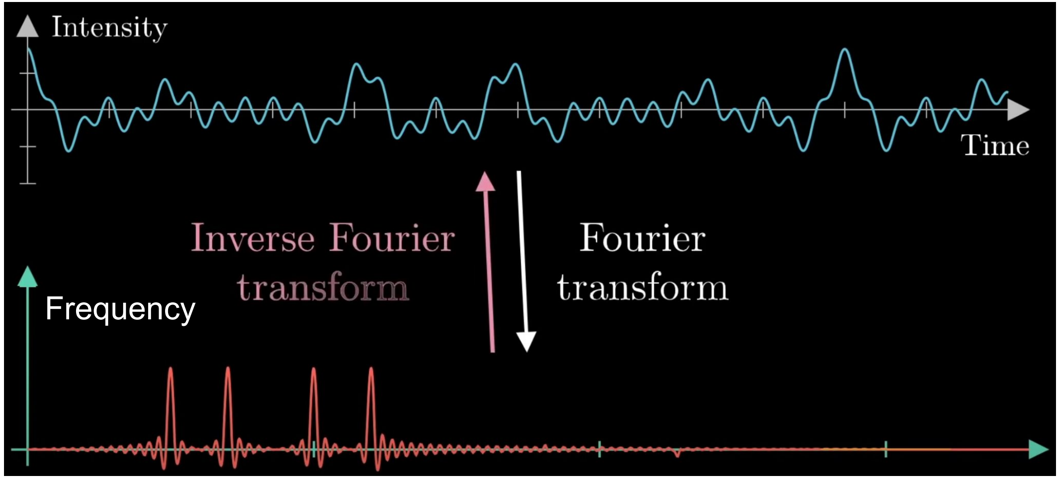


Source: Real Engineering

Magnetic resonance imaging (MRI)

- 2D image of each slice is then created by measuring phase





Source: Real Engineering & 3B1B

Digital images representation: frequency domain

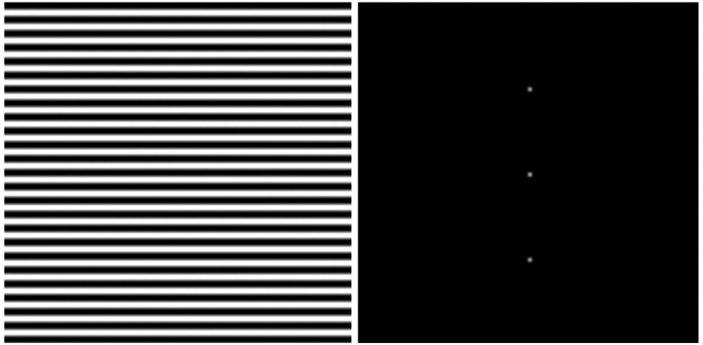
Discrete Fourier transform (DFT) of an image *f* of size M

$$F(u,v) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)e^{-j\,2\pi\left(\frac{um}{M}+\frac{vn}{N}\right)}$$

Inverse DFT

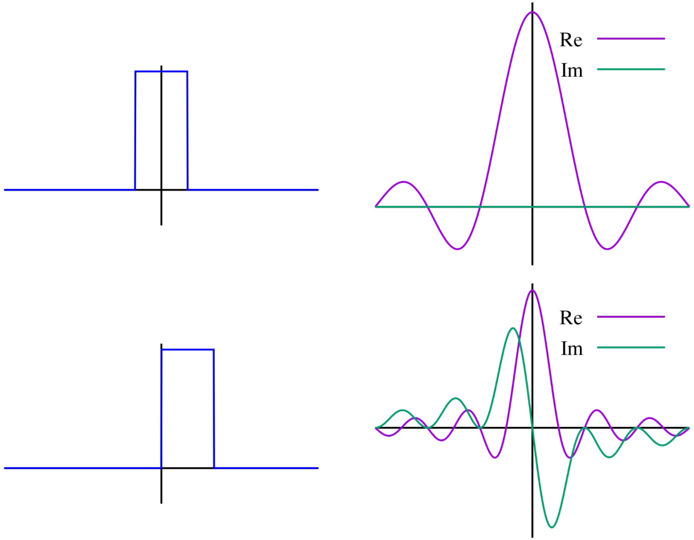
$$f(m,n) = \frac{1}{MN}\sum_{u=0}^{M-1}\sum_{v=0}^{N-1} F(u,v)e^{+j\,2\pi\left(\frac{um}{M}+\frac{vn}{N}\right)}$$

Single frequency



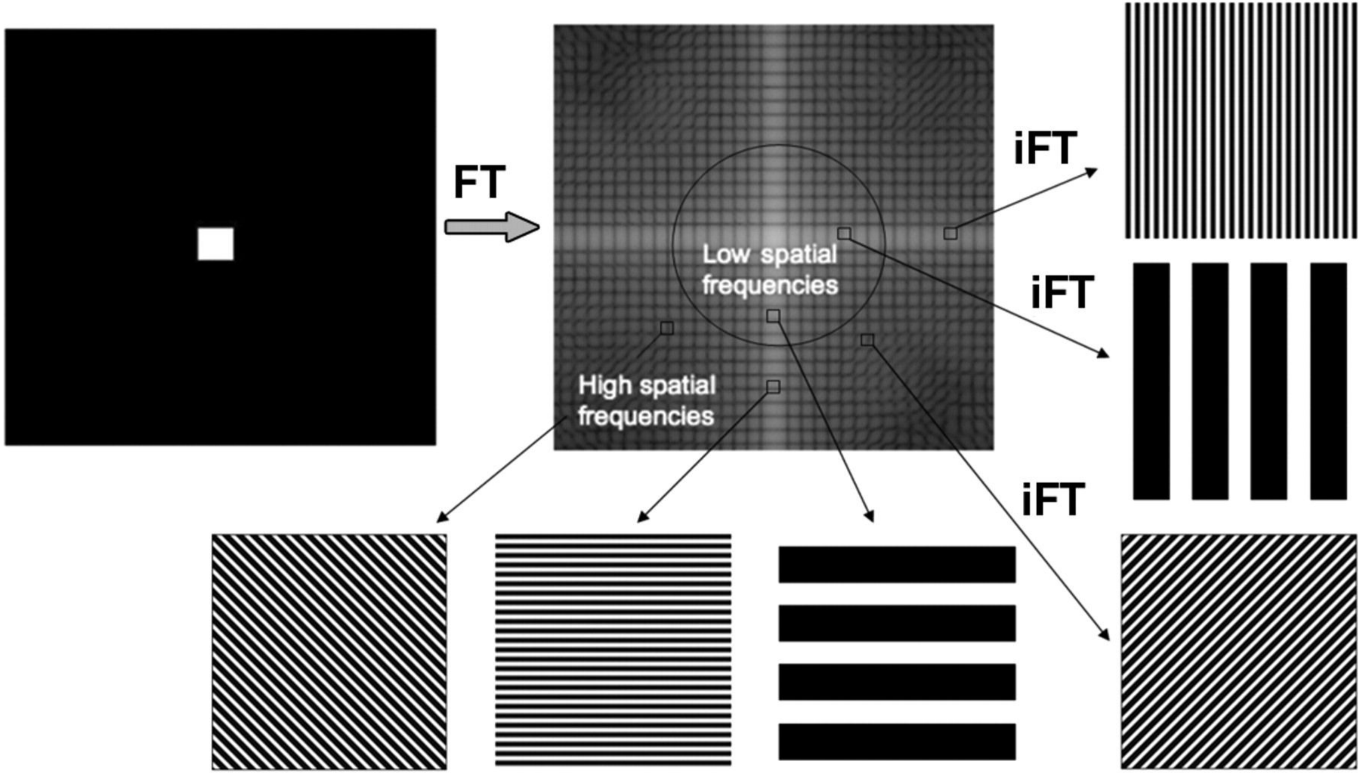
FT

Adapted from Claim et al. 2008



Adapted from wikimedia

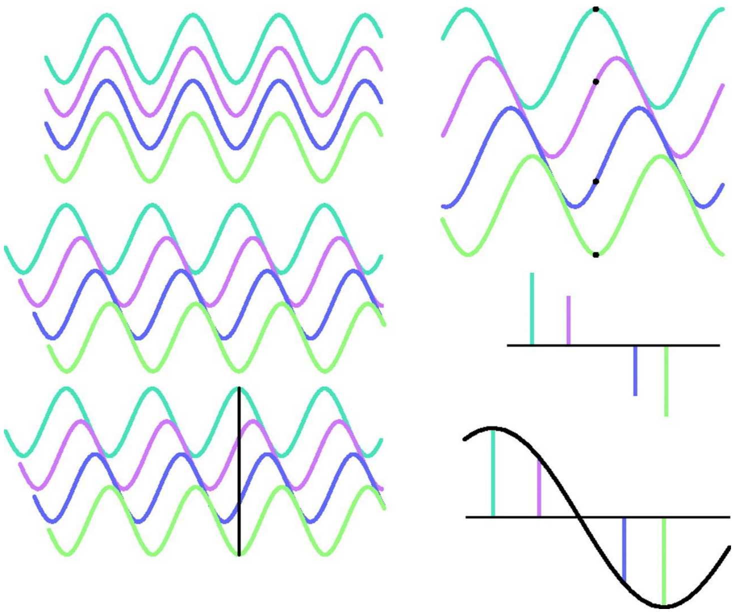
2D DFT: Fourier space allows to sum-up the frequences

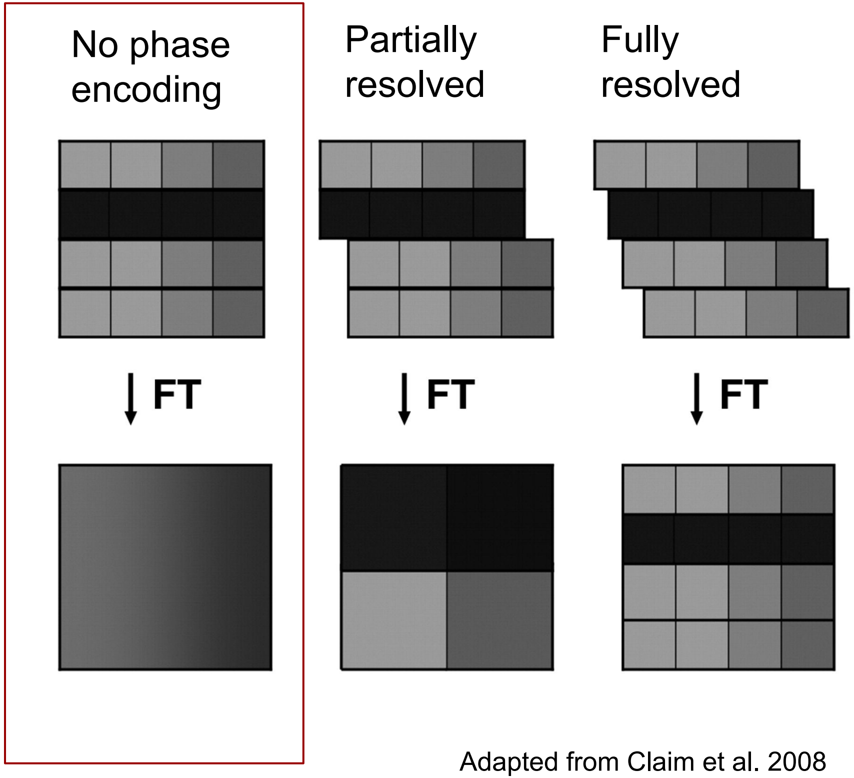


Adapted from Claim et al. 2008

Magnetic resonance imaging (MRI): phase encoding

Cosine waves with phase shift





Adapted from Claim et al. 2008

Paper 3:

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Decoding tumour phenotype by noninvasive imaging using a quantitative radiomics approach

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