Al-Mustaqbal University
College of Health and Medical Technologies
Radiological Techniques Department

# Magnetic Resonance Imaging

## First Semester
## Lecture 5,6 : Principles of MRI

By

**Dr. Mohanad Ahmed Sahib**
**MSc. Ph.D. Radiology technology**

**Assistant lecturer**
**M. A. Mohammed**
**MS.C. Theoretical Nuclear Physics**

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**Introduction:**

There are many factors available to the technologist when setting up a sequence. The appropriate selection of the parameters determines the **weighting, improved quality of images and sensitivity to pathology**. Therefore, the technologist should be aware of these factors and their interrelation so that optimal quality of the images can be obtained. The following are the factors discussed below which affect the quality of the image.

**Performing an MR examination principles demands multiple choices:**

i. The acquisition parameters

ii. The imaging plane orientation, Type of coil, slice thickness, matrix size, number of excitations, etc.

## FACTORS AFFECTING THE SNR

**Field of View (FOV)**

**FOV is one of the important factors affecting the SNR.**

An image consists of a FOV that relates to the region of interest (anatomy) covered The field of view ranges from 10 to 50 cm for most of the equipment. Therefore, if the entire spinal cord is to be imaged in the sagittal plane, its upper and lower parts need complementary series of pulse sequences.

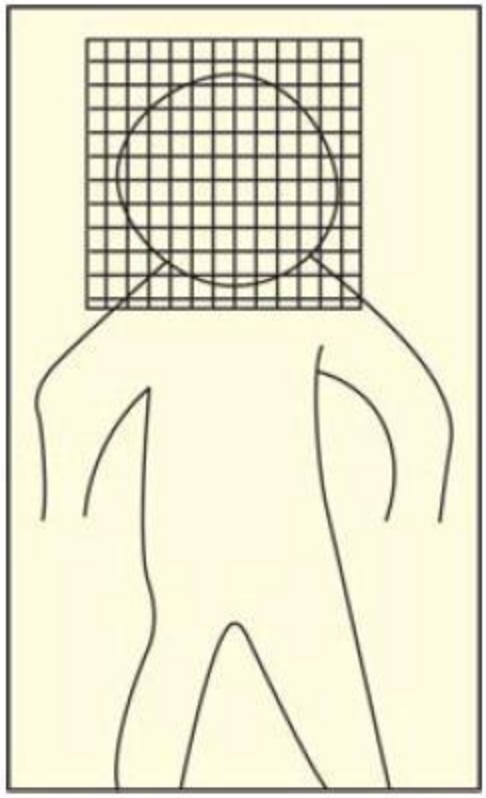

**Fig . (1): Field of view**

**FOV controls spatial resolution and SNR.**

- **Small FOV produces ↑ (high) resolution ↓ (low) SNR**
- **and increases the minimum TE value = SAT pulses**
- **Decreases the number of slices in an acquisition.**

At a given matrix size (i.e., number of pixels on the two image coordinates), the FOV determines pixel size, e.g. at a FOV of 24 cm and a matrix size of 256 × 256 pixels, the pixel size is 0.9 mm × 0.9 mm (240 mm/256).

FOV = 175 mm FOV = 325 mm

High-resolution Low-resolution SNR = 100 percent SNR = 345 percent. It is critical that the technologist should understand the relationship between signal-to-noise and FOV. SNR is proportional to square of the FOV.

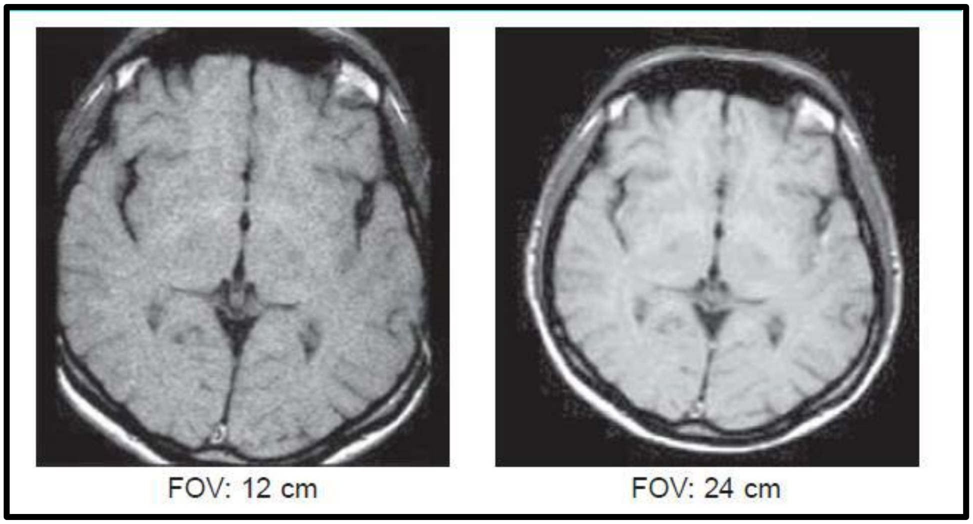


Fig .(2) : **SNR ~ FOV2**

For example, having a FOV reduced from 24 to 12 cm results in, a signal-to noise reduction of 75 percent.

**Note : In practice, the reduction in FOV requires some change that results in increased SNR**

## Spatial Resolution

Spatial resolution is defined as the ability to separate closely spaced anatomical details.

## Slice Thickness

To give each slice a thickness, a band of nuclei must be excited by the excitation pulse. Increase of slice thickness, increases SNR, coverage of anatomy and partial volume whereas spatial resolution is decreased. As slice thickness (increases), resolution (decreases) and SNR (increases). Decrease of slice thickness, reduces SNR, coverage of anatomy and partial volume whereas spatial resolution is increased.

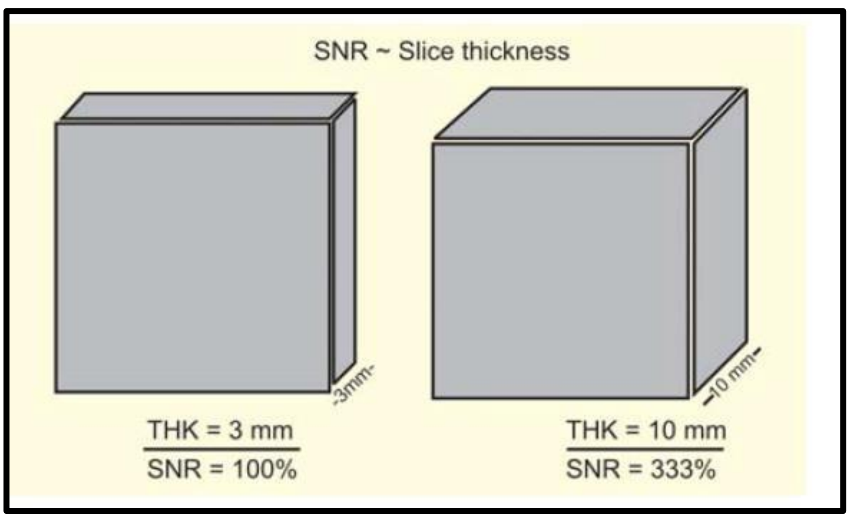


Fig.(3 ) : SNR-Slice thickness

The basic values of slice thickness ranges from 3 to 15 mm. Slice thickness controls resolution and SNR.

The technologist should be aware that as the slice thickness is increased or decreased, there will be a corresponding change in the S/N ratio for the image. If one slice is acquired at a 6 mm thickness, and another slice is acquired at a 3 mm thickness (with all other factors equal), the second slice will have one-half the signal of the first slice. Since the noise is essentially unchanged, the effect is that the S/N ratio will be cut in half for the second slice.

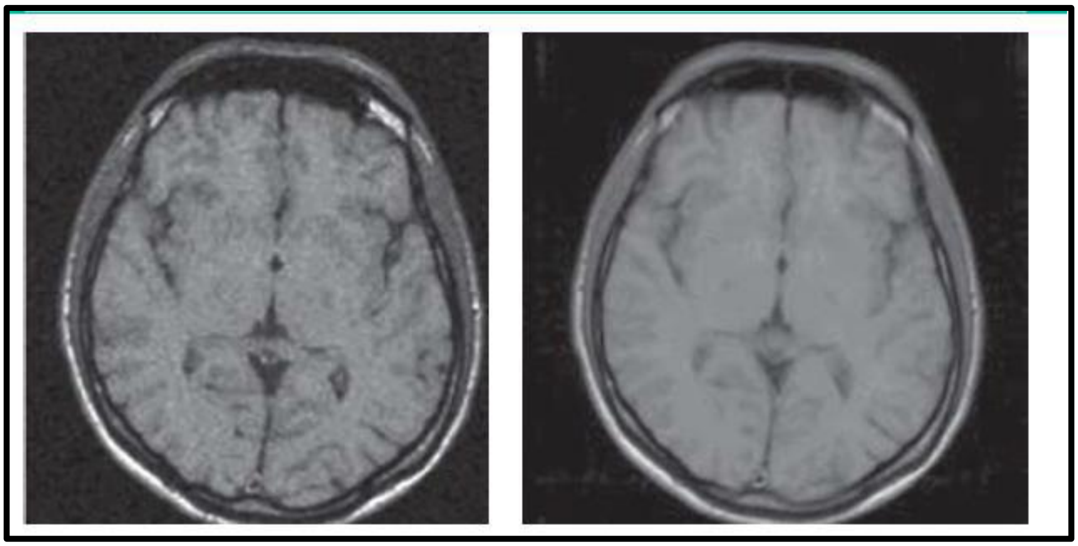

Fig.(4 ): MRI image , SNR-Slice thickness

Ideally, we would like to obtain images from, infinitely thin sections. The thicker the slice, the more partial volume, which implies that certain structures may be hidden by overlying tissues.

On the other hand, SNR and CNR are improved for larger slice thickness.

## Spacing

Spacing is the gap between two slices. When acquiring a multiplanar, single acquisition, spacing controls cross-talk. As spacing ↑ (increases), cross-talk ↓ (decreases) Typically, a spacing that is 20 percent of the slice thickness is sufficient to minimize cross-talk.

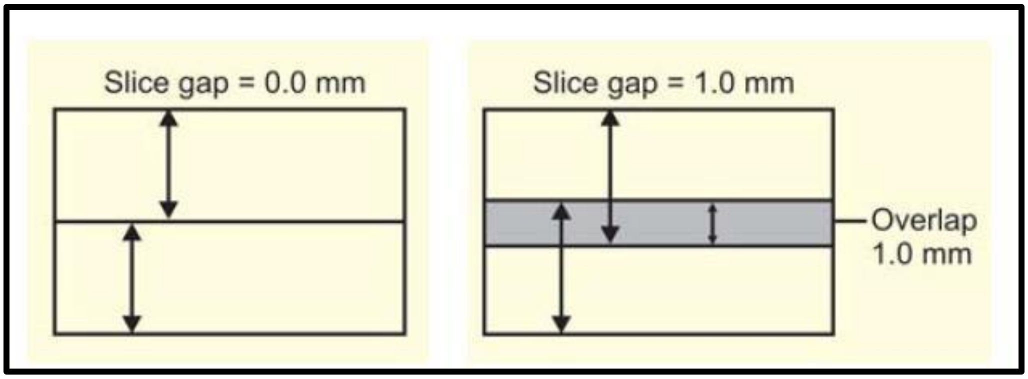


Fig.(5 A & B ) : ( fig A) Contiguous slice.(fig B) Overlapping slices

As no. of slices (increases), scan time also (increases) Ideally, we would like to obtain our images from completely contiguous slices. In practice, there is always some excitation outside the slice boundaries. This means that when exciting a particular slice with a RF pulse, partial excitation of neighboring slices will cause an alteration in image contrast, or the effective TR for every slice is less than determined by TR.

## Matrix Size

The matrix size is represented by two figures. The first figure usually relates to the number of frequency samples taken, whereas the second relates to the number of phase encodings performed. For example 256 × 128 indicates that 256 frequency samples are taken during readout and 128 phase encodings are performed. A course matrix corresponds to less number of pixels and fine matrix corresponds to more number of pixels. In all digital imaging methods, and therefore in MR too, the image is divided into small picture elements called pixels. Each individual pixel corresponds to the intensity and amplitude of MR signal represented on gray scale.

The dimensions of the matrix can be changed. The most commonly used matrix is 256 × 256. Some systems offer low-resolution (128 × 128) and or/high-resolution (512 × 512) matrixes. At a given FOV, matrix size determines pixel size and thus spatial resolution. Therefore, an image obtained with 128 × 256 pixels is typically less well resolved in the Y dimension than one obtained with 256 × 256 pixels.

However, all other parameters being equal, the 256 × 256 image has a factor of 2 less SNR, while it requires twice the scan time.

**Pixel:** Acronym for a picture element, the smallest discrete part of a digital image display.

**Voxel:** Volume element, the element of the three-dimensional space (3D-space) corresponding to a pixel, for a given slice thickness.

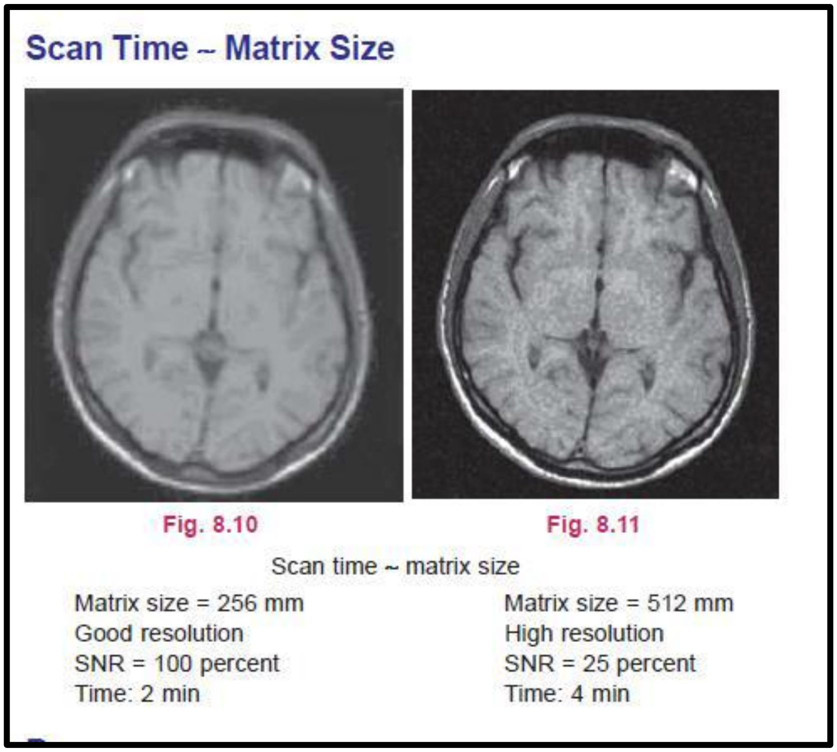


Fig (6) : Relation between scan time and matrix size.

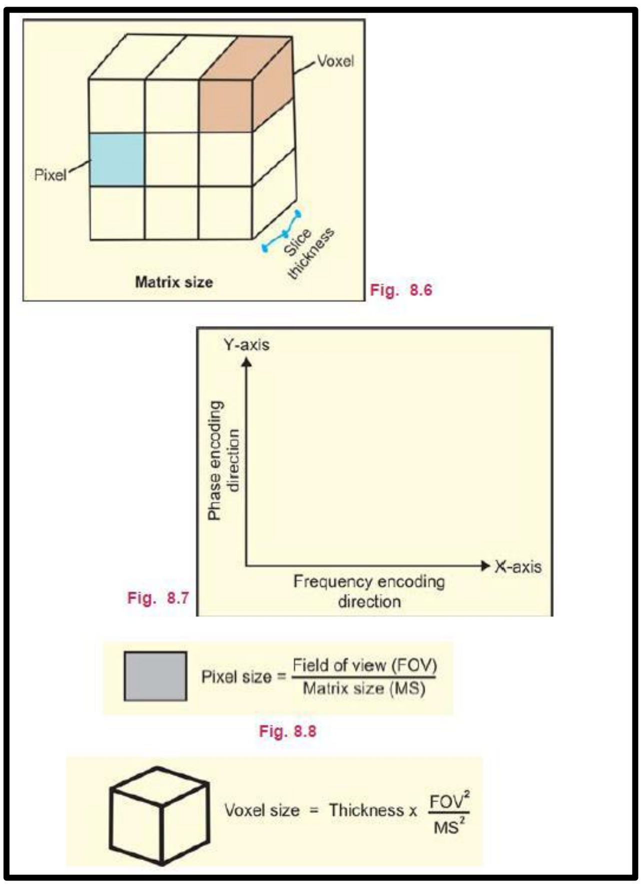


Fig (7) : Marix ,pixel & voxel

## Number of Excitations or Number of Signal Averages (NEX/NSA)

Every individual signal which contributes to form a MR image, can be received once or collected several times using repeated excitations. Hence, the average signal value is used to generate the image. When the number of excitations are increased, the error (the noise) doubt and the measurements are more precise. In practice, the number of excitations ranges from 1 to 6. The number of excitations (Nex) implies the number of times a particular line in sampled in K space. K space refers to the raw data of an image.

A line in K space corresponds to the spin echo obtained at a particular setting of the phase encoding gradient. Scan time is proportional to Nex.

By increasing the number of excitations, the SNR is improved and *vice versa*.

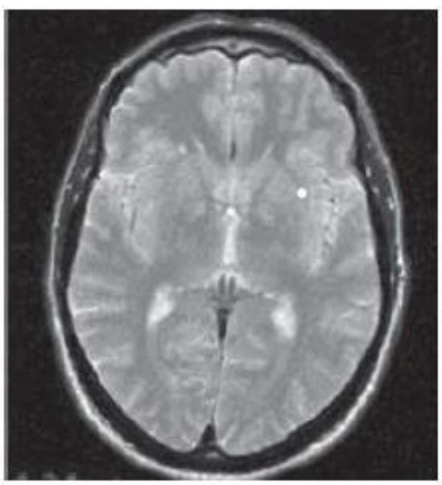

**Fig. 8.12**
Nex = 2
Scan time = 1.28 min
SNR = 100 percent

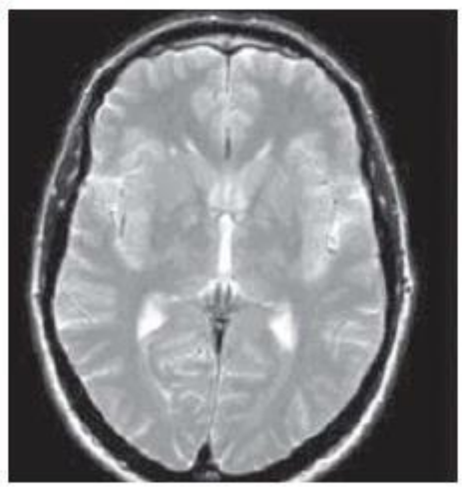

**Fig. 8.13**
Nex = 4
Scan time = 2.48 min
SNR = 141 percent

## Image Acquisition Time (Examination Time)

The longer the scan time, the more chances that the patient moves and generates, more artifacts that prevent the interpretation of the images. Hence, optimum scanning time is to be maintained so that appreciable quality of images can be obtained which are free of artifacts (motion artifacts).

**For a given patient, the duration of an MR examination depends on several factors.**

- Getting the patient settled and centering the area to be studied.
- The number of areas to be examined.
- The number and characteristics of the pulse sequences used.
- The acquisition time (T) of a sequence is given by the following formula:

$$\textit{Acquisition Time (T)} = TR \times N \times Nex$$

Where, TR is the repetition time,

N is the number of phase encodings in the matrix

Nex is the number of excitations

Acquisition Time = TR × N × Nex

= 400 × 160 × 2 = 128 000 milli sec = 128 sec = 2.14 minutes

## Image (Data) Acquisition Time

The time required to gather a complete set of image data. The total time for performing a scan must be taken into consideration. The additional image reconstruction time when determining how quickly the image(s) may be viewed.

Increase of TR increases the scan time and similarly increasing the number of phase encodings in a matrix increases the scan time and *vice versa*. Improving the SNR by increasing Nex also increases the imaging time and *vice versa*.

## Frequency

Frequency axis of the acquisiton matrix. The number of cycles or separations of a periodic process per unit time. In electromagnetic radiation, it is usually expressed in units of Hertz (Hz), where 1 Hz = 1 cycle.

Increase the frequency matrix to produce (high) resolution, (low) SNR and less number of slices.

## Phase

In a periodic function (such as rotational or sinusoidal motion), the position relative to a particular part of the cycle. Phase controls scan time for most pulse sequence database and may control resolution.

*Nex*: Select a Nex value that produces sufficient SNR.

## Auto Shim

Auto shim is typically selected when the FOV center is not at isocenter. A preparation phase is performed in which small gradient amplitudes are determined which optimize the main magnetic field homogeneity. The small gradients remain present during the scan.

## Signal-to-Noise Ratio (SNR)

It is defined as the ratio of the amplitude of the signal generated to the average amplitude of the noise. Quality of image is mainly characterized by its SNR. Increase of signal increases the SNR and *vice versa*. **The following are the factors that affect the SNR:**

- Coil type
- Volume of the voxel

**Proton density of the region of interest under examination**

- TR, TE and Flip angle
- Nex
- Receive bandwidth
- FOV

Scan time, spatial resolution, SNR are mathematically related.

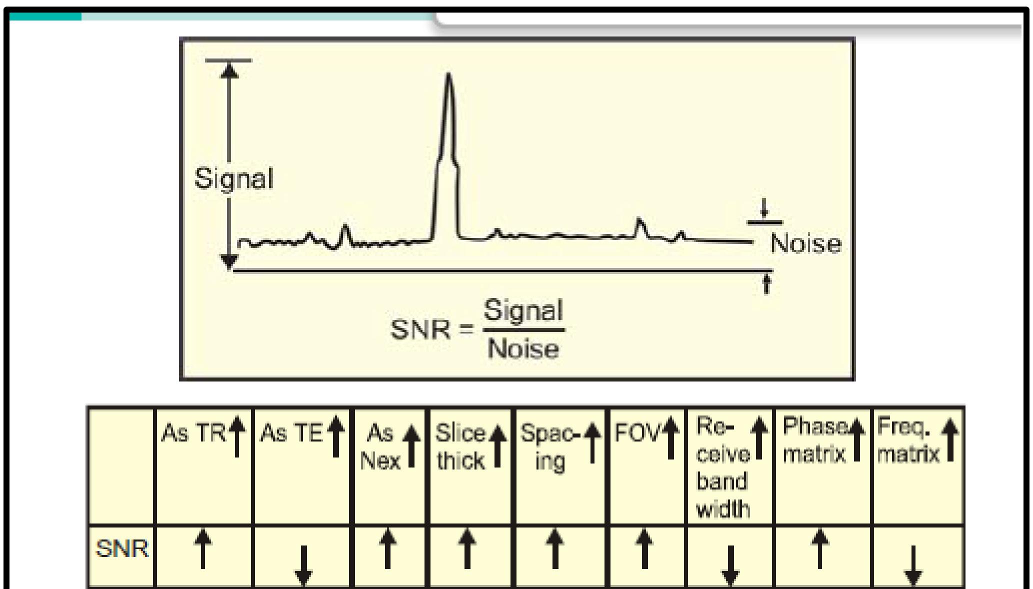


**Fig. 8.14:** Various factors which contributes to change of SNR

Fig. (9) : Various factors which contributes to change of SNR

## Contrast-to-Noise Ratio (CNR)

It is defined as the difference in the SNR of two adjacent areas. The factors that affect CNR are the same as that of SNR.

## Bandwidth (BW)

A general term referring to a range of frequencies (e.g.contained in a signal or passed by a signal processing system). This is the range of frequencies that are acquired by the readout gradient. As bandwidth is decreased, noise is reduced thereby increasing the SNR. If the bandwidth is reduced to half, SNR is increased by 40 percent but increases the sampling time. Bandwidth defines the number of frequencies. We can change the bandwidth with RF pulses. Frequency can be swapped with phase direction by champing the entry in (Freq DIR), following the table sum.

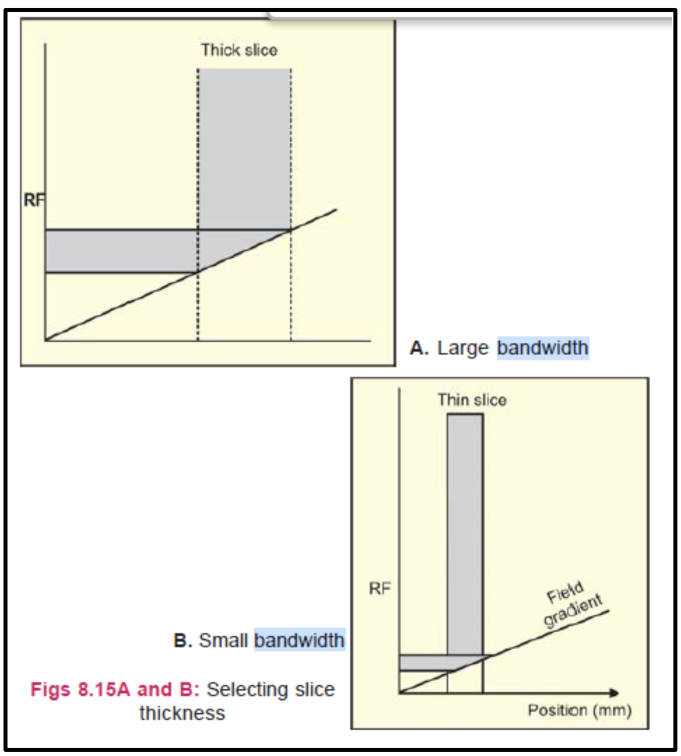


Fig (10 A&B): Selecting slice thickness

## The principles of the Image reconstruction

The mathematical process of converting the composite signals obtained during the data acquisition phase into an image.

## GRADIENTS

In order to spatially encode the NMR signal, a gradient magnetic field is superimposed on the static magnetic field. The gradients place the nuclei in a slightly different magnetic field depending on their location.

## SLICE-SELECT

In order to confine excitation to a single slice only, an RF pulse containing a narrow band of frequencies is applied, in conjunction with the gradient located in the plane perpendicular to the imaging plane. In an axial image in the x-y plane, for example, the slice-selection gradient is Gz. The gradient is applied only during the RF excitation pulse. Only that plane of nuclei located with its z position such that its Larmor Frequency matches that of the applied RF will be excited to produce a signal.

## Slice Orientation

- Superior Inferior (axial plane)
- Right Left (sagittal plane)
- Anterior Posterior (coronal plane.

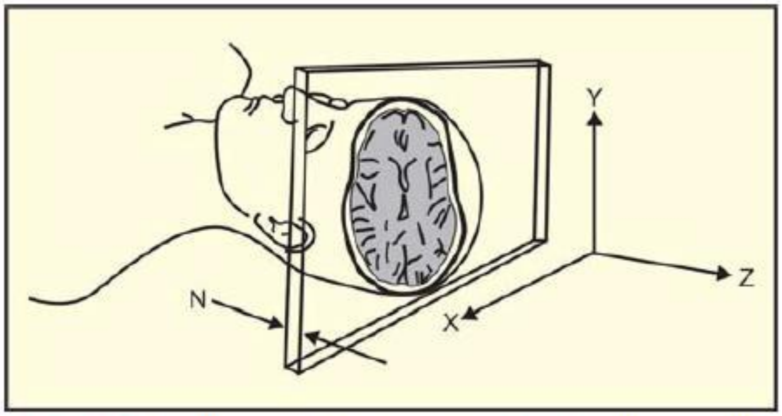


**Fig. 8.17:** A gradient is applied along the z-axis in conjunction with a narrow band RF pulse to confine excitation to a single slice only

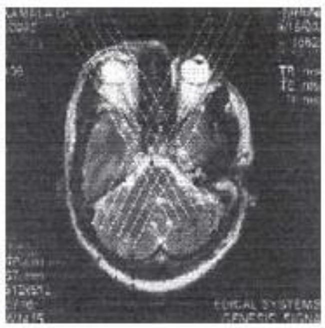

**Fig. 8.18A:** The orientation of simple oblique slices can be specified by rotating a slice

Fig (11) : A&B

# Posttest

1. **Numerate the factors which effect the SNR on the image?**
2. **What are the relation between the SNR with the slice thickness and FOV.**
3. **Compare in the table the relation which effect the time and resolution of image with the small anatomical structures like pituitary?**