## Theoretical Lecture

## Acquisition, SNR, Pixel, voxel, and matrix size

### Acquisition

- The receive coil must be positioned at right angles to the main magnetic field ($B_0$).
  - Bo is a very strong magnetic field; much stronger than the RF signal we are about to receive. That means if we position the coil such that $B_o$ goes through the coil an enormous current is induced, and the tiny current induced by the RF wave is overwhelmed. We will only see a lot of speckles (called: noise) in our image. Therefore, we have to make sure that the receive coil is positioned in such a way that B0 can't go through the coil. The only way to achieve this is to position the receive coil at right angles to $B_0$ as shown in Figure 1.

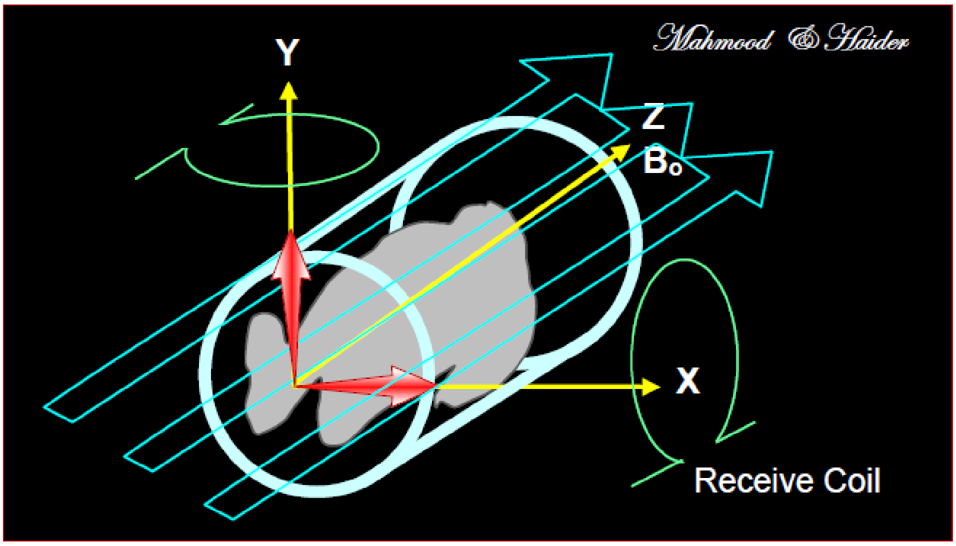



Figure 1: The receive coil at right angles to $B_0$.

- Determine the positioning of the coils so that they form a right angle with $B_0$ means we can receive signals from processes only when the right angles be a between the coils and B0 which happens to be T2 relaxation.

- The signal that is received is strong in the beginning and quickly becomes weaker due to T2 relaxation. Figure2.

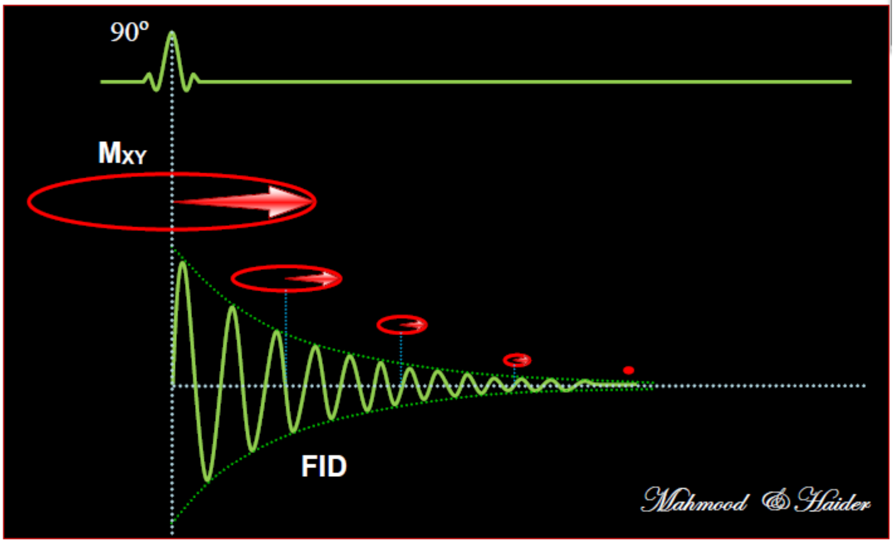



Figure 2: Free Induction Decay.

## Computing and Display

In general, system of MRI consists of five major components: magnet, gradient systems, RF coil system, receiver, and computer system. Figure 3 shows the entire process graphically.

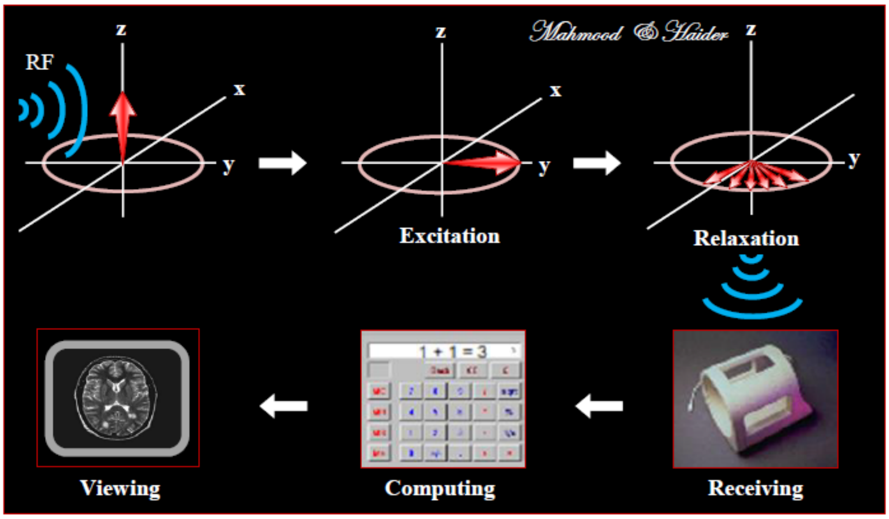
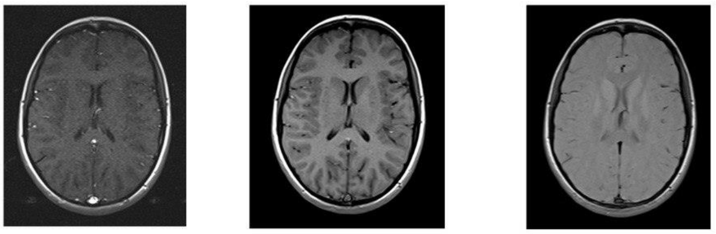



Figure 3: the entire process graphically.

## Signal to Noise ratio (SNR)

SNR is the intensity of the signal measured in the region of interest divided by the standard deviation of the signal intensity in a region outside the anatomy or the object being imaged (i.e. a region from which no tissue signal is obtained).

- The relationship between the MR signal and the amount of image noise present is expressed as the signal-to-noise ratio (SNR).
- The SNR has a direct effect on the contrast resolution.
- The definition of contrast resolution is the difference in SNR between two adjacent areas.
- If the SNR is improved, then the contrast resolution of the image is improved; if the SNR is low, then the contrast resolution of the image is poor see figure below.



TR 200 TE 15 Low tissue contrast Low SNR | TR 500 TE 15 High tissue contrast High SNR | TR 1000 TE 15 Low tissue contrast High SNR

Image noise results from a number of different factors but it comes mainly from the tissue of the patient's body (RF emission due to thermal motion) and electronics inherent in the imaging process.

***These factors can be classified into two classes:***

- ❖ Fixed factors: Imperfections of the MR system such as magnetic field in homogeneities, thermal noise from the RF coils, pulse sequence design, patient-related factors resulting from body movement or respiratory motion.
- ❖ Factors under the operator's control
  - RF coil to be used

- Sequence parameters: voxel size (limiting spatial resolution), number of averaging, receiver bandwidth.

***The SNR is dependent on the following parameters:***

- Size of the (image) matrix
- Field of view
- Slice thickness and receiver bandwidth
- Number of acquisitions
- Scan parameters (TR, TE, flip angle)
- Magnetic field strength
- Selection of the transmit and receive coil (RF coil)

**Matrix**

A matrix is an array of numbers in rows and columns. The horizontal lines in matrices are called rows and the vertical lines are called columns figure4. A matrix with m rows and n columns is called an m-by-n matrix (or m * n matrix) and m and n are called its dimensions. The matrix used in MRI determines the scan resolution. Typical matrix dimensions are in the range of 128 to 512 mm.

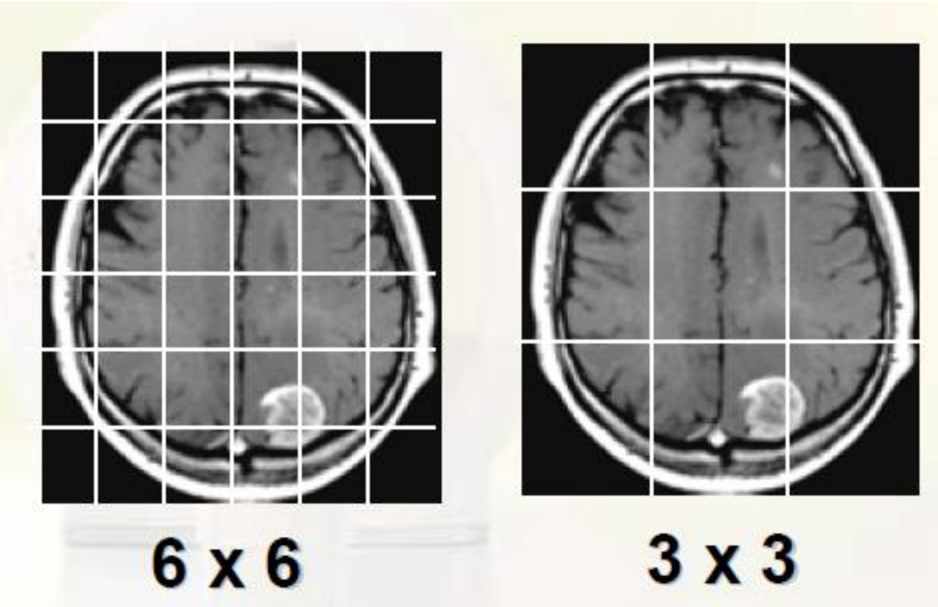



Figure 4: the matrix.

## Pixel

*A pixel* represents the smallest sampled 2D element in an image figure5. It has dimensions given along two axes in mm, dictating in-plane spatial resolution. Pixel sizes range in clinical MRI from mm (e.g., 1 3 1 mm²) to sub-mm.

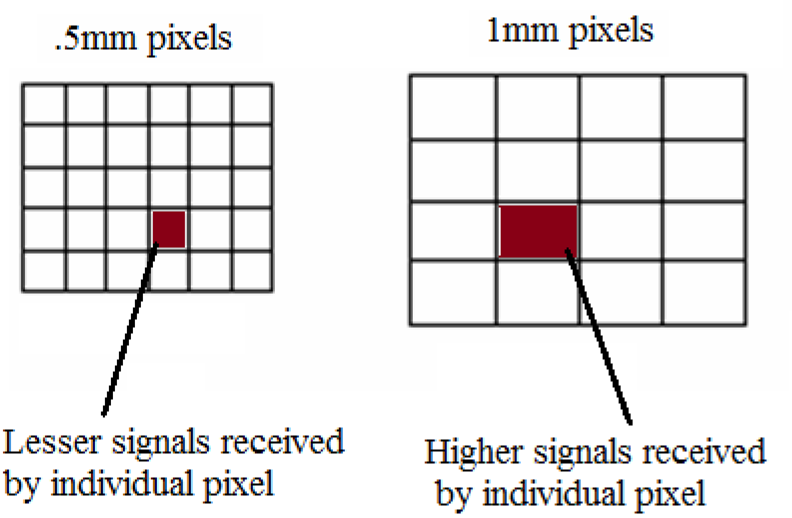



Figure5: The pixel.

## Voxel

A voxel is the volume element, defined in 3D space. Its dimensions are given by the pixel, together with the thickness of the slice (the measurement along the third axis) figure 6.

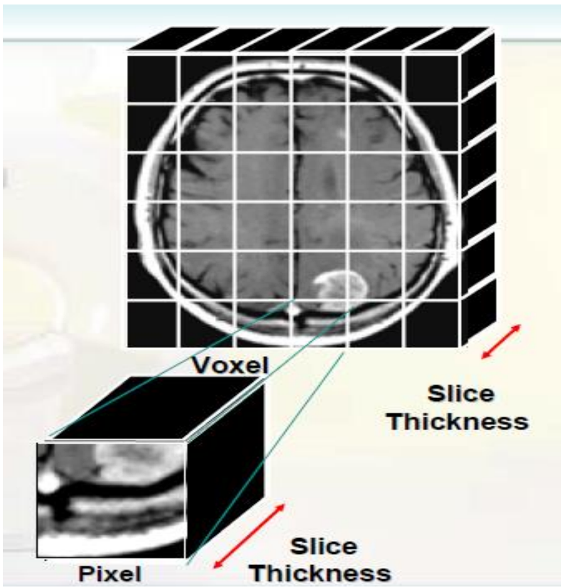



Figure 6: The voxel.

*The voxel volume determine by:*

1- The field of view (FOV).
2- Pixel size.
3- The slice thickness.

## Field of view

The field of view is the size of the area that the matrix of phase and frequency encoding cover (the dimensions of the exact anatomic region included in a scan) (figure 7). Dividing the field of view by the matrix size gives you the in-plane voxel size; hence, increasing the field of view in either direction increases the size of the voxels and decreases the resolution. Decreasing the field of view improves the resolution.

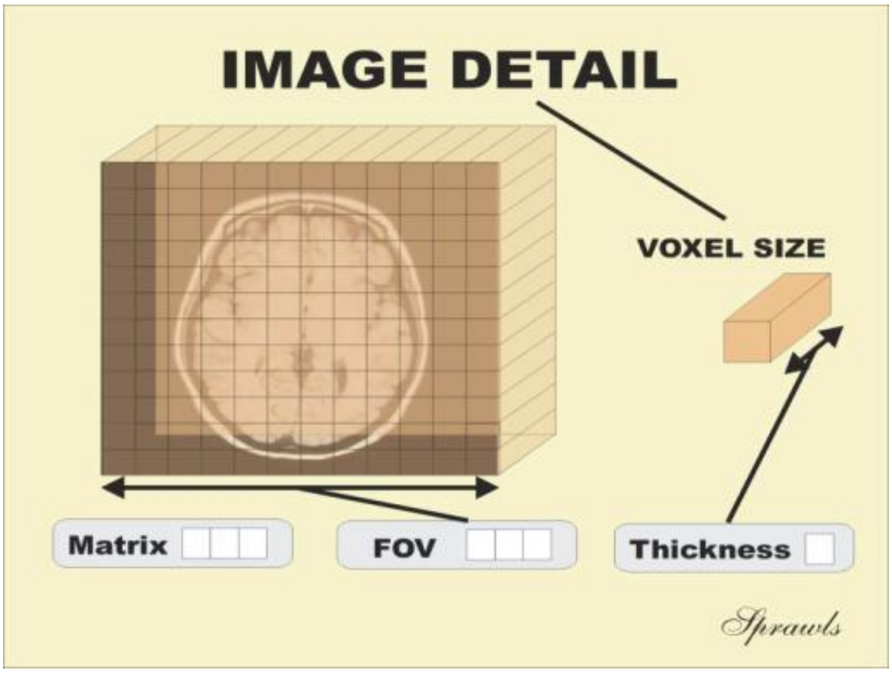



**Figure7**: Image shows the matrix, FOV, thickness and voxel size.

## Matrix size

The matrix size is the number of frequency encoding steps, in one direction; and the number of phase encoding steps, in the other direction of the image plane. Assuming everything else is constant, increasing the number of frequency encodings or the number of phase steps results in improved resolution. Increasing the number of phase steps increases the time of the acquisition proportionately. This is why images that have fewer phase encodings than frequency encodings, e.g., 128x256 or 192x256 will be used. Matrices are two types:

- **Coarse matrices**: they have a small number of pixels in the field of view. and
- **Fine matrices**: they have a large number of pixels in the field of view.

An example of a coarse matrix is 128 × 128, whereas a fine matrix is 512 × 512 (figure 8)

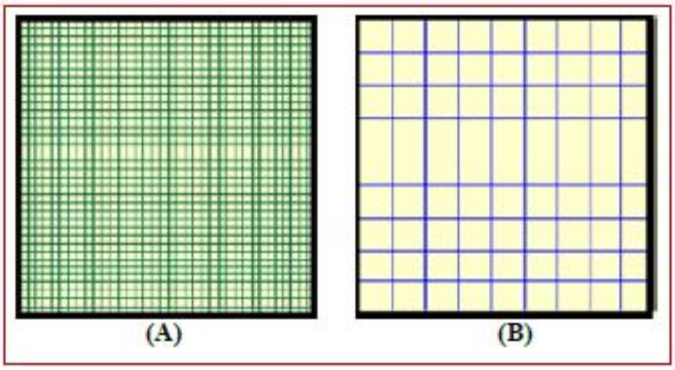



**Figure 8:** Types of matrix: (A) Fine Matrix (B) Coarse Matrix.

## Calculating pixel size and voxel size

$$\textbf{The pixel size} = \frac{\text{FOV}}{\text{matrix}} \times \frac{\text{FOV}}{\text{matrix}} \quad (mm^2)$$

$$\textbf{The voxel size} = \frac{\text{FOV}}{\text{matrix}} \times \frac{\text{FOV}}{\text{matrix}} \times \textit{thickness} \quad (mm^3)$$

Determines the in-plane resolution. Reducing the FOV, increasing the matrix number, or reducing the slice thickness results in an image with reduced voxel volume (figure 9).

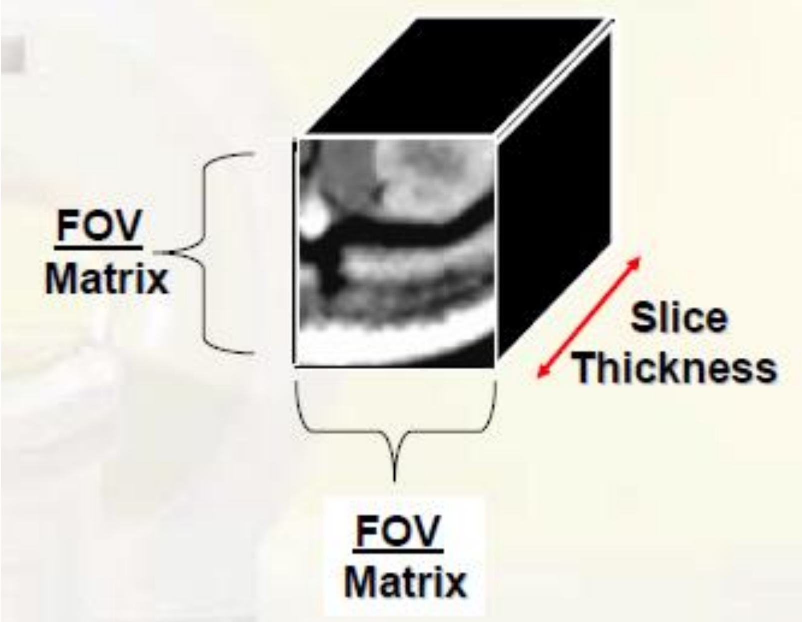



Figure 9: shows the pixel size and voxel size.

SNR is directly proportional to voxel size (assuming that the number of phase encoding steps is held constant). Small voxels produce MR images with high spatial resolution but a lower signal-to-noise ratio (SNR), and thus may appear "grainy" compared with images acquired with a larger voxel volume.

One of the major factors that affects signal strength is the volume of the individual voxels. The signal intensity is proportional to the total number of protons contained within a voxel. Large voxels, that contain more protons, emit stronger signals and result in less image noise.

Unfortunately, as we have discovered, large voxels reduce image detail. Therefore, when the factors for an imaging procedure are being selected, this compromise between signal-to-noise ratio and image detail must be considered.

***Questions:***

1. Why the receive coil must be positioned at right angles to the main magnetic field?

2. What are the factors that cause image noise? List them?
3. List the parameters that effect on the SNR?
4. What is the relationship between FOV and SNR?
5. Explain briefly hoe the voxel size effect on the SNR?
6. Why images that have fewer phase encodings than frequency encodings?