SAWA UNIVERSITY

Equip. Techniques of MRI

Gradient Coils: Types and Function

جامعة ساوة

كلية التقنيات الصحية والطبية

قسم تقنيات الأشعة والسونار

المرحلة الثالثة

رقم المحاضرة (2)

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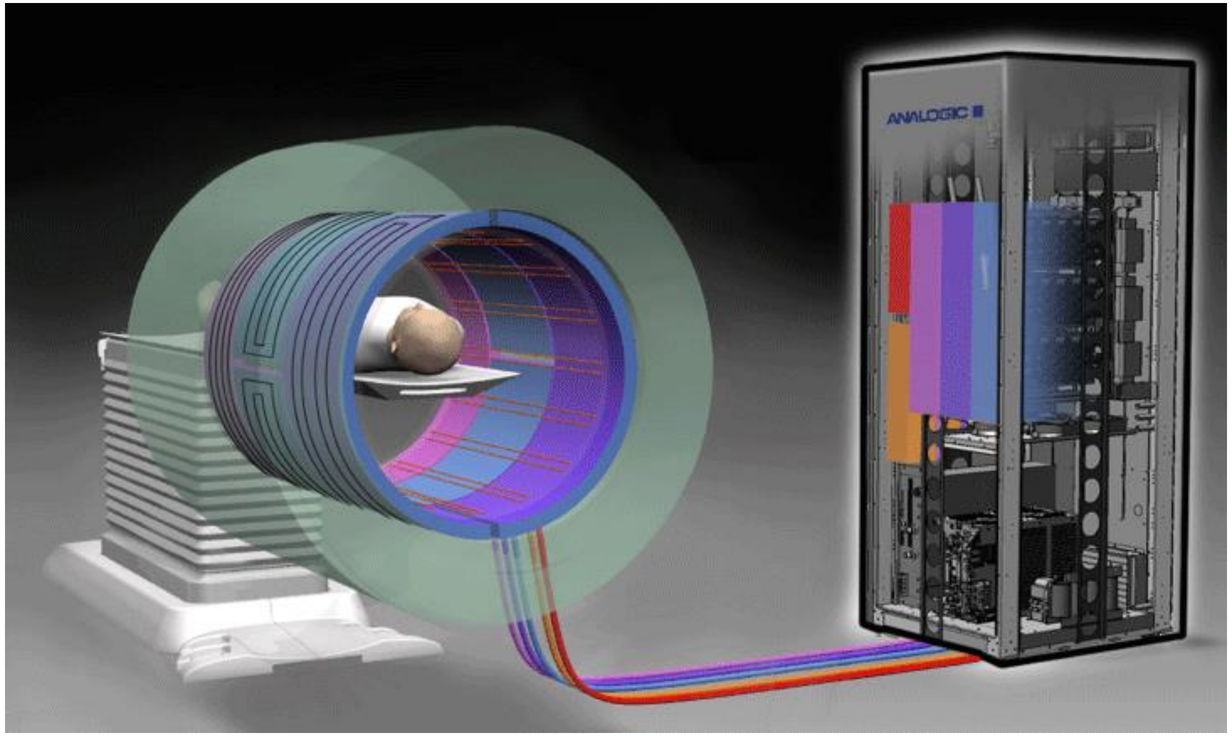
Gradients

The spatial characteristics of an MR image are produced by actions of the gradients applied during the acquisition phase. Magnetic field gradients are used first to select slices and then give the RF signals the frequency and phase characteristics that create the individual voxels. As we will see later, a gradient in one direction is used to create the slices, and then gradients in the other directions are used to cut the slices into rows and columns to create the individual voxels. However, these functions can be interchanged or shared among the different gradient coils to permit imaging in any plane through the patient's body. The functions performed by the various gradients usually occur in a specific sequence. During each individual image acquisition cycle the various gradients will be turned on and off at specific times. As we will see later, the gradients are synchronized with other events such as the application of the RF pulses and the acquisition of the RF signals.

- Protons in the body, especially hydrogen protons (because of their abundance in water), align with a powerful magnetic field (B0). When exposed to a radiofrequency (RF) pulse, these protons get excited and emit signals as they relax back into alignment with the magnetic field.
- The process of signal localization and image formation heavily depends on **gradient coils**.



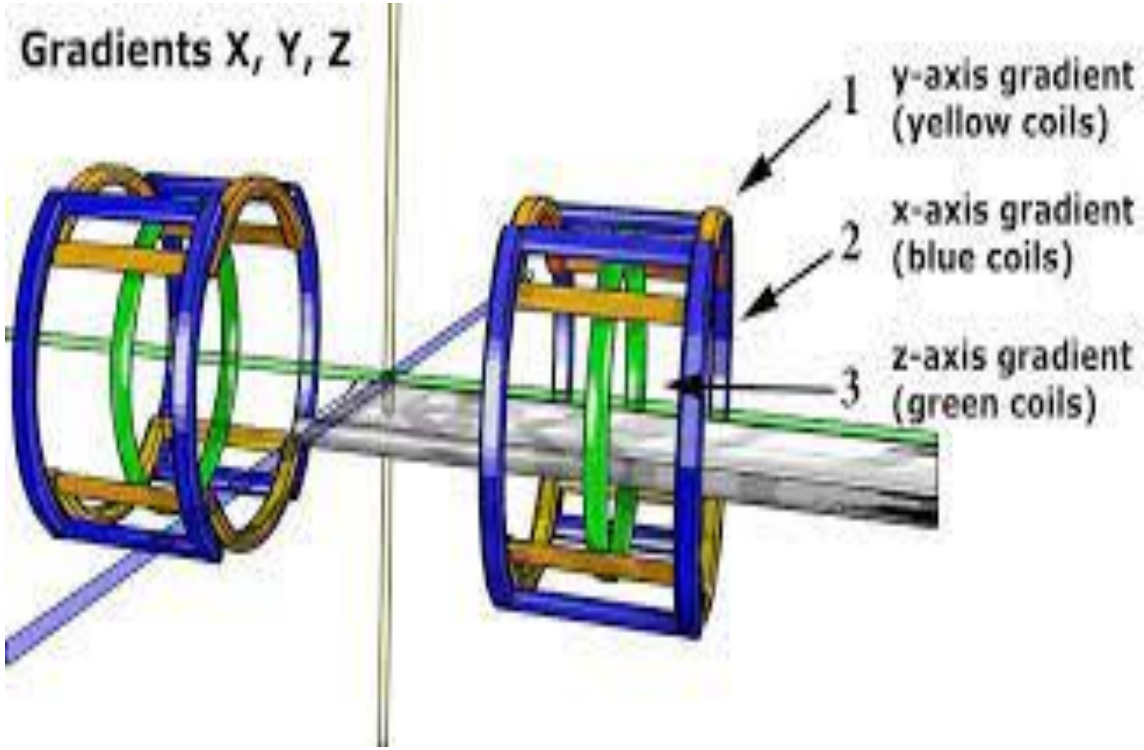
Types of Gradient

1- Linear Gradient Coils: These are the standard type of gradient coils used in MRI to produce magnetic field gradients along the three principal axes (X, Y, Z). They are responsible for spatial encoding, slice selection, and frequency/phase encoding.

Configuration: In an MRI scanner, there are typically three sets of gradient coils, each oriented along one of the three principal axes (X, Y, Z). These coils create gradients in the magnetic field in these directions, enabling 3D imaging.

Current and Magnetic Field: The gradient coils work by passing a controlled electrical current through them. This generates a secondary magnetic field that superimposes on the main magnetic field of the MRI scanner, causing the magnetic field strength to vary linearly with position.

- **X-gradient coil:** Controls the left-right (lateral) direction.
- **Y-gradient coil:** Controls the anterior-posterior (front-back) direction.
- **Z-gradient coil:** Controls the head-foot (axial) direction.



2- Zonal Gradient Coils:: These coils are used to produce magnetic field gradients over localized regions or zones within the imaging area. They are often applied in specialized imaging sequences where specific areas of interest are targeted. Zonal gradient coils play a crucial role in the process of spatial encoding in MRI, enabling the differentiation of signals from different locations within the imaging volume. They work in conjunction with other gradient coils (such as slice-selective and phase-encoding gradients) to manipulate the magnetic field in three dimensions, ultimately producing high-resolution images of the internal structures of the body. Overall, zonal gradient coils are essential components of modern MRI systems, contributing to the system's ability to generate detailed and informative images for diagnostic purposes in healthcare settings.

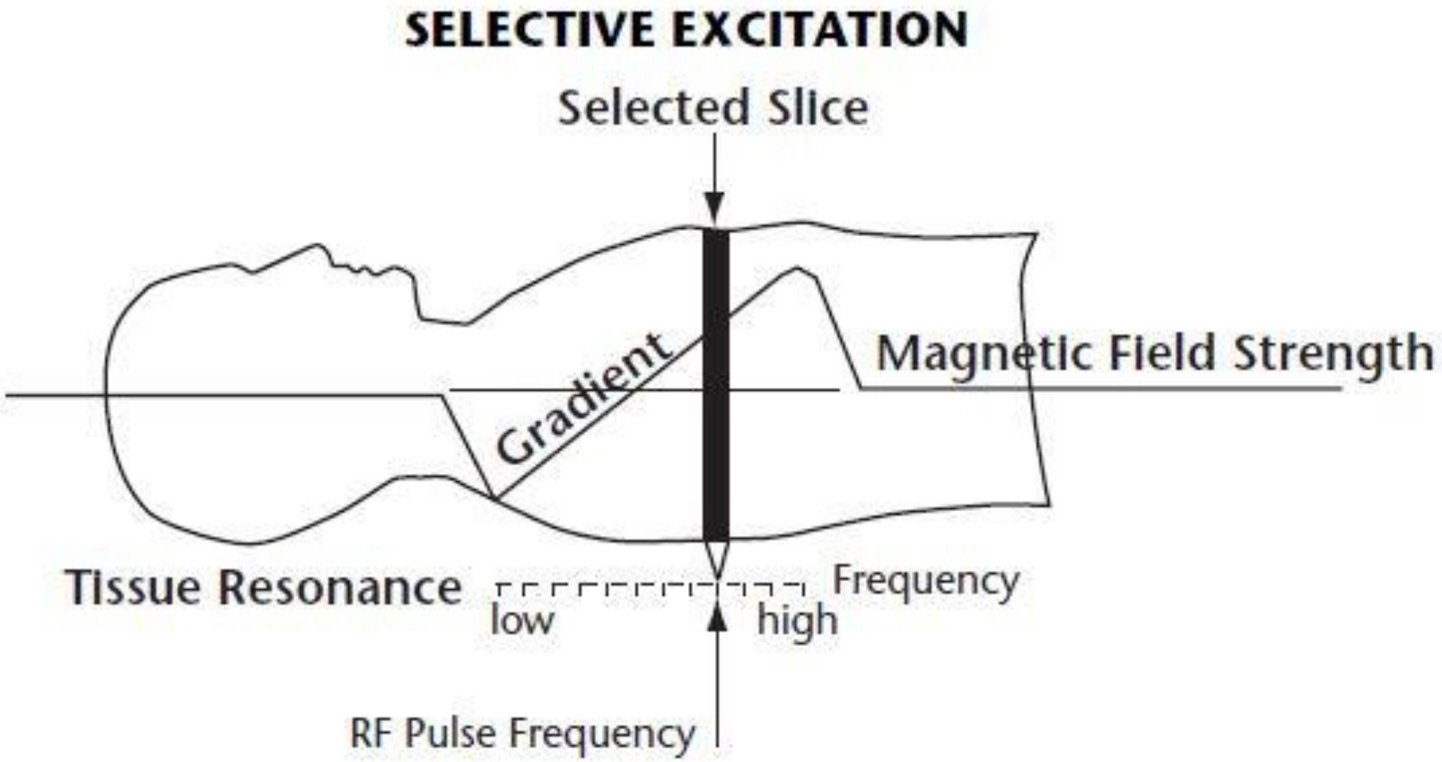
3- Non-linear gradient coils:: generate uniform gradients across the imaging volume, non-linear gradient coils are designed to create spatially varying magnetic fields with non-linear characteristics. The use of non-linear gradient coils in MRI offers several advantages, including improved image quality, reduced imaging time, and enhanced spatial encoding capabilities. By introducing non-linearities into the gradient fields, these coils can help mitigate imaging artifacts, improve signal-to-noise ratio, and enable advanced imaging techniques such as parallel imaging and magnetic resonance fingerprinting. Non-linear gradient coils are particularly useful in applications that require precise spatial encoding and high-resolution imaging, such as functional MRI (fMRI), diffusion tensor imaging (DTI), and magnetic resonance spectroscopy (MRS). Their unique design allows for more flexible and efficient gradient control, leading to enhanced imaging performance and diagnostic capabilities in clinical and research settings.

4-Actively shielded gradient coils : These gradient coils are designed to actively counteract and cancel out the stray magnetic fields, thereby reducing interference with the main magnetic field and improving image quality. The actively shielded gradient coils consist of the gradient coil itself, which generates the desired magnetic field gradients for spatial encoding, as well as a set of additional shield coils that produce opposing magnetic fields to neutralize the stray fields. By actively controlling the currents in the shield coils, these gradient coils can effectively reduce the impact of external magnetic interference and improve the homogeneity of the main magnetic field within the imaging volume. The use of actively shielded gradient coils in MRI systems helps to enhance image resolution, reduce artifacts, and improve the overall performance of the imaging process. By minimizing the effects of stray magnetic fields, these coils contribute to more accurate and reliable imaging results, making them valuable components in high-quality MRI systems.

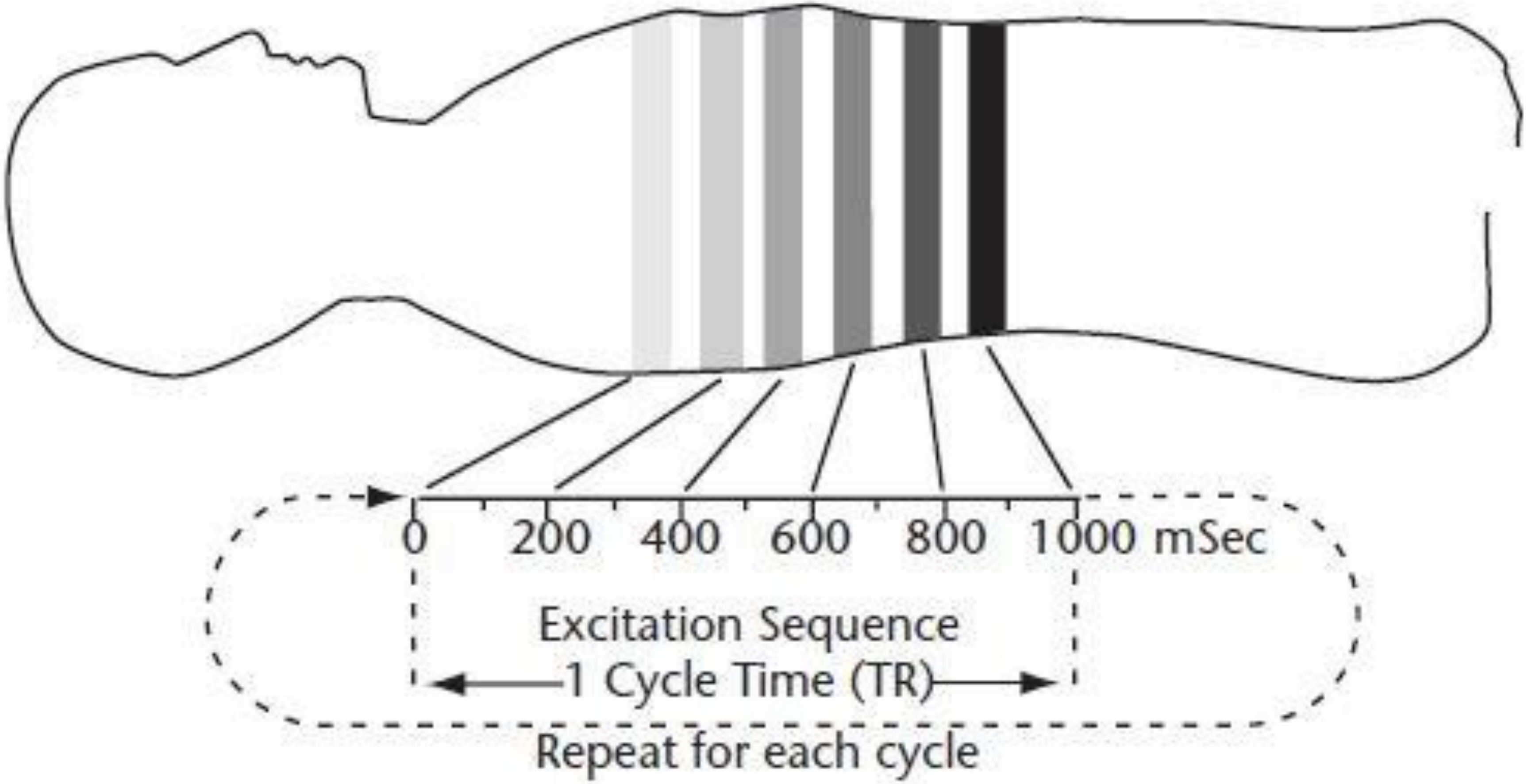
Functions of Gradient Coils

1- Slice Selection

Gradient coils are used for slice selection, which involves exciting and imaging a specific slice or section of the body. By applying a gradient along the z-axis (slice-select gradient), a particular slice is selectively excited and imaged while suppressing signals from other slices. This slice selection capability enables the acquisition of images in multiple planes and the reconstruction of three-dimensional anatomical structures with high spatial resolution.

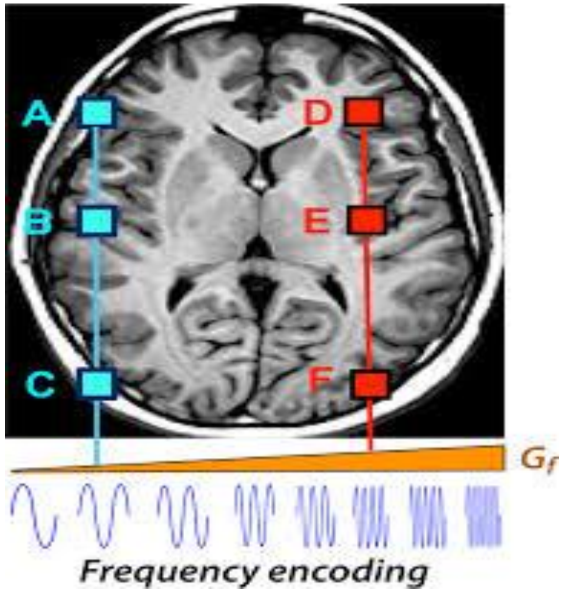


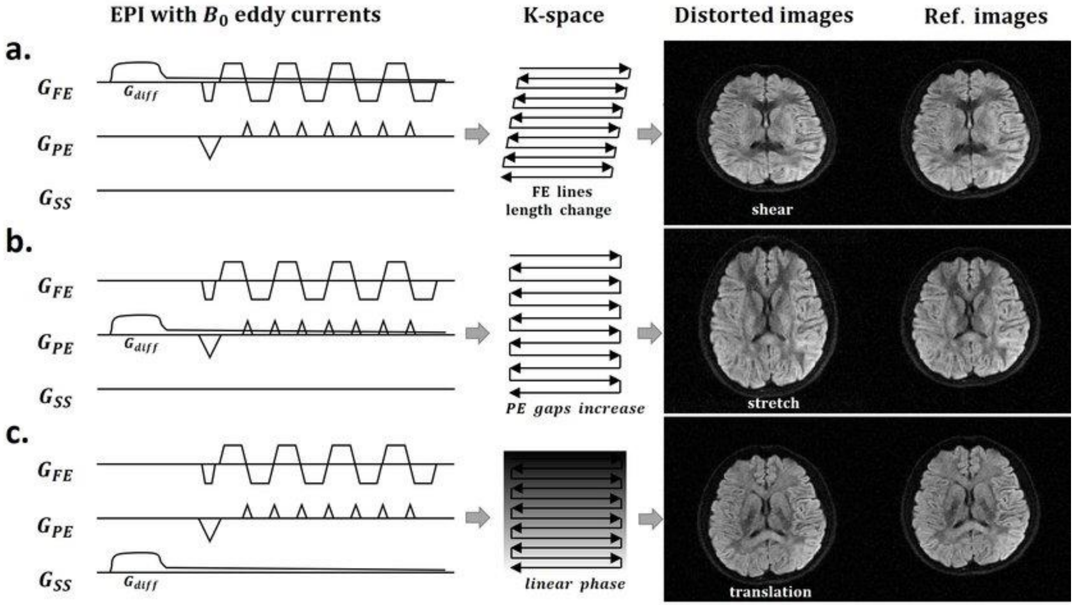
MULTIPLE SLICE IMAGING



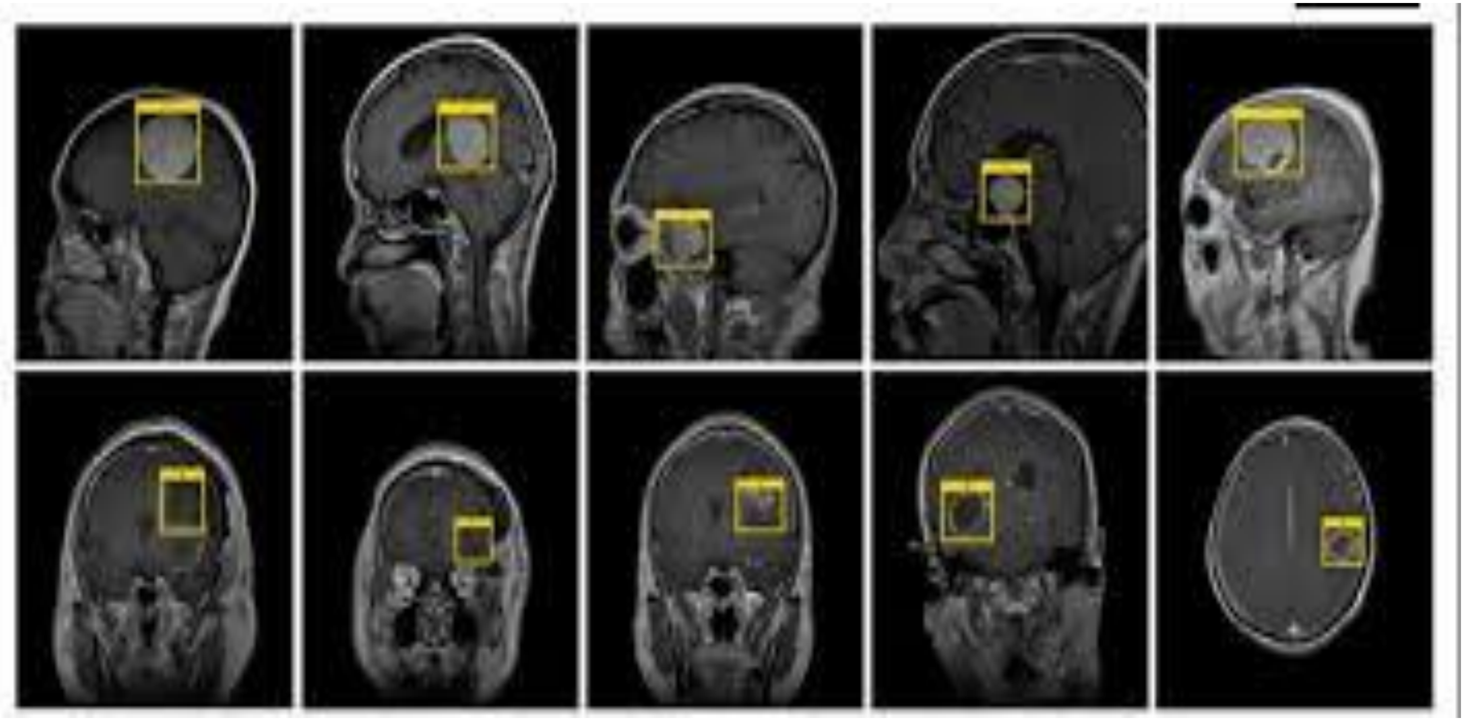
2- Spatial Encoding: Gradient coils create magnetic field gradients in the x, y, and z directions within the imaging volume. These gradients vary linearly across the imaging region. By applying these gradients during the MRI scan, different regions of the body experience different magnetic field strengths. This spatial variation allows for the spatial encoding of signals emitted by protons in the body tissues. The spatial encoding provided by gradient coils enables the differentiation of signals originating from different locations within the imaging volume. This differentiation is crucial for reconstructing detailed cross-sectional images of the body.

3- Frequency Encoding:•In MRI, the frequency of the signal emitted by protons is directly related to the strength of the magnetic field experienced by those protons. By varying the strength of the gradients along a specific direction (typically the x-axis or y-axis), different frequencies are assigned to signals from different spatial locations. This frequency encoding, in conjunction with spatial encoding, allows the MRI system to map the spatial information contained in the signal and reconstruct it into a coherent image.





4- Image Localization: Gradient coils play a crucial role in localizing the origin of the MRI signal within the imaging volume. By precisely controlling the gradients in all three directions, the MRI system can accurately determine the spatial position of the signal within the imaging volume. This precise localization allows for the reconstruction of detailed images with accurate spatial information, facilitating the visualization of internal structures and abnormalities in the body.



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