

Name of the Course: EIBX01
Biomedical Instrumentation
MODULE V

Magnetic Resonance Imaging
(MRI)



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MAGNETIC RESONANCE IMAGING

- Magnetic resonance imaging technique makes use of the RF region of the EM spectra to provide an image
- A patient is placed in an external magnetic field which causes the magnetization of protons of hydrogen atoms in the body
- Due to magnetization these protons align and precess about the external magnetic field
- Now a radio frequency pulse at resonant frequency is transmitted into the patient under controlled condition
- Due to resonance condition the individual proton responds by emitting a radio frequency signal. This is called NMR signal



MAGNETIC RESONANCE IMAGING

- **These emitted signals by the protons, during their return from higher energy state to ground state are picked up by RF coils and processed by computers using FT techniques to produce and image.**
- **Advantage**
 - Superior contrast resolution
 - Direct multiplanar imaging
 - Absence of harmful radiation



MAGNETIC RESONANCE PHENOMENON

- In our body 80% are hydrogen atoms
- Hydrogen atom has a positively charged nucleus which contains only one proton
- It is spinning and a Nuclear moment is associated with it
- Magnetic moment depends on mass, charge and rate of spin of the nucleus
- Spinning of nuclei is random and can be pointed in any direction
- In the presence of a large external magnetic field its axis of rotation will precess about the magnetic field B
- Each spin state has different energy



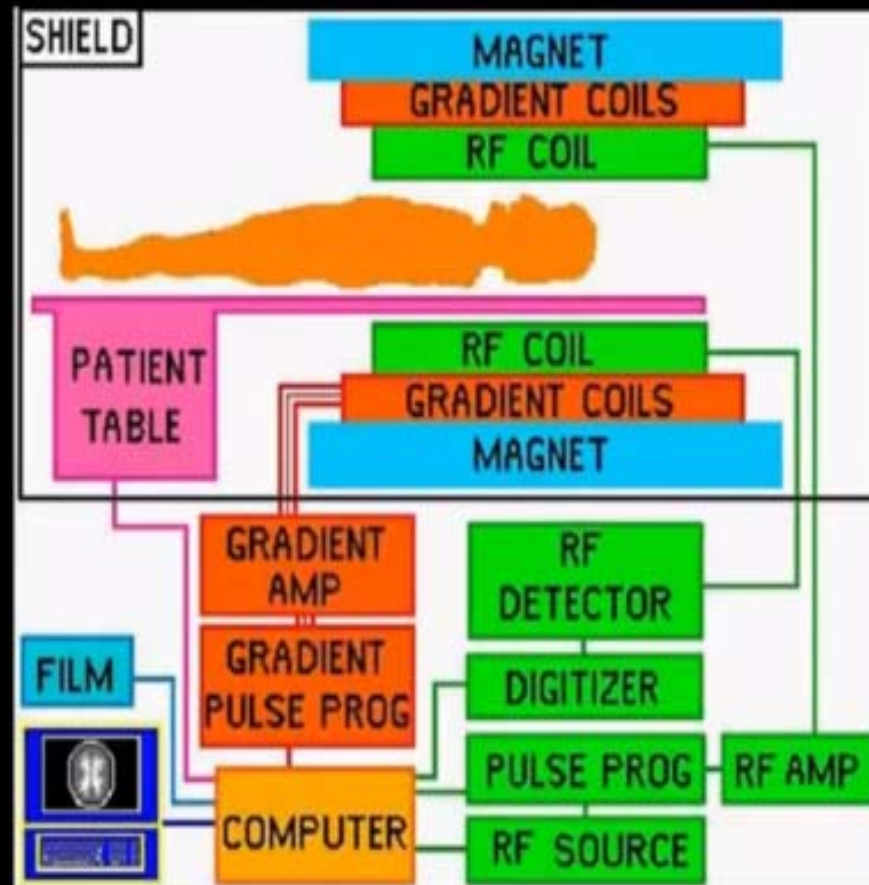
MAGNETIC RESONANCE PHENOMENON

- **At equilibrium lower state has more nuclei than the higher state**
- **Using radio frequency radiation the nuclei from the lower energy state can be raised to higher energy state**
- **The excited nuclear spin slowly return to its equilibrium state emitting radio frequency signal called NMR**



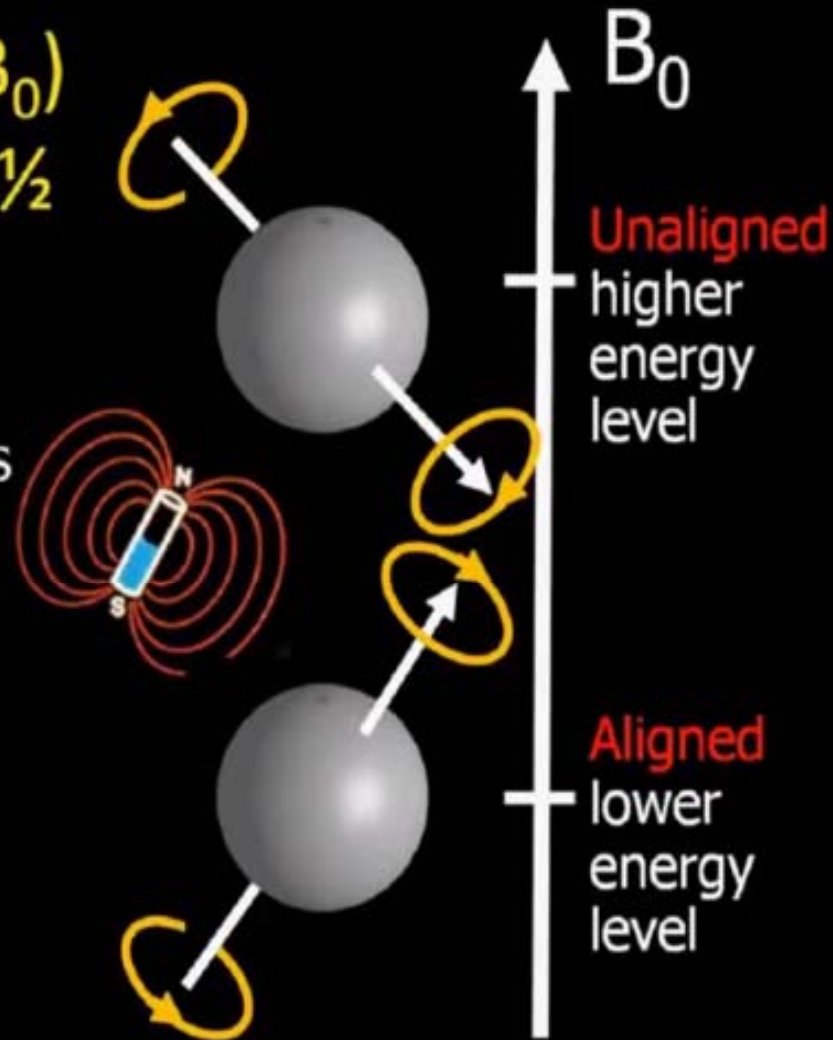
MRI Hardware

- Magnet 1.5T or 3.0T
- Radio Frequency Coil
- Gradient Coils
- Computer

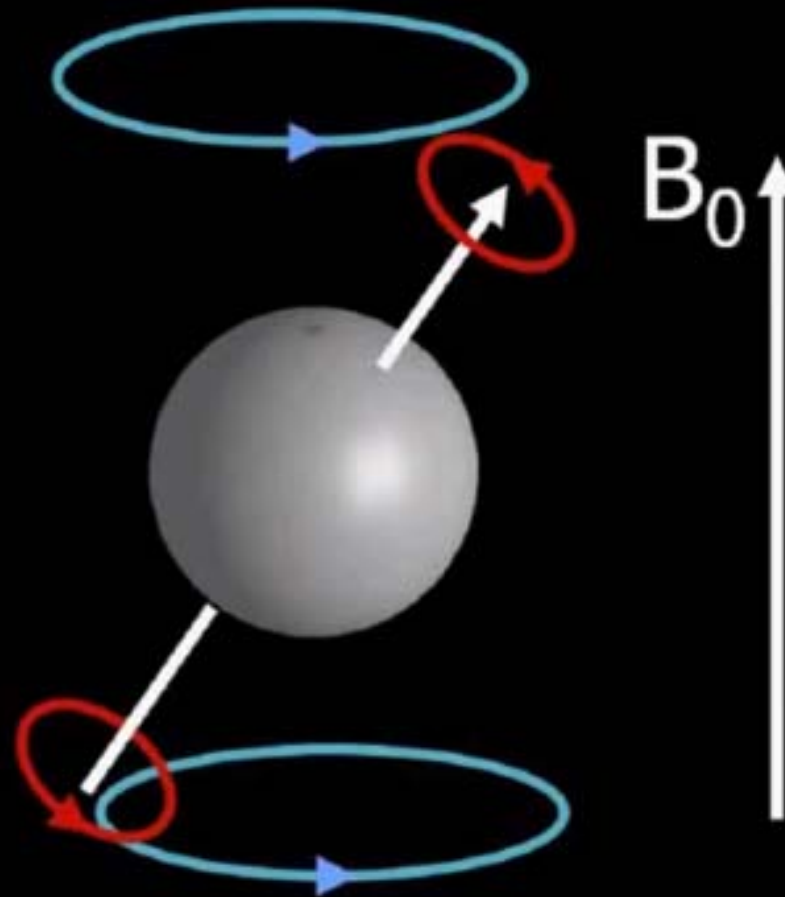
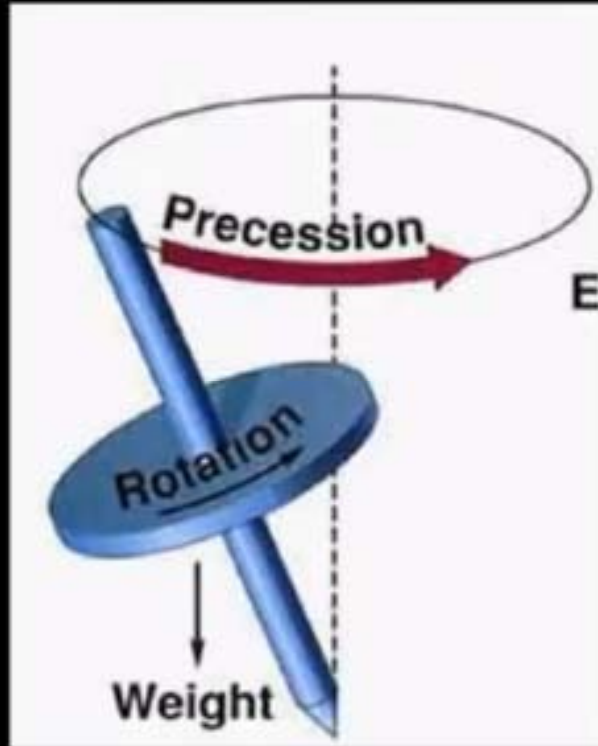


Magnetic Field (B_0) and Proton Spin $\frac{1}{2}$

- Protons spin and behave similar to **small magnets**
- From Quantum Mechanics can either be **aligned** or be **unaligned** with B field
- Small energy difference between the two
- **More protons will be aligned in the lower energy**



Magnetic Field and Precession



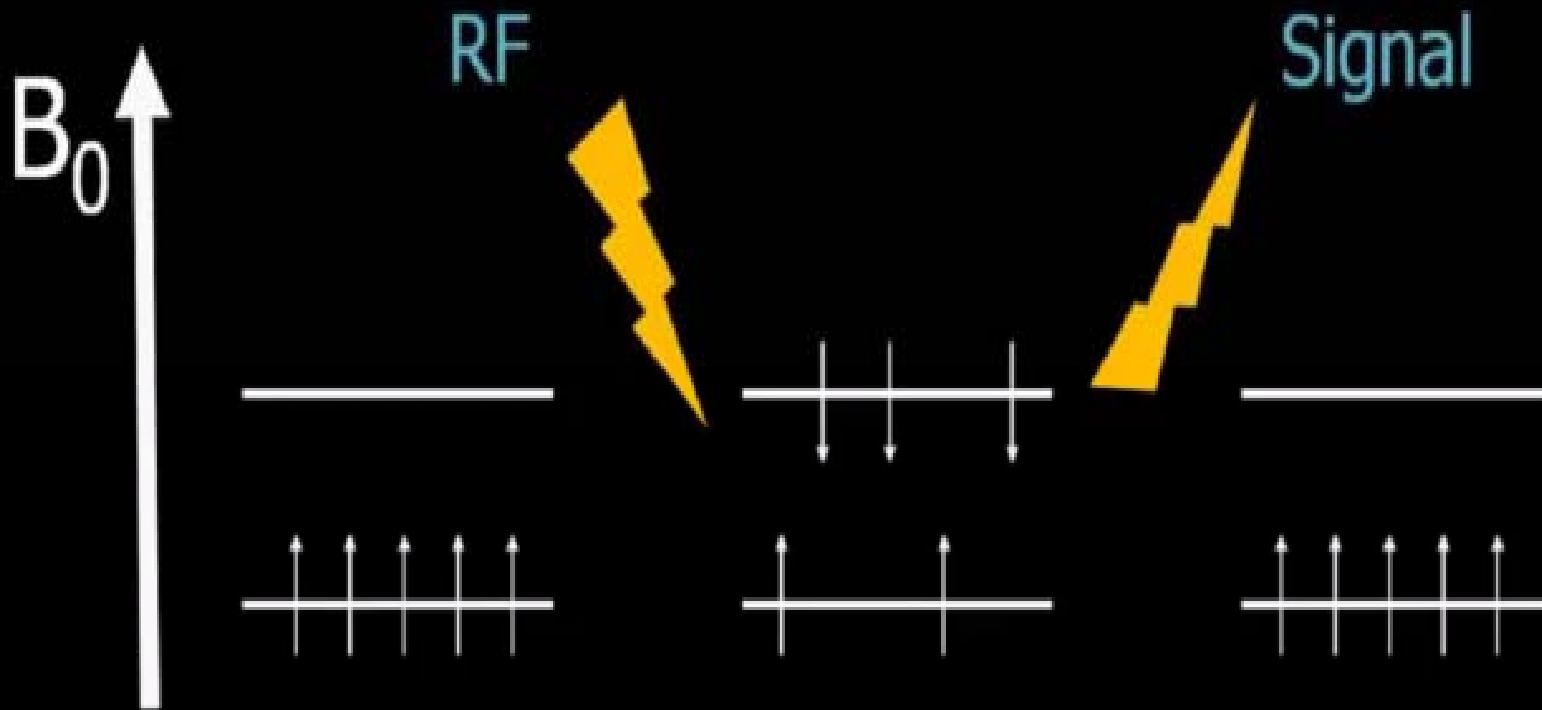
Precession (Larmor) frequency

$$f = \gamma B_0$$

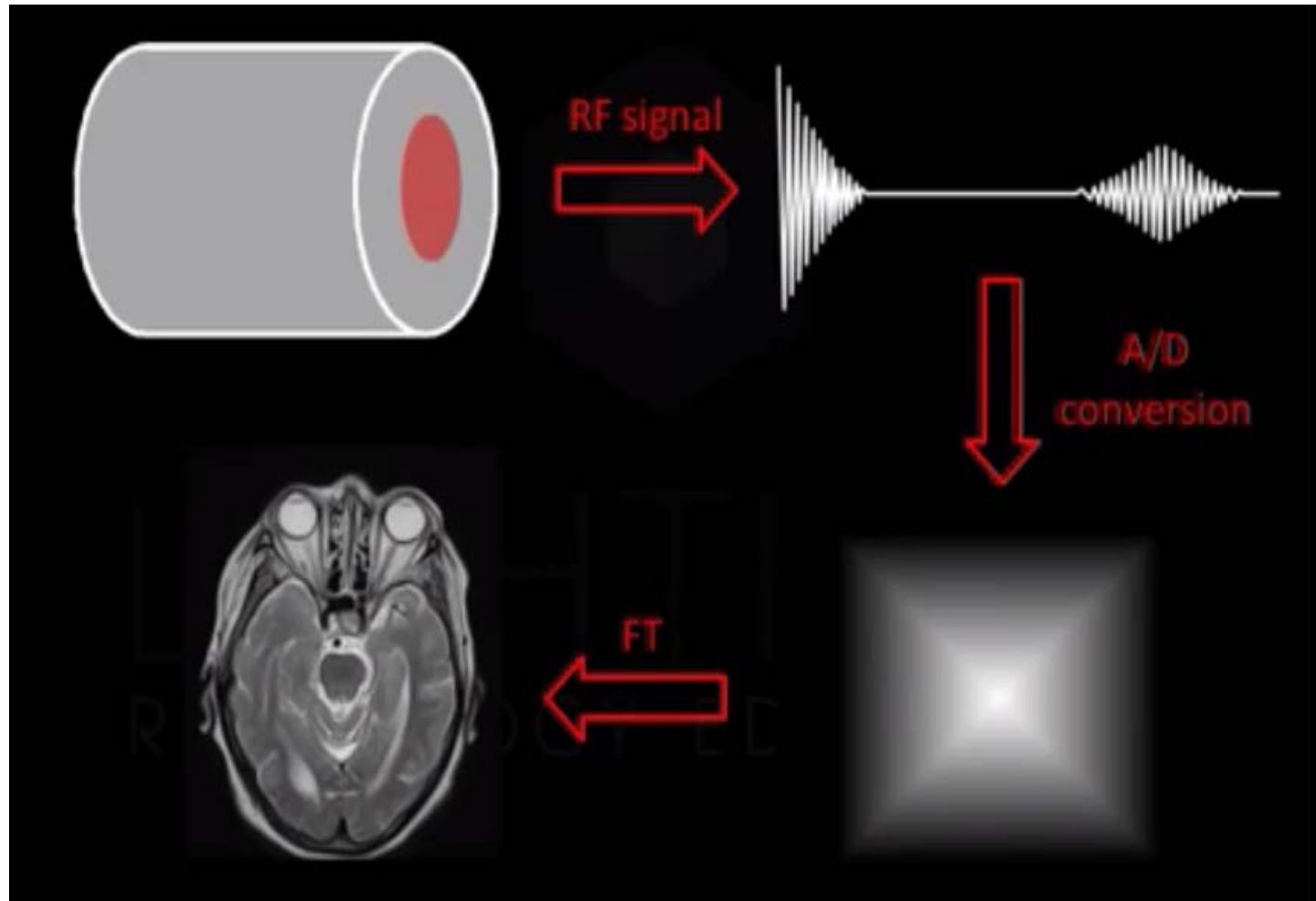
- Gyromagnetic ratio is 42.6 MHz/Tesla
- For $B = 1.5$ Tesla, $f = 65$ MHz
- For $B = 3.0$ Tesla, $f = 130$ MHz
- Excited protons are selected by frequency



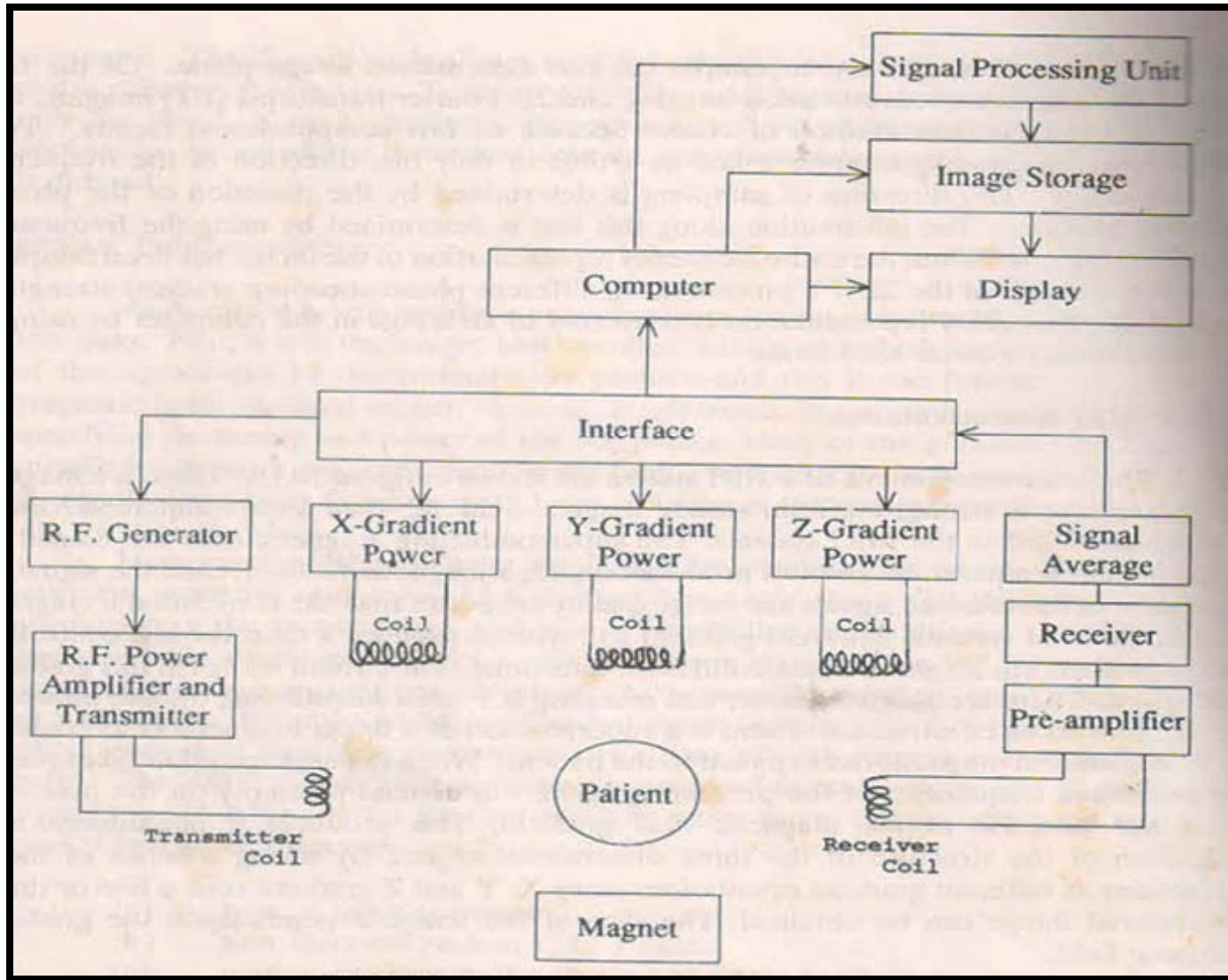
Radio Frequency (RF) pulse



HOW AN MRI IMAGE IS FORMED?



BLOCK DIAGRAM OF MRI



MRI INSTRUMENTATION

- There is a magnet which provides a strong, uniform, steady magnetic field B_0
- Now a days superconducting magnets are used in MRI systems
- The superconducting magnetic coils are cooled to liquid helium temperature and can produce very high magnetic fields.
- Hence signals to noise ratio of the received signals and image quality are better than conventional magnets used in the MRI systems
- Different gradient coil systems produce a time varying controlled spatial non-uniform magnetic fields in different directions



MRI INSTRUMENTATION

- **The patient is kept in this gradient field space.**
- **There are also transmitter and receiving RF coils surrounding the site on which the image is to be constructed**
- **There is a superposition of a linear magnetic field gradient on to the uniform magnetic field applied to the patient**
- **When this superposition takes place, the resonance frequencies of the precessing nuclei will depend on the positions projections of the structure of the three dimensional object.**



MRI INSTRUMENTATION ...

- **By taking a series of these projections at different gradient orientations using X, Y and Z gradient coils a two or a three dimensional image can be obtained.**
- **The slice of the image depends upon the gradient magnetic field**
- **The gradient magnetic field is controlled by computer and that field can be positioned in three planes (X, Y and Z).**
- **The transmitter provides the RF signal pulses**

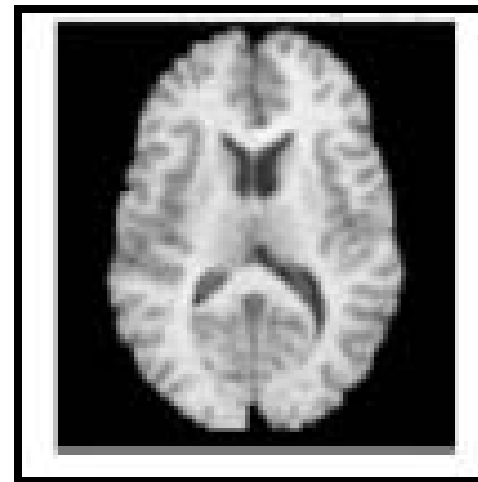
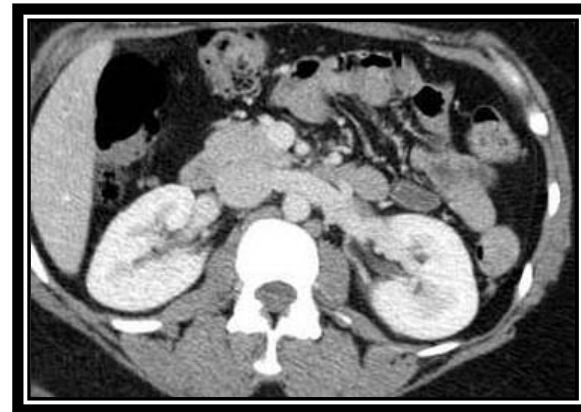
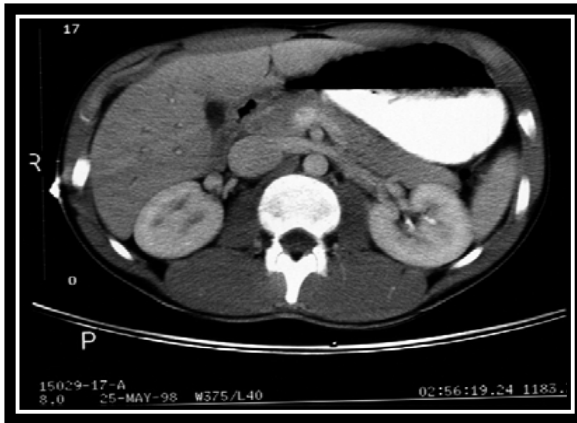


MRI INSTRUMENTATION ...

- The received nuclear magnetic resonance signal is picked up by the receiver coil and is fed into the receiver for signal processing
- By two dimensional Fourier Transformation, the image is constructed by the computer and is displayed on the television screen



IMAGES OBTAINED USING MRI



BIOLOGICAL EFFECTS OF MRI IMAGING

- **HEATING DUE TO THE RF POWER:** temperature increase produced in the head of MR imaging would be 0.3°C.
- **STATIC MAGNETIC FIELD:** slight decrease in cognitive skills, mitotic delay, in slime moulds.
- **ELECTRIC CURRENT INDUCTION DUE TO RAPID CHANGE IN MAGNETIC FIELD:** ventricular fibrillation.



ADVANTAGES OF MR IMAGING SYSTEM

- **Provides substantial contrast between soft tissues that are nearly identical.**
- **Cross sectional images without any orientation.**
- **Offer potential for physiological imaging.**



ADVANTAGES OF MR IMAGING SYSTEM

- **Alternative contrast mechanisms provide promising possibilities of new diagnostics.**
- **Requires no moving parts, as in CT.**
- **Uses no ionizing radiation.**

