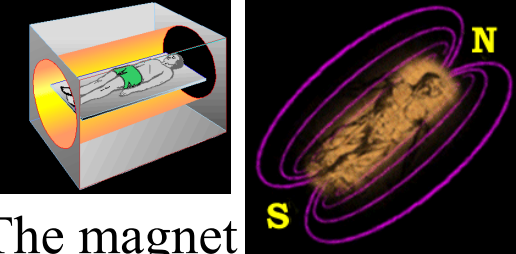


- ### SIX MAIN COMPONENTS OF MRI SYSTEM
- Magnet
 - Gradient Coils
 - RF Coils
 - Electronic Support System
 - Computer
 - Display
- 2



The magnet

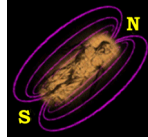
The magnet applies a static (homogeneous) magnetic field which align and precess the nuclei in the body.

3



Gradient Coils

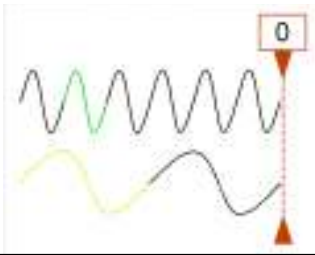
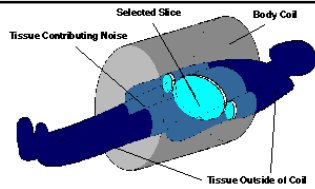
The gradient coils apply a variant of magnetic field strengths over the patient.



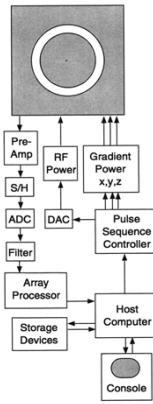
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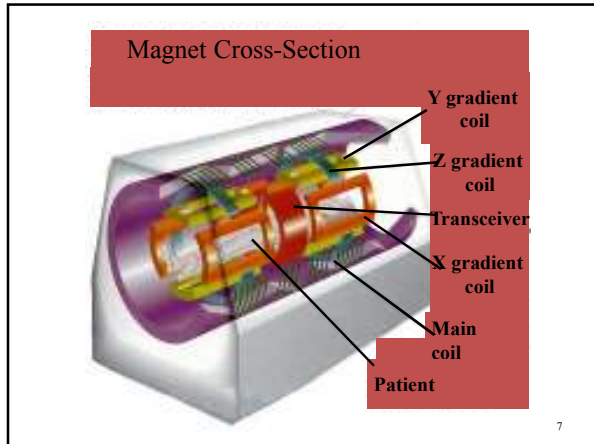
RF Coil or Antennae

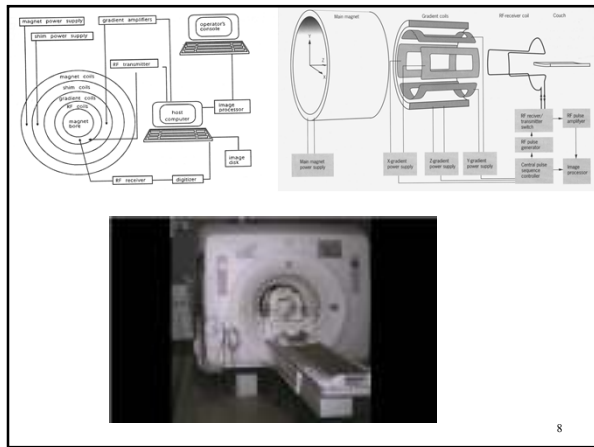
When radio frequencies are applied, the atoms absorb it and net magnetization changes.

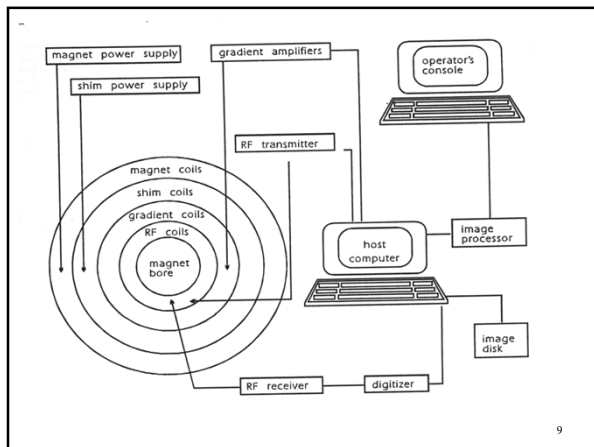


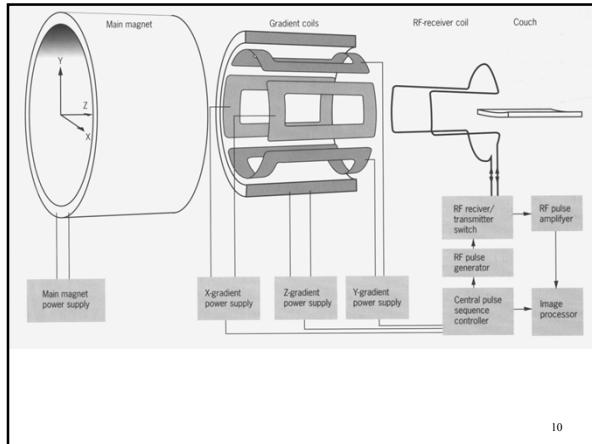
Electronic Support System












OVERVIEW of the MRI SYSTEM

MAGNET

A magnet used for MRI must provide a large enough opening to comfortably fit a patient and a high degree of magnetic field homogeneity.

The magnet's purpose is to align the net magnetization of the patient's protons and to establish the protons' resonant frequency.

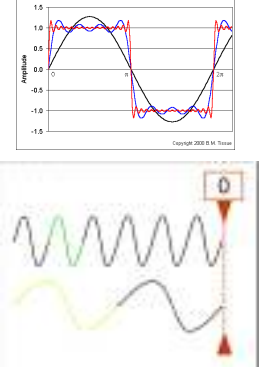


MRI Core

PULSE SEQUENCE CONTROLLER

The pulse sequence controller is responsible for the timing and performance of each system component.

The pulse sequence controller dictates when and how much gradient power is needed to vary the magnetic field and spatially encode the MR signal.

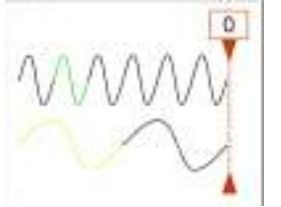


PULSE SEQUENCE CONTROLLER

The pulse sequence controller also dictates when the RF energy must be transmitted and for how long.

The signal power amplifier must be converted into an analog continuous waveform.

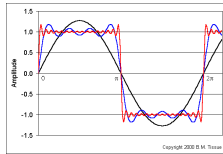
The conversion is performed by the digital-to-analog converter (DAC).



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DIGITAL-TO-ANALOG CONVERTER DAC

The digital-to-analog converter is responsible for converting the digital instructions from the **pulse sequence controller** into a continuous analog wave form that is then passed through the **RF power amplifier**.

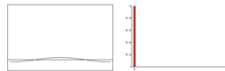


14

ARRAY PROCESSOR

The array processor is used to reconstruct images from raw data.

It is in the array processor that the Fourier transform is applied.

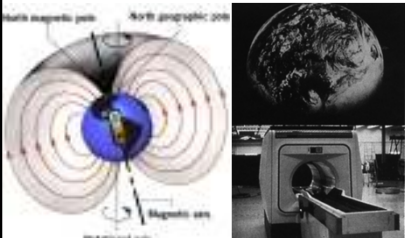


15

Prescan

- These tasks must be done before scanning can be done:
 - Tune coil
 - Shim magnetic field
 - Set center frequency
 - Adjust transmit attenuation (RF Power Level)
 - Adjust receiver attenuation (Receiver Gain)
- Failure to properly tune and match the coil may result in noisy images with poor contrast.

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The diagram on the left shows Earth's magnetic field lines, with labels for 'North magnetic pole', 'North geographic pole', and 'Magnetic axis'. To the right is a photograph of an MRI machine.

Earth .00005 Tesla (.5 Gauss)

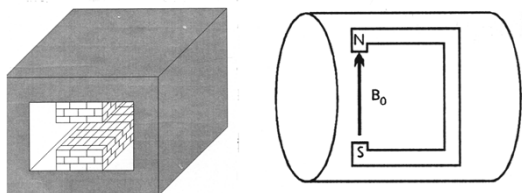
MRI 0.1 to 2.0 Tesla (1,000 to 20,000 Gauss)

The strength of a magnetic field is measured in units of induction, either Tesla or Gauss.

One Tesla equals 10,000 Gauss equals 10 kilogauss.

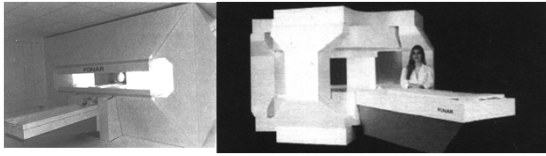
17

PERMANENT MAGNET



Permanent magnets are constructed from hundreds of permanently magnetized ceramic bricks.

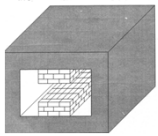
18



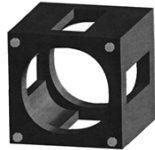
The bricks are assembled such that their magnetic fields all face in the same direction.

Once assembled, their magnetic fields add together to make a strong enough field to perform MRI.

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PERMANENT MAGNET



- The two magnetic field are connected to an iron frame which acts to support the weight of the magnet as well as focus and constrain the field.

- This configuration establishes a vertical magnetic field, the most common permanent magnet designs.

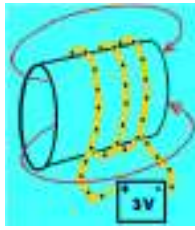
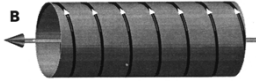
20

Permanent Magnet

- Costs less to operate
- Allow larger bore size
- Accommodate larger patients
- Less chemical shift
- Smaller space requirements
- Heavy
- Field to about 0.3 tesla
- Cannot be "turned off"
- Require air-conditioning at a constant temperature to keep stable
- Require longer scan times

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ELECTROMAGNET



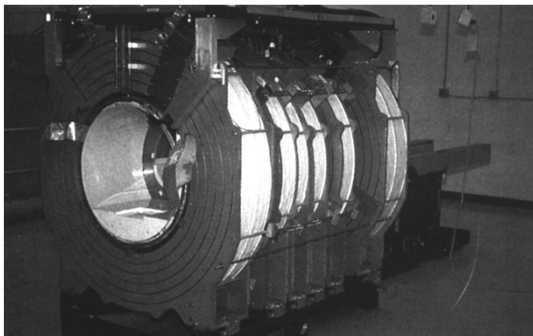
Electromagnets are made from coils of wire through which an electric current is passed.

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ELECTRO or RESISTIVE MAGNET



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The diagram shows a cylindrical coil of wire. On the left, a vertical arrow labeled 'FIELD' points upwards. A horizontal arrow labeled 'B' points to the left from the center of the coil. Below the coil is a label 'wire'. To the right, a cross-section of the wire is shown with current flowing to the right, indicated by a horizontal arrow labeled 'current'. The wire is represented as a series of circles with '+' signs. A vertical oval labeled 'magnetic field lines' encircles the wire, with an arrow indicating a clockwise direction when viewed from the right.

By passing an electrical current through a coil made from looped niobium titanium wire, a magnetic field through the center of the coil is generated.

Both resistive and superconducting magnets share this basic principle.

25

The diagram shows two solenoids. The left one is a standard cylinder with a horizontal arrow labeled 'B' pointing to the left. The right one is a solenoid with a T-shaped handle, also with a horizontal arrow labeled 'B' pointing to the left.

A basic law of magnetism states that if a charged particle is moved a distance along a path, a magnetic field will be generated perpendicular to the direction of the particle's motion.

The direction of the magnetic field, when current flows through a coil of wire, is determined by the direction of the current.

26

The left image is a photograph of a large, complex superconducting magnet assembly with multiple cylindrical sections. The right image is a diagram of a square loop of wire with red and yellow nodes at the corners and midpoints, and a green arrow indicating current flow.

- To create strong electromagnetic fields, large amounts of currents must be used.
- The resistance built up in the wire will produce heat reducing the efficiency of the current and the reduction of the magnetic field through heat loss.

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RESISTIVE MAGNET

- Resistive magnets are electromagnets consisting of an air core or iron core wrapped with a long coil of wire.
- Resistive magnets may be designed to be vertical or horizontal magnetic fields up to about 0.3 Tesla in strength.
- Field strength is limited by the amount of power needed.
- A benefit of resistive magnets is the ability to shut the magnetic down quickly by simply turning off the power supply.
- A drawback to resistive magnets is the energy usage and water cooling requirements.

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RESISTIVE MAGNET

- Can be quickly turned off
- Low- to mid- magnetic field
- High power consumption
- Water cooling is required

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SUPERCONDUCTIVE MAGNET



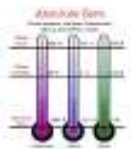
30



- The entire system must be super cooled using liquid helium.
- By reducing the temperature down to near absolute zero, there is virtually no resistance in the wires.
- Stronger magnetic fields can be obtained with a superconducting magnet.

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SUPERCONDUCTING MAGNETS



- Superconducting magnets are electromagnets super-cooled to near absolute zero.
- The coil of wire is made of Niobium Titanium.

32

CRYOGENS



33

SUPERCONDUCTIVE MAGNETS

- Large service requirements
- Cryogen maintenance requirements
- Large magnetic fringe field
- Magnetic field can be turned off
- Low power consumption
- High magnetic fields
- Stable magnetic field with homogeneity

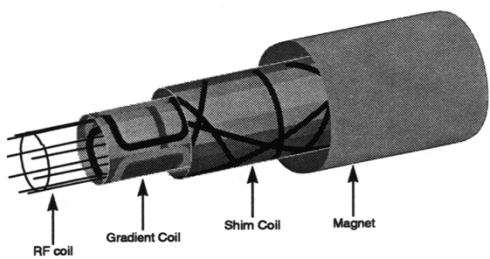
34

Quench

- "Unexpected loss of superconductivity in a superconducting magnet that causes heating and very rapid vaporization of the cryogens such as liquid helium.
- This can cause damage to the magnet and can force the atmosphere out of the scanner room potentially causing anoxic conditions."

35

Magnet Components



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Magnetic Shielding

- Magnetic shielding assures that no one comes within the 5 Gauss limit line before going through the proper screening procedures.
- With shielding the fringe field drops off to approximately the 5 Gauss limit line when outside of the scan room.

37

Magnetic Shielding

- Magnetic fringe fields must be minimized for patient safety and can be compensated for by the use of magnetic shielding.
 - Passive-shielding
 - Active-shielding
 - Self-shielding

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Shielding Design

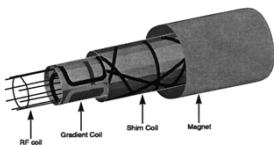
- Passive-shielding uses steel in the walls of the scan room.
- Active-shielding uses solenoid magnets outside the cryogen bath that restrict the magnetic field lines to an acceptable location.
- Self-shielding uses steel in the magnet housing.

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RF Shielding

- RF Shielding assures that radio frequencies in the outside environment do not penetrate the MR scan room.
- Copper and stainless steel are used to create a Faraday cage inside the scan room to assure that no stray radio frequencies get in or out of the scan room.

40

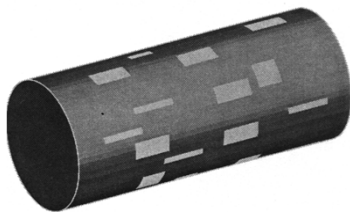


The Shims

• **Shimming** is the process by which magnetic field inhomogeneities are greatly reduced.

• **Shimming** can be accomplished in two ways: passively and actively.

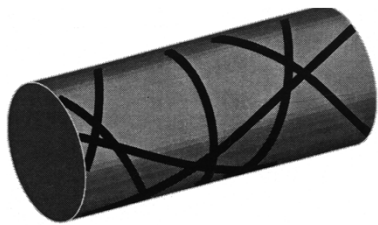
41



PASSIVE SHIM

Passive shimming uses iron plates arranged at specific locations on the surface of the cylinder.

42

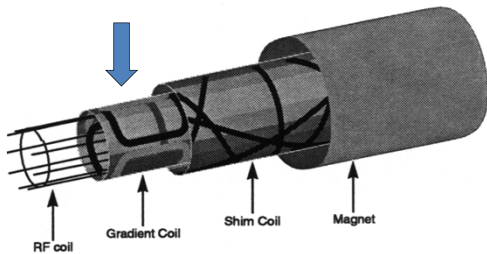


ACTIVE SHIM

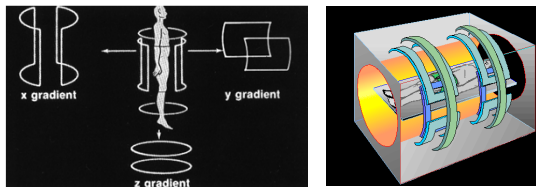
Coils of various geometry are selectively energized in order to produce local changes in the magnetic field where necessary.

43

GRADIENT COILS

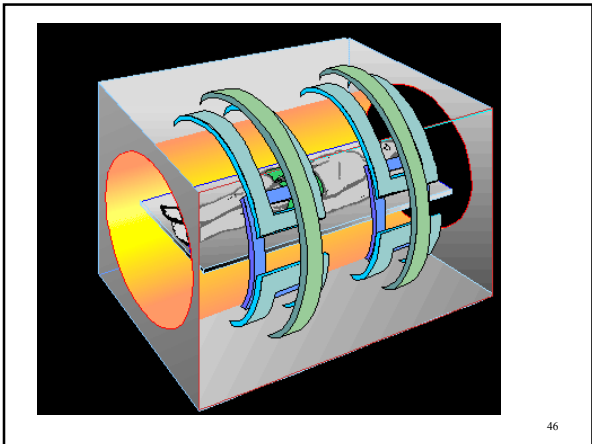


44

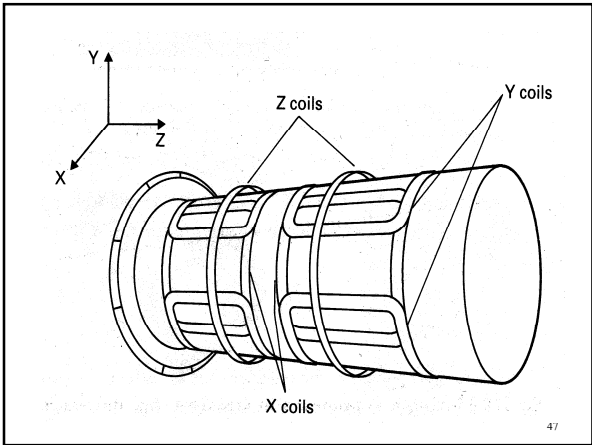


Gradient magnetic fields are used to spatially vary the magnetic field from one point in space to another.

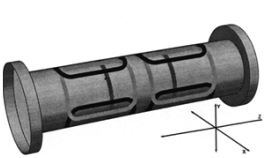
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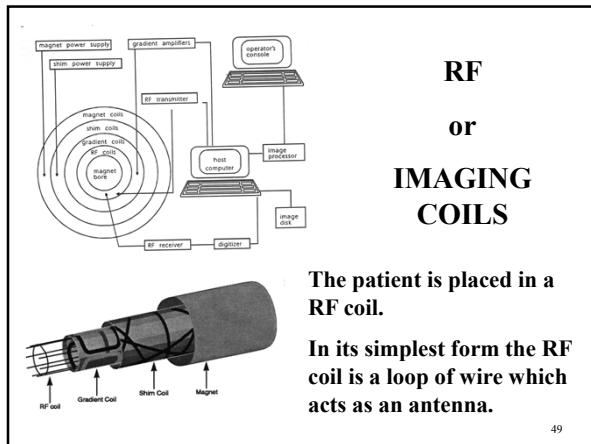
47



GRADIENT COILS

- The gradient coils are thick bands of conductive material wrapped around a cylinder that fits inside the shim cylinder.
- There are three sets of coil pairs wrapped onto the cylinder's surface.
- There are also three gradient power amplifiers that drive electrical current through the gradient coils.

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RF or IMAGING COILS

The patient is placed in a RF coil.

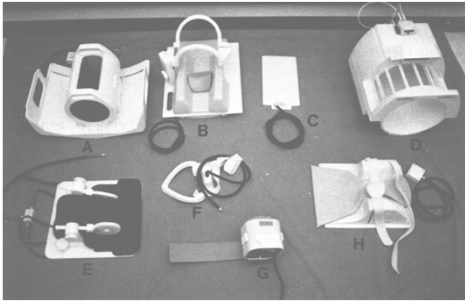
In its simplest form the RF coil is a loop of wire which acts as an antenna.

IMAGING COILS

- The closer a coil is to the area to be excited, the less RF energy needed to create transverse magnetization.
- The closer the receiver coil to the excited volume, the more signal detected.
- Therefore, surface coils improve the signal-to-noise ratio(SNR).

COIL FUNCTION

- Two types of RF coils: transmitter coils and receiver coils.
- A single RF coil used for both transmitting the RF energy and receiving it.
- One coil as a transmitter and a second coil as a receiver.
- The transmitter coil must be large enough and positioned and shaped in such a way as to distribute the RF energy uniformly.
- When two different coils are used the coils must be decoupled or electrically isolated from one another so that energy is applied to only one coil at a time.



RECEIVER COILS

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Volumetric Coils

- A volume coil both transmits RF and receives MR signal and is often called a transceiver.
- Even though volume coils are responsible for uniform excitation over a large area, because of their large size produce images with a lower SNR than other types of coils.
- The signal quality produced by volume coils has been significantly increased by doubling the coil sets within the imaging coil creating *quadrature excitation and detection*.
- This enables the signal to be transmitted and received by two pairs of coils.

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Helmholtz Coil

- A Helmholtz configuration can be described as two coils working in tandem.
- The Helmholtz pair differs from the quadrature coil in that it is actually two linear coils.
- The purpose is to improve the signal through a volume of tissue.
- Only useful in horizontal magnetic fields.

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Solenoid Coils

- Solenoid coils are used with vertical field magnets.
- Most are separate transmit and receive coil configurations.
- Cannot be used with horizontal magnetic fields.

55

Quadrature / Multi-channel Coils

- Use two or more sets of coils – sensitive to signal from only one polarization.
- Increased signal-to-noise, compared to linear coils.
- Increase speed of reception.
- Quad Coil can be transmit and receive coils.
- Less susceptible to artifacts when tilted.

56

Phased Array

- Several small coils in a coil holder is an array coil.
- Can switch between using one coil by itself or by using multiple coils together for larger coverage.
- In this way, the signal-to-noise ratios of a small coil can be combined to image a large area of interest.

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