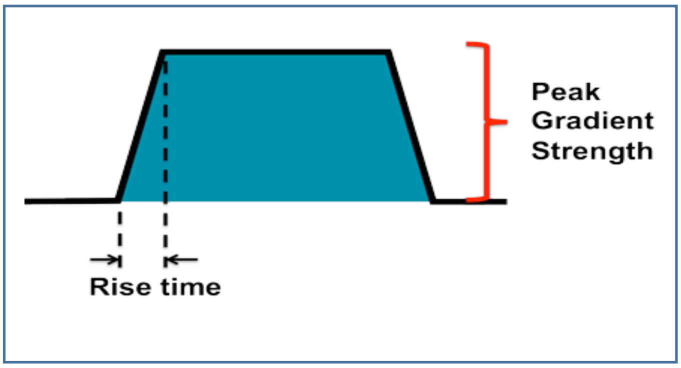
Theoretical Lecture

Gradient specifications & *Radiofrequency (RF) Coils*

Gradient specifications

- Both spatial resolution and imaging speed depend upon good gradient performance, and scanners do differ in their gradient specifications.
- Electrical currents are pulsed on and off during imaging, and gradients typically have a trapezoidal waveform as shown in the diagram blew from which different measurements are derived.



The first value to look for on the specification sheet is

1- Maximum (or peak) gradient strength. This is quoted in units of millitesla per meter (mT/m).

- **Most 1.5 T to 3.0 T superconducting whole-body scanners have maximum gradient strengths in the range of 30-45 mT/m.**
- **Lower field (<0.5T) permanent scanners are in the 15-25 mT/m range.**
- **For the best performance concerning peak gradient strength, bigger is better.**

2- Rise time

In reality, the gradient needs a little time to reach maximum power and to power down. **The time it takes to reach maximum power is called** ***Rise***

Time. Rise time is measured in milliseconds, and is typically in the range of 0.1-0.3 msec for most scanners.

Slew rate is the speed at which a **gradient** can be turned on and off, and is defined as **the maximum gradient strength** of the gradient divided by the **rise time**.

$$\boldsymbol{slew\ rate = \frac{peak\ gradient\ strength}{Rise\ Tiime}}$$

Slew rates are measured in units of **Tesla per meter per second** (**T/m/s**).

Example:

If the gradient ramps from 0 to peak amplitude of 30 mT/m in 0.5 msec, find the slew rate?

Answer:

$$slew\ rate = \frac{peak\ gradient\ strength}{Rise\ Tiime}$$

$$slew\ rate = \frac{(30-0)\ mT/m}{0.5\ msec} = 60\ T/m/sec$$

- The slew rate influences the minimum attainable Repetition Time (TR) and Time to Echo (TE) for conventional MR imaging.

- ***Repetition Time (TR)*** is the amount of time between successive RF pulse sequences applied to the same slice.
- ***Time to Echo (TE)*** is the time between the delivery of the RF pulse and the receipt of the echo signal.

- High-field superconducting scanners boast slew rates in the 150-200 T/m/s range.

- Superconducting open scanners in the 100-120 T/m/s range.

- Lower field permanent scanners on the order of 50 T/m/s

The need for strong gradients and high slew rates depends on your intended scanner use. If cardiac or brain imaging is anticipated, then powerful gradients are mandatory. If the intended scanner use is for orthopedics, however, such demanding gradients may not be required.

Radiofrequency (RF) Coils

The radiofrequency (RF) system includes the set of components for transmitting and receiving the radiofrequency waves involved in exciting the nuclei, selecting slices, applying gradients and in signal acquisition.

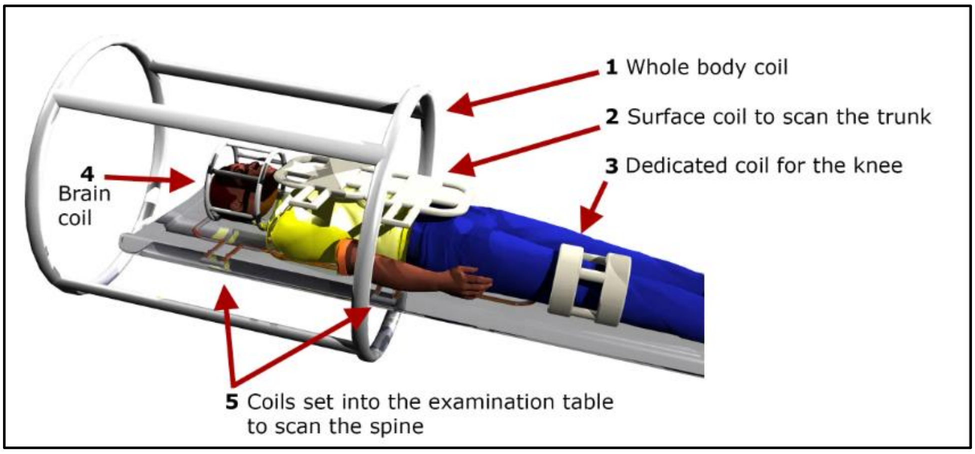


Figure1: RF coils.

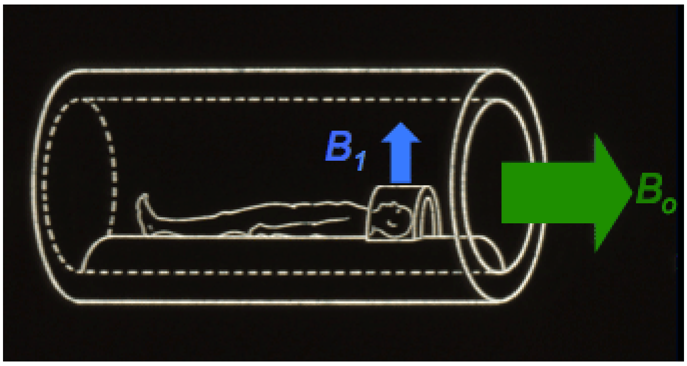
- ***RF coils*** are coils produce magnetic field perpendicular to the main magnetic field. It should be close to the imaging part.

RF coils made for:

a) Receive only.
b) Transmit only.
c) Transmit and receive.

Sending and Receiving Coils

RF-coils generate an oscillating/rotating magnetic field (denoted B_1) that is perpendicular to the static main magnetic field when employed as transmitters (B_o). Energy is deposited into the spin system if the oscillation of B_1 closely matches the natural precession of nuclear spins near the Larmor frequency, causing a change in its net alignment. The transmit RF-coil produces the B_1 field in response to a strong current provided by the scanner's DC supply. B_1 is normally turned on for only a few milliseconds at a time, known as "RF-pulses." The nuclear spin system can be rotated by variable flip angles, such as 90° or 180°, by modifying the size or length of these B_1 pulses.



RF-coils are responsible for detecting the MR signal when employed as receivers. The coil in which an induced electric current is created can capture the oscillating net magnetic flux from the excited spin system. To extract frequency and phase information, the current is amplified, digitized, and filtered.

Types of RF coils includes (Figure 2).

- Volume coils (include Body coil, Head coil and knee coil).
- Surface coils.
- Phased array coils.

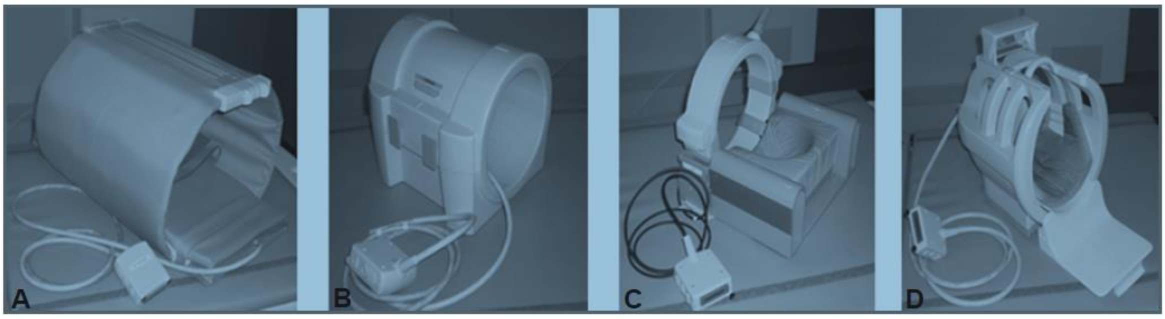


Figure2: (A) Body coil, (B) Knee coil, (C) Head and shoulder coil, and (D) Head coil

- The sending coil of an MRI system is usually built into the bore of the magnet, while the receiving coil is located on the patient table (Figure 3).

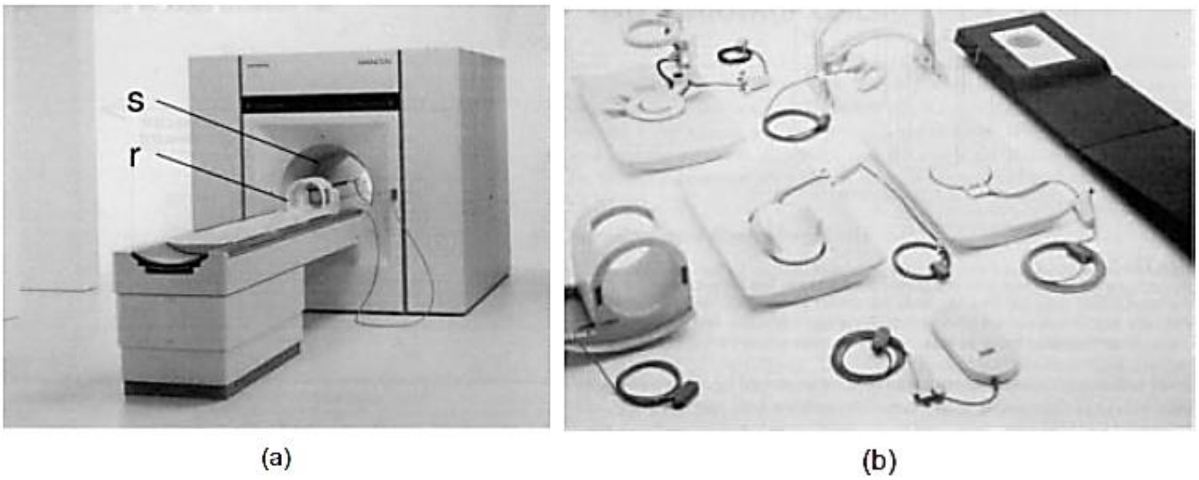


Figure 3: (a); The radio-frequency (RF) coil for sending is usually located within the bore of the magnet, while the RF coil for receiving is located on the patient table. **(b);** a set of RF "surface coils" for imaging various body parts.

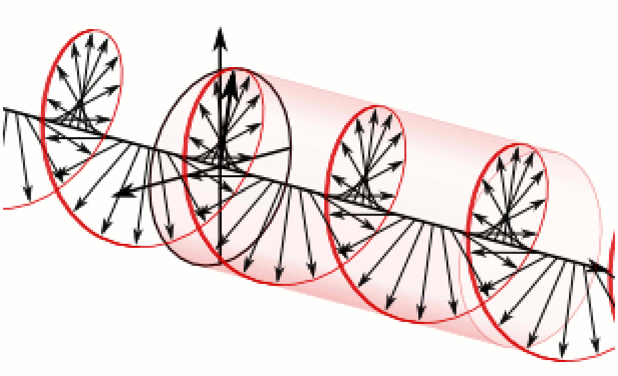
Volume RF coils

Volume coils are the transmit and receive radiofrequency coils which are used to both transmit and receive the radiofrequency signal in MRI.

The design of a volume coil is to provide a homogeneous RF field inside the coil which is highly desirable for transmission, but is less ideal when the region of interest is small. The large field of view of volume coils means that by receiving the noise that they receive from the whole body, not just the region of interest.

The main body coil transmits RF to the patient, and it will typically be circularly polarized (generating a field rotating at the Larmor frequency) (figure 4).

Figure 4: circular polarization; circular polarization of an electromagnetic wave is a polarization state in which, at each point, the electromagnetic field of the wave has a constant



The body coil is also often able to act as a receiver and allows large volumes of the body and multistation whole-body imaging to be achieved.

- ***Body coil***; which is a volume coil built into the bore of the magnet which transmits the radiofrequency for most examinations. It transmits RF and receives MR signals, e.g. chest, and abdomen .
- ***Head coils;*** Smaller homogeneous volume coils are used for brain imaging, and it transmits and receives the signal.