SAWA UNIVERSITY

Equip. Techniques of MRI

Magnetic Resonance Imaging System Components Introduction and Overview

جامعة ساوة

كلية التقنيات الصحية والطبية

قسم تقنيات الأشعة والسونار

المرحلة الثالثة

رقم المحاضرة (1)

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1. Introduction And Overview

Magnetic resonance imaging (MRI) is a medical imaging process that uses a magnetic field and radio frequency (RF) signals to produce images of anatomical structures, of the presence of disease, and of various biological functions within the human body. MRI produces images that are distinctly different from the images produced by other imaging modalities. A primary difference is that the MRI process can selectively image several different tissue characteristics. A potential advantage of this is that if a pathologic process does not alter one tissue characteristic and produce contrast, it might be visible in an image because of its effect on other characteristics. This causes the MRI process to be somewhat more complex than most imaging methods. In order to optimize an MRI procedure for a specific clinical examination, the user must have a good knowledge of the characteristics of the magnetic resonance (MR) image and how those characteristics can be controlled. The MRI system consists of several major components, as shown in Figure 1. At this time, we will introduce the components and indicate how they work together to create the MR image. The heart of the MRI system is a large magnet that produces a very strong magnetic field. The patient's body is placed in the magnetic field during the imaging procedure. The magnetic field produces two distinct effects that work together to create the image.

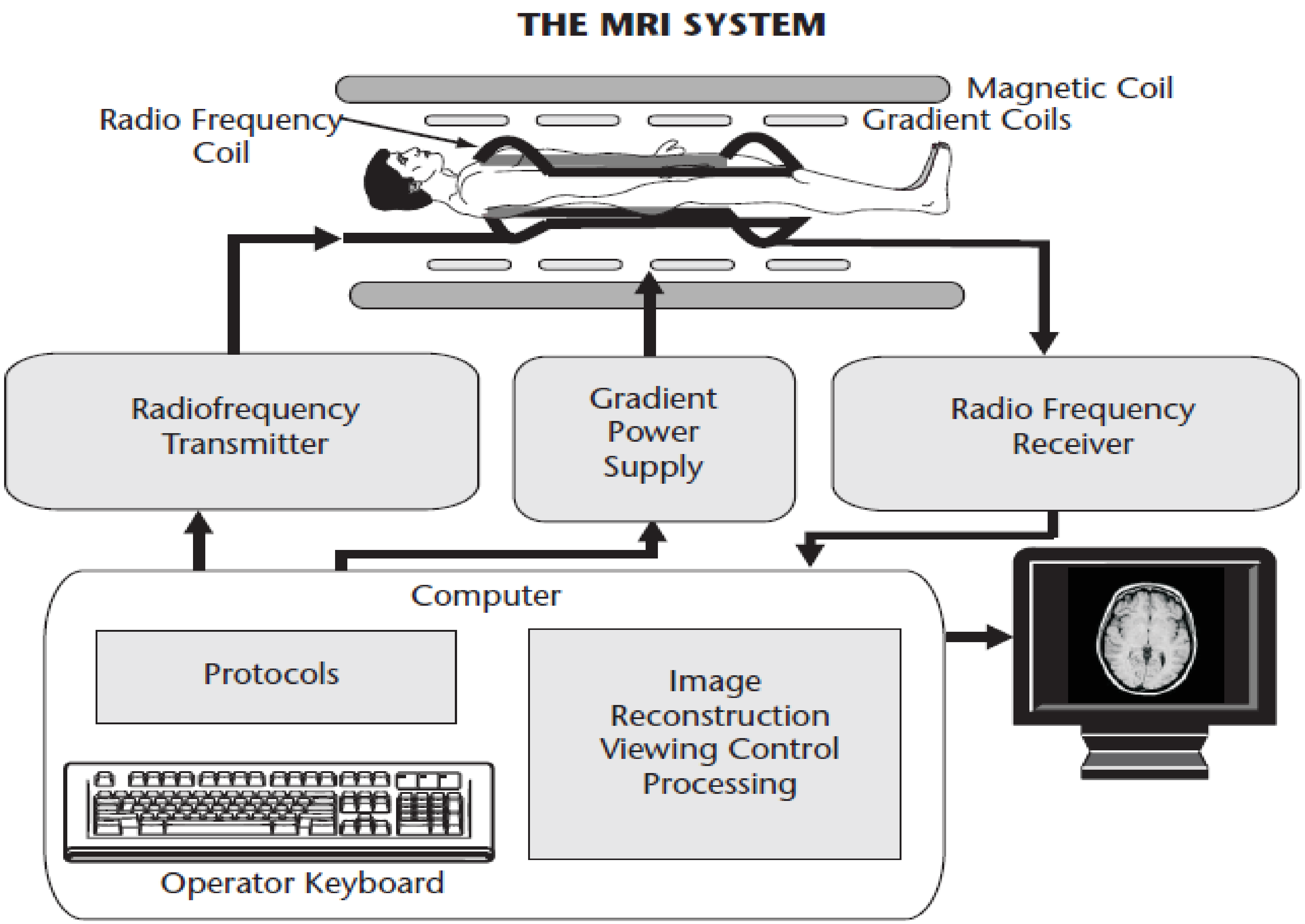


Figure 1. The major components of the Magnetic Resonance Imaging System.

1.1. Tissue Magnetization

When the patient is placed in the magnetic field, the tissue becomes temporarily magnetized because of the alignment of the protons, as described previously. This is a very low-level effect that disappears when the patient is removed from the magnetic field. The ability of MRI to distinguish between different types of tissue is based on the fact that different tissues, both normal and pathologic, will become magnetized to different levels or will change their levels of magnetization (i.e., relax) at different rates.

1.2. Tissue Resonance

The magnetic field also causes the tissue to “tune in” or resonate at a very specific radio frequency. That is why the procedure is known as magnetic resonance imaging. It is actually certain nuclei, typically protons, within the tissue that resonate. Therefore, the more comprehensive name for the phenomenon that is the basis of both imaging and spectroscopy is nuclear magnetic resonance (NMR). In the presence of the strong magnetic field the tissue resonates in the RF range. This causes the tissue to function as a tuned radio receiver and transmitter during the imaging process. The production of an MR image involves twoway radio communication between the tissue in the patient’s body and the equipment.

1.3. The Magnetic Field

Figure 2 shows the general characteristics of a typical magnetic field. At any point within a magnetic field, the two primary characteristics are **field direction** and **field strength.**

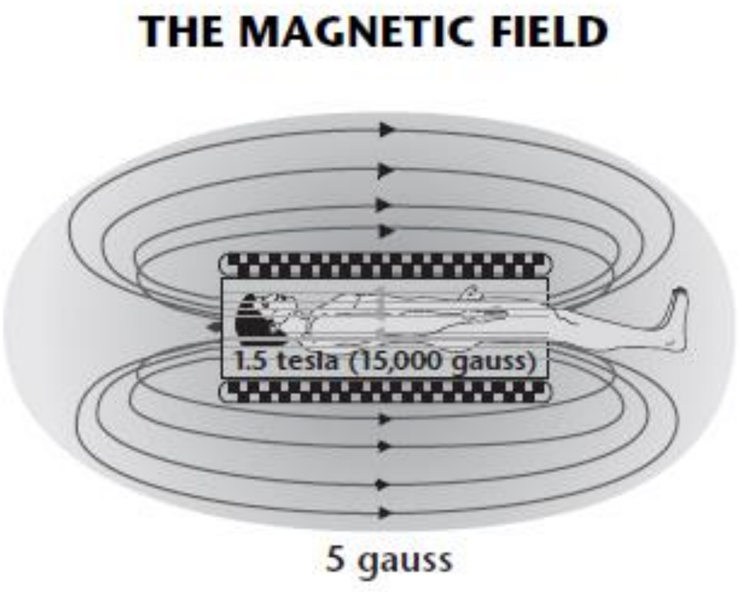


Figure 2-2. The magnetic field produced by superconducting magnets.

2. Magnets

There are several different types of magnets that can be used to produce the magnetic field. Each has its advantages and disadvantages.

1.1 Superconducting Magnets

Most MRI systems use superconducting magnets. The primary advantage is that a superconducting magnet is capable of producing a much stronger and stable magnetic field than the other two types (resistive and permanent) considered below. A superconducting magnetic is an electromagnet that operates in a superconducting state. A superconductor is an electrical conductor (wire) that has no resistance to the flow of an electrical current. This means that very small superconducting wires can carry very large currents without overheating, which is typical of more conventional conductors like copper. It is the combined ability to construct a magnet with many loops or turns of small wire and then use large currents that makes the strong magnetic fields possible.

A characteristic of most superconducting magnets is that they are in the form of cylindrical or solenoid coils with the strong field in the internal bore. A potential problem is that the relatively small diameter and the long bore produce claustrophobia in some patients. Superconducting magnetic design is evolving to more open patient environments to reduce this concern.

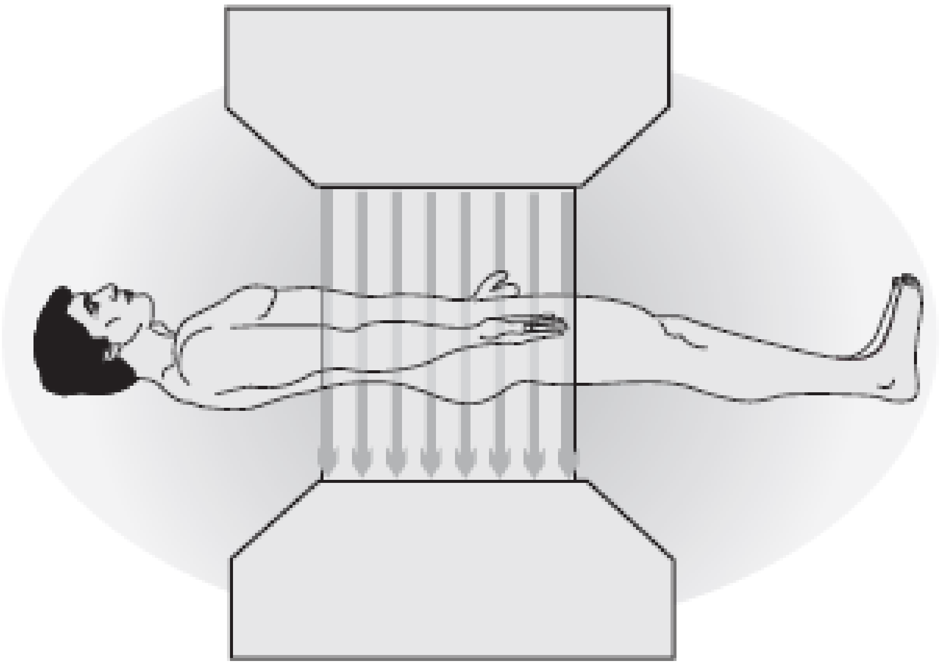
2.2 Resistive Magnets

A resistive type magnet is made from a conventional electrical conductor such as copper. The name “resistive” refers to the inherent electrical resistance that is present in all materials except for superconductors. When a current is passed through a resistive conductor to produce a magnetic field, heat is also produced. This limits this type of magnet to relatively low field strengths.

2.3. Permanent Magnets

It is possible to do MRI with a non-electrical permanent magnet. An obvious advantage is that a permanent magnet does not require either electrical power or coolants for operation. However, this type of magnet is also limited to relatively low field strengths. Both resistive and permanent magnets are usually designed to produce vertical magnetic fields that run between the two magnetic poles, as shown in Figure 3. Possible advantages include a more open patient environment and less external field than superconducting magnets.

PERMANENT OR RESISTIVE MAGNETS



The Magnetic Field

Arrows Indicate Field Direction

Figure 3. The magnetic field produced by typical resistive or permanent magnets.

3. Gradients

When the MRI system is in a resting state and not actually producing an image, the magnetic field is quite uniform or homogeneous over the region of the patient’s body. However, during the imaging process the field must be distorted with gradients. A gradient is just a change in field strength from one point to another in the patient’s body. The gradients are produced by a set of gradient coils, which are contained within the magnet assembly. During an imaging procedure the gradients are turned on and off many times. This action produces the sound or noise that comes from the magnet. The effect of a gradient is illustrated in Figure 4. When a magnet is in a “resting state,” it produces a magnetic field that is uniform or homogenous over most of the patient’s body. In this condition there are no gradients in the field. However, when a gradient coil is turned on by applying an electric current, a gradient or variation in field strength is produced in the magnetic field.

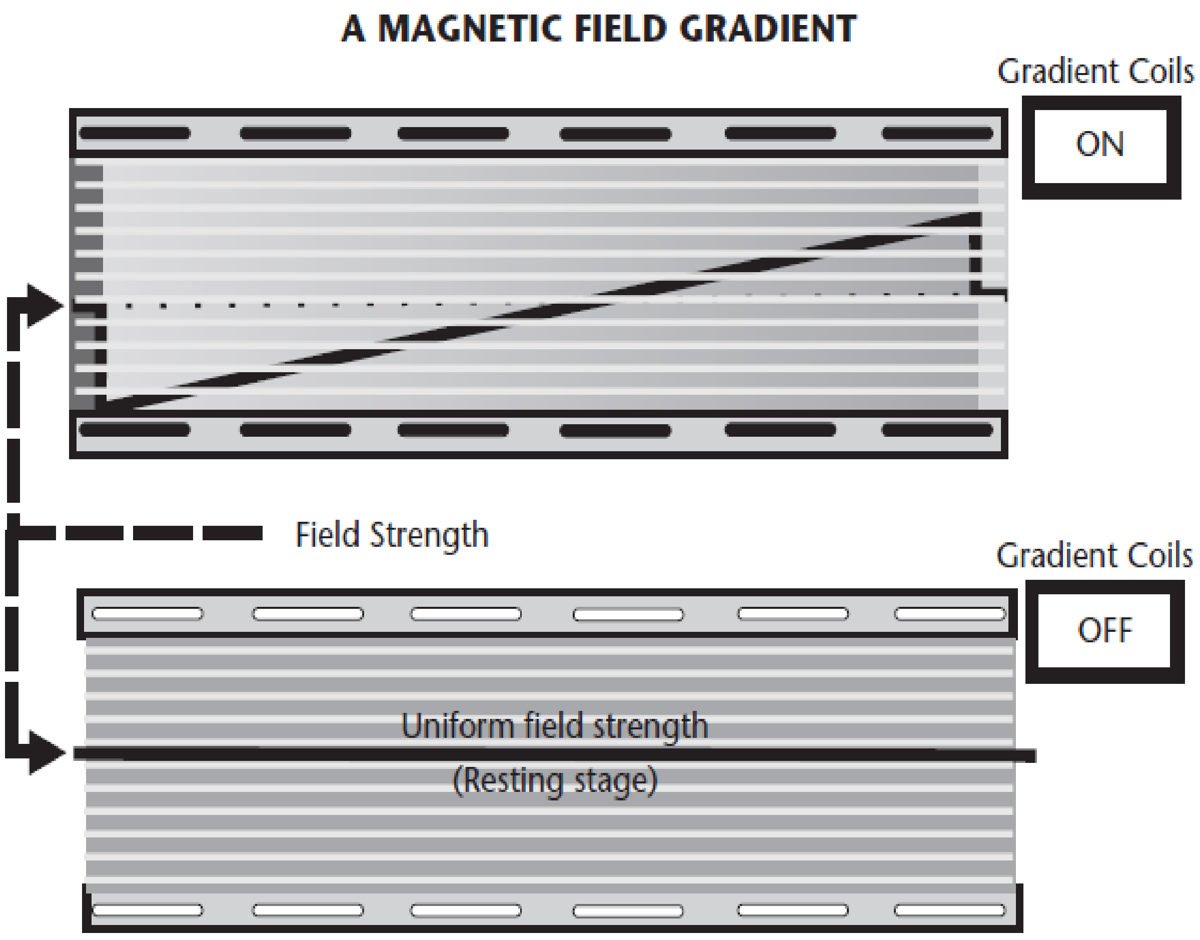


Figure 4. A magnetic field gradient produced by a current in the gradient coil.

4. Shimming

One of the requirements for good imaging is a homogeneous magnet field. This is a field in which there is a uniform field strength over the image area. Shimming is the process of adjusting the magnetic field to make it more uniform. Inhomogeneities are usually produced by magnetically susceptible materials located in the magnetic field. The presence of these materials produces distortions in the magnetic field that are in the form of inhomogeneities. This can occur in both the internal and external areas of the field. Each time a different patient is placed in the magnetic field, some inhomogeneities are produced. There are many things in the external field, such as building structures and equipment, that can

produce inhomogeneities. The problem is that when the external field is distorted, these distortions are also transferred to the internal field where they interfere with the imaging process. Inhomogeneities produce a variety of problems that will be discussed later.

5. Magnetic Field Shielding

The external magnetic field surrounding the magnet is the possible source of two types of problems. One problem is that the field is subject to distortions by metal objects (building structures, vehicles, etc.) as described previously. These distortions produce inhomogeneities in the internal field. The second problem is that the field can interfere with many types of electronic equipment such as imaging equipment and computers. It is a common practice to reduce the size of the external field by installing shielding as shown in Figure 5. The principle of magnetic field shielding is to provide a more attractive return path for the external field as it passes from one end of the magnetic field to the other. This is possible because air is not a good magnetic field conductor and can be replaced by more conductive materials, such as iron. There are two types of shielding: passive and active.

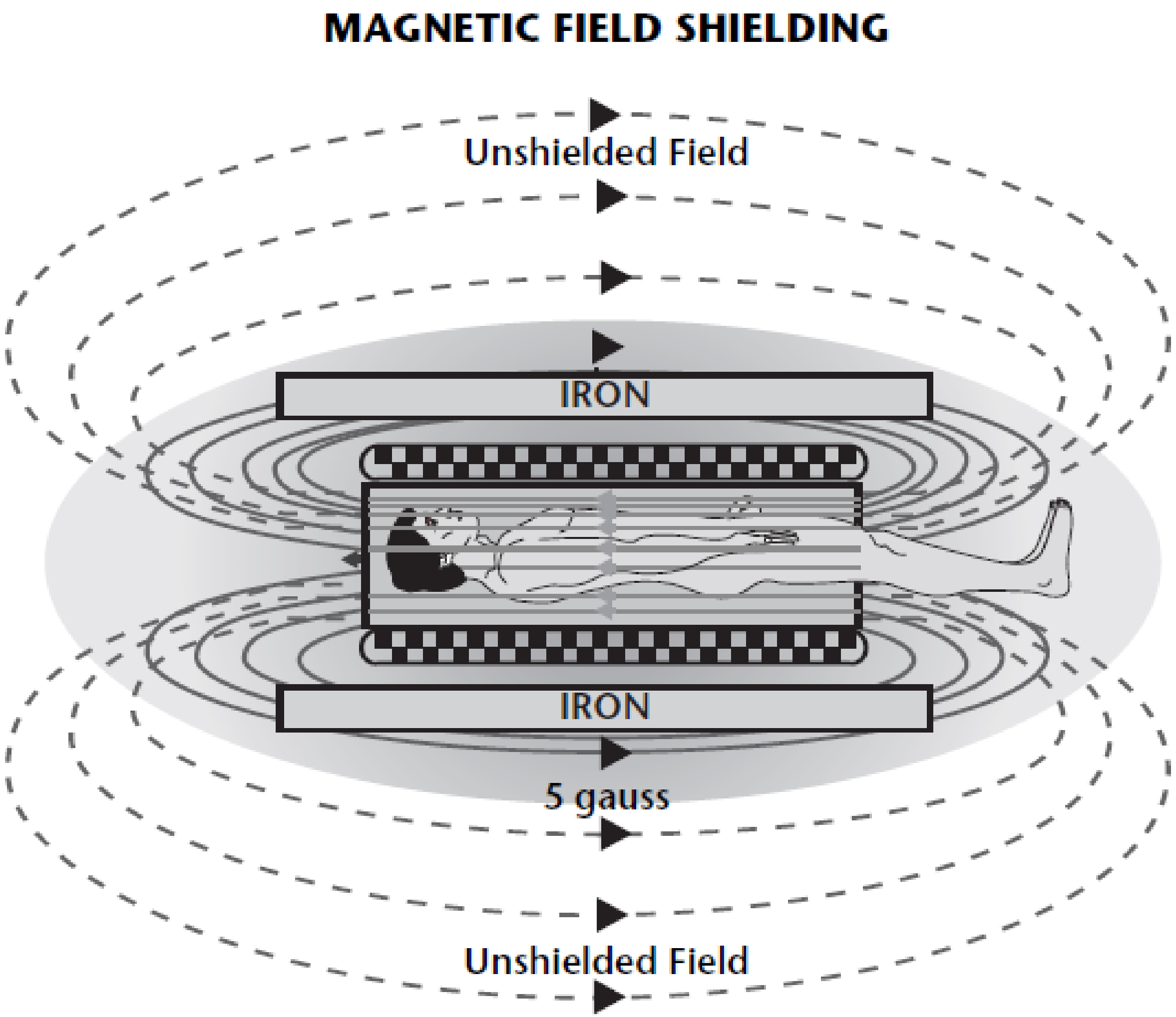


Figure 5. The principle of magnetic field shielding.

6. The Radio Frequency System

The radio frequency (RF) system provides the communications link with the patient’s body for the purpose of producing an image. All medical imaging modalities use some form of radiation (e.g., x-ray, gamma-ray, etc.) or energy (e.g., ultrasound) to transfer the image from the patient’s body. The MRI process uses RF signals to transmit the image from the patient’s body. The RF energy used is a form of non-ionizing radiation. The RF pulses that are applied to the patient’s body are absorbed by the tissue and converted to heat. A small amount of the energy is emitted by the body as signals used to produce an image. Actually, the image itself is not formed within and transmitted from the body. The RF signals provide information (data) from which the image is reconstructed by the computer. However, the resulting image is a display of RF signal intensities produced by the different tissues.

7. Computer Functions

A digital computer is an integral part of an MRI system. The production and display of an MR image is a sequence of several specific steps that are controlled and performed by the computer.

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