Chapter 3

NMR Imaging System Configurations

Introduction

Computerized tomography has expanded to include several different areas, including X-ray CT, ECT, and NMR CT. Although these systems differ slightly in terms of the energy band, the principles of physical phenomena involved, and the reconstruction algorithms. CT systems in general, regardless of the specific modes, comprise three basic parts: data acquisition, processing, and display.

The data acquisition part is the most important element of a CT system. It characterizes the system. The data acquisition part includes sources, detectors, controllers, data acquisition electronics, and scanner gantry. After it receives analog signals containing image information, it converts those signals to digital form and transfers them to the processing stage.

The second part is the processing system, in which the measured and quantized data are manipulated and reconstructed to create the desired images. The processing of data are usually performed by general computers with a suitable reconstruction algorithm.

The third component is the display part, on which the observer examines and analyzes the object. A general system block diagram is shown in Fig. 3-1.

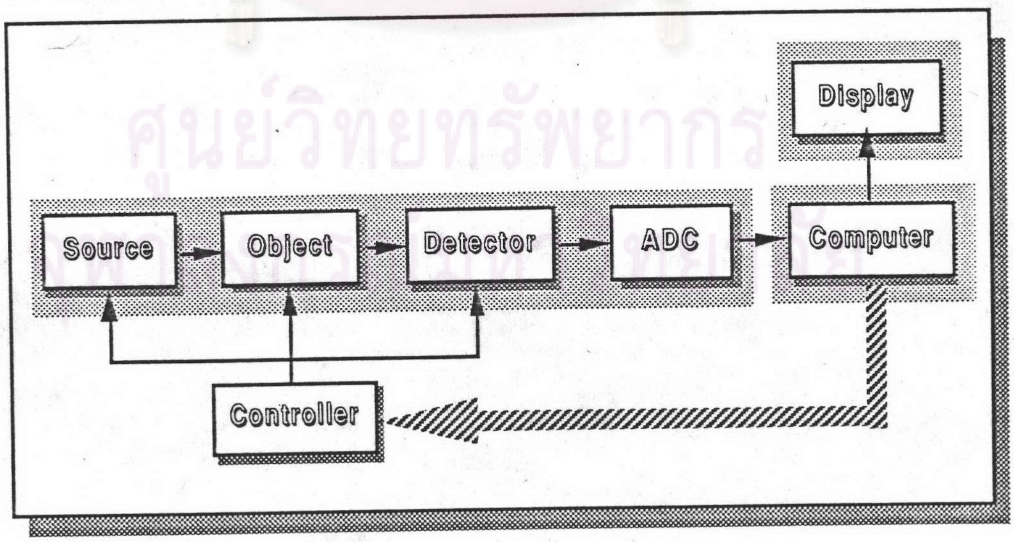

Fig 3-1. Block Diagram of the general CT system.

NMR Imaging System Instrumentation

In NMR CT, the imaging system can be divided into three basic parts: the NMR section, the electronics, and the computer. The NMR section includes the main magnet, which provides the static main magnetic field; the gradient coil for generating magnetic field gradients; and the RF coil, which transmits and receives the RF signals. The electronic part includes a pulse shaper, a data acquisition component, transmitter and receiver amplifiers. The computer performs image data processing and system control, and finally displays the reconstructed images.

A block diagram of a typical NMR imaging system is illustrated in Fig. 3-2. The details of each unit is explained in the following.

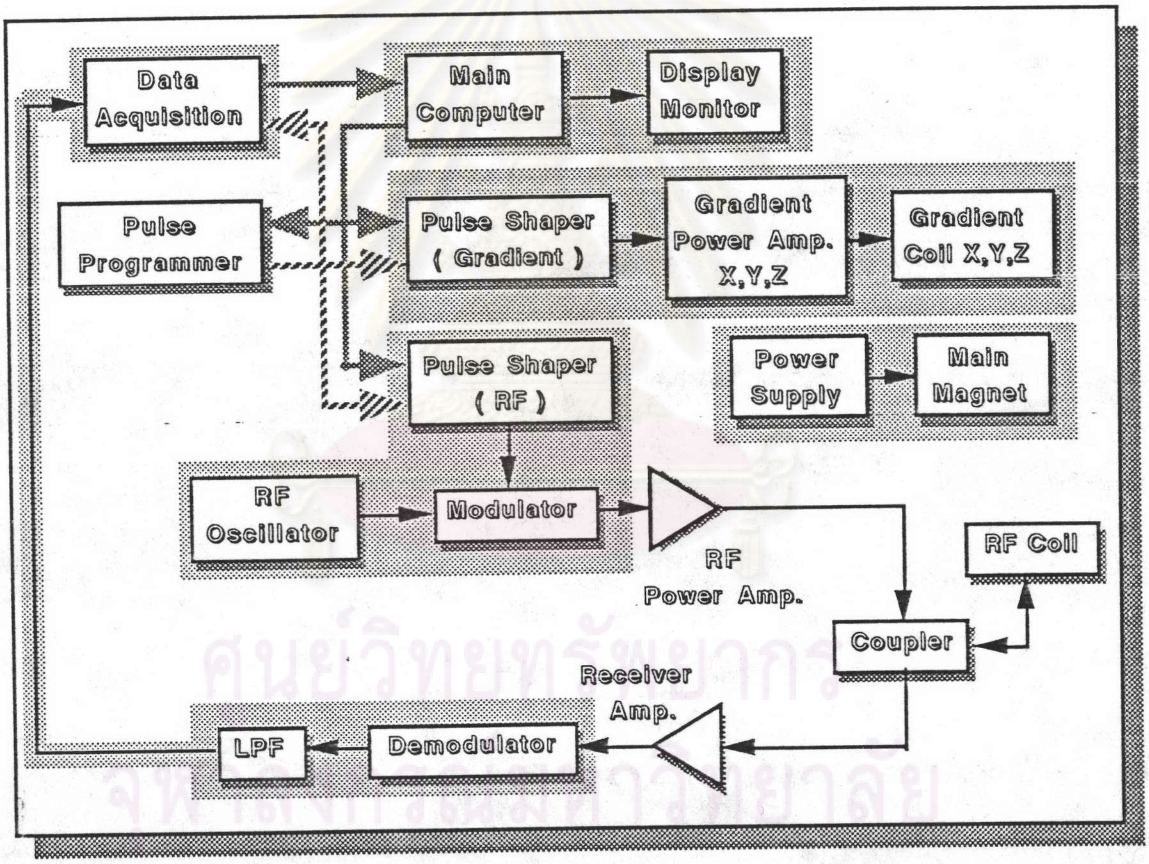

Fig. 3-2 Block diagram of a typical NMR imaging system.

1. Main Computer Unit

The main computer manages operation-process sequences, generates RF and gradient waveforms and reconstructs images after data acquisition.

Operation-process sequences are recorded in the main computer as required by imaging techniques. However, user can modified the sequences by vary some parameters to suit the specific needs. The recorded sequence is then transferred to the pulse programmer which controls the operations of other units.

User creates RF and gradient pulse waveforms by specify the graphics representation of desired waveforms or by using time-value table. Waveforms generated in the main computer are transferred to a pulse shaper, where data in digital form are converted to analog form.

In the final process, the acquired signal are transferred from data acquisition unit to the main computer and are used for the reconstruction of the image. The main computer performs the reconstruction process by executing specific image reconstruction algorithm. After reconstruction, the images are displayed on display unit.

2. Pulse Programmer Unit

Operation-process sequences from the main computer are transferred to the pulse programmer. These informations are in digital form which present the synchronization of the related units in performing the imaging process. Pulse programmer transforms this information into a sequence of pulses. Specific output pulses are sent to specific units. These pulses are used to initiate them to perform their operations in the correct time.

3. Pulse Shaper Unit

Pulse shaper unit has two separate elements, for RF and gradient sections. RF and gradient pulse waveforms generated in the main computer which contain the description of pulse shape in digital format are converted to analog form by a digital-to-analog convertor (DAC). Outputs from gradient pulse shaper are sent to gradient power amplifiers while RF pulse shaper feeds the signal through modulator unit.

4. Gradient Power Amplifier and Gradient Coil Unit

The gradient pulses are amplified by three separate gradient power amplifiers for x,y, and z axis. Since the gradient pulse frequency falls in audio frequency (AF) range, typical audio power amplifiers with good stability and capable to supply enough current for gradient coils can be used to performs this task. The gradient is then applied to x-, y-, and z-gradient coils after being amplified in the gradient power amplifiers.

5. Modulator and RF Power Amplifier Unit

The RF waveform from the pulse shaper is modulated with the referenced RF signal in the modulator. The enveloped RF signal is amplified through the RF power amplifier, and transferred to the RF coil via the coupler.

6. Coupler Unit

The coupler circuit effectively switches on and off between the transmitting and receiving operations. On transmitting operation, the RF coil receives the signal from the RF power amplifier. The transmitted RF pulse excites nuclear spins in the sample. On receiving operation, the induced signal in RF coil is sent directly to the input of receiver amplifier.

7. Receiver Amplifier

The nuclear signal induced on the RF coil by precessing spins is amplified by receiving amplifier to make it suitable for demodulator unit.

8. Demodulator Unit

The amplified nuclear signal from receiving amplifier is demodulated with the referenced RF signal. This demodulated signal which falls in AF range is then sent to the data acquisition unit via a low-pass filter. The purpose of this low-pass filter is to remove any undesired signals from the demodulated signal by determining its frequency. This improves the reliability of data acquisition unit especially on analog-to-digital convertor (ADC).

9. Data Acquisition Unit

The analog demodulated signal containing image information is converted to digital form in data acquisition unit. This process is often performed by an ADC. During the acquisition process, some data processing are performed through the use of appropriate software or fixed hardware devices. Averaging is most often used since the repetitive property of the detected signal. With the synchronized trigger signal, the signal-to-noise ratio of the signal can be improved. The output of the ADC is put into the buffer memory until a set of data has been collected, then transmitted to the main computer.