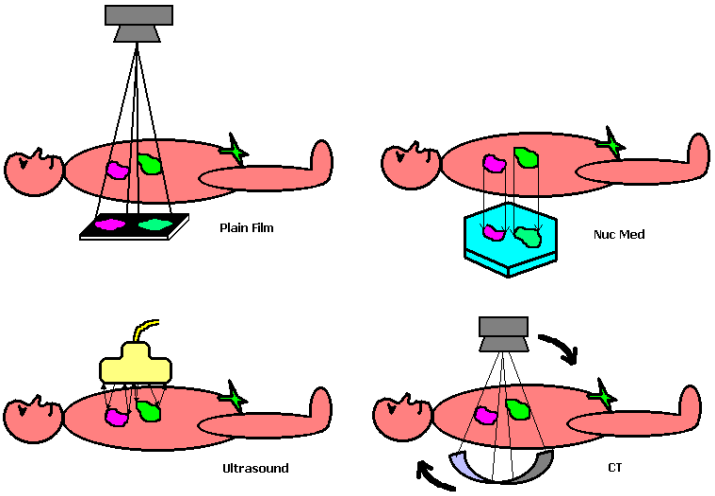
Spatial Encoding
Part 1 – Slice Selection

Matthew Benbow, Superintendent Radiographer, Royal Bournemouth Hospital
BAMRR News Editor

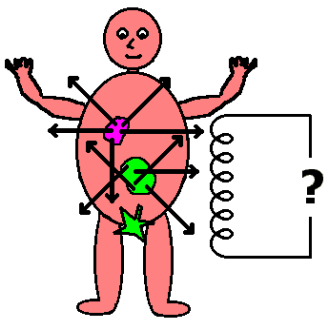
Introduction

For any medical imaging modality it is necessary for the receiving device to display the output in an order that correlates to the patient's anatomy, i.e. that the resultant image represents the patient.

With plain radiography and Nuclear Medicine, the patient is positioned directly in front of the receiving device, and therefore the anatomy is projected directly into a corresponding position to that found in vivo. With Ultrasound, the signals are reflected back to the transducer, but remain in their true anatomical positions. Even though in CT the detectors rotate, at any given time in this rotation the anatomy is being mapped such that the reconstruction system can create a true image. MRI however is different.



MRI scanning produces many signals of varying strengths from within the patient, and these induce currents within the receiving coil. The difference from other imaging modalities is that there is no direct correlation between the signal origin and where it is received by the detector system (coil), and thereby translated into the position it will appear in the final image. To put this simply, signals produced in the patient can generate a current in any part of the receive coil. So how does this system know where all these signals have originated? Without 'tagging' the signals with accurate spatial information it would be impossible to reorder them and therefore create an image.



So how is this done? The answer is 'Spatial Encoding' and as it is a three dimensional problem, can be explained by three distinct processes. This first article in this set of three tackles the first dimension, 'Slice Selection'.

Slice Selection

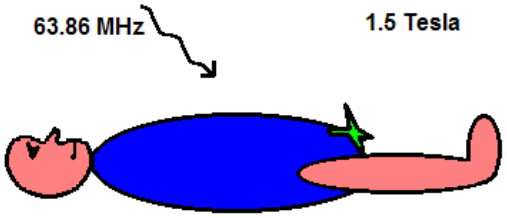
NB For ease of description, the following explanation will describe the process for true axial slice acquisition. However, by using alternative gradients, or indeed a combination of each gradient system, the scanner system is of course able to perform these functions in any direction and therefore produce any obliquity the user chooses to prescribe.

To reduce the problem of where in three dimensions space a signal came from, down to a two dimensional problem which will be continued in the next issue, a process called Slice Selection is performed. This ensures that at any given time, only protons in the slice of interest will produce a signal, i.e. only one slab at a time across the patient (in this case axial) will be imaged.

When the patient is placed in a magnetic field the Larmor Equation states that their hydrogen protons will precess at predictable frequency. In this example we will consider a 1.5Tesla system, so the precessional frequency will be:

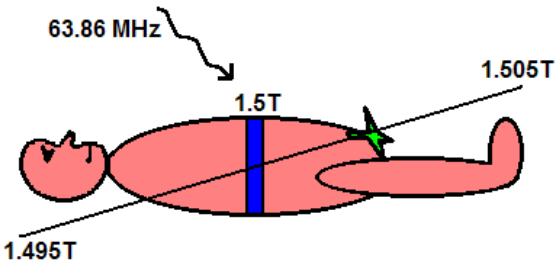
1.5 (Tesla) x 42.57 (the gyromagnetic constant for hydrogen) = 63.86 MHz

If radio frequency matching this frequency is introduced, then all of the hydrogen protons will receive a maximal energy transfer and be ‘flipped’ into a higher energy state – this being resonance.



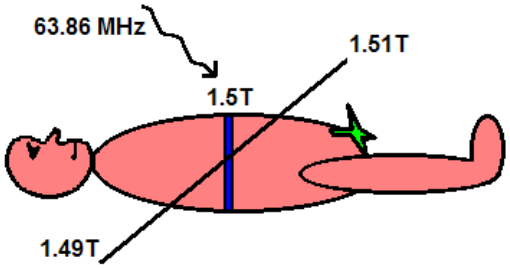
Whilst having all protons excited in this way purposely occurs in 3D imaging sequences, we will concentrate on standard 2D imaging for the moment. In 2D imaging we need to only excite one slab of tissue, or slice is excited at a time. So how is this achieved?

To do this a Slice Selection Gradient is used, and in our example of an axial acquisition, this will therefore utilise the z axis gradient system. By switching this gradient on, the magnetic field experienced by the patient can be made to be slightly stronger than 1.5T at one end of the patient, and slightly weaker at the other. The result of this is that the protons at the higher field end will spin faster and those at the lower field slower than 63.86 MHz.

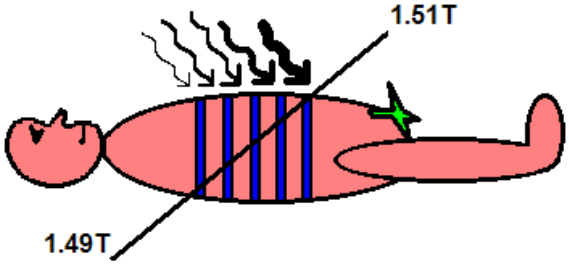


This gradient is left ‘on’ when the RF pulse is introduced. Due to the properties of resonance whereby energy transfer only occurs where frequencies match, only protons precessing at the same frequency to that introduced will achieve the energy transfer, i.e. be flipped into a high energy state. In this way, we can achieve a condition where only one slice can be excited. This has therefore reduced our spatial encoding problem to a two dimensional problem whereby we now only need to know from where in the x and y direction of this slice each signal originates, to enable the scanner to be able to create an image. How this is done will be covered in next two issues of BAMRR news.

When you choose to scan a thinner slice, the scanner achieves this by setting a stronger slice select gradient. With a stronger gradient, the distance along the patient, again in this case the z direction, where the precessional frequency would match closely enough to the proton spins for resonance to occur well would be smaller, and hence the slice width excited would be thinner.



So this explains how to excite one slice, but we rarely scan a single slice. Usually we acquire a series of several slices in one acquisition, so how is this achieved? To do this, multiple radio frequencies are introduced in turn at subtly differing frequencies corresponding to the precessional frequencies of protons at each required slice location. Where the introduced RF and the gradient affected precessional frequencies match, resonance will occur, and the slice will be excited. Within one TR several slice positions can be achieved in this way. Each slice excitation takes an amount of time, but generally several can be fitted within your chosen TR. When the TR time is reached, the scanner must go back and re-excite the first slice again to perform the next phase encoding (see next time) and therefore there will always be a limit to how many slices can be obtained in each TR. This explains why increasing your TR will generally allow you to acquire more slice positions.



In the next issue of BAMRR new we will examine Phase Encoding.