1st Semester

كلية المأمون الجامعة

قســــم تقنيات الأشــــعة

المرحلة الثالثة

Equipment Techniques of Magnetic Resonance Imaging

مدرس مساعد : عماد الربيعي
MSc Medical Imaging / MRI Applications

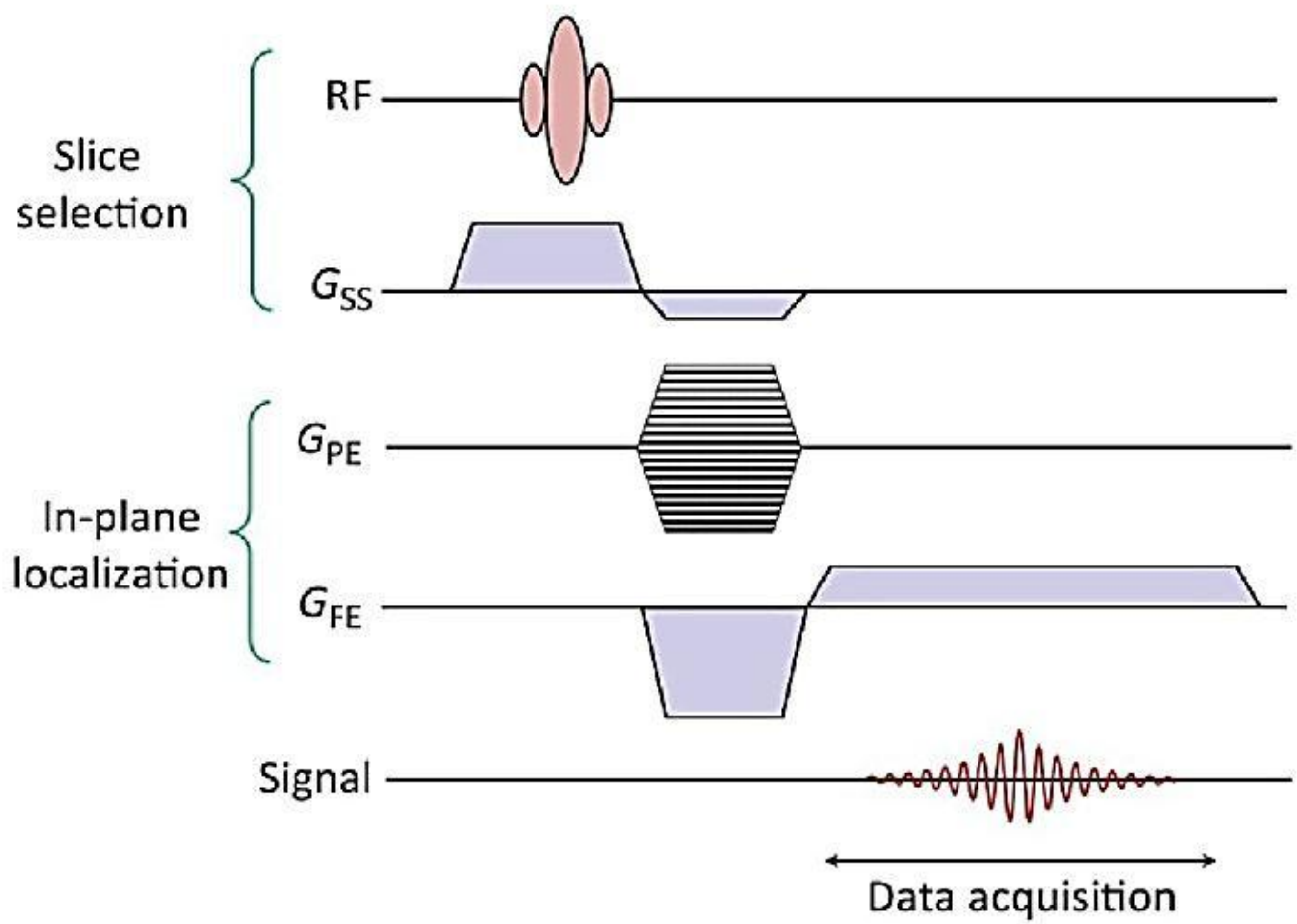
Lecture 6

Gradient Coils (Spatial Encoding)

Larmor Equation: $Wo = y. Bo$

Gradient coils are an essential component of magnetic resonance imaging (MRI) systems. These coils are used to create spatially varying magnetic fields within the MRI scanner, ***which allows for the encoding of spatial information in the MRI signal****. There are three sets of gradient coils in an MRI system:* ***the x-gradient coil, y-gradient coil, and z-gradient coil.*** *Each set of coils is responsible for creating a magnetic field that varies along one of the three* ***spatial dimensions*** *(x, y, or z) within the imaging volume. By applying controlled currents to these gradient coils, the strength and direction of the magnetic field can be varied in a precise and controlled manner. This variation in magnetic field strength allows for* ***spatial encoding*** *of the MRI signal, which is essential for producing high-resolution images with detailed anatomical information.*

Larmor Equation: ***Wo = y. Bo***



Larmor Equation: ***Wo = y. Bo***

Head Lines

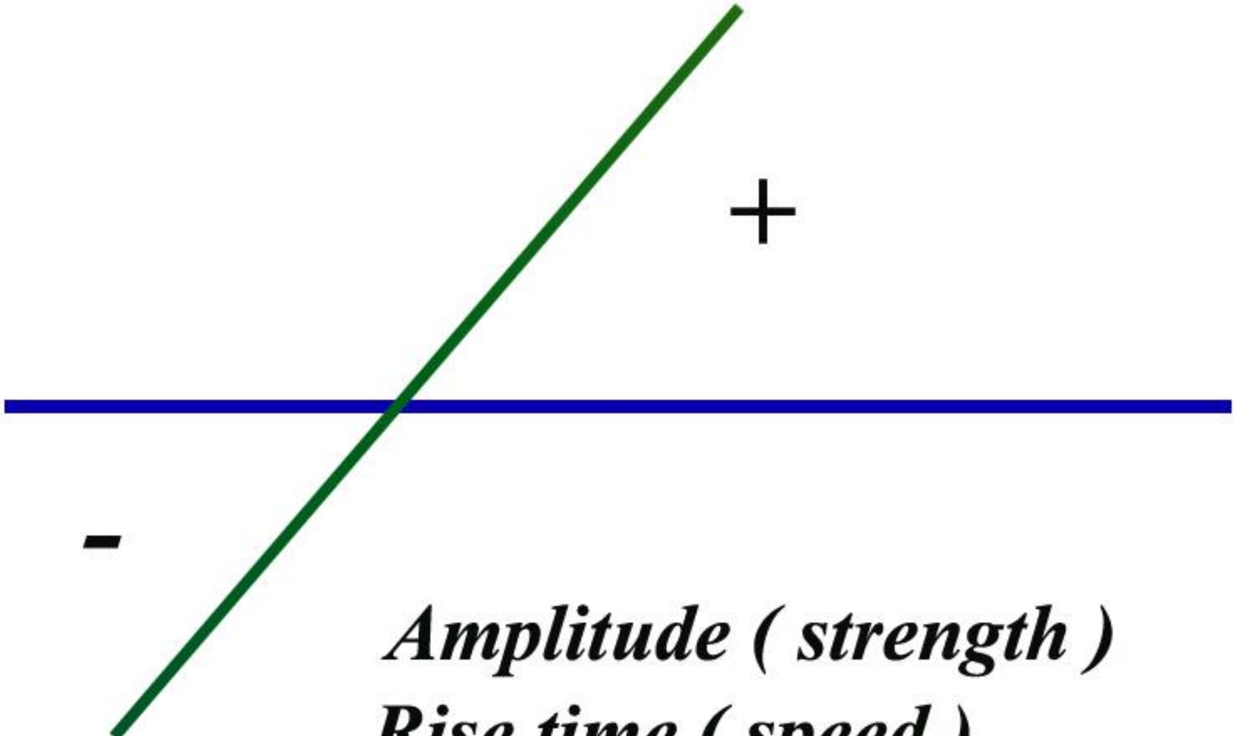
- *Gradient magnetic fields are superimposed over the primary magnetic field.*
- *Gradient magnetic fields are produced by applying **current** to the gradient coils.*
- *There are **three sets** of gradient coils in MR systems.*
- *The term **amplitude** refers to the severity of the slope of the gradient magnetic field(**strength** of the gradient system). The speed at which a gradient magnetic field attains its maximal amplitude is identified by its **rise time**.*
- *The maximal amplitude of gradient magnetic fields is described in units of millitesla per meter (mT / m).*

Larmor Equation: ***Wo = y. Bo***

- ***Polarity*** *(either positive or negative) refers to whether the gradient magnetic field is creating a field greater than or less than the frequency of* B_0.
- *To express gradient performance is slew rate.*
- ***Slew rate*** *refers to the acceleration of the gradient magnetic field to its maximal amplitude.*
- *Slew rate is expressed in units of Tesla/meter/second (T / m/sec).*
- *Currently, typical slew rates for gradient systems range from approximately* ***20 to over 200*** *T/m/sec.*

Slew rate = amplitude / rise time

Larmor Equation: *Wo = y. Bo*



Amplitude (strength)

Rise time (speed)

Slew rate (acceleration)

Slew rate = amplitude / rise time

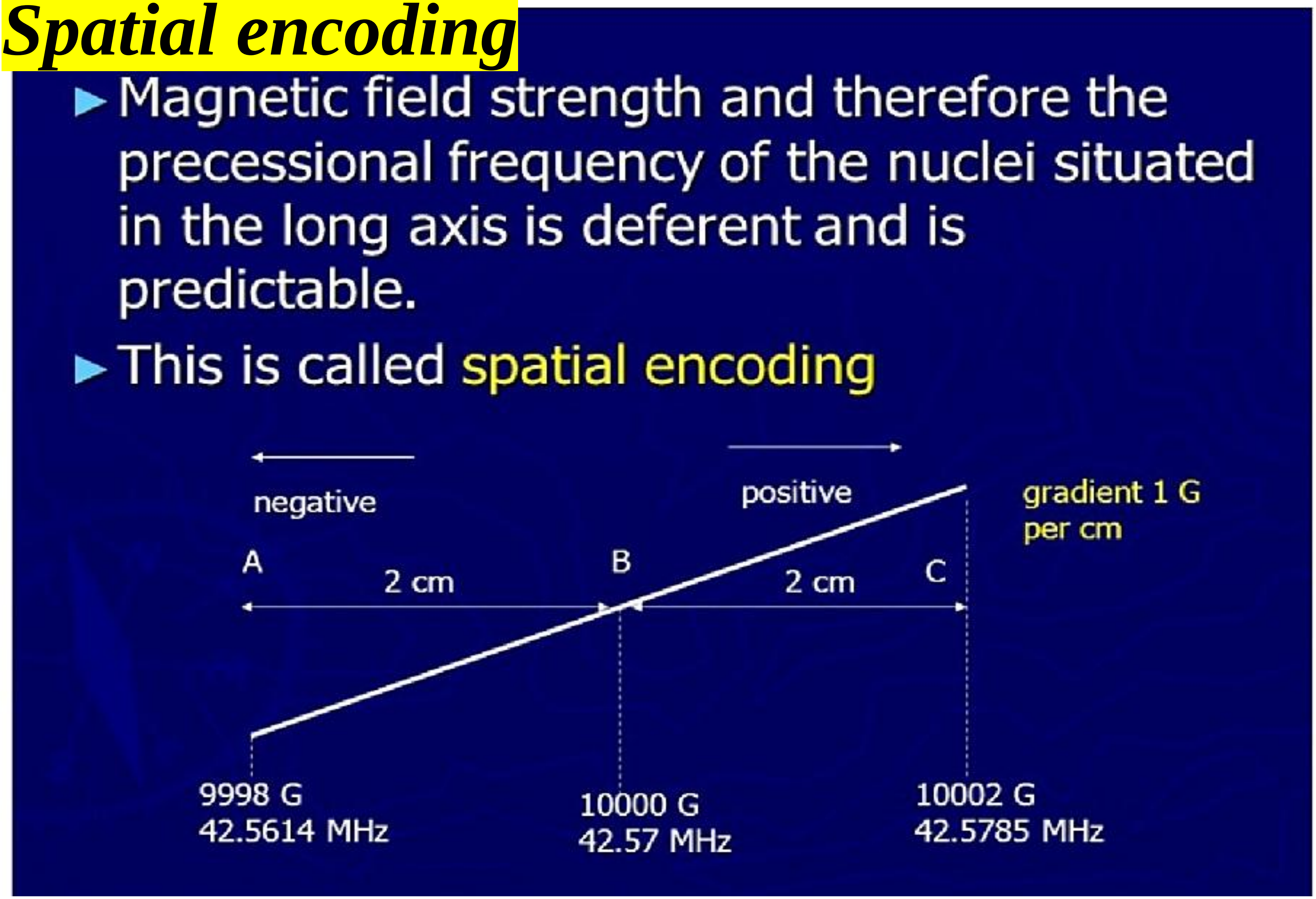
Larmor Equation: $Wo = y. Bo$

MRI Gadient Slew Rates Compared

Manufacturer	Model	Amplitude (mT/m)	Slew Rate (mT/m/ms)
GE	HiSpeed	23	77
GE	EchoSpeed	23	120
GE	Signa HD/HDxt	33	120
GE	Signa HDe	33	50
GE	Optima 450w	34	150
Siemens	Harmony Turbo	20	25
Siemens	Harmony Sprint	30	75
Siemens	Harmony Quantum	30	150
Siemens	Avanto Q-Engine	33	125
Siemens	Avanto SQ-Engine	45	200
Philips	Power	30	75
Philips	Master	30	150
Philips	Pulsar	33	80
Philips	Nova	33	160
Philips	Ingenia	45	200
Toshiba	Excelart AG	30	50
Toshiba	Vantage AGV	30	50
Toshiba	Vantage XGV	30	130

Larmor Equation: ***Wo = y. Bo***

Spatial encoding



Larmor Equation: ***Wo = y. Bo***

Gradient coils type

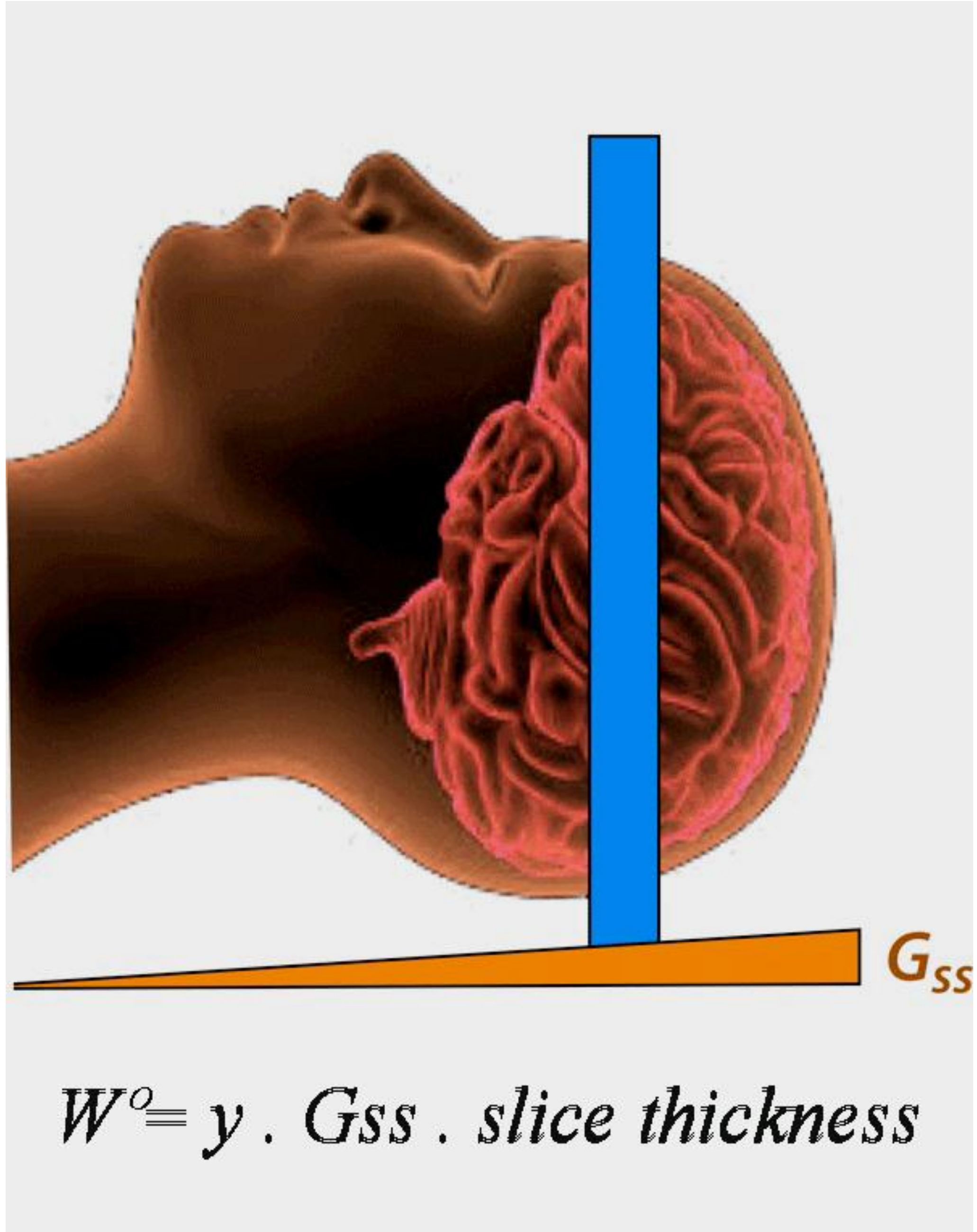
First of all, a slice selection gradient (GSS) is used to select the anatomical volume of interest. Within this volume, the position of each point will be encoded vertically and horizontally by applying a phase encoding gradient (GPE), and
a frequency-encoding gradient (GFE).

Larmor Equation: ***Wo = y. Bo***

1- Slice Selection (GSS)

The first step of spatial encoding consists in selecting the slice plane. To do this, a magnetic field gradient, the Slice Selection Gradient (GSS), is applied perpendicular to the desired slice plane (***Z direction*** *) .This is added to B0, and the protons present a resonance frequency variation proportionate to GSS (Larmor equation). An RF Pulse is* ***simultaneously*** *applied, with the same frequency as that of the protons in the desired slice plane. This causes a shift in the magnetization of only the protons on this plane. As none of the hydrogen nuclei located outside the slice plane are excited, they will not emit a signal. The RF pulse associated with the slice selection gradient.*

Larmor Equation: ***Wo = y. Bo***

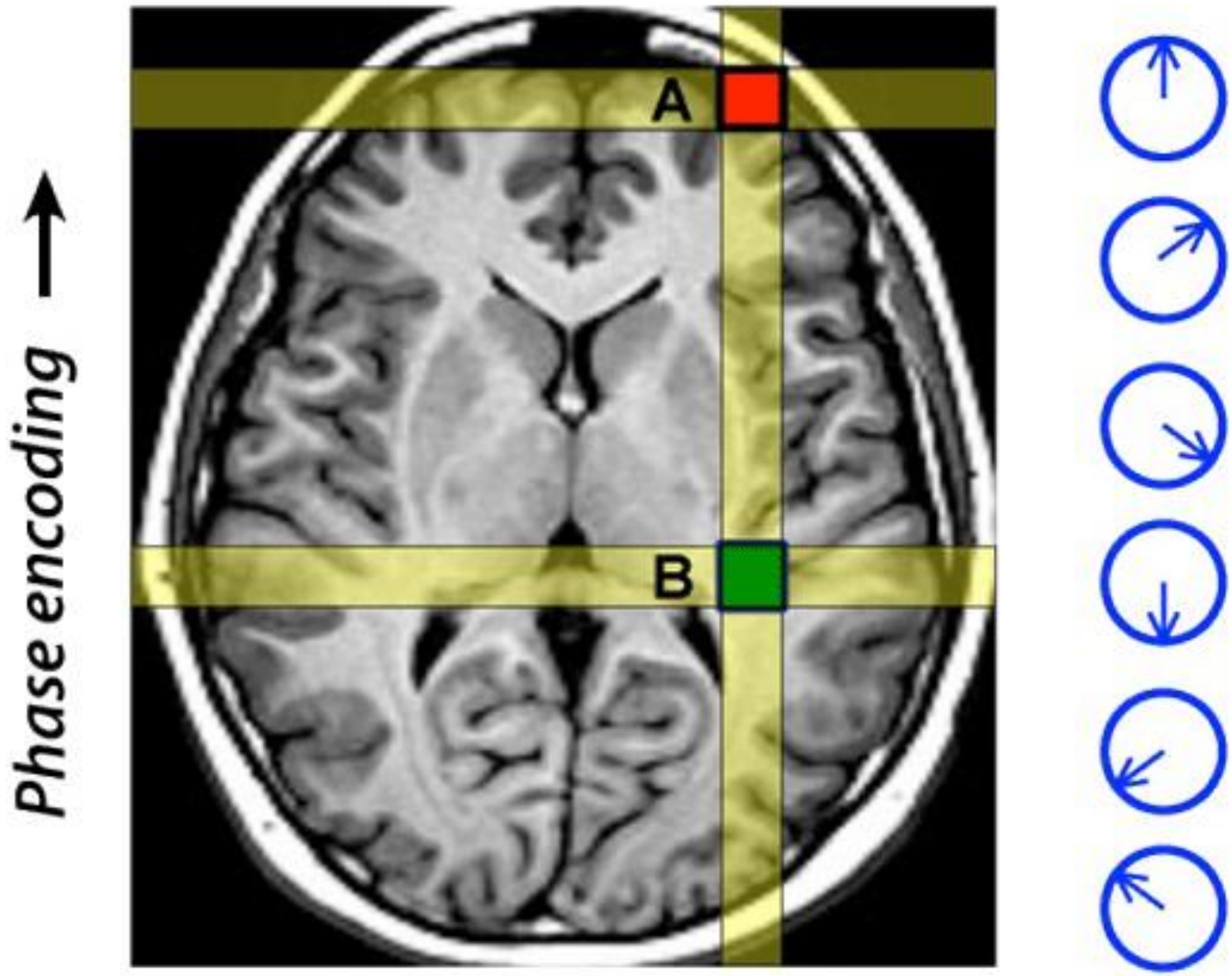


Larmor Equation: ***Wo = y. Bo***

2- Phase Encoding

The second step in spatial encoding consists in applying a ***phase*** *encoding (modified)gradient, which we will choose to apply in the vertical direction (* ***Y direction*** *). The phase encoding gradient (****GPE****) intervenes for a limited time period. While it is applied, it modifies the spin resonance frequencies, inducing dephasing.*

Larmor Equation: *Wo = y. Bo*



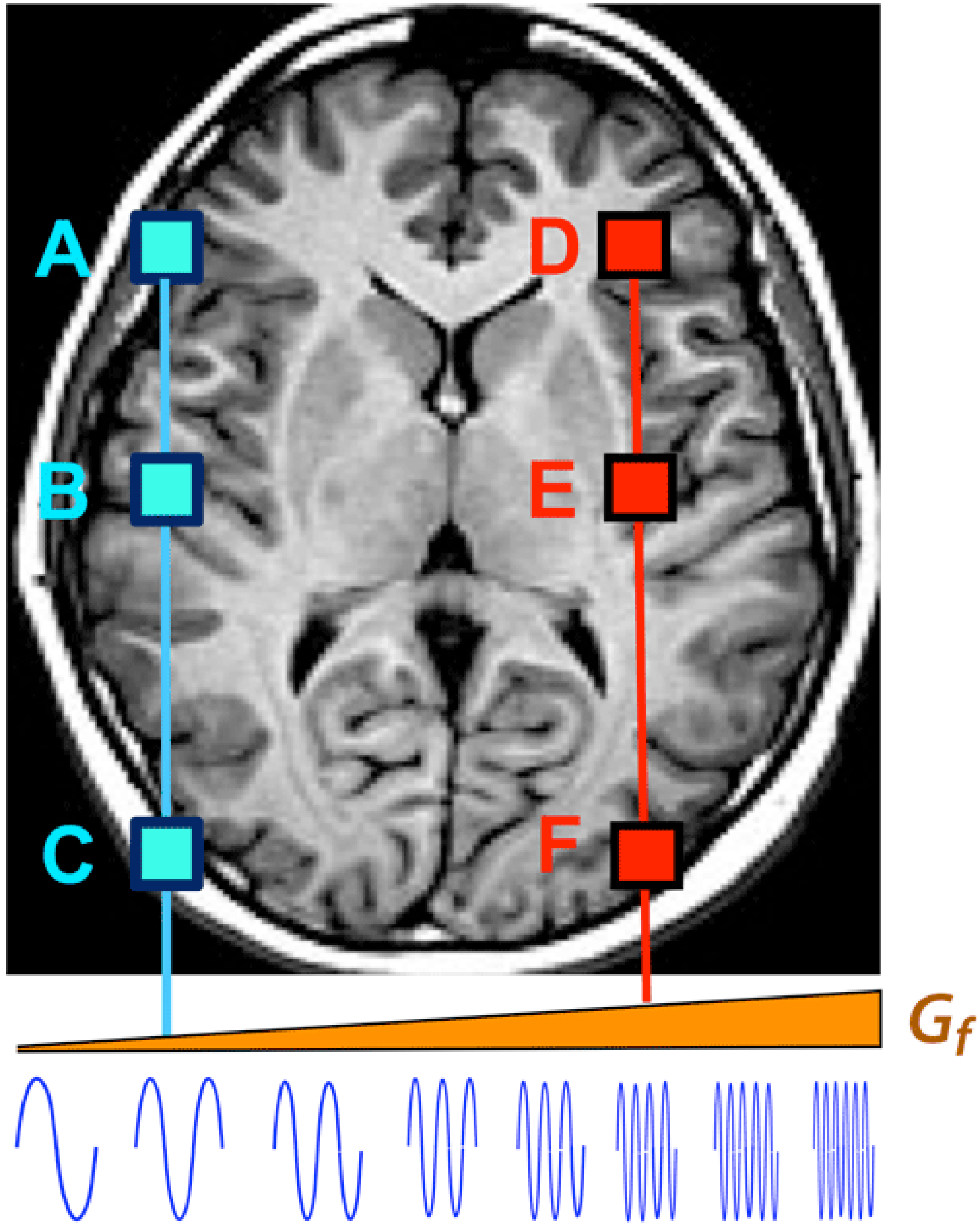
Larmor Equation: ***Wo = y. Bo***

3- Frequency Encoding

the final step in spatial encoding consists in applying a ***frequency*** *encoding(modified) gradient, when the signal is received, in the last direction horizontal (* ***X direction****). This modifies the Larmor frequencies in the horizontal direction throughout the time it is applied.*

This gradient is called
"read out" or "frequency encoding" gradient.

Larmor Equation: *Wo = y. Bo*



Frequency encoding