Gradients, Phase and Magnetisation

FMRIB Graduate Course
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Outline

Simple model of magnetisation behaviour

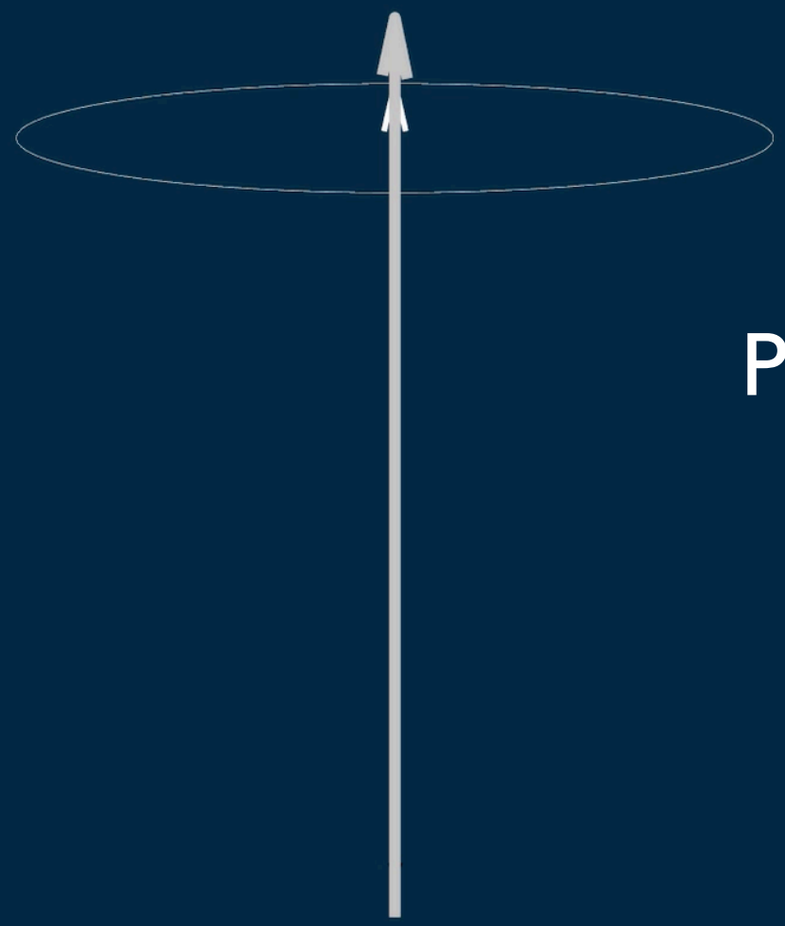
Action of magnetisation in response to gradient magnetic fields

Fourier Transform intuition

Role of gradients in an imaging experiment

Magnetisation

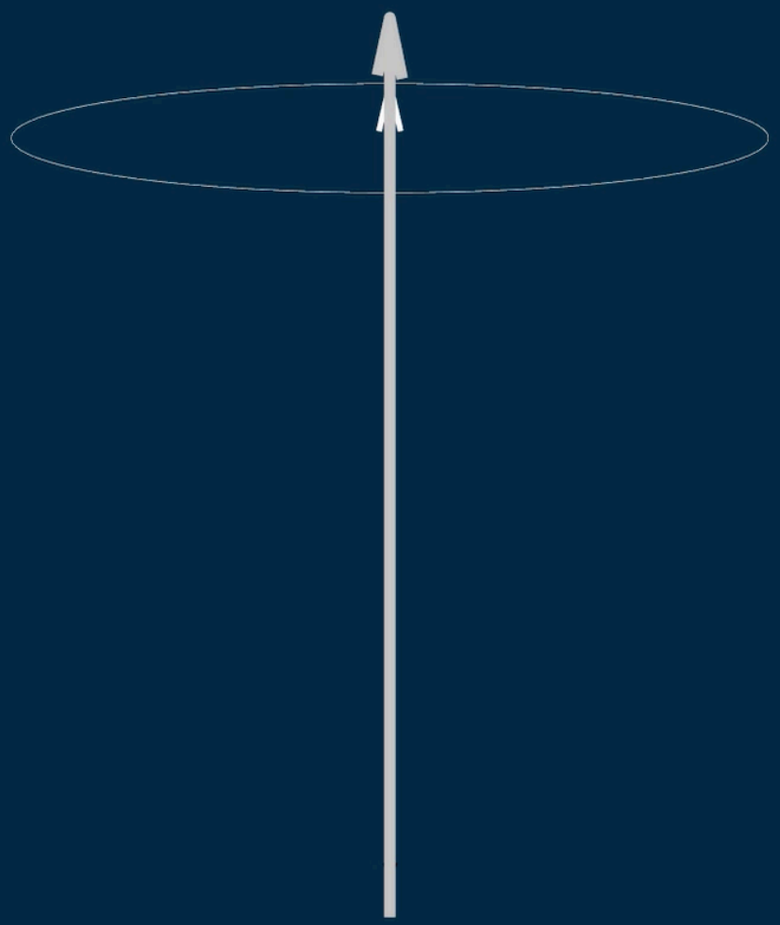
B_0 Magnetic Field Direction



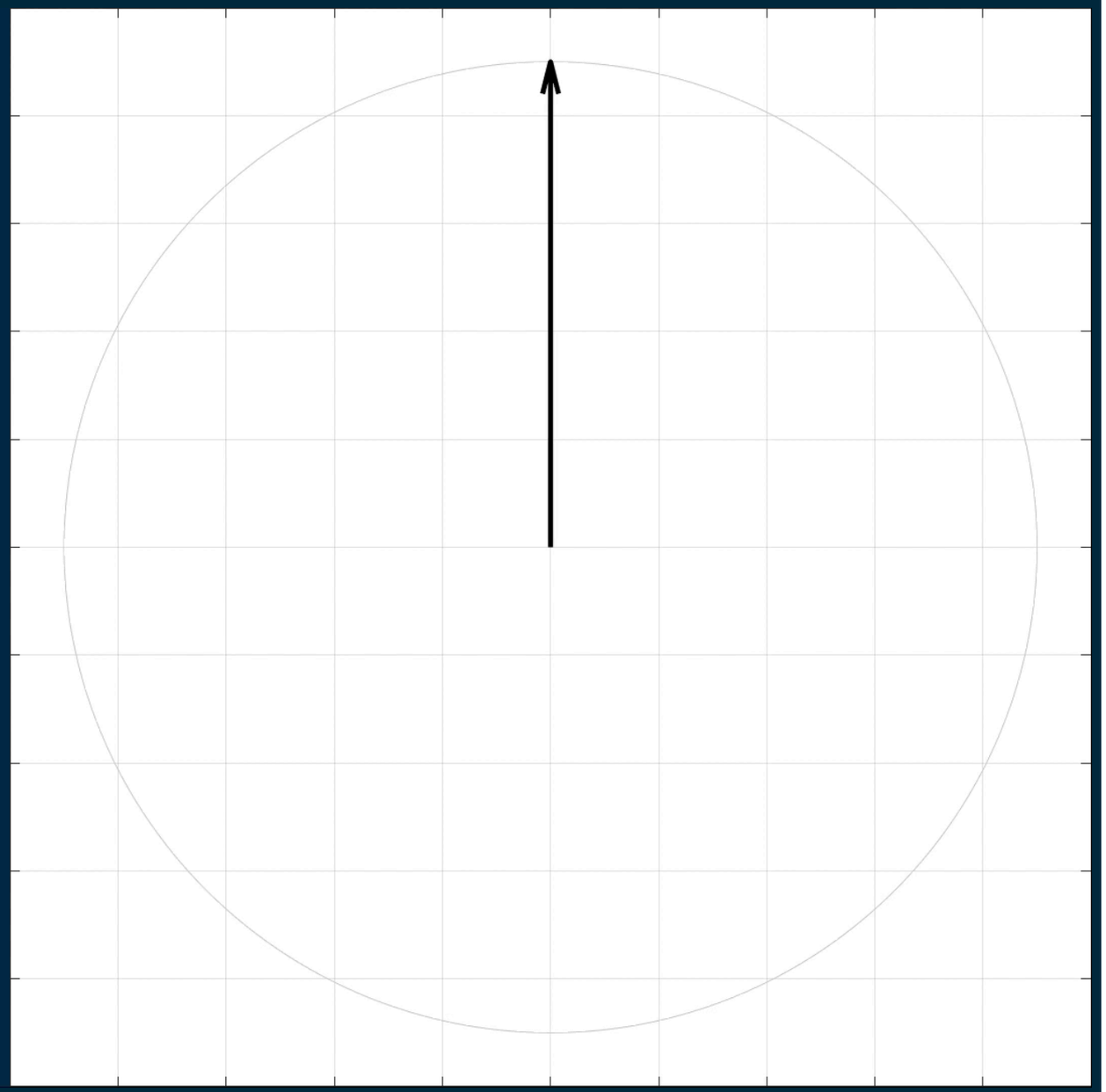
Precessing / Rotating Magnetisation within each voxel

Transverse (x-y) Magnetisation

Transverse Magnetisation

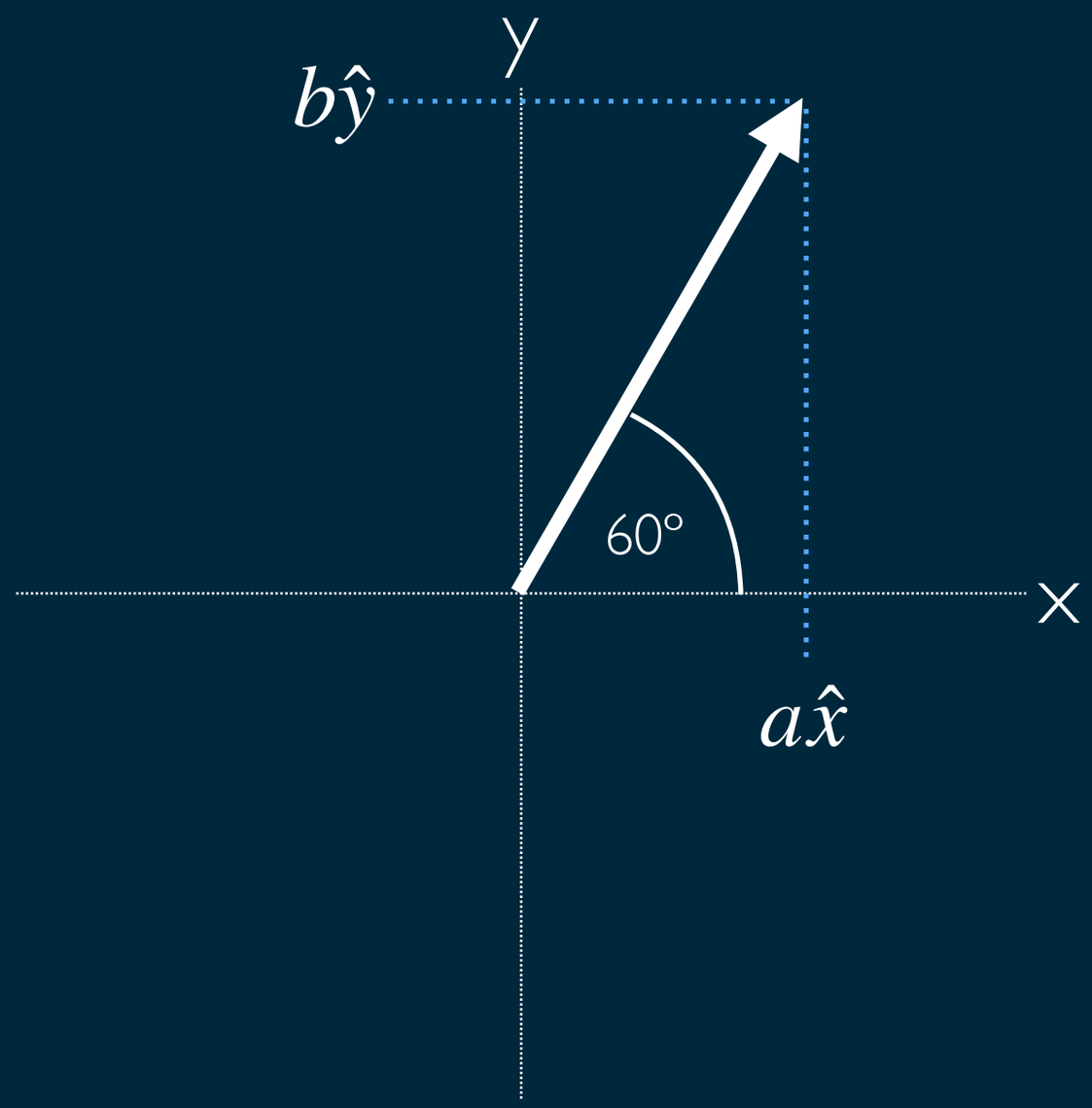


3D View



Component in x-y plane

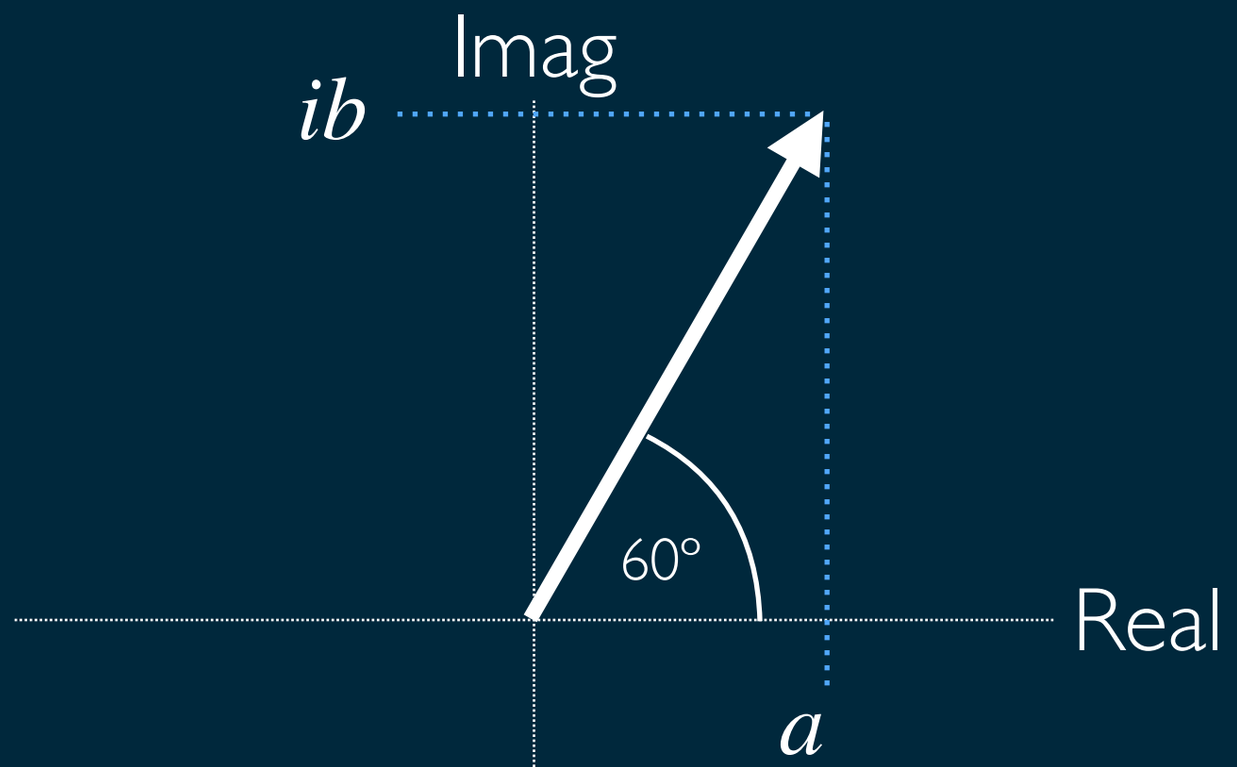
Phase



$$M = (a, b)$$

Angle / Rotation / Orientation / Direction of Magnetisation

Phase



$$M = a + ib$$

Can be represented using complex numbers

Larmor Equation

$$\omega = \gamma \times B$$

This equation describes the speed of rotation (precession) for the magnetisation

Larmor Equation

$$\omega = \gamma \times B$$

Frequency

Frequency is the speed of rotation

Larmor Equation

Gyromagnetic Ratio

$$\omega = \gamma \times B$$

Frequency

The gyromagnetic ratio is a physical constant

$$\gamma_{^1H} \approx 2\pi \cdot 42.5 \text{ MHz/T}$$

Larmor Equation

Gyromagnetic Ratio

$$\omega = \gamma \times B$$

Frequency

Magnetic Field Strength

Strength of the **total** magnetic field

Larmor Equation

$$\omega = \gamma \times B$$

Frequency	Main Magnetic Field Strength
~64 MHz	1.5 T
~128 MHz	3.0 T
~300 MHz	7.0 T

Larmor Equation

$$\omega = \gamma \times B$$

Frequency	Main Magnetic Field Strength
Slower	Weaker
Faster	Stronger

Weaker Field

Stronger Field

Slower Precession

Faster Precession

Weaker Field

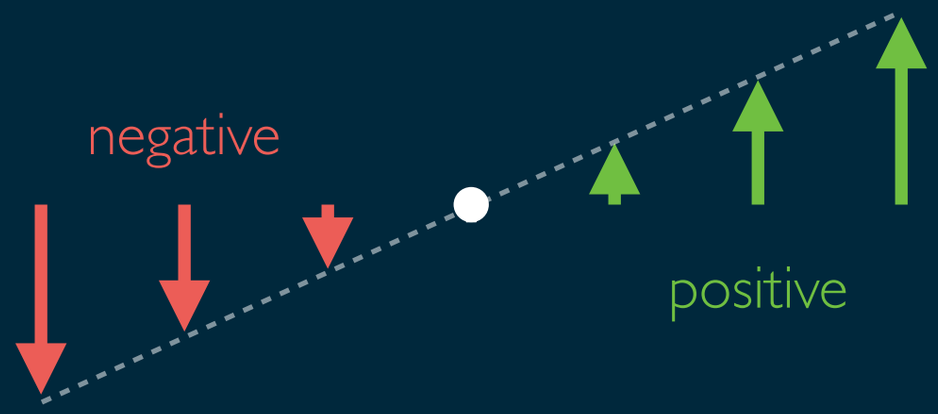
Stronger Field

Slower Precession

Faster Precession

Sources of Magnetic Fields

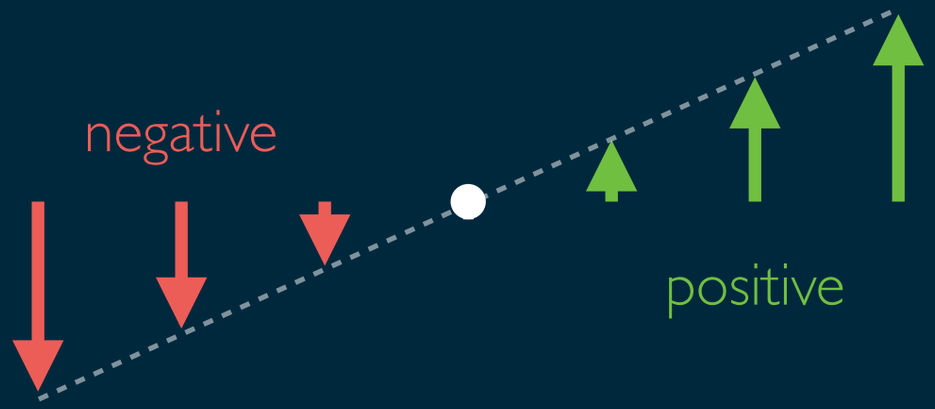
B_0 Main Magnetic Field
Constant Strength
Always On



Gradient Magnetic Fields ($G_{x/y/z}$)
Spatially varying strength
Can turn on and off

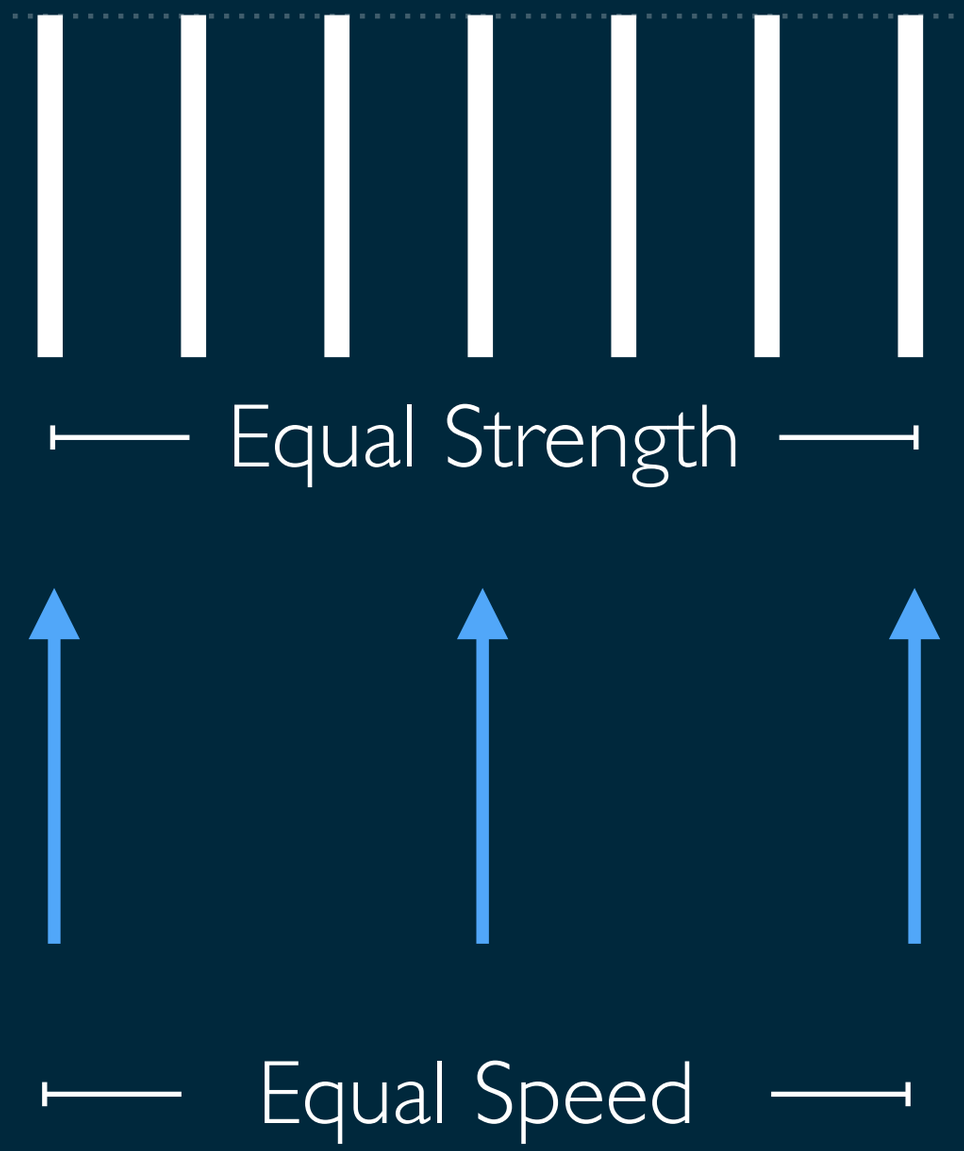
Sources of Magnetic Fields

B_0 Main Magnetic Field
Constant Strength
Always On



Gradient Magnetic Fields ($G_{x/y/z}$)
Spatially varying strength
Can turn on and off

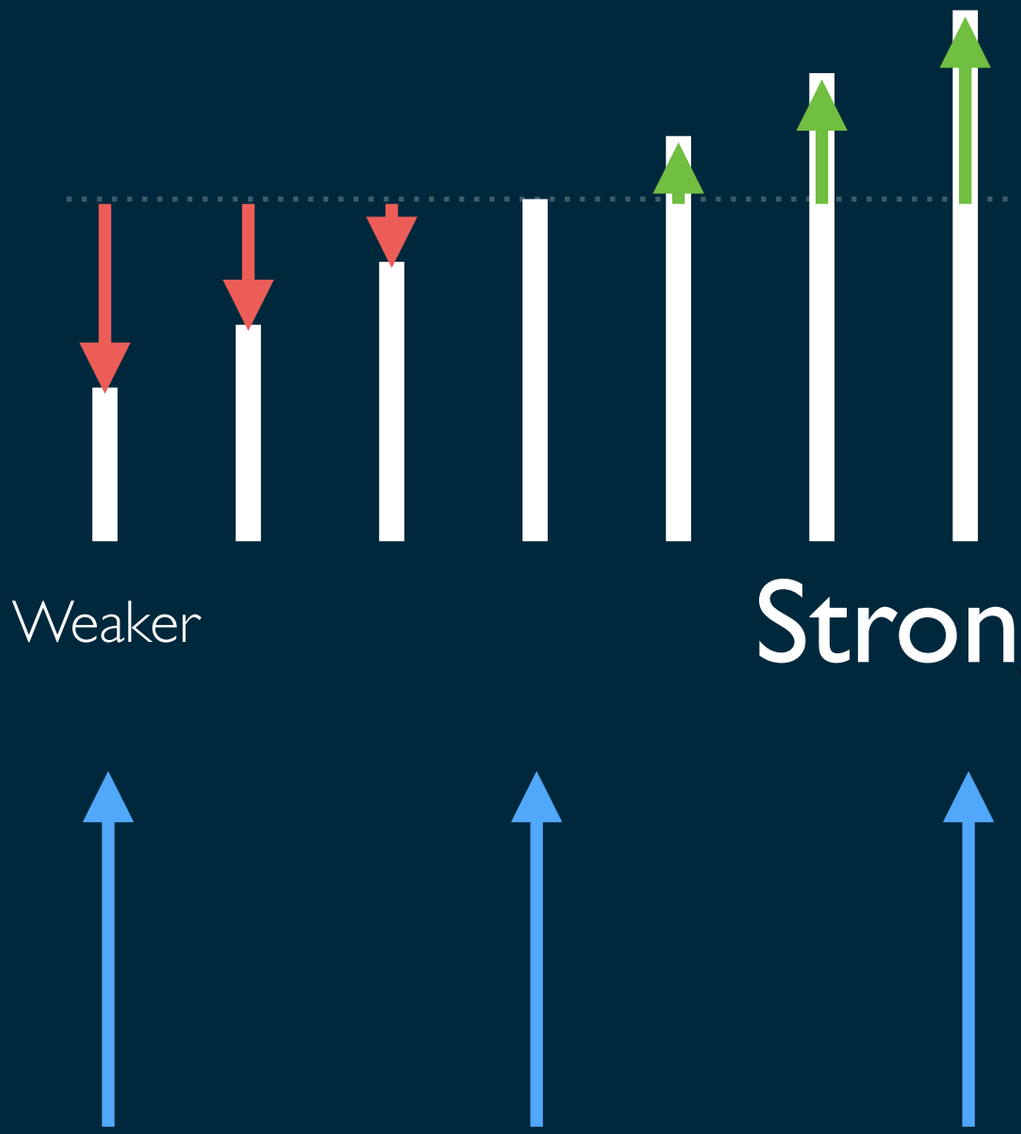
Total Magnetic Field



Magnetic Field with Gradient **OFF**

Magnetisation Precession

Total Magnetic Field



Weaker

Stronger

Magnetic Field with Gradient **ON**

Slower

Faster

Magnetisation Precession

Total Magnetic Field

Stronger

Weaker

left ($-x$)

right ($+x$)

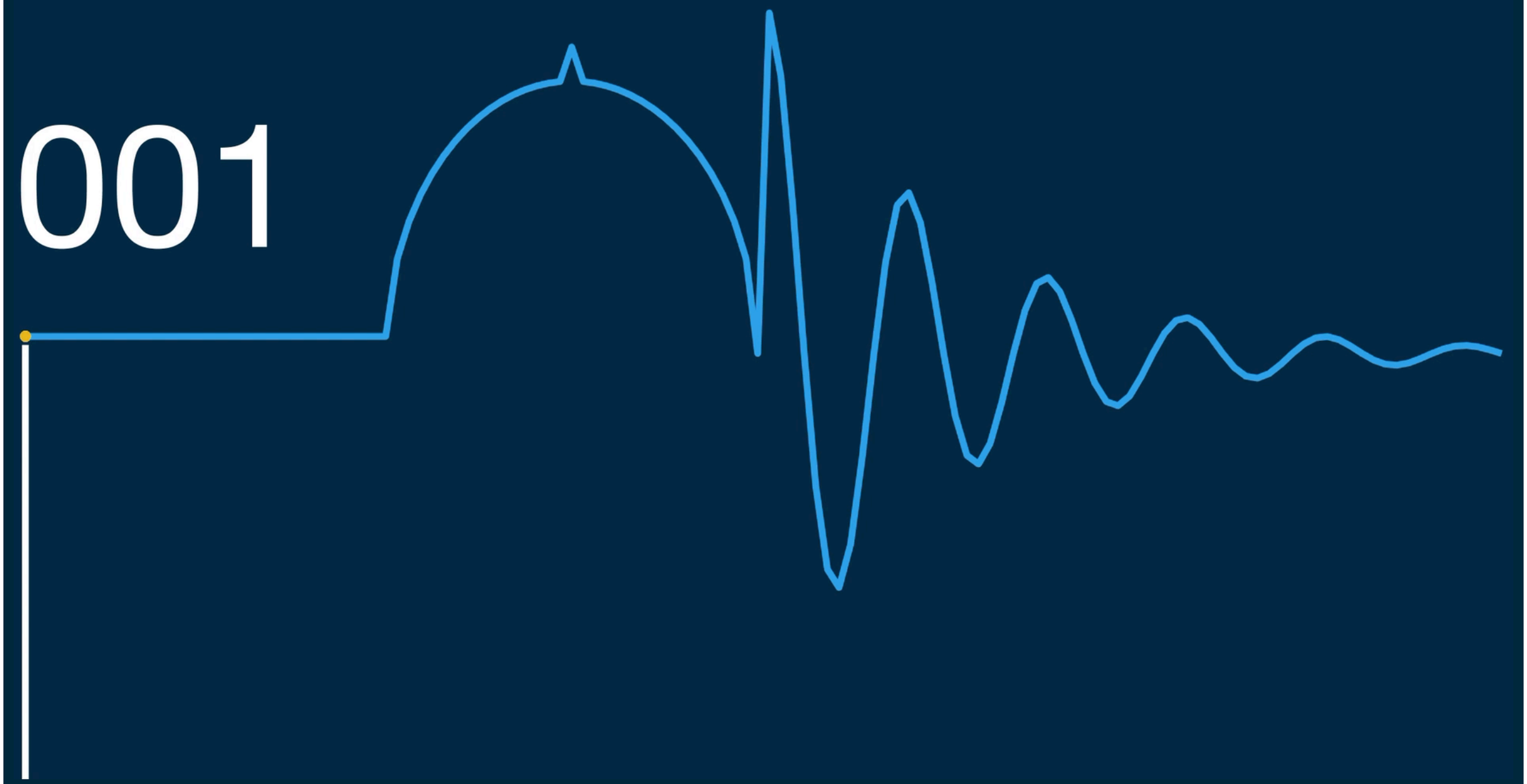
Slower

Faster

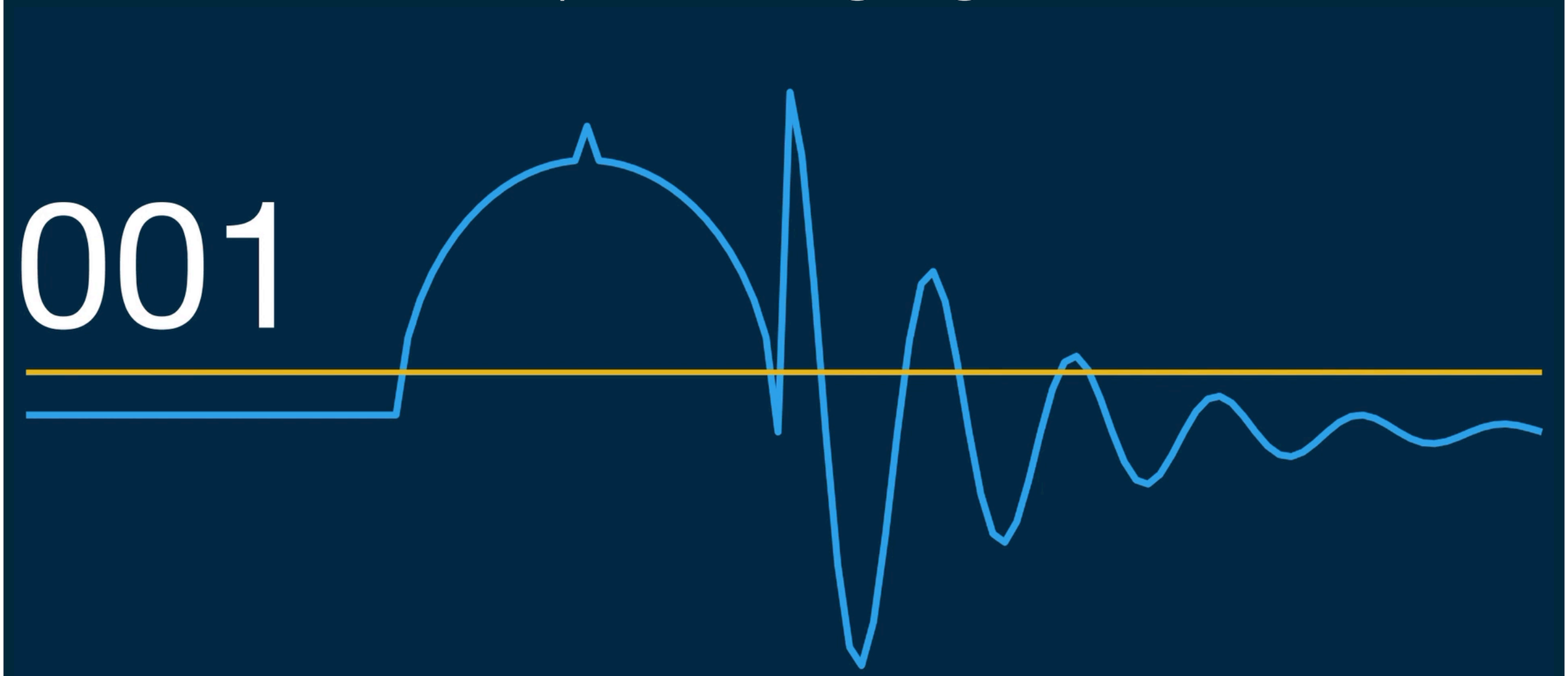
Gradients cause precession rate to change across space

"Wave-like" spatial patterns of phase emerge at any given time

Representing Signals



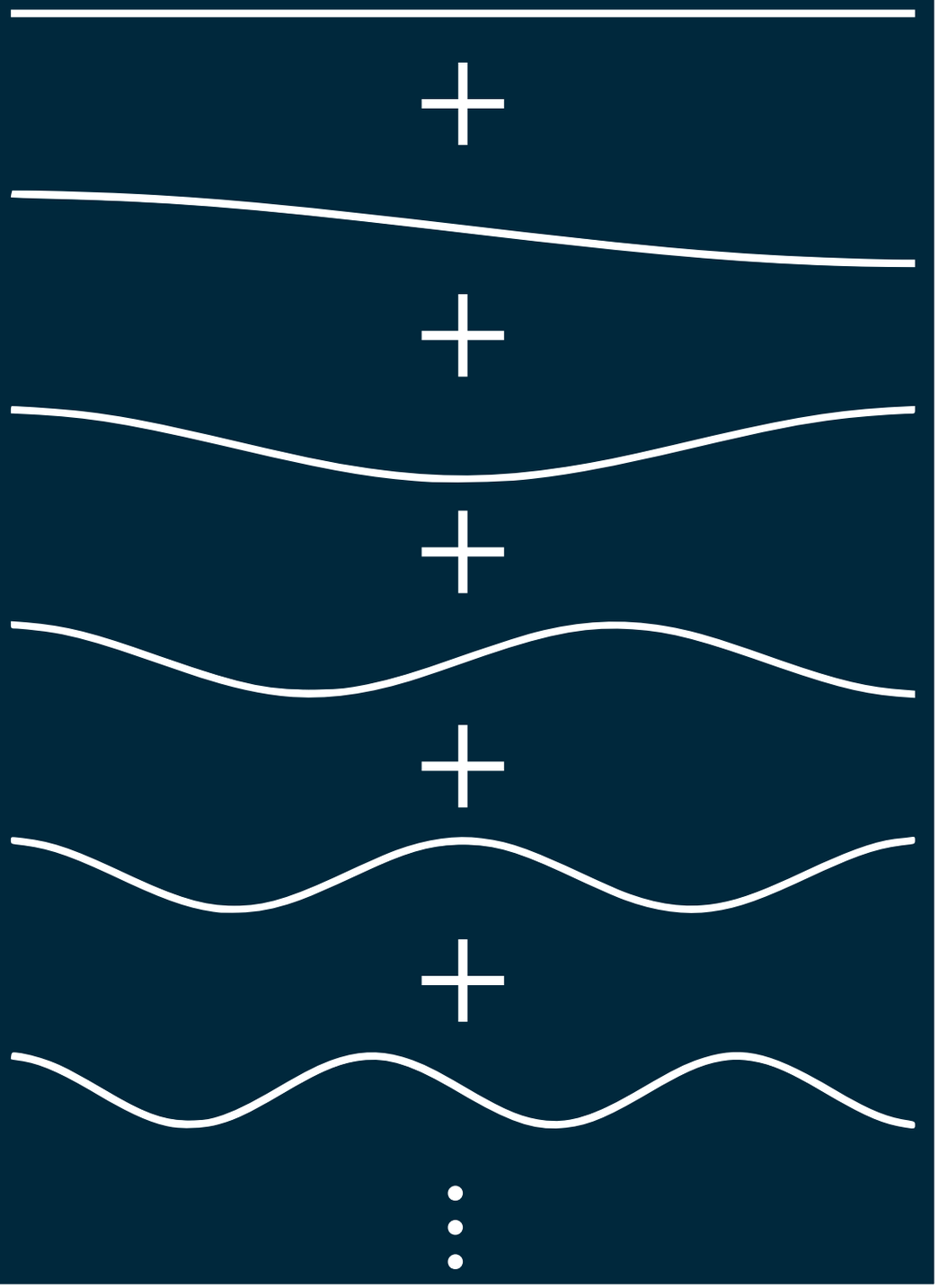
Representing Signals



using sinusoidal spatial “wave” patterns

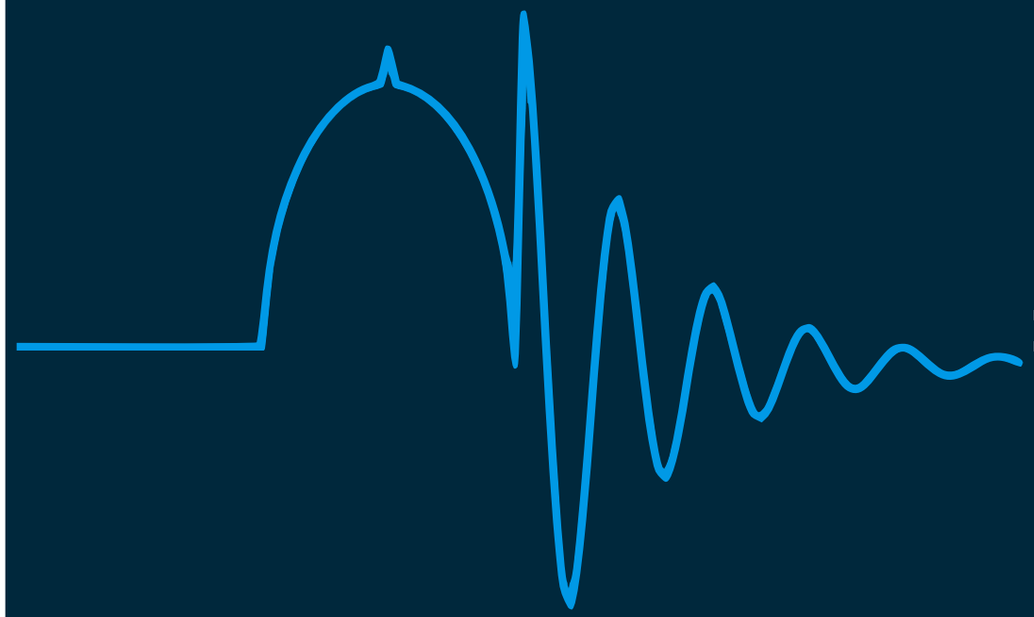
Universal Ingredients

=



Waves with different wavelengths

Fourier Transform



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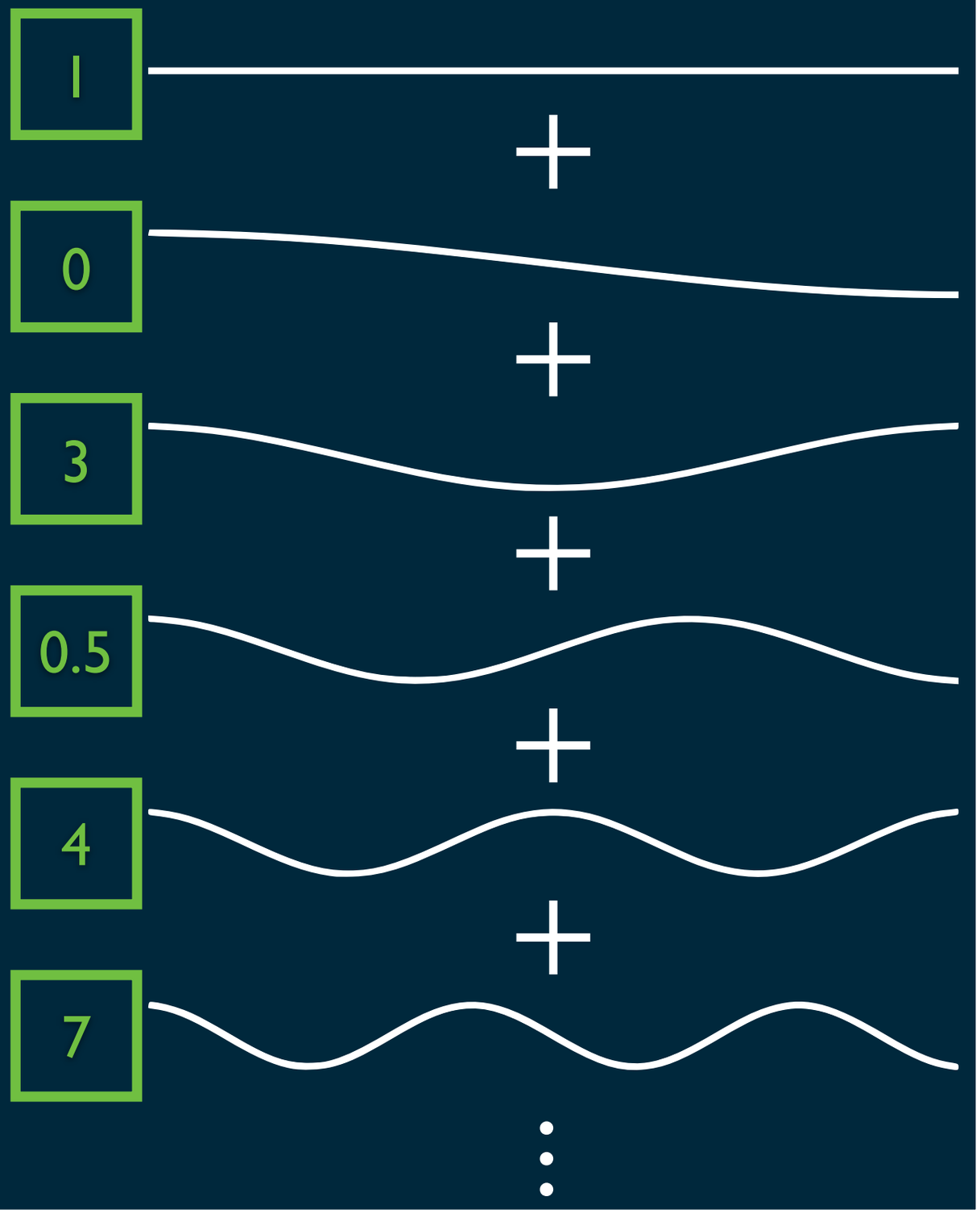


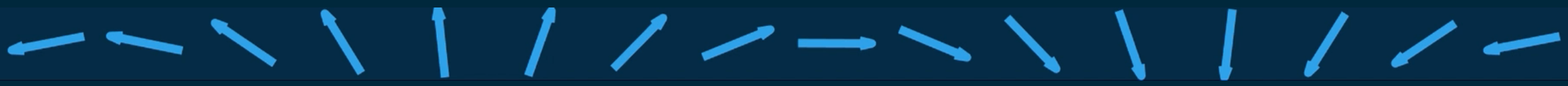
How to combine these universal ingredients?

Need to determine weight of each wave

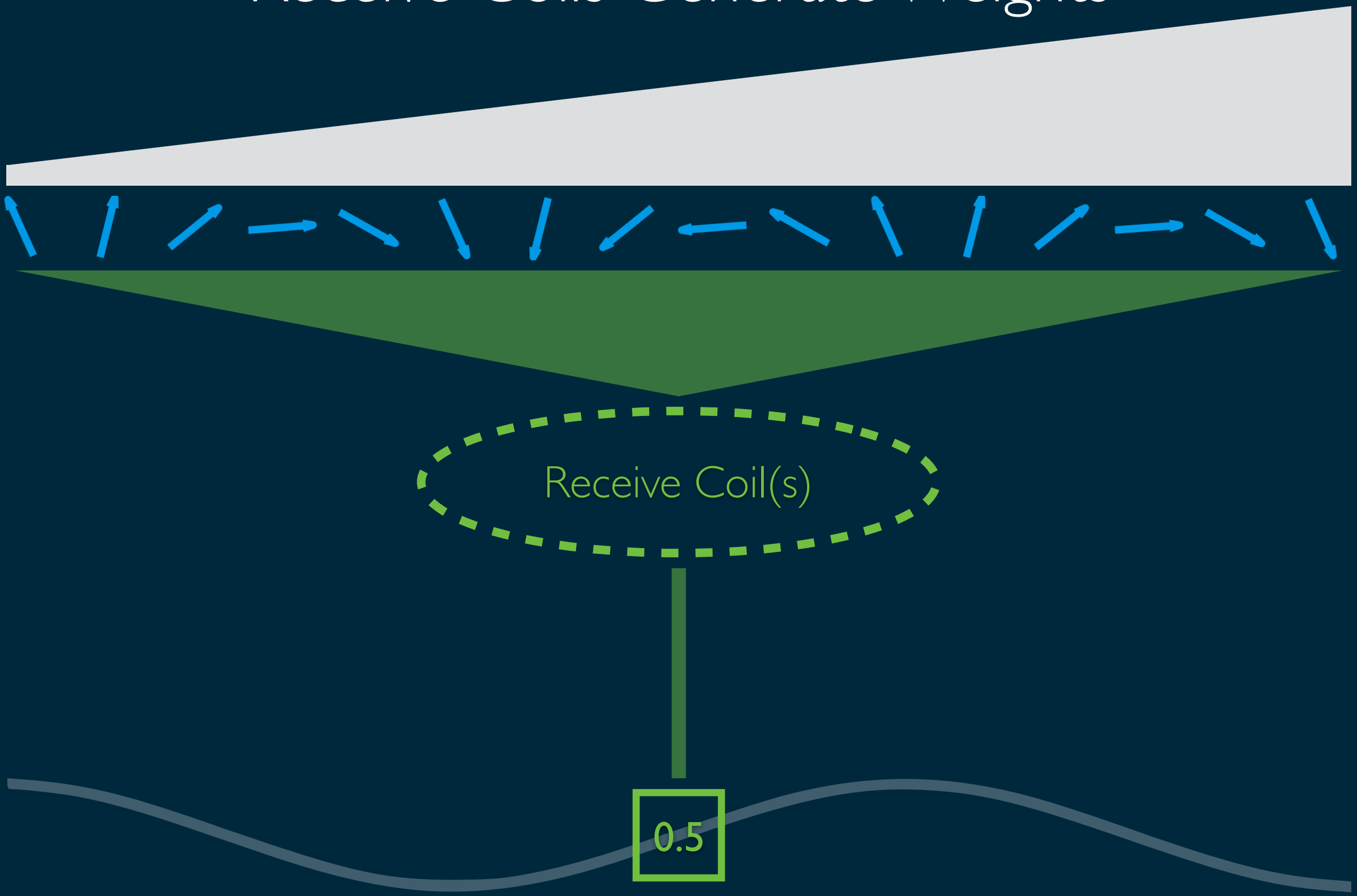
Gradients and the Fourier Transform

Gradients and the Fourier Transform

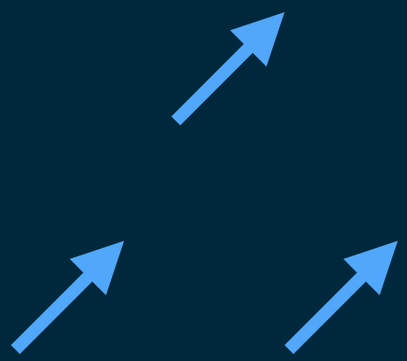
Gradients and the Fourier Transform



Receive Coils Generate Weights

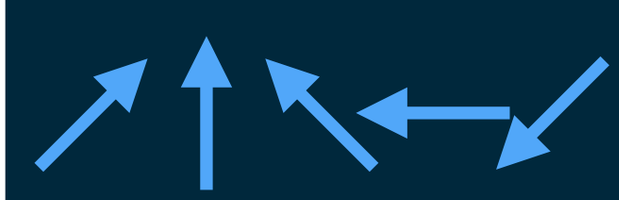


Summary



Every voxel's magnetisation points in some **direction**

Precession **rate** of magnetisation is controlled by the magnetic field **strength** it sees



Varying the field across space using a **gradient** generates **wave**-like patterns in the magnetisation

All signals/images can be **represented** by a combination of different **waves** (Fourier Transform)

Gradients and receive coils find the **Fourier Transform** representation of an object by setting up **waves** over it and evaluating their **weights**