

Milano, 17 – 19 giugno 2009

III Convegno Nazionale di Ecocardiografia

Imaging non Invasivo di II livello

Principi di base per la formazione dell'imaging RM

S. Biasi

COMPONENTI DEL SISTEMA

- Magnete
- Bobine di radiofrequenza
- Bobine di gradiente
- Bobine ausiliarie
- Computer



IL MAGNETE

Superconduttore: genera un campo magnetico statico la cui potenza è misurata in Tesla.

1.5 T è equivalente a 15,000 Gauss (il campo magnetico terrestre è circa 0,5 Gauss)

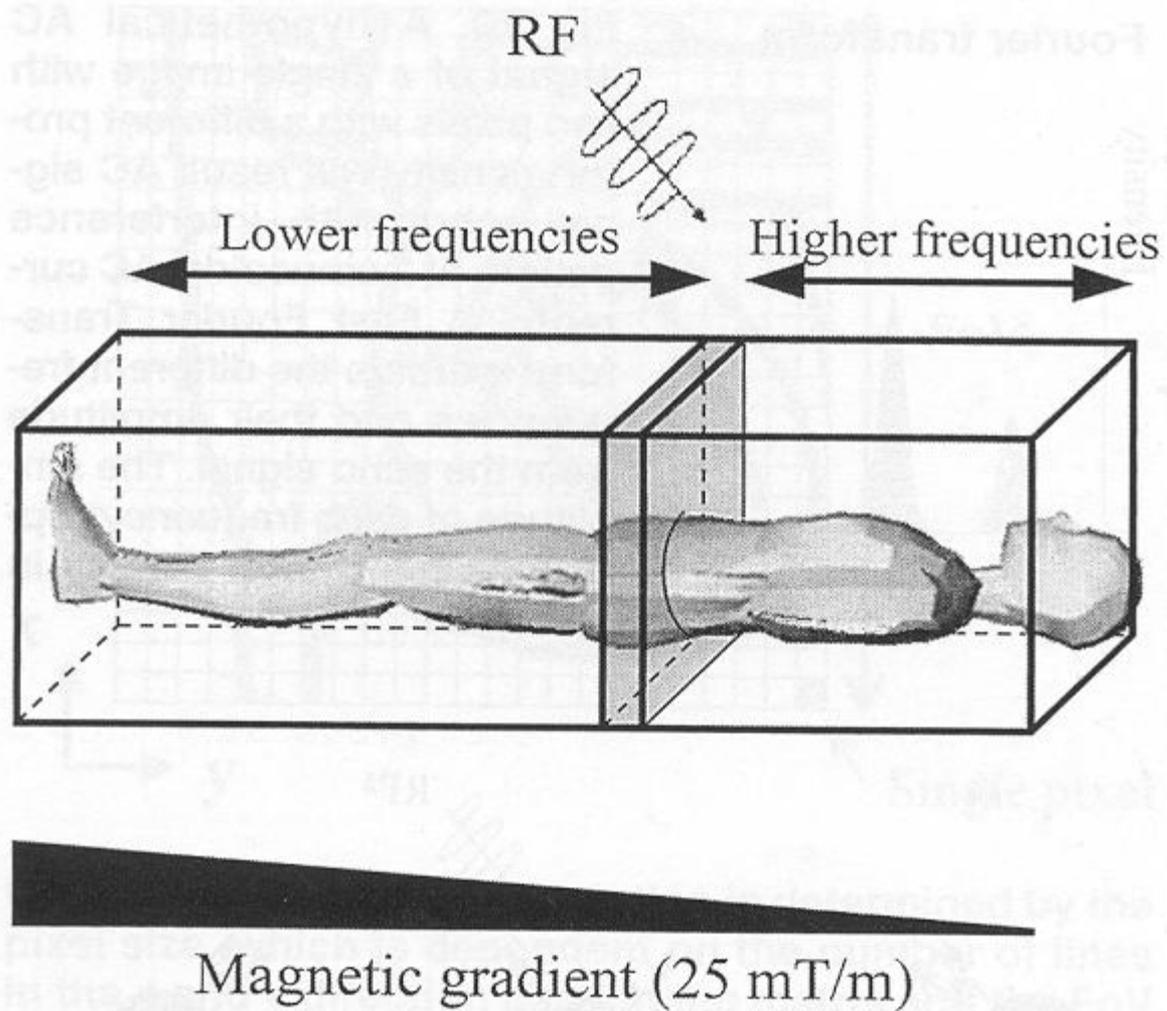
Funzione: creare un campo magnetico, il più omogeneo possibile, costante nello spazio e nel tempo. (fluttuazioni < 0,001%)

Specifica più importante: l'intensità del campo prodotto.

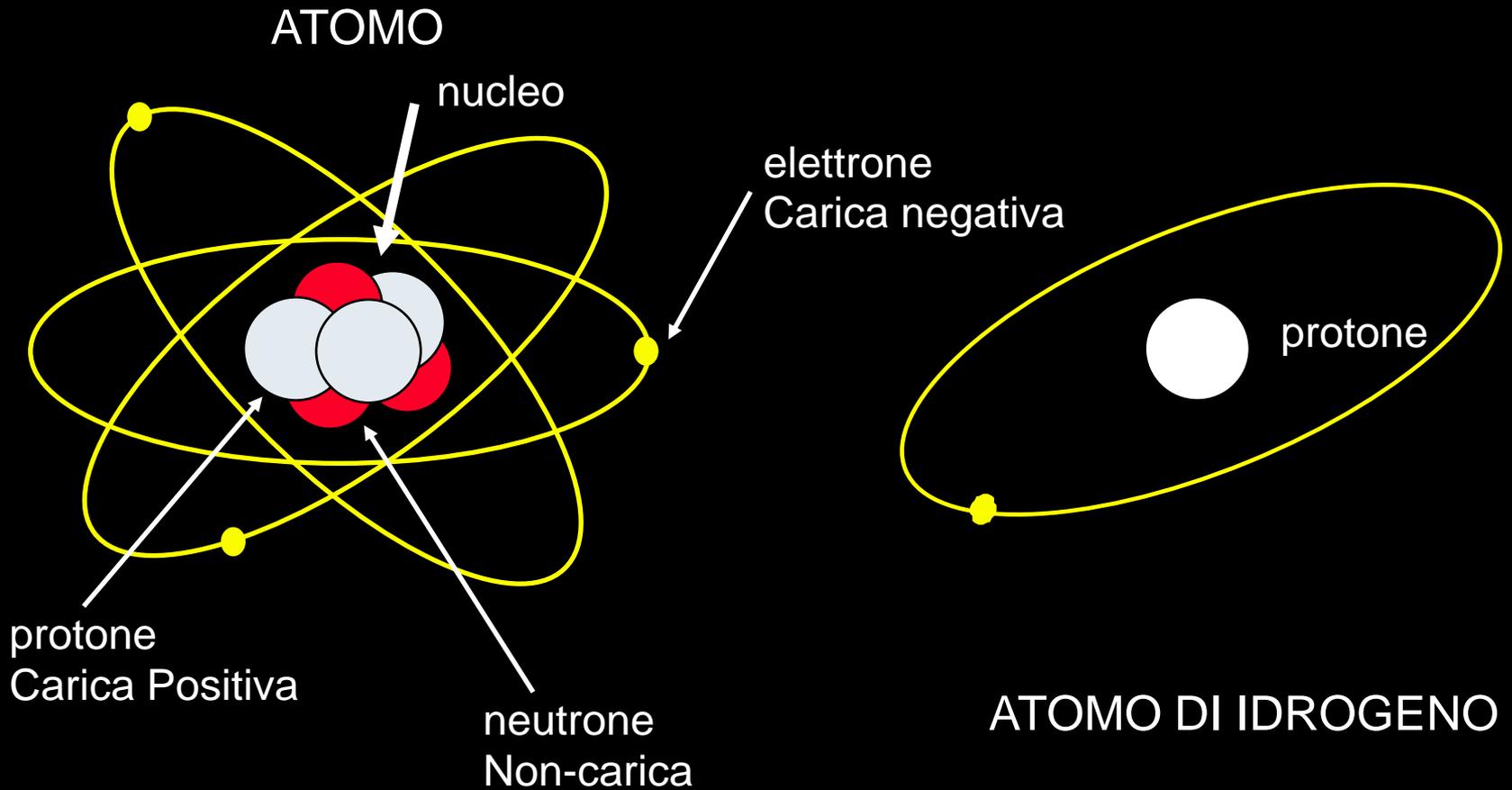
Campi di maggiore intensità aumentano il rapporto segnale/rumore, permettono risoluzioni più alte e scansioni più rapide.

Presupposti Teorici

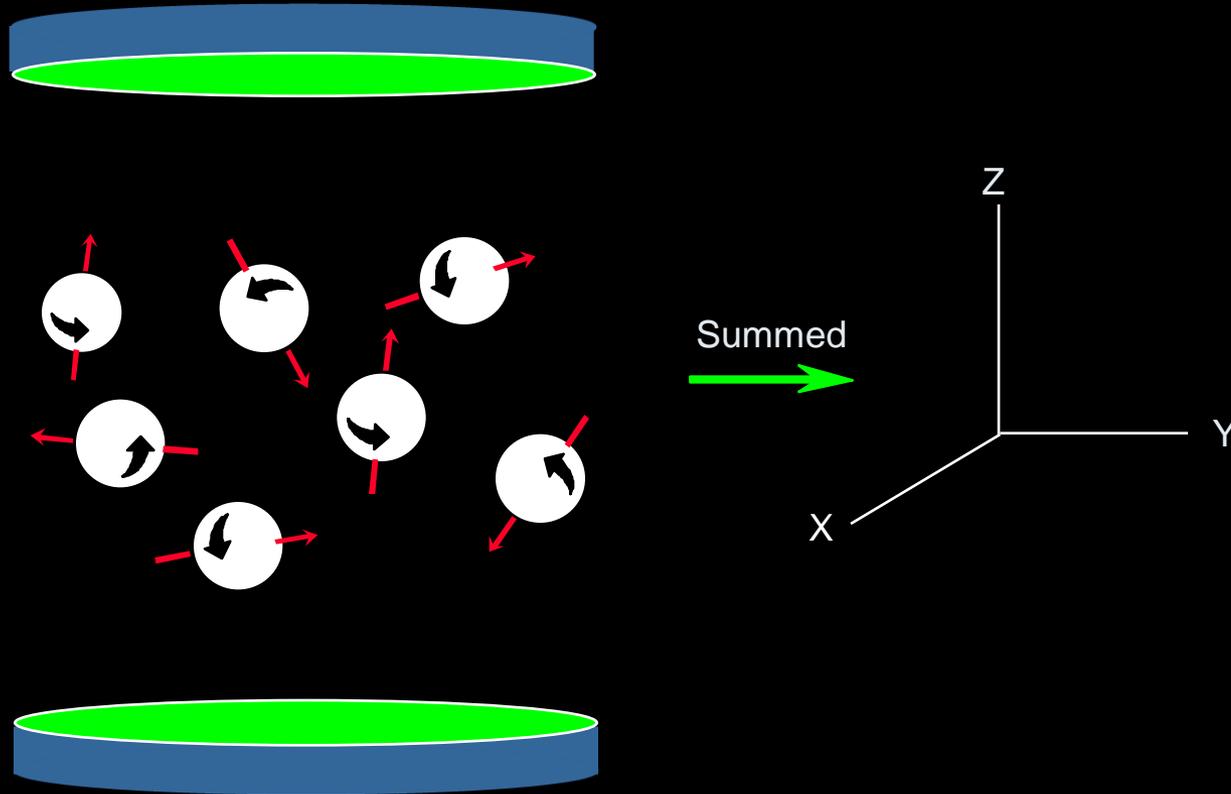
Cosa succede quando posizioniamo un corpo nel magnete ?



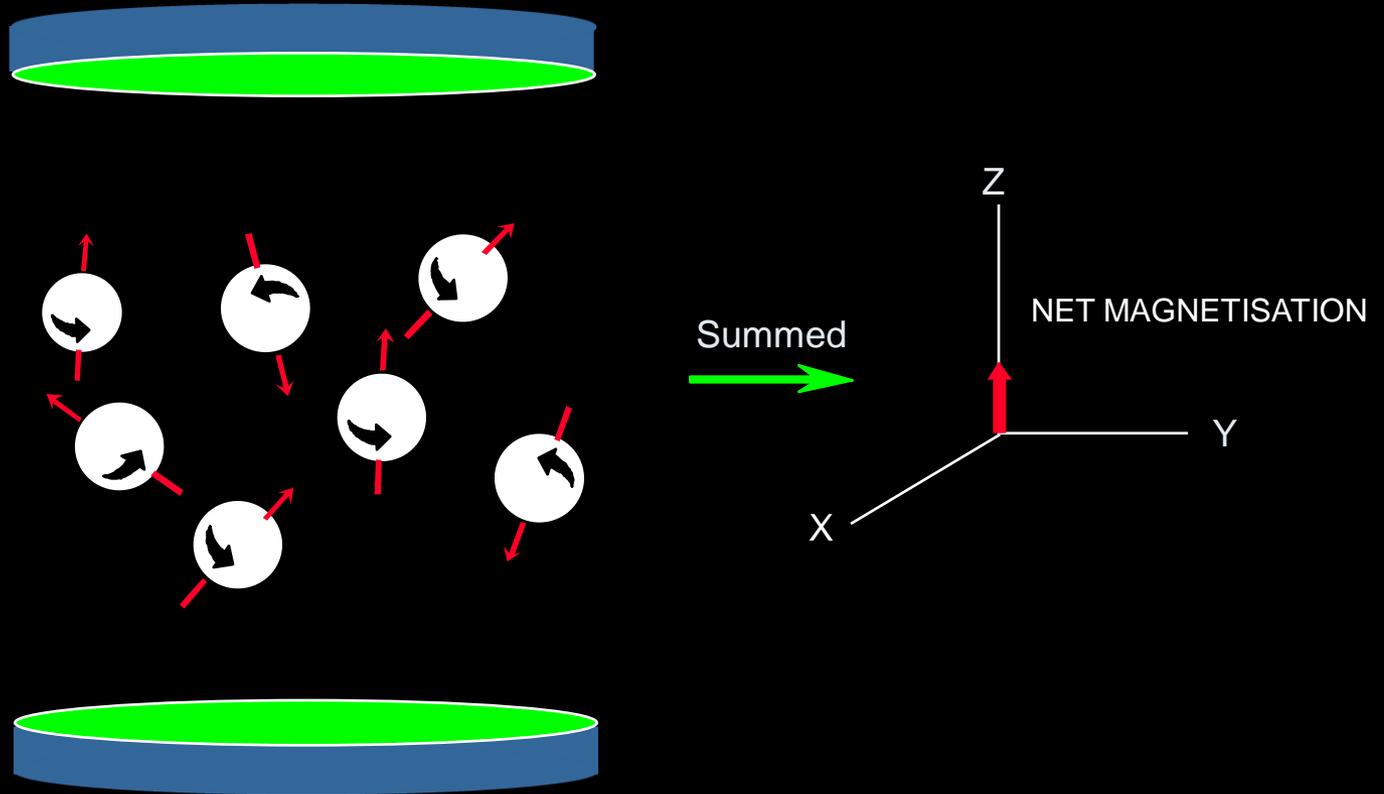
Nuclei, Protoni e Spin



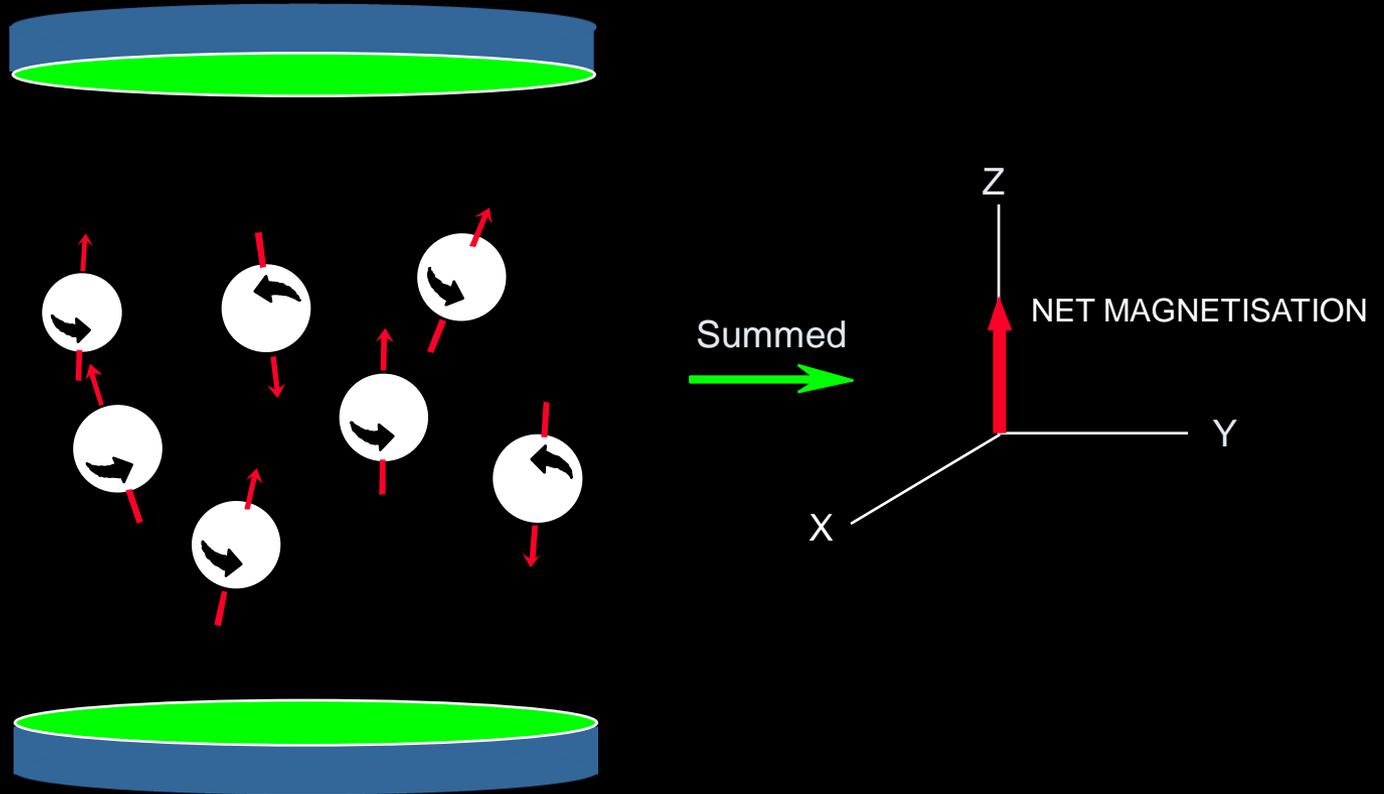
Nuclei in un Campo Magnetico



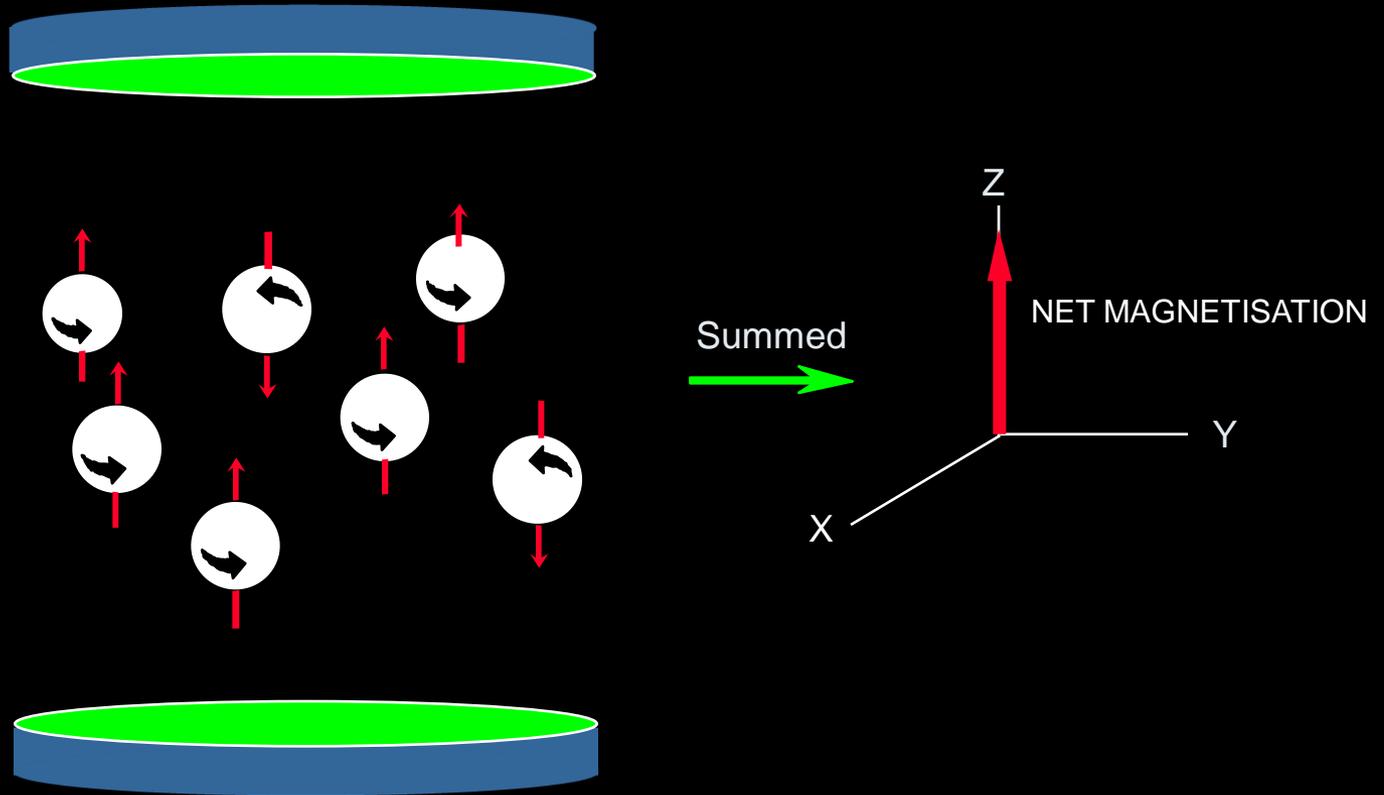
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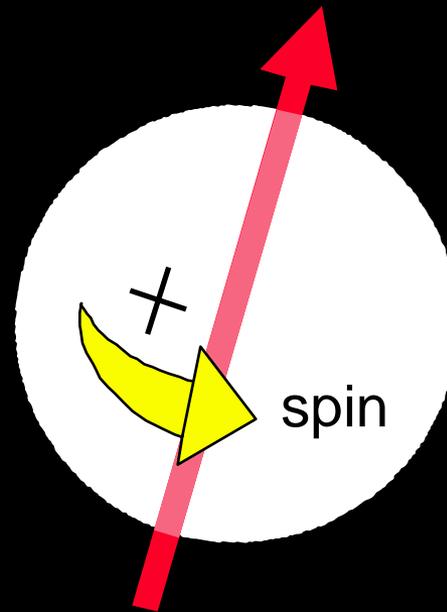
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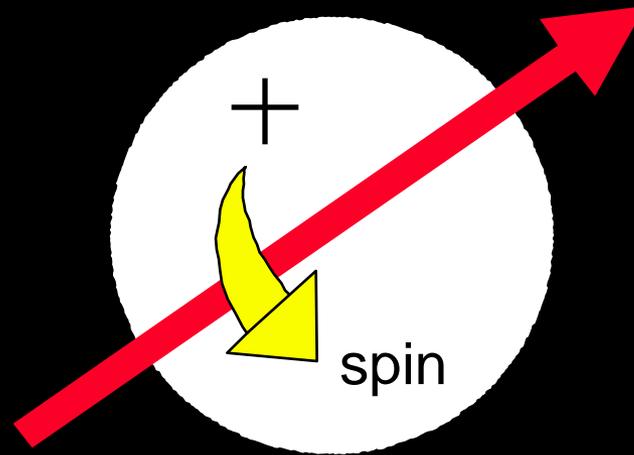
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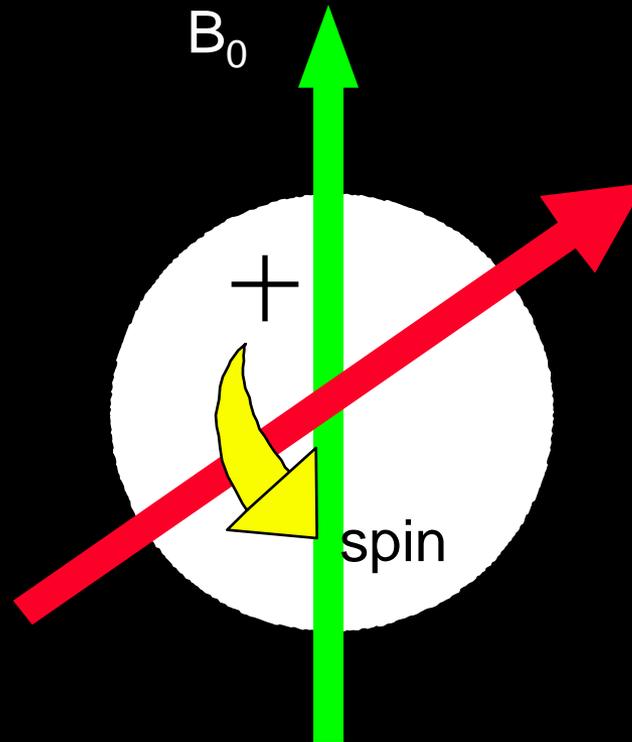
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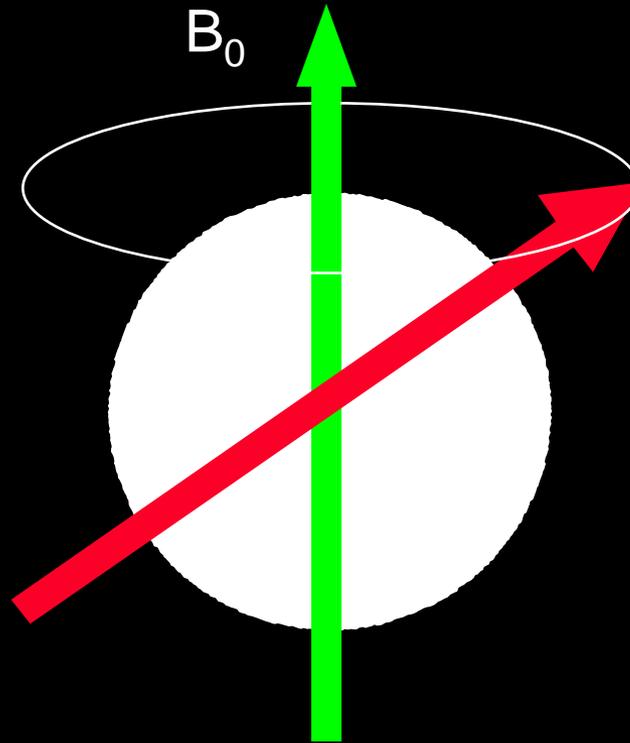
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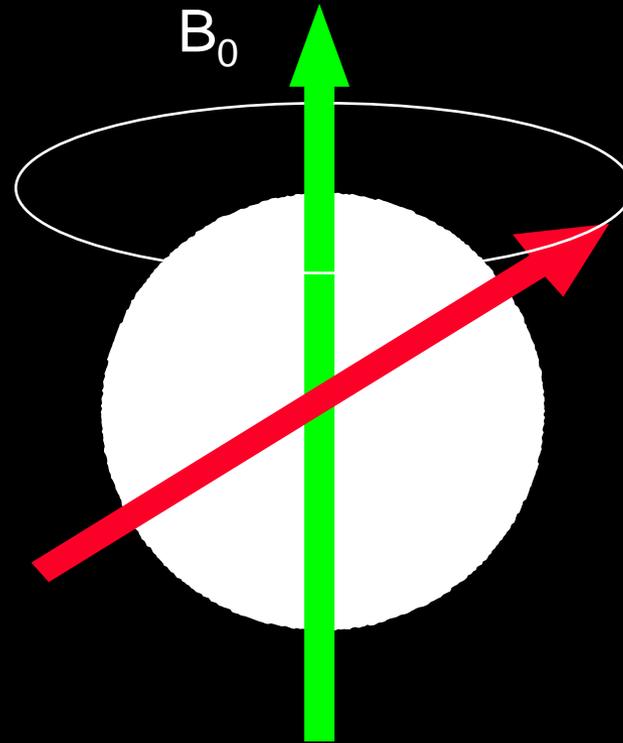
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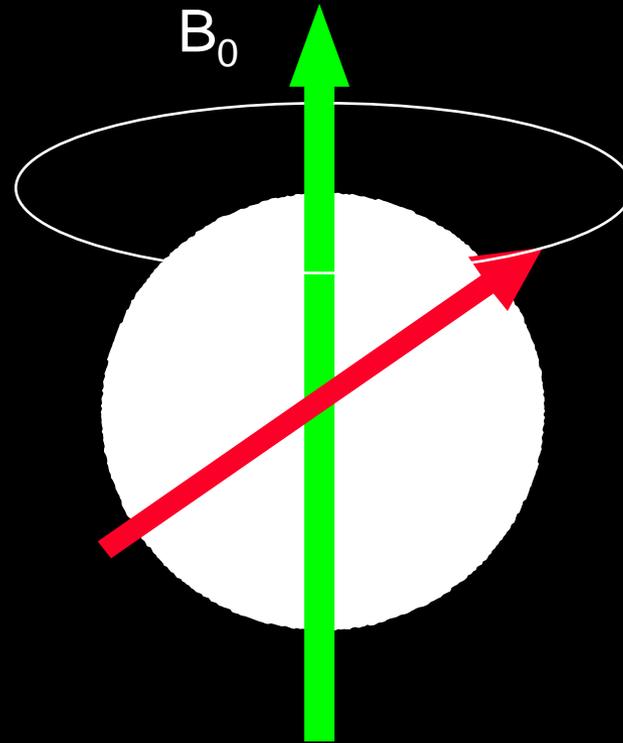
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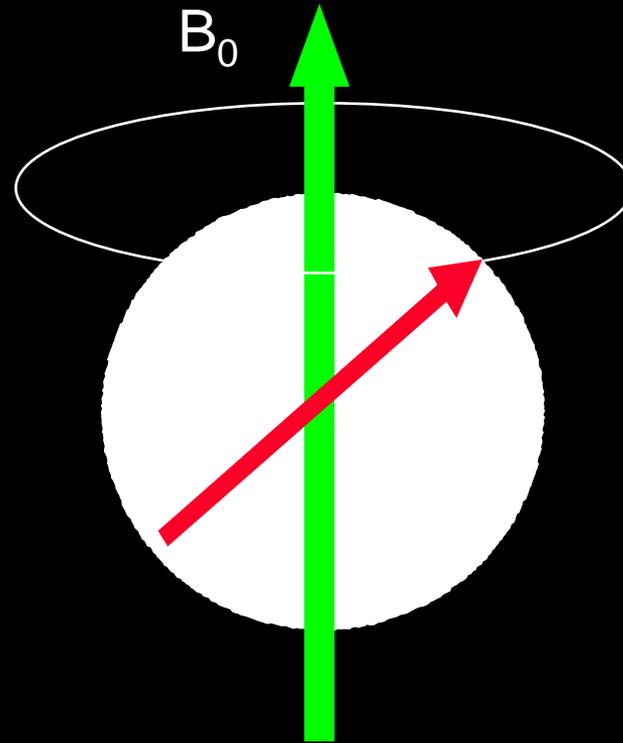
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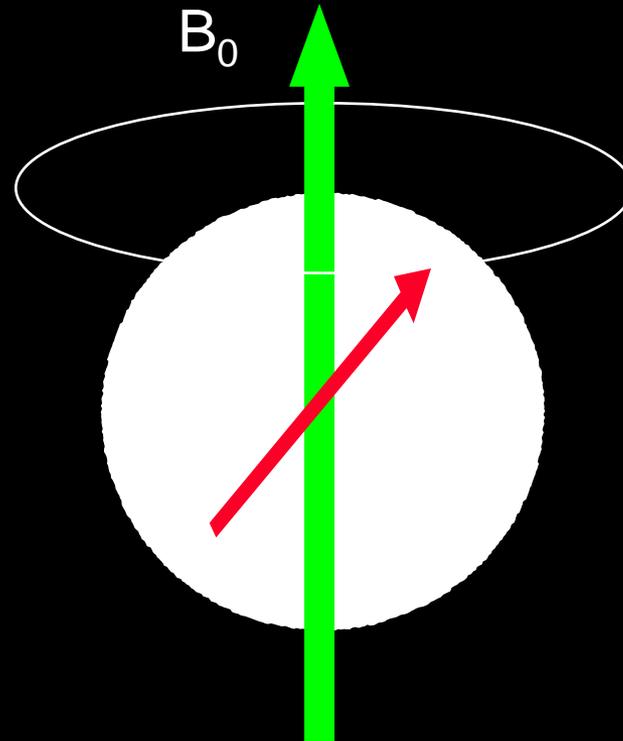
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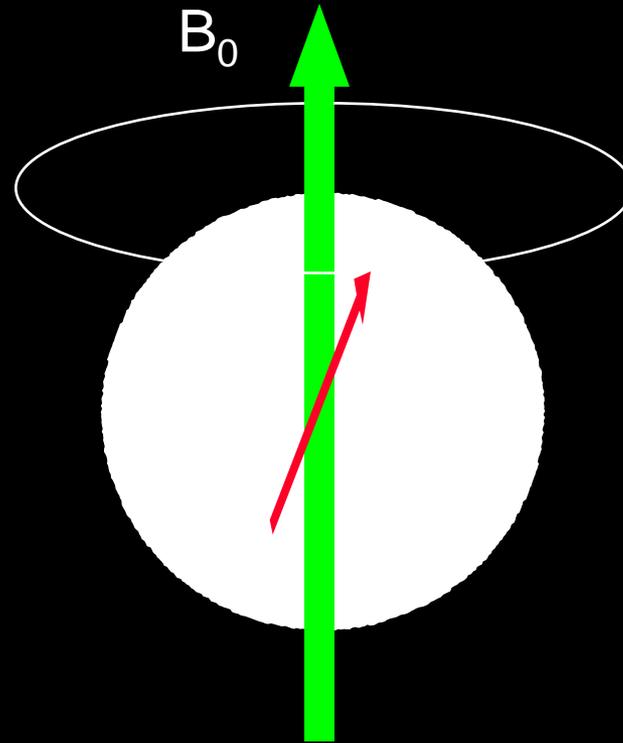
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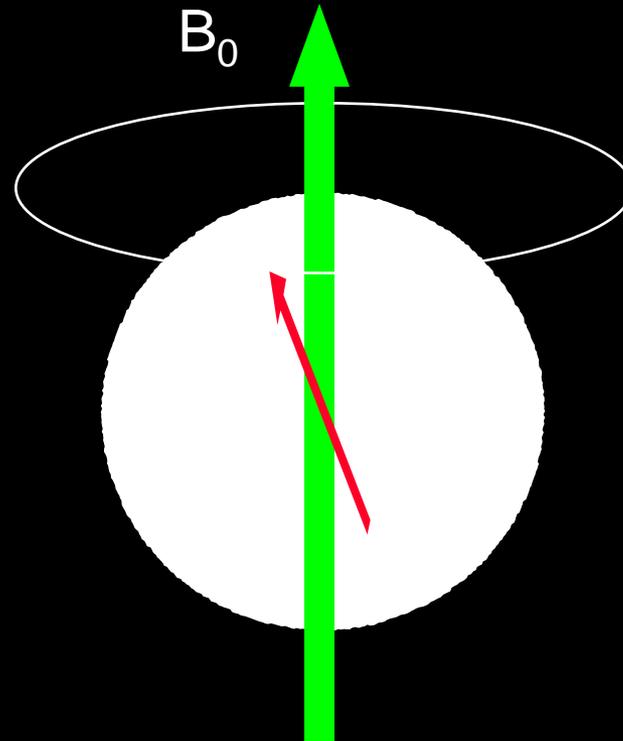
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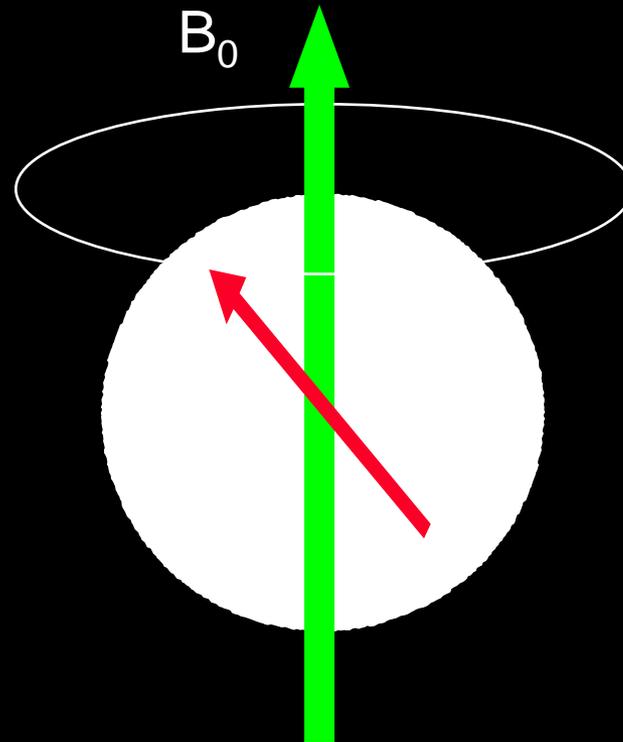
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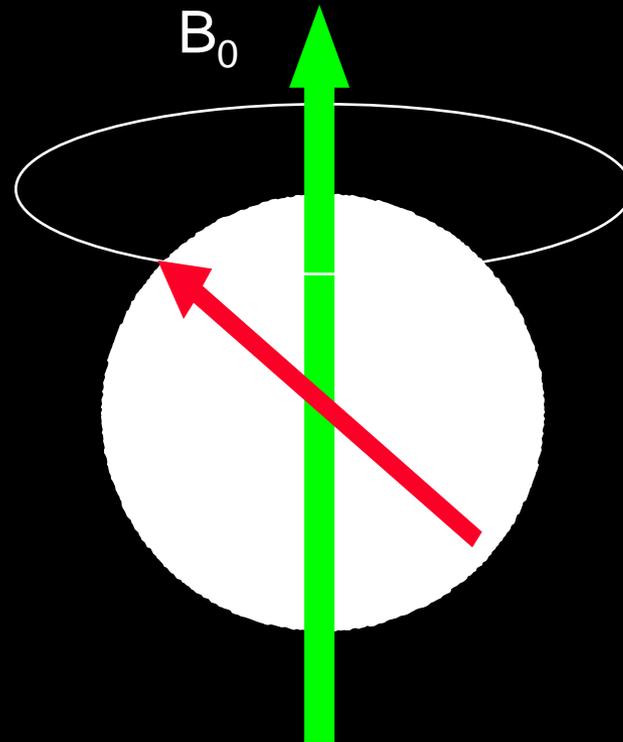
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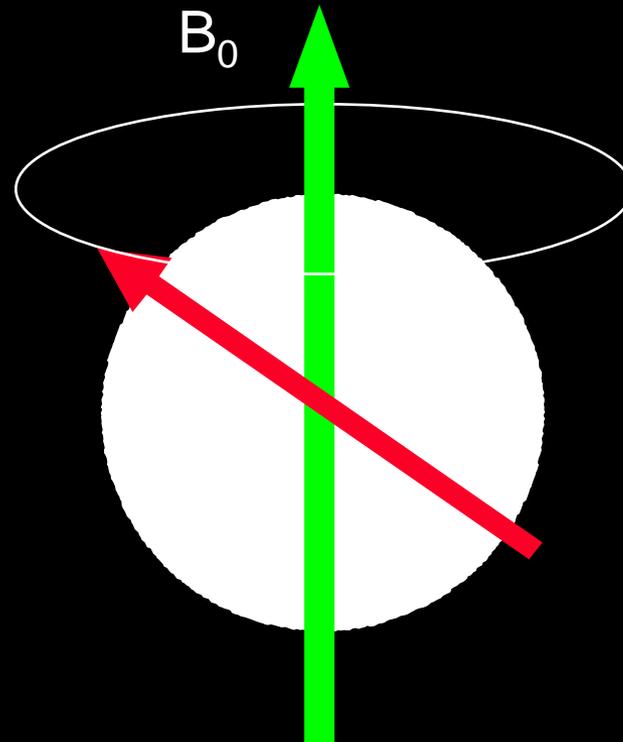
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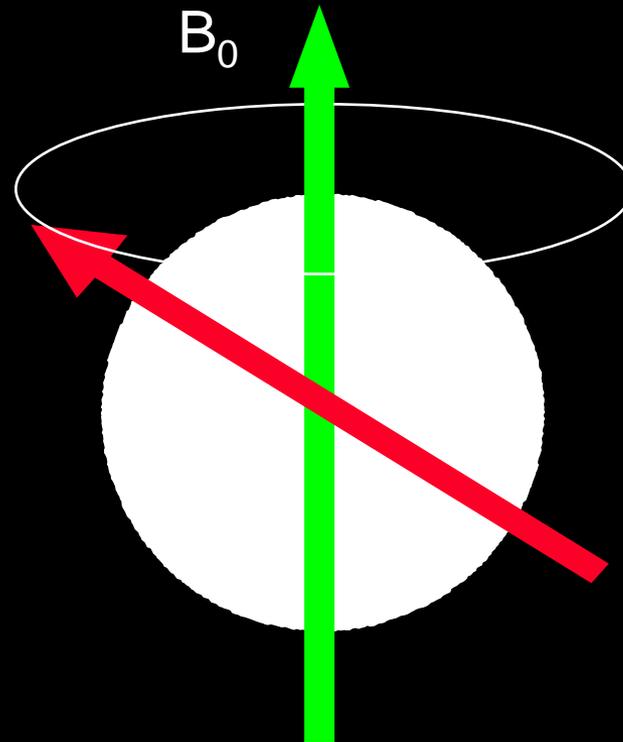
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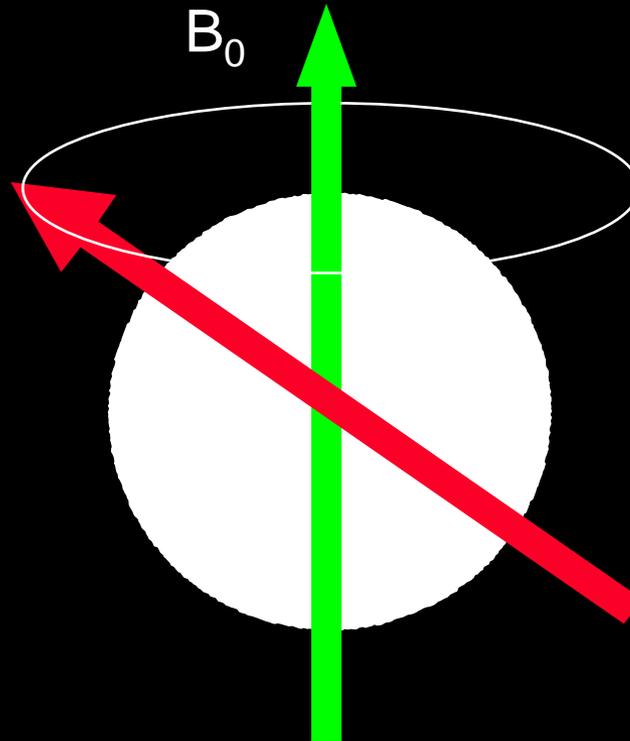
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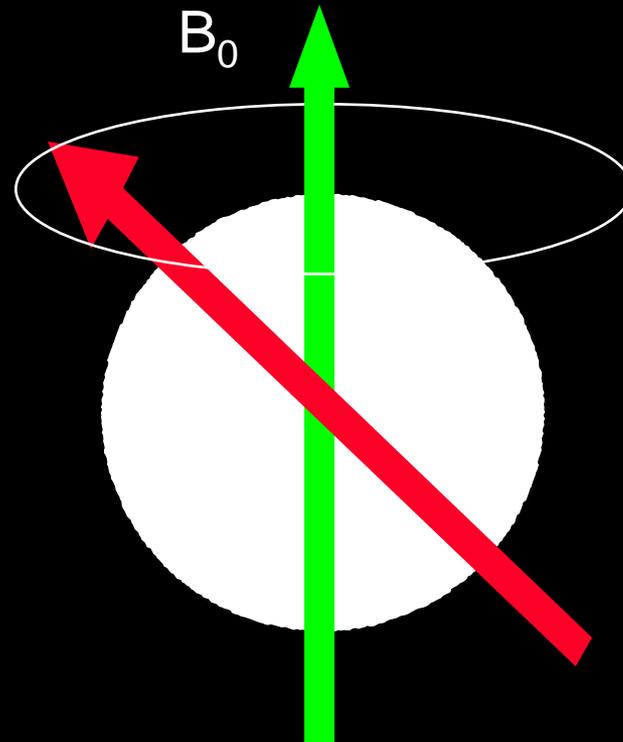
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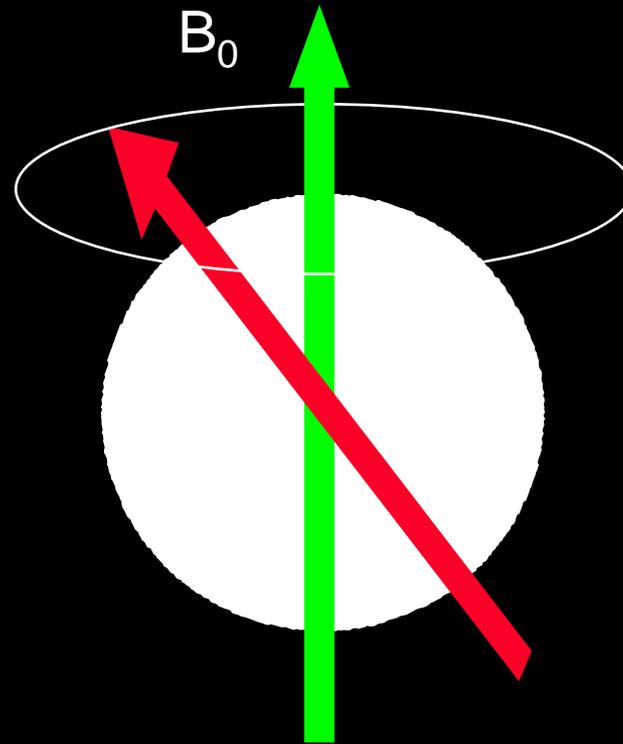
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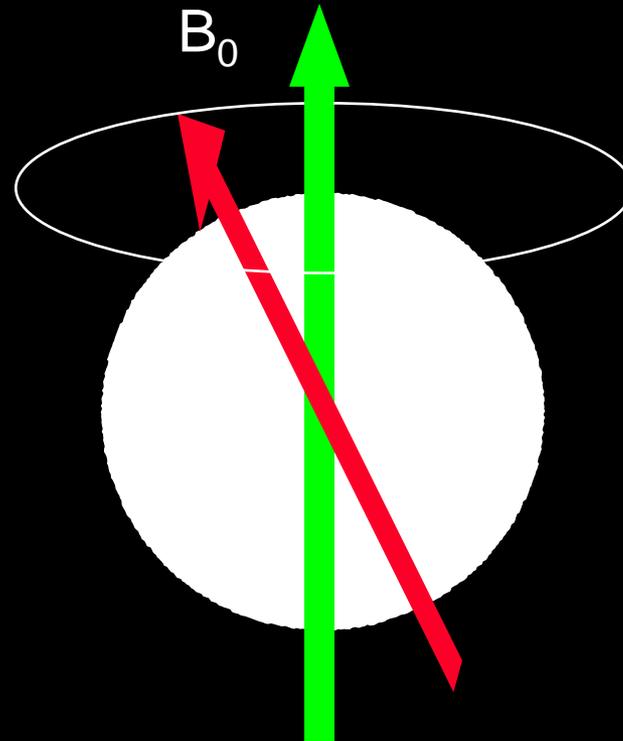
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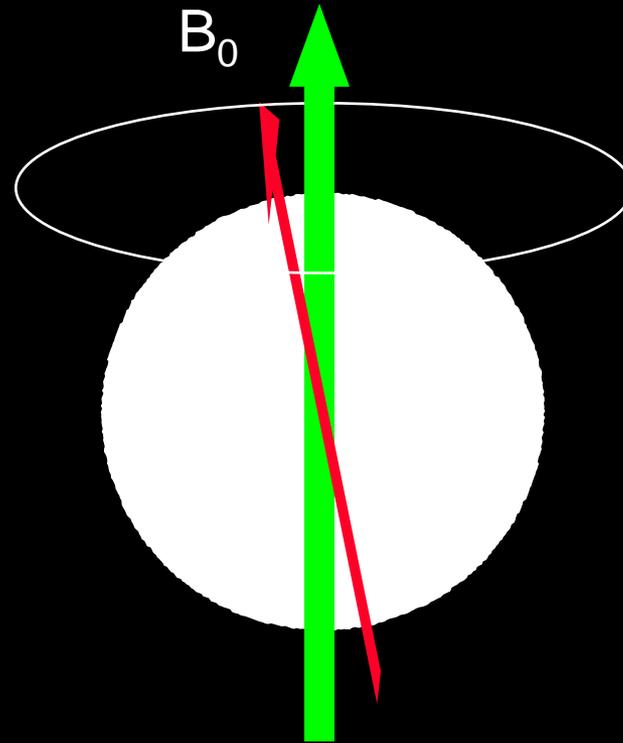
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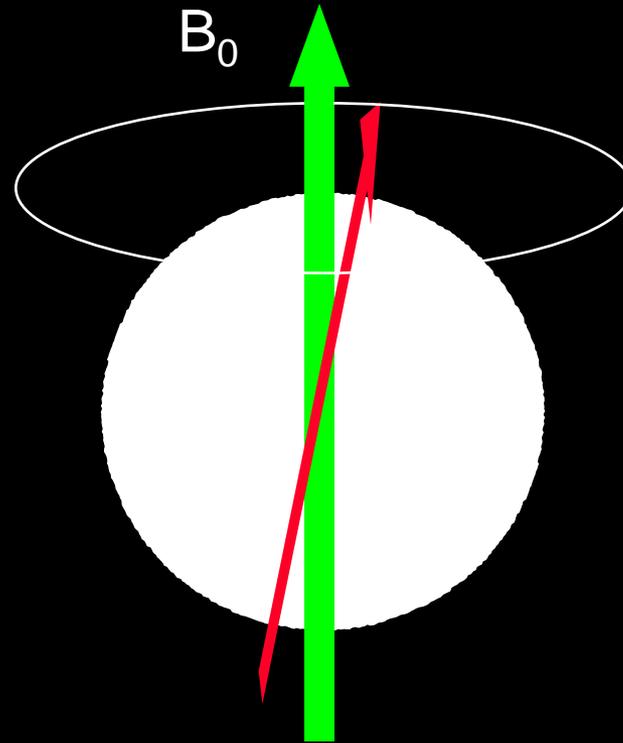
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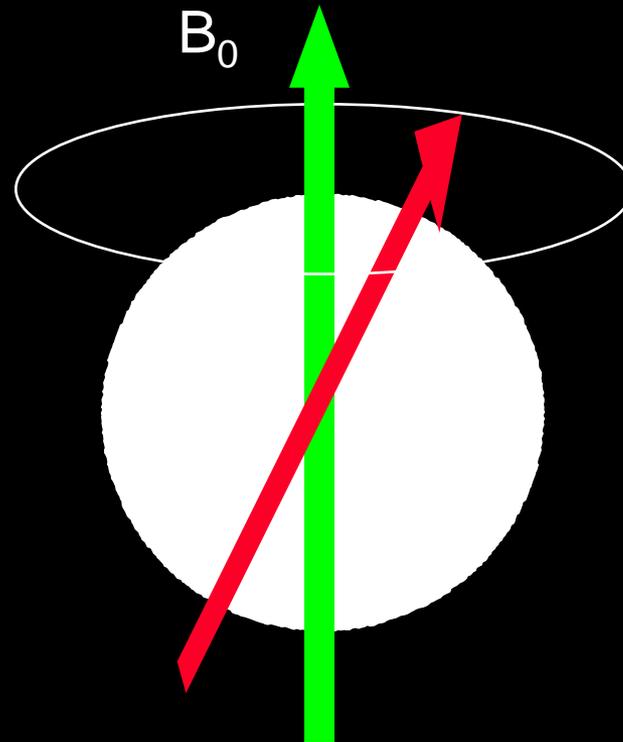
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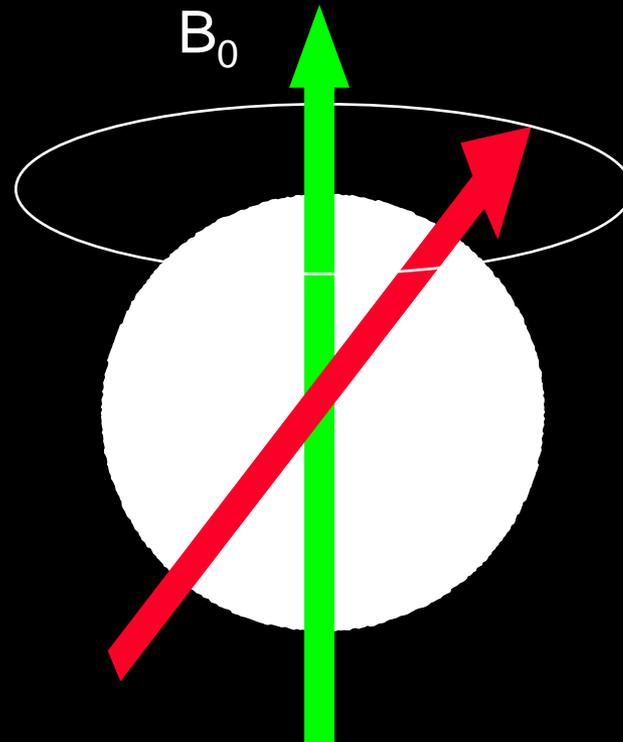
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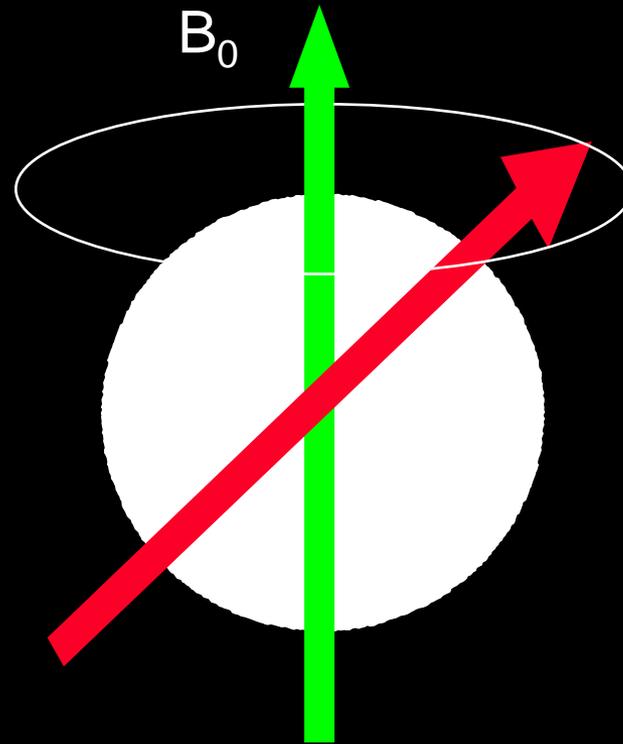
Precessione



Precessione



Precessione



$$f_0 = \gamma \times B_0$$

Precessione

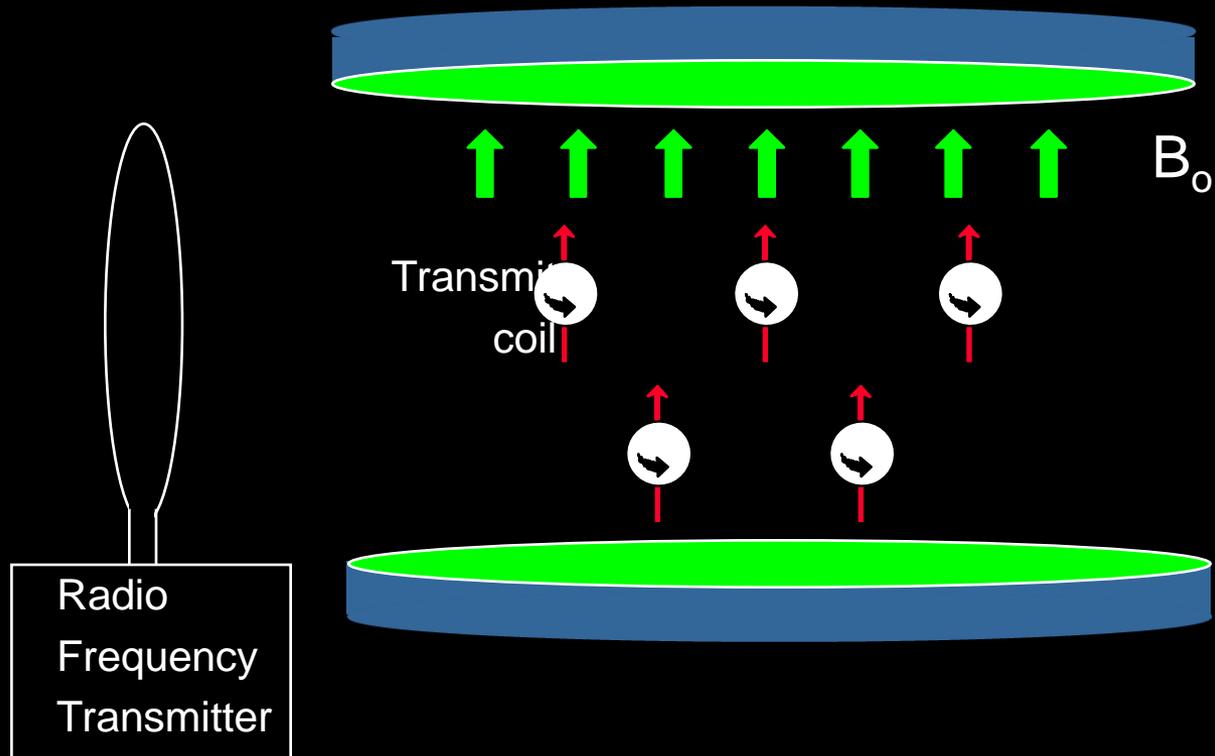
- Ha una frequenza tipica (Larmor) che si trova nell'ordine dei MHz e quindi nel campo delle Radio Frequenze.
- Per 1 T la frequenza per l'atomo di idrogeno è di 42 MHz.

MR : generazione del segnale

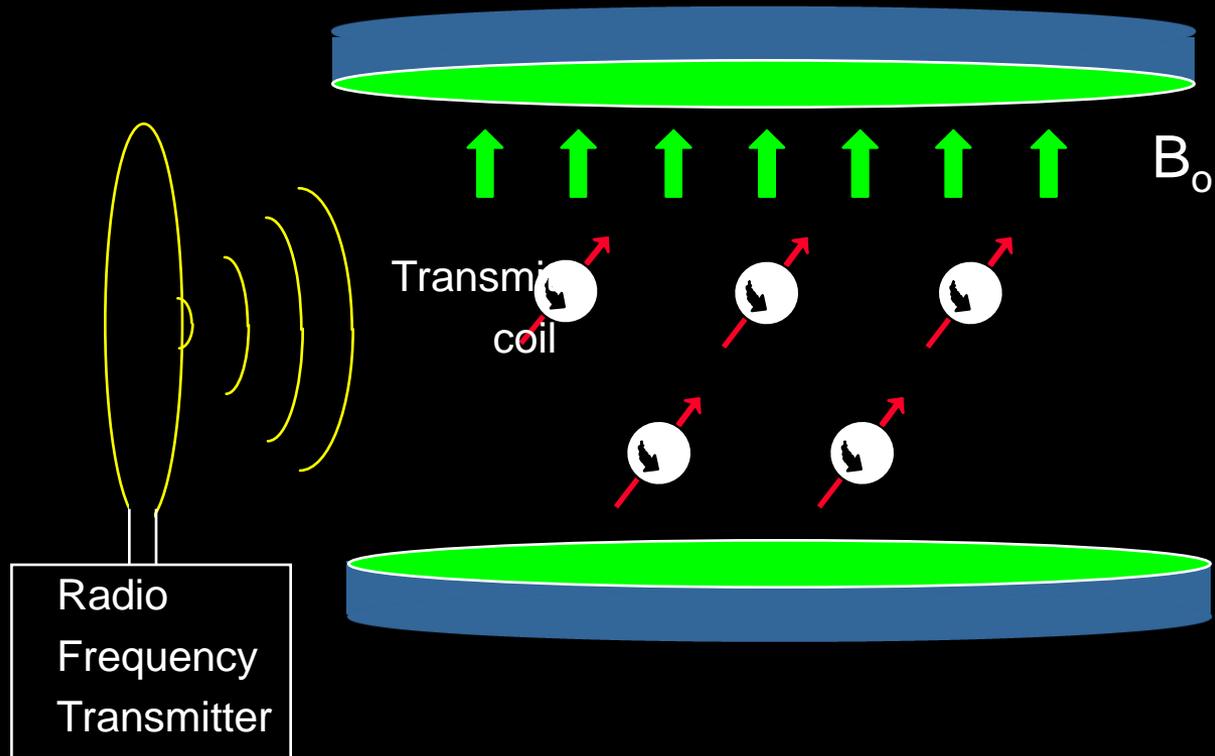
Tecniche di acquisizione

- Eccitazione
- Rilassamento

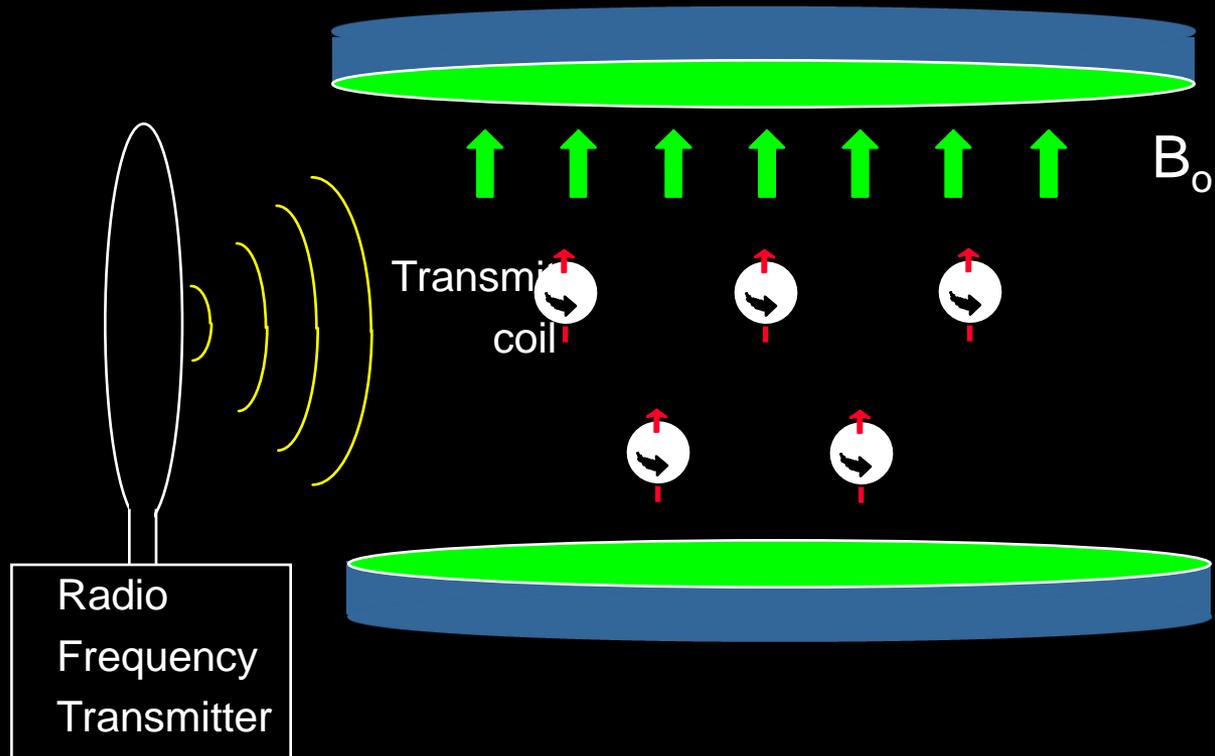
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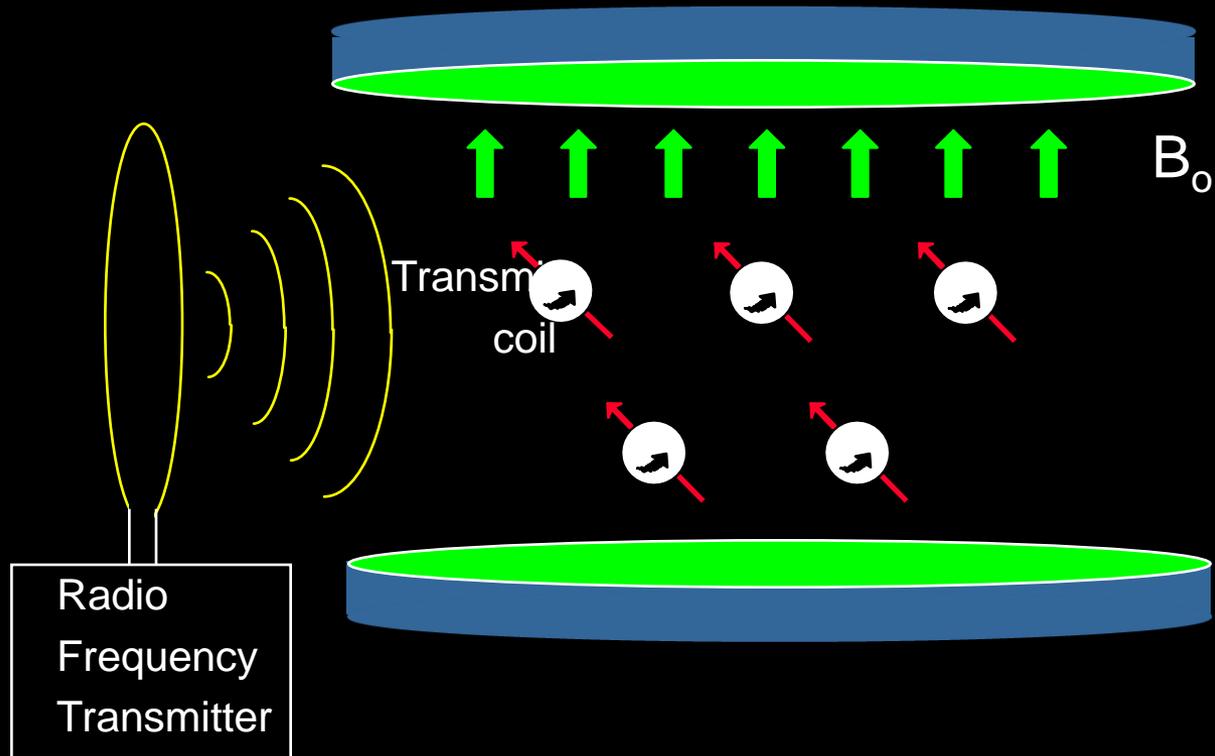
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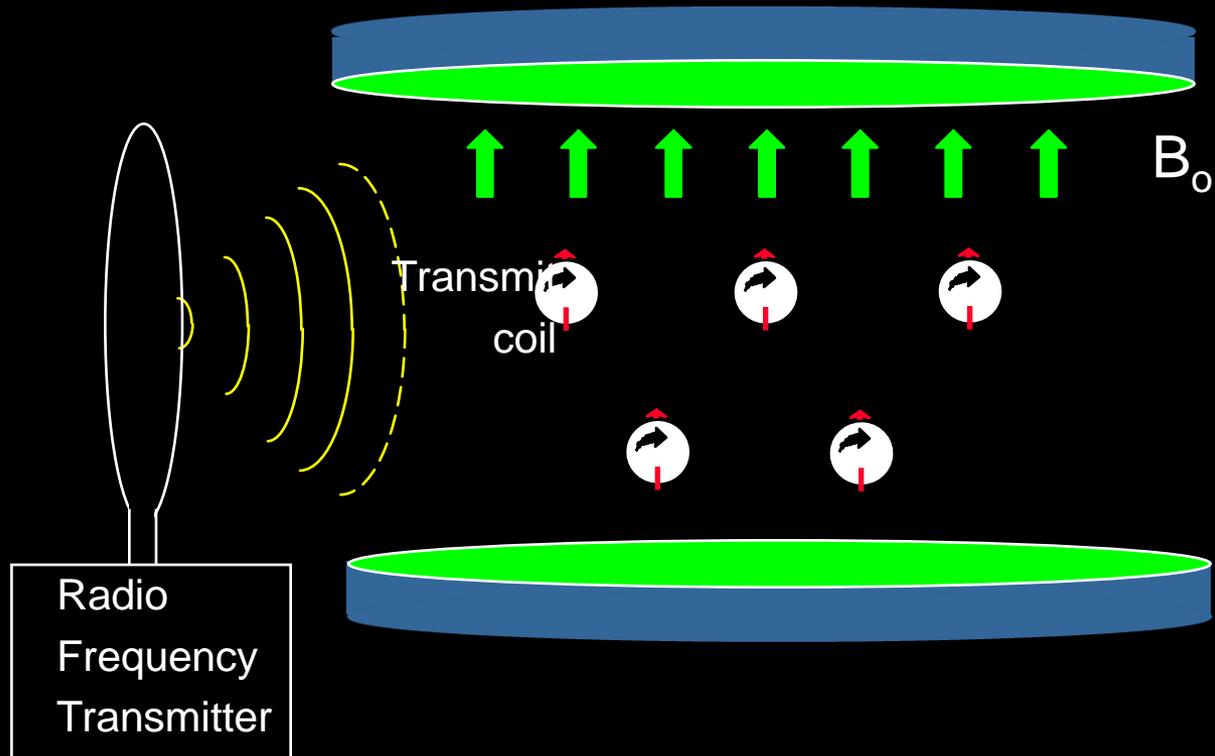
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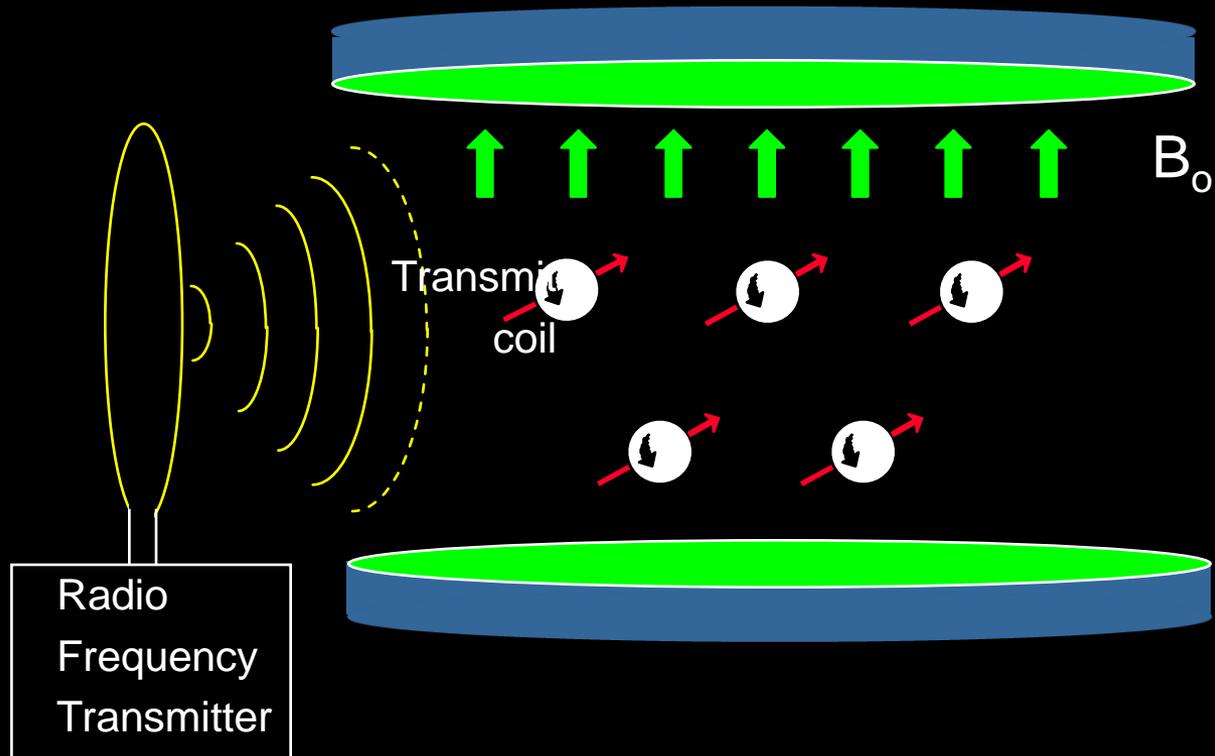
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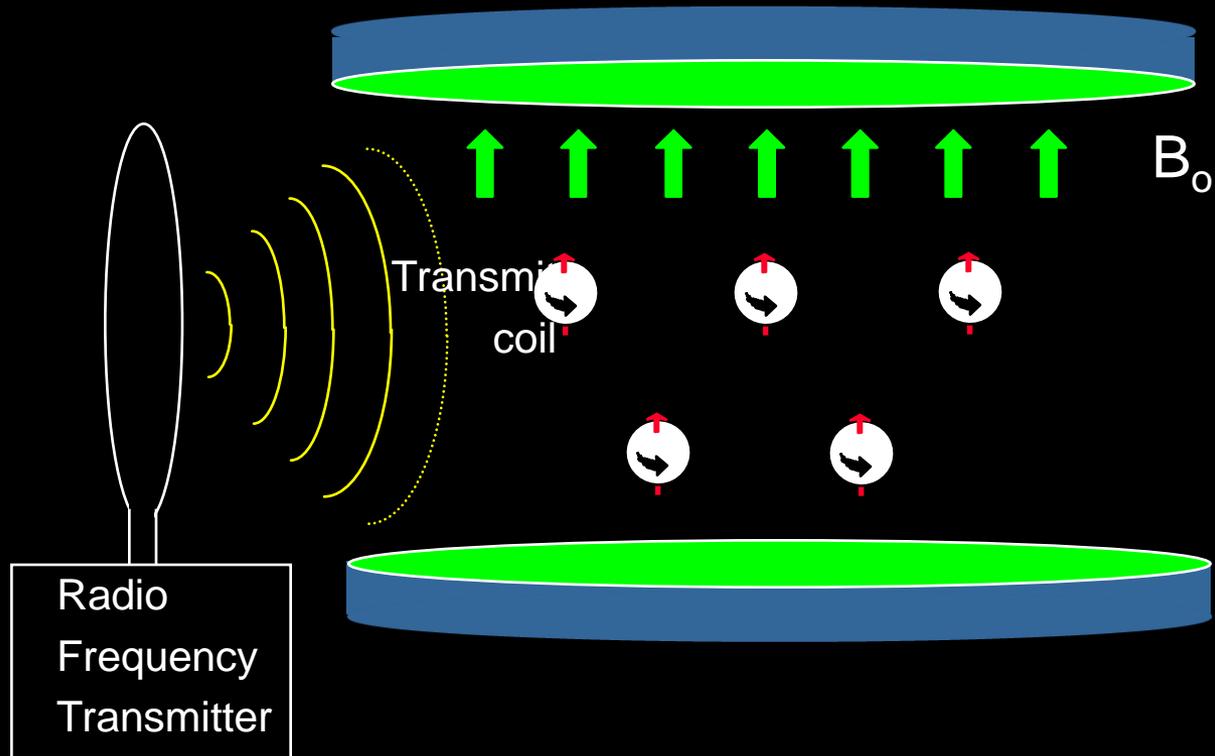
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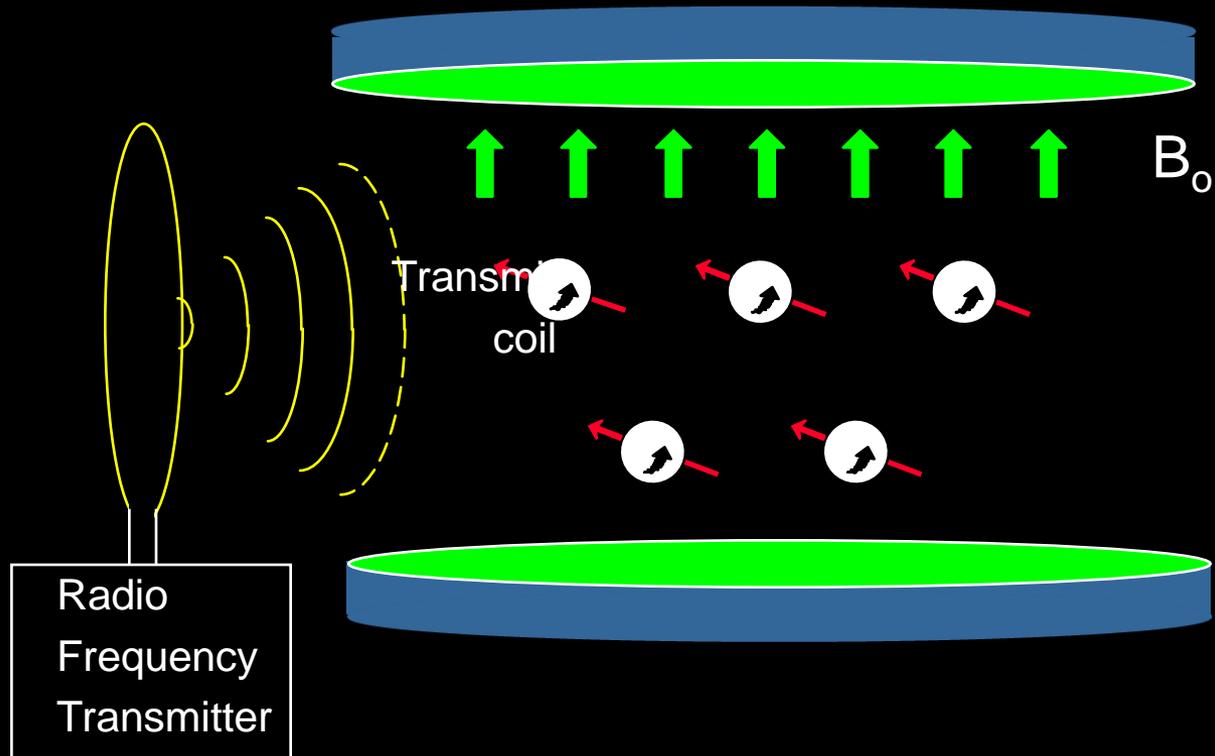
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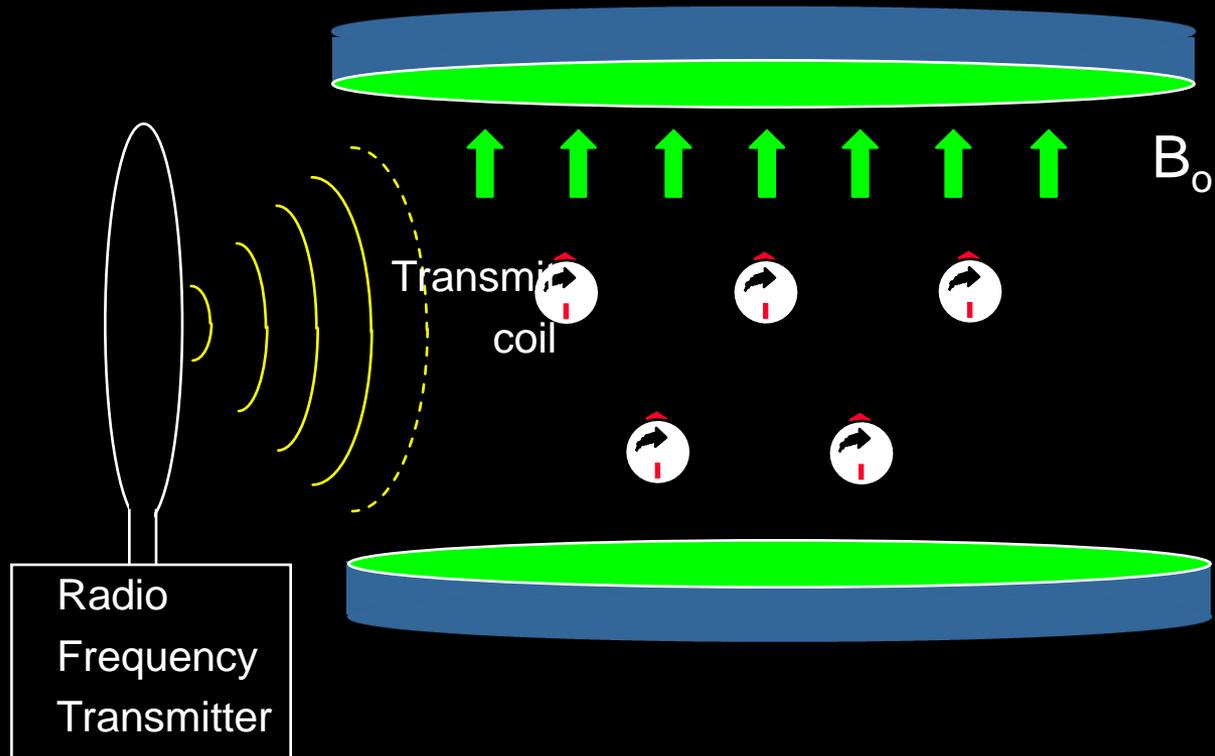
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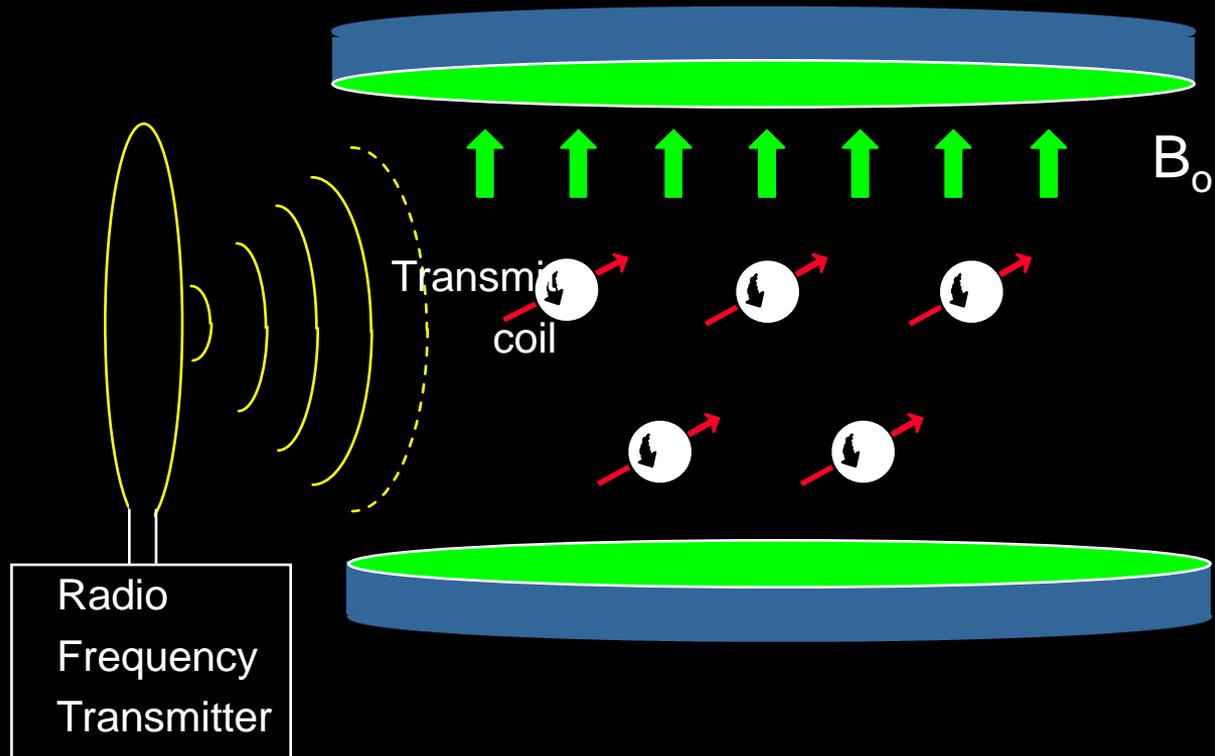
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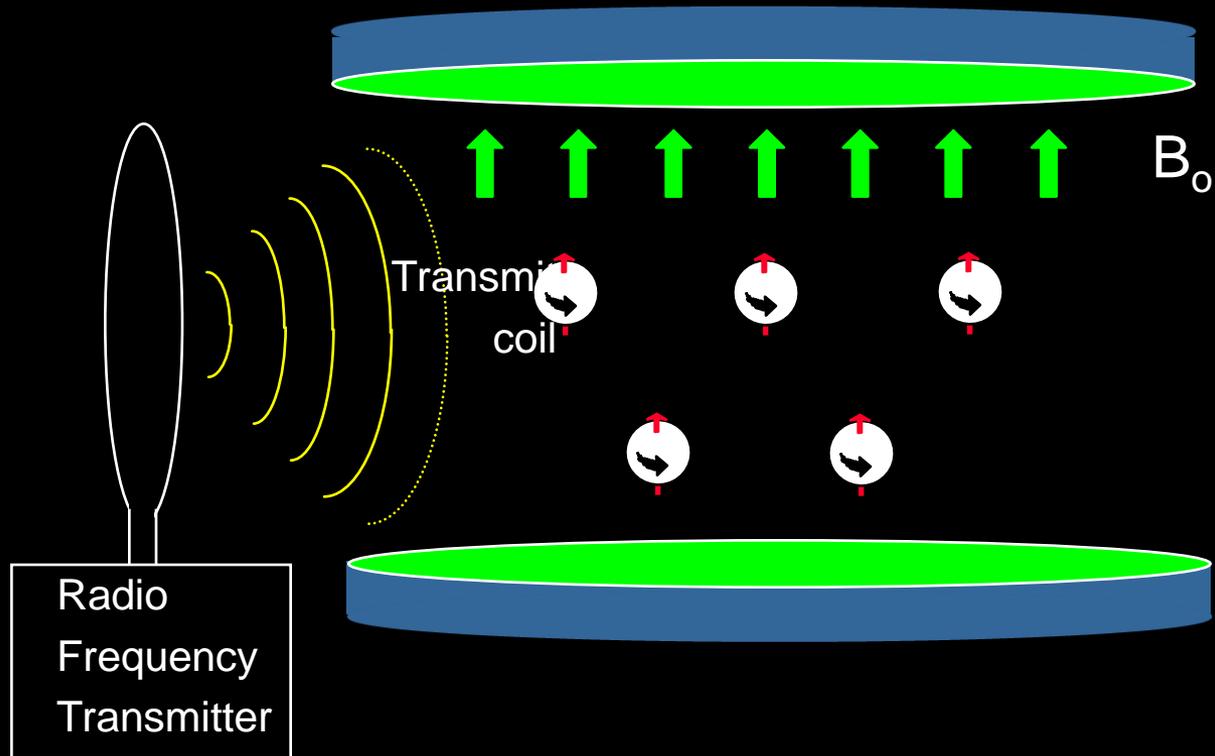
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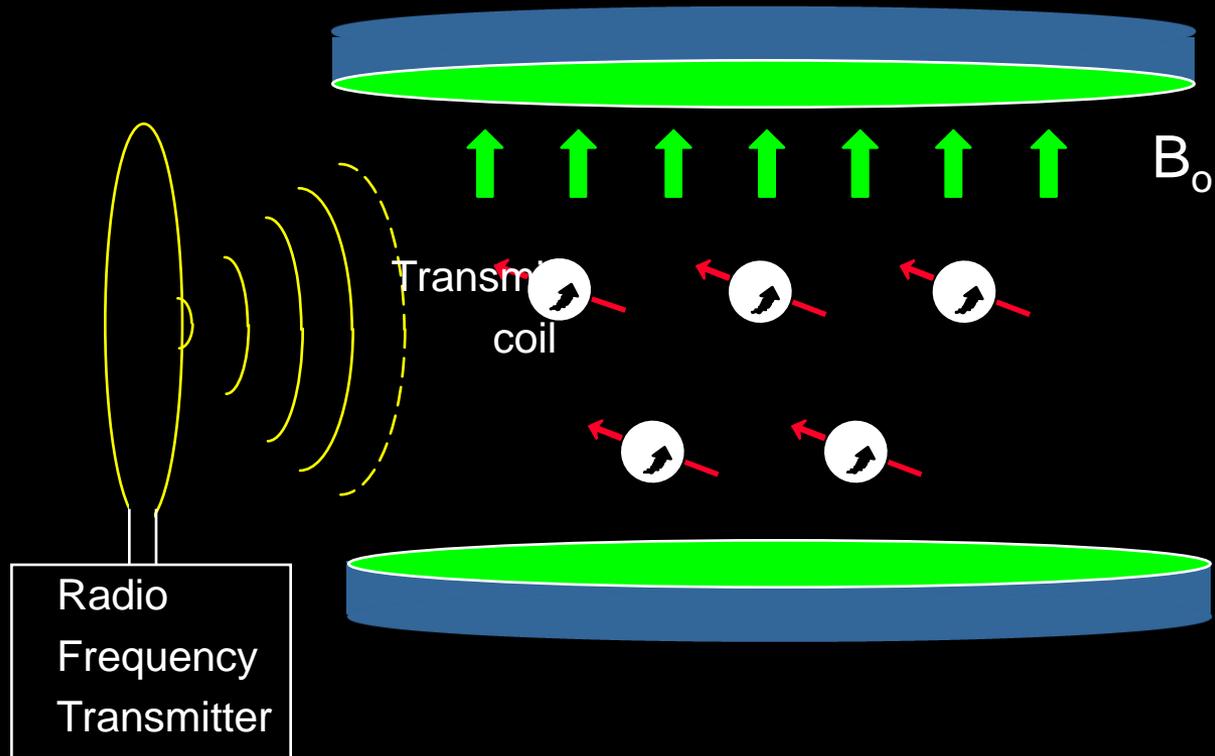
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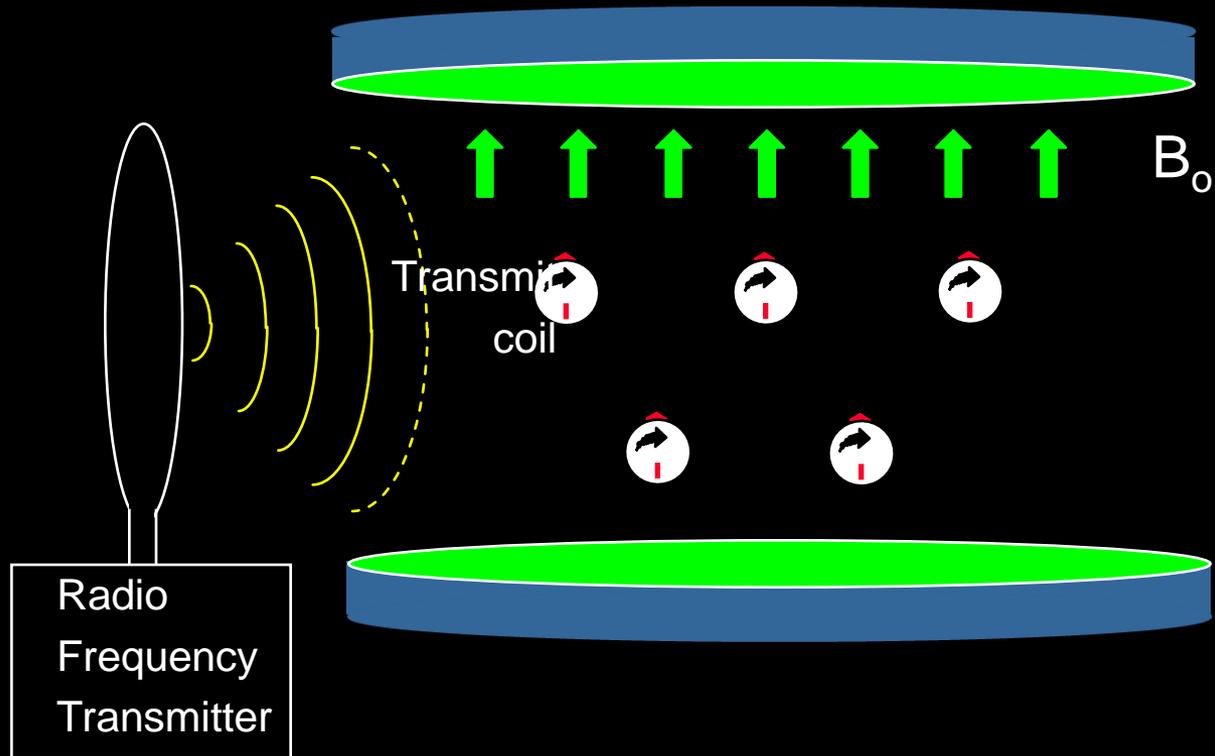
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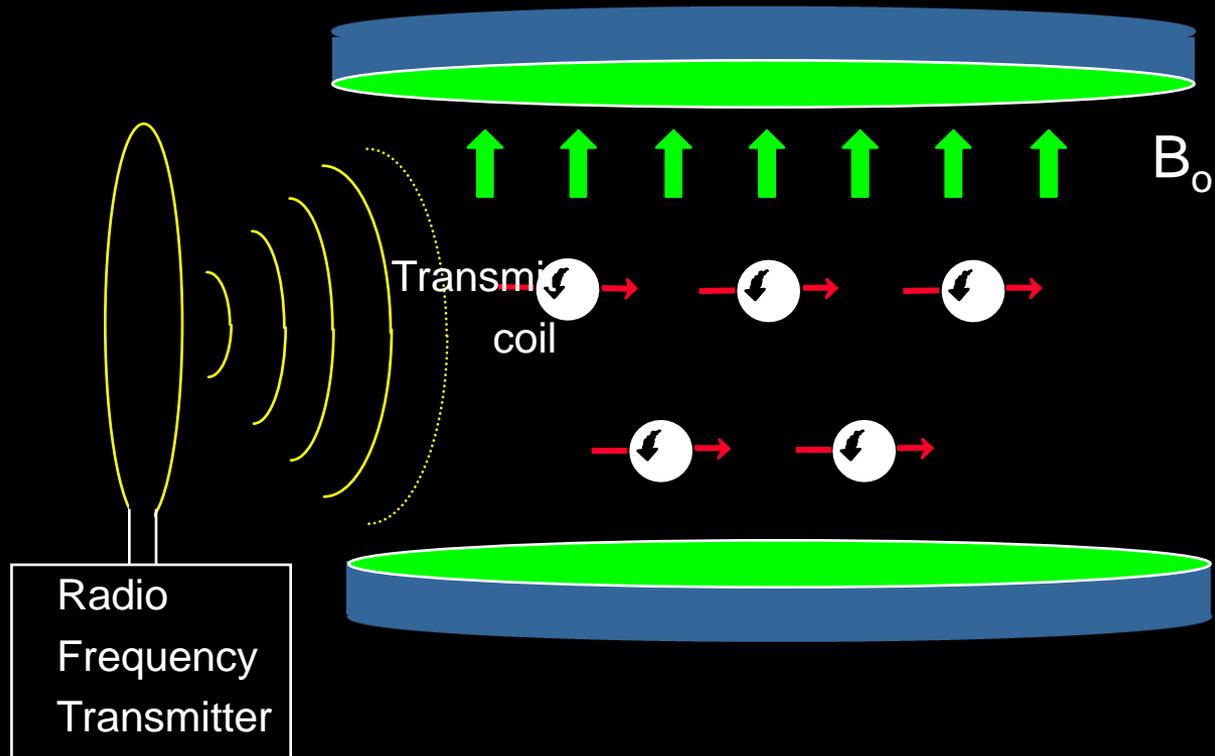
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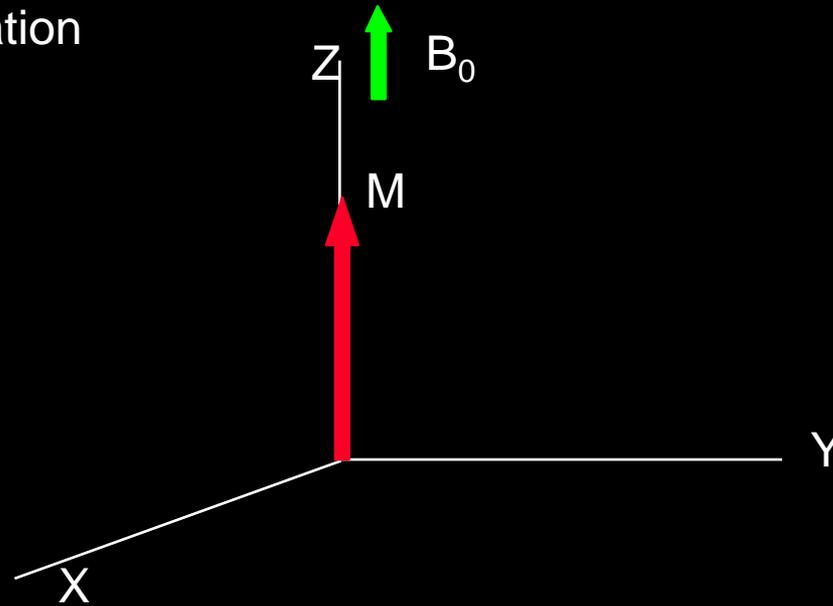


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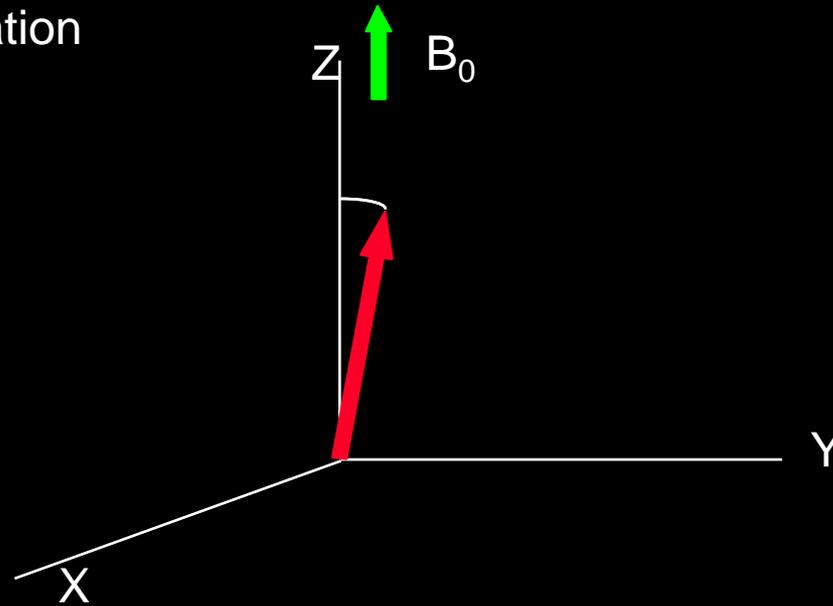
Excitation

net magnetisation
and
90° pulse



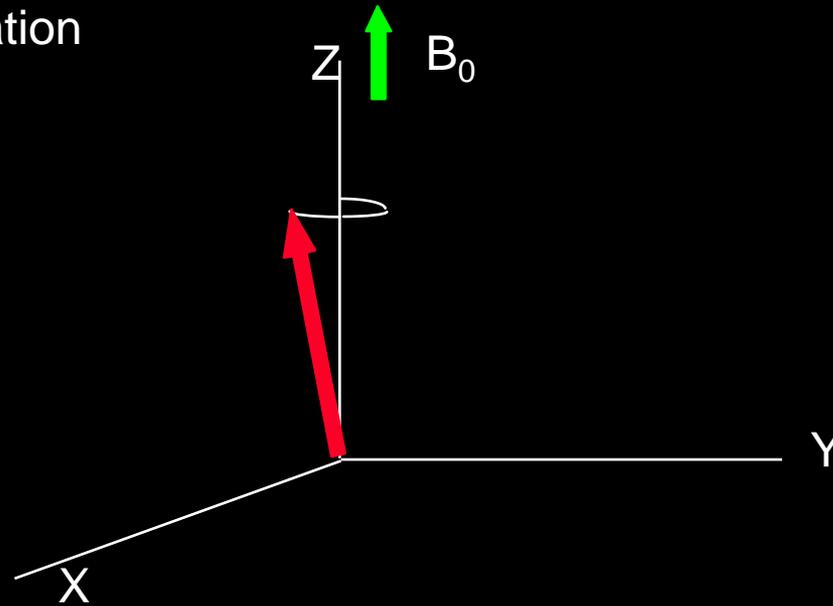
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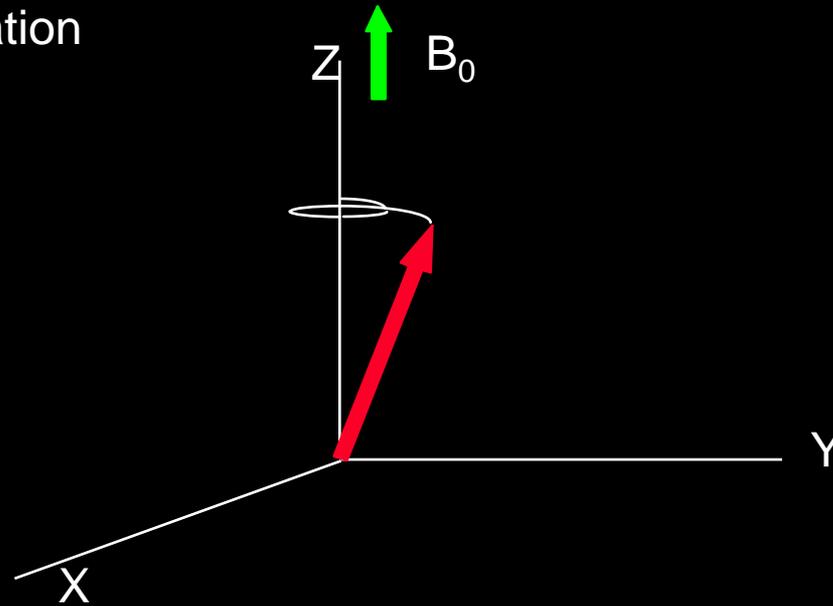
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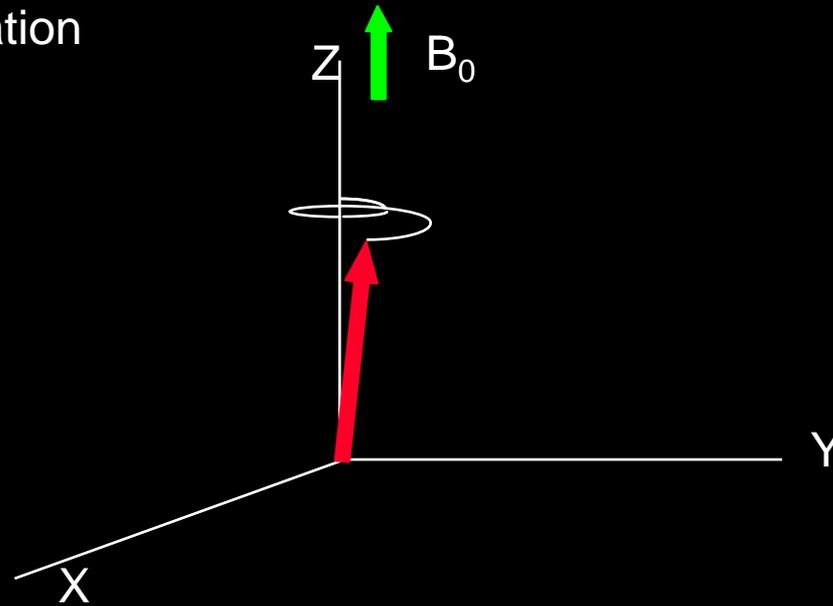
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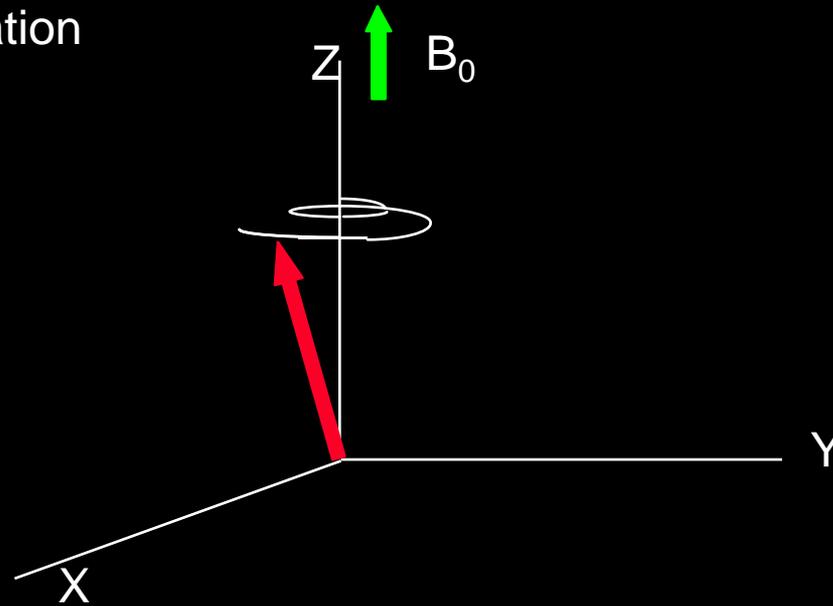
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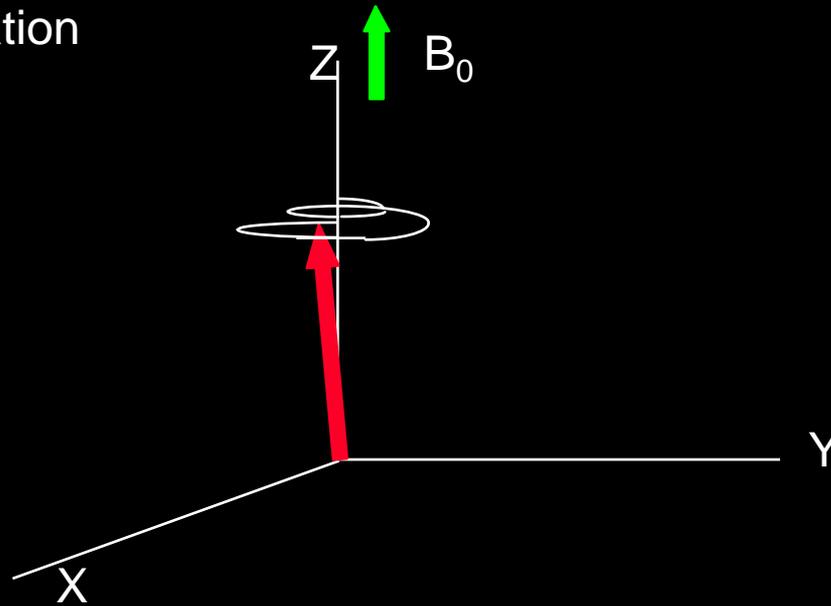
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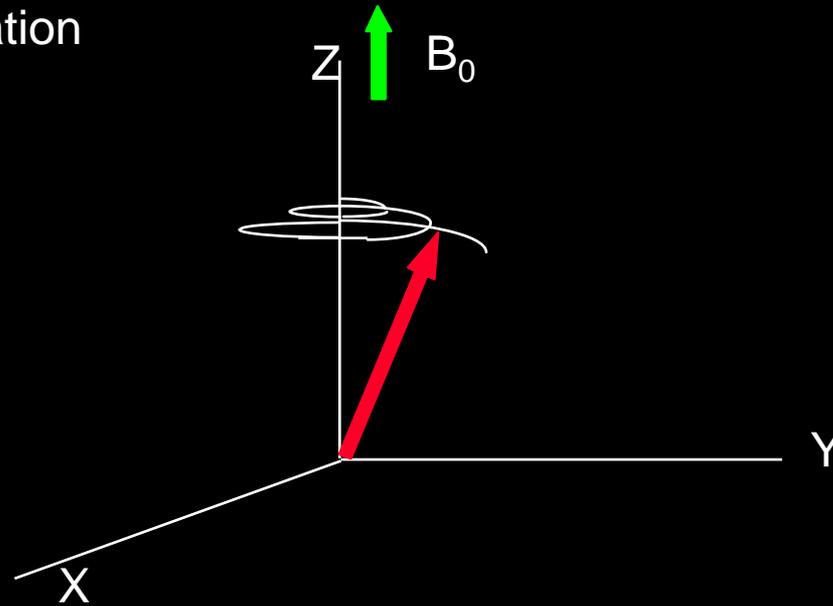
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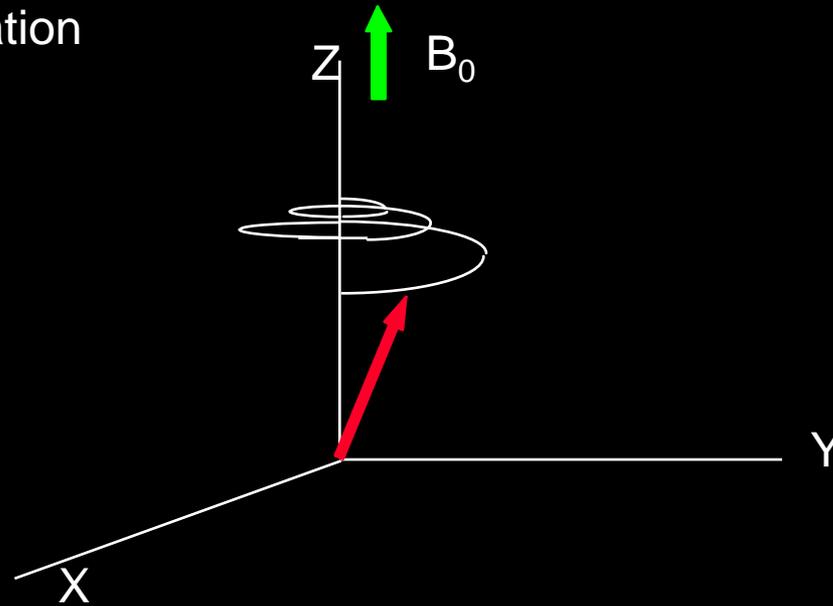
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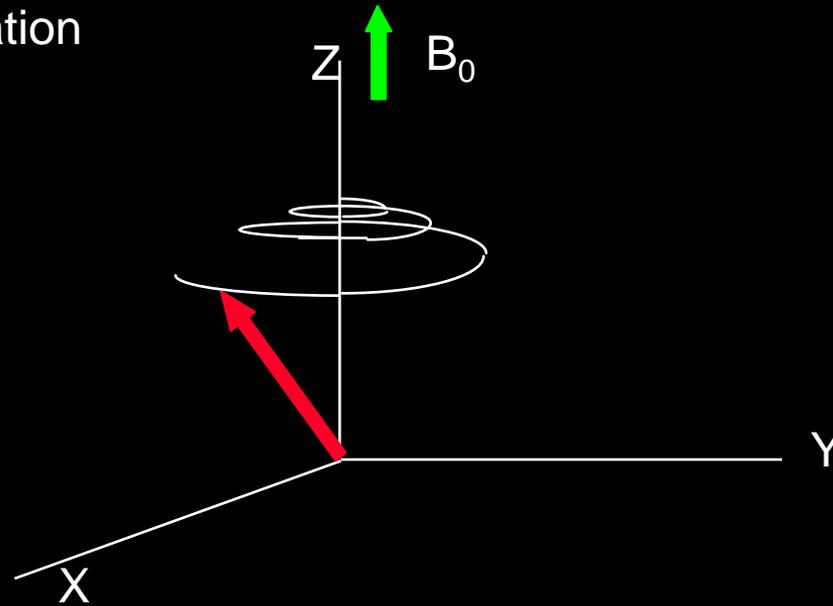
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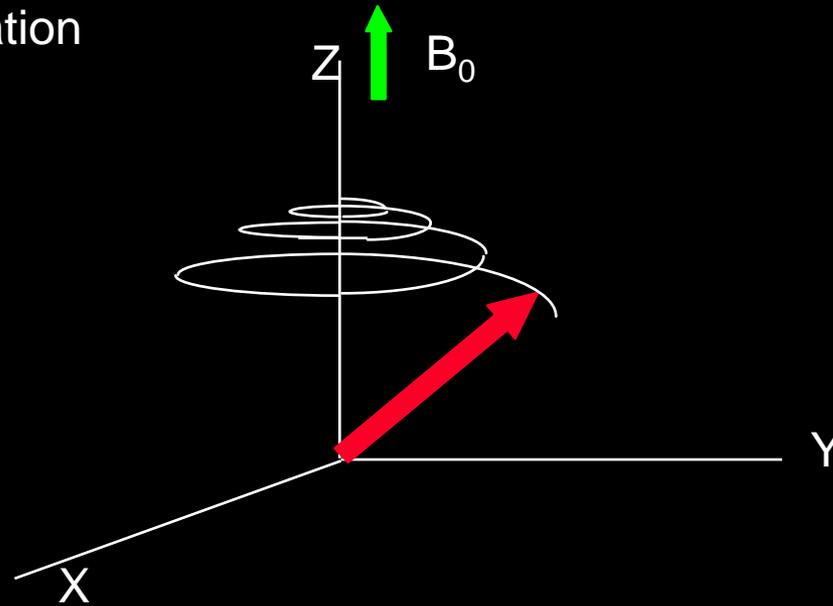
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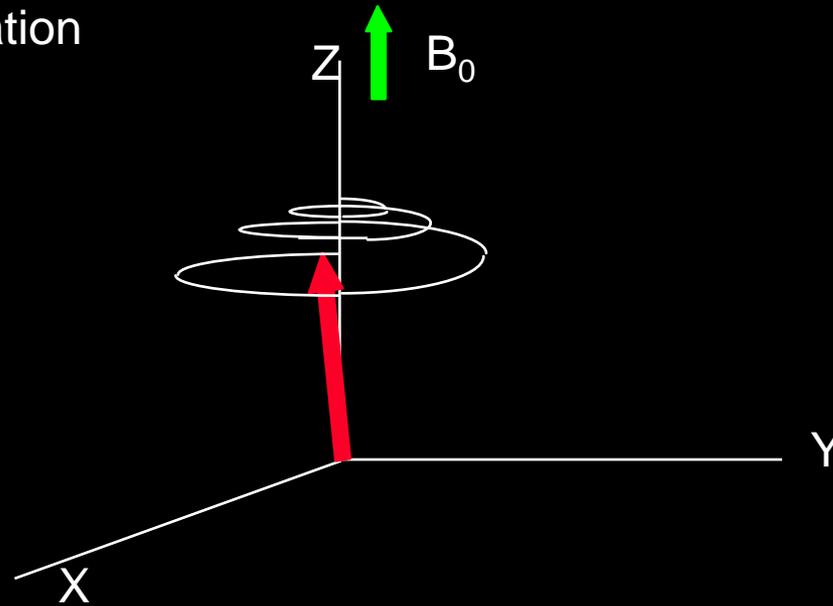
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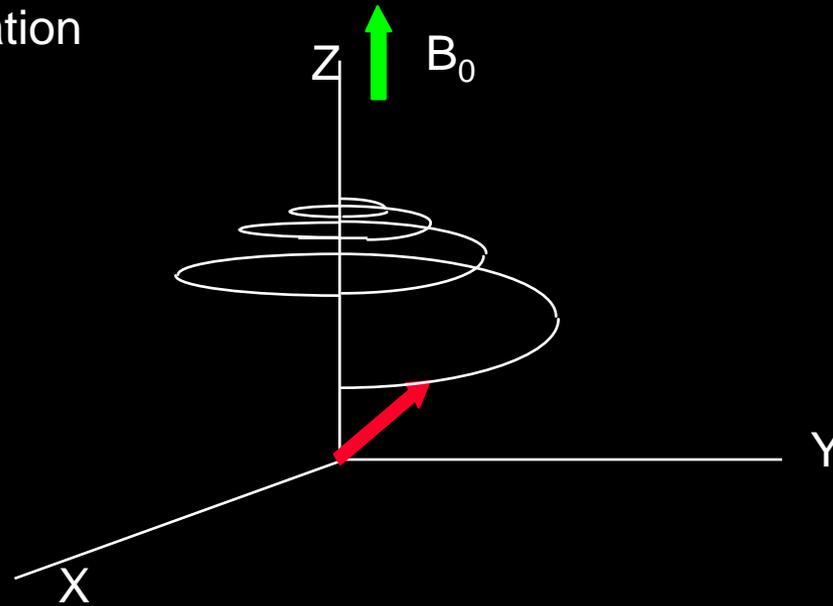
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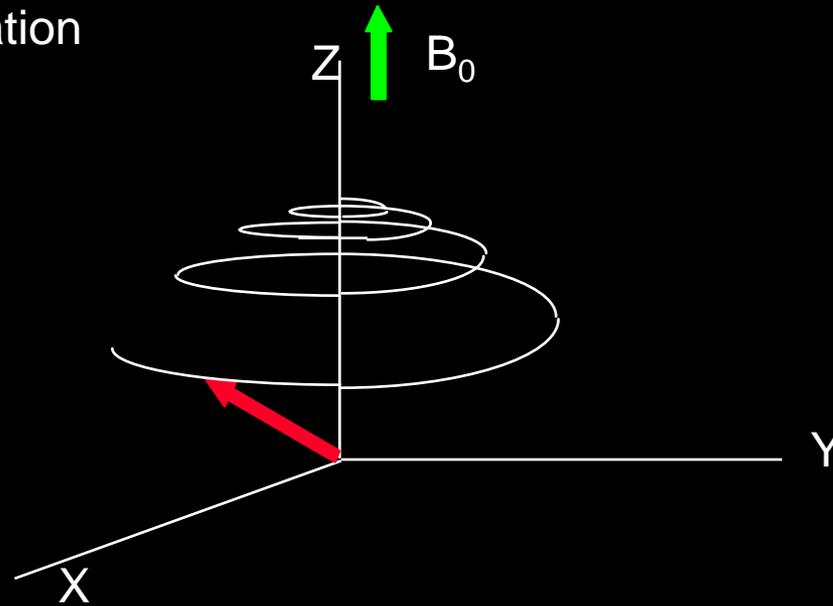
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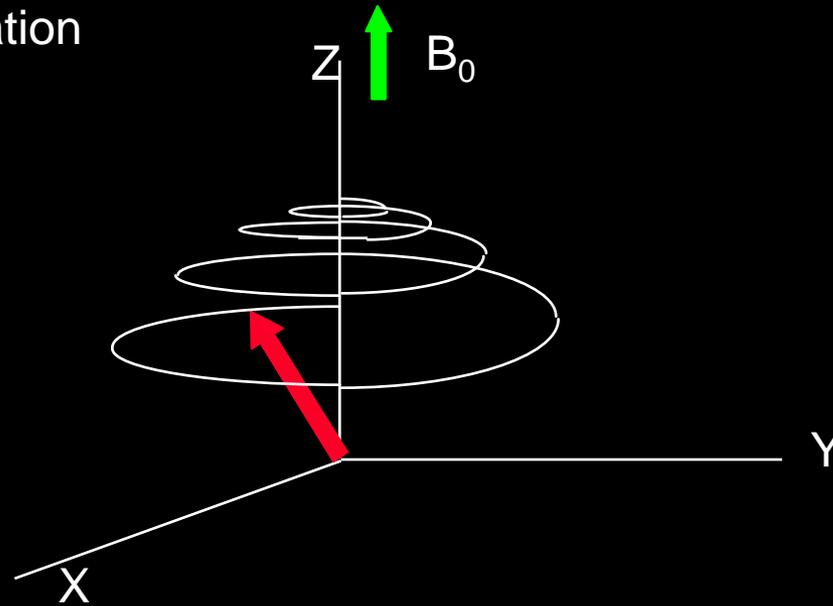
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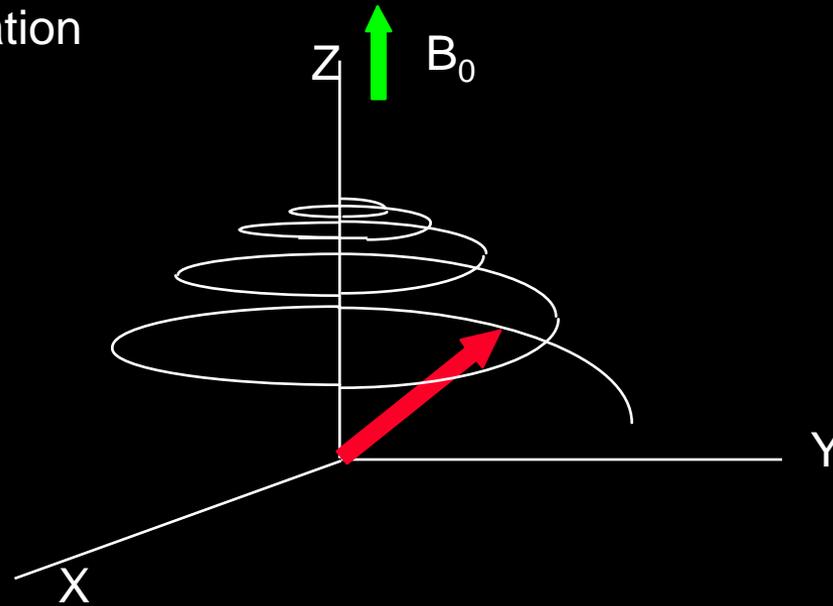
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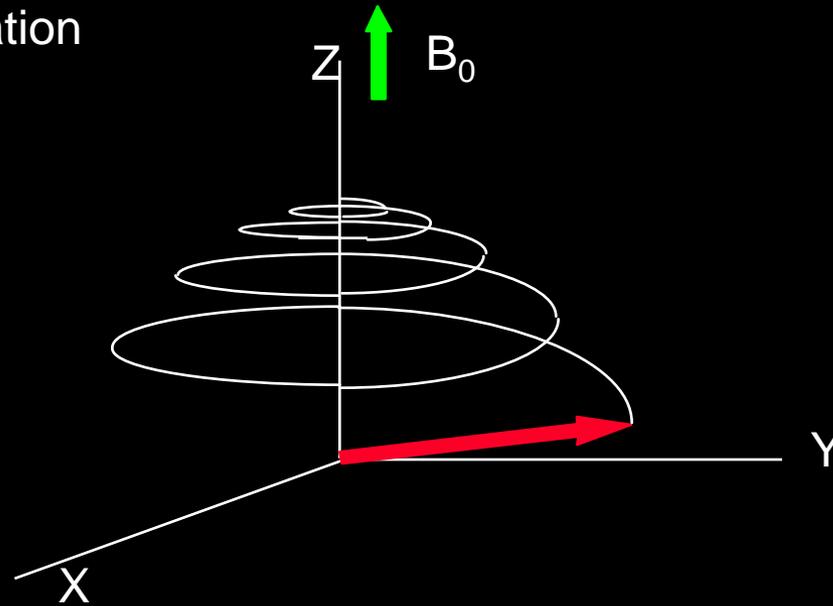
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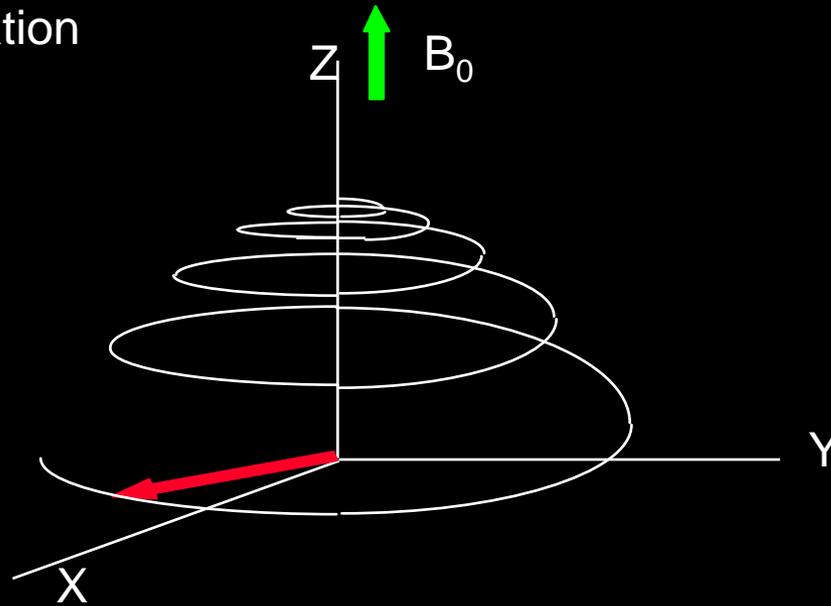
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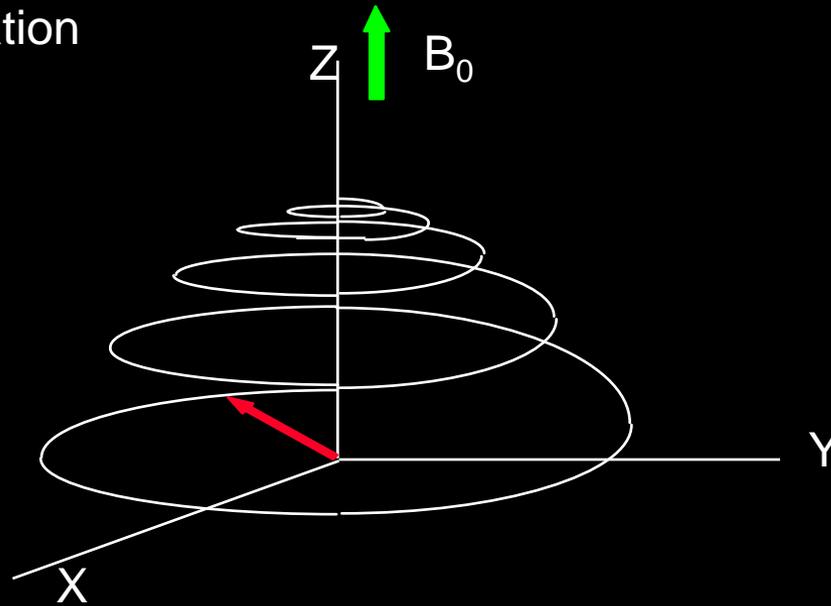
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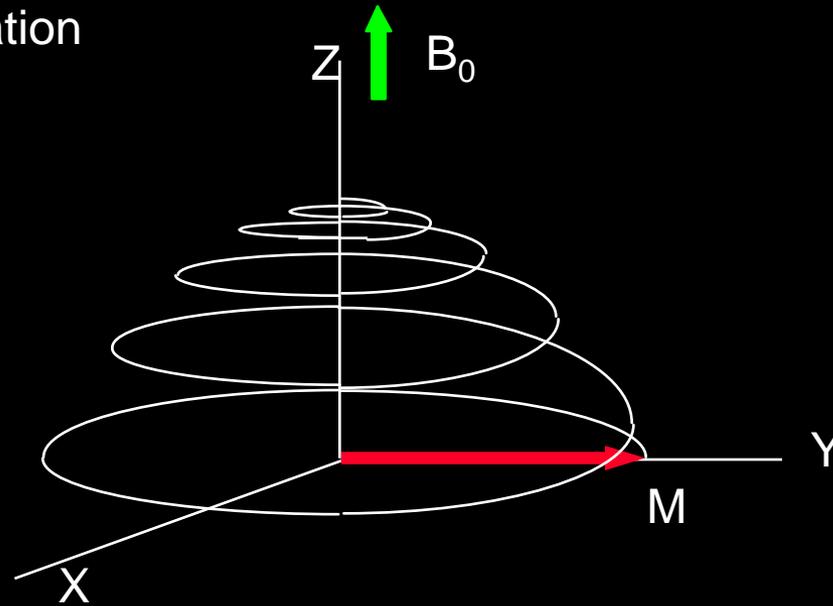
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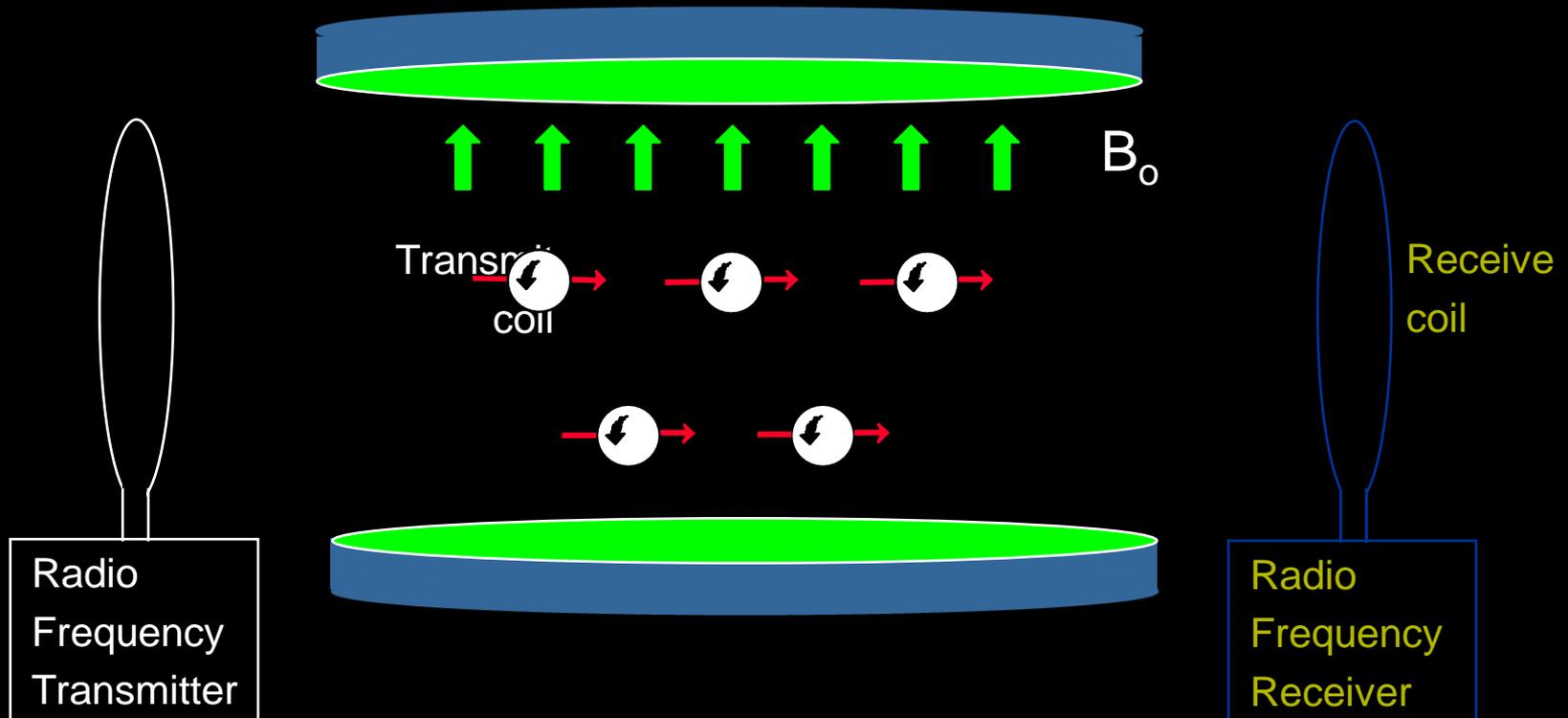


MR : generazione del segnale

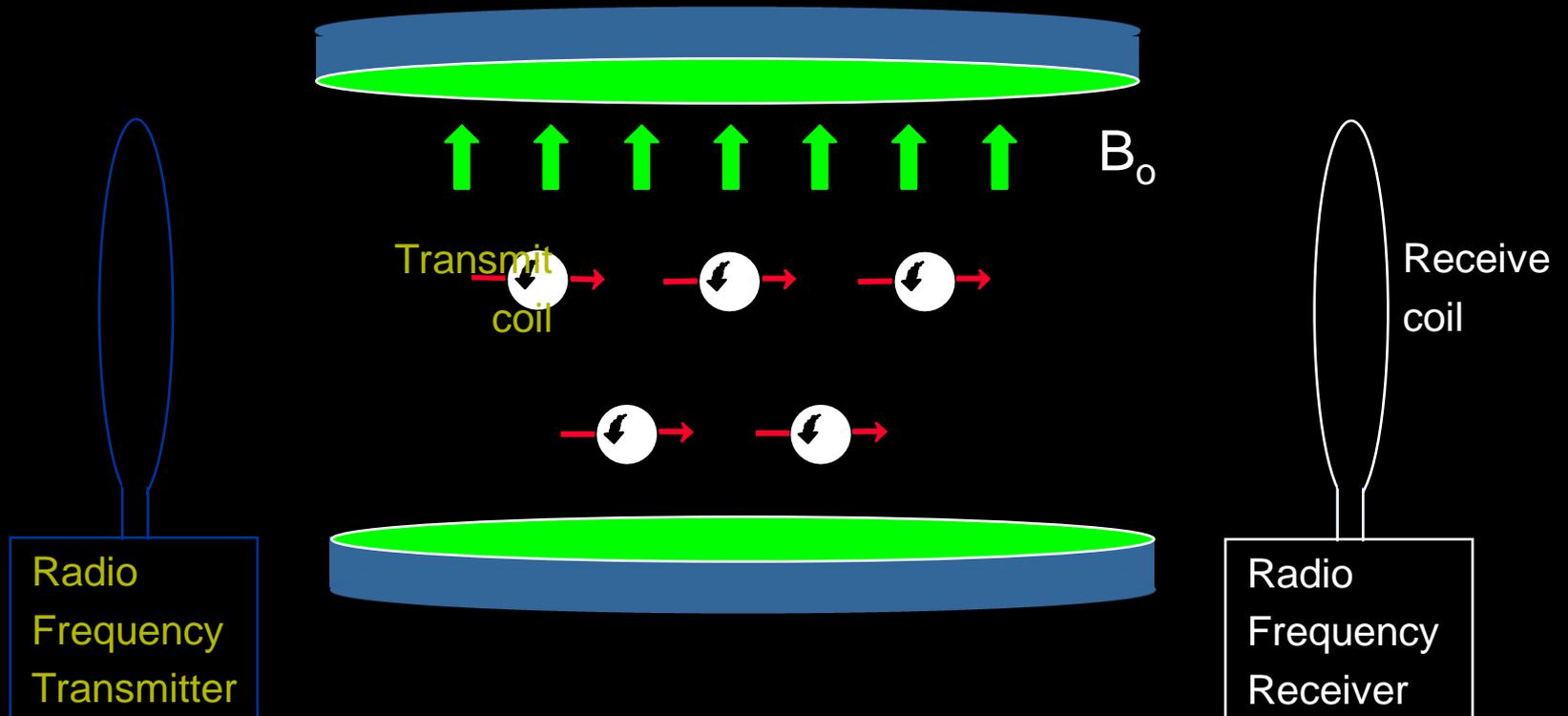
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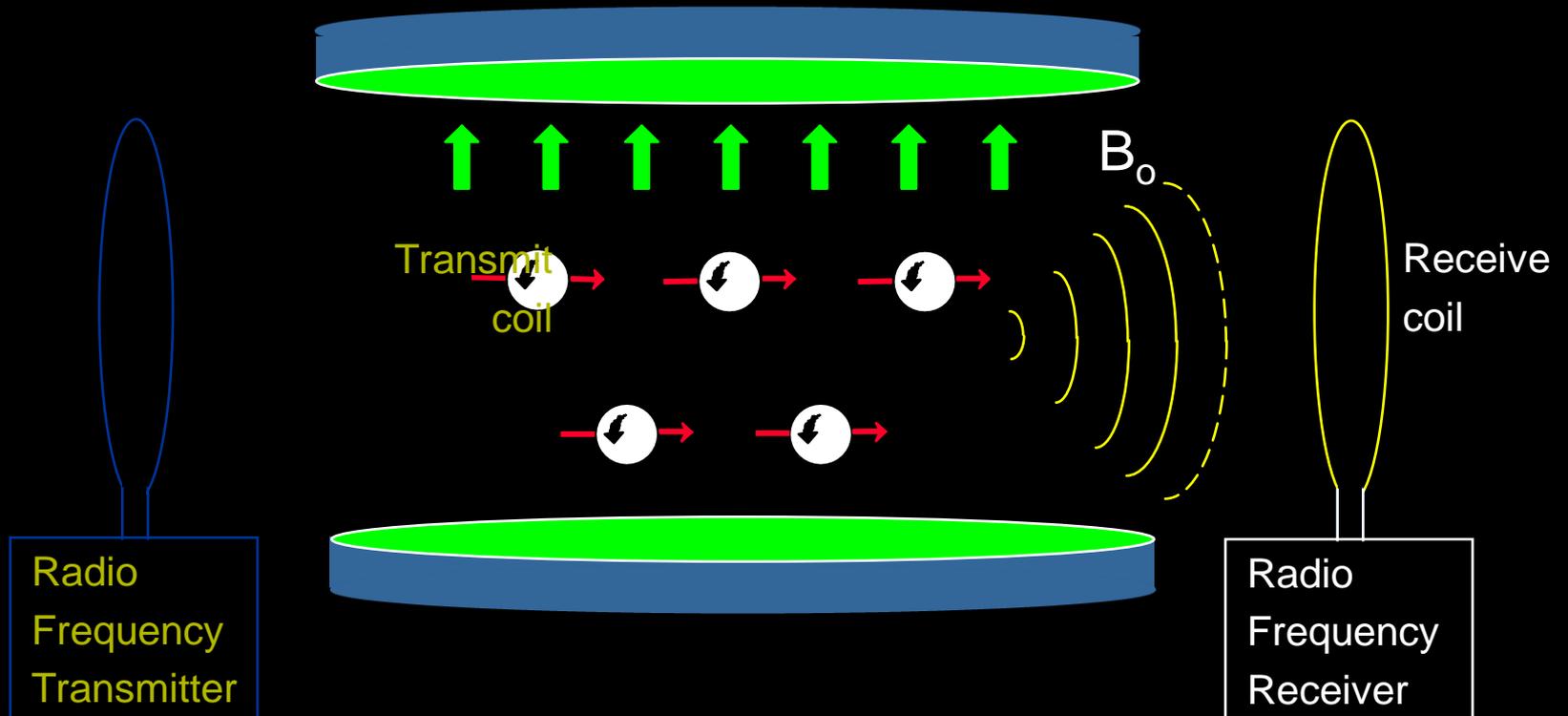
Relaxation



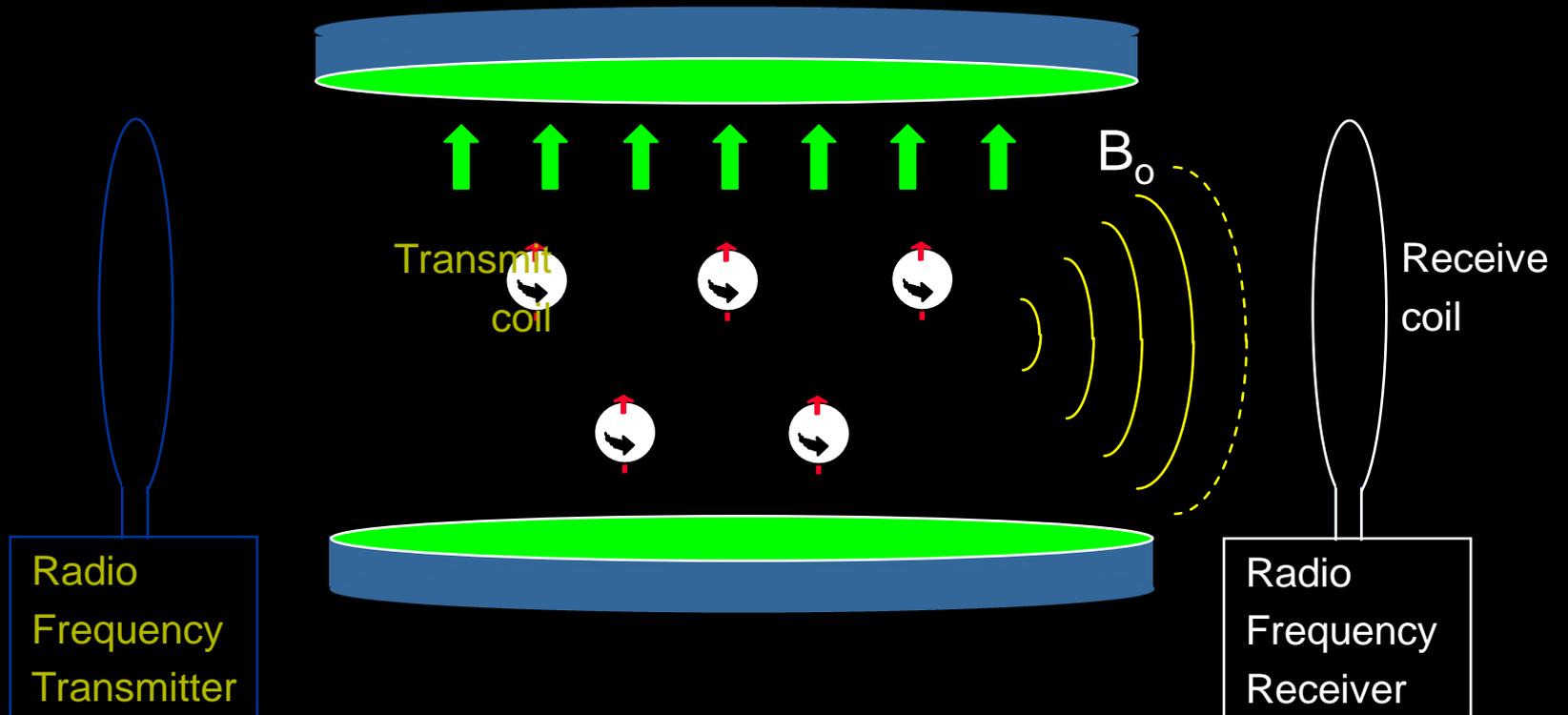
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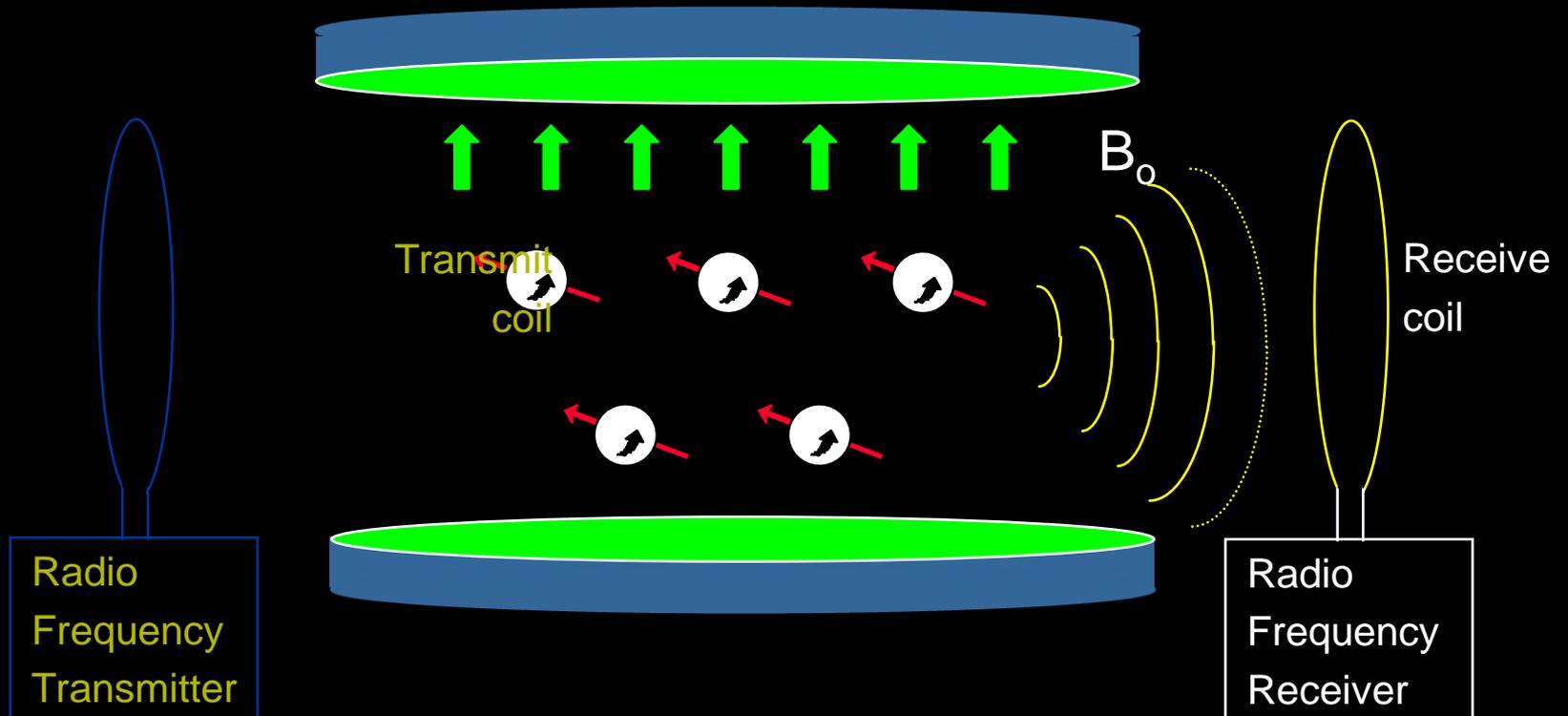
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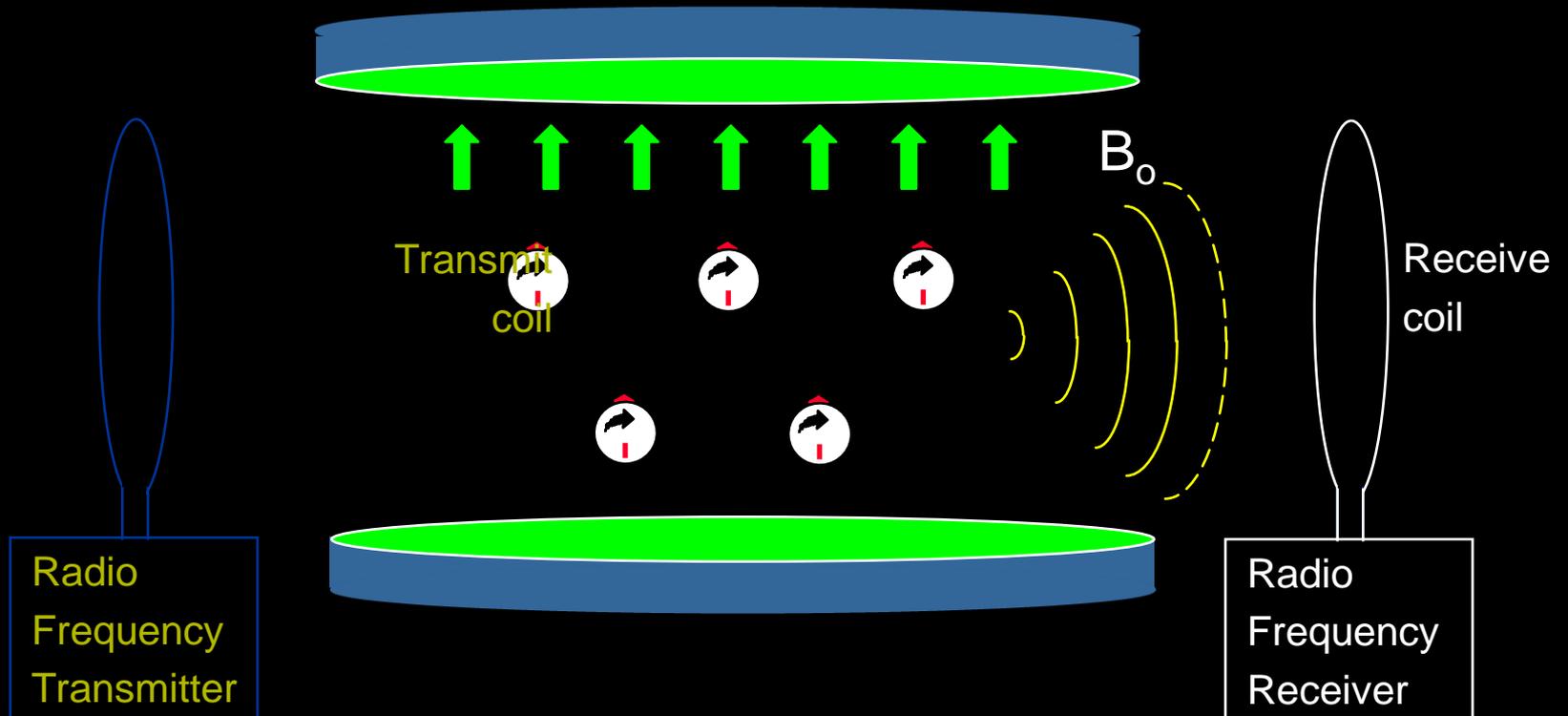
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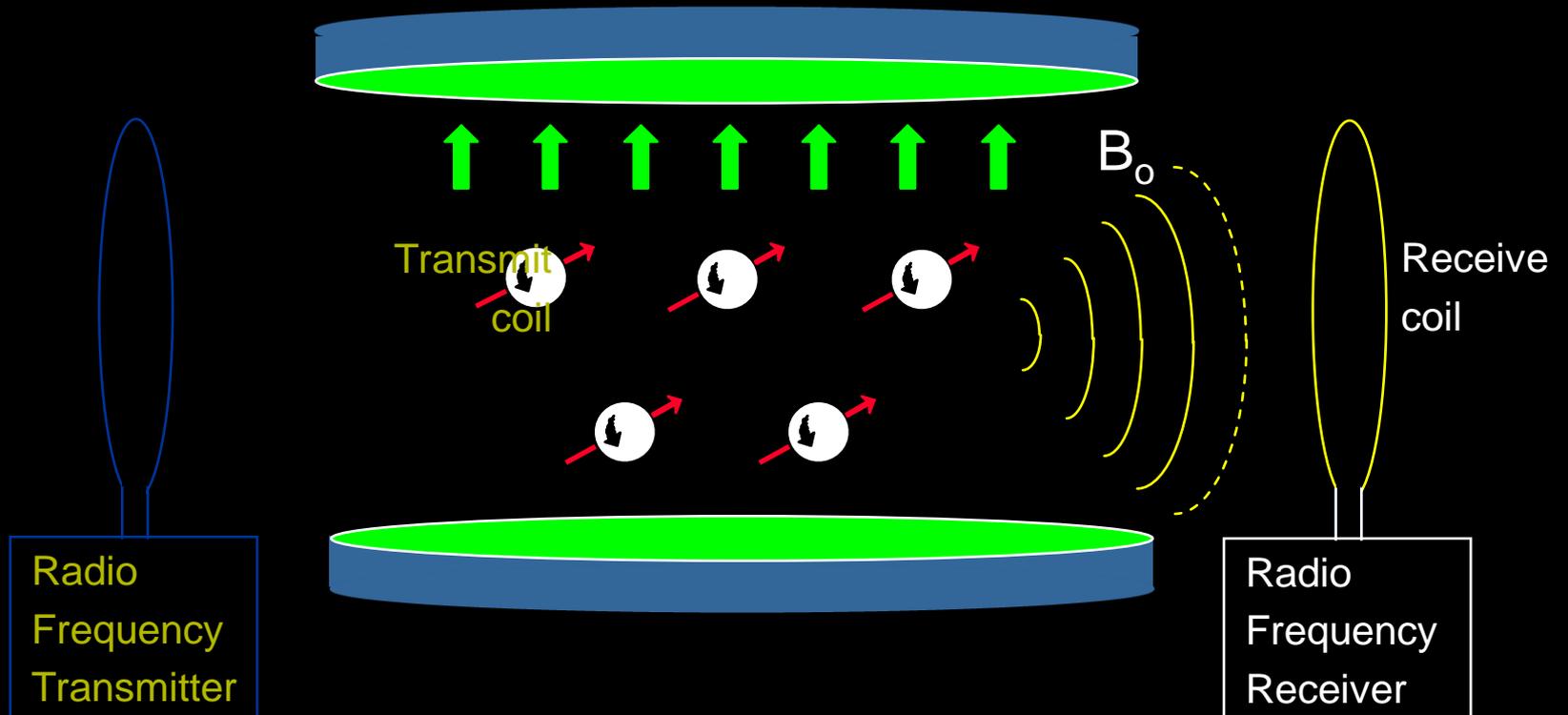
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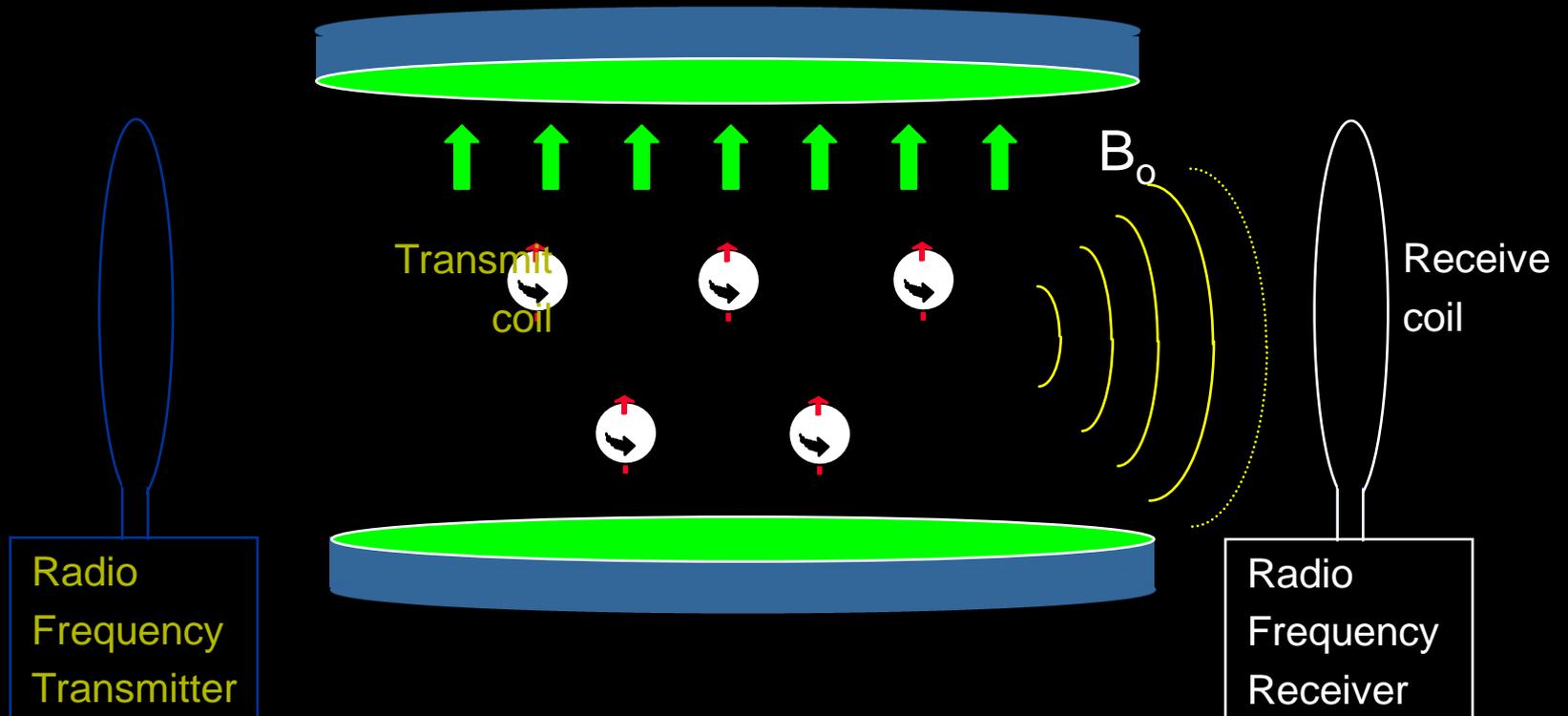
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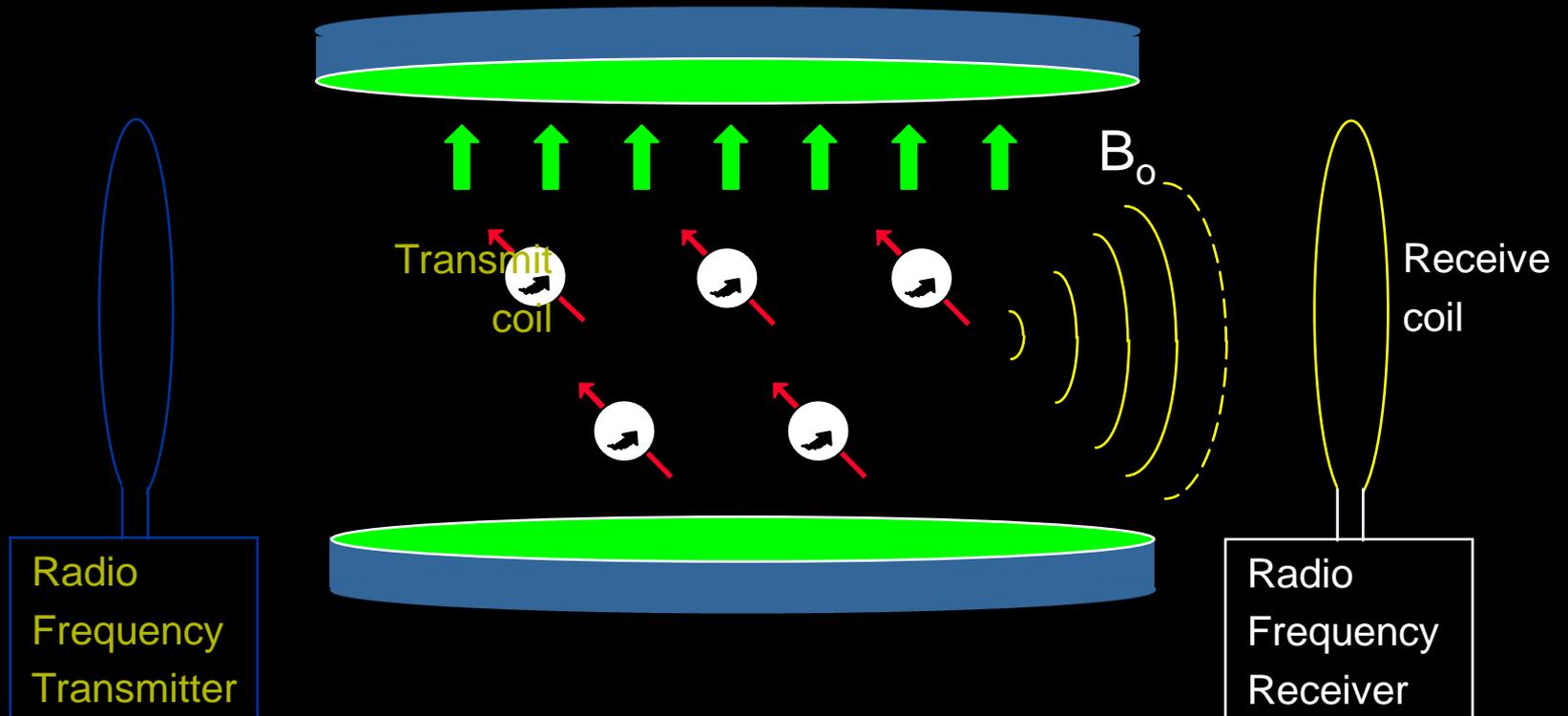
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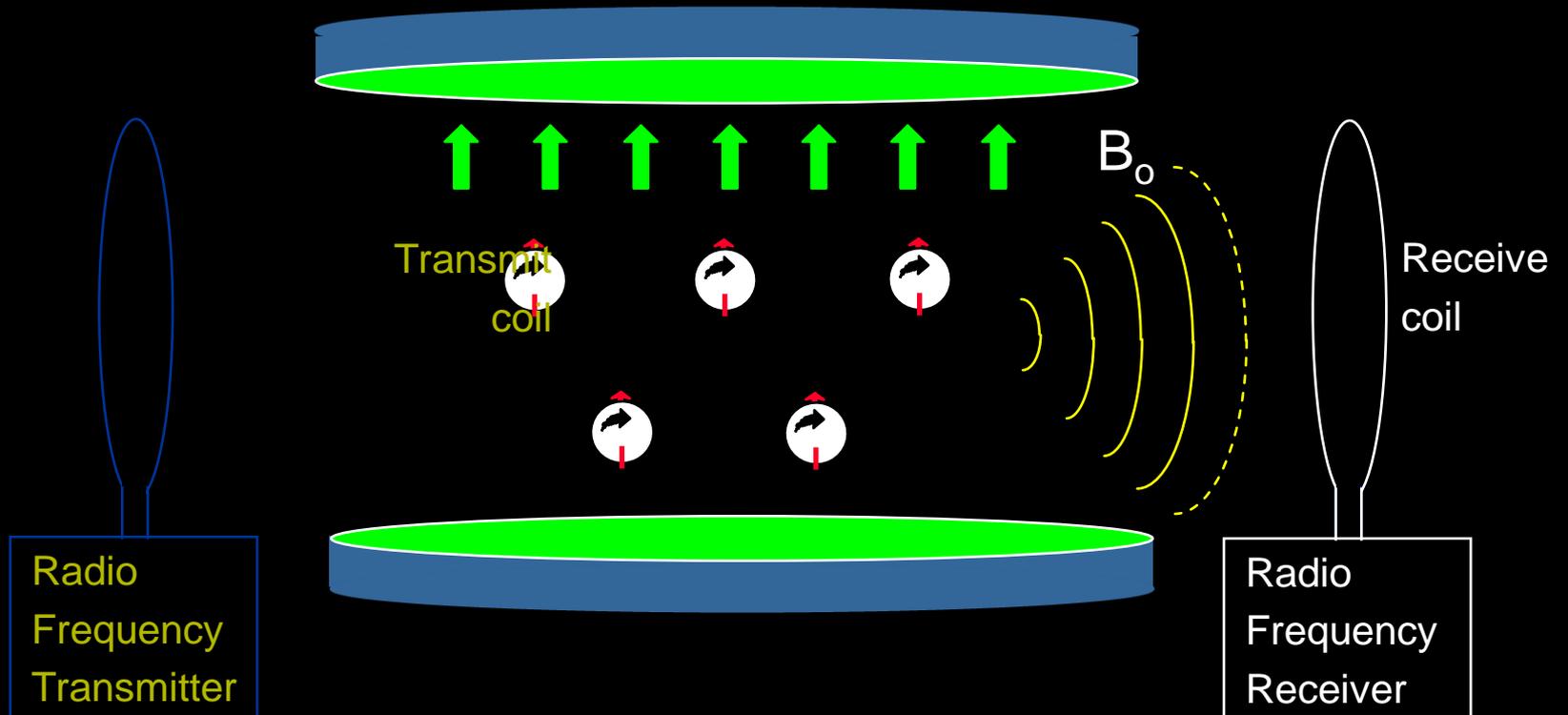
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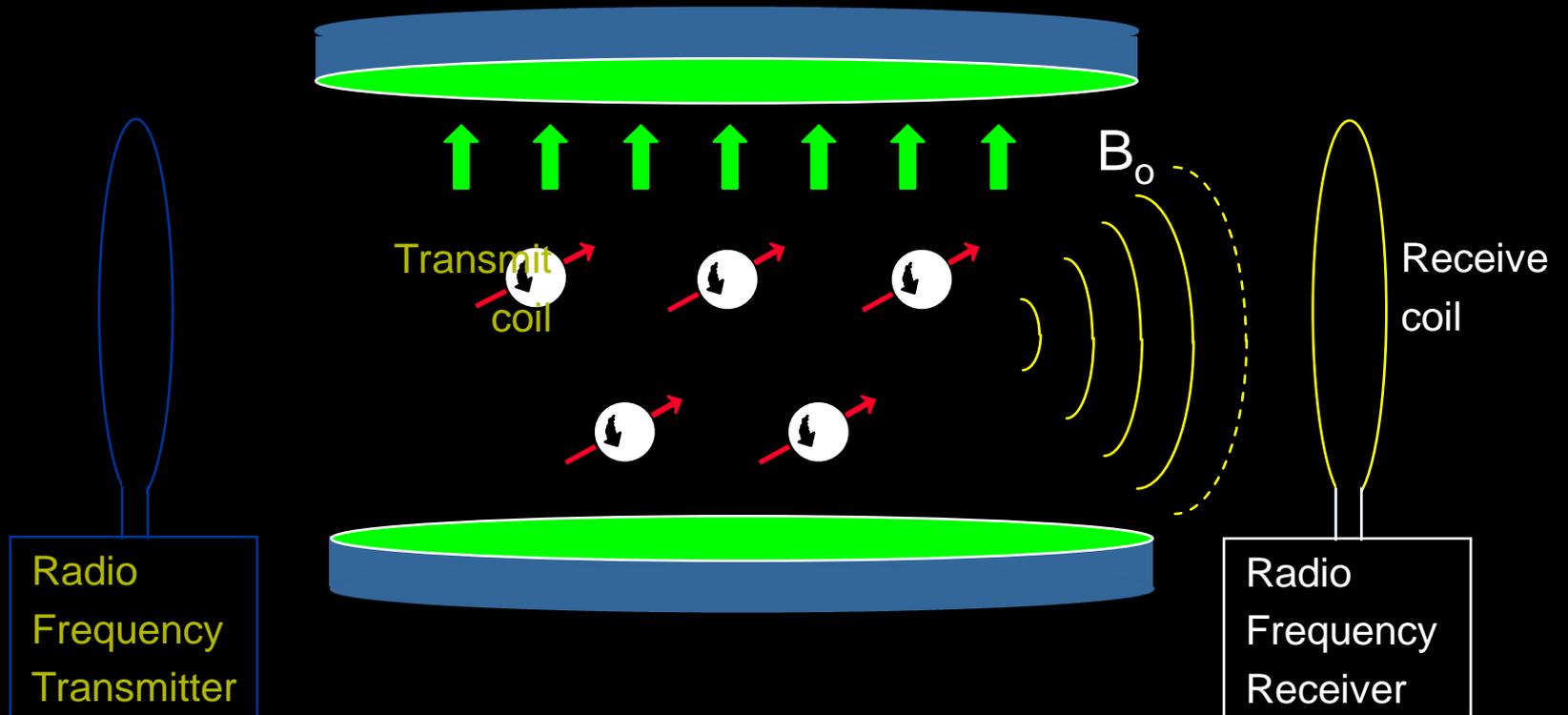
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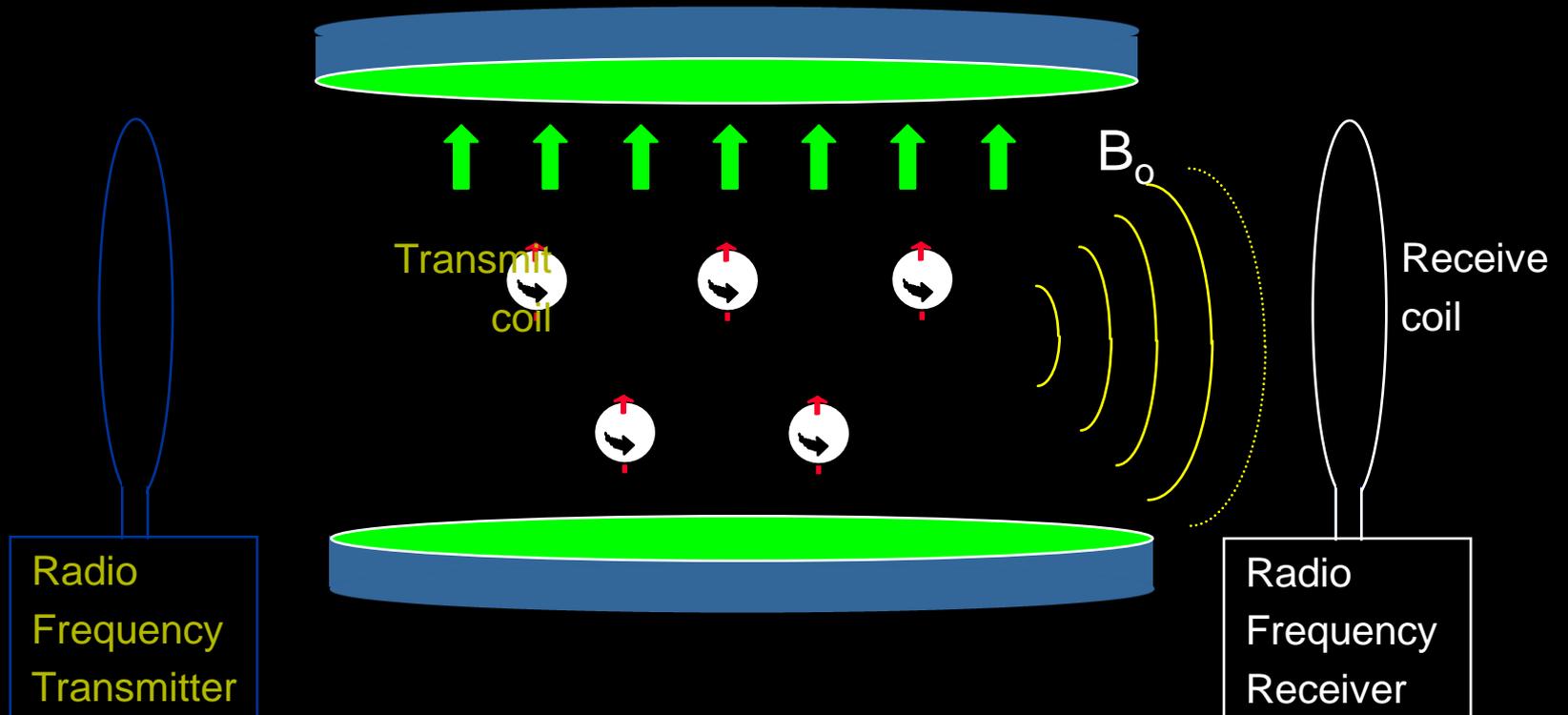
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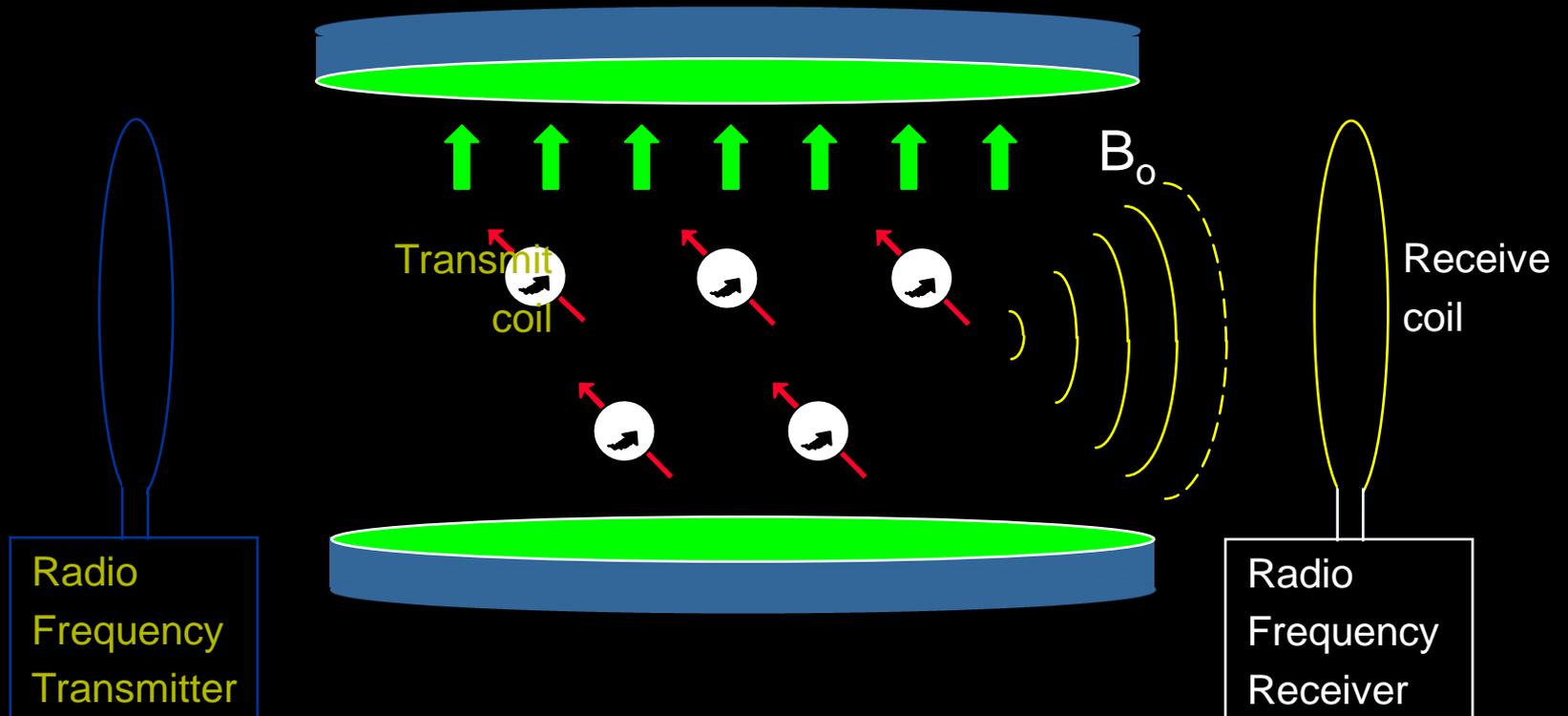
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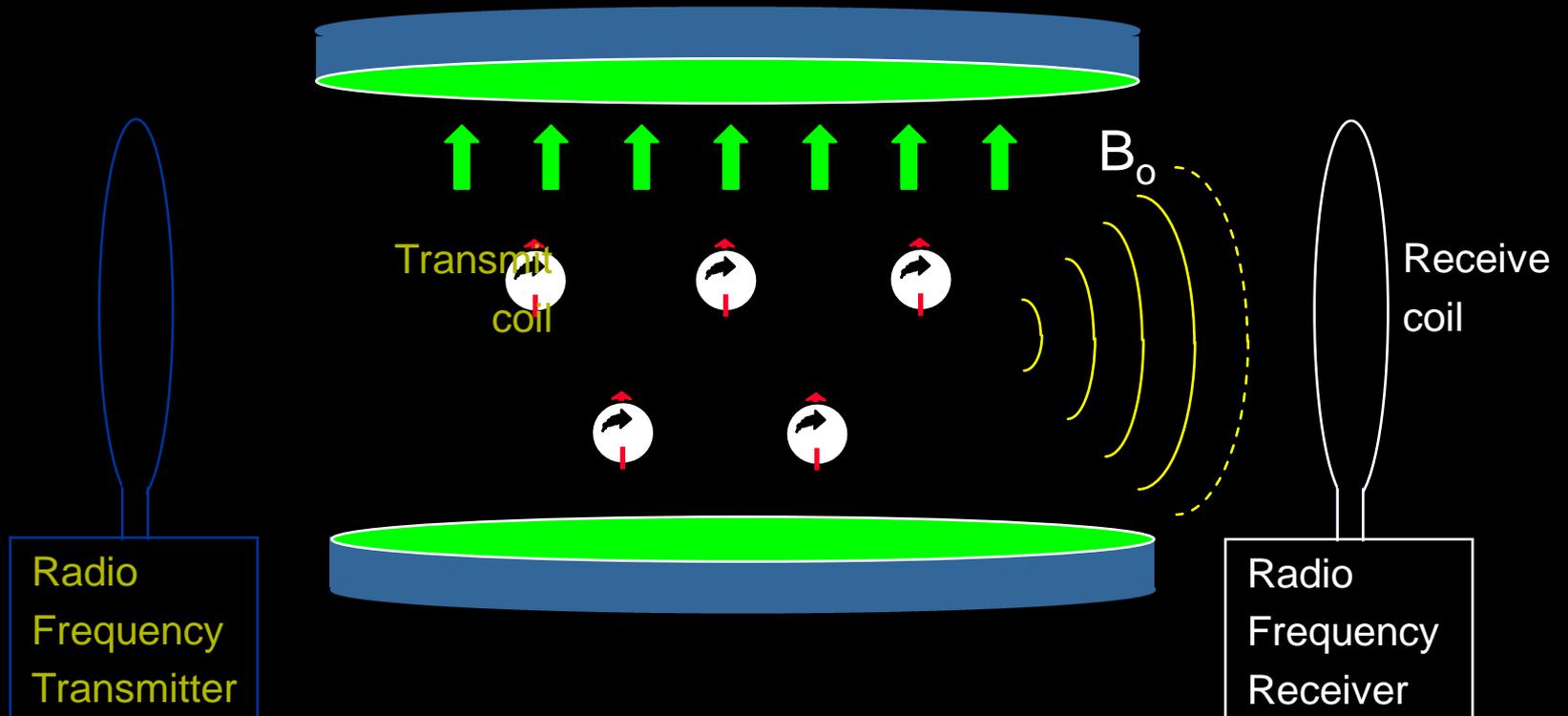
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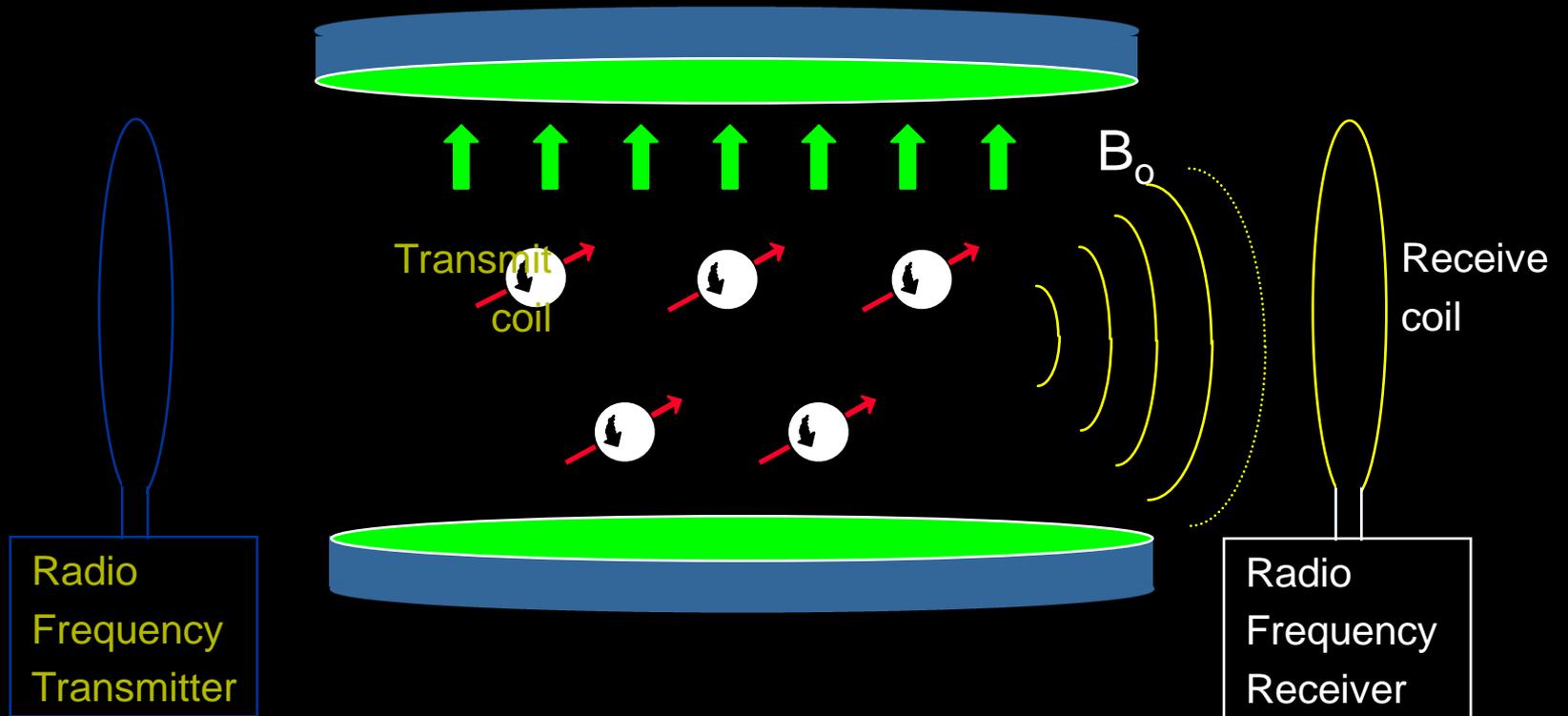
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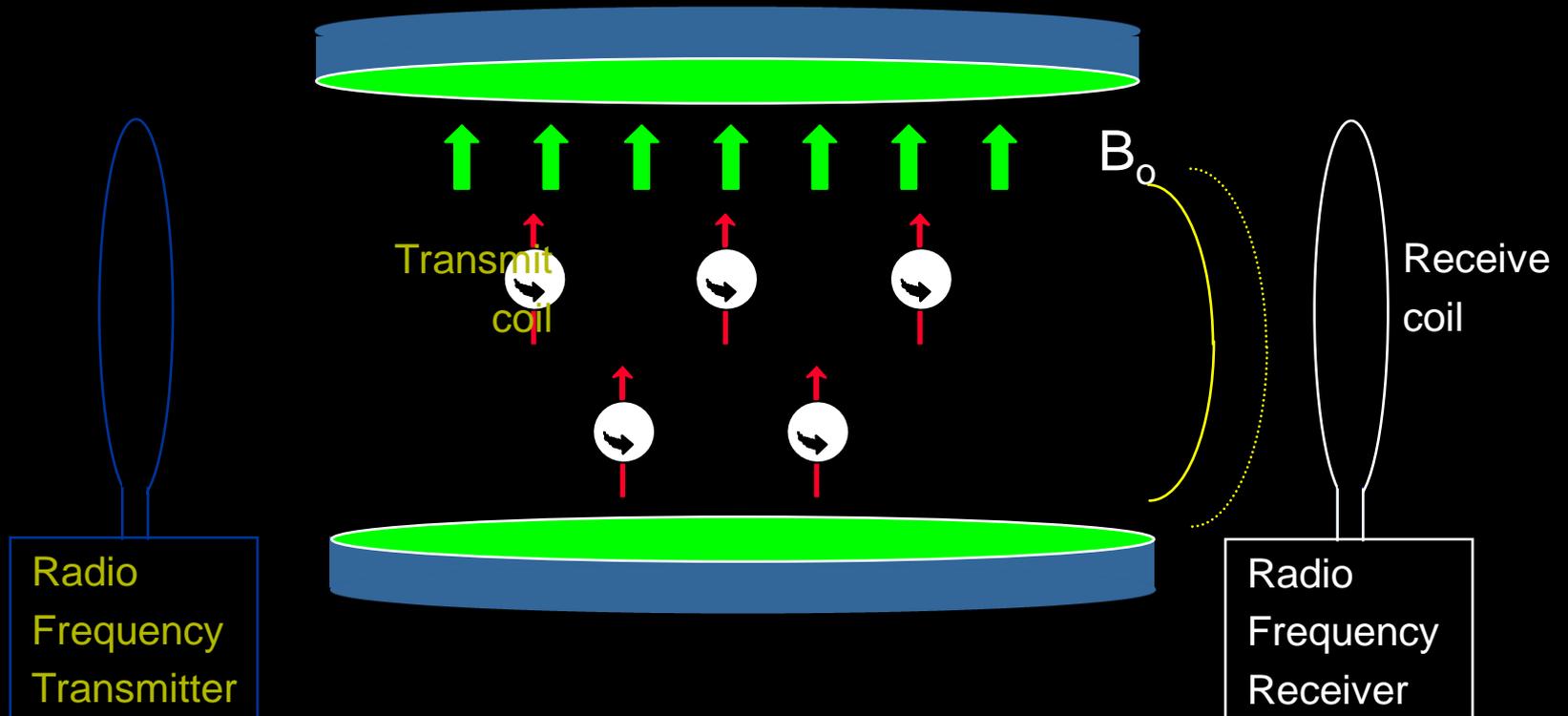
Relaxation



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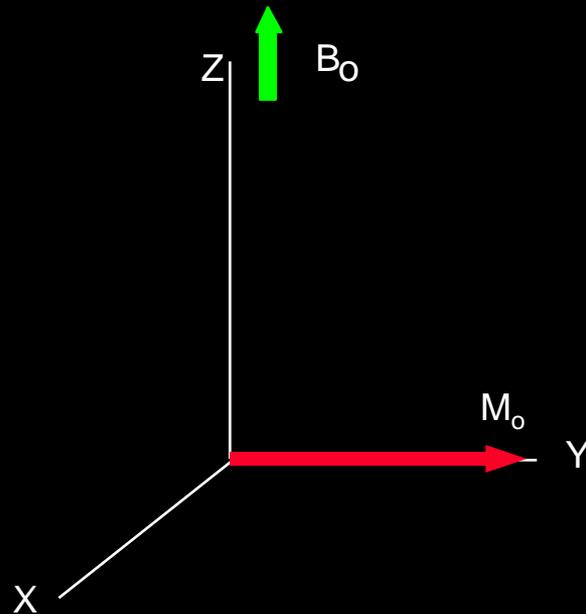


Relaxation



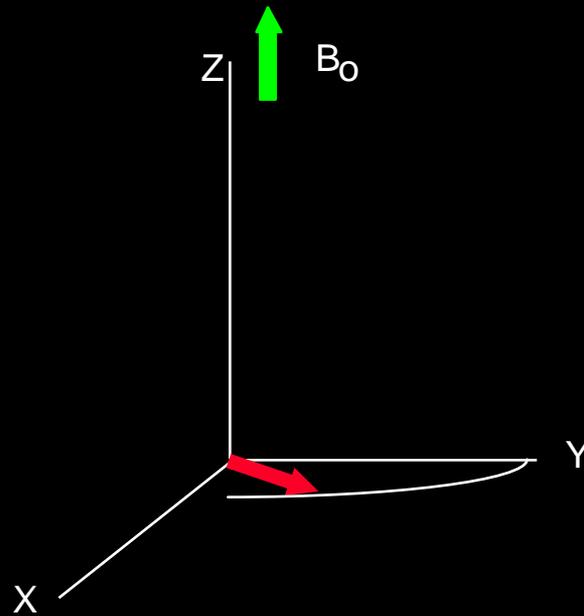
MR signal characteristics

Relaxation proces



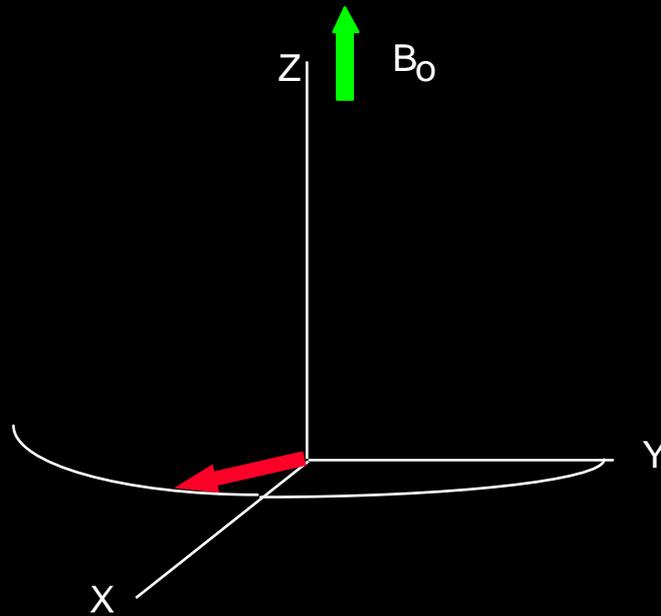
MR signal characteristics

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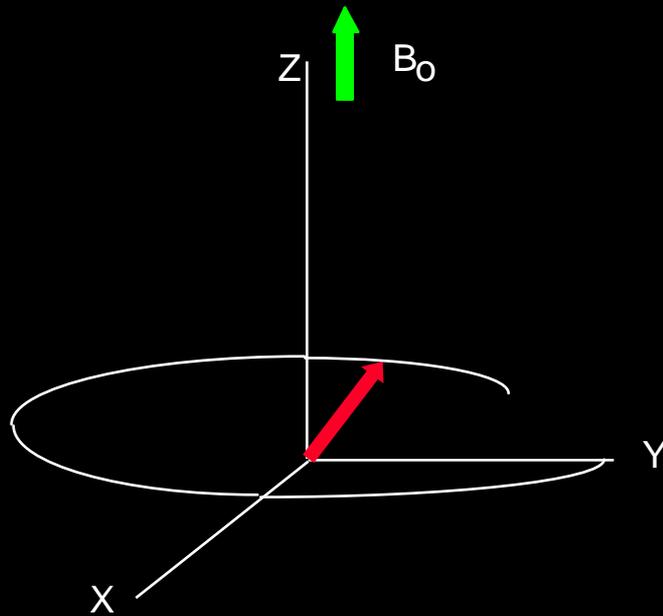
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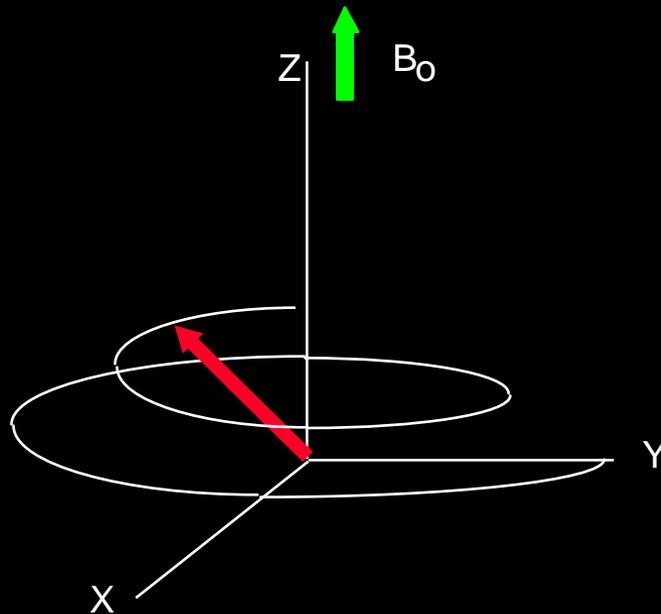
MR signal characteristics

Relaxation proces



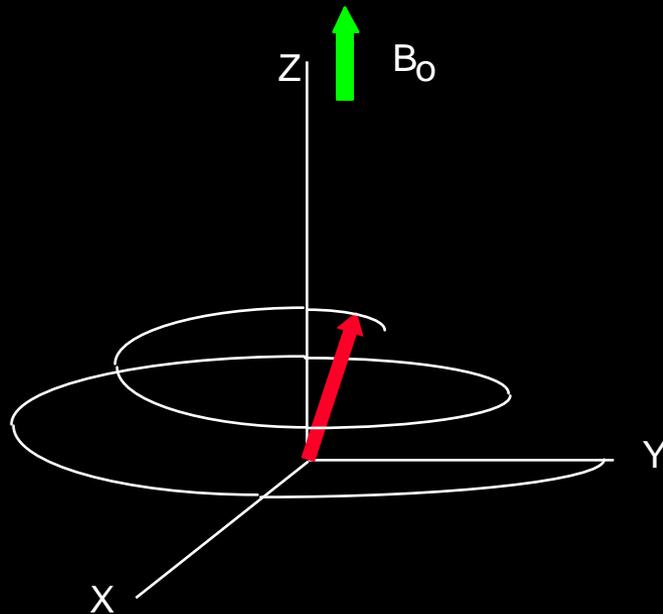
MR signal characteristics

Relaxation proces



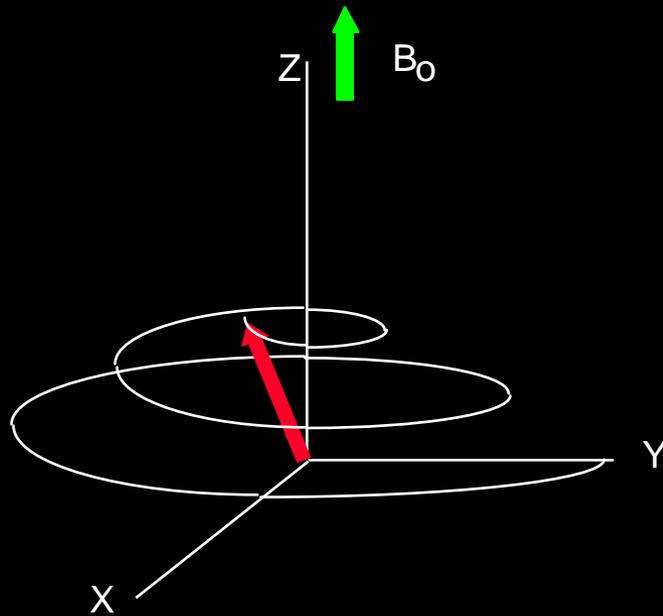
MR signal characteristics

Relaxation proces



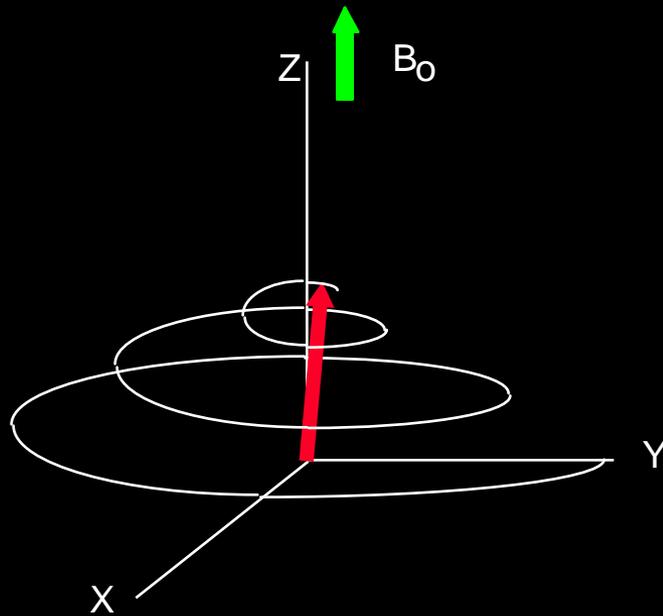
MR signal characteristics

Relaxation proces



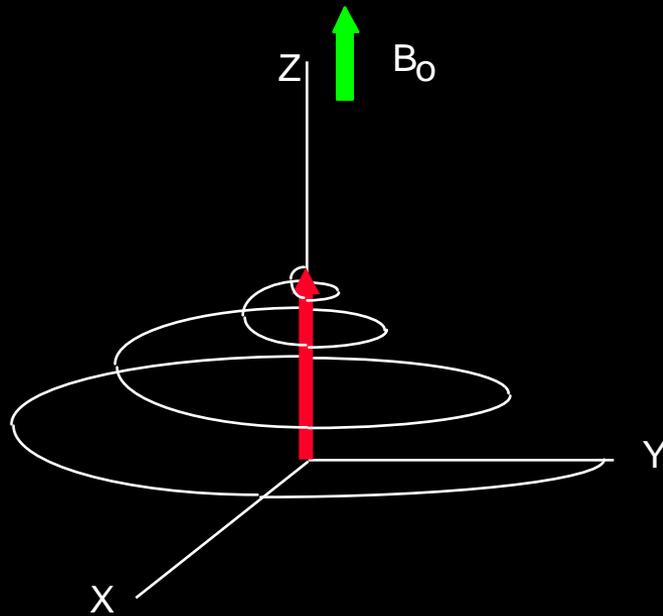
MR signal characteristics

Relaxation proces



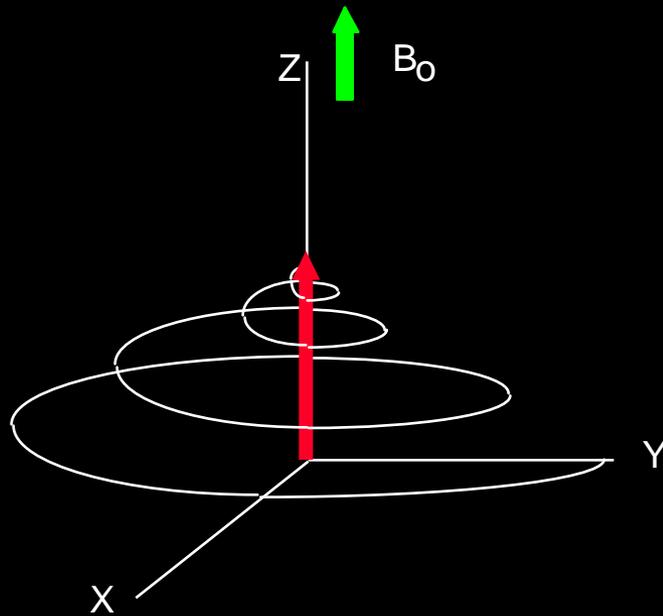
MR signal characteristics

Relaxation proces



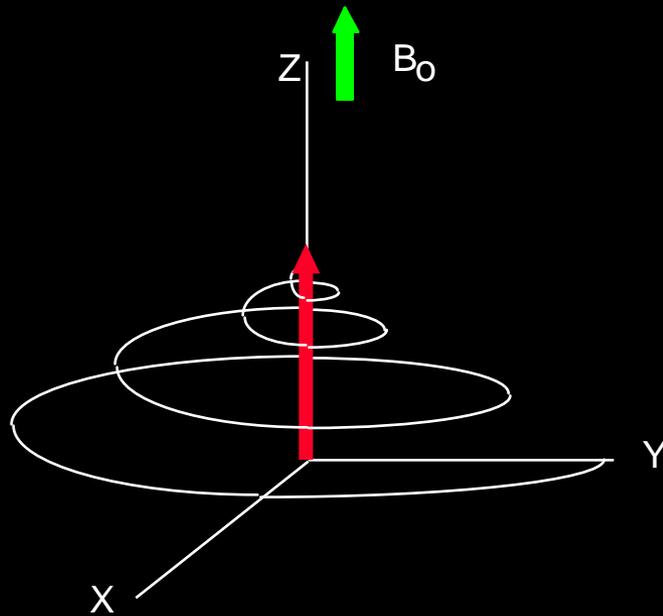
MR signal characteristics

Relaxation proces



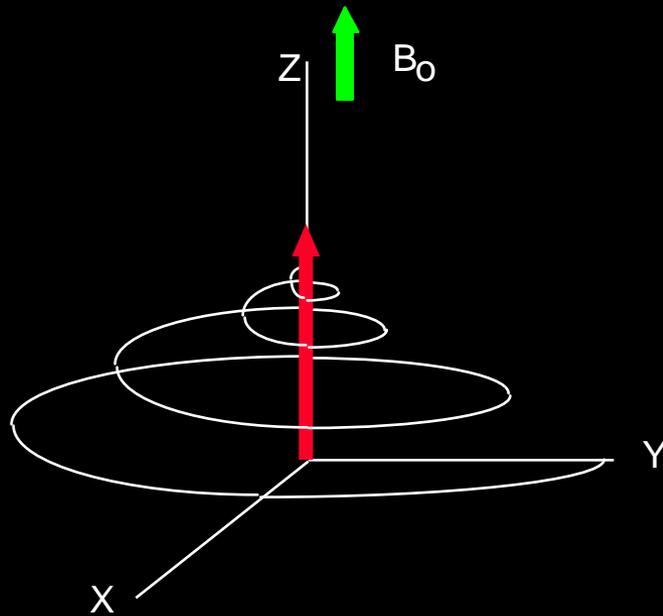
MR signal characteristics

Relaxation proces



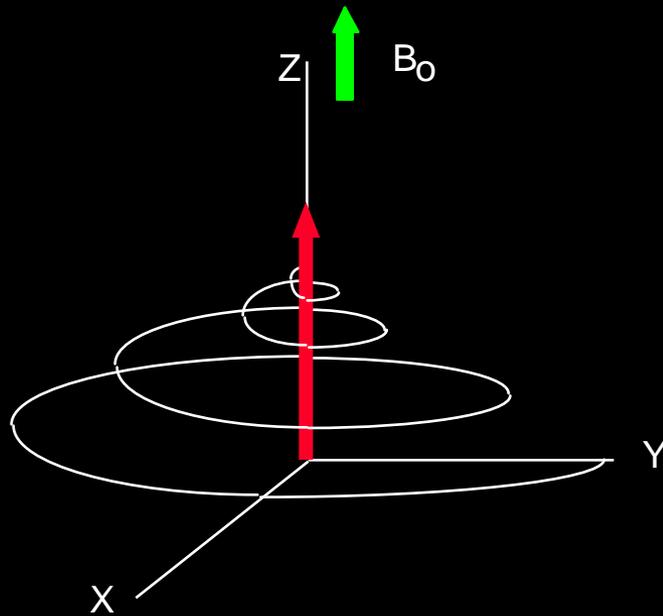
MR signal characteristics

Relaxation proces



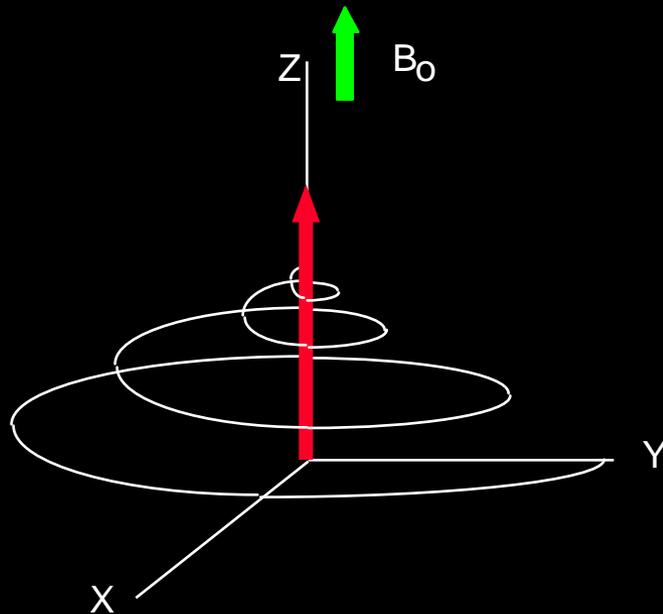
MR signal characteristics

Relaxation proces



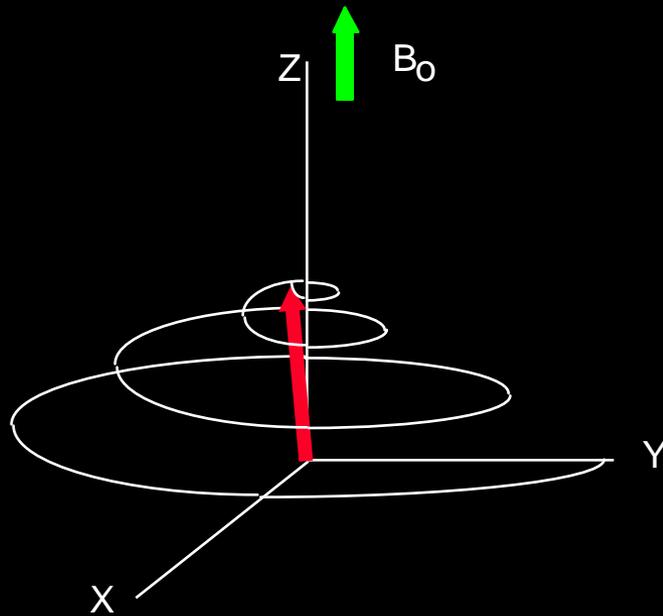
MR signal characteristics

Relaxation proces



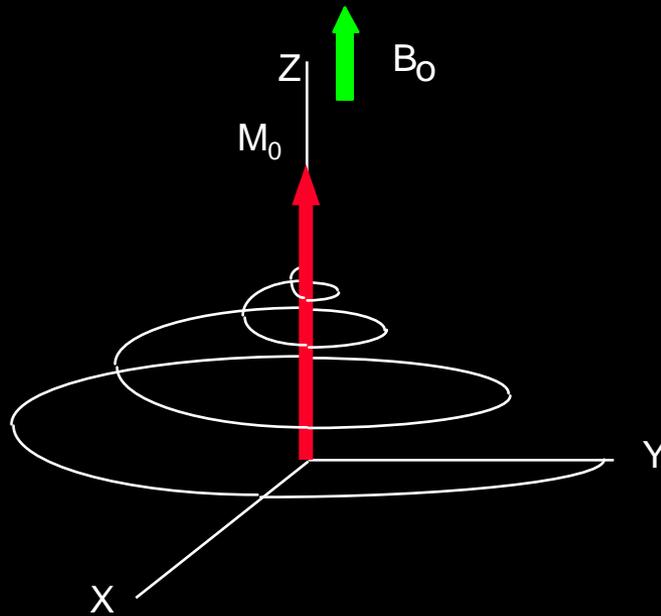
MR signal characteristics

Relaxation proces



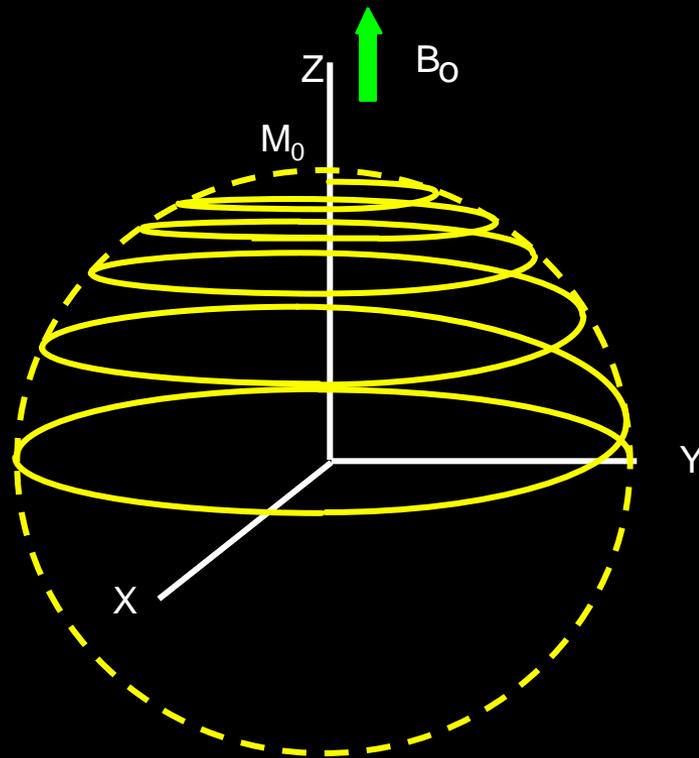
RM: caratteristiche del segnale

Processo di Rilassamento



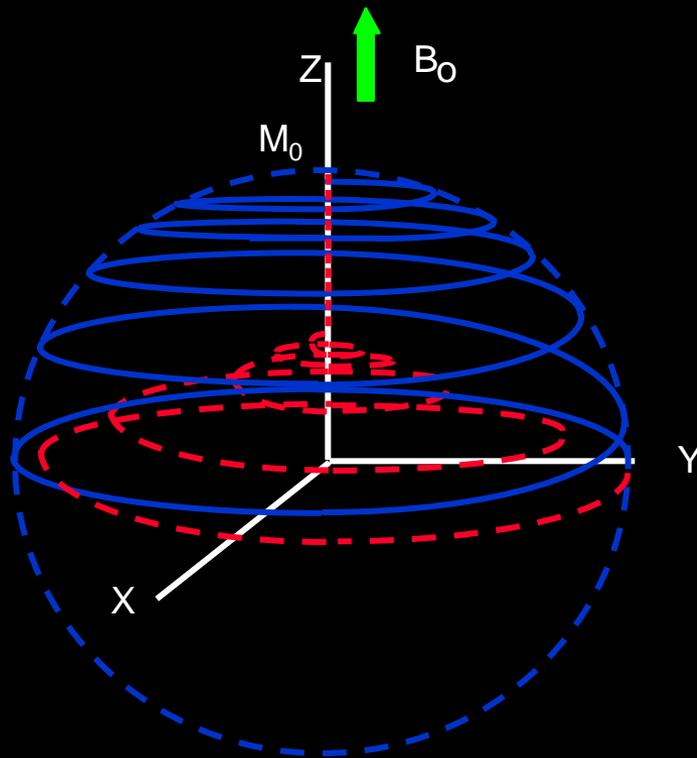
RM: caratteristiche del segnale

Eccitazione e Rilassamento



RM: caratteristiche del segnale

Eccitazione e Rilassamento



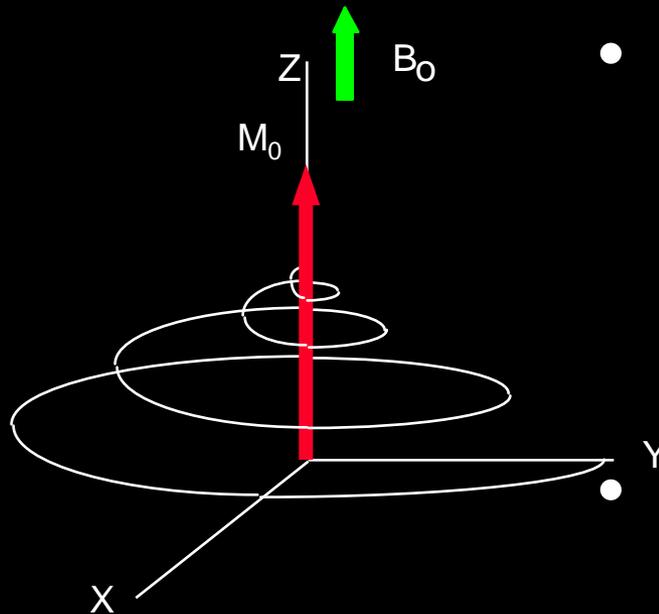
Excitation

Relaxation

RM: caratteristiche del segnale

processi di rilassamento

Relaxation processes:



- spin-spin relaxation in xy plane (T2)
- spin-lattice relaxation along z-axis (T1)

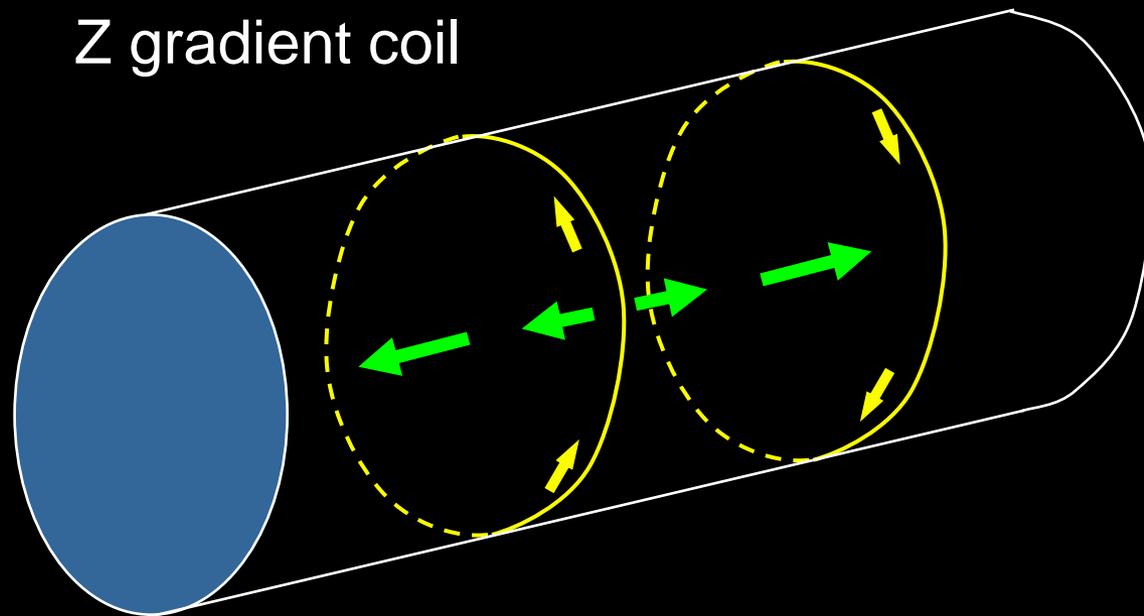
Costanti T1 – T2

- sono espressione di proprietà fisiche diverse
- sono indipendenti l'una dall'altra
- sono funzione dell'intensità del campo magnetico

Bobine di Gradiente

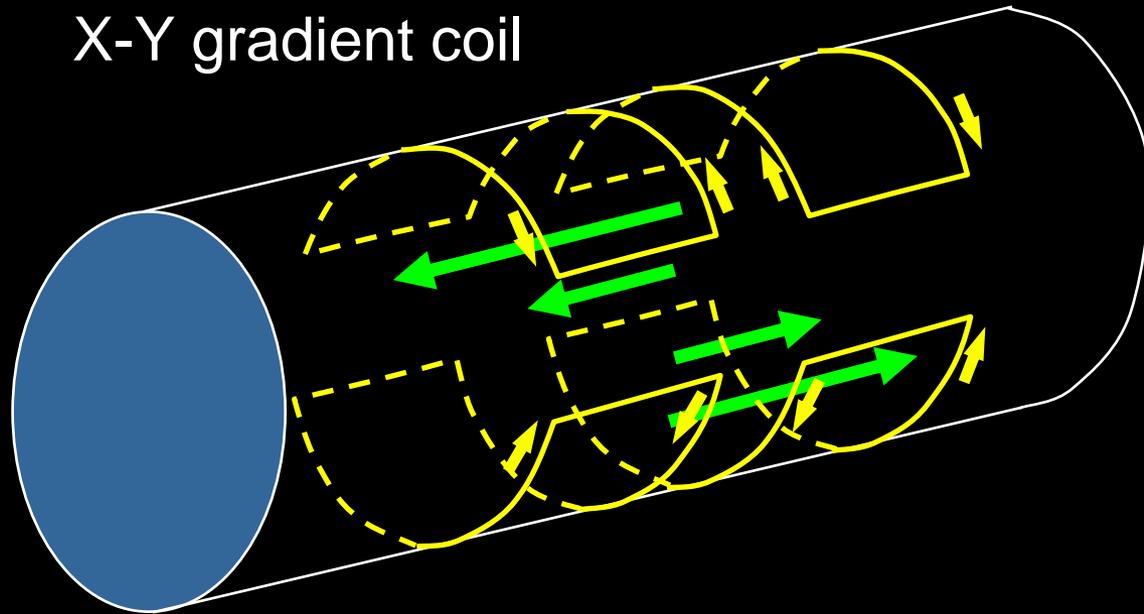
- **Caratteristica** : generare campi magnetici che variano linearmente di intensità lungo una direzione, e sono uniformi rispetto agli altri due.
- **Effetto**: modificare la frequenza di risonanza dei nuclei in maniera dipendente dalla posizione spaziale, secondo le direttive della sequenza di eccitazione.
- **Proprietà** : alto rendimento energetico
bassa induttanza
bassa resistenza

Gradient field



Gradient field

X-Y gradient coil



Radiofrequenza - Gradienti

- **Gli impulsi di radiofrequenza** hanno la funzione di perturbare l'equilibrio degli spin e generare il segnale.
- **Gli impulsi di gradiente** influenzano la frequenza e la fase del segnale ricevuto e sono necessari all'ottenimento dell'immagine.

Codifica Spaziale

Dopo l'eccitazione tutti i nuclei risuonano alla stessa frequenza ed il segnale non contiene informazioni sulla posizione.

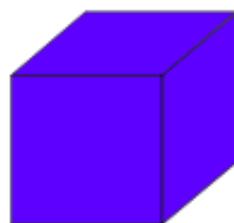
La codifica spaziale si ottiene da una **frequenza** risonante **posizione dipendente**

Una frequenza di risonanza **posizione dipendente** è prodotta da un **campo magnetico posizione dipendente**

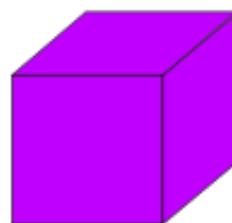
(= magnetic field **gradient**)

Vi sono 3 gradienti di campo magnetico nelle 3 direzioni dello spazio **X, Y and Z gradient**

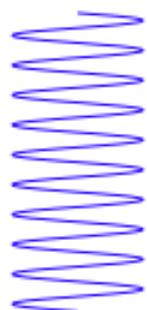
Intensità del gradiente di lettura



Campioni



Segnali RF
emessi



+



||



Segnale RF
rilevato



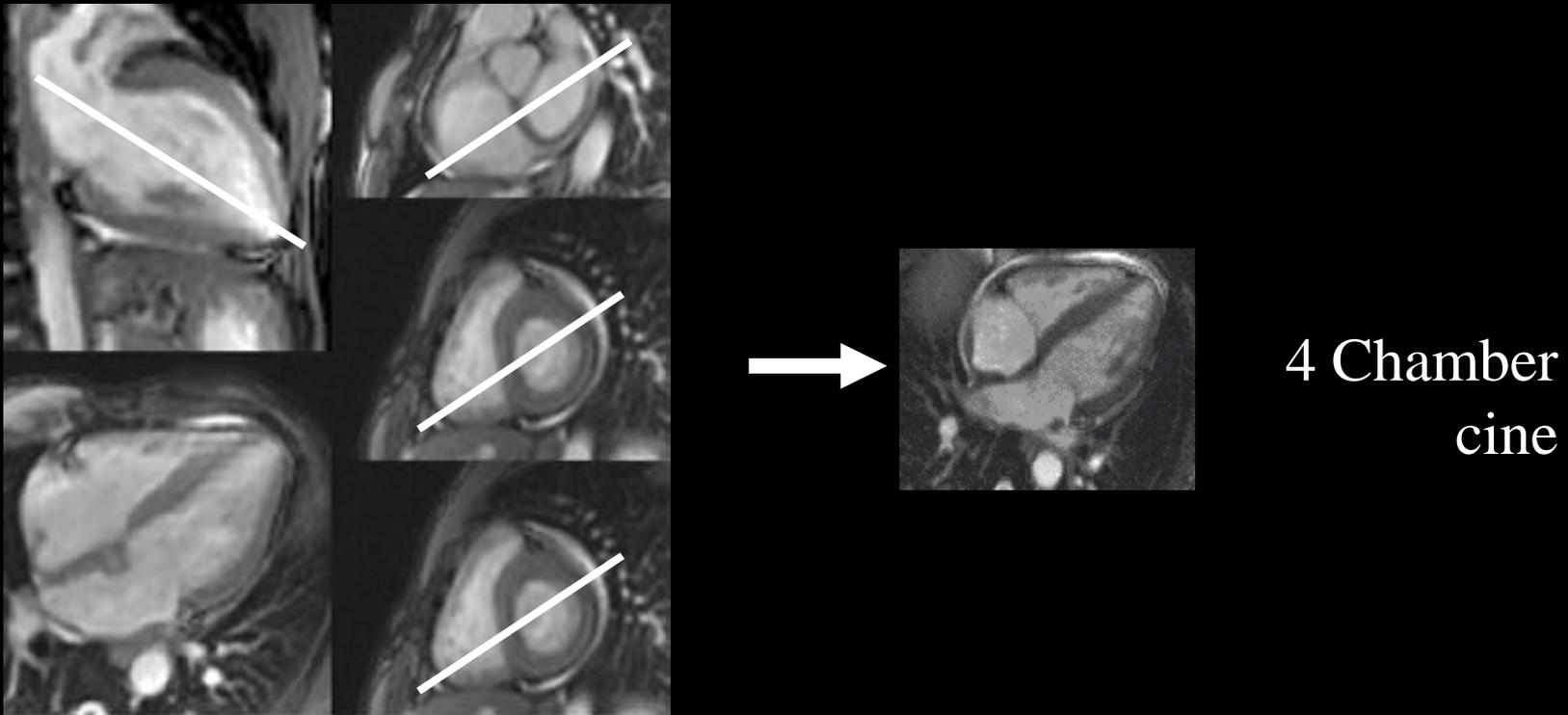
Trasformata di
Fourier

Processi per l'Imaging

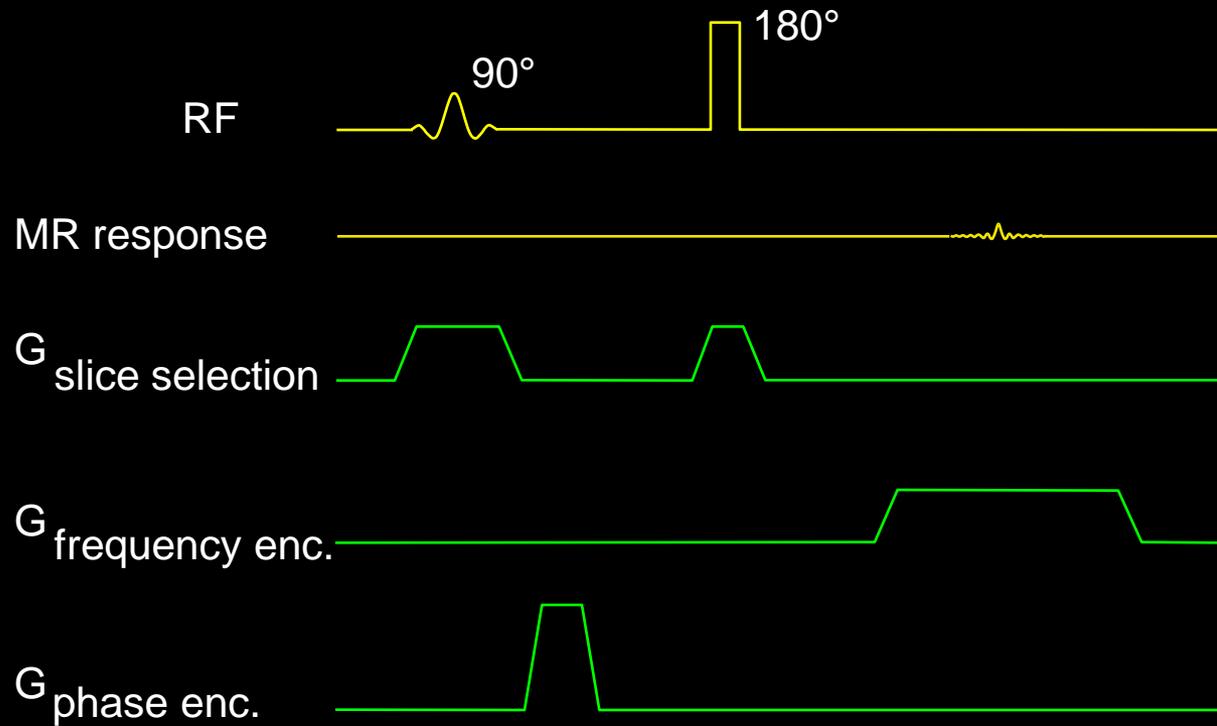
- Selezione della Slice
- Codifica di Frequenza
- Codifica di Fase

5: 4 camere cine

Now pilot the 4 chamber cine: through the apex, and the maximum lateral dimensions of both ventricles, avoiding the LVOT



Pulse sequence



Pulse sequence

RF _____

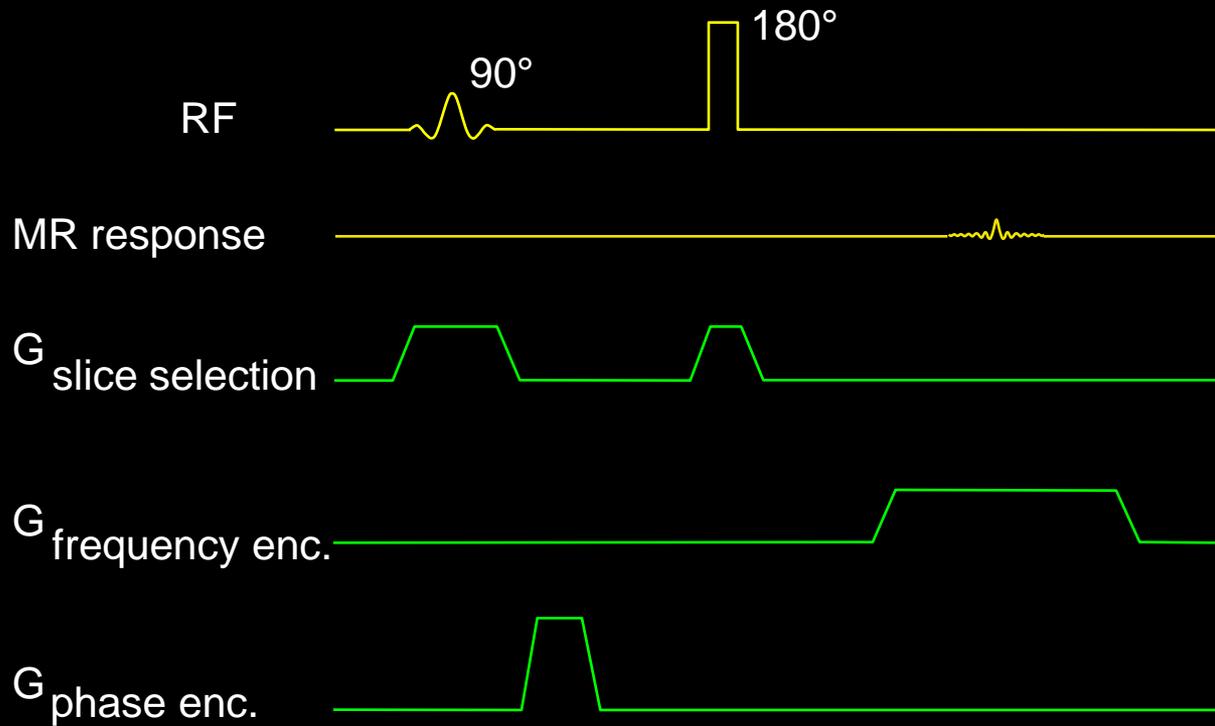
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

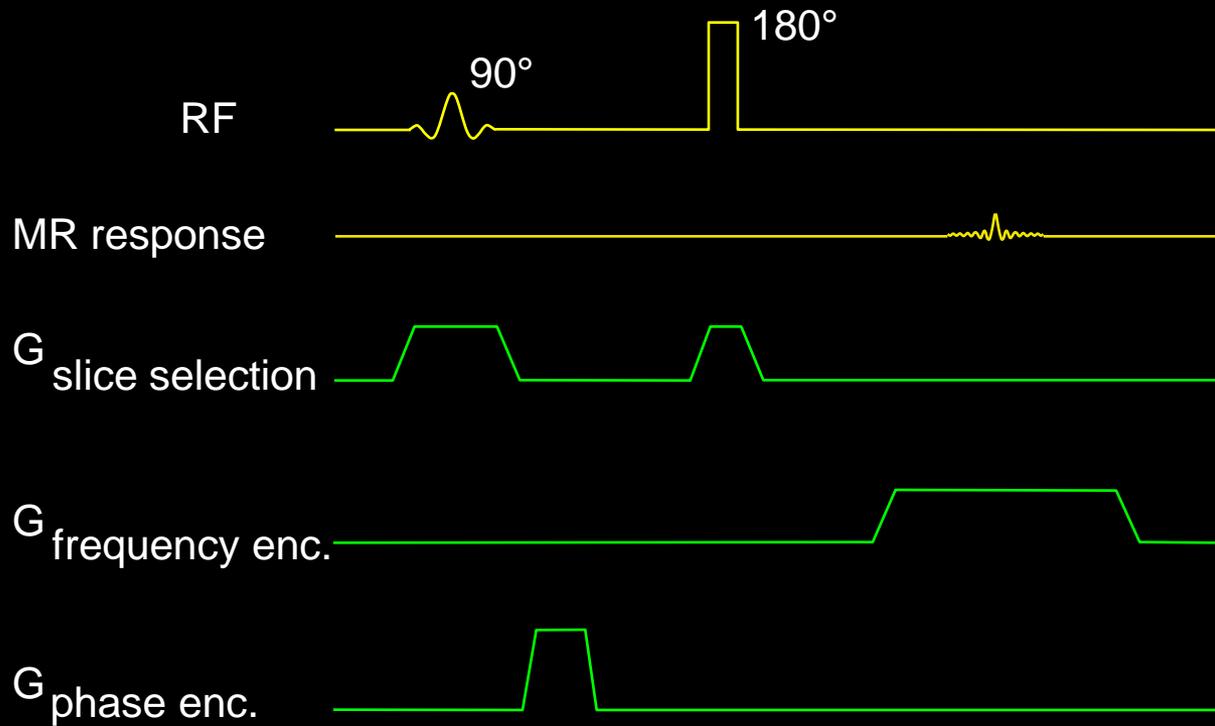
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

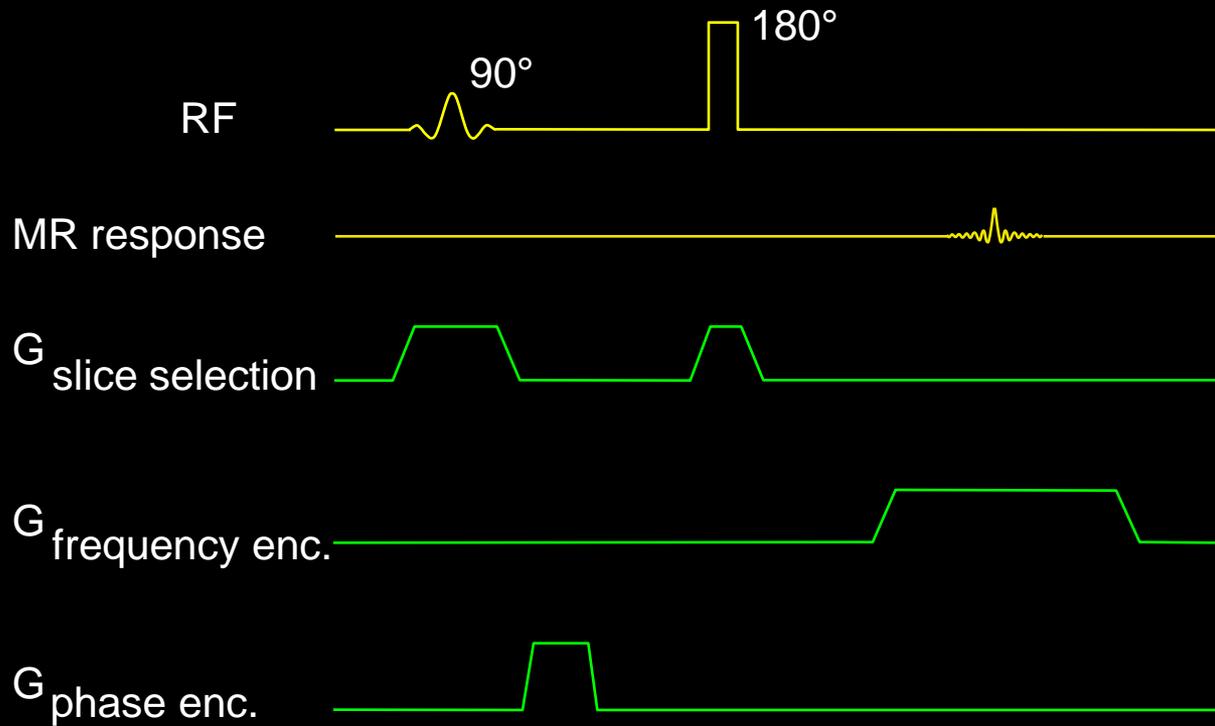
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

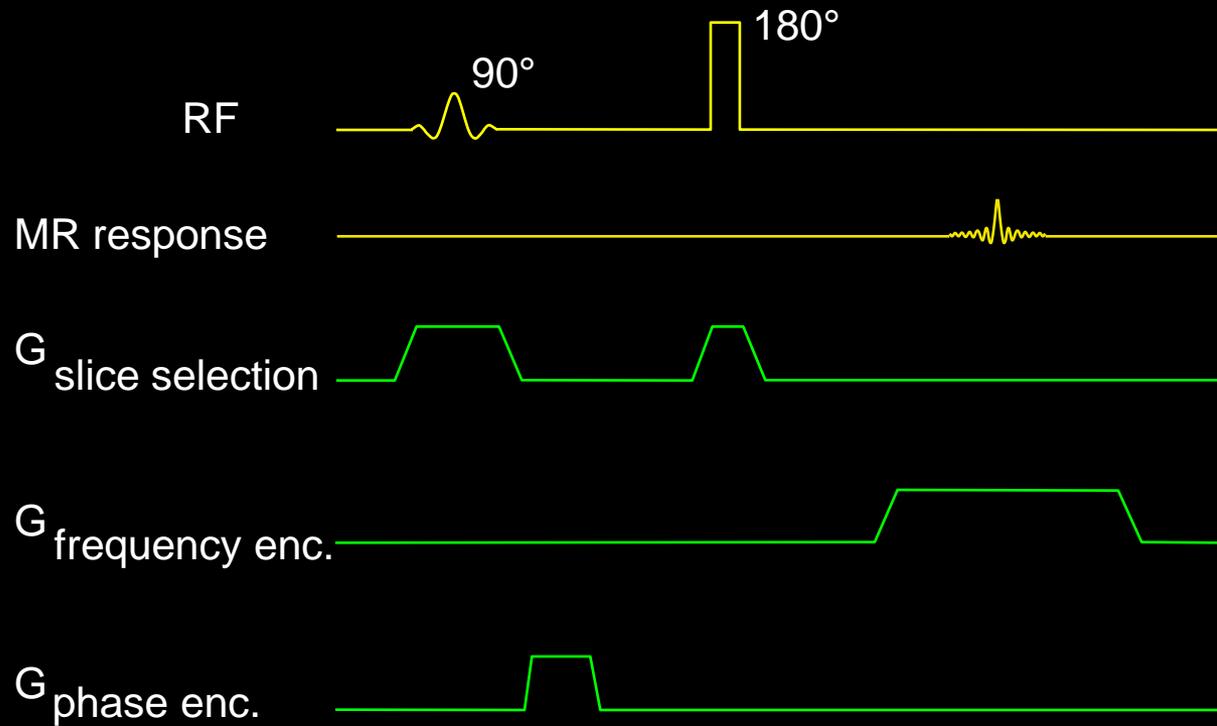
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

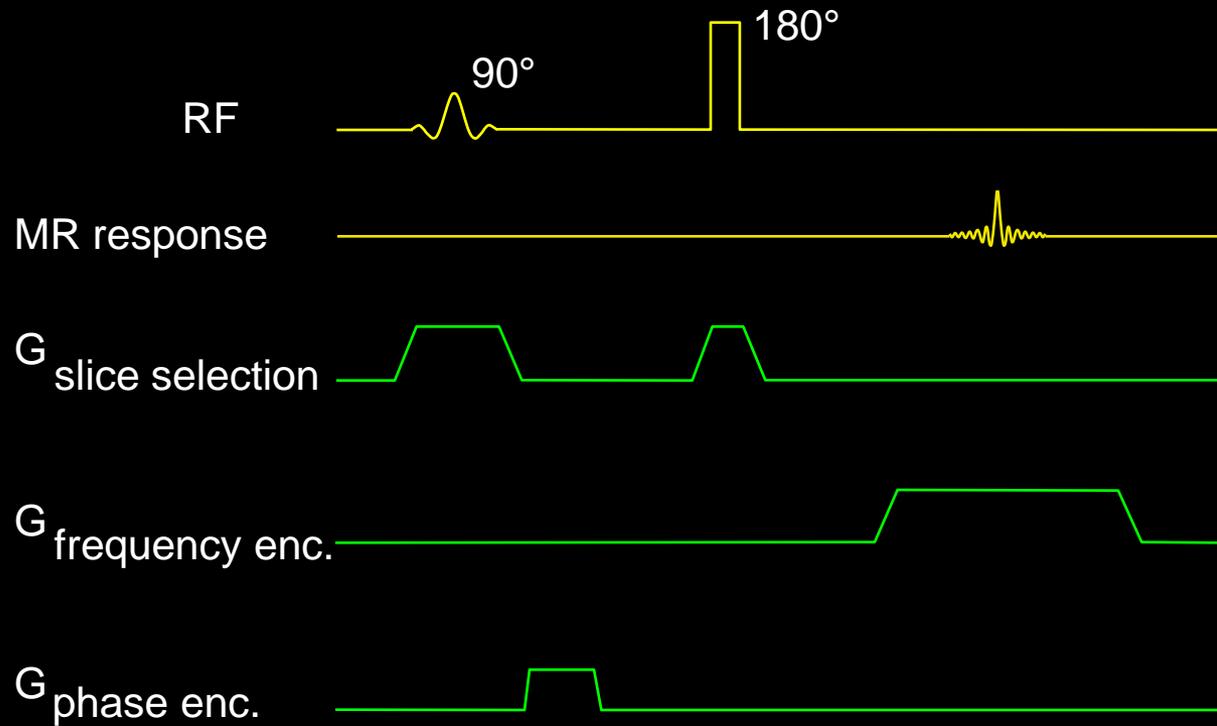
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

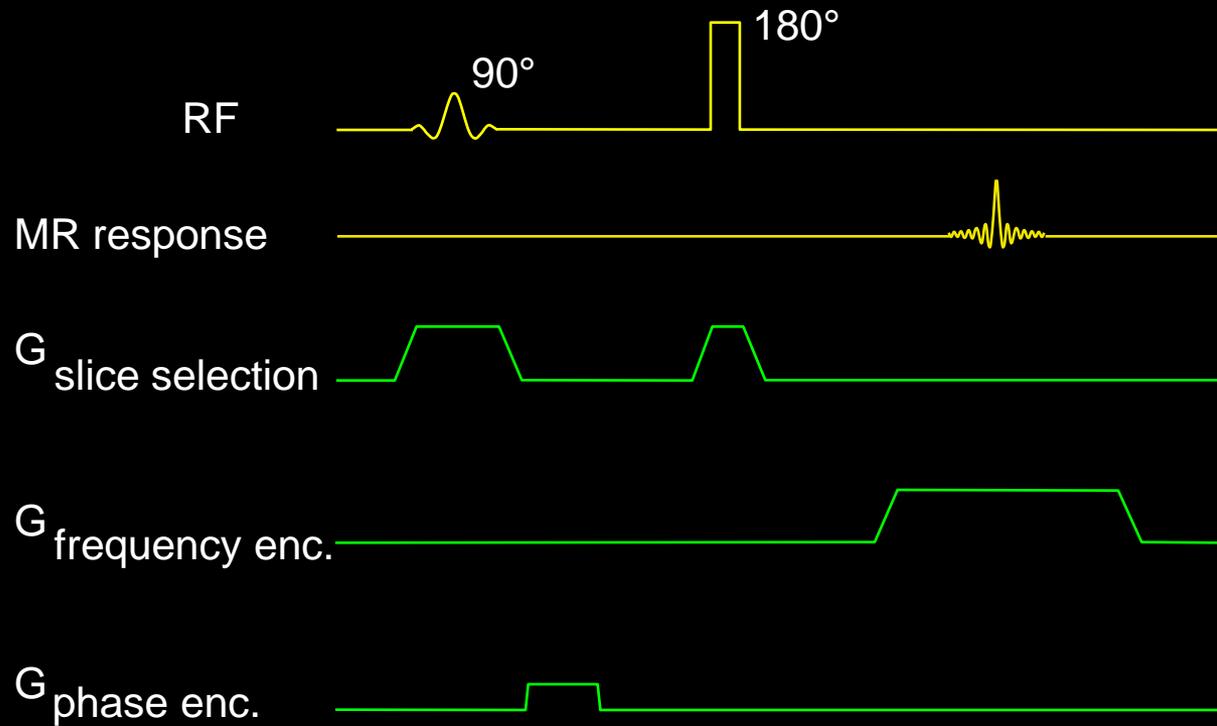
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

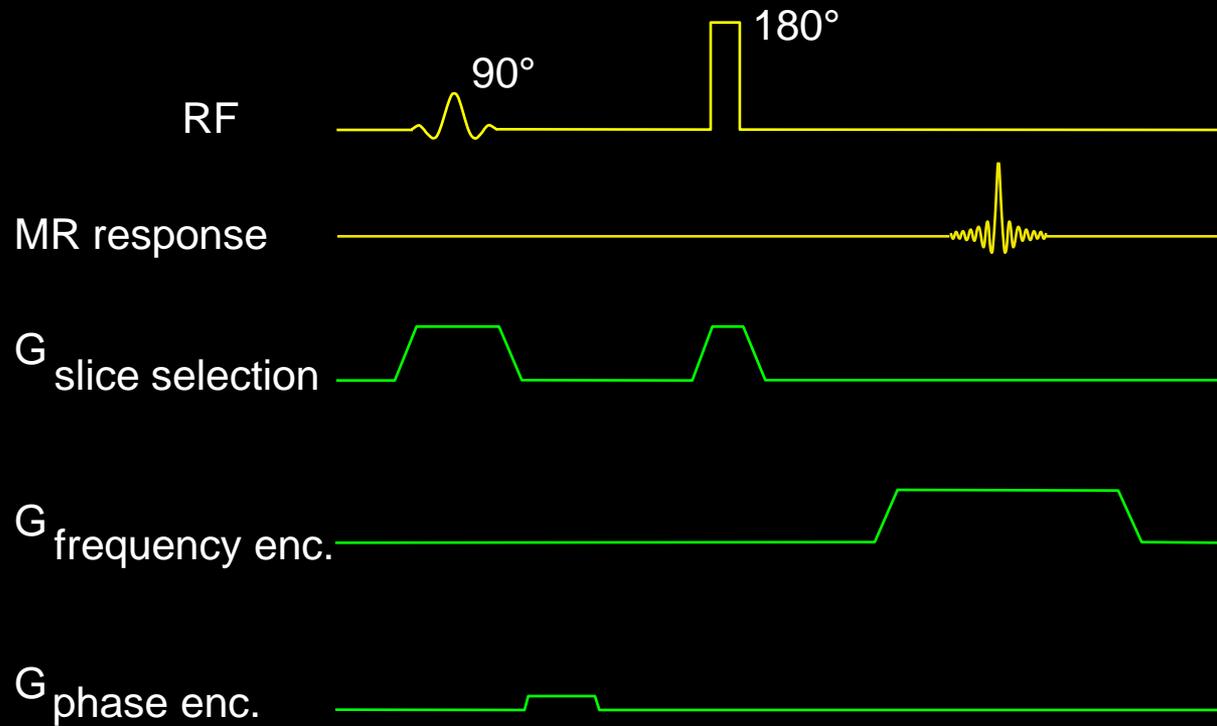
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence

RF _____

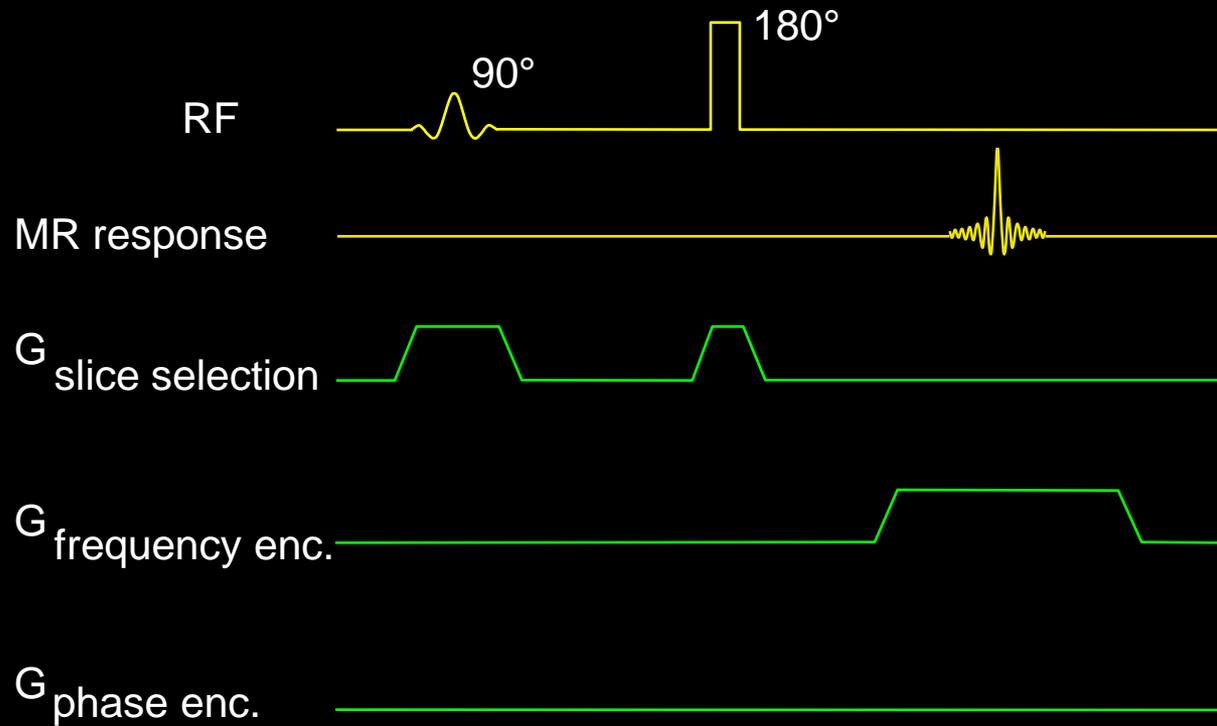
MR response _____

$G_{\text{slice selection}}$ _____

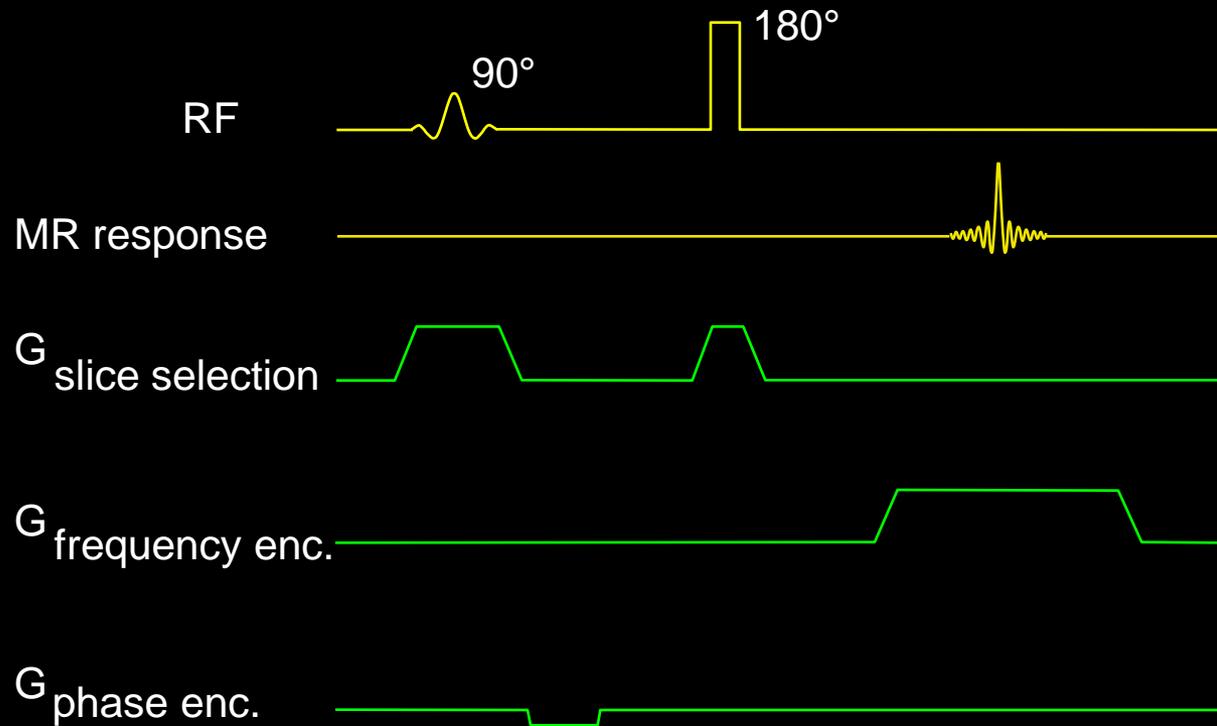
$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence



Pulse sequence

RF _____

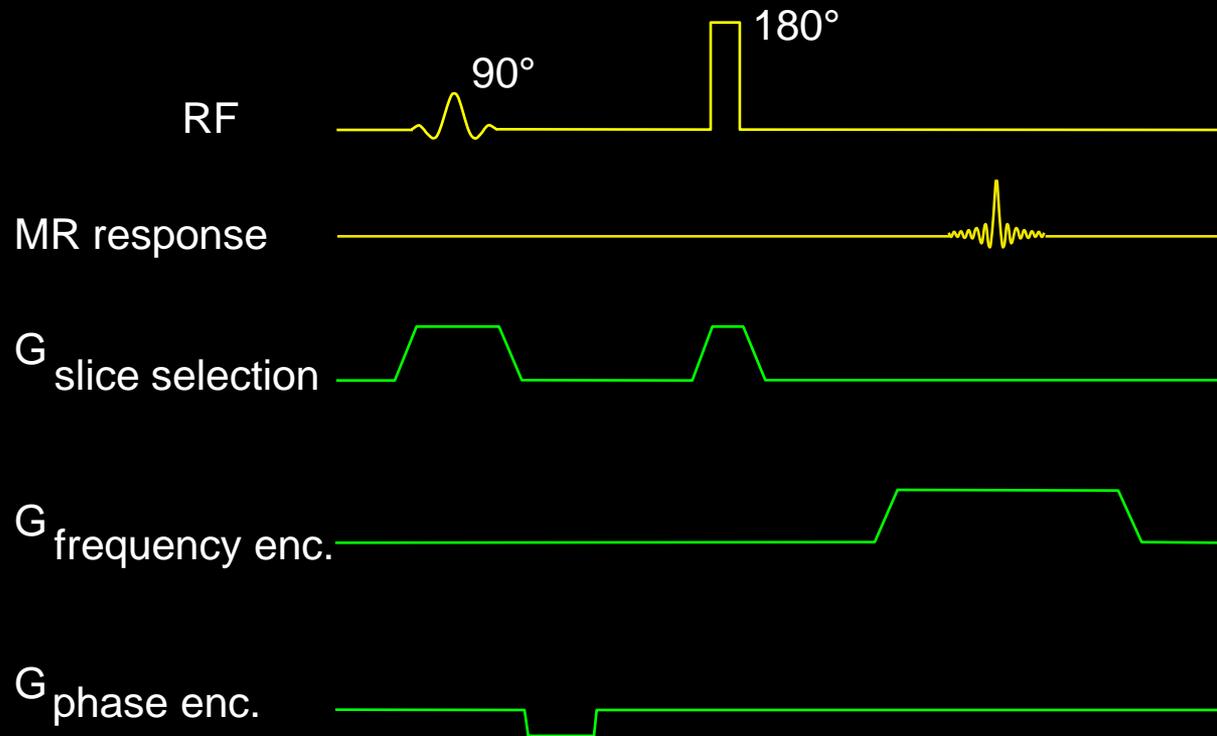
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

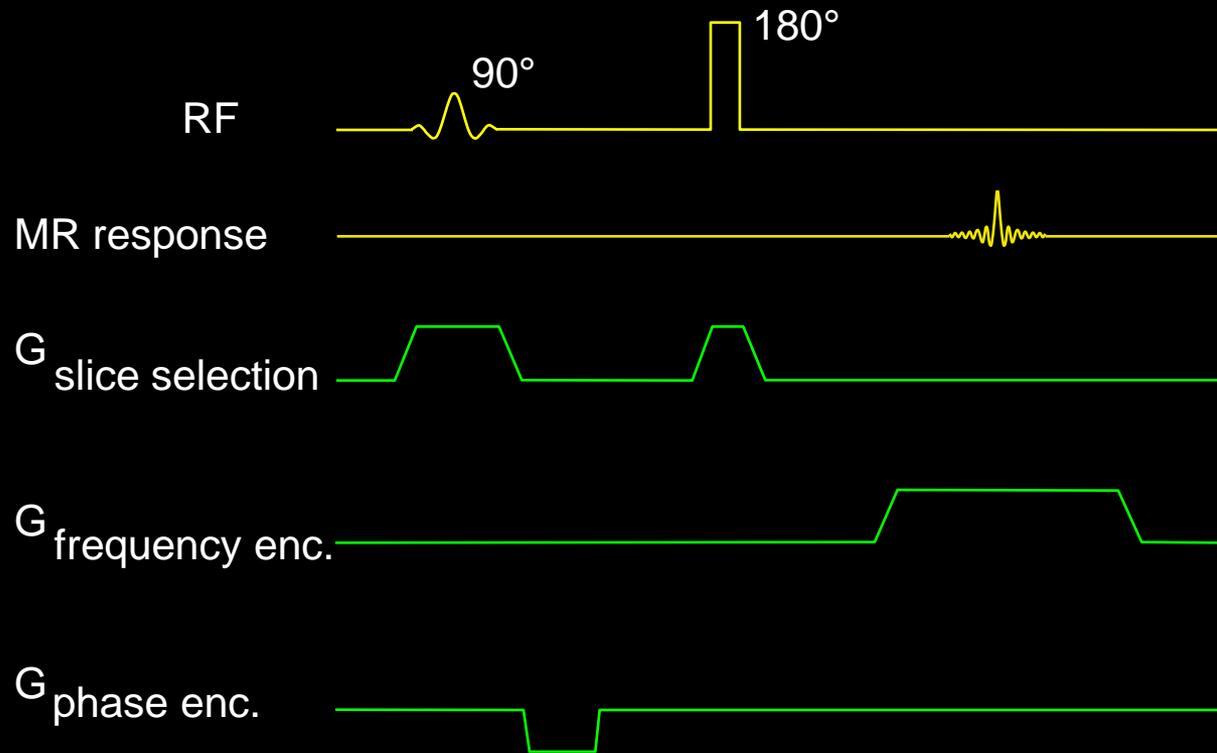
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

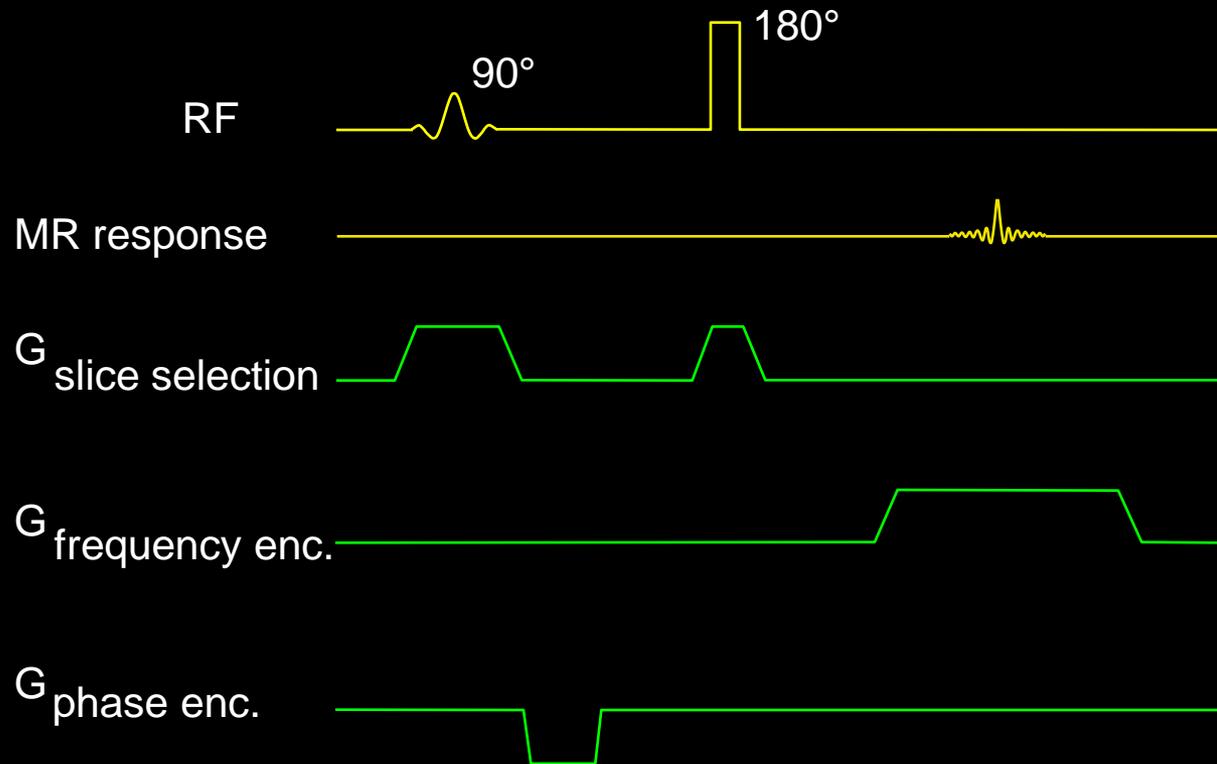
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

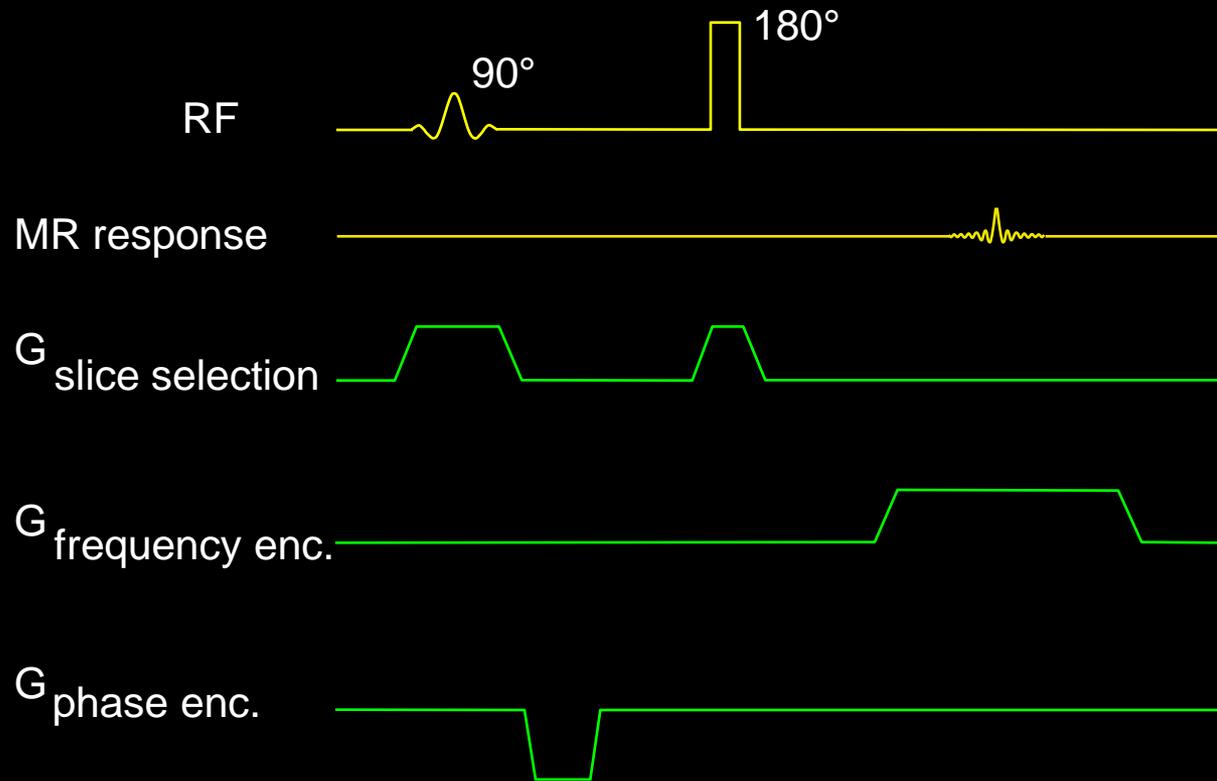
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

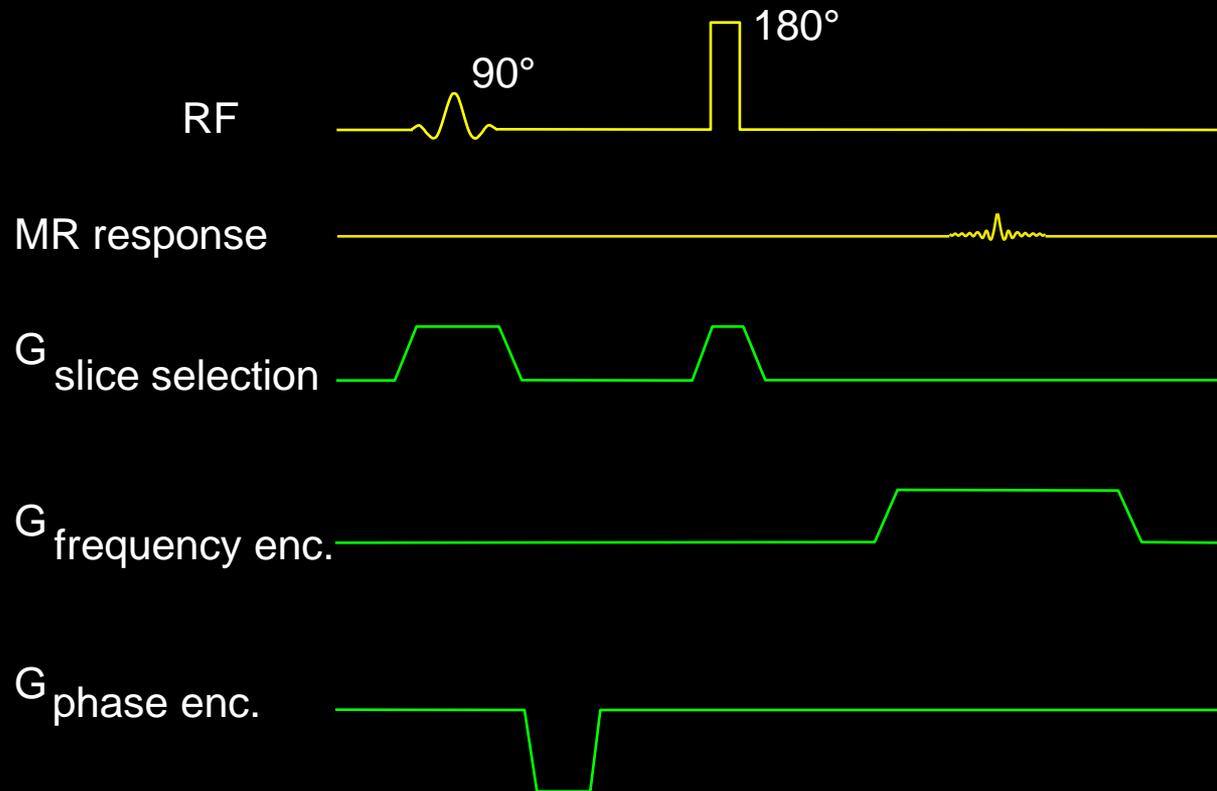
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

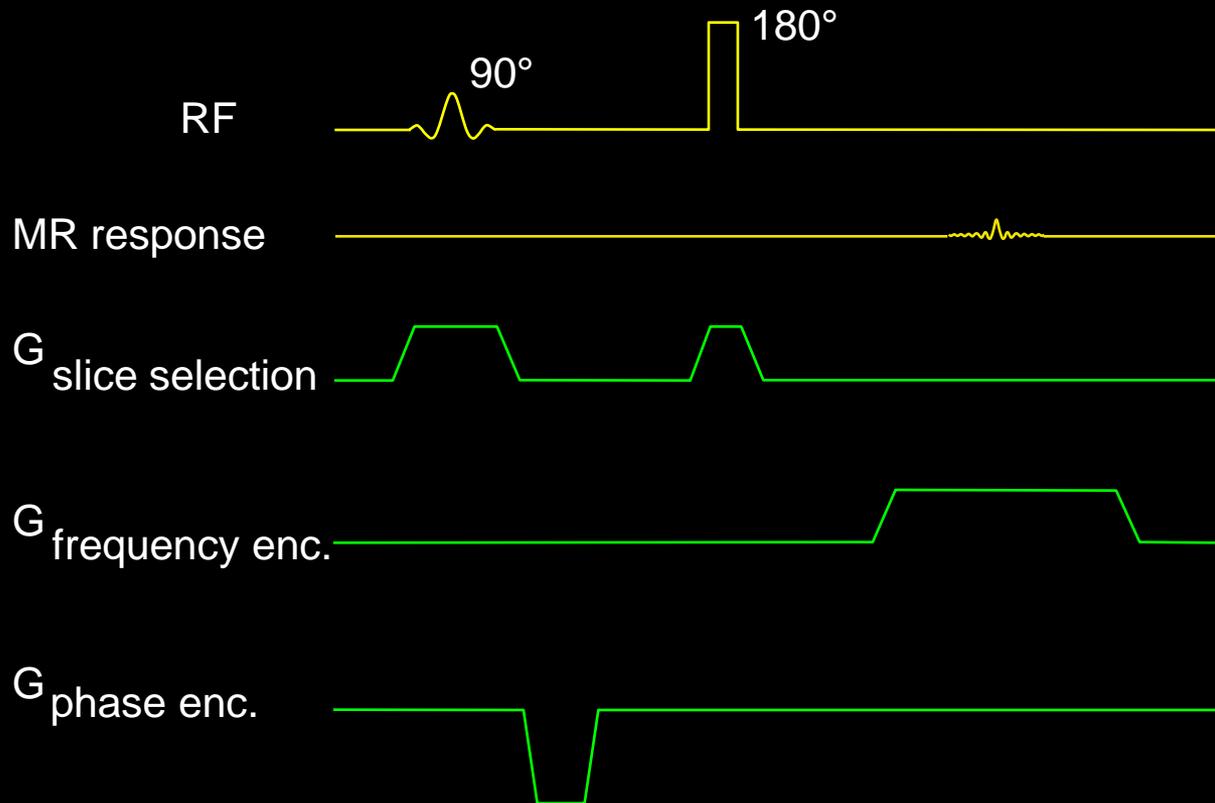
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

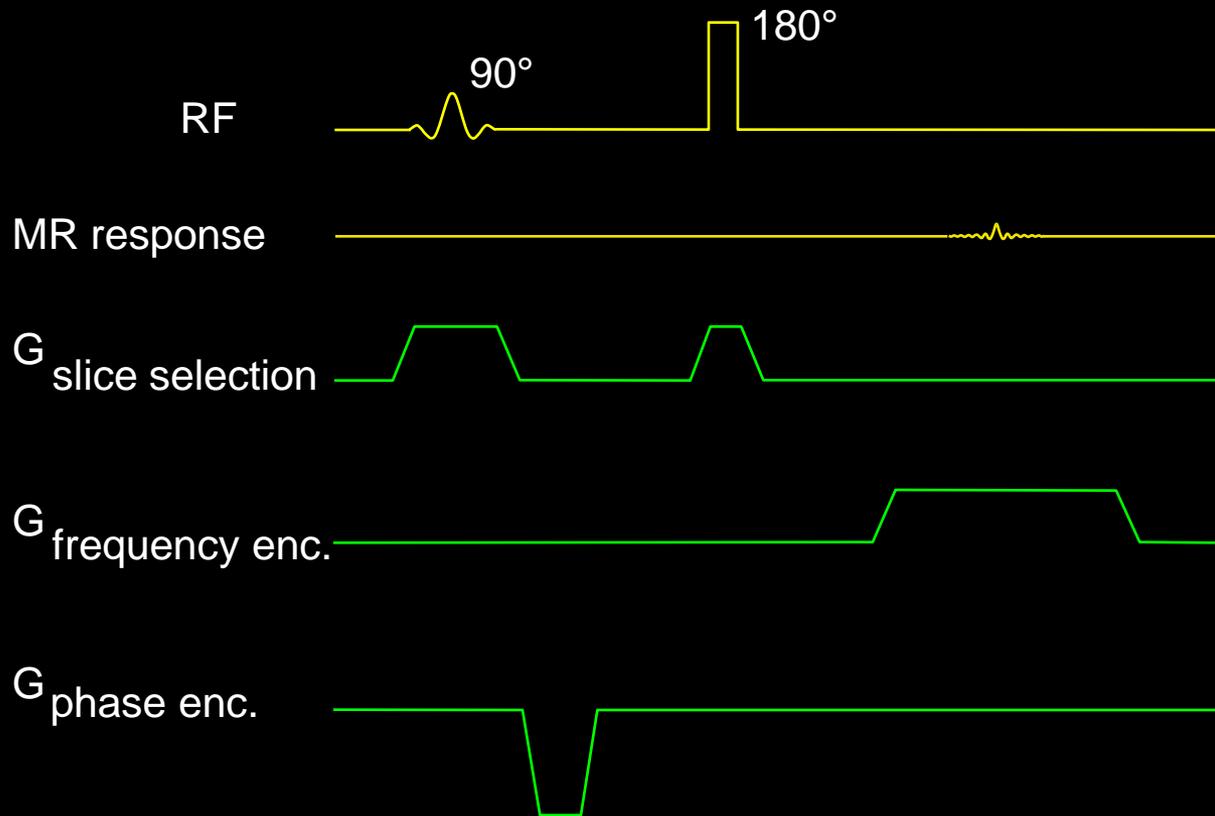
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

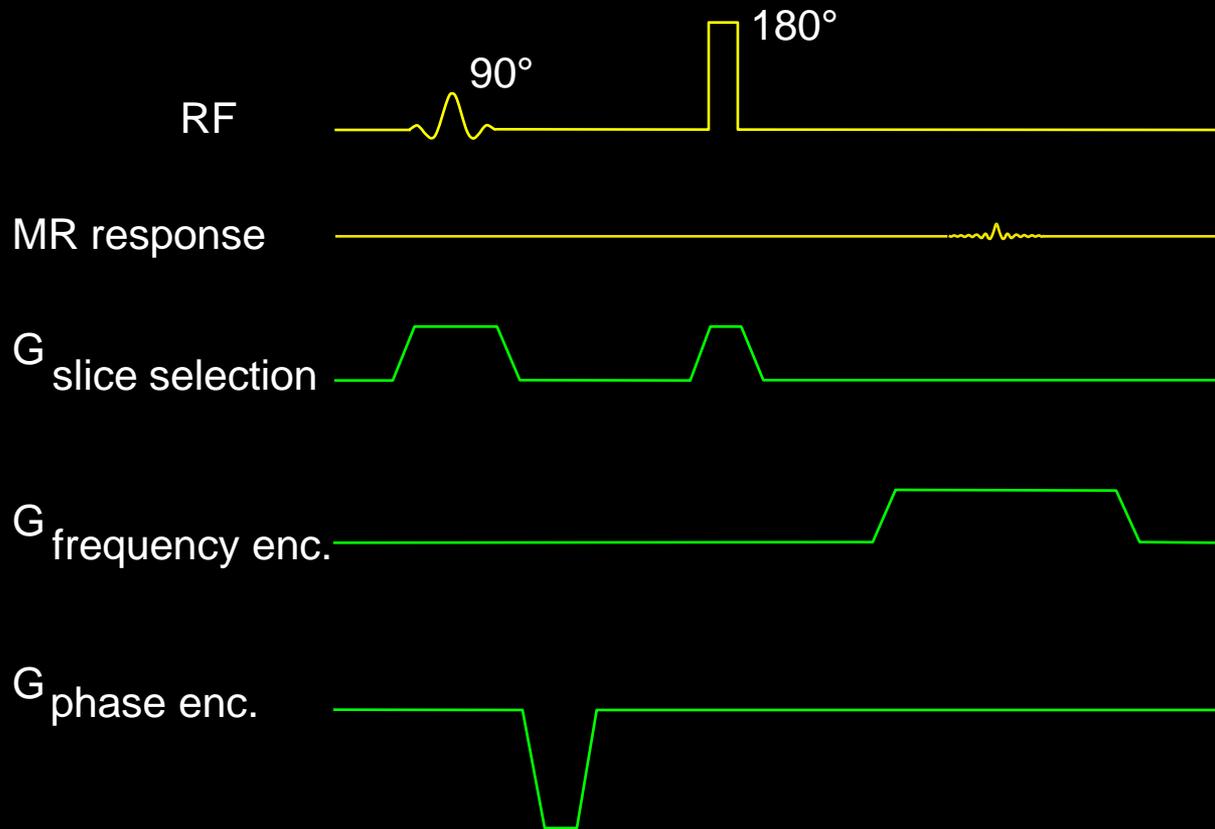
MR response _____

$G_{\text{slice selection}}$ _____

$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence



Pulse sequence

RF _____

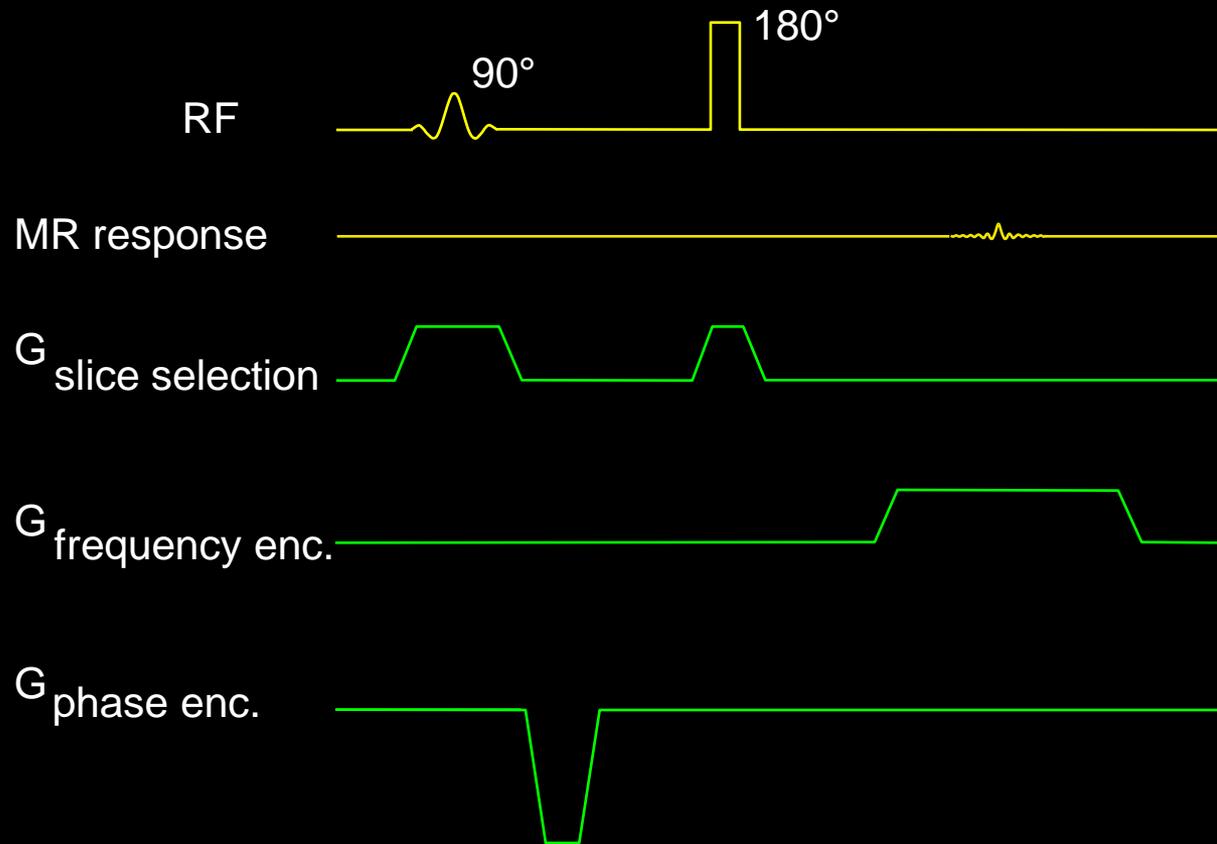
MR response _____

$G_{\text{slice selection}}$ _____

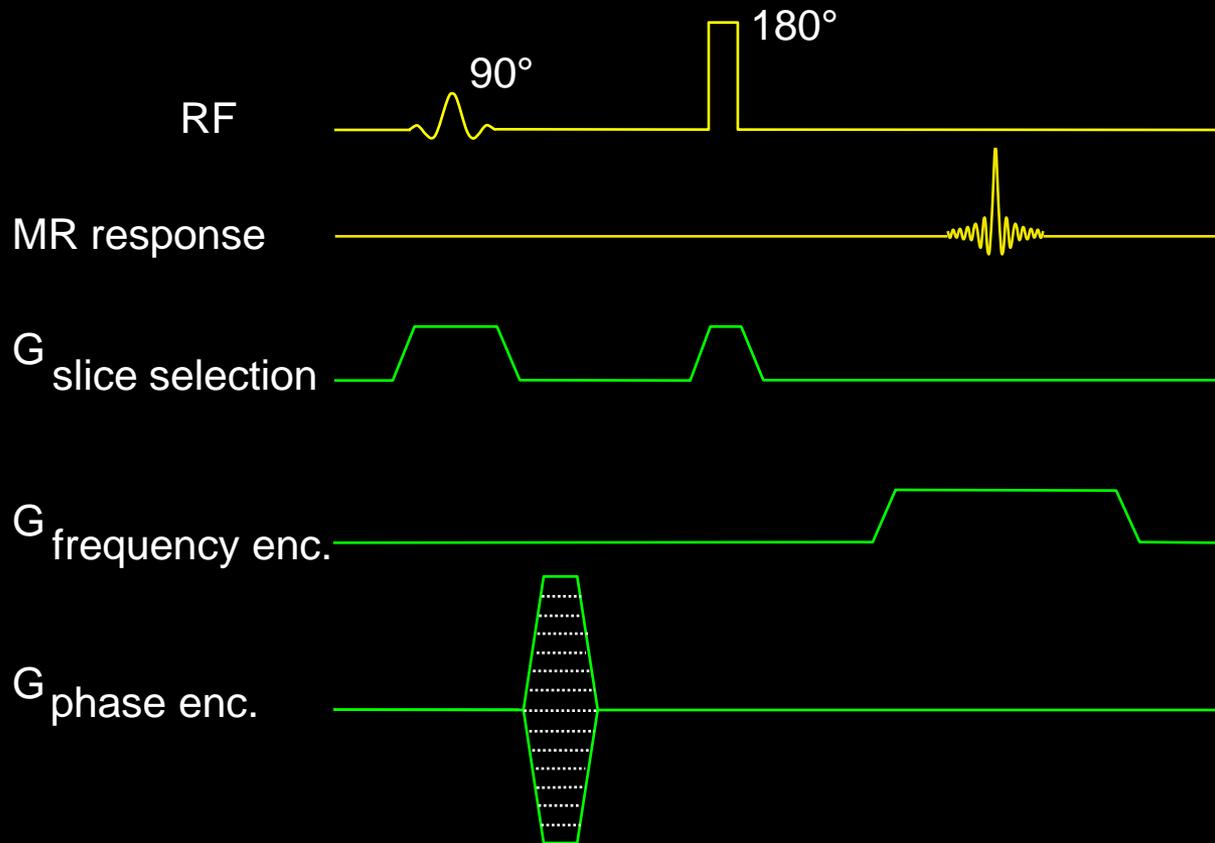
$G_{\text{frequency enc.}}$ _____

$G_{\text{phase enc.}}$ _____

Pulse sequence

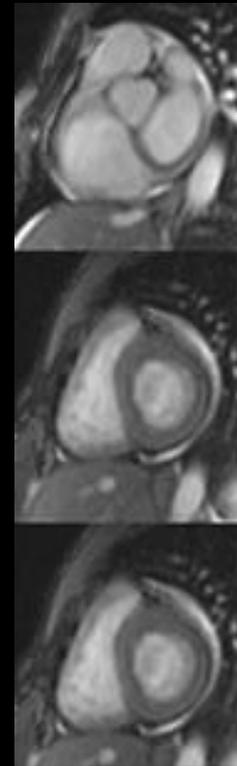
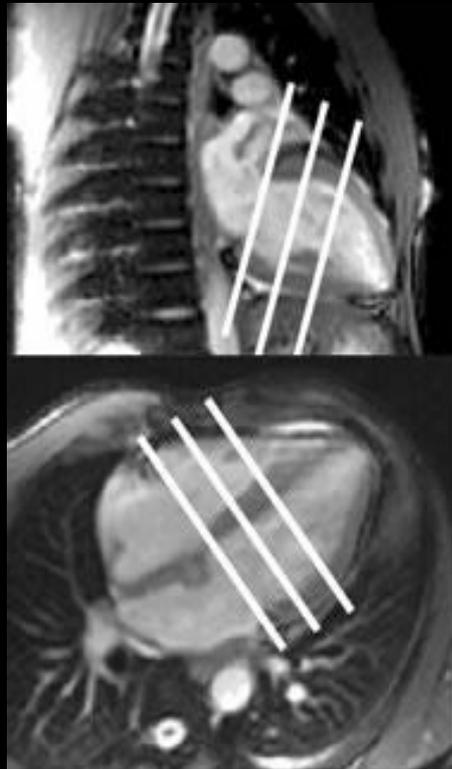


Pulse sequence



4: Short axis (SA) pilots

VLA and
HLA pilots



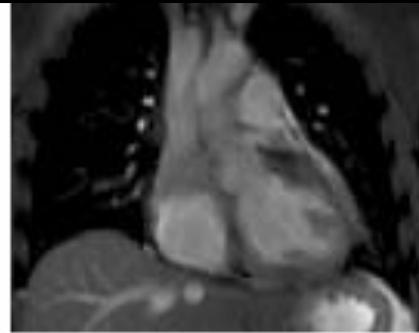
SA pilots

1.- multislice

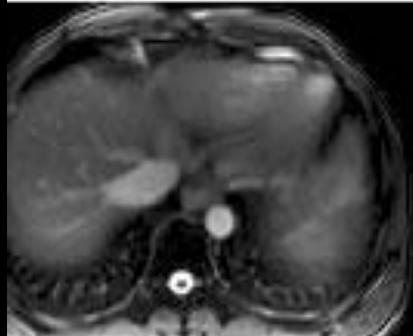
Sagittale



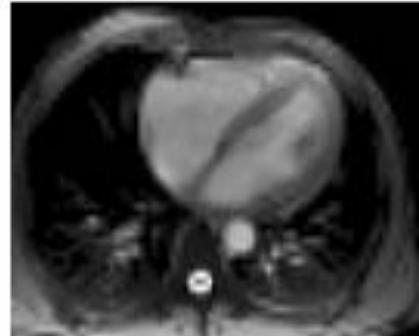
Coronale



Transverso 1



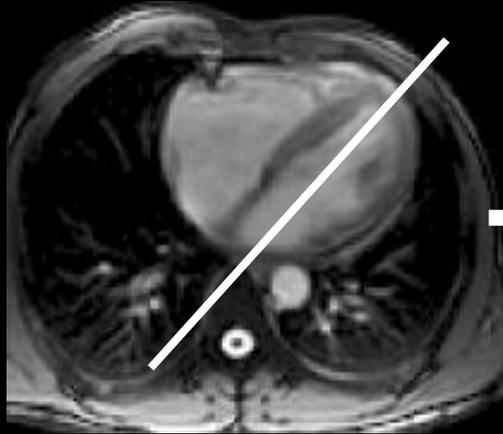
Transverso 2



2. Vertical Long axis (VLA)

Orientare la slice lungo del ventricolo sin. in senso mitrale apex – non necessariamente in modo completamente parallelo

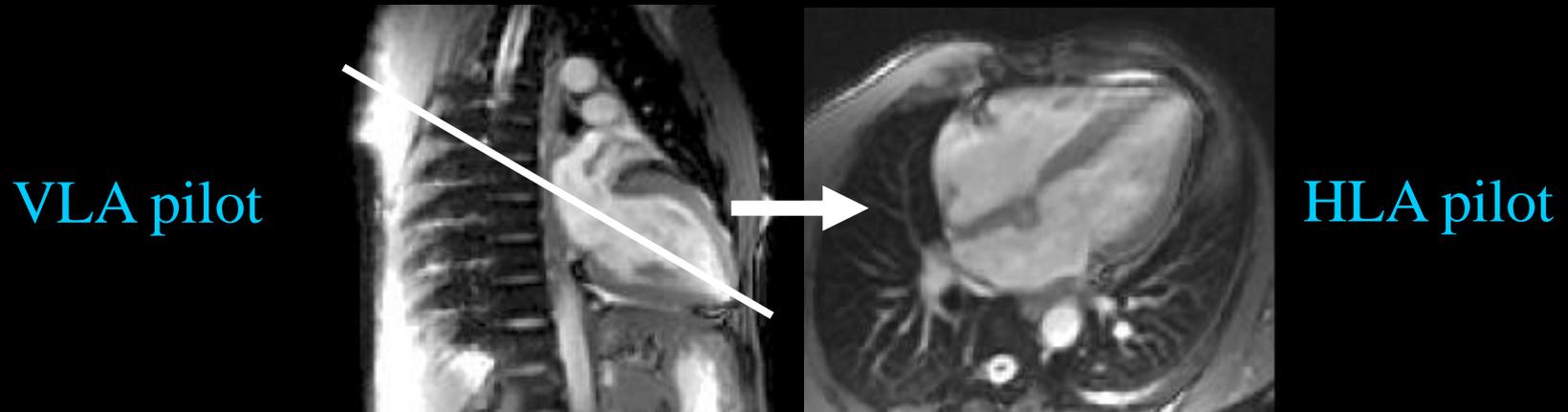
Transverse
pilot



VLA pilot

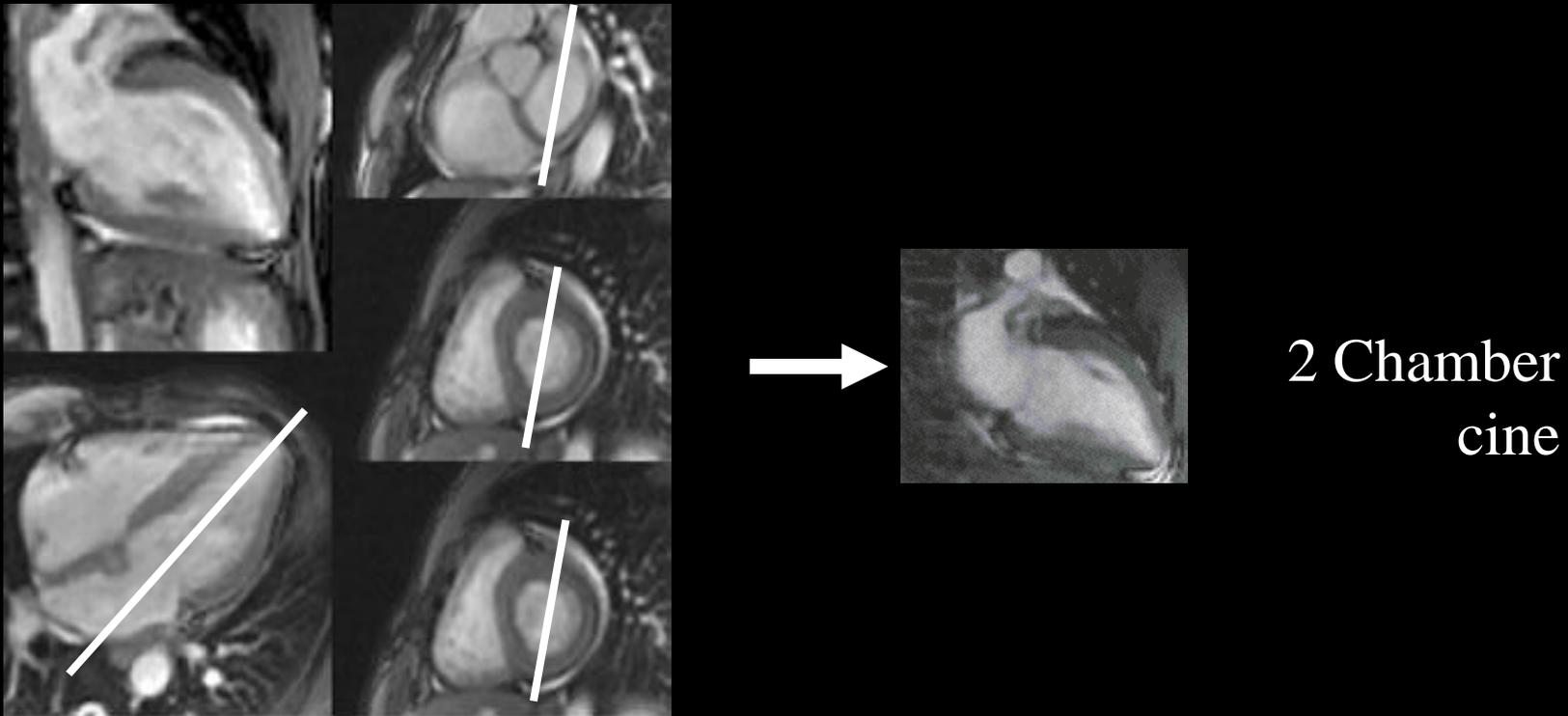
3. 4 camere

Usando la VLA pilot acquisita prima, positionare la slice passando tra valvola mitrale ed apice.

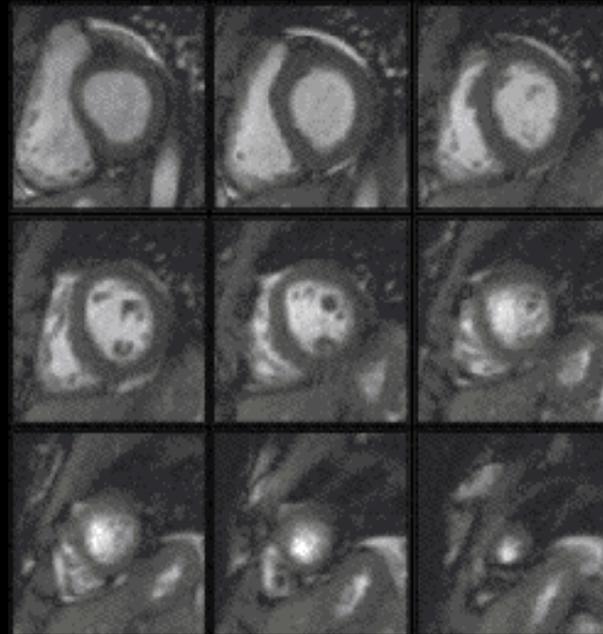
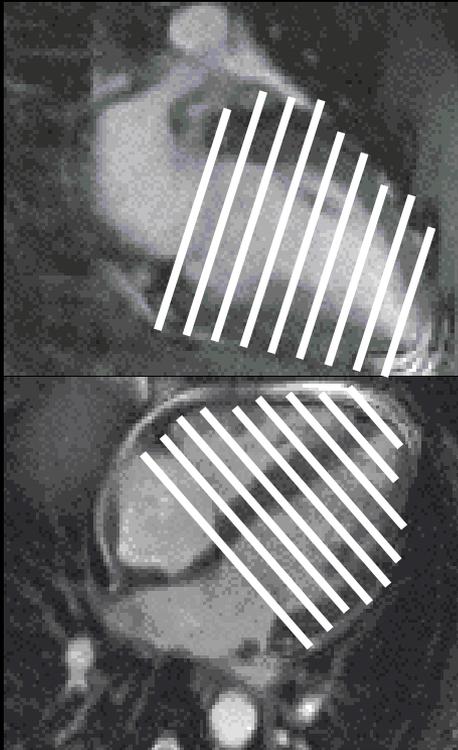


6:Due camere cine

And pilot the 2 chamber cine – through the apex and mid anterior wall/mid inferior wall on the short axis slices – avoiding the LV outflow tract



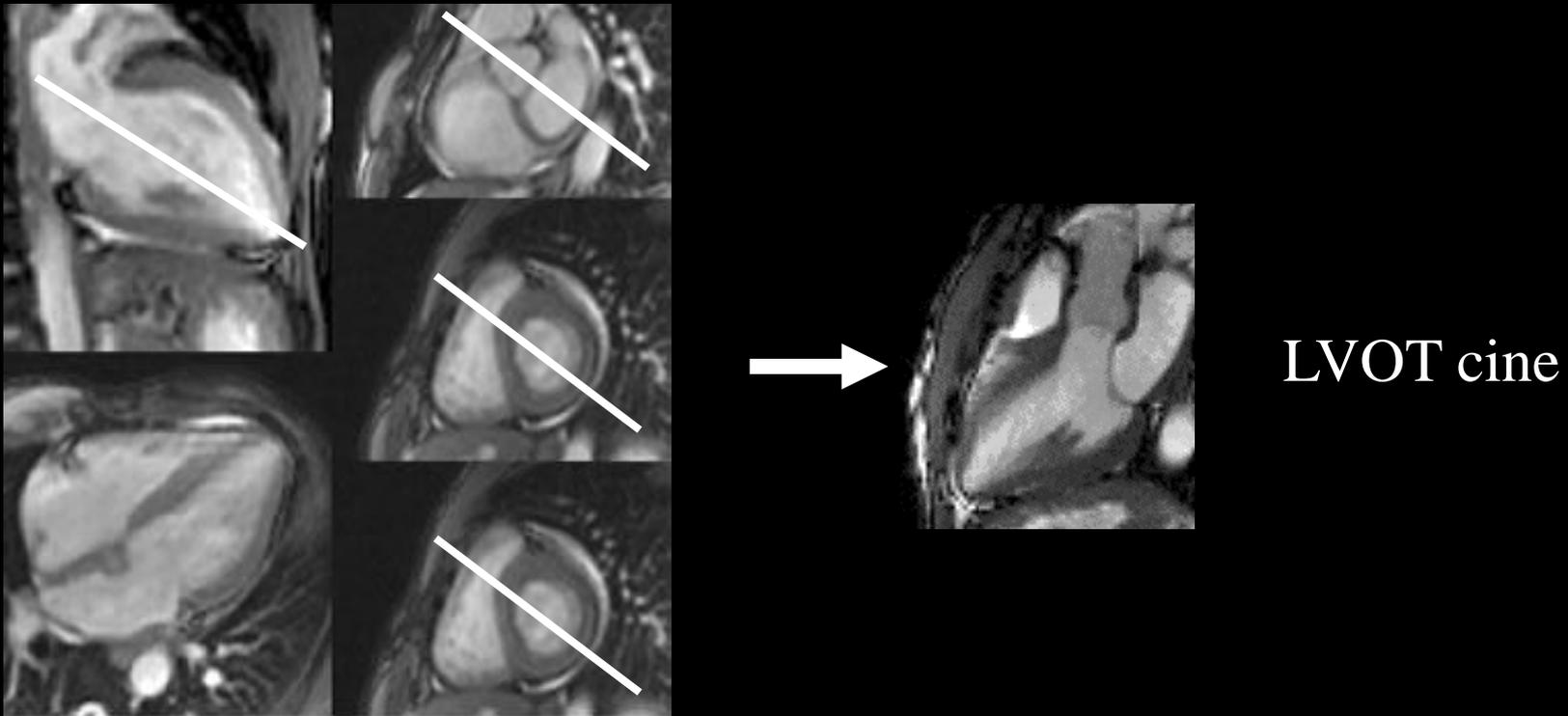
7: Short axis stack



SA stack

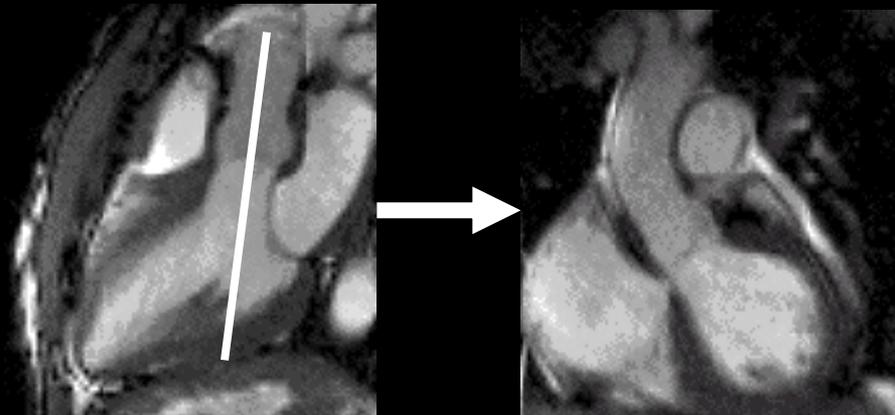
8: LVOT cine

If you want to, modify the 4 chamber using the basal SA pilot by twisting the plane until it goes through the aortic valve into the ascending aorta. This is the LVOT view (parasternal long axis or apical 3 chamber by echo)



9: LVOT coronale cine

A second LVOT view can be piloted perpendicular to the initial LVOT view (LVOT coronal view)



LVOT cine
(coronale)

Classificazione dei devices impiantati

2007

- **MR safe** : *nessun pericolo conosciuto in qualunque ambiente MR* (non conduttori non magnetici)
- **MR conditional**: *non si conoscono rischi in specifici ambienti MR*
- **MR unsafe** : *che include articoli conosciuti come pericolosi in qualunque ambiente MR*

Rischi MR

Legati al paziente

Claustrofobia

Grandi obesi

Primi mesi di gravidanza

Situazioni di emergenza

Scarsa compliance del Paziente

Pazienti instabili

Rischi MR

Campo Magnetico Statico

- Attrazione di un oggetto ferromagnetico nello scanner (effetto proiettile).
- Rotazione o dislocamento di un oggetto ferromagnetico o malfunzionamento di devices con parti ferromagnetiche mobili.

Rischi RM

Gradienti

- L'alternarsi rapido dell'applicazione di gradienti può indurre correnti elettriche in devices con proprietà di conduzione e potenzialmente possono eccitare tessuti come nervi periferici. (virtualmente ciò non dovrebbe accadere)
- Disturbi acustici: quando le correnti oscillano nel campo delle audio frequenze il disturbo che ne può risultare può superare i 100 dB.

Rischi RM

Energia delle radiofrequenze

- Aumento della temperatura (generalmente $< 1^\circ$).
- Alcuni devices (leads dei pm) possono agire da antenna e convogliare ulteriore energia aumentando il calore.
- Cavi che formano loops larghi sono antenne più efficienti di quelli corti e dritti.
- La presenza di PM permanenti disconnessi o di leads di defibrillatori devono essere considerati una controindicazione assoluta.

Safety of RM in Pts with cardiac devices 2007

PM e Defibrillatori

Migrazione dei devices

Riscaldamento

Effetto antenna dei leads

Potenziale riprogrammazione di un device nel campo magnetico anche quelli con modalità “fail safe”

Malgrado alcuni studi recentemente pubblicati la

“Commisssione ritiene che PM ed ICD debbano essere ancora considerati a forte relativa controindicazione per RM”.

Safety of RM in Pts with cardiac devices

2007

- Dopo 6 mesi dall'impianto si ritiene che i devices siano ben assestati.
- Stent coronarici, periferici o aortici sono per la maggior parte non o debolmente ferromagnetici (conditional per alcuni).
- Stent coronarici e drug eluting stent che non sono ferromagnetici possono essere scannerizzati anche a 3T in qualunque momento.
- Stent coronarici debolmente ferromagnetici possono essere scannerizzati dopo 6 settimane.
- Protesi valvolari o anelli per valvuloplastica non ferromagnetiche o debolmente ferromagnetiche sono considerati sicuri. Altri conditional.
- Devices occlusivi (difetti setto atriale) debolmente ferromagnetici possono essere scannerizzati dopo sei mesi.

Nephrogenic Systemic Fibrosis

Contrasto (Gadolinio)

Clinica : inizia con prurito e gonfiore delle estremità seguita da indurimento severo e progressivo della cute. Le lesioni della pelle sono placche eritematose che confluiscono in placche sempre più consistenti.

Diagnosi : per esclusione confermata da biopsia.

Prognosi : regressione della malattia è inusuale
progressione in disabilità fisica - perdita di autonomia

Nephrogenic Systemic Fibrosis

Contrasto (Gadolinio)

Il Gadolinio contiene elettroni dispari che interagiscono con le molecole d'acqua circostante e quindi generano contrasto.

Il Gadolinio libero non legato è estremamente tossico, ma quando è chelato ad un legante il suo profilo di sicurezza migliora in modo drammatico con una escrezione renale che aumenta di 500 volte.

In soggetti con funzione renale normale l'emivita di eliminazione è di 1h 30'.
con funzione renale gravemente compromessa è di 34 h
in dialisi peritoneale solo il 69% è eliminato in 22 giorni
in emodialisi l'eliminazione avviene da 1 a 4 giorni

Tempo che intercorre tra infusione di Gd e sintomi: da 2 giorni a 18 mesi.

Nephrogenic Systemic Fibrosis

Contrasto (Gadolinio)

Meccanismo probabile : il lungo tempo di eliminazione permette la rottura dei legami.

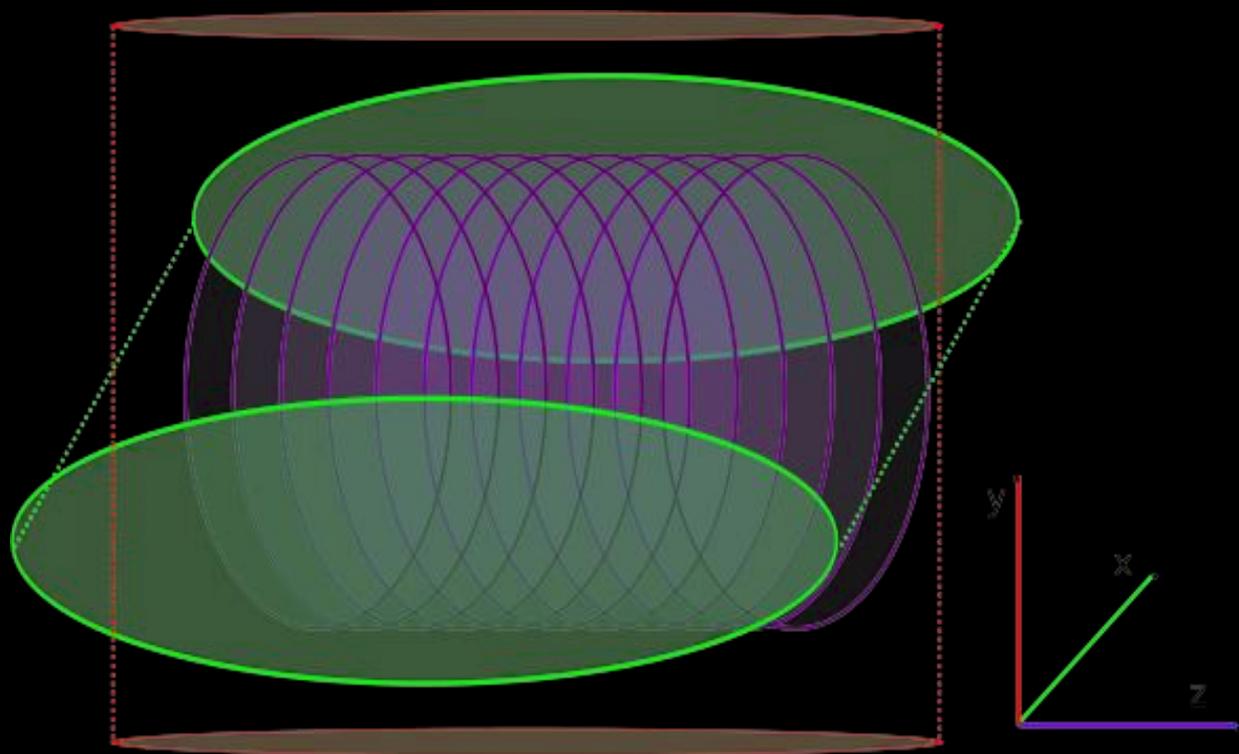
Raccomandazioni:

In pazienti con insufficienza renale moderata ($\text{GFR} < 60 \text{ mL/min}$) o malattia renale ultimo stadio ($\text{GFR} < 15 \text{ mL/min}$) valutare bene il rischio beneficio ed eventualmente scegliere altri mezzi diagnostici, se possibile.

In pazienti con insufficienza renale da moderata a grave, considerare la possibilità di ricorrere a dialisi subito dopo l'esame.

Free Induction Decay

Dopo l'impulso gli spin tenderanno a ritornare al loro stato di allineamento lungo il campo (rilassamento), tramite una bobina ricevente viene misurato l'andamento della magnetizzazione nel piano perpendicolare al campo magnetico principale (FID)



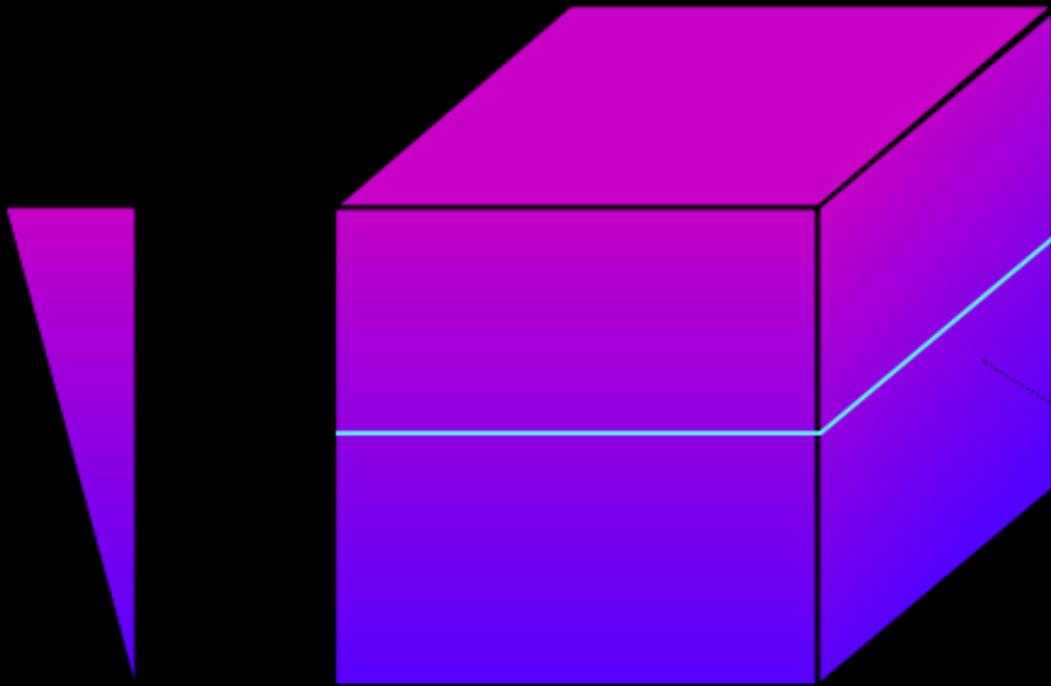
Codifica Spaziale

Dopo l'eccitazione tutti i nuclei risuonano alla **stessa frequenza** ed il segnale non contiene **informazioni sulla posizione**.

Spatial encoding is achieved by **position dependent resonant frequency**

A position dependent resonant frequency is produced by a **position dependent magnetic field** (= magnetic field **gradient**)

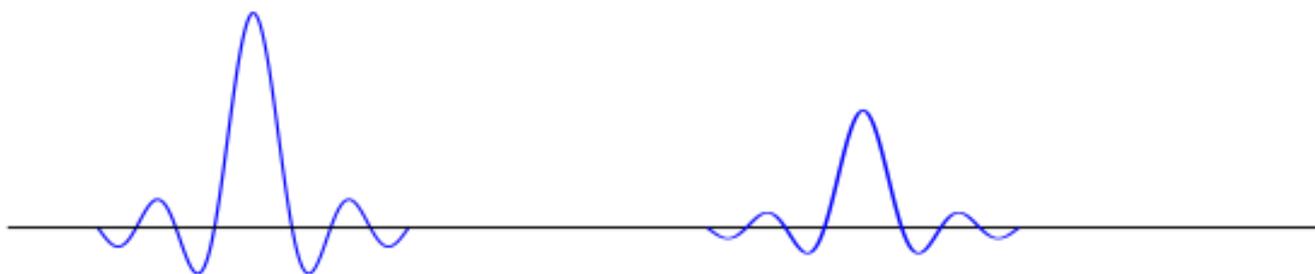
There are 3 magnetic field gradients in the 3 directions in space: **X, Y and Z gradient**



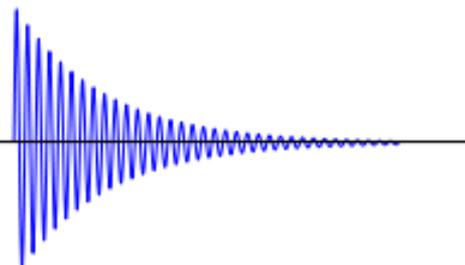
Segnali RF trasmessi
(involuppo)

180°

90°



Segnale ricevuto (FID)



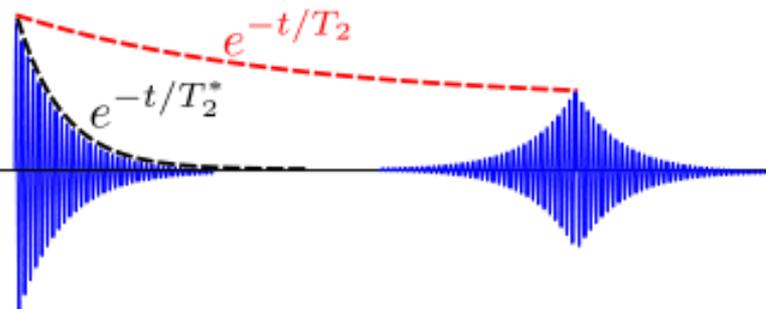
Segnali RF trasmessi
(involuppo)

90°

180°



Segnale ricevuto (FID)

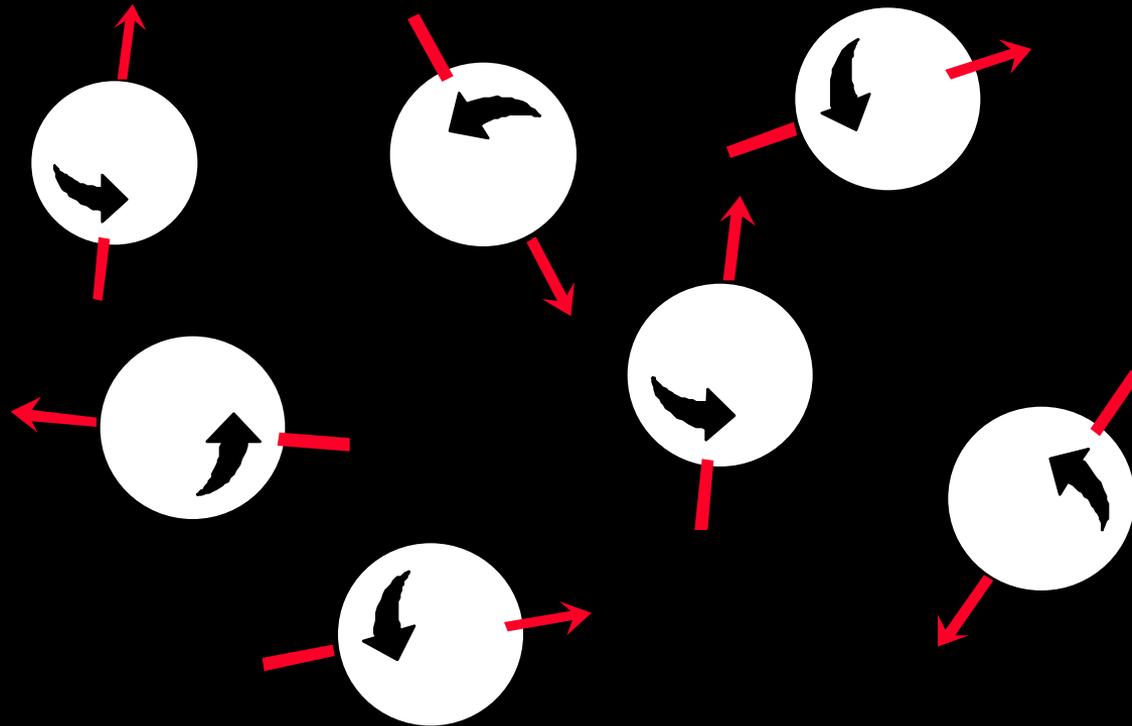


Magnetic Resonance Imaging

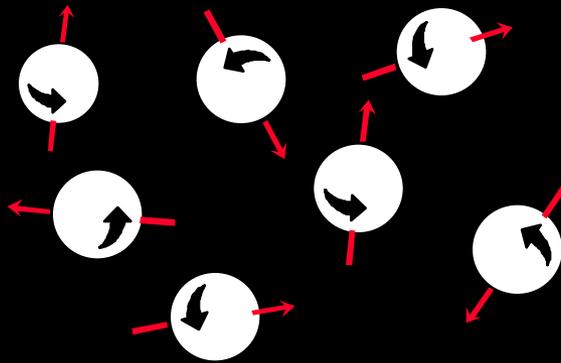
Basics

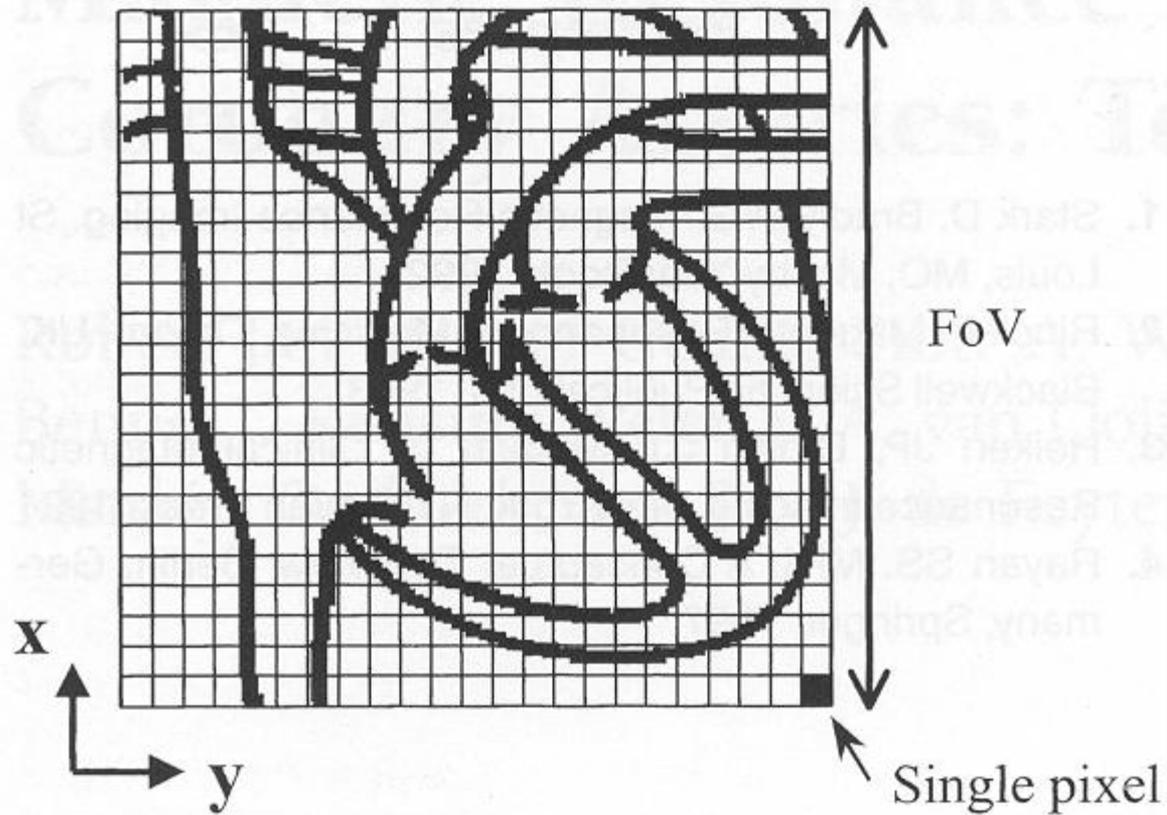
- The magnet, which is usually superconducting, produces
- the static magnetic field whose strength is measured
- in Tesla (e.g., 1.5-T or 3-T; 1.5-T is equivalent to 15,000
- Gauss, and the Earth's magnetic field is approximately 0.5
- Gauss). A stable, homogeneous field is required about the
- area of interest. Resistive gradient coils within the bore of
- the magnet produce the gradient fields, and the currents
- within these coils are driven by the gradient amplifiers. The
- performance of the gradient system determines the speed of
- the MR acquisition. A radiofrequency (RF) coil (antenna) is
- coupled to an RF amplifier to excite the patient's protons
- with RF pulses, and this (or another more localized surface
- coil) is coupled to the receiver to measure the resultant
- signal. A computer is required to control the scanner and
- generate the images, which are then displayed in static,
- dynamic (cine) modes. Post-processing tools are extensive
- and used both for quantitation and for image display.

Protoni



Protoni





RISOLUZIONE SPAZIALE

- LA RISOLUZIONE SPAZIALE è FUNZIONE DELLE DIMENSIONI DEL VOXEL .
- VOXEL= dimensioni Pixel x Spessore della fetta
- Più piccolo è il voxel maggiore è la risoluzione spaziale ma più debole è il segnale misurato.

RISOLUZIONE

- Spessore
- FOV
- Matrice

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CONTRASTO

DIPENDE da:

- TR
- TE
- Flip angle
- Mezzo di Contrasto
- Sequenza

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Rapporto segnale rumore

- Dipende da:
- Voxel
- Acquisizioni
- Potenza del campo
- Bobina
- Ampiezza di banda