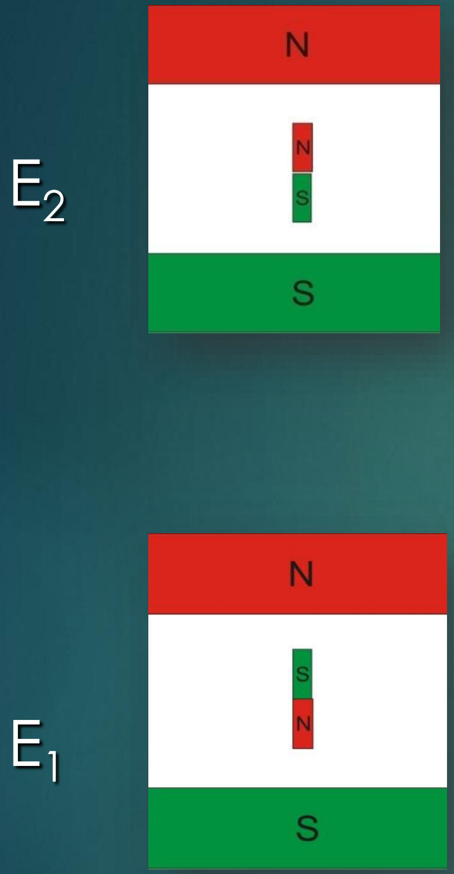
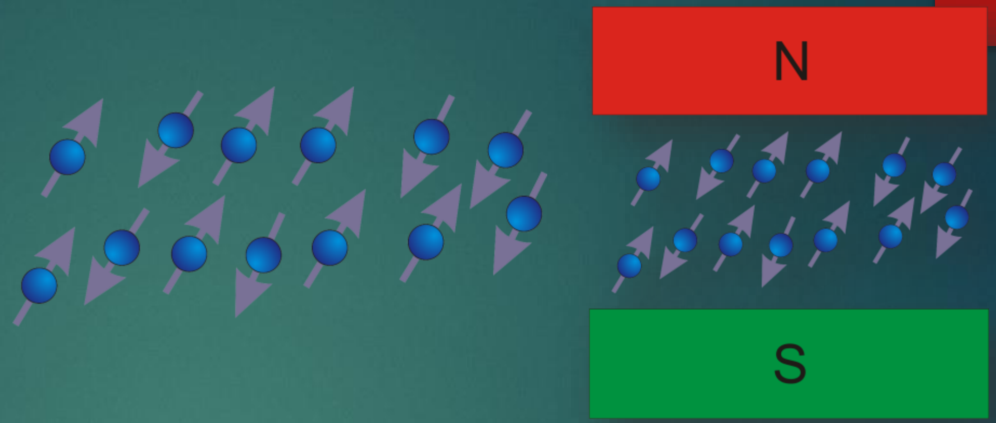
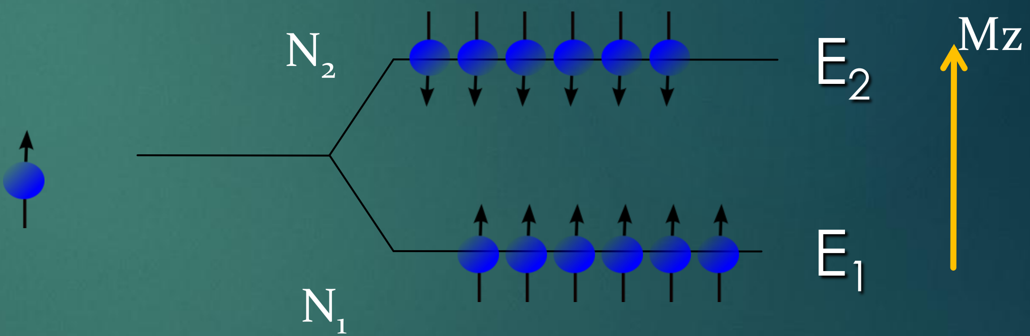
Imidžing magnetnom rezonancijom

Spinovi u magnetnom polju





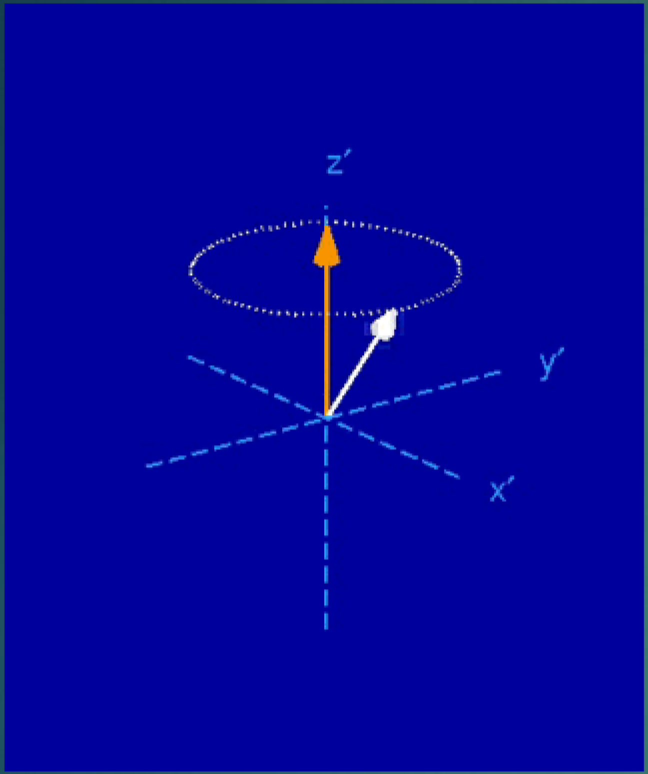


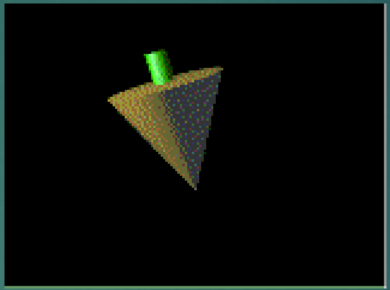
$E_2 - E_1 \sim B = h\nu$

$N_1 - N_2 \uparrow$ kada $B\uparrow$

$Mz = \Sigma \uparrow - \Sigma \downarrow$

Precesija i Larmorova jednačina



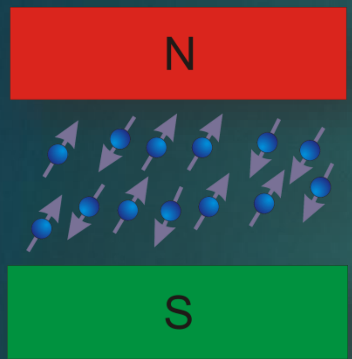


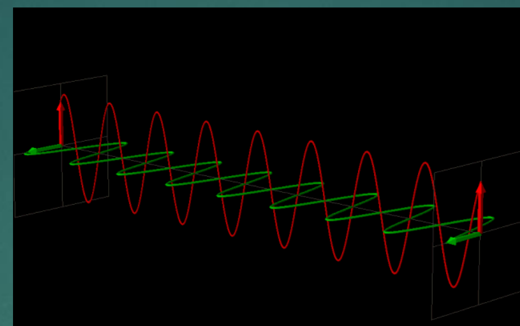
$$\omega = (e/2m)B = \gamma B$$

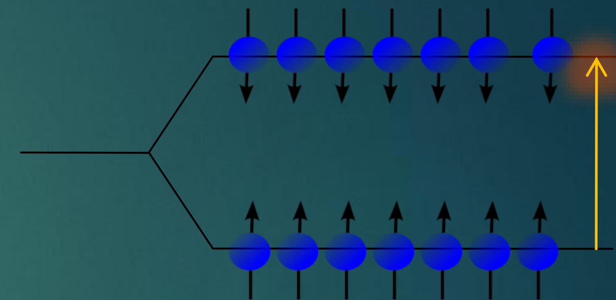
$$\omega = 2\pi\nu = \gamma B/2\pi$$

$$E_2 - E_1 = h\nu = \omega/2\pi = \gamma B/2\pi$$

Uvođenje ekscitacije i magnetna rezonancija

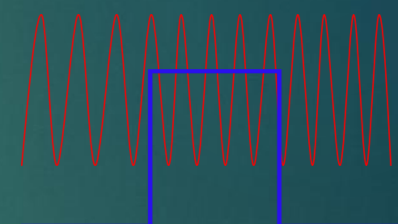






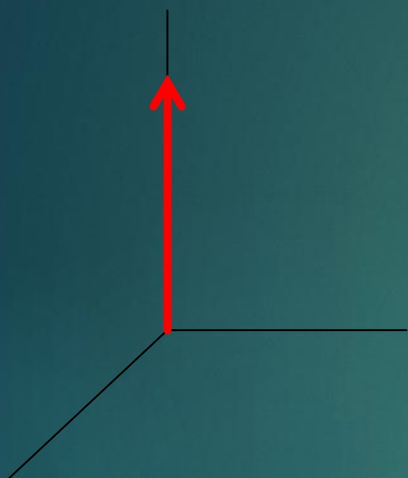
$$B_1 = B_{01} \sin(\omega t)$$

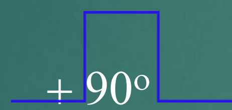
Elektromagnetni talas frekvencije jednake Larmorovoj

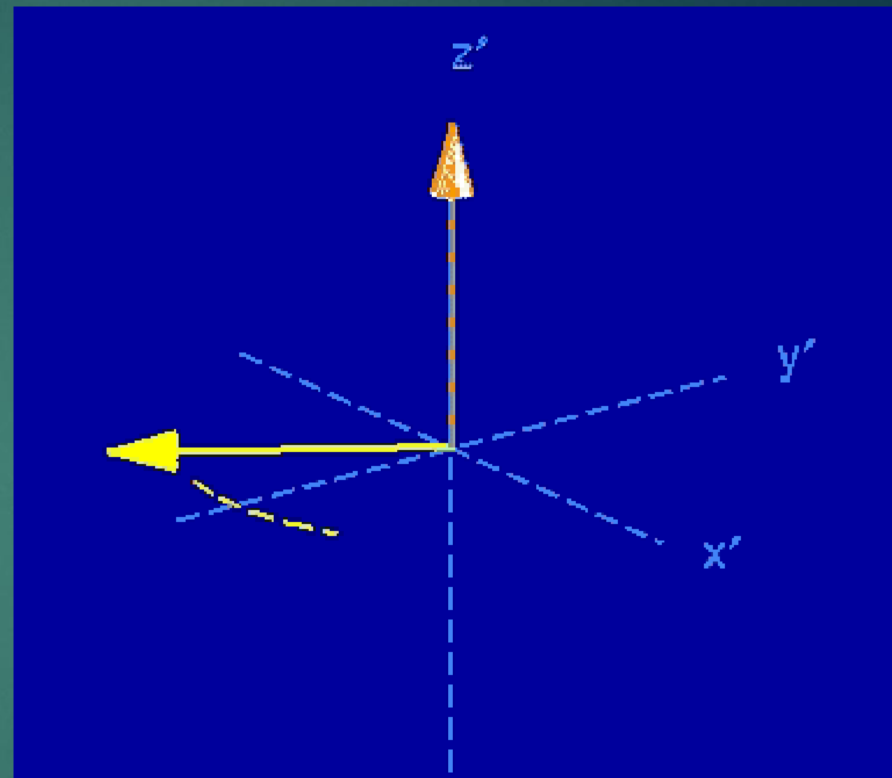


B_{01} je amplituda vektora magnetnog polja

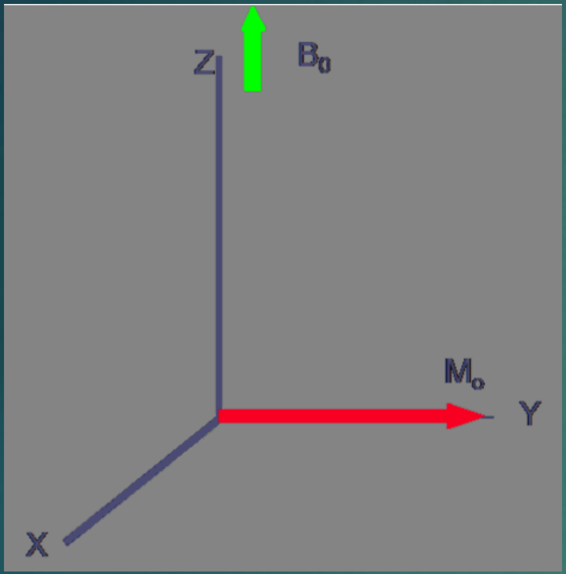
Od vremena t zavisi koliko će spinova preći u više energetsko stanje i za koji ugao će magnetizacija biti oborena ka xy ravni

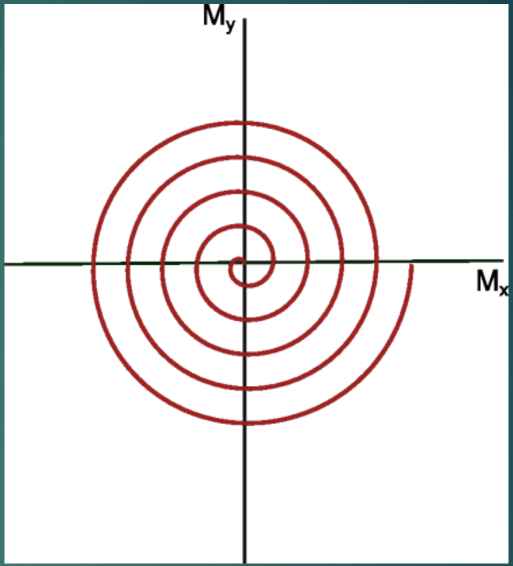



+ 90°

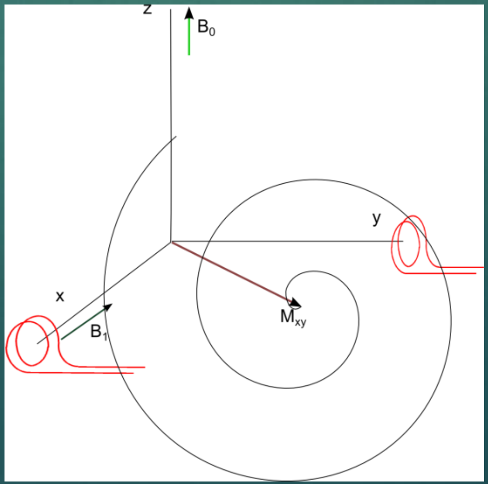

z'
y'
x'

Ponašanje magnetizacije posle pulsa od 90^0

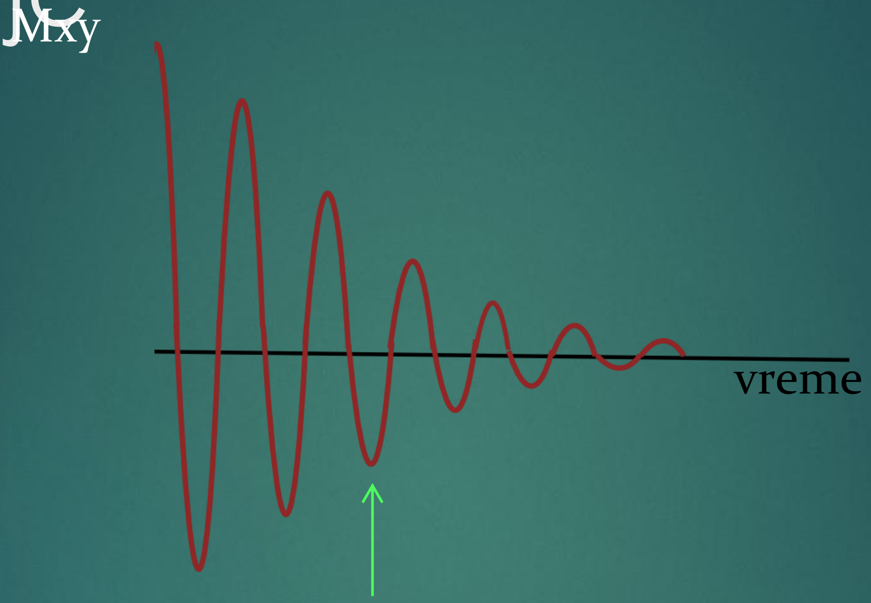




M_x



Detekcija raspada slobodne indukcije

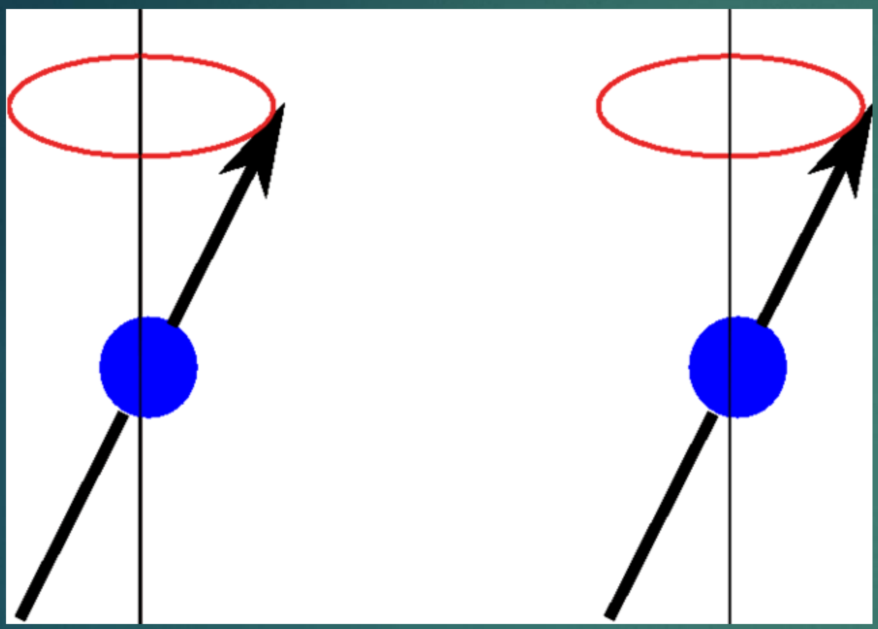


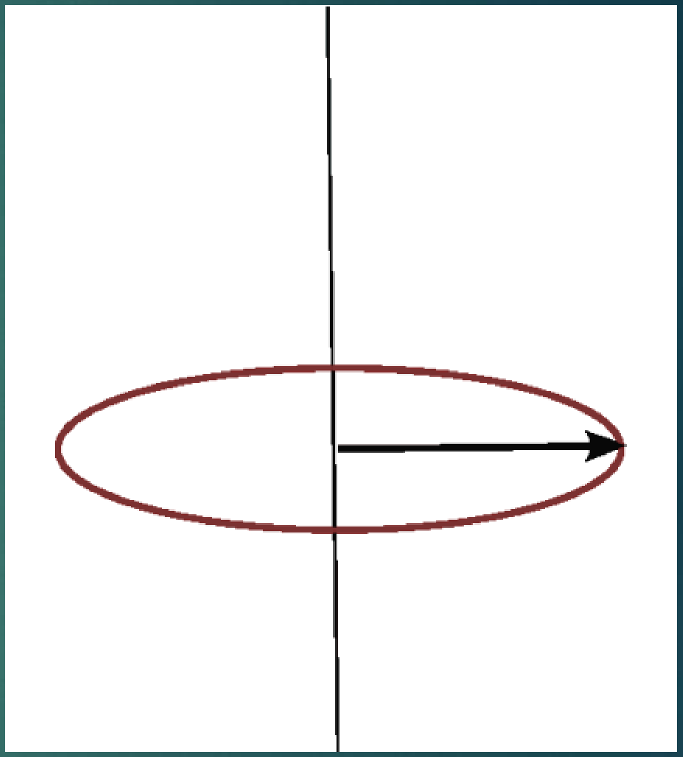
NMR signal

Raspad slobodne indukcije (free induction decay)

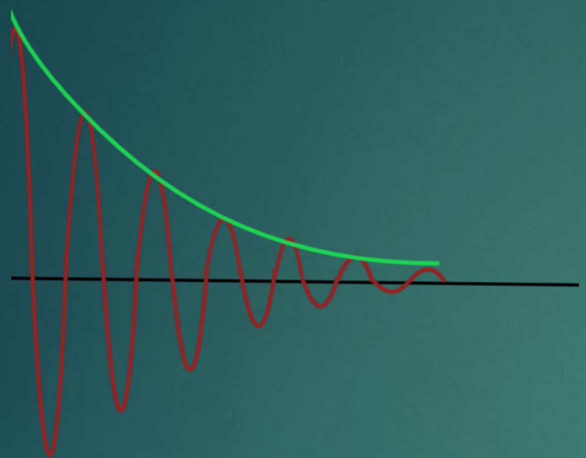
$$M_{xy} = M_0\,[\cos(\omega t + \varphi) + i sin(\omega t + \varphi)]e^{-\frac{t}{T_2}}$$

Spin-spin relaksacija

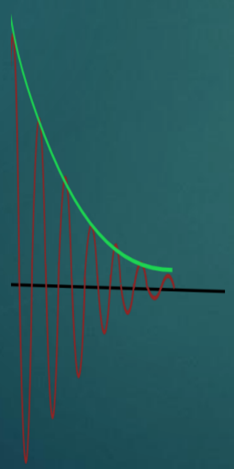




T2 vreme relaksacije



$$M_{xy} = M_0 \cos(\omega t) e^{-\frac{t}{T_2}} = M_0 e^{-i\omega t} e^{-\frac{t}{T_2}}$$



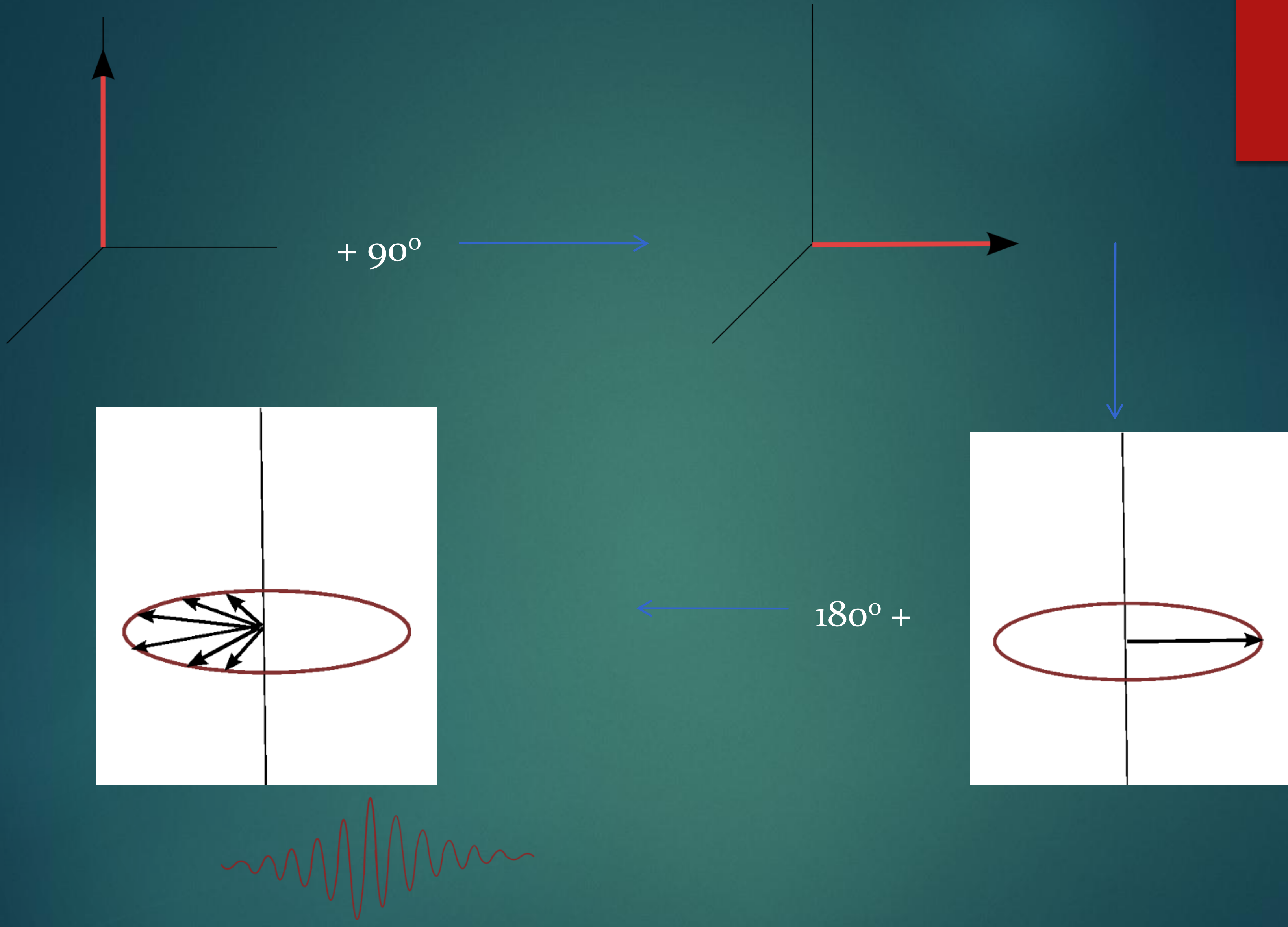
$$M_{xy} = M_0 e^{-\frac{TE}{T_2 *}}$$

- vreme = 0 M_{xy} je proporcionalno broju spinova (spinska gustina, protonska gustina)

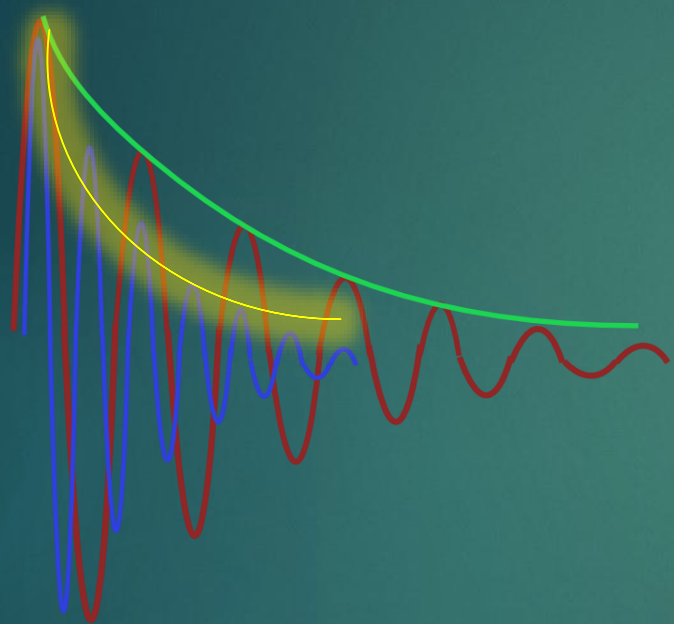
- Vremenska konstanta eksponencijalnog opadanja magnetizacije se naziva spin-spin vreme relaksacije T_2

- U stvarnosti magnetizacija opada brže zbog nehomogenosti magnetnog polja u sistemu

Vremensko opadanje magnetizacije je u tom slučaju karakteriše konstanta T_2^*


+ 90º
180º +

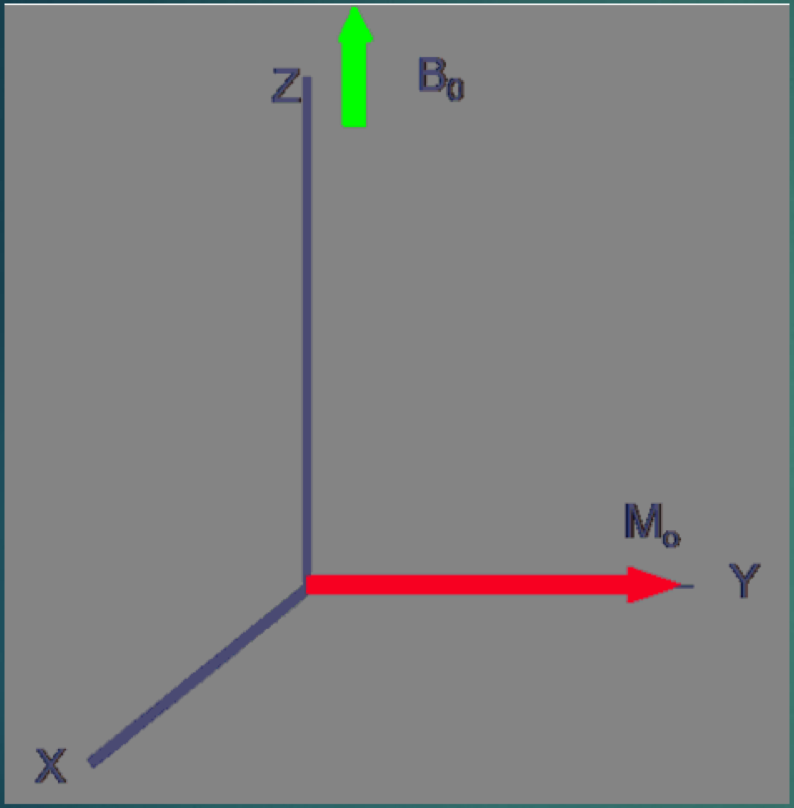
FID i spin eho

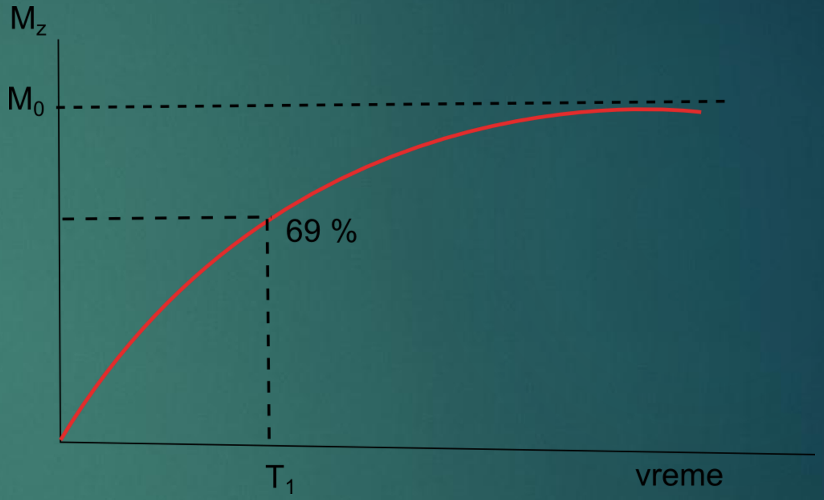


FID

EHO

Spin-rešetka vreme relaksacije (T_1)





$$M_z = M_0\left(1 - e^{-\frac{TI}{T_1}}\right)$$

Od čega zavisi NMR signal

$$S = N_p\left(1 - e^{-\frac{t_1}{T_1}}\right)e^{-\frac{t_2}{T_2}}$$

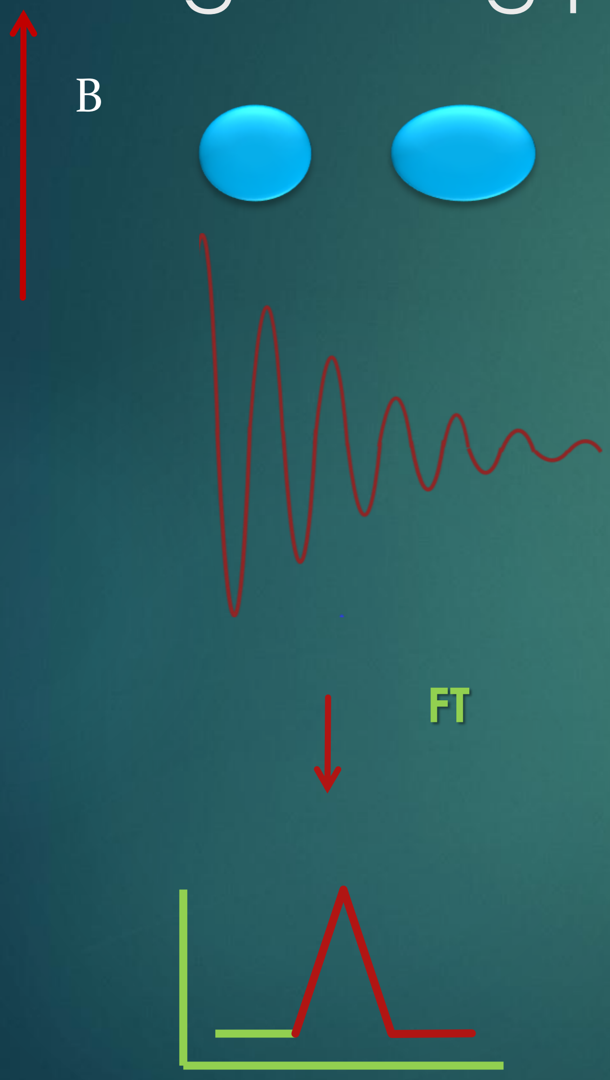
N_p broj spinova (protona), spinska gustina

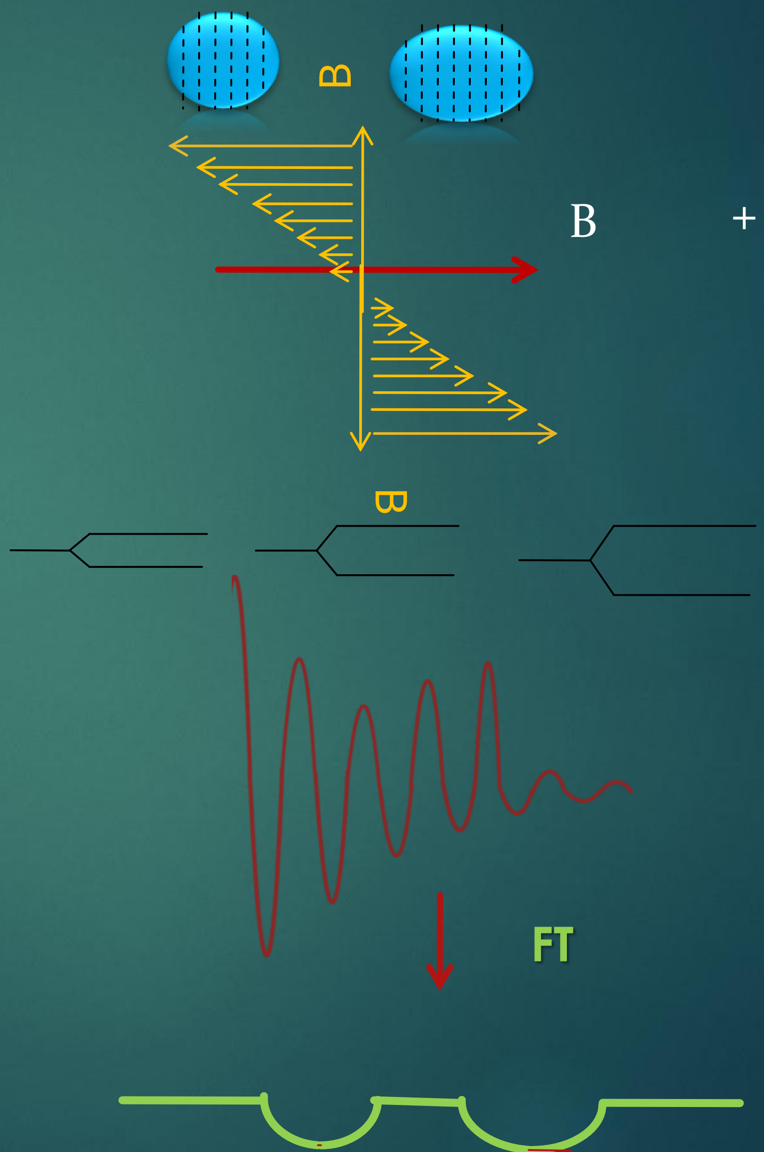
TR, TE parametri akvizicije signala

T_1 –spin-rešetka vreme relaksacije

T_2 –spin-spin vreme relaksacije

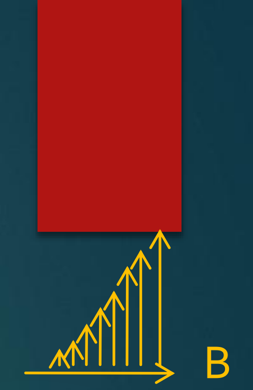
Dobijanje MR slike - gradijent magnetnog polja

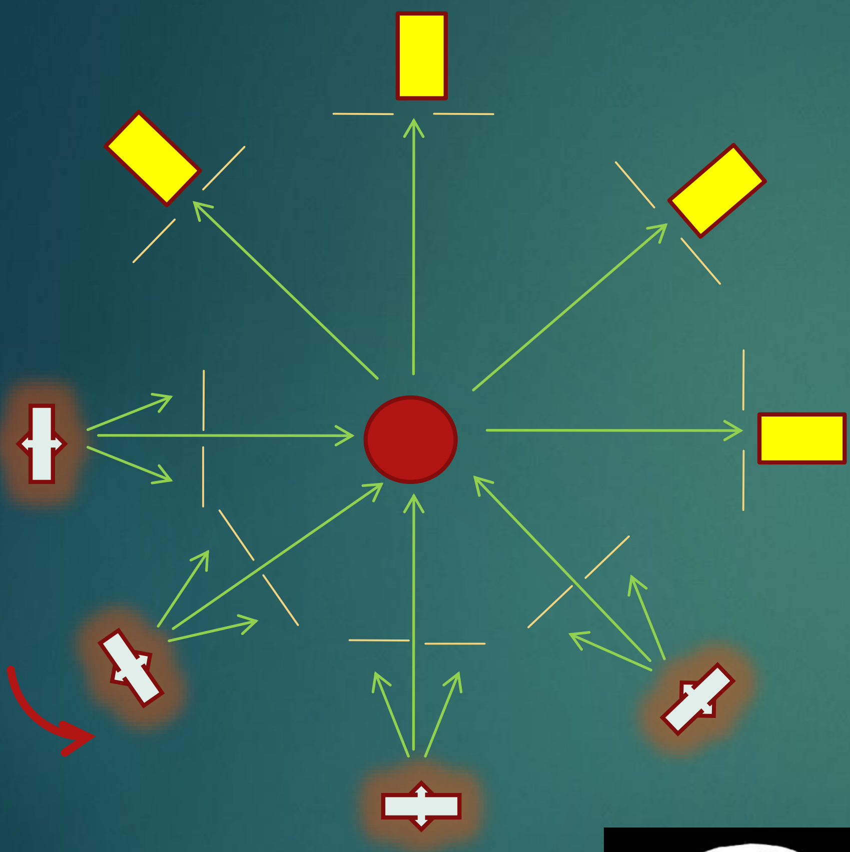


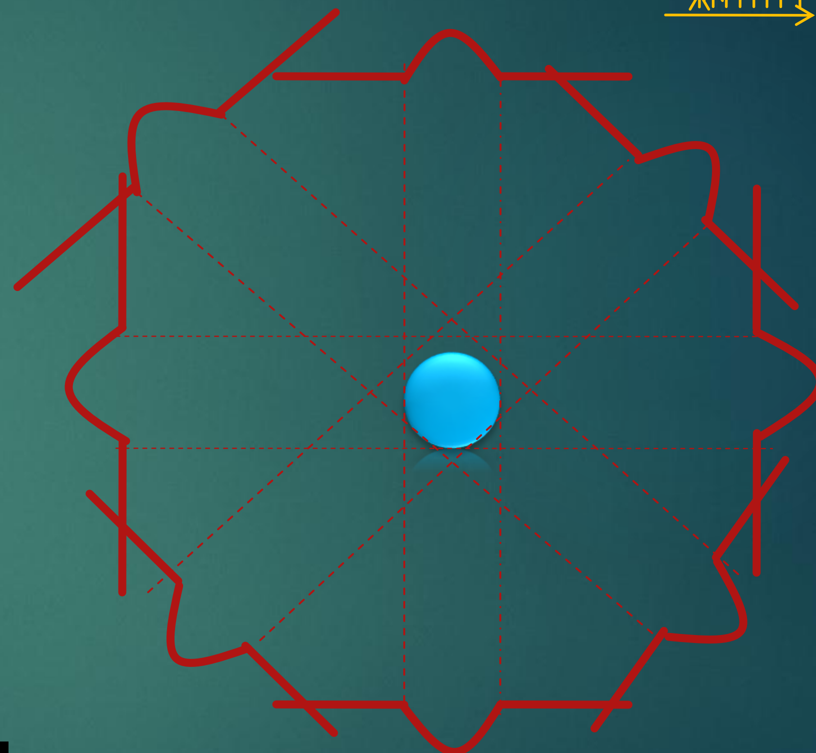


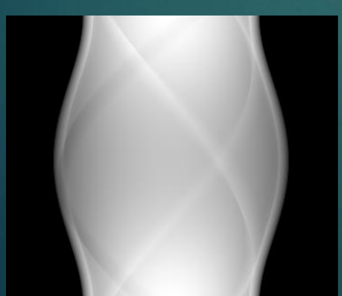
$+ \; B = B_o + xG_x$

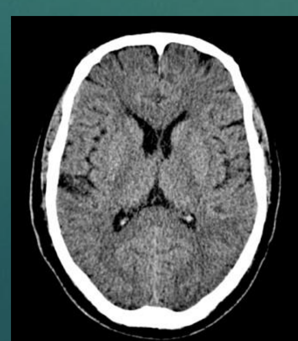
Gradijent magnetnog polja (2)







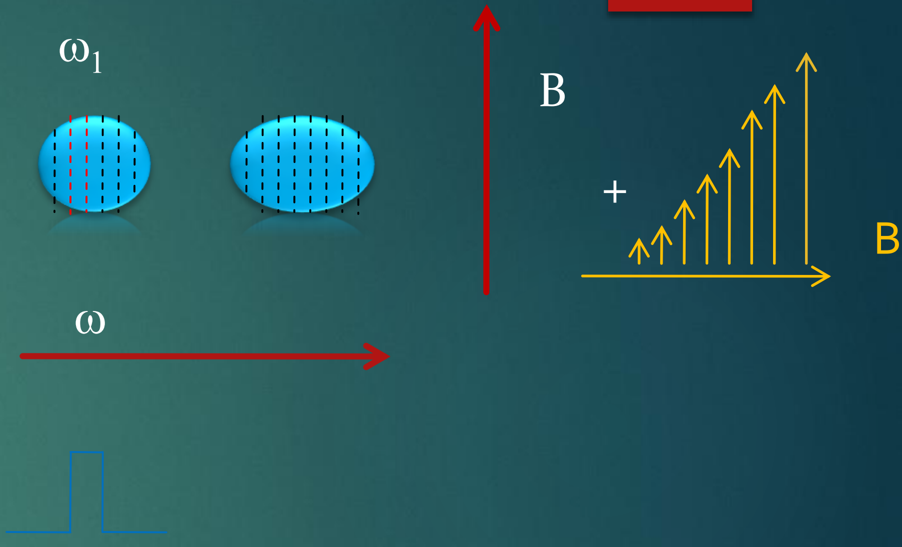


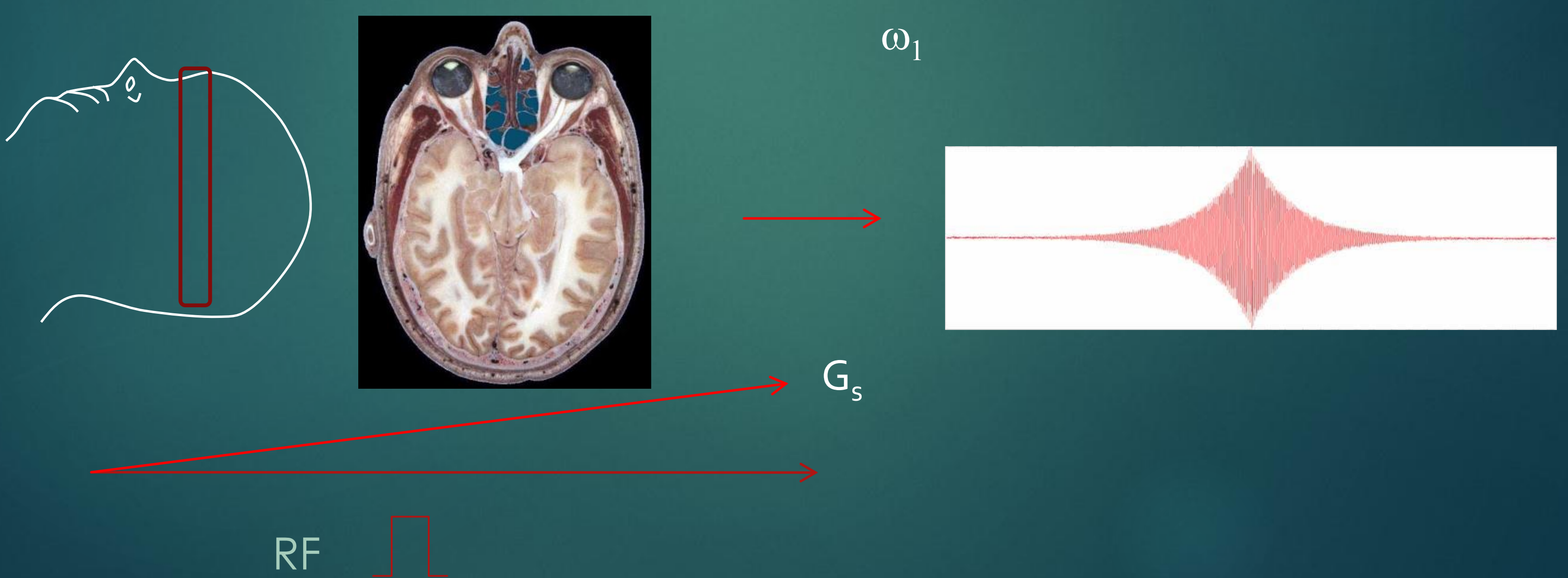


NMR zeugmatografija

Gradijent magnetnog polja (2)

- $B = B_o + xG_x$
- $\omega = \gamma(B_o + xG_x)$

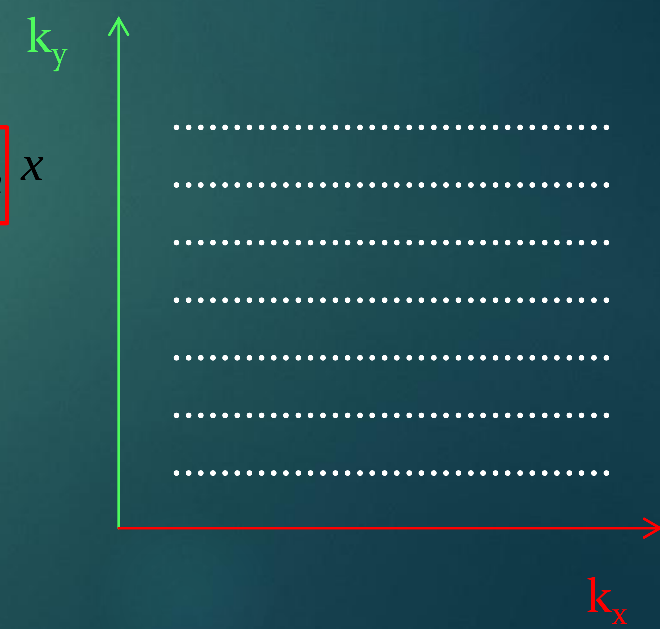




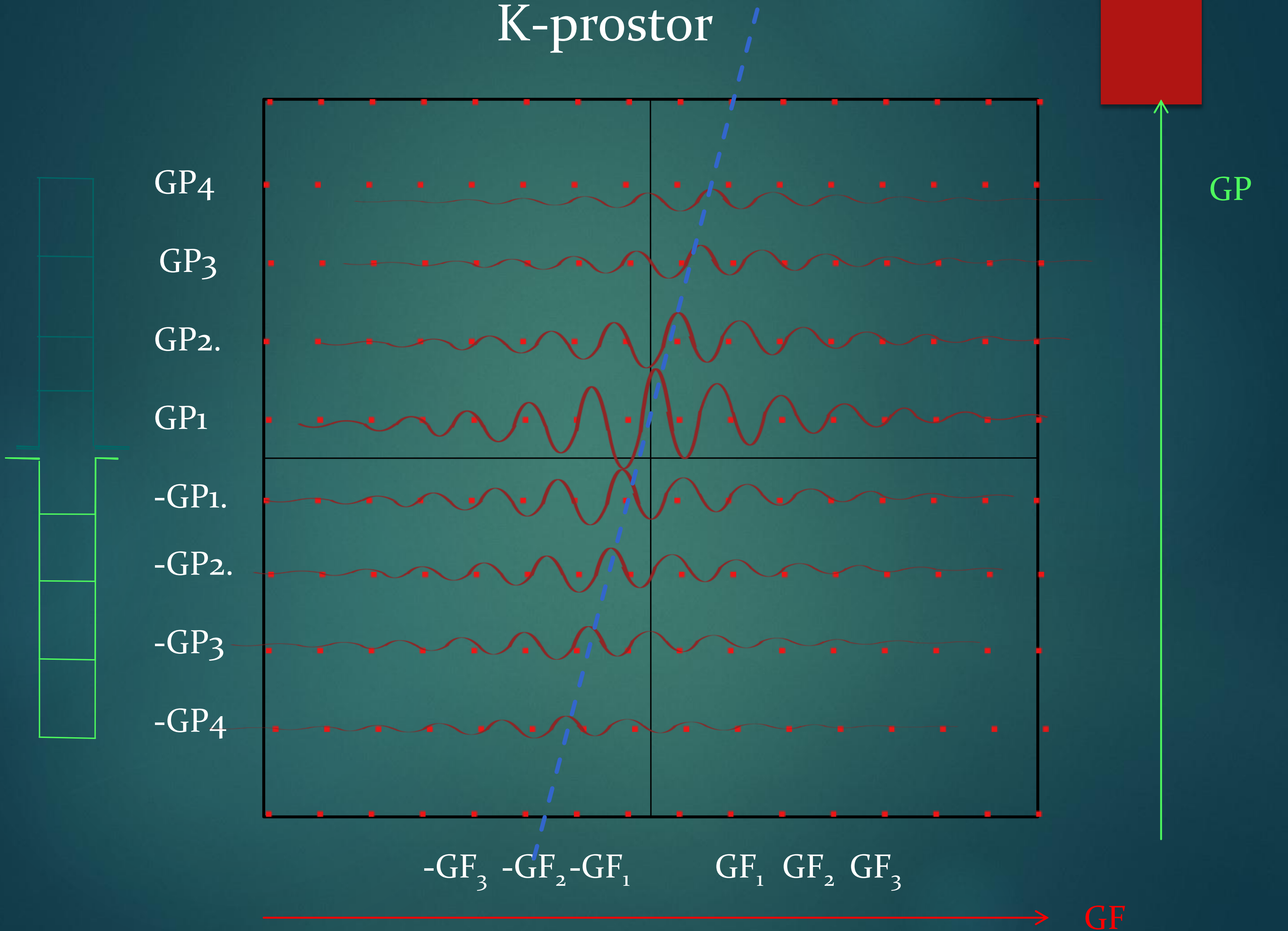
+ dva gradijenta

- $B=B_o+ xG_x$ gradijent izbora preseka +
- $B=B_o+ xG_x + yG_y$ gradijent izbora faze +
- $B=B_o+ xG_x + yG_y + zG_z$ gradijent frekventnog kodiranja

$$M_{xy} = M_0 e^{-i\gamma B_0 t} e^{-i\gamma G z t x} e^{\underbrace{\boxed{-i\gamma G_y t_f}}_{= k_y} y} e^{\underbrace{\boxed{-i\gamma G_x t_n}}_{= k_x} x}$$

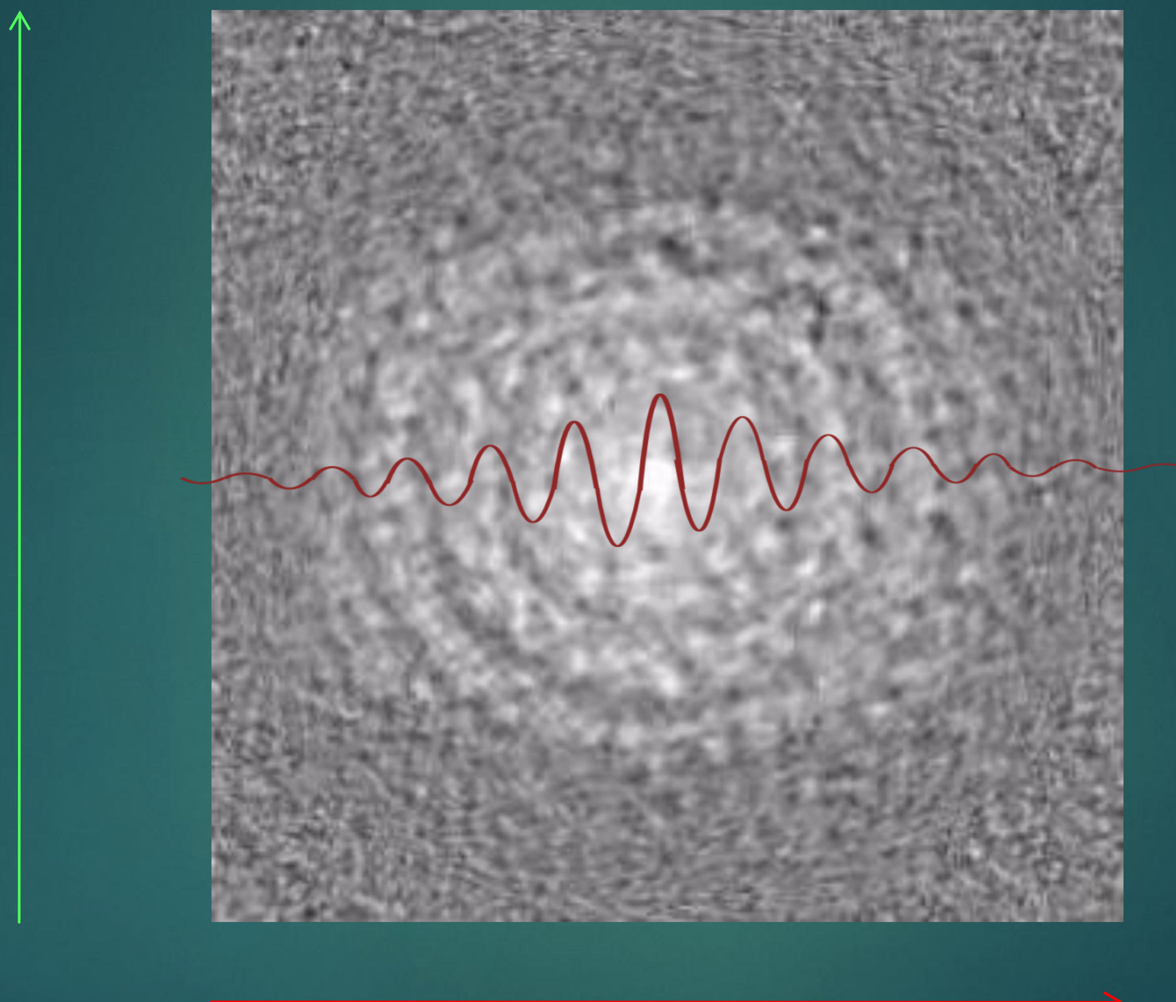


K-prostor



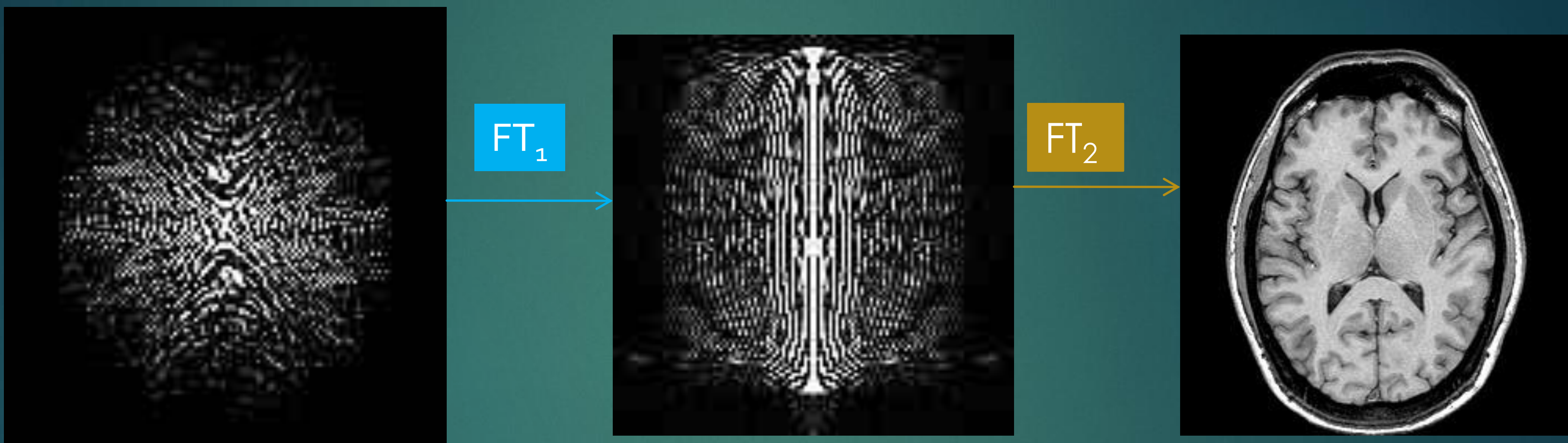
Slika K-prostora

Fazno kodiranje



Frekvenciono kodiranje

Od K-prostora do slike



Pulsne sekvencije i mehanizmi kontrasta

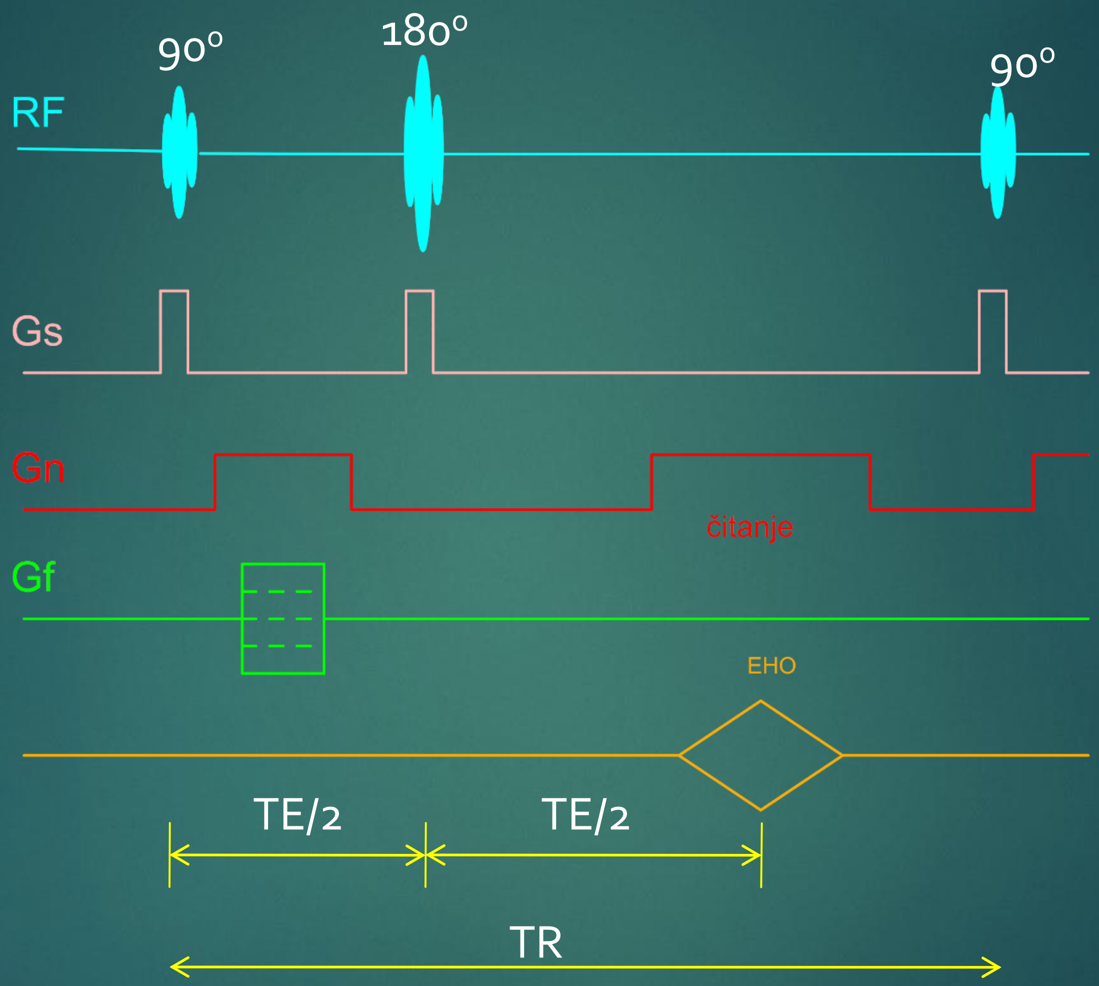
Pulsne sekvencije, osnovni pojmovi

- Podsećaju na notni zapis

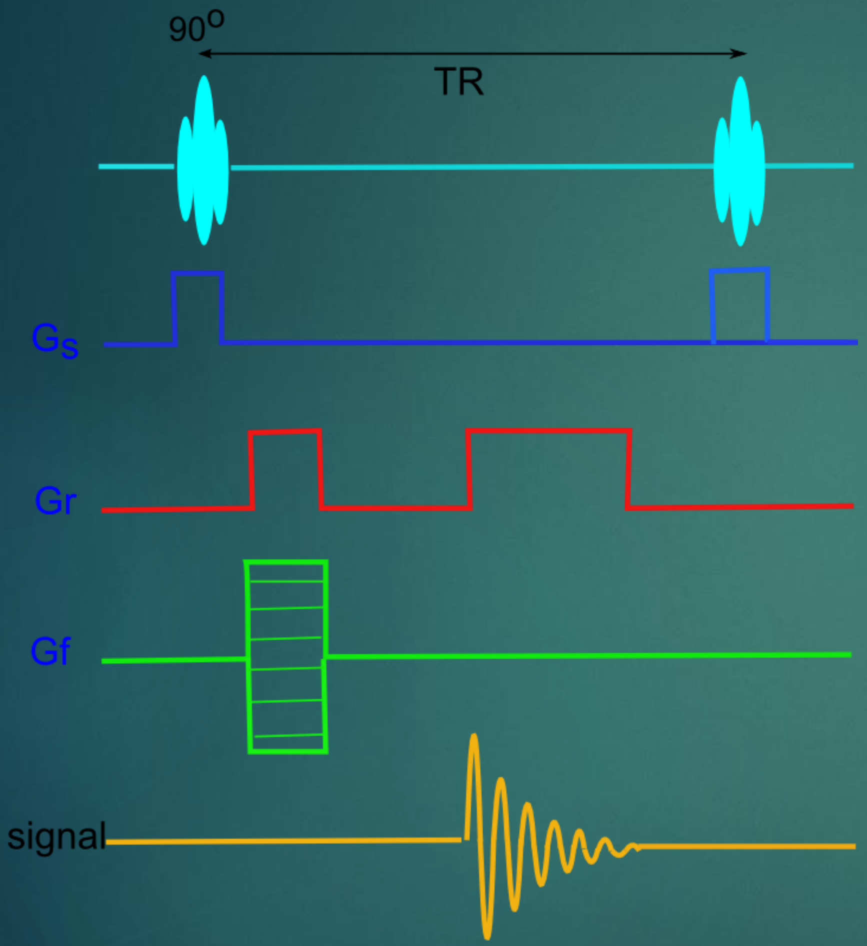
- Određuju redosled, polaritet, međusobni odnos i trajanje RF pulseva i gradijenata koji se koriste pri formiranju MRI slike.

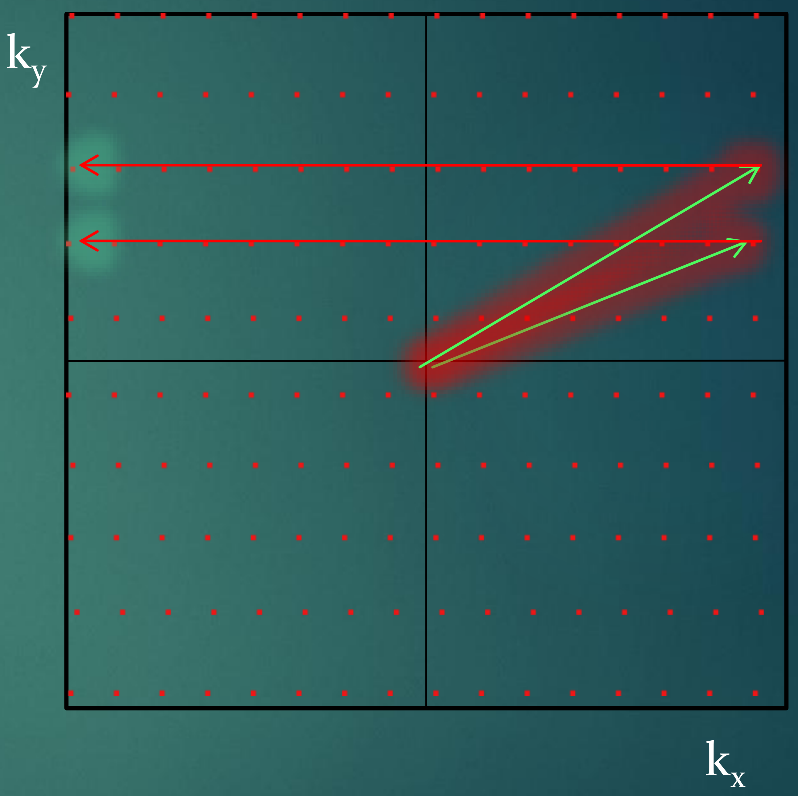
- Obavezan je jedan radiofrekventni puls od 90° i tri gradijenta. U zavisnosti od tipa sekvencije može biti prisutno jedan ili više RF pulseva.

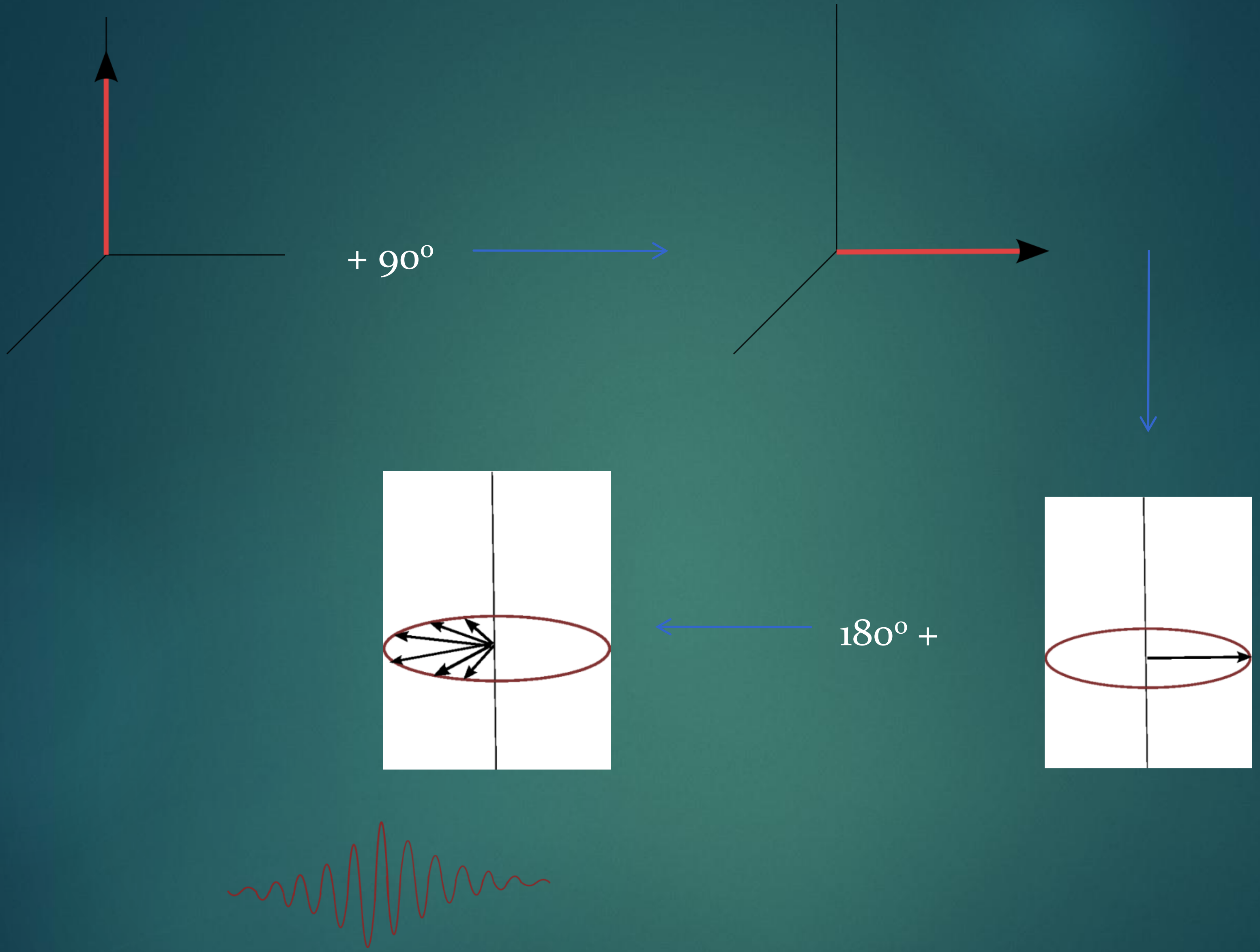
Spin eho



Osnovna MRI sekvencija







+ 90⁰
180⁰ +