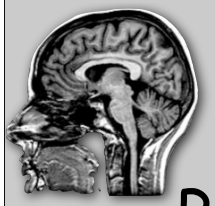
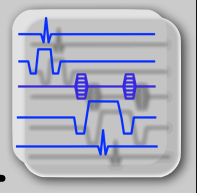




Principles of MRI

EE225E / BIO265

Lecture 13

Instructor: Miki Lustig
UC Berkeley, EECS

Small Tip-Angle Approximation

- Solution for general Eq. at time t=T

$$M_{xy}(\vec{r},T) = iM_0 \int_{-\infty}^{T} \gamma B_1(t) e^{-i2\pi \vec{k}(t)\cdot\vec{r}} dt$$

,where

$$\vec{k}(t) = \frac{\gamma}{2\pi} \int_t^T \vec{G}(\tau) d\tau$$

- k(t) is area of the <u>remaining</u> gradient

Example: Slice Selection

$$M_{xy}(z,T) = iM_0 \int_0^T \gamma B_1(t) e^{-i2\pi k_z(t) z} dt$$

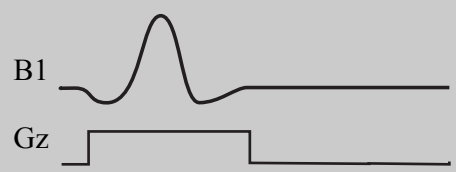
- This is not exactly a Fourier transform
- Would like:

$$M_{xy}(z,T) = iM_0 \int_K W(k) e^{-i2\pi k_z z} dk_z$$

$$W(k) = \frac{2\pi B_1(k)}{|G(k)|}$$

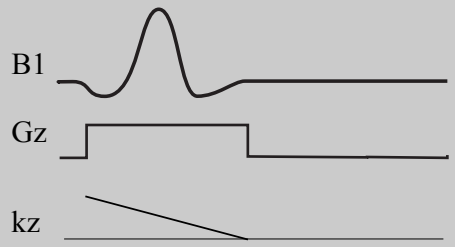
Example: Slice Selection

$$M_{xy}(z,T) = iM_0 \int_0^T \gamma B_1(t) e^{-i2\pi k_z(t) z} dt$$

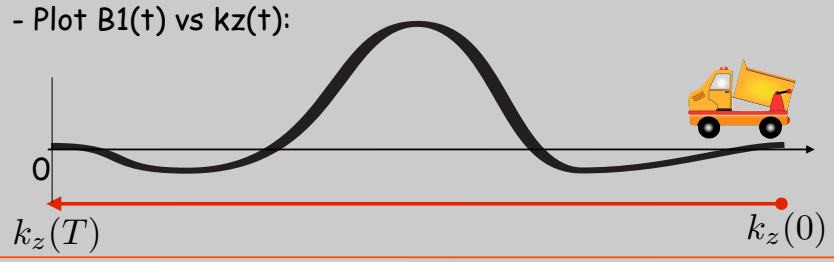


- First find $k_z(t)$
- Map B1(t) to $k_z(t)$ -- account for speed!
- Compute the integral (Fourier transform)

Example: Slice Selection

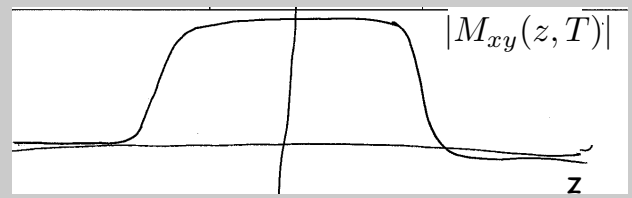


- Plot B1(t) vs kz(t):



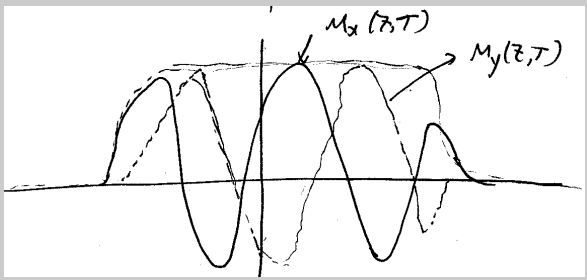
Example: Slice Selection

- B1 is not centered in k-space
- We get the right magnitude Mxy

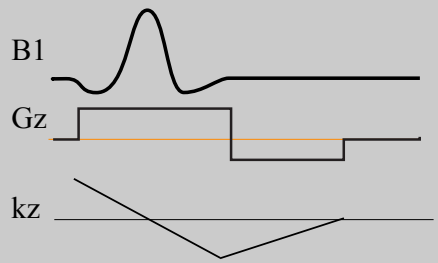


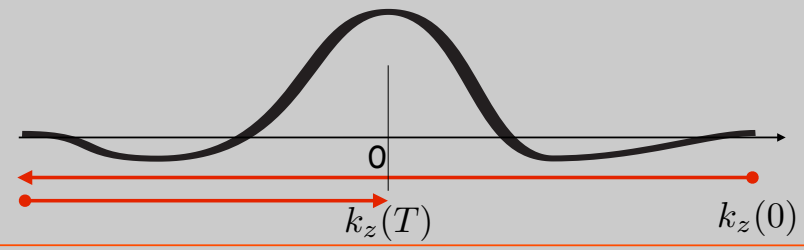
Example: Slice Selection

- But we get phase across the slice.... signal cancels!

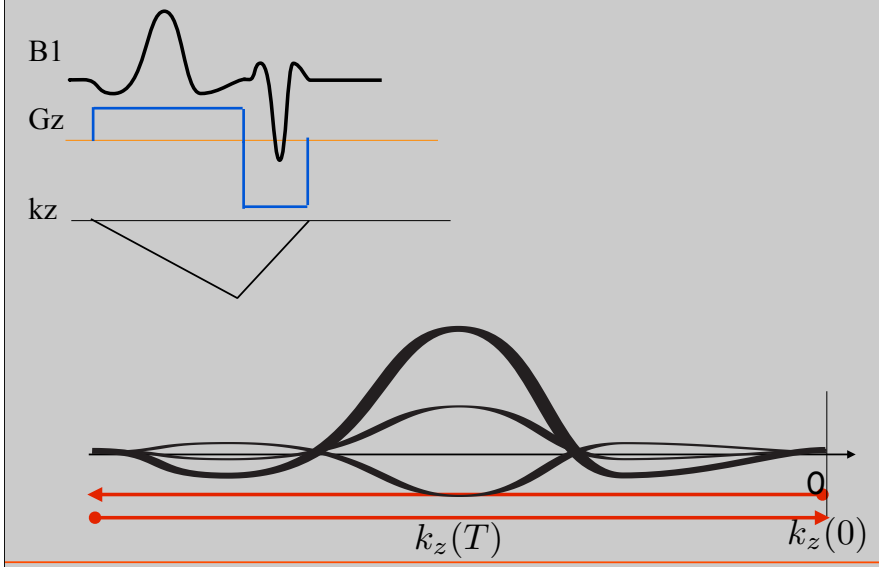


k-Space Weighting Example



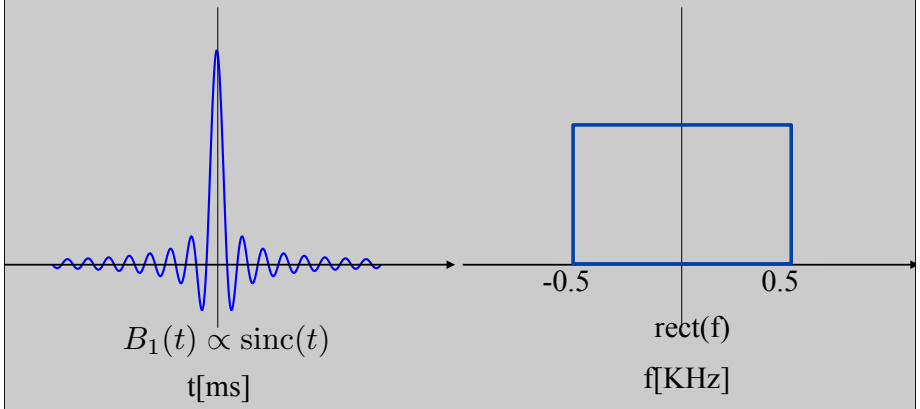


k-Space Weighting Example



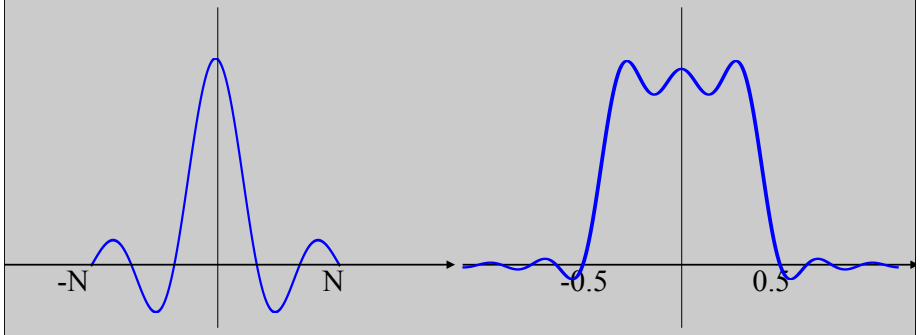
RF Pulse Design

- Choose, B1(t) with a nice transform



Not prectical, since sinc is continuous indefinitely

Truncated sinc

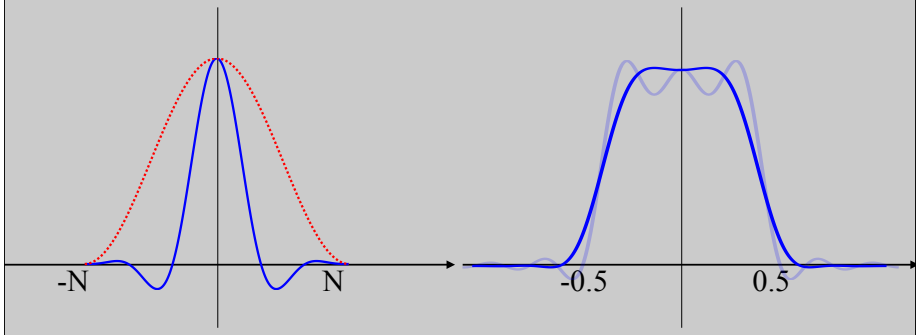


$B_1(t) \propto \mathrm{sinc}(t)\mathrm{rect}(t/2N)$

rect(f)*2N sinc(2Nf)

Too much Ripple!

Windowed sinc



$B_1(t) \propto \mathrm{sinc}(t)w(t/2N)$

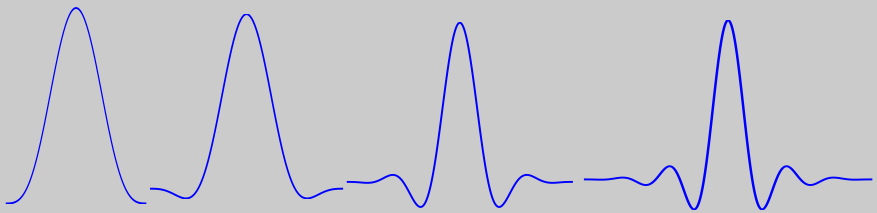
rect(f)*2N W(2Nf)

Hanning Window

Characterization of Pulse Shape

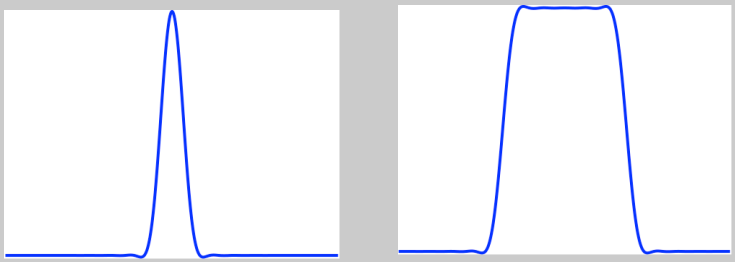
Time-Bandwidth Product

T(BW) = (2N)1 = 2N ⇒ Total # of zero crossings



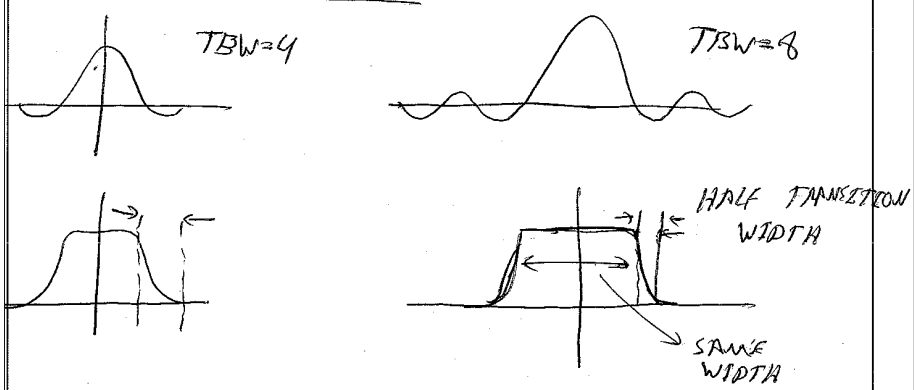
TBW=2	TBW=4	TBW=8	TBW=12
rapid imaging	180	90	slab and saturation

Slice Profile



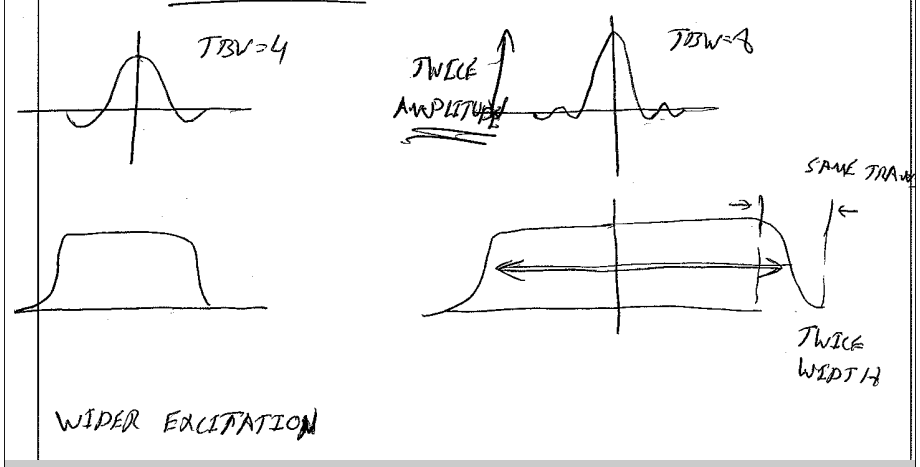
TBW=2 TBW=12

IF WE FIX BANDWIDTH AND MAKE T LONGER



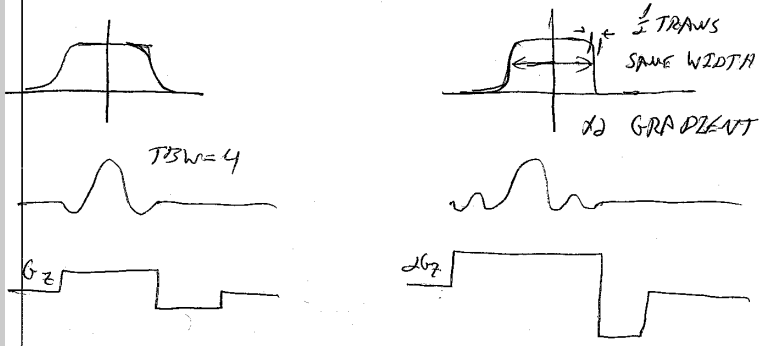
MORE SELECTIVE PROFILE.

IF WE FIX DURATION INCREASE BW



WIDER EXCITATION

TYPICALLY IN MRI WE FIX DURATION, AND ADJUST THE GRADIENT AMP. TO COMPENSATE FOR FOR THE INCREASE IN BW



DOUBLE BW (kHz)
DOUBLE GRADIENT (kHz/cm)
⇒ SAME WIDTH !

EXAMPLE

WE WANT A TBW=8 PULSE WITH 2[ms] DURATION

SLICE THICKNESS IS 1[cm], WHAT IS THE GRADIENT AMP?

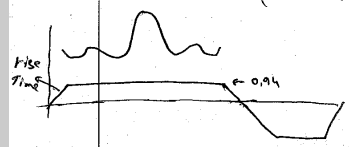
$T(BW) = 8$

$2ms\ BW = 8 \Rightarrow BW = 4\ kHz$

$\Delta z = 1\ cm$

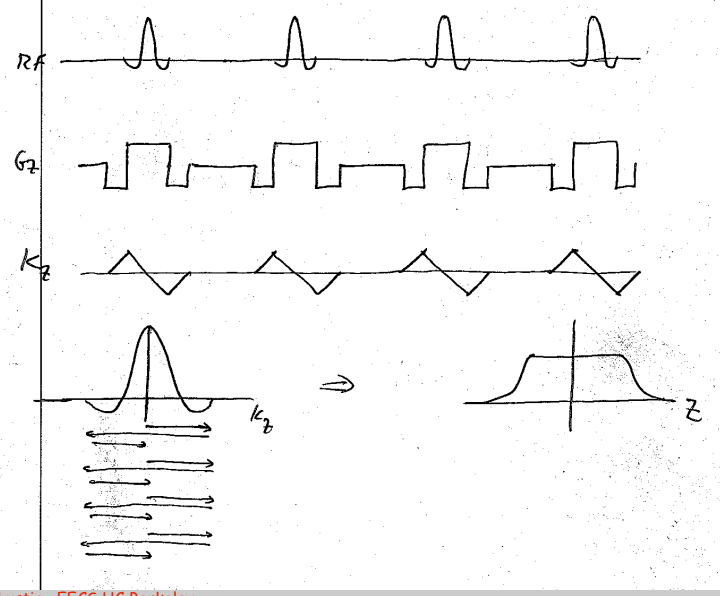
$\underbrace{\frac{\gamma}{2\pi} G \Delta z}_{BW} = 4\ kHz$

$\left(4.257\ \frac{kHz}{G}\right) G \cdot (1\ cm) = 4\ kHz \Rightarrow G = 0.94\ \frac{G}{cm}$



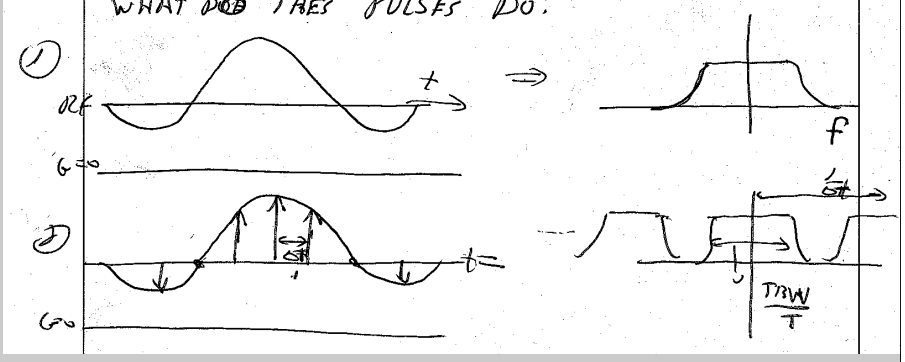
Q: WHAT IS G IF SLICE = 0.5 cm?
A: $G = 1.88\ \frac{G}{cm}$
Q: WHAT IF $G_{max} = 0.94\ \frac{G}{cm}$?
TBW=4 ⇒ LESS SELECTIVE
T=4ms ⇒ LONGER DURATION.

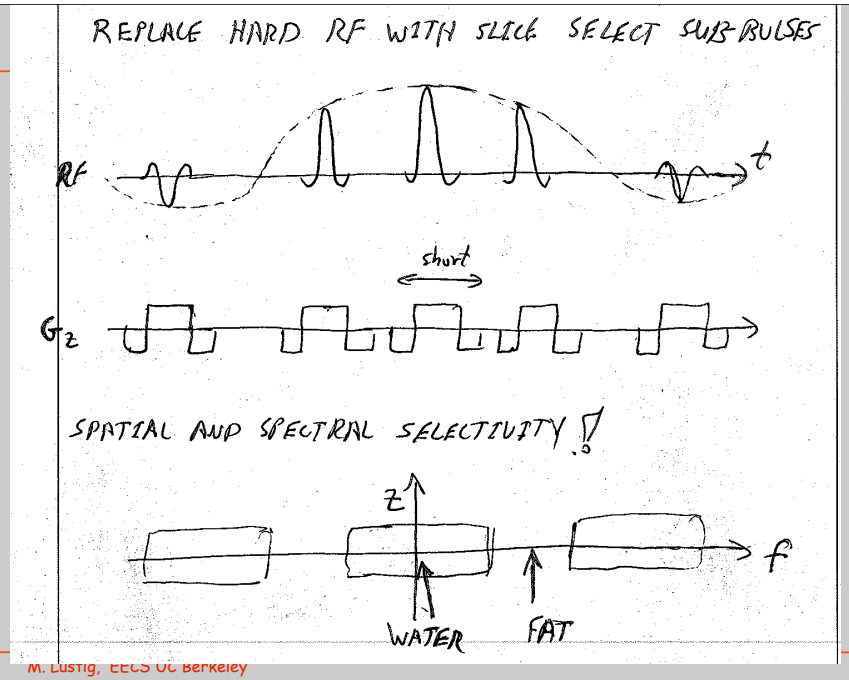
WHAT DOES THIS PULSE DO?



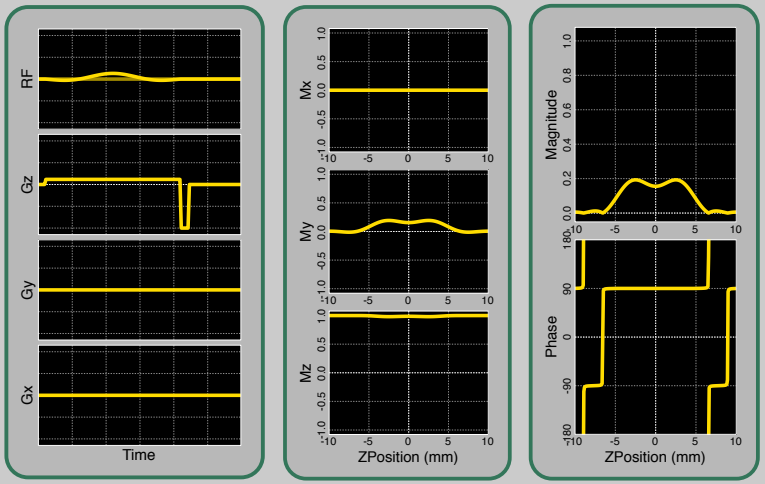
SPECTRAL PULSE

WHAT DOES THES PULSES DO?

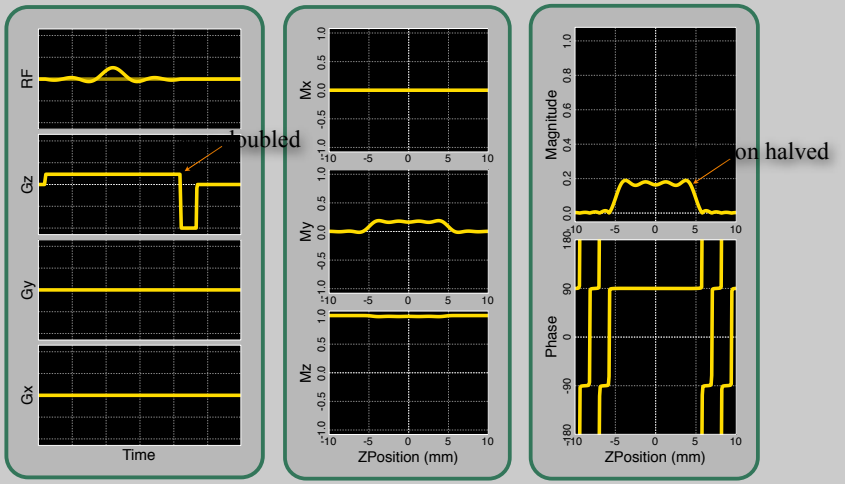




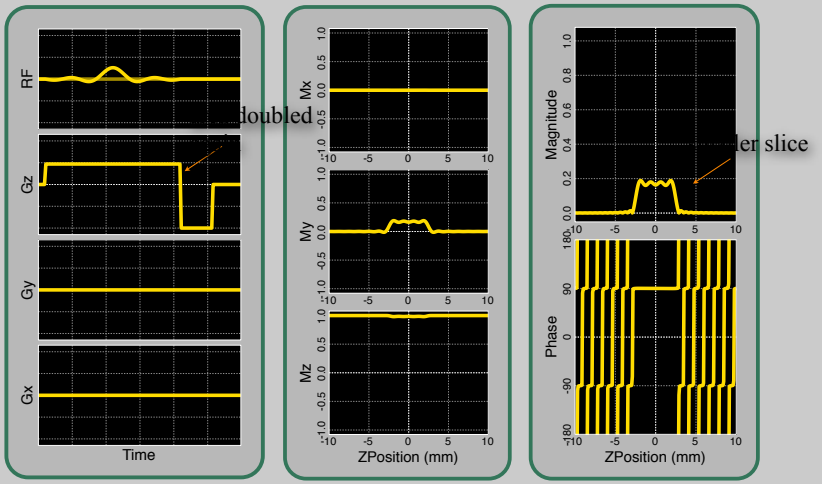
TBW=4, flip = 10, slice = 10mm, duration =2ms



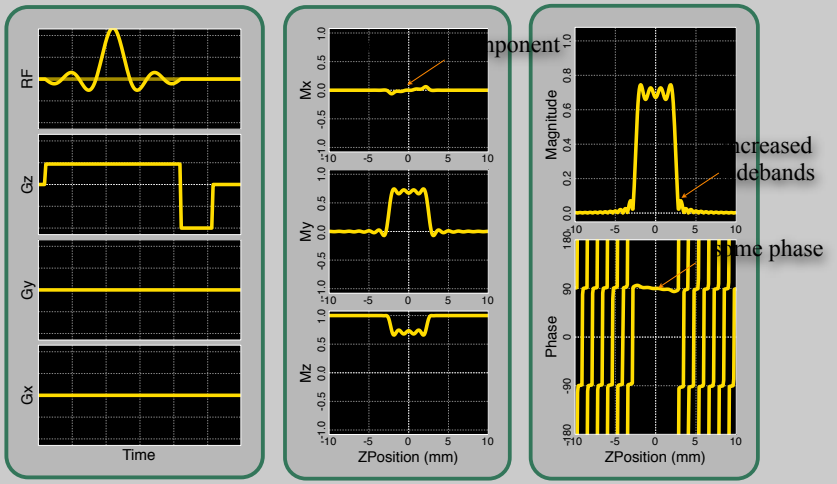
TBW=8, flip = 10, slice = 10mm, duration =2ms



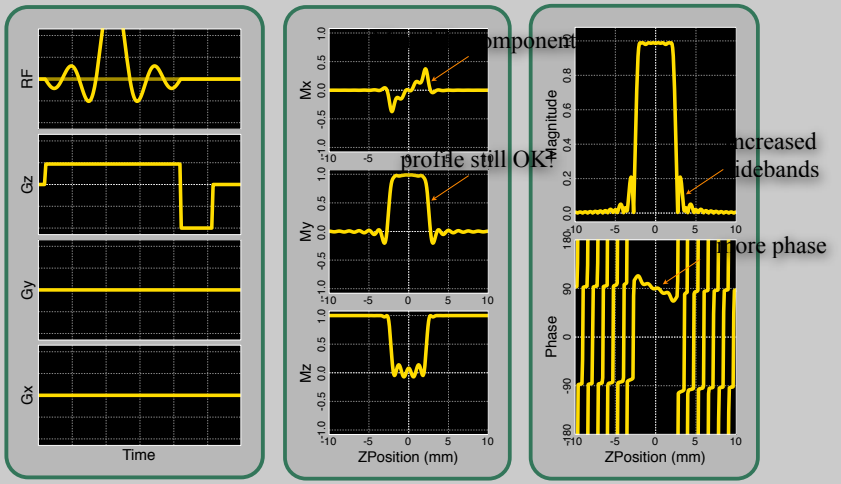
TBW=8, flip = 10, slice = 5mm, duration =2ms



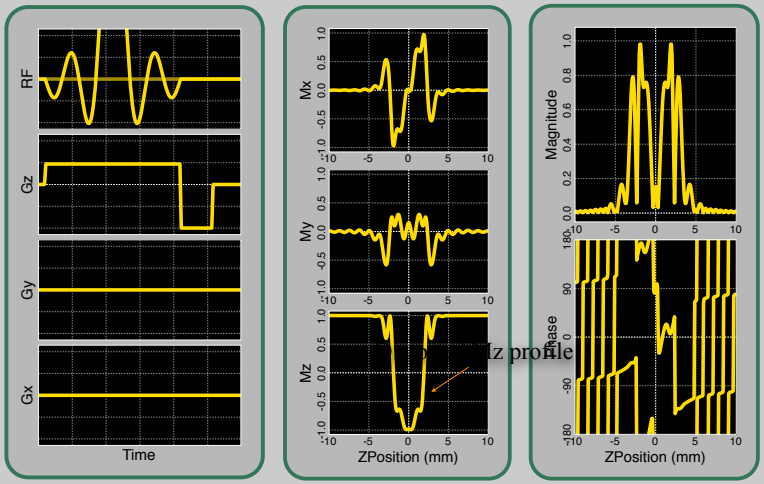
TBW=8, flip = 45, slice = 5mm, duration =2ms



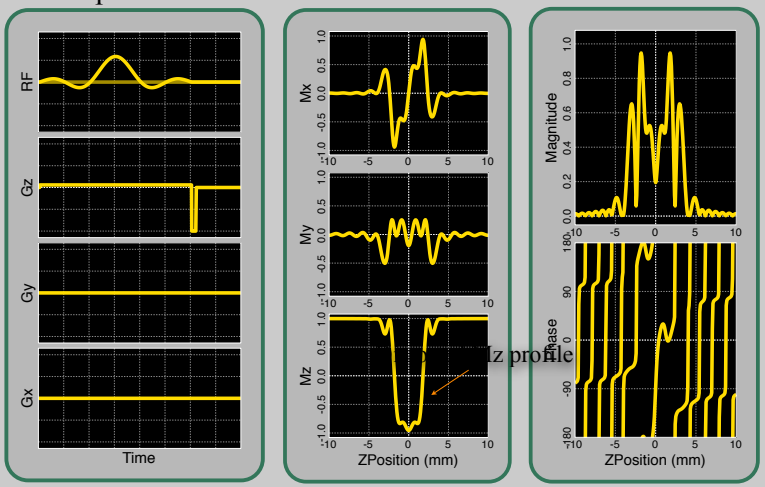
TBW=8, flip = 90, slice = 5mm, duration =2ms



TBW=8, flip = 180, slice = 5mm, duration =2ms

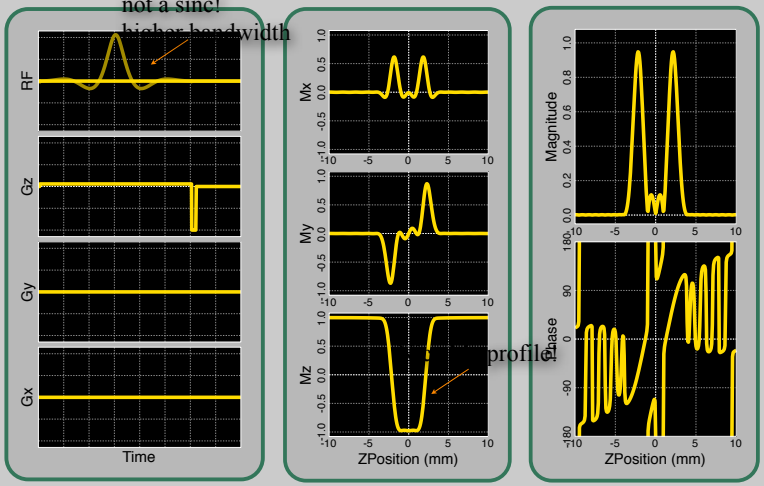


180
small-tip Pulse

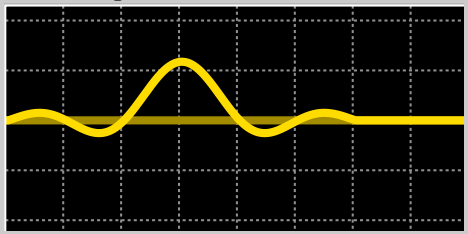


180

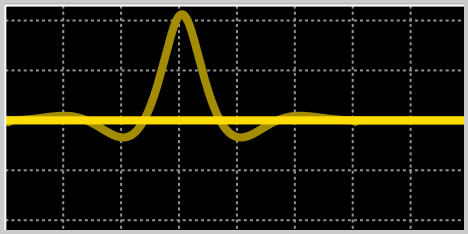
SLR Pulse



"small-tip" 180



SLR 180



Spectral-Spatial Pulse