LECTURE 14 MRI IMAGING

LAST TIME:

MRI PHYSICS - WHERE DO THE SIGNALS COME FROM

CONTRAST - WHY IS MRI INTERESTING

THIS TIME:

LOCALIZATION - HOW DO WE MAKE AN IMAGE

FIRST IDEA

FOCUS RF TO A SPOT, AS IN OPTICS OR ULTRASOUND

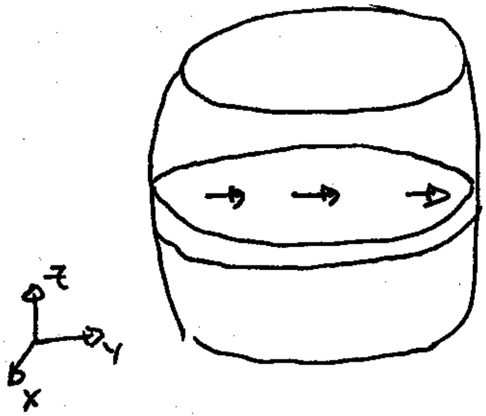
PROBLEM: $\lambda = 50$ cm AT 1.5 T, NOT USEFUL

SECOND IDEA

FREQUENCY IS EASY TO MEASURE

IF TWO POSITIONS HAVE DIFFERENT RESONANT FREQUENCIES, WE CAN TELL THEM APART.

ASSUME WE HAVE EXCITED A SLICE OF AN OBJECT



IN LAB FRAME: PRECESSING AT ω_0

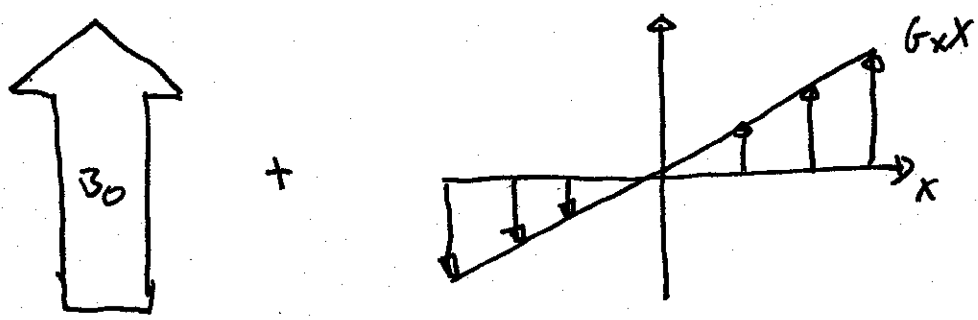
IN ROTATING FRAME: FIXED

SINCE EVERYTHING IS PRECESSING AT SAME FREQUENCY
NO WAY TO TELL SPINS APART

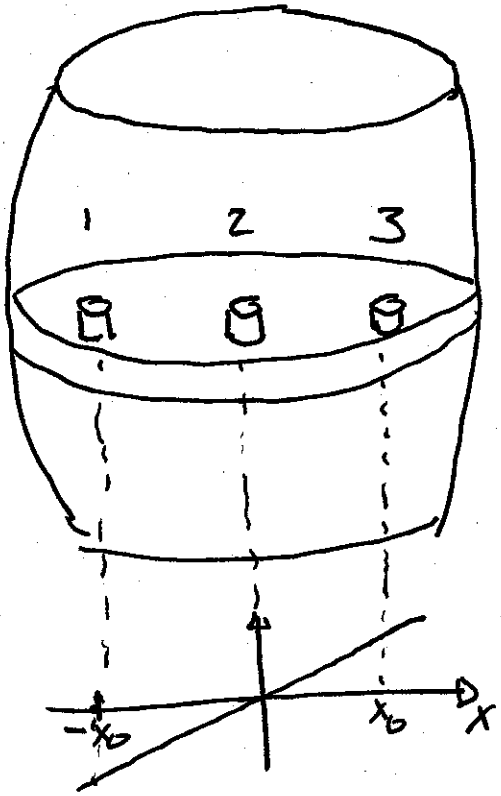
ADD AN ADDITIONAL FIELD THAT VARIES LINEARLY
IN SPACE

$$B_z = B_0 + G_x X$$

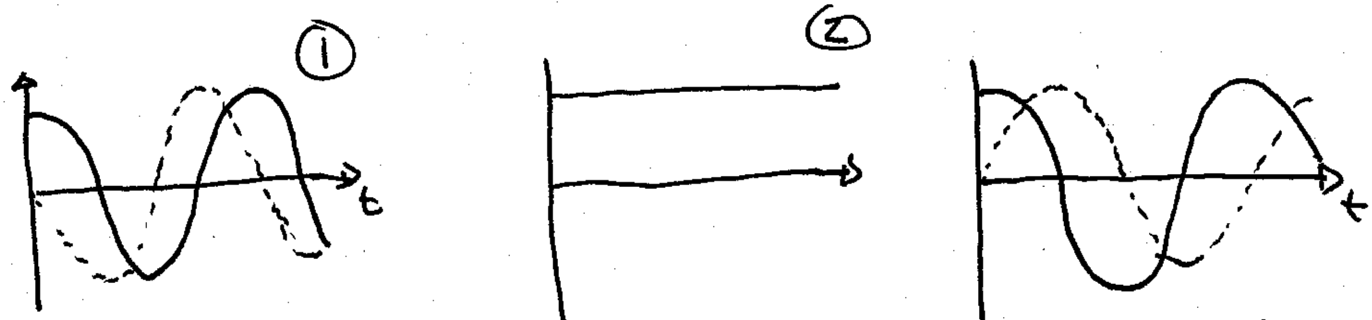
<u>GRADIENT FIELD</u>



IF OUR SLICE HAS THREE SAMPLES IN IT

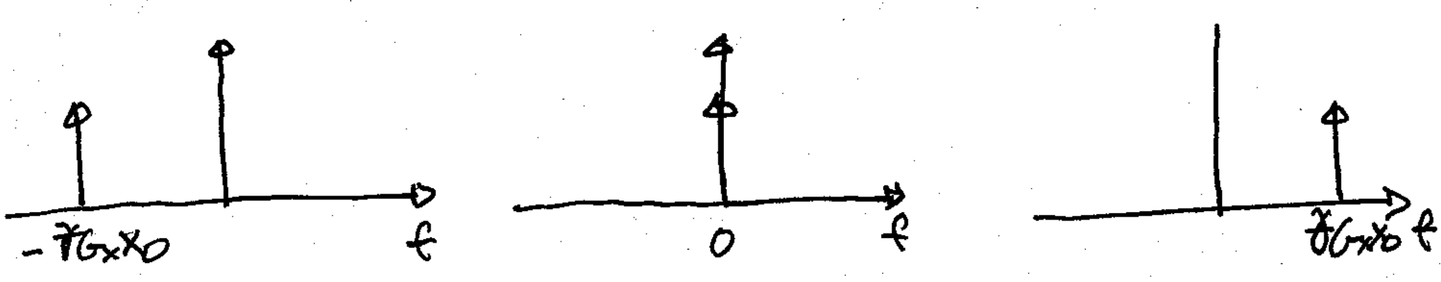


IN THE ROTATING FRAME, WE SEE

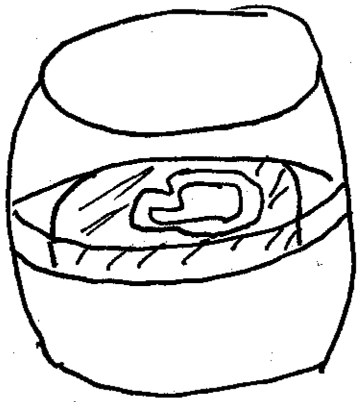


$f = -\gamma G_x x_0$ $\qquad$ $f = 0$ $\qquad$ $f = +\gamma G_x x_0$

THE SPECTRUM OF THESE SIGNALS ARE



IN GENERAL THE OBJECT WILL BE EXTENDED



small "m"

$$m_{xy}(x,y;0)$$

position, time

IF WE APPLY A GRADIENT IN X AND Y

$$B_z = B_0 + G_x x + G_y y$$

FREQUENCY IS

$$\gamma B_z = \gamma B_0 + \gamma G_x x + \gamma G_y y$$

IN ROTATING FRAME

$$\gamma B_{z,r} = \gamma G_x x + \gamma G_y y$$

THE PHASE OF M_{xy} IS INTEGRAL OF FREQUENCY

$$\phi = 2\pi \gamma G_x x t + 2\pi \gamma G_y y t$$

MAGNETIZATION AT TIME t IS

$$m_{xy}(x,y;t) = m_{xy}(x,y;0)\, e^{-j2\pi(\gamma G_x x t + \gamma G_y y t)}$$

RECEIVED SIGNAL IS INTEGRAL OVER SPACE

$$s(t) = \int_x \int_y m_{xy}(x,y;t)\,dx\,dy$$

$$= \int_x \int_y m_{xy}(x,y;0)\, e^{-j2\pi(\gamma G_x x t + \gamma G_y y t)}\,dx\,dy$$

$$= \int_x \int_y m_{xy}(x,y;0)\, e^{-j2\pi(\underbrace{(\gamma G_x t)}_{u} x + \underbrace{(\gamma G_y t)}_{v} y)}\,dx\,dy$$

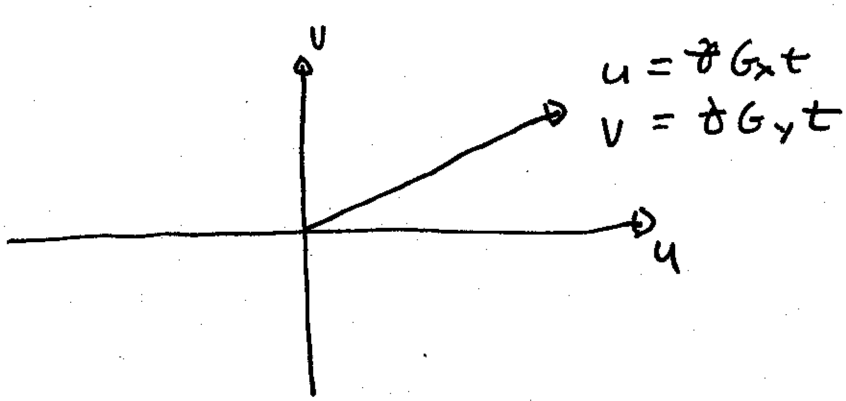
$$= \int_x \int_y m_{xy}(x,y;0)\, e^{-j2\pi(ux + vy)}\,dx\,dy \Big|_{\substack{u = \gamma G_x t \\ v = \gamma G_y t}}$$

$$s(t) = \underline{M}(u,v)\Big|_{\substack{u = \gamma G_x t \\ v = \gamma G_y t}}$$

WHERE

$$\underline{M}(u,v) = \mathcal{F}\{m(x,y;0)\}$$

IN SPATIAL FREQUENCY

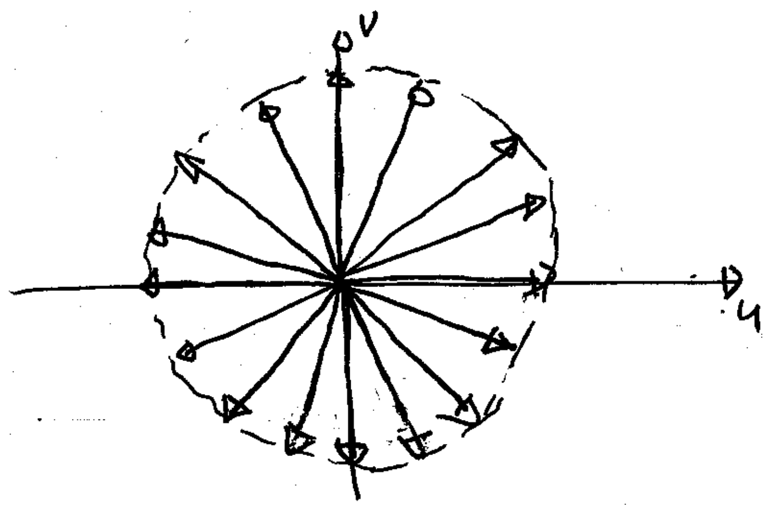


WE ACQUIRE ONE RADIAL SPOKE OF 2D FOURIER TRANSFORM OF $m(x,y;0)$

IF WE REPEAT WITH

$$G_x = G_0 \cos\theta$$
$$G_y = G_0 \sin\theta$$

FOR $0 < \theta < 2\pi$, WE COVER A DISK IN SPATIAL FREQUENCY

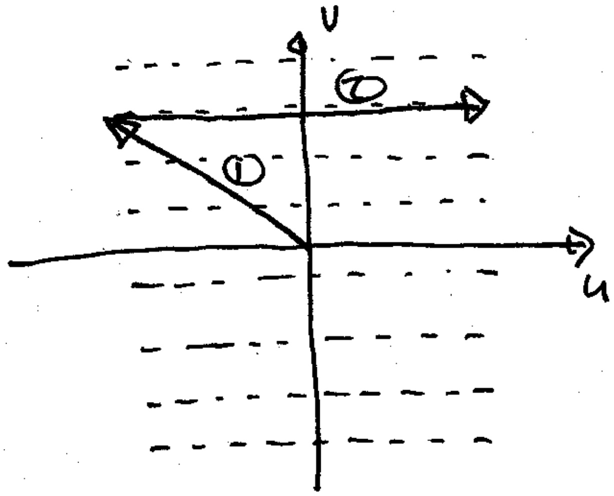


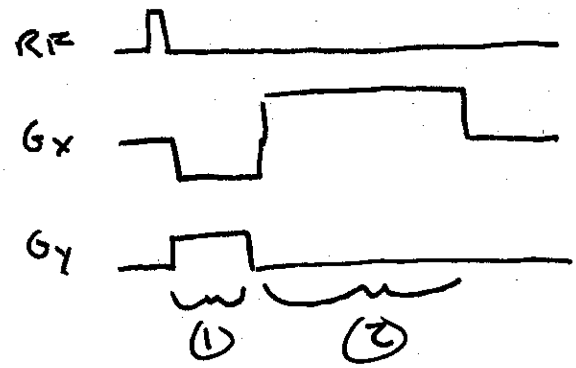
WE CAN THE RECONSTRUCT WITH PROJECTION RECONSTRUCTION AS IN CT!

SPIN WARP

WHAT WE WOULD REALLY LIKE IS AN ACQUISITION THAT IS EASY TO RECONSTRUCT.

A 2D CARTESIAN ACQUISITION COULD BE RECONSTRUCTED WITH A 2DFFT





DURING 1, WE MOVE TO BEGINNING OF LINE

DURING 2, WE ACQUIRE ONE LINE

REPEAT N TIMES, WITH DIFFERENT G_Y'S

G_X IS THE READOUT GRADIENT

G_Y IS THE PHASE ENCODE GRADIENT

THIS IS CALLED 2DFT OR SPIN-WARP

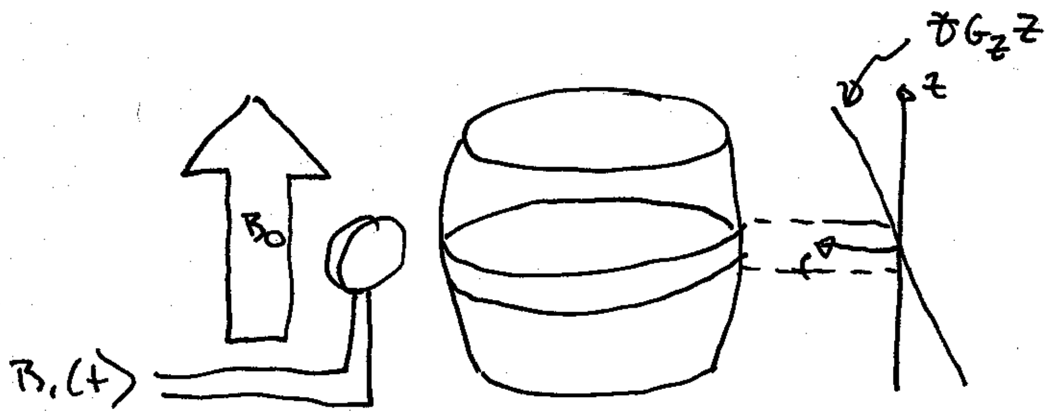
VERY WIDELY USED.

SELECTIVE EXCITATION

MRI IS FUNDAMENTALLY 3D

HOW DO WE EXCITE A SLICE?

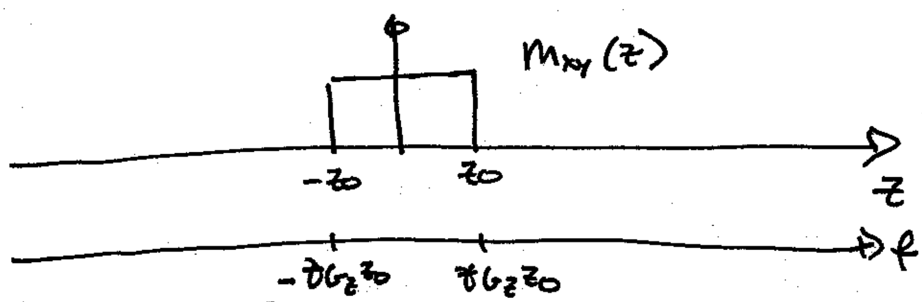
JUST AS IN IMAGING, USE FREQUENCY.



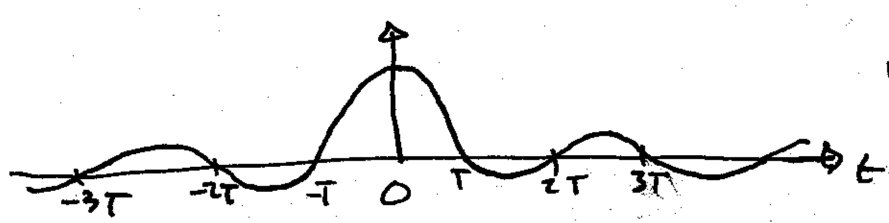
APPLY A GRADIENT IN z, THEN

APPLY A BANDLIMITED RF PULSE

IF WE WANT A SQUARE PROFILE FROM $\pm z_0$

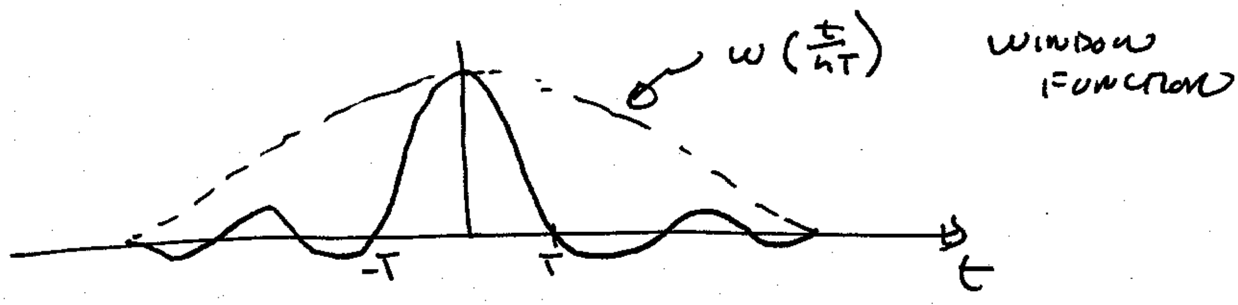


WE WANT AN RF PULSE WITH A BANDWIDTH $\pm \gamma G_z z_0$



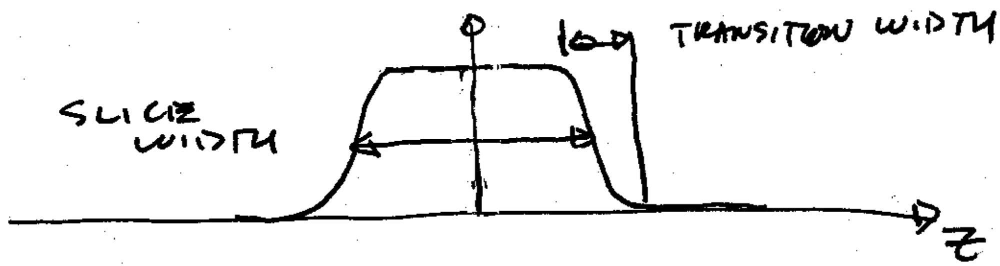
$B_1(t) = \mathrm{sinc}\left(\frac{t}{T}\right)$

IN PRACTICE, WE WILL LIMIT THE PULSE LENGTH



$$B_1(t) = \mathrm{sinc}\left(\frac{t}{T}\right) w\left(\frac{t}{nT}\right)$$

THIS GIVES A SLICE PROFILE



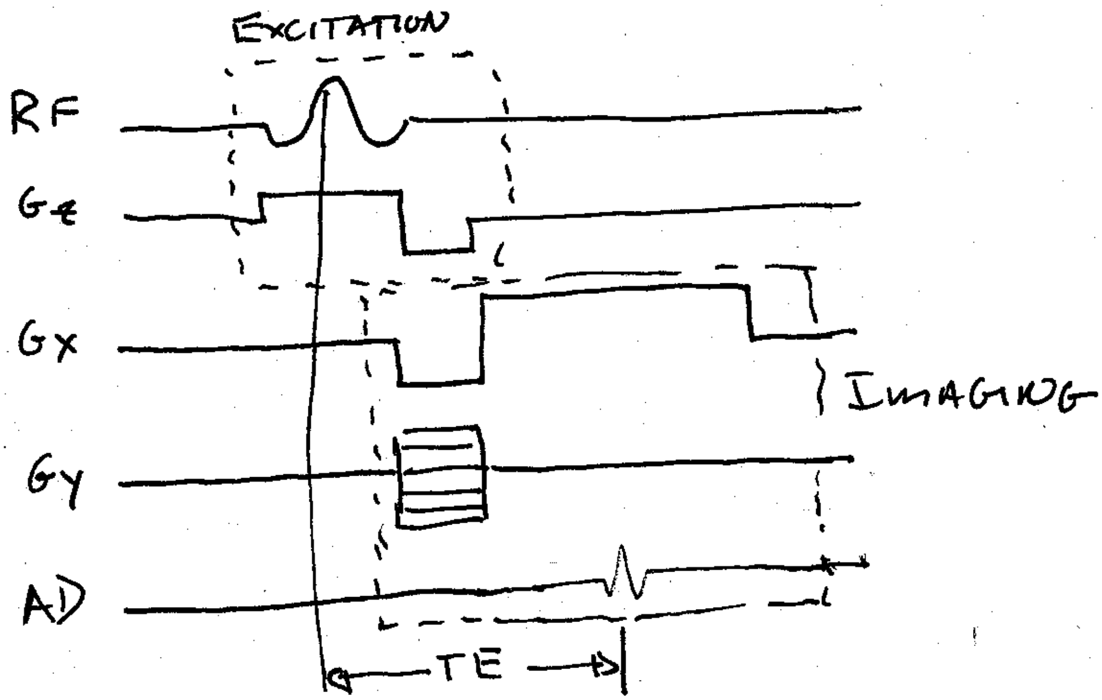
$$\mathcal{F}\{B_1(t)\} = T\,\mathrm{rect}(Tf) * (nT)\,W(nTf)$$

BUT $f = \gamma G_z z$, SO

$$m_{xy}(z) = \underbrace{T\,\mathrm{rect}(T\gamma G_z z)}_{\text{SLICE WIDTH}} * \underbrace{(nT)\,W(nT\gamma G_z z)}_{\text{TRANSITION WIDTH}}$$

PULSE SEQUENCE

IF WE COMBINE IMAGING, EXCITATION WE GET A COMPLETE PULSE SEQUENCE



NEXT TIME:

COMBINING IMAGING WITH CONTRAST