Lecture 7

ASSIGNMENT

READ p 43-47 ON SPINORS

LAST TIME

EPI 2D PULSES

TODAY

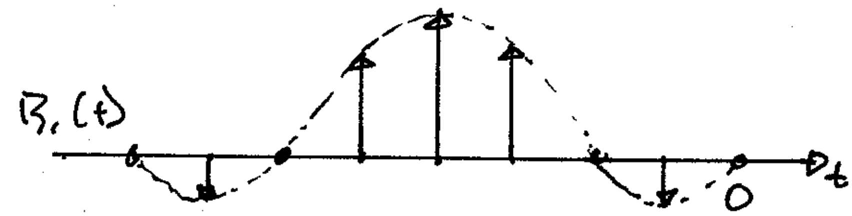
SPECTRAL - SPATIAL PULSES
EDDY CURRENTS

NEXT TIME

SPIN DOMAIN

SPECTRAL PULSES

HARD PULSE SEQUENCE

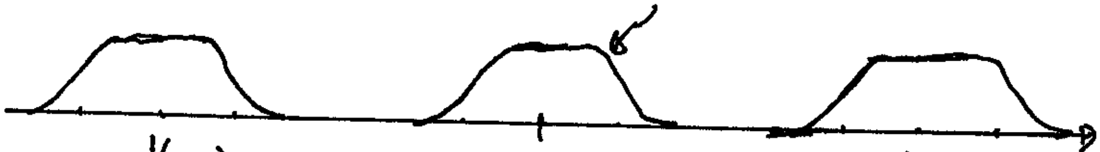


$\gamma B_1(\tau)\delta(\tau - \tau_i)$

IMPULSES ⇒
SHORT, TALL RECTANGLES

$$m_{xy}(f,0) = i m_0 \int_{-\infty}^{0} \gamma B_1(\tau)\delta(\tau-\tau_i)\, e^{i 2\pi f(t-\tau)}\, d\tau$$

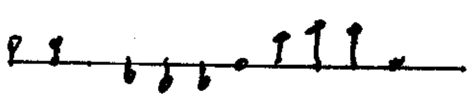
$$= i m_0 \sum_{n=-\infty}^{0} \gamma B_1(\tau_n)\, e^{i 2\pi f(\Delta T) n}$$



COMMON USE: VERY SELECTIVE SPECTRAL PULSES

CONTINUOUS:

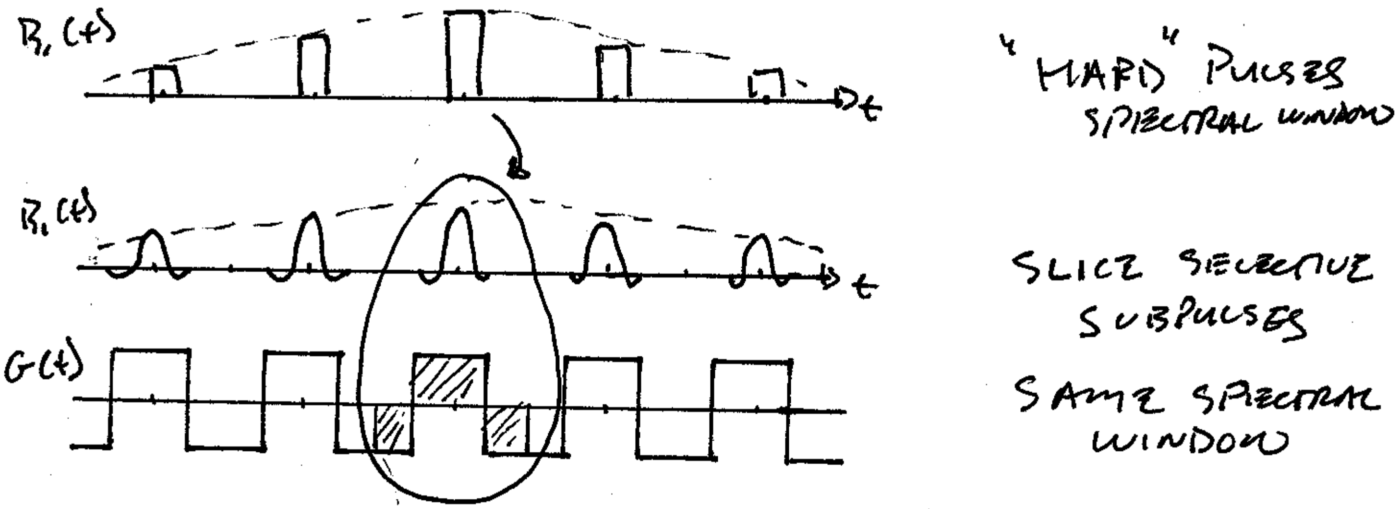
HARD:

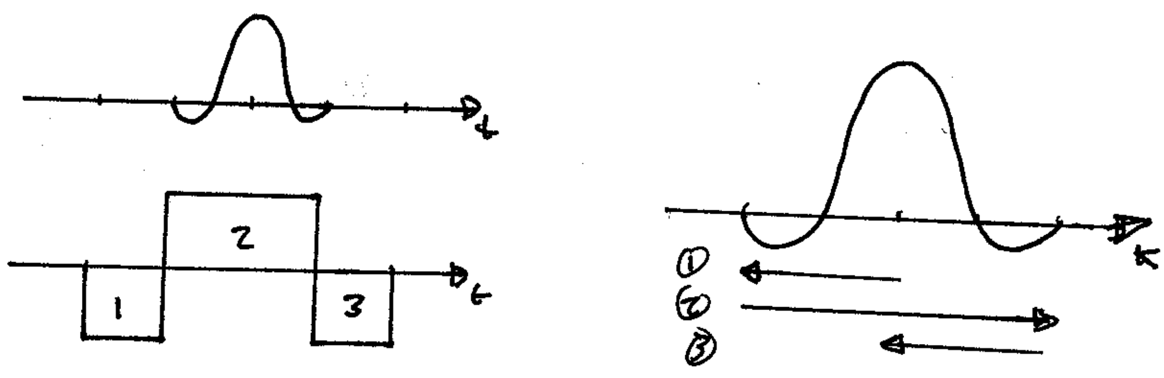


LONG, LOW AMPLITUDE PULSES
HAVE PROBLEMS
NOISE EXCITATION, RF DUTY CYCLE
QUANTIZATION

HARD PULSE SEQUENCE
OFF MOST OF THE TIME
QUANTIZATION NOT A PROBLEM
CAN USE PULSEWIDTH MODULATION

ADD SPATIAL SELECTIVITY TO A SPECTRAL PULSE





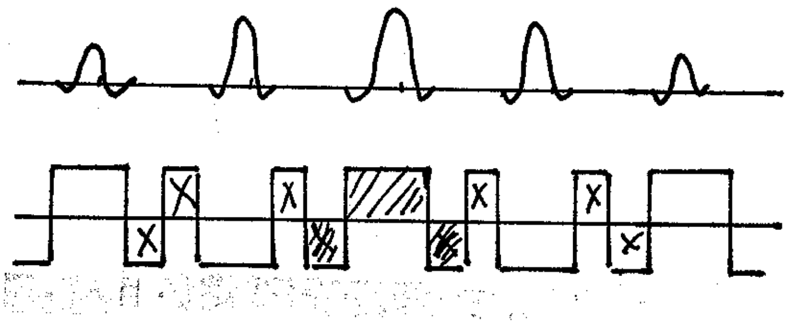
EACH SUBPULSE STARTS AND ENDS AT $k_z = 0$

DOES NOT DEPHASE PREVIOUS SUBPULSES

REFOCUSES THIS SUBPULSE

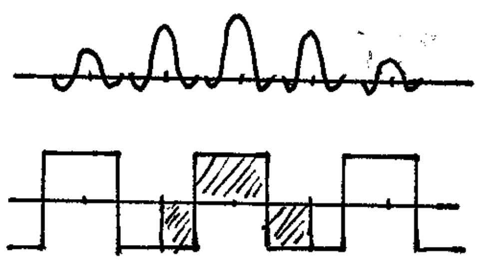
FLYBACK DESIGN

MORE EFFICIENT SOLUTION



INVERT GRADIENT ON ALTERNATE SUBPULSES

CANCEL REFOCUSING LOBES



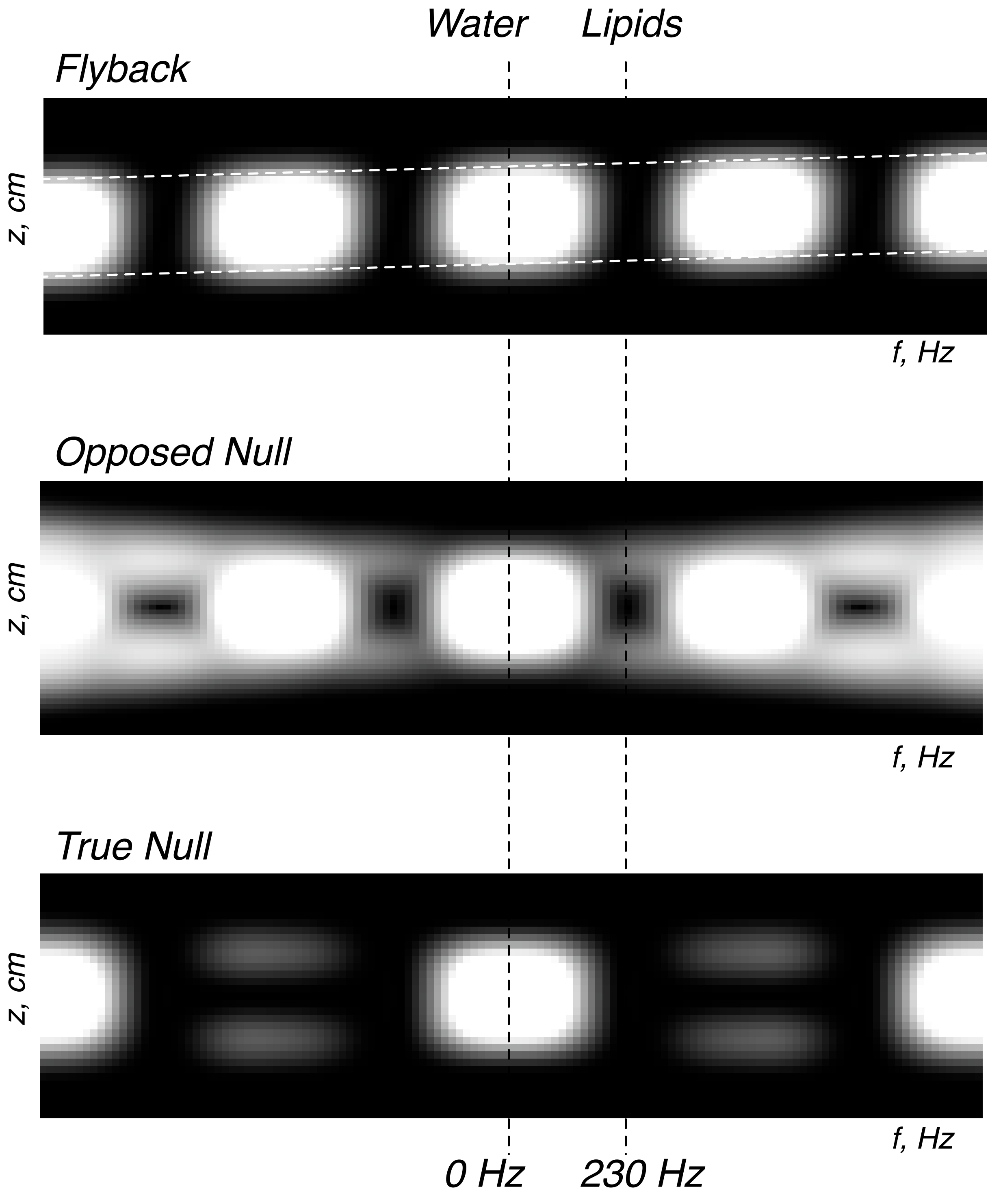
REFOCUSING LOBES PART OF ADJACENT PULSES

TWICE SPECTRAL BANDWIDTH FOR SAME GRADIENT AREA

OPPOSED NULL DESIGN

TRUE NULL DESIGN

Spectral-Spatial Profiles

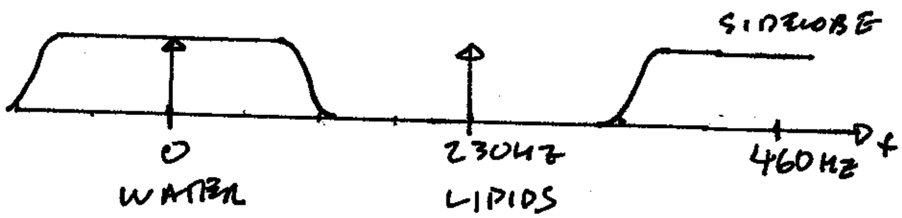


DESIGN EXAMPLE

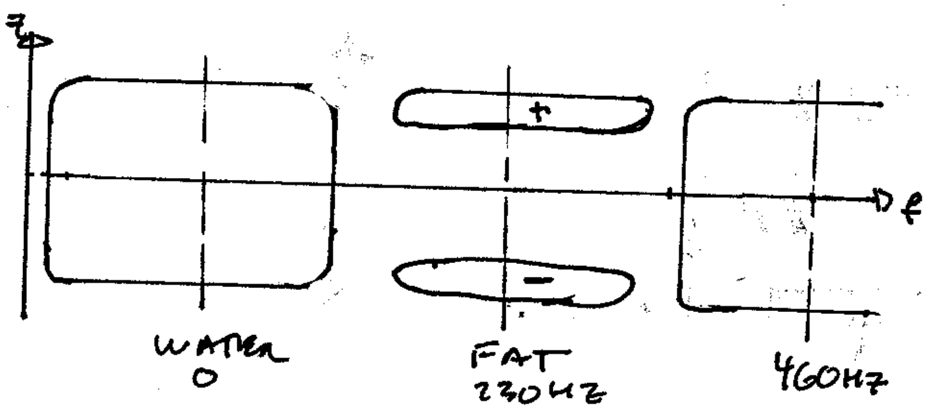
WATER SELECTIVE EXCITATION, LIPIDS SUPPRESSED

1.5T SCANNER

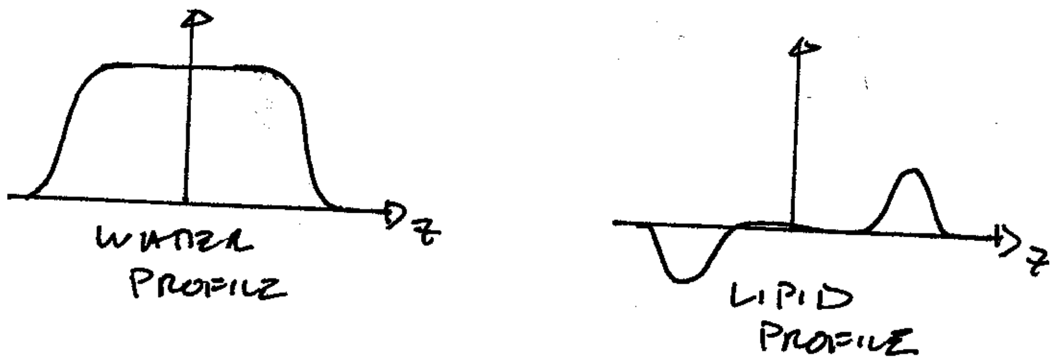
OPPOSED NULL DESIGN



SPECTRUM



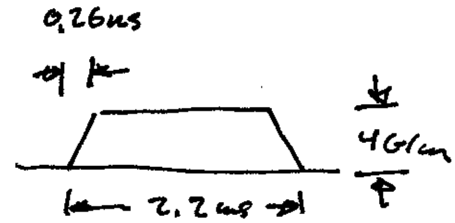
SIDELOBE STRUCTURE



SLICE PROFILES

LIPID PROFILE TENDS TO INTEGRATE TO ZERO

$\Delta T = \frac{1}{460 Hz} = 2.2 ms$



AT 4G/cm, SR 150

$2 k_{z,max} = (2.2 - .26) 4 (4.257) = 33$ CYCLES/cm

$\Delta z = 0.03$ cm

WITH A TBW=4 SUBPULSES, SLICE THICKNESS IS

$4(\Delta z) = 0.12$ cm

$= 1.2$ mm

ENOUGH GRADIENT AREA FOR VERY THIN SLICES.

<u>SPECTRAL ENVELOPE</u>

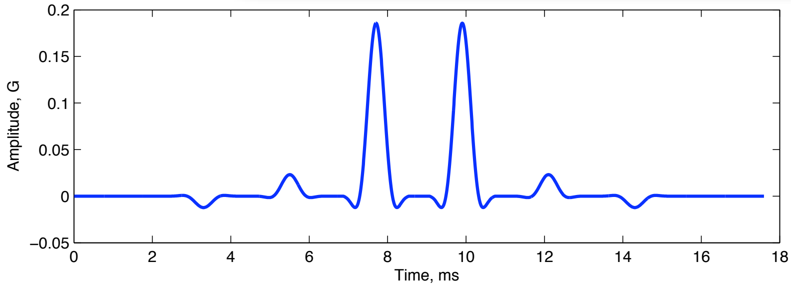
ASSUME TBW=4 SPECTRAL ENVELOPE

± 2ppm PASSBAND ~ ±125HZ

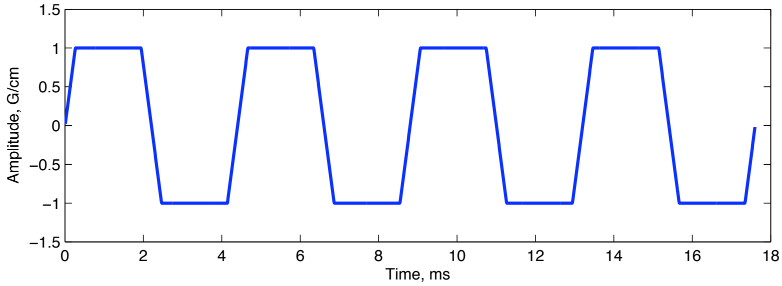
$T(0.250) = 4$

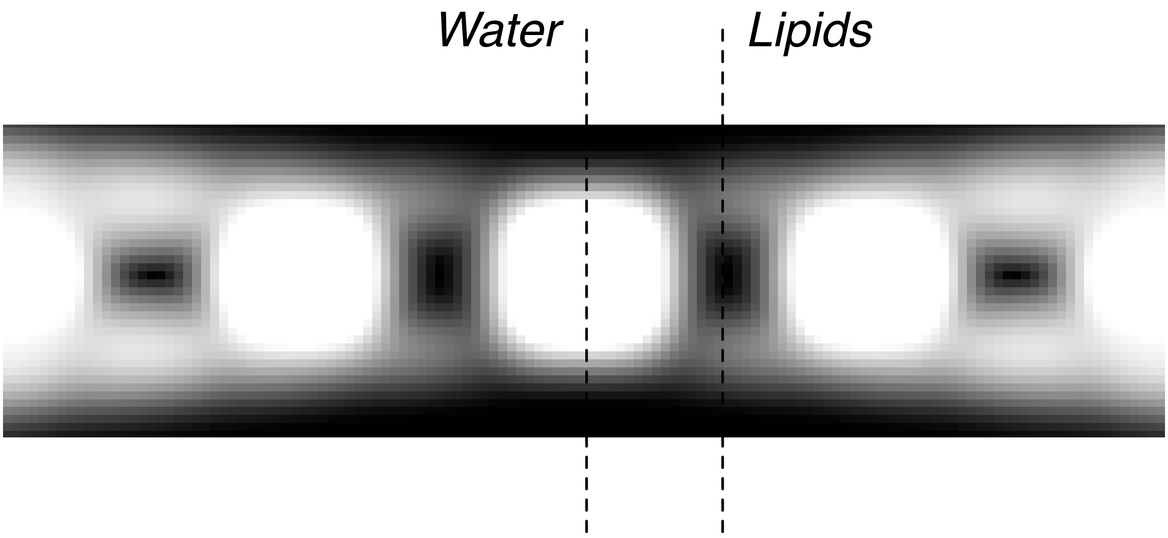
$\underline{T = 16 ms}$

Opposed Null Design

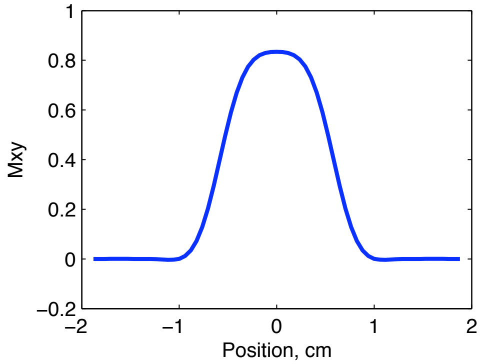


2.2 ms Sublobes
8 Sublobes
250 Hz Spectral Passband
17.2 ms nominal length
13.2 ms actual length

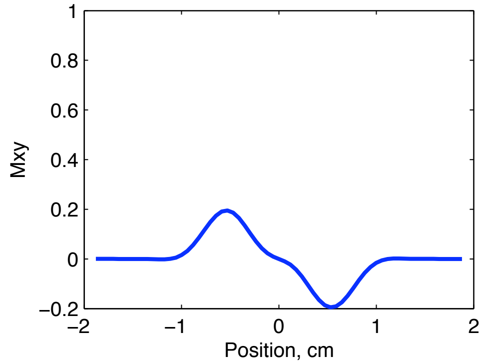




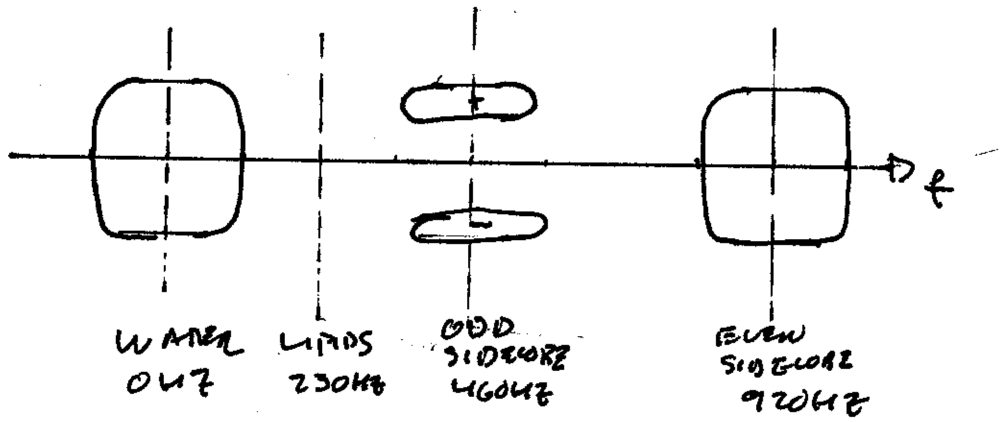
Water Spatial Profile



Lipid Spatial Profile



TRUE NULL / FLYBACK DESIGN



$$\Delta T = \frac{1}{0.92\,\text{kHz}} = \underline{1.09\,\text{ms}}$$

$$2k_{z,max} = (1.09 - 0.26)\cdot 4 \cdot 4.257 = 14 \text{ cycles/cm}$$

$$\Delta z = 0.07\,\text{cm} = 0.7\,\text{mm}$$

FOR A TBW = 4

$$4(\Delta z) = 2.8\,\text{mm}$$

JUST ENOUGH FOR MANY APPLICATIONS

SPECTRAL ENVELOPE

SAME AS BEFORE

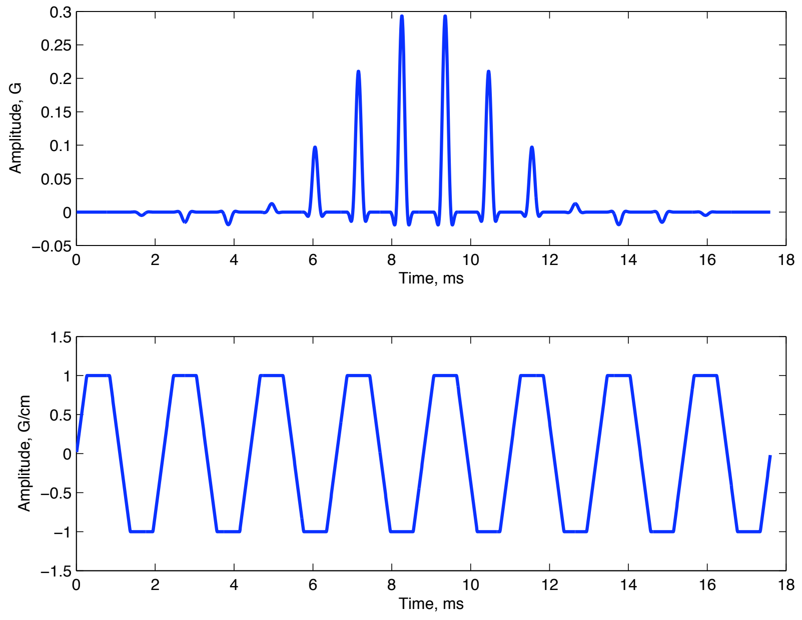
SAMPLED TWICE AS OFTEN

FLYBACK

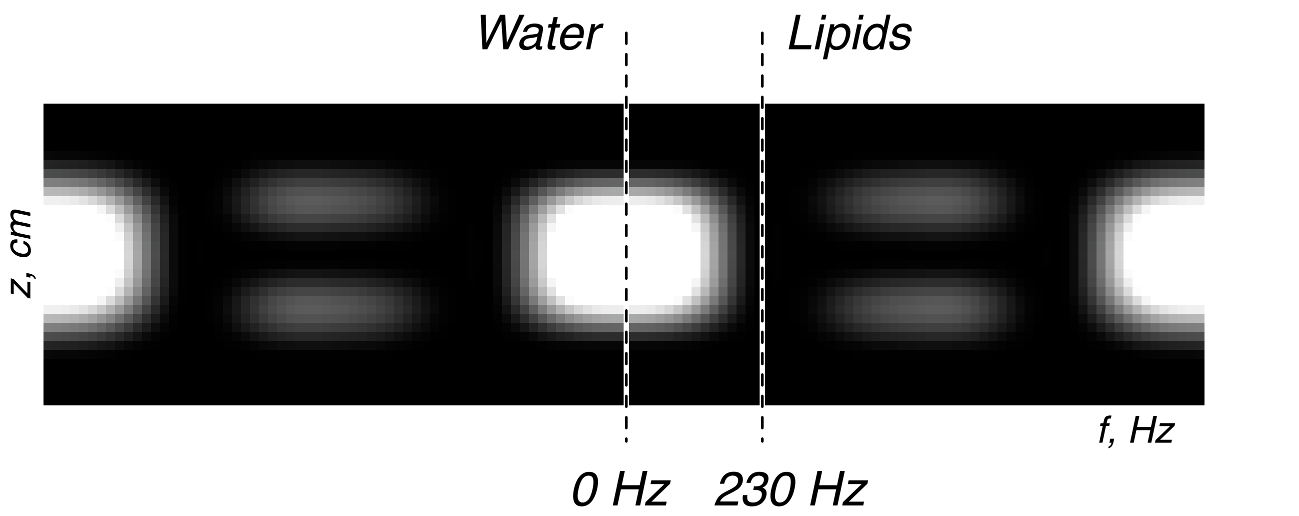
DOUBLE POSITIVE GOING RF SUBPULSES

ZERO NEGATIVE GOING RF SUBPULSES

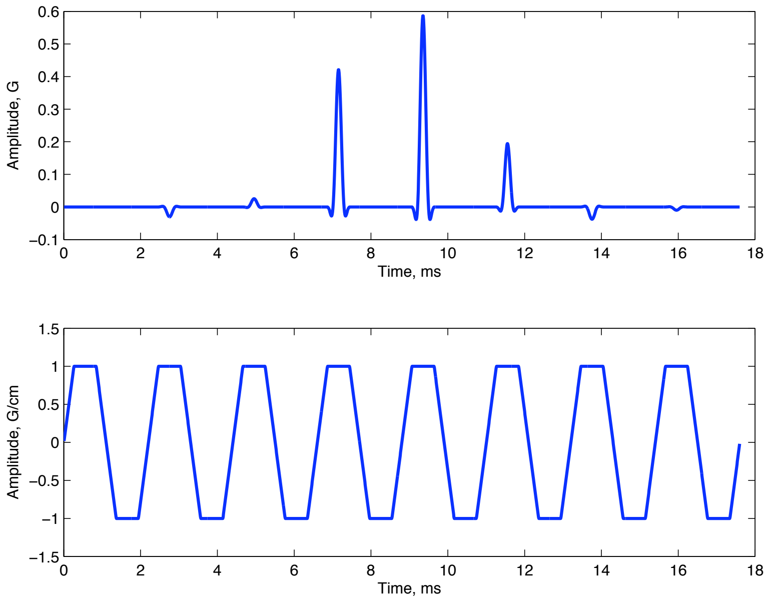
True Null Design



1.1 ms Sublobes
16 Sublobes
250 Hz Spectral Passband
17.2 ms nominal length
15 ms actual length

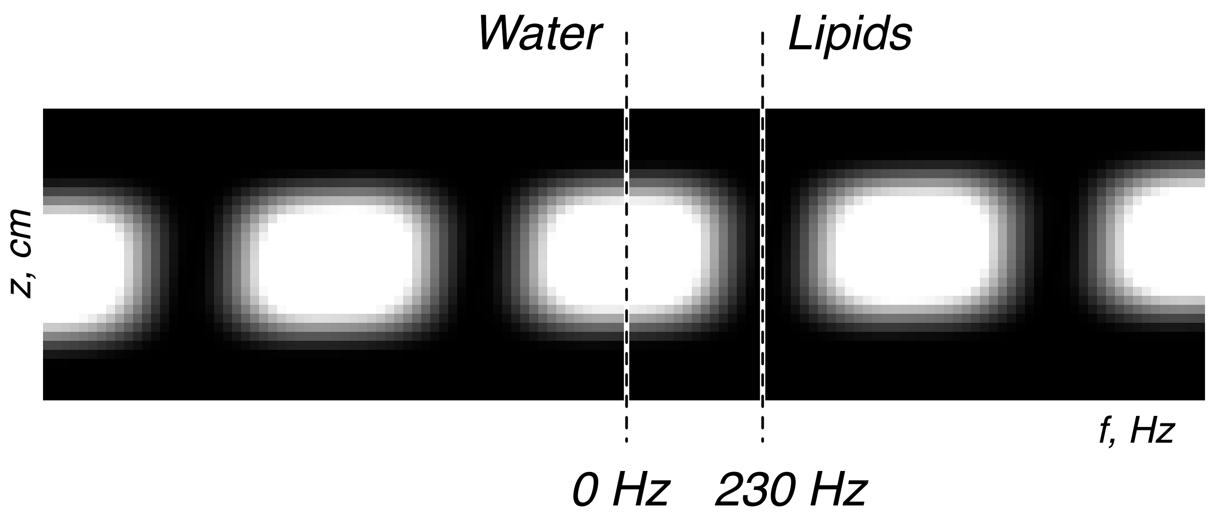


Flyback Design



1.1 ms Sublobes
16 Sublobes
250 Hz Spectral Passband
17.2 ms nominal length
15 ms actual length

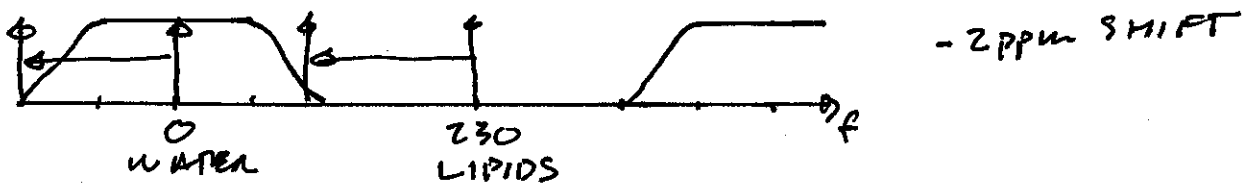
Every other subplulse from true null design



OTHER PRACTICAL CONSIDERATIONS

B_0 HOMOGENEITY

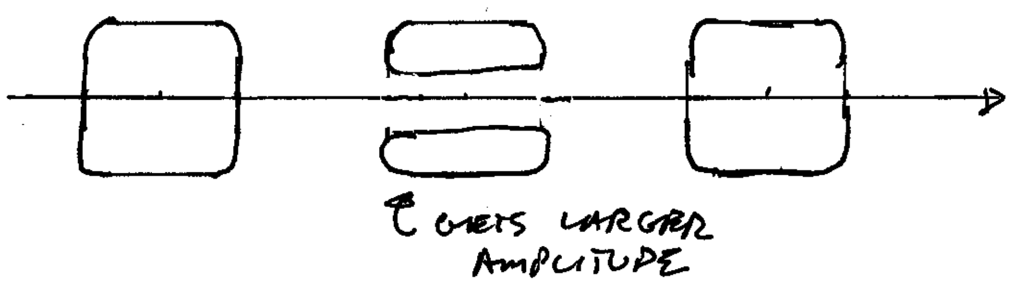
CAN SHIFT WATER OUT OF PASSBAND
OR LIPIDS INTO PASSBAND



DELAY

EFFECT DEPENDS ON TYPE OF DESIGN

STRENGTHENS OPPOSED NULL SIDELOBE

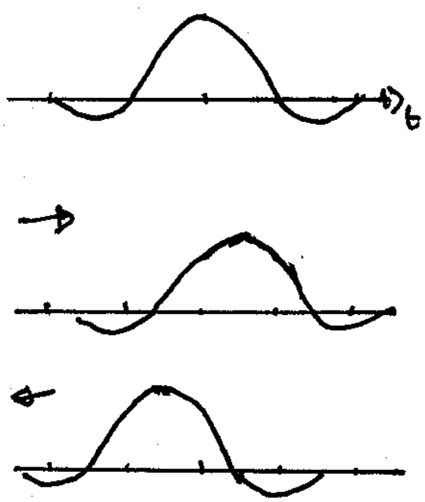


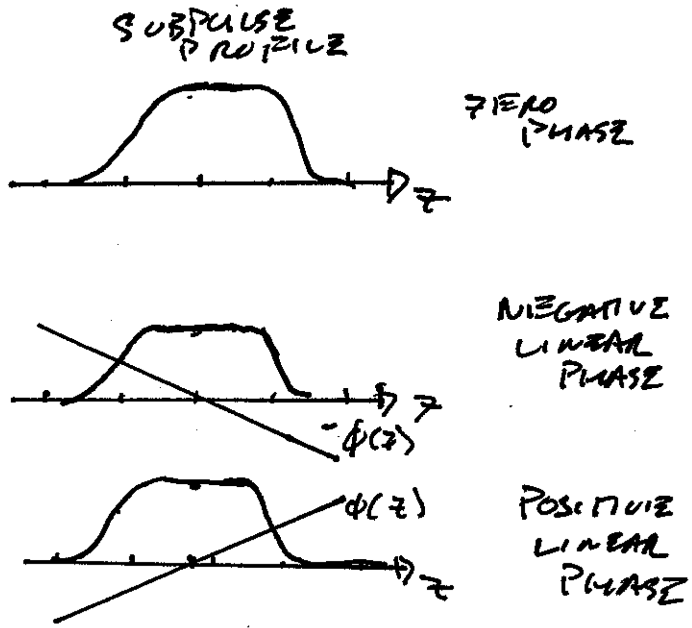
FLYBACK / TRUE NULL:
NO EFFECT

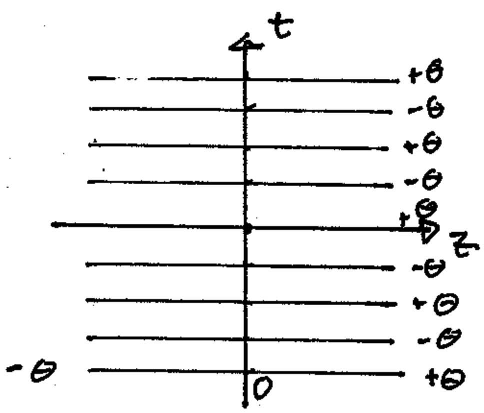
OPPOSED NULL:
MAY INCREASE LIPID SIGNAL
(DEPENDS ON OBJECT)

DELAY

SUBPULSE DELAY





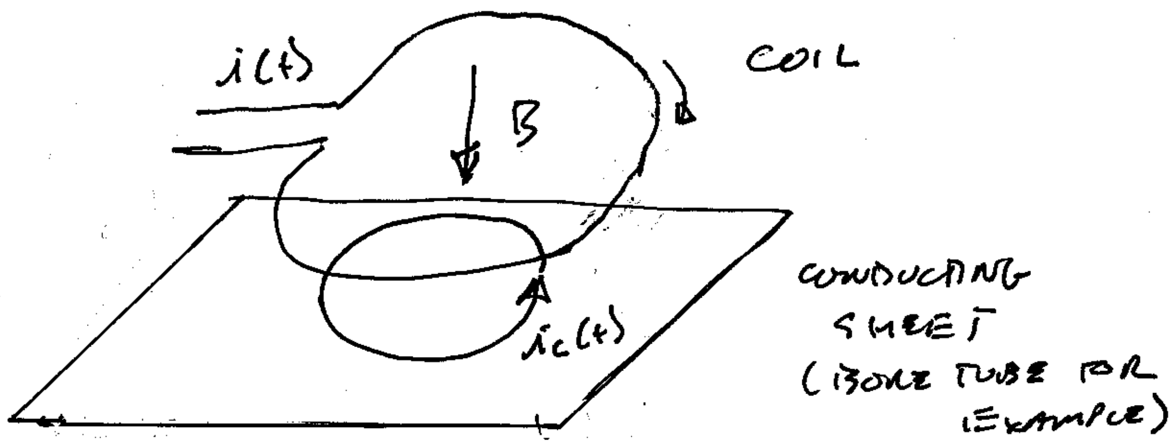


PHASE MODULATION THAT INCREASES WITH Z

PRODUCES N/2 OPPOSED NULL SIDELOBE

EDDY CURRENTS

RAPIDLY SWITCHED GRADIENT COIL CURRENTS INDUCTIVELY COUPLE TO OTHER CONDUCTING STRUCTURES IN THE BORE



EDDY CURRENTS PRODUCE FIELDS THAT OPPOSE THE GRADIENT FIELDS

MANY CONDUCTING STRUCTURES

⇒ MANY TIME CONSTANTS

MODEL EDDY CURRENT FIELDS AS

$$B_e(\underline{x},t) = \underbrace{b_0(t)}_{B_0 \text{ TERM}} + \underbrace{\underline{x}\cdot\bar{g}(t)}_{\text{LINEAR TERM}} + \underbrace{\cdots}_{\text{HIGHER ORDER TERMS}}$$

TAYLOR SERIES EXPANSION

B_0 TERM

SPATIALLY UNIFORM

TIME DEPENDENT FREQUENCY SHIFT

CORRECT BY FREQUENCY TRACKING

LINEAR TERM

LOOKS LIKE A GRADIENT

CORRECT BY GRADIENT PREEMPHASIS

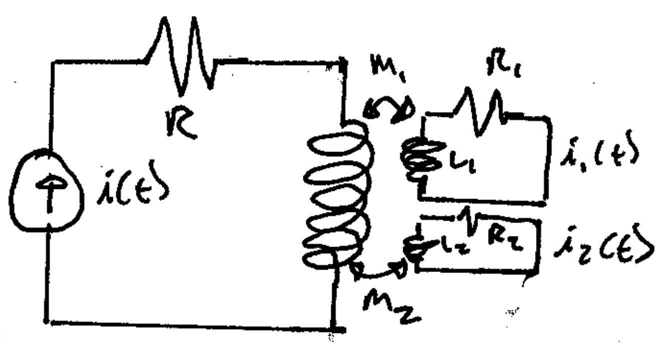
HIGHER ORDER TERMS

HARD TO CORRECT

MOTIVATION FOR SHEILDED GRADIENTS

USUALLY IGNORED

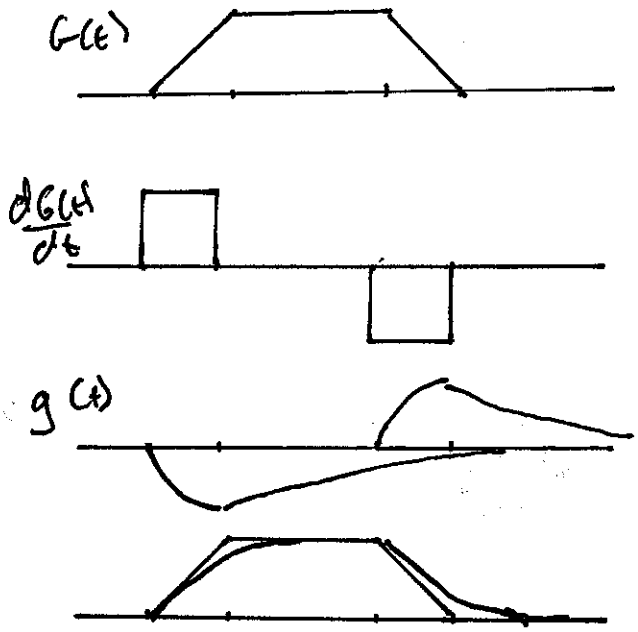
MODEL INDUCTIVELY COUPLED LR CIRCUITS



$$g(t) = -\frac{dG(t)}{dt} * e(t)$$

EDDY CURRENT "GRADIENT"

$$e(t) = H(t) \sum_n \alpha_n e^{-t/\tau_n}$$



APPLIED GRADIENT

EDDY CURRENT FIELDS

$-\frac{dG(t)}{dt} * e(t)$

TOTAL GRADIENT

$G(t) + g(t)$

RESULT:

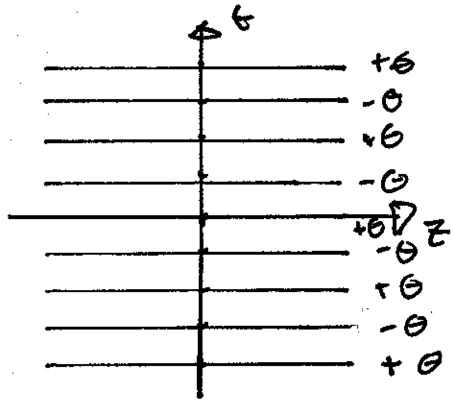
LINEAR EDDY CURRENTS

GRADIENT OCCURS SLIGHTLY LATER THAN WE EXPECT DELAY

B_0 EDDY CURRENTS

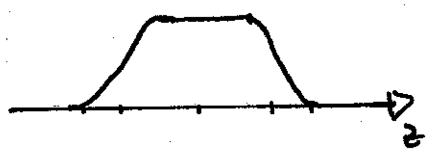
FIELD MODULATION THAT IS PROPORTIONAL TO GRADIENT.

THIS IS THE PROBLEM FOR OPPOSED NULL DESIGNS

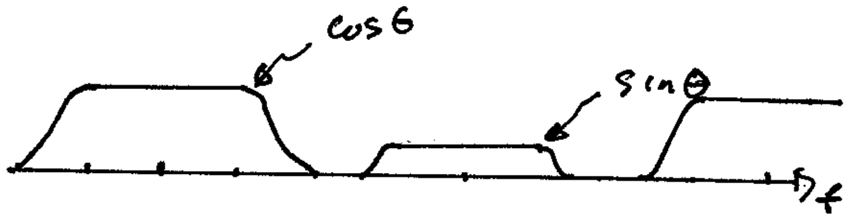


EVERY OTHER LINE MODULATED

$$e^{\pm i\theta} = \cos\theta + i\sin\theta$$



SUBPULSE PROFILE



SPECTRAL PROFILE

COS θ TERM DOES NOT OSCILLATE

MAIN LOBE ATTENUATION

SIN θ ALTERNATES (+, −, +, −)

REPLICATES MAIN LOBE AT N/2 !

TYPICAL VALUES, $\theta = 30^\circ$

⇒ 50% SIDELOBE

<u>CATASTROPHIC FAILURE.</u>

COMPARISON

OPPOSED NULL DESIGN

- THINNEST SLICES
- FRAGILE (DELAYS, EDDY CURRENTS)
- LIPID SUPPRESSION VARIABLE (HOMEWORK 4!)
- USEFUL AT 3T

TRUE NULL DESIGN

- MUCH MORE ROBUST
- THICKER SLICES
- LIPID SUPPRESSION MORE RELIABLE

FLYBACK DESIGN

- SIMILAR TO TRUE NULL
- TWICE THE PEAK RF POWER
- FLOW COMPENSATED