IMAGE CONTRAST:

- LOOKING AT OUR BASIC MRI IMAGING EQN., WE SEE THAT OUR SIGNAL IS ALWAYS WEIGHTED SPATIALLY BY THE SPIN DENSITY (OR PROTON DENSITY, PD, FOR ^{1}H IMAGING):

$$s(t) = \int_x \int_y m(x,y)\, e^{-i2\pi\left[k_x(t)x + k_y(t)y\right]} dy\, dx$$

$m(x,y)$ ↑ SPIN DENSITY (WE ALSO WRITE AS $\rho(x,y)$).

HOWEVER, THE SIGNAL EQN. ONLY TELLS PART OF THE STORY. WE CAN DO A LOT WITH α (OUR FLIP ANGLE), TR (OUR REPETITION TIME), TE (OUR ECHO TIME), AND OTHER PULSE SEQUENCE VARIATIONS TO CHANGE OUR SIGNAL BASED ON THINGS LIKE:

T_1, T_2, CHEMICAL SHIFT, FLOW, AND OTHERS...

NOTE THAT MAGNETIZATION VECTORS (OR SPINS) ARE CONSTANTLY CHANGING IN LENGTH AND DIRECTION (AND THUS OUR SIGNAL IS CONSTANTLY IN FLUX). WHAT DETERMINES OUR IMAGE CONTRAST??

IMAGE CONTRAST IS LARGELY DETERMINED BY RELATIVE SIGNAL LEVELS OF DIFFERENT TISSUES WHEN WE SAMPLE THE CENTER OF K-SPACE!

↓ SIGNAL LEVELS AT OUR ECHO TIME TE!

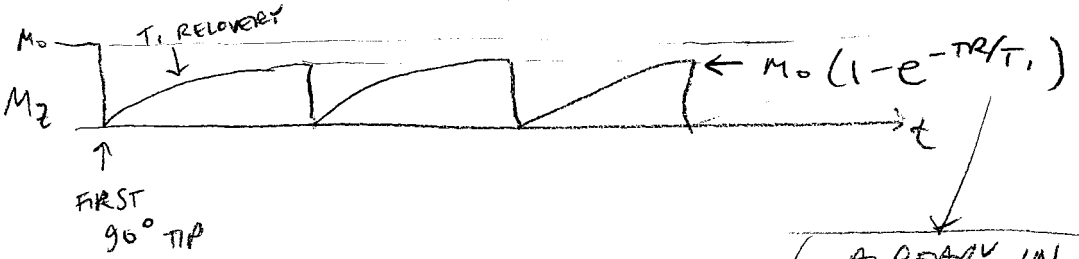
- LET'S LOOK AT SOME BASIC CONTRAST MECHANISMS.

SATURATION-RECOVERY SEQUENCE

"SATURATION" MEANS A 90° TIP, MAKING $M_z \to 0$.

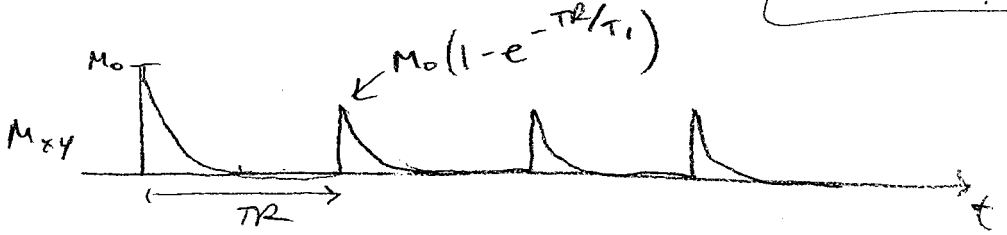
ASSUME $TR >> T_2$ (LONG TR COMPARED TO LONGEST T_2's IN OUR SAMPLE)

LET'S LOOK AT M_z:



ALREADY IN STEADY STATE AT 2ND TIP!

LOOKING AT M_{xy} (OUR SIGNAL):



WITHOUT T_2 DECAY, OUR IMAGE INTENSITY IS:

$$I(x,y) = k\,\rho(x,y)\left(1 - e^{-TR/T_1(x,y)}\right)$$

k: CATCH-ALL CONSTANT (M_0, COIL SENSITIVITY, ETC...)

AFTER EXCITATION, WE SAMPLE SIGNAL AT THE ECHO TIME TE. T_2 DECAY (OR T_2^*, DEPENDING) OCCURS DURING THAT TIME, AND WE HAVE:

$$I(x,y) = k\,\rho(x,y)\left(1 - e^{-TR/T_1(x,y)}\right)e^{-TE/T_2(x,y)}$$

HOW CAN WE GET DIFFERENT KINDS OF CONTRAST WITH A SATURATION-RECOVERY SEQUENCE??

T_1-WEIGHTED CONTRAST: - SHORT TE ($TE \ll T_2$)

$e^{-\frac{TE}{T_2(x,y)}} \approx 1$.

ONLY T_1 WEIGHTING (AND PROTON DENSITY, BUT WE ALWAYS GET THAT!)

SHORTER T_1 TISSUES ARE BRIGHTER!

T_2-WEIGHTED CONTRAST: - INTERMEDIATE TE ($TE \approx T_2$)

- LONG TR ($TR > \sim 3T_1$)

$e^{-\frac{TR}{T_1(x,y)}} \approx 0$,

AND T_1 TERM GOES AWAY!

LONGER T_2 TISSUES ARE BRIGHTER!

PROTON DENSITY (PD) CONTRAST:

- SHORT TE ($TE \ll T_2$)
- LONG TR ($TR > \sim 3T_1$)

T_1 AND T_2 TERMS GO AWAY.
LEFT W/ PD CONTRAST ONLY!

YOU CAN OPTIMIZE CONTRAST BETWEEN DIFFERENT TISSUES BY USING THESE EQUATIONS AND SOLVING FOR TR, TE THAT MAXIMIZES THE CONTRAST OF INTEREST!

PULSE SEQUENCE OPTIMIZATION

GENERAL EXCITATION-RECOVERY SEQUENCE

AGAIN ASSUME $TR >> T_2$ ($M_{xy} \rightarrow 0$ BY THE END OF A REPETITION)

- INSTEAD OF A 90° PULSE, WE APPLY A TIP OF α DEGREES.
- NOW A M_z COMPONENT REMAINS AFTER EACH EXCITATION IF $\alpha \neq 90°$!

NEED TO SOLVE FOR THE STEADY-STATE SIGNAL!

SEE P. 151 OF NISHIMURA

I'M GOING TO HAVE YOU SIMULATE THE CASE WHEN TR IS NOT $<< T_2$ ON THE HOMEWORK, SO UNDERSTAND THE SIGNAL DERIVATION!

DERIVATION YIELDS:

$$I(x,y) = k\,\rho(x,y)\,\frac{\left[1 - e^{-TR/T_1(x,y)}\right]\sin\alpha}{1 - e^{-TR/T_1(x,y)}\cos\alpha}$$

↑ THIS ASSUMES $TE \approx 0$ (SMALL TE)

WE CAN ALSO INCLUDE T_2 DECAY:

$$I(x,y) = k\,\rho(x,y)\,\frac{\left[1 - e^{-TR/T_1(x,y)}\right]\sin\alpha}{1 - e^{-TR/T_1(x,y)}\cos\alpha}\,e^{-TE/T_2(x,y)}$$

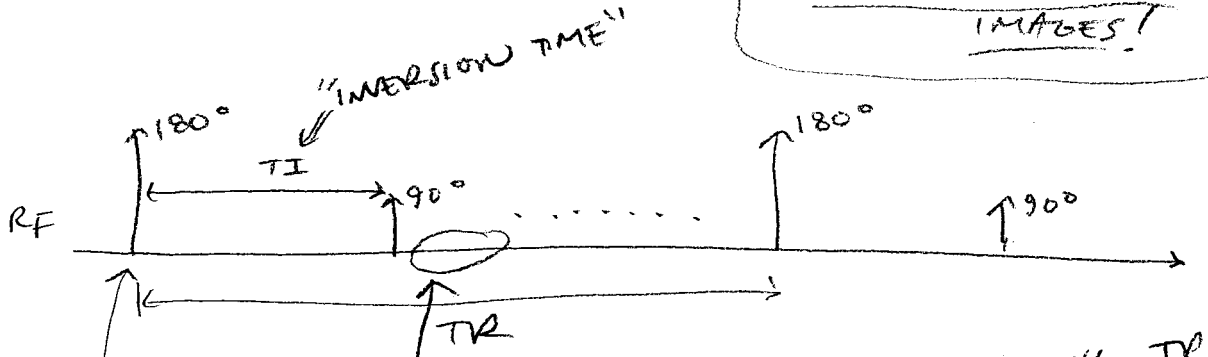
FOR A GIVEN T_1, WE CAN SOLVE FOR FLIP ANGLE α THAT YIELDS MAXIMUM SIGNAL FOR A GIVEN TR. THIS IS CALLED THE "ERNST ANGLE".

INVERSION-RECOVERY SEQUENCE

- ALLOWS US TO SELECTIVELY NULL OR KILL THE SIGNAL FROM TISSUES WITH A CERTAIN T_1!

• VERY USEFUL FOR NULLING CSF SIGNAL IN BRAIN.

CEREBROSPINAL FLUID ⇒ $T_1 \approx 4$ s.
$T_2 \approx 2$ s.
VERY BRIGHT SIGNAL ON T_2-WEIGHTED IMAGES!



① "INVERT" MAGNETIZATION

② IMAGE IN HERE, WITH INVERSION TIME TI CHOSEN WHEN UNDESIRED TISSUE MAGNETIZATION VECTOR PASSES THROUGH ZERO ($M_z = 0$ FOR TISSUE WE DON'T WANT)

③ WAIT A LONG TR FOR FULL RECOVERY