Assignment

Read 31-43, 67-76 in text

HW 1 will go out Thursday

Today

Class Structure

Characteristics of RF

Next

Small-TIP Angle Solution

Excitation k-space

Fourier Design of Slice Selective Pulsed
LECTURE 1: CHARACTERISTICS OF RF

BASICS OF SLICE SELECTION

\[ B_0 \]
\[ w = \omega B_0 \]
\[ \gamma = 2\pi \times 4.257 \text{ rad/G} \]

POLARIZATION

\[ w = \omega \gamma \]

LINEAR GRADIENT + BANDLIMITED RF

\[ J(\beta, \gamma) \]

CHOOSE \( \beta, \gamma \) TO HAVE BANDLIMITED SPECTRUM
OTHER GEOMETRIES

SLAB

CYLINDER

VOXEL

TYPES OF OPERATORS

EXCITATION

INVERSION

SPIN ECHO

EACH CAN BE DONE IN ANY OF THE GEOMETRIES!
Typical sizes of the magnetic fields in MRI

\[ B_0 \quad 15,000 \, G \quad (1.5\, T) \]
\[ G \quad (\text{g/cm})(20\, \text{cm}) = 80\, G \]
\[ B_1 \quad \frac{1}{4} G \quad \text{(Earth's field is } \frac{1}{2} G!) \]
RF is the weakest field in MRI.

Typical power used to generate these fields

\[ B_0 \quad \text{None} \quad \text{(Supercon, Always on)} \]
\[ G \quad 2\, \text{kw/channel} \quad \text{(Simple Pulse SEQ)} \]
\[ B_1 \quad 20\, \text{kw}! \quad \text{(Body Amp, 1.5T)} \]

Where does the power go?

20 kw Peak power for RF Amp
2 kw Average power (10\% Duty Cycle)
200 W Dissipated in subject (50\% of)
20 W Impacted to spins (non-selective)

Not very efficient!
PHYSICAL EFFECTS (NORMAL OPERATION)

Bo None (except for motion in fringe fields)
G None (operate below PNS, ignore noise)
B1, Wating (1-2°C)

RF Power Deposition

Measured as Specific Absorption Rate (SAR)

Basic Concept: Limit temperature rise to:

1°C Head
2°C Body
3°C Extremities

For any 1g of tissue.

This is the same temperature rise as produced by exercise, body can deal with it.

Same limits as ultrasound, cell telephones

Hard to measure!
SAR DEPENDS ON:

Tissue Vascularization
Tissue Conductivity
Tissue Geometry
Coil Volume
Pulse Sequence

Power per any one gram of tissue

8 W/kg Head/Body 5 minutes
12 W/kg Extremity 5 minutes

Average Power over Body Part

3 W/kg Head 10 minutes
4 W/kg Body 15 minutes

These all require models of power deposition for a particular body part very dependent on geometry.
SAR Dependence

\[ \text{SAR} \propto B_1^2 B_0^2 \text{(af)} \]

Seldom a Problem at 0.5 T
Can be a Problem at 1.5 T
Always an Issue at 3.0 T

Typical RF Parameters

Amplitude:

Actually measured in G or mT
GE whole body systems (0.5-3T)
Max \( B_1 \), head \( \sim \frac{1}{4} \) G
Max \( B_1 \), body \( \sim \frac{1}{8} \) G

Frequently quote \( B_1 \) in kHz (Protons)

How fast would magnetization spin with a constant \( B_1 \)?

\[ B_1 (\text{kHz}) = \frac{\frac{\pi}{24}}{1} \ B_1 (\text{G}) \]

\( \frac{1}{4} \) G \( \Rightarrow \) 1 kHz

2 π Rotation in 1 ms
8 π Rotation in kHz
Typical $R_i^2$ Parameters

Homogeneity (@1.5T)

- Head coil ~ 10 Hz
- Body coil ~ 30 Hz
- Surface coil ~ 100 Hz

Tolerance to $B_i$ variations is an important concern, and not easy to achieve.