

High-Field MRI

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Why We Need High Field?

- **Higher Signal-to-Noise Ratio**
 - Scan time
 - Resolution
- **Functional Study**
 - Better Spectral Resolution
 - Image of Other Nucleus (e.g. Na)
 - More BOLD Contrast

Source of MR Signal

- Larmor

$$\omega = \gamma B_0$$

- Magnetization

$$M \propto \gamma^2 B_0$$

- Received Signal

$$S \propto \omega M \propto \gamma^3 B_0^2$$

But, the Noise...

$$N \propto (a \omega^{1/2} + b \omega^2)^{1/2}$$

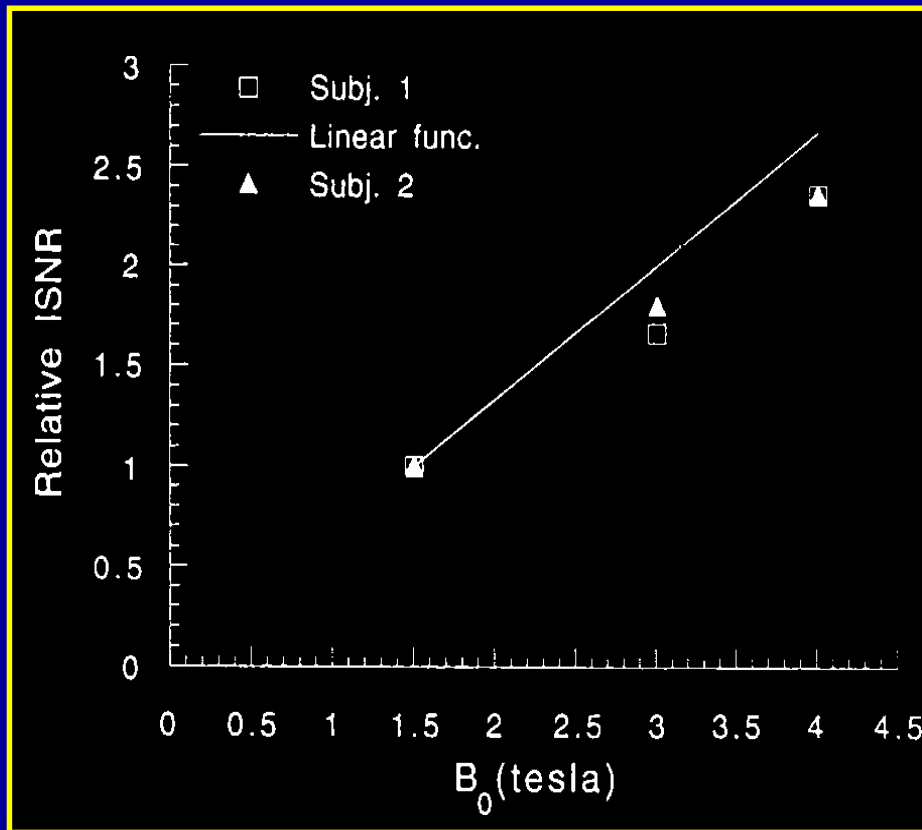


Coil loss



Body loss

Finally, the SNR...



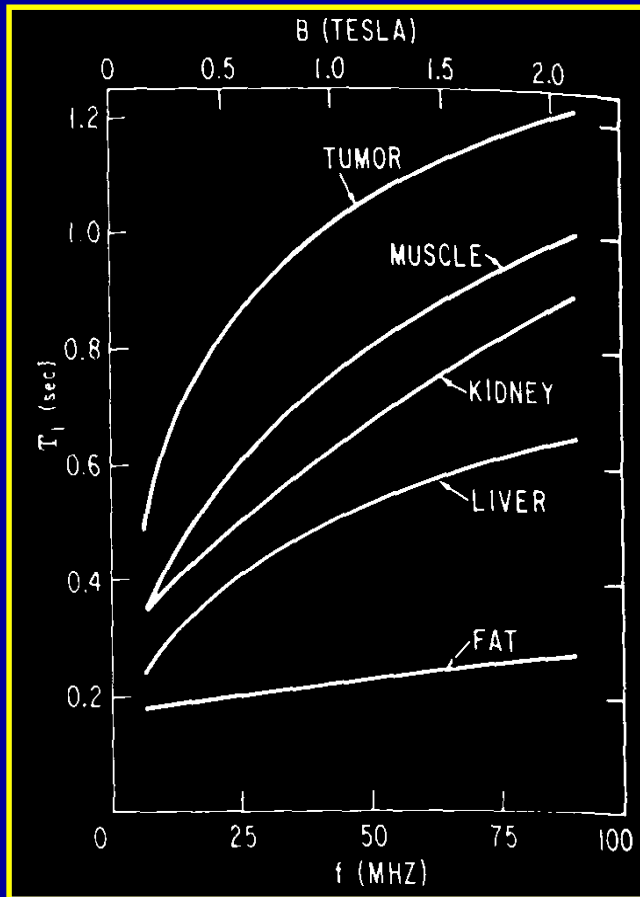
$$\frac{\gamma^3 B_0^2}{(a \omega^{1/2} + b \omega^2)^{1/2}}$$

$$\propto \gamma^2 B_0$$

Good Image

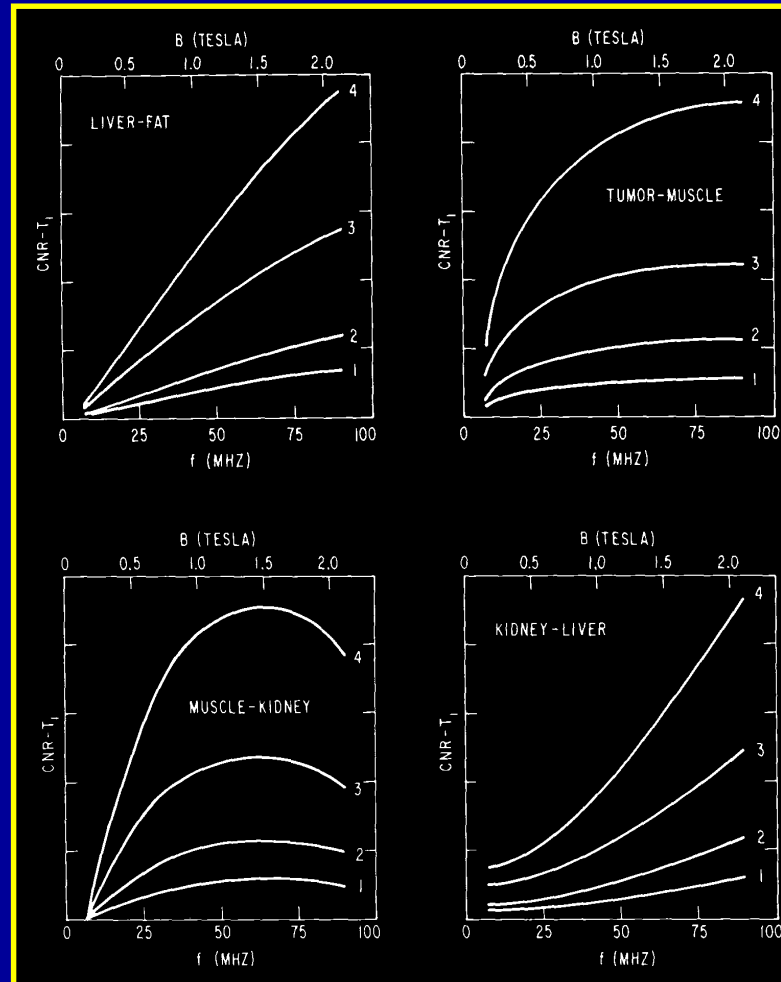
- SNR
- Spatial resolution
- CNR
 - T1
 - T2
 - Proton density

T1 Relaxation



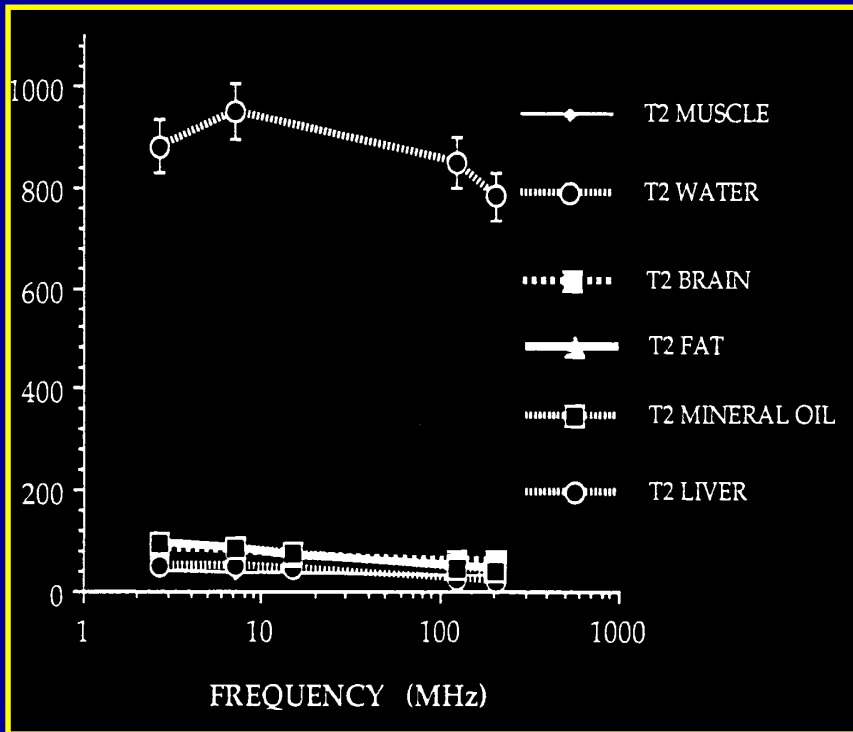
- Converge ?
- TR (scan time)
- SNR

T1 Contrast

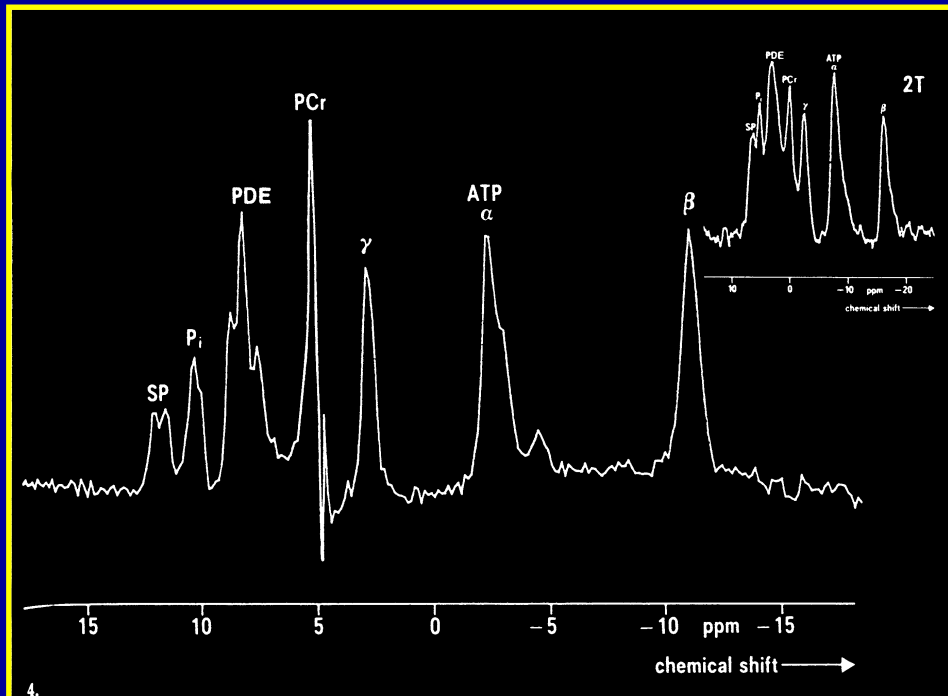


T2 Relaxation

- TE
- Line-width
- SNR



Spectroscopy



- Spectral resolution
 - Chemical shift $\propto B_0$
- Temporal & spatial resolution
 - SNR
- Metabolite at low concentration
- Other nucleus

$$\text{SNR} \propto \gamma^2 B_0$$

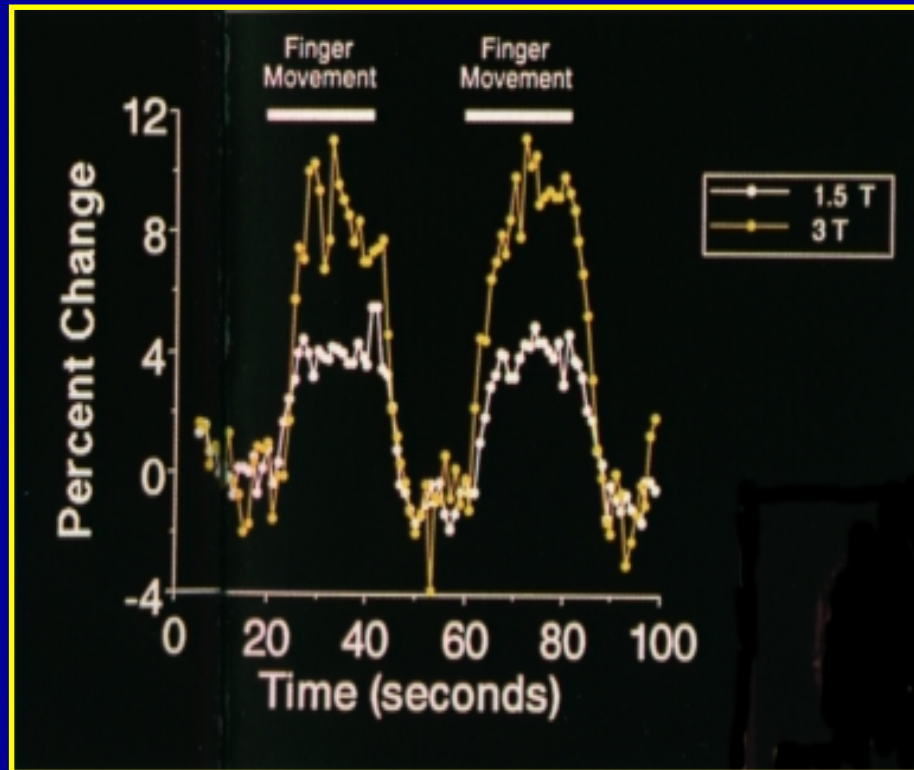
Problems

- **Off-resonance effect**
 - mis-registration

$$\Delta x = \Delta B_0 / G$$

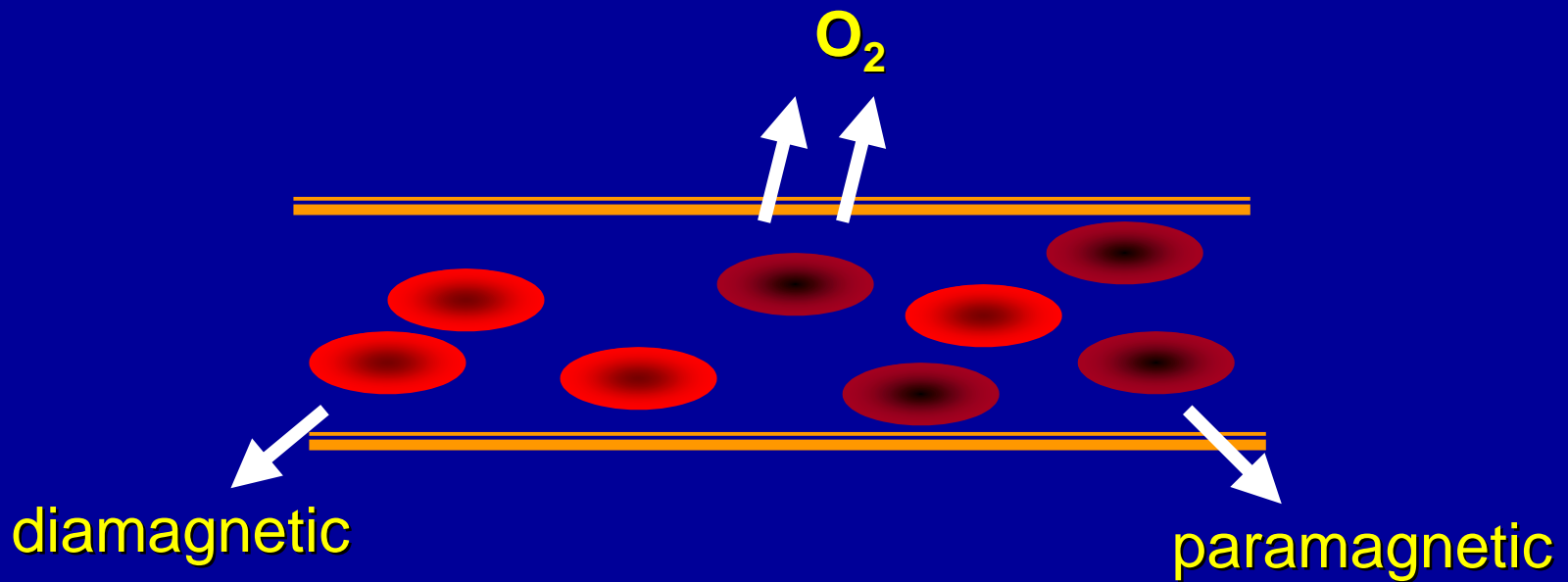
- incomplete inversion
- **Relaxation change**
 - T2

BOLD *f* MRI



Signal Source

- Deoxy-hemoglobin



$$\mathbf{B} = \mu_0 (1 + \chi) \mathbf{H}$$

Consider....

- Generated field is localized
- Diffusion not so fast

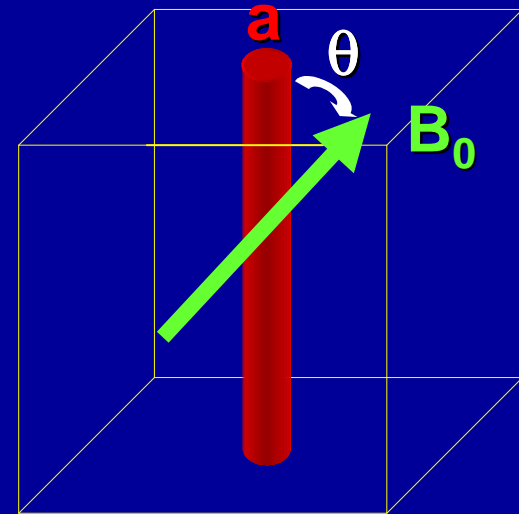
Susceptibility Effect

- Inside:

$$\Delta B \propto \Delta\chi B_0 (3\cos^2 \theta - 1)$$

- Outside

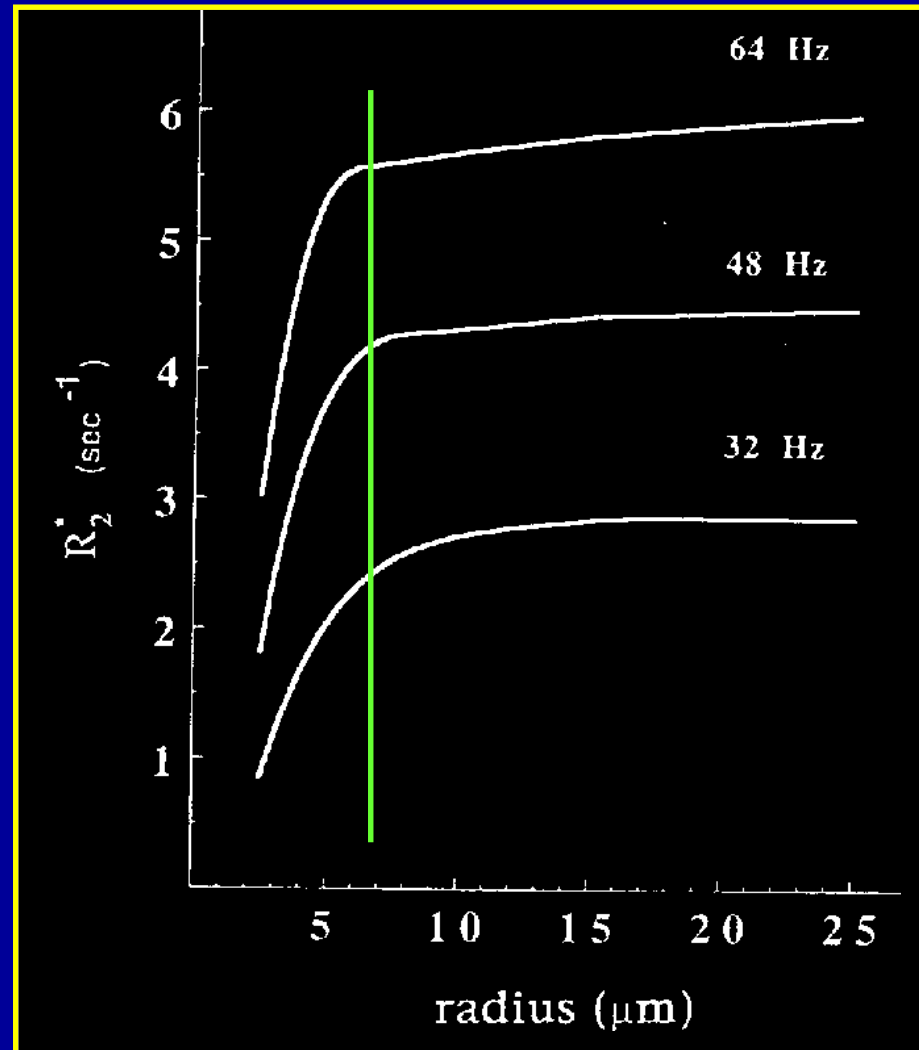
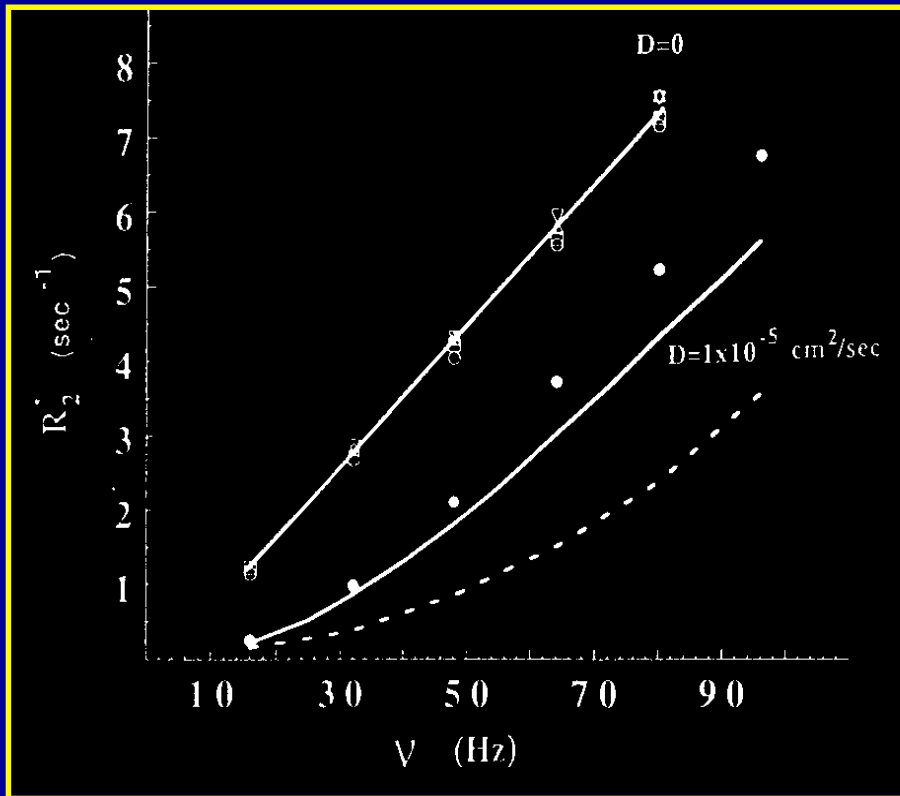
$$\Delta B \propto \Delta\chi B_0 (a/r)^2 \sin^2 \theta$$



L

$$b = \pi a^2 L / L^3$$

Simulation



R2* Change

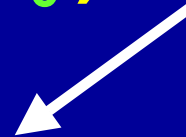
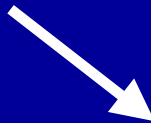
- $R2^* = 1/T2^*$

Large vessel

Small vessel



- $R2^* = \alpha \Delta\chi B_0 b_L + \beta (\Delta\chi B_0)^2 b_s p$



Blood volume

Active vessel

MR Signal Change

$$S/N = S_0/N \exp[- TE (R2^* + \Delta R2^*)]$$

$$\text{-) } S/N = S_0/N \exp[- TE R2^*]$$

$$\Delta S/N = S_0/N \exp[- TE R2^*]$$

$$(\exp[- TE \Delta R2^*] - 1)$$

$$\approx S_0/N \exp[- TE R2^*] (TE \Delta R2^*)$$

Field Dependence

- Optimal TE=T2*

$$\Delta S/N \propto \Delta R2^* / R2^*$$

- Remember...

$$\Delta R2^* = \alpha \Delta\chi B_0 b_L + \beta (\Delta\chi B_0)^2 b_S p$$

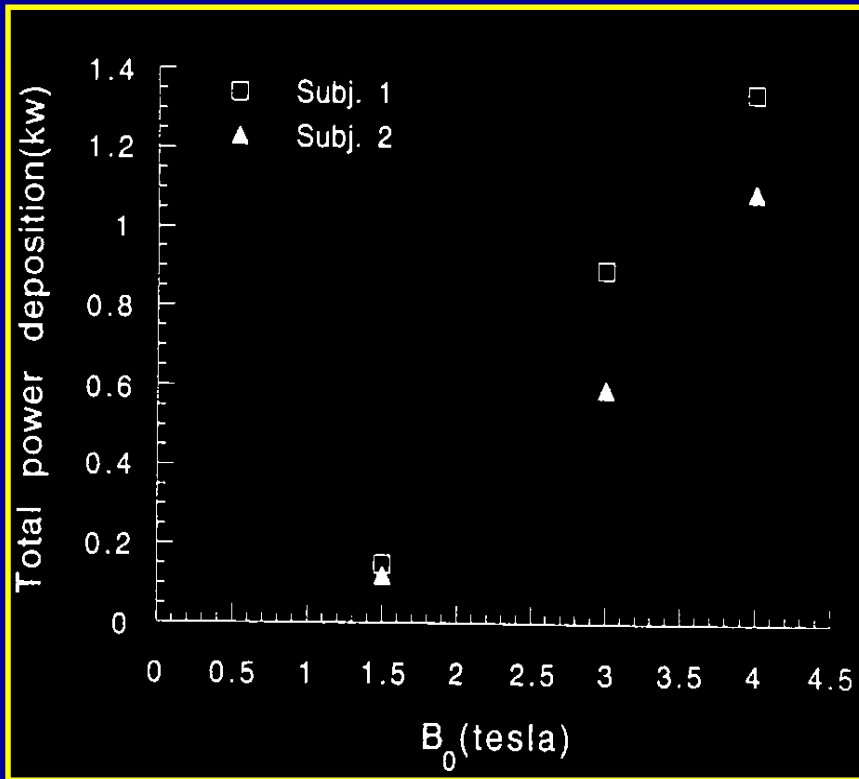
- Experiment...

R2* : less than linear

Other Problems Are...

- $\n
- **Artifacts**
 - susceptibility
 - RF penetration
 - eddy current
 - chemical shift
 - motion
 - field inhomogeneity
- **Safety**

RF Power Deposition



Remember:

$$P \propto B_0^4$$

...So, ZCDF