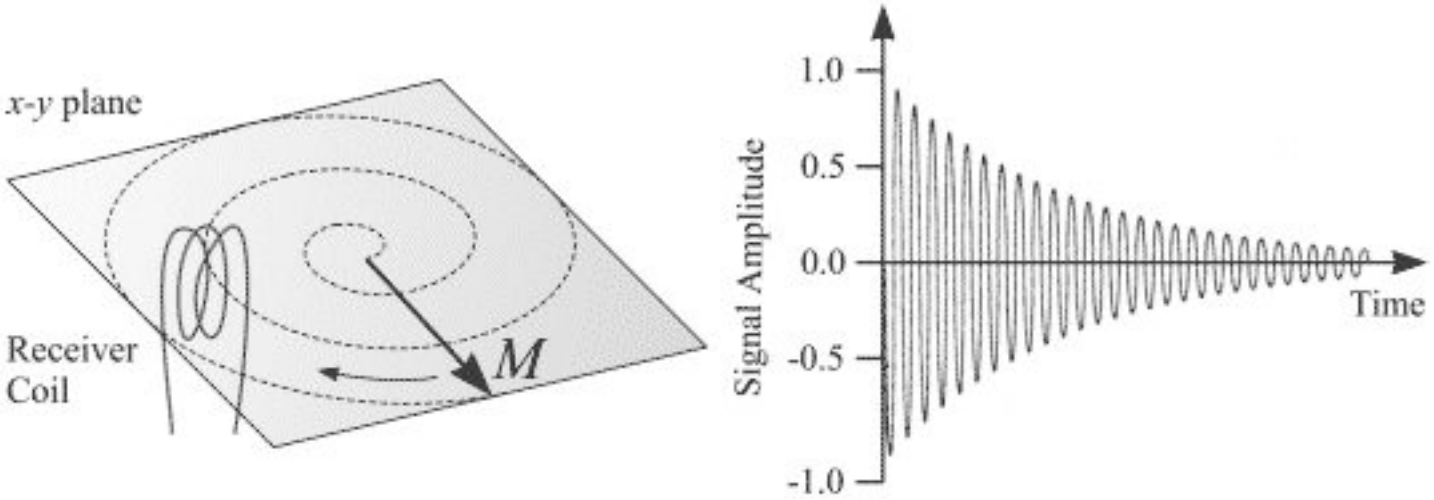
Bioengineering 208
Magnetic Resonance Imaging

Winter 2007
Lecture 6

- RF Coils
  - MR signal detection
  - Reciprocity
  - Coil Q and Noise
  - Classes of RF coils
  - Coil Geometry

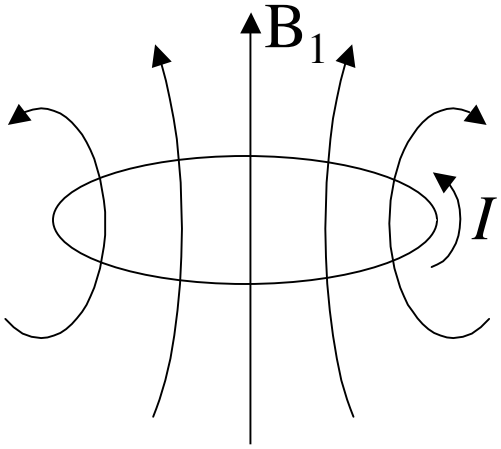
MR Signal Detection



Faraday's Law of Induction: $\oint_C \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{A}$

Reciprocity

The spatial distribution the sensitivity of an RF coil is proportional to the field generated by a unit current flowing in the coil



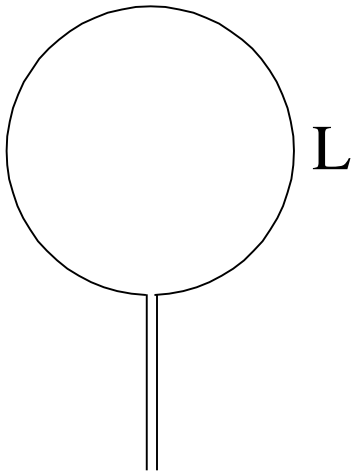
If unit current I produces a transverse RF field B_1, then transverse magnetization M_{xy} induces:

$$Voltage \propto \int B_1(r) \bullet M_{xy}(r) dV$$

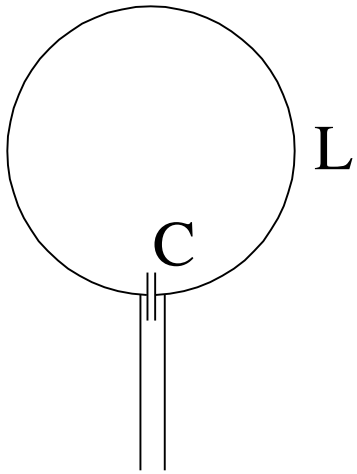
Note: Only transverse components of B_1 and M count

For (a lot) more details, see: http://coecs.ou.edu/Tamer.S.Ibrahim/Reciprocity_In_MRI.htm

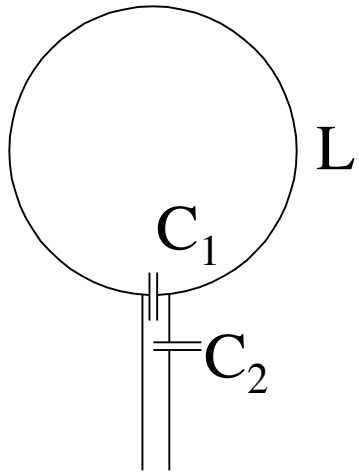
RF Coil Basics



$Z=R+j\omega L$
$\sim (1+100j)\Omega$



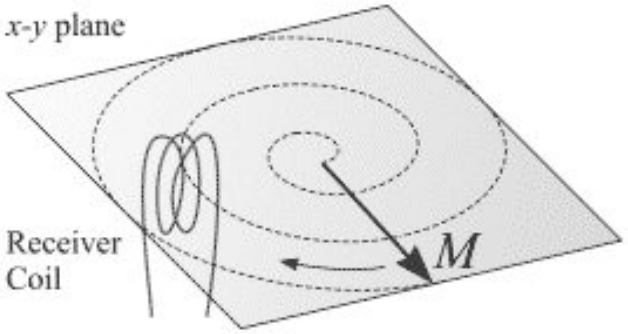
$Z=R+j(\omega L-1/\omega C)$
$\sim 1\Omega$ (tuned to ω_L)

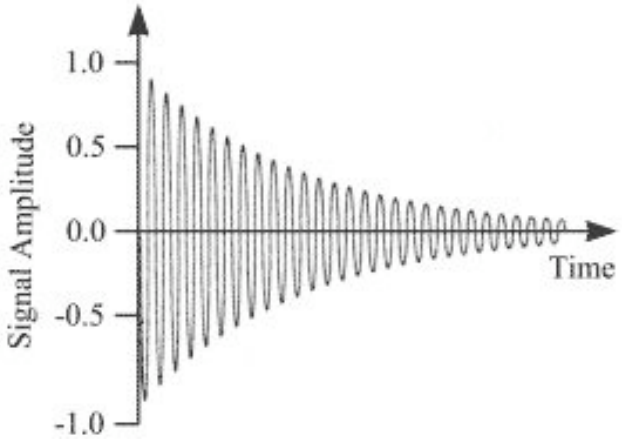


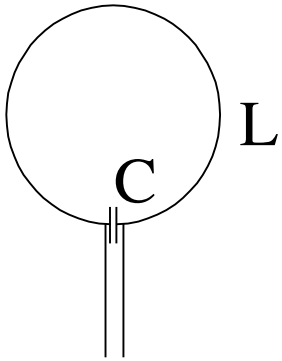
Z can be tuned to ω_L
and matched to 50Ω

C2 represents "Capacitive Coupling"
Inductive Coupling is also useful

RF Coil Q

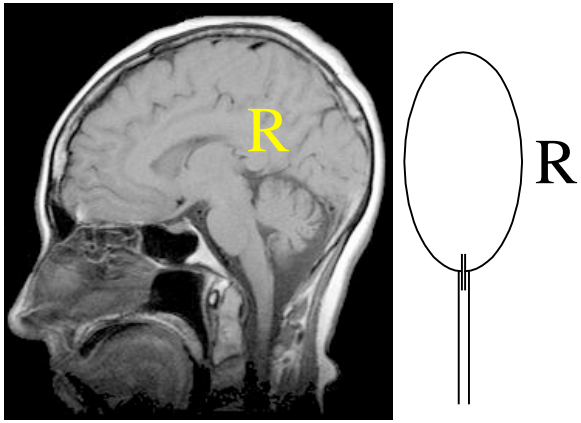






- Definition: Q = # oscillations before amplitude -> 1/e
  - or: 1/(fractional energy loss per oscillation)
- $Q(spins) = \omega_L T_2 \sim 10$ million
- Q(coil+sample) ~ 20-500
- Therefore: spins **cannot** be closely coupled to coil
- So, what limits coil Q?

Coil losses and Sample losses



$$\frac{1}{Q_{total}} = \frac{1}{Q_{coil}} + \frac{1}{Q_{sample}}$$

- Sample losses are <u>not</u> from spins, but from random thermal motion of ions in sample
- Goal: minimize noise by minimizing losses
- Not much control over Q_{sample}
- Try to get $Q_{coil} >> Q_{sample}$
- Maximize: $\frac{B_1(ROI)}{\int |B_1| dV}$ (roughly)

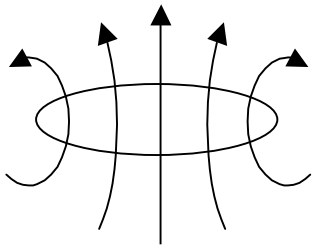
Classes of RF coils

- Transmit Only: Used only to apply RF pulses - typically large with uniform B_1
- * Receive Only: Used only to receive RF signal - optimized for high sensitivity
- * Transmit / Receive: Apply RF pulses and receive signal through same coil
- * Multicoil Arrays: Typically Receive Only, used to increase sensitivity over large ROI

* These need active and/or passive T/R switching

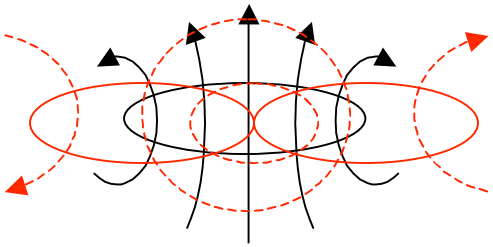
RF Coil Geometries

- Surface Coil:

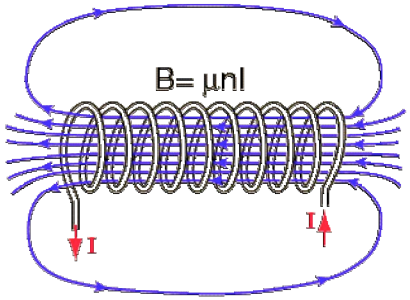


Where is B_z?

- Quadrature Surface Coil:



- Solenoid:



- Birdcage Coil: