Lec 10

(MRI: the role of B_o and B_1 fields)

- A nucleus with either an odd number of protons or odd number of neutrons will have a net magnetic moment.
- Why does ^{14}N have a net magnetic moment then?

Nuclide	Number of Protons	Number of Neutrons
^{1}H	1	0
^{2}H	1	1
^{13}C	6	7
^{14}N	7	7
^{17}O	8	9
^{19}F	9	10
^{23}Na	11	12
^{31}P	15	16
^{39}K	19	20

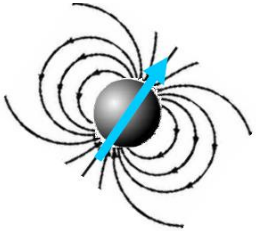
Net bulk magnetization is along B_o

Bulk magnetization: $\mathbf{M} = \sum_{i=1}^{N} \mathbf{m}_i$

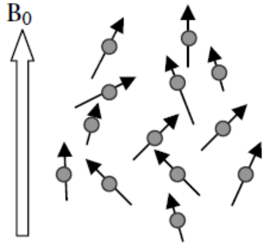
$\langle M_z \rangle \neq 0$, $\langle M_x \rangle = 0$, $\langle M_y \rangle = 0$

What happens during MRI? (1)

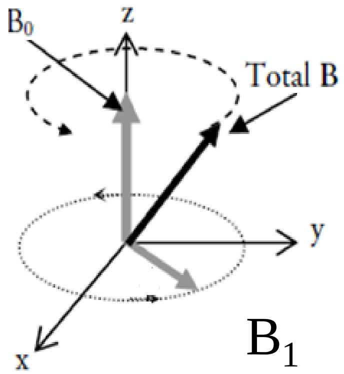
1. Hydrogen nuclei in tissue have "spin angular momentum" and associated magnetic moment.



2. In an external magnetic field (B_o), M_z lines up with B_o (along z-axis).

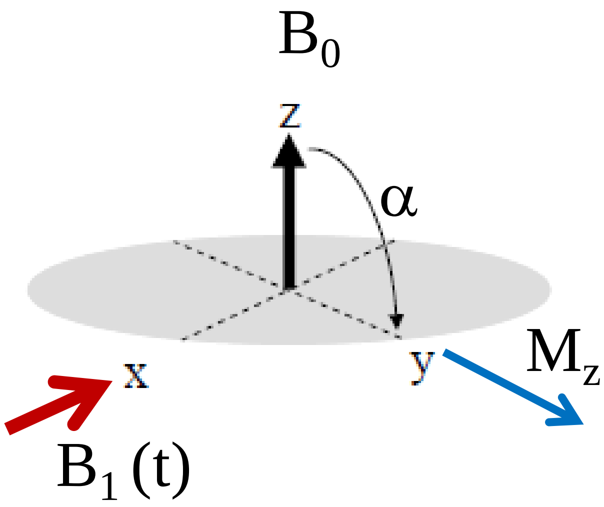


3. A rotating magnetic field (B_1) pulse is applied along x-axis.

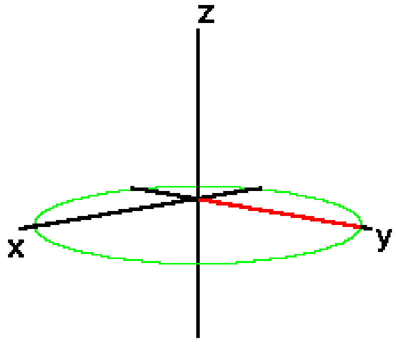


What happens during MRI? (2)

4. B_1 pulls away magnetization (M_z) from the z-axis with an angle α.



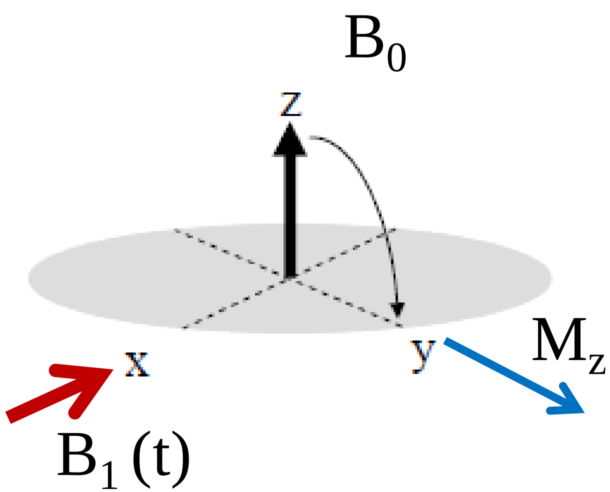
5. M_z rotates around z-axis at the "Larmor frequency".



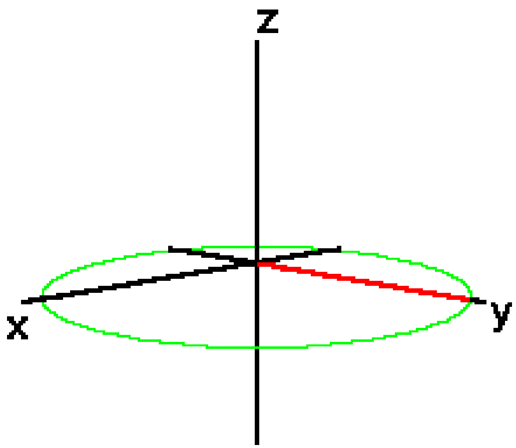
What happens in $B_1(t)$ field?

Magnetization in X-Y plane: RF field

- Apply RF pulse (10-100 MHz) B_1 along x-axis.
- B_1 (~ μT- mT) << B_o (~T).



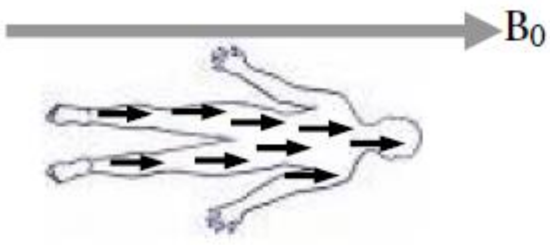
Net magnetization in xy plane (for π/2 pulse).



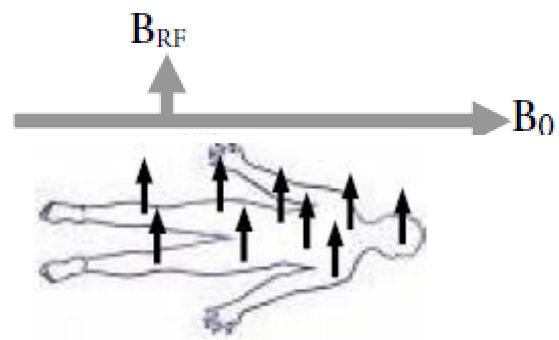
- M_z starts rotating about z-axis
- M_z returns to its equilibrium position along z-axis when RF field is turned off

If the magnitude of B_1 is much smaller (~ mT) than B_o (~ T), then how is it possible that B_1 can flip some spins?

How do we detect M_z?



Can't detect constant M_z (with B_o alone).

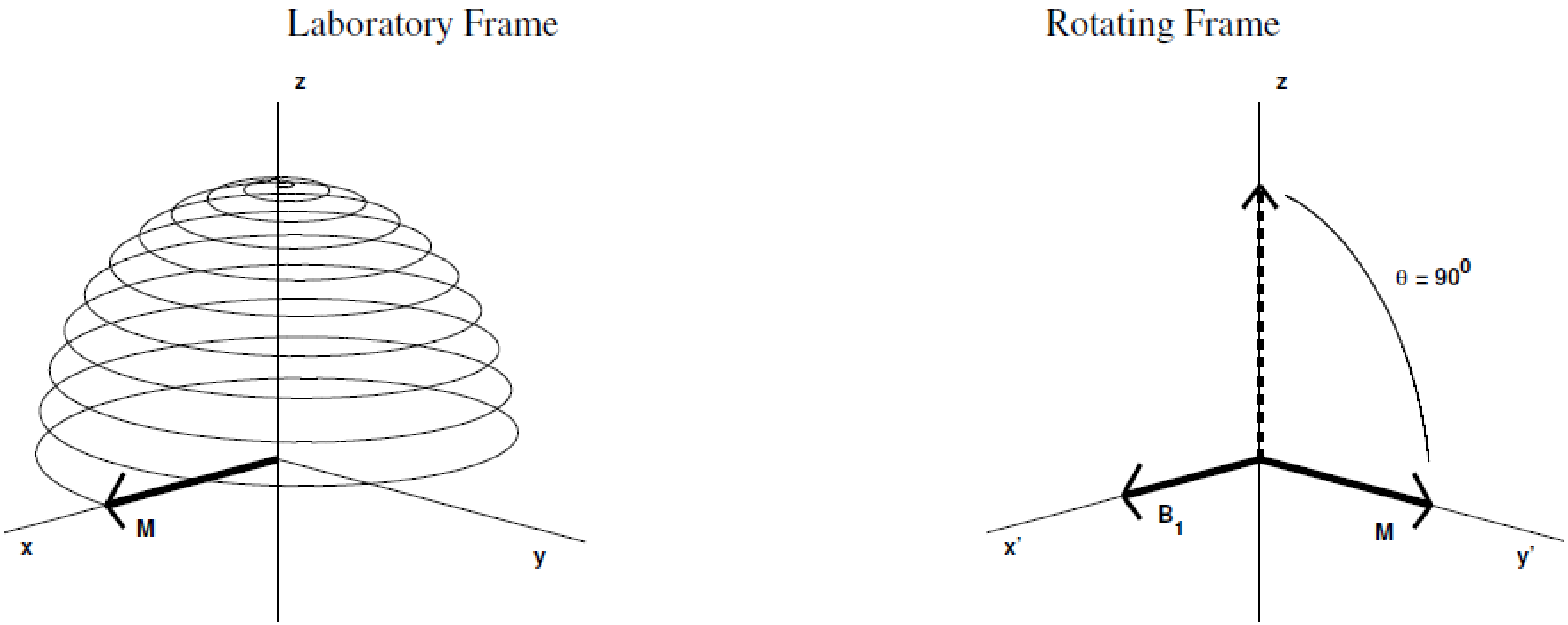


Can detect <u>time-varying</u> flux of M_z (generated using B_o and B_1)

RF coils for generating B_1 can also detect the voltage signal (Faraday induction).

$$V \sim - d\Phi/dt$$

We introduce a rotating reference frame. Why?

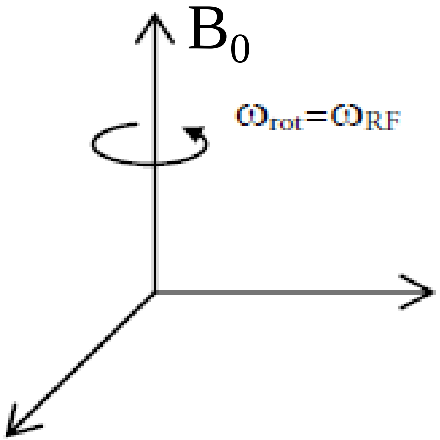


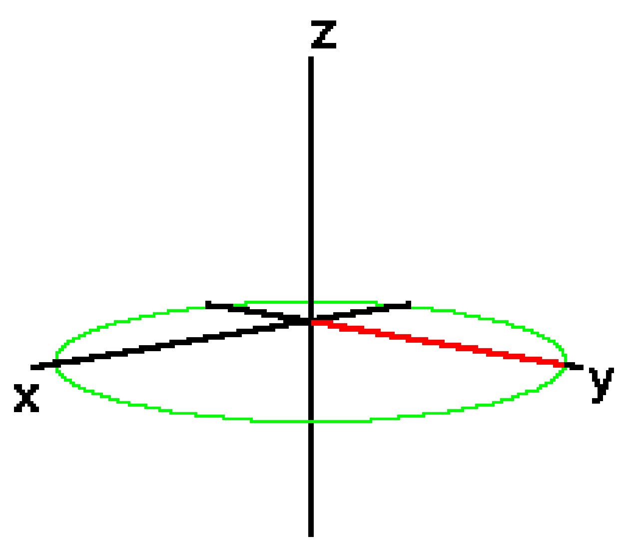
- In reality, each spin sees a slightly different magnetic field. Solving equations (that describe the time evolution of the magnetization vector, **M**) becomes a nightmare.
- All MRI hardware has been designed to work assuming a rotating reference frame.

Frame rotates <u>about z-axis</u> with Larmor frequency.

Lab frame coordinates: x, y, z

Rotating frame coordinates: x′, y′, z′





What do we see if we are sitting on the rotating frame?

B_1 is constant.

B_o vanishes.