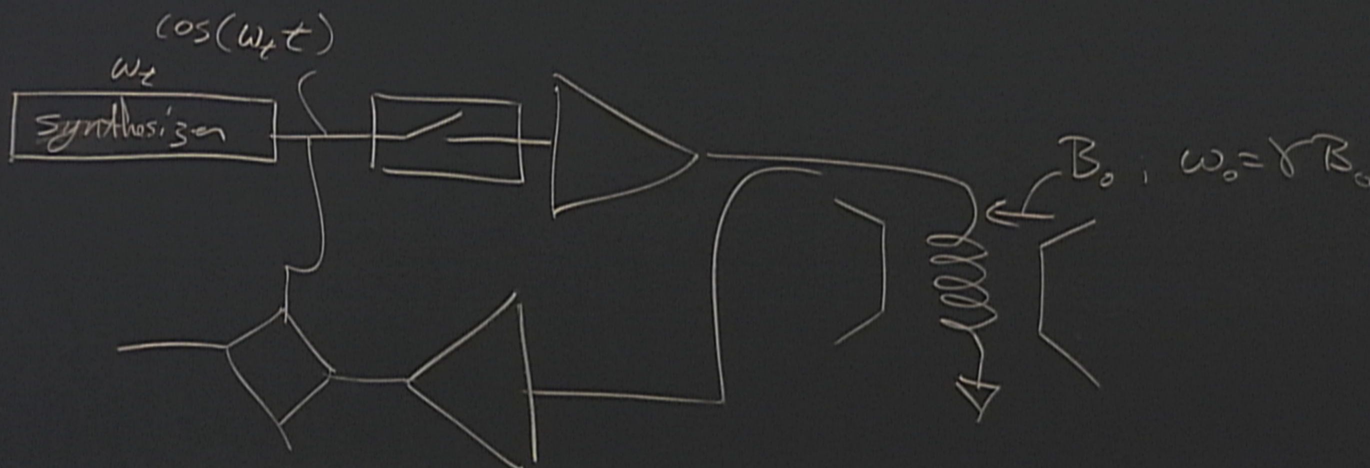
Title: 13/14 PSI - Explorations in Quantum Information - Lecture 9

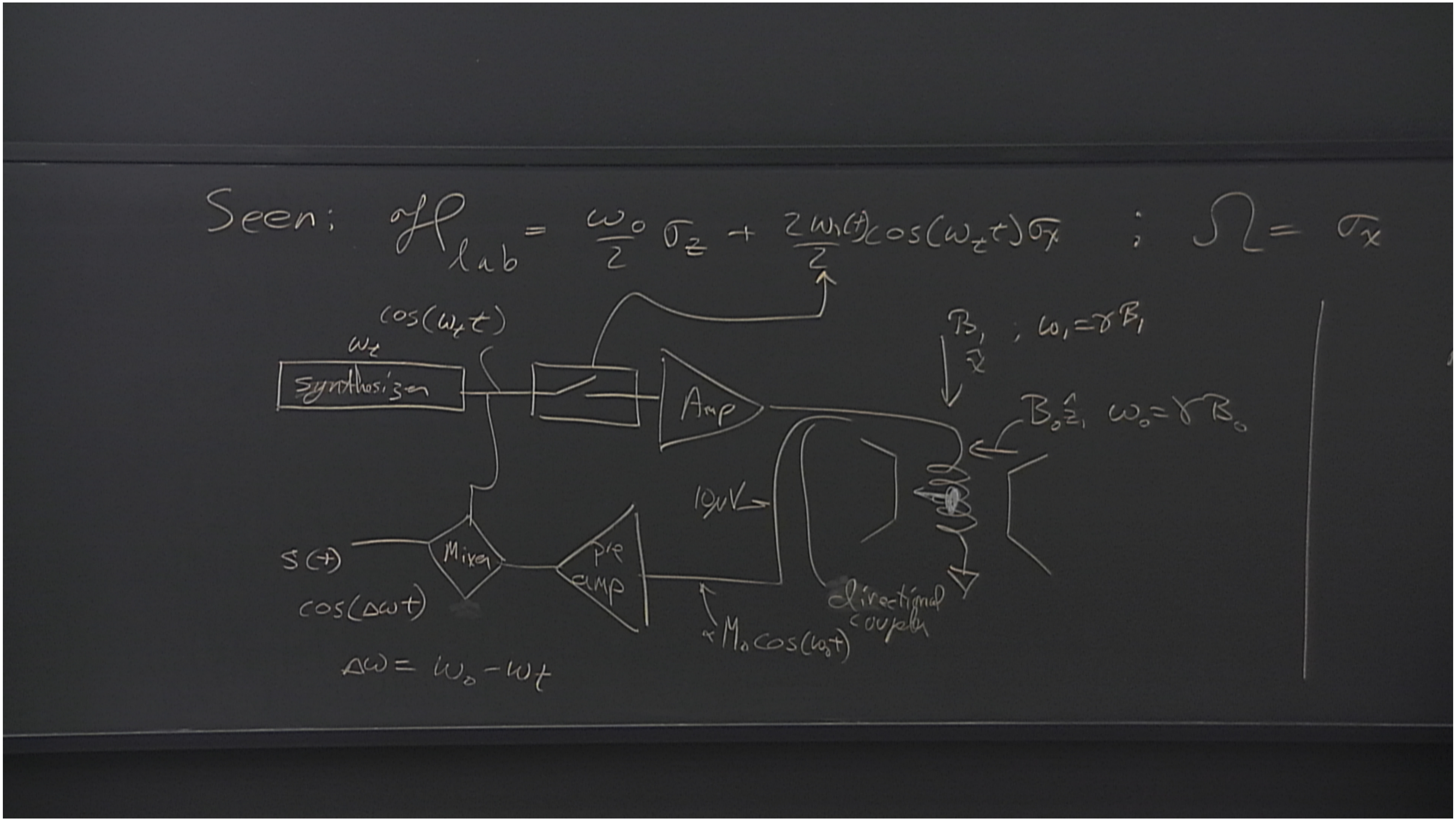
Date: Mar 27, 2014 09:00 AM

URL: http://pirsa.org/14030039

Abstract:

Seen: $\mathcal{H}_{lab} = \frac{\omega_0}{2}\sigma_z + \frac{2\omega_1}{2}\cos(\omega_t t)\sigma_x$




Seen: $\mathcal{H}_{lab} = \frac{\omega_0}{2}\sigma_z + \frac{2\omega_1(t)}{2}\cos(\omega_t t)\sigma_x$; $\Omega = \sigma_x$
$\cos(\omega_t t)$
ω_t
Synthesizer
Amp
B_1 ; $\omega_1 = \gamma B_1$
$\hat{x}$
$B_0 \hat{z}$, $\omega_0 = \gamma B_0$
$10\mu V$
Mixer
pre amp
$S(t)$
$\cos(\Delta\omega t)$
$\propto M_0 \cos(\omega_0 t)$
directional coupler
$\Delta\omega = \omega_0 - \omega_t$

$$)\sigma_x \quad ; \quad \Omega = \sigma_x \quad : \quad \eta_x = \frac{d}{dt}\int \frac{\vec{M}\cdot\vec{B}_1}{|B_1|}\, d\Omega$$

$$, \ \omega_1 = \gamma B_1$$

$$\mathcal{H}_{rot} = \frac{\Delta\omega}{2}\sigma_z + \frac{\omega_1}{2}\sigma_x$$

$$B_0 \hat{z}, \ \omega_0 = \gamma B_0$$

Bloch

$$\frac{dM_x}{dt} = -\Delta\omega\, M_y - \frac{M_x}{T_2}$$

$$\frac{dM_y}{dt} = \Delta\omega\, M_x - \omega_1 M_z - \frac{M_y}{T_2}$$

$$\frac{dM_z}{dt} = \underbrace{}_{\text{precession}} \underbrace{\omega_1 M_y}_{\text{nutation}} - \frac{M_z}{T_1} + \frac{M_0}{T_1}$$

spin-spin

spin lattice

equilibrium

$$\frac{1}{T_{2p}} = \frac{1}{2}\frac{1}{T_2} + \frac{1}{2}\frac{1}{T_1}$$

$$T_{2p} = \frac{2T_1 T_2}{T_1 + T_2}$$

$\omega_1 = 0$

$\vec{M}(0) = M_0 \hat{x}$: $M_x(t) = M_0 \cos(\Delta\omega t) e^{-t/T_2}$

$M_y(t) = M_0 \sin(\Delta\omega t) e^{-t/T_2}$

$M_z(t) = M_0 (1 - e^{-t/T_1})$

$$T_1 \leq T_2$$

$\omega_1 \neq 0$

$\vec{M}(0) = M_0 \hat{z}$

$M_x(t) = 0$

$M_y(t) = M_0 \sin(\omega_1 t) e^{-t/T_{2p}}$

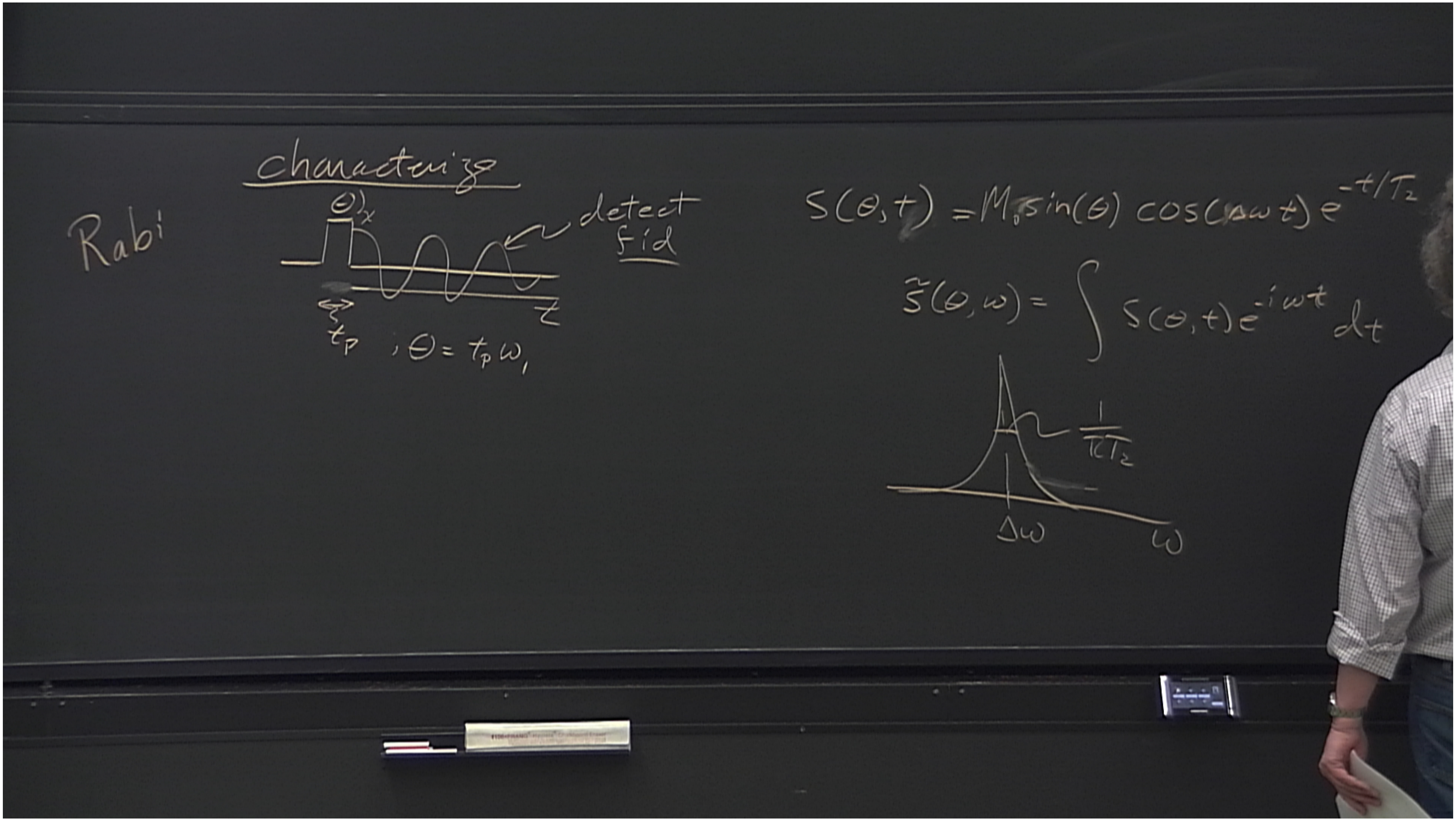
$M_z(t) = M_0 \cos(\omega_1 t) e^{-t/T_{2p}}$

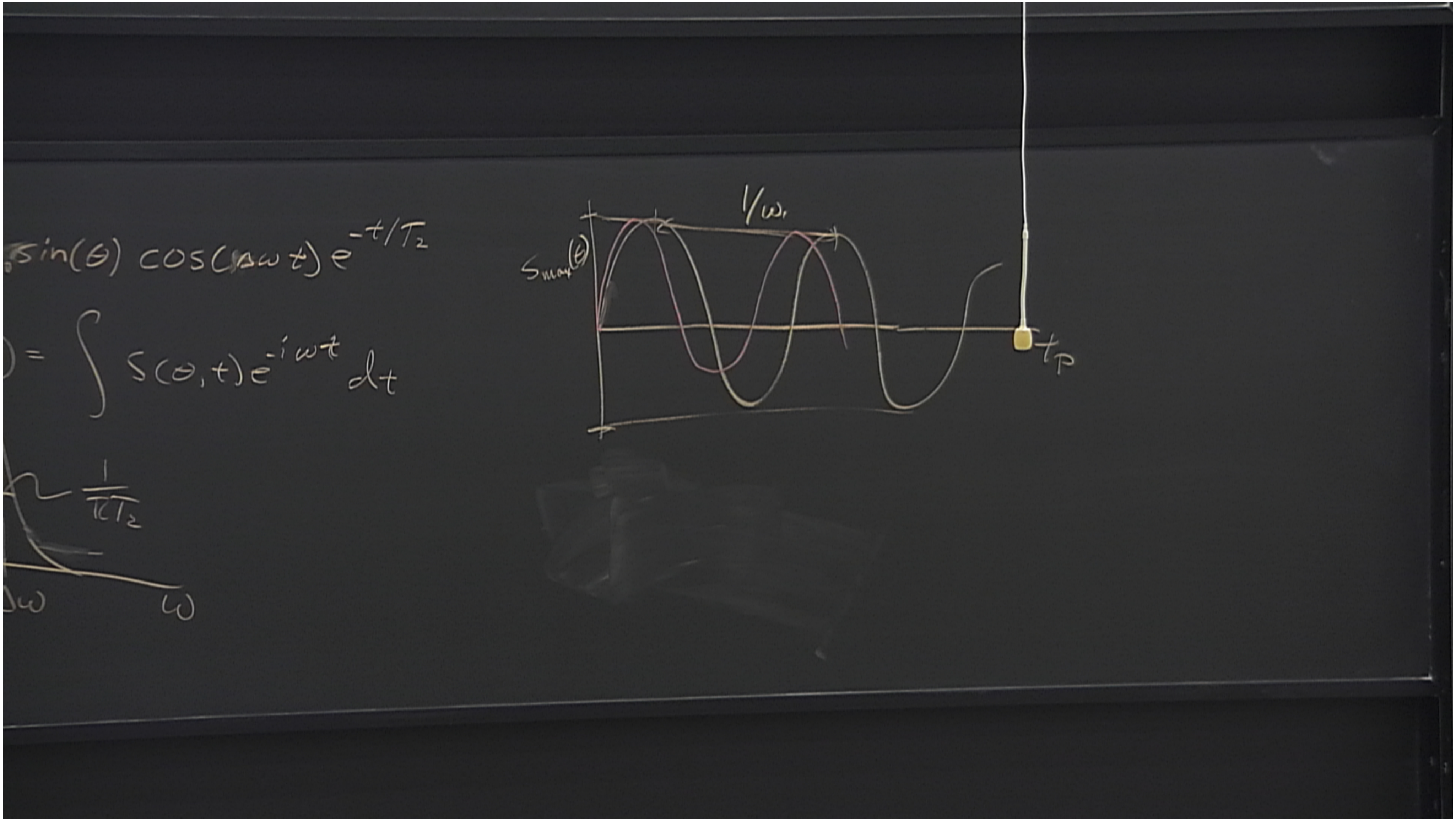
Blo

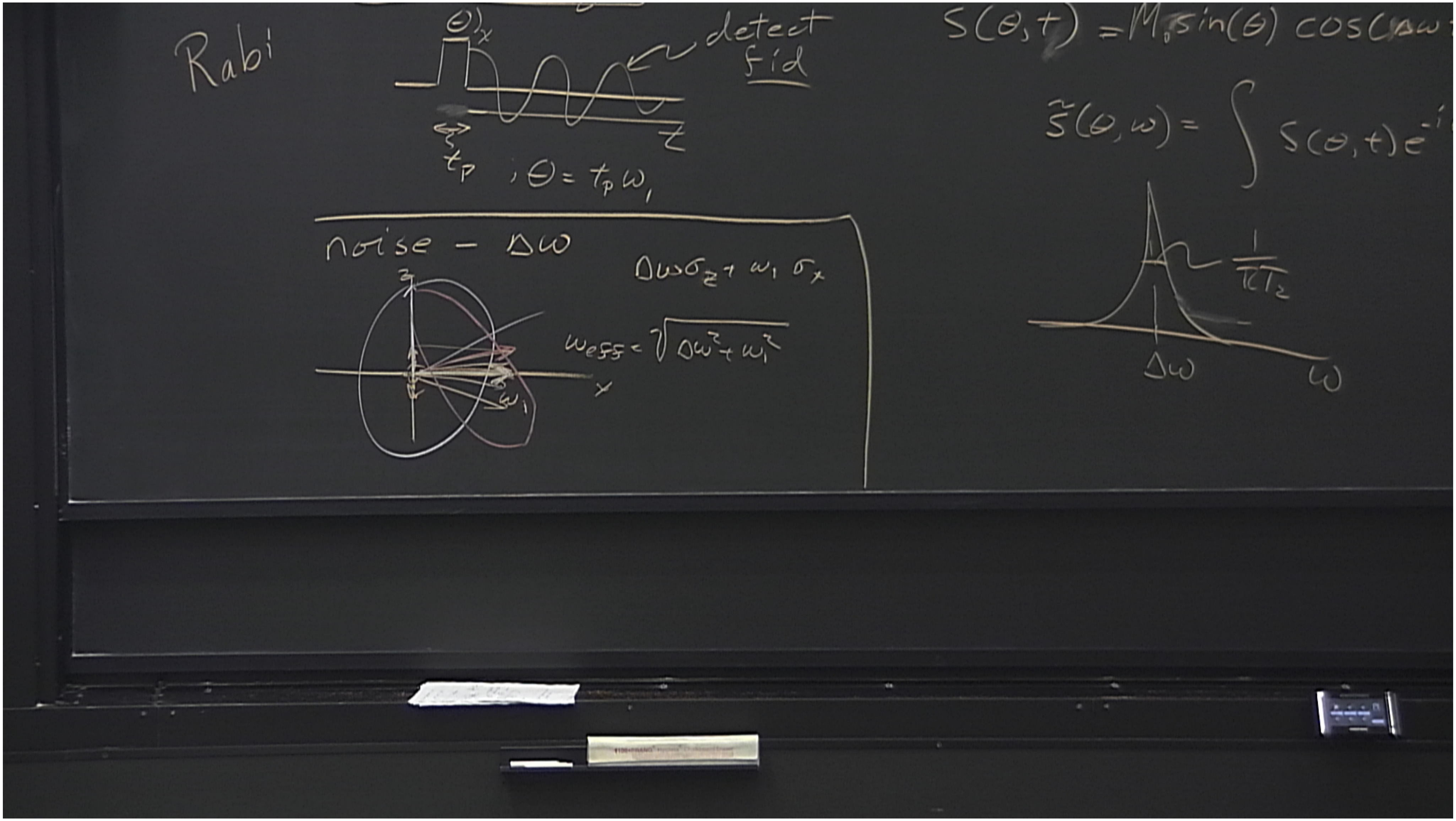
$\frac{dM_x}{dt} =$

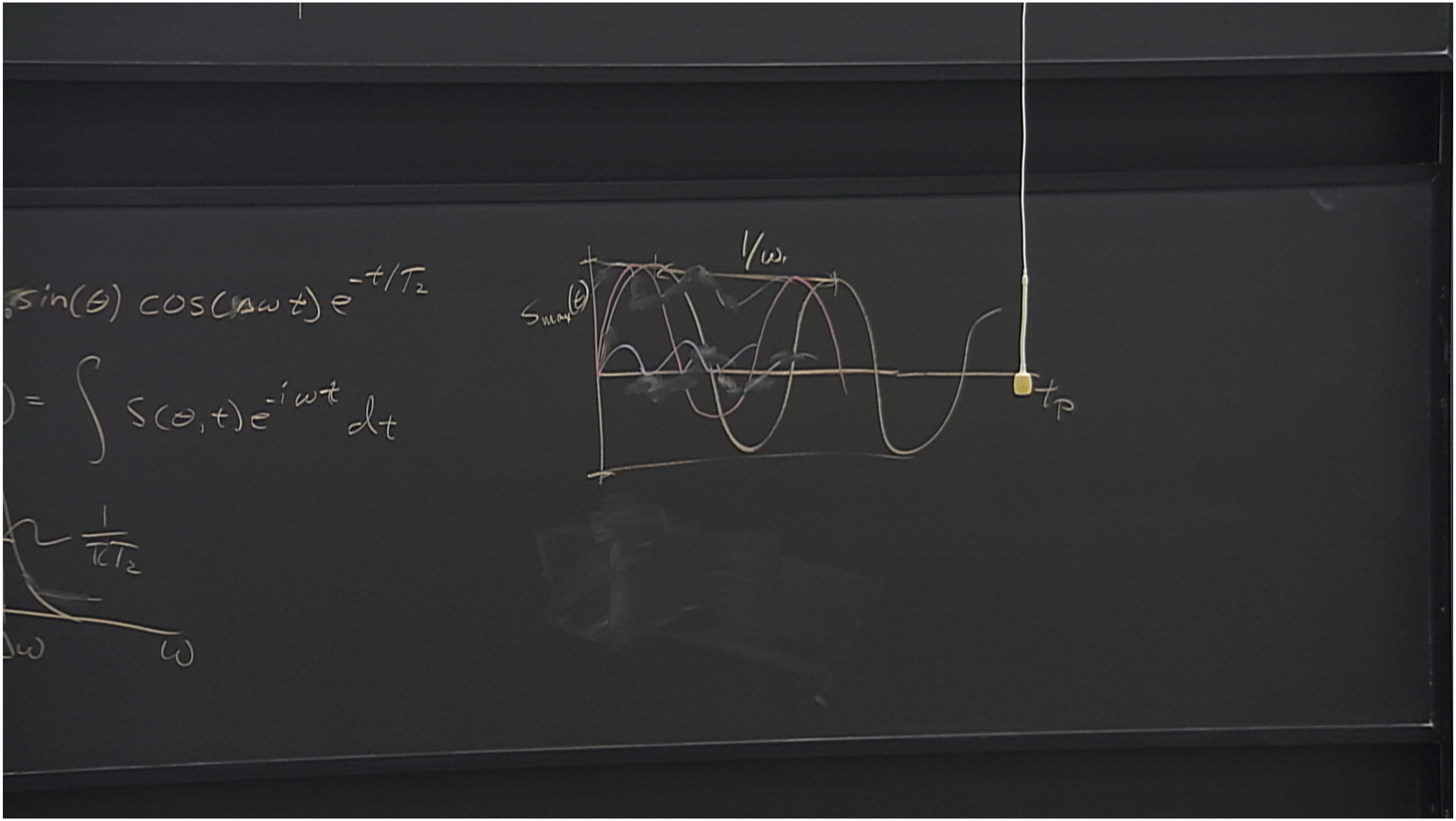
$\frac{dM_y}{dt} =$

$\frac{dM_z}{dt} =$

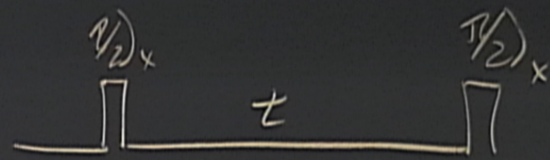

Rabi
characterize
$(\theta)_x$
detect
fid
t
t_p , $\theta = t_p \omega_1$
$S(\theta, t) = M_0 \sin(\theta) \cos(\Delta\omega t) e^{-t/T_2}$
$\tilde{S}(\theta, \omega) = \int S(\theta, t) e^{-i\omega t} dt$
$\frac{1}{\pi T_2}$
$\Delta\omega$
ω


sin(θ) cos(Δω t) e^{-t/T_2}
= ∫ S(θ, t) e^{-iωt} dt
1/πT_2
Δω
ω
1/ω_1
S_max(t)
t_p

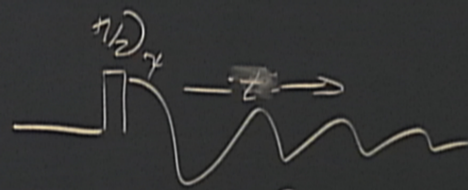

Rabi
detect
fid
$(\Theta)_x$
t_p ; $\Theta = t_p \omega_1$
t
noise - $\Delta\omega$
$\Delta\omega \sigma_z + \omega_1 \sigma_x$
$\omega_{eff} = \sqrt{\Delta\omega^2 + \omega_1^2}$
z
x
ω_1
$S(\theta, t) = M_0 \sin(\theta) \cos(\Delta\omega$
$\tilde{S}(\theta, \omega) = \int S(\theta, t) e^{-i}$
$\frac{1}{\pi T_2}$
$\Delta\omega$
ω


sin(θ) cos(Δω t) e^{-t/T_2}
) = ∫ S(θ,t) e^{-iωt} dt
1/πT_2
Δω
ω
1/ω_1
S_max(θ)
t_p

Ramsey



: neutron



$M_0 \cos(\Delta\omega t) e^{-t/T_2}$

$$S(t) = M_0 \int P(\Delta\omega) \cos(\Delta\omega t) e^{-t/T_2} \, d\Delta\omega$$

$P(\Delta\omega) \equiv$ cl

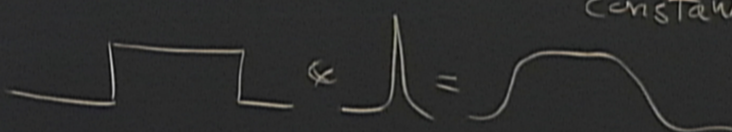
$\ldots \Delta\omega t) e^{-t/T_2}$

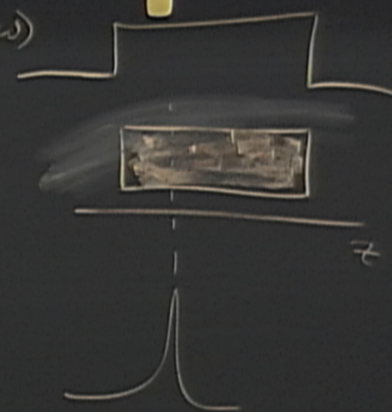
$\ldots d\Delta\omega$

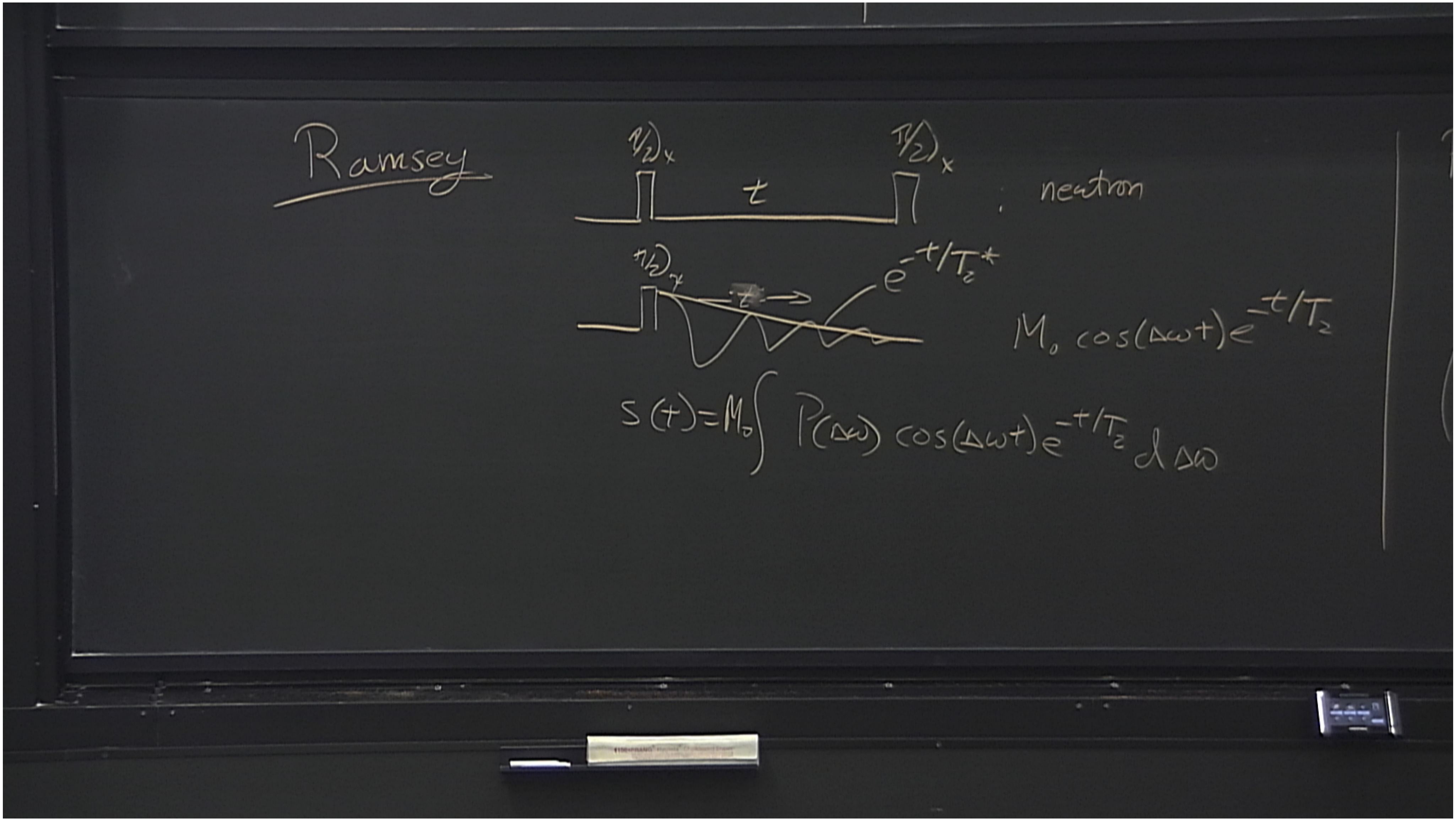
$P(\Delta\omega) \equiv$ classical dist.

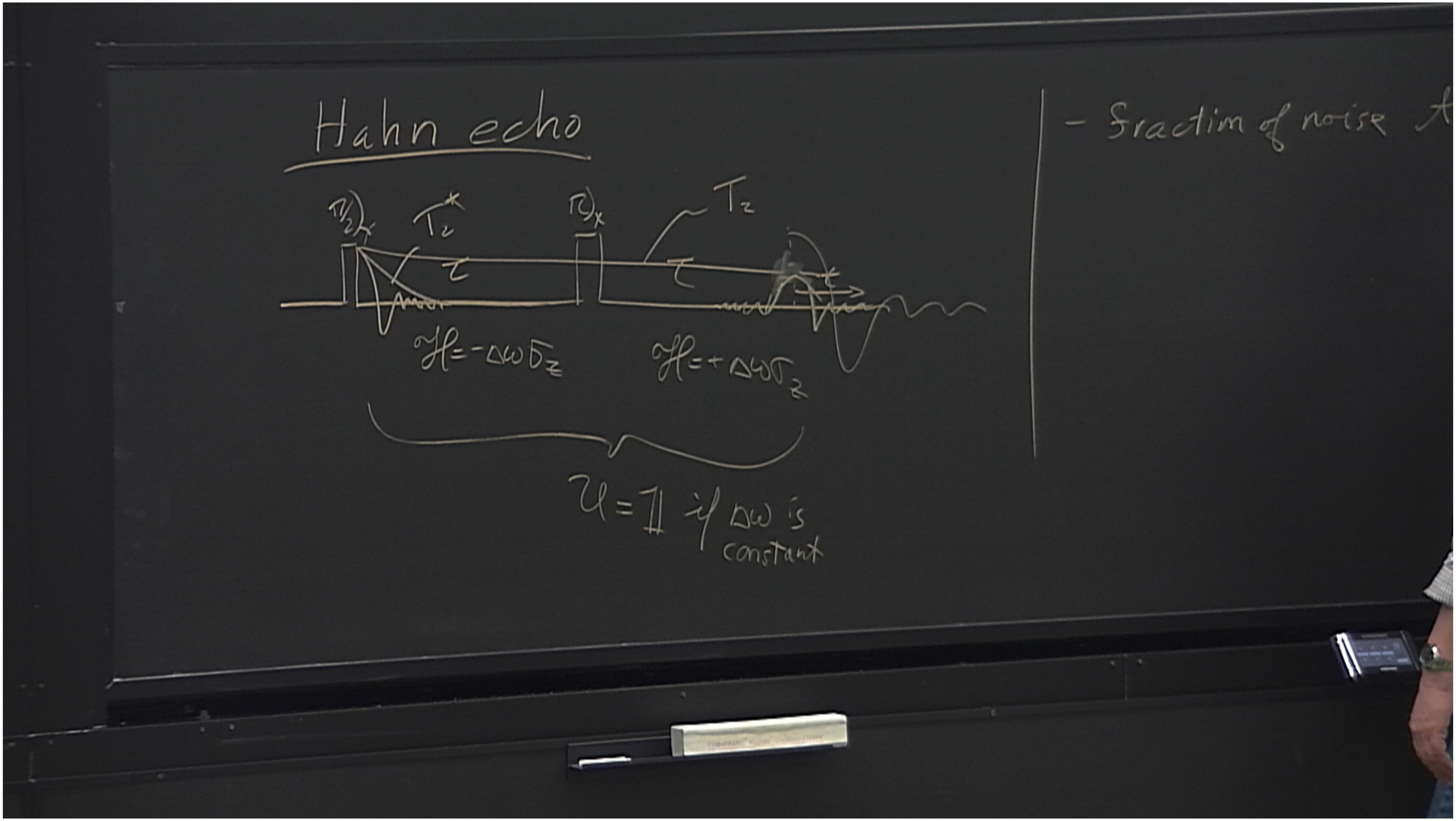
$\mathcal{F}\{s(t)\} = P(\Delta\omega) \circledast \mathcal{L}(T_2)$

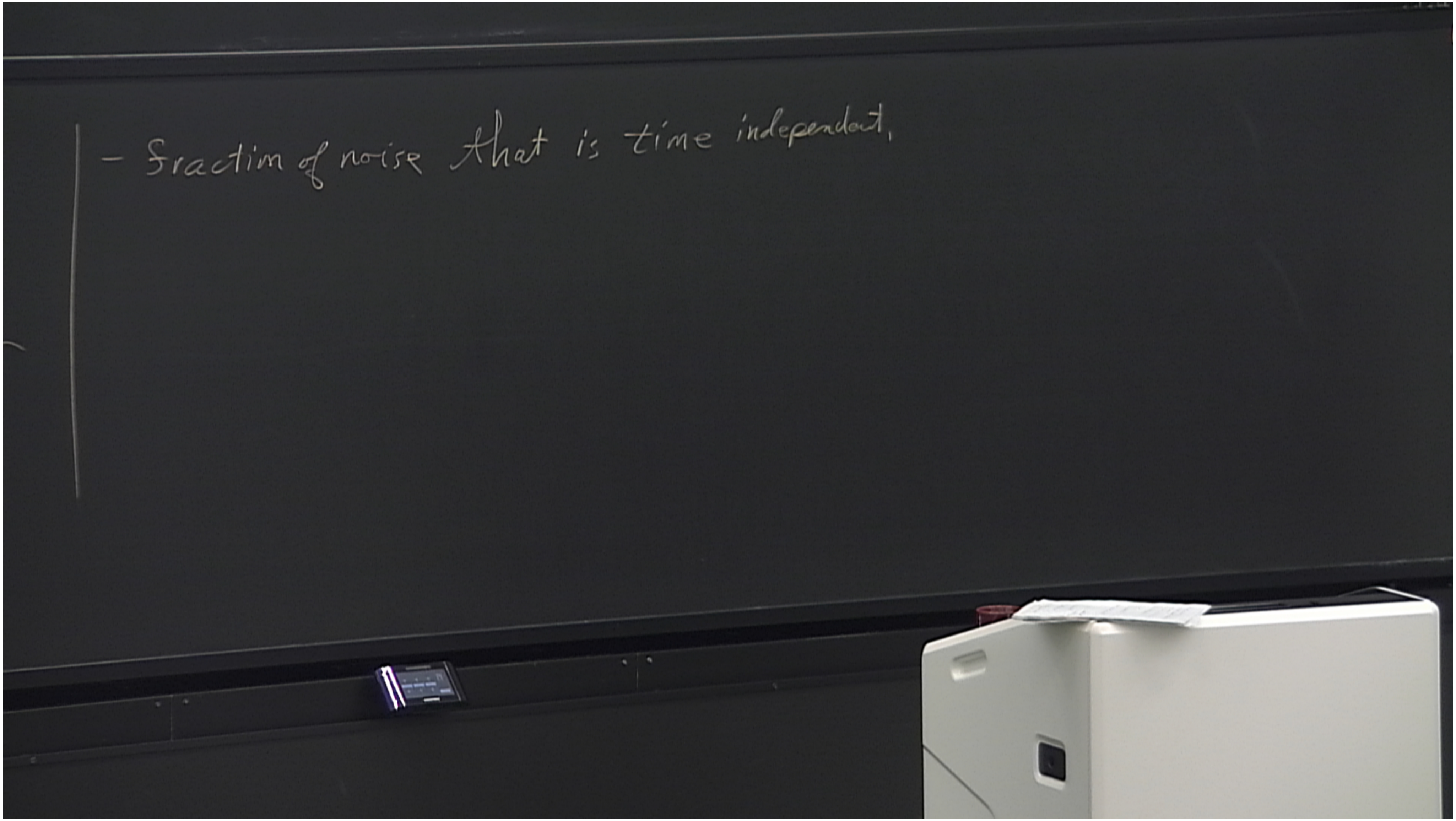
$B(z) = B_0 \hat{z} + \underbrace{\partial B_z / \partial z}_{\text{constant}} \, z$

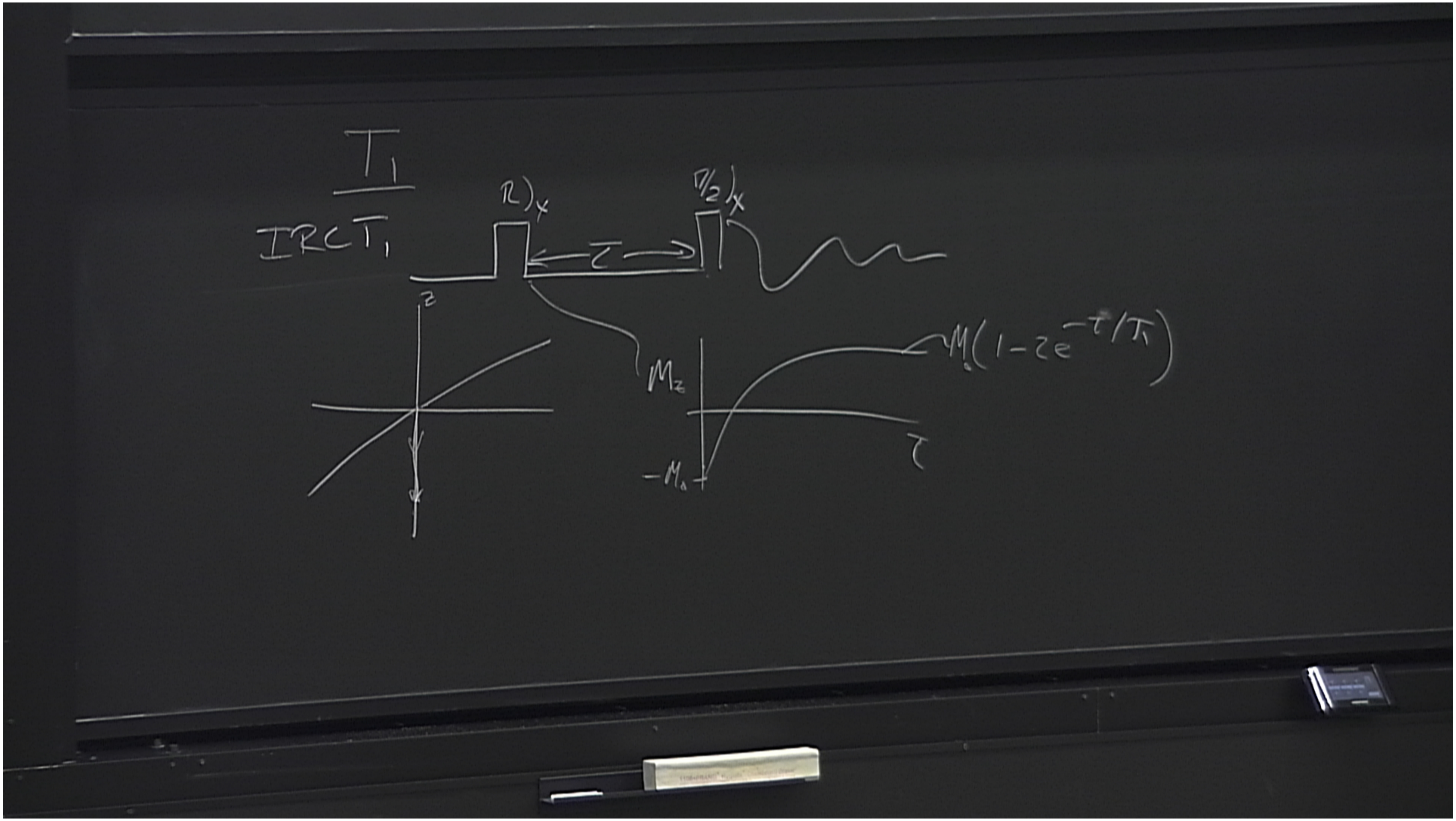


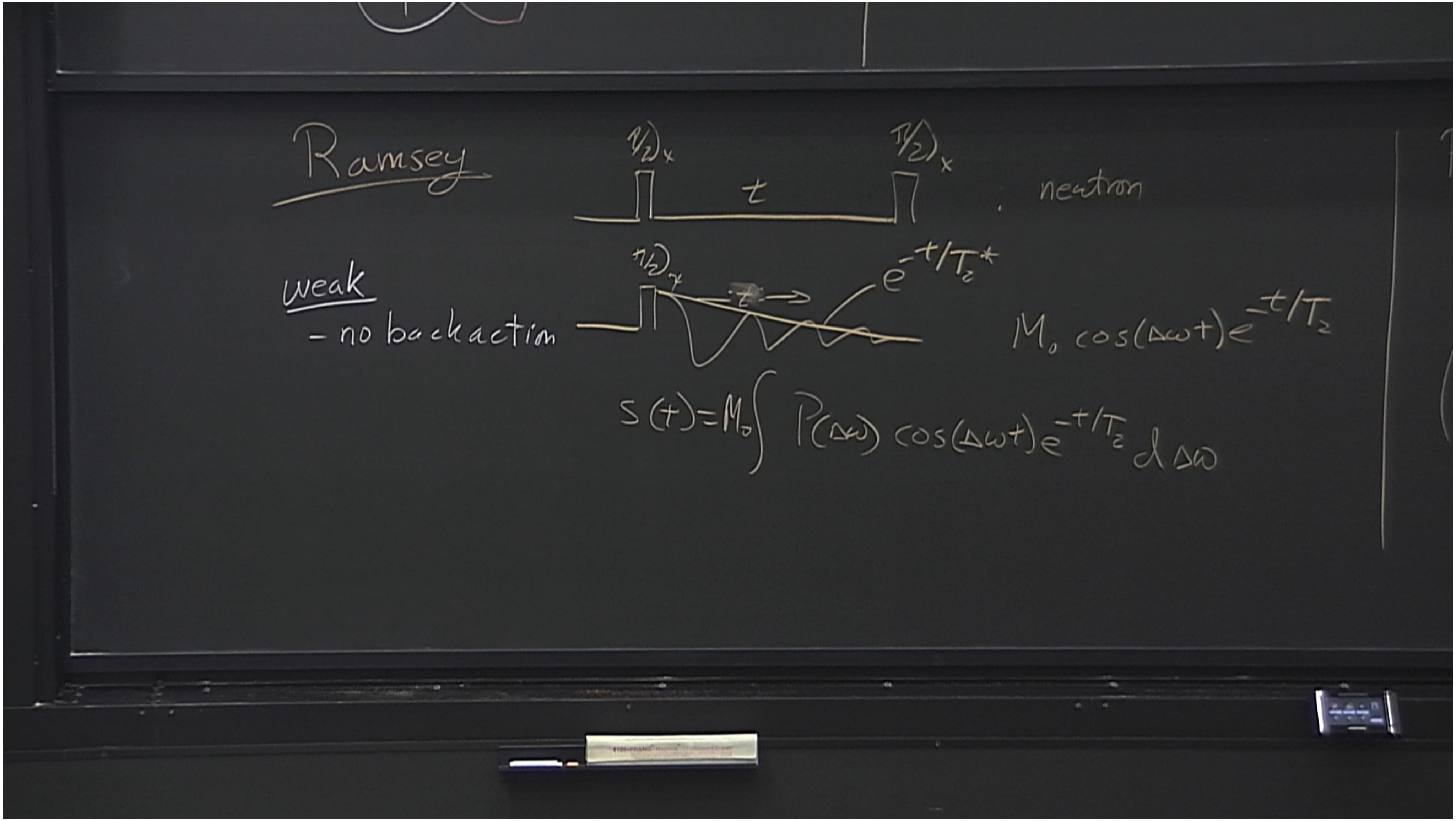


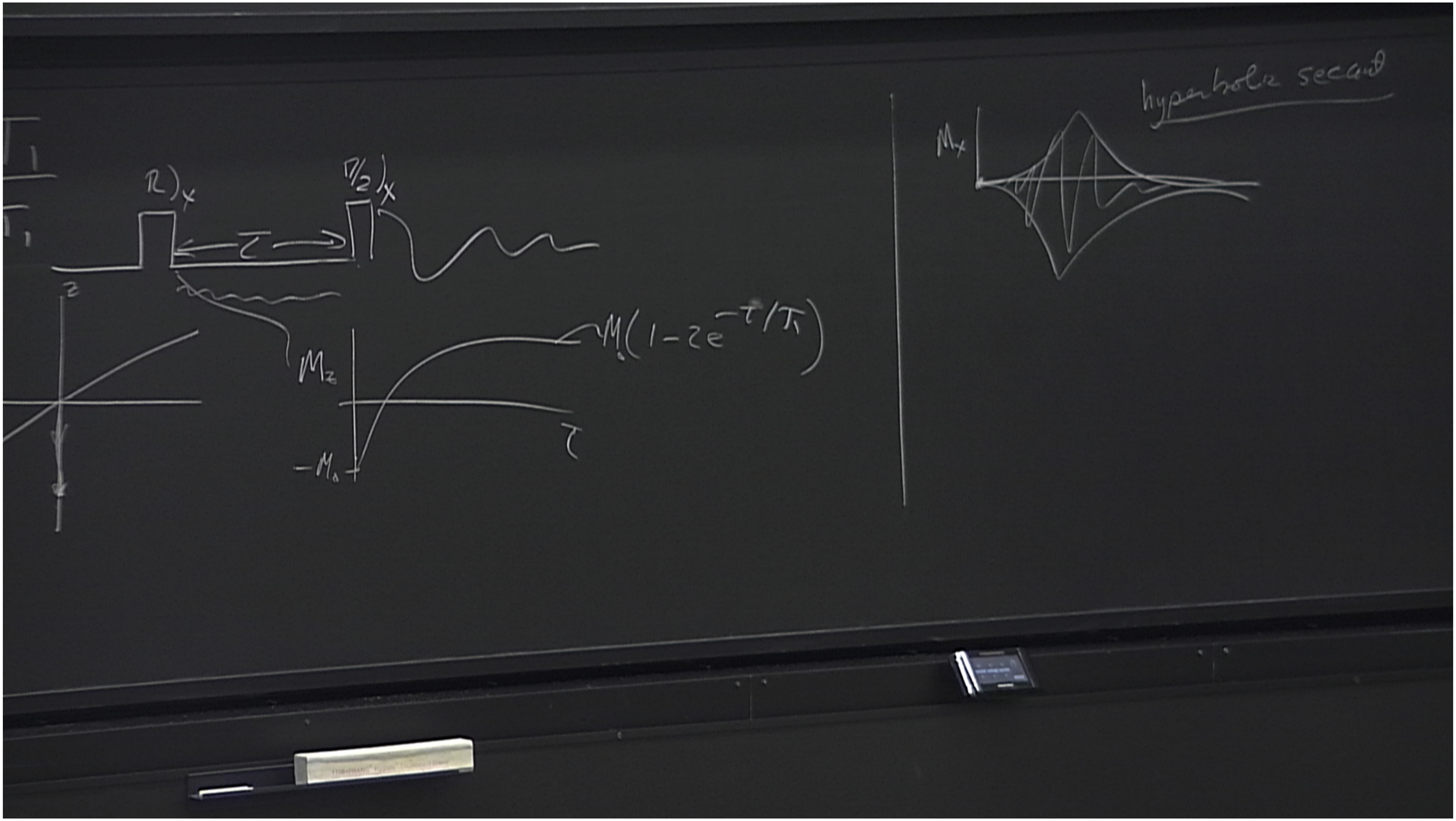

Ramsey
$\pi/2)_x$
$\pi/2)_x$
t
: neutron
$\pi/2)_x$
$t \rightarrow$
e^{-t/T_2^*}
$M_0 \cos(\Delta\omega t) e^{-t/T_2}$
$S(t) = M_0 \int P(\Delta\omega) \cos(\Delta\omega t) e^{-t/T_2} \, d\Delta\omega$


Hahn echo
$\pi/2)_x$
T_2^*
τ
$\pi)_x$
T_2
τ
$\mathcal{H} = -\Delta\omega\,\sigma_z$
$\mathcal{H} = +\Delta\omega\,\sigma_z$
$U = \mathbb{1}$ if $\Delta\omega$ is constant
- fraction of noise


- fraction of noise that is time independant,


T1
IRCT1
π)x
π/2)x
τ
z
Mz
−M0
M(1 − 2e^(−τ/T1))
τ


Ramsey
$\pi/2)_x$
t
$\pi/2)_x$
: neutron
weak
- no backaction
$\pi/2)_x$
t
e^{-t/T_2^*}
$M_0 \cos(\Delta\omega t) e^{-t/T_2}$
$S(t) = M_0 \int P(\Delta\omega) \cos(\Delta\omega t) e^{-t/T_2} \, d\Delta\omega$

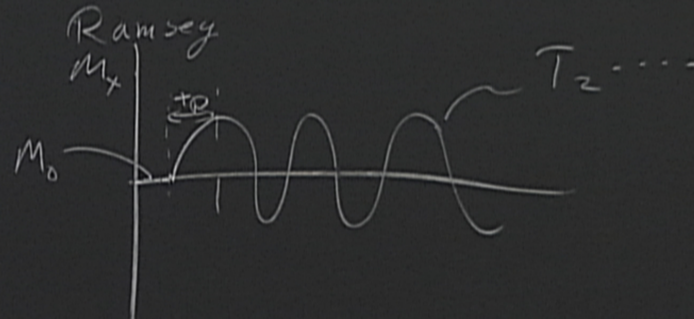

hyperbolic secant
$\pi)_x$
$\pi/2)_x$
τ
M_z
$-M_0$
$M_0(1-2e^{-\tau/T_1})$
M_x

σ_x ; $\Omega = \sigma_x$; $\eta_x = \frac{d}{dt}\int \frac{\vec{M}\cdot\vec{B}_1}{|B_1|}\, d\Omega$

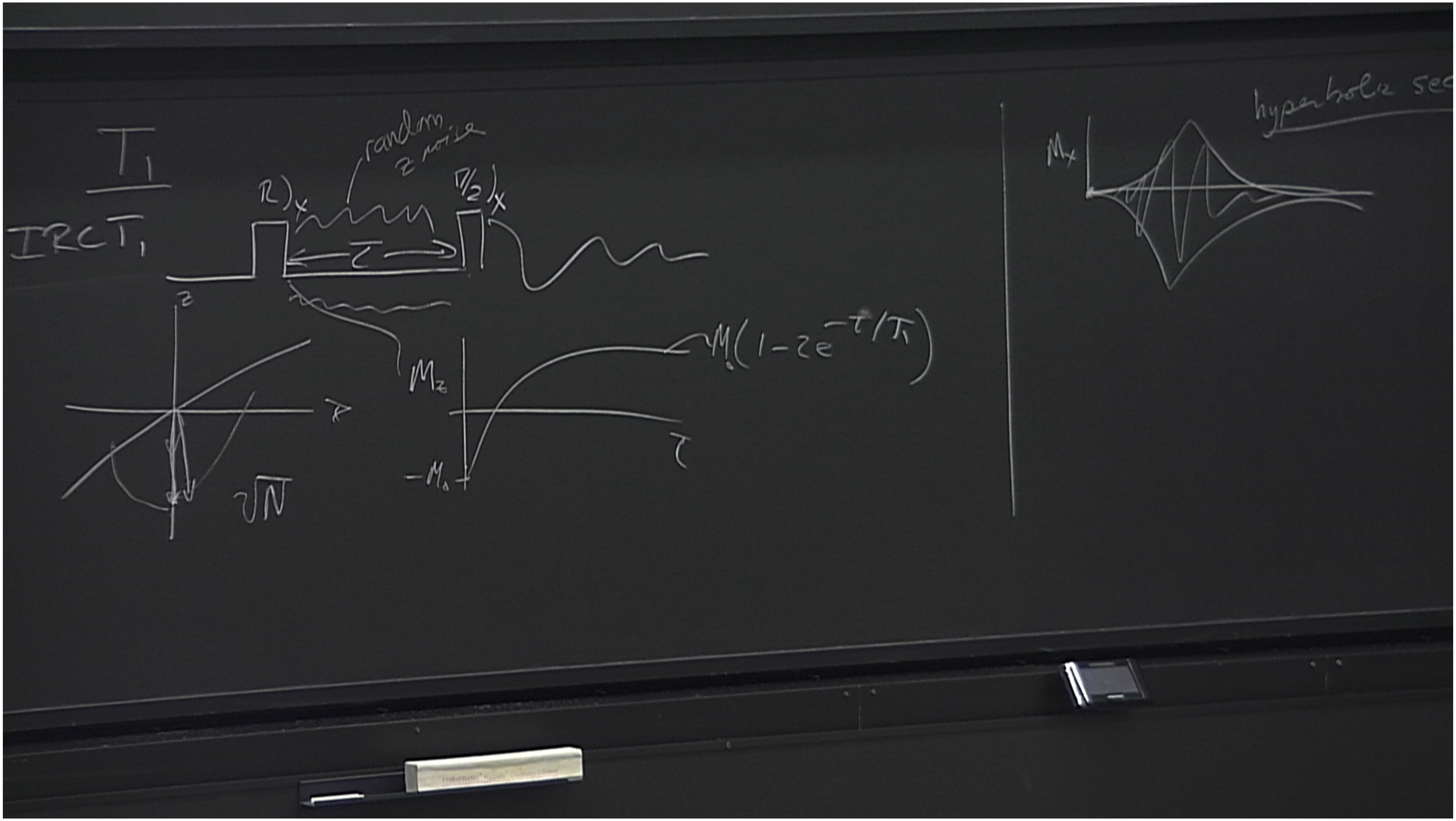
$\omega_1 = \gamma B_1$

$B_0\hat{z}$, $\omega_0 = \gamma B_0$

$$\mathcal{H}_{rot} = \frac{\Delta\omega}{2}\sigma_z + \frac{\omega_1}{2}\sigma_x$$



Back action signal induces a current that creates a field that rotates the spins



T1
IRCT1
random
z noise
π/2)x
Mz
−M0
Mx
hyperbolic sec