Magnetic Field Measurement in a Kicker Magnet

Andrea Merlo
Supervisor: Luciano Elementi

Fermilab Research Center
Technical Division - Magnet System Department

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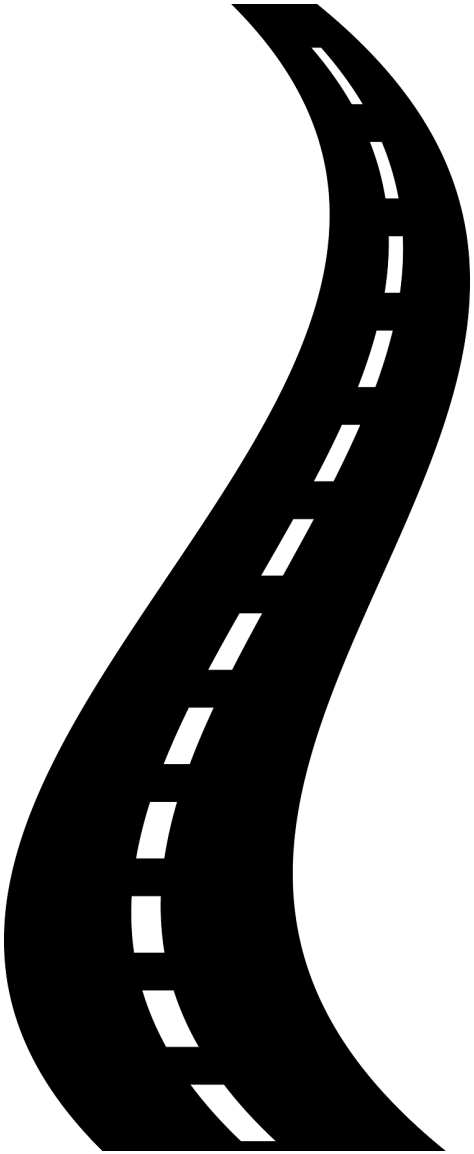
Overview



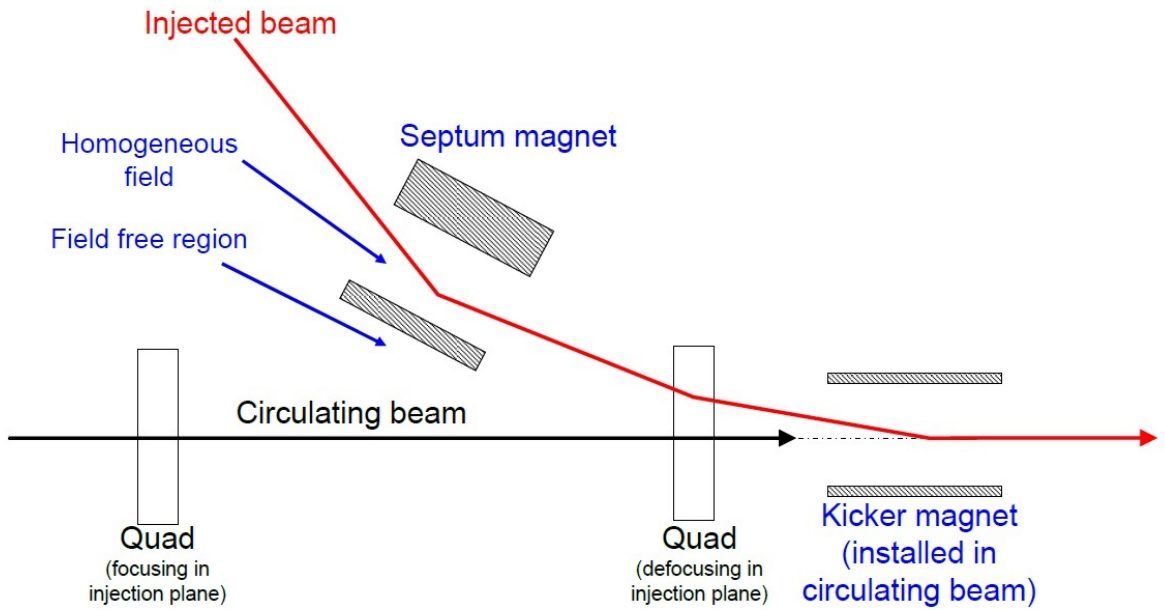
- Goal
- Overview
- Kicker Magnet
- Preliminary Analysis
- Magnetic Field
- Results
- Conclusions

Goal of the Project

Measurement of the Magnetic Field inside a Kicker Magnet

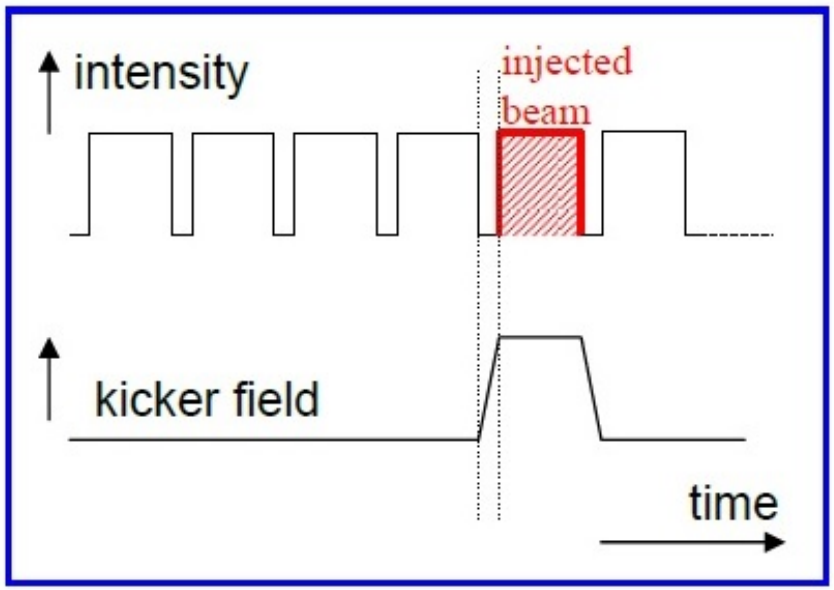
- ⇝ Kicker Magnet
- ⇝ 50 Ohm Transmission Line Probe
- ⇝ Integrated Magnetic Field
- ⇝ Local Modelization of the Field

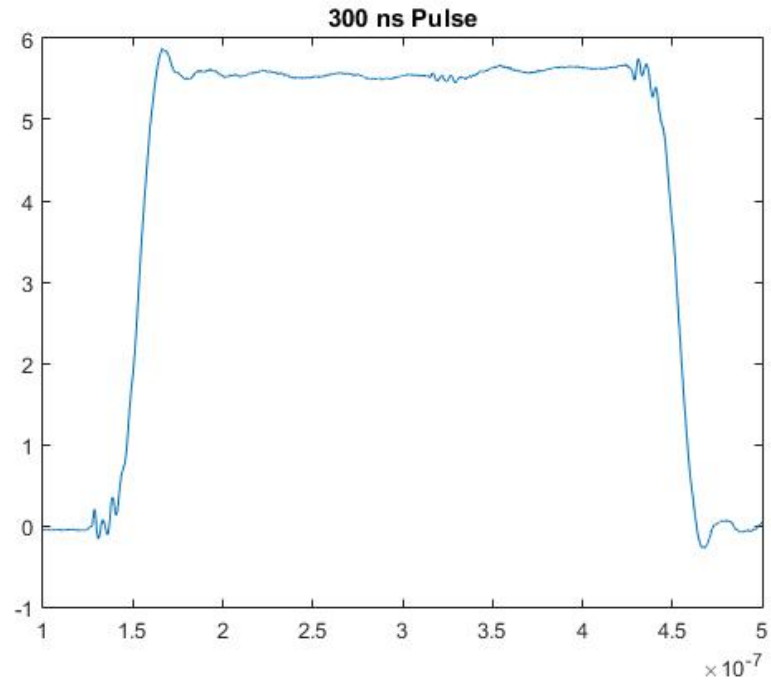
Kicker Magnet



- Pulsed Dipole Magnet with very fast rise and fall time (50 $\sim$ 100 ns)
- Role of a Kicker System:
  - Beam Injection
  - Beam Extraction
  - Beam Clearing

Kicker Magnet



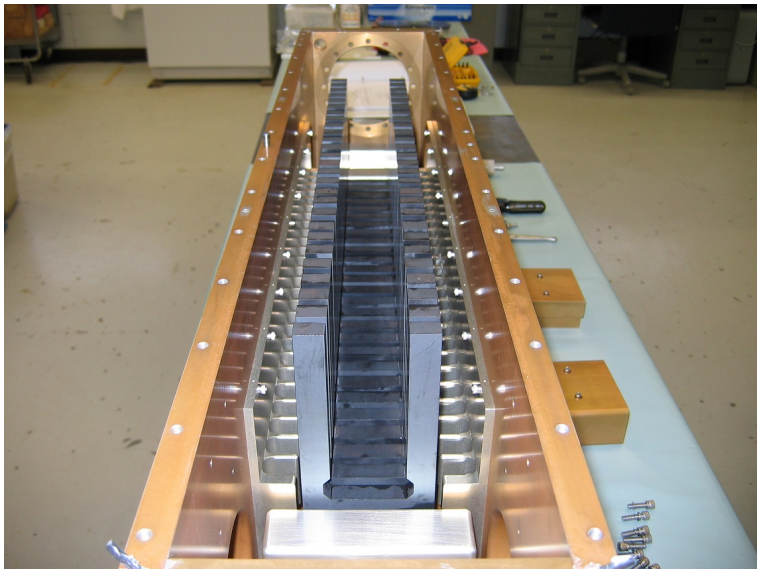


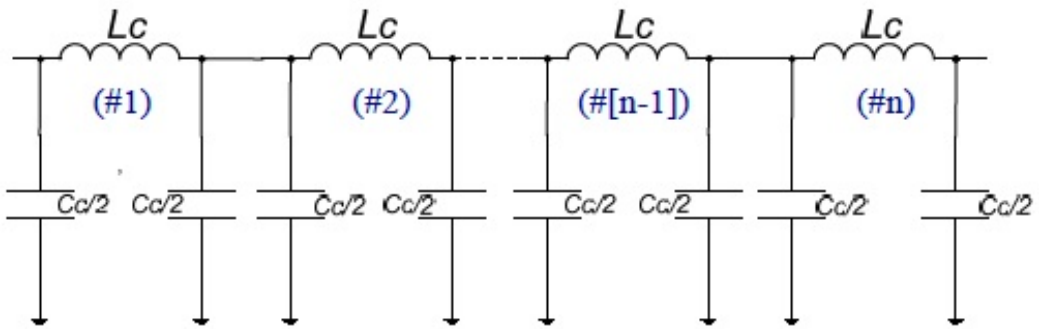
Requirements

- High Time Resolution
- Flatness of the Pulse
- Low Ripple
- Locally identical Cell by Cell

Kicker Magnet

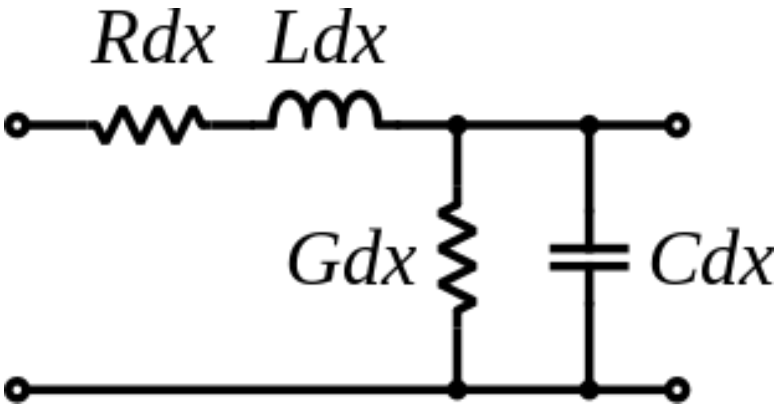
Transmission Line Kicker Magnet





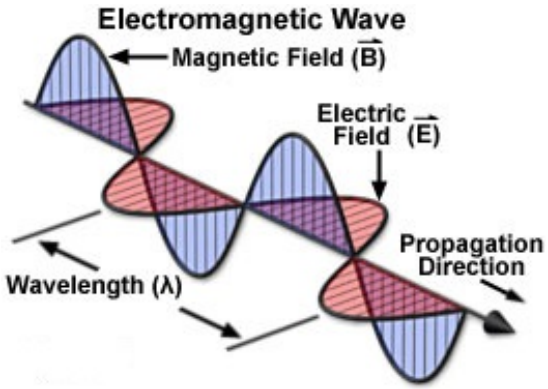
- Many cells to behave as a coaxial cable
- Ferrite C-cores and High Voltage Capacitance Plates sandwiched togheter

Transmission Line



$$\frac{\partial V(x)}{\partial x} = -(R + j\omega L)I(x)$$
$$\frac{\partial I(x)}{\partial x} = -(G + j\omega C)V(x)$$

$\downarrow$

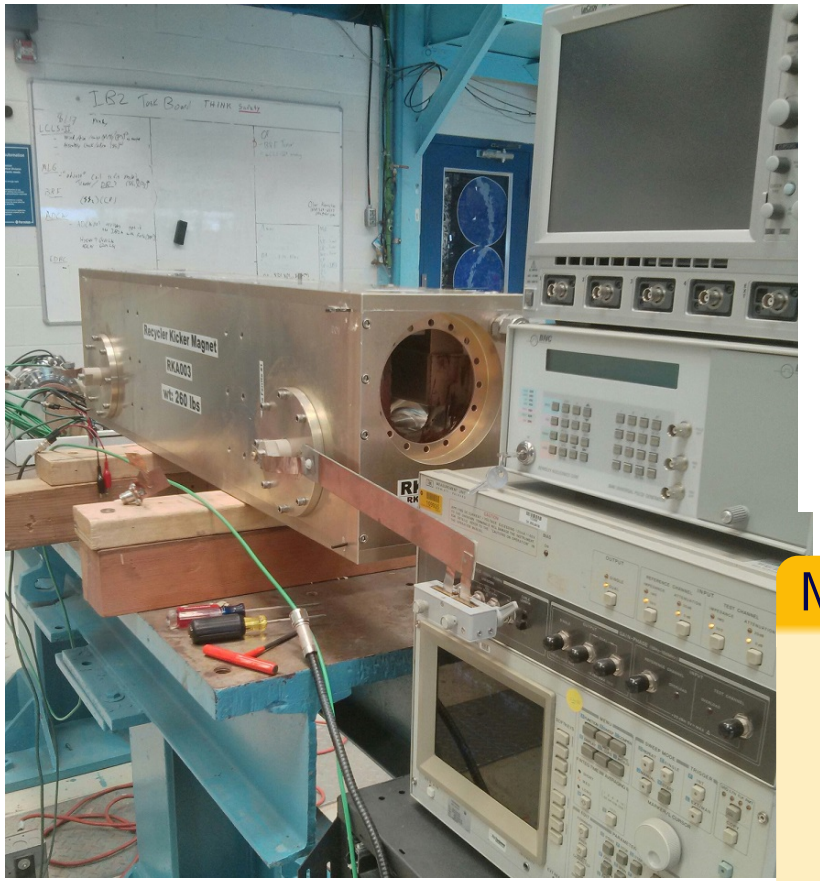


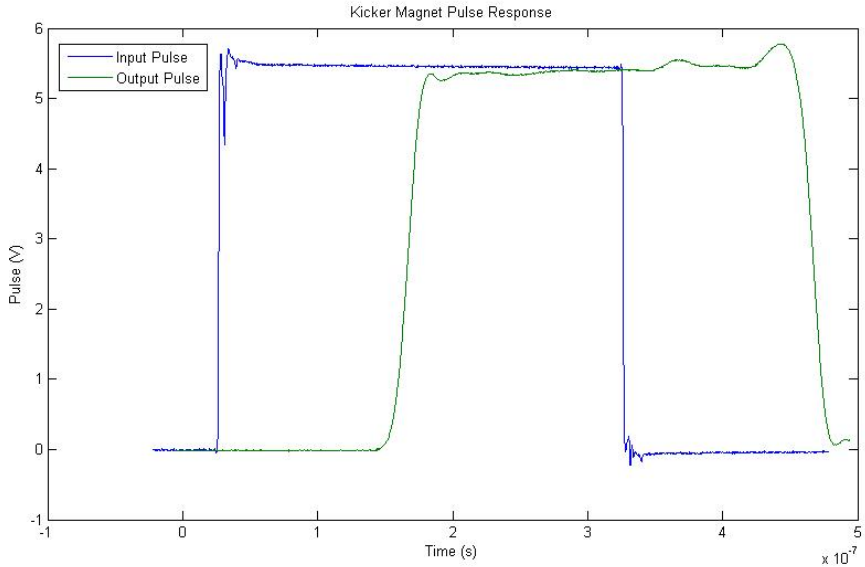
$$\frac{V(x)}{I(x)} = Z_0 = \sqrt{\frac{R + jL}{G + jC}}$$

$$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}, \tau = n \cdot \sqrt{L_c \cdot C_c}$$

Recycler 50 Ohm Kicker Magnet

Kicker Magnet

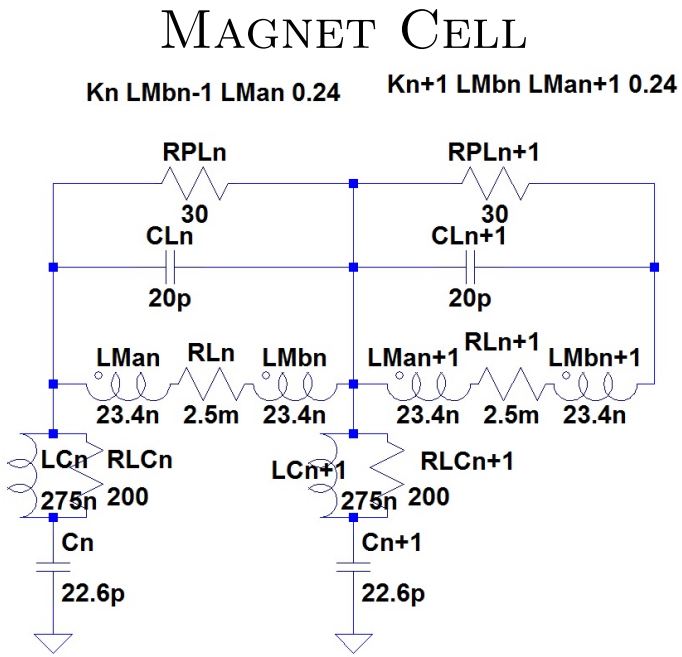


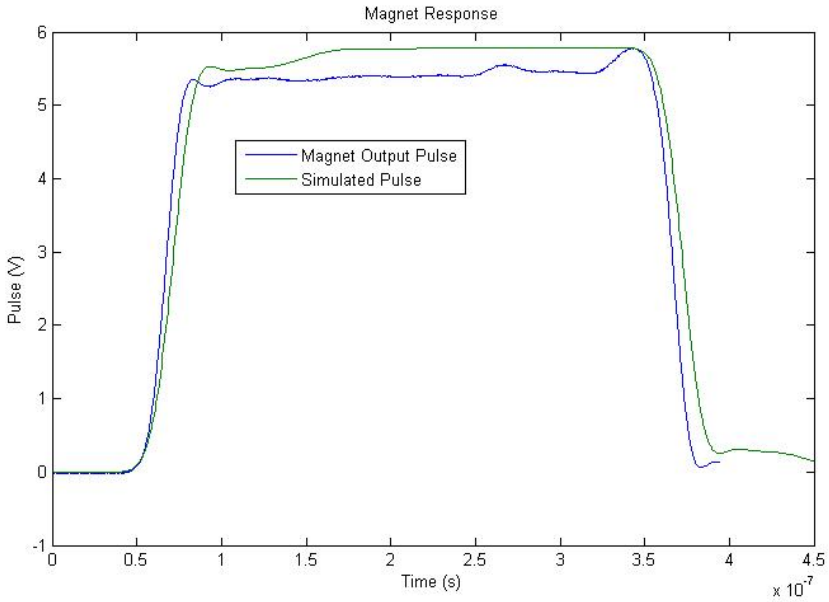


Model Parameters

- $C = 703.7 \pm 0.5\ pF$
- $L = 1.73 \pm 0.08\ \mu H$
- $Z_0 = 51.6 \pm 0.2\ \Omega$
- $T_D = 15.7\ ns$

Kicker Simulation





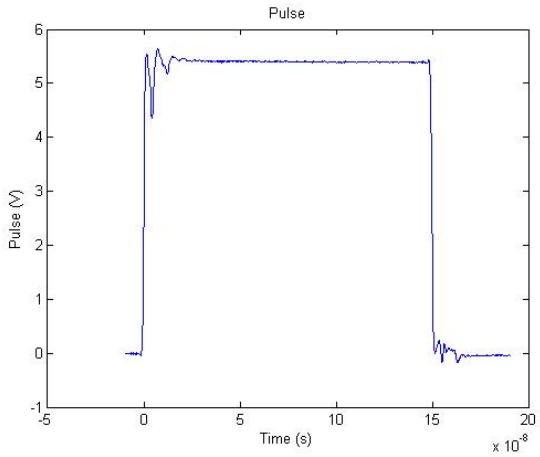
- $Simulated_{RiseTime} = 36.9\ ns$
- $Simulated_{Width} = 240.652\ ns$

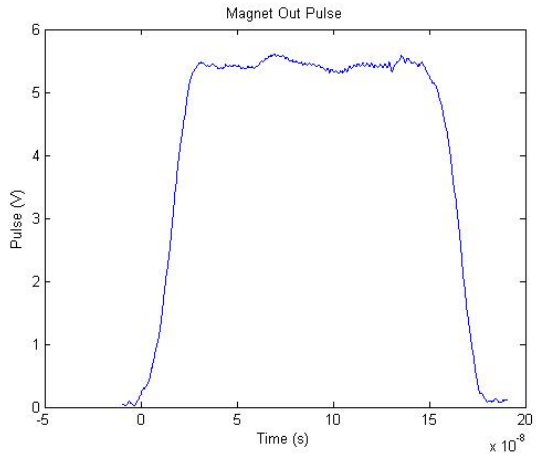
- $Pulse_{RiseTime} = 28.8\ ns$
- $Pulse_{Width} = 256.6\ ns$

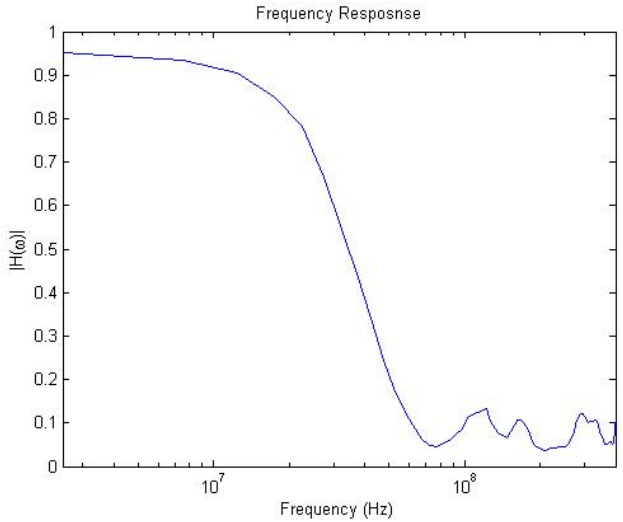
End Effects has to be modeled in a more detailed way

Pulse Analysis

150 ns Pulse into the Magnet

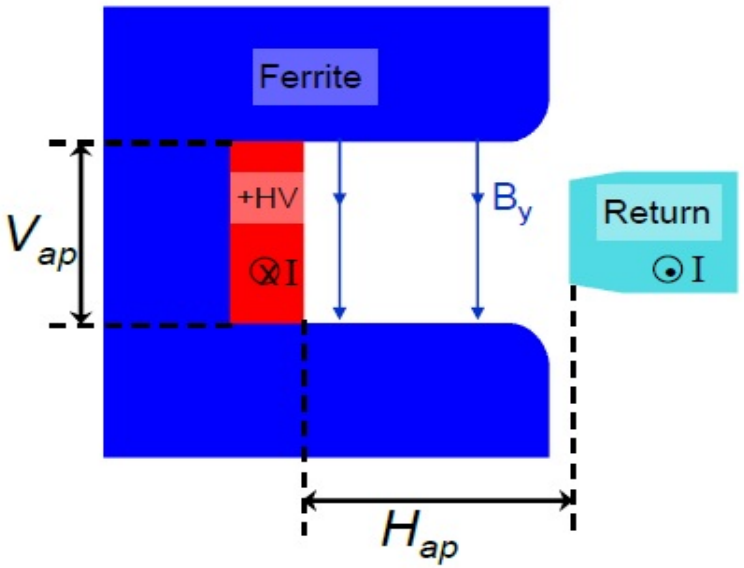






Behaves as a LC Low-Pass Filter

Magnetic Field



$$|\mathbf{B(x,t)}| = \mu_0 \frac{N \cdot I(t)}{V_{ap}}, N \simeq 1$$

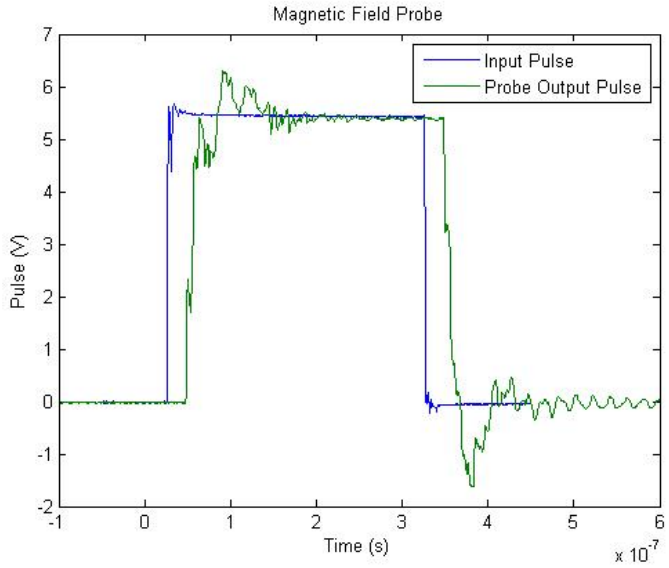
Angular Deflection

$$\Theta = \frac{0.3}{p} \int_0^l B_y dx = \frac{0.3}{p} \cdot l_{eff} \cdot |B_y|$$

p is the **beam momentum**, l_{eff} is the **effectve length**

Coil Probe

Probe

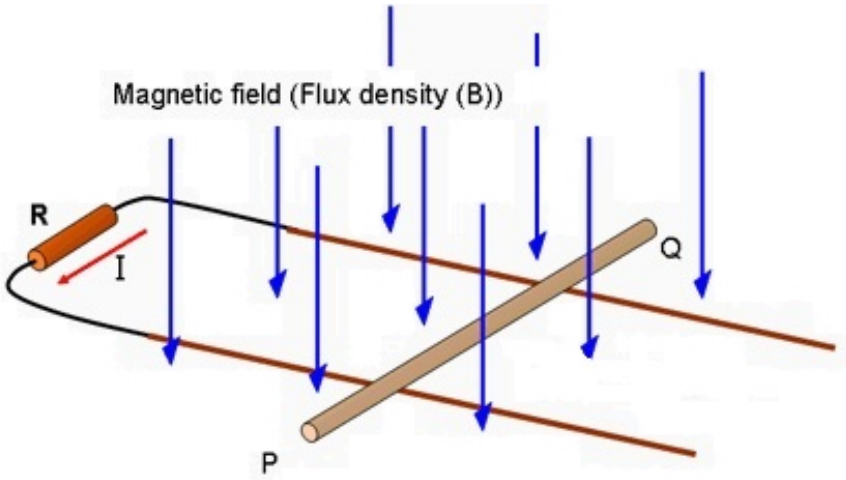


Matched Coaxial Cable Probe

- Not Perfectly Matched Terminance
- $Z_0 = 52.5 \pm 0.2\ \Omega$
- $T_D = 6.6\ ns$
- Area $= 0.126795\ m^2$

Coil Probe

Magnetic Induction



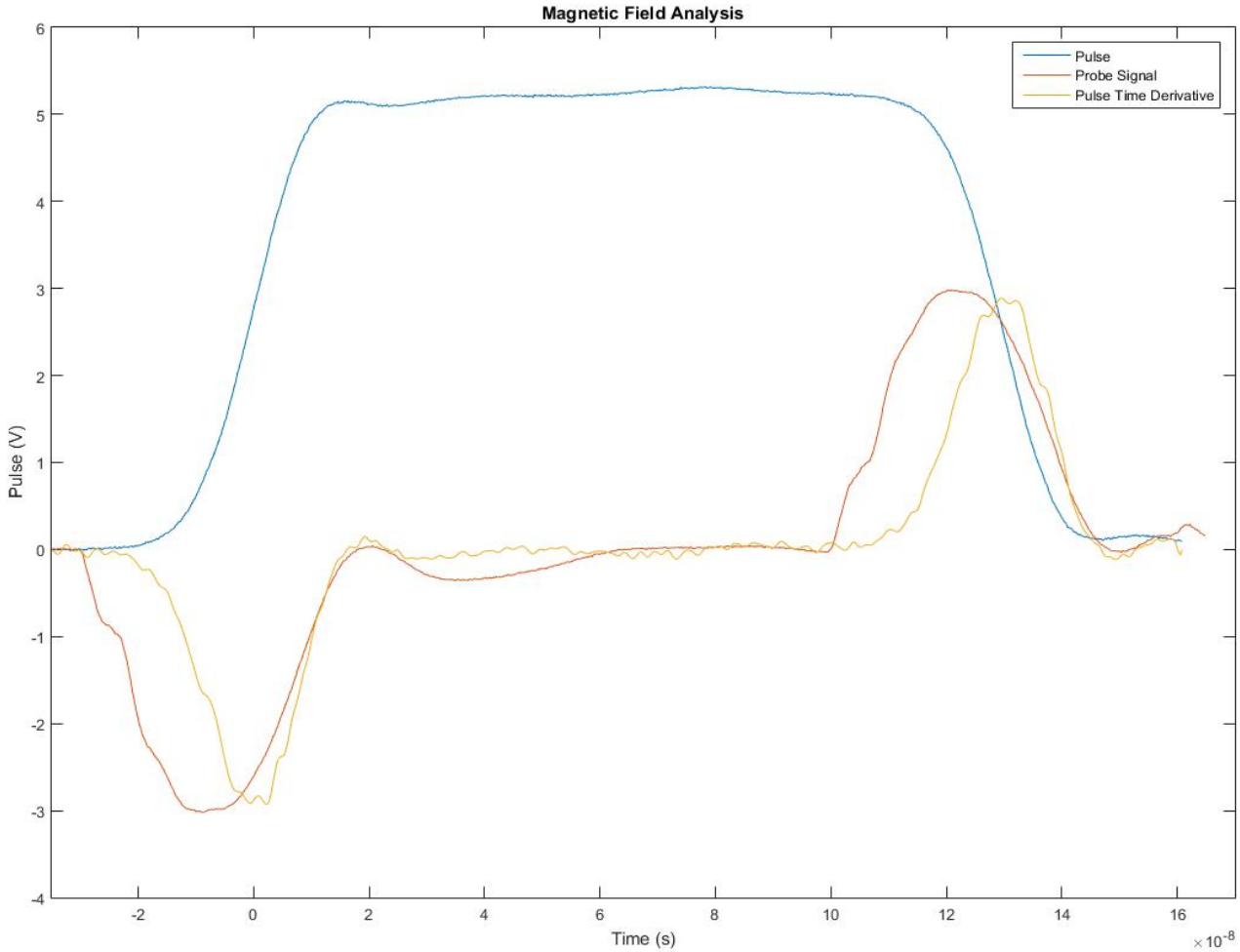
$$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{\partial}{\partial t} \int_S \mathbf{B} \cdot d\mathbf{S}$$

$$\downarrow$$

$$\Delta V = -\frac{\partial \Phi}{\partial t} \propto -\frac{\partial V}{\partial t}$$

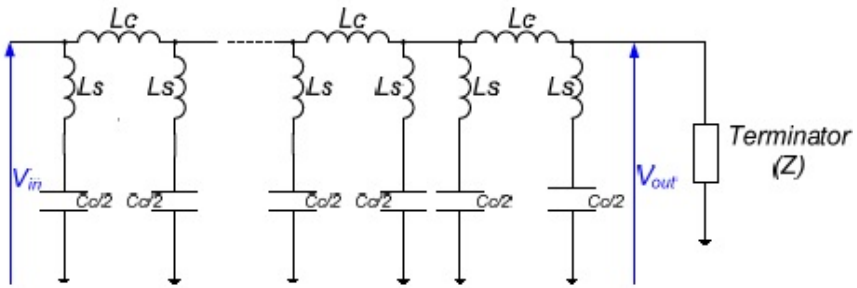
Propagating Pulse through the magnet $\rightarrow$ **Forming Pulse** through the probe

Magnetic Field Analysis



Probe's Signal is mismatched from the **Time Derivative of the Pulse**

Magnetic Flux



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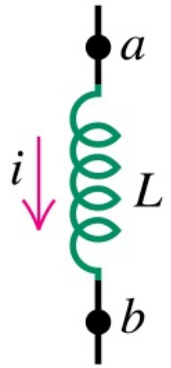


$$V_{ab} = \frac{di}{dt} L$$

$$V_{in} - V_{out} = L \cdot \frac{\partial i}{\partial t}, \Phi = L \cdot i$$

$$\int (V_{in} - V_{out}) dt = \Phi$$

Lossless Transmission Line

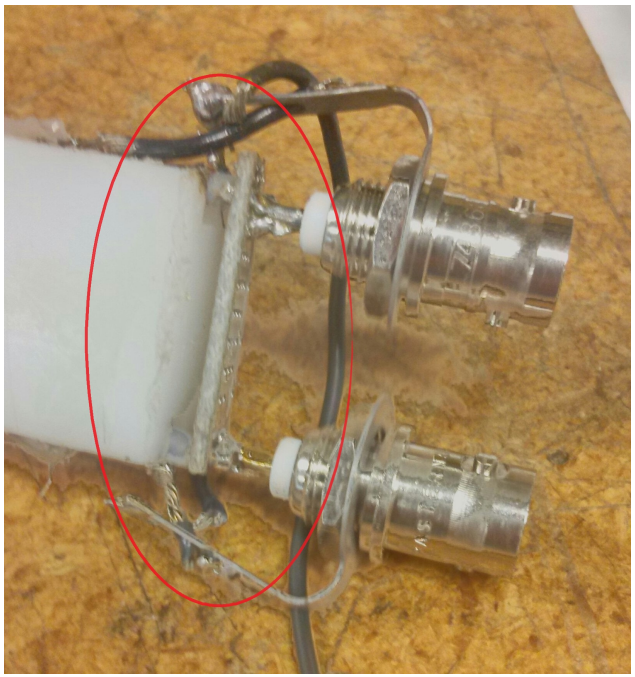
$$V_{in} - V_{out} = -\xi(t) \cdot \frac{A_{magnet}}{A_{probe}}$$

New Probe

New Custom Probe

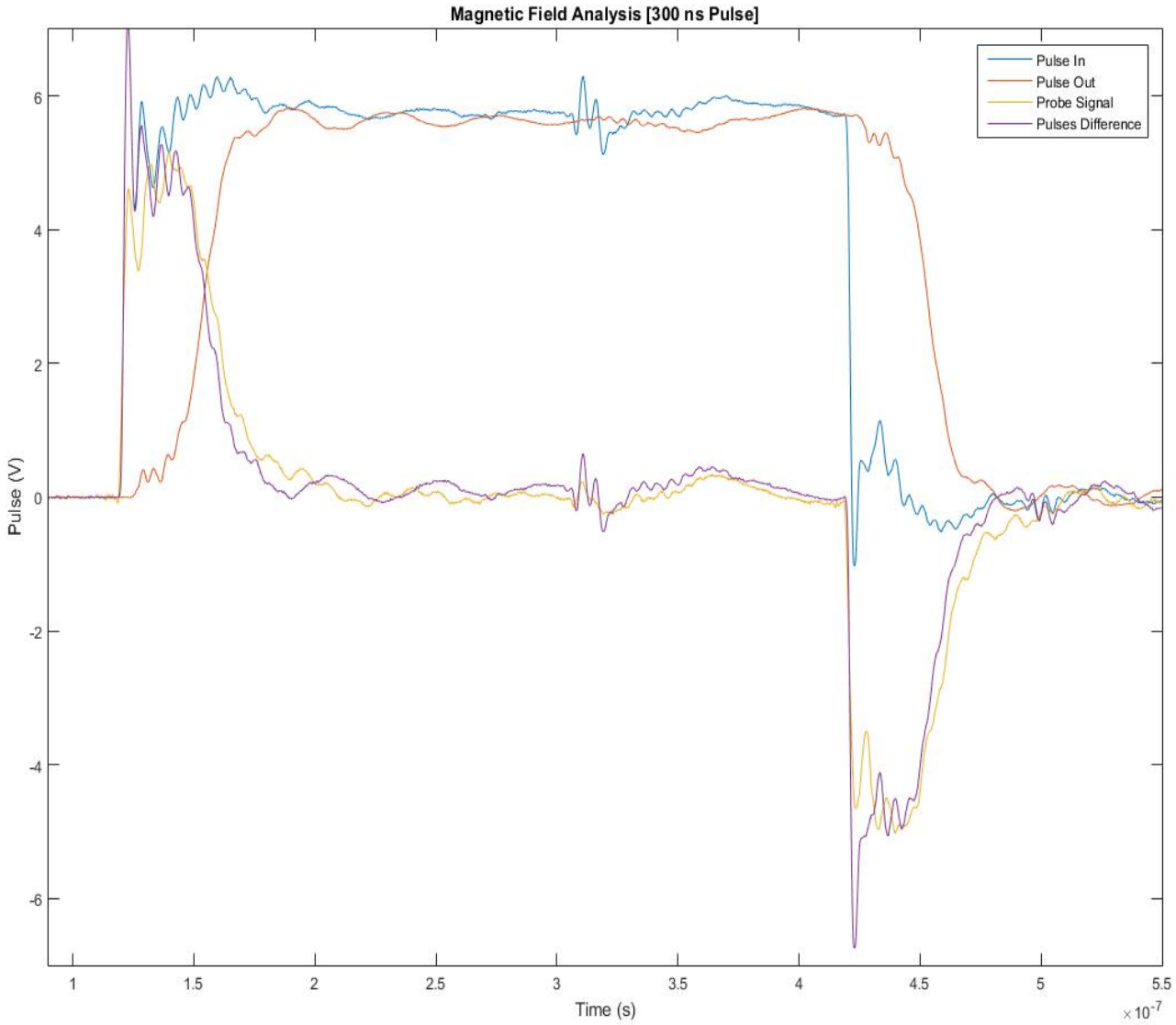
Model Parameters

- $L_{probe} = 106.934$ cm
- $Z_0 = 46.7\ \Omega$
- $T_D = 26.6\ ns$



Protoboard End

Magnetic Field Analysis



Characteristics

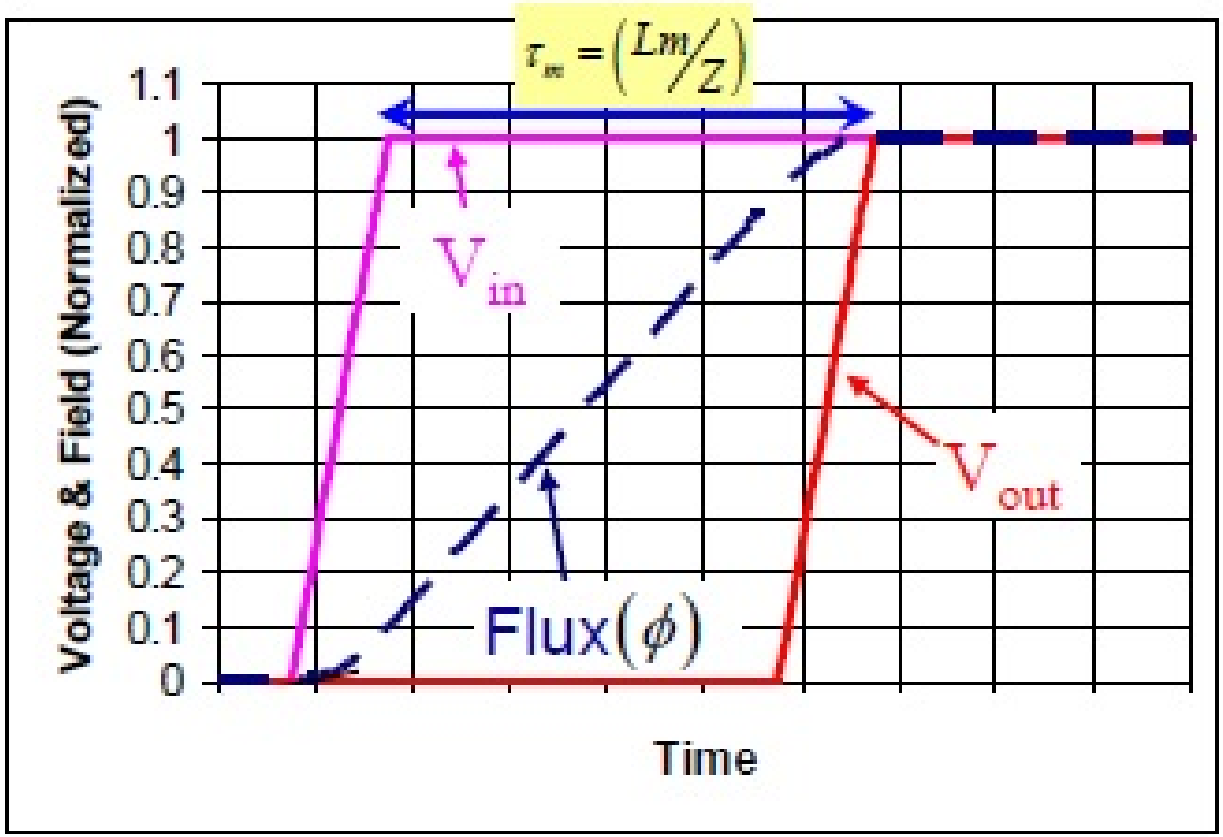
- ⇝ Low-Pass Filter due to the Probe
- ⇝ Pulse Intensity Mismatch

Intensity Adjustment

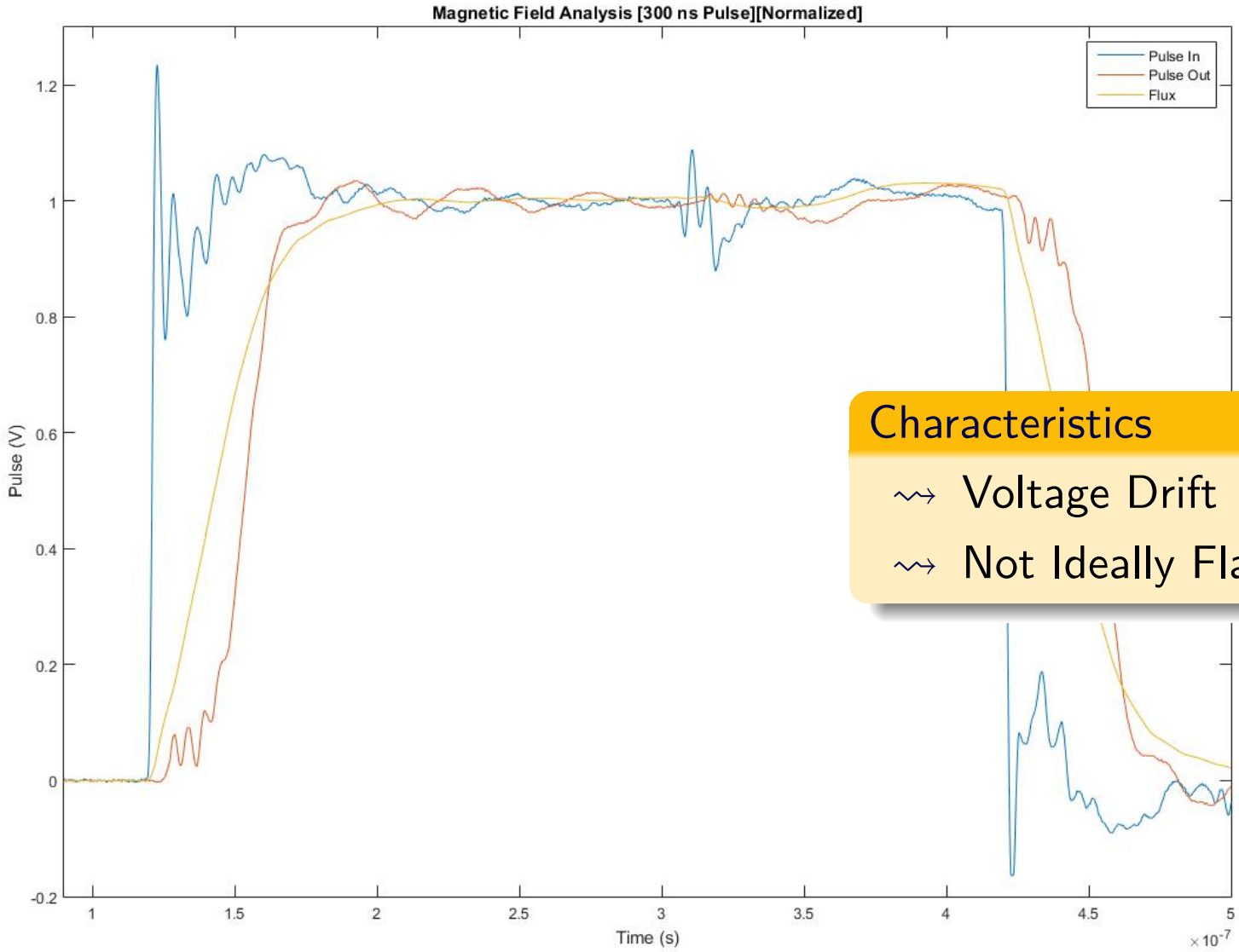
1.14 as Normalization Coefficent

Flux

$$\Phi = -\frac{A_{magnet}}{A_{probe}} \int (V_{in} - V_{out}) dt$$



Flux



Characteristics

- ⇝ Voltage Drift
- ⇝ Not Ideally Flat

Further Developments

- Better understanding of the key parameters for the kicker SPICE Simulation
- Model and simulation of the forming pulse throught the probe
- High Voltage Field Measurements (10 KV)
- Two Cell Long Probe in order to model Field Cell by Cell

Acknowledgment

- Study of the Transmission Line Theory
- Impedance Measuremetns
- Magnetic Field Measurements
- Probe's Design and Built
- Data Analysis

Conclusions

Two months of full learnings:

- ⇝ RF Applications
- ⇝ Accelerrator Magnet
- ⇝ Pspice Simulation
- ⇝ Hands-on

Thanks to

Luciano Elementi

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