Internal Model Control for a Self-Tuning Delay-Locked Loop in UWB Communication Systems

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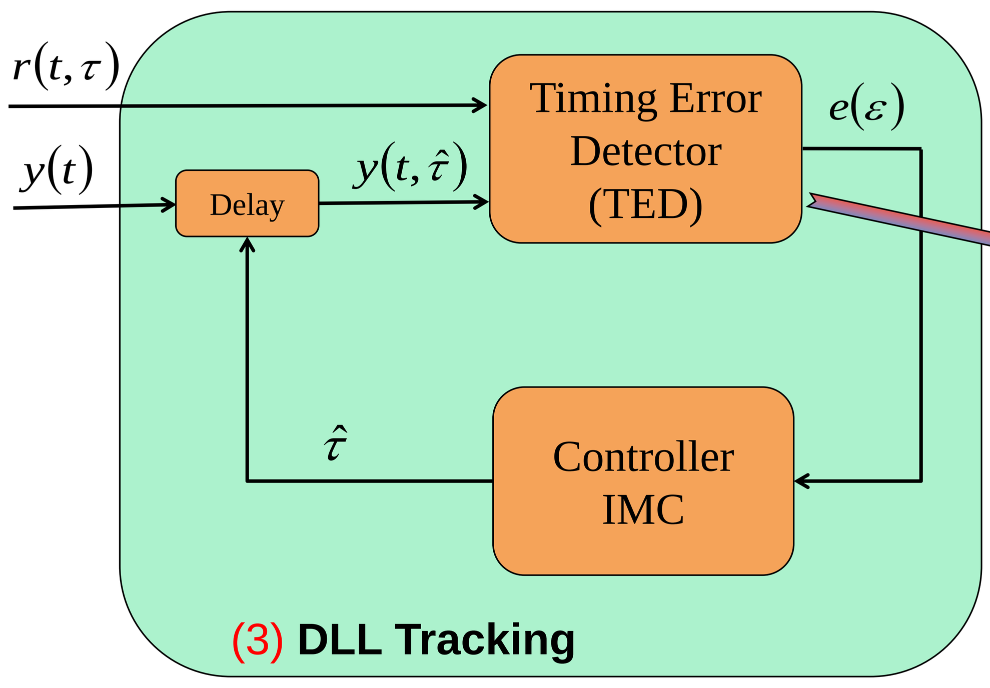
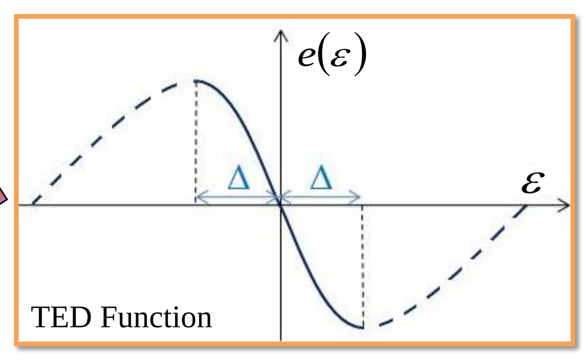
Context & Methodology

- Timing synchronization represents a major challenge in carrying out highly efficient ultra-wideband (UWB) communications
- Therefore, the aim of my research is to show how we achieved better timing synchronization with low-complexity and high performance
- My doctoral thesis studies the following three points :
  1. Signal Detection
  2. Timing Acquisition
  3. Tracking and Control

Tracking Structure



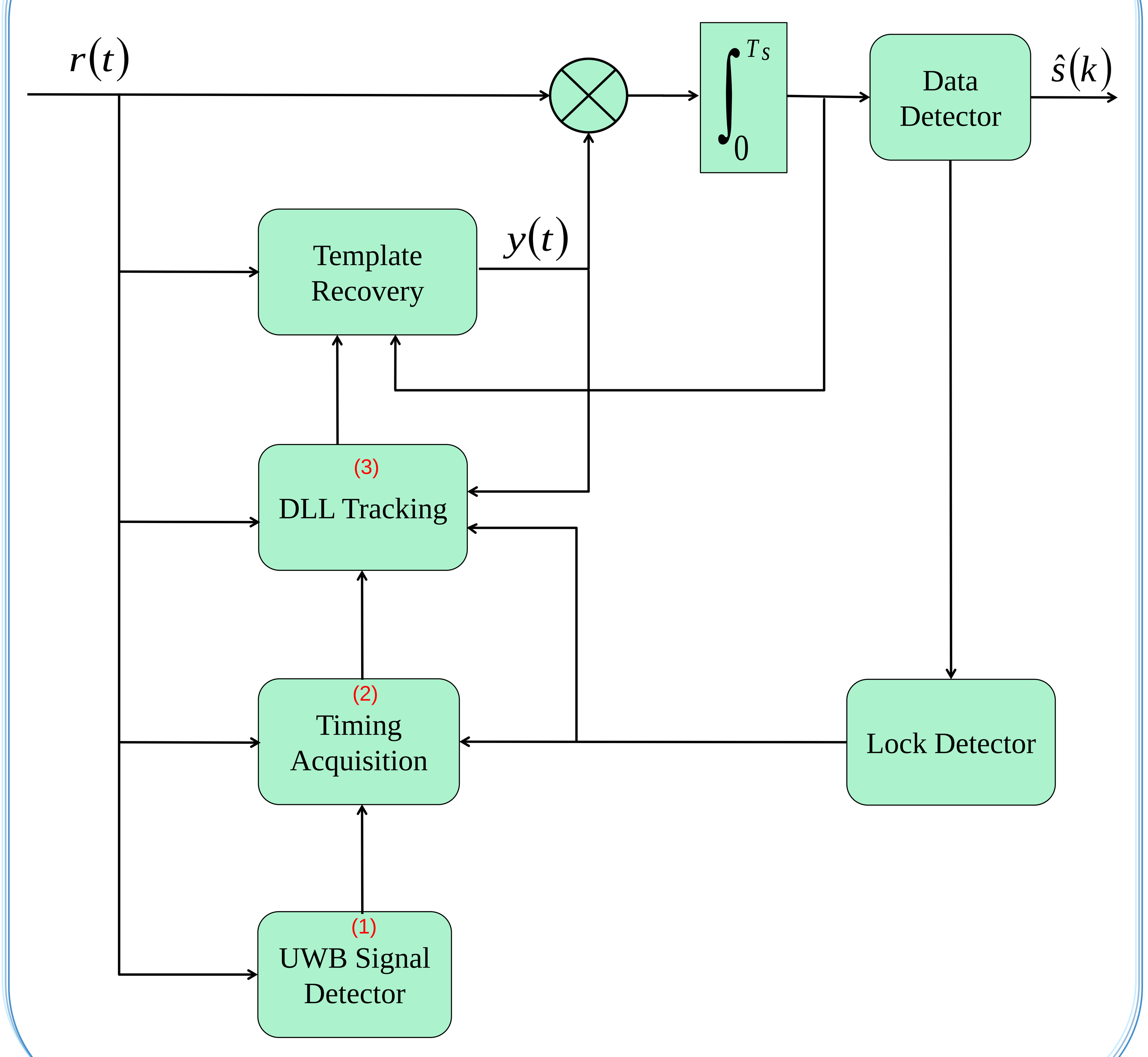
- Time Offset: $\varepsilon = \tau - \hat{\tau}$



$$e(\varepsilon) = \mathbb{S}(\varepsilon) + N_{eq}$$

- $\mathbb{S}(\varepsilon)$: S-curve function
- N_{eq} : Equivalent tracking noise

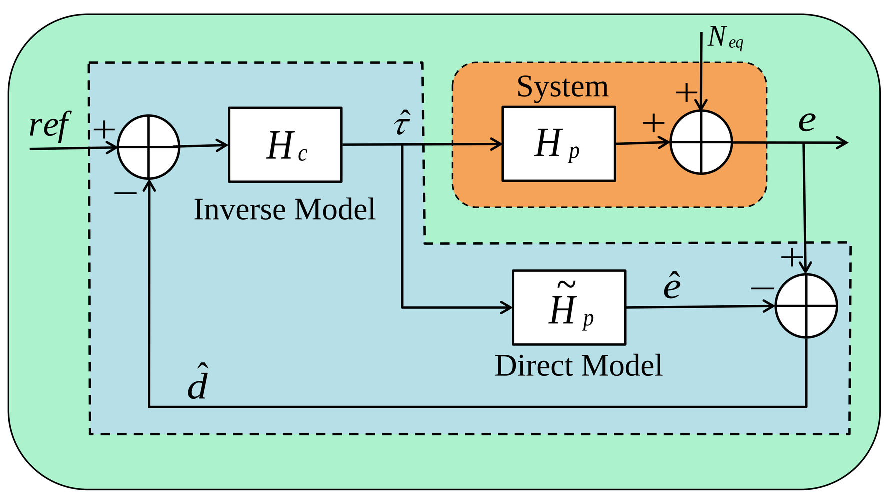
Synchronization System



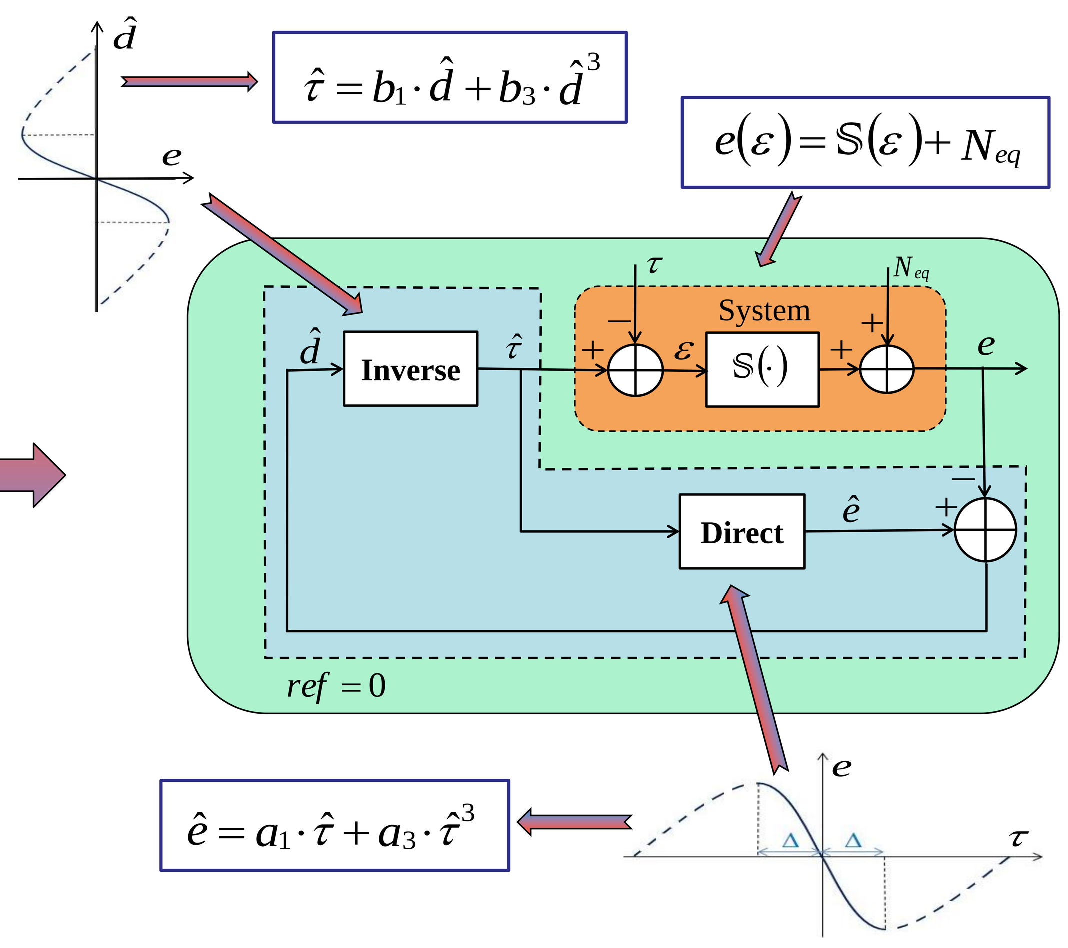
Internal Model Control Approach

"It is a novel control strategy in the communication domain"

- Objective of IMC :
  1. Make the output (e) track set-point (ref)
  2. Reject the effect of disturbances (N_{eq})



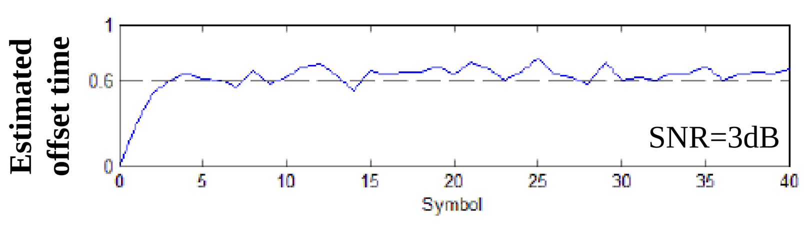
- Hypotheses:
  (1) $\tilde{H}_p(z) = H_p(z)$
  (2) $H_c(z) = \tilde{H}_p(z)^{-1}$



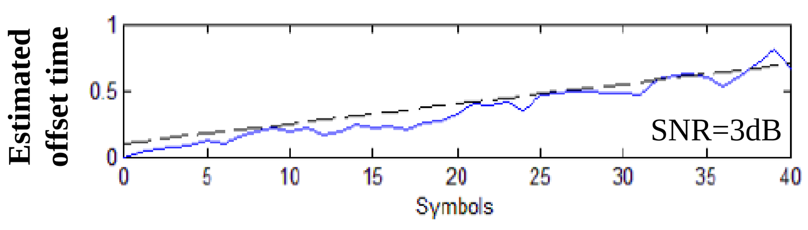
Direct & Inverse model design steps

1. Generate input/output data set $[\hat{\tau}_1, \hat{\tau}_2, \hat{\tau}_3, \cdots, \hat{\tau}_N]$ $[e_1, e_2, e_3, \cdots, e_N]$
2. Select the model structure (order) for S-curve system and its inverse
3. Compute the model coefficients $\{a_1, a_3, b_1, b_3\}$ using Least-Squares solution

Simulation Results



Evolution of the Modified DLL Tracking with τ = 0.6



Evolution of the Modified DLL Tracking with Doppler Effect τ = 0.1 + 0.01 t

The system parameters & The tracking performance

Direct model	$\hat{e} = 3.5 \cdot \hat{\tau} - 1.1 \cdot \hat{\tau}^3$	$R^2 \approx 1$
Inverse model	$\hat{\tau} = 0.2 \cdot \hat{d} + 0.02 \cdot \hat{d}^3$	$R^2 = 0.998$
Estimation error variance	0.0027 for τ = 0.6	
	0.096 for τ = 0.1 + 0.01 t	

R^2 : determination coefficient

Summary & Perspective

- Summary :
  - Presented my thesis methodology for improving the synchronization system
  - Designed the controller unit in the tracking level using Internal Model Control strategy
  - Showed Direct and Inverse model synthesis and the tracking performance for static and dynamic (Doppler Effect) transmission channel
- Perspective :
  - Modify the IMC structure for improving the tracking performance of UWB system, taking into account Doppler Effect

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