

# Application Example

# Echo Cancellation

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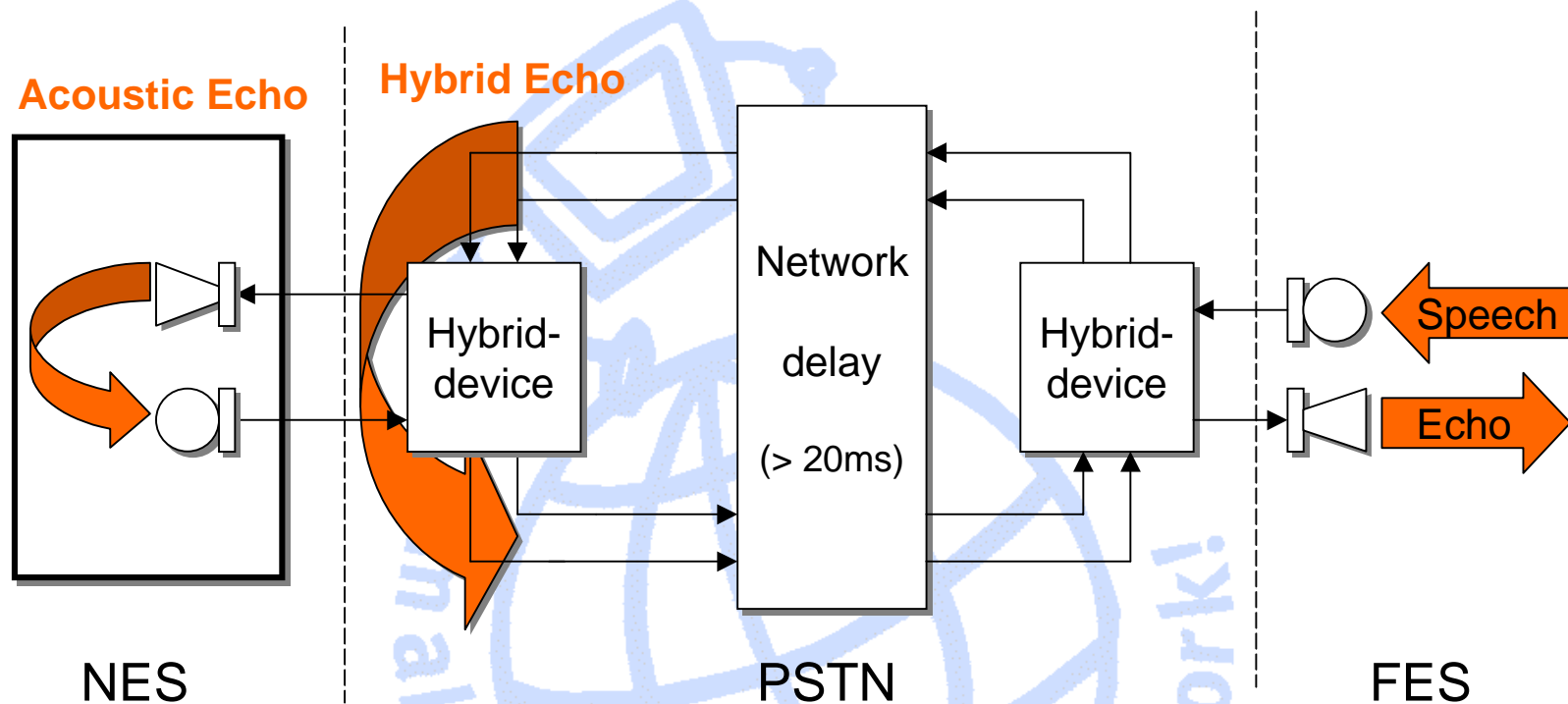
# Agenda

- **Types of Echo Cancellation**
- **Adaptive Filter Solution for Echo Cancellation**
- **Realisation and Simulation in Matlab / Simulink**
- **Target Code Generation and Integration**
- **Summary and Outlook**

# Introduction

- **What is an echo?**
  - **Return-coupling with more than 40ms**
- **Why reduce an echo?**
  - **Disturbance during speaking**
- **Where is the Echo Cancellation required?**
  - **Hands-free dialog system**
  - **Mobile network**
  - **Satellite connection**
  - **Music and Studio Area**

# Origin and Types of Echoes

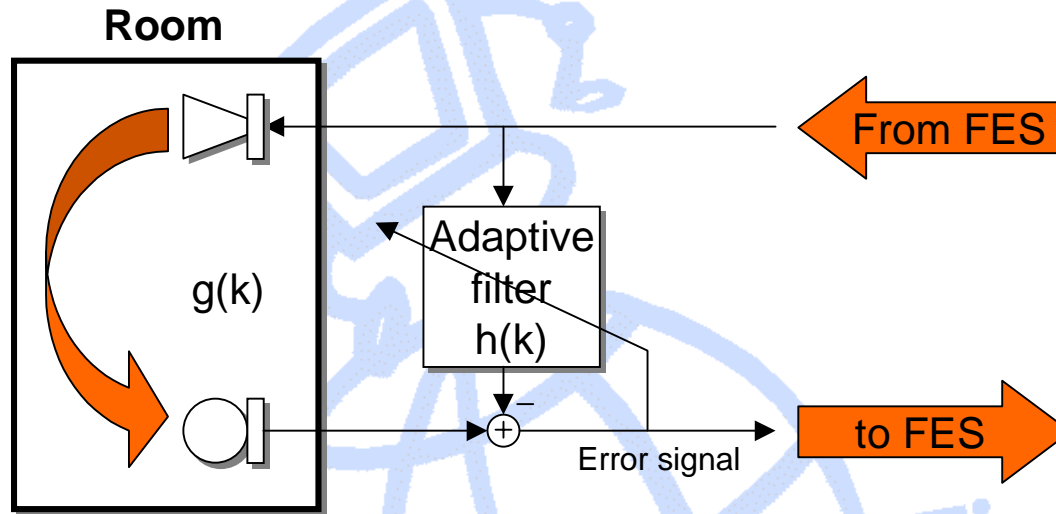


- **Hybrid Echo** is cancelled by the network-services.
- **Acoustic Echo** is to be cancelled easily by the NES.

# Types of Echo Cancellation

- **Speech Balance:**
  - Small development expense
  - Loss of speech quality
  - No full duplex talk
- **Frequency Separation:**
  - Small development expense
  - Low speech quality
- **Adaptive Filters:**
  - Small production costs
  - High flexibility
  - High complexity
  - High computational costs

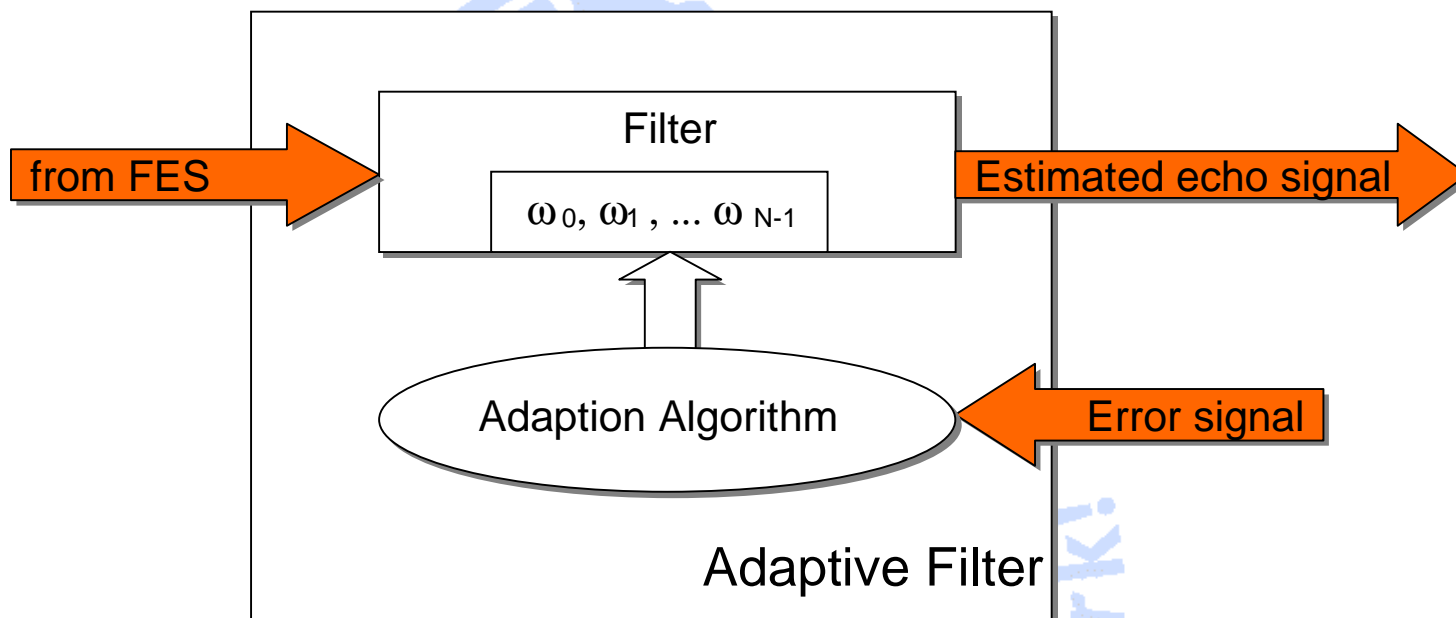
# Echo Cancellation using Adaptive Filters



- Operation Method:

- Calculate optimal  $h(k)$
- Minimize error signal
- If  $h(k) = g(k) \rightarrow$  signal to FES = 0

# Adaptive Filter Structure

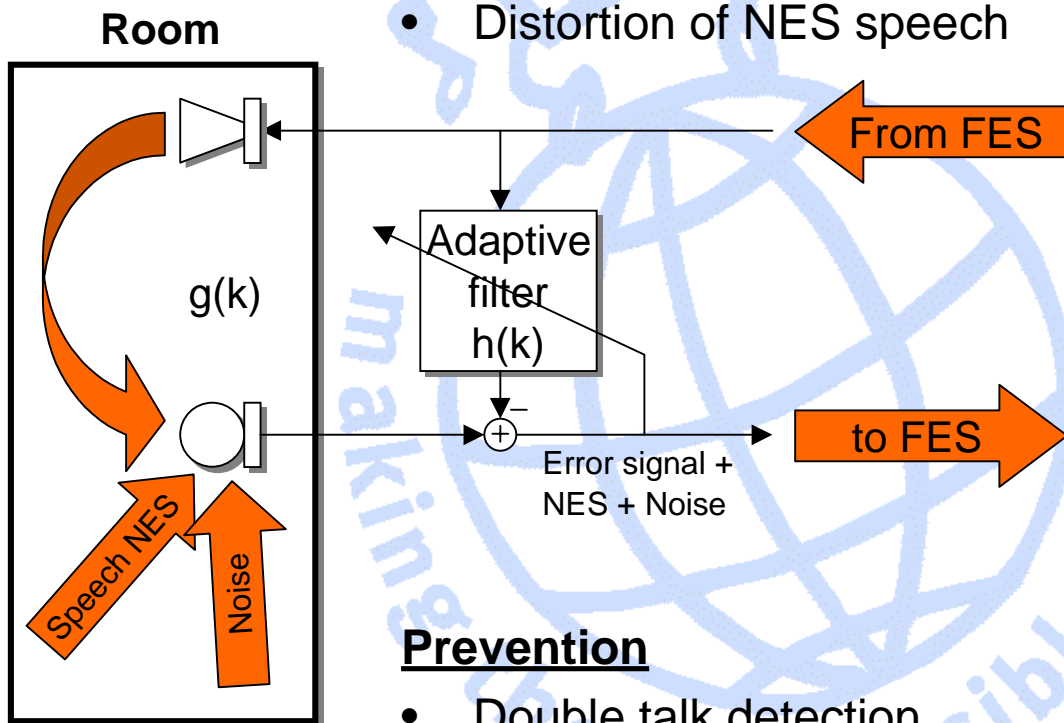


- Any digital filter type (FIR or IIR)
- Any adaption algorithm (LMS, nLMS, RLS, ...)

# Difficulties from Double Talk and Noise

## Problem

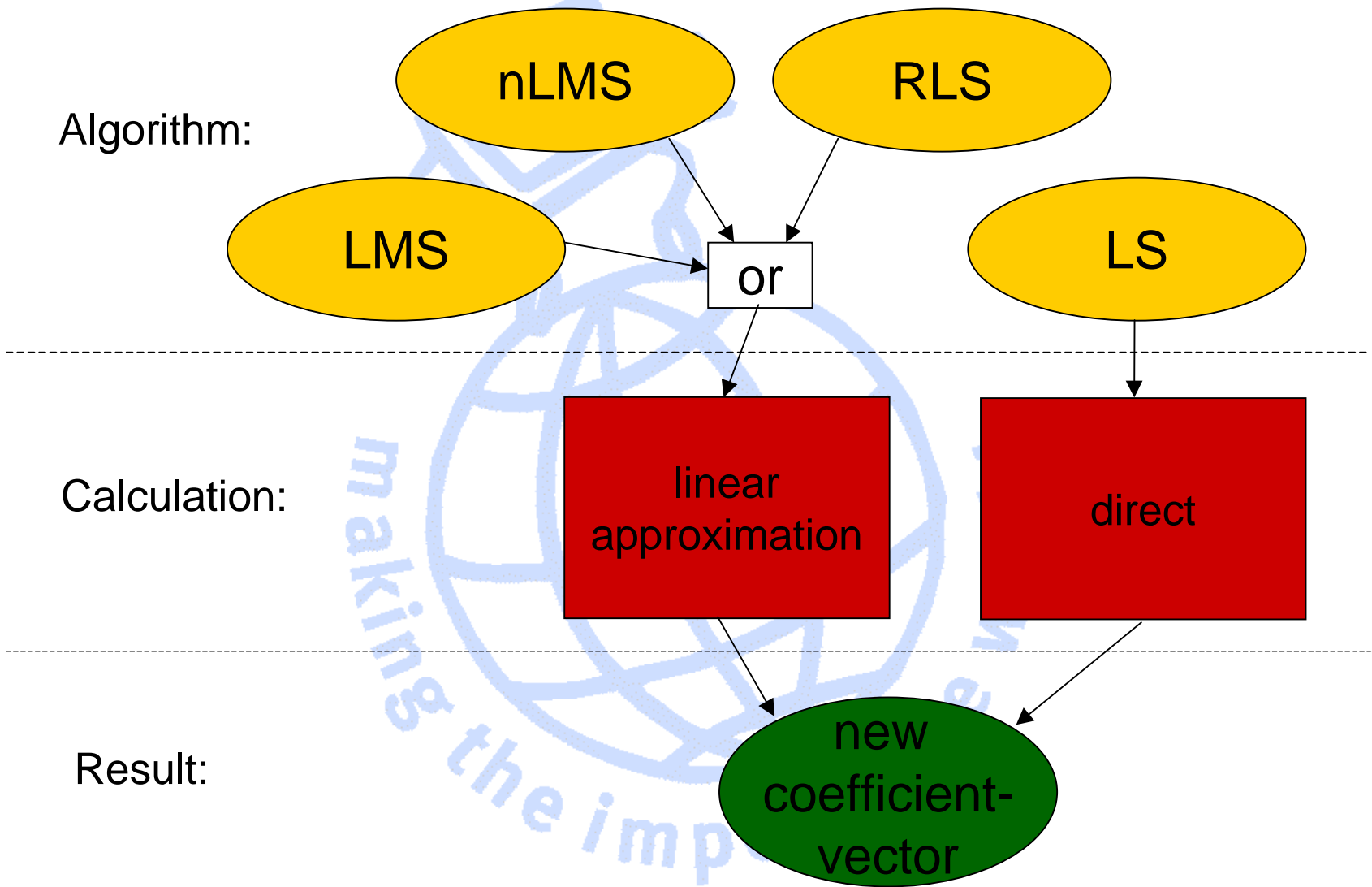
- Additional noise and talk from NES to echo signal
- No pure error signal anymore
- Distortion of NES speech



## Prevention

- Double talk detection
- Stop adaption during double talk

# Algorithm Types



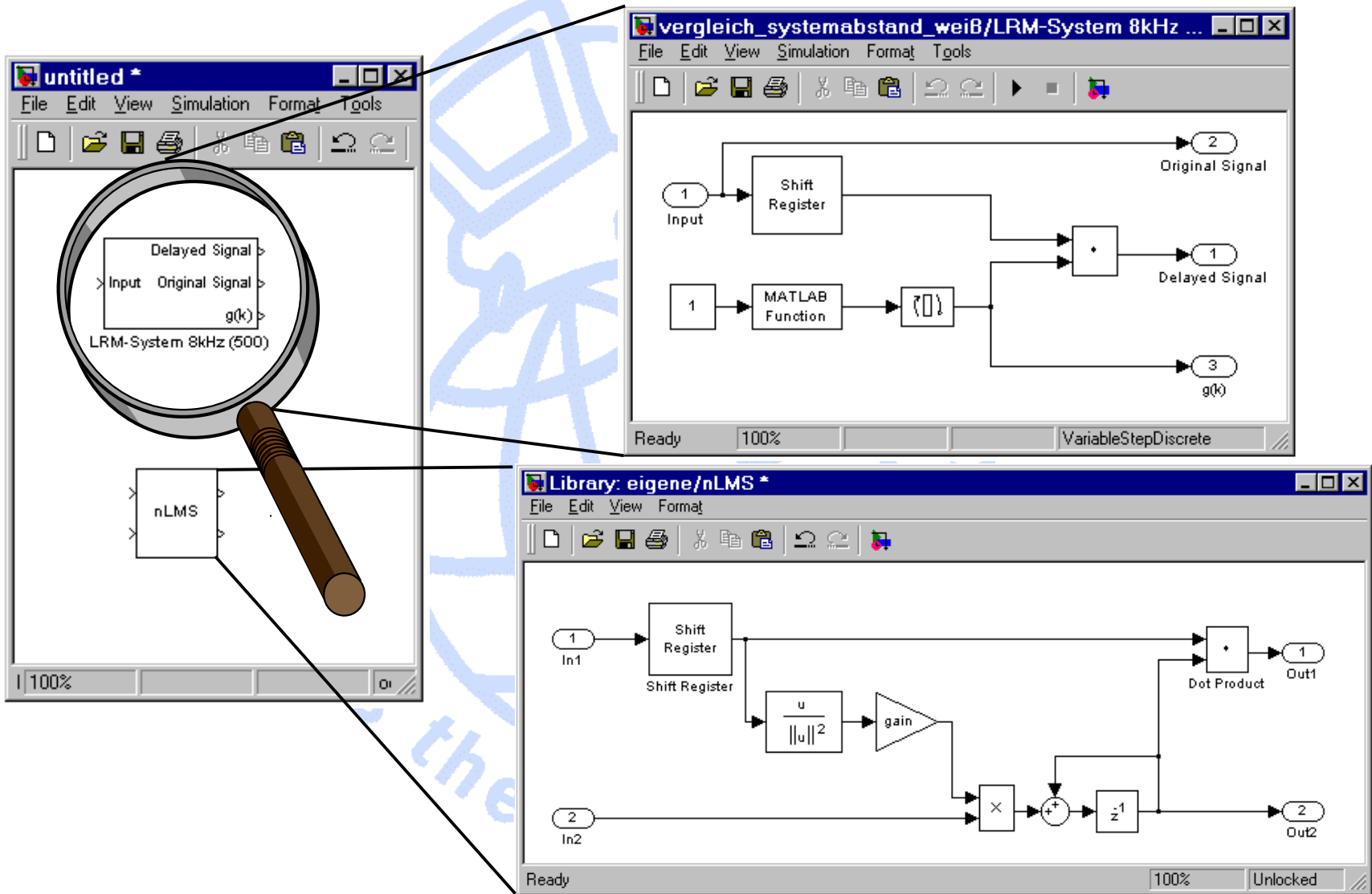
# Choosing an Optimal Solution

Algorithm	LMS	nLMS	RLS
Convergence time	very slow	slow	fast
Stability	very stable	stable	very instable
Complexity	very simple	simple	high
MIPS Consumption	very low	low	high
Implementation	very simple	simple	difficult

Calculation	direct	linear approximation
Convergence time	very fast	slow
Computational Costs	very high	low

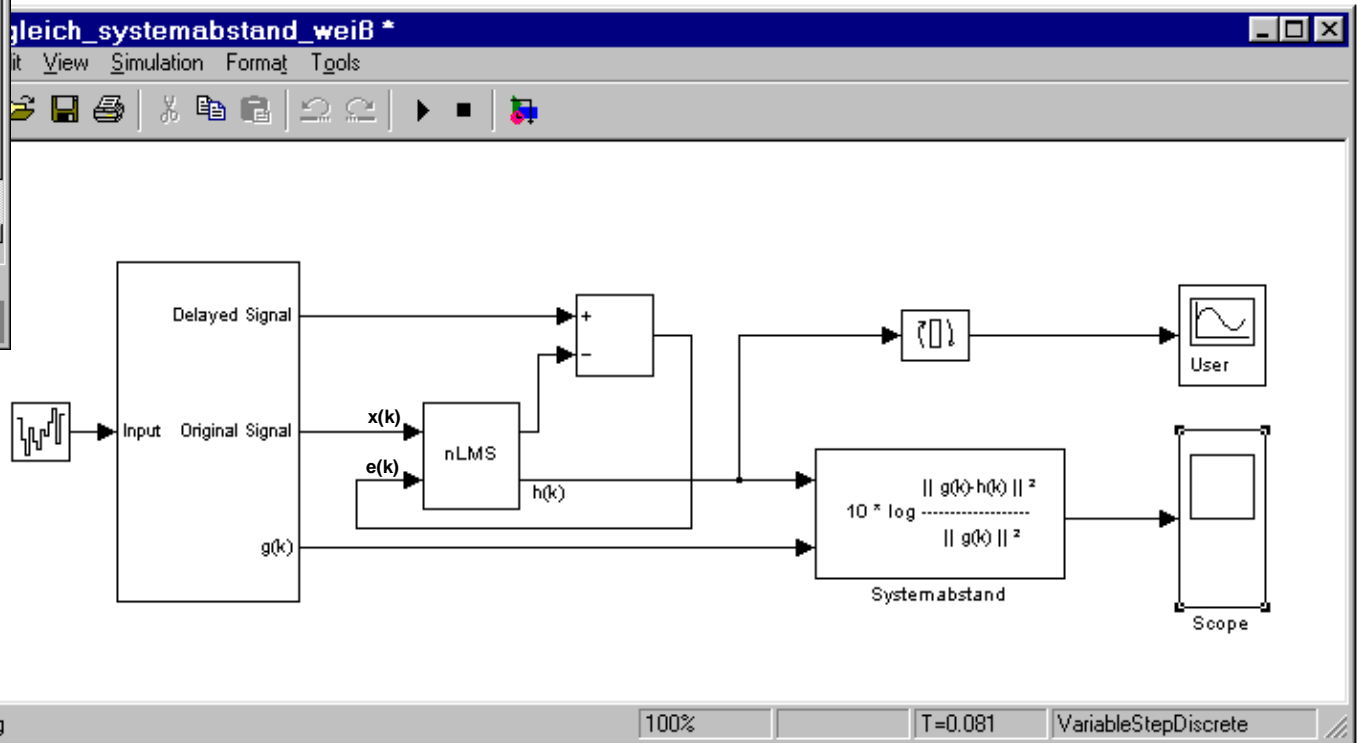
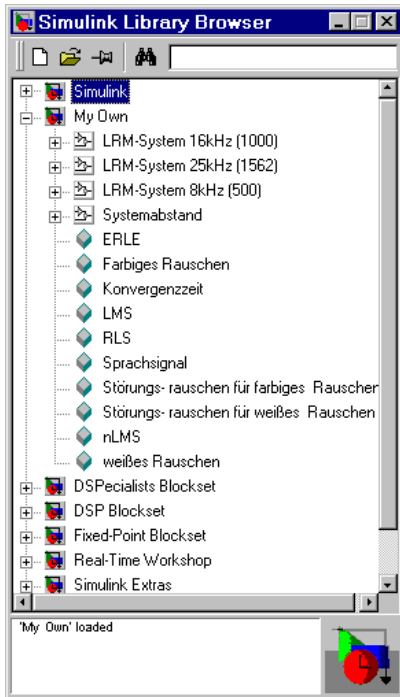
**nLMS with linear approximation is the best solution for hands free telecommunication**

# Block Generation with Standard Libraries



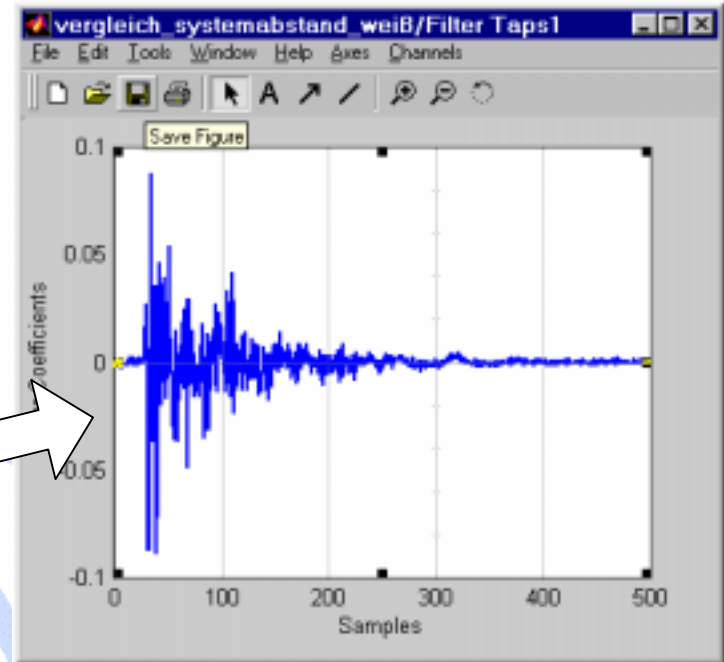
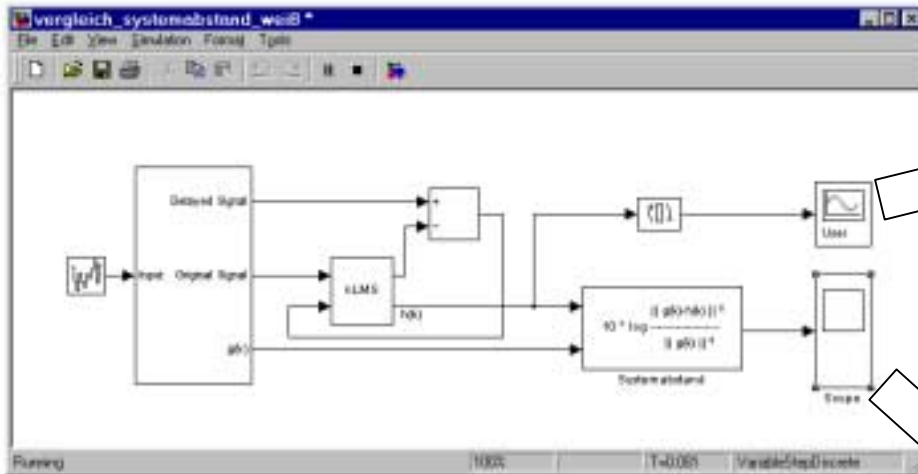
# Realisation in Matlab / Simulink

- Click-and-drag the blocks into the model
- Click-and-drag sources and sinks into the model
- Connect blocks
- Start the simulation

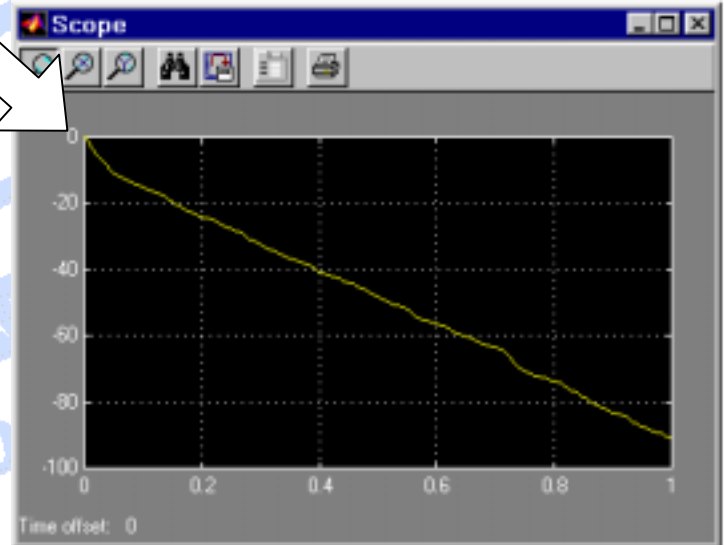


# Presentation of Simulation

- Open sink-blocks



- Optimize view of sink-blocks
- Analysis the results
- Copy results into Matlab-Workspace
- Print or copy window



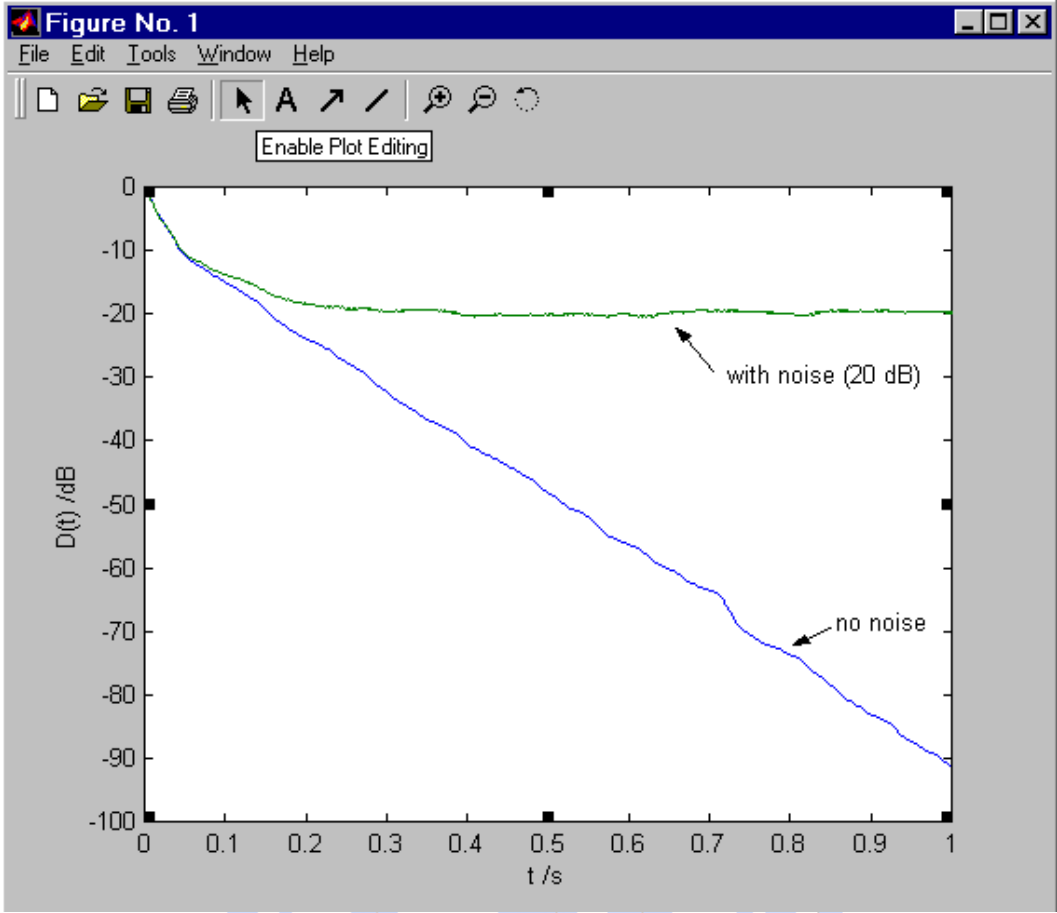
# Simulation Results (1/2)

- **Input and Noise Signal**
  - White noise with low correlation
- **Adaptive Filter Length**
  - Room impulse response length

nLMS (aproximation)	no noise	with noise (-20dB)
Convergence time (10 dB)	45 ms	45 ms
max. ERLE	→ ∞	→ 20dB

- **Convergence time is a function of**
  - Algorithm type
  - Calculation type
  - Filter length
- **Maximum echo return loss enhancement is a function of**
  - Filter length
  - NES speech and noise power

# Simulation Results (2/2)

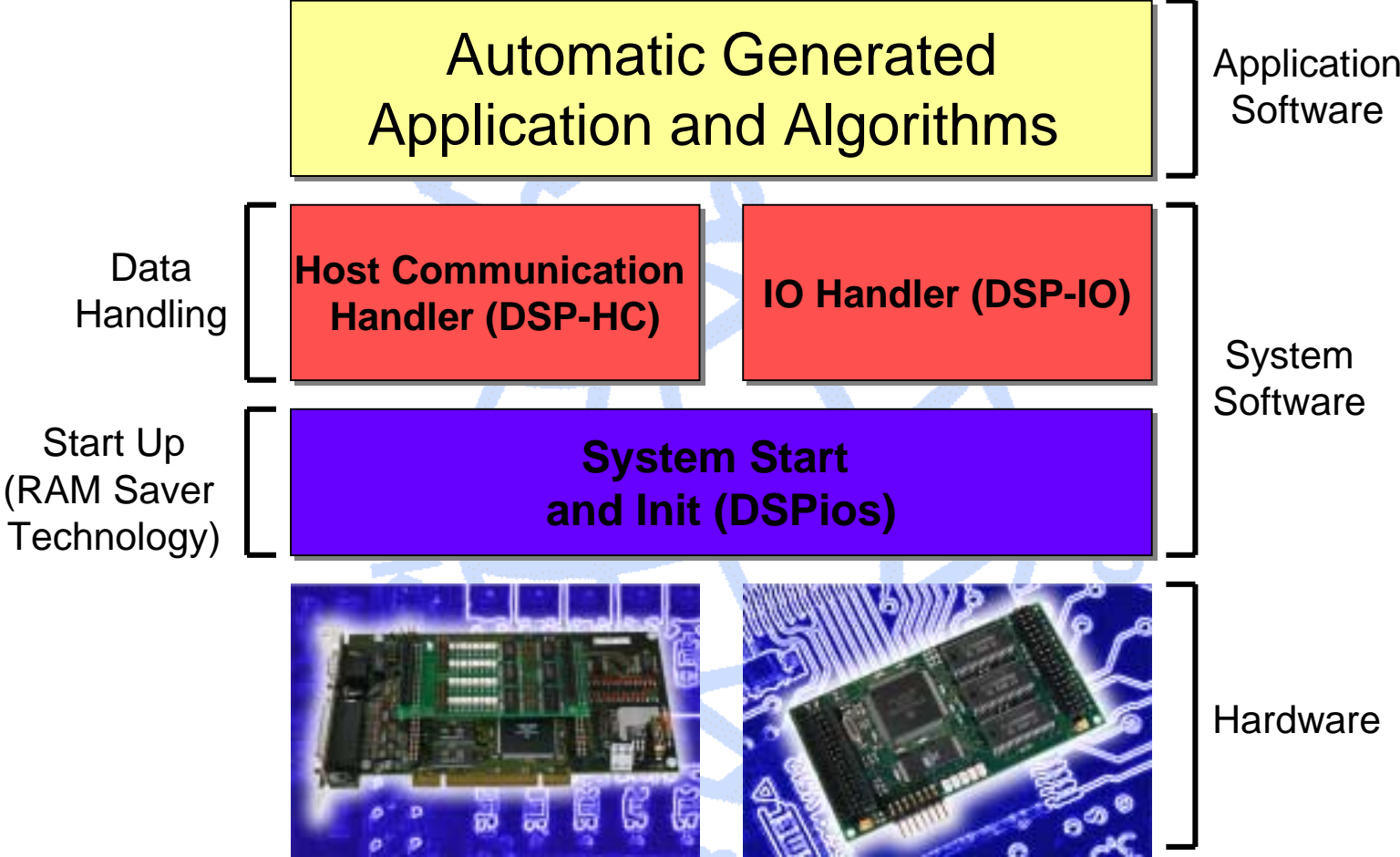


Convergence for white signal as input and with -20dB noise  
( $f_a = 8$  kHz,  $\mu = 1$ ,  $N = 500$ )

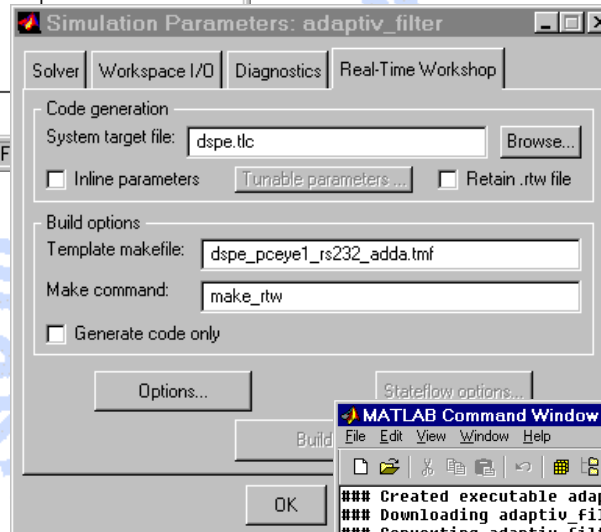
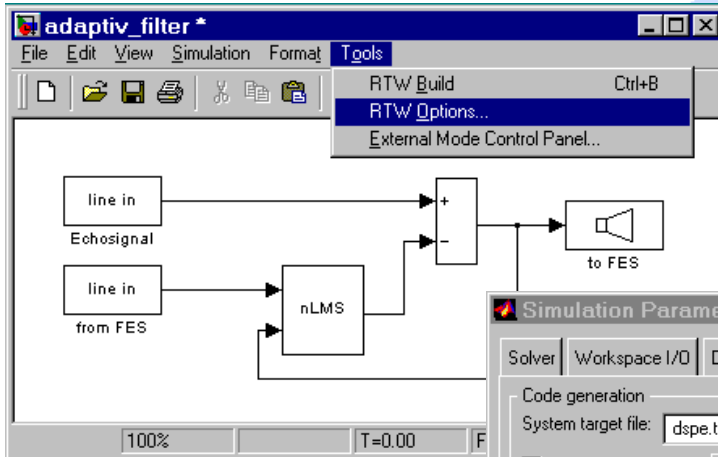
# Types of Target Code Generation

- **Target software implementation manual and separate for each block in assembler**
  - High run time efficiency
  - Error prone
  - Very long development time → **Long time to market**
- **Automatic C-code generation by the Real Time Workshop**
  - High consumption of DSP resources (MIPS, Memory)
  - short development time → **High product costs**
- **DSPecialists Solution (Automatic Code Generation / Target Integration)**
  - Very efficient target code generation (C functions call assembler modules)
  - Short development time for prototypes and products
  - Very safe design with proven modules → **Optimal design**

# Hardware and System Software



# Download using RTW to Target



- Build model
- Choose target
- Start download
- Type `d` for download

```
##### Created executable adaptiv_filter.cld
##### Downloading adaptiv_filter: gmake -f adaptiv_filter.mk download
##### Converting adaptiv_filter
      1 Datei(en) kopiert
      1 Datei(en) kopiert
perl D:\MATLABR11\rtw\c\dsp\tools\fix_model.pl adaptiv_filter
##### Downloading adaptiv_filter ...
perl D:\MATLABR11\rtw\c\dsp\tools\down_drv.pl adaptiv_filter.cld D:\MATLABR11\rtw\c\dsp\
Do you want to download (d) or install (i) created model? (a) to abort download
```

# Summary and Outlook

- **Echo Cancellation has increasing importance**
  - in mobile telephone market
  - in hands free telecommunication
  - due to desire for higher quality standards
- **Echo Cancellation with adaptive filters**
  - is a flexible solution
  - raises speech quality
  - needs high computational power
  - parts of the algorithms can be processed by hardware resources (e.g. coprocessor)
- **Optimal design methods for algorithms in product hardware**
  - no hardware know-how necessary
  - short design cycles
  - assembler efficient
- **Services offered by DSPecialists**
  - adaption of simulink blocks and designing new blocks for code generation
  - design of DSP systems with hardware and system software (start-up, host communication, IO-handling)
  - design of application and target integration with simulink
  - sells tool-chains