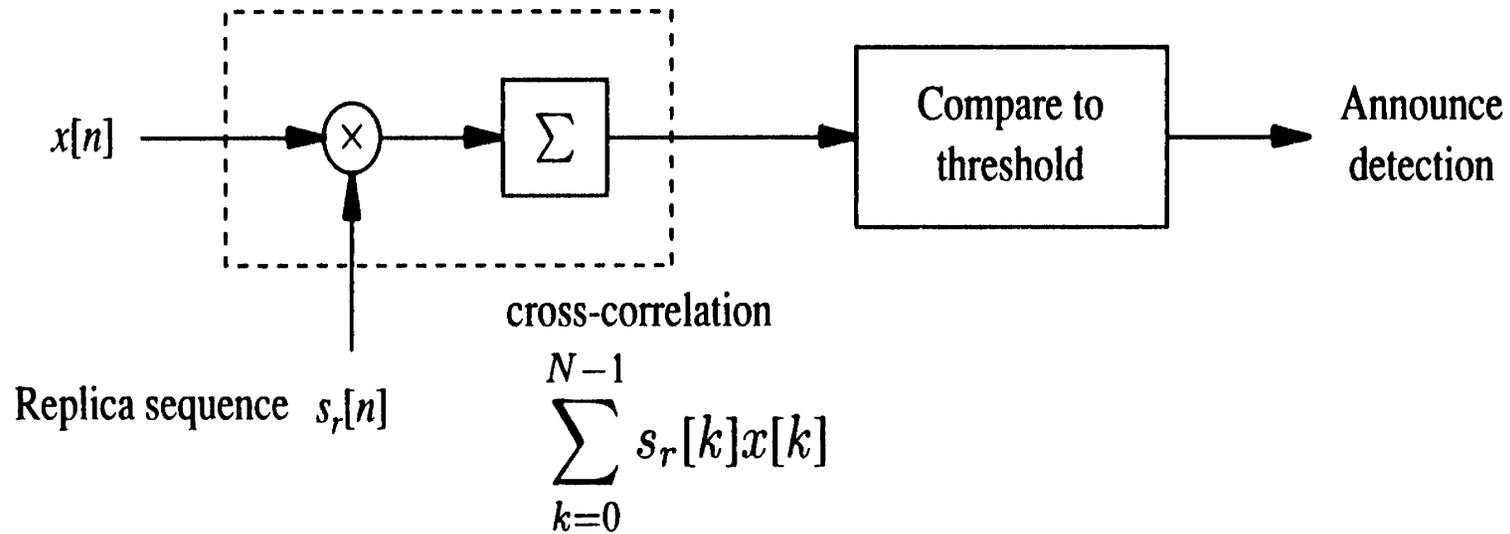


# STATISTICAL SIGNAL PROCESSING

## APPLICATIONS

- COMMUNICATIONS
  - Analog, Digital
- RADAR and SONAR
- SURVEILLANCE/INTELLIGENCE
  - Classification, Localization
  - Signals Intelligence
- SPEECH and IMAGE MODELING

# SIGNAL DETECTION

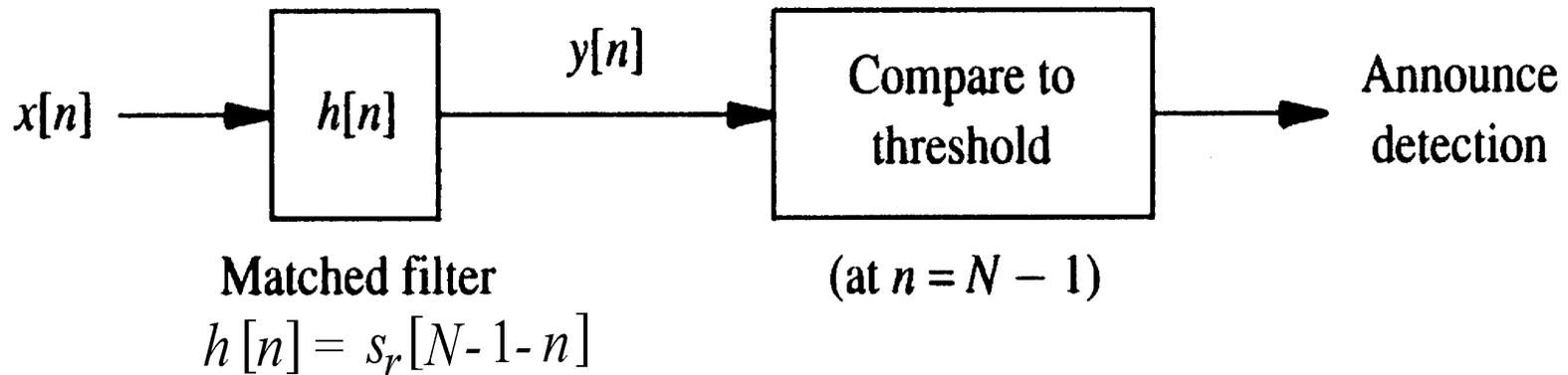


$$x[n] = s[n] + w[n]$$

↖  
deterministic  
signal

↙  
uncorrelated  
(white) noise

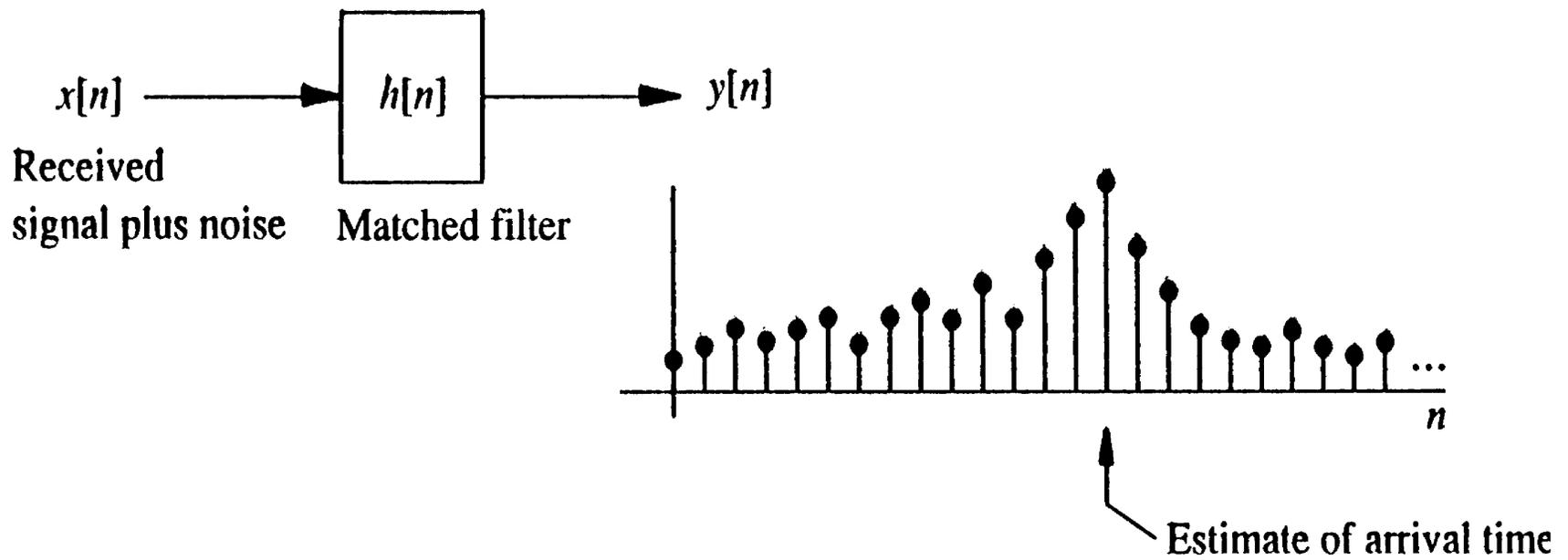
# MATCHED FILTER DETECTOR



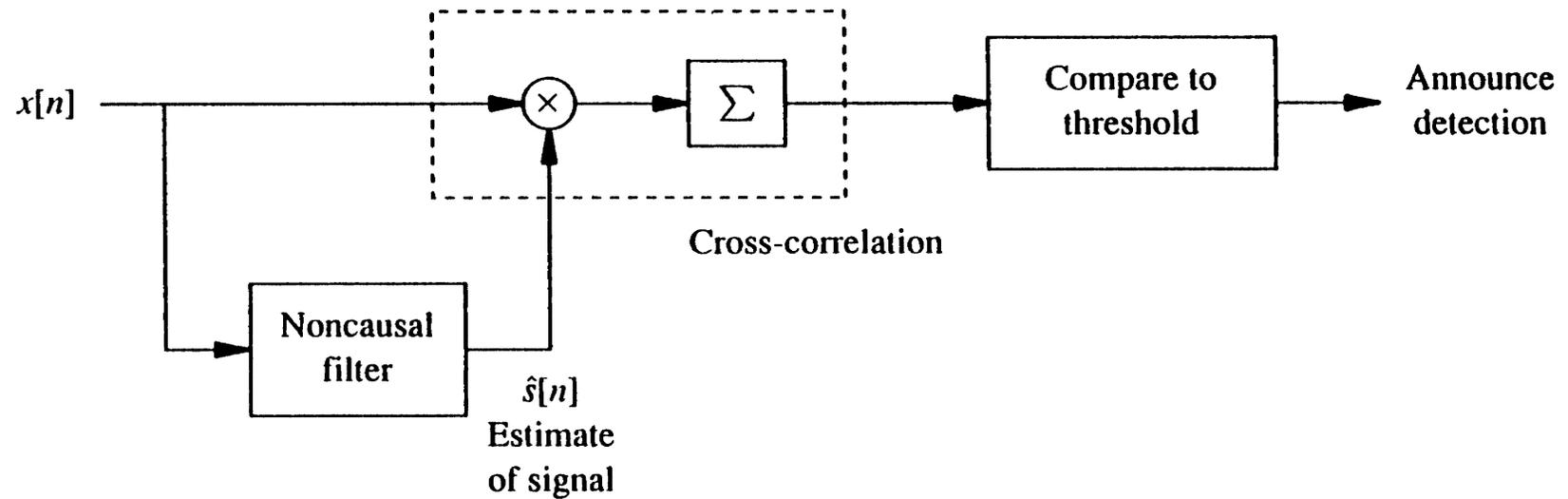
$$y[n] = h[n] * x[n] = \sum_{k=0}^{N-1} h[n-k] x[k]$$

$$y[N-1] = \sum_{k=0}^{N-1} h[N-1-k] x[k] = \sum_{k=0}^{N-1} s_r[k] x[k]$$

# ESTIMATED TIME OF ARRIVAL (MATCHED FILTER)



# ESTIMATOR-CORRELATOR DETECTOR



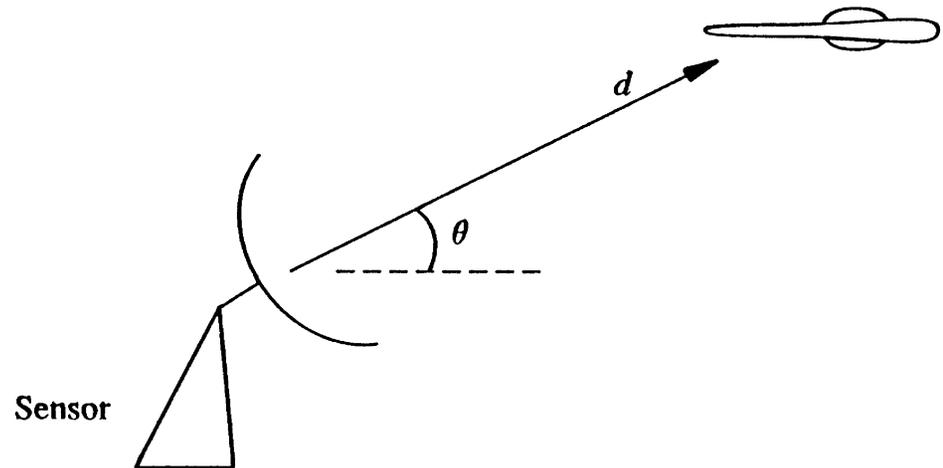
$$x[n] = s[n] + w[n]$$

zero – mean  
Gaussian  
random signal

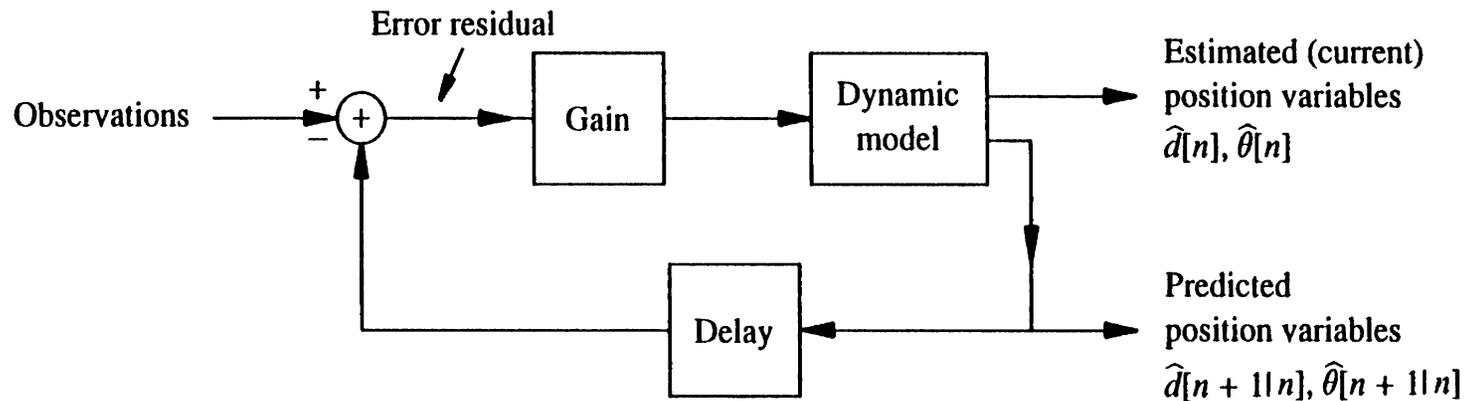
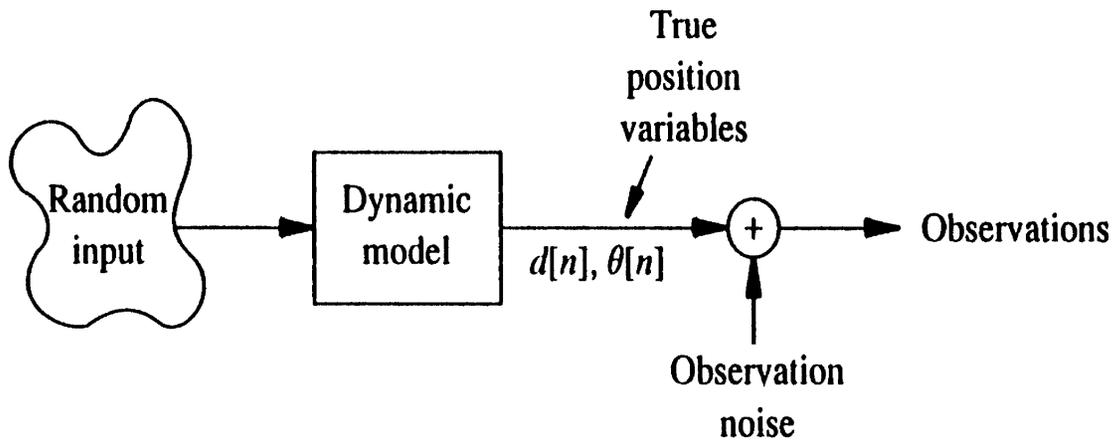
white noise

# TARGET TRACKING

- Target satisfies known dynamic equation.
- Input driving target motion is (at least partly) random.
- Position observation is corrupted by noise.



# TARGET TRACKING (cont'd.)



# **SPEECH PROCESSING**

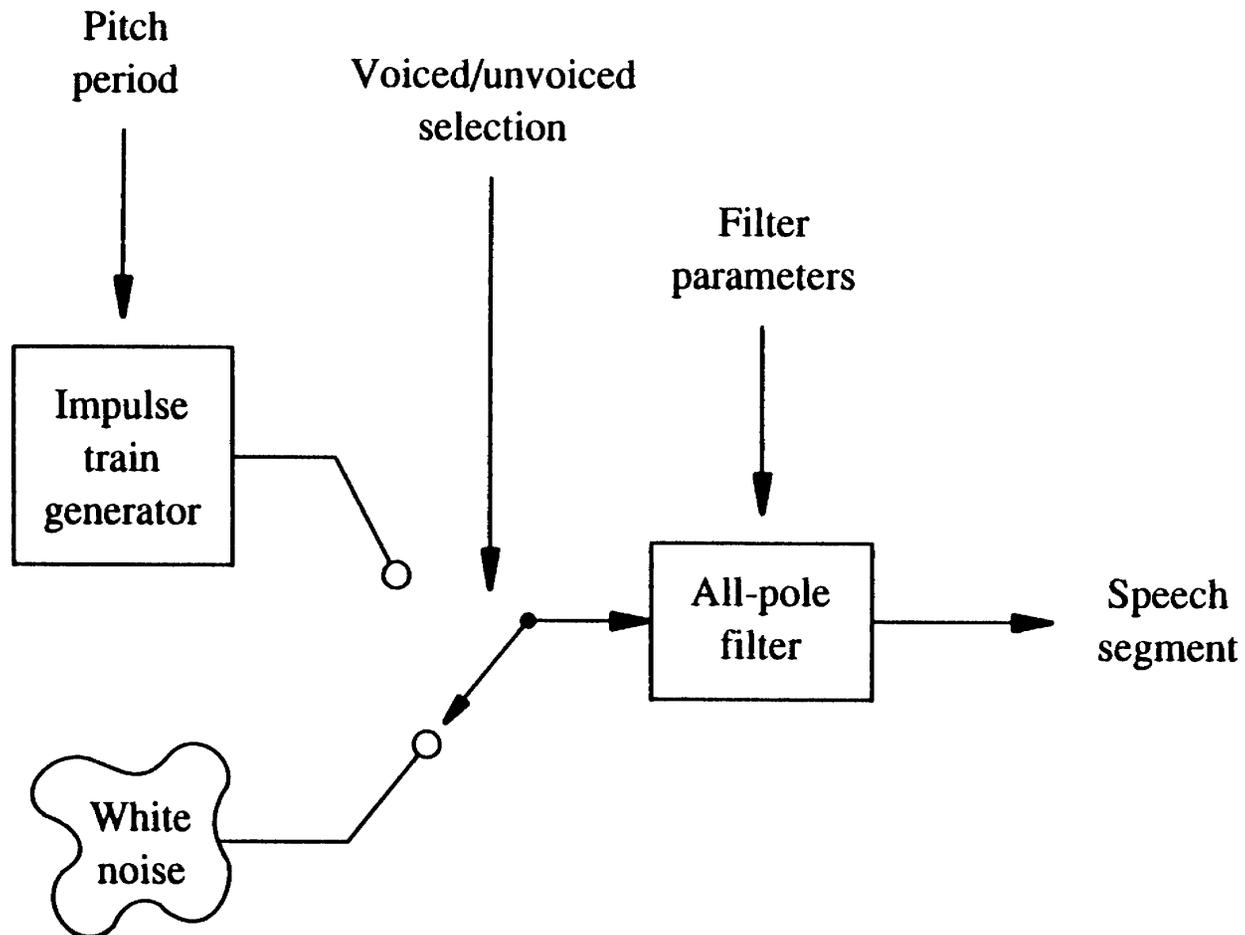
## **ANALYSIS**

- Break up speech waveform into short segments
- Determine voiced/unvoiced
- If voiced, find pitch period
- Determine filter coefficients and gain

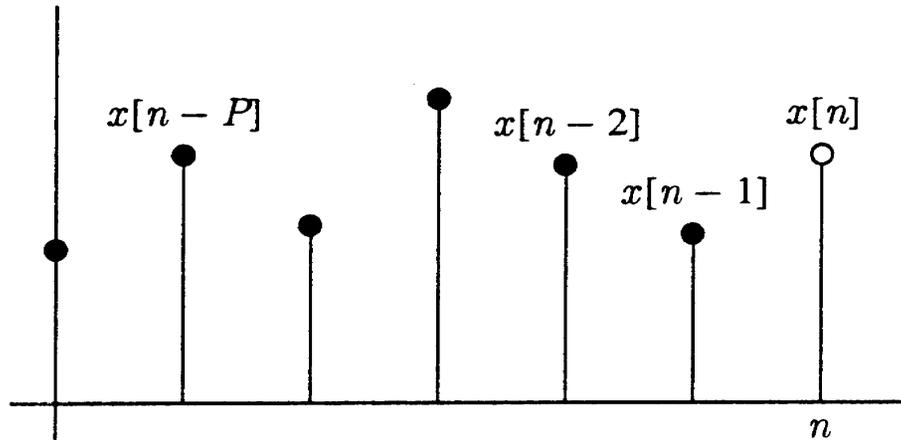
## **SYNTHESIS**

- Generate speech as concatenation of short segments

# SPEECH SYNTHESIS MODEL



# LINEAR PREDICTION



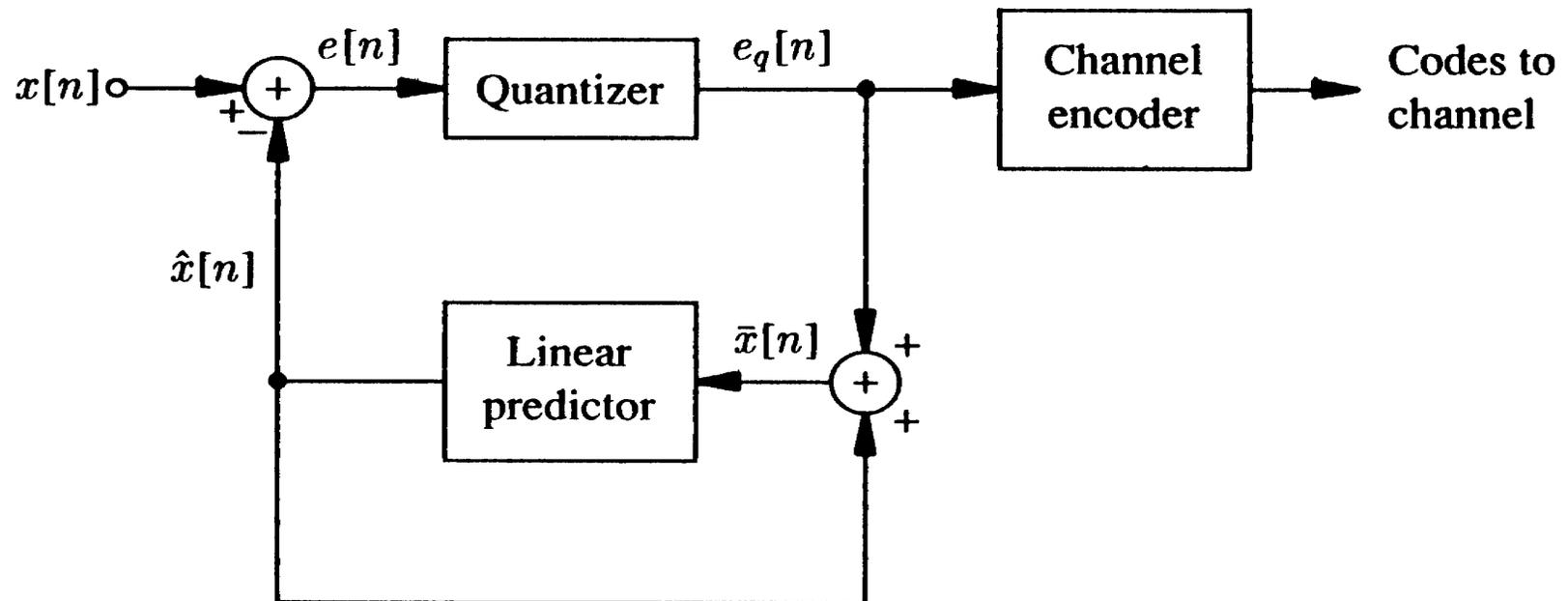
- Signal is predicted from past values:

$$\hat{x}[n] = -a_1x[n-1] - a_2x[n-2] - \dots - a_Px[n-P]$$

$$\varepsilon[n] = x[n] - \hat{x}[n]$$

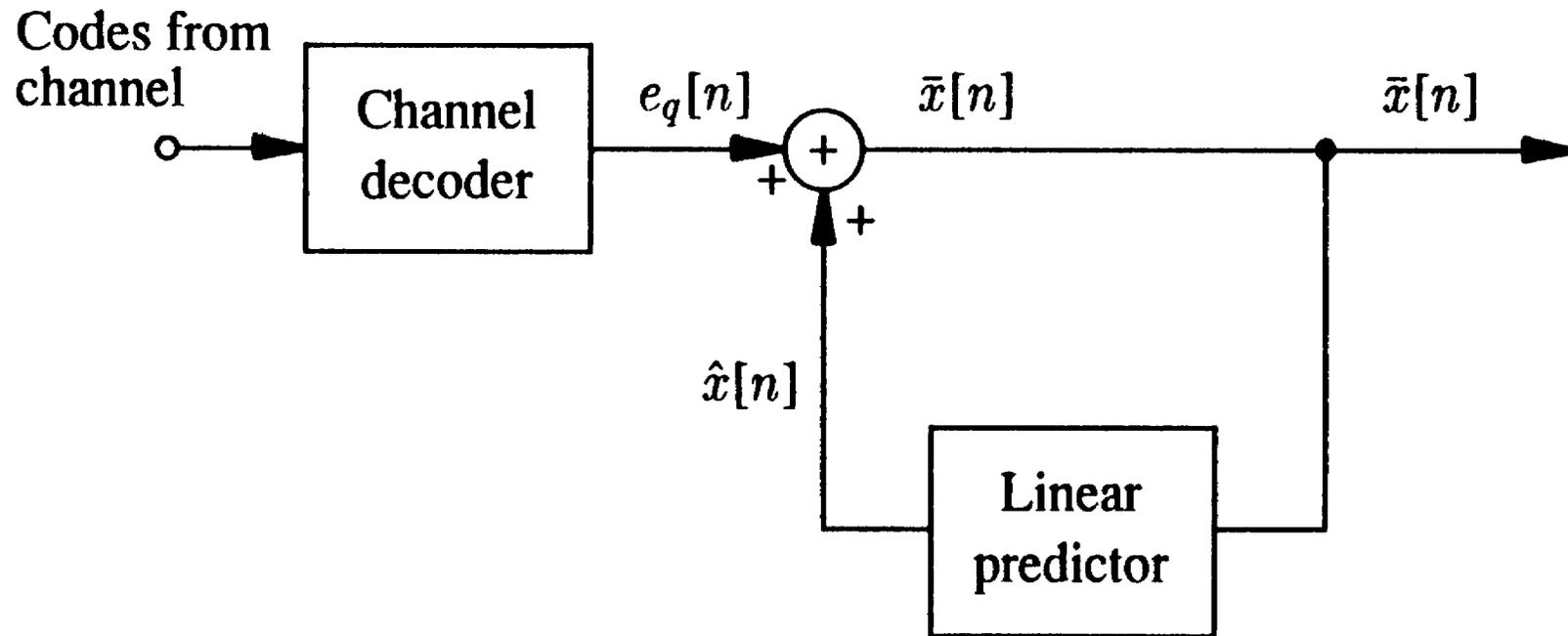
# LINEAR PREDICTIVE CODING

## TRANSMITTER



# LINEAR PREDICTIVE CODING (cont'd.)

## RECEIVER



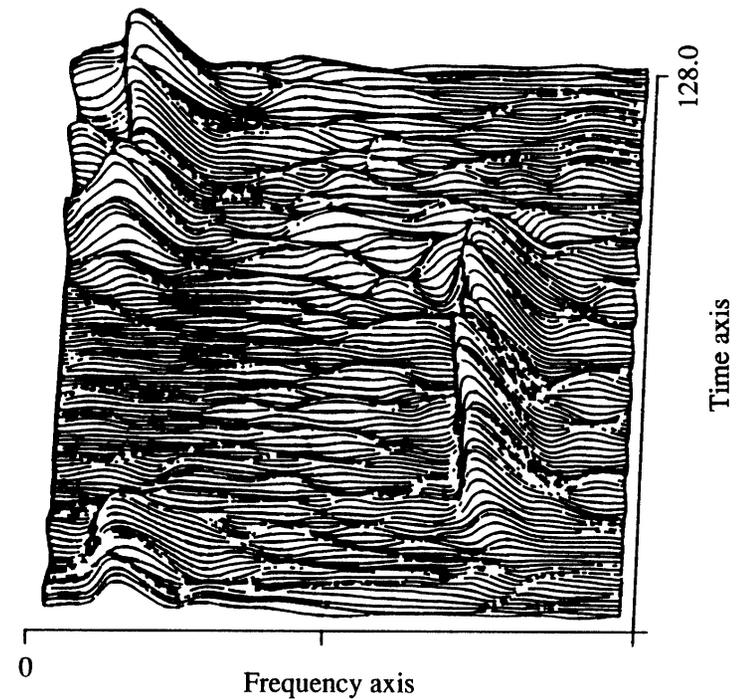
# SPECTRUM ESTIMATION

## CLASSICAL

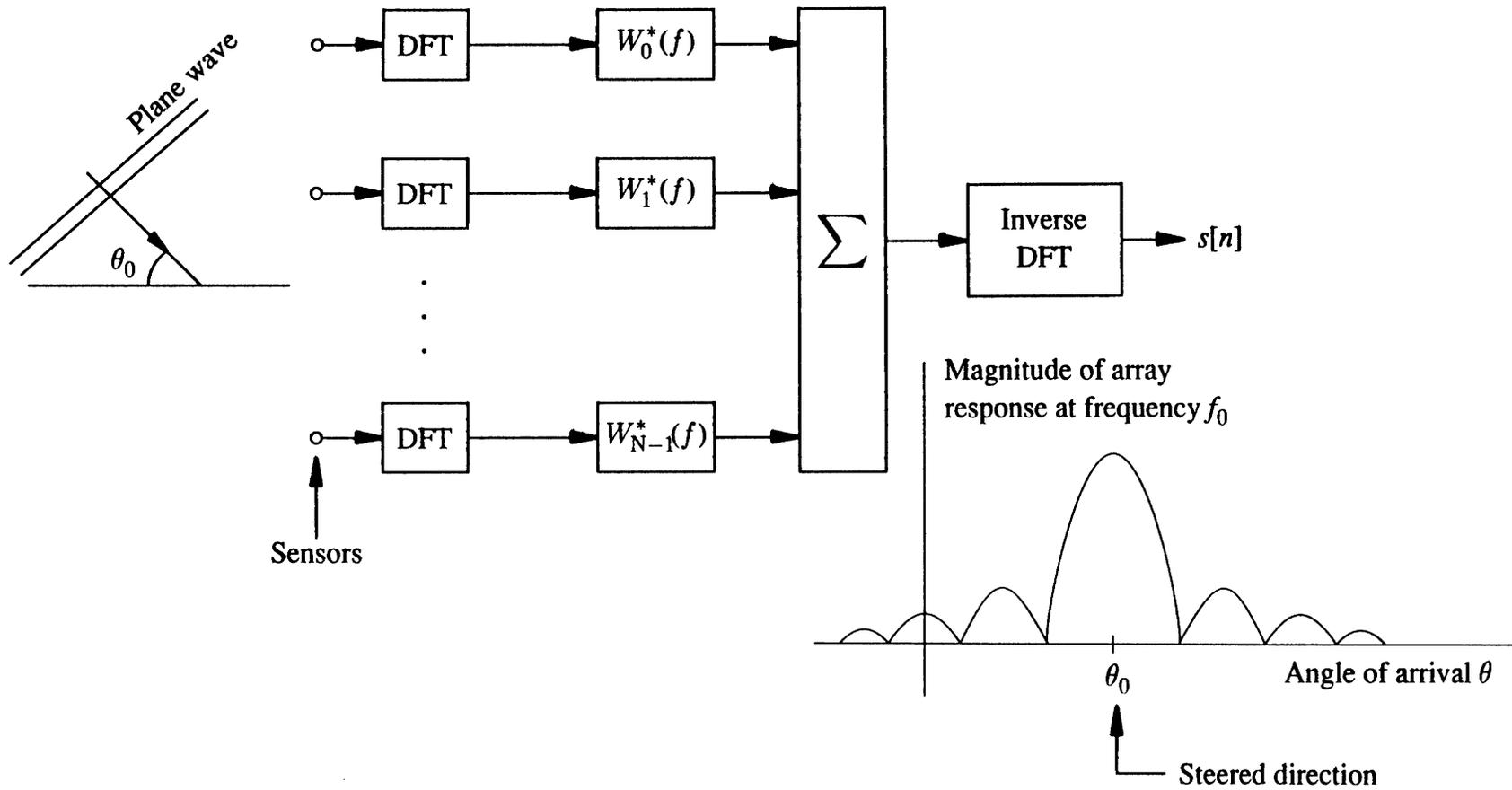
- DFT
- Windowed DFT

## MODEL-BASED

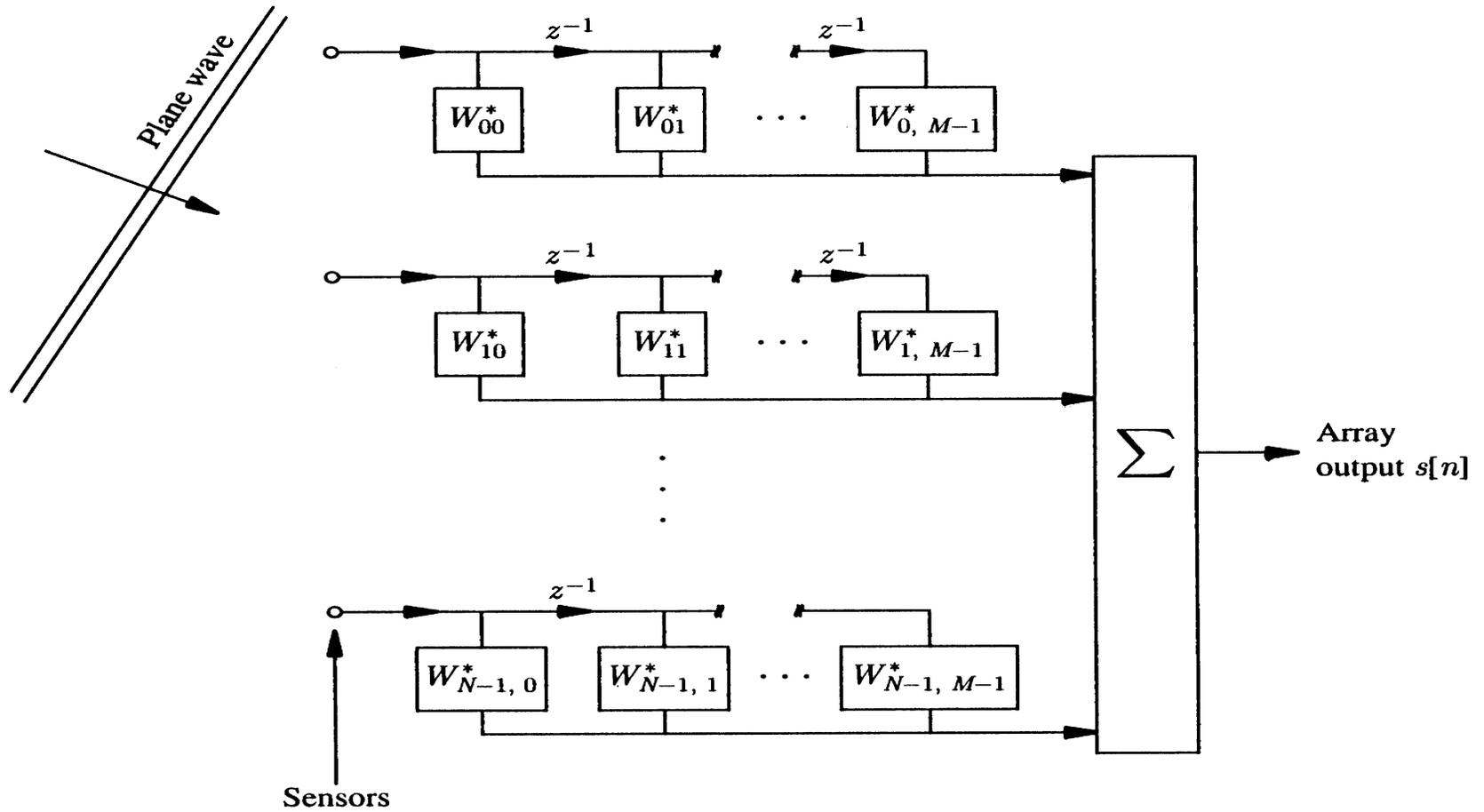
- Statistical signal modeling
- Linear prediction
- Linear Algebraic analysis



# BEAMFORMING



# FILTERED BEAMFORMER



# TOPICS TO BE COVERED

- Discrete and continuous random processes
- Second moment characterization of random signals
- Processing of random signals by linear systems
- Statistical estimation
- Optimal filtering