



**SNS COLLEGE OF TECHNOLOGY**

**Coimbatore – 35**

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING**

19ECT311/ Wireless Communication

IV ECE/ VII SEMESTER

Unit IV - **MULTIPATH MITIGATION TECHNIQUES**

**Topic 1 : Equalization**



# Introduction



- Three techniques are used independently or in tandem to improve receiver signal quality
- *Equalization* compensates for ISI created by multipath with time dispersive channels ( $W > B_C$ )
  - Linear equalization, nonlinear equalization
  - counters the effects of time dispersion (ISI)
- *Diversity* also compensates for fading channel impairments.
  - Implemented by using two or more receiving antennas
  - Spatial diversity, antenna polarization diversity, frequency diversity, time diversity
  - Reduces the depth and duration of the fades experienced by a receiver in a flat fading (narrowband) channel



# Introduction

- *Channel Coding* improves mobile communication link performance by adding redundant data bits in the transmitted message
  - Channel coding is used by the Rx to detect or correct errors introduced by the channel (Post detection technique)
  - Block code and convolutional code



# Equalization Techniques

- ✓ The term *equalization* can be used to describe any signal processing operation that minimizes ISI
- ✓ Two operation modes for an adaptive equalizer
  - Training and tracking
- ✓ Known, fixed-length training sequence is sent by the transmitter
- ✓ The training sequence is typically a pseudorandom binary signal or a fixed, prescribed bit pattern
- ✓ Immediately following this training sequence, the user data is sent



# Adaptive Equalisation

- The adaptive equalizer at the receiver utilizes a recursive algorithm to evaluate the channel
- Estimate filter coefficients to compensate for the channel
- As user data are received, the adaptive algorithm of the equalizer tracks the changing channel
- As a consequence, the adaptive equalizer is continually changing its filter characteristics over time



# Activity



- Imagine folding a paper in half once
- Then take the result and fold it in half again; and so on
- How many times can you do that?

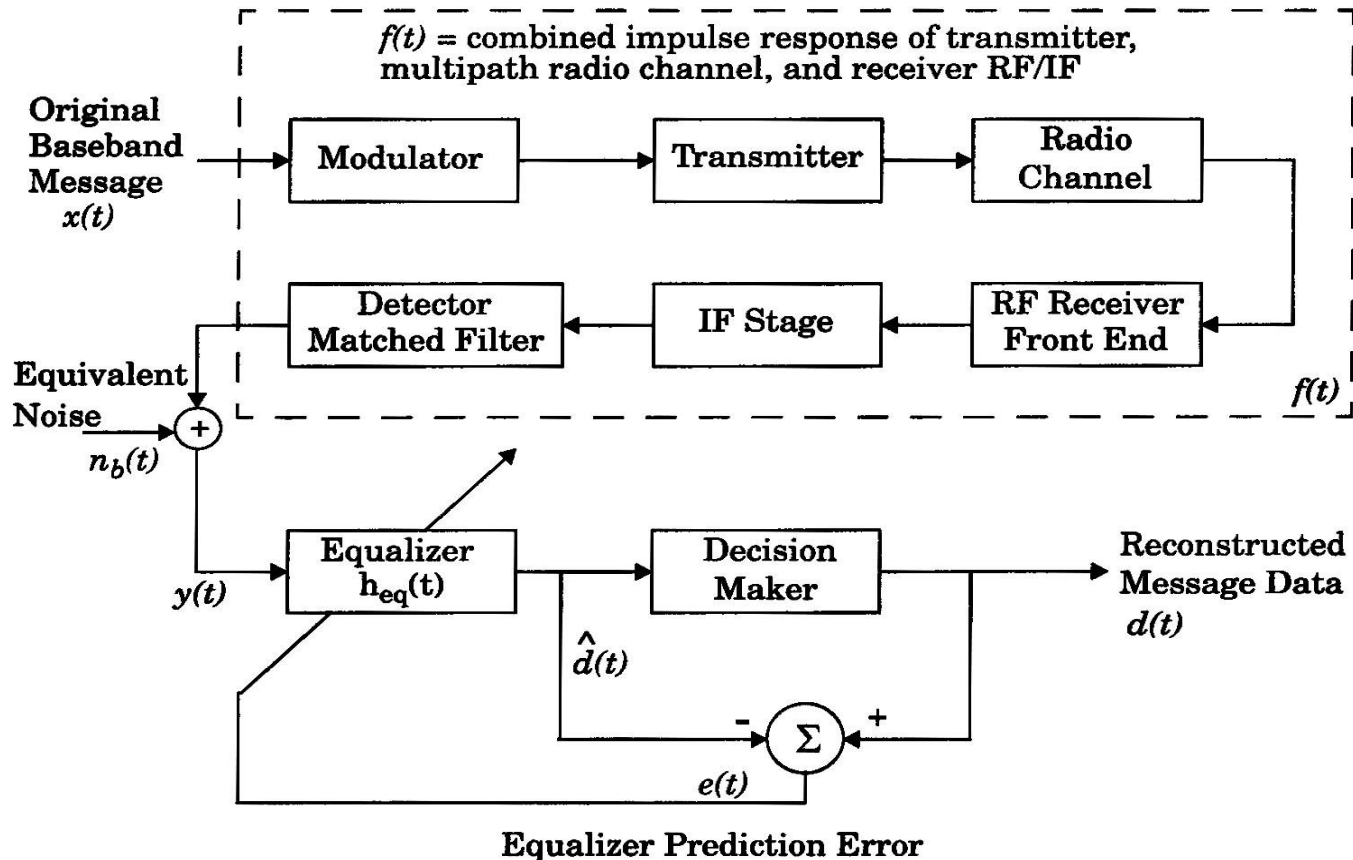


# Adaptive Equalisation

- ✓ Three factors affect the time spanning over which an equalizer converges:
  - Equalizer algorithm
  - Equalizer structure
  - Time rate of change of the multipath radio channel
- ✓ TDMA wireless systems are particularly well suited for equalizers



# Adaptive Equalisation



Block diagram of a simplified communications system using an adaptive equalizer at the receiver.





# Adaptive Equalisation

The output of equaliser

$$\begin{aligned}\hat{d}(t) &= x(t) \otimes f^*(t) \otimes h_{eq}(t) + n_b(t) \otimes h_{eq}(t) \\ &= x(t) \otimes g(t) + n_b(t) \otimes h_{eq}(t)\end{aligned}$$

- $x(t)$  is the original information signal
- $f(t)$  is the combined complex baseband impulse response of the transmitter, channel and the RF/IF sections of the receiver
- $f^*(t)$  is the complex conjugate of  $f(t)$
- $n_b(t)$  is the baseband noise at the input of the equalizer
- $\otimes$  denotes the convolution operation
- $h_{eq}(t)$  is impulse response of the equalizer



# Adaptive Equalisation

The desired output of equaliser

$$\hat{d}(t) = x(t)$$

To get this

$$g(t) = f^*(t) \otimes h_{eq}(t) = \delta(t)$$

Goal of equalisation is satisfy the above equation.

In Frequency domain,

$$H_{eq}(f) F^*(-f) = 1$$

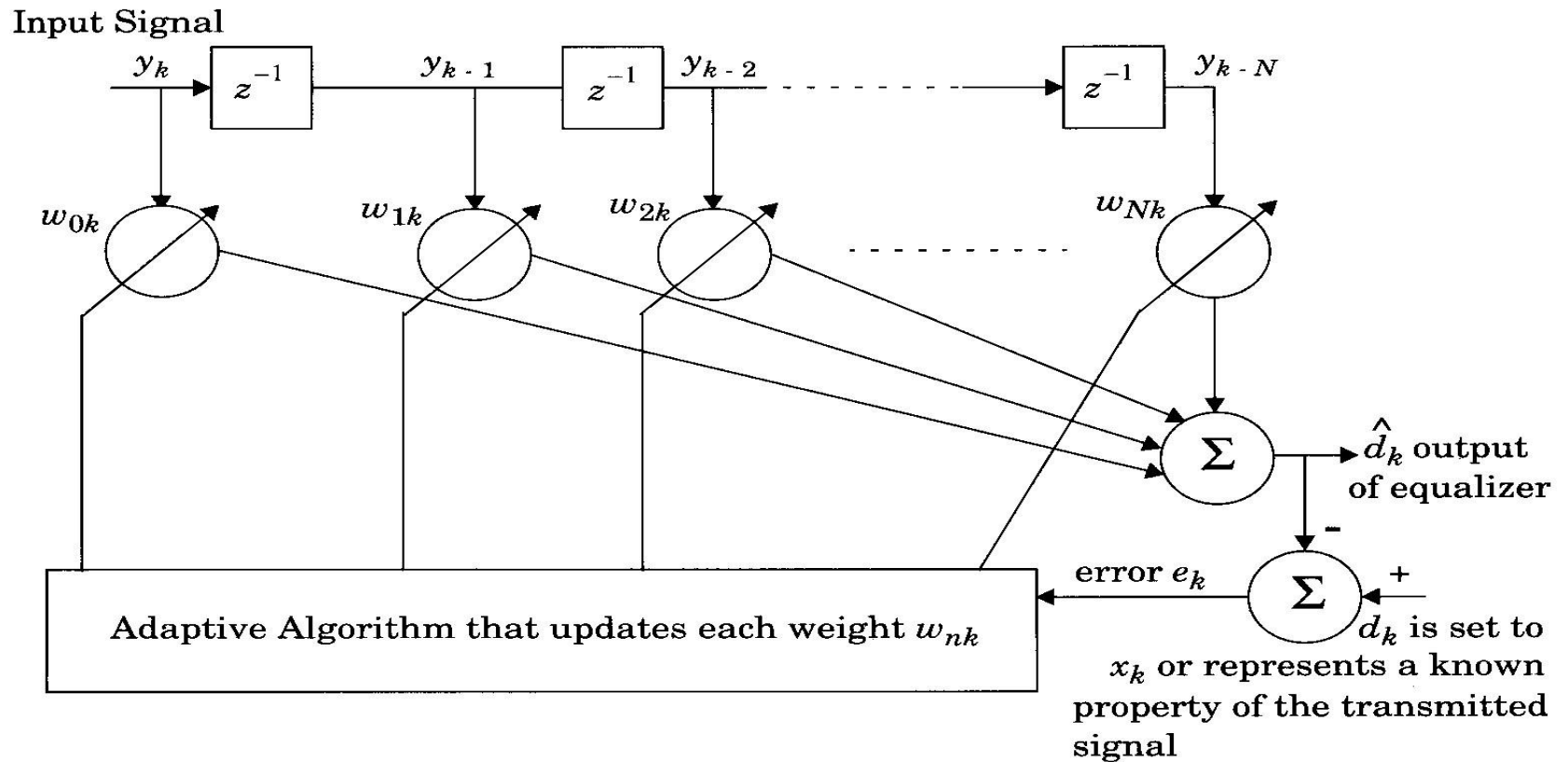


# Adaptive Equalization

- If the channel is frequency selective, the equalizer enhances the frequency components with small amplitudes and attenuates the strong frequencies in the received frequency response
- For a time-varying channel, an adaptive equalizer is needed to track the channel variations



# Basic Structure of Adaptive Equalizer



A basic linear equalizer during training.



# Basic Structure of Adaptive Equalizer

- Transversal filter with  $N$  delay elements,  $N+1$  taps, and  $N+1$  tunable complex weights
- These weights are updated continuously by an adaptive algorithm
- The adaptive algorithm is controlled by the error signal  $e_k$

$$e_k = \hat{d}_k - d_k$$



# Basic Structure of Adaptive Equalizer

- Classical equalization theory : using training sequence to minimize the cost function

$$E[e(k) e^*(k)]$$

- Recent techniques for adaptive algorithm : blind algorithms
  - Constant Modulus Algorithm (CMA, used for constant envelope modulation)
  - Spectral Coherence Restoral Algorithm (SCORE, exploits spectral redundancy or cyclostationarity in the Tx signal)



# Assessment



➤ **What are the modes of adaptive equalizer?**

- a) Training mode
- b) Tracking mode
- c) Both of the mentioned**
- d) None of the mentioned

➤ **The ISI and adjacent channel interference is removed by**

- a) Cancelling filter
- b) Port processing equalizer
- c) Both of the mentioned**
- d) None of the mentioned





# THANK YOU