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Coimbatore – 35
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

16EC401 / 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

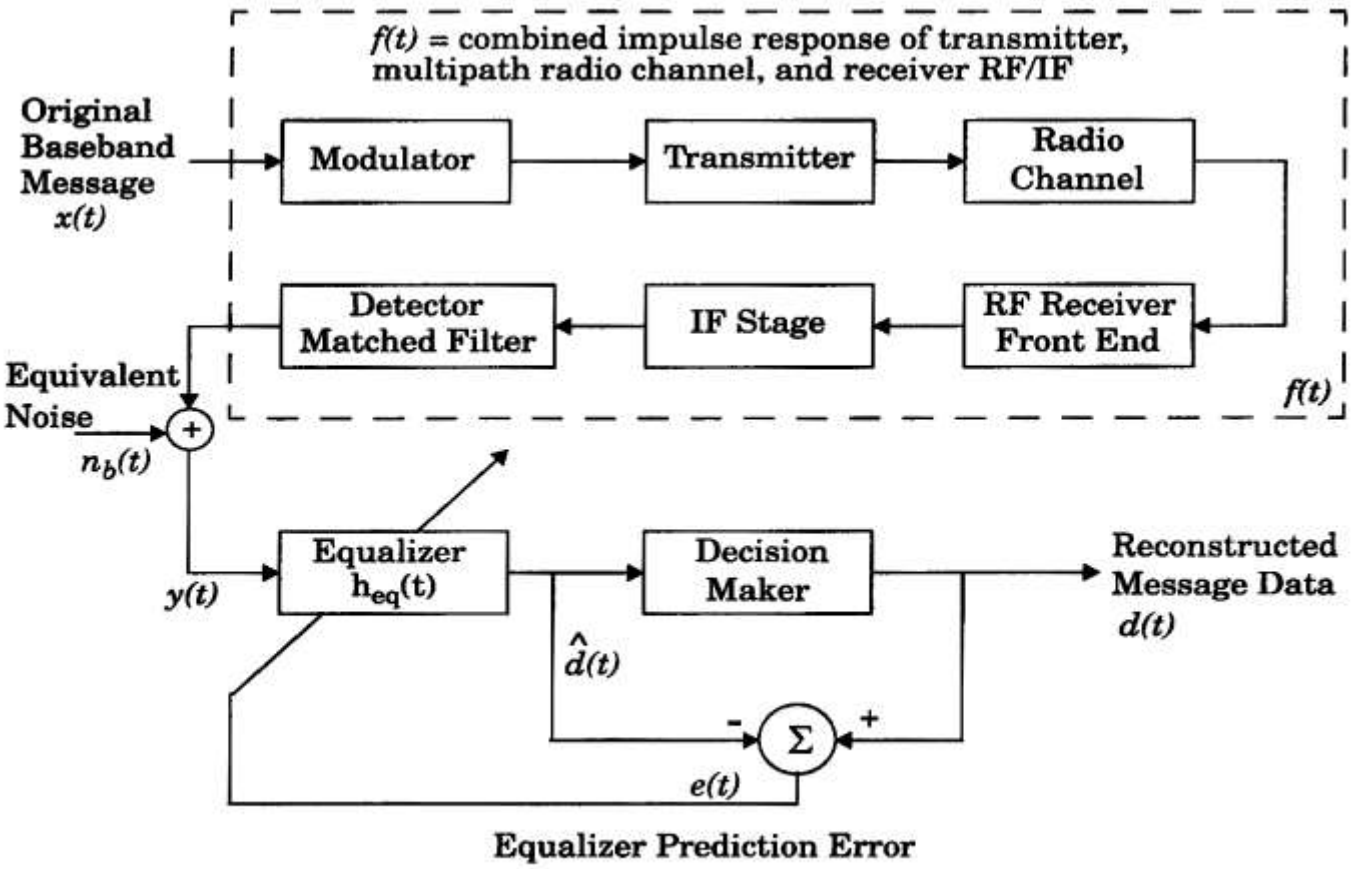
Activity

- 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

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

- 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

- heq (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.

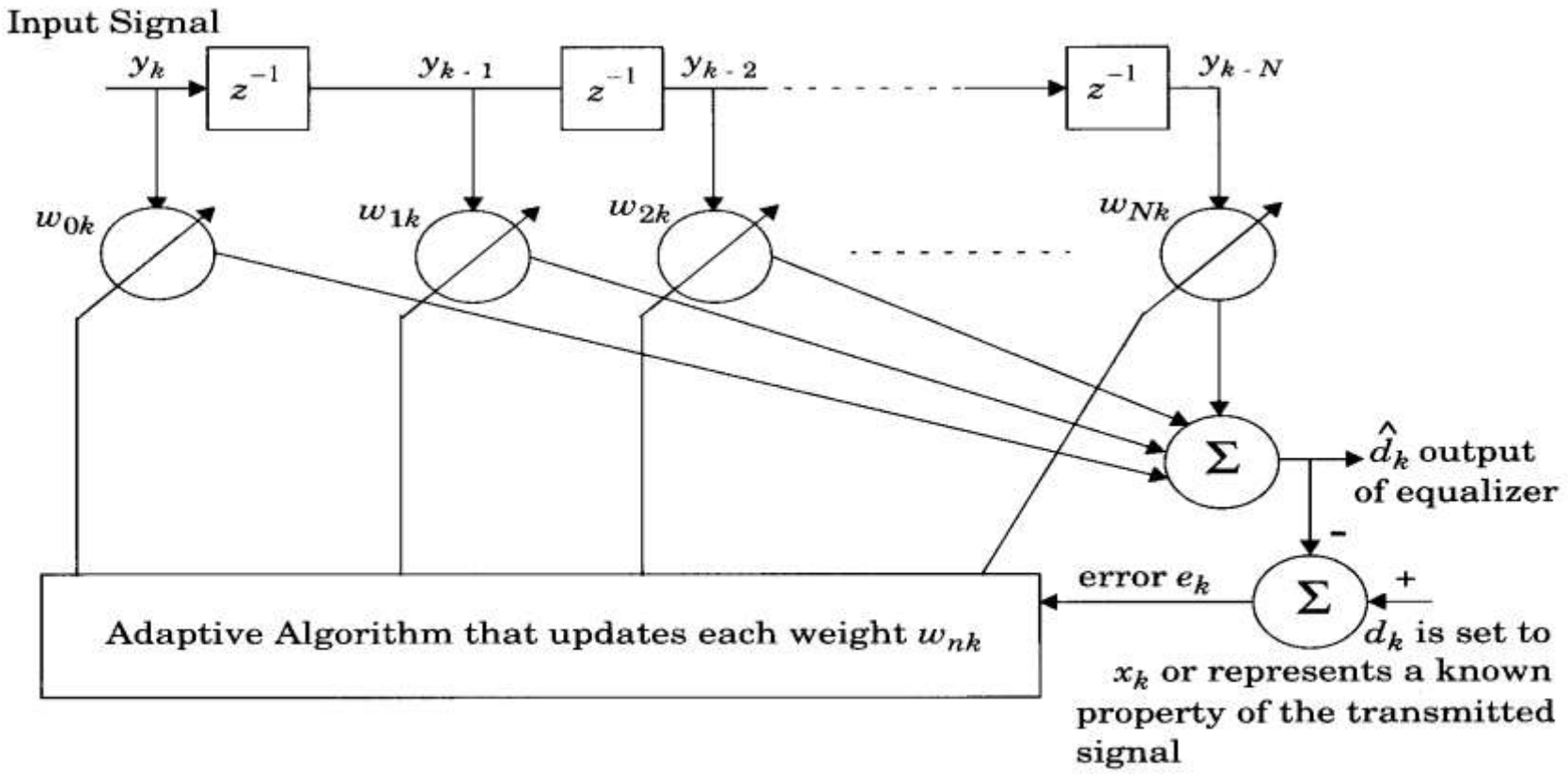
In Frequency domain,

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

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

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

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