

UWB: Pulse Modulation & Timing Synchronization

Learn to design, model and synchronise pulse-based UWB systems, from modulation and channel models to receivers, MAC and positioning.

56

MODULES

119

TOPICS

COURSE OVERVIEW

This course examines the fundamentals of ultra-wideband (UWB) communications, covering its history, regulatory background, applications, and the distinction between pulse-based and multicarrier approaches. It then addresses issues unique to UWB, including antennas, propagation and channel models, modulation types, A/D sampling, timing acquisition, receiver structures and multiple access, before moving into single-carrier and OFDM-based modulation schemes with their channel estimation and detection methods. The course continues through optimum and low-complexity receiver design, timing synchronisation techniques for coarse and flexible timing resolution, and acquisition for ad hoc multiple access, alongside analog-to-digital conversion approaches and digital and analog/digital transceiver architectures. It closes with medium access control, radio resource management, pulsed signal and narrowband receiver modelling, multiband access techniques, and location, tracking and positioning methods for UWB systems.

WHO THIS COURSE IS FOR

RF Engineers

Communications Engineers

Systems Design Engineers

Wireless Network Engineers

Signal Processing Engineers

LEARNING OBJECTIVES

- Explain the fundamentals, history and regulatory context of UWB
- Compare pulse-based and multicarrier UWB modulation types
- Describe propagation, channel models and antenna issues in UWB
- Analyse single-carrier and OFDM-based modulation and channel estimation
- Evaluate optimum and low-complexity receiver structures for UWB
- Apply timing synchronisation and acquisition techniques for UWB signals
- Assess multiple access, MAC and radio resource management schemes
- Interpret location, tracking and positioning techniques in UWB systems

56 Modules, 119 Topics

01

Fundamentals

TOPICS

Overview of UWB · History · Regulatory · Applications · Pulse- or Multicarrier-Based UWB

02

Issues Unique to UWB

TOPICS

Antennas · Propagation and Channel Model · Modulations · A/D Sampling · Timing Acquisition · Receiver Structures · Multiple Access

03

Emerging Technologies

TOPICS

Low-Complexity Noncoherent Receivers · Location-Based Sensor Networks · Time Reversal · MAC · Future Directions

01

Overview

TOPICS

- Evolution and Definition
- Major Differences from Narrowband and CDMA Systems
- Types of UWB Modulation
- UWB Applications

02

Single-Carrier-Based Modulation

TOPICS

Time-Hopping PPM · Other Types of Modulations · Channel Estimation · Signal Detection

03

OFDM-Based Modulation

TOPICS

Channel Estimation · Interference Suppression · Conclusion and Further Reading

01

Introduction

TOPICS

UWB Pulse Propagation · Generalized Multipath Model · IEEE 802.15.4a Channel Model · UWB Pulse Signal Detection

02

Optimum Receiver

TOPICS

- Generalized RAKE Receiver
- Optimum Receiver with Intersymbol Interference
- Receiver with Time-Reversal Channel Impulse Response
- Optimum Receiver with Multiuser Detection

01

Introduction

02

Signal Model

03

Signal Detection and Symbol-Level Acquisition

TOPICS

Analog Energy Detectors · Discrete-Time Energy Detectors

04

SAT and MAT: Templates with and without Timing

05

Coarse Synchronization Using Symbol-Rate Samples

TOPICS

- Discrete-Time Correlator Output Model under Mistiming
- CML Timing Synchronization
- Analytic and Simulated Performance

06

Synchronization with Flexible Timing Resolution

TOPICS

- Timing-Offset Search via Sample Mean Square
- Timing-Offset Search via Cross-Correlation Mean Square
- Comparative Study and Implementation Aspects

07

Timing Acquisition for Ad Hoc Multiple Access

TOPICS

- Training-Based Multiuser TOE
- Blind Synchronization for Multiuser Ad Hoc Access
- TOE Performance Analysis
- Demodulation and BER Sensitivity to Mistiming

01

Introduction

02

Signal Model

03

Error Performance in Indoor Environments

TOPICS

- Pulse Amplitude Modulation and Pulse Position Modulation
- Receiver with Self-Derived Template Waveforms
- System with Multiple Antennas

01

Introduction

02

Analog-to-Digital Conversion via Signal Expansion

03

Mixed-Signal Communication Receivers Based on A/D Conversion via Signal Expansion

TOPICS

- Transmitted Signal and Channel Model
- Digital Linear Receivers Based on ADC via Signal Expansion

04

Analog-to-Digital Conversion in the Frequency Domain

05

Frequency-Domain Mixed-Signal Receivers

TOPICS

- Multicarrier Communication Systems Based on A/D Conversion in the Frequency Domain
- Relationship to the Fourier Series Coefficients
- Mixed-Signal Transmitted-Reference Receiver

01

Introduction

02

Status of UWB Transceiver Design

03

Digital UWB Receivers

TOPICS

PPM-Based TH-UWB System Model · Channel Estimation Techniques · Design of Linear Receivers · Some Thoughts about Complexity Reduction · Finite Resolution Digital Receivers

04

Analog/Digital UWB Transceivers

TOPICS

Near Full-Rate TR Transceivers · Full-Rate TR Transceivers

01

Introduction

TOPICS

Overview of IEEE 802.15.3 MAC · Overview of MBOA MAC

02

QoS Scheduling in PNC

TOPICS

Problem Definition · Deadline-Aware Scheduling Algorithm · Calculation of the Reserved CTA

03

Simulation Results

TOPICS

Power Management in IEEE 802.15.3 · Problem Definition · Proposed Approach · Simulation Results

04

Adaptive Dly-ACK

TOPICS

Problem Definition · Adaptive Dly-ACK · Simulation Results

05

Ad Hoc Networks

TOPICS

Child Piconet · Independent Piconets

01

Introduction

02

Radio Resource Management

TOPICS

- Pulse-Based UWB Physical Layer Characteristics
- Challenges and Opportunities

03

Multiple Access

TOPICS

Exclusive versus Concurrent Transmissions · Code Assignment · Interference Mitigation in TH-UWB

04

Overhead Reduction

TOPICS

ACK Mechanisms · Long Acquisition Time

05

Power/Rate Allocation

TOPICS

Power Allocation · Rate Guarantee · Rate Control · Cross-Layer Design

01

Introduction

02

Pulsed UWB Signal Model

03

Narrowband Receiver Model

04

Equivalent Receiver Model and Response to a Pulse

05

Response to a Pulse Sequence

06

Simulating the Response to a Pulse Sequence

TOPICS

I/Q Component Formulation · Simulation Parameters · Normalization · **Example Filter Response:** The n-Pole Filter

07

General Properties of the IF Output

TOPICS

Case 1: Pulse Rate Less than IF Bandwidth · **Case 2:** Pulse Rate Greater than IF Bandwidth

08

Power Spectral Density

09

Discrete PDF PSD Example: Equally Spaced, Equally Likely Time Offsets

10

Continuous PDF PSD Examples

TOPICS

The Poisson Process · Continuous PDF Uniform Random Pulse Position · Comparison of PSD and Simulation Results · Statistical Properties of the Output Envelope

01

Introduction

02

Digital-Carrier Multiband User Codes

TOPICS

Baseband Single-Carrier UWB · Baseband Multicarrier UWB

03

Low Duty-Cycle Access in the Presence of NBI

TOPICS

General Rake Reception Model · SINR Analysis · Simulations and Numerical Results

04

Improved Rate Access in the Presence of Multipath

TOPICS

Rake Reception Model with IFI · Performance Comparisons · Simulated Examples · Multiuser Interference Mitigation

01

Introduction

02

Time-of-Arrival Estimation

TOPICS

Estimation Accuracy · Energy-Collection-Based TOA Estimation · Two-Stage TOA Estimation · Simulation Results

03

Location and Tracking

TOPICS

Position Estimation · Tracking · Simulation Results

04

Location in Distributed Architectures

TOPICS

Overview · Proposed Algorithm · Simulation Results

05

Theoretical Positioning Accuracy

TOPICS

Analysis Tool · Hyperbolic Location Accuracy

WHAT IS INCLUDED

Everything You Need to Succeed

- Koenig course material for every module
- Delivery by certified instructors and subject matter experts
- Hands-on exercises throughout the course
- Course completion certificate from Koenig

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