

# OFDM

Orthogonal Frequency Division Multiplexing

## for Advanced Wireless Communications

Prior to its use in wireless systems, OFDM was more common known as DMT and found use in ADSL. The field of wireless communications has become more and more important in the past years, and new, advanced systems will go into operation soon. Examples are 3rd generation mobile telephone systems like UMTS, indoor communication systems like HIPERLAN and broadcast systems like DVB (digital video broadcast).

**OFDM** is now a bandwidth efficient digital modulation technique which forms the basis of many wireless standards currently under development. OFDM techniques are extremely popular for wireless communications and are the base algorithm technology for standards as 802.11, 802.16 and 802.20. The 3-day short course incorporates everything from the fundamentals, advantages and disadvantages of OFDM modulation to receive synchronisation techniques and case studies of cutting edge standards.



developed and  
presented by

**steepest ascent**

<http://www.steepestascent.com>

27. – 29. May 2008

Munich, Germany

09. – 11. December 2008

Munich, Germany

## OFDM – Orthogonal Frequency Division Multiplexing

### Course objective

In this course the necessary mathematical theory is presented on a “need to know basis” in a intuitive style. Through the use of simulation and DSP demonstrations attendees shall quickly learn the key principles required for a more complete understanding.

### Audience

This course has been carefully designed to present the complex mathematical theory often associated with wireless systems in an intuitive and straightforward style to a wide audience of engineers and project managers. The following prior experience is useful but not essential: Fundamentals of DSP, basic communication systems, Bachelor level mathematics

### Course Presentation

- 45 % lectures and presentations
- 15 % Tutorial discussion
- 40 % Workshop with DSP Software hand-on simulation
- Multimedia CD: hypertext of all notes, multimedia presentations, over 100 DSP audio demos, over 300 DSP demos, DSP simulation software support
- Course documentation: comprehensive 6 volume set of materials (more than 1200 pages)



### Instructor

This course will be led by Professor Bob Stewart and integrate presentations and design sessions from other experienced design engineers from Steepest Ascent.

**Prof Bob Stewart** has extensive experience presenting industry DSP courses in the USA and Europe. He is currently a faculty member of the Department of Electronic and Electrical Engineering at the University of Strathclyde. Prior to joining the University of Strathclyde, Prof Stewart was a visiting professor in Dept of Electrical Engineering at the University of Minnesota in 1990, and a visiting scholar at the University of Southern California in 1986/7. Since 1997 he has been a part-time visiting professor at UCLA.

### Services

Following services are included in the fee for this 3-day technical course: participation at the course/workshop, catering during coffee breaks , soft drinks, lunch, course documentation

The lectures are given in English. The course will be held from 9.00 a.m. to 6.00 p.m. The hotel has allocated a number of rooms. Please make your booking directly with the hotel referring to "hueggenberg gbr".

### Upcoming Training Courses

- **DSP, DSP for FPGAs and DVB-H** in Munich and Scotland
- **In House:** All courses are available for on-site presentation for your company.

## 3 Day OFDM Short Course

**Single Carrier Modulation Review:** Modulation Review, Single Carrier: Transmit & Receive, Quadrature amplitude modulation (QAM), Orthogonal carrier principles, Symbol Mapping: from QPSK to 256-QAM, Pulse shaping techniques (RRC), Matched filtering techniques, Channel noise and other imperfections, QAM - Complex Arithmetic Representations, Complex baseband multipath channels, Time & frequency channel dispersion, Inter-Symbol Interference (ISI)

**DSP OFDM "Components" Review:** The generic wireless communication system, z-domain representation of signals and systems, The Discrete Fourier Transform (DFT), The Fast Fourier Transform (FFT), The inverse FFT (IFFT), Windowing for FFTs, Digital FIR/IIR filters, Adaptive DSP techniques (LMS, RLS/QR)

**OFDM Principles:** Historical perspective: DMT, Motivation for multi-carrier vs single-carrier, Introduction to OFDM, The structure of an OFDM signal, Sub-carrier symbol structure, Generation of OFDM symbols using the IFFT, Cyclic prefix (guard interval)

**OFDM signal bandwidth:** Pragmatic OFDM Implementation, Current applications: ADSL, 802.11, 802.16, DAB, Multipath interference on an OFDM symbol, Protecting against multipath using cyclic prefix, Reducing bandwidth (windowing vs filtering), Oversampling strategies, The use of channel coding COFDM, Generic OFDM transmitter structure

**Power Considerations:** OFDM dynamic range considerations, Peak-to-average power ratio (PAR), Crest factor measurements and limits, RF Amplifier clipping considerations, Intermodulation components, General out of band power generation, Minimising / reducing PAR

**Propagation Channels:** AWGN Channels, Multipath Propagation and Channel Models, Delay Spread Values and Time Variations, Loss of orthogonality in OFDM signals, Fast and slow fading environments, Channel performance simulation (BER rates)

**Single Carrier Synchronisation and Receiver:** Design, Optimal receiver structure, Maximum Likelihood parameter estimation, Phase recovery, Frequency recovery, Symbol recovery, Equalisation techniques, Error Vector Magnitude (EVM) measurements

**OFDM Receiver Design:** Inter-Carrier Interference (ICI), Carrier frequency offset, Sensitivity to timing errors, Symbol timing recovery, Frequency domain equalisers (subcarrier), Effects of phase noise, Synchronisation using training symbols, Synchronisation using cyclic extension

**Advanced and Emerging OFDM Architectures:** DSP Hardware / Software cost for Physical Layer OFDM, Beamforming strategies, Flash-OFDM, MIMO (Multiple Input / Multiple output) techniques, CDMA Review, Multicarrier CDMA (MC-CDMA), Frequency hopping OFDMA, OFDMA vs MC-CDMA

**OFDM based Standards:** 802.11 - Physical Layer and MAC, 802.16 - Physical Layer and MAC, WiMax and 802.16e, 802.20: Mobile Broadband Wireless Access, (MBWA), 802.20: FDD and TDD Proposals, 802.20: MC 625k mode / iBurst, Some thoughts... 802.16e versus 802.20, 3GPP Long Term Evolution (LTE), LTE: E-UTRA: Downlink OFDMA and Uplink, SC-FDMA, 3G Market: 802 competition or 802 compatibility? UWB (Ultra wideband) use of OFDM.

### Achievable Skills

- On completion of this course, attendees will have a good understanding of:
- Key DSP algorithmic techniques for implementation of OFDM wireless system
  - The main components of an OFDM transmitter
  - The design strategies and components for an OFDM based receiver
  - The use of OFDM within various wireless standards
  - The DSP hardware and software implementation cost of OFDM implementation
  - The advantages (and some disadvantages) over techniques such as spread spectrum
  - Methods for channel equalisation & channel coding
  - Synchronisation techniques for OFDM based systems
  - Future evolution of OFDM systems towards more beamforming and MIMO systems



## Registration

This written registration is effective. The number of participants is limited. The invoice will be mailed with the confirmation of course registration. Please register minimum two weeks before the course starts

- via mail to hueggenberg gbr, Maximilianstraße 8, DE-82319 Starnberg – or –
- via fax to: +49-8151-55 50 09-10 – or –
- via e-mail to [info@hueggenberg.com](mailto:info@hueggenberg.com).

Terms and Conditions: Invoices have to be settled for participation. For a written cancellation within six weeks before course starts a fee of 200 € plus VAT per person is due. A deregistration within two weeks before the course will cost 50 % of registration fee plus VAT per person. For non-attendance or late notice the whole fee plus VAT per person will be charged. A substitute of the registered participant will be accepted. hueggenberg gbr reserves the right to cancel or modify the course and place at short notice and will not accept liability for costs incurred by participants or their organisations for cancelled travel arrangements and/or accommodation reservations.

Herewith I bindingly register for the **3-day technical course OFDM for Wireless Communications** at the following date. I accept the terms and conditions.

- 27. – 29. May 2008 in Munich, Germany
- 09. – 11. December 2008 in Munich, Germany
  
- € 1.980,00 regular fee
- € 1.790,00 early registration until 49 days before course
- € 1.690,00 per participant of two from the same company
- € 1.590,00 per participant of three or more from the same company
- € 1.090,00 University Rate (Please enclose evidence.)

Herewith I bindingly register for the **4-day technical course OFDM including DVB-H** at the following date. I accept the terms and conditions.

- 27. – 30. May 2008 in Munich, Germany
- 09. – 12. December 2008 in Munich, Germany
  
- € 2.450,00 regular fee
- € 2.210,00 early registration until 49 days before course
- € 2.090,00 per participant of two from the same company
- € 1.960,00 per participant of three or more from the same company
- € 1.350,00 University Rate (Please enclose evidence.)

All fees exclude state value added tax.

Name \_\_\_\_\_

Company \_\_\_\_\_

Title / Position / Department \_\_\_\_\_

Street / Mail box \_\_\_\_\_

Country-Zip Code-Town \_\_\_\_\_

Telephone \_\_\_\_\_ Fax \_\_\_\_\_

Email \_\_\_\_\_

Date Signature \_\_\_\_\_

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