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Adaptive pulse shaping for OFDM System

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ABSTRACT

The main purposes of this dissertation are to prove that, using the adaptive pulse shaping in CP-OFDM symbol timing synchronization can compensate the channel impulse response for low dispersion channels, while keeping the symbol timing offset estimator simple at the same time. It also studies the feasibility of using artificial neural networks as a real-time pulse shape generator. Finally, this research studies the different methods of implementing this artificial neural network and compares its speeds.

An optimization algorithm was used to generate a set pulse shapes, corresponding to a set of channel impulse responses, where each pulse shape could compensate the channel impulse response effect on the CP-OFDM timing offset estimator. The optimization process is very computationally expensive to be used in real time, thus the feasibility of using artificial neural network as a real time pulse shape generator was studied. A feed forward artificial neural network was trained to carry on this task. Then three implementations (CPU, DSP and FPGA) of this neural network were created. Finally, the three implementation were compared.

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
ADSL	Asymmetric Digital Subscriber Line
AI	Artificial Inelegant
ANN	Artificial Neural Network
argmax	Argument of the function at its maximum value
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CCS	Code Composer Studio
CIR	Channel Impulse Response
CP-OFDM	Cyclic Prefix OFDM
CPU	Central Processing Unit
DAB	Digital Audio Broadcast
DAC	Digital to Analog Converter
DC	Direct Current
DCE	Dispersive Channel Estimator
DFT	Discrete Fourier Transform
DOS	Disk Operating System
DSP	Digital Signal Processor
DVB-T	Digital Video Broadcast – Terrestrial
Est.	Estimator
ETSI	European Telecommunications Standards Institute
FDM	Frequency division multiplexing
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FMT	Filtered Multi-Tone
FPGA	Field Programmable Gate Array
GA	Genetic Algorithm
HDSL	High data rate Digital Subscriber Line
IBI	Inter-Block Interference
ICI	Inter-Carrier Interference
IDFT	Inverse Discrete Fourier Transform
IFFT	Inverse Fast Fourier Transform
IR	Impulse Response
ISI	Inter-Symbol Interference
LEO	Low Erath Orbit
LUT	Look-Up Table
MC	Maximum Correlation

ML	Maximum Likelihood
MMSE	Minimum Mean Square Error
MSE	Mean Square Error
NDCE	Non-Dispersive Channel Estimator
NDCE-WPS	Non-Dispersive Channel Estimator-With Pulse Shaping
OBS	Obstructed path
OFDM	Orthogonal Frequency Division Multiplexing
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
RC	Raised Cosine
RC	Raised Cosine
RF	Radio Frequency
RMS	Root Mean Square
SIR	Signal to Interference Ratio
SNR	Signal to Noise Ratio
TS	Training Set
TU	Typical Urban
TZ-OFDM	Trailing Zeros OFDM
UHF	Ultra High Frequencies
Var.	Variance
VHDL	VHSIC Hardware Description Language
VHSIC	Very High Speed Integrated Circuit
WLAN	Wireless Local Area Network
ZP-OFDM	Zero Padded OFDM

LIST OF SYMBOLS

L_{Path}	Path Loss
λ	Wave length
R	Distance
α	Path loss exponent
σ	Variance
$n(t)$	Noise
N_o	power spectrum density
$h(t)$	Channel impulse response
$\delta(t)$	Dirac delta function
$H(f)$	Channel transfer function
$\Delta\tau$	Channel Impulse response sampling time
$h(t)_b$	Channel impulse response at base band
$H(f)_b$	Channel transfer function at base band
ω_c	Carrier angular velocity
τ_n	Delay
τ_l	Channel impulse response length
τ_X	Clipped Channel impulse response length at X dB
τ_{nX}	Delays corresponding to paths within X dB of the maximum
τ_d	RMS channel delay spread
$\bar{\tau}$	The mean excess delay
$\overline{\tau^2}$	The expected value of τ^2
a_n	The amplitude of the channel impulse response at delay τ_n
B_c	Coherence bandwidth
f_c	Carrier frequency
c	Speed of light
v	Signal velocity
f_D	Doppler frequency
T_c	Coherence time
B_{signal}	Signal bandwidth
T_{symbol}	Symbol duration
N	Number of sub-channels (OFDM symbol without guard period)
$D(t)$	Base band transmitted signal
$D[x]$	Encoded data for single sub-channel
$X[k]$	In-phase component of encoded data for single sub-channel
$Y[k]$	Quadrature component of encoded data for single sub-

	channel
f_k	Sub-channel carrier frequency
K	Sub-channel number
Δf	Sub-channel frequency spacing
$r_i[n]$	The n^{th} sample from the i^{th} received complex OFDM symbol in base band
$R[k]$	Base band received signal in frequency domain
$S[n]$	Transmitted complex OFDM symbol in base band
$S[k]$	Base band transmitted signal in frequency domain
$SIR(k)$	Signal interference ratio at the k^{th} sub-carrier
Z	The ratio of the transmitter clock rate to the receiver clock rate
θ_k	Phase rotation at the k^{th} sub-carrier
$q^i(n)$	FMT transmitter i^{th} sub-channels filter impulse response
$g^i(n)$	FMT receiver i^{th} sub-channels filter impulse response
$G^i(f)$	FMT receiver i^{th} sub-channels filter transfer function
$Q^i(f)$	FMT transmitter i^{th} sub-channels filter transfer function
$Q(n)$	FMT transmitter sub-channels filter impulse response at base band
$\tilde{s}_M(i)$	Data block with length M
F_M^{-1}	IFFT matrix
s_M	Time domain block vector for the transmitted data
I_{CP}	The CP generation matrix
$s_{CP}(i)$	Transmitted signal in matrix form for CP-OFDM
$r_{CP}(i)$	Received signal in matrix form for CP-OFDM
H_{ISI}	Inter symbol interference matrix
H_{IBI}	Inter block interference matrix
$n_P(i)$	Noise matrix
$r_M(i)$	Time domain block vector for the received data
I_{ZP}	The ZP generation matrix
$s_{ZP}(i)$	Transmitted signal in matrix form for ZP-OFDM
$r_{ZP}(i)$	Received signal in matrix form for ZP-OFDM
$PM(l)$	The periodicity metric for MMSE estimator
θ_{est}	Estimated Symbol timing offset
L	Guard interval length in OFDM
P	OFDM symbol length including guard period
PWR_θ	The Power of symbol starting at sample θ
CC_θ	Complex Correlation of two symbols starting at sample θ
θ	Symbol timing offset
C_r	The correlation matrix of the received signal
N_o	Noise spectral density

$\nabla f(x_0)$	Gradient of f(x) at x_0
H_0	Hessian matrix of f(x) at x_0
g_0	Gradient of f(x) at x_0
K	Boltzmann constant
T_{temp}	Temperature of the system
T_{sample}	OFDM sampling period
$\Delta f_{sub\text{-}carrier}$	OFDM sub-carriers spacing
T	Sampling time
T_{FMT}	FMT symbol time

Chapter 1

Introduction

In high bit rate digital communication systems two, of the major impairments are the presence of transmission channels with highly fluctuating impulse response over the wide band of the signal and the limited resources of bandwidth. Orthogonal Frequency Division Multiplexing (OFDM) systems provide an effective solution to these problems, allowing for simple frequency domain equalization as well as for improving the transmission quality in a multiplexing framework, by providing frequency diversity and saving up to 40% of the signal bandwidth. The information stream is in fact partitioned into a high number of sub-streams, each one modulated over a different sub-carrier, therefore achieving a higher efficiency.
For this reason, OFDM modulation has been adopted by several high data rate digital communication standards in the last few years, such as the ADSL and HDSL for high bit rate transmission over the twisted pair and the wireless local area network (WLAN) in the USA, the digital terrestrial radio broadcasting of sounds and television (DAB and DVB-T) and the high performance radio local area network (HiperLAN) in Europe [1].

On the other hand, the use of OFDM systems with a high number of sub-carriers and hence a high efficiency has some drawbacks. For a filterless OFDM system with guard interval, as are the most commonly considered OFDM systems for their low complexity, the major drawback is its high sensitivity to synchronization non idealities due to the channel blurring effect. The operation of such a system in a portable or even mobile environment calls for a very precise acquisition and tracking of the correct synchronization. A lot of work has been done in this field to compensate the channel blurring effect by using complex synchronizers [2]. Using these complex synchronizers is against the OFDM philosophy, so it is proposed to use pulse shaping with the simple Maximum likelihood synchronizers, originally build for AWGN, to compensate the channel blurring effect in a dispersive channel.