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Time Domain & Frequency Domain Equalizers for Digital Lines

A Thesis
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بسم الله الرحمن الرحيم

شَهِدَ اللَّهُ أَنَّهُ لَا إِلَٰهَ إِلَّا هُوَ وَالْمَلَائِكَةُ وَأُولُو الْعِلْمِ قَائِمًا بِالْقِسْطِ ۚ
لَا إِلَٰهَ إِلَّا هُوَ الْعَزِيزُ الْحَكِيمُ

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STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Electrical Engineering (Electronics and Communication Engineering).

The work included in this thesis was carried out by the author at the Electronics and Communications Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

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Date: 24^{th} June, 2006.

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List of Symbols and abbreviations:

δ	A small positive constant.
$\partial\xi / \partial w_k$	The vector of gradient of the mean-square error.
$a(i)$	The desired response.
$a^{\wedge}_n$	The vector of tap-inputs in the feedback section.
$\mathbf{a_k[n]}$	Real-valued data sequences operating at a sampling rate of F_T.
a_n	System output, training sequence.
$\mathbf{b_k[n]}$	Real-valued data sequences operating at a sampling rate of F_T.
$\boldsymbol{c_k}$	The combination of the feed-forward and feed-back tap-weights.
$E\,[\,.\,]$	The statistical expectation operator.
e_n	The prediction error.
f	SFIR filter.
$\mathbf{F_c}$	Cutoff frequency.
f_{opt}	The optimum shortened filter.
$\mathbf{F_T}$	Transmission frequency.
h_0	The channel impulse response that occur after the main sample.
$H_{ch}(f)$	Bandpass frequency response.
$H_{sh}(f)$	The shortened frequency response.
$H_{eq}(f)$	The FEQ equalizer transfer function.
h_e	The estimated channel impulse response.
h_{eq}	The time domain response of equalizer.
h_{eff}	Effective channel impulse response.
h_{sh}	The shortening impulse response.
h_k	System impulse response.
h_{wall}	Samples outside the window of size N_b from the effective channel impulse response.

h_{win}	Samples inside the window of size N_b from the effective channel impulse response.
I	The identity matrix.
j_n	The combination of input samples for both sections.
L_h	The length of carrier serving area impulse response.
N	up-sampled factor
N_b	the desired length of shortened impulse response
N_f	Number of taps of SIRF filter.
q_{opt}	The optimum eigenvector corresponding to the maximum eigenvalue.
q_{min}	the smallest eigenvector associated with the smallest eigenvalue of the matrix C.
$R_{ex}(k)$	The cross-correlation function.
$\mathrm{R_{XX}}$	The correlation matrix.
$\mathbf{u_k[n]}$	Real sequence.
v	Cyclic prefix.
$\hat{w}_k^{(1)}$	The tap-weights of the feed-forward section.
$\hat{w}_k^{(2)}$	The tap-weights of the feed-back section.
$\hat{w}_k(n)$	The estimate taps weight vector.
w_k	The set of adaptive filter coefficients , taps weight vector.
W_k	The vector composed of the impulse response samples of the transversal filter.
W_k^T	The transpose of W_k.
W_{opt}	The optimal weight vector.
$\mathrm{x[n]}$	Composite signal.
$\mathrm{x_a(t)}$	Transmitted analog signal.
x_n	System input, the vector of tap-inputs in the feed-forward section.
X_{n-k}	The vector composed of the input samples to the system.

$y(i)$	The output produced by *N* taps transversal filter whose tap inputs (at time *i*).
y[n]	Received digital signal.
$y_a(t)$	Received analog signal.
$\boldsymbol{\alpha_k}$	Set of complex sequences.
λ^{n-i}	The *forgetting factor*.
μ	A small positive constant called the step-size parameter.
ξ	The mean-square error.
Φ [n]	The correlation matrix.

2B1Q	2 binary, 1 quaternary.
4B3T	4 binary, 3 ternary.
ADSL	Asymmetric DSL.
AMI	Alternate mark inversion.
ANSI	American National Standards Institute.
ARMA	Auto-Regressive Moving-Average.
ATM	Asynchronous Transfer Mode.
ATU-C	ADSL Transmission Unit at the Central office.
ATU-R	ADSL Transmission Unit at the Remote.
AWG	American Wire Gauge.
BER	Bit Error Rate.
BRITE	Basic Rate ISDN Transmission Extension.
CAP	Carrier-less Amplitude/Phase modulation.
CDSL	Consumer DSL.
CMA	Constant Modulus Algorithm.
CO	Central Office.
CRC	Cyclic Redundancy Codes.
CSA	Carrier Serving Area.
DFT	Discrete Fourier Transform.
DLC	Digital Loop Carrier.
DMT	Discrete Multi-Tone.
DOCSIS	Data Over Cable System Interface Specification.

DSL	Digital Subscriber Line.
ECH	Echo Cancellation.
FDM	Frequency Division Multiplexing.
FEC	Forward Error Control.
FEQ	Frequency Domain Equalizer.
FFT	Fast Fourier Transform.
FIR	Finite Impulse Response.
FSK	Frequency Shift Keying.
HDSL	High bit rate DSL.
IDSL	ISDN DSL.
IP	Internet Protocol.
ISDN	Integrated Service Digital Network.
ISI	Inter-symbol interference.
LMS	Least-Mean-Square.
LPF	Low-pass filter.
MCM	Multi-Carrier Modulation.
MDF MPEG-1	Main Distributing Frame. Moving Pictures Expert Group
MSSNR	The Maximum Shortening SNR.
MSE	Mean Square Error.
MVL	Multiple Virtual Line.
OFDM O. S	Orthogonal Frequency Division Multiplexing. Optimal Shortening.