Simulator of physical layer of ADSL modem

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Contents

Revision history

ver	date	author	description of changes
0	23.2.2007	Mazanec	document creation
0	23.2.2009	Mazanec	translation to ENG

1 Introduction

The report presents source code of the ADSL toolbox, which is Matlab implementation of physical layer of the ADSL modem.

ADSL toolbox itself consists of several sets of functions:

- transmitting set – prefixed with: ***tx***_*Name*
- simulation of transmission environment set – prefixed with: ***tx_rx***_*Name*
- receiver set – prefixed with: ***rx***_*Name*
- equalization at the receiver set – named after each used algotithm (***cna, mds, uec, utc,*** *etc.*)

ADSL toolbox uses *Signal Processing*, *Optimization* a *Communication toolbox* from Matlab ver. 14 or later.

2 Top level script – `do_tx_rx_rand11_adslsim.m`

Script `do_tx_rx_rand11_adslsim.m` presents an example of use of ADSL toolbox functions. It simulates following parts of ADSL transmission chain: initialization, transmission of user data, equalization at receiver.

```
[br_Mbps, BER, MMSE, params] = do_tx_rx_rand11_adslsim( SNR ,...
                                                        eq_type ,...
                                                        Ns ,...
                                                        loop_num ,...
                                                        noisemodel ,...
                                                        lower_bitload)
```

Input:

SNR	[dB], singal to added noise ratio, type of noise is defined by `noisemodel`
eq_type	['string'], equalizer algorithm : UEC, UTC, MinISI, MBR, MDS, CNA, MSSNR or MGSNR
Ns	No. of data symbols to transfer
loop_num	(1. . . 6), type of ADSL channel reference model (CSA # loop)
noisemodel	(0 or 1), 0. . . AWGN, 1. . . Model no.1
lower_bitload	(0 or 1), 0. . . No, 1. . . Yes, Bitload algorithm correction by lowering the enumerated theoretical values

Output:

Default values: br_Mbps = 0; BER = NaN; MMSE = NaN;

br_Mbps	achieved bit-rate
BER	Bit Error Ratio during data symbols transfer
MMSE	for MSE algorithms - informative value that tells how close the algorithm got to optimum design

Pre-defined and internal varialbles in output data structure – `params`

params.Ntused	no. of used tones (subcarriers), given by bitload algorithm according to given channel model
params.cplen	(=40), length of cyclic prefix in data symbols
params.Gam	Gamma [dB], internal, necesary SNR reserve for a given N-state QAM
params.Gamgap	Γ [dB], dtto
params.Codgain	Coding gain [dB], dtto
params.Margin	Margin [dB], dtto
params.power	TX Power [dBm], internal const, scaling to real-world values of power
params.Nb	length of target impulse response (TIR) for some TEQ algorithms
params.Nw	length of equalization filter response (filter order)
params.Ntu	used tones mask
params.bn	n-bits per tone, bitload vector
params.delay	optimal system delay
params.bDMT0	estimation of channel capacity: [bits/symbol], theoretical value of channel capacity
params.RDMT0	estimation of channel capacity: [Mbps], maximal theoretical value of channel throughput bit-rate
params.SNRgeo	estimation of channel capacity: [dB], geometric average of relation between channel response and per-tone SNR

3 Bitload algorithm – `waterfill.m`

- The function estimates the bitload of ADSL channel by method of Rate-Adaptive Waterfilling.
- `[Enlv, bn] = waterfill(Sh, Sn, InputPower)`
  - Sh: Power spectral density of channel response.
  - Sn: Power spectral density of added noise.
  - InputPower: internal constant for real-world power scaling (e.g.: 20dBm).
  - Enlv: output vector of estimated energy levels (per tone).
  - bn: output vector of estimated bitload values (number of bits per tone).

4 TEQ algorithms

A set of functions for equalizer filter design.

- UTC: Unit Tap Constraint to MSE algorithm, `utc.m`,
  dependency: `correlations.m`
  `[bopt, wopt, d, MSE, iopt, Dv]=utc(trainingSignal, RxTraining, Nb, Nw, Dmin,... Dmax, 0)`
- UEC: Unit Energy Constraint to MSE algorithm, `uec.m`,
  dependency: `correlations.m , eigen.m`
  `[bopt, wopt, d, MSE, Dv]=uec(trainingSignal, RxTraining, Nb, Nw, Dmin, Dmax, 0)`
- MSSNR: Max Shortening SNR, `mssnr.m`,
  `[wopt, d, Dv] = mssnr(h, cplen, Nw, Dmin, Dmax, 0)`
- MinISI: Min Intersymbol Interference, `minisi.m`,
  dependency: `obje.m , geosnr.m , maxeig.m`
  `[wopt, d, Dv, retval] = minisi(Sx, Sn, Sh, h, Nd, Nb, Nw, Dmin, Dmax,... usedChannels, 0)`
- MBR: Maximizing BitRate, `mbr_adv.m`,
  dependency: `obje.m , geosnr.m`
  `[wopt, d, Dv, retval] = mbr_adv(Sx, Sn, usedChannels, h, Nd, Nb, Nw, Dmin,... Dmax, Wsub, gamgap, Codgain, Margin, numIter, 0)`
- MGSNR: Max Geometric SNR, `geo.m`,
  dependency: `correlations.m , objective.m , objectiveconfun.m`
  `[bopt, wopt, d, MSE, Dv, retval] = geo(trainingSignal, RxTraining, Nb, Nw, Nd,... Dmin, Dmax, MSEmax, Binit, 0, usedChannels)`
- MDS: Min Delay Spread, `mds.m`,
  dependency: `mdsobj.m`
  `[wopt retval] = mds(winit, h, Nd, Nw, iter)`
- CNA: Carrier Nulling Algorithm, `cna.m`,
  dependency: `cnaobj.m`
  `[wopt retval] = cna(winit, RxTraining, Nd, Nw, Ntu, iter)`
- **Important output variables of TEQ functions:**
  - wopt: optimal TEQ coefficients found by alg.
  - bopt: optimal TIR coefficients found by alg.
  - d: optimal system delay found by alg.
  - retval: return value, if non-zero, iterative algorithm inside failed with an error
- **Important input variables of TEQ functions:**
  - trainingSignal: transmitted training sequence signal
  - RxTraining: received training sequence signal
  - Dmin $\rightarrow$ Dmax: system delay range to find an optimum
  - Sx, Sh and Sn: power spectral densities of input signal: x, noise: n, or channel: h
  - iter: maximal no. of iterations allowed to iterative algotithm
  - Nb, Nw, Ntu and Nd: dtto , in stucture `params`

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References

[1] Bingham, J. A. C. *ADSL, VDSL and Multicarrier Modulation*. A Wiley-Interscience Publication, John Wiley & Sons, Inc., New York, USA, 2000.

[2] Cioffi, J. M., Al-Dhahir, N. M. W. Efficiently Computed Reduced-Parameter Input-Aided MMSE Equalizers for ML Detection: A Unified Approach. *IEEE Trans. on Information Theory*, 42(3):903–915, May 1996.

[3] Van Acker, K. Equalization and Echo Cancellation for DMT Modems. SISTA-ESAT K.U. Leuven, Belgium, January 2001.

[4] Ysebaert, G. Equalization and echo Cancellation in DMT-based Systems. SISTA-ESAT K.U. Leuven, Belgium, April 2004.