# ADSL Receiver Modeling - Literature Survey

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**Abstract**

*Our project models and simulates the receiver part of an ADSL (Asymmetric Digital Subscriber Line) modem as per the draft specifications of the G.Lite ADSL draft standard [1]. We intend to combine our model with the model for the channel and transmitter in order to simulate a complete ADSL system.*

## 1 Introduction

Our project intends to model the receiver part of an ADSL (Asymmetric Digital Subscriber Line) modem. Trying to transmit data at a high rate in both (upstream and downstream) directions over a single pair of wires can lead to neither side being able to send or receive data. ADSL overcomes this by transmitting data at a high rate downstream and a lower rate upstream by frequency division multiplexing. It has the ability to transfer data at 9 Mb/s downstream and up to 1 Mb/s upstream. [2]. It has the ability to share the channel with voice based telephony by using frequency division multiplexing.

## 2 Objectives

The primary objective of the survey is to study the working of ADSL and also figure out feasible methods of modeling an ADSL modem based on the specifications in the G.Lite draft standard [1]. We also wanted to survey the literature for implementation details of the different blocks of an ADSL transceiver – the Time Domain Equalizer, Bit decoder and bandwidth optimization algorithms. The secondary objective is to give a summary of our plans for modeling and simulation.

## 3 Literature Survey

Digital Subscriber Line (DSL) transceivers make use of adaptive digital signal processing techniques to deal with the wide range of channel impairments encountered in the real world. It is important to accurately simulate the transmitter to get performance comparable to that of the hardware [3]. The original ADSL architecture uses quadrature amplitude modulation (QAM) to transmit data on the downstream channel [4]. This uses a single carrier frequency to modulate the signal. QAM allows telephony and the reverse channel to be frequency division multiplexed on the same pair of wires. This setup has no self-near-end crosstalk or reverse crosstalk which is what gives us the ability to transmit data over long distances. However it does have self-far-end crosstalk which needs to be modeled as a source of performance limitation along with background noise [4]. The upstream and downstream data rates cannot be equal because it is not possible to do frequency division without degradation in performance. The single carrier systems have problems adapting to wide variations in telephone lines.

An alternative to using a single frequency is to use multiple carrier frequencies. This dives the channel into sub-channels and the modem transmits data on each one. One way to get multiple channels is using Fast Fourier Transform (FFT), which gives rise to Discrete Multitone (DMT). As can be seen from Figure 1, the DMT transmitter encodes bits into symbols, does an Inverse Fourier Transform on the symbols, and then passes them through a D/A converter after adding a cyclic prefix. The cyclic prefix is needed to eliminate inter symbol interference caused by the channel [6]. However addition of symbols reduces the throughput. Since the length of cyclic prefix needs to be at least equal to the duration of the channel impulse response mi-

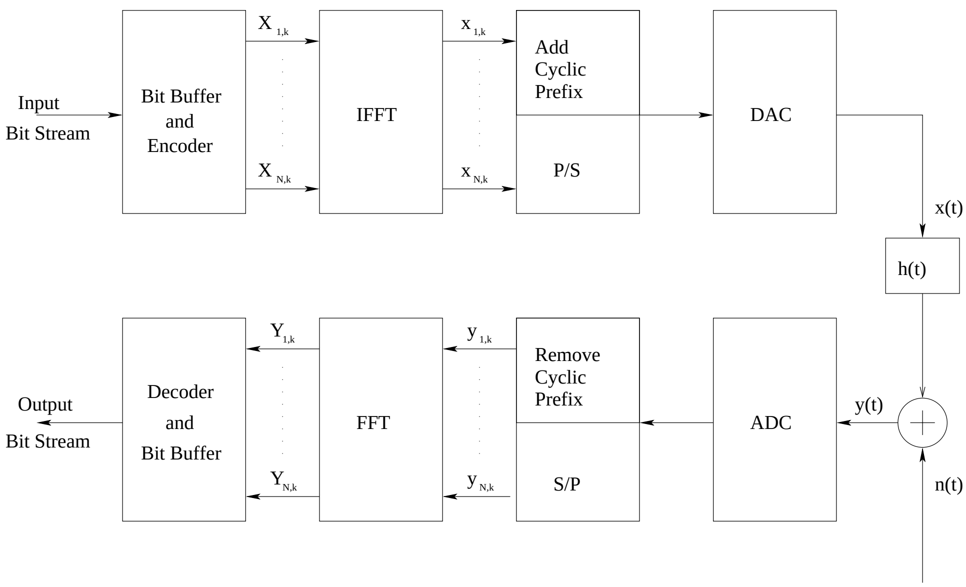


Figure 1: Block Diagram of the DMT transceiver (P/S and S/P mean parallel-to-serial and serial-to-parallel converters, respectively) [5]

nus one, a channel equalizer is used to minimize this reduction in throughput. These type of equalizers are called Time Domain Equalizer (TEQ) [7].

It was shown in [8] that the greatest throughput, for a given computational complexity, of a DMT transceiver can be accomplished using an equalizer that shortens the impulse response of the channel and a CP. In [9] the authors developed a computationally efficient algorithm that could achieve impulse response shortening unhindered by stability problems and realizable in real-time using off-the-shelf digital signal processing (DSP) hardware. In Figure 1 the TEQ would lie between the ADC and the block which removes the CP.

According to the G.Lite standard the receiver determines the optimal bandwidth allocation for the loop and communicates it to the transmitter. Water-pouring-based energy distribution algorithms are computationally impractical to implement. In [10] the authors presented a computationally efficient method for finding the optimal transmission bandwidth in terms of either maximizing the overall data throughput or maximizing the system performance margin given a fixed target data rate for high speed data transmission.

The encoding method used can also affect the performance of the ADSL system. According to Kerpez [11] using an interleaved Reed-Solomon code can greatly improve ADSL performance as compared to Trellis codes. The Reed-Solomon code virtually eliminates errors due to impulse noise and also provides a Signal to Noise gain in the presence of crosstalk.

We will be implementing a receiver for the G.lite draft standard. The standard uses DMT to transmit data over the channel. It uses separate channels for upstream and downstream transmission, obviating the need to implement echo cancellation. The standard specifies 256 downstream and 32 upstream channels. It is a splitterless implementation of DSL with a bandwidth of 1.6 Mb/s upstream and 64 Kb/s downstream.

# 4 Implementation Plans

Our simulation plan is to assume that the receiver has done all the startup and handshaking with the transmitter. This makes the assumption that all the channel parameters are known and do not change. Since we are implementing the G.Lite standard [1], the upstream and downstream are separated in the frequency domain and there is no need to do any echo cancellation.

The development will be done using synchronous data flow (SDF) in Agilent EEsof. The model for the receiver will be combined with the models for the channel and the transmitter in order to simulate the entire ADSL system. We will narrow the interpretation of the standard as needed to simplify the modeling.

The main impact of our project will be to provide a complete model of an ADSL system in conjunction with the transmitter and channel model being developed by the other groups.

## References


[1] "Splitterless asymmetric digital subscriber line (ADSL) transceivers - draft recommendation G.992.2," tech. rep., International Telecommunication Union, February 1999.

[2] K. Maxwell, "Asymmetric digital subscriber line: Interim technology for the next forty years," *IEEE Communications Magazine*, vol. 3401, pp. 100–106, October 1996.

[3] J. M. MacDonald and G. Young, "Computer simulation of digital subscriber loop transceivers," in *Sixth International Conference on Digital Processing of Signals in Communications*, pp. 169–174, 1991.

[4] K. J. Kerpez and K. Sistanizadeh, "High bit rate asymmetric digital communications over telephone loops," *IEEE Transactions on Communications*, vol. 43, June 1995.

[5] N. Al-Dhahir and J. M. Cioffi, "Optimum finite-length equalization for multicarrier transceivers," *IEEE Transactions on Communications*, vol. 44, pp. 56–64, January 1996.

[6] A. Ruiz, J. M. Cioffi, and S. Kasturia, "Discrete multiple tone modulation with coset coding for the spectrally shaped channel," *IEEE Transactions on Communications*, vol. 40, pp. 1012–1029, June 1992.

[7] B. Farhang-Boroujeny and M. Ding, "An eigen-approach to the design of near-optimum time domain equalizer for dmt transceivers," in *Proceeding of IEEE International Conference on Communications*, (Vancouver, Canada), pp. 937–941, June 1999.

[8] J. S. Chow and J. M. Cioffi, "A cost-effective maximum likelihood receiver for multicarrier systems," in *Proceedings of the IEEE International Conference on Communications*, pp. 948–952, June 1992.

[9] P. J. W. Melsa, R. C. Younce, and C. E. Rohrs, “Impulse response shortening for discrete multitone transceiver,” *IEEE Transactions on Communications*, vol. 44, pp. 1662–1672, December 1996.

[10] P. S. Chow and J. M. Cioffi, “Bandwidth optimization for high speed data transmission over channels with severe intersymbol interference,” in *Proceedings of IEEE Global Telecommunications Conference*, pp. 59–63, December 1992.

[11] W. Y. Chen, *DSL Simulation Techniques and Standards Development for Digital Subscriber Line Systems.* Macmillan Technical Publishing, 1998.