SYMMETRICAL HIGH-SPEED DIGITAL SUBSCRIBER LINE (SHDSL) CHANNEL MODELLING

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ABSTRACT

Symmetrical high-speed digital subscriber line (SHDSL) is a data communication technology for equal transmits and receive data rate over the copper telephone lines. Difference from other DSL technologies, SHDSL uses multi-level pulse-amplitude modulation (PAM) together with trellis coding. It is much faster than a conventional voiceband modem that can provide nowadays. In this study the speed of the SHDSL system was evaluated and estimated by observing the Bit Error Rate (BER) during simulation process. Simulation of SHDSL single line base band and transceiver was conducted by given the information to the system including a transmitter, a receiver and a channel model. This simulation, perform a certain state of trellis code and using a certain rate convolution with corresponding of Viterbi algorithm at the receiver part. In the channel part, the calculation of signal-to-ratio (SNR) was performed and this includes the insertion loss in the channel, Far-end crosstalk (FEXT) and Near-end crosstalk (NEXT), and Power Spectral Density (PSD). All this is referred to the standard ITU-T G.991.2. For the result of this study, the BER achieve is 10^{-6} with transmitted bits of 10^{6} bits. The BER achieved is based on the calculated SNR and the value of SNR to get BER 10^{-6} is around 37dB. It is assuming that the BER can be achieve 10^{-7} by transmit 10^{9} of bits. By performing this simulation with the result stated, the SHDSL can be estimate its speed.

ABSTRAK

Simetri kelajuan tinggi talian pelanggan digital (SHDSL) adalah teknologi komunikasi data untuk memancar sama dan menerima kadar data melalui talian telefon tembaga. Perbezaan daripada teknologi DSL lain, SHDSL menggunakan pelbagai peringkat modulasi nadi amplitud (PAM) bersama-sama dengan trellis pengkodan. Ia adalah lebih cepat daripada modem jalur suara konvensional yang boleh memberikan masa kini. Dalam kajian ini kelajuan sistem SHDSL itu dinilai dan dianggarkan dengan memerhatikan Kadar Bit Error (BER) semasa proses simulasi. Simulasi band asas SHDSL baris dan transceiver dikendalikan diberikan maklumat untuk sistem termasuk sebuah pemancar, penerima dan model saluran. Simulasi ini, melaksanakan keadaan tertentu kod jari-jari dan menggunakan kekusutan kadar tertentu dengan sepadan algoritma Viterbi di bahagian penerima. Dalam bahagian saluran, pengiraan isyarat kepada nisbah (SNR) telah dilaksanakan dan ini termasuk kehilangan sisipan dalam saluran, Far-end crosstalk (FEXT) dan Near-end crosstalk (NEXT), dan kuasa spektral Ketumpatan (PSD). Semua ini disebut standard ITU-T G.991.2 itu. Untuk hasil daripada kajian ini, BER mencapai adalah 10^{-6} dengan bit dihantar 10^{6} bit. The BER dicapai adalah berdasarkan SNR dikira dan nilai SNR untuk mendapatkan BER 10^{-6} adalah sekitar 37dB. Ia menganggap bahawa BER boleh mencapai 10^{-7} oleh penghantar 10^{9} bit. Dengan melakukan simulasi ini dengan keputusan yang dinyatakan, SHDSL boleh menjadi menganggarkan kelajuannya.

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ABBREVIATIONS

ADSL	Asymmetric Digital Subscriber Line
AFE	Analog Front End
BER	Bit Error Rate
DFE	Decision Feedback Equalizer
DMT	Discrete Multitoned Transmission
DSL	Digital Subscriber Line
DSP	Digital Signal Processor
FEXT	Far-end Crosstalk
FFE	Feed Forward Equalizer
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FPGA	Field Programmable Gate Array
HDSL	High-Bit-Rate Digital Subscriber Line
IL	Insertion Loss
ISDN	Integrated Services Digital Network
ITU-T	International Telecommunication Union Standardization
LMS	Least Mean Squares

MIMO	Multi Input Multi Output
MIPS	Million Instruction Per Second
NEXT	Near-end Crosstalk
PAM	Pulse Amplitude Modulation
PBO	Power Backoff
PDR	Payload Data Rate
PMD	Physical Medium Dependent
POTS	Plain Old Service
QAM	Quadrature Amplitude Modulation
RX	Receive
SDSL	Symmetric Digital Subscriber Line
SHDSL	Symmetric High-Speed Digital Subscriber Line
SNR	Signal-to-Noise Ratio
STU	SHDSL Transceiver Unit
STU-C	STU at the Central Office
STU-R	STU at the Remote End
SRU	SHDSL Regenerator Unit
TCM	Trellis Coded Modulation
TCPAM	Trellis Coded Pulse Amplitude Modulation
THP	Tomlinson-Harashima Precoder
TM	Telecom Malaysia
TM R&D	Telecom Malaysia Research and Development
TX	Transmit
VDSL	Very-High-Bit-Rate Digital Subscriber Line

CHAPTER 1

INTRODUCTION

1.1 Project Overview

Digital Subscriber Line (DSL) is a broadband high-speed internet technology that brings high-bandwidth information to homes and offices over ordinary copper telephones lines analog form and back to digital form. Digital data is transmitted directly to the computer, as is, exploiting the maximum bandwidth and the wide range of unused frequencies available in the existing copper wire of telephone networks for high-speed broadband communication. Moreover, the signal can also be separated if one chooses, so that some of the bandwidth is used to transmit an analog signal for simultaneously using the telephone line for voice.

DSL can achieve higher data-transfer-rates than dail-up modems by utilizing more of the available bandwidth in a local loop. The old telephone service only makes use very limited amount of the lower frequencies. But the bandwidth of the old telephone service is enough for transmitting reasonable-quality analog voice. Although the service is enough for transmitting reasonable-quality of data but it is unable to transmit high-speed data. Most DSL technology sent their digital signals over twisted-copper telephone lines (local loop) using amplitude-modulated analog tones. This technique is referred to as discrete multitoned transmission (DMT). Today, there are many type of DSL technology as shown in Table 1.

Table 1.1: DSL Technology version since 1999 to 2005

Family	**ITU**	**Name**	**Ratified**	**Maximum Speed Capability**
ADSL	G.992.1	G.dmt	1999	7 Mbps down, 800 kbps up
ADSL2	G.992.3	G.dmt.bis	2002	8 Mbps down, 1 Mbps up
ADSL2plus	G.992.5	ADSLplus	2003	24 Mbps down, 1 Mbps up
ADSL2-RE	G.992.3	Reach Extended	2003	8 Mbps down, 1 Mbps up
SHDSL (update 2003)	G.991.2	G.SHDSL	2003	5.6 Mbps up/down
VDSL	G.993.1	Very-high-data-rate DSL	2004	55 Mbps down, 15 Mbps up
VDSL2 – 12 MHz long reach	G.993.2	Very-high-data-rate DSL 2	2005	55 Mbps down 30 Mbps up
VDSL2 – 30 MHz short reach	G.993.2	Very-high-data-rate DSL 2	2005	100 Mbps up/down

SHDSL is the first standardized multi-bit-rate symmetric DSL for data rates between 192kbit/s up to 2312kbit/s. A state-level trellis coded PAM line code is used for this technology. At present, SHDSL system uses PAM modulation and trellis coded modulation and is hence more spectral efficient than HDSL. It uses two-way baseband transmission and will cause NEXT and FEXT interference to other system. The specification is given in ITU-T Recommendation G.991.2 [1].

When compared to other symmetric transport technologies such as SDSL and HDSL, SHDSL boasts approximately 30 percent greater reach. A good example is that the highest bit rate defined in the standard (2.3 Mbps) is supported at loop length up to 2.3 kilometers.

1.2 Problem Statement

In SHDSL, FEXT and NEXT is the interference happen when the signal travel in both directions. The impact of the special correlation characteristic of these noises impacts the performance of SHDSL when a cable or binder is used in a MIMO configuration. MIMO configurations involve the combined or joint processing of more than one, single, twisted pair loop. Even though SHDSL can support at high data rate, there is still possibility that the BER of the system is high.

1.3 Objectives

To complete this project, there are several objectives need to achieve. The objectives of this study are:

I. To design and develop channel model for SHDSL in MATLAB for MIMO system based on TCPAM.
II. To propose and develop a noise cancellation technique for FEXT and NEXT.
III. To introduced modelling and performance study of SHDSL using TM copper cable data (insertion loss, FEXT and NEXT).

1.4 Scope of work

The scope of the study is designing a channeling model for SHDSL system. The design of SHDSL system will be use MATLAB software. From the simulation result the data generated (data transmit) will be compare with the receive data and the BER will be monitor. If the result did not get as mentioned, the MATLAB coding need to be troubleshoot and identify the bug in the coding thus insert the new coding. The flow for work are as follows:

1. Develop and design channel model in MATLAB programming for MIMO system based on Trellis Coded Modulation (TCM) and Pulse Amplitude Modulation (PAM) to predict achievable bit rate performance. The design of the system is followed on the block diagram and the specification is followed ITU-T G.991.2 standard.
2. Development of workable noise cancellation technique FEXT and NEXT model for the SHDSL. The specification is followed ITU-T G.991.2 standard.
3. Performance study and modeling of SHDSL based on TM copper cable (IL, FEXT and NEXT), thus calculate the SNR. The SNR specification is followed ITU-T G.991.2 standard.
4. Run the simulation and display the result BER and SNR.
5. Report writing and result dissemination.

1.5 Project Significance

At the end of this project I will be able to understand the basic knowledge and information on whole process of research methodology by completing the SHDSL project. The understanding about principle and how the system works including the components and materials involve can be achieved in the progress during this project.

CHAPTER 2

LITERRATURE REVIEW

2.1 Digital Subscriber Line (DSL)

There are many advances in symmetric DSL technology since its first develop and introduce in the early 90's. The technology opened a new dimension of communication technology that recognizing bandwidth on the local copper loops are not limited by the application, voice or Plain Old Service (POTS). The combination of new line code and Digital Signal Processor (DSP) techniques can provide greater bandwidth. Line codes, when combined with other techniques will reduce power, achieve longer reach, improve performance and encode more data within the spectrum of frequency. This new line codes technology was called as Trellis Coded PAM (TCPAM). The amount of usable bandwidth available over a loop is dependent on a number of factors, including loop length, impedance, signal power, frequency and line coding techniques. The higher the frequency, the greater the attenuation, and the smaller the signal becomes when it is received at the far end. The strength of the received signal decreasing as the frequency increases.

There are two general categories of DSL which are symmetric and asymmetric. Symmetric DSL provides the same service bit-rate in both upstream and downstream directions. While asymmetric DSL (ADSL) provides more downstream bit-rate (from the network to the user) than upstream bit-rate. To date, SHDSL represents the best of several symmetric DSL technologies employs trellis-coded pulse-amplitude modulation (TCPAM) providing greater reach, spectral compatibility, low power and application flexibility.

2.2 Overview on Asymmetric Digital Subscriber Line (ADSL) Technology

Asymmetric digital subscriber line (ADSL) uses existing twisted pair telephone lines to create access paths for high-speed data communications and transmits at speeds up to 8.1 Mbps to a subscriber. This exciting technology is in the process of overcoming the technology limits of the public telephone network by enabling the delivery of high-speed Internet access to the vast majority of subscribers' homes at a very affordable cost.

Delivery of ADSL services requires a single copper pair configuration of a standard voice circuit with an ADSL modem at each end of the line, creating three information channels – a high speed downstream channel, a medium speed upstream channel, and a plain old telephone service (POTS) channel for voice. Data rates depend on several factors including the length of the copper wire, the wire gauge, presence of bridged taps, and cross-coupled interference. The line performance increases as the line length is reduced, wire gauge increases, bridge taps are eliminated and cross-coupled interference is reduced. The modem located at the subscriber's premises is called an ADSL transceiver unit-remote (ATU-R), and the modem at the central office is called an ADSL transceiver unit-central office (ATU-C). The ATU-Cs take the form of circuit cards mounted in the digital subscriber line access multiplexer (DSLAM). A residential or business subscriber connects their PC and modem to a RJ-11 telephone outlet on the wall. The existing house wiring usually carries the ADSL signal to the NID located on the customer's premises.

2.3 Overview of SHDSL System Performance

SHDSL is a flexible multi-bit-rate system, which support symmetric user data rates from 192 kbit/s to 2312 kbit/s. SHDSL is a guaranteed service, in which that the system technology must deliver a certain data rate in order to achieve 10^{-7} bit error at certain distance under worse case noise condition. The line code use for SHDSL is 16-level trellis coded baseband PAM, which also use for HDSL2. The use of convolution encoders is to increase loop performance give a major impact from earlier technology that use the same baseband PAM such as ISDN or HDSL, which use uncoded 4-level PAM. For the convolution rate, rate-1/2 code rate is used. Three information bits are mapped onto a 16-level PAM symbol and since the latency requirements do not allow use outer feed-forward encoders, trellis coders with large numbers of states are used to provide the necessary coding gain. For example, trellis code with 128 states provides 4.6 dB effective coding gain; 256 states provide 4.9 dB, and 512 states provide 5.1 dB coding gain [2].

In this study, show a general structure of SHDSL or HDSL transceiver. The main difference of SHDSL and HDSL is the additional of trellis encoder and decoder and the use of Tomlinson precoding. Figure 1 shows the block diagram of typical realization of an SHDSL system.

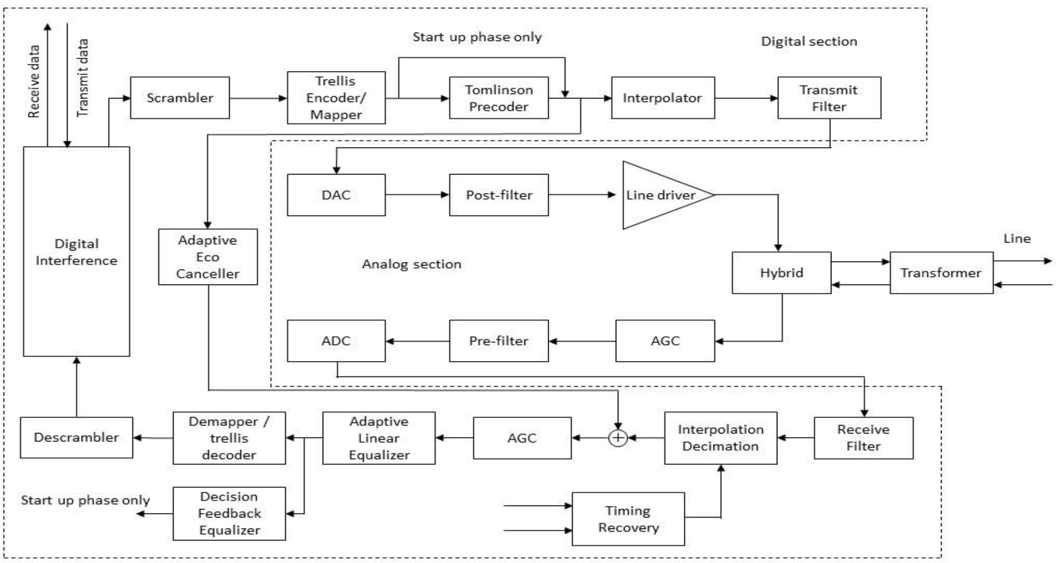

Figure 2.1: Typical Realization of an SHDSL System