Advanced Signal Processing 1

Digital Subscriber Line

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1. Introduction

As a transmission technology, digital subscriber line was originally developed for the Intergraded Service Digital Network (ISDN) Basic Rate Access channel to describe the physical layer. DSL is not a service- it is a transmission technology that can be used to support a wide variety of services. Different DSL equipment implementations are required to support different service. Today, DSL or xDSL is used as a generic name for any DSL system.

In this seminar work will be discuss about development history, transceiver structure, performance objectives, network interface, standards of DSL, and service of DSL.

2. History of DSL

The DSL technology was developed at the ANSI working group T1D1.3, mainly during 1985 and 1986. An initial version of the standard document for DSL was delivered during 1988.
DSL provides transmission capability for a single ISDN Basic Access customer over a nonloaded, two - wire telephony loop. Transmission throughput is 160 kbps (payload throughput 144 kbps and overhead throughput 16 kbps).The payload throughput is shared into two B channels (digital telephony) and one D channel (signalling and packetization).
For the two- wire, full - duplex transmission exist three methods:

1. Frequency Division Multiplex - FDM
With the FDM or FDD (Frequency Division Duplex), the two directions of transmission are assigned to different frequency bands.
Thus same line code and symmetrical bandwidth, the range of the system was determined by the range of the lossier frequency band. Cause heavy range penalty, FDM was ruled out for the DSL.

2. Time Compression Multiplex - TDM
In this case, the two directions of transmission are separated in time. The transmission occurs in half- duplex mode. The quiescent period between bursts must be long enough to allow for slight errors in synchronisation between opposite ends of the transmission path and to permit transients to die down sufficiently. That requires the baud rate of aprox. 2.25 times.

The principle of TCM burst
The first row represents data to be transmitted from a CO(Central Office) to a subscriber. The second row represents continuous data to be transmitted from subscriber to a CO.
The compressed CO - to - subscriber data and compressed subscriber - to - CO are shown in the third row. The fourth row is the decompressed CO - to - subscriber data arrived at the subscriber end. And. the fifth row is the decompressed subscriber - to - Co data arriving at the CO end.

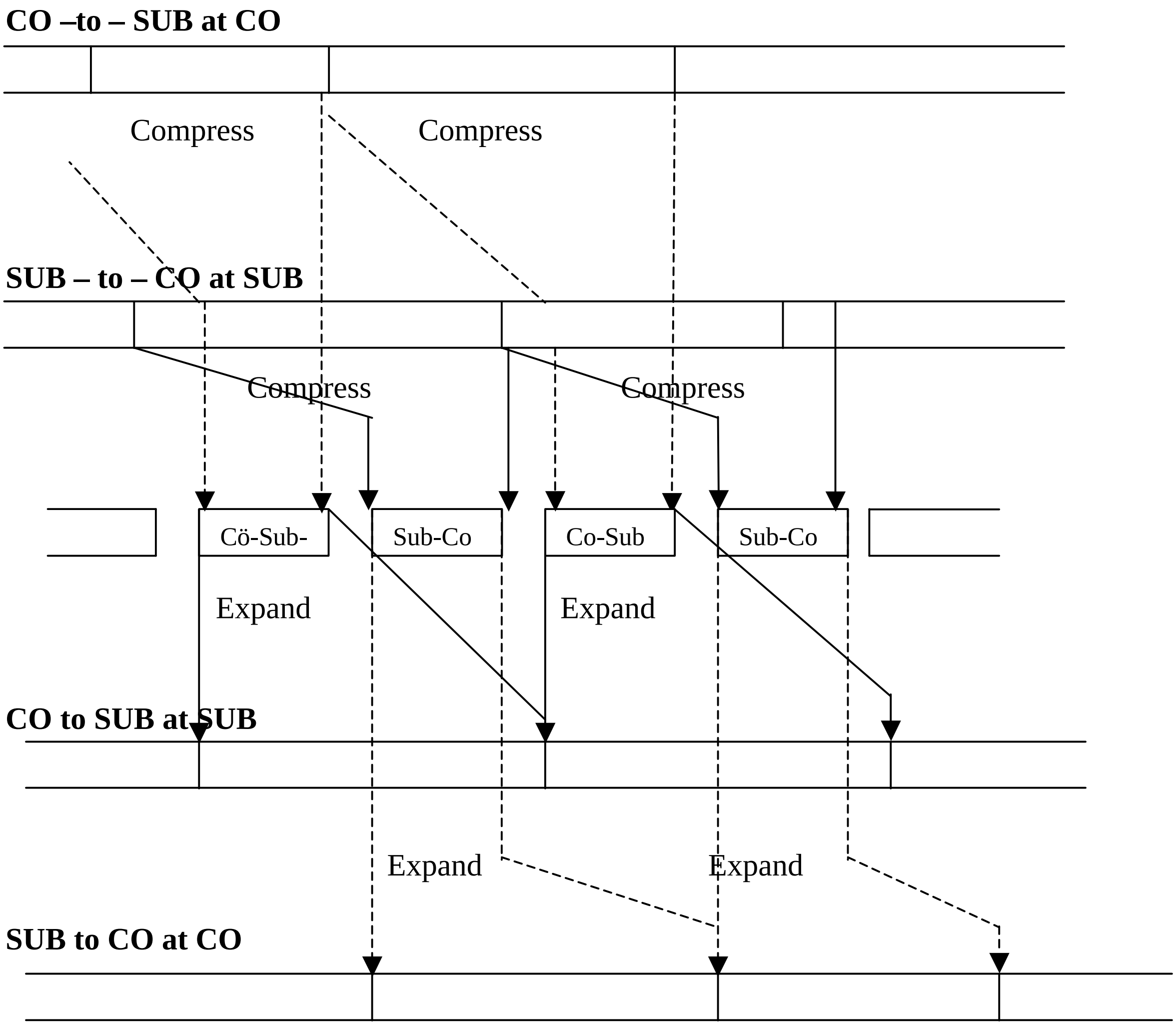


Fig.2.1 TCM Burst Principle

3. Echo Cancellation - EC

The two directions of transmission are separated by hybrid circuit and echo canceller. The hybrid circuit provide only 15 dB of separation and echo cancellation 60 dB. 60 dB is required to remove the residual echo. In other words, 75 dB is required to make the residual echo level much lower than the weak received signal level over a long telephone subscriber loop.

The central points in the choice between this methods are transmission loss, echo level, compatibility with other systems, and system complexity. The TCM system has the advantage of not requiring an echo canceller, as the separation of different transmission directions occurs in time. The EC system is more complex .

2.1 DSL Line Codes

DSL Line Codes and Relative Performance Parameters:

Code	**Input**	**Output**	**Bit/Symbol**	**Redundancy**	**Margin**
2B1Q	2 bits	1 quaternary	2	0	12 dB
3B2T	3 bits	2 ternary	3/2	1/9	9-10 dB
4B3T	4 bits	3	4/3	11/27	9-10 dB
AMI	1 bit	1	1	1/3	6-8 dB
MDB	1 bit	1	1	1/3	6-8 dB
Mannchaster	1 bit	1 bit	1	0	2-4 dB

The codes considered in the ANSI T1D1.3 working group. There are two general characteristic of line code that are determinants of their transmission performance:
the transmit symbol pulse shape and the logic bit encoding of the symbol. Both affect the spectrum of a code.

3B2T – maps the eight possible combinations of three bits of information into the nine possible combinations of two ternary symbols
4B3T – maps 16 possible combination of four bits of information into the 27 possible combinations of three ternary symbols.
MDB (Modified Duobinary) – baud rate = bit rate
AMI (Alternate Mark Inversion) – baud rate = information rate

The choice between line codes is depended on system cost and implementation issues.

3. DSL Transceiver Structure and Line Code

In the Figure .3.1 is to see a general DSL transceiver structure

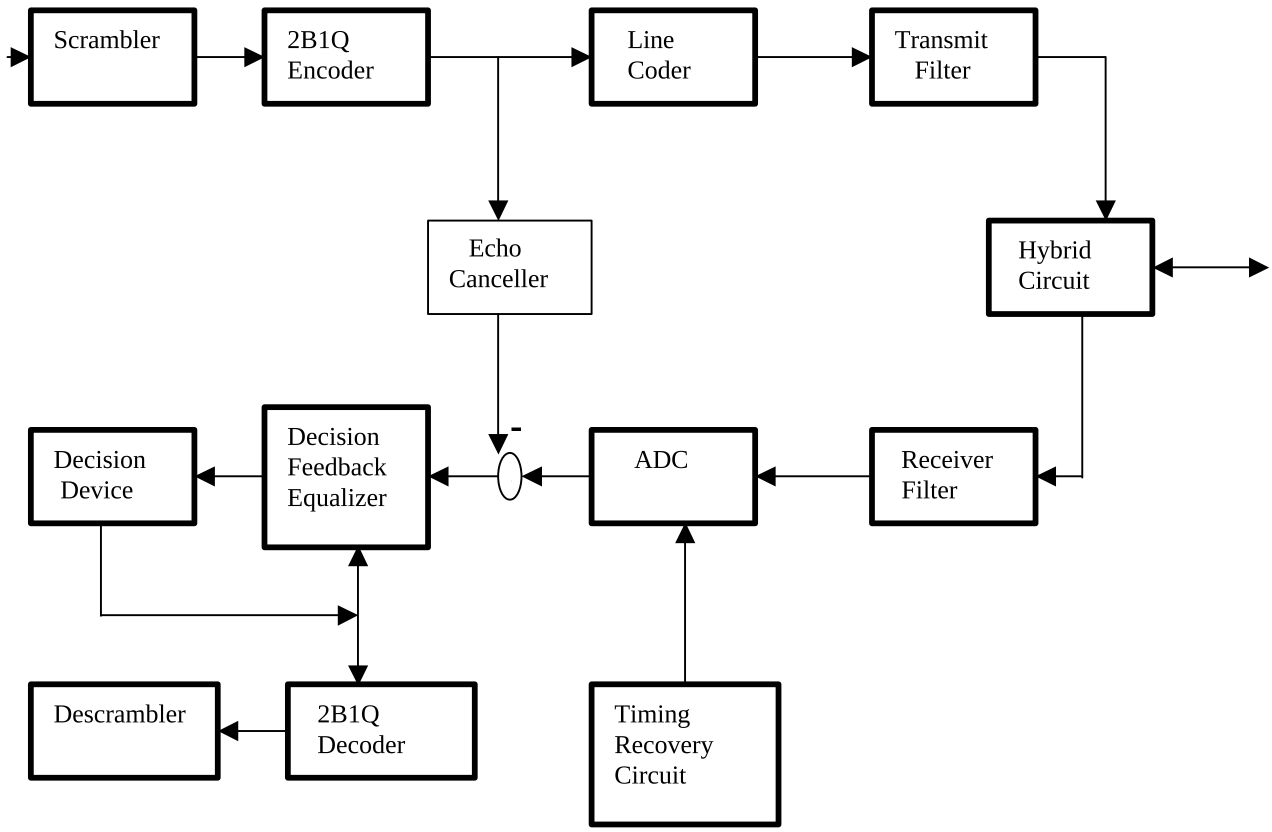


Fig. 3.1 General DSL transceiver Structure

The data is first scrambled to prevent long stream of zeros or nons. Every two bits of transmit signal are encoded into a symbol through 2B1Q encoder. The symbol or baud rate is therefore one - half of the bit rate. It is send to line encoder, which can be a Digital to Analog Converter with or without a digital pulse shaping function.
A Butterworth lowpass filter second order is used for transmission of filter and receiver filter. The transmission filter reduces the out- of - band energy and the receiver filter minimises the out - of - band noise. The preamplifier brings the received signal to the proper voltage level.
The same data symbols are sent to the echo - canceller - which resembles the equivalence of the echo path, including transmit filter, hybrid circuits, receiver filter, and ADC at the ADC sampling rate.
The decision device is a four- level threshold detector corresponding to the 2B1Q line code. Here generated symbols are converted back to informations bits trough the 2B1Q decoder. The binary bit information is descrambled to obtain the original data stream.

3.1 DSL 2B1Q Line Code Parameters

2B1Q line code coverts block of two consecutive signal bits into a single, four - level pulse. The signalling baud rate is the half of the information rate.

general transceiver parameters

Line Code	2B1Q
Bandwidth	40 kHz
Baud rate	80 kHz
Line rate	160 kbps
Transmit power	12.99 dBm

The sampling rate or baud rate is 80 kHz, resulting in a 3 dB transmission bandwidth of 40 kHz. For the 2B1Q line code, each baud carries two bits of information and therefore is the transmission throughput 160 kbps. The max. transmit output voltage is 2.2 V ad for a lie impedance of 135 Ohm, the total transmit power is 12.99 dBm.

3.2 DSL Equalizer Requirements

The length of the decision feedback equalizer should be long enough to cover the duration of the equivalent channel impulse response. This is the combination of the transmit filter, transmit transformer, the twisted - pair loop channel, the receiver transformer, and the receiver filter.

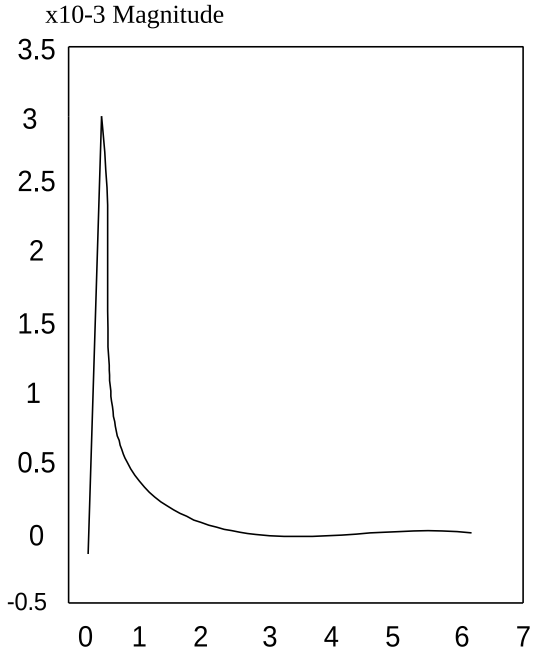


Fig. 3.2 Impulse response of the 15 kft, 26 - Gauge Loop

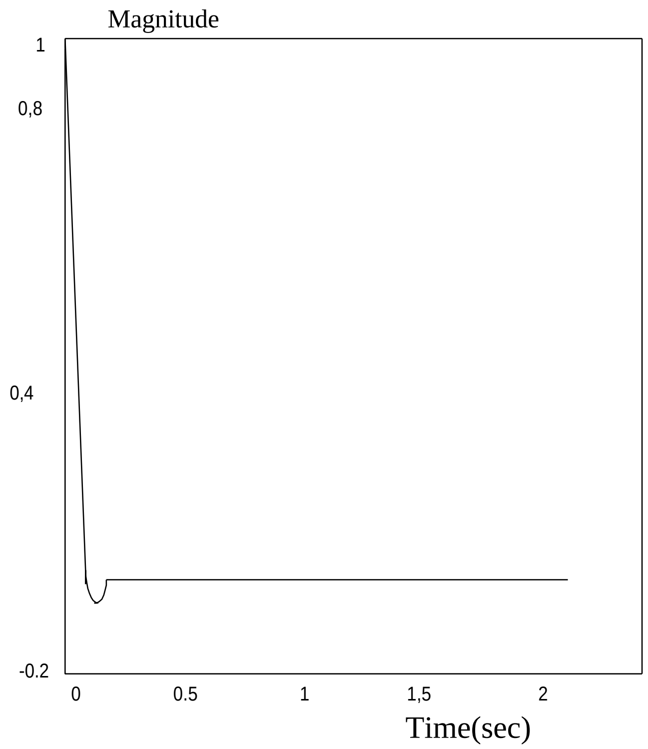


Fig. 3.3 Impulse response of the Butterworth Filter

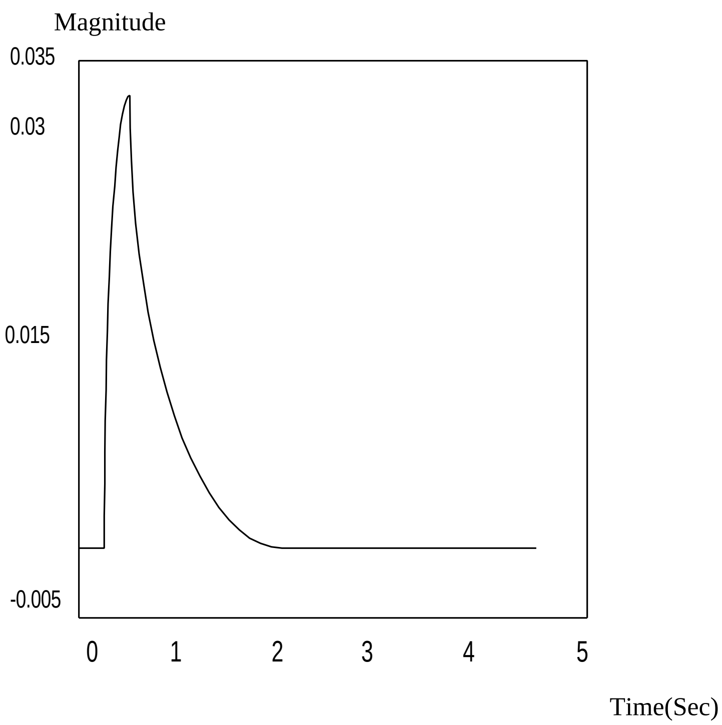


Fig. 3.4 Impulse response of the Equivalent Channel

3.3 DSL Echo Canceller Requirements

The length of the echo canceller should be enough to cover the duration of the equivalent echo path impulse response. The equivalent echo path is the combination of the transmit filter, the echo path, ad the receiver filter.

3.4 DSL Timing Recovery Circuits

DSL timing recovery circuits can be implemented with the spectral line method.

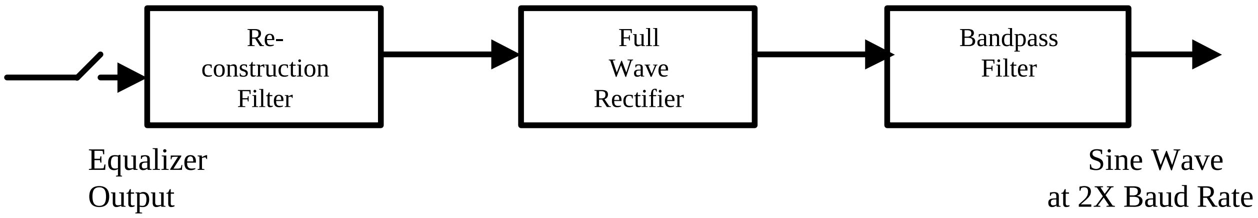


Fig. 3.6 A spectral line timing recovery circuit

Reconstruction filter generates an analog version of the equalised and echo - cancelled signal.
Full- wave rectfilter generates harmonics of the received signal.
Band- pass filter selects the desired sampling frequency.

The timing recovery circuit can be implemented with digital circuits with a sampling rate that is a least three to four times the baud rate.

4. DSL Performance Objectives

The performance of the DSL is decided by the transmission characteristics of the twisted-pair telephone loop, the receiver front - end noise level, and the structure of the DSL transceiver. Because of the use of the echo – cancellation – based full – duplex method, the dominant noise component at the receiver front end is the self Near End Crosstalk (NEXT). The self – Next is induced by neighbouring DSL transmitter.

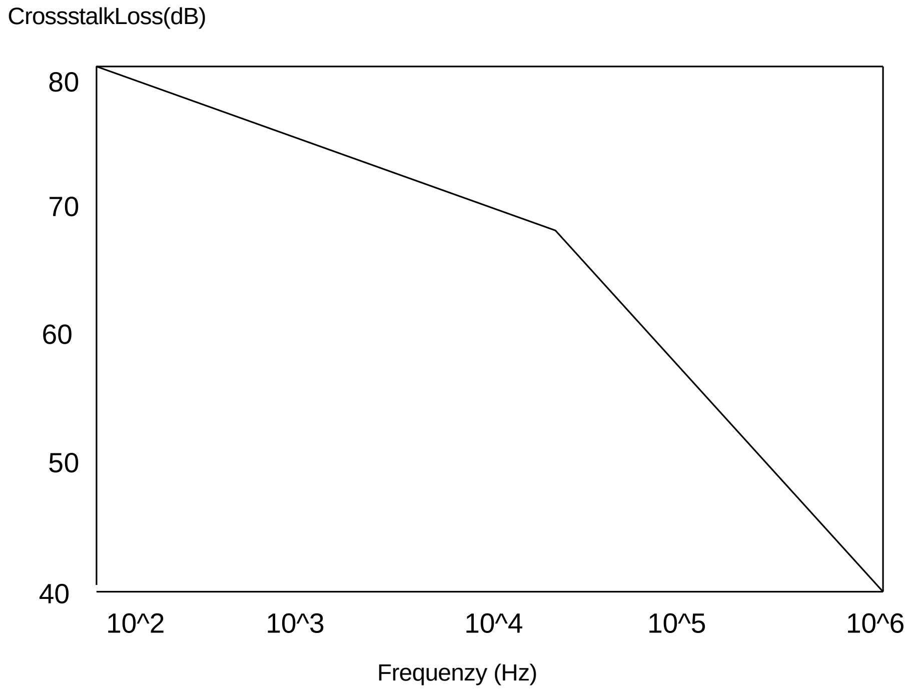


Fig. 4.1 NEXT Model

The NEXT noise level depends on the transmit signal level and the NEXT loss. The DSL NEXT loss model is derived from the 1 percent, 49 – disturber NEXT loss model.
And, the performance of DSL system can be estimated through computer simulation. A white binary sequence is generated and encoded as a random data symbol sequence. The binary sequence is generated at the data transmission rate and 2B1Q encoded into symbol rate.
A white Gaussian sequence is generated to drive the NEXT filter. Also, it is generated at the simulation sampling rate.

5. DSL Network Interfaces

DSL was developed for the Basic Rate Access ISDN interface with two B ad one D channel. The total transmission throughput for this channels is 144 kbps and the transmission throughput of DSL is 160 kbps. The 16 kbps difference is allocated for overhead channel. B channels can be used for either POTS or data application, or they can be reserve multiplexed to provide a digital link between end users with transmission throughput of 128 kbps. The D channel ca be used for packet - oriented application, to send switching signal (SS7). And, the overhead channel connects DSL transceivers at both ends after the initialization of the DSL link. The overhead channel consists of timing and framing information, consuming a throughput of 12 kbps, and the network operation information, consuming throughput of 4 kbps.
A DSL is designed to provide Basic Rate Access ISDN connection between an ISDN capable Central Office (CO) and subscriber ISDN terminal equipment.

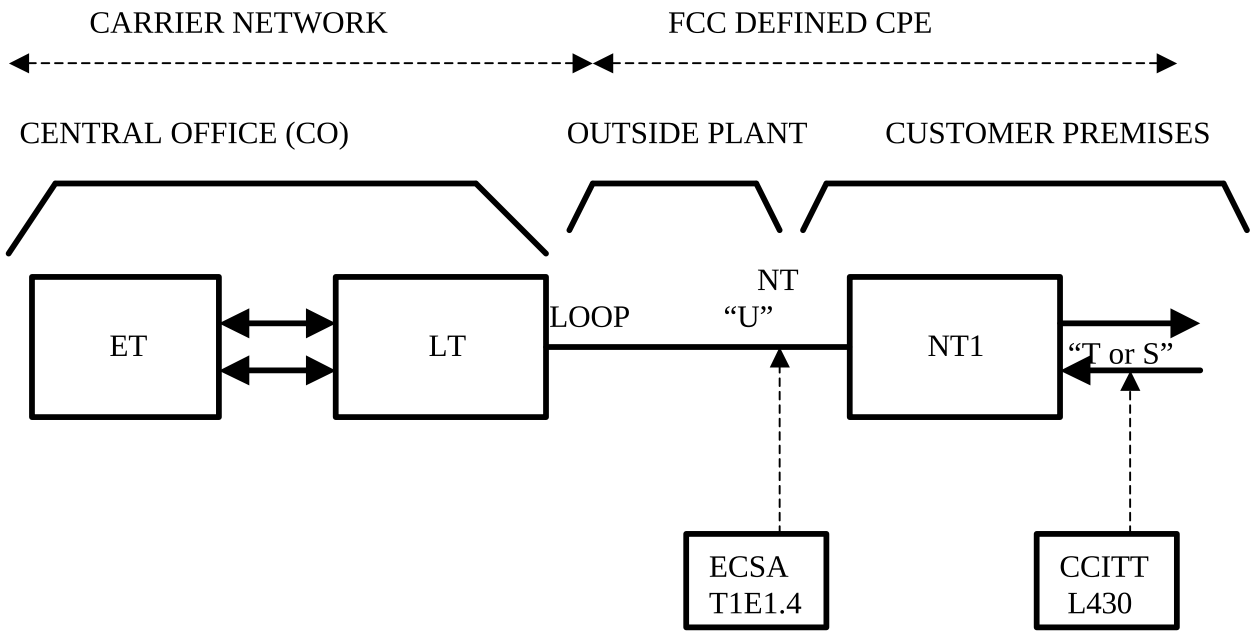


Fig. 5.1 Components of a DSL link

- Line Termination (LT) - the DSL transceiver at the CO side
- Network Termination 1 (NT1) -the DSL transceiver a the subscriber side
- U interface - the connection between a DSL transceiver and the twisted - pair loop for LT and NT1
- T interface - the connection between an NT1 and subscriber terminal equipment (TE)
- Network Termination 2 (NT2) - placed between an NT1 and TE
- S interface - the connection between NT2 and TE
- Exchange Termination (ET) - connects the telephone network to an LT

6. DSL Standards

The key features of the ANSI 2B1Q DSL standards are:

6.1 DSL Gray Encoder

The 2B1Q line code use the Gray encoder to encode every two bits into a quaternary symbol:

First Bit (Sign)	Second Bit (Magnitude)	Quaternary Symbol (Quat)
1	0	+3
1	1	+1
0	1	-1
0	0	-3

6.2 DSL Pulse Mask

The DSL line signal from a transmitter should confirm the pulse mask defined in the time domain.

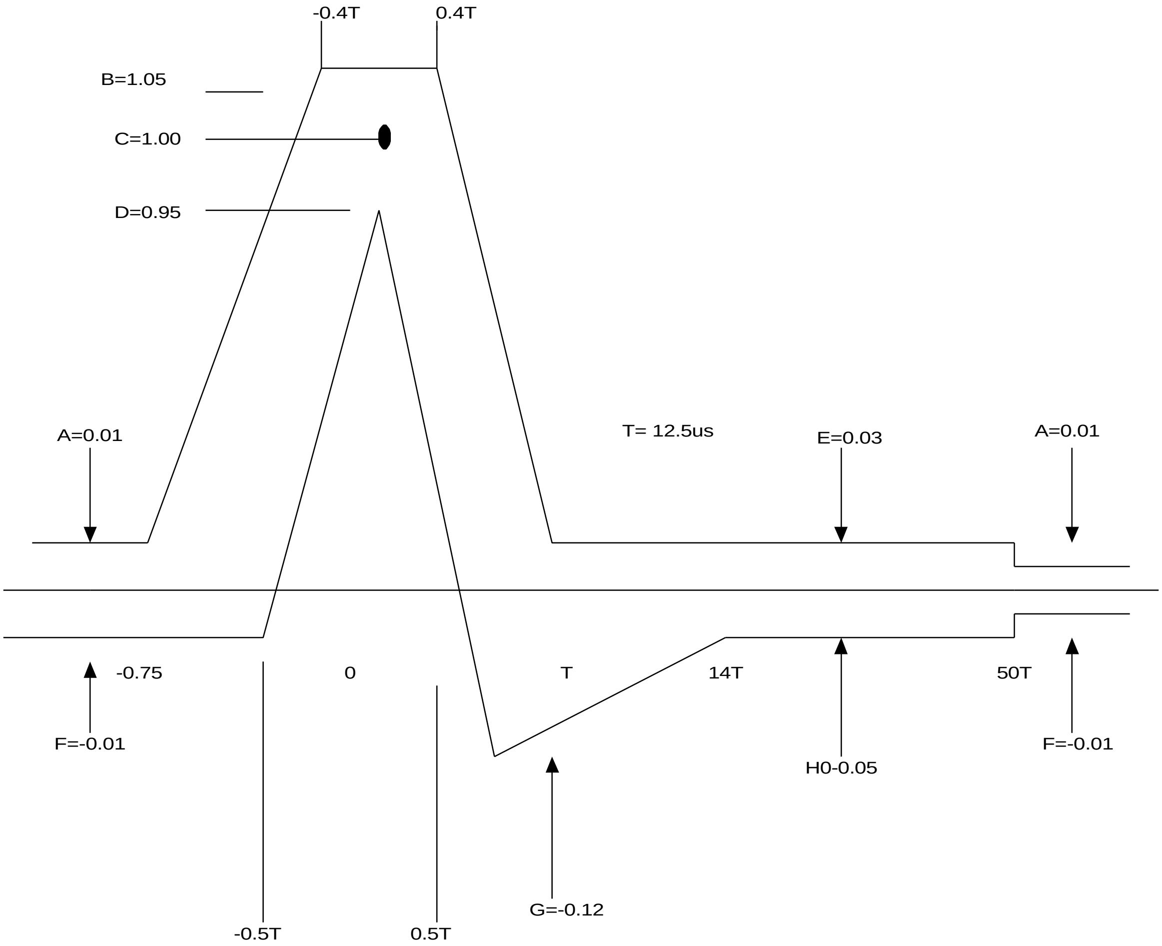


Fig. 5.1 DSL Pulse Mask

The compliance can be achieved by choosing the proper combination of a transmitter filter and a hybrid circuit. The transmit pulse shape can be measured in real time using either a single pulse or a known pulse sequence with some signal processing. Label A trough H are used for easy reference of any pulse mask violation.

6.3 Transmit Power Mask

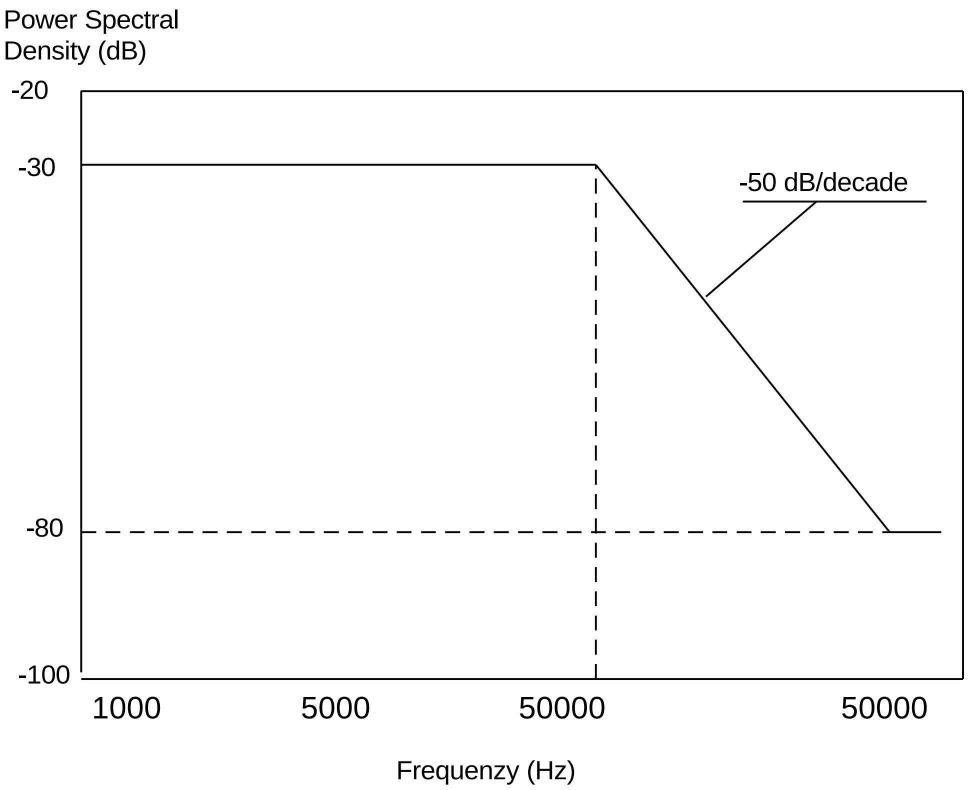


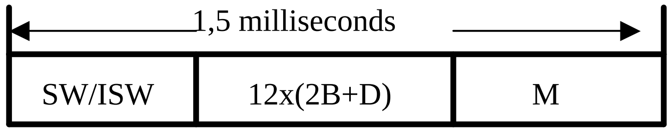
Fig. 5.2 DSL Power Mask

The upper boundary of the average power spectral density of the transmit signal is shown in Fi. 5.2, which can be summarized as that the power density should be - 30 dBm/Hz from 0 Hz to 50 kHz/ decade attenuation from - 30 dBm/ Hz at 50 kHz to -80 dBm/ Hz at 500kHz, and -80 dBm/Hz above 500 kHz.

6.4 Frame Structure

A DSL frame has 120 quats with length of 1.5 milliseconds.

FRAME



FUNCTION	SYNC WORD	2B+ D	OVERHEAD
# QUATS	9	108	3
QUAT POSITION	1-9	10- 117	118-120
# BITS	18	216	6
BIT POSITIONS	1-18	19 – 234	235 - 240

Frames in the NT – to – network direction are offset from
frames in the network to – NT direction by 60 +- 2 quats.

Fig.5.3 DSL Frame Structure

DSL frame starts with a Synchronization Word (SW) of 9 quats, followed by 108 of information payload quats, which consist of 12 groups of two B channel bytes and two D channel bits, and ends with 3 quats of M bits.

Super Frame Structure

It consist of eight frames. The SW of first frame is inverted.

SW : +3 +3 -3 -3 -3 +3 -3 +3 +3

ISW: -3 -3 +3 +3 +3 -3 +3 -3 -3

7. Business – class DSL

Business – class DSL applications (VPN, VoDSL, and FRoDSL) essentially carry service performance quarantees to safeguard mission – critical business applications in contrast to the best effort performance of simple high speed access. Total Business DSL supports a full range of services such IP, FR, TDM, and ATM. It supports multiple traffic types and applications (voice, data ,video) with optimized coverage and with full management support.

VoDSL provides multi – line (typically 4- 12 phone lines) voice capability over a DSL connection using low – latency ATM virtual circuits. The voice traffic is routed to a VoDSL gateway and then to the PSTN. This approach offers DSL customer the cost and convenience advantages of using a single service provider for both data and voice needs, without the need to have additional phone lines provisioned. A single copper pair can meet both the voice and data needs of many small – or medium – size businesses. DSL networks are packet – based, allowing VoDSL to use the bandwidth of DSL connection dynamically. This means that voice calls only need to consume bandwidth when a call is active, and du to low bandwidth utilisation of voice services relative to data services, several voice calls can traverse a DSL connection simultaneously.

FRoDSL, when combined with an end – to – end service level management system, fulfills both critical elements of the value proposition:

1. economical access to the frame relay network
2. equivalent or better service performance guarantees

In short, FRoDSL allows customers to do what they've already been doing for quite some time – only at lower cost. It will significantly lower the cost of provisioning frame relay services to a customer by reducing the cost of the local access portion of the network

7. Conclusion

DSL is local loop technology that can be provisioned over the existing local loops, either from the CO to the service user or point – to- point in campus environments.
DSL is a family of technologies that address a full range of multiservice applications for service user based on specific requirements.
DSL based service are not just about speed, or about the explosive growth of the Internet.
They are about applications and opportunities.

8. References

1. Dr. Walter Y. Chen, DSL Simulation Techniques and Standards Development for Digital Subscriber Line Systems
2. Pardayne Corporation, The DSL Sourcebook, The Comprehensive Resource On digital Subscriber Line Technology