Loop Diagnostics in DSL

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Abstract— **Internet Service Providers (ISP) today are striving to improve the way they interface with customers throughout the DSL subscription and provisioning process. The key for improving the DSL start-up process is to promise the customer solid, maximum achievable data rate and then stand behind it. For this, DSL Service Providers should have adequate information about their physical networks to make promises with a high enough level of confidence. Loop diagnostics provides necessary information about the physical loop makeup. Loop Diagnostics also reduces DSL provisioning and maintenance expenses while providing a more positive experience for customers. This paper aims to interpret the measurements from loop diagnostics in a generic and sensible manner, so that it can be used as a common reference by all ISPs.**

I. INTRODUCTION

The local loop twisted pair cable running from the exchange to subscriber has been optimized for analog voice only. When high frequency digital signals like DSL are used, more optimization might be required depending on the line conditions. For example, Load coils extend the range of voice, but seriously limit DSL. Bridge tap is a method used for cabling the telephone lines, DSL signals find an impedance discontinuity at the un-terminated end, and reflect back through the cable pair.

Efficient testing procedures are necessary when high-frequency signal like DSL is used on the existing copper line.ADSL2 and ADSL2+ standard has in built physical loop diagnostics feature. This feature when used effectively will be an efficient tool to detect the local loop anomalies, like opens, shorts, bridge tap, and crosstalk.

II. DSL PERFORMANCE DEGRADERS

The major causes which degrades the dataflow in the copper line are bridge Taps, load Coils, split Pairs, crosstalk Noise and RF Interference.

A. *Bridge Tap*

A bridge tap (refer Fig 1) is a section of cable that is not in the direct path between the central office and the subscriber.

Bridge taps can be extremely harmful to digital signals. They create a second path for the digital signal. The length of the bridge tap is commonly referred to as a lateral. When the signal travels down the lateral, it is reflected at the open end creating noise back on the main cable pair. A bridge tap can greatly reduce the rate at which DSL can be supported and in severe cases, prevent the link from turning up. There are some key factors for determining the effect of a bridge tap on DSL performance.

Digital Subscriber Line can be affected by bridged tap, depending on where the tap is bridged. Far away from customer's location, better performance. DSL signals find an impedance discontinuity at the un-terminated end, and reflect back through the cable pair. The echo signal is now out of phase and mixed with the original, creating, among other impairments, attenuation distortion. ARU-R receives both signals, gets confused and "takes errors" or cannot sync. If the bridged tap is long, the signal bounces back only in much attenuated form. Therefore, the modem will ignore the weaker signal and show no problem. Most subscriber loop pairs in the world have bridged taps, so it definitely isn't always a DSL killer. Based on field-testing, the worst scenarios for bridge taps (for ADSL) seem to be when the bridge tap is within 1,000 feet from either modem and between 200 to 500 feet long.

B. *Load Coils*

Load coils are inductors having a typical value of 88mh. Load coils boost the transmit power level for voice frequencies (i.e. between 300Hz and 3 kHz) for extending loops (beyond 5.5 km) in PSTN. However, beyond 3.1 kHz, the power level drops below that of unloaded cable. Hence this is ideal only for voice transmission. But, ADSL or other DSL services that use the higher frequencies cannot pass through load coils. Therefore, it is critical to remove all load coils before deploying ADSL or other high frequency signals.

Load coils are placed at regular intervals. The first coil appears 3,000 feet from the central office and subsequent load coils are placed at every 6,000 feet there after. As exchanges are moving closer to the subscriber, load coils are not required and can be removed.

C. *Split Pairs*

Split pairs occur when one conductor in a pair becomes separated from the other conductor. Improper splicing or wire

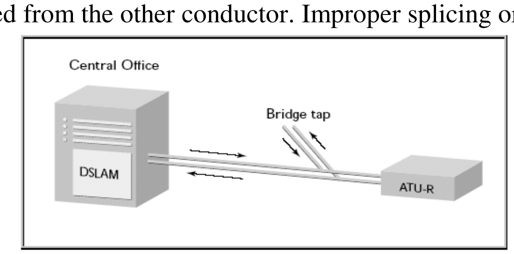

Fig: 1 Brigetap

labeling causes Split pairs. Split pairs result in noise, crosstalk and radiation, and seriously degrade ADSL services.

D. *Crosstalk*

Individual wires that compose twisted-pair lines are insulated, and the twisting of these lines into cables limits electromagnetic interference to nearby lines. However, because the shielding between lines is not perfect, signals from one line can couple onto other lines. As a result, a local receiver can detect signals transmitted on other lines, thus increasing the noise power and degrading the received signal quality on that line. The coupling of unwanted signals from one or more lines into another line is known as crosstalk.

The level of crosstalk is dependent on many factors such as the number of interferers, their proximity to the line of interest, relative powers and spectral shapes of the interferers, and the frequency band over which crosstalk occurs and it can take two forms: *near-end crosstalk* and *far-end crosstalk*.

Near-end crosstalk (NEXT), occurs when a local receiver detects signals transmitted on other lines by one or more local transmitters. (Refer Fig: 2)

Far-end crosstalk (FEXT) occurs when a local receiver detects signals transmitted in its frequency band by one or more remote transmitters. (Refer Fig: 3)

III. Loop Diagnostic features in ADSL

ADSL2/2+ standard support two types of line diagnostics features.

- SELT – Single ended line testing
- DELT – Dual ended line testing

A. *SELT*

Single-ended loop testing (SELT), is an automated way of testing a DSL loop from the central office (CO). SELT can be used to determine loop length, the location of Bridge taps, the length of Bridge taps and the gauge of loop segments. SELT can help service providers determine where shorts, opens are occurring in the line and the location of load coils. It also provides the service providers a clear idea about line noise and other interference characteristics.

Since discussion of SELT test is out of scope of this work, we will focus on the other loop diagnostics feature, DELT.

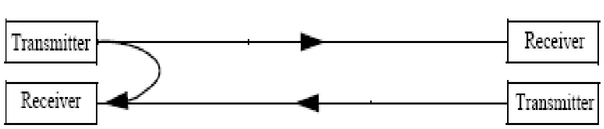

Fig : 2 Crosstalk - NEXT

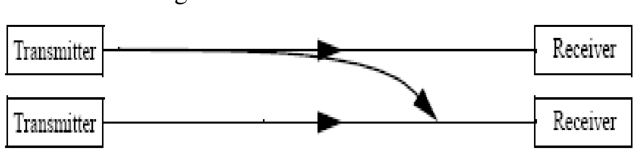

Fig : 3 Crosstalk - FEXT

B. *DELT*

DELT, as defined by the ADSL2/2+ (G.992.3/5) ITU-T standard, falls under loop diagnostics mode. DELT can be done only when ADSL2 modems are connected to both ends of the line (CO side and CPE side). DELT enables the measurement of line conditions at both ends without dispatching maintenance technicians to attach test equipment to the CPE side. This information helps to determine the location and the sources of impairments caused by crosstalk, radio-frequency interference and bridge taps. On performing DELT, the standard compliant modem collects and presents the following parameters (for both Upstream & Downstream) in their Management Information Base (MIB).

- Channel Characteristics Function H(f) per sub-channels
- Quiet Line Noise PSD QLN(f) per sub-channel
- Signal-to-Noise Ratio SNR(f) per sub-channel
- Line Attenuation (LATN) sub-channel
- Signal Attenuation (SATN) sub-channel
- Signal-to-Noise Margin (SNRM) sub-channel
- Attainable Net Data Rate (ATTNDR) sub-channel
- Actual Aggregate Transmit Power(ACTATP)sub-channels

These parameters are measured for each of the 256 or 512 bins (the available bandwidth into a fixed number of parallel, independent sub-channels) in the ADSL2 and ADSL2+ standards, respectively. Trends among these values can be signs of specific problems on the loop and that can reveal opportunities for line conditioning.

We will be focusing on first 3 parameters, i.e. Channel Characteristics Function H(f), Quiet Line Noise PSD QLN(f) and Signal-to-Noise Ratio SNR(f) for our discussion. Short definitions of these DELT parameters are given in the following section.

C. *DELT Parameters*

1) *Channel Characteristics Function Hlog(f) per sub-channel*

The channel characteristics function H(f) is the frequency response of the channel, i.e., amplitude magnification and phase shift at each frequency point, which can be used for analyzing the physical copper loop condition, for example, determining line quality and presence of bridge taps. Its magnitude values are depicted in a logarithmic scale, Channel characteristics, Hlog(f).This function yields valuable information about the physical condition of the copper loop and its topology.

2) *Quiet Line Noise PSD QLN(f) per sub-channel*

The quiet line noise PSD QLN(f) for a particular sub-carrier is the rms (Root Mean Square) level of the noise present on the line, in absence of ADSL signals. Quiet line noise provides a wideband spectral analysis function. QLN(f) can be used for analyzing crosstalk or RF interference, for example, spikes in a plot of this data would indicate interferers. QLN is depicted in dBm/Hz.

3) *Signal-to-Noise Ratio SNR(f) per sub-channel*

The signal-to-noise ratio SNR(f) for a particular sub-carrier is a real value that represents the ratio between the received signal power and the received noise power for that sub-carrier. The SNR(f) data provides the user with information about the capacity of the line. The signal-to-noise ratio can be used to derive the impact of topology or spectral issues on a line. The combination of Hlog(f), QLN(f) and SNR(f) can be used to troubleshoot why the data rate is not able to reach the maximum in a given loop.

D. DELT Process

The process of obtaining DELT parameters has been included in the standard, allowing interoperability between manufacturers. To begin this process, one or both of the DSL transceivers requests to enter into diagnostics mode. During this mode, the physical media dependent sublayers of the central office and the CPE collect information about the state of the connection and the loop as they pass through the initialization process. Once information collection is complete, the two transceivers exchange the raw statistics they have obtained using a robust, low bit rate "diagnostics link," which can be established even in cases where the modems do not normally sync. This information is then available to the modem or DSLAM management software using the standard G.ploam (G.997.1) MIB fields.

E. DELT Sequence

- Either ATU-C or ATU-R or both can initiate DELT and force the other terminal into DELT
- During the diagnostics states, channel information gathered during the previous states are exchanged
  - ✓ All messages use half-duplex BPSK on each frequency bin at the rate of one bit per 8 DMT symbols.
  - ✓ Training in DELT may take several minutes as data is passed slowly to handle a very low signal to noise ratio.
- After DELT Op-state is reached, line goes quiet, and operator must first abort before starting a data initialization.

F. Results of DELT

DELT results provide three crucial benefits. The first is improving stability and connection rates for the current customer base by identifying loop anomalies. Next is identifying sources of transient noise and interference as causes for rate loss, connection drops and failures. The third is developing an up-to-date and evolving database of the copper plant and loop-specific data rate capacities. This last feature allows service providers to increase customer data rates with prior knowledge of the limits of the loop.

G. Procedure for field diagnostics

The following flow chart indicates the different steps to be followed while conducting the field diagnostics (refer Fig: 4).

Test Category	*Interpreted Results*	
Loop Topology	Loop length	
	Bridged taps	Near CO
		Near CPE
Spectral Analysis	Intrinsic crosstalk noise,such as HDSL, T1,	
	Extrinsic noise such as AM and EMI interference	

Table : 1 Test categories and Results

IV. LOOP DIAGNOSTICS USING DELT

The various parameters like channel characteristics, SNR and quiet line noise obtained for different ports with different loop lengths from DELT are plotted for easy understanding.

The results obtained from DELT when interpreted give information on the following category (refer Table:1)

A. Bridgetap

A bridge tap of 100m was introduced near CPE and there effect on the line characteristics is also plotted in Fig :5.From this, it is clear that Channel characteristics, Hlog drops below -10db for the given bridge tap.

Quite line noise (QLN) in normal loop as well as loop with Bridge tap near CPE, lies between -130 dBm to -140 dBm. So the quiet line noise graph indicates very little or no change when Bridge tap is introduced (refer Fig:6)

So information about bridge tap can be obtained from channel characteristics curve. The magnitude of dB lost can be obtained from SNR curve as shown in fig:7

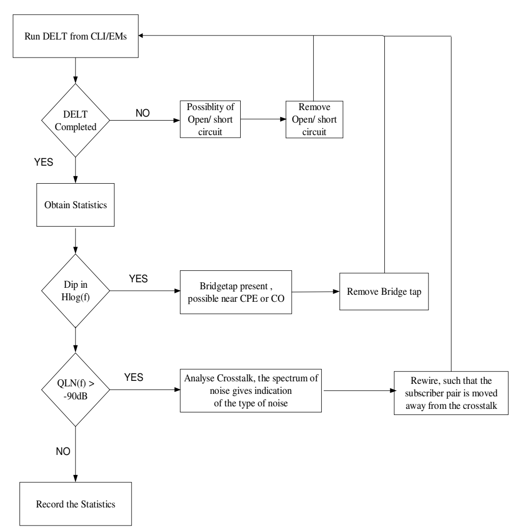

Fig 4: Field Diagnostics Test Procedure

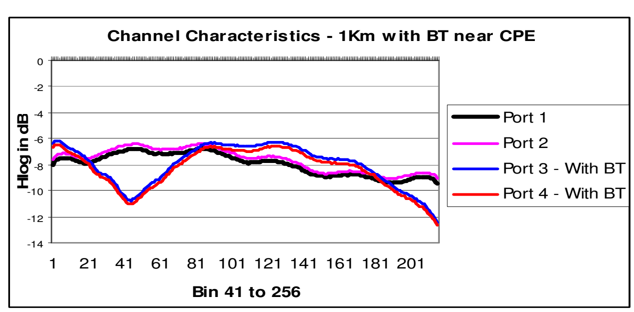

Fig : 5 Hlog in 1Km loop with BT near CPE

B. Noise

A split pair of 1m was given between 2 ADSL ports and its effect on quiet line noise is also given.The channel characteristic graph does not show any effect because of split pairs.(refer Fig:8)

The quiet line noise indicates an increase in the noise level of more than 20dB for the entire spectrum because of a split pair of 1m length. (refer Fig : 9)

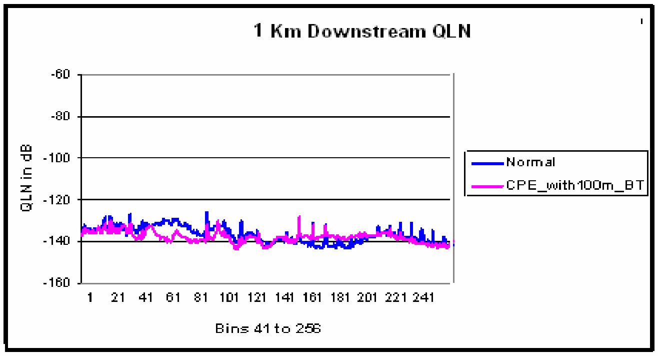

Fig :6 QLN in 1Km loop with BT near CPE

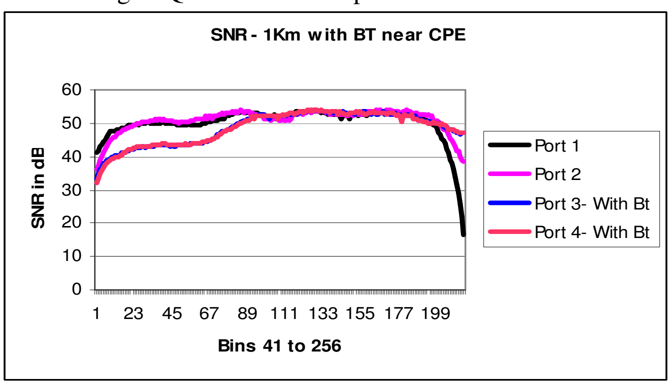

Fig :7 SNR in 1Km loop with BT near CPE

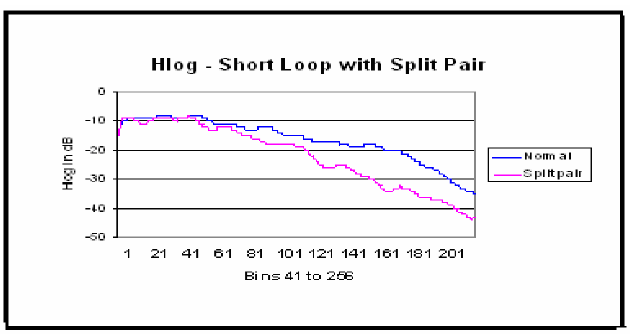

Fig :8 Hlog in short loop with Split pair SNR

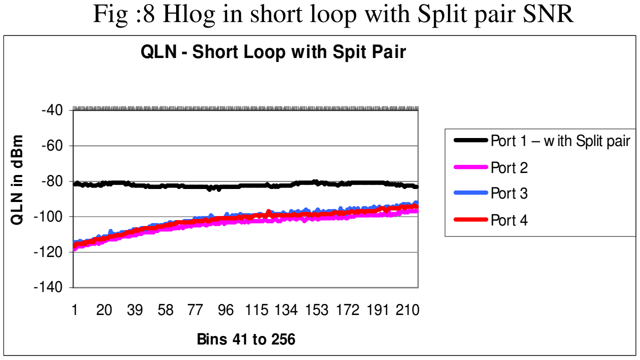

Fig :9 QLN in short loop with Split pair

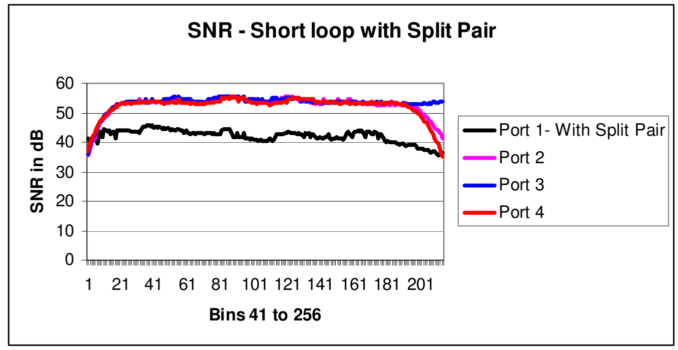

Fig :10 SNR in short loop with Split pair

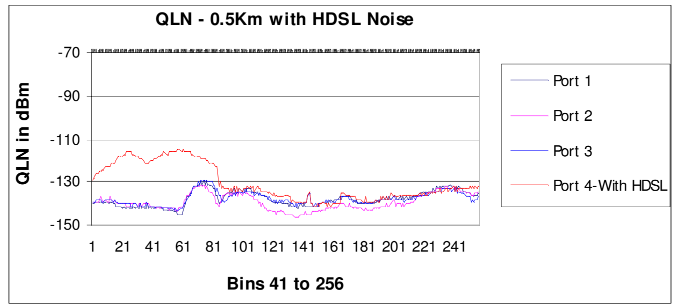

Fig :11 QLN in 0.5Km loop HDSL Noise

From the Quiet line noise graph we can identify the type of noise like T1, ISDN, HDSL and ADSL depending on the spectrum affected. As we can see from the Fig:10 because of a split pair the signal to noise ratio has dropped to 40 -45dB from the normal.

V. CASE STUDY

The DELT parameters are obtained from 4 ports installed at IIT, Madras. The quiet line noise graph is given below. (refer fig:11)

From the QLN graph its clear that port -4's quiet line noise affects the frequencies till 392KHz .When we analyzed what are the other services taken in the cable pair bundle, we came to know existence of a HDSL link between the computer center and the Director's home. The cable coming from the Computer center was cut near the exchange end MDF but that didn't give any improvement in the data rate. The DELT ran in this condition also. DELT results clearly reflect crosstalk because of HDSL. Because the cable was cut the HDSL CO was keeping on trying for the sync, putting full band energy leading to severe crosstalk.

The cable was rewired in the 100 pair cable bundle running from exchange MDF, ADSL pair was away from the HDSL interferer and also after some rewiring in the customer premises this issue got solved. The Data rate of 19Mbps was obtained after making necessary corrections.

VI. CONCLUSION

This paper discussed about the DSL performance degrading elements and Loop Diagnostics method, DELT. This paper mainly focuses on the measurement analysis of the parameters obtained from DELT to identify the effect of Bridgetap, Split pair and HDSL noise sources on the loop performance.

VII. FUTURE WORK

ADSL/2/2+ is currently being deployed as a mainstream broadband technology by Indian telecom operators. At the same time, they are gearing up for the next step of the DSL evolution: VDSL/VDSL2 (Very High-speed Digital subscriber Line), G993.2 standard from ITU-T, promises to deliver 100Mbps symmetrical traffic on short copper loops. With this background, loop diagnostics tests can be performed as an extension of this thesis work to qualify the copper loop for very high VDSL frequencies.

REFERENCES

[1] International Telecommunication Union – Telecommunication G.997.1 , Physical layer management for digital subscriber line (DSL) transceivers*,* 2003

[2] Bernardo Celaya de la Torre, "DSL LINE TESTER USING WIDEBAND FREQUENCY DOMAIN REFLECTOMETRY", Thesis, University of Saskatchewan ,2004

[3] Martin Nilsson "Management of a DSL copper network using built-in loop qualification tools", Thesis, The Royal Institute of Technology, 2005.

[4] www.aware.com/dsl/whitepapers/index.htm

[5] Banyan networks Ltd , Sudha C, Whitepaper, Loop diagnostics, 2005

[6] E. Van den Bogaert, T. Bostoen, J. Van Elsen, R. Cendrillon and M. Moonen, DSM in Practice: performance Results of Iterative Water-filling Implemented on ADSL Modems, 2003

[7] ftp://ftp.esat.kuleuven.ac.be/pub/SISTA/cendrillon/reports/04-32.pdf - Performance Results of Iterative Water-filling Implemented on ADSL Modems

[8] A. S. Tanenbaum, *Computer Networks*, 3rd Ed., Prentice Hall, New Delhi, 1994.

[9] Sunrise telecom, Raymond L. Chong, "*Detection of Bridge tap using frequency domain analysis*", US patent No. 6417672 B1, Jul 2002