

# Effective Provisioning of Broadband on the Local Loop

*A practical introduction to testing DSL*

White Paper LOOPTESTWP

*Testing the World's Digital Networks*



TrendCommunications

### INTRODUCTION

The effective use of existing copper voice grade infrastructure and the requirement to transport substantially more than a single voice channel across a copper pair has been a constant target for Network Operators and equipment vendors for the past twenty years. By employing digital signalling and efficient line coding techniques to provide a Digital Subscriber Loop or DSL, a wide variety of services have been deployed globally. One familiar form of DSL is IDSL, a technology that underpins the widely deployed ISDN services. However the growth in fast Internet access, video on demand and other related consumer and business services has forced the bandwidth requirements beyond the IDSL 144kbps rates to faster DSL technologies.

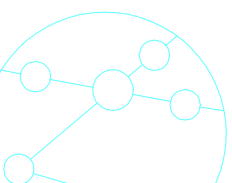
The broadband medium reach (< 10 km) service technologies are many but include:

- Asymmetric DSL (ADSL) which is mainly aimed at domestic users providing up to 8Mbps to the customer and 500kbps towards the network.
- High bit rate DSL (HDSL) and Symmetrical DSL (SDSL), both are symmetrical services providing up to 2Mbps and are widely deployed as leased line replacement for business users.

The recently ratified SHDSL standard (ITU G.991.2) builds on the symmetrical service offering to provide a multi-technology variable bandwidth transport medium where at long last an agreed standard of interoperability between equipment vendor products exists from the onset.

Despite the global deployment of DSL technologies and the major steps taken towards DSL modem standardisation, the point has not yet been reached where service deployment is trouble free. The experience from regions where wide deployment of the newer DSL services has taken place has been quite the opposite.

DSL deployment has been hindered by a number of commercial and technological issues. In the USA, there exists effective competition in the provisioning of the local loop or 'last mile' of copper connecting the local exchange to the subscriber. This has provided low tariffs and innovative service distribution methods. These along with readily available consumer applications and a cultural affiliation to the use of online services have boosted the rollout of ADSL and SDSL services.



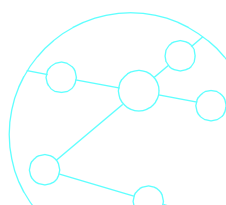
In Europe the political environment has governed the speed of deployment of services like ADSL. In Germany the political will has driven a wide expansion of the service while the lack of a political driver in France, UK and many other European countries has slowed deregulation and competition for the local loop to a point where large scale deployment is only just becoming a reality. The problems with deployment are now becoming increasingly limited to technical issues.

ADSL and SHDSL systems currently under deployment mainly consist of a layered technology approach. The copper pair is modulated using DMT (discrete multiple tone), CAP (carrier-less amplitude and phase) or TCPAM (Trellis-Coded Phase Amplitude Modulation) signalling. Symbols are based on a constellation format structured into frames and super frames making up the DSL layer line coding and providing the data pipe. Commonly on top of the DSL layer is an ATM transport layer. The ATM layer offers quality of service and the virtual circuit control. Above the ATM layer may be found the PPP and IP layers. Point-to-Point Protocol is used to authenticate the user and provide an IP address to the customer terminal. The application layers (Internet Application access) is provided at the IP layers and above. To provide a correctly operating service, each layer must function correctly and effectively.

The technological problems encountered during the volume deployment are significant when understanding the multiple technologies involved and the external effects on their operation. These problem areas and methods of isolation and detection are further explored below.

### Qualification

The copper conductors carrying the service are rarely perfect for any technology that exceeds the 300Hz to 4kHz bandwidths typical of an analogue telephony service. With an increase in upper frequency range and service bandwidth, the effects of impairments on the copper pair become more pronounced. Commonly found features of the copper plant include bridge taps or laterals, load coils extensively used in North America for boosting the reach of audio frequency signals and poor pair balance relative to ground often referred to as longitudinal balance. Each of these will provide a severe attenuation, notching effect or even a complete block on high frequency signalling. Variations in pair twist ratios, split pairs, medium resistance junctions, impedance differences on joined cable types all lead to a reduction in noise immunity and an increase in the induced interference within the cable bundle.



Conventional copper pair quality testing such as measurements of insertion loss, balance and cross-talk rely on single frequency testing.

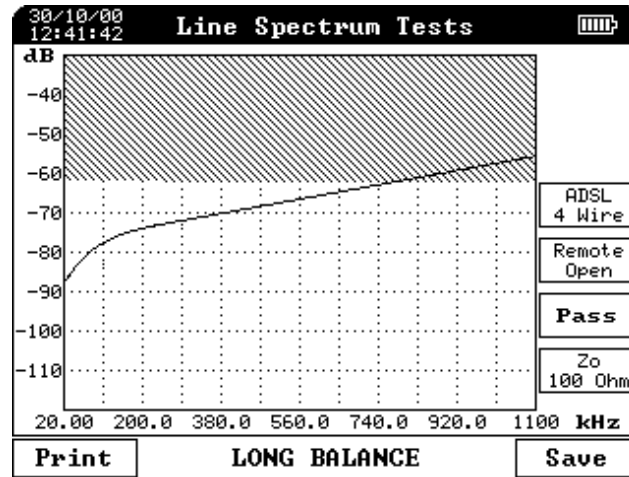
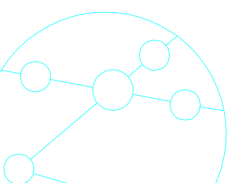


Figure 1 Spectral Balance Measurement

This is adequate for the narrow bandwidths used for analogue telephony but the effects vary significantly across the wider bandwidths associated with ADSL or SHDSL. A spot frequency measurement may register a pass where a large portion of the service bandwidth may be unusable or seriously degraded. Figure 1 shows an example of a balance measurement and shows the variation of longitudinal balance with frequency. The example shows that the mask threshold is exceeded for higher frequencies but the test passes at lower frequencies. It shows that spot frequency measurements may be fine as a quick check but can be wildly inaccurate.

Testing the copper quality degradation effect on the service at installation is only part of the story. As the percentage of pairs in the bundle being used for DSL increases, the interference effects of services sharing the same bundle will become more pronounced. It is critical therefore that the pair quality is properly assessed before deploying the service if a high utilisation of the bundle is to be realised. Figure 2 shows the degradation caused to the bits per channel training rate of an ADSL (over POTS) service by a service on an adjacent pair within a bundle. This occurs where poor cross-talk immunity exists between the pairs in the bundle (y axis shows bits per symbol and x axis shows the tone frequency allocation).



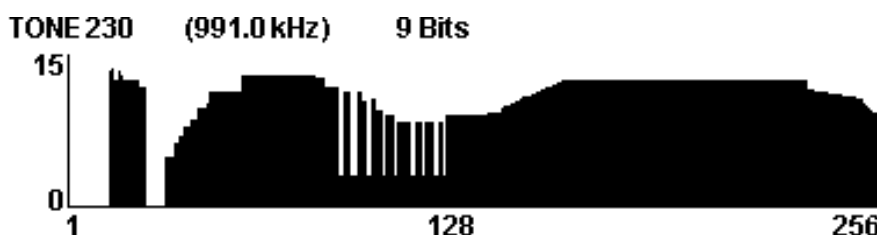


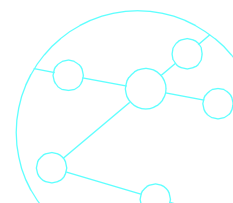
Figure 2 Cross-talk Interference

So in practice, what are the line parameters that need to be tested, what is their effect and how are they measured? Most of these parameters accumulate to provide the same effects. For example poor balance provides low noise immunity which in turn increases emissions and cross-talk.

Table 1 breaks down each of the commonly measured line parameters, what their effect is to a DSL service and how the measurement is performed.

Parameter	Cause/Effect	Test Type
Return Loss	IMPEDENCE MISMATCH INCORRECT TERMINATION PRESENCE OF BRIDGED TAPS	Single ended test measures the reflected signal – ideally line should be terminated
Insertion Loss	LINE LENGTH TOO GREAT UNSUITABLE CABLE INSUFFICIENT BANDWIDTH	Two-ended test with one tester transmitting and the other receiving
Noise	ENVIRONMENTAL NOISE THERMAL / MECHANICAL EFFECTS, CROSSTALK	Single-ended test measured over the service spectrum
Near End Cross-talk (NEXT)	UNSUITABLE CABLE POOR BALANCE SPLIT PAIRS	Single ended two pair test, transmitting on one pair and receiving on the other at the same end of the bundle. Measures the induced signal level.
Far End Cross-talk (FEXT)	UNSUITABLE CABLE POOR BALANCE SPLIT PAIRS	Two ended two pair test, transmitting on one pair at one end and receiving on the other pair at the other end of the bundle.
Longitudinal balance	LOW INSULATION, SPLIT PAIRS. Poor balance reduces reach and reduces noise immunity.	Single ended test. Measures the impedance to ground for each conductor in the pair and provides a comparison
General cable problems - breaks, shorts, bridge taps, high resistance joints and split pairs	A wide range of causes. All contribute to degrading the service reach and reducing immunity.	TDR test - Single ended test.

Table 1 Copper Pair Parameters



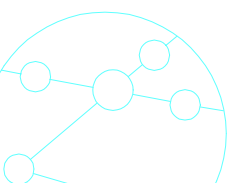
Some operators have taken the decision to not test the copper before installing the modem equipment and in some cases this may pay off since the complexities of deploying a DSL service lie equally if not more extensively in the upper layers.

### Service Installation

Service installation and commissioning is not without its problems. Up until recently in the USA it was taken as a general 'rule of thumb' that an ADSL installation would average 3 truck rolls before the service was operating satisfactorily. With the growth of 'self install' where the customer obtains the DSL modem and a splitter box from a high street retailer, as a move to cut costs, the problem can only grow. A survey conducted by Efficient Networks in the USA found that 'around 42% of DSL self-installers had to contact the helpdesk during installation' and the average time spent identifying and solving the genuine problems was nine hours. (source: America's Network, September 2001).

The key to cutting the time spent deploying the service lies with effective problem resolution. Effective problem resolution in turn depends on accurate fault location. Many methods of achieving this have been tried. Providing fault diagnosis software on a PC as an installation test is one method tried with limited success. This will work if the service is partially functional and a complete IP layer connection between an Internet Service Provider (ISP) and the customer PC is available, but is of no benefit if no connection can be made. A copper test head at the main distribution frame linked to the network management system provides only a limited viewpoint. Even the DSLAM management system with its complex list of statistics and routing tables will only provide a subset of the information needed to isolate type and location of any possible network problem.

Centralised fully automated network testing is technically impractical and commercially prohibitive for residential DSL services in particular where the geographical population density is low. With the move to de-skilling or 'multi-skilling', there is a definite need for the first-line maintenance technician to carry tools capable of investigating the problem and then providing the necessary information to enable the support technicians to correct the fault with a minimal number of further visits to the field.



## Maintenance

The installation service process should provide the necessary detail to the maintenance technicians to diagnose and correct faults at any point between the customer PC and the WEB site or internet service that the customer wishes to access. To achieve this and make the low cost high penetration DSL business model work, a sound service test strategy must be in place that clearly segments the service to allow clear fault location and diagnosis.

To achieve this aim, the service and network topology must be clearly understood.

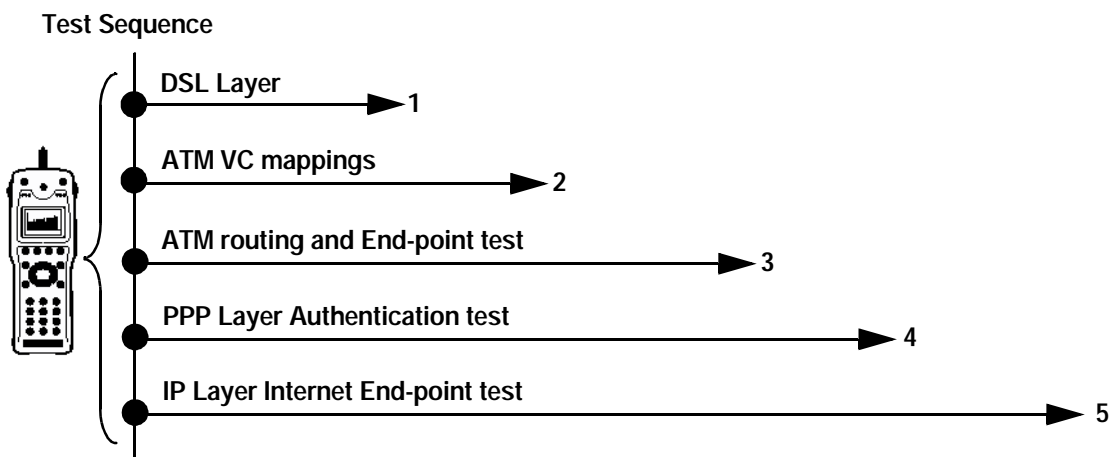
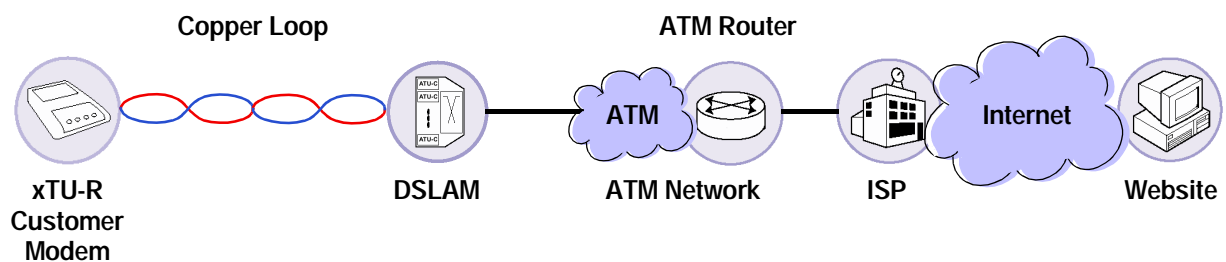
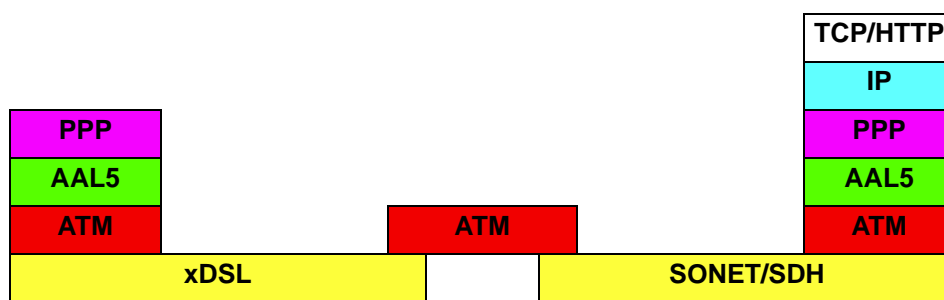
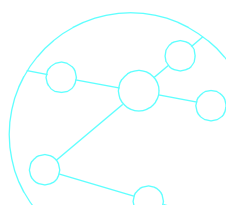


Figure 3 DSL Service, Protocol Layer Map and Test Segments



As shown in the DSL service diagram and protocol model in figure 3. A typical ADSL service from customer modem to ISP consists of several different layered technologies. In order to correctly locate and identify a fault condition, the test equipment deployed must be capable of conducting tests at the DSL, ATM, AAL5, PPP and IP layers.

Table 2 details the minimum test requirements for each layer.

Layer	Minimum	Location Test
DSL	Channel bit rate evaluation, Capacity, Attenuation, Noise Margin and bits per channel mapping.	Tests between the Customer Modem and the DSLAM line card at point 1 (e.g. ATU-C)
ATM	Virtual Circuit Mappings, Node and end point determination using F5 OAM PING.	Tests ATU-R, DSLAM (point 2) and ATM network mappings and routing between the Customer Modem and the ATM switch serving the ISP (point 3).
AAL5	AAL5 statistics.	Identifies packet loss and the quality of the virtual circuit between the DSLAM and the Customer Modem.
PPP	PPPoE / PPPoA with PAP / CHAP support for authentication.	Tests from the Customer interface to the ISP gateway (point 4).
IP	IP PING	Tests from the Customer interface to a known WEB site (point 5).

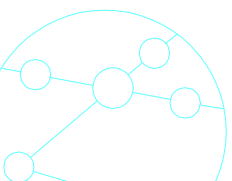
Table 2

The segments for each layer test are shown in figure 3. This five-stage test strategy should take under 60 seconds to perform and will provide fault location and diagnosis for the technician, reducing fault correction time and cutting the travelling costs.

All layers are very important to consider but many operators have neglected to test the ATM layer and this has cost them significant time and money. Whilst ATM technology appears complex to the subscriber loop technicians, the test methodology is very simple. Common ATM layer problems that occur include:-

- Wrong or crossed virtual circuits at the DSLAM manifesting themselves as one way traffic or no access to the ISP or application server.
- Disparities between the virtual circuit mappings, hard configured in the customer ADSL modem and the mapping tables in the DSLAM.
- Incorrect routing of the virtual circuit through the ATM network providing an incorrect end point.

A combination of the use of a simple cell-stream analyser and the transmission of F5 OAM loop-back cells acting like a PING can identify and locate all of these problems simply and effectively. It is important to remember that if the ATM layer is mis-configured then the service will not work.



## Summary

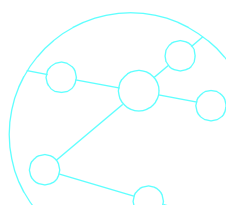
The definite need to test the copper infrastructure prior to installation of the DSL service is open to argument. Indeed some operators opt for no pre-qualification and reap the short-term gains while others pre-qualify individual pairs or qualify pairs in bulk and guarantee minimal problems for the future. The second option will certainly ensure that a larger percentage of the bundle can be used for broadband services. Probably the most important copper test capability lies in the second line network maintenance role to allow problems of interference, pair interaction and in-service copper faults to be isolated. In the current environment a comprehensive DSL service tool is of most benefit to the network installation and maintenance technicians.

The most important feature of any DSL service test solution for field use is the combination of a simple one-button, fully automated test sequence for the first line technician allied with a multi-layer analysis and capture facility. Thus providing the second or third line support technicians with the information they require without the need for repeat visits.

Accurate fault location is of course becoming more critical for any DSL test solution as competition for the local loop becomes greater and the field test solution becomes an independent arbitrator.

The multi-layer five point test strategy detailed above will provide the network operator with a complete picture of the service. It provides a segmented approach to fault location that has been missing from conventional test strategies. This strategy also fills the ATM system test gap that has been overlooked by network operators and test vendors to date. This omission has left a large blind spot for the network technicians to deal with and has caused many time-consuming problems in the installation and commissioning process.

Although the discussion has centred generally on ADSL technology based services, the strategies can be applied to any multi-layer DSL service to reduce resource requirements and speed field deployment. A number of field portable testers exist today that will provide the copper and service test capabilities detailed above, examples of such include AuroraPresto and ALT2000 from Trend Communications Ltd, Agilent Technologies and Aten among others.



## Reference Material

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