Chapter 1

Introduction

Only a few years ago, even the most enlightened telecommunication's engineer might ask:

"Is there a need for a hardware simulator to model a fixed access twisted copper pair?"

For voice, fixed line access is a mature technology. Ever since telecommunication networks employed switching, subscribers have been connected to the network operator's closest switch via an access network, usually consisting of a single twisted copper or aluminium pair of wires. In the UK alone, the incumbent telco, BT, has over 36 million subscriber pairs. It is therefore reasonable to question if there is a need for a hardware system to simulate the behaviour of a twisted copper pair. Such a widely deployed, mature technology, should be fully understood? Yes and no. The key to this question is bandwidth. Access technology over the last century has provided a perfectly adequate 4 kHz low bandwidth service dedicated to analogue voice conveyance. Since the mid 1980s, personal computers have increasingly pervaded residential homes. Initially, home computing was informationally isolated from the outside world, with data transfer only through removable magnetic media. The 1990s witnessed a major change in the way in which home computers were used. The widespread growth of the 'Internet' and particularly the development of Graphical User Interfaces (GUIs) such as Netscape and Microsoft's Internet Explorer fuelled a revolution in the way home users viewed their PCs. These developments projected the PC from a useful and entertaining novelty almost to the point of a 'must have' gateway to the outside world.

The increase in CPU speeds and the reduction in volatile and permanent memory storage costs have stretched the PC's capacity from manipulation of essentially text-based information to the arena of 'multimedia'. Whereas text-based data transfers can be satisfied by low bit rate transmission, multimedia applications such as real time video transfer and other interactive services require high bit rates for an acceptable Quality of Service (QOS). Even non-real time multimedia data transfers of items such as pictures require high transmission bit rates to give acceptable download times for end users. Consider a large e-mail of several hundred words, approximately 1 kilobyte in size. Using a standard

56 kbit/s modem, the e-mail could be downloaded within a second. Now consider the same e-mail with an enclosure of a single high quality 1 Megabyte bit map image. Using the same modem, the e-mail could take more than two and a half minutes to download!

The existing access network provided the logical choice to connect PCs to the outside world, commonly referred to as connecting to the Internet. However, this choice was driven mainly by cost and convenience – a computer engineer would never have opted for a 4 kHz band limited analogue drop cable to the nearest digital switching unit given a blank piece of paper! Although not ideal, by using multilevel Quadrature Amplitude Modulation (QAM) signalling, modem engineers have managed to squeeze transmission rates upto a maximum of 56 kbit/s through the analogue access network with no modifications to its structure. 56 kbit/s provides fast enough transmission for most text based applications, but not multimedia, hence methods were needed to provide higher bit rates.

One solution for providing home users with greater data rates is to digitise the access loop. The Integrated Services Digital Network offers data rates of upto 144 kbit/s, with 128 kbits/s reliably available to the end user. ISDN is a great improvement over analogue modem systems, especially since it offers a reliable service - the data rate offered by all ISDN lines is always 128 kbits/s, whereas analogue modems rarely achieve their maximal throughput and what is provided is unreliable in that it may vary during the holding time of a data connection. Although an improvement, 128 kbits/s isn’t really enough for multimedia applications and is an expensive solution considering the gain in bit rate.

Both ISDN and analogue QAM modems use baseband transmission. DSL modems employ passband transmission by modulating data onto carrier frequencies much higher than the spectrum occupied by analogue voice signals. The expansion of the Power Spectral Density (PSD) mask over baseband transmission introduces new behaviour which DSL modems must accommodate. Classically, twisted copper access pairs used in voice telephony are fully characterised by their transmission performance and signalling resistance. The transmission performance, measured in dB, is the maximum signal attenuation before the level of extraneous noise becomes unacceptable to the customer. On residential lines a figure of 10 dB is a common upper limit. The signalling resistance is the resistance seen by signalling (dial tone, ringing etc). The maximum allowable signalling resistance is of the order of a kilo Ohm. Over the broader utilised spectrum, the line’s frequency response exhibits much greater variation and with higher frequency operation, the effects of crosstalk from other high bit rate lines becomes very significant and prevents the line from being viewed in isolation.

The susceptibility to crosstalk at higher frequencies is the core driver for a DSL line simulator. DSL modem designers such as Fujitsu have difficulty in recreating a realistic test line for evaluating their equipment. To test baseband modems operating to a few tens of kHz, coiled reels of access cables are used which provide an adequate test environment because the signals are affected mainly by the lines low frequency transmission performance. When differential transmission with twisted copper pairs is employed the crosstalk from neighbouring access pairs within the same bundle is negligible. For voice band QAM modems, the transmission rate is predominately limited by noise and insertion loss. Essentially the line under test can be viewed in isolation from similar neighbouring call carrying lines. Coiled bundles of access pairs cannot be used for testing DSL modems as the close coiling of the same line induces self crosstalk, so designers are forced to use long runs of stretched out cable in a fashion similar to real life to avoid self self-crosstalk due to the signal under test. Additionally, crosstalk from neighbouring DSL lines is significant and is often the limiting factor to the modem's achievable bit rate. With a physical test line, a designer must inject interfering DSL signals along other copper pairs within the same access bundle in order to recreate a realistic test environment. On a real physical access bundle, this is both difficult and expensive to do and time consuming to alter the test environment.

A compact PC based line simulator that simulates both the physical line characteristics throughout the transmission spectrum and the effect of crosstalk from neighbouring DSL lines within the same theoretical access bundle is therefore very desirable. Significantly, once the test environment is under PC control it can be instantly reconfigurable both interms of the physical line characteristics and crosstalk.

The aim of this project is to investigate both the technical and commercial feasibility of making a line simulator for use with Very high bit rate Digital Subscriber Line (VDSL) and Asymmetrical Digital Subscriber Line (ADSL) modems.