ADSL Testing Moves Out of the Lab

Martin Rowe -April 01, 1999

Recently, my cousin asked me to send an e-mail to her daughter at her junior high school. To my surprise, I discovered that Gina's school has no ordinary Internet connection. The school has an asymmetric digital subscriber line (ADSL) connection to a local Internet service provider (ISP).[1] ADSL has moved out of the lab and the field trials and now is available to homes, businesses, and even schools. ADSL currently makes up about 6% of all broadband connections. By 2004, ADSL is expected to take the lead in broadband subscribers with 37% market share compared to cable modems at 26%.[2] Even though ADSL installations have begun, several versions of the technology still exist. And the PC industry is pushing for a scaled-down version of ADSL to sell to the mass market. As a result, testing of ADSL products must occur at several stages, ranging from the lab to the production floor to the telco that test products for deployment to the technician who installs ADSL service.

Two years ago, ADSL testing consisted almost entirely of physical-layer tests on simulated local loops.[3] Engineers tested new designs for conformance to ANSI T1.413, which defines discrete multitone (DMT) communications between a subscriber's ADSL modem and a central office digital subscriber line access multiplexer (DSLAM).[4] The DSLAM equipment located at a telco contains an ADSL transceiver unit-central office (ATU-C) while the modem at the subscriber's premises is often called an ADSL transceiver unit-remote (ATU-R).

New ADSL chip set and full transceiver designs still require rigorous physical-layer testing, but in production, manufacturers may perform a few parametric tests. Manufacturers more often test for bit-error rate and other functional attributes.

Manufacturers also test their ADSL products for how well they connect to Ethernet and asynchronous transfer mode (ATM) networks.

ADSL chip sets—like analog modems—have built-in test features. Chip sets have loopback features that let you test the devices' transmitter and receiver circuits. The loopback tests can take place within the chips or over a simulated local loop to a remote transceiver. Manufacturers often start testing by using the chip set's local-loopback feature.

Figure 1 shows a typical setup for remote loopback testing. Loopback tests let manufacturers know that the chip set's transmitter and receiver function properly. Because ADSL is asymmetric, upstream and downstream directions use different data rates. The upstream's slower speed limits testing to about 600 kbps. Loopback tests can't test an ATU-R chip set at the receivers full speed, nor can they test an ATU-C at full downstream speed. Manufacturers could test their chip sets at full speed by using an ATU-C chip set to test an ATU-R chip set and vice versa. Because they often perform functional tests only, manufacturers typically test at the maximum upstream rate only and use the same type of device at both ends of a loop.

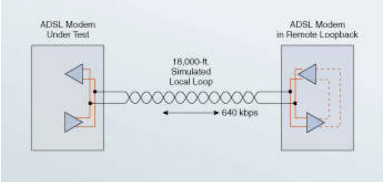

Figure 1. Remote loopback in an ADSL chip set lets one ADSL transceiver test another.

Once they know that their chip sets function properly, manufacturers such as Alcatel Microelectronics (Zaventem, Belgium) and Texas Instruments (Dallas, TX) perform tests for parameters such as:

- Spectral power. Manufacturers measure the power in each downstream transmit tone used in an ATU-R and in each upstream transmit tone of an ATU-C.
- Cross modulation. Manufacturers shut off some tones and measure any leakage from adjacent tones.
- Frequency response. Using a spectrum analyzer, manufacturers can test for bits per tone.
- Noise ratio. In this test, manufacturers measure the noise on the line with all tones turned on, then with all tones turned off.
- Control interface. Manufacturers must verify that the ATU-R's or ATU-C's control interface properly responds to commands from a host computer.

After completing these tests, manufacturers test the device's ability to communicate with a device over a simulated local loop. Manufacturers often simulate local loops to 18,000 feet and test for transmission errors.

ADSL chip set makers also test their devices for how well they transport data. Typically, the DSLAM is connected to an ATM network at the CO. Subscriber modems typically transport data within ATM cells or Ethernet packets. Therefore, chip makers often test for the passing of data using both protocols.

Once ADSL chip sets are assembled into modems, modem makers perform similar tests to those performed by chip makers. This time, however, the modem builder tests not only the chip set but also the phone line interface circuits, which include a transformer and a line driver IC. Because ADSL uses up to 256 tones for transporting data, an ADSL modem—particularly the ATU-C—must drive significant current into the local loop. An ADSL driver IC can supply as much as 400 mA of peak current.[5]

Production ATE

Test Engineers at Alcatel USA (Plano, TX) use an ATE system to test both ATU-Cs and ATU-Rs. The system tests for both physical parameters and for data transport. Tests begin through the chip set's loopback feature, which verifies modem functionality. After the loopback tests, Alcatel performs several parametric tests. One such test is for multitone power ratio. In this test, a manufacturer compares the power that the UUT produced with all tones off to the power produced with all tones on.

In an idle channel noise test. Alcatel's system measures the noise levels that an ADSL transmitter puts out if it has an idle channel (a tone not in use). Each ADSL product manufacturer has to decide how much noise is acceptable.

Alcatel USA also produces DSLAMs. Engineers test ATU-Cs in the DSLAMS for power levels in the tones at frequencies up to 1.1 MHz. In a production test, a test system measures dynamic range and SNR in transmitted signals. To perform these tests, the tester turns on all 256 tones at once. After taking 32 ksamples of measurements in the time domain, the tester performs an FFT on the data. In the frequency domain, the FFT lets Alcatel engineers see noise (spectrum spreading of tones) and power levels in the tones.

When testing ATU-Rs, manufacturers perform more tests on the receiver than on the transmitter because of ADSL's higher downstream data rates. Alcatel tests receiver circuits by simulating transmitted tones with an arbitrary waveform generator. The test system then measures the ATU-R's sensitivity to each tone.

Alcatel then tests the ATU-C's and ATU-R's abilities to send and receive data over simulated local loops. Production tests require measurement of Ethernet and ATM traffic, which includes bit-error rate (BER) tests. To perform these measurements, Alcatel uses an ATM traffic analyzer and a protocol analyzer for measuring errors in Ethernet traffic.

Two years ago, engineers at the telcos were performing physical-layer tests: bit-error rate (BER) measurements in the presence of simulated RF noise, crosstalk, and impulse noise. Today, telcos such as U S West (Minneapolis, MN) test the ADSL products through higher-layer tests. Dan Edeen, senior engineer at U S West points out he used to measure the physical layer performance of ADSL modems. Now, he puts his time into testing new features and functions of the products that his company installs at its COs and at customer sites.

Edeen tests ATU-Rs and ATU-Cs for BER and for traffic throughput. ATU-Cs use Ethernet connections to the subscriber's computer. DSLAMs connect to the digital network and transfer data to ISPs. **Figure 2** shows how the company's equipment works in an installation. A DSLAM contains a plain-old telephone service (POTS) splitter that isolates voice and data signals at the central office, then combines them for transmission on the local loop. For data, the DSLAM connects to an ATM switch, which distributes data to ISPs and corporate networks, typically over leased lines.

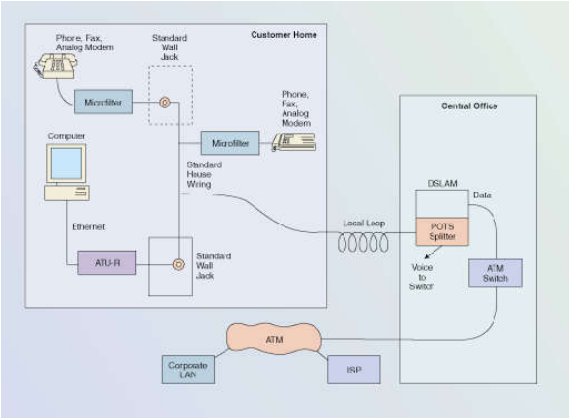

Figure 2. One version of splitterless ADSL service requires microfilters to separate ADSL signals from POTS signals. (Courtesy of U S West.)

The ADSL products that U S West installs use rate adaptive DSL (RADSL) technology; the subscriber can choose among several levels of service (data rates). Service ranges from 256 kbps downstream/256 kbps upstream for $40 per month to 7 Mbps downstream/1 Mbps upstream for $840 per month—plus ISP charges. The data rate that a subscriber can buy may be limited by the characteristics of the subscriber's local loop. Therefore, some customers may not be able to subscribe to the service they want because their local lines won't support their preferred data rates.

For the telco to know how each local loop performs, it must test each loop. Here's another place where ADSL testing has moved out of the lab. Technicians use portable equipment to test the local loops for throughput and noise. Bill Moten, product marketing manager at TTC (Germantown, MD) explains that these tests are important to ensure that the subscriber gets the quality of service he or she ordered. The local-loop measurements also help set the maximum and minimum rates of service that the ADSL modem can use. Unfortunately, if the minimum rate is set too high, then the customer's modem will never synchronize to the ATU-C at the telco—the customer's connection won't work.

If noise appears at certain frequencies during the tests on a local loop, the technician can find the source of the noise and crosstalk in the bundle of wires that contains the subscriber's loop. For example, noise at 772 kHz indicates that noise is coming from a T1 line in the same bundle. That frequency is the Nyquist frequency of the T1's 1.544 MHz. Noise at 196 kHz comes from a high-bit-rate digital subscriber line (HDSL) service.

Splitters and Filters

Right now, ADSL service that U S West sells requires subscribers to use the ATU-R equipment that the company provides. In addition, subscribers must install a small filter (called a microfilter) at each POTS device (each phone, analog modem, or fax machine) connected to the same phone line as the ADSL service. Some ADSL services require that the telco install a splitter on the subscriber side of the network interface device (NID) box. A splitter contains high-pass and low-pass filters that separate the voiceband POTS signals from the ADSL signals. These installations always require a visit from a technician. Sending a technician to a subscriber's premises is expensive. U S West's distributed splitter system (Fig. 2) uses a splitter at the CO to separate POTS and ADSL signals. This eliminates the need for a technician to install a splitter, but still requires the subscriber to install the filters.

A splitterless version of ADSL is vying to become a standard. For now, it's called DSL-Lite or G.Lite. G.Lite modems are based on ANSI T1.413, the standard for full-rate ADSL.[6] Now sanctioned by the International Telecommunications Union (ITU), G.Lite has begun appearing in modems built into new PCs, most notably those from Compaq. With G.Lite, subscribers should be able to buy any ADSL modem and subscribe to a service.

G.lite modems use only 96 tones for data rather than the 256 tones used by full-rate ADSL modems. (**Fig. 3**). The fewer tones limit the bandwidth to 420 kHz, a data rate of about 1 Mbps downstream and 512 kbps upstream. G.lite modems are designed to be compatible with the full-rate ATU-C systems at the telco side, but without letting the ATU-C assign data channels to tones greater than 96.[7] G.Lite modems use less bandwidth, and hence less power, than full-rate ADSL modems. Because the bandwidth of G.Lite modems is about half that of full-rate ADSL, their total power usage drops by about 3 dB.[8]

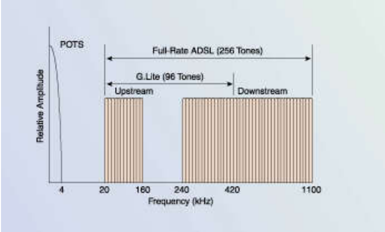

Figure 3. G.Lite ADSL uses less bandwidth than full-rate ADSL.

POTS Interference

ADSL subscribers should be able to use an analog dial-up modem or fax machine concurrently with an ADSL modem on the same phone line. Users might, for example, have an ADSL subscription for Internet service and still need to use a dial-up modem to get their office e-mail.

Splitterless ADSL equipment has testing issues that don't appear with full-rate, splittered ADSL systems. Testing of splitterless ADSL modems requires testing with POTS signals: on-hook/off-hook impulses, dial tones, DTMF dialing tones, pulses from pulse dialers, voice tones, analog-modem signals, and caller-ID data. Splitterless ADSL must also work with impairments caused by home wiring. Typical home telephone wires use a flat design, not a twisted pair. In benchmark tests, Aware (Bedford, MA) used 500 ft of flat 24 AWG wire, then added bridged taps and telephones at 50-ft. intervals.[9] When you test any ADSL design, be sure to test using the flat phone wire that is available in any hardware store.

According to Bill Timm, G.Lite development manager at Texas Instruments, manufacturers of splitterless ADSL products should test their designs with at least five POTS devices connected to the same line. You should test for any and all phones going off-hook during an ADSL downstream transmission. Even though G.Lite devices have high-pass filters, those filters work only for

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