xDSL Service Integration

The new regulations of copper loop and the new technologies have defined a competitive environment where multiple operators are using the local loop as the access network. In this new paradigm, it is necesary to test not only the capabilities of the installed plant, but also the limits in the use of these technologies (ADSL, SDSL, POTS, ISDN, E1,..) when bundling in a multioperator pace.

probucle 1.4

Testing the world's digital networks

TrendCommunications

FIRST MILE: TECHNICAL AND POLITICAL ISSUES

The indirect access is defined as the facility provided by the dominat operator to other operators that allows to provide services using the the dominant operator local loop and xDSL technologies.

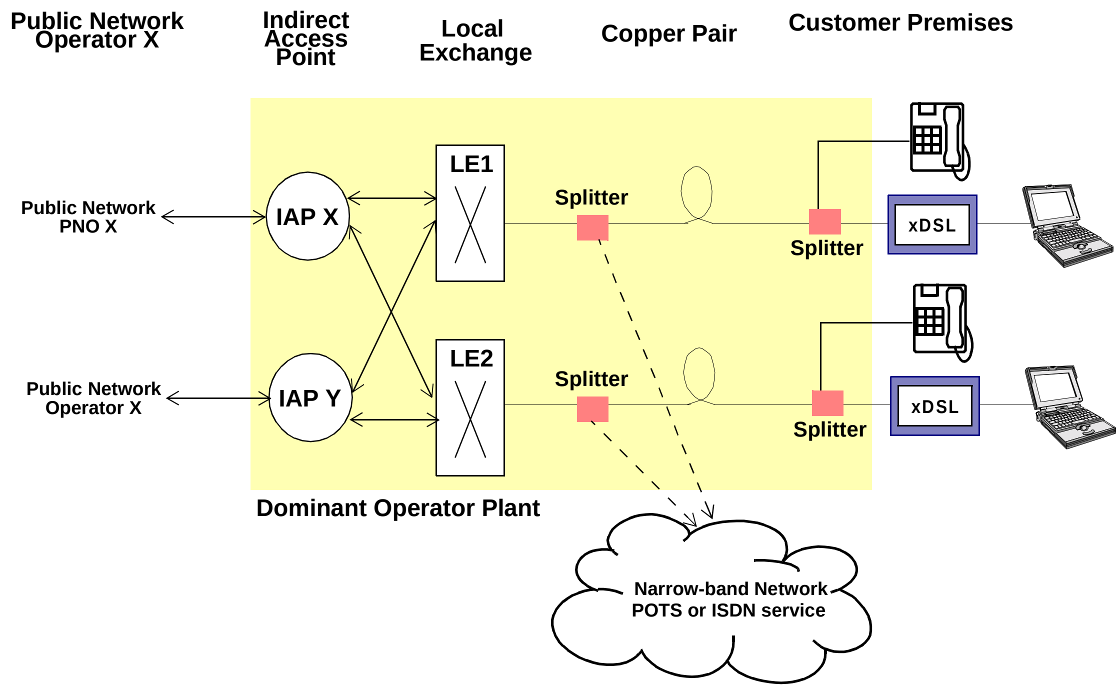


Figure 1 *ADSL system reference model (ITU-T G.992.1).*

Objectives

The DSL technologies use modem equipment that transform the copper local loop, used for voice and low rate modem communications, into a high-speed access to multimedia services.

DSL is a modem technology and the reachable rate depends on the quality of the loop.

Most of the copper loops were used before for analog transmissions in the voice band. As long as the bandwidth of the DSL signal is much bigger than the legacy services, it is necessary to verify the state of the local loop before a DSL installation.

The possible problems can be grouped:

1. The requirements of the DSL signal are more restricted in noise level and available bandwidth.
2. The magentic coupling increases at higher frequecies. It is necessary to know the side effects from one pair to another when transporting DSL signals, and also the limit of DSL signals transported in the same bundle.

This document describes the procedure and the necesary measurements to establish a reliable DSL service.

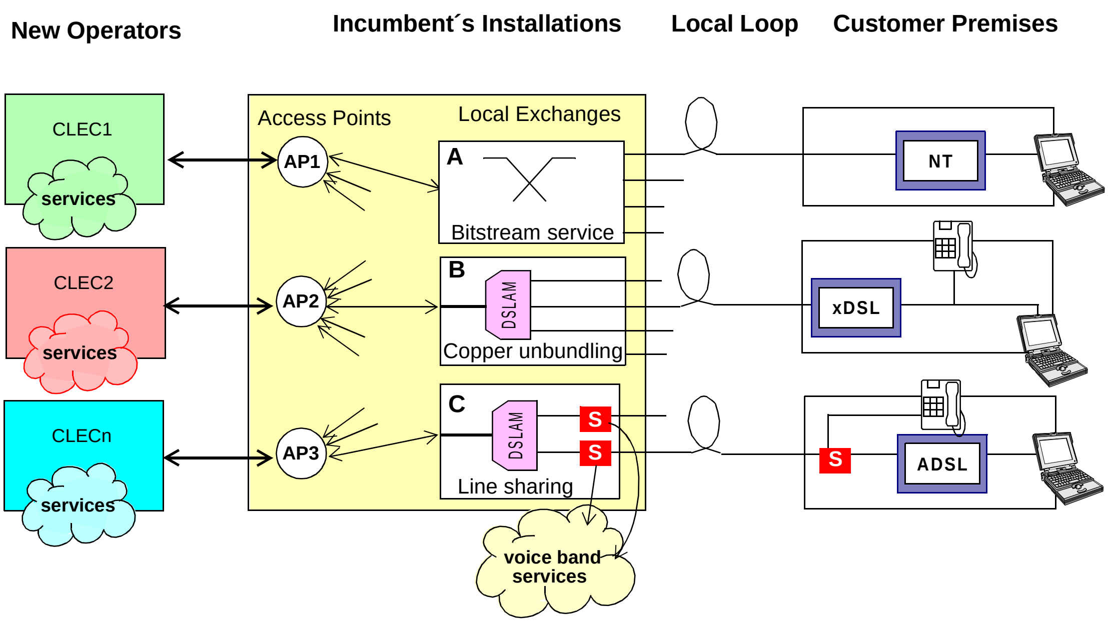


Figure 1 *Coexistence of CLECs and ILEC by means of local loop unbundling*
The local exchange A provides bitstream services the CLEC1 by means of any technology. In B, the CLEC2 rents all the local loop frequencies, while in C, the ILEC maintains the legacy service like voice and lends the ADSL frequencies to the CLEC3.

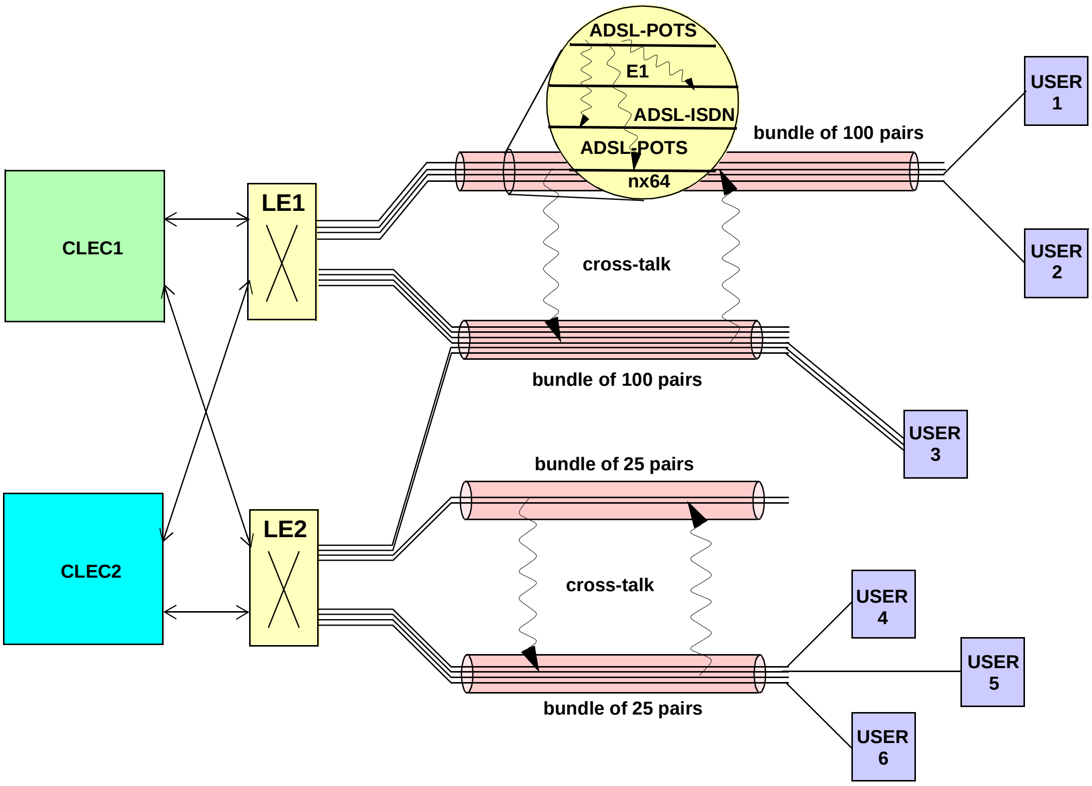


Figure 2 *When the pairs are not isolated, they are exposed to cross-talk, the physical phenomenon that consists of the spureous transference of energy from a metallic wire to the adjacents.*

SEQUENCE

The DSL certification test cover for the local loop is a sequence of three groups of measurements:

1. Electromagenetic parameters of the copper loop that do not depend on the information signal.
2. Analog measurements of the DSL signal, including spectral characterization and crosstalk.
3. The digital measurements pay attention to the framed signals sent like BER.

Usually, the electromagnetic measurements are made once, and the analog and digital ones must be made for each combination of technologies used.

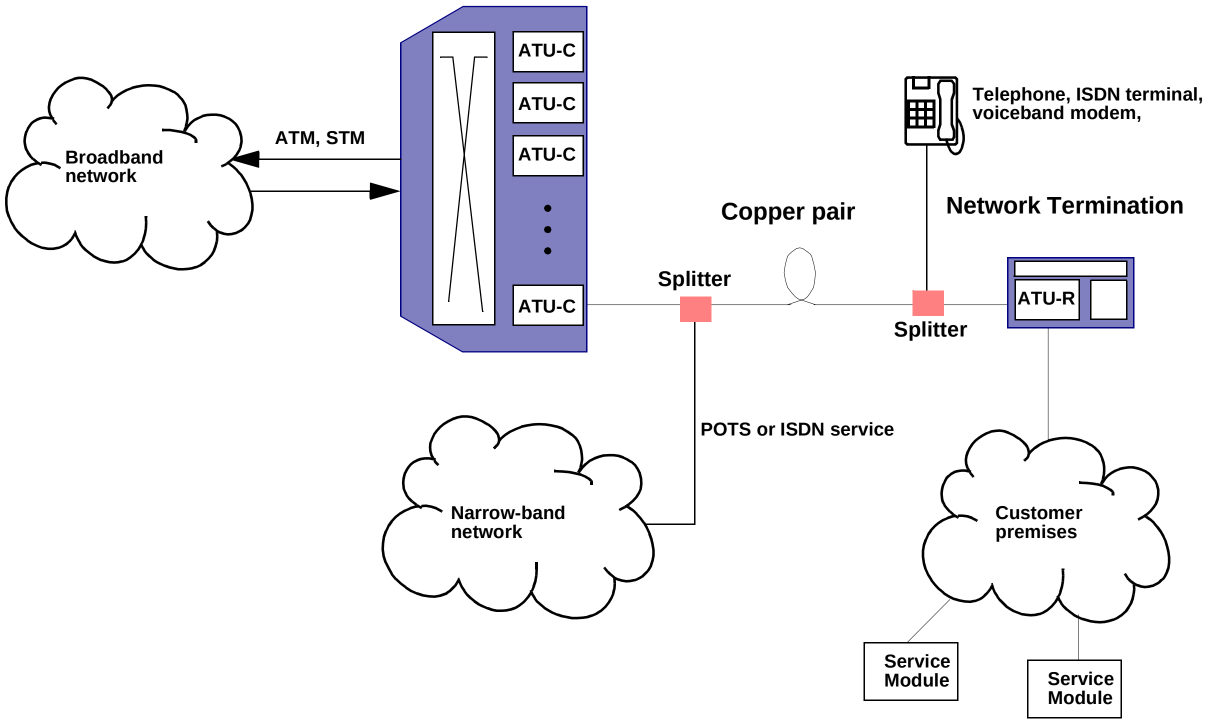


Figure 2 ADSL system reference model (ITU-T G.992.1).

REFERENCE MODEL

The G.992.1 and G.992.2 ITU-T recommendations describe a generic local loop that identifies the elements of the model and their functionality.

The most important characteristic of the DSL reference model is the capacity to provide service over POTS and over ISDN, because the DSL bands of frequencies are different. These signals are splitted by using low pass and high pass filters.

GROUP 1: COPPER QUALIFICATION

The measurements of the group 1 allow you to characterize the copper pair at the level of electric parameters, regardless of the signal travelling in it.

Main Technical Parameters

The following list determines the set of technical parameters relevant to the qualification of the metallic subscriber loop.

- Longitudinal balance [dB]
- RMS noise level, [dBm]
- Attenuation [dB]
- Return loss [dB]

General

Many of the parameters used for the copper qualification are functions of frequency and, therefore, the right way of expressing the obtained measurement results is by means of a frequency graph. Many times, it is necessary to check that a result expressed as explained fits with predefined requirements in some points or at determined frequencies. Graphically, this is equivalent to a superposition of the graphic results with a mask. The graph must be inside the allowed zone of the mask.

Another factor to be considered is that all the characteristic parameters of the copper pair are functions of such ambient variables as the temperature. The environmental conditions recorded when performing the certification tests must be the same as the normal operative conditions, and the temperature recorded during the test must be specified in the results.

Longitudinal Balance

One of the sources of degradation of an information signal in a metallic wire is the interference of external fields. The level of tolerance of conductors to external electromagnetic fields decreases when their length is increased and, therefore, some preventive measurements are necessary, in order to avoid degradation of the information carried in the signal.

The longitudinal balance is the way to measure tolerance to interferences from an external electromagnetic field over a balanced line. The balanced lines are characterized by high immunity to electromagnetic interferences, due to the cancel feature of induced tensions of the same level in the two wires. This immunity is never perfect, because of the small differences in the tension in respect to the common ground. These small differences are measured with the longitudinal balance.

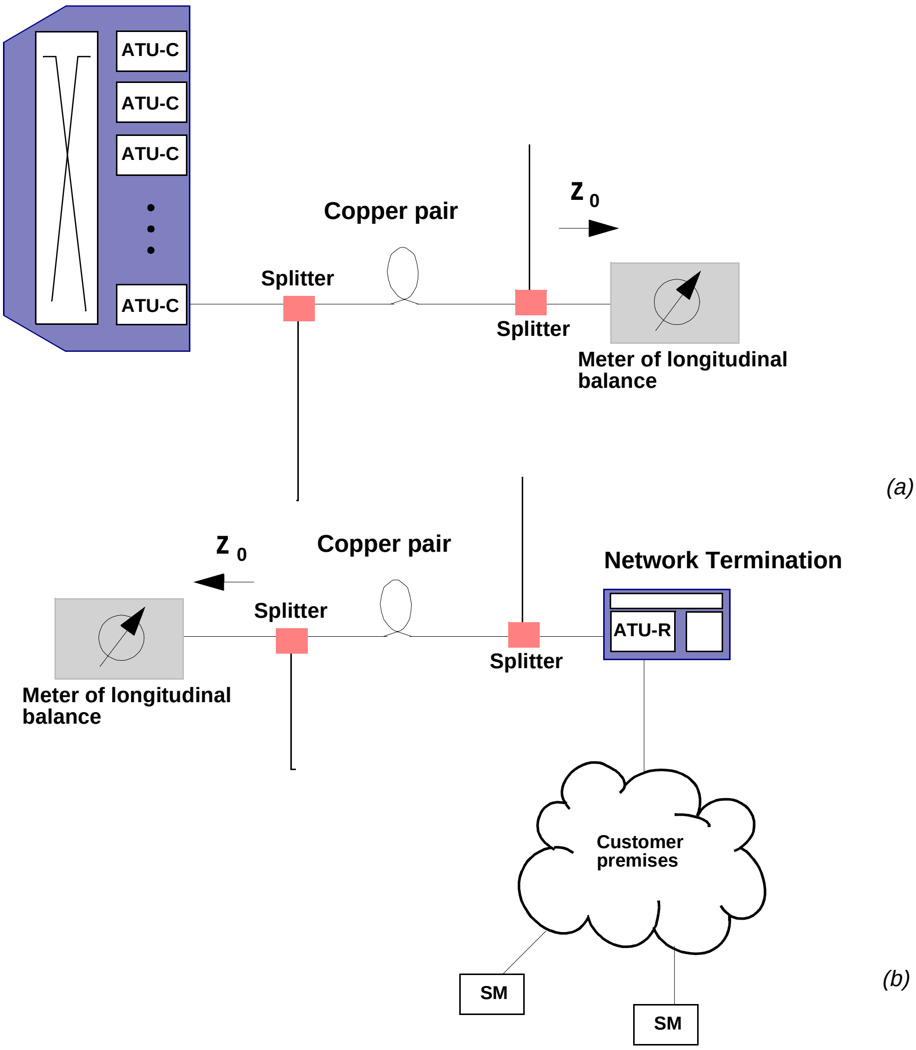


Figure 3 *(a) Longitudinal balance measured from the customer premises*
(b) Longitudinal balance measured from the central office

The longitudinal balance is defined in ITU-T G.117 and ITU-T Rec. O.9 to be coefficient between the longitudinal tension and the transversal tension produced by it.

$$LCL = 20\log\left|\frac{V_{T1}}{V_{L1}}\right|$$

These recommendations also describe the method used to measure the longitudinal balance.

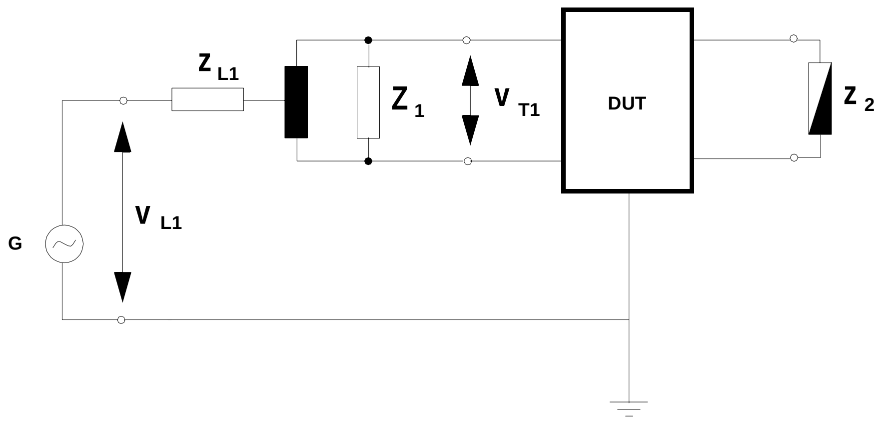


Figure 4 Longitudinal balance measured as recommended in ITU-T G.117 and O.9

Attenuation

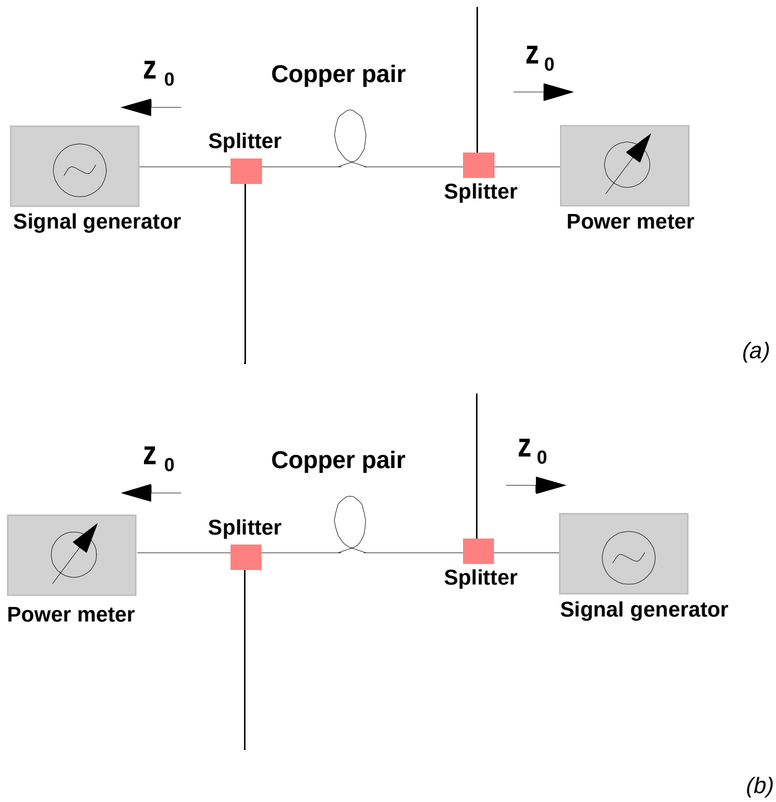


Figure 6 *(a) Attenuation measured from the customer premises*
(b) Attenuation measured from the central office

The attenuation or insertion loss is the main factor that limits the wire length. The attenuation depends on the signal frequency. It is normal for high frequencies to have an attenuation higher than that of low frequencies, and it is therefore a cause of distortion.

The attenuation measurement is made by entering a signal in one end of the pair and measuring the power received at the other end.

Noise

Noise is an aleatory perturbation of termal or other nature that degrades the information signal and makes its reception more difficult, especially if this signal has a low power level.

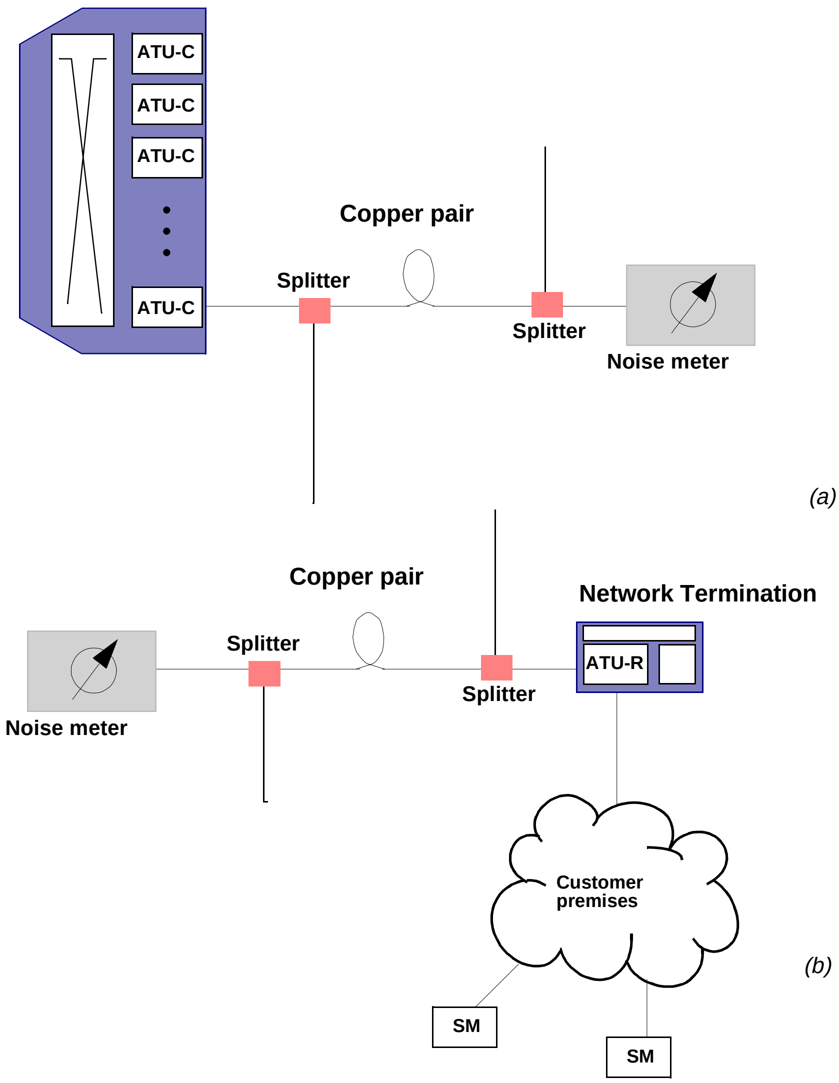


Figure 7 *(a) Noise measured from the customer premises*
(b) Noise measured from the central office

The noise level can be quantified in different ways. One of them is through its power spectrum. Another option is to measure only the RMS value of the noise. This simplification is convenient particularly if the power spectrum of the noise is constant over all frecuencies of interest.

The main problem of a noise measurement is to make sure that the result obtained is only noise, because other spureous signals can be received and the result may be significantly altered. Therefore, it is important to isolate the lines of undesirable interference sources that may be received.

Return Loss

Return loss is one cause of performance decrease in signal transmission over a transmission line.

In order to maximize the power delivered from a source to a transmission line, the impedance of the generator must be adapted to the line impedance. To maximize the power in the load impedance adaptation is also necessary. Misadaptations cause a loss of power at the receiver and performance decrease in the transmitter. When the power cannot be received by the load, it is reflected to the transmitting side.

To measure the efficiency of the generator sending power to the load, the return loss is defined as follows:

$$L_{ret} = 10\log\frac{P_i}{P_r}$$

The power loss is the logaritmic quotient between the power sent by the generator and the power reflected.

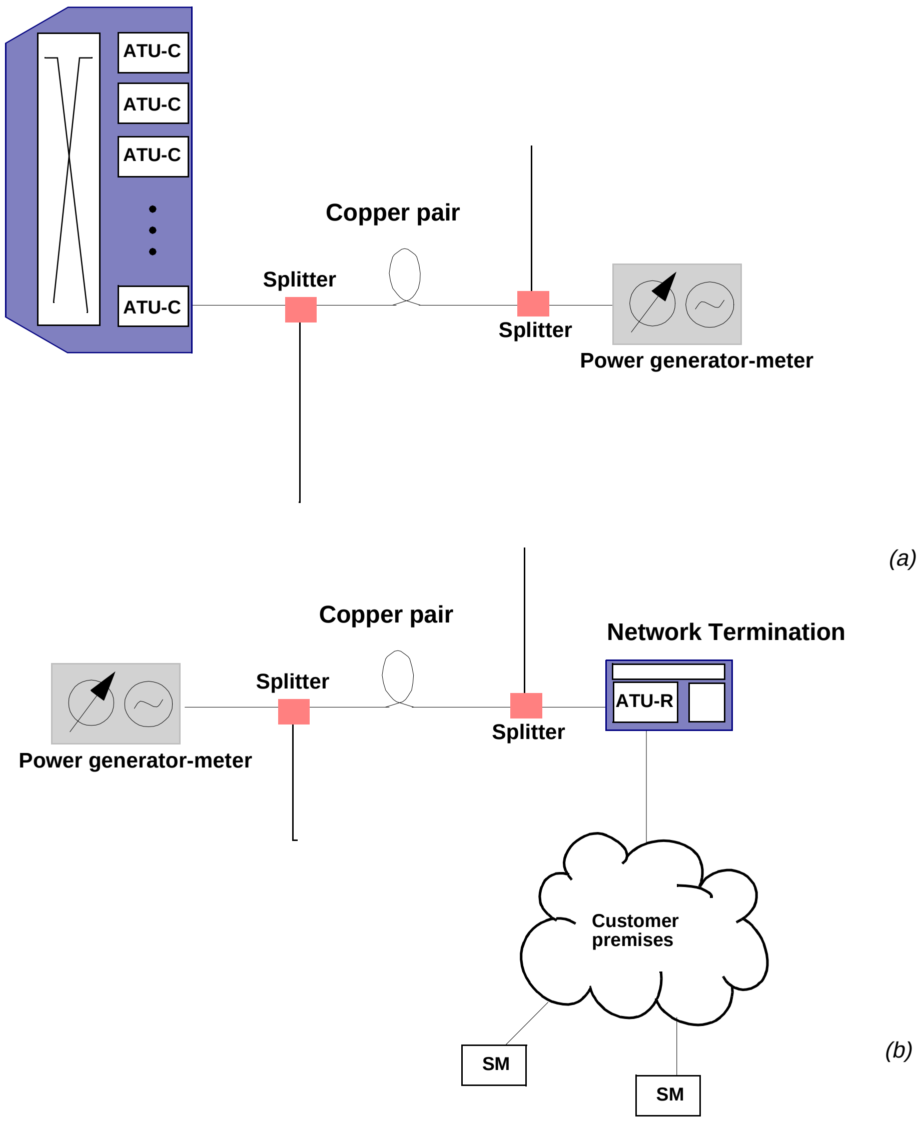


Figure 8 *(a) Return loss measured from the customer premises*
(b) Return loss measured from the central office

GROUP 2: ANALOG MEASUREMENTS

The measurements of the second group are analog. That is, they characterize the received signal at electric level. If the measurement is made over the same line where the signal is transmitted, we can talk about spectral characterization of the received line, and if it is made over another line, we can talk about a cross-talk measurement.

Spectral Characterization of the Received Signal

A model of signals modulated with DMT is more intelligible if it is made over frequencies rather than in time domain. This is because the DMT signal is composed of a high number of sub-carriers that make its analysis in time domain complex.

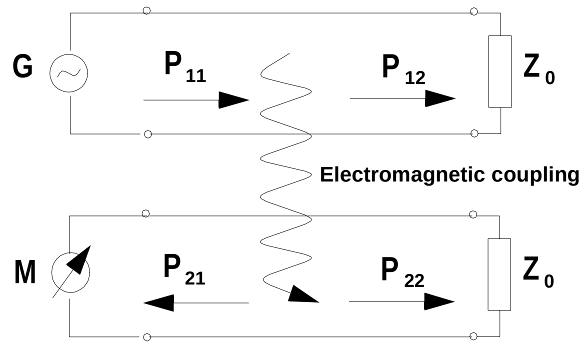
The power spectrum density of the received signals must be adapted to minimum conditions in order for the signals to be demodulated by the corresponding receiver, an ATU-C or an ATU-R.

Cross-talk

Cross-talk is defined as the spureous transference of energy from a wire to the adjacents, due to the electromagnetic coupling between them.

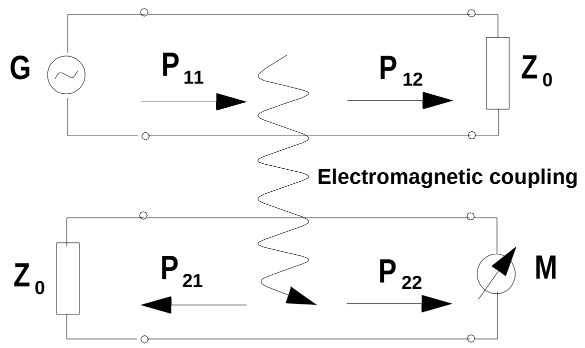
It is necessary to define and distinguish the concepts of NEXT and FEXT. NEXT is the cross-talk measured at the same side where the interfering test signal is generated and FEXT is the cross-talk measured in the far end opposite to the interfering test signal.

The cross-talk measurements can be considered as group 1 measurements, if the test signal used is sinusoidial or otherwise different from an information signal.



NEXT

$$a_N = P_{11} - P_{21} [dB]$$



FEXT

$$a_F = P_{11} - P_{22} [dB]$$

The measurement and the theoretical caracterization of the NEXT is easier than that of the FEXT. The theoretical formulation of FEXT is a function of the length of the line, but NEXT does not depend on the length of the wires.

Another aspect related with the cross-talk measurement is a consequence of the organization of groups of copper pairs in bundles. The electromagnetic coupling between pairs of the same bundle is not the same as the coupling between pairs in adjacent bundles. These two situations must be considered separately. When different signals are put together in coupled pairs, the effects caused by every signal must be taken into account.

Cross-talk is characterized by its power spectrum density or by the total power induced in the interfered pair. The theoretical power spectrum of some diaphonic interferences, FEXT and NEXT, is specified in the Rec. G.996.1.

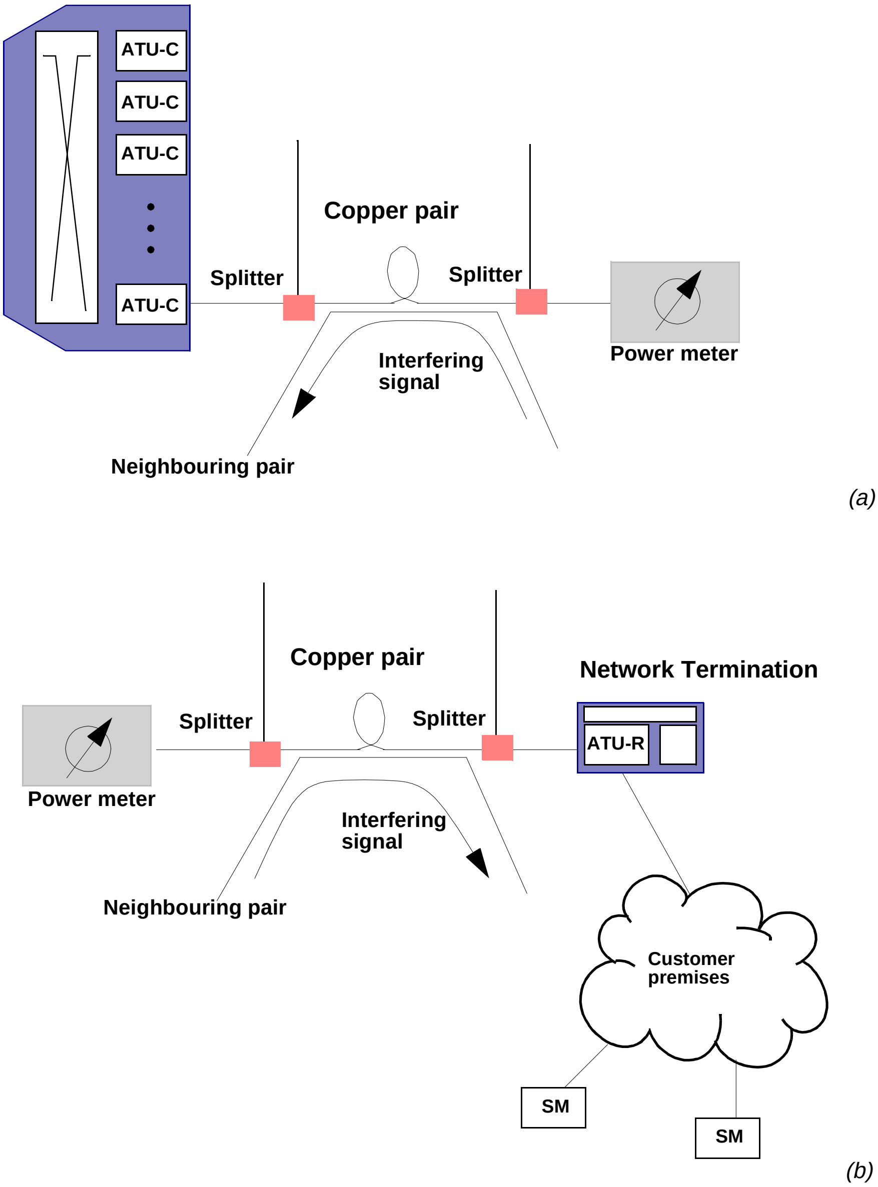


Figure 9 *(a) NEXT measured from the customer premises*
(b) NEXT measured from the central office

The limits of cross-talk could be specified according to a mask with acceptable and unacceptable zones delimited, but it is easier to define the limit of other parameters (BER or total cross-talk power) for each type of cross-talk.

GROUP 3: DIGITAL MEASUREMENTS

Digital measurements are the ones where the object of the measurement is not an electrical parameter of a signal or a pair, but a digital parameter, such as a bit, a frame or a superior entity.

The most important digital parameter to define the characteristics of a transmission system is the error rate in a bit or BER. If the system uses DMT modulation, the bit rates of ascendent and descendent transmission depend on the concrete state of noise and interferences in the pair. This is why they are an acceptable way to define the operational state of the line in the measurements.

Once verified that the BER and the transmission and reception rates are within accepted limits, it is still necessary to make a continuity check at the IP level of the loop.

BER

A BER measurement can be performed in different ways, depending on the interface used for the test instruments. A measurement performed at the ATM level includes the instruments of both the central and the user. In other words, they depend on the DSLAM and the DSL modem. The measurements at the DSL level, in their turn, are independent of the DSLAM and the modem.

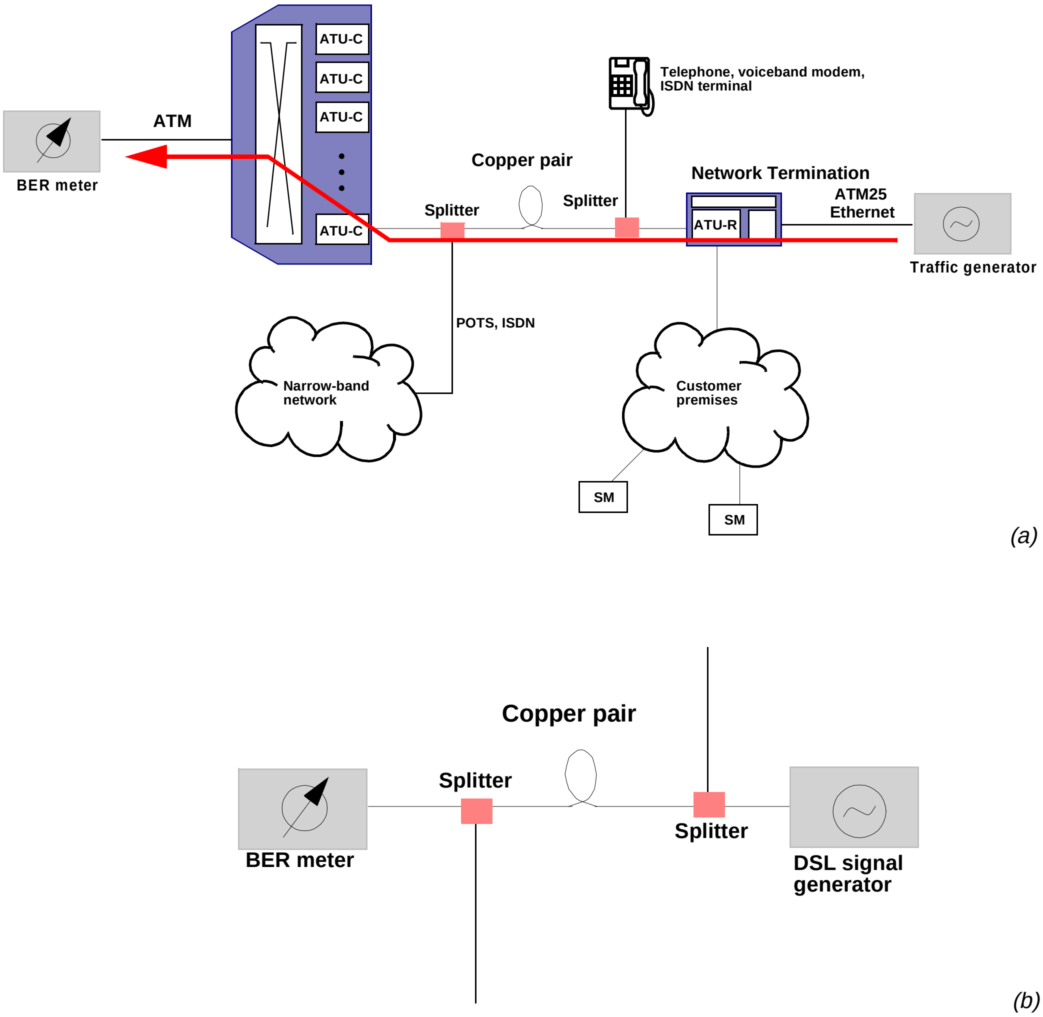


Figure 10 *(a) BER measurement at the ATM level made from the central office*
(b) BER measurement at the DSL level made from the central office

To be able to make a highly reliable estimation, the BER of the channel under test must provide a minimum number of bits. For this reason, the time of the measurement depends on the transmission rate. The measurement time must be over 20 minutes for measurements under 1544 kbit/s. However, for measurements over 6 Mbit/s, 100 seconds is enough.

Technology	Frequency Margins
Over 6 Mbit/s	100 s
1544 Mbit/s	500 s
Under 1544 Mbit/s	20 min

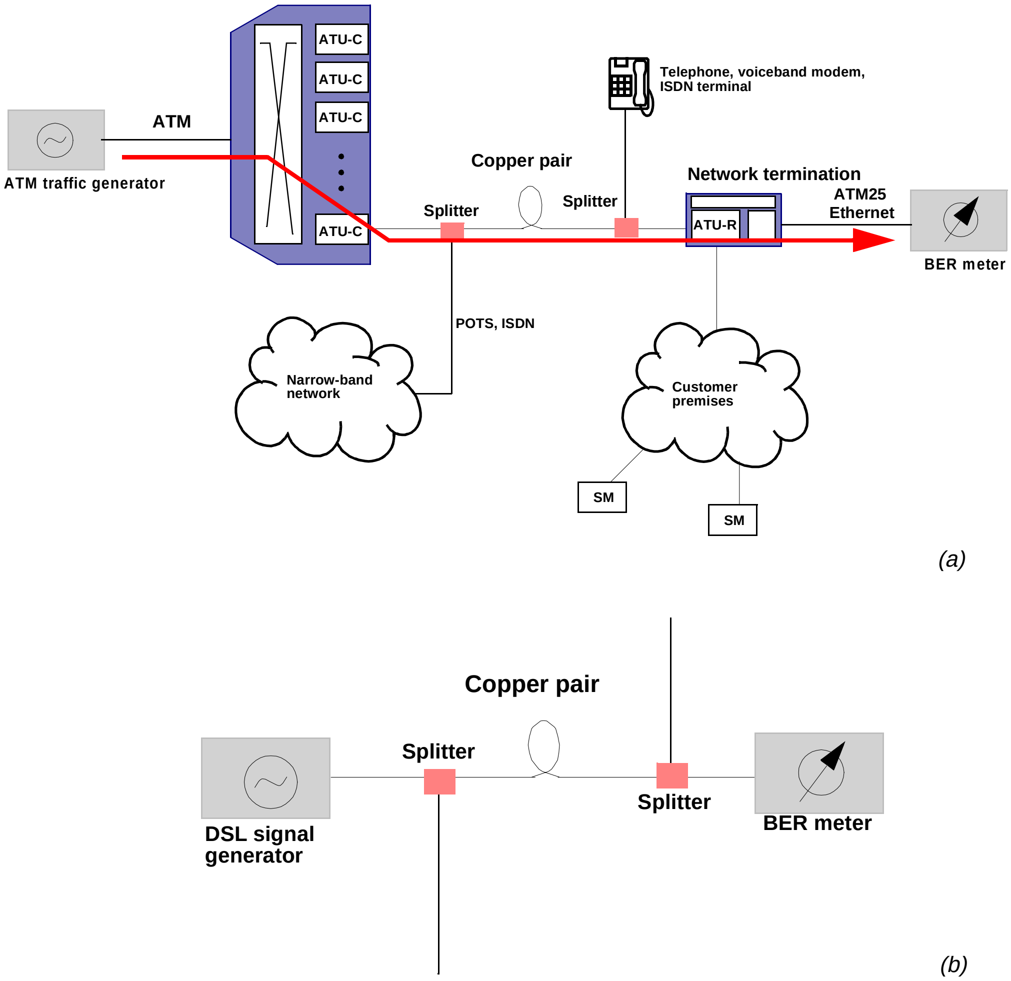


Figure 11 *(a) BER measurement at ATM level made from the user premises*
(b) BER measurement at DSL level made from the user premises

Ascending and Descending Bit Rates

Those transmission systems that are based on DTM modulation assign a transport of a certain amount of information to each subcarrier. This depends on the transmission capacity of the sub-band associated with the subcarrier. As a result, you obtain a variable transmission rate that depends on the quality of the link.

Continuity Check at IP Level

This measurement is to verify that the whole system is correctly configured. This is done by analyzing the transparency of the communication over the link that connects the DSLAM to the ATM network and to the user.

An IP ping is generated in the user premises and sent by the corresponding VPI/VCI. If the configuration of the transmission system is correct, you should receive an answer through the same channel.

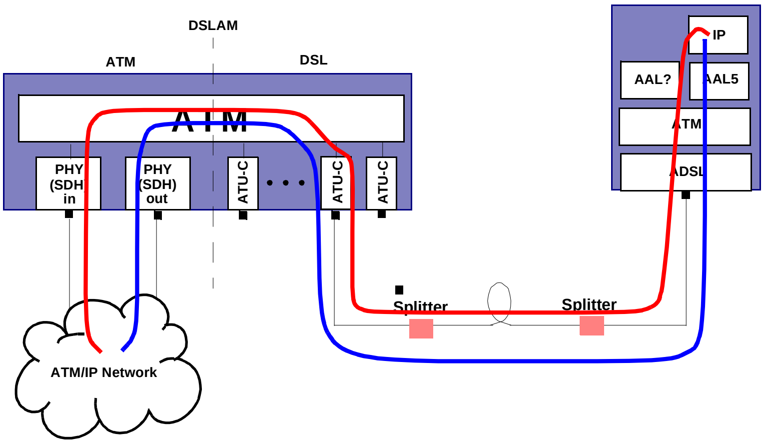


Figure 12 *Continuity check at IP level.*

APPENDIX A: RECOMMENDED VALUES FOR COPPER QUALIFICATION

- RMS Noise Level

Technology	Frequency margin	Noise (RMS)
HDSL 2B1Q	10 - 300 kHz	< -40 dBm
ADSL	26 - 1100 kHz	< -45 dBm

- Attenuation

Technology	Attenuation
HDSL 2B1Q (4 wires)	< 32 dB @ 150 kHz, 150 Ω
HDSL 2B1Q (2 wires)	< 27 dB @ 300 kHz, 150 Ω
ADSL 2M1 (6.144 kbit/s)	< 13 dB @ 40 kHz, 150 Ω < 25 dB @ 300 kHz, 150 Ω < 47 dB @ 1100 kHz, 150 Ω
ADSL 2M2 (4.096 kbit/s)	< 15 dB @ 40 kHz, 150 Ω < 30 dB @ 300 kHz, 150 Ω < 56 dB @ 1100 kHz, 150 Ω
ADSL 2M3 (2.048 kbit/s)	< 17 dB @ 40 kHz, 150 Ω < 35 dB @ 300 kHz, 150 Ω < 65 dB @ 1100 kHz, 150 Ω

- Return losses

Technology	Return losses
HDSL 2B1Q (4 wires)	< 15 dB @ 150 kHz, 150 Ω
HDSL 2B1Q (2 wires)	< 15 dB @ 300 kHz, 150 Ω
ADSL	< 10 dB @ 26 kHz, 150 Ω < 15 dB @ 1100 kHz, 150 Ω

- Cross-talk

Technology	Cross-talk
HDSL 2B1Q (4 wires)	< 65 dB @ 150 kHz, 150 Ω
HDSL 2B1Q (2 wires)	< 65 dB @ 300 kHz, 150 Ω

Technology	Cross-talk
ADSL	< 65 dB @ 26 kHz, 150 Ω < 60 dB @ 1100 kHz, 150 Ω

- Longitudinal balance

Technology	Longitudinal balance
HDSL 2B1Q	> 42.5 dB @ 150 kHz, 150 Ω (ETSI TS 101 135 V1.5.3)
HDSL CAP	> 42.5 dB @ 150 kHz, 150 Ω (ETSI TS 101 135 V1.5.3)
ADSL	> 40 dB @ 30-1104 kHz, 150 Ω
SDSL	> 42.5 dB @ 1100 kHz, 150 Ω (ETSI TS 101 524 V1.1.1)

- Insulation

Technology	Insulation
HDSL 2B1Q	50 MΩ @ 0 Hz with GND, 800 MΩ x km @ 0 Hz between the wires
HDSL CAP	50 MΩ @ 0 Hz with GND, 800 MΩ x km @ 0 Hz between the wires
ADSL	50 MΩ @ 0 Hz with GND
SDSL	50 MΩ @ 0 Hz with GND

APPENDIX B: SPECTRAL MASKS FOR G.992.1 SIGNAL

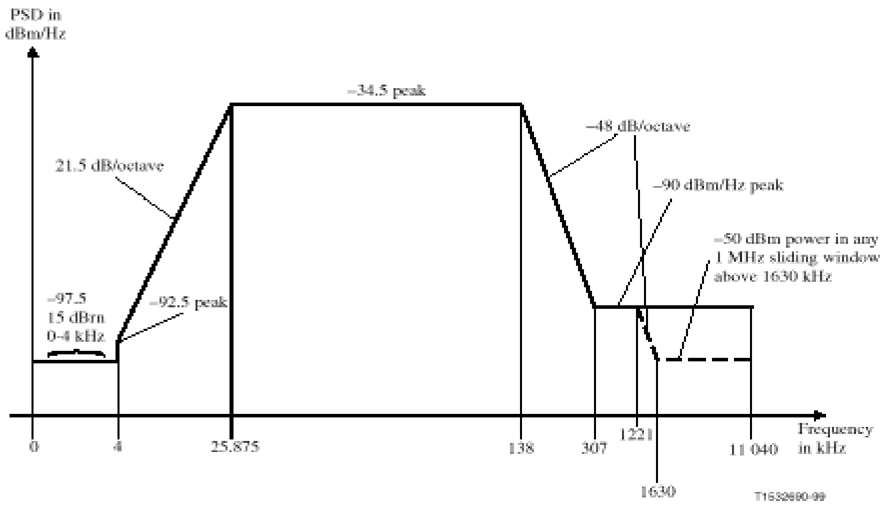


Figure 13 *Power spectrum density mask for the ATU-R.*

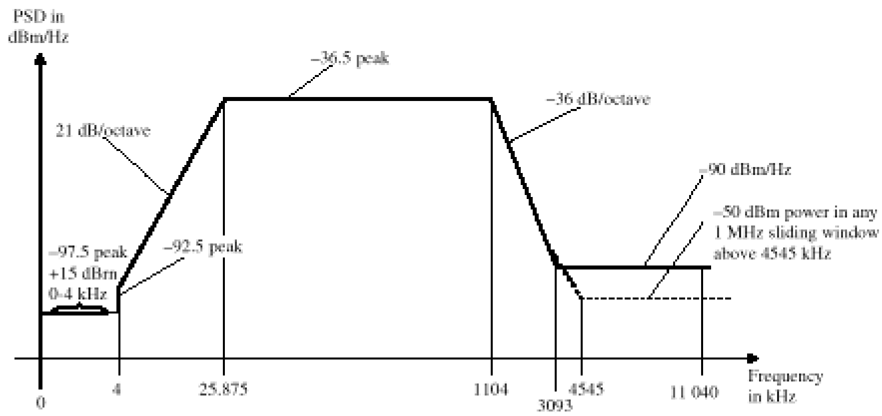


Figure 14 *Power spectrum density mask for the ATU-C*

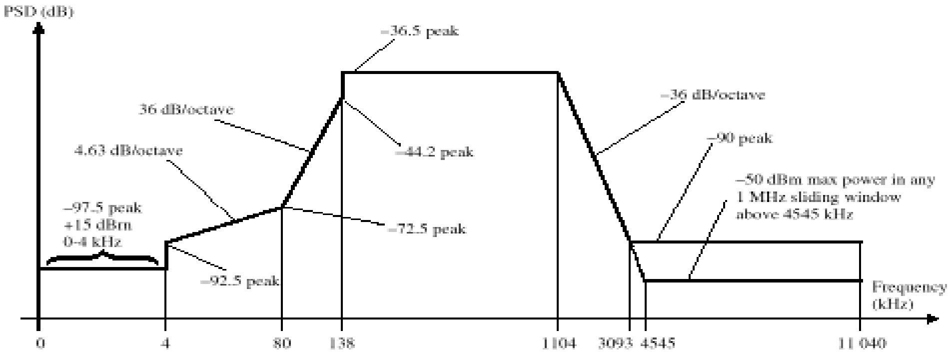


Figure 15 Power spectrum density mask for the ATU-C for reduced NEXT.

Appendix C: Theoretic Spectral Characteristics of Different Types of Cross-Talk Interferences

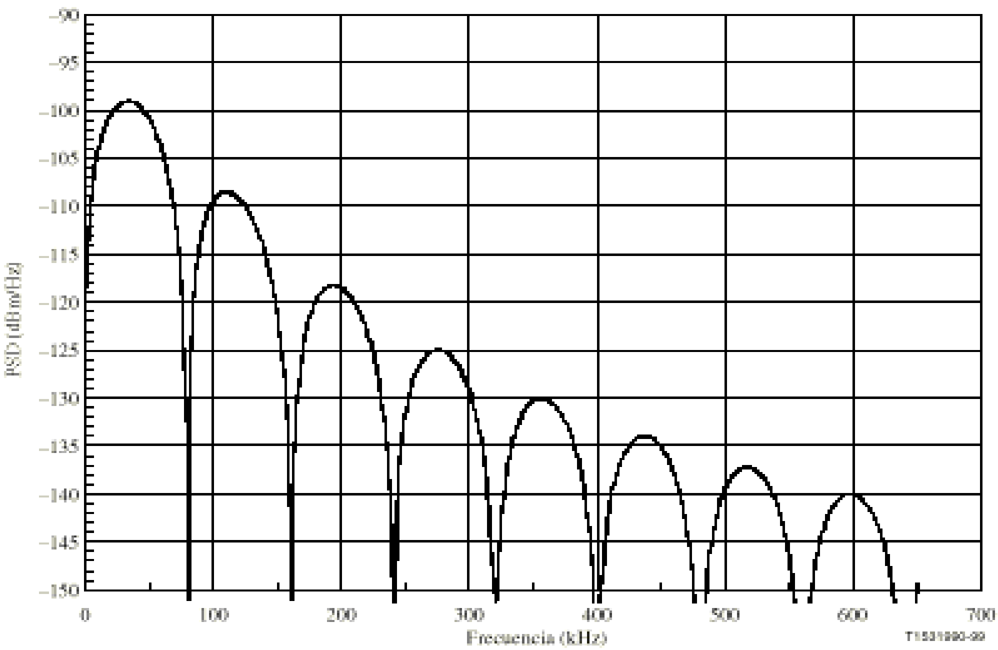


Figure 16 DSL NEXT with 24 disturbers.

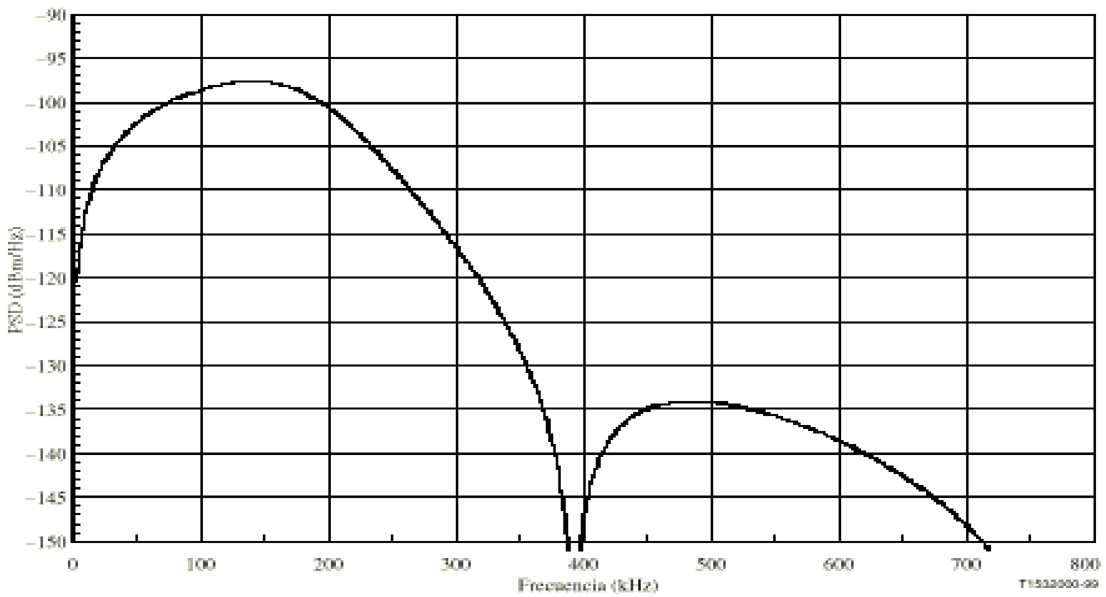


Figure 17 HDSL NEXT with 10 disturbers.

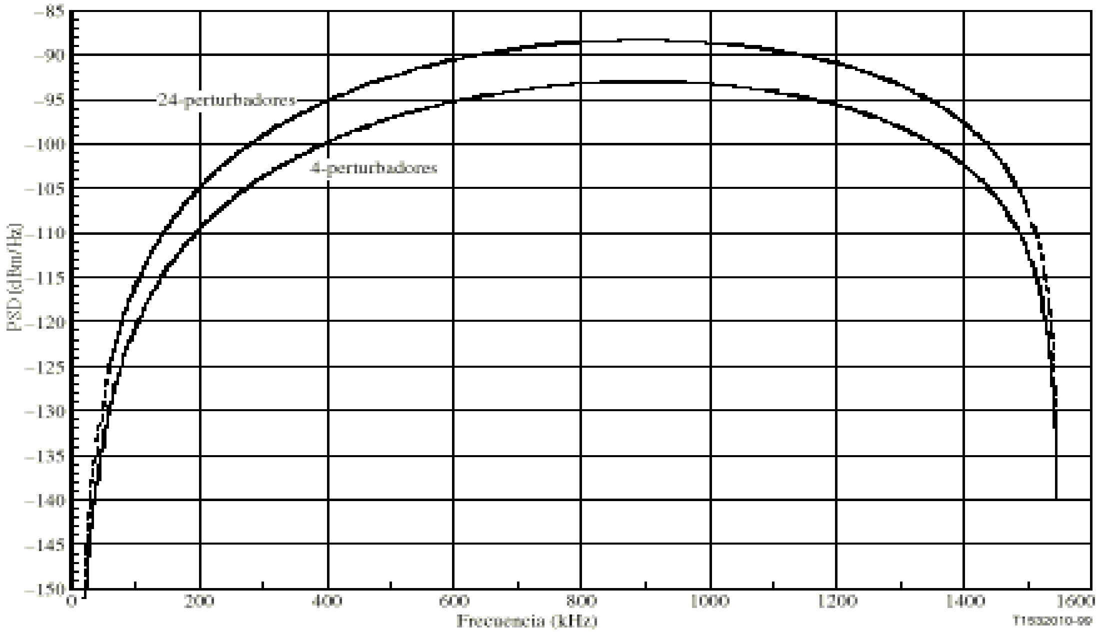


Figure 18 NEXT of T1 of 4 and 24 disturbers.

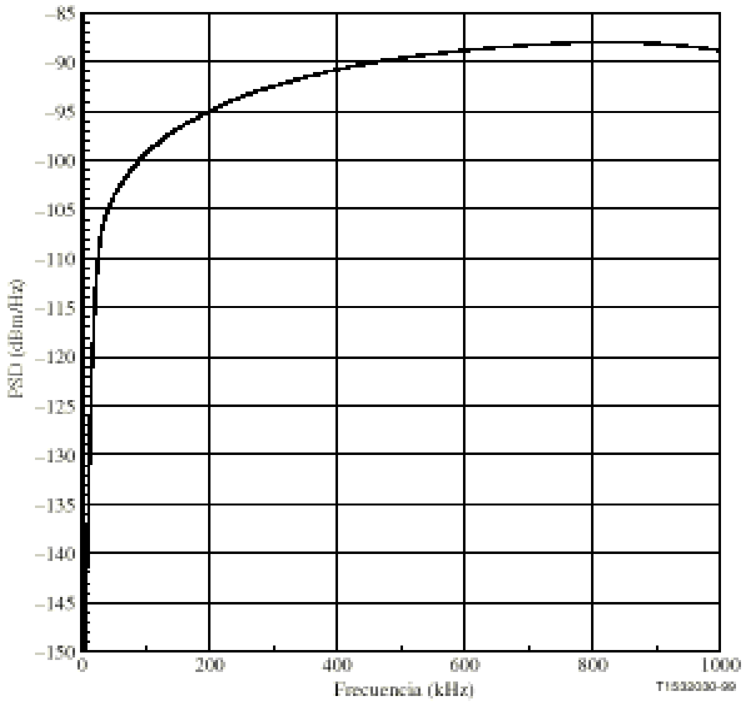


Figure 19 NEXT of G.992.1 signals towards the destination with 10 disturbers towards the origin.

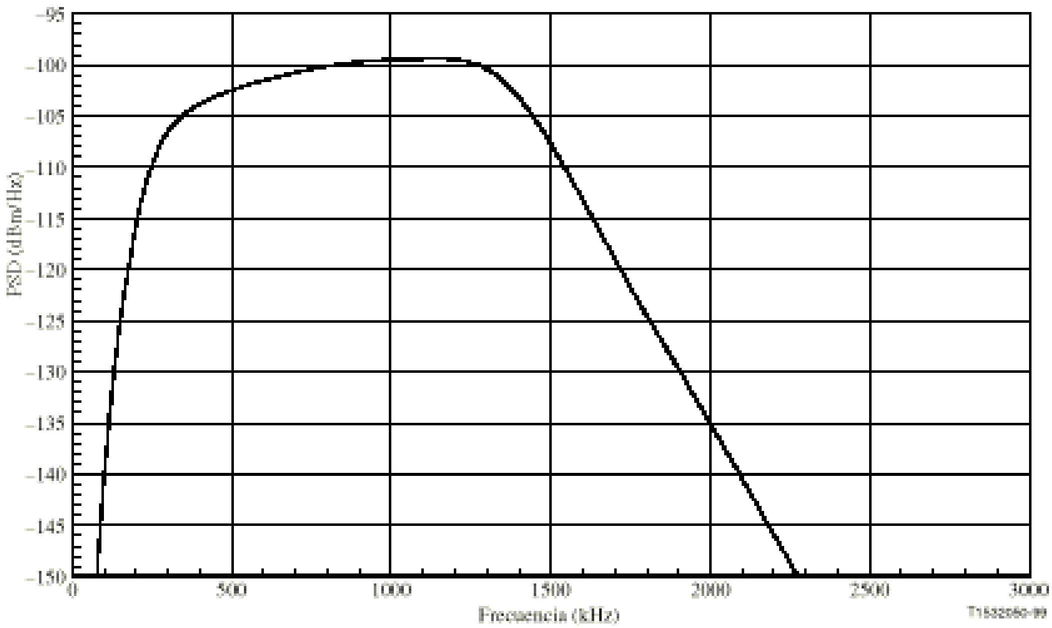


Figure 20 NEXT of G.992.1 signals towards the origin with 10 disturbers towards the destination.

For more information, see the ITU-T recommendation 961.1.

Appendix D: Performing Measurements. Practical Points of View

Topological Characterization of Measurement Environment

You need a map, in which the physical parameters of the pairs are defined, together with the location of the measurement points (the ends of the pairs). The physical parameters include:

1. Length
2. Cable type
3. Presence of secondary branches (and length and caliber, if applicable)
4. Packing of pairs in groups.

To identify these parameters, you do not need a measurement instrument, but the parameters must be supplied by the network providers. They are identified and classified depending on their features, for example Short Pair, Medium Pair, Long Pair and Very Long Pair.

Copper Qualification

This is carried out by means of the measurements that are performed as follows.

1. *Insulation resistance between cables and between each cable and mass*.

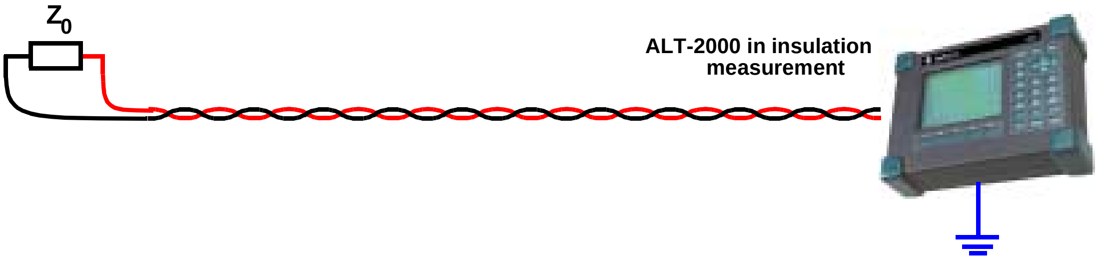


Figure 21 ALT-2000 performing an insulation measurement of a copper pair.

Another measurement to be made is that of DC insulation between the cables and the ground. The result is expressed in three values in Ω.

2. *Return losses.*

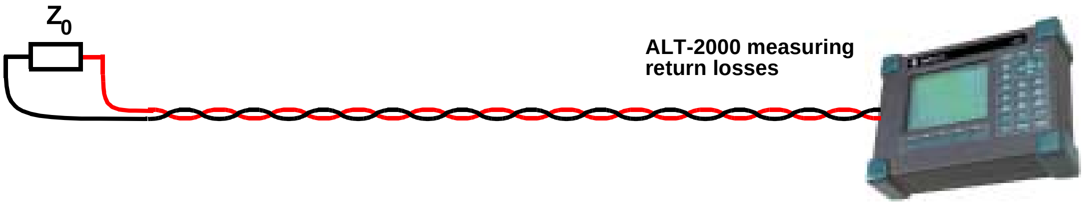


Figure 22 ALT-2000 making a return loss measurement of a copper pair.

The values of return losses (dB) are given in the interval of significant frequencies, between 1 kHz and 1.1 MHz.

3. *Longitudinal balance.*

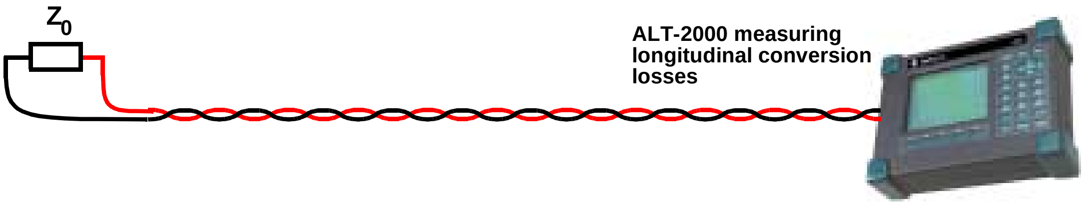


Figure 23 ALT-2000 making an insulation measurement of a copper pair.

The values of longitudinal balance are given (dB) in the interval of significant frequencies, between 1 kHz and 1.1 MHz.

4. *Noise level.*

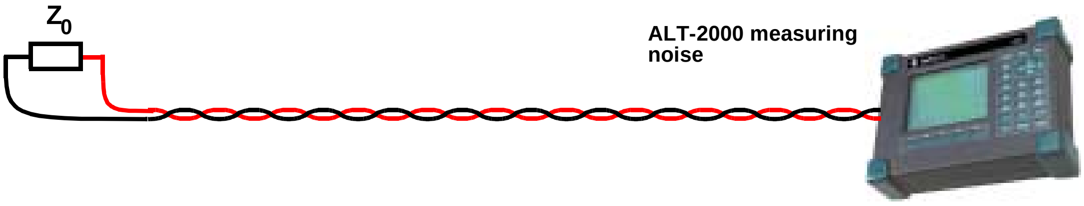


Figure 24 ALT-2000 measuring the noise level of a copper pair.

The measurement is performed by adapting the far end, e.g. inserting a value resistance equal to the line impedance.

The result is the RMS value and significant values inside the bandwidth, between 1kHz and 1.1 MHz.

5. *Insertion losses.*

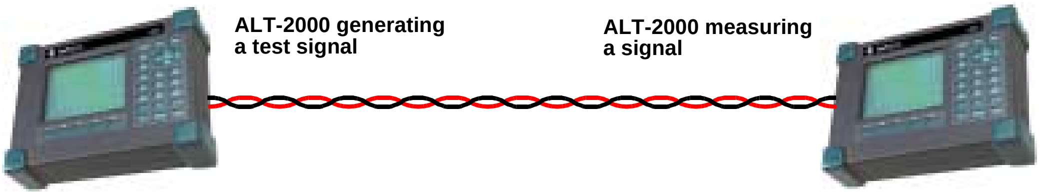


Figure 25 ALT-2000 measuring insertion losses in a copper pair.

Significant values are taken from the frequency response of the pair, in the frequency interval, between 1 kHz and 1.1 MHz.

Characterization of the Received DSL Signal

There are two ways to characterize the received signals.

1. *Analyzing the interfering signals.* By means of cross-talk measurements, each possible interfering signal can be characterized in the DSL transmission. The DSL signals themselves can be found amongst them.

- *Aurora Presto* or, alternatively, an ATU-C combined with *Victoria ATM/IP* is used to generate the signal.
- The FEXT and NEXT cross-talk measurement is made between pairs belonging to the same group and pairs belonging to different, adjacent groups, with only one interfering signal and for each type of pair.
- For signals where both the transmission and the reception take place in the same pair, the measurement is repeated, generating both ascend-

ing and descending traffic, in order to obtain the parameters in both directions of transmission.

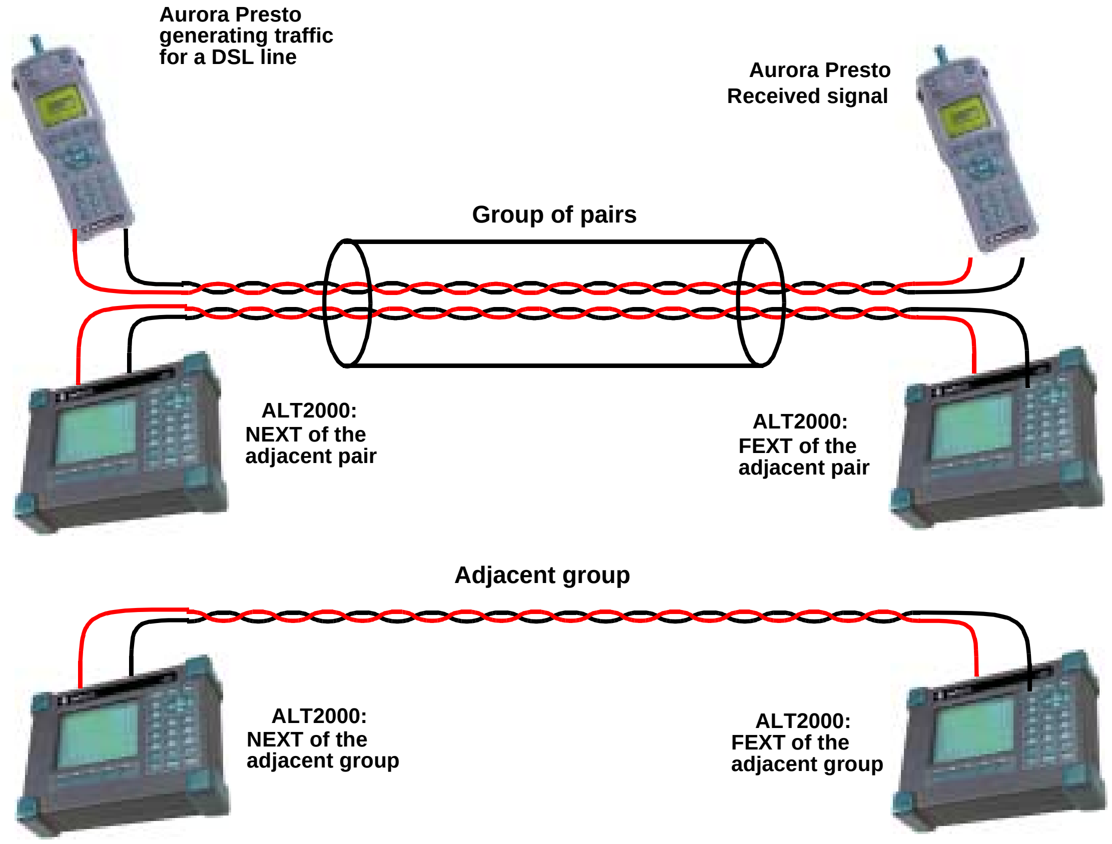


Figure 26 Cross-talk measurement for an interferer injected in the channel by Aurora Presto.

2. *Analyzing the received signal*, for the specified sceneries of interferers.

   In this case, the measurement is determined by the following parameters:

- Identificators of the pair used to transmit the test signal
- Identificators of the pairs belonging to a group
- Identificators of the pairs belonging to the adjacent group
- s_1^1 test signal
- s_i^1 signal, interferers of a group
- s_i^2 signal, interferers of the adjacent group

The BER may be measured either at DSL or ATM level. Making the measurements at ATM levels has certain advantages:

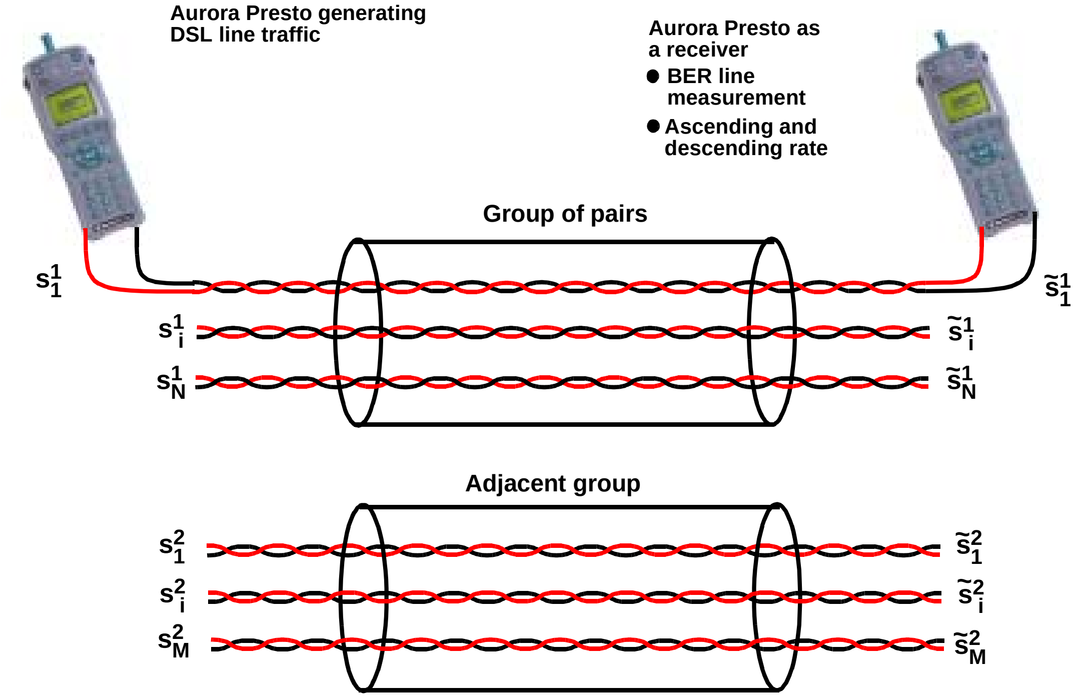


Figure 27 Measuring a signal in the presence of many interfering signals.

- Possibility to use the same test instruments in all the tests, varying the xTU-C and xTU-R
- Independence of minimum requirements concerning the technology

On the other hand, an ATM level measurement may obtain results that depend on the xTU-C and xTU-R.

Concerning the measurement procedure, it is suggested:

- To make the BER measurements at line level and ATM level in sceneries with an ADSL/POTS and ADSL/ISDN test signal, and only at ATM level for SDSL sceneries.

- To use the ascendent and descendent limit rates as an extra requirement in all the sceneries where the test signal is modulated with DMT.

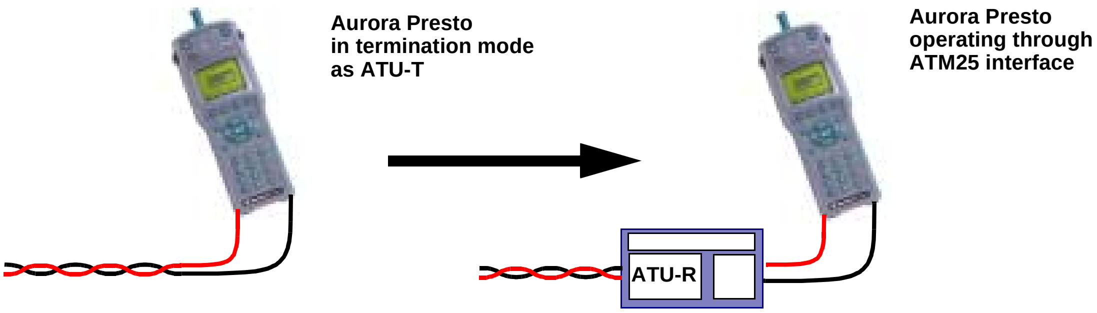


Figure 28 Measurement on an ATM25 interface, instead of a measurement on a DSL interface at the user premises.

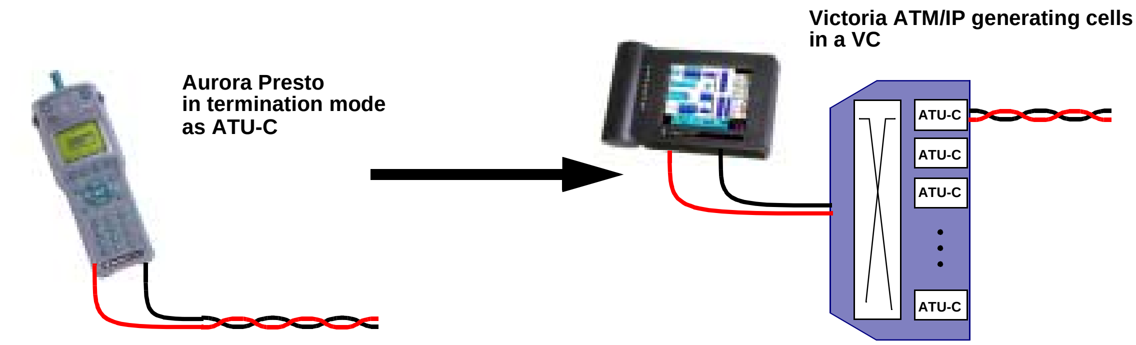


Figure 29 Measurement on an ATM interface, instead of a DSL interface at the central.

- To obtain the spectral power density of FERF and NEXT for each scenery, when there is no test signal. Also, to obtain BER and ascending and descending rates (if applicable) and obtain BER and ascending and descending rates also in the presence of a test signal (if applicable)
- Providing that the DSL technologies are multiplexed in the same wire as POTS and ISDN, all the measurements where DSL signals appear are made in the presence of POTS or ISDN. To generate ISDN traffic, test traffic generated by a PC is used. For POTS, the interference is generated according to the ITU-T recommendation G.996.1