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Technical Report

Compatibility of POTS terminal equipment with xDSL systems

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Foreword

This Technical Report (TR) has been produced by ETSI Project Analogue Terminals and Access (ATA).

1 Scope

The present document reviews technical issues on the mutual compatibility of current and future analogue POTS terminal equipment with xDSL systems operating at frequencies up to 30 MHz. The present document considers both TE intended to support simultaneous operation with xDSL on the same analogue cable pair, and TE co-existing with xDSL systems in the same access cables. The impact of home LANs working on the same cable pair as the POTS and xDSL systems is also considered. Where reference is made to the network termination point e.g. in relation to the installation of splitters or filters, this is applicable at the customer premises end of the local loop only. Issues relating to the network end of the local loop are not considered in the present document.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ETSI TBR 21: "Terminal Equipment (TE); Attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNS) of TE (excluding TE supporting the voice telephony service) in which network addressing if provided, is by means of Dual Tone Multi Frequency (DTMF) signalling".

[2] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on Radio Equipment and Telecommunications Terminal Equipment and the mutual recognition of their conformity. OJ L 91, 7.4.1999, p. 10.

[3] Directive 98/13/EC of 12 February 1998 relating to telecommunications terminal equipment and satellite earth station equipment, including the mutual recognition of their conformity. OJ L 74, 12.3.1998, p. 1.

[4] Council directive 90/387/EEC of 28 June 1990 on the establishment of the internal market for telecommunications services through the implementation of open network provisions. OJ L 192, 24.7.90, p. 1.

[5] Directive 97/51/EC of the European Parliament and of the Council amending Council directives 90/387/EEC and 92/44/EEC for the purpose of adaptation to a competitive environment in telecommunications.

[6] Commission directive 90/388/EEC of 28 June 1990 on competition in the markets for telecommunications services. OJ L 192, 24.7.90, p. 10.

[7] Commission directive 96/19/EC of 13 March 1996 amending Directive 90/388/EEC with regard to the implementation of full competition in telecommunications markets.

[8] Directive 98/10/EC of the European Parliament and of the Council of 26 February 1998 on the application of open network provision (ONP) to voice telephony and on universal service for telecommunications in a competitive environment. OJ L 101, 1.4.1998, p. 24.

[9] Council Directive 89/336/EEC of 3 May 1989 on the approximation of the laws of the Member States relating to electromagnetic compatibility. OJ L 139, 23.5.1989, p. 19.

[10] CISPR 22 (1997): "Information Technology Equipment – Radio disturbance characteristics - Limits and methods of measurement".

[11] CISPR 24 (1997): "Information Technology Equipment – Immunity characteristics – Limits and methods of measurement".

[12] ETSI EG 201 120: "Public Switched Telephone Network (PSTN); Method of rating terminal equipment so that it can be connected in series and/or in parallel to a Network Termination Point (NTP)".

[13] ETSI TR 101 728: "Analogue Terminals and Access (ATA) Study of POTS/ADSL splitters".

[14] EN 50136 Part 1-3: "Alarm systems - Alarm transmission systems and equipment; Part 1-3: Requirements for systems with digital communicators using the public switched telephone network".

[15] EN 50136 Part 2-3: "Alarm systems - Alarm transmission systems and equipment; Part 2-3: Requirements for equipment used in systems with digital communicators using the public switched telephone network".

[16] ETSI EN 301 437: "Terminal Equipment (TE); Attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNs) of TE supporting the voice telephony service in which network addressing, if provided, is by means of Dual Tone Multi Frequency (DTMF) signalling".

[17] ETSI TBR 38: "Public Switched Telephone Network (PSTN); Attachment requirements for a terminal equipment incorporating an analogue handset function capable of supporting the justified case service when connected to the analogue interface of the PSTN in Europe".

[18] ITU-T Recommendation G.121: "Loudness ratings (LRs) of national systems".

[19] ITU-T Recommendation G.122: "Influence of national systems on stability and talker echo in international connections".

[20] ITU-T Recommendation Q.552: "Transmission characteristics at 2-wire analogue interfaces of digital exchanges".

[21] ETSI EN 300 001: "Attachments to Public Switched Telephone Network (PSTN); General Technical Requirements for Equipment Connected to an Analogue Subscriber Interface in the PSTN".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

ADSL lite: simplified form of ADSL system which does not use a POTS splitter at the customer premises

DSL regular: DSL system which incorporates a POTS splitter to separate the POTS and DSL services

POTS splitter: device located at the customers premises, typically consisting of a high and low pass filter, used to separate the downstream and combine the upstream POTS and DSL services. Part of the splitter, typically the high pass filter function, may be incorporated as part of the DSL modem

xDSL: generic term for any type of DSL system

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

ACE	Alarm Comunicating Equipment
ADSL	Asymmetric Digital Subscriber Line
CISPR	International Special Committee on Radio Interference (a subcommittee of IEC)
CTE	Circuit Terminating Equipment
DSL	Digital Subscriber Line
DTMF	Dual Tone Multi Frequency
FEXT	Far End Crosstalk
IEC	International Electrotechnical Commission
LP	Loop Disconnect
NEXT	Near End Crosstalk
NTP	Network Terminating Point
POTS	Plain Ordinary Telephone System
PSD	Power Spectral Density
PSTN	Public Switched Telephone Network
QoS	Quality of Service
STMR	SideTone Masking Rate
TBT	Technical Barriers to Trade
TCAM	Telecommunication Conformity Assessment and Market Surveillance Committee
TE	Terminal Equipment
VDSL	Very high bit-rate Digital Subscriber Line
WTO	World Trade Organization

4 General

4.1 Background

Virtually all-terminal equipment intended for connection to an analogue interface of the PSTN is designed to communicate using the voice band (typically 300 Hz to 3 400 Hz). Such equipment, whether a telephone, modem, fax etc. is generally regarded as POTS equipment. The harmonized technical attachment requirements for POTS equipment are to be found in TBR 21 [1] and EN 301 437 [16]. The out-of-band transmitted signal limits in these documents are only defined for frequencies up to 200 kHz. DSL systems provide higher bandwidth 2-way communication over the same (metallic) local loop by using frequencies above the voice band.

4.2 DSL system types

In the present document, DSL systems are divided into two main categories.

One category requires the use of a splitter device connected at or replacing the existing NTP in order to separate out the POTS and SDL services. The POTS services may continue to use the existing customer wiring/installation. It is not practicable for the user to install the splitter device and this will normally be installed by the network operator.

The other category does not make use of a splitter, and uses the existing wiring/installation to carry both POTS and DSL services. This approach has the advantages of imposing no installation costs on the network operator for installing a splitter, and permits the user to simply plug in a DSL terminal in the same way as a POTS terminal, but there are some technical disadvantages in terms of bandwidth and reliability of transmission.

For simplicity throughout the present document the splitterless category is referred to as DSLlite and the category using a splitter is referred to as DSLregular. The generic term used in the present document for all DSL systems is xDSL.

5 Technical issues

The harmonized technical attachment requirements for POTS equipment defined in TBR 21 [1] and EN 301 437 [16] were agreed after consideration of POTS services only. Resulting from this restriction, a number of potential undesirable interactions may occur when POTS and DSL services are deployed on the same local loop.

5.1 Interaction of POTS terminal equipment on xDSL systems

5.1.1 Out-of-band signals

There are two distinct issues here. The first issue is that if DSL terminals are required to meet the requirements of TBR 21 [1], then DSLlite terminals would fail the specified out of band limits of subclause 4.7.3.4. It needs to be made clear (by whom?) that TBR 21 [1] does not apply to DSL terminals.

The second issue is that TE meeting the requirements of TBR 21 [1] and EN 301 437 [16] may send signals at frequencies above 200 kHz at levels which disrupt xDSL services on the same loop, or in severe cases on other pairs in the same cable via crosstalk. Clearly some guidance on the levels of sending signals above 200 kHz for POTS terminals needs to be provided. Three different operating scenarios may be visualized for POTS terminals:

a) "Ordinary" POTS TE connected to local loops supporting POTS services only i.e. no support for xDSL services;

b) "DSL friendly" POTS TE directly connected to local loops supporting POTS and xDSL services;

c) "Ordinary" POTS TE connected via filtering devices to local loops supporting POTS and xDSL services.

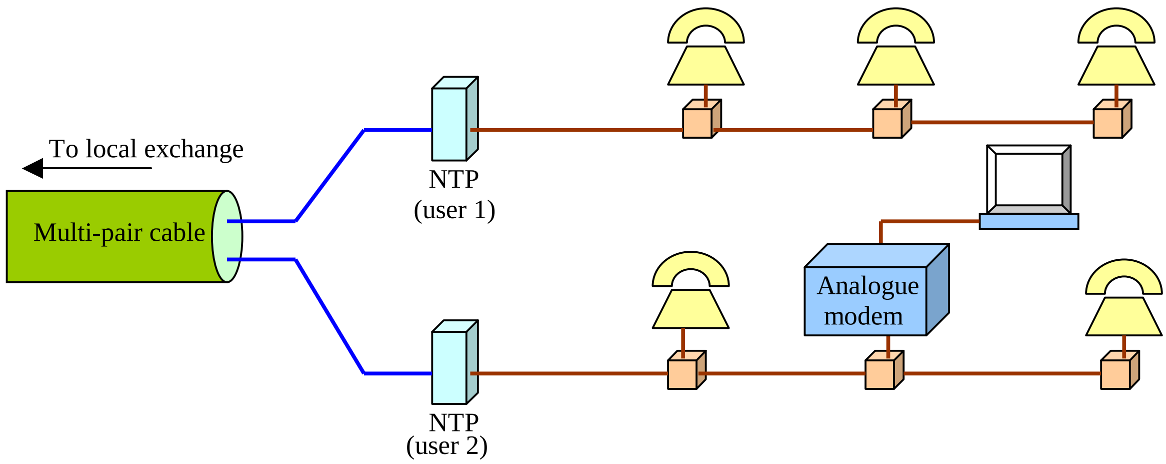

Figure 1a: Ordinary POTS terminals with no DSL services

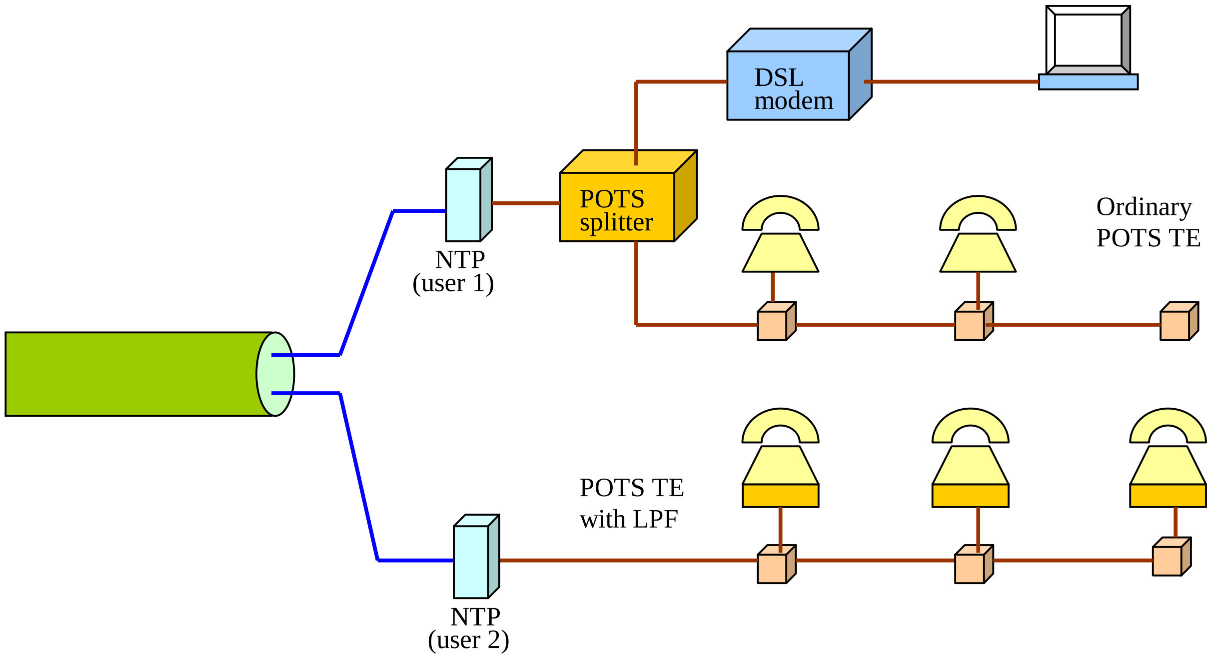

Figure 1b: DSL "friendly" POTS with DSL services

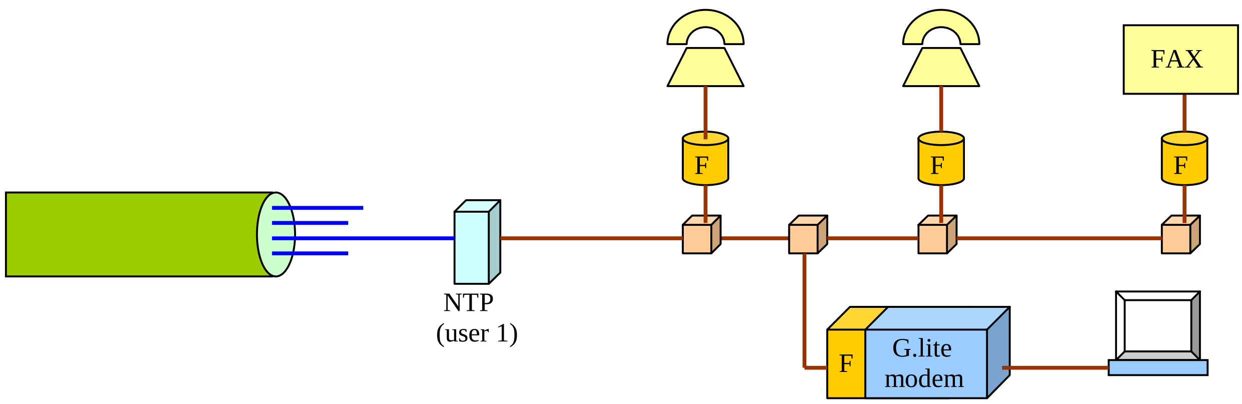

Figure 1c: Ordinary POTS terminals connected by filters

When specifying and implementing DSL systems it needs to be remembered that:

- the new systems will have to coexist with the extremely large installed base of POTS terminals which mostly have unknown performance at DSL frequencies;
- the existing customer premises wiring environments are mostly unscreened and relatively poorly balanced and are likely to introduce unwanted signals, which could be significantly larger than the proposed TM6 out-of-band limits.

5.1.1.1 Directly connected "ordinary" POTS

This scenario, as shown in figure 1a is the most common scenario at present and applies to most situations where xDSL services have yet to be introduced. Terminals can be expected to comply with the out-of-band requirements of TBR 21 [1] for frequencies up to 200 kHz. As TBR 21 [1] does not specify requirements for out-of-band frequencies above 200 kHz, there is a possibility that terminals may transmit signals in this region which could affect future DSL operation. Any out-of-band signals from the terminals of user 1 which reach user 2 telephones by crosstalk in the multi-pair cable will normally be inaudible as they are above the range of normal hearing. Similarly, any out-of-band signals from the terminals of user 1, which reach user 2 non-voice POTS terminals by crosstalk in the multi-pair cable, are extremely unlikely to cause problems. There is no adverse cost impact for POTS terminals in this scenario as no additional filtering is required.

5.1.1.2 Directly connected "DSL friendly" POTS

In this scenario, shown in figure 1b, the POTS terminals of user 2 contain additional filtering at frequencies above 200 kHz to ensure satisfactory performance on local access loops supporting both POTS and xDSL services such as that of user 1. Although most likely to be used for "splitterless" applications e.g. G.Lite, such terminals could include the low pass filter functionality of a conventional POTS Splitter filter. Information on proposals for extending the out-of-band limits of POTS terminals from 200 kHz to 30 MHz may be found in annex B.

Further investigative work needs to be carried out in order to assess the impact of the proposed limits on the design of POTS terminals with regard to both practicability of implementation, and the cost impact.

5.1.1.3 "Ordinary" POTS connected via filters

This scenario, as shown in figure 1c is representative of DSLlite application, and uses "ordinary" POTS TE together with purpose designed filters to achieve the required out of band performance to coexist with xDSL systems. These low pass type filters are physically small and are provided with the appropriate connectors for ease of connection into the line cords of existing POTS terminals by the user. This approach has the advantage that any additional costs are born only by those users receiving the DSL services. However in order to design the required filters, some knowledge of the out-of-band performance of "ordinary" POTS TE is to be assumed. In the absence of any further information, it should be assumed that the maximum levels of out-of-band signals in the frequency range 200 kHz to 30 MHz do not exceed the limit specified at 200 kHz in TBR 21 [1] i.e. a maximum level of –58,5 dBV (when measured with a bandwidth of 10 kHz).

Rather than impose more stringent out-of-band limits on all POTS terminals, it may be more acceptable to use a low pass filter in series with each POTS terminal when DSL services are added. This approach would have the advantages of:

a) permitting the use of existing POTS equipment on the same line as DSL services;

b) putting the cost of filtering onto the DSL users only.

5.1.2 Out-of-band impedance

The impedance requirements for POTS equipment defined in TBR 21 [1] and EN 301 437 [16] have two major impacts on the coexistence with DSL systems. Firstly the impedance presented by the POTS TE to the loop is only defined for the on-line state, and secondly, the on-line impedance is only defined for the voice band. There is nothing in the existing requirements, which prevent the TE from presenting a low impedance at xDSL frequencies and seriously attenuating the DSL signals.

Measurements on numerous different models of POTS telephones shows that these often have an input impedance of the order of 20 Ω at DSL frequencies in both the on-hook and off-hook conditions. This is due to the presence of filter components intended to reduce the susceptibility of the terminals to radio broadcast signals picked up on the local loop or user premises wiring. Installations with several of such terminals connected to a single local loop can severely attenuate the DSL signals, effectively reducing the service range.

Measurements carried out in the UK on a number of different types of telephone show impedances typically as low as 25 Ω during the on-line state. This is largely due to the capacitative loading effects of emc suppression incorporated in the telephone to avoid reception of broadcast radio services. Some designs of POTS terminals, particularly those with a high degree of integration such as electronic hook switches etc. also present a capacitative load during the off-line state as a result of protection from damage due to line borne transients and this can also reduce the level of xDSL signals. It should also be considered that a typical user installation may have several POTS terminals effectively connected in parallel on a single loop thereby severely attenuating the DSL signals, and effectively reducing the service range.

Unless controlled in some way, this loading effect could prove to be more significant in reducing DSL range/service penetration than that due to crosstalk of out-of-band signals from POTS terminals.

5.1.3 Remote line testing

It is common practice for network operators to carry out regular tests on their subscriber lines as part of their Quality of Service commitment. Specific components may be incorporated into the NTP or into the splitter to assist with line testing. Test components incorporated into the existing NTPs vary widely between different networks and may possibly have an adverse effect on DSL performance. Some information on NTP components may be found in EN 300 001 [21] clause 8. Depending on how the line testing is performed, there may be an impact on the xDSL service e.g. a short duration line break, or an impedance change causing a variation in signal level. Such disturbances, if present, are likely to be different for each network and should be checked out with the network operator concerned.

5.1.4 Effect of POTS signals on DSL systems

Apart from the unwanted out-of-band signals discussed in subclause 5.1.1 there are a number of other types of signal commonly present in traditional POTS systems, which have the capability to disturb operation of DSL systems. Although these signals are outside the nominal DSL frequency bands, the magnitude of the signals used and transients generated can cause misoperation of DSL systems unless adequately filtered out.

5.1.4.1 LD signalling

Loop Disconnect (LD) signalling is a technique commonly used to signal the required directory number from a terminal to the local exchange. It operates by inserting a number of short duration breaks (dial pulses) into the steady state loop current established on the local loop. Although the dial pulses occur at a typical frequency of 10 Hz which is well below the DSL frequency band, the transient voltages generated during signalling can be extremely high due to the inductive feed circuits used by many types of local exchange, and can cause misoperation of DSL systems if not adequately filtered out. Similar transients are caused by the use of the Register Recall facility, and when the terminal changes between the on-hook and off-hook states.

5.1.4.2 Ringing signals

The ringing signal used by POTS systems consists of a cadenced sinusoid of approximately 25 Hz and level up to 100 volt r.m.s. The harmonic components generated in some circumstances may reach extremely high values, depending on the waveform. The ringing signal may be accompanied by changes to the dc conditions e.g. polarity reversal which can generate large transients.

5.1.4.3 Subscribers metering signals

Some networks use transverse signals in the range 12–16 kHz for the transmission of metering information related to cost of calls. Whether these signals may interfere with DSL signals is not clear, but will depend on the performance of the filters used. One possibility is to consider turning these metering signals off when DSL systems are deployed.

5.1.4.4 Subscriber Display signalling

The signals used to convey information for Calling Line Identity, Message Waiting, Advice of Charge etc. are typically low level and confined to the voice band and so are unlikely to have any impact on DSL systems. Some networks however precede the signalling message with a polarity reversal to alert the terminal to an incoming message. The polarity reversals are often accompanied by large transients.

5.1.5 Alarm communication devices

A large number of user premises employ monitored alarm systems in accordance with EN 50136 parts 1-3 [14] and 2-3 [15], which automatically call into a monitoring centre to relay alarm activations such as intruder alert, fire on premises etc. They typically consist of an Alarm Communicating Equipment (ACE) connected in series between the NTP and the POTS terminals, this arrangement allowing the ACE to take priority over the POTS terminals during an alarm condition. This may lead to problems when adding DSL terminals to such an installation. For DSL systems requiring a POTS splitter function it is necessary to decide which side of the ACE the splitter should be connected and this may be dependent on the physical connection arrangements available – which are most likely to be network operator dependent. For splitterless DSL systems the complications are different. For example the positioning of distributed filters will be influenced by whether the ACE presents a low shunt impedance or high series impedance to the DSL signals. There is no obvious solution to these possible problems. They are identified in the present document, but solutions will require liaison/negotiation between the providers of the DSL services and providers of the POTS/alarm services themselves.

5.2 Interaction of xDSL systems on POTS

5.2.1 Demodulation of DSL signals

Unless special precautions are incorporated into the design, most POTS terminals will be subject to interference from high frequency signals such as DSL signals appearing on the local loop. This is because most modern terminals employ solid-state devices at some point in the transmission path, and these can demodulate the high frequency signals resulting in unwanted signals appearing in the voice band. The requirement for POTS terminals to be polarity independent virtually ensures that a diode bridge is employed in the line interface of most POTS terminals, increasing the possibility of demodulation. In order to prevent most POTS from demodulating broadcast radio signals, some emc filtering is usually incorporated, and this will provide some measure of protection from DSL signals.

CISSPR 24 [11], the immunity standard for CTE, requires that equipment (e.g. POTS) operates normally in the presence of conducted interfering signals of the order of 3 V (emf) and in field strengths of 3 V/m. The susceptibility to conducted signals is usually specified for common mode signals only since this is the typical nature of broadcast signals picked up by telephone wires. For situations where POTS and DSL services are supplied by the same local loop, the interfering (DSL) signals will generally be transverse in nature rather than longitudinal. It is probable that the majority of unwanted signals will be picked up by unbalanced and unscreened home wiring rather than the wiring of the local loop.

More information on the emc susceptibility of typical POTS terminals is required in order to progress this aspect.

5.2.2 Crosstalk

The presence of DSL signals on a subscriber line would normally be due to the user subscribing to both POTS and DSL services on that local loop. However it is possible for a POTS service only subscriber to have significant levels of DSL signals on his local line due to the presence of crosstalk. This mainly occurs in multi-pair access cables and is due to slight imbalances in (unwanted) coupling between individual pairs in a multipair cable. Crosstalk in multipair access cables has been found to be a significant factor in capacity limiting noise for DSL systems. More information on crosstalk can be found in annex A.

5.2.3 Splitterless DSL systems

In user installations where distributed filters are used, the DSL modem is directly connected to the PSTN line and should thus meet the relevant POTS access requirements so as not to adversely affect other POTS terminals connected to the same PSTN line.

5.3 Impact of "home LANS" on POTS and xDSL

The recent appearance of some "home LANS" which use out-of-band signals over a customers telephone wiring for non traditional telephony purposes (such as PC – Printer – Server intercommunication) further complicates the POTS/xDSL scenario. Such systems are likely to adversely affect the operation of both POTS and xDSL services depending on the frequencies and power levels used, modulation techniques etc.

The Home Phoneline Networking Alliance (HomePNA) is an association of companies working together to ensure adoption of a single, unified phoneline networking standard. The initial HomePNA standard, released in 1988 was for a system with a 1 Mb/s capability. This utilizes the band 5,5 MHz to 9,5 MHz. In December 1999 version 2 was announced providing a capability of 10 Mb/s using the same frequency band with a more complex coding structure. At the present time, these standards have not been adopted by recognized standards bodies such as ITU, IEEE, or ETSI. It has been found that filters are needed to: a) prevent low frequency signals from POTS terminals e.g. LD signalling, on/off hook transitions from significantly affecting the data transmission; and b) prevent the data signals from reaching the POTS terminals where some (audible) demodulation otherwise occurs.

There is some concern that the band chosen for transmission is incompatible with VDSL transmission, (which could necessitate the use of a filter at the NTP to avoid crosstalk from the HomePNA system affecting VDSL users on different loops in the same cable bundle), and that the modulation techniques and power levels used will generate significant emc problems due to radiation from the user premises wiring.

Further information on the technical performance of home LAN systems needs to be collected and considered before the full impact can be assessed and any filters specified.

5.4 Impact of EMC induced signals

Unwanted out-of-band signals generated by terminal equipment is only one possible source of interfering signals. Another source, possibly of greater importance, is that due to emc signals induced directly into the telephone wiring at the users premises. This is due to the operation for example of domestic apparatus such as refrigerators, freezers, dishwashers, etc. in the proximity of the users telephone wiring. Most user telephone wiring is likely to be unscreened and unbalanced, so the transient signals picked up by the wiring are likely to be at levels significantly higher than the proposed out-of-band limits for POTS terminals.

On factor, which helps, is that most sources of induced emf signals (unlike the POTS out-of-band signals) are likely to be intermittent in nature. This is why in practice there is no significant occurrence of emc induced problems with POTS telephony services. The induced emc signals are likely to have a greater impact on the transmission of DSL signals such as to cause data transmission errors unless appropriate error mitigation schemes are used.

5.5 Use of filters

Two types of filter are used for xDSL systems; POTS splitters for DSLregular, and low pass filters for DSLlite.

5.5.1 POTS splitter filters

In essence these comprise both low and high pass filters. The low pass filter is used to couple the POTS services to the local loop and to isolate the DSL signals from the POTS terminals, and the high pass filter couples the DSL signals to the local loop whilst preventing the voiceband, signalling and ringing signals from reaching the DSL modem. In practice, the high and low pass filter functions are likely to be physically separated. The high pass filter function is usually incorporated as part of the DSL modem, whereas the low pass function is more likely to form part of the network termination point (NTP).

Technical requirements for the low pass section of a POTS splitter filter may be found in TR 101 728 [13]. Specification of the technical requirements for the high pass section of a POTS splitter filter is the responsibility of ETSI TM6.

5.5.2 Distributed low pass filters

Recent field trials of DSLlite equipment jointly carried out by a group of manufacturers and a north American network operator have proved the viability of the splitterless DSLlite technology, achieving maximum data rates for distances up to 15 000 feet (4,5 Km). It was found necessary to include one or more low pass filters in series with the POTS terminals in order to reliably achieve the maximum data rates. The filters were also found to have a significant effect in reducing the interference problems - both on-hook and off-hook - caused by telephones, fax machines and modems etc.

These filters are usually 2 or 3 pole designs with a typical cut-off frequency of 10 kHz, and are physically presented as small adapters, which the user inserts in the line cord of the POTS terminals. Filters are available for terminals with 600 Ω resistive, and complex impedances.

The low pass filter can also have an adverse effect on the performance of the POTS terminal. It can modify both D.C and A.C. characteristics. Guidance on the D.C. voltage drop and voice-band insertion loss may be found in EG 201 120 [12]. The major effect of the filter is likely to be on the performance of ordinary telephones particularly with regard to sidetone. A temporary document on the effects of filters on sidetone performance was tabled at ATA#5 and is included in annex C. This indicates that sidetone performance is likely to be acceptable where the terminals or network equipment has an impedance Z_R, but unacceptable sidetone performance may arise where equipment with other impedances is used.

A problem can arise with the use of these filters where several are used on the same local loop. Under some combinations the interactions between filters can cause a resonance in the voice band with unpleasant results on speech – particularly to the sidetone performance. This problem does not occur on installations where a single POTS splitter filter is used.

At the specially convened meeting on xDSL held at Stockley Park (UK) on 29th September, a proposal was made for splitting the work of defining the requirements for the low and high pass sections of the filters between ETSI ATA and TM6 according to a proposed set of reference impedances. These reference impedances are shown in annex D.

6 Cost implications

In an ideal situation, the incremental cost of providing DSL services would fall only on the DSL users. In reality, due to the unknown/unspecified behaviour of existing POTS terminals at DSL frequencies and the existence of crosstalk in the access network cables, the ideal situation cannot be realized.

The costs implications affecting the user installation associated with introducing DSL services via the local loop fall into three categories:

a) costs associated with reducing the out-of-band signals produced by POTS terminals in a band previously unspecified;

b) costs associated with the provision of POTS/DSL splitter filters for DSLregular applications;

c) costs associated with the provision of distributed filters for DSLlite applications.

In assessing the cost implications, it is highly desirable that significant cost penalties should not be imposed on all simple POTS terminals in order to provide higher value DSL services to a minority of users. The average additional cost per terminal for all types of POTS terminals is not known but could be fairly low since any existing filtering to minimize the susceptibility to broadcast radio signals will also help reduce any out-of-band signals. The cost impact of improving the out-of-band performance may be less acceptable in a low cost simple POTS terminal than for a higher cost, greater functionality POTS terminal. There is some evidence however, that a number of simple POTS telephones currently provide sufficiently good out-of-band performance to meet the proposed "DSL compatible" proposals.

However the installed base of POTS terminals is so large that even if all new POTS terminals were "DSL compatible", they would still be in a minority for some considerable time to come. Any roll-out of DSL systems will have to recognize this fact and make alternative provision. It is unrealistic to expect users to replace their existing POTS terminals with new "DSL compatible" terminals for the altruistic reason of improving the DSL performance of other users. There is more chance that users of DSLlite may upgrade their POTS terminals in order to improve their own DSLlite performance, but it is more likely they will just add distributed filters to their existing POTS terminals to achieve the same effect.

With POTS/DSL splitters there are two components to the cost. One part is the cost of the filter itself. This is most likely to be only the low pass filter function as the high pass function will probably be integrated with the DSL modem. The second cost component is that associated with installation. This filter cannot simply be plugged in to an existing extension socket, as with DSLlite, but requires some rewiring of the customer premises to insert the filter in series between the incoming local loop and the users extensions. This may be achieved by replacing the NTP by a new variety, which incorporates the filter function. Whichever way it is implemented requires the attendance of a skilled operator as this is beyond the capability of most users. **It may prove necessary for a network operator to install the POTS splitter filter at the premises of users who do not subscribe to DSL services in order to keep crosstalk levels low enough to provide adequate DSL services to other users in the same cable pair/binder group. This could prove to be the dominant cost factor.**

Unlike the POTS/DSL splitters, the distributed filters only have an intrinsic cost associated with them since they are installed by the user. This type of filter may be provided "free" with the DSLlite modem itself.

It is possible that the cost of a "DSL compatible" POTS terminal may prove to be less than the cost of a comparable existing POTS terminal together with a distributed filter.

7 Regulatory issues

7.1 General

This clause considers the relationship between the European legislation - EU Directives - and DSL systems.

It is recognized that:

- WTO agreement on the reduction of Technical Barriers to Trade (TBT) (see note) are increasingly influencing the Telecommunications sector, limiting the freedom of a specific country or region to adopt unnecessarily restrictive measures;

NOTE: WTO Agreement on Technical Barriers to Trade, Article 2.2 (Preparation, Adoption and Application of Technical Regulations by Central Government Bodies): "Members shall ensure that technical regulations are not prepared, adopted or applied with a view to or with the effect of creating unnecessary obstacles to international trade. For this purpose, technical regulations shall not be more trade-restrictive than necessary to fulfil a legitimate objective, taking account of the risks non-fulfilment would create".

- DSL systems had a particular development in USA, where the level of regulation is normally considered very low.

The present document does not intend to suggest a specific solution for regulation but recognizes that the standardization activity should be intensified to promote appropriate technical solutions with or without support from regulatory measures. If regulatory measures will be taken in any of the concerned areas this should not be done before a specific technical study identifies exactly the impact of such a measure. The present document aims to contribute to a preliminary general clarification in the different areas.

7.2 EU legislation in place

7.2.1 Sector specific legislation

There are a number of EU Directives covering products and services related to telecommunications access networks. Among the sector specific directives there are the **Open Network Provision directives** covering the public portion of the network, and the Terminal directive 98/13/EC [3], which will be replaced by the **R&TTE directive 1999/5/EC** [2] from 8 April 2000. The legal division between these regimes is at the Network Termination Point (NTP) (see note below), see figure 2, which describes three example cases:

- case 1 where the public network operator terminates the access network by separating the POTS service from the xDSL service, and delivers these as two separate interfaces to the end user;

- case 2 where there is no physical separation of the POTS and DSL services at the termination of the public portion of the network, but the combined signal is presented to the user. The combined signal is then normally available at all connection points in the user installation;

- case 3 represents a more likely situation where the high pass filter function of the splitter is incorporated into the DSL modem itself, which in turn presents a data NTP to the user.

NOTE: Definition from the ONP Framework directive 90/387/EEC [4]: "network termination point" shall mean the physical point at which a user is provided with access to a public telecommunications network. The locations of network termination points shall be defined by the national regulatory authority and shall represent a boundary, for regulatory purposes, of the public telecommunications network".

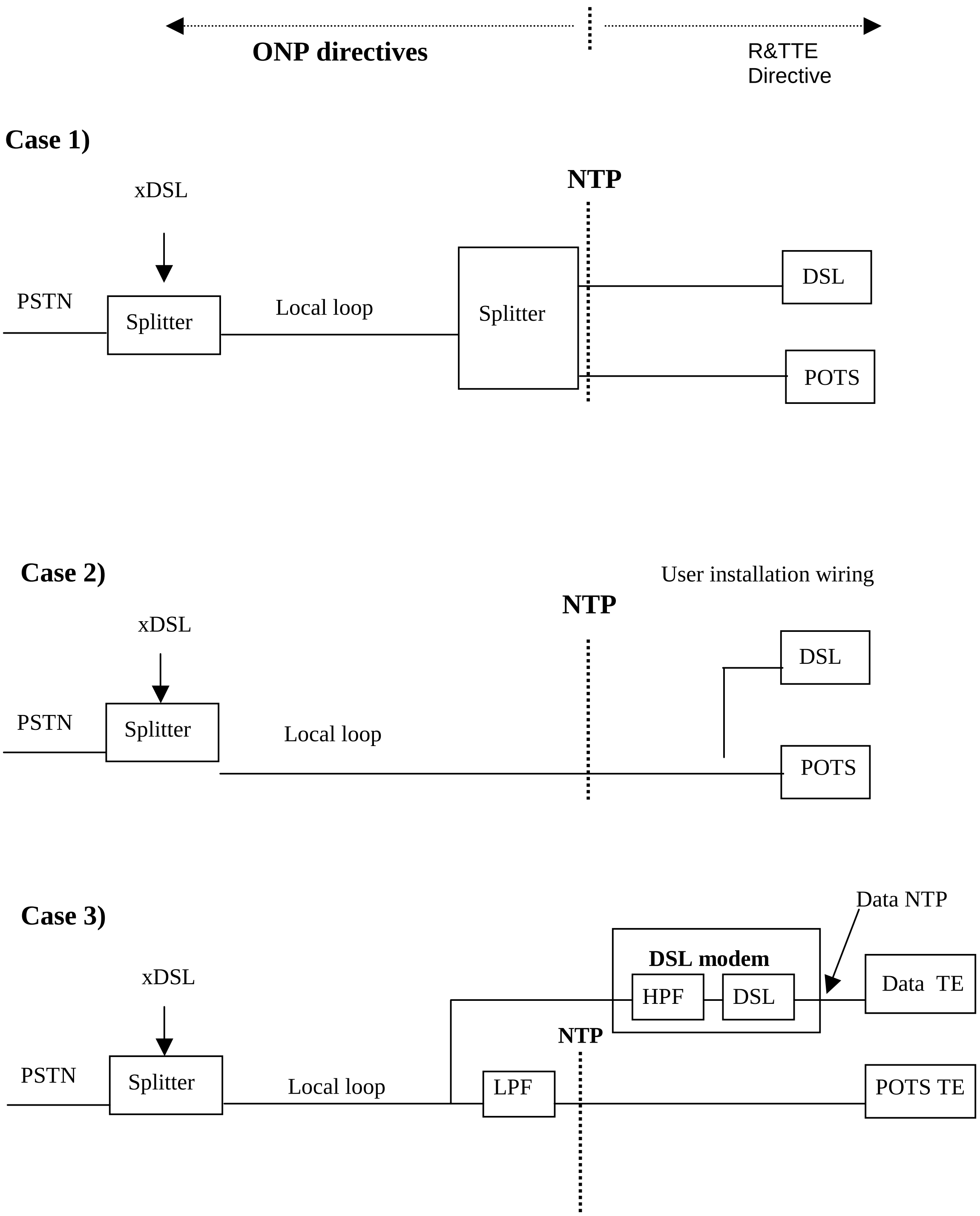

Figure 2: Directives in relation to the NTP

The ONP Framework directive 90/387/EEC [4] was amended by directive 97/51/EC [5] "for the purpose of adaptation to a competitive environment in telecommunications". Likewise the ONP Services directive 90/388/EEC [6] was amended by directive 96/19/EC [7] "with regard to the implementation of full competition in telecommunications markets". The ONP directives now aim at achieving full competition in the telecommunications field.

There are a number of specific ONP directives in force, related to different aspects such as provision of voice telephony and universal service (directive 98/10/EC [8]), leased lines and interconnection of networks.

7.2.2 Horizontal legislation - EMC Directive

EMC is a horizontal area of regulation, covered by the **EMC Directive 89/336/EEC** [9]. The directive requires that equipment:

- has a sufficiently low unintended emission such that "the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment and other apparatus to operate as intended";
- "has an adequate level of intrinsic immunity of electromagnetic disturbance to enable it to operate as intended".

The emission standards used for regulatory purposes are generally prepared by IEC/CISPR, which is responsible for protection of radio spectrum (above 148,5 kHz). These standards ensure that the radio spectrum is sufficiently free from noise to enable a successful operation of licensed radio services.

The immunity standards from IEC/CISPR aim to ensure that equipment continue to operate as intended in the presence of a radio signal (i.e. above 148,5 kHz), and that it can withstand transient impulses without the need for a reset or manual restart procedure.

Apart from the EMC directive there are other Community instruments which are relevant to the issue of xDSL in the local loop. Among these are general **competition law**, which is increasingly being used to ensure fair competition in the provisions of telecommunications services. It is likely that future regulation, arising from the EU Commission's 1999 review of the telecommunications regulatory framework, will to a higher degree than today rely on existing general regulation such as competition laws and consumer protection measures.

7.3 EU legislation addressing compatibility of POTS terminal equipment with xDSL systems

7.3.1 Issues related to the R&TTE directive

The aspects of the R&TTE directive 1999/5/EC [2] which are most relevant for the present document are:

- **Article 3.3.b** which states that "..the Commission may decide that apparatus within certain equipment classes or apparatus of particular types shall be so constructed that: ...it does not harm the network or its functioning nor misuse network resources, thereby causing an unacceptable degradation of service";
- **Article 4.2** which requires that "operators publish accurate and adequate technical specifications of such interfaces before services provided through those interfaces are made publicly available, and regularly publish any updated specifications. The specifications shall be in sufficient detail to permit the design of telecommunications terminal equipment capable of utilizing all services provided through the corresponding interface. The specifications shall include, inter alia, all the information necessary to allow manufacturers to carry out, at their choice, the relevant tests for the essential requirements applicable to the telecommunications terminal equipment".

Application of **Article 3.3.b** has been studied by a Commission ad-hoc group. The conclusions are available for TCAM, the committee established by Article 13 of the R&TTE directive. The report concludes that the possible application of this essential requirement should be restricted to the case where no terminating unit at the NTP exists (such as case 2 in figure 2.

Another Commission ad-hoc group has studied **Article 4.2** and given some recommendations on its interpretation. The report states among other things: "Terminal manufacturers and suppliers should note that the purpose of the publication is to permit the design of terminals capable of functioning correctly. Assuming that the information published is adequate and accurate, the task of ensuring the interworking with and via the network rests with terminal manufacturers, as does the compliance to Essential Requirements".

Thus it is expected that public network operators in their publications indicate what can cause harm to their networks. This does not mean that such aspects are within the "essential requirement" as given by Article 3.3.b – the application of that article is decided by the EU Commission following the procedures of Article 15 of the R&TTE directive (involvement of TCAM). Notwithstanding the regulatory aspects of this issue, technical solutions should be found to solve potential problems, taking account of all factors including costs and the presence of existing terminals on the EU market.

Private installations

The physical configuration of a private installation in Europe may look very different in different countries. In some European countries the cabling system within a building having e.g. 30 or more private homes is already considered out of the public network (i.e. on the user side of the NTP) and in other countries only the socket of each home is a private installation. Furthermore, the majority of the private installations have several terminals from different generations installed in series, parallel or other more complex configurations with connecting cables often passing near important disturbing sources (PCs, or other digital technique based equipment operating in the most different frequencies, electrical devices, etc).

In some countries there are some level of regulation of installations, however it is likely that such regulation will be withdrawn.

It should be noted that the R&TTE directive does not address co-existence of terminals in a private installation. Therefore aspects related to co-existence need to be handled by the parties involved (the EMC issues are discussed in subclause 7.3.3).

7.3.2 Issues related to the ONP directives

The access network is a key component in the telecommunications infrastructure providing the physical access for the delivery of services to end-users. In the fixed network, the provision of end-user access is still controlled by the incumbent operators in most European countries. For new entrants, building alternative access networks is both costly and time consuming. Consequently, competition in this area has so far been quite low.

Having in mind the particular high price and delay of new lines installations and the enormous increase of traffic resulting from the liberalization policies, the existing cabling system may be considered a "limited resource" justifying a management similar to radio frequencies or addressing resources.

In many countries, regulatory measures are therefore considered to remove barriers associated with the access network in order to stimulate competition and innovation, e.g. introduction of new broadband services. One such measure is "local loop unbundling" where incumbents are required to open their access networks in such a way that new entrants can rent subscriber lines or transmission capacity for gaining physical access to their own customers.

We can expect that both the incumbent and new operators will introduce new high-speed transmission systems in the access networks. This will have a number of technical implications, as detailed in clause 5.

Current EU directives do not specifically regulate or propose policies for local loop unbundling. Whether or not to require local loop unbundling is a matter for national authorities, and different approaches already exist amongst the Member States. A number of Member States' regulators are resistant to the unbundling of direct access to the transmission medium in view of the crosstalk management and service maintenance issues which would arise. In these Member States it is possible that alternative methods of unbundling may be pursued (e.g. provision of digital "bit stream access").

In some Member states the authorities consider that there is sufficient competition in provision of access to end users, and thus do not require any unbundling of the wired local loop.

However where such competition is not yet established, national authorities, before making any decision either way, need information on the technical constraints associated with xDSL. Thus there is a need for an agreed frequency plan in cables forming the local loop.

In conclusion, is seems unlikely that a single unbundling philosophy will apply throughout the Member States in the foreseeable future.

7.3.3 Issues related to the EMC directive

7.3.3.1 European radio emission issues

See subclause 7.2.2 for background.

Recital 12 (see note 1) of the EMC Directive 89/336/EEC [9] addresses protection of telecommunications networks from disturbances. However, none of the CISPR emission standards are written to protect fixed telecommunications equipment. CISPR has recently agreed on limits for longitudinal signals on telecommunications (and similar) lines in their standard CISPR 22 [10], measured as conducted emission in the frequency band 150 kHz to 30 MHz. Testing is done via a line simulator having a defined unbalance to earth in order to simulate real cables.

NOTE 1: Recital 12: "Whereas it is nevertheless possible that equipment might disturb radiocommunications and telecommunications networks; whereas provision should therefore be made for a procedure to reduce this hazard".

Emission requirements related to transverse out-of-band signals (which could prevent telecommunications equipment from "operating as intended") have normally been treated as "harm to the network" and included in access standards used for regulation of terminal equipment (see subclause 7.3.1).

Considering that the EMC directive is for Europe only, and noting the WTO TBT agreement (see subclause 7.1), it is most likely that any regulatory treatment of transverse out-of-band signals be kept as "harm to the network" rather than "conducted emission under the EMC directive".

Regarding immunity to disturbances, the international standard prepared by IEC/CISPR, CISPR 24 [11], does not include aspects related to out-of-band (for the equipment in question) transverse signals appearing on a telecommunications line. The immunity requirements relate to incoming longitudinal signals (150 kHz to 80 MHz). Noting the WTO TBT agreement (see subclause 7.1), immunity to transverse out-of-band signals will most likely be kept outside of regulation. These matters of co-existence of terminals should be handled by industry standards, prepared with all players involved. This includes the case of co-existence of POTS and xDSL terminals.

NOTE 2: When performing immunity tests according to the CISPR requirements, there will be a certain amount of conversion of the longitudinal test signals into a transverse signal due to unbalance at the input port of the equipment under test. In practice the equipment therefore needs some protection against incoming (unwanted) transverse signals in order to meet the immunity requirements of e.g. CISPR 24 [11]. However, the magnitude of such a transverse signal is normally considerably smaller than an intended transverse xDSL signal appearing on the line. Thus the behaviour of a POTS terminal in the presence of such xDSL signals is not known.

7.3.3.2 National radio emission issues

In addition to the EMC requirements and standards as specified in subclause 7.3.3.1 to cover the regulatory issues, there is also the issue of national regulations or specifications that are proposed by certain Regulators from EC Member States using their own National Telecommunications legislation.

For example, the UK (Radiocommunications Agency) and German Regulator (RegTP) are concerned that the advent of broadband telecommunications systems on extended networks such as PLC and DSL will increase the potential for unacceptable interference to radio reception in MF and HF bands. They propose national regulations that address this issue in the context of treaty obligations to protect the spectrum for radio services. They are concerned not only with short-range effects in the region of transition from near-field to far-field, but also with the ensemble far-field noise-floor implications of ubiquitous deployment.

The UK RA and the German RegTP have drafted standards that could be used as a basis for arbitration in the event of interference. Although there is no requirement for a priori compliance to these standards, they provide manufacturers and network operators a basis for system development and design. They would also need to be taken into account in development of new standards for wire-transmission equipment. These draft standards specify different limits and therefore effectively prevent the application of uniform market entry throughout Europe. It should also be noted that the levels specified in these additional requirements could impose a technical barrier to the deployment of the DSL technology in Europe.

8 Spectrum management

8.1 Spectrum management of the access network

At a specially convened meeting on xDSL held at Stockley Park (UK) on 29th September 1999, there was consensus for the need for a frequency management plan for proper deployment of xDSL systems, particularly in the context of unbundling of the local loop i.e. opening the delivery of DSL services via the local loop to competition. This was required urgently and should be harmonized throughout Europe as far as is practicable. Effective spectrum management is understood to consist of two elements: firstly the availability of a commonly agreed set of spectrum management principles, rules, or guidelines, and secondly, the means for effectively policing the spectrum management plan itself.

Without adequate spectrum management in operation, the potential application/market penetration would be severely restricted and could prevent the viability of successful commercial deployment of DSL systems.

The general consensus was that TM6 is the body with the required skills to prepare the spectrum management plan. Subsequently at the 16th meeting of TM6 held in Amsterdam in November 1999, a work item for spectrum management of the access network (local loop) was approved. The objective of this work item is to provide a reference set of definitions of spectral management quantities to simplify and harmonize the description of network specific spectral management documents, without making any specific choice on the technology mix that may use the access network. It was accepted that this activity does not cover all the spectral management aspects that should be studied within ETSI TM6. Additional work items will need to be raised for the additional work.

8.2 Spectrum management of the user network

There has been some debate as to whether a spectrum management plan is needed for the user or home network. Spectrum planning of the access network is required to ensure the mix and percentage fill of the access loops with respect to the different DSL technologies with their different spectral/level characteristics is mutually beneficial to all users. The type(s) of DSL technology available to a specific user will be decided by the local service providers – the user will not have unlimited choice from all the DSL types. Spectral management of the user network in this meaning will not therefore be required. If however spectral management of the user network covers issues such as types of filters required, placement of filters in the user network etc. then this may need to be covered in some way. Much of this information can be regarded as guidance, installation information, etc. and is likely to be made freely available by the local network operator or service supplier.

9 Standards

9.1 Requirements for xDSL compatible POTS terminals

It is recommended that a (voluntary) technical standard for "xDSL Friendly" POTS terminals be produced. Such a standard should define requirements and test methods for aspects not currently included in TBR 21 [1] including:

- out-of-band sending performance above 200 kHz. It may be worth considering the use of two compliance levels one setting an out of band limit appropriate to work with POTS splitter filters (e.g. a maximum level of –58,5 dBV from 200 kHz to 30 MHz), and on which incorporates the effect of the POTS splitter low pass filter (as shown in annex B);
- on-hook and off-hook impedances above 25 kHz;
- on-hook and off-hook balance about earth;
- susceptibility to DSL signals.

Voice-band signal level measurements on POTS terminals are usually performed with the harmonized impedance Z_R defined in TBR 21 [1] used as a load. However for emc measurements and DSL measurements it is more common to use a resistive load of 120 or 135 Ω. It is recommended considering the use of a revised reference impedance Z_{rf} as shown in figure 3. This provides a smooth change of impedance from a resistive 120 Ω at DSL frequencies to the higher value complex impedance used in the voice band.

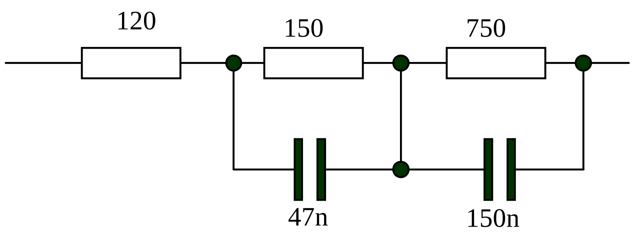

Figure 3: Proposed new reference impedance Z_{rf}

9.2 POTS/ADSL splitter filter requirements

It has been agreed that the requirements for POTS/DSL splitters need to be identified. The task of defining the high pass and low pass functions has been partitioned between ETSI groups TM6 and ATAc respectively and is currently in progress.

9.3 Requirements for distributed filters

It is recommended that a (voluntary) technical standard to define the requirements for distributed filters for DSLlite applications be produced. Key factors requiring attention are:

- the amount of attenuation of the unwanted out-of-band signals produced by the POTS TE;
- the amount of attenuation of high frequency signals to prevent demodulation by the POTS TE;
- impedance matching so the low impedance POTS terminals do not significantly attenuate the wanted DSL signals. Consideration should be given as to whether a single standard for working with harmonized (Z_{ref}) and non harmonized impedance POTS terminals can be achieved, or if different (National) variants will be required.

9.4 Requirements for homeLAN filters

One of the areas identified for further study is that of the interfering effects of homeLAN systems introducing unacceptable signal levels at DSL frequencies into the local loop. This may require the definition of a new filter type depending on the outcome of the proposed study.

9.5 Spectrum management of user installations

No need is perceived for a spectrum management plan for user installations. There may be a need for a user guide however to provide information on the use of different types of filters, where they need to be placed etc. Whether there is a real need for such a guide may become clearer as work on the access network planning rules, definition of filter requirements etc. proceeds.

10 Conclusions and recommendations

10.1 Conclusions

It can be concluded that in order to support the satisfactory introduction of new DSL services to the users by means of the existing wired access networks, several new deliverables will be required. Some of these have already been identified and work on them started, others may need to be introduced at a later date. In some cases investigations may be needed to ascertain whether certain deliverables are needed at all.

10.2 Recommendations

Standards are required for the following items:

- Requirements for xDSL compatible POTS terminals.
- Requirements for POTS/DSL splitters for DSLregular systems. (This may be split into separate documents for the high pass and low pass filter functions).
- Requirements for distributed low pass filters for DSLlite systems.

The following areas are recommended for further study to ascertain whether any standards or other deliverables will be required.

- The impact of home LANs on DSL systems, including consideration of the possible requirement for a filter specification.
- The need for a home/user network spectrum management plan.

Annex A (informative): Crosstalk

Any crosstalk, or unwanted coupling of signals between separate pairs, in a multiple pair cable has a major impact on the deployment of DSL services via the local loop. The chief sources of crosstalk are shown in figure A.1.

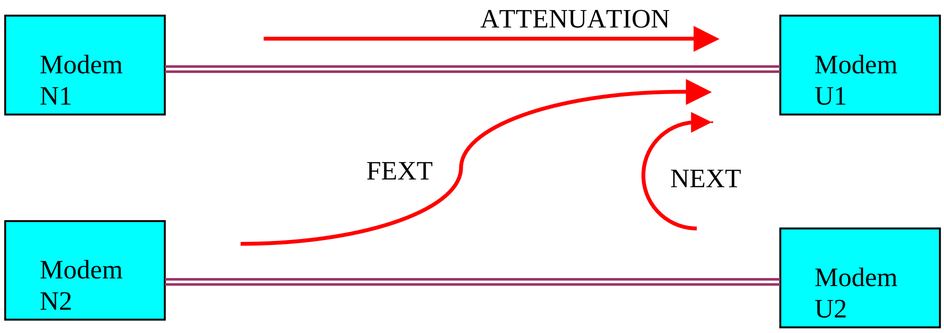

Figure A.1: sources of crosstalk

For example, take the case of the signals arriving at the user modem U1. The wanted signal is transmitted downstream by the network modem N1, and arrives at the receiving modem U1 in attenuated form due to the cable loss. Modem U1 also receives some signal from the downstream transmission N2 via crosstalk between cable pairs 1 and 2. This unwanted signal is known as Far End Xtalk (FEXT). Modem U1 also receives some unwanted signal, the Near End Xtalk (NEXT), from the upstream transmission of modem U2. Modem U1 in fact receives some crosstalk from each of the other pairs carrying DSL transmissions. The limiting factor for providing an acceptable transmission capability is the carrier to interference ratio. As the attenuation and crosstalk are frequency dependent, the carrier to interference ratio, and hence the service limits of range and bandwidth, will depend on the type of DSL system(s) used, and percentage of pairs using DSL, as well as the cable characteristics. For a fixed cable type, the effective service limits are reduced as the service take-up increases. For these reasons it is essential to have an agreed spectrum management regime to maximize the potential of the existing access loops.

Annex B (informative): Out-of-band sending limits for POTS terminals

A proposal for modifying the TBR 21 [1] out-of-band limits by extending the requirements from 200 kHz to 30 MHz in order to produce DSL compatible POTS terminals was produced by TM6 and input to ATA This is shown in figure B.1.

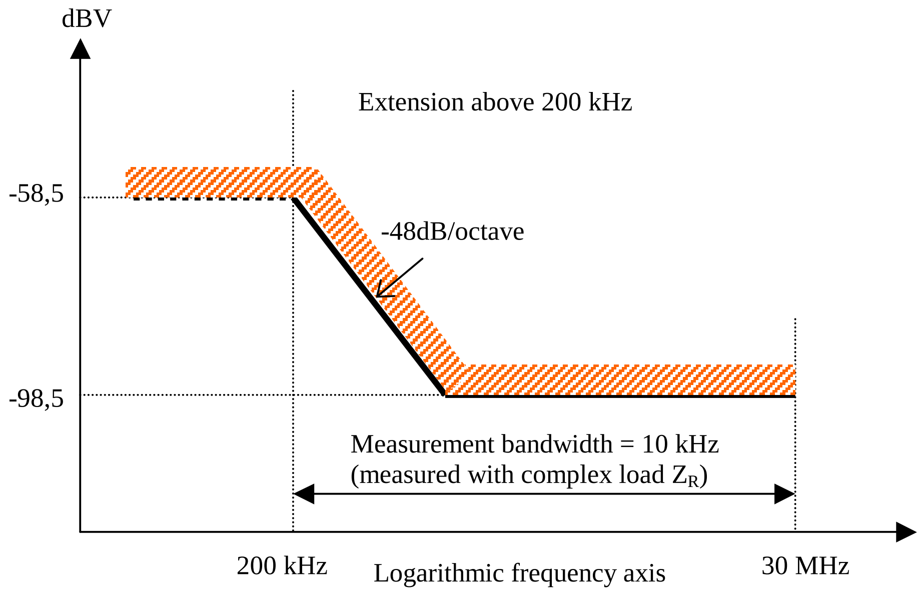

Figure B.1: Extended out of band limits (for DSLlite compatibility) proposed by TM6

Most POTS terminals are not designed to transmit signals above voice band. Any out-of-band signals, which do occur, are usually due to leakage of internal clock and sampling signals. Although the proposed extended limits shown in figure B.1 initially look severe, it may not be so stringent to meet in reality. Some initial measurements made on a few different types of POTS terminals by Nortel indicate that some existing types of telephone meet the requirement without modification. One type passed while in the transmission state but failed during DTMF signalling due to leakage of the 3,59 MHz DTMF generator master clock signal.

A more recent proposal from TM6 to extend the out-of-band mask of TBR 21 [1] from 200 kHz to 30 MHz to protect VDSL transmission systems is shown in the following table.

Frequency kHz	Impedance	Sending level U	Measurement bandwidth Hz	Spectral voltage dBV/√Hz
11 200	Z_R Z_R	-58,5 dBV -58,5 dBV	1 kHz 1 kHz	-88,5 -88,5
200 500	135 Ω 135 Ω	-60 dBV -90 dBV	1 kHz 1 kHz	-90 -120
500 30 000	135 Ω 135 Ω	-60 dBV -60 dBV	1 MHz 1 MHz	-120 -120

Annex C (informative): The effect of Splitters on Sidetone and Echo Loss

As well as straight-forward requirements like e.g. the d.c. resistance to earth, there are a few parameters, which are more important for the voice transmission quality of the telephony service. These are: attenuation, transparency (impedance disturbance by the splitters) and signal distortion caused by the d.c. current. They have also a large impact on the price of a splitter (and maybe on the physical size).

To study this, with the goal of obtaining acceptable parameters, the characteristics of a real splitter (from an ADSL supplier) were incorporated into a mathematical model, which allowed transparency, side tone (STMR), and hybrid echo loss calculations to be carried out.

Next step is to derive parameter values, which can be used in a standard.

Contents of this annex:

1) calculation of the (impedance) transparency. This is the return loss against an impedance Z when the splitter is terminated with the same Z;

2) calculation of the influence of inserting splitters on the STMR of a Z_{ref} based telephone set;

3) the influence of splitters on the "echo loss" of the local exchange hybrid;

4) the effect of splitters on older equipment;

5) conclusions.

C.1 Impedance Transparency

Transparency is expressed as the return loss of the splitter impedance against impedance Z when the splitter is terminated with the same Z.

The return loss of the splitter was calculated against 3 different terminations, while the splitter is terminated with same 3 impedances. These 3 impedances are "a", "b" and "c" from the STMR-test in TBR 38 [17], representing a short line, Z_{ref} and a long line.

They are:

"a" = 82 Ω+(600 Ω // 68 nF) (short line)

"b" = Z_R (the harmonized European impedance)

"c" = 220 Ω+(1800 Ω // 150 nF) (long line)

The results of the return loss calculations are in figures C.1a, C.1b and C.1c.

In figure C.1a, we have a return loss of > 14 dB up to 2600 Hz. Figure C.1b shows that the splitter has been developed for a return loss of > 14 dB against Z_R. Figure C.1c shows a very low return loss against impedance "c".

Conclusion:

A high return loss against Z_R does not assure a high return loss for other relevant impedances.

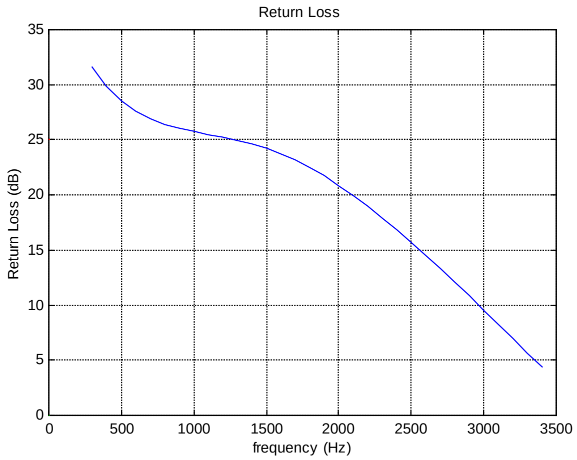

Figure C.1a:

Return loss against

82 Ω + (600 // 68 nF)

The splitter is terminated with the same impedance.

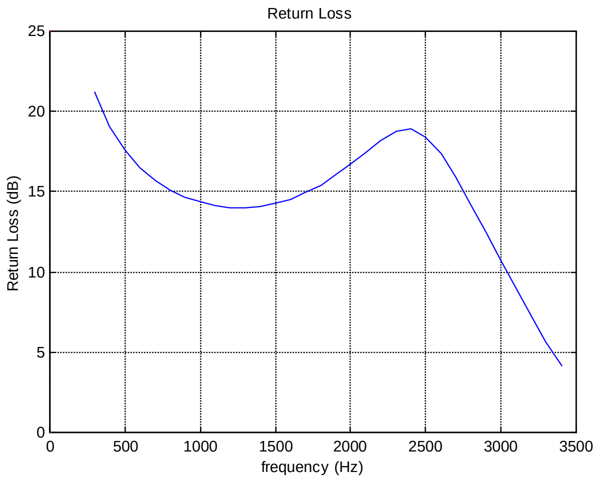

Figure C.1b:

Return loss against Z_R

270 Ω + (750 // 150 nF)

The splitter is terminated with the same impedance.

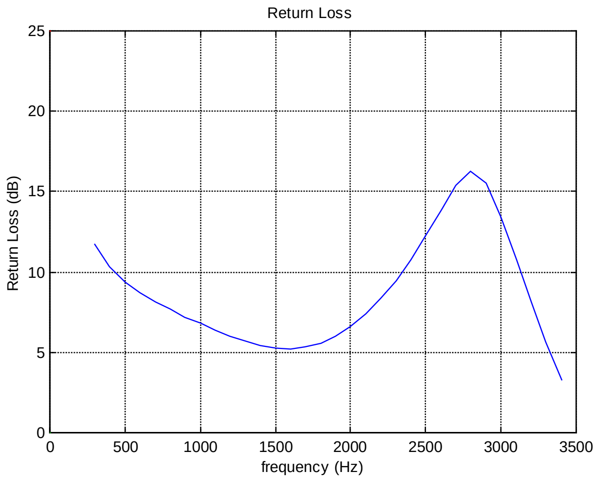

Figure C.1c:

Return loss against

220 Ω + (1800 // 150 nF)

The splitter is terminated with the same impedance.

C.2 The influence of inserting splitters on the STMR

Calculations were made on a model of a TBR 38 [17] phone, connected to a line with a termination (the exchange) at the other end, and with a splitter on both ends (figure C.2).

For the send and receive characteristic of the phone, values halfway between the lower and upper limit of TBR 38 [17], are chosen.

The cable has 0,5 mm copper pairs (R=171 Ω / km; C = 50 nF/km; L = 0,8 mH/km).

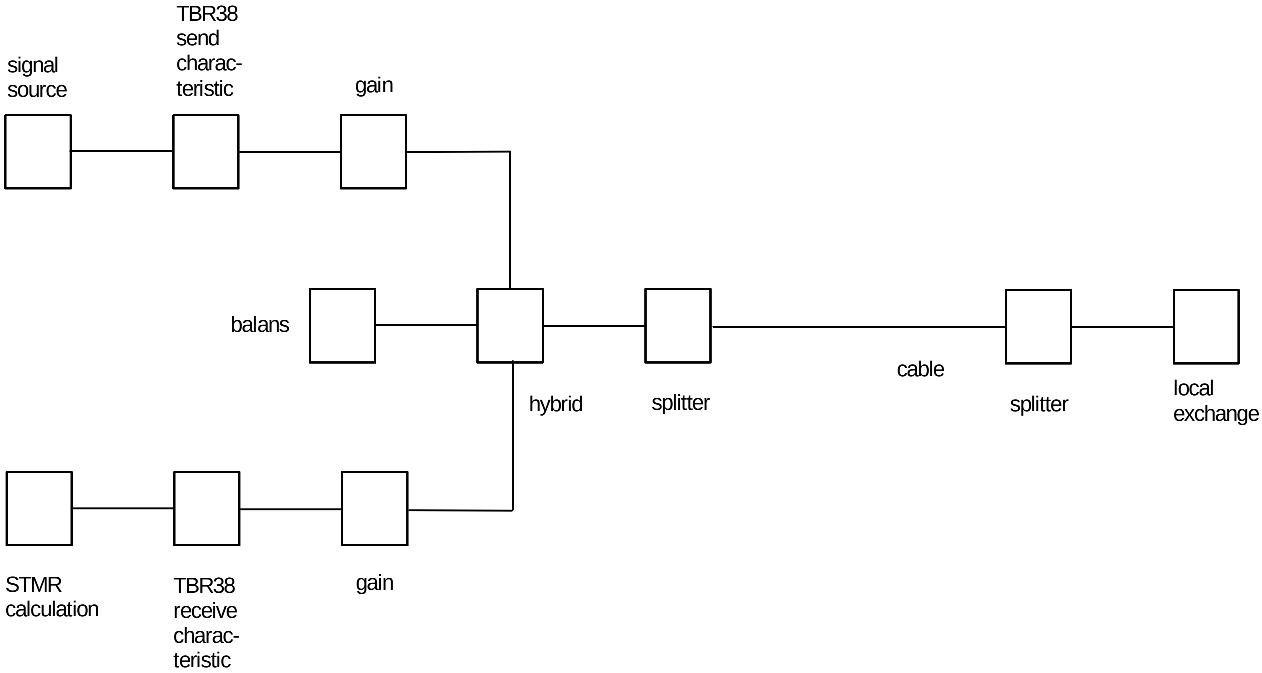

Figure C.2: Calculation model

Results:

Figures C.3a and C.3b give the results of the calculation, with splitters (figure C.3b) and without splitters (figure C.3a in the line for a TBR 38 [17] phone with a balance network equal to Z_R and an exchange impedance of Z_R.

Figures C.4a and C.4b give the results of a similar situation, but with an exchange impedance of 600 Ω.

Conclusions:

The splitters are causing a lower STMR value, but the lower values are within the "preferred range" for STMR of 7 to 12 dB, defined by ITU-T Recommendation G.121 [18].

The splitters are optimized for Z_R, so one can expect other (lower?) results for (older) telephone sets with a more simple balance network.

This is an important issue which warrants further investigation.

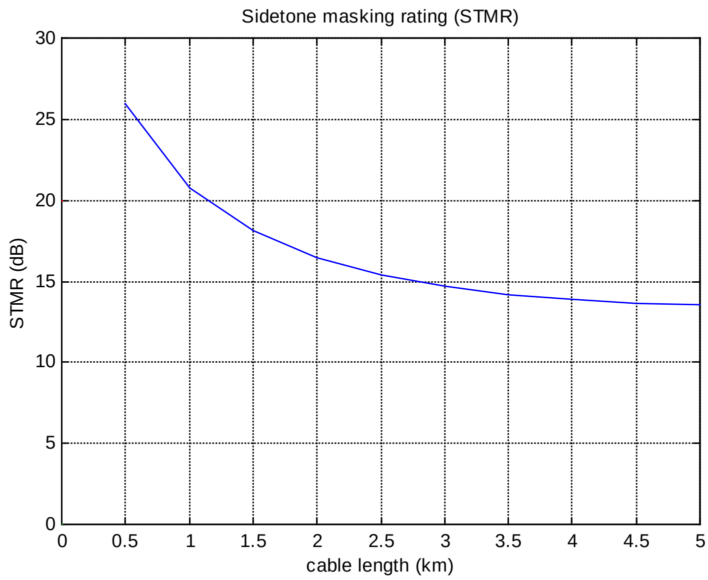

Figure C.3a: Calculation of Sidetone masking Rating (STMR)

TE = TBR 38; TE-balance = Z_{ref}; Local exchange termination = Z_{ref};

No splitters connected.

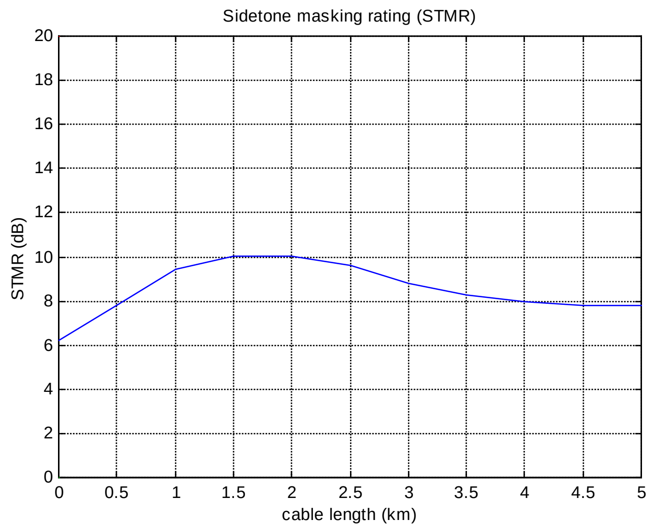

Figure C.3b: Calculation of Sidetone masking Rating (STMR)

TE = TBR 38; TE-balance = Z_{ref} Local exchange termination = Z_{ref};

Two splitters connected (one at the TE-side, the other at the exchange side).

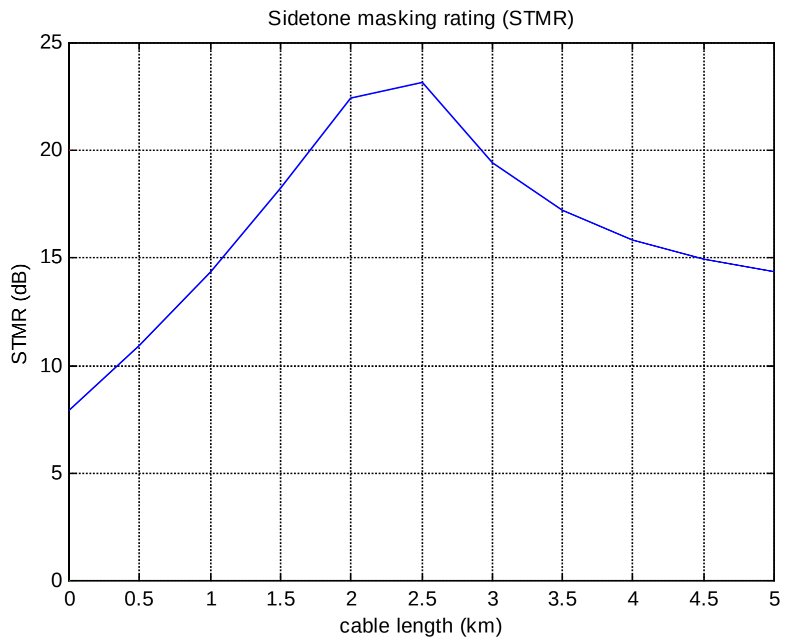

Figure C.4a: Calculation of Sidetone masking Rating (STMR)

TE = TBR 38 TE-balance = Z_{ref} Local exchange termination = 600 Ω;

No splitters connected.

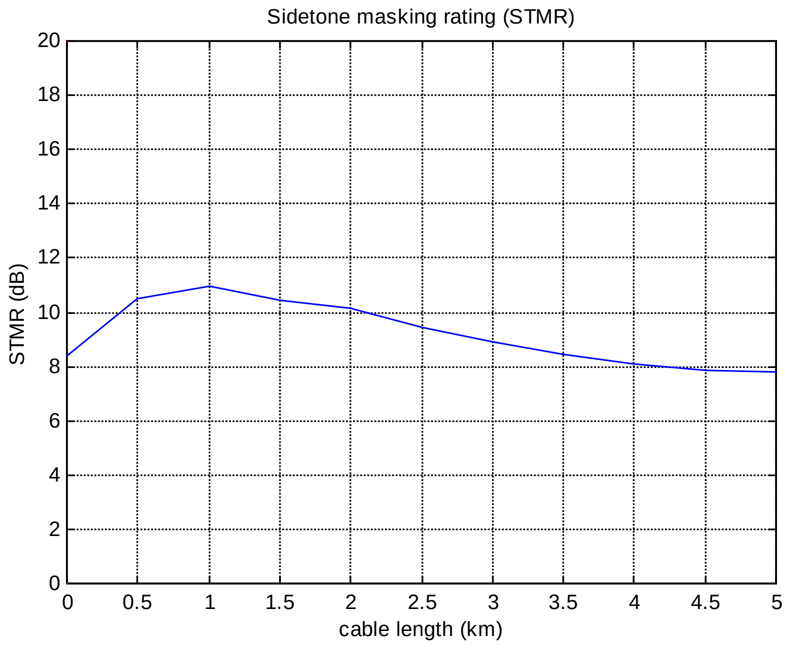

Figure C.4b: Calculation of Sidetone masking Rating (STMR)

TE = TBR 38 TE-balance = Z_{ref} Local exchange termination = 600 Ω;

Two splitters connected (one at the TE-side, the other at the exchange side).

C.3 The influence of splitters on the "echo loss" of the local exchange hybrid

In this clause, calculations were made on the echo loss of the local exchange hybrid with and without splitters in the local line.

A Hybrid model was used, with R- and T-pads in the four-wire circuit. The 2-wire connection of the hybrid is connected to a line (local loop). Splitters can be inserted in the line and the results calculated.

Hybrid echo is commonly expressed as a graph of (echo) loss (dB) against frequency. ITU has developed a method to apply a frequency dependant weighting which allows us to express it as only one number (ITU-T Recommendation G.122 [19]).

For the local exchange balance network, the recommended balance impedance of Appendix I of ITU-T Recommendation Q.552 [20] was used, which is optimized for Z_{ref} based TEs by different cable lengths. The balance impedance is: 230 Ω + (1 040 Ω // 160 nF).

It should be noted that the balance impedance of ITU-T Recommendation Q.552 [20] is probably not the optimum in networks with a mix of 600 Ω and Z_R based terminal equipments.

Results:

The results are shown in figure C.5a (without splitters) and C.5b (with splitters).

Conclusion:

With the splitters inserted, we have a lower echo loss, but it fulfils the requirements. ITU requires (ITU-T Recommendation G.122 [19]) a mean value of 15 + N dB or more (with a few dB standard deviation), where N is the number of cascaded 4-wire sections. In a modern digital network N=1 in most situations.

So for the situation considered here, with impedance's, the balance and the splitter based on Z_R, the results are within the limit.

For older exchanges with impedance's different from Z_R and, in some cases, a more simple balance network, more problems may be expected. Some of these issues are investigated in clause 4 of this annex.

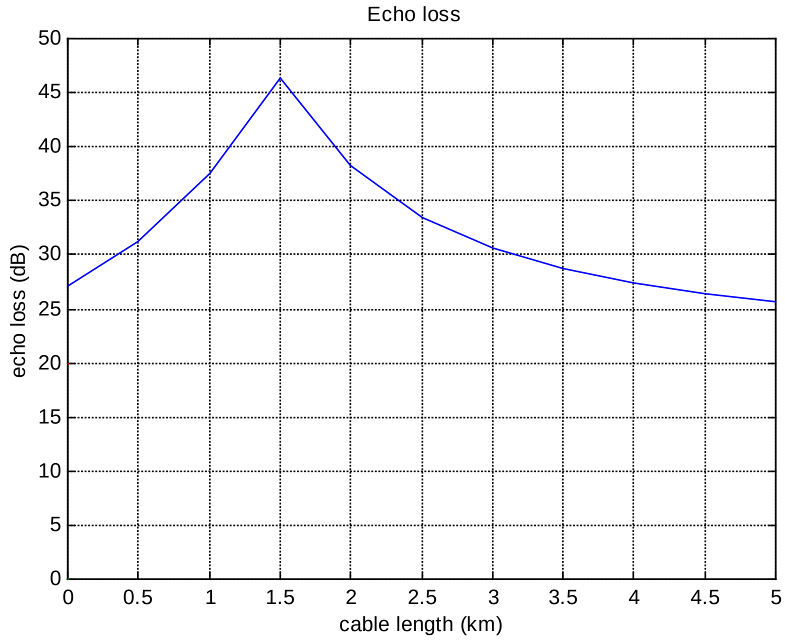

Figure C.5a: Echo loss of local exchange hybrid

Local exchange impedance = Z_R Local exchange balance = 230 Ω + (1 040 Ω // 160 nF)

TE impedance = Z_R T-pad = 0 dB; R-pad = 7 dB

No splitters connected

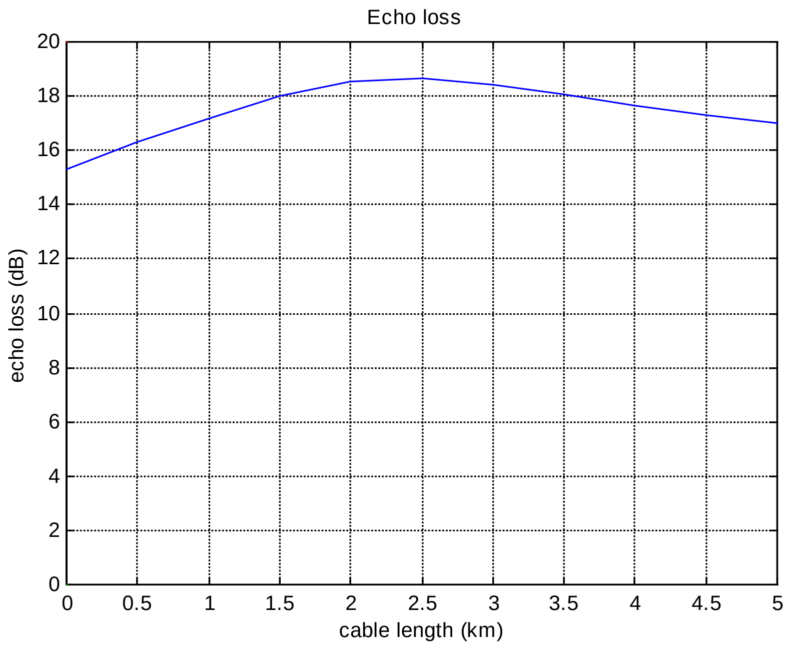

Figure C.5b: Echo loss of local exchange hybrid

Local exchange impedance = Z_R Local exchange balance = 230 Ω + (1040 Ω // 160 nF)

TE impedance = Z_R T-pad = 0 dB; R-pad = 7 dB

Two splitters connected (one at the TE-side, the other at the exchange side)

C.4 The effect of splitters on older equipment

In The Netherlands for example, there are some older types of exchange in service that have a balance network of: 820 Ω + 1 µF.

Decisive for the "echo loss " is the mismatch between the balance network and the impedance seen by the hybrid at the 2-wire port.

To study this, the return loss was calculated for the following cases:

- from the balance network against Z_R (figure C.6a);
- from the balance network against one splitter terminated with Z_R (figure C.6b);
- from the balance network against two splitters terminated with Z_R (figure C.6c).

Conclusions:

If splitters are used in combination with exchanges which are not based on Z_R (most of today's installed base of exchanges), it becomes important to study this situation and specify return loss requirements for these cases (i.e. not only a return loss requirement against Z_R).

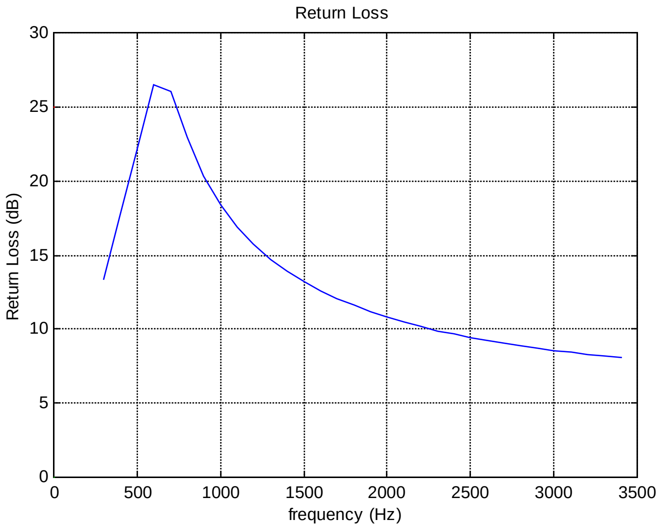

Figure C.6a:

Return loss from

Z=820 Ω + 1 µF

against Z_R

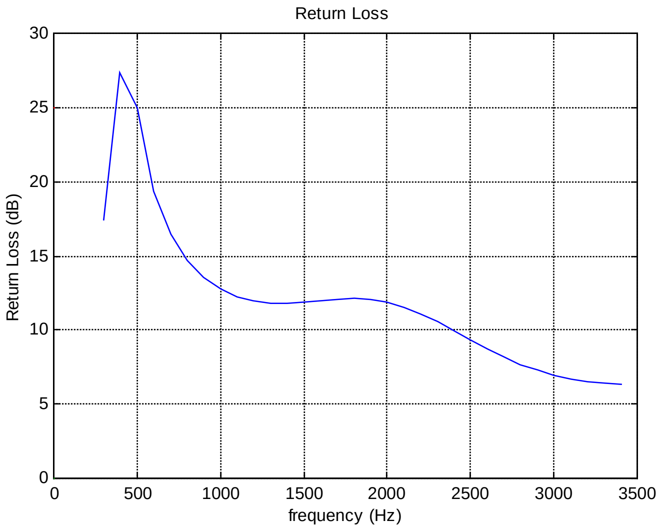

Figure C.6b:

Return loss from

Z=820 + 1 µF

against one splitter

terminated with Z_R

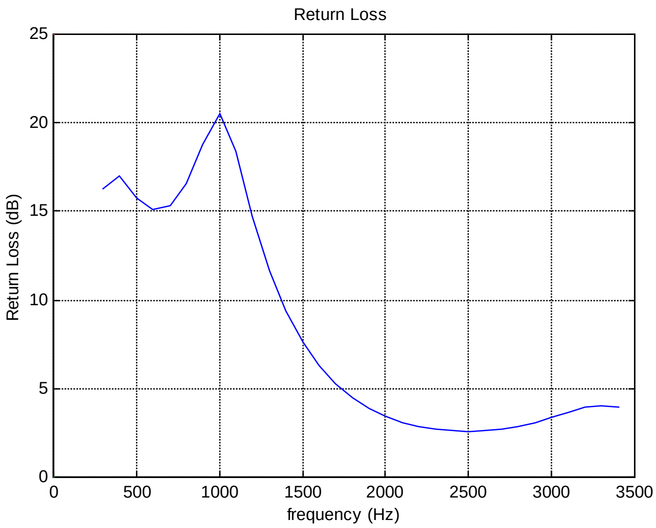

Figure C.6c:

Return loss from

Z=820 + 1 µF

against two splitters

terminated with Z_R

C.5 Conclusions

For Z_R based equipment:

A commercially available POTS/ADSL splitter was examined, and calculations made on STMR and "hybrid echo loss" as a function of cable length.

The examined splitter is Z_R based (> 14 dB return loss when terminated with and compared against Z_R). In combination with Z_R based TE (EN 301 437 [16] / TBR 38 [17]) the STMR is decreased after inserting splitters, but remains within the "preferred range" for STMR (7 - 12 dB).

The "echo loss" of a Z_R based local exchange hybrid is reduced by inserting splitters, but still remains within the limit.

Because the values for STMR and echo loss without splitters are far from the limit, they remain within the limit after inserting splitters.

For "non Z_R" based equipment:

For existing and older equipment with e.g. 600 Ω impedance and in some cases a simple balance network, STMR and echo loss values are even without splitters close to the limit. The degradation of STMR and echo loss by inserting slitters can cause a situation with not fulfilling the STMR and/or the echo loss limits.

It is recommended more study should be made on the requirements for splitters intended for use with "non Z_R" based equipment. A lot of (most of) the current TE and exchange equipment is "non Z_R" based.

Only a "Z_R based" return loss requirement seems not sufficient for a lot of existing equipment.

Annex D (informative): Reference impedances for POTS Splitters

The task of defining the requirements for the POTS splitter filters is currently in progress within ETSI. The work content has been shared such that the high pass filter requirements are the responsibility of ETSI TM6, and the low-pass filter requirements are the responsibility of ETSI AT. In order to ensure proper co-ordination between the work of the two groups, the following reference model and impedances have been agreed by the two groups.

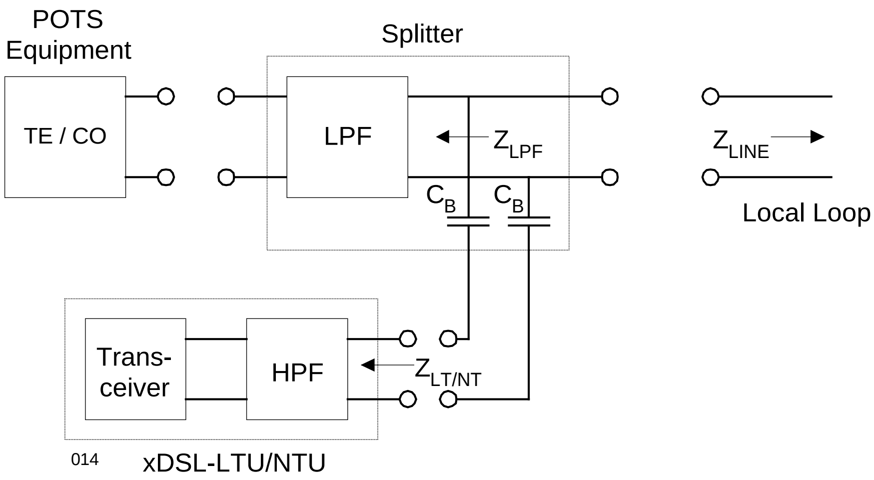

Figure D.1: POTS/DSL Splitter - Reference model

As shown in figure D.1 the high pass filter is usually incorporated into the DSL modem itself, whereas the blocking capacitors are usually associated with the low pass filter.

History

Document history		
V1.1.1	June 2000	Publication