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Technical Report

Access, Terminals, Transmission and Multiplexing (ATTM); Study of issues related to POTS injection in the customer wiring from xDSL VoIP Home Gateway

Reference

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

It addresses the major issues related with the performances of VoIP customer installations exploiting the re-injection of the POTS service locally generated by the Home Gateway in the customer premises wiring, without electrically disconnecting it from the external line.

The present document is fully in line with the initiative "eEurope 2002 - An Information Society For All", under "The contribution of European standardization to the eEurope Initiative, A rolling Action Plan" especially under the key objective of a cheaper, faster and secure Internet.

Introduction

Current ETSI standards on POTS/xDSL filters are based on the assumption of a classic xDSL deployment, either from the exchange or from the cabinet, with the POTS signals respectively injected at the central office or at the cabinet side of the local loop.

Voice over IP (VoIP) technology is however progressively replacing the traditional telephone service provided from the Central Office. This technology, originally mainly used by IP Operators to complement their "triple play" offer, is now being increasingly adopted also by the incumbent Operators to significantly cut the costs of the Central Office Switching Equipment and of the copper access network and to integrate the telephone service provision into the multimedia IP transmission and management platforms.

In the VoIP telephony provision scenario the POTS signals are typically locally generated from the POTS interface of the Home Gateway. However, despite having abandoned the access network existing infrastructure, VoIP operators are still willing to take advantage of the existing customer wiring and POTS terminals, in order to achieve the seamless transition from the traditional POTS service to IP telephony. To this purpose, the POTS signals are locally re-injected in the user premises networks. To allow the self-installation by the customer for minimising the deployment time and costs, and to accommodate the constraints implicit in distributed architectures, the re-injection technique is used for distributed architectures without galvanically separating the customer wiring from the external line.

The resulting operating conditions of distributed filters when used in these applications are quite peculiar and differ substantially from those assumed as a basis for their standardisation. The present document addresses the associated technical issues.

1 Scope

The present document identifies the major issues affecting the speech and xDSL performances of customer installations exploiting the VoIP telephony provision through the re-injection of the analogue telephony service, as generated at the POTS interface of the xDSL Home Gateway, in the customer premises network without electrically disconnecting it from the external line.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ETSI TS 102 971: "Access and Terminals (AT); Public Switched Telephone Network (PSTN); Harmonized specification of physical and electrical characteristics of a 2-wire analogue interface for short line interface".

[i.2] ETSI TR 102 021: "Terrestrial Trunked Radio (TETRA); User Requirement Specification TETRA Release 2".

[i.3] ETSI TBR 038: "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".

[i.4] ETSI ES 203 038: "Speech and multimedia Transmission Quality (STQ); Requirements and tests methods for terminal equipment incorporating a handset when connected to the analogue interface of the PSTN".

[i.5] ETSI ES 201 970: "Access and Terminals (AT); Public Switched Telephone Network (PSTN); Harmonized specification of physical and electrical characteristics at a 2-wire analogue presented Network Termination Point (NTP)".

[i.6] ETSI TS 101 952-1: "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 1: Generic specification of the low pass part of DSL over POTS splitters including dedicated annexes for specific xDSL variants".

[i.7] ETSI TS 101 952-1-5: "Access network xDSL transmission filters; Part 1: ADSL splitters for European deployment; Sub-part 5: Specification for ADSL over POTS distributed filters".

[i.8] EN 60950-1: "Information technology equipment - Safety - Part 1: General requirements".

[i.9] IEEE 802: "IEEE Standard for Local and metropolitan area networks".

[i.10] IEEE 802.11: "IEEE Standard for Information technology-Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.11] Broadband Forum TR-127: "Dynamic Testing of Splitters and In-Line filters with xDSL Transceivers".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

access network: network connecting the Local Exchange with the customer wiring. Often referred to as "local loop"

Customer Premises Network (CPN): in-house IP network connecting the Home Gateway to the customer IP devices

distributed filter: low pass filter that is added in series with each of the parallel connected POTS TEs

NOTE: Each of the parallel connected filters (in the in-house cabling) is known as a distributed filter. These filters are also known as In-line filters or microfilters.

far end echo: speech that is fed back to the talker in a telephony connection with a round trip delay (i.e. the delay between talking and hearing the feedback) greater than 5 ms, resulting in a distinguishable echo

FXS port (interface): POTS interface of Home Gateways

home gateway: gateway between the Access Network (AN) and the Customer Premises Network (CPN)

NOTE: For the purposes of the present document the Home Gateway, besides implementing the xDSL and networking functionalities allowing the customer access to IP services, also features a local POTS interface allowing the access to the VoIP telephony services by means of plain POTS terminal equipment.

hybrid: circuit used in the POTS transmission link in COs and HGs (provided with POTS interface) for implementing the four wires/two wires transition between the speech codec and the POTS interface

NOTE: This circuit operates as a bridge with an internal balance impedance which is intended to match as well as possible the impedance presented by the POTS line.

local loop: See access network.

microfilter: distributed filter

off-hook: state of the POTS equipment at either end of a loop connection when the NTP terminal equipment is in the steady loop state

on-hook: state of the POTS equipment at either end of a POTS loop connection when the NTP terminal equipment is in the quiescent state

passive splitters: splitters containing exclusively passive components

POTS re-injection: delivery scheme by which the POTS service, as locally generated from the POTS interface of the xDSL Home Gateway, is injected into the customer premises telephone wiring without electrically disconnecting it from the external line

POTS/xDSL splitter: circuit separating the transmission of POTS signals and DSL signals, enabling the simultaneous transmission of both services on the same twisted pair

sidetone: speech that is fed back to the talker in a telephony connection with a round trip delay (i.e. the delay between talking and hearing the feedback), of less than approximately 5 ms, making it indistinguishable from the original utterance

triple play services: services combining Data, Voice and Video

unbundling: process whereby a local loop owned and operated by a providing operator is made available in whole or in part to a requesting operator for the provision of services to a user

xDSL: covers ADSL and VDSL families only

NOTE: E.g. SDSL is not covered by this abbreviation in the present document.

3.2 Symbols

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

RL_{CO}	Return loss at the POTS interface of the POTS/xDSL splitter at the CO side
RL_{TE}	Return loss at the POTS interface of the TE microfilter for the traditional xDSL deployment
RL_{RI}	Return loss at the POTS port of the microfilters for the re-injection scheme
Z_{AC}	Generic name for the AC POTS impedance models
Z_{DSL}	Impedance model of the input filter of a particular xDSL
Z_{OnHo}	Impedance modelling multiple parallel on-hook phones
Z_R	European harmonized complex reference POTS impedance

3.3 Abbreviations

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

AC Alternating Current
ADSL Asymmetric Digital Subscriber Line
CO Central Office

NOTE: ≡ Local Exchange ≡ LE.

CPE Customer Premise Equipment

NOTE: ≡ Terminal Equipment ≡ TE.

CPN Customer premises network

NOTE: See definition.

DC Direct Current
DSL Digital Subscriber Line
DSLAM Digital Subscriber Line Access Multiplexer
ERL Echo Return Loss
ETH Ethernet interface

NOTE: See IEEE 802 [i.9].

FXS Foreign eXchange Station
HG Home Gateway
IP Internet Protocol
LE Local Exchange

NOTE: ≡ Central Office.

NTP Network Termination Point
OLO Other Licensed Operator
PLT Power Line Telecommunication
POTS Plain Old Telephone Service

NOTE: Used throughout instead of PSTN.

PSTN Public Switched Telephone Network
RL Return Loss
STB Set-Top Box
TE Terminal Equipment

NOTE: E.g. Telephone, Fax, Voiceband modem etc.

VoIP Voice over IP
VDSL Very high speed Digital Subscriber Line
WiFi Wireless Fidelity ISO/IEC local area network standard

NOTE: See IEEE 802.11 [i.10] family.

μF microfilter - distributed filter

4 The background: from the PSTN to VoIP telephony

The xDSL deployment (originally ADSL) has been originally based on the provision by incumbent Operators of both telephony and xDSL services from the Central Office. In this scenario, VoIP telephony was initially offered only by IP service providers within their triple play services, basing their offer on the use of Home Gateways associating, to the typical networking features of xDSL transceivers, a POTS interface, sometimes referred to as FXS, operating as the POTS interfaces of the PSTN cards of the COs. In case of OLO operators operating within total unbundling arrangements, the VoIP service often replaces the PSTN telephony from the CO and the local loop is only used for carrying xDSL signals.

While abandoning the access network existing infrastructure for telephony provision, VoIP operators are however eager to keep exploiting the existing customer wiring and POTS terminals in order to achieve a seamless transition from the PSTN to IP telephony. To pursue this strategy, in total replacement scenarios the customer POTS wiring is connected to the FXS interface of the Home Gateway.

Depending on the xDSL customer wiring architecture, e.g. centralised splitter vs. distributed filtering, different methods are used for injecting the VoIP telephony service into the customer wiring. These methods are quickly reviewed in the following, paying then particular attention to the one based on the re-injection of the POTS signals in distributed architectures and to its implications on the speech and xDSL performances of customer installations.

4.1 Customers plants with centralised splitter

The typical xDSL deployment scheme based on the use of a central splitter at the customer premises is shown in Figure 1. For these plants, the provision of VoIP telephony by OLO operators, intended to replacing the PSTN telephony from the CO, basically occurs by transforming the scheme shown in figure 1 into the one represented in figure 2.

The POTS interface of Home Gateways is standardised by TS 102 971 [i.1], aimed at assuring the correct interworking with POTS CPEs both with respect to POTS signalling and feeding conditions and to the speech transmission performances. In fact, TS 102 971 [i.1] is coherent both with the CPE characteristics, as specified by TS 103 021 [i.2], TBR 038 [i.3] and TS ES 203 038 [i.4], and with the PSTN access characteristics, as presented at the NTP, specified by ES 201 970 [i.5].

In particular, the loop current generated by the POTS interface of HGs is required to be in the range between 18 mA and 70 mA, 25 ÷ 40 mA recommended, and the open circuit DC voltage is required not to exceed 78 V, but not be less than 38 V. The open circuit ringing AC voltage is required not to exceed 100 V_{rms} at the POTS interface and the total harmonic distortion is required not to exceed 10 %. In case of ringing without DC, the transitions from ringing voltage to DC are required to occur without any waveform discontinuity.

As concerns the speech transmission aspects, the impedance presented by the POTS interface of the HG when in the loop state is specified to be the reference ETSI impedance Z_R, and the hybrid used in the HG for implementing the four wires/two wires transition between the speech codec and the POTS interface is also required to be balanced against Z_R.

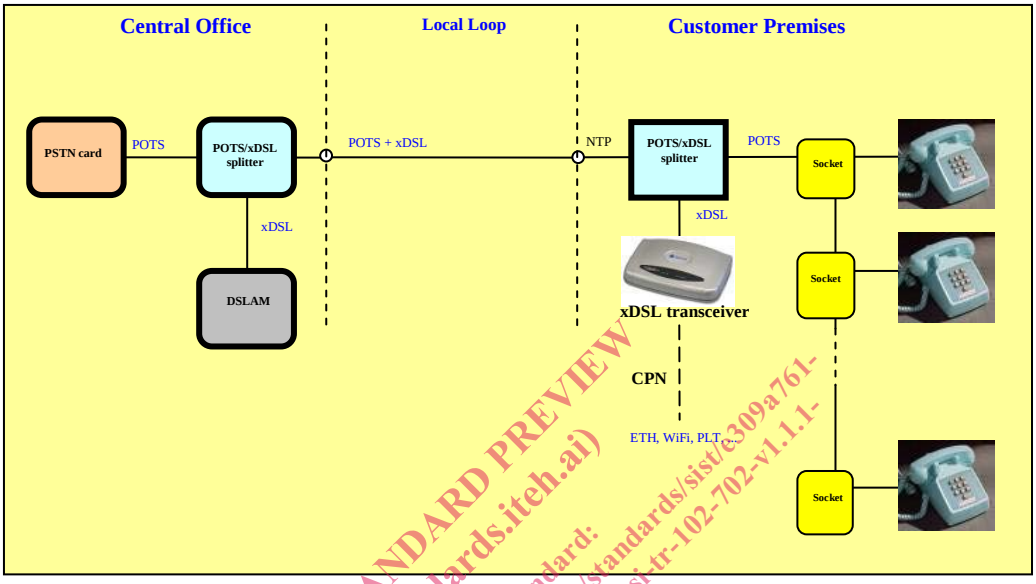

Figure 1: Telephony and xDSL deployment from the CO - centralised splitter

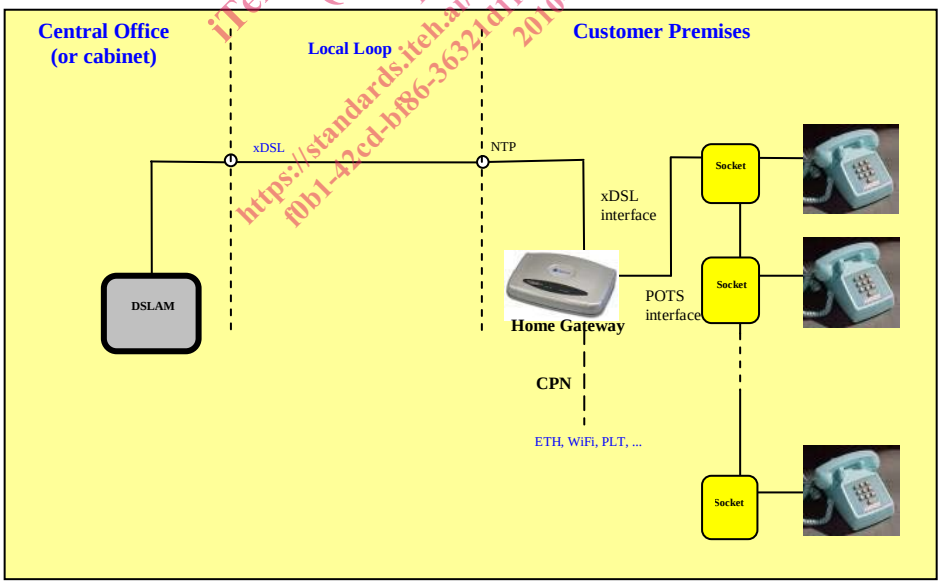

Figure 2: Total replacement of PSTN by VoIP telephony

The compliance with mentioned ETSI standards by the POTS interface at the HG and by the POTS CPEs assures the optimal speech transmission performance of the VoIP delivery scheme as shown in figure 2. However, this approach has some drawbacks from the point of view of provisioning time and cost and of the customer installation flexibility. Namely:

- The switchover from the PSTN deployment (see figure 1) to VoIP deployment (see figure 2) requires the technical intervention at the Customer premises by the Operator staff, or by outsourced technical personnel, for removing the splitter and sectioning the customer plant from the external network.

- To avoid any lack of service to the Customer, the mentioned switchover should be perfectly synchronised with the discontinuation of the PSTN service and with the completion of the associated number portability procedure.

- In order not to re-wire the customer premises, the HG is better connected at the NTP or at the first socket.

The last point is quite relevant as the key driver of the triple-play offer are the multimedia services, normally delivered from a set-top-box conveniently placed near a TV screen and connected to the CPN coming from the HG. This constraint may result into the need to set-up in the customer premises a high speed data connection between the HG and the STB, which would be avoided if the HG could be placed close to the latter. For the above mentioned reasons there may be a strong business case for some Operators to adopt, as far as possible, distributed filtering architectures as an alternative to the one illustrated in figure 2.

4.2 Customer plants with distributed filtering

The functional diagram of a typical xDSL platform based on distributed filtering is as shown in figure 3. The distributed filters are intended to be a convenient solution enabling the self-installation by the user. The performance of both the POTS and xDSL services may however be reduced when using distributed filters instead of a central splitter. It is however known that this potential impairment is not significant in ADSL deployments, while in VDSL applications the distributed architecture generally results into a decrease of the theoretically available bit rate due to the multiple reflections in the customer wiring. This notwithstanding, this may be considered as a fair price to be paid by those Operators aiming at a faster and cheaper VDSL development.

In the example shown in figure 3 the xDSL transceiver is connected to the second socket of the customer plant, but it would work even if connected to any other socket. The provision of VoIP telephony in a "total PSTN replacement" scenario is achieved by transforming the scheme shown in figure 3 into the one represented in figure 4, where the HG can be connected to any socket of the customer wiring. Contrarily to figure 2, in this case no sectioning occurs at the NTP interface and the customer installation can be easily modified by the user itself.

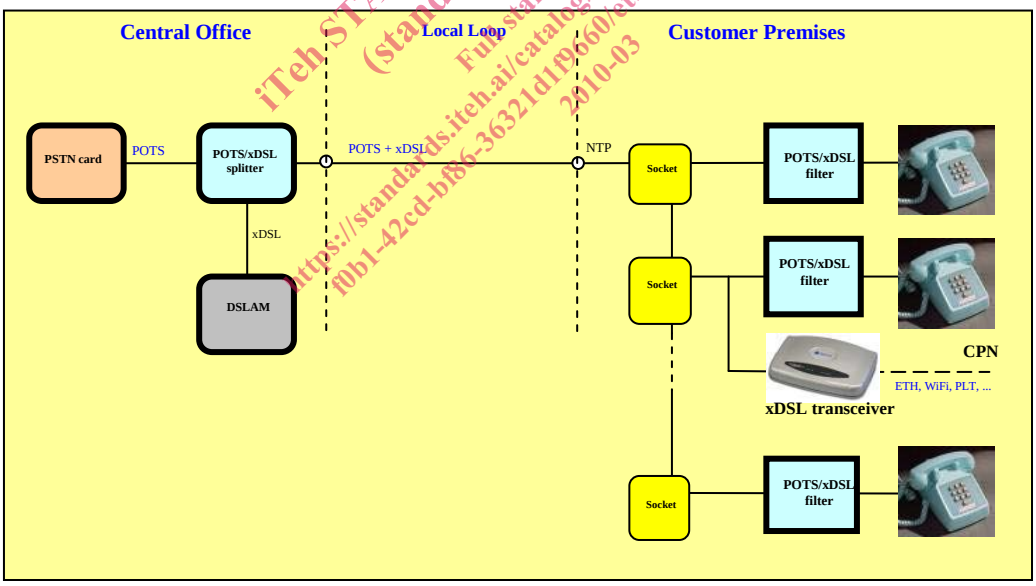

Figure 3: Functional diagram of a typical xDSL platform based on distributed filtering

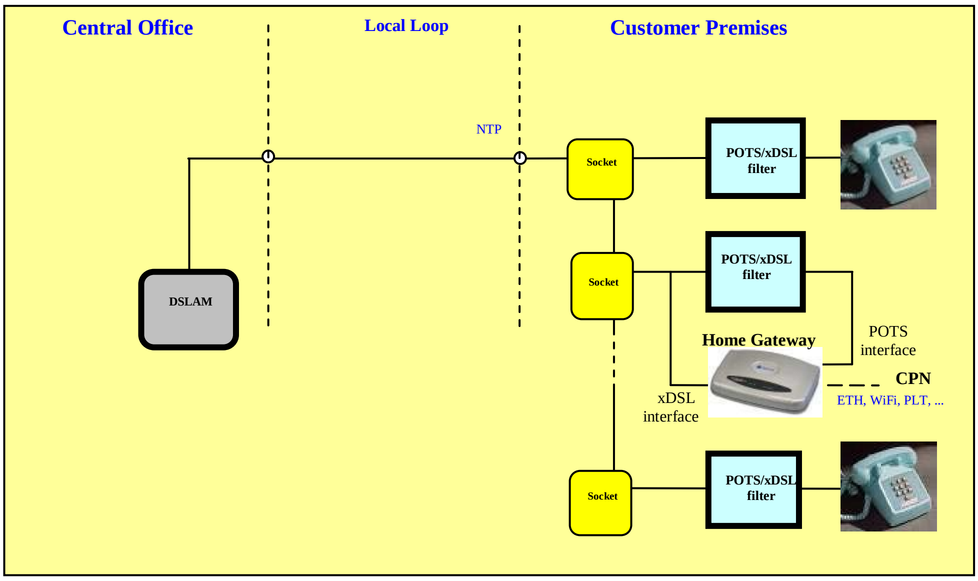

Figure 4: Total replacement of PSTN by VoIP telephony (distributed filtering architecture)

As shown in figure 4, the POTS (FXS) interface of the Home Gateway is re-injected into the customer wiring by means of a POTS/xDSL filter, the same way as the PSTN port of the CO is connected to the loop through the POTS splitter (see figure 1). A major difference however exists with respect to the classic PSTN deployment from the CO as in this case the POTS interface is located at the same side of the local loop as the customer wiring, this resulting into a number of functional differences with respect to the classic scheme:

- the local loop is no longer a transmission line for the POTS signalling and telephony signals, but it only acts as a load in the POTS transmission chain, which is totally within the customer wiring;
- both the terminal side and the line side of the POTS connection are close to the customer xDSL transceiver, while in the classic deployment schemes (see figures 1 and 3) the CO side of the POTS connection is closer to the network transceiver (DSLAM);
- safety issues may arise if the Home Gateway used has been developed by targeting only the total replacement scenario depicted in figure 2, where the customer plant is electrically isolated from the local loop. In fact, in this case the HG could have been developed without galvanically isolating its POTS interface from the other circuits and metallic accessible parts, as is mandatory for the public line interfaces of telecommunication equipment (see clause 5.3).

From the provisioning point of view, to avoid any lack of service to the customer and to prevent conflicts between the CO and HG POTS interfaces, also in this case the self-installation of the VoIP delivery configuration should be synchronised with the discontinuation of the PSTN service from the network and with the completion of the associated number portability procedure by the previous Operator. Suitable provisioning procedures or appropriate technical means are then to be put in place for assuring that the POTS interface of the HG is connected to the customer wiring only after the PSTN service discontinuation has occurred.

5 Technical issues of POTS re-injection

As described above, the VoIP provision by POTS re-injection techniques significantly modifies the operating conditions of the customer loop and of the POTS/xDSL microfilters, as compared with those assumed as their originally intended use, on which the requirements and test methods of applicable technical standards are based. This applies in particular to the POTS path configuration, and then to the associated speech transmission performances, and to the potentially different susceptibility of xDSL transceivers to POTS disturbances.

5.1 Speech transmission quality

Two aspects are of utmost interest when comparing the speech transmission performances of the traditional xDSL deployment scheme based on distributed filtering against the VoIP deployment scheme based on re-injection: Frequency Response Characteristics and Return Loss performances.

To investigate these issues, the POTS transmission paths shown in functional diagrams in figures 3 and 4 can be instanced as in figures 5 and 6 respectively.

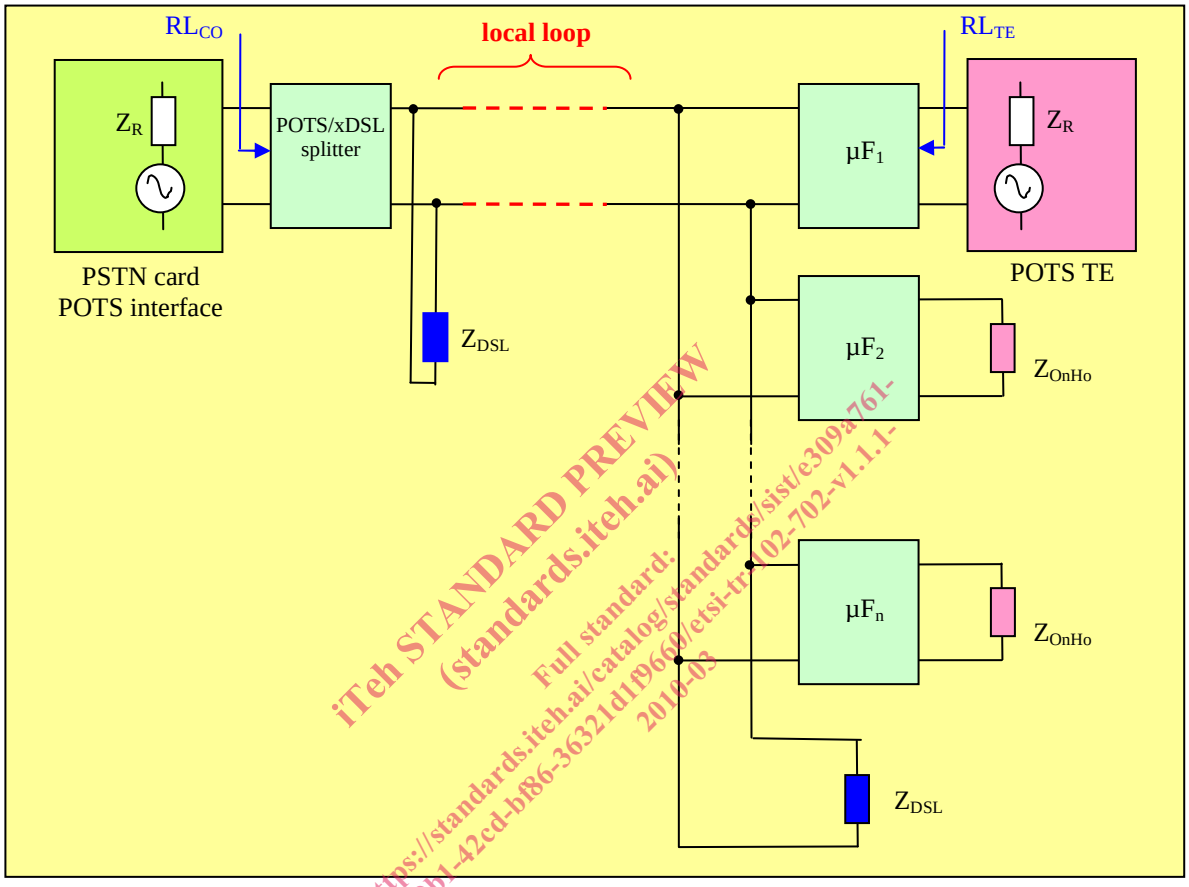

Figure 5: POTS transmission path of traditional xDSL deployment