ETSI TS 101 548-2 V1.1.1 (2021-06)

TECHNICAL SPECIFICATION

Access, Terminals, Transmission and Multiplexing (ATTM); European Requirements for Reverse Powering of Remote Access Equipment; Part 2: Coaxial Cable Networks

Reference
DTS/ATTM-0633

Keywords
cables, coaxial, powering, reverse, RPF

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

Foreword

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

The present document is part 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [1].

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

As various Operators consider the deployment of fibre-fed remote nodes that contain G.fast DSLAM equipment [i.1], it is necessary to consider the means of powering such remotely located equipment. One such method, known as "reverse power feed", transmits the power from the customer premises to the fibre-fed remote node using a point to point coaxial cable network. The present document defines a reverse power feed transmission standard which allows Operators to source suitably compliant equipment for inclusion in their networks.

1 Scope

The present document defines architectures and specifications for reverse powering of a remote network node from one or multiple G.fast CPEs over Point to Point (P2P) coaxial cable (coax), where there is no coexistence with other services over an operational Hybrid Fibre Coax (HFC) network. The present document specifies the reverse powering for two coax configurations with G.fast as described in Annex D.1 of BBF TR-285 [3], Issue 1 Amendment 1: G.fast with satellite TV and G.fast only. The relevant clauses to ETSI TS 101 548-1 [1] are referenced where appropriate.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 101 548-1: "Access, Terminals, Transmission and Multiplexing (ATTM); European Requirements for Reverse Powering of Remote Access Equipment; Part 1: Twisted Pair Networks".

[2] EN 62368-1: "Audio/video, information and communication technology equipment - Part 1: Safety requirements", produced by CENELEC.

[3] Broadband Forum TR-285: "Broadband Copper Cable Models".

[4] Broadband Forum TR-301: "Architecture and Requirements for Fiber to the Distribution Point".

[5] EN 60728-11: "Cable networks for television signals, sound signals and interactive services - Part 11: Safety" Edition 4.0 2016-3, produced by CENELEC.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] Recommendation ITU-T G.9700: "Fast access to subscriber terminals (G.fast) - Power spectral density specification".

[i.2] Recommendation ITU-T G.9701: "Fast access to subscriber terminals (G.fast) - Physical layer specification".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

Core Conductor (CC): conductor at the center of a coax cable, normally a solid wire

diplexer: passive device that implements frequency-domain multiplexing, in which the two ports (in different frequency bands) are multiplexed onto a third port Consequently, the input signals can coexist on the output port without interfering with each other

metallic connection: physical connectivity providing a DC path between two points, typically provided via a coaxial cable

normal operation: state of a system (i.e. a DPU reversely powered by a PSE) reached after the start-up procedure has been completed

Outer Shield Conductor (OSC): conductor surrounding the core conductor insulation, normally a braided conductive material

power splitter: device that performs a frequency splitting/combining function between the AC part of the services being carried (which can include G.fast based services) and the injected DC electrical power

RG-x: Radio Guide - Standard Coaxial Cable designations

start-up mode: start-up procedure of a system (powering part of a DPU and PSE)

3.2 Symbols

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

Ω	Ohm
μF	micro Farad
nF	nano Farad
U-R	Reference point at CPE containing both DC power and service data
U-R2	Reference point at CPE containing the filtered service data
U-R2P	Reference point at CPE containing the injected DC power
U-O	Reference point at DPU containing both DC power and service data
U-O2	Reference point at DPU containing the filtered service data
U-O2P	Reference point at DPU containing the extracted DC power
U-OG	Reference Point at DPU containing the G.fast signal
U-OS	Diplexer Reference Point at the DP
U-RG	Reference Point at CPE containing the G.fast signal
U-RS	Diplexer Reference poin at CP
SAT TV	Reference Point at DPU containing the satellite TV signal
STB TV	Reference Point at CPE containing the satellite TV signal

3.3 Abbreviations

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

AC	Alternating Current
ACM	Alternating Current Mains
ATA	Analogue Telephone Adapter
BAT	Battery
BBA	Battery Back-up Available
CC	Core Conductor
CO	Central Office
CP	Customer Premises

CPE ME	CPE's Management Entity
CPE	Customer Premises Equipment
CPF	Common Power Feed
DC	Direct Current
DGL	Dying Gasp Loss
DN	Distribution Network
DP	Distribution Point
DPU ME	DPU's Management Entity
DPU	Distribution Point Unit
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
ECL	Error Line Condition
ELC	Error Line Condition
FTU	G.fast Transceiver Unit

NOTE: See Recommendation ITU-T G.9701 [i.2].

FTU-O	FTU at the DPU
FTU-R	FTU at the remote site
HON	Higher Order Node
IFN	Intensity of current Feed Now
MDSU	Metallic Detection based Start-Up protocol
MDU	Multi Dwelling Unit
ME	Management Entity
MELT	Metallic Loop Test
MET	Main Earthing Terminal
NMS	Network Management System
NT	Network Termination
NTE	Network Termination Equipment
OAM	Operations And Maintenance
OSC	Outer Shield Conductor
PC	Power Class
PE	Power Extractor
PHY	Physical (layer)
PIS	Potential Ignition Source
PME-C	CPE's Power Management Entity
PME-D	DPU's Power Management Entity
PMT	Power Management Transceiver
PS	Power Splitter
PSD	Power Spectral Density
PSE	Power Source Equipment
PSE-IE	Power Source Equipment - Injected Energy
PSU	Power Supply Unit (including the combiner function if multiple lines are active)
RBW	Resolution Bandwidth
RG	Radio Guide - Standard Coaxial Cable designations
RPF	Reverse Power Feed
RPFA	Reverse Power Feed Architecture
RPFA-CGO	Reverse Power Feed Architecture - Coax G.fast Only
RPFA-CGS	Reverse Power Feed Architecture - Coax G.fast with Satellite TV
R_{SIG}	Signature Resistor
SAT	Satellite
SG	Service Gateway
SIG	Signature
SR	Short Range
STB	Set Top Box
VA	Volt Ampere
VPSE	Steady state voltage from PSE

4 Introduction to Reverse Power Feed

The basic architecture of a fibre-fed remote node with reverse power feed over coax is shown in Figure 1.

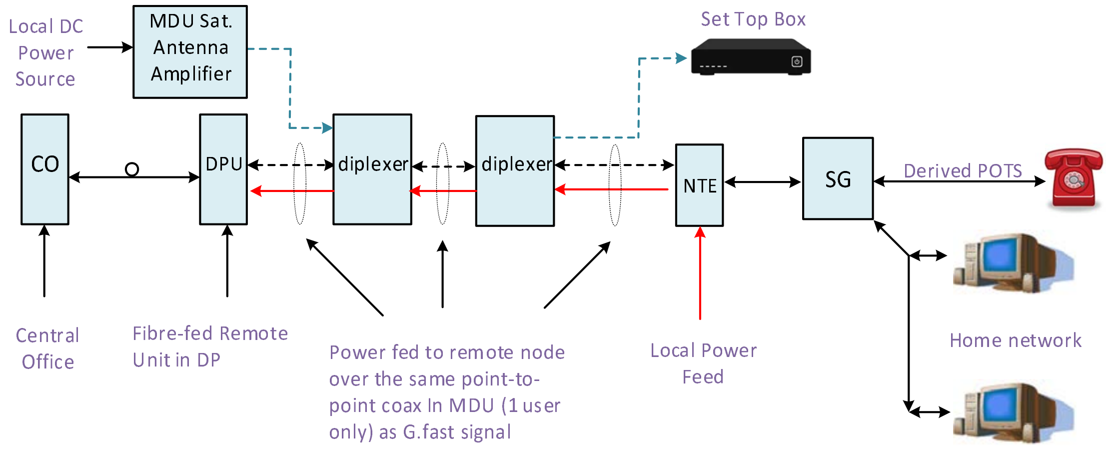

Figure 1: Generic Fibre-fed Remote Node Coaxial Architecture with Reverse Power Feed

Figure 1 applies to two architecture scenarios, G.fast co-existing with Satellite TV and G.fast on its own. It shows power being injected at the NTE from a local power source (located within the home and/or building) which traverses the coaxial cable to power a fibre-fed remote node, located at the Distribution Point (DP).This is the same coaxial cable that is used to transport the G.fast signal between the home and the fibre-fed remote node. Voice service can also be implemented as derived POTS from the Service Gateway (SG). In the case of G.fast with satellite TV, a set of diplexers is required to merge the satellite TV signals onto the same coax as used for the reverse power feed and G.fast signals. Furthermore, reverse powering is not compatible with any use case where a DC component is used in the signalling between the Set Top Box and the satellite TV distribution equipment.

An issue with regards to reverse powered fibre-fed nodes is that of who or what is responsible for the powering of common circuitry contained within the node. It is easy to envisage that an individual user should be responsible for the powering of the remote line terminating/driver electronics corresponding to his particular circuit. However, it is not so easy to determine who or what is responsible for powering of say the DPU that terminates the fibre link.

The present document defines the following two deployment scenarios:

- Scenario 1 - DPU located G.fast only
- Scenario 2 - DPU located G.fast with satellite television

These two scenarios are shown below. These are derived from Figures 25 and 26 in TR-285 [3].

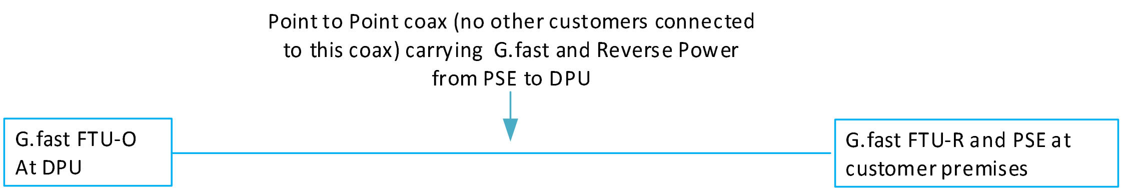

Figure 2: Coax configuration for DPU located G.fast only

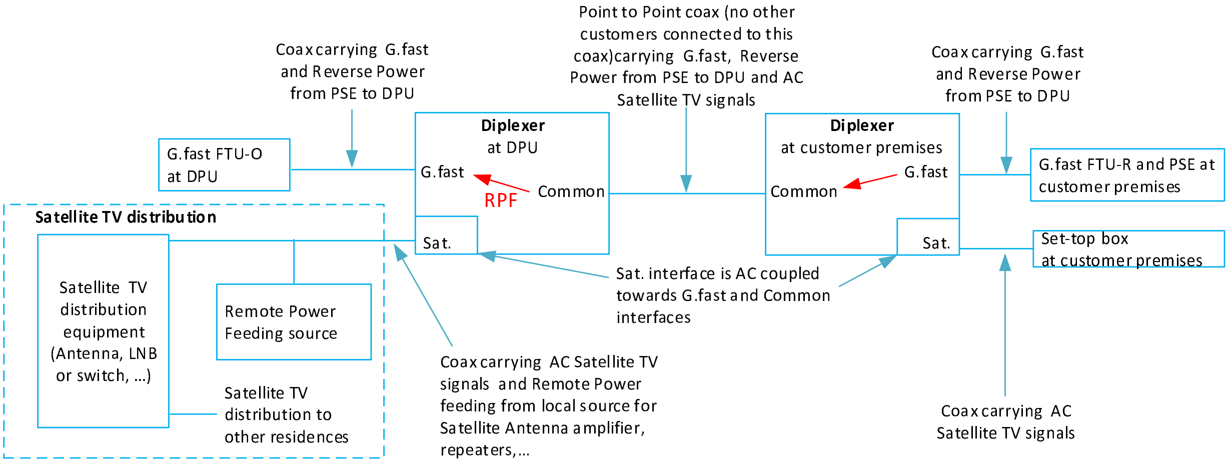

Figure 3: Coax configuration for DPU located G.fast with Satellite TV

In the present document, two different implementations of Power Source Equipment (PSE) for Customer Premises are considered: standalone (i.e. a two box model where the PSE and NTE are separate) or integrated (i.e. a single box model where the PSE and NTE are integrated). In these implementations, the Power Splitter (PS) may either be integrated or stand alone.

5 Reverse Power Feed Architectures

5.1 Basics of RPF

Reverse power feed is one of three DPU powering methods defined in TR-301 [4]. Here, the DPU draws its power from the customer premises via the coaxial cable running between those premises and the DPU. The reverse power feed capacity and DPU power consumption need to be such that the DPU can be fully operational when only a single customer is connected. Any back-up battery would be located in the customer premises.

The other two methods are:

- Forward Power from a Network Power Node. In this case, any back-up battery would be located at the network power node.
- Local Power from AC mains source. In this case, any back-up battery would be located at the DPU location.

The combination of reverse powering with one or both of the other two methods is outside the scope of the present document.

Reverse powering shall have two power splitters (one located at the customer premises and another at the remote node) to enable power to be inserted at the customer end of a link and extracted at the remote node. Each power splitter performs a frequency splitting and combining function between the G.fast service being carried and the injected DC electrical power.

Within the remote node, if it operates with multiple power-fed lines then there shall be a power extraction and combiner unit. The purpose of this unit is to combine the multiple power feed inputs to produce a single power source output. The power load should be shared amongst the input power sources.

The technical specifications in the present document shall apply to each architecture described below as one of the two options shown in Table 1. The optional reverse power battery backup at the customer premises is illustrated in block BAT for each reference models in Figure 4 and Figure 5.

Table 1: Architecture Options for Reverse Power Feed Over Coax

Option	Name	Description
1	RPFA-CGO	Reverse Power Feed Architecture - Coax G.fast Only
2	RPFA-CGS	Reverse Power Feed Architecture - Coax G.fast with Satellite TV

5.2 Reverse Power Feed Coax Architecture - G.fast Only (RPFA-CGO)

The functional reference model of the reverse power feed coax architecture with G.fast only (RPFA-CGO) is shown in Figure 4 (single derived POTS port) and Figure 5 (single derived POTS port distributed over internal in-premises wiring). In each case, derived POTS (i.e. an ATA connected to the service gateway) is an option, shown as red dashed lines. The associated reference points are detailed in Table 2.

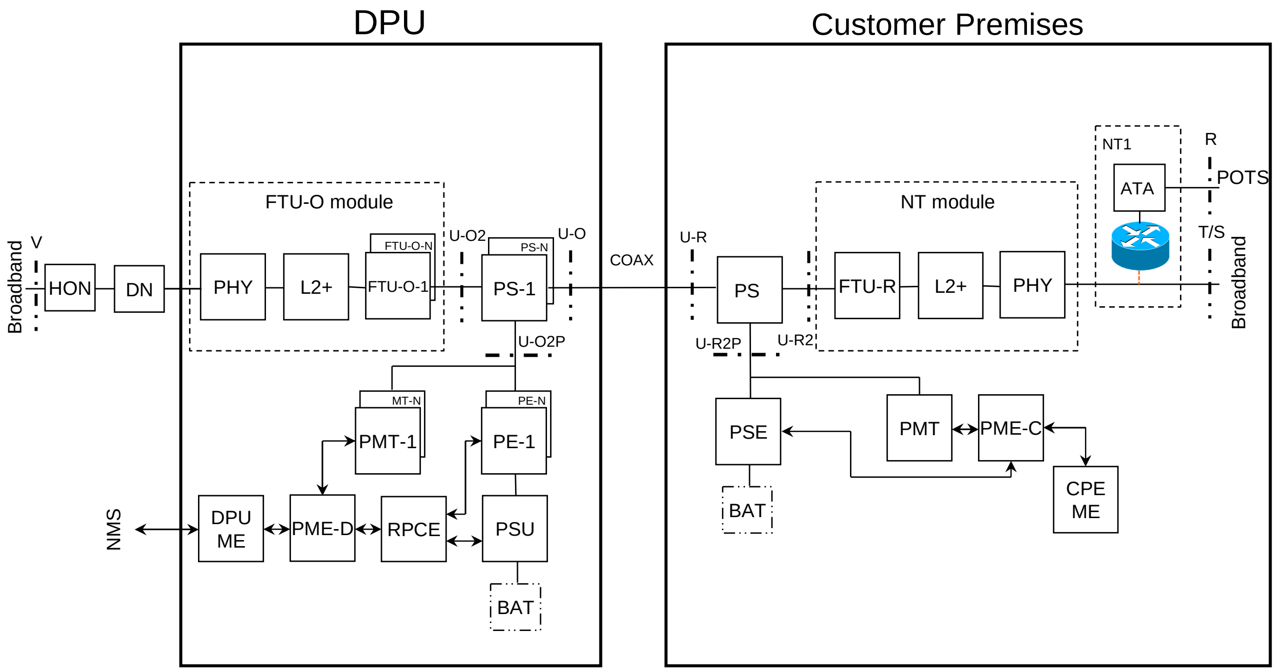

Figure 4: RPFA-CGO Reference Model with a single derived POTS port

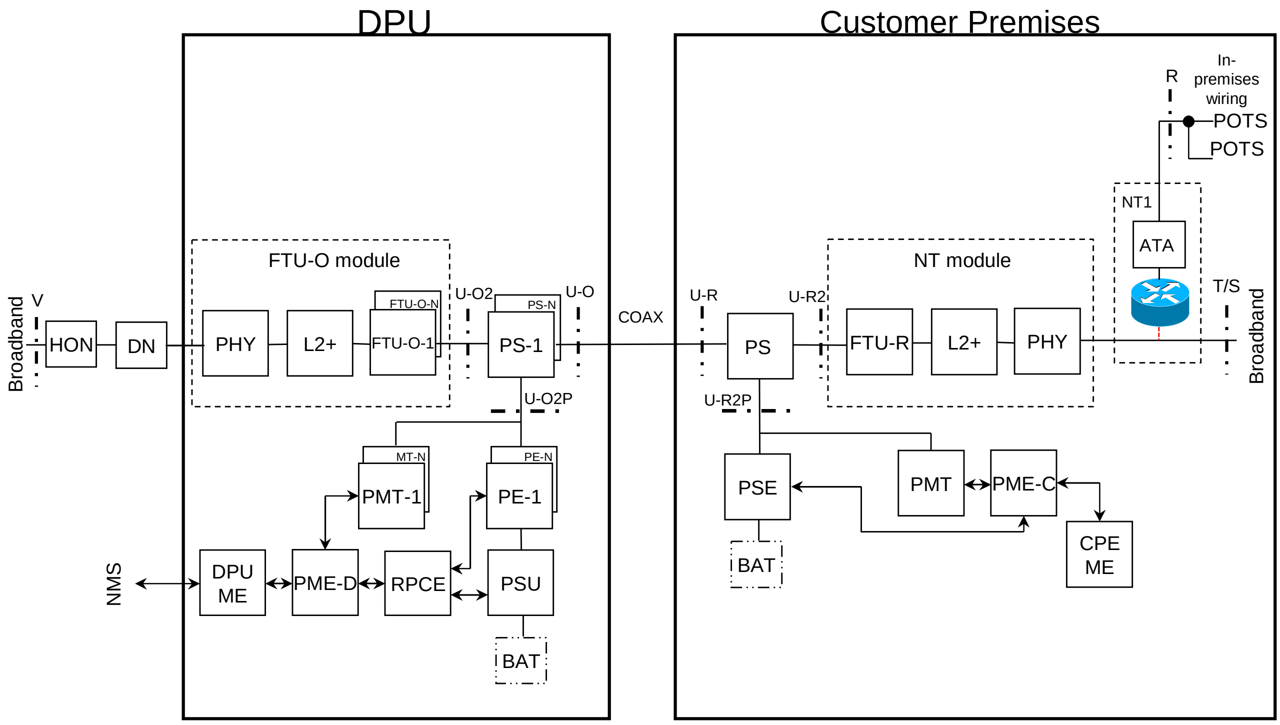

Figure 5: RPFA-CGO Reference Model with a derived POTS port distributed over In-premises wiring

Table 2: RPFA-CGO Reference Points

Reference Point	Broadband Signals	Reverse Power Feeding	Satellite TV Signals
U-O2	Yes	Yes	No
U-O2P	No	Yes	No
U-O/U-R	Yes	Yes	No
U-R2P	No	Yes	No
U-R2	Yes	No	No

Table 2 indicates whether the listed signals can be present at the various reference points.

5.3 Reverse Power Feed Coax Architecture with G.fast and Satellite TV (RPFA-CGS)

The functional reference model of the reverse power feed coax architecture together with G.fast and Satellite TV (RPFA-CGS) is shown in Figure 6 (single derived POTS port) and Figure 7 (single derived POTS port distributed over internal in-premises wiring). In each case, derived POTS (i.e. an ATA connected to the service gateway) is an option, shown as red dashed lines. The associated reference points are detailed in Table 3.

This architecture option does not cover scenarios where there is any signalling with DC components used between the Satellite receiver and the STB.

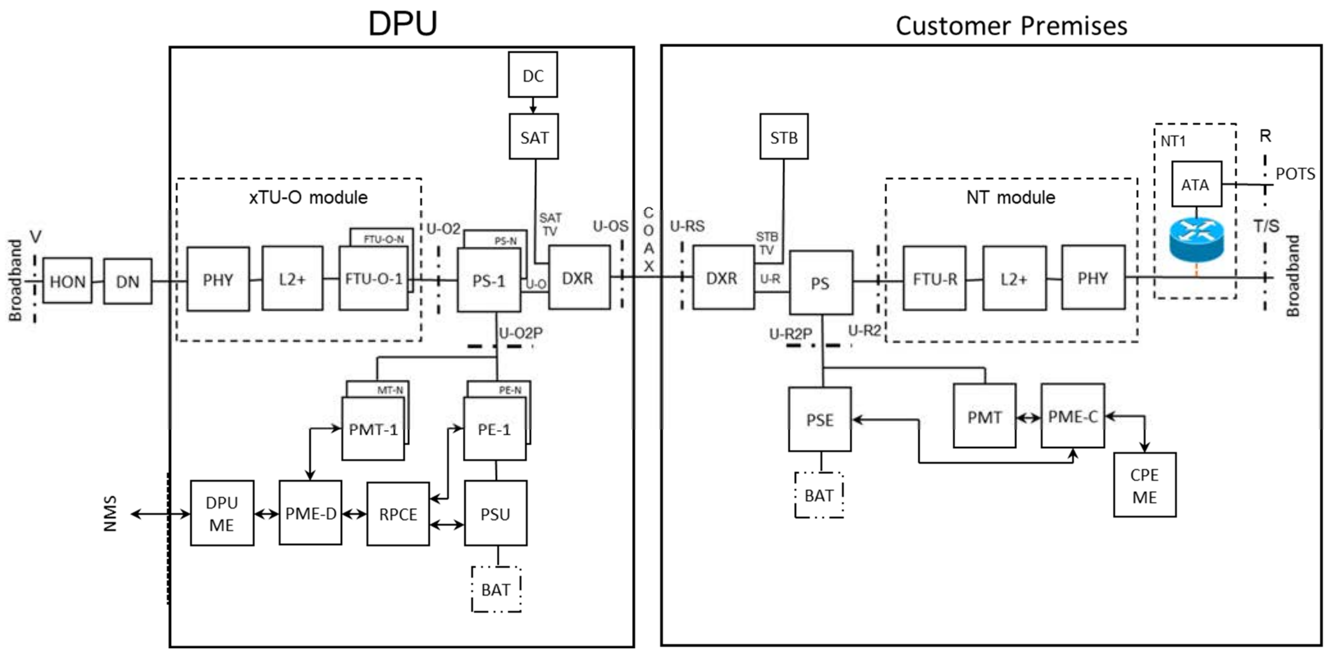

Figure 6: RPFA-CGS Reference Model with a single derived POTS port

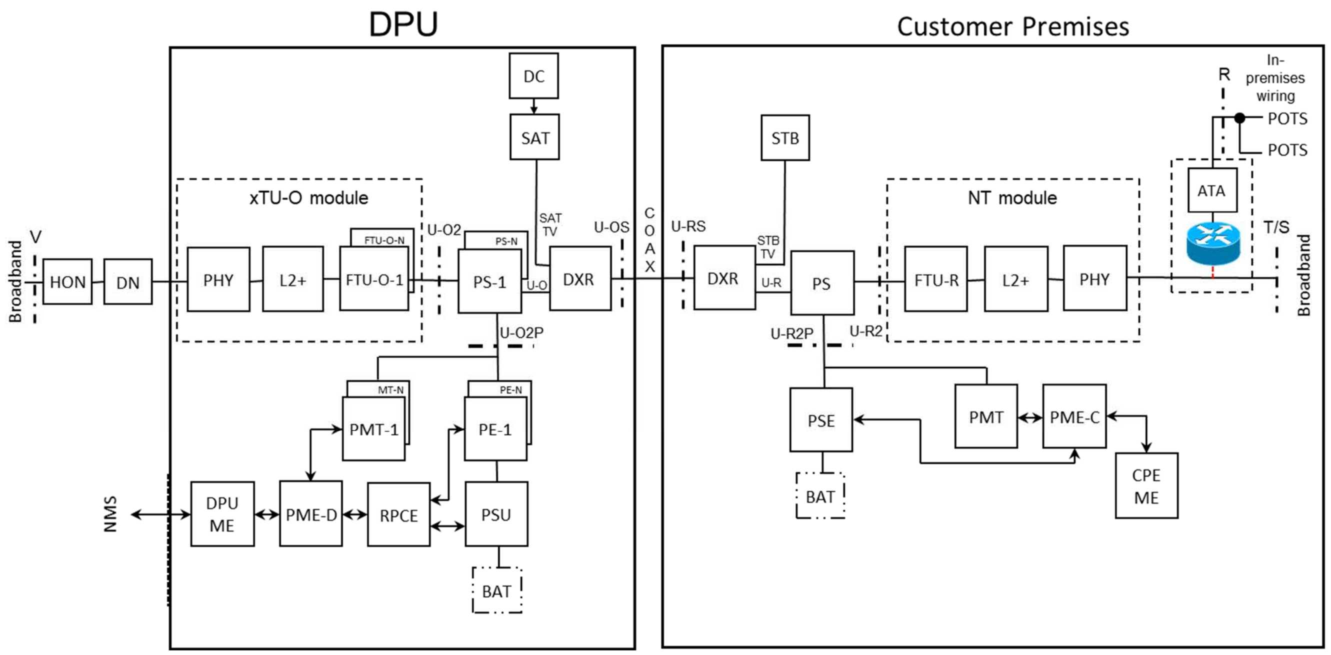

Figure 7: RPFA-CGS Reference Model with a derived POTS port distributed over In-premises wiring

Table 3: RPFA-CGS Reference Points

Reference Point	Broadband Signals	Reverse Power Feed	Satellite TV Signals
U-O2	Yes	Yes	No
U-O2P	No	Yes	No
U-OS/U-RS	Yes	Yes	Yes
U-O	Yes	Yes	No
U-R2P	No	Yes	No
U-R2	Yes	No	No
U-R	Yes	Yes	No
SAT TV	No	No	Yes
STB TV	No	No	Yes

Table 3 indicates whether the listed signals can be present at the various reference points.

6 Reverse Power Feed Start-Up Protocol

6.1 Introduction

6.1.1 General

As shown in clause 5, Reverse Power Feed of a G.fast DPU can be applied in conjunction with Satellite TV, in which case the MDU satellite amplifier is locally powered by a separate DC source.

The procedure defined below shall be followed to guarantee proper interaction between the elements of the RPF system (DPU - PSE - Diplexers). This procedure shall allow a proper start-up of RPF, and should cover all further states of the RPF system (start-up mode, normal operation, shut down, error conditions).

As opposed to RPF over twisted pair, a plain old telephone cannot be connected to a coax PSE, therefore off hook phone detection and a POTS Exchange (foreign) DC voltage detection are not requirements for the PSE. However, it is good practice to detect DC foreign voltages before applying DC power as the PSE shall not inject full power when a foreign voltage is present.

The following power source requirements apply (clause 8.2 of TR-301 [4]):

1) The PSE of a single active line shall be able to power its DPU in both mains-powered and battery-powered (when available) operation.

2) The PSE shall send a Dying Gasp indication to the DPU after it has lost both mains and battery power (if available) and before it removes power from the line.

3) The PSE shall remove power from a line upon the detection of a fault condition.

4) During normal operation, if any of these fault conditions occur, the PSE shall remove power and return to the start-up procedure:

   a) Presence of an open circuit.

   b) Presence of a short circuit.

5) In the case where the PSE detects a fault condition, the PSE shall not inject full power on the line.

6) The PSE shall verify that all of the following conditions are met, before injecting full power:

   a) Absence of an open circuit.

   b) Absence of a short circuit.

   c) Absence of a foreign DC voltage on the line.

e) Detection of a DPU that supports reverse powering.

f) Correct matching of the PSE RPF Class with the DPU RPF Class.

7) The PSE output voltage shall have a fixed polarity (see clause 7.3.3).

The equivalent network model of the above line related fault conditions (further referred to as the Error Line Conditions ELC 0 to ELC 2) is shown in Figure 8.

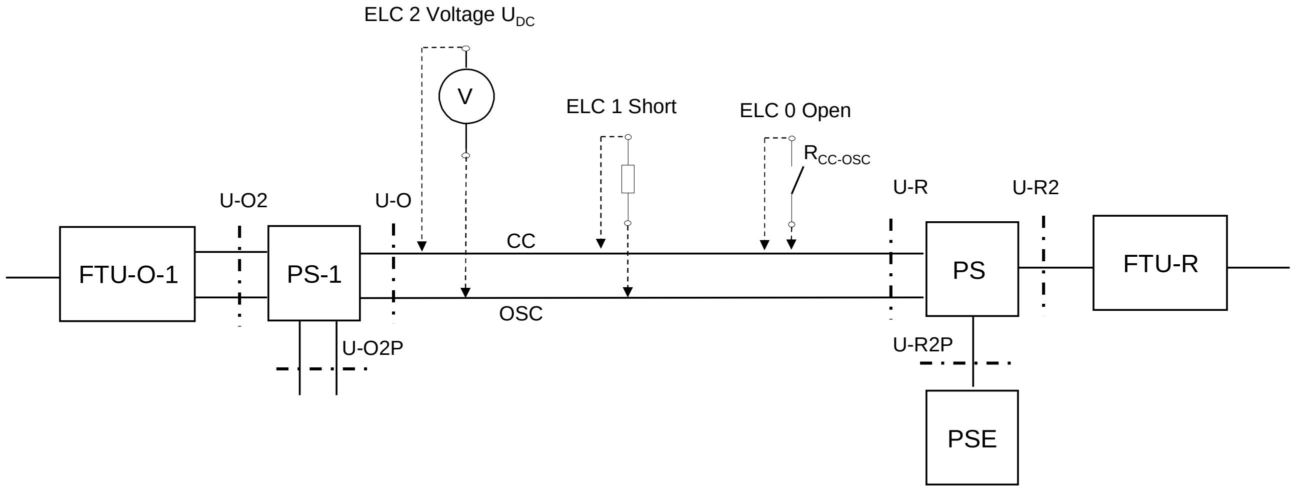

Figure 8: Illustration of an Error Line Conditions network model

The Error Line Condition parameters and detection criteria for the ELC network model are defined in Table 4.

Table 4: Error Line Condition Parameters and Detection Criteria

Error Line Condition	Description	Parameter	Detection Criteria
ELC 0	Open CC to OSC	R_{Emin} = 1 MΩ C_{Emax} = 100 nF	$R_{CC-OSC} \geq R_{Emin}$ for a duration exceeding 300 ms (see note) $C_{CC-OSC} \leq C_{Emax}$
ELC 1	Short CC to OSC	R_{Emax} = 140 Ω	$R_{CC-OSC} \leq R_{Emax}$
ELC 2	Foreign DC voltage	$U_{CC-OSCDCEmax}$ = 3 V	$\lvert U_{CC-OSCDC} \rvert \geq U_{CC-OSCDCEmax}$
NOTE: This duration is set such that the definition of ELC 0 does not overlap with the Maintain Power Signature definition as defined in Note 4 of Table 8.			

The RPF start-up protocol shall use the detection criteria listed in Table 4 to ensure detection of Error Line Conditions (ELCs).

NOTE 1: Any non-DC blocking 75 Ω termination should be replaced by DC blocking components or protected by the diplexer, otherwise the PSE will not start due to the Error Line Condition (ELC 1).

NOTE 2: Any surge protectors installed in the cable infrastructure with an operating voltage lower than VPSE as defined in Table 6, should be replaced with a component with an operating voltage exceeding this value.

6.2 Metallic Detection based Start-Up (MDSU) Protocol

The PSE and DPU shall implement the metallic detection based start-up (MDSU) protocol, as described in clause 6.2 of ETSI TS 101 548-1 [1], for the two architecture scenarios defined in clause 5, Table 1: "No Satellite TV" (RPFA-CGO) and "With Satellite TV" (RPFA-CGS). Whereby:

- "Tip" or "Tip wire" is replaced by "Core Conductor (CC)".
- "Ring" or "Ring wire" is replaced by "Outer Shield Conductor (OSC)".
- Detection of an off-hook phone at start-up or during normal operations is not required.

- Any reference to ELC 0, ELC 1 and ELC 2 of clause 6.2 of ETSI TS 101 548-1 [1] refer to ELC 0, ELC 1 and ELC 2 of Table 4.

The MDSU protocol is based on detection of a resistive signature located in the DPU, that is a 25 kΩ resistor R_{SIG} bridged across the Outer Shield Conductor and the Core Conductor of the coax cable. The detection signature is part of the functional block SIG, as shown in Figure 11 of ETSI TS 101 548-1 [1].

Voltage at the U-R and U-R2P interface supplied by the PSE during detection, classification and start-up shall have the same polarity as defined in clause 7.3.3.

6.3 RPF Dying Gasp and Indication Primitives

The PSE shall provide the RPF Dying Gasp and Indication Primitives DGL, BAT, ACM and BBA defined in clause 6.3 of ETSI TS 101 548-1 [1]. The RPF Dying Gasp and Indication Primitives shall either be sent to the DPU by using the RPF OAM channel or by the Embedded Pulse Signalling method, specified in clause 6.3 of ETSI TS 101 548-1 [1]. If RPF OAM is available, these primitives shall be sent using the RPF OAM channel instead of the Embedded Pulse Signalling method (see clause 6.3 of TS 101 548-1 [1]).

6.4 RPF Operations and Maintenance

This clause applies to the single box model only, where the PSE and CPE are integrated.

The purpose of RPF Operations and Maintenance (OAM) is to exchange the management information between the CPE ME and the DPU ME. The following shall be exchanged:

- the RPF Dying Gasp and Indication Primitives defined in clause 6.3;
- the parameters NTE-CPF, PSE-PC, RPF-IFN, PSE-IE defined in clause 6.4 of ETSI TS 101 548-1 [1]; and
- the parameter PSE-SUF, is defined in clause 6.4 of ETSI TS 101 548-1 [1]:
    - Definitions of ELC 0, ELC 1 and ECL 2 for the coax scenario are in Table 4.
    - ELC 3 used in ETSI TS 101 548-1 [1] is not applicable in the coax scenario.

The RPF OAM definition is out of scope for the present document.

7 Reverse Power Feed Characteristics

7.1 Safety Aspects

7.1.1 Background

Safety aspects of Reverse Power Feed is covered by EN 62368-1 [2]. Additionally, for the Reverse Power Feed Coax Architecture RPFA-CGS, EN 60728-11 [5] applies also, as the RPF system can be connected to a cable network used to distribute television signals. Requirements for powering from the subscriber premises over cable networks are defined in clause 8.2 of EN 60728-11 [5].

Note that as the RPF voltage exceeds 34 Vdc, EN 60728-11 [5] imposes restrictions on the accessibility of the RPF voltage. Furthermore, the RPF voltage exceeds the maximum allowed operation voltage for drop or subscriber cables for which the voltage rating is not specified by the manufacturer as defined in clause 8.1.3 of EN 60728-11 [5], therefore only cables with specified and sufficient voltage rating shall be used for RPF.

Reverse powering shall be capable of energizing a DPU by a single customer over a single coaxial cable between the customers' premises and that powered device. That cable, besides reverse (DC) powering may be also carrying DSL data, and Satellite TV.

In all cases for both architecture options (clauses 5.2 and 5.3) the coax cable has to be rated to carry the RPF voltage by the cable manufacturer.

7.2 RPF Range options and Classes

Reverse Powering over coaxial cable networks considers only the 60 V DC Short Range (SR) option, the Long Range option is not considered. Table 5 specifies three short range RPF classes, which includes the maximum power, DC voltage and the line current. These classes are similar to the Short Range Classes defined for Reverse Powering over Twisted Pair ETSI TS 101 548-1 [1].

Table 5: Short range reverse power feed class specifications

Parameter	RPF Class SR1 Safety Note (a)	RPF Class SR2 Safety Note (a)	RPF Class SR3 Safety Note (b)
EN 62368-1 [2] PSE and DPU Electrical energy source classification	ES1	ES1	ES1
EN 62368-1 [2] PSE Power Source classification	PS1	PS1	PS2
Maximum power injected at U-R2P interface by PSE with external power splitter Or Maximum power injected at U-R interface by PSE with internal power splitter	10 VA	15 VA	21 VA
Maximum DC Voltage between CC and OSC	60 V	60 V	60 V
EN 60728-11 [5] Maximum recommended current during normal operation Safety Note (c)	2 A	2 A	2 A
EN 60728-11 [5] Maximum recommended current during permanent short circuit Safety Note (c)	4 A	4 A	4 A
Minimum Reach Resistance supported by a DPU (see clause 7.3.2.1)	43 Ω	43 Ω	43 Ω
SAFETY NOTE (a): According to EN 62368-1 [2]: Neither an 'arcing PIS' (Potential Ignition Source) nor a 'resistive PIS' is considered to exist in a PS1 circuit because of the limits of the power source (< 15 W). No safeguard is thus required. In this RPF class a single-port DPU will not be subject to a power exceeding the PS1 limit, while a multi-port DPU can be subject to a total power (sum across the ports) exceeding the PS1 limit. **SAFETY NOTE (b):** According to EN 62368-1 [2]: A PS2 circuit (>15 W, but < 100 W) has a level of energy that might give rise to ignition (arcing and/or resistive PIS) and subsequently requires special safeguards. In this RPF class a single-port, a multi-port DPU and any device connected to the PSE, can be subjected to a total power exceeding the PS1 limit. **SAFETY NOTE (c):** According to EN 60728-11 [5]: Maximum allowed currents for coaxial cables with a typical diameter of 5 to 10 mm, during 'Normal Operation' and 'Permanent short-circuit respectively.			

NOTE: RPF noise limits: noise generated by RPF circuits can significantly impact the G.fast and Satellite TV service over the coax cable. Implementations of the PSE, diplexer and DPU circuits should give due attention to minimize the impact on the G.fast and Satellite TV service.

7.3 PSE and DPU PE electrical specification

7.3.1 PSE electrical specification

7.3.1.1 PSE electrical specification on interface U-R2P

Electrical specification of PSE on interface U-R2P will be the same for all architectural options. In the case where the PSE has an internal power splitter and the U-R2P is an internal interface, the electrical specifications of Table 6 apply to the U-R interface of the PSE.

Table 6: PSE electrical specification on interface U-R2P

Parameter	Symbol	Unit	Min	Max	Comments
Steady state output voltage	V_{PSE}	V	55,75	60	Typical 57 V. Total output voltage deviation, including initial set up, load/ line, temperature regulations is +5 %, -2,2 % Up to 60 V to allow for transient conditions. (See note 2.)
Continuous output current in Power_ON state for RPF Class SR1	I_{PSE_SR1}	mA	161	$P_{out\_SR1\text{-}MAX}/V_{PSE}$	See note 1.
Continuous output current in Power_ON state for RPF Class SR2	I_{PSE_SR2}	mA	241	$P_{out\_SR2\_MAX}/V_{PSE}$	See note 1.
Continuous output current in Power_ON state for RPF Class SR3	I_{PSE_SR3}	mA	336	P_{out_SR3MAX}/V_{PSE}	See note 1.
Continuous output power for Class SR1	P_{out_SR1}	W	8,98	10	$P_{out\_Sri\_min} = V_{PSE\_min} \times I_{PSE\_Sri\_min}$ $P_{out\_Sri\_max} = V_{PSE} \times I_{PSE\_Sri\_max}$ Where: i is SR class 1, 2, 3.
Continuous Output power for Class SR2	P_{out_SR2}	W	13,44	15	
Continuous Output power Class SR3	P_{out_SR3}	W	18,73	21	
Overload time limit	T_{CUT}	ms	50	75	See note 1.
Inrush current	I_{INRUSH}	mA		450	To allow start up transients measurement should be taken during power up and 1 ms after $V_{PSE} > 30$ V.

NOTE 1:

a) The PSE shall remain in Reverse Powering Mode state if I_{PSE_SRi} remains below $I_{PSE\_SRi,min}$, in absence of any fault condition.

b) The PSE shall remain in Reverse Powering Mode state, in absence of any fault condition (for example ELC 1) if I_{PSE_SRi} exceeds $I_{PSE\_SRi,min}$ or $I_{PSE\_SRi,max}$, but for no longer than T_{cut_min}.

c) If I_{PSE_SRi} exceeds $I_{PSE\_SRi,min}$ for longer than T_{cut_min}, the PSE may return to quiescent state; or it may remain in Reverse Powering Mode in absence of any fault condition.

d) If I_{PSE_SRi} exceeds $I_{PSE\_SRi,max}$ for longer than T_{cut_max}, the PSE shall return to quiescent state.

NOTE 2: Vpse is a PSE output voltage and is measured according to, paragraph 6.2.2 of EN 62368-1 [2].

The cumulative duration of $T_{cut,max}$ and $T_{cut,min}$ is measured with a sliding window of at least 1 000 ms but no longer than 1 500 ms. A graphical representation of this set of rules is shown in Figure 9.

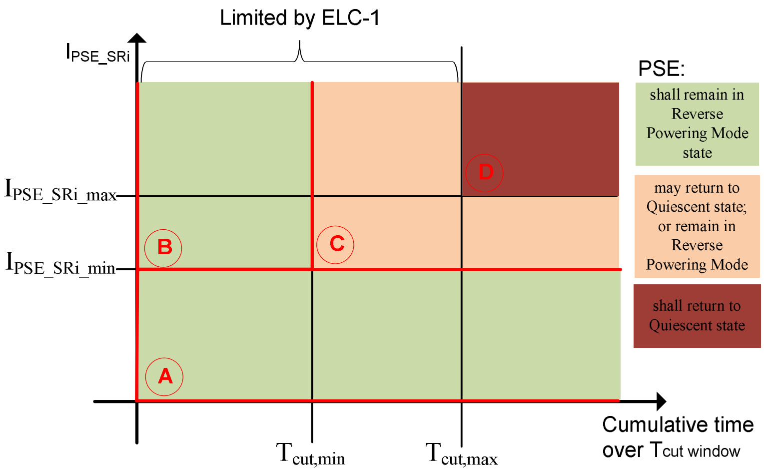

Figure 9: Graphical representation of note 2 in Table 6

7.3.1.2 Earthing Requirements at Customer Premises

To protect against hazardous voltage between the coaxial cable network and other accessible metal framework within Customer Premises the OSC of coaxial cables entering or leaving customer premise may be included in the equipotential bonding system of the building according to national regulations.

The equipotential bonding is preferably carried out directly at the entry point of coaxial cables to the building by means of an equipotential bonding conductor between the OSC and the Main Earthing Terminal (MET) of the building.

7.3.2 DPU electrical specification

7.3.2.1 Reach Resistance definition

The reach resistance of a DPU, $R_{reach,dpu,}$ is the maximum loop resistance, including all series elements, between the U-O and the U-R2P interface for PSE's with an external power splitter, and between the U-O and the U-R interface for PSEs with an internal power splitter, through which the DPU can be powered by any amount of users, including a single user, while providing service to all those users or the single user, without exceeding the maximum continuous input current for the RPF class in question for any user. R_{reach_dpu} shall be determined using the minimum continuous output current, $I_{PSE\_SRi,min}$ and the minimum steady state output voltage, $V_{PSE,min,}$ for the RPF class off the DPU.

Whereby, the Loop resistance, R_{loop}, is defined as the total DC resistance measured between the Outer Shield Conductor and Core Conductor at one reference point while shorting the other Outer Shield Conductor and Core Conductor at the other reference point:

- Loop resistance between U-O and U-RP2 is illustrated in Figure 10.
- Loop resistance between U-O and U-R is illustrated in Figure 11.

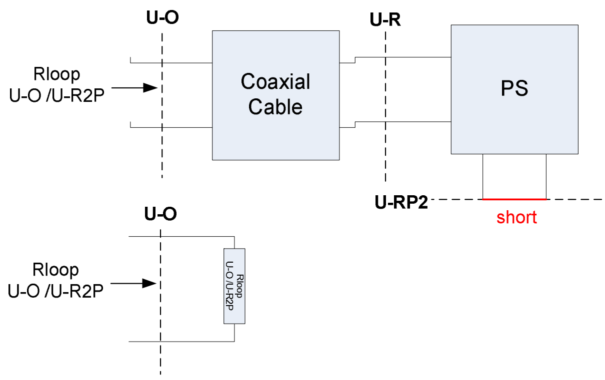

Figure 10: Loop resistance U-R2P to U-O interface

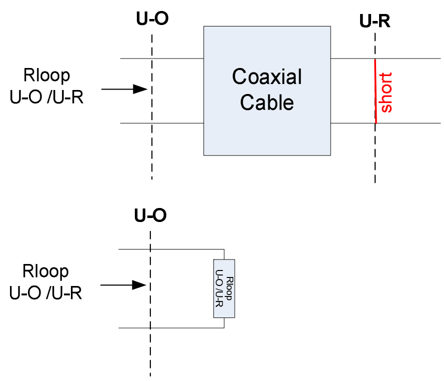

Figure 11: Loop resistance U-R to U-O interface

A DPU shall support a minimum reach resistance of 43 Ω as defined in Table 5, in order to be compliant to the present document. Any element, such as a copper cable, a connector, an over-current protector, a power splitter, etc. placed between the U-O and the U-R2P interface for PSEs with external power splitter, and between the U-O and the U-R interface for PSEs with internal power splitter, shall consume part of the reach resistance budget. In case an element cannot be modelled as a resistance, the equivalent loop resistance of the element shall be used, which shall be determined while a current equal to $I_{PSE,SRi,min}$, for i = 1,2,3, is flowing through the element in question.

Table 7 shows the supported loop length and loop resistance of a DPU with a reach resistance of 43 Ω for various, typical, coaxial cable types, in case a PSE with internal power splitter is used and the entire reach resistance is allocated to each cable type.

Table 7: Coaxial cable lengths for a loop resistance of 43 Ω

Cable Type	CC Type	OSC Type	Loop Resistance (Ω/m)	Equivalent Length (m)
RG-6	Bare copper	Copper	0,0236	1 822
	Bare copper covered steel	Aluminium	0,154	279
RG-59	Bare copper	Tinned copper	0,0361	1 191
	Bare copper covered steel	Aluminium	0,262	164

7.3.2.2 DPU electrical specification at U-O interface

Table 8 defines the DPU electrical specification at the U-O interface for RPFA-CGO and RPFA-CGS.

Table 8: DPU electrical specification at U-O interface for RPFA-CGO, and RPFA-CGS

Parameter	Symbol	Unit	Min	Max	Comments
Maximum continuous input current in Power_ON state for RPF Class SR1	I_{DPU_SR1}	mA	N/A	161	(See note 1)
Maximum continuous input current in Power_ON state for RPF Class SR2	I_{DPU_SR2}	mA	N/A	241	
Maximum continuous input current in Power_ON state for RPF Class SR3	I_{DPU_SR3}	mA	N/A	336	
Maximum available continuous input power for Class SR1	$P_{DPU\_UO\_SR1}$	W	N/A	7,861	Max available continuous DPU input power if loop resistance is 43 Ω, (see note 2)
Maximum available continuous input power for Class SR2	$P_{DPU\_UO\_SR2}$	W	N/A	10,938	
Maximum available continuous input power for Class SR3	$P_{DPU\_UO\_SR3}$	W	N/A	13,877	
Maintain power signature current	I_{DPU_MPS}	mA	10	N/A	(See note 4)
DPU current time derivative	dI/dt_{DPU_lmt}	mA/µs	N/A	1	(See note 5)

NOTE 1: The instantaneous input current at the U-O interface may exceed the maximum continuous input current at the U-O interface. However, the DPU shall guarantee that the instantaneous input current does not violate the PSE overload time limit as defined in Table 6.

NOTE 2: In essence the DPU may not exceed the maximum continuous input current in Power_ON state for the RPF class in question. The input power limitation is a mere consequence of the loop resistance and the RPF class.

NOTE 3: Electrical specifications of this table shall not apply to architectures which require POTS Adapters which might be powered by a PSE.

NOTE 4: In order to maintain power supply from a PSE, the DPU shall sink a dc current equal to or above the Maintain Power Signature current, I_{DPU_MPS}, for a minimum duration of at least 75 ms with a repetition period of maximum 325 ms, e.g. when a PSE is operating on battery power and the DSL is in a low power link state.

NOTE 5: In order to prevent false ELC 3 detections by a PSE, while it is reverse powering a port of a DPU the following applies to any port of a DPU, reverse powered by a PSE: In absence of fault conditions the time derivative of the current at the U-O interface, d(IDPU_UO)/dt, shall be below dI/dtDPU_lmt. If d(IDPU_UO)/dt exceeds dI/dtDPU_lmt, the DPU shall sink a current lower than 25 mA for at least 4 ms, immediately or up to 1 ms later after violation of dI/dtDPU_lmt, The diagram below illustrates these timing aspects. Under these conditions and in absence of any fault condition, the PSE shall continue to supply reverse power to the port in question of the DPU. Remark that at any given time the DPU shall not violate the PSE overload time limit as defined in Table 6. A d(IDPU_UO)/dt greater than zero means an instantaneous power demand increase of a port of DPU. 25 mA is lower than the minimum current an off-hook phone will sink, if it is exposed to a voltage of at least VPSE,min, according to the off-hook phone (ELC 3) model.

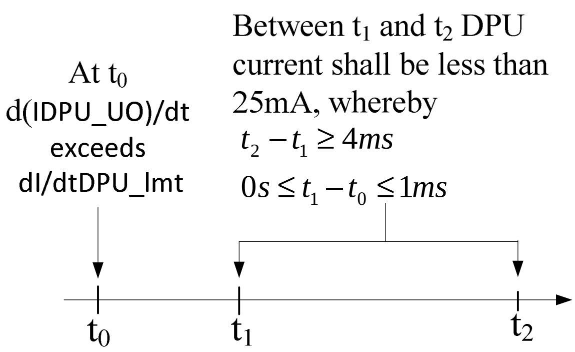

Figure 12

7.3.3 Polarity requirements

The PSE output voltage at the U-R/U-RG and U-R2P shall have a fixed polarity. The CC at U-R,/U-RG and U-R2P interfaces shall be the negative terminal, the OSC at U-R/U-RG and U-R2P interface shall be the positive terminal.

The DPU input voltage at the U-O interface shall have a fixed polarity. The CC at U-O interfaces shall be the negative terminal, the OSC at the U-O interface shall be the positive terminal. Applying a voltage up to 60 V with the opposite polarity shall not damage the DPU, however normal operation is not required.

The embedded pulse signalling method, as defined in clause 6.3 of ETSI TS 101 548-1 [1], may result in voltages of a negative polarity appearing at the U-O interface, this shall not impair normal operation of the DPU.

7.3.4 DPU earthing requirements

7.3.4.0 DPU earthing alternatives

The present document does not list any requirements on the earthing of the OSC at the U-O interface. Clauses 7.3.4.1 through 7.3.4.3 provide different earthing strategies for a DPU port, each with their own advantages and caveats. The earthing strategy can impact the total current through an OSC of a port, this current shall not exceed EN 60728-11 [5] Maximum recommended current during normal operation, listed in Table 5.

Note that some country regulations impose that the OSC of coaxial cables are bonded to earth, either within or external to the equipment. Furthermore, if the OSC is isolated from earth it may be subjected to transient voltages, refer to EN 62368-1 [2] for more information.

7.3.4.1 OSCs bonded together and to earth

A DPU may bond the OSCs of each port together and to earth at the U-O interface. This may result in ground or stray current between the DPU earthing point and the different Customer Premise earthing points. Ground potential differences between these different earthing points may result in additional current through the OSC, on top of the RPF current. Additionally, it is possible that OSC of a single port of a DPU carries more RPF current than what a single PSE can provide. Care shall be taken to ensure that the total current through the OSC of any port does not exceed the EN 60728-11 [5] Maximum recommended current during normal operation, listed in Table 5.

7.3.4.2 OSCs bonded together and isolated from earth

A DPU may bond the OSCs of each port together and isolate all OSCs from earth at the U-O interface. The DC resistance between OSC and earth should exceed 2 MΩ, measured with test voltages of 60 Vdc and -60 Vdc. This ensures that no ground or stray current can flow between the DPU earthing point and the Customer Premise earthing Points. However, ground potential differences between each of the earthing points of the PSEs can result in additional current through the OSC. Additionally, as multiple OSCs are bonded together, is it possible that the OSC of a port carries more RPF current than a single PSE can provide, therefore it is recommended to restrict the total current consumption, across all ports of the DPU to below the EN 60728-11 [5] Maximum recommended current during normal operation, listed in Table 5.

7.3.4.3 OSCs isolated from each other and isolated from earth

A multi-port DPU may provide port-to-port and port-to-earth isolation. The DC resistance between the OSC and CC of any two ports at the U-O interface, should exceed 2 MΩ, measured with test voltages of 60 Vdc and -60 Vdc, whereby the OSC and CC are shorted per port. This earthing strategy ensures that no ground or stray currents can flow between the DPU and Customer Premise earthing points.

7.4 Micro-interruption requirements

7.4.1 PSE micro-interruption requirements

The PSE shall comply to clause 7.6.1 of ETSI TS 101 548-1 [1].

7.4.2 DPU micro-interruption specification

The DPU shall comply to clause 7.6.2 of ETSI TS 101 548-1 [1].

8 Power Splitter Characteristics

8.1 General

The DPU and the CPE power splitters shall have a high impedance at the frequencies used by the G.fast to minimize the impact on the data transmission performance.

Figure 13 and Figure 14 show the internal structure of the CPE power splitter and DPU power splitter respectively, for the RPFA-CGO and RPFA-CGS architecture options. Figure 13 and Figure 14 illustrate the case of a standalone power splitter and may not directly represent an integrated solution.

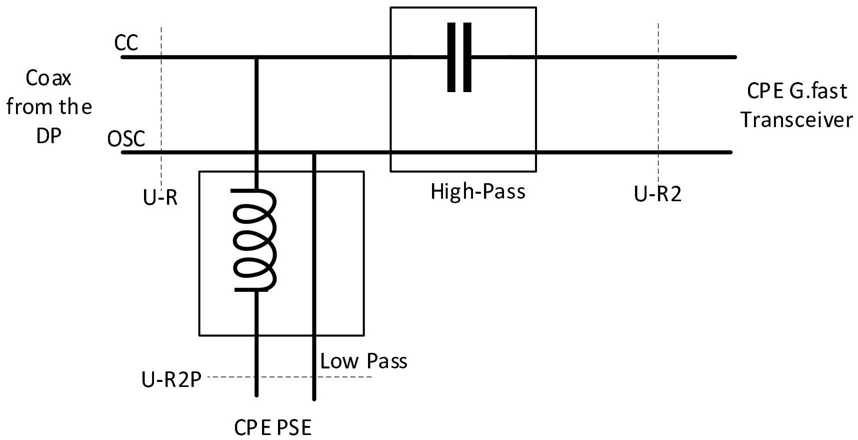

Figure 13: CPE Power Splitter for RPFA-CGO and RPFA-CGS

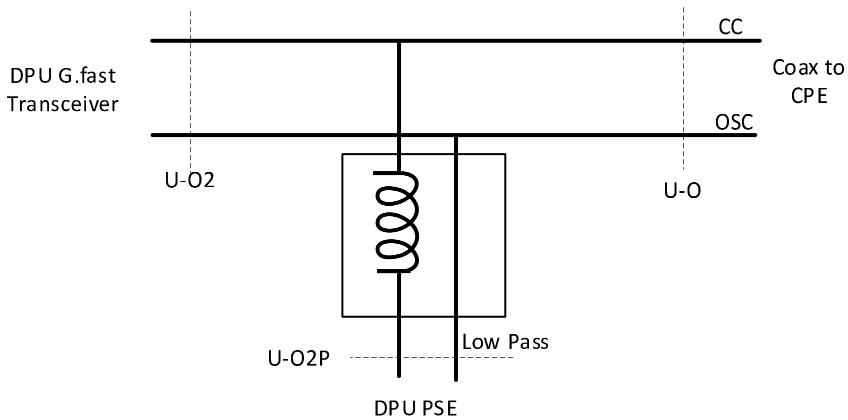

Figure 14: DPU Power Splitter for RPFA-CGO and RPFA-CGS

The power splitters need to comply with the following requirements to maintain a good performance of the reverse power feed function:

- The DPU power splitter shall have a low voltage drop such as to minimize the power loss when extracting the reverse power feed from the loop.
- The CPE power splitter shall have a low voltage drop such as to minimize the power loss when injecting the reverse power feed onto the loop.

8.2 Power Splitter class definition

Table 9 defines a set of Power Splitter (PS) classes to guarantee compatibility with broadband access services between the U-O2 and U-R2 interface, through the U-O and U-R interface.

All AC electrical specifications for power splitters, as defined in clause 8.3, for the paths from the U-O2 to the U-O interface, from the U-O to the U-O2 interface, from the U-R2 to the U-R interface and from U-R to the U-R2 interface, shall be applicable between $f_{min,ps}$ and $f_{max,ps}$.

Table 9: Power Splitter Class Definitions

Class	$f_{min,ps}$	$f_{max,ps}$	Compatible with service between U-O2 and U-R2 interface	Reverse Power Feed Architectures
Class GO	2 MHz	106 MHz	G.fast 106 MHz profile (106c)	RPFA-CGO RPFA-CGS
Class GO+	2 MHz	212 MHz	G.fast 212 MHz profile (212c)	RPFA-CGO RPFA-CGS

8.3 Power Splitter Requirements

8.3.1 General

The requirements in this clause are applicable to power splitters and need to be complied with in order to ensure correct operation of RPF and DSL services. It is recognized that where the power splitter is integrated into a DPU or CPE that it will not be feasible to test to all requirements in the complete system, however all requirements should be met in the design of the power splitter.

8.3.2 DSL Insertion Loss

Table 10 defines the DSL Insertion losses for the DPU and CPE power splitter. The DPU power splitter DSL insertion loss is measured by comparing the DSL signal level at the U-O interface with and without the DPU power splitter inserted between the U-O2, U-O2P and U-O interfaces.

The CPE power splitter DSL insertion loss is measured by comparing the DSL signal level at the U-R2 interface with and without the CPE power splitter inserted between the U-R2, U-R2P and U-R interfaces.

The DSL insertion loss shall be measured with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

NOTE: Implementations should give due attention to minimize the insertions loss variation over the entire power range, i.e. from minimum to maximum power delivery.

Table 10: DSL Insertion Loss

Frequency Band	Signal Level	DPU PS	CPE PS
$f_{min,ps}$ to 30 MHz	2,1 V peak between CC and OSC (see note)	±0,5 dB	±0,5 dB
30 MHz to $f_{max,ps}$	2,1 V peak between CC and OSC (see note)	±1 dB	±1 dB
NOTE: +2 dBm into 75 Ω with peak-to-rms voltage ratio = 6.			

8.3.3 DSL Impedance Conversion

The DPU power splitter DSL impedance conversion is measured by performing a 2-wire return loss measurement at the U-O2 interface with the DPU power splitter inserted between the U-O2, U-O2P and U-O interfaces and with a reference 75 Ω load connected to the U-O interface.

The CPE power splitter DSL impedance conversion is measured by performing a 2-wire return loss measurement at the U-R interface with the CPE power splitter inserted between the U-R, U-R2P and U-R2 interfaces and with a reference 75 Ω load connected to the U-R2 interface.

The DSL impedance conversion shall be measured with active reverse power feed delivering minimum and maximum power to the U-R and U-O2P interfaces.

Table 11 defines the impedance conversion requirements for the DPU and CPE Power Splitter.

Table 11: Impedance Conversion

Frequency Band	Signal Level	DPU PS	CPE PS
$f_{min,ps}$ to 30 MHz	2,1 V peak between CC and OSC (see note)	> 20 dB	> 20 dB
30 MHz to $f_{max,ps}$	2,1 V peak between CC and OSC (see note)	> 14 dB	> 14 dB
NOTE: +2 dBm into 75 Ω with peak-to-rms voltage ratio = 6.			

8.3.4 DSL-Band Noise Attenuation

The required DSL-band noise attenuation of the power splitter is a function of the DSL-band noise produced by the Reverse Power feed, for details refer to clause 7.2.

8.3.5 DSL Port DC Isolation Resistance

The CPE power splitter shall provide DC isolation on the DSL port. The DC isolation is measured on the U-R interface between CC and OSC when shorting OSC and CC at the U-R2P interface and leaving the U-R2P open-circuit. The DSL port isolation resistance requirements are defined in Table 12.

Table 12: DSL Port Isolation Resistance

Measurement Voltage	CPE PS
250 V	> 1 MΩ

8.3.6 Passband Metallic Connection

To accommodate power transfer from the PSE towards the DPU the DPU PS shall provide a metallic connection between:

- the OSC at the U-O interface and the OSC at the U-O2P interface; and
- the CC at the U-O interface and the CC at the U-O2P interface.

The PSE PS shall provide a metallic connection between:

- the OSC at the U-R interface and the OSC at the U-R2P interface; and
- the CC at the U-R interface and the CC at the U-R2P interface.

NOTE: Implementations should give due attention to minimize the DC resistance of said metallic connections. As these consume part of the reach resistance budget of the DPU.

8.3.7 Pass band DC isolation

The PSE and DPU power splitter shall have minimal impact on the MDSU protocol and the embedded pulse signalling between the PSE and DPU. Therefore, the DC isolation resistance between CC and OSC at the U-R interface and the DC isolation resistance between CC and OSC at the U-O interface, shall exceed the value listed in Table 13.

Table 13: Passband DC isolation

Measurement Voltage	Resistance
100 V	1 MΩ

9 RPF diplexer requirements

9.1 General

Architecture option RFPA-CGS requires a diplexer at the CP and DP side, to merge the satellite TV signals onto the same coax as used for the reverse power feed and G.fast signals. A comprehensive set of requirements for this diplexer is not provided in the present document, refer to TR-285 [3] for further requirements. Furthermore, it is assumed that any signalling between the set top box and satellite TV equipment is properly shielded from the Reverse Power Feed by diplexer. No additional requirements are imposed on DPU or PSE power splitters, compliancy to the requirements listed in clause 8 is assumed to be sufficient. Figure 15 shows a black box representation of the diplexer at the DP and CP side.

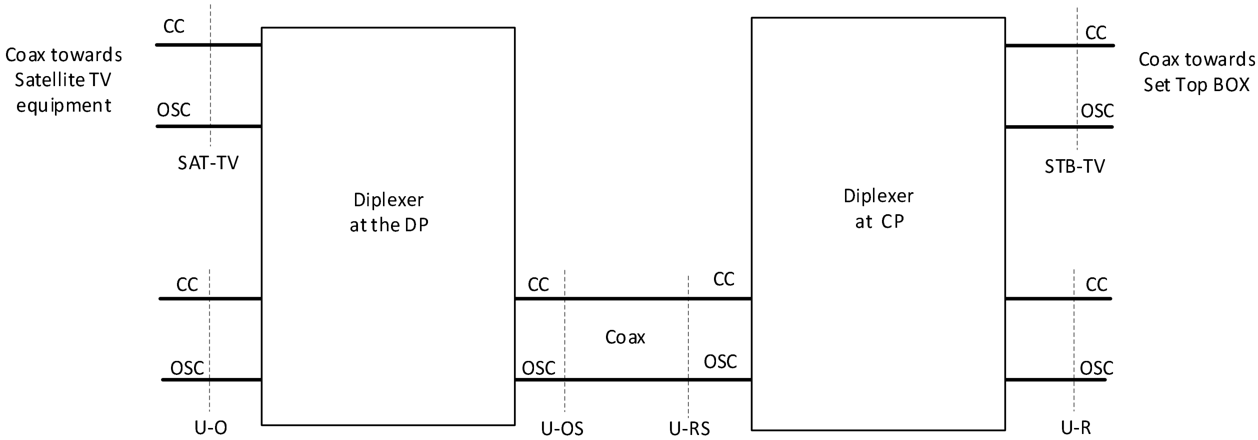

Figure 15: Diplexer at the CP and DP side

9.2 Reverse power feed to Satellite TV DC isolation resistance

The diplexer shall provide DC isolation between:

- the CC of the SAT-TV interface and CC of the U-O interface; and
- the CC of the SAT-TV interface and CC of the U-OS interface; and
- the CC of the STB-TV interface and CC of the U-R interface; and
- the CC of the STB-TV interface and CC of the U-RS interface.

The DC isolation between any two CCs shall be measured while the remaining CC is left open. The DC isolation shall exceed the resistance listed in Table 14.

Table 14: Diplexer Isolation Resistance

Measurement Voltage	Resistance
250 V	1 MΩ

9.3 Reverse Power Feed Passband

9.3.1 Passband Metallic Connection

To accommodate power transfer from the PSE towards the DPU the diplexer at the DP side shall provide a metallic connection between:

- the OSC at the U-O interface and the OSC at the U-OS interface; and

- the CC at the U-O interface and the CC at the U-OS interface.

The diplexer at the CP side shall provide a metallic connection between:

- the OSC at the U-R interface and the OSC at the U-RS interface; and
- the CC at the U-R interface and the CC at the U-RS interface.

NOTE: Implementations should give due attention to minimize the DC resistance of said metallic connections. As these consume part of the reach resistance budget of the DPU.

9.3.2 Pass band DC isolation

The diplexer at the DP and CP side shall not impact the MDSU protocol and the embedded pulse signalling between the PSE and DPU. Therefore, the DC isolation resistance between CC and OSC at the U-OS, U-O, U-RS and U-R interfaces, shall exceed the value listed in Table 15, while SAT-TV and STB-TV port are terminated with 75 Ω.

Table 15: Passband DC isolation

Measurement Voltage	Resistance
100 V	1 MΩ

Annex A (informative): Change History

Version	Information about changes
V1.1.1	First Version

History

Document history		
V1.1.1	June 2021	Publication