Technical Report

Committee T1 - Telecommunications

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Single-Carrier Rate Adaptive Digital Subscriber Line (RADSL)

Prepared by T1E1.4 Working Group on Digital Subscriber Line (DSL) Access

Alliance for Telecommunications Industry Solutions

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Document T1E1.4/99-161R3
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Foreword

This technical report (TR) describes the physical layer of the Rate Adaptive Asymmetrical Digital Subscriber Line (RADSL)[1] interface to metallic loops. The report should be of interest and benefit to system implementers, network providers, service providers and customers using Internet, voice, data and video services.

This technical report describes the interfacing of RADSL transmission units at the remote end (ATU-R) and at the central office end (ATU-C) and the transport capability of both units. A single twisted pair of telephone wires is used to connect the ATU-C to the ATU-R. RADSL systems operate over a variety of twisted wire pairs and in the presence of typical impairments (e.g., crosstalk and noise).

This technical report documents the work performed by the T1E1.4 RADSL Ad Hoc Group and no further work on this subject in T1E1 is expected. Some aspects of this TR are common with ANSI T1.413. ANSI T1.413 is the ANSI Standard for ADSL. However, this TR is not intended to provide interoperability with T1.413.

Suggestions for improvements of this Technical Report would be welcomed. They should be sent to the Alliance for Telecommunications Industries Solutions, 1200 G Street, NW, Suite 500 Washington, DC 20005.

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[1] The acronym RADSL is commonly used to refer to both asymmetric and symmetric rate-adaptive digital subscriber lines.

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1. Scope and Purpose

1.1 Scope

This technical report describes the interface between the telecommunication network and the customer installation in terms of their interaction and electrical characteristics using single-carrier modulation. The recommendations in this document apply to a Rate Adaptive Digital Subscriber Line (RADSL) system, which include Physical Media Dependent (PMD) sub-layer and Physical Transmission Convergence (PTC) sub-layer, and interfaces to higher layer entities.

Transmission from the network to the customer premises is referred to as the downstream channel and supports line rates up to approximately 8 Mbit/s. Transmission from the customer premises to the network is referred to as the upstream channel and supports line rates up to approximately 1 Mbit/s. Both the downstream and upstream channels are frequency division multiplexed (FDM) above the voice band analog channel.

The transmission system is designed to operate on single twisted metallic cable pairs with mixed gauges. The system is based on the use of cables without loading coils, but bridged taps are acceptable with the exception of unusual situations.

1.2 Purpose

This technical report permits network providers an expanded use of existing copper facilities for the support of rate adaptive data applications and multimedia services. Physical medium dependent (PMD) sub-layer aspects, physical transmission convergence (PTC) sub-layer methods, and maintenance functions are described for both network equipment and equipment at the remote location.

Specifically, this document

- describes the transmission technique used to support the simultaneous transport of POTS and the upstream and downstream channels of the rate adaptive digital signals on a single twisted pair;
- describes the line modulation and the spectral composition of signals transmitted by both RADSL Transceiver Unit at the Central office (ATU-C) and that at the remote location (ATU-R);
- describes the receive signals at both the ATU-R and ATU-C;
- describes electrical and mechanical specifications of a network interface;
- describes a common logical interface to the ATM-TC, Packet-TC, Bit-Synchronous-TC and EOC-TC sublayers;
- describes operation and maintenance communications over an Embedded Operations Channel (EOC);
- describes the exchange of information sequences during start-up to establish system configuration and transmission link; and
- describes performance objectives and test procedures.

2. References

ITU-T (CCITT) Recommendation V.32 (1988), *A Family of 2-Wire, Duplex Modems Operating at Data Signaling Rates of up to 9600 Bit/S for Use on the General Switched Telephone Network and on Leased Telephone-Type Circuits*

ANSI T1.231-1997, *American National Standard for Telecommunications - Digital Hierarchy - Layer 1 In-Service Digital Transmission Performance Monitoring*

ANSI T1.401-1993, *American National Standard for Telecommunications - Interface between Carriers and Customer Installations - Analog Voice-Grade Switched Access Lines Using Loop-Start and Ground-Start Signaling*

ANSI T1.413-1995, *American National Standard for Telecommunications - Network and Customer Installation Interfaces - Asymmetric Digital Subscriber Line (ADSL) Metallic Interface*

ANSI T1.413-1998, *American National Standard for Telecommunications – Network and Customer Installation Interfaces – Asymmetric Digital Subscriber Line (ADSL) Metallic Interface*

ANSI/EIA/TIA-571-1991, *Environmental Considerations for Telephone Terminals*

ANSI/EIA RS-422A-1978, *Electrical Characteristics of Balanced Voltage Digital Interface Circuits*

Y. Chen, G. H. Im, and J. J. Werner, "Design of Digital Carrierless AM/PM Transceivers," AT&T Contribution T1E1.4/92-149, August 19, 1992

R.L. Cupo, et al., "Combined Trellis Coding and DFE Through Tomlinson Precoding," *IEEE Journal on Selected Areas in Communications*, Vol. 9, No. 6, August 1991

ANSI T1.601-1992, *American National Standard for Telecommunications* - *Integrated Services Digital Network (ISDN) Basic Access Interface for Use on Metallic Loops for Application on the Network Side of the NT (Layer 1 Specification)*

IEEE Standard 455-1985, *Test Procedures for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band*

T1 Technical Report No. 28, February 1994, *High-Bit-Rate Digital Subscriber Lines (HDSL)*

Bellcore Technical Advisory TA-NWT-001210, *Generic Requirements for High-Bit-Rate Digital Subscriber Lines*

ADSL Line MIB, Working Text DRAFT document WT-015-RevB, June 1997

ISO 3309-1979, "HDLC frame structure"

RFC1662, "PPP in HDLC-like Framing," July 1994

RFC1700, "Assigned Numbers," October 1994

ITU-T *Draft New Recommendation G.994.1 – Handshake Procedure for Digital Subscriber Line (DSL) Transceivers*, approved by SG15, June 1999

3. Definitions, Abbreviations, Symbols and Acronyms

3.1 Definitions

Aggregate data rate	The data rate transmitted by a RADSL system in any one direction. It includes both net data rate and data rate overhead used by the system for CRC, EOC, synchronization of the various data streams, and fixed indicator bits for OAM. It includes FEC redundancy.
Bridge(d) Taps	Sections of un-terminated twisted-pair wire connected in parallel across the wire pair under consideration.
Class 1	Single Upstream and Downstream Channel.
Class 2	Single Upstream and Downstream Channel with the addition of a low speed symmetric bit sync channel (Isochronous channel) for the support of certain delay applications sensitive to variations in delay.
CSA loops	A set of loops within the CSA defined by T1 Technical Report No. 28 (1994).
Downstream	ATU-C to ATU-R direction (network to customer direction).
Loading coils	Inductors placed in series with the cable at regular intervals in order to improve the voice band response; removed for DSL use.
Net data rate	The total data rate that is available to user data in any one direction.
POTS splitter	A low-pass/high-pass pair of filters that separate high (RADSL) and low (POTS) frequency line signals.
Splitter	A low-pass/high-pass pair of filters that separate high (RADSL) and low (POTS) frequency signals.
Upstream	ATU-R to ATU-C direction (customer to network direction).
Voice band	The 0.3 to 3.4 kHz frequency band, based on Bellcore local switching systems generic requirement (LSSGR) and transmission system generic requirement (TSGR) specifications.

3.2 Abbreviations, symbols and acronyms

⊕	Exclusive-or; modulo-2 addition
AAL1	ATM Adaptation Layer 1
ADSL	Asymmetric digital subscriber line
AGC	Automatic Gain Control
AIS	Alarm Indication Signal
AM	Amplitude modulation
ANSI	American National Standards Institute
AOC	ADSL Overhead Control Channel
ATM	Asynchronous Transfer Mode
ATU	ADSL/RADSL Transceiver Unit
ATU-C	ADSL/RADSL Transceiver unit, central office end
ATU-R	ADSL/RADSL Transceiver unit, remote terminal end
BB	Broadband
BC	Byte Count
BER	Bit error ratio
BERT	Bit error ratio test
bps or bits/s	Bits per second
CAP	Carrierless Amplitude and Phase modulation
CBR	Constant Bit Rate
CI	Customer Installation
CLP	Cell Loss Priority
CO	Central Office
CPE	Customer Premise Equipment
CRC	Cyclic Redundancy Check
CSA	Carrier Serving Area
dBm	dB reference to 1 milliWatt, i.e., 0 dBm = 1 milliWatt
DCM	Direct Cell Mapping
DPM	Direct Packet Mapping
DS	Downstream
DSL	Digital Subscriber Line
EDC	Error Detection Code
EOC	Embedded Operations Channel
ERL	Echo-Return Loss, as defined by IEEE Std 743-1984
ES	Errored Second
FAW	Frame Alignment Word
FDM	Frequency-division multiplexing
FEBE	Far-End Block Error

FEC	Forward Error Correction
FERF	Far-End Receiver Error
FEXT	Far-end crosstalk
FM	Frequency Modulation
GF	Galois field
GFC	Generic Function Code
HDSL	High-bit-rate Digital Subscriber Line
HEC	Header Error Check
ID code	Vendor identification code
ISDN	Integrated services digital network
ITU	International Telecommunication Union
kbit/s	Kilobits per second
kbps	Kilobits per second
LOCD	Loss-of-Cell Delineation
LOF	Loss of frame
LOM	Loss of Maintenance cells
LOS	Loss of signal
LSB	Least Significant Bit
Mbit/s	Megabits per second
Mbps	Megabits per second
MBS	Monitored Block Size
MSB	Most significant bit
MSB	Most Significant Byte
MSE	Mean squared error
NB	Narrowband
NEXT	Near-end crosstalk
NI	Network interface
NIC	Number of Included Cells
NMB	Number of Monitored Blocks
NT	Network termination
OA&M	Operations, Administration, and Maintenance
OAM	Operations, Administration and Maintenance
OSI	Open systems interconnection (7 layer model)
PDN	Premises Distribution Network
PL-OAM	Physical Layer - OAM
PMD	Physical Media Dependent
POTS	Plain Old Telephone Service (also known as message telecommunications service, MTS); services using the voice band

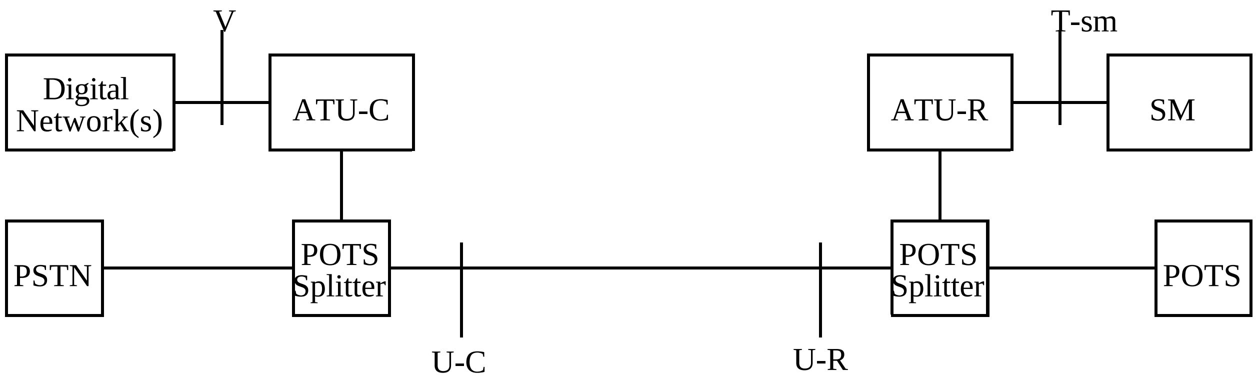
PRBS	Pseudo-random bit sequence
PSD	Power Spectral Density
PSN	PL-OAM Sequence Number
PSTN	Public Switched Telephone Network
PTC	Physical Transmission Convergence sub-layer
PTI	Payload Type Indicator
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RADSL	Rate-Adaptive Asymmetrical Digital Subscriber Line
RDI	Remote defect indication
RFI	Remote failure indication
RS	Reed-Solomon
RT	Remote Terminal
RX	Receive/receiver
RXD-DS	Received data, downstream
RX-DS-EOC	Receive downstream EOC
RX-DS-F	Receive Downstream Fast stream
RX-DS-I	Receive Downstream Interleaved stream
RXD-US	Received data, upstream
RX-US-EOC	Receive upstream EOC
RX-US-F	Receive Upstream Fast stream
RX-US-I	Receive Upstream Interleaved stream
S/P	Serial-to-Parallel
SER	Symbol error ratio
SES	Severely Errored Second
SM	Service Module
SNR	Signal-to-Noise Ratio
SONET	Synchronous Optical Network
SRL high	SRL in a band from approximately 2200 to 3400 Hz
SRL low	SRL in a band from approximately 260 to 500 Hz
SRL	Singing Return Loss, as defined by IEEE Std 743-1984
SSS	Self-Synchronizing Scrambler
STM	Synchronous Transfer Mode
T	Interface(s) between ATU-R and CI or home network)
TBD	To be determined
TC	Transmission Convergence sublayer
TP	Transmission Path
T-SM	Interface(s) between ATU-R and SM(s)

T-SM, T-sm	Interface(s) between ATU-R and SM(s)
TX	Transmit/transmitter
TXD-DS	Transmitted data, downstream
TX-DS-EOC	Transmit downstream EOC
TX-DS-F	Transmit Downstream Fast stream
TX-DS-I	Transmit Downstream Interleaved stream
TXD-US	Transmitted data, upstream
TX-US-EOC	Transmit upstream EOC
TX-US-F	Transmit Upstream Fast stream
TX-US-I	Transmit Upstream Interleaved stream
U-C	Loop Interface – Central Office end
U-R	Loop Interface – Remote Terminal end
US	Upstream
UTC	Unable to comply
V	Logical interface between ATU-C and a digital network element such as one or more switching systems
VCI	Virtual Channel Identifier
VPI	Virtual Path Identifier
X	The logical interface between ATU-C and the POTS splitter

4. Reference Models

4.1 System Reference Model

The system reference model shown in Figure 1 illustrates the physical blocks required to provide RADSL service.



NOTES:
1. The V interface is defined in terms of logical functions, not physical functions.
2. The V interface may consist of interface(s) to one or more switches.
3 Implementation of the V and T-sm interfaces is optional when interfacing elements are integrated into a common element.
4. The splitter function, or a portion thereof, may be integrated within the ATU.
5. A digital carrier facility (e.g., SONET) may be interposed at the V interface when the ATU-C is located at a remote site.
6. More than one type of T-sm interface may be defined, and more than one type of T-sm interface might be provided from an ATU-R.

Figure 1 - RADSL Functional Reference Model

4.2 General RADSL Transceiver System Model

Figure 2 shows the layering structure used to describe the functionality of the ATU-R and ATU-C. The PMD sub-layer defines the functionality associated with modulation and demodulation of the line signal. The PTC sub-layer provides framing, channelization, and forward error correction. The higher entity TC sub-layers (ATM-TC, Packet TC, Bit synchronous TC, and EOC TC) interface the corresponding higher layer protocols to the physical layer.

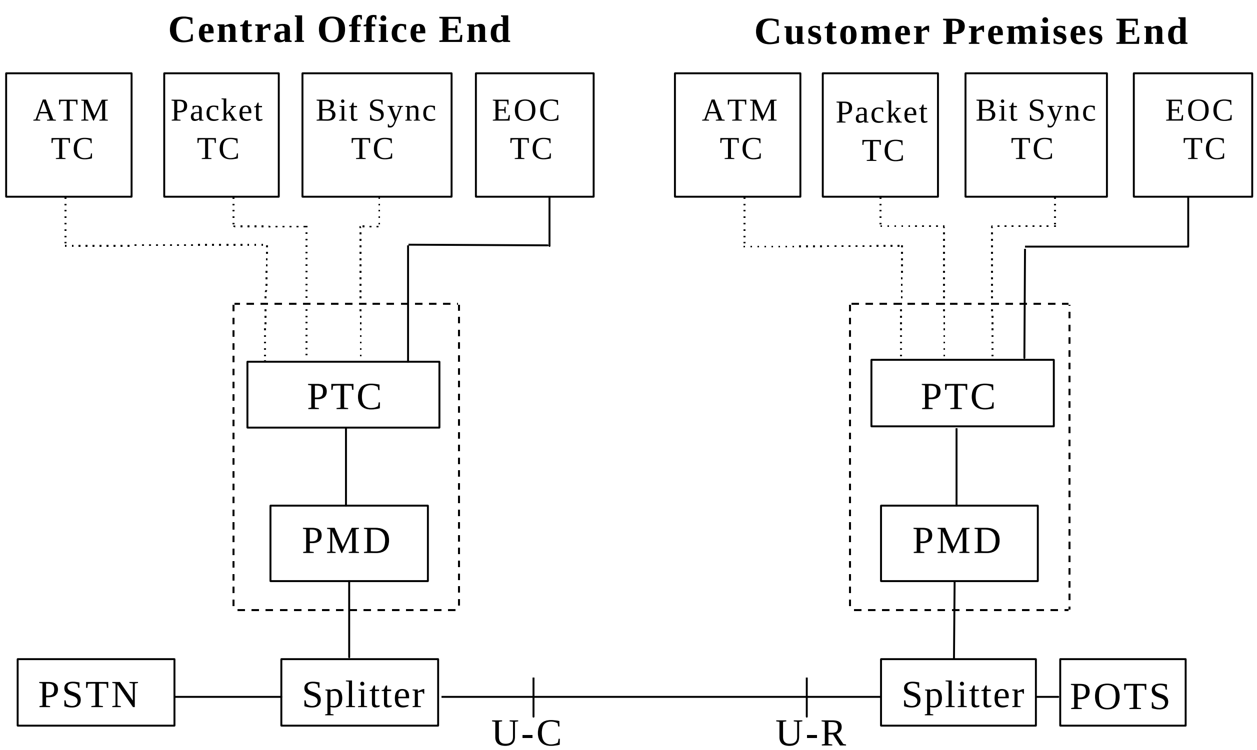


Figure 2 - RADSL Single-Carrier System Functional Model

4.3 Service Class Definition

Two classes of service are defined for RADSL transport.

Class 1 service is defined as the transport of a single channel upstream and a single channel downstream. Relative to the PTC interface shown in the system model of Figure 2, the data channel contains either an ATM- or packet-based payload. This data channel is not sensitive to system latency.

Class 2 service is defined as the transport of a single data channel (ATM-based or packet-based) along with a bit synchronous channel (e.g. an embedded 160 kb/s ISDN channel) in both the upstream and downstream directions. This bit synchronous channel is sensitive to system latency, so any forward error correction in the PTC layer is bypassed. Support of Class 2 service is optional.

In both classes, an embedded operations channel (EOC) is provided.

5. Single-Carrier RADSL Physical Layer Descriptions

This chapter describes the modem's specifications for the PMD and PTC layers of Single-Carrier RADSL.

5.1 System Model

The following block diagrams further describe a RADSL system in more detail. Figure 3 depicts a Single-Carrier RADSL system from an Input/Output Stream Format. Subsequent figures provide increasing levels of detail.

5.1.1 Single-Carrier RADSL System Block Diagram and Input/Output Stream Format

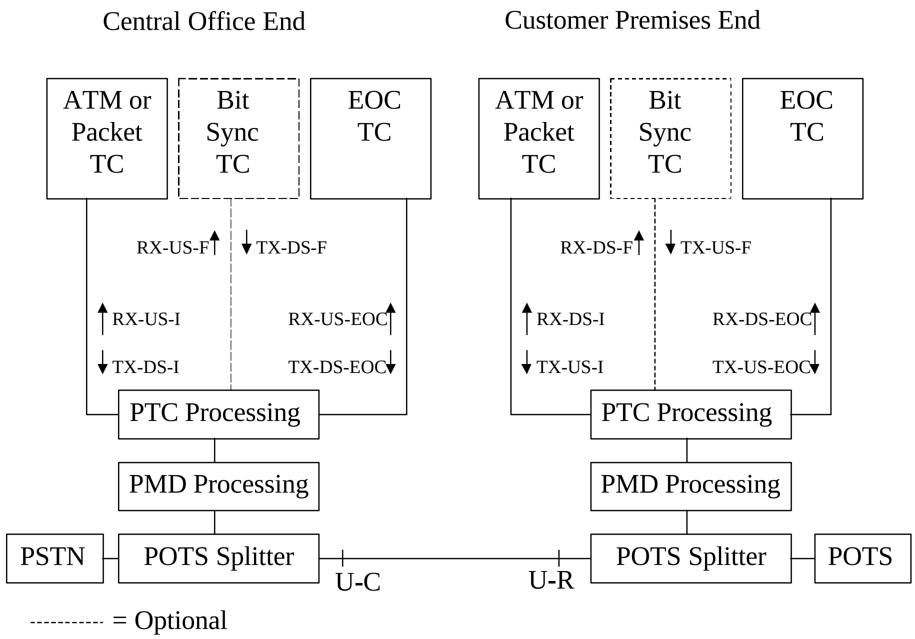


Figure 3 - Single-Carrier RADSL System Block Diagram and Input/Output Stream Format

5.1.2 Functional Transmitter Reference Model

A Single-Carrier RADSL system can be based on CAP (Carrierless Phase and Amplitude Modulation) and/or QAM (Quadrature Amplitude Modulation) single-carrier modulation techniques. This technical report describes the functionality needed to implement an ATU-R that supports both single-carrier modulations (dual-mode) and an ATU-C that supports either single-carrier modulation (single mode), as depicted in Figure 5. Note that it is anticipated that a Central Office will implement either CAP or QAM in its ATU-Cs. As depicted in Figure 5, there is a single interface between the Central Office and the Customer location.

Regardless of the specific single-carrier modulation technique, a Single-Carrier RADSL transmitter implements common functionality as depicted below in Figure 4. A profile map of transmitter functionality is provided in Figure 6 to describe the functions to be provided in the ATU-R. Either the Profile A – CAP-Based System in Figure 7 or Profile B – QAM-Based System in Figure 8 may be implemented in the ATU-C.

5.1.2.1 Common

The reference model below describes the functions that are common to a Single-Carrier RADSL transmitter regardless of the specific underlying single-carrier modulation technique.

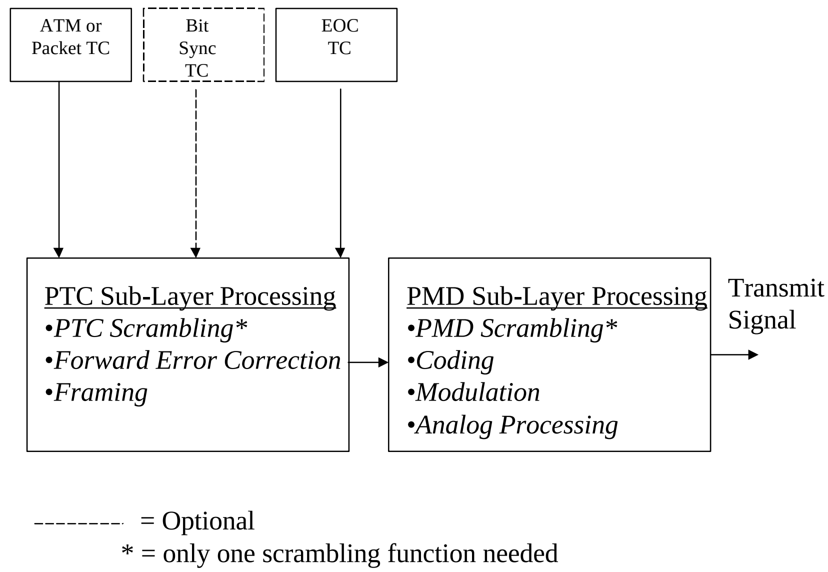


Figure 4 - Functional Transmitter Reference Model

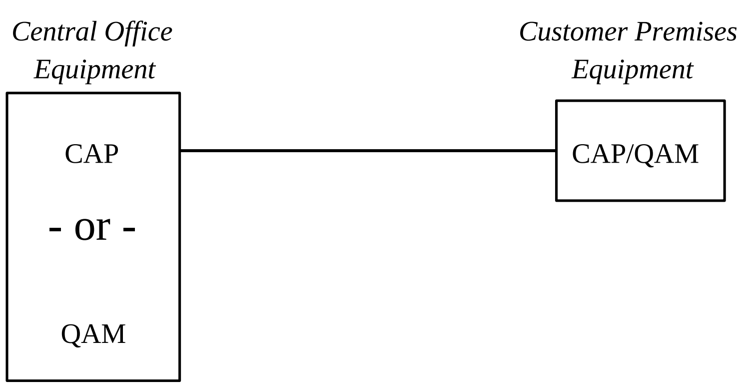


Figure 5 - Reference Model

5.1.2.2 Profile Map of Transmitter Functionality

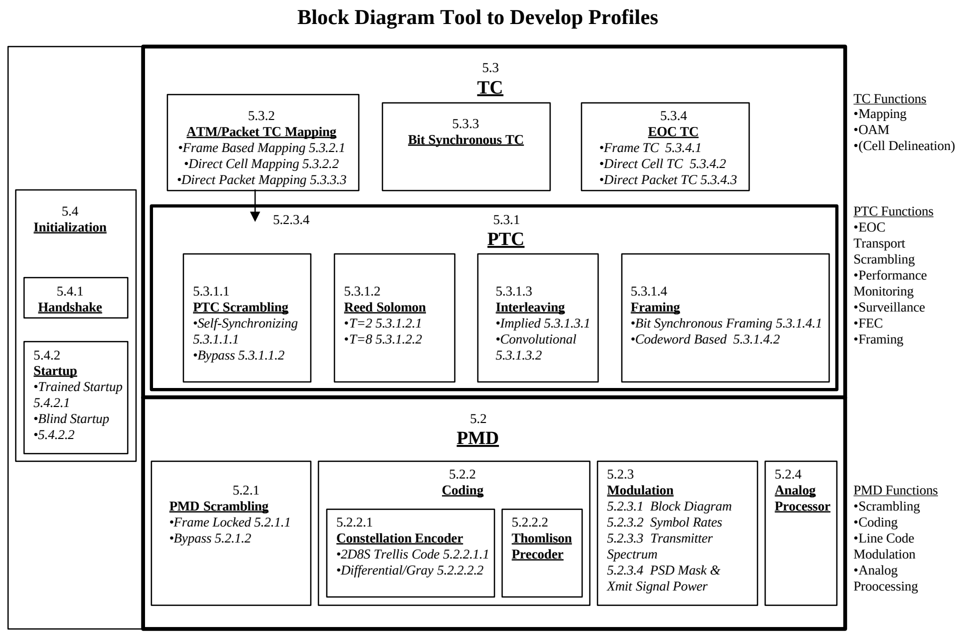


Figure 6 - Block Diagram Tool to Develop Profiles

5.1.2.3 Profiles

This section depicts two profiles – i.e., “highlighted” examples of the above Block Diagram. The first is Profile A, which shows the relevant sections and functional components of a CAP-based system highlighted in **bold**. The second is Profile B, which shows the relevant sections and functional components of a QAM-based system highlighted in **bold**.

Profile A - CAP-Based System

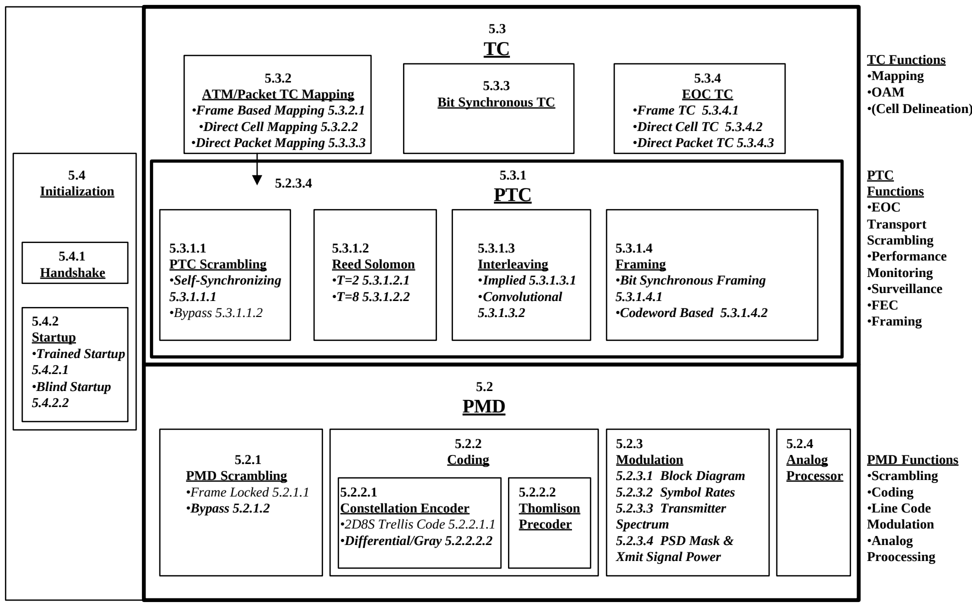


Figure 7 - Profile A – CAP-Based System

Profile B - QAM-Based System

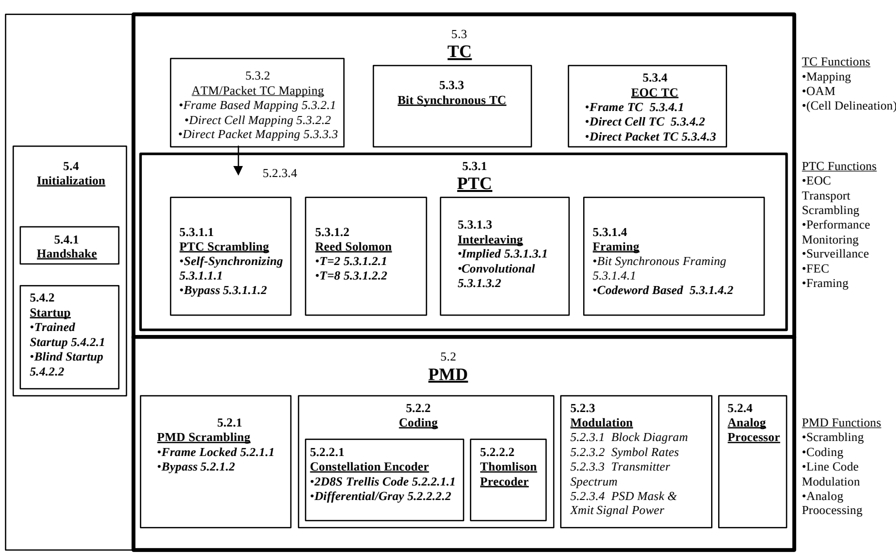


Figure 8 – Profile B – QAM-Based System

5.2 Physical Medium Dependent (PMD) Sublayer

The purpose of the PMD sub-layer is to modulate the serial bit stream output by the TC sub-layer for transmission across the twisted pair channel. This section describes the associated functionality.

PMD functions include scrambling, coding, line code modulation and analog processing.

5.2.1 PMD Scrambling

PMD scrambling may be performed per the frame locked method described below or PTC Scrambling may be performed per the self-synchronizing method described in section 5.3.1.1.1.

5.2.1.1 Frame Locked

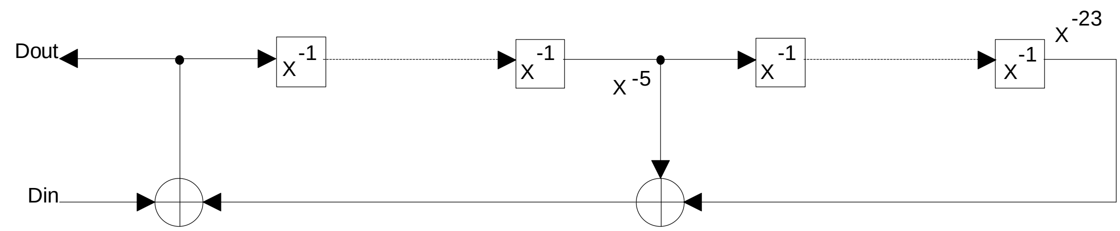
The frame locked scrambler/descrambler, included in each transceiver, will be different in the two directions of transmission. The generating polynomials are as follows:

(1) Customer premises transceiver (ATU-R) = $1 \oplus x^{-18} \oplus x^{-23}$

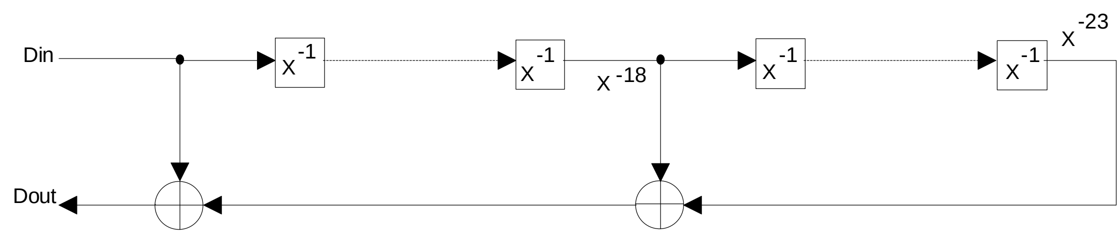
(2) Exchange transceiver (ATU-C) = $1 \oplus x^{-5} \oplus x^{-23}$

The scramblers and descramblers are shown in Figure 9 as they operate during start-up: the self-synchronizing mode. At the transmitter, the scrambler will effectively divide (modulo 2) the bits sequence by the generating polynomial. The coefficients of the quotients of this division, taken in descending order, form the data sequence that appears at the output of the data scrambler. At the receiver, the received bit sequence will be multiplied (modulo 2) by the polynomial to recover the original bit stream.

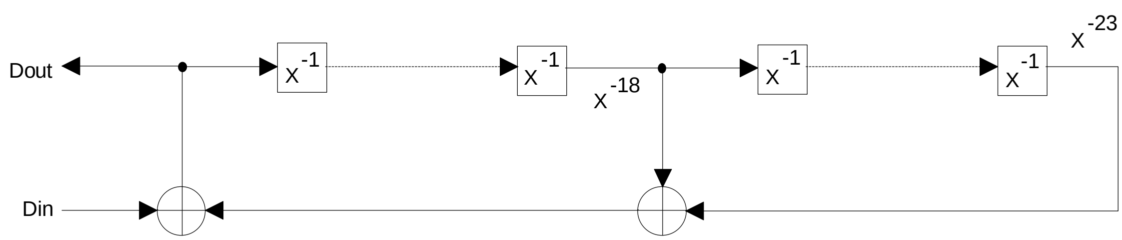
During data transfer, the scramblers are locked and the scrambled sequence is added (modulo 2) at the transmitter and subtracted (modulo 2) at the receiver as indicated in Figure 10. The transfer from the self-synchronizing mode to the locked mode occurs with the transmit data being all 1's. The transfer to locked mode does not require synchronization of the transfer at the two ends.



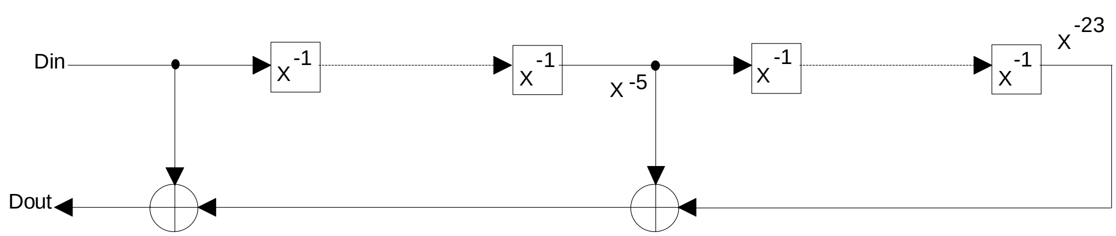
(a) ATU-C Transmit Scrambler



(b) ATU-C Receive Descrambler

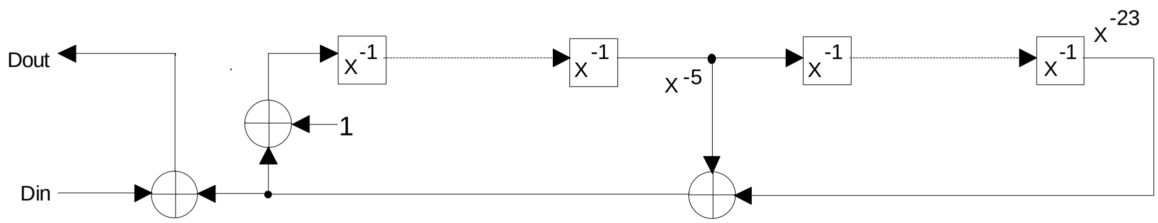


(c) ATU-R Transmit Scrambler

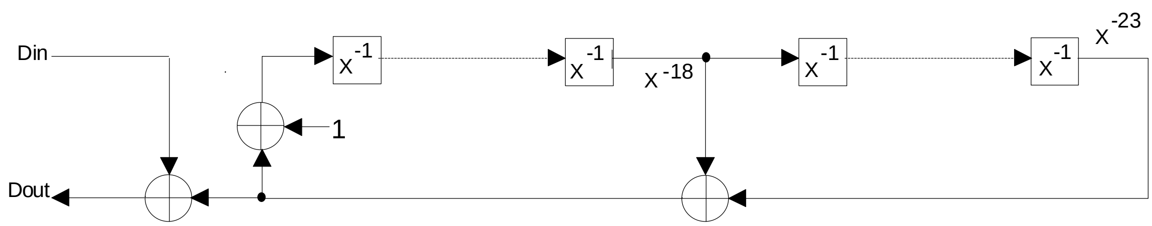


(d) ATU-R Receive Descrambler

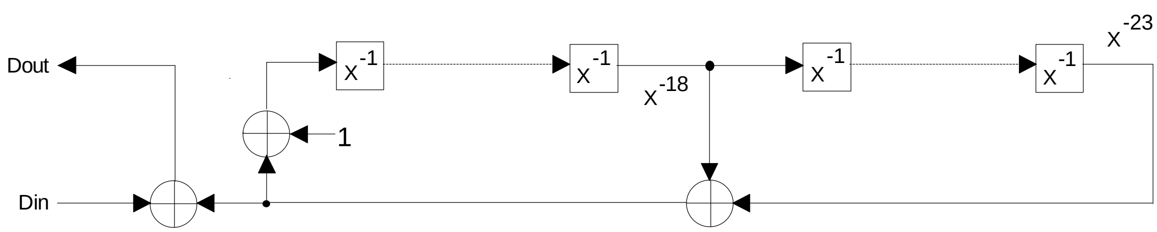
Figure 9 - Frame Locked Scrambler/Descrambler During Start-up Mode



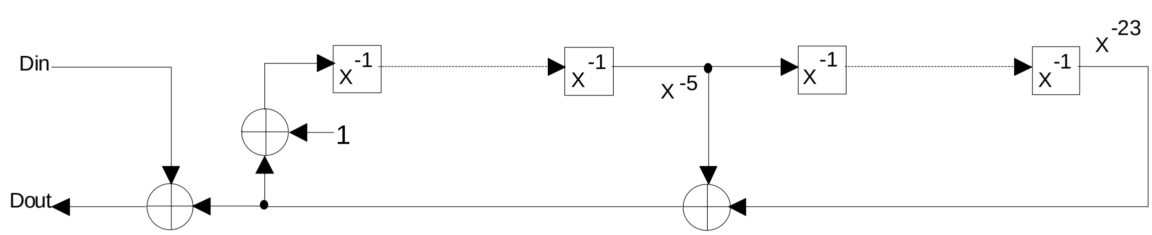
(a) ATU-C Transmit Scrambler



(b) ATU-C Receive Descrambler



(c) ATU-R Transmit Scrambler



(d) ATU-R Receive Descrambler

Figure 10 - Frame Locked Scrambler/Descrambler During Data Mode

5.2.1.2 Bypass PMD Scrambling

PMD scrambling may be bypassed as in Profile B.

5.2.2 Coding

PMD coding may include a constellation encoding function and a *Tomlinson* precoder.

5.2.2.1 Constellation Encoder

There are two methods of constellation encoding, 2-dimensional 8-state (2D8S) Trellis and Differential/Gray.

5.2.2.1.1 2D8S Trellis Code

The 2-dimensional 8-state trellis encoder shown in Figure 11 will be used during data mode, regardless of the number of points in the signal constellation. This trellis code uses the same convolutional encoder as that defined in ITU Recommendation V.32. The trellis is shown in Figure 12. Figure 13 shows the 8-point, 32-point, and 128-point constellations during data mode, while Figure 14 shows the 16-point, 64-point, and 256-point constellations during data mode.

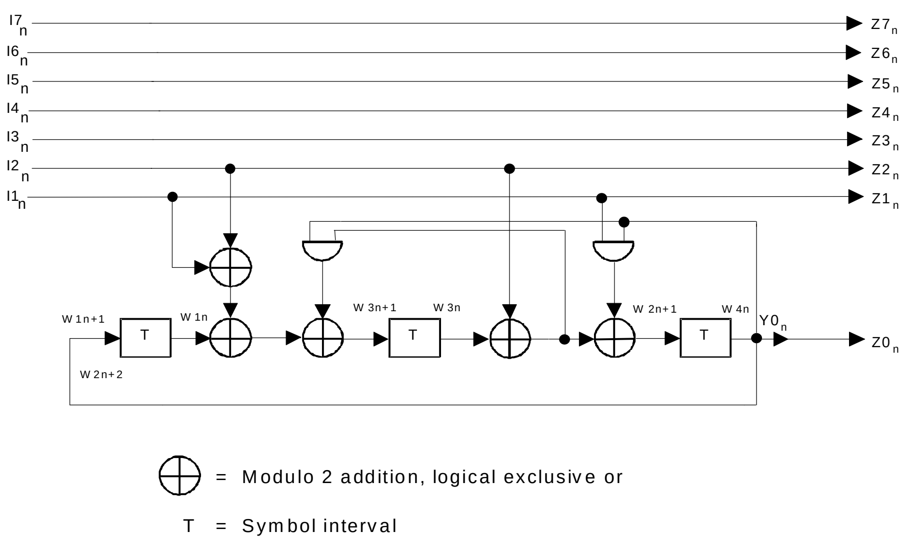


Figure 11 - 2-dimensional 8-state Trellis Encoder

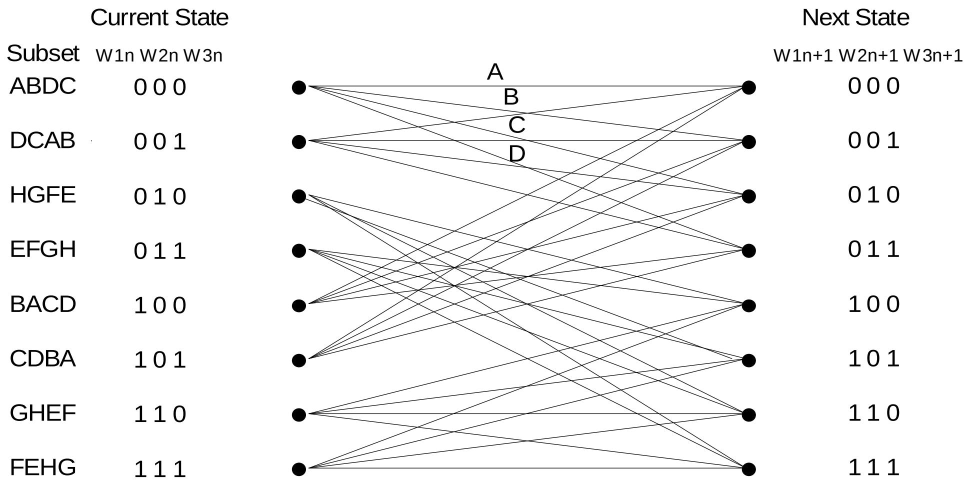
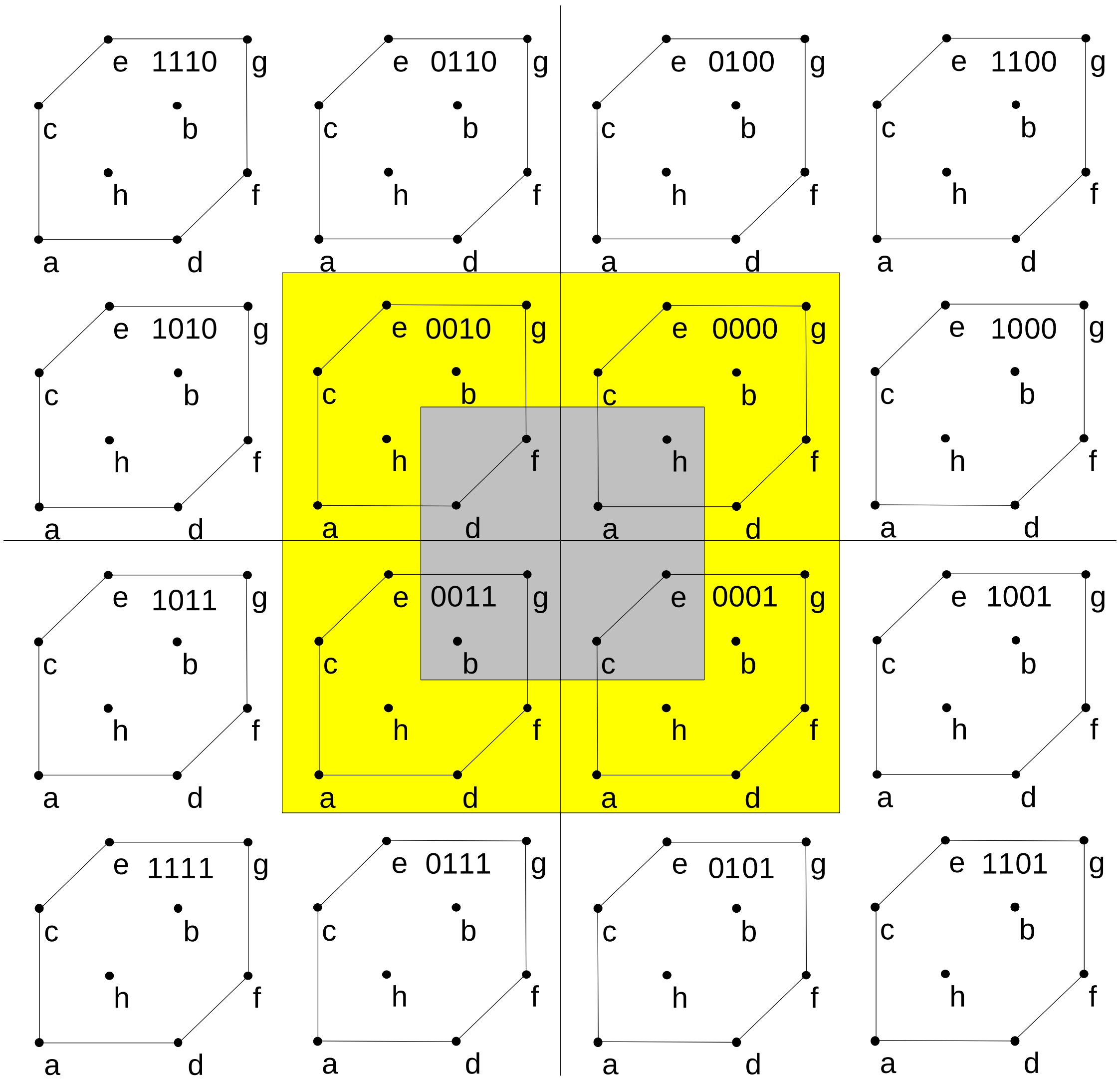


Figure 12 - Trellis Diagram of a 2-dimensional 8-state Code

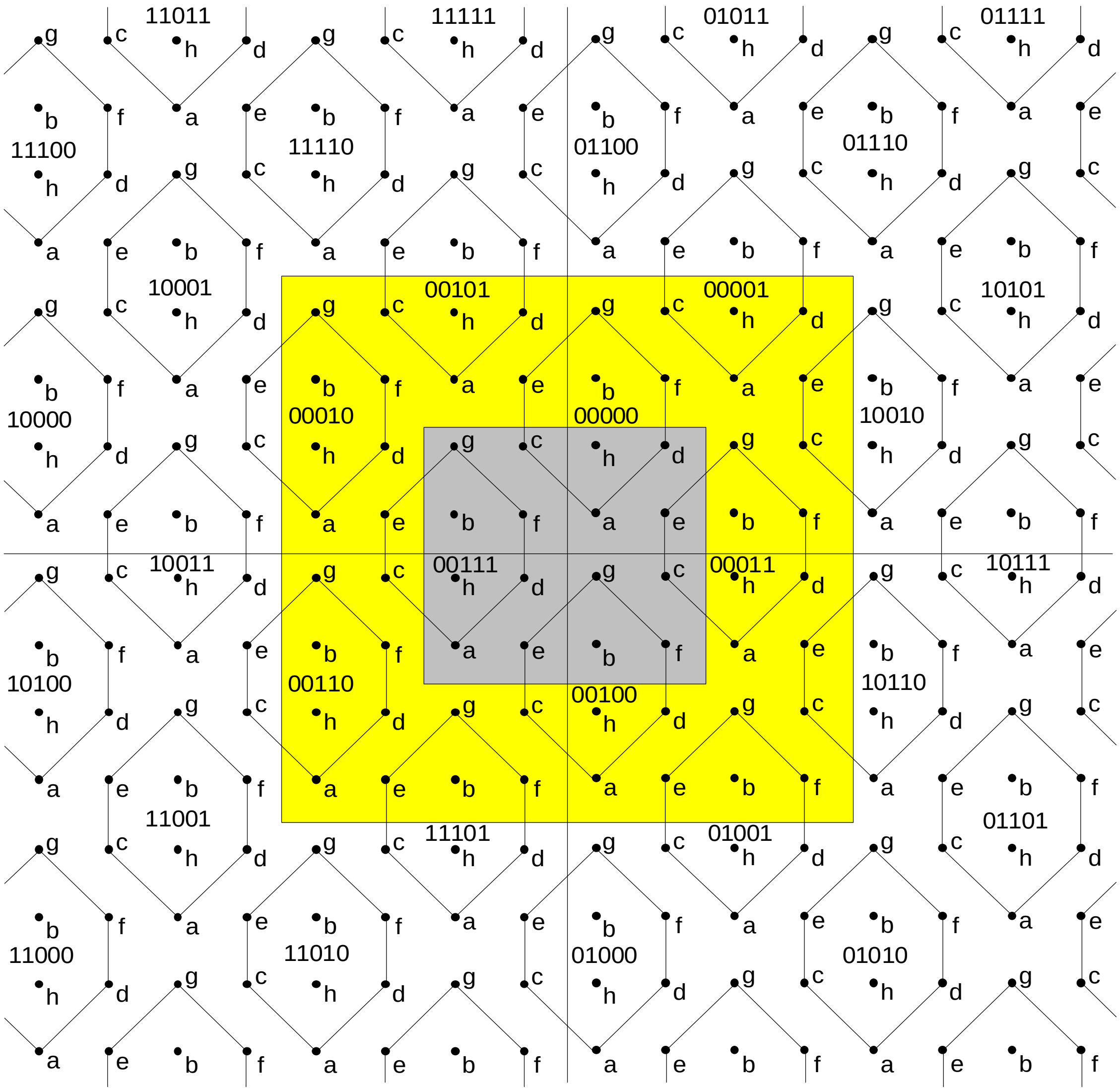


Subset Bit Mapping

SBS[2:0]
a - 000
b - 010
c - 100
d - 110
e - 011
f - 101
g - 111
h - 001

8 Points - SBS[2:0]
32 Points - A[4:3], SBS[2:0]
128 Points - A[6:3], SBS[2:0]
A[ ] defines the MSB values

Figure 13 - 8-point, 32-point, and 128-point Constellations During Data Mode



Subset Bit Mapping

SBS[2:0]
a - 000
b - 010
c - 100
d - 110
e - 011
f - 101
g - 111
h - 001

16 Points - A3, SBS[2:0]
64 Points - A[5:3], SBS[2:0]
256 Points - A[7:3], SBS[2:0]
A[ ] defines the MSB values

Figure 14 - 16-point, 64-point, and 256-point Constellations During Data Mode

5.2.2.1.2 Differential/Gray

For differential/Gray coding, constellations of size 4, 16, 32, 64, 128, and 256 must be supported by both transmitters. For a given constellation of size 2^M, the Serial-to-Parallel converter in Figure 15 accepts contiguous, non-overlapping blocks of *M* modulator input bits and maps each block into an *M*-bit word. The sequence of modulator input bits arrives at the transmitter line rate, while the sequence of *M*-bit S/P output words occurs at the symbol rate. The first bit of an *M*-bit block received at the S/P input is considered the Most Significant Bit (MSB), and the last bit in the block is the Least Significant Bit (LSB).

The Bit-To-Symbol Mapper maps each *M*-bit word into an In-Phase and Quadrature QAM symbol component. The sequence of in-phase and quadrature symbols, denoted I_n and Q_n, respectively, are derived from the sequence of *M*-bit words, as follows. Denote the MSB of the *n*th *M*-bit word by b_n^{M-1}, and denote the next (second) MSB of that same M-bit word as b_n^{M-2}. Then the quadrant differential encoding scheme used by the QAM coder uses the sequences a_n and b_n, defined by

(3) $$a_n = \overline{(b_n^{M-1} \oplus b_n^{M-2})} \cdot (b_n^{M-2} \oplus a_{n-1}) + (b_n^{M-1} \oplus b_n^{M-2}) \cdot (b_n^{M-2} \oplus b_{n-1})$$

and

(4) $$b_n = \overline{(b_n^{M-1} \oplus b_n^{M-2})} \cdot (b_n^{M-1} \oplus b_{n-1}) + (b_n^{M-1} \oplus b_n^{M-2}) \cdot (b_n^{M-1} \oplus a_{n-1})$$

The ordered pair (a_n, b_n) determines the quadrant, in the (I_n, Q_n) plane, of the *n*th transmitted symbol, according to the rule shown below in Table 1.

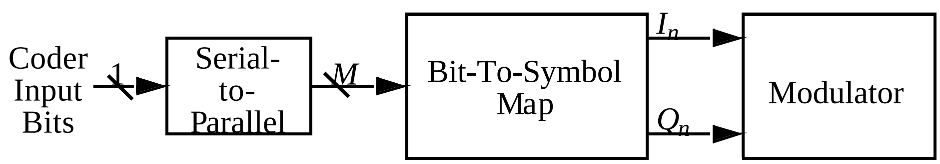


Figure 15 - Differential / Gray Coder Block Diagram

For CAP-4/QAM-4, I_n and Q_n alone determine the value of the transmitted symbol. For the larger constellations, the remaining *M*-2 bits of the *n*th *M*-bit word, $\{b_n^{M-3}, b_n^{M-4}, \ldots, b_n^0\}$, are needed to determine the symbol value within the selected quadrant. Figure 16 and Figure 17 show the mapping of $\{b_n^{M-3}, b_n^{M-4}, \ldots, b_n^0\}$ to I_n and Q_n for each of these QAM constellations, under the assumption that a_n and b_n are both zero, i.e., that the *n*th transmitted QAM symbol lies in the first quadrant. In these figures, the bits are listed in the order $\{b_n^{M-3}, b_n^{M-4}, \ldots, b_n^0\}$. The mapping of $\{b_n^{M-3}, b_n^{M-4}, \ldots, b_n^0\}$ to I_n and Q_n for quadrants 2, 3, and 4 is obtained by rotating Figure 16 and Figure 17 counterclockwise by 90, 180, and 270 degrees, respectively.

Table 1 - Mapping of a_n and b_n to Symbol Quadrant

a_n	b_n	Sign of I_n	Sign of Q_n	Quadrant
0	0	+	+	First
0	1	+	-	Fourth
1	0	-	+	Second
1	1	-	-	Third

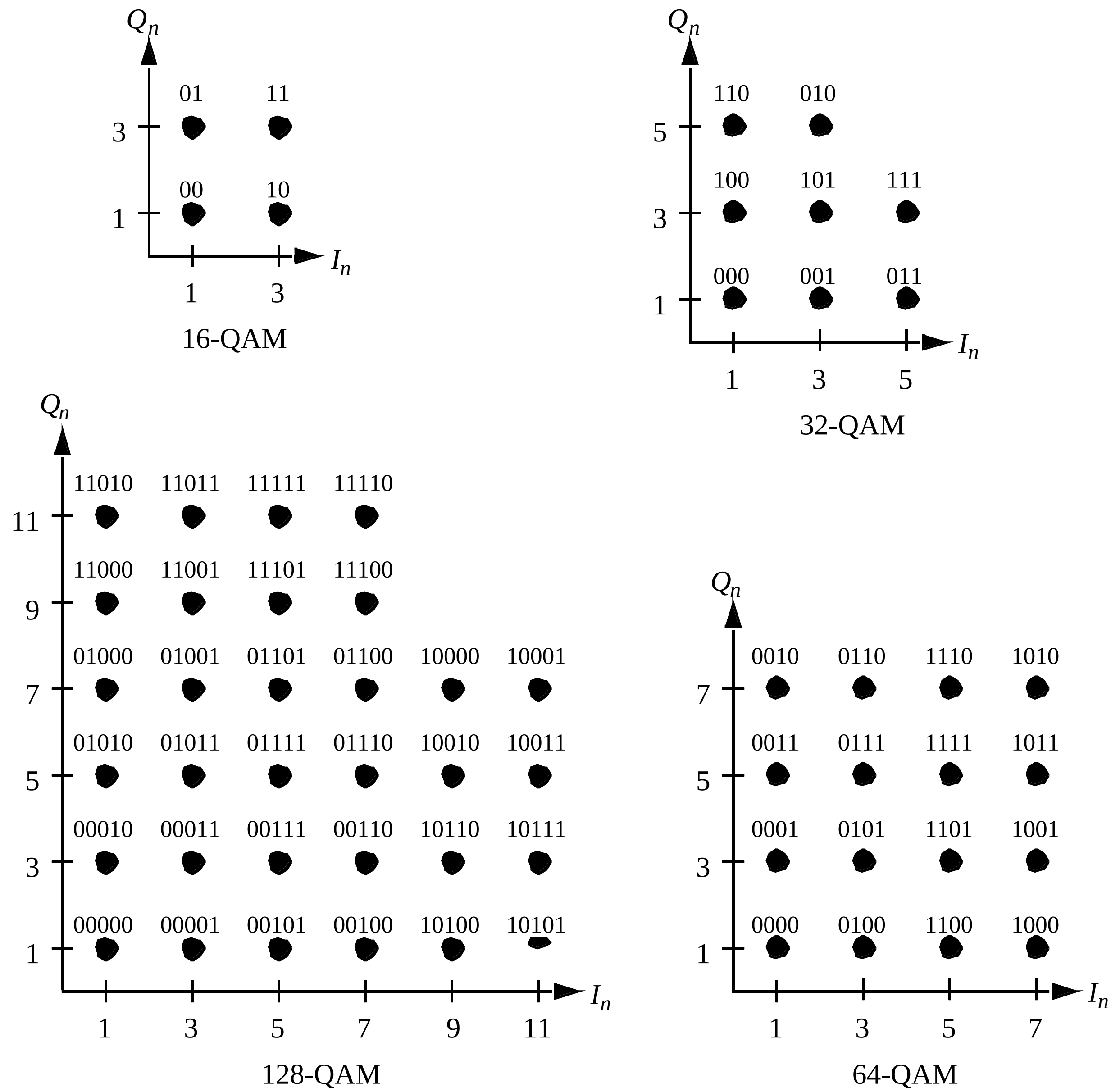


Figure 16 - First Quadrant Bit-to-Symbol Mappings for 16 - 128 QAM

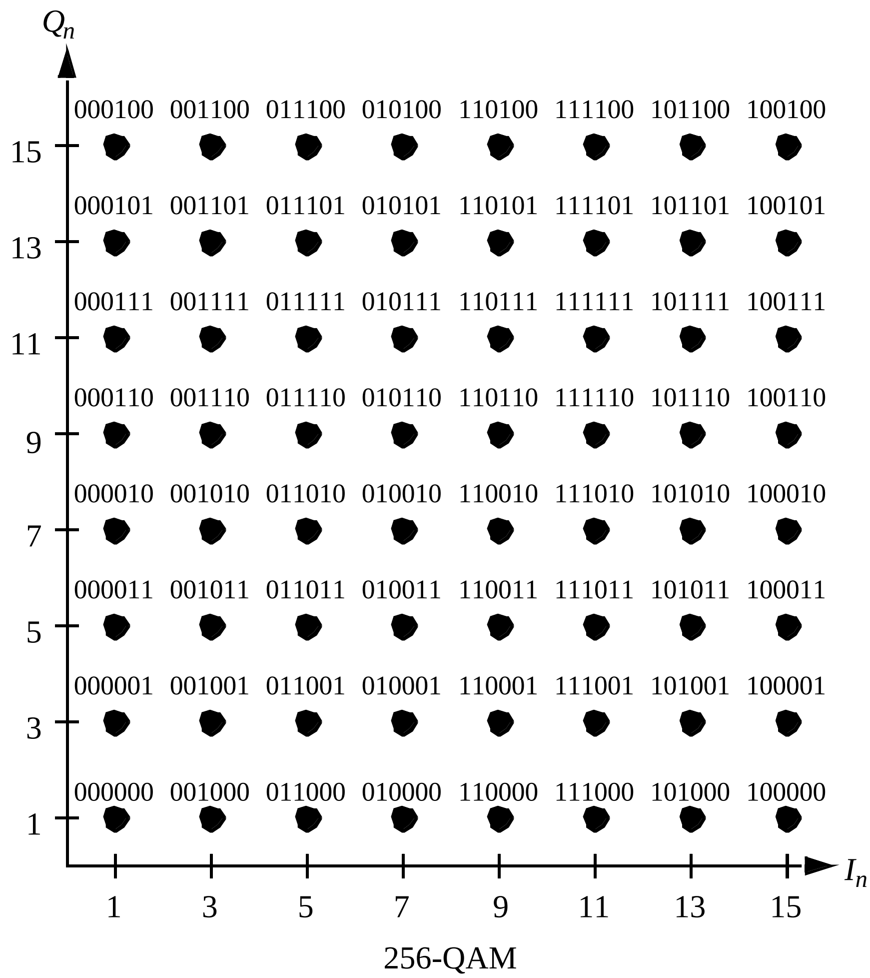


Figure 17 - First Quadrant Bit-to-Symbol Mapping for 256-QAM

5.2.2.2 Tomlinson Precoder

The Tomlinson precoder implements the functionality shown in Figure 18. At system start-up, the Tomlinson coefficients p_1 through p_N are set to zero. During the initialization process, non-zero coefficients may be loaded into the precoder, as controlled by the selected initialization procedure.

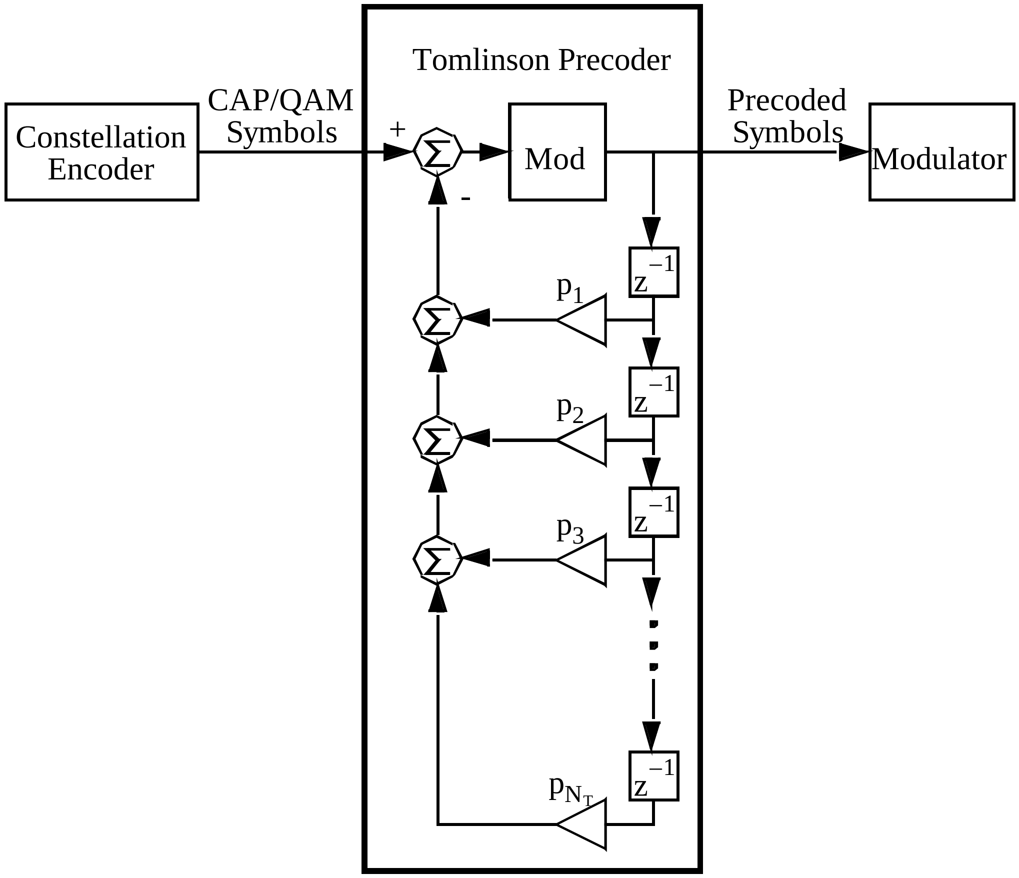


Figure 18 - Tomlinson Precoder Block Diagram

5.2.3 Modulation

5.2.3.1 Block Diagrams

One of two single-carrier modulations may be used, CAP or QAM. A CAP modulated signal is formed according to the transmitter block diagram of Figure 19. A QAM modulated signal is formed according to the transmitter block diagram of Figure 20.

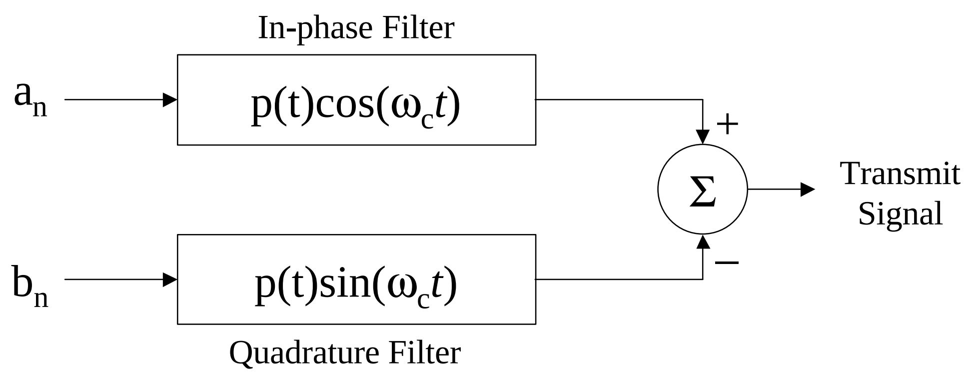


Figure 19 - CAP Transmitter Block Diagram

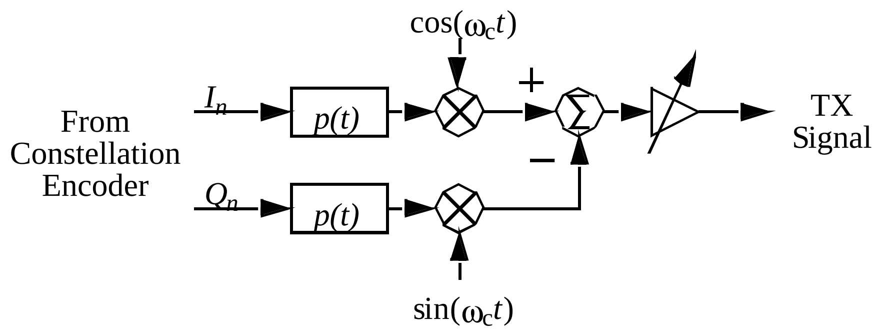


Figure 20 - QAM Transmitter Block Diagram

5.2.3.2 Symbol Rates

5.2.3.2.1 Mandatory Symbol Rates

The predefined mandatory downstream symbol rates for both CAP and QAM modulation are:

136 kBaud
170 kBaud
340 kBaud
680 kBaud
952 kBaud

The predefined mandatory upstream symbol rates for both CAP and QAM modulation are:

85 kBaud

In an actual implementation, the upstream and downstream symbol rates may differ from the nominal value by an amount not to exceed 50 ppm.

5.2.3.2.2 Optional CAP Symbol Rates

Support for optional *variable* symbol rates for CAP modulation (i.e. other rates beyond the above predefined rates) may be defined according to the following *rule*:

The downstream symbol rate clock is defined as $f_{Baud,Down} = \frac{34.56 \cdot N_0}{D_0 D_1}$ in MHz, where N_0 and D_1 are integers in the range from 1 to 256, D_0 is an integer in the range from 1 to 48, and $1/2.3 < N_0 / D_0 < 3.2$.

The upstream symbol rate clock is defined as $f_{Baud,Up} = \frac{2 \cdot f_{Baud\_Down}}{D_2}$ in MHz, where D_2 is an integer in the range from 2 to 32. For the variable symbol rate case, the parameters N_0, and D_0 to D_2 allow downstream symbol rate selection in the range from approximately 64 kBaud to 1088 kBaud, and upstream symbol rate selection in the range from approximately 4 kBaud to 136 kBaud. Proper selection of N_0, D_0, D_1, and D_2 allows provisioning of arbitrarily small step sizes.

The *maximum downstream channel symbol rate* is 1088 kBaud ± 25 ppm, and the maximum upstream channel symbol rate is 136 kBaud ± 25 ppm.

The symbol rates will be selected in either the pre-defined mode or variable symbol rate mode with all parameters passed during transceiver start-up as described in Section 5.4.2.1.

The data symbol bit rates are determined by the symbol rate, the rate of the trellis code, and rate of the Reed-Solomon (RS) code. The bit rate is computed by $R_b = m \cdot (N/K) \cdot f_{Symbol}$, where m is the number of data bits per symbol in the constellation, N and K are the codeword and information field sizes respectively of the RS code and f_{Symbol} is the symbol rate of the respective upstream and downstream channels. The downstream channel bit rates range up to approximately 8 Mb/s depending on the RS codeword size, and the upstream channel bit rate range up to approximately 1 Mb/s.

The predefined symbol rates applicable to the downstream channel include 136, 340, and 680 kBaud. All downstream channel variable symbol rates must fall within the PSD mask of Figure 21.

The predefined symbol rate applicable to the upstream channel is 85 kBaud. All upstream channel variable symbol rates must fall within the PSD mask of Figure 22.

5.2.3.2.3 Optional QAM Symbol Rates

In addition to the mandatory upstream symbol rates, transmitters using QAM modulation may also support any upstream symbol rate $1/T_{US}$ given by

(5) $$1/T_{US} = B_{US} \text{ symbols/sec}$$

where B_{US} is any integer satisfying

(6) $$20{,}000 \le B_{US} \le 100{,}000$$

In an actual implementation, the upstream symbol rate may differ from the nominal value by an amount not to exceed 50 ppm.

In addition to the mandatory downstream symbol rates, transmitters using QAM modulation may also support any downstream symbol rate $1/T_{DS}$ given by

(7) $$1/T_{DS} = B_{DS} \text{ symbols/sec}$$

where B_{DS} is any integer satisfying

(8) $$40{,}000 \le B_{DS} \le 952{,}000$$

In an actual implementation, the upstream symbol rate may differ from the negotiated nominal value by an amount not to exceed 50 ppm.

5.2.3.3 Transmitter Spectrum

5.2.3.3.1 Mandatory Center Frequencies

For the predefined mandatory symbol rates in Section 5.2.3.2.1, the corresponding center frequencies are defined in Table 2.

Table 2 - Mandatory Center Frequencies

Upstream Channel Symbol Rate	Center Freq. f_c (kHz)
85 kBaud	85.0
Downstream Channel Symbol Rate	**Center Freq f_c (kHz)**
136 kBaud	318.2
170 kBaud	340.0
340 kBaud	435.5
680 kBaud	631.0
952 kBaud	787.4

5.2.3.3.2 Optional QAM Center Frequencies

In addition to the mandatory center frequencies, transmitters using QAM modulation may also support any upstream center frequency $f_{C,US}$ with the nominal value

(9) $$f_{C,US} = C_{US} \text{ Hz}$$

and any downstream center frequency $f_{C,DS}$ with the nominal value

(10) $$f_{C,DS} = C_{DS} \text{ Hz}$$

C_{US} can be any integer satisfying

(11) $$34{,}000 + \frac{1}{2T_{US}} \le C_{US} \le 134{,}000 - \frac{1}{2T_{US}}$$

where $1/T_{US}$ is the upstream symbol rate in use at the time.

C_{DS} can be any integer satisfying

(12) $$144{,}000 + \frac{0.6}{T_{DS}} \le C_{DS} \le 1{,}104{,}000 - \frac{1}{2T_{DS}}$$

where $1/T_{DS}$ is the downstream baud rate in use at the time.

In an actual implementation, the center frequency may differ from the nominal value by an amount not to exceed 50 ppm.

5.2.3.4 PSD Mask & Transmit Signal Power

Figure 21 presents the power spectral density mask for the downstream (the ATU-C transmitter) signal and Figure 22 presents the power spectral density mask for the upstream signal (the ATU-R transmitter). The low frequency stop band is defined as the voice band; the high frequency stop band is defined as frequencies greater than 138 kHz. The downstream mask is as defined in ANSI T1.413-1998 Annex Figure F.1. The upstream mask is as defined in ANSI T1.413-1998 Figure 32. They are included here for convenience to the reader.

Signals fall within the power spectral density mask defined in ANSI T1.413-1998. Downstream transmit signals will not exceed the appropriate downstream mask at any frequency, while having average transmit power, measured across a 100 ohm load, that satisfies

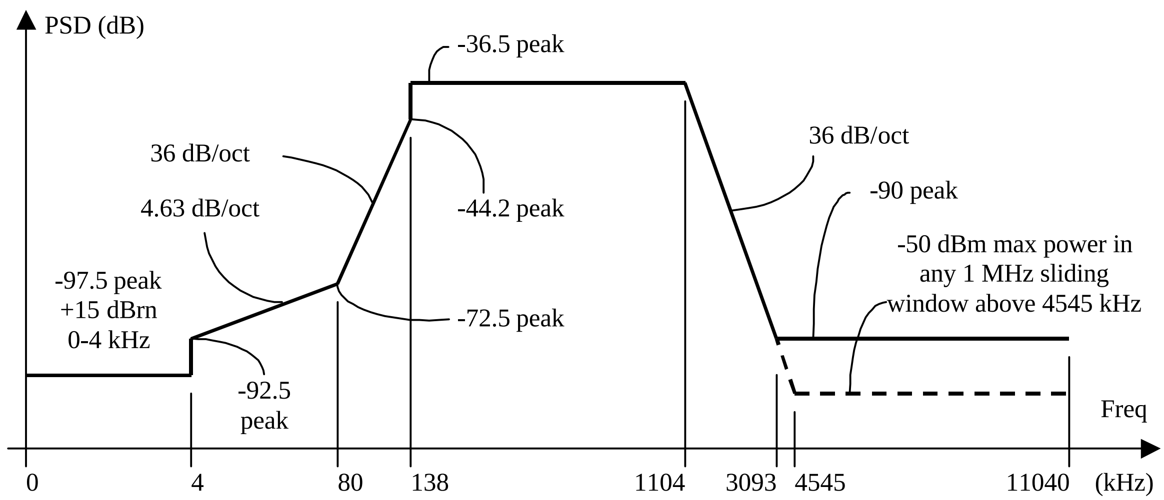
(13) $$P_{DS} \leq -40 + 10\log_{10}(1/T_{DS})\,\mathrm{dBm}$$

where $1/T_{DS}$ is the downstream symbol rate.

Upstream transmit signals will not exceed the appropriate upstream mask at any frequency, while having average transmit power, measured across a 100 ohm load, that satisfies

(14) $$P_{US} \leq -38 + 10\log_{10}(1/T_{US})\,\mathrm{dBm}$$

where $1/T_{US}$ is the upstream symbol rate.

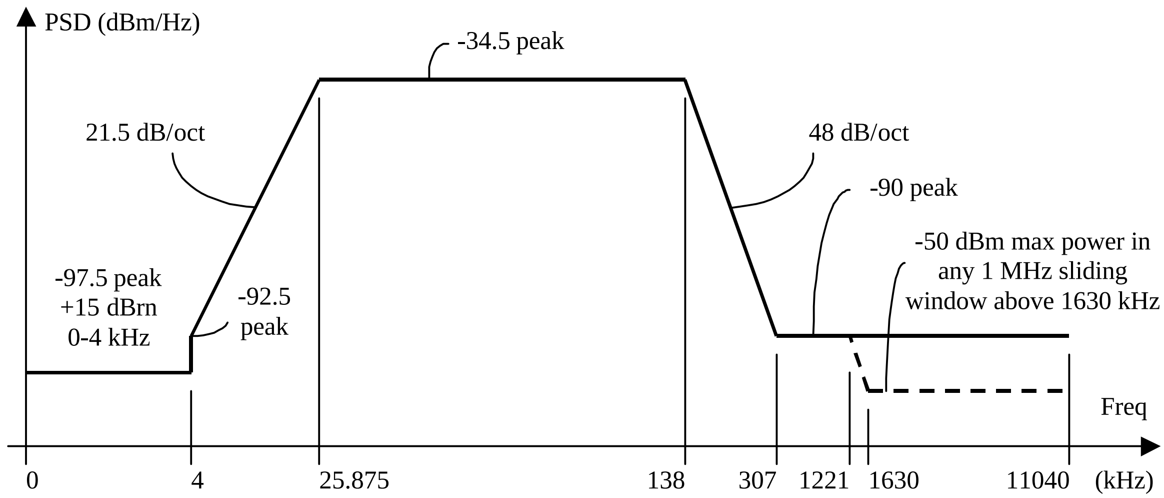


NOTES

1. All PSD measurements are in 100 ohm; the POTS band aggregate power measurement is in 600 ohm. All PSD and power measurements are made at the U-C interface (see Figure 1); the signals delivered to the PSTN are specified in ANNEX E.
2. The breakpoint frequencies and values are exact; the indicated slopes are approximate.
3. Above 25.875 kHz, the peak PSD is measured with a 10 kHz resolution bandwidth
4. The power in a 1 MHz sliding window is measured in 1 MHz bandwidth, starting at the measurement frequency.

FREQUENCY BAND (kHz)	EQUATION FOR LINE (dBm/Hz)
0 < f < 4	-97.5, with max power in the in 0-4 kHz band of +15 dBrn
4 < f < 80	$-92.5 + 4.63 \times \log_2 (f/4)$
80 < f < 138	$-72.5 + 36 \times \log_2 (f/80)$
25.875 < f < 1104	-36.5
1104 < f < 3093	$-36.5 - 36 \times \log_2(f/1104)$
3093 < f < 4545	–90 peak, with max power in the [f, f + 1 MHz] window of $(-36.5 - 36 \times \log_2(f/1104) + 60)$ dBm
4545 < f < 11040	-90 peak, with max power in the [f, f+1MHz] window of -50 dBm

Figure 21 - Downstream PSD Mask



FREQUENCY BAND (kHz)	EQUATION FOR LINE (dBm/Hz)
0 < *f* < 4	-97.5, with max power in the in 0-4 kHz band of +15 dBrn
4 < *f* < 25.875	$-92.5 + 21.5 \times \log_2(f/4)$
25.875 < *f* < 138	-34.5
138 < *f* < 307	$-34.5 - 48 \times \log_2(f/138)$
307 < *f* < 1221	-90
1221 < *f* < 1630	–90 peak, with max power in the [*f*, *f* + 1 MHz] window of $(-90 - 48 \times \log_2(f/1221) + 60)$ dBm
1630 < *f* < 11040	-90 peak, with max power in the [*f*, *f*+1MHz] window of -50 dBm

NOTES

1. All PSD measurements are in 100 ohms; the voice band aggregate power measurement is in 600 ohms.
2. All PSD and power measurements will be made at the U-R interface (see Figure 1); the signals delivered to the POTS are specified in ANNEX E.
3. The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate.
4. Above 25.875 kHz, the peak PSD will be measured with a 10 kHz resolution bandwidth.
5. The power in a 1 MHz sliding window is measured in 1 MHz bandwidth, starting at the measurement frequency.

Figure 22 - Upstream PSD Mask

5.2.4 Analog Processor

The details of the analog processor functionality are implementation specific. Corresponding requirements are described in Section 6.

5.3 Transmission Convergence (TC) Sublayer

TC functions include mapping, QAM and optional cell delineation. The TC also contains a Physical Transmission Convergence (PTC) sub-sub layer. The PTC functions include EOC transport, performance monitoring, surveillance, FEC, framing, scrambling and handshake.

5.3.1 Physical Transmission Convergence

5.3.1.1 PTC Scrambling

PTC scrambling may be performed per the self-synchronizing method described below or PMD scrambling may be performed per the frame locked method described in section 5.2.1.1.

5.3.1.1.1 Self Synchronizing

Self-synchronizing scramblers and descramblers are based on a polynomial of order 23 with two feedback taps. Different generating polynomials are used for the upstream and downstream channels. Functional block diagrams of the upstream and downstream scramblers and descramblers are shown in Figure 23. The operation of these devices is described by the following equations.

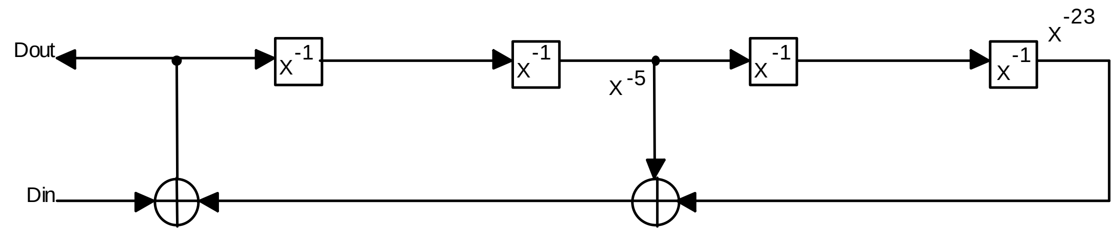
(15) $$\text{Downstream Scramblers:} D_{out}(n) = D_{in}(n) \oplus D_{out}(n-5) \oplus D_{out}(n-23)$$

(16) $$\text{Downstream Descramblers:} D_{out}(n) = D_{in}(n) \oplus D_{in}(n-5) \oplus D_{in}(n-23)$$

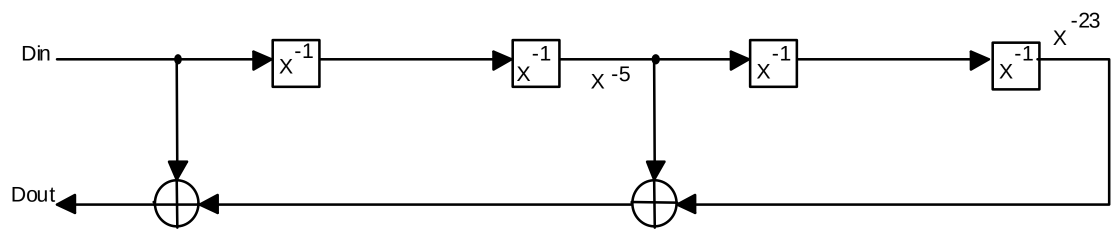
(17) $$\text{Upstream Scramblers:} D_{out}(n) = D_{in}(n) \oplus D_{out}(n-18) \oplus D_{out}(n-23)$$

(18) $$\text{Upstream Descramblers:} D_{out}(n) = D_{in}(n) \oplus D_{in}(n-18) \oplus D_{in}(n-23)$$

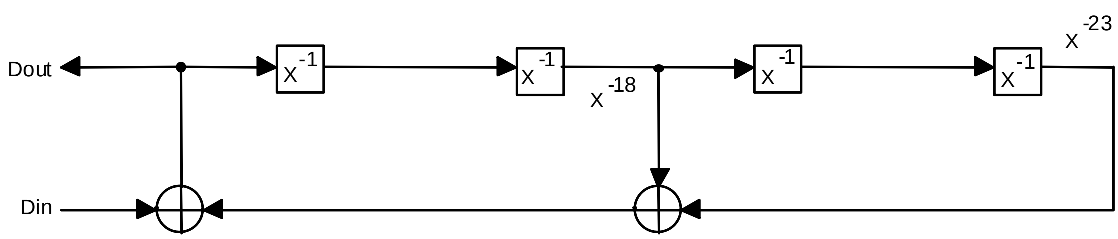
For codeword-based framing, PTC scrambling is applied to the AOC and payload octets only, as shown in Figure 23 and not to the FEC redundancy octets. As shown in Figure 23 the coded and uncoded payload streams require separate scramblers and descramblers. In the case of the alternate Class 1 frame described in 5.3.1.4.2.2.2, PTC scrambling is applied to the AOC, payload, and FCS fields. The state of the scrambler is frozen while the framer pulls bits from a source other than that scrambler's output.



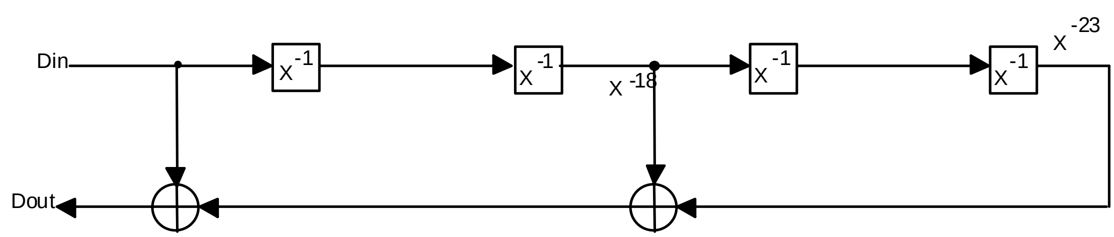
(a) ATU-C Transmit Scrambler



(b) ATU-R Receive Descrambler



(c) ATU-R Transmit Scrambler



(d) ATU-C Receive Descrambler

Figure 23 - PTC Scrambler and Descrambler Functional Block Diagrams

5.3.1.1.2 Bypass PTC Scrambling

PTC scrambling may be bypassed as in Profile A.

5.3.1.2 Reed Solomon

5.3.1.2.1 T=2 Symbol (Byte) Code

A two symbol (byte) error correcting Reed-Solomon code is defined for the CAP-based RADSL system. In this case, four redundant check bytes will be appended to the *K* message bytes m_0, m_1,..., m_{k-1} to form a Reed-Solomon codeword of size $N = K + 4$. The check bytes are computed from the message byte using the equation:

(19) $$C(x) = M(x) \cdot x^4 \bmod g(x)$$

where:

(20) $$M(x) = m_0 \cdot x^{k-1} \oplus m_1 \cdot x^{k-2} \oplus \cdots \oplus m_{k-1} \cdot x \oplus m_k$$ is the message polynomial,

(21) $$C(x) = c_0 \cdot x^3 \oplus c_1 \cdot x^2 \oplus c_2 \cdot x^1 \oplus c_3$$ is the check polynomial, and

(22) $$g(x) = (x \oplus a^1)(x \oplus a^2)(x \oplus a^3)(x \oplus a^4)$$ is the generator polynomial.

The RS code is performed in the Galois Field GF(2^8), where α is the primitive element that satisfies the primitive binary polynomial $p(x) = x^8 \oplus x^4 \oplus x^3 \oplus x^2 \oplus 1$. The data byte is identified with the Galois Field element d_7a^7Å d_6a^6Å …Å d_0.

The message size *K* is defined in Section 5.3.1.4 for the various configurations.

5.3.1.2.2 T=8 Symbol (Byte) Code

The representation of the Galois Field (GF256) for the T=8 Reed-Solomon code uses the primitive polynomial

(23) $$p(x) = x^8 \oplus x^4 \oplus x^3 \oplus x^2 \oplus 1$$

The generator polynomial is defined as

(24) $$G(x) = \left(x \oplus a^0\right) \cdot \left(x \oplus a^1\right) \cdot \ldots \cdot \left(x \oplus a^{15}\right)$$

For codeword based framing, the codewords are computed across the AOC and Coded Payload frame fields, as shown in Figure 25. Other frame elements are not coded.

5.3.1.3 Interleaving

5.3.1.3.1 Implied Convolutional

The interleaving method for the Reed-Solomon Code uses an *implied* convolutional interleaving method that inserts the parity symbols into appropriate locations within the original data sequence and the resulting codewords are constructed via the convolutional interleaving rules. The input data (message) symbols stay in their original sequence when transmitted on the subscriber line. Figure 24 shows a functional transmitter block diagram of the forward error correction block with interleaving. The effect of interleaving to a depth *D* is provided by entering the input data symbols into the appropriate encoder in a sequence corresponding to the interleaving rules; convolutional interleaving is recommended for efficient use of memory. Each encoder has a rate of (*N,K*), where *N* is the codeword size and *K* is the number of data symbols (message size) in the codeword. The value of *N* and *K* may be selected at start-up; the recommended default values of *N* and *K* are 68 and 64 respectively. The multiplexer inserts the parity symbols of each encoder into the appropriate locations within the original transmit data sequence.

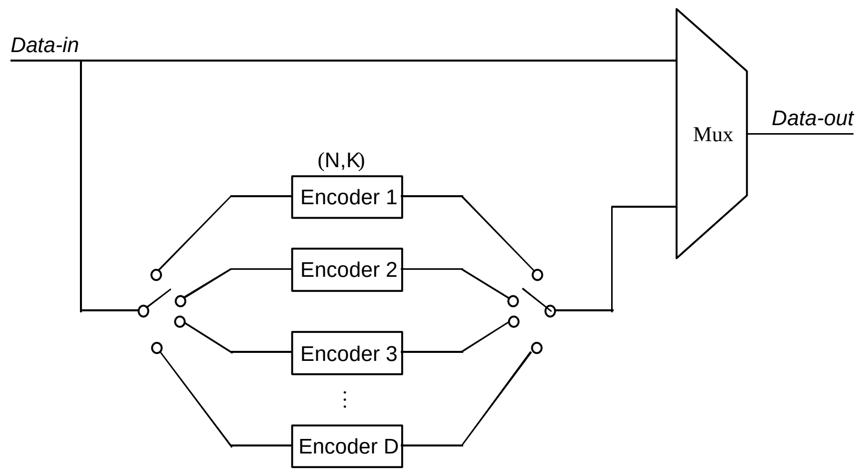


Figure 24 - Transmitter Structure for the Reed-Solomon Code Interleaving

Figure 25. shows the codeword construction with implied interleaving. The symbol *m* represents the time index of the data block containing both data and parity symbols. The data symbols are sequentially written into the rows of the matrix and also read from the rows of the matrix in the same sequence. The parity symbols $P_j(k)$, j = 1, 2, …, *D* are inserted into the matrix using the following rules for the case where $N > D$:

a) Define parameter $L_j = (j-1) \times \left[\frac{N}{D}\right]$, where j = 2, 3,…, *D* and L_1 = N, and where [*x*] denotes the greatest integer function of the argument *x*. The parameter L_j defines the row location of the (*N* - *K*)-th parity symbol for codeword $P_j(k)$ where the argument *k* = 1, 2,..., *N-K* represents the parity symbol index for the *j*-th codeword.

b) The parity symbols $P_j(k)$ *k* = 1, 2,…, *N--K* of codeword *j* are placed in matrix locations $A_m(i, j)$, where $i = L_j - (N-K) + k$ is the row location and *j* is the matrix column that also represents the codeword.

In this specification the value of *N* is always greater than *D*. The maximum value of interleave memory is 3.8 kBytes and the maximum value for *D* is $D_{\max} = \left[\frac{3.8 \text{ kBytes}}{N}\right]$, where [*x*] is the greatest integer function of argument *x* and *N* is the codeword size.

With the convolutional assignment of the parity symbols, the codewords are constructed between adjacent data blocks. Because the index *m* increases with increasing time, a codeword with parity symbols in block *m* will have its associated data symbols in blocks *m* and *m* -1 for codewords *j* = 2, 3,…, D. For codeword *j* = 1, the whole codeword resides in current block *m*.

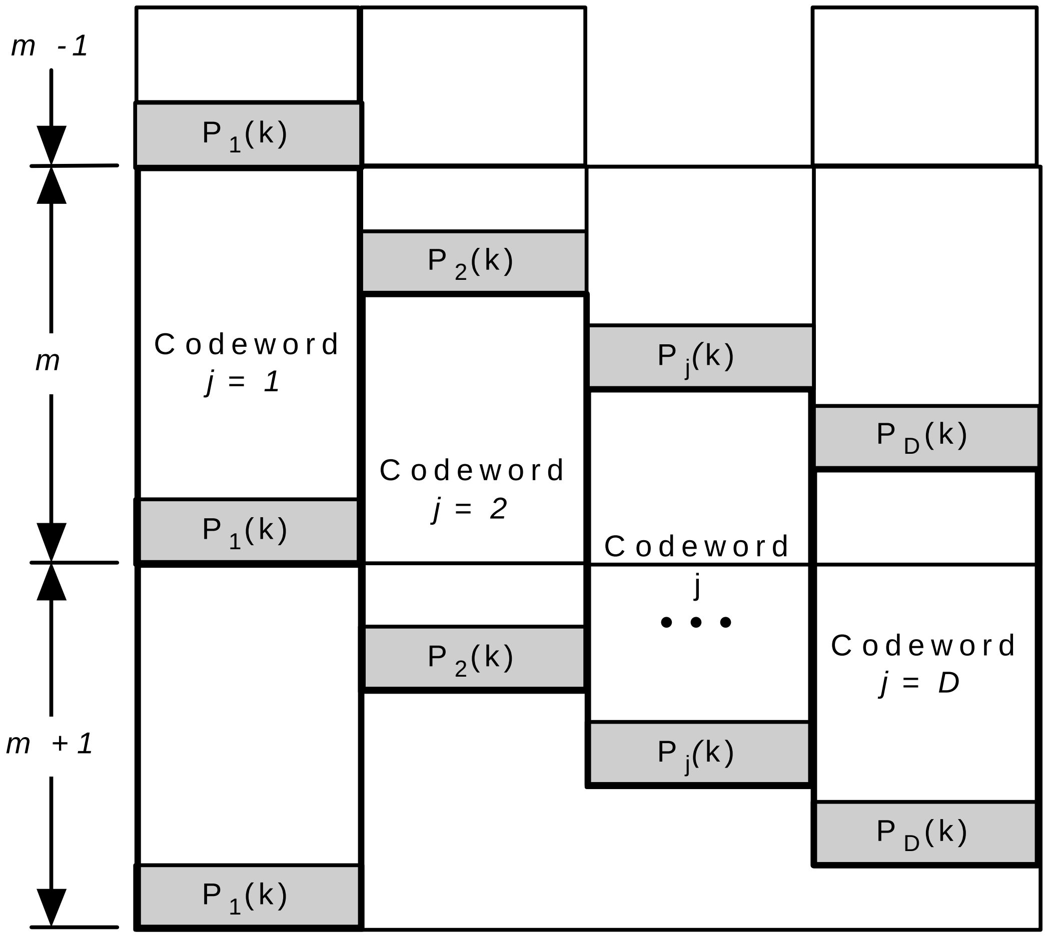


Figure 25 - Codeword construction

5.3.1.3.2 Convolutional - Ramsey Type 2

If selected, the codewords are applied to a Ramsey Type-2 interleaver. The interleaver depth, *D*, can be set to 1 (no interleaving), 2, 4, 8, or 16 codewords. The interleaving depths for the upstream and downstream channels can be set to independent values.

Interleaver functionality at a depth *D* is described as follows. Denote the symbols of a given Reed-Solomon codeword by the sequence $\{S_0, S_1, S_2, S_{3,} \ldots, S_{N-1}\}$. S_0 and S_1 always correspond to octets located in the first and second AOC octet positions in a frame, respectively, while S_k is an octet located in the position of the $(k-1)'\mathrm{th}$ coded payload octet position in a frame, for $2 \le k \le N-17$. Finally, S_k is an octet located in the $(k-N+17)'\mathrm{th}$ FEC Redundancy octet position in a frame, for $N-16 \le k \le N-1$.

Then define the interleaver input/output time index, l , such that for every integer value of l , a new Reed-Solomon symbol (octet) is input to the interleaver, while simultaneously another Reed-Solomon symbol (possibly the same one just input) is output from the interleaver. The symbols of the most recent Reed-Solomon encoder output codeword $\{S_0, S_1, S_2, S_{3,} \ldots, S_{N-1}\}$ are applied, in the indicated order, as the newest portion of the interleaver input. That is, S_k is the input at time index $l = a + k$ for some constant integer a and all k satisfying $0 \le k \le N-1$. For this input symbol sequence and an interleaving depth of *D*, the interleaver works as follows. For any given Reed-Solomon symbol S_k applied as input to the interleaver at time index $l = l_0$, that same Reed-Solomon symbol is output from the interleaver at time index $l = l_0 + (D-1)k$.

5.3.1.4 Framing

5.3.1.4.1 Bit Synchronous Framing

One or any combination of three types of TC formats may be supported by the bit synchronous frame: Direct Cell Map, Direct Packet Map, and Frame Based Mapping. These Mappings are described in later sections of this document.

5.3.1.4.1.1 Features

The frame based TC provides the following features:

- fault monitoring - Far End Block Error (FEBE) and Remote Alarm Indicator (RAI),
- performance monitoring - CRC on the frame,
- dying gasp indication,
- reserved bytes for future growth which includes Embedded Operation Channel (EOC), Network Timing Reference (NTR), and
- payload of 424 bytes.

5.3.1.4.1.2 Physical Layer Frame Format

The format of the frame and its fields are shown in Figure 26 and Table 3.

<table>
<tr><th></th><th colspan="8">Bit</th></tr>
<tr><th>Octet</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td>1</td><td colspan="7">Sync word (7 bits)</td><td>FEBE</td></tr>
<tr><td>2-54</td><td colspan="8">slot 1</td></tr>
<tr><td>55-372</td><td colspan="8">slot 2 to 7</td></tr>
<tr><td>373-425</td><td colspan="8">slot 8</td></tr>
<tr><td>426</td><td>dying gasp</td><td colspan="7">Reserved</td></tr>
<tr><td>427</td><td colspan="8">EOC</td></tr>
<tr><td>428-430</td><td colspan="8">Growth</td></tr>
<tr><td>431</td><td colspan="8">NTR</td></tr>
<tr><td>432</td><td colspan="6">CRC-6</td><td>RAI</td><td>Rsvd</td></tr>
</table>

Figure 26 - Frame format

Table 3 - Fields of the frame

Frame Byte Number	Frame Bit Number	Number of Bits	Description
1	1–7 8	7 1	Frame Alignment Word Far End Block Error (FEBE) indicator bit
2–54	9–432	424	Payload
55–107	433–856	424	Payload
108–425	857–3400	2544	Payload
426	3401 3401–3408	1 7	Dying Gasp Reserved (set to ‘0’)
427	3409–3416	8	EOC
428–430	3417–3440	24	Growth (set to ‘0’)
431	3441–3448	8	Reserved: NTR (set to ‘0’)
432	3449–3454 3455 3456	6 1 1	Cyclic Redundancy Check (CRC-6) Remote Alarm Indication (RAI) bit Reserved (set to ‘0’)

5.3.1.4.1.3 Frame Fields

5.3.1.4.1.3.1 Sync Word (Byte 1)

The Frame Alignment word is a seven-bit Barker code. Bit 1 is the most significant bit; bit 1 is transmitted first. See Table 4.

Table 4 - Frame Alignment Barker Code

	MSB						LSB
Bit Number	1	2	3	4	5	6	7
Bit value	1	1	1	0	0	1	0

5.3.1.4.1.3.2 Far End Block Error (FEBE)

The FEBE bit is set to indicate that one or more frames have been received with CRC errors since the last transmitted frame. A value of ‘1’ indicates errors; ‘0’ indicates no errors.

5.3.1.4.1.3.3 Remote Alarm Indication (RAI)

When the local receiver enters Out of Frame alarm state, the local transmitter will set this bit to notify the remote end of its status. A value of ‘1’ indicates Alarm; ‘0’ indicates no Alarm.

5.3.1.4.1.3.4 Dying Gasp

The ATU-R will set this field to ‘1’ if loss of power is detected. During normal operation, the ATU-R will set this field to ‘0’. Algorithms for declaring and clearing dying gasp require additional study.

5.3.1.4.1.3.5 Reserved (bits 2-7 in Byte 426)

Bits 2-7 in byte 426 are reserved for possible future features enhancements. The framer will set bits 2 -7 in byte 426 to “0” in the transmitted frames. Until this field is defined, the receiver is not required to validate this field but must include it in the CRC-6 validation.

5.3.1.4.1.3.6 EOC (Byte 427)

Byte 427 is reserved for use as an Embedded Operations Channel. The EOC supports data that can be sent autonomously from either ATU-C or ATU-R. Annex H provides an example of a protocol stack that may be used to support the EOC functions.

5.3.1.4.1.3.7 Growth (Bytes 428-430)

Bytes 428–430 are reserved for possible future features enhancements. The framer will set all bits in the Growth field to all zeros in the transmitted frames. Until this field is defined, the receiver is not required to validate this field but must include it in the CRC-6 validation.

5.3.1.4.1.3.8 Network Timing Reference (NTR)

Byte 431 is reserved for possible future use as a Network Timing Reference (NTR), such that the NTR can be conveyed over the link by locking the PMD and network clocks. Functionality of this field is undefined presently. The framer will set all bits in the NTR field to all zeros in the transmitted frames. Until this field is defined, the receiver is not required to validate this field but must include it in the CRC-6 validation.

5.3.1.4.1.3.9 Cyclic Redundancy Check Field (CRC-6)

Bits 1–6 (the six most significant bits) of byte 432 constitute the Cyclic Redundancy Check (CRC) field of each frame.

A CRC allows detection of certain transmission errors. A CRC error counter in the receiver circuitry is periodically accessed by that unit’s microprocessor, so that performance statistics (errored seconds, etc.) can be tallied and retrieved on demand.

The CRC-6 bits are calculated on bits 9–3448 of the frame. That is, the CRC calculations include the ATM Cell bits, User Channel, EOC, Growth, and NTR bytes. The CRC generator polynomial is $1 + x + x^6$. The CRC register is initialed to zeros at the beginning of each frame’s calculation.

Here is an example frame showing the results of the CRC calculation:

- All payloads have all zeros, except the HEC bytes (which have the correct value: 55 [hex]).
- Reserved byte 426 is all zeros.
- Reserved byte 427 is all ones.
- Reserved bytes 428–431 are all zeros.
- The six-bit CRC value transmitted in this frame is 31 (hex).

Note that the bits of the FEBE and RAI fields are *not* included in the CRC-6 computation.

5.3.1.4.1.4 Bit Order

The frame is transmitted starting with the lowest byte to the highest byte. Within the byte, the lowest numbered bit (LSB) is transmitted then the higher numbered bits. Let b(j,k) denotes the *k*th bit of *j*th byte. The bit transmission sequence is {[b(j,k),k=1 to 8], j=1 to 432}.

5.3.1.4.2 Codeword Based

The codeword-based frame multiplexes coded and uncoded payloads, an EOC, the FEC redundancy, and other framing overhead signals. Two framing classes are possible, one that must be supported by all ATU-Cs and ATU-Rs, and one that is optional to support.

The mandatory frame class is intended for the transport of coded payloads, with no transport capability for uncoded payload streams. The coded streams are protected against channel impairments with an interleaved Reed-Solomon code. This framing class is suitable for systems intended for the transport of data and video services, referred to as Class 1 systems.

The optional framing class, in addition to transporting coded payloads protected by FEC, can also transport a programmable amount of uncoded payload. With this optional framing class the network operator can dedicate up to 50% of a system's total payload capacity to uncoded payload streams. Furthermore, this framing class is designed to minimize the latency experienced by the uncoded streams as they pass through a transceiver pair. Systems that require the use of this optional framing class are referred to as Class 2 systems.

5.3.1.4.2.1 Framer Functional Block Diagrams

Figure 27 shows functional block diagrams of the upstream and downstream codeword-based framers. These block diagrams indicate which streams are to be processed by the PTC scrambler and FEC blocks, and the order in which scrambling and FEC processing are to occur. As these attributes are identical in both of the two framing classes, Figure 27 applies to them each. However, the dashed lines for the uncoded payload streams indicate that these streams are supported only in the Class 2 frame, not for Class 1.

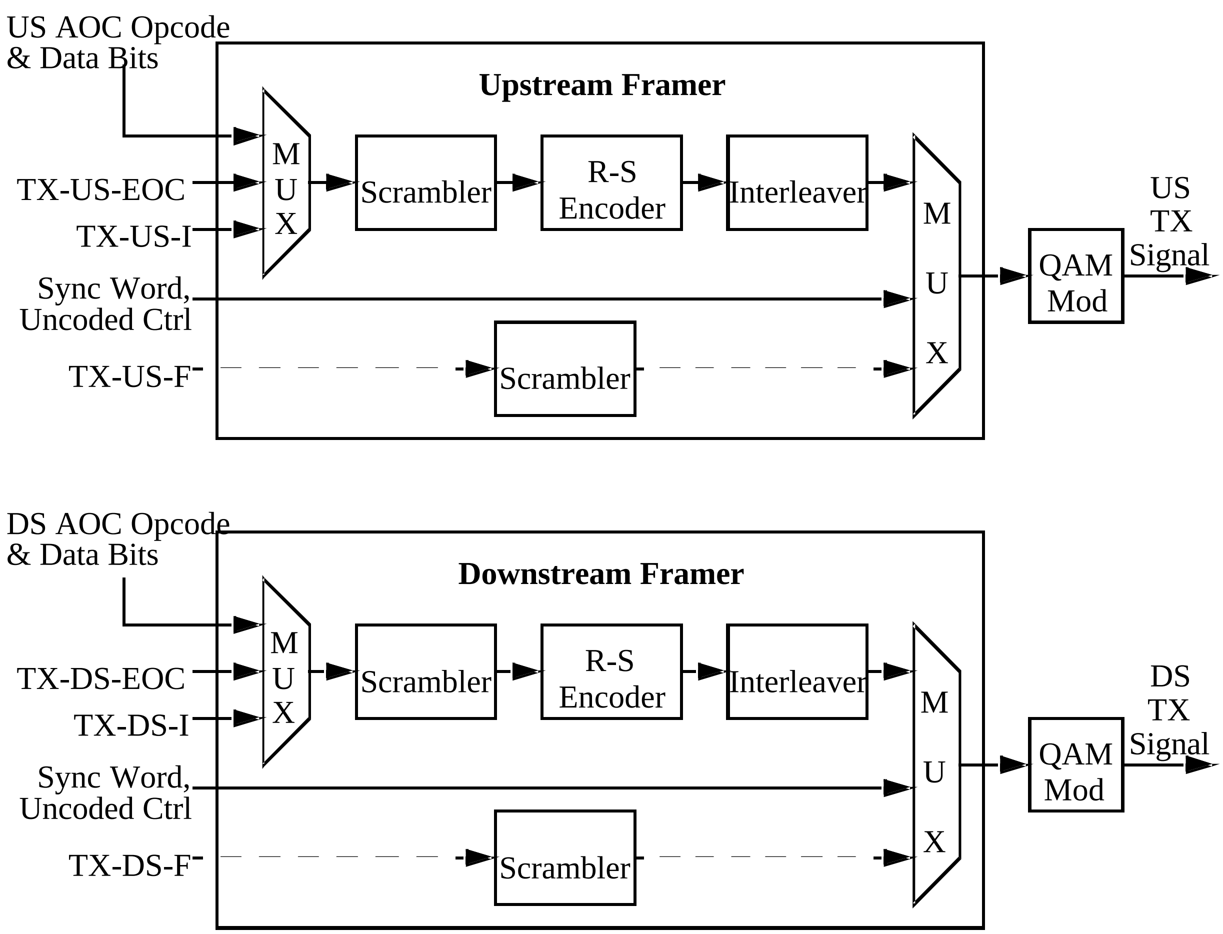


Figure 27 - Upstream and Downstream Codeword-Based Framer Functional Block Diagrams

5.3.1.4.2.2 Class 1 Frame Format

The Class 1 frame format defines the order in which various bits are output from the framer to the PMD sub-layer, and the type of processing that each transport stream is to encounter. This section describes two Class 1 framing formats, one that must be supported by all ATU-Cs and ATU-Rs, and one that may optionally be supported.

5.3.1.4.2.2.1 Mandatory Class 1 Frame

The frame format requiring mandatory support is shown in Figure 28. All of the entities shown in Figure 28 are octets. The mandatory frame contains a 2-octet sync word, a 1-octet uncoded control word, a 2-octet AOC word, a variable number of Coded Payload octets, and 16 octets of FEC Redundancy. The 2-octet AOC word, the Coded Payload octets, and the 16 octets of FEC redundancy together constitute a Reed-Solomon codeword of length *N* octets. The allowed values of *N* are all odd integers satisfying $137 \le N \le 253$. The default value for *N* that all transceivers must support is 249. Other odd integer values of *N* satisfying $137 \le N \le 253$ are optional to support.

The frame fields in Figure 28 are derived as follows. For an octet-wide implementation of the payload interfaces, the coded payload octets shown in Figure 28 are the same as those transmitted/received across those interfaces (following scrambling). For a bit-wide (serial) coded payload interface, successive blocks of 8 scrambled bits are mapped into coded payload frame octets, with the first bit in each block transmitted/received across the interface assigned to the frame octet Most Significant Bit (MSB).

The Sync Word, Uncoded Control, and FEC Redundancy fields are filled with bits generated internally by the PTC sub-layer, with values described in subsequent subsections.

The contents of the AOC field are determined as follows. If the current AOC Opcode octet, described in Section 5.4.2.2.1, is such that its two MSBs have the binary value 11, then the two MSBs of the AOC frame field (prior to scrambling) are binary 11, and the remaining 14 bits contain the next scrambled 14 bits to be transmitted from the EOC streams. Alternatively, if the MSB of the current AOC Opcode is a zero, then the AOC frame field contains the present scrambled AOC Opcode octet followed by the present scrambled AOC Data octet. Finally, system operation with the two MSBs of the current AOC Opcode set to binary 10 is reserved for future definition and use.

This usage of the AOC frame field allows it to transport both the EOC streams and AOC initialization and adaptation messages, but not both at the same time. This does not represent a loss in useful system functionality since the AOC initialization and adaptation messages are used to modify parameters of the PTC and PMD sub-layers, which may result in the loss of transparency for the EOC streams anyway. Because of this, the system is not expected to respond to EOC flows while changes in PTC and PMD parameters are being negotiated or executed through AOC initialization and adaptation. In this sense, AOC initialization and adaptation message processing take precedence over EOC message transport and processing.

It is the responsibility of higher layer TC processing to source and sink bits at the correct rate to the payload and EOC frame fields.

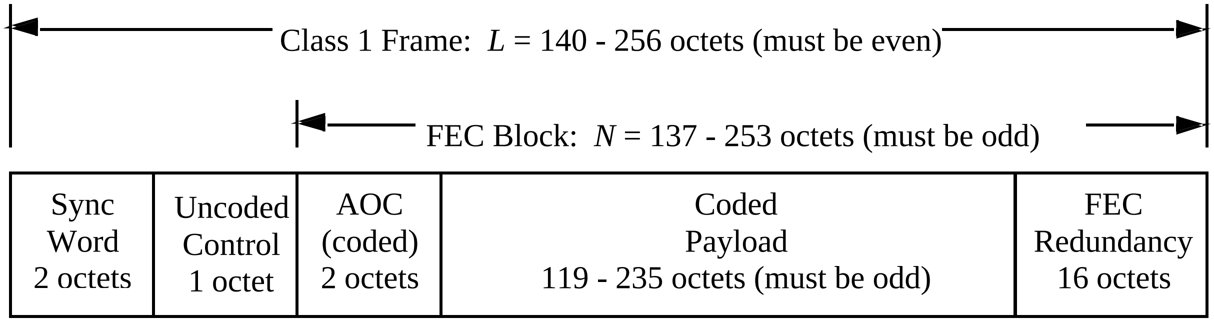


Figure 28 - Mandatory Class 1 Frame Format

For an interleaving depth of 1 (which corresponds to no interleaving), the octets within the AOC, Coded Payload, and FEC Redundancy fields of a given frame constitute a single Reed-Solomon codeword. For interleaving depths other than one, these same fields in a given frame contain octets from multiple Reed-Solomon codewords. Since the frame format indicates the order in which bits are transmitted by the QAM modulator, the effect of interleaving is to disperse the transmission of octets from a given Reed-Solomon codeword across multiple frames. Reed Solomon coding and interleaving are discussed in more detail below.

5.3.1.4.2.2.2 Optional Class 1 Frame

In certain circumstances, it may be desirable to disable Reed-Solomon FEC in a QAM RADSL link. As described in Section 5.4.2.2.1.3, ATU-Cs and ATU-Rs may disable their Reed-Solomon encoders and decoders. In this case, the Class 1 frame structure used for transmission onto the line is that shown in Figure 29. The Sync Word, Uncoded Control, and AOC fields are identical to those of the mandatory Class 1 frame with FEC shown in Figure 28. The payload field in this case has a fixed length of 246 octets. The Frame Check Sequence (FCS) is calculated across the AOC and Payload fields only, as described in Section 5.3.1.4.2.6, and represents the remainder polynomial in a CRC-8 calculation.

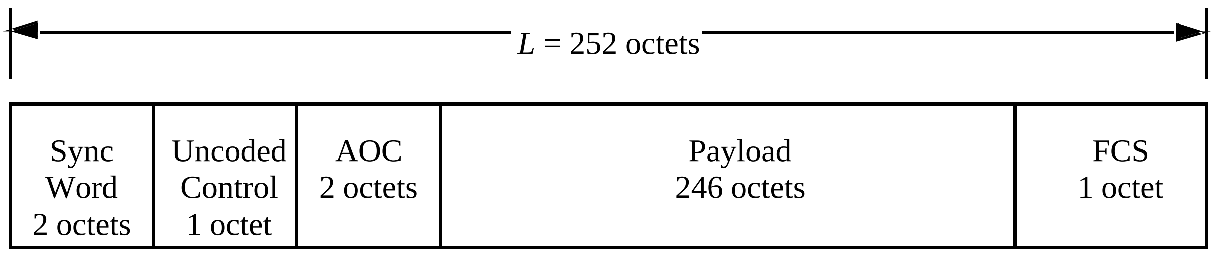


Figure 29 - Optional Class 1 Frame Format with FEC Disabled

5.3.1.4.2.3 Class 2 Frame Format

The Class 2 frame format defines the order in which various bits are output from the framer to the PMD sub-layer, and the type of processing that each transport stream is to encounter. ATU-C or ATU-R support of the Class 2 frame format is optional.

The Class 2 frame format described in this section has the following features:

– The frame allows the transport of uncoded payload along with the coded payloads, up to approximately 50% of overall payload capacity.

– The uncoded payload is distributed throughout the frame so as to minimize the associated transport latency.

– The Class 2 frame structure by itself allows the delineation of Reed-Solomon blocks, and the payload and parity within those blocks, so that an additional layer of framing is not needed.

The Class 2 frame format is shown in Figure 30. This frame is identical to the Class 1 frame of Figure 28; except that Uncoded Payload octets are alternated with the Reed-Solomon codeword octets. Specifically, the frame consists of *L* octets, and starts with the 2-octet Sync Word followed by the 1-octet Uncoded Control field. The remainder of the frame consists of alternating groups of uncoded payload and Reed-Solomon codeword octets.

When a Class 2 frame structure is requested over the AOC initialization and adaptation channel, the three integers *L*, *U*, and *C* are specified. As mentioned above, *L* indicates the total number of octets in the Class 2 frame. Following the Uncoded Control octet is *U* octets of Uncoded Payload. Following this is *C* octets of Reed-Solomon codeword. As shown in Figure 30, the transmission of *U* Uncoded octets alternates with *C* Reed-Solomon octets until the end of the *L*-octet frame is reached. The last group of *f* octets in the frame may be either Uncoded Payload or Reed-Solomon octets, and need not be the full *U* or *C* octets long. Reed-Solomon codeword octets are transmitted in the same order as in the Class 1 frame shown in Figure 28, i.e., 2 octets of AOC, followed by the Coded Payload octets, followed by the 16 octets of FEC redundancy.

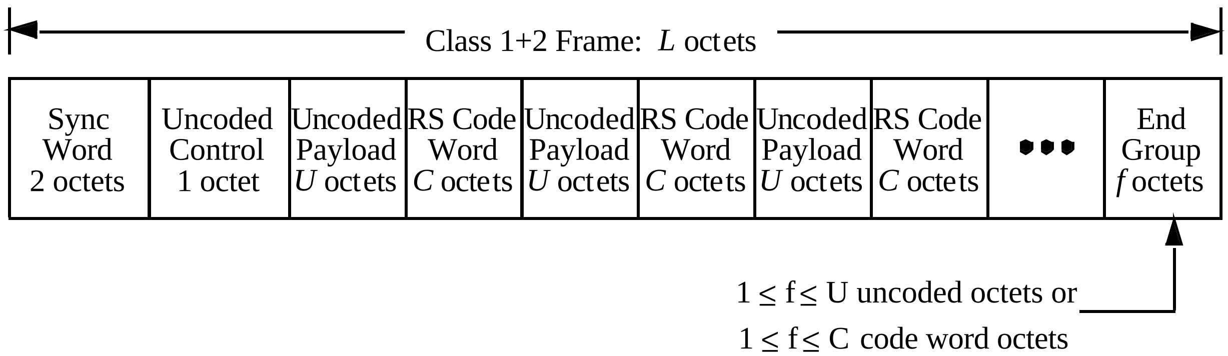


Figure 30 - General Class 2 Frame Structure

Frames of length L = 252 octets are mandatory to support, while support for other values of L are optional. Only certain values of L, U, and C are valid for a Class 2 frame. For L = 252 octets, all valid combinations of U and C are mandatory to support. An (L,U,C) triplet is valid if and only if it satisfies all of the conditions listed in Equations (25) through (32) below.

(25) $$140 \le L \le 256$$

(26) $$U \le C$$

(27) $$U \le 126$$

(28) $$C \le 253$$

The number of octets per Reed-Solomon codeword is denoted as N where

(29) $$N = C\left\lfloor \frac{L-3}{U+C} \right\rfloor + \Psi\left\{ L - 3 - U - (U+C)\left\lfloor \frac{L-3}{U+C} \right\rfloor \right\}$$

with

(30) $$\lfloor x \rfloor = \text{greatest integer} \le x$$

and

(31) $$\Psi(x) = \begin{cases} x, & x \ge 0 \\ 0, & x < 0 \end{cases}$$

N must be odd and satisfy

(32) $$137 \le N \le 253$$

Finally, notice that the Class 1 frame can be considered a special case of the Class 2 frame, with U = 0.

5.3.1.4.2.4 Frame Synchronization

Frame synchronization is achieved through the 2-octet Sync Word. The value of the Sync Word for both upstream and downstream transmission is 0x3F0C.

5.3.1.4.2.5 Uncoded Control

Except for the LSB, the Uncoded Control field in all Class 1 and Class 2 frames is for future specification. In the interim, the other bits may be used for vendor-specific purposes.

In the downstream direction, the LSB of the Uncoded Control field contains the bit c_trig. The usage of this bit is described in section 5.4.2.2.2.4. In the upstream direction, the LSB of the Uncoded Control field contains the bit dying_gasp. This bit is set to 0, unless a loss of ATU-R functionality is imminent, in which case it is set and held at 1 until the ATU-R is reset.

5.3.1.4.2.6 Frame Check Sequence

For the optional Class 1 frame without FEC shown in Figure 29, a Frame Check Sequence (FCS) is calculated across the AOC and Payload frame fields. The FCS octet shown in Figure 29 is the remainder resulting from a CRC-8 calculation on these fields, with the MSB of each octet the first applied to the CRC generator. The CRC-8 generator polynomial is given by

(33) $$G(x) = x^8 + x^2 + x + 1$$

The CRC generator is initiated to all 1's at the beginning of each frame and the result is bit-wise inverted before appending it at the end of the frame.

5.3.2 ATM/Packet TC Mapping

TC mapping may include frame-based mapping, direct-cell mapping, or direct-packet mapping.

5.3.2.1 Frame-Based Mapping

5.3.2.1.1 Physical Layer Frame Format

The format of the frame and its fields are shown in Figure 31 and Table 5.

	Bit							
Octet	1	2	3	4	5	6	7	8
1	Sync Word (7 bits)							FEBE
2-54	ATM cell 1							
	ATM cell 2							
	ATM cell 3							
	ATM cell 4							
	ATM cell 5							
	ATM cell 6							
	ATM cell 7							
373-425	ATM cell 8							
426	LPR	Reserved						
427	EOC							
428-430	Growth							
431	NTR							
432	CRC-6						RDI	Reserved

Figure 31 - Frame format

Table 5 - Fields of the frame

Frame Octet Number	Frame Bit Number	Number of Bits	Description
1	1–7	7	Frame Sync Word
	8	1	Far End Block Error Indicator (FEBE)
2–54	9–431	424	Payload: ATM cell 1
55–107	432–855	424	Payload: ATM cell 2
108–160	856–1279	424	Payload: ATM cell 3
161–213	1280–1703	424	Payload: ATM cell 4
214–266	1704–2127	424	Payload: ATM cell 5
267–319	2128–1551	424	Payload: ATM cell 6
320–372	2552–2975	424	Payload: ATM cell 7
373–425	2976–3400	424	Payload: ATM cell 8
426	3401	1	Dying Gasp Indicator
	3401–3408	7	Reserved (all 0's)
427	3409–3416	8	EOC
428–430	3417–3440	24	Reserved: Growth (all 0's)
431	3441–3448	8	Reserved: NTR (all 0's)
432	3449–3454	6	Cyclic Redundancy Check (CRC-6)
	3455	1	Remote Defect Indication (RDI)
	3456	1	Reserved (all 0's)

5.3.2.1.2 Frame Fields

5.3.2.1.2.1 Bit Order

The frame is transmitted starting with the lowest numbered octet. Octets follow sequentially to the highest numbered octet. Within each octet, the lowest numbered bit (MSB) is transmitted followed by the higher numbered bits. Let b(j,k) denotes the *k*th bit of the *j*th octet. The bit transmission sequence is {[b(j,k),k=1 to 8], j=1 to 432}.

5.3.2.1.2.2 Frame Sync Word (Octet 1)

The Frame Sync word is a seven-bit Barker code used to determine frame alignment.

Table 6 - Frame Sync Word

Bit Position 1 transmitted first	2	3	4	5	6	7 transmitted last
1	1	1	0	0	1	0

5.3.2.1.2.3 Far End Block Error Indicator (FEBE)

The FEBE indicator is asserted in the near-end transmit frame to indicate that one or more near-end receive frames have incurred the CRC anomaly since the previous near-end transmit frame. A value of ‘1’ indicates FEBE is asserted; ‘0’ indicates no errors.

The FEBE indicator is used to report errors to the febe-i anomaly in the performance and surveillance services. The febe-f anomaly is not used with Frame Mapped mode.

5.3.2.1.2.4 Payload

Eight ATM cells are transported per frame in octets 2–425. Time order of the cells (when required) correlates to the transmit bit/octet order in the frame. Idle cells may be inserted as fill.

All payload cells are required to have valid HEC in accordance with I.432. The receive framer validates the HEC on all valid receive frames. HEC validation errors are considered HEC anomalies.

5.3.2.1.2.5 Remote Defect Indicator (RDI)

The near-end transmit framer asserts the RDI indicator in the transmit frame whenever its near-end receive framer is in the Out of Frame (OOF) state. An indicator value of ‘1’ indicates Alarm; ‘0’ indicates no Alarm.

The RDI indicator is used to report the rdi defect in the performance and surveillance services.

5.3.2.1.2.6 Loss of Power Indicator (LPR)

LPR is only supported from the ATU-R towards the ATU-C. The ATU-R sets this field to ‘1’ if loss of power is detected. During normal operation, the ATU-R sets this field to ‘0’.

The LPR indicator is used as input to report the lpr defect in the performance and surveillance services. Reception at the ATU-C of a single valid frame with an LPR indicator set causes the far-end lpr defect to be asserted against the ATU-R. This lpr defect is cleared when the ATU-C receives 3 valid frames from the ATU-R and all other far-end defects are cleared.

5.3.2.1.2.7 Reserved (bits 2-7 in Octet 426)

Bits 2 - 7 in byte 426 are reserved for possible future features enhancements. Currently, the transmit framer sets bits 2 -7 in byte 426 to “0” in the transmitted frames.

5.3.2.1.2.8 EOC (Octet 427)

Octet 427 is reserved for use as an Embedded Operations Channel.

5.3.2.1.2.9 Growth (Octets 428-430)

Octets 428–430 are reserved for possible future features enhancements. Currently, the transmit framer sets all bits in the Growth field to all zeros in the transmitted frames.

5.3.2.1.2.10 Network Timing Reference (NTR)

Octet 431 is reserved for possible future use as a Network Timing Reference, such that can be conveyed over the link by locking the PMD and network clocks. Currently, the transmit framer sets all bits in the NTR field to all zeros in the transmitted frames.

5.3.2.1.2.11 Cyclic Redundancy Check Field (CRC-6)

Bits 1–6 (the six most significant bits) of octet 432 constitute the Cyclic Redundancy Check (CRC-6) field of each frame. The CRC-6 bits are calculated on bits 9 – 3448 (i.e. octets 2 - 432 inclusive) of the frame using the CRC generator polynomial is $1 + x + x^6$. Note that the FEBE and RDI fields are ex*cluded* from the CRC-6 computation.

5.3.2.1.3 Framing

The Frame Mapped mode framing algorithm consists of 3 states: out-of-frame (OOF), SYNC, and in-frame (IF). The state diagram for framing described below is provided as an illustration:

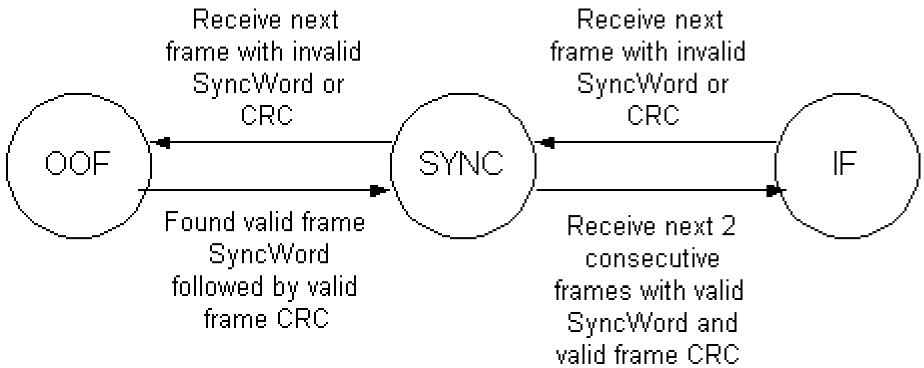


Figure 32 - Framing State Diagram

The framing state machine initializes to the OOF state. The receive framer searches the incoming bit stream for a valid frame Sync word to determine frame alignment. When a valid Sync word is detected, CRC-6 is computed over the received frame. If the CRC-6 is valid, the receive framer transitions to the SYNC state. Otherwise, the frame continues to search for a frame alignment in the OOF state. Frame alignment is only adjusted in the OOF state. In the SYNC state, the next 2 frames must be valid in order for the framer to transition to the IF state. Once in-frame operation has been achieved, any Sync word or CRC-6 error causes the framer to re-enter the SYNC state. Any further frame errors in the SYNC state cause the framer to revert back to OOF.

5.3.2.2 Direct Cell Mapping

The Transmission Convergence Layer Description defines the ATM cell-based framing structure utilized on the interface.

Specifically the Transmission Convergence Layer Description:

- describes the ATM based transmission convergence sublayer employed on both the upstream and downstream data paths;
- describes the F3 OAM cell flow between the ATU-C and the ATU-R, defines the content of the F3 cell structure;
- describes the Performance Monitoring features contained within the definition; and
- describes the Embedded Operations Channel (EOC) functions of the F3 cell.

5.3.2.2.1 Transmission Convergence Layer Reference Model

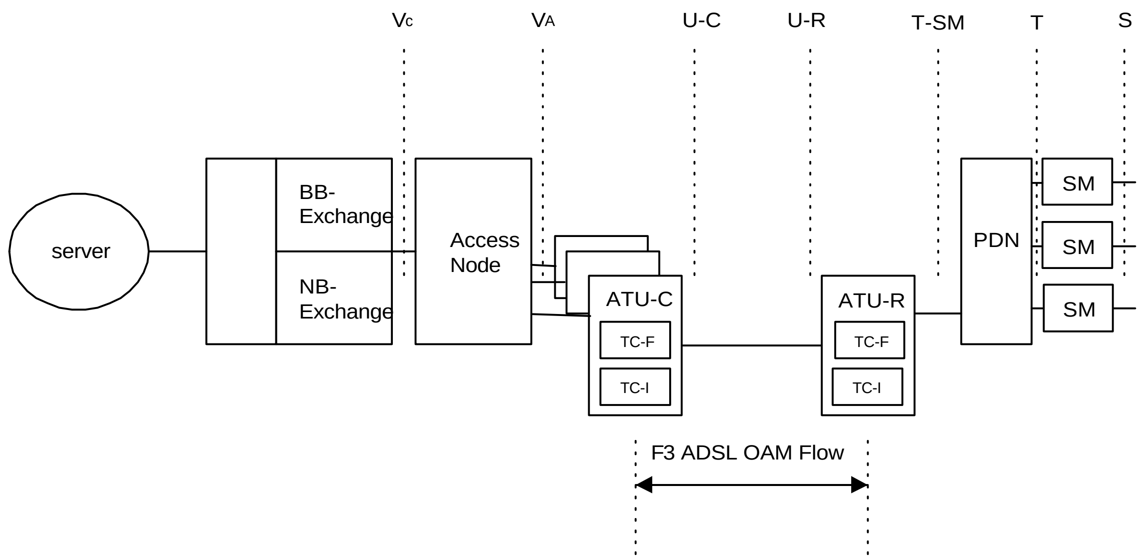


Figure 33 - Network Reference Model

Figure 33 illustrates the generally accepted reference model for a network supplying ATM services over ADSL transport. This document proposes specifications for the U interface PMD and TC sublayers, as well as an F3 OAM flow. The implementation of multiple latency paths (TC layers) is optional.

5.3.2.2.2 PMD-TC Sublayers

5.3.2.2.2.1 Transfer Rate

The data transfer rate at the U interface varies between 7168 kbps and 640 kbps in the downstream U-C to U-R direction, and between 1088 kbps and 90.6 kbps in the U-R to U-C direction. The physical layer may derive its timing from the signal received across the Vc interface, or provide it locally.

5.3.2.2.2.2 Transmission Frame Adaptation

ATM Cells are carried over the U interface as a continuous stream of cells in a cell based format. Cell structure is as recommended in ITU-I.361.

5.3.2.2.2.3 Contiguous Transmission

Cells are to be transmitted contiguously, with no special or intervening symbols.

5.3.2.2.2.4 Cell Delineation

Cell-header delineation provides identification of the cell boundaries at the receiver.

Full cell-header delineation is required in the TC layers at both ATU-C and ATU-R receivers. It should be implemented as specified in ITU-I.432.4.5, with ALPHA=7 and DELTA=8 as recommended by ITU-I.432 for cell-based streams. (It is up to the implementer to leave the ALPHA and DELTA parameters variable, since their modification will not affect inter-operability.)

Downstream path (U-C to U-R) should use the Self-Synchronizing Scrambler (SSS) as specified in ITU-I.432.

Upstream path (U-R to U-C) should also use the Self-Synchronizing Scrambler (SSS).

5.3.2.2.2.5 HEC Header Sequence Generation/Verification

As the SSS is used in both downstream and upstream paths, no transmit header error check sequence modifications are needed. Header verification at the receiver is not required to perform single bit error corrections. HEC generation where necessary will be as described in ITU-I.432 section 4.3.2 including the recommended modulo 2 addition of the pattern 0101010101b to the HEC bits. The generator polynomial coefficient set used and the HEC sequence generation procedure will be in accordance with ITU-I.432.

5.3.2.2.2.6 Cell Rate Decoupling

Idle cells are inserted by each DSL transmitter for the purpose of cell rate decoupling, and are simply discarded at the receiver. The cell header fields for idle cells will be coded as specified in ITU-I.432.

5.3.2.2.2.7 Inband Dying Gasp Indication

The Dying Gasp indication is transmitted from the ATU-R to the ATU-C upon detecting loss of power. Typical implementations provide only 10s of milliseconds of indication.

In this specification, Dying Gasp will be indicated by continuously transmitting the bit pattern 01010101b for as long as possible after detection by the ATU-R of loss of power. The pattern is transmitted repetitively without cell headers.

Detection of the dying gasp pattern at the ATU-C is considered valid after 80 consecutive instances of the pattern have been observed at the receiver, with no more than one bit received in error. The ATU-C should latch this indication, to be further validated with subsequent Loss of Cell header delineation (LOC) and Loss of Signal (LOS). Should the validation with LOC and LOS fail, no dying gasp is indicated, and the latched indication is retired.

The Dying Gasp transmission by the ATU-R will bypass the transmit scrambler (it is assumed here that the PMD layer implements its own scrambler.) Thus, the dying gasp detector can be implemented in parallel with the header delineation mechanism at the receiver.

No requirement is made to transmit Dying Gasp indications from the ATU-C, or to detect the pattern at the ATU-R.

Where several logical streams are present (fast, interleaved, etc.), this pattern should be transmitted in all available paths. Note that the latency of the interleaved paths, if comparable to the indication time provided by the power supply storage capacity, may prevent the indication from ever making it to the line.

5.3.2.2.3 Cell Based ADSL F3 OAM Flow

A cell based F3 OAM flow would convey information relating to configuration and performance monitoring between the ATU units terminating an individual U interface. The cells which comprise this flow are inserted and extracted as overhead by the ATUs, and are not passed over the V-C interface (between the ATU-C and network multiplexing equipment) or the T/S interface (between the ATU-R and customer data equipment). Both these reference points are described in ANSI T1.413, Section 4.1 “System Reference Model.”

The F3 flow contains an embedded operations channel (EOC) that duplicates functionality present in the T1.413 standard.

In the case where several logical paths exist simultaneously on the ADSL line (e.g. fast and interleaved,) the F3 flow should be carried on only one of the logical paths, the fast path being the default. A provisioning option allows the user to select an alternate path for the F3 flow, should they wish to.

The format for an ADSL F3 information cell is diagrammed in Figure 34. The functions provided by this F3 flow are outlined in detail below. The field definitions are in brief:

- F3 Cell Format Identifier - When set to pattern 0x01, indicates conformance to the F3 cell format identified in the Figure 34. Different values in this field could identify other variations of the ITU-I.432 F3 definition, and would cause the ATU-C unit to default to the 0x01 format identified below for the downstream path.
- PSN - PL-OAM Sequence Number as per ITU-I.432.
- FUNC. CTL. BIT MAP - A bit mapped field that allows payload in this F3 cell to be selectively included/excluded.

- EOC_PTR - This single-octet field contains a pointer to the first valid octet of Embedded Operations Channel bandwidth within this F3 cell.
- STATUS IND. BIT MAP - A bitmapped field containing status indications for loss of signal (LOS), loss of cell boundary (LOC), and loss of OAM cells (LOM).
- 8 kHz REFERENCE - A two-octet field used to transfer an 8 kHz network clock reference from the ATU-C to the ATU-R for use in supporting some AAL1 CBR traffic types.
- NIC - Number of included cells is a 10-bit count (as defined by ITU-I.432) of the number of cells included between the previous and the present F3 cells (excluding the F3 cells themselves.)
- MBS - Monitored Block Size indicates the number of cells used to calculate a single EDC.
- NMB-EDC - Number of Monitored Block Error Detection Code checksums to follow - indicates the number of blocks covered by this F3 cell.
- CRC-Bn - Error Detection Code residual (CRC value) for Block n.
- FEBE_count (n) Far End Block Error Count since last F3 cell for time interval n. Here time interval “n” is the current (most recent) interval, “n-1” is the previous interval, and “n-2” is the least recent interval. Two previous intervals and one current interval are present in an attempt to keep this data contiguous in the event of lost F3 cells.
- FEBE_mark - Contains three bit-mapped fields, only one of which should be set at any time. When set, the bit indicates that the FEBE_count field above it corresponds to the last count to be reported in its one-second interval. The next time period FEBE_count will therefore represent the first reported FEBE_count for the next 1-second interval.
- EOC Byte n - The actual Embedded Operations Channel.
- CRC - A cyclic redundancy checksum covering the payload bytes of this F3 cell.

H1	GFC	VPI 7:4	
H2	VPI 3:0	VCI 15:12	
H3	VCI 11:4		
H4	VCI 3:0	PTI	CLP
H5	HEC		
1	F3 Cell Format Identifier		
2	PSN		
3	FUNC. CTL. BIT MAP		
4	EOC_PTR		
5	STATUS IND. BIT MAP		
6	Reserved for 8 Khz Ref.		
7	Reserved for 8 Khz Ref.		
8 9	NIC		
10	MBS		
11	NMB-EDC		
12	CRC_B1		
13	CRC_B2		
14	CRC_B3		
15	CRC_B4		
16	CRC_B5		
17	CRC_B6		
18	CRC_B7		
19	CRC_B8		
20	CRC_B9		
21	CRC_B10		
22	FEBE_count (n)		
23	FEBE_count (n-1)		
24	FEBE_count (n-2)		
25	FEBE_mark		
26-43	Open for PMON or EOC use		
44	EOC Payload 1		
45	EOC Payload 2		
46	EOC Payload 3		
47 48	CRC-10		

Figure 34 - ADSL OAM F3 Cell Format

5.3.2.2.3.1 Header Fields

5.3.2.2.3.1.1 Cell Address

The F3 cell will be set to the VPI/VCI combination set forth in ITU-I.361 and ITU-I.432, namely (0,0).

5.3.2.2.3.1.2 Payload Type Indicator

For an F3 PL-OAM flow cell, the payload type indicator field should be set to value 100b or 4.

5.3.2.2.3.1.3 Use of GFC and CLP controls

Generic Function Control (GFC) and Cell Loss Priority (CLP) fields are to be set to 0000b and 1b respectively, per ITU-I.361 and ITU-I.432.

5.3.2.2.3.2 F3 Cell Format Identifier

A reserved field in the ITU-I.432 definition is used here to identify variants of that definition. The F3 cell format specified herein varies to the extent that EOC, Status Indicator, and 8 kHz Reference transfer functions have been added. Thus, the first F3 cell payload octet on the ADSL U interface carries a value other than the idle pattern that ITU-432 indicates. See Table 7.

Table 7 - F3 Cell Format Identifier

Identifier Value	F3 Cell Type
0x00	Reserved
0x01	ADSL U Interface F3 cell format as specified herein.
0x02 - 0xFF	Reserved

5.3.2.2.3.3 PL-OAM Sequence Number (PSN)

An eight-bit field, which increments in each successive OAM cell, is designed to have a sufficiently large count so as to always be able to distinguish cell loss events. Counting is done modulo 256.

5.3.2.2.3.4 Function Control Bit Map (FCBM)

The Function Control Bit Map register is a seven-bit field. It is bit-mapped by the F3's OAM cell function, plus one bit used for Embedded Operations Channel (EOC) flow control indication. The function control bits allow F3 and OAM features of the cell to be selectively activated, making it possible to have a different cell rate for each function independently. In normal operation, it is expected that all features of this F3-OAM cell (except 8 kHz ref.) will remain active in each occurrence of the cell. The bit reserved for EOC flow control with opposite-end ATU equipment is not used at this time, but may be implemented in future equipment to tell the opposite-end ATU to cease transmitting until the local unit is ready to accept more data. If implemented, the active hold-off state is a "one." The actual allocation of bits to functions is shown in Figure 35.

7	6	5	4	3	2	1	0
EOC Flow Control	Reserved	Reserved	EOC Enable	Block Based PM Enable	NIC NMB MBS-EDC Enable	8 Khz Network Reference Enable	Status Indicators Enable

Figure 35 - Function Control Field Bit Assignments

Function control bits should be set to "1" to indicate an active F3-OAM function, and "0" for inactive. Reserved bits should be set to the "0" or inactive state. For normal operation, standard configuration is 0x1D (Status Indicators, NIC/NMB/MBS, Block-Based PM, and EOC enabled, 8Khz Ref. Disabled).

Bit Function meaning is as follows:

Status Indicators Enable - Asserting this bit inserts the Status Indicator Bit Map (SIBM) field into the F3 cell, and a '0' in this bit disables the SIBM byte. 0x6A would be read from the SIBM field in the F3 cell in the case of this bit being disabled.

8 kHz Network Reference Enable - Asserting this bit inserts the 8 kHz Network Reference fields into the F3 cell, and a '0' in this bit disables that function of these 2 bytes. Note that this function is not supported at this time, and 0x6A data will be read from the 8 kHz reference field when disabled.

NIC/NMB/MBS Enable - Asserting this bit inserts the NIC, NMB, and MBS fields into the F3 cell, and a ‘0’ in this bit deletes those fields, returning 0x6A data in these bytes instead.

Block-Based PM Enable - Asserting this bit inserts a CRC-8 byte into the F3 cell for each block monitored, as defined by the number of monitored blocks (NMB). This enable is meaningless unless used in conjunction with the NIC/NMB/MBS enable bit, as the far end will not be able to interpret the CRC value and how many blocks of CRC-8’s to check, unless values for MBS and NMB are known. If this function is disabled, a 0x6A value will be contained in consecutive bytes for the number of blocks identified in the NMB's.

EOC Enable - Asserting this bit inserts the EOC payload bytes into the F3 cell, and a ‘0’ in this bit turns off the EOC payload support, returning 0x6A data in the EOC payload area instead.

EOC Flow Control Bit - Asserting this bit tells the transmitting end to hold off transmission of any more EOC transmission until the receiving end is ready for more data. EOC traffic will not use this bit at this time, and this bit will normally remain a ‘0’ (ignored).

5.3.2.2.3.5 Status Indicator Bit Map (SIBM)

The status indicators field is one octet wide, mapped functional status to bits. It is used to provide status of the local receiver to the unit transmitting at the far end. Status Indicator Field bits are to be filled in by the transmitter originating the F3 cell, based on its receiver/unit states. The allocation of status bits to receiver sections is shown in Figure 36.

7	6	5	4	3	2	1	0
Reserved	Reserved	TP-AIS	TP-FERF	Loopback Active	Loss of F3-OAM (LOM)	Loss of Cell Delineation (LOC)	Loss of Signal (LOS)

Figure 36 - Status Indicator Field Bit Assignments

Bit Function meaning is as follows:

LOS (Loss of Signal) = “1” indicates loss of valid signal at the receiver.

LOC (Loss of Cell Delineation) = “1” indicates loss of cell delineation at the receiver.

LOM (Loss of F3 OAM Cell) = “1” indicates no valid F3 cells received in the last 10 expected F3 cell periods

Loopback Active = “1” indicates that a loopback or other service-affecting diagnostic feature is presently active on this module.

TP-FERF (Transmission Path Far End Receive Failure) - operate as defined in ITU-I.432. Reserved bits are to be transmitted in the “0” state.

TP-AIS (Transmission Path Alarm Indication Signal - operate as defined in ITU-I.432. Reserved bits are to be transmitted in the “0” state.

5.3.2.2.3.6 8 kHz Network Reference Transfer

In order to support certain AAL1 CBR traffic types at the S interface, it may be necessary to supply at the CPE an 8 kHz reference clock that can be traced to a network clock source. The F3 cell format defined herein reserves two octets for the periodic transfer of information necessary to provide a frequency locked clock transfer. Two octets are reserved, so that at very slow F3 cell rates reference information will not be lost due to counter rollover. A 16-bit counter transfer type implementation using these two octets will be sufficient for all programmable F3 cell rates. The method used to perform the frequency-lock transfer is left for further discussion, and is currently not supported.

Embedded Operations Channel (EOC)

A communications channel is provided by this cell in both the upstream and downstream directions. The principle features of the EOC are:

- variable bandwidth per F3 cell (can be used to keep the EOC bit rate relatively constant over a wide range of PMD bit rates, also can be used to slow the EOC for low cost ATU implementations utilizing slower microprocessors, as well as allowing the EOC to capture up to 85 percent of the PMD bandwidth for applications like software upgrade loading, etc.) and
- link layer protocol follows RFC 1662 “PPP in HDLC-like Framing.”

5.3.2.2.3.6.1 EOC_PTR

This one-octet field holds a pointer to the first valid octet of EOC physical layer bandwidth within the current F3 cell. The pointer field will hold the number of the first information field octet containing EOC payload within this F3 cell. In keeping with the notations used within ITU-I.432, octets within the F3 cell information field are numbered 1-48, with the first octet after the header error check octet being numbered 1. If no EOC payload is available to transmit, then the EOC_PTR will contain 0x00 (0 octets of EOC payload are contained in the current F3 cell.)

Note that the EOC_PTR does not always point to the beginning of the F3 cell payload that is available/configured for EOC use. For example, if 10 octets of the F3 cell are currently configured as available for EOC payload (octets numbered 37 through 46) then the valid EOC_PTR field values are 37 through 46, and 0. EOC_PTR set to 37 would indicate 10 bytes of EOC payload in this F3 cell, EOC_PTR set to 46 would indicate only one byte of EOC payload within this F3 cell, and EOC_PTR set to 0 indicates that no EOC payload was available to transmit at the time this F3 cell was generated.

This feature of the F3 cell is useful for implementation purposes; specifically, it allows the higher layer processes which generate the EOC payload to be significantly decoupled from the F3 cell generator process. Without this feature - complex controls and process deadlines are needed to ensure that the F3 cell generator has received enough octets from the EOC payload process before F3 cell transmission time occurs. (If 10 octets are configured as EOC bandwidth, then at least 10 octets must be available from the EOC payload process each time an F3 cell is to be generated - using this feature, if only 3 octets are available when the F3 cell is generated, then only 3 octets will be transmitted in the EOC payload area.) It also eliminates the need to scan through an entire EOC payload field of flags for every F3 cell, when no EOC commands are being sent (by indicating 0 octets using the EOC_PTR.) The transmission of full EOC payload fields containing flags is not precluded however (for simple HDLC transmitter solutions, the receiver should negotiate less EOC bandwidth per F3 cell in this case, to reduce the overhead introduced by the continuous flag stream between commands.)

5.3.2.2.3.6.2 EOC Payload

The EOC payload area is a variable number of octets, always justified toward the end of the cell. It may occupy anywhere from one octet (number 46,) to all of the octets from the last enabled F3 cell function to number 46. In the F3 cell diagram shown in Figure 34, octets 26 through 46 are available for use. If the function control bit map were to specify that Block-Based PM functions were disabled, then octets 12 through 46 would be available for the EOC. Similarly, if the NIC, MBS, and NMB-EDC fields can be disabled, octets 8 through 46 become available for EOC use. If the Status Indicators and 8 kHz reference functions can be further disabled, maximum EOC payload bandwidth of 42 octets per F3 cell is available (octets 5 through 46). In normal operation, it is expected that all features of this F3-OAM cell will remain active in each occurrence of the cell (NIC, MBS, NMB-EDC, and Status Indicators), with the exception of the 8 kHz reference function.

It is desirable in the implementation to limit the number of EOC octets transmitted per F3 cell to less than the total available in some cases. This is to ensure that EOC payload streams on higher speed physical layers will not overwhelm implementations utilizing low horsepower microprocessors at the receiver. The appropriate bandwidth per F3 cell number can be negotiated between transmitter and receiver through communications in higher layers, or alternatively - a fixed EOC payload rate in octets/second could be specified herein, and the transmitter would simply just meet that rate as best it could at each physical layer rate.

Order of transmission is such that successive message octets are allocated to EOC payload octets numbered in increasing order. Following the conventions of ITU-I.361, bits within each octet are transmitted in decreasing order, starting with bit 8.

For example, 5 octet message [0x7E 0x01 0x02 0x03 0x04 0x05 0x7E], if transmitted by itself in a single F3 cell, would be allocated to the EOC payload octets (shown in Figure 37).

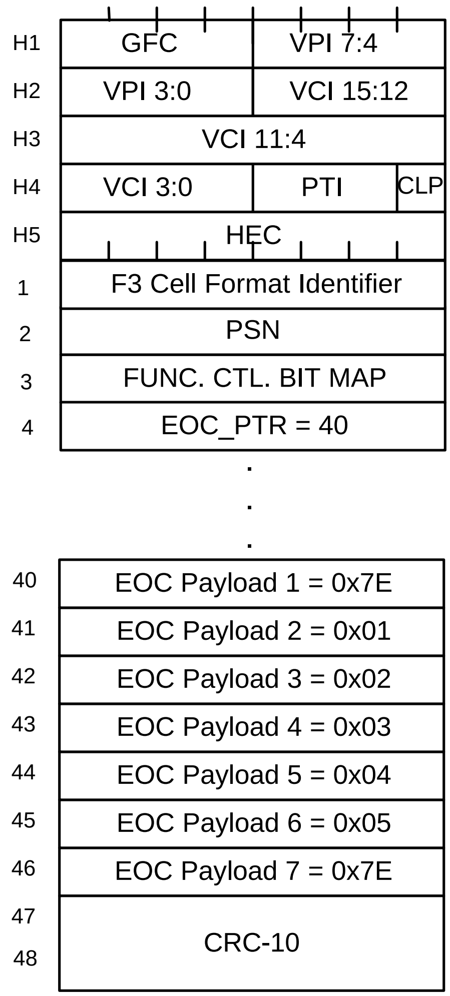


Figure 37 - EOC Payload Mapping into F3

5.3.2.2.3.7 F3 Cell Rate Descriptors

5.3.2.2.3.7.1 Number of Included Cells (NIC) Field

The number of included cells field indicates the total number of cells transmitted between the last F3 cell and this one. It does not include in its count either the previous or the current F3 cell. Per ITU-432, this 10-bit field should always contain a number in the range 26 to 512 (No more than 1 PL-OAM cell in 27 cells, and no fewer than one in 513 cells). The NIC is computed as the Monitored Block Size (MBS) multiplied by the Number of Monitored Blocks (NMB). This gives a NIC value of 100 for all but the slowest DSL rates (refer to Table 8 - F3 Cell Parameters). Figure 38 details the mapping of the 10-bit NIC to the two octets that it occupies.

7	6	5	4	3	2	1	0	
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	NIC[9:8]		8
NIC[7:0]								9

Figure 38 - F3 NIC Field

5.3.2.2.3.7.2 Monitored Block Size (MBS) Field

The monitored block size field identifies the number of cells that have been included in each EDC checksum value. The minimum number of cells that could be covered by a single checksum, would be the 26 cells specified by ITU-I.432 as a minimum number of cells between PL-OAM cells. The largest number of cells that can be covered by a single EDC checksum is 255. The mapping of this value to its octet is shown in Figure 39. When the NMB-EDC field is 0 (the out of service state), the value of this field is meaningless and should not be interpreted. (See Figure 40.)

7	6	5	4	3	2	1	0	
MBS[7]	MBS[6]	MBS[5]	MBS[4]	MBS[3]	MBS[2]	MBS[1]	MBS[0]	10

Figure 39 - F3 MBS Field

5.3.2.2.3.7.3 Number of Monitored Blocks - Error Detection Code (NMB-EDC) Field

The number of monitored blocks field indicates how many checksummed blocks of cells have been monitored since the last F3 cell. There will be a number of EDC checksums included in the payload of this F3 cell, each one corresponding to one of the blocks having thus been monitored. Valid entries for this 8-bit field run from 1 to 31 (although per ITU-I.432, the entire octet is allocated). In the case where 31 is used, no EOC bandwidth is available. Zero may also be seen in the NMB field, during an out-of-service condition in which a continuous stream of F3 cells is being received - presumably for the purpose of maintenance or software upgrade. Per ITU-I.361, the mapping of bits to this field follows the most significant bit transmitted first rule as shown in Figure 40. See “Block-Based Performance Monitoring” for more details on the NMB field.

7	6	5	4	3	2	1	0	
NMB-EDC[7]	NMB-EDC[6]	NMB-EDC[5]	NMB-EDC[4]	NMB-EDC[3]	NMB-EDC[2]	NMB-EDC[1]	NMB-EDC[0]	11

Figure 40 - F3 NMB Field

5.3.2.2.3.8 Block-Based Performance Monitoring

To facilitate performance monitoring, the cell stream is segregated into blocks containing integral numbers of cells. A CRC is performed over each block, and communicated to the receiver at the far end using an F3 cell where it is compared with the CRC calculated over the received block. ITU-Bellcore-ANSI standards in the past have assumed a one-to-one correspondence between block CRC errors and bit errors, and that assumption is used herein as well.

The number of cells in a block is variable and the number of blocks monitored per F3 cell is variable. As these parameters are varied, the bandwidth incurred through the use of this method varies also. ITU-I.432 specifies that F3 cells should occur no closer than once every 27 cells, and no farther apart than once every 513 cells (3.7 % overhead to 0.2 % overhead respectively). The recommendations in this paper attempt to maintain the F3 cell overhead at a fixed 1.0 % overhead (1 F3 cell per 100 traffic cells). This appears to be practical for all except the slowest physical layer bit rates.

5.3.2.2.3.8.1 Block Size Determination.

ITU-G.826 defines block-based performance monitoring, and therein specifies that for the data rates available to ADSL systems, that block size should be somewhere between 2000 and 8000 bits. Block sizes for this ADSL system is typically 4240 bits, with actual block size values for various DSL rates shown in Table 8. The CRC8 algorithm employed by T1.413 transport systems will be used for the CRC over each block.

Each CRC covers all bits within a block between F3 cells, but does not cover any of the F3 cell itself which is guarded by its own CRCs.

(34) This CRC8 is computed as: $x^8 + x^4 + x^3 + x^2 + 1$

5.3.2.2.3.8.2 EDC Field Bit Map

The mapping of CRC checksum residuals to the EDC fields within the F3 cell is shown in Figure 41.

7	6	5	4	3	2	1	0
x7	x6	x5	x4	x3	x2	x1	x0

Figure 41 F3 Block CRC (EDC) Field

The loading of EDC-Checksum values into the F3 cell payload area will be such that values are transmitted from least recent block to most recent block (i.e., the least recent EDC value will occupy octet number 11, with the most recent EDC value followed by the FEBE).

5.3.2.2.3.8.3 Far-End Performance Reporting

The count of block errors having been received since the last F3 cell are tallied once per F3 cell, and communicated to the far end such that each end of the ADSL link can report full performance data for both ends. This information is transmitted in the Far End Block Error Count (FEBE_count) fields of the F3 cell. See Figure 42.

In each F3 cell, the FEBE count for the most recent monitoring period is sent, along with the FEBE counts for the preceding two monitoring periods. The redundant data is sent in an effort to maintain the continuity of this data flow through the loss of one or two successive F3 cells.

The FEBE count data must also be segregated into one-second windows by the monitoring end, as it is unlikely that the F3 cell rate in either path will fit well into one-second intervals. Seconds-based performance reporting is defined below. When the FEBE count for any monitoring period covers the end of a one second interval, only the block errors that occurred in the previous one-second period are to be reported in that FEBE count. The remainder of the block errors having occurred since the last F3 cell will be reported in the FEBE count for the next period.

A bit in the FEBE_mark field is set whenever any one of the three FEBE count values being reported represents the end of a one-second interval. There is a bit in the FEBE_mark field corresponding to each of the three FEBE count values (for time periods n, n-1 and n-2). The link end receiving the FEBE count information is free to synchronize the far-end one-second intervals with its own local one-second intervals for reporting purposes (through a buffering scheme).

When a buffering scheme is used to synchronize the far-end one-second-interval data with the local one-second-interval data, the buffer needs to be managed such that it is always empty at the beginning of any 15-minute-monitoring period. (If, for example, due to subtle clock rate differences between the local and remote systems, an extra one-second period remains in the buffer at the end of the 15-minute period, it should be read and included in the previous 15-minute period. This should only happen rarely.)

The size of the FEBE_count field was designed to accommodate the maximum number of errors that could occur within a reporting period. In the case of asymmetric line rates, the worse case is for maximum line rate downstream and minimum rate upstream. This definition is further subject to the constraint that no FEBE_count will contain counts for longer than a one-second period. This will help to keep the performance monitoring scheme more open. As such,

> At 7168 Kbps, 10 cells / block = 1691 Blocks / second
>
> and at 272 Kbps, 2 cells / block, and 14 blocks / F3 cell = 0.044 Sec/F3 cell.
>
> We need a FEBE_count field that can hold (2 * 1691 blocks/sec * 0.044 sec) = 149
>
> and an 8-bit field is sufficient to convey the FEBE count information.

Severely Defective Periods (SDP), as defined by ITU-G.826, can be created by events that are not reportable in this format (i.e. loss of an F3 cell at the receiver, etc.) and must be reported to the far end somehow. One bit is further allocated for each of the reported periods, to be set in conjunction with the one-second-mark bit for that field, should an event have happened during that one-second interval which caused it to become a Severely Defective Period. If a SDP is not indicated in conjunction with the one-second mark, this bit should be transmitted as 0.

The SDP bits are meaningless when their corresponding one-second mark bit is not set.

7	6	5	4	3	2	1	0	
FEBE_count [7:0]								FEBE_count

Reserved	Reserved	SDP Mark (n-2)	SDP Mark (n-1)	SDP Mark (n)	1 Sec. Mark in FEBE (n-2)	1 Sec. Mark in FEBE (n-1)	1 Sec Mark in FEBE (n)	FEBE_mark

Figure 42 - F3 Far End Block Error (FEBE) Fields

(Only one of the three FEBE_count bytes is shown.)

The mapping of FEBE information is then as follows: The three FEBE_count and one FEBE_mark fields always immediately follow the EDC fields (however many there are) in the F3 cell. Per ITU-I.361, *Broadband BISDN ATM Layer Specification*, the count values should be transmitted in decreasing order, starting with the most significant bit.

5.3.2.2.3.8.4 Severely Errored Second (SES) Definition

Any one-second period containing one or more block errors is designated an errored second. A severely errored second is defined by a count of N or more block errors within that one-second period. In the past, the ITU, Bellcore, and ANSI have defined N as that number of block errors per second that are experienced when the error rate on the line being monitored is 1E-3 or greater.

Currently, ITU-G.826 defines the SES threshold as the point where 30% or more of the blocks monitored have been received in error.

In either case, the SES threshold must vary with the PHY layer bit rate. Examples of both SES definitions are given in Table 8.

5.3.2.2.3.9 F3 Payload Checksum

This field provides checksum monitoring of the F3 cell payload contents. The use of the CRC-10 algorithm specified in ITU-I.432 is required. This checksum covers all but the last two octets of the F3 cell payload section. Per the ATM Forum, the CRC-10 used with all OAM cells is:

(35) $x^{10} + x^9 + x^5 + x^4 + x + 1$

The mapping of the CRC residual to F3 cell bytes is shown in Figure 43.

7	6	5	4	3	2	1	0	
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	x9	x8	47
x7	x6	x5	x4	x3	x2	x1	x0	48

Figure 43 - F3 Cell CRC-10

Reserved bits will be transmitted as 0.

5.3.2.2.3.10 F3 Cell Parameters for PMD Layer Bit Rates

Table 8 illustrates the set of F3 cell parameters for the RADSL system. The table shows the effect of the periodic F3 cell rate, with respect to the total line rate. The table also shows the impact to cell delineation and 8kHz samples as a function of total line rate. The table is helpful when determining the effective user bandwidth (that which is actually delivered to the customer).

Table 8 - F3 Cell Parameters

Bit Rate (kbps)	Cells/ Block	Bits/ Block	F3 SIZE AND RATE			CELL DELINEATION				
			Blocks/ F3 Cell	Blocks/ Second	F3 Cell Period	Frame Time (SSS) us	8 kHz Counts per F3	Comm. Channel Bytes per F3	Baud Rate	Total OH
7168	10	4240	10	1673.8	0.006	118	48	6	8034	0.99%
6272	10	4240	10	1464.6	0.007	135	55	6	7030	0.99%
5120	10	4240	10	1195.6	0.008	166	67	7	6695	0.99%
4480	10	4240	10	1046.1	0.010	189	76	8	6695	0.99%
3200	10	4240	10	747.2	0.013	265	107	12	7174	0.99%
2688	10	4240	10	627.7	0.016	315	127	14	7030	0.99%
2560	10	4240	10	597.8	0.017	331	134	14	6695	0.99%
2240	10	4240	10	523.1	0.019	379	153	16	6695	0.99%
1920	10	4240	10	448.3	0.022	442	178	19	6815	0.99%
1600	10	4240	10	373.6	0.027	530	214	21	6277	0.99%
1280	10	4240	8	298.2	0.027	663	215	23	6858	1.23%
960	10	4240	6	222.7	0.027	883	216	25	7423	1.64%
640	10	4240	4	147.3	0.027	1,325	217	27	7952	2.44%
1088	10	4240	7	253.0	0.028	779		24	6939	1.41%
952	10	4240	6	220.8	0.027	891		25	7362	1.64%
816	10	4240	5	188.7	0.027	1,039		26	7849	1.96%
680	10	4240	4	156.5	0.026	1,247		25	7823	2.44%
544	10	4240	4	125.2	0.032	1,559		27	6759	2.44%
408	10	4240	3	93.1	0.032	2,078		28	6953	3.23%
272	14	5936	2	44.2	0.045	3,118		29	5132	3.45%
90	14	5936	1	14.2	0.071	9422		30	3396	6.67%

5.3.2.3 Direct-Packet Mapping

For Further Study. (However, information on this type of mapping is included in ADSL Forum documentation.)

5.3.2.4 PTC – TC Interface

Figure 3 shows up to six logical data streams flowing between the PTC and TC blocks in both the ATU-R and the ATU-C. Each of these 12 logical streams is one octet wide. Streams TX-DS-I, RX-DS-I, TX-US-I, and RX-US-I carry transmit and receive downstream and upstream coded payload data, respectively.

Streams TX-DS-EOC, RX-DS-EOC, TX-US-EOC, and RX-US-EOC carry transmit and receive downstream and upstream EOC data, respectively. Streams TX-DS-F, RX-DS-F, TX-US-F, and RX-US-F, which are optional to support, carry transmit and receive downstream and upstream bit synchronous data. All serialized processing performed on these streams by the PTC sub-layer is performed with the MSB of each octet transmitted first.

5.3.3 Bit Synchronous TC

For Further Study.

5.3.4 EOC TC

The following sections describe the protocol for EOC transport and management for the three TC sublayers: Frame TC, Direct Cell TC, and Direct Packet TC.

5.3.4.1 Frame TC

The Embedded Operations Channel (EOC) for single-carrier RADSL is used to transfer management information between the ATU-R and the ATU-C. The EOC information interchange is based upon a command/response model. The ATU-C only issues commands; the ATU-R only responds to commands. Commands and responses may be pipelined. Responses are correlated with commands via a tag field in the PDU. Both the command and response functions are stateless.

5.3.4.1.1 EOC Protocol Encapsulation

The EOC is based on the octet-synchronous HDLC protocol described in RFC-1662. Multiprotocol extensions allow the EOC channel to transport protocols beyond the fundamental commands specified herein.

5.3.4.1.2 Octet-Synchronous HDLC

The Frame Mapped mode transports octets in the TC-layer framing overhead for the EOC. This octet stream is further encoded in RFC-1662 octet synchronous HDLC to deliver the EOC information payload packets. The RFC-1662 EOC frame structure is depicted below:

0x7E	Flag
0xFF	HDLC Address field
0x03	HDLC Control field = UI frame
Information Payload . . .	
FCS	LSB of CRC-16
FCS	MSB of CRC-16
0x7E	Flag

Figure 44 - RFC-1662 EOC frame structure

5.3.4.1.2.1 Flags, Address, and Control Fields

As per RFC-1662, these single octet fields have all fixed values. The same frame flag value (0x7E) is used for both opening and closing the EOC frame. The Address and Control fields correspond to a Q.922 header. However, RFC-1662 only supports point-to-point datagram operation at this time. Hence, only the broadcast Address value of 0xFF and unnumbered information (UI) Control field value of 0x03 are currently allowed.

5.3.4.1.2.2 Information Payload

The information payload consists of an integral number of octets, and the payload is octet aligned. The content of the Information Payload field is transported transparently through the EOC channel using the RFC-1662 octet encoding technique.

Data within the information payload is encoded to avoid aliasing data with EOC framing octets. When the information payload PDU contains either of the RFC-1662 framing octets, 0x7E (Flag) or 0x7D (Control Escape), these octets are substituted with unique octets sequences in the SDU. In summary, the following substitutions are made:

- an information payload PDU octet of 0x7E is encoded as 0x7D-5E in the SDU
- an information payload PDU octet of 0x7D is encoded as 0x7D-5D in the SDU.

On reception, the inverse substitution is made to translate the received SDU back into the PDU. The following receive decoding is made:

- an information payload SDU sequence of 0x7D-5E is replaced by 0x7E in the PDU
- an information payload SDU sequence of 0x7D-5D is replaced by 0x7D in the PDU
- an information payload SDU sequence of 0x7D-7E aborts the frame.

5.3.4.1.2.3 Frame Check Sequence (FCS)

A 16 bit FCS mechanism is employed. This is the CRC-CCITT generating polynomial:

(36) $1 + x^{5} + x^{12} + x^{16}$

The FCS-16 is calculated over all bits of the Address, Control, and Information Payload fields of the frame. RFC-1662 contains a suggested implementation of the CRC-16 generation and verification.

5.3.4.1.2.4 Invalid Frame

The following conditions result in an invalid EOC frame:

- frames that are too short (less than 4 octets between flags);
- frames that contain the RFC-1662 frame abort sequence (i.e., 0x7D-7E);
- frames that contain invalid escape octet sequences (i.e., 0x7D-XX other than 0x7D-5E, 0x7D-5D, or 0x7D-7E).

Invalid frames are discarded. Subsequently, the receiver immediately becomes ready to detect the beginning flag of the next EOC frame.

5.3.4.1.2.5 Time Fill

Inter-frame time fill is accomplished by inserting Flag octets (0x7E) on the EOC transport channel. Inter-octet time fill is not supported.

5.3.4.1.3 Multiprotocol Encapsulation

In order to identify the EOC protocol and allow for future protocol extensions, the contents of the EOC information payload uses LLC/SNAP encapsulation. The Framed Mapped EOC management protocol is identified by a particular IEEE 802 Organizational Unique Identifier and its Protocol ID. The EOC information payload format is:

0xAA	LLC DSAP
0xAA	LLC SSAP
0x03	LLC Control Field = UI
0x00	SNAP OUI 1st octet
0x90	SNAP OUI 2nd octet
0x12	SNAP OUI 3rd octet
0x00	SNAP Protocol ID 1st octet
0x01	SNAP Protocol ID 2nd octet
Information Datagram . . .	

Figure 45 - EOC information payload

5.3.4.1.3.1 LLC/SNAP Headers

The Link Layer Control header is a 3-octet multiprotocol header defined by IEEE.

The SNAP header consists of a 3-octet IEEE 802 Organizational Unique Identifier and its 2 octet Protocol ID. The Frame Mapped EOC management protocol has assigned OUI 0x00-90-12 and uses the fixed Protocol ID of 0x00-01.

5.3.4.1.4 Information Datagram for EOC Management

All information datagrams used for Frame Mapped management have the following format:

Datagram Length
Datagram Tag
Datagram Version
Datagram Command/Response Message ID
Message-Specific Information Fields . . .

Figure 46 – EOC Information Datagram

5.3.4.1.4.1 Datagram Length

The Length field is a single unsigned octet field indicating the total number of octets in the information datagram. The minimum value for the Length field is 4; the maximum value is 255.

5.3.4.1.4.2 Datagram Tag

The Tag field is a single unsigned octet field used to correlate EOC responses with commands.

When an EOC command datagram is sent from the ATU-C, an arbitrary value is inserted in the Tag field. The ATU-R response datagram must contain the Tag field value used by the command datagram. Generally, command datagrams should strive to sequence Tag values modulo 256 to minimize aliasing; however, this is not required.

5.3.4.1.4.3 Datagram Version

The Version field is a single unsigned octet field. It defines the EOC management protocol message set being used. The Version field current has a fixed value of 0x01.

5.3.4.1.4.4 Datagram Message ID and Message-Specific Fields

The Command/Response message ID field is a single unsigned octet field. Commands are defined as having a field value of 0x00 through 0x7F. Responses have the values 0x80 through 0xFF.

The message-specific fields are comprised of a variable number of octets. For each Message ID, there exists a particular set of message–specific fields with a fixed length. The length of the message-specific field can be derived by subtracting the number of datagram overhead octets (i.e., 4) from the value of the Datagram Length.

5.3.4.2 Direct Cell TC

This section specifies the Data-Link Layer protocol that provides the embedded operations channel (EOC) transport service.

A brief description of the EOC physical layer operation is included in this document because of the integrated nature of the framing protocol and the physical layer functionality. See Figure 47.

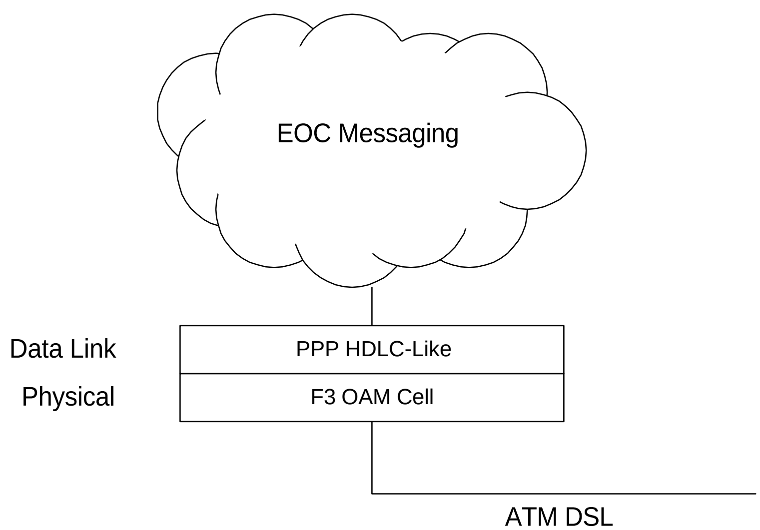


Figure 47 - EOC Protocol Stack

5.3.4.2.1 F3 Cell EOC Structure (Physical Layer)

The EOC physical layer bit transport is provided within a sub-field of octets in the F3 OA&M flow. This includes two control fields and a contiguous variable-length payload field.

5.3.4.2.1.1 EOC Control Fields

5.3.4.2.1.1.1 Function Control Bit Map (FCBM)

This register provides control functionality of the EOC including enabling and flow control. This allows dynamic selection of F3 cell bandwidth and an out-of-band flow control mechanism. This register has other functionality controlled by the bits marked as "reserved," which are not covered in this document. The function control bits allow F3 and OA&M features of the cell to be selectively activated, making it possible to have a different cell rate for each function independently. In normal operation, it is expected that all features of this F3-OA&M cell, except for the 8-kHz reference, will remain active in each occurrence of the cell, with only the EOC flow control signal showing activity. The actual allocation of bits to functions is shown in Figure 48.

7	6	5	4	3	2	1	0
EOC Flow Control	Reserved	Reserved	EOC Enable	Reserved	Reserved	Reserved	Reserved

Figure 48 - Function Control Field Bit Assignments

Function control bits should be set to "1" to indicate an active F3-OA&M function, and "0" for inactive. The EOC flow control bit, when "1", indicates a request to stop transmission in the EOC being carried in the opposite path ("1" received by the ATU-C is a request by the ATU-R to turn off the downstream EOC).

5.3.4.2.1.1.1.1 EOC Flow Control Bit

The flow control bit simply indicates to the transmitter of the sending ATU that the receiving ATU's buffers are filling.

0 - Transmit enabled

1 - Stop transmitting (set the EOC Ptr field to a value of zero and send no EOC octets)

This flow-control bit will not be incorporated in initial implementations and will be set to '0'.

5.3.4.2.1.1.1.2 EOC Enable Bit

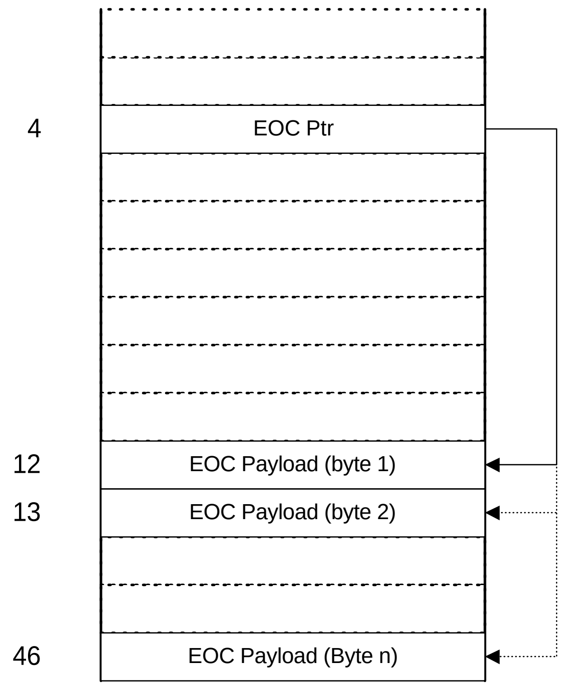
The EOC enable bit indicates the EOC bytes (payload and control bytes) are allocated for EOC purposes.

0 - EOC disabled (all EOC bytes may be allocated to other services)

1 - EOC defined bytes are allocated for the EOC services.

5.3.4.2.1.1.2 EOC Pointer

The EOC pointer is an index pointer to the first valid EOC cell byte within the EOC payload field. The value contained in this byte is the cell payload index of the first valid used EOC payload byte. The pointer has a valid range of 12 through 46, and 0. The EOC block is contained in the contiguous byte stream, starting with the byte pointed to by the EOC Ptr field, up to and including byte 46 (first byte referenced at 1) of the payload.



EOC Ptr = 12
Total EOC payload bytes = 35

Figure 49 - EOC Allocation Diagram

The example in Figure 49 illustrates EOC bandwidth allocation using the EOC Ptr field. In this example the EOC payload is 35 bytes. The EOC Ptr field is set at the transmitting end to point to the first valid byte of the EOC payload. The receiver then retrieves the payload bytes starting at the location pointed to by the EOC Ptr field to byte 46 of the cell payload. Note that the EOC payload data (including any end padding, if present) is always justified from the bottom of the EOC payload allocation of the F3 cell. This means that the start of the EOC bandwidth is variable, based on the desired EOC payload size/EOC pointer value, but the end of the EOC payload is fixed at byte 46, the bottom of the F3 cell.

An EOC Ptr field value greater then 46 is out of range for this pointer. In this case, the EOC payload should be treated as empty. In the event the EOC Ptr field is pointing to a starting address that is beyond the maximum allowable bandwidth of the EOC payload (index value smaller than allowed), it should be treated as an empty cell also. Refer to Appendix A for specific details regarding the absolute maximum bandwidth conditions of the EOC payload.

Any error conditions induced in the EOC Ptr field that cause it to point to a valid region, but not to the correct location, are left for error recovery in the data-link-layer protocol.

5.3.4.2.2 EOC Payload Data Link Framing Structure

The EOC payload field defined in the previous section provides a byte-oriented transport for the inter-ATU communications. Encapsulated within this physical layer transport is the data link layer framing protocol, which encapsulates the EOC message.

The data-link-layer protocol is based on the *PPP in HDLC-like Framing Protocol* described in RFC 1622. Any differences between RFC 1622 and the EOC data link framing structure described in this document relate primarily to byte order of multi-byte objects, such as CRC and length fields. Where there are differences, this document takes precedence.

This byte-oriented protocol is used to frame messages and provide a reliable transport mechanism for transporting EOC messages of various lengths. This type of protocol includes overhead bytes in the form of a protocol header and trailer. The header provides address and control functionality while the trailer includes the Frame Check Sequence (CRC checksum).

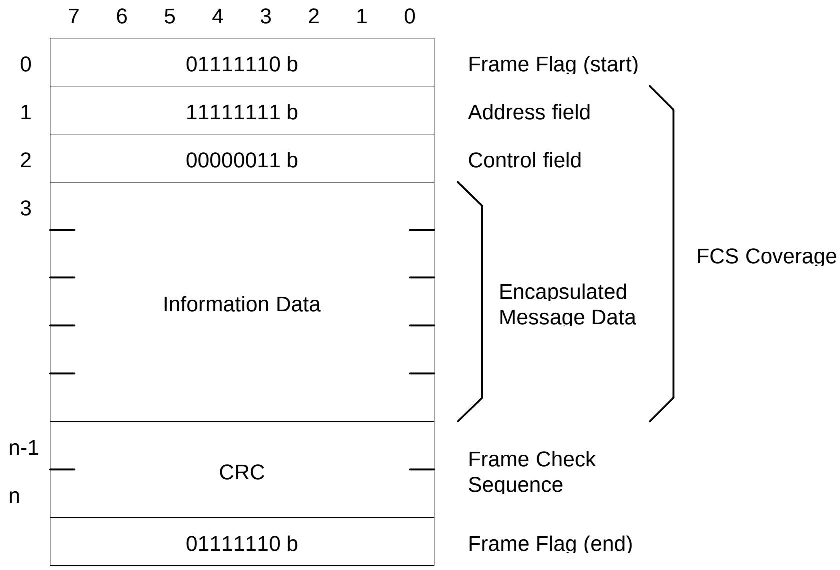


Figure 50 - PPP HDLC-Like Framing Structure

5.3.4.2.2.1 Frame Flag

Each frame is bound by a start and stop flag sequence of the value 01111110b (0x7E). A single flag may be used as a stop and start sequence between consecutive frames. Two contiguous flag sequences are an idle-line or empty-frame condition.

5.3.4.2.2.2 Header

5.3.4.2.2.2.1 Address Field

The address field is set to 11111111b for current messaging. No other values are allowed.

5.3.4.2.2.2.2 Control Field

The control field is set to 00000011b for current messaging. No other values are allowed.

5.3.4.2.2.3 Information Data

The information field contains the Layer-2 and Layer-3 data and may vary in length from 6 to 1020 bytes. The format of this data area is described in Section G.2.4.

5.3.4.2.2.4 Frame Check Sequence

The frame check sequence in this implementation is a 16-bit CRC with the generator polynomial:

(37) $X^{16} + X^{12} + X^5 + X^0$

The CRC is computed over the entire frame beginning with the address field and ending with the last byte of the information data. The flag sequence is not included in the calculation. The 16-bit resulting value is complimented and stored into the Frame-Check Sequence field with the most significant byte (MSB) first and the least significant byte (LSB) next.

5.3.4.2.2.5 Octet Stuffing

The only unusual thing about this protocol structure is that certain octet values must be escaped with two octet replacements. Octet stuffing is done after the frame has had the Frame Check Sequence applied but before the frame is transmitted. After Frame Check Sequence computation, the transmitter examines the entire frame between the two Flag Sequences (01111110b). Each octet that is equal to either a Flag Sequence or Control Escape octet (01111101b) is replaced by a two-octet sequence consisting of the Control Escape octet followed by the original octet exclusive-OR'd with 00100000b:

0x7E is encoded as 0x7D, 0x5E (Flag Sequence)

0x7D is encoded as 0x7D, 0x5D (Control Escape)

Octet unstuffing is done as octets are received, but before the frame is checked for frame check sequence. On reception, before Frame Check Sequence computation, each Control Escape octet is removed and the following octet is exclusive-OR'd with 00100000b.

5.3.4.2.2.6 EOC Field Packing

The packing of the data link frame will be in ascending order within the EOC field, where the first octet of the frame is loaded into the EOC cell location pointed to by the EOC Ptr field. Each successive octet of the frame is loaded into the next available location in F3 cell EOC payload. The data-link frame begins with the start flag sequence and continues sequentially with the address field and so forth.

The diagram in Figure 51 illustrates the loading of EOC payload into the F3 cells. In this diagram the data-link frame shown spans two F3 cells, but could have been packed in one cell.

The octets loaded into the EOC field on the top of the diagram show 'bottom packing'. The octets of the data-link frame are bottom justified and the EOC Ptr field is adjusted to point to the first valid octet of the message and not necessarily the first available EOC field location. The receiver should retrieve the octets from the location indicated by the EOC Ptr field to the end of the cell.

The remaining octets of the data-link frame are loaded starting at the first available location of the EOC field (usually location 12) of the next available F3 cell. The octets unused at the end of the EOC field must be loaded with the flag sequence (0x7E) to pad the message out to the end of the cell.

The start of the data-link frame (flag, address, control, etc.) is loaded to the lower index value within the EOC field and placed in ascending order.

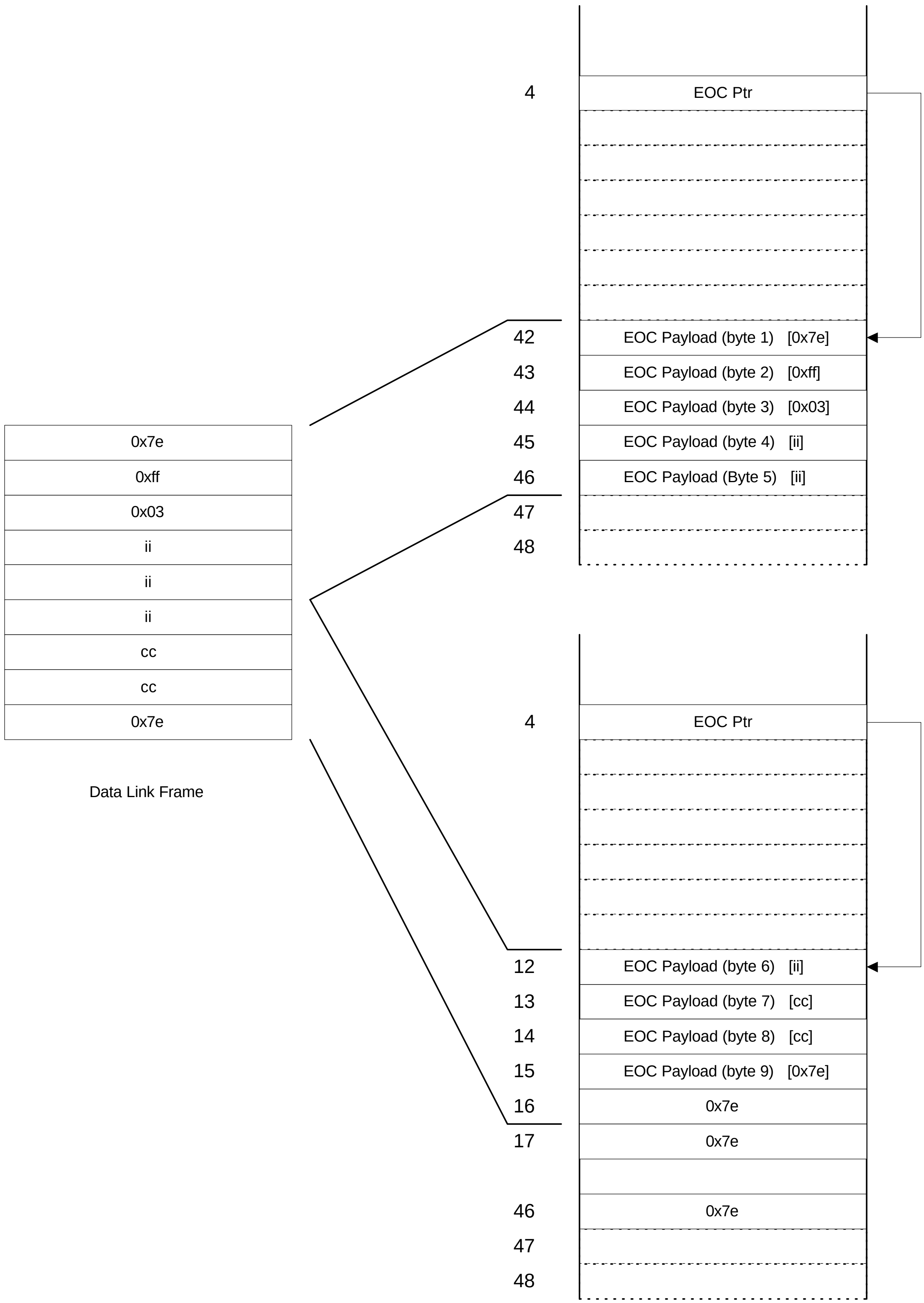


Figure 51 - EOC Field Packing

5.3.4.2.2.7 Multi-Cell Frames

Data-link frames that span more than one F3 cell are simply segmented by loading contiguous octets from the frame into available EOC payload bandwidth as the F3 cells become available. It is not required that segments of the frame be loaded into contiguous F3 cells. It is the responsibility of the receiver to continually search for the start and stop flags across F3 cells. An F3 cell may be skipped by simply setting the EOC Ptr field to zero. If the EOC Ptr field is zero or an invalid number, the receiver should treat the EOC payload within the cell as empty. The data-link layer process must maintain its previous state across empty EOC payload cells.

5.3.4.2.3 Encapsulated Message Data Structure

The PPP HDLC-like framing structure described in the previous section provides a message encapsulation mechanism that allows the message data to be reliably found within the transmitted byte stream, checked for transmission induced bit errors, and received correctly.

The data-link layer is further expanded within the information field by the addition of more overhead bytes. These additional byte fields allow for the implementation of additional Layer 2 functionality similar to that provided by the PPP protocol.

Coding of these additional data fields is shown in Figure 52.

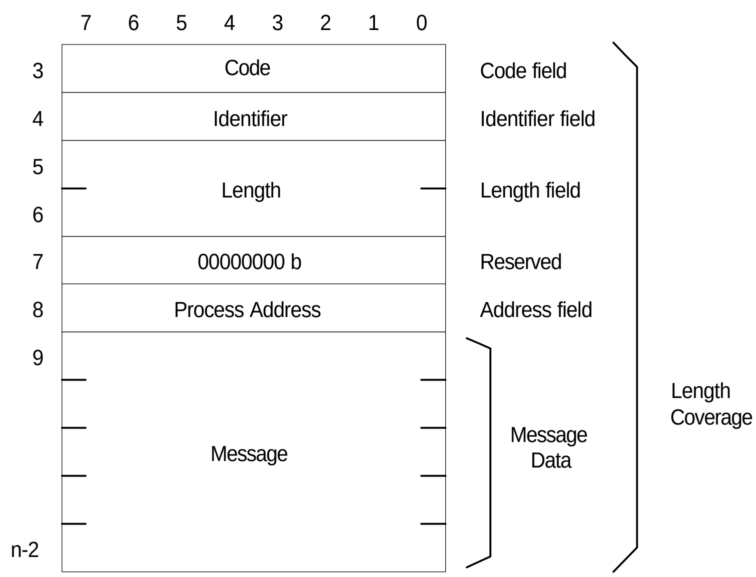


Figure 52 - Encapsulated Message Data Structure

5.3.4.2.3.1 Data Structure

5.3.4.2.3.1.1 Code Field

The Code field is one octet and identifies the kind of packet that this is. Table 9 below shows the allowed Code fields defined. Note that the Code field must be odd in order to be consistent with the ISO 3309 address extension mechanism for HDLC encapsulation. Section 5.3.4.2.3.2 details Layer 2 operation with definitions of the Code field.

Table 9 - Code Field Values

0x01	Establish_Request
0x81	Establish_ACK
0x03	Echo_Request
0x83	Echo_Reply
0x11-0x1F	User_Data
0x91-0x9F	User_Data_ACK

5.3.4.2.3.1.2 Identifier Field

The Identifier field is one octet, and aids in matching requests and replies. When a packet is received with an invalid Identifier field, the packet should be silently discarded. An invalid Identifier is one that is equal to or less than the previous identifier received. This field must be filled by a number which is greater than the Identifier of the previous frame sent. The identifier field in the reply should match the request identifier.

5.3.4.2.3.1.3 Length Field

The Length field is two octets, and indicates the number of octets in the encapsulated message data area of the packet, including the Code, Identifier, Length, Reserved, Address, and Message Data Fields. The length is stored with the most significant byte first, then the least significant byte next. Note that the minimum length is always 6. This length indicates inclusion of the Code, Identifier, Length, Reserved, and Address fields. The maximum length value is 1020.

5.3.4.2.3.1.4 Reserved Field

This field should be set to zero.

5.3.4.2.3.1.5 Address Field

This field is used to address the message processing task that is sending or should be receiving this message. Any number is valid and the currently used address range is 0x01-0xFF.

5.3.4.2.3.1.6 Message Data

The Message Data field is zero or more octets, as indicated by the Length field. The format of the Data field is determined by the Code field.

5.3.4.2.3.2 Layer 2 operation

5.3.4.2.3.2.1 Data Link Establishment

After the physical ADSL layer is connected and cell synchronization has occurred, the EOC data link can be established. It is expected that each end of the EOC link will go through the “link establishment” phase.

To establish the link, the transmitting ATU sends a message to the receiving ATU with the Code Field set to 0x01 (Establish Request). The complete format of the request message is shown in Figure 53. Upon successful reception of the Establish Request message by the receiving ATU, an acknowledgement message is returned to the transmitting ATU with the Code Field set to 0x81 (Establish ACK). The complete format of the acknowledgment message is shown in Figure 54.

	7 6 5 4 3 2 1 0	
3	00000001 b	Code
4	N(S)	Identifier
5	00000000 b	Length
6	00000110 b	
7	00000000 b	Reserved
8 (n-2)	Process Address	Address

Figure 53 - Establish Request Message

	7 6 5 4 3 2 1 0	
3	10000001 b	Code
4	N(S)	Identifier
5	00000000 b	Length
6	00000110 b	
7	00000000 b	Reserved
8 (n-2)	Process Address	Address

Figure 54 - Establish ACK Message

During link establishment, a timer is used to control retransmission of the Request message. The Request message will be retransmitted forever with five seconds used as the retransmit timer value. Once an ACK is received by the transmitting ATU, it considers the link to be up and operational.

5.3.4.2.3.2.2 Data Link Integrity

During normal operation, an ATU will periodically test the link to determine if it is still in communication with its neighbor ATU. This check is done through transmission of an Echo Request message. If there is no other traffic, the transmitting ATU will send Echo Request messages every 15 seconds to test the link. The message format is shown in Figure 55. The receiving ATU should respond to the request with an Echo Reply message with the reply Identifier field set to the value sent in the request message. The reply message format is shown in Figure 56.

	7 6 5 4 3 2 1 0	
3	00000011 b	Code
4	N(S)	Identifier
5	00000000 b	Length
6	00000110 b	
7	00000000 b	Reserved
8 (n-2)	Process Address	Address

Figure 55 - Echo Request Message

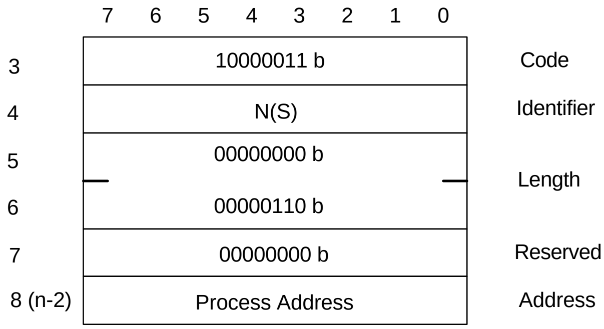


Figure 56 - Echo Reply Message

A timer will be used to time-out any transmitted packets. The time-out used will be five seconds. Any packet will be retransmitted up to three times. If the three retransmissions of a packet fail, the transmitting ATU will consider that the link is down and the ATU will revert to the link startup phase and try again to establish the link by sending Establish Request messages.

Note that in this implementation both the ATU-C and ATU-R will periodically send Echo Request messages toward the opposite ATU to check on link integrity.

5.3.4.2.3.2.3 User Data Messages

The transmission of Layer 3 messages uses the User Data and User Data ACK codes. When an ATU is ready to send a message from an application, it will pass the message to Layer 2 where, it is wrapped in a User Data message and sent as a packet to the neighbor ATU. The receiving ATU must acknowledge the received packet by sending a User Data ACK message to the originator ATU within five seconds. If the packet is not acknowledged, the ATU originating the message will retransmit the packet again and wait for an ACK. If the packet is acknowledged, the originating ATU considers that packet exchange complete and will transmit the next packet if one is ready to transmit. If the packet is unacknowledged after three retransmission attempts, the originator ATU will consider the link down and will revert to the link establishment phase. Note that the Identifier field of the message is used to match messages with acknowledgements. A typical User Data message is shown in Figure 57. The ACK message is shown in Figure 58.

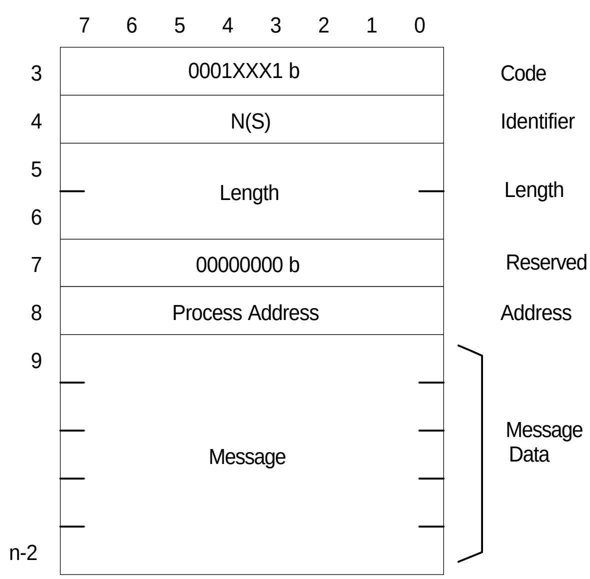


Figure 57 - User Data Message

Octet	7 6 5 4 3 2 1 0	
3	1001XXX1 b	Code
4	N(S)	Identifier
5	00000000 b	Length
6	00000110 b	
7	00000000 b	Reserved
8 (n-2)	Process Address	Address

Figure 58 - User Data ACK

Note that the User Data Code field value covers a range of acceptable values. This is for implementation of specific future options. Only User Data code 0x11 and User Data ACK code 0x91 are currently used.

5.3.4.3 Direct Packet TC

For Further Study.

5.4 Initialization

Initialization of the ATU-C and the ATU-R is accomplished in two phases. The first initialization phase is a handshake. The purpose of the handshake is to inform the ATU-R of the profile supported by the ATU-C. The second initialization phase is a start-up. The purpose of the start-up is to complete the activation sequence needed for both the ATU-C and ATU-R to enter into an operational state. Prior to initialization, single-carrier RADSL systems should utilize G.hs (*Draft New Recommendation G.994.1 – Handshake Procedure for Digital Subscriber Line (DSL) Transceivers*, approved by ITU-T SG15, June 1999) and NSF (non-standard facilities) to identify themselves.

5.4.1 Handshake

The CO unit can be deployed with either a CAP profile or QAM profile and the CPE unit support both. The profile selection at the CPE is performed using a handshake technique. A handshake mechanism is used for the CPE unit to identify the CO unit profile.

Prior to the execution of the single-carrier system initialization, the network and customer end transceivers exchange a simple sequence of tones as shown in Figure 59. Following this tone handshake the transceivers commence with the initialization procedure selected during the handshake for the selected profile.

Figure 1 shows the sequence exchange of the handshake proposal. The handshake sequence is initiated by the customer-end transceiver (ATU-R), which transmits one or two tones, referred to as the Capabilities Tones, for a period of $500 \pm 5\,\mathrm{ms}$. The frequencies of the Capabilities Tones, listed in Table 10, indicate which profile the ATU-R needs to support. Within 250 ms of receiving the beginning of the Capabilities Tones, the network end transceiver (ATU-C) responds by transmitting a single tone referred to as the Selection Tone and also serves as an acknowledgement. The frequency of this tone indicates the ATU-C's selection of the profile to use, as shown in Table 11. The ATU-C stops transmission of the Selection Tone within 250 ms of receiving the end of the Capabilities Tones.

The two transceivers then begin the initialization sequence that corresponds to the selected profile, as selected by the Selection Tone, $500 \pm 5\,\mathrm{ms}$ after termination of the Capabilities Tones.

The amplitude of the sinusoids to be used in each of the Capabilities Tones is –2 dBm. The amplitude of the sinusoid used in the Selection Tone is –4 dBm.

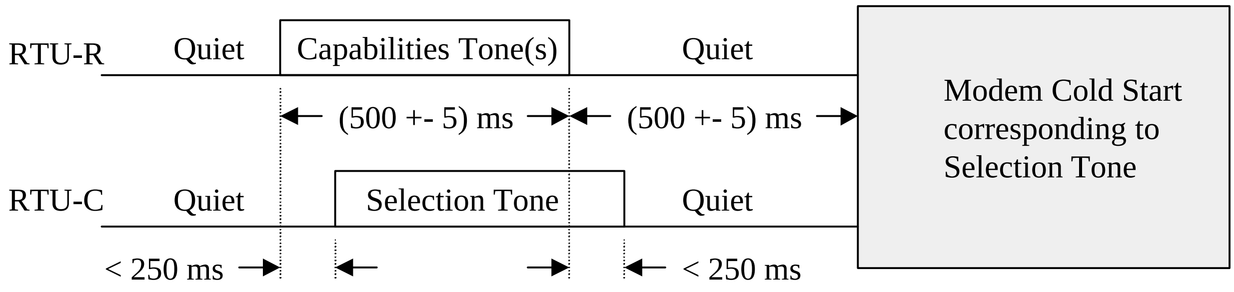


Figure 59 - Proposed Tone Handshake for Identifying and Selecting RADSL Profile

Table 10 - Mapping Between Tone Frequencies and Line Codes in the Capabilities Tones

Profile	Tone Frequency
CAP	68 kHz
QAM	85 kHz

Table 11 - Mapping Between Tone Frequency and Line Code in the Selection Tone

Profile	Tone Frequency
CAP	282 kHz
QAM	306 kHz

5.4.2 Start-up

Start-up may be accomplished in blind or trained modes. Rate adaptive primitives are described. Exhaustive search procedures are left to the reader's discretion. The system does use adaptive equalization to adapt to changing line conditions. However, if the changes are too severe, fast retrain may be invoked.

5.4.2.1 Trained Start-up

This section describes the various signals and bit sequences used during start-up. Various start-up modes are defined as follows:

1. **Initialization at Installation (*cold-start*) -** This start-up is performed at service installation, where the modem assumes no prior channel knowledge, and performs an exhaustive search of the best configuration (highest bit rate for a specified margin) for the loop and noise environment.
2. **Session -** The transceiver starts up with the configuration of the previous session. During this time, the transceiver determines if the bit rate should be increased or decreased based on the signal quality received.
3. **Specific Configuration -** This start-up mode forces a specific configuration and does not search for an alternative one.

4. **Warm Start-Up Procedure -** Defines a faster method to re-establish a communication session between the local and remote transceivers by eliminating the configuration negotiation phase and starting up with the same specific configuration as the previous session.

The procedures below define a set of *primitive start-up sequences*, which may be selected by the system operator. Definitions of the above mentioned start-up mode(s) are constructed with the passing of appropriate data within the start-up procedures.

5.4.2.1.1 Definitions relative to start-up procedures

5.4.2.1.2 Transparency

Prior to the completion of activation, transmission on the subscriber line is not transparent; the signals that are present at the line interface are special to the start-up patterns generated by the RADSL transceiver. The transceiver provides transparent transmission of the payload data after the termination of the individual activation procedure.

5.4.2.1.2.1 Signal Quality (SQ)

The signal quality (SQ) parameter is estimated at the receivers in the ATU-C and ATU-R. This value is used to estimate the bit error ratio (BER) or SNR margin of the received data. It takes into account the total signal-to-interference (SIR) ratio, where the interference includes background noise, crosstalk, residual inter-symbol interference, residual echo from the neighboring upstream or downstream channel, and distortion.

5.4.2.1.2.2 T

Symbol interval of the transmit signal.

5.4.2.1.3 Transmitted Signals

The following sub-sections describe the transmitted signals during activation.

5.4.2.1.3.1 Silent

No signal is transmitted to the line during this state.

5.4.2.1.3.2 S0' (CS0' and RS0') Signal

The S0 signal is used as an alerting or *wake-up* sequence to initiate transceiver activation. The sequence uses the generating polynomial of $1 \oplus x^{-5} \oplus x^{-6}$ seeded with bits [000001]. The bit to symbol mapping for the S0 sequence is two points, namely ± A as defined in Figure 65.

5.4.2.1.3.2.1 CS0

The S0 signal transmitted from the ATU-C is labeled CS0.

5.4.2.1.3.2.2 RS0

The S0 signal transmitted from the ATU-R is labeled RS0.

5.4.2.1.3.3 S0' (CS0' and RS0') Signal

CS0’ and RS0’ are the same physical signals as their corresponding CS0 and RS0, however, its duration is at least 252*T (4*63 symbol intervals) where T is the symbol interval of the corresponding upstream or downstream (T_C) signal. For the upstream channel, the symbol rate is 85 kBaud, and for the downstream channel the symbol rate is 136 kBaud.

5.4.2.1.3.4 S1 (CS1 and RS1) Signal

The S1 signal is an uncoded 16-CAP signal sequence. In the downstream channel, this signal is called *CS1* and in the upstream channel, this signal is called *RS1*.

5.4.2.1.3.4.1 CS1

CS1 uses the generating polynomial $1 \oplus x^{-5} \oplus x^{-23}$ and the line signal symbol rate is that selected in the trailer data exchange field. This sequence is only transmitted in the downstream direction.

5.4.2.1.3.4.2 RS1

RS1 uses the generator polynomial $1 \oplus x^{-18} \oplus x^{-23}$ and the line signal symbol rate is that selected in the trailer data exchange field. This sequence is only transmitted in the upstream direction.

5.4.2.1.3.5 16-CAP (S5)

This signal may be any arbitrary uncoded 16-CAP signal sequence. This signal is also referred to as S5

5.4.2.1.3.6 S2 (CS2 and RS2) Signal

The S2 signal is an uncoded 16-CAP signal sequence. CS2 and RS2 define the respective sequences in the downstream and upstream channels.

5.4.2.1.3.6.1 CS2

In the downstream direction, the ATU-R transmitter initiates the data mode scrambler (Figure 10a). The scrambler generator polynomial for CS2 is 1 ⊕ *x*r -5 ⊕ x^{-23} seeded with all zeros. The signal constellation is 16-CAP.

5.4.2.1.3.6.2 RS2

In the upstream direction, the ATU-R transmitter initiates the data mode scrambler (Figure 10c). The scrambler generator polynomial for RS2 is $1 \oplus x^{-18} \oplus x^{-23}$ seeded with all zeros. The signal constellation is 16-CAP.

5.4.2.1.3.7 16-CAP (S5) + Precode

This is the 16-CAP (S5) signal as defined above with the Tomlinson Precoder enabled.

5.4.2.1.3.8 CS3 Signal

The CS3 signal is a coded 16-CAP signal that includes the data mode scrambler (Figure 10a) in the frame locked condition, i.e. with all zeros data sequence transmitted. The trellis code and Tomlinson precoder are enabled for the transmission of CS3. The corresponding symbol rate is that chosen in the negotiation phase of the alerting sequence.

5.4.2.1.3.9 RS3

In the upstream direction, the RS3 signal is a coded *N*-CAP signal that includes the data mode scrambler (Figure 10c) in the frame locked condition, i.e., with the all zeros data sequence transmitted. The trellis code and Tomlinson precoder are enabled for the transmission of CS3. The corresponding symbol rate and constellation size are those chosen in the negotiation phase of the alerting sequence.

5.4.2.1.3.10 CS4

CS4 is a coded *N*-CAP signal transmitted in the downstream direction that includes the data mode scrambler (Figure 10) in the frame locked condition, i.e., with the all zeros data sequence transmitted. The trellis code and Tomlinson precoder are enabled for the transmission of CS3. The corresponding symbol rate and constellation size are those chosen in the negotiation phase of the alerting sequence.

5.4.2.1.3.11 S6 (CS6 and RS6)

The S6 signal is the uncoded 16-CAP signal with the Tomlinson precoding enabled. In the downstream direction, the ATU-C uses the generator polynomial $1 \oplus x^{-5} \oplus x^{-23}$; the corresponding transmit signal is referred to as CS6. In the upstream direction, the ATU-R uses the generator polynomial $1 \oplus x^{-18} \oplus x^{-23}$; the corresponding transmit signal is referred to as RS6.

5.4.2.1.3.12 S7 (CS7 and RS7)

The S7 signal is the uncoded 16-CAP signal with Tomlinson precoding enabled and the scrambler reset. In the downstream direction, the ATU-C transceiver uses the generator polynomial $1 \oplus x^{-5} \oplus x^{-23}$; the corresponding transmit signal is referred to as CS7. In the upstream direction, the ATU-R uses the generator polynomial $1 \oplus x^{-18} \oplus x^{-23}$; the corresponding transmit signal is referred to as RS7.

5.4.2.1.4 Timers

This section defines the timers to be used in the activation sequence. Values for the timers are listed in section 5.4.2.1.4.8, which correspond to the activation sequences defined in sections 5.4.2.1.5 and 5.4.2.1.8.

5.4.2.1.4.1 T1 ($T1_W$)

Time out or maximum response time for the ATU-C replying to an RS0 from the ATU-R.

5.4.2.1.4.2 T2 ($T2_W$)

The time it takes the ATU-C transmitter to send a CS1 upon completion of CS0 plus trailer sequence. The ATU-R may use this timer to determine the receive time of sequence CS1.

5.4.2.1.4.3 T3 ($T3_W$)

Defines the time it takes for the ATU-R receiver to detect CS1 and respond with sequence RS1.

5.4.2.1.4.4 T4 ($T4_W$)

Timer in the ATU-R used to determine the reset time of the data mode scrambler in the ATU-R.

5.4.2.1.4.5 T5

Start time for transmission of the Tomlinson coefficients in the ATU-R.

5.4.2.1.4.6 T6 ($T6_W$)

Start of the Reed-Solomon code frame. This is an exact number used in the activation sequence in that it has no tolerance specified.

5.4.2.1.4.7 T7 ($T7_W$)

Transmission time of 16-CAP + Precode followed by CS4 in the ATU-C and 16-CAP + Precode followed by RS3 in the ATU-R during the Reed-Solomon code locking phase.

5.4.2.1.4.8 Timer Values

Table 12 below defines the timer values in the activation sequences. Note that some timer values are expressed in terms of symbol intervals, where T_{340} (T_{85}) is the symbol interval of the 340(85) kBaud symbol clock, and T is the symbol interval selected during the negotiation phase.

Table 13 defines the equivalent timer values for the warm start-up activation sequence.

Table 12 - Timer Values for the Activation Sequence

Timer	Lower Bound	Upper Bound
T1	$64*T_{340}$	$4000*T_{340}$
T2	100 ms	180 ms (<340 kBaud) 600 ms (>340 kBaud)
T3	100 ms	180 ms (<340 kBaud) 600 ms (>340 kBaud)
T4	(210 kBaud ±10k)* T_{340}	
T5	(150 kBaud ±1k)* T_{340}	
T6	200k*T (f_B <= 340kBaud) 400k*T (340 < f_B < 680 kBaud) 600k*T (f_B > 680 kBaud)	
T7	(180 kBaud ±10k)*T (f_B <= 340 kBaud) (360 kBaud ±10k)*T (340 < f_B < 680 kBaud) (540 kBaud ±10k)*T (f_B > 680 kBaud)	

Table 13 - Timer Values for the Warm Start Activation Sequence

Timer	Lower Bound	Upper Bound
T1	$64*T_{340}$	$4000*T_{340}$
T2	100 ms	180 ms (<= 340 kBaud) 600 ms (>340 kBaud)
T3	100 ms	180 ms (<= 340 kBaud) 600 ms (>340 kBaud)
T4	(210kBaud ±10k)* T_{340}	
T5	350 ± 5 ms	
T6	200k*T (f_B < 340 kBaud) 400k*T (340 < f_B < 680 kBaud) 600k*T (f_B > 680 kBaud)	
T7	(180 kBaud ±10k)*T (f_B <=340 kBaud) (360 kBaud ±10k)*T (340 < f_B < 680 kBaud) (540 kBaud ±10k)*T (f_B > 680 kBaud)	

5.4.2.1.5 Customer Initiated Activation Sequence

The customer-initiated activation is shown in Figure 60 and a description follows below.

5.4.2.1.5.1 Alerting ("Wake Up") Stage

Alerting is initiated by the ATU-R transmitting the RS0 sequence followed by a trailer that contains information for system configuration and rate negotiation. The structure of the alerting phase is shown in Figure 60 below.

Following the RS0 sequence is a trailer block that contains configuration data. In this first event of RS0, the trailer data is configured as a *poll* packet.

Once detecting the alerting sequence RS0, the system responds with sequence CS0.

The trailer data to the CS0 sequence is configured as a *reply* packet, responding to the *poll* from the ATU-R.

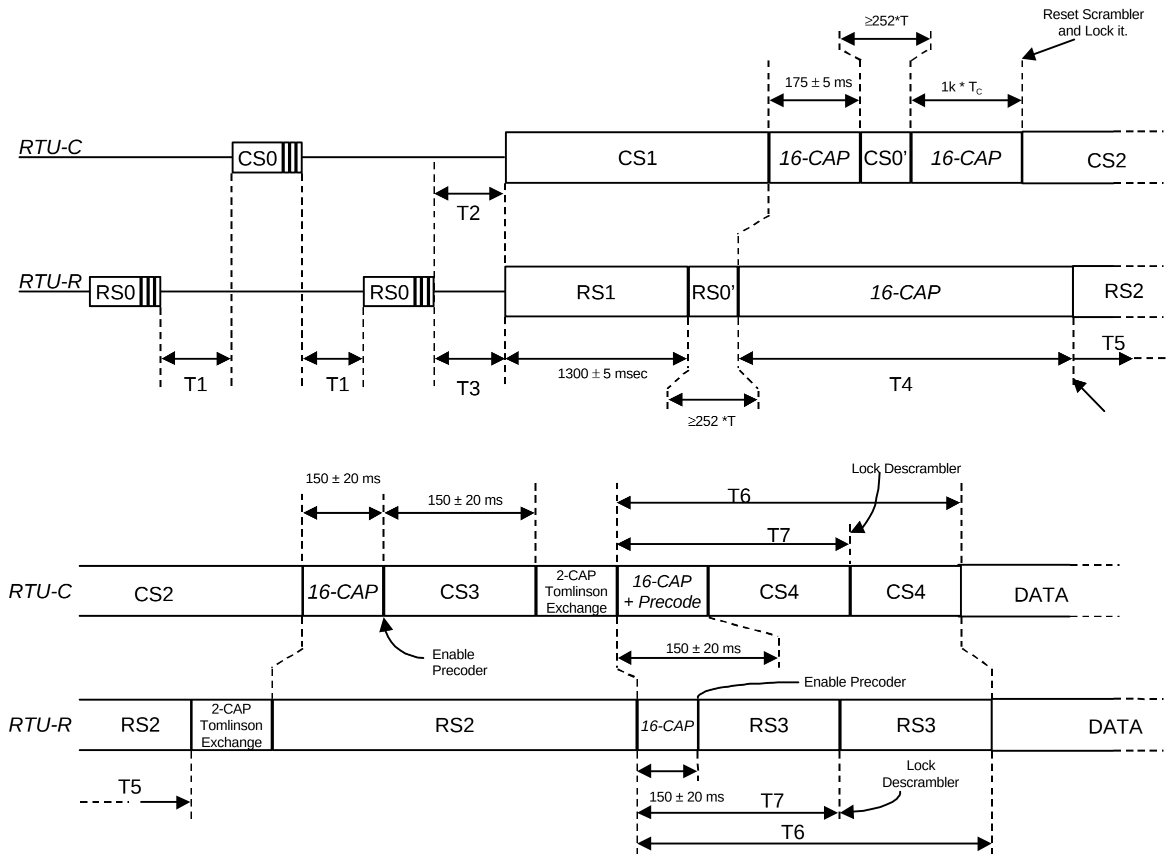


Figure 60 - Activation Sequence with ATU-R Initiated Calling

5.4.2.1.5.2 Alerting Phase Trailer Information

5.4.2.1.5.2.1 Encoding of Trailer Data Bits

The symbol rates for the upstream and downstream channels in this phase are 340 kBaud for the downstream channel and 85 kBaud for the upstream channel.

A logic ONE in a trailer data bit is encoded by sending one complete cycle of the 2^6-1 pseudo-random (PN) sequence at the corresponding channel baud rate using the constellation in Figure 65.

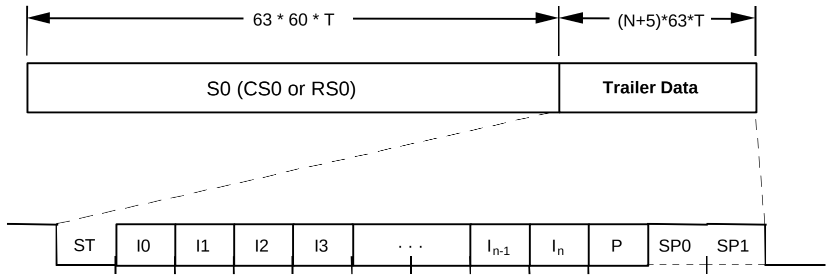
A logic ZERO bit is encoded by sending the 0 symbol defined in Figure 65.

The duration of S0 (CS0 or RS0) is 63*60*T, where T is the respective downstream or upstream symbol interval.

The duration of the trailer data is (n+5)*63*T; where n+5 is the number of trailer data bits, including the start bit (ST), parity bit (P), two stop bits (SP0 and SP1); and T is the respective downstream or upstream symbol interval. The value of *n* for this version of the specification is 63.

5.4.2.1.5.2.2 Definition of Trailer Data Bits

This section describes the alerting phase trailer information shown Figure 61.



Key :

ST	Start Bit = 0
I_0 - I_n	Data Bits
$I_{7, 15, 23, 31}$	1=Additional Data Byte Included 0=Last Byte
P	Parity Bit (Odd Parity)
SPx	Stop Bit = 1 (Two Stop Bits)

Figure 61 - Alerting Phase of Activation Sequence

5.4.2.1.5.2.3 First Byte

The first byte consists of bits i0 - i7.

Bits “i1,i0” are defined as follows:
“00” = data mode, “01” = run 511 bit error ratio test (BERT) for 10 seconds, “10” = run BERT for 30 seconds, “11” = run BERT for 2 minutes.

Bits i2 and i3 define the transmit signal power reduction: “i2,i3” range from “00” to “11”, where “00” identifies no power reduction (0dB), “01” = 6 dB reduction, “10” = 12 dB reduction, and “11” = 18 dB reduction.

Bit i4 defines the trailer packet as either a poll (“0”) or reply (“1”).

Bit i5 defines the start-up request as normal start (“0”) or warm start (“1”).

Bit i6 defines the start-up capability as normal start (“0”) or warm start (“1”).

Bit i7 is a continuation bit, where if it is set to “1” a byte follows.

5.4.2.1.5.2.4 Second Byte

The second byte consists of bits i8 through i15. The lower four bits (i8 - i11) define the specification version supported. Bit i12 is defined as the variable Baud clock mode request, where “1” = variable baud mode and “0” = predefined baud mode. Bit i13 is defined as the variable Baud clock mode capability where “1” = variable baud rate and “0” = predefined baud mode. Bit i14 defines auto selection *(“0”)* or predefined *(“1”)* constellation mode. Bit i15 is the continuation bit.

5.4.2.1.5.2.5 Third Byte

The third byte consists of bits i16 through i23, where i16 through i19 define the symbol clock selection and is summarized as follows:

Table 14 - Symbol Clock Selection

i19, i18, i17, i16:	Downstream/Upstream Baud clocks
0000	340 kBaud / 136 kBaud
0001	680 kBaud / 136 kBaud
0010	952 kBaud / 136 kBaud
0011	1088 kBaud / 136 kBaud
0100	136 kBaud / 136 kBaud.
0101	340 kBaud / 85 kBaud
0110	680 kBaud / 85 kBaud

Bits i20 - i22 are reserved for future growth and set to zero. Bit i23 is a continuation bit.

5.4.2.1.5.2.6 Fourth Byte

The fourth byte contains symbol rates capability and consists of bits i24 through i31, where bit i31 is reserved for the continuation bit.

The fourth byte describes the symbol rate capability, where a “1” identifies that the capability exists:

Table 15 - Symbol rate capability selection

Bit	Downstream/Upstream Symbol Rate Capability
i24	340 kBaud / 136 kBaud
i25	680 kBaud / 136 kBaud
i26	952 kBaud / 136 kBaud
i27	1088 kBaud / 136 kBaud
i28	136 kBaud / 136 kBaud
i29	340 kBaud / 85 kBaud
i30	680 kBaud / 85 kBaud
i31	Continuation bit

5.4.2.1.5.2.7 Fifth Byte

The fifth byte defines the first seven bits of Baud clock variable N0:
I32-I38 = N0[6:0]
I39 = continuation bit.

5.4.2.1.5.2.8 Sixth byte

The sixth byte defines the eighth bit of N0 and Baud clock variable D0:
I40-I45 = D0[5:0]
I46 = N0[7]
I47 = continuation bit.

5.4.2.1.5.2.9 Seventh Byte

The seventh byte defines the first seven bits of Baud clock variable D1:
I48-I54 = D1[6:0]
I55 = continuation bit.

5.4.2.1.5.2.10 Eighth Byte

The eighth byte defines the eighth bit of D1 and Baud clock variable D2:
I56-I60 = D2[4:0]
I61 = reserved
I62 = D1[7]
I63 = continuation bit.

5.4.2.1.5.3 Transceiver Training

Transceiver training is defined in the activation sequence of Figure 60.

5.4.2.1.5.4 Tomlinson Precoder Coefficient Exchange

Transfer of the Tomlinson coefficients is done by switching to the 2-CAP signal constellation, which is defined using points A and B in the uncoded 256-point constellation in Figure 67.

The data frame structure used to transmit the coefficients is shown in Figure 62.

The following sub-sections define the data in the *Data Block* field.

5.4.2.1.5.4.1 Size - 1 word [16 bits]

As shown in Figure 62, the first 8 bits (1 byte) in the data block field defines the size of the data block in terms of the number of bytes. The number in this field is a binary number that identifies the number of bytes following the *Size* byte. The msb is transmitted first.

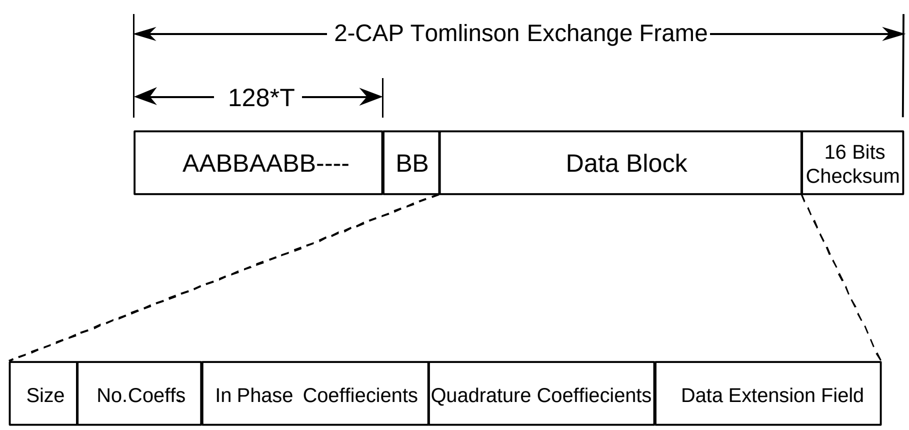


Figure 62 - Tomlinson Coefficient Exchange Frame Structure

5.4.2.1.5.4.2 Number of Coefficients (No.Coeffs.) in the Tomlinson Precoder **-** *1 word*

The lower 8 bits of this 16-bit word defines the number of complex coefficients in the Tomlinson precoder. The minimum number of taps is 16 for the downstream channel and 3 for the upstream channel.

5.4.2.1.5.4.3 In-Phase Coefficients **-** N *words*

The coefficients are transmitted in the sequence $c_0, c_1, \cdots, c_{N-1}$, where N is the number of coefficients. This field contains the in-phase coefficients to the precoder feedback filter.

5.4.2.1.5.4.4 Quadrature Coefficients **-** N *words*

This field contains the quadrature phase coefficients to the precoder feedback filter.

5.4.2.1.5.4.5 Requested CAP Constellation (N-CAP Req.) **-** *2 words*

Two words are reserved for the constellation size request; one for the downstream channel and the other for the upstream channel.

Table 16 - Constellation Request for Downstream Channel

Bit Location	Description
B0=0	reserved
B1	8-CAP, 2D8S Trellis Code Enabled
B2	16-CAP, 2D8S Trellis Code Enabled
B3	32-CAP, 2D8S Trellis Code Enabled
B4	64-CAP, 2D8S Trellis Code Enabled
B5	128-CAP, 2D8S Trellis Code Enabled
B6	256-CAP, 2D8S Trellis Code Enabled
B7	256-CAP, 2D8S Trellis Code Disabled
B8-B15	Reserved bits; bits are set to “0”

5.4.2.1.5.4.6 Channel Constellation Capability **-** *2 words*

These words identify which constellations the transceiver can support in the upstream and downstream channels. Each bit position corresponds to a constellation configuration. A value of 1 in the bit field indicates that the system supports the associated constellation; a value of 0 indicates that the system does not support the associated constellation. Note that bits 0, 1, and 9-15 are reserved and are all set to the default zero value.

Table 17 - Upstream and Downstream Channel Constellation Capability

Bit Location	Description
B0=0	reserved
B1	8-CAP, 2D8S Trellis Code Enabled
B2	16-CAP, 2D8S Trellis Code Enabled
B3	32-CAP, 2D8S Trellis Code Enabled
B4	64-CAP, 2D8S Trellis Code Enabled
B5	128-CAP, 2D8S Trellis Code Enabled
B6	256-CAP, 2D8S Trellis Code Enabled
B7	256-CAP, 2D8S Trellis Code Disabled
B8-B15	Reserved bits; bits are set to “0”

5.4.2.1.5.4.7 Transmit Power (Tx Power) - 1 word

This 16-bit word describes the transceiver’s transmit power setting in dBm.

5.4.2.1.5.4.8 Receiver Gain1 (Rx Power) - 1 word

This 16-bit word describes the associated receiver’s input gain setting in dB.

5.4.2.1.5.4.9 Received Signal Quality (Rcvr SQ) - 1 word

This 16-bit word describes the associated receiver’s output SNR in dB during start-up. The signal quality is equal to 49.34-10 log x in dB. If x = 0 then the signal quality is >49.34 dB.

5.4.2.1.5.4.10 Reserved - 1 word

This word is reserved for future growth and contains zeros.

5.4.2.1.5.4.11 RS Code Configuration Request (RS Req.) and Capability (RS Cap.) - 2 words.

The Reed-Solomon code is a two-symbol error correcting code. The default size for both the downstream and upstream is (N,K) = (68,64).

A *short* interleave depth is defined to be of size D = 4. The first word contains the RS Code configuration request information and the second word contains the RS Code configuration capability. Table 18 defines the bit assignments for the RS Code request word and capability word.

Table 18 - RS Code Configuration Request (Capability)

Bit No. (0-15)	Description
0	Downstream *Short* interleave requested (supported)
1	Downstream *Long* interleave depth requested (supported)
2	Downstream *Variable* interleave depth requested (supported)
3	Downstream *Default Codeword Size* requested (supported)
4	Downstream *Variable Codeword Size* requested (supported)
5	Upstream *Short* interleave requested (supported)
6	Upstream *Long* interleave depth requested (supported)
7	Upstream *Variable* interleave depth requested (supported)
8	Upstream *Default Codeword Size* requested (supported)
9	Upstream *Variable Codeword Size* requested (supported)
10-15	Reserved

5.4.2.1.5.4.12 Downstream RS Code Interleaving Depth Size (RS Depth) - 1 word

This is a 16-bit integer that contains the RS code interleaving depth size.

5.4.2.1.5.4.13 Upstream RS Code Variable Codeword Size (RS Size) - 1 word

This is a 16-bit integer that contains the RS code interleaving depth size.

5.4.2.1.5.4.14 Vendor Identification (Vendor ID) - 1 word

This field contains the vendor identification number as defined in Annex D of ANSI standard T1.413-1998 and Annex D of this technical report as well.

5.4.2.1.5.4.15 Vendor Specific - 4 words

Four words are reserved for vendor-specific use.

5.4.2.1.5.4.16 Receiver Gain2 (Rx Power) - 1 word

This 16-bit word describes the associated receiver’s input gain setting in linear scale, where 0x800 = 1.

5.4.2.1.5.4.17 Downstream and Upstream RS Code Variable Codeword Size (RS Size) - 1 word

This is a 16-bit integer that contains the RS codeword size for both the upstream and downstream channels. The upper byte contains the upstream codeword size and the lower byte contains the downstream codeword size.

5.4.2.1.5.4.18 Service Class Definition – 1 word

This is a 16-bit word that defines the service class, framer presence and configuration.

Bit 0 defines service class configuration: ‘0’ = class 1; ‘1’ = class 2.

Bit 1 defines framer presence: ‘0’ = framer not present; ‘1’ = framer present.

Bit 2 identifies the class 1 payload type: '0' = ATM based and '1' = packet based payload.

Bits 3-15 are reserved for future growth and set to '0'.

5.4.2.1.5.4.19 Checksum - 1 word

This field contains the two's complement of a zero run checksum.

5.4.2.1.6 RS Time Stamp

Transfer of the Reed-Solomon Time Stamp is done by switching to the 2-CAP signal constellation structure used for Tomlinson exchange, i.e., transmission of points A and B defined in the uncoded 256-point constellation in Figure 67.

The structure of the Reed Solomon Time Stamp sequence is shown in Figure 63. The data frame starts with the transmission of 256=128*2 symbols (2 points) with the repetitive sequence of points AABBAABB---AABB for synchronization and identification of the start of the coefficient data frame. This is followed with the Reed-Solomon marker symbol sequence, BB, which identifies the time stamp.

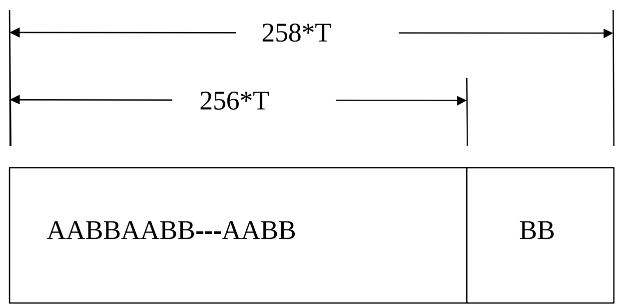


Figure 63 - Reed-Solomon Time Stamp Structure

After completion of the time stamp sequence, the ATU-C starts timer T6; correspondingly, the ATU-R receiver starts its T6 timer when it has finished receiving the time stamp.

5.4.2.1.7 Lock Descrambler

Immediately after sending the Reed-Solomon time stamp, the ATU-C transmits 150 ±20 msec of *16-CAP + Precode.* The ATU-C then sends the sequence CS4 for the duration of timer T7 and then locks the descrambler.

The ATU-C sends the *16-CAP + Precode signal* for 150 ±20 msec immediately after receiving the RS time stamp. The ATU-R then sends the RS3 signal for the duration of timer T7 and then locks its descrambler

5.4.2.1.8 Central Office Initiated Activation Sequence

Initiation from the central office location is provided by the ATU-C initiating a *poll* packet, i.e. RS0 sequence followed by a trailer with a poll identifier bit set accordingly. This poll initiates the activation procedure defined in section 5.4.2.1.9.2.

5.4.2.1.9 Warm Start

5.4.2.1.9.1 Customer Premises Initiated Warm Start

The warm start-up activation sequence is shown in Figure 64.

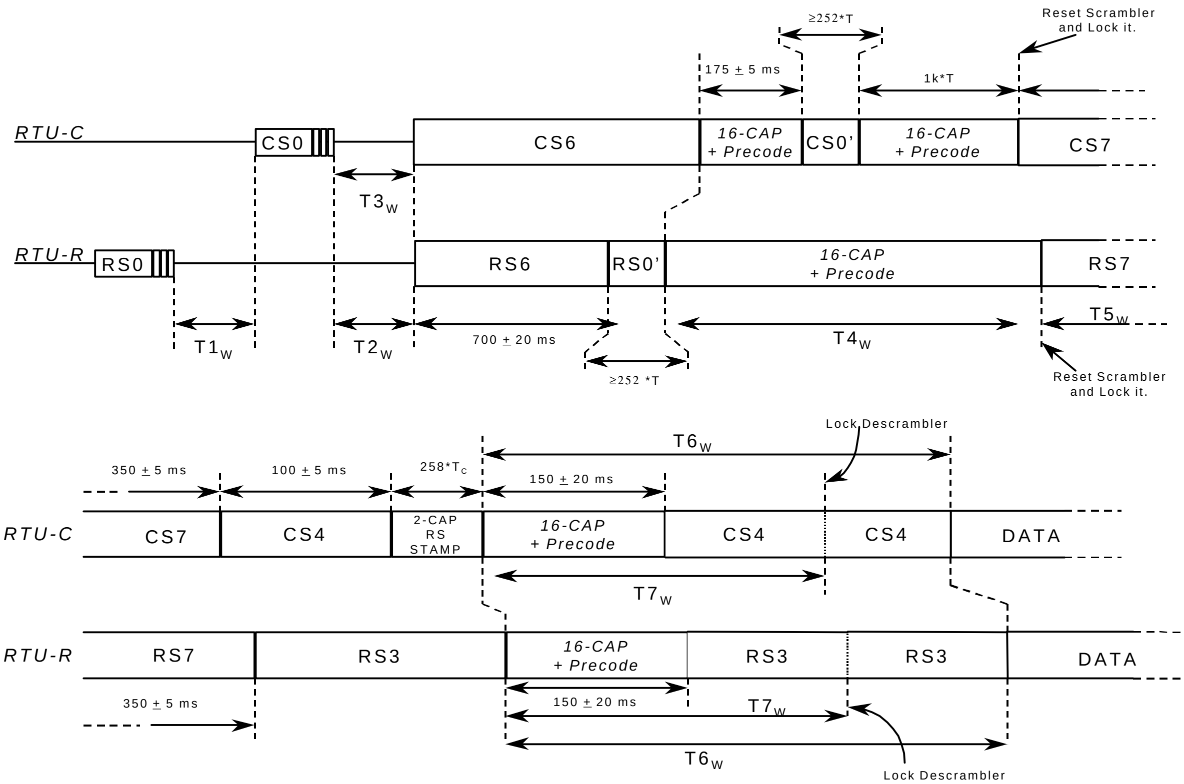


Figure 64 - Warm Start-up Activation Sequence with ATU-R Initiated Calling

5.4.2.1.9.2 Central Office Initiated Warm Start

Warm start initiation from the central office is provided by the ATU-C initiating a poll packet. Once initiated, the warm start sequence is the same as defined in Figure 64.

5.4.2.1.10 Signal Constellations During Start-Up

An uncoded mode is used during the start-up procedure, as described in Section 5.1.7. An uncoded one-dimensional signal constellation is shown in Figure 65. Figure 66 shows the uncoded 16-CAP signal constellation. Figure 67 shows an uncoded 256-CAP signal constellation. In all cases, Z0 is the lsb.

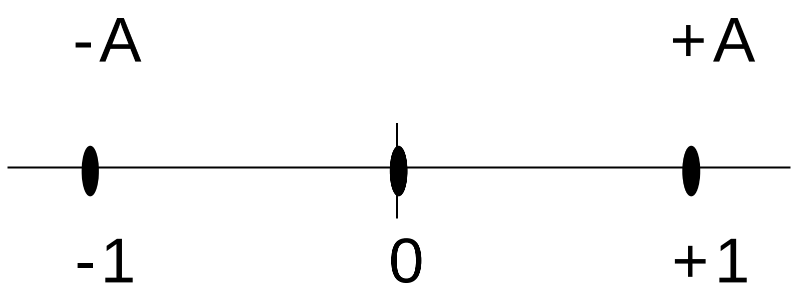


Figure 65 - Uncoded One Dimension 2-Point Signal Constellation

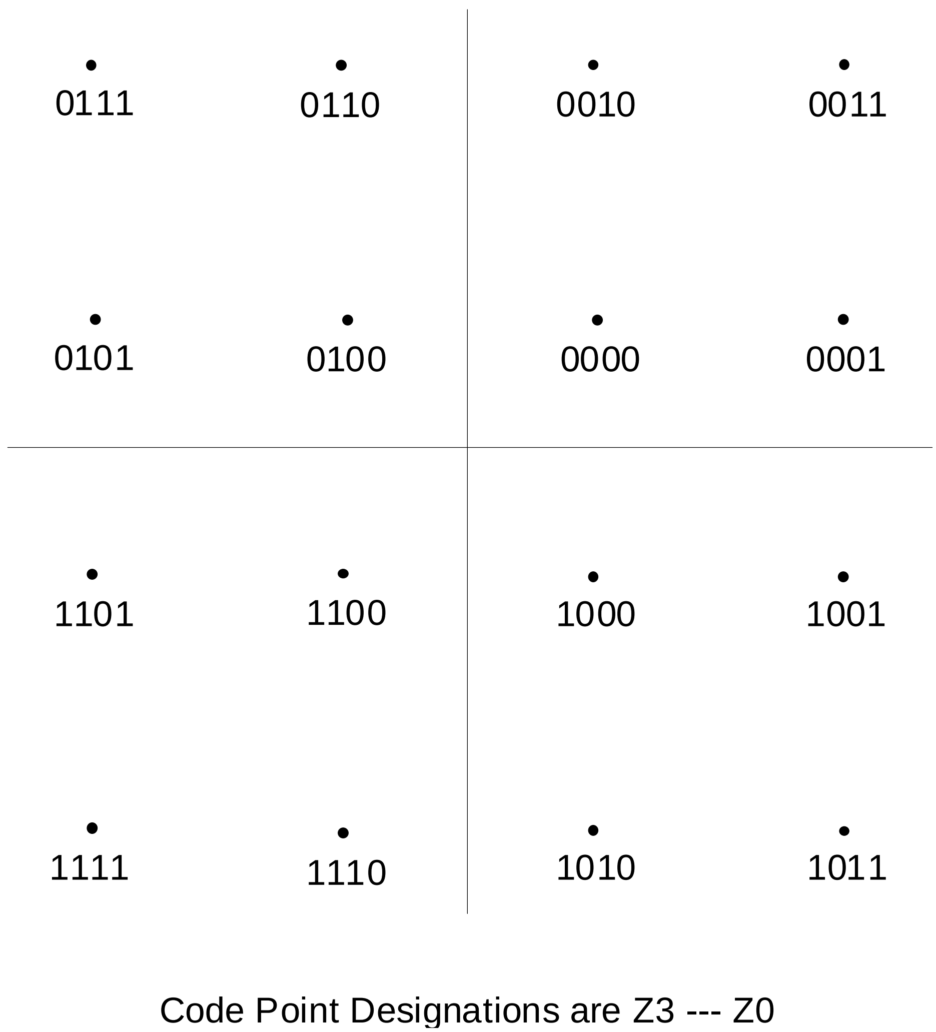
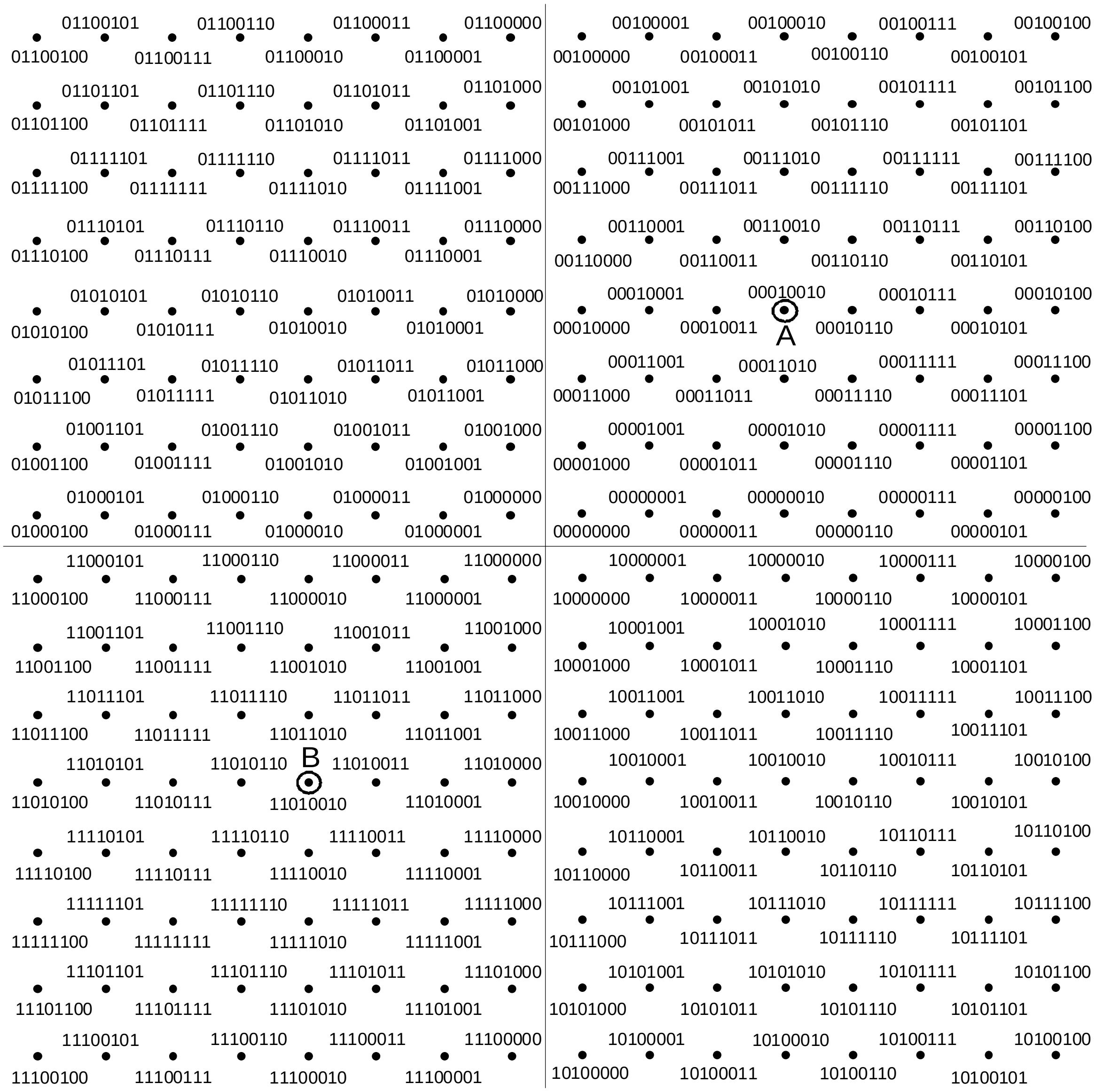


Figure 66 - Uncoded 16-CAP Signal Constellation



Code Point Designations are Z7 --- Z0

Figure 67 - Uncoded 256-CAP Signal Constellation

5.4.2.2 Blind Start-up

5.4.2.2.1 RADSL Operations Channel (AOC)

5.4.2.2.1.1 Overview

Relationship Between the AOC and the PTC and PMD Sub-Layers

A RADSL Operations Channel (AOC) is present in the QAM RADSL system to transport PMD and PTC initialization and adaptation messages between an ATU-R and ATU-C pair. As discussed in Section 5.4.2.2.1.1 the AOC is carried through the coded 2-octet AOC field present in each Class 1 and Class 2 frame. The content of each 2-octet AOC frame field is referred to as an AOC message. Conceptually, an AOC processor resides within the PTC sub-layer. The ATU-C masters AOC messages between itself and the ATU-R. AOC messages always originate from the ATU-C. These messages are used to help establish links between an ATU-C and ATU-R and to allow for the negotiation of new PTC and PMD parameter values.

Transport of EOC Streams Using the AOC

As discussed previously in Section 5.4.2.2.1, the AOC is also used to carry the bits of the EOC message streams TX-US-EOC, TX-DS-EOC, RX-US-EOC, and RX-DS-EOC. When a link exists between an ATU-R and ATU-C pair, and when the AOC is not being used to negotiate or modify the parameters of a link, the AOC frame field is used to transport the EOC stream. The lack of EOC transparency during PTC and PMD initialization and adaptation would occur with or without this multiplexing within the AOC frame field, since many transmission parameter changes can be expected to result in a temporary loss of EOC and payload throughput.

When the AOC processor has no initialization and adaptation message to send, it sets the two MSBs of the first AOC frame field octet to 11, and inserts the next octet of the TX-US-EOC or TX-DS-EOC stream into the least significant octet of the AOC frame field. As described below, the first octet of every AOC frame field is referred to as the AOC opcode. The set of AOC opcodes whose two MSBs are 11 are collectively referred to by the single opcode name "IDLE." Thus receipt of an IDLE opcode by an AOC processor indicates that the least significant octet of that AOC message contains the next octet in the RX-US-EOC or RX-DS-EOC stream.

When the AOC processor has an initialization and adaptation message to send, EOC transparency is interrupted, and the MSB of the transmitted AOC opcode will become a zero, indicating transmission of an AOC message other than IDLE. When the AOC message handshake described in Section 5.4.2.2.1.2 is complete, and when the ATU-C/ATU-R link is re-established following the corresponding parameter changes, EOC transport over the AOC is again enabled.

It is anticipated that certain EOC messages will affect some of the same PTC and PMD parameters that are modifiable by the AOC message set. The same may be true for OAM&P messages carried in the payload of the transported data (e.g., F3 - F5 cell streams, SNMP messages at the IP layer, etc.). As the AOC processor can and should be a component of the overall OAM&P platform, coordination between OAM&P messages carried through the EOC, AOC, and payload channels is to be expected.

AOC Message Types

AOC messages consist of a single-octet opcode followed by one octet of data. Each AOC message is one of three types. COMMAND-type messages are sent from the ATU-C to the ATU-R, and are intended to convey information to and/or request action from the recipient. ECHO messages are commands echoed from the ATU-R to the ATU-C, and are intended to acknowledge receipt of a COMMAND-type message and indicate the ATU-R's understanding of the message. Finally, STATUS-type messages consist of the IDLE and Unable to Comply (UTC) messages. All message types are used in a handshaking process designed to increase the reliability of AOC communication. The UTC message is used to indicate the ATU-R's inability to comply with the command.

The following subsections describe the AOC message set and the handshaking protocol used to reliably communicate AOC messages between an ATU-C and ATU-R.

5.4.2.2.1.2 AOC Message Handshake

Motivation

The AOC COMMAND-type messages are used to control and trigger changes in PTC and PMD operating characteristics, such as baud rates and frame structures. To avoid the execution of unintended PTC and PMD changes caused by channel transmission errors, two layers of robust processing are used in the AOC message handshake. The first layer consists of the inclusion of the AOC field in the coded portion of the transmit frame. The second layer consists of an echoed command handshake between the two entities attempting to communicate a message. Combining these two layers of processing results in an AOC message passing protocol that is extremely resilient in the presence of channel errors.

The echoed command handshake also allows for AOC processors with a wide range of processing speeds to function effectively in AOC message passing. Rather than transmitting each component of the handshake for a fixed number of frames or fixed length of time, and risk missing messages and/or experiencing timing synchronization difficulties, the handshake is driven by a state machine that guarantees avoidance of these problems.

Handshake Rules and Flow Charts

Figure 68 illustrates the handshake that occurs between the ATU-C and the ATU-R, under the assumptions that the ATU-R can comply with the transmitted command and that all handshake components are received error-free (following FEC). The signals shown for both ATU-C and ATU-R refer to the AOC message being transmitted by each as a function of time. Each message lasts for a length of time corresponding to the number of transmit frames for which the AOC frame field contains the indicated message. The diagonal lines between sender and recipient messages indicate that detection of the first message transition triggers the second indicated transition. Because of interleaving, channel, and processing delays, there can be considerable delay in these trigger events.

Figure 68 starts with both sender and recipient transmitting the IDLE AOC message, which is a necessary condition at the start of a new transfer. The ATU-C then begins and continues transmitting a COMMAND-type message, which the ATU-R eventually detects. The message received at the ATU-R is only provisionally accepted and will change if uncorrectable transmission errors occur in the AOC field. When the ATU-R has received three consecutive identical AOC commands, the COMMAND-type message is accepted and latched. The ATU-R then responds by beginning and continuing to transmit an echo of the received and accepted COMMAND message. If the ATU-R is unable to comply, it will transmit a UTC message instead of echoing the COMMAND message.

As described below, the data field of an ECHO-type message contains the data field of the COMMAND message if it was a write COMMAND or the read data if it was a read COMMAND. When the ATU-C detects the arrival of three correct and consecutive ECHO-type responses, it responds by beginning and continuing to transmit the IDLE message. When the ATU-R hears the IDLE message it stops transmitting the ECHO or UTC message and transmits IDLE in its place. At this point, when both stations have progressed back to transmitting the IDLE message, the AOC command passing sequence is complete, and for this example, is deemed a success. Note that the UTC message from the ATU-R is a valid response to an AOC COMMAND message from the ATU-C.

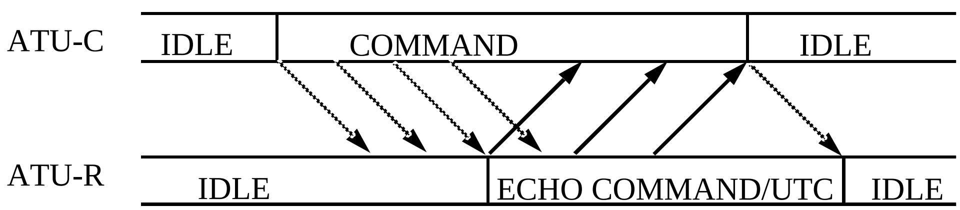


Figure 68 - Example of a Handshake for a Successfully Communicated Command

An example of a handshake delayed by transmission errors is represented in Figure 69. This handshake occurs when the ATU-R's received (shown in Figure 69) or echoed message, as received by the ATU-C, reflects a transmission error of either the COMMAND or ECHO messages, respectively. In this case, the ATU-C continues sending the COMMAND message. When the ATU-R receives three correct and consecutive COMMAND messages, it responds by beginning and continuing to transmit the corresponding ECHO-type message. When the ATU-C receives three correct and consecutive ECHO-type responses, it responds by beginning and continuing to transmit the IDLE message as in the previous example. The ATU-R continues sending the echoed message until it receives the IDLE message from the ATU-C.

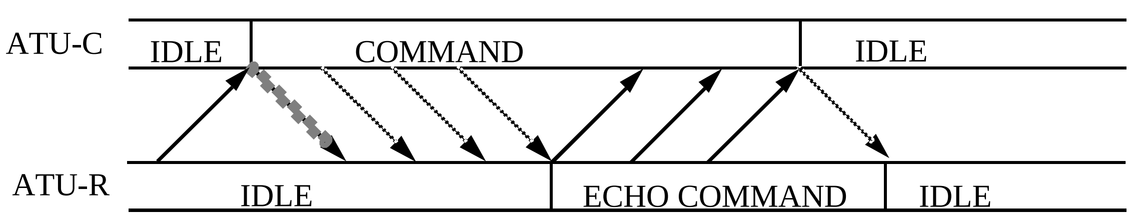


Figure 69 - Example of a Handshake for a Corrected, Communicated Command

The AOC handshake flow charts to be implemented by the ATU-C and ATU-R are shown in Figure 70 and Figure 71, respectively. These flow charts allow the ATU-C/ATU-R pair to send/receive AOC commands, and contain escape mechanisms in the event of state machine hang-up.

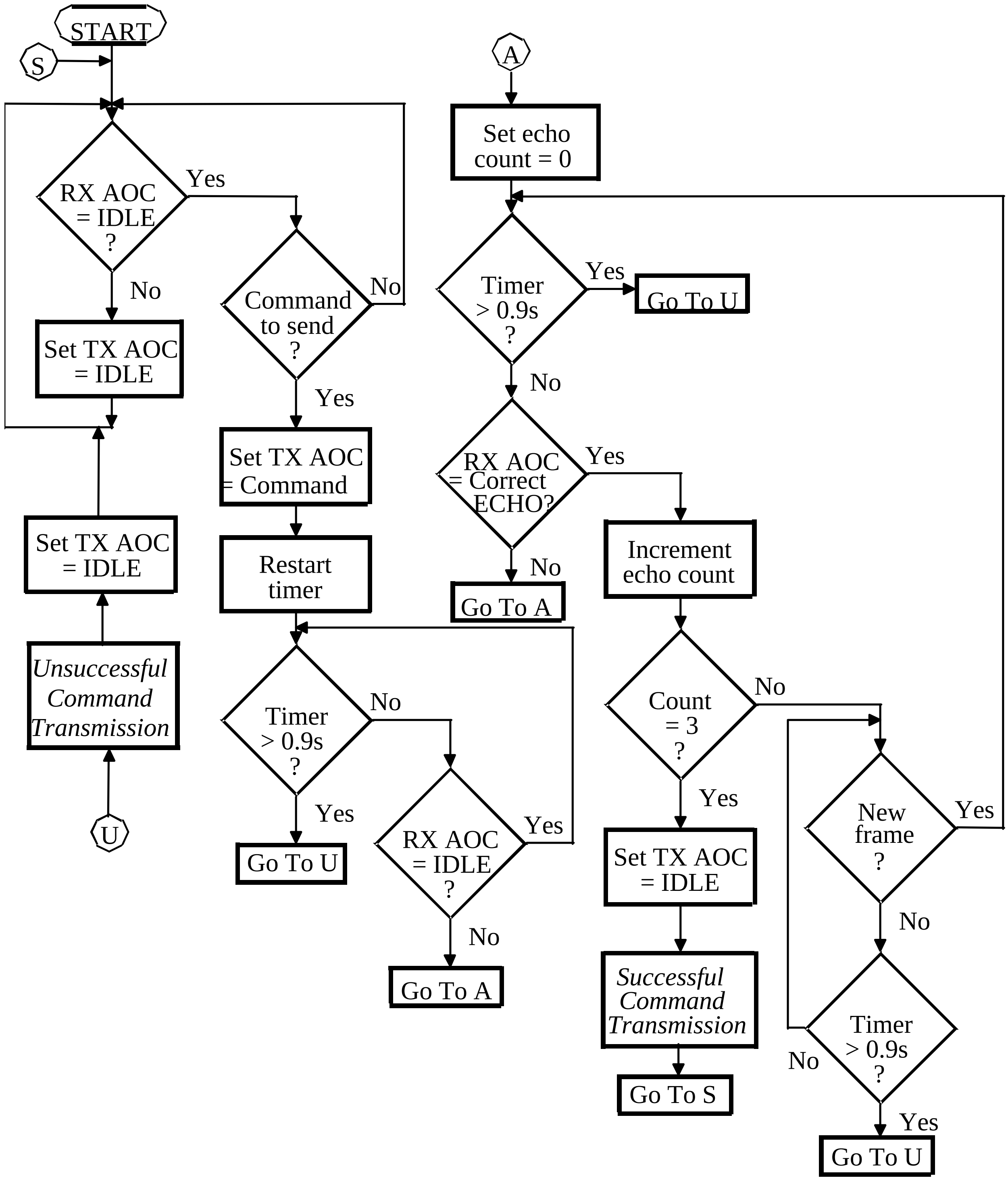


Figure 70 - ATU-C AOC Handshaking Flow Chart

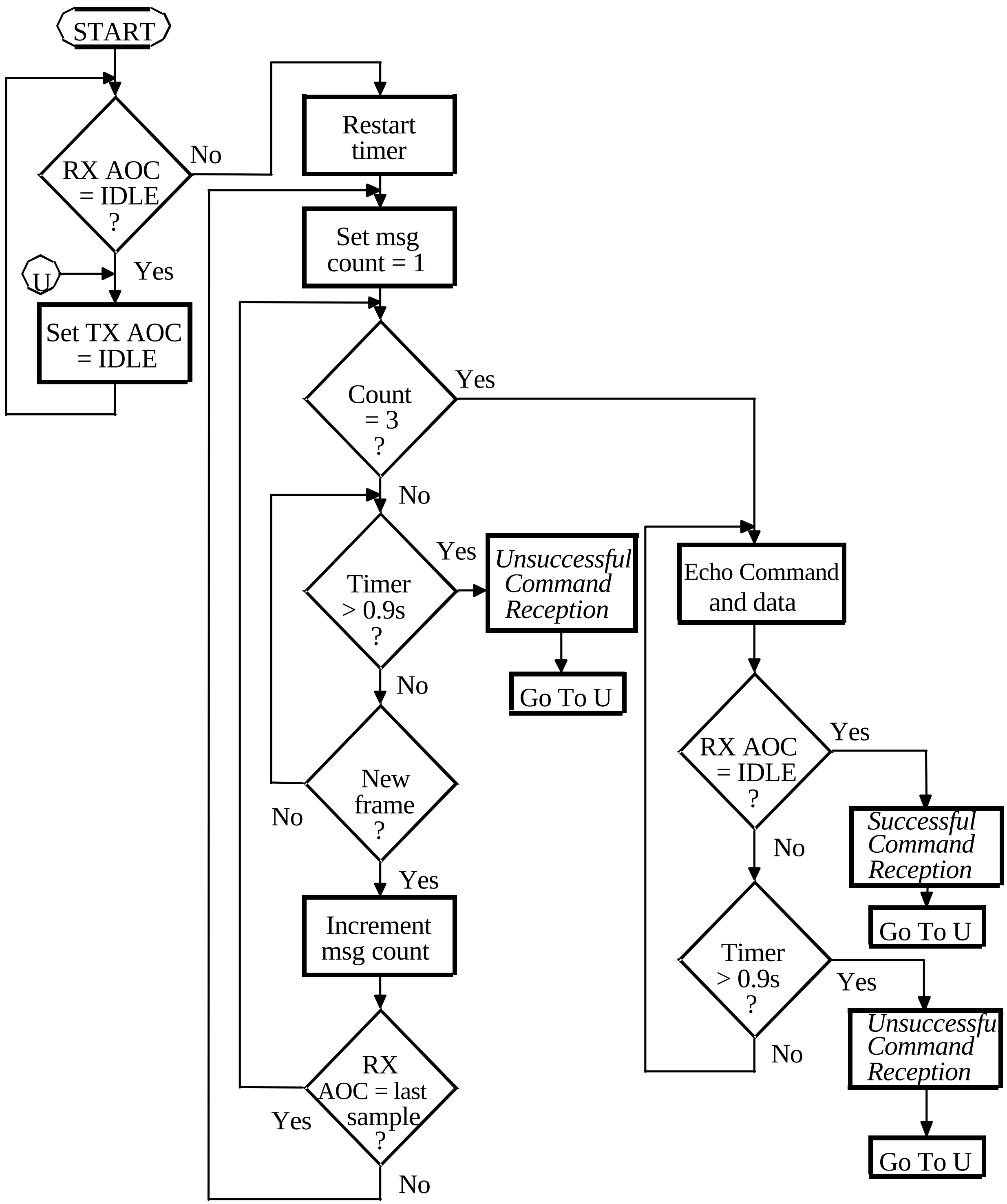


Figure 71 - ATU-R AOC Handshaking Flow Chart

5.4.2.2.1.3 AOC Message Set

The following tables define the opcode and data field values of all valid AOC messages. Different AOC messages are grouped in different tables according to overall functionality associated with that set. Table 19 contains the IDLE and UTC messages. Table 20 contains messages used in performance monitoring. Table 21 contains messages used to directly trigger changes in upstream or downstream PMD parameters, as described in Section 8. In addition to opcode (first octet) and data field (second octet) information, each table contains an indication of the message type, along with a message description. Table 21 also contains message classification information used in Section 5.4.2.2.2.4. ECHO-type messages sent from the ATU-R use the same opcode value as the COMMAND-type message that is being echoed. The data field of an ECHO-type message contains the same data as sent in a COMMAND (WRITE) message and the data requested from a COMMAND (READ) message.

Table 19 - Data-Independent STATUS-type and ACK-type AOC Messages

Message Name	Message Type	Opcode Field	Data Field	Description
IDLE	STATUS	0xFF	0x00	EOC transport
UTC	ECHO	0xF0	Same as message being UTC'ed	Unable To Comply message

Table 20 - Performance Monitoring and Control AOC Messages

Message Name	Message Type	Opcode Field	Data Field	Description
SNRREQ	COMMAND (READ) and ECHO	0x01	COMMAND: All zeros. ECHO: Expect ATU-R's RX SNR estimate, in dB, coded as an unsigned fraction with binary point immediately before the LSB	Request that ATU-R send SNR data in the return data field
SNRDATA	COMMAND (WRITE) and ECHO	0x02	ATU-C's RX SNR estimate, in dB, coded as an unsigned fraction with binary point immediately before the LSB	Sent to indicate ATU-C RX SNR estimate in dB
THRPUT	COMMAND (WRITE) and ECHO	0x03	All 0's to set THRPUT=0. All 1's to set THRPUT=1.	Sets or resets the value of the THRPUT flag in the ATU-R.
THRPUTREQ	COMMAND (READ) and ECHO	0x04	COMMAND: All zeros. ECHO: Expect ATU-R's THRPUT flag: all 0's to set THRPUT=0. All 1's to set THRPUT=1.	Request that ATU-R send the value of THRPUT
CORERREQ	COMMAND (READ) and ECHO	0x05	COMMAND: All zeros ECHO: Expect ATU-R's CORERR data as unsigned integer = # of errors (saturates at 255)	Request that ATU-R send number of errors corrected by RS in the return data field since the last CORERREQ
CORERR	COMMAND (WRITE) and ECHO	0x06	Unsigned integer = # of errors (saturates at 255)	Report number of errors corrected by RS in ATU-C since last time CORERR sent
UCERREQ	COMMAND (READ) and ECHO	0x07	COMMAND: All zeros. ECHO: Expect ATU-R's UCERR data as unsigned integer = # of errors (saturates at 255)	Request that ATU-R send number of uncorrectable errors by RS in the return data field since the last UCERREQ
UCERR	COMMAND (WRITE) and ECHO	0x08	Unsigned integer = # of errors (saturates at 255)	Report number of uncorrectable errors by RS in ATU-C since last time UCERR sent
HECREQ	COMMAND (READ) and ECHO	0x09	COMMAND: All zeros. ECHO: Expect ATU-R's HEC data as unsigned integer = # of errors (saturates at 255)	Request that ATU-R send number of ATM HEC errors since the last HECREQ
HEC	COMMAND (WRITE) and ECHO	0x0A	Unsigned integer = # of errors (saturates at 255)	Report number of ATM HEC errors in the ATU-C since last time HEC sent

Table 21 - Messages Used to Trigger PMD Parameter Changes

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
D_RESET	COMMAND (WRITE) and ECHO	L1	0x1D	0x20	Request to reset ATU-R DS channel to default
U_RESET	COMMAND (WRITE) and ECHO	L1	0x1E	0x22	Request to reset ATU-R US channel to default
RESET	COMMAND (WRITE) and ECHO	L1	0x1F	0x24	Request to reset ATU-R US and DS channels to default
D_BAUDQH	COMMAND (WRITE) and ECHO	L3	0x20	Most significant octet (of 3) of the unsigned integer B_{DS}	Request that DS baud rate be changed and DS constellation set to QPSK
D_BAUDQM	COMMAND (WRITE) and ECHO	L2	0x21	2nd Most significant octet (of 3) of the unsigned integer B_{DS}	Request that DS baud rate be changed and DS constellation set to QPSK
D_BAUDQL	COMMAND (WRITE) and ECHO	L1	0x22	Least significant octet (of 3) of the unsigned integer B_{DS}	Request that DS baud rate be changed and DS constellation set to QPSK
D_BAUDH	COMMAND (WRITE) and ECHO	L3	0x23	Most significant octet (of 3) of the unsigned integer B_{DS}	Request that DS baud rate be changed and DS constellation left as is
D_BAUDHREQ	COMMAND (READ) and ECHO	L3	0x24	COMMAND: All zeros. ECHO: Most significant octet (of 3) of the unsigned integer B_{DS}	Request that the ATU-R send the DS baud rate
D_BAUDM	COMMAND (WRITE) and ECHO	L2	0x25	2nd Most significant octet (of 3) of the unsigned integer B_{DS}	Request that DS baud rate be changed and DS constellation left as is
D_BAUDMREQ	COMMAND (READ) and ECHO	L2	0x26	COMMAND: All zeros. ECHO: 2nd Most significant octet (of 3) of the unsigned integer B_{DS}	Request that the ATU-R send the DS baud rate
D_BAUDL	COMMAND (WRITE) and ECHO	L1	0x27	Least significant octet (of 3) of the unsigned integer B_{DS}	Request that DS baud rate be changed and DS constellation left as is

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
D_BAUDLREQ	COMMAND (READ) and ECHO	L1	0x28	COMMAND: All zeros. ECHO: Least significant octet (of 3) of the unsigned integer B_{DS}	Request that the ATU-R send the DS baud rate
D_CONSTEL	COMMAND (WRITE) and ECHO	L1	0x29	Unsigned integer = # of constellation points	Request that DS constellation be changed
D_CONSTELREQ	COMMAND (READ) and ECHO	L1	0x2A	COMMAND: All zeros. ECHO: Unsigned integer = # of constellation points	Request that the ATU-R send DS constellation size
D_INTERLV	COMMAND (WRITE) and ECHO	L1	0x2B	Unsigned integer = interleaving depth	Request that DS interleaving depth be changed
D_INTERLVREQ	COMMAND (READ) and ECHO	L1	0x2C	COMMAND: All zeros. ECHO: Unsigned integer = interleaving depth	Request that the ATU-R send DS interleaving depth
D_PSD	COMMAND (WRITE) and ECHO	L1	0x2D	Unsigned integer = negative of PSD level in dBm/Hz	Request that DS PSD level be changed
D_PSDREQ	COMMAND (READ) and ECHO	L1	0x2E	COMMAND: All zeros. ECHO: Unsigned integer = negative of PSD level in dBm/Hz	Request that the ATU-R send DS PSD level
D_FRAME3	COMMAND (WRITE) and ECHO	L3	0x2F	Unsigned integer = *L* value	Request that DS frame structure be changed, 1st of 3 commands. *U* = 0 implies Class 1 frame. *U* = *C* = 0 implies Class 1 frame w/out FEC. *U* != 0 implies Class 2 frame
D_FRAME3REQ	COMMAND (READ) and ECHO	L3	0x30	COMMAND: All zeros ECHO: Unsigned integer = *L* value	Request that the ATU-R send DS frame structure, 1st of 3 commands. *U* = 0 implies Class 1 frame. *U* = *C* = 0 implies Class 1 frame w/out FEC. *U* != 0 implies Class 2 frame
D_FRAME2	COMMAND (WRITE) and ECHO	L2	0x31	Unsigned integer = *U* value	Request that DS frame structure be changed, 2nd of 3 commands. See D_FRAME3.

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
D_FRAME2REQ	COMMAND (READ) and ECHO	L2	0x32	COMMAND: All zeros. ECHO: Unsigned integer = *U* value	Request that the ATU-R send DS frame structure, 2nd of 3 commands. See D_FRAME3.
D_FRAME1	COMMAND (WRITE) and ECHO	L1	0x33	Unsigned integer = *C* value	Request that DS frame structure be changed, 3rd of 3 commands. See D_FRAME3.
D_FRAME1REQ	COMMAND (READ) and ECHO	L1	0x34	COMMAND: All zeros. ECHO: Unsigned integer = *C* value	Request that the ATU-R send DS frame structure, 3rd of 3 commands. See D_FRAME3.
D_CENFR3	COMMAND (WRITE) and ECHO	L3	0x35	Most significant octet of C_{DS}	DS center frequency change request, 1st of 3
D_CENFR3REQ	COMMAND (READ) and ECHO	L3	0x36	COMMAND: All zeros. ECHO: Most significant octet of C_{DS}	Request that the ATU-R send DS center frequency, 1st of 3
D_CENFR2	COMMAND (WRITE) and ECHO	L2	0x37	Second most significant octet of C_{DS}	DS center frequency change request, 2nd of 3
D_CENFR2REQ	COMMAND (READ) and ECHO	L2	0x38	COMMAND: All zeros. ECHO: Second most significant octet of C_{DS}	Request that the ATU-R send DS center frequency, 2nd of 3
D_CENFR1	COMMAND (WRITE)	L1	0x39	Least significant octet of C_{DS}	DS center frequency change request, 3rd of 3
D_CENFR1REQ	COMMAND (READ) and ECHO	L1	0x3A	COMMAND: All zeros. ECHO: Least significant octet of C_{DS}	Request that the ATU-R send DS center frequency, 3rd of 3
D_MAND	COMMAND (WRITE)	L1	0x3B	Indicates which mandatory DS baud rate and center frequency to use	Select mandatory DS baud rate and center frequency indicated in data field
D_MANDREQ	COMMAND (READ) and ECHO	L1	0x3C	COMMAND: All zeros. ECHO: Indicates which mandatory DS baud rate and center frequency to use	Request that the ATU-R send the mandatory DS baud rate and center frequency being used

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
D_DFE1RHREQ	COMMAND (READ) and ECHO	L3	0x3D	COMMAND: All zeros ECHO: MS octet of ATU-R 1st DFE tap real part (2's comp.). MSB weight = -2	Request that ATU-R send the MS octet (of 3) of 1st ATU-R DFE tap, real part
D_DFE1RMREQ	COMMAND (READ) and ECHO	L2	0x3E	COMMAND: All zeros ECHO: 2nd MS octet of ATU-R 1st DFE tap real part.	Request that ATU-R send the 2nd MS octet (of 3) of 1st ATU-R DFE tap, real part
D_DFE1RLREQ	COMMAND (READ) and ECHO	L1	0x3F	COMMAND: All zeros ECHO: LS octet of ATU-R 1st DFE tap real part	Request that ATU-R send the LS octet (of 3) of 1st ATU-R DFE tap, real part
D_DFE1IHREQ	COMMAND (READ) and ECHO	L3	0x40	COMMAND: All zeros ECHO: MS octet of ATU-R 1st DFE tap imag[2] part (2's comp.). MSB weight = -2	Request that ATU-R send the MS octet (of 3) of 1st ATU-R DFE tap, imag part
D_DFE1IMREQ	COMMAND (READ) and ECHO	L2	0x41	COMMAND: All zeros ECHO: 2nd MS octet of ATU-R 1st DFE tap imag part.	Request that ATU-R send the 2nd MS octet (of 3) of 1st ATU-R DFE tap, imag part
D_DFE1ILREQ	COMMAND (READ) and ECHO	L1	0x42	COMMAND: All zeros ECHO: LS octet of ATU-R 1st DFE tap imag part	Request that ATU-R send the LS octet (of 3) of 1st ATU-R DFE tap, imag part
D_DFENRHREQ	COMMAND (READ) and ECHO	L3	0x43	COMMAND: All zeros ECHO: MS octet of ATU-R next DFE tap real part (2's comp.). MSB weight = -2	Request that ATU-R send the MS octet (of 3) of next ATU-R DFFE tap, real part
D_DFENRMREQ	COMMAND (READ) and ECHO	L2	0x44	COMMAND: All zeros ECHO: 2nd MS octet of ATU-R next DFE tap real part.	Request that ATU-R send the 2nd MS octet (of 3) of next ATU-R DFFE tap, real part
D_DFENRLREQ	COMMAND (READ) and ECHO	L1	0x45	COMMAND: All zeros ECHO: LS octet of ATU-R next DFE tap real part	Request that ATU-R send the LS octet (of 3) of next ATU-R DFFE tap, real part

[2] Imaginary (imag).

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
D_DFENIHREQ	COMMAND (READ) and ECHO	L3	0x46	COMMAND: All zeros ECHO: MS octet of ATU-R next DFE tap imag part (2's comp.). MSB weight = -2	Request that ATU-R send the MS octet (of 3) of next ATU-R DFE tap, imag part
D_DFENIMREQ	COMMAND (READ) and ECHO	L2	0x47	COMMAND: All zeros ECHO: 2nd MS octet of ATU-R next DFE tap imag part.	Request that ATU-R send the 2nd MS octet (of 3) of next ATU-R DFE tap, imag part
D_DFENILREQ	COMMAND (READ) and ECHO	L1	0x48	COMMAND: All zeros ECHO: LS octet of ATU-R next DFE tap imag part	Request that ATU-R send the LS octet (of 3) of next ATU-R DFE tap, imag part
U_BAUDQH	COMMAND (WRITE) and ECHO	L3	0x90	Most significant octet (of 3) of the unsigned integer B_{US}	Request that US baud rate be changed and US constellation set to QPSK
U_BAUDQM	COMMAND (WRITE) and ECHO	L2	0x91	2nd Most significant octet (of 3) of the unsigned integer B_{US}	Request that US baud rate be changed and US constellation set to QPSK
U_BAUDQL	COMMAND (WRITE) and ECHO	L1	0x92	Least significant octet (of 3) of the unsigned integer B_{US}	Request that US baud rate be changed and US constellation set to QPSK
U_BAUDH	COMMAND (WRITE) and ECHO	L3	0x93	Most significant octet (of 3) of the unsigned integer B_{US}	Request that US baud rate be changed and US constellation left as is
U_BAUDHREQ	COMMAND (READ) and ECHO	L3	0x94	COMMAND: All zeros. ECHO: Most significant octet (of 3) of the unsigned integer B_{US}	Request that the ATU-R send US baud rate
U_BAUDM	COMMAND (WRITE) and ECHO	L2	0x95	2nd Most significant octet (of 3) of the unsigned integer B_{US}	Request that US baud rate be changed and US constellation left as is
U_BAUDMREQ	COMMAND (READ) and ECHO	L2	0x96	COMMAND: All zeros. ECHO: 2nd Most significant octet (of 3) of the unsigned integer B_{US}	Request that the ATU-R send US baud rate

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
U_BAUDL	COMMAND (WRITE) and ECHO	L1	0x97	Least significant octet (of 3) of the unsigned integer B_{US}	Request that US baud rate be changed and US constellation left as is
U_BAUDLREQ	COMMAND (READ) and ECHO	L1	0x98	COMMAND: All zeros. ECHO: Least significant octet (of 3) of the unsigned integer B_{US}	Request that the ATU-R send US baud rate
U_CONSTEL	COMMAND (WRITE) and ECHO	L1	0x99	Unsigned integer = # of constellation points	Request that US constellation be changed
U_CONSTELREQ	COMMAND (READ) and ECHO	L1	0x9A	COMMAND: All zeros. ECHO: Unsigned integer = # of constellation points	Request that the ATU-R send constellation size
U_INTERLV	COMMAND (WRITE) and ECHO	L1	0x9B	Unsigned integer = interleaving depth	Request that US interleaving depth be changed
U_INTERLVREQ	COMMAND (READ) and ECHO	L1	0x9C	COMMAND: All zeros. ECHO: Unsigned integer = interleaving depth	Request that the ATU-R send interleaving depth
U_PSD	COMMAND (WRITE) and ECHO	L1	0x9D	Unsigned integer = negative of PSD level in dBm/Hz	Request that US PSD level be changed
U_PSDREQ	COMMAND (READ) and ECHO	L1	0x9E	COMMAND: All zeros. ECHO: Unsigned integer = negative of PSD level in dBm/Hz	Request that the ATU-R send US PSD level
U_FRAME3	COMMAND (WRITE) and ECHO	L3	0x9F	Unsigned integer = *L* value	Request that US frame structure be changed, 1st of 3 commands. *U* = 0 implies Class 1 frame. *U* = *C* = 0 implies Class 1 frame w/out FEC. *U* != 0 implies Class 2 frame
U_FRAME3REQ	COMMAND (READ) and ECHO	L3	0xA0	COMMAND: All zeros. ECHO: Unsigned integer = *L* value	Request that the ATU-R send US frame structure used, 1st of 3 commands. *U* = 0 implies Class 1 frame. *U* = *C* = 0 implies Class 1 frame w/out FEC. *U* != 0 implies Class 2 frame

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
U_FRAME2	COMMAND (WRITE) and ECHO	L2	0xA1	Unsigned integer = *U* value	Request that US frame structure be changed, 2nd of 3 commands. See U_FRAME3.
U_FRAME2REQ	COMMAND (READ) and ECHO	L2	0xA2	COMMAND: All zeros. ECHO: Unsigned integer = *U* value	Request that the ATU-R send US frame structure used, 2nd of 3 commands. See U_FRAME3.
U_FRAME1	COMMAND (WRITE) and ECHO	L1	0xA3	Unsigned integer = *C* value	Request that US frame structure be changed, 3rd of 3 commands. See U_FRAME3.
U_FRAME1REQ	COMMAND (READ) and ECHO	L1	0xA4	COMMAND: All zeros. ECHO: Unsigned integer = *C* value	Request that the ATU-R send US frame structure used, 3rd of 3 commands. See U_FRAME3.
U_CENFR3	COMMAND (WRITE) and ECHO	L3	0xA5	Most significant octet of C_{US}	US center frequency change request, 1st of 3
U_CENFR3REQ	COMMAND (READ) and ECHO	L3	0xA6	COMMAND: All zeros. ECHO: Most significant octet of C_{US}	Request that the ATU-R send US center frequency used, 1st of 3
U_CENFR2	COMMAND (WRITE) and ECHO	L2	0xA7	Second most significant octet of C_{US}	US center frequency change request, 2nd of 3
U_CENFR2REQ	COMMAND (READ) and ECHO	L2	0xA8	COMMAND: All zeros. ECHO: Second most significant octet of C_{US}	Request that the ATU-R send US center frequency used, 2nd of 3
U_CENFR1	COMMAND (WRITE) and ECHO	L1	0xA9	Least significant octet of C_{US}	US center frequency change request,3rd of 3
U_CENFR1REQ	COMMAND (READ) and ECHO	L1	0xAA	COMMAND: All zeros. ECHO: Least significant octet of C_{US}	Request that the ATU-R send US center frequency used, 3rd of 3
U_MAND	COMMAND (WRITE) and ECHO	L1	0xAB	Indicates which mandatory US baud rate and center frequency to use	Select mandatory US baud rate and center frequency indicated in data field
U_MANDREQ	COMMAND (READ) and ECHO	L1	0xAC	COMMAND: All zeros. ECHO: Indicates which mandatory US baud rate and center frequency	Request that the ATU-R send mandatory US baud rate and center frequency used

Message Name	Message Type	L1/L2 Class	Opcode Field	Data Field	Description
U_TOM1RHREQ	COMMAND (WRITE) and ECHO	L3	0xAD	MS octet of ATU-R 1st Tomlinson precoder tap real part (2's comp.). MSB weight = -2	Value of MS octet (of 3) of 1st ATU-R Tomlinson precoder tap, real part
U_TOM1RMREQ	COMMAND (WRITE) and ECHO	L2	0xAE	2nd MS octet of ATU-R 1st Tomlinson precoder tap real part (2's comp.).	Value of 2nd MS octet (of 3) of 1st ATU-R Tomlinson precoder tap, real part
U_TOM1RLREQ	COMMAND (WRITE) and ECHO	L1	0xAF	LS octet of ATU-R 1st Tomlinson precoder tap real part (2's comp.).	Value of LS octet (of 3) of 1st ATU-R Tomlinson precoder tap, real part
U_TOM1IHREQ	COMMAND (WRITE) and ECHO	L3	0xA0	MS octet of ATU-R 1st Tomlinson precoder tap imag part (2's comp.). MSB weight = -2	Value of MS octet (of 3) of 1st ATU-R Tomlinson precoder tap, imag part
U_TOM1IMREQ	COMMAND (WRITE) and ECHO	L2	0xA1	2nd MS octet of ATU-R 1st Tomlinson precoder tap imag part (2's comp.).	Value of 2nd MS octet (of 3) of 1st ATU-R Tomlinson precoder tap, imag part
U_TOM1ILREQ	COMMAND (WRITE) and ECHO	L1	0xA2	LS octet of ATU-R 1st Tomlinson precoder tap imag part (2's comp.).	Value of LS octet (of 3) of 1st ATU-R Tomlinson precoder tap, imag part
U_TOMNRHREQ	COMMAND (WRITE) and ECHO	L3	0xA3	MS octet of ATU-R next Tomlinson precoder tap real part (2's comp.). MSB weight = -2	Value of MS octet (of 3) of next ATU-R Tomlinson precoder tap, real part
U_TOMNRMREQ	COMMAND (WRITE) and ECHO	L2	0xA4	2nd MS octet of ATU-R next Tomlinson precoder tap real part (2's comp.).	Value of 2nd MS octet (of 3) of next ATU-R Tomlinson precoder tap, real part
U_TOMNRLREQ	COMMAND (WRITE) and ECHO	L1	0xA5	LS octet of ATU-R next Tomlinson precoder tap real part (2's comp.).	Value of LS octet (of 3) of next ATU-R Tomlinson precoder tap, real part
U_TOMNIHREQ	COMMAND (WRITE) and ECHO	L3	0xA6	MS octet of ATU-R next Tomlinson precoder tap imag part (2's comp.). MSB weight = -2	Value of MS octet (of 3) of next ATU-R Tomlinson precoder tap, imag part
U_TOMNIMREQ	COMMAND (WRITE) and ECHO	L2	0xA7	2nd MS octet of ATU-R next Tomlinson precoder tap imag part (2's comp.)	Value of 2nd MS octet (of 3) of next ATU-R Tomlinson precoder tap, imag part
U_TOMNILREQ	COMMAND (WRITE) and ECHO	L1	0xA8	LS octet of ATU-R next Tomlinson precoder tap imag part (2's comp.).	Value of LS octet (of 3) of next ATU-R Tomlinson precoder tap, imag part

5.4.2.2.2 Link Initialization and Adaptation

5.4.2.2.2.1 Introduction

The link initialization and adaptation process provides a robust procedure for establishing and modifying the parameters of the upstream and downstream channels. Initialization and adaptation of a RADSL circuit can be conceptually divided into the following sequence of high-level steps:

Step A. Automatically establish upstream and downstream links with a default set of system parameters.

Step B. Modify the parameters of the upstream channel, perhaps iteratively, using a robust protocol that utilizes SNR measurement at the ATU-C and communication over the existing AOC, until the desired upstream channel parameters are fully established. By definition, the parameters that can be modified in this way are baud rate, center frequency, constellation size, interleaving depth, transmit PSD level, and framing structure.

Step C. Modify the parameters of the downstream channel, perhaps iteratively, using a robust protocol that utilizes SNR measurement at the ATU-R and communication over the existing AOC, until the desired downstream channel parameters are fully established. By definition, the parameters that can be modified in this way are baud rate, center frequency, constellation size, interleaving depth, transmit PSD level, and framing structure.

Step D. Commence throughput of data streams across the V and T-sm interfaces.

Step E. Allow for the ongoing monitoring and modification of the above channel parameters.[3]

Conceptually, implementation of these steps requires the operation of three types of algorithms:

- A Type 1 algorithm implementing the AOC handshake protocol.
- A Type 2 algorithm that uses AOC messages and other inputs to establish the default links and to execute transmission parameter change requests.
- A Type 3 algorithm that provides the parameter modification requests for an algorithm of Type 2, with the intent of meeting some specific set of system goals.

Of these three algorithm types, this specification describes Types 1 and 2 only. The Type 1 AOC handshake protocol was described in Section 5.4.2.2.1.2, and the Type 2 protocol is described in the present section. Requirements pertaining to algorithm Type 3 are unspecified in this document, as different applications for RADSL systems may generate their own unique requirements in this area. The Type 3 algorithm run in the ATU-C integrating system will help determine the unique systems capabilities of that link, as desired and established by the network operator, without negative impact on ATU-C/ATU-R interoperability. As a result, the requirements pertaining to algorithm Type 3 are left to the discretion of network operators and their vendors.

The following subsections describe the requirements for the Type 2 algorithm that is to be run in ATU-Cs and ATU-Rs.

5.4.2.2.2.2 Default Initial Link and U_MAND / D_MAND Data

Default Initial Link

To ensure robust system start-up, the default initial link uses low symbol rates for both the upstream and downstream channels, as well as the smallest specified constellation size, which is QPSK. The FEC is enabled during the initial link to provide error protection for the AOC, which carries all subsequent parameter change protocol traffic. The interleaver is initially disabled so as to increase start-up speed.

[3] Modification of the parameters of an active channel may involve the temporary loss of, or error to, transported data throughput.

Table 22 below presents the values to be used for all configurable parameters during the initial link phase. As described in Section 5.4.2.2.2.1, the system moves out of the initial link phase through responding to requests from the Type 3 algorithm that one or more of these parameters be changed.

Table 22 - Configurable Parameters for the Initial Upstream and Downstream Channels

Parameter	Upstream Channel Value	Downstream Channel Value
Baud Rate	84 kBaud	126 kBaud
Constellation	QPSK	QPSK
Interleaving Depth	1	1
Transmit PSD Level	-38 dBm/Hz	-40 dBm/Hz
Center Frequency	84 kHz	315.6 kHz
Frame Structure	*L* = 252, *U* = 0, *C* = 249 (Class 1)	*L* = 252, *U* = 0, *C* = 249 (Class 1)

U_MAND and D_MAND Baud Rates and Center Frequencies

Of the many baud rates supportable by the system, a small number are mandatory to support. In Table 20 the D_MAND and U_MAND COMMAND-type AOC messages are used to allow configuration of the downstream and upstream links, respectively, with one of these mandatory baud rates. In addition, these AOC commands also require that the channel center frequency be set to a particular value corresponding to the selected mandatory baud rate. The purpose of these commands is to allow the system to be rapidly configured to one of several common (baud rate, center frequency) pairs with the execution of just a single L1 handshake. Table 23 and Table 24 below list the upstream and downstream baud rates and center frequencies associated with the U_MAND and D_MAND commands.

Table 23 - Upstream Baud Rates and Center Frequencies Corresponding to the U_MAND AOC Commands

U_MAND Data Field	Upstream Baud Rate	Upstream Center Frequency
0x01	20 kBaud	58 kHz
0x02	40 kBaud	68 kHz
0x03	84 kBaud	84 kHz
0x04	100 kBaud	93.6 kHz
0x05	120 kBaud	105.6 kHz
0x06	136 kBaud	115.2 kHz

Table 24 - Downstream Baud Rates and Center Frequencies Corresponding to the D_MAND AOC Commands

D_MAND Data Field	Downstream Baud Rate	Downstream Center Frequency
0x01	40 kBaud	225.6 kHz
0x02	40 kBaud	264 kHz
0x03	126 kBaud	277.2 kHz
0x04	126 kBaud	315.6 kHz
0x05	160 kBaud	297.6 kHz
0x06	160 kBaud	336 kHz
0x07	252 kBaud	352.8 kHz
0x08	252 kBaud	391.2 kHz
0x09	336 kBaud	403.2 kHz
0x0A	336 kBaud	441.6 kHz
0x0B	504 kBaud	504 kHz
0x0C	504 kBaud	542.4 kHz
0x0D	672 kBaud	604.8 kHz
0x0E	672 kBaud	643.2 kHz
0x0F	806.4 kBaud	685.44 kHz
0x10	806.4 kBaud	723.84 kHz
0x11	1008 kBaud	844.8 kHz

5.4.2.2.2.3 AOC Usage in Initialization and Adaptation

The AOC is used both in the establishment of the initial system link and in the communication of messages requesting subsequent changes in link parameters.

Table 21 lists a set of COMMAND-type and ECHO-type messages used specifically to request changes in system parameters. Other COMMAND-type and ECHO type messages described in Section 5.4.2.2.1.3 are also used in support of the Type 1, Type 2, and Type 3 initialization and adaptation algorithms. Section 5.4.2.2.2.4 describes in detail the means by which the AOC is used in support of the initialization and adaptation process.

5.4.2.2.2.4 Transceiver State Machines for Initialization and Adaptation

Introduction

The sequence of signals to be generated by an ATU-C and ATU-R in initializing and adapting link parameters is described by the state machines of Figure 72 and Figure 73. These state machines are described in detail. As seen in these figures, for both the ATU-C and ATU-R, many of the state transitions are driven by the successful or unsuccessful transmission or receipt of specific Table 20 AOC messages from the other end. Other transition drivers for both the ATU-C and ATU-R are state time-outs, received Loss of Signal (LOS) or Loss of Frame (LOF), and status of receiver equalizer and frame synchronization subsystems. The ATU-C additionally receives transitions drivers in the form of link parameter change requests from its Type 3 algorithm. The ATU-R also uses the receipt of the signal C_TRIG, described below, as a transition driver.

Each state in Figure 72 and Figure 73 indicates by name the type of transmit signal that the transceiver is to output while residing in that state. State names in Figure 72 and Figure 73 are shown italicized and bold, while the corresponding transmit signal names are neither. These transmit signals, which are framed and error corrected as per Figure 28 - Figure 30,[4] are fully defined in the paragraph below. All of these signals contain, in the AOC field of their frames, specific AOC messages drawn from Table 18 through Table 20 (often just the IDLE AOC command). The next paragraph defines the signals present in the states of Figure 72 and Figure 73 by specifying the possible contents of AOC, Uncoded Control, Uncoded Payload, and Coded Payload frame fields.

Initialization and Adaptation Transmit Signals

With the exception of C_QUIET and R_QUIET, all of the transmit signals indicated in the state machines of Figure 72and Figure 73 are fully framed and error corrected, according to the Class 1 or Class 2 frame structure currently in use. Transmission of C_QUIET and R_QUIET involves driving the line with zero volts.

For all other signals the coded and uncoded payload octet fields contain either all ones (scrambled ones) or data streams received from the corresponding TC sub-layer, depending on the status of the separate THRPUT flag contained in each transceiver. As shown in Table 19 the THRPUT flag can be set or reset for both ATU-C and ATU-R simultaneously through the AOC channel, once the transceivers are in the *C_ACTIVE* and *R_ACTIVE* states. The individual THRPUT flags are also reset at different locations in the state machines of Figure 72 and Figure 73. If THRPUT = 1 within the ATU-C, then signals C_ACQUIRE, C_DATA, and C_TRIG in Figure 72 contain coded and uncoded data streams received from the corresponding TC sub-layer. If THRPUT = 0 within the ATU-C, the coded and uncoded payload fields for C_ACQUIRE, C_DATA, and C_TRIG contain all ones (scrambled ones in the coded field case). The identical relationship exists between the THRPUT flag within the ATU-R and the ATU-R transmit signals R_ACQUIRE and R_DATA.

Table 25 below specifies the AOC message that each state machine transmit signal is to contain in its AOC field. Signals C_ACQUIRE, C_TRIG, and R_ACQUIRE always carry IDLE, and hence cannot be used to transmit or receive AOC commands. Signals C_DATA and R_DATA can carry any valid AOC message. The AOC messages relevant to the state machines of Figure 72 and Figure 73 are the SNRDATA and L1 - L3 COMMAND-type messages from Table 20, and the ACK-type and STATUS-type messages used in the corresponding handshaking.

Finally, the c_trig bit in the LSB of the downstream Uncoded Control frame field equals 0 for all ATU-C transmit signals, except for C_TRIG. In C_TRIG, this bit is set to 1.

Table 25 - AOC Messages Carried in Signals Assigned to States in Figure 72 and Figure 73

Signal	AOC Field
C_QUIET	N/A
C_ACQUIRE	IDLE
C_TRIG	IDLE
C_DATA	Any valid sequence of AOC messages
R_QUIET	N/A
R_ACQUIRE	IDLE
R_DATA	Any valid sequence of AOC messages

[4] The only exception to this are signals C_QUIET and R_QUIET, which consist of driving the line with zero volts.

ATU-C Initialization and Adaptation State Machines

The ATU-C initialization and adaptation state machine is shown in Figure 72. In Figure 72 each rounded block represents a state, with squared blocks containing instruction to be performed when transitioning between the indicated states. Each state block contains the state name and number in bold italics, followed by the name of the transmit signal (not italicized) that the ATU-C is to output while residing in that state. Each of the four transmit signals in Figure 72 is described in the paragraph above on Initialization and Adaptation Transmit Signals.

The state machine operation is analyzed in the following subsections through a description of each state.

S1: C_POWERUP

This state is entered following a reset or cycling of the ATU-C power, and through the other paths indicated in Figure 72. Included in these are a detected loss of upstream signal while in states *S3* through *S12*, and a loss of received upstream frame while in states *S5* through *S12.* While in state *S1* the ATU-C transmits C_QUIET. The ATU-C transitions to state *S2* if the absence of a received upstream signal from the other end of the line is detected.

While in *S1* the ATU-C transmitter and receiver are configured to the default conditions described in Section 5.4.2.2.2.2 and the flag values THRPUT = 0 and RETRY = 0 are assigned. The structure TXMEM contains storage for an image of the downstream transmitter parameters listed in Table 22, minus the downstream constellation. When in *S1* the parameter values of the default downstream transmitter, except with the default center frequency replaced with $C_{DS} = 278\,\mathrm{kHz}$, are stored in TXMEM. This parameter set in Figure 72 is referred to as “Backup.” The stored transmitter parameter values in TXMEM may be overwritten with other (possibly non-default) values in the transition between *S5* and *S6*.

For the ATU-C in *S1*, it must transition to *S2* within 500 msec of the ATU-R beginning to transmit R_QUIET.

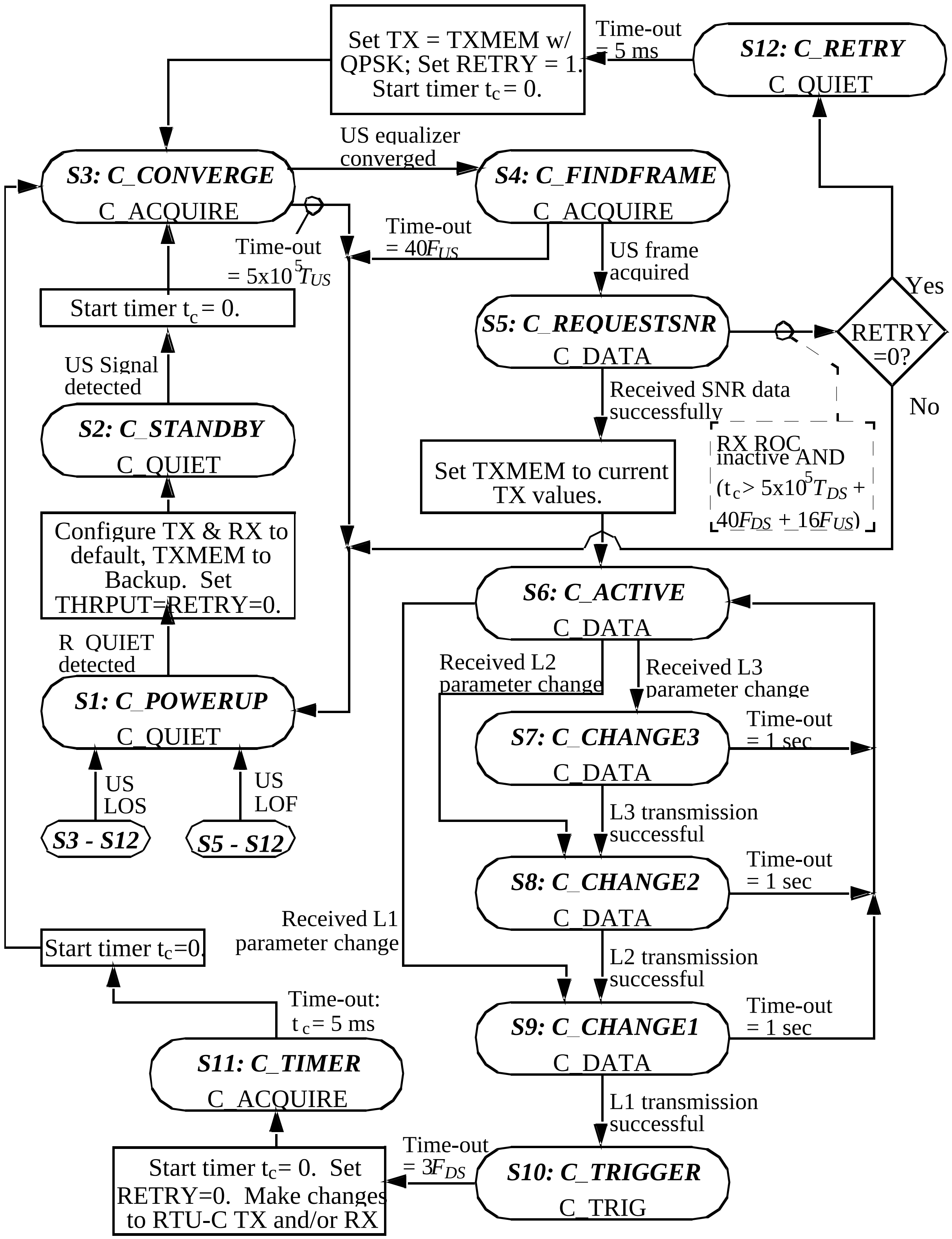


Figure 72 - ATU-C Initialization and Adaptation State Machine

S2: C_STANDBY

In this state the ATU-C transmits C_QUIET and waits for an upstream received signal to be detected. Once this occurs the timer t_c is reset to zero and begins to run, and state *S3* is entered.

S3: C_CONVERGE

In this state, the ATU-C transmits C_ACQUIRE while attempting to converge the upstream equalizer (i.e., to reliably detect upstream QAM symbols). This state is entered from state *S2* following a system reset, or whenever a change in one or more of the downstream and/or upstream transmission parameters has been made. Upon entering this state the ATU-C equalizer may already be converged (e.g., a change in only a downstream parameter has been requested), or it may be nearly converged but require fine tuning (e.g., a change in upstream constellation size, or very small change in upstream baud rate), or it may be in need of major adjustment (e.g., a large change in upstream baud rate).

After entering *S3* the ATU-C has 5×10^5 upstream QAM symbol periods ($5 \times 10^5 T_{US}$) in which to converge its upstream equalizer. If convergence is not achieved within this time the ATU-C returns to state *S1*. If convergence is reached before this time, the system immediately transitions to *S4*. In the case of convergence, the system enters state *S4* as soon as convergence occurs, i.e., without waiting for the full time-out period to elapse.

Loss of upstream received signal while in this state causes a transition to *S1*.

S4: C_FINDFRAME

In this state, the ATU-C processes the received upstream bit stream in an attempt to acquire the upstream frame, which by definition here includes decoding of the upstream Reed-Solomon codewords. If such acquisition occurs within 40 upstream frame periods $(40F_{US})$, the system transitions to *S5*. If not, the ATU-C returns to *S1*. In the case of successful acquisition, *S5* is entered as soon as acquisition occurs. While in *S4* the ATU-C transmits C_ACQUIRE.

Loss of upstream received signal while in this state causes a transition to *S1*.

S5: C_REQUESTSNR

Upon reaching this state the ATU-C receiver has converged its equalizer and acquired upstream frame. The ATU-C now waits for an indication as to whether the downstream receiver has converged its own equalizer and acquired downstream frame, and if so what quality of downstream transmission is being achieved. To this effect the ATU-C transmits a SNRREQ COMMAND-type message to the ATU-R and obtains both pieces of information through successful reception of the echo from SNRREQ. If the initial SNRREQ transmission fails, as defined in Figure 70, the ATU-C attempts successive SNRREQ transmission until a successful transmission occurs, or S5 times out. While in state *S5* the ATU-C transmits C_DATA, which allows for the necessary AOC communication.

If an SNRREQ message is successfully transmitted, as defined by the AOC protocol flow chart of Figure 70, the ATU-C then enters *S6*. On its way, the TXMEM storage locations are overwritten with the values presently in use by the downstream transmitter.

Alternatively, if a successful transmission of SNRREQ has not occurred when the timer t_c count reaches $t_c = 5x10^5 T_{DS} + 40F_{DS} + 16F_{US}$ (maximum downstream convergence plus acquisition time, plus maximum interleaving delay for the AOC), then the acquisition of the downstream signal can be assumed to have failed. In this case, the next state to be entered depends on the value of the RETRY flag within the ATU-C.

RETRY = 0 indicates that the failed downstream acquisition was either the first one attempted following a departure from state *S6,* or the first one following emergence from the reset state *S*1. In the first case both the ATU-C and ATU-R will automatically set their downstream parameters to match those last used while in the active state, *S6*. The only exception to this is the downstream constellation, which is set to QPSK. With the downstream channel reset to the state used prior to the last change (again, except possibly for constellation), downstream acquisition is tried once again. This course of events is initiated through a transition from *S5* to *S12*.

In the second case, downstream acquisition has failed with the default set of downstream parameters. It is worthwhile to attempt start-up at a lower center frequency. In leaving state S1, TXMEM was configured with the corresponding parameters, so that passing from *S5* to *S12* will result in a downstream acquisition attempt using default downstream parameters, except with a lower center frequency of 278 kHz.

If RETRY = 1, the most recent downstream failure is the result of having just followed the RETRY path. In this case, the ATU-C is to pass from *S5* to *S1*.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

S6: C_ACTIVE

An ATU-C resides in this state when both upstream and downstream channels are acquired and no transmission parameter changes are being negotiated or implemented. During *S6* the ATU-C transmits C_DATA. When the system containing the ATU-C requests a change in transmission parameter, control is passed either to state *S7*, *S8*, or *S9*, depending on whether the requested change is listed in Table 20 as L3, L2, or L1, respectively.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

S7: C_CHANGE3

In this state the ATU-C is to attempt, repeatedly if necessary, the transmission of the requested L3 COMMAND-type AOC message. If such transmission is successful, as defined by the flow chart of Figure 70, control then passes to *S8*. If after 1 second of trying, a successful transmission has not yet occurred, control is returned to *S6*. While in *S7* the ATU-C continues to transmit C_DATA, so that customer throughput, if enabled by THRPUT = 1, is maintained.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

S8: C_CHANGE2

In this state the ATU-C is to attempt, repeatedly if necessary, the transmission of an L2 COMMAND-type AOC message. The specific L2 command to be communicated depends on the path taken to arrive in *S8*. If *S8* was arrived at through *S7*, the L2 command is the one associated with the continuation of the L3 command just communicated. If the ATU-C traveled directly from *S6* to *S8*, the L2 command is the one just requested by the ATU-C integrating platform.

If the correct L2 COMMAND-type message is transmitted successfully, as defined by the flow chart of Figure 70, control then passes to *S9*. If after 1 second of trying, a successful transmission has not yet occurred, control is returned to *S6*. While in *S8* the ATU-C continues to transmit C_DATA, so that customer throughput, if enabled by THRPUT = 1, is maintained.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

S9: C_CHANGE1

In this state the ATU-C is to attempt, repeatedly if necessary, the transmission of an L1 COMMAND-type AOC message. The specific L1 command to be communicated depends on the path taken to arrive in *S9*. If *S9* was arrived at through *S8*, the L1 command is the one associated with the continuation of the L2 command just communicated. If the ATU-C traveled directly from *S6* to *S9*, the L1 command is the one just requested by the ATU-C integrating platform.

If the correct L1 COMMAND-type message is transmitted successfully, as defined by the flow chart of Figure 70, control then passes to *S10*. If after 1 second of trying, a successful transmission has not yet occurred, control is returned to *S6*. While in *S9* the ATU-C continues to transmit C_DATA, so that customer throughput, if enabled by THRPUT = 1, is maintained.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

S10: C_TRIGGER and S11: C_TIMER

These two states are tightly coupled, and as a result are described together in this single subsection. In state *S10,* the ATU-C transmits the signal C_TRIG for exactly three frames then enters *S11*, where it immediately begins transmitting C_ACQUIRE. The resulting transmission of exactly 3 downstream frames with the c_trig bit set is used by the ATU-R to synchronize its entry into state *R_CONVERGE* with the ATU-C's entry into *C_CONVERGE*.

Immediately after transmitting C_TRIG for three frames the ATU-C resets and restarts the timer t_c. The ATU-C then resets the RETRY flag and makes the changes to its transmitter and/or receiver corresponding to the parameter change(s) just negotiated. When t_c reaches 5 msec the timer is reset and restarted again, and state *S3* is entered to attempt acquisition with the new transmission parameter settings.

Loss of upstream received signal or frame while in either of these states causes a transition to *S1*.

S12: C_RETRY

The purpose of this state is to synchronize the ATU-R's entry into state *R_CONVERGE* with the ATU-C's entry into *C_CONVERGE*, in the absence of downstream communication. In state *S12,* the ATU-C transmits C_QUIET for 5 msec. During this time, the ATU-C configures its transmitter to the parameters stored in TXMEM, with a constellation of QPSK. Once this is finished, the RETRY flag is set, the timer t_c is reset and restarted, and the system enters state *S3*.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

ATU-R Initialization and Adaptation State Machine

The ATU-R initialization and adaptation state machine is shown in Figure 73. The conventions for interpreting this figure are the same as those described for Figure 72. The state machine operation is analyzed in the following subsections through a description of each state.

S1: R_POWERUP

This state is entered following a reset or cycling of the ATU-R power, and for the other paths indicated in Figure 73. Included in these are a detected loss of downstream signal while in states *S3* through *S10*, and a loss of received downstream frame while in states *S5* through *S10*. While in state *S1* the ATU-R transmits R_QUIET. The ATU-R transitions to state *S2* if the absence of a received downstream signal from the other end of the line is detected.

When leaving *S1* (or while in it) the ATU-R transmitter and receiver are configured to the default conditions described in Section 5.2.5.2, and the flag values THRPUT = 0 and RETRY = 0 are assigned. The structure RXMEM contains storage for an image of the downstream receiver parameters listed in Table 22, minus the downstream constellation. When exiting *S1* the parameter values stored in RXMEM are those of the default downstream receiver, except with the default center frequency replaced with $C_{DS} = 278\ \mathrm{kHz}$. This parameter set in Figure 73 is referred to as "Backup." The stored receiver parameter values in RXMEM may be overwritten with other (possibly non-default) values in the transition between *S5* and *S6*.

S2: R_STANDBY

In this state, the ATU-R transmits R_QUIET for at least 500 msec. At the conclusion of this time the ATU-R transitions to *S3* when a CONNECT signal from the CPE is asserted. CONNECT is an implementation-specific signal used by the CPE to instruct the ATU-R to initiate and maintain a connection with the network. Some CPE may use a CONNECT signal that is permanently asserted, while others may be toggled under hardware or software control. CONNECT is meant to signify the desirability of a connection, and should not be unasserted solely because of a return of the ATU-R to *S1*, unless such functionality is specifically desired in the CPE.

S3: R_CONVERGE

In this state, the ATU-R transmits R_ACQUIRE while attempting to converge the downstream equalizer (i.e., to reliably detect downstream QAM symbols). This state is entered from state *S2* following a system reset, or whenever a change in one or more of the downstream and/or upstream transmission parameters has been made. Upon entering this state the ATU-R equalizer may already be converged (e.g., a change in only an upstream parameter has been requested), or it may be nearly converged but require fine tuning (e.g., a change in downstream constellation size, or very small change in downstream baud rate), or it may be in need of major adjustment (e.g., a large change in downstream baud rate).

After entering *S3* the ATU-R has 5×10^5 downstream QAM symbol periods ($5 \times 10^5 T_{DS}$) in which to converge its downstream equalizer. If convergence is reached before this time, the system immediately transitions to *S4*. In the case of convergence, the system enters state *S4* as soon as convergence occurs, i.e., without waiting for the full time-out period to elapse.

If convergence is not achieved within this time the ATU-R either returns to state *S1* or enters state *S11*, depending on the value of the RETRY flag. If RETRY = 0 the ATU-R has 5 msec in which to configure its downstream receiver with the values stored in RXMEM, along with a QPSK constellation, and set RETRY = 1 before entering state *S11*. This path of the state machine allows the downstream channel to attempt acquisition with the parameters stored in RXMEM.

Loss of downstream received signal while in this state causes a transition to *S1*.

S4: R_FINDFRAME

In this state the ATU-R processes the received downstream bit stream in an attempt to acquire the downstream frame, including decoding of downstream Reed-Solomon codewords. If such acquisition occurs within 40 downstream frame periods $(40F_{DS})$, the system transitions to *S5*. In the case of successful acquisition, *S5* is entered as soon as acquisition occurs.

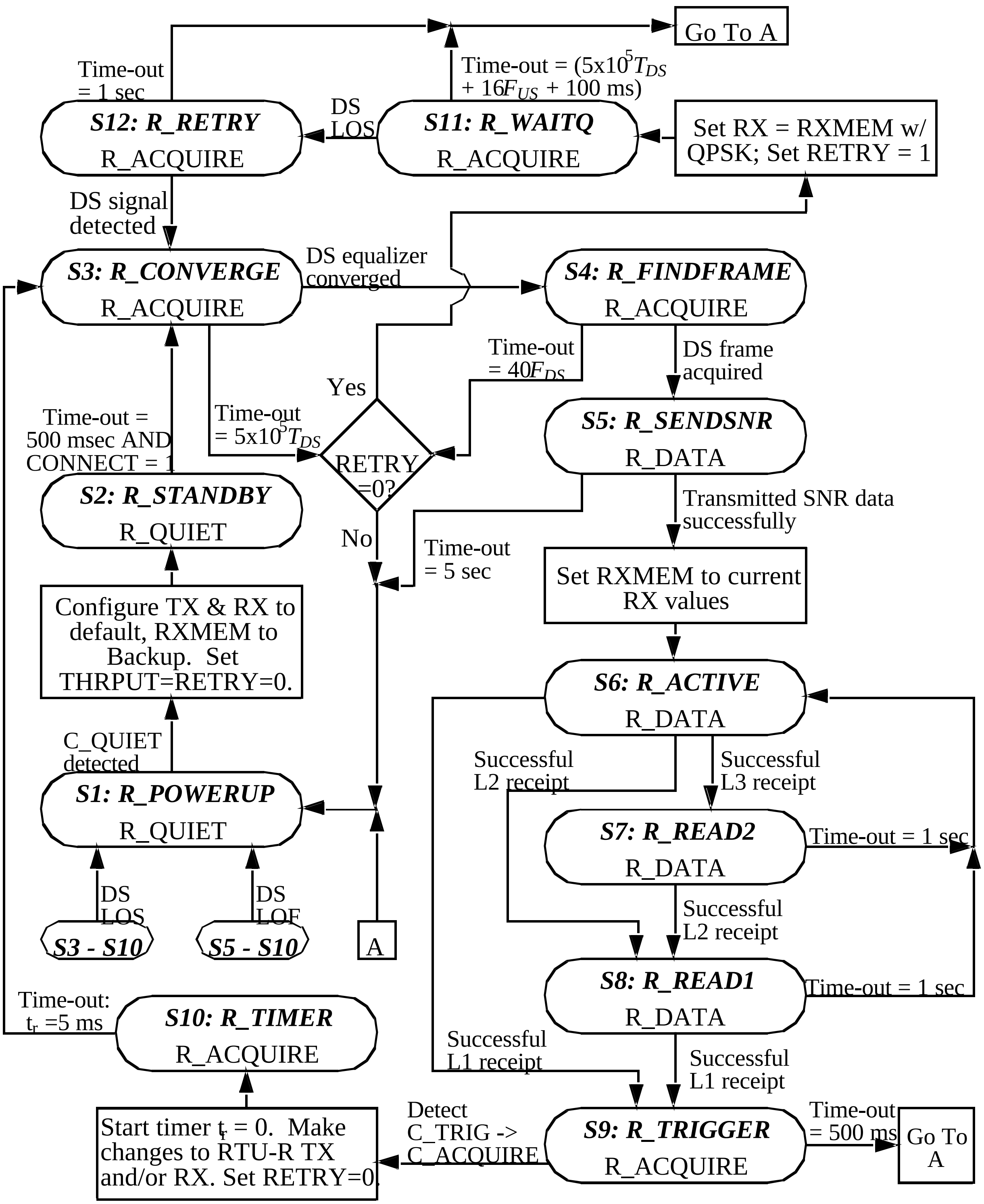


Figure 73 - ATU-R Initialization and Adaptation State Machine

If acquisition is not achieved within this time the ATU-R either returns to state *S1* or enters state *S11*, depending on the value of the RETRY flag. If RETRY = 0 the ATU-R has 5 msec in which to configure its downstream receiver with the values stored in RXMEM, along with a QPSK constellation, and set RETRY = 1 before entering state *S11*. This path of the state machine allows the downstream channel to attempt acquisition with the parameters stored in RXMEM. While in *S4* the ATU-C transmits C_ACQUIRE. Loss of upstream received signal while in this state causes a transition to *S1*.

S5: R_SENDSNR

In this state, the ATU-R transmits R_DATA. Upon reaching *S5* the ATU-R receiver has converged its equalizer and acquired downstream frame. While in state *S5* the ATU-R awaits the successful transmission of the SNRREQ command and echo messages, as defined by Figure 71, initiated by the ATU-C. Successful transmission of SNRREQ causes the ATU-R to transition to state *S6*. In the process, the current downstream receiver parameters are stored in RXMEM.

Failure to transmit the SNRREQ handshake is due either to an upstream acquisition failure, or to a fault in the ATU-C. In the latter case, the 5-second time-out will eventually force the ATU-R back to state *S1*. In the former case, the ATU-C will force the ATU-R into state *S1* through a downstream LOS prior to this time-out.

Loss of downstream received signal or frame while in this state causes a transition to *S1*.

S6: R_ACTIVE

An ATU-R resides in this state when both upstream and downstream channels are acquired and no transmission parameter changes are being negotiated or implemented. During *S6,* the ATU-R transmits R_DATA. If the ATU-R successfully receives from the ATU-C one of the AOC COMMAND-type messages listed in Table 21, as defined in Figure 71, the ATU-R then transitions to either state *S7*, *S8*, or *S9*, depending on whether the received command is listed in Table 21as L3, L2, or L1, respectively.

Loss of downstream received signal or frame while in this state causes a transition to *S1*.

S7: R_READ2

In this state the ATU-R transmits R_DATA and awaits the successful reception of the L2 COMMAND-type message corresponding to the L3 COMMAND received while in the previous state. If successful reception of this specific COMMAND-type message does not occur within 1 second of entering *S7*, then control of the ATU-R is returned to *S6*. If successful reception does occur, as defined in Figure 70, the control passes to *S8*.

Loss of downstream received signal or frame while in this state causes a transition to *S1*.

S8: R_READ1

In this state the ATU-R transmits R_DATA and awaits the successful reception of the L1 COMMAND-type message corresponding to the L2 COMMAND received while in the previous state. If successful reception of this specific COMMAND-type message does not occur within 1 second of entering *S8*, then control of the ATU-R is returned to *S6*. If successful reception does occur, as defined in Figure 70, the control passes to *S9*.

Loss of downstream received signal or frame while in this state causes a transition to *S1*.

S9: R_TRIGGER

In this state the ATU-R transmits R_ACQUIRE and monitors the c_trig bit in the Uncoded Control field of the downstream frame. When the received value of c_trig changes in value from 0 to 1, signifying a transition from downstream transmit signal C_DATA to C_TRIG, the ATU-R will wait two more full frames and then the timer t_r is reset and restarted, and the flag RETRY reset. The ATU-R transmitter and/or receiver parameters changed by the AOC handshake just completed are implemented, and state *S10* entered. Alternatively, if a C_TRIG-to-C_ACQUIRE transition is not detected within 500 msec of entering state *S9*, then control of the ATU-R is returned to *S1*.

Loss of upstream received signal or frame while in this state causes a transition to *S1*.

S10: R_TIMER

In this state, the ATU-R transmits R_ACQUIRE while waiting for timer t_r to reach 5 msec. Once this occurs the ATU-R enters state *S3*.

Loss of downstream received signal or frame while in this state causes a transition to *S1*.

S11: R_WAITQ

In this state, the ATU-R transmits the signal R_ACQUIRE while waiting for arrival of a downstream LOS. If this occurs within $(5x10^5 T_{DS} + 16F_{US} + 100\,\text{msec})$ of entering *S11*, then control is passed to *S12*. Otherwise, the ATU-R is returned to *S1*.

S12: R_RETRY

In this state, the ATU-R transmits R_ACQUIRE while awaiting the arrival of a downstream signal from the other end of the line. When this signal arrives, the ATU-R transitions immediately to state *S3*. If this does not occur within 1 second of entering *S12*, then the ATU-R transitions to state *S1*.

5.5 Performance Objectives

Table 26 contains objectives for upstream and downstream line rates, when operating over the specified loops and in the presence of the specified noise, for links utilizing Trellis Coded Modulation. Table 27 contains objectives for upstream and downstream line rates for systems that do not utilize Trellis Coded Modulation. Note that in both tables the indicated interferers for each test are summed together with AWGN with a PSD of -140 dBm/Hz, then scaled by the indicated margin amount, to form a composite noise power spectral density. Section 9 contains more performance information related to Loop Plant Characteristics, Impairment and Testing.

Table 26 - Performance Objectives for Systems Utilizing TCM

				Crosstalk disturbers (see note)			
Test loops	**DS line rate (kbps)**	**US line rate (kbps)**	**Margin (dB)**	**RADSL self-FEXT**	**HDSL NEXT**	**DSL NEXT**	**T1 NEXT adj. binder**
T1.601 (7)	1700	425	6	--	--	24	--
T1.601 (13)	2040	425	6	--	--	24	--
CSA (4)	5684	680	6	24	--	24	--
CSA (6)	5684	425	6	--	20	--	--
CSA (7)	5684	680	6	10	--	10	--
Mid-CSA	4896	680	3	--	--	--	4
Mid-CSA	4896	680	3	--	--	--	10

Table 27 - Performance Objectives for Systems Not Utilizing TCM

				Crosstalk disturbers (see note)			
Test loops	**DS line rate (kbps)**	**US line rate (kbps)**	**Margin (dB)**	**RADSL self-FEXT**	**HDSL NEXT**	**DSL NEXT**	**T1 NEXT adj. binder**
T1.601 (7)	1600	420	6	--	--	24	--
T1.601 (13)	2340	370	6	--	--	24	--
CSA (4)	5740	672	6	24	--	24	--
CSA (6)	6200	468	6	--	20	--	--
CSA (7)	5740	672	6	10	--	10	--
Mid-CSA	5740	672	3	--	--	--	4
Mid-CSA	5190	672	3	--	--	--	10

5.6 Maintenance

5.6.1 Functions

The following in-service performance monitoring and surveillance functions are provided via EOC messages:

- Line related primitives:
  - Near-end anomalies: fec-i, fec-f, crc-i, crc-f
  - Far-end anomalies: ffec-i, ffec-f, febe-i, febe-f
  - Near-end defects: los and sef
  - Far-end defects: los and rdi
- Payload related primitives:
  - Near-end anomalies: ncd-i, ncd-f, ocd-i, ocd-f, hec-i, hec-f
  - Far-end anomalies: fncd-i, fncd-f, focd-i, focd-f, fhec-i, fhec-f
  - Near-end defects: lcd-i, lcd-f
  - Far-end defects: flcd-i, flcd-f
- Other indicators, parameters and signals:
  - Near-end primitive: lpr
  - Far-end primitive: lpr
- Line failures:
  - Near-end failures: LOS, LOF, LPR
  - Far-end failures: LOS, RFI, LPR

- Payload failures:
  - Near-end failures: NCD-I, NCD-F, LCD-I, LCD-F
  - Far-end failures: FNCD-I, FNCD-F, FLCD-I, FLCD-F

Definitions of these primitives are provided in Section 8.2. Performance monitoring functions are provided at the ATU-C and are optional at the ATU-R. Details on performance data storage and reporting are provided in Section 8.2.

The following sections describe the EOC message sets for carrying the indicators related to the above primitives for each of the 3 mappings: Frame Based EOC Messages, Direct Cell EOC Messages, and Direct Packet EOC Messages.

5.6.2 EOC Messages

5.6.2.1 Frame Based EOC Messages

5.6.2.1.1 Datagram Message ID and Message-Specific Fields

The Command/Response message ID field is a single unsigned octet field. Commands are defined as having a field value of 0x00 through 0x7F. Responses have the values 0x80 through 0xFF.

The Message IDs supported are:

Table 28 – Command/Response Message IDs

Command Message IDs	
0x00	Get_Inventory
0x01	Get_Test_Parms
0x02	Get_Indicators

Response Message IDs	
0x80	Inventory
0x81	Test_Parms
0x82	Indicators

5.6.2.1.2 Get_Inventory Command Message

The Get_Inventory command may only be issued by the ATU-C. The purpose of the datagram is to retrieve the ATU-R equipment identification. The ATU-R responds to this command by sending the Inventory response datagram back to the ATU-C. The format of the Get_Inventory datagram is:

Table 29 – Get_Inventory Command Message

0x04	Datagram Length
[1 octet]	Datagram Tag
0x01	Datagram Version
0x00	Get_Inventory Message ID
[null]	Message-Specific Fields

5.6.2.1.3 Get_Test_Parms Command Message

The Get_Test_Parms command is sent to the ATU-R to retrieve the results of in-service loop tests. This command may only be issued by the ATU-C. In response, the ATU-R sends the Test_Parms response datagram back to the ATU-C. The format of the Get_Test_Parms datagram is:

Table 30 – Get_Test_Parms Command Message

0x04	Datagram Length
[1 octet]	Datagram Tag
0x01	Datagram Version
0x01	Get_Test_Parms Message ID
[null]	Message-Specific Fields

5.6.2.1.4 Get_Indicators Command Message

The Get_Indicators command is sent to the ATU-R to retrieve performance monitoring indicators. Single bit indicators are conveyed via the framing overhead. Multi-bit indicators are retrieved through the EOC as a result of this command. This command may only be issued by the ATU-C. In response, the ATU-R sends the Indicators response datagram back to the ATU-C. The format of the Get_Indicators datagram is:

Table 31 – Get_Indicators Command Message

0x04	Datagram Length
[1 octet]	Datagram Tag
0x01	Datagram Version
0x02	Get_Indicators Message ID
[null]	Message-Specific Fields

5.6.2.1.5 Inventory Response Message

The Inventory response message is only issued by the ATU-R in response to a Get_Inventory command. The purpose of the datagram is to report the ATU-R equipment identification. The format of the Inventory datagram is:

Table 32 – Inventory Response Message

0x2C	Datagram Length
[1 octet]	Datagram Tag
0x01	Datagram Version
0x80	Inventory Message ID
[4 octets]	Vendor ID
[4 octets]	Vendor Version
[32 octets]	Serial Number

5.6.2.1.5.1 VendorID field

The Vendor ID field is a 4-octet field that identifies the vendor of the ATU-R equipment.

It is recommended that the ATU-R vendor use the "Vendor identification numbers" assigned by ANSI T1.413-1998. The encoding of this field is an unsigned big-endian 32-bit integer.

5.6.2.1.5.2 Vendor Version field

The Vendor Version field is a 4-octet field that identifies the ATU-R vendor's equipment variant. The encoding and syntax of this field is defined by each vendor. Typical use of this field includes enabling proprietary ATU-R features with specific equipment, and determining when ATU-R equipment should be upgraded.

5.6.2.1.5.3 Serial Number field

The Serial Number field is a 32-octet string that is ATU-R vendor specific. The encoding and syntax of this field is defined by each vendor.

5.6.2.1.6 Test_Parms Response Message

The Test_Parms response message is only issued by the ATU-R in response to a Get_Test_Parms command. The purpose of the datagram is to report the ATU-R in-service loop test results. The format of the Test_Parms datagram is:

Table 33 – Test_Parms Response Message

0x08	Datagram Length
[1 octet]	Datagram Tag
0x01	Datagram Version
0x81	Test_Parms Message ID
[2 octets]	Mean Signal Quality
[2 octets]	0dB Mean Signal Quality

5.6.2.1.6.1 Mean Signal Quality field

The Mean Signal Quality field is a 2-octet field (16-bit unsigned big-endian integer) that contains an encoded measurement of the ATU-R receiver's S/N. The S/N reading in dB is derived from the following equation:

(38) $S/N\ (dB) = 58.4 - 10 \log_{10} (\text{Mean Signal Quality})$

5.6.2.1.6.2 0dB Signal Quality field

The 0dB Signal Quality field is a 2-octet (16-bit unsigned big-endian integer) field that contains an encoded value that can use used to derive the Margin. Margin is defined as the margin in dB over that which is required to produce a bit error rate of 10^{-7} in the presence of additive white gaussian noise. The equation is

(39) $\text{Margin (dB)} = 58.4 - 10 \log_{10}(\text{Mean Signal Quality}) - (\text{0dB Signal Quality} * 10)$

5.6.2.1.7 Indicators Response Message

The Indicators response message is only issued by the ATU-R in response to a Get_Indicators command. The purpose of the datagram is to report the ATU-R performance monitoring primitives and general parameters. The format of the Indicators datagram is:

Table 34 – Indicators Response Message

0x14	Datagram Length
[1 octet]	Datagram Tag
0x01	Datagram Version
0x82	Indicators Message ID
[4 octets]	FEC
[4 octets]	HEC
[4 octets]	Message Count
[4 octets]	Frame Count

5.6.2.1.7.1 Forward Error Correction (FEC) field

The FEC indicator field is a 4-octet (32-bit unsigned big-endian integer) field that contains the count of errored Reed-Solomon codewords that were corrected at the ATU-R receiver. When the counter reaches its maximum value, it wraps around and starts increasing again from zero. The ATU-C uses the difference between two consecutive reads of this parameter to determine the number of corrected Reed-Solomon errors in a specific period.

The FEC indicator is used to report errors to the ffec-i anomaly in the performance and surveillance services.

Note that the FEC indicator field is coherent with the Message Count field. This property allows the ATU-C to calculate the FEC error rate.

5.6.2.1.7.2 Header Error Correction (HEC) field

The HEC indicator field is a 4-octet (32-bit unsigned big-endian integer) field that contains the count of errors found in the cell header HEC field at the ATU-R receiver. The HEC counter is incremented for each payload cell in which HEC errors are detected. When the counter reaches its maximum value, it wraps around and starts increasing again from zero. The ATU-C uses the difference between two consecutive reads of this parameter to determine the number of uncorrected HEC errors in a specific period.

The HEC indicator is used to report errors to the fhec-i anomaly in the performance and surveillance services.

Note that the HEC indicator field is coherent with the Frame Count field (from which cell count can be derived). This property allows the ATU-C to calculate the HEC error rate.

5.6.2.1.7.3 Message Count field

The Message Count field is a 4-octet (32-bit unsigned big-endian integer) field that contains the count of received FEC messages at the ATU-R receiver. The counter is incremented once upon receiving each message. When the counter reaches its maximum value, it wraps around and starts increasing again from zero. The ATU-C uses the difference between two consecutive reads of this parameter to determine the number of FEC messages received by the ATU-R in a specific period.

5.6.2.1.7.4 Frame Count field

The Frame Count field is a 4-octet (32-bit unsigned big-endian integer) field that contains the count of received TC-layer frames at the ATU-R receiver. The counter is incremented once upon receiving a TC frame. When the counter reaches its maximum value, it wraps around and starts increasing again from zero. The ATU-C uses the difference between two consecutive reads of this parameter to determine the number of TC frames received by the ATU-R in a specific period.

The Frame Count field can also be used to ascertain the number of ATM cells received at the ATU-R. Frame Mapped mode always transports a fixed number of ATM cells per frame.

5.6.2.2 Direct Cell EOC Messages

The Direct Cell EOC Message set is described in ANNEX A.

5.6.2.3 Direct Packet EOC Messages

For further study.

6. Electrical characteristics

This section describes the electrical characteristics of the single-carrier RADSL system.

6.1 DC characteristics

All requirements of this technical report will be met in the presence of all POTS loop currents from 0†mA to 100 mA, and differential loop voltages as follows:

- DC voltages of 0 V to 105 V;
- ringing signals of 40 V to 150 V rms at any frequency from 15.3 Hz to 68 Hz with a DC component in the range from 0 V to 105 V.

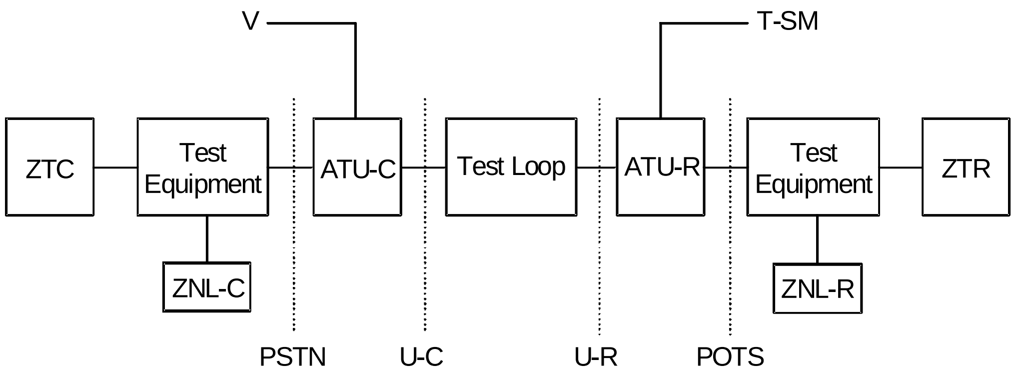
The DC resistance from tip-to-ring at the PSTN interface with the U-C interface shorted, or at the POTS interface with the U-R interface shorted, will be less than or equal to 25 ohms. The DC resistance from tip to ground and from ring to ground at the PSTN interface with the U-C interface open, or at the POTS interface with the U-R interface open will be greater than or equal to 5 M ohms.

6.2 Voice Band Characteristics

6.2.1 Metallic (Differential Mode)

A common test setup will be used for measurement of the voice band insertion loss, attenuation distortion, delay distortion, noise, and distortion. All measurements will be performed between the PSTN and POTS interfaces of the ATU-C and ATU-R, respectively, with a variety of reference loops between the U-C and U-R reference points. The test loops will be homogeneous loops of either 24 AWG or 26 AWG wire.

Figure 74 defines the test configuration and the value of the test components for all electrical characteristics defined in this section, unless otherwise specified. Not all equipment will be required for all tests.



ZTC = 900 ohms in series with 2.16 μF for return loss measurements
= 900 ohms for loss and noise measurements
ZTR = 600 ohms
ZNL-C = 800 ohms in parallel with the series connection of a 100 ohm resistor and a 50 nF capacitor
ZNL-R = 1330 ohms in parallel with the series connection of a 348 ohms resistor and a 100 nF capacitor

Figure 74 - Test Set-up for Transmission and Impedance Measurements

6.2.1.1 Insertion Loss

For each of the test loops, and using the test setup shown in Figure 74, the insertion loss from the PSTN interface to the POTS interface will be measured with and without the ATU-C and ATU-R connected to the test loop. The impedance of the test equipment at the PSTN interface will be 900 ohms, and the impedance at the POTS interface will be 600 ohms.

The increase in insertion loss at 1004 Hz on any of the test loops, due to the addition of the splitters, will be less than or equal to 1.0 dB.

6.2.1.2 Attenuation Distortion

The variation of insertion loss with frequency of the combination of POTS splitters will be measured using the test setup in Figure 74. The impedance of the test equipment at the PSTN interface will be 900 ohms, and the impedance of the test equipment at the POTS interface will be 600 ohms. The added attenuation distortion of the combined POTS splitters relative to loss at 1 kHz measured using each of the test loops identified above will be not more than ± 1.0 dB at any frequency between 0.2 kHz and 4 kHz to allow for V.PCM.

6.2.1.3 Delay Distortion

The delay distortion of the POTS splitter will be measured using the test setup of Figure 74. The increase in envelope delay distortion between 0.6 kHz and 3.2 kHz caused by the two POTS splitters in each of the two test loops will be less than 200 microseconds and less than 250 microseconds at 4 kHz to allow for V.PCM.

6.2.2 Longitudinal (Common Mode)

6.2.2.1 Longitudinal Output Voltage

The ATU-C will present to the U-C interface, and the ATU-R will present to the U-R interface, a longitudinal component whose rms voltage in any 3.4 kHz bandwidth averaged over a 1 second period, is less than -50 dBV over the frequency range 100 Hz to 1.5 MHz. Compliance with this limitation is required with a longitudinal termination having an impedance equal to or greater than a 100 ohm resistor in series with a 0.15 uF capacitor.

Figure 75 defines a measurement method for longitudinal voltage. For direct use of this test configuration, the ATU under test will be able to generate a line signal in the absence of a received signal. The ground reference for these measurements will be the building or green wire ground at the ATU.

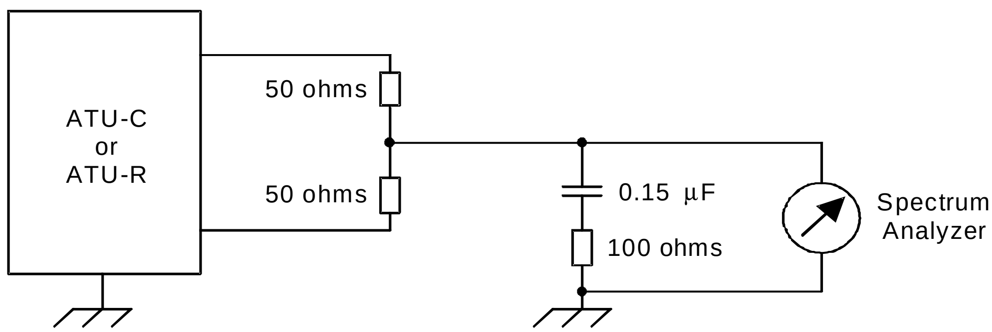


Figure 75 - Measurement Method for Longitudinal Output Voltage

6.2.2.2 Longitudinal Balance

The longitudinal balance at the PSTN and POTS interfaces will be greater than 58 dB from 0.2 kHz to 1 kHz and greater than 53 dB at 3 kHz, measured in accordance with IEEE Standard 455-1985.

6.3 RADSL Band Longitudinal Balance

The longitudinal balance is given by the following equation:

(40)

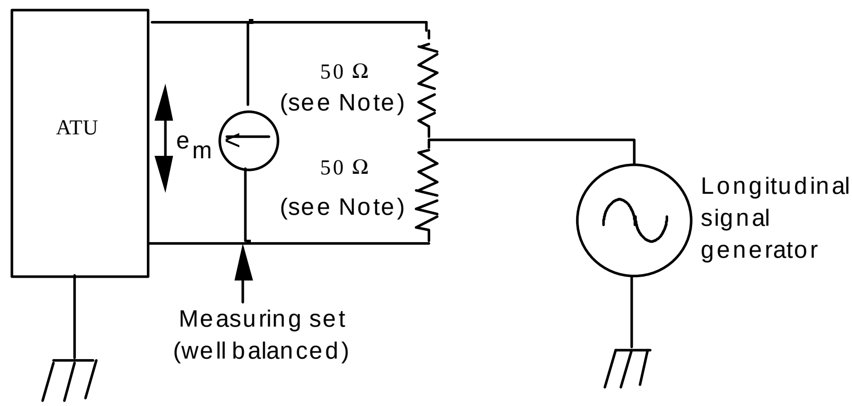
$$LBal = 20 \log \left| \frac{e_l}{e_m} \right| \text{dB}$$

where

e_l = the applied longitudinal voltage (referenced to the building or green wire ground of the ATU)
e_m = the resultant metallic voltage appearing across a terminating resistor (usually 100 Ohm);

The balance of both the ATU-C and ATU-R will be greater than 40 dB between 20 kHz and 1500 kHz.

Figure 76 defines a measurement method for longitudinal balance. For direct use, the measurements should be performed with the ATU-C or ATU-R powered up, but inactive, driving zero volts.



NOTE - These resistors to be matched to better than 0.03% tolerance

Figure 76 - Measurement Method for Longitudinal Balance (above 20 kHz)

7. Interfaces to higher layer TC

7.1 Interface to ATM-TC

This interface transports ATM cells between the ATM-TC sub-layer and the PTC sub-layer, transported as a logical stream of cell octets. The bit rate of this ATM cell stream is equal to the corresponding payload portion of the RADSL line rate, i.e., no ATM cell rate decoupling is performed by the ATU-R or ATU-C.

7.2 Interface to Packet-TC

This interface transports packets between the Packet-TC sub-layer and the PTC sub-layer, transported as a logical stream of bits. The bit rate of this packet stream is equal to the corresponding payload portion of the RADSL line rate, i.e., no inter-packet fill or flags are generated or removed by the ATU-R or ATU-C.

7.3 Bit Sync-TC Interface

This interface transports a synchronous bit stream between the Bit Synchronous TC sub-layer and the PTC sub-layer, transported as a logical stream of bits. The bit rate of this synchronous stream is equal to the corresponding payload portion of the RADSL line rate, i.e., no bit stuffing is performed by the ATU-R or ATU-C.

7.4 EOC-TC Interface

This interface transports the EOC bit-stream between the EOC TC sub-layer and the PTC sub-layer, transported as a logical stream of octets. The bit rate of this stream is equal to the corresponding payload portion of the RADSL line rate, i.e., no EOC message rate decoupling is performed by the ATU-R or ATU-C.

8. Operations and Maintenance

8.1 Embedded Operations channel (EOC)

An embedded operations channel for communication between the ATU-C and ATU-R will be used for in-service and out-of-service maintenance, and for retrieval of ATU-R status information and RADSL performance monitoring parameters. The EOC protocol stack consists of physical layer, link layer, transport layer and application layer. The application transport and link layers are identical for all mapping methods. Different physical layers are used for the different mapping methods: frame mapping, direct cell mapping and direct packet mapping. The mapping methods are described in section 5.3.2. The related EOC TCs are described in section 5.3.4. The related EOC messages are described in section 5.6.2. Common EOC primitives used for in-service performance monitoring and surveillance are described below.

8.2 In-Service Performance Monitoring and Surveillance

8.2.1 ADSL Line related primitives

8.2.1.1 Near-end anomalies

Four near-end anomalies are defined:

- *Forward Error Correction (fec-i) anomaly:* An fec-i anomaly occurs when a received FEC code for the interleaved data stream indicates that errors have been corrected;
- *Forward Error Correction (fec-f) anomaly:* An fec-f anomaly occurs when a received FEC code for the fast data stream indicates that errors have been corrected.
- *Cyclical Redundancy Check (crc-i) anomaly:* A crc-i anomaly occurs when a received CRC code for the interleaved data stream is not identical to the corresponding locally-generated code;
- *Cyclical Redundancy Check (crc-f) anomaly:* A crc-f anomaly occurs when a received CRC code for the fast data stream is not identical to the corresponding locally-generated code.

8.2.1.2 Far-end anomalies

Similarly, four far-end anomalies are defined:

- *Far-end Forward Error Correction (ffec-i) anomaly:* An ffec-i anomaly is a fec-i anomaly detected at the far end. It is reported once per codeword by the designated indicator for each transmission mode.
- *Far-end Forward Error Correction (ffec-f) anomaly:* An ffec-f anomaly is an fec-f anomaly detected at the far end. It is reported once per codeword by the designated indicator for each transmission mode. The ffec-f anomaly will occur and terminate in the same way as the febe-i anomaly;
- *Far-end Block Error (febe-i) anomaly:* A febe-i anomaly is a crc-i anomaly detected at the far-end. It is reported once per TC-layer frame/block by the designated indicator for each transmission mode;
- *Far-end Block Error (febe-f) anomaly*: A febe-f anomaly is a crc-f anomaly detected at the far-end. It is reported once per TC-layer block/frame by the designated indicator for each transmission mode. The febe-f anomaly will occur and terminate in the same way as the febe-i anomaly.

8.2.1.3 Near-end defects

Two near-end defects are defined:

- *Loss-Of-Signal defect (los):* A pilot tone reference power will be established by averaging the ADSL pilot tone power for 0.1 sec. after the start of steady state data transmission (i.e., after initialization), and a threshold will be set at 6 dB below the reference power. A los defect occurs when the level of the received ADSL pilot tone power, averaged over a 0.1 sec. period, is lower than the threshold, and terminates when this level, measured in the same way, is at or above the threshold;
- *Severely Errored Frame (sef) defect:* A sef defect occurs when the contents of two consecutively received ADSL synchronization symbols do not correlate with the expected content over a subset of the tones. A sef defect terminates when the content of two consecutively received ADSL synchronization symbols correlate with the expected contents over the same subset of the tones.

- The correlation method, the selected subset of the tones, and the threshold for declaring the sef defect condition are implementation discretionary.

8.2.1.4 Far-end defects

Two near-end defects are defined

- *Far-end Loss-Of-Signal (los) defect:* A far-end los defect is a los defect detected at the far-end. It is reported by the designated indicator for each transmission mode;
- *Far-end Remote Defect Indication (rdi) defect:* An rdi defect is a sef defect detected at the far-end. It is reported once per TC-layer block/frame by the designated indicator for each transmission mode.

8.2.2 ADSL payload related primitives

8.2.2.1 Near-end anomalies

Six near-end anomalies are defined:

- *No Cell Delineation (ncd-i) anomaly:* An ncd-i anomaly occurs immediately after ATM Cell TC start-up when ATM data are allocated to the interleaved buffer and as long as the cell delineation process has not attained cell delineation. Once cell delineation is acquired, subsequent losses of cell delineation will be considered ocd-i anomalies;
- *No Cell Delineation (ncd-f) anomaly:* An ncd-f anomaly occurs immediately after ATM Cell TC start-up when ATM data are allocated to the fast buffer and as long as the cell delineation process has not attained cell delineation. Once cell delineation is acquired, subsequent losses of cell delineation will be considered ocd-f anomalies;
- *Out of Cell Delineation (ocd-i) anomaly:* An ocd-i anomaly occurs when ATM data are allocated to the interleaved buffer and the cell delineation process fails. An ocd-i anomaly terminates when the cell delineation process transitions from a delineated to a non-delineated state or when the lcd-i defect maintenance state is entered;
- *Out of Cell Delineation (ocd-f) anomaly:* An ocd-f anomaly occurs when ATM data are allocated to the fast buffer and the cell delineation process fails. An ocd-f anomaly terminates when the cell delineation process transitions from a delineated to a non-delineated state or when the lcd-f defect maintenance state is entered;
- *Header Error Check (hec-i) anomaly*: An hec-i anomaly occurs when an ATM cell header error check fails on the interleaved data stream;
- *Header Error Check (hec-f) anomaly*: An hec-f anomaly occurs when an ATM cell header error check fails on the fast data stream.

8.2.2.2 Far-end anomalies

Similarly, six far-end anomalies are defined:

- *Far-end No Cell Delineation (fncd-i) anomaly:* An fncd-i anomaly is a ncd-i anomaly detected at the far-end. It is reported once per TC-layer frame/block by the designated indicator for each transmission mode. An fncd-i anomaly occurs immediately after ATU start-up and terminates when its associated indicator is deasserted;
- *Far-end No Cell Delineation (fncd-f) anomaly:* An fncd-f anomaly is a ncd-f anomaly detected at the far-end. It is reported once per TC-layer frame/block by the designated indicator for each transmission mode. The fncd-f anomaly will occur and terminate in the same way as the fncd-i anomaly;
- *Far-end Out of Cell Delineation (focd-i) anomaly:* An focd-i anomaly is an ocd-i anomaly detected at the far-end. It is reported once per TC-layer frame/block by the designated indicator for each

- transmission mode. A focd-i anomaly occurs if no fncd-i anomaly is present and a received indicator is asserted.
- *Far-end Out of Cell Delineation (focd-f) anomaly:* An focd-f anomaly is an ocd-f anomaly detected at the far-end. It is reported once per TC-layer frame/block by the designated indicator for each transmission mode. The focd-f anomaly will occur and terminate in the same way as the focd-i anomaly;
- *Far-end Header Error Check (hec-i) anomaly*: An fhec-i anomaly is a hec-i anomaly detected at the far end. It is reported once per errored ATM cell by the designated indicator for each transmission mode;
- *Far-end Header Error Check (hec-f) anomaly*: A fhec-f anomaly is a hec-f anomaly detected at the far end. It is reported once per errored ATM cell by the designated indicator for each transmission mode. The fhec-f anomaly will occur and terminate in the same way as the fhec-i anomaly.

8.2.2.3 Near-end defects

Two near-end defects are defined:

- *Loss of Cell Delineation (lcd-i) defect*: A lcd-i defect occurs when at least one ocd-i anomaly is present in each of 4 consecutive TC-layer frames/blocks and no sef defect is present. An lcd-i defect terminates when no ocd-i anomaly is present in 4 consecutive TC-layer frames/blocks;
- *Loss of Cell Delineation (lcd-f) defect*: An lcd-f defect occurs when at least one ocd-f anomaly is present in each of 4 consecutive TC-layer frames/blocks and no sef defect is present. An lcd-f defect terminates when no ocd-i anomaly is present in 4 consecutive TC-layer frames/blocks;

8.2.2.4 Far-end defects

Two near-end defects are defined:

- *Far-end Loss of Cell Delineation (flcd-i) defect*: An flcd-i defect is an lcd-i defect detected at the far-end and is reported by the ncd-i indicator. A flcd-i defect occurs when a focd-i anomaly is present and 4 consecutively received ncd-i indicators are coded 0 and no rdi defect is present. A flcd-i defect terminates if 4 consecutively received ncd-i indicators are coded 1.
- *Far-end Loss of Cell Delineation (flcd-f) defect*: An flcd-f defect is an lcd-f defect detected at the far-end and is reported by the ncd-f indicator. A flcd-f defect occurs and terminates in the same way as the flcd-i defect.

8.2.3 Other ADSL indicators, parameters and signals

8.2.3.1 Other near-end primitives

One other near-end primitive is defined:

Loss-of-power (lpr): An lpr primitive occurs when the ATU electrical supply (main) power drops to a level equal to or below the manufacturer-determined minimum power level required to ensure proper operation of the ATU. An lpr primitive terminates when the power level exceeds the manufacturer determined minimum power level.

8.2.3.2 Other far-end primitives

Similarly, one other far-end primitive is defined:

Far-end Loss-of-power (lpr): A far-end lpr primitive is an lpr primitive detected at the far-end and is reported by the designated indicator for each transmission mode.

8.2.4 ADSL Line Failures

8.2.4.1 Near-end failures

The following near-end failures will be provided at the ATU-C and the ATU-R:

- *Loss-of-signal (LOS):* An LOS failure is declared after 2.5 ± 0.5 s of contiguous los defect, or, if los defect is present when the criteria for LOF failure declaration have been met (see LOF definition below). An LOS failure is cleared after 10 ± 0.5 s of no los defect.
- *Loss-of-frame (LOF):* An LOF failure is declared after 2.5 ± 0.5 s of contiguous sef defect, except when a los defect or failure is present (see LOS definition above). A LOF failure is cleared when LOS failure is declared, or after 10 ± 0.5 s of no sef defect.
- *Loss-of-power (LPR):* An LPR failure is declared after the occurrence of an lpr primitive, followed by other, to-be-determined conditions. This definition is under study.

8.2.4.2 Far-end failures

The following far-end failures will be provided at the ATU-C (ATU-R is at the far-end), and are optional at the ATU-R (ATU-C is at the far-end).

- *Far-end Loss-Of-Signal (LOS) failure:* A far-end LOS failure is declared after 2.5 ± 0.5 seconds of contiguous far-end los defect, or, if far-end los defect is present when the criteria for LOF failure declaration have been met (see LOF definition below). A far-end LOS failure is cleared after 10 ± 0.5 seconds of no far-end los defect.
- *Far-end Remote Failure Indication (RFI) failure:* An RFI failure is declared after 2.5 ± 0.5 seconds of contiguous rdi defect, except when a far-end los defect or failure is present (see LOS definition above). A RFI failure is cleared when far-end LOS failure is declared, or after 10 ± 0.5 seconds of no rdi defect.
- *Far-end Loss-of-PoweR (LPR) failure:* A far-end LPR failure is declared after the occurrence of a far-end lpr primitive followed by 2.5 ± 0.5 seconds of contiguous near-end los defect. A LPR failure is cleared after 10 ± 0.5 seconds of no near-end los defect.

8.2.5 ADSL Payload Failures

8.2.5.1 Near-end failures

The following near-end failures will be provided at the ATU-C and the ATU-R:

- *NCD-I failure:* An NCD-I failure is declared when a ncd-i anomaly persists for more than 2.5 ± 0.5 seconds after the start of SHOWTIME. An NCD-I failure terminates when no ncd-i anomaly is present for more than 10 ± 0.5 seconds.
- *NCD-F failure:* An NCD-F failure is declared when a ncd-f anomaly persists for more than 2.5 ± 0.5 seconds after the start of SHOWTIME. An NCD-F failure terminates when no ncd-f anomaly is present for more than 10 ± 0.5 seconds.
- *LCD-I failure:* A LCD-I failure is declared when a lcd-i defect persists for more than 2.5 ± 0.5 seconds. A LCD-I failure terminates when no lcd-i defect is present for more than 10 ± 0.5 seconds.
- *LCD-F failure:* A LCD-F failure is declared when a lcd-f defect persists for more than 2.5 ± 0.5 seconds. A LCD-F failure terminates when no lcd-f defect is present for more than 10 ± 0.5 seconds.

8.2.5.2 Far-end failures

The following far-end failures will be provided at the ATU-C (ATU-R is at the far-end), and are optional at the ATU-R (ATU-C is at the far-end).

- *Far-end No Cell Delineation (FNCD-I) failure:* An FNCD-I failure is declared when a fncd-i anomaly persists for more than 2.5 ± 0.5 seconds after the start of SHOWTIME. An FNCD-I failure terminates when no fncd-i anomaly is present for more than 10 ± 0.5 seconds.
- *Far-end No Cell Delineation (FNCD-F) failure:* An FNCD-F failure is declared when a fncd-f anomaly persists for more than 2.5 ± 0.5 seconds after the start of SHOWTIME. An FNCD-F failure terminates when no fncd-f anomaly is present for more than 10 ± 0.5 seconds.
- *Far-end Loss of Cell Delineation (FLCD-I) failure:* An FLCD-I failure is declared when a flcd-i defect persists for more than 2.5 ± 0.5 seconds. An FLCD-I failure terminates when no flcd-i defect is present for more than 10 ± 0.5 seconds.
- *Far-end Loss of Cell Delineation (FLCD-F) failure:* An FLCD-F failure is declared when a flcd-f defect persists for more than 2.5 ± 0.5 seconds. An FLCD-F failure terminates when no flcd-f defect is present for more than 10 ± 0.5 seconds.

8.2.6 Performance Monitoring Functions

Near-end performance monitoring (PM) functions will be provided at the ATU-C, and are optional at the ATU-R. Far-end performance monitoring functions will be provided at the ATU-C (ATU-R is at the far-end), and are optional at the ATU-R (ATU-C is at the far-end).

8.2.6.1 Performance data storage

The following data parameters are defined:

- A current 15-minute and a current 1-day register will be provided for each near-end and for each far-end failure count and performance parameter;
- A previous 15-minute and a previous 1-day register will be provided for each near-end and for each far-end failure count and performance parameter;
- A current and a previous register will be provided for each near-end and for each far-end test parameter;
- A shared resource of 96 individual 15-minute registers per failure count and performance parameter will be assignable on-demand to a specific ADSL link. These registers should not exceed about 10 % of the total dedicated failure count and performance parameter memory resource requirements for all links over which this resource is shared;
- Register sizes will either accommodate maximum event counts or values, or have a minimum size of 16 bits;
- Register operation (e.g., pegging at the maximum value, resetting, setting of invalid data flag, etc.) will comply with clause 9 of ANSI T1.231-1997;
- Register invalid data flags will be set if the ATUs are powered down during all or part of the accumulation interval (15 minute or one day).

8.2.6.2 Performance data reporting

Threshold Crossing Alerts and Failures will be reported autonomously. The ATU-C will allow the OSS and the ATU-R will allow the NMS to inhibit such autonomous reporting. The mechanism for inhibiting autonomous reporting is outside the scope of this technical report (see ANSI T1.231-1997).

Performance data reporting will be done in accordance with section 9 of ANSI T1.231-1997.

8.3 Metallic testing

This section is reserved for future study.

8.4 Out-of-service testing

This topic is addressed by the ADSL Forum and proposed for further study in liaison with the ADSL Forum.

8.5 Requirements to support OAM of the segment between ATU-R and SM

This section is reserved for future study.

9. Loop plant characteristics, impairments, and testing

Loop plant characteristics are specified in Annex E and Annex F of this specification, in Annex G of ANSI T1.601-1992, and in section 11, Loop Plant, Impairments, and Testing, of ANSI T1.413-1998.

10. Physical characteristics

Refer to section 13, Physical Characteristics, of ANSI T1.413-1998.

11. Environmental Conditions

Refer to section 14, Environmental, of ANSI T1.413-1998.

ANNEX A

Power Spectral Density of Crosstalk Disturbers

Refer to Annex B, Power Spectral Density of Crosstalk Disturbers, of ANSI T1.413-1998.

ANNEX B

Characteristics of Test Impulse Waveforms

Refer to Annex C, Characteristics of Test Impulse Waveforms, of ANSI T1.413-1998.

ANNEX C

Vendor Identification Numbers

The vendor identification numbers can be found in Annex D, Vendor Identification Numbers, of ANSI T1.413-1998 and updates made available by T1E1.4.

ANNEX D

POTS Low-Pass Filter

Refer to Annex E, POTS Splitter Requirements, of ANSI T1.413-1998.

ANNEX E

Characteristics of Typical Telephone Cables

Refer to Annex G, Characteristics of Typical Telephone Cables, of ANSI T1.413-1998.

ANNEX F

Overvoltage, Surge Protection, and EMC

Refer to Annex O.2, Additional References on Overvoltage, Surge Protection, and EMC, in ANSI T1.413-1998.

ANNEX G

ATM Direct Cell Mapping Mode, EOC transport and Performance Monitoring

G.1 Introduction

This annex specifies the Embedded Operations Channel (EOC) message set for Direct Cell Mapping Mode as described in 5.3.2.2.

This annex addresses definition of the Embedded Operations Channel (EOC) command set only, required for ATU-R unit provisioning and status retrieval. This annex does not address either the hardware drivers or data link layer protocols required for EOC operation (error handling, retries, etc.).

G.1.1 Definitions and Acronyms

AAL1 – ATM Adaptation Layer 1

ADSL – Asymmetric Digital Subscriber Line

ASIC – Application-Specific Integrated Circuit

ATM – Asynchronous Transfer Mode

ATU-C – RADSL termination unit, central office end

ATU-R – RADSL termination unit, remote terminal end

CAP – Carrierless Amplitude and Phase modulation

DSL – Digital Subscriber Line

EOC – Embedded Operations Channel

FEC – Forward Error Correction

FIFO – First In-First Out

FLASH – Electronically erasable, programmable read-only memory (EEPROM)

FPGA – Field-Programmable Gate Array

GAIN – Refers to receive gain

HEC – Header Error Check

kbps – Kilobits per second

LED – Light-Emitting Diode

Mbps – Megabits per second

PCB – Printed Circuit Board

PIM – Personality Interface Module

POTS – Plain Old Telephone Service (also message telecommunications service or MTS)

SLADE – Subscribe Line Analog Device

SLIDE – Subscriber Line Interface Device

SOC – Start of Cell

SONET – Synchronous Optical Device

SRAM – Static Random Access Memory

TBD – To be Determined

UTOPIA – Universal Test and Operations PHY Interface for ATM

G.2 EOC Message Structure

The EOC message is divided into two distinct sections. The first section provides the header information which includes a Code Set identification value, a sequence number, and the message type. The second section is the message-specific data field.

Table 35 - Message Structure

Octet #	7	6	5	4	3	2	1	0	
0									CodeSet
1									Sequence Number
2	C/R								Opcode
3									
									Message Data
n - 1									
n									

G.2.1 Code Set

This octet defines the message set opcodes supported as well as the structure of each of the messages information fields. There are various code set blocks to accommodate the various types of message sequences. Code Set 0x00 is reserved for the 'Read Vendor Code' request message. This code set message is fixed and will not be changed.

Table 36 - CodeSet Definitions

Code Set	Description
0x00	Read Vendor Code, Reset
0x01 - x0F	Unused, Reserved
0x10	Reserved
0x11	Reserved
0x12 - x3F	Unused, Reserved
0x40 - xFB	Unused, Reserved
0xFC	EOC Message Set Version 2.0
0xFD	Reserved
0xFE	Reserved
0xFF	Reserved

G.2.2 Sequence Number

This octet defines a simple modulo 256 sequence counter that may be used to mark messages and track responses. Each new message issued contains a previous-sequence-number+1 count value. This number rolls over to 0 as the next sequence number after a sequence number of 255 is reached. Each message response should contain the same sequence number as the corresponding originating message command for response tracking.

G.2.3 Opcode

This octet defines the message and the structure of the information field.

G.2.4 Message Data

Data field contents of the message.

G.2.5 Byte Order of Multiple-Byte Values

The following example is given to clarify the byte order of multi-byte values. Because various semiconductor products use different ordering, the following convention is used within the format of the commands and responses. The most significant byte of a multi-byte value will be placed in the lower address byte of the field.

For example, if bytes 7, 8, 9, and 10 were filled in, a message or response field with a value of 100,000 (0x000186a0) it would be sent as:

Table 37 – Byte Order of Multiple-Byte Values

Byte #	Value
7	0x00
8	0x01
9	0x86
10	0xA0

G.3 EOC Message Set

G.3.1 Reserved Fields

All reserved fields in the data segment of a message will be 0x00 filled.

G.3.2 Opcodes

Table 38 - Normal Message Opcode Set

Message	Command ID	Response ID
Read VendorIDCode[1, 2]	0x40	0xC0
Run SelfTest[1]	0x02	0x82
RequestCorruptCrc[1]	0x07	0x87
RequestCorruptCrcEnd[1]	0x08	0x88
Exchange ATUID	0x12	0x92
Read CPEID	0x13	0x93
Read ConfigCPE	0x14	0x94
Read ConfigPVC	0x34	0xB4
Read MACtable	0x35	0xB5
Read ConfigDSL	0x46	0xC6
Read EthernetStats	0x36	0xB6
Exchange SignalStatsDSL	0x16	0x96
Read Status ATU	0x17	0x97
Read Status CPE	0x41	0xC1
Set Clock	0x18	0x98
Set ConfigCPE	0x1A	0x9A
Set ConfigPVC	0x3A	0xBA
Set ConfigMAC	0x3B	0xBB
Set ConfigDSL	0x44	0xC4
Set Loopback	0x1B	0x9B
Reset[2]	0x1C	0x9C
Read TrafficStats	0x1D	0x9D
Set ExcessiveErrorSec	0x1E	0x9E
Read CLEI	0x43	0xC3

[1] Messages supported in T1.413 (format of message may not be exactly as defined in specification)
[2] Special CodeSet for this message (code set = 0x00)

G.3.2.1 Universal Opcodes

G.3.2.1.1 **Code Set Retrieval and ATU-R Reset (Codeset 0x00)**

G.3.2.1.1.1 Read VendorIDCode

This EOC message is initiated by the CO line-card to retrieve the EOC message set code and vendor code supported by the remote ATU-R unit. This information is required before any subsequent communications between the ATU-C unit and the ATU-R unit can take place.

The VendorID code field will be retrieved from the ATU-R unit, and will return a 0x0000 in that field to specify that the vendor ID field is not supported by this version of the software subsystem, as is the case of the first release of code supporting this EOC message set.

Currently, the SupportedCodeSet field will provide support of EOC message set definition of 0xFC.

This command is a special request command type that uses a code set value of 0x00 to obtain the actual code set that will be supported for all other normal messages.

This command is used by the ATU-C to obtain the vendor (manufacturer) identification code from the ATU-R unit, as well as the code set type supported.

Table 39 – Read VendorIDCode Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	1	0	0	0	0	0	0	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	1	0	0	0	0	0	0	Opcode
2									Vendor ID
1									Supported CodeSet

Field Description:

VENDOR ID – The vendor code is a 16-bit value defined by ANSI T1.413-1998 Annex D. 0x0000 specifies this field is not supported (no vendor ID).

SUPPORTED CODE SET – This defines the code set that will be used for all normal messages. Valid code set values are defined in section 2.1. The response to this command from currently supported ATU-R units is 0xFC (EOC Message Set version 2.0).

A return value of 0x00 in this field, or return of a non-supported, reserved code set, represents an invalid condition, and EOC communication will not be validated.

Current valid data for this field:

Table 40 - Supported Code Set Field Values

0x00 - 0x0F	Invalid values
0x10	Reserved
0x11	Reserved
0x12 - 0x3F	Invalid values
0x40 - 0xFB	(Reserved for new code sets, currently invalid)
0xFC	EOC Message Set version 2.0
0xFD	Reserved
0xFE - 0xFF	Invalid values

G.3.2.1.1.2 Reset

Command ID = 0x1C, Response ID = 0x9C (common code set 0x00)

This command forces ATU-R to reset.

Table 41 – Reset Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	1	1	0	0	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	1	0	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set. The ATU-R unit executes a card reset immediately following the response to the reset command.

G.3.2.2 Opcodes for Codeset 0xFC

G.3.2.2.1 **RunSelfTest**

Command ID = 0x02, Response ID = 0x82 (code set 0xFC)

The RunSelfTest message is used by the CO line-card, to initiate a self-test action on the connected ATU-R unit. The response to this command by the ATU-R unit is simply an acknowledgment that it has accepted the self-test request. Actual results of the ATU-R unit self-test are returned in the response message to an EOC ReadStatus command, in the two-byte DiagCode field (refer to response description for the EOC ReadStatus command described in G.3.2.2.8). Valid self-test diagnostics error codes are documented in the EOC ReadStatus response message.

Table 42 – RunSelfTest Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	0	0	0	1	0	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	0	0	0	1	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.2 **RequestCorruptCrc**

This command forces the ATU-R to begin sending corrupt DSL CRC blocks. This condition is latched until the 'RequestCorruptCrcEnd' command is dispatched by the line processor.

Table 43 – RequestCorruptCrc Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	0	0	1	1	1	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	0	0	1	1	1	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.3 **RequestCorruptCrcEnd**

Command ID = 0x08, Response ID = 0x88 (code set 0xFC)

This command forces the ATU-R to stop sending corrupt DSL CRC blocks. This command should be sent following a 'RequestCorruptCrc' command described above. For the ATU-R unit to terminate sending of bad CRC-errored blocks following a 'RequestCorruptCrc' command, execution of this command is the only mechanism (other than a reset or reboot) to turn that function off, as there is no time-out termination of this function.

Table 44 – RequestCorruptCrcEnd Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	0	1	0	0	0	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	0	1	0	0	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.4 **ExchangeATUID**

Command ID = 0x12, Response ID = 0x92 (code set 0xFC)

This command is issued by the ATU-C to exchange version numbers and other information between the ATU-C and ATU-R units.

Note that information exchanged in this command is informational and vendor-specific. Response information is not interpreted by the ATU-C unit and is passed transparently up to the management system for interpretation. The ATU-R unit may not implement usage of this information from the ATU-C.

Table 45 – ExchangeATUID Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	0	0	1	0	Opcode
1									(Reserved)
4									ATUC_AppSoftwareID
8									ATUC_HardwareID
20									ATUC_SerialNumber
20									ATUC_ModelNumber
1									ATUC_Star_ID
4									ATUC_GTI_FirmwareVer
4									ATUC_GTI_WrapperVer
4									ATUC_BootSoftwareID
2									(Reserved)

Field Description:

ATUC_APPSOFTWAREID – Indicates the application software version number. This is the version of the operational software executing (or supported) by the ATU-C unit. The length of this field is four bytes.

ATUC_HARDWAREID – Indicates the ATU-C framer ID plus PCB ID. This is an encoded hardware identification number, based on the framer/TC layer, transceiver type, and PCB version/revision number. The length of this field is eight bytes.

ATUC_SERIALNUMBER – Indicates the serial number of the ATU-C assembly. The length of this field is 20 bytes.

ATUC_MODELNUMBER – Indicates the model number of the ATU-C assembly. The length of this field is 20 bytes.

ATUC_STAR_ID – This field contains the current ATUC STARLET chipset ID.

ATUC_GTI_FIRMWAREVER – This field contains the firmware version number of the GTI-supplied STARLET code loaded on the ATU-C unit STARLET device.

ATUC_GTI_WRAPPERVER – Contains the firmware version number of the system vendor-supplied wrapper code loaded on the ATU-C unit, which interfaces with the STARLET device code.

ATUC_BOOTSOFTWAREID – Indicates the ATUC boot process software version number. The length of this field is four bytes.

Table 46 - ExchangeATUID Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	0	0	1	0	Opcode
1									ATU-R_AppType
4									ATU-R_AppSoftwareID
8									ATU-R_HardwareID
20									ATU-R_SerialNumber
20									ATU-R_ModelNumber
1									ATU-R_Star_ID
4									ATU-R_GTI_FirmwareVer
4									ATU-R_GTI_WrapperVer
4									ATU-R_BootSoftwareID
2									ATU-R_ActiveCPEInterfaces

Field Description:

ATUAPPTYPE – Indicates the application software type running on the ATU-R unit. This information is used by the ATU-C unit to determine if the ATU-R has the ability to be downloaded with a new application, or not.

Valid application types for this field are:

Table 47 - Supported ATUAppType Field Values

0x00 - Download-able application

0x01 - ROM-only (cannot download)

0x02 ~ **0xFF** - Reserved

ATU-R_APPSOFTWAREID – Indicates the application software version number. This is the version of the operational software executing (or supported) by the ATU-R unit. The length of this field is four bytes.

ATU-R_HARDWAREID – Indicates the ATU-R framer ID plus PCB ID. This is an encoded hardware identification number, based on the framer/TC layer, transceiver type, and PCB version/revision number. The length of this field is eight bytes.

ATU-R_SERIALNUMBER – This field returns the serial number of the ATU-R assembly. The length of this field is 20 bytes.

ATU-R_MODELNUMBER – This field returns the model number of the ATU-R assembly. The length of this field is 20 bytes.

ATU-R_STAR_ID – This field contains the current STARLET chipset ID.

ATU-R_GTI_FIRMWAREVER – This field contains the firmware version number of the GTI-supplied STARLET code loaded on the ATU-R unit STARLET device.

ATU-R_GTI_WRAPPERVER – This field contains the firmware version number of the system vendor-supplied wrapper code loaded on the ATU-R unit, which interfaces with the STARLET device code.

ATU-R_BOOTSOFTWAREID – Indicates the ATU-R boot process software version number. The length of this field is four bytes.

ACTIVECPEINTERFACES – Indicates active CPE interfaces on ATU-R. This is a bit field, and length of this field is two bytes. CPE information may be retrieved independently for a particular interface using the *ReadCPEID* command.

G.3.2.2.5 **ReadCPEID**

Command ID = 0x13, Response ID = 0x93 (code set 0xFC)

This command is used by the ATU-C to obtain the ATU-R CPE's type, and hardware and software ID information.

Note that information exchanged in this command is informational and vendor-specific. Response information is not interpreted by the ATU-C unit, and is passed transparently up to the management system for interpretation. The ATU-R unit may not implement usage of this information from the ATU-C.

Table 48 – ReadCPEID Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	0	0	1	1	Opcode
2									CPE_IF

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R.

Table 49 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** – Reserved

Table 50 - ReadCPEID Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	0	0	1	1	Opcode
1									CPEType
4									SoftwareID
4									HardwareID

Field Description:

CPETYPE – Indicates the type of CPE interface on the ATU-R unit which is the target of this command (i.e., ATM-25 or 10BaseT).

Valid data values for this field are:

Table 51 – Supported CPEType Field Values

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 BaseT (transparent routed)

0x1x ~ **0xFx** - Reserved

SOFTWAREID – Indicates the software version of CPE-specific application code loaded on the ATU-R unit (i.e., if the CPE interface uses purchased 10BaseT bridge code, then the software ID version of that application code should be contained in this field). This four-byte field is in ASCII format.

HARDWAREID1 – This field contains the hardware for any CPE-specific hardware contained on the ATU-R unit. This CPE-specific hardware might be a PIM-type baby board or other hardware that might be specific to the CPE which is not covered by the ATU-RHardwareID field of the ReadATUID EOC command.

G.3.2.2.6 **ReadConfigCPE**

Command ID = 0x14, Response ID = 0x94 (code set 0xFC)

This command is issued by the ATU-C to obtain provisioned ATU-R CPE configuration.

Note that information exchanged in this command is informational and vendor-specific. Response information is not interpreted by the ATU-C unit, and is passed transparently up to the management system for interpretation. The ATU-R unit may not implement usage of this information from the ATU-C.

Note that the information contained in the response to this command is dependent on the CPE interface type.

Table 52 – ReadConfigCPE Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	0	1	0	0	Opcode
2									CPE_IF
1									CPEType

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 53 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates the type of CPE interface on the ATU-R unit which is the target of this command (i.e., ATM-25 or 10BaseT).

Table 54 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced) - DEFAULT CPE type

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** - Reserved

G.3.2.2.6.1 Ethernet CPE I/F Configuration

The command configuration field is specific to the interface being configured. For configuration of the 10BaseT Ethernet interface (bridge operation), the following command fields are valid. The interface being configured is identified in the CPE_Type field.

Table 55 – ReadConfigCPE Response for Ethernet CPE I/F Configuration

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	0	1	0	0	Opcode
2									CPE_IF
1	0x02								CPEType
1	0	0	0	0	0	0	X	X	CPE State
2									Composite CR
2									Bridge Aging Time

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 56 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates the type of CPE interface on the ATU-R unit which is the target of this command (i.e., ATM-25 or 10BaseT).

Table 57 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (Enhanced)

0x08 - 10 Base T (Transparent routed)

0x1x ~ **0xFx** - Reserved

CPE STATE – It indicates the CPE state.

Table 58 – Supported CPE State Field Values

Bit 0 - Interface.	'0' = Disabled, '1' = Enabled
Bit 1 - Bridge Mode.	'0' = Learning, '1' = Static

COMPOSITE CR – Indicates the composite upstream cell rate in cells per second.

Valid range is 0 to 30000.

Table 59 – Supported Composite CR Field Values

0	When '0', cell rate follows line rate.
1 - 30000	Upstream cell rate in cells-per-second
30001-65535	Invalid upstream cell rate specified. Previous provisioned cell rate is maintained.

BRIDGE AGING TIME – Bridge entry aging time in seconds. Range of 0-65535 with 0 equal to no aging. Default is 1800 seconds (30 minutes).

G.3.2.2.7 **ExchangeSignalStatsDSL**

Command ID = 0x16, Response ID = 0x96 (code set 0xFC)

This command is issued by the ATU-C to exchange signal statistics with the ATU-R.

Table 60 – ExchangeSignalStatsDSL Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	0	1	1	0	Opcode
2									ATUC_Margin
2									ATUC_Gain
2									ATUC_XmtPower
2									ATUC_Gain1
2									ATUC_Gain2
2									ATUC_MeanSqError

Field Description:

ATUC_MARGIN – Indicates the signal to noise margin (tenths of a dB), where 0db = 10^{-7} Bit Error Rate (BER) of the ATU-C transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATUC_GAIN – Indicates the current calculated receiver gain (tenths of a dB) of the ATU-C transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATUC_XMTPOWER – Indicates the current transmit power level (tenths/DBM) of the ATU-C transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATUC_GAIN1 – Indicates the current raw receive gain 1 of the ATU-C transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATUC_GAIN2 – Indicates the current raw receive gain 2 of the ATU-C transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATUC_MEANSQERROR – Indicates the current mean square root of the ATU-C transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

Table 61 - ExchangeSignalStatsDSL Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	0	1	1	0	Opcode
2									ATU-R_Margin
2									ATU-R_Gain
2									ATU-R_XmtPower
2									ATU-R_Gain1
2									ATU-R_Gain2
2									ATU-R_MeanSqError

Field Description:

ATU-R_MARGIN – Indicates the signal-to-noise margin (tenths of a dB), where 0db = 10^{-7} Bit Error Rate (BER) of the ATU-R transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATU-R_GAIN – Indicates the receiver gain (tenths of a dB), of the ATU-R transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATU-R_XMTPOWER – Indicates the transmit power level (tenths/DBM), of the ATU-R transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATU-R_GAIN1 – Indicates the current raw receive gain 1 of the ATU-R transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATU-R_GAIN2 – Indicates the current raw receive gain 2 of the ATU-R transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

ATU-R_MEANSQERROR – Indicates the current mean square root of the ATU-R transceiver. A value of 0x7FFF in this field indicates that invalid data exists for this parameter.

G.3.2.2.8 ReadStatusATU

Command ID = 0x17, Response ID = 0x97 (code set 0xFC)

This command is used by the ATU-C to obtain the ATU-R status.

Table 62 – ReadStatusATU Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	0	1	1	1	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	0	1	1	1	Opcode
1	0	0	0	0	0	0	X	X	ATU-R Status
2									ATU-R DiagCode

Field Description:

ATU-R STATUS – Indicates the loopback status.

Table 63 – Supported ATU-R Status Field Values

'00' = No loopback
'01' = DSL loopback downstream to upstream
'10' = CPE loopback
'11' = Reserved

ATU-R DiagCode – Indicates the ATU-R diagnostic error. This is a 16-bit-wide bit field. Some error types, because of their nature, may not allow the ATU-R unit to be in an operable state to report these errors, or even allow the EOC channel to operate. Each bit in the bit field is latched until the cause for the error is removed.

A '0' indicates inactive state; a '1' indicates the active state of the event. All unused or reserved bits must indicate the inactive state (0).

Bit field meanings are:

Table 64 – ATU-R DiagCode Filed Bit Meanings

Bit 0	Failed CPU RAM test
Bit 1	Failed CPU ROM test
Bit 2	Reserved
Bit 3	Reserved
Bit 4	Reserved
Bit 5	Failed Transceiver Channel Initialization
Bit 6	Failed Transceiver Channel Start-up
Bit 7	Reserved
Bit 8	Failed Transceiver Periodic status
Bit 9	Unused (0)
Bit 10	Failed Transceiver Verify test
Bit 11	Invalid Checksum on internal serial number
Bit 12	Reserved
Bit 13	Reserved
Bit 14	Reserved
Bit 15	Reserved

G.3.2.2.9 **ReadStatusCPE**

Command ID = 0x41, Response ID = 0xC1 (code set 0xFC)

This command is issued by the ATU-C to obtain the ATU-R CPE status.

Table 65 – ReadStatusCPE Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	1	0	0	0	0	0	1	Opcode
2									CPE_IF
1									CPEType

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bit-mapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 66 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates the type of CPE interface on the ATU-R unit which is the target of this command (i.e., ATM-25 or 10BaseT).

Table 67 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (Enhanced)

0x08 - 10 Base T (Transparent routed)

0x1x ~ **0xFx** – Reserved

Table 68 – ReadStatusCPE Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	1	0	0	0	0	0	1	Opcode
2									CPE_IF
1									CPEType
1	0	0	0	0	0	0	0	X	CPE Status
1	0	0	0	0	0	0	0	X	CPE Alarms

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 69 – Supported CPE I/F Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates the type of CPE interface on the ATU-R unit which is the target of this command (i.e., ATM-25 or 10BaseT).

Table 70 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** - Reserved

CPE STATUS – Indicates the CPE link.

Table 71 – Supported CPE Status Field Values

'0' = Unavailable

'1' = Operational

CPE ALARMS – Indicates the CPE receive HEC Error daily/hourly alarm.

Table 72 – Supported CPE Alarms Field Values

'0' = No alarm

'1' = Alarm condition, threshold met or exceeded.

G.3.2.2.10 **SetClock**

Command ID = 0x18, Response ID = 0x98 (code set 0xFC)

This command forces the ATU-R to set its clock.

Table 73 – SetClock Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	1	0	0	0	Opcode
1									Seconds
1									Minutes
1									Hours
1									Days
1									Months
1									Years
1									DayOfWeek
1									HundredsYears (Century)

Field Description:

SECONDS – Indicates the current second. Valid range of this value is 0x00-0x3B (0-59 decimal).

MINUTES – Indicates the current minute. Valid range of this value is 0x00-0x3B (0-59 decimal).

HOURS – Indicates the current hour. Valid range of this value is 0x00-0x17 (0-23 decimal).

DAYS – Indicates the current day. Valid range of this value is 0x01-0x1F (1-31 decimal).

MONTHS – Indicates the current month. Valid range of this value is 0x01-0x0C (1-12 decimal).

YEARS – Indicates the current year. Valid range of this value is 0x00-0x63 (0-99 decimal).

DAYOFWEEK – Indicates the current day of the week. Valid range of this value is 0x01-0x7 (1-7 decimal).

HUNDREDSYEARS – Indicates the current century, indicating the first two digits (hundreds) of the year. Valid range of this value is 0x13-0x15 (19-21 decimal), indicating the ability to set years 1900 through 2199.

Table 74 – SetClock Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	0	0	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.11 **SetConfigDSL**

Command ID = 0x44, Response ID = 0xC4 (code set 0xFC)

This command forces ATU-R to set its DSL line configuration.

Table 75 – SetConfigDSL Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	1	0	0	0	1	0	0	Opcode
2									ATU-R_XmtPower
1	0	0	0	0	0	0	0	X	ATU-R_Interleaving
1	0	0	0	0	0	0	0	X	ATU-R_ErrorCorrection

Field Description:

ATUR_XMTPOWER – This value indicates the requested transmit power of the ATU-R unit. This parameter is specified in dB.

Downstream valid transmit power levels are:

Table 76 – Supported ATUR_XmtPower Field Values

0.0dB - Full power

-3.0dB - Full power -3 dB

-6.0dB - Full power -6 dB

-9.0dB - Full power -9 dB

-12.0dB - Full power -12 dB

Note that all values represented in dB are floating point values stored as integers. The decimal point is implied between upper and lower bytes. For example, 1250 represents 12.50 dB.

ATU-R_INTERLEAVING – This parameter configures the interleaving function of the ATU-R.

Valid settings are:

Table 77 – Supported ATU-R_Interleaving Field Values

'0' = Interleaving function OFF

'1' = Interleaving function ON

ATU-R_ERRORCORRECTION – This parameter configures the interleaving function of the ATU-R. Valid settings are:

Table 78 – Supported ATU-R_ErrorCorrection Field Values

'0' = Error Correction OFF

'1' = Error Correction ON

Table 79 – SetConfigDSL Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	1	0	0	0	1	0	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.12 ReadConfigDSL

Command ID = 0x46, Response ID = 0xC6 (code set 0xFC)

This command reads the configured ATU-R DSL line configuration.

Table 80 – ReadConfigDSL Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	1	0	0	0	1	1	0	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	1	0	0	0	1	1	0	Opcode
2									ATU-R_XmtPower
1	0	0	0	0	0	0	0	X	ATU-R_Interleaving
1	0	0	0	0	0	0	0	X	ATU-R_ ErrorCorrection

Field Description:

ATUR_XMTPOWER – This value indicates the current transmit power of the ATU-R unit. This parameter is specified in dB.

Downstream valid transmit power levels are:

Table 81 – Supported ATUR_XmtPower Field Values

0.0dB - Full power

-3.0dB - Full power -3 dB

-6.0dB - Full power -6 dB

-9.0dB - Full power -9 dB

-12.0dB - Full power -12 dB

Note that all values represented in dB are floating point values stored as integers. The decimal point is implied between upper and lower bytes. For example, 1250 would represent 12.50 dB.

ATU-R_INTERLEAVING – This parameter configures the interleaving function of the ATU-R. Valid settings are:

Table 82 – Supported ATU-R_Interleaving Field Values

‘0’ = Interleaving function OFF

‘1’ = Interleaving function ON

ATU-R_ERRORCORRECTION – This parameter configures the error correction function of the ATU-R. Valid settings are:

Table 83 – Supported ATU-R_ErrorCorrection Field Values

‘0’ = Error Correction OFF

‘1’ = Error Correction ON

G.3.2.2.13 **SetConfigCPE**

Command ID = 0x1A, Response ID = 0x9A (code set 0xFC)

This command forces ATU-R to configure the CPE interface device.

Table 84 – SetConfigCPE Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	1	0	1	0	Opcode
2									CPE_IFType
1									CPEType
	CPE-Specific Configuration DATA								(Refer to section 3.2.2.13.1)

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 85 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - 0xFFxx - Reserved

CPETYPE – Indicates a CPE type (technology).

Table 86 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** - Reserved

ETHERNET CPE I/F CONFIGURATION – The command configuration field is specific to the interface being configured. For configuration of the 10BaseT Ethernet interface, the following command fields are valid:

Table 87 – Ethernet CPE I/F Configuration 10BaseT Command

10BaseT Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	0	0	0	X	X	CPE State
2									Composite CR
2									Bridge Aging Time

Field Description:

CPE STATE – It indicates the CPE state.

Table 88 – Supported CPE State Field Values

Bit 0 - Interface. '0' = disabled, '1' = enabled

Bit 1 - Bridge Mode. '0' = learning, '1' = static

COMPOSITE CR – Indicates the composite upstream cell rate in cells-per-second. Valid range is 0 to 30000.

Table 89 – Supported Composite CR Field Values

0	When '0', cell rate follows line rate.
1 - 30000	Upstream cell rate in cells-per-second
30001-65535	Invalid upstream cell rate specified. Previous provisioned cell rate is maintained.

BRIDGE AGING TIME – Bridge entry aging time in seconds. Range of 0-65535 with 0 equal to no aging. Default is 1800 seconds (30 minutes).

Table 90 - Ethernet CPE I/F Configuration 10BaseT Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	0	1	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.14 SetLoopback

Command ID = 0x1B, Response ID = 0x9B (code set 0xFC)

This command forces ATU-R to set Loopback.

Table 91 – SetLoopback Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	1	0	1	1	Opcode
1									Type
4									Timeout

Field Description:

TYPE – Indicates a type of loopback. (See 3.2.13, Read Status)

TIMEOUT – Indicates a time-out duration, in seconds, before automatic disable. Field length is four bytes. Valid values for this field are:

Table 92 – Supported Timeout Field Values

0x00000000 - Time-out = 0. Loopback is not enabled.

0x00000001 - 0x00015180 Time-out range is from 1 to 86,400 seconds, in one-second increments.

0x00015181 - 0xFFFFFFFF - Invalid range. Loopback is not enabled.

Table 93 – SetLoopback Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	0	1	1	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.15 **ReadTrafficStats**

Command ID = 0x1D, Response ID = 0x9D (code set 0xFC)

This command is used by the ATU-C to obtain an ATU-R PM 15MIN traffic statistics.

Table 94 – ReadTrafficStats Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	1	1	0	1	Opcode
1									PM15MinBinNum

Field Description:

PM15MINBINNUM – Indicates a 15-minute performance monitoring data bin (1 - 96).

Table 95 – ReadTrafficStats Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	1	0	1	Opcode
1									PM15MinBinNum
1									BinDoneFlag
2									DnHECErrorSec
2									UpBfrOverflowSec
4									DnTotalCells
2									RxHECErrorSec
2									DiscardedTranslationCellSec

Field Description:

PM15MinBinNum – Indicates the latest valid PM BIN number available. Valid BIN numbers are:

Table 96 – Supported PM15MinBinNum Field Values

0x00 = No valid data available

0x01-0x60 = 15 minute BINs. for 1 day (1-96 decimal).

0x01 = 12:00 am-12:14 am

0x02 = 12:15 am-12:29 am

0x03 = 12:30 am-12:44 am

*

*

*

0x60 = 11:45 pm-11:59 pm

0x61 - **0xFF** - Reserved

BinDoneFlag – This bit indicates the bin completion status.

'0'- Not done

'1' - Completed

DnHECErrorSec – This is a two-byte field, indicating the downstream HEC error seconds.

Count Values:

0x0000-0xFFFF

UpBfrOverflowSec – This is a two-byte field, indicating the upstream buffer overflow seconds.

Count Values:

0x0000 - 0xFFFF

DnTotalCells – This is a four-byte field, indicating the downstream total valid cell count value.

Count values:

0x00000000 - 0xFFFFFFFF

RxHECErrorSec – Two-byte field indicating the receive HEC error seconds.

Count values:

0x0000 - 0xFFFF

DiscardedTranslationCellSec – Two-byte field indicating the received discarded VPI translation cells.

Count values:

0x0000 - 0xFFFF

G.3.2.2.16 SetExcessiveErrorSec

Command ID = 0x1E, Response ID = 0x9E (code set 0xFC)

This command informs the ATU-R that an excessive DSL error second occurred.

Table 97 – SetExcessiveErrorSec Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	0	1	1	1	1	0	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	1	1	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.17 **ReadCLEI**

Command ID = 0x43, Response ID = 0xC3 (code set 0xFC)

This command is used by the ATU-C to obtain the CLEI code of the ATU-R unit.

Table 98 - ReadCLEI Command/Response

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	1	0	0	0	0	1	1	Opcode

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	1	0	0	0	0	1	1	Opcode
20									CLEI_Code

Field Description:

CLEI CODE – For a product containing a CLEI code, the alphanumeric code can be translated into a text string and reported via the ReadCLEI command to an element management system. A CLEI code is a series of alphanumeric characters printed onto a barcode-type label that is scanable. It is used to identify a product. Twenty bytes have been allocated for the CLEI code. Should the string be less than 20 bytes, then the trailing bytes should contain ASCII 0s.

G.3.2.2.18 **ReadEthernetStats**

Command ID = 0x36, Response ID = 0xB6 (code set 0xFC)

This command is used by the ATU-C to obtain ATU-R Ethernet traffic statistics.

Table 99 – ReadEthernetStats Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	1	1	0	1	1	0	Opcode
1	0	0	0	0	0	0	0	X	Clear

Field Description:

CLEAR:

'0' = Normal Read

'1' = Read and clear counters

Table 100 – ReadEthernetStats Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	1	0	1	Opcode
4									Monitored Seconds
4									Octets Received
4									Octets Transmitted
4									Packets Received
4									Packets Transmitted
4									Inbound Packet Errors
4									Outbound Packet Errors
4									Errorless Inbound packets Discarded
4									Received Packets CRC Error
4									Received RUNT Frames
4									Transmit Collisions
4									JABBER Errors
4									Transmit Under-runs
4									Long Receive Frames
4									Missed Receive Frames
4									Output Queue Length

Field Description:

MONITORED SECONDS – Number of seconds since counts last cleared.

OCTETS RECEIVED – Number of bytes received.

OCTETS TRANSMITTED – Number of bytes transmitted.

PACKETS RECEIVED – Number of Ethernet frames received.

PACKETS TRANSMITTED – Number of Ethernet frames transmitted.

INBOUND PACKET ERRORS – Number of received errored packets.

OUTBOUND PACKET ERRORS – Number of transmitted errored packets.

ERRORLESS INBOUND PACKETS DISCARDED – Number of received packets discarded because they were not read in time from the receiver.

RECEIVED PACKETS CRC ERROR – Number of received packets that had CRC errors.

RECEIVED RUNT FRAMES – Number of received frames that were too short.

TRANSMIT COLLISIONS – Number of collisions seen by the transmitter.

JABBER ERRORS – Number of times the transmitter did not turn off properly.

TRANSMIT UNDER-RUNS – Number of times the transmitter did not finish transmitting a frame completely.

LONG RECEIVE FRAMES – Number of Ethernet frames received that were larger than 1518 bytes.

Missed Receive Frames – Number of received Ethernet frames that were not read out before being overwritten by the next frame.

Output Queue Length – Size of current output queue in outstanding frames.

G.3.2.2.19 **SetConfigPVC**

Command ID = 0x3A, Response ID = 0xBA (code set 0xFC)

This command configures an ATM PVC on the ATU-R.

Table 101 - SetConfigPVC

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	1	1	1	0	1	0	Opcode
2									CPE_IF
1									CPEType
1									PVC Number
1	0	0	0	0	X	X	X	X	Port Control
1	0	0	0	0	0	0	0	X	PVC State
2									VPI
2									VCI
2									PCR
2									SCR
1									MBS
1									CDVT

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 102 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPEType – Indicates a CPE type (technology).

Table 103 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** - Reserved

PVC NUMBER – This value is the logical number of the PVC we are commanding:

Table 104 – Supported PVCNumber Field Values

0x00 - LAN
0x01 - PVC #1
0x02 - PVC #2
0x03 - PVC #3
0x04 - PVC #4
0x05 - PVC #5
0x06 - PVC #6
0x07 - PVC #7
0x08 - PVC #8
0x09 - **0xFF** - Reserved

PORT CONTROL – This byte controls the enable/disable of various bridge/PVC parameters related to broadcast/multicast handling and FCS handling.

This register is a bit field, with the following bit meanings:

Table 105 – Port Control Register Bit Meanings

Bit 0 - Use this PVC for Broadcast frames only	‘0’ = No, ‘1’ = Yes
Bit 1 - Enable forwarding of all broadcast frames	‘0’ = No, ‘1’ = Yes
Bit 2 - Enable forwarding of multicast frames	‘0’ = No, ‘1’ = Yes
Bit 3 - Enable frame FCS preservation	‘0’ = No, ‘1’ = Yes

PVC STATE – This byte controls the connect/disconnect state of the PVC.

‘0’ = Disconnect PVC

‘1’ = Connect PVC

VPI – Indicates the VPI of this PVC. Valid range is 0-4095.

VCI – Indicates the VCI of this PVC. Valid range is 0-65535.

PCR – Indicates the Peak Cell Rate for this PVC in cells per second. Valid range is 0-30,000.

SCR – Indicates the Sustainable Cell Rate for this PVC in cells per second. Valid range is 0-30000.

MBS – Indicates the Maximum Burst Size for this PVC in cells at the PCR rate. Valid range is 0-255.

CDVT – Indicates the Cell Delay Variation Tolerance in cell times. Valid range is 0-255.

Table 106 – SetConfigPVC Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	1	1	1	0	1	0	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.20 **ReadConfigPVC**

Command ID = 0x34, Response ID = 0xB4 (code set 0xFC)

This command is used by the ATU-C to read the current configuration of an ATM PVC.

Table 107 – ReadConfigPVC Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	1	1	0	1	0	0	Opcode
2									CPE_IF
1									CPEType

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 108 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates a CPE type (technology).

Table 109 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** – Reserved

Table 110 – ReadConfigPVC Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	1	1	0	1	0	0	Opcode
2									CPE_IF
1									CPEType
1									PVC Number
1	0	0	0	0	X	X	X	X	Port Control
1	0	0	0	0	0	0	0	X	PVC State
2									VPI
2									VCI
2									PCR
2									SCR
1									MBS
1									CDVT

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 111 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates a CPE type (technology).

Table 112 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** – Reserved

PVC NUMBER – This value is the logical number of the PVC we are commanding.

Table 113 – Supported PVC Number Field Values

0x00 - LAN

0x01 - PVC #1

0x02 - PVC #2

0x03 - PVC #3

0x04 - PVC #4

0x05 - PVC #5

0x06 - PVC #6

0x07 - PVC #7

0x08 - PVC #8

0x09 - **0xFF** - Reserved

PORT CONTROL – This byte controls the enable/disable of various bridge/PVC parameters related to broadcast/multicast handling.

This register is a bit field, with the following bit meanings:

Table 114 – Port Control Register Bit Meanings

Bit 0 - Use this PVC for Broadcast frames only	'0' = No, '1' = Yes
Bit 1 - Enable forwarding of all broadcast frames	'0' = No, '1' = Yes
Bit 2 - Enable forwarding of multicast frames	'0' = No, '1' = Yes
Bit 3 - Enable frame FCS preservation	'0' = No, '1' = Yes

PVC STATE – This byte controls the connect/disconnect state of the PVC.

'0' = Disconnect PVC

'1' = Connect PVC

VPI – Indicates the VPI of this PVC. Valid range is 0-4095.

VCI – Indicates the VCI of this PVC. Valid range is 0-65535.

PCR – Indicates the Peak Cell Rate for this PVC in cells per second. Valid range is 0-30,000.

SCR – Indicates the Sustainable Cell Rate for this PVC in cells per second. Valid range is 0-30,000.

MBS – Indicates the Maximum Burst Size for this PVC in cells at the PCR rate. Valid range is 0-255.

CDVT – Indicates the Cell Delay Variation Tolerance in cell times. Valid range is 0-255.

G.3.2.2.21 **SetConfigMAC**

Command ID = 0x3B, Response ID = 0x9B (code set 0xFC)

This command allows the ATU-C to add or delete statically configured Ethernet MAC addresses to the ATU-R Bridge tables. Note that the command is a variable length command that can contain from one to 16 addresses.

Table 115 – SetConfigMAC Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	1	1	1	0	1	1	Opcode
2									CPE_IF
1									CPEType
6									MAC Address
1									Port
1									State
	--								*(Additional Addresses - up to 16 Max.)*
	--								
	--								
6									*MAC Address*
1									*Port*
1									*State*

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 116 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates a CPE type (technology).

Table 117 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (Enhanced)

0x08 - 10 Base T (Transparent routed)

0x1x ~ **0xFx** - Reserved

MAC ADDRESS – A fully defined 48-bit Ethernet MAC address.

PORT – This value is the logical number of the Bridge Port associated with this MAC address.

Table 118 – Supported Port Field Values

0x00 - LAN

0x01 - PVC #1

0x02 - PVC #2

0x03 - PVC #3

0x04 - PVC #4

0x05 - PVC #5

0x06 - PVC #6

0x07 - PVC #7

0x08 - PVC #8

0x09 - 0xFF - Reserved

STATE – This byte controls the add/remove state of the address.

Table 119 – Supported State Field Values

'0x00' = Do Nothing

'0x01' = Add address to table

'0x02' = Remove address from table

Table 120 – SetConfigMAC Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	1	0	1	1	Opcode

No response data is returned, other than the command opcode returned in the response, with the message response flag set.

G.3.2.2.22 **ReadMACtable**

Command ID = 0x35, Response ID = 0x95 (code set 0xFC)

This command allows the ATU-C to read out, or dump, the ATU-R Bridge MAC address table.

Table 121 – ReadMACTable Command

Command

# of Octets	7	6	5	4	3	2	1	0	
1	0	0	1	1	1	0	1	1	Opcode
2									CPE_IF
1									CPEType
1									Entry

Field Description:

CPE_IF – Indicates which interface of CPEType is the target of this command. This field is in bitmapped format, and only one bit in the field may be set at one time (one CPE selected). This bit field indicates support of up to four interfaces, however it is not anticipated that more than one or two of any interface type will be supported per ATU-R. If there is only one I/F of CPEType, this field should always be set to 0x0001.

Table 122 – Supported CPE_IF Field Values

0x0000 - No I/F selected

0x0001 - I/F 1

0x0002 - I/F 2

0x0004 - I/F 3

0x0008 - I/F 4

0x001x - Reserved

0x002x - Reserved

0x004x - Reserved

0x008x - Reserved

0x008x - Reserved

0x01xx - **0xFFxx** - Reserved

CPETYPE – Indicates a CPE type (technology).

Table 123 – Supported CPEType Field Values

0x00 - Field not used

0x01 - ATM 25.6 (Mbps)

0x02 - 10 Base T (Bridge)

0x04 - ATM 25.6 (enhanced)

0x08 - 10 Base T (transparent routed)

0x1x ~ **0xFx** - Reserved

ENTRY – Group table entry to read. Valid range is 0x00-0xFF. Each group entry returns up to 16 MAC addresses.

Table 124 – ReadMACTable Response

Response

# of Octets	7	6	5	4	3	2	1	0	
1	1	0	0	1	0	1	0	1	Opcode
1									Count
6									MAC Address
1									Port
1	0x00								Reserved
	--								*(Additional Addresses - up to 16 Max.)*
	--								
	--								
6									*MAC Address*
1									*Port*
1	*0x00*								*Reserved*

Field Description:

COUNT – Indicates the number of MAC Address, Port, Reserved grouped entries that are in this response. Valid range is 0x00 - 0x10.

MAC ADDRESS – Fully defined 48-bit Ethernet MAC address.

PORT – This value is the logical number of the Bridge Port associated with this MAC address.

Table 125 – Supported Port Field Values

0x00 - LAN

0x01 - Port #1

0x02 - Port #2

0x03 - Port #3

0x04 - Port #4

0x05 - Port #5

0x06 - Port #6

0x07 - Port #7

0x08 - Port #8

0x09 - **0xFF** - Reserved

RESERVED – This byte is always set to zero.