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G.992.1

Amendment 1

(03/2003)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

Asymmetric digital subscriber line (ADSL) transceivers

Amendment 1: Revised Annex C, new Annex I and new Appendix V

ITU-T Recommendation G.992.1 (1999) – Amendment 1

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ITU-T Recommendation G.992.1

Asymmetric digital subscriber line (ADSL) transceivers

Amendment 1

Revised Annex C, new Annex I and new Appendix V

Summary

This amendment provides the G.992.1 revision (revision of Annex C, addition of Annex I and addition of Appendix V). It includes the changes introduced by G.992.1 (1999) Corrigendum 2.

Revised Annex C covers specific requirements for an ADSL system operating in the same cable as ISDN as defined in Appendix III/G.961.

Annex I covers ADSL system with improved performance on short loops operating in the same cable as TCM-ISDN as defined in Appendix III/G.961.

Appendix V contains some example overlapped PSD Masks for use in a TCM-ISDN crosstalk environment.

Source

Amendment 1 to ITU-T Recommendation G.992.1 (1999) was approved by ITU-T Study Group 15 (2001-2004) under the ITU-T Recommendation A.8 procedure on 16 March 2003. This amendment includes ITU-T Rec. G.992.1 (1999) Amendment 1/Corrigendum 1 (12/2003).

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Annex C

Specific requirements for an ADSL system operating in the same cable as ISDN as defined in Appendix III of ITU-T Rec. G.961

C.1 Scope

This annex describes those specifications that are unique to an ADSL system coexisting in the same binder as TCM-ISDN as defined in Appendix III/G.961. The clauses in this annex provide supplementary and replacement material to the clauses in the main body. The nature of the material is parenthetically indicated in the clause heading. The modifications described in this annex allow a performance improvement from the ADSL system specified in Annex A in an environment coexisting with TCM-ISDN in the same cable. This annex also defines those parameters of this ADSL system that have been left undefined in the main body of this Recommendation. It is recommended that ADSL system implementing Annex C also implements Annex A.

This annex defines several optional operating modes or "profiles", negotiable through G.994.1, to allow limited independent control of:

– FEXT and NEXT period transmission in both upstream and downstream directions;
– overlapped and non-overlapped spectrum downstream during FEXT and NEXT periods.

These new optional profiles (defined in C.3.4 as Profiles 1 to 6) offer improved robustness and extended reach compared to the previously defined operating modes.

C.2 Terms and abbreviations

C.2.1 Definitions

This annex defines the following terms:

C.2.1.1 bitmap-F_C: ATU-R transmitter bitmap under TCM-ISDN FEXT noise generated at ATU-C.

C.2.1.2 bitmap-F_R: ATU-C transmitter bitmap under TCM-ISDN FEXT noise generated at ATU-R.

C.2.1.3 bitmap-N_C: ATU-R transmitter bitmap under TCM-ISDN NEXT noise generated at ATU-C.

C.2.1.4 bitmap-N_R: ATU-C transmitter bitmap under TCM-ISDN NEXT noise generated at ATU-R.

C.2.1.5 dual bitmap: The Dual Bitmap method has dual bit rates under the FEXT and NEXT noise from TCM-ISDN.

C.2.1.6 **FEXT bitmap**: Similar to the Dual Bitmap method, however, transmission only occurs during FEXT noise from TCM-ISDN.

C.2.1.7 **$FEXT_C$ duration**: TCM-ISDN FEXT duration at ATU-C estimated by the ATU-R.

C.2.1.8 **$FEXT_C$ symbol**: DMT symbol transmitted by ATU-R during TCM-ISDN FEXT.

C.2.1.9 **$FEXT_R$ duration**: TCM-ISDN FEXT duration at ATU-R estimated by the ATU-C.

C.2.1.10 **$FEXT_R$ symbol**: DMT symbol transmitted by ATU-C during TCM-ISDN FEXT.

C.2.1.11 **hyperframe**: 5-superframe structure which synchronized TTR.

C.2.1.12 **$NEXT_C$ duration**: TCM-ISDN NEXT duration at ATU-C estimated by the ATU-R.

C.2.1.13 **$NEXT_C$ symbol**: DMT symbol transmitted by ATU-R during TCM-ISDN NEXT.

C.2.1.14 **$NEXT_R$ duration**: TCM-ISDN NEXT duration at ATU-R estimated by the ATU-C.

C.2.1.15 **$NEXT_R$ symbol**: DMT symbol transmitted by ATU-C during TCM-ISDN NEXT.

C.2.1.16 **subframe**: Ten consecutive DMT symbols (except for sync symbols) according to TTR timing.

C.2.2 Abbreviations

This annex uses the following abbreviations:

N_{SWF} Sliding Window frame counter

TTR TCM-ISDN Timing Reference

TTR_C Timing reference used in ATU-C

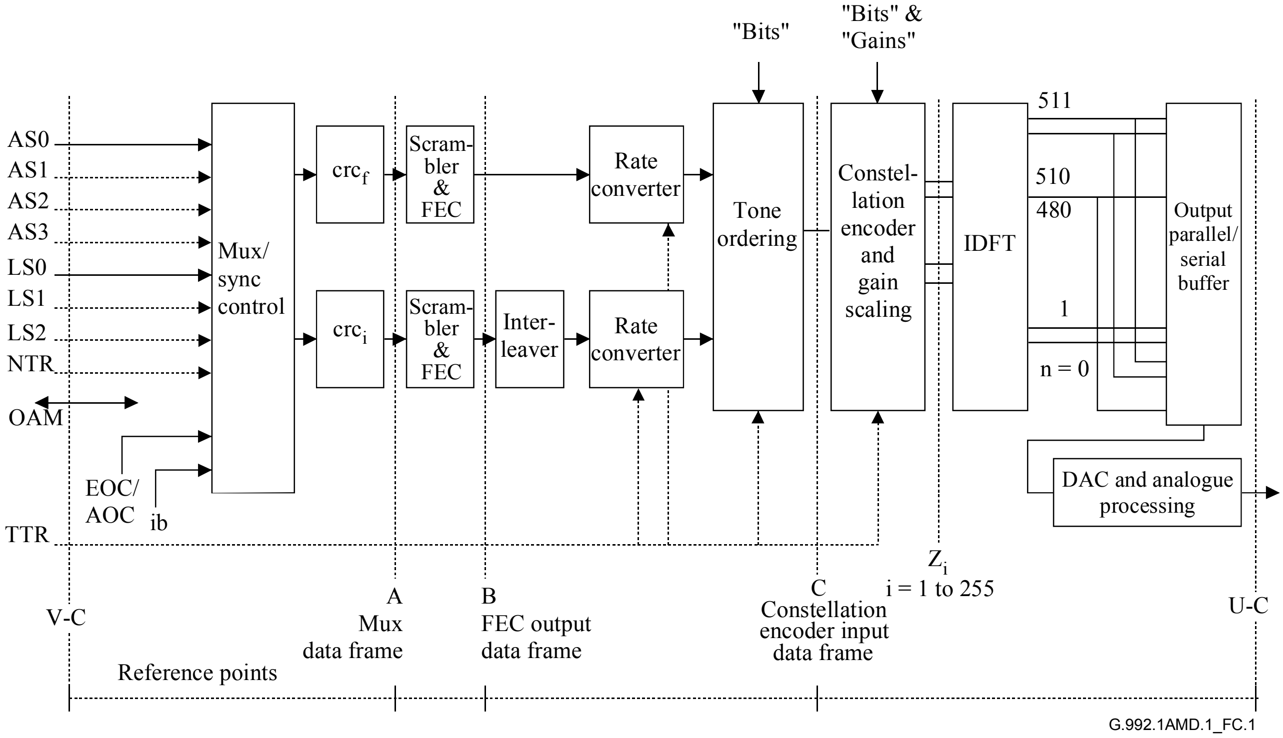
TTR_R Timing reference used in ATU-R

UI Unit Interval

C.3 Reference models

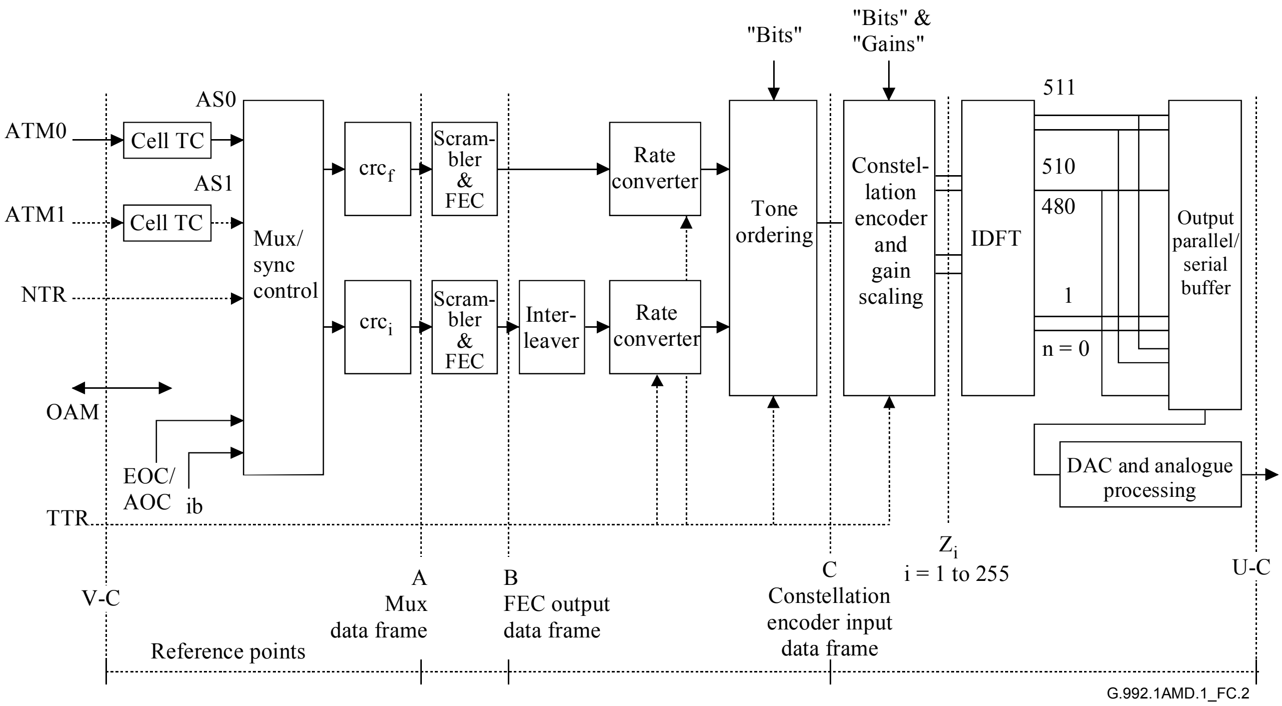
C.3.1 ATU-C transmitter reference model (replaces figures in 5.1)

See Figures C.1 and C.2.



NOTE – The TTR may be generated in ATU-C without being provided from the TCM-ISDN clock.

Figure C.1/G.992.1 – ATU-C transmitter reference model for STM transport

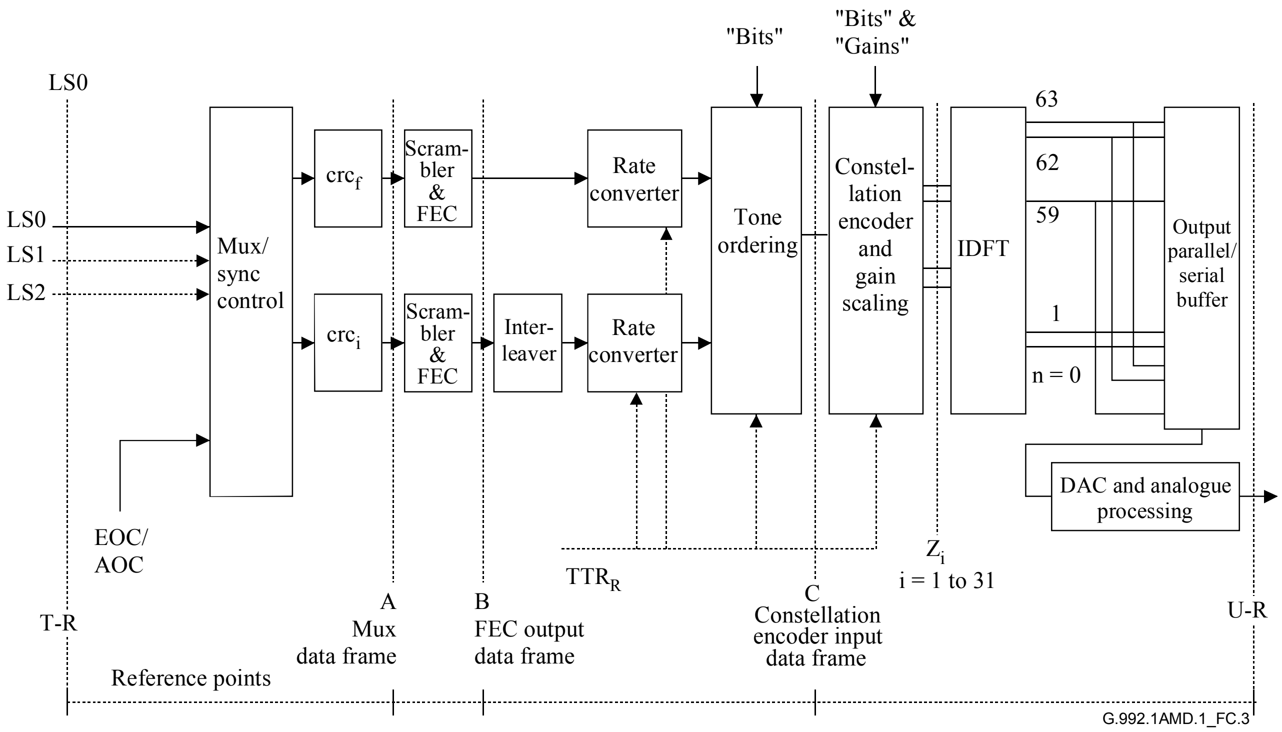


NOTE – The TTR may be generated in ATU-C without being provided from the TCM-ISDN clock.

Figure C.2/G.992.1 – ATU-C transmitter reference model for ATM transport

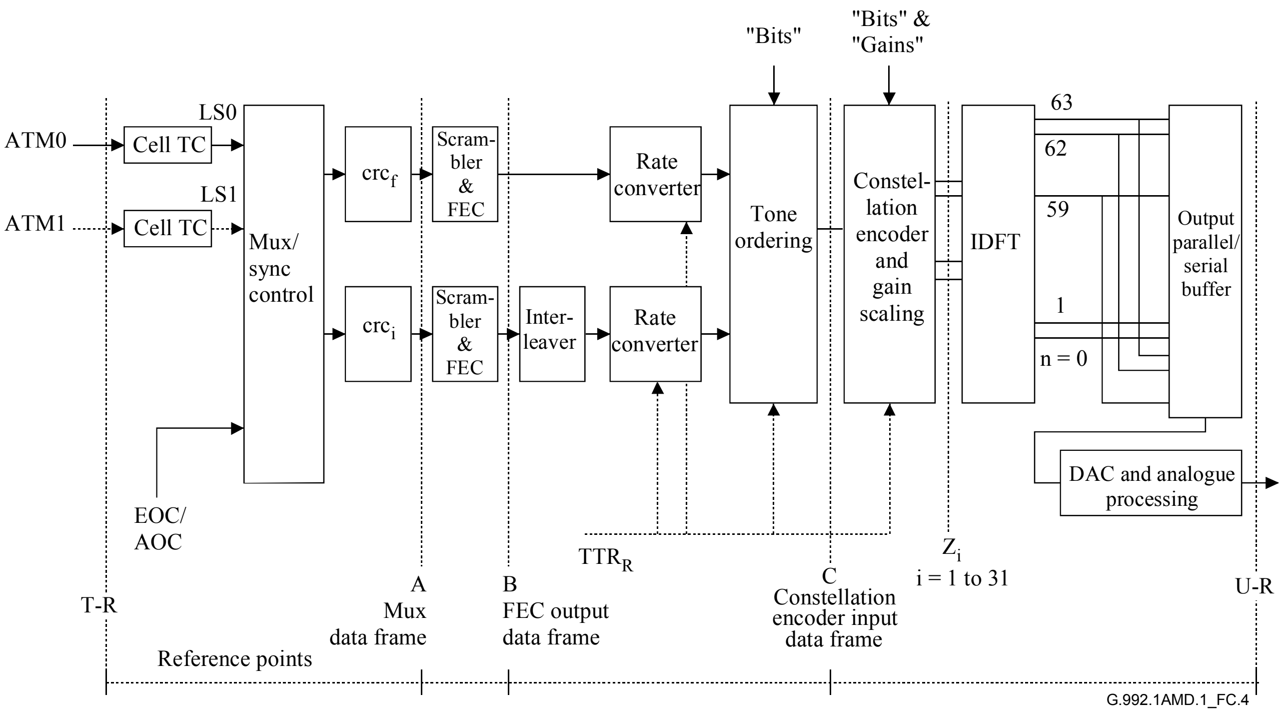
C.3.2 ATU-R transmitter reference model (replaces figures in 5.2)

See Figures C.3 and C.4.



NOTE – The TTR_R shall be generated in ATU-R from the received TTR_C signal, and it is locked to 690 periods of upstream sampling clock (276 kHz).

Figure C.3/G.992.1 – ATU-R transmitter reference model for STM transport



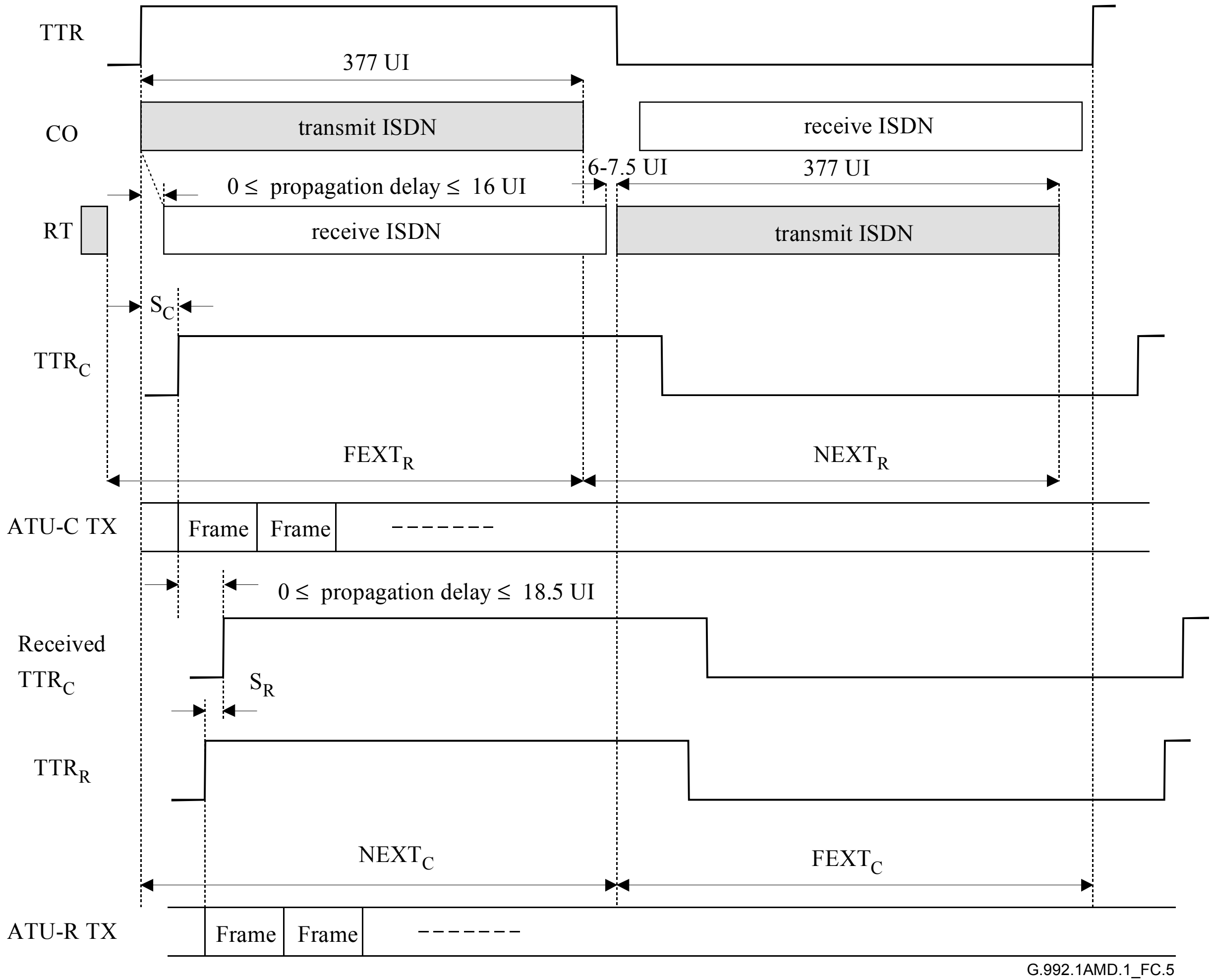
NOTE – The TTR_R shall be generated in ATU-R from the received TTR_C signal, and it is locked to 690 periods of upstream sampling clock (276 kHz).

Figure C.4/G.992.1 – ATU-R transmitter reference model for ATM transport

C.3.3 ATU-C/R transmitter timing model (replacement for 5.3)

C.3.3.1 TCM-ISDN crosstalk timing model (new)

Figure C.5 shows the timing chart of the crosstalk from TCM-ISDN.



1 UI = 3.125 µs

$FEXT_R$ and **$NEXT_R$** are estimated by ATU-C

$FEXT_C$ and **$NEXT_C$** are estimated by ATU-R

TTR	TCM-ISDN timing reference
TTR_C	Timing reference used in ATU-C
Received TTR_C	Received TTR_C at ATU-R
TTR_R	Timing reference used in ATU-R
S_C	55 × 0.9058 µs: Offset from TTR to TTR_C
S_R	–42 × 0.9058 µs: Offset from received TTR_C to TTR_R

Figure C.5/G.992.1 – Timing chart of the TCM-ISDN crosstalk

The data stream of TCM-ISDN is transmitted in TTR period. CO transmits the stream in the first half of the TTR period and RT transmits in the second half of the TTR period. ATU-C receives NEXT noise from the ISDN in the first half of the TTR period and FEXT noise from the ISDN in the second half of the TCM-ISDN period. On the other hand, ATU-R receives FEXT noise from the ISDN in the first half of the TTR period and NEXT noise from the ISDN in the second half of the TTR period.

As defined in C.7.6.2 and C.7.8.3, the ATU-C shall estimate the $FEXT_R$ and $NEXT_R$ duration at ATU-R, and the ATU-R shall estimate $FEXT_C$ and $NEXT_C$ duration at ATU-C taking propagation delay on the subscriber line into consideration.

The ATU-C shall transmit any symbols by synchronizing with the TTR_C. The ATU-R shall transmit any symbols synchronizing with the TTR_R generated from received TTR_C.

C.3.3.2 Sliding window (new)

Figure C.6 shows the timing chart of the transmission for the Annex C downstream at ATU-C.

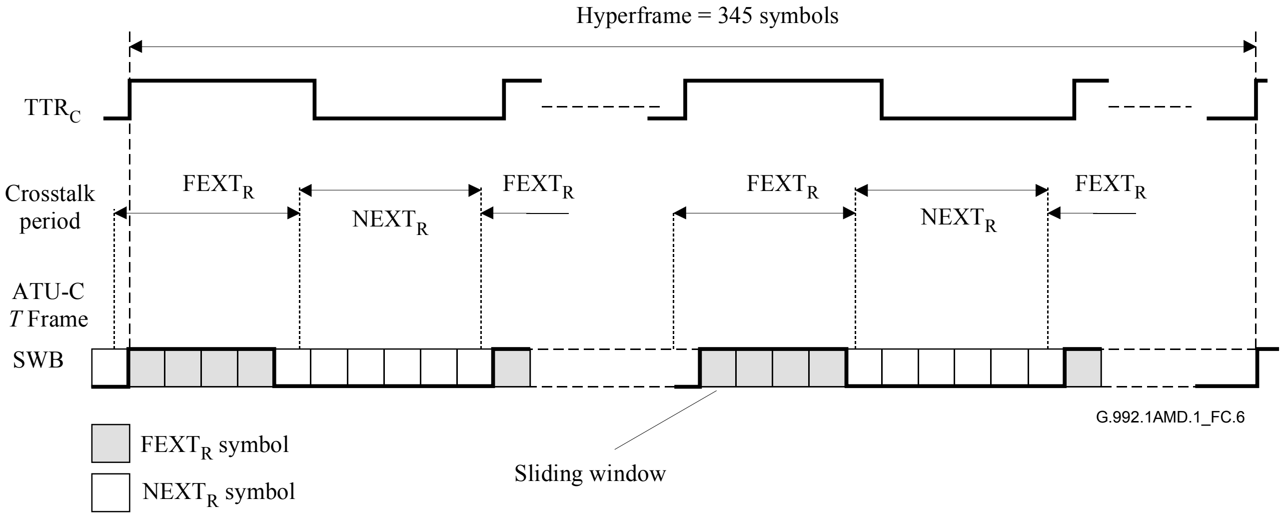


Figure C.6/G.992.1 – Sliding window for downstream symbols

The sliding window defines the transmission symbols under the crosstalk noise environment synchronized to the period of TTR. The $FEXT_{C/R}$ symbol represents the symbol completely inside the $FEXT_{C/R}$ duration. The $NEXT_{C/R}$ symbol represents any symbol containing the $NEXT_{C/R}$ duration. Thus, there are more $NEXT_{C/R}$ symbols than $FEXT_{C/R}$ symbols.

The ATU-C decides which transmission symbol is $FEXT_R$ or $NEXT_R$ symbol according to the sliding window and transmits it with the corresponding bit table. Similarly, the ATU-R decides the transmission symbol is a $FEXT_C$ or $NEXT_C$ and transmits it with the corresponding bit table. Although the phase of the sliding window is asynchronous with $TTR_{C/R}$, the pattern is fixed to the 345 frames of the hyperframe.

C.3.3.3 ATU-C symbol synchronization to TTR (new)

345 symbols are 34 cycles with cyclic prefix of TTR_C (or 32 cycles of TTR_C without cyclic prefix). This implies a PLL lock at the ATU-R.

C.3.3.4 Dual Bitmap switching (new)

The ATU-C transmits $FEXT_R$ symbols using Bitmap-F_R (in $FEXT_R$ duration), and transmits $NEXT_R$ symbols using Bitmap-N_R (in $NEXT_R$ duration) according to the result of initialization. The ATU-R transmits $FEXT_C$ symbols using Bitmap-F_C (in $FEXT_C$ duration), and transmits $NEXT_C$ symbols using Bitmap-N_C (in $NEXT_C$ duration) in the same manner.

The ATU-C shall have the capability to disable Bitmap-N_C and Bitmap-N_R (see C.4.5 and C.5.3). As an option, an ATU-C may have the ability to enable or disable Bitmap-N_C independently of Bitmap-N_R. This is controlled by way of the profiles negotiated through G.994.1.

C.3.3.5 Loop timing at ATU-R (new)

The phase relation between received symbol and transmitted symbol of ATU-R at the reference point U-R shall meet the phase tolerances as shown in Figure C.7.

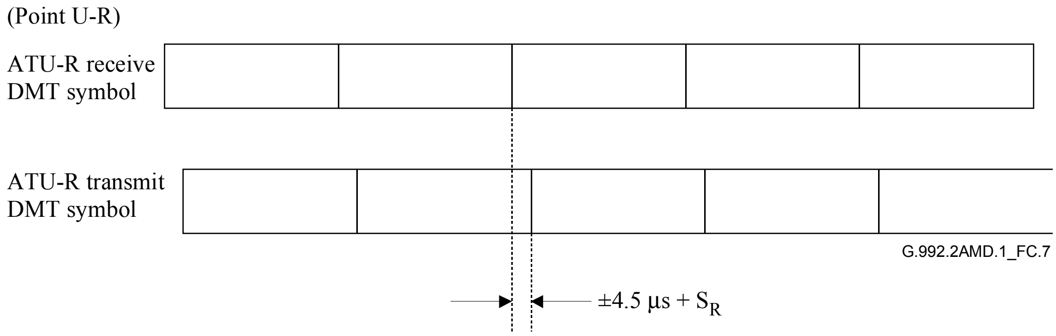


Figure C.7/G.992.1 – Loop timing for ATU-R

C.3.4 Operating modes (new)

The following profiles are defined to support independent control of FEXT and NEXT bitmaps in the upstream and downstream directions, as well as independent control of the downstream spectrum for each downstream bitmap:

Profile 1

For Profile 1, upstream transmission only uses Bitmap-F_C, and downstream transmission only uses Bitmap-F_R with non-overlapped spectrum.

Profile 2

For Profile 2, upstream transmission uses both Bitmap-F_C and Bitmap-N_C, and downstream transmission uses both Bitmap-F_R and Bitmap-N_R. Non-overlapped spectrum is used with both downstream bitmaps.

Profile 3

For Profile 3, upstream transmission only uses Bitmap-F_C, and downstream transmission only uses Bitmap-F_R with overlapped spectrum. An example of a downstream PSD mask for this operating mode is shown in Figure V.3 and described in Table V.3.

Profile 4

For Profile 4, upstream transmission uses both Bitmap-F_C and Bitmap-N_C, and downstream transmission uses both Bitmap-F_R and Bitmap-N_R. Overlapped spectrum is used with both downstream bitmaps.

Profile 5

For Profile 5, upstream transmission only uses Bitmap-F_C, and downstream transmission uses both Bitmap-F_R and Bitmap-N_R. Non-overlapped spectrum is used with Bitmap-N_R, and overlapped spectrum is used with Bitmap-F_R. An example of a downstream PSD mask for use with Bitmap-N_R is shown in Figure V.1 and described in Table V.1. An example of a downstream PSD mask for use with Bitmap-F_R is shown in Figure V.2 and described in Table V.2.

Profile 6

For Profile 6, upstream transmission uses both Bitmap-F_C and Bitmap-N_C, and downstream transmission uses both Bitmap-F_R and Bitmap-N_R. Non-overlapped spectrum is used with Bitmap-N_R, and overlapped spectrum is used with Bitmap-F_R. An example of a downstream

PSD mask for use with Bitmap-N_R is shown in Figure V.1 and described in Table V.1. An example of a downstream PSD mask for use with Bitmap-F_R is shown in Figure V.2 and described in Table V.2.

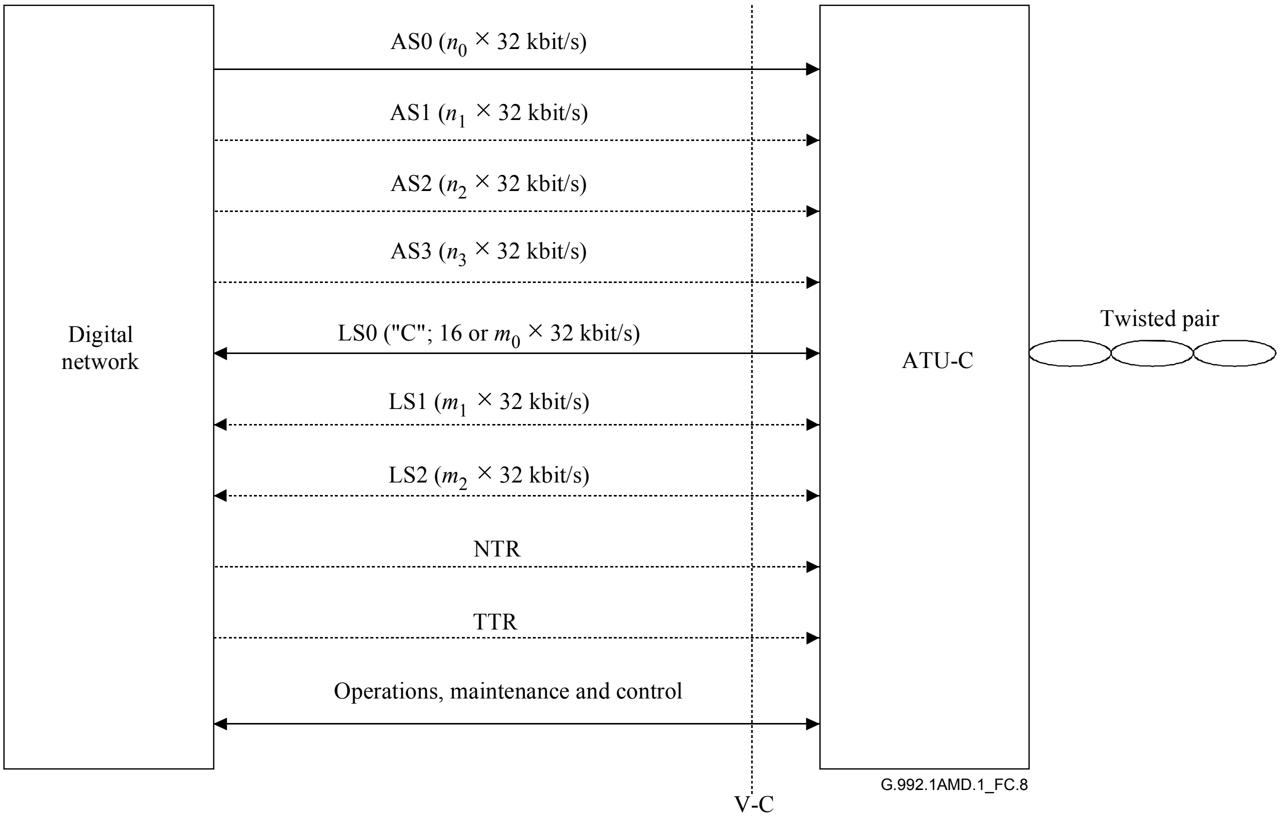
Table 11.5/G.994.1 contains the code points to support these profiles.

C.4 ATU-C functional characteristics (pertains to clause 7)

C.4.1 STM transmission protocols specific functionality (pertains to 7.1)

C.4.1.1 ATU-C input and output V interface for STM transport (replaces figure in 7.1.1)

See Figure C.8.



NOTE 1 – Optional bearer channels (both duplex and simplex) and features are shown with dotted lines.
NOTE 2 – TTR may be generated in the ATU-C without being provided from the V-C reference point.

Figure C.8/G.992.1 – ATU-C functional interfaces for STM transport at the V-C reference point

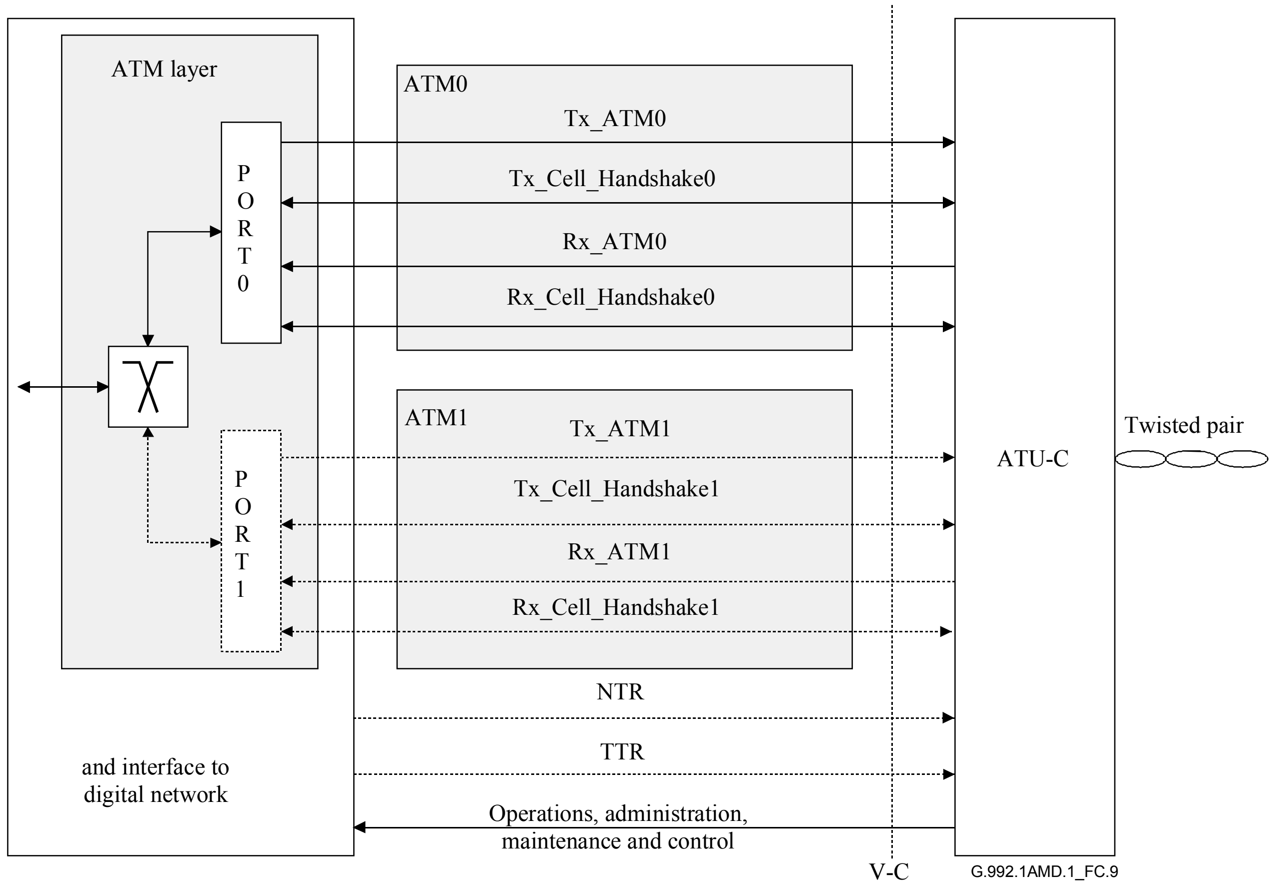
C.4.1.2 Payload transfer delay (supplements 7.1.4)

Since Annex C uses a rate converter, the maximum payload transfer delay is longer than specified values in 7.1.4. The additional one-way transfer delay due to the rate converters shall be less than 1.7 ms for fast data and 13 ms for interleaved data.

C.4.2 ATM transmission protocols specific functionalities (pertains to 7.2)

C.4.2.1 ATU-C input and output V interface for ATM transport (replaces figure in 7.2.1)

See Figure C.9.



NOTE – TTR can be generated in the ATU-C without being provided from the V-C reference point.

Figure C.9/G.992.1 – ATU-C functional interfaces to the ATM layer at the V-C reference point

C.4.2.2 Payload transfer delay (supplements 7.2.2)

Since Annex C uses a rate converter, the maximum payload transfer delay is longer than specified values in 7.2.2. The additional one-way transfer delay due to the rate converters shall be less than 1.7 ms for fast data and 13 ms for interleaved data.

C.4.3 Framing (pertains to 7.4)

C.4.3.1 Superframe structure (supplements 7.4.1.1)

Since the rate converter reorders the user data and overhead bit-level data to create hyperframes, the input data frames to the constellation encoder are different than those defined in 7.4.1.1.

C.4.3.2 Hyperframe structure (replaces 7.4.1.3)

Annex C uses the hyperframe structure shown in Figure C.10. Figure C.10 shows the phase relationship between the TTR_C and the hyperframe at the point U-C. Each hyperframe is composed of 5 superframes, which are numbered from 0 to 4. In order to indicate the boundary of the hyperframe, the inverse synch symbol is used for the 4th superframe (SPF#3), which is generated from a tone-by-tone 180-degree phase reversal of the synchronization symbol (see C.4.7.1) except for the pilot tone.

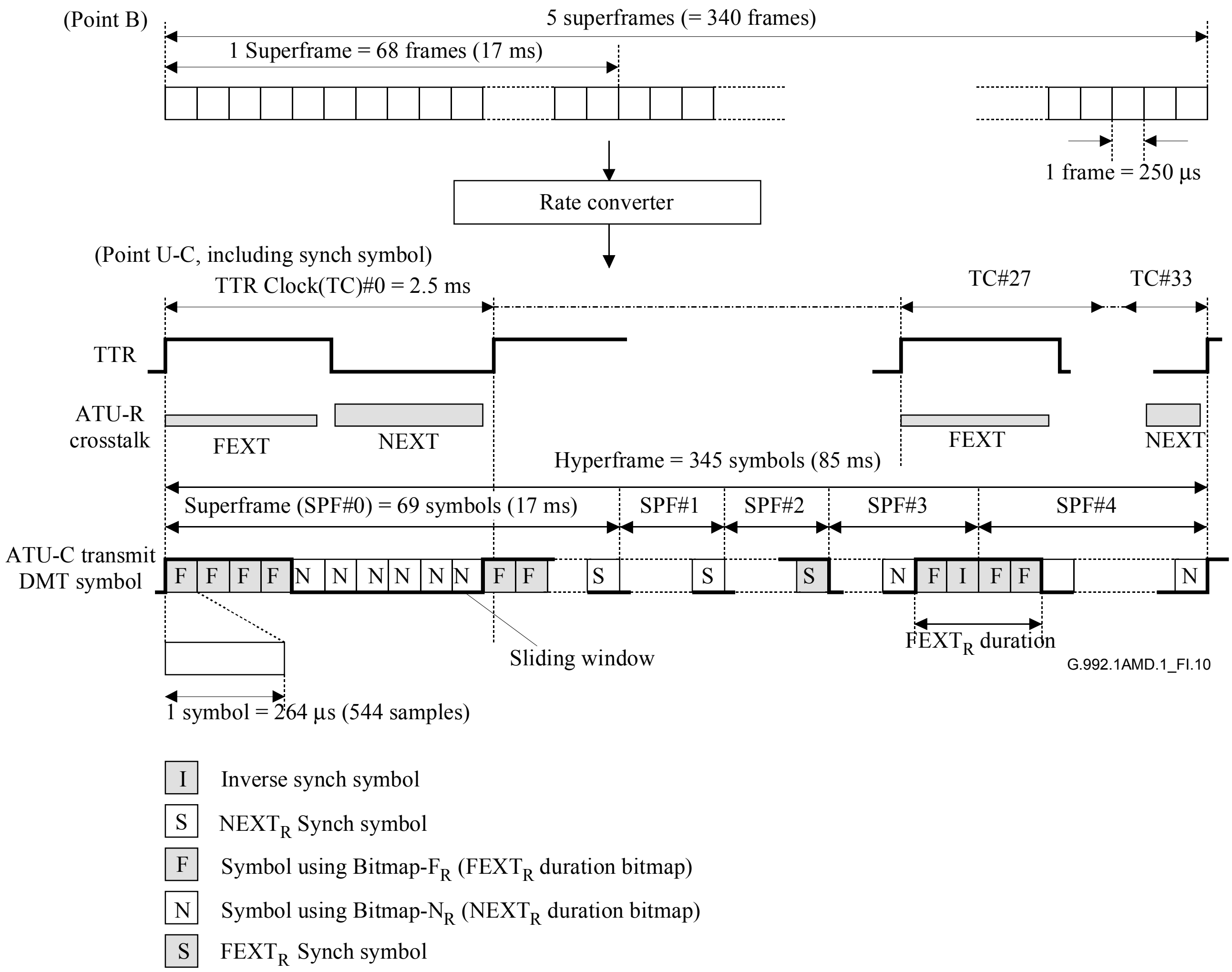


Figure C.10/G.992.1 – Hyperframe structure for downstream

The bit-level data stream from the rate-converter is extracted according to the size of Bitmap-F_R and Bitmap-N_R using the sliding window (see C.3.3.2).

In order to make the bit rate to be a multiple of 32 kbit/s, the dummy bits are inserted at the end of hyperframe by the rate converter (see C.4.4.2). The hyperframe is composed of 345 DMT symbols, numbered from 0 to 344. Each symbol is assigned as $FEXT_R$ or $NEXT_R$ symbol in a $FEXT_R$ or $NEXT_R$ duration (see C.2), and the following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to at ATU-C transmitter (see Figure C.11).

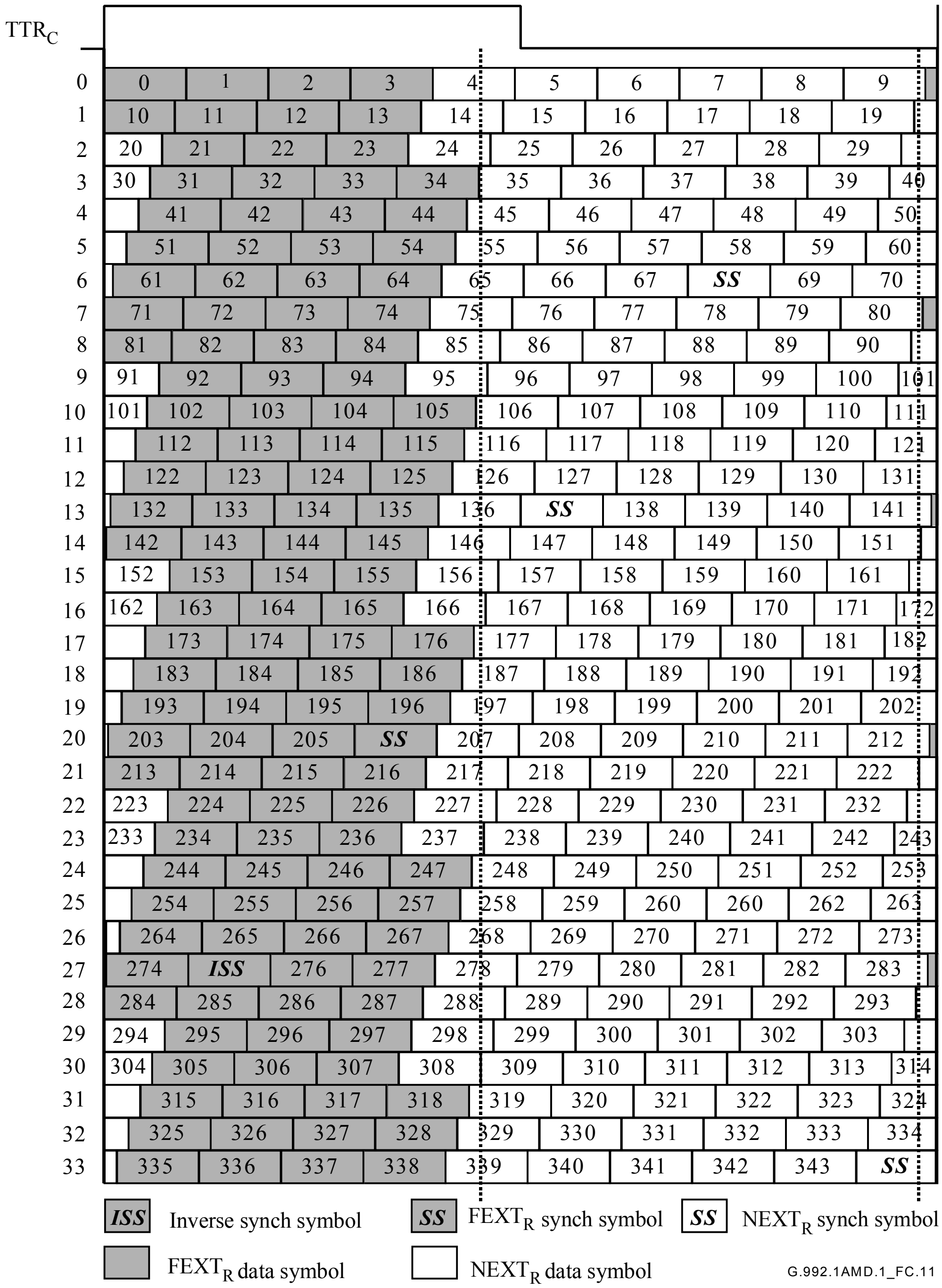


Figure C.11/G.992.1 – Symbol pattern in a hyperframe with cyclic prefix – Downstream

For $N_{dmt} = 0, 1, ..., 344$

$S = 272 \times N_{dmt} \bmod 2760$

if $\{ (S + 271 < a) \text{ or } (S > a + b) \}$ then $FEXT_R$ symbol

else then $NEXT_R$ symbol

where a = 1243, b = 1461.

Thus, 128 DMT symbols are allocated in the $FEXT_R$ duration, and 217 DMT symbols are allocated in the $NEXT_R$ duration. The symbols are composed of:

$FEXT_R$ symbol:

Number of symbol using Bitmap-F_R = 126

Number of synch symbol = 1

Number of inverse synch symbol = 1

$NEXT_R$ symbol:

Number of symbol using Bitmap-N_R = 214

Number of synch symbol = 3

For modems not using any of the profiles defined in C.3.4, and modems using Profile 1, during FEXT Bitmap mode, the ATU-C shall transmit only the pilot tone in $NEXT_R$ symbols. For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The remaining Profiles, i.e., Profiles 2, 4, 5 and 6 use the dual bitmap technique.

C.4.3.3 Subframe structure (replaces 7.4.1.4)

A subframe is 10 consecutive DMT symbols (except for synch symbols) as shown in Table C.1. The 34 subframes form a hyperframe.

Table C.1/G.992.1 – Subframe (downstream)

Subframe No.	DMT symbol No.	Note
0	0-9	
1	10-19	
2	20-29	
3	30-39	
4	40-49	
5	50-59	
6	60-70	#68 is synch symbol
7	71-80	
8	81-90	
9	91-100	
10	101-110	
11	111-120	
12	121-130	
13	131-141	#137 is synch symbol
14	142-151	
15	152-161	
16	162-171	
17	172-181	
18	182-191	
19	192-201	
20	202-212	#206 is synch symbol
21	213-222	

Table C.1/G.992.1 – Subframe (downstream)

Subframe No.	DMT symbol No.	Note
22	223-232	
23	233-242	
24	243-252	
25	253-262	
26	263-272	
27	273-283	#275 is inverse synch symbol
28	284-293	
29	294-303	
30	304-313	
31	314-323	
32	324-333	
33	334-344	#344 is synch symbol

C.4.4 Dual bitmapping and rate conversion (replaces 7.15)

The functions of the rate converter (see C.4.4.2), tone ordering (see C.4.6), constellation encoding, and gain scaling shall use one of two bitmaps stored in the ATU. This method is called the Dual Bitmap.

C.4.4.1 Dual Bitmap (new)

The Dual Bitmap method has individual bit rates under the FEXT and NEXT noise, and this needs an additional bit and gain table, $\{b_i, g_i\}$, and ordered bit table, b'_i, for the tone ordering. The dual bitmaps are switched synchronized with the sliding window pattern of NEXT/FEXT symbols. The number of bits and the relative gains to be used for every tone are calculated in the bit loading algorithm during the initialization sequence, and transmitted in R-B&G.

C.4.4.2 Rate converter (new)

The rate converter buffering changes the data frame boundaries between the reference points B and C according to Bitmap-F_R, Bitmap-N_R and the sliding window. Two independent rate converters are prepared for fast data and interleaved data. The amount of fast and interleaved data in Bitmap-F_R and Bitmap-N_R shall be calculated with the following formulae and illustrated in Figure C.12:

If $t_{Rf} \leq n_{R\max}$:

$$n_{Rf} = t_{Rf}$$

$$n_{Ri} = n_R - n_{Rf}$$

$$f_{Rf} = t_{Rf}$$

$$f_{Ri} = f_R - f_{Rf}$$

If $t_{Rf} > n_{R\max}$:

$$n_{Rf} = n_{R\max}$$

$$n_{Ri} = 0$$

$$f_{Rf} = \begin{cases} f_{Rf4} = \left\lceil \dfrac{t_{Rf} \times 10 - n_{Rf} \times 6}{4} \right\rceil \\ f_{Rf3} = \left\lceil \dfrac{t_{Rf} \times 10 - n_{Rf} \times 7}{3} \right\rceil \end{cases}$$

$$f_{Ri} = \begin{cases} f_{Ri4} = f_R = f_{Rf4} \\ f_{Ri3} = f_R - f_{Rf3} \end{cases}$$

where:

t_{Rf} is the number of allocated bits in one frame for fast bytes at the reference point B;

t_{Ri} is the number of allocated bits for interleaved bytes at the reference point B;

f_{Rf} and n_{Rf} are the numbers of fast bits in Bitmap-F_R and Bitmap-N_R, respectively;

f_{Rf3} is the number of fast bits in Bitmap-F_R if the subframe (see C.4.3.3) contains 3 Bitmap-F_R except for synch symbols;

f_{Rf4} is the number of fast bits in Bitmap-F_R if the subframe contains 4 Bitmap-F_R except for synch symbols;

f_{Ri} and n_{Ri} are the numbers of interleaved bits in Bitmap-F_R and Bitmap-N_R, respectively;

n_R is the number of total bits in Bitmap-N_R, which is specified in the B&G tables.

During FEXT Bitmap mode, n_{Rf} and n_{Ri} are zero.

To convert the bit rate to be a multiple of 32 kbit/s, the dummy bits for fast data are inserted to the tail of each subframe, and the dummy bits for interleaved data are inserted to the end of the Hyperframe. The number of the dummy bits shall be as follows:

If $t_{Rf} \leq n_{R\max}$:

$$dummy_{Rf} = 0$$

$$dummy_{Ri} = (f_{Ri} \times 126 + n_{Ri} \times 214) - t_{Ri} \times 340$$

If $t_{Rf} > n_{R\max}$:

$$dummy_{Rf4} = (f_{Rf} \times 4 + n_{Rf} \times 6) - t_{Rf} \times 10$$

$$dummy_{Rf3} = (f_{Rf} \times 3 + n_{Rf} \times 7) - t_{Rf} \times 10$$

$$dummy_{Ri} = (f_{Ri4} \times 96 + f_{Ri3} \times 30) - t_{Ri} \times 340$$

If the fast data buffer uses single latency only, additional dummy bits are inserted at the tail of each FEXT symbol in the 4 Bitmap-F_R constructed subframe. The number of additional dummy bits inserted at the tail of each FEXT symbol shall be as follows:

$$dummy_{SRf} = f_{Rf3} - f_{Rf4}$$

The receiver shall determine Bitmap-F_R and Bitmap-N_R so that $dummy_{Ri}$ is less than 126, $dummy_{Rf4}$ is less than 4 and $dummy_{Rf3}$ is less than 3 in the initialization sequence. At the receiver, the inserted dummy bits shall be removed.

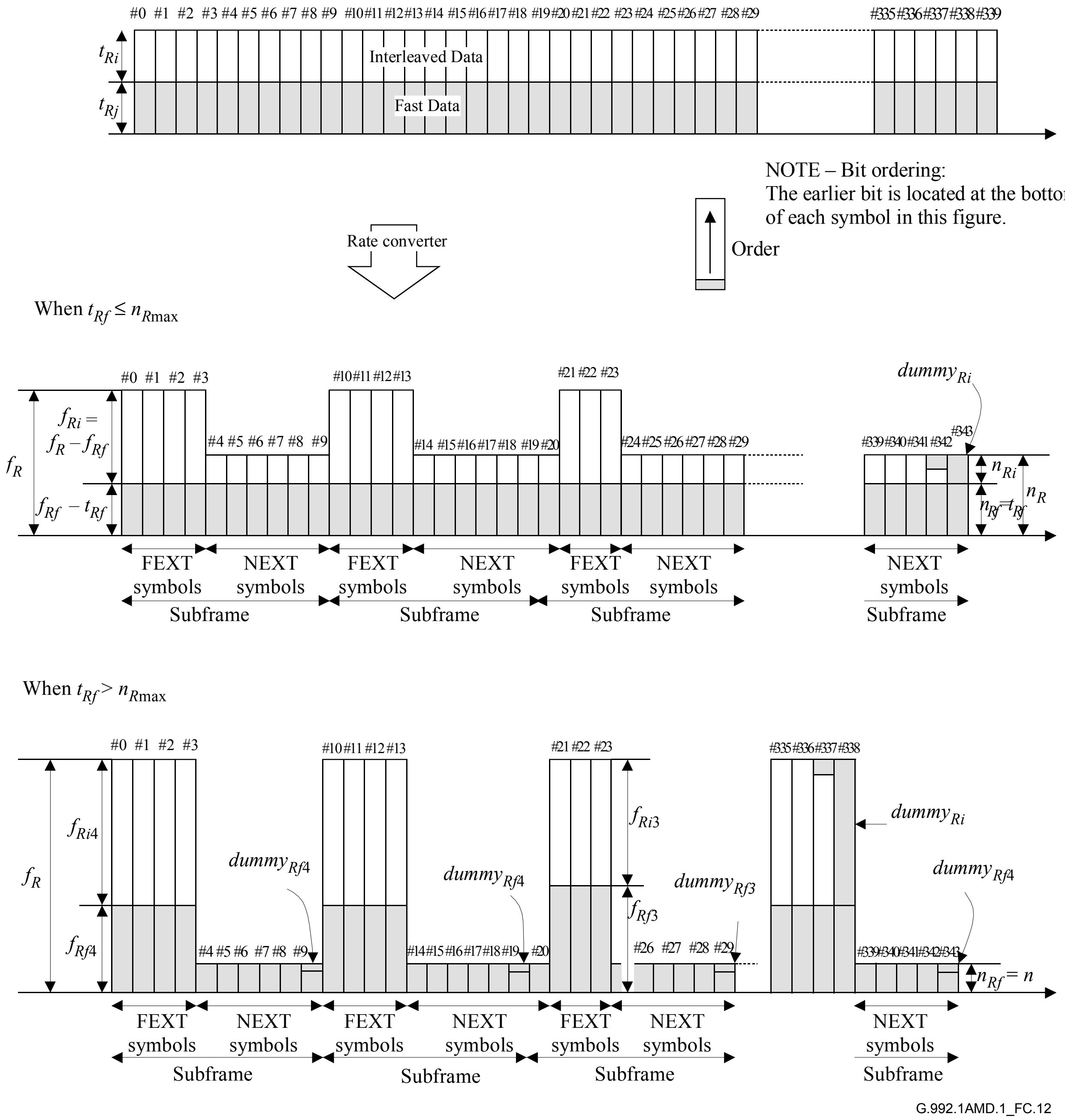


Figure C.12/G.992.1 – Bit distribution for rate converter under dual latency and Dual Bitmap mode

C.4.5 FEXT bitmapping (replaces 7.16)

The FEXT bitmapping mode uses the Dual Bitmapping technique (C.4.4) to transmit data only during FEXT. As an option, modems may have the ability to enable or disable Bitmap-N_R independently of Bitmap-N_C in order to control the FEXT bitmapping mode upstream and downstream independently. For modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall transmit only the pilot tone during the $NEXT_R$ symbol. For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The ATU-R disables Bitmap-N_C and shall not transmit any signal during the $NEXT_C$ symbol (see Figures C.10 and C.13).

For modems not using any of the profiles defined in C.3.4, the Dual versus FEXT bitmapping mode is selected during G.994.1 using bit "DBM" (see 10.2 and 10.3). For modems using any of the profiles defined in C.3.4, the bitmapping mode is selected during G.994.1.

C.4.6 Tone ordering (replacement for 7.7)

A DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analogue converter. The error signal caused by clipping can be considered as an additive negative impulse for the time sample that was clipped. The clipping error power is almost equally distributed across all tones in the symbol in which clipping occurs. Clipping is therefore most likely to cause errors on those tones that, in anticipation of a higher received SNR, have been assigned the largest number of bits (and therefore have the densest constellations). These occasional errors can be reliably corrected by the FEC coding if the tones with the largest number of bits have been assigned to the interleave buffer.

The numbers of bits and the relative gains in two bitmaps to be used for every tone are calculated in ATU-R receiver, and sent back to ATU-C according to a defined protocol (see 10.9.14). The pairs of numbers are typically stored, in ascending order of frequency or tone numbers i, in bit and gain tables for Bitmap-F_R and Bitmap-N_R.

For Bitmap-F_R, the "tone-ordered" encoding shall first assign f_{Rf} bits from the rate converter (see C.4.4.2) to the tones with the smallest number of bits assigned to them, and the remaining f_{Ri} bits to the remaining tones. For Bitmap-N_R, it shall first assign n_{Rf} bits from the rate converter to the tones with the smallest number of bits assigned to them, and the remaining n_{Ri} bits to the remaining tones.

All tones shall be encoded with the number of bits assigned to them; one tone in each bitmap may therefore have a mixture of bits from the fast and interleaved buffers.

The ordered bit tables b'_{iF} and b'_{iN} shall be based on the original bit tables b_{iF} and b_{iN} as follows:

For $k = 0$ to 15 {

From the bit table, find the set of all i with the number of bits per tone $b_i = k$

Assign b_i to the ordered bit allocation table in ascending order of i

}

Two ordered bit tables for Bitmap-F_R and Bitmap-N_R shall be prepared. A complementary de-ordering procedure should be performed in ATU-R receiver. It is not necessary, however, to send the results of the ordering process to the receiver because the bit tables F_R and N_R were originally generated in ATU-R, and therefore those tables have all the information necessary to perform the de-ordering.

C.4.7 Modulation (pertains to 7.11)

C.4.7.1 Inverse synchronization symbol (replaces 7.11.4)

Except for the pilot tone, inverse synchronization symbol shall be generated from a tone-by-tone 180 degree phase reversal of synchronization symbol (i.e., + maps to –, and – maps to +, for each of the 4-QAM signal constellation).

C.4.7.2 Synchronization symbol (supplements 7.11.3)

Bits d_{2i+1} and d_{2i+2}, which modulate the pilot carrier that has tone index i, shall be overwritten by {0,0}, generating the (+,+) constellation point.

C.4.8 ATU-C downstream transmit spectral mask (replaces 7.14)

The downstream spectral mask(s) of Annex C shall fall within the masks defined in Annex A. For modems not using any of the profiles defined in C.3.4, when C-MSG1 bit 16 is 0, the PSD mask specified in A.1.3 shall be used. When C-MSG1 bit 16 is 1, the PSD mask specified in A.1.2 shall be used.

For modems complying with Profiles 1 and 2, C-MSG1 bit 16 shall be set to 0. For modems complying with Profiles 3 to 6, C-MSG1 bit 16 shall be set to 1.

The ATU-C may use different PSD masks during $FEXT_R$ symbols and $NEXT_R$ symbols. These masks may differ from, but shall fall within, the masks defined in Annex A. Example PSD masks can be found in Appendix V.

C.5 ATU-R functional characteristics (pertains to clause 8)

C.5.1 Framing (pertains to 8.4)

C.5.1.1 Superframe structure (replaces 8.4.1.1)

The superframe structure of ATU-R transmitter is identical to that of ATU-C transmitter, as specified in C.4.3.1.

C.5.1.2 Hyperframe structure (replaces 8.4.1.3)

The hyperframe structure of ATU-R transmitter is functionally similar to that of ATU-C transmitter, except that the inverse synch symbol is used in the 1st superframe (SPF#0) (see Figure C.13). The hyperframe is composed of 345 DMT symbols, numbered from 0 to 344. Each symbol is under $FEXT_C$ or $NEXT_C$ duration (see C.5.3), and the following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to at ATU-R transmitter (see Figure C.14).

For $N_{dmt} = 0, 1, \ldots, 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { ($S > a$) and ($S + 271 < a + b$) } then $FEXT_C$ symbol

else then $NEXT_C$ symbol

where a = 1315, b = 1293.

128 DMT symbols are allocated in the $FEXT_C$ duration, and 217 DMT symbols are allocated in the $NEXT_C$ duration. The symbols are composed of:

$FEXT_C$ symbol:

- Number of symbol using Bitmap-F_C = 126
- Number of synch symbol = 1
- Number of inverse synch symbol = 1

$NEXT_C$ symbol:

- Number of symbol using Bitmap-N_C = 214
- Number of synch symbol = 3

During FEXT bitmapping mode, the ATU-R shall not transmit any signal.

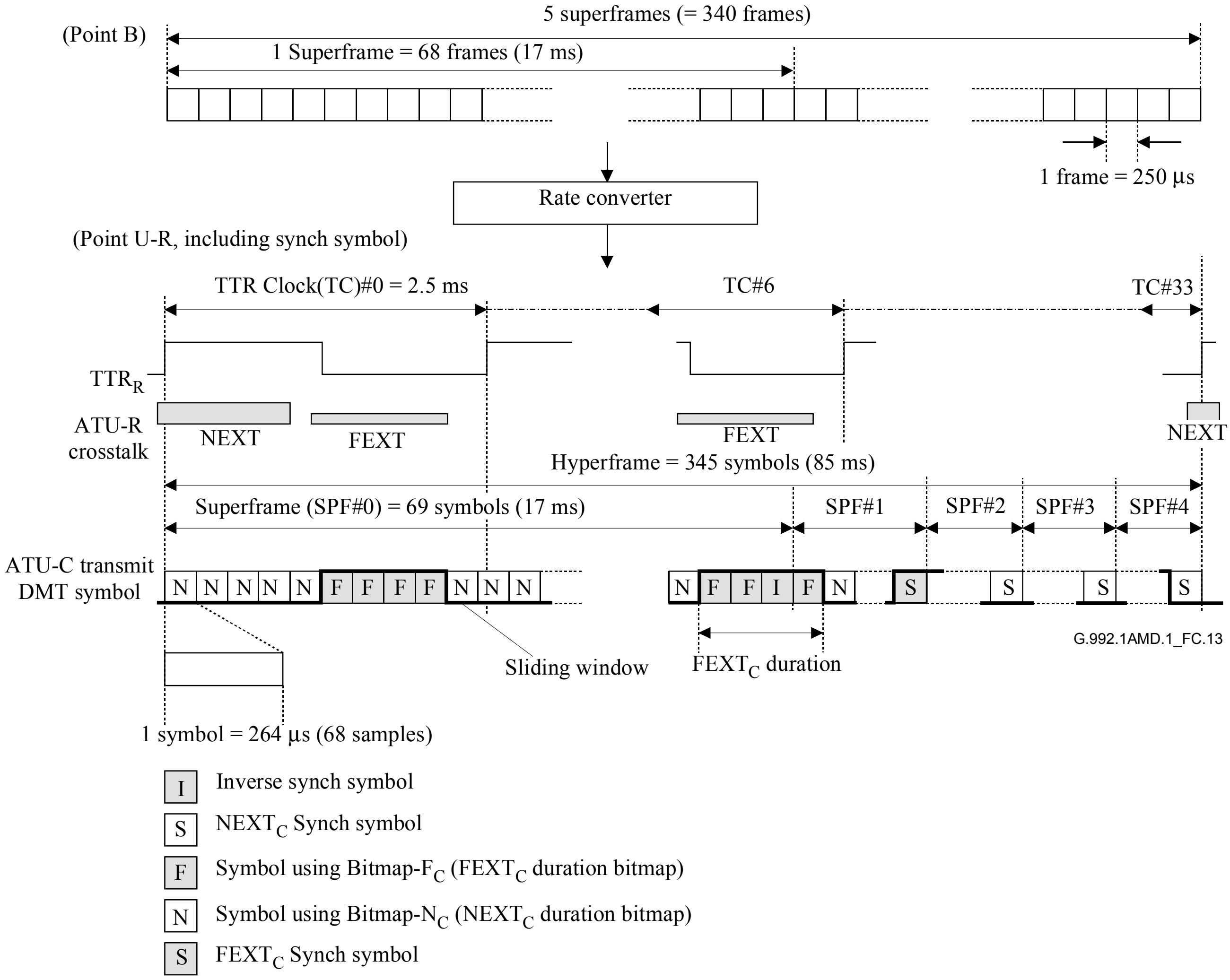


Figure C.13/G.992.1 – Hyperframe structure for upstream

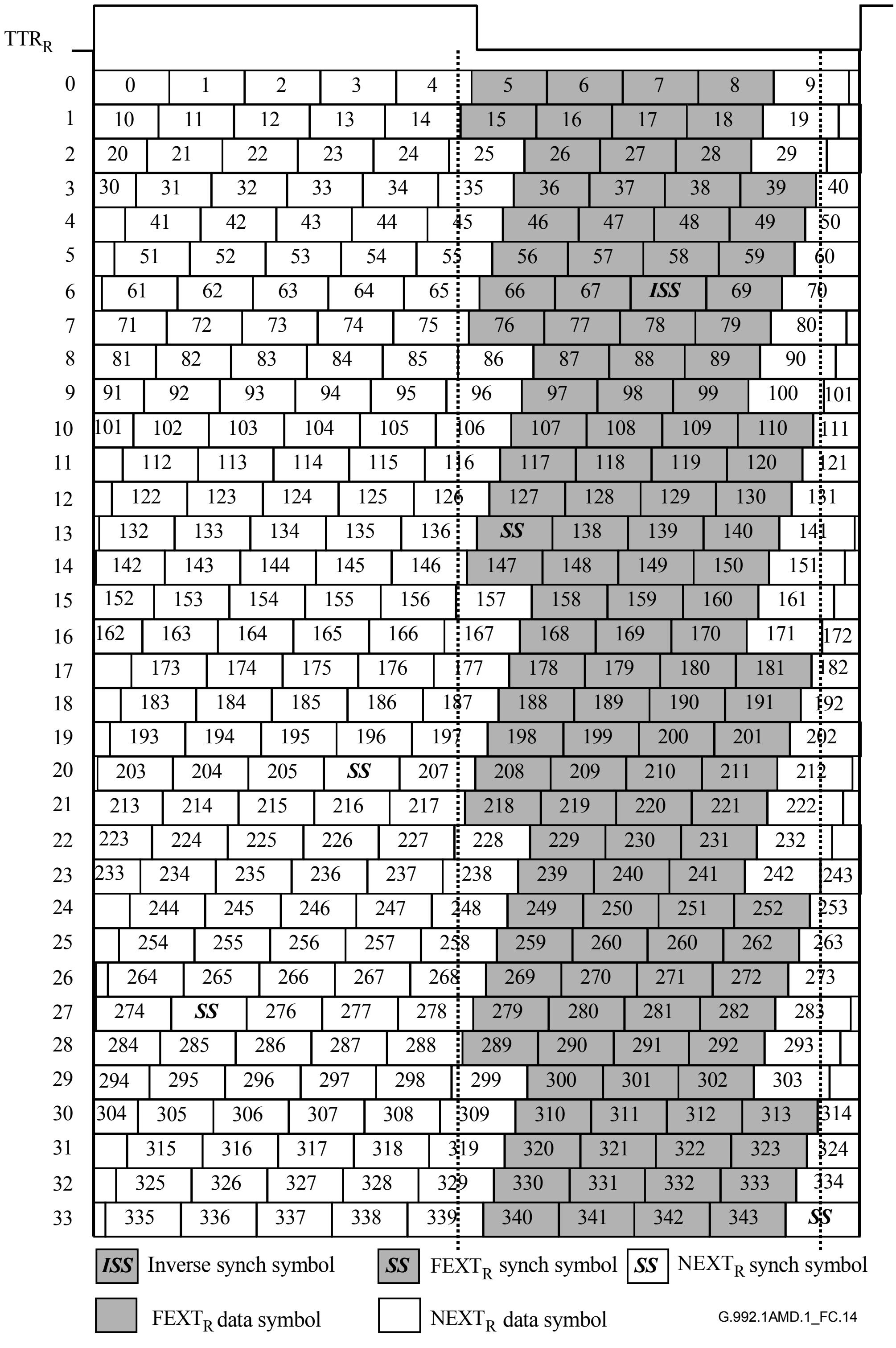


Figure C.14/G.992.1 – Symbol pattern in a hyperframe with cyclic prefix – Upstream

C.5.1.3 Subframe structure (replaces 8.4.1.4)

A subframe is 10 consecutive DMT symbols (except for synch symbols) as shown in Table C.2. The 34 subframes form a hyperframe.

Table C.2/G.992.1 – Subframe (upstream)

Subframe No.	DMT symbol No.	Note
0	0-9	
1	10-19	
2	20-29	
3	30-39	
4	40-49	
5	50-59	
6	60-70	#68 is inverse synch symbol
7	71-80	
8	81-90	
9	91-100	
10	101-110	
11	111-120	
12	121-130	
13	131-141	#137 is synch symbol
14	142-151	
15	152-161	
16	162-171	
17	172-181	
18	182-191	
19	192-201	
20	202-212	#206 is synch symbol
21	213-222	
22	223-232	
23	233-242	
24	243-252	
25	253-262	
26	263-272	
27	273-283	#275 is synch symbol
28	284-293	
29	294-303	
30	304-313	
31	314-323	
32	324-333	
33	334-344	#344 is synch symbol

C.5.2 Dual bitmapping and rate conversion (replaces 8.15)

The function of the rate converter (see C.5.2.2), tone ordering (see C.5.4), constellation encoding, and gain scaling shall use one of two bitmaps stored in the ATU. This method is called the Dual Bitmap.

C.5.2.1 Dual Bitmap (new)

The Dual Bitmap switching shall be the same as for the downstream data, specified in C.4.4.1. The number of bits and the relative gains to be used for every tone are calculated in the bit loading algorithm during the initialization sequence, and transmitted in C-B&G.

C.5.2.2 Rate converter (new)

The rate converter buffering changes the data frame boundaries between the reference points B and C according to Bitmap-F_C, Bitmap-N_C and the sliding window. Two independent rate converters are prepared for fast data and interleaved data. The amounts of fast and interleaved data in Bitmap-F_C and Bitmap-N_C shall be calculated in the following formulae:

If $t_{Cf} \leq n_{C\max}$:

$$n_{Cf} = t_{Cf}$$

$$n_{Ci} = n_C - n_{Cf}$$

$$f_{Cf} = t_{Cf}$$

$$f_{Ci} = f_C - f_{Cf}$$

If $t_{Cf} > n_{C\max}$:

$$n_{Cf} = n_{C\max}$$

$$n_{Ci} = 0$$

$$f_{Cf} = \begin{cases} f_{Cf4} = \left\lceil \dfrac{t_{Cf} \times 10 - n_{Cf} \times 6}{4} \right\rceil \\ f_{Cf3} = \left\lceil \dfrac{t_{Cf} \times 10 - n_{Cf} \times 7}{3} \right\rceil \end{cases}$$

$$f_{Ci} = \begin{cases} f_{Ci4} = f_C - f_{C4} \\ f_{Ci3} = f_C - f_{Cf3} \end{cases}$$

where:

- t_{Cf} is the number of allocated bits in one frame for fast bytes at the reference point B;
- t_{Ci} is the number of allocated bits for interleaved bytes at the reference point B;
- f_{Cf} and n_{Cf} are the numbers of fast bits in Bitmap-F_C and Bitmap-N_C, respectively;
- f_{Cf3} is the number of fast bits in Bitmap-F_C if the subframe (see C.5.1.3) contains 3 Bitmap-F_C except for synch symbols;
- f_{Cf4} is the number of fast bits in Bitmap-F_C if the subframe contains 4 Bitmap-F_C except for synch symbols;
- f_{Ci} and n_{Ci} are the numbers of interleaved bits in Bitmap-F_C and Bitmap-N_C, respectively;
- n_C is the number of total bits in Bitmap-N_C, which is specified in the B&G tables.

During FEXT bitmap mode, n_{Cf} and n_{Ci} are zero.

To convert the bit rate to be a multiple of 32 kbit/s, the dummy bits for fast data are inserted to the tail of each subframe, and the dummy bits for interleaved data are inserted to the end of the Hyperframe. The number of the dummy bits shall be as follows:

If $t_{Cf} \leq n_{C\max}$:

$$dummy_{Cf} = 0$$

$$dummy_{Ci} = (f_{Ci} \times 126 + n_{Ci} \times 214) - t_{Ci} \times 340$$

If $t_{Cf} > n_{C\max}$:

$$dummy_{Cf4} = (f_{Cf} \times 4 + n_{Cf} \times 6) - t_{Cf} \times 10$$

$$dummy_{Cf3} = (f_{Cf} \times 3 + n_{Cf} \times 7) - t_{Cf} \times 10$$

$$dummy_{Ci} = (f_{Ci4} \times 96 + f_{Ci3} \times 30) - t_{Ci} \times 340$$

If the fast data buffer uses single latency only, additional dummy bits are inserted at the tail of each FEXT symbol in the 4 Bitmap-F_C constructed subframe. The number of additional dummy bits inserted at the tail of each FEXT symbol shall be as follows:

$$dummy_{SCf} = f_{Cf3} - f_{Cf4}$$

The receiver shall determine Bitmap-F_C and Bitmap-N_C so that $dummy_{Ci}$ is less than 126, $dummy_{Cf4}$ is less than 4 and $dummy_{Cf3}$ is less than 3 in the initialization sequence. At the receiver, the inserted dummy bits shall be removed.

C.5.3 FEXT Bitmapping (replaces 8.16)

The FEXT Bitmapping mode uses the Dual Bitmapping technique (C.4.4) to transmit data only during FEXT. As an option, modems may have the ability to enable or disable Bitmap-N_R independently of Bitmap-N_C in order to control the FEXT Bitmapping mode upstream and downstream independently. For modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall transmit only the pilot tone during the $NEXT_R$ symbol. For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The ATU-R disables Bitmap-N_C and shall not transmit any signal during the $NEXT_C$ symbol (see Figures C.10 and C.13).

For modems not using any of the profiles defined in C.3.4, the Dual versus FEXT bitmapping mode is selected during G.994.1 using bit "DBM" (see 10.2 and 10.3). For modems using any of the profiles defined in C.3.4, the bitmapping mode is selected during G.994.1.

C.5.4 Tone ordering (pertains to 8.7)

The tone ordering algorithm shall be the same as for the downstream data, specified in C.4.4.

For Bitmap-F_C, the "tone-ordered" encoding shall first assign f_{Cf} bits from the rate converter (see C.5.2.2) to the tones with the smallest number of bits assigned to them, and the remaining f_{Ci} bits to the remaining tones. For Bitmap-N_C, it shall first assign n_{Cf} bits from the rate converter to the tones with the smallest number of bits assigned to them, and the remaining n_{Ci} bits to the remaining tones. Two ordered bit tables for Bitmap-F_C and Bitmap-N_C shall be prepared.

C.5.5 Modulation (pertains to 8.11)

C.5.5.1 Inverse synchronization symbol (replaces 8.11.4)

Inverse synchronization symbol shall be generated from a tone-by-tone 180 degree phase reversal of Synchronization symbol (i.e., + maps to –, and – maps to +, for each of the 4-QAM signal constellation).

C.5.5.2 Gain scaling in synchronization symbol (new)

At initialization time, the sync symbol reference transmit PSD level shall be set at the nominal PSD level +10log(g_{sync}^2) dBm/Hz, with g_{sync}^2 defined as the average g_i^2 value over the used (i.e., $b_i > 0$) subcarriers in the NEXT or FEXT bitmap, whichever results in the highest average gain. The sync symbol reference transmit PSD shall not be updated with used subcarrier gain changes during SHOWTIME.

C.5.6 ATU-R upstream transmit spectral mask (supplements 8.14)

The upstream spectral mask of this annex uses the same mask as Annex A.

C.6 EOC Operation and Maintenance (pertains to clause 9)

C.6.1 ADSL line related primitives (supplements 9.3.1)

C.6.1.1 ADSL line related near-end defects (supplements 9.3.1.3)

Two near-end defects are further defined:

- **Loss-of-signal (LOS)**: The ADSL power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.
- **Severely errored frame (SEF)**: A SEF defect occurs when the content of two consecutively received ADSL synchronization symbols in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R, does not correlate with the expected content over a subset of the tones. An SEF defect terminates when the content of two consecutively received ADSL synchronization symbols in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R, correlate with the expected contents over the same subset. The correlation method, the selected subset of tones, and the threshold for declaring these defect conditions are implementation discretionary.

C.6.1.2 ADSL line related far-end defects (supplements 9.3.1.4)

Loss-of-signal is further defined:

- **Loss-of-signal (LOS)**: The ADSL power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.

C.6.2 Test parameters (supplements 9.5)

C.6.2.1 Near-end test parameters (supplements 9.5.1)

The near-end primitives are further defined:

- **Attenuation (ATN)**: The received signal power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.
- **Signal-to-Noise ratio (SNR) margin**: During FEXT Bitmap mode, this primitive represents the snr margin in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R.

C.6.2.2 Far-end test parameters (supplements 9.5.2)

The far-end primitives are further defined:

- **Attenuation (ATN)**: The received signal power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.
- **Signal-to-Noise ratio (SNR) margin**: During FEXT Bitmap mode, this primitive represents the snr margin in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R.

C.7 Initialization (pertains to clause 10)

C.7.1 Initialization with hyperframe (replaces 10.1.5)

The exchange of messages between ATU-C and ATU-R shall be performed in $FEXT_C$ and $FEXT_R$. The DMT symbol has two symbol rates: one is 4.3125 kBaud for the symbol without a cyclic prefix, and the other is 4 × 69/68 kBaud for the symbol with a cyclic prefix. 32 times of the TTR has the same period as 345 times of the 4.3125 kBaud, and 34 times of the TTR is the same as 345 times of 4 × 69/68 kHz.

During FEXT Bitmap mode, the ATU-R shall not transmit any signal during the $NEXT_C$ symbols duration.

For modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall transmit only the pilot tone as the $NEXT_R$ signal except:

- C-PILOT1 (C-PILOT1A) which is accompanied by a signal to allow the ATU-C to indicate the phase of TTR_C to the ATU-R (see C.7.4.1);
- C-QUIETn where no signal is transmitted.

For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols.

For Profiles 2, 4, 5 and 6, the ATU-C may transmit data and pilot during the $NEXT_R$ symbols.

The ATU-C begins transmitting C-PILOT1 at the beginning of the hyperframe without cyclic prefix. The ATU-C informs the phase of the TTR_C to ATU-R during C-PILOT1. The ATU-R begins transmitting R-REVERB1 at the beginning of the hyperframe without cyclic prefix. The ATU-R performs the training of any receiver equalizer using this phase information of the TTR_R generated from received TTR_C.

From C-PILOT1 to C-SEGUE1, the following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to at ATU-R (see Figure C.15).

For $N_{dmt} = 0, 1, \ldots, 344$

$S = 256 \times N_{dmt} \bmod 2760$

if { ($S + 255 < a$) or ($S > a + b$) } then $FEXT_R$ symbols

else then $NEXT_R$ symbols

where a = 1243, b = 1461.

In order to enter C-RATES1 at the beginning of the hyperframe with cyclic prefix, the number of symbols from C-PILOT1 to C-SEGUE1 shall be a multiple of 345 DMT symbols.

From R-REVERB1 to R-SEGUE1, the following numerical formula gives the information which duration N_{dmt}-th symbol belongs to at ATU-C (see Figure C.16).

For $N_{dmt} = 0, 1, \ldots, 344$

$S = 256 \times N_{dmt} \bmod 2760$

if { ($S > a$) and ($S + 255 < a + b$) } then $FEXT_C$ symbols

else then $NEXT_C$ symbols

where a = 1315, b = 1293.

From C-RATES1 to C-SEGUE3, the number of symbols is a multiple of 345 DMT symbols. The following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to. ATU-C transmits the message data in $FEXT_R$ symbols (see Figure C.11).

For $N_{dmt} = 0, 1, \ldots , 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { $(S + 271 \geq a)$ and $(S \leq a + b)$ } then $NEXT_R$ symbols

else then $FEXT_R$ symbols

where a = 1243, b = 1461.

The ATU-R enters R-REVERB3 at the beginning of the hyperframe with cyclic prefix, which is extracted from received signal. From R-REVERB3 to R-SEGUE5, the number of symbols is a multiple of 345 DMT symbols. The following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to. ATU-R transmits the message data in $FEXT_C$ symbols (see Figure C.14).

For $N_{dmt} = 0, 1, \ldots , 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { $(S > a)$ and $(S + 271 < a + b)$ } then $FEXT_C$ symbols

else then $NEXT_C$ symbols

where a = 1315, b = 1293.

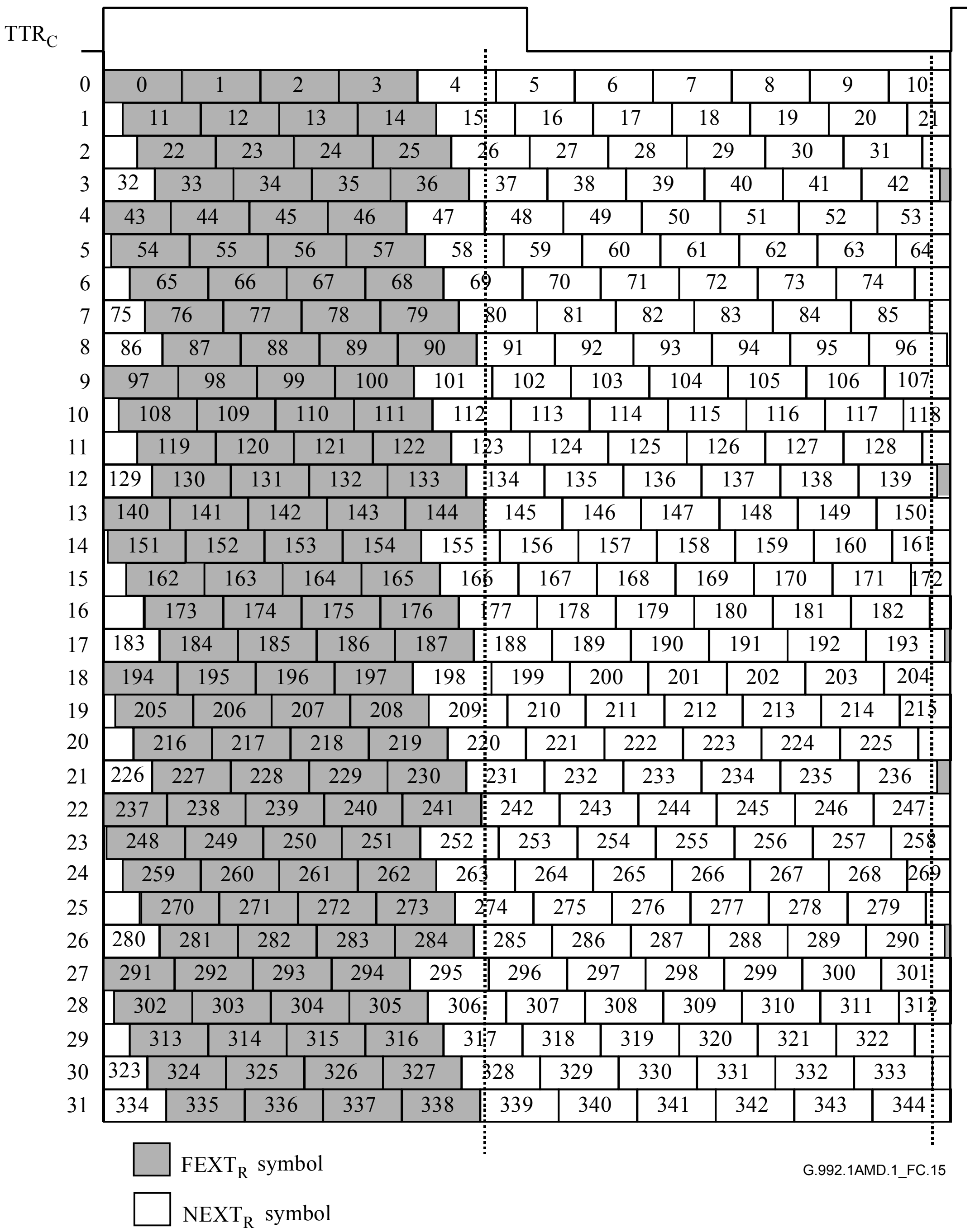


Figure C.15/G.992.1 – Symbol pattern in a hyperframe without cyclic prefix – Downstream

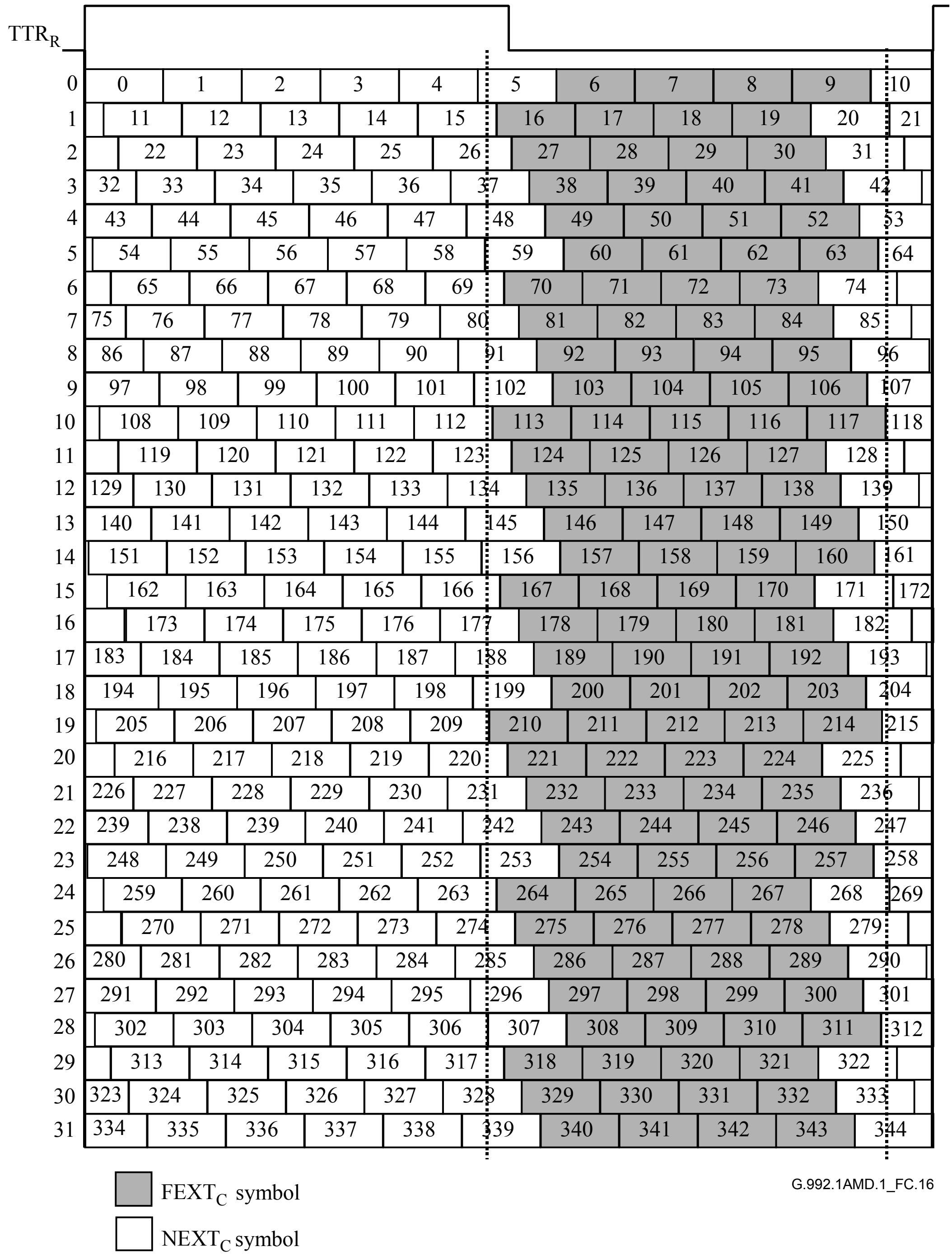


Figure C.16/G.992.1 – Symbol pattern in a hyperframe without cyclic prefix – Upstream

C.7.2 Handshake – ATU-C (supplements 10.2)

From C-SILENT1, the ATU-C may transition to either C-TONES or C-INIT under instruction of the network operator.

C.7.2.1 CL messages (supplements 10.2.1)

Table C.3/G.992.1 – ATU-C CL message bit definitions for Annex C

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e., only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall be only performed by the ATU-C. If it is set to ONE in a CL message, it must be set to ONE in subsequent MS messages from either the ATU-C or ATU-R (only applicable for G.992.1 Annex C) (Note).
Profile 1	If set to ONE, this bit shall indicate that the ATU-C supports Profile 1.
Profile 2	If set to ONE, this bit shall indicate that the ATU-C supports Profile 2.
Profile 3	If set to ONE, this bit shall indicate that the ATU-C supports Profile 3.
Profile 4	If set to ONE, this bit shall indicate that the ATU-C supports Profile 4.
Profile 5	If set to ONE, this bit shall indicate that the ATU-C supports Profile 5.
Profile 6	If set to ONE, this bit shall indicate that the ATU-C supports Profile 6.
SPar(2) bit	**Definition**
C-PILOT	If set to ONE, this bit shall indicate that the ATU-C supports negotiation of the optional pilot tones and TTR indication signals. This bit shall be set to ONE to indicate support for any of the profiles defined in C.3.4.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of pilot tone on subcarrier 64.
$n_{C\text{-}PILOT1} = 48$	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of pilot tone on subcarrier 48.
$n_{C\text{-}PILOT1} = 32$	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of pilot tone on subcarrier 32.
$n_{C\text{-}PILOT1} = 16$	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of pilot tone on subcarrier 16.
A_{48}/B_{48}	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of TTR indication signal A_{48}/B_{48}.
A_{24}/B_{24}	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of TTR indication signal A_{24}/B_{24}.
C-REVERB33-63	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of TTR indication signal C-REVERB33-63.
C-REVERB6-31	If the C-PILOT bit is set to ONE, this bit shall also be set to ONE, indicating that the ATU-C supports transmission of TTR indication signal C-REVERB6-31.
NOTE – The DBM bit is only used to maintain backward compatibility with G.992.1 (1999) Annex C. If any of the profile bits (Table 11.5/G.994.1) are set to ONE in a received CLR message, DBM shall be set to ONE in the CL message and shall be ignored by the ATU-R.	

C.7.2.2 MS messages (supplements 10.2.2)

Table C.4/G.992.1 – ATU-C MS message bit definitions for Annex C

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e., only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall be only performed by ATU-C. This bit shall be set to ONE if it was set to ONE in a previous CL message (only applicable for G.992.1 Annex C) (Note 1).
Profile 1	If set to ONE, this bit shall indicate that the ATU-C is selecting Profile 1.
Profile 2	If set to ONE, this bit shall indicate that the ATU-C is selecting Profile 2.
Profile 3	If set to ONE, this bit shall indicate that the ATU-C is selecting Profile 3.
Profile 4	If set to ONE, this bit shall indicate that the ATU-C is selecting Profile 4.
Profile 5	If set to ONE, this bit shall indicate that the ATU-C is selecting Profile 5.
Profile 6	If set to ONE, this bit shall indicate that the ATU-C is selecting Profile 6.
SPar(2) bit	**Definition**
C-PILOT	If set to ONE, this bit shall indicate that the ATU-C wishes to select a pilot tone and TTR indication signal. This bit shall be set to ONE to select one of the profiles defined in C.3.4.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	If set to ONE, this bit shall indicate that the ATU-C is selecting the pilot tone on subcarrier 64 (Note 2).
$n_{C\text{-}PILOT} = 48$	If set to ONE, this bit shall indicate that the ATU-C is selecting the pilot tone on subcarrier 48 (Note 2).
$n_{C\text{-}PILOT1} = 32$	If set to ONE, this bit shall indicate that the ATU-C is selecting the pilot tone on subcarrier 32 (Note 2).
$n_{C\text{-}PILOT1} = 16$	If set to ONE, this bit shall indicate that the ATU-C is selecting the pilot tone on subcarrier 16 (Note 2).
A_{48}/B_{48}	If set to ONE, this bit shall indicate that the ATU-C is selecting TTR indication signal A_{48}/B_{48} (Note 2).
A_{24}/B_{24}	If set to ONE, this bit shall indicate that the ATU-C is selecting TTR indication signal A_{24}/B_{24} (Note 2).
C-REVERB33-63	If set to ONE, this bit shall indicate that the ATU-C is selecting TTR indication signal C-REVERB33-63 (Note 2).
C-REVERB6-31	If set to ONE, this bit shall indicate that the ATU-C is selecting TTR indication signal C-REVERB6-31 (Note 2).
NOTE 1 – The DBM bit is only used to maintain backward compatibility with G.992.1 (1999) Annex C. NOTE 2 – One and only one pilot tone bit, and one and only one TTR indication signal bit shall be set in an MS message.	

C.7.3 Handshake – ATU-R (supplements 10.3)

Upon command from the host controller, the ATU-R shall initiate handshaking by transitioning from the R-SILENT0 state to either the G.994.1 R-TONES-REQ state or the R-INIT state.

C.7.3.1 CLR messages (supplements 10.3.1)

Table C.5/G.992.1 – ATU-R CLR message bit definitions for Annex C

NPar(2) bit	Definition
DBM	This bit shall be set to ONE.
Profile 1	If set to ONE, this bit shall indicate that the ATU-R supports Profile 1.
Profile 2	If set to ONE, this bit shall indicate that the ATU-R supports Profile 2.
Profile 3	If set to ONE, this bit shall indicate that the ATU-R supports Profile 3.
Profile 4	If set to ONE, this bit shall indicate that the ATU-R supports Profile 4.
Profile 5	If set to ONE, this bit shall indicate that the ATU-R supports Profile 5.
Profile 6	If set to ONE, this bit shall indicate that the ATU-R supports Profile 6.
SPar(2) bit	**Definition**
C-PILOT	If set to ONE, this bit shall indicate that the ATU-R supports negotiation of the optional pilot tones and TTR indication signals. This bit shall be set to ONE to indicate support for any of the profiles defined in C.3.4.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	This bit shall be set to ONE, indicating that the ATU-R supports reception of pilot tone on subcarrier 64.
$n_{C\text{-}PILOT1} = 48$	If set to ONE, this bit shall indicate that the ATU-R supports reception of pilot tone on subcarrier 48.
$n_{C\text{-}PILOT1} = 32$	If set to ONE, this bit shall indicate that the ATU-R supports reception of pilot tone on subcarrier 32.
$n_{C\text{-}PILOT1} = 16$	If set to ONE, this bit shall indicate that the ATU-R supports reception of pilot tone on subcarrier 16.
A_{48}/B_{48}	This bit shall be set to ONE, indicating that the ATU-R supports reception of either TTR indication signal A_{48} or B_{48} (Note).
A_{24}/B_{24}	If set to ONE, this bit shall indicate that the ATU-R supports reception of either TTR indication signal A_{24} or B_{24} (Note).
C-REVERB33-63	If set to ONE, this bit shall indicate that the ATU-R supports reception of TTR indication signal C-REVERB33-63.
C-REVERB6-31	If set to ONE, this bit shall indicate that the ATU-R supports reception of TTR indication signal C-REVERB6-31.
NOTE – A_{48} and A_{24} shall not be used for Profile 3.	

C.7.3.2 MS messages (supplements 10.3.2)

Table C.6/G.992.1 – ATU-R MS message NPar(2) bit definitions for Annex C

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e. only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall be only performed by ATU-C. This bit shall be set to ONE if it was set to ONE in a previous CL message (only applicable for G.992.1 Annex C). (Note 1).
Profile 1	If set to ONE, this bit shall indicate that the ATU-R is selecting Profile 1.
Profile 2	If set to ONE, this bit shall indicate that the ATU-R is selecting Profile 2.
Profile 3	If set to ONE, this bit shall indicate that the ATU-R is selecting Profile 3.
Profile 4	If set to ONE, this bit shall indicate that the ATU-R is selecting Profile 4.
Profile 5	If set to ONE, this bit shall indicate that the ATU-R is selecting Profile 5.
Profile 6	If set to ONE, this bit shall indicate that the ATU-R is selecting Profile 6.
SPar(2) bit	**Definition**
C-PILOT	If set to ONE, this bit shall indicate that the ATU-R wishes to select a pilot tone and TTR indication signal. This bit shall be set to ONE to select one of the profiles defined in C.3.4.
NPar(3) bit	**Definition**
$n_{C\text{-PILOT1}} = 64$	If set to ONE, this bit shall indicate that the ATU-R is selecting the pilot tone on subcarrier 64 (Note 2).
$n_{C\text{-PILOT1}} = 48$	If set to ONE, this bit shall indicate that the ATU-R is selecting the pilot tone on subcarrier 48 (Note 2).
$n_{C\text{-PILOT1}} = 32$	If set to ONE, this bit shall indicate that the ATU-R is selecting the pilot tone on subcarrier 32 (Note 2).
$n_{C\text{-PILOT1}} = 16$	If set to ONE, this bit shall indicate that the ATU-R is selecting the pilot tone on subcarrier 16 (Note 2).
A_{48}/B_{48}	If set to ONE, this bit shall indicate that the ATU-R is selecting the TTR indication signal A_{48}/B_{48} (Note 2).
A_{24}/B_{24}	If set to ONE, this bit shall indicate that the ATU-R is selecting the TTR indication signal A_{24}/B_{24} (Note 2).
C-REVERB33-63	If set to ONE, this bit shall indicate that the ATU-R is selecting the TTR indication signal C-REVERB33-63 (Note 2).
C-REVERB6-31	If set to ONE, this bit shall indicate that the ATU-R is selecting the TTR indication signal C-REVERB6-31 (Note 2).

NOTE 1 – The DBM bit is only used to maintain backward compatibility with G.992.1 (1999) Annex C.

NOTE 2 – One and only one pilot tone bit, and one and only one TTR indication signal bit shall be set in an MS message.

C.7.3.3 MP messages (new)

Table C.6a/G.992.1 – ATU-R MP message bit definitions for Annex C

NPar(2) bit	Definition
DBM	This bit shall be set to ONE if it was set to ONE in a previous CL message (Note 1).
Profile 1	If set to ONE, this bit shall indicate that the ATU-R is proposing to use Profile 1.
Profile 2	If set to ONE, this bit shall indicate that the ATU-R is proposing to use Profile 2.
Profile 3	If set to ONE, this bit shall indicate that the ATU-R is proposing to use Profile 3.
Profile 4	If set to ONE, this bit shall indicate that the ATU-R is proposing to use Profile 4.
Profile 5	If set to ONE, this bit shall indicate that the ATU-R is proposing to use Profile 5.
Profile 6	If set to ONE, this bit shall indicate that the ATU-R is proposing to use Profile 6.
SPar(2) bit	**Definition**
C-PILOT	If set to ONE, this bit shall indicate that the ATU-R wishes to propose a pilot tone and TTR indication signal. This bit shall be set to ONE to propose one of the profiles defined in C.3.4.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of pilot tone on subcarrier 64 (Note 2).
$n_{C\text{-}PILOT1} = 48$	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of pilot tone on subcarrier 48 (Note 2).
$n_{C\text{-}PILOT1} = 32$	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of pilot tone on subcarrier 32 (Note 2).
$n_{C\text{-}PILOT1} = 16$	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of pilot tone on subcarrier 16 (Note 2).
A_{48}/B_{48}	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of TTR indication signal A_{48}/B_{48} (Note 2).
A_{24}/B_{24}	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of TTR indication signal A_{24}/B_{24} (Note 2).
C-REVERB33-63	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of TTR indication signal C-REVERB33-63 (Note 2).
C-REVERB6-31	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of TTR indication signal C-REVERB6-31 (Note 2).
NOTE 1 – The DBM bit is only used to maintain backward compatibility with G.992.1 (1999) Annex C. NOTE 2 – One and only one pilot tone bit, and one and only one TTR indication signal bit shall be set in an MP message.	

C.7.4 Transceiver training – ATU-C (supplements 10.4)

During transceiver training from C-REVERB1 to C-SEGUE1 except C-PILOTn and C-QUIETn, the ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols when Bitmap-N_R is enabled (Dual Bitmap mode). For modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall not transmit the $NEXT_R$ symbols except pilot tone when Bitmap-N_R is disabled (FEXT Bitmap mode). For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The duration of each state is defined as Figure C.21.

C.7.4.1 C-PILOT1 (supplements 10.4.2)

The ATU-C shall start the N_{SWF} (sliding window frame) counter from 0 immediately after entering C-PILOT1, and increment the N_{SWF} counter modulo 345 after transmission of each DMT symbol. According to the sliding window function and this counter, the ATU-C decides to transmit all of the subsequent symbols in either $FEXT_R$ or $NEXT_R$ symbols (for example, see Figures C.11, C.15 and C.19).

C-PILOT1 has two signals.

The first signal is the pilot tone as a single frequency sinusoid.

For Profiles 1 and 2, the frequency of the pilot tone shall be selected from one of the following choices:

1) $f_{\text{C-PILOT1}}$ = 276 kHz ($n_{\text{C-PILOT1}}$ = 64);
2) $f_{\text{C-PILOT1}}$ = 207 kHz ($n_{\text{C-PILOT1}}$ = 48).

For Profiles 3 to 6, the frequency of the pilot tone shall be selected from one of the following choices:

1) $f_{\text{C-PILOT1}}$ = 276 kHz ($n_{\text{C-PILOT1}}$ = 64);
2) $f_{\text{C-PILOT1}}$ = 207 kHz ($n_{\text{C-PILOT1}}$ = 48);
3) $f_{\text{C-PILOT1}}$ = 138 kHz ($n_{\text{C-PILOT1}}$ = 32);
4) $f_{\text{C-PILOT1}}$ = 69 kHz ($n_{\text{C-PILOT1}}$ = 16).

For modems not using any of the profiles defined in C.3.4, the frequency of the pilot tone shall be:

$f_{\text{C-PILOT1}}$ = 276 kHz ($n_{\text{C-PILOT1}}$ = 64)

Transmitters that use any of the profiles defined in C.3.4 shall support all of the pilot tones specified for the supported profiles. For backwards compatibility, receivers shall support $n_{\text{C-PILOT1}}$ = 64. Support of the other pilot tones by a receiver is optional. The pilot tone shall be selected during G.994.1.

The second signal is the TTR indication signal used to transmit $NEXT_R$/$FEXT_R$ information. The ATU-R can detect the phase information of the TTR_C from this signal.

For Profiles 1 and 2, the TTR indication signal shall be selected from one of the following choices:

1) A_{48} signal – the constellation encoding of the 48th carrier with 2-bit constellation as follows:

   (+ , +) to indicate a $FEXT_R$ symbol;

   (+ , –) to indicate a $NEXT_R$ symbol.

2) C-REVERB33-63 – subcarriers 33 through 63 of C-REVERB, transmitted only in the first four DMT symbols of each hyperframe in C-PILOT1 to indicate the beginning of the hyperframe.

For Profile 3, the TTR indication signal shall be selected from one of the following choices:

1) B_{48} signal – the constellation encoding of the 48th carrier with 2-bit constellation as follows:

   (+ , –) to indicate the first and the last symbol in consecutive $FEXT_R$ symbols;

   (+ , +) to indicate the other symbols in consecutive $FEXT_R$ symbols.

2) B_{24} signal – the constellation encoding of the 24th carrier with 2-bit constellation as follows:

   (+ , –) to indicate the first and the last symbol in consecutive $FEXT_R$ symbols;

   (+ , +) to indicate the other symbols in consecutive $FEXT_R$ symbols.

3) C-REVERB6-31 – subcarriers 6 through 31 of C-REVERB, transmitted only in the first four DMT symbols of each hyperframe in C-PILOT1 to indicate the beginning of the hyperframe.

For Profiles 4 to 6, the TTR indication signal shall be selected from one of the following choices:

1) A_{48} signal – the constellation encoding of the 48th carrier with 2-bit constellation as follows:

   (+ , +) to indicate a $FEXT_R$ symbol;

   (+ , –) to indicate a $NEXT_R$ symbol.

2) A_{24} signal – the constellation encoding of the 24th carrier with 2-bit constellation as follows:

   (+ , +) to indicate a $FEXT_R$ symbol;

   (+ , –) to indicate a $NEXT_R$ symbol.

3) C-REVERB6-31 – subcarriers 6 through 31 of C-REVERB, transmitted only in the first four DMT symbols of each hyperframe in C-PILOT1 to indicate the beginning of the hyperframe.

For modems not using any of the profiles defined in C.3.4, the TTR indication signal shall be:

– A_{48} signal – the constellation encoding of the 48th carrier with 2-bit constellation as follows:

   (+ , +) to indicate a $FEXT_R$ symbol;

   (+ , –) to indicate a $NEXT_R$ symbol.

Transmitters that use any of the profiles defined in C.3.4 shall support all of these TTR indication signals specified for the supported profiles. For backwards compatibility, receivers shall support TTR indication signal A_{48}. Support for the other TTR indication signals by a receiver is optional. The TTR signal shall be selected during G.994.1.

C.7.4.2 C-PILOT1A (supplements 10.4.3)

C-PILOT1A has two signals and it is the same transmitted signal as C-PILOT1 (see C.7.4.1).

C.7.4.3 C-REVERB3 (supplements 10.4.11)

In order to synchronize the first symbol of C-RATES1 with the beginning of the hyperframe and to inform the entering timing of C-RATES1 to the ATU-R, the first symbol of C-SEGUE1 shall be transmitted inside of the $FEXT_R$ duration as shown in Figure C.17. Therefore, the duration of C-REVERB3 is 3628 DMT symbols.

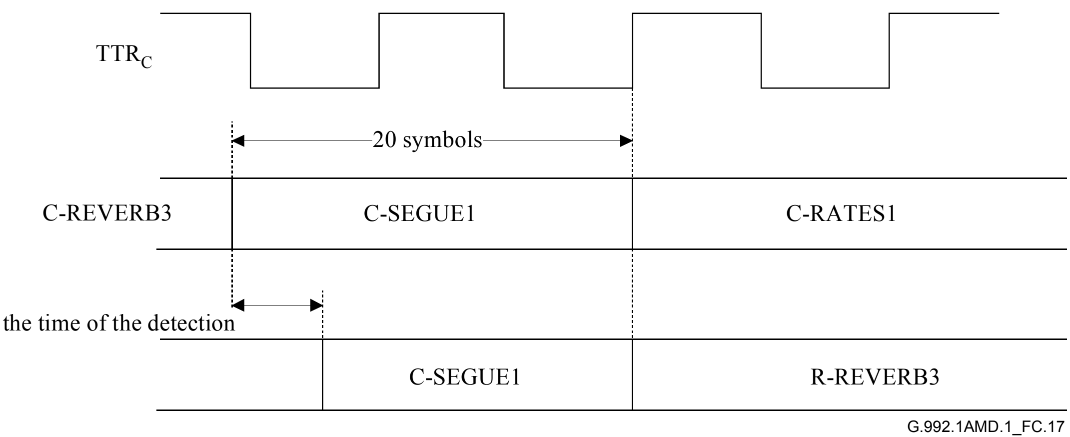


Figure C.17/G.992.1 – Timing diagram from C-SEGUE1 to C-RATES1

C.7.4.4 C-REVERB1 (supplements 10.4.5)

Bits d_{2i+1} and d_{2i+2}, which modulate the pilot carrier that has tone index i, shall be overwritten by {0,0}, generating the (+,+) constellation point.

C.7.5 Transceiver training – ATU-R (supplements 10.5)

During transceiver training from R-REVERB1 to R-SEGUE1 except R-QUIETn, the ATU-R shall transmit both $FEXT_C$ and $NEXT_C$ symbols when Bitmap-N_C is enabled (Dual Bitmap mode) and shall not transmit $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode). The duration of each state is defined as Figure C.21.

C.7.5.1 R-QUIET2 (supplements 10.5.1)

The ATU-R enters R-REVERB1 after it completes timing recovery and Hyperframe synchronization from C-PILOT1/C-PILOT1A.

C.7.5.2 R-REVERB1 (supplements 10.5.2)

The data pattern used in R-REVERB1 is the pseudo-random upstream sequence PRU defined in 8.11.3 and repeated here for convenience:

$$\begin{cases} d_n = 1 & \text{for } n = 1 \text{ to } 6 \\ d_n = d_{n-5} \oplus d_{n-6} & \text{for } n = 7 \text{ to } 64 \end{cases} \qquad \text{(C.10-1)}$$

The ATU-R shall start its N_{SWF} counter immediately after entering R-REVERB1, and then increment the N_{SWF} counter with modulo 345 from 0 when it transmits each DMT symbol. The ATU-C and ATU-R shall have the same value since hyperframe alignment between the ATU-C and ATU-R shall be maintained. According to the sliding window and this counter, the ATU-R decides to transmit all of the subsequent symbols in either the $FEXT_C$ or the $NEXT_C$ symbol.

C.7.5.3 R-QUIET3 (replaces 10.5.3)

The final symbol of R-QUIET3 accommodates the frame alignment of the transmitter to that of the receiver. It may be shortened by any number of samples. The maximum duration of R-QUIET3 is 6145 DMT symbols.

C.7.5.4 R-REVERB2 (supplements 10.5.5)

After ATU-R detects C-SEGUE1, the ATU-R enters R-SEGUE1. The maximum duration of R-REVERB2 is 3643 DMT symbols.

C.7.6 Channel analysis (ATU-C) (supplements 10.6)

ATU-C shall transmit only $FEXT_R$ symbols from C-RATES1 to C-CRC2. For modems not using any of the profiles defined in C.3.4 and modems using Profiles 1, 2, 4, 5 and 6, the ATU-C shall not transmit the $NEXT_R$ symbols except for the pilot tone. For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. During C-MEDLEY, the ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols when Bitmap-N_R is enabled (Dual Bitmap mode). For modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall not transmit $NEXT_R$ symbols except the pilot tone, when Bitmap-N_R is disabled (FEXT Bitmap mode). For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The duration of each state is defined in Figure C.21.

C.7.6.1 C-SEGUE1 (supplements 10.6.1)

The duration of C-SEGUE1 is 20 symbols in order that the first symbol of C-SEGUE1 shall be inside of the $FEXT_R$ duration.

C.7.6.2 C-MEDLEY (supplements 10.6.6)

Basically, the definition of C-MEDLEY is the same as 10.6.6, except for the duration of the SNR estimation at ATU-R for the downstream. With the periodical noise of TCM-ISDN, SNR also changes in the same cycle, as shown in Figure C.18. When Bitmap-N_R is enabled ATU-C transmits the signal in both of $NEXT_R$ and $FEXT_R$ symbols, and the ATU-R estimates two SNRs from the received $NEXT_R$ and $FEXT_R$ symbols, respectively, as defined in Figure C.19.

The following formula gives the information that received N_{dmt}-th DMT symbol belongs to:

For $N_{dmt} = 0, 1, \dots, 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { ($S + 271 < a$) or ($S > d$) } then symbol for estimation of $FEXT_R$ SNR

if { ($S > b$) and ($S + 271 < c$) } then symbol for estimation of $NEXT_R$ SNR

where a = 1243, b = 1403, c = 2613, d = 2704.

When Bitmap-N_R is disabled (FEXT Bitmap mode), the ATU-C only transmits the signal in $FEXT_R$ symbols, and the ATU-R estimates the SNR from the received $FEXT_R$ symbols. For modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall transmit only the pilot tone as $NEXT_R$ symbol. For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The number of bits of $NEXT_R$ shall be no more than the number of bits of $FEXT_R$.

For modems that use any of the profiles defined in C.3.4, the PRD sequence generator at the transmitter shall continue to be updated during $NEXT_R$ symbols when Bitmap-N_R is disabled (FEXT Bitmap mode).

NOTE – For modems not using any of the profiles defined in C.3.4, the PRD sequence generator at the transmitter is either always updated or always stopped during $NEXT_R$ symbol when Bitmap-N_R is disabled (FEXT Bitmap mode). The receiver should be able to support both modes of transmitter operation.

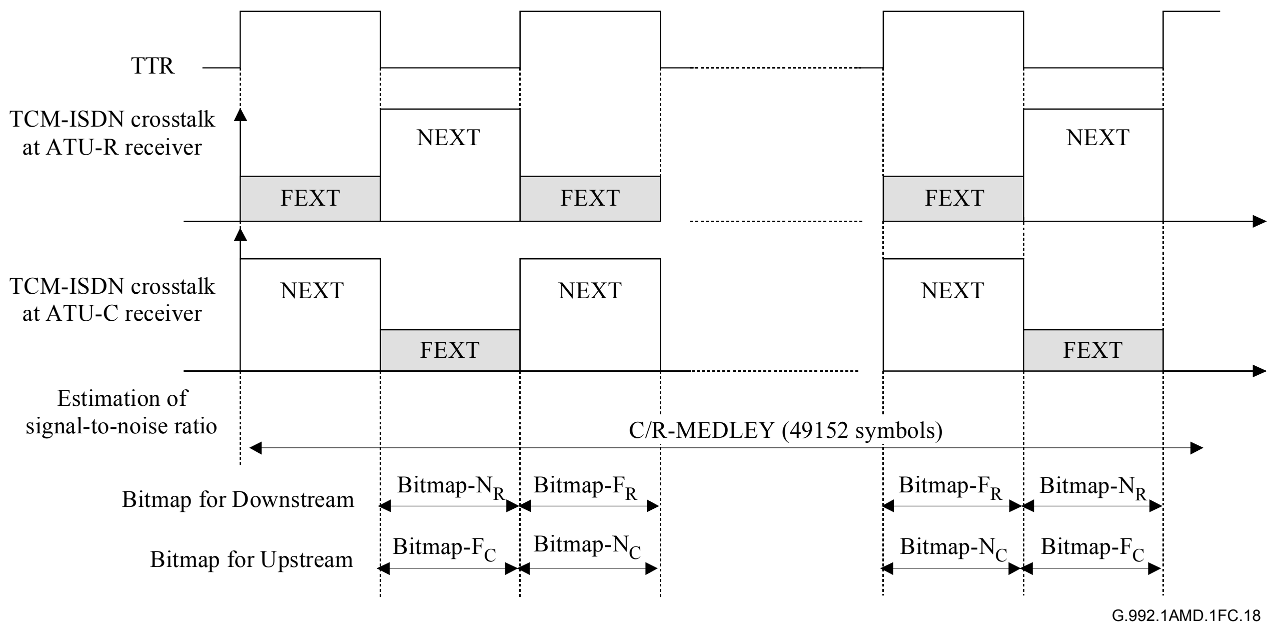


Figure C.18/G.992.1 – Estimation of periodic signal-to-noise ratio

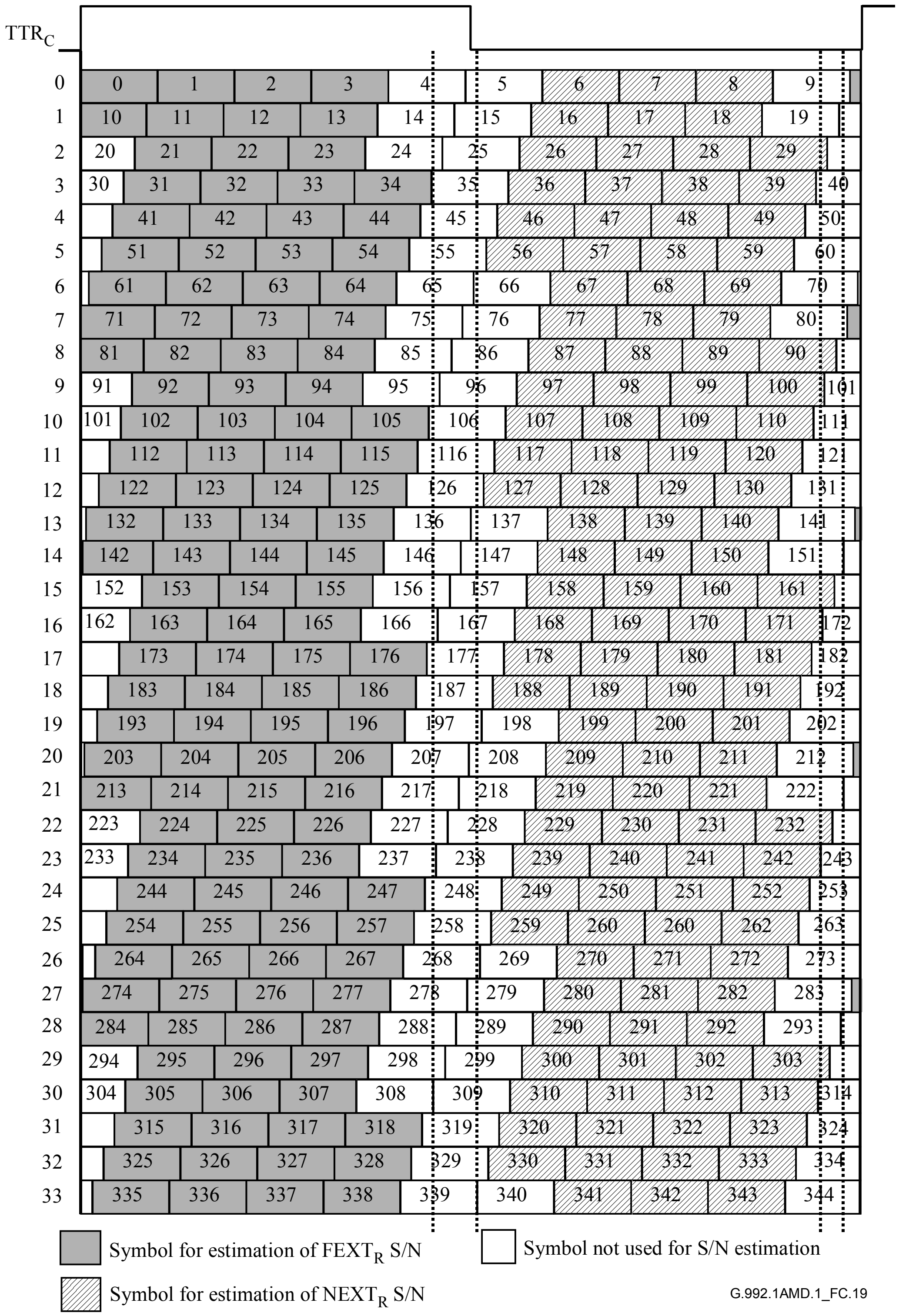


Figure C.19/G.992.1 – Symbol pattern in a hyperframe for S/N estimation – Downstream

C.7.7 Channel analysis (ATU-R) (supplements 10.7)

From R-RATES1 to R-CRC2, the ATU-R shall transmit only the $FEXT_C$ symbols and shall not transmit the $NEXT_C$ symbols. In R-SEGUE2 and R-MEDLEY, the ATU-R shall transmit both $FEXT_C$ and $NEXT_C$ symbols when Bitmap-N_C is enabled (Dual Bitmap mode) and shall not transmit $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode). The duration of each state is defined in Figure C.21.

C.7.8 R-SEGUE1 (supplements 10.7.1)

The maximum duration of R-SEGUE1 is 14 symbols (see Figure C.17).

C.7.8.1 R-REVERB3 (supplements 10.7.2)

The ATU-R shall start R-REVERB3 aligned with the beginning of a hyperframe.

C.7.8.2 R-SEGUE2 (supplements 10.7.3)

The duration of R-SEGUE2 is 13 symbols.

C.7.8.3 R-MEDLEY (supplements 10.7.8)

Basically, the definition of R-MEDLEY is the same as 10.7.8, except for the duration of the SNR estimation at ATU-C for the upstream. With the periodical noise of TCM-ISDN, SNR also changes in the same cycle, as shown in Figure C.18. When Bitmap-N_C is enabled, the ATU-R shall transmit the signal in both of $NEXT_C$ and $FEXT_C$ symbols, and ATU-C shall estimate two SNRs from the received $NEXT_C$ and $FEXT_C$ symbols, respectively, as defined in Figure C.20.

The following numerical formula gives the information that received N_{dmt}-th DMT symbol belongs to:

For $N_{dmt} = 0, 1, \ldots, 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { $(S > b)$ and $(S + 271 < c)$ } then symbol for estimation of $FEXT_C$ SNR

if { $(S + 271 < a)$ } then symbol for estimation of $NEXT_C$ SNR

where a = 1148, b = 1315, c = 2608.

When Bitmap-N_C is disabled (FEXT Bitmap mode), the ATU-R only transmits the signal in $FEXT_C$ symbols, and the ATU-C estimates the SNR from the received $FEXT_C$ symbols. The number of bits of $NEXT_C$ shall be no more than the number of bits of $FEXT_C$.

For modems that use any of the profiles defined in C.3.4, the PRU sequence generator at the transmitter shall continue to be updated during $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode).

NOTE – For modems not using any of the profiles defined in C.3.4, the PRU sequence generator at the transmitter is either always updated or always stopped during $NEXT_C$ symbol when Bitmap-N_C is disabled (FEXT Bitmap mode). The receiver should be able to support both modes of transmitter operation.

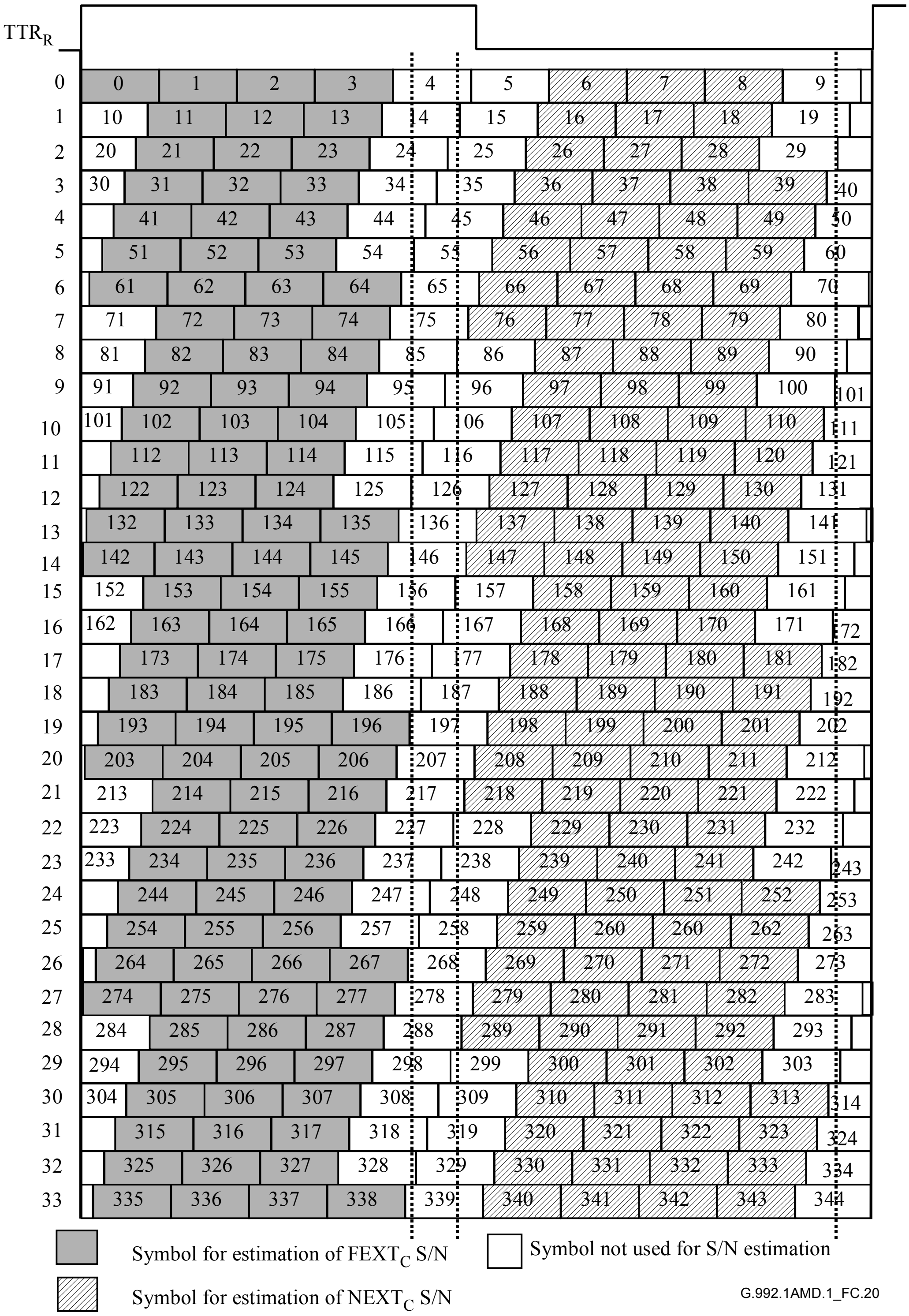
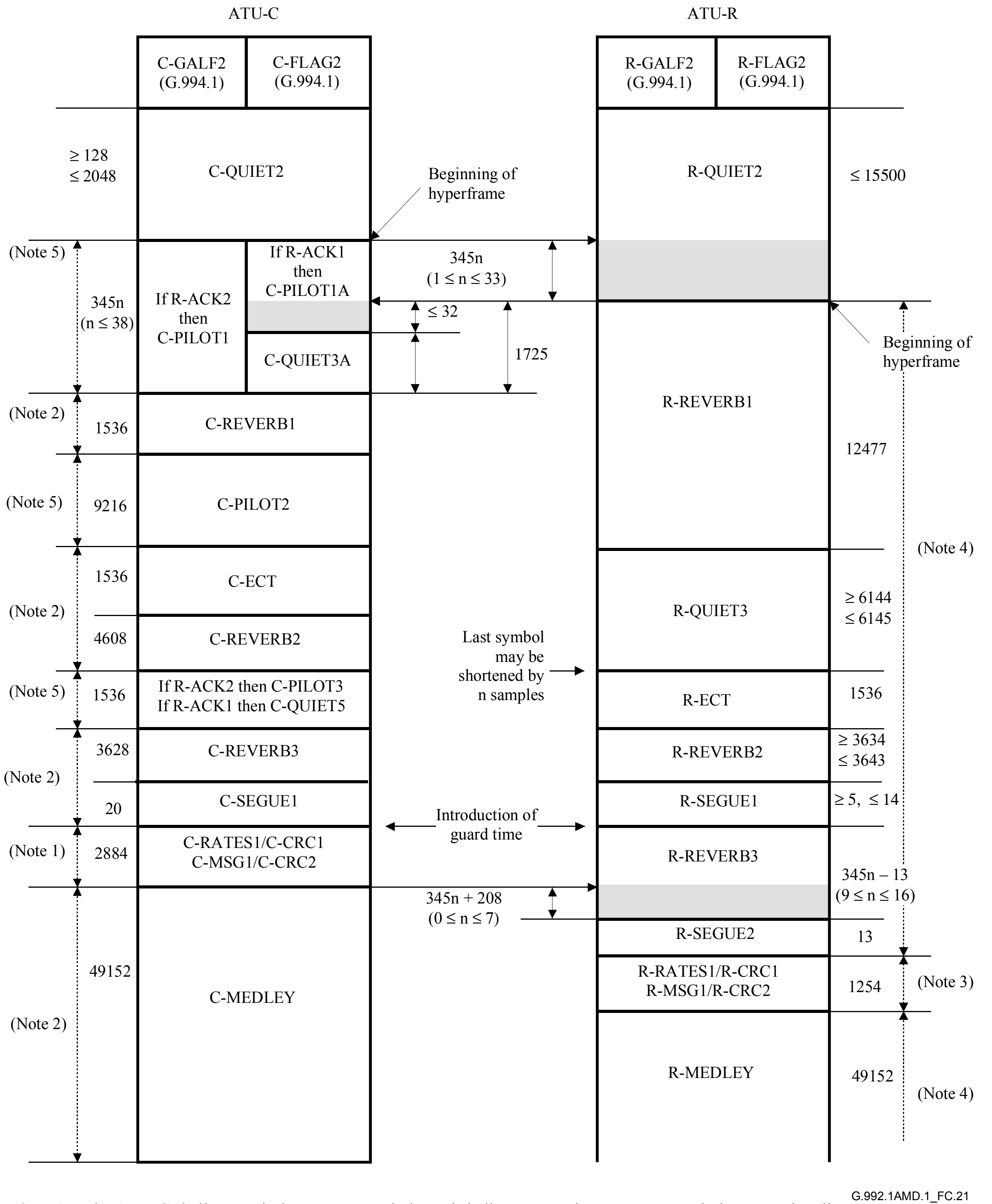


Figure C.20/G.992.1 – Symbol pattern in a hyperframe for S/N estimation – Upstream



NOTE 1 – The ATU-C shall transmit the $FEXT_R$ symbols, and shall not transmit as $NEXT_R$ symbols except the pilot tone.

NOTE 2 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols, when Bitmap-N_R is enabled (Dual Bitmap mode). ATU-C shall not transmit the $NEXT_R$ symbols except pilot tone, when Bitmap-N_R is disabled (FEXT Bitmap mode).

NOTE 3 – The ATU-R shall transmit the $FEXT_C$ symbols, and shall not transmit the $NEXT_C$ symbols.

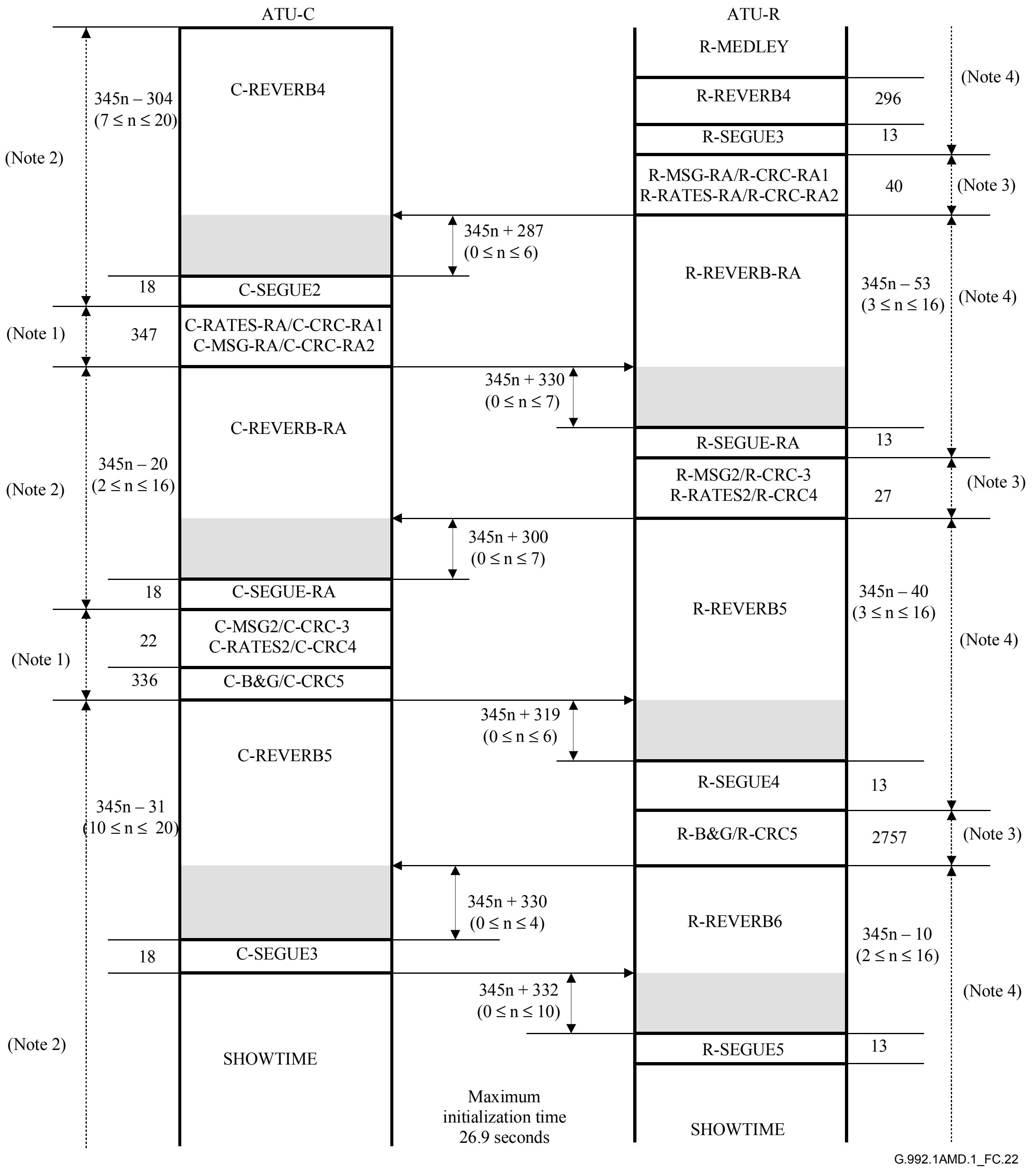
NOTE 4 – The ATU-R shall transmit both $FEXT_C$ symbols and $NEXT_C$, when Bitmap-N_C is enabled (Dual Bitmap mode). ATU-R shall not transmit $NEXT_C$ symbols, when Bitmap-N_C is disabled (FEXT Bitmap mode).

NOTE 5 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols.

Figure C.21/G.992.1 – Timing diagram of the initialization sequence – Part 1

C.7.9 Exchange – ATU-C (supplements 10.8)

During C-RATESn, C-MSGn, C-B&G, and C-CRCn, the ATU-C shall transmit the $FEXT_R$ symbol. In the other signals, the ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols when Bitmap-N_R is enabled (Dual Bitmap mode), and, for modems not using any of the profiles defined in C.3.4 and modems using Profile 1, shall not transmit the $NEXT_R$ symbols except pilot tone when Bitmap-N_R is disabled (FEXT Bitmap mode). For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols. The duration of each state is defined in Figure C.22.



NOTE 1 – The ATU-C shall transmit the $FEXT_R$ symbols, and shall not transmit as $NEXT_R$ symbols except the pilot tone.

NOTE 2 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols, when Bitmap-N_R is enabled (Dual Bitmap mode). ATU-C shall not transmit the $NEXT_R$ symbols except pilot tone, when Bitmap-N_R is disabled (FEXT Bitmap mode).

NOTE 3 – The ATU-R shall transmit the $FEXT_C$ symbols, and shall not transmit the $NEXT_C$ symbols.

NOTE 4 – The ATU-R shall transmit both $FEXT_C$ symbols and $NEXT_C$, when Bitmap-N_C is enabled (Dual Bitmap mode). ATU-R shall not transmit $NEXT_C$ symbols, when Bitmap-N_C is disabled (FEXT Bitmap mode).

NOTE 5 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols.

Figure C.22/G.992.1 – Timing diagram of the initialization sequence – Part 2

C.7.9.1 C-MSG2 (supplements 10.8.9)

For modems not using any of the profiles defined in C.3.4 and modems using Profiles 1, 2, 4, 5 or 6:

$n_{1C\text{-}MSG2} = 43$

$n_{2C\text{-}MSG2} = 91$

For Profile 3:

$n_{1C\text{-}MSG2} = 13$

$n_{2C\text{-}MSG2} = 25$

C.7.9.1.1 Total number of bits per symbol supported (supplements 10.8.9.3)

The maximum number of bits per symbol is defined at the reference point B, that is calculated from the $FEXT_C$ and $NEXT_C$ downstream channel performance (e.g., if the maximum numbers of bits that can be supported in $FEXT_C$ and $NEXT_C$ symbols are 111 and 88 {Total number of bits per symbol supported} = (111 × 126 + 88 × 214)/340 = 96).

NOTE – The number of symbols per hyperframe is 340. The number of FEXT symbols is 126. The number of NEXT symbols is 214.

C.7.9.2 C-B&G (replaces 10.8.13)

C-B&G shall be used to transmit to the ATU-R the bits and gains information, Bitmap-F_C $\{b_1, g_1, b_2, g_2, \ldots, b_{31}, g_{31}\}$, and Bitmap-$N_C$ $\{b_{33}, g_{33}, b_{34}, g_{34}, \ldots, b_{63}, g_{63}\}$, that are to be used on the upstream carriers. b_i of Bitmap-F_C indicates the number of bits to be coded by ATU-R transmitter onto the i-th upstream carrier in $FEXT_C$ symbols; g_i of Bitmap-F_C indicates the scale factor, relative to the gain that was used for that carrier during the transmission of R-MEDLEY, that shall be applied to the i-th upstream carrier in $FEXT_C$ symbols. Similarly, b_i of Bitmap-N_C indicates the number of bits onto the $(i - 32)$-th upstream carrier in $NEXT_C$ symbols; g_i of Bitmap-N_C indicates the scale factor that shall be applied to the $(i - 32)$-th upstream carrier in $NEXT_C$ symbols.

Because no bits or energy will be transmitted at DC or one-half the sampling rate, b_0, g_0, b_{32}, g_{32}, b_{64}, and g_{64} are all presumed to be zero and shall not be transmitted.

The C-B&G information shall be mapped in a 992-bit (124 byte) message m defined by:

$$m = \{m_{991}, m_{990}, \ldots, m_1, m_0\} = \{g_{63}, b_{63}, \ldots, g_{33}, b_{33}, g_{31}, b_{31}, \ldots, g_1, b_1\}, \qquad \text{(C.10-2)}$$

with the MSB of b_i and g_i in the higher m index and m_0 being transmitted first. The message m shall be transmitted in 124 symbols, using the transmission method as described in 10.8.9.

When Bitmap-N_C is disabled (FEXT Bitmap mode), b_i and g_i of Bitmap-N_C shall be set to zero.

C.7.9.3 C-SEGUE3 (replaces 10.8.16)

The duration of C-SEGUE3 is 18 symbols. Following C-SEGUE3, the ATU-C completes the initialization and enters C-SHOWTIME. In C-SHOWTIME, ATU-C shall transmit the signal using Bitmap-F_R and Bitmap-N_R with the sliding window.

When Bitmap-N_R is disabled (FEXT Bitmap mode), for modems not using any of the profiles defined in C.3.4 and modems using Profile 1, the ATU-C shall transmit only the pilot tone as $NEXT_R$ symbols. For Profile 3, the ATU-C shall not transmit any signal in $NEXT_R$ symbols.

C.7.10 Exchange – ATU-R (supplements 10.9)

ATU-R shall transmit only the $FEXT_C$ symbols in R-MSGn, R-RATESn, R-B&G, R-CRCn. In other signals, the ATU-R shall transmit both $FEXT_C$ and $NEXT_C$ symbols when Bitmap-N_C is enabled (Dual Bitmap mode) and shall not transmit $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode). The duration of each state is defined in Figure C.22.

C.7.10.1 R-MSG-RA (supplements 10.9.2)

Replace Table 10-15 with Table C.7.

Table C.7/G.992.1 – Assignment of 80 bits of R-MSG-RA (Annex C)

Suffix(ces) of m_i (Note 1)	Parameter (Note 2)
79-68	Reserved for ITU-T
67-56	$B_{fast\text{-}max}$
55-49	Number of RS overhead bytes, (R)
48-40	Number of RS payload bytes, K
39-32	Number of tones carrying data (ncloaded)
31-25	Estimated average loop attenuation
24-21	Coding gain
20-16	Performance margin with selected rate option
15-14	Reserved for ITU-T
13-12	Maximum Interleave Depth
11-0	Total number of bits per DMT symbol, B_{max}
NOTE 1 – Within the separate fields the least significant bits have the lowest subscripts. NOTE 2 – All reserved bits shall be set to 0.	

C.7.10.1.1 Total number of bits supported (B_{max}) (replaces 10.9.2.8)

This parameter shall be defined as in R-MSG2; see C.7.9.1.

C.7.10.1.2 $B_{fast\text{-}max}$ (new)

$B_{fast\text{-}max}$ is the maximum number of bits of the fast buffer for fast data transmitted on the condition that the bits of the fast data can be equally assigned to all FEXT-symbols and NEXT-symbols.

Fast Buffered Data $B_{fast\text{-}max}$ is t_f.

C.7.10.2 R-MSG2 (supplements 10.9.8)

$N_{1R\text{-}MSG2} = 10$

$N_{2R\text{-}MSG2} = 20$

C.7.10.2.1 Total number of bits per symbol supported (supplements 10.9.8.3)

The maximum number of bits per symbol is defined at the reference point B, that is calculated from the $FEXT_R$ and $NEXT_R$ downstream channel performance. For example, if the maximum numbers of bits that can be supported in $FEXT_R$ and $NEXT_R$ symbols are 111 and 88, the total number of bits per symbol supported is (111 × 126 + 88 × 214)/340 = 96.

NOTE – The number of symbols per hyperframe is 340, the number of FEXT symbols is 126, and the number of NEXT symbols is 214.

C.7.10.3 R-B&G (replaces 10.9.14)

The purpose of R-B&G is to transmit to ATU-C the bits and gains information, Bitmap-F_R $\{b_1, g_1, b_2, g_2, ... , b_{255}, g_{255}\}$, and Bitmap-$N_R$ $\{b_{257}, g_{257}, b_{258}, g_{258}, ... , b_{511}, g_{511}\}$, to be used on the downstream subcarriers. b_i of Bitmap-F_R indicates the number of bits to be coded by ATU-C transmitter onto the i-th downstream subcarrier in $FEXT_R$ symbols; g_i of Bitmap-F_R indicates the scale factor that shall be applied to the i-th downstream subcarrier in $FEXT_R$ symbols, relative to the gain that was used for that carrier during the transmission of C-MEDLEY. Similarly, b_i of

Bitmap-N_R indicates the number of bits onto the $(i-256)$-th downstream carrier in $NEXT_R$ symbols; g_i of Bitmap-N_R indicates the scale factor that shall be applied to the $(i-256)$-th downstream carrier in $NEXT_R$ symbols. Because no bits or energy will be transmitted at DC or one-half the sampling rate, b_0, g_0, b_{256}, g_{256}, b_{512} and g_{512} are all presumed to be zero, and are not transmitted. When subcarrier 64 is reserved as the pilot tone, b_{64} and b_{320} shall be set to 0, and, for modems not using any of the profiles defined in C.3.4 and modems using Profiles 1, 2, 4, 5 or 6, g_{64} and g_{320} shall be set to g_{sync}. For Profile 3, g_{64} shall be set to g_{sync} and g_{320} shall be set to 0. When subcarrier 48 is reserved as the pilot tone, b_{48} and b_{304}, shall be set to 0, and, for modems not using any of the profiles defined in C.3.4 and modems using Profiles 1, 2, 4, 5 or 6, g_{48} and g_{304} shall be set to $g_{sync.}$ For Profile 3, g_{48} shall be set to g_{sync} and g_{304} shall be set to 0. When subcarrier 32 is reserved as the pilot tone, b_{32} and b_{288}, shall be set to 0, and, for modems not using any of the profiles defined in C.3.4 and modems using Profiles 1, 2, 4, 5 or 6, g_{32} and g_{288} shall be set to g_{sync}. For Profile 3, g_{32} shall be set to g_{sync} and g_{288} shall be set to 0. When subcarrier 16 is reserved as the pilot tone, b_{16} and b_{272}, shall be set to 0, and, for modems not using any of the profiles defined in C.3.4 and modems using Profiles 1, 2, 4, 5 or 6, g_{16} and g_{272} shall be set to g_{sync}. For Profile 3, g_{16} shall be set to g_{sync} and g_{272} shall be set to 0. The value g_{sync} represents the gain scaling applied to the sync symbol.

The R-B&G information shall be mapped in a 8160-bit (1020 byte) message m defined by:

$$m = \{m_{8159}, m_{8158}, \dots, m_1, m_0\} = \{g_{511}, b_{511}, \dots, g_{257}, b_{257}, g_{255}, b_{255}, \dots, g_1, b_1\}, \quad (C.10\text{-}3)$$

with the MSB of b_i and g_i in the higher m index and m_0 being transmitted first. The message m shall be transmitted in 1020 symbols, using the transmission method as described in 10.9.8.

When Bitmap-N_R is disabled (FEXT bitmap mode), b_i and g_i of Bitmap-N_R shall be set to zero.

C.7.10.4 R-SEGUE5 (replaces 10.9.17)

The duration of R-SEGUE5 is 13 symbols. Following R-SEGUE-5, ATU-R completes the initialization and enters R-SHOWTIME. In R-SHOWTIME, ATU-R shall transmit the signal using Bitmap-F_C and Bitmap-N_C with the sliding window.

When Bitmap-N_C is disabled (FEXT bitmap mode), ATU-R shall not transmit $NEXT_C$ symbols.

C.8 AOC On-line adaptation and reconfiguration (pertains to clause 11)

C.8.1 Bit swap request (replaces 11.2.3)

The receiver shall initiate a bit swap by sending a bit swap request to the transmitter via the AOC channel. This request tells the transmitter which subcarriers are to be modified. The format of the request is shown in Table C.8.

Table C.8/G.992.1 – Format of the bit swap request message

Message header	Message field 1-4		
$\{11111111_2\}$ (8 bits)	Bitmap index (1 bit)	Command (7 bits)	Subchannel index (8 bits)

The request shall comprise nine bytes as follows:

- an AOC message header consisting of 8 binary ones;
- message fields 1-4, each of which consists of one-bit bitmap index, a seven-bit command followed by a related eight-bit subchannel index. One-bit bitmap index and valid seven-bit commands for the bit swap message shall be as shown in Table C.9. In Table C.9, the MSB for the bit swap request command represents the Bitmap index. For downstream data, Bitmap index equals 0 indicates Bitmap-F_R, and Bitmap index equals 1 indicates Bitmap-N_R. Similarly for upstream data, Bitmap index equals 0 indicates Bitmap-F_C, and 1

indicates Bitmap-N_C. The eight-bit subchannel index is counted from low to high frequencies with the lowest frequency subcarrier having the number zero. The subcarrier index zero shall not be used;

- the bit swap between $FEXT_{C/R}$ symbols and $NEXT_{C/R}$ symbols is not allowed.

Table C.9/G.992.1 – Bit swap request command

Value (8 bits)	Interpretation
$y0000000_2$	Do nothing
$y0000001_2$	Increase the number of allocated bits by one
$y0000010_2$	Decrease the number of allocated bits by one
$y0000011_2$	Increase the transmitted power by 1 dB
$y0000100_2$	Increase the transmitted power by 2 dB
$y0000101_2$	Increase the transmitted power by 3 dB
$y0000110_2$	Reduce the transmitted power by 1 dB
$y0000111_2$	Reduce the transmitted power by 2 dB
$y0001xxx_2$	Reserved for vendor discretionary commands
NOTE – y is "0" for $FEXT_{C/R}$ symbols, and "1" for $NEXT_{C/R}$ symbols of the sliding window.	

The bit swap request message (i.e., header and message fields) shall be transmitted five consecutive times.

To avoid g_i divergence between ATU-C and ATU-R after several bit swaps, for a g_i update of Δ dB the new g_i value should be given by:

$$g_i' = (1/512) \times round(512 \times g_i \times 10\exp(\Delta/20)) \quad \text{(C.11-1)}$$

C.8.2 Extended bit swap request (supplements 11.2.4)

The format of the extended bit swap request is shown in Table C.10.

Table C.10/G.992.1 – Format of the bit swap request message

Message header	Message field 1-6		
{11111100_2} (8 bits)	Bitmap index (1 bit)	Command (7 bits)	Subchannel index (8 bits)

In the same manner as the bit swap request, each of the massage fields of the extended bit swap request consists of one-bit bitmap index, a seven-bit command followed by a related eight-bit subchannel index.

C.8.3 Bit swap acknowledge (supplements 11.2.5)

The bit swap superframe counter number shall only indicate the last superframe (SPF#4) of a hyperframe.

The new bit and/or transmit power table(s) shall then take effect starting from the first frame (frame 0) of SPF#0 of a hyperframe.

If the bit swap superframe counter number contained in the received bit swap acknowledge message does not indicate SPF#4, then the new table(s) shall take effect starting from frame 0 of SPF#0 of the next hyperframe.

Annex I

Specific requirements for an ADSL system with improved performance on short loops operating in the same cable as ISDN as defined in Appendix III of ITU-T Rec. G.961

I.1 Scope

This annex describes those specifications that are unique to an ADSL system coexisting in the same binder as TCM-ISDN as defined in Appendix III/G.961. This annex provides supplementary and replacement material to the clauses in the main body. The nature of the material is parenthetically indicated in the clause heading. The modifications described in this annex allow a performance improvement from the ADSL system specified in Annex C for short loops in an environment coexisting with TCM-ISDN in the same cable. This annex also defines those parameters of this ADSL system that have been left undefined in the main body of this Recommendation. It is recommended that ADSL system implementing Annex I also implements Annex C.

I.2 Terms and abbreviations

I.2.1 Definitions

This annex defines the following terms:

I.2.1.1 Bitmap-F_C: ATU-R transmitter bitmap under TCM-ISDN FEXT noise generated at ATU-C.

I.2.1.2 Bitmap-F_R: ATU-C transmitter bitmap under TCM-ISDN FEXT noise generated at ATU-R.

I.2.1.3 Bitmap-N_C: ATU-R transmitter bitmap under TCM-ISDN NEXT noise generated at ATU-C.

I.2.1.4 Bitmap-N_R: ATU-C transmitter bitmap under TCM-ISDN NEXT noise generated at ATU-R.

I.2.1.5 dual bitmap: The Dual Bitmap method has dual bit rates under the FEXT and NEXT noise from TCM-ISDN.

I.2.1.6 FEXT bitmap: Similar to the Dual Bitmap method, however, transmission only occurs during FEXT noise from TCM-ISDN.

I.2.1.7 $FEXT_C$ duration: TCM-ISDN FEXT duration at ATU-C estimated by the ATU-R.

I.2.1.8 $FEXT_C$ symbol: DMT symbol transmitted by ATU-R during TCM-ISDN FEXT.

I.2.1.9 $FEXT_R$ duration: TCM-ISDN FEXT duration at ATU-R estimated by the ATU-C.

I.2.1.10 $FEXT_R$ symbol: DMT symbol transmitted by ATU-C during TCM-ISDN FEXT.

I.2.1.11 hyperframe: 5-superframe structure which synchronized TTR.

I.2.1.12 $NEXT_C$ duration: TCM-ISDN NEXT duration at ATU-C estimated by the ATU-R.

I.2.1.13 $NEXT_C$ symbol: DMT symbol transmitted by ATU-R during TCM-ISDN NEXT.

I.2.1.14 $NEXT_R$ duration: TCM-ISDN NEXT duration at ATU-R estimated by the ATU-C.

I.2.1.15 $NEXT_R$ symbol: DMT symbol transmitted by ATU-C during TCM-ISDN NEXT.

I.2.1.16 NSC: The highest subcarrier index that can be used for downstream transmission (i.e., the subcarrier index corresponding to the Nyquist frequency) For example, NSC = 256 for a downstream channel using the frequency band up to 1.104 MHz; NSC = 512 for a downstream channel using the frequency band up to 2.208 MHz.

I.2.1.17 Subframe: 10 consecutive DMT symbols (except for sync symbols) according to TTR timing.

I.2.2 Abbreviations

This annex uses the following abbreviations:

N_{SWF} Sliding Window frame counter

TTR TCM-ISDN Timing Reference

TTR_C Timing reference used in ATU-C

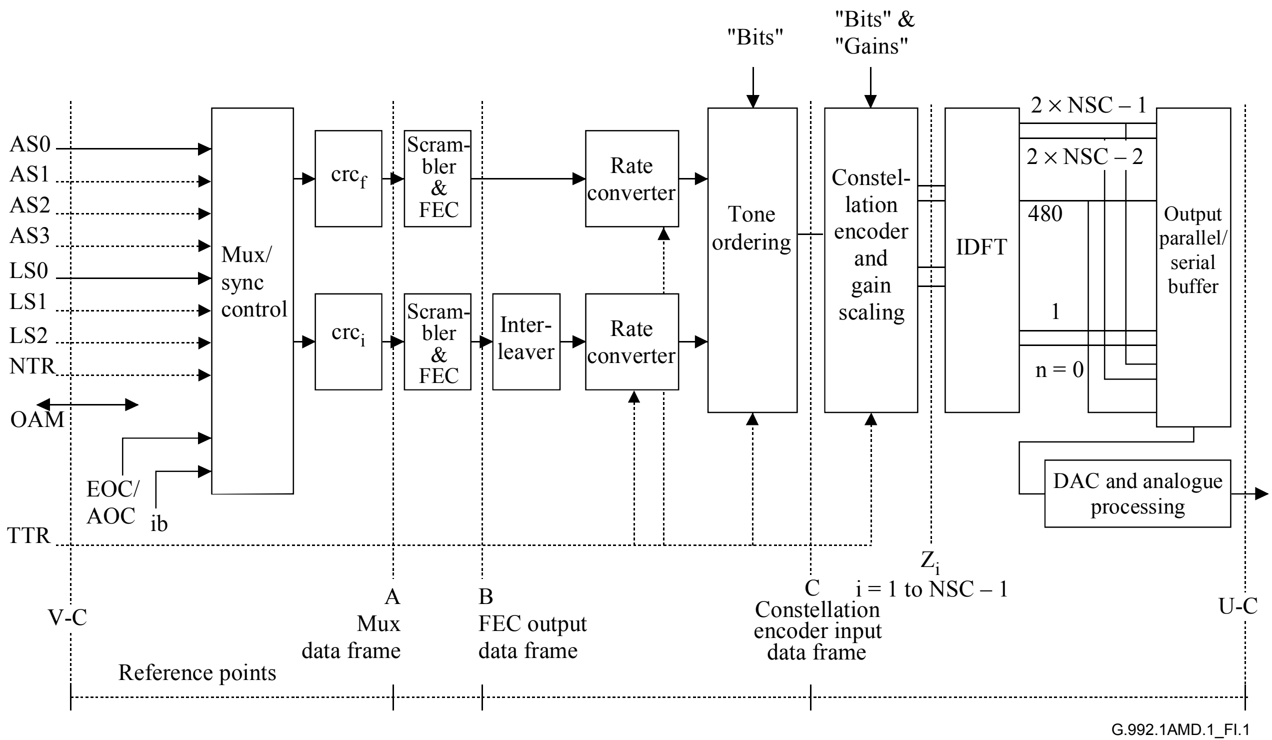
TTR_R Timing reference used in ATU-R

UI Unit Interval

I.3 Reference models

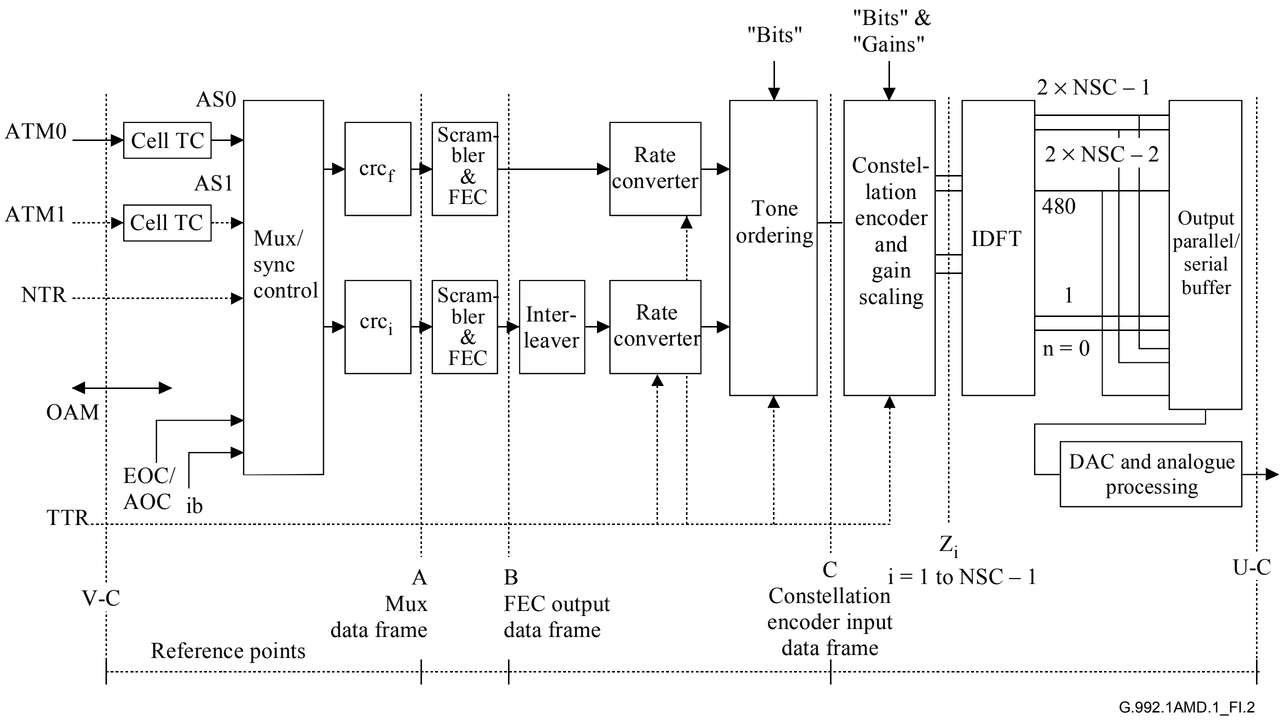
I.3.1 ATU-C transmitter reference model (replaces figures in 5.1)

See Figures I.1 and I.2.



NOTE – The TTR may be generated in ATU-C without being provided from the TCM-ISDN clock.

Figure I.1/G.992.1 – ATU-C transmitter reference model for STM transport

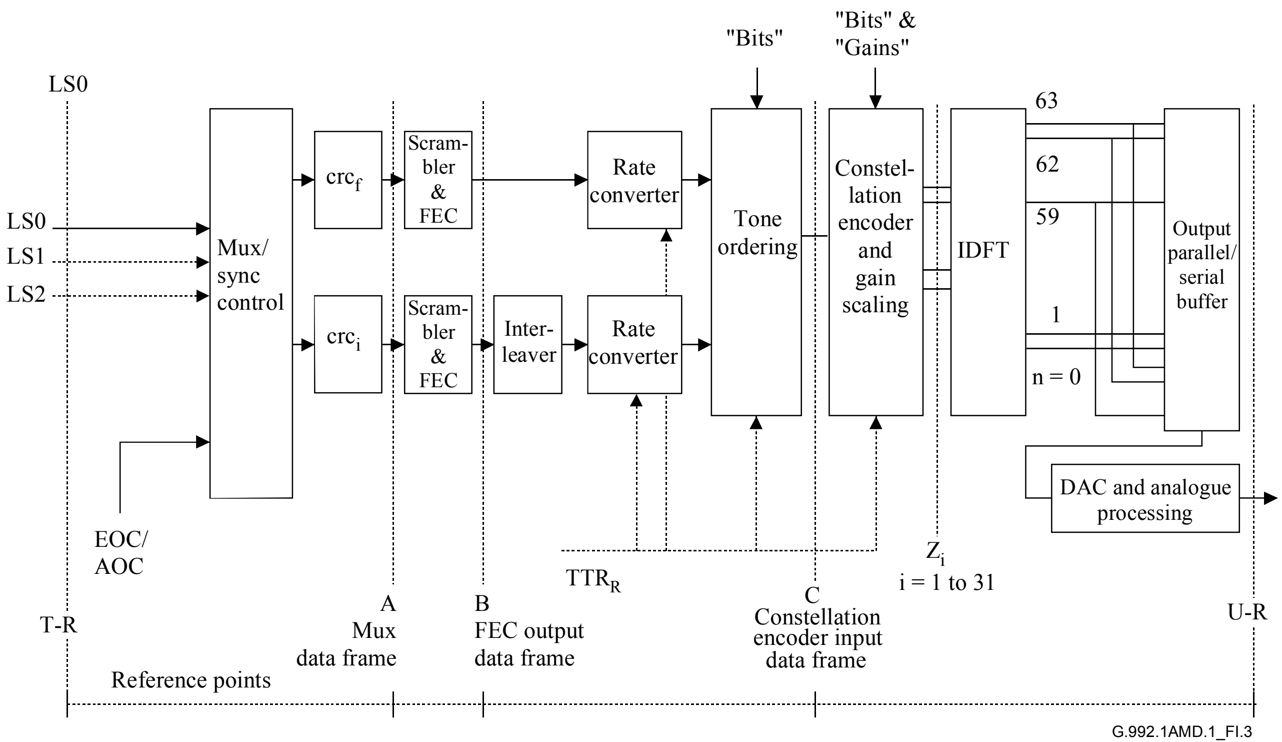


NOTE – The TTR may be generated in ATU-C without being provided from the TCM-ISDN clock.

Figure I.2/G.992.1 – ATU-C transmitter reference model for ATM transport

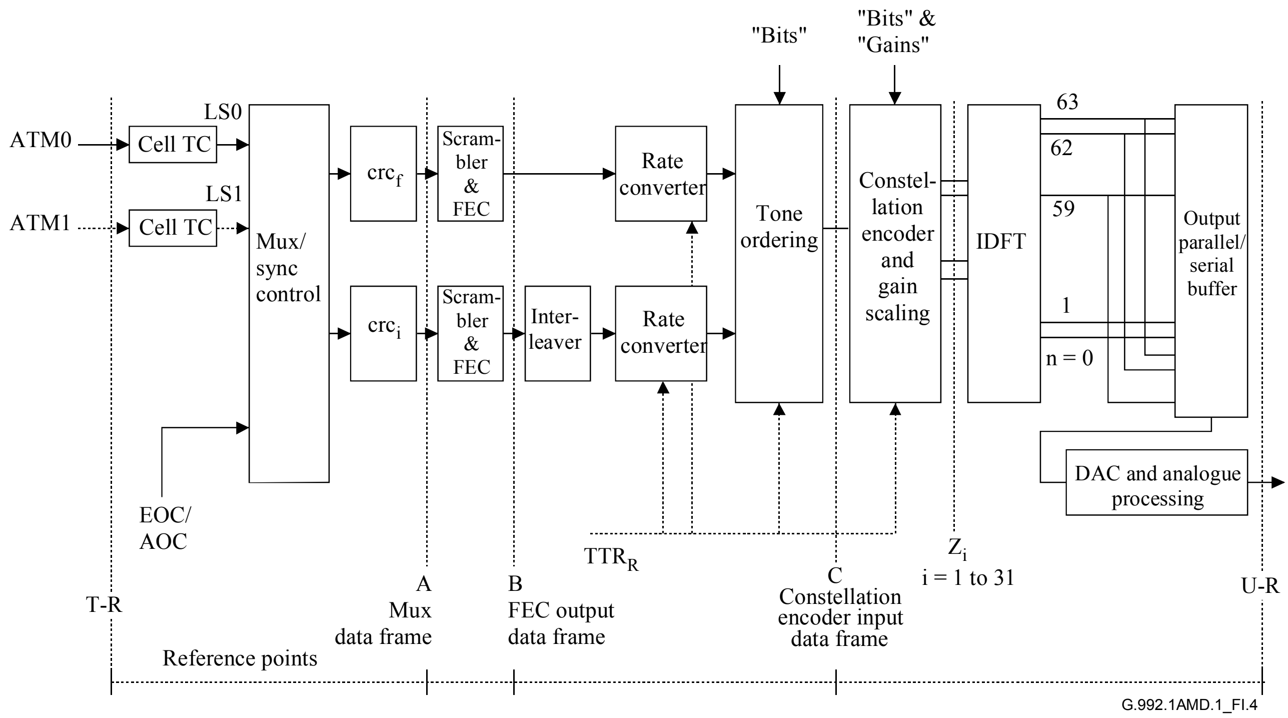
I.3.2 ATU-R transmitter reference model (replaces figures in 5.2)

See Figures I.3 and I.4.



NOTE – The TTR_R shall be generated in ATU-R from the received TTR_C signal, and it is locked to 690 periods of upstream sampling clock (276 kHz).

Figure I.3/G.992.1 – ATU-R transmitter reference model for STM transport



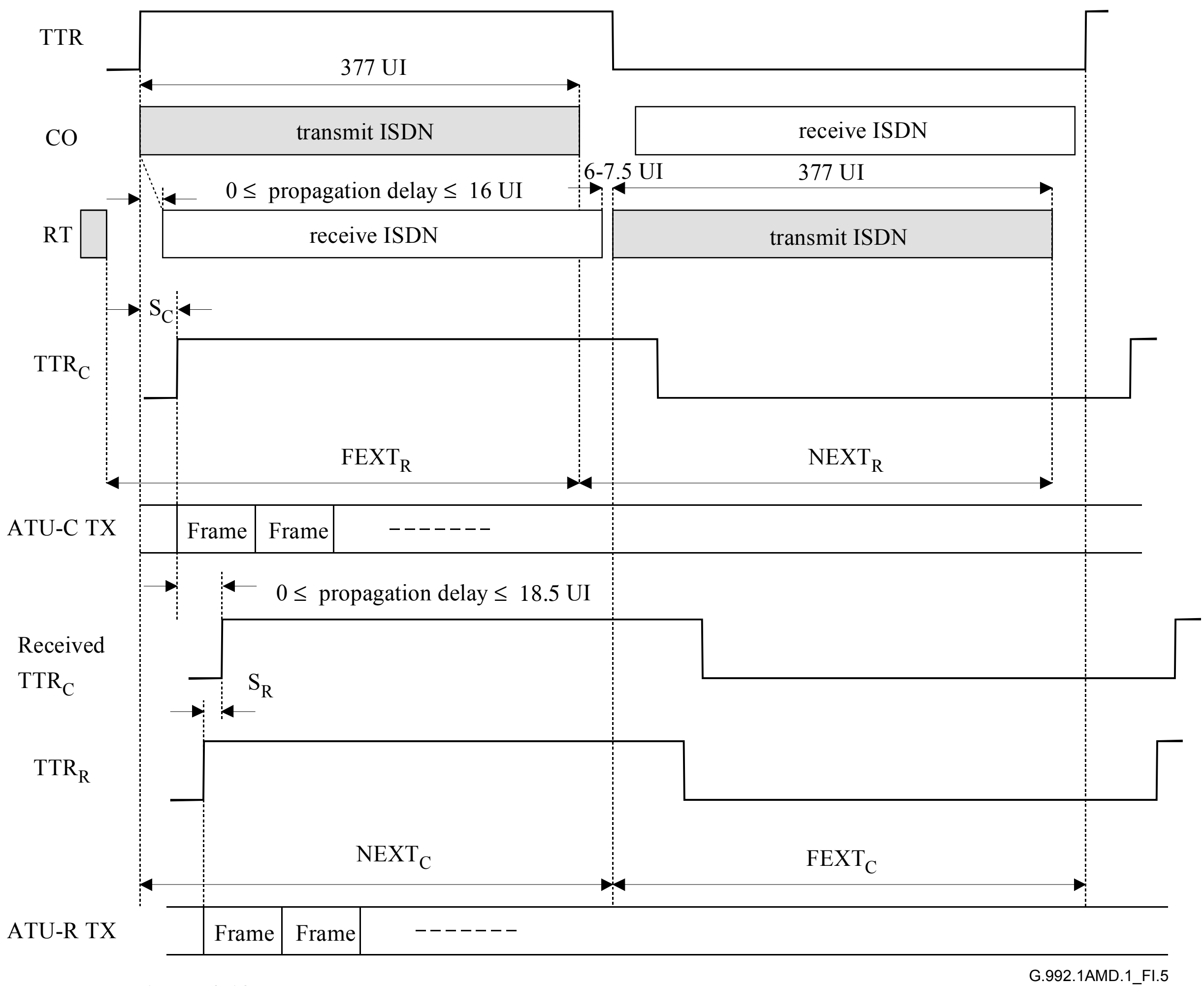
NOTE – The TTR_R shall be generated in ATU-R from the received TTR_C signal, and it is locked to 690 periods of upstream sampling clock (276 kHz).

Figure I.4/G.992.1 – ATU-R transmitter reference model for ATM transport

I.3.3 ATU-C/R transmitter timing model (replacement for 5.3)

I.3.3.1 TCM-ISDN crosstalk timing model (new)

Figure I.5 shows the timing chart of the crosstalk from TCM-ISDN.



1 UI = 3.125 µs

FEXT$_R$ and **NEXT$_R$** are estimated by ATU-C

FEXT$_C$ and **NEXT$_C$** are estimated by ATU-R

TTR	TCM-ISDN timing reference
TTR_C	Timing reference used in ATU-C
Received TTR_C	Received TTR_C at ATU-R
TTR_R	Timing reference used in ATU-R
S_C	55 × 0.9058 µs: Offset from TTR to TTR_C
S_R	–42 × 0.9058 µs: Offset from received TTR_C to TTR_R

Figure I.5/G.992.1 – Timing chart of the TCM-ISDN crosstalk

The data stream of TCM-ISDN is transmitted in TTR period. CO transmits the stream in the first half of the TTR period and RT transmits in the second half of the TTR period. ATU-C receives NEXT noise from the ISDN in the first half of the TTR period and FEXT noise from the ISDN in the second half of the TCM-ISDN period. On the other hand, ATU-R receives FEXT noise from the ISDN in the first half of the TTR period and NEXT noise from the ISDN in the second half of the TTR period.

As defined in I.7.6.2 and I.7.8.3, the ATU-C shall estimate the $FEXT_R$ and $NEXT_R$ duration at ATU-R, and the ATU-R shall estimate $FEXT_C$ and $NEXT_C$ duration at ATU-C taking propagation delay on the subscriber line into consideration.

The ATU-C shall transmit any symbols by synchronizing with the TTR_C. The ATU-R shall transmit any symbols synchronizing with the TTR_R generated from received TTR_C.

I.3.3.2 Sliding window (new)

Figure I.6 shows the timing chart of the transmission for the Annex I downstream at ATU-C.

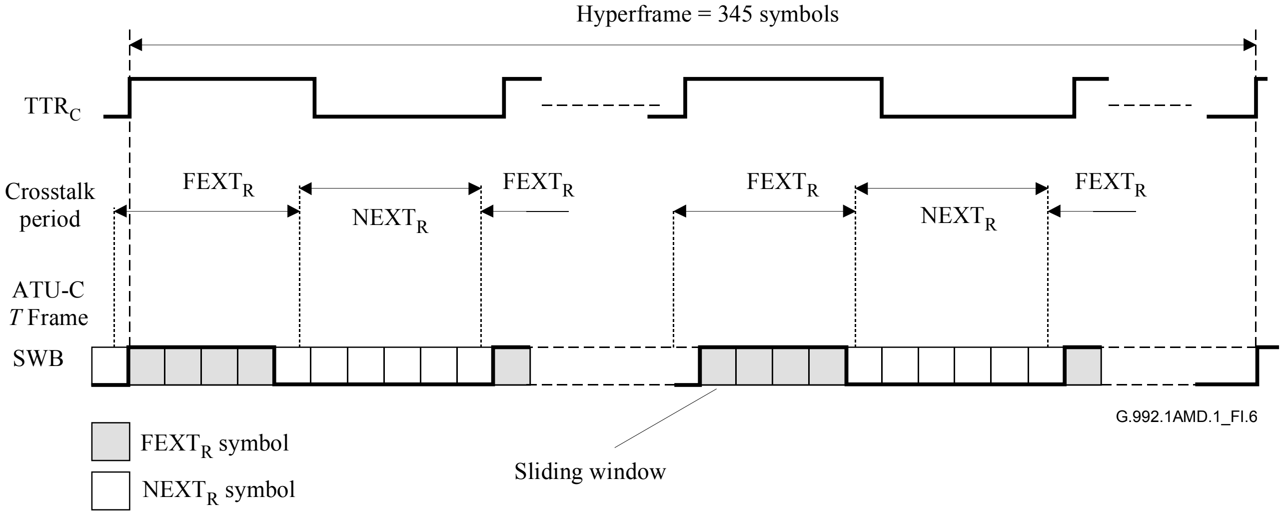


Figure I.6/G.992.1 – Sliding window for downstream symbols

The sliding window defines the transmission symbols under the crosstalk noise environment synchronized to the period of TTR. The $FEXT_{C/R}$ symbol represents the symbol completely inside the $FEXT_{C/R}$ duration. The $NEXT_{C/R}$ symbol represents any symbol containing the $NEXT_{C/R}$ duration. Thus, there are more $NEXT_{C/R}$ symbols than $FEXT_{C/R}$ symbols.

The ATU-C decides which transmission symbol is $FEXT_R$ or $NEXT_R$ symbol according to the sliding window and transmits it with the corresponding bit table. Similarly, the ATU-R decides the transmission symbol is a $FEXT_C$ or $NEXT_C$ and transmits it with the corresponding bit table. Although the phase of the sliding window is asynchronous with $TTR_{C/R}$, the pattern is fixed to the 345 frames of the hyperframe.

I.3.3.3 ATU-C symbol synchronization to TTR (new)

345 symbols are 34 cycles with cyclic prefix of TTR_C (or 32 cycles of TTR_C without cyclic prefix). This implies a PLL lock at the ATU-R.

I.3.3.4 Dual Bitmap switching (new)

The ATU-C transmits $FEXT_R$ symbols using Bitmap-F_R (in $FEXT_R$ duration), and transmits $NEXT_R$ symbols using Bitmap-N_R (in $NEXT_R$ duration) according to the result of initialization. The ATU-R transmits $FEXT_C$ symbols using Bitmap-F_C (in $FEXT_C$ duration), and transmits $NEXT_C$ symbols using Bitmap-N_C (in $NEXT_C$ duration) in the same manner.

The ATU-C shall have the capability to disable Bitmap-N_C and Bitmap-N_R (see I.4.5 and I.5.3).

I.3.3.5 Loop timing at ATU-R (new)

The phase relation between received symbol and transmitted symbol of ATU-R at the reference point U-R shall meet the phase tolerances as shown in Figure I.7.

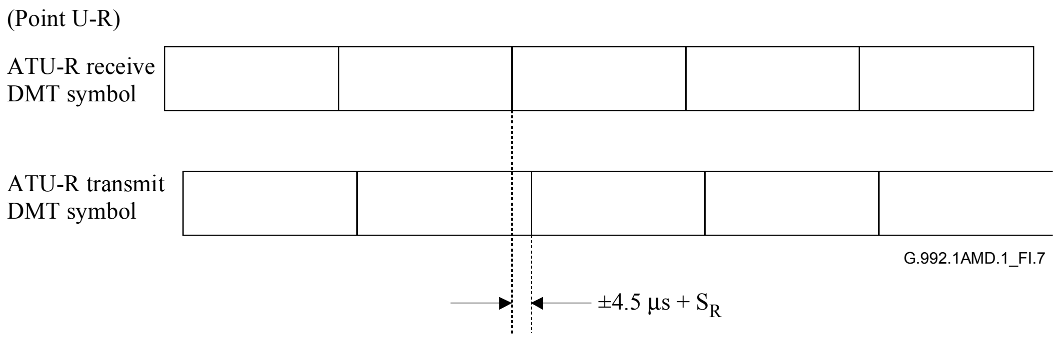


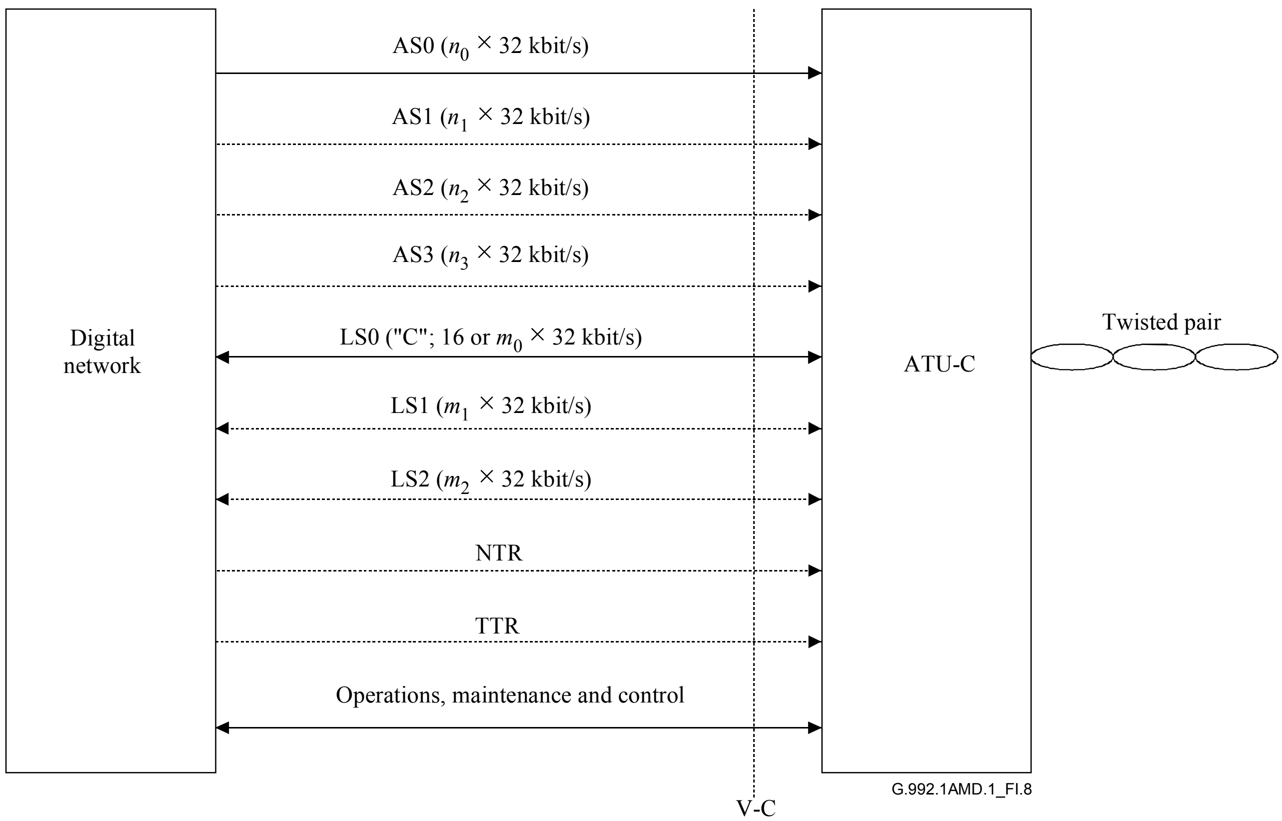
Figure I.7/G.992.1 – Loop timing for ATU-R

I.4 ATU-C functional characteristics (pertains to clause 7)

I.4.1 STM transmission protocols specific functionality (pertains to 7.1)

I.4.1.1 ATU-C input and output V interface for STM transport (replaces figure in 7.1.1)

See Figure I.8.



NOTE 1 – Optional bearer channels (both duplex and simplex) and features are shown with dotted lines.
NOTE 2 – TTR may be generated in the ATU-C without being provided from the V-C reference point.

Figure I.8/G.992.1 – ATU-C functional interfaces for STM transport at the V-C reference point

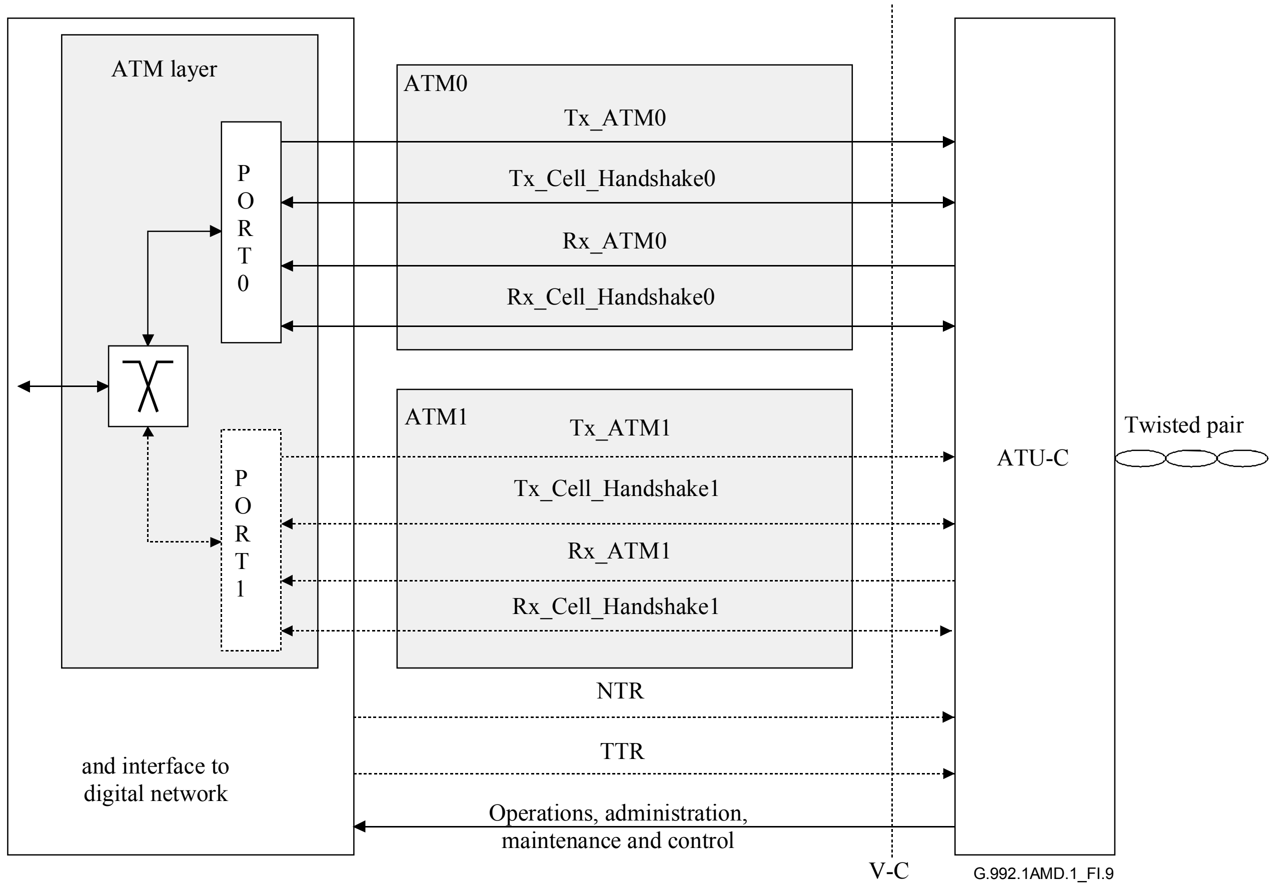
I.4.1.2 Payload transfer delay (supplements 7.1.4)

Since this annex uses a rate converter, the maximum payload transfer delay is longer than specified values in 7.1.4. The additional one-way transfer delay due to the rate converters shall be less than 1.7 ms for fast data and 13 ms for interleaved data.

I.4.2 ATM transmission protocols specific functionalities (pertains to 7.2)

I.4.2.1 ATU-C input and output V interface for ATM transport (replaces figure in 7.2.1)

See Figure I.9.



NOTE – TTR can be generated in the ATU-C without being provided from the V-C reference point.

Figure I.9/G.992.1 – ATU-C functional interfaces to the ATM layer at the V-C reference point

I.4.2.2 Payload transfer delay (supplements 7.2.2)

Since this annex uses a rate converter, the maximum payload transfer delay is longer than specified values in 7.2.2. The additional one-way transfer delay due to the rate converters shall be less than 1.7 ms for fast data and 13 ms for interleaved data.

I.4.3 Framing (pertains to 7.4)

I.4.3.1 Superframe structure (supplements 7.4.1.1)

Since the rate converter reorders the user data and overhead bit-level data to create hyperframes, the input data frames to the constellation encoder are different than those defined in 7.4.1.1.

I.4.3.2 Hyperframe structure (replaces 7.4.1.3)

This annex uses the hyperframe structure shown in Figure I.10. Figure I.10 shows the phase relationship between the TTR_C and the hyperframe at the point U-C. Each hyperframe is composed of 5 superframes, which are numbered from 0 to 4. In order to indicate the boundary of the hyperframe, the inverse synch symbol is used for the 4th superframe (SPF#3), which is generated from a tone-by-tone 180-degree phase reversal of the synchronization symbol (see I.4.7.1) except for the pilot tone.

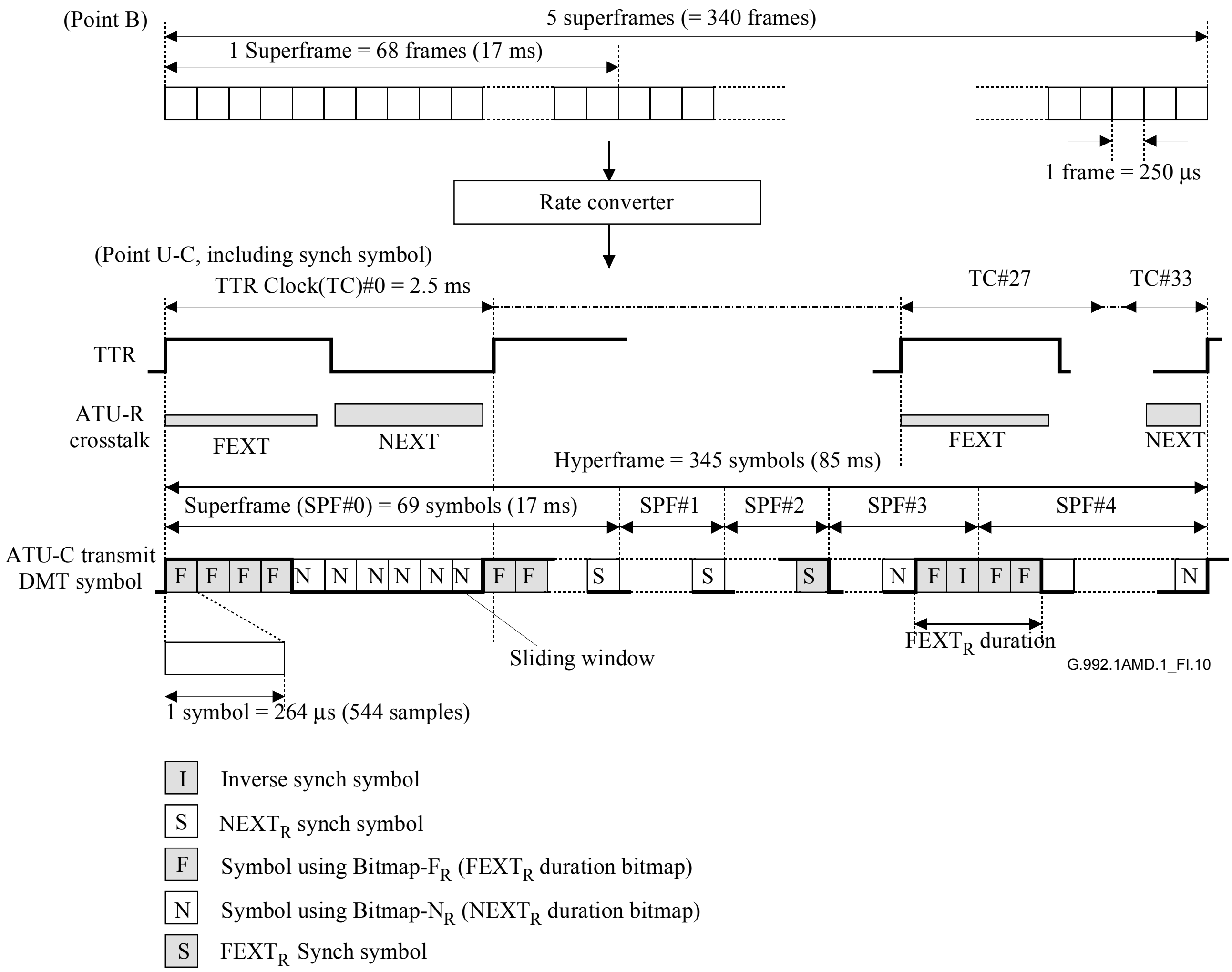


Figure I.10/G.992.1 – Hyperframe structure for downstream

The bit-level data stream from the rate-converter is extracted according to the size of Bitmap-F_R and Bitmap-N_R using the sliding window (see I.3.3.2).

In order to make the bit rate to be a multiple of 32 kbit/s, the dummy bits are inserted at the end of hyperframe by the rate converter (see I.4.4.2). The hyperframe is composed of 345 DMT symbols, numbered from 0 to 344. Each symbol is assigned as $FEXT_R$ or $NEXT_R$ symbol in a $FEXT_R$ or $NEXT_R$ duration (see I.2), and the following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to at ATU-C transmitter (see Figure I.11).

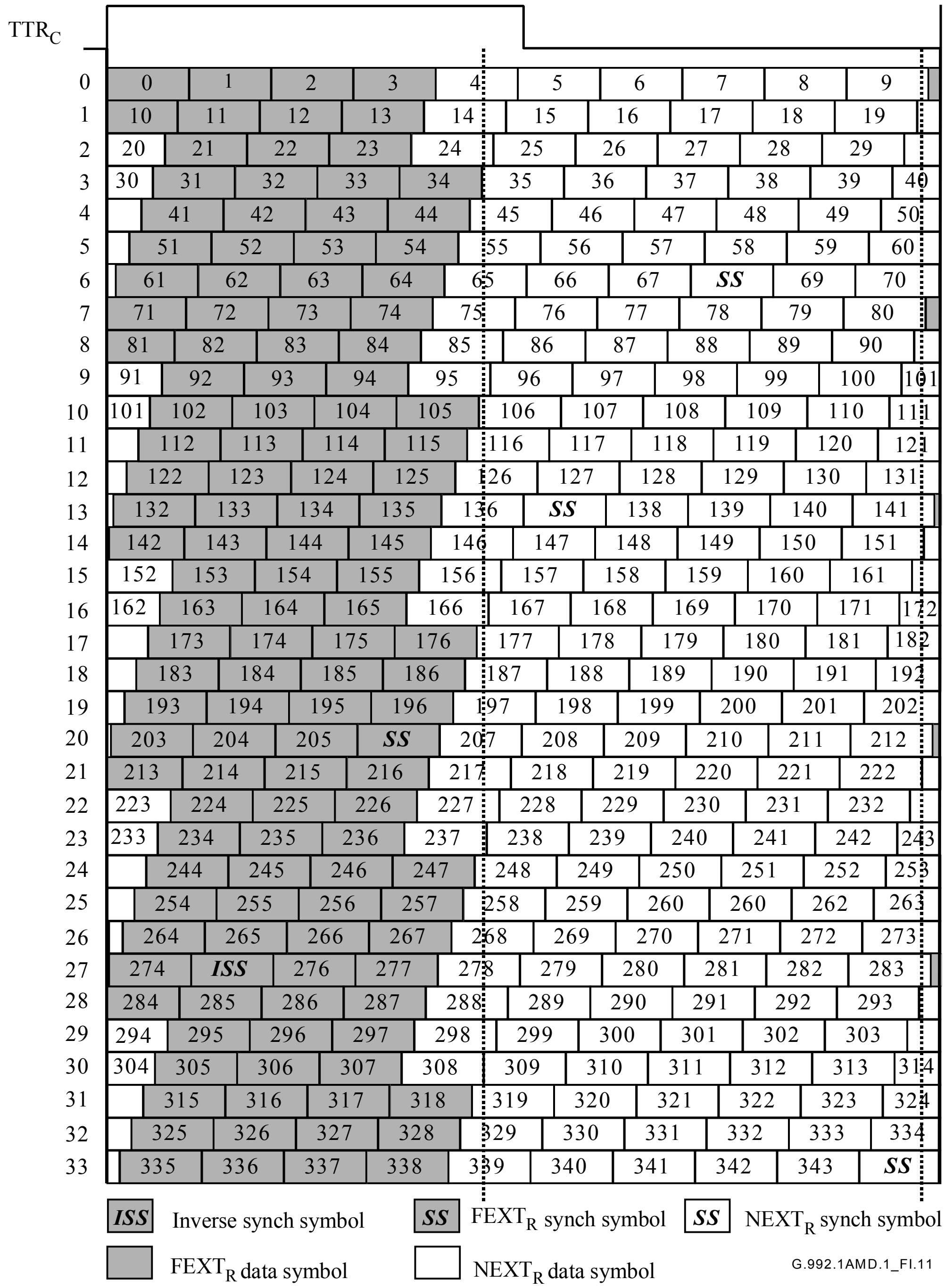


Figure I.11/G.992.1 – Symbol pattern in a hyperframe with cyclic prefix – Downstream

For $N_{dmt} = 0, 1, ..., 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { $(S + 271 < a)$ or $(S > a + b)$ } then FEXT$_R$ symbol

else then NEXT$_R$ symbol

where a = 1243, b = 1461.

Thus, 128 DMT symbols are allocated in the $FEXT_R$ duration, and 217 DMT symbols are allocated in the $NEXT_R$ duration. The symbols are composed of:

$FEXT_R$ symbol:

Number of symbol using Bitmap-F_R = 126

Number of synch symbol = 1

Number of inverse synch symbol = 1

$NEXT_R$ symbol:

Number of symbol using Bitmap-N_R = 214

Number of synch symbol = 3

During FEXT Bitmap mode, the ATU-C shall transmit only the pilot tone in $NEXT_R$ symbols.

I.4.3.3 Subframe structure (replaces 7.4.1.4)

A subframe is 10 consecutive DMT symbols (except for synch symbols) as shown in Table I.1. The 34 subframes form a hyperframe.

Table I.1/G.992.1 – Subframe (downstream)

Subframe No.	DMT symbol No.	Note
0	0-9	
1	10-19	
2	20-29	
3	30-39	
4	40-49	
5	50-59	
6	60-70	#68 is synch symbol
7	71-80	
8	81-90	
9	91-100	
10	101-110	
11	111-120	
12	121-130	
13	131-141	#137 is synch symbol
14	142-151	
15	152-161	
16	162-171	
17	172-181	
18	182-191	
19	192-201	
20	202-212	#206 is synch symbol
21	213-222	
22	223-232	
23	233-242	

Table I.1/G.992.1 – Subframe (downstream)

Subframe No.	DMT symbol No.	Note
24	243-252	
25	253-262	
26	263-272	
27	273-283	#275 is inverse synch symbol
28	284-293	
29	294-303	
30	304-313	
31	314-323	
32	324-333	
33	334-344	#344 is synch symbol

I.4.3.4 Reduced overhead framing with merged fast and sync bytes (modifies 7.4.3.2)

In S = 1/2n framing mode (see I.4.9), there are n sync bytes per symbol time. The contents of the sync bytes is the same as in regular framing except that it repeats at n times the rate causing the superframe to be 68/n symbols in length.

The contents of the sync bytes are shown in Table 7-6. In S = 1/2n framing mode, "Frame Number" in column 1 in Table 7-6 is replaced by "Sync Byte Index Number".

As a result of the increase in superframe rate, the superframe contents is carried more frequently. For the case when n = 2, the EOC and AOC bandwidth doubles, thereby transferring actual messages at twice the rate. The CRC byte is carried twice as frequently and therefore the maximum error rate rises from just over 58 per second to 117 per second. Where the duration of an error condition is measured, this needs to be taken into consideration. The indicator bits are also sent twice as often, which needs to be taken into consideration for statistics collection.

I.4.4 Dual bitmapping and rate conversion (replaces 7.15)

The functions of the rate converter (see I.4.4.2), tone ordering (see I.4.6), constellation encoding, and gain scaling shall use one of two bitmaps stored in the ATU. This method is called the Dual Bitmap.

I.4.4.1 Dual Bitmap (new)

The Dual Bitmap method has individual bit rates under the FEXT and NEXT noise, and this needs an additional bit and gain table, $\{b_i, g_i\}$, and ordered bit table, b'_i, for the tone ordering. The dual bitmaps are switched synchronized with the sliding window pattern of NEXT/FEXT symbols. The number of bits and the relative gains to be used for every tone are calculated in the bit loading algorithm during the initialization sequence, and transmitted in R-B&G.

I.4.4.2 Rate converter (new)

The rate converter buffering changes the data frame boundaries between the reference points B and C according to Bitmap-F_R, Bitmap-N_R and the sliding window. Two independent rate converters are prepared for fast data and interleaved data. The amount of fast and interleaved data in Bitmap-F_R and Bitmap-N_R shall be calculated with the following formulae and illustrated in Figure I.12:

If $t_{Rf} \le n_{R\max}$:

$$n_{Rf} = t_{Rf}$$

$$n_{Ri} = n_R - n_{Rf}$$

$$f_{Rf} = t_{Rf}$$

$$f_{Ri} = f_R - f_{Rf}$$

If $t_{Rf} > n_{R\max}$:

$$n_{Rf} = n_{R\max}$$

$$n_{Ri} = 0$$

$$f_{Rf} = \begin{cases} f_{Rf4} = \left\lceil \dfrac{t_{Rf} \times 10 - n_{Rf} \times 6}{4} \right\rceil \\ f_{Rf3} = \left\lceil \dfrac{t_{Rf} \times 10 - n_{Rf} \times 7}{3} \right\rceil \end{cases}$$

$$f_{Ri} = \begin{cases} f_{Ri4} = f_R = f_{Rf4} \\ f_{Ri3} = f_R - f_{Rf3} \end{cases}$$

where:

- t_{Rf} is the number of allocated bits in one frame for fast bytes at the reference point B;
- t_{Ri} is the number of allocated bits for interleaved bytes at the reference point B;
- f_{Rf} and n_{Rf} are the numbers of fast bits in Bitmap-F_R and Bitmap-N_R, respectively;
- f_{Rf3} is the number of fast bits in Bitmap-F_R if the subframe (see I.4.3.3) contains 3 Bitmap-F_R except for synch symbols;
- f_{Rf4} is the number of fast bits in Bitmap-F_R if the subframe contains 4 Bitmap-F_R except for synch symbols;
- f_{Ri} and n_{Ri} are the numbers of interleaved bits in Bitmap-F_R and Bitmap-N_R, respectively;
- n_R is the number of total bits in Bitmap-N_R, which is specified in the B&G tables.

During FEXT Bitmap mode, n_{Rf} and n_{Ri} are zero.

To convert the bit rate to be a multiple of 32 kbit/s, the dummy bits for fast data are inserted to the tail of each subframe, and the dummy bits for interleaved data are inserted to the end of the Hyperframe. The number of the dummy bits shall be as follows:

If $t_{Rf} \leq n_{R\max}$:

$$dummy_{Rf} = 0$$

$$dummy_{Ri} = (f_{Ri} \times 126 + n_{Ri} \times 214) - t_{Ri} \times 340$$

If $t_{Rf} > n_{R\max}$:

$$dummy_{Rf4} = (f_{Rf} \times 4 + n_{Rf} \times 6) - t_{Rf} \times 10$$

$$dummy_{Rf3} = (f_{Rf} \times 3 + n_{Rf} \times 7) - t_{Rf} \times 10$$

$$dummy_{Ri} = (f_{Ri4} \times 96 + f_{Ri3} \times 30) - t_{Ri} \times 340$$

If the fast data buffer uses single latency only, additional dummy bits are inserted at the tail of each FEXT symbol in the 4 Bitmap-F_R constructed subframe. The number of additional dummy bits inserted at the tail of each FEXT symbol shall be as follows:

$$dummy_{SRf} = f_{Rf3} - f_{Rf4}$$

The receiver shall determine Bitmap-F_R and Bitmap-N_R so that $dummy_{Ri}$ is less than 126, $dummy_{Rf4}$ is less than 4 and $dummy_{Rf3}$ is less than 3 in the initialization sequence. At the receiver, the inserted dummy bits shall be removed.

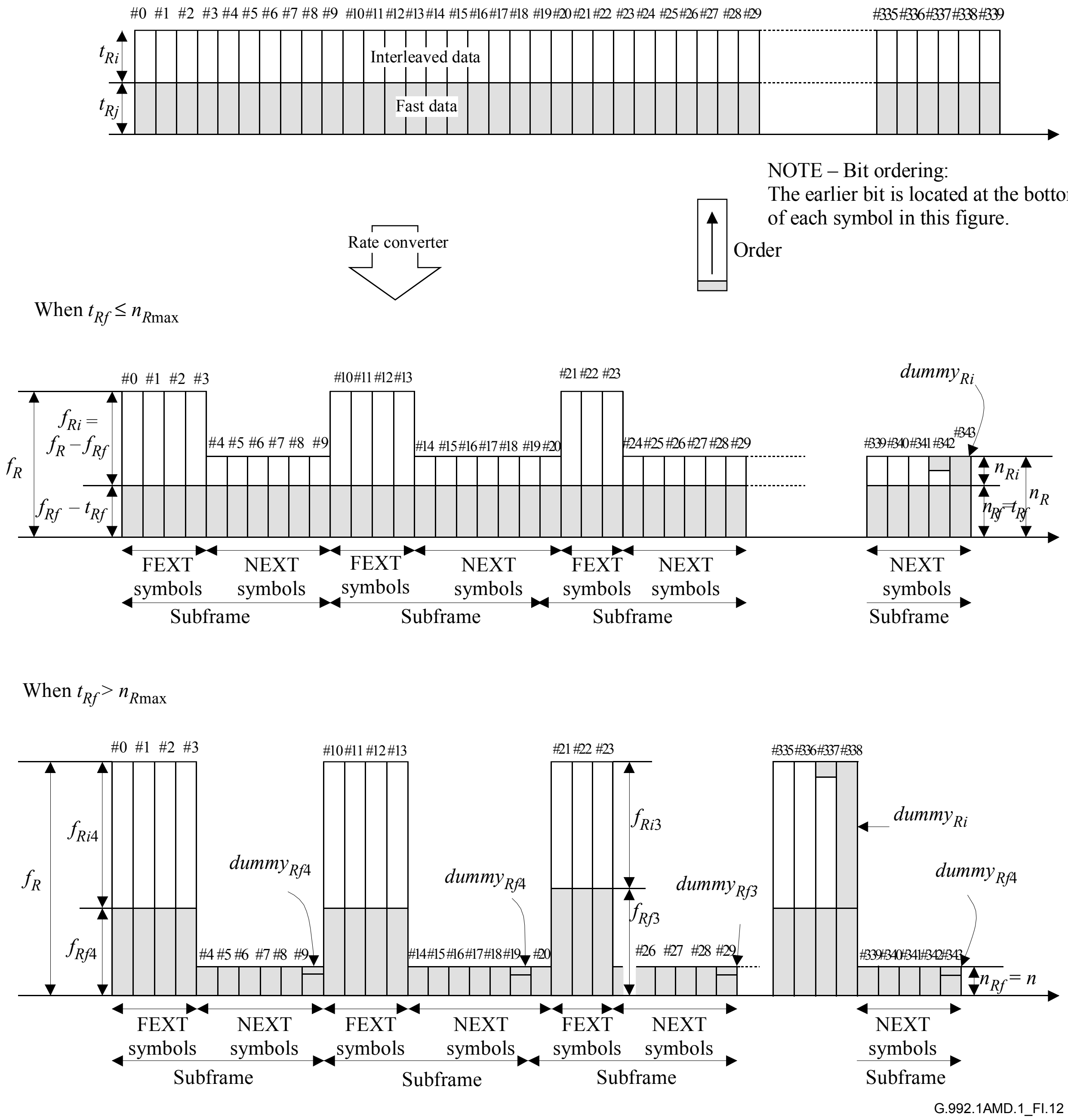


Figure I.12/G.992.1 – Bit distribution for rate converter under dual latency and Dual Bitmap mode

I.4.5 FEXT Bitmapping (replaces 7.16)

The FEXT Bitmapping mode uses the Dual Bitmapping technique (I.4.4) to transmit data only during FEXT. The ATU-C shall transmit only the pilot tone during the $NEXT_R$ symbol. The ATU-R disables Bitmap-N_C and shall not transmit any signal during the $NEXT_C$ symbol (see Figures I.10 and I.17).

The Dual versus FEXT bitmapping mode is selected during G.994.1 using bit "DBM" (see 10.2 and 10.3).

I.4.6 Tone ordering (replacement for 7.7)

A DMT time-domain signal has a high peak-to-average ratio (its amplitude distribution is almost Gaussian), and large values may be clipped by the digital-to-analogue converter. The error signal caused by clipping can be considered as an additive negative impulse for the time sample that was clipped. The clipping error power is almost equally distributed across all tones in the symbol in which clipping occurs. Clipping is therefore most likely to cause errors on those tones that, in anticipation of a higher received SNR, have been assigned the largest number of bits (and therefore have the densest constellations). These occasional errors can be reliably corrected by the FEC coding if the tones with the largest number of bits have been assigned to the interleave buffer.

The numbers of bits and the relative gains in two bitmaps to be used for every tone are calculated in ATU-R receiver, and sent back to ATU-C according to a defined protocol (see 10.9.14). The pairs of numbers are typically stored, in ascending order of frequency or tone numbers i, in bit and gain tables for Bitmap-F_R and Bitmap-N_R.

For Bitmap-F_R, the "tone-ordered" encoding shall first assign f_{Rf} bits from the rate converter (see I.4.4.2) to the tones with the smallest number of bits assigned to them, and the remaining f_{Ri} bits to the remaining tones. For Bitmap-N_R, it shall first assign n_{Rf} bits from the rate converter to the tones with the smallest number of bits assigned to them, and the remaining n_{Ri} bits to the remaining tones.

All tones shall be encoded with the number of bits assigned to them; one tone in each bitmap may therefore have a mixture of bits from the fast and interleaved buffers.

The ordered bit tables b'_{iF} and b'_{iN} shall be based on the original bit tables b_{iF} and b_{iN} as follows:

For $k = 0$ to 15 {

From the bit table, find the set of all i with the number of bits per tone $b_i = k$

Assign b_i to the ordered bit allocation table in ascending order of i

}

Two ordered bit tables for Bitmap-F_R and Bitmap-N_R shall be prepared. A complementary de-ordering procedure should be performed in ATU-R receiver. It is not necessary, however, to send the results of the ordering process to the receiver because the bit tables F_R and N_R were originally generated in ATU-R, and therefore those tables have all the information necessary to perform the de-ordering.

I.4.7 Modulation (pertains to 7.11)

I.4.7.1 Inverse synchronization symbol (replaces 7.11.4)

Except for the pilot tone, inverse synchronization symbol shall be generated from a tone-by-tone 180 degree phase reversal of synchronization symbol (i.e., + maps to –, and – maps to +, for each of the 4-QAM signal constellation).

I.4.7.2 Data subcarriers (modifies 7.11.1.1)

The channel analysis signal defined in 10.6.6 allows for a maximum of NSC – 1 carriers (at frequencies $n\Delta f$, $n = 1$ to NSC – 1) to be used.

I.4.7.3 Nyquist frequency (modifies 7.11.1.3)

The carrier at the Nyquist frequency (#NSC) shall not be used for user data and shall be real valued; other possible uses are for further study.

I.4.7.4 Modulation by the inverse discrete Fourier transform (replaces 7.11.2)

The modulating transform defines the relationship between the 2 × NSC real values x_n and the Z_i:

$$x_n = \sum_{i=0}^{2\times NSC-1} \exp\left(\frac{j\pi ni}{NSC}\right) Z_i \qquad \text{for } n = 0 \text{ to } 2\times\text{NSC}-1 \qquad (7\text{-}21)$$

The value of NSC shall be 512 for this annex.

The constellation encoder and gain scaling generate only NSC – 1 complex values of Z_i. In order to generate real values of x_n, the input values (NSC – 1 complex values plus zero at DC and one real value for Nyquist if used) shall be augmented so that the vector Z has Hermitian symmetry. That is:

$$Z_i = \text{conj}\left(Z'_{2\times NSC-i}\right) \quad \text{for } i = \text{NSC}+1 \text{ to } 2\times\text{NSC}-1 \tag{7-22}$$

I.4.7.5 Synchronization symbol (modifies 7.11.3)

The synchronization symbol permits recovery of the frame boundary after micro-interruptions that might otherwise force retraining.

The data symbol rate, f_{symb} = 4 kHz, the carrier separation, Δf = 4.3125 kHz, and the IDFT size, N = 2 × NSC, are such that a cyclic prefix of 15.625% × NSC samples could be used. That is, when NSC = 256, there are 40 samples in the cyclic prefix.

$$(512+40)\times 4.0 = 512\times 4.3125 = 2208 \tag{7-23}$$

The cyclic prefix shall, however, be shortened to 12.5% × NSC samples, and a synchronization symbol (with a nominal length of NSC × 2.125 samples) is inserted after every 68 data symbols. That is:

$$(2+0.125)\times NSC\times 69 = (2+0.15625)\times NSC\times 68 \tag{7-24}$$

The data pattern used in the synchronization symbol shall be the pseudo-random sequence PRD, (d_n, for n = 1 to 2 × NSC) defined by:

$$d_n = 1 \qquad \text{for } n = 1 \text{ to } 9 \tag{7-25}$$

$$d_n = d_{n-4} \oplus d_{n-9} \qquad \text{for } n = 10 \text{ to } 2\times\text{NSC} \tag{7-26}$$

The first pair of bits (d_1 and d_2) shall be used for the DC and Nyquist subcarriers (the power assigned to them is zero, so the bits are effectively ignored); the first and second bits of subsequent pairs are then used to define the X_i and Y_i for i = 1 to NSC – 1 as shown in Table 7-13.

The period of the PRD is only 511 bits, so d_{n+511} is equal to d_n. The d_1-d_9 shall be re-initialized for each synchronization symbol, so each symbol uses the same data.

The two bits that modulate the pilot carrier, shall be overwritten by {0,0}: generating the {+,+} constellation.

The minimum set of subcarriers to be used is the set used for data transmission (i.e., those for which $b_i > 0$); subcarriers for which $b_i = 0$ may be used at a reduced PSD as defined in transmit PSD paragraphs of Annexes A, B and C. The data modulated onto each subcarrier shall be as defined above; it shall not depend on which subcarriers are used.

I.4.7.6 Cyclic prefix (replaces 7.12)

The last 12.5% × NSC samples of the output of the IDFT (x_n for n = 2 × NSC – 0.125 × NSC to 2 × NSC – 1) shall be prepended to the block of 2 × NSC samples and read out to the digital-to-analogue converter (DAC) in sequence. For example, when NSC = 256, the subscripts, n, of the DAC samples in sequence are 480 ... 511, 0 ... 511.

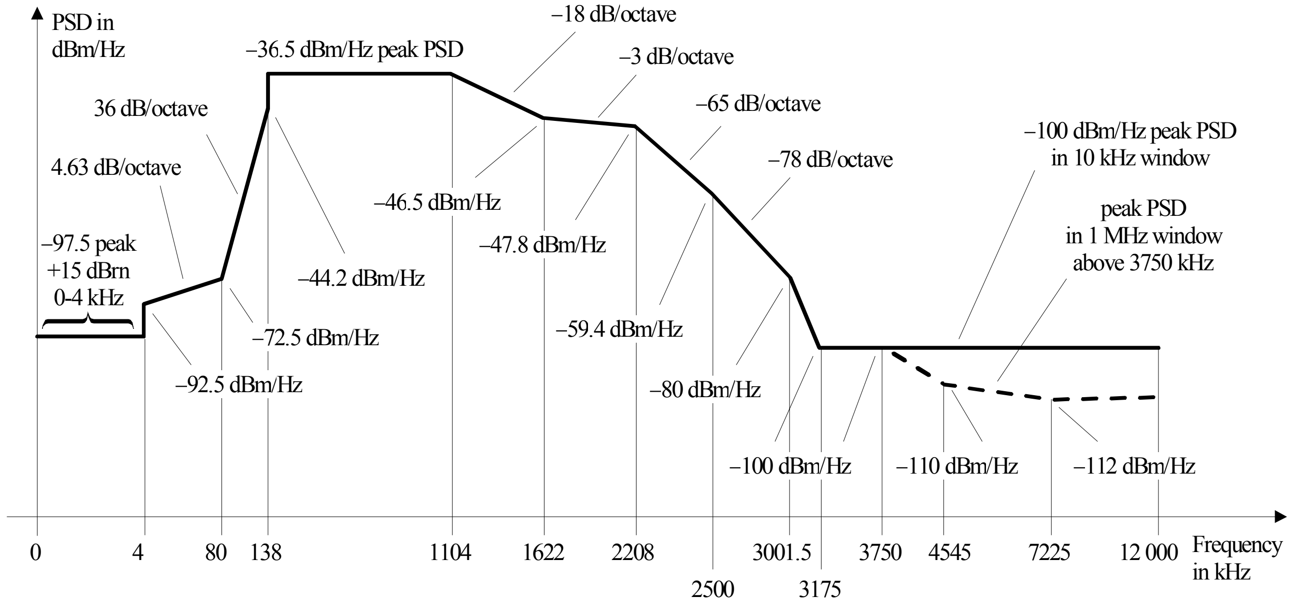
The cyclic prefix shall be used for all symbols beginning with the C-RATES1 segment of the initialization sequence, as defined in 10.6.2.

I.4.8 ATU-C Downstream transmit spectral mask (replaces 7.14)

The downstream spectral mask of this annex is as specified in this clause. When C-MSG1 bit 16 is 0, the PSD mask as specified in I.4.8.1 shall be used. When C-MSG1 bit 16 is 1, the PSD mask as specified in I.4.8.2 shall be used.

I.4.8.1 Downstream non-overlapped PSD mask definition

The non-overlapped PSD mask is defined with absolute peak values in Figure I.13. The low-frequency stop band is defined for frequencies below 138 kHz (tone 32); the high-frequency stop band is defined at frequencies greater than 2208 kHz (tone 512). The in-band region of this PSD mask is the frequency band from 138 kHz to 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	Measurement Bandwidth
0	–97.5	100 Hz
4	–97.5	100 Hz
4	–92.5	100 Hz
10	interpolated	10 kHz
80	–72.5	10 kHz
138	–44.2	10 kHz
138	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12 000	–100	10 kHz

Additionally, the PSD mask shall be satisfying following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	Measurement Bandwidth
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12 000	–112	1 MHz

G.992.1AMD.1_FI.13

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the Measurement Bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [f, f + 1 MHz] window shall conform to the specification at frequency f.

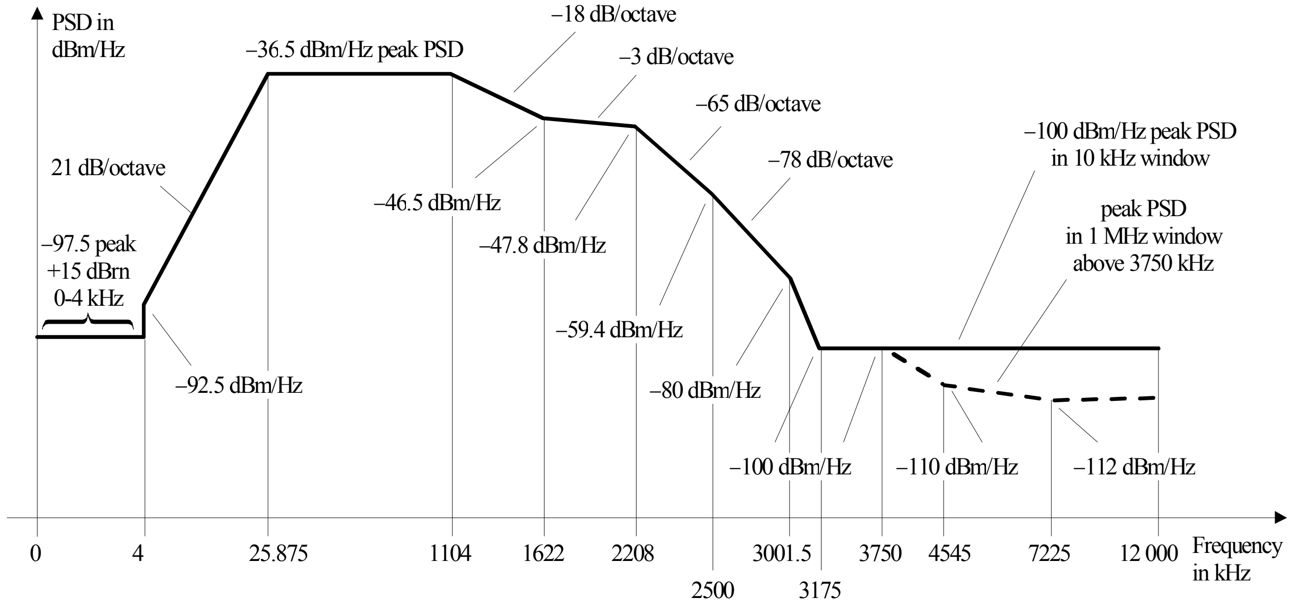
NOTE 5 – The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.

NOTE 6 – All PSD and power measurements shall be made at the U-C interface.

Figure I.13/G.992.1 – Non-overlapped downstream channel PSD mask

I.4.8.2 Downstream overlapped PSD mask definition

The overlapped PSD mask is defined with absolute peak values in Figure I.14. The low-frequency stop band is defined for frequencies below 25.875 kHz (tone 6); the high-frequency stop band is defined at frequencies greater than 2208 kHz (tone 512). The in-band region of this PSD mask is the frequency band from 25.875 kHz to 2208 kHz.



Frequency (kHz)	PSD level (dBm/Hz)	Measurement Bandwidth
0	–97.5	100 Hz
4	–97.5	100 Hz
4	–92.5	100 Hz
10	interpolated	10 kHz
25.875	–36.5	10 kHz
1104	–36.5	10 kHz
1622	–46.5	10 kHz
2208	–47.8	10 kHz
2500	–59.4	10 kHz
3001.5	–80	10 kHz
3175	–100	10 kHz
12 000	–100	10 kHz

Additionally, the PSD mask shall be satisfying following requirements:

Frequency (kHz)	PSD level (dBm/Hz)	Measurement Bandwidth
3750	–100	1 MHz
4545	–110	1 MHz
7225	–112	1 MHz
12 000	–112	1 MHz

G.992.1AMD.1_FI.14

NOTE 1 – All PSD measurements are in 100 Ω; the POTS band total power measurement is in 600 Ω.

NOTE 2 – The breakpoint frequencies and PSD values are exact; the indicated slopes are approximate. The breakpoints in the tables shall be connected by linear straight lines on a dB/log(*f*) plot.

NOTE 3 – MBW specifies the Measurement Bandwidth. The MBW specified for a certain breakpoint with frequency f_i is applicable for all frequencies satisfying $f_i < f \leq f_j$, where f_j is the frequency of the next specified breakpoint.

NOTE 4 – The power in a 1 MHz sliding window is measured in a 1 MHz bandwidth, starting at the measurement frequency, i.e., power in the [f, f + 1 MHz] window shall conform to the specification at frequency f.

NOTE 5 – The step in the PSD mask at 4 kHz is to protect V.90 performance. Originally, the PSD mask continued the 21 dB/octave slope below 4 kHz hitting a floor of –97.5 dBm/Hz at 3400 Hz. It was recognized that this might impact V.90 performance, and so the floor was extended to 4 kHz.

NOTE 6 – All PSD and power measurements shall be made at the U-C interface.

Figure I.14/G.992.1 – Overlapped downstream channel PSD mask

I.4.8.3 Spectral shaping of in-band region of PSD spectrum

In order to shape the ATU-C PSD, frequency dependent gains, called spectral shaping values (ssv_i), shall be applied on each tones during initialization and showtime. The ssv_i values shall be represented with 1 bit before and 10 bits after the decimal point.

Table I.2 defines the corner points defining the nominal PSD shape of the inband region as gain in dB, i.e., log_ssv_i. Log_ssv_i on other tones shall be linearly interpolated between corner points on a logarithmic scale for the gain (dB) and a linear scale for the frequency (Hz). Note that the corner points defined in Table I.2 are relative values. Table I.3 defines the similar corner points for the overlapped spectrum.

Table I.2/G.992.1 – Corner points for the non-overlapped nominal in-band PSD shape

Tone index	Log_ssv_i (dB)	Comments
32	0	138 kHz defines the beginning of the inband region. No shaping is applied in the low stop band.
255	0	1104 kHz
376	–10	1622 kHz (–10 = –50 – Nominal_PSD_lowband)
511	–11.3	2208 kHz (–11.3 = –51.3 – Nominal_PSD_lowband)

Table I.3/G.992.1 – Corner points for the overlapped nominal in-band PSD shape

Tone index	Log_ssv_i (dB)	Comments
6	0	25.875 kHz defines the beginning of the inband region. No shaping is applied in the low stop band.
255	0	1104 kHz
376	–10	1622 kHz (–10 = –50 – Nominal_PSD_lowband)
511	–11.3	2208 kHz (–11.3 = –51.3 – Nominal_PSD_lowband)

The spectral shaping values shall be converted from logarithmic scale (log_ssv_i, dB values) to linear ssv_i values according to:

$$ssv_i = \frac{Round\left(1024 \times 10^{\frac{\log\_ssv_i}{20}}\right)}{1024}$$

These points are not passed at initialization but are provided here for reference.

The combined accuracy of the process of linear interpolation of the log_ssv_i values and the process of conversion to linear ssv_i values shall be strictly less than one half lsb of the 10 bits after the decimal point format of the linear ssv_i values. No error shall be introduced when log_ssv_i equals 0 dB or is interpolated between log_ssv_i values, which equal 0 dB.

NOTE 1 –The above definition ensures that the maximum deviation between ssv_i values used by transmitter and receiver is 1 lsb.

NOTE 2 – The above needs an accuracy that is strictly <1/2 lsb. An accuracy of =1/2 lsb, will lead to inaccurate results.

The absolute values of the transmit PSD are obtained by scaling the relative shaping values with a NOMINAL_PSD_lowband, defined for the lower in-band frequencies. Note that the nominal in-band transmit PSD is frequency dependent. The NOMINAL_PSD_lowband is –40 dBm/Hz for both the overlapped and non-overlapped spectra.

NOTE 3 – In-band PSD spectral shaping is applied prior to the IFFT.

NOTE 4 – The value of MAXNOMATPds may be limited by regional regulations.

I.4.8.4 Transmit signals with limited transmit power

For cases where the transmit signal must be limited to a maximum aggregate total power (e.g., ATP_{dsmax} = +20 dBm), then

a) During initialization the PSD transmit level is specified as an offset from the nominal value, i.e., (Nominal_PSD_lowband + $ssv_i - x$ – power cutback) dB, and all values of $g_i = 1$ for the offset value x and power cutback. The same value of offset x is used for both overlapped and non-overlapped cases. The value of x shall be the greater of 0 dB and (21.3 – ATP_{dsmax}) dB. For ATP_{dsmax} = 20 dBm, the corresponding value of x shall be 1.3 dB.

b) If $b_i > 0$, then valid range for g_i is [–14.5 to + 2.5 + x] (dB);

   If $b_i < 0$, then g_i shall be in the [g_{sync} – 2.5 to g_{sync} + 2.5] (dB) range;

   If $b_i = 0$, then g_i shall be equal to 0 (linear) or in the [–14.5 to g_{sync}] (dB) range;

   For Annex I, $g_{sync} \le x$ dB.

The g_i values shall be constrainted by following relation:

Constraint on g_i values	$\sum_{i=6}^{511} ssv_i^2 \times g_i^2 \le \sum_{i=6}^{511} ssv_i^2$

I.4.8.5 Alternative flat-shaped spectrum

On short loops that would normally require a substantial amount of power cutback, the flat PSD spectrum may be used to better utilize the capacity in the higher frequency bins. Tables I.4 and I.5 define the ssv_i values for the flat shaped non-overlapped and overlapped PSDs.

Table I.4/G.992.1 – Corner points for the flat non-overlapped nominal in-band PSD shape

Tone index	Log_ssv_i (dB)	Comments
32	11.3	138 kHz defines the beginning of the inband region. No shaping is applied throughout the passband.
511	11.3	2208 kHz

Table I.5/G.992.1 – Corner points for the flat overlapped nominal in-band PSD shape

Tone index	Log_ssv_i (dB)	Comments
6	11.3	25 kHz defines the beginning of the inband region. No shaping is applied throughout the passband.
511	11.3	2208 kHz

The specification of power cutback for this spectral shape is for further study.

I.4.8.6 Egress control

G.992.1 Annex I equipment shall be able to reduce the PSD below –80 dBm/Hz for the Amateur radio band between 1.81 MHz and 2.00 MHz.

I.4.8.7 ATU-C selectable downstream inband spectral shaping (supplements I.4.8.3)

As an optional extension to the fixed downstream inband spectral shape defined in I.4.8.3 by Tables I.2 (non-overlapped spectrum) and I.3 (overlapped spectrum), an ATU-C may specify a downstream inband spectral shape by passing subcarrier indices and Log_ssv_i values to the ATU-R in a G.994.1 CL message.

The optional downstream inband spectral shaping parameters are defined in I.7.2 and I.7.3. If the spectrum shaping downstream Spar(2) bit is set to ONE in a CL message, the associated subcarrier index and Log_ssv_i Npar(3) parameters define an inband spectral shape.

An ATU-C (ATU-R) may indicate support for this option by setting the spectrum shaping downstream #3 (ATU-C selected ssv_i) Npar(2) bit to ONE in a CL (CLR) message.

The ATU-C (ATU-R) shall select the downstream inband spectral shape to be used by setting one of the spectrum shaping downstream #n Npar(2) bits in an MS message. If no CLR/CL exchange transaction is included in the G.994.1 session, and spectrum shaping downstream #3 (ATU-C selected ssv_i) is selected, the spectrum shaping indicated in the last previous CLR/CL exchange shall apply.

The spectral shaping for each subcarrier i (ssv_i) shall be defined as a function of the frequency breakpoints and spectral scalings exchanged during G.994.1 for all sub-carriers, index 1 to $2 \times \text{NSC} - 1$, as:

– the spectral shaping (log_ssv_i, dB value) of the lowest breakpoint frequency if the subcarrier is below the lowest breakpoint frequency (i.e., flat extension to lower frequencies);

– the spectral shaping (log_ssv_i, dB value) of the highest breakpoint frequency if the subcarrier is above the highest breakpoint frequency (i.e., flat extension to higher frequencies);

– otherwise interpolated between spectral shaping of the lower and higher breakpoint frequency with linear relationship between the spectral shaping (log_ssv_i, dB value) and linear frequencies (Hz) (i.e., interpolation with constant dB/Hz slope).

I.4.9 Support of higher downstream bit rates with optional S = 1/2n (replaces 7.6.4)

With a rate of 4000 data frames per second and a maximum of 255 bytes (maximum RS codeword size) per data frame, the ADSL downstream line rate is limited to approximately 8 Mbit/s per latency path. The line rate limit can be increased beyond this for the interleaved path by mapping 2n RS codewords into one FEC data frame (i.e., by using S = 1/2n in the interleaved path). S = 1/2n shall be used in the downstream direction only over bearer channel AS0.

For a selected value of $n \geq 1$, the K_I data bytes per interleaved mux data frame shall be packed into 2n RS codewords, split into n equal parts, each consisting of 2 consecutive RS codewords. This forces rate adaptation to occur in 32n kbit/s increments. Each of the n parts of the data frame shall begin with a sync byte and shall obey the rules defined in Table I.6 for insertion of dummy bytes. The smallest value of n that can support the K_I data bytes shall be used.

Support of S = 1/2 (i.e., n = 1) is mandatory, and S = 1/4 (i.e., n = 2) is optional.

The resulting data frame structure shall be as shown in Figure I.15.

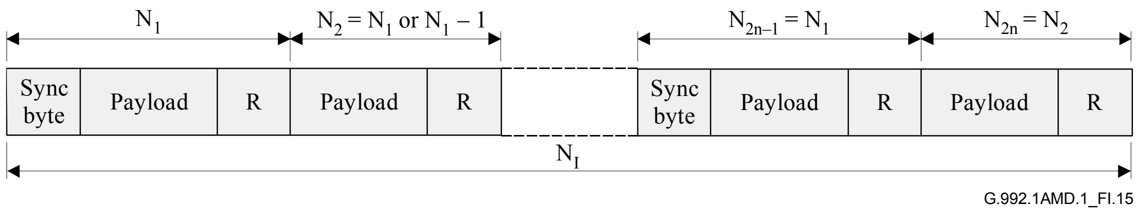


Figure I.15/G.992.1 – Data frame for *S* = 1/2n mode

When K_I is divisible by 2n, the 2n codewords have the same length $N_{2i-1} = N_{2i} = (K_I/2n + R_I)$ for i = 1 to n, otherwise the odd-numbered codewords are equal and are one byte longer than the even-numbered codewords, i.e., $N_{2i-1} = (K_I + n)/2n + R_I$ bytes, and $N_{2i} = (K_I - n)/2n + R_I$ bytes for i = 1 to n. For the FEC output data frame, $N_I = \sum_{i=1}^{n} Ni$, with $N_I < 512n - 1$ bytes.

The convolutional interleaver requires all codewords to have the same odd length. To achieve the odd codeword length, insertion of dummy (not transmitted) bytes may be required. For *S* = 1/2n, the dummy byte addition to the odd-numbered and/or even-numbered codewords at the input of the interleaver shall be as in Table I.6.

Table I.6/G.992.1 – Dummy byte insertion at interleaver input for *S* = 1/2n

N_{2i-1}	N_{2i}	Dummy byte insertion action
Odd	Odd	No action
Even	Even	Add one dummy byte at the beginning of all codewords
Odd	Even	Add one dummy byte at the beginning of each even numbered codeword
Even	Odd	Add one dummy byte at the beginning of each odd-numbered codeword and two dummy bytes at the beginning of each even-numbered codeword [the de-interleaver shall insert one dummy byte into the de-interleaver matrix on the first byte and the (D + 1) th byte of the corresponding codeword to make the addressing work properly]

I.4.10 Support of higher downstream bit rates with optional *S* = 1/3 (new)

Figure I.16 shows the Mux Data Frame structure for an optional *S* = 1/3 framing mode. As shown in the figure, the codeword sizes for this framing mode are restricted to being of equal length N. The corresponding data rate using *S* = 1/3 is represented by 32 × (3N – 1) kbit/s, where N may take on integer values from 171 to 255. With the restriction of equal codeword lengths in this optional *S* = 1/3 mode, the bit rate step size is 96 kbit/s, for bit rates operating in the range of approximately 16 Mbit/s to 24 Mbit/s. The overhead for this frame structure is 32 kbit/s.

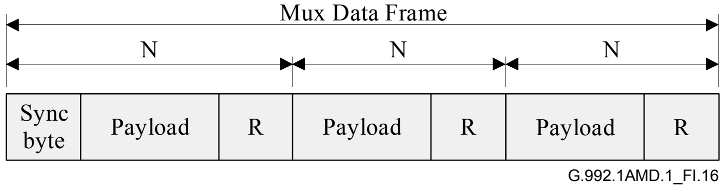


Figure I.16/G.992.1 – Mux data frame structure for optional *S* = 1/3 framing mode

I.5 ATU-R functional characteristics (pertains to clause 8)

I.5.1 Framing (pertains to 8.4)

I.5.1.1 Superframe structure (replaces 8.4.1.1)

The superframe structure of ATU-R transmitter is identical to that of ATU-C transmitter, as specified in I.4.3.1.

I.5.1.2 Hyperframe structure (replaces 8.4.1.3)

The hyperframe structure of ATU-R transmitter is functionally similar to that of ATU-C transmitter, except that the inverse synch symbol is used in the 1st superframe (SPF#0) (see Figure I.17). The hyperframe is composed of 345 DMT symbols, numbered from 0 to 344. Each symbol is under $FEXT_C$ or $NEXT_C$ duration (see I.5.3), and the following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to at ATU-R transmitter (see Figure I.18).

For $N_{dmt} = 0, 1, \ldots, 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { (S > a) and (S + 271 < a + b) } then $FEXT_C$ symbol

else then $NEXT_C$ symbol

where a = 1315, b = 1293.

128 DMT symbols are allocated in the $FEXT_C$ duration, and 217 DMT symbols are allocated in the $NEXT_C$ duration. The symbols are composed of:

$FEXT_C$ symbol:

- Number of symbol using Bitmap-F_C = 126
- Number of synch symbol = 1
- Number of inverse synch symbol = 1

$NEXT_C$ symbol:

- Number of symbol using Bitmap-N_C = 214
- Number of synch symbol = 3

During FEXT Bitmapping mode, the ATU-R shall not transmit any signal.

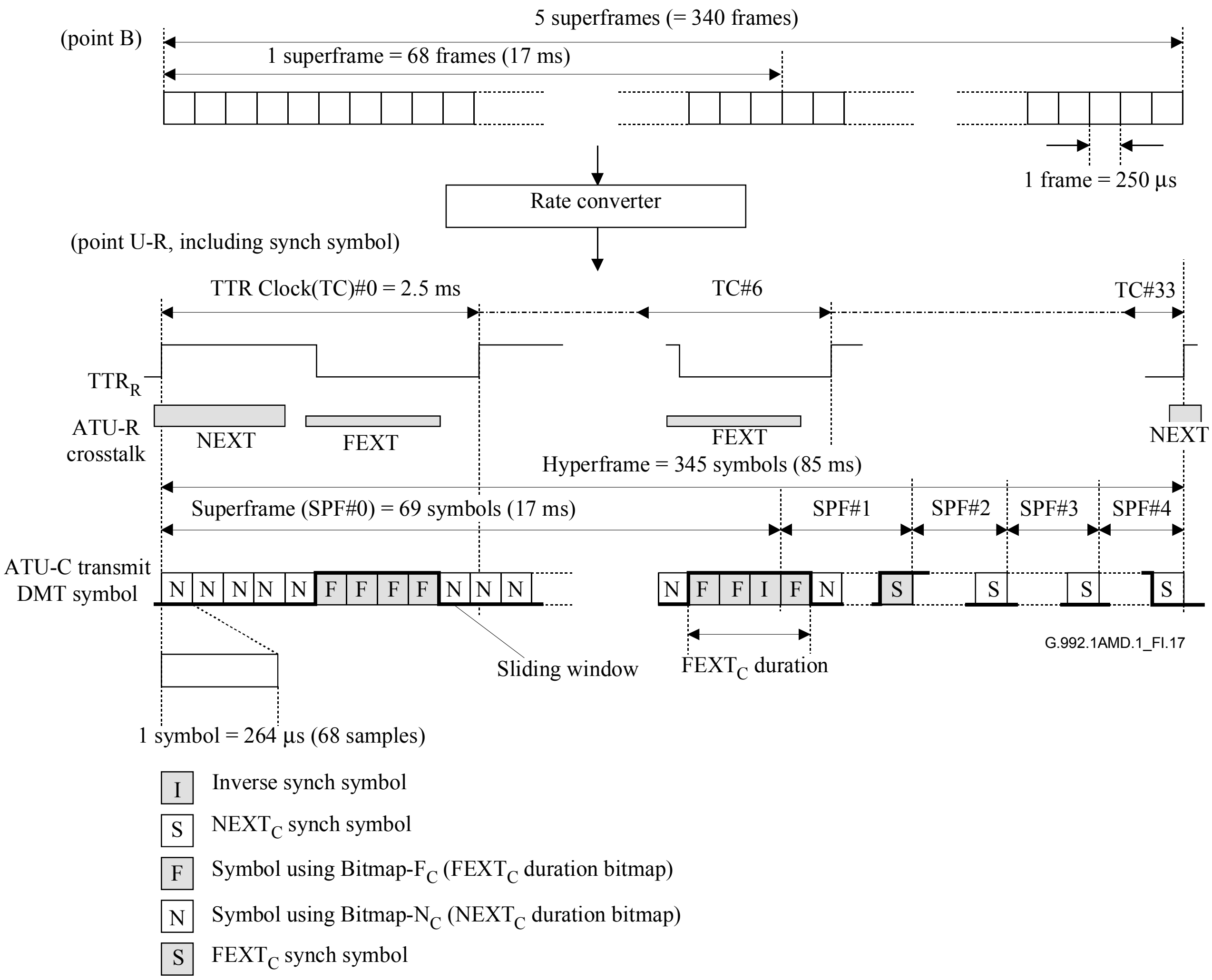


Figure I.17/G.992.1 – Hyperframe structure for upstream

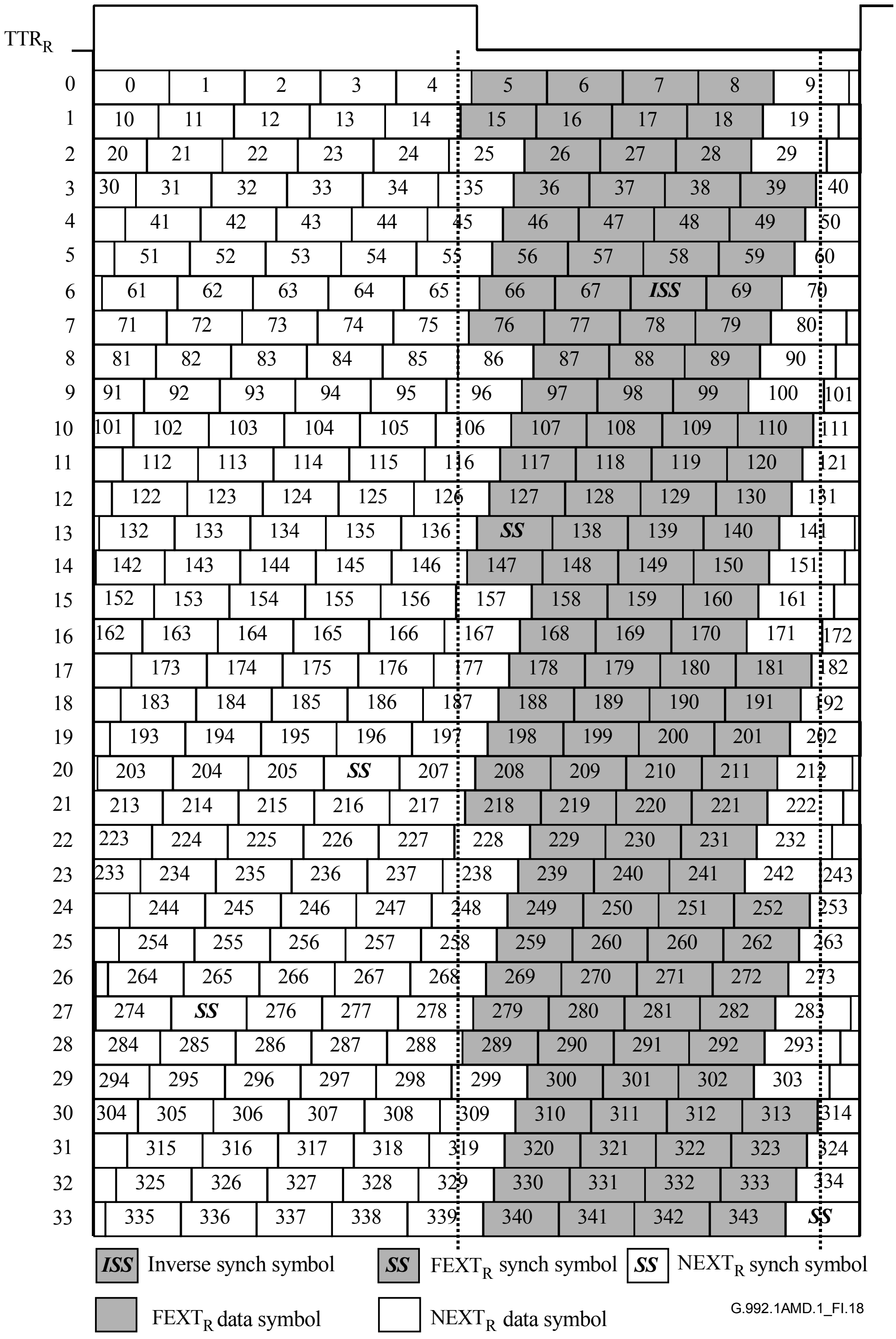


Figure I.18/G.992.1 – Symbol pattern in a hyperframe with cyclic prefix – Upstream

I.5.1.3 Subframe structure (replaces 8.4.1.4)

A subframe is 10 consecutive DMT symbols (except for synch symbols) as shown in Table I.7. The 34 subframes form a hyperframe.

Table I.7/G.992.1 – Subframe (upstream)

Subframe No.	DMT symbol No.	Note
0	0-9	
1	10-19	
2	20-29	
3	30-39	
4	40-49	
5	50-59	
6	60-70	#68 is inverse synch symbol
7	71-80	
8	81-90	
9	91-100	
10	101-110	
11	111-120	
12	121-130	
13	131-141	#137 is synch symbol
14	142-151	
15	152-161	
16	162-171	
17	172-181	
18	182-191	
19	192-201	
20	202-212	#206 is synch symbol
21	213-222	
22	223-232	
23	233-242	
24	243-252	
25	253-262	
26	263-272	
27	273-283	#275 is synch symbol
28	284-293	
29	294-303	
30	304-313	
31	314-323	
32	324-333	
33	334-344	#344 is synch symbol

I.5.2 Dual bitmapping and rate conversion (replaces 8.15)

The function of the rate converter (see I.5.2.2), tone ordering (see I.5.4), constellation encoding and gain scaling shall use one of two bitmaps stored in the ATU. This method is called the Dual Bitmap.

I.5.2.1 Dual Bitmap (new)

The Dual Bitmap switching shall be the same as for the downstream data, specified in I.4.4.1. The number of bits and the relative gains to be used for every tone are calculated in the bit loading algorithm during the initialization sequence, and transmitted in C-B&G.

I.5.2.2 Rate converter (new)

The rate converter buffering changes the data frame boundaries between the reference points B and C according to Bitmap-F_C, Bitmap-N_C and the sliding window. Two independent rate converters are prepared for fast data and interleaved data. The amounts of fast and interleaved data in Bitmap-F_C and Bitmap-N_C shall be calculated in the following formulae:

If $t_{Cf} \leq n_{C\max}$:

$$n_{Cf} = t_{Cf}$$

$$n_{Ci} = n_C - n_{Cf}$$

$$f_{Cf} = t_{Cf}$$

$$f_{Ci} = f_C - f_{Cf}$$

If $t_{Cf} > n_{C\max}$:

$$n_{Cf} = n_{C\max}$$

$$n_{Ci} = 0$$

$$f_{Cf} = \begin{cases} f_{Cf4} = \left\lceil \dfrac{t_{Cf} \times 10 - n_{Cf} \times 6}{4} \right\rceil \\ f_{Cf3} = \left\lceil \dfrac{t_{Cf} \times 10 - n_{Cf} \times 7}{3} \right\rceil \end{cases}$$

$$f_{Ci} = \begin{cases} f_{Ci4} = f_C - f_{C4} \\ f_{Ci3} = f_C - f_{Cf3} \end{cases}$$

where:

- t_{Cf} is the number of allocated bits in one frame for fast bytes at the reference point B;
- t_{Ci} is the number of allocated bits for interleaved bytes at the reference point B;
- f_{Cf} and n_{Cf} are the numbers of fast bits in Bitmap-F_C and Bitmap-N_C, respectively;
- f_{Cf3} is the number of fast bits in Bitmap-F_C if the subframe (see I.5.1.3) contains 3 Bitmap-F_C except for synch symbols;
- f_{Cf4} is the number of fast bits in Bitmap-F_C if the subframe contains 4 Bitmap-F_C except for synch symbols;
- f_{Ci} and n_{Ci} are the numbers of interleaved bits in Bitmap-F_C and Bitmap-N_C, respectively;
- n_C is the number of total bits in Bitmap-N_C, which is specified in the B&G tables.

During FEXT bitmap mode, n_{Cf} and n_{Ci} are zero.

To convert the bit rate to be a multiple of 32 kbit/s, the dummy bits for fast data are inserted to the tail of each subframe, and the dummy bits for interleaved data are inserted to the end of the hyperframe. The number of the dummy bits shall be as follows:

If $t_{Cf} \le n_{C\max}$:

$$dummy_{Cf} = 0$$

$$dummy_{Ci} = (f_{Ci} \times 126 + n_{Ci} \times 214) - t_{Ci} \times 340$$

If $t_{Cf} > n_{C\max}$:

$$dummy_{Cf4} = (f_{Cf} \times 4 + n_{Cf} \times 6) - t_{Cf} \times 10$$

$$dummy_{Cf3} = (f_{Cf} \times 3 + n_{Cf} \times 7) - t_{Cf} \times 10$$

$$dummy_{Ci} = (f_{Ci4} \times 96 + f_{Ci3} \times 30) - t_{Ci} \times 340$$

If the fast data buffer uses single latency only, additional dummy bits are inserted at the tail of each FEXT symbol in the 4 Bitmap-F_C constructed subframe. The number of additional dummy bits inserted at the tail of each FEXT symbol shall be as follows:

$$dummy_{SCf} = f_{Cf3} - f_{Cf4}$$

The receiver shall determine Bitmap-F_C and Bitmap-N_C so that $dummy_{Ci}$ is less than 126, $dummy_{Cf4}$ is less than 4 and $dummy_{Cf3}$ is less than 3 in the initialization sequence. At the receiver, the inserted dummy bits shall be removed.

I.5.3 FEXT Bitmapping (replaces 8.16)

The FEXT Bitmapping mode uses the Dual Bitmapping technique (I.4.4) to transmit data only during FEXT. The ATU-C shall transmit only the pilot tone during the $NEXT_R$ symbol. The ATU-R disables Bitmap-N_C and shall not transmit any signal during the $NEXT_C$ symbol (see Figures I.10 and I.17).

The Dual versus FEXT bitmapping mode is selected during G.994.1 using bit "DBM" (see 10.2 and 10.3).

I.5.4 Tone ordering (pertains to 8.7)

The tone-ordering algorithm shall be the same as for the downstream data, specified in I.4.4.

For Bitmap-F_C, the "tone-ordered" encoding shall first assign f_{Cf} bits from the rate converter (see I.5.2.2) to the tones with the smallest number of bits assigned to them, and the remaining f_{Ci} bits to the remaining tones. For Bitmap-N_C, it shall first assign n_{Cf} bits from the rate converter to the tones with the smallest number of bits assigned to them, and the remaining n_{Ci} bits to the remaining tones. Two ordered bit tables for Bitmap-F_C and Bitmap-N_C shall be prepared.

I.5.5 Modulation (pertains to 8.11)

I.5.5.1 Inverse synchronization symbol (replaces 8.11.4)

Inverse synchronization symbol shall be generated from a tone-by-tone 180-degree phase reversal of synchronization symbol (i.e., + maps to –, and – maps to +, for each of the 4-QAM signal constellation).

I.5.5.2 Gain scaling in synchronization symbol (new)

At initialization time, the sync symbol reference transmit PSD level shall be set at the nominal PSD level +10 log(g_{sync}^2) dBm/Hz, with g_{sync}^2 defined as the average g_i^2 value over the used (i.e., $b_i > 0$) subcarriers in the NEXT or FEXT bitmap, whichever results in the highest average gain. The sync symbol reference transmit PSD shall not be updated with used subcarrier gain changes during SHOWTIME.

I.5.5.3 Nyquist frequency (supplements 8.11.1.2)

The Nyquist frequency for this annex is specified in A.2.5.

I.5.5.4 Modulation by the inverse discrete Fourier transform (supplements 8.11.2)

See A.2.1.

I.5.5.5 Synchronization symbol (supplements 8.11.3)

See A.2.2.

I.5.6 ATU-R upstream transmit spectral mask (supplements 8.14)

The upstream spectral mask of this annex uses the same mask as Annex A.

I.5.7 Cyclic prefix (supplements 8.12)

See A.2.3.

I.6 EOC operation and maintenance (pertains to clause 9)

I.6.1 ADSL line related primitives (supplements 9.3.1)

I.6.1.1 ADSL line related near-end defects (supplements 9.3.1.3)

Two near-end defects are further defined:

- **Loss-of-signal (LOS)**: The ADSL power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.
- **Severely errored frame (SEF)**: A SEF defect occurs when the content of two consecutively received ADSL synchronization symbols in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R, does not correlate with the expected content over a subset of the tones. An SEF defect terminates when the content of two consecutively received ADSL synchronization symbols in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R, correlate with the expected contents over the same subset. The correlation method, the selected subset of tones, and the threshold for declaring these defect conditions are implementation discretionary.

I.6.1.2 ADSL line related far-end defects (supplements 9.3.1.4)

Loss-of-signal is further defined:

- **Loss-of-signal (LOS)**: The ADSL power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.

I.6.2 Test parameters (supplements 9.5)

I.6.2.1 Near-end test parameters (supplements 9.5.1)

The near-end primitives are further defined:

- **Attenuation (ATN)**: The received signal power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.
- **Signal-to-Noise ratio (SNR) margin**: During FEXT Bitmap mode, this primitive represents the snr margin in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R.

I.6.2.2 Far-end test parameters (supplements 9.5.2)

The far-end primitives are further defined:

- **Attenuation (ATN)**: The received signal power shall be measured only in the $FEXT_C$ duration at ATU-C, or only in the $FEXT_R$ duration at ATU-R.
- **Signal-to-Noise ratio (SNR) margin**: During FEXT Bitmap mode, this primitive represents the snr margin in the $FEXT_C$ duration at ATU-C, or in the $FEXT_R$ duration at ATU-R.

I.6.3 Data registers in the ATU-R (supplements 9.2.4)

For the $S = 1/2n$ framing mode (see I.4.9), the downstream RS_I shall be the number of parity bytes per sync byte, i.e., $RS_I = R_I/(n \times S)$.

I.7 Initialization (pertains to clause 10)

I.7.1 Initialization with hyperframe (replaces 10.1.5)

The exchange of messages between ATU-C and ATU-R should be performed in $FEXT_C$ and $FEXT_R$. The DMT symbol has two symbol rates: one is 4.3125 kBaud for the symbol without a cyclic prefix, and the other is 4 × 69/68 kBaud for the symbol with a cyclic prefix. 32 times of the TTR has the same period as 345 times of the 4.3125 kBaud, and 34 times of the TTR is the same as 345 times of 4 × 69/68 kHz.

During FEXT Bitmap mode, the ATU-R shall not transmit any signal during the $NEXT_C$ symbols duration and the ATU-C shall transmit only the pilot tone as the $NEXT_R$ signal except:

- C-PILOT1 (C-PILOT1A) which is accompanied by a signal to allow the ATU-C to indicate the phase of TTR_C to the ATU-R (see I.7.4.1);
- C-QUIETn where no signal is transmitted.

The ATU-C begins transmitting C-PILOT1 at the beginning of the hyperframe without cyclic prefix. The ATU-C informs the phase of the TTR_C to ATU-R during C-PILOT1. The ATU-R begins transmitting R-REVERB1 at the beginning of the hyperframe without cyclic prefix. The ATU-R performs the training of any receiver equalizer using this phase information of the TTR_R generated from received TTR_C.

From C-PILOT1 to C-SEGUE1, the following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to at ATU-R (see Figure I.19).

For $N_{dmt} = 0, 1, \dots, 344$

$S = 256 \times N_{dmt} \bmod 2760$

if $\{ (S + 255 < a) \text{ or } (S > a + b) \}$ then $FEXT_R$ symbols

else then $NEXT_R$ symbols

where a = 1243, b = 1461.

In order to enter C-RATES1 at the beginning of the hyperframe with cyclic prefix, the number of symbols from C-PILOT1 to C-SEGUE1 shall be a multiple of 345 DMT symbols.

From R-REVERB1 to R-SEGUE1, the following numerical formula gives the information which duration N_{dmt}-th symbol belongs to at ATU-C (see Figure I.20).

For $N_{dmt} = 0, 1, \ldots, 344$,

$S = 256 \times N_{dmt} \bmod 2760$

if { ($S > a$) and ($S + 255 < a + b$) } then $FEXT_C$ symbols

else then $NEXT_C$ symbols

where a = 1315, b = 1293.

From C-RATES1 to C-SEGUE3, the number of symbols is a multiple of 345 DMT symbols. The following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to. ATU-C transmits the message data in $FEXT_R$ symbols (see Figure I.11).

For $N_{dmt} = 0, 1, ..., 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { ($S + 271 \geq a$) and ($S \leq a + b$) } then $NEXT_R$ symbols

else then $FEXT_R$ symbols

where a = 1243, b = 1461.

The ATU-R enters R-REVERB3 at the beginning of the hyperframe with cyclic prefix, which is extracted from received signal. From R-REVERB3 to R-SEGUE5, the number of symbols is a multiple of 345 DMT symbols. The following numerical formula gives the information which duration N_{dmt}-th DMT symbol belongs to. ATU-R transmits the message data in $FEXT_C$ symbols (see Figure I.18).

For $N_{dmt} = 0, 1, ..., 344$

$S = 272 \times N_{dmt} \bmod 2760$

if { ($S > a$) and ($S + 271 < a + b$) } then $FEXT_C$ symbols

else then $NEXT_C$ symbols

where a = 1315, b = 1293.

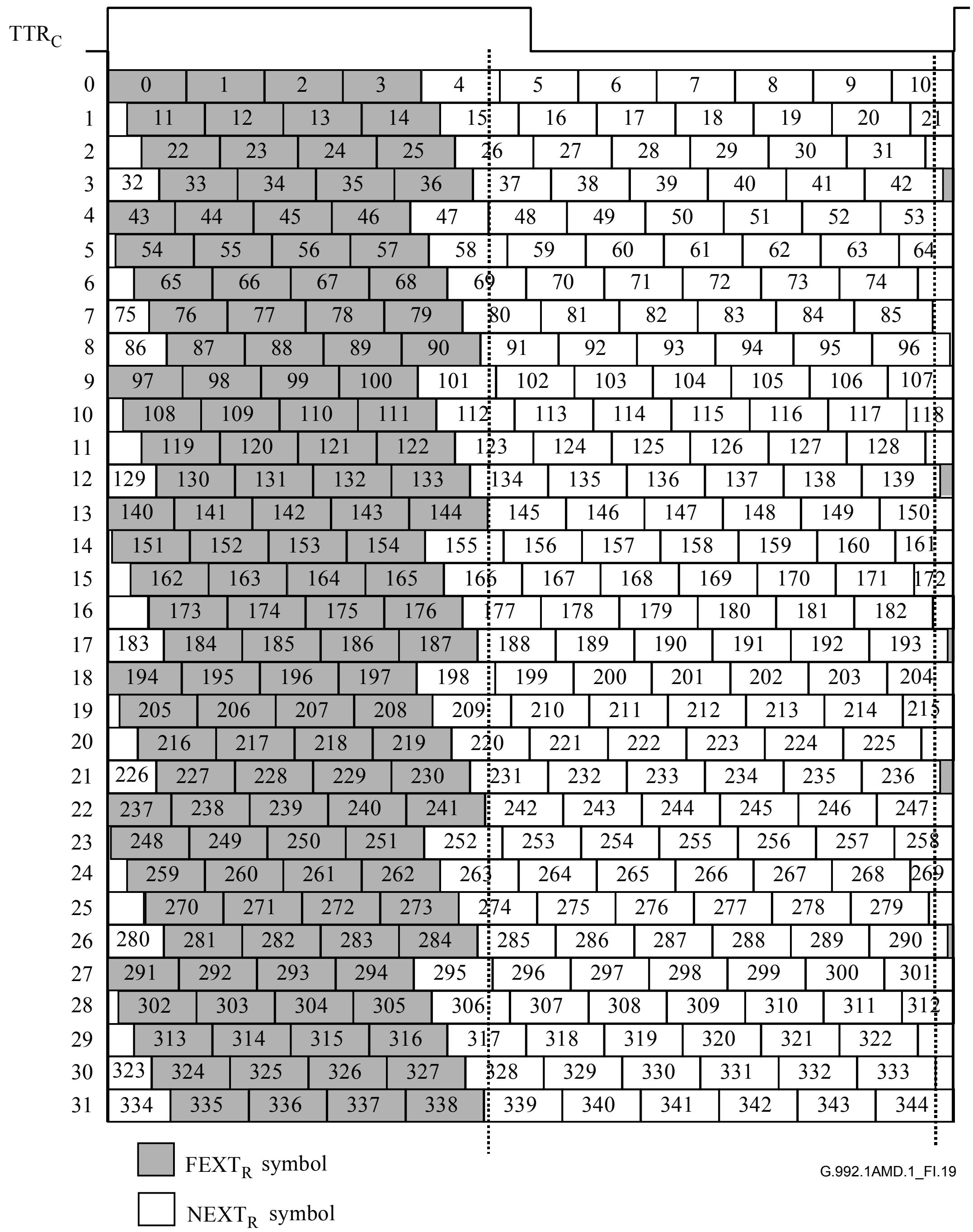


Figure I.19/G.992.1 – Symbol pattern in a hyperframe without cyclic prefix – Downstream

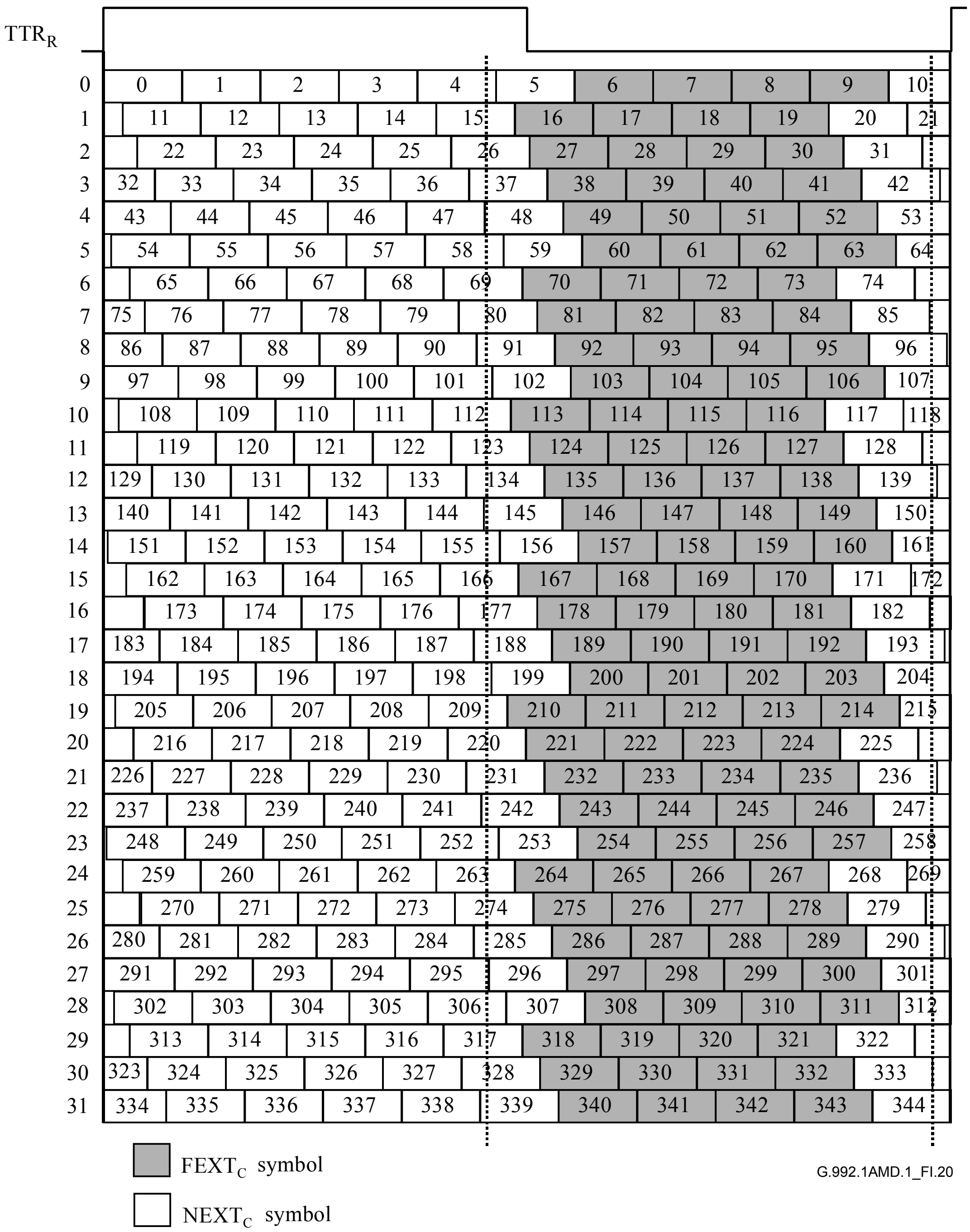


Figure I.20/G.992.1 – Symbol pattern in a hyperframe without cyclic prefix – Upstream

I.7.2 Handshake – ATU-C (supplements 10.2)

I.7.2.1 CL messages (supplements 10.2.1)

See Table I.8.

Table I.8/G.992.1 – ATU-C CL message NPar(2) bit definitions for this annex

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e., only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall be only performed by the ATU-C. If it is set to ONE in a CL message, it must be set to ONE in subsequent MS messages from either the ATU-C or ATU-R.
Spectral shaping downstream #1 (shaped ssv_i)	This bit shall be set to ONE.
Spectral shaping downstream #2 (flat ssv_i)	This bit shall be set to ONE.
Spectrum shaping downstream #3 (ATU-C selected ssv_i)	If this bit is set to ONE, it indicates that the ATU-C supports downstream inband spectrum shaping selectable by the ATU-C using the exchange of ssv_i values according to I.4.8.7.
SPar(2) bit	**Definition**
C-PILOT	This bit shall be set to ONE to indicate that the ATU-C supports negotiation of the optional pilot tone.
Spectrum shaping downstream	If this bit is set to ONE, it indicates that the ATU-C is specifying a downstream inband spectral shape using the exchange of ssv_i values according to I.4.8.7.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	This bit shall be set to ONE, indicating that the ATU-C supports transmission of pilot tone on subcarrier 64.
$n_{C\text{-}PILOT1} = 128$	This bit shall be set to ONE, indicating that the ATU-C supports transmission of pilot tone on subcarrier 128.
A_{48}	This bit shall be set to ONE, indicating that the ATU-C supports transmission of TTR indication signal A_{48}.
Subcarrier index/log_ ssv_i	A parameter block of pairs of a subcarrier index and the spectrum shaping log_ ssv_i value at that subcarrier. Pairs shall be transmitted in ascending subcarrier index order. Each pair shall be represented as 4 octets. The parameter block length shall be a multiple of 4 octets. Codepoints shall be structured as: • The subcarrier index shall be a 12-bit unsigned value, indicating subcarrier index 1 to 2 × NSCds-1, coded in bits 6 down to 1 in octet 1, bits 6 down to 1 in octet 2; • The spectrum shaping log_tssi values shall be represented in logarithmic scale as a 7-bit unsigned value in –0.5 dB steps, ranging from 0 dB (value 0) to –62.5 dB (value 125), coded in bit 1 of octet 3 and bits 6 down to 1 in octet 4. Values 126 and 127 are reserved.

I.7.2.2 MS messages (supplements 10.2.2)

See Table I.9.

Table I.9/G.992.1 – ATU-C MS message NPar(2) bit definitions for this annex

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e., only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall be only performed by ATU-C. This bit shall be set to ONE if it was set to ONE in a previous CL message.
Spectral shaping downstream #1 (shaped ssv_i)	If set to ZERO, this bit shall indicate that "shaped ssv_i" is not selected. If set to ONE, this bit shall indicate that "shaped ssv_i" is selected. This mode selection shall only be performed by the ATU-C (Note 2).
Spectral shaping downstream #2 (flat ssv_i)	If set to ZERO, this bit shall indicate that "flat ssvi" is not selected. If set to ONE, this bit shall indicate that "flat ssv_i" is selected. This mode selection shall only be performed by the ATU-C (Note 2).
Spectrum shaping downstream #3 (ATU-C selected ssv_i)	If set to ZERO, this bit shall indicate that "ATU-C selected ssv_i" is not selected. If set to ONE, this bit shall indicate that "ATU-C selected ssv_i" is selected. This mode selection shall only be performed by the ATU-C (Note 2).
SPar(2) bit	**Definition**
C-PILOT	This bit shall be set to ONE to indicate that the ATU-C wishes to select a pilot tone.
Spectrum shaping downstream	This bit shall be set to ZERO.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	If set to ONE, this bit shall indicate that the ATU-C is selecting the pilot tone on subcarrier 64 (Note 1).
$n_{C\text{-}PILOT1} = 128$	If set to ONE, this bit shall indicate that the ATU-C is selecting the pilot tone on subcarrier 128 (Note 1).
A_{48}	This bit shall be set to ONE.
NOTE 1 – One and only one pilot tone bit shall be set in an MS message. NOTE 2 – One and only one Npar(2) spectrum shaping downstream bit shall be set in an MS message.	

I.7.3 Handshake – ATU-R (supplements 10.3)

I.7.3.1 CLR messages (supplements 10.3.1)

See Table I.10.

Table I.10/G.992.1 – ATU-R CLR message NPar(2) bit definitions for this annex

NPar(2) bit	Definition
DBM	This bit shall be set to ONE.
Spectral shaping downstream #1 (shaped ssv_i)	This bit shall be set to ONE.
Spectral shaping downstream #2 (flat ssv_i)	This bit shall be set to ONE.
Spectrum shaping downstream #3 (ATU-C selected ssv_i)	If this bit is set to ONE, it indicates that the ATU-R supports downstream inband spectrum shaping selectable by the ATU-C using the exchange of ssv_i values according to I.4.8.7.
SPar(2) bit	**Definition**
C-PILOT	This bit shall be set to ONE to indicate that the ATU-R supports negotiation of the optional pilot tone.
Spectrum shaping downstream	This bit shall be set to ZERO.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	This bit shall be set to ONE, indicating that the ATU-R supports reception of pilot tone on subcarrier 64.
$n_{C\text{-}PILOT1} = 128$	If set to ONE, this bit shall indicate that the ATU-R supports reception of pilot tone on subcarrier 128.
A_{48}	This bit shall be set to ONE.

I.7.3.2 MS messages (supplements 10.3.2)

Table I.11.

Table I.11/G.992.1 – ATU-R MS message NPar(2) bit definitions for this annex

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e., only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall be only performed by ATU-C. This bit shall be set to ONE if it was set to ONE in a previous CL message.
Spectral shaping downstream #1 (shaped ssv_i)	If set to ZERO, this bit shall indicate that "shaped ssv_i "is not selected. If set to ONE, this bit shall indicate that "shaped ssv_i "is selected. This mode selection shall only be performed by the ATU-C.
Spectral shaping downstream #2 (flat ssv_i)	If set to ZERO, this bit shall indicate that "flat ssv_i "is not selected. If set to ONE, this bit shall indicate that "flat ssv_i "is selected. This mode selection shall only be performed by the ATU-C (Note 2).
Spectrum shaping downstream #3 (ATU-C selected ssv_i)	If set to ZERO, this bit shall indicate that "ATU-C selected ssv_i" is not selected. If set to ONE, this bit shall indicate that "ATU-C selected ssv_i" is selected. This mode selection shall only be performed by the ATU-C (Note 2).
SPar(2) bit	**Definition**
C-PILOT	This bit shall be set to ONE to indicate that the ATU-R wishes to select a pilot tone.
Spectrum shaping downstream	This bit shall be set to ZERO.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	If set to ONE, this bit shall indicate that the ATU-R is selecting the pilot tone on subcarrier 64 (Note 1).
$n_{C\text{-}PILOT1} = 128$	If set to ONE, this bit shall indicate that the ATU-R is selecting the pilot tone on subcarrier 128 (Note 1).
A_{48}	This bit shall be set to ONE.
NOTE 1 – One and only one pilot tone bit shall be set in an MS message. NOTE 2 – One and only one Npar(2) spectrum shaping downstream bit shall be set in an MS message.	

I.7.3.3 MP messages (new)

Table I.11a.

Table I.11a/G.992.1 – ATU-R MP message NPar(2) bit definitions for this annex

NPar(2) bit	Definition
DBM	If set to ZERO, this bit shall indicate Bitmap-N_R and Bitmap-N_C are enabled (Dual Bitmap mode) and are used to transmit data. If set to ONE, this bit shall indicate Bitmap-N_R and Bitmap-N_C are disabled (FEXT Bitmap mode), i.e., only Bitmap-F_R and Bitmap-F_C are used to transmit data by ATU-C and ATU-R respectively. This mode selection shall only be performed by ATU-C. This bit shall be set to ONE if it was set to ONE in a previous CL message.
Spectral shaping downstream #1 (shaped ssv_i)	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of "shaped ssv_i".
Spectral shaping downstream #2 (flat ssv_i)	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of "flat ssv_i".
Spectrum shaping downstream #3 (ATU-C selected ssv_i)	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of "ATU-C selected ssv_i".
SPar(2) bit	**Definition**
C-PILOT	This bit shall be set to ONE to indicate that the ATU-R wishes to propose a pilot tone.
Spectrum shaping downstream	This bit shall be set to ZERO.
NPar(3) bit	**Definition**
$n_{C\text{-}PILOT1} = 64$	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of pilot tone on subcarrier 64 (Note).
$n_{C\text{-}PILOT1} = 128$	If set to ONE, this bit shall indicate that the ATU-R is proposing the use of pilot tone on subcarrier 128 (Note).
A_{48}	This bit shall be set to ONE.
NOTE – One and only one pilot tone bit shall be set in an MP message.	

I.7.4 Transceiver training – ATU-C (supplements 10.4)

During transceiver training from C-REVERB1 to C-SEGUE1 except C-PILOTn and C-QUIETn, the ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols when Bitmap-N_R is enabled (Dual Bitmap mode), and shall not transmit the $NEXT_R$ symbols except pilot tone when Bitmap-N_R is disabled (FEXT Bitmap mode). The duration of each state is defined as Figure I.25.

I.7.4.1 C-PILOT1 (supplements 10.4.2)

The ATU-C shall start the N_{SWF} (sliding window frame) counter from 0 immediately after entering C-PILOT1, and increment the N_{SWF} counter modulo 345 after transmission of each DMT symbol. According to the sliding window function and this counter, the ATU-C decides to transmit all of the subsequent symbols in either $FEXT_R$ or $NEXT_R$ symbols (for example, see Figures I.11, I.19 and I.23).

C-PILOT1 has two signals.

The first signal is the pilot tone, a single frequency sinusoid at $f_{\text{C-PILOT1}}$ defined as:

$$X_k = \begin{cases} 0, & k \neq n_{\text{C-PILOT1}}, 0 \leq k \leq NSC \\ A_{\text{C-PILOT1}}, & k = n_{\text{C-PILOT1}} \end{cases}$$

The frequency of the pilot tone shall be selected from one of the following choices during G.994.1 as:

1) $f_{\text{C-PILOT1}}$ = 276 kHz ($n_{\text{C-PILOT1}}$ = 64);

2) $f_{\text{C-PILOT1}}$ = 552 kHz ($n_{\text{C-PILOT1}}$ = 128).

Transmitters that support this annex shall support both of these pilot tones.

The second signal is the TTR indication signal used to transmit $NEXT_R$/$FEXT_R$ information. The ATU-R can detect the phase information of the TTR_C from this signal. The TTR indication signal shall be selected during G.994.1 as:

A_{48} signal – the constellation encoding of the 48th carrier with 2-bit constellation as follows:

(+ , +) to indicate a $FEXT_R$ symbol;

(+ , –) to indicate a $NEXT_R$ symbol.

I.7.4.2 C-PILOT1A (supplements 10.4.3)

C-PILOT1A has two signals and it is the same transmitted signal as C-PILOT1 (see I.7.4.1).

I.7.4.3 C-REVERB3 (supplements 10.4.11)

In order to synchronize the first symbol of C-RATES1 with the beginning of the hyperframe and to inform the entering timing of C-RATES1 to the ATU-R, the first symbol of C-SEGUE1 shall be transmitted inside of the $FEXT_R$ duration as shown in Figure I.21. Therefore, the duration of C-REVERB3 is 3628 DMT symbols.

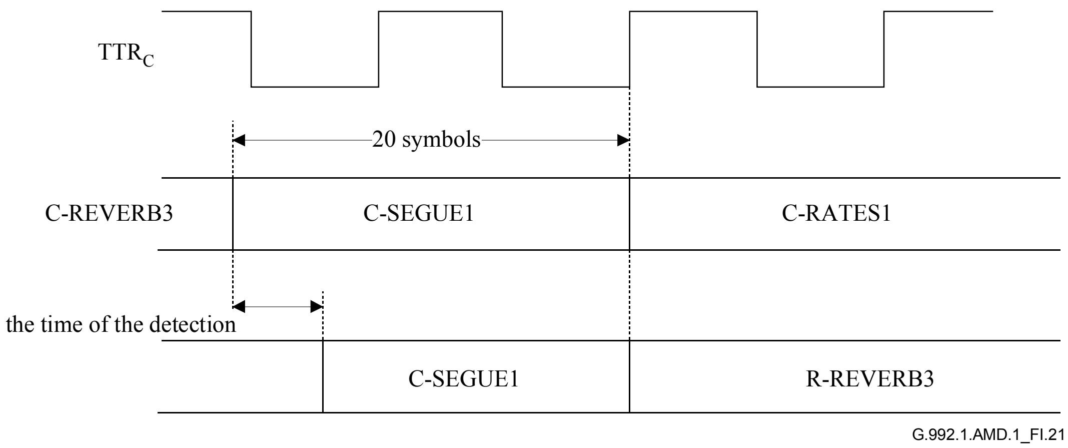


Figure I.21/G.992.1 – Timing diagram from C-SEGUE1 to C-RATES1

I.7.4.4 C-REVERB1 (replaces 10.4.5)

C-REVERB1 is a signal that allows the ATU-C and ATU-R receiver to adjust its automatic gain control (AGC) to an appropriate level. The data pattern used in C-REVERB1 shall be the pseudo-random downstream sequence (PRD), d_n for n = 1 to 2 × NSC, defined in I.4.7.5 and repeated here for convenience:

$$\begin{aligned} d_n &= 1 && \text{for } n = 1 \text{ to } 9 \\ d_n &= d_{n-4} \oplus d_{n-9} && \text{for } n = 10 \text{ to } 2 \times \text{NSC} \end{aligned} \qquad (10\text{-}1)$$

The bits shall be used as follows: the first pair of bits (d_1 and d_2) is used for the DC and Nyquist subcarriers (the power assigned to them is, of course, zero, so the bits are effectively ignored); then the first and second bits of subsequent pairs are used to define the X_i and Y_i for i = 1 to NSC – 1 as defined in Table 7-13.

The period of PRD is only 511 bits, so d_{n+511} is equal to d_n. The bits d_1 to d_9 shall be re-initialized for each symbol, so each symbol of C-REVERB1 is identical.

The two bits that modulate the pilot carrier shall be overwritten by {0,0}: generating the {+,+} constellation.

The duration of C-REVERB1 is 512 (repeating) symbols without cyclic prefix.

I.7.4.4.1 Power cutback (supplements 10.4.5.1)

See A.3.1.

I.7.5 Transceiver training – ATU-R (supplements 10.5)

During transceiver training from R-REVERB1 to R-SEGUE1 except R-QUIETn, the ATU-R shall transmit both $FEXT_C$ and $NEXT_C$ symbols when Bitmap-N_C is enabled (Dual Bitmap mode) and shall not transmit $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode). The duration of each state is defined as Figure I.25.

I.7.5.1 R-QUIET2 (supplements 10.5.1)

The ATU-R enters R-REVERB1 after it completes timing recovery and Hyperframe synchronization from C-PILOT1/C-PILOT1A.

I.7.5.2 R-REVERB1 (supplements 10.5.2)

The data pattern used in R-REVERB1 is the pseudo-random upstream sequence PRU defined in 8.11.3 and repeated here for convenience:

$$\begin{cases} d_n = 1 & \text{for } n = 1 \text{ to } 6 \\ d_n = d_{n-5} \oplus d_{n-6} & \text{for } n = 7 \text{ to } 64 \end{cases} \qquad \text{(I.10-1)}$$

The ATU-R shall start its N_{SWF} counter immediately after entering R-REVERB1, and then increment the N_{SWF} counter with modulo 345 from 0 when it transmits each DMT symbol. The ATU-C and ATU-R shall have the same value since hyperframe alignment between the ATU-C and ATU-R shall be maintained. According to the sliding window and this counter, the ATU-R decides to transmit all of the subsequent symbols in either the $FEXT_C$ or the $NEXT_C$ symbol.

I.7.5.3 R-QUIET3 (replaces 10.5.3)

The final symbol of R-QUIET3 accommodates the frame alignment of the transmitter to that of the receiver. It may be shortened by any number of samples. The maximum duration of R-QUIET3 is 6145 DMT symbols.

I.7.5.4 R-REVERB2 (supplements 10.5.5)

After ATU-R detects C-SEGUE1, the ATU-R enters R-SEGUE1. The maximum duration of R-REVERB2 is 3643 DMT symbols.

I.7.6 Channel analysis (ATU-C) (supplements 10.6)

ATU-C shall transmit only $FEXT_R$ symbols, and shall not transmit the $NEXT_R$ symbols except the pilot tone from C-RATES1 to C-CRC2. During C-MEDLEY, the ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols when Bitmap-N_R is enabled (Dual Bitmap mode). The ATU-C shall not transmit $NEXT_R$ symbols except the pilot tone, when Bitmap-N_R is disabled (FEXT Bitmap mode). The duration of each state is defined in Figure I.25.

I.7.6.1 C-SEGUE1 (supplements 10.6.1)

The duration of C-SEGUE1 is 20 symbols in order that the first symbol of C-SEGUE1 shall be inside of the $FEXT_R$ duration.

I.7.6.2 C-MEDLEY (replaces 10.6.6)

C-MEDLEY is a wideband pseudo-random signal used for estimation at the ATU-R of the downstream SNR. The data to be transmitted are derived from the pseudo-random sequence, PRD, and modulated as defined in 10.4.5. In contrast to C-REVERB1, however, the cyclic prefix is used and the data sequence continues from one symbol to the next (i.e., d_1 to d_9 are not re-initialized for each symbol); since PRD is of length 511, and 2 × NSC bits are used for each symbol, the subcarrier vector for C-MEDLEY therefore changes from one symbol period to the next. The pilot subcarrier is overwritten by the (+,+) signal constellation. C-MEDLEY is transmitted for 16384 symbol periods. Following C-MEDLEY the ATU-C shall enter the state C-REVERB4.

Basically, the definition of C-MEDLEY is as given above, except for the duration of the SNR estimation at ATU-R for the downstream. With the periodical noise of TCM-ISDN, SNR also changes in the same cycle, as shown in Figure I.22. The ATU-C transmits the signal in both of $NEXT_R$ and $FEXT_R$ symbols, and the ATU-R estimates two SNRs from the received $NEXT_R$ and $FEXT_R$ symbols, respectively, as defined in Figure I.23.

The following formula gives the information that received N_{dmt}-th DMT symbol belongs to:

For N_{dmt} = 0, 1, … , 344

$S = 272 \times N_{dmt} \bmod 2760$

if { (S + 271 < a) or (S > d) } then symbol for estimation of $FEXT_R$ SNR

if { (S > b) and (S + 271 < c) } then symbol for estimation of $NEXT_R$ SNR

where a = 1243, b = 1403, c = 2613, d = 2704.

When Bitmap-N_R is disabled (FEXT Bitmap mode), ATU-C shall transmit only the pilot tone as $NEXT_R$ symbol. The number of bits of $NEXT_R$ shall be no more than the number of bits of $FEXT_R$.

At the transmitter, the PRD sequence generator shall continue to be updated during $NEXT_R$ symbols when Bitmap-N_R is disabled (FEXT Bitmap mode).

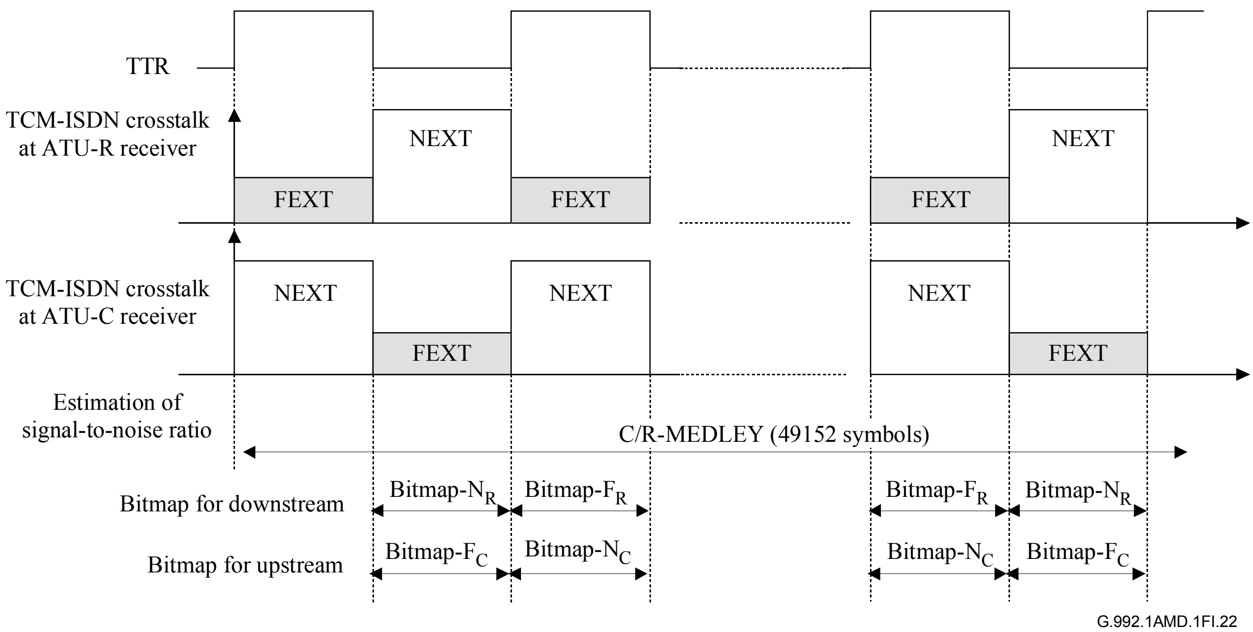


Figure I.22/G.992.1 – Estimation of periodic signal-to-noise ratio

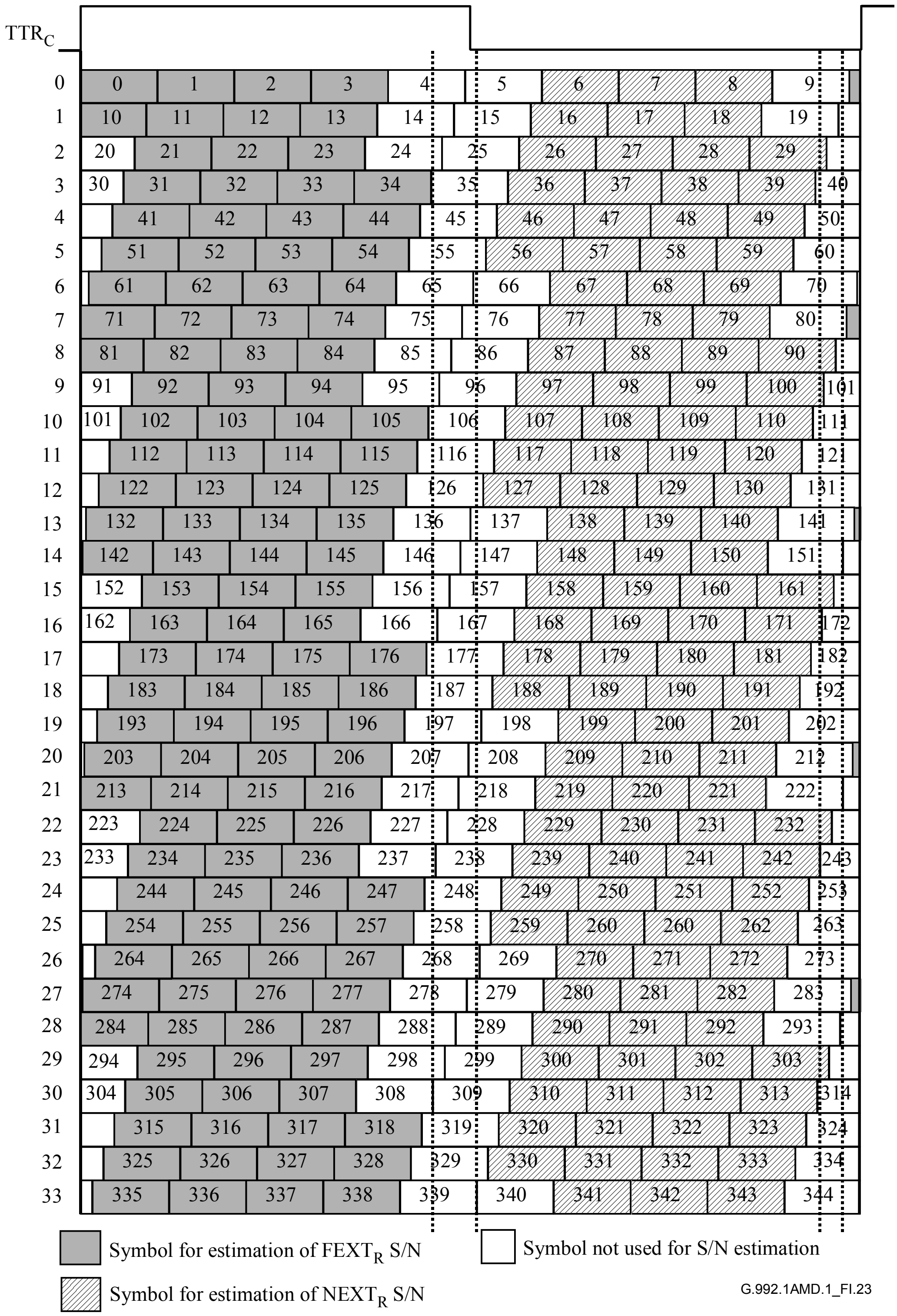


Figure I.23/G.992.1 – Symbol pattern in a hyperframe for S/N estimation – Downstream

I.7.6.3 C-RATES1 (supplements 10.6.2)

In order to support data rates greater than 16 Mbit/s, the B_I field has 10 bits. The RRSI fields shall use the same extended syntax as defined in I.7.9.4 for C-RATES-RA.

For the S = 1/2n framing mode (see I.4.9), the downstream RS_I shall be the number of parity bytes per sync byte, i.e., $RS_I = R_I/(n \times S)$.

I.7.7 Channel analysis (ATU-R) (supplements 10.7)

From R-RATES1 to R-CRC2, the ATU-R shall transmit only the $FEXT_C$ symbols and shall not transmit the $NEXT_C$ symbols. In R-SEGUE2 and R-MEDLEY, the ATU-R shall transmit both $FEXT_C$ and $NEXT_C$ symbols when Bitmap-N_C is enabled (Dual Bitmap mode) and shall not transmit $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode). The duration of each state is defined in Figure I.25.

I.7.8 R-SEGUE1 (supplements 10.7.1)

The maximum duration of R-SEGUE1 is 14 symbols (see Figure I.21).

I.7.8.1 R-REVERB3 (supplements 10.7.2)

The ATU-R shall start R-REVERB3 aligned with the beginning of a hyperframe.

I.7.8.2 R-SEGUE2 (supplements 10.7.3)

The duration of R-SEGUE2 is 13 symbols.

I.7.8.3 R-MEDLEY (supplements 10.7.8)

Basically, the definition of R-MEDLEY is the same as 10.7.8, except for the duration of the SNR estimation at ATU-C for the upstream. With the periodical noise of TCM-ISDN, SNR also changes in the same cycle, as shown in Figure I.22. ATU-R shall transmit the signal in both of $NEXT_C$ and $FEXT_C$ symbols, and ATU-C shall estimate two SNRs from the received $NEXT_C$ and $FEXT_C$ symbols, respectively, as defined in Figure I.24.

The following numerical formula gives the information that received N_{dmt}-th DMT symbol belongs to:

For $N_{dmt} = 0, 1, \ldots, 344$

$S = 272 \times N_{dmt} \bmod 2760$

if $\{ (S > b) \text{ and } (S + 271 < c) \}$ then symbol for estimation of $FEXT_C$ SNR

if $\{ (S + 271 < a) \}$ then symbol for estimation of $NEXT_C$ SNR

where a = 1148, b = 1315, c = 2608.

When Bitmap-N_C is disabled (FEXT Bitmap mode), the ATU-R shall not transmit $NEXT_C$ symbol. The number of bits of $NEXT_C$ shall be no more than the number of bits of $FEXT_C$.

At the transmitter, the PRU sequence generator shall continue to be updated during $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode).

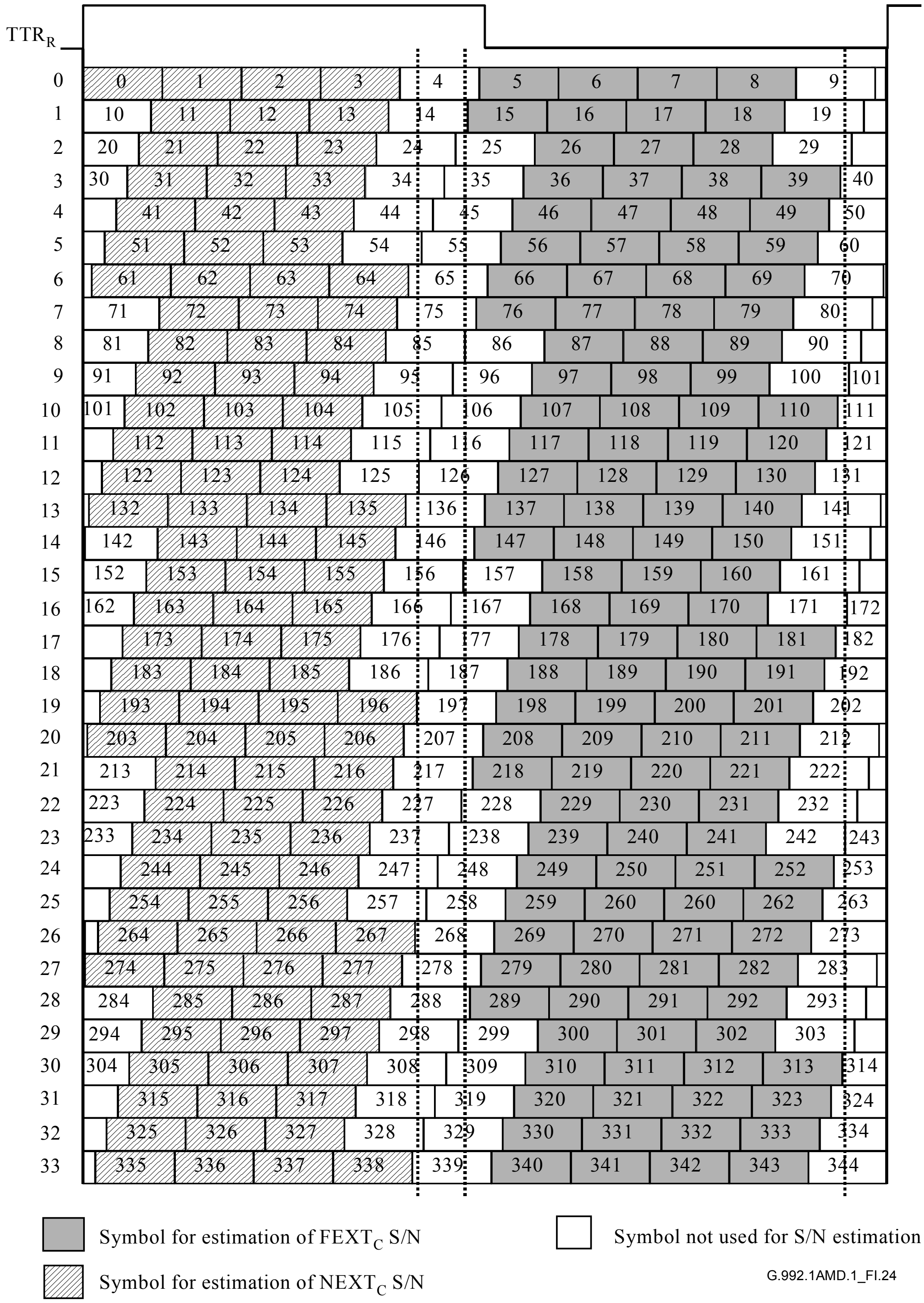
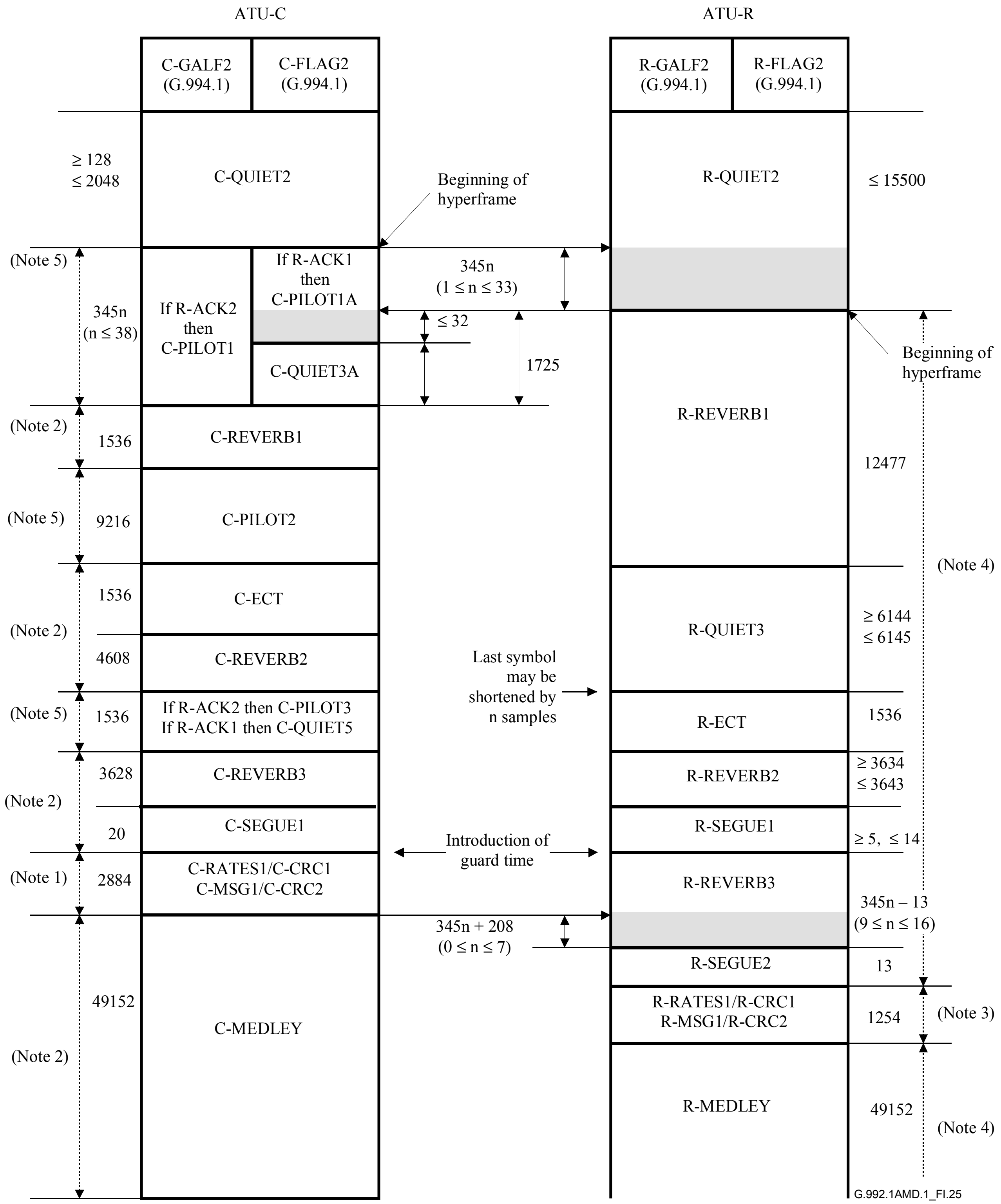


Figure I.24/G.992.1 – Symbol pattern in a hyperframe for S/N estimation – Upstream



NOTE 1 – The ATU-C shall transmit the $FEXT_R$ symbols, and shall not transmit as $NEXT_R$ symbols except the pilot tone.

NOTE 2 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols, when Bitmap-N_R is enabled (Dual Bitmap mode). ATU-C shall not transmit the $NEXT_R$ symbols except pilot tone, when Bitmap-N_R is disabled (FEXT Bitmap mode).

NOTE 3 – The ATU-R shall transmit the $FEXT_C$ symbols, and shall not transmit the $NEXT_C$ symbols.

NOTE 4 – The ATU-R shall transmit both $FEXT_C$ symbols, when Bitmap-N_C is enabled (Dual Bitmap mode). ATU-R shall not transmit $NEXT_C$ symbols, when Bitmap-N_C is disabled (FEXT Bitmap mode).

NOTE 5 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols.

Figure I.25/G.992.1 – Timing diagram of the initialization sequence – Part 1

I.7.8.4 R-MSG1 (supplements 10.7.6)

Table I.12/G.992.1 – Assignment of 48 bits of R-MSG1

Suffix(ces) of m_i (Note 1)	Parameter (Note 2)
47-20	Reserved for future use
19	Support of S = 1/4 mode (see I.4.9)
18	Support of S = 1/3 mode (see I.4.10)
17	Trellis coding option
16	Overlapped spectrum option (Note 3)
15	Unused (shall be set to "1")
14	Support of S = 1/2 mode (see I.4.9) (Note 4)
13	Support of dual latency downstream
12	Support of dual latency upstream
11	Network Timing Reference
10, 9	Framing mode
8-4	Reserved for future use
3-0	Maximum numbers of bits per subcarrier supported

NOTE 1 – Within the separate fields the least significant bits have the lowest subscripts.

NOTE 2 – All reserved bits shall be set to "0".

NOTE 3 – The initialization sequence allows for interworking of overlapped and non-overlapped spectrum implementations. Therefore, this indication is for information only.

NOTE 4 – Since the S = 1/2 mode is mandatory for this annex, a modem supporting this annex shall set this bit to binary ONE.

I.7.8.4.1 *S* = 1/3 option (new)

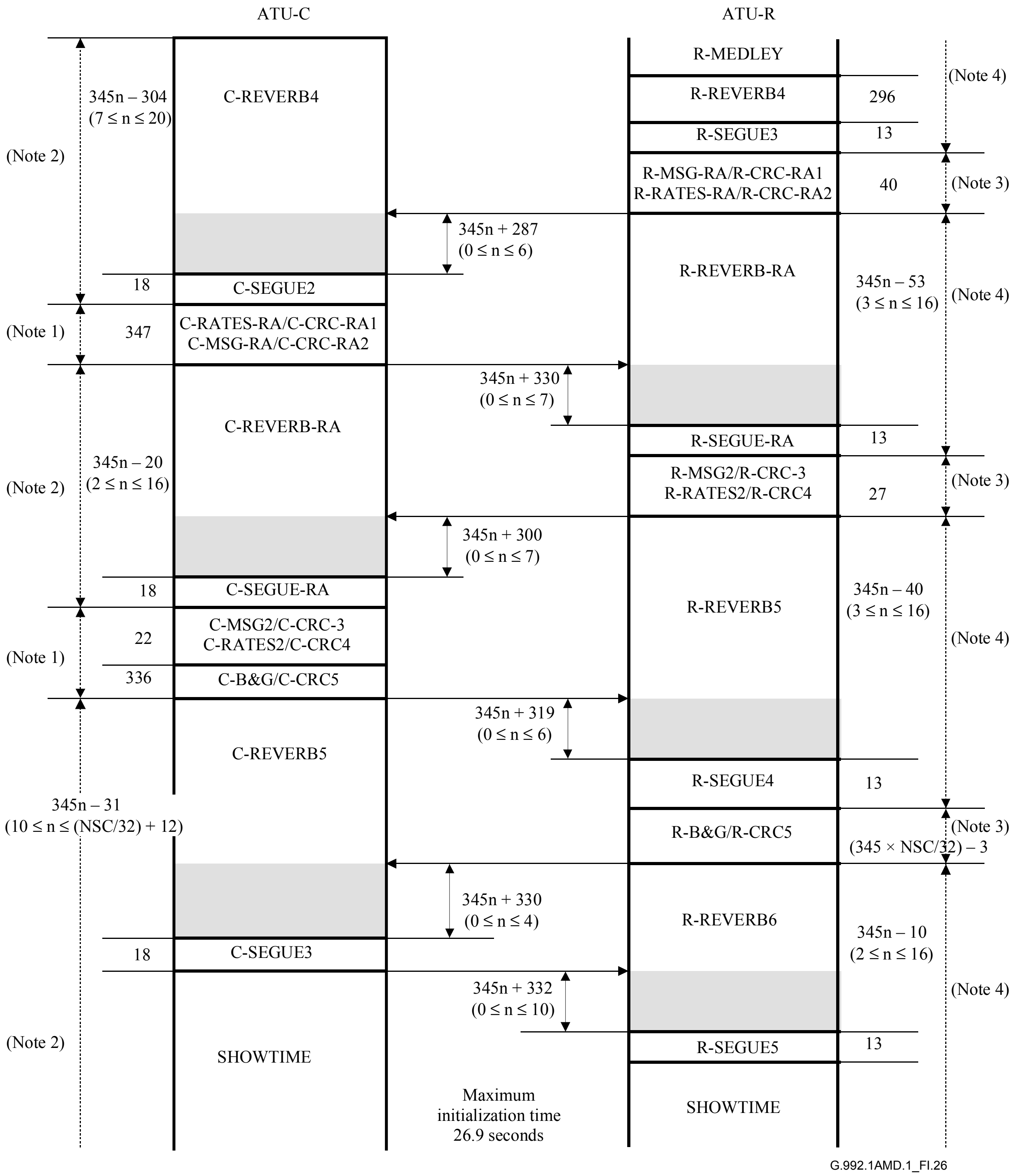
m_{18} = 1 indicates that the ATU-R supports the optional S = 1/3 mode, m_{18} = 0 indicates that S = 1/3 is not supported.

I.7.8.4.2 *S* = 1/4 option (new)

m_{19} = 1 indicates that the ATU-R supports the optional S = 1/4 mode, m_{19} = 0 indicates that S = 1/4 is not supported.

I.7.9 Exchange – ATU-C (supplements 10.8)

During C-RATESn, C-MSGn, C-B&G, and C-CRCn, the ATU-C shall transmit the $FEXT_R$ symbol. In the other signals, the ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols when Bitmap-N_R is enabled (Dual Bitmap mode), and shall not transmit the $NEXT_R$ symbols except pilot tone when Bitmap-N_R is disabled (FEXT Bitmap mode). The duration of each state is defined in Figure I.26.



NOTE 1 – The ATU-C shall transmit the $FEXT_R$ symbols, and shall not transmit as $NEXT_R$ symbols except the pilot tone.

NOTE 2 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols, when Bitmap-N_R is enabled (Dual Bitmap mode). ATU-C shall not transmit the $NEXT_R$ symbols except pilot tone, when Bitmap-N_R is disabled (FEXT Bitmap mode).

NOTE 3 – The ATU-R shall transmit the $FEXT_C$ symbols, and shall not transmit the $NEXT_C$ symbols.

NOTE 4 – The ATU-R shall transmit both $FEXT_C$ symbols, when Bitmap-N_C is enabled (Dual Bitmap mode). ATU-R shall not transmit $NEXT_C$ symbols, when Bitmap-N_C is disabled (FEXT Bitmap mode).

NOTE 5 – The ATU-C shall transmit both $FEXT_R$ and $NEXT_R$ symbols.

Figure I.26/G.992.1 – Timing diagram of the initialization sequence – Part 2

I.7.9.1 C-MSG2 (supplements 10.8.9)

$n_{1C\text{-}MSG2} = 43$

$n_{2C\text{-}MSG2} = 91$

I.7.9.1.1 Total number of bits per symbol supported (supplements 10.8.9.3)

The maximum number of bits per symbol is defined at the reference point B, that is, calculated from the $FEXT_C$ and $NEXT_C$ downstream channel performance (e.g., if the maximum numbers of bits that can be supported in $FEXT_C$ and $NEXT_C$ symbols are 111 and 88 {Total number of bits per symbol supported} = (111 × 126 + 88 × 214)/340 = 96).

NOTE – The number of symbols per hyperframe is 340. The number of FEXT symbols is 126. The number of NEXT symbols is 214.

I.7.9.1.2 Estimated average upstream loop attenuation (supplements 10.8.9.1)

See A.3.2.

I.7.9.2 C-B&G (replaces 10.8.13)

C-B&G shall be used to transmit to the ATU-R the bits and gains information, Bitmap-F_C $\{b_1, g_1, b_2, g_2, \ldots, b_{31}, g_{31}\}$, and Bitmap-$N_C$ $\{b_{33}, g_{33}, b_{34}, g_{34}, \ldots, b_{63}, g_{63}\}$, that are to be used on the upstream carriers. b_i of Bitmap-F_C indicates the number of bits to be coded by ATU-R transmitter onto the i-th upstream carrier in $FEXT_C$ symbols; g_i of Bitmap-F_C indicates the scale factor, relative to the gain that was used for that carrier during the transmission of R-MEDLEY, that shall be applied to the i-th upstream carrier in $FEXT_C$ symbols. Similarly, b_i of Bitmap-N_C indicates the number of bits onto the $(i - 32)$-th upstream carrier in $NEXT_C$ symbols; g_i of Bitmap-N_C indicates the scale factor that shall be applied to the $(i - 32)$-th upstream carrier in $NEXT_C$ symbols.

Because no bits or energy will be transmitted at DC or one-half the sampling rate, b_0, g_0, b_{32}, g_{32}, b_{64}, and g_{64} are all presumed to be zero and shall not be transmitted.

The C-B&G information shall be mapped in a 992-bit (124-byte) message m defined by:

$$m = \{m_{991}, m_{990}, \ldots, m_1, m_0\} = \{g_{63}, b_{63}, \ldots, g_{33}, b_{33}, g_{31}, b_{31}, \ldots, g_1, b_1\}, \quad \text{(I.10-2)}$$

with the MSB of b_i and g_i in the higher m index and m_0 being transmitted first. The message m shall be transmitted in 124 symbols, using the transmission method as described in 10.8.9.

When Bitmap-N_C is disabled (FEXT Bitmap mode), b_i and g_i of Bitmap-N_C shall be set to zero.

I.7.9.3 C-SEGUE3 (replaces 10.8.16)

The duration of C-SEGUE3 is 18 symbols. Following C-SEGUE3, the ATU-C completes the initialization and enters C-SHOWTIME. In C-SHOWTIME, ATU-C shall transmit the signal using Bitmap-F_R and Bitmap-N_R with the sliding window.

When Bitmap-N_R is disabled (FEXT Bitmap mode), ATU-C shall transmit only the pilot tone as $NEXT_R$ symbols.

I.7.9.4 C-RATES-RA (supplements 10.8.3)

Table I.13/G.992.1 – RRSI fields of C-RATES-RA

	← bits →							
fields	7	6	5	4	3	2	1	0
RS_F	0	0	value of RS_F MSB … LSB					
RS_I	B_8 (AS0)	B_9 (AS0)	value of RS_I MSB … LSB					
S	I_9	I_8	value of S MSB … LSB					
I	I_7	I_6	I_5	I_4	I_3	I_2	I_1	I_0
FS(LS2)	value of FS(LS2) *set to* $\{00000000_2\}$							

The RS_I field has been extended to include the most significant bit B_9 of B_I (AS0), the number of payload bytes in the AS0 bearer channel in the downstream interleave buffer, in bit 6. This is to support the higher data rates for the optional $S = 1/4$ and $S = 1/3$ modes.

The S field shall be coded $\{100100_2)$ to indicate $S = 1/4$, and $\{100011_2\}$ to indicate $S = 1/3$.

For the $S = 1/2n$ framing mode (see I.4.9), the downstream RS_I shall be the number of parity bytes per sync byte, i.e., $RS_I = R_I/(n \times S)$.

I.7.10 Exchange – ATU-R (supplements 10.9)

ATU-R shall transmit only the $FEXT_C$ symbols in R-MSGn, R-RATESn, R-B&G, R-CRCn. In other signals, the ATU-R shall transmit both $FEXT_C$ and $NEXT_C$ symbols when Bitmap-N_C is enabled (Dual Bitmap mode) and shall not transmit $NEXT_C$ symbols when Bitmap-N_C is disabled (FEXT Bitmap mode). The duration of each state is defined in Figure I.26.

I.7.10.1 R-MSG-RA (supplements 10.9.2)

Replace Table 10-15 with Table I.14.

Table I.14/G.992.1 – Assignment of 80 bits of R-MSG-RA (Annex I)

Suffix(ces) of m_i (Note 1)	Parameter (Note 2)
79-71	Reserved for ITU-T
70	Extension to number of RS payload bytes, K
69, 68	Extension to number of tones carrying data (ncloaded)
67-56	$B_{fast\text{-}max}$
55-49	Number of RS overhead bytes, (R)
48-40	Number of RS payload bytes, K
39-32	Number of tones carrying data (ncloaded)
31-25	Estimated average loop attenuation
24-21	Coding gain
20-16	Performance margin with selected rate option
15	Reserved for ITU-T
14	Extension to total number of bits per DMT symbol, B_{max}
13-12	Maximum Interleave Depth
11-0	Total number of bits per DMT symbol, B_{max}
NOTE 1 – Within the separate fields the least significant bits have the lowest subscripts. NOTE 2 – All reserved bits shall be set to 0.	

I.7.10.1.1 Total number of bits supported (B_{max}) (replaces 10.9.2.8)

This parameter shall be defined as in R-MSG2; see I.7.9.1.

I.7.10.1.2 $B_{fast\text{-}max}$ (new)

$B_{fast\text{-}max}$ is the maximum number of bits of the fast buffer for fast data transmitted on the condition that the bits of the fast data can be equally assigned to all FEXT-symbols and NEXT-symbols.

Fast Buffered Data $B_{fast\text{-}max}$ is t_f.

I.7.10.2 R-MSG2 (supplements 10.9.8)

Table I.15/G.992.1 – Assignment of 32 bits of R-MSG2

Suffix(ces) of m_i (Note 1)	Parameter (Note 2)
31-25	Estimated average loop attenuation
24-21	Reserved for future use
20-16	Performance margin with selected rate option
15	Reserved for future use
14	Extension to total number of bits per DMT symbol, B_{max}
13-12	Reserved for future use
11-0	Total number of bits per DMT symbol, B_{max}
NOTE 1 – Within the separate fields the least significant bits have the lowest subscripts. NOTE 2 – All reserved bits shall be set to "0".	

$N_{1R\text{-}MSG2} = 10$

$N_{2R\text{-}MSG2} = 20$

I.7.10.2.1 Total number of bits per symbol supported (supplements 10.9.8.3)

The maximum number of bits per symbol that the downstream channel can support is encoded into bits 14 and 11-0.

The maximum number of bits per symbol is defined at the reference point B, that is, calculated from the $FEXT_R$ and $NEXT_R$ downstream channel performance. For example, if the maximum numbers of bits that can be supported in $FEXT_R$ and $NEXT_R$ symbols are 111 and 88, the total number of bits per symbol supported is (111 × 126 + 88 × 214)/340 = 96.

NOTE – The number of symbols per hyperframe is 340, the number of FEXT symbols is 126, and the number of NEXT symbols is 214.

I.7.10.2.2 Estimated average downstream loop attenuation (supplements 10.9.8.1)

See A.3.3.

I.7.10.3 R-B&G (replaces 10.9.14)

The purpose of R-B&G is to transmit to ATU-C the bits and gains information, Bitmap-F_R $\{b_1, g_1, b_2, g_2, \ldots, b_{NSC-1}, g_{NSC-1}\}$, and Bitmap-$N_R$ $\{b_{NSC+1}, g_{NSC+1}, b_{NSC+2}, g_{NSC+2}, \ldots, b_{2\times NSC-1}, g_{2\times NSC-1}\}$, to be used on the downstream subcarriers. b_i of Bitmap-F_R indicates the number of bits to be coded by ATU-C transmitter onto the i-th downstream subcarrier in $FEXT_R$ symbols; g_i of Bitmap-F_R indicates the scale factor that shall be applied to the i-th downstream subcarrier in $FEXT_R$ symbols, relative to the gain that was used for that carrier during the transmission of C-MEDLEY. Similarly, b_i of Bitmap-N_R indicates the number of bits onto the (i – NSC)-th downstream carrier in $NEXT_R$ symbols; g_i of Bitmap-N_R indicates the scale factor that shall be applied to the (i – NSC)-th downstream carrier in $NEXT_R$ symbols. Because no bits or energy will be transmitted at DC or one-half the sampling rate, b_0, g_0, b_{NSC}, g_{NSC}, $b_{2\times NSC}$, and $g_{2\times NSC}$ are all presumed to be zero, and are not transmitted. When subcarrier 64 is reserved as the pilot tone, b_{64} and b_{NSC+64}, shall be set to 0, g_{64} and g_{NSC+64} shall be set to g_{sync}. When subcarrier 128 is reserved as the pilot tone, b_{128} and $b_{NSC+128}$, shall be set to 0, g_{128} and $g_{NSC+128}$ shall be set to g_{sync}. The value g_{sync} represents the gain scaling applied to the sync symbol.

The R-B&G information shall be mapped in a (2 × NSC – 2) × 16-bit ((2 × NSC – 2) × 2 byte) message m defined by:

$$m = \{m_{(2\times NSC-2)\times 16-1}, m_{(2\times NSC-2)\times 16-2}, \cdots, m_1, m_0\} = \{g_{2\times NSC-1}, b_{2\times NSC-1}, \cdots, g_{NSC+1}, b_{NSC+1}, g_{NSC-1}, b_{NSC-1}, \cdots, g_1, b_1\} \quad \text{(I.10-3)}$$

with the MSB of b_i and g_i in the higher m index and m_0 being transmitted first. The message m shall be transmitted in (2 × NSC – 2) × 2 symbols, using the transmission method as described in 10.9.8.

When Bitmap-N_R is disabled (FEXT Bitmap mode), b_i and g_i of Bitmap-N_R shall be set to zero.

I.7.10.4 R-SEGUE5 (replaces 10.9.17)

The duration of R-SEGUE5 is 13 symbols. Following R-SEGUE-5, ATU-R completes the initialization and enters R-SHOWTIME. In R-SHOWTIME, ATU-R shall transmit the signal using Bitmap-F_C and Bitmap-N_C with the sliding window.

When Bitmap-N_C is disabled (FEXT Bitmap mode), ATU-R shall not transmit $NEXT_C$ symbols.

I.8 AOC On-line adaptation and reconfiguration (pertains to clause 11)

I.8.1 Bit swap request (replaces 11.2.3)

The receiver shall initiate a bit swap by sending a bit swap request to the transmitter via the AOC channel. This request tells the transmitter which subcarriers are to be modified. The format of the request is shown in Table I.16.

Table I.16/G.992.1 – Format of the bit swap request message

Message header	Message field 1-4			
$\{11111111_2\}$ (8 bits)	Bitmap index (1 bit)	Subchannel index – bits 10 and 9 (2 bits)	Command (5 bits)	Subchannel index – bits 8 to 1 (8 bits)

The request shall comprise nine bytes as follows:

- an AOC message header consisting of 8 binary ones;
- message fields 1-4, each of which consists of a one-bit bitmap index, subchannel index bits 10 and 9, and a five-bit command followed by bits 8 to 1 of the subchannel index. One-bit bitmap index, subchannel index bits 10 and 9, and valid five-bit commands for the bit swap message shall be as shown in Table I.17. In Table I.17, the MSB for the bit swap request command represents the Bitmap index. For downstream data, Bitmap index equals 0 indicates Bitmap-F_R and Bitmap index equals 1 indicates Bitmap-N_R. Similarly for upstream data, Bitmap index equals 0 indicates Bitmap-F_C, and 1 indicates Bitmap-N_C. The next 2 bits are subchannel index bits 10 and 9. The ten-bit subchannel index is counted from low to high frequencies with the lowest frequency subcarrier having the number zero. The subcarrier index zero shall not be used;
- the bit swap between $FEXT_{C/R}$ symbols and $NEXT_{C/R}$ symbols is not allowed.

Table I.17/G.992.1 – Bit swap request command

Value (8 bits)	Interpretation
$yzz00000_2$	Do nothing
$yzz00001_2$	Increase the number of allocated bits by one
$yzz00010_2$	Decrease the number of allocated bits by one
$yzz00011_2$	Increase the transmitted power by 1 dB
$yzz00100_2$	Increase the transmitted power by 2 dB
$yzz00101_2$	Increase the transmitted power by 3 dB
$yzz00110_2$	Reduce the transmitted power by 1 dB
$yzz00111_2$	Reduce the transmitted power by 2 dB
$yzz01xxx_2$	Reserved for vendor discretionary commands
NOTE 1 – y is "0" for $FEXT_{C/R}$ symbols, and "1" for $NEXT_{C/R}$ symbols of the sliding window.	
NOTE 2 – Subchannel index = zz_2 × 256 + subchannel index value from lower 8-bit field.	

The bit swap request message (i.e., header and message fields) shall be transmitted five consecutive times.

To avoid g_i divergence between ATU-C and ATU-R after several bit swaps, for a g_i update of Δ dB the new g_i value should be given by:

$$g_i' = (1/256) \times round(256 \times g_i \times 10\exp(\Delta/20)) \qquad \text{(I.11-1)}$$

I.8.2 Extended bit swap request (supplements 11.2.4)

The format of the extended bit swap request is shown in Table I.18.

Table I.18/G.992.1 – Format of the bit swap request message

Message header	Message field 1-6			
{11111100_2} (8 bits)	Bitmap index (1 bit)	Subchannel index – bits 10 and 9 (2 bits)	Command (5 bits)	Subchannel index – bits 8 to 1 (8 bits)

In the same manner as the bit swap request, each of the message fields of the extended bit swap request consists of one-bit bitmap index, a five-bit command followed by a related ten-bit subchannel index.

I.8.3 Bit swap acknowledge (supplements 11.2.5)

The bit swap superframe counter number shall only indicate the last superframe (SPF#4) of a hyperframe.

The new bit and/or transmit power table(s) shall then take effect starting from the first frame (frame 0) of SPF#0 of a hyperframe.

If the bit swap superframe counter number contained in the received bit swap acknowledge message does not indicate SPF#4, then the new table(s) shall take effect starting from frame 0 of SPF#0 of the next hyperframe.

I.9 POTS splitter

For operation according to this annex, the E.4/G.992.3 requirements applying over a frequency band up to 1104 kHz shall be met over a frequency band up to 2208 kHz.

Appendix V

Example overlapped PSD masks for use in a TCM-ISDN crosstalk environment

This appendix defines example shaped overlapped downstream PSD masks for use in a TCM-ISDN crosstalk environment. These masks may be used with Annex C modes of operation that use overlapped PSDs.

V.1 Example downstream PSD masks for use with Profiles 5 and 6

In this clause, two example downstream PSD masks are described. They may be used for downstream Dual Bitmap modes with overlapped spectrum. In general, using overlapped spectrum downstream may result in NEXT to the upstream channel. To meet spectrum compatibility requirements, the frequency components overlapping the upstream channel are shaped to reduce the crosstalk. The first example is a spectrally shaped mask used during the NEXT phase of the TTR clock. The second PSD mask has an alternative spectral shaping and is designed for use during the FEXT phase of the TTR clock.

V.1.1 Downstream shaped overlapped PSD mask for use during NEXT periods

The shaped overlapped spectral mask for use during NEXT periods of the TTR clock is defined in Table V.1 and shown plotted in Figure V.1. Spectral shaping is provided in the frequency band overlapping the ADSL upstream channel. Adherence to this mask will result in spectral compatibility with other systems deployed in an access network in a TCM-ISDN crosstalk environment.

Note that the definitions given in Table V.1 and Figure V.1 are those of a PSD mask. The corresponding PSD template is 3.5 dB below the mask at all frequencies.

Table V.1/G.992.1 – Tabulation of a shaped overlapped downstream PSD mask for use during NEXT periods of the TTR clock

Frequency f (kHz)	PSD (dBm/Hz) Peak values
$0 < f < 4$	–97.5, with max power in the 0-4 kHz band of +15 dBrn
$4 < f < 32$	–94.5
$32 < f < 109$	–94.5 + 20.65 log2(f/32)
$109 < f < 138$	–58 + 58 log2(f/109)
$138 < f < 200$	–38.3 + 3.36 log2(f/138)
$200 < f < 1104$	–36.5
$1104 < f < 3093$	–36.5 – 36 log2(f/1104)
$3093 < f < 4545$	–90, peak with max power in the [f, f + 1 MHz] window of (–36.5 – 36 × log2(f/1104) + 60) dBm
$4545 < f < 11040$	–90 peak, with max power in the [f, f + 1 MHz] window of –50 dBm

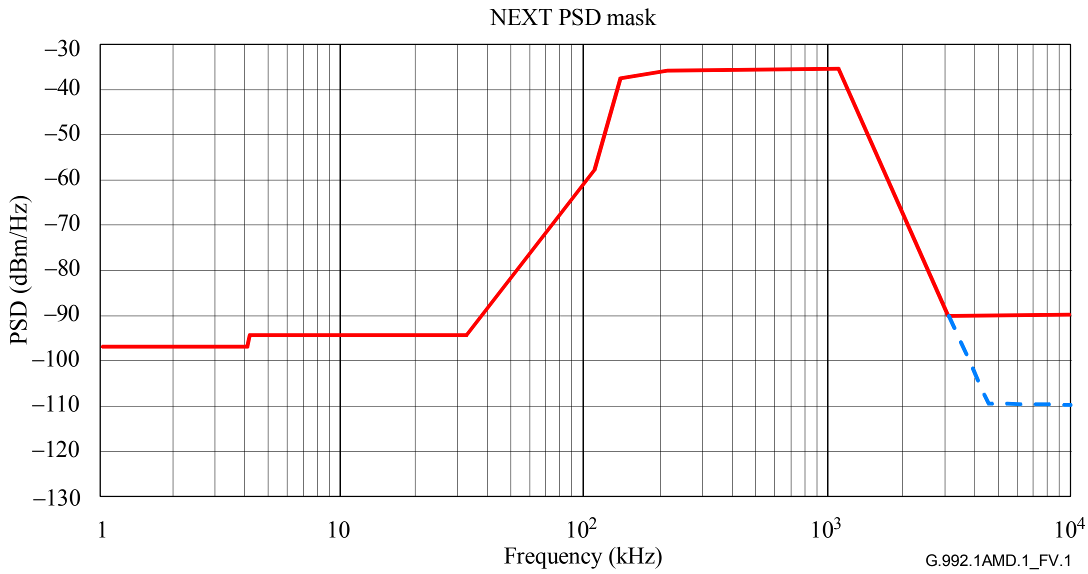


Figure V.1/G.992.1 – A shaped overlapped downstream PSD mask for use during NEXT periods of the TTR clock

V.1.2 Downstream shaped PSD mask for use during FEXT periods

The shaped overlapped spectral mask for use during FEXT periods of the TTR clock is defined in Table V.2 and shown plotted in Figure V.2. Spectral shaping is provided in the frequency band overlapping the ADSL upstream channel. Adherence to this mask will result in spectral compatibility with other systems deployed in an access network in a TCM-ISDN crosstalk environment.

Note that the definitions given in Table V.2 and Figure V.2 are those of a PSD mask. The corresponding PSD template is 3.5 dB below the mask at all frequencies.

Table V.2/G.992.1 – Tabulation of a shaped overlapped downstream PSD mask for use during FEXT periods of the TTR clock

Frequency *f* (kHz)	PSD (dBm/Hz) Peak values
$0 < f < 4$	–97.5, with max power in the 0-4 kHz band of +15 dBrn
$4 < f < 4.8$	–94.5
$4.8 < f < 50$	$-94.5 + 11.0 \log2(f/4.8)$
$50 < f < 126$	$-57.5 + 15.7 \log2(f/50)$
$126 < f < 1104$	–36.5
$1104 < f < 3093$	$-36.5 - 36 \log2(f/1104)$
$3093 < f < 4545$	–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 $[f, f + 1$ MHz$]$ window of –50 dBm

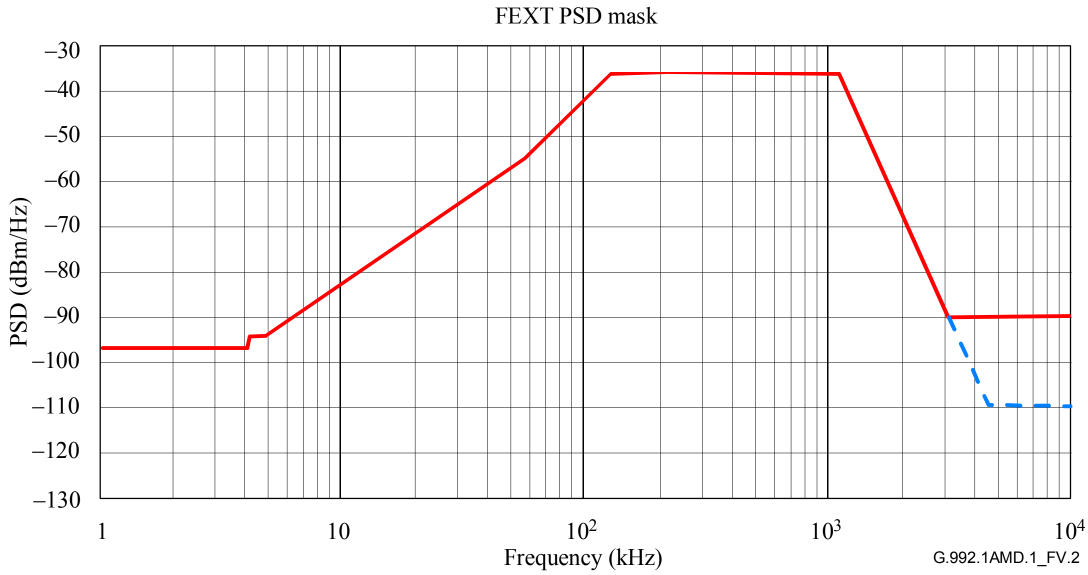


Figure V.2/G.992.1 – A shaped overlapped downstream PSD mask for use during FEXT periods of the TTR clock

V.2 Example downstream PSD mask for use with Profile 3

An example shaped overlapped spectral mask for use with Profile 3 is defined in Table V.3 and shown in Figure V.3. Spectral shaping is provided in the frequency band overlapping the ADSL upstream channel. Adherence to this mask will result in spectral compatibility with other systems deployed in an access network in a TCM-ISDN crosstalk environment.

Note that the definitions given in Table V.3 and Figure V.3 are those of a PSD mask. The corresponding PSD template is 3.5 dB below the mask at all frequencies.

Table V.3/G.992.1 – Tabulation of a shaped downstream PSD mask for Profile 3

Frequency *f* (KHz)	**PSD (dBm/Hz) Peak values**
$0 < f < 4$	–97.5, with max power in the in 0-4 kHz band of +15 dBrn
$4 < f < 5$	–92.5 + 18.64 log2(*f*/4)
$5 < f < 5.25$	–86.5
$5.25 < f < 16$	–86.5 + 15.25 log2(*f*/5.25)
$16 < f < 32$	–62 + 25.5 log2(*f*/16)
$32 < f < 1104$	–36.5
$1104 < f < 3093$	–36.5 – 36 log2(*f*/1104)
$3093 < f < 4545$	–90 peak, with max power in the [*f*, *f* + 1 MHz] window of (–36.5 – 36 × log2 (*f*/1104) + 60) dBm
$4545 < f < 11040$	–90 peak, with max power in the [*f*, *f* + 1 MHz] window of –50 dBm

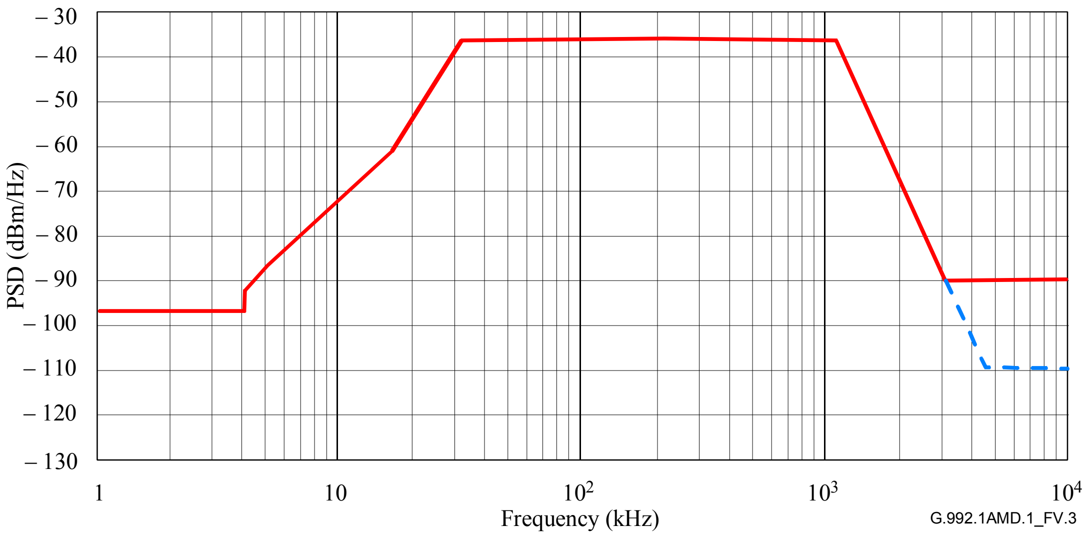


Figure V.3/G.992.1 – A shaped downstream PSD mask for Profile 3

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