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OF ITU

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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ITU-T Recommendation G.992.1

Asymmetric digital subscriber line (ADSL) transceivers

Amendment 1

Revised Annex C, new Annex I and new Appendix V

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

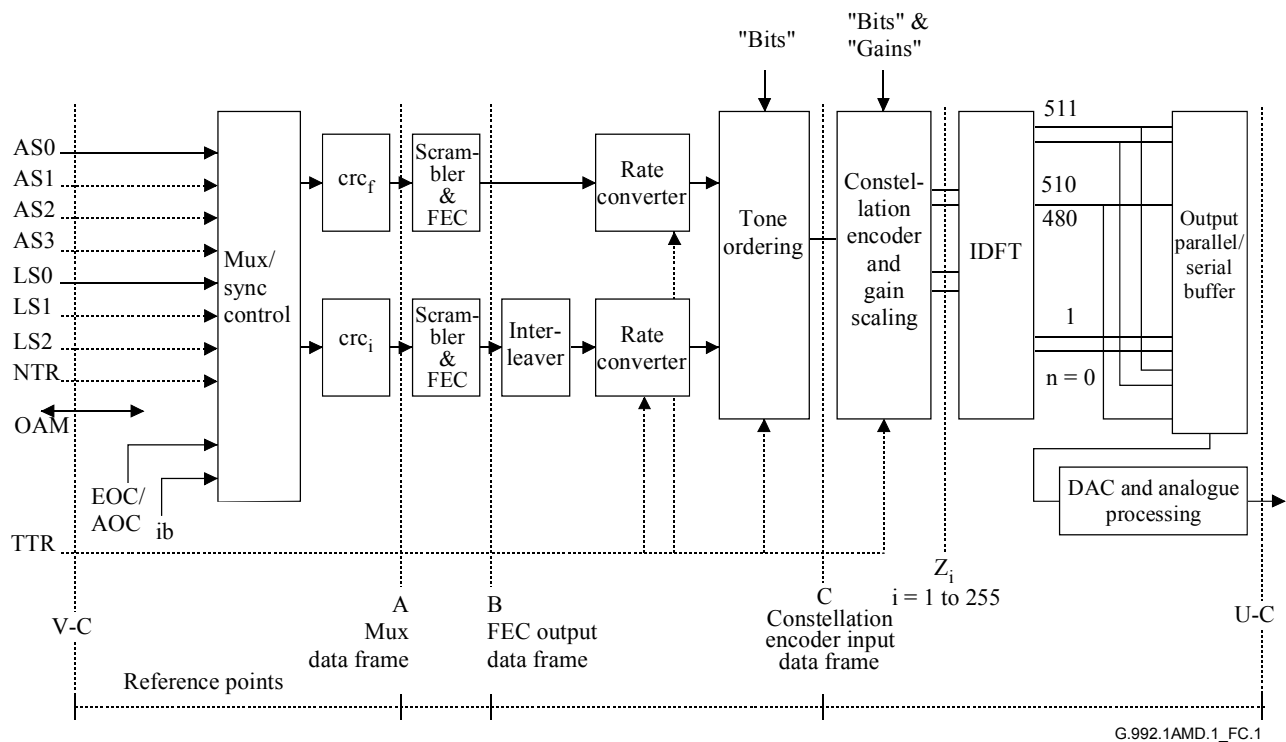
This annex uses the following abbreviations:

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

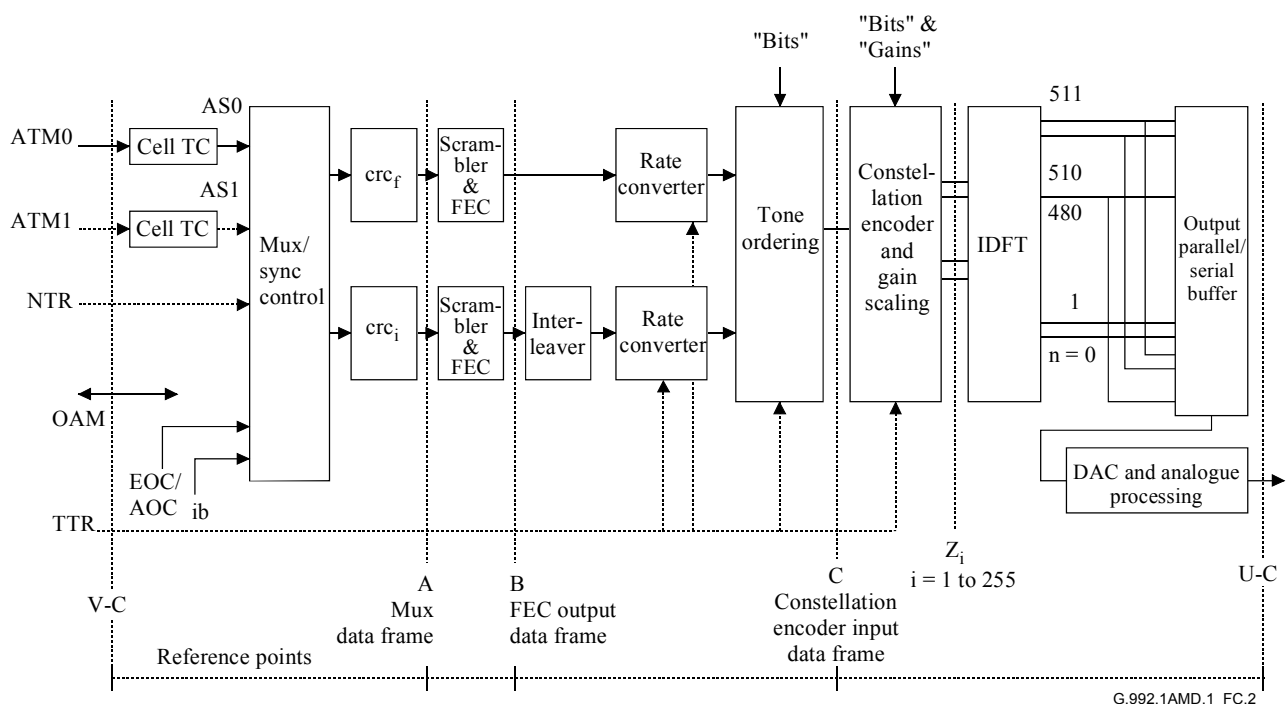
C.3.1 ATU-C transmitter reference model (replaces figures in 5.1)

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

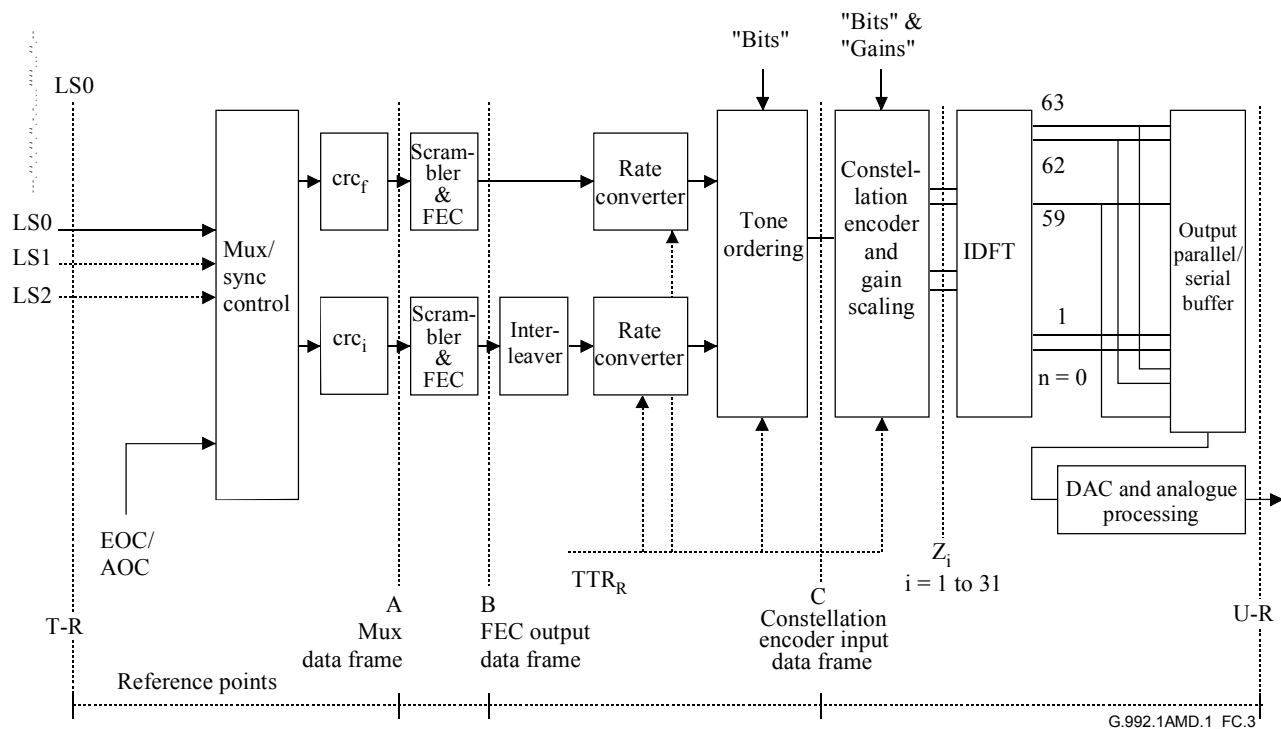


NOTE – The TTR may be generated in ATU-C without being provided from the TCM-ISDN clock.

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

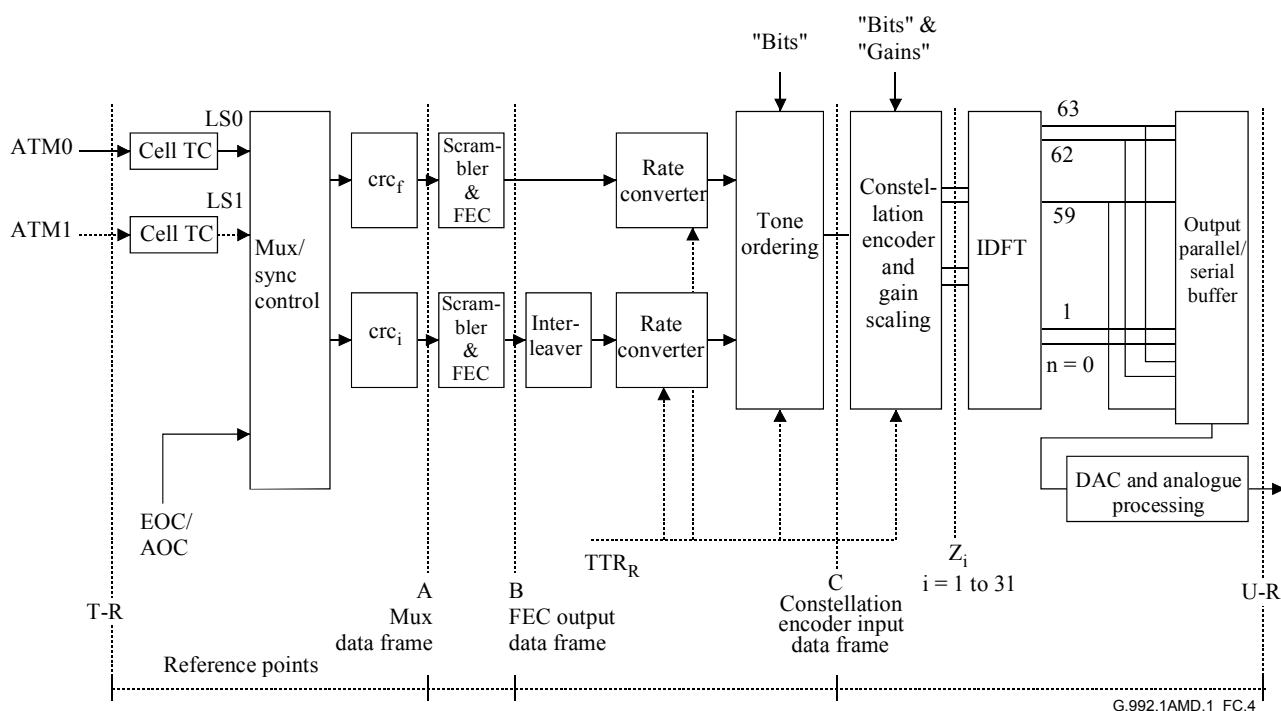
C.3.2 ATU-R transmitter reference model (replaces figures in 5.2)

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



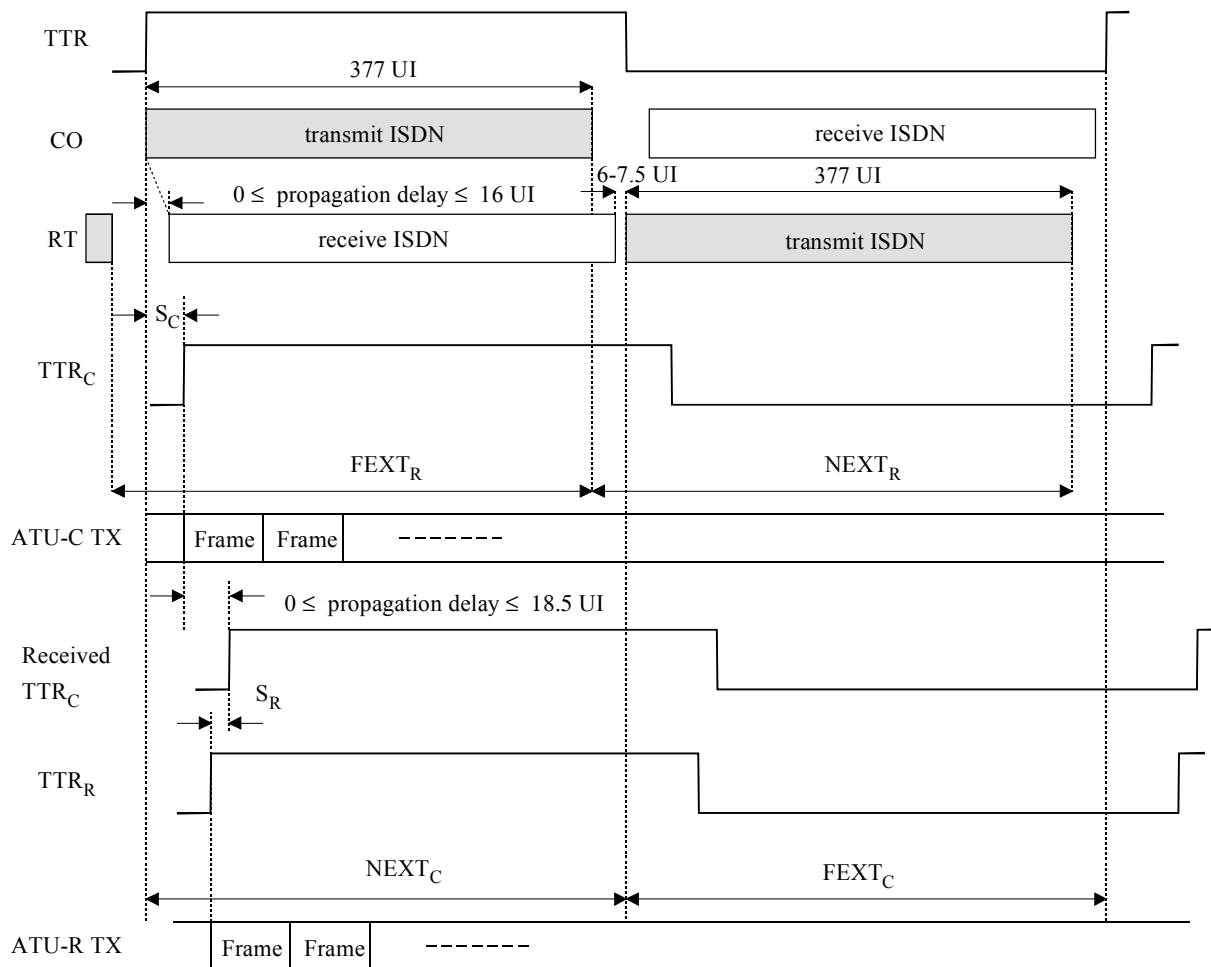
NOTE – The TTR_R shall be generated in ATU-R from the received TTR_C signal, and it is locked to 690 periods of upstream sampling clock (276 kHz).

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.



G.992.1AMD.1_FC.5

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.

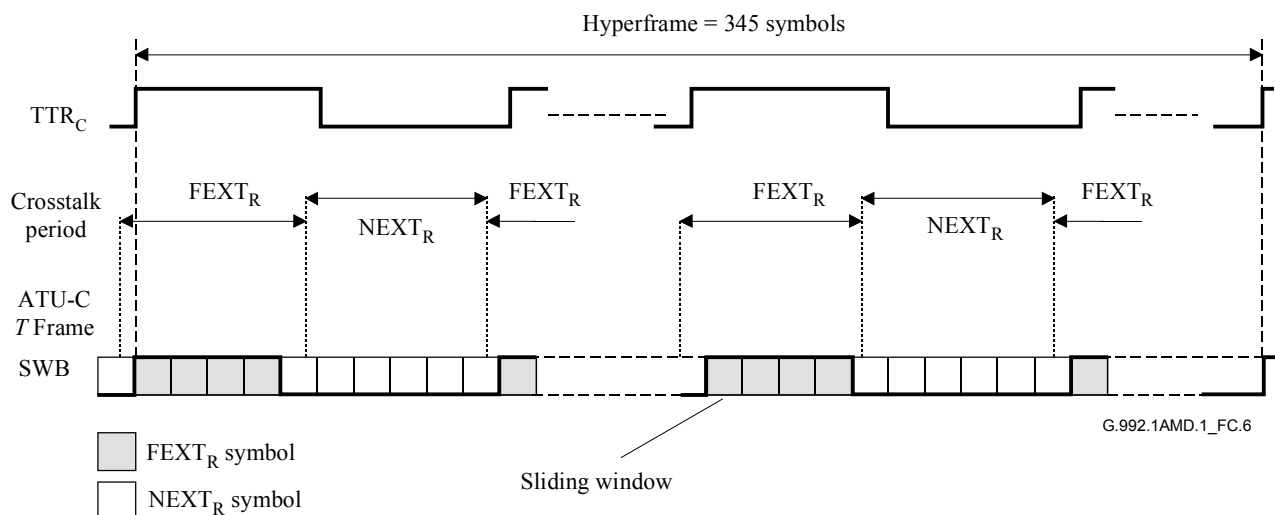


Figure C.6/G.992.1 – Sliding window for downstream symbols

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.

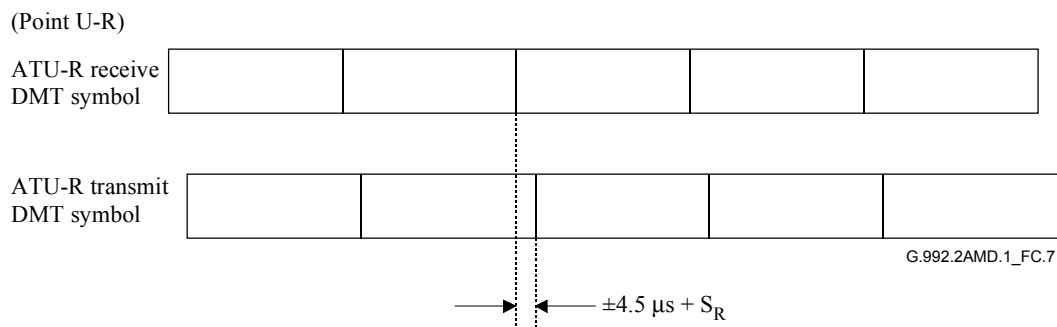


Figure C.7/G.992.1 – Loop timing for ATU-R

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.

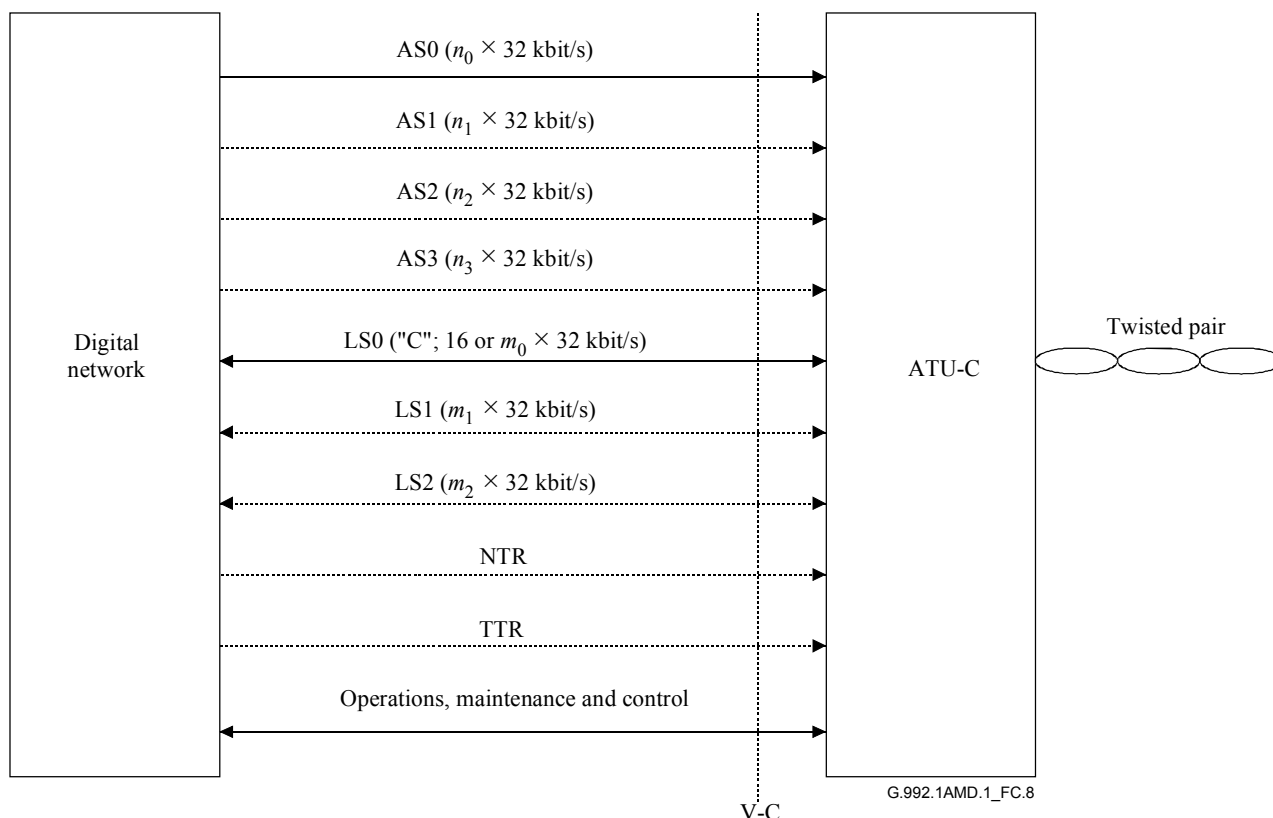
Table 11.5/G.994.1 contains the code points to support these profiles.

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

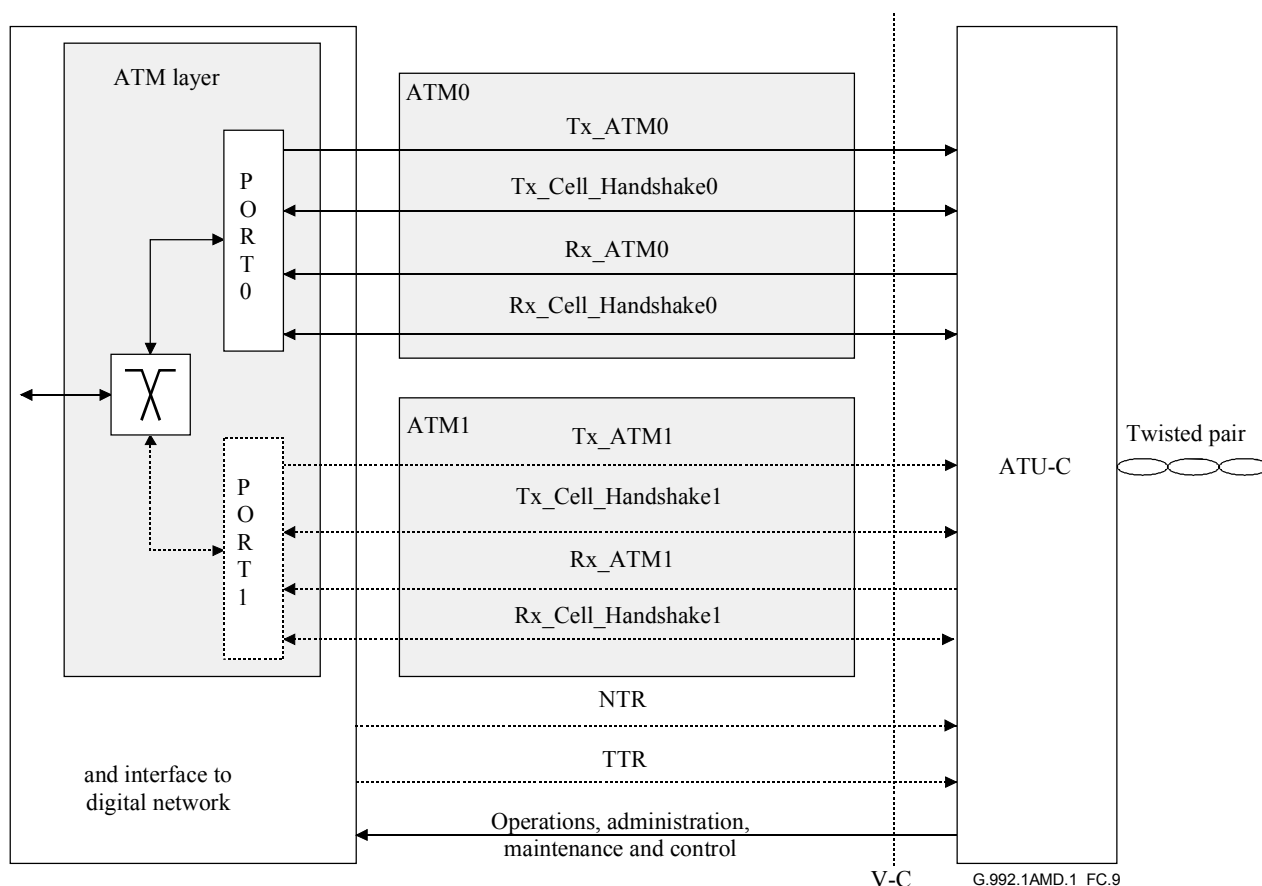
C.4.1.2 Payload transfer delay (supplements 7.1.4)

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.

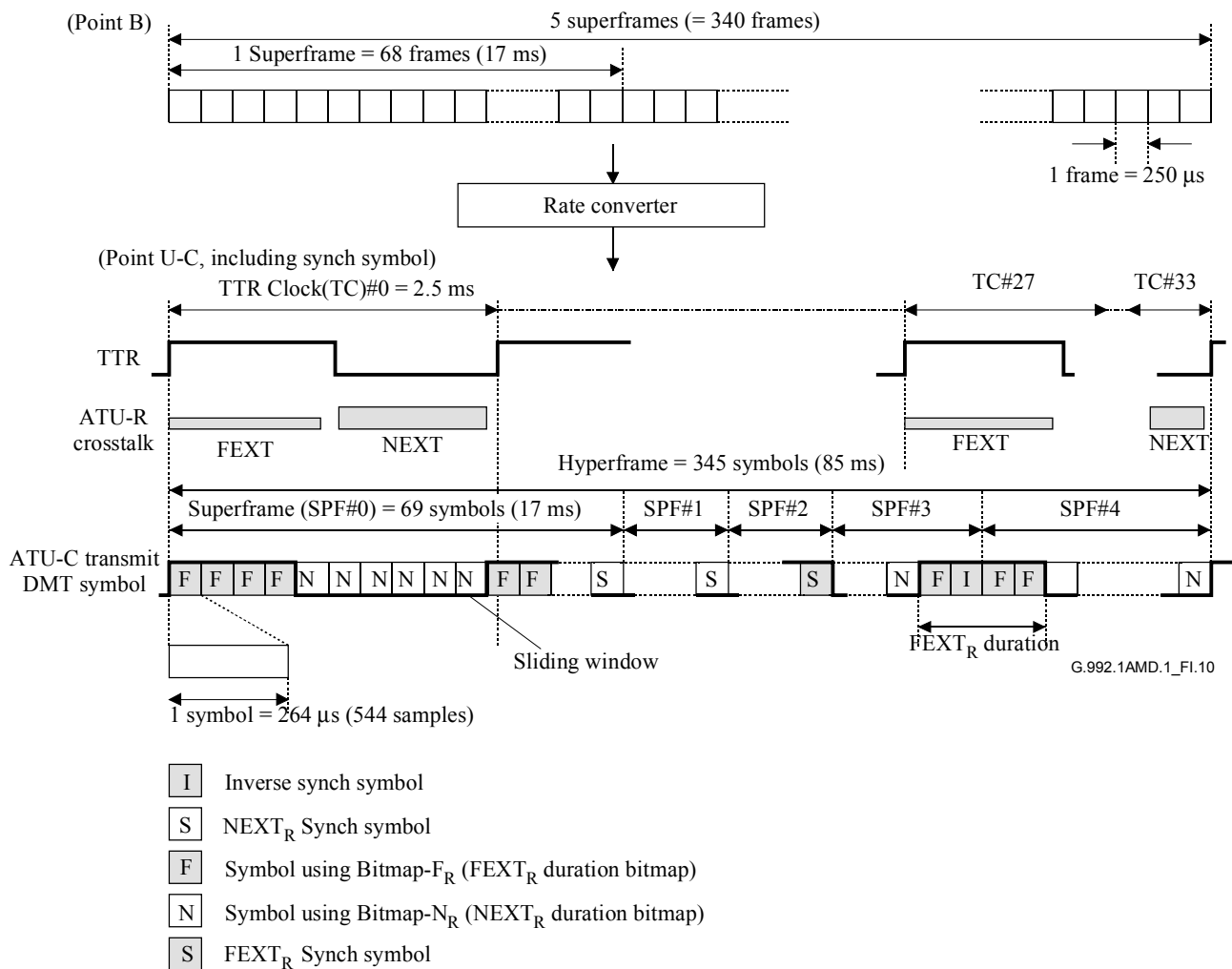


Figure C.10/G.992.1 – Hyperframe structure for downstream

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).

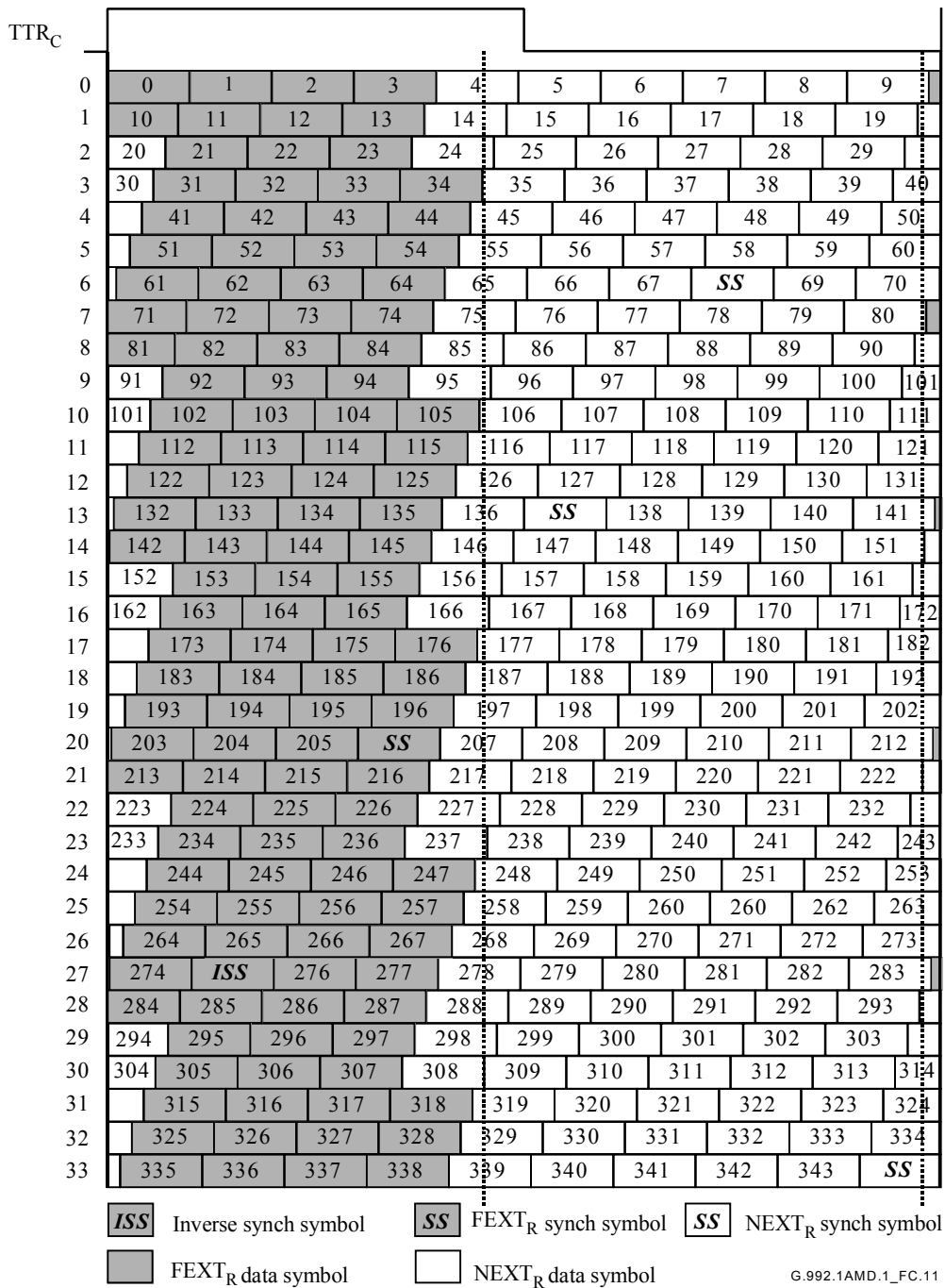


Figure C.11/G.992.1 – Symbol pattern in a hyperframe with cyclic prefix – Downstream

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

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

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 $t_{Rf} \leq n_{Rmax}$:

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

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

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

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

If $t_{Rf} > n_{Rmax}$:

$$n_{Rf} = n_{Rmax}$$

$$n_{Ri} = 0$$

$$f_{Rf} = \begin{cases} f_{Rf4} = \left\lfloor \frac{t_{Rf} \times 10 - n_{Rf} \times 6}{4} \right\rfloor \\ f_{Rf3} = \left\lfloor \frac{t_{Rf} \times 10 - n_{Rf} \times 7}{3} \right\rfloor \end{cases}$$

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

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 $t_{Rf} \leq n_{Rmax}$:

$$dummy_{Rf} = 0$$

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

If $t_{Rf} > n_{Rmax}$:

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

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

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

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.

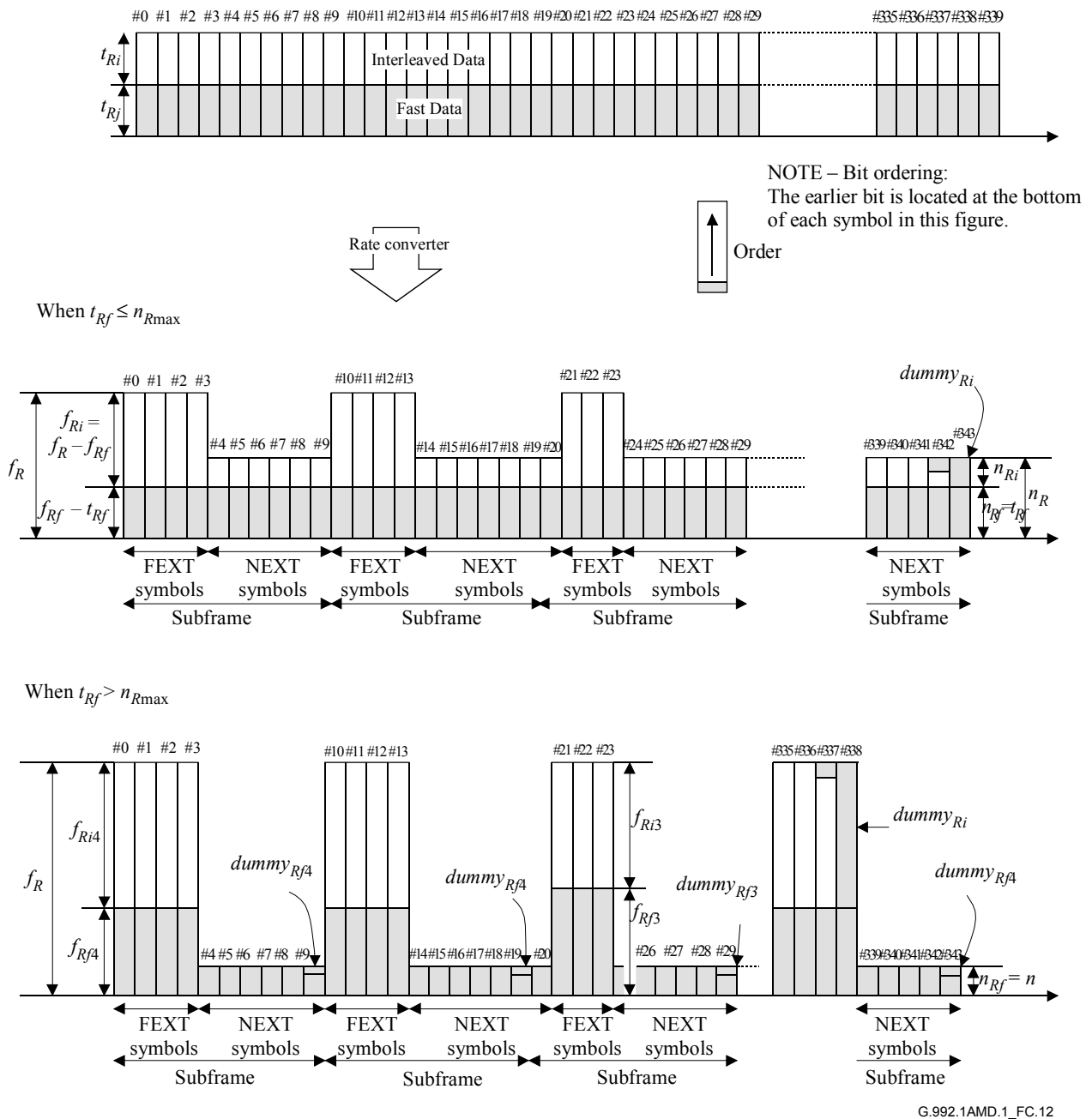


Figure C.12/G.992.1 – Bit distribution for rate converter under dual latency and Dual Bitmap mode

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, ..., 344

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

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.

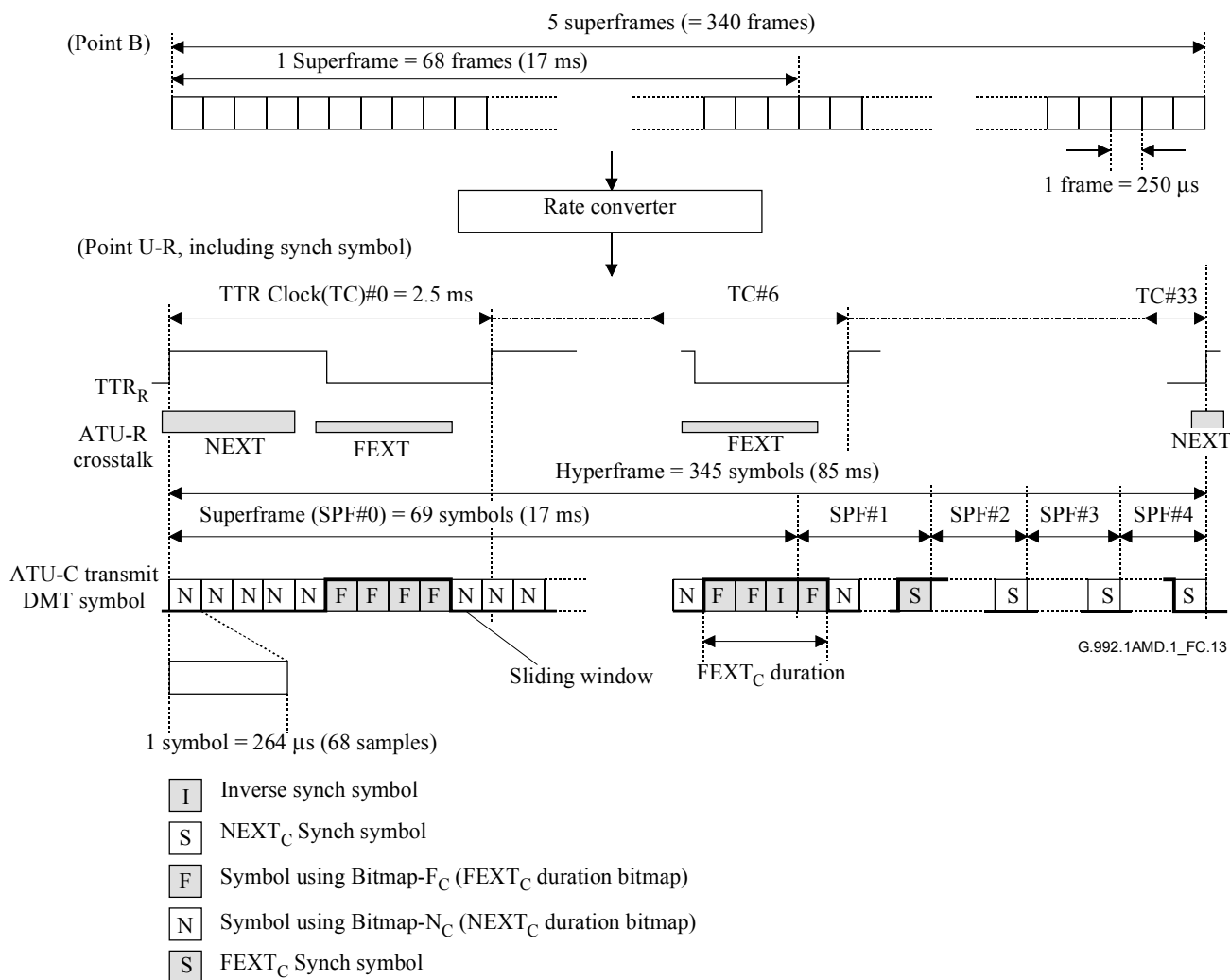


Figure C.13/G.992.1 – Hyperframe structure for upstream

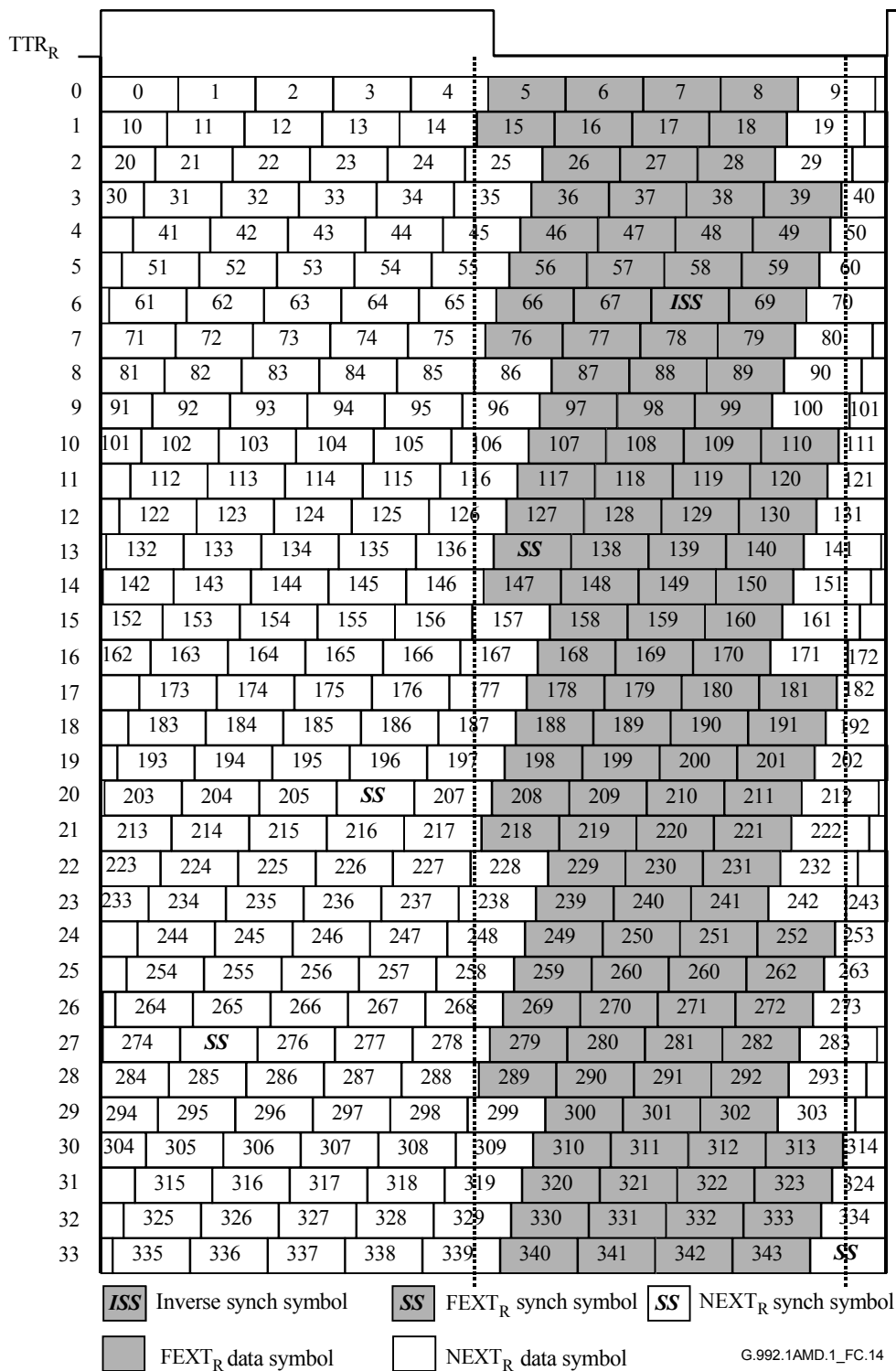


Figure C.14/G.992.1 – Symbol pattern in a hyperframe with cyclic prefix – Upstream

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 $t_{cf} \leq n_{Cmax}$:

$$\begin{aligned}n_{cf} &= t_{cf} \\n_{ci} &= n_C - n_{cf} \\f_{cf} &= t_{cf} \\f_{ci} &= f_C - f_{cf}\end{aligned}$$

If $t_{cf} > n_{Cmax}$:

$$\begin{aligned}n_{cf} &= n_{Cmax} \\n_{ci} &= 0 \\f_{cf} &= \begin{cases} f_{cf4} = \left\lfloor \frac{t_{cf} \times 10 - n_{cf} \times 6}{4} \right\rfloor \\ f_{cf3} = \left\lfloor \frac{t_{cf} \times 10 - n_{cf} \times 7}{3} \right\rfloor \end{cases} \\f_{ci} &= \begin{cases} f_{ci4} = f_C - f_{cf4} \\ f_{ci3} = f_C - f_{cf3} \end{cases}\end{aligned}$$

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 $t_{Cf} \leq n_{Cmax}$:

$$dummy_{Cf} = 0$$

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

If $t_{Cf} > n_{Cmax}$:

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

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

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

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 $+10\log(g_{\text{sync}}^2)$ 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 $4 \times 69/68$ 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 $4 \times 69/68$ 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-QUIET_n 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_{dmf}-th DMT symbol belongs to at ATU-R (see Figure C.15).

For N_{dmf} = 0, 1, ..., 344

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

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_{dmf}-th symbol belongs to at ATU-C (see Figure C.16).

For N_{dmf} = 0, 1, ..., 344

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

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

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

if $\{ (S + 271 \geq a) \text{ and } (S \leq a + b) \}$ 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 $N_{\text{dmt}} = 0, 1, \dots, 344$

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

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

else then NEXT_C symbols

where $a = 1315$, $b = 1293$.

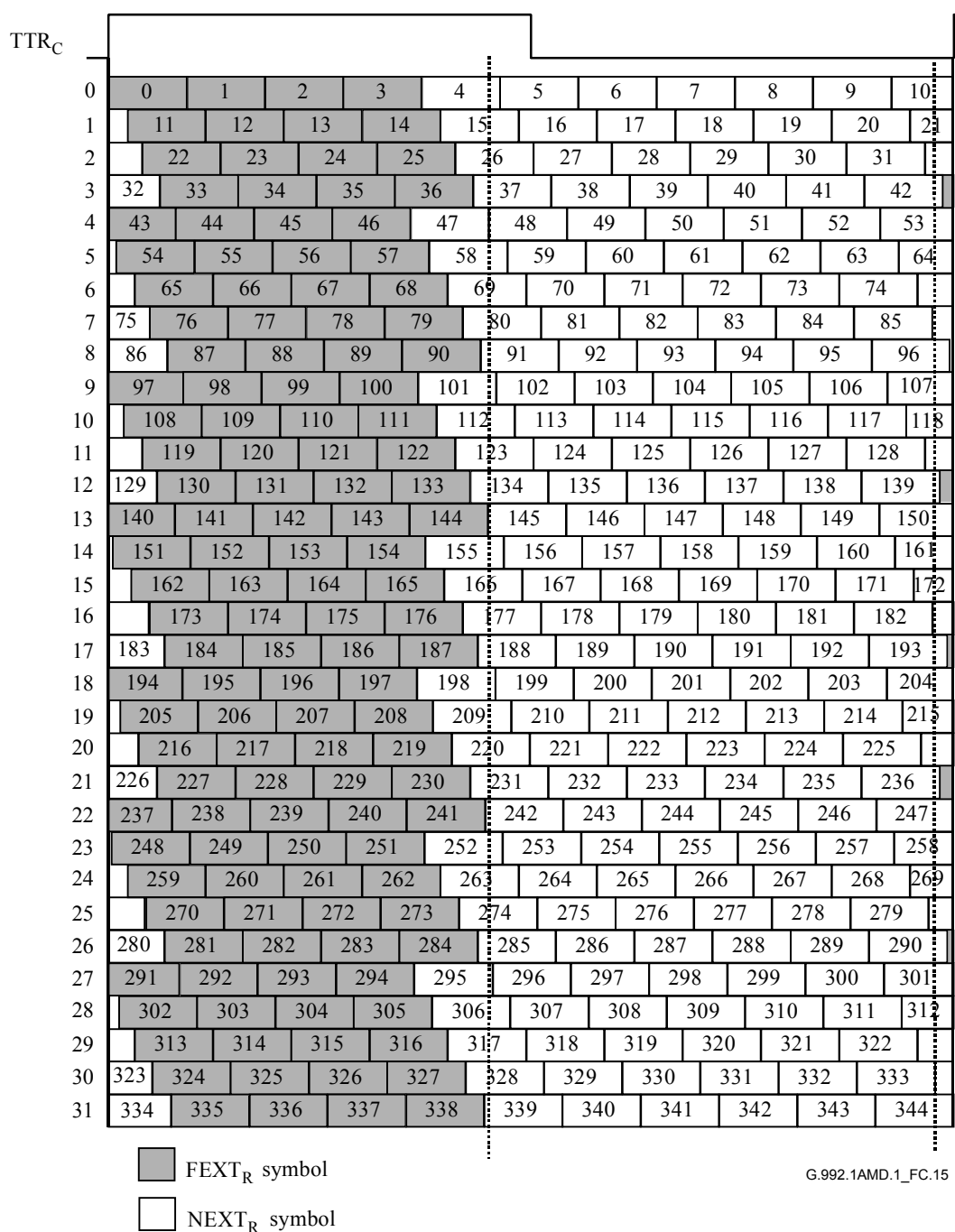


Figure C.15/G.992.1 – Symbol pattern in a hyperframe without cyclic prefix – Downstream

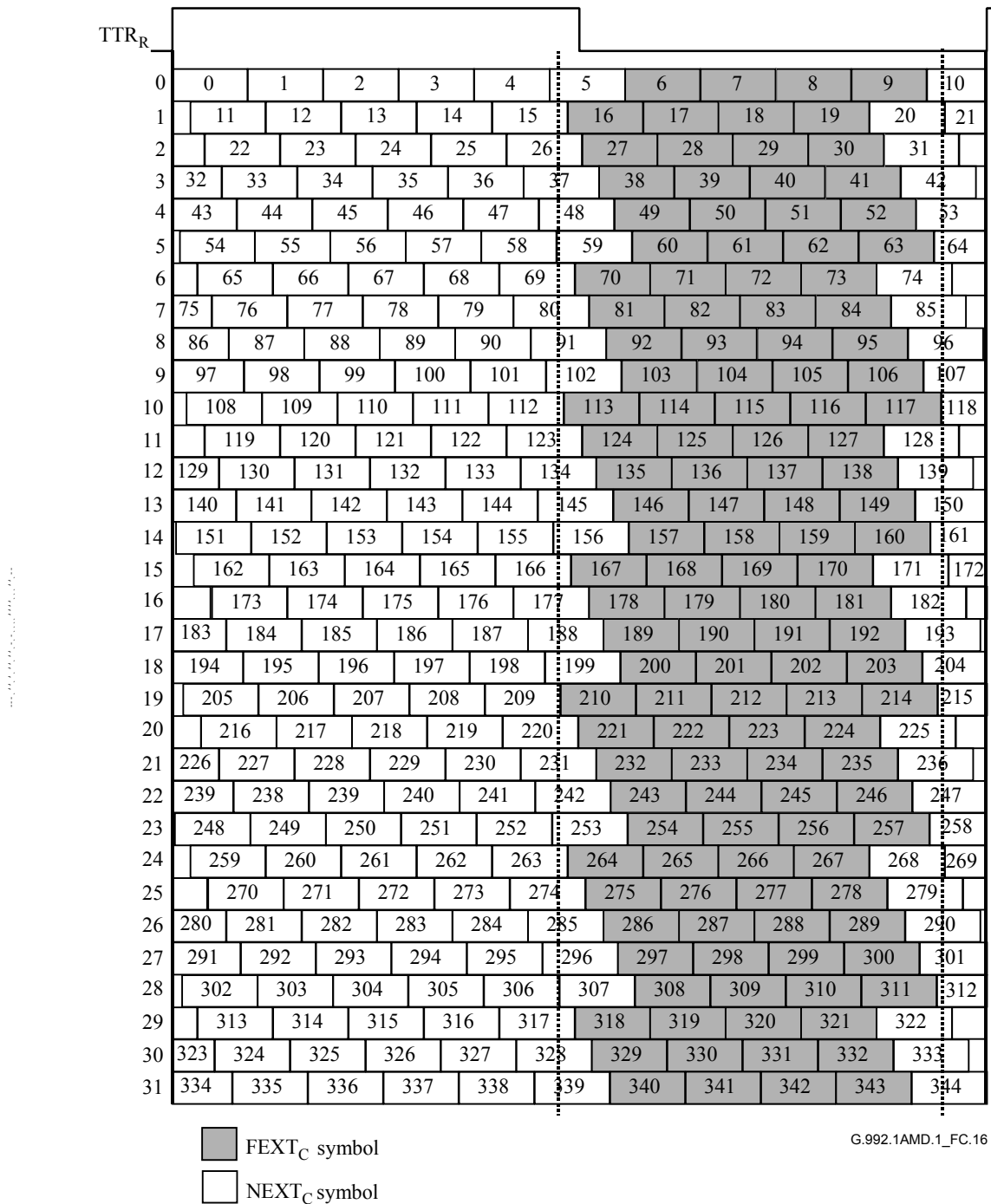


Figure C.16/G.992.1 – Symbol pattern in a hyperframe without cyclic prefix – Upstream

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-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-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-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-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.	