International Telecommunication Union

# ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

# G.975.1
## Corrigendum 2
(07/2013)

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

Digital sections and digital line system – Optical fibre submarine cable systems

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# Forward error correction for high bit-rate DWDM submarine systems

## Corrigendum 2

Recommendation ITU-T G.975.1 (2004) – Corrigendum 2

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**TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS**

| | |
|---|---|
| INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS | G.100–G.199 |
| GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS | G.200–G.299 |
| INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES | G.300–G.399 |
| GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES | G.400–G.449 |
| COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY | G.450–G.499 |
| TRANSMISSION MEDIA AND OPTICAL SYSTEMS CHARACTERISTICS | G.600–G.699 |
| DIGITAL TERMINAL EQUIPMENTS | G.700–G.799 |
| DIGITAL NETWORKS | G.800–G.899 |
| DIGITAL SECTIONS AND DIGITAL LINE SYSTEM | G.900–G.999 |
| General | G.900–G.909 |
| Parameters for optical fibre cable systems | G.910–G.919 |
| Digital sections at hierarchical bit rates based on a bit rate of 2048 kbit/s | G.920–G.929 |
| Digital line transmission systems on cable at non-hierarchical bit rates | G.930–G.939 |
| Digital line systems provided by FDM transmission bearers | G.940–G.949 |
| Digital line systems | G.950–G.959 |
| Digital section and digital transmission systems for customer access to ISDN | G.960–G.969 |
| **Optical fibre submarine cable systems** | **G.970–G.979** |
| Optical line systems for local and access networks | G.980–G.989 |
| Access networks | G.990–G.999 |
| MULTIMEDIA QUALITY OF SERVICE AND PERFORMANCE – GENERIC AND USER-RELATED ASPECTS | G.1000–G.1999 |
| TRANSMISSION MEDIA CHARACTERISTICS | G.6000–G.6999 |
| DATA OVER TRANSPORT – GENERIC ASPECTS | G.7000–G.7999 |
| PACKET OVER TRANSPORT ASPECTS | G.8000–G.8999 |
| ACCESS NETWORKS | G.9000–G.9999 |

*For further details, please refer to the list of ITU-T Recommendations.*

## Recommendation ITU-T G.975.1

# Forward error correction for high bit-rate DWDM submarine systems

## Corrigendum 2


### Summary

Corrigendum 2 to Recommendation ITU-T G.975.1 (2004) covers the following functionalities:

– Corrections to the minimal polynomials of clauses I.3.2.1 and I.3.2.2.
– Corrections to Figure I.9 – BCH(3860,3824) frame format in clause I.3.2.3.
– Corrections to Figure I.11 – BCH(2040,1930) frame format in clause I.3.2.3.
– Editorial clarification of the BCH code length in clause I.4


### History

| Edition | Recommendation | Approval | Study Group |
|---|---|---|---|
| 1.0 | ITU-T G.975.1 | 2004-02-22 | 15 |
| 1.1 | ITU-T G.975.1 (2004) Cor. 1 | 2006-02-17 | 15 |
| 1.2 | ITU-T G.975.1 (2004) Cor. 2 | 2013-07-12 | 15 |

# Recommendation ITU-T G.975.1

## Forward error correction for high bit-rate DWDM submarine systems

## Corrigendum 2

### 1) Clause I.3.2.1

*Revise clause I.3.2.1, BCH(3860,3824) code, as follows:*

#### I.3.2.1 BCH(3860,3824) code

The BCH(3860,3824) code is a binary code. The generator polynomial of the code is given by:

$$G(x) = M_1(x)M_3(x)M_5(x)$$

~~$M_i(x) = \prod_{j=1}^{12}(x - \alpha^{i*j})$~~

$$M_i(x) = \prod_{j=1}^{12}(x - \alpha^{i*2j})$$

where $M_i(x)$ are minimal polynomials and $\alpha$ is a root of the binary primitive polynomial $x^{12} + x^{11} + x^8 + x^6 + 1$. The BCH(3860,3824) codeword consists of 3824 information bits and 36 parity bits. The BCH(3860,3824) can correct up to 3 bit errors in a single codeword.

### 2) Clause I.3.2.2

*Revise clause I.3.2.2, BCH(2040,1930) code, as follows:*

#### I.3.2.2 BCH(2040,1930) code

The BCH(2040,1930) code is a binary code. The generator polynomial of the code is given by:

$$G(x) = M_1(x)M_3(x)M_5(x)M_7(x)M_9(x)M_{11}(x)M_{13}(x)M_{15}(x)M_{17}(x)M_{19}(x)$$

~~$M_i(x) = \prod_{j=1}^{11}(x - \alpha^{i*j})$~~

$$M_i(x) = \prod_{j=1}^{11}(x - \alpha^{i*2j})$$

where $M_i(x)$ are minimal polynomials and $\alpha$ is a root of the binary primitive polynomial $x^{11} + x^2 + 1$. The BCH(2040,1930) codeword consists of 1930 information bits and 110 parity bits. The BCH(2040,1930) can correct up to 10 bit errors in a single codeword.

### 3) Clause I.3.2.3, Figure I.9

*Revise the dummy data fields in Figure I.9 as follows:*

### I.3.2.3 Frame structure

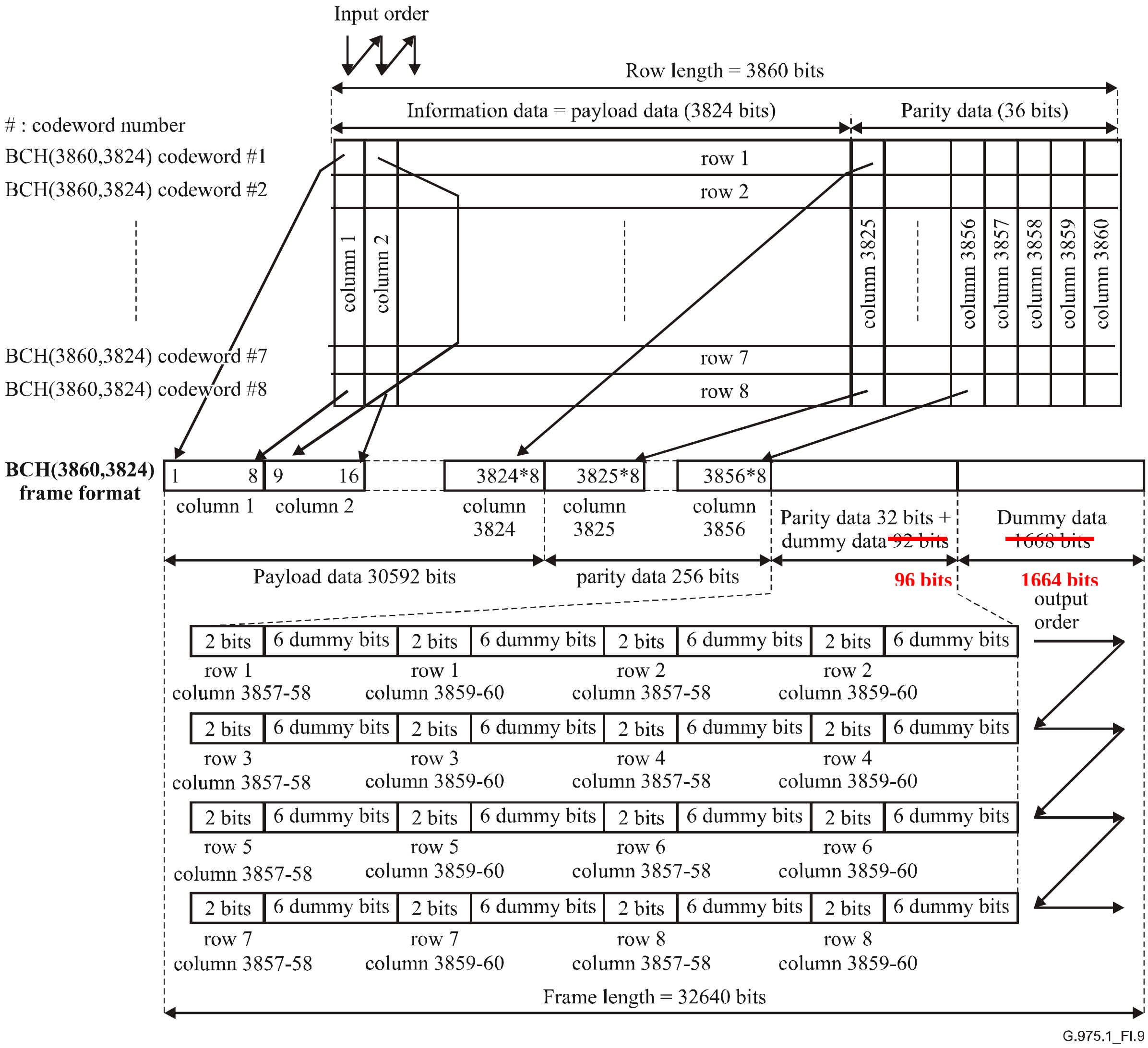
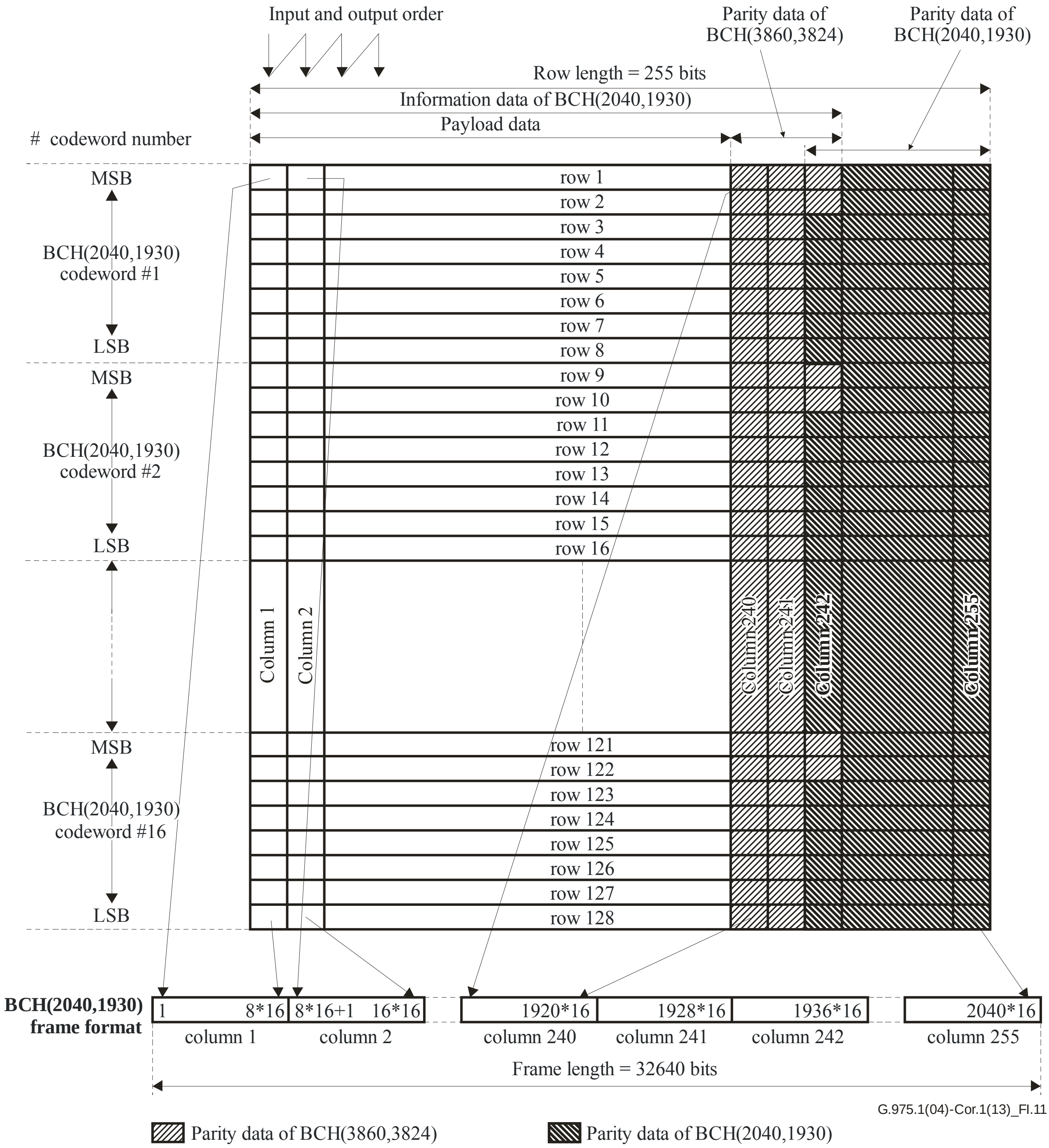



**Figure I.9 – BCH(3860,3824) frame format**

### 4) Clause I.3.2.3, Figure I.11

*Add a note to Figure I.11 as shown below:*




NOTE – The area from row 17 to 120 of Column 242 is used for parity data of both BCH(3860,3824) and BCH(2040,1930) in the following manner:

– row (1+8*n), row (2+8*n) @ n=2~14; Parity data of BCH(3860,3824)

– row (3+8*n) ~ row (8+8*n) @ n=2~14; Parity data of BCH(2040,1930).

**Figure I.11 – BCH(2040,1930) frame format**

## 5) Clause I.4

*Revise clause I.4 "RS(1023,1007)/BCH(2047,1952)super FEC code" as follows:*

## I.4 RS(1023,1007)/BCH(~~2047~~2040,1952) super FEC code

### I.4.1 Overview

This Super FEC consists of two interleaved codes:

– RS(1023,1007) parent outer code, m = 10, T = 8.

– BCH(2047,1952) parent inner code, m = 11, T = 8 shortened to BCH(2040,1952).

These two interleaved codes are targeted at providing additional coding gain on the standard G.709/Y.1331 ODU payload while maintaining the exact data rates at the G.709/Y.1331 OTU, i.e., 7% overhead.

### I.4.2 Super FEC algorithm

#### I.4.2.1 Code interleaving

The ODU payload consists of 16 × 239 × 4 × 8 bits = 122368 bits in total. These 122368 bits are divided into 16 groups and are then encoded with 15 RS(781,765) and one RS(778,762) code, both of which are shortened codes of the parent code listed above. Note that the parent code above operates on an m = 10 Galois Field, so data are grouped into dectets and are operated on accordingly. If we number the ODU payload bits as odu[0], odu[1] up to odu[122367], then the interleaving can be clearly explained. Keep in mind that odu[0] is the first transmitted bit, followed by odu[1] and so on up to odu[122367], i.e., in G.709/Y.1331 terms, {odu[0], odu[1], odu[2], odu[3], odu[4], odu[5], odu[6], odu[7]} = 0xf6, the first OA1 byte in the G.709/Y.1331 frame.

Using this convention, we will now pack the odu bits into the payload portion of the RS codes. This first RS code RS[0] is an RS(781,765) over m = 10. Thus we need to pack 765 × 10 bits into the first 765 dectets of this code. Thus bits odu[0]...odu[9] form the first dectet of the first RS code. Bits odu[10]...odu[19] form the second dectet of RS[0]. The bits are repeatedly packed into 765 dectets of RS[0] for a total of 7650 bits, i.e., odu[0]...odu[7649]. At this point, the data is then RS encoded over m = 10 and T = 8, and 2T parity symbols are added to the code. Thus, the next 16 × 10 bits consist of RS parity.

We will now consider the OTU output data. This consists of 16 × 255 × 4 × 8 bits or 130560 bits. We will number these bits otu[0]...otu[130559]. The first RS code is now mapped to the output otu, i.e., odu[0]...odu[7649] → otu[0]...otu[7649]. The next 160 bits of RS parity are now mapped to the otu, i.e., rsparity[0]...rsparity[159] → otu[7650]...otu[7809].

Having completed the first RS code, the next 7650 bits of odu are mapped to the otu, i.e., odu[7650]...odu[15299] → otu[7810]...otu[15459]. These 765 dectets are RS encoded, and the 160 bits of RS parity are inserted into the outgoing otu, i.e., rsparity[0]...rsparity[159] → otu[15460]...otu[15619].

This process is repeated for all 15 RS codes in the same manner. For the 16th and final code, there are 122368 – 15 × 765 × 10 = 7618 bits of remaining odu. These bits are packed into 762 dectets. The final 2 bits, which are missing are 0 filled and packed into the last dectet. These 762 dectets are RS encoded with an RS(778,762) code. Again 160 bits of parity are added to the outgoing otu. Thus odu[~~114749~~114750]...odu[122367] → otu[~~117149~~117150]...otu[124767]. Note that the last 2 bits are 0 filled for the purpose of RS encoding; however, they are not actually transmitted into the outgoing otu. The 160 parity bits are added as follows: rsparity[0]...rsparity[159] → otu[124768]...otu[124927].

Having completed the RS outer code, the BCH inner code is now added to the otu. The 124928 otu bits are then mapped into 64 identical BCH codes of BCH(~~2047~~2040,1952) with m = 11 and T = 8, the parent code is shown above. This requires the 124928 bits to be grouped into 64 partitions of 1952 bits. The BCH mapping is as follows: otu[0] is used as the first bit for BCH[0]. otu[1] is used as the first bit for BCH[1] repeatedly until otu[63] is used as the first bit for BCH[63]. Then otu[64] is used as the second bit for BCH[0]. otu[65] is used as the second bit for BCH[1]. This process is repeated until all 124928 otu bits are consumed by the 64 BCH codes.

For each of the 64 BCH codes, the 1952 payload bits are encoded and 88 parity bits are added to the output. The 88 bits result from the product of T = 8 and m = 11 for the BCH codes. The BCH parity is added to the output otu as follows:

BCH[0] bchparity[0] → otu[124928], BCH[1] bchparity[0] → otu[124929] repeatedly until BCH[63] bchparity[0] → otu[~~124992~~124991]. Then the next bit of each BCH code is added to the output otu, i.e., BCH[0] bchparity[1] → otu[~~124993~~124992]. This is repeated until all 64 BCH codes have exhausted their 88 parity bits. i.e., BCH[63] bchparity[87] → otu[130559] the last bit of the output otu frame.

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### I.4.4 Redundancy ratio

The redundancy ratio of the Interleaved RS(1023,1007)/BCH(~~2047~~2040,1952) Code is 7%, the same as the legacy RS FEC as defined in ITU-T Rec. G.975.

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| | |
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