INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

H.223
Annex D
(05/99)

SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

Infrastructure of audiovisual services – Transmission multiplexing and synchronization

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Multiplexing protocol for low bit rate multimedia communication

Annex D: Optional multiplexing protocol for low bit rate multimedia mobile communication over highly error-prone channels

ITU-T Recommendation H.223 – Annex D

(Previously CCITT Recommendation)

ITU-T H-SERIES RECOMMENDATIONS

AUDIOVISUAL AND MULTIMEDIA SYSTEMS

For further details, please refer to ITU-T List of Recommendations.

ITU-T RECOMMENDATION H.223

MULTIPLEXING PROTOCOL FOR LOW BIT RATE MULTIMEDIA COMMUNICATION

ANNEX D

Optional multiplexing protocol for low bit rate multimedia mobile communication over highly error-prone channels

Summary

Described in this annex are error robust adaptation layers as an extension of Recommendation H.223. They are specified as an optional definition of Annex C/H.223. These adaptation layers use Reed-Solomon codes, which represent an alternative to RCPC coding, as defined in Annex C/H.223, for error correction.

Source

Annex D to ITU-T Recommendation H.223 was prepared by ITU-T Study Group 16 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 27th of May 1999.

FOREWORD

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Recommendation H.223

MULTIPLEXING PROTOCOL FOR LOW BIT RATE MULTIMEDIA COMMUNICATION

ANNEX D

Optional multiplexing protocol for low bit rate multimedia mobile communication over highly error-prone channels

(Geneva, 1999)

D.1 Scope

In this annex, an optional level 3 protocol of the H.223 mobile extensions is specified. In order to maintain compatibility, the basic features of the level 3 protocol described in Annex C/H.223 shall be included.

D.2 Acronyms and definitions

ARQ	Automatic Repeat reQuest
CF	Control Header Field
CRC	Cyclic Redundancy Check
FEC	Forward Error Correction
SRS	Shortened Reed-Solomon (code)

D.3 Multiplex (MUX) layer specification

See C.3/H.223.

D.4 Adaptation layer

D.4.1 AL1M

D.4.1.1 Framework of AL1M

See C.4.1.1/H.223.

D.4.1.2 Primitive exchanged between AL1 and AL1M

See C.4.1.2/H.223.

D.4.1.3 Functions of AL1M

AL1M provides the following functions:

- optional error detection and indication;
- optional sequence numbering;
- optional forward error correction;

•	optional support of retransmission via ARQI[1];
•	optional AL-SDU splitting for framed frames.

### D.4.1.4	Format and structure of AL1M

The format of the AL1M can be seen in Figure D.1.

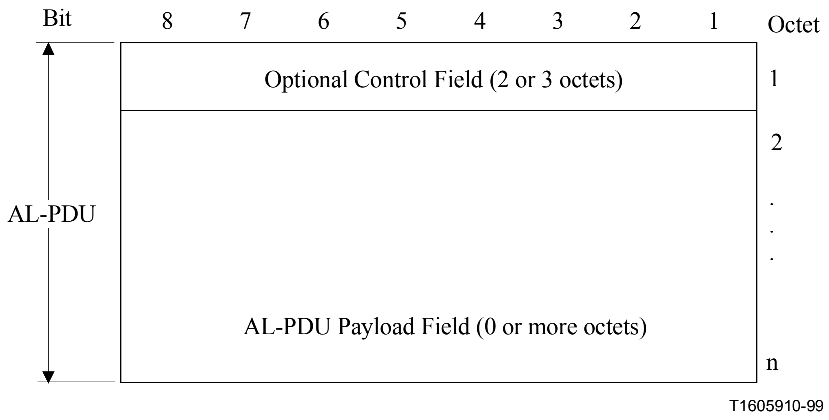

Figure D.1/H.223 – Format of the AL-PDU of the AL1M

The AL-PDU payload shall consist of either an I-PDU or a S-PDU. If a S-PDU is transmitted, the length of the AL-PDU payload is 0, otherwise it is an I-PDU. In the following descriptions the AL-PDU payload is assumed to be an I-PDU unless some other indication is given. The maximum length of AL-PDUs that an AL1M receiver can accept shall be signalled via the H.245 capability exchange.

In contrast to AL1 of Recommendation H.223, the AL-SDU is not always directly mapped to the AL-PDU payload, see Figure D.2. The application layer (AL1 user) transfers its data through AL-SDUs to the adaptation layer. The adaptation layer forms its own AL-SDUs* from the AL-SDUs. The length of the AL-PDU can be derived from the procedure given in D.4.1.7.1. The AL-PDU is formed by the AL-PDU payload and the optional Control Field (CF).

[1] Note that ARQII is not supported.

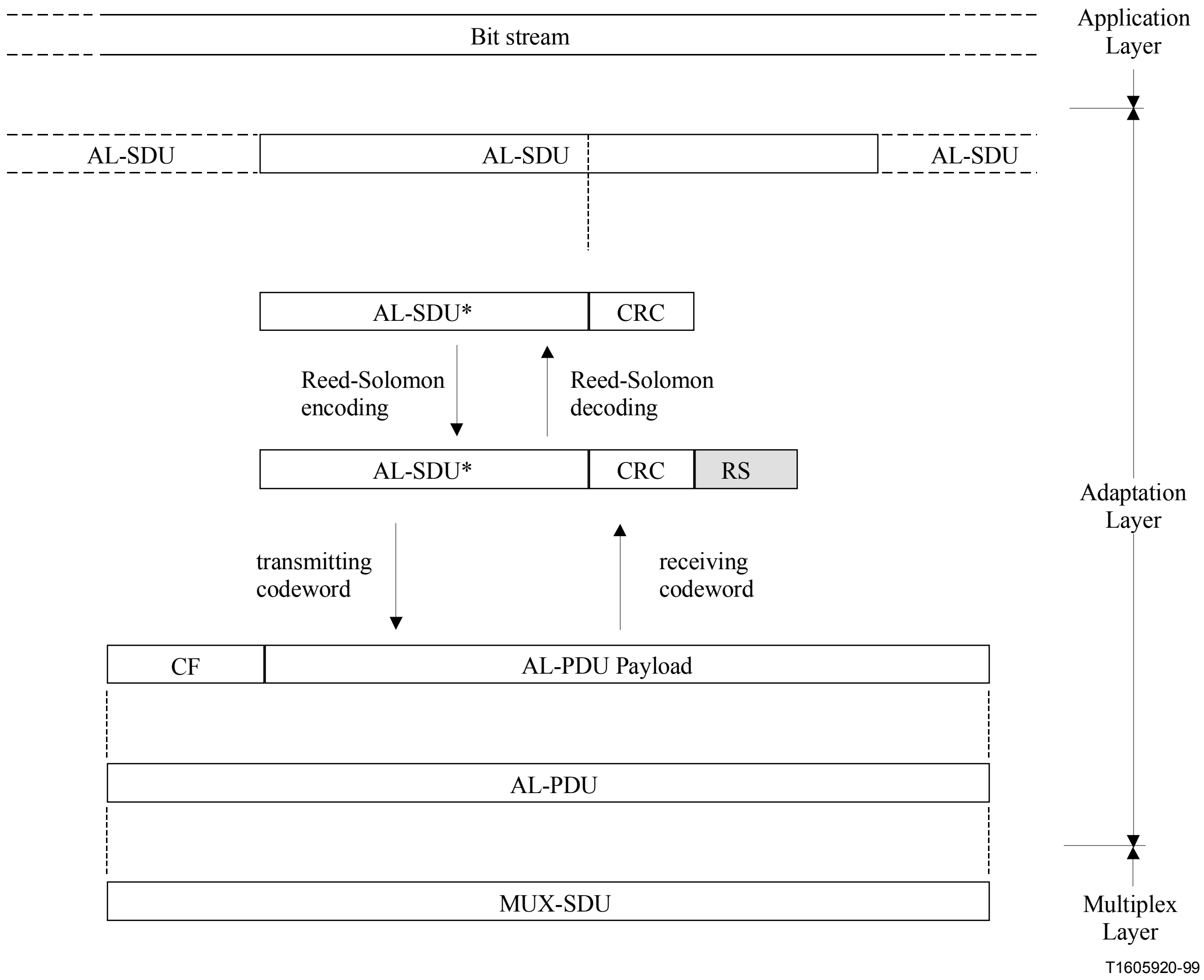

Figure D.2/H.223 – AL1M structure

The error protocol allows the AL1M to operate the following two modes:

FEC_ONLY In this mode an AL-SDU* with a CRC is Reed-Solomon encoded with a code rate r ≤ 1.0. The length of the AL-SDU* shall be shorter than $255 - 2e_{target} - l_{CRC}/8$. The resulting AL-PDU consists only of an AL-PDU payload field. Splitting mode is not supported. In this mode, no retransmission is possible.

ARQ If the mode is set to ARQI (only ARQI supported), it is possible to request retransmissions.

When ARQI is used, each (re)transmission shall contain the same encoded data. Therefore, the AL-PDU of each retransmission of the same SN shall contain the identical number of octets.

D.4.1.5 Control Field (CF)

See C.4.1.5/H.223.

D.4.1.6 Procedures for splitting an AL-SDU (splitting mode)

Only in framed transfer mode, the adaptation layer may split the AL-SDU into one or several AL-SDU*s if the use of this splitting procedure is signalled by the OpenLogicalChannel message. This procedure is mandatory for the receiver. In the event that AL-SDU is longer than $255 - 2e_{target} - l_{CRC}/8$ octets, transmitter shall apply this splitting procedure. In the event that AL-SDU is shorter than $255 - 2e_{target} - l_{CRC}/8$ octets, transmitter may apply this splitting procedure.

Each AL-SDU* is transmitted as described in D.4.1.7. To identify the end of an AL-SDU, the last AL-SDU* of the AL-SDU shall be marked by setting the RN field to logical "1", otherwise the RN field shall be set to "0".

D.4.1.7 Procedures for encoding and decoding the AL-PDU payload

See C.4.1.7/H.223.

D.4.1.7.1 Evaluation of the AL-PDU (I-PDU) length

The following parameters are given:

- l_v length of AL-PDU in bits;
- t length of AL-SDU* in bits;
- e_{target} correction ability of the SRS code in octets;
- l_h length of the control header (CF) field in bits;
- l_{CRC} length of the Cyclic Redundancy Check (CRC) field in bits.

The length l_v of the AL-PDU can be evaluated by the following equation:

$$l_v = l_h + t + l_{CRC} + 16e_{target} \quad \text{(D-1)}$$

The parameters l_v, t and l_{CRC} shall be byte aligned. Equation (D-1) shall be used by the AL1M transmitter. At the AL1M receiver the length of the AL-SDU* t shall be evaluated by the following equation:

$$t = l_v - l_h - l_{CRC} - 16e_{target} \quad \text{(D-2)}$$

Both equations shall be calculated in octets, as illustrated by the following example:

Example

The AL1M wants to transmit an AL-SDU* of t = 376 bits (47 octets), e_{target} = 2, l_h = 24 bits (3 octets), l_{CRC} = 16 bits (2 octets). Using the equation (D-1), the length of the AL-PDU is l_v = 56 octets. The instant rate r_{result} can be evaluated by:

$$r_{result} = \frac{t + l_{CRC}}{l_v - l_h} \quad \text{(D-3)}$$

In this example $r_{result} = \frac{49}{53} \approx 0.9245$.

D.4.1.7.2 Cyclic Redundancy Check (CRC)

The CRC provides error detection capability across the entire AL-SDU*, however no CRC may be used. The CRC is appended to the AL-SDU* before the error correction coding procedure is done. The CRC is used by the AL1M receiver to verify whether the decoding attempt of the error correction algorithm is error-free. CRC lengths of 8, 16 and 32 bits are supported. The length of the CRC field shall be specified during the H.245 OpenLogicalChannel procedure.

Description of the CRC polynomials:

a) 8-bit CRC: see 7.3.3.2.3/H.223;

b) 16-bit CRC: see 7.4.3.2.3/H.223;

c) 32-bit CRC: see 8.1.1.6.2/V.42.

D.4.1.7.3 Shortened Reed-Solomon encoder

The channel encoder is based on a Shortened Reed-Solomon (SRS) encoder with correction ability e_{target}, where e_{target} can be selected as an arbitrary integer value satisfying $0 \le 2e_{target} \le 255 - (t + l_{CRC})/8$, where t and l_{CRC} denote length of AL-SDU* and length of CRC, respectively. At the AL1M sending unit, the AL-PDU payload is generated by Reed-Solomon encoding of the concatenated field of the AL-SDU* and CRC field. The Reed-Solomon encoding of the CRC field starts with the highest order term of the polynomial representing the CRC field. At the AL1M receiving entity, the concatenation of AL-SDU* and CRC field may be reconstructed by Reed-Solomon decoding. As this code is systematic the receiver may also directly extract the CRC protected AL-SDU* from the received bit stream without Reed-Solomon decoding. The SRS code defined in the Galois field GF(2^8) is generated from a generator polynomial $g(x) = (x-\alpha)(x-\alpha^2)\text{K}\ (x-\alpha^{2e_{target}})$, where $\alpha^i\,(0 \le i \le 254)$ denotes a root of the primitive polynomial $m(x) = x^8 + x^4 + x^3 + x^2 + 1$. Table D.I.1 shows binary 8-tuple representations for α^i. A shift register realization is shown in Figure D.3.

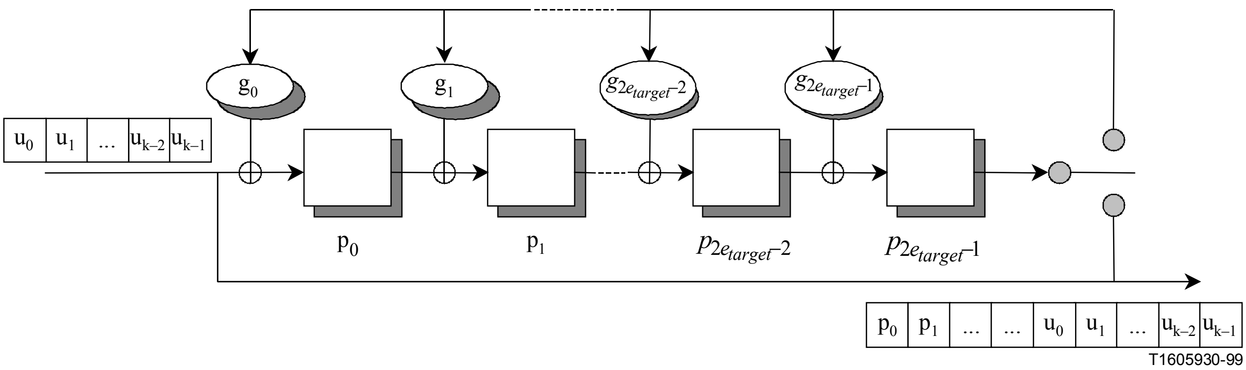

Figure D.3/H.223 – Shift register realization for Reed-Solomon encoder

Each element of the message sequence $\boldsymbol{u} = (u_{k-1}, u_{k-2}, \text{K}\ , u_1, u_0)$ corresponds to that of AL-SDU* and CRC in octets. The parity check polynomial $p(x)$ is calculated as:

$$\begin{aligned} p(x) &= x^{2e_{target}} \cdot u(x) \bmod g(x) \\ &= p_{2e_{target}-1} x^{2e_{target}-1} + p_{2e_{target}-2} x^{2e_{target}-2} + \Lambda + p_1 x + p_0 \end{aligned} \tag{D-4}$$

where $u(x)$ denotes the message polynomial defined as:

$$u(x) = u_{k-1} x^{k-1} + u_{k-2} x^{k-2} + \Lambda + u_1 x + u_0 \tag{D-5}$$

From (D-4) and (D-5), the code polynomial is given by:

$$\begin{aligned} c(x) = {} & u_{k-1} x^{2e_{target}+k-1} + u_{k-2} x^{2e_{target}+k-2} + \Lambda + u_1 x^{2e_{target}+1} + u_0 x^{2e_{target}} \\ & + p_{2e_{target}-1} x^{2e_{target}-1} + p_{2e_{target}-2} x^{2e_{target}-2} + \Lambda\ p_1 x + p_0 \end{aligned} \tag{D-6}$$

Example

- $e_{target} = 2$
- $u = (u_2, u_1, u_0) = (\alpha^4, \alpha^7, \alpha^{231})$
- $l_{CRC} = 8$

In this example, u_2, and u_1 are assumed to be AL-SDU* and u_0 be CRC. According to the procedure of 7.3.3.2.3/H.223, CRC polynomial $b(x)$ is given by:

$$b(x) = x^7 + x^5 + x^3 + x^2 + x + 1 \quad \text{(D-7)}$$

Then, $u_0 = \alpha^{231}$ is obtained.

The generator polynomial $g(x)$ is given by:

$$\begin{aligned} g(x) &= (x-\alpha)(x-\alpha^2)(x-\alpha^3)(x-\alpha^4) \\ &= x^4 + \alpha^{76}x^3 + \alpha^{251}x^2 + \alpha^{81}x + \alpha^{10} \end{aligned} \quad \text{(D-8)}$$

Each element of the message sequence u = (α^4, α^7, α^{231}) corresponds to that of AL-SDU* and CRC in octets. The parity check polynomial $p(x)$ is then calculated as:

$$\begin{aligned} p(x) &= x^4\left(\alpha^4x^2 + \alpha^7x + \alpha^{231}\right) \bmod g(x) \\ &= \alpha^{34}x^3 + \alpha^{12}x^2 + \alpha^{189}x + \alpha^{188} \end{aligned} \quad \text{(D-9)}$$

From (D-8) and (D-9), the code polynomial is given by:

$$c(x) = \alpha^4x^6 + \alpha^7x^5 + \alpha^{231}x^4 + \alpha^{34}x^3 + \alpha^{12}x^2 + \alpha^{189}x + \alpha^{188} \quad \text{(D-10)}$$

Therefore, the code sequence $c = (\alpha^4, \alpha^7, \alpha^{231}, \alpha^{34}, \alpha^{12}, \alpha^{189}, \alpha^{188})$ is obtained.

Figure D.4 shows a shift register realization of this example.

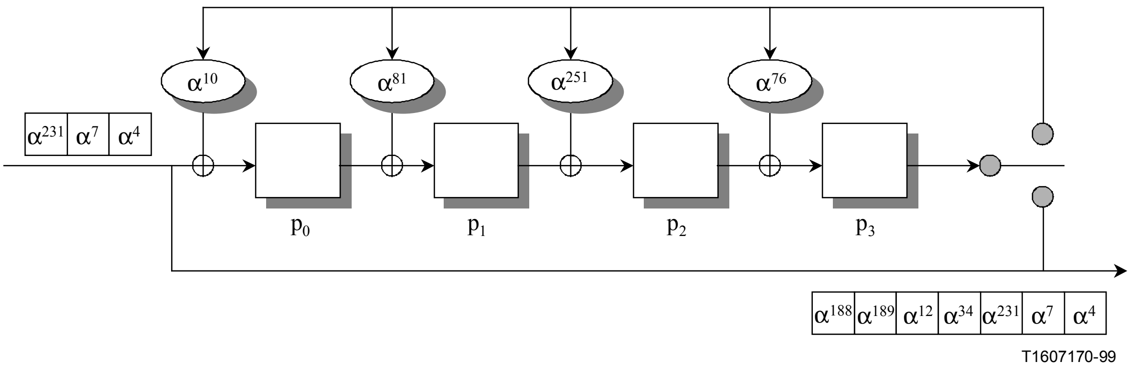

Figure D.4/H.223 – Example of Reed-Solomon encoder (e_{target} = 2)

D.4.1.8 Encoding procedure: AL-SDU* (I-PDU) to AL-PDU

The following steps are necessary to obtain an AL-PDU from an AL-SDU*.

1) The CRC of the length required in the H.245 OpenLogicalChannel message field shall be added to the AL-SDU*.
2) Generate the encoded data by passing the AL-SDU* plus CRC through the Reed-Solomon encoder.

3) For the first transmission read the highest order term of the code polynomial (e.g. u_{k-1} in Figure D.3). The first octet of the output (e.g. u_{k-1} in Figure D.3) is the first octet of the AL-PDU payload field.

4) If required (as indicated in the H.245 OpenLogicalChannel message), the Control Field (CF) shall be added at the beginning of the AL-PDU.

These steps are valid for the modes FEC_ONLY and ARQI.

Figure D.5 illustrates the encoding procedures of the AL1M at the transmitter side.

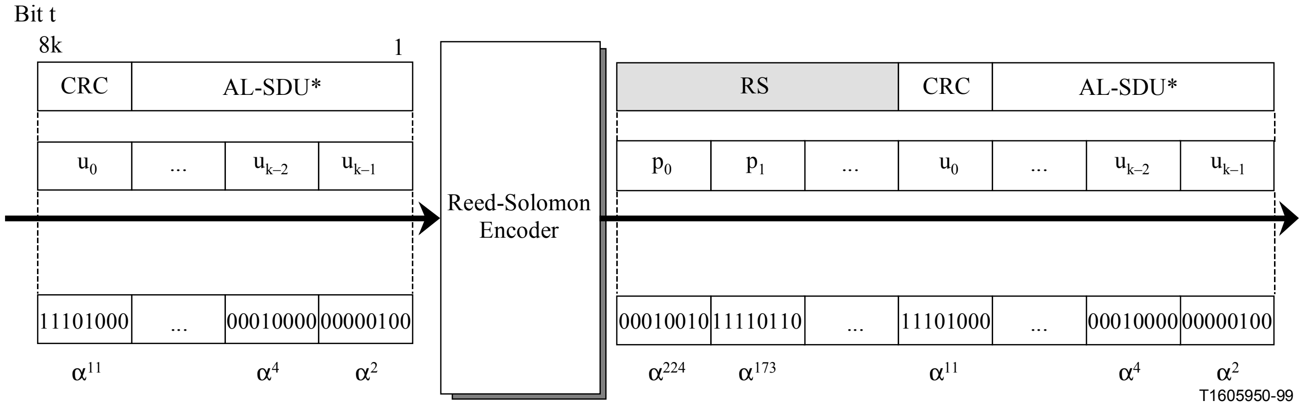

Figure D.5/H.223 – Encoding procedure of the AL1M at the transmitter side

D.4.1.9 Decoding of the AL-PDU payload (I-PDU)

The receiver may check the received systematic symbols before decoding the Reed-Solomon code. If CRC check fails, any kind of Reed-Solomon decoding may be used.

After Reed-Solomon decoding, the CRC may be used to check the correctness of the decoding attempt. If the CRC fails, another retransmission may be requested, or the wrong data may be given to the AL1M user with an appropriate Error Indication (EI) message. If error correction fails, the receiver may use the decoded information symbols or the systematic symbols before Reed-Solomon decoding as received in the AL-SDU*. Again passing the wrong data to the AL1M user along with an EI message.

If ARQI retransmission procedure is used, each retransmission gives the same data as the previous one. After each decoding attempt, the decoding result may be checked by the CRC.

D.4.1.10 Procedures for abort

See C.4.1.11/H.223.

D.4.1.11 Procedures for error control

See C.4.1.12/H.223.

D.4.1.12 Retransmission procedures (ARQI)

See C.4.1.13/H.223.

D.4.2 AL2M

See C.4.2/H.223.

D.4.3 AL3M

See C.4.3/H.223. AL3M in Annex D shall use SRS code in stead of RCPC code.

APPENDIX I

(to Annex D to H.223)

Binary representation for α^i

This appendix expresses the binary representation for α^i over GF(2^8) used in Annex D/H.223. In a binary represented α^i ($u^{(8)}, u^{(7)}, u^{(6)}, u^{(5)}, u^{(4)}, u^{(3)}, u^{(2)}, u^{(1)}$), $u^{(1)}$ is defined as LSB and $u^{(8)}$ as MSB.

Table D.I.1/H.223 – Binary representation for α^i ($0 \le i \le 254$) over GF(2^8)

α^i	Binary rep.	α^i	Binary rep.	α^i	Binary rep.	α^i	Binary rep.
0	00000000	α^{63}	10100001	α^{127}	11001100	α^{191}	01000001
α^{0}	00000001	α^{64}	01011111	α^{128}	10000101	α^{192}	10000010
α^{1}	00000010	α^{65}	10111110	α^{129}	00010111	α^{193}	00011001
α^{2}	00000100	α^{66}	01100001	α^{130}	00101110	α^{194}	00110010
α^{3}	00001000	α^{67}	11000010	α^{131}	01011100	α^{195}	01100100
α^{4}	00010000	α^{68}	10011001	α^{132}	10111000	α^{196}	11001000
α^{5}	00100000	α^{69}	00101111	α^{133}	01101101	α^{197}	10001101
α^{6}	01000000	α^{70}	01011110	α^{134}	11011010	α^{198}	00000111
α^{7}	10000000	α^{71}	10111100	α^{135}	10101001	α^{199}	00001110
α^{8}	00011101	α^{72}	01100101	α^{136}	01001111	α^{200}	00011100
α^{9}	00111010	α^{73}	11001010	α^{137}	10011110	α^{201}	00111000
α^{10}	01110100	α^{74}	10001001	α^{138}	00100001	α^{202}	01110000
α^{11}	11101000	α^{75}	00001111	α^{139}	01000010	α^{203}	11100000
α^{12}	11001101	α^{76}	00011110	α^{140}	10000100	α^{204}	11011101
α^{13}	10000111	α^{77}	00111100	α^{141}	00010101	α^{205}	10100111
α^{14}	00010011	α^{78}	01111000	α^{142}	00101010	α^{206}	01010011
α^{15}	00100110	α^{79}	11110000	α^{143}	01010100	α^{207}	10100110
α^{16}	01001100	α^{80}	11111101	α^{144}	10101000	α^{208}	01010001
α^{17}	10011000	α^{81}	11100111	α^{145}	01001101	α^{209}	10100010
α^{18}	00101101	α^{82}	11010011	α^{146}	10011010	α^{210}	01011001
α^{19}	01011010	α^{83}	10111011	α^{147}	00101001	α^{211}	10110010
α^{20}	10110100	α^{84}	01101011	α^{148}	01010010	α^{212}	01111001
α^{21}	01110101	α^{85}	11010110	α^{149}	10100100	α^{213}	11110010
α^{22}	11101010	α^{86}	10110001	α^{150}	01010101	α^{214}	11111001

Table D.I.1/H.223 – Binary representation for α^i ($0 \le i \le 254$) over GF(2^8) *(continued)*

α^i	Binary rep.	α^i	Binary rep.	α^i	Binary rep.	α^i	Binary rep.
α^{23}	11001001	α^{87}	01111111	α^{151}	10101010	α^{215}	11101111
α^{24}	10001111	α^{88}	11111110	α^{152}	01001001	α^{216}	11000011
α^{25}	00000011	α^{89}	11100001	α^{153}	10010010	α^{217}	10011011
α^{26}	00000110	α^{90}	11011111	α^{154}	00111001	α^{218}	00101011
α^{27}	00001100	α^{91}	10100011	α^{155}	01110010	α^{219}	01010110
α^{28}	00011000	α^{92}	01011011	α^{156}	11100100	α^{220}	10101100
α^{29}	00110000	α^{93}	10110110	α^{157}	11010101	α^{221}	01000101
α^{30}	01100000	α^{94}	01110001	α^{158}	10110111	α^{222}	10001010
α^{31}	11000000	α^{95}	11100010	α^{159}	01110011	α^{223}	00001001
α^{32}	10011101	α^{96}	11011001	α^{160}	11100110	α^{224}	00010010
α^{33}	00100111	α^{97}	10101111	α^{161}	11010001	α^{225}	00100100
α^{34}	01001110	α^{98}	01000011	α^{162}	10111111	α^{226}	01001000
α^{35}	10011100	α^{99}	10000110	α^{163}	01100011	α^{227}	10010000
α^{36}	00100101	α^{100}	00010001	α^{164}	11000110	α^{228}	00111101
α^{37}	01001010	α^{101}	00100010	α^{165}	10010001	α^{229}	01111010
α^{38}	10010100	α^{102}	01000100	α^{166}	00111111	α^{230}	11110100
α^{39}	00110101	α^{103}	10001000	α^{167}	01111110	α^{231}	11110101
α^{40}	01101010	α^{104}	00001101	α^{168}	11111100	α^{232}	11110111
α^{41}	11010100	α^{105}	00011010	α^{169}	11100101	α^{233}	11110011
α^{42}	10110101	α^{106}	00110100	α^{170}	11010111	α^{234}	11111011
α^{43}	01110111	α^{107}	01101000	α^{171}	10110011	α^{235}	11101011
α^{44}	11101110	α^{108}	11010000	α^{172}	01111011	α^{236}	11001011
α^{45}	11000001	α^{109}	10111101	a^{173}	11110110	α^{237}	10001011
α^{46}	10011111	α^{110}	01100111	α^{174}	11110001	α^{238}	00001011
α^{47}	00100011	α^{111}	11001110	α^{175}	11111111	α^{239}	00010110
α^{48}	01000110	α^{112}	10000001	α^{176}	11100011	α^{240}	00101100
α^{49}	10001100	α^{113}	00011111	α^{177}	11011011	α^{241}	01011000
α^{50}	00000101	α^{114}	00111110	α^{178}	10101011	α^{242}	10110000
α^{51}	00001010	α^{115}	01111100	α^{179}	01001011	α^{243}	01111101
α^{52}	00010100	α^{116}	11111000	α^{180}	10010110	α^{244}	11111010
α^{53}	00101000	α^{117}	11101101	α^{181}	00110001	α^{245}	11101001
α^{54}	01010000	α^{118}	11000111	α^{182}	01100010	α^{246}	11001111

Table D.I.1/H.223 – Binary representation for α^i ($0 \le i \le 254$) over GF(2^8) *(concluded)*

α^i	Binary rep.	α^i	Binary rep.	α^i	Binary rep.	α^i	Binary rep.
α^{55}	10100000	α^{119}	10010011	α^{183}	11000100	α^{247}	10000011
α^{56}	01011101	α^{120}	00111011	α^{184}	10010101	α^{248}	00011011
α^{57}	10111010	α^{121}	01110110	α^{185}	00110111	α^{249}	00110110
α^{58}	01101001	α^{122}	11101100	α^{186}	01101110	α^{250}	01101100
α^{59}	11010010	α^{123}	11000101	α^{187}	11011100	α^{251}	11011000
α^{60}	10111001	α^{124}	10010111	α^{188}	10100101	α^{252}	10101101
α^{61}	01101111	α^{125}	00110011	α^{189}	01010111	α^{253}	01000111
α^{62}	11011110	α^{126}	01100110	α^{190}	10101110	α^{254}	10001110

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