**IEEE P802.15**

**Wireless Personal Area Networks**

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| Abstract | Proposed draft text for 15.4t | |
| Purpose | For consideration in the development of the 15.4t standard | |
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* FCS field

The FCS field contains a 16-bit ITU-T CRC or a 32-bit CRC equivalent to ANSI X3.66-1979. The FCS is calculated over the MHR and MAC payload parts of the frame; these parts together are referred to as the calculation field. Devices compliant with one or more of the SUN PHYs or TVWS PHYs shall implement the 4-octet FCS. Devices compliant with the 2450 MHz, 2000 kb/s MSK PHY with the PHR Extended PHR Field set to one shall implement the 4-octet FCS; otherwise, they shall implement the 2-octet FCS (18.1.1.2).

The 2-octect FCS shall be calculated using the following standard generator polynomial:

*G*16(*x*) = *x*16 + *x*12 + *x*5 + 1

The 2-octet FCS shall be calculated for transmission using the following algorithm:

* Let *M*(*x*) = *b*0*xk–*1 + .*b*1*xk–*2 + .… + *bk*–2*x* + *bk*–1 be the polynomial representing the sequence of bits for which the checksum is to be computed.
* Multiply *M*(*x*) by *x*16, giving the polynomial *x*16  *M*(*x*)*.*
* Divide *x*16  *M*(*x*) modulo 2 by the generator polynomial, *G*16(*x*)*,* to obtain the remainder polynomial, *R*(*x*) = *r*0*x*15 + .*r*1*x*14 + .… + *r*14*x* + *r*15
* The FCS field is given by the coefficients of the remainder polynomial, *R(x)*.

Here, binary polynomials are represented as bit strings, in highest polynomial degree first order.

As an example, consider an Ack frame with no payload and the following 3 octet MHR:



The FCS for this case would be the following:



A typical implementation is depicted in Figure 7-4.



The 4-octet FCS is calculated using the following standard generator polynomial of degree 32:



The 4-octet FCS is the one’s complement of the (modulo 2) sum of the two remainders in a) and b):

* The remainder resulting from [(*xk* × (*x*31 + *x*30 +...)] divided (modulo 2) by *G*32(*x*), where the value *k* is the number of bits in the calculation field.
* The remainder resulting from the calculation field contents, treated as a polynomial, is multiplied by *x*32 and then divided by *G*32(*x*).

At the transmitter, the initial remainder of the division shall be preset to all ones and then modified via division of the calculation field by the generator polynomial *G*32(*x*). The one’s complement of this remainder is the 4-octet FCS field. The FCS field is passed to the PHY commencing with the coefficient of the highest order term.

At the receiver, the initial remainder shall be preset to all ones. The serial incoming bits of the calculation field and FCS, when divided by *G*32(*x*) in the absence of transmission errors, result in a unique nonzero remainder value. The unique remainder value is the polynomial shown:

Upon transmission, if the length of the calculation field is less than 4 octets, the FCS computation shall assume padding the calculation field by appending zero value octets to the most significant bits to make the calculation field length exactly 4 octets; however, these pad bits shall not be transmitted. Upon reception, if the length of the calculation field is less than 4 octets, the received calculation field shall be appended with zero value octets to the most significant bits to make the calculation field length exactly 4 octets prior to computing the FCS for validation.



As an example, consider an Ack frame with no payload and the following 3-byte MHR:



Prior to FCS computation, the zero padded calculation field is given as follows:



The 4-octet FCS for this case would be the following:



* PHY constants

The constants that define the characteristics of the PHY are presented in Table 11-1. These constants are hardware dependent and cannot be changed during operation.

|  |  |  |
| --- | --- | --- |
| * PHY constants | | |
| Constant | Description | Value |
| aMaxPHYPacketSize | The maximum PSDU size (in octets) the PHY shall be able to receive. | 2047 for SUN, TVWS, RCC, ~~and~~ LECIM FSK, and 2450 MHz, 2000 kb/s MSK PHYs. For LECIM DSSS PHY, this is not a constant; refer to *phyLecimDsssPsduSize*. 127 for all other PHYs |
| *aTurnaroundTime* | RX-to-TX or TX-to-RX turnaround time (in symbol periods), as defined in 10.2.1 and 10.2.2 | For the SUN, TVWS and LECIM FSK PHYs, the value is 1 ms expressed in symbol periods, rounded up to the next integer number of symbol periods using the ceiling() function.[[1]](#footnote-1) For the LECIM DSSS PHY, the value is 1 ms expressed in modulation symbol periods, rounded up to the next integer number of symbol periods using the ceiling() function. For the 2450 MHz, 2000 kb/s MSK PHY, the value is 384 symbol periods. The value is 12 for all other PHYs. |
| *aLeipDelayTime* | The delay between the start of the SFD and the LEIP, as described in 19.6. | 0.815 ms |
| *aCCATime* | The time required to perform CCA detection. | For the SUN PHYs other than SUN O-QPSK, the duration of 8 symbol periods, as defined in 6.1. For the SUN O-QPSK PHY, this value is defined in Table 22-24. For all other PHYs, the duration of 8 symbol periods. |

* MSK PHY
* PPDU formats

The MSK PHY shall use the PPDU formats described in 12.1, except that the Preamble field is 32 symbols (4 octets) and the bits in each octet shall be “10101010.” In addition, the PHR field format for the 2450 MHz, 2000 kb/s PHY shall be as described in 18.1.1.

18.1.1 2450 MHz, 2000 kb/s PHY PHR field format

The PHR field for the 2450 MHz, 2000 kb/s PHY shall be formatted as illustrated in Figure 18-X.

|  |  |  |  |
| --- | --- | --- | --- |
| Bits: 0-6 | 7 | 8-11 | 12-15 |
| Frame Length LSB | Extended PHR | Frame Length MSB | Reserved |

Figure 18‑X: Format of the PHR

18.1.1.1 Frame Length LSB Field

The Frame Length is defined as the total number of octets contained in the PSDU (i.e., PHY payload). The Frame Length LSB Field specifies the lower seven bits of the Frame Length.

18.1.1.2 Extended PHR Field

The Extended PHR Field shall be set to one if the Frame Length MSB field follows, and shall be set to zero otherwise. Note that this field also indicates the length of the FCS (7.2.10).

18.1.1.3 Frame Length MSB Field

The Frame Length MSB Field specifies the upper four bits of the Frame Length (18.1.1.1).

* Data rate

The default data rate of the MSK PHY shall be 250 kb/s. Additional optional data rates for the 433 MHz and 2450 MHz bands are shown in Table 18-1.

|  |  |  |
| --- | --- | --- |
| * Data rates for MSK PHY | |  |
| DataRate as used in MCPS-DATA primitives | Data rate (kb/s) | Band (MHz) |
| 1 | 31.25 | 433 |
| 2 | 100 | 433 |
| 3 | 250 | 433 |
| 4 | 2000 | 2450 |

The optional data rates for the 433 MHz band are not available on all channels. Table 18-2 shows the allowed data rates for the 433 MHz channels and their associated channel numbers.

|  |  |
| --- | --- |
| * Data rate channel map | |
| Data rate (kb/s) | Channel |
| 31.25 | 0 to 14 |
| 100 | 1, 4, 7, 10, 13 |
| 250 | 2, 7, 12 |

* SFD for the MSK PHY

The SFD for the MSK PHY shall be contain the value given in Table 18-3. The SFD is transmitted starting from the leftmost bit (b0).

|  |
| --- |
| * Value of the SFD field for the MSK PHY |
| SFD (b0b15) |
| 1110 0110 1101 0000 |

* MSK modulation
* Reference modulator diagram

The functional block diagram in Figure 18-1 is provided as a reference for specifying the MSK PHY modulation. It should be noted the preamble is not included in the whitening scheme.



* Data whitening

Data whitening for the MSK PHY shall use the procedure described in 17.2.3

* Bit-to-symbol mapping

The bit rate and symbol rate are equal. The mapping of bits to frequency shall be as described in Table 18-4.

|  |  |
| --- | --- |
| * Bit to frequency mapping | |
| Bit | Frequency |
| 0 | *f c*–*f* |
| 1 | *fc* +*f* |

, In Table 18-4, *fc* is the channel center frequency as defined in Table 10-7 and Table 10-8 and f is given by:

*f* =



where

*Ts* is the symbol rate

* Signal modulation

The 2450 MHz, 2000 kb/s MSK modulation shall be GMSK modulation with BT = 0.5. The MSK modulation of all other band and data rate combinations ~~MSK modulation~~ shall be FSK with modulation index h = 0.5. This modulation index corresponds to minimum frequency spacing that allows two FSK signals to be coherently orthogonal.

As shown in Figure 18-2, MSK modulation has two possible frequencies over any symbol interval, which differs in frequency by half the bit rate as follows:

*f*2 – *f*1 = ½ *Tb*

This is the smallest frequency difference that allows two signals to be orthogonal.



* MSK PHY requirements
* Operating frequency range

The MSK PHY specifies the following two optional frequency bands:

* 433.05 MHz to 434.79 MHz
* 2400 MHz to 2483 MHz
* Transmit PSD mask

The PSD mask for the MSK PHY is shown in Table 18-5.

The transmitted spectral products shall be less than the limits specified in Table 18-5. For both relative and absolute limits, average spectral power shall be measured using a 100 kHz resolution bandwidth. For the relative limit, the reference level shall be the highest average spectral power measured within ±1 MHz, ±600 kHz, ±300 kHz, or ±100 kHz of the carrier frequency (respective to data rate).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| * MSK PHY transmit PSD limit | | | | |
| Frequency band | Data rate | Frequency | Relative limit | Absolute limit |
| 433 MHz | 31.25 ksymbols/s | |*f* – *fc*| > 200 kHz | –20 dB | –20 dBm |
| 100 ksymbols/s | |*f* – *fc*| > 600 kHz | –20 dB | –20 dBm |
| 250 ksymbols/s | |*f* – *fc*| > 1.2 MHz | –20 dB | –20 dBm |
| 2450 MHz | 250 ksymbols/s | |*f* – *fc*| > 1.2 MHz | –20 dB | –20 dBm |
| 2000 ksymbols/s | |*f* – *fc*| > 3.5 MHz | –20 dB | –30 dBm |

* Symbol rate

Transmission of the symbol rate for 433 MHz band shall be either 31.25 ksymbol/s, 100 ksymbol /s, or 250 ksymbol/s with an accuracy of ±300 × 10-6.

The transmitted symbol rate for 2450 MHz band shall be either 250 ksymbol/s with an accuracy of ±300 × 10-6, or 2000 ksymbol/s with an accuracy of ±40 × 10-6.

* Transmit center frequency tolerance

The MSK PHY shall have a transmit center frequency tolerance of ±40 × 10-6.

* Transmit power

The MSK PHY in the 433 MHz band shall be capable of transmitting at a power level of at least –3 dBm.

The MSK PHY in the 2450 MHz band shall be capable of transmitting at a power level of at least –13 dBm.

* Receiver maximum input level of desired signal

The MSK PHY shall have a receiver maximum input level greater than or equal to –20 dBm using the measurement as described in 10.1.7.

* Modulation frequency deviation tolerance

Modulation frequency tolerance is measured as a percentage of maximum frequency deviation *f*.

Modulation frequency deviation shall be constrained within ±30% of maximum frequency deviation *f* as defined in 18.4.3.

* Zero crossing tolerance

All zero crossing shall be constrained within ±12.5% of symbol time.

1. The function ceiling() returns the smallest integer value greater than or equal to its argument value. [↑](#footnote-ref-1)