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Smart Body Area Network (SmartBAN); Enhanced Ultra-Low Power Physical Layer

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Smart Body Area Network (SmartBAN).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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1 Scope

The present document specifies the ultra-low power physical layer (PHY) Smart BAN.

The present document applies to short range, wireless communication between wearable sensors devices and the hub coordinator. The present document specifies the PHY for transmitting on the medium.

The present document describes:

- packet formats;
- modulation;
- forward error correction.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 325 (V1.1.1) (2015-04): "Smart Body Area Network (SmartBAN); Low Complexity Medium Access Control (MAC) for SmartBAN".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols apply:

D	Delay
$\oplus$	eXclusive OR (XOR)

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

Ack	Acknowledgement
BAN	Body Area Network
BCH	Broadcast Channel
BT	Bandwidth Time product
CCA	Clear Channel Assessment
CRC	Cyclic Redundancy Check
ED	Energy Detection
FEC	Forward Error Correction
GSFK	Gaussian Frequency Shift Keying
IFS	Inter-Frame Spacing
ISM	Industrial, Scientific and Medical
MAC	Medium Access Control
MPDU	MAC Protocol Data Unit
PHY	Physical Layer
PLCP	Physical Layer Convergence Protocol
PPDU	PHY Protocol Data Unit
PSDU	Physical Layer Service Data Unit

4 Introduction and Background

Modern medical and health monitoring equipment are moving towards the trend of wireless connectivity between the data collection or control centre and the medical devices or sensors. Therefore, the need for a standardized communication interface and protocol between the actors are required. This network of actors performing some medical monitoring or functions is called a Smart Body Area Network (Smart BAN).

The present document specifies the physical layer procedure for Smart BAN.

5 General PHY Framework

5.0 Introduction

This clause provides the basic PHY framework for the nodes and hubs.

5.1 Frequency Spectrum

The frequency of operation shall fall within 2 401 MHz - 2 481 MHz. The channels shall be arranged in blocks of 2 MHz with centre frequencies:

$$f_c = 2\,402 + 2 \times n \text{ MHz, for } n = 0 \text{ to } 39,$$

where n is the channel number.

Table 1 shows the mapping of the channel number to data channel number and control channel number.

Table 1: Mapping of Channel Number to Data and Control Channel Numbers

Channel Number	Centre Frequency (MHz)	Channel Type	Data Channel Number	Control Channel Number
0	2 402	Control		0
1	2 404	Data	0	
…		Data		
11	2 424	Data	10	
12	2 426	Control		1
13	2 428	Data	11	
…		Data		
38	2 478	Data	36	
39	2 480	Control		2

6 Packet Formats

6.1 Physical-Layer Protocol Data Unit (PPDU)

6.1.0 PPDU Structure

Figure 1: PPDU Structure

6.1.1 Preamble

PPDUs have a sixteen bit preamble used for frequency synchronization, timing synchronization, and automatic gain control.

The preamble for all PPDUs shall be 1010101010101010.

6.1.2 PLCP Header

6.1.2.0 PLCP Header Structure

The PLCP Header is structured as illustrated in Figure 2. The PLCP header consist of the Packet Length, PHY Scheme, Reserved, BCH Parity Bits, and the Header Parity fields.

The PLCP header shall be scrambled by the procedure described in clause 7.4.

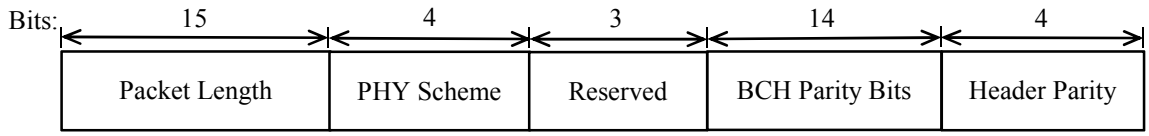

Figure 2: PLCP Header Structure

6.1.2.1 Packet Length

The packet length field indicates the length of the PSDU.

6.1.2.2 PHY Scheme

The PHY Scheme field describes the forward error control (FEC) type and the repetition type the PPDU employs. The mapping of the field bits is as described in Table 2.

6.1.2.3 BCH Parity Bits

The BCH Parity Bits field shall be generated using a BCH (36,22,t=2) code defined in clause 7.3.3 to protect the Packet Length, PHY Scheme, and Reserved fields.

6.1.2.4 Header Parity

The Header Parity field shall be generated by the CRC polynomial $1 + x + x^4$ on the Packet Length, PHY Scheme, Reserved, and BCH Parity Bits fields.

Table 2: PHY Scheme field bit mapping

Field Value b0 b1	FEC Type
00	None
01	BCH(127,113,2)
10	Reserved
11	Reserved

Field Value b2 b3	Repetition Type
00	None
01	2
10	4
11	Reserved

6.1.3 PSDU

The Physical-Layer Service Data Unit (PSDU) is either an encoded or uncoded MAC Protocol Data Unit (MPDU) as defined clause 6.1 of [1]. The MPDU may be encoded using a BCH (127,113,t=2) code. The encoding procedure shall be described in clause 7.3. The PSDU shall be scrambled using the procedure described in clause 7.4.

7 Modulation and Error Control

7.1 PPDU Formation

The PPDU is formed from the following process described in Figure 3. The dashed boxes represent operations that are optional.

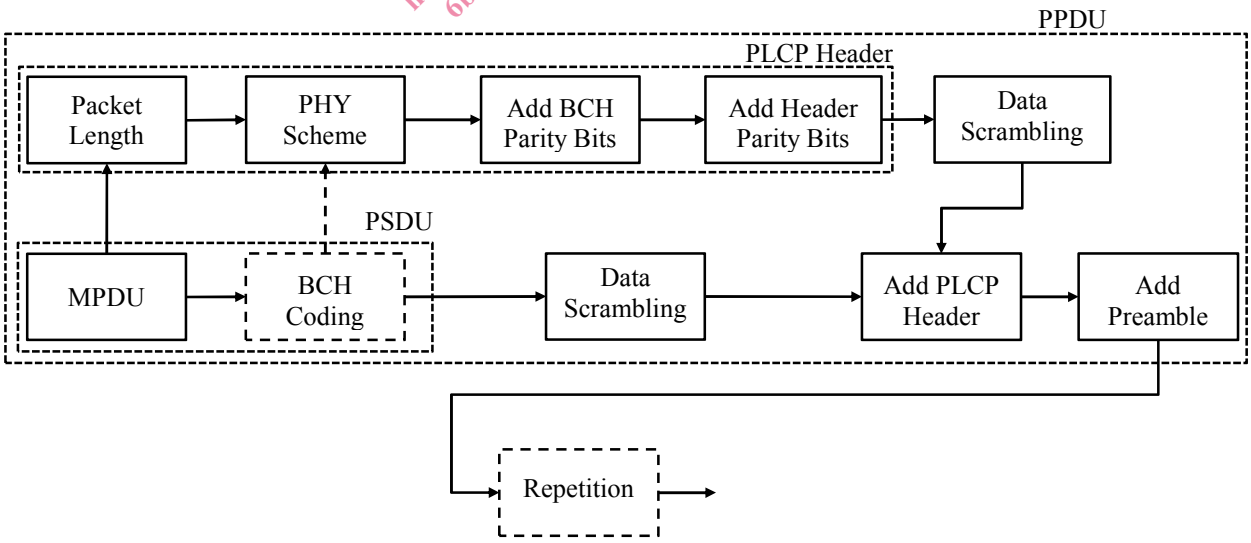

Figure 3: Transmitter Physical Layer Chain

7.2 Modulation

The modulation is Gaussian Frequency Shift Keying (GSFK) with a bandwidth-bit period product BT = 0,5, and modulation index h = 0,5.

A symbol rate, T_{sym}, of 1 MSymbols/s shall be supported in both Control and Data Channels.

Table 3: Physical Layer Throughput

Channel (Data/Control)	Information Flow	Symbol Rate (MSymbols/s)	Code Rate	Repetition	Information Rate (Mbps)
Data/Control	Downlink/Uplink	1,0	1	1	1,0
Data/Control	Downlink/Uplink	1,0	1	2	0,5
Data/Control	Downlink/Uplink	1,0	1	4	0,25
Data/Control	Downlink/Uplink	1,0	113/127	1	0,89
Data/Control	Downlink/Uplink	1,0	113/127	2	0,44
Data/Control	Downlink/Uplink	1,0	113/127	4	0,22

7.3 Repetition and Forward Error Control (FEC)

7.3.1 Repetition

The hubs and nodes may implement repetition coding to reduce errors if required. Should repetition coding be implemented, this shall be indicated in the PHY Scheme field in clause 6.1.2.3. Two repetition schemes shall be supported, 2-repetition, repeating the entire PPDU 2 times, and 4-repetition, repeating the entire PPDU 4 times.

When repetition is employed, the original PPDU along with its repeated versions shall be treated as one single PPDU.

An example of 2-repetition and 4-repetition is shown in Figure 4.

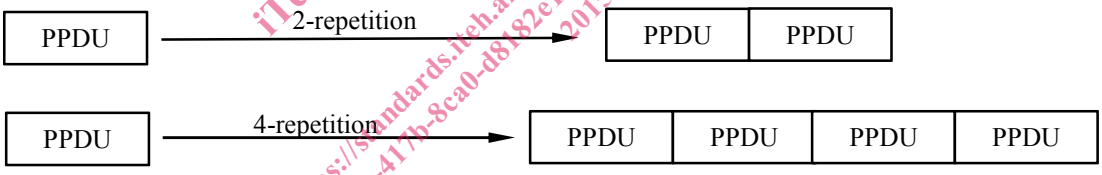

Figure 4: An example of 2-repetition and 4-repetition

7.3.2 BCH (127,113,*t*=2) Encoding

For error correction control of MPDU, a systematic BCH(127,113,*t*=2) code may be employed. *t* indicates the maximum number of bits that can be corrected. The generator polynomial of the BCH(127,113,*t*=2) code is:

$$g(x) = x^{14} + x^9 + x^8 + x^6 + x^5 + x^4 + x^2 + x + 1. \quad (1)$$

The encoding process is as follows:

1) Calculate the number of padding bits, $N_{padding}$. The number of padding bits depends on the length of the MPDU, L_{MPDU}, and can be calculated as:

$$N_{padding} = \left\lceil \frac{L_{MPDU}}{k} \right\rceil \times k - L_{MPDU},$$

where k = 113,

2) Append $N_{padding}$ zero bits to the end of the MPDU

3) Partition the padded MPDU into subpackets with length of *k*

4) Compute the parity bits for each subpackets using the generator polynomial g(*x*)