**IEEE P802.15**

**Wireless Personal Area Networks**

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| Re: | [802.15.4k LECIM DSSS PHY draft text] |
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## Low Energy Critical Infrastructure Monitoring Direct Sequence Spread Sequence (LECIM DSSS) PHY

## LECIM DSSS PPDU format

For convenience, the PPDU structure is presented so that the leftmost field as written in this standard shall be transmitted or received first. All multiple octet fields shall be transmitted or received least significant octet first, and each octet shall be transmitted or received least significant bit (LSB) first.

The PPDU shall be formatted as illustrated in Figure 1.



Figure 1 PPDU Format

### SHR

The SHR or Synchronization Header is a field which may be used for obtaining frequency, symbol, and frame synchronization. It consists of two sub-fields, the preamble and the start of frame delimiter (SFD). It is possible to recover a fixed length frame without the use of a SFD, or SHR.

#### Preamble

The preamble is a sub-field which may be used to obtain symbol timing and frequency offset. A preamble length of 0, 2, 4 octets may be commissioned.

Preamble16 = [-1 -1 1 1 1 1 1 1 -1 1 -1 1 1 -1 -1 1]

Preamble32 = [ T.B.D. ]

#### SFD

The SFD or start frame delimiter is a sub-field which may be used to indicate the beginning of the frame.

SFD = [ T.B.D. ]

### PHR

The PHR or PHY Header is a field used to indicate the length of a variable length PHY payload. When the PHY payload is commissioned to a fixed size, the PHR is elided. For variable length PHY payloads of up to 128 octets, the PHR is a one octet and represents a payload of n+1 octets where n = 0..127. For variable length PHY payloads of 129-2048 octets, the PHR is two octets as illustrated in Figure 1.

## Modulation and spreading

### Data rates

TBD

### Reference modulator diagram

The functional block diagram in Figure 1 is provided as a reference for specifying the LECIM DSSS PHY modulation. All binary data contained in the SHR, PHR, and PSDU shall be encoded using the modulation shown in Figure 2.



Figure 2 Reference modulator diagram

### Convolutional FEC encoding

Same as 802.15.4-2011 UWB PHY section 14.3.3.2?

### Interleaver

TBD

### Differential encoding

Same as 802.15.4-2011 BPSK PHY section 11.2.3?

### Bit-to-symbol and symbol-to chip encoding

The bit-to-symbol mapper converts bits into binary symbols through the mapping:

$$x\left[n\right]= \left\{\begin{matrix}1, if b\left[n\right]=0\\-1, if b\left[n\right]=1\end{matrix}\right.$$

These binary symbols are then spread to chip-rate with spreading factor SF. This process is illustrated explicitly in Figure 3 below where SF = 8. The symbols are first up-sampled SF times and interpolated using a scaled boxcar filter, i.e. the symbol is repeated SF times at chip-rate as illustrated in Figure 4. Note that this is a mathematical representation of the direct sequence spreading operation. This process can be implemented in an alternative manner that is mathematically equivalent. The up-sampled symbols are multiplied by a specified Gold Code to create the spread signal.



Figure 3 Bit-to-chip diagram



Figure 4 Boxcar filter

#### Gold code generator

Gold Code sequences are a large family of easily parameterized PN sequences with good periodic cross-correlation and off-peak auto-correlation properties. A Gold Code sequence is derived from the binary addition (XOR) of two Maximum Length Sequences (m-sequences, or MLS) as illustrated in Figure 5. The m-sequences are generated using Fibonacci Linear Feedback Shift Registers (LFSR). Each LFSR is constructed from primitive (or prime) polynomials over Galois Field 2 (GF[2]). The resulting sequences thus constitute segments of a set of Gold sequences. The specific m-sequences listed below are the preferred pair as described in the 3rd Generation Partnership Project (3GPP) Technical Specification 25.213. The Gold Sequence can be parameterized by setting the Initialization Vector of LFSR2 to different values (LFSR1 is always initialized to 0x1).

* m = 25 (Length of LSFR)
* n = 2m-1 = 33,554,431 (Length of Gold Code)
* n+2 = 33,554,433 (Total Gold Sequences) = {a, b, a\*b, a\*Tb, a\*T2b, …}

LFSR (MLS) generator polynomials:

* p1(x) = x25 + x2 + 1
* p2(x) = x25 + x3 + x2 + x + 1



Figure 5 Gold Code generator

### BPSK/O-QPSK modulation

#### BPSK modulation

Same as 802.15.4-2011 BPSK PHY section 11.2.5?

##### Pulse shape

Same as 802.15.4-2011 BPSK PHY section 11.2.5.1?

##### Chip transmission order

Same as 802.15.4-2011 BPSK PHY section 11.2.5.2?

#### O-QPSK modulation

The chip sequences representing each data symbol are modulated onto the carrier using O-QPSK with pulse shaping. For even-indexed symbol, the even-indexed chips are modulated onto the in-phase (I) carrier, and odd-indexed chips are modulated onto the quadrature-phase (Q) carrier. For odd-indexed symbol, even-indexed chips are modulated onto the quadrature-phase (Q) carrier, and odd-indexed chips are modulated onto the in-phase (I) carrier. To form the offset between I-phase and Q-phase chip modulation, the Q-phase chips shall be delayed by Tc with respect to the I-phase chips, as illustrated in Figure 1, where Tc is the inverse of the chip rate.



Figure 6 O-QPSK chip modulation

##### Pulse shape

Same as 802.15.4-2011 BPSK PHY section 10.2.6?

##### Chip transmission order

Same as 802.15.4-2011 BPSK PHY section 10.2.7?