## Low Energy Critical Infrastructure Monitoring Direct Sequence Spread Sequence (LECIM DSSS) PHY

## LECIM DSSS PPDU format

TBD

### SHR

#### Preamble

#### SFD

### PHR

## 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 1.



Figure 1 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 2 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. 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 2 Bit-to-chip diagram



Figure 3 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 4. The m-sequences are generated from two Fibonacci Linear Feedback Shift Registers (LFSR), each with an even number of relatively prime taps. 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 + x22 + 1
* p2(x) = x25 + x24 + x23 + x22 + 1



Figure 4 Gold Code generator

### 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?