**IEEE P802.15**

**Wireless Personal Area Networks**

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| Title | **Non-Coherent PHY Layer proposal for 15.4ab TFD** |
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| Re: | Contribution to IEEE 802.15.4ab  |
| Abstract |  |
| Purpose | This submission proposes text to for the IEEE Std 802.15.4ab specification framework document.  |
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# PHY – Non-coherent option

## Introduction

In this document, we propose optional PHY layer parameters aimed at non-coherent data comms while ensuring orthogonality with secure ranging applications. Coexistence with legacy devices is considered in this proposal.

The benefits of such non-coherent detection can be summarized as:

* Obviating the need for RF carrier generation.
* Fast (sub ms) channel hopping is possible (with the help of fast synthesizer

settling time). This leads to efficient duty cycling between frames.

* Fast radio start-up (few ms) is possible.
* Relaxed requirements of the frequency and phase accuracy of the system.
* Coverage benefits from multipath within SOI due to lower phase sensitivity compared with coherent detection.
* High symbol rate of the PHY layer allows to reduce frame airtime.
* Reduced latency due to shorter frame time.
* Allows for aggressive duty cycle of the radio which results in a much higher energy efficiency of the radio.
* Long preambles are not required for data streaming and this can further reduce frame overhead.

The proposed additions to HRP complement existing and proposed capabilities for ranging and sensing applications and can be used without undue disruption of those links.

## Channel plan

Center frequencies *fc* can be any integer multiple of 124.8 MHz and are characterized by an integer number *Nc* according to

*fc* = 499.2 MHz + *Nc* 124.8 MHz

where it is proposed to let *Nc* range from 0 to 97 to cover from the current HRP channel 0 (*fc* = 499.2 MHz) up to 12,608.4 MHz. This takes into account both the desire to have overlapping channels (e.g. for sensing applications) and to provide for a potential extension of the UWB spectrum beyond 10.6 GHz.

It is proposed that the actual values of *Nc* are defined by the higher layers, taking into account the local regulatory conditions in the place of operation.

~~Add rows to Table 10-9:~~

| ~~Channel number~~ | ~~Center frequency (MHz)~~ | ~~HRP UWB band~~ |
| --- | --- | --- |
| ~~16~~ | ~~6739.2~~ | ~~High Band~~ |
| ~~17~~ | ~~6864.0~~ |
| ~~18~~ | ~~7113.6~~ |
| ~~19~~ | ~~7238.4~~ |
| ~~20~~ | ~~7363.2~~ |
| ~~21~~ | ~~7612.8~~ |
| ~~22~~ | ~~7737.6~~ |
| ~~23~~ | ~~7862.4~~ |
| ~~24~~ | ~~8112.0~~ |
| ~~25~~ | ~~8236.8~~ |
| ~~26~~ | ~~8361.6~~ |
| ~~27~~ | ~~8611.2~~ |
| ~~28~~ | ~~8736.0~~ |
| ~~29~~ | ~~8860.8~~ |
| ~~30~~ | ~~9110.4~~ |
| ~~31~~ | ~~9235.2~~ |
| ~~32~~ | ~~9360.0~~ |
| ~~33~~ | ~~9609.6~~ |
| ~~34~~ | ~~9734.4~~ |
| ~~35~~ | ~~9859.2~~ |
| ~~36~~ | ~~10108.8~~ |
| ~~37~~ | ~~10233.6~~ |
| ~~38~~ | ~~11107.2~~ | ~~Extended High Band~~ |
| ~~39~~ | ~~11232~~ |
| ~~40~~ | ~~11356.8~~ |
| ~~41~~ | ~~11481.6~~ |
| ~~42~~ | ~~11606.4~~ |
| ~~43~~ | ~~11731.2~~ |
| ~~44~~ | ~~11856.0~~ |
| ~~45~~ | ~~11980.8~~ |
| ~~46~~ | ~~12105.6~~ |
| ~~47~~ | ~~12230.4~~ |
| ~~48~~ | ~~12355.2~~ |
| ~~49~~ | ~~12480.0~~ |
| ~~50~~ | ~~12604.8~~ |

## Preamble symbol structure

* The 499.2 MHz chip rate of the current HRP PHY is maintained.
* A symbol consists of 24 chips, corresponding to a 20.8 MHz symbol rate
* Active chips are located in the beginning of the symbol. Lower amplitude transmitters may increase the symbol power by having 1, 2 or 4 active chips.



## SYNC

The SYNC sequence uses an OOK modulation to transmit repetitions of 1/0 symbols. The phase of the pulses shall be scrambled to whiten the spectrum. The existing LFSR will be used for this, initialized with a 0/1/0/1/... sequence.

Supported SYNC sequence lengths shall be 16, 32, 64 and 128 symbols.

## SFD

• Proposal:32 bits sequence.

• Use a list of orthogonal sequences for added network separation opportunity.

The following sequences are proposed based on minimizing the maximum cross correlation between SFD sequences (left most bit transmitted first):

* 5EA6C11D
* BF166129
* B94F9606
* A5843F66
* 9B52FC60
* 6819CBD5
* F29F5C88
* EE415A3C

## Payload symbol structure

The 499.2 MHz chip rate of the current HRP PHY is maintained.

The payload symbol shall use the same number of active chips as the preamble symbol.

### On-off keying

A symbol consists of 24 chips, corresponding to a 20.8 MHz symbol rate.

The burst within the symbol is either active when transmitting a ‘1’ or inactive when transmitting a ‘0’.



### Burst position modulation

A symbol consists of 24 chips, corresponding to a 20.8 MHz symbol rate.

The burst is either located at the beginning of the first or second half of the symbol. An active burst in the first position corresponds to a ‘0’ bit, in the second position to a ‘1’.



### Manchester OOK

A symbol consists of 48 chips, corresponding to a 10.4 MHz symbol rate.

The burst is either located at the beginning of the first or second half of the symbol. An active burst in the first position corresponds to a ‘0’ bit, in the second position to a ‘1’.



## PHR

From the PHR onwards, the phase of the pulses shall be scrambled using the existing LFSR, initialized with the preamble sequence 1/0/1/0/1/0/…

The PHR always uses the Manchester OOK symbol.

Definition of the 19 bits PHR bits to be decided. Potentially include:

* Number of pulses per symbol (3 options)
* Payload modulation format
* Puncturing ratios
* Payload length (255 bytes max payload)

Error correction: SECDED or K==7 CC based.

## Forward error correction

The existing convolutional code with constraint length K=7 will be used, with optional puncturing ratios 1/1, 4/3, 5/3 and 2/1

## Conclusion

An optional non-coherent mode tailored to low-power, low-latency data communications with minimal impact on standard definition is proposed in this document. Among other benefits cited in the introduction, the proposed optional PHY modifications increase the trade-off space by introducing more options for low power, higher rate communications. Moreover, it reduces the potential for disrupting ranging applications by shortening packet duration and symbol structure.

## References

* [15-22-0409-04-04ab-Non-coherent HRP Option for data communication - channel plan and experiment](https://mentor.ieee.org/802.15/dcn/22/15-22-0409-04-04ab-non-coherent-hrp-option-for-data-communication-channel-plan-and-experiment.pptx)
* [15-21-0585-04-04ab-low-power-operation-for-non-ranging-applications](https://mentor.ieee.org/802.15/dcn/21/15-21-0585-02-04ab-low-power-operation-for-non-ranging-applications.pdf)
* [15-22-0297-04-04ab-non-coherent-hrp-option-for-data-communication](https://mentor.ieee.org/802.15/dcn/22/15-22-0297-00-04ab-non-coherent-hrp-option-for-data-communication.pdf)
* [15-22-0047-04-04ab-mac-layer-considerations-for-uwb-data-streaming](https://mentor.ieee.org/802.15/dcn/22/15-22-0047-01-04ab-mac-layer-considerations-for-uwb-data-streaming.pdf)