Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [Partial proposal on adding SUN FSK to two Japanese VHF bands]
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Re: [Response to TG 802.15.4ad Call for Proposals (IEEE 802.15-24/0488r1)]

Abstract: [This document includes a partial proposal on adding SUN FSK to two Japanese VHF bands.]

Purpose: [Partial proposal on adding SUN FSK to two Japanese VHF bands]

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Abstract

- In response to the TG 802.15.4ad Call for Proposals [1], this partial proposal aims to extend the existing SUN FSK MCSs, which are supported by many off-the-shelf radio modules, to two Japanese VHF bands where the use of SUN PHYs has not yet been defined.
- This revision reorganizes [3] to better address the Proposal Criteria outlined in the Next Generation SUN PHY Technical Guidance Document [2].

Proposal Criteria: The Scope of Proposal

*"**The Scope of proposal**: with reference to the PAR requirements"*

- This partial proposal aims to extend the existing SUN FSK MCSs, which are supported by many off-the-shelf radio modules, to two Japanese VHF bands where the use of SUN PHYs has not yet been defined. It aligns with the PAR's *"802.15.4ad Scope of the Project"* statement: *"The amendment also defines frequency bands based on updated regional regulations."*

Proposal Criteria: Use Cases

*"**Use cases**: Provide a reference to the Use case document https://mentor.ieee.org/802.15/dcn/23/15-23-0625-10-04ad-collection-of-use-cases-for-next-gen-sun-phy.xlsx and summarize the Use cases that the proposal addresses."*

- This proposal addresses low-speed applications in the VHF band for outdoor environments. The relevant use cases in the Collection of Use Cases for Next Generation SUN PHY [4] include:
  - Disaster prevention monitoring – Low speed
  - Infrastructure monitoring – Low speed
  - Agriculture – Low speed
  - Fisheries – Low speed
  - Intelligent transportation systems – Low speed

Proposal Criteria: Complexity and Receiver Sensitivity

*"**Complexity**: The complexity should not be significantly higher compared to existing SUN PHYs. Proposals should be compatible with low-cost, low-power devices."*

- This proposal strictly focuses on adding existing SUN FSK MCSs to new frequency bands without introducing additional complexity to existing SUN PHYs. As a result, it remains compatible with low-cost, low-power devices.

*"**Receiver Sensitivity**: if the proposal addresses the required OFDM mode specified in the PAR, then this OFDM mode shall have a sensitivity of at least -120dBm with an occupied channel bandwidth of at least 500 kHz as specified in FCC 15.247"*

- The receiver sensitivity requirement for OFDM modes specified in the PAR does not apply to this proposal, as it focuses solely on adding FSK modes to the Japanese VHF band.

Proposal Criteria: Data Rate and Channel Bandwidth

*"**Data Rate**: One mode with an effective payload data rate higher than of 2.4 Mbps. Proposers are encouraged to propose modes with higher data rates."*

- This proposal does not introduce an operating mode with an effective payload data rate exceeding 2.4 Mbps. However, the proposed modes can be integrated with other proposed modes to fulfill this requirement.

"***Channel Bandwidth***: Proposers should support a minimum channel spacing of 200kHz for the OFDM modes to meet the regulation in specific regions. Proposers should support at least one mode with an occupied channel bandwidth of at least 500kHz as specified in FCC 15.247. Proposers should consider the current channel plans specified for IEEE 802.15.4 SUN PHYs."

- This requirement does not apply, as the proposal is limited to the two Japanese VHF bands.

Proposal Criteria: Performance Evaluation

*"**Performance Evaluation**: Proposers are strongly encouraged to show simulation results for the applicable application scenarios. Channel model and interference model for simulations are described in the appendices. When performing computer simulations, the PSDU length in a packet should be 250 bytes for transmission rates faster than the current 802.15.4-2020 SUN-defined transmission rate, and 64 and 20 bytes for slower transmission rates than 50 kbit/s. The required PER should be 1% when transmitting 64 and 20 bytes for slower transmission rates than 50 kbit/s and 10% when transmitting 250 bytes for the rest of the transmission rates. Proposals should describe the on-air duration of the overall packet."*

- Simulation results for the existing SUN FSK MCSs in the VHF-High Band are provided in response to the *"**Multipath Robustness**"* criterion.
  - The simulation is conducted using the AWGN channel, and two channel models for frequencies below 500 MHz as described in Annex A of the Next Generation SUN PHY Technical Guidance Document [2].

Proposal Criteria: Mandatory and Optional Features and Forward Error Correction

*"**Mandatory and Optional Features**: Proposals shall clearly stipulate the mandatory and optional behaviors/features."*

- This proposal does not change any optional features of existing SUN PHYs (FSK) to mandatory, nor does it change mandatory features to optional.

*"**Forward Error Correction**: The use of a least an optional FEC should be possible in all modes."*

- This partial proposal does not introduce any new optional FEC.

Proposal Criteria: Modulation

*"**Modulation**: The proposer should describe modulation."*

- This proposal uses both 2-FSK and 4-FSK from the existing SUN FSK, with the following parameters:
  - 2-FSK
    - Modulation Index: 0.5
    - Gaussian Filter with BT product of 0.5
  - 4-FSK
    - Modulation Index: 0.33
    - Gaussian Filter with BT product of 0.5

Proposal Criteria: Symmetrical Links and Crystal Tolerance

*"**Symmetrical Links**: It should be possible to use the same class of devices for transmit and receive."*

- This proposal does not change the existing IEEE 802.15.4 MAC behaviors, where the same class of devices can be used for both transmit and receive.

*"**Crystal Tolerance**: The PHY should support oscillator tolerances comparable to the existing SUN PHYs."*

- This proposal does not alter oscillator tolerance requirements to the existing SUN PHYs.

Proposal Criteria: PHY Frame Structure

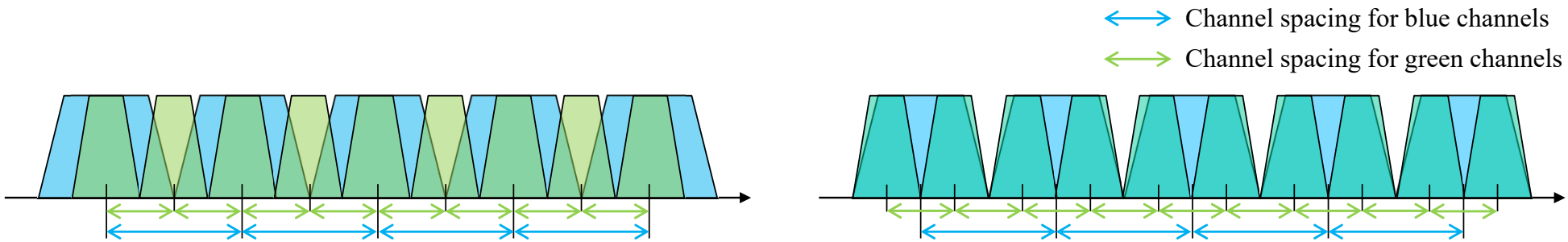
*"**PHY Frame Structure**: The PHY should be based on the existing SUN PHY specifications. Include packet length here – describe packet length vs PER for simulation and maybe other w.r.t. Use cases"*

- This proposal does not alter the existing SUN FSK specifications. For the existing SUN FSK, the packet length consists of the PHY payload size plus 8 – 68 octets, depending on the preamble length.
- The proposal includes data rates slower than 50 kbps, which are used for applications like GPS tracking, intermittent monitoring, etc. [3]. For these slower data rates, the packet payload size is typically only tens of bytes. Simulation is performed with a PSDU size of 20 bytes for data rates slower than 50 kbps, and 250 bytes for other data rates.

Proposal Criteria: Coexistence Features

*"**Coexistence Features**: It is highly recommended that the proposer explains how interference to existing IEEE 802.15.4 networks can be avoided."*

- This proposal targets the two Japanese VHF bands, which currently have no existing IEEE 802.15.4 networks operating. However, to improve coexistence among channels with different bandwidths within the same band, the proposed channel plans aim to minimize spectral overlap by aligning the edges of the channels, rather than their center frequencies.



Aligning center frequencies of the channels

Aligning edges of the channels

Proposal Criteria: Operational Bands (1/3)

*"**Operational Bands**: At least one of the operational bands relevant to the scope of the project should be supported."*

- This proposal aims to add the existing SUN FSK MCSs to the following Japanese VHF bands.
  - VHF-High Band [5]
    - 170 – 177.5 MHz
    - 217.5 – 222 MHz
  - Unmanned Mobile Image Transmission System (UMITS) Band [6]
    - 169.05–169.3575 MHz
    - 169.8075–170 MHz

Proposal Criteria: Operational Bands (2/3)

- The proposed operating modes in the VHF High Band are summarized below.
- The proposed data rates for 2-FSK and 4-FSK fall within the range defined for other frequency bands, spanning from the lowest to the highest rates: 4.8 kbps to 400 kbps for 2-FSK (MI = 0.5) and 9.6 kbps to 800 kbps for 4-FSK (MI = 0.33).

Frequency band (MHz)	Parameter	Operating mode						
		#1	#2	#3	#5	#7	#9	#11
170 – 177.5 217.5 – 222	Data rate (kb/s)	5	10	20	40	75	150	300
	Modulation	2-FSK	2-FSK	2-FSK	2-FSK	2-FSK	2-FSK	2-FSK
	Modulation index	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Channel spacing (kHz)	12.5	12.5	25	50	100	200	400
				#4	#6	#8	#10	#12
	Data rate (kb/s)			25	50	100	200	400
	Modulation			4-FSK	4-FSK	4-FSK	4-FSK	4-FSK
	Modulation index			0.33	0.33	0.33	0.33	0.33
	Channel spacing (kHz)			25	50	100	200	400

Proposal Criteria: Operational Bands (3/3)

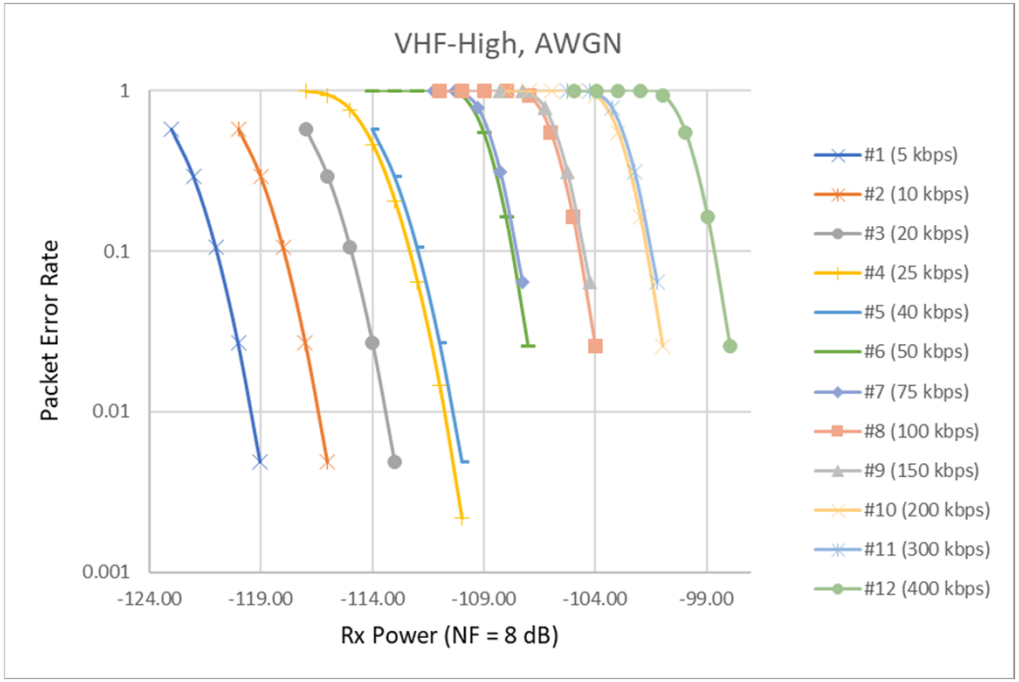
- The proposed operating modes in the UMITS Band are summarized below.
- The proposed data rates in the UMITS Band differ from those in the VHF High Band, even for the same channel spacing, due to regulatory requirements.

Frequency band (MHz)	Parameter	Operating mode					
		#1	#3	#5	#7	#9	#11
169.05 – 169.3575 169.8075 – 170	Data rate (kb/s)	5	10	20	40	80	120
	Modulation	2-FSK	2-FSK	2-FSK	2-FSK	2-FSK	2-FSK
	Modulation index	0.5	0.5	0.5	0.5	0.5	0.5
	Channel spacing (kHz)	12.5	25	50	100	200	300
		#2	#4	#6	#8	#10	#12
	Data rate (kb/s)	8	16	32	64	128	192
	Modulation	4-FSK	4-FSK	4-FSK	4-FSK	4-FSK	4-FSK
	Modulation index	0.33	0.33	0.33	0.33	0.33	0.33
	Channel spacing (kHz)	12.5	25	50	100	200	300

Proposal Criteria: Multipath Robustness (1/2)

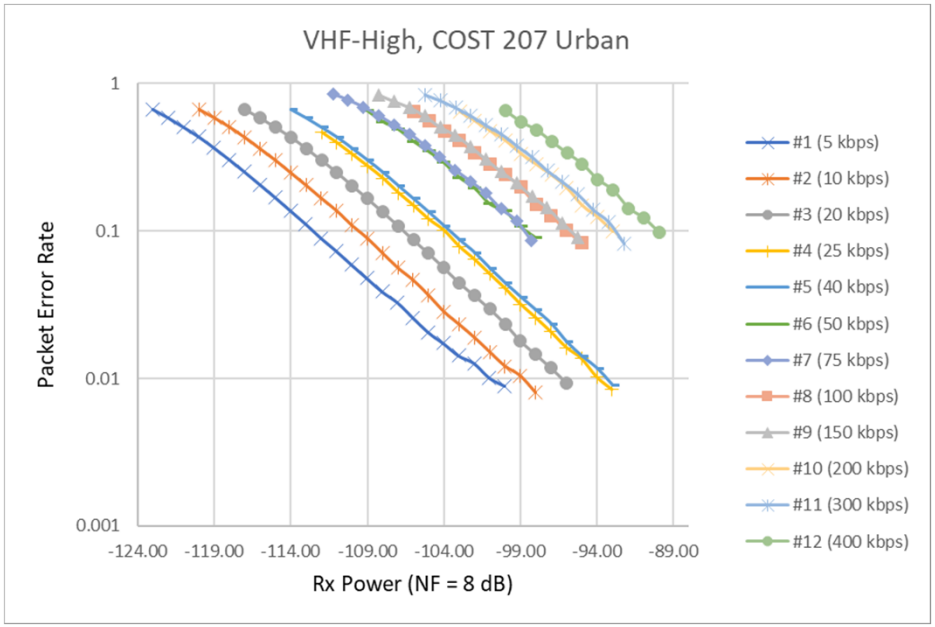
*"**Multipath Robustness**: The proposer should describe the immunity to multi-path reception. Simulation results using the Channel Model defined in Annex A are strongly encouraged."*

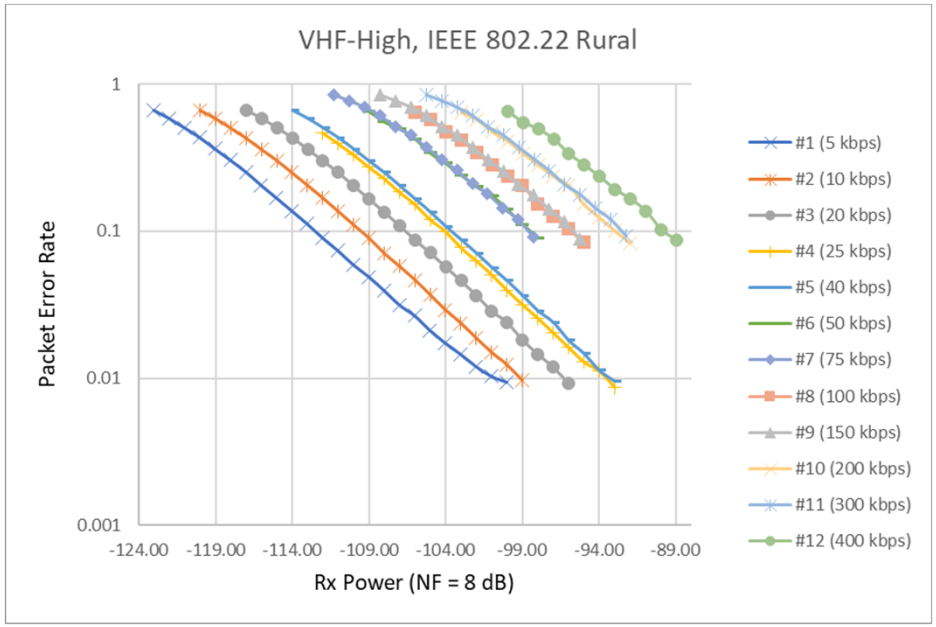
- The PER performance (AWGN channel) of the proposed SUN FSK MCSs in the VHF High Band is shown on the right.
  - Rx Power in the figure is calculated as follows: $Rx\ Power = 10log_{10}(kTB) + NF + SNR$ (dB)
  - Compared to operating modes with 2-FSK, operating modes with 4-FSK require approximately 3 dB more received power to achieve the same PER for the same channel bandwidth, but they provide data rates that are 25% to 33% faster.



Proposal Criteria: Multipath Robustness (2/2)

- The PER performance of the proposed SUN FSK MCSs in the VHF High Band is shown in the figures below (COST 207 Urban on the left, IEEE 802.22 Rural on the right).
  - Except for the required received power, these figures exhibit the same characteristics as those with the AWGN channel.





Proposal Criteria: Interference Robustness

*"**Interference Robustness**: The proposer should describe the immunity to interference. Simulation results using the interference model defined in Annex B are strongly encouraged."*

- This proposal aims to add the existing SUN FSK MCSs to two Japanese VHF bands, for which the Interference Models in Annex B [2] do not apply for the following reasons:
  - The VHF-High Band currently has no incumbents that could interfere with the proposed radios.
  - The UMITS Band is a licensed band with a spectrum management system in place to prevent interference with other radios.
- However, these VHF bands are exposed to significant man-made noise. To mitigate such high-level noise, this proposal defines narrowband MCSs that can reduce the noise power (where B in the thermal noise power kTB represents the bandwidth) at signal reception.

Proposal Criteria: Scalability

*"**Scalability**: The overall packet (including required preambles, headers, synchronization parts...) should be sufficiently scalable to cover the expected extended ranges and potential high number of nodes and interferers, while targeting the expected performance and energy efficiency."*

- This proposal limits its scope to adding existing SUN FSK MCSs to new frequency bands and does not propose any new features specifically aimed at addressing scalability. However, it can be merged with any optional features that enhance the scalability of the existing SUN FSK MCSs.

References

[1] P. Beecher, “TG 802.15.4ad Call for Proposals,” IEEE 802.15-24/0488r1.

[2] J. Robert, P. Beecher, H. Harada, “Next Generation SUN PHY Technical Guidance Document,” IEEE 802.15-24/0061r16.

[3] M. Takai, S. Kitazawa, S. Kajita, “Diversified Range IoT (DR-IoT) for Disaster Response Applications,” IEEE 802.15-24/0507r1.

[4] J. Robert, “Collection of Use Cases for Next Generation SUN PHY,” IEEE 802.15-23/0625r10.

[5] Ministry of Internal Affairs and Communications, “Consultation on the regulatory rules of the VHF-High Band,” (Japanese).

[6] Information and Communications Council, “Report on the regulatory rules of the 169 MHz band systems,” (Japanese).