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

Submission Title: [**Evaluation Methods for Transmission Characteristics of IEEE 802.15.4ad in the Presence of Interference**]

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Re: [Wireless Next Generation, Long Range extension enhancements to 802.15.4-2020]

Abstract: Propose interference models to evaluate proposed systems for IEEE 802.15.4ad. A part of this contribution was supported from the commissioned research (No.05101) by National Institute of Information and Communications Technology (NICT) , Japan.

Purpose: Propose channel models to evaluate proposed systems for IEEE 802.15.4ad.

Evaluation Methods for Transmission Characteristics of IEEE 802.15.4ad in the Presence of Interference

July 15, 2024

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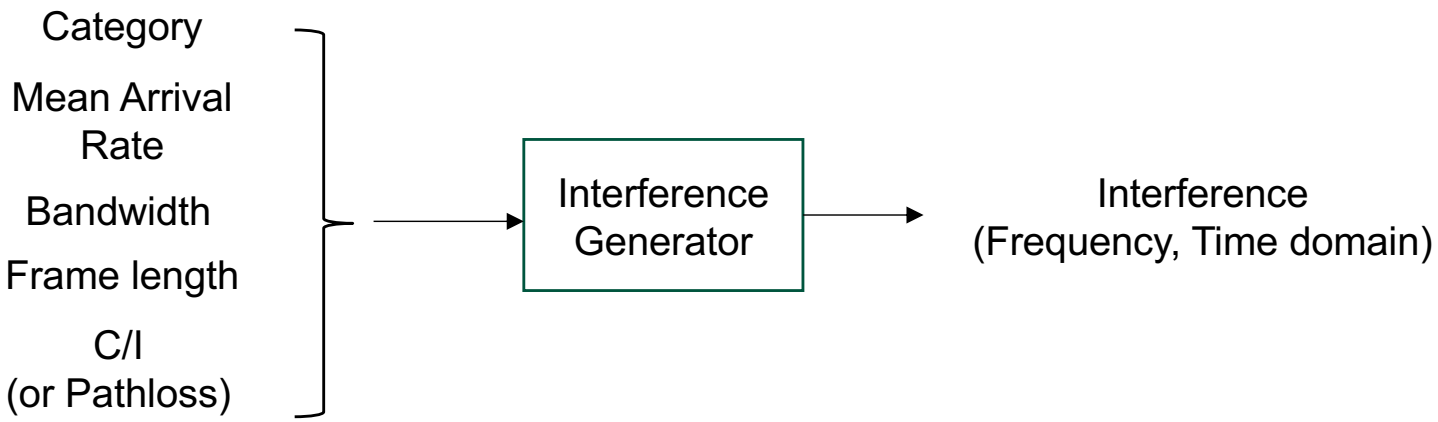
Background

- The group is considering to generate various interference signals in a given frequency band and use them for the evaluation of transmission characteristics for 802.15.4ad system.
- However, this would require the proposers of the PHY scheme to include a frequency hopping scheme in their proposal and to evaluate the transmission characteristics of the proposed scheme over a wide bandwidth.
- However, simulating over the wide band increases simulation time and limits the programing language (such as C or MATLAB) used for simulation, which provides less flexibility to the proposer.
- In this contribution, the interference is generated over multiple bands, but the simulation of the transmission characteristics only observes around the hopped center frequency.

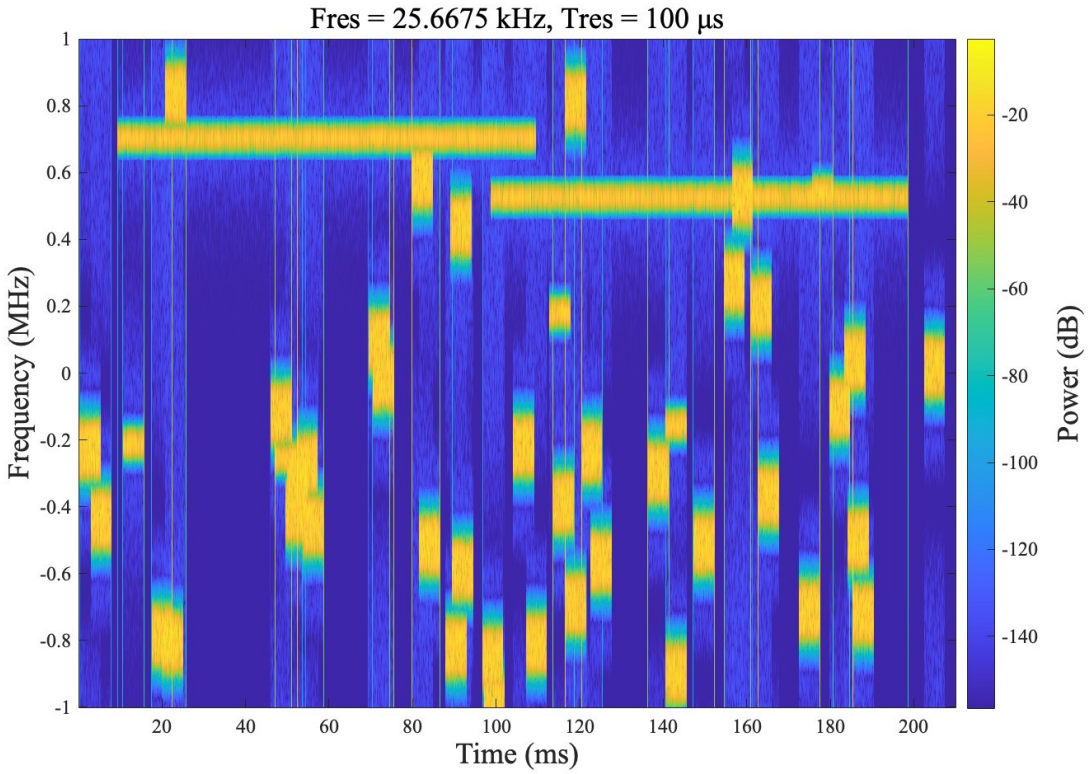
Interference generation



Interference is generated as band-limited white noise; center frequency is randomly generated within the observation bandwidth

Interference generation example

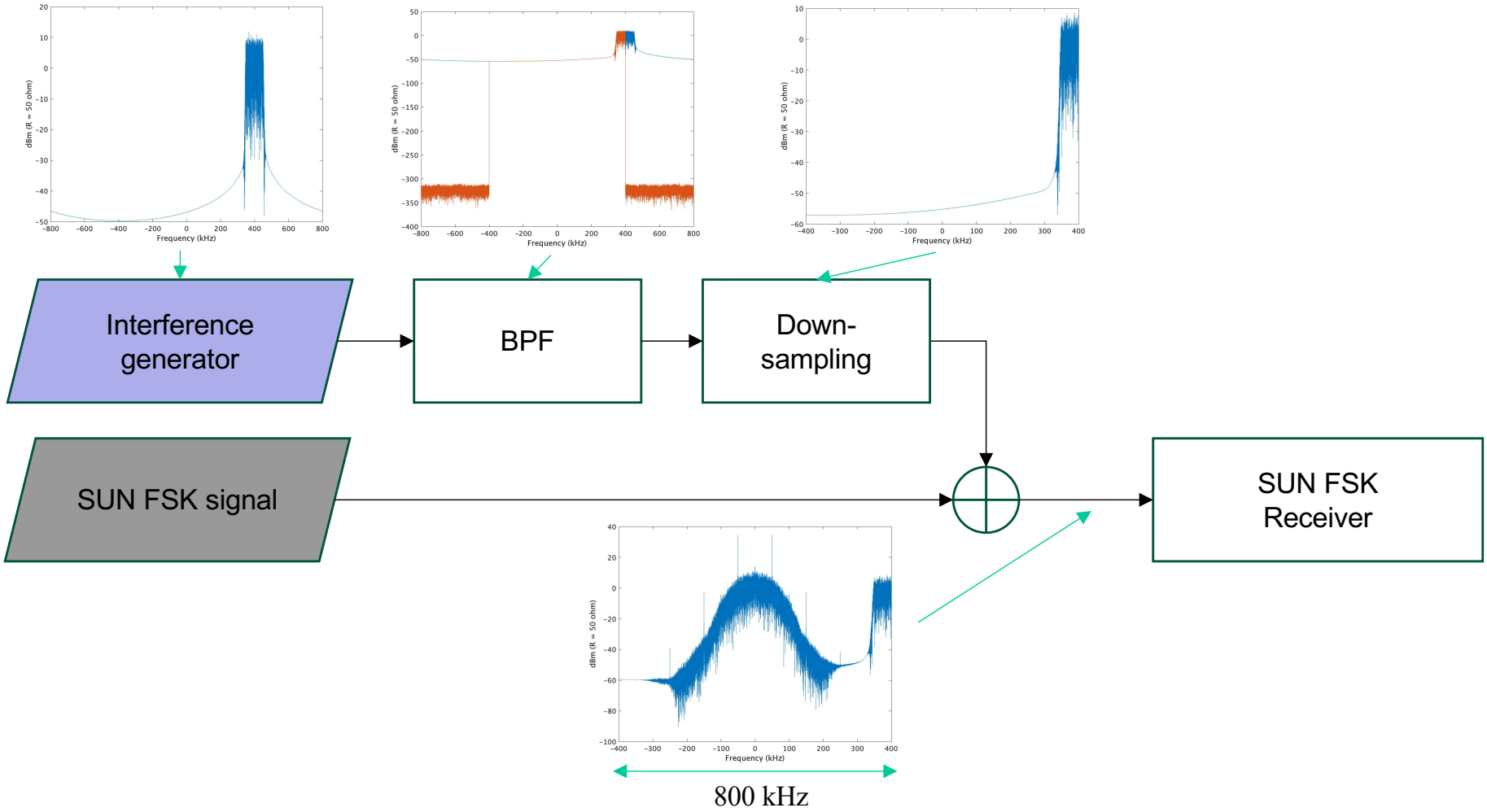
Category	Mean Arrival Rate [1/s/km²/MHz]	Bandwidth [kHz]	Frame length [ms]
1	0.8	100	5
2	0.15	20	5
3	0.04	10	100
4	0.01	1000	30



Assumed C/I is 0dB

Incorporation of the generated interference signals into a transmission evaluation simulator

(Example of SUN FSK signal with 400 kHz bandwidth)



Issues to use generated interference signal

- Sample rate of interference layer
  - In order to describe a discrete frequency-time domain field with a bandwidth of 2 MHz, a sample rate of at least 2 MHz is required
  - In order to add to the signal component, the sample rate of the field must be a least common multiple (LCM) of the signal and the bandwidth of the field
    - This means that the sample rate of the field must also be changed according to the sample rate of the signal.
  - As the number of packets in the simulation increases, the field becomes more difficult to handle because of its file size.

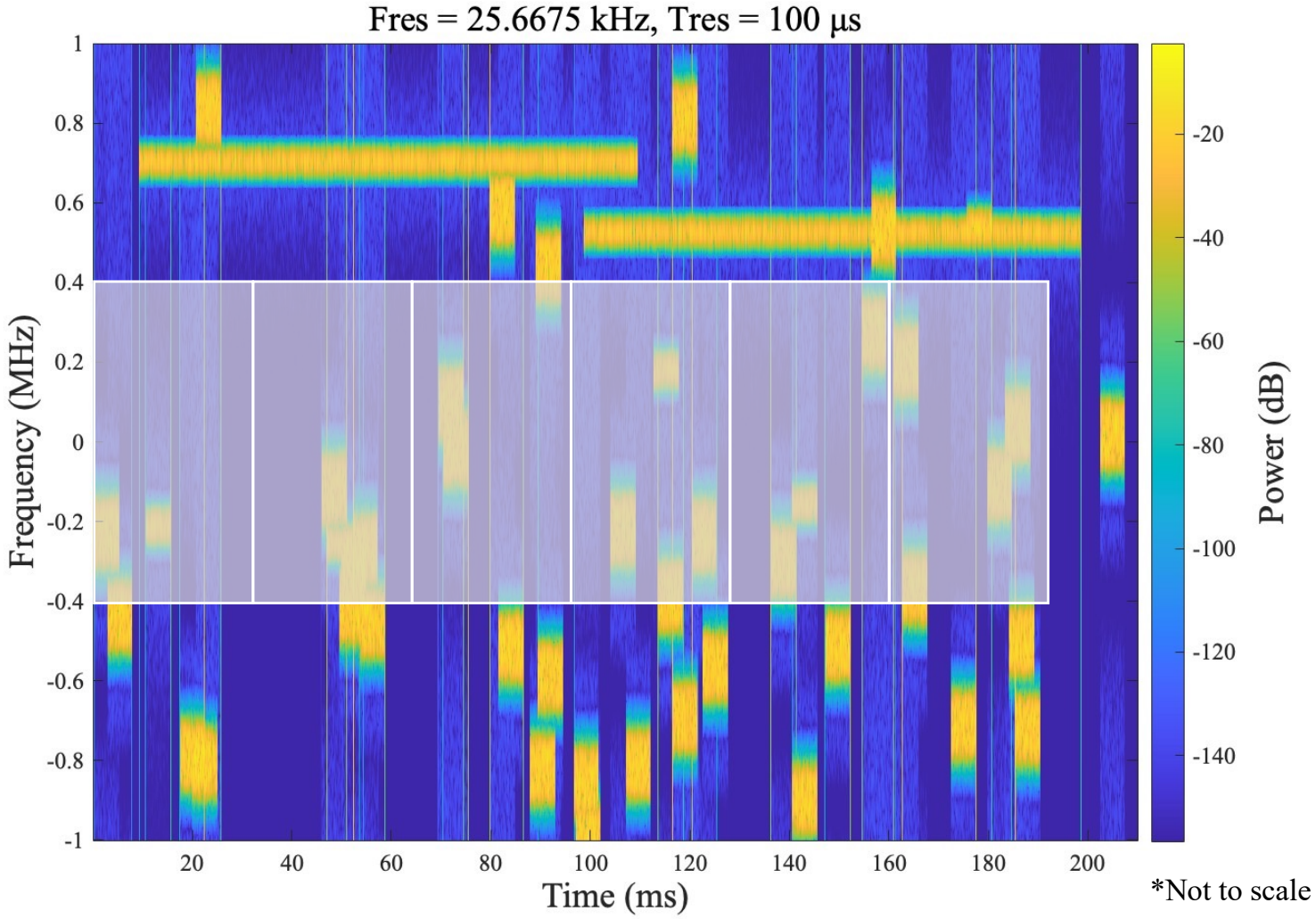
Need to consider to store only information about interference (time index, bandwidth, power) and interference is generated at the time of transmission of each packet

Comparison of characteristics **when the center frequency of the desired signal is changed by frequency hopping** without changing generated interference

- Case1: w/o frequency hopping
- Case2: with frequency hopping: Center frequency of signal hops randomly either 0 or 400 kHz
- Case 3: with frequency hopping: Center frequency of signal hops randomly (0 or 400 or -400 kHz)

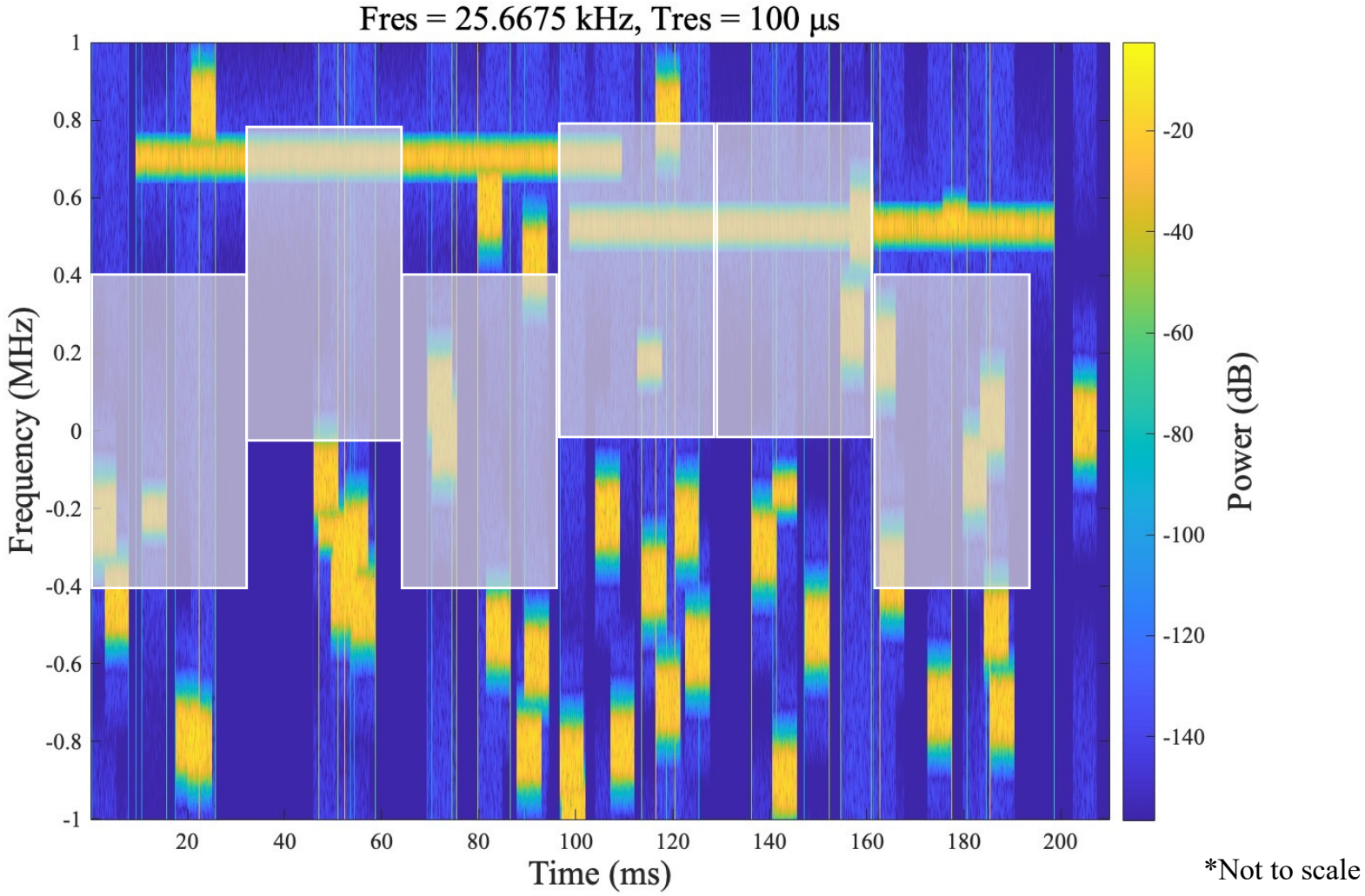
- Desired wave
  - SUN FSK
  - Bandwidth: 400 kHz
  - Sampling rate: 800 kHz
  - preamble 120 bit + SFD 16 bit + PHR 16 bit + PSDU 2000 bit + tail bit 6 bit + pad bit 10 bit
  - Convolutional code (R=1/2, K=4)

Case1: w/o frequency hopping



*Not to scale

Case2: with frequency hopping: Center frequency of signal hops randomly either 0 or 400 kHz



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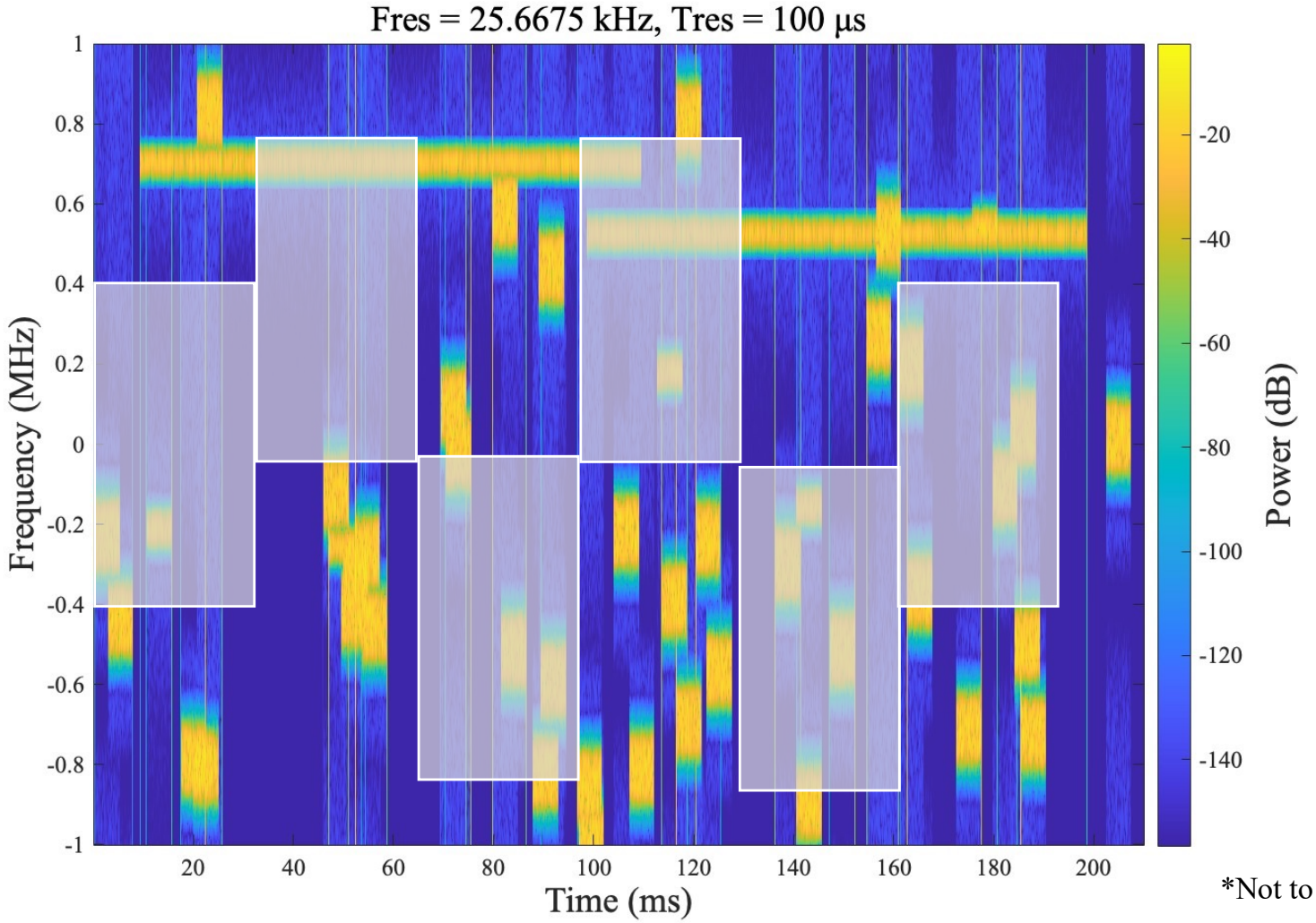
Case 3: with frequency hopping: Center frequency of signal hops randomly (0 or 400 or -400 kHz)



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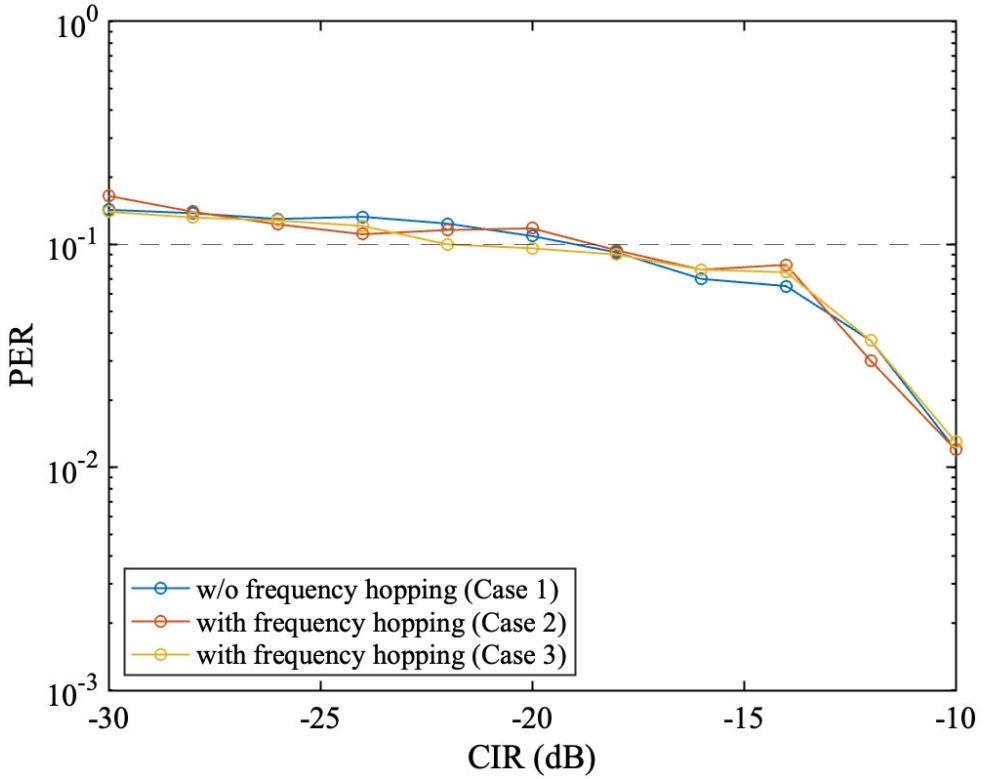
Transmission characteristic evaluation

- Carrier-to-Interference Ratio (CIR)–PER characteristic



No significant change in three cases.

Conclusion

- If the interference is uniformly distributed, there is no significant change in PER as a result of frequency hopping.
  - **Therefore, the frequency hopping can be simulated by observing only one frequency slot: a slot centered at 0 Hz. It is not necessary to observe all the slots for frequency hopping.** We can reduce the sampling rate, and there is no need to frequency-shift the signal components.
- Even when simulating frequency hops due to non-uniformly distributed interference, it is better to use the method proposed here.
  - Instead of actual interference, only the Category, Mean Arrival Rate, Bandwidth, and Length are generated and stored.
  - Based on these properties, the interference is dynamically generated at the sampling rate of the signal component. **Assuming frequency hopping of A Hz, the signal component does not actually hop, but the interference component is shifted by $-A$ Hz.**
  - This approach reduces the file size and can also cope with changes in the sampling rate of the signal components, etc.