Modeling the Spectral Occupation for the Use in Cognitive Radios

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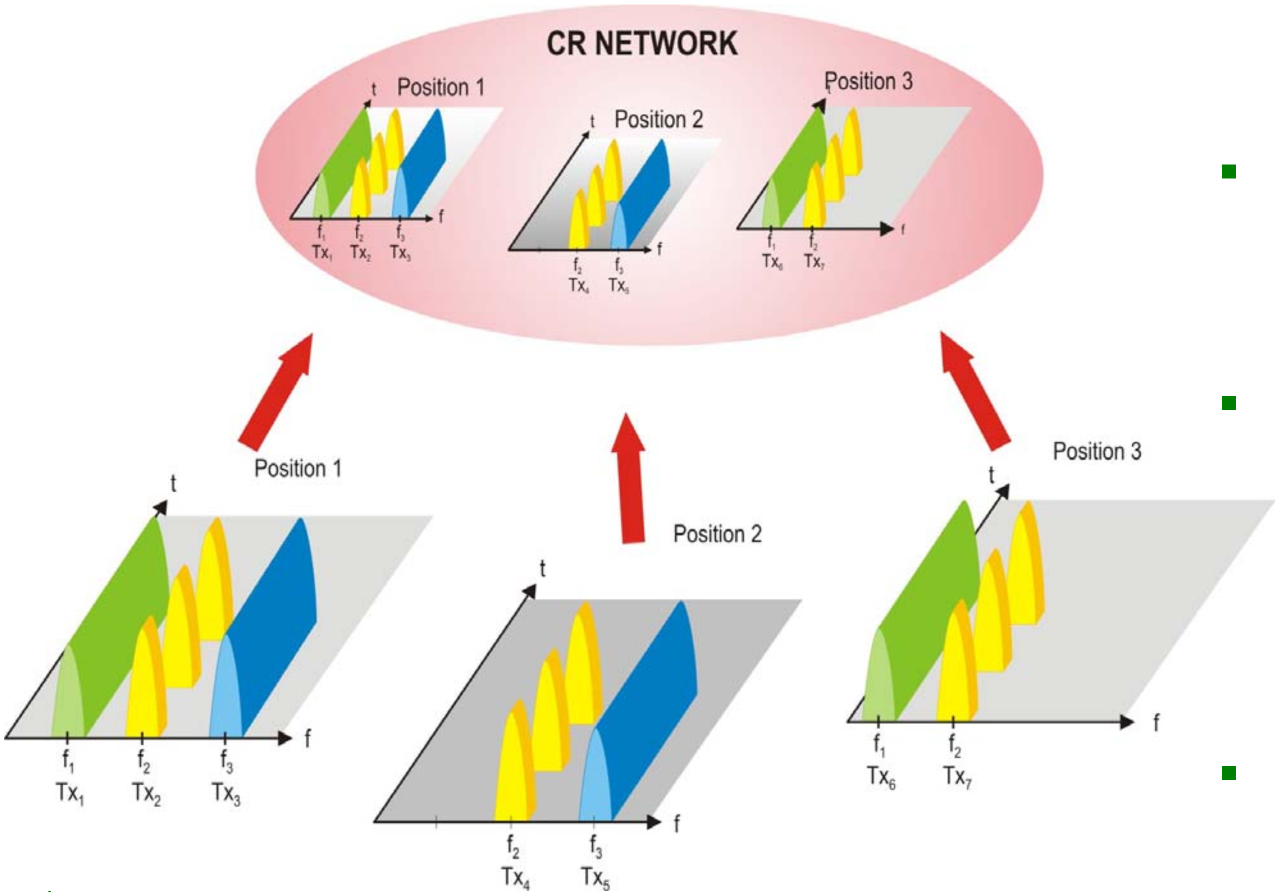
Overview

- Options for the signalization and storing of spectral occupation
  - Knowledge of the standard parameters required

- Parameter estimation for an unknown standard
  - Channel segmentation
  - Estimation of channel periodicities
  - Mean within the periodic Interval

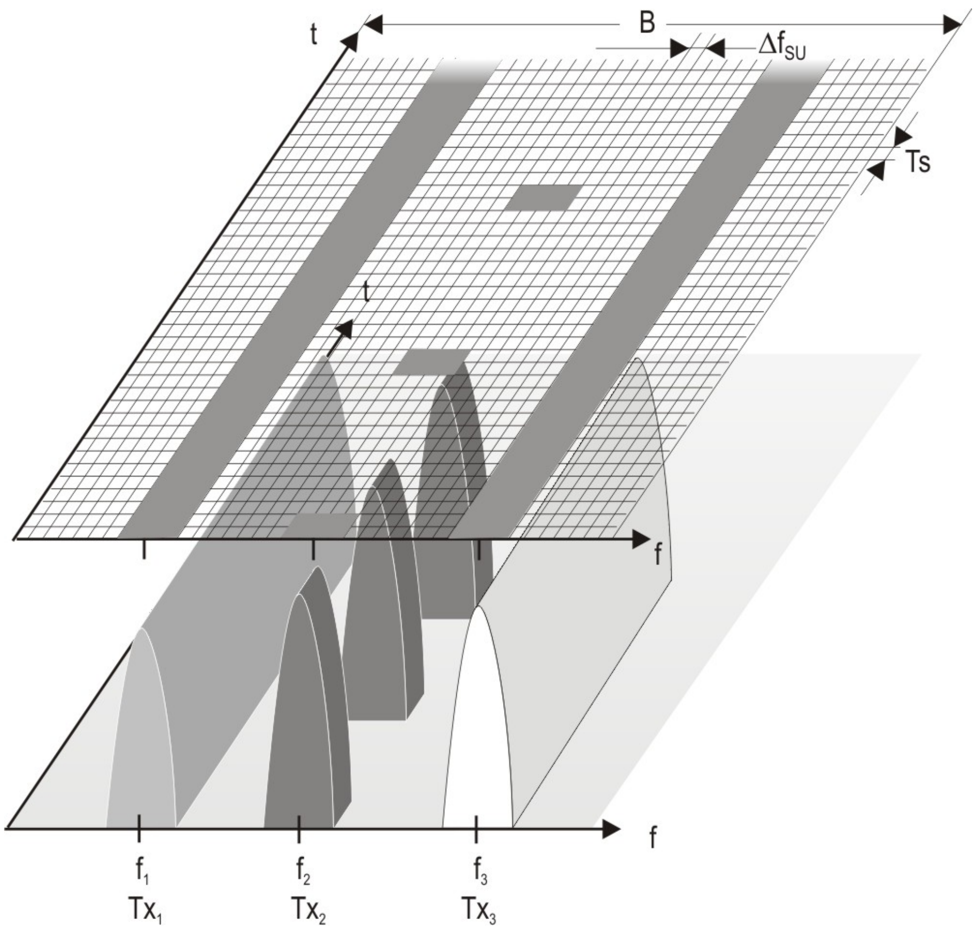
CR Scenario



- **CR nodes signal spectral occupation to the CR network**
  - Positions of nodes are known
- **CR network builds occupation statistics**
  - Probability of channel access
- **CR network identifies common white spaces**

- **Scope of this work: signalization and occupation statistics**

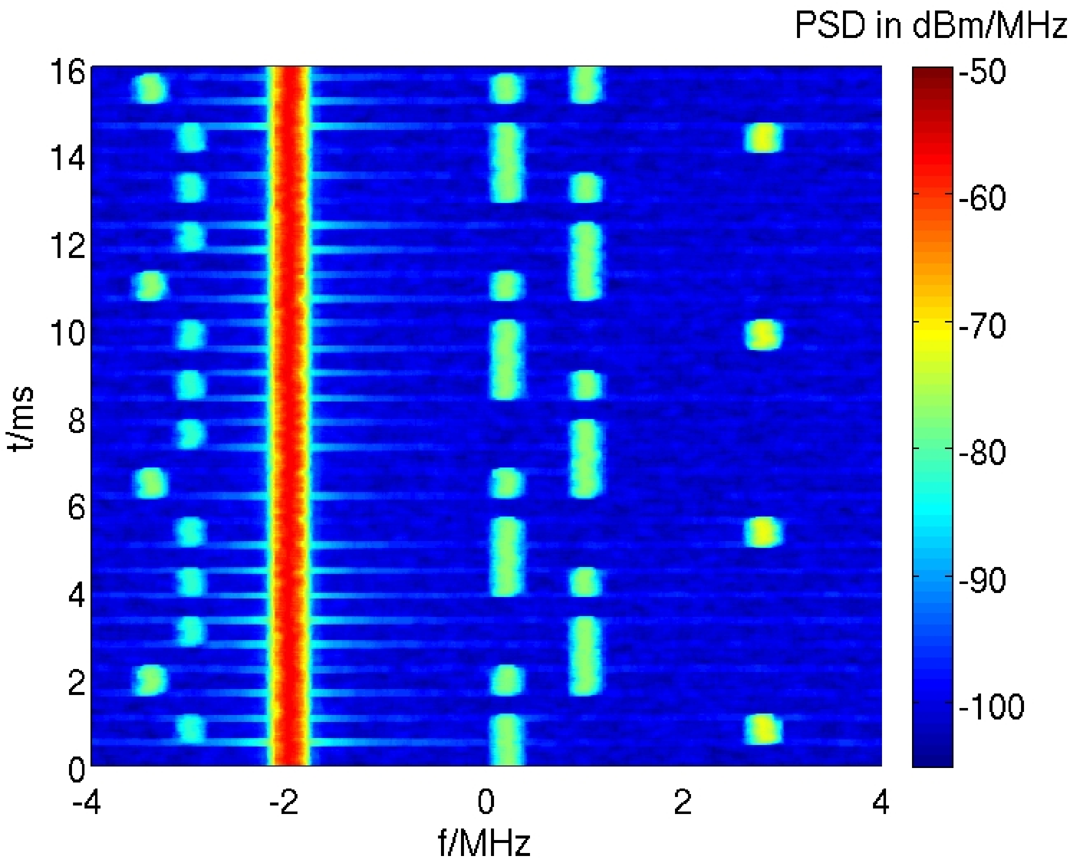
Objectives of a Signalization within a CR Network



- **Transmission of the spectral occupation to the CR network**

1. **Compression for signalization and occupation statistic**
   - ⇒ Definition of the signalization and storage efficiency per CR node: Γ defined as signalization bits per observed bandwidth and duration
2. **Position and time stamp possible**
3. **Power information**
4. **Prediction of the occupation**
   - Reduction of Interference

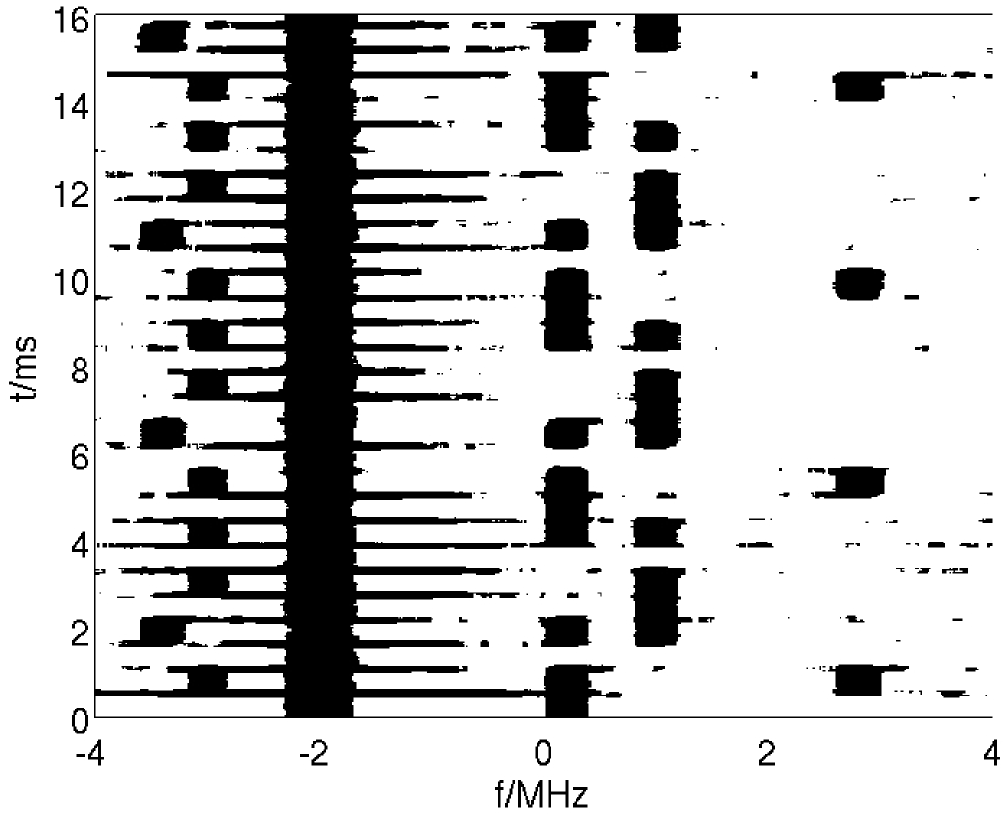
Signalization without further Compression



- **Illustration of the signalization and storage options at the example of simulated GSM data**

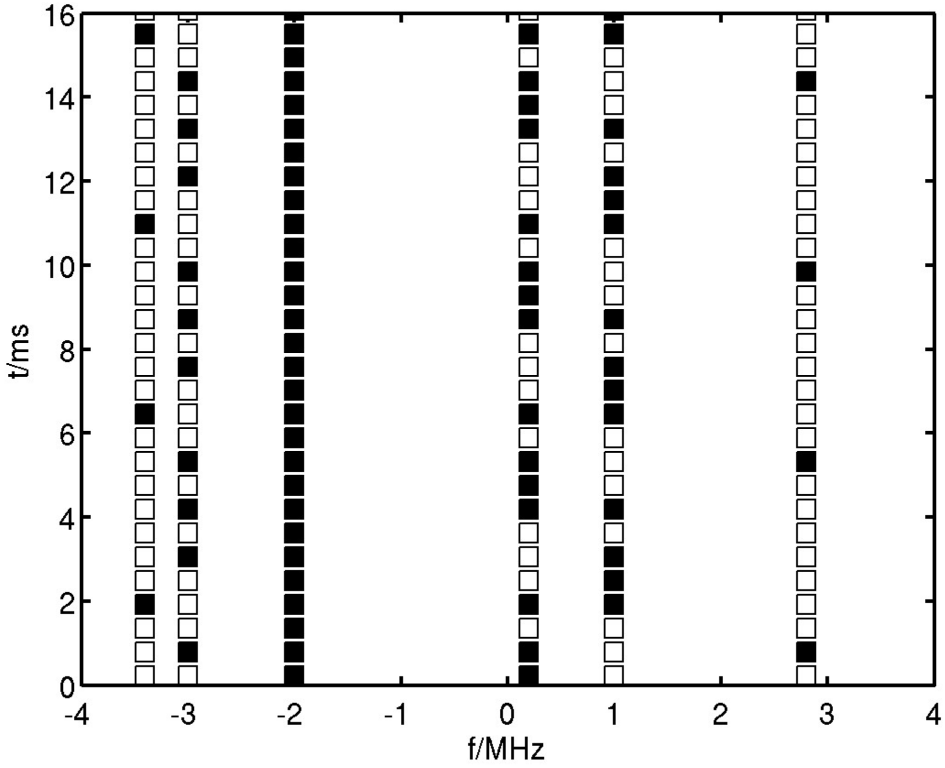
- **Signalization / storage of the spectrogram without further compression**
  - For comparison purposes only
  - Γ_{Spec} = 24 bit/s/Hz at 12 Bit resolution

Signalization after Occupied / Unoccupied Decision



- **Occupied / unoccupied decision**
  - Continuous signalization required
  - Γ_{Bin} = 2 bit/s/Hz
- **Image compression algorithms deliver an insufficient compression**

Signalization and Occupation Statistics with Knowledge of the Standard



Signalization and occupation statistics:

1. **Fixed standard parameters, PSD_{max}, position, etc.**
   Assumption for this slide: GSM standard is known

2. **Changing user behavior**
   - Γ_{GSM} = 1 bit / 200 kHz / 577 µs = 0,0087 bit/s/Hz if all channels are occupied
   - Drastic Compression
   - Target for signalization overhead

- **Efficient prediction possible**

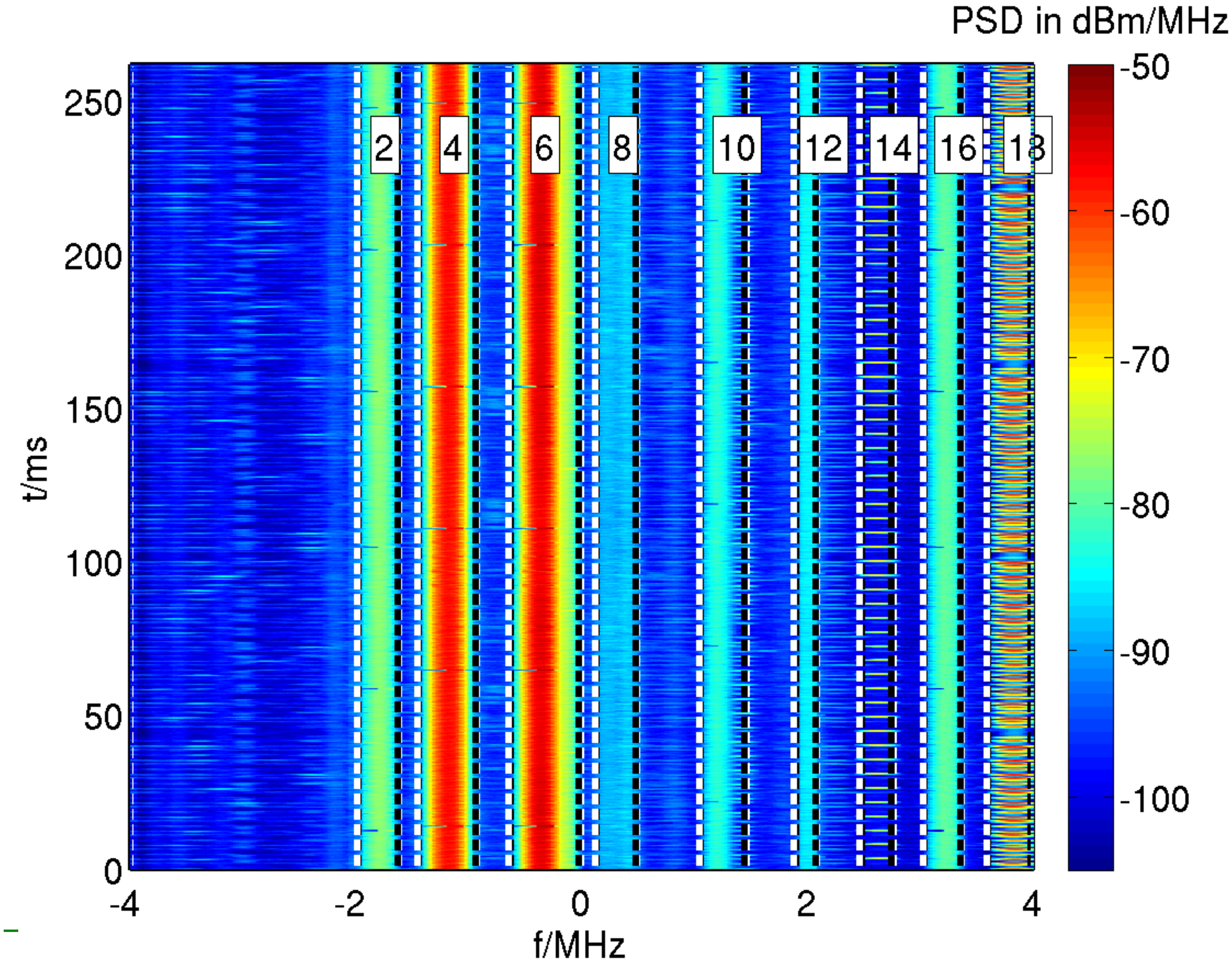
Signalization for Unknown Standards

- **Estimation of the parameters for an unknown or flexible standard**
  - ISM bands contain unknown transmitters.
  - Parameters may not be clearly defined in the standard, such as for radar applications.
  - Parameters of known standards may not be obtained by the CR node, if its A/D converter is too small.
- **Assumption for the following slides: Parameters of the standard as center frequency, bandwidth, TDMA structure, etc. are unknown.**

- **Processing at the CR Node**
  1. Spectral estimation
  2. Automatic channel segmentation
  3. Estimation of the channel power of each channel
  4. Estimation of the channel power periodicities
  5. Mean within the periodic interval
- **Signalization of these parameters to the network**
- **Reconstruction of the spectral occupation within the CR network**

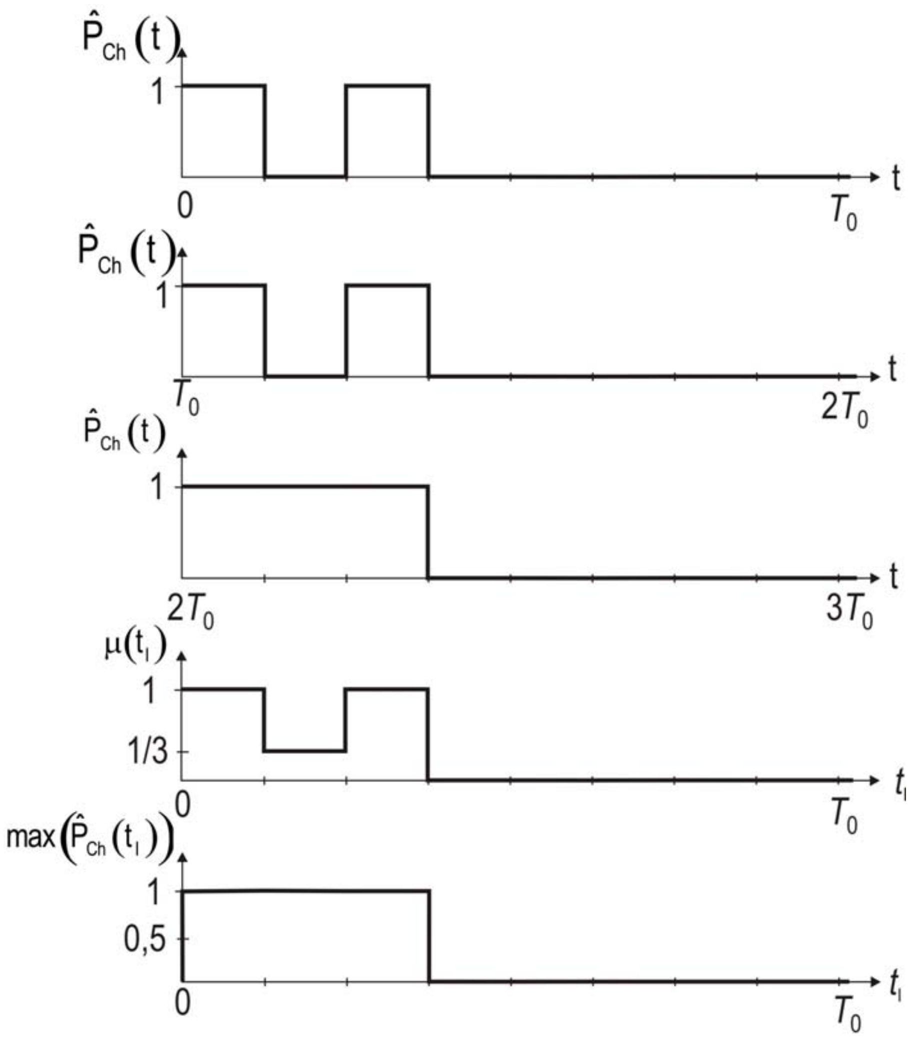
GSM Scenario

- Channel segmentation
- T_0 Estimation using YIN method



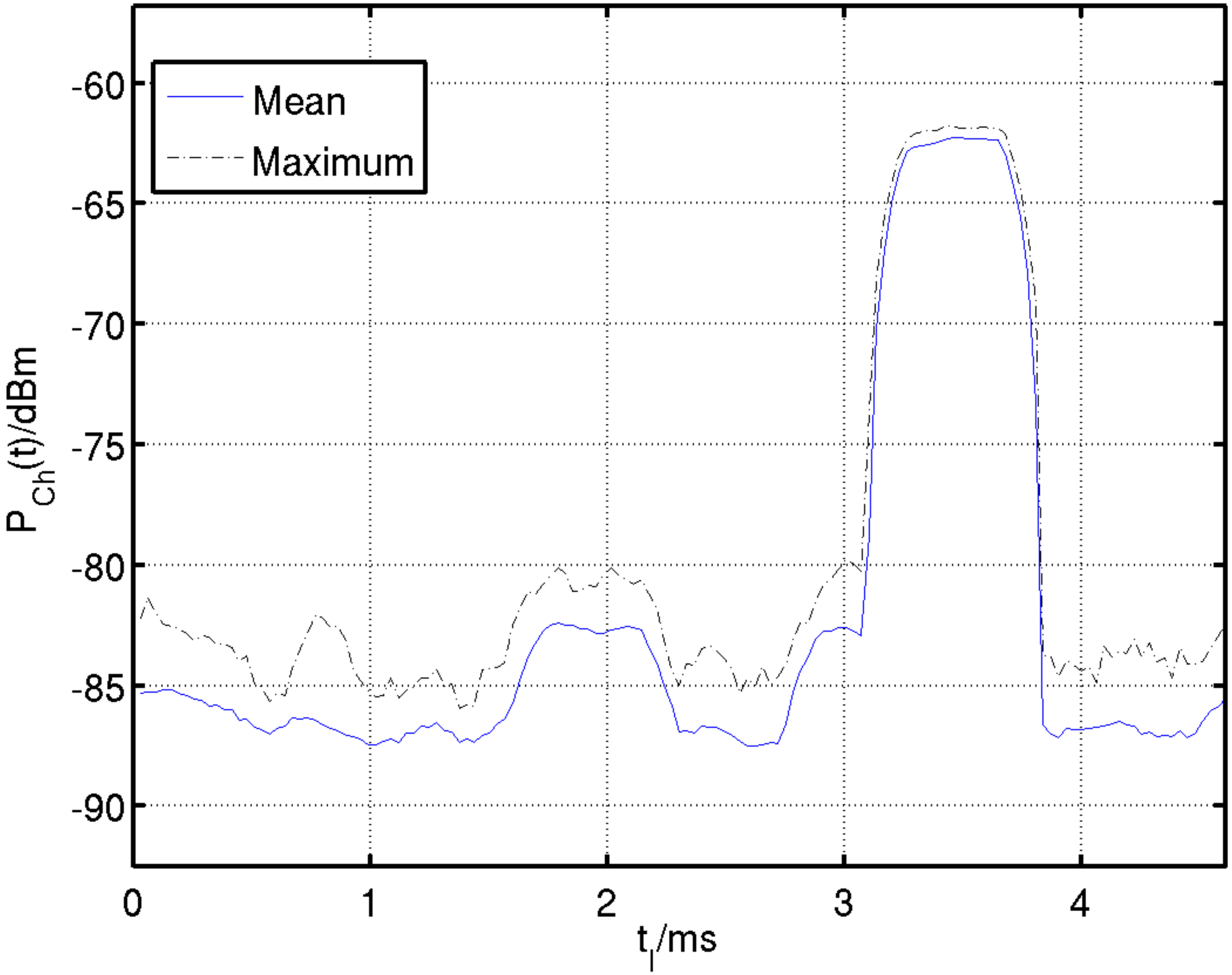
Channel	T_0 / ms	T_0 / 4,6154 ms
1	119,998	25,9995
2	4,616	1,0001
3	96,917	20,9987
4	4,614	0,9998
5	59,989	12,9975
6	124,612	26,9994
7	55,399	12,0031
8	73,849	16,0005
9	4,617	1,0003
10	4,607	0,9981
11	120,000	25,9999
12	69,227	14,9993
13	4,615	1,0000
14	4,615	1,0000
15	4,611	0,9991
16	4,613	0,9994
17	4,617	1,0002
18	119,999	25,9999

Mean within T_0



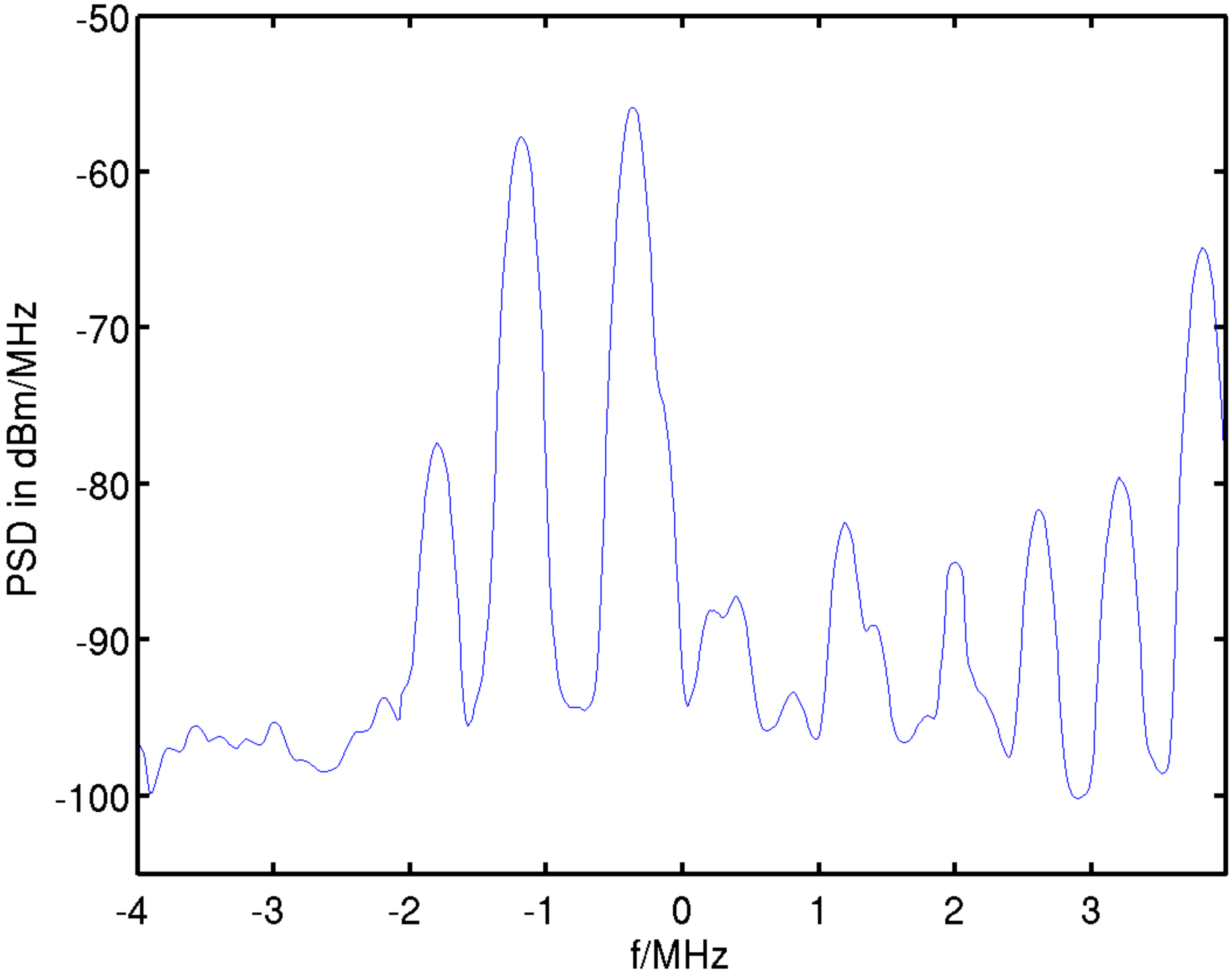
- **Splitting the channel power vector in intervals of duration T_0**
- **Mean and Max within the interval T_0**

Mean and Max Channel 14 GSM Scenario

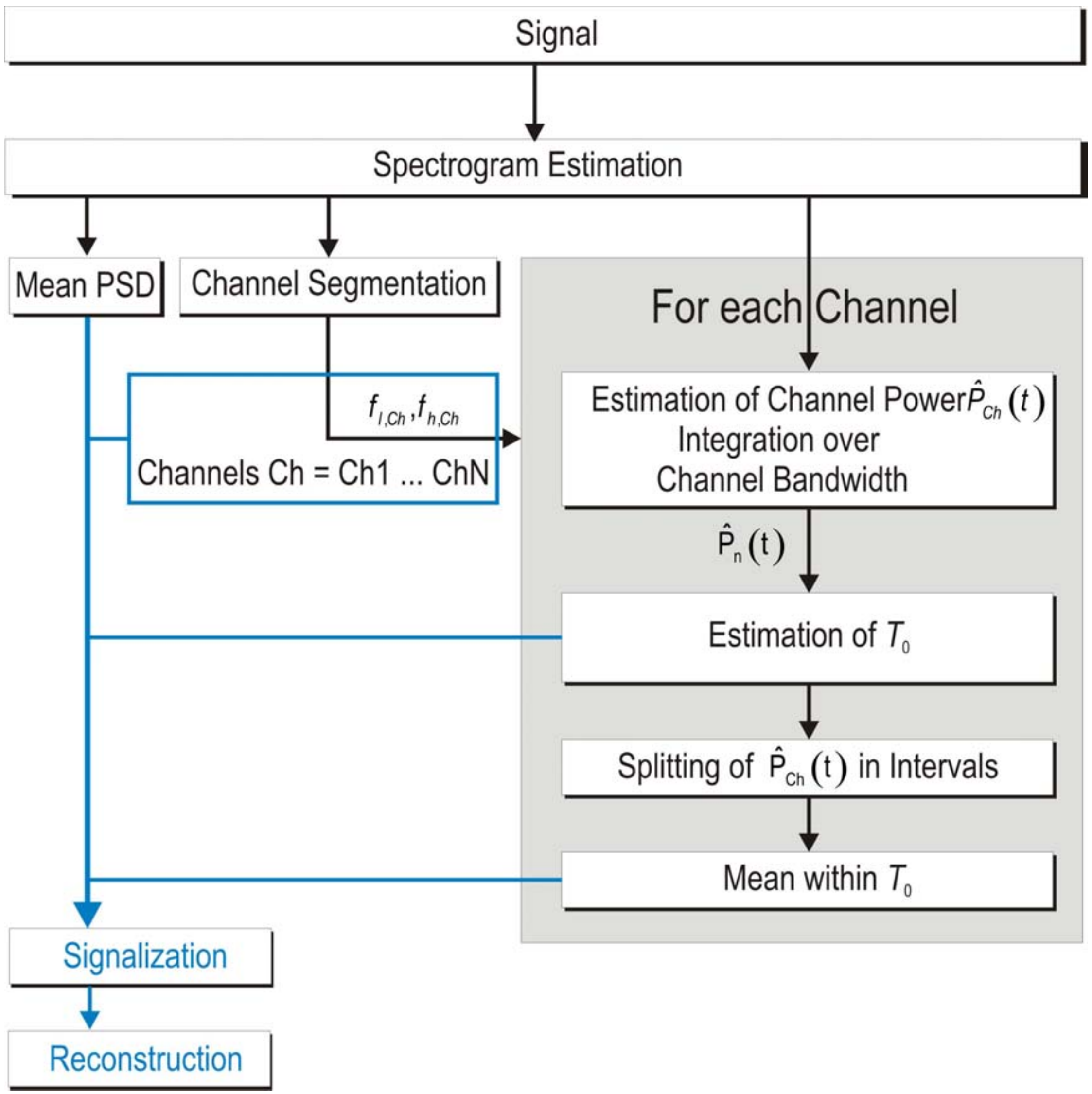


- Channel 14 of the GSM Scenario
- Mean and Max within T_0

Spectrum GSM Scenario



Overview CR Parameter Estimation and Signalization



Reconstruction of the Occupation

- **Normalized PSD in the channel**

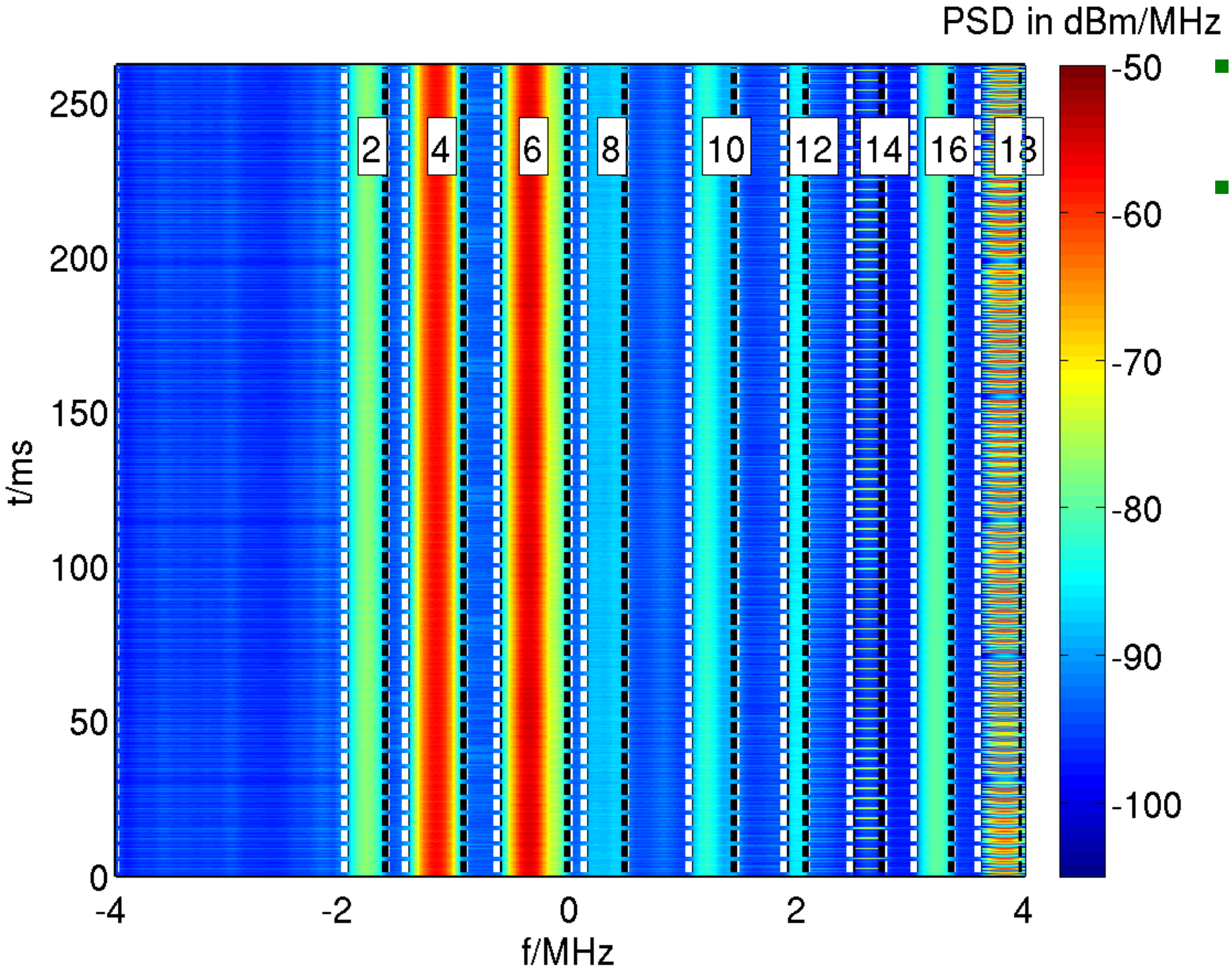
$$\widehat{S}_{Norm}(f) = \widehat{S}(f) / \sum_{f=\widehat{f}_l}^{\widehat{f}_h} \widehat{S}(f)$$

where $\widehat{S}(f)$ **is defined as the PSD in channel** ***ChN*****.**

- **Reconstructed spectrogram**

$$\widehat{S}_{Recon}(f,t) = \left(\mu(t_I) - \widehat{N}_0(\widehat{f}_h - \widehat{f}_l)\right) \widehat{S}_{Norm}(f) + \widehat{N}_0$$

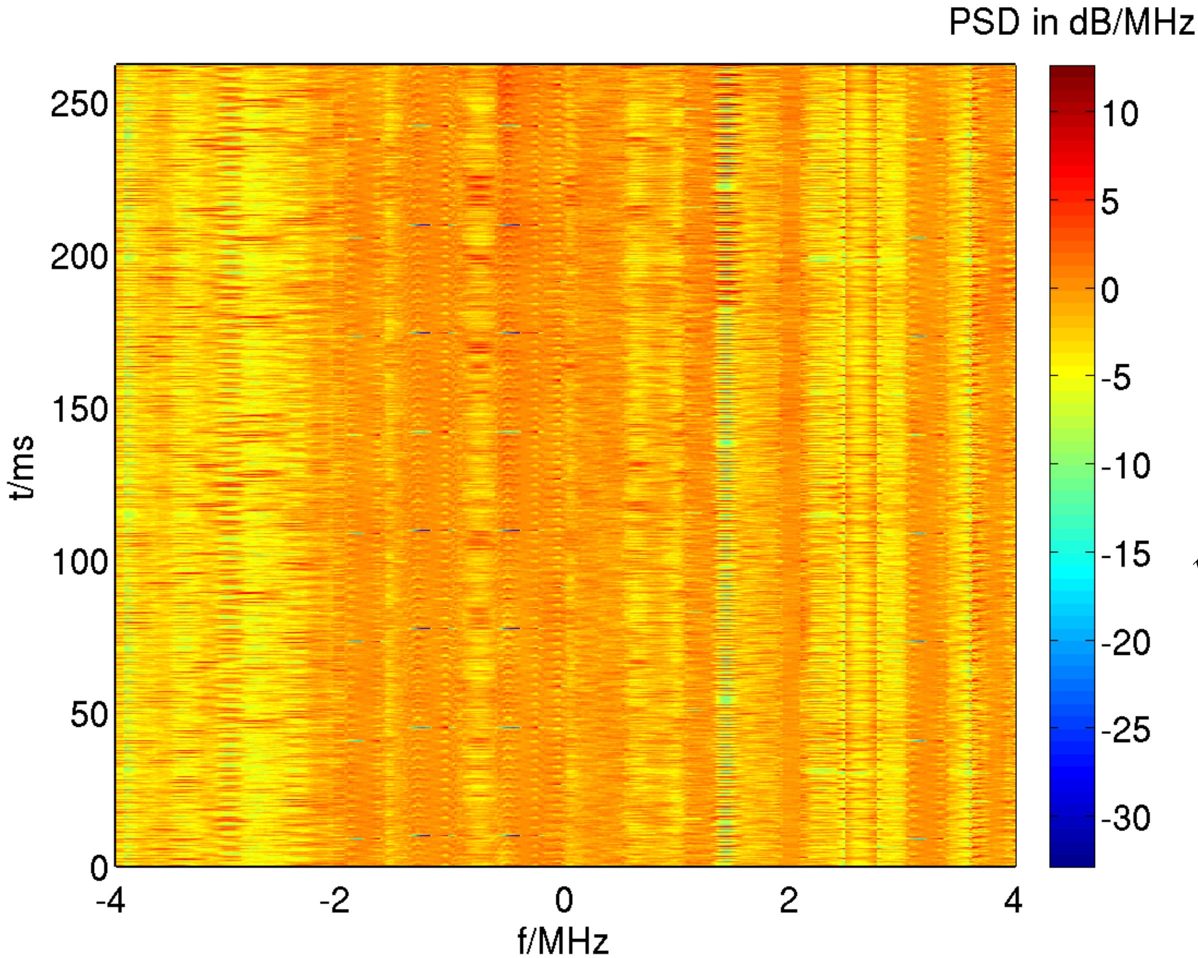
Reconstruction GSM Scenario



- Γ=0.1605 bits/s/Hz
- Compression factor 150

Difference Original and Reconstruction Scenario GSM

$$S_{Err}(f,t) = \widehat{S}_{Recon}(f,t) - S(f,t)[dB]$$

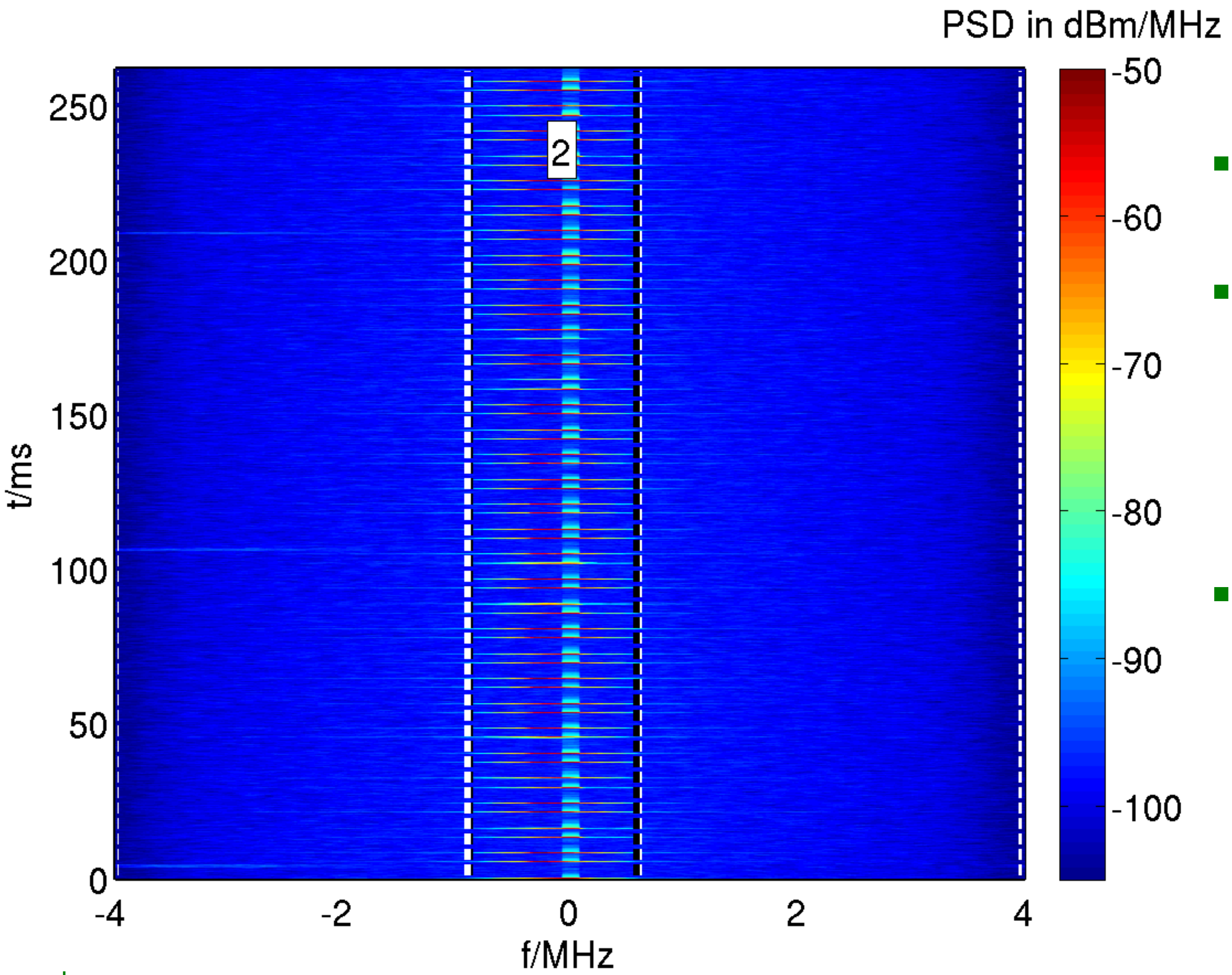


$$\sqrt{MSE_{all}} = 2.70\text{dB}$$

$$\sqrt{MSE_{nopred}} = 2.67\text{dB}$$

$$\sqrt{MSE_{predonly}} = 2.71\text{dB}$$

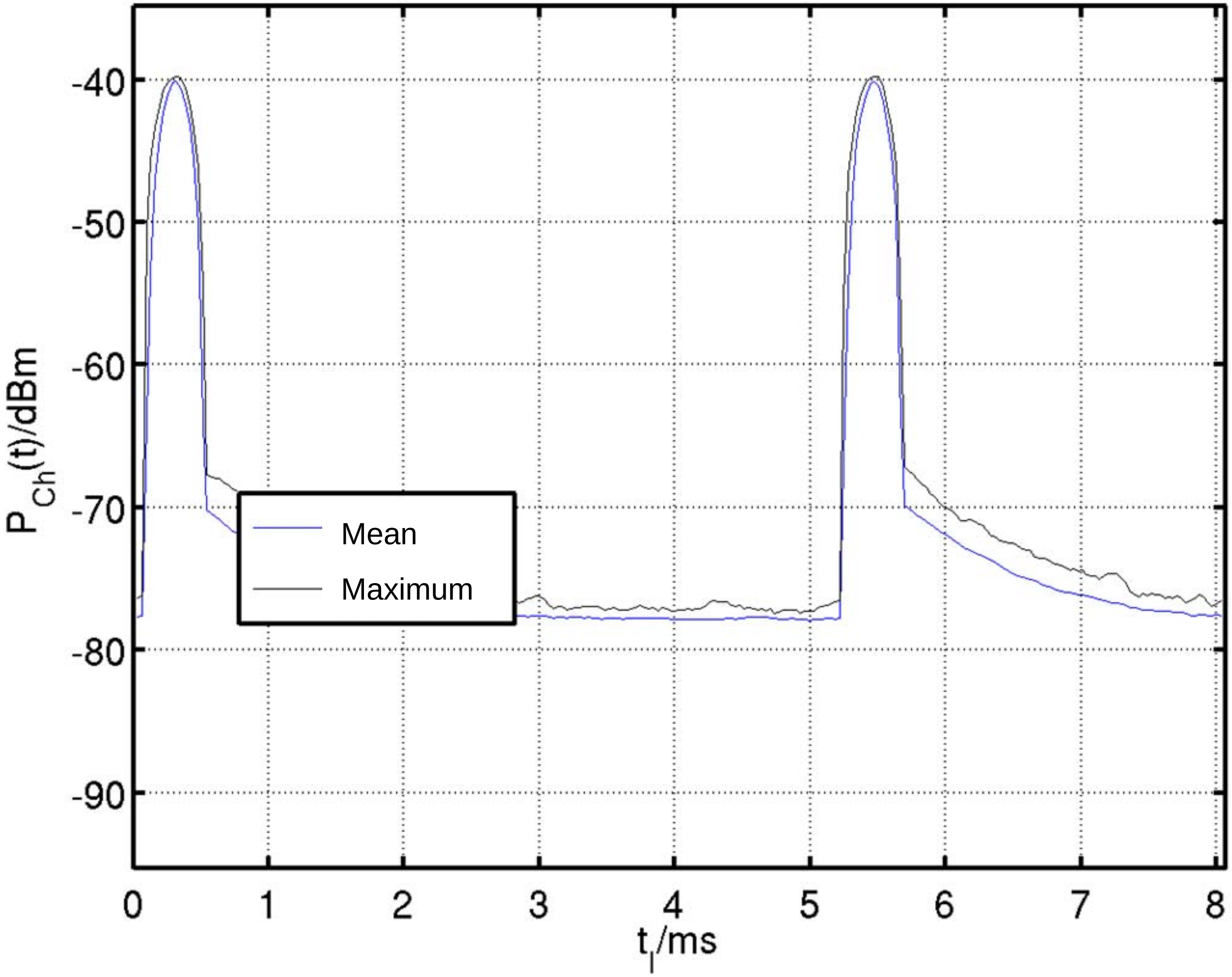
Scenario Wireless Mouse



- Spectrogram of a wireless mouse in the 2.4 GHz ISM band
- Channel segmentation
- Estimation of the channel power $\hat{P}_{Ch}(t)$ through integration over the channel bandwidth
- T_0 estimation using YIN method:

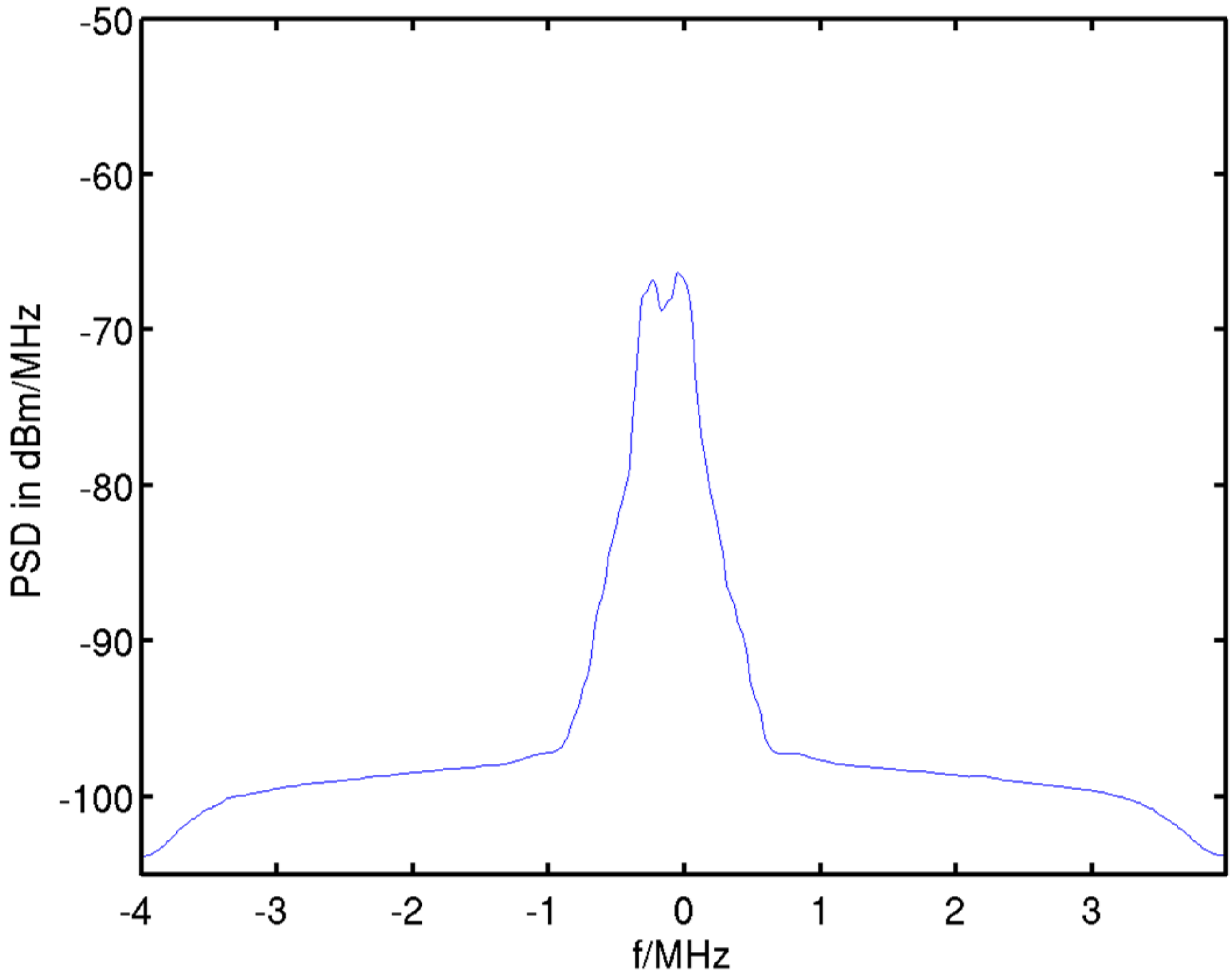
Channel	T_0/ms
1	96.6679
2	8.0566
3	8.0584

Channel Power

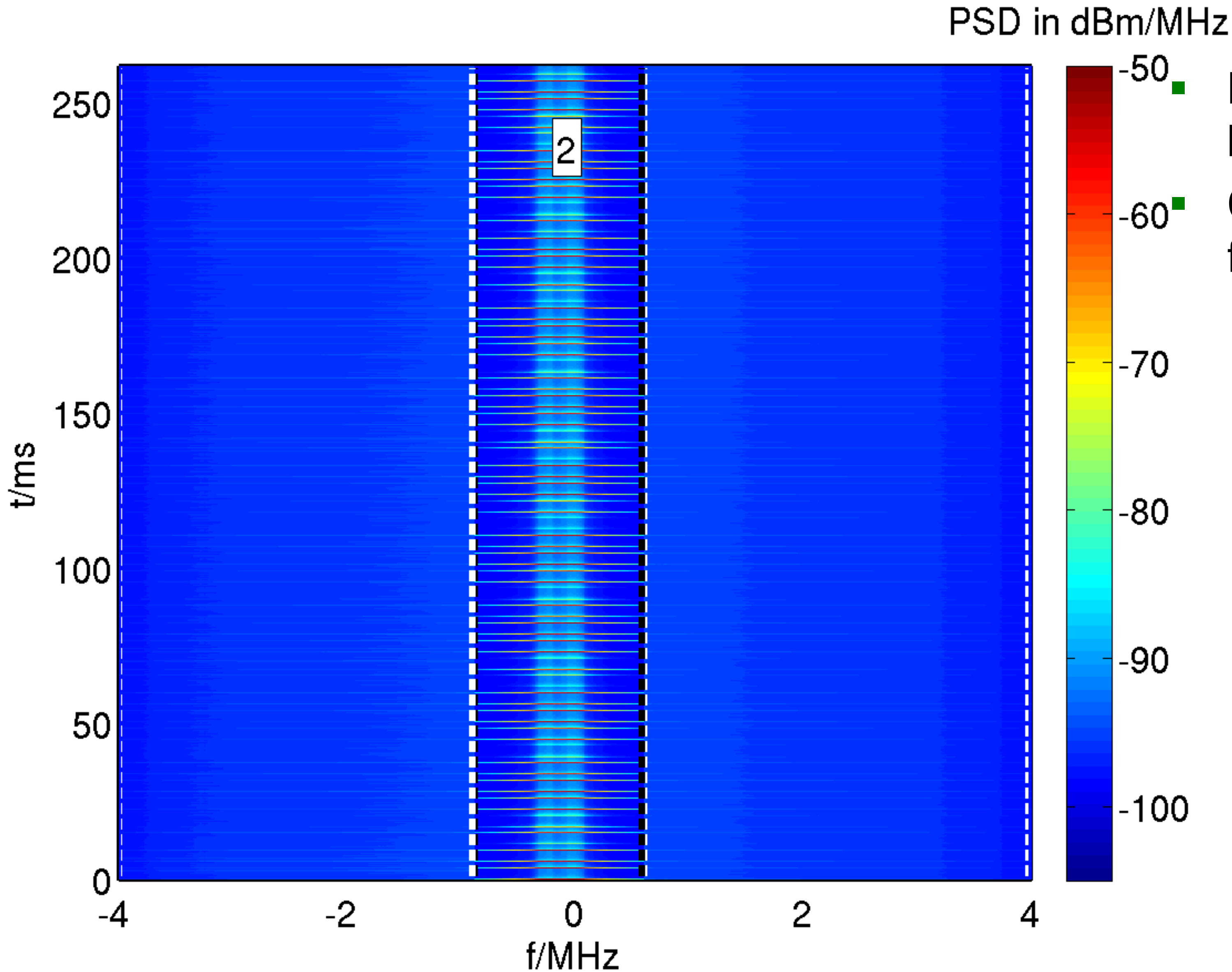


- Illustration of channel 2
- Mean and Maximum within the periodic interval

PSD Scenario Wireless Mouse



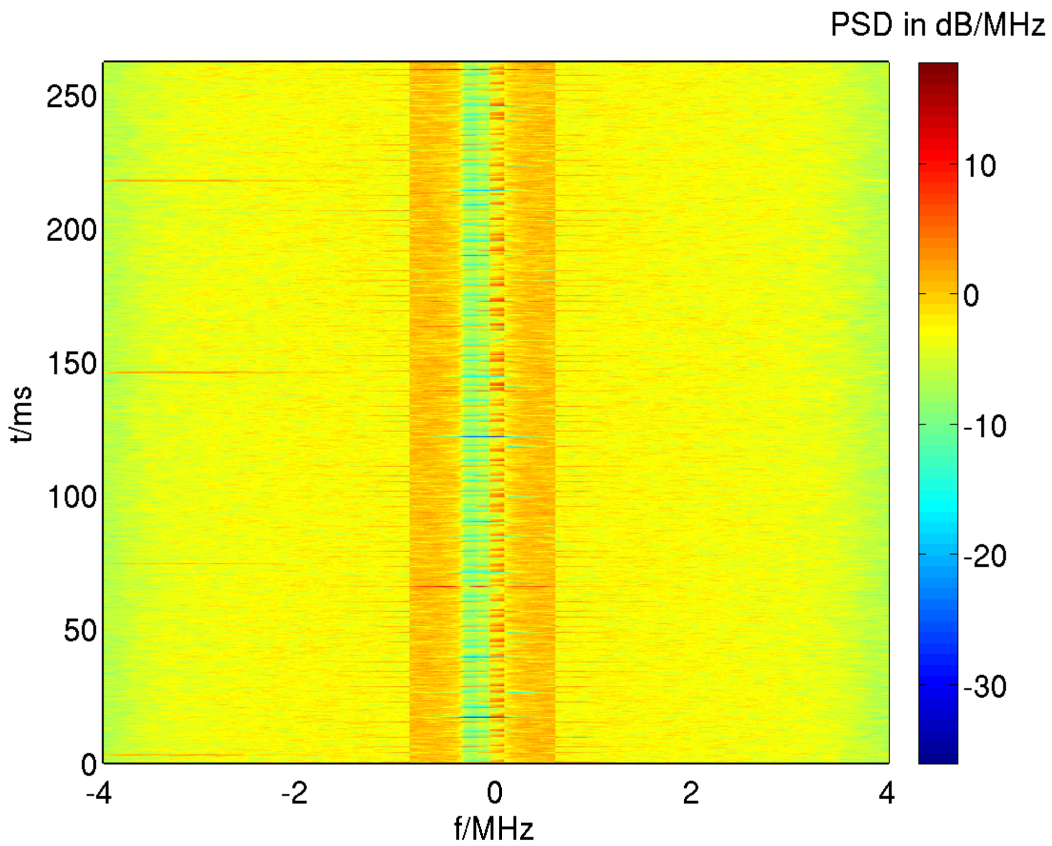
Reconstruction Scenario Wireless Mouse



- Γ=0.0231 bits/s/Hz
- Compression factor 1000

Difference between Original and Reconstruction

$$S_{Err}(f,t) = \widehat{S}_{Recon}(f,t) - S(f,t)[dB]$$



$$\sqrt{MSE_{all}} = 3.85\text{dB}$$

$$\sqrt{MSE_{nopred}} = 3.84\text{dB}$$

$$\sqrt{MSE_{predonly}} = 3.87\text{dB}$$

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Thank you for your attention!