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

Submission Title: [Consideration of MR-FSK Channelization and Clock Frequency Tolerance Using Filtered FSK]

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Abstract: [Evaluation of the MR-FSK channelization scheme and the effect of clock frequency tolerance with filtered FSK as modulation format.]

Purpose: [Technical discussion. Presented to the 802.15.4g SUN Task Group for consideration.]

Consideration of MR-FSK Channelization and Clock Frequency Tolerance Using Filtered FSK

18th January 2011

Khanh Tuan Le

AGENDA

- Background
- Parameters of Interest
- Assessment Data
- Signal Spectrum
- Discussion

Background

- This contribution is submitted as a follow-up to the discussion of the DCN834rev1 at the November meeting in Dallas.
- Comments addressed: CID #186
- Since the 802.15.4g MR-FSK PHY specifies the use of *filtered* frequency shift keying for good co-existence practice, the most realistic way to evaluate the channelization scheme and the effect of clock frequency tolerance is by using a filtered FSK signal.
- GFSK with BT=0.5 will be used as the filtered FSK modulation format in this evaluation.

Parameters of Interest

Reference: P802.15.4g/D2

- The single sided clock frequency tolerance is defined as:

$$T \le min\left(\frac{T_0 \times R \times h \times F_0}{R_0 \times h_0 \times F}, 50ppm\right)$$

Max frequency tolerance:

±30 ppm for the 902-928 MHz band

±15 ppm for the 2400-2483.5 MHz band

- Adjacent channel rejection ≥ 10 dB
- Alternate channel rejection ≥ 30 dB

Adjacent/Alternate Channel Rejection Specifications

- 6.12a.4 Radio specification
  ….
  The adjacent channel rejection shall be greater or equal to 10 dB.
  The alternate channel rejection shall be greater or equal to 30 dB.

- 6.12a.4.3 Receiver jamming resistance

  The adjacent channel rejection shall be measured as follows: the desired signal shall be a compliant MR-FSK PHY signal, as defined in 6.12a.1, of pseudo-random data at the center frequency of the desired channel. The desired signal is input to the receiver at a level 3 dB above the receiver sensitivity given in 6.12a.4.2.
  In either the adjacent or the alternate channel, an unmodulated carrier in the center of that channel is input at the level specified in 6.12a.4 relative to the level of the desired signal. The test shall be performed for only one interfering signal at a time. The receiver shall meet the error rate criteria defined in 6.1.7 under these conditions.

Adjacent Channel Rejection Test

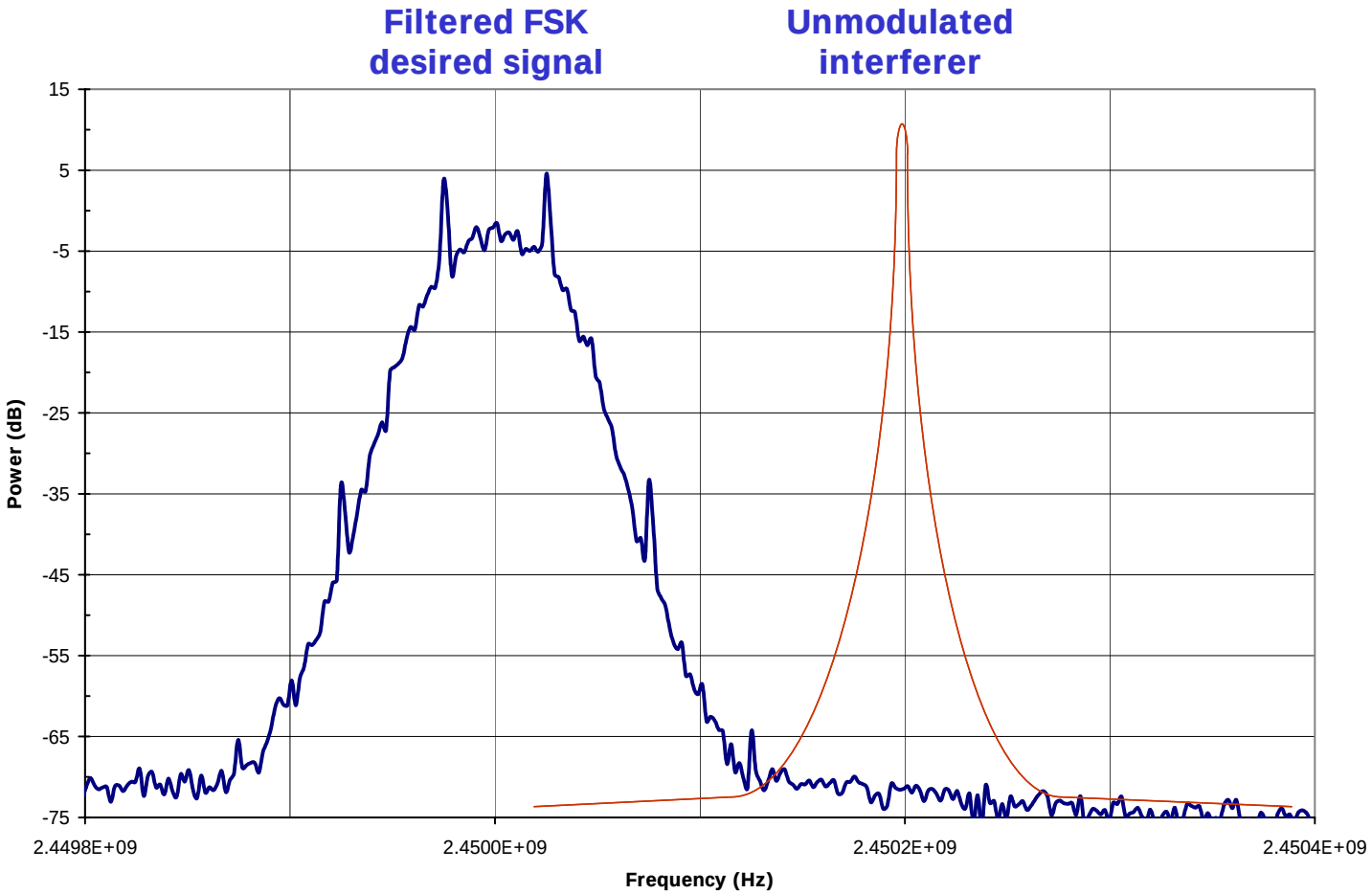
- Desired signal:

Modulated signal at the center of the wanted channel

- Interfering signal:

Unmodulated carrier with 10 dB higher power at the center of the adjacent channels (one at a time)

- No frequency offset



Adjacent channel rejection test as specified by P802.15.4g/D2

- Figure shows test case with interferer at upper adjacent channel.
- Equivalent test case for the lower adjacent channel.

Alternate Channel Rejection Test

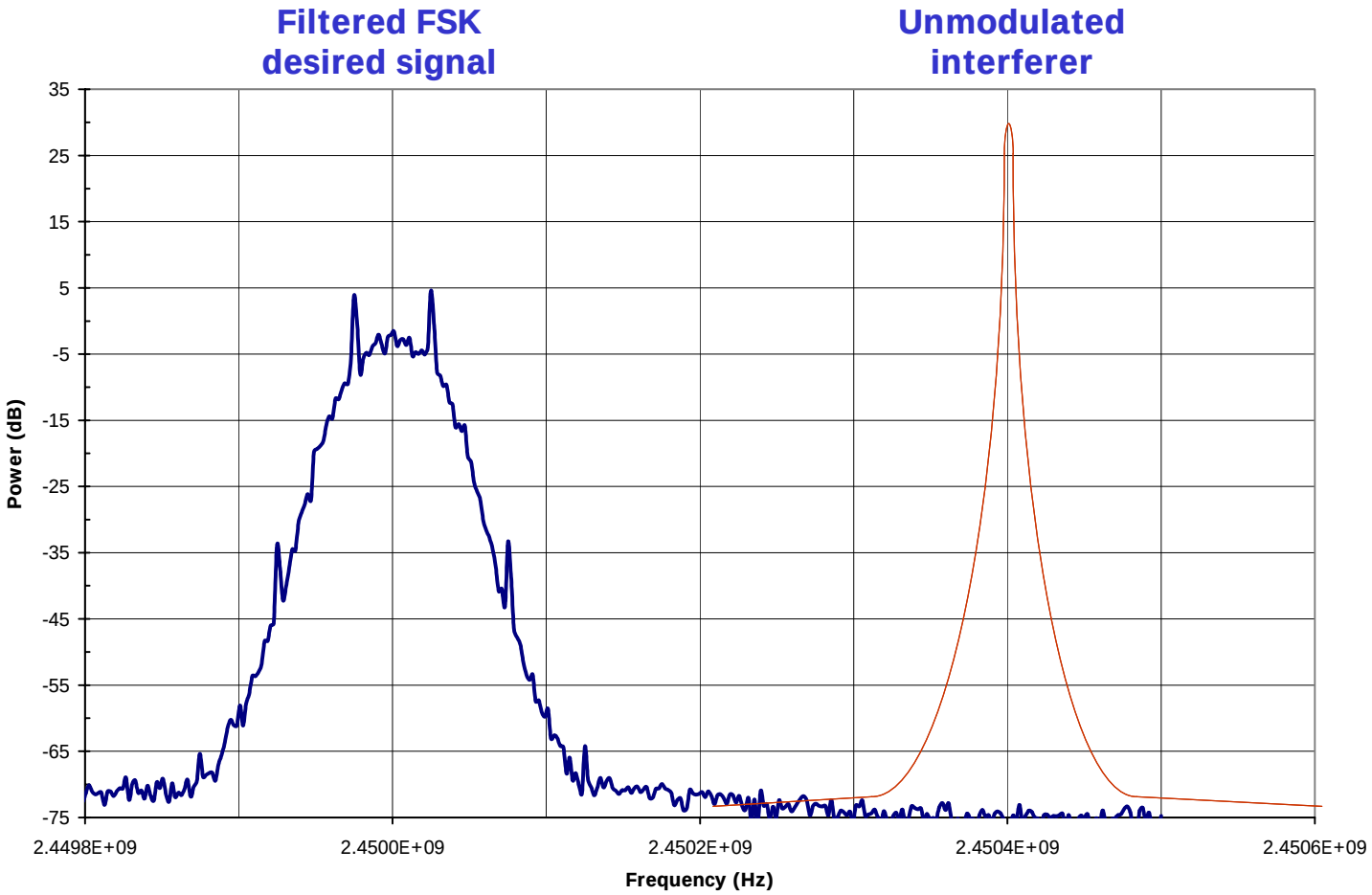
- Desired signal:

Modulated signal at the center of the wanted channel

- Interfering signal:

Unmodulated carrier with 30 dB higher power at the center of the alternate channels (one at a time)

- No frequency offset



Alternate channel rejection test as specified by P802.15.4g/D2

- Figure shows test case with interferer at upper alternate channel.
- Equivalent test case for the lower alternate channel.

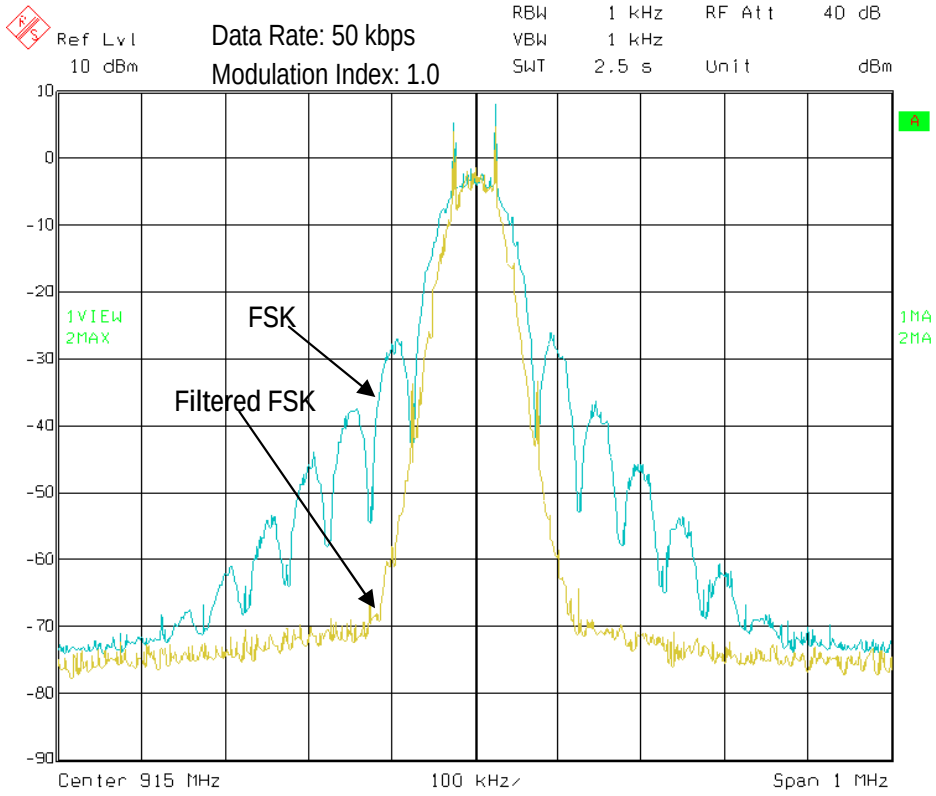
Assessment Data

- Data rate = 50 kbps
- Modulation index = 1.0
- Nominal channel spacing: 200 kHz
- The interfering signal in the adjacent channel is a modulated signal with the same modulation characteristics as the wanted signal.

Please note that this is more realistic than the nominal test definition.

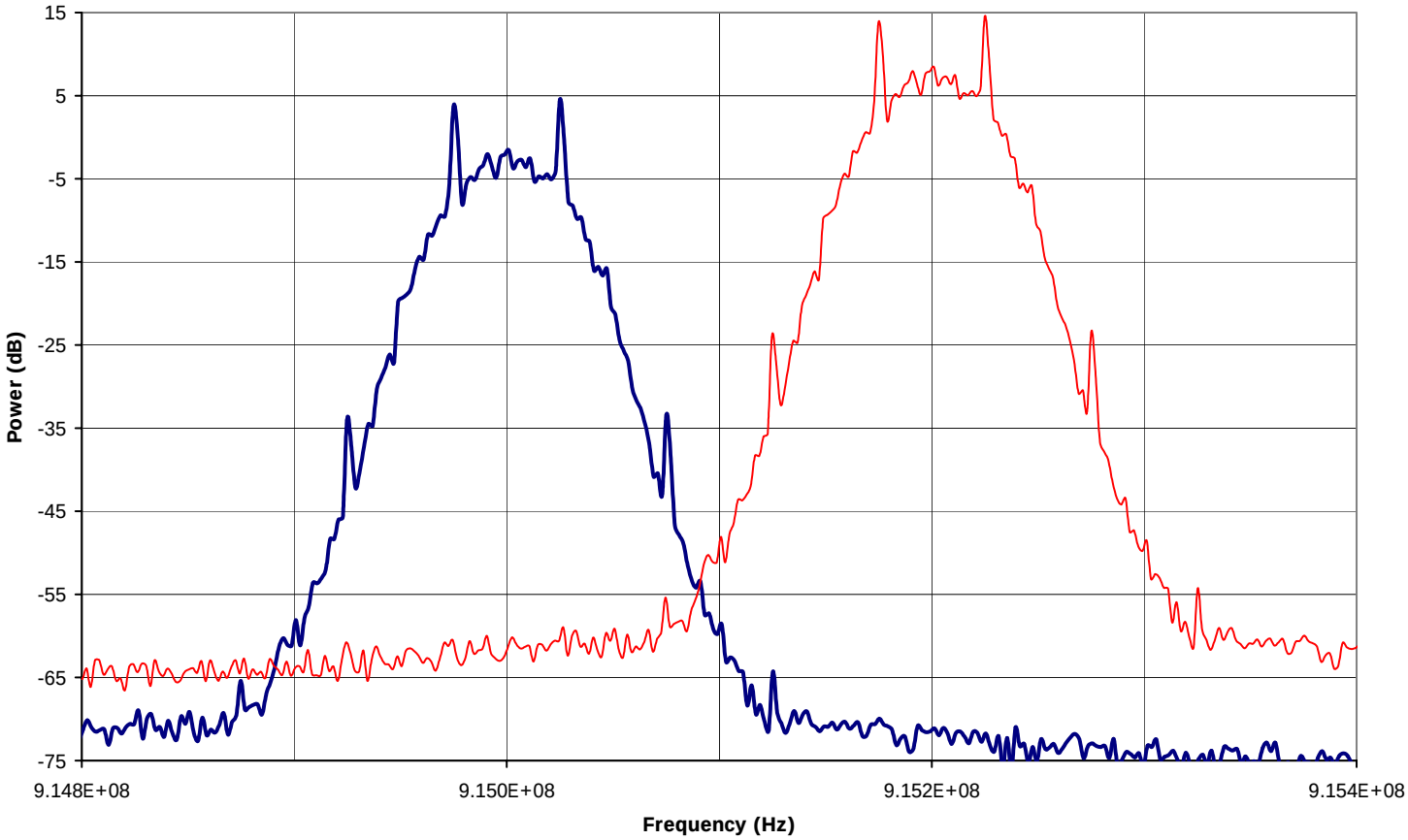
- The adjacent channel signal power is 10 dB higher than the wanted signal (according to P802.15.4g/D2).
- For *worst case* assessment the wanted and adjacent channel signals are offseted by the max frequency tolerance value specified in P802.15.4g/D2.

Please note that this is much worse than the nominal test definition.



Filtered FSK Signals at 915 MHz, ±0 ppm

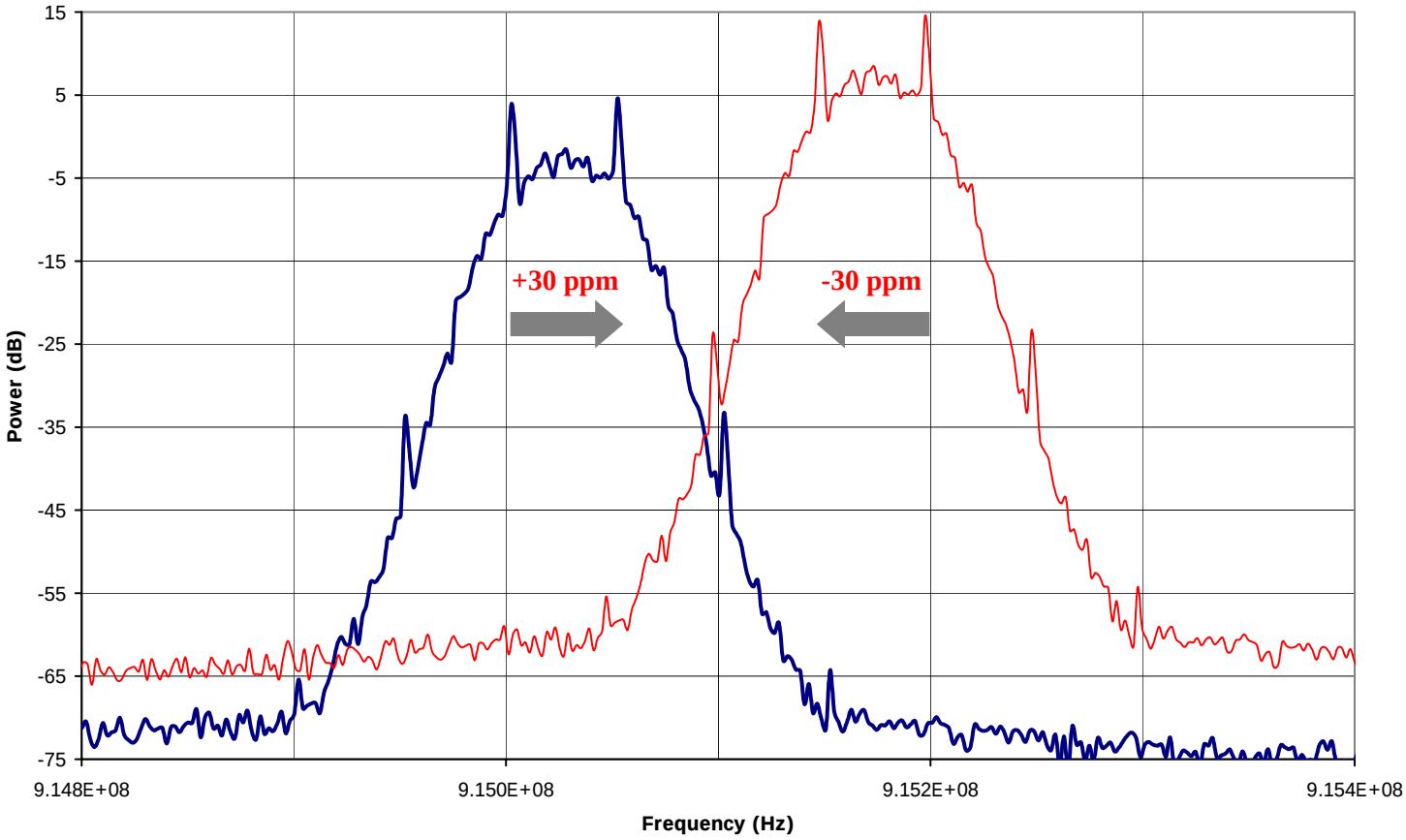
- Wanted channel: 915.0 MHz
- Adjacent channel: 915.2 MHz
- Adjacent channel power relative to wanted channel: +10 dB



- Figure shows the case with interferer at upper adjacent channel.
- Equivalent case for the lower adjacent channel.

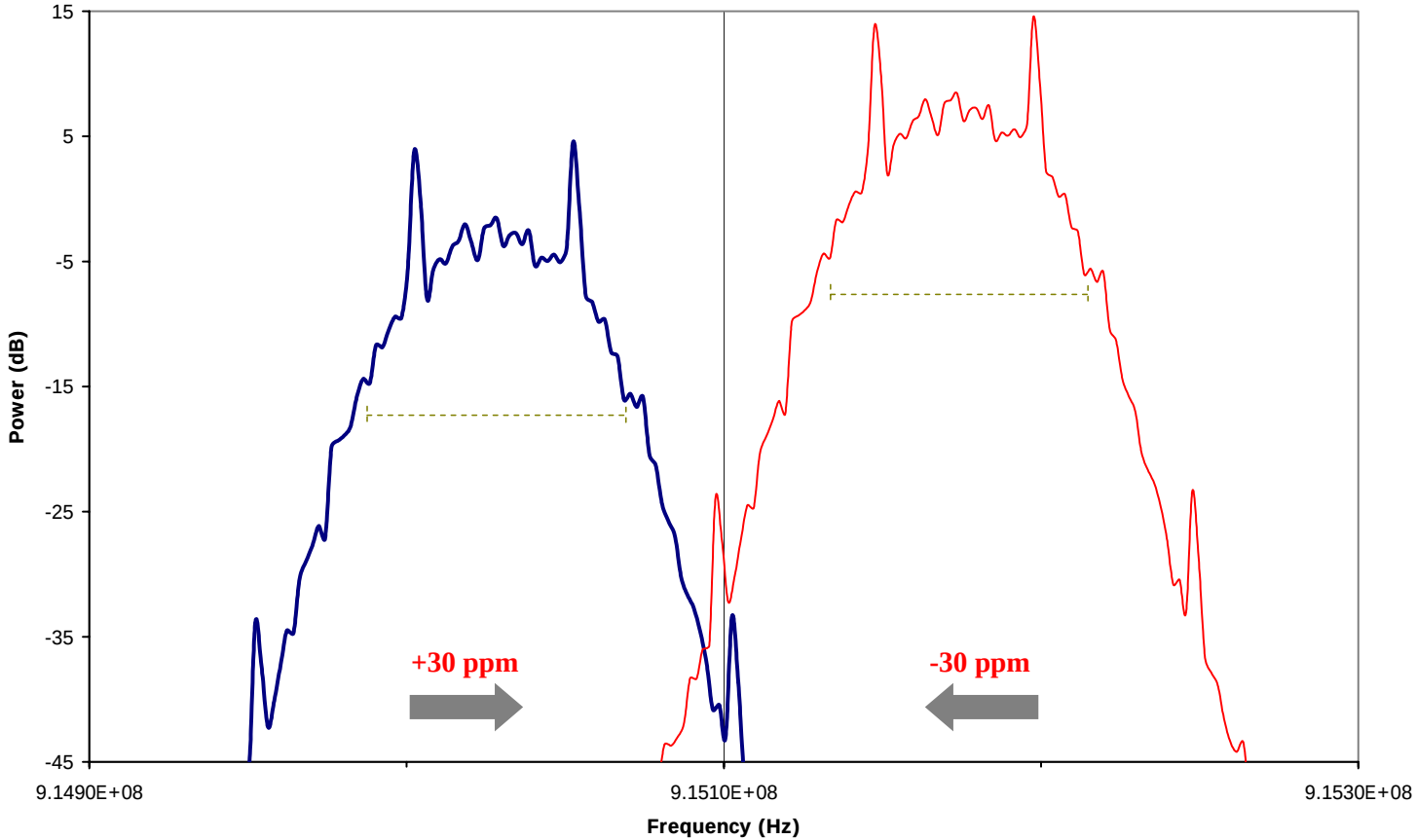
Filtered FSK Signals at 915 MHz, ±30 ppm (1)

- Negligible interfering power leakage from adjacent channel at max frequency tolerance and worst case offset.



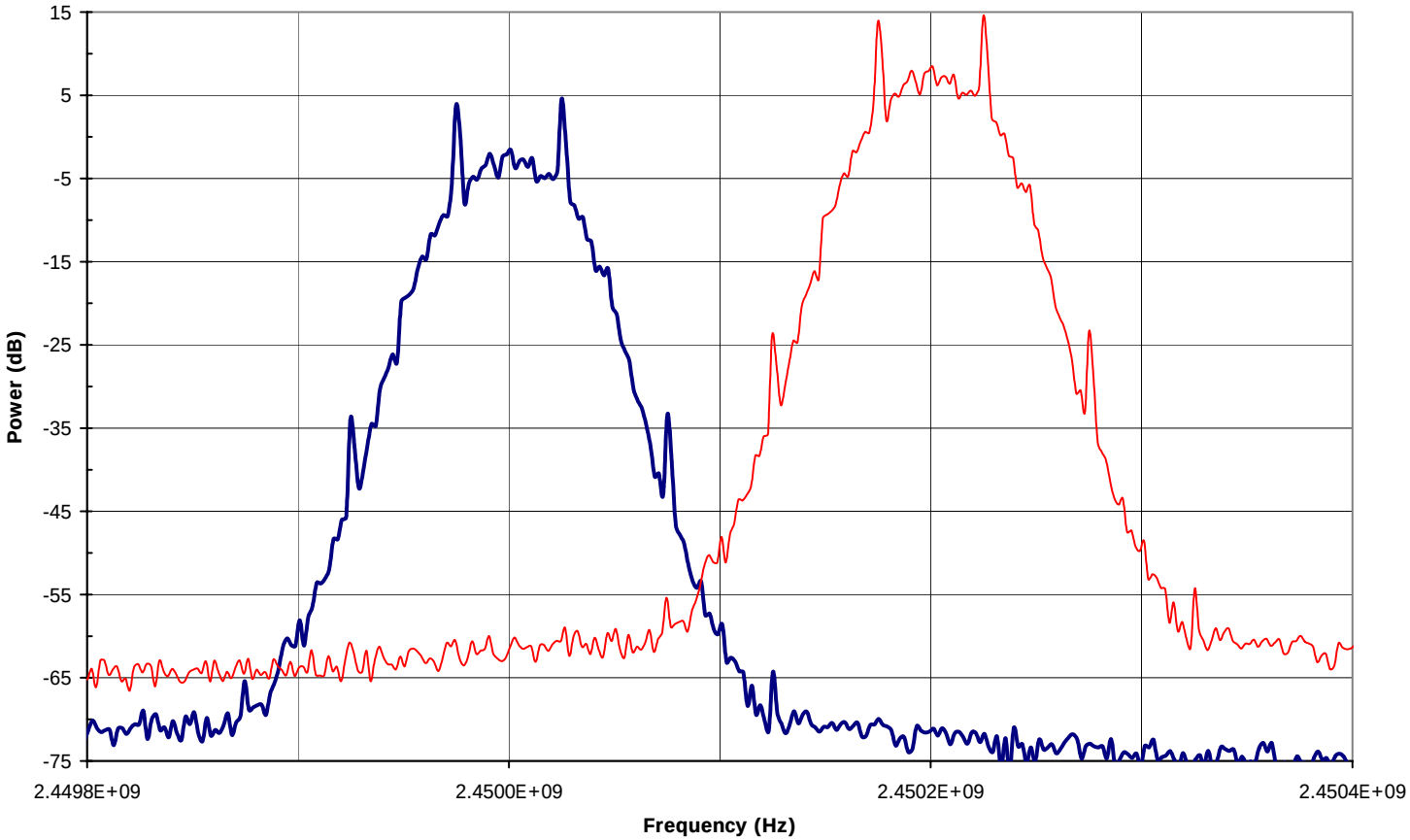
Filtered FSK Signals at 915 MHz, ±30 ppm (2)

- Excellent conditions for signal demodulation at max frequency tolerance and worst case offset.



Filtered FSK Signals at 2450 MHz, ±0 ppm

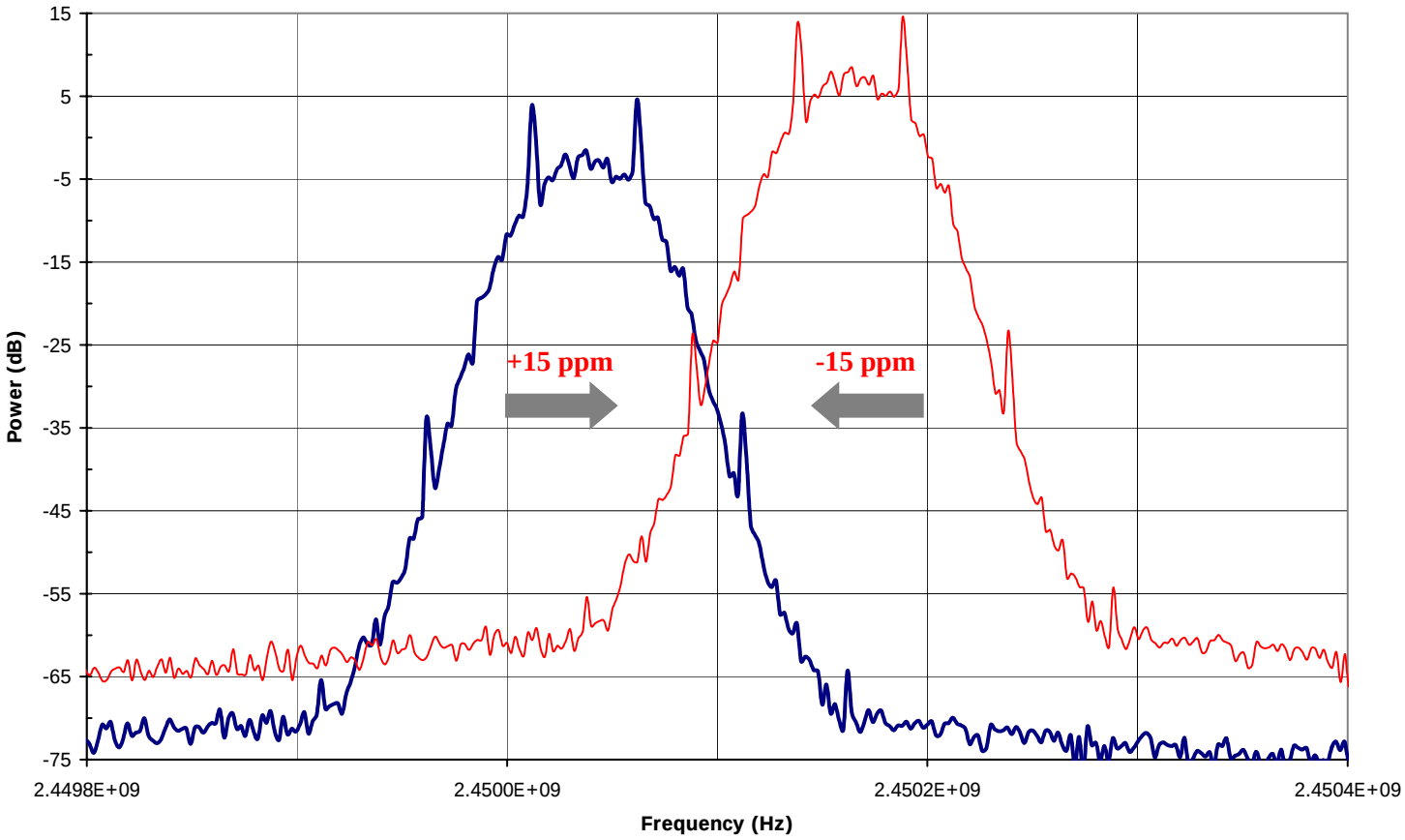
- Wanted channel: 2450.0 MHz
- Adjacent channel: 2450.2 MHz
- Adjacent channel power relative to wanted channel: +10 dB



- Figure shows the case with interferer at upper adjacent channel.
- Equivalent case for the lower adjacent channel.

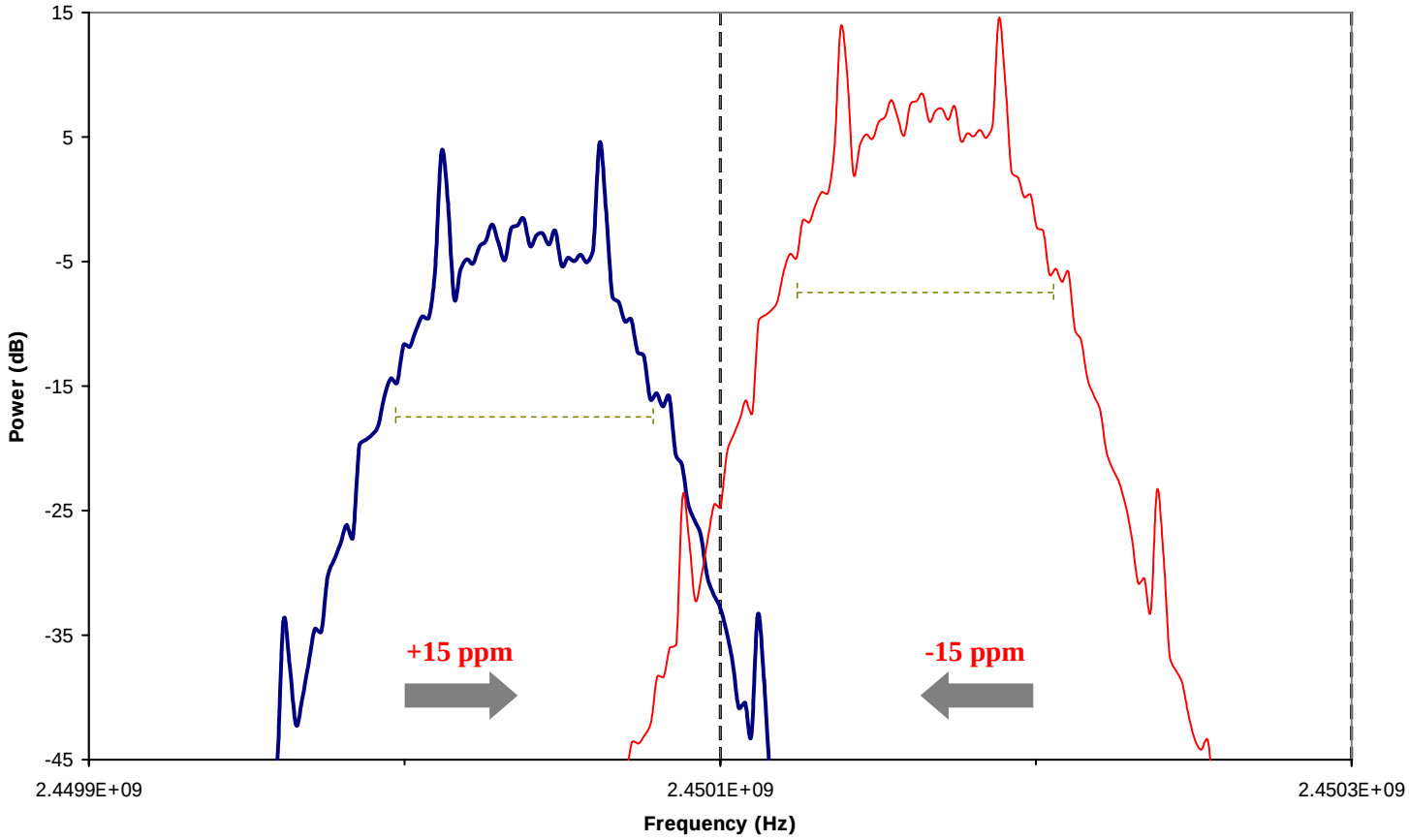
Filtered FSK Signals at 2450 MHz, ±15 ppm (1)

- Negligible interfering power leakage from adjacent channel at max frequency tolerance and worst case offset.



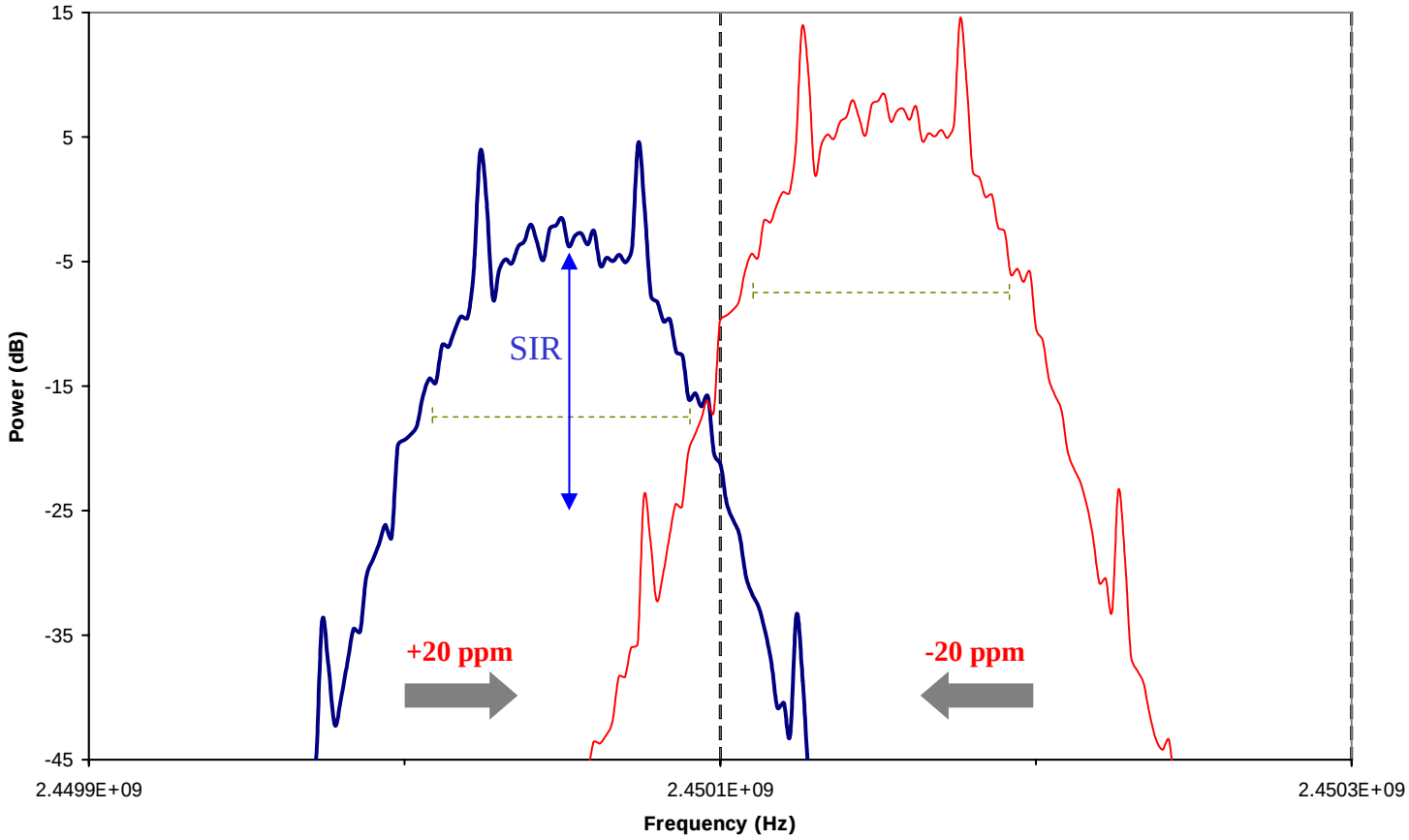
Filtered FSK Signals at 2450 MHz, ±15 ppm (2)

- ±15 ppm (max frequency tolerance)
- Worst case frequency offset
- All signal power contained within the channel
- Good conditions for signal demodulation



Filtered FSK Signals at 2450 MHz, ±20 ppm

- ±20 ppm (33% higher than currently specified)
- Worst case frequency offset
- Most of signal power (>99%) still contained within the channel
- Adequate conditions for signal demodulation



Discussion (1)

- The adjacent and alternate channel test using ‘an unmodulated carrier in the center of that channel’ is most likely too optimistic.
  The recommendation is to change the interfering signal in the adjacent channel to a modulated signal in order to achieve more realistic evaluation of the receiver performance.
  The MR-O-QPSK and MR-OFDM PHY options use modulated interferer.
- The existing channel scheme and clock frequency tolerance work well at the 2400-2483.5 MHz band.
  A clock tolerance of ±20 ppm seems feasible at the 2.4 GHz band without further changes.

Discussion (2)

- Receiver selectivity is important for overall system performance
- The adjacent channel and alternate channel rejection requirements of respectively +10 dB and +30 dB are at an appropriate level for the 802.15.4g MR-FSK channelization scheme

Proposed Comment Resolution

- **CID 186**
  Comment: “Channel spacing of 200 kHz for the 2400-2483.5 MHz band is not recommended (due to the relative high carrier frequency).”
  Proposed change: “Consider a channel spacing of 400 kHz.”

  Proposed resolution:
  AP: The currently defined channelization works well. No change required.

  Recommended improvement:
  In 6.12a.4.3 change the interfering signal in the adjacent and alternate channel to a modulated signal with the same characteristics as the wanted signal.

Thank you!