Transmit Center Frequency Tolerance for MR-FSK

Michael Schmidt - ATMEL

November 10, 2010

IEEE P802.15
Wireless Personal Area Networks

Title:	Transmit Center Frequency Tolerance for MR-FSK
Date Submitted:	November 10, 2010
Source:	Michael Schmidt - Atmel (email: michael.schmidt@atmel.com)
Re:	Task Group 15.4g LB59 comment resolution
Abstract:	Comment resolutions related to MR-FSK PHY
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Motivation

This document describes the proposed resolution of LB59 on some comments related to MR-FSK PHY regarding the transmit center frequency tolerance.
CIDs: #186 # 687

According to P802.15.4g/D2, MPM support (section 6.1a) and requirements on the single sided clock frequency tolerance *Tol* (section 6.12a.4) will impose the following requirements on a 4g device:

frequency band (MHz)	channel spacing (kHz)	h	f_s (kbit/s)	max. *Tol* (ppm)
470-510	200	1	50	≈ 50
863-870	200	1	50	≈ 30
902-928	200	1	50	≈ 30
950-958	200	1	50	≈ 30
2400-2483.5	200	1	50	≈ 15

- Binary FSK with modulation index $h = 1$ and symbol rate $f_s = 1/T$.

[1] John G. Proakis, Digital Communications, 3-rd edition.

- Binary FSK with modulation index $h = 1$ and symbol rate $f_s = 1/T$.
- The power spectral density is given by[1]

$$S_{xx}(f) = \frac{4T}{\pi^2}\left[\frac{\cos(\pi fT)}{1-(2fT)^2}\right]^2 + L_{\delta}^{\pm\frac{1}{2T}}(f)$$

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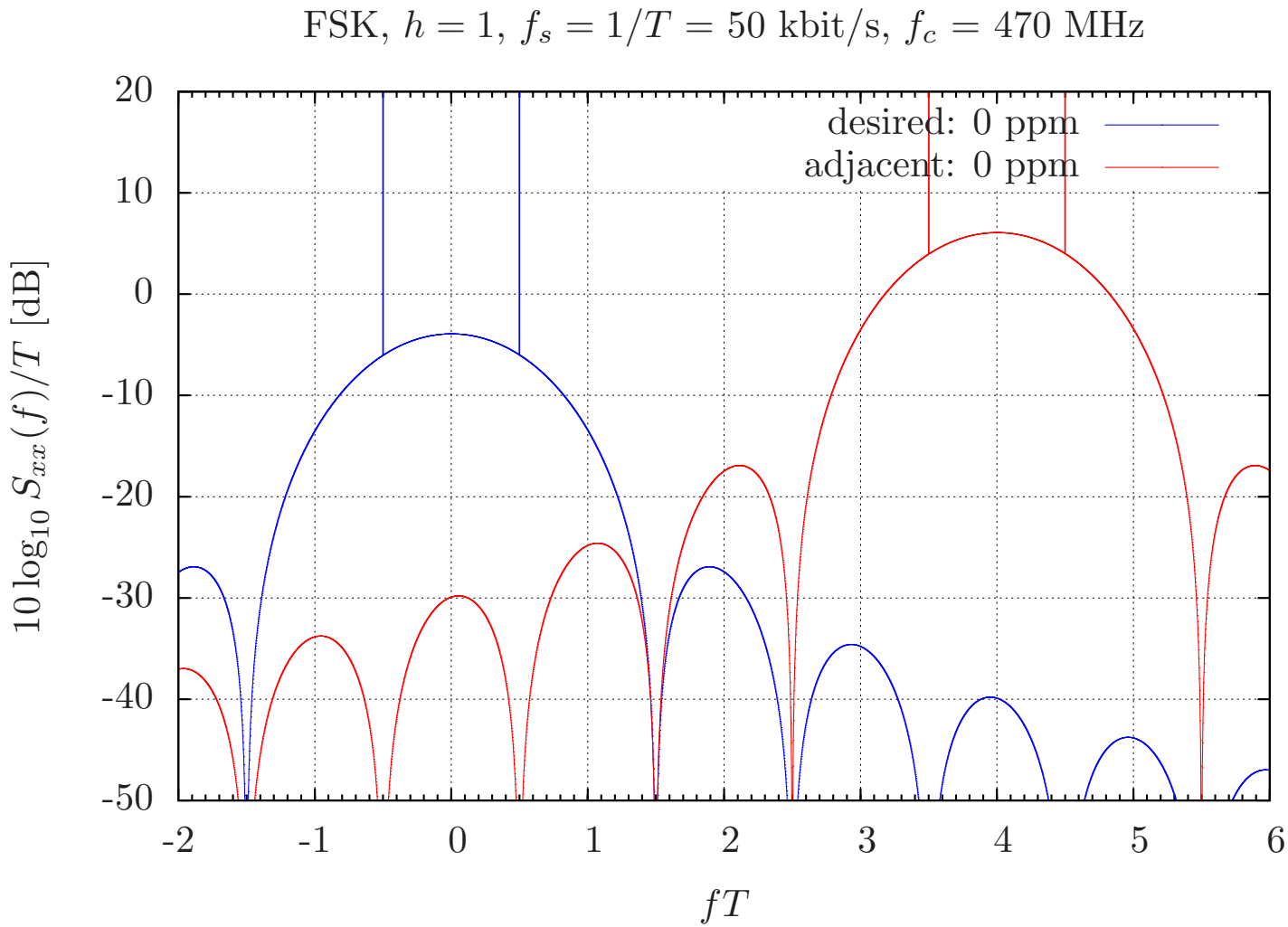
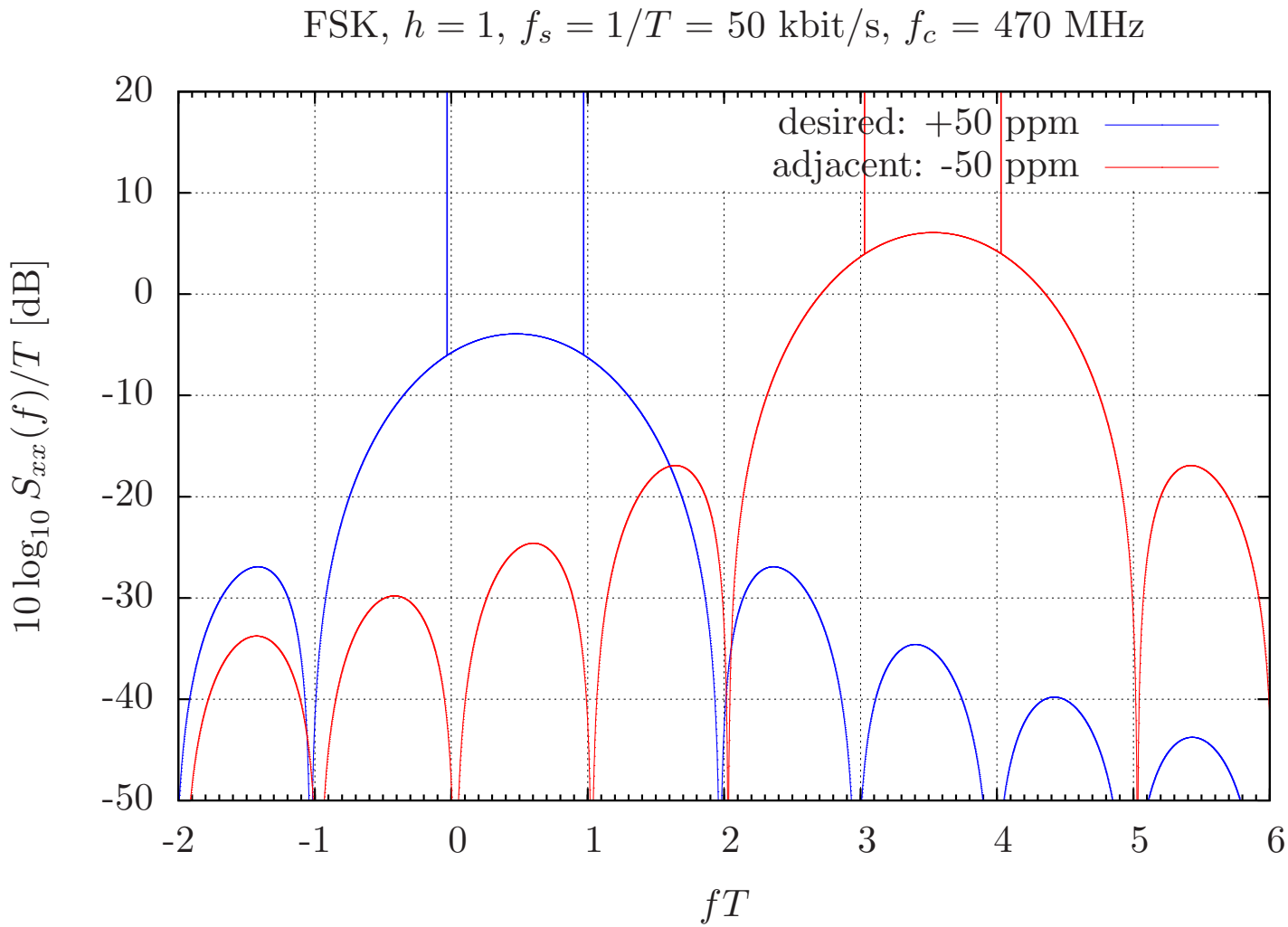
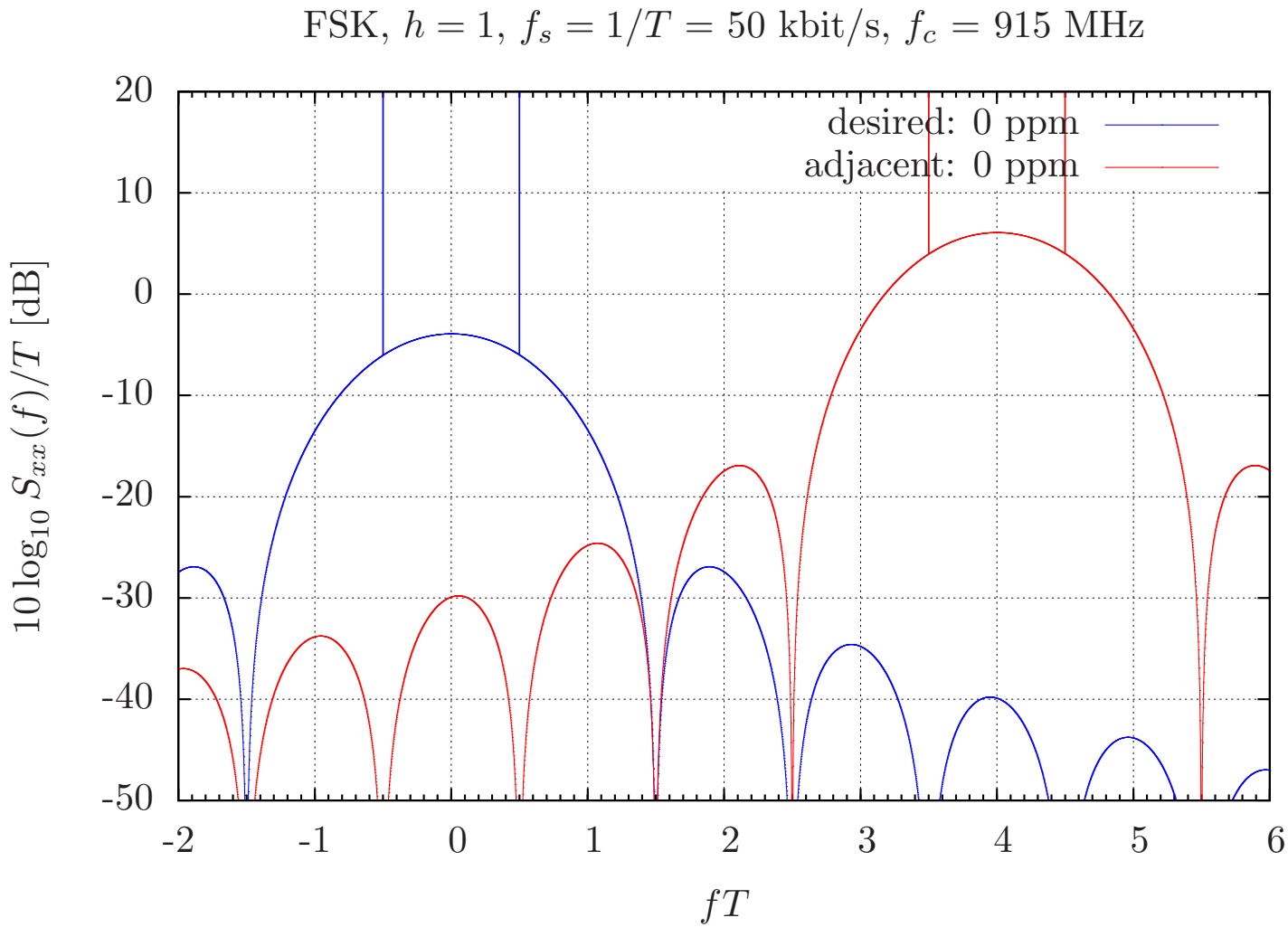
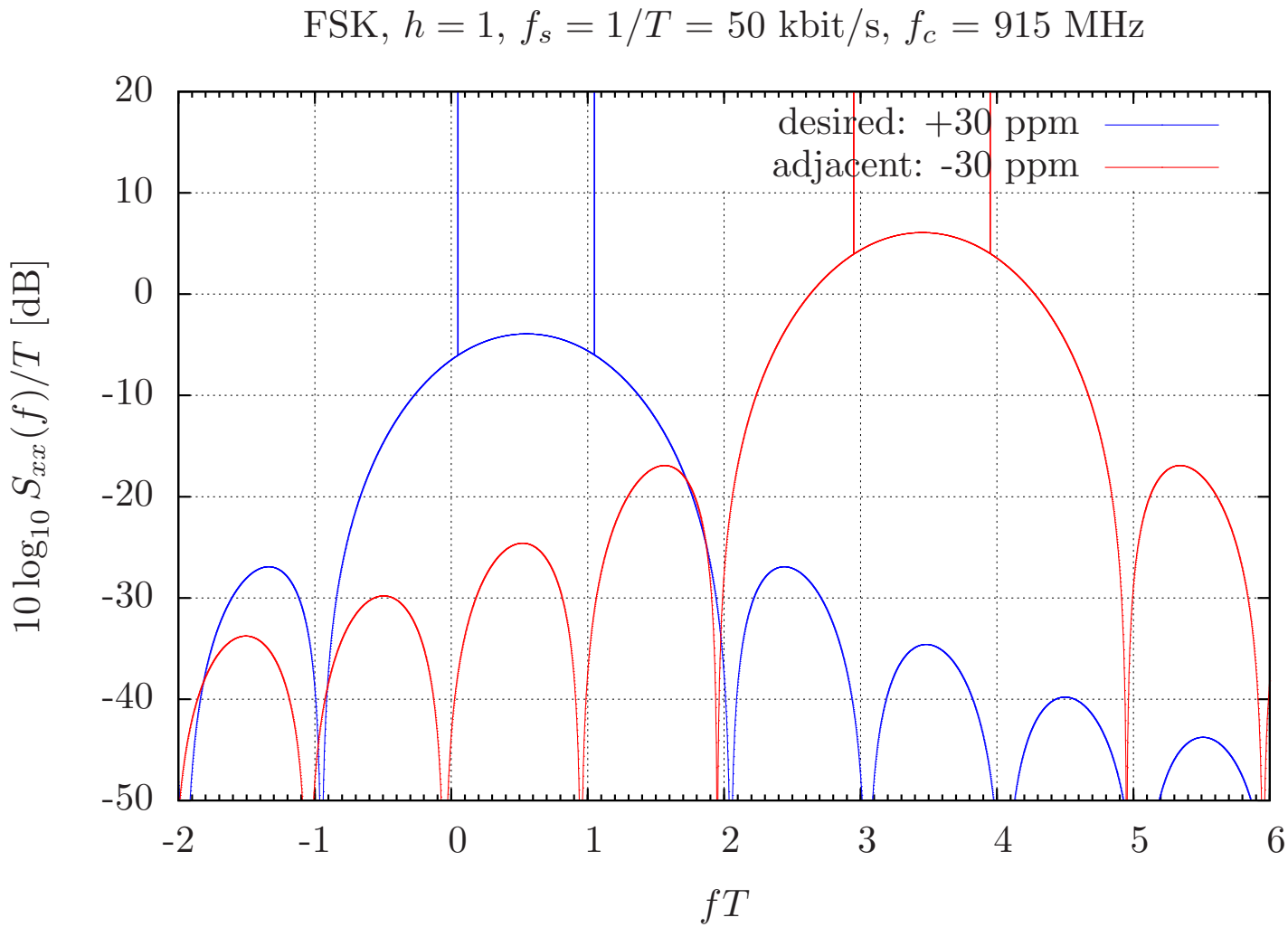
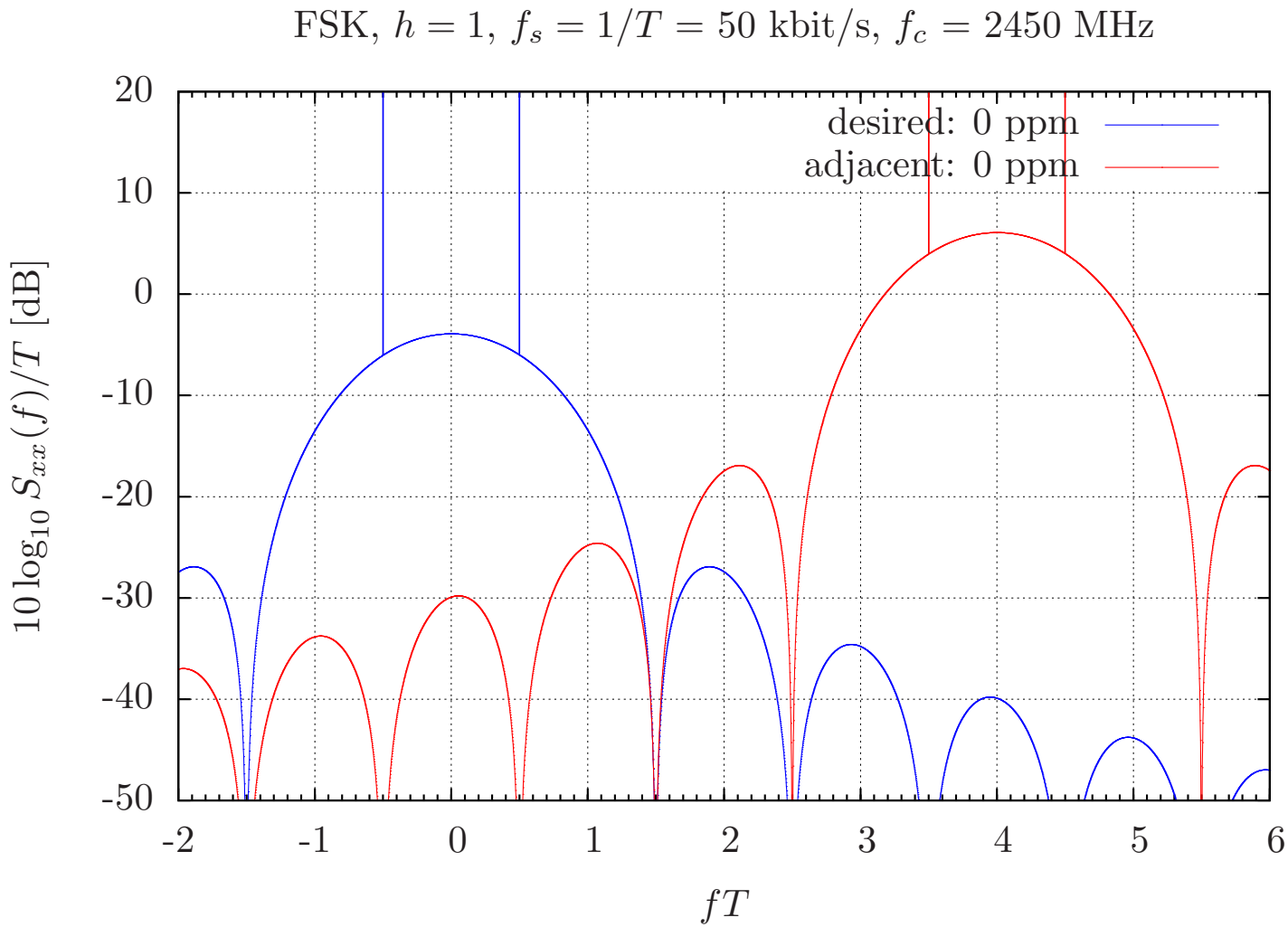
- The power of the adjacent channel is 10 dB above the desired channel.
- Let ϵ be the frequency tolerance in ppm.
- The desired channel is shifted $+\epsilon$ ppm w.r.t. the carrier frequency $f_c^{desired}$.
- The adjacent channel is shifted $-\epsilon$ ppm w.r.t. the carrier frequency $f_c^{adjacent}$.

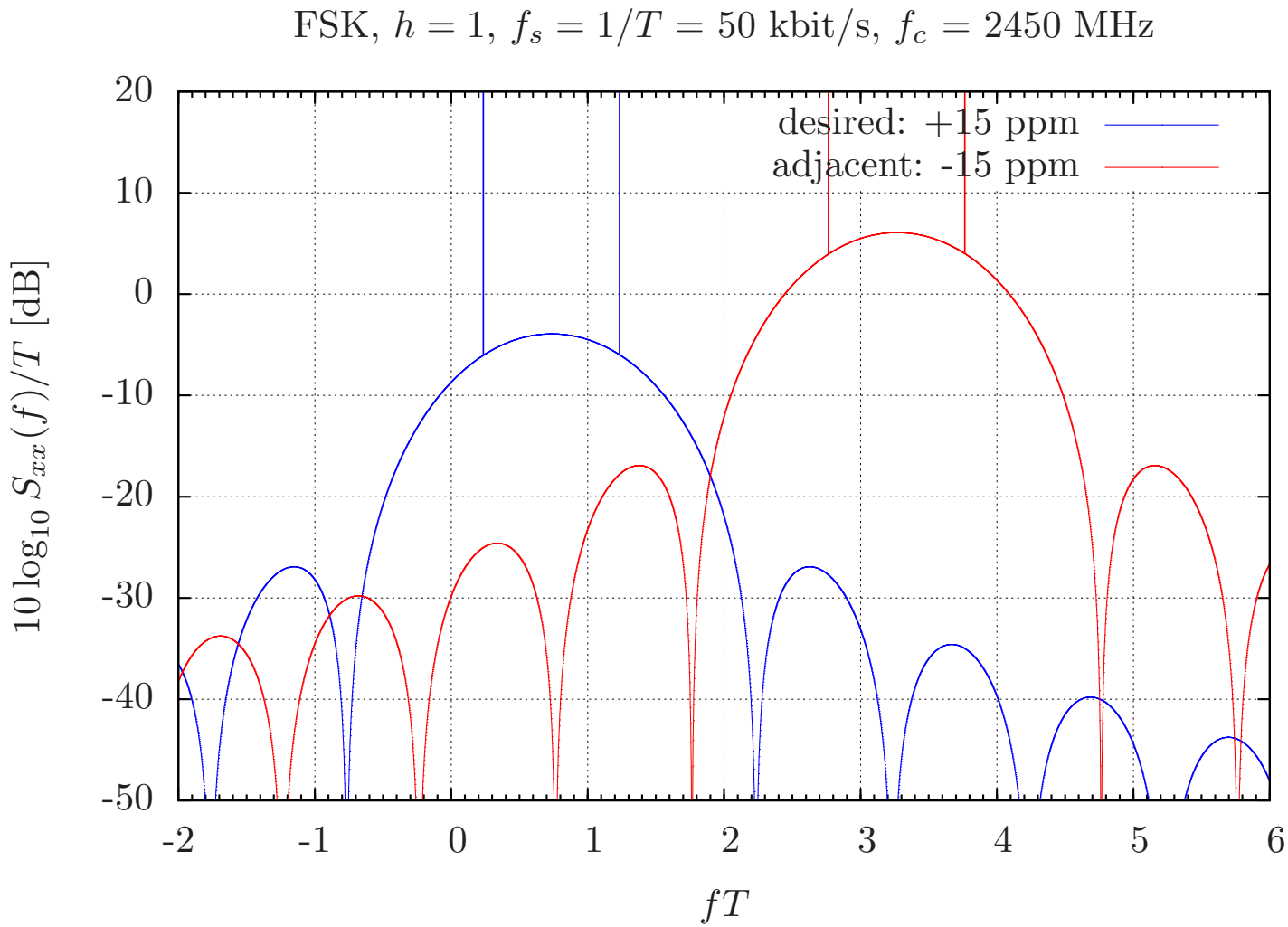

FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 470$ MHz
desired: 0 ppm
adjacent: 0 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT

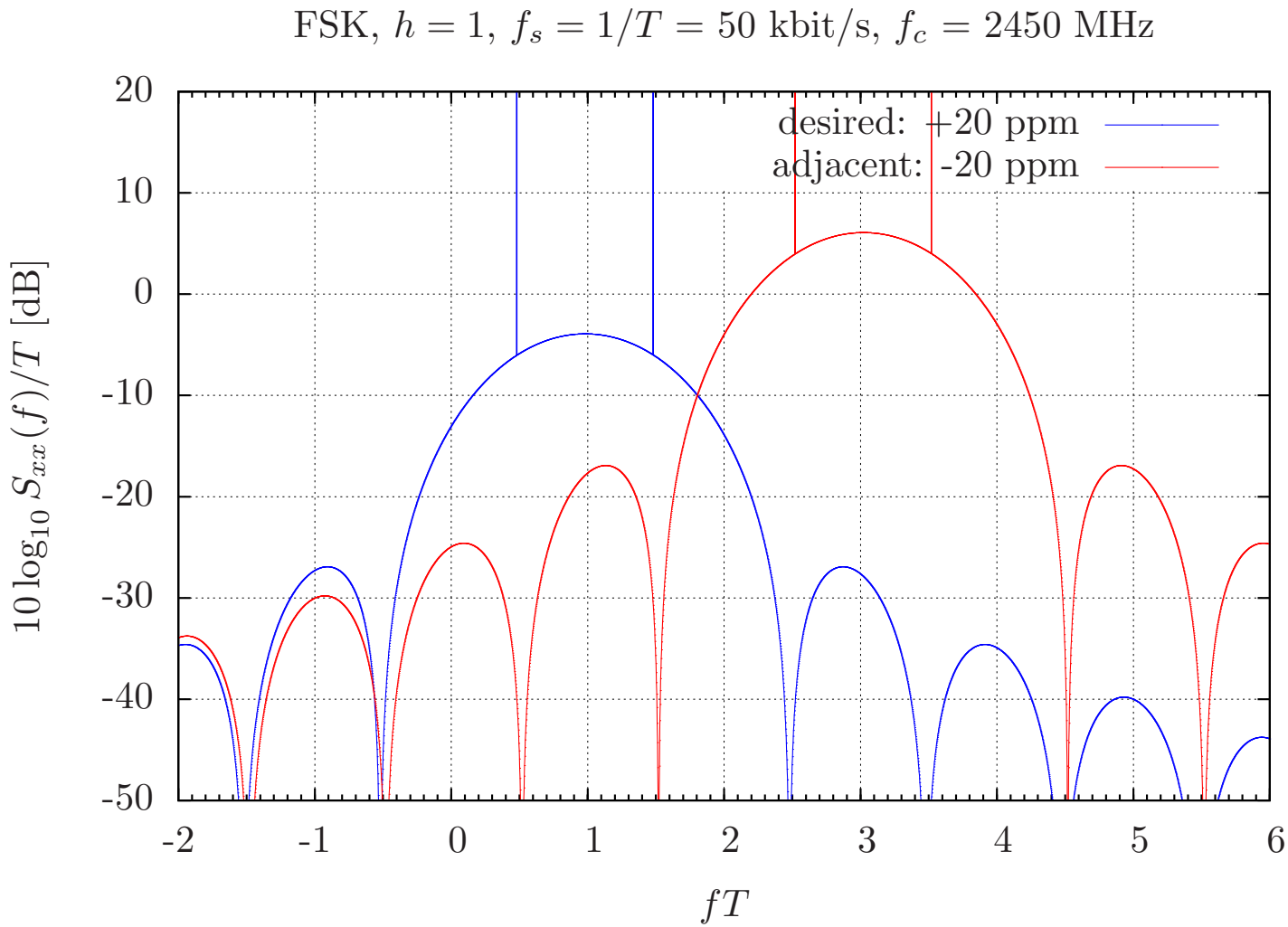

FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 470$ MHz
desired: +50 ppm
adjacent: -50 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
fT
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6

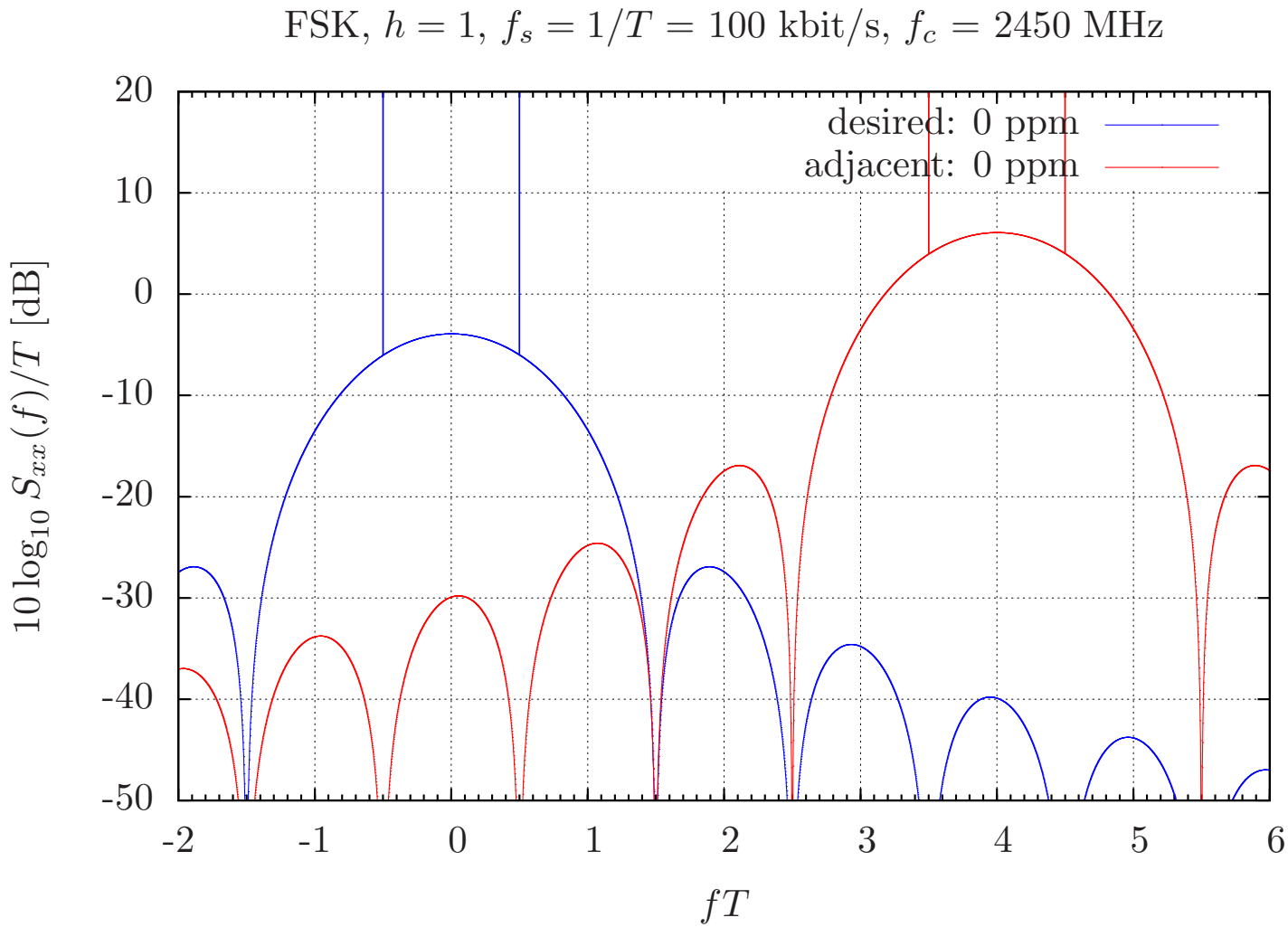

FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 915$ MHz
desired: 0 ppm
adjacent: 0 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT

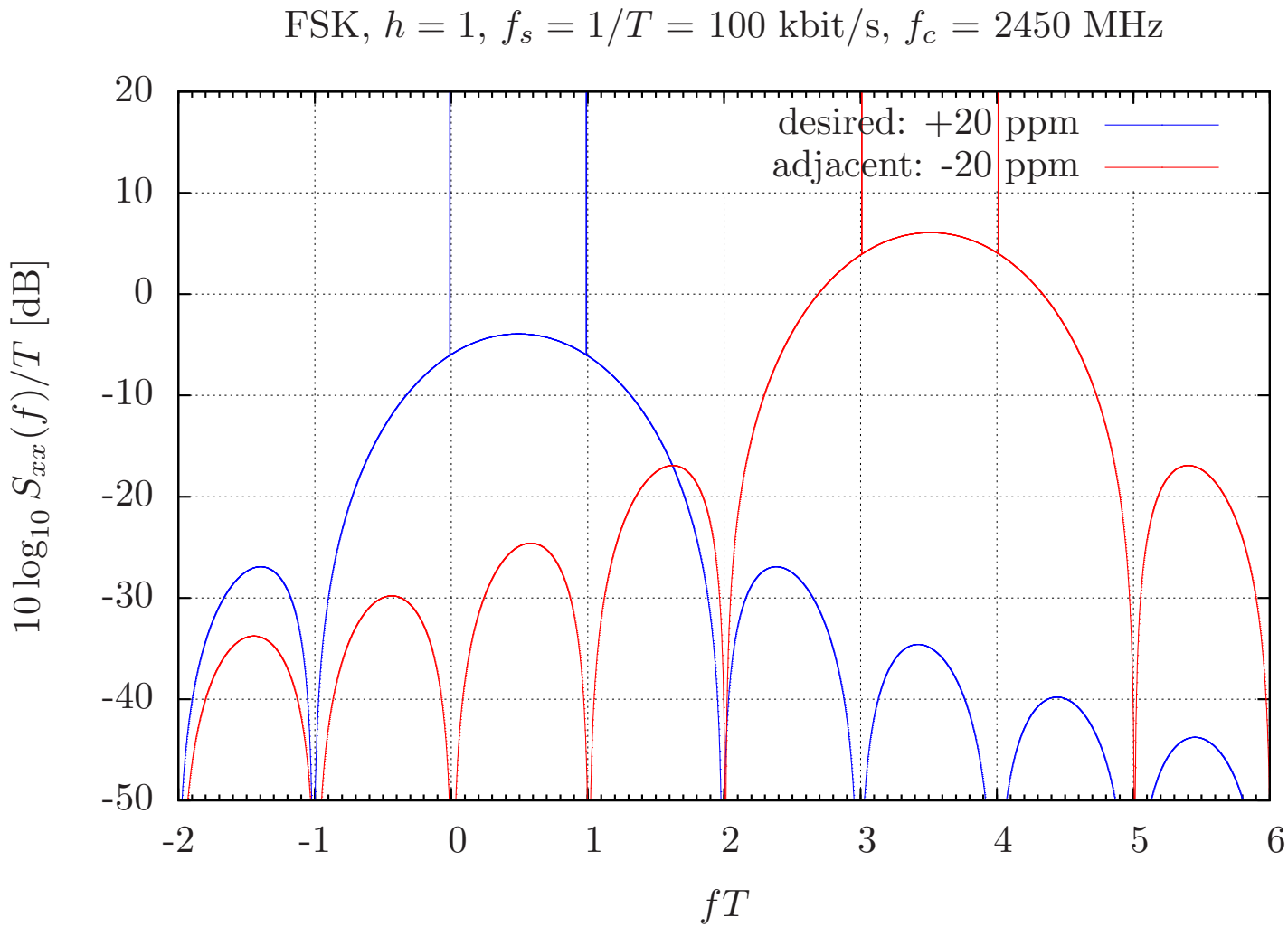

FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 915$ MHz
desired: +30 ppm
adjacent: -30 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT


FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 2450$ MHz
desired: 0 ppm
adjacent: 0 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT


FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 2450$ MHz
desired: +15 ppm
adjacent: -15 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT


FSK, $h = 1$, $f_s = 1/T = 50$ kbit/s, $f_c = 2450$ MHz
desired: +20 ppm
adjacent: -20 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT


FSK, $h = 1$, $f_s = 1/T = 100$ kbit/s, $f_c = 2450$ MHz
desired: 0 ppm
adjacent: 0 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT


FSK, $h = 1$, $f_s = 1/T = 100$ kbit/s, $f_c = 2450$ MHz
desired: +20 ppm
adjacent: -20 ppm
$10 \log_{10} S_{xx}(f)/T$ [dB]
20
10
0
-10
-20
-30
-40
-50
-2
-1
0
1
2
3
4
5
6
fT

- At the 2400-2483.5 MHz band, the transmit center frequency tolerance is ± 15 ppm maximum for the mandatory mode (FSK, $f_s = 50$ kbit/s, $h = 1$).

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- This does not harmonize with the specification of the MR-OFDM and MR-O-QPSK PHY (both PHYs tolerate up to ± 20 ppm).

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- This does not harmonize with the specification of the MR-OFDM and MR-O-QPSK PHY (both PHYs tolerate up to ± 20 ppm).
- Compared to the tolerance of ± 40 ppm (IEEE-802.15.4-2006), even the required ± 20 ppm will add noticeable costs for test, calibration and board design.

- At the 2400-2483.5 MHz band, the transmit center frequency tolerance is ± 15 ppm maximum for the mandatory mode (FSK, $f_s = 50$ kbit/s, $h = 1$).
- This does not harmonize with the specification of the MR-OFDM and MR-O-QPSK PHY (both PHYs tolerate up to ± 20 ppm).
- Compared to the tolerance of ± 40 ppm (IEEE-802.15.4-2006), even the required ± 20 ppm will add noticeable costs for test, calibration and board design.
- Hence, care should be taken with regard to the transmit center frequency tolerance.

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  - The requirements on the spectral mask are quite relaxed.
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  - There is no coding gain for the mandatory modes.
  - There influence due to clock frequency tolerance is quite substantial.

- The MR-FSK PHY mandates at least 10 dB adjacent channel rejection.
- However:
  - The requirements on the spectral mask are quite relaxed.
  - There is no processing gain.
  - There is no coding gain for the mandatory modes.
  - There influence due to clock frequency tolerance is quite substantial.
- Though the specification are consistent with regard to the receiver jamming resistance (see section 6.12a.4.3, assuming an unmodulated carrier at a fixed offset), there will be moderate adjacent channel rejection in practical applications at 2400-2483.5 MHz.

Recommendation #1 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to $\pm$20 ppm.

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- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).

Recommendation #1 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 100 kbit/s

Recommendation #1 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 100 kbit/s
- Proposed change:

Recommendation #1 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 100 kbit/s
- Proposed change:

frequency band (MHz)	channel spacing (kHz)	h	f_s (kbit/s)	max. Tol (ppm)
2400-2483.5	~~200~~ $\rightarrow$ 400	1	~~50~~ $\rightarrow$ 100	~~$\approx$ 15~~ $\rightarrow\approx$ 20

Recommendation #2 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.

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- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).

Recommendation #2 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 150 kbit/s

Recommendation #2 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 150 kbit/s
- Consider a reduced modulation index of $h = 0.5$

Recommendation #2 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 150 kbit/s
- Consider a reduced modulation index of $h = 0.5$
- Proposed change:

Recommendation #2 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Consider a higher symbol rate of 150 kbit/s
- Consider a reduced modulation index of $h = 0.5$
- Proposed change:

frequency band (MHz)	channel spacing (kHz)	h	f_s (kbit/s)	max. Tol (ppm)
2400-2483.5	~~200~~ $\rightarrow$ 400	0.5	~~50~~ $\rightarrow$ 150	~~$\approx$ 15~~ $\rightarrow\approx$ 20

Recommendation #3 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to $\pm$20 ppm.

Recommendation #3 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).

Recommendation #3 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Keep symbol rate at 50 kbit/s

Recommendation #3 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Keep symbol rate at 50 kbit/s
- Proposed change:

Recommendation #3 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.
- Consider a channel spacing of 400 kHz (still supporting ≥ 75 hopping channels).
- Keep symbol rate at 50 kbit/s
- Proposed change:

frequency band (MHz)	channel spacing (kHz)	h	f_s (kbit/s)	max. Tol (ppm)
2400-2483.5	~~200~~ $\rightarrow$ 400	1	50	~~$\approx$ 15~~ $\rightarrow\approx$ 20

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ± 20 ppm.

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to $\pm$20 ppm.
- Keep channel spacing at 200 kHz

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to $\pm$20 ppm.
- Keep channel spacing at 200 kHz
- Keep symbol rate at 50 kbit/s

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to $\pm$20 ppm.
- Keep channel spacing at 200 kHz
- Keep symbol rate at 50 kbit/s
- reduce ACR requirement from 10 dB to 0 dB

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to $\pm$20 ppm.
- Keep channel spacing at 200 kHz
- Keep symbol rate at 50 kbit/s
- reduce ACR requirement from 10 dB to 0 dB
- reduce AACR requirement from 30 dB to 20 dB

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ±20 ppm.
- Keep channel spacing at 200 kHz
- Keep symbol rate at 50 kbit/s
- reduce ACR requirement from 10 dB to 0 dB
- reduce AACR requirement from 30 dB to 20 dB
- Proposed change:

Recommendation #4 for 2400-2483.5 MHz

- Harmonize clock frequency tolerance to ±20 ppm.
- Keep channel spacing at 200 kHz
- Keep symbol rate at 50 kbit/s
- reduce ACR requirement from 10 dB to 0 dB
- reduce AACR requirement from 30 dB to 20 dB
- Proposed change:

frequency band (MHz)	channel spacing (kHz)	h	f_s (kbit/s)	max. *Tol* (ppm)
2400-2483.5	200	1	50	~~≈ 15~~ $\rightarrow \approx 20$