Wireless M-Bus Implementation with CC112x / CC120x High Performance Transceiver Family

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Keywords

- *Wireless M-Bus (868, 433, 169 MHz)*
- *Meter reading*
- *Data rate offset and drift*
- *Frequency offset and drift*
- *MSP430*
- *ETSI 300 220 v2.3.1 compliance*
- *wM-Bus N-mode full compliance*
- *CC1120, CC1121, CC1125, CC1175, CC1200*

1 Introduction

This application note describes how the CC112x and CC120x high performance line transceivers, when used together with the ultra-low power MSP430 microcontrollers, implement a fully compliant Wireless M-Bus (wM-Bus) sub-system.

The EN13757-4:2012 draft is a European communication standard for wireless readout of meters and defines the physical and the data link layers. The CC112x and CC120x have market leading sensitivity and blocking performance and combined with the ability to comply with frequency offset and data rate variations, as defined in S- and T-mode, they are a perfect fit for metering and sub-metering high-volume wM-Bus applications.

The Na/b/c/d/e/f modes define 16-bit preamble length. The WaveMatch(tm) feature allows packet reception with preamble length of only 4 bits. Thus CC112x family is a fully N-mode compliant transceiver for 169 MHz wM-Bus systems such as smart gas or water meters.

Various MSP430 devices are capable of running the TI wM-Bus stack, including the latest addition of the Wolverine family – TI's ULP FRAM-based MSP430 micro-controllers.

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2 Abbreviations

BER	Bit Error Rate
CRC16	Cyclic Redundancy Check of 16 bits, is commonly used in wM-Bus
DUT	Device Under Test
EM	Evaluation module
(G)FSK	(Gaussian) Frequency Shift Keying
IF	Intermediate Frequency
ISM	Industrial, Scientific, Medical
kcps	Chip rate, kchips/second
LNA	Low Noise Amplifier
MCU	Micro Controller Unit
NRZ	Non Return to Zero
PA	Power Amplifier
PER	Packet Error Rate
RX	Receive
SRD	Short Range Device
TX	Transmit
wM-Bus	Wireless Metering Bus (see EN13757-4 and -3 documents)

3 Summary of CC1120 wM-Bus Compliance

Mode	Parameter	RX Sensitivity at PER=80% with 20 Bytes Payload (per EN13757-4)	Comment
S1,S2	Sensitivity	–109 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets all Corners	
T1, T2	Sensitivity	–105.6 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets all Corners	
R2	Sensitivity	–114.5 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets all Corners	
C1, C2	Sensitivity	-105.3 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets All Corners	
N(1,2)a/b/e/f	Sensitivity	-119.7 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets All Corners	
N(1,2)c/d	Sensitivity	–121.1 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets all Corners	
Ng	Sensitivity	–114.3 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr (16-bits preamble as in N-mode is fully supported)
	Frequency offset, data rate and deviation worst case	Meets all Corners	
F	Sensitivity	–119.5 dBm	Meets EN13757-4:2012 specification definition. Fulfills highest class receiver Hr
	Frequency offset, data rate and deviation worst case	Meets all corners	

Table 1. CC1120 wM-Bus Performance Summary

4 Wireless M-Bus

The wireless M-Bus standard specifies the communication between a *meter and an "other"* system component, e.g. mobile/stationary readout devices or data collectors, see Figure 1.

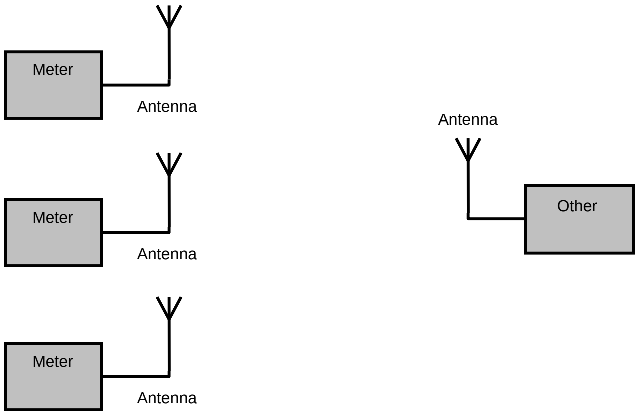

Figure 1. Wireless M-Bus Communication System

Three original PHY Layer modes from 2005 were defined in [1] for the communication between a meter and an "*other*":

- S-Mode, Stationary Mode
  - S1-Mode, one-way communication from *meter* to *"other"*
  - S1m-Mode, one-way communication from *meter* to *"other"*
  - S2-Mode, two-way communication between *meter* and *"other"*
- T-Mode, Frequent Transmit Mode
  - T1-Mode, one-way communication from *meter* to *"other"*
  - T2-Mode, two-way communication between *meter* and *"other"*
- R-Mode, Frequent Receive Mode
  - R2-Mode, two-way communication between *meter* and *"other"*

The three new modes, introduced in 2011, are also supported by CC112x performance line:

- N-Mode, Stationary Mode
  - N1-Mode, one-way communication from *meter* to *"other"*
  - N2-Mode, two-way communication from *meter* to *"other"*
  - N2g-Mode, two-way communication between *meter* and *"other"*
- C-Mode, Frequent Transmit Mode
  - C1-Mode, one-way communication from *meter* to *"other"*
  - C2-Mode, two-way communication between *meter* and *"other"*
- F-Mode, Frequent Transmit Mode
  - F1-Mode, one-way communication from *meter* to *"other"*
  - F2-Mode, two-way communication between *meter* and *"other"*

In addition, two more modes, named P and Q, were defined in the EN13757-5:2008 standard, with the goal to support the implementation of wM-Bus Repeaters. Both P and Q modes are defined for the 868MHz ISM band and are fully supported by the CC112x family. In this document P and Q modes are not reviewed due to their limited use in real world applications so far.

4.1 Wireless M-Bus Physical Layer

This document will address the most popular wM-Bus modes: S, T, C, R, N and F. Table 2 shows the mapping between the different wireless M-Bus modes and the different SRD bands used.

Mode	SRD Band
S1, S2-Mode	868 MHz
T1, T2-Mode	868 MHz
C1, C2-Mode	868 MHz
R2-Mode	868 MHz
N1, N2-Mode	169 MHz
F1, F2-Mode	433 MHz

Table 2. Most Popular wM-Bus Modes

Since the Wireless M-Bus standard operates in the 868-870 MHz, 433 MHz or 169 MHz ISM bands, the radio requirements must also comply with the ETSI EN 300 220 [2] and CEPT/ERC/REC 70-03 E [3] standards.

Using the TI wM-Bus Stack on a MSP430 [5] a fully compliant solution, including the OMS profile v3.0.1 for Germany and NTA8130 for Netherlands, is available today. This application note will focus on the RF parameters and wM-Bus compliance of CC1120 high performance line transceiver devices.

Three different performance classes for RX sensitivity performance are defined in the Wireless M-Bus standard for each mode. The CC112x devices fulfill the highest performance class Hr for each of the described modes (S, T, C, R, N and F).

5 Measurement Setup

For the sensitivity measurements an RF generator, capable of generating a given telegram or data packet, is used to apply an RF signal with known signal strength.

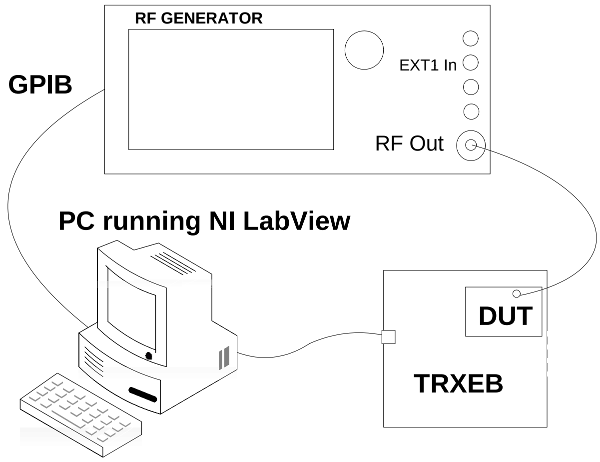

Figure 2. RF Generator and DUT (CC1120EM) Setup for Sensitivity

For the selectivity and blocking measurements an RF generator, capable of generating a given telegram or data packet, is used to apply a RF signal with known signal strength. In addition a second signal generator is used as an interferer at a given frequency with programmable level. The two RF signals are applied to the DUT using an RF combiner.

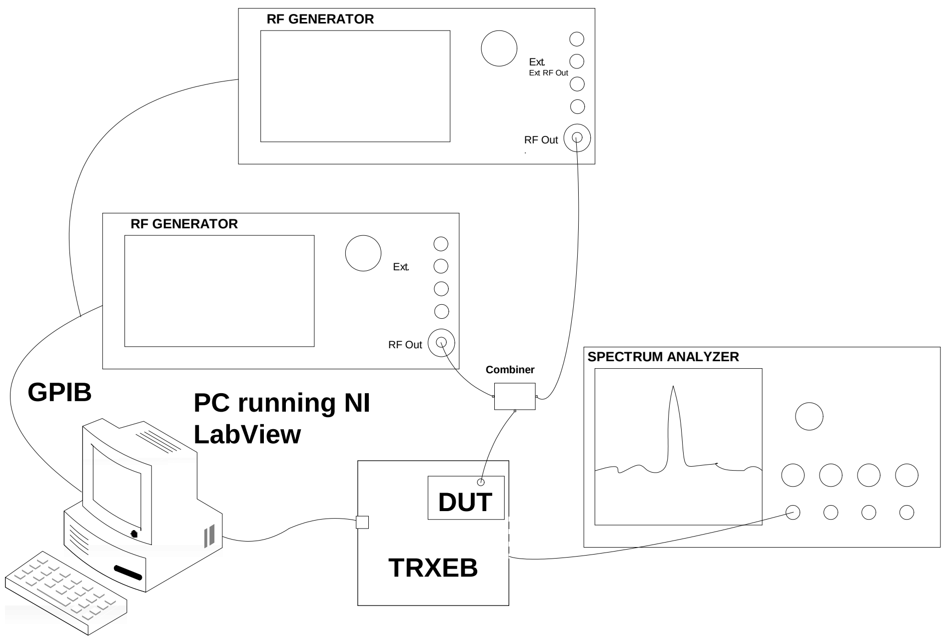

Figure 3. Two RF Generator and DUT (CC1120EM) Setup for Blocking and Selectivity

- For each wM-Bus mode, 6 different CC1120EM boards are tested at room temperature (25^{o}C) and 3V supply. For T-mode 250 kHz RX BW is required to handle the 12% data rate tolerance hence CC1125EMs with 40 MHz XTAL are tested.
- The system is calibrated to account for the cable loss between generator(s) and DUT.
- The frequency offset between DUT and RF generator is compensated for.
- Sensitivity / Packet Error Rate (PER) is tested according to EN13757-4:2012 draft: 80% PER with 20 bytes payload; and additionally for 20% PER with 8 bytes payload and 1% PER with 8 bytes payload.
- The CC1120EM board (TI reference design) uses a single antenna 50 ohm SMA connector – also known as combined TX and RX design. The sensitivity (PER) is measured with a combined match at the single antenna port (SMA connector) - see Figure 4.

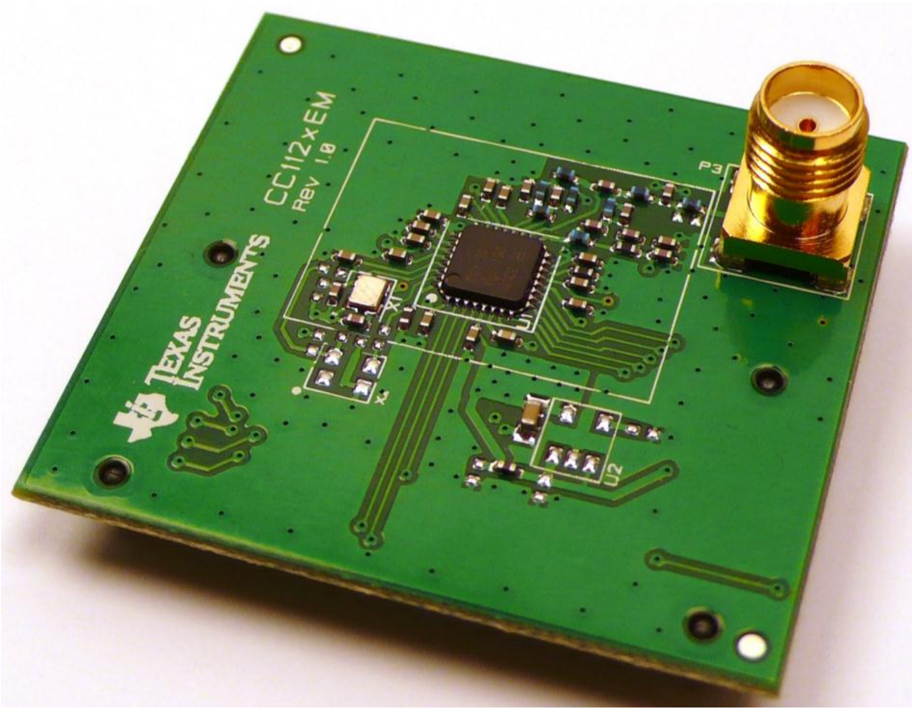

Figure 4. CC1120EM

6 S-Mode Measurement Results

Table 3 gives the test conditions used (see also S-mode definition in Appendix [16]):

Parameter	
TX/RX Centre Frequency [MHz]	868.3
Modulation	2-FSK
Frequency Deviation [kHz]	±50
Chip rate [kcps]	32.768
RX Filter Bandwidth [kHz]	200

Table 3. S-mode Test Conditions

Packet format: preamble (n=15) x (01) + sync word “000111011010010110” + P byte payload + CRC16; with n ≥ 15 for the sub-mode S2 (short header)

6.1 S-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
868.3	-109	80	20
	-108.2	20	8
	-106.8	1	8

Table 4. S-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

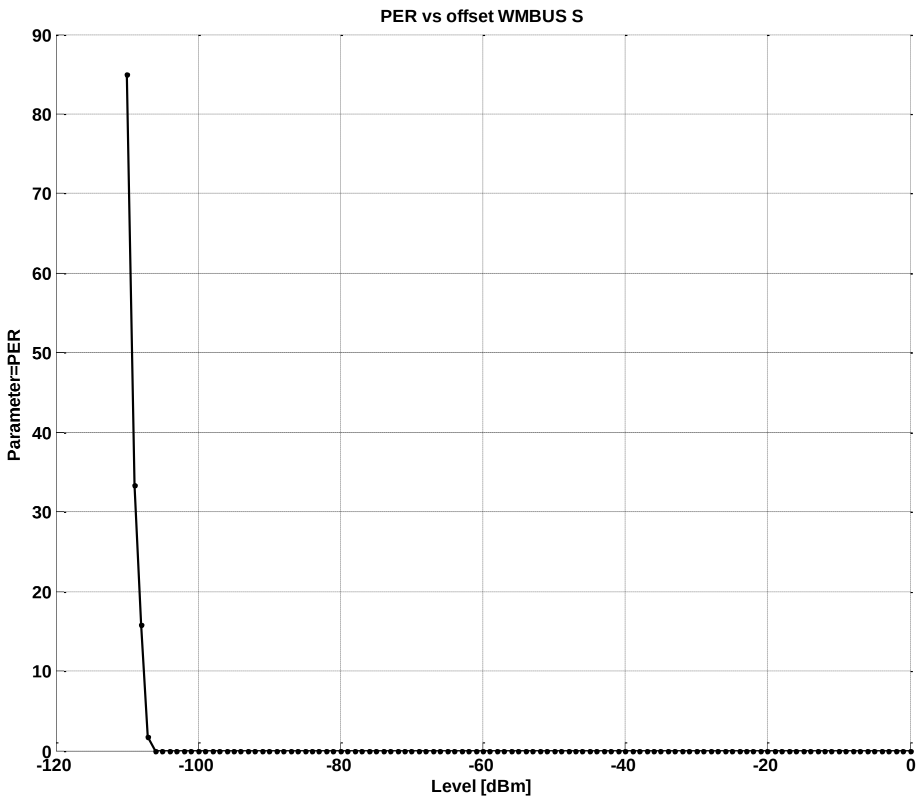

Figure 5. S-mode PER vs Input Power Level

6.2 S-mode RX Sensitivity vs Frequency Offset

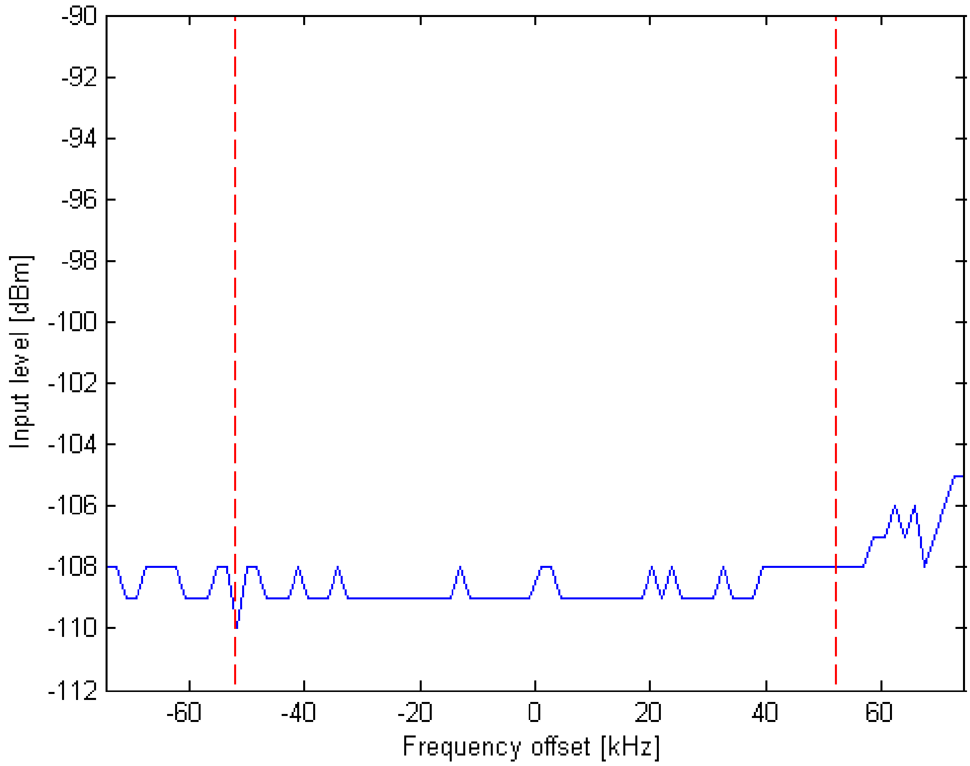

Figure 6. S-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 6 show the EN13757-4:2012 Draft limits for frequency offset.

6.3 S-mode RX Sensitivity vs Frequency Deviation

S-mode allows the frequency deviation parameter to vary from ±40 kHz to ±80 kHz, where ±50 kHz is the nominal value. Table 5 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
868.3	-105.4	40
	-108.2	50 (nominal)
	-107.8	80

Table 5. S-mode Typical 20% PER Sensitivity

6.4 S-mode RX Sensitivity vs Data Rate Offset

S-mode allows the chip rate to vary up to ±2% during one packet frame. Table 6 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Chip Rate [kcps]
868.3	-108.3	32.1
	-108.2	32.768 (nominal)
	-108.3	33.4

Table 6. S-mode Typical 20% PER Sensitivity for 8 Bytes Payload

6.5 S-mode Blocking Performance

S-mode blocking performance is shown in Figure 7.

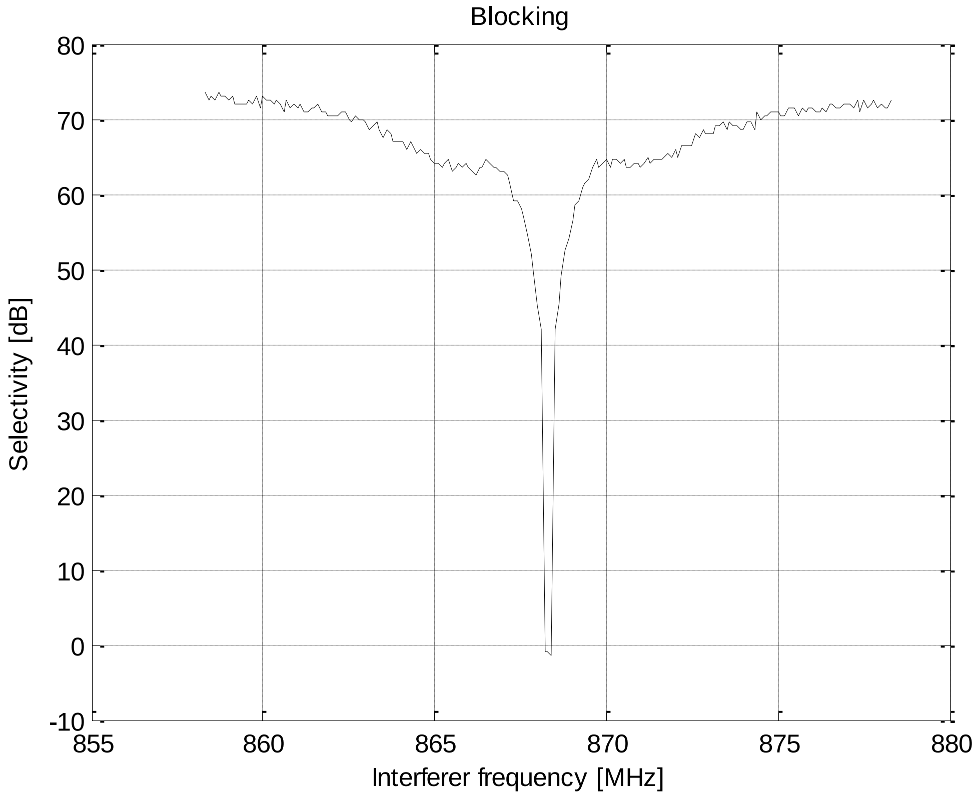

Figure 7. S-mode Blocking Performance

6.6 S-mode Performance Summary

- CC1120 achieves -109 dBm RX sensitivity in wM-Bus S-mode, which is 9 dB better than S-mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus S-mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 supports the Manchester encoding (TX) and decoding (RX) of the payload data in HW inside the Packet Engine – this saves code size and complexity for the data packet handling code in the MCU.

- CC1120 supports meets the ETSI Category 2 blocking requirements.

- CC1120 complies with the S-mode highest receiver performance class.

7 T-mode Measurement Results

Table 3 gives the test conditions used (see also T-mode definition in Appendix [17]):

Parameter	
TX/RX Centre Frequency [MHz]	868.95
Modulation	2-FSK
Frequency Deviation [kHz]	±50
Chip rate [kcps]	100
RX Filter Bandwidth [kHz]	250

Packet format: preamble (n=19) x (01) + sync word “00001111001” + P byte payload + CRC

7.1 T-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
868.95	-105.6	80	20
	-103.8	20	8
	-101.8	1	8

Table 7. T-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1125 chip pin).

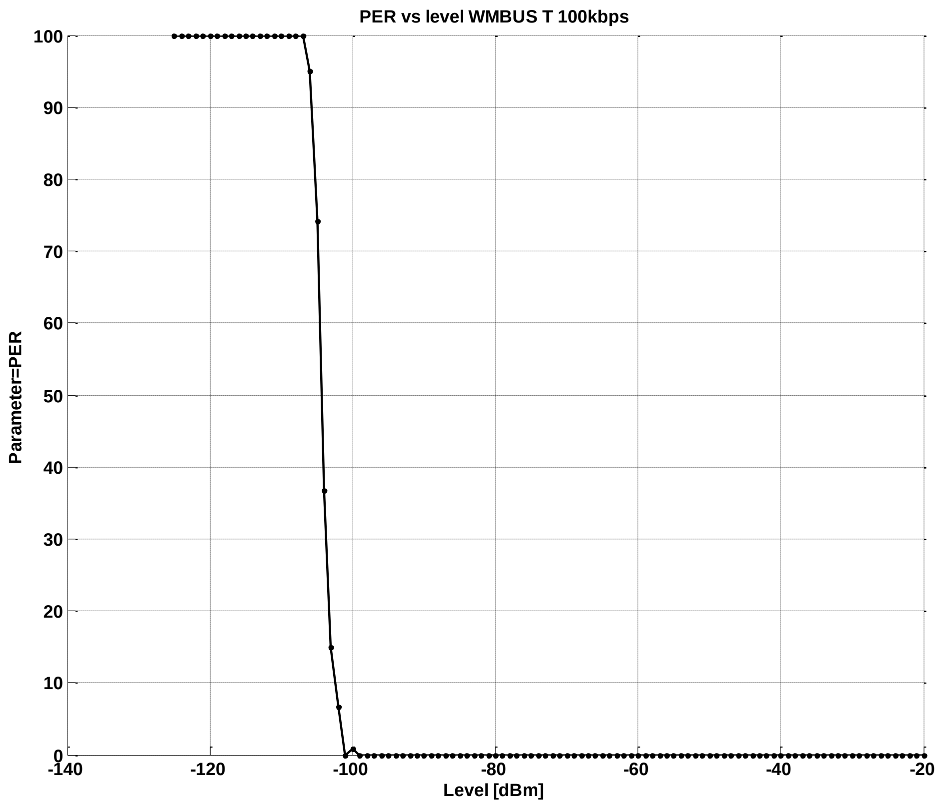

Figure 8. T-mode PER vs Input Power Level

7.2 T-mode RX Sensitivity vs Frequency Offset

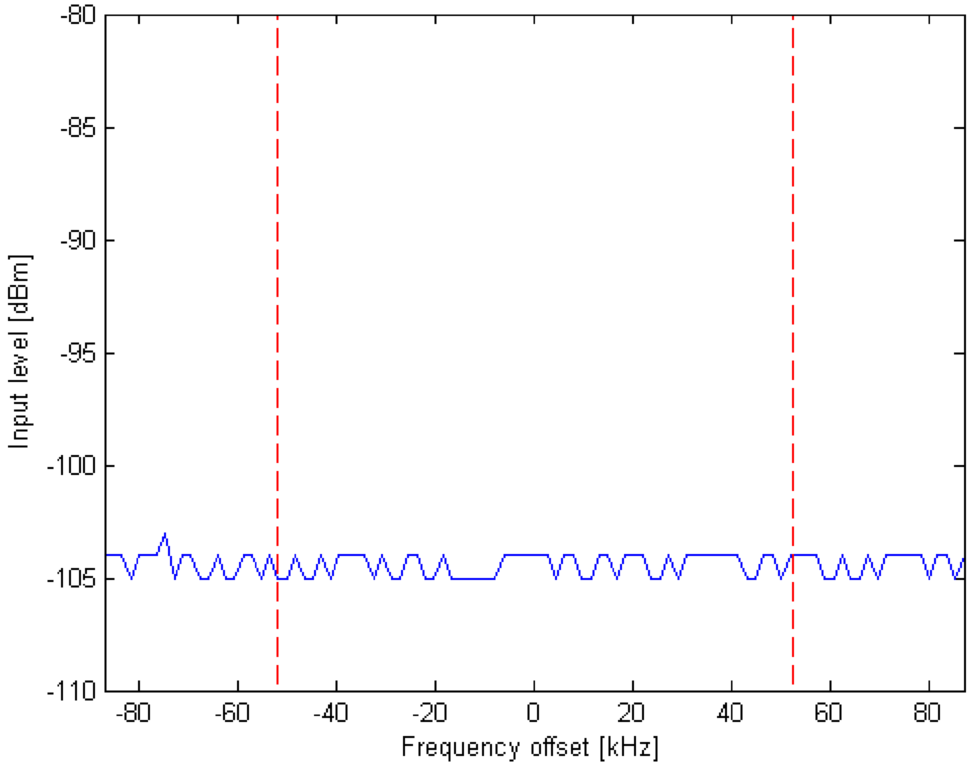

Figure 9. T-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 9 show the EN13757-4:2012 Draft limits for frequency offset.

7.3 T-mode RX Sensitivity vs Frequency Deviation

T-mode allows the frequency deviation parameter to vary from ±40 kHz to ±80 kHz, where ±50 kHz is the nominal value. Table 8 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
868.95	-102.3	40
	-103.8	50 (nominal)
	-103.8	80

Table 8. T-mode Typical 20% PER Sensitivity

7.4 T-mode RX Sensitivity vs Data Rate Offset

T-mode allows the chip rate to vary up to ±12% during the one packet frame. Table 9 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Chip Rate [kcps]
868.95	-103.9	88
	-103.8	100 (nominal)
	-102.9	112

Table 9. T-mode Typical 20% PER Sensitivity for 8 Bytes Payload

7.5 T-mode Blocking Performance

T-mode blocking performance is shown in Figure 10.

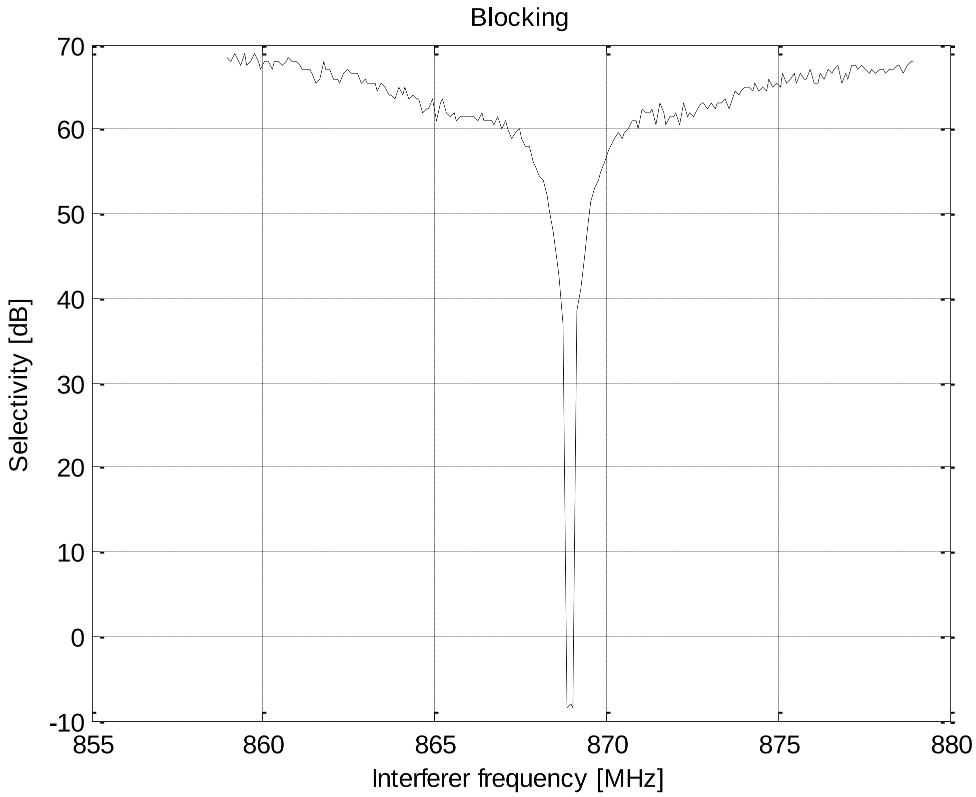

Figure 10. T-mode Blocking Performance

7.6 T-mode Performance Summary

- CC1125 achieves -105.6 dBm RX sensitivity in wM-Bus T-mode, which is 5.6 dB better than T-mode requirements in wM-Bus standard [1].

- CC1125 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus T-mode telegrams can be received or transmitted using the CC1125 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions, e.g. from 88 kbps to 112 kbps and from +-40 kHz to +-80 kHz deviation.

- CC1125 does not support 3-of-6 encoding (TX) and decoding (RX) in HW - this can be handled by look-up tables in the data packet processing code in the MCU.

- CC1125 meets the ETSI Category 2 blocking requirements.

- CC1125 complies with the T-mode highest receiver performance class.

8 R-mode Measurement Results

Table 10 gives the test conditions used (see also R-mode definition in Appendix [19]):

Parameter	
TX/RX Centre Frequency [MHz]	868.33
Modulation	2-FSK
Frequency Deviation [kHz]	±6.0
Chip rate [kcps]	4.8
RX Filter Bandwidth [kHz]	50

Table 10. R-mode Test Conditions

Packet format: preamble (n=39) x (01) + sync word "000111011010010110" + P byte payload + CRC16.

8.1 R-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
868.33	-114.5	80	20
	-113.8	20	8
	-111.7	1	8

Table 11. R-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

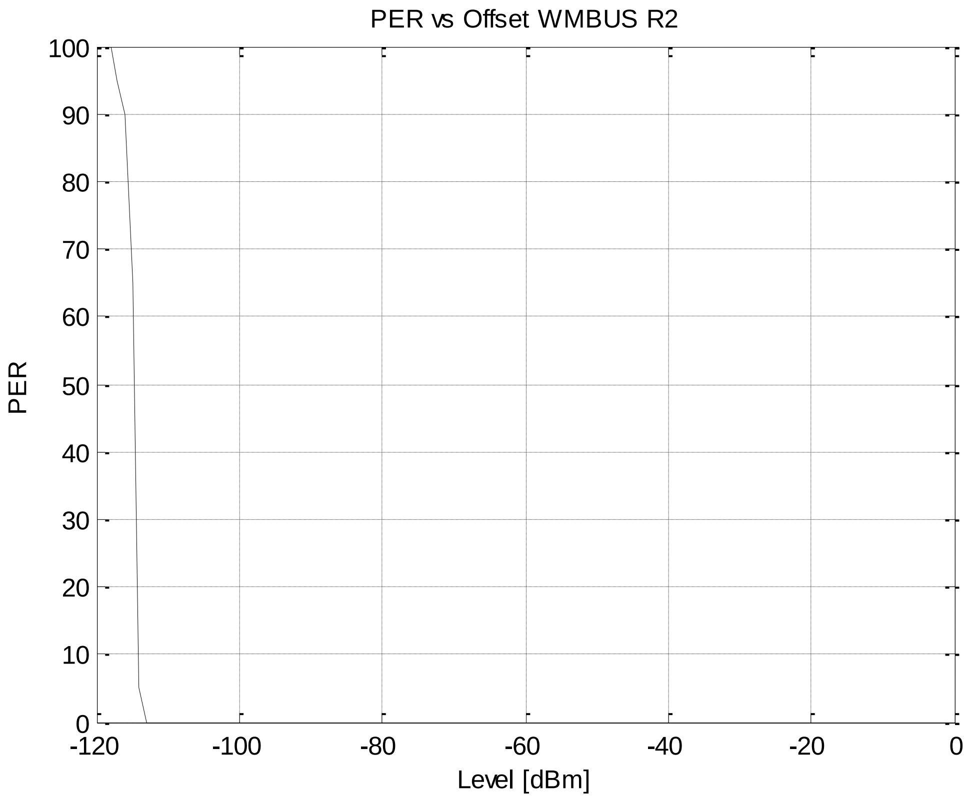

Figure 11. R-mode PER vs Input Power Level

8.2 R- mode RX Sensitivity vs Frequency Offset

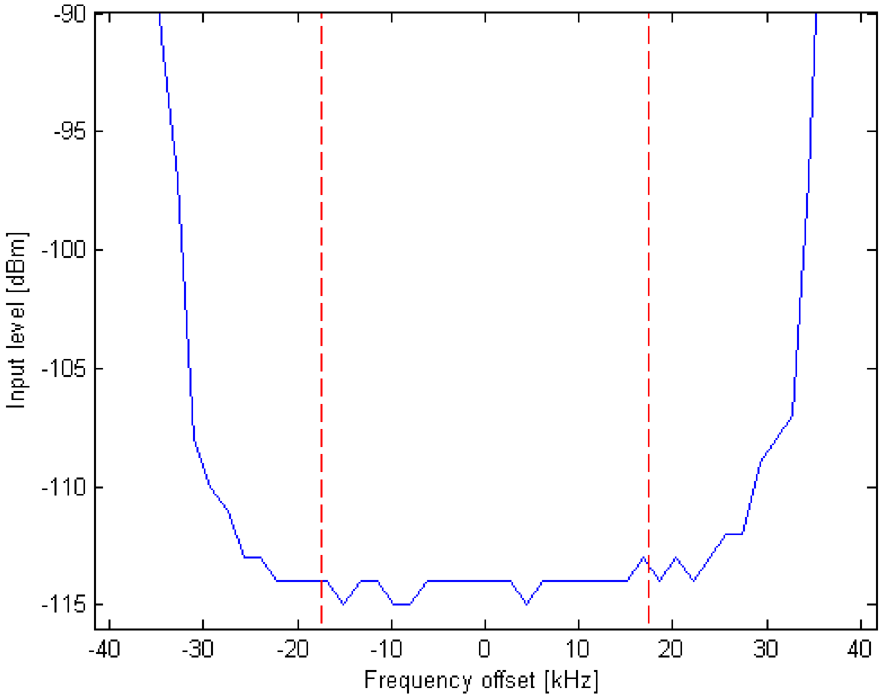

Figure 12. R-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 12 show the EN13757-4:2012 Draft limits for frequency offset.

8.3 R- mode RX Sensitivity vs Frequency Deviation

R-mode allows the frequency deviation parameter to vary from ±4.8 kHz to ±7.2 kHz, where ±6.0 kHz is the nominal value. Table 12 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
868.33	-112.9	4.8
	-113.8	6.0 (nominal)
	-112.9	7.2

Table 12. R-mode Typical 20% PER Sensitivity for 8 Bytes payload

8.4 R-mode RX Sensitivity vs Data Rate Offset

R-mode allows the chip rate to vary up to ±1.5% during the one packet frame. Table 13 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Chip Rate [kcps]
868.33	-113.7	4.73
	-113.8	4.8 (nominal)
	-113.6	4.87

Table 13.R-mode Typical 20% PER Sensitivity for 8 Bytes Payload

8.5 R-mode Blocking Performance

R-mode blocking performance is shown in Figure 13.

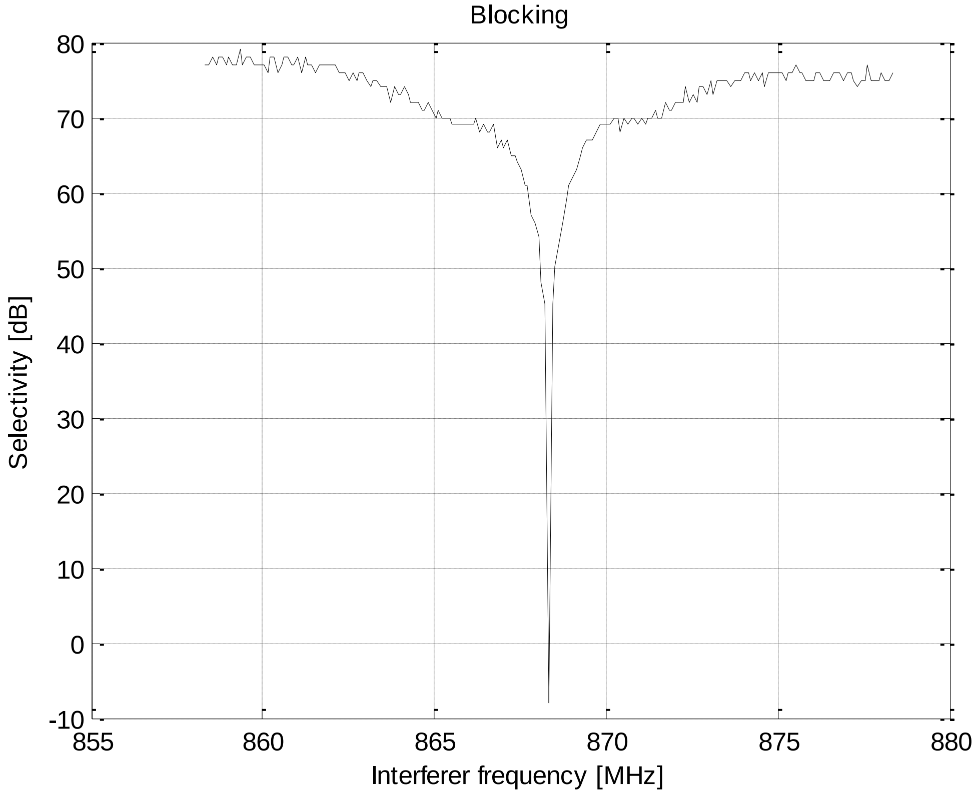

Figure 13. R-mode Blocking Performance

8.6 R-mode Performance Summary

- CC1120 achieves -114.5 dBm RX sensitivity in R-mode, which is 9.5 dB better than the R-mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus R-mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 supports the Manchester encoding (TX) and decoding (RX) for R-mode by HW in the Packet Engine – this saves code size and complexity for the data packet code in the MCU.

- CC1120 meets the ETSI Category 2 blocking requirements for R-mode.

- CC1120 complies with the R-mode highest receiver performance class.

9 C-mode Measurement Results

The C-mode (also “compact mode) was introduced as an improvement to the T-mode. A new packet format Frame B is defined (backwards compatible with T-mode using Frame A). Table 14 gives the test conditions used (see also C-mode definition in Appendix [18]):

Parameter	
TX/RX Centre Frequency [MHz]	868.95
Modulation	2-FSK
Frequency Deviation [kHz]	±45.0
Chip rate [kcps]	100
RX Filter Bandwidth [kHz]	200

Table 14. C-mode Test Conditions

Packet format: preamble (n=16) x (01) + sync word “0101010000111101 0101010011001101” + P byte payload + CRC16.

9.1 C-mode RX sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
868.95	-105.3	80	20
	-104.0	20	8
	-102.0	1	8

Table 15. C-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

9.2 C-mode RX Sensitivity vs Frequency Offset

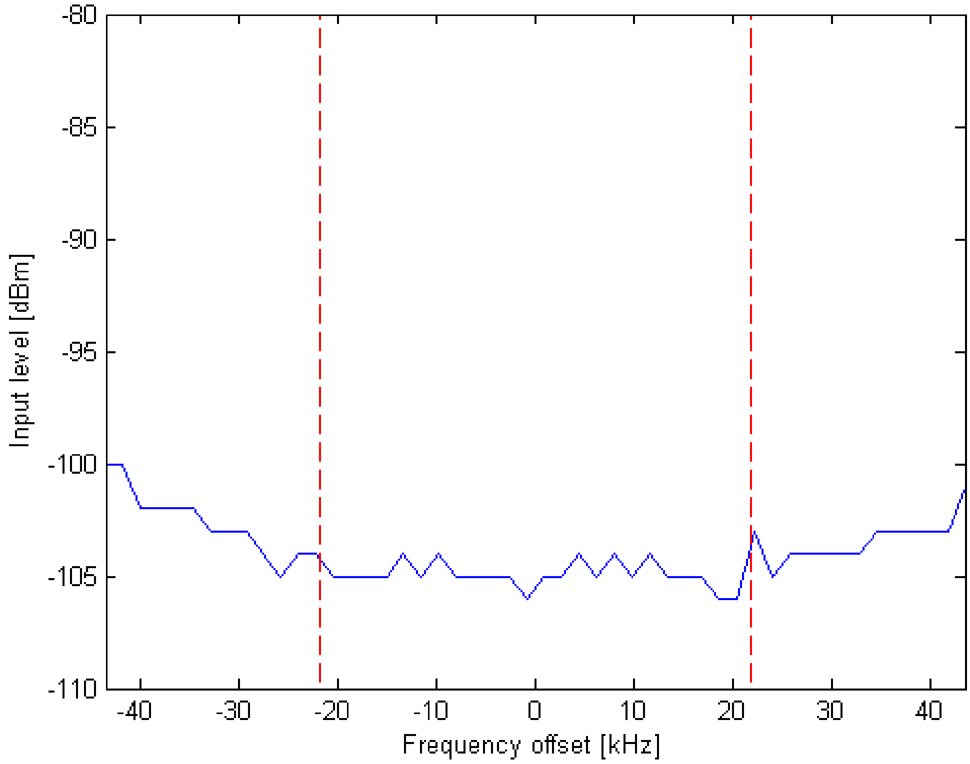

Figure 14. C-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 14 show the EN13757-4:2012 Draft limits for frequency offset.

9.3 C-mode RX Sensitivity vs Frequency Deviation

C-mode allows the frequency deviation parameter to vary from ±33.75 kHz to ±56.25 kHz, where ±45.0 kHz is the nominal value. Table 16 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
868.95	-102.8	33.75
	-104.0	45.0 (nominal)
	-104.3	56.25

Table 16. C-mode Typical 20% PER Sensitivity for 8 Bytes Data Payload

9.4 C-mode RX Sensitivity vs Data Rate Offset

C-mode chip rate tolerance is ±100 ppm. There is no variation in RX sensitivity as a function of the chip rate tolerance.

9.5 C-mode Blocking Performance

C-mode blocking performance is shown in Figure 15.

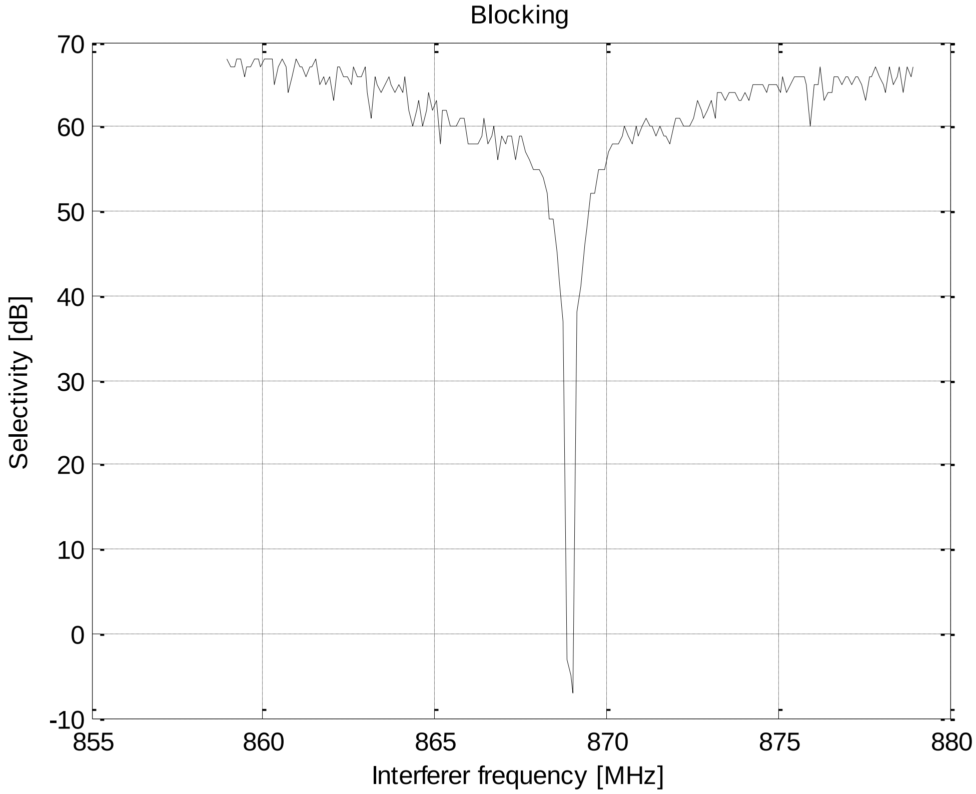

Figure 15. C-mode Blocking Performance

9.6 C-mode Performance Summary

- CC1120 achieves -105.3 dBm RX sensitivity in wM-Bus C-mode, which is 5.3 dB better than C-mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus C-mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 does supports NRZ encoding (TX) and decoding (RX) in HW by default

- CC1120 supports Frame A and Frame B reception simultaneously by using the regular Sync Word for T-mode.

- CC1120 meets the ETSI Category 2 blocking requirements.

- CC1120 complies with the C-mode highest receiver performance class.

10 Na/b/e/f-mode Measurement Results

Table 17 gives the test conditions used (see also N-mode definition in Appendix [20]):

Parameter	
TX/RX Centre Frequency [MHz]	169.41
Modulation	2-GFSK
Frequency Deviation [kHz]	±2.4
Bit rate [kbps]	4.8
RX Filter Bandwidth [kHz]	11.76

Table 17. Na/b/e/f-mode Test Conditions

Packet format: preamble (n=8) x (01) + sync word "11110110 10001101" + P byte payload + CRC16.

10.1 Na/b/e/f-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
169.41	-119.7	80	20
	-118.2	20	8
	-116.4	1	8

Table 18. Na/b/e/f-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

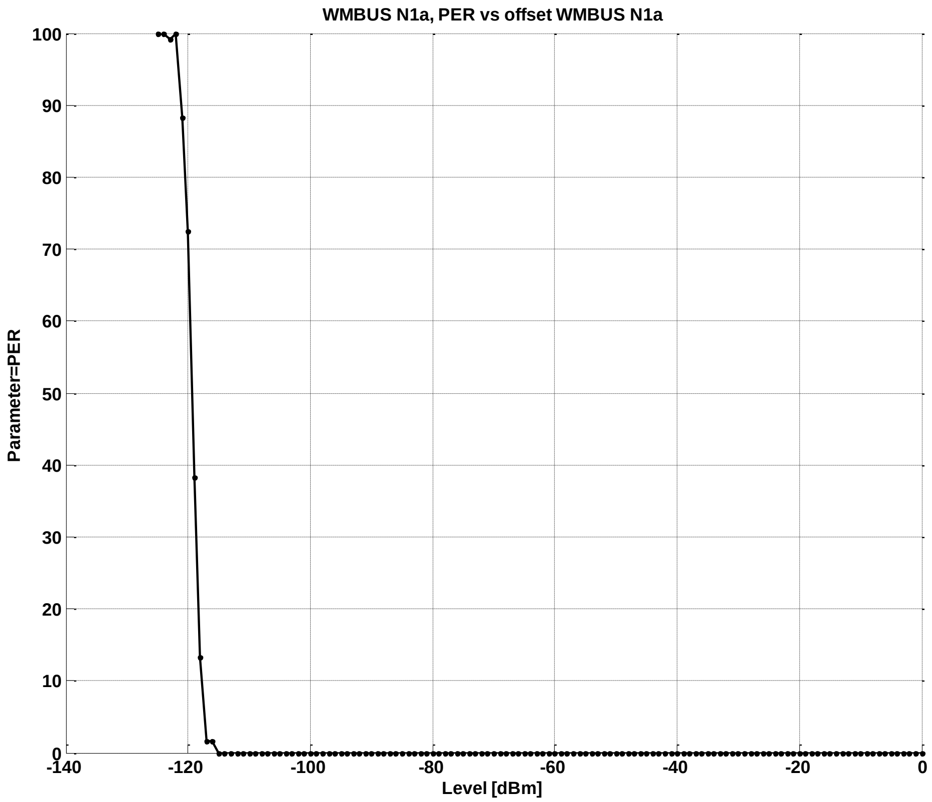

Figure 16. Na/b/e/f-mode PER vs Input Power Level

10.2 Na/b/e/f- mode RX Sensitivity vs Frequency Offset

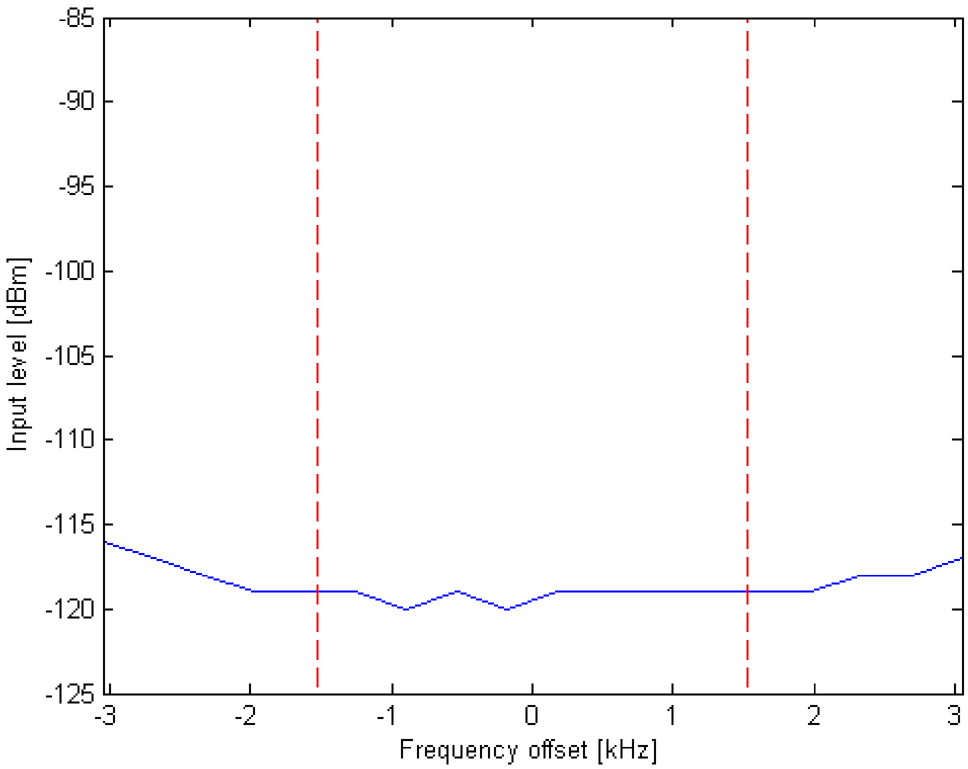

Figure 17. Na/b/e/f-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 17 show the EN13757-4:2012 Draft limits for frequency offset.

10.3 Na/b/e/f-mode RX Sensitivity vs Frequency Deviation

Na/b/e/f-mode allows the frequency deviation parameter to vary from ±1.68 kHz to ±3.12 kHz, where ±2.4 kHz is the nominal value. Table 19 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
169.41	-117.6	1.68
	-118.2	2.4 (nominal)
	-118.3	3.12

Table 19. Na/b/e/f -mode Typical 20% PER Sensitivity with 8 Byte Data Payload

10.4 Na/b/e/f-mode RX Sensitivity vs Data Rate Offset

Na/b/e/f-mode bit rate tolerance is ±100 ppm. There is no variation in RX sensitivity as a function of bit rate tolerance.

10.5 Na/b/e/f-mode Blocking Performance

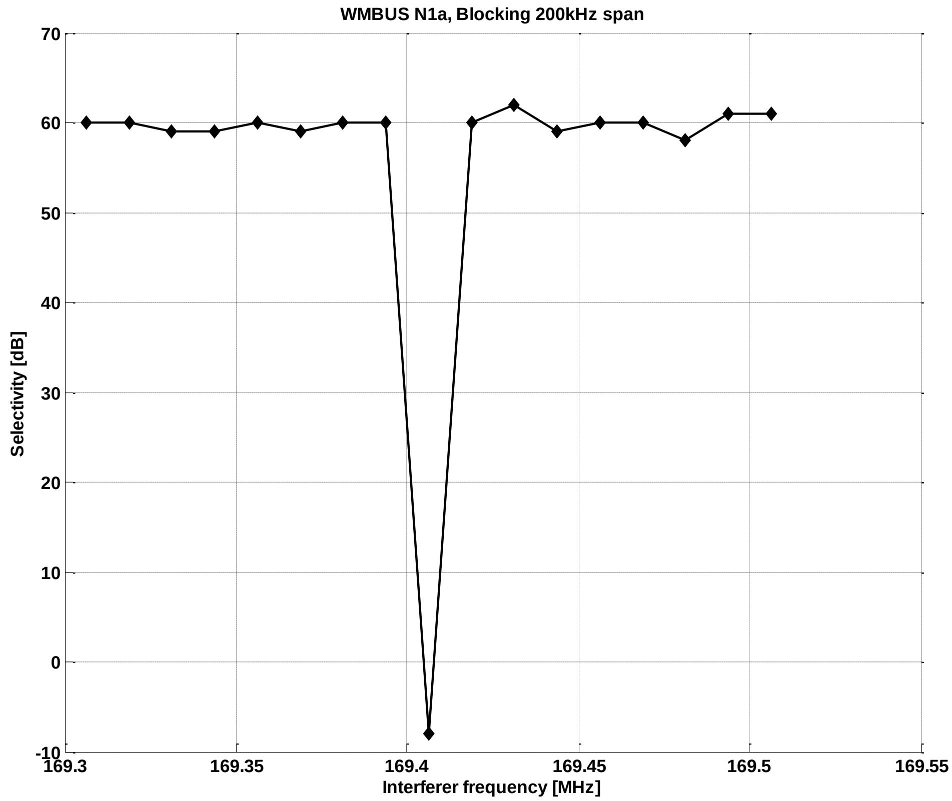

Figure 18. Na/b/e/f-mode Blocking Performance with 200 kHz Span.

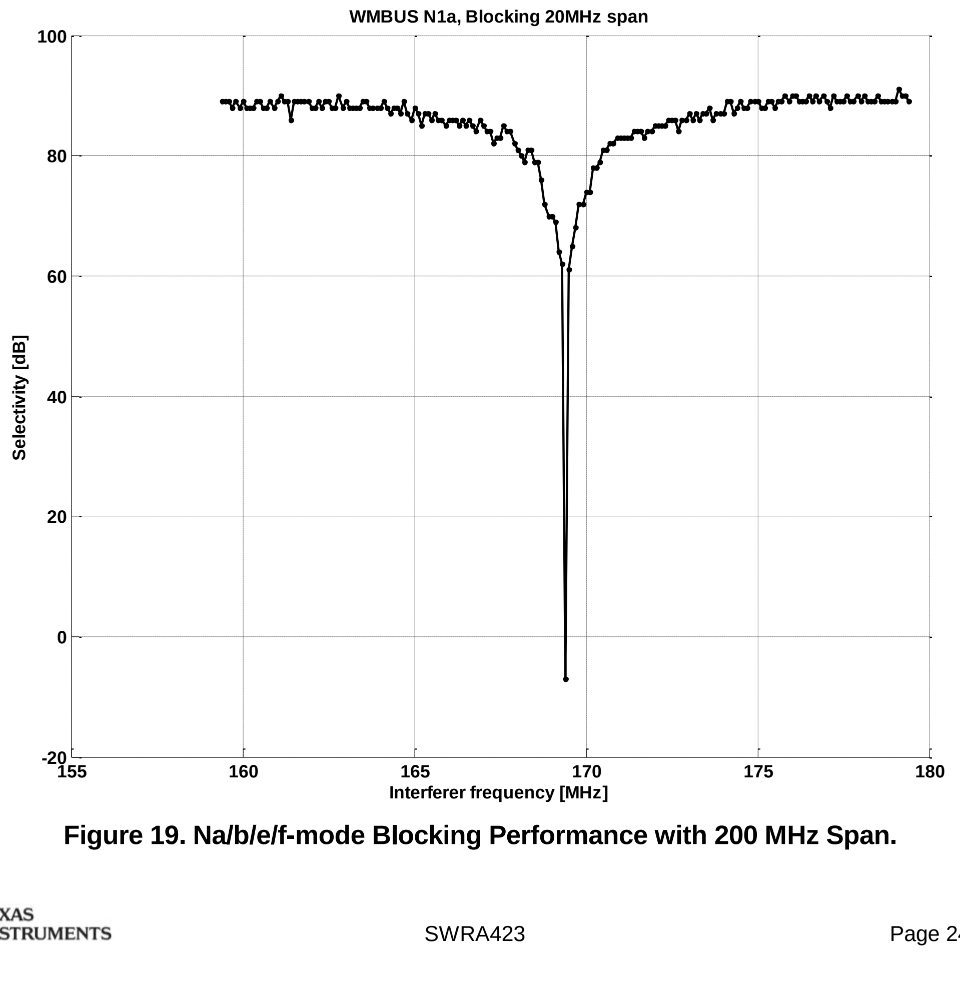

Figure 19. Na/b/e/f-mode Blocking Performance with 200 MHz Span.

10.6 Na/b/e/f-mode Performance Summary

- CC1120 achieves -119.7 dBm RX sensitivity in wM-Bus Na/b/e/f-mode, which is 7.7 dB better than Na/b/e/f -mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus N Na/b/e/f -mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 supports NRZ encoding (TX) and decoding (RX) in HW by default.

- CC1120 supports Frame A and Frame B reception simultaneously using its DualSync feature in the Packet engine to search for two 16-bit Sync Words concurrently.

- CC1120 meets the ETSI Category 2 blocking requirements.

- CC1120 complies with the Na/b/e/f-mode highest receiver performance class.

11 Nc/d-mode Measurement Results

Table 20 gives the test conditions used (see also N-mode definition in Appendix [20]):

Parameter	
TX/RX Centre Frequency [MHz]	169.43
Modulation	2-GFSK
Frequency Deviation [kHz]	±2.4
Bit rate [kbps]	2.4
RX Filter Bandwidth [kHz]	10.52

Table 20. Nc/d-mode Test Conditions

Packet format: preamble (n=8) x (01) + sync word "11110110 10001101" + P byte payload + CRC16.

11.1 Nc/d-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
169.43	-121.1	80	20
	-119.7	20	8
	-118.1	1	8

Table 21. Nc/d-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

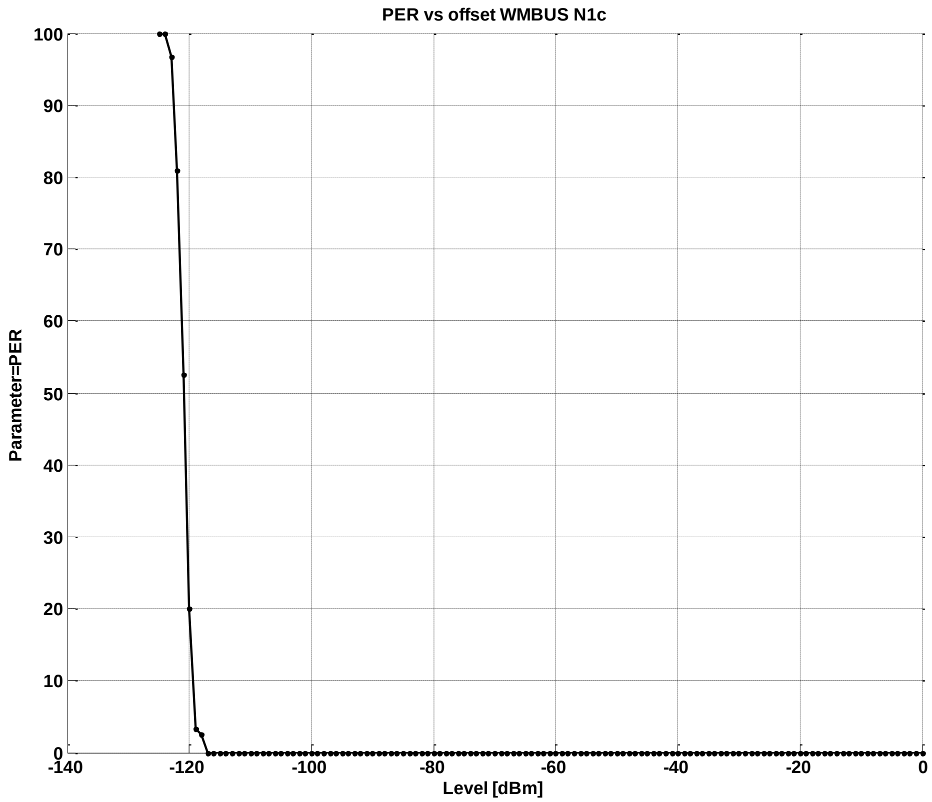

Figure 20. Nc/d-mode PER vs Input Power Level

11.2 Nc/d-mode RX Sensitivity vs Frequency Offset

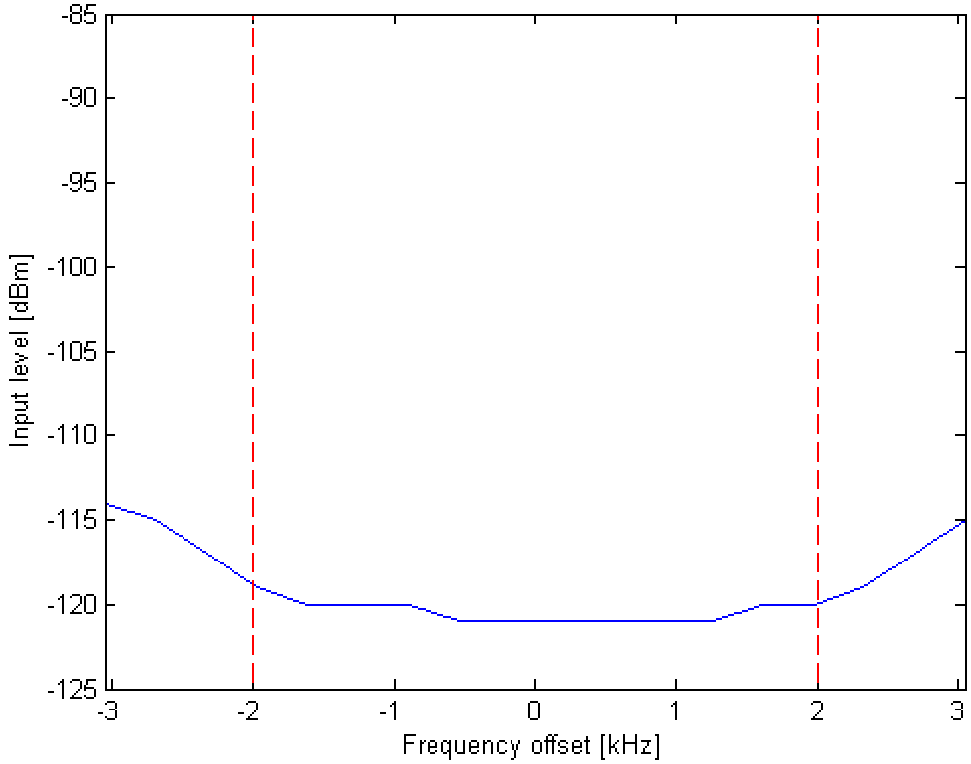

Figure 21. Nc/d-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 21 show the EN13757-4:2012 Draft limits for frequency offset.

11.3 Nc/d-mode RX Sensitivity vs Frequency Deviation

Nc/d-mode allows the frequency deviation parameter to vary from ±1.68 kHz to ±3.12 kHz, where ±2.4 kHz is the nominal value. Table 22 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
169.43	-119.2	1.68
	-119.7	2.4 (nominal)
	-120.6	3.12

Table 22. Nc/d -mode Typical 20% PER Sensitivity with 8 Byte Data Payload

11.4 Nc/d-mode RX Sensitivity vs Data Rate Offset

Na/b/e/f-mode bit rate tolerance is ±100 ppm. There is no variation in RX sensitivity as a function bit rate tolerance.

11.5 Nc/d-mode Blocking Performance

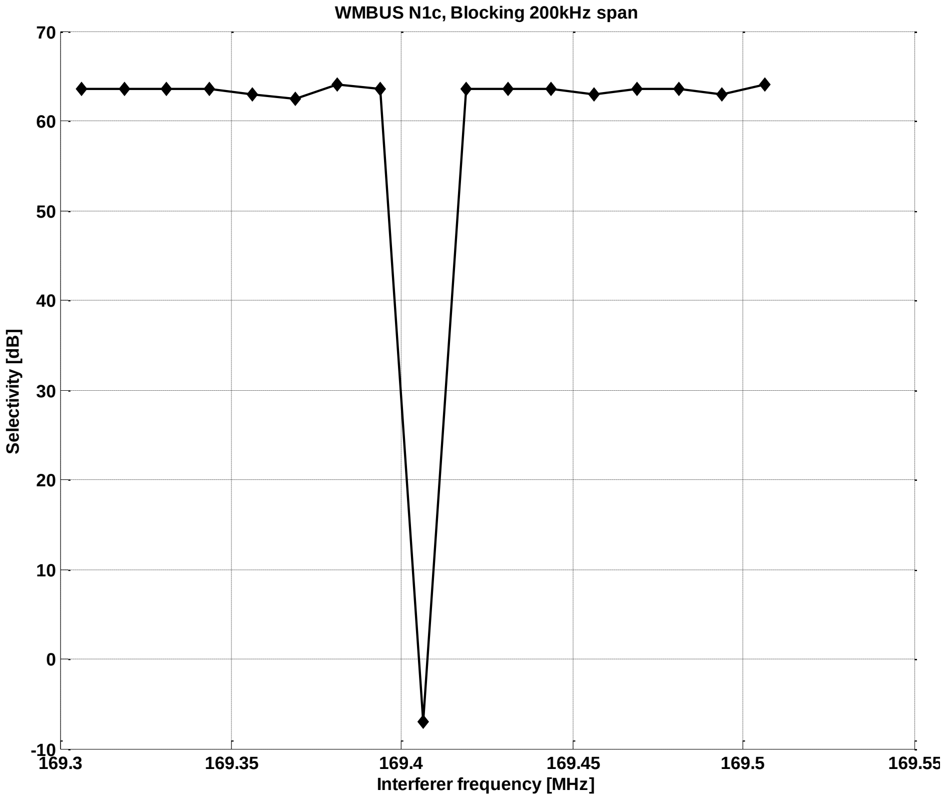

Figure 22. Nc/d-mode Blocking Performance with 200 kHz Span.

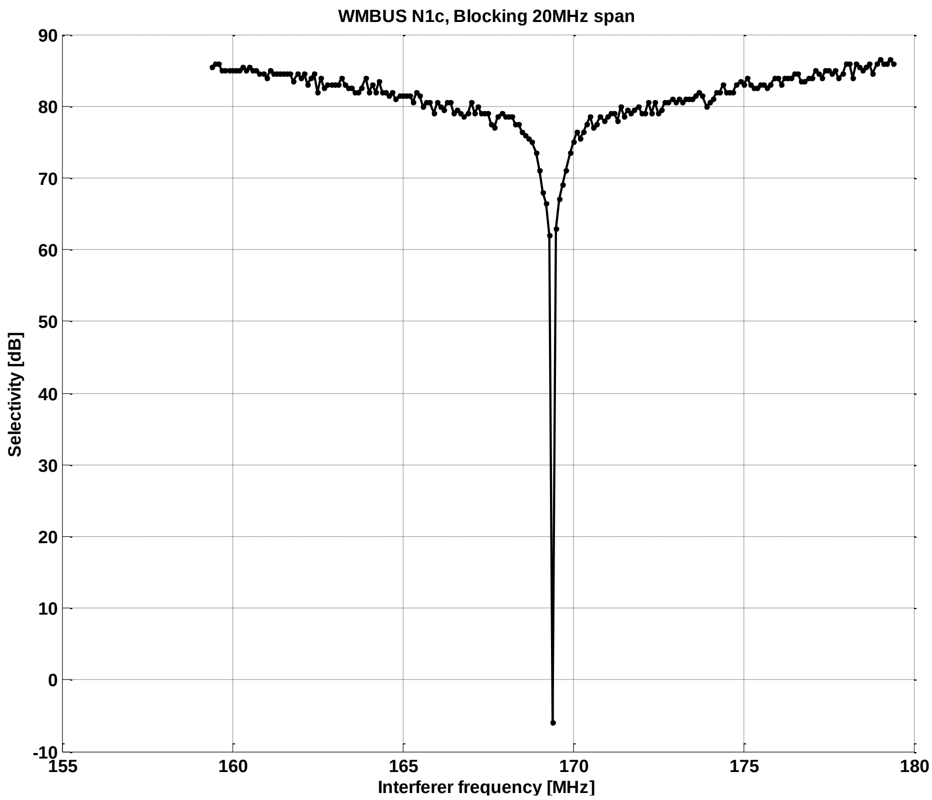

Figure 23. Nc/d-mode Blocking Performance with 200 MHz Span.

11.6 Nc/d-mode Performance Summary

- CC1120 achieves -121.1 dBm RX sensitivity in wM-Bus Nc/d-mode, which is 6.1 dB better than Nc/d -mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus Nc/d-mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 does supports NRZ encoding (TX) and decoding (RX) in HW by default.

- CC1120 supports Frame A and Frame B reception simultaneously using its DualSync feature in the Packet engine to search for two 16-bit Sync Words concurrently.

- CC1120 meets the ETSI Category 2 blocking requirements.

- CC1120 complies with the Nc/d-mode highest receiver performance class.

12 Ng-mode Measurement Results

Table 23 gives the test conditions used (see also N-mode definition in Appendix [20]):

Parameter	
TX/RX Centre Frequency [MHz]	169.40
Modulation	4-GFSK
Frequency Deviation [Hz]	7200
Bit rate [bps]	19200
RX Filter Bandwidth [kHz]	28.6

Table 23. Ng-mode Test Conditions

Packet format: preamble (n=8) x (01) + sync word “11110110 10001101” + P byte payload + CRC16.

12.1 Ng-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
169.41	-114.3	80	20
	-113.2	20	8
	-111.0	1	8

Table 24. Ng-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

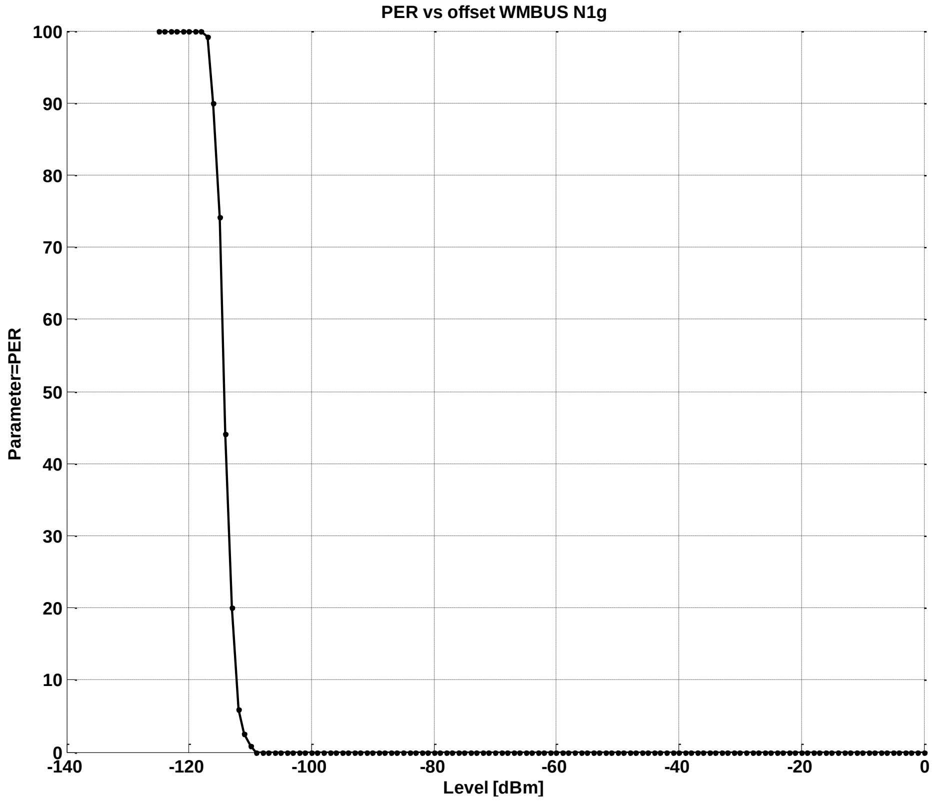

Figure 24. Ng-mode PER vs Input Power Level

12.2 Ng-mode RX Sensitivity vs Frequency Offset

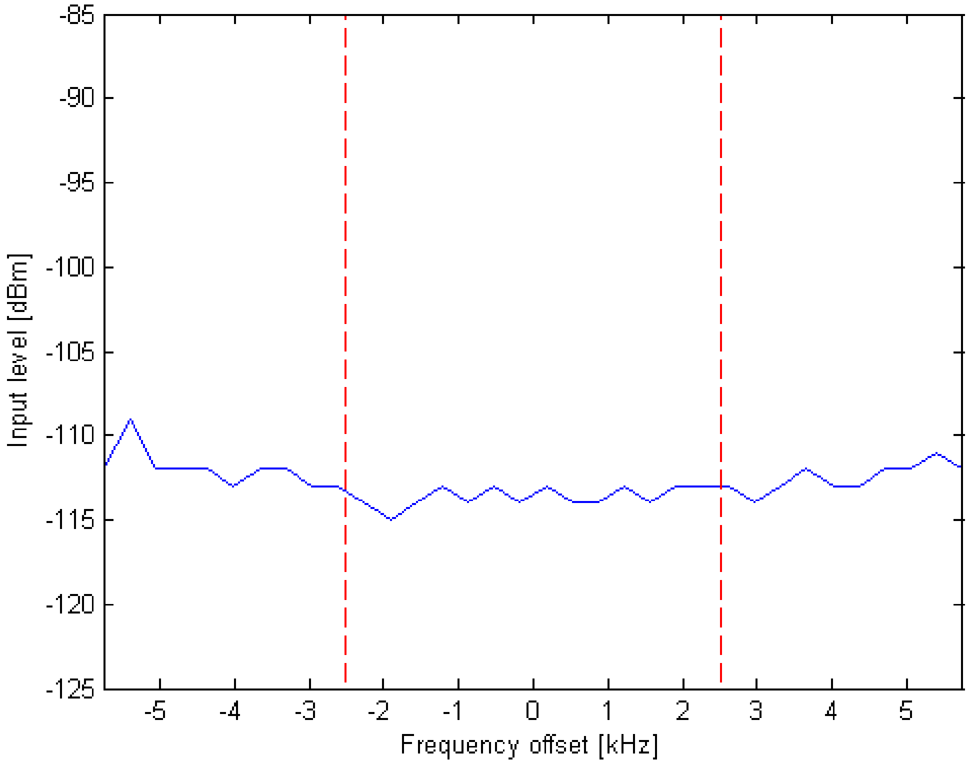

Figure 25. Ng-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 25 show the EN13757-4:2012 Draft limits for frequency offset.

12.3 Ng-mode RX Sensitivity vs Frequency Deviation

Ng-mode allows the frequency deviation parameter to vary from ±5.04 kHz to 9.36 kHz, where ±7.2 kHz is the nominal value. Table 25 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
169.41	-110.3	6.12
	-113.2	7.20 (nominal)
	-112.3	8.28

Table 25. Ng-mode Typical 20% PER Sensitivity with 8 Byte Data Payload

12.4 Ng-mode RX Sensitivity vs Data Rate Offset

Ng-mode bit rate tolerance is ±100 ppm. There is no variation in RX sensitivity as a function bit rate tolerance.

12.5 Ng-mode Blocking Performance

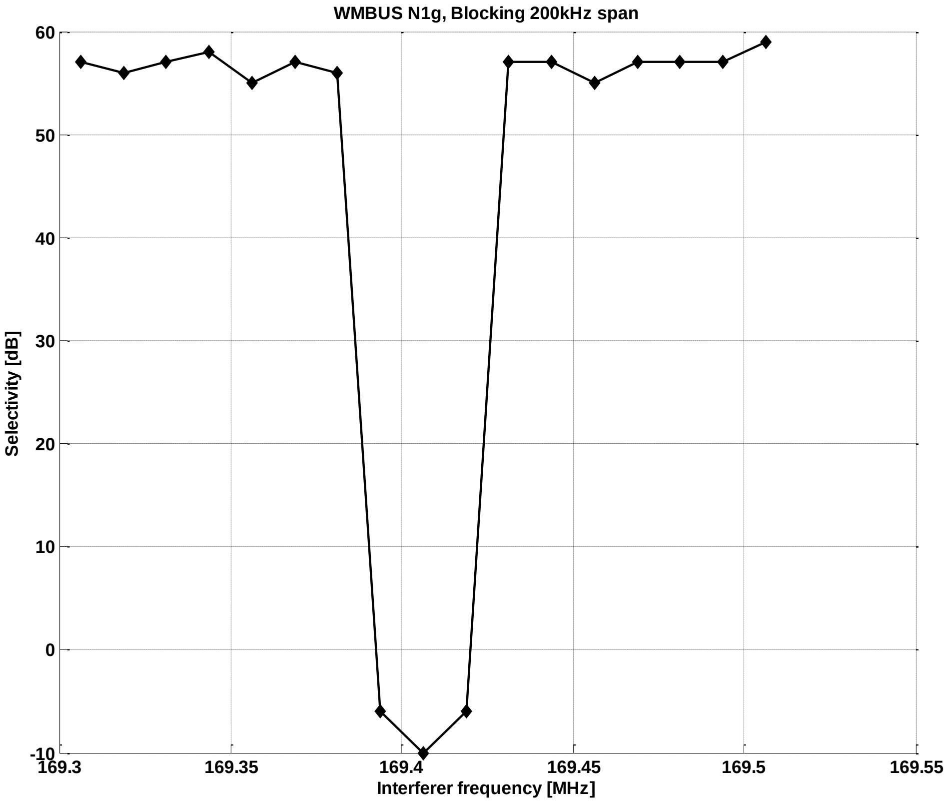

Figure 26. Ng-mode Blocking Performance with 200 kHz Span.

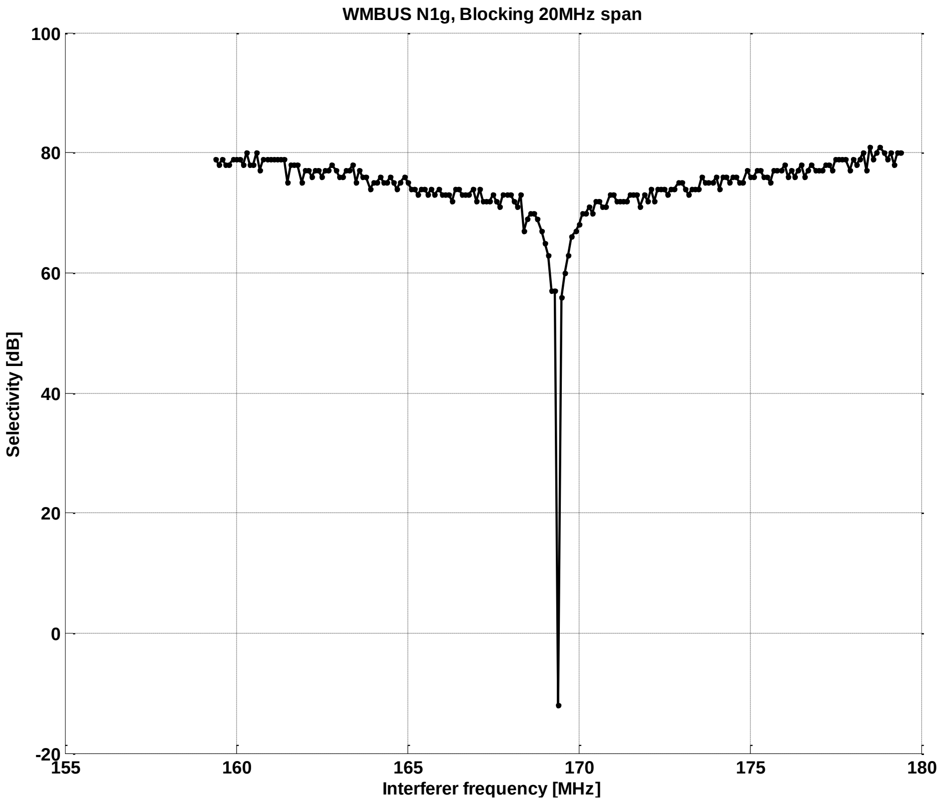

Figure 27. Ng-mode Blocking Performance with 200 MHz Span.

12.6 Ng-mode Performance Summary

- CC1120 achieves -114.3 dBm RX sensitivity in wM-Bus Ng-mode, which is 10.3 dB better than Ng-mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus Ng-mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 does supports NRZ encoding (TX) and decoding (RX) in HW by default.

- CC1120 supports Frame A and Frame B reception simultaneously: either using its DualSync feature in the Packet engine to search for two 16-bit Sync Words concurrently.

- CC1120 meets the ETSI Category 2 blocking requirements.

- CC1120 complies with the Ng-mode highest receiver performance class.

13 F-mode Measurement Results

Table 26 gives the test conditions used (see also F-mode definition in Appendix [21]):

Parameter	
TX/RX Centre Frequency [MHz]	433.82
Modulation	2-FSK
Frequency Deviation [kHz]	5.5
Bit rate [kbps]	2.4
RX Filter Bandwidth [kHz]	28

Table 26. F-mode Test Conditions

Packet format: preamble (n=8) x (01) + sync word "11110110 10001101" + P byte payload + CRC16.

13.1 F-mode RX Sensitivity

Frequency [MHz]	Typical Sensitivity [dBm]	PER [%]	P = Payload Bytes
433.82	-119.5	80	20
	-119.7	20	8
	-117.4	1	8

Table 27. F-mode Typical Sensitivity

NOTE: RX sensitivity numbers are measured at the single antenna port with combined TX/RX matching (and not at the CC1120 chip pin).

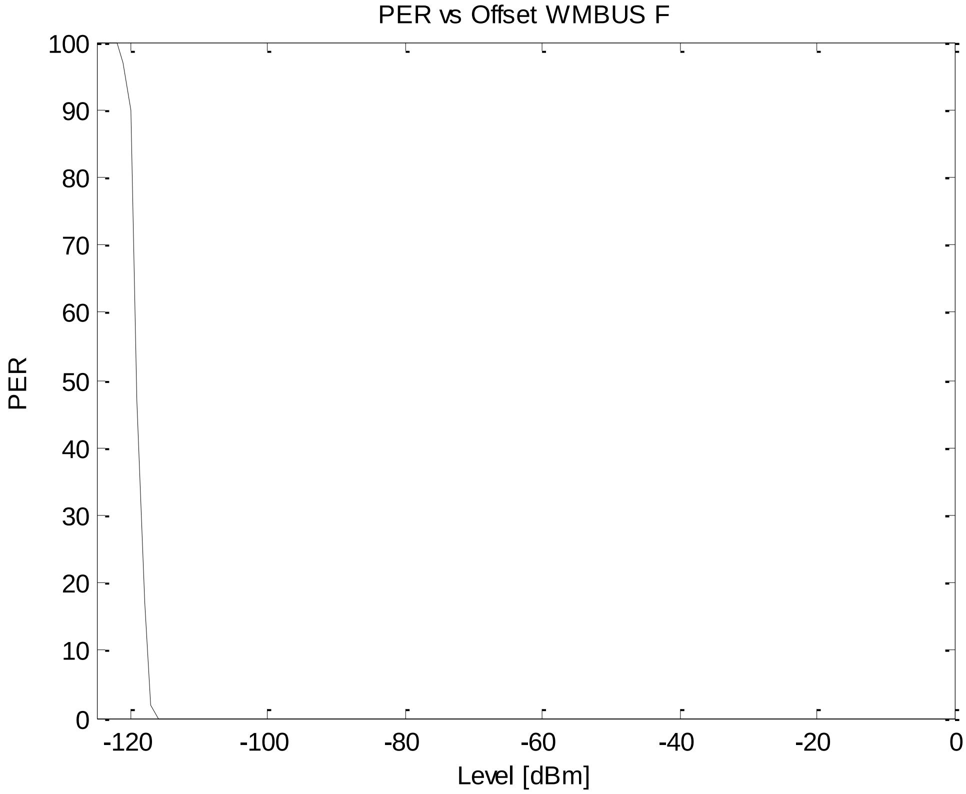

Figure 28. F-mode PER vs Input Power Level

13.2 F-mode RX Sensitivity vs Frequency Offset

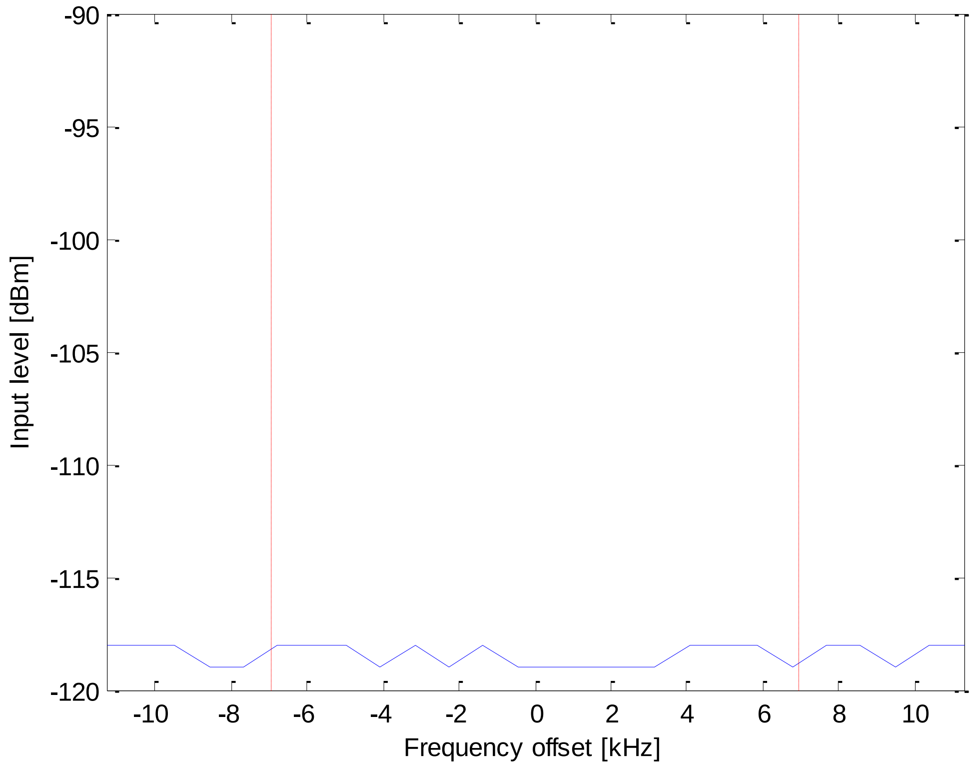

Figure 29. F-mode PER vs Frequency Offset vs Input Power Level

Red lines in Figure 29 show the EN13757-4:2012 Draft limits for frequency offset.

13.3 F-mode RX Sensitivity vs Frequency Deviation

F-mode allows the frequency deviation parameter to vary from ±4.8 kHz to ±7.0 kHz, where ±5.5 kHz is the nominal value. Table 28 gives the measurement results.

Frequency [MHz]	Typical Sensitivity [dBm]	Deviation [kHz]
433.82	119.3	4.8
	119.5	5.5
	119.8	7.0

Table 28. F-mode Typical 80% PER Sensitivity with 20 Byte Data Payload

13.4 F-mode RX Sensitivity vs Data Rate Offset

F-mode bit rate tolerance is ±100 ppm. There is no variation in RX sensitivity as a function bit rate tolerance.

13.5 F-mode Blocking Performance

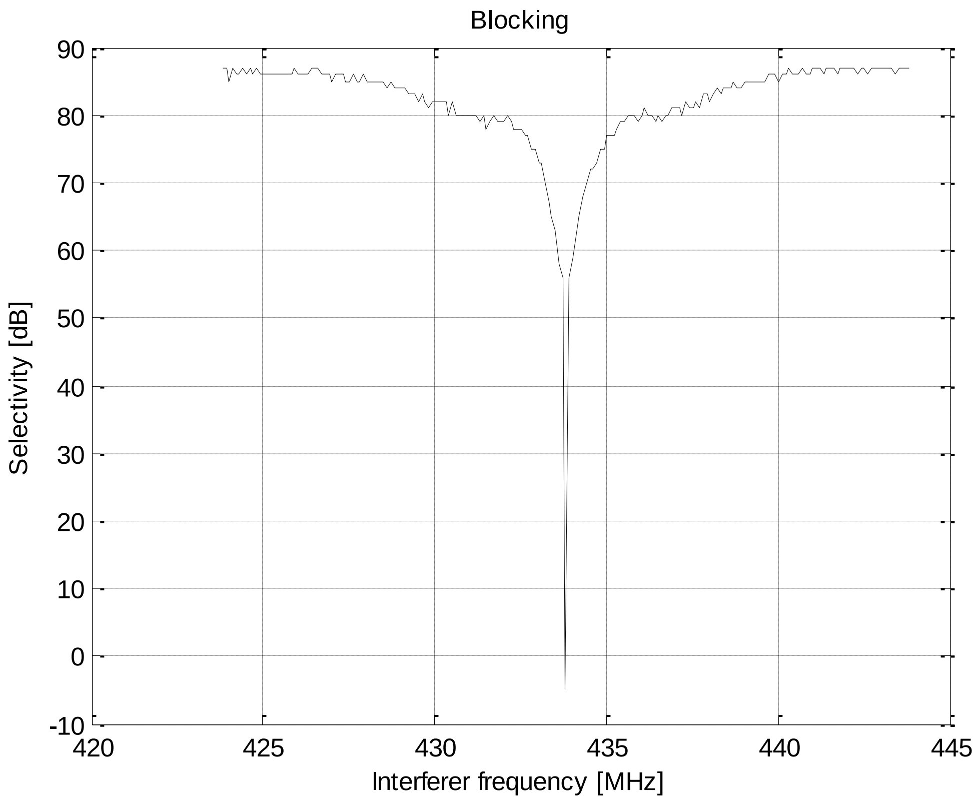

Figure 30. F-mode Blocking Performance with 200 MHz Span.

13.6 F-mode Performance Summary

- CC1120 achieves -119.5 dBm RX sensitivity in wM-Bus F-mode, which is 4.5 dB better than F-mode requirements in wM-Bus standard [1].

- CC1120 meets all worst case parameters for frequency offset error, data rate error and frequency deviation error as defined in wM-Bus standard [1].

- wM-Bus F-mode telegrams can be received or transmitted using the CC1120 built-in Packet engine (RX and TX FIFO mode) in all worst case conditions.

- CC1120 does supports NRZ encoding (TX) and decoding (RX) in HW by default.

- CC1120 supports Frame A and Frame B reception simultaneously using its DualSync feature in the Packet engine to search for two 16-bit Sync Words concurrently.

- CC1120 supports meets the ETSI Category 2 blocking requirements for 433Mhz

- CC1120 complies with the F-mode highest receiver performance class.

14 References

[1] European standard EN 13757-4:2012 Draft "Communication system for meters and remote reading of meters”.

[2] ETSI EN 300220 V2.3.1: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW”

[3] CEPT/ERC/Recommendation 70-03: “Relating to the use of Short Range Devices (SRD)”

[4] Design Note DN005 CC11xx Sensitivity versus Frequency Offset and Crystal Accuracy

[5] “Introducing TI’s complete WMBus solution”: http://www.ti.com/lit/ml/slyt433/slyt433.pdf

[6] TI CC1120 development kit: http://www.ti.com/tool/cc1120dk

[7] CC1120EM 169 MHz Reference Design (swrc220)

[8] CC1120EM 420/470 MHz Reference Design (swrc221)

[9] CC112x IPC 868/915 MHz 4-Layer Ref. Design Rev1.0 (swrr107)

[10] CC112x IPC 868/915 MHz 2-Layer Ref. Design Rev1.0 (swrr106)

[11] CC112x EM 868/915 MHz Reference Design (swrc224)

15 Document History

Revision	Date	Description/Changes
SWRA423	2013.02.20	Initial release.

16 Appendix: S-mode Parameters

Characteristic	Mode	Sym	Min	Typ	Max	Unit	Note
Centre frequency (transmit only Meter, S1-submode)			868,25	868,30	868,35	MHz	~ 60×10^{-6} (ppm)
Centre frequency (Other Device and S2-mode)			868,278	868,300	868,322	MHz	~ 25×10^{-6} (ppm)
FSK Deviation			±40	±50	±80	kHz	
Chip rate transmit		f_{chip}		32,768		kcps	
Chip rate tolerance					±1,5	%	
Digital bit jitter [a]					±3	us	
Data rate (Manchester) [b]				$f_{chip} \times ½$		bps	
Preamble length including bit/byte-sync, both directions	S2, S1-M		48			chips	
Preamble length including bit/byte-sync	S1	PL	576			chips	Optional for S2
Postamble (trailer) length [c]			2		8	chips	
Response delay [d] (Other Device to Meter communication)		t_{RO}	3		50	ms	

Characteristic	Mode	Sym	Min	Typ	Max	Unit	Note
FAC Transmission delay [e f]	S2	t_{TxD}	N×1000 -0,5	N×1000	N×1000 +0,5	ms	N=2, 3,or 5
FAC Time out [g]	S2	t_{TO}	25		30	s	

a The bit jitter shall be measured at the output of the micro-controller or encoder circuit.

b Each bit shall be coded as 2 chips (Manchester encoding).

c The postamble (trailer) shall consist of n=1 to 4 "ones" i.e. the chip sequence is n × (01).

d Response delay: The receiver shall be ready for the reception of a response in a time shorter than the minimum response delay, and shall be receiving at least until the maximum response delay (referred to the end of previous transmission)..

e FAC Transmission delay: describes the duration which a meter shall delay the first response to a received message from Other Device referred to its last transmission. This delay shall also be applied between the first response of the Meter and the next repeated response of the Meter and all following repeated responses during the Frequent Access Cycle (FAC). The reference time point shall be the end of preamble (end of sync sequence) of the meter transmission. For timing diagrams see Annex E.

f The selected timeslot N shall be the same throughout the Frequent Access Cycle.

g FAC Time out: is the time period between the last successful reception of a frame from the Other Device during the Frequent Access Cycle (FAC) and the moment where the repetition of the last response of the Meter shall be stopped (end of Frequent Access Cycle).

Table 29. TX Parameters for S-mode (as defined in [1])

Characteristic	Class	Symb	Min	Typ	Max	Unit	Note
Sensitivity (BER < 10^{-2}) or (PER < 0,8) [a]	H_R	P_o	-100	-105		dBm	
Blocking performance [b]	L_R		3			Category	
Blocking performance [b c]	M_R		2			Category	
Blocking performance [b c d]	H_R		2			Category	
Acceptable chip rate tolerance		D_{fchip}			± 2	%	
Chip rate (Meter)		f_{chip}		32,768		kcps	

[a] At a frame size of 20 bytes.

[b] Receiver category according to ETSI EN 300 220-1, V2.3.1:2010, 4.1.1.

[c] Additional requirement for Class M_R and Class H_R receivers: The equipment shall meet the immunity requirements as specified in ETSI EN 301 489-1, V1.8.1:2008, 9.2.

[d] Additional requirement for Class H_R receivers: Adjacent band selectivity shall be > 40 dB when measured according to ETSI EN 300 220-1, V2.3.1:2010, 8.3.

Table 30. RX Parameters for S-mode (as defined in [1])

17 Appendix: T-mode Parameters

As one of the “original” wM-Bus modes, T-mode was defined almost 10 years ago, when integrated RF transceivers such as CC1101 or CC1120 were not available. The old discrete RF implementations delivered high variation in terms of data rate used, frequency offset and chip rate during transmission. This is the reason why T-mode defines such large tolerances for the chip rate (90-110 kcps), FSK deviation (±40 to ±80 kHz) and chip rate variation of up to ±1.5%. The PHY layer requirements of T-mode are summarized in Table 31.

Characteristic	Mode	Sym	Min	Typ	Max	Unit	Note
Centre frequency (Meter to Other Device)	T1, T2		868,90	868,95	869,00	MHz	~ 60×10^{-6} (ppm)
Centre frequency (Other Device to Meter)	T2		868,278	868,300	868,322	MHz	~ 25×10^{-6} (ppm)
FSK Deviation (Meter to Other Device)	T1, T2		± 40	± 50	± 80	kHz	
FSK Deviation (Other Device to Meter)	T2		± 40	± 50	± 80	kHz	
Chip rate transmit (Meter to Other Device)	T1, T2	f_{chip2}	90	100	110	kcps	
Rate variation within header + frame (meter)	T1, T2	D_{fchip}		0	±1	%	
Data rate [a] (Meter to Other Device, 3 out of 6 encoding)	T1, T2	f_{chip2}		$f_{chip} \times 2/3$		bps	
Chip rate transmit (Other Device to Meter)	T2			32,768		kcps	
Chip rate tolerance (Other Device to Meter)	T2				± 1,5	%	
Digital bit jitter [b]	T2				± 3	µs	
Data rate (Other Device to Meter, Manchester encoding)	T2			$f_{chip2} \times ½$		bps	
Preamble length including bit/byte-sync, both directions	T1, T2	PL	48			chips	
Postamble (trailer) length [c]	T1, T2		2		8	chips	
Response delay [d] (Other Device to Meter communication)	T2	t_{RO}	2		3	ms	
FAC Transmission delay [e f]	T2	t_{TxD}	N×1000 -0,5	N×1000	N×1000 +0,5	ms	N=2, 3,or 5
FAC Time out [g]	T2	t_{TO}	25		30	s	

[a] Each nibble (4 bits) shall be coded as 6 chips, see Table 10.

[b] The bit jitter shall be measured at the output of the microprocessor or encoder circuit.

[c] The postamble (trailer) shall consists of at least of at least two alternating chips. If the last chip of the CRC was a zero, then the minimum postamble shall be "10", otherwise it's shall be "01".

[d] Response delay: The receiver shall be ready for the reception of a response in a time shorter than the minimum response delay, and shall be receiving at least until the maximum response delay (referred to the end of previous transmission).

[e] FAC Transmission delay: describes the duration which a Meter shall delay the first response to a received message from Other Device referred to its last transmission. This delay shall also be applied between the first response of the Meter and the next repeated response of the Meter and all following repeated responses during the Frequent Access Cycle (FAC). The reference time point shall be the end of preamble (end of sync sequence) of the Meter transmission. For timing diagrams see Annex E.

[f] The selected timeslot N shall be the same throughout the Frequent Access Cycle.

[g] FAC Time out: is the time period between the last successful reception of a frame from the Other Device during the Frequent Access Cycle (FAC) and the moment where the repetition of the last response of the Meter shall be stopped (end of Frequent Access Cycle).

Table 31. Transmit Parameters for T-mode (as defined in [1])

Characteristic	Mode/ Class	Sym	Min	Typ	Max	Unit	Note
Sensitivity (BER < 10^{-2})or (PER < 0,8) [a]	H_R	P_o	-100	-105		dBm	
Blocking performance [b]	L_R		3			Category	
Blocking performance [b c]	M_R		2			Category	
Blocking performance [b c d]	H_R		2			Category	
Acceptable header chip rate range: (Other Device)	T1, T2	f_{chip}	88	100	112	kcps	~± 12 %
Acceptable chip rate variation during header and frame: (Other Device)	T1, T2	D_{fchip}		0	± 2	%	
Chip rate (Meter)	T2	f_{chip}		32,768		kcps	
Acceptable chip rate tolerance (Meter)	T2	D_{fchip2}		0	± 2	%	

[a] At a frame size of 20 bytes

[b] Receiver category according to ETSI EN 300 220-1, V2.3.1:2010, 4.1.1.

[c] Additional requirement for Class M_R and Class H_R receivers: The equipment shall meet the immunity requirements as specified in ETSI EN 301 489-1, V1.8.1:2008, 9.2.

[d] Additional requirement for Class H_R receivers: Adjacent band selectivity shall be > 40 dB when measured according to ETSI EN 300 220-1, V2.3.1:2010, 8.3.

Table 32. Receive Parameters for T-mode (as defined in [1])

The receiver requirement, named "Acceptable header chip rate range: (Other Device)", is one of the most challenging ones for a RF transceiver to meet, as it requires dedicated HW support in the demodulator to handle such wide data rate variation. Nevertheless, CC1120 easily fulfills this requirement, due to its in-built demodulator support of ±12.5% data rate variation.

18 Appendix: C-mode Parameters

The C-mode (also called “compact” mode) can be viewed as the “next generation” T-mode, with its 100 kcps from Meter to Other device. In order to save battery power for the meters, C-mode uses simple NRZ coding (no “3 out of 6” anymore), introduces the Frame format B (where CRC16 fields are reduced to maximum two) and also adds the new frequency for Other-to-Meter communication. Due to the new Frame format B changes in the encryption scheme were also introduced – now AES-128 CTR mode is mandatory, as it allows to encrypt telegrams “on the fly” without the addition of padding (or fill-up) bytes, which the previous AES-128 CBC required in order to obtain multiple of 16 Bytes blocks.

A newly introduced frequency of 869.525 MHz is in an ETSI sub-band, where 500 mW (+27 dBm) EIRP can be applied. This allows for significantly higher link budget (13 dB more than in T-mode) from Other-to-Meter and can thus reduce system cost. Other devices are typically stationary data collectors, which have much higher available power budget (compared to meters) and can afford to transmit with +500 mW EIRP.

Due to high efficiency power amplifiers (PA), like CC1190, battery powered operation for such Data Collectors is realistic. The addition of an LNA function in the RX path as well as antenna diversity in the Data Collector significantly improves the RX sensitivity and extends the link budget for Meter-to-Other, as most Meters already operate in transmit at the ETSI limit of +14 dBm EIRP.

In summary C-mode reduces the length of the telegram compared to T-mode and lowers the requirements for the RF transceivers, by using much narrower tolerances than T-mode, as shown in Tables below.

Characteristic	Mode	Sym	Min	Typ	Max	Unit	Note
Centre frequency (Meter to Other Device)	C1, C2		868,928	868,950	868,972	MHz	± 25 ppm
Centre frequency (Other Device to Meter)	C2		869,503	869,525	869,547	MHz	± 25 ppm
FSK Deviation [a] (Meter to Other Device)	C1, C2		± 33,75	± 45	± 56,25	kHz	
GFSK Deviation [a] (Other Device to Meter)	C2		± 18,75	± 25	± 31,25	kHz	
GFSK relative bandwidth	C2	BT		0,5			
Chip rate (Meter to Other Device)	C1, C2	f_{chip}		100		kcps	
Chip rate (Other Device to Meter)	C2	f_{chip}		50		kcps	
Chip rate tolerance	C1, C2				± 100	ppm	
Data rate [b]	C1, C2			f_{chip}		bps	
Preamble length	C1, C2	PL	32		32	chips	
Synchronization length	C1, C2	SL	32		32	chips	
Fast response delay (default) [c d e] (Other Device to Meter communication)	C2	t_{RO}	99,5	100	100,5,	ms	

Characteristic	Mode	Sym	Min	Typ	Max	Unit	Note
Slow response delay [c d e] (Other Device to Meter communication)	C2	t_{RO_slow}	999,5	1000	1000,5	ms	
Fast response delay (default) [c d] (Meter to Other Device communication)	C2	t_{RM}	99,5	100	100,5	ms	
Slow response delay [c d] (Meter to Other Device communication)	C2	t_{RM_slow}	999,5	1000	1000,5	ms	
FAC Transmission delay [f g]	C2	t_{TxD}	N×1000 - 0,5	N×1000	N×1000+ 0,5	ms	N= 2,3 or 5
FAC Time out [h]	C2	t_{TO}	25		30	s	

[a] 75 - 125% of nominal deviation Measured in centre of chip (frequency vs. time eye opening) transmitting a 9 bit pseudo-random (PN9) sequence, min/max based on the root-mean-square (rms) error value.

[b] All bits are NRZ coded.

[c] After receiving a frame the responding unit must start the transmission of preamble after the specified response delay. The response delay is measured from the reception time of the last bit of the frame. For timing diagrams see Annex E.

[d] The use of slow or fast response delay is specified in the "Communication Control Field" of the Extended Link Layer – refer to section 12.2.2. For timing diagrams see Annex E. If an Extended Link Layer is not included in the frame, the default response delay shall be used.

[e] If the frame is repeated (specified in the "Communication Control Field" of the Extended Link Layer – refer to section 12.2.2) the Other Device shall instead use a shorter response delay (t_{RR} or t_{RR_slow}) being 85 ms shorter than the corresponding t_{RO} or t_{RO_slow}. This enables bi-directional communication to be repeated without loss of communication speed. The frame from meter to Other Device shall be repeated with a delay less than 5 ms (t_{DRFE}). For timing diagrams see Annex E.

[f] FAC Transmission delay: This delay shall be applied between the first response of the meter and the next repeated response of the meter and all following repeated responses during the Frequent Access Cycle (FAC). The reference time point shall be the end of preamble (end of sync sequence) of the meter transmission. For timing diagrams see Annex E.

[g] The selected timeslot N shall be the same throughout the Frequent Access Cycle.

[h] FAC Time out: This is the time period between the last successful reception of a frame from the Other Device during the Frequent Access Cycle (FAC) and the moment where the repetition of the last response of the meter shall be stopped (end of Frequent Access Cycle).

Table 33. Transmit Parameters for C-mode (as defined in [1])

Characteristic	Class	Sym	Min	Typ	Max	Unit
Sensitivity (BER < 10^{-2}) or (PER < 0.8) (Other Device) [a]	H_R	P_o	-100	-105		dBm
Sensitivity (BER < 10^{-2}) or (PER < 0.8) (Meter) [a]	H_R	P_o	-95			dBm
Blocking performance [b]	L_R		3			Category
Blocking performance [b c]	M_R		2			Category
Blocking performance [b c d]	H_R		2			Category

[a] At a frame size of 20 bytes

[b] Receiver category according to ETSI EN 300 220-1, V2.4.1:2012, 4.1.1.

[c] Additional requirement for Class MR and Class HR receivers: The equipment shall meet the immunity requirements as specified in ETSI EN 301 489-1, V1.8.1:2008, 9.2 and in EN 301 489-3, V1.4.1:2002.

[d] Additional requirement for Class H_R receivers: Adjacent band selectivity shall be > 40 dB when measured according to ETSI EN 300 220-1, V2.3.1:2010, 8.3.

Table 34. Receive Parameters for C-mode (as defined in [1])

19 Appendix: R-mode Parameters

Characteristic	Sym	Min	Typ	Max	Unit	Note
Centre frequency (Other Device)			868,330		MHz	
Centre frequency (Meter)			868,030 +n × 0,06		MHz	
Frequency tolerance (Meter/Other Device)			0	± 17	kHz	~20 × 10^{-6} (ppm)
FSK Deviation		± 4,8	±6	± 7,2	kHz	
Chip rate (wakeup and communications)			4,8		kcps	
Chip rate tolerance (wakeup and communications)			0	± 1,5	%	
Digital bit jitter [a]				± 15	µs	
Data rate (Manchester encoding) [b]			f_{chip} × ½		bps	
Preamble length including bit/byte-sync	PL	96			chips	
Postamble (trailer) length [c]		2		8	chips	
Response delay [d] (Other Device to Meter communication)	t_{RO}	3		50	ms	
Response delay [d] (Meter to Other Device communication)	t_{RM}	10		10 000	ms	
FAC Transmission delay [e f]	t_{TxD}	N×1000 -1	N×1000	N×1000 +1	ms	N=5, 7 or 13
FAC Time out [g]	t_{TO}	25		30	s	

a The bit jitter shall be measured at the output of the micro-controller or encoder circuit.

b Each bit shall be coded as 2 chips (Manchester encoding).

c The postamble (trailer) shall consists of $1 \leq n \leq 4$ "ones" i.e. the chip sequence shall be n × (01).

d Response delay: The receiver shall be ready for the reception of a response in a time shorter than the minimum response delay, and shall be receiving at least until the maximum response delay (referred to the end of previous transmission). The response delay t_{RO} shall be used if the CI-field of received frame is 81_h, otherwise the response delay t_{RM} shall be used.

e FAC Transmission delay: describes the duration which a Meter shall delay the first response to a received message from Other Device referred to its last transmission. This delay shall also be applied between the first response of the Meter and the next repeated response of the Meter and all following repeated responses during the Frequent Access Cycle (FAC). The reference time point shall be the end of preamble (end of sync sequence) of the Meter transmission.

f The selected timeslot N shall be the same throughout the Frequent Access Cycle.

g FAC Time out: is the time period between the last successful reception of a frame from the Other Device during the Frequent Access Cycle (FAC) and the moment where the repetition of the last response of the Meter shall be stopped (end of Frequent Access Cycle).

Table 35. Transmit Parameters for R-mode (as defined in [1])

Characteristic	Class	Symb.	Min	Typ	Max	Unit	Note
Sensitivity (BER < 10^{-2}) or (PER < 0,8) [a]	H_R	P_o	-105	-110		dBm	
Blocking performance [b]	L_R		3			Category	
Blocking performance [b c]	M_R		2			Category	
Blocking performance [b c d]	H_R		2			Category	
Acceptable chip rate range		f_{chip}	4,7	4,8	4,9	kcps	~ ±2 %
Acceptable chip rate variation during header and frame		Df_{chip}		0	±0,2	%	

[a] At a frame size of 20 bytes.

[b] Receiver category shall be according to ETSI EN 300 220-1 V2.4.1:2012, 4.1.1

[c] Additional requirement for Class M_R and Class H_R receivers: The equipment shall meet the immunity requirements as specified in ETSI EN 301 489-1, V1.8.1:2008 , 9.2.

[d] Additional requirement for Class H_R receivers: Adjacent band selectivity shall be > 40 dB when measured according to ETSI EN 300 220-1, V2.3.1:2010,8.3.

Table 36. Receive Parameters for R-mode (as defined in [1])

20 Appendix: N-mode Parameters

In alignment with ETSI 300220v2.3.1, a new narrow-band “N”-mode physical (PHY) layer has been introduced within the draft EN13757-4:2011 document. The main reason for N-mode is to further increase the link budget for RF communication between meters and data collectors.

The 75 kHz ETSI band at 169.400 MHz has been split into 6 narrowband channels of 12.5 kHz each. Four channels of 4.8 kbps and two with 2.4 kbps, all using GFSK modulation, have been defined. A secondary communications link, capable of 19.2 kbps with 4-GFSK modulation, has been added as well with the purpose of optimizing data throughput in optional multi-hop links (e.g. from the Data Collector to the backhaul system) or could be used for battery power savings in the smart meters, if the distance to the data collector allows the usage of this higher data rate.

Submode	Channel [b]	Centre frequency [MHz]	Channel spacing [kHz]	GFSK [kbps]	4 GFSK [kbps]	Frequency tolerance [± kHz]
N1a, N2a	1a [c]	169,406250	12,5	4,8		1,5
N1b, N2b	1b	169,418750	12,5	4,8		1,5
N1c, N2c	2a	169,431250	12,5	2,4		2,0
N1d, N2d	2b	169,443750	12,5	2,4		2,0
N1e, N2e	3a	169,456250	12,5	4,8		1,5
N1f, N2f	3b [c]	169,468750	12,5	4,8		1,5
N2g	0 [d]	169,437500	50		19,2	2,5
a	1	169,412500	25			
a	2	169,437500	25			
a	3	169,462500	25			

a These channels are optional and reserved for future use or national specific use.
b Channel designation according to EU commission decision 2005/928/EC.
c These channels have to be preferred, when meter transmission needs to be retransmitted.
d This channel may be used for multi-hop retransmission of meter data as specified in EN 13757-5. The duty cycle for transmission from the meter shall be limited to 0,02 % in this channel.

Table 37. Frequencies for N-mode (as defined in [1])

Characteristic	Data rate	Sym	Min	Typ	Max	Unit	Note
GFSK Modulation (modulation index 2,0)	2,4 kbps		±1,68	±2,4	±3,12	kHz	70-130% of nominal deviation [a]
GFSK Modulation (modulation index 1,0)	4,8 kbps		±1,68	±2,4	±3,12	kHz	70-130% of nominal deviation [a]
4GFSK Modulation (modulation index 0,5)	19,2 kbps			-7,2, -2,4, +2,4, +7,2		kHz	
4GFSK peak modulation	19,2 kbps		±5,04		±9,36	kHz	70-130% of nominal deviation [a]
GFSK/4GFSK relative bandwidth	All	BT		0.5			
Bit/symbol rate tolerance	All				±100	ppm	
Preamble length	All	PL	16		16	bits or symbols	
Synchronization length	All	SL	16		16	bits or symbols	
Postamble (trailer) length	All			0		bits or symbols	
Fast response delay [b] (Other Device to Meter)	All	t_{RO}	99,5	100	100,5	ms	
Slow response delay [b] (Other Device to Meter)	2,4 kbps 4,8 kbps 19,2 kbps	t_{RO_slow}	2099,5 1099,5 1099,5		2100,5 1100,5 1100,5	ms	
FAC transmission delay [c d] (N2a to N2f)	2,4 kbps 4,8 kbps	t_{TxD}	N×100 0 -0,5	N×1000	N×100 0+0,5	ms	N=5,7 or 13
FAC transmission delay [c d] (N2g only)	19,2 kbps	t_{TxD}	N×100 0 -0,5	N×1000	N×100 0+0,5	ms	N= 2,3 or 5
FAC time out [e]	All	t_{TO}	25		30	s	

[a] Measured in centre of outer symbol (frequency vs. time eye opening) transmitting PN9 sequence, min/max based on rms error value

[b] The transmitter must start transmitting the preamble within this time delay after last bit of received frame.The use of slow or fast response delay is specified in the "Communication Control Field" of the Extended Link Layer – refer to section 12.2.2.3. For timing diagrams see Annex E. If an Extended Link Layer is not included in the frame, the default response delay shall be used.

[c] FAC Transmission delay: describes the duration which a Meter shall delay the first response to a received message from an Other Device referred to its last transmission. This delay shall also be applied between the first response of the Meter and the next repeated response of the Meter and all following repeated responses during the Frequent Access Cycle (FAC). The reference time point shall be the end of preamble (end of sync sequence) of the Meter transmission.

[d] The selected timeslot N shall be the same throughout the Frequent Access Cycle

[e] FAC Time out: is the time period between the last successful reception of a frame from the Other Device during the Frequent Access Cycle (FAC) and the moment where the repetition of the last response of the Meter shall be stopped (end of Frequent Access Cycle).

Table 38. Modulation and Timing for N-modes (as defined in [1])

Characteristic	Class	Sym	Min	Typ	Max	Unit	Note
Sensitivity (BER $<10^{-2}$) or (PER <0,8) [a] (Other Device /Meter) GFSK	H_R	P_O	-115	-123		dBm	2,4 kbps
Sensitivity (BER $<10^{-2}$) or (PER <0,8) [a] (Other Device /Meter) GFSK	H_R	P_O	-112	-120		dBm	4,8 kbps
Sensitivity (BER $<10^{-2}$) or (PER <0,8) [a] (Other Device /Meter) 4GFSK	H_R	P_O	-104	-107		dBm	19,2 kbps
Blocking Performance [b]	L_R		3			Category	
Blocking Performance [b c]	M_R		2			Category	
Blocking Performance [b c d]	H_R		2			Category	

a At a frame size of 20 bytes.

b Receiver category according to ETSI EN 300 220-1, V2.3.1-2010; 4.1.1.

c Additional requirements for Class M_R and Class H_R receivers: The equipment shall meet the immunity requirements as specified in ETSI EN 301 489-1, V1.8.1:2008, 9.2

d Additional requirement for Class H_R receivers: Adjacent band selectivity shall be > 40 dB when measured according to ETSI EN 300 220-1, V2.3.1:2010, 8.3.

Table 39. Receive Parameters for N-mode (as defined in [1])

21 Appendix: F-mode Parameters

Characteristic	Sym	Mode	Min	Typ	Max	Unit	Note
Centre frequency		All	433,813	433,82	433,827	MHz	16 ppm
FSK Deviation [a]		F2, F2-m	± 4.8	±5.5	± 7.0	kHz	
Data rate		F2, F2-m		2.4		kcps	
Data rate tolerance		All			± 100	ppm	
Response delay [b] (Meter to Other Device)	t_{RM}	F2-m	3	50	4000	ms	
Fast response delay [c d] (Other Device to Meter)	t_{RO}	F2	99,5	100	100,5	ms	
Slow response delay [c d] (Other Device to Meter)	t_{RO_slow}	F2	999,5	1000	1000,5	ms	
FAC transmission delay [e f]	t_{TxD}	F2	N×1000 -0,5	N×1000	N×1000 +0,5	ms	N= 5,7 or 13
FAC time out [g]	t_{TO}	F2	25		30	s	

[a] 75 - 125% of nominal deviation Measured in centre of chip (frequency vs. time eye opening) transmitting a 9 bit pseudo-random (PN9) sequence, min/max based on the root-mean-square (rms) error value. selected

[b] The time a Meter shall delay the response to a received message from an Other Device.

[c] After receiving a frame the responding unit must start the transmission of preamble after the specified response delay. The response delay is measured from the reception time of the last bit of the frame. For timing diagrams see Annex E.

[d] The use of slow or fast response delay is specified in the "Communication Control Field" of the Extended Link Layer – refer to section 12.2.2.3. For timing diagrams see Annex E. If an Extended Link Layer is not included in the frame, the default response delay shall be used.

[e] FAC Transmission delay: This delay shall be applied between the first response of the meter and the next repeated response of the meter and all following repeated responses during the Frequent Access Cycle (FAC). The reference time point shall be the end of preamble (end of sync sequence) of the meter transmission. For timing diagrams see Annex E.

[f] The selected timeslot N shall be the same throughout the Frequent Access Cycle.

[g] FAC Time out: This is the time period between the last successful reception of a frame from the Other Device during the Frequent Access Cycle (FAC) and the moment where the repetition of the last response of the Meter shall be stopped (end of Frequent Access Cycle).

If the frame is repeated (specified in the "Communication Control Field" of the Extended Link Layer – refer to section 12.2.2) the Other Device shall instead use a shorter response delay (t_{RR} or t_{RR_slow}) being 85 ms shorter than the corresponding t_{RO} or t_{RO_slow}. This enables bi-directional communication to be repeated without loss of communication speed. The frame from Meter to Other Device shall be repeated with a delay less than 5 ms (t_{DRF}). For timing diagrams see Annex E.

Table 40. Transmit Parameters for F-mode (as defined in [1])

Characteristic	Class	Sym	Min	Typ	Max	Unit	Note
Sensitivity (BER <10^{-2}) or (PER < 0,8) [a]	H_R	P_O	-115	-117		dBm	2.4 kbps
Blocking performance [b]	L_R		3			Category	
Blocking performance [b c]	M_R		2			Category	
Blocking performance [b c d]	H_R		2			Category	

[a] At a frame size of 20 bytes.

[b] Receiver category according to ETSI EN 300 220-1, V2.3.1-2010; 4.1.1.

[c] Additional requirements for Class M_R and Class H_R receivers: The equipment shall meet the immunity requirements as specified in ETSI EN 301 489-1, V1.8.1:2008, 9.2.

[d] Additional requirement for Class H_R receivers: Adjacent band selectivity shall be > 40 dB when measured according to ETSI EN 300 220-1, V2.3.1:2010, 8.3.

Table 41. Receive Parameters for F-mode (as defined in [1])

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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