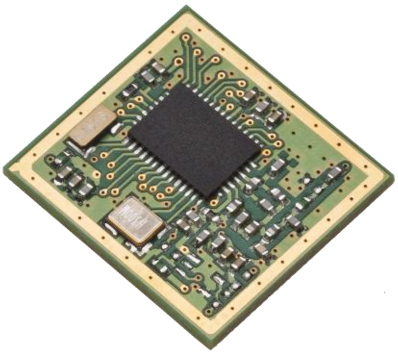
iM871A Wireless M-Bus

Application Note AN007

Sensitivity measurements with the iM871A Starter Kit



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1.0	Created, Preliminary Version
1.1	C1 and C2-Mode added to document

Aim of this Document

This application note describes how to verify the conformity to the Wireless M-Bus standard EN 13757-4.

Table of Contents

1. General

The iM871A is an ultra-low-power, high-performance, pre-certified Wireless M-Bus module fully compliant with EN 13757 part 4, Wireless M-Bus standard.

The module offers a cost-effective wireless solution for smart metering applications connecting water, heat, electricity and gas meters with data concentrators. It operates in the 868 MHz frequency band and it supports all unidirectional and bidirectional Wireless M-Bus modes (S1, S2, T1, T2, R2, C1 and C2) and the highest power class defined by the Wireless M-Bus standard.

With a standby current of less than 1 μA, the iM871A is well suited for battery powered devices like water and gas meters. The pre-certified module provides a serial interface as well as analog and digital inputs and outputs and can easily be integrated into a meter. With its integrated Wireless M-Bus protocol stack it will reduce the development time and cost. The iM871A can achieve a link budget up to 120 dB, resulting in exceptional RF range and communication performance.

For detailed information about the iM871A refer to [1].

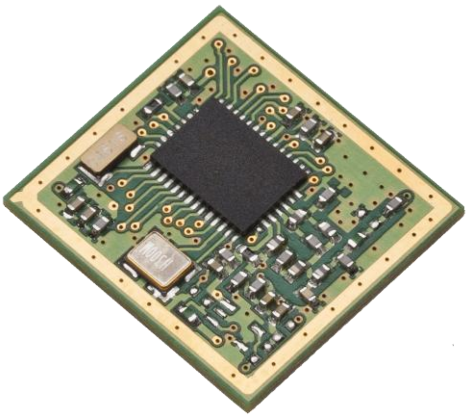

Figure 1-1: iM871A

2. Bit and Packet Error Rate

Real transmission channels affect a decrease of the performance of the whole communication system. The quality of communication can be degraded by rising distance between the communication units and interfering systems communicating on adjacent channels (e.g.). Consequently the communication systems should provide a high link budget, as well as sufficient channel selectivity of the receiver.

A high link budget can be reached by transmitting a RF signal with high power level. But the main part of the link budget is additionally given by the receiver sensitivity. The receiver sensitivity describes a minimum input signal power level which allows signal processing with acceptable error rates.

The sensitivity is typically obtained by applying an adequate modulated signal to the receiver. Then the signal power level is increased/decreased until the desired Bit Error Rate (BER) or Packet Error Rate (PER) is reached.

The difference between BER and PER simply is given by the view of error level, i.e. the BER is described by the number of corrupted bits occurring in a received signal. In contrast the PER describes the number of whole corrupted packets, which are received.

If the PER is being analyzed, it has to be kept in mind, that a packet consists of further more blocks in addition to the payload, e.g. a sync-word or a CRC checksum. They have to be included to the packet length, against any preamble sequence, which has to be excluded. So there are two different kinds of length descriptions used in the following: L describes the whole packet length, L' is the packet length excluding the preamble sequence.

Assuming independent and uniformly distributed bit errors, the PER can be approximated by a given packet length L' using the BER as follows by Equation 1. Alternatively the BER can be obtained by a given PER.

$$PER = 1 - (1 - BER)^{L'} \Leftrightarrow BER = 1 - (1 - PER)^{1/L'} \qquad \text{(Eq. 1)}$$

The results of typical M-Bus packets (as given in Chapter 6.1) are depicted in Figure 2-1. The relation between BER and PER of the R2-Mode is equal to the S1 mode example here, because there is only a difference in the length of the preamble sequence.

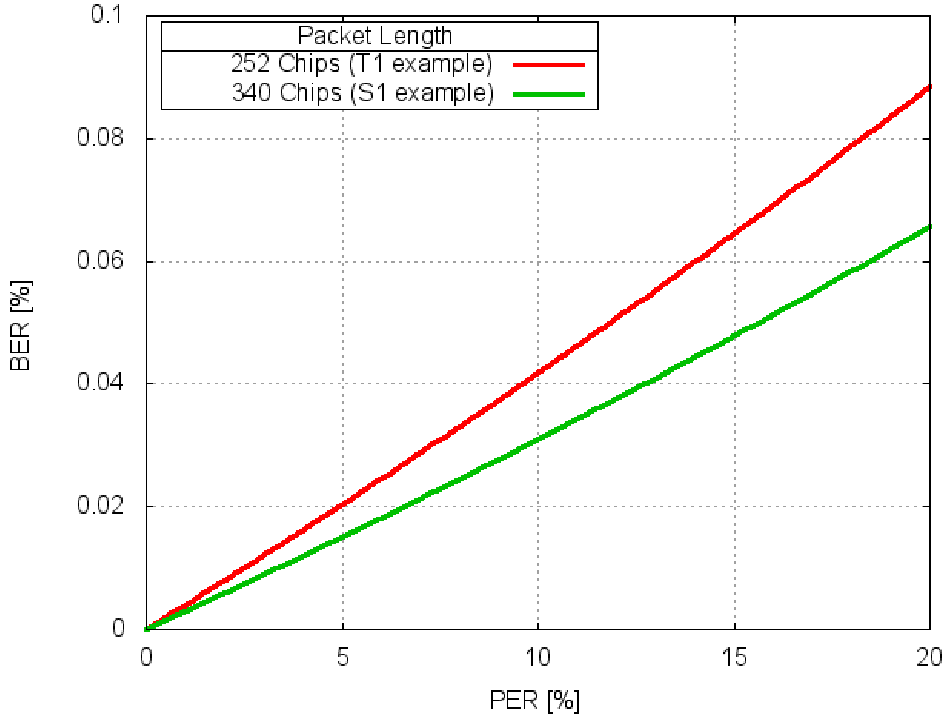

Figure 2-1: BER vs. PER with packets excluding preamble

Finally, as depicted in Figure 2-1, a PER of 20 % leads to a BER which is less than 0.1 %.

Using this relation the developer is not only able to evaluate the system performance on the physical layer, but it is also possible to get performance data of the firmware running on the module.

3. Sensitivity Measurements with the iM871A

Sensitivity measurements with the iM871A can be done by different approaches. A very easy way for obtaining first performance data of the iM871A is given by the provided Radio Link Test as described in [2]. Using additional attenuators, this method can be extended for emulating desired 'distances'.

A disadvantage of this method is the missing possibility for testing communication with devices transmitting with a frequency offset, e.g. caused by different temperatures. Other parameters which can degrade the system performance are an alternative frequency deviation in modulation or a tolerance in data rate.

Therefore an exact evaluation as required by the Wireless M-Bus Standard EN13757-4 [3] needs testing with defined source signals. So it is recommended to use an adequate RF Signal Generator, e.g. Rohde & Schwarz SMIQ06B.

3.1 Test Setup

Figure 3-1 gives an overview of the test setup, which should be used for evaluating the iM871A's system performance.

The RF Signal Generator is used for transmitting RF signals. It should be configured as given in Chapter 3.2. The RF output of the Signal Generator has to be connected to the RF SMA Connector *X6* of the iM871A's Adapter Board. The connection should be done via an adequate 50 Ω RF coaxial cable. The attenuation of the cable should be noted.

The power supply of the Starter Kit easily can be done via an USB connection to *J1* of the Starter Kit, which is required for the communication with the Wireless M-Bus Studio [4], running on a PC. In this case, the Switch *S1* has to be set to 'USB' and the iM871A is supplied by an voltage of 3 V. If the module should be supplied with a different supply voltages, an external power supply can be connected to *X8* of the Demo Board or two AAA Batteries can be used. In both cases, *S1* has to be switched to 'BAT'.

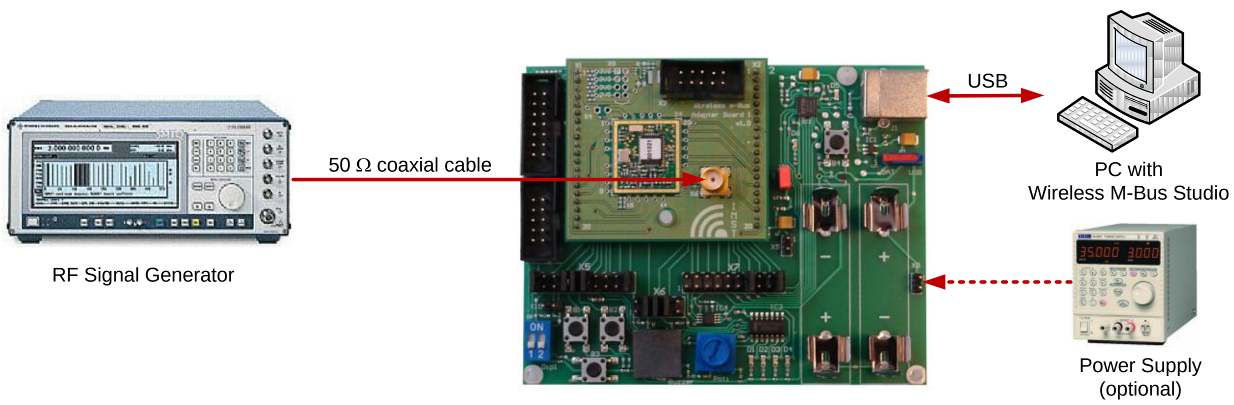

Figure 3-1: Test setup for evaluating the iM871A sensitivity performance[1]

[1] Figures obtained from manufacturers Websites

3.2 Generating RF Test Signals

For reproducible measurement results, testing should be performed using defined RF signals. Therefore it is recommended to obtain RF test signals of a RF signal generator. The configuration of the signal generator depends on the Wireless M-Bus mode and the device mode which is represented by the iM871A (meter or other). The basic settings can be obtained from Table 3-1. The parameters of the signal generator to be set are

- Center frequency
- Frequency deviation
- Data rate[1]
- Binary structure of Wireless M-Bus Packet

Desired iM871A (Receive) Mode		**Required Signal Generator Settings[2]**			
Wireless M-Bus Mode	**Device Mode**	**Modulation Parameter**	**Data Rate [kbps]**	**Center Frequency [MHz]**	**Packet Structure**
S1	Other	2-FSK	32.768	868.3	Appendix 6.1.1
S1-m	Other	2-FSK	32.768	868.3	
S2	Meter	2-FSK	32.768	868.3	
	Other	2-FSK	32.768	868.3	
T1	Other	2-FSK	100	868.95	Appendix 6.1.2
T2	Meter	2-FSK	32.768	868.3	
	Other	2-FSK	100	868.95	
R2	Meter	2-FSK	4.8	868.33	Appendix 6.1.3
	Other	2-FSK	4.8	$868.03 + 0.06n \,\vert_{n=1..9}$	
C1	Other	2-FSK	100	868.95	Appendix 6.1.4
C2	Meter	2-GFSK, BT=0.5	50	869.525	
	Other	2-FSK	100	868.95	

Table 3-1: Parameter settings of the signal generator for appropriate Wireless M-Bus modes

After the signal generator has been configured, the modulated RF test signal can be applied to the RF connector of the iM871A Starter Kit (Connector X6). It is recommended, to use a cable connection between the module and the signal generator, because the final measurement results have to be calibrated with the attenuation between the two devices. Finally the sensitivity level P_0 is given by the transmitted power level P_{TX} of the signal generator minus the cable attenuation α_0.

$$P_0\,[dBm] = P_{TX}\,[dBm] - \alpha_0\,[dB] \qquad \text{(Eq. 2)}$$

[1] The signal generator doesn't care of signal coding thus the data rate is given by kbps either than kcps here

[2] The signal generator settings have to be that parameter, which are expected by the iM871A using the appropriate device mode. For more details refer to [3].

3.3 Configuration of the iM871A

Relating to the device mode selected by Table 3-1, the iM871A has to be configured with the desired mode. This could be done using the provided Wireless M-Bus Studio.

If C1 or C2-Mode is desired to be used, the Wireless M-Bus Firmware has to be of version 1.2 (or later).

First make sure, that the iM871A is successfully connected to the Wireless M-Bus Studio. If the device is configured with the default factory parameters, only the device mode, the link mode and the radio channel (only if using link mode R2) have to be configured as required. The configuration can be done via the Configuration Page, as depicted in Figure 3-2.

Please refer to [2] for further information concerning the Wireless M-Bus Studio.

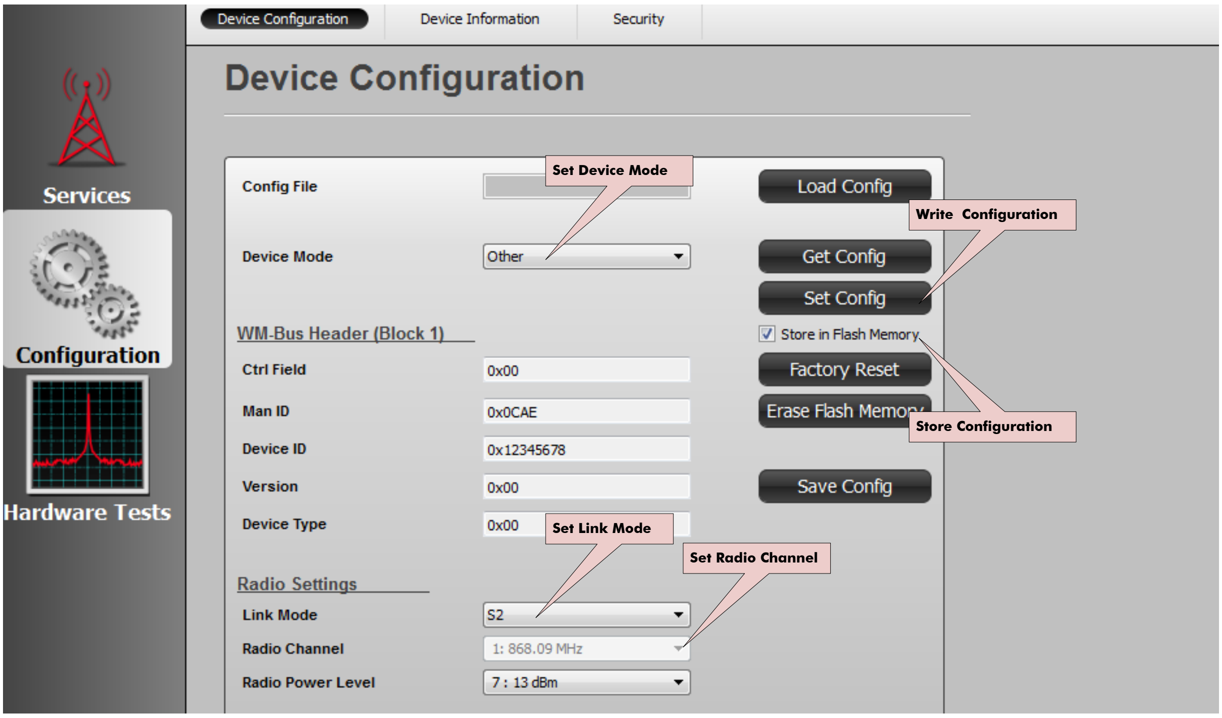

Figure 3-2: Required configuration parameters for testing

In case of using the device in meter-mode, the RX-Window size should be set to 0 ms. If not, the device will stay in low power mode until a packet is received.

3.4 Obtaining Packet Information

The iM871A supports different kinds of statistical counters related to the processed packets. To get information about this counters, the System Status Page should be viewed. As depicted in Figure 3-3 the number of valid received packets (since the last device reset) can be obtained by clicking the Read Status button.

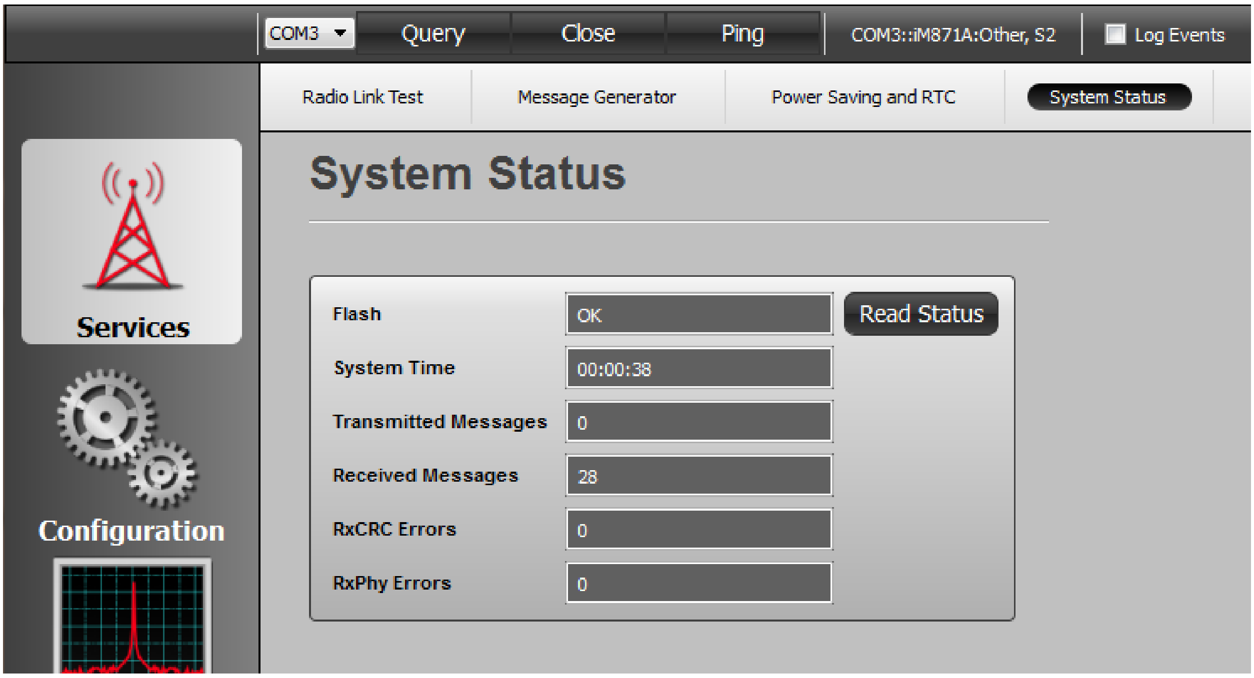

Figure 3-3: Obtaining packet information of the iM871A

If a packet is sent by the signal generator with an adequate power level the counter for valid packets (Received Messages) increases.

3.5 Calculating Packet Error Rate

To calculate the *PER*, it is required to know the number of transmitted packets N_{TX} by the signal generator, as well as the number of valid received packets N_{Val} by the iM871A. Then the *PER* is given by the following Equation 3.

$$PER\ [\%] = \left(1 - \frac{N_{Val}}{N_{TX}}\right) \cdot 100\% \qquad \text{(Eq. 3)}$$

4. Performing PER Tests

In the following the sensitivity of the iM871A versus different RF parameters will be obtained as required by [3]. The Wireless M-Bus standard specifies minimum receiver sensitivity versus

- Frequency offset of the center frequency f_C
- Variation of frequency deviation Δf_C
- Tolerance of data rate f_{kbps}

Finally, measurement data can be obtained which give a characterization of the RF performance data. In the following, these diagrams are measured as instructed by the Wireless M-Bus specification, which specifies a maximum PER of less than 20%.

The measurements are done using the following measurement parameters:

- 200 packets per data point (packet structure as described in Chapter 6.1)
- Packet transmit interval $T_{TX} \gg \frac{L}{f_{kbps}}$

Mode	T_{Tx} [ms]
S	40
T	25
R2	150
C	40

Table 4-1: Packet transmit interval of measurements

- The measurements are done with constant temperature of 25°C using an Temperature Test Chamber
- An external supply voltage of 3.0 V is used

4.1 Sensitivity versus Center Frequency Offset

In [3] a sensitivity level versus frequency offset is defined. Using S and T mode with the highest power class requirements, a minimum of -100 dBm over a frequency offset of ±50 kHz has to be reached. In R2 Mode there should be a minimum of -105 dBm for an offset of ±17 kHz to fulfill the requirements of the highest power class. C mode requires, depending on the device mode, -100 dBm if acting as Other and -95 dBm if the device is in meter mode. A frequency offset of ±22 kHz is required for both. Obtaining measurement data of the iM871A, the results are as follows:

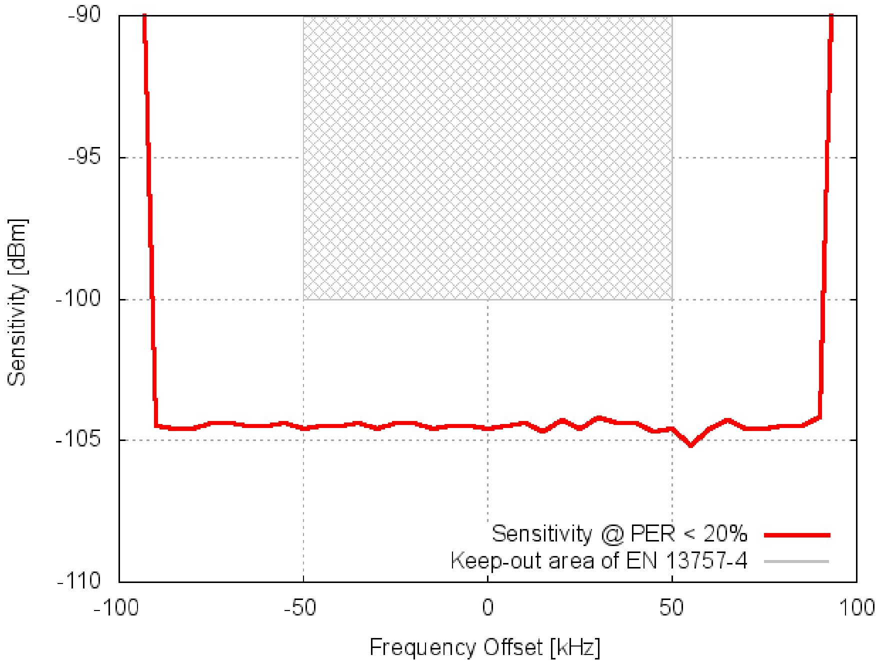

Figure 4-1: S-Mode receiver sensitivity vs. frequency offset at PER ≤ 20%, f_C=868.3 MHz, Δf_C=80 kHz, f_{kbps}=32.768 kbps

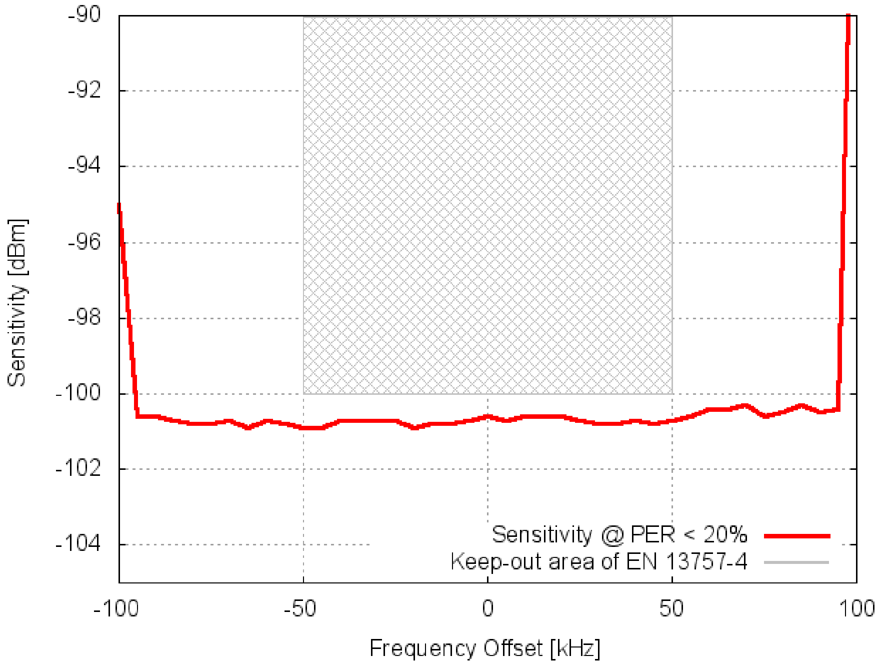

Figure 4-2: T-Mode receiver sensitivity vs. frequency offset at PER ≤ 20%, f_C=868.95 MHz, Δf_C=80 kHz, f_{kbps}=100 kbps

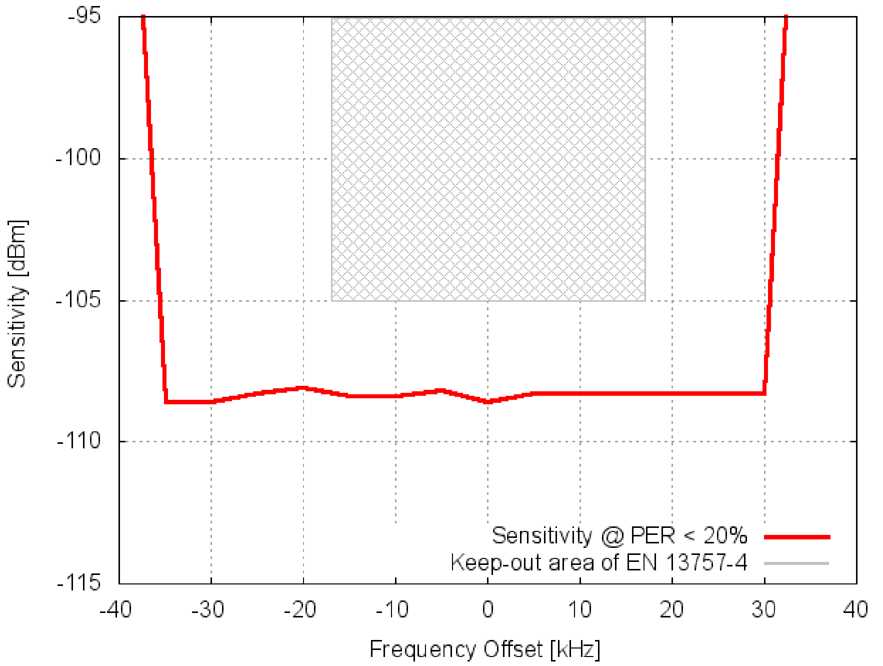

Figure 4-3: R2-Mode receiver sensitivity vs. frequency offset at PER ≤ 20%, f_C=868.09 MHz (Channel 1), Δf_C=7.2 kHz, f_{kbps}=4.8 kbps

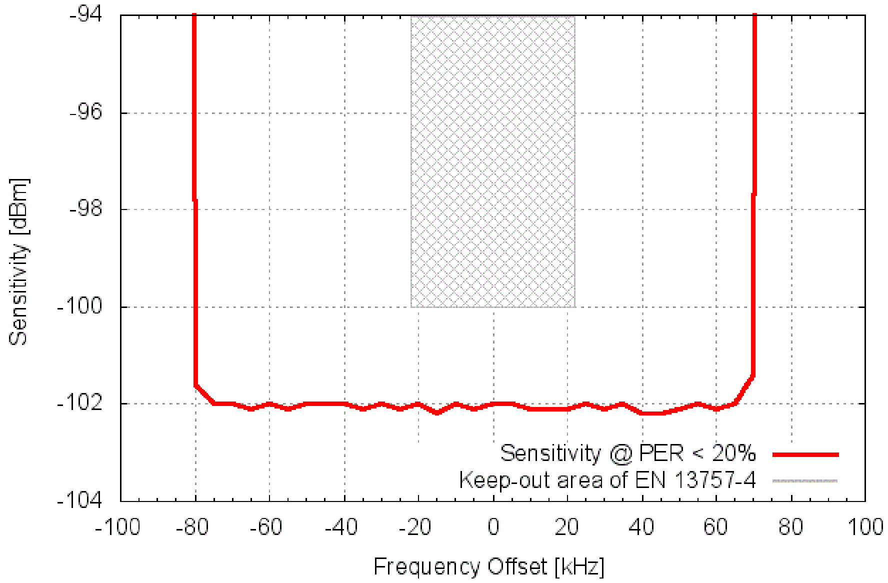

Figure 4-4: C2-Mode (Other) receiver sensitivity vs. frequency offset at PER ≤ 20%, f_C=868.95 MHz, Δf_C=47 kHz, f_{kbps}=100 kbps

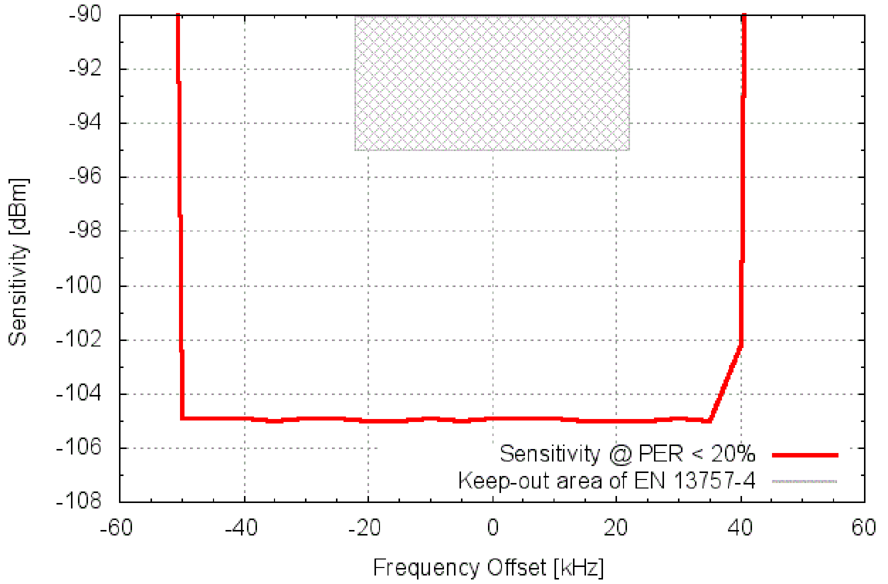

Figure 4-5: C2-Mode (Meter) receiver sensitivity vs. frequency offset at PER ≤ 20%, f_C=869.525 MHz, Δf_C=27 kHz, f_{kbps}=50 kbps

4.2 Sensitivity versus Frequency Deviation

For fully conformity to [3] the minimum sensitivity limit of S and T mode of -100 dBm has to be complied for a frequency deviation between 40 and 80 kHz. Using R2 mode, the sensitivity level has to be greater than -105 dBm for a frequency deviation between 4.8 and 7.2 kHz. C mode requires a minimum sensitivity to operations with frequency deviations between 23 and 27 kHz (meter mode) and between 43 and 47 kHz (other mode). The minimum sensitivity level is -95 dBm for meter mode and -100 dBm for other mode. The measurement result of the iM871A can be found in the following diagrams.

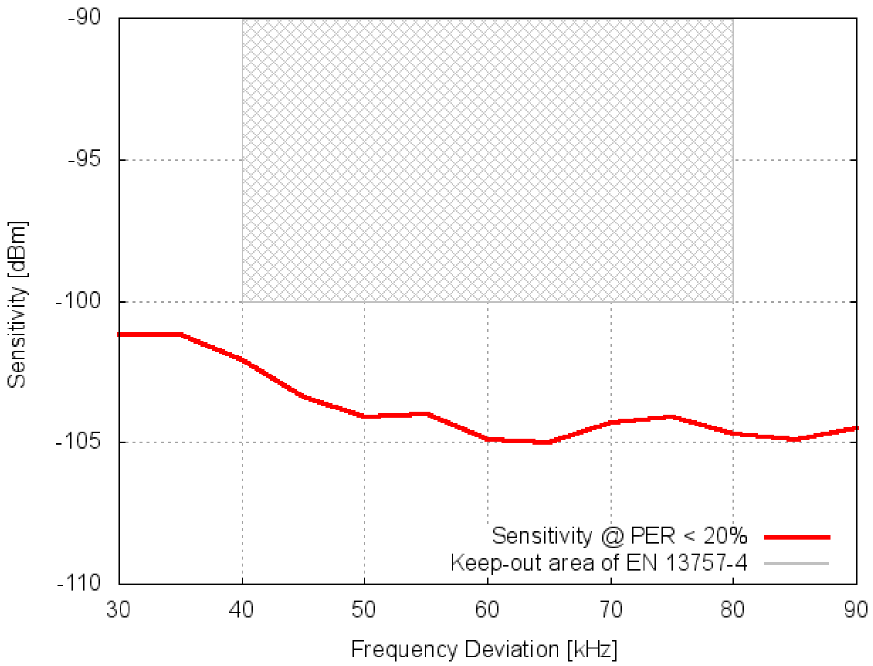

Figure 4-6: S-Mode receiver sensitivity vs. frequency deviation at PER ≤ 20%, f_C=868.3 MHz, f_{kbps}=32.768 kbps

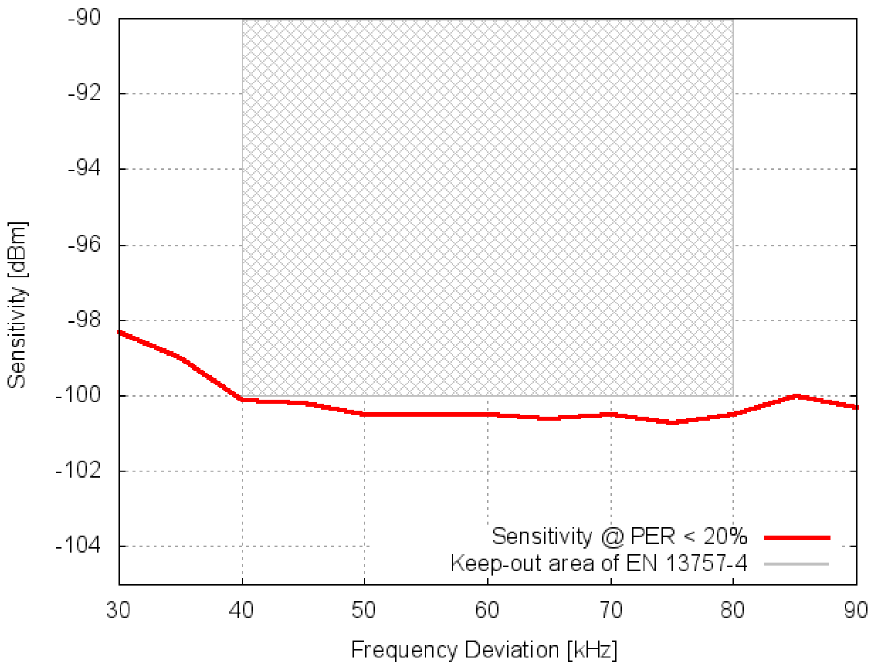

Figure 4-7: T-Mode receiver sensitivity vs. frequency deviation at PER ≤ 20%, f_C=868.95 MHz, f_{kbps}=100 kbps

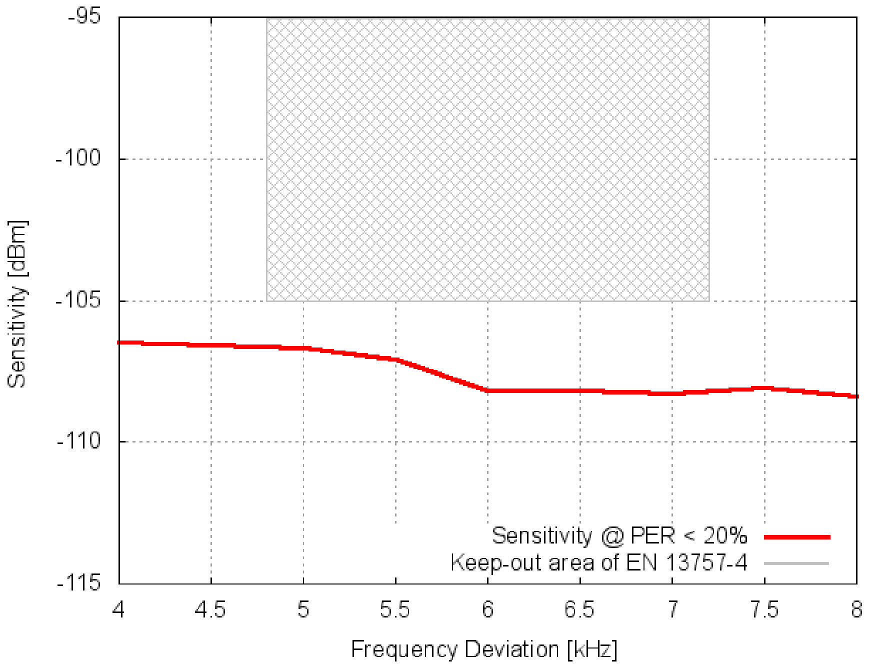

Figure 4-8: R2-Mode receiver sensitivity vs. frequency deviation at PER ≤ 20%, f_C=868.09 MHz (Channel 1), f_{kbps}=4.8 kbps

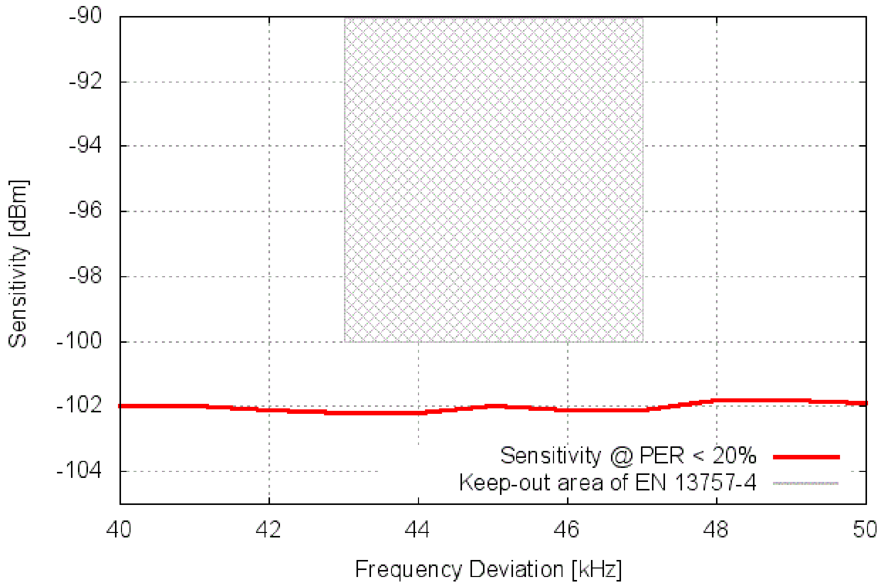

Figure 4-9: C2-Mode (Other) receiver sensitivity vs. frequency deviation at PER ≤ 20%, f_C=868.95 MHz, f_{kbps}=100 kbps

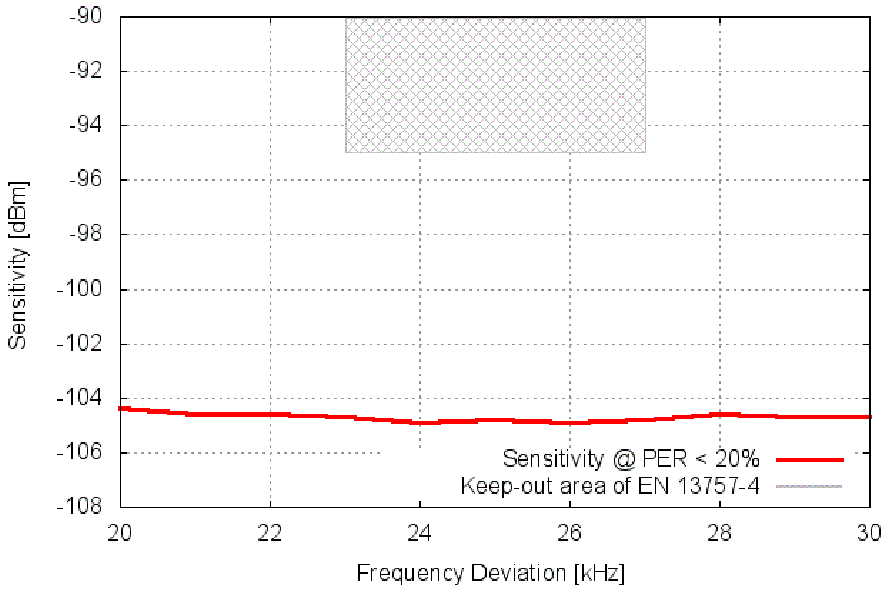

Figure 4-10: C2-Mode (Meter) receiver sensitivity vs. frequency deviation at PER ≤ 20%, f_C=869.525 MHz, f_{kbps}=50 kbps

4.3 Sensitivity versus Data Rate

Wireless M-Bus systems which are fully compliant to [3] have to be resistant against data rate variations. Therefore a minimum sensitivity level of -100 dBm (S and T mode) and -105 dBm (R2 Mode) is defined for data rate tolerances of up to 1.5 % by the highest power class. Additionally there is a data rate range given for T-Mode between 90 and 110 kcps. In C mode, a data rate error of ±100 ppm should be able to be processed in meter and other mode. Here, the minimum sensitivity level are -95 dBm in meter mode and -100 dBm in other mode again. The measurement results of the iM871A are as follows:

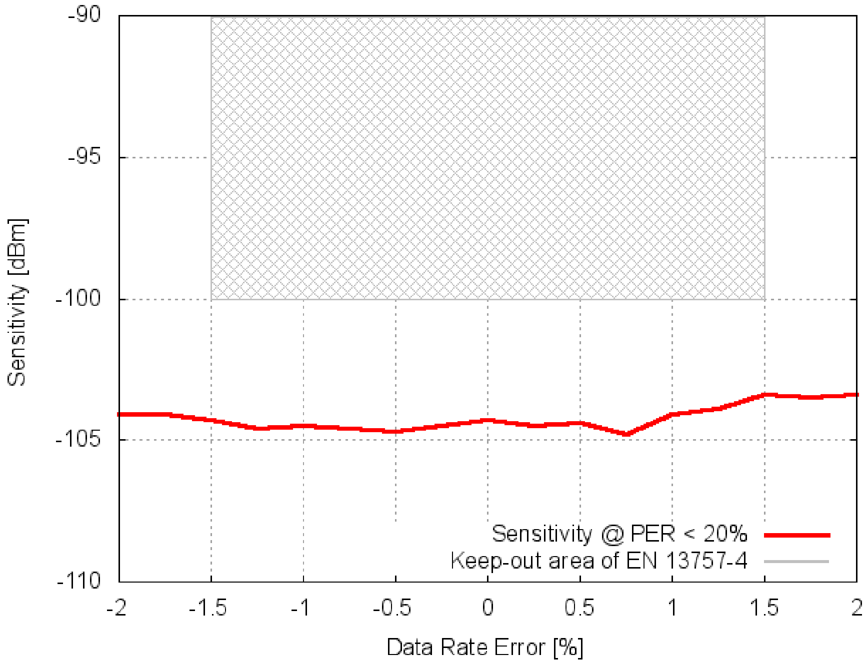

Figure 4-11: S-Mode receiver sensitivity vs. data rate tolerance at PER ≤ 20%, f_C=868.3 MHz, Δf_C=80 kHz, f_{kbps}=32.768 kbps

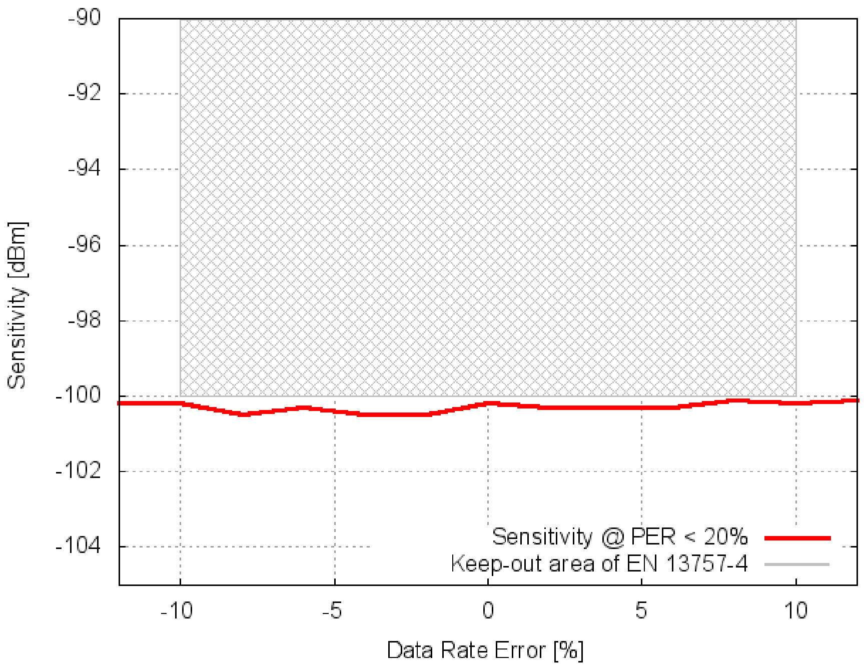

Figure 4-12: T-Mode receiver sensitivity vs. data rate tolerance at PER ≤ 20%, f_C=868.95 MHz, Δf_C=80 kHz, f_{kbps}=100 kbps

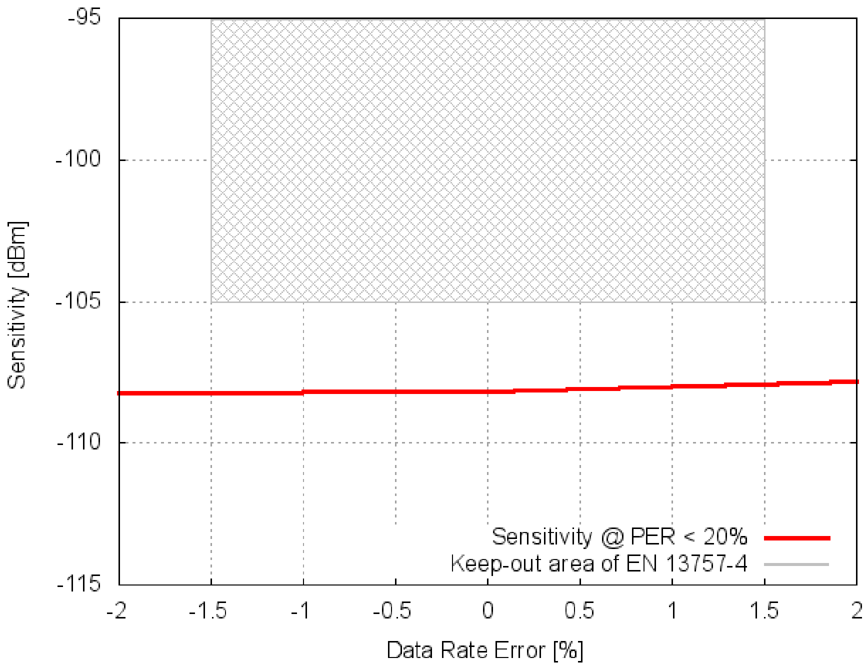

Figure 4-13: R2-Mode receiver sensitivity vs. data rate tolerance at PER ≤ 20%, f_C=868.09 MHz (Channel 1), Δf_C=7.2 kHz, f_{kbps}=4.8 kbps

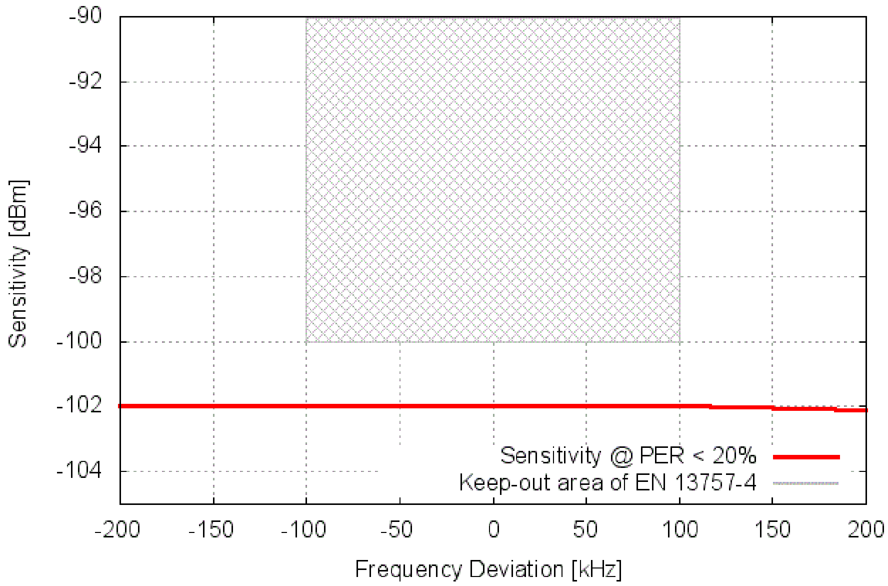

Figure 4-14: C2-Mode (Other) receiver sensitivity vs. data rate tolerance *at PER ≤ 20%, f_C=868.95 MHz, Δf_C=47, f_{kbps}=100 kbps*

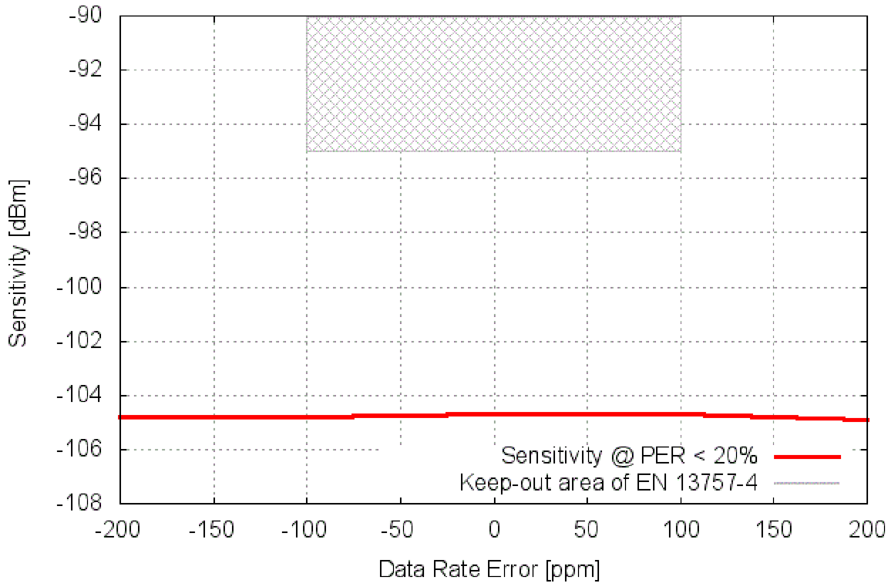

Figure 4-15: C2-Mode (Meter) receiver sensitivity vs. data rate tolerance *at PER ≤ 20%, f_C=869.525 MHz, Δf_C=27 kHz, f_{kbps}=50 kbps*

5. Conclusion

In this document a method is given which allows obtaining relevant performance data of the iM871A's receiver. With this method an evaluation of the iM871A can be performed for verifying the compliancy to the Wireless M-Bus Standard EN13757-4:2011 [3].

As shown by the measurement results in Chapter 4, the iM871A is able to fulfill the requirements of S and T Mode using the highest power class, which requires a minimum sensitivity level of -100 dBm versus a frequency offset of up to ±50 kHz. Furthermore this requirements are fulfilled using frequency deviation of modulation of 40 to 80 kHz and a data rate tolerance of up to 1.5 %.

In S-Mode the iM871A provide a sensitivity level of -104.5 dBm and in T-Mode it is possible to reach -101 dBm. Using the R2-Mode, the Wireless M-Bus standard requires -105 dBm if using the highest power class. As shown by the measurements, the iM871A is able to provide a sensitivity level of -108.5 dBm.

Additionally the iM871A is able to act in C mode. In other mode, the iM871A is able to receive signals down to a sensitivity level of -102 dBm. If acting as Meter, it is possible to receive signals down to -104 dBm, which is 9 dB above the required limit of the Wireless M-Bus standard.

Summarizing, the iM871A provides with its high sensitivity level an excellent receiver performance. Additionally, the iM871A is able to transmit with a RF power level up to +14 dBm. With its high receiver sensitivity and a maximum RF output power level, the iM871A provides a link budget greater than 6 dB, as required by the Wireless M-Bus Standard. This improvement should be kept in mind, because an increase of the link budget of 6 dB leads to an doubling of free space distance.

6. Appendix

6.1 Wireless M-Bus Telegram Structures

In the following the telegrams used for verification of the iM871A are listed. These telegrams are equal to the telegrams described in the appendix of [3].

- Preamble
- Wireless M-Bus sync-word
- Payload
- Postamble
- CRC

6.1.1 S1-Mode

L = 898 L' = 340

```
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
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0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0100 0111 0110 1001 0110
1010 1010 0101 0101 1001 1010 1001 1010 0110 0110 0101 0110
1010 1010 0101 1010 1001 0101 0110 1010 1001 1001 1001 0110
1010 0101 1001 1010 1010 1001 1010 0110 1010 1010 1010 1001
1010 1010 1001 0101 1001 1010 1001 1010 1001 1010 1001 0101
1001 0101 0110 1010 1010 1010 0110 0101 1010 1001 1010 0101
1001 1010 1010 0101 1001 0110 1001 1001 0110 1010 1001 0101
1010 1001 0101 0110 1001 0110 0101 1001 01
```

6.1.2 T1-Mode

L = 290 L' = 252

```
0101 0101 0101 0101 0101 0101 0101 0101 0101 0100 0011 1101
0101 1010 1001 0111 0001 1100 1001 1011 0010 0101 1011 0100
0100 1110 1100 0110 0101 1010 0010 1101 1100 0011 0100 1110
0101 1000 1101 0101 1001 0011 0111 0001 1100 0111 0001 0011
0100 1110 1100 0101 1010 0011 0011 0100 1011 0111 0000 1011
0110 1001 1001 1011 0001 0011 0011 0111 0010 0110 1011 0001
01
```

6.1.3 R2-Mode

L = 424 L' = 340

0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101
0101 0101 0101 0101 0101 0101 0101 0101 0101 0001 1101 1010
0101 1010 1010 1001 0101 0110 0110 1010 0110 1001 1001 1001
0101 1010 1010 1001 0110 1010 0101 0101 1010 1010 0110 0110
0101 1010 1001 0110 0110 1010 1010 0110 1001 1010 1010 1010
1010 0110 1010 1010 0101 0110 0110 1010 0110 1010 0110 1010
0101 0110 0101 0101 1010 1010 1010 1001 1001 0110 1010 0110
1001 0110 0110 1010 1001 0110 0101 1010 0110 0101 1010 1010
0101 0110 1010 0101 0101 1010 0101 1001 0110 0101

6.1.4 C2-Mode (Other & Meter)

L = 264 L' = 228

0101 0101 0101 0101 0101 0101 0101 0101 0101 0100 0011 1101 0101
0100 1100 1101 0001 0100 0100 0100 1010 1110 0000 1100 0111 1000
0101 0110 0011 0100 0001 0010 0000 0001 0000 0100 0101 0000 0011
1111 0111 0010 0000 0000 0001 0001 0010 0010 0011 0011 0100 0100
0101 0101 0110 0110 0111 0111 1000 1000 1001 1001 1011 1101 1011
0001

6.2 List of Measurement Devices

Power Supply:	TTI QL355P
Signal Generator:	Rhode & Schwarz, SMIQ06B
DUT:	IMST GmbH, Wireless M-Bus Starter Kit with Module iM871A, Firmware: WMBus (Version 0.3), Host: Wireless M-Bus Studio (Version 0.1.9)
Temperature Test Chamber:	Vötsch, VT4002
RF Cable:	Suhner, Sucoflex 104
PC:	Standard Windows-PC

6.3 List of Abbreviations

BER = Bit Error Rate

CRC = Cyclic Redundancy Check

PER = Packet Error Rate

RF = Radio Frequency

USB = Universal Serial Bus

6.4 List of Symbols

α_0 = RF Cable Attenuation (dB)

BER = Bit Error Rate

Δf_C = Frequency Deviation (Hz)

f_C = Center Frequency (Hz)

f_{kbps} = Data Rate (bps)

L = Packet length (including Preamble)

L' = Packet length (excluding preamble)

N_{TX} = Number of transmitted packets

N_{Val} = Number of received valid packets

PER = Packet Error Rate

P_0 = Sensitivity Level (dBm)

P_{TX} = Transmitted Power Level (dBm)

T_{TX} = Packet Transmit Interval(s)

6.5 List of Figures

6.6 List of Tables

6.7 References

[1] iM871A Datasheet

[2] Wireless M-Bus Studio User Manual

[3] EN13575-4:2011
Communication systems for meters and remote reading of meters

[4] http://www.wireless-solutions.de

7. Regulatory Compliance Information

The use of radio frequencies is limited by national regulations. The radio module has been designed to comply with the European Union's R&TTE (Radio & Telecommunications Terminal Equipment) directive 1999/5/EC and can be used free of charge within the European Union. Nevertheless, restrictions in terms of maximum allowed RF power or duty cycle may apply.

The radio module has been designed to be embedded into other products (referred as "final products"). According to the R&TTE directive, the declaration of compliance with essential requirements of the R&TTE directive is within the responsibility of the manufacturer of the final product. A declaration of conformity for the radio module is available from IMST GmbH on request.

The applicable regulation requirements are subject to change. IMST GmbH does not take any responsibility for the correctness and accuracy of the aforementioned information. National laws and regulations, as well as their interpretation can vary with the country. In case of uncertainty, it is recommended to contact either IMST's accredited Test Center or to consult the local authorities of the relevant countries.

8. Important Notice

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