WiMOD - iM880B

Application Note AN016 / Version 1.1

RF Settings

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1.0	Preliminary version.
1.1	Table 3-1, Table 7-1, Table 7-2 and Table 7-3 updated

Aim of this Document

Aim of this document is to give an overview about the possible RF settings of iM880B for the 868 MHz frequency band.

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1 Overview

Aim of this document is to give an overview about the possible RF settings for iM880B in LoRa^{TM} mode, especially the frequency settings for the 868 MHz frequency band.

2 Introduction

The iM880B is a compact, low power, bidirectional radio module for the 868 MHz frequency band using Semtech's LoRa^{TM} spread spectrum modulation technique. The module provides ultra-long range spread spectrum communication and high interference immunity whilst minimising current consumption.

The LoRa^{TM} modulation, in contrast to conventional modulation techniques, permits an increase in link budget and increases immunity to in-band interference. It achieves sensitivities 8 dB better than traditional FSK modulation and it also provides significant advantages in both blocking and selectivity, solving the traditional design compromise between range, interference immunity and energy consumption.

In LoRa^{TM} mode the iM880B offers three bandwidth options of 125 kHz, 250 kHz, and 500 kHz with spreading factors ranging from 7 to 12 and four different error detection and correction schemes. This provides a maximum of flexibility for user application.

Spreading Factor	Chips/Symbol	SNR [dB]
7	128	-7.5
8	256	-10
9	512	-12.5
10	1024	-15
11	2048	-17.5
12	4096	-20

Table 2-1: Spreading Factors from the data sheet of Sx1272

Note that the spreading factor must be known in advance on both transmit and receive sides of the radio link as different spreading factors are orthogonal to each other.

To further improve the robustness of the radio link iM880B provides cyclic error coding with different coding rates.

Coding Rate	Cyclic Coding Rate	Overhead Ratio
1	4/5	1.25
2	4/6	1.5
3	4/7	1.75
4	4/8	2

Table 2-2: Coding Rate of iM880B

3 Applicable Frequency Bands and Sub-Bands

Following table depicts the applicable frequency bands within the 868 MHz band for "Non-Specific Short Range Devices" specified in the ERC Recommendation 70-03, [2].

Band	Edge Frequencies		Field Power	Spectrum Access	Band Width
g (Note1,2)	863 MHz	870 MHz	+14 dBm	0.1% or LBT+AFA	7 MHz
(Note 2)	863 MHz	870 MHz	-4.5 dBm / 100 kHz	0.1% or LBT+AFA	7 MHz
(Note 2)	865 MHz	870 MHz	-0.8 dBm / 100 kHz	0.1% or LBT+AFA	5 MHz
(Note 1)	865 MHz	868 MHz	+14 dBm	1% or LBT+AFA	3 MHz
g1	868.0 MHz	868.6 MHz	+14 dBm	1% or LBT+AFA	600 kHz
g2	868.7 MHz	869.2 MHz	+14 dBm	0.1% or LBT+AFA	500 kHz
g3	869.4 MHz	869.65 MHz	+27 dBm	10% or LBT+AFA	250 kHz
g4	869.7 MHz	870 MHz	+14 dBm	1% or LBT+AFA	300 kHz
g4	869.7 MHz	870 MHz	+7 dBm	No requirement	300 kHz
Note1: Modulation bandwidth ≤ 300 kHz is allowed. Preferred channel spacing is ≤ 100 kHz. Note2: Sub-bands for alarms are excluded (see ERC/REC 70-03 Annex 7).					

Table 3-1: Applicable Frequency Bands for Non-Specific Short Range Devices.

Note: 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.

4 Frequency Setting

The iM880A uses a 32 MHz crystal for its RF oscillator. The carrier frequency f_{RF} is given by:

$$f_{RF} = f_{STEP} * F_{rf}[23,0],$$

where F_{rf} is a 24 bit register value of Sx1272 and the frequency synthesizer step given by:

$$f_{STEP} = 32\ \text{MHz} / 2^{19}$$

$$\Rightarrow \quad F_{rf}[23,0] = \text{floor}\ (f_{RF} / f_{STEP})$$

See "Radio Configuration Field" of [4].

5 Frequency Error

Generally the total frequency error f_e of an oscillator is mainly a combination of the initial error f_{eini}, temperature drift error f_{etemp} and aging error f_{eage}.

$$f_e \approx f_{eini} + f_{etemp} + f_{eage}$$

For the iM880B the following maximum frequency errors are specified:

- initial frequency variation of ±10 ppm
- frequency variation within the temperature range of -40°C to +85°C is ±15 ppm
- frequency variation due to ageing over 10 years is ±5 ppm

The maximum total frequency variation is ±30 ppm (±26kHz at 868MHz).

The following figure depicts the typically frequency drift versus the temperature range of the iM880B.

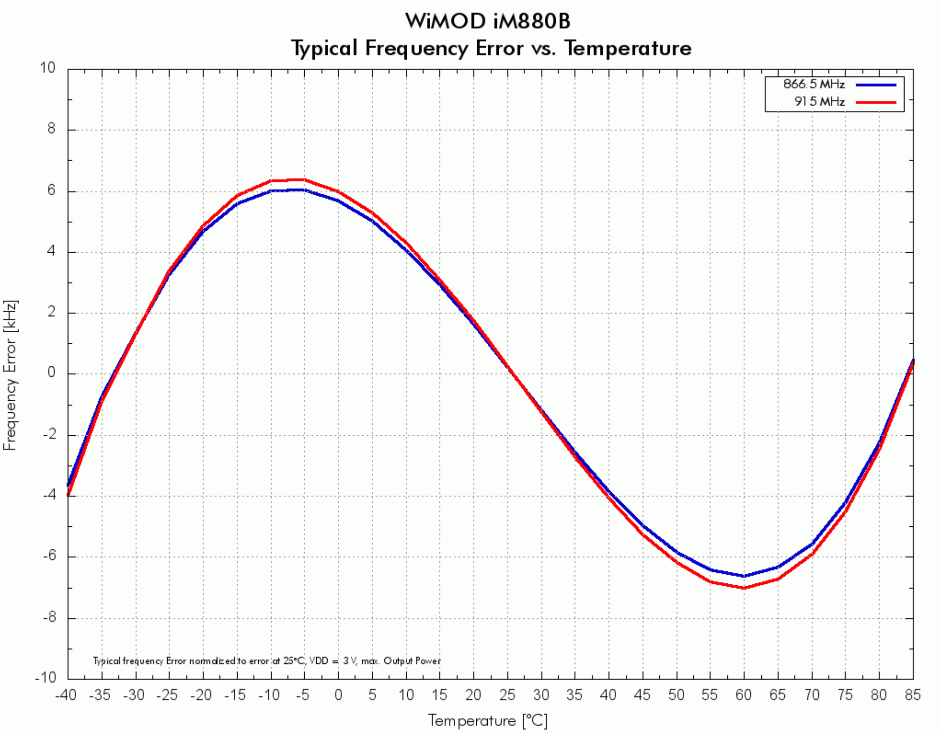


Figure 5-1: Frequency error vs. temperature.

6 Modulation Bandwidth

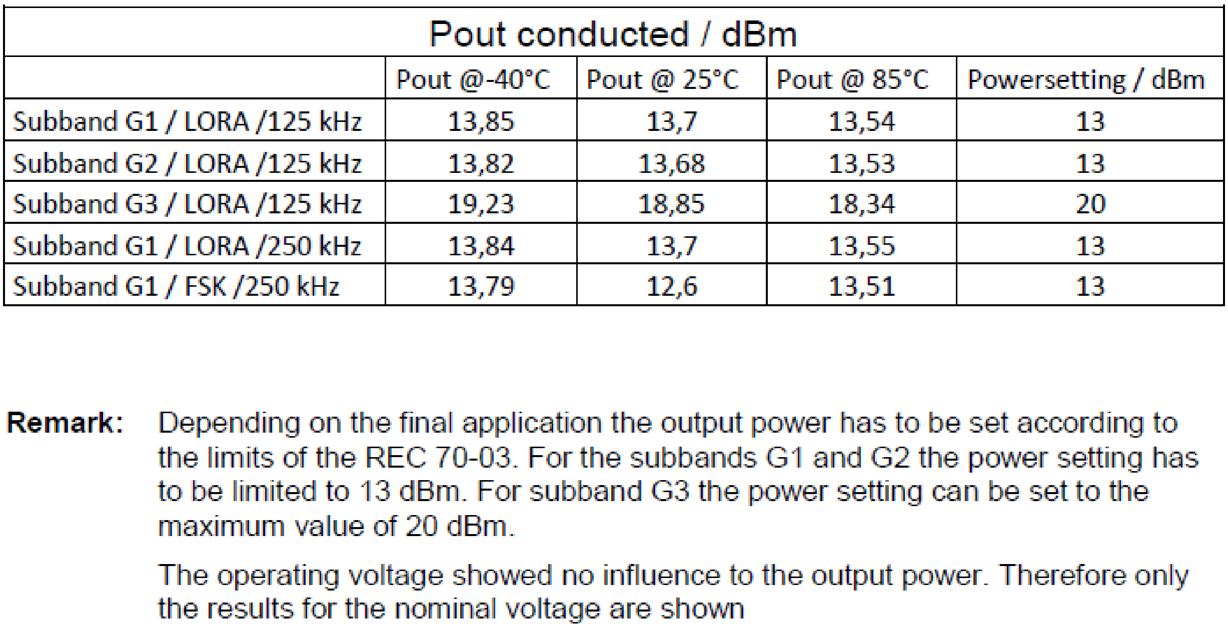
Within ETSI EN 300 220 [3] the modulation bandwidth is given as “the difference between the two frequencies f_a and f_b obtained with a resolutions bandwidth 1 kHz and level 1 μW”.

This emission limits must be met under both normal and extreme conditions (frequency error and drift). Additional requirements e.g. for emission limits at the band edge frequencies are given also in [3].

Due to the fact that in LoRa™ mode the iM880B offers three signal bandwidth options 125 kHz, 250 kHz, 500 kHz and six different spreading factors all reasonable combinations of modulation bandwidth are given within the following tables.

All measurements have been carried out conducted for temperature range from -40°C to +85°C and therefore consider initial frequency error and temperature drift error.

Within [6] the following measurements results have been determined:



Pout conducted / dBm				
	Pout @-40°C	Pout @ 25°C	Pout @ 85°C	Powersetting / dBm
Subband G1 / LORA /125 kHz	13,85	13,7	13,54	13
Subband G2 / LORA /125 kHz	13,82	13,68	13,53	13
Subband G3 / LORA /125 kHz	19,23	18,85	18,34	20
Subband G1 / LORA /250 kHz	13,84	13,7	13,55	13
Subband G1 / FSK /250 kHz	13,79	12,6	13,51	13

Remark: Depending on the final application the output power has to be set according to the limits of the REC 70-03. For the subbands G1 and G2 the power setting has to be limited to 13 dBm. For subband G3 the power setting can be set to the maximum value of 20 dBm.

The operating voltage showed no influence to the output power. Therefore only the results for the nominal voltage are shown

Figure 6-1: Measurement results from ERM report.

Depending on the used antenna and frequency subband the corresponding power settings has to be used. E.g. if the antenna is an ideal half wave dipole with 2.15dBi gain the power setting for G1 subband should not exceed 13 dBm.

6.1 Signal Bandwidth Setting 125 kHz

The smallest signal bandwidth for the iM880B in LoRa™ mode is 125 kHz. With this configuration the highest sensitivity can be achieved.

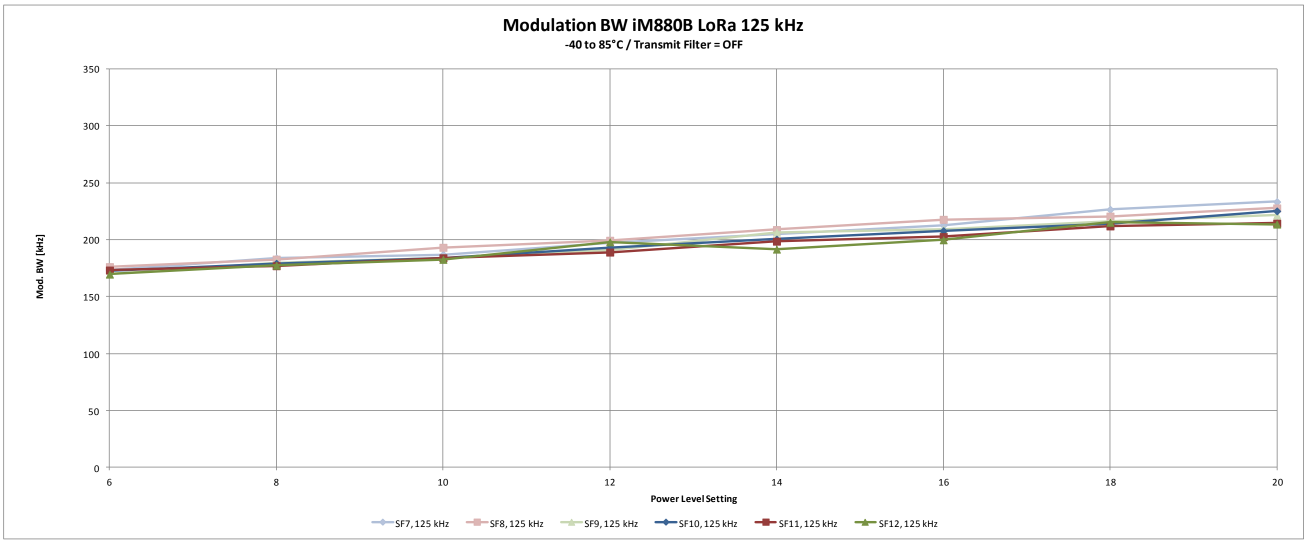


Figure 6-2: Modulation bandwidth of a 125 kHz LoRa signal.

6.2 Signal Bandwidth Setting 250 kHz

In addition to 125 kHz signal bandwidth iM880B provides the 250 kHz bandwidth setting. In comparison with the smallest signal bandwidth setting this setting enables an increase the effective data rate, but also decreases sensitivity.

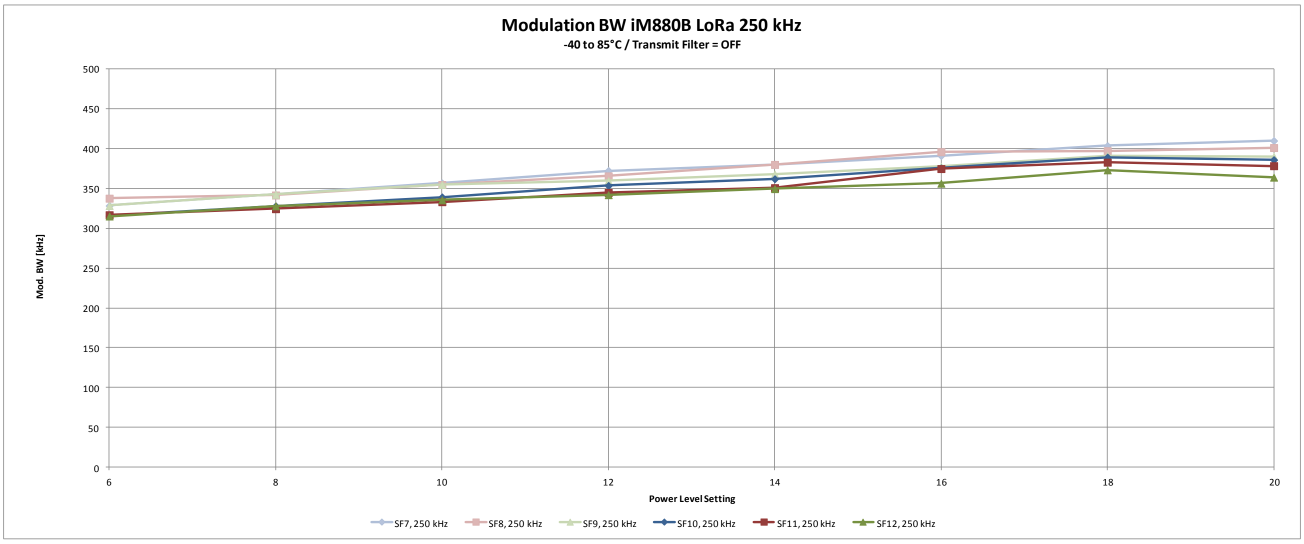


Figure 6-3: Modulation bandwidth of a 250 kHz LoRa signal.

6.3 Signal Bandwidth Setting 500 kHz

The highest signal bandwidth of iM880B in LoRa^{TM} mode allows using the maximum of effective data rate.

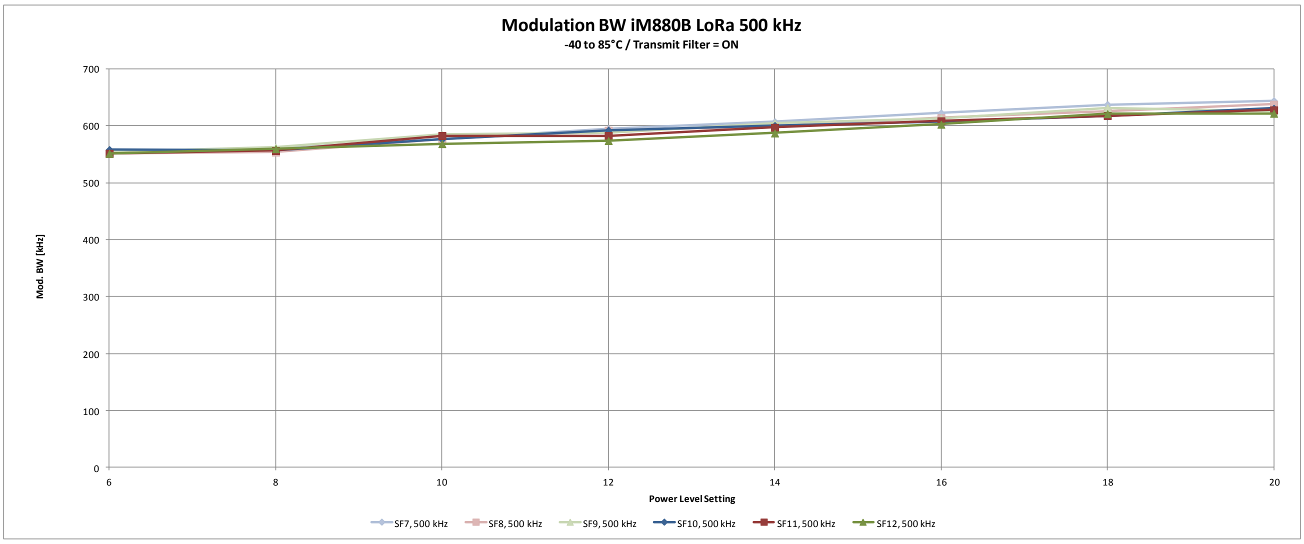


Figure 6-4: Spectrum of a 500 kHz LoRa signal.

7 Recommended Frequency Settings

The iM880B uses the PA-BOOST power amplifier of the Sx1272. Power levels of -4.5 dBm and -0.8 dBm are not accessible and are therefore not considered.

7.1 Signal Bandwidth Setting 125 kHz

Band	Edge Frequencies		Field Power	Lowest Center Frequency	Highest Center Frequency
	f_a	f_b			
g (Note1,2)	863 MHz	870 MHz	+14 dBm	f_a + 0.13 MHz	f_b – 0.13 MHz
	865 MHz	868 MHz	+14 dBm	f_a + 0.13 MHz	f_b – 0.13 MHz
g1	868.0 MHz	868.6 MHz	+14 dBm	f_a + 0.13 MHz	f_b – 0.13 MHz
g2	868.7 MHz	869.2 MHz	+14 dBm	f_a + 0.13 MHz	f_b – 0.13 MHz
g3	869.4 MHz	869.65 MHz	+20 dBm	869.525 MHz	869.525 MHz
g4	869.7 MHz	870 MHz	+14 dBm	869.850 MHz	869.850 MHz
g4	869.7 MHz	870 MHz	+7 dBm	869.850 MHz	869.850 MHz
Note1: Modulation bandwidth ≤ 300 kHz is allowed. Preferred channel spacing is ≤ 100 kHz. Note2: Sub-bands for alarms are excluded (see ERC/REC 70-03 Annex 7).					

Table 7-1: Center frequencies for settings 125 kHz LoRa signal bandwidth.

7.2 Signal Bandwidth Setting 250 kHz

Band	Edge Frequencies		Field Power	Lowest Center Frequency	Highest Center Frequency
	f_a	f_b			
g (Note1,2)	863 MHz	870 MHz	+14 dBm	Note 3	Note 3
	865 MHz	868 MHz	+14 dBm	f_a + 0.2 MHz	f_b – 0.2 MHz
g1	868.0 MHz	868.6 MHz	+14 dBm	f_a + 0.2 MHz	f_b – 0.2 MHz
g2	868.7 MHz	869.2 MHz	+14 dBm	868.950 MHz	868.950 MHz
g3	869.4 MHz	869.65 MHz	+27 dBm	-	-
g4	869.7 MHz	870 MHz	+14 dBm	-	-
g4	869.7 MHz	870 MHz	+7 dBm	-	-
Note1: Modulation bandwidth ≤ 300 kHz is allowed. Preferred channel spacing is ≤ 100 kHz. Note2: Sub-bands for alarms are excluded (see ERC/REC 70-03 Annex 7).					

Table 7-2: Center frequencies for settings 250 kHz LoRa signal bandwidth.

Note 3: The use of 863 MHz to 870 MHz with signal bandwidth of 250 kHz is possible when reducing the output power so that the modulation bandwidth is less than 300 kHz.

7.3 Signal Bandwidth Setting 500 kHz

Band	Edge Frequencies		Field Power	Lowest Center Frequency	Highest Center Frequency
	f_a	f_b			
g (Note1,2)	863 MHz	870 MHz	+14 dBm	-	-
	865 MHz	868 MHz	+14 dBm	f_a + 0.4 MHz	f_b – 0.4 MHz
g1	868.0 MHz	868.6 MHz	+14 dBm	868.300 MHz*	868.300 MHz*
g2	868.7 MHz	869.2 MHz	+14 dBm	-	-
g3	869.4 MHz	869.65 MHz	+27 dBm	-	-
g4	869.7 MHz	870 MHz	+14 dBm	-	-
g4	869.7 MHz	870 MHz	+7 dBm	-	-
Note1: Modulation bandwidth ≤ 300 kHz is allowed. Preferred channel spacing is ≤ 100 kHz. Note2: Sub-bands for alarms are excluded (see ERC/REC 70-03 Annex 7). *Only in combination with Spectral Transmit Filter setting.					

Table 7-3: Center frequencies for settings 500 kHz LoRa signal bandwidth.

8 Duty Cycle

To design a communication system not only the range is of interest. Also data throughput and duty cycle are important. The duty cycle requirements from [2] are given in column “Spectrum Access” of Table 3-1. A systems duty cycle is given as the sum of all total packet air times within one hour related to one hour. To calculate the packet air time the structure of a RF packet must be known.

8.1 Packet Structure

The following figure outlines the message format which is used for communication purposes. The HCI message must contain a Destination Endpoint Identifier and a Message Identifier followed by the user payload. The first 24 Bits of the user payload must include the destination address information, Destination Group Address and Destination Device Address.

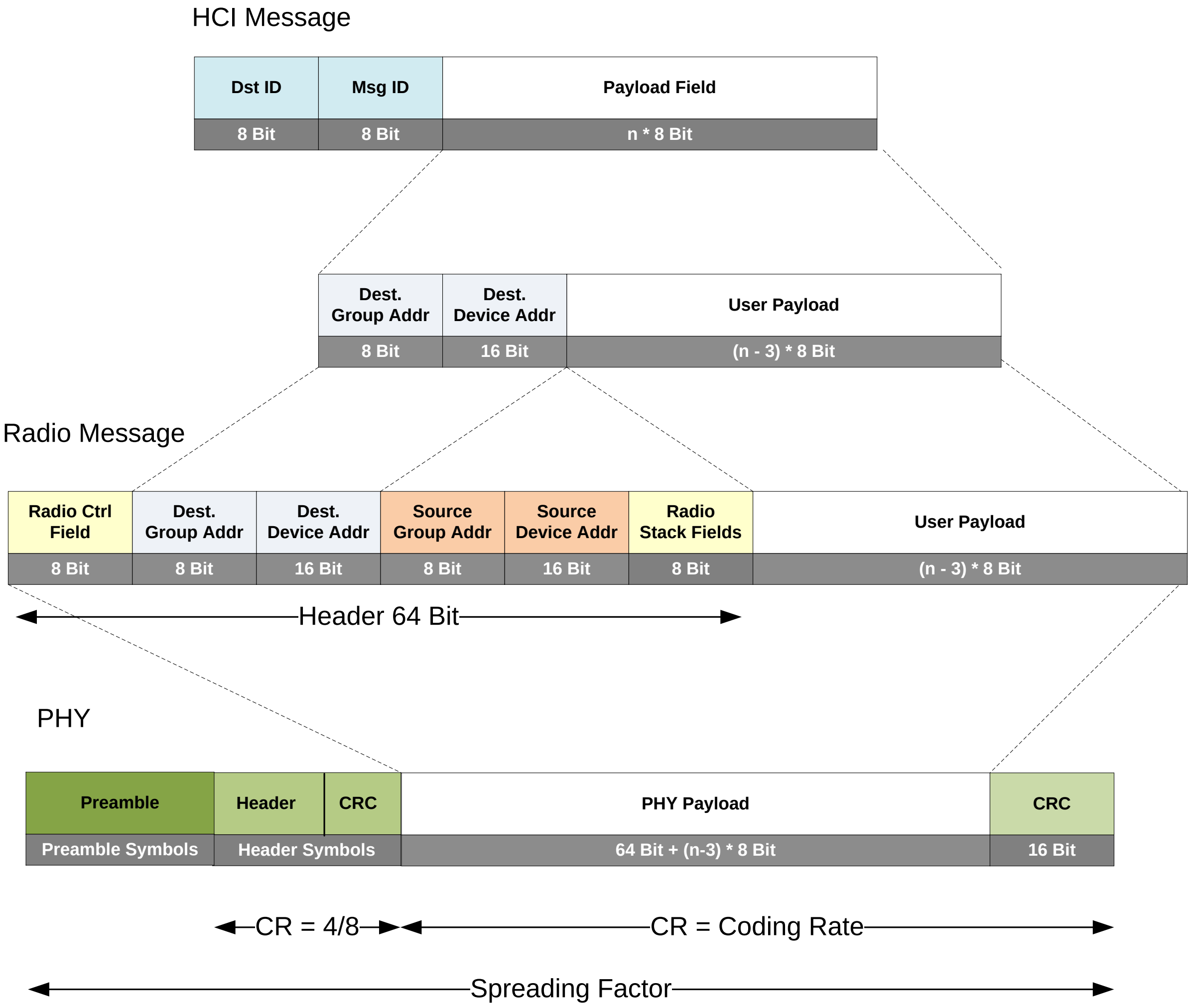


Figure 8-1: iM880B packet structure

The firmware of the module extends the data with 6 additional Bytes, the Radio Control Field, the Source Address Information and the Radio Stack Field.

Within the transceiver frontend (Sx1272) this data is extended with a PHY-Preamble, a PHY-Header including its own CRC and a PHY-Payload-CRC. The (explicit) header is error coded with a coding rate of CR = 4/8 separately. The payload and the PHY-CRC is error coded according to the configured coding rate (CR). The whole packet is then spread with the configured spreading factor (SF).

8.2 Air Time and RF Data Rate

In LoRa™ mode the packet air time is influenced by the:

- payload size (3 Byte destination address information)
- the firmware adds 6 Bytes overhead
- bandwidth option (SB =125 kHz, 250 kHz, 500 kHz)
- spreading factor (SF = 7, 8, 9, 10, 11, 12)
- error correction scheme (CR = 4/5, 4/6, 4/7, 4/8)
- preamble length (8 symbols are used)
- header mode (explicit header is used)
- low data rate optimization (activated for SB = 125 kHz and SF = 11, 12)

Semtech provides a tool [5] to calculate the packet air time for different configurations. With this packet air time the duty cycle and the equivalent bit rate can be calculated.

Appendix

8.3 List of Abbreviations

8.4 List of Figures

8.5 List of Tables

8.6 References

[1] Semtech Sx1272 Data Sheet from www.semtech.com

[2] REC Recommendation 70-03 “Relating to the use of Short Range Devices (SRD)”, Tromsø 1997, CEPT ECC subsequent amendments 9 th October 2012

[3] ETSI EN 300 220-1, V2.4.1 “Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW”; Part 1: Technical characteristics and test methods. May 2012.

[4] WiMODLR_HCI_Spec.pdf from www.wireless-solutions.de

[5] LoRa calculator from http://www.semtech.com/apps/product.php?pn=SX1272

[6] ERM_Testreport_WiMOD_iM880B.pdf, ERM Test Report: ETSI EN 300 220-2 V2.4.1 (2012-01)

9 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.

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