WiMOD - iM880A

Application Note AN012 / Version 1.1

RF Settings

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1.1	Chapter 8 added

Aim of this Document

Aim of this document is to give an overview about the possible RF settings for iM880A.

Table of Contents

1 Overview

Aim of this document is to give an overview about the possible RF settings for iM880A in LoRa™ mode, especially the frequency settings.

2 Introduction

The iM880A is a compact, low power, bidirectional radio module for the 868 MHz frequency band using Semtech's LoRa™ spread spectrum modulation technique. The module provides ultra-long range spread spectrum communication and high interference immunity whilst minimising current consumption.

The LoRa™ 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™ mode the iM880A 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 iM880A 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 iM880A

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
	865 MHz	868 MHz	+6.2 dBm / 100 kHz	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:

$$f_{STEP} = 32\ \text{MHz} / 2^{19} \approx 61.0\ \text{Hz}$$

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}.

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

With the iM880A, there is a expected inital frequency error of ±10 ppm. During production test, this inital frequency error is calibrated below a range of ±1 kHz[1].
The following figure depicts the typically frequency drift versus the temperature range of the iM880A.

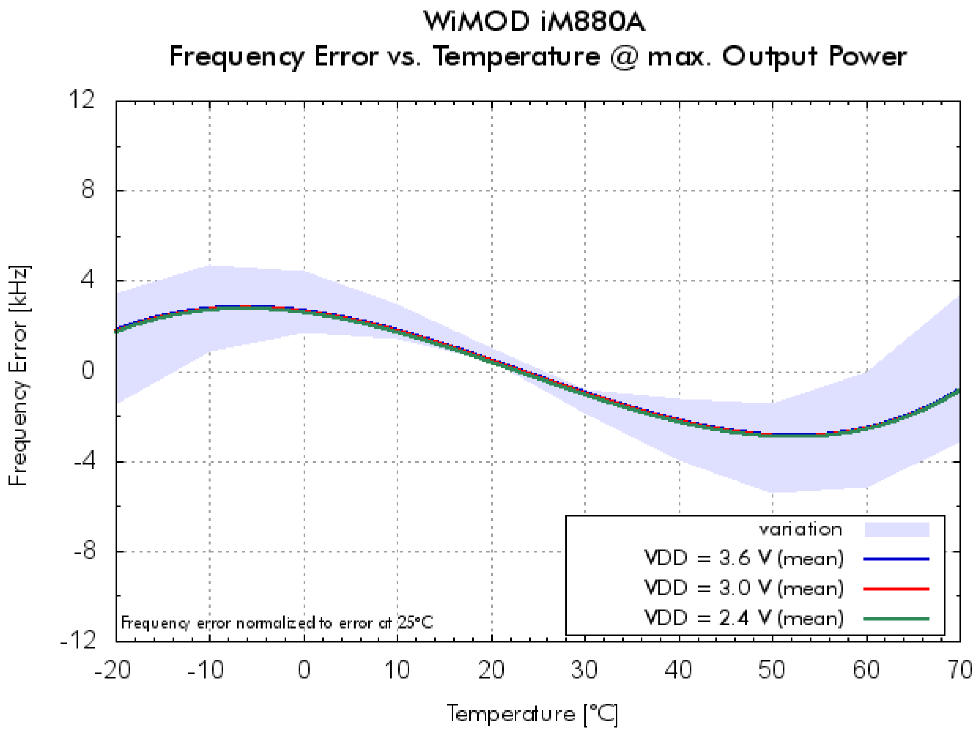

Figure 5-1: Frequency error vs. temperature.

The frequency error due to aging is determined by:

$$f_{eage} \approx \pm 8.7 \text{ kHz (up to 10 years @ 25°C)}$$

[1] IMST Firmware is required

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 iM880A 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 -20°C to +70°C and therefore consider initial frequency error and temperature drift error.

6.1 Signal Bandwidth Setting 125 kHz

The smallest signal bandwidth for the iM880A in LoRa™ mode is 125 kHz. With this configuration the highest sensitivity can be achieved.

For the 125 kHz signal bandwidth setting up to +20 dBm output power can be configured, see chapter 3 and chapter 7.

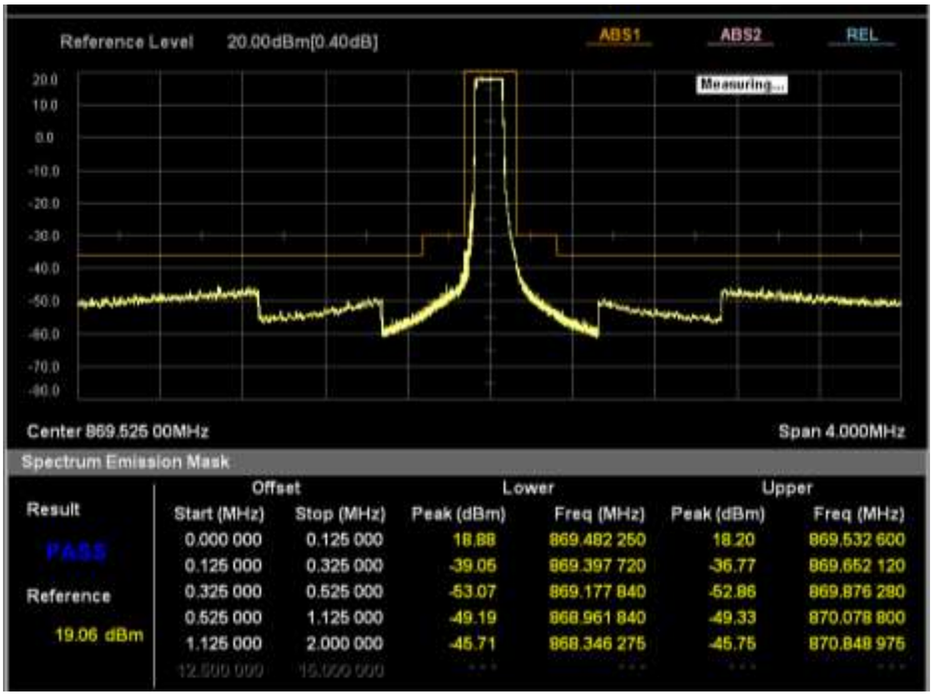

Figure 6-1: Spectrum of a 125 kHz LoRa signal with +20 dBm setting for g3 band.

Field Power	Signal Bandwidth Setting	Spreading Factor	Typical Modulation Bandwidth
+14 dBm	125 kHz	7	191 kHz
+14 dBm	125 kHz	8	180 kHz
+14 dBm	125 kHz	9	177 kHz
+14 dBm	125 kHz	10	175 kHz
+14 dBm	125 kHz	11	176 kHz
+14 dBm	125 kHz	12	175 kHz
VDD = 2.4 - 3.6 V; T = -20°C – +70°C if nothing else stated			

Table 6-1: Typical modulation bandwidth for settings 125 kHz LoRa signal bandwidth and +14 dBm output power.

Field Power	Signal Bandwidth Setting	Spreading Factor	Typical Modulation Bandwidth
+20 dBm	125 kHz	7	207 kHz
+20 dBm	125 kHz	8	201 kHz
+20 dBm	125 kHz	9	195 kHz
+20 dBm	125 kHz	10	192 kHz
+20 dBm	125 kHz	11	191 kHz
+20 dBm	125 kHz	12	190 kHz
VDD = 2.4 - 3.6 V; T = -20°C – +70°C if nothing else stated			

Table 6-2: Typical modulation bandwidth for settings 125 kHz LoRa signal bandwidth and +20 dBm output power.

6.2 Signal Bandwidth Setting 250 kHz

In addition to 125 kHz signal bandwidth iM880A 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.

For the 250 kHz signal bandwidth setting up to +14 dBm output power are reasonable for conducted measurements, see chapter 3 and chapter 7.

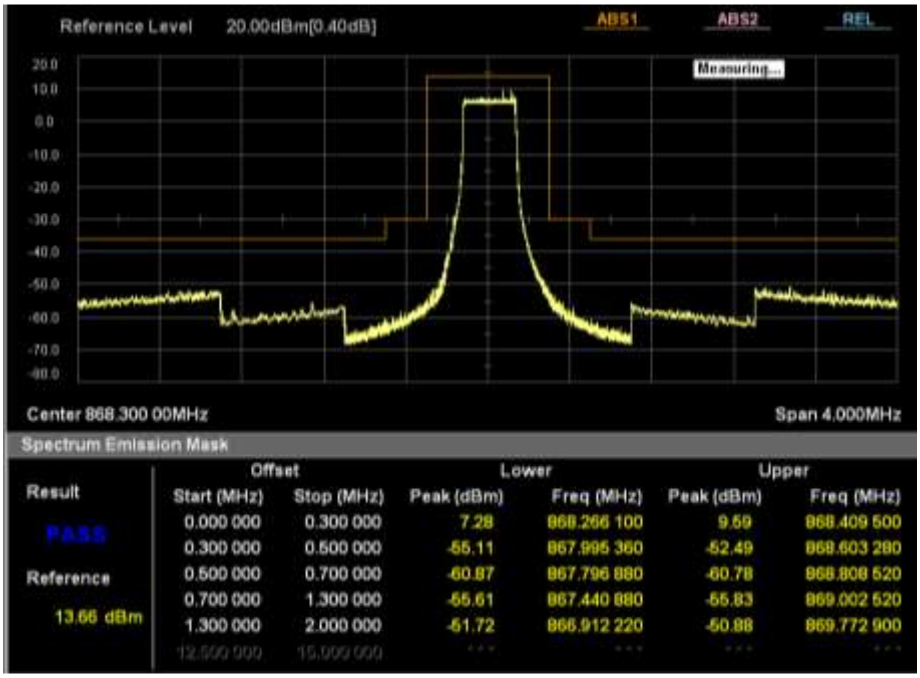

Figure 6-2: Spectrum of a 250 kHz LoRa signal with +14 dBm setting for g1 band.

Field Power	Signal Bandwidth Setting	Spreading Factor	Typical Modulation Bandwidth
+14 dBm	250 kHz	7	354 kHz
+14 dBm	250 kHz	8	346 kHz
+14 dBm	250 kHz	9	331 kHz
+14 dBm	250 kHz	10	331 kHz
+14 dBm	250 kHz	11	326 kHz
+14 dBm	250 kHz	12	328 kHz
VDD = 2.4 - 3.6 V; T = -20°C – +70°C if nothing else stated			

Table 6-3: Typical modulation bandwidth for settings 250 kHz LoRa signal bandwidth and +14 dBm output power.

6.3 Signal Bandwidth Setting 500 kHz

The highest signal bandwidth of iM880A in LoRa™ mode allows using the maximum of effective data rate.

For the 500 kHz signal bandwidth setting up to +14 dBm output power are reasonable for conducted measurements, see chapter 3 and chapter 7.

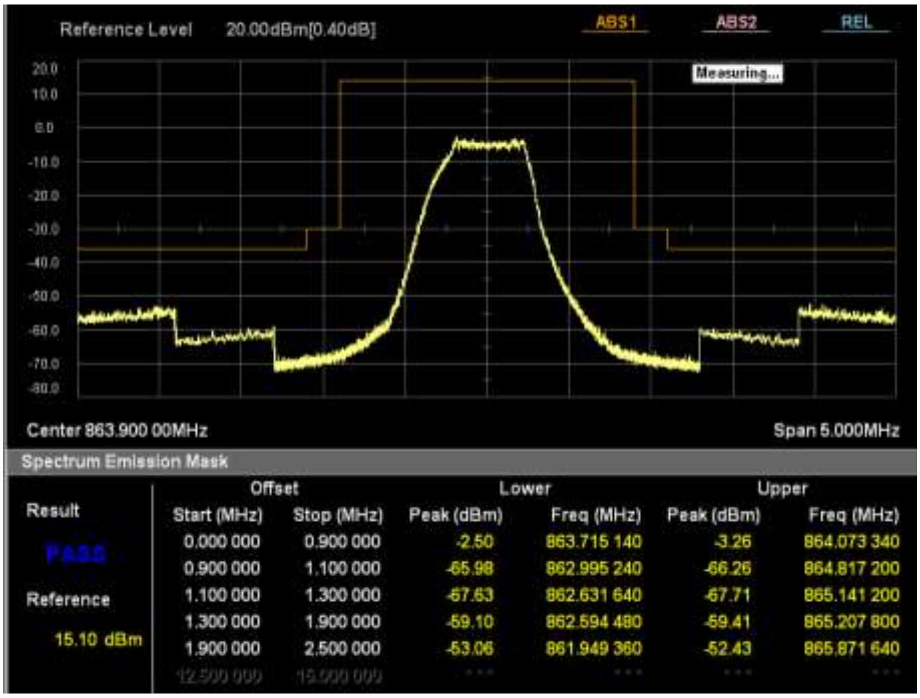

Figure 6-3: Spectrum of a 500 kHz LoRa signal with +14 dBm.

Field Power	Signal Bandwidth Setting	Spreading Factor	Typical Modulation Bandwidth
+6 dBm	500 kHz	7	655 kHz
+6 dBm	500 kHz	8	624 kHz
+6 dBm	500 kHz	9	571 kHz
+6 dBm	500 kHz	10	565 kHz
+6 dBm	500 kHz	11	568 kHz
+6 dBm	500 kHz	12	568 kHz
VDD = 2.4 - 3.6 V; T = -20°C – +70°C if nothing else stated			

Table 6-4: Typical modulation bandwidth for settings 500 kHz LoRa signal bandwidth and +6 dBm output power.

Field Power	Signal Bandwidth Setting	Spreading Factor	Typical Modulation Bandwidth
+14 dBm	500 kHz	7	740 kHz
+14 dBm	500 kHz	8	718 kHz
+14 dBm	500 kHz	9	687 kHz
+14 dBm	500 kHz	10	675 kHz
+14 dBm	500 kHz	11	676 kHz
+14 dBm	500 kHz	12	676 kHz
VDD = 2.4 - 3.6 V; T = -20°C – +70°C if nothing else stated			

Table 6-5: Typical modulation bandwidth for settings 500 kHz LoRa signal bandwidth and +14 dBm output power.

6.3.1 Spectral Transmit Filter

Some applications may find to useful to avail the full 500 kHz signal bandwidth within the g1 band, see chapter 3. Therefore iM880A provides an additional spectral transmit filter. This filter can be switched on/off via the HCI Interface, see [4].

Field Power	Signal Bandwidth Setting	Spreading Factor	Typical Modulation Bandwidth
+14 dBm	500 kHz	7	551 kHz
+14 dBm	500 kHz	8	546 kHz
+14 dBm	500 kHz	9	546 kHz
+14 dBm	500 kHz	10	545 kHz
+14 dBm	500 kHz	11	553 kHz
+14 dBm	500 kHz	12	548 kHz
VDD = 2.4 - 3.6 V; T = -20°C – +70°C if nothing else stated			

Table 6-6: Typical modulation bandwidth for settings 500 kHz LoRa signal bandwidth, +14 dBm output power and spectral transmit filter on.

7 Recommended Frequency Settings

The iM880A 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 f_a	f_b	Field Power	Lowest Center Frequency	Highest Center Frequency
g (Note1,2)	863 MHz	870 MHz	+14 dBm	f_a + 0.13 MHz	f_b – 0.13 MHz
	865 MHz	868 MHz	+6.2 dBm / 100 kHz	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 f_a	f_b	Field Power	Lowest Center Frequency	Highest Center Frequency
g (Note1,2)	863 MHz	870 MHz	+14 dBm	Note 3	Note 3
	865 MHz	868 MHz	+6.2 dBm / 100 kHz	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, see Table 6-3.

7.3 Signal Bandwidth Setting 500 kHz

Band	Edge Frequencies f_a	f_b	Field Power	Lowest Center Frequency	Highest Center Frequency
g (Note1,2)	863 MHz	870 MHz	+14 dBm	-	-
	865 MHz	868 MHz	+6.2 dBm / 100 kHz	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.

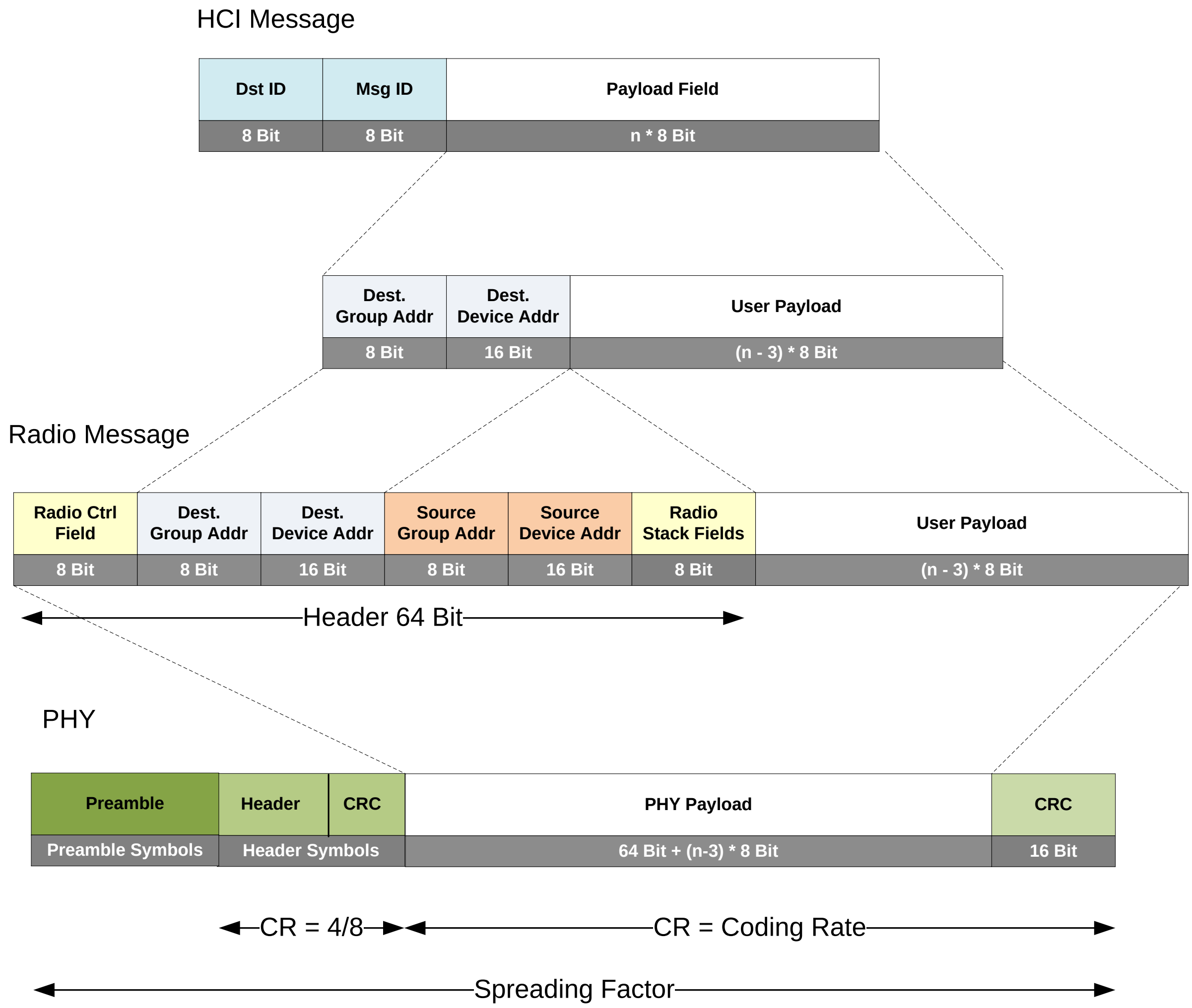

Figure 8-1: iM880A packet structure

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 hole 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

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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