Application Report
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TI LPRF EASYMODE

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ABSTRACT

This application report describes the frame format and physical layer (PHY) parameters for TI LPRF EasyMode (***EasyMode50K***), which provides unified, simple, and well defined PHY modes supported by all sub-1 GHz radio devices from LPRF.

Contents

List of Figures

List of Tables

1 Introduction

EasyMode is intended to provide unified, simple, and well defined PHY modes that can be supported by all sub-1 GHz radio devices from TI LPRF. This document details the frame format and PHY parameter definitions for ***EasyMode50K***, which is the primary option of TI LPRF EasyMode. Typical RF performance data using the ***EasyMode50K*** definition is provided for representative sub-1 GHz radios from TI LPRF, namely the SimpleLink™ CC1200, CC1120, and CC110L low power and high performance RF transceivers.

1.1 Acronyms Used in This Document

Acronym	Description
CRC	Cyclic Redundancy Check
FCS	Frame Check Sum
FEC	Forward Error Correction
GFSK	Gaussian Frequency Shift Keying
ISM	Industrial Scientific and Medical
PER	Packet Error Rate
PHR	PHY Header
PHY	Physical Layer
SFD	Start-of-Frame Delimiter
SNR	Signal-to-Noise-Ratio
SRD	Short Range Devices

2 PHY Parameters

The critical physical layer parameters for the overall system performance are the data rate and modulation format. For the primary EasyMode option ***EasyMode50K***, the same physical layer parameters as the IEEE 802.15.4g [1] MR-FSK mandatory mode is chosen because it provides a good balance between SNR performance, range, and transmission time (network collisions). Gaussian frequency shift keying (GFSK) modulation is used for high spectral efficiency and good co-existence properties without any impact on performance or power consumption.

The PHY parameters for the ***EasyMode50K*** are listed in Table 1.

Data whitening (scrambling) and Forward Error Correction (FEC) are not used.

Table 1. PHY Parameters and Device Support

Mode	Symbol Rate [ksps]	Data Rate [kbps]	Modulation	Frequency Deviation, Modulation Index (h)	Channel Spacing [kHz]	LPRF Device Support
EasyMode50K	50	50	GFSK (1)	±25 kHz, h=1.0	200 (2)	All

(1) BT=0.5

(2) Only applicable for channelized systems.

The ***EasyMode50K*** definitions are suitable for systems targeting the license exempt ISM/SRD frequency bands and respective regions as indicated in Table 2. Typical channel frequency and output power for the various frequency bands are also shown in Table 2.

Table 2. Typical *EasyMode50K* Channel Frequency and Output Power

Region and Applicable Regulations	Commonly referred to as	Frequency Band	Typical Channel Frequency (1)	Typical Output Power (2)
China				
The Chinese short-range wireless regulatory standards	'433 MHz' (3) '470 MHz' '779 MHz'	433.00-434.79 MHz 470-510 MHz 779-787 MHz	433.2 MHz 471.0 MHz 786.5 MHz	+10 dBm +14 dBm +10 dBm
Europe				
ETSI EN 300 220 ETSI EN 300 220 ETSI EN 303 204	'433 MHz' (3) '868 MHz' '873 MHz'	433.05-434.79 MHz 863-870 MHz 870-876 MHz	433.2 MHz 868.3 MHz 872.0 MHz	+10 dBm +14 dBm +14 dBm
Japan				
ARIB STD-T108	'920 MHz' ('950 MHz')	920-928 MHz (950-958 MHz)	920.6 MHz	+13 dBm
USA				
FCC CFR47 Part 15.231 FCC CFR47 Part 15.247	'433 MHz' (3)/ '315 MHz' '915 MHz'	260-470 MHz 902-928 MHz	433.2 MHz 920.6 MHz	+6 dBm (4) +14 dBm

(1) Typical channel frequencies are suggestions. The operating frequencies can be changed to suit the target system design.
(2) Typical output power levels are suggestions. The output power can be changed to optimize the target system design given the applicable regional regulations.
(3) The 433 MHz and 915/920 MHz frequency bands are almost 'world-wide' below 1 GHz.
(4) Duty cycling assumed to facilitate higher output power compared to continuous transmission power limit.

3 Frame Format

The common frame format for EasyMode is shown in Figure 1 and includes the following fields:

- Preamble
- Start-of-Frame Delimiter (SFD) or synchronization word
- PHY header (PHR) containing the length field
- Payload
- Frame Check Sequence (FCS) or CRC field

Figure 1. EasyMode Frame Format

3.1 Preamble

The ***EasyMode50K*** Preamble field is four bytes long and contains four multiples (4x) of the 8-bit sequence "01010101" for GFSK.

CC110L uses a '10101010' preamble sequence but this does not have any impact on RF performance or interoperability with the other radios.

3.2 Start-of-Frame Delimiter (SFD) or Synchronization Word

The ***EasyMode50K*** SFD is a 2-byte sequence as shown in Table 3 and is the same SFD as defined by the IEEE 802.15.4g standard for un-coded frames.

Table 3. EasyMode SFD Sequence

	Modulation	SFD Length	SFD Sequence
EasyMode50K	GFSK	2 bytes	0111 1010 0000 1110

3.3 PHY Header (PHR)

The EasyMode PHR is a 1-byte long length field, capable of specifying up to 255 bytes for the payload.

3.4 Payload

For EasyMode the maximum payload size is 61 bytes. The default payload size for EasyMode (for example, used in SmartRF™ Studio) is 20 bytes.

The 1-byte PHR, 61 bytes maximum payload and an optional two status bytes give total frame size of up to 64 bytes, which fits the FIFO size on all TI LPRF sub-1 GHz radios.

Reference condition for receive sensitivity performance is PER < 10% using a payload of 20 bytes.

3.5 Frame Check Sequence (FCS)

The EasyMode FCS field contains a 16-bit CRC that is calculated over the PHR and payload. The CRC polynomial is CRC16 ($x^{16} + x^{15} + x^2 + 1$) with the CRC register reset to all 1's.

4 Typical RF Performance

Typical receive RF performance using the ***EasyMode50K*** definition is provided for representative sub-1 GHz radios from TI LPRF, namely the SimpleLink CC1200, CC1120, and CC110L low power and high performance RF transceivers.

CC1120 [2] and CC1200 [3], members of the TI RF Performance Line family, are fully integrated single-chip radio transceivers designed for high performance at very low-power and low-voltage operation in cost-effective wireless systems. CC1120 and CC1200 are mainly intended for the ISM/SRD frequency bands at 164 – 192 MHz, 274 – 320 MHz, 410 – 480 MHz, and 820 – 960 MHz.

CC110L [4], member of the TI RF Value Line family, is a cost optimized and low power sub-1 GHz RF transceiver for the 300 – 348 MHz, 387 – 464 MHz, and 779 – 928 MHz ISM/SRD frequency bands. The CC110L is based on the popular CC1101 RF transceiver, and RF performance characteristics are identical.

Typical receive sensitivity, selectivity, and blocking performance data for CC1120, CC1200, and CC110L are shown in Table 4 for the following conditions:

- T_A = 25°C, VDD = 3.0 V
- Frame format as defined in Section 3
- Frequency: 920.6 MHz
- Channel spacing: 200 kHz (only relevant for receive selectivity measurement)
- Payload length: 20 bytes
- PER < 10%

For the same data rate and frame format, the packet error rate (PER) is strongly dependent on the length of the payload. It should be noted that the PER specification for the ***EasyMode50K*** is significantly more stringent than the bit error rate of 10^{-2} (which is specified by ETSI EN 300 220) used in the CC1120 and CC1200 data sheets [2], [3]. The typical receive sensitivity values in Table 4 are, therefore, approximately 2 dB worse than the corresponding sensitivities in the device-specific data sheets.

Table 4. Typical RF Performance Data Using the *EasyMode50K* Definition

Parameter	CC1120	CC1200	CC110L
Receive Sensitivity [dBm]	-107	-107	-102
Receive Selectivity (1) [dB]			
Adjacent Channel Rejection (± 200 kHz)	41	39	30
Alternate Adjacent Channel Rejection (± 400 kHz)	49	45	31
Receive Blocking Performance (1) [dB]			
± 1 MHz	60	57	46
± 2 MHz	64	63	52
± 10 MHz	70	65	61

(1) Receive selectivity and blocking are measured with the desired signal 3 dB greater than the sensitivity level.

5 References

1. IEEE Std 802.15.4g™-2012 standard: http://www.ieee.org
2. *CC1120 High-Performance RF Transceiver for Narrowband Systems Data Sheet* (SWRS112)
3. *CC1200 Low-Power, High-Performance RF Transceiver Data Sheet* (SWRS123)
4. *CC110L Value Line Transceiver Data Sheet* (SWRS109)

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