CMOSTEK

AN280

CMT216xA Low-frequency Receiving Function User Guide

Overview

This document provides detailed description and application guide of CMT216xA low-frequency receiving (hereinafter referred to as LFRX) function.

The document is oriented to users engaging in CMT216xA development. It details the LFRX usage information and the related registers, convenient for users to look up related function and register usage during product developing.

The product models covered in this document are shown in the table below.

Table 1. Product Models Covered in This Document

Product Model	Single-ended PA	Differential PA	12-Bit ADC	Operational Amplifier	Low-frequency Wake-up	External 32.768 kHz	Package
CMT2160A		●	● 4-ch				SOP14
CMT2162A	●		● 8-ch		●		SSOP20
CMT2163A	●	●	● 9-ch		●	●	TSSOP28
CMT2165A	●		●12-ch	●		●	TSSOP28
CMT2168A	●		●12-ch	●	●	●	QFN32

Notes:

The performance and related parameters of each product model are not covered in this document. Please refer to the datasheet document of each model for this kind of information. The packaging scale, silk screen and ordering information of each product model is covered in the corresponding datasheet document as well. As for the detailed function and usage of CMT216xA series, please refer to CMT216xA User Guide.

Reading Guidelines:

1. This document is oriented to users who are well grounded in the CMT216xA and start to developing the LFRX function.

2. Before reading this document, suggest users read *CMT216xA User Guide first to get basic knowledge of* CMT216xA, which helps users get more profound understanding of this document.

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1 Introduction to LFRX

Integrated with a low-frequency receiver (LFRX), the CMT216xA is a low-power ASK/OOK receiver chip with 1~3 axis antennas. The receiver is built in with such functions as low-noise and low-power analog front end circuit, automatic gain control algorithm and signal strength indication (RSSI), supporting automatically adjusted antenna resonant capacitors.

When using single-axis (1 axis) or multiple-axis (2 or 3 axes) scanning antenna, it only consumes a quiescent current of 4.6 μA and achieves a sensitivity of 70 μVrms when receiving an OOK signal of 4 kbps in carrier sensing operating mode, feasible for various applications with low-power and low-frequency wake-up requirement, like such low-frequency active RFID applications as PKE, positioning, work attendance checking, entry and exit management.

The main features are as below.

- 1~3 axis ASK/OOK receiver.
- Frequency range: 15~250 kHz.
- Embedded automatic calibration of antenna resonance.
- Sensitivity: 70μVrms @ 4kbps, with power consumption and sensitivity being adjustable.
- Support for carrier frequency detection or SNR detection.
- Built in with automatic gain control algorithm (AGC).
- RSSI detection with a range of 0 ~ 37, with 3 dB/step.
- Support for single-channel or multi-channel scanning mode, with power consumption being 4.6 μA in frequently receiving condition (in the listen state with carrier detection).
- Data rate range: 1~8 kbps.
- Support for matching based wakeup with 1~4 bytes sync word (Sync) and 1~4 bytes wakeup word (Wakeup ID).
- Support for Manchester code (Wakeup ID and Data) with data synchronization clock output.
- Support for multiple intermittent operating modes (Duty Cycle).
- Built-in 32 kHz RC oscillator with a precision of 1%.
- Support for external 32.768 kHz crystal oscillator.

2 General Functional Block Diagram

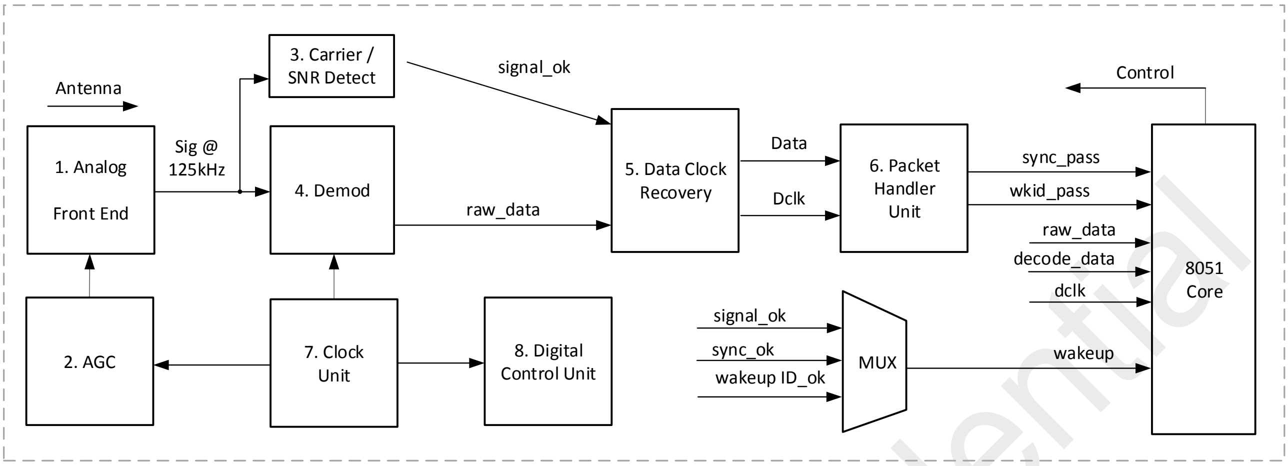

Figure 1. General Functional Block Diagram of CMT216xA LFRX

It includes the below sub-modules.

1. Analog front end: low-frequency receive analog front end
2. AGC: automatic gain control unit
3. Carrier / SNR detect: carrier / SNR detection unit
4. Demod: demodulation module
5. Data clock recovery: data clock recovery unit
6. Packet handler unit: packet processing unit
7. Clock unit: clock output unit
8. Digital control unit: digital control unit

3 Performance Specification

Table 2. CMT216XA LFRX Performance Specification

Item	Description		Typ.	Unit
Frequency			15 ~ 250	kHz
Input Resistance	Parallel with antenna		1.2 ~ 150	KΩ
Tuning Capacitance	Parallel with antenna		0 ~ 37.2	pF
Sensitivity	Listen = Carrier Detect	1 kbps	65	μVrms
		2 kbps	65	μVrms
		4 kbps	70	μVrms
		8 kbps	80	μVrms
Sensitivity	Listen = SNR Detect (SNR = 8dB)	1 kbps	70	μVrms
		2 kbps	70	μVrms
		4 kbps	70	μVrms
		8 kbps	70	μVrms
Current (Always RX)	Sleep	/	1.8	μA
	Listen	Carrier Detect	4.6	μA
		SNR Detect	5.7	μA
	Decode	/	5.7	μA
Current (Duty Cycle)	Fixed Duty Cycle	RX Time = 150 ms Sleep Time = 300 ms	2.8	μA
		RX Time = 150 ms Sleep Time = 600 ms	2.4	μA
	T1 T2 Extend	RX Time = 5 ms Sleep Time = 10 ms	2.9	μA
		RX Time = 5 ms Sleep Time = 20 ms	2.5	μA
		RX Time = 5 ms Sleep Time = 40 ms	2.2	μA
		RX Time = 5 ms Sleep Time = 80 ms	2.0	μA
Clock Accuracy	32 kHz RC Oscillator		<1%	

Notes:

1. If nothing else stated, all above measurement results are obtained under the conditions of VDD = 3 V, Frequency = 125 kHz, Data Rate = 4 kbps, Power Consumption = 7 and using internal 32 kHz RC oscillator. If using the external 32.768 kHz, it needs to add 150 nA to each current measurement result.

4 Analog Front End

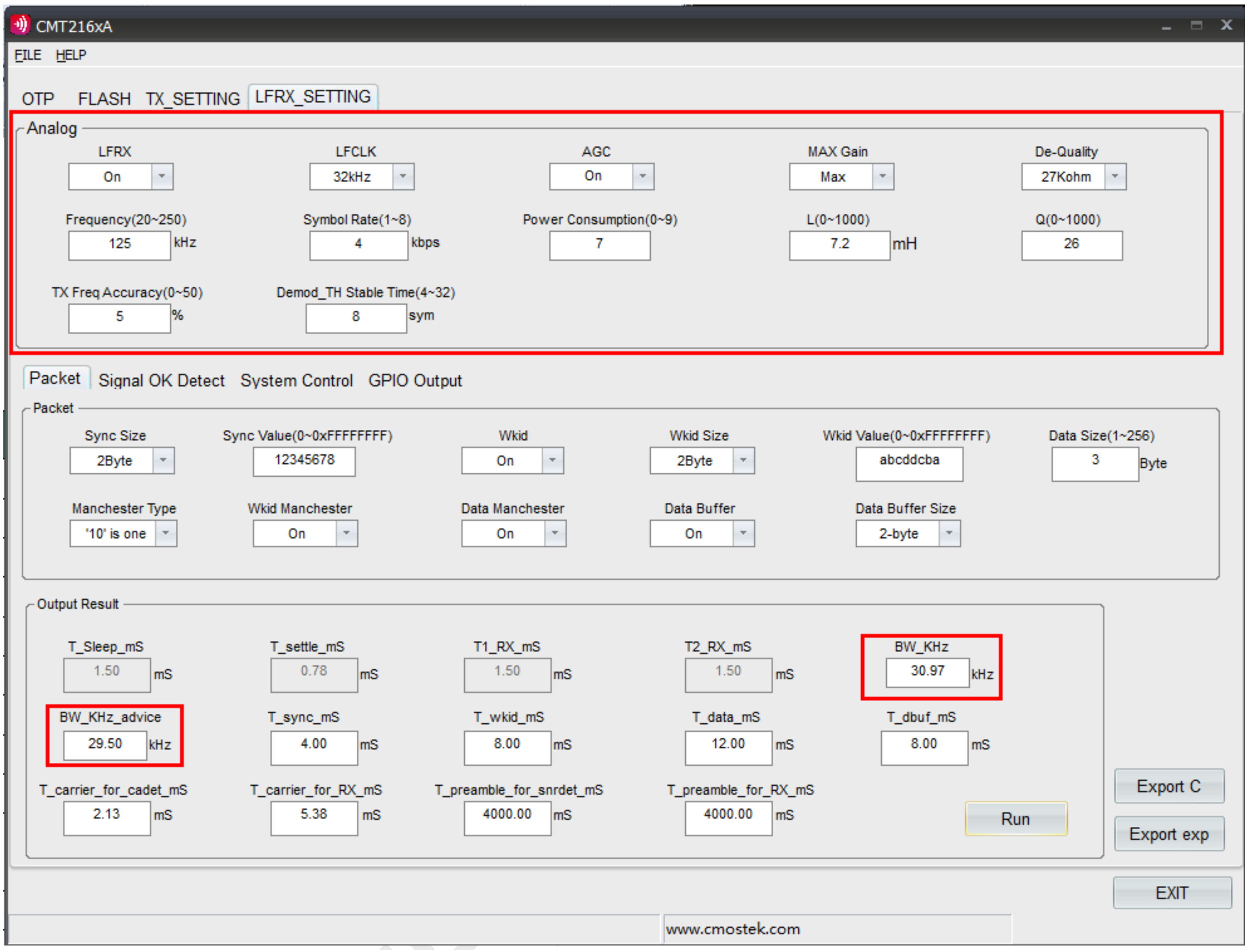

Figure 2. Analog Front End Configuration Screen in CMT216x RFPDK

Table 3. Analog Front End Configuration in CMT216xA RFPDK

Configuration Item	Configuration Options/Range	Default	Description
LFRX	Off / On	On	LFRX disabling/enabling.
Frequency	15~250 kHz	125 kHz	Receiving signal carrier frequency.
Symbol Rate	1~8 kbps	4 kbps	Receiving signal data rate.
Demod TH Stable Time	4~32 symbols	8 sym	Demodulation threshold stabilization time in symbol.
AGC	Off / On	On	AGC disabling/enabling.
MAX Gain	MAX ~ (MAX – 42dB)	MAX	Selecting the maximum gain of the receiver to control the receiving sensitivity.
De-Quality R	1.2~150 KΩ	37 KΩ	Selecting the on-chip Q-reduced resistor value of the receiving antenna.
Clock	Internal RC OSC	√	Selecting the internal 32 kHz RC oscillator.
	External LFXO		Selecting the external 32.768 kHz crystal oscillator.

Configuration Item	Configuration Options/Range	Default	Description
Power Consumption	0 ~ 9	7	10-step power (current) configuration, associated with low-frequency performance. The higher the value, the better the performance. It increases about 200 nA with each step increased.
L	0~1000mH	4.9 mH	The introduced antenna inductance value. Fill the value according to the actual antenna parameters.
Q	0~1000	26	Q value of the antenna inductance.
TX Freq Accuracy	0~50%	5%	Transmitter transmission frequency precision, generally the same as the clock precision of the base station MCU.
BW_KHz	-	-	Current antenna bandwidth calculated by RFPDK.
BW_KHz_advice	-	-	Recommended antenna bandwidth calculated by RFPDK.

4.1 Antenna Resonant Frequency Adjustment

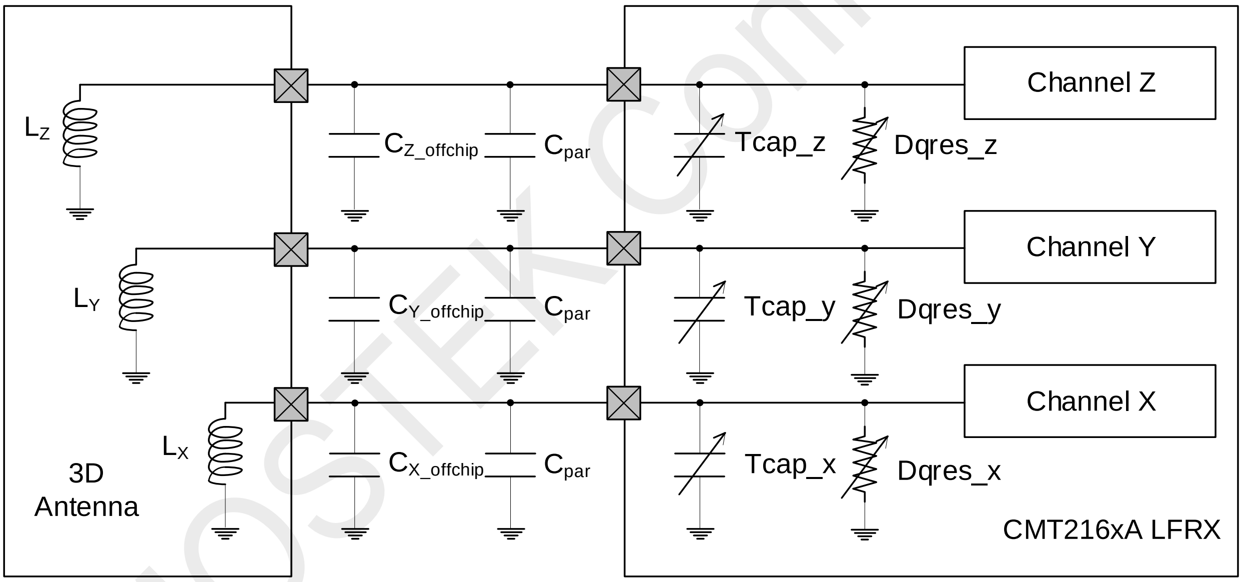

Figure 3. LFRX External Antenna and Capacitor Schematic

As shown in the above figure, the low-frequency antenna of LFRX is a mH-class winding inductor in general. To achieve optimal receiving performance, users need to add an off-chip capacitor to produce resonance with the antenna inductor.

The considerations of adjusting the antenna resonance frequency are as follows.

- Ground unused antenna input interfaces.
- On the PCB board, there is a clearance area below the inductor antenna. The casing around antenna should not use metal materials and a space of at least 2 mm should be placed between the casing and the antenna. A space of at least 3 mm should be reserved between antennas to prevent mutual interference.
- Each off-chip capacitor can be formed by 1 or 2 capacitors. The off-chip capacitor values corresponding to the commonly

used antennas are listed in the table below.

- Except parasitic capacitor, the CMT216xA provides an adjustable capacitor with a maximum value of 37.2 pF and an adjusting step of 1.2 pF.
- The automatic adjusting is performed once upon the chip power-on with a default adjusting frequency of 125 kHz. If requiring to adjust to another frequency value, users need to modify LFRX_ANT_REF (in the register LFRX_IF_TH_L in Bank1 of the Block1 area, with the address of 0xC3) and then execute the antenna adjusting API again. Please see example programs for more details.
- Upon re-adjusting, users need to call the API cal_lfrx_osc_amplitude_calibration first to fulfill antenna oscillation amplitude adjusting, then call the API cal_lfrx_osc_frequency_calibration to fulfill antenna oscillation frequency adjusting.

Table 4. Off-chip Capacitance of Commonly Used Antennas

Antenna Inductance	Off-chip Capacitance	Parasitic Capacitance	On-Chip Tuning Capacitance	Total Capacitance	Resonant Frequency
2.3 mH	680pF + 2.2pF	4pF	19.2pF	705.4pF	125.0kHz
5 mH	220pF + 82pF	4pF	19.2pF	325.2pF	124.9kHz
7.2 mH	180pF + 20pF	4pF	19.2pF	223.2pF	125.6kHz
9.0 mH	150pF + 6.8pF	4pF	19.2pF	180.0pF	125.1kHz
10.0 mH	100pF + 39pF	4pF	19.2pF	162.2pF	125.0kHz

The calibration flow is shown in the figure below.

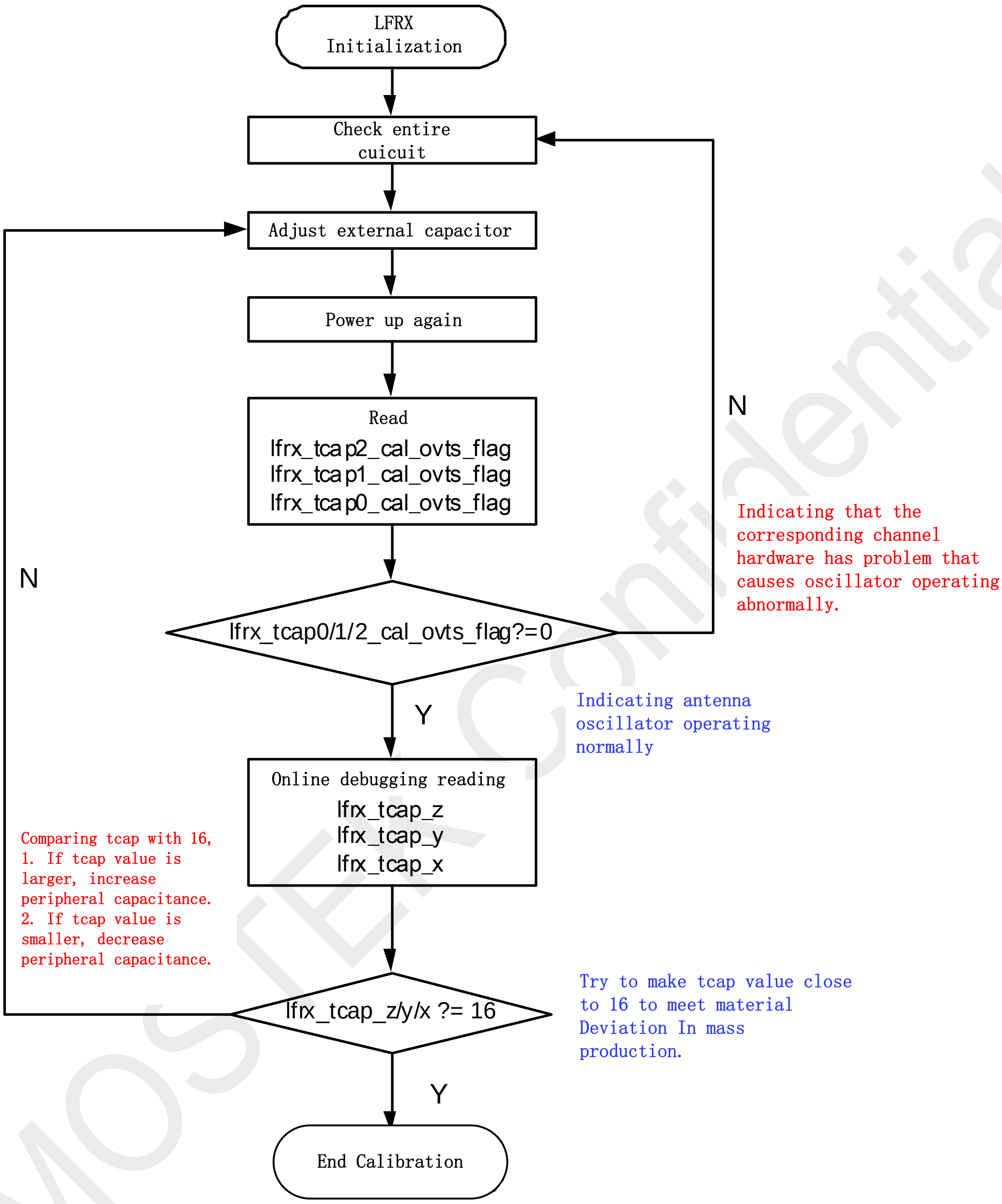

Figure 4. LFRX External Antenna Resonance Frequency Calibration Flowchart

Considerations of antenna frequency calibration are as follows.

1. Suggest users perform this adjustment flow in the product design phase, then to fix the design BOM.
2. When doing automatic antenna frequency adjustment, do not solder off-chip Q-value resistors to avoid affecting the normal operation of the antenna oscillator.
3. The antenna oscillator circuit can be output to Timer A/B's capture function TACCI0/1 or TBCCI0/1. Users can measure the antenna oscillator frequency by program. Refer to the program examples for details.
4. Tcap2 corresponds to the Z channel capacitor, Tcap2 to Z channel capacitor and Z channel capacitor to X channel capacitor.
5. Through software, users can set capacitance value to the TCAP register set (in BLock0 area) including the 3 registers CAL_LFRX_TCAP2 (for Z axis), CAL_LFRX_TCAP1 (for Y axis) and CAL_LFRX_TCAP0 (for X axis) with a address range of 0x34 - 0x36.

4.2 Q Factor Reduction Resistor of Antenna

1. Tune the Q factor reduction resistor according to receiving distance, namely the greater the resistance is, the smaller the antenna's LC filter bandwidth, the higher the gain and the better the sensitivity.

2. The CMT216xA provide a tunable Q factor reduction resistor ranging from 1.2 to 150 kΩinternally. Alternatively, users can choose a Q factor reduction resistor of 2 MΩ(namely close the function) then solder an off-chip resistor to reduce LC antenna's Q factor.

3. Don't make the antenna bandwidth too narrow, otherwise it will impact the duty cycle of the demodulated data due to excessive signal filtering.

4. Input the Q factor and inductance values of the antenna on RFPDK GUI, the current LC antenna bandwidth BW_KHz and the recommended bandwidth BW_KHz_advice will display. Users can adjust De-Quality R to make BW_KHz ≥ BW_KHz_advice.

5. When using 8 kbps data rate, users should ensure the Q factor value of the antenna of the transmission station should not be too high, otherwise it will affect the signal duty cycle. The Q factor value of the antenna of the transmission station can be tuned through the series resistor of the transmission antenna.

4.3 Data Rate

Table 5. Available Data Rates of CMT216xA

Use Internal 32 kHz RC Clock		Use External 32.768 kHz Crystal Clock	
Internal Data Rate	Corresponding Pulse Width	Internal Data Rate	Corresponding Pulse Width
8.00 kbps	125.0 μs	8.19 kbps	122.1 μs
5.33 kbps	187.5 μs	5.46 kbps	183.1 μs
4.00 kbps	250.0 μs	4.10 kbps	244.1 μs
3.20 kbps	312.5 μs	3.28 kbps	305.2 μs
2.67 kbps	375.0 μs	2.73 kbps	366.2 μs
2.29 kbps	437.5 μs	2.34 kbps	427.2 μs
2.00 kbps	500.0 μs	2.05 kbps	488.3 μs
1.78 kbps	562.5 μs	1.82 kbps	549.3 μs
1.60 kbps	625.0 μs	1.64 kbps	610.4 μs
1.45 kbps	687.5 μs	1.49 kbps	671.4 μs
1.33 kbps	750.0 μs	1.37 kbps	732.4 μs
1.23 kbps	812.5 μs	1.26 kbps	793.5 μs
1.14 kbps	875.0 μs	1.17 kbps	854.5 μs
1.07 kbps	937.5 μs	1.09 kbps	915.5 μs
1.00 kbps	1000.0 μs	1.02 kbps	976.6 μs

Notes:

1. The accurate data rates supported by CMT216xA internally are listed in the below table. Suggest that the actual data rates users input in CMT216xA RFPDK should be as close as possible to the values listed in the above table. If there's relatively large gap, suggest users trying to use Manchester coding in the transmitted and received packet format to avoid a long series of 0 or 1 (except the long series of 1 in the carrier detection)
2. On the CMT216xA RFPDK GUI, Demod TH Stable Time is the stabilization time the demodulation threshold.

4.4 AGC and RSSI

AGC is the gain algorithm of the auto-control amplifier, which helps control the signal output amplitude within a certain range. Users can configure the maximum gain (corresponding to MAX GAIN on CMT216xA RFPDK GUI) to control the LFRX's sensitivity. Theoretically , the larger the gain, the better the sensitivity and vice versa.

RSSI is the signal strength indication. Users can call API to get LFRX_AGC_ INDEX (the CUS_LFRX31 register in Block0 area with an address of 0x72). The larger the RSSI value, the larger signal strength with a range of 0 - 43.

However, subject to the limitation of MAX Gain and De-Quality R, the actual RSSI range is as follows.

1. The minimum LFRX_AGC_INDEX value is LFRX_AGC_MIN_INDEX.
2. When LFRX_AGC_INDEX <= 14, RSSI = LFRX_AGC_INDEX.
3. When LFRX_AGC_INDEX >=15, RSSI = LFRX_AGC_INDEX – LFRX_DQRES.

Notes:

The register values of LFRX_AGC_MIN_INDEX and LFRX_DQRES can be exported after auto-calculation in CMT216xA RFPDK.

4. If the MCU needs to use the RSSI data, it should read the RSSI as soon as possible before transmission data packets end. Otherwise after transmission data packets end, only noise is being received with RSSI being reducing to a minimum value gradually.

4.5 Sensitivity Tuning

On the CMT216xA RFPDK GUI, 3 options are available for sensitivity tuning, namely MAX Gain, De-Quality R and Power Consumption.

- For the option MAX Gain, it benefits in large adjusting range and keeping antenna filtering with high Q-factor, however it cannot reduce power consumption.
- For the option De-Quality R, it benefits in large adjusting range, however antenna filtering performance declines and it cannot reduce power consumption.
- For the option power consumption, it benefits in power consumption reducing as sensitivity being reduced and keeping antenna filtering with high Q-factor, however adjusting range is relatively limited.

4.6 Clock Source

The CMT216xA LFRX has 2 clock source options.

- On-chip LPOSC, the 32 kHz RC with a precision of less than 1%. The clock cycle is 31.25 us.
- If users require relatively high clock precision, the external 32.768 kHz oscillator is recommended. The clock cycle is 30.518 us

Users can configure clock source by calling API sys_enable_low_32khz_clock. See *AN282 CMT216x API Library Usage Guide* for details.

5 Operating State

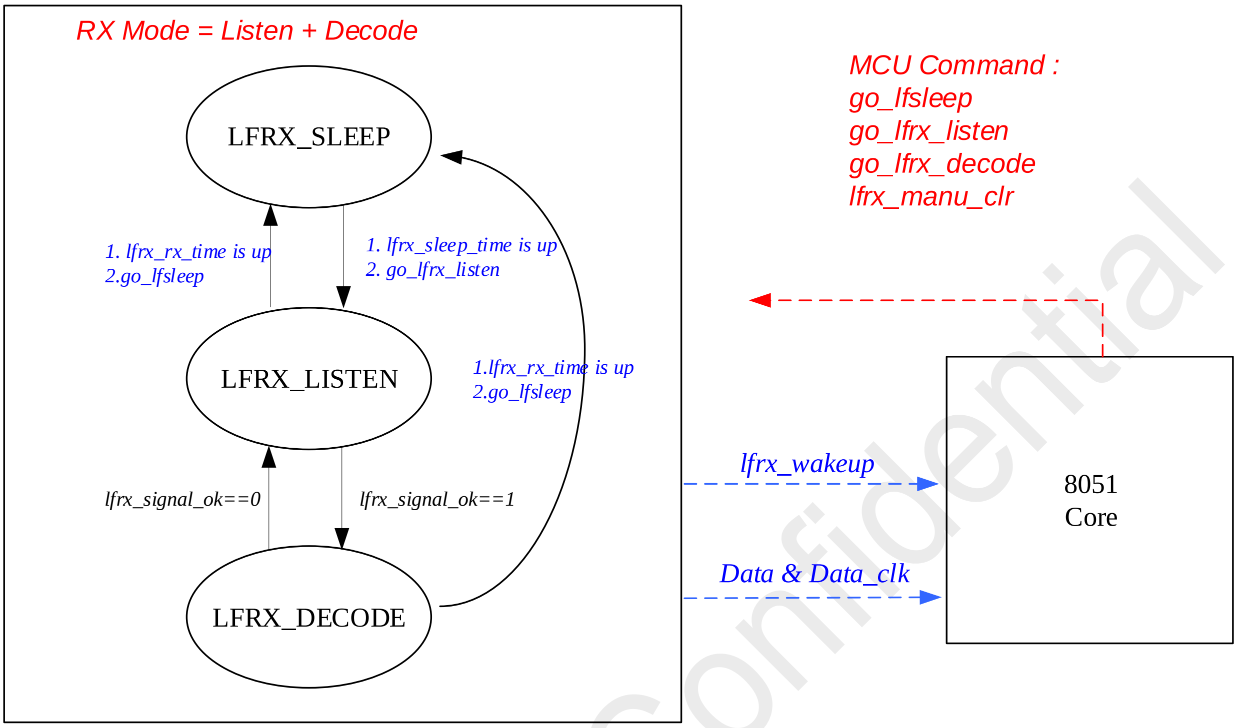

Figure 5. CMT216xA LFRX Operating State Transition Diagram（Listen + Decode）

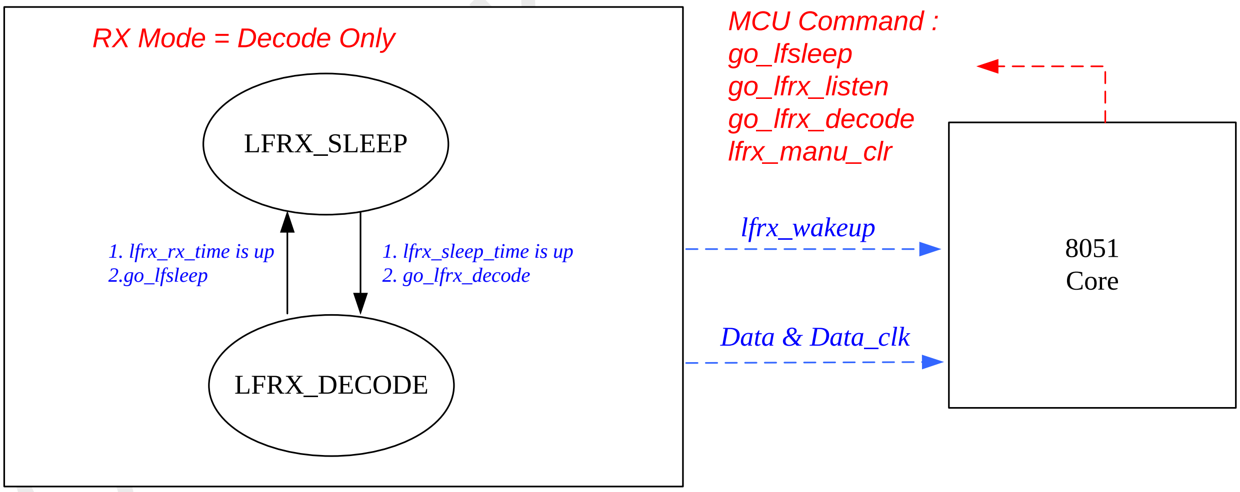

Figure 6. CMT216xA LFRX Operating State Transition Diagram（Decode Only）

The CMT216xA LFRX supports 3 operating states and the conditions for transition between the states are different, however the 8051 core commands have the top priority.

- Sleep（LFRX_SLEEP）
- Listen（LFRX_LISTEN）
- Demodulate and Decode（LFRX_DECODE）

5.1 Sleep State

In the always-RX mode, it can enter the LFRX_SLEEP state only by configuring GO_LFSLEEP (the bit0 of the CUS_SYSCTL10 register with a address of 0x57 in Block0 area). In the LFRX_SLEEP sate, all the LFRX circuits are closed and it does not consume current other than static leakage current in theory.

In the Duty Cycle RX mode, when the RX clock of LFRX ends counting or it enters the LFRX_SLEEP state through configuring the GO_LFSLEEP bit, only the 32 kHz low-frequency clock and Timer of LFRX consume current.

5.2 Listen State

Switching from the LFRX_SLEEP state to the LFRX_LISTEN state consumes about 781 us. In the LFRX_LISTEN, when the low-frequency transmitter sends packets with specific Preambles, the CMT216xA LFRX can detect the signal qualification through carrier or SNR, namely whether satisfying LFRX_SIGNAL_OK = 1, thereby triggers LFRX to switch from the LFRX_LISTEN state (consume relatively low power) to the LFRX_DECODE (consume relatively high power) to perform data packet decoding and other subsequent processing.

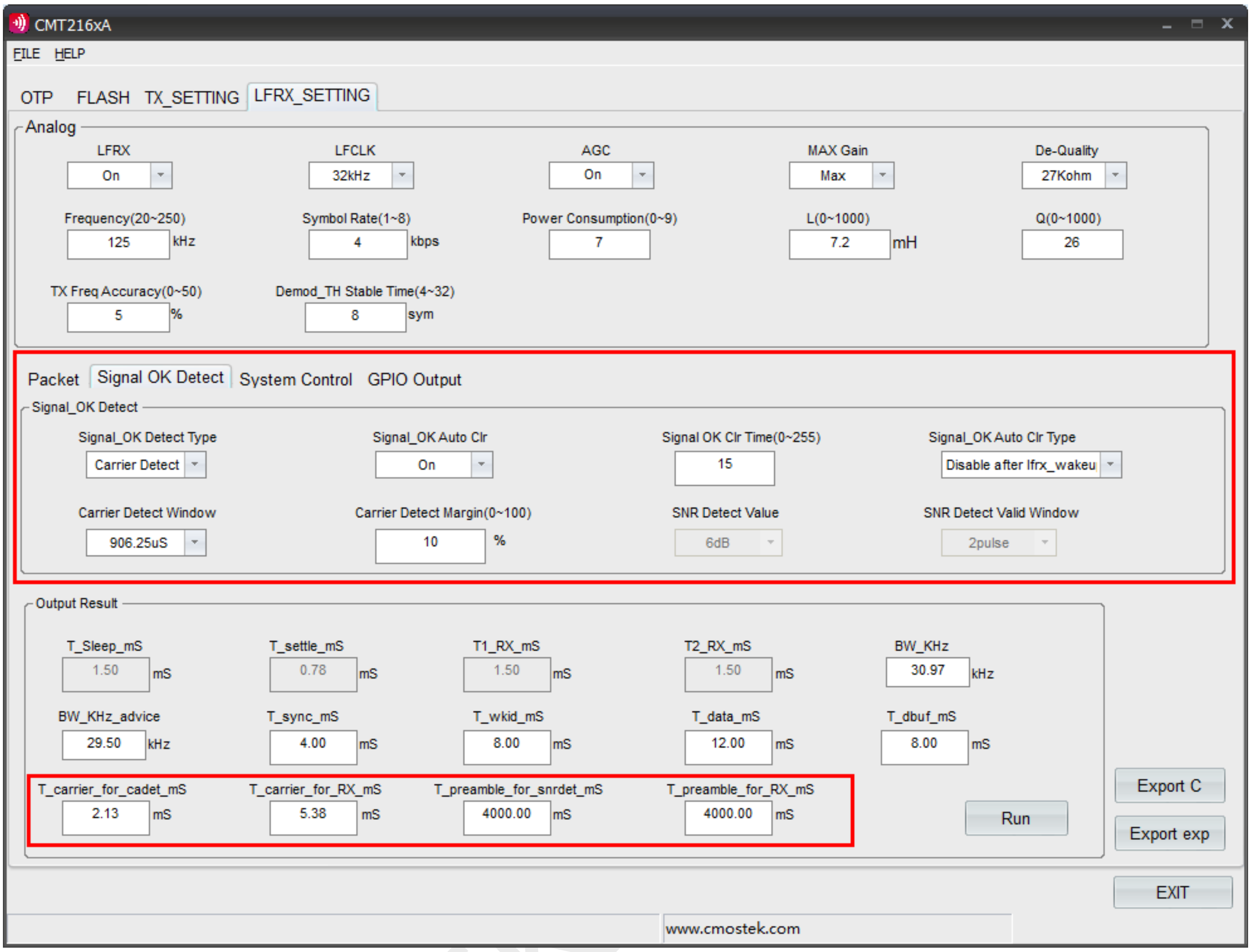

Figure 7. Valid Signal Detection Configuration Screen on RFPDK

Table 6. Valid Signal Detection Configuration on RFPDK

Configuration Item	Option Value	Default	Description
Signal_OK Detect Type	Carrier Detect	√	Carrier frequency detection.
	SNR Detect		Signal to noise ratio detection.
Signal_OK Auto Clear	On	√	Enable the auto-clearing function of the Signal_OK signal.
	Off		Disable the auto-clearing function of the Signal_OK signal.
Signal_OK Auto Clear Time	0 ~ 255	30	The auto-clearing time of the Signal_OK signal with a step of 4ms. Max = 1020 ms. (when selecting the internal 32 KHz RC OSC)
			With a step of 3.9 ms. Max = 996 ms. (when selecting the external 32.768 kHz LFXO)
Signal_OK Auto Clear Type	Enable all the time		As long as the time window of Signal_OK Auto Clear Time is met, it can fulfill auto-clearing to switch from the Decode state to the Listen state.
	Disable after lfrx_wakup = 1	√	If the MCU is woken up, it will disable the auto-clearing function instantly, then the MCU will send manual-clearing signal lfrx_manu_clr = 1 at the appropriate time. If the MCU is not woken up, the auto-clearing function is always enabled.
Carrier Detect Window	156.25 ~ 7906.25μS （32kHz RC OSC）	906.25μS	Time window length for carrier frequency detection.
	152.59 ~ 7720.95 μS （32.768kHz LFXO）	885.01μS	
Carrier Detect Margin	0~100 %	10%	Carrier frequency detection tolerance range.
SNR Detect Value	3~18 dB	8 dB	SNR threshold for SNR detection.
SNR Detect Valid Window	1 ~ 8 pulses	2 pulses	The number of successive pulses that meet the preset SNR to recognize a signal with valid SNR.
T_carrier_for_cadet_mS	-	-	The minimum carrier length required by carrier frequency detection, which is calculate by the CMT216xA RFPDK.
T_carrier_for_RX_mS	-	-	The minimum carrier length required by always-RX process, which is calculated by the CMT216xA RFPDK, including the time required for antenna scanning and AGC.
T_preamble_for_snrdet_mS	-	-	The minimum preamble length required for SNR detection, which is calculated by the CMT216xA RFPDK.
T_preamble_for_RX_mS	-	-	The minimum preamble length required by always-RX process, which is calculated by the CMT216xA RFPDK, including the time required for antenna scanning and AGC.

5.2.1 LFRX_SIGNAL_OK Clearing Function

When the detection of carrier frequency or SNR is passed, LFRX_SIGNAL_OK will be set to 1 and it will enter the LFRX_DECODE state. If LFRX_SIGNAL_OK is not cleared to 0 thereafter, it will have large current consumption due to staying in LFRX_DECODE for a long time and will affect the normal operation of the next receiving process. Therefore, an auto-clearing mechanism for LFRX_SIGNAL_OK is required. There are 3 methods available for auto-clearing LFRX_SIGNAL_OK internally and exiting the LFRX_DECODE state.

1. In the Always_RX mode, LFRX_SIGNAL_OK, namely the timeout based auto-clearing function, is enabled by configuring Signal_OK Auto Clear as On. When the timeout condition is satisfied, LFRX switches from the Decode state to the Listen state. The timeout time is configured through Signal_OK Auto Clear Time with a step of 4 ms, ranging from 4 ms to 1020 ms. Note that Signal_OK Auto Clear Time should be more than the time of a data packet to ensure complete receiving.

2. Based on item 1, Signal_OK Auto Clear Type can be configured to set whether to continue enabling auto-clearing function after MCU's wake-up. In the disabling case, the MCU needs to configure LFRX_MANU_CLR to 1 (bit2 of register CUS_SYSCTL11 with a address of 0x68 in Block0 area) to reset the whole LFRX receiver.

3. In the Duty_Cycle_RX mode, once RX time ends, LFRX_SIGNAL_OK is cleared and it switches from the Decode state to the Sleep state. In another case, if the MCU is woken up and RX time is prolonged, MCU needs to configure LFRX_MANU_CLR to 1 to reset the LFRX receiver. Therefore, in the Duty_Cycle_RX mode, it's unnecessary to enable the auto-clearing function, namely just configuring Signal_OK Auto Clear as off is fine.

5.2.2 Carrier Frequency Detection

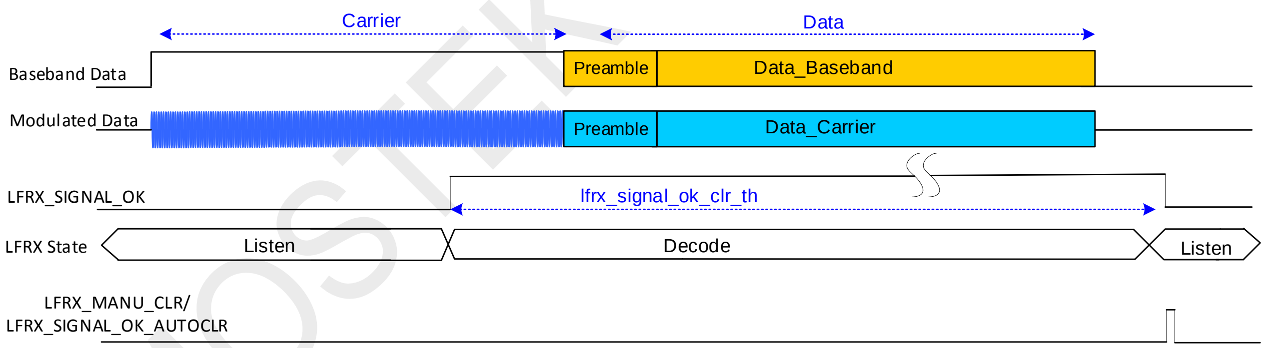

Figure 8. Carrier Frequency Detection Timing

When LFRX_SIGNAL_OK_TYPE is set as 0, the carrier frequency detection function is selected.

- When LFRX operates in the Always RX mode, users can check *T_carrier_for_RX_mS* on the CMT216xA RFPDK GUI to get transmission carrier total length.
- When LFRX operates in the Duty_Cycle RX mode, users can refer to Section 8 for related discussion on transmission carrier total length.
- The carrier is followed by a certain length of Preamble to make the modulation threshold more stable. Users can

check T_preamble_for_RX_mS on the CMT216xA RFPDK GUI to get the required Preamble length, which is relevant to Demod TH Stable Time on RFPDK, namely the more the required time of the modulation threshold, the more the required time of Preamble.

- The more the *Carrier Detect Window*，the less the chance of false triggering by noise interference.

5.2.3 Signal to Noise Ratio Detection

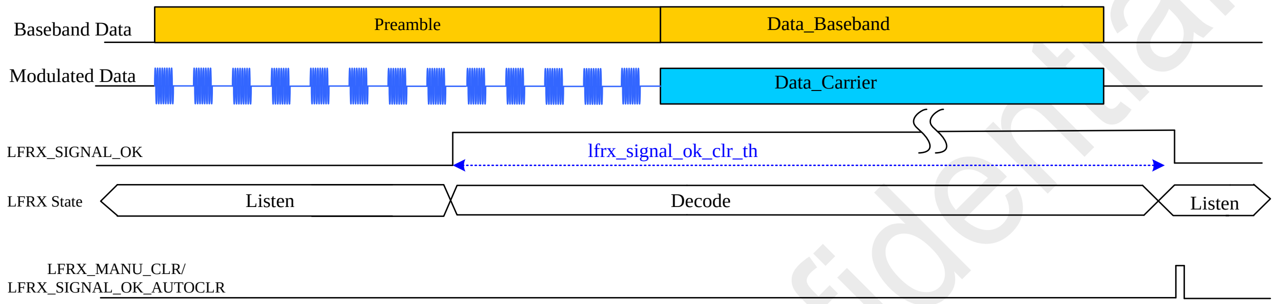

Figure 9. Signal to Noise Ratio Detection Timing

When LFRX_SIGNAL_OK_TYPE is set to 1, the SNR detection function is selected.

- When LFRX operates in the Always RX mode, users can check T_preamble_for_RX_mS on the CMT216xA RFPDK GUI to get transmitted Preamble total length, including the time for SNR detection, antenna scanning, AGC functioning and demodulation threshold settling time.
- When LFRX operates in the Duty_Cycle RX mode, users can refer to Section 8 for related discussion on transmitted Preamble total length. The
- The more the SNR Detect Valid Window，the less the chance of false triggering by noise interference.

5.3 Decode State

The considerations on decoding is as follows.

1. The CMT216xA RFPDK will automatically calculate the required bandwidths of the filters for decoding.
2. Demod TH Stable Time is the stabilization time of demodulation threshold. The more the parameter value is, the more the Preamble length required for the threshold stabilization.
3. It should not have too much gap between the actual data rates and the values listed in Table 5, otherwise, it may cause data synchronization error.
4. Ensure to clear LFRX_SIGNAL_OK before exit the Decode state (See Section 5.2.1 for details).

6 Packet Format

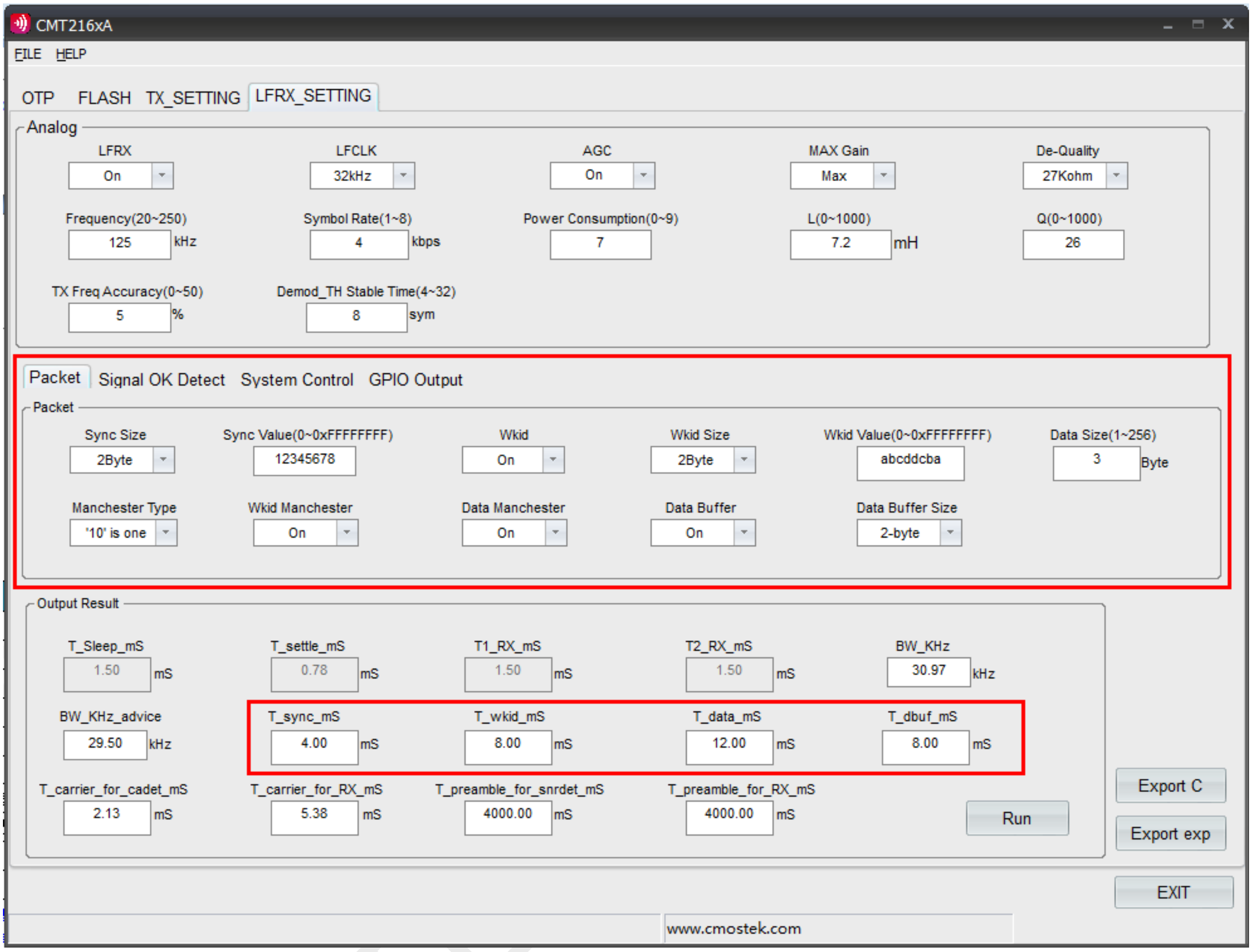

Figure 10. Packet Format Configuration on CMT216xA RFPDK GUI

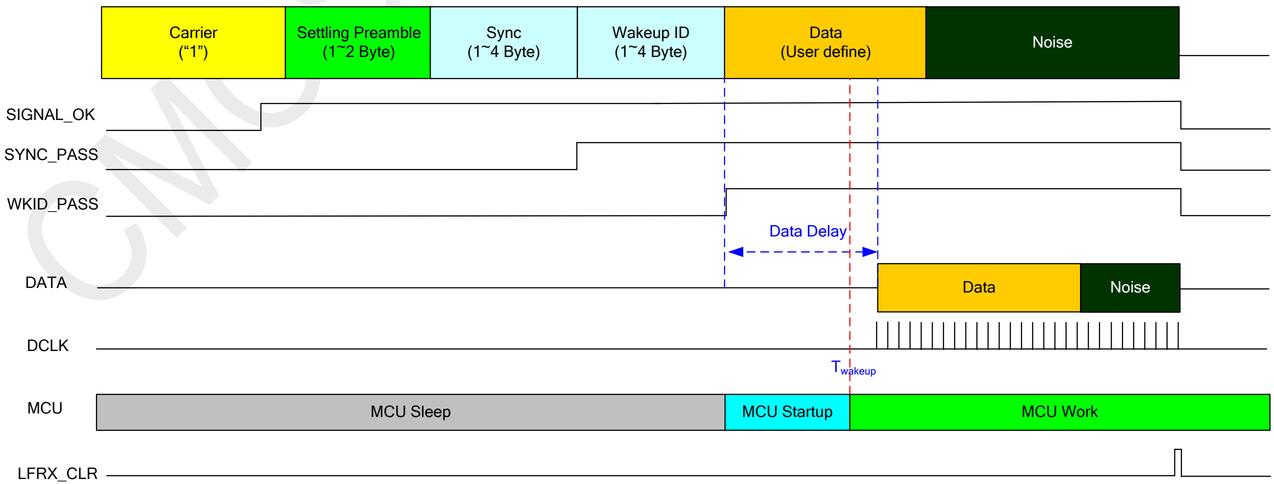

Figure 11. Packet Format Timing for Signal_OK Detect Type as Carrier Detect

Table 7. Packet Format Configuration on CMT216xA RFPDK

Configuration Item	Configuration Options	Default	Description
Sync Size	1~4 Byte	3 Byte	Sync length.
Sync Value	/	0x595AA5	Sync value.
Wkid	1~4 Byte	1 Byte	Wakeup ID length.
Wkid Value	/	0x23	Wakeup ID value.
Manchester Type	"01" is one	√	*01* represents *1* in Manchester encoding.
	"10" is one		*10* represents *1* in Manchester encoding.
Wkid Manchester	Off / On	On	Disable/enable Wakeup ID in Manchester encoding.
Data Manchester	Off / On	On	Disable/enable Data in Manchester encoding.
Data Size	1~256 Byte	2 Byte	The raw Data length after decoding.
Data Buffer	Off / On	On	Disable/enable Data buffer.
Data Buffer Size	0.5 ~ 4 Byte	2 Byte	Data buffer length, calculated using decoding data rate. The calculated result is displayed as T_dbuf_mS on the CMT216xA RFPDK
T_sync_mS	-	-	Sync time length, calculated by the CMT216xA RFPDK.
T_wkid_mS	-	-	Wkid time length, calculated by the CMT216xA RFPDK.
T_data_mS	-	-	Data time length, calculated by the CMT216xA RFPDK.
T_dbuf_mS	-	-	Data buffer time length, calculated by the CMT216xA RFPDK.

Special considerations:

1. Suggest the sync length should not be less than 2 bytes as the data output to the encoder is possibly error data before the signal link demodulation become stable, which may cause false detection of sync.

2. Sync does not support Manchester encoding. It can only be NRZ encoding. Try not to have long series of 0 or 1 in the data, otherwise it may cause demodulation error.

3. The consideration of introduce data buffer is that, upon LFRX triggering MCU wake-up, the MCU cannot process low-frequency data demodulation at once, as it needs to have BOOT process first to load the code such as OTP to PRAM then the software can parse the low-frequency demodulation output data. Therefore, as a user friendly design, data buffer is introduced in LFRX to delay the output of low-frequency demodulation data. The data buffer size can be configured through Data Buffer Size on the CMT216xA RFPDK. Then buffer time can be calculated based on the data rate after demodulation (display as T_dbuf_mS on RFPDK).

4. To judge whether Manchester decoding error data is received, the internal MCU can read MAN_DECODE_ERR_FLAG (bit7 of the CUS_LFRX32 registr in Block0 area). The external MCU can read the Manchester decoding error flag on GPIO (need to configure the mapping to GPIO by internal software) to judge whether the received data having Manchester error.

5. As for reading the RSSI value, it must be read at the time point Twakeup as shown in the above figure, namely ensure the raw data is still in transmitting at the transmission end (transmitting is not finished yet), otherwise the value obtained is unreliable.

7 Antenna Mode

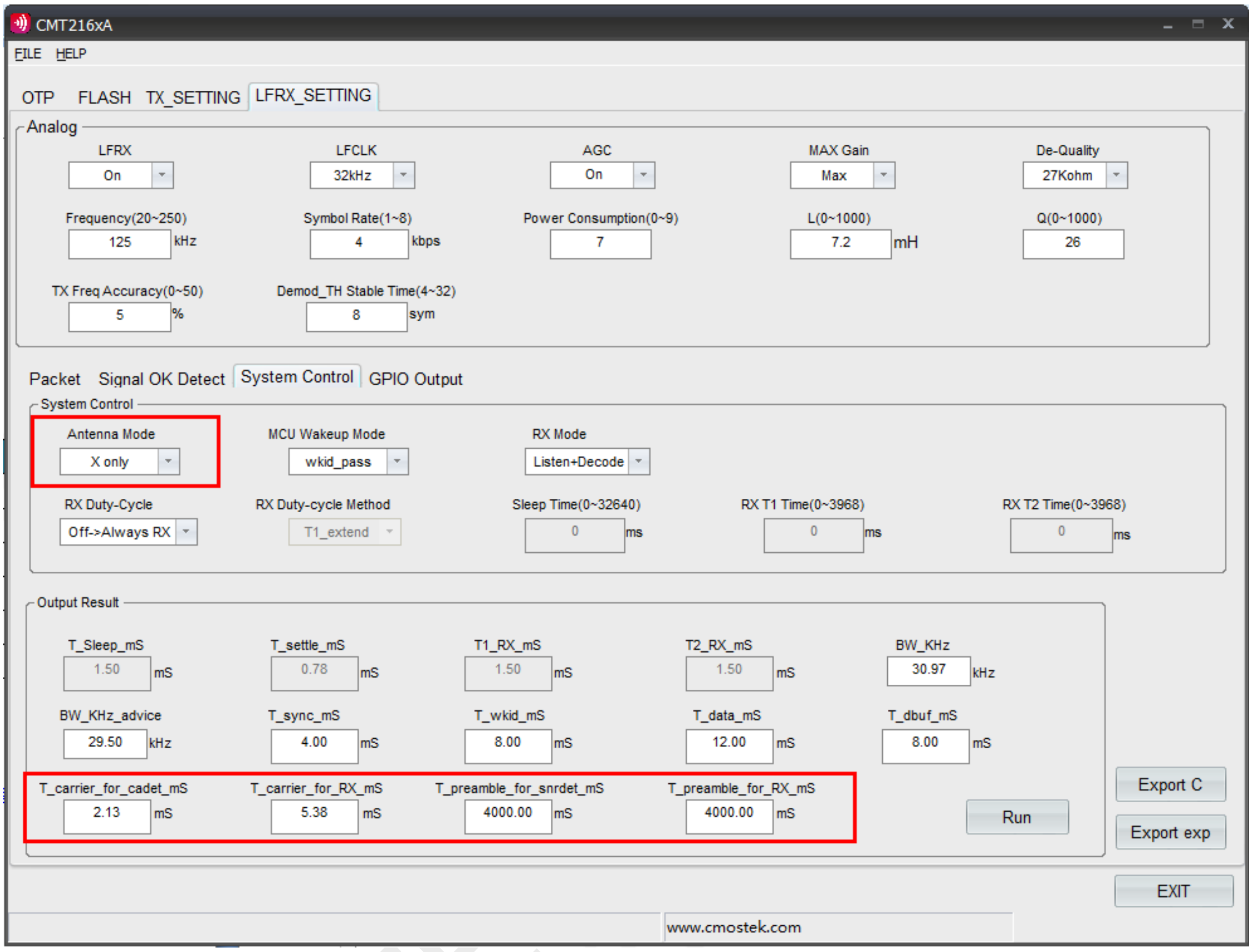

Figure 12. Antenna Mode Configuration on CMT216xA RFPDK

Table 8. Antenna Mode Configuration on CMT216xA RFPDK

Configuration Item	Configuration	Default	Description
Antenna Mode	Normal	Scan X+Y	Non-scanning antenna mode.
	Scan X+Y		Scanning X-axis and Y- axis antenna mode.
	Scan X+Y+Z		Scanning X-axis, Y- axis and Z- axis antenna mode.

- Please be noted that, the above mode selection will affect the below calculated parameters in Table 6. Users need to pay attention to the change of parameters below.
  - T_carrier_for_cadet_mS.
  - T_carrier_for_RX_mS.
  - T_preamble_for_snrdet_mS.
  - T_preamble_for_RX_mS.

8 Receiving Mode

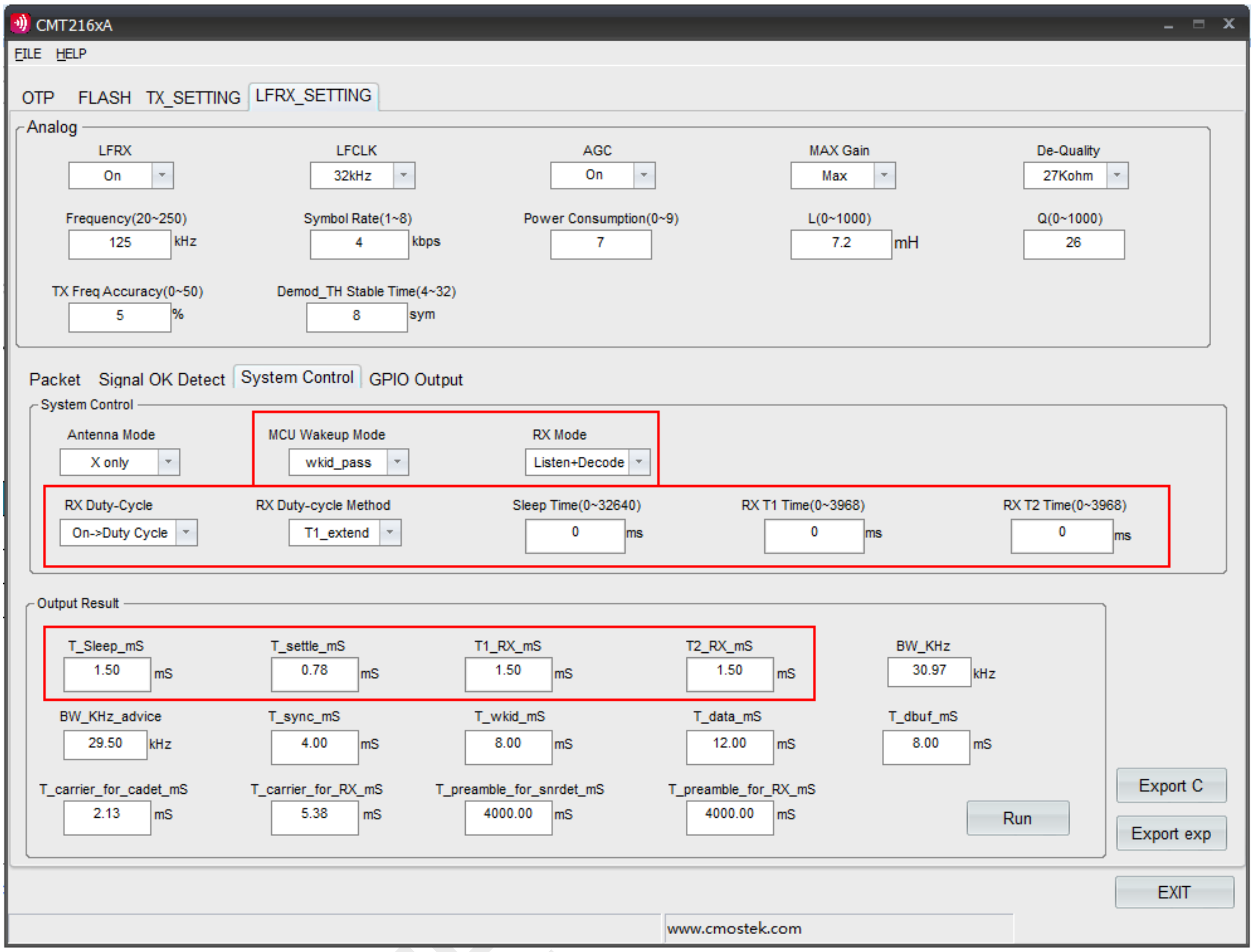

Figure 13. Receiving Mode Configuration on CMT216xA RFPDK

Table 9. Receiving Mode Configuration on CMT216xA RFPDK (1)

Configuration Item	Configuration Options	Default	Description
MCU Wakeup Mode	signal_ok		Select LFRX_SIGNAL_OK as 1 to wake up MCU.
	sync_pass		Select LFRX_SYNC_PASS as 1 to wake up MCU.
	wkid_pass	√	Select LFRX_WKID_PASS as 1 to wake up MCU.
MCU Selection	Internal MCU	√	LFRX_WAKEUP is for waking up internal MCU only.
	External MCU_1		LFRX_WAKEUP is for waking up the external MCU only (configure mapping to specified GPIO). The internal MCU does not use it.
	External_MCU_2		LFRX_WAKEUP is for waking up the external MCU only. The internal MCU does not use it.
RX Mode	Listen + Decode	√	When receiving, it uses both the Listen and Decode state.
	Only Decode		When receiving, it uses the Decode state only.

Notes:

1. Better close the output function of GPIO when the internal MCU is used, to minimize power consumption. Please refer to Section 9 for related configuration details.
2. LFRX supports multi-antenna scanning mode only when RX Mode is Listen + Decode. It supports single antenna or normal mode multi-antenna only when RX Mode is Only Decode.
3. When external MCU is used, it can co-work with the external clearing function of Signal_OK. See Section 9 GPIO Configuration for more details.

Figure 14.Receiving Mode Configuration on CMT216xA RFPDK (2)

Configuration Item	Configuration Options	Default	Description
RX Duty-Cycle	Off →Always RX	√	Always RX mode
	On → Duty Cycle		Duty cycle RX mode
RX Duty-Cycle Method	Fixed Duty Cycle		Fixed duty cycle for RX and sleep.
	T1 Extend		During T1 duration, RX waits for LFRX_WAKEUP ==1. If it is satisfied, give control to MCU, otherwise skip to the sleep state when the T1 duration ends.
	T1 T2 Extend	√	During T1 duration, RX waits for LFRX_SIGNAL_OK==1. If it is satisfied, extend to the time duration T2. Then RX waits for LFRX_WAKEUP ==1, if it is satisfied, give control to MCU, otherwise skip to the sleep state when the T1 or T2 duration ends.
Sleep Time	0~32640 mS	0	LFRX Sleep time configured by users.
RX T1 Time	0~3968 mS	0	RX T1 time configured by users.
RX T2 Time	0~3968 mS	0	RX T2 time configured by users.
T_sleep_mS	-	-	The actual LFRX Sleep time calculated automatically by CMT216xA RFPDK.
T_settle_mS	-	-	The actual startup time calculated automatically by CMT216xA RFPDK.
T1_RX_mS	-	-	The actual T1_RX time calculated automatically by CMT216xA RFPDK.
T2_RX_mS	-	-	The actual T2_RX time calculated automatically by CMT216xA RFPDK.

8.1 Always RX State

Select RX Duty-Cycle as Off, configure LFRX by MCU after power-up, then MCU enters the sleep mode. Thereafter, LFRX enters the Always RX mode.

Special considerations:

- Set Signal_OK Auto Clear as On. Set a proper value for Signal_OK Auto Clear Time to make the window cover the whole data packet.
- Once the MCU is woken up and complete the task, configure LFRX_MANU_CLR to 1 for clearing.
- For each packet, the Carrier and Preamble should be larger than $T_{carrier\_for\_RX\_mS}$ and $T_{preamble\_for\_RX\_mS}$ respectively, which are displayed on RFPDK.

8.2 Fixed Duty Cycle RX

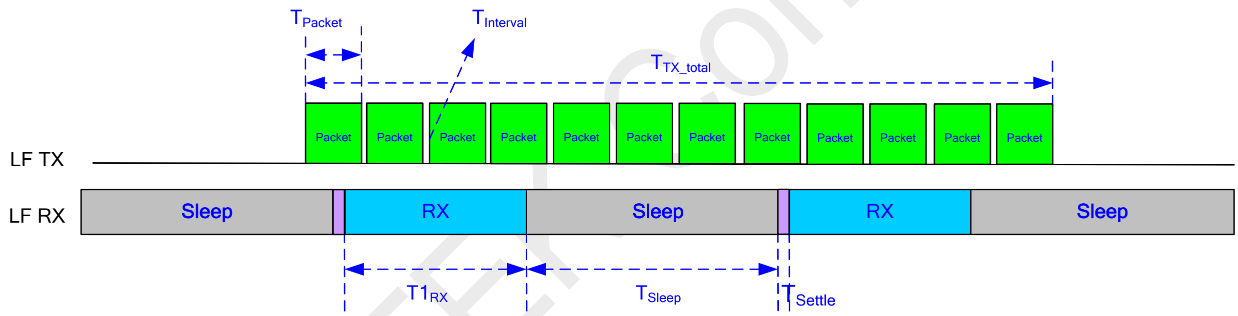

Figure 15. Fixed Duty Cycle RX Mode

- T_{Settle} = 781 us, the startup settling time.
- Set *Signal_OK Auto Clear* as *Off*. Once the MCU is woken up and complete the task, configure LFRX_MANU_CLR to 1 for clearing.
- Make the total successive TX time $T_{TX\_total} > 2*T1_{RX} + 2*T_{Settle} + T_{Sleep}$ to ensure at least one receiving duration is covered.
- Make the fixed RX duration $T1_{RX} > 2*T_{Packet} + T_{Interval}$ to ensure at least one packet can be received during each RX.
- For each packet, the Carrier and Preamble should be larger than $T_{carrier\_for\_RX\_mS}$ and $T_{preamble\_for\_RX\_mS}$ respectively, which are displayed on RFPDK.

8.3 T1 Extended Duty Cycle RX

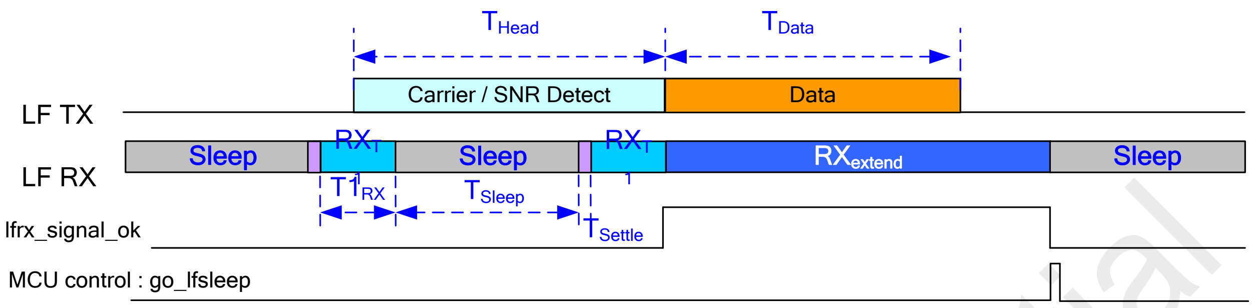

Figure 16. T1 Extended Duty Cycle RX Mode

Notes:

- T_{Settle} = 781 us, the startup settling time.
- Set *Signal_OK Auto Clear* as *Off*. Once the MCU is woken up and complete the task, configure LFRX_MANU_CLR to 1 for clearing.
- **Set *MCU_Wakeup_Mode* as *signal_ok*.**
- Since the triggering condition is the same, once it is detected that LFRX_WAKEUP is selected as LFRX_SIGNAL_OK during T1 and it is valid when being set as 1, the time extending is triggered along with MCU wake-up.
- Make the Carrier and Preamble satisfy the below 2 requests respectively to ensure at least one receiving duration is covered.

$$T_{Head} > 2*T1_{RX} + 2*T_{Settle} + T_{Sleep} + (T_{carrier\_for\_RX\_mS} - T_{carrier\_for\_cadet\_mS}),$$

or

$$T_{Head} > 2*T1_{RX} + 2*T_{Settle} + T_{Sleep} + (T_{preamble\_for\_RX\_mS} - T_{preamble\_for\_snrdet\_mS})$$

- T1 should be not less than $T_{carrier\_for\_cadet\_mS}$ or $T_{preamble\_for\_snrdet\_mS}$, which are displayed on CMT216xA RFPDK.
- Since it is not a strict condition triggering MCU wake-up in this mode, it's subject to interference, which may cause triggering MCU wake-up falsely.

8.4 T1 + T2 Extended Duty Cycle RX Mode

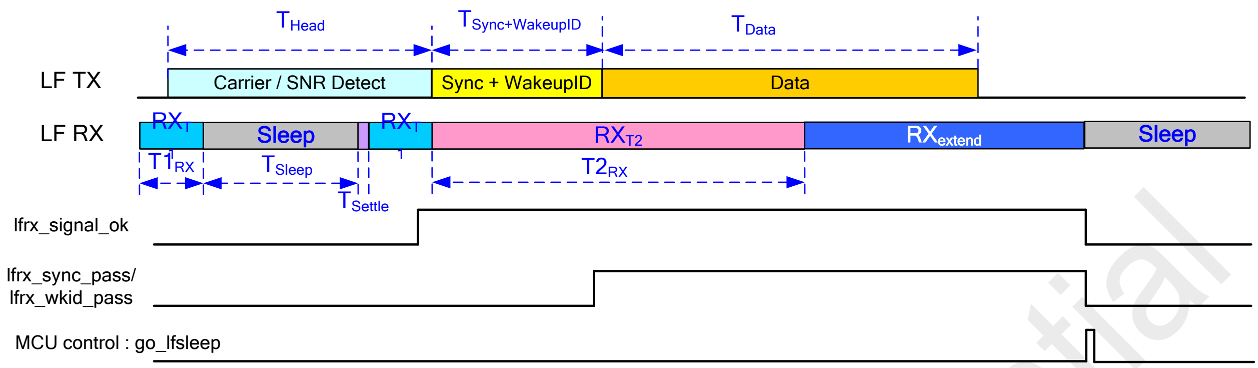

Figure 17. T1 + T2 Extend Duty Cycle RX Mode

Notes:

- T_{Settle} = 781 us, the startup settling time.
- Slect Signal_OK Auto Clear function as Off; set LFRX_MANU_CLR to 1 for clearing after the MCU wakeup task is finished.
- Select MCU_Wakeup_Mode as sync_pass or wkid_pass.
- Once detecting LFRX_SIGNAL_OK being valid value 1 (namely carrier wave or SNR detection being valid) in T1 time, extend the time to T2.
- Once detecting LFRX_WAKEUP being valid value 1 (namelysync_pass or wkid_pass being valid) in T2 time, wake up the MCU.
- Make the Carrier and Preamble satisfy the below 2 requests respectively to ensure at least one receiving duration is covered.

$$T_{Head} > 2*T1_{RX} + 2*T_{Settle} + T_{Sleep} + (T_{carrier\_for\_RX\_mS} - T_{carrier\_for\_cadet\_mS}),$$

or

$$T_{Head} > 2*T1_{RX} + 2*T_{Settle} + T_{Sleep} + (T_{preamble\_for\_RX\_mS} - T_{preamble\_for\_snrdet\_mS})$$

- T1 should be no less than $T_{carrier\_for\_cadet\_mS}$ or $T_{preamble\_for\_snrdet\_mS}$, which are displayed on CMT216xA RFPDK.
- T2 timer must satisfy $T2_{RX} > T_{Head} + T_{sync} + T_{wkid}$.

9 GPIO Configuration

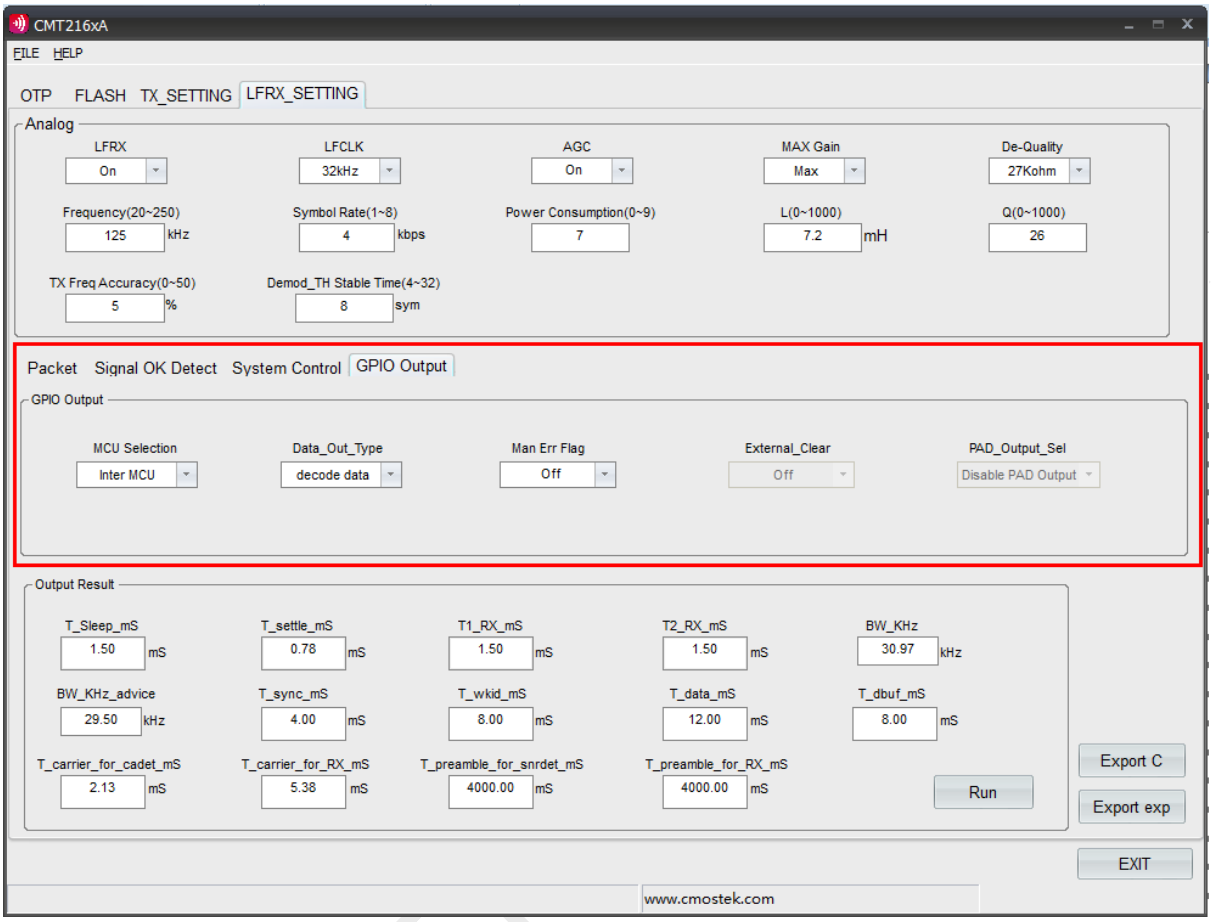

Figure 18. Receiving Mode Configuration on CMT216xA RFPDK

Table 10. GPIO Related Configuration on CMT216xA RFPDK

Configuration Item	Configuration Options	Default	Description
Data Out Type	raw data		Modulation data.
	cdr data		Data after clock synchronization.
	decode data	√	Encoded data.
External Clear	Off / On	Off	Disable/enable the external LFRX_SIGNAL_OK clearing function. Input positive pulse with a width larger than 100 us.
Man Err Flag	Off / On	Off	Disable/enable outputting Manchester code error flag to PAD.
PAD Output Sel	Disable	√	Disable outputting to PAD.
	group1		A4 (Input): External Clear A5(Output): LFRX_WAKEUP A6(Output): Data A7(Output): Dclk B5(Output): LFRX_MAN_ERR_FLAG
	group2		A4 (Input): External Clear A1(Output): LFRX_WAKEUP A2(Output): Data A3(Output): Dclk B6(Output): LFRX_MAN_ERR_FLAG

10 Related Registers and APIs

Table 11. Related Registers and APIs

Name	Area	Sub-area	Address	Reset Value	Function
CUS_LFRX3	Block0	--	0x12	0x3F	Low-frequency wake-up configuration register 3.
CUS_LFRX4	Block0	--	0x13	0x68	Low-frequency wake-up configuration register 4.
CUS_LFRX5	Block0	--	0x14	0x8F	Low-frequency wake-up configuration register 5.
CUS_LFRX6	Block0	--	0x15	0xFE	Low-frequency wake-up configuration register 6.
CUS_LFRX7	Block0	--	0x16	0x61	Low-frequency wake-up configuration register 7.
CUS_LFRX8	Block0	--	0x17	0xB3	Low-frequency wake-up configuration register 8.
CUS_LFRX9	Block0	--	0x18	0xE4	Low-frequency wake-up configuration register 9.
CUS_LFRX10	Block0	--	0x19	0xEF	Low-frequency wake-up configuration register 10.
CUS_LFRX11	Block0	--	0x1A	0x15	Low-frequency wake-up configuration register 11.
CUS_LFRX12	Block0	--	0x1B	0x13	Low-frequency wake-up configuration register 12.
CAL_LFRX_TCAP2	Block0	--	0x34	0x10	Low-frequency wake-up internal matching capacitor register 2 (Z-axis antenna)
CAL_LFRX_TCAP1	Block0	--	0x35	0x10	Low-frequency wake-up internal matching capacitor register 1 (Y-axis antenna)
CAL_LFRX_TCAP0	Block0	--	0x36	0x10	Low-frequency wake-up internal matching capacitor register 0 (X-axis antenna)
CAL_LFRX_OSC_CODE	Block0	--	0x37	0x00	NA
CUS_SYSCTL3	Block0	--	0x50	0x00	System control register 3
CUS_SYSCTL4	Block0	--	0x51	0x01	System control register 4
CUS_SYSCTL5	Block0	--	0x52	0x00	System control register 5, T1 configuration of low-frequency duty cycle RX.
CUS_SYSCTL6	Block0	--	0x53	0x00	System control register 6, T2 configuration of low-frequency duty cycle RX.
CUS_SYSCTL7	Block0	--	0x54	0x00	System control register 7, sleep time 1 configuration of low-frequency duty cycle RX.
CUS_SYSCTL8	Block0	--	0x55	0x10	System control register 8, sleep time 2 configuration of low-frequency duty cycle RX..
CUS_SYSCTL9	Block0	--	0x56	0x29	System control register 9.
CUS_SYSCTL10	Block0	--	0x57	0x00	System control register 10, low-frequency RX manual state control register.
CUS_LFRX15	Block0	--	0x58	0x72	Low-frequency wake-up configuration register 15.
CUS_LFRX16	Block0	--	0x59	0xAD	Low-frequency wake-up configuration register 16.
CUS_LFRX17	Block0	--	0x5A	0x59	Low-frequency wake-up configuration register 17, SyncValue[7:0].
CUS_LFRX18	Block0	--	0x5B	0x5A	Low-frequency wake-up configuration register 18, SyncValue[15:8].
CUS_LFRX19	Block0	--	0x5C	0xA5	Low-frequency wake-up configuration register 19, SyncValue[23:16].
CUS_LFRX20	Block0	--	0x5D	0x00	Low-frequency wake-up configuration register 20, SyncValue[31:24].
CUS_LFRX21	Block0	--	0x5E	0x23	Low-frequency wake-up configuration register 21, WakeupID[7:0]
CUS_LFRX22	Block0	--	0x5F	0x00	Low-frequency wake-up configuration register 22, WakeupID[15:8]
CUS_LFRX23	Block0	--	0x60	0x00	Low-frequency wake-up configuration register 23, WakeupID[23:16]
CUS_LFRX24	Block0	--	0x61	0x00	Low-frequency wake-up configuration register 24, WakeupID[31:24]
CUS_LFRX25	Block0	--	0x62	0x1C	Low-frequency wake-up configuration register 25
CUS_LFRX26	Block0	--	0x63	0x50	Low-frequency wake-up configuration register 26
CUS_LFRX27	Block0	--	0x64	0x31	Low-frequency wake-up configuration register 27, low-frequency rate selection.
CUS_LFRX28	Block0	--	0x65	0x7C	Low-frequency wake-up configuration register 28.

Name	Area	Sub-area	Address	Reset Value	Function
CUS_LFRX29	Block0	--	0x66	0x65	Low-frequency wake-up configuration register 29.
CUS_LFRX30	Block0	--	0x67	0x1E	Low-frequency wake-up configuration register 30.
CUS_SYSCTL11	Block0	--	0x68	0x80	System control register 11.
CUS_SYSCTL12	Block0	--	0x69	0x00	System control register 12.
CUS_SYSCTL18	Block0	--	0x6F	0x00	System control register 18.
CUS_LFRX31	Block0	--	0x72	0x00	Low-frequency wake-up configuration 31.
CUS_LFRX32	Block0	--	0x73	0x00	Low-frequency wake-up configuration 32.
CUS_LFRX33	Block0	--	0x74	0x00	Low-frequency wake-up configuration 33
CLK_SYS_DIV	Block1	Bank0	0x8F	0x00	System clock frequency division register.
LFRX_IF_TH_H	Block1	Bank1	0xC1	0x00	Frequency calibration output capture channel selection.
LFRX_IF_TH_L	Block1	Bank1	0xC3	0x7D	Target calibration frequency.

Notes:

1. Please refer to *AN286 CMT216xA Register Manual* for more details.

Table 12. Related APIs

API Name	API Function
sys_get_lfrx_state	Get the current operating state of LFRX
lfrx_setup_config	Configure the LFRX module. The configuration values are generated by the
lfrx_enable_lfrx_osc_out	Enable the low-frequency antenna resonant frequency output.
lfrx_disable_lfrx_osc_out	Disable low-frequency antenna resonant frequency output.
cal_lfrx_osc_amplitude_calibration	Calibrate the amplitude of low-frequency antenna resonance.
cal_lfrx_osc_frequency_calibration	Calibrate the frequency of low-frequency antenna resonance.

Notes:

1. Please refer to *AN282 CMT216xA API Library Usage Guide* for more details.

11 Revise History

Table 13. Revise History Records

Version No.	Chapter	Description	Date
0.5C	All	Initial version	2019/12/25

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