Introduction

The CMT2251A is a true single-chip, ultra low power and high performance device that consists of an OOK RF receiver, a data decoder and 1 PWM output pin for various 300 to 480 MHz wireless applications. The decoder supports 1920 and 1527 packet formats. The chip is part of the CMOSTEK NextGenRF™ family, which includes a complete line of transmitters, receivers and transceivers.

The RFPDK (Radio Frequency Products Development Kit) is a PC application developed by CMOSTEK for the NextGenRF™ product line. Differing from traditional RF chip configuration methods, which usually require complex software programming and register-based controlling, the RFPKD revolutionarily simplifies the NextGenRF™ product configurations. The user can easily complete the product configuration by just clicking and inputting a few parameters. After that, the product can be directly used in the RF system without performing any further configurations.

This document describes the details of how to configure the features/parameters of the CMT2251A with the RFPDK.

To help the user to develop their application with CMT2150A and CMT2251A easily, CMOSTEK provides **CMT2150A/2251A One-Way RF Link Development Kits** that enables the user to quickly evaluate the performance, demonstrate the features and develop the application. The Development Kits includes:

- RFPDK
- USB Programmer
- CMT2150A-EM (Tx module)
- CMT2250A-EM (Rx on-off control module)
- CMT2251A-EM (Rx PWM control module)

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1. Getting Started

Install RFPDK on the computer. The detail of the installation can be found in Chapter 7 of “AN103 CMT2251A Development Kits User’s Guide”.

Setup the development kits as shown in Figure 1 before configuring the CMT2251A. The Application with CMT2251A can be CMT2251A-EM V1.0 provided by CMOSTEK, or the PCB designed by the user with CMT2251A.

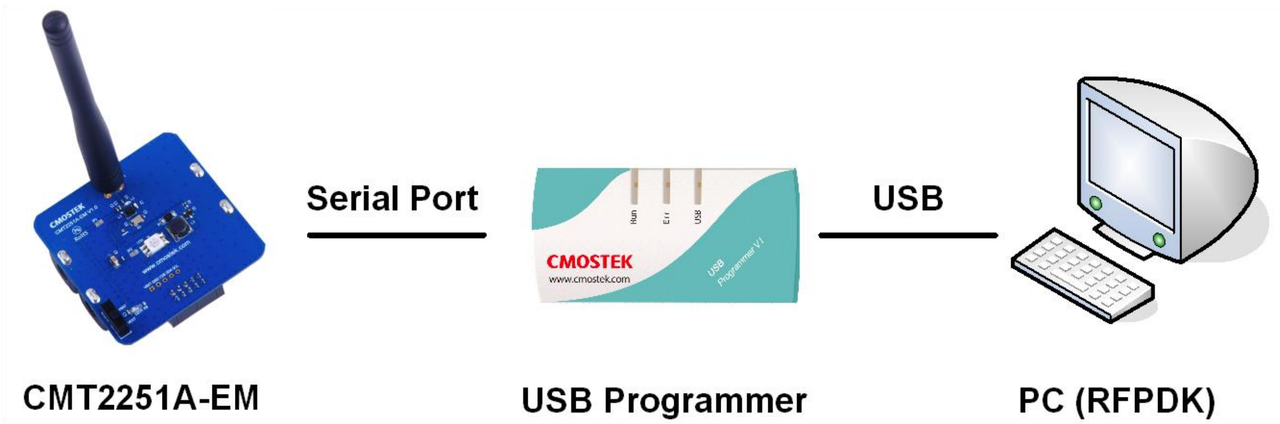

Figure 1. CMT2251A Configuration Setup

Start the RFPDK from the computer’s desktop and select CMT2251A in the Device Selection Panel shown in Figure 2. Once a device is selected, the Device Control Panel appears as shown in Figure 3. Because the Advanced Mode covers all the configurable features / parameters while the Basic Mode only contains a subset, the Advanced Mode is described in this document.

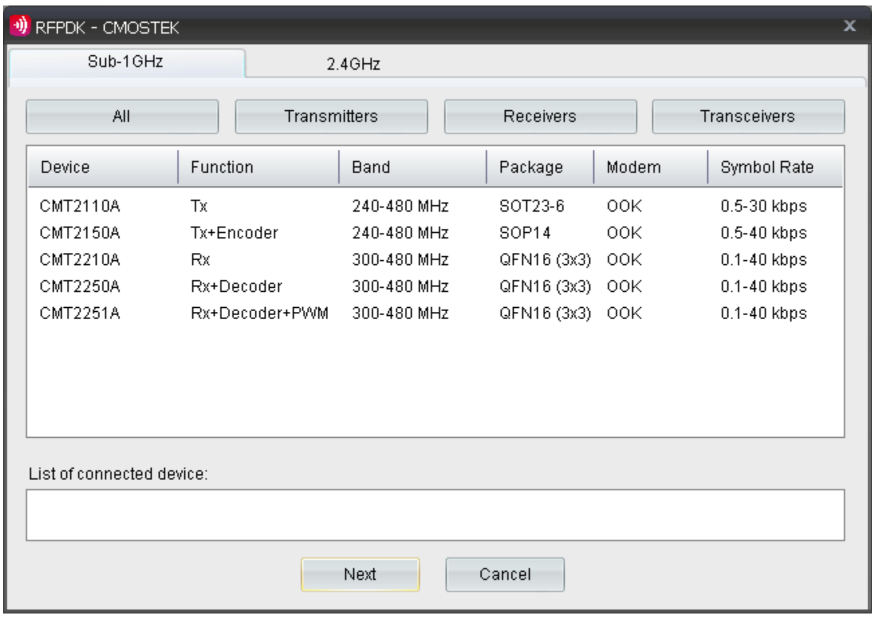

Figure 2. Device Selection Panel

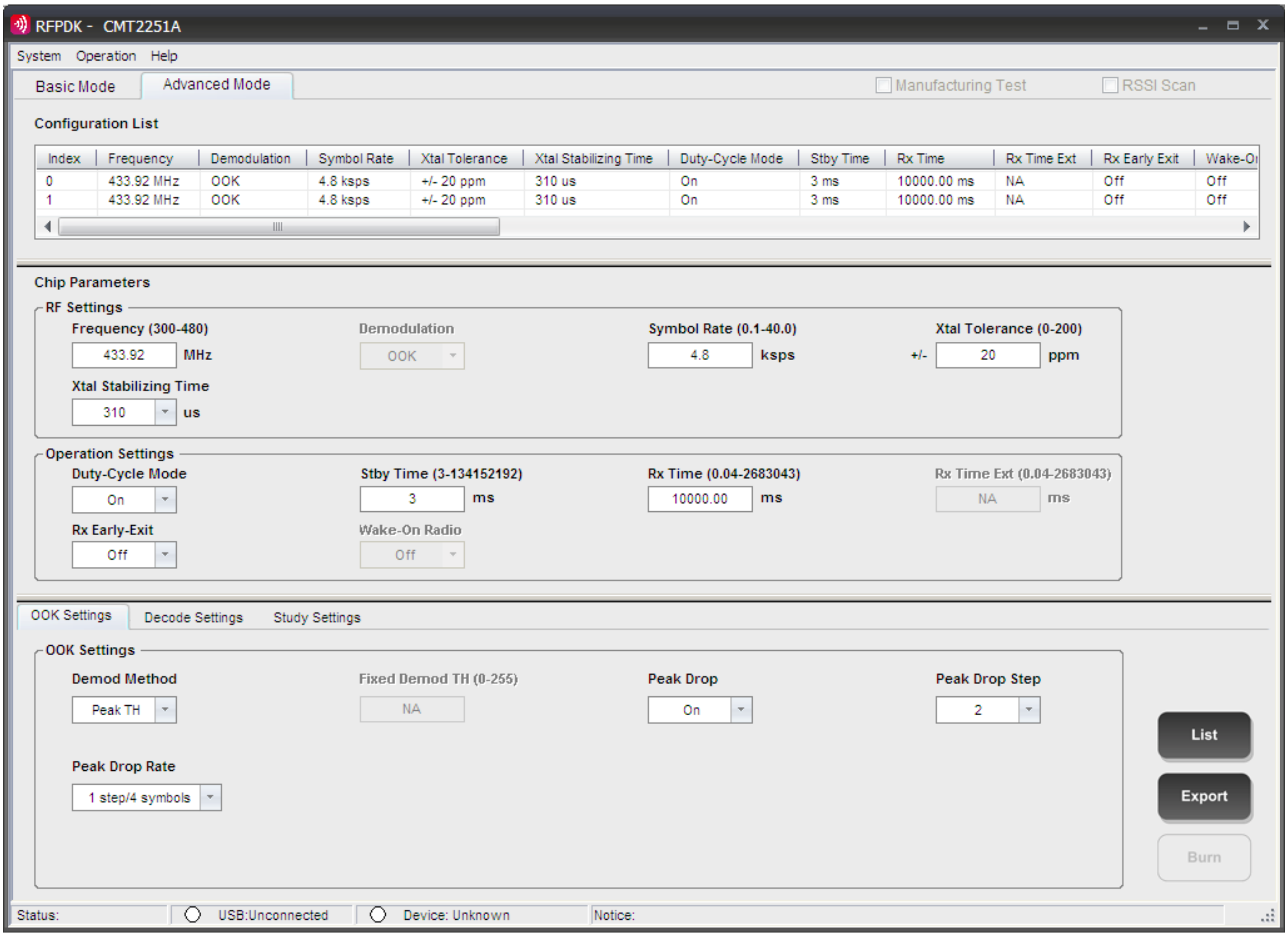

Figure 3. Advanced Mode of Device Control Panel

2. RF Settings

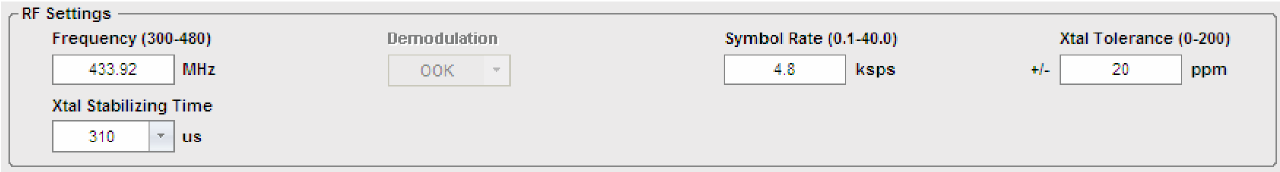

Figure 4. RF Settings

Table 1. RF Settings Parameters

Parameters	Descriptions	Default	Mode
Frequency	The receive radio frequency, the range is from 300 to 480 MHz, with resolution of 0.01 MHz.	433.92 MHz	Basic Advanced
Demodulation	The demodulation type, only OOK demodulation is supported in this product.	OOK	Basic Advanced
Symbol Rate	The receiver symbol rate, the range is from 0.1 to 40.0 ksps, with resolution of 0.1 ksps.	4.8 ksps	Basic Advanced
Xtal Tolerance	The sum of the crystal frequency tolerance of the Tx and the Rx, the range is from 0 to ±200 ppm.	±20 ppm	Basic Advanced
Xtal Stabilizing Time	Time for the device to wait for the crystal to get settled after power up. The options are: 78, 155, 310, 620, 1240 or 2480 us.	310 us	Basic Advanced

2.1 Frequency

CMT2251A covers a wide range of the receive radio frequency from 300 to 480 MHz. The frequency is accurate to two decimal places on the RFPDK.

2.2 Demodulation

CMT2251A only supports OOK demodulation.

2.3 Symbol Rate

With OOK demodulation, CMT2251A supports 0.1 – 40.0 ksps symbol rate. The symbol rate tolerance of the device is from –25% to +25% of the “Symbol Rate” configured on the RFPDK. For example, if the user set the symbol rate to 9.6 ksps on the RFPDK, the covered symbol rate of the transmitted data is from 7.2 to 12 ksps. If the user set it to 40 ksps, the covered range is from 30 to 40 ksps. Any symbol rate outside the range of 0.1 – 40 ksps is not supported.

2.4 Xtal Tolerance

This is the sum of the crystal frequency tolerance of the transmitter and receiver. The input range is from 0 to ±200 ppm. The wide range of crystal tolerance allows very low cost crystal to be used in the applications.

Assuming the crystal tolerance of the transmitter is ±10 ppm, and the crystal tolerance of the receiver is ±20 ppm, the user shall enter the total tolerance of ±30 ppm on the RFPDK. The RFPDK takes this into account to calculate the receiving bandwidth. When the crystal tolerance increases, the bandwidth is increased and the sensitivity is reduced.

It is also recommended for the user to perform on-field testing of the sensitivity with the desired setting of the Xtal Tolerance.

2.5 Xtal Stabilizing Time

This defines the time for the device to wait for the crystal to get stable after it is powered up. The user shall select one of the six options provided on the RFPDK that is most suitable for the crystal used in the applications.

3. Operation Settings

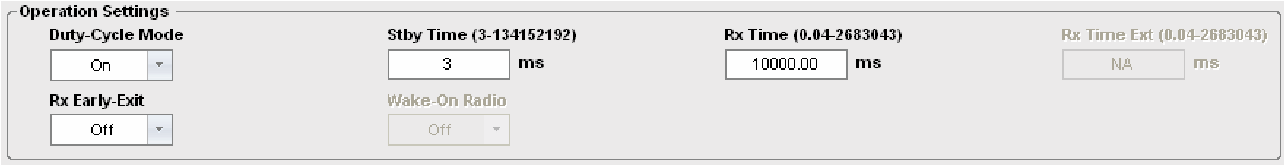

Figure 5. Operation Settings

Table 2. Operation Settings Parameters

Parameters	Descriptions	Default	Mode
Duty-Cycle Mode	Turn on/off the duty-cycle mode, the options are: on or off.	On	Basic Advanced
Stby Time	The standby (stby) time in duty-cycle mode, the range is from 3 to 134,152,192 ms.	3 ms	Basic Advanced
Rx Time	The receive time in duty-cycle mode, the range is from 0.04 to 2,683,043.00 ms. The default value is different when the Wake-On Radio (WOR) is turned on or off.	10,000.00 ms (WOR is off) or 20.00 ms (WOR is on)	Basic Advanced
Rx Time Ext	The extended receive time in duty-cycle mode, the range is from 0.04 to 2,683,043.00 ms.	200.00 ms	Advanced
Rx Early Exit	Turn on/off the Rx early exit function, the options are: on or off. It is only available when the Wake-On Radio is turned on.	Off	Advanced
Wake-On Radio	Turn on/off the wake-on radio function, the options are: on or off. It is only available when the Duty-Cycle Mode is turned on.	Off	Advanced

3.1 Duty-Cycle Mode

This allows the user to determine how the radio is controlled, as shown in the figure below.

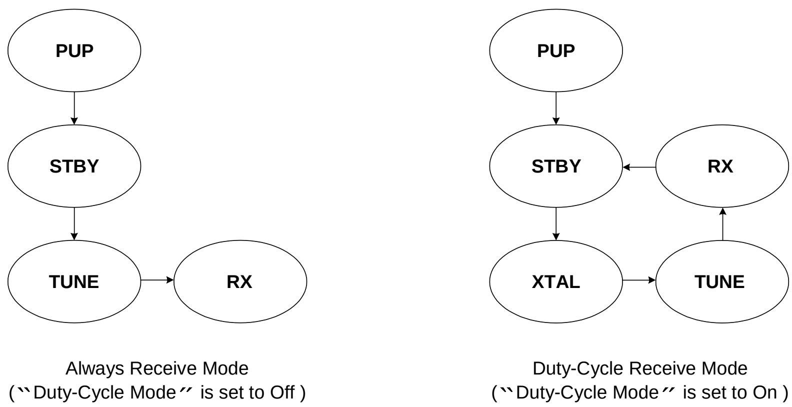

Figure 6. Radio Operation with Duty-Cycle Mode On and Off

3.1.1 Always Receive Mode

If the Duty-Cycle Mode is turned off, the device will go through the Power Up (PUP) sequence, stay in the STBY state for about 3 ms, tune the receive frequency, and finally stay in the RX state until the device is powered down. The power up sequence, which takes about 4 ms to finish, includes the task of turning on the crystal and calibrating the internal blocks. The device will continuously receive the incoming RF signals during the RX state and perform the decoding to control the PWM output. The figure below shows the timing characteristics and current consumption of the device from PUP to RX.

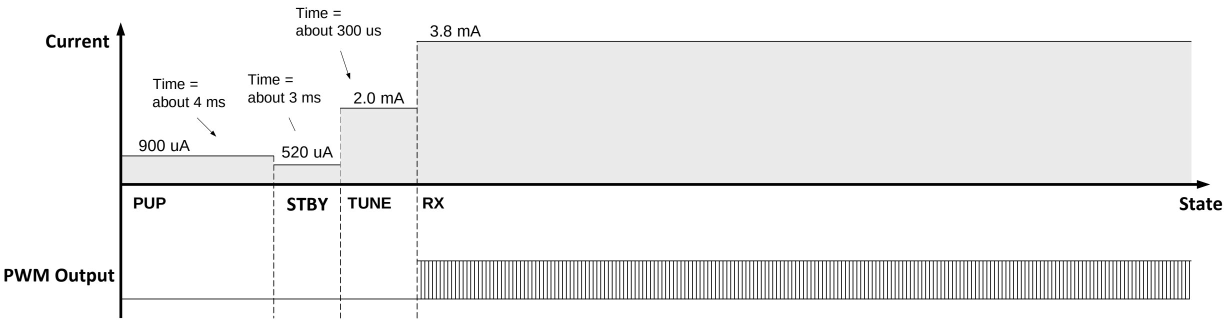

Figure 7. Timing and Current Consumption for Always Receive Mode

3.1.2 Duty-Cycle Receive Mode

If the Duty-Cycle Mode is turned on, after the PUP the device will automatically repeat the sequence of STBY, XTAL, TUNE and RX until the device is powered down. This allows the device to re-tune the synthesizer regularly to adept to the changeable environment and therefore remain its highest performance. The device will continuously receive any incoming signals during the RX state and perform the decoding to control the PWM output. The PWM output is available since the beginning of the first RX state and is adjustable in each RX state since then. The PUP sequence consumes about 9.5 ms which is longer than the 4 ms in the Always Receive Mode. This is because the LPOSC, which drives the standby timer, must be calibrated during the PUP.

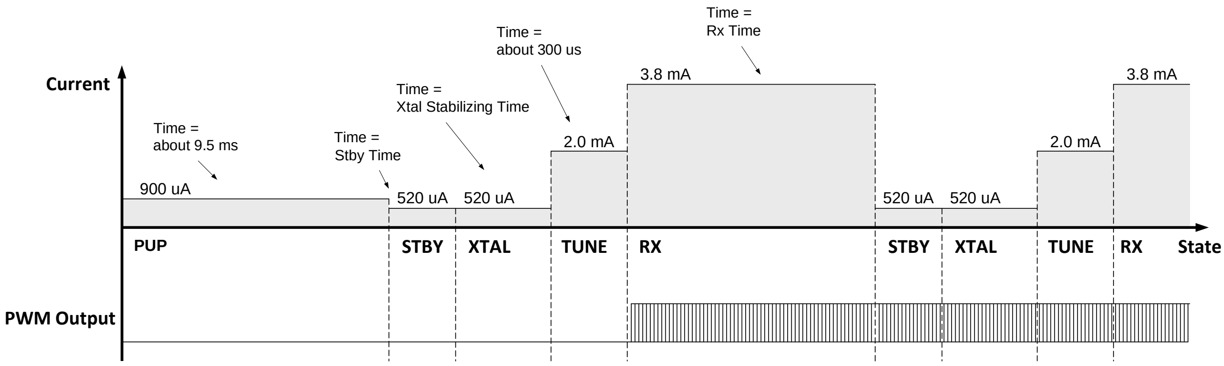

Figure 8. Timing and Current Consumption for Duty-Cycle Receive Mode

It is strongly recommended for the user to turn on the Duty-Cycle Mode option. The advantages are:

- Maintaining the highest performance of the device by regular frequency re-tune.
- Increasing the system stability by regular standby (resetting most of the blocks except the crystal).
- Saving power consumptions of both of the Tx and Rx device.

As long as the Stby Time and Rx Time are properly configured, the transmitted data can always be captured by the device.

3.2 Stby Time, Rx Time

When the Duty-Cycle Mode is turned on, the Stby Time and Rx Time is opened to the user to configure. Proper setting of these two values is important for the device to work in an expected scenario.

3.2.1 Easy Configuration

When the user wants to take the advantage of maintaining the highest system stability and performance, and the power consumption is not the first concern in the system, the Easy Configuration can be used to let the device to work in the duty-cycle mode without complex calculations, the following is a good example:

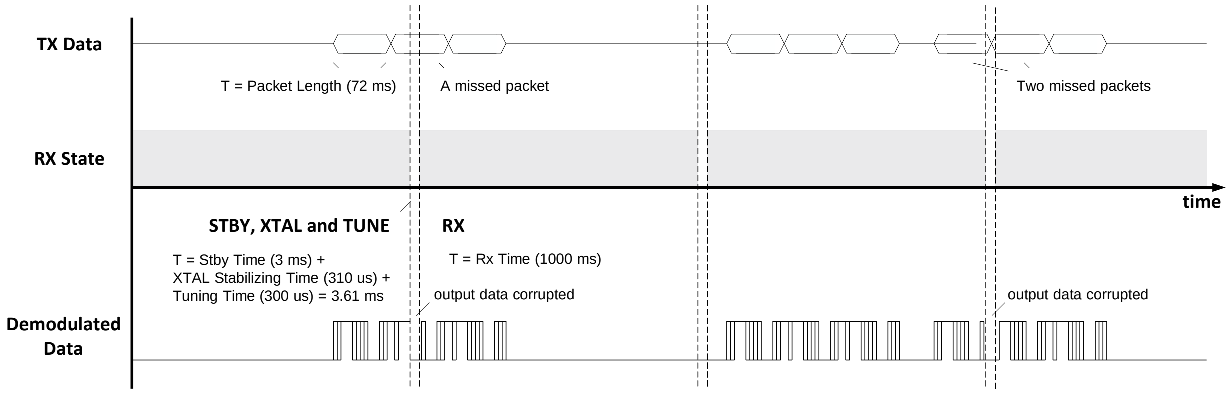

Figure 9. Tx and Rx relationship of Easy Configuration

In this example, the Tx device transmits the data at 1.2 ksps and there are 60 symbols in one data packet. Thus, the packet length is 72 ms. The user can do the following:

- Set the Stby Time to the minimum value of 3 ms.
- Set the Rx Time to 1 second which is much longer than the packet length.
- Let the Tx device to send out 3 continuous data packets in each transmission.

Because the Stby Time is very short, the non-receive time is only about 3.61 ms (the sum of the Stby Time, XTAL stabilizing time and the tuning time), which is much shorter than the packet length of 72 ms. Therefore, this non-receive time period will only have a chance to corrupt no more than 2 packets receiving. During the non-receive time period, the demodulated data will be 0.

Because the Rx Time is very long, and 3 continuous data packets are sent in each transmission, there is at least 1 packet that can be completely received by the device and get demodulated with no corruption. The packet can be decoded successfully.

3.2.2 Precise Configuration

If the system power consumption is a sensitive and important factor in the application, the Precise Configuration can be used.

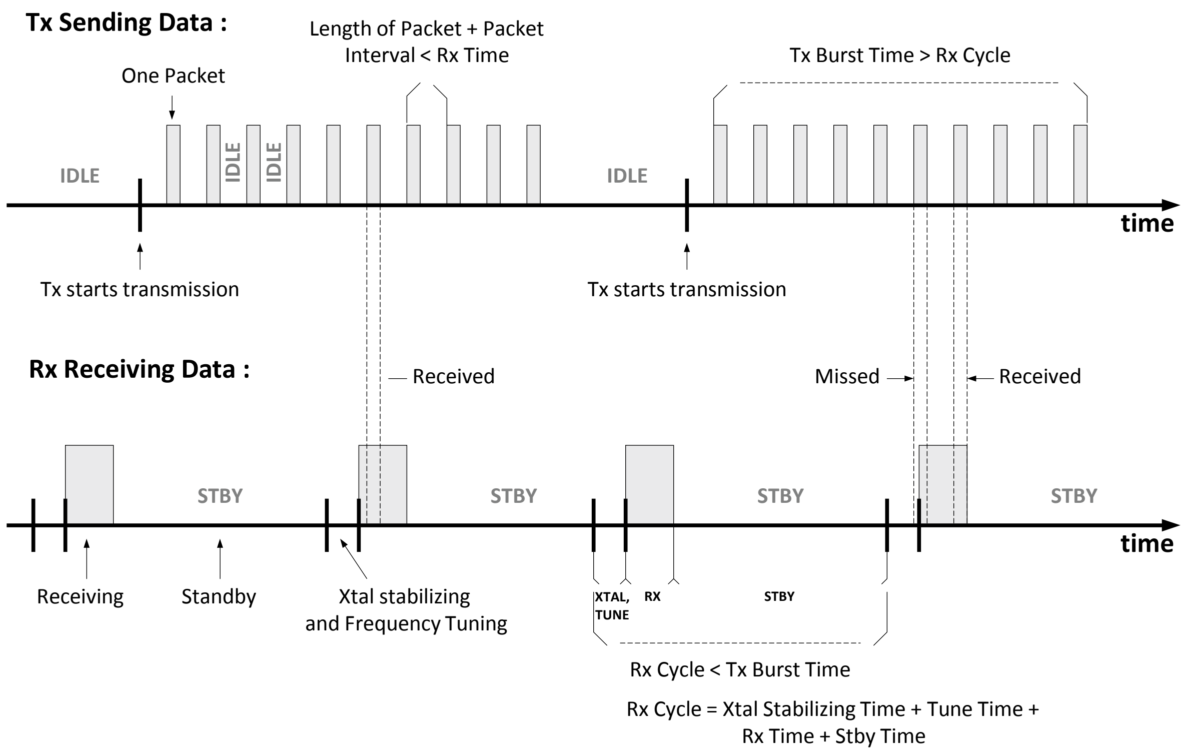

Figure 10. Tx and Rx Relationship of Precise Configuration

The above figure is a conceptual diagram to explain the timing relationships between the Tx and the Rx device. The user will have to make some trade-off amount the packet length, packet interval, Tx burst time, Rx receive time and Rx standby time, to optimize the power consumption of the Rx device. Two requirements must be fulfilled:

- Length of Packet + Packet Interval < Rx Time
- Tx Burst Time > Rx Cycle

The Rx Time must always be longer than the packet length plus the packet interval which is determined by the Tx setting (symbol rate, number of symbol per packet, etc). This ensures that the receiver always has a chance to capture at least 1 packet within a Tx Burst. Normally, it is recommended for the user to set the Rx Time to be longer than 2 or more packets plus the intervals, especially when the application environment is noisy and interferential. The user must also ensure the Rx Cycle, which is the sum of Tune, Rx and Stby Time, is shorter than the Tx Burst Time. In another words, it must be ensured that at least 1 RX state happens during 1 Tx Burst.

3.3 Wake-On Radio

The wake-on radio function is only supported for 1920 packet format. It is an effective power consumption saving technique that minimizes the receive time while it guarantees that the device can successfully capture the transmitted data. The following application examples are provided for better understanding.

Please note that the standby timer which is driven by the LPOSC has ±1% frequency tolerance. The receive timer is driven by the crystal oscillator therefore the timer accuracy is crystal-dependent.

3.3.1 Application Example 1: Fixed Duty

Table 3. Fixed Duty Configurations

Options	Value
Stby Time	5,000 ms
Rx Time	400 ms
Rx Time Ext	NA
Wake-On Radio	Off
Preamble	NA
Rx Early Exit	Off
Valid Reception	1 packet

The standby and receive time is fixed to 5,000 ms and 400 ms, respectively.
The Xtal Stabilizing Time is set to 310 us.

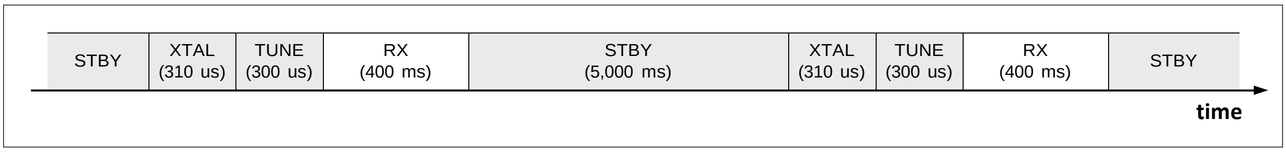

Figure 11. Fixed Duty Operation

After a successful power up, the device enters the STBY state. When it reaches the standby timeout of 5,000 ms, it switches to XTAL state to wait for the crystal to get stable. Subsequently it takes about 300 us to tune the frequency synthesizer to the desired frequency. Once the frequency synthesizer is locked, the device starts receiving. When the Rx timer is timeout at 400 ms, the device switches back to the STBY state and repeat the same cycle continuously until it is powered down.

In this example, the non-receive time is 5,000 + 0.31 + 0.3 = 5,000.61 ms. The receive time is 400 ms. Therefore, according to the principle introduced in the “Precise Configuration”, the Tx burst time must be longer than 5,400.61 ms, and 2 data packets must appear during the RX state for safety.

3.3.2 Application Example 2: Wake on Preamble

Table 4. Wake on Preamble Configurations

Options	Value
Stby Time	800 ms
Rx Time	20 ms
Rx Time Ext	200 ms
Wake-On Radio	On
Preamble	16-symbol
Rx Early Exit	Off
Valid Reception	1 packet

The wake-on radio function provides a powerful scheme to save the power. In this example, the receive time is set to 20 ms which is much shorter than the packet length. The standby time is 800 ms.

When there is no effective signal received, the radio acts like the one introduced in the Application Example 1. Because the Rx time is much shorter, more power is saved.

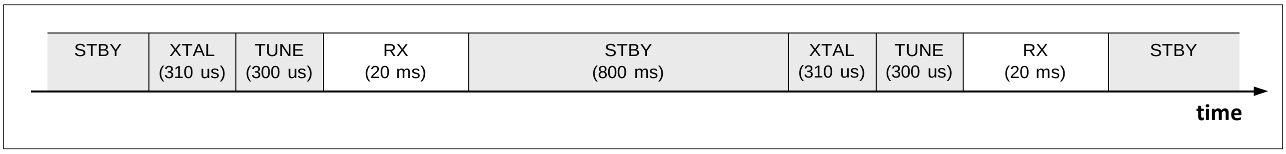

Figure 12. Preamble Wake-On Operation without Preamble Detected

If a valid preamble is received, the RX state is extended to RX EXT state which is long enough for more than 2 data packets reception. A valid preamble means the preamble of the size (16-symbol in this example) defined on the RFPDK. Please note that the preamble defined for the Rx device is not necessarily the entire preamble length that is transmitted by the Tx device.

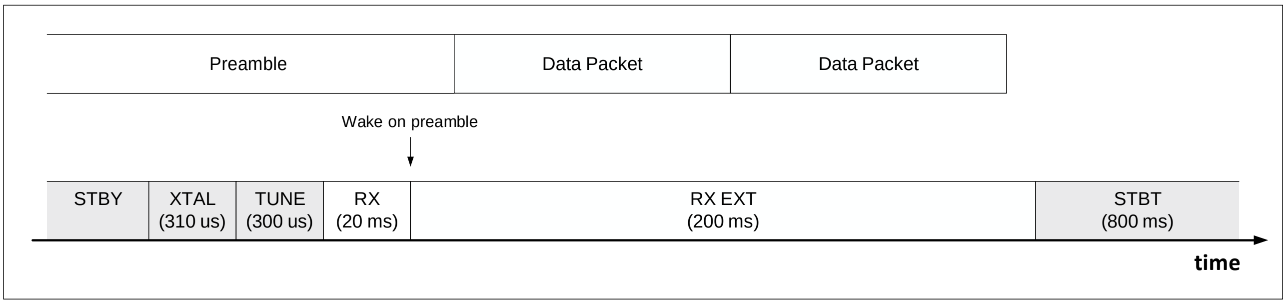

Figure 13. Preamble Wake-On Operation with Preamble Detected

In order to ensure that the preamble can be captured by the Rx, the RX EXT must be longer than the valid preamble which is 16-symbol.

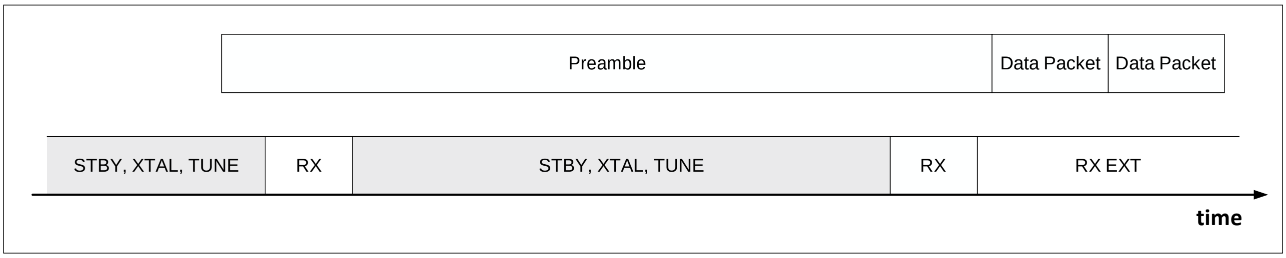

Figure 14. The Transmitted Preamble Length

Also, as shown in the above figure, for the Tx device, the transmitted preamble length must be long enough to ensure the Rx reception:

Preamble Length > RX + STBY + XTAL + TUNE + RX

The longer the transmitted preamble length is, the more power the Tx device consumes in each transmission. Therefore, this example is suitable for the application where the Tx device does not send out data very often, and the Rx device is very sensitive about the current consumption.

In most of the applications, it is recommended that the CMT2251A can be paired with the CMT2150A (Low-Cost 240 – 480 MHz

OOK Stand-Alone Transmitter with Encoder). However, since the maximum size of the preamble sent by CMT2150A is only 16-symbol, the size might not be long enough to fulfill the WOR timing requirement introduced above. In this case, it is suggested to use the stand-alone transmitter CMT2110A (Low-Cost 240 – 480 MHz OOK Transmitter) with an external MCU to pair with the CMT2251A. The external MCU can produce the data packet with any length of preamble that is required.

3.4 Rx Early Exit

Rx Early Exit function allows the device to exit the RX state as soon as a certain number of packets defined by “Valid Reception” have been successfully received and decoded. This function is only available in duty-cycle receive mode. It is designed to further save the power consumption by shortening the receive time. The below are a few application examples.

3.4.1 Application Example 1: Fixed Duty with Rx Early Exit

Table 5. Fixed Duty with “Rx Early Exit = On” Configurations

Options	Value
Stby Time	5,000 ms
Rx Time	400 ms
Rx Time Ext	NA
Wake-On Radio	Off
Preamble	NA
Rx Early Exit	On
Valid Reception	1 packet

This example is based on the one descript in Chapter 3.3.1. When no signal is being transmitted, the device works in the fixed duty mode. The Rx Time is 400 ms.

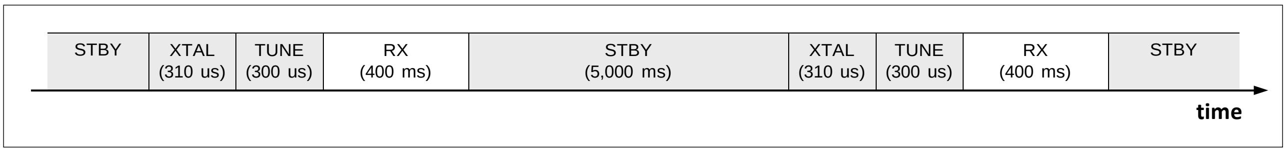

Figure 15. Fixed Duty Operation

Because the Rx Early Exit function is turned on and the “Valid Reception” is set to 1 packet, the device automatically exits the RX state as soon as 1 valid packet is successfully captured. As shown in the below figure, due to the happening of the early exit event, the device only stay in the RX state for 160 ms in the current cycle, saving 240 ms from the original 400 ms.

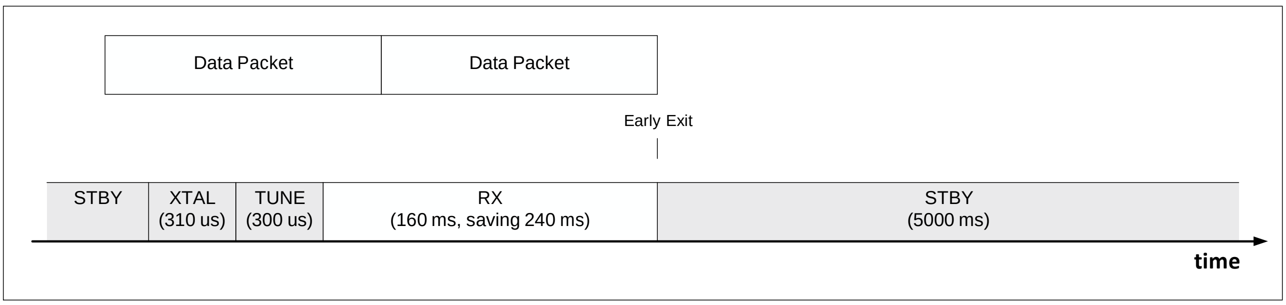

Figure 16. Fixed Duty with Rx Early Exit Operation

3.4.2 Application Example 2: Wake on Preamble with Rx Early Exit

Table 6. Wake on Preamble with "Rx Early Exit = On" Configurations

Options	Value
Stby Time	800 ms
Rx Time	20 ms
Rx Time Ext	200 ms
Wake-On Radio	On
Preamble	16-symbol
Rx Early Exit	On
Valid Reception	2 packets

This example is based on the one descript in Chapter 3.3.2.

Because the Rx Early Exit function is turned on and the "Valid Reception" is set to 2 packets, the device automatically exits the RX state as soon as 2 identical valid packets are successfully captured. As shown in the below figure, due to the happening of the early exit event, in the current cycle the Rx Time Ext is shortened from 200 ms to 150 ms.

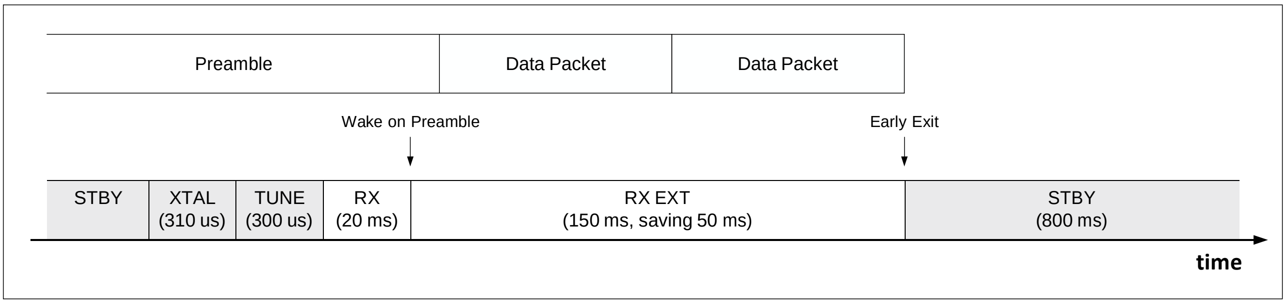

Figure 17. Preamble Wake-On with Rx Early Exit

4. OOK Settings

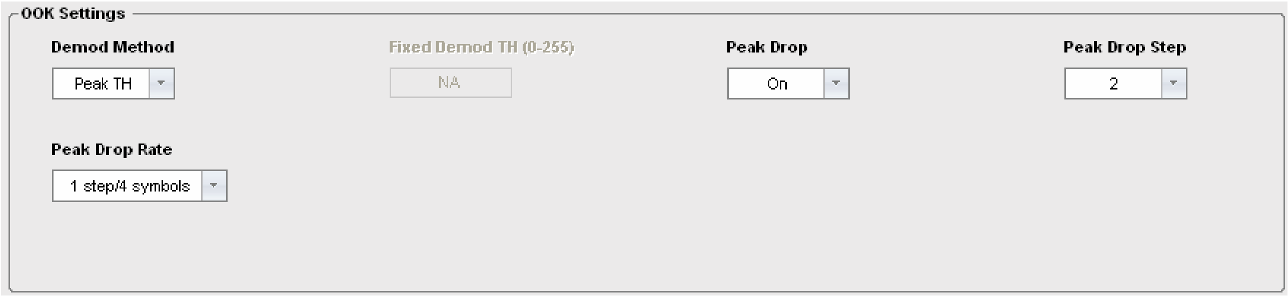

Figure 18. OOK Settings

Table 7. OOK Settings

Parameters	Descriptions	Default	Mode
Demod Method	The OOK demodulation methods, the options are: Peak TH, or Fixed TH.	Peak TH	Advanced
Fixed Demod TH	The threshold value when the Demod Method is “Fixed TH”, the range is from 0 to 255. It is only available when the Demod Method is set to Fixed TH.	80	Advanced
Peak Drop	Turn on/off the RSSI peak drop function, the options are on, or off.	On	Advanced
Peak Drop Step	The RSSI peak drop step size, the options are: 1, 2, 3, 5, 5, 9, 12 or 15.	2	Advanced
Peak Drop Rate	The RSSI peak drop rate, the options are: 1 step/4 symbols, 1 step/2 symbols, 1 step/1 symbols, or 1 step/0.5 symbols.	1 step/4 symbols	Advanced

4.1 Demod Method

The OOK demodulation is done by comparing the RSSI to a demodulation threshold. The threshold is an 8-bit binary value that is comparable to the 8-bit digitized RSSI.

4.1.1 Fixed Threshold Method

When the “Demod Method” is set to Fixed TH, once the RSSI goes above the threshold, logic 1 is output as the demodulated signal, otherwise logic 0 is output. The demodulated signal is then sent to the decoder to perform packet decoding and PWM output controlling.

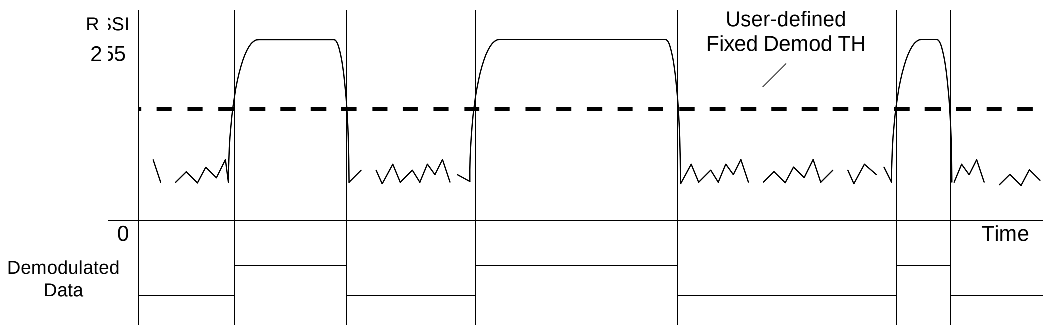

Figure 19. OOK Demodulation Using Fixed Threshold

4.1.2 Peak Threshold Method

When the "Demod Method" is set to "Peak TH", the demodulator dynamically detects the peak value of the RSSI. The comparison threshold (Demod TH) is then obtained by reducing N dB from the peak. The magnitude of N is internally calculated according to the different bandwidths, symbol rates and filtering settings.

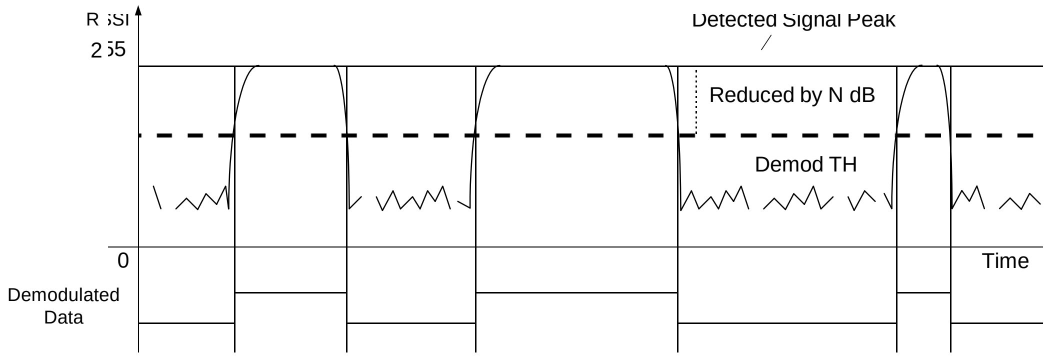

Figure 20. OOK Demodulation Using Peak-N Threshold

When the signal disappears, the peak is detected on the noise floor (see more descriptions in the next section).

To compare the two different modes, the Peak TH mode is used by default on the RFPDK, due to its high adaptability to the different environments and it is carefree for the user. The Fixed TH mode allows the system to only receive the signals whose strength is above a preset value, which is helpful for the user to control the communication distance between the Tx and the Rx.

4.2 Fixed Demod TH

This parameter defines the value of the fixed threshold. It is only available when the Demod Method is set to Fixed TH.

4.3 Peak Drop Step, Peak Drop Rate

When using the Peak TH mode, the Peak Drop function is very useful to deal with the long string of logical "0" on the received data.

When the Peak Drop function is turned off, the dynamically detected peak remains 8 symbols. This means within a moving 8-symbol time window the peak value of the RSSI will be recorded to calculate the demodulation threshold. This might have problem when a string longer than 8 symbols of logical "0" appears, as shown in the below figure.

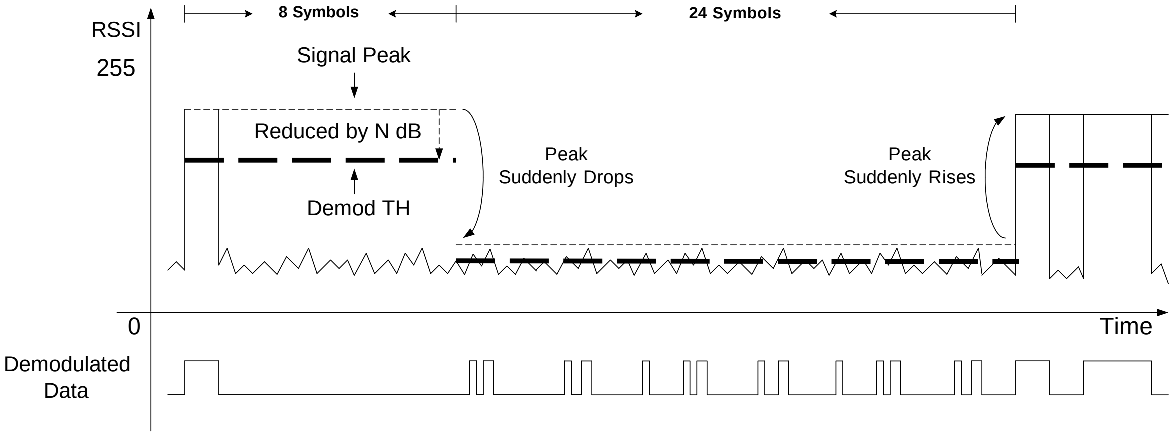

Figure 21. OOK Demodulation Using Peak-N Threshold, with Peak Drop Off

As shown in the above figure, the transmitter sends out a "1" symbol followed by thirty-one "0" symbols. After the signal peak stands for 8 symbols, it suddenly drops to just above the floor noise. From that point the detected peak is actually the floor noise peak and the demodulated data is unpredictable. The last 24 symbols of "0" are then lost or partially lost. Practically, the similar situation does exist and this will lead to failure of demodulation.

The problem can be resolved by turning on the Peak Drop function. It allows the detected peak to drop slowly in order to recognize more symbols of "0". The following figure gives an example. In this example, the Peak Drop Step parameter is set to 12 (RSSI code) on the RFPDK, with the Peak Drop Rate set to 1 step per 2 symbols.

The value of the Peak Drop Step defines how many RSSI codes the signal peak drops each time. The value of Peak Drop Rate defines how fast the peak drop is performed.

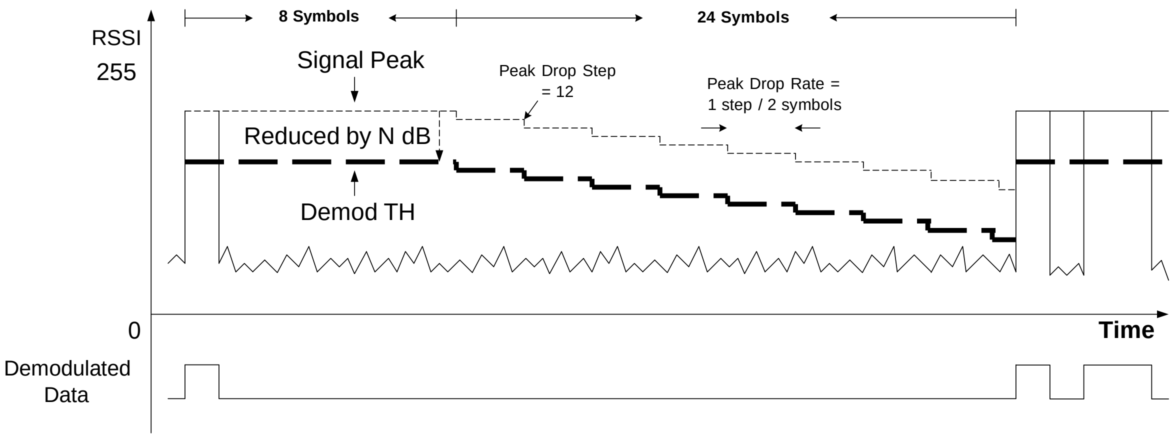

Figure 22. OOK Demodulation Using Peak-N Threshold, with Peak Drop On

As shown in the above figure, after remaining 8 symbols, the peak drops step by step until the next '1' symbol comes. The demodulation threshold drops accordingly to the peak and stays above the noise floor during the long '0' sequence, and therefore allows the device to produce the correct demodulation result. The longer it takes for the peak to drop to the noise floor, the more "0" the system can demodulate. In practice, the bottom of the dropping is the noise floor which varies depending on the different environments. Below is an example to calculate the total drop time:

Assuming the signal peak is 240, to drop from 239 to 0, the total drop time is computed by:

Drop Time = 240 / Peak Drop Step / Peak Drop Rate, units in Rx symbols

Since the maximum step size is 15 (in terms of RSSI code) and the highest rate is 1 step per 0.5 symbol, the fastest peak drop from 239 to 0 is: 240 / 15 / (1/0.5) = 8-symbol time. Since the minimum step is 1 and the lowest rate is 1 step per 4 symbols, the slowest peak drop from 239 to 0 is: 240 / 1 / (1/4) = 960-symbol time.

It should be noticed that, in the above computations the "time" is measured in "numbers of the Rx symbol" according to the symbol rate configured on the RFPDK. The user should take the symbol rate offset into account during the calculations. For instance, if the Rx symbol rate is set to 4.8 ksps while the Tx actually transmits the data at 3.6 ksps (with -25% offset), the signal peak only stands for 6 symbols (at 3.6 ksps) instead of 8 symbols before starting the dropping. Also, the peak drop rate doubles.

CMOSTEK recommends turning on the peak drop function on the RFPDK. By default, the step is set to 2 and the rate is set to 1 step per 4 symbols, and thus it takes 480 symbols to drop from 239 to 0. This default setting fulfills the requirements in most of the wireless applications using OOK. The user does not have to change them unless particular situation are found, such as, the transmitted signals are very small, symbol rate offset is too large, or the string of '0' is too long.

5. Decode Settings

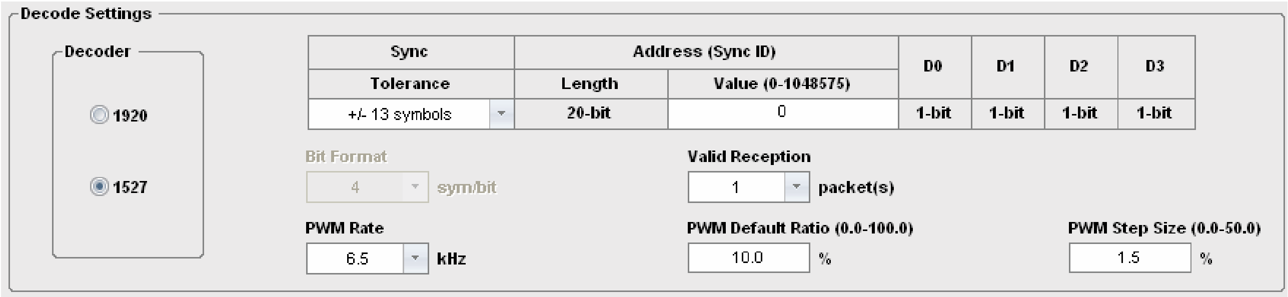

Figure 23. Decode Settings

Table 8. Decode Settings Parameter

Parameter	Descriptions	Default	Mode
Decoder	Select the packet decoding format; the options are: 1920 and 1527. See Table 10, Table 11 and Table 12 for the configurable parameter in each format.	1527	Basic Advanced
PWM Rate	This defines the PWM rate. The options are 6.5 or 13 kHz.	6.5 kHz	Basic Advanced
PWM Default Ratio	This defines the PWM default duty ratio. The range is 0.0 % – 100.0 %.	10.0%	Basic Advanced
PWM Step Size	This defines the PWM step size to increase/decrease the PWM duty ratio. The range is from 0.0% - 50.0%.	1.5%	Basic Advanced
Bit Format	This tells the device how many symbols are used to construct a single bit in the 1920 mode. The options are: 3, 4, 5 or 6 sym/bit. The Bit Format is fixed at 4 sym/bit in 1527.	3	Advanced
Valid Reception	This defines how many identical packets the device consecutively received represent a valid reception, the options are: 1 packet, 2 packets, 3 packet s or 4 packets.	1 packet	Advanced

5.1 Decoder

The device supports 2 types of decoding formats: 1920 and 1527. The packets of these 2 modes have different structures as introduced in the below sub-sections. The following is a feature summary:

Table 9. Feature Summary of the 3 Decoding Formats

Format	Bit Format	Sync ID Length	Data Length	CRC	ID Study	Wake-On Radio
1920	3/4/5/6 sym/bit	1 – 32 bits	4 bits	Support	Support	Support
1527	4 sym/bit	20 bits	4 bits	NA	Support	Not Support

In the below explanation (also on the RFPDK), the packet structural diagrams show all the elements in the packets, as well as the available options corresponding to each element.

Furthermore, some elements in the packet are measured in the unit of "symbol", while some of them are measured in the unit of "bit". For those which have the unit of "bit", one "bit" is constructed (encoded) by several "symbols". In the figures, "SYM" represents the word symbol.

5.1.1 1920 Normal Packet Structure

The normal packet is used to control the PWM output. It contains an optional Preamble, a 32-symbol Head_N indicating the current packet is a Normal packet, a Sync ID, 4-bit Data and an optional 8-symbol CRC.

Preamble	Head_N	Address (Sync ID)			D0	D1	D2	D3	CRC
		Length (1-32)		Value (0-4294967295)					
None	32-symbol	32	bit(s)	0	1-bit	1-bit	1-bit	1-bit	Disable

Figure 24. 1920 Normal Packet Structure

Table 10. Configurable Parameters in 1920 Packet

Parameter	Descriptions	Default	Mode
Preamble	The size of the valid preamble, the options are: None, 8-symbol, 16-symbol, 24-symbol or 32-symbol.	None	Basic Advanced
Address (Sync ID) Length	The range of the Sync ID Length is from 1 to 32 bits.	32 bits	Basic Advanced
Address (Sync ID) Value	The value of the Sync ID has the range from 0 to 2^{Length}-1.	0	Basic Advanced
CRC	The CRC validation increases the reliability of the reception. The options are: Enable or Disable.	Disable	Basic Advanced

- **Preamble**

The pattern of a 16-symbol preamble is shown below:

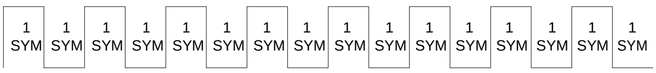

Figure 25. 1920 16-symbols Preamble Pattern

Typically, if the WOR (Wake-On Radio) function is turned on, the preamble is used to extend the receive time. Please see Chapter 3.3.2 for considerations of using the WOR function in the application of "Extended by Preamble".

- **Head_N**

The user does not need to control the Head_N because it is automatically generated by the CMT2150A and recognized by the CMT2251A. The pattern of Head_N is shown below.

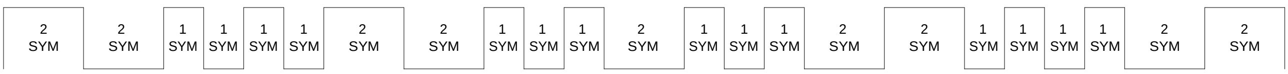

Figure 26. 1920 Head_N Pattern

■ Address (Sync ID)

The Sync ID is sent and received starting from the LSB. For example, if the “Sync ID Length” is set to 16 and the “Sync ID Value” is set to 1, the binary value of the Sync ID is “0000 0000 0000 0001”. In this case, bit<0> = 1 is received first and bit<15> = 0 is received at the end of the Sync ID field.

■ D0, D1, D2, D3

These are the 4 data bits D0, D1, D2, D3 received to control the PWM output. D0 is received first.

■ CRC

The optional 8-symbol CRC field can increase the reliability of the transmission, while it also increases the entire packet length. By default it is disabled to save the time and power for each transmission. The CRC polynomial is:

$$\text{CRC Result} = X^8 + X^5 + X^4 + 1$$

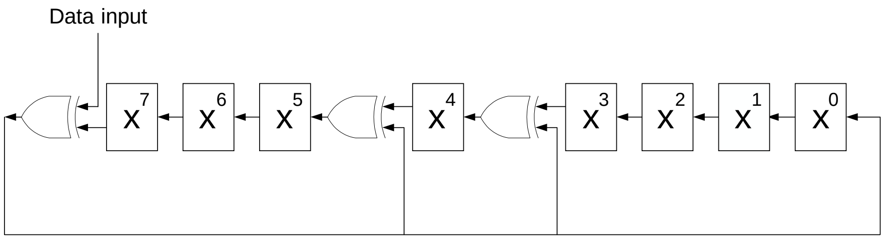

Figure 27. 1920 CRC Polynomial

5.1.2 1920 Study Packet Structure

The study packet is used for the device to learn the Sync ID from the transmitter in order to pair with the transmitter. It contains an optional Preamble, a 32-symbol Head_S, a Sync ID and an optional 8-symbol CRC.

Preamble 16-symbol	Head_S 32-symbol	Address (Sync ID) configurable 1-32 bits	CRC 8-symbol

Figure 28. 1920 Study Packet Structure

The Study Packet structure is not illustrated on the RFPDK since the settings of Preamble, Sync ID and CRC are identical to those of the Normal Packet. Differing from the Head_N in the Normal Packet, the Head_S indicates the current packet is a Study Packet. Also, the Study Packet does not contain the data field. The pattern of Head_S is shown below:

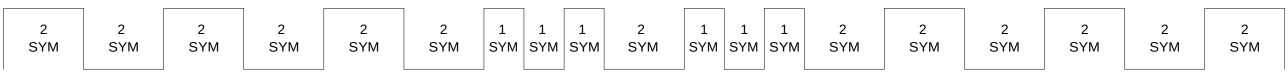

Figure 29. 1920 Head_S Pattern

5.1.3 1920 Bit Format

In 1920 packet, a single bit can be constructed (encoded) by 3, 4, 5 or 6 symbols. The user can select the desired value of the “Bit Format” parameter on the RFPDK. Please note that only the Sync ID field and the D0, D1, D2, D3 field have the unit of “bit”.

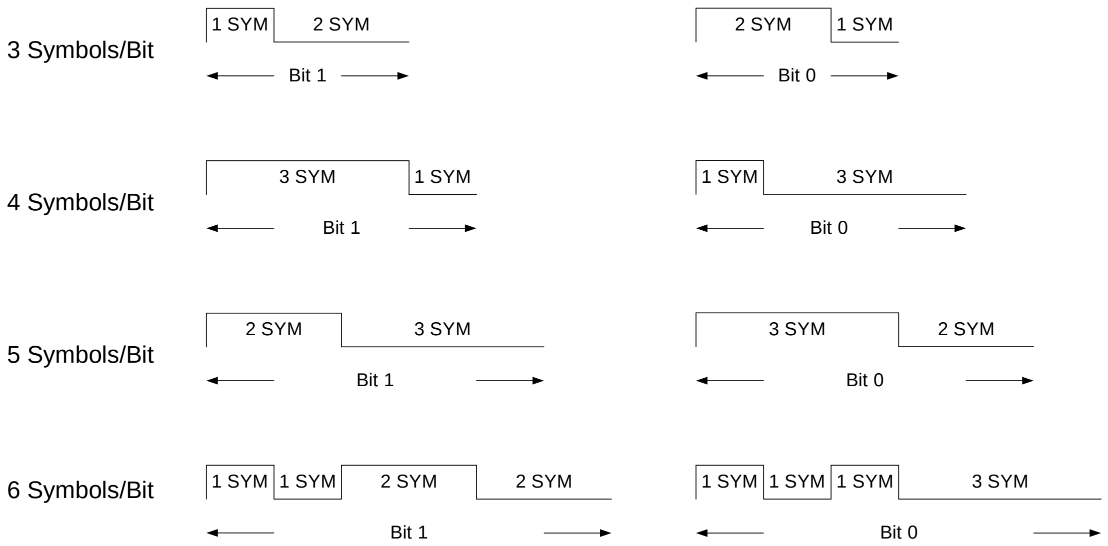

Figure 30. 1920 Bit Format Options

It must be noticed that the Bit Format setting of the receiver and the transmitter must be identical. In order to reduce the length of the entire packet and therefore increase the reliability and robustness of the wireless communication between the receiver and the transmitter, it is recommended to select 3 or 4 symbols per bit.

5.1.4 1527 Normal Packet Structure

The traditional 1527 packet contains a 32-symbol Sync, a 20-bit Address (Sync ID) and 4-bit Data. CMOSTEK has defined a 1527 Study Packet to support the ID study in 1527 mode. The traditional packet introduced here is called the "1527 Normal Packet".

Sync	Address (Sync ID)		D0	D1	D2	D3
Tolerance	Length	Value (0-1048575)				
+/- 13 symbols	20-bit	0	1-bit	1-bit	1-bit	1-bit

Figure 31. 1527 Normal Packet Structure

Table 11. Configurable Parameters in 1527 Packet

Parameter	Descriptions	Default	Mode
Sync	The Sync is 1 high symbol followed by 31 low symbols. The user can determine whether or not to introduce tolerance of detecting the 31 low symbols. The options are: No Tolerance, +/- 6 symbols, +/- 13 symbols, or +/- 20 symbols.	+/- 13 symbols	Basic Advanced
Address (Sync ID) Value	The range of the value is from 0 to 2^{20}-1. This is because the Sync ID Length is fixed at 20 for 1527.	0	Basic Advanced

In the traditional 1527 format, 8 OSC clocks are equal to 1 LCK, 4 LCK are equal to 1 symbol. By using the CMT2251A pairing with CMT2150A, the user does not need to adjust the OSC to determine the symbol rate, because the symbol rate is directly programmed. The Bit Format is fixed at 4 symbols (16 LCK) per bit.

- **Sync**

The Sync pattern is shown below:

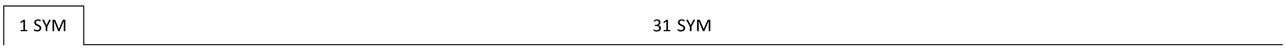

Figure 32. 1527 Sync Pattern

During the reception, the CMT2250A dynamically detects the pattern of the Sync to identify whether a 1527 packet is coming. In some circumstances, the 31 consecutive 0 (low symbols) can bring challenges into the demodulation and bit synchronization. Because the 31 zeros come along with some data rate offsets can lead to incorrect counting of the number of zeros during the reception of the Sync. As a result, the device failed to recognize the packet.

To avoid this happening, the CMT2251A allows the user to introduce some tolerance of detecting these 31 low symbols. This means the device does not necessarily capture 1 high symbol followed by 31 low symbols to identify this is a valid 1527 Sync. For example, if +/- 13 symbols of detecting tolerance is introduced to the device, 1 high symbol followed by 18 – 44 symbols can represent a valid 1527 Sync.

- **Address (Sync ID)**

The Sync ID is sent and received starting from the LSB. For example, if the "Sync ID Value" is set to 1, the binary value of the Sync ID is "0000 0000 0000 0000 0001". In this case, bit<0> = 1 is received first and bit<19> = 0 is received at the end of the Sync ID field.

- **D0, D1, D2, D3**

These are the 4 data bits D0, D1, D2, D3 received to control the PWM output. D0 is received first.

5.1.5 1527 Study Packet Structure

The 1527 Study packet contains a 32-symbol Head_S and a 20-bit Address (Sync ID), as shown below.

Head_S 32-symbol	Address (Sync ID) 20 bits

Figure 33. 1527 Study Packet Structure

The Study Packet structure is not illustrated on the RFPDK since there is no option for the user to select. The Head_S indicating that the current packet is a study packet has the identical pattern to that of the 1920, as shown below:

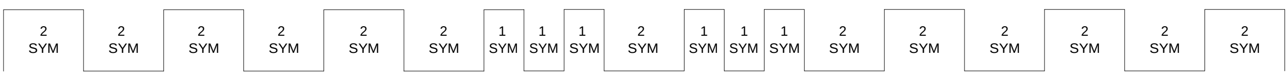

Figure 34. 1527 Head_S Pattern

5.1.6 1527 Bit Format

In 1527 packet, a single bit is constructed by 4 symbols, as shown below. The user can select the desired value of the "Bit Format" parameter on the RFPDK. Please note that only the Sync ID field and the D0, D1, D2, D3 field have the unit of "bit".

Figure 35. 1527 Bit Format Options

5.2 Bit Format

In 1920 packet, a single data bit can be constructed (encoded) by 3, 4, 5 or 6 symbols. The user must configure this parameter according to the bit format of the transmitter. For the conventional 1527 packet, the bit format is 4 sym/bit.

5.3 Valid Reception

This defines how many identical packets the device consecutively received represent a valid reception. For example, if it is set to 2 packets, the device only change the duty ratio of the PWM output after consecutively receiving 2 identical valid packets. Setting this parameter to 4 packets leads to the highest reliability of the communication with most time and power consumed in each transmission.

The below are some computation of the packet length and the time consumption.

If "4 symbols per bit" is used as the "Bit Format", and the "Sync ID Length" is set to 24, the entire 1920 normal packet contains 16 (Preamble) + 32 (Head_N) + 4 x 24 (Sync ID) + 4 x 4 (D0, D1, D2, D3) + 8 (CRC) = 168 symbols. The study packet contains 16 (Preamble) + 32 (Head_S) + 4 x 24 (Sync ID) + 8 (CRC) = 152 symbols.

If the "Symbol Rate" is set to 4.8 ksps, it takes about 35 ms to transmit/receive an entire 1920 normal packet and 31.66 ms to transmit/receive an entire 1920 study packet.

It shall be reminded that, in this case, the 35 ms is the minimum time for the receiver to respond to the transmitter after the user press down the push-button on the transmitter which triggers the data sending. In fact, as the "Valid Reception" is by default set to 2 packets, the minimum time for each normal transmission is about 70 ms.

5.4 PWM Rate

This defines the PWM signal rate. It can be either 6.5 kHz or 13 kHz.

5.5 PWM Default Ratio

This defines the PWM default duty ratio. The following shows a PWM cycle and the definition of the duty ratio:

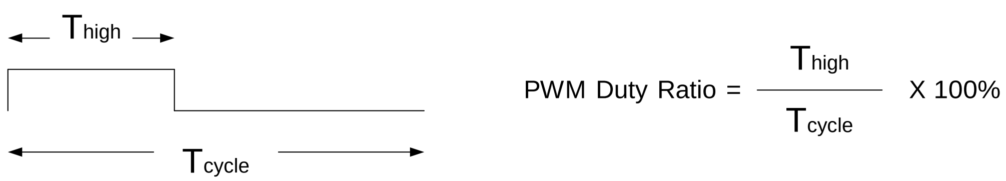

Figure 36. PWM Cycle and Duty Ratio

On the RFPDK, the range of the default duty ratio is 0.0% – 100.0%, with the accuracy to 1 decimal point. The device produces the PWM output with the default duty ratio after it is powered up, until the ratio is changed by receiving commands from the transmitter.

5.6 PWM Step Size

This defines the step to increase/decrease the PWM duty ratio. It has the adjustable range from 0.0% to 50.0%. For instance, if it is set to 50.0%, it takes 2 steps for the device to increase the PWM duty ratio from 0.0% to 100.0%. Using the PWM Button Mode of CMT2150A, the 4 commands are used to control the PWM output, as shown below:

Table 12. PWM Commands

Commands	D0	D1	D2	D3	Description
On	1	1	0	0	Setting the PWM output to 100% of duty ratio
Off	1	1	1	1	Setting the PWM output to 0% of duty ratio
Increase	0	0	1	0	Increase the PWM duty ratio by 1 step
Decrease	0	0	0	1	Decrease the PWM duty ratio by 1 step

The D0 – D3 is the data field in the packet. Please note that the speed of adjusting the PWM duty ratio is not only determined by the step size, but also by the symbol rate, the packet formats and the number of packets representing a valid reception.

6. Study Settings

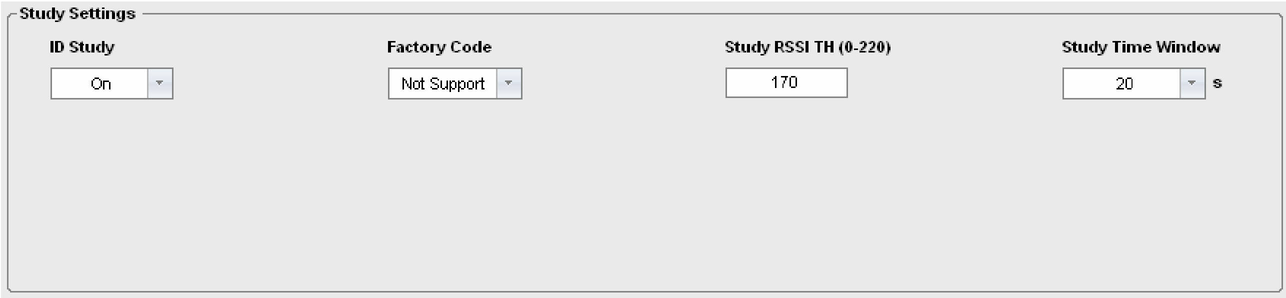

Figure 37. Study Settings

Table 13. Study Settings Parameter

Parameter	Descriptions	Default	Mode
ID Study	Turn on/off the Sync ID study function, the options are: On or Off. The ID Study is only supported in 1920 and 1527 mode.	On	Basic Advanced
Factory Code	This option is only available when ID Study is turned on. It tells the device to support or not support the Factory Code. It can only be set to “Support” in 1920 mode.	Not Support	Advanced
Study RSSI TH	The study is only allowed when the detected RSSI is higher than this 8-bit RSSI threshold, the range is from 0 to 220.	170	Advanced
Study Time Window	This defines the time window in which the study is allowed after the power up. The options are: Always Open, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56 or 60 seconds.	20 s	Advanced

6.1 ID Study

The ID Study function, which is supported in 1920 and 1527 modes, allows the device to receive the Sync ID sent by the transmitter and burns it into the local EEPROM. Since then, the receiver’s Sync ID is identical to that of the transmitter and therefore the two devices are paired. The Sync ID, which is one of the elements of the packet, is sometime called Addressed in some communication protocols. The lengths of the Sync ID are different in the different packet formats. In 1920 format, it is from 1 to 32 bits. In 1527 format, it is fixed at 20 bits.

6.2 Factory Code Study

For the interest of some of the CMOSTEK’s customers, a unique 8-bit Factory Code is assigned to each of them to distinguish their products from the others’. This avoids that the receiving device designed and sold by one customer learns the Sync ID sent by a transmitting device of another customer. This Factory Code is the 8 LSBs (bit 7 – 0) of the Sync ID. Only in 1920 mode the Factory Code can be supported.

When the Factory Code is not supported, as normal, the 8 LSBs of the Sync ID are used as part of the Sync ID, and can be studied as part of the Sync ID.

When the Factory Code is supported, the 8 LSBs of the Sync ID are assigned by CMOSTEK and fixed in the factory. This means, the 8 LSBs of the Sync ID cannot be studied during the ID Study (pairing) process. In this case, the device is only able to recognize the Sync ID that contains the same Factory Code sent by the transmitter. The user must burn the Factory Code into both of the transmitter and receiver during the manufacturing.

On the other hand, since the 8 LSBs of the Sync ID are used as the Factory Code, during the manufacturing process the counting of the Sync ID shall start on the bit 8. The CMOSTEK manufacturing tool is able to map the user-defined ID to the correct position of the Sync ID in the device. If the users want to design their own Sync ID management tool, please consult CMOSTEK for more details.

In 1527 mode, the Factory Code is not supported, and therefore the 8 LSBs of the Sync ID are used as part of the Sync ID, and can be studied as part of the Sync ID.

6.3 Study RSSI TH

This threshold is an 8-bit code that is comparable to the 8-bit RSSI. During the study process, the device firstly detects if the RSSI of the incoming signal is higher than this threshold. If not, the study is forbidden. Therefore, the Study RSSI TH helps the user to limit the communication distance in which the device can study the Sync ID from the transmitter.

It is suggested for the user to perform on-field testing and adjustment of the transmitting power of the Tx, and the Study RSSI TH of the Rx to define the communication distance for ID study. The RFPDK for CMT2251A provides a “RSSI Scan” function to perform the on-line scanning of the RSSI. Once the “RSSI Scan” window is opened, it dynamically displays the real-time RSSI level detected by the device. The user can use this information to setup the proper value of the Study RSSI TH. Please refer to “AN115 Pairing CMT2150A and CMT2251A” for more details of adjusting the study distance.

Please note that this threshold only impact the ID studying, not the normal communication.

6.4 Study Time Window

In many applications, the Tx and Rx pairing (ID Study) is only performed in a short time period after the devices are powered up. This parameter defines the time window in which the study is allowed after the power up of the device. As one of the options, the window can always be opened and therefore no time limitation is there for studying.

7. Document Change List

Table 14. Document Change List

Revision	Chapter	Description of Changes	Date
0.8		Initial released version	2014-07-29

8. Contact Information

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