CMOSTEK

AN128

CMT2213A Configuration Guideline

Introduction

The CMT2213A is ultra low power, high performance, low-cost (G)FSK/OOK stand-alone RF receiver for various 300 to 480 MHz wireless applications. The chip is part of the CMOSTEK NextGenRF™ family, which includes a complete line of transmitters, receivers and transceivers.

Table 1. Part Number Covered in this Document

Product	Modulation/ Frequency	Sensitivity	Rx Current	Embedded EEPROM	Standalone Operation
CMT2213A	(G)FSK/OOK 300-480 MHz	-111 dBm (433.92 MHz, 1 ksps, 0.1% BER/FSK)	4.3 mA (433.92 MHz/FSK)	√	√

The RFPDK (RF 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 CMT2213A with the RFPDK.

To help the user develop their application with CMT2213A and CMT2113A easily, CMOSTEK provides **CMT2113A/2213A 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
- RF-EB (evaluation board for NextGenRF™ products)
- CMT2113A-EM (Tx module)
- CMT2213A-EM (Rx module)

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1. Getting Started

Install RFPDK on the computer. The detail of the installation can be found in "AN103 CMT211xA/221xA One-Way RF Link Development Kits User's Guide".

Setup the development kits as shown in Figure 1 before configuring the CMT2213A. The Application with CMT2213A can be CMT2213A-EM provided by CMOSTEK, or the PCB designed by the user with CMT2213A.

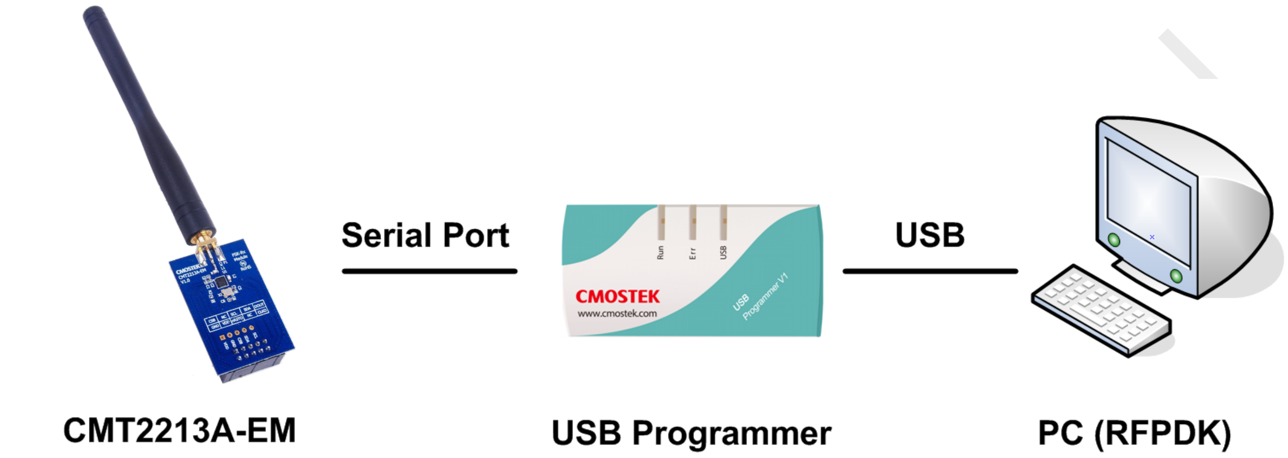

Figure 1. CMT2213A Configuration Setup

Start the RFPDK from the computer's desktop and select CMT2213A in the Device Selection Panel shown in the figure below. Once a device is selected, the Device Control Panel appears as shown in Figure 3. Because thes Advanced Mode covers all the configurable features/parameters while the Basic Mode only contains a subset, the Advanced Mode is described in this document.

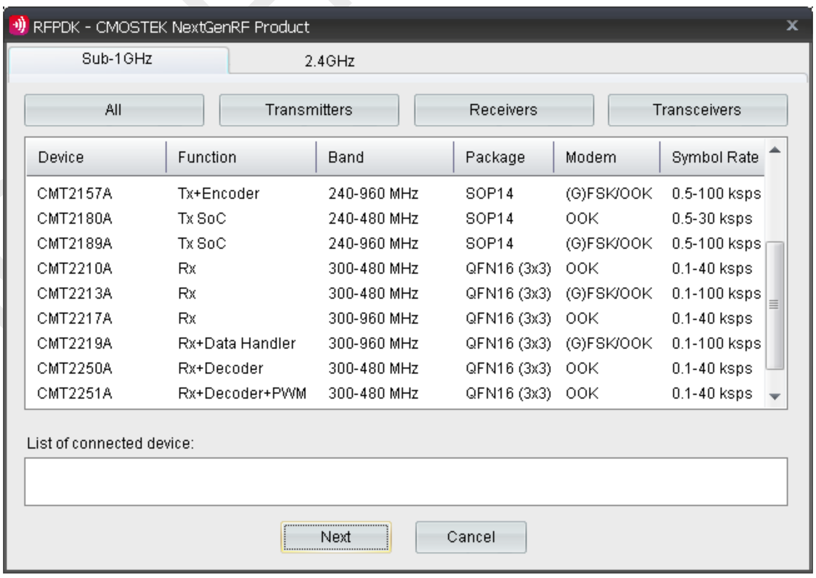

Figure 2. Device Selection Panel

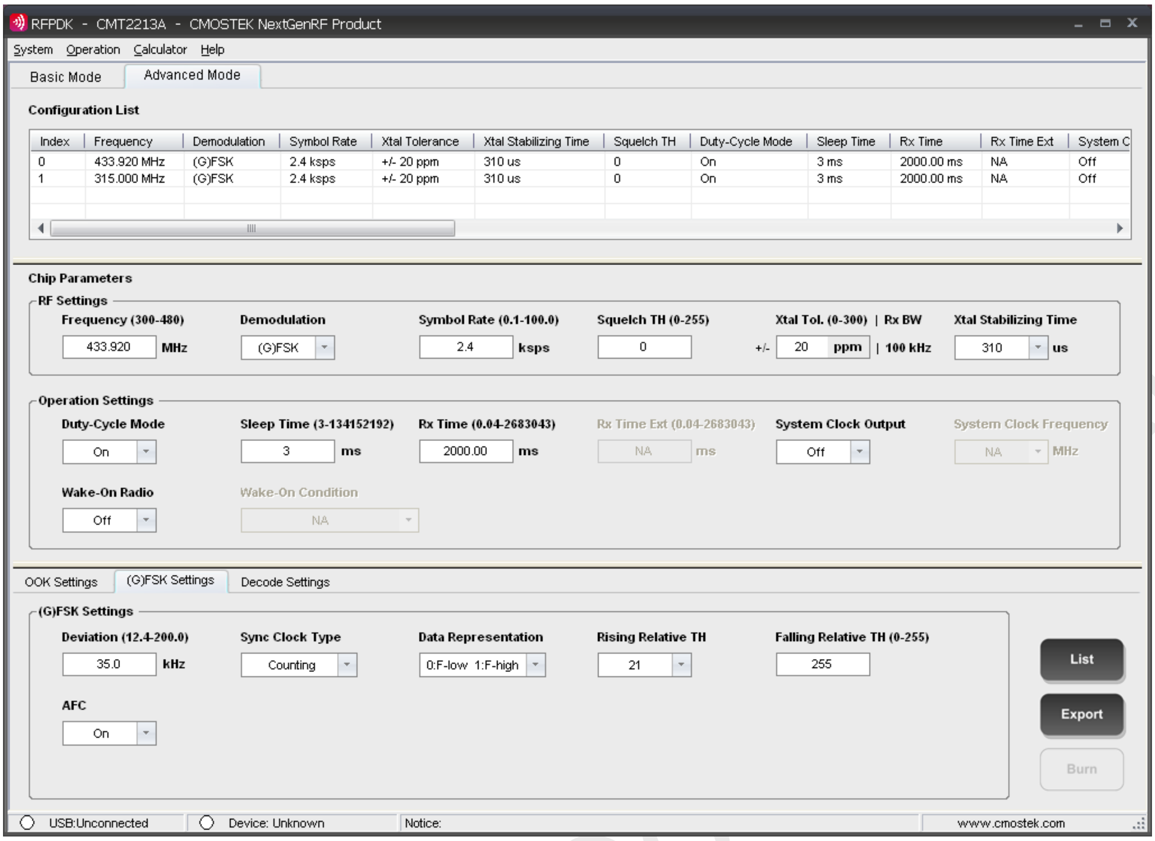

Figure 3. Advanced Mode of Device Control Panel

2. RF Settings

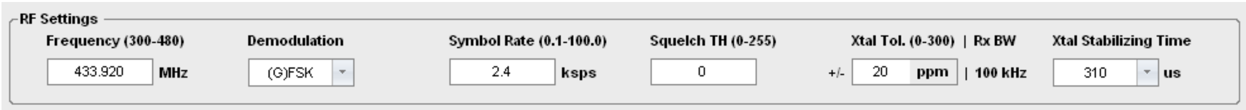

Figure 4. RF Settings

Table 2. RF Settings Parameters

Parameters	Descriptions	Default	Mode
Frequency	The receive radio frequency, the range is from 300 to 480 MHz, with resolution of 0.001 MHz.	433.920 MHz	Basic Advanced
Demodulation	The demodulation type, (G)FSK and OOK demodulation types are supported in this product.	(G)FSK	Basic Advanced
Symbol Rate	The receiver symbol rate, the range is from 0.1 to 100.0 ksps, with resolution of 0.1 ksps.	2.4 ksps	Basic Advanced
Squelch TH	The threshold of the squelch circuit to suppress the noise, the range is from 0 to 255.	0	Basic Advanced
Xtal Tol. | Rx BW	The sum of the crystal frequency tolerance of the Tx and the Rx, the range is from 0 to ±300 ppm. And the calculated BW is configured and displayed.	±20 ppm | 100 kHz	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

CMT2213A 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

CMT2213A supports (G)FSK and OOK demodulation.

2.3 Symbol Rate

With (G)FSK demodulation, CMT2213A supports 0.1 – 100.0 ksps symbol rate. Normally, the symbol rate tolerance of the device is from –30% to +30% of the "Symbol Rate" configured on the RFPDK. For example, the user set the symbol rate to 9.6 ksps on the RFPDK, the covered symbol rate of the transmitted data is from 6.7 to 12.5 ksps. If the user set it to 100 ksps, the covered range is from 70 to 100 ksps. Any symbol rate outside the range of 0.1 – 100 ksps is not supported. The less symbol rate offset exists between the transmitter and the receiver, the less sensitivity is lost. The following data can be used as a reference.

Please note that when the "Tracing" method is used to recover the sync clock (see chapter 4.4.2), the symbol rate tolerance is from –9% to +9%.

With OOK demodulation, CMT2213A supports 0.1 – 40.0 ksps symbol rate. Normally, the symbol rate tolerance of the device is from –80% to +100% of the "Symbol Rate" configured on the RFPDK. For example, the user set the symbol rate to 9.6 ksps on the RFPDK, the covered symbol rate of the transmitted data is from 1.92 to 19.2 ksps. If the user set it to 40 ksps, the covered range is from 8 to 40 ksps. Any symbol rate outside the range of 0.1 – 40 ksps is not supported. The less symbol rate offset exists between the transmitter and the receiver, the less sensitivity is lost. The following data can be used as a reference.

It should be noticed that, if the Wake-on Radio (see Chapter 3.3 Wake-On Radio, Wake-On Condition) function is turned on, the symbol rate tolerance changes to -25% to +25%.

2.4 Squelch TH

The Squelch Threshold is used to mute the audio output of the receiver in the absence of the desired radio signal. Since the RSSI is digitized to an 8-bit binary value that has the range from 0 to 255, the squelch threshold is designed to be an 8-bit binary value that is comparable to the digitized RSSI.

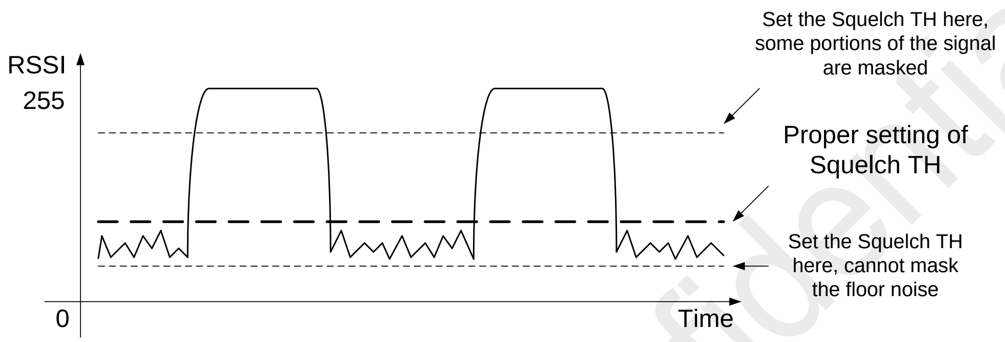

Figure 5. Squelch Threshold

When the received signal strength falls below this threshold the output of the receiver is muted. The user shall set the squelch threshold just above the background radio noise level. Setting a larger threshold requires higher received signal strength to un-mute the receiver, which also means the receiving sensitivity becomes lower. When the radio muting is not required, the squelch threshold can be set to 0 to avoid any potential lost in the sensitivity.

The best way to find the proper value of the Squelch TH is to observe the demodulation output on DOUT. Without any effective signal being transmitted in the channel, the DOUT stays logic 0 while the threshold is set over the noise floor, and outputs random sequence of 0 and 1 while the threshold is set below the noise floor. The user is able to find a value that is just over the noise floor by try and error.

In OOK demodulation, the Squelch Threshold only takes effect when the OOK demodulation method is set to “Peak TH”.

2.5 Xtal Tol. | Rx BW

This is the sum of the crystal frequency tolerance of the transmitter and receiver. The input range is from 0 to ±300 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, which is displayed on the right hand side of the input Xtal tolerance. When the crystal tolerance increases, the bandwidth is increased and the sensitivity is reduced. However, the powerful AFC function can minimize the frequency error due to the crystal tolerance and therefore maintains the highest sensitivity performance.

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

2.6 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

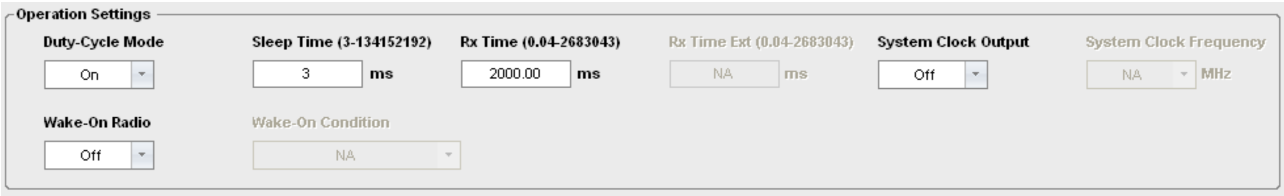

Figure 6. Operation Settings

The available operating options for the radio control are listed in the table below.

Table 3. 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
Sleep Time	The sleep 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 receive mode, the range is from 0.04 to 2,683,043.00 ms.	2,000 ms	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. It is only available when Wake-On Radio is turned on.	200.00 ms	Advanced
System Clock Output	Turn on/off the system clock output on CLKO, the options are: on or off.	Off	Advanced
System Clock Frequency	The system clock output frequency, the options are: 13.000, 6.500, 4.333, 3.250, 2.600, 2.167, 1.857, 1.625, 1.444, 1.300, 1.182, 1.083, 1.000, 0.929, 0.867, 0.813, 0.765, 0.722, 0.684, 0.650, 0.619, 0.591, 0.565, 0.542, 0.520, 0.500, 0.481, 0.464, 0.448, 0.433, 0.419 or 0.406 MHz. It is only available when System Clock Output is turned on.	6.500 MHz	Advanced
Wake-On Radio	Turn on/off the wake-on radio function, the options are: on or off.	Off	Advanced
Wake-On Condition	The condition to wake on the radio, the option is: Extended by Preamble, or Extended by RSSI. It is only available when Wake-On Radio is turned on.	Extended by Preamble	Advanced

3.1 Duty-Cycle Mode

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

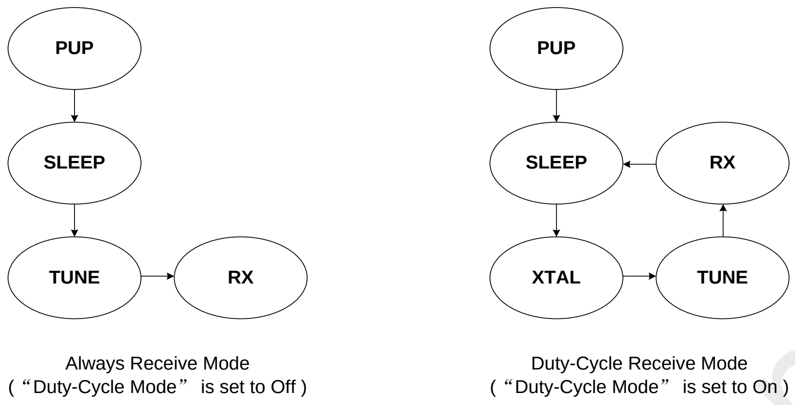

Figure 7. Radio Operation with Duty-Cycle Mode On and Off

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 SLEEP 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 send out the demodulated data on the DOUT pin. The configurable system clock is also output from the CLKO pin if it is enabled in the Advanced Mode on the RFPDK (see Chapter 4 System Clock for more details). The figure below shows the timing characteristics and current consumption of the device from the PUP to RX.

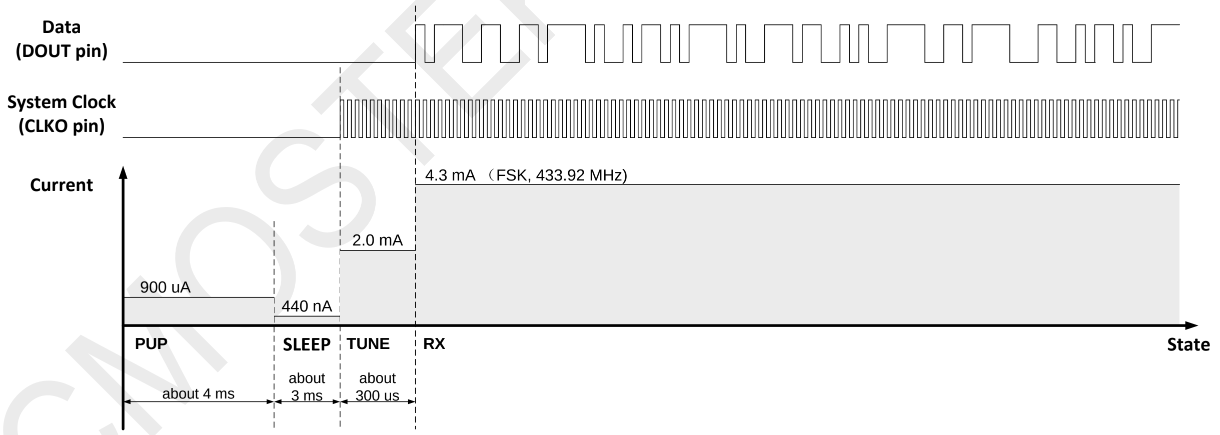

Figure 8. Timing and Current Consumption for Always Receive Mode

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 SLEEP, 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 send out the demodulated data on the DOUT pin. The configurable system clock output is output from the CLKO pin during the TUNE and RX state. 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 sleep timer, must be calibrated during the PUP.

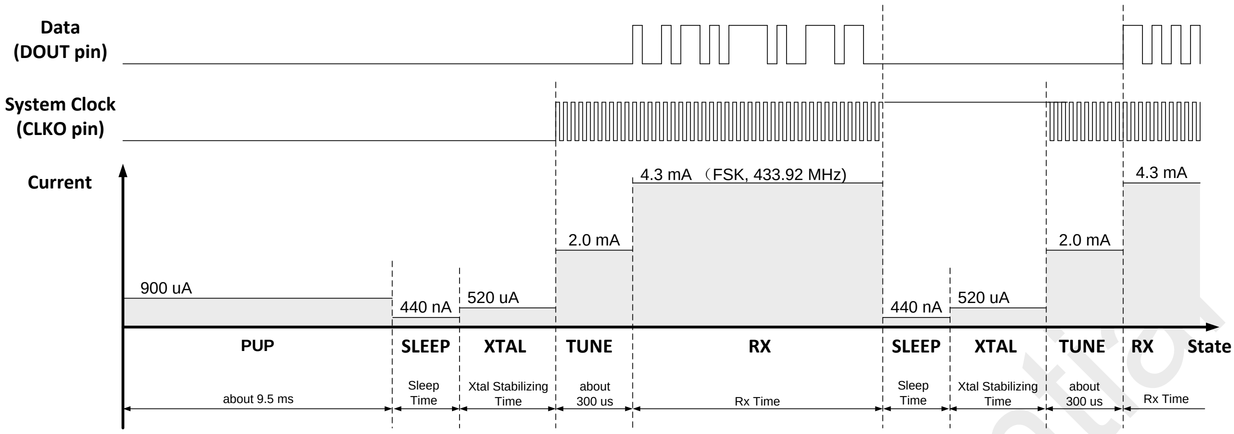

Figure 9. Timing and Current Consumption for Duty-Cycle Receive Mode

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 sleep (resetting most of the blocks).
- Saving power consumptions of both of the Tx and Rx device.

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

3.2 Sleep Time, Rx Time

When the Duty-Cycle Mode is turned on, the Sleep 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:

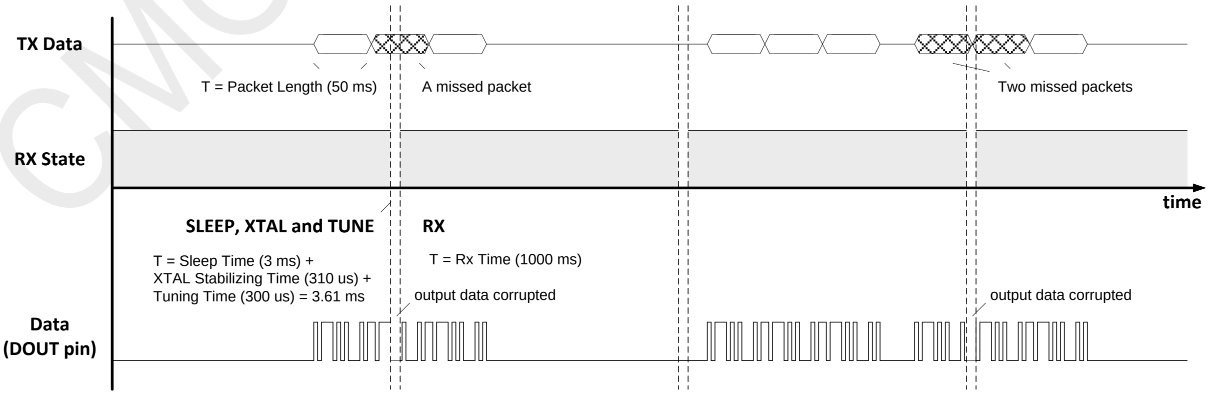

Figure 10. Tx and Rx relationship of Easy Configuration

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 50 ms. The user can do the following:

- Set the Sleep 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 Sleep Time is very short, the non-receive time is only about 3.61 ms (the sum of the Sleep Time, XTAL stabilizing time and the tuning time), which is much shorter than the packet length of 50 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 DOUT pin will output logic 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 sent out via the DOUT pin with no corruption. The external MCU will only need to observe the DOUT pin status to perform data capturing and further data processing.

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.

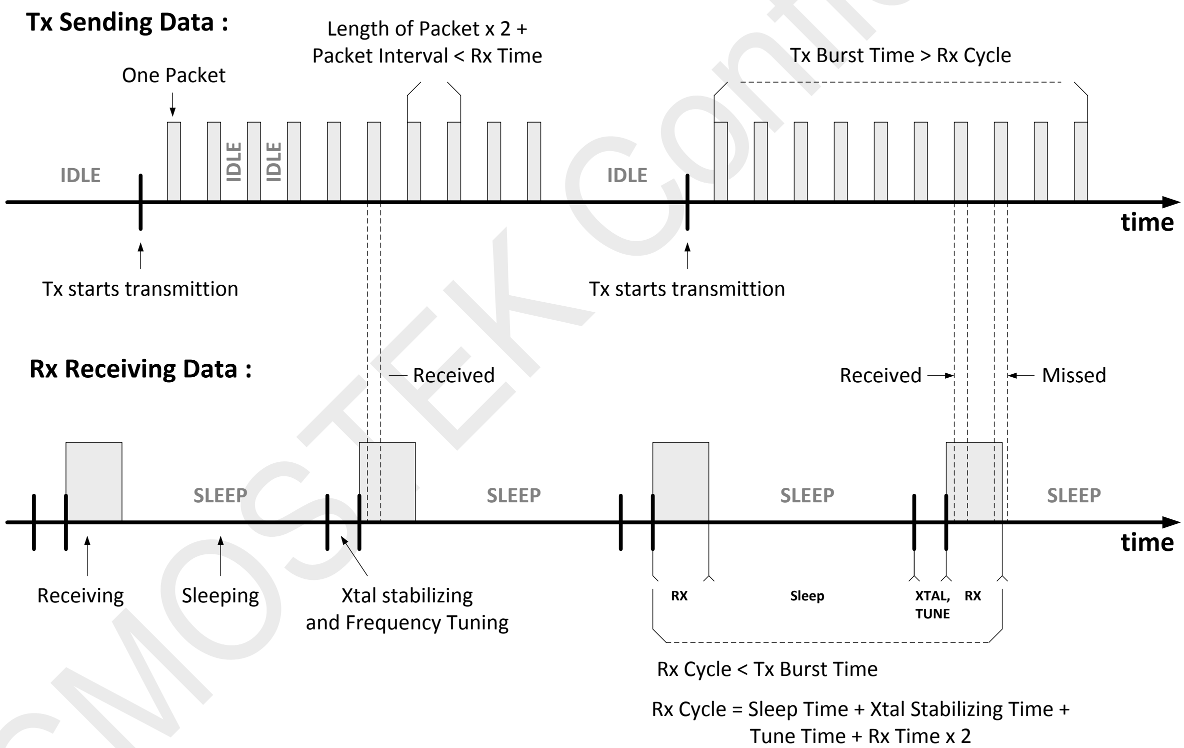

Figure 11. Tx and Rx Relationship of Precise Configuration

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 sleep time, to optimize the power consumption of the Rx device. Two requirements must be fulfilled:

- Length of Packet x 2 + Packet Interval < Rx Time
- Tx Burst Time > Rx Cycle, where Rx Cycle = Xtal Stabilizing Time + Tune Time + Rx Time x 2 + Sleep Time

The Rx Time must always be longer than the packet length times two 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 that the Rx Cycle 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, Wake-On Condition

The wake-on radio function 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 good understanding.

Please note that the sleep 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 4. Fixed Duty Configurations

Options	Value
Sleep Time	5,000 ms
Rx Time	400 ms
Rx Time Ext	NA
Wake-On Radio	Off
Wake-On Condition	NA
Preamble Size	NA

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

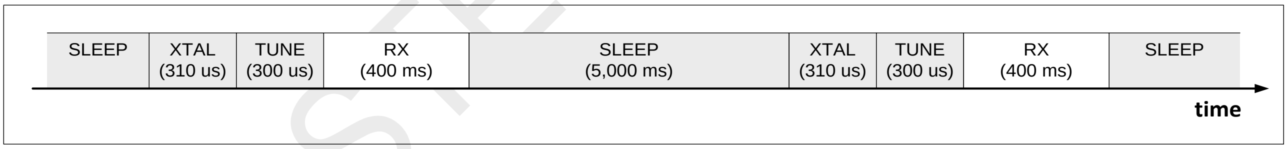

Figure 12. Fixed Duty Operation

After a successful power up, the device enters the SLEEP state. When it reaches the sleep 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 SLEEP 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 5. Wake on Preamble Configurations

Options	Value
Sleep Time	800 ms
Rx Time	20 ms
Rx Time Ext	200 ms
Wake-On Radio	On
Wake-On Condition	Extended by Preamble
Preamble Size	2-byte

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 sleep 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.

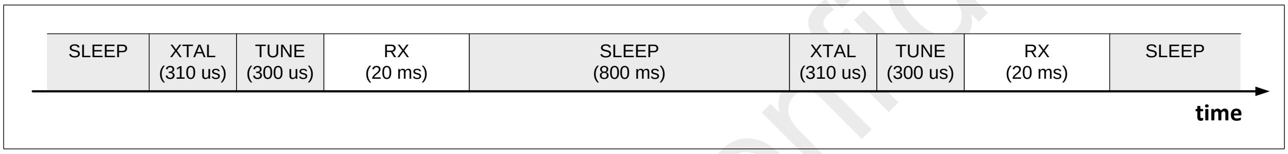

Figure 13. Preamble Wake-On Operation without Preamble Detected

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

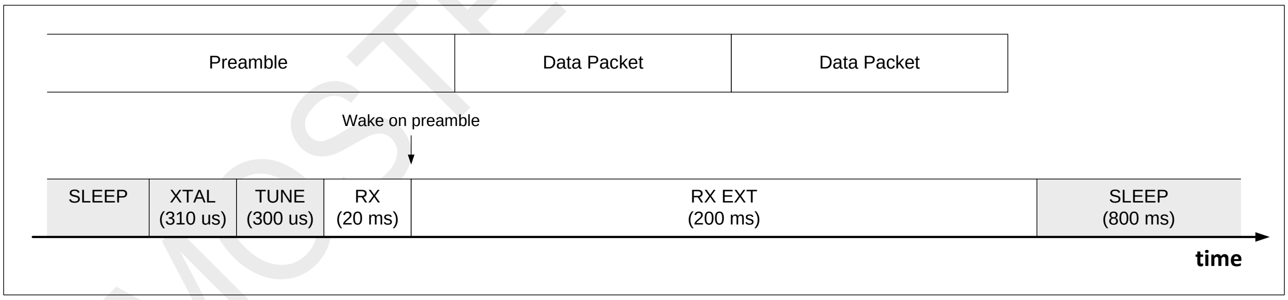

Figure 14. Preamble Wake-On Operation with Preamble Detected

In order to ensure that the preamble can be captured by the Rx, the RX EXT must be longer than the valid preamble size which is 2-byte.

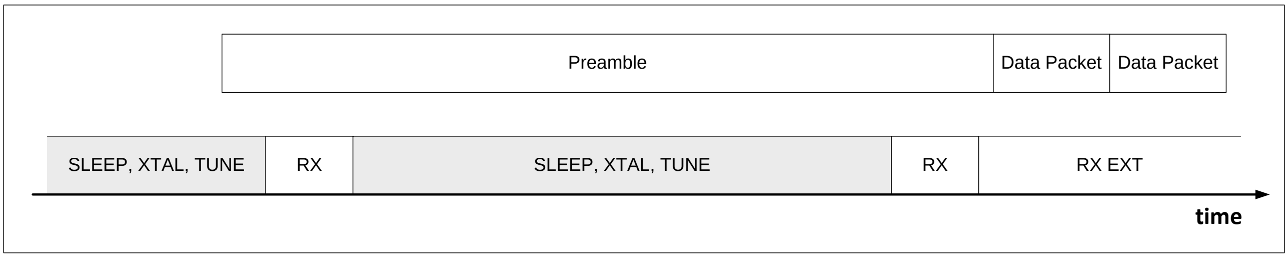

Figure 15. The Transmitted Preamble Length

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 + SLEEP + 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.

3.3.3 Application Example 3: Wake on RSSI

Table 6. Wake on RSSI Configurations

Options	Value
Sleep Time	800 ms
Rx Time	20 ms
Rx Time Ext	200 ms
Wake-On Radio	On
Wake-On Condition	Extended by RSSI
Preamble Size	NA

This is similar to the Application Example 2, but the wake-on condition is changed to a valid RSSI. Once a valid RSSI is detected, the RX state is extended to RX EXT which is long enough for more than 2 data packets reception.

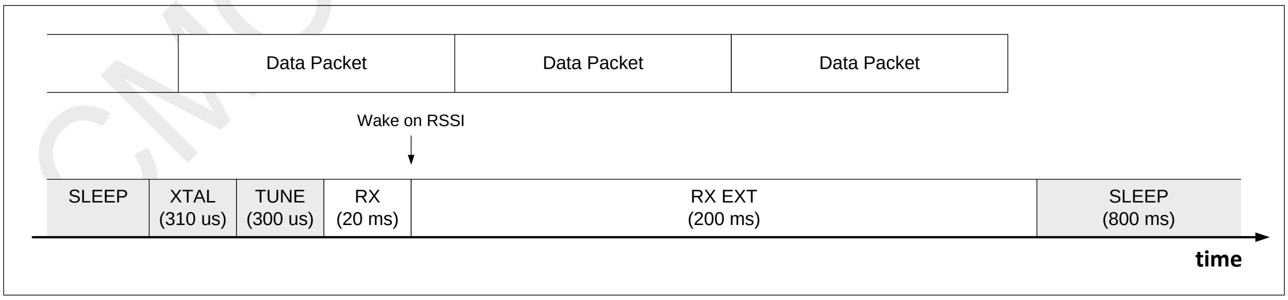

Figure 16. RSSI Wake-On Operation with RSSI Detected

The timing requirement obeys the rules introduced in the “Precise Configuration”.

This example is only suitable for the application where the noise level is known and the squelch threshold is properly set to mask the noise. This is because any incoming noise higher than the squelch threshold leads to a valid RSSI produced that can wake on the radio. As a result, the goal of saving the power consumption cannot be reached.

3.4 System Clock Output, System Clock Frequency

If the system clock output is enabled on the RFPDK, a continuous clock signal divided down from the 26 MHz crystal clock is output via the CLKO pin to drive the external MCU or other devices. The selectable clock frequency has a wide range from 0.406 to 13 MHz. As introduce in the Chapter 3.1 and 3.2, this clock is only available when the device is not in the SLEEP and XTAL state.

The user can either use this clock to drive the external MCU, or as an indication of the device working status. In some circumstances, the MCU can treat this clock as an interrupt to synchronize the working status to that of the device.

4. OOK Settings

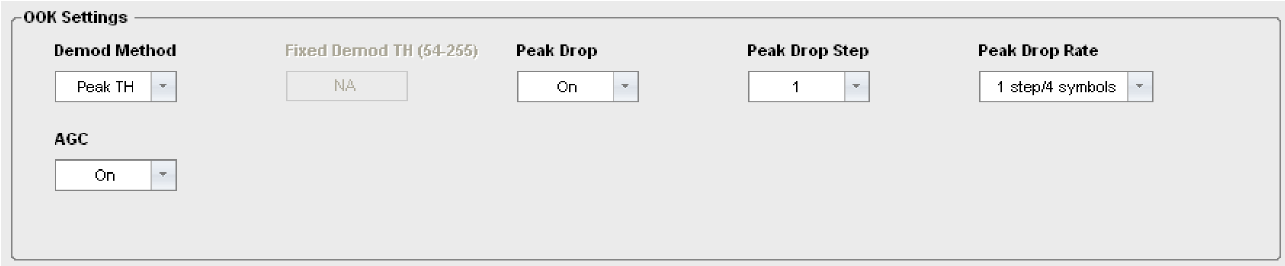

Figure 17. OOK Settings

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 minimum input value is the value of Squelch Threshold set on the RFPDK, the maximum value is 255.	60	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, 6, 9, 12 or 15.	1	Advanced
Peak Drop Rate	The RSSI peak drop rate, the options are: 1 step/4 symbols, 1 step/2 symbols, 1 step/1 symbol, or 1 step/0.5 symbol.	1 step/4 symbols	Advanced
AGC	Automatic Gain Control, the options are: on or off.	On	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.

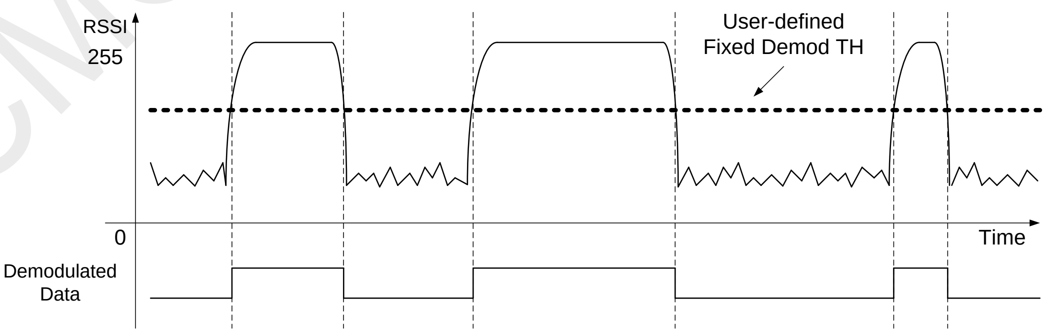

Figure 18. OOK Demodulation Using Fixed Threshold

The minimum value of the Fixed Demod TH is always higher than the Squelch Threshold, because anything lower than the squelch threshold is muted, and therefore setting the Fixed Demod TH lower than the squelch threshold is meaningless.

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.

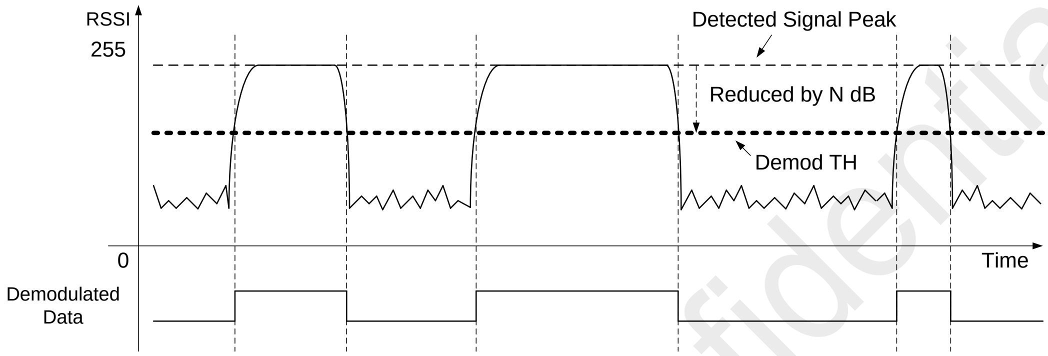

Figure 19. OOK Demodulation Using Peak - N Threshold

When the signal disappears, the peak is detected on the noise floor (see more descriptions in the Section 4.3). A proper setting of Squelch Threshold holds its functionality of muting the floor noise when there is no valid signal being received.

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. The minimum value of this parameter can be set is the value of the Squelch Threshold. This is because anything below the Squelch Threshold is muted. Setting the demodulation threshold below the Squelch Threshold is insignificant. It is unused when the demodulation method is set to Peak 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.

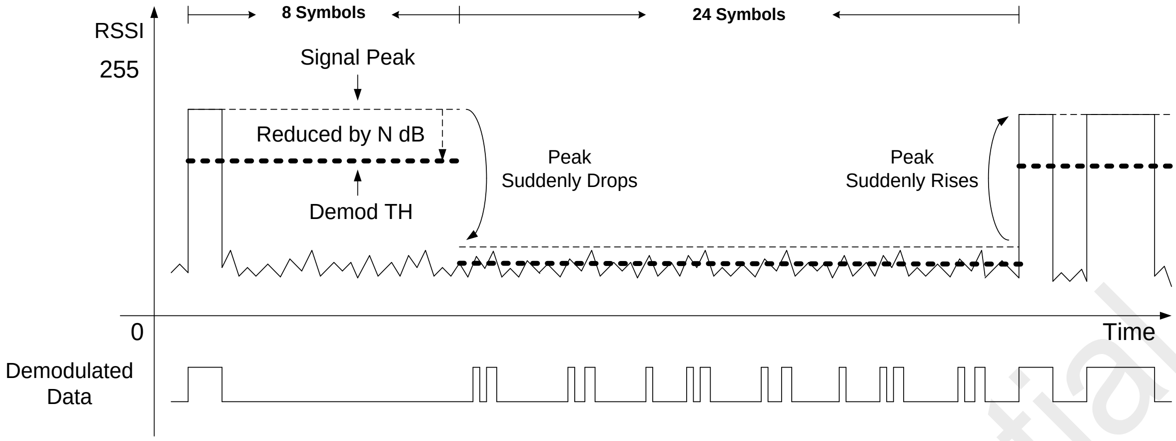

Figure 20. OOK Demodulation Using Peak - N Threshold, with Peak Drop Off

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.

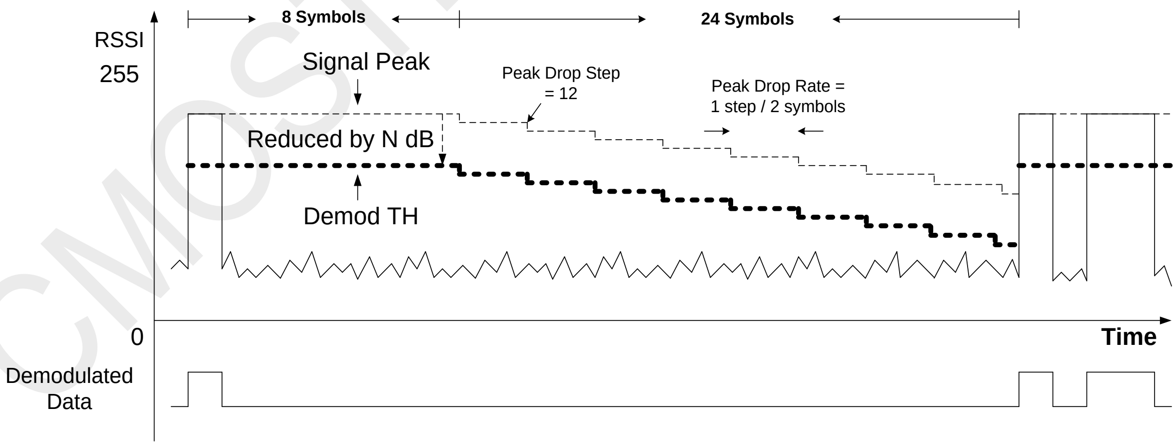

Figure 21. OOK Demodulation Using Peak - N Threshold, with Peak Drop On

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 either the Squelch Threshold defined on the RFPDK when all the noise are muted by the threshold, or 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 2.4 ksps, the signal peak only stands for 4 symbols (at 2.4 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.

4.4 AGC

The Automatic Gain Control option is available for the device to have better blocking immunity performance for OOK demodulation. It is recommended to turn on the AGC during the normal operation.

5. (G)FSK Settings

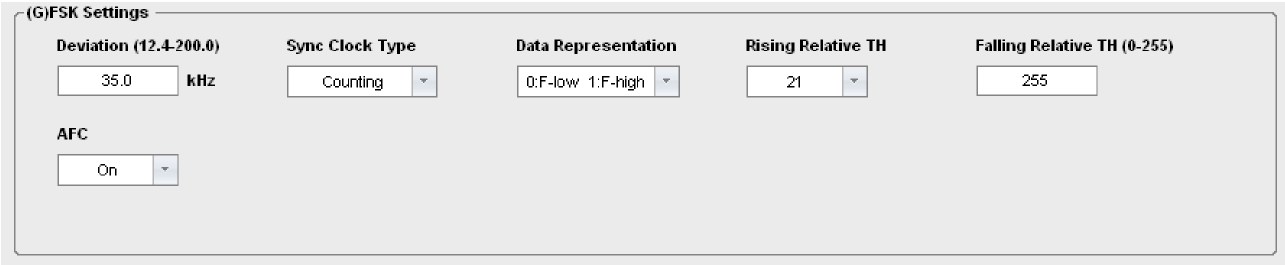

Figure 22. (G)FSK Settings

Table 8. (G)FSK Settings Parameters

Parameters	Descriptions	Default	Mode
Deviation	The (G)FSK frequency deviation. The minimum value of the deviation is equal to Frequency (MHz) x Xtal Tolerance (ppm) / 0.7. The maximum value of deviation is equal to 220 kHz - Frequency (MHz) x Xtal Tolerance (ppm).	35.0 kHz	Basic Advanced
Data Representation	To select whether the frequency “Fo + Fdev” represent data 0 or 1. The options are: 0: F-high 1:F-low, or 0: F-low 1:F-high.	0: F-low 1:F-high	Basic Advanced
Sync Clock Type	This parameter allows the user to select the method to perform the clock data recovery. The options are: tracing or counting.	Counting	Advanced
Rising Relative TH	This is the relative threshold to trigger the (G)FSK demodulation. It is measured in terms of RSSI code. The options are: 0, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 36, 42, 54, 66, or 90.	21	Advanced
Falling Relative TH	This is the relative threshold to shut down the (G)FSK demodulation. It is measured in terms of RSSI code. The range is from 0 to 255.	255	Advanced
AFC	Turn on/off the Automatic Frequency Control function. The options are: On or Off.	On	Advanced

5.1 Deviation

The device supports a wide range of deviations. The deviation is the maximum instantaneous difference between the modulated frequency and the nominal carrier frequency Fo.

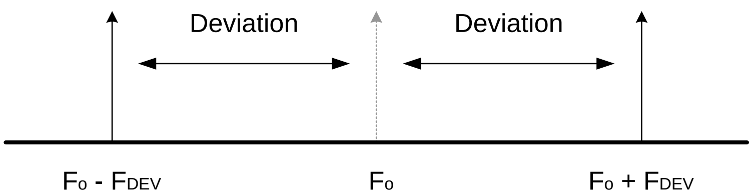

Figure 23. (G)FSK Deviation

A proper selection of the deviation is regarding to the modulation index and the frequency error between the TX and the RX. The modulation index is given by:

$$\text{Modulation Index} = \frac{\text{Deviation x 2}}{\text{Symbol Rate}}$$

The value of crystal tolerance dominates the frequency error:

$$\text{Frequency Error} \quad >= \quad \text{Xtal Tolerance x Frequency}$$

By obeying the following rules, the RFPDK automatically computed the minimum value of the deviation that can be configured.

$$\text{Deviation} \quad >= \quad \text{Symbol Rate x 2}$$

$$\text{Deviation} \quad >= \quad \frac{\text{Frequency Error}}{0.7}$$

This means the Modulation Index cannot be less than 1. Also, the deviation must be larger than the frequency error in order to guarantee the reception.

The RFPDK also computes the maximum value of the deviation that can be configured. The following rule is obeyed:

$$\text{Deviation} \quad <= \quad 220\ \text{kHz} - \text{Frequency Error}$$

Therefore, once the Symbol Rate and Xtal Tolerance are configured on the RFPDK, the configurable range of the Deviation is automatically obtained.

5.2 Data Representation

This parameter determines whether the frequency “Fo + Fdev” modulated frequency represent data 1, or data 0. It should be set according to the transmitter’s configurations.

5.3 Rising Relative TH, Falling Relative TH

When the device is in the RX state, the RF front end continuously passes signals and noises into the digital (G)FSK demodulator.

The (G)FSK demodulator is turned on when the RSSI has increased a certain value (defined by the Rising Relative TH) in a short time window, and turned off when RSSI has decreased a certain value (defined by the Falling Relative TH) in the same time window. The short time window is either 1-symbol or 2-symbol time, which is automatically determined by the device according to different symbol rates. This design has the advantage of detecting valid signals in environments with time varying noise floor.

The default value of the ‘Rising Relative TH’ is 21, which is approximately 7 dB. It determines how sensitive the demodulator is triggered by the increasing RSSI. In the application where the noise level fluctuate more than 7 dB, it should be set larger to avoid mistakenly triggering. The mistakenly triggering does not affect the receiving performance, but only consumes more power.

The default value of the ‘Falling Relative TH’ is also set to 255. It determines how sensitive the demodulator is turned off by decreasing RSSI. Setting this value maximum indicates that the demodulator cannot be turned off by the RSSI, but it will be turned off when the chip goes to SLEEP state.

At the point when the device enters the RX state, the chip always detects the increasing amount from ground (0 in RSSI code) to the incoming signal. However, there is no way for the chip to tell that whether the incoming signal is the valid signal or the noise. The below paragraphs describe the two circumstances.

At the instance that the device is switched into the RX state, if it is the valid signal being transmitted by the TX and the increasing amount is larger than the Rising Relative TH, the demodulator is turned on and starts sending out the valid demodulated data, as shown in the below figure.

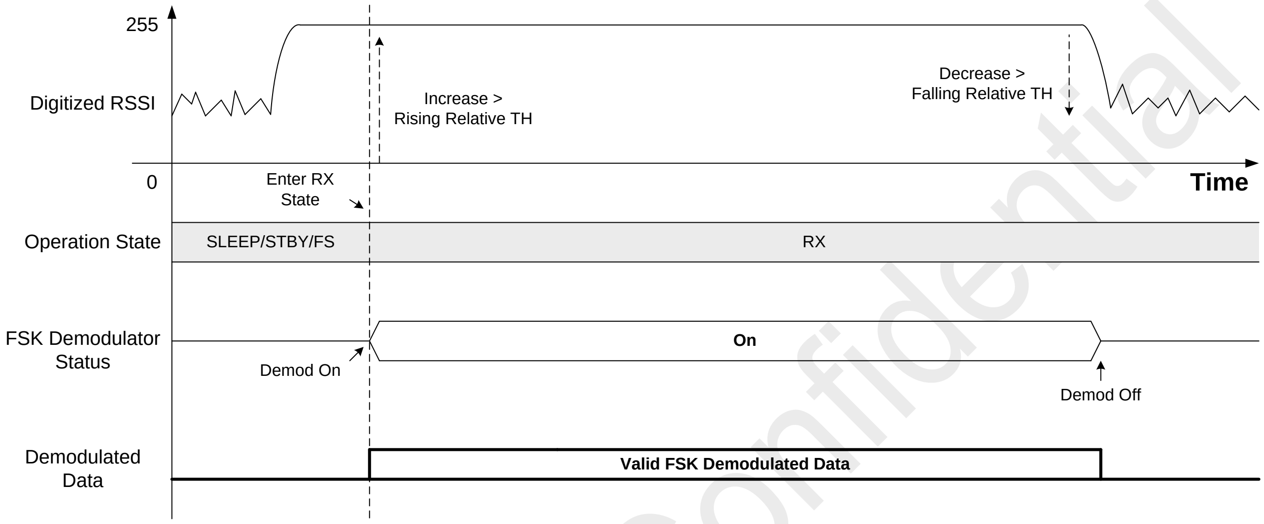

Figure 24. Entering RX with Signal Being Transmitted

At the instance that the device is switched into the RX state, if the incoming signal is the noise and the increasing amount from 0 to the noise level has exceeded the Rising Relative TH, the demodulator is also turned on. As a result, the noise is demodulated and output from the beginning of the RX state till the first bit of the valid transmitted signal comes, as shown in the below figure.

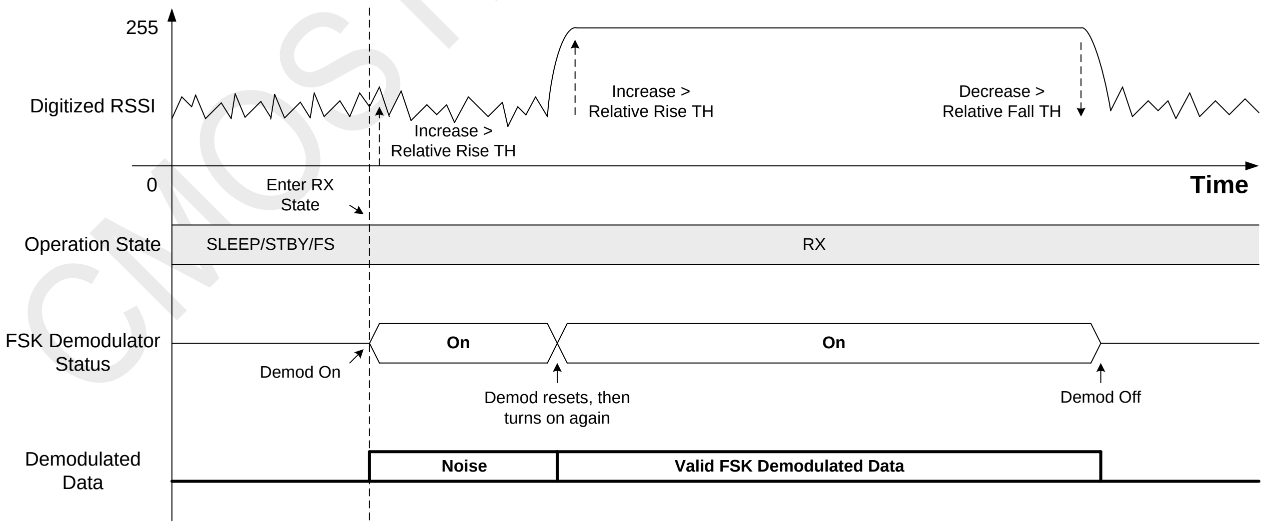

Figure 25. Entering RX with Noise

Once the valid signal comes, the demodulator will reset itself immediately and restart to receive the data. In the subsequent data transmission in the same RX cycle, this will not happen again since the decreasing from valid signal to noise will turn off the demodulator if the Falling Relative TH is properly set. The user program on the external MCU shall ignore this “noise” period at the beginning of the RX state. On the other hand, if a proper value of the “Squelch Threshold” is set above the noise floor, the noise is muted.

When the incoming RF signal is sourced from an instrument, such as a signal generator, the (G)FSK demodulator might not be able to turn on/off effectively while the signal magnitude is changed. This is because the short time window to detect the RSSI change is only 1-symbol or 2-symbol time, but the signal sourced from the instrument might take a longer time to change from one level to another, which is determined by the characteristics of the instruments. This might lead to misunderstanding of the device behavior while testing the device in the lab.

To overcome this problem, it is suggested for the user to reset the chip every time the signal magnitude on the instrument is set to a new value. As introduced above, if the Rising Relative TH is properly set, every time the device enters to RX state, the detected RSSI change is dramatic from 0 to the current RSSI (a lot shorter than the time window) and will always trigger the demodulator and therefore output the demodulated data.

5.4 Sync Clock Type

The optional types of the sync clock are: No Sync Clock, Counting and Tracing. When the AFC is turned on (see Section 4.5), the sync clock must be set to either counting or tracing.

5.4.1 Counting

The counting method has the advantage of having a +/- 30% tolerance of symbol rate error, while it has a drawback of requiring frequent transitions on the data to adjust the sync clock rate. If there is no transition happens in 3-4 symbols and the symbol rate error is significantly large, the clock recovery and data capturing will start to go wrong.

5.4.2 Tracing

The tracing method has a different principle. Acting like a DPLL, it takes a few symbols for the sync clock generator to “trace” the TX symbol rate and eventually lock to the same symbol rate. It can only tolerate +/- 9% of symbol rate error. However, with the same symbol rate error, tracing method allows the receiver to correctly sample a much longer string of “0” than the counting method.

Using the tracing method, the default characteristic of the receiver allow 10 – 15 symbols of the consecutive “0” to be correctly sampled, while tolerating +/- 9% of symbol rate error. It is always recommended for the user to avoid transmitting long string of “0” by encoding the data using the Manchester, data-whitening or similar encoding techniques.

5.4.3 No Sync Clock

When the Sync Clock is turned off by choosing “No Sync Clock”, the receiver does not suffer from the long string “0” because the demodulated data is only transparently sent out to the data pin without any internal capturing. However, in this case, since the preamble detection cannot be performed without the sync clock, the AFC must be turned off. Also, the WOR condition of “Extended by Preamble” cannot be used. The symbol rate tolerance is also +/- 30%.

5.5 AFC

The Automatic Frequency Control (AFC) is useful to minimize the RF frequency error between the TX and the RX. The frequency error is usually caused by the crystals tolerance on the two sides. The AFC on the receiver improves the sensitivity performance during the transmission. The increased sensitivity can vary from 1 – 3 dB in different receiver settings. If AFC is turned on, the Sync Clock Type must be set to either “Tracing” or “Counting” because the synchronization clock is required to detect the preamble which is used to trigger the AFC. By default the AFC is turned off to allow “No Sync Clock” to be used.

The AFC is triggered by detecting a valid preamble. The preamble size is defined in the Decoding Setting (see next chapter). After detecting a valid preamble, it takes 4 – 8 symbols for the AFC circuit to remove most of the frequency error. It is recommended for the user to transmit at least 8-symbol of preamble more than the preamble size defined on the RFPDK, so that the AFC can be done during the reception of the preamble and increase the sensitivity during the subsequent sync or data receptions. The figure below shows the AFC timing characteristics with the preamble size is set to 16-symbol.

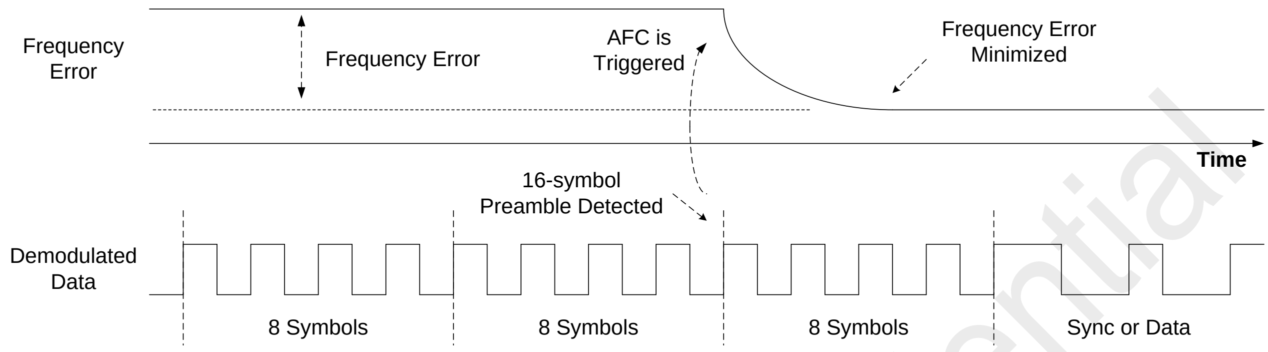

Figure 26. AFC Timing Characteristics

When the tracing method is used to recover the sync clock and the transmitted data is encoded to avoid long string of "0", turning on the AFC can achieve the highest sensitivity performance of the device.

6. Decode Settings

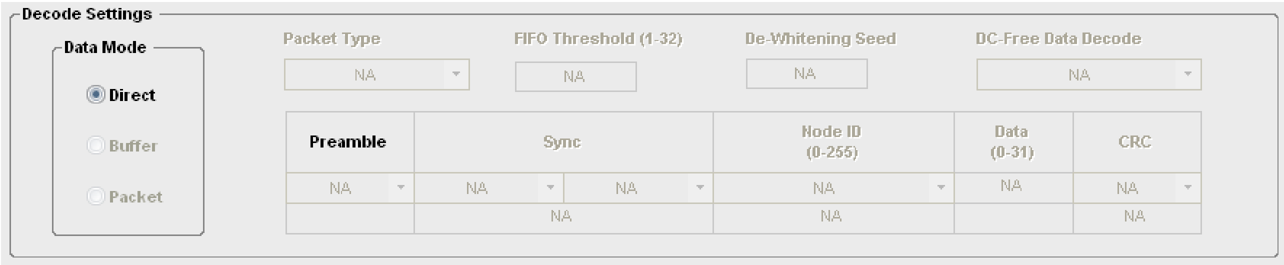

Figure 27. Decode Settings

Direct data mode, which is required in this product, means that the demodulated data is output via the DOUT pin. The available options of data decoding in the direct mode are:

Table 9. Decode Settings Parameter

Parameter	Descriptions	Default	Mode
Preamble	The size of the valid preamble, the options are: 1-byte, 2-byte, 3-byte, or 4-byte. It is only available when WOR is on.	2-byte	Advanced

6.1 Preamble

The preamble detection is used when the wake-on radio is turned on and the wake-on condition is set to “Extended by Preamble”, or when the AFC is turned on. Once the preamble detection is used, the Sync Clock Type must be set to either Counting or Tracing.

7. Document Change List

Table 10. Document Change List

Rev. No	Chapter	Description of Changes	Date
0.8	All	Initial released version	2014-08-22
0.9	4	Adding Chapter 4. OOK Settings	2015-03-18

8. Contact Information

Hope Microelectronics Co., Ltd

Address: 2/F,Building3,Pingshan Private Enterprise science and Technology Park,Xili Town,Nanshan District,Shenzhen,China

Tel: +86-755-82973805

Fax: +86-755-82973550

Email: sales@hoperf.com

hoperf@gmail.com

Website: http://www.hoperf.com

http://www.hoperf.cn