WDS User's Guide for EZRadio® Devices

1. Introduction

Wireless Development Suite (WDS) is a software utility used to configure and test the Silicon Labs line of ISM band RFICs.

This document only describes the WDS for the EZRadio product family. This document is valid for the following EZRadio ICs:

- Si4355
- Si4455

It is recommended that one first read "AN796: Wireless Development Suite General Description."

2. EZRadio Device Applications

2.1. Radio Configuration Application

The behavior and RF configuration of the EZRadio radios can be set by the EZConfig array after Power On Reset. The basic settings cannot be modified after configuration. Only a few parameters can be changed during normal operation (center frequency, output power, interrupt properties, etc.). The radio performance can be verified or an example source code can be generated by following three basic steps in the Radio Configuration Application:

1. Select the Example Project that best fits the expected application or laboratory measurement.
2. Configure the desired radio parameters, packet related settings, and setup the desired interrupts and GPIO functionalities.
3. Generate the EZConfig array and select the desired deploy option.

These steps are well separated within the Radio Configuration Application as shown in Figure 1, and it is highly recommended that they are used in this order:

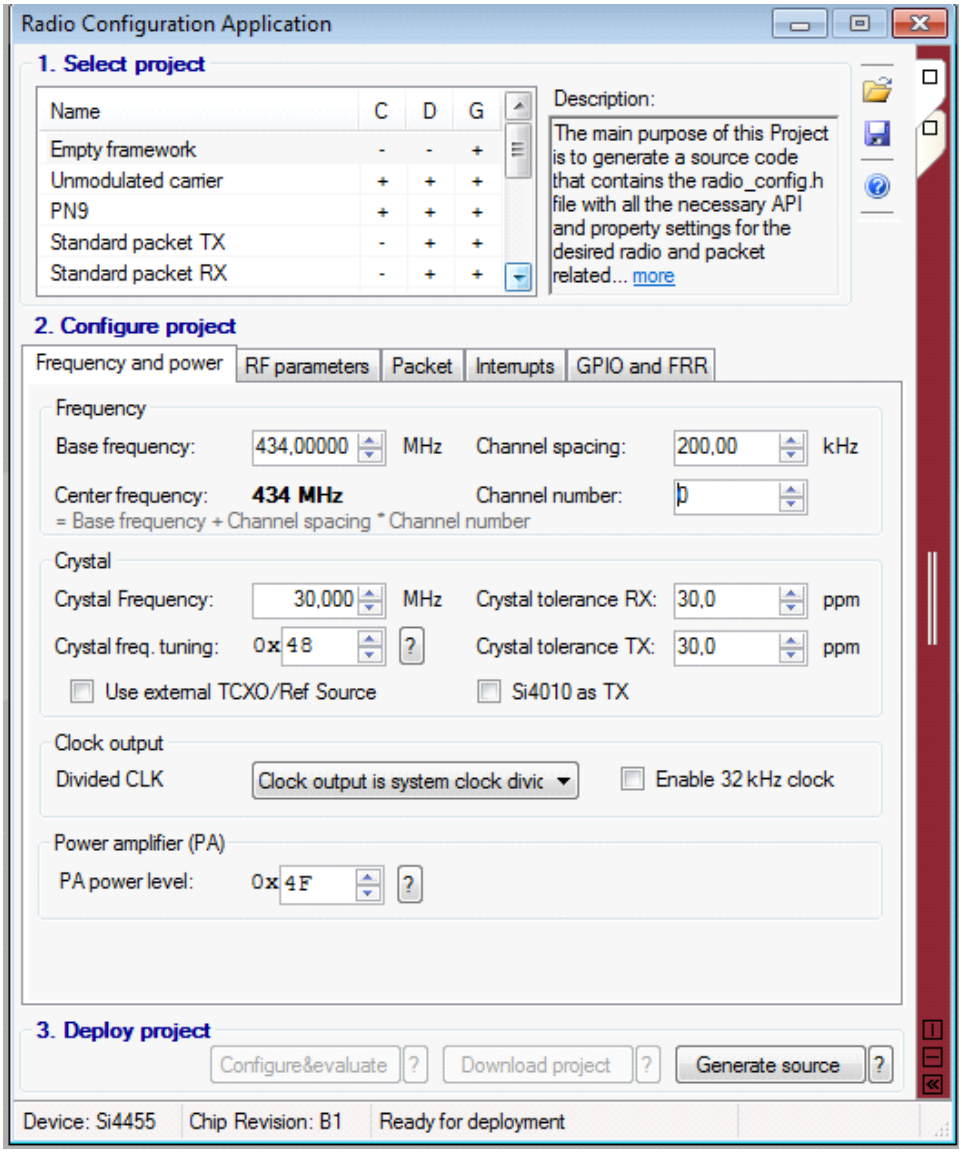

Figure 1. Radio Configuration Application

The general workflow of the Radio Configuration Application is shown in Figure 2.

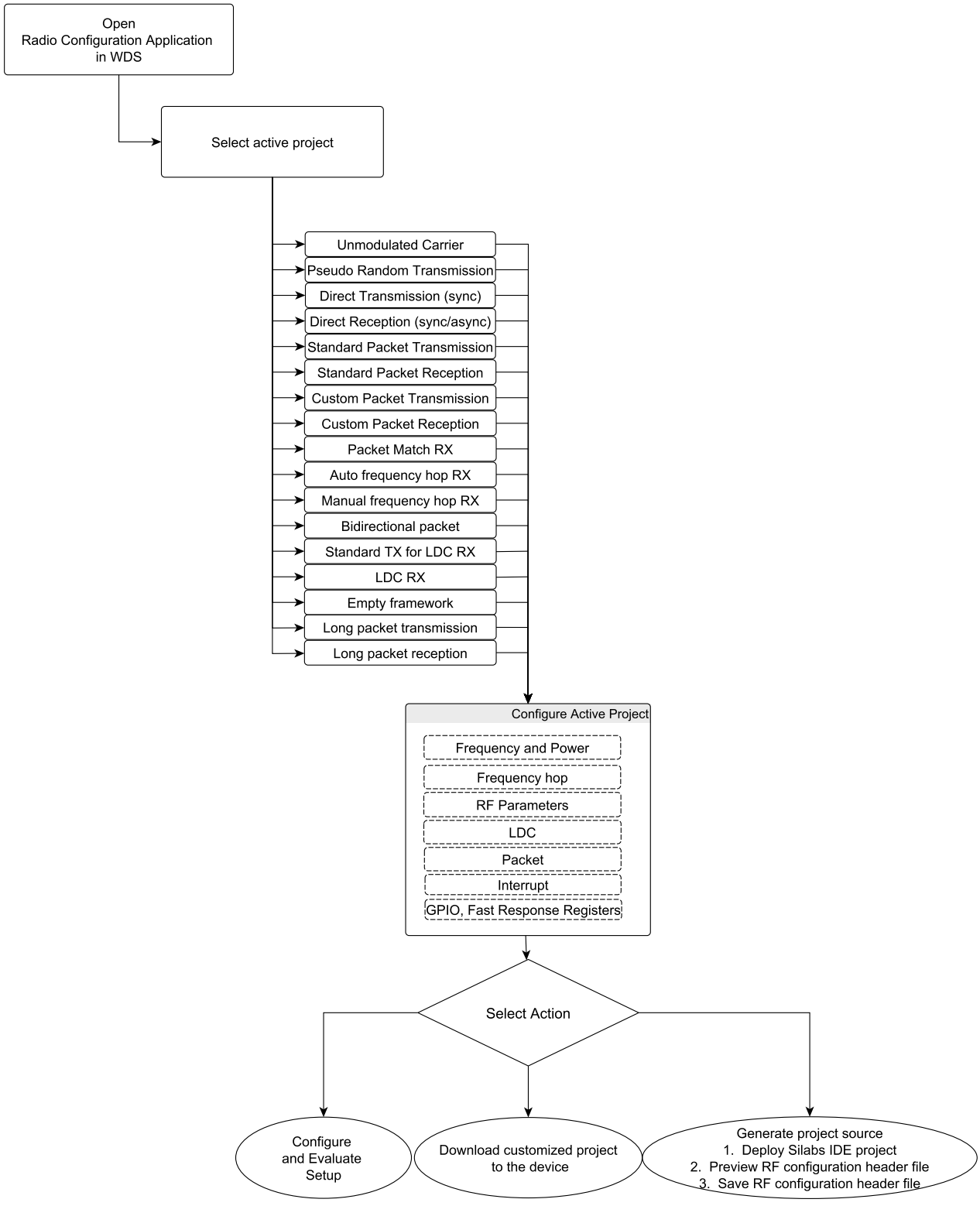

Figure 2. WDS Workflow

2.1.1. Select Example Project

The basic functions of the radio are represented as Projects. Each Project has a well-defined behavior (e.g., placing the radio into continuous transmission mode for TX related measurements) or purpose (e.g., generating an empty framework with the desired radio configuration for FW development). The list of the available projects is summarized by their behavior and purpose in the following table:

Table 1. Project Behavior and Purpose

Name	Behavior	Purpose (Deployment Options)		
		Config & Evaluate	Download Project	Generate Source
Empty Framework	The main purpose of this Project is to generate a source code that contains the radio_config.h file with all the necessary API and property settings for the desired radio and packet related settings. It does not contain any application code, so it is a good starting framework for FW developers.	–	–	+
Unmodulated Carrier	This project configures the radio with the selected radio parameters and sets the radio onto continuous transmit mode. Using this Project, most of the transmission related characteristics can be verified with lab equipment (e.g., output power, frequency accuracy, etc.).	+	+	+
PN9 Random Modulated TX	This project configures the radio with the selected radio parameters and sets the radio onto continuous PN9 random modulated transmit mode. Using this Project, the modulated transmission related characteristics can be verified with lab equipment (e.g., occupied bandwidth, output power, etc.)	+	+	+
Direct TX	This project configures the radio with the selected radio parameters and sets the radio onto continuous modulated transmit mode. The modulation source is a user selectable GPIO, the user needs to feed the data through this pin. The radio can provide data clock for sampling purposes that is available on another selected GPIO.	+	+	+
Direct RX	This Project configures the radio with the selected radio parameters and sets the radio onto continuous receive mode. The received data is provided on a selected GPIO. In addition the data clock is available on a user selectable GPIO. This Project is typically used to evaluate the receiver characteristics (e.g., sensitivity, blocking, etc.) of the radio by measuring bit error rate with lab equipment.	+	+	+

Table 1. Project Behavior and Purpose (Continued)

Name	Behavior	Purpose (Deployment Options)		
		Config & Evaluate	Download Project	Generate Source
Standard Packet TX	This Project configures the radio with the selected radio parameters and waits for a user interaction. If the Project is loaded to the development board, then the push buttons trigger the packet transmission. The corresponding LED blinks showing the packet transmission. **Note:** The Project sends a special packet that can be received with a development board loaded with the "Standard Packet RX" project. It doesn't provide the flexibility to change the packet configuration.	–	+	+
Standard Packet RX	This Project configures the radio with the selected radio parameters, sets the radio onto receive mode and waits for packets (LED1 is turned on while the board is in receive mode). If the Project is loaded to the development board, then the host MCU processes the received packets and blinks the LEDs accordingly: a) if a valid packet is received, then LED2-4 shows the number of push buttons pressed on the transmit side for a short period of time (the number is encoded in BCD format). b) if the received packet cannot be interpreted, then all the LEDs blink. **Note:** The Project can interpret packets sent by the "Standard Packet TX" Project. This Project can be used to test the interoperability of the EZRadio devices with EZRadioPRO devices or with the Si4010. It does not provide the flexibility to customize the packet configuration. This Project can be also used to test the interoperability of the EZRadioPRO devices and development kit with other EZRadio devices. The Project is capable of receiving packets from the Si4010 key fobs or from the Si4x6x development boards. Be sure that the RF configuration of the EZRadio device matches the settings of the EZRadioPRO example Project or the Si4010 key fob.	–	+	+

Table 1. Project Behavior and Purpose (Continued)

Name	Behavior	Purpose (Deployment Options)		
		Config & Evaluate	Download Project	Generate Source
Custom Packet TX	These Projects work similarly to the Standard TX or RX with the exception that the packet configuration can be customized as well. This example Project also supports receiving packet with variable length. It is the user's responsibility to set the same packet configuration for both projects, otherwise they cannot work together. The LEDs help to identify the different packet receive states of the receiver. LED1 is turned on while in receive mode. Upon packet reception: - LED2 turns on if the Synch Word of the received packet matches the settings. - LED3 turns on if the CRC of the received packet is valid. - LED4 turns on if the payload content of the received packet is the same as the expected packet content specified in WDS. Make sure to set the same packet content for both the transmit or the receive side, otherwise the Custom Packet RX Project will not be able to validate the payload content.	+	+	+
Custom Packet RX		+	+	+
Bidirectional Communication	This Project configures the radio with the selected radio parameters, sets the radio into receive mode and waits for packets or user interaction. Both nodes (development boards) must be deployed with the same project. In case the project is loaded to the board, the user can press any of the push buttons on a development board to send a packet. The receiver board will blink the LED upon packet reception and transmits back an acknowledgment. If the acknowledgment packet is received correctly, then the originator will blink the LED as well. The Project is a good example for FW developers of how a bidirectional communication can be realized with the EZRadioPRO devices. It also provides an example of how the radio needs to be configured for variable packet length, since the Project transmits packets with different lengths upon the pressing of different buttons. This project is a simple demonstration how a bidirectional communication needs to be built up and it can be used for basic range testing as well.	–	+	+

Table 1. Project Behavior and Purpose (Continued)

Name	Behavior	Purpose (Deployment Options)		
		Config & Evaluate	Download Project	Generate Source
Range Test Application	The Range Test Application is a standalone tool that is used to verify the link performance between two nodes by performing range test. The demo has several built in, predefined radio settings for all the major frequency bands. Those can be used to compare the communication range for different data rate settings. The Application can be configured through the onscreen menu system of the board and does not require a PC connection. Refer to the “AN655: Range Test Application for the EZRadio and EZRadioPRO Devices” application note for more details on this project.	–	+	–
Triggered PER Measurement	This project controls a laboratory PER (packet error rate) measurement where the PER values of a specific radio configuration can be observed. The measurement triggers a connected RF signal generator to transmit the specific number of packets with configured trigger interval, counts the correctly received packets, and calculates the actual PER value.	+	–	–

2.1.2. Configure the Radio

The middle section of the Radio Configuration Application is used to configure the desired radio and packet related settings. Since there are several configuration options, they are grouped within different tabs. Each tab is described in the following section.

Note: The actual view of the configuration tabs and the available configuration options depend on the selected Project, the selected radio and/or selected configuration options. The following section shows an example of the Custom Packet RX project using GFSK modulation.

2.1.2.1. Frequency and Power Tab

The basic frequency, crystal, and power amplifier related settings can be accessed on the “Frequency and power” tab. The center frequency is configurable within the band supported by the development board or in any of the supported bands of the radio in simulation mode. The radio also supports setting up the frequency as a channel number, which enables the user to quickly change frequency with a single API command for fast frequency hopping. The channel spacing and the actual channel number can be defined here.

Note: Channel 0 refers to the base frequency.

It is important to accurately define the crystal frequency and crystal accuracy for both sides of the link, since the receive configuration (modem parameters, receive bandwidth, etc.) will be calculated by WDS based on these crystal parameters. The "Si4010 as TX" checkbox sets the TX side crystal tolerance to the value proper for the Si4010 transmitter Soc. If an external clock source is used (such as TCXO or other digital clock source), then the “Use external crystal” setting must be enabled.

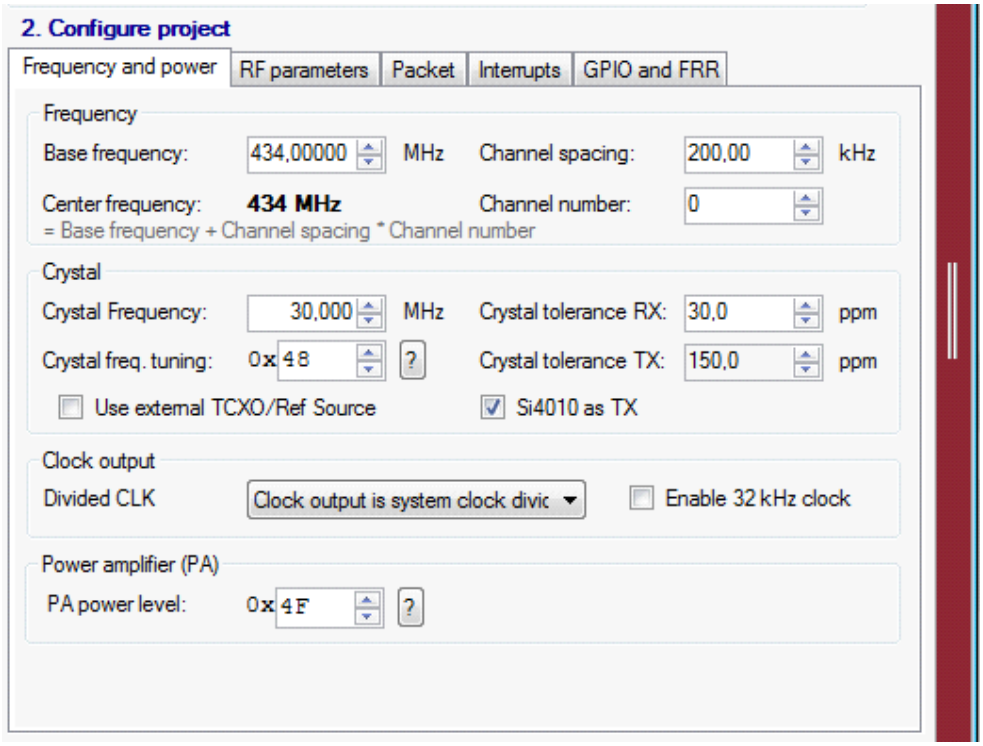

Figure 3. Frequency and Power Tab

2.1.2.2. RF Parameters Tab

The desired modulation mode, data rate, and specific RF settings can be set on the “RF parameters” tab. First the user can select between using the bandwidth value recommended (i.e. automatically calculated) by WDS, based on the user provided RX/TX crystal accuracy or the user can set the bandwidth manually. Then WDS provides recommended settings in a table the user can choose from. The chosen setting can be modified in the custom settings section of the tab. The user can define the modulation mode, the data rate, the deviation, or the OOK bandwidth settings in the first column. Besides those settings it is important to define the preamble patter of the data packet for optimal receive configurations.

High- and low-performance mode refers to the receive operation of the EZRadioPRO devices (it may not be available for all devices). In low-performance mode, both the receiver current consumption and the sensitivity is lower compared to high-performance mode. It provides a possibility for the user to optimize the parameters for optimal range or battery life time.

If bit error rate is measured on PN9 random data or a data stream without preamble and/or synchron word is received, then “Enable BER mode” must be set.

Note: In case of legacy protocols, it may require further optimization to achieve stable data reception.

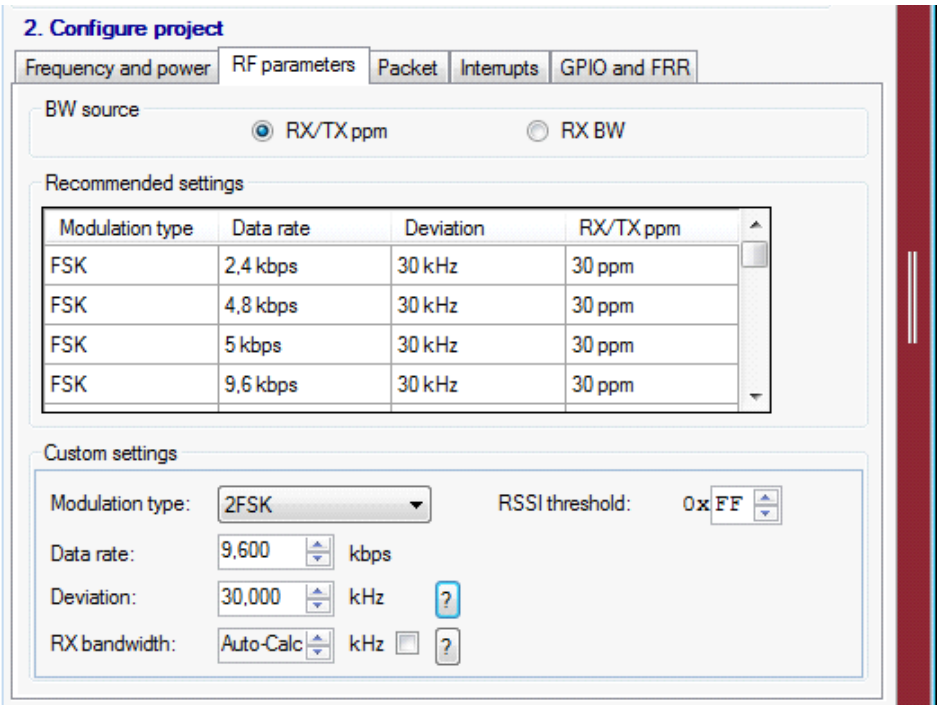

Figure 4. RF Parameters Tab

2.1.2.3. Packet Tab

In packet mode the data is transmitted from the FIFO in transmit mode and the received bytes are stored in the receive FIFO. If further processing is required in the data bytes stored in the FIFO (e.g., Manchester coding, CRC calculation, etc.), then the packet handler block of the radio processes the data before packet transmission or after packet reception. The packet handler is a complex block and it has several configuration properties that may be confusing for non-experienced users. To simplify the configuration, WDS provides the option to set up the desired packet configuration in a graphical representation on the “Packet” tab.

The actual packet configuration is shown in the middle of the tab. By clicking on the different fields, such as Preamble, SynchWord, and Payload/CRC, the appropriate configuration tab is selected automatically below the packet. This allows the user to configure those fields separately, one-by-one.

The Manchester encoding and CRC calculation data processing options are shown in different colors. These can be enabled or disabled and appear just below the packet configuration as lines with the same color as the data processing option. This helps the user to easily verify that the different fields are configured correctly.

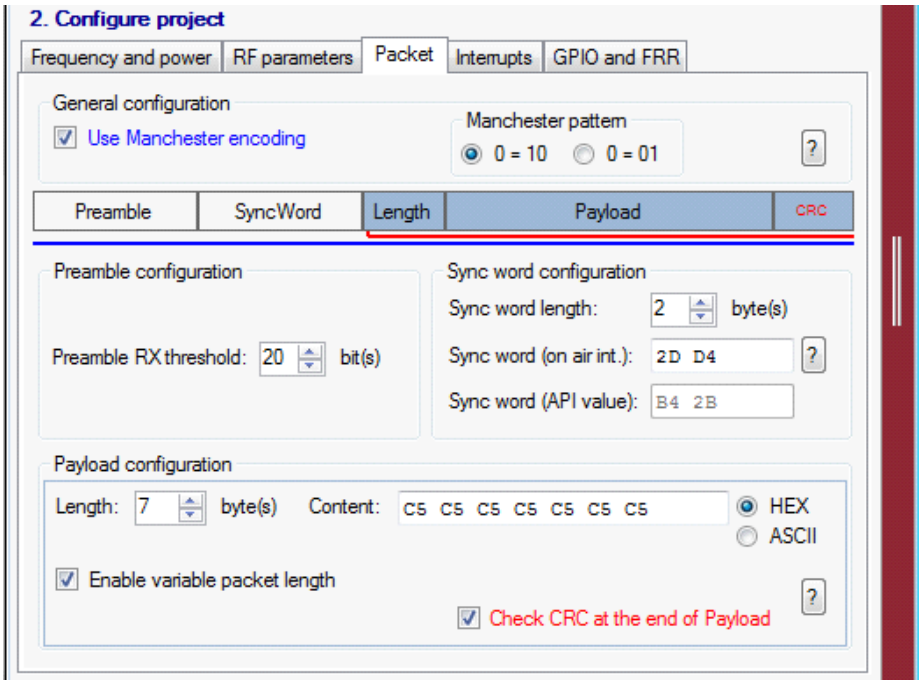

Figure 5. Packet Configuration

2.1.2.4. Interrupts Tab

On the “Interrupts” tab, the desired interrupt option can be set.

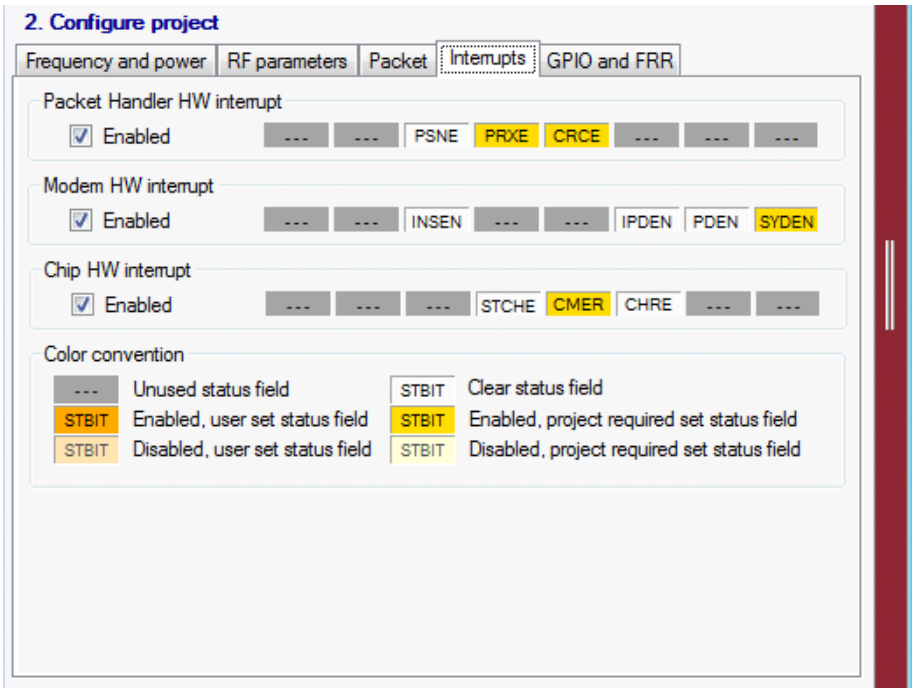

Figure 6. Set Interrupts

Note: Refer to the API description documents for more information on the available interrupt options and configuration.

2.1.2.5. GPIO and FRR Tab

On the “GPIO and FRR” tab, the desired functionalities can be assigned for the general purpose IOs and for the fast response registers.

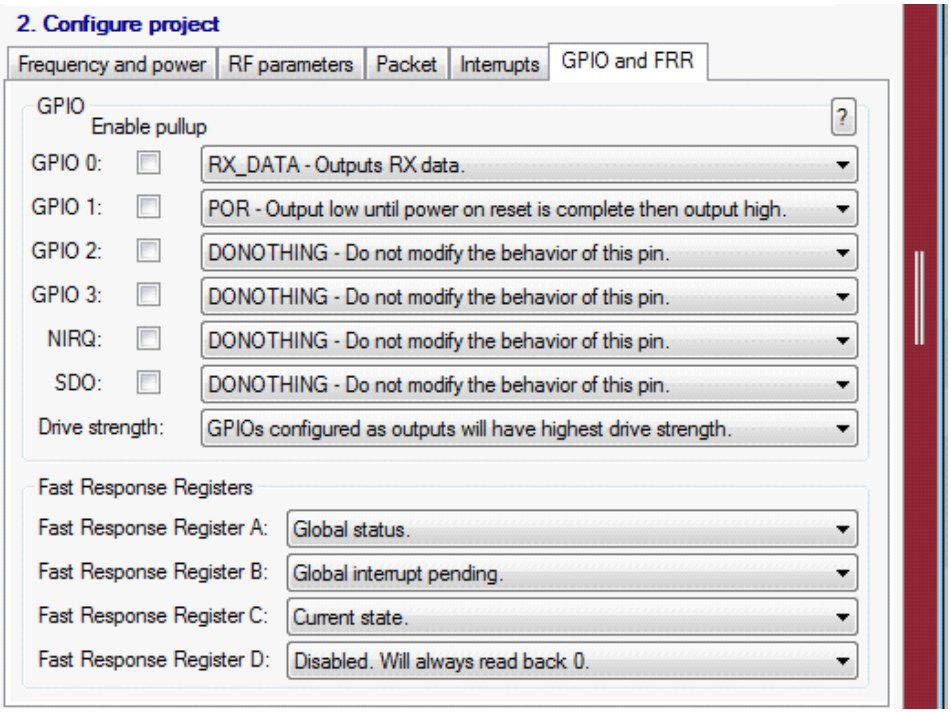

Figure 7. Assign GPIO and Fast Response Register Operation

Note: Refer to the API description documents for more information on the available GPIO and Fast Response Register options and configuration.

The EZRadio devices are very flexible, resulting in a high number of configuration options. In order to save time during development, WDS supports saving the actual status and settings of the Radio Configuration Application (including the selected Project and all settings on all the tabs) so that they can be reloaded anytime later on.

In case technical help is needed, it is also recommended that the user send the configuration file with the support questions. Doing so will allow the application engineer to quickly identify the desired radio parameters and packet configuration. Please use the Save/Load icons on the top right corner of the Application as shown in Figure 8.

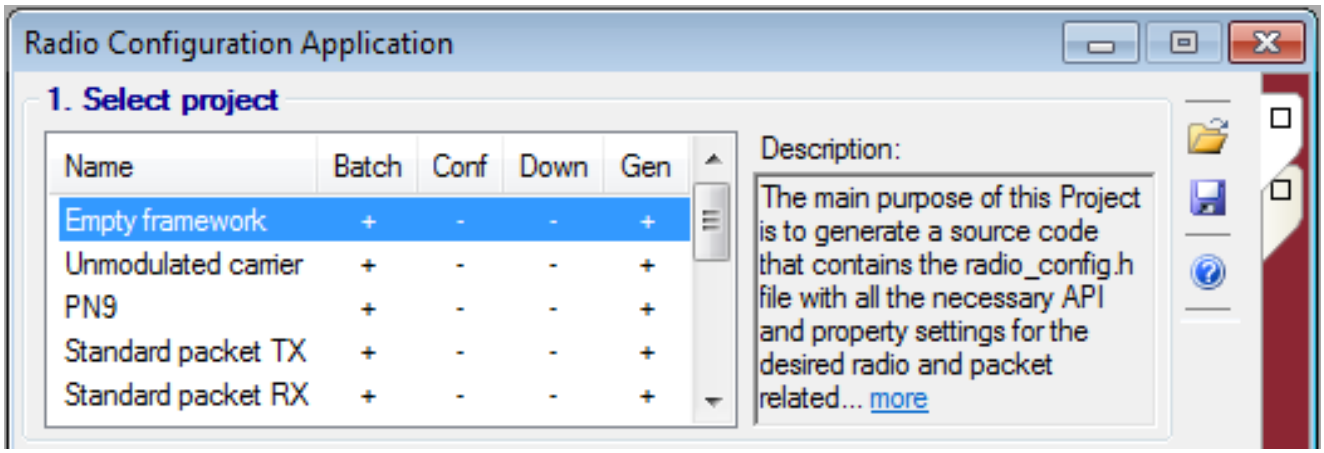

Figure 8. Radio Configuration Application

2.1.3. Project Deployment

2.1.3.1. Configure and Evaluate

The radio operation and characteristics can be verified by selecting the “Configure & evaluate” option. In this case, WDS downloads a special FW into the connected development tool. The FW makes it possible to configure the radio from the PC GUI and provides access to status information of the connected device. Once the FW is loaded to the development board, a new window appears that is used to show the actual status information of the radio and to control the laboratory measurement.

This is the easiest way to verify basic radio parameters and data sheet parameters (e.g., output power, bit error rate, etc.). However, in this mode, WDS does not show what API commands are sent to the radio during configuration.

Note: After disconnecting the development board from the PC, the WDS test FW remains in the development board that is not functional without the GUI.

The following sections summarize the Projects that are available for “Configure & evaluate” deployment, together with their options and purposes.

Unmodulated Carrier, PN9 and Direct TX

The most common RF measurement is to verify the output power and the harmonics/spurs of the radio in transmit mode. For this purpose, the “Unmodulated Carrier” lab measurement can be used.

In addition to the unmodulated parameters, it is important to verify the occupied bandwidth and shape of the transmitted, modulated signal frequency spectrum. The “PN9” or “Direct TX” lab measurements are suitable for this purpose. Both tests behave the same way (they set the radio into continuous modulated transmit mode), but the modulation source is different. The internal PN9 random generator is used to modulate the output power in “PN9” test mode. However, sometimes, the host MCU generates the modulation data. For such purposes, the “Direct TX” lab measurement is recommended, which expects the data on one of the GPIOs of the radio.

During these tests, the GUI allows the user to change a couple of basic parameters, such as center frequency, output power, and crystal frequency tuning. It is also possible to read back status information, such as fast response register values, etc.

This is a practical test to fine-tune the center frequency. Due to the crystal tolerances and possible mismatch between the internal capacitance of the crystal circuit and the load capacitance of the crystal, the radio may work on a slightly different frequency than expected. The crystal frequency tuning property can be used to cancel the frequency error by simply fine tuning its value while monitoring the exact center frequency with a spectrum analyzer.

Direct RX

Direct RX mode can be used to verify the most common receive RF performance characteristics, such as sensitivity, blocking, selectivity, etc. This test sets the radio into continuous receive mode and outputs the received data bits on one of the GPIOs of the radio. The recovered data clock is also provided on a different GPIO for synchronization purposes. Using an RF signal generator with bit error rate measurement options, most of the receiver parameters can be evaluated.

This lab measurement also allows reading status information and monitoring of the interrupt status registers. WDS also enables fine tuning of basic RF parameters, such as center frequency and crystal frequency.

Custom Packet TX

If the application transmits packets, the user should verify the transmit side of the link. The Custom Packet TX test can be used for this purpose. WDS allows the user to define the contents of the packet and to initiate packet transmission with the “Start TX” button, which sends the packet once. If desired, the packet content can be changed before sending the next packet.

This lab measurement allows the user to read information and monitor the interrupt status registers. WDS also enables fine tuning of basic RF parameters, such as center frequency, output power, and crystal frequency.

Custom Packet RX

When using packet-based communication, it is useful to check whether the radio receives the expected packet correctly or to check the sensitivity by measuring the packet error rate. The Custom Packet RX test is suitable for

this, since the radio can be placed into receive mode where it waits to receive a packet. Once a valid packet is received, the user can read the FIFO content by pressing the “Read” button. The radio then must be placed back to receive mode with the “Restart RX” button.

This lab measurement also allows the user to read back status information and monitor the interrupt status registers. WDS also enables fine tuning of basic RF parameters, such as center frequency and crystal frequency.

Triggered PER

This project is useful for measuring the sensitivity of the radio by using specific RF and packet configurations. The project configures and controls a laboratory PER (packet error rate) measurement where the PER values of a specific radio configuration can be observed. The measurement triggers a connected RF signal generator to transmit the specific number of predefined packets with configured timeout, counts the received packets, and calculates the actual PER value. Changing the output power of the generator gives the ability to measure the sensitivity of the radio.

The packet trigger input of the generator should be connected to the RX_STATE output signal of the radio available on a user-defined RF_GPIO (RF_GPIO0 by default) connector of the development board. The RF output of the generator should be connected to the antenna connector of the development board (See Figure 9). The packets sent by the signal generator are needed to have the same packet structure and RF parameters which were configured on the Radio Configuration Application.

Note:

1. The user can reconfigure the following signals to one of the RF_GPIO pins on the “GPIO and FRR” tab of the RCA, if the predefined ones are used for other purposes:
   - RX_STATE: trigger signal to generator, predefined to RF_GPIO0
2. It is required that one use CRC check at the end of the packet to ensure the packet is received without any bit error. Otherwise, the received packet count and calculated PER values might be false.
3. The following fast response register configurations are required for the proper operation:
   - Fast Response Register A: Packet Handler status
   - Fast Response Register B: Modem status

After deploying the project, the "Packet trigger interval" and "Number of packets" can be set. The “Number of packets” can also be configured to infinite by selecting the “Infinite” checkbox.

Pressing the “Start” button starts the measurement. The generator will be continuously triggered with the configured trigger interval. The measurement can be stopped with the "Stop" button and restarted with the "Start" button. The measurement runs as far as all the packets are triggered (ie., “Number of packets”).

The following parameters are displayed during measurement to provide information on the quality of the link:

- Measurement status
- Number of triggered packets
- Number of detected preambles
- Number of detected sync words
- Number of received packets
- Number of lost packets (calculated from the numbers of triggered and received packets)
- PER value (calculated from the numbers of triggered and received packets)

Note: When changing any of the radio or measurement parameters, the measurement has to be restarted with the "Start" button..

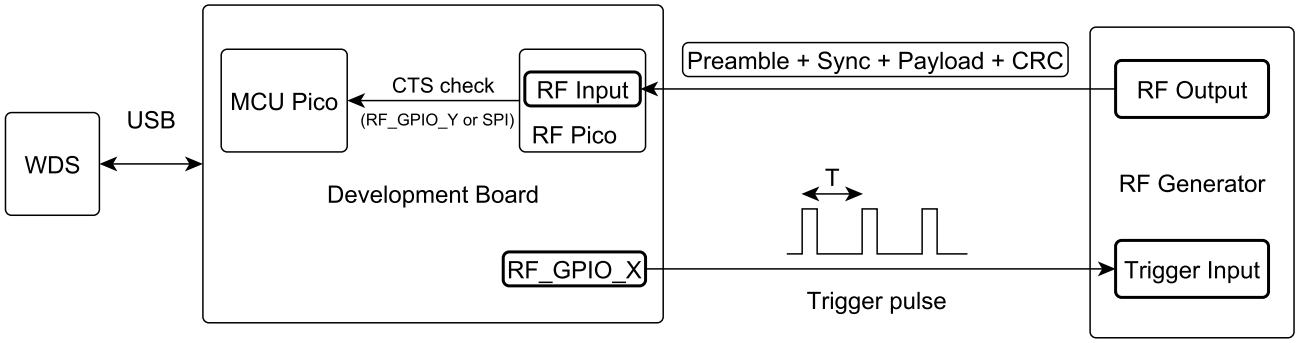

Figure 9. Triggered PER Measurement Setup

2.1.3.2. Download Project

Selecting the “Download project” option causes the WDS to customize the radio and packet related configuration of the project and load it onto the development board. Since the FW is loaded into the host MCU, the development board can run that anytime even without PC connection. This is a useful feature for verifying the range between two development boards (using a simple packet TX or packet RX project with customized RF parameters) or measuring radiated performances in an antenna chamber or at the test house.

The “Download project” feature does not require installing any other FW development tools to the PC (such as FW development environment or compilers); therefore, WDS can be easily used by anyone who is concentrating on the RF parameter verification. Once the optimization is finished, the entire source of the example Project code (with the customized radio parameters) can be deployed by selecting the “Generate source” code option.

2.1.3.3. Generate Source

The entire source code of the customized Example Project is accessible through the “Generate source” option. The source code can be opened in the Silicon Labs IDE. For that purpose, the Silicon Labs IDE must be installed on the PC beforehand. If a different IDE or compiler is used or the source code is intended to be used with a different MCU, then one is advised to save the source code to the PC and use the “make files” in the project folder. The Example Projects are developed for the Silicon Labs C8051F930 MCU.

Note: The silicon Labs IDE can be downloaded from the Silicon Labs WEB site: www.silabs.com.

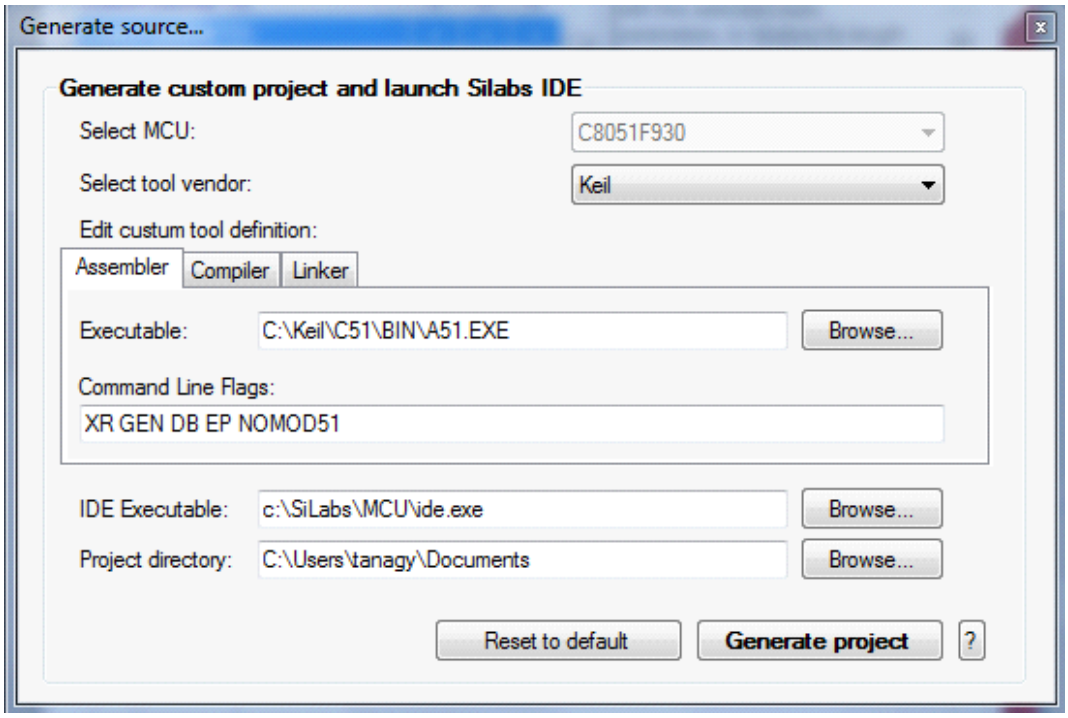

Figure 10. IDE Launcher

The radio configurations are stored in the radio_config.h within the example project. The header file is generated by the WDS. The header file can be previewed and saved separately, without saving the entire source project too.

For more details of the Example Project, the radio configuration header file, and the required SW development tools, refer to *AN692: Si4355/4455 Programming Guide and Sample Codes*.

EZRadio devices have a built-in modem to demodulate the received data. The modem is a complex hardware block and its behavior is configured through numerous Properties. In case any reception related settings are changed, the WDS runs a calculator to define the modem configuration Properties.

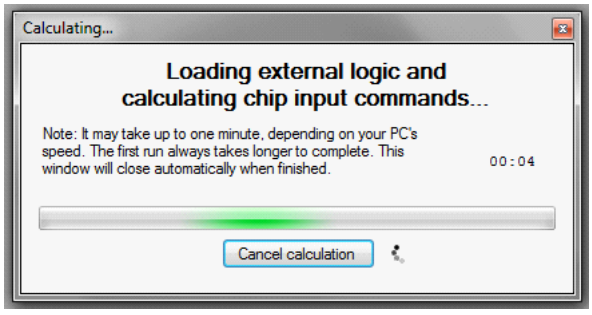

Figure 11. WDS shows the Status of the Modem Properties Calculation

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