AN1294: Configuring Antenna Diversity for OpenThread

This application note describes how to use Project Configurator and Component Editor in Simplicity Studio 5 to configure Antenna Diversity in OpenThread applications. Both receive and transmit antenna diversity configuration are discussed.

The information in this application note applies to OpenThread SDK releases beginning with 1.1.0.0.

KEY POINTS

- Describes antenna diversity and the transmit and receive implementations.
- Provides instructions and examples for configuring transmit and receive antenna diversity.
- Includes additional configuration information if antenna diversity is implemented with a FEM.
- Lists the Antenna Diversity Command Line Interface commands and steps for disabling the CLI if not desired.

1 About Antenna Diversity

Antenna diversity is a technique used to improve radio performance by using two different antennas to transmit and/or receive messages. For a more detailed explanation of the problems with signal transmission and reception in indoor environments and how antenna diversity can mitigate those problems, see:
https://www.silabs.com/documents/public/white-papers/using-antenna-diversity-to-create- highly-robust-radio-links.pdf.

Antenna diversity may be applied to transmission (Tx) and/or reception (Rx). Diversity is achieved using an external RF switch, either standalone or as part of a FEM (Front End Module) / LNA (Low Noise Amplifier).

The Tx algorithm uses reception of the packet acknowledgement (ACK) to determine if it should change antennas. If the device does not receive an ACK after packet transmission it toggles the RF switch to the other antenna and tries again. It retries two more times, for a total of four attempts, before the MAC (Media Access Layer) fails the transmit up to the network layer. Specifically, the worst-case scenario is as follows:

- New MAC packet transmitted on antenna 1.
- No ACK received so antenna is switched to antenna 2.
- MAC retransmit #1 sent on antenna 2.
- No ACK received, so antenna is switched to antenna 1.
- MAC retransmit #2 sent on antenna 1.
- No ACK received, so antenna is switched to antenna 2.
- MAC retransmit #3 sent on antenna 2.
- No ACK received, so antenna is switched to antenna 1.
- (MAC retries have exhausted, so MAC fails transmit to network layer).
- The next transmit will start on antenna 1.

If transmission is successful, at the beginning of the next transmission the device starts on the last successfully-used antenna.

In Rx antenna diversity with RSSI (Received Signal Strength Indicator), the receiver alternates between antenna 1 and antenna 2 during the timing search looking for a valid timing pattern on the incoming signal. When a valid timing pattern is found, antenna diversity tries to select the best antenna for receiving the rest of the frame. To achieve this, the signal quality for the currently active antenna is saved/updated at every subsequent antenna switch. Therefore, at the first timing detect event the algorithm already has a fresh quality metric for one antenna.

To perform a valid comparison between antenna 1 and antenna 2, the radio switches simultaneously with the timing detect event to the other antenna to perform a signal quality evaluation/update there. Finally, antenna quality results get compared, and the algorithm selects the better antenna for packet reception. If the better antenna is the current antenna, then the Rx operation carries on with packet reception without further antenna switching. If the better antenna is the other antenna, then the radio switches to that one, reacquires timing and carries on with packet reception on that antenna.

In antenna diversity, longer preambles are often used to provide the antenna diversity algorithm time to detect and evaluate the signal on each antenna to ensure that a true preamble is found. However, shorter preambles are preferred as they reduce MCU on-time and in turn reduce MCU current consumption. The RSSI measurement technique for evaluating signal quality requires less preamble time than other methods such as timing correlation.

Note: Antenna Rx diversity is available for testing and evaluation purposes on the Gecko SDK suite. Due to the short preambles on the 802.15.4 packets, customers will need to make their own assessment on the performance and production readiness of this feature.

Rx and Tx antenna diversity are independent operations. In practice this means that, for example, Tx antenna diversity will begin the next transmission on the last successfully used antenna for Tx (for example antenna 1), even though in the intervening receive Rx antenna diversity found better signal quality on antenna 2.

2 Configuring Antenna Diversity

The antenna diversity configuration options available for OpenThread consist of selecting Rx and/or Tx antenna diversity and configuring the underlying peripherals correctly. To configure antenna diversity, you must be familiar with your device's overall antenna configuration, that is, if it uses a FEM/LNA for either Tx or Rx, and also be familiar with the device's pin layout. Check the data sheet for your device for these settings or contact Silicon Labs Support if you have questions.

These instructions assume you have installed Simplicity Studio 5 and the OpenThread SDK (Software Development Kit), and that you have a project open in the Simplicity IDE (integrated development environment).

The steps to set up antenna diversity are described in detail below. In summary:

1.   Install the Antenna Diversity component.
2.   Configure the RAIL Utility - Antenna Diversity Configuration component.
3.   Configure Antenna Pin configurations.
4.   Configure the FEM (Optional).

2.1   Install Antenna Diversity Component

1.   On the SOFTWARE COMPONENTS tab, search for **antenna** in the 'component's name' search field (at the top right).
2.   Under OpenThread components, select the **Antenna Diversity** component and click **Install** as shown in the following figure.
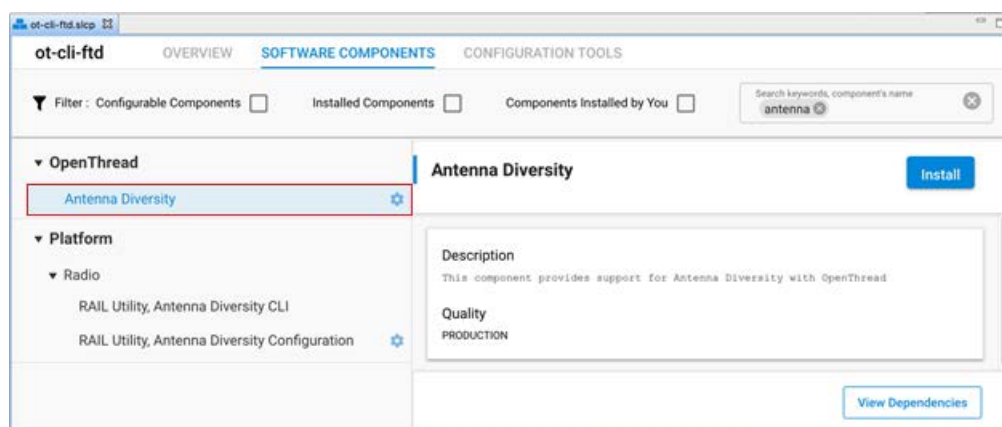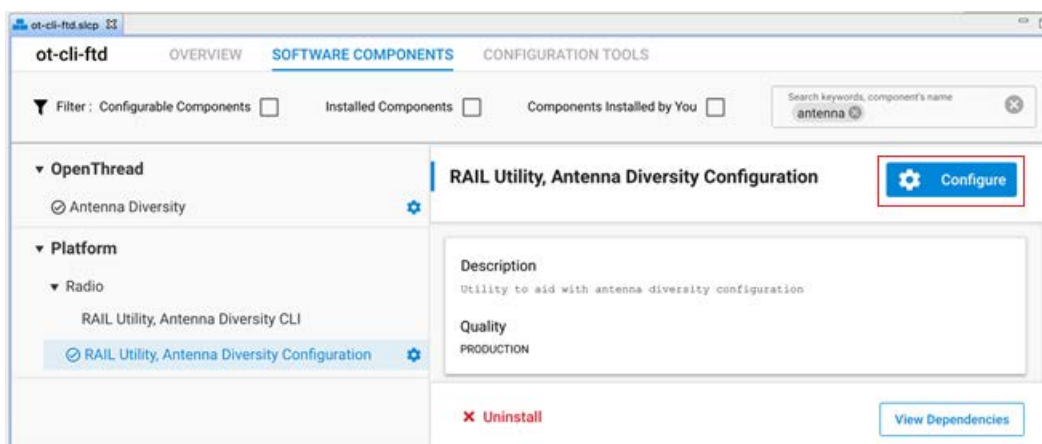

Installing the Antenna Diversity component will install the RAIL Utility, Antenna Diversity Configuration component for your project.

> **Note:**   For Silicon Labs OpenThread SDK releases prior to 1.2.0.0, select and install the **RAIL Utility, Antenna Diversity Configuration** component directly under Platform components.

2.2   Configure RAIL Utility - Antenna Diversity Configuration Component

Once the Antenna Diversity Configuration component is successfully installed, click **Configure** or the configure symbol next to the RAIL Utility - Antenna Diversity Configuration component name as shown in the following figure.

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Configuring Antenna Diversity

2.2.1 Configure Tx Diversity

The default configuration in the Antenna Diversity Configuration component for Tx Diversity is disabled. To enable Tx Diversity, select the **Enable Antenna Diversity** option from the Tx Antenna Diversity Mode drop-down menu as shown in the following figure.
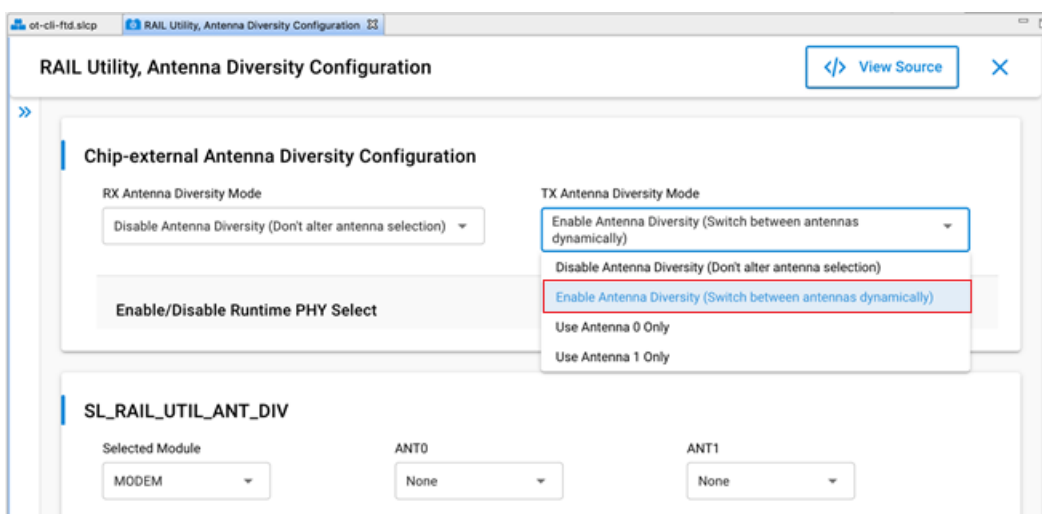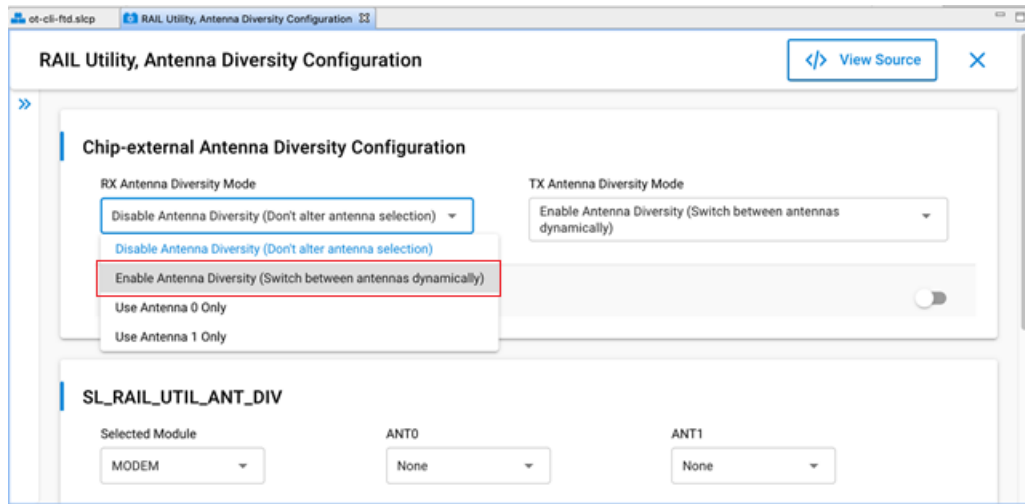

The different options for TX Antenna Diversity Mode are as follows:

- **Disable Antenna Diversity:** Antenna Diversity component does not control ANTENNA_SELECT_GPIO.
- **Enable Antenna Diversity:** Tx antenna selection is dynamic and Tx diversity is enabled.
- **Use Antenna 0 only:** ANTENNA_SELECT_GPIO is set to high during Tx.
- **Use Antenna 1 only:** ANTENNA_SELECT_GPIO is set to low during Tx.

2.2.2 Configure Rx Diversity

The default configuration in the Antenna Diversity Configuration component for Rx Diversity is disabled. To enable Rx Diversity, select the **Enable Antenna Diversity** option from the Rx Antenna Diversity Mode drop-down menu as shown in the following figure.

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Similar to TX Antenna Diversity Mode, the different options for RX Antenna Diversity Mode are as follows:

- **Disable Antenna Diversity:** Antenna Diversity component does not control ANTENNA_SELECT_GPIO.
- **Enable Antenna Diversity:** Rx antenna selection is dynamic and Rx diversity is enabled.
- **Use Antenna 0 only:** ANTENNA_SELECT_GPIO is set to high during Rx.
- **Use Antenna 1 only:** ANTENNA_SELECT_GPIO is set to low during Rx.

2.2.3 Configure Rx and Tx Diversity

To configure both Rx and Tx antenna diversity, select the **Enable Antenna Diversity** option for both the Rx and Tx Antenna Diversity Mode as shown in the following figure.
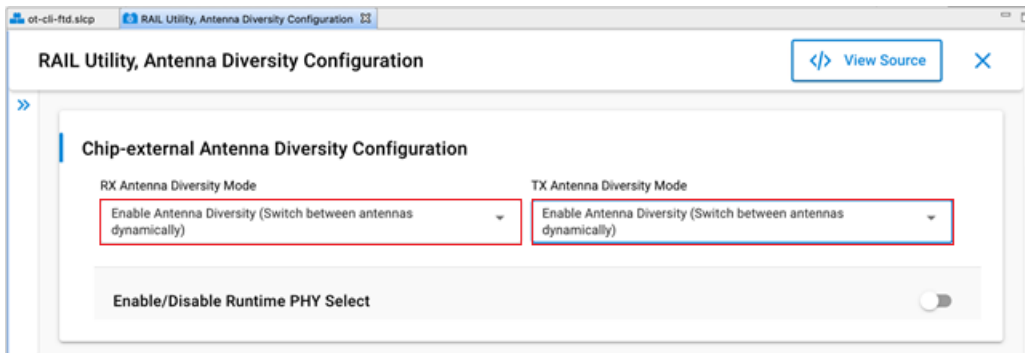
2.3   Configure Antenna Pin Configurations

To configure Antenna pins, use the **SL_RAIL_UTIL_ANT_DIV** section of the component configurations.

The available antenna pins are:

Antenna select (ANT0): Pin used to control the external antenna switch.

Complementary antenna select (ANT1): Pin for the inverted external antenna signal.

For Rx Antenna Diversity (either alone or with Tx diversity), you **must** select the antenna port pin through the Modem peripheral.
1.   From the **Selected Module** drop-down menu, select the **MODEM** option.
2.   Select the pins for **Antenna Select (ANT0)** and, if applicable, **Complementary antenna select (ANT1)**. The Antenna select signal goes high to select Antenna 0 and low to select Antenna 1.
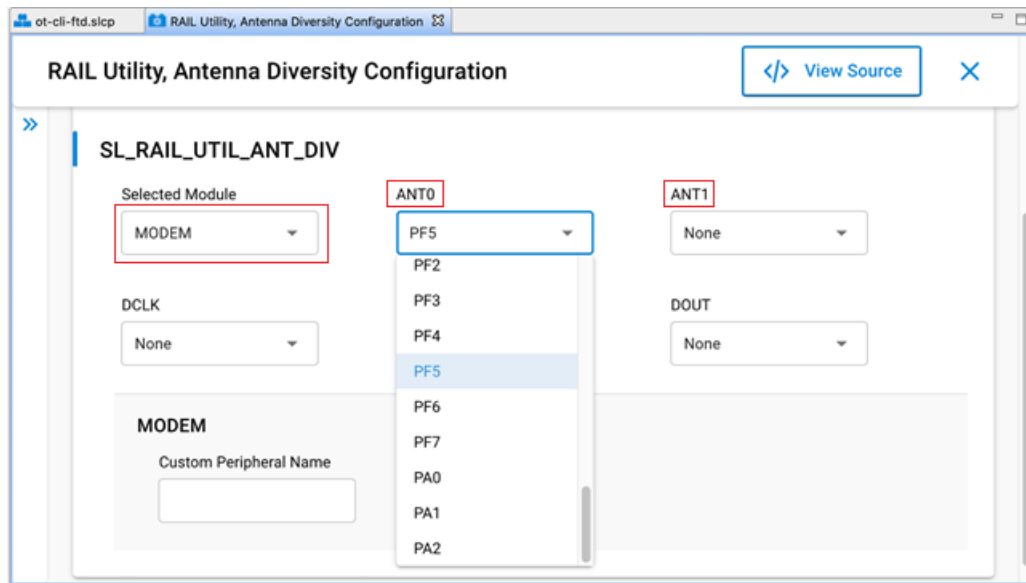
For Tx Antenna Diversity (being configured alone), you can set the **Antenna select (ANT0)** and the **Complementary antenna select (ANT1)** pins either directly or Tx Antenna Diversity can inherit the setting from Modem Peripheral.

Note: Do not modify DCLK, DIN, and DOUT.
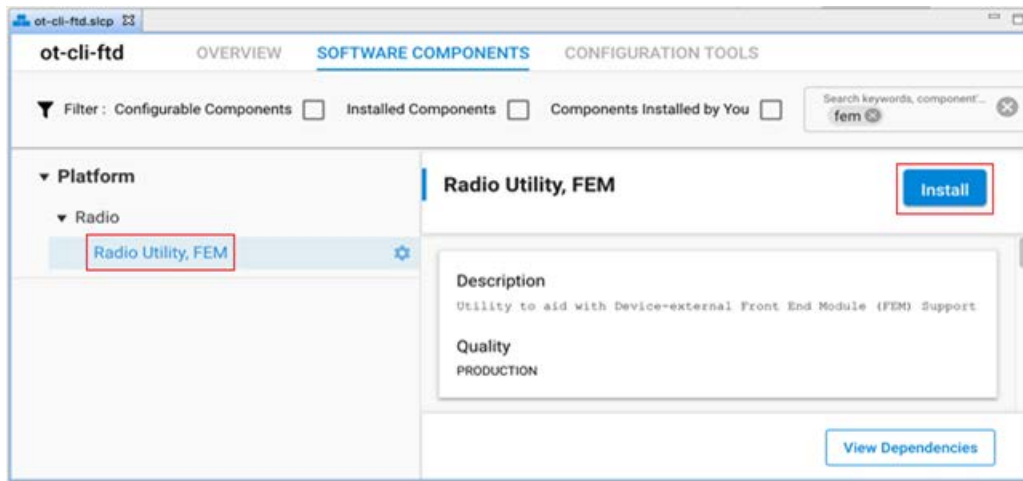
2.4   Configure the FEM (optional)

If antenna diversity is implemented using a FEM, you must:
1.   Install the Radio Utility, FEM component.
2.   Configure the component.

2.4.1   Install Radio Utility, FEM Component

This procedure is similar to the one for Antenna Diversity.
1.   On the SOFTWARE COMPONENTS tab, search for **fem** in the 'component's name' search field (at the top right).
2.   Under Platform components, select the **Radio Utility, FEM** component and click **Install** as shown in the following figure.

2.4.2 Configure the FEM Component

Once the FEM component is successfully installed, click **Configure** or the configure symbol next to the component name and configure the options as per the FEM datasheet.
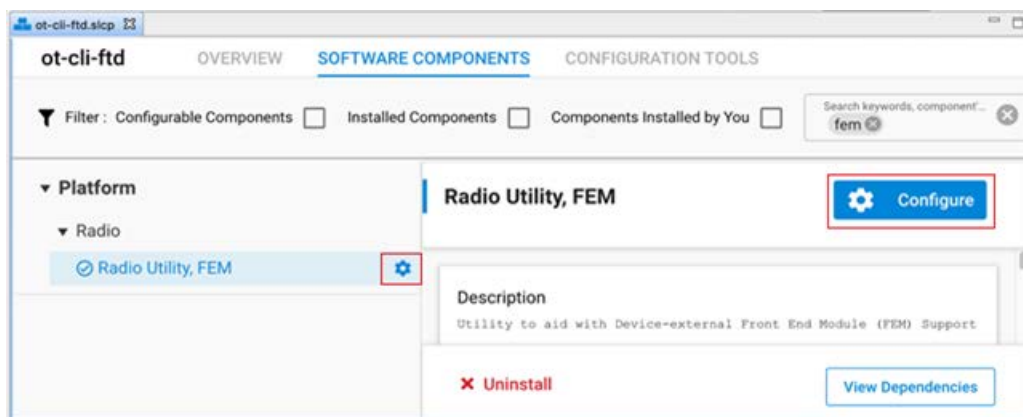
Not all FEM configuration options apply to all FEMs. Specifically **Bypass** and **Tx Power** only apply to FEMs with the pins to support the features. Check your FEM datasheet for the settings required.

Note: Because there are a limited number of PRS channels, you must take care so they do not conflict with channels that might be selected in other plugins.

The main FEM configuration options are:

Enable RX mode: Configures RX mode on the FEM. This option is disabled by default and must be enabled along with the Antenna Diversity Component for the underlying antenna diversity radio configuration settings to be used. If it is disabled, then the standard radio configuration settings are used.

Enable TX mode: Configures TX mode on the FEM. This option is disabled by default.

Enable Bypass Mode (Optional): Enables communication that bypasses the LNA (Low Noise Amplifier).

Enable TX High Power Mode (Optional): Enables high power Tx, Enable low power Tx if disabled.

RX PRS channel (SL_FEM_UTIL_RX): PRS Channel for Rx control (FEM pin CRX). If no Tx is defined, it is a dual-use (Rx/Tx) pin. The options are Disabled or a channel number. Select the PRS channel first and then configure it by selecting the port/pin as shown in the following figure.
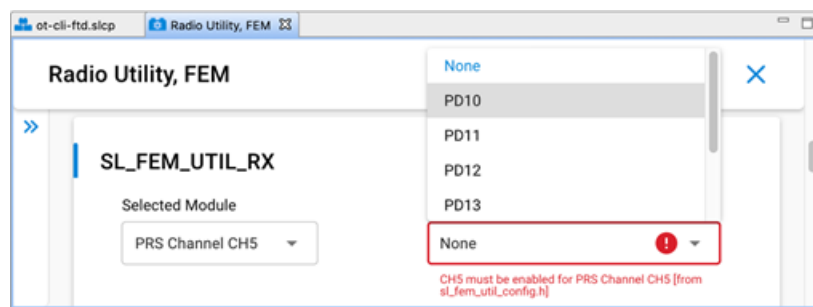
Sleep PRS channel (SL_FEM_UTIL_SLEEP): PRS channel for sleep control (FEM pin CSD). The options are Disabled or a channel number. If the setting is enabled, it must be configured to be the channel immediately following the RX PRS channel. If set incorrectly, it will result in a compile error. Once a channel is enabled, the **PRS channel output pin** can be configured.

TX PRS channel (SL_FEM_UTIL_TX): PRS channel for Tx control (FEM pin CTX). The options are Disabled or a channel number. If the setting is disabled, then the software assumes that the FEM pin CRX is a dual use pin. Once a channel is enabled, the **PRS channel output pin** can be configured.

Bypass Pin (SL_FEM_UTIL_BYPASS): If the FEM has a pin for the bypass signal (CPS), select it.

TX power pin. (SL_FEM_UTIL_TX_HIGH_POWER): If the FEM has a pin for Tx power mode (CHL), select it.

3   Configuring Antenna Diversity Command Line Interface

OpenThread SDK releases beginning with 1.1.0.0 provide a means to query and set Rx and Tx diversity modes using the Antenna Diversity CLI. Support for the Antenna Diversity CLI is:

- Enabled by default.
- Available as a configuration option on the **OpenThread Antenna Diversity** component.
- Requires the OpenThread CLI and Antenna Diversity components installed in your project.
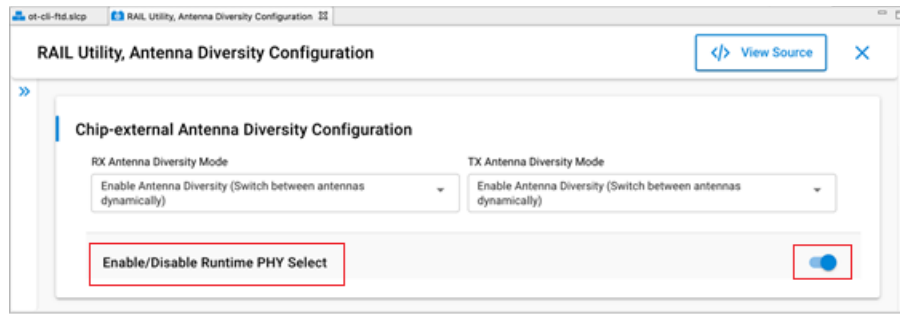
Note: For Silicon Labs OpenThread SDK releases prior to 1.2.0.0, the Antenna Diversity CLI is available as a configuration option on the OpenThread CLI component.

The complete list of supported Antenna Diversity CLI commands is summarized in the following table.
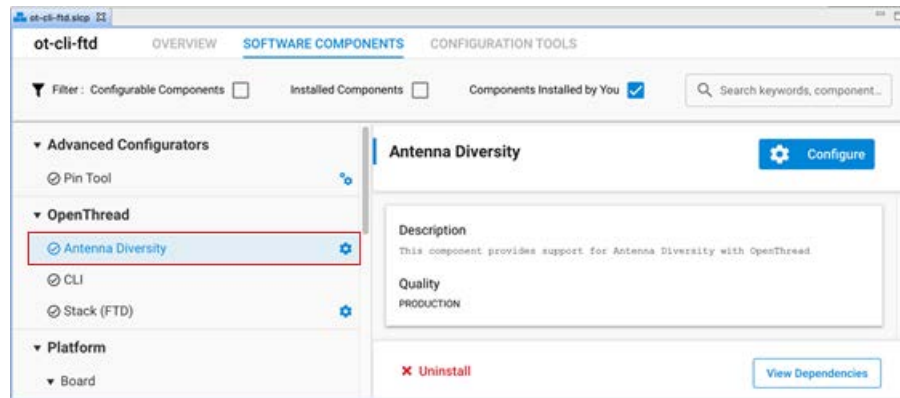
Table 3-1. Antenna Diversity CLI Commands

Command	Command Description	API Function	Arguments		
			Name	Type	Description
antenna get-tx-mode	Returns the current setting for the Antenna Tx Diversity mode.	sl_rail_util_ant_div_get_tx_antenna_mode	N/A	N/A	Interpretation of returned results for get operations and permissible values for set operations are as follows: SL_RAIL_UTIL_ANTENNA_MODE_DISABLED: 0 (Don't alter antenna selection) SL_RAIL_UTIL_ANTENNA_MODE_ENABLE1: 1 (Use antenna 1) SL_RAIL_UTIL_ANTENNA_MODE_ENABLE2: 2 (Use antenna 2) SL_RAIL_UTIL_ANTENNA_MODE_DIVERSITY: 3 (Choose antenna 1 or 2 dynamically)
antenna set-tx-mode	Sets Tx Diversity mode to argument.	sl_rail_util_ant_div_set_tx_antenna_mode	Tx Antenna Mode	uint8_t	
antenna get-rx-mode	Returns the current setting for Antenna Rx Diversity mode.	sl_rail_util_ant_div_get_rx_antenna_mode	N/A	N/A	
antenna set-rx-mode	Sets Rx Diversity mode to argument.	sl_rail_util_ant_div_set_rx_antenna_mode	Rx Antenna Mode	uint8_t	
antenna get-active-phy	Returns the current PHY being used.	sl_rail_util_get_active_radio_config	N/A	N/A	-

Tx diversity settings can be changed using the CLI without any restriction. However, Rx Diversity options that require switching from standard PHY to diversity PHY or vice-versa are only permitted when the **Runtime PHY Select** configuration option on the RAIL Utility Antenna Diversity Configuration component is enabled as shown in the following figure.
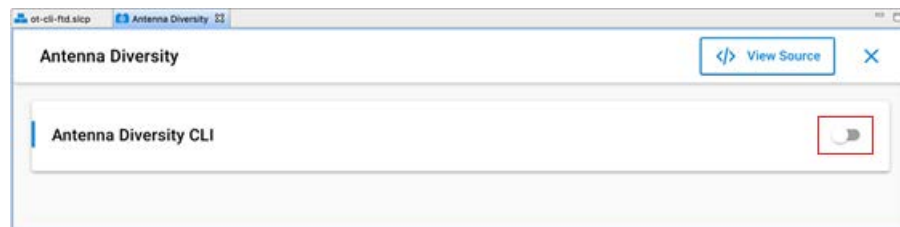
3.1   Disable Antenna Diversity CLI Support

1.   Open the configuration options of the OpenThread **Antenna Diversity** component.

2.   Disable the option.

Note: For Silicon Labs OpenThread SDK releases prior to 1.2.0.0, disable the Antenna Diversity CLI configuration option on the Open-Thread CLI component.

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Silicon Laboratories Inc.
400 West Cesar Chavez
Austin, TX 78701
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