

# AN14463

## Antenna Diversity

Rev. 1.0 — 24 January 2025

Application note

### Document information

Information	Content
Keywords	Antenna, Wi-Fi, Bluetooth, Bluetooth LE, 802.15.4, diversity, single antenna, dual antenna, front-end, radio performance
Abstract	Explains antenna diversity feature, single antenna design, and dual antenna design.



## 1 About this document

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Antenna diversity feature is used to improve and optimize the signal quality. The front-end design includes two or more antennas to reduce the effects of interference. This document explains the different types of RF front-end antenna configurations with and without antenna diversity. Each design has specific benefits related to cost, radio priority, and more. Contact your NXP representative for more information and guidance on which design is best suited to your application.

### 1.1 Supported devices

This document applies to the following wireless SoCs:

- IW416
- IW610
- AW611
- IW611
- IW612
- 88W8987
- RW610
- RW612
- 88W8801

## 2 Wi-Fi antenna diversity algorithm

Antenna diversity is used to determine the best suited antenna for real time performance. The feature can be enabled by firmware when the NXP wireless SoC is in client mode. The firmware must evaluate and compare each antenna at a set evaluation interval to determine which antenna best fits the environmental condition. At every evaluation interval, the firmware checks the performance of each antenna for the following parameters:

- TX frame error rate (FER)
- RX signal to noise ratio (SNR)
- Number of missed beacons

The evaluation interval is user configurable and dynamic. By default, the evaluation interval is set to trigger every 6 seconds but the interval may scale with the SNR measured on the current antenna.

- $10 < \text{SNR} < 40$ : user configured time (the default is 6 seconds)
- $\text{SNR} \leq 10$ : 0.5x of user configured time (the default is 3 seconds)
- $\text{SNR} \leq 5$ : 0.25x of user configured time (the default is 1.5 seconds)
- $\text{SNR} \geq 40$ : 2x of user configured time (the default is 12 seconds)

The firmware compares the measurement of each antenna parameters (FER, SNR, and number of missed beacons), and selects the best antenna based on the following:

- If the difference between the two antenna FER values is greater than 5% over 100 TX attempts, the antenna with the lowest FER is selected.
- If the difference between the two antenna SNR is greater than 3 dB, the antenna with the highest SNR is selected.
- If the difference between the number of missed beacons between the two antennas is greater than five beacons, the antenna with the lowest number of missed beacons is selected.

The selected antenna is used until the next evaluation interval, when the evaluation and comparison cycle is repeated.

[Figure 1](#) illustrates the antenna diversity algorithm.

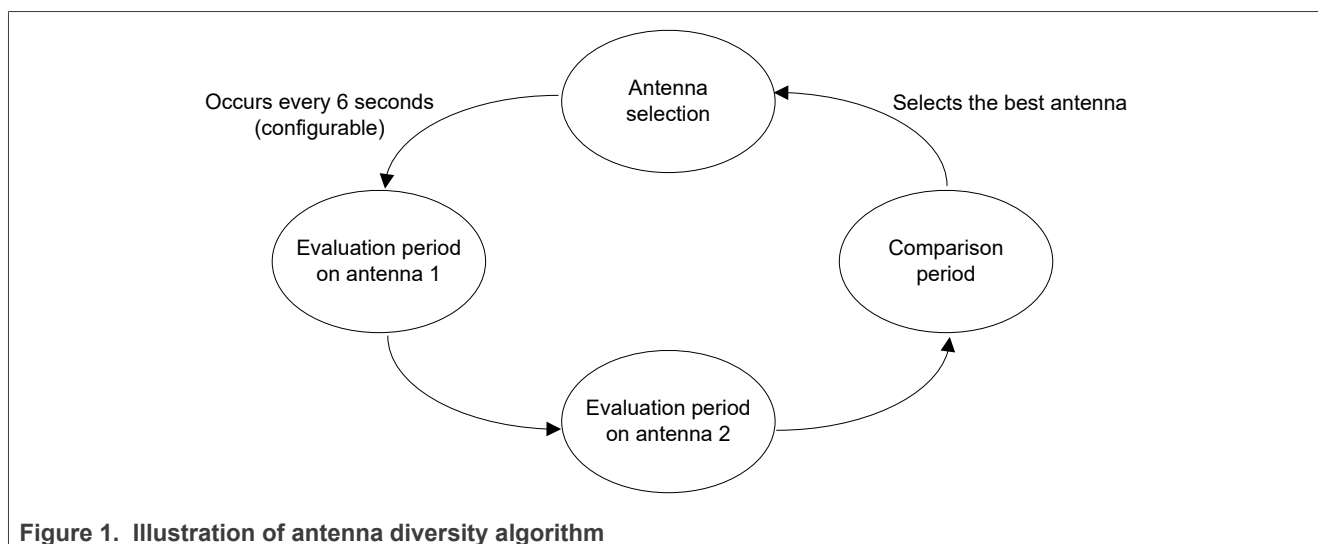


Figure 1. Illustration of antenna diversity algorithm

### 3 Front-end configurations

The antenna diversity setup depends on the front-end design. This document covers the following front-end designs:

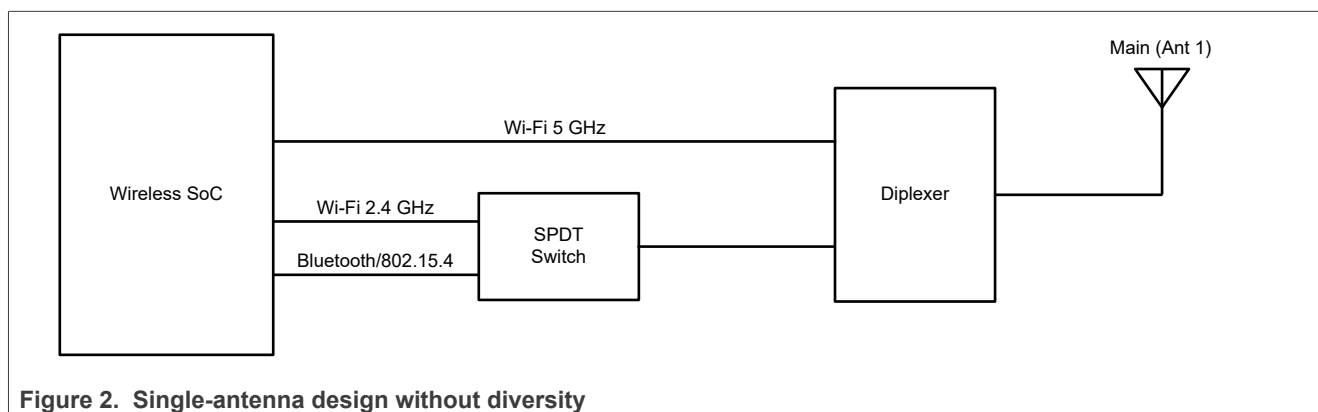
- Single-antenna design
- Dual-antenna design

#### 3.1 Single-antenna design

In a single-antenna design, the Wi-Fi and Bluetooth/802.15.4 radios share the same antenna.

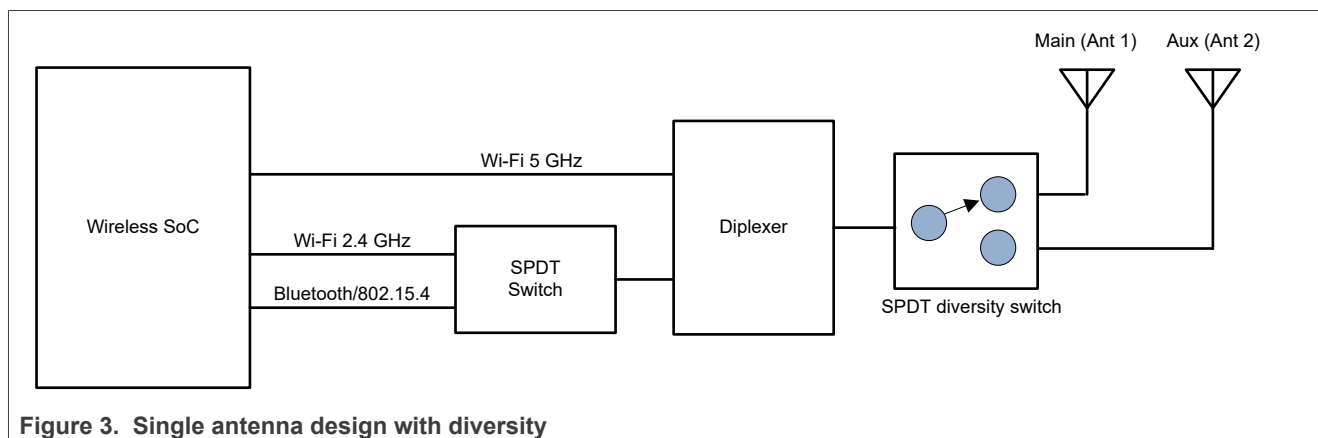
- A single pole double throw (SPDT) switch is used between the 2.4 GHz Wi-Fi and Bluetooth/802.15.4 radios.
- A diplexer is used between the 5 GHz Wi-Fi radio and SPDT switch.

[Figure 2](#) illustrates a single-antenna design without diversity.



To enable antenna diversity on a single antenna design, an additional SPDT diversity switch and auxiliary antenna are required. The additional SPDT switch is used to select the best antenna based on the firmware algorithm ([Section 2](#)).

[Figure 3](#) illustrates a single-antenna design with diversity.

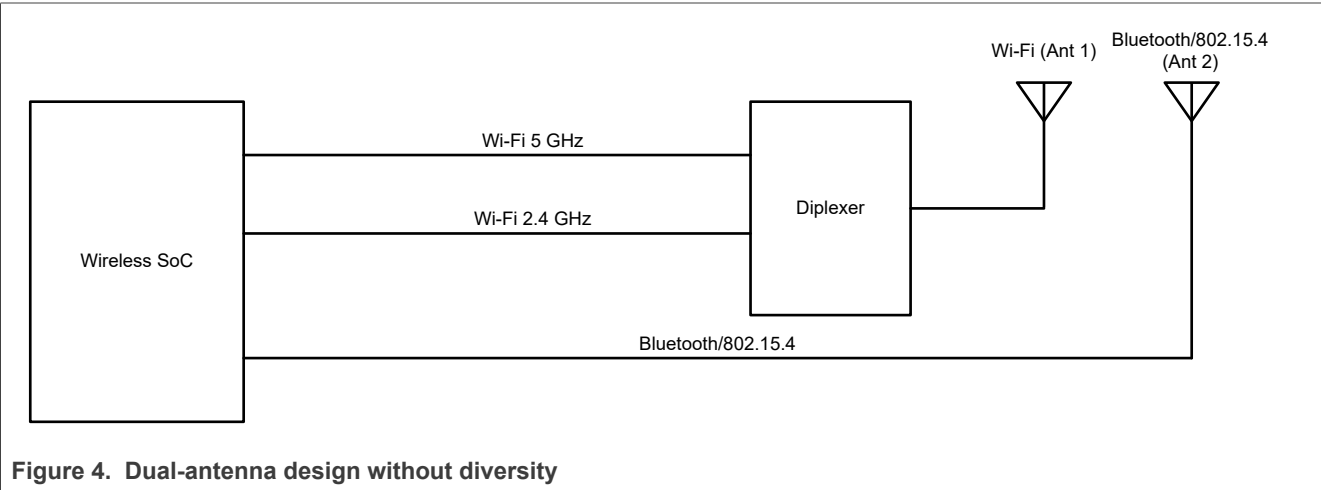


3.2 Dual-antenna design

In a dual-antenna design, the Wi-Fi and Bluetooth/802.15.4 radios use separate antennas. The operation of the Wi-Fi and Bluetooth/802.15.4 radios is simultaneous given the appropriate antenna isolation.

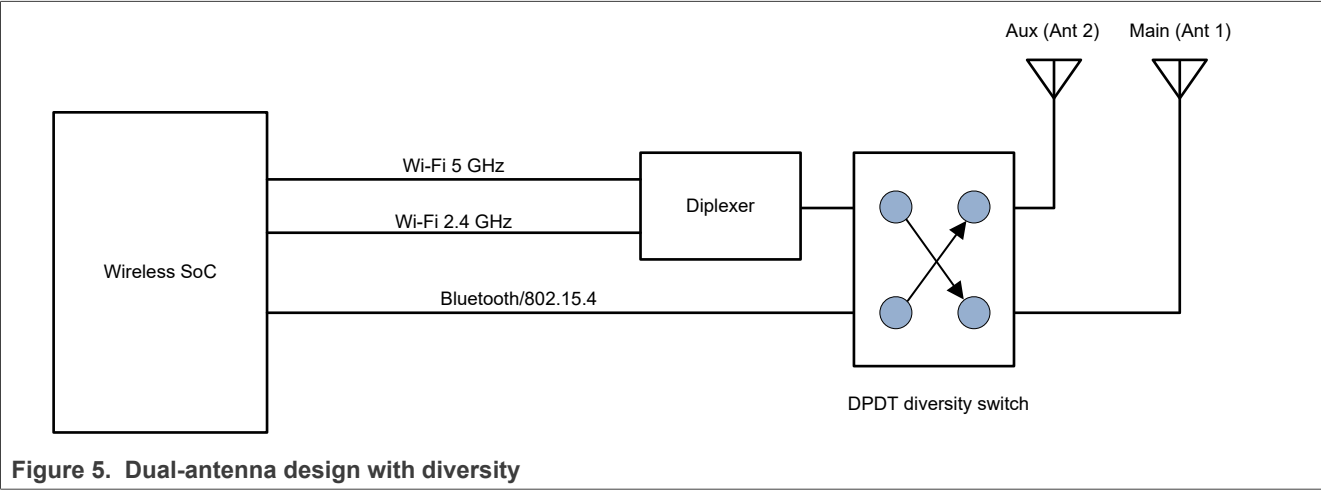
- The diplexer between the Wi-Fi radio and the antenna is used for the 2.4 GHz and 5 GHz RF paths.
- The Bluetooth/802.15.4 radio uses a separate antenna.

Figure 4 illustrates a dual-antenna design without diversity.



To enable antenna diversity on a dual-antenna design, an additional double pole double throw (DPDT) switch is added after the diplexer. The DPDT switch is used to select the best antenna based on the antenna diversity algorithm. When the Wi-Fi and Bluetooth/802.15.4 radios operate simultaneously, the firmware allocates the best antenna to the Wi-Fi radio. The DPDT switch allocates the other antenna to the Bluetooth/802.15.4 radio.

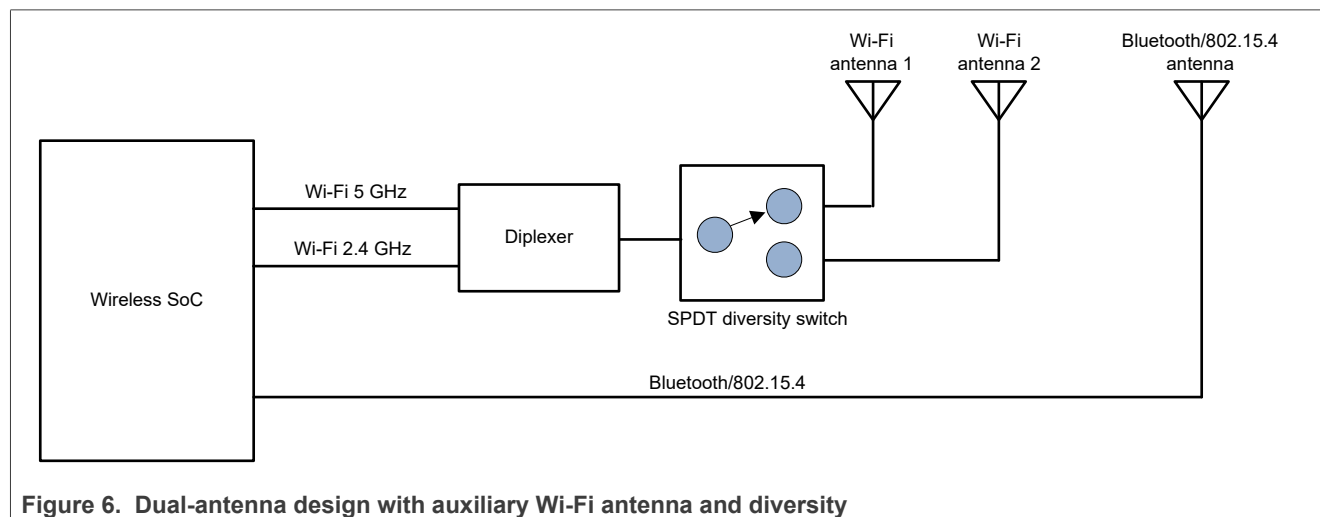
Figure 5 illustrates a dual-antenna design with diversity.



The dual-antenna design can also include an auxiliary Wi-Fi antenna that supports diversity, and a separate antenna for Bluetooth/802.15.4 radio without antenna diversity. In this configuration, the Wi-Fi and Bluetooth/802.15.4 radios can operate simultaneously given the appropriate antenna isolation.

- An SPDT diversity switch is used to select the best antenna for Wi-Fi.
- The Bluetooth/802.15.4 radio operates on a separate antenna.

[Figure 6](#) illustrates the dual-antenna design with the auxiliary Wi-Fi antenna that supports diversity.



## 4 RF Front-end (FE) switch setting configuration

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The Wi-Fi and Bluetooth/802.15.4 front-end parameters are configurable using the calibration data. The front-end parameters are used:

- To enable antenna diversity.
- To configure the RF controls of the SPDT or DPDT switch.

Use additional parameters in the calibration data to optimize the radio transmit power and reduce TX frame error rate (FER), RX signal to noise ratio (SNR), and the number of missed beacons. Refer to [\[1\]](#), [\[2\]](#), [\[3\]](#), [\[4\]](#), [\[5\]](#), or [\[6\]](#).

## 5 Enabling antenna diversity

Antenna diversity is enabled by software during runtime. The procedure depends on the operating system of the host device.

### 5.1 Linux and Android

To enable antenna diversity on an NXP wireless SoC with a Linux/Android host platform:

- Wait for the firmware download to complete.
- Go to the directory with the configuration file of the wireless SoC. The path is `/proc/mwlan/adapter0/config`.
- Issue the command to set the antenna configuration.

```
echo "antcfg=<Antenna mode> <Evaluation interval (ms)>" > /proc/mwlan/adapter0/config
```

Table 1. Command parameters

Parameter	Description
Antenna mode	Antenna mode for TX/RX 0x1 = RF path set to Antenna 1 (disable antenna diversity) 0x2 = RF path set to Antenna 2 (disable antenna diversity) 0xffff = Enable antenna diversity
Evaluation interval	Evaluation interval in milliseconds (ms) Enter interval as a hexadecimal number The default value is 0x1770 (6000 ms) <b>Note:</b> This parameter is only needed when <i>Antenna mode</i> is set to 0xffff.

Example of command to enable antenna diversity with a 6 second evaluation interval:

```
echo "antcfg=0xffff" > /proc/mwlan/adapter0/config
```

Example of command to disable antenna diversity and set TX/RX path to Antenna 1:

```
echo "antcfg=1" > /proc/mwlan/adapter0/config
```

Command to readback the antenna diversity configuration:

```
cat /proc/mwlan/adapter0/config
```

Example of command readback:

```
hardware_status=0
netlink_num=31
drv_mode=7
hsssetpara=7,0xff,200,400
sdcmd52rw=0 0x0 0x00
rf_test_mode=0
antcfg=0xffff 6000 1
```

The values in bold show that antenna diversity is enabled with a 6000ms evaluation time and the current antenna is set to 1.



5.2 FreeRTOS

To enable antenna diversity on the wireless SoC with a FreeRTOS host platform:

- Wait for the firmware download to complete.
- Issue the command to set the antenna configuration.

```
wlan-set-antcfg <Antenna mode> <Evaluation interval>
```

Table 2. Command parameters

Parameter	Description
Antenna mode	Antenna mode for TX/RX 0x1 = RF path set to Antenna 1 (disable antenna diversity) 0x2 = RF path set to Antenna 2 (disable antenna diversity) 0xffff = enable antenna diversity
Evaluation interval	Evaluation interval in milliseconds (ms) Enter interval as a decimal number The default value is 6000 <b>Note:</b> This parameter is only needed when <i>Antenna mode</i> is set to 0xffff.

Example of command to enable antenna diversity with a 6 second evaluation interval:

```
wlan-set-antcfg 0xffff
```

Example of command to disable antenna diversity and set TX/RX path to Antenna 1:

```
wlan-set-antcfg 1
```

Command to readback the antenna diversity configuration:

```
wlan-get-antcfg
```

Example of command readback:

```
Mode of Tx/Rx path is : ffff
Evaluate time : 6000
Default diversity mode.
Current antenna is Ant1
```

The return values in bold show that antenna diversity is enabled with a 6000 ms evaluation time and current antenna set to 1.

## 6 Abbreviations

Table 3. Abbreviations

Abbreviation	Definition
Ant	antenna
DPDT	double dipole pole throw
FE	front-end
FEM	front-end module
FER	frame error rate
LE	low energy
SDPT	single dipole pole throw
SNR	signal to noise ratio

## 7 References

- [1] Application note – 88W8801 Calibration Structure ([link](#))
- [2] Application note – 88W8987 Calibration Structure ([link](#))
- [3] Application note – AN12794: IW416 Calibration Structure ([link](#))
- [4] Application note – AN13983: Calibration Structure for AW611, IW611, and IW612 ([link](#))
- [5] Application note – AN13639: Calibration Structure for RW61x
- [6] Application note – AN14308: Calibration Structure for IW610 ([link](#))

## 8 Note about the source code in the document

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## 9 Revision history

Table 4. Revision history

Document ID	Release date	Description
AN14463 v.1.0	24 January 2025	• Initial version

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