Hardware App Note

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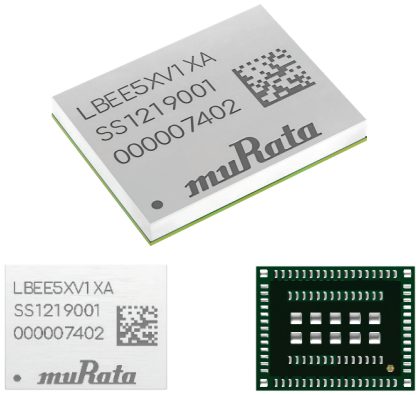
Wi-Fi® + Bluetooth® Combo Module

Infineon CYW54591 Chipset for 802.11a/b/g/n/ac 2X2 MIMO, RSDB + Bluetooth 5.2

Hardware Application Note - Rev. 7.0

- Design Name: Type 1XA
- Module P/N: LBEE5XV1XA



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About This Document

This application note covers hardware development and provides how to design the schematic and layout, and reference RF performance for engineers who will assemble the product.

Audience & Purpose

This document is targeted towards system integrators for Wi-Fi/Bluetooth solutions using Murata Type 1XA (CYW54591) module, based on IFX LBEE5XV1XA chipset.

Document Conventions

Table 1 describes the document conventions.

Table 1: Document Conventions

Conventions	Description
	**Warning Note** Indicates very important note. Users are strongly recommended to review.
	**Info Note** Intended for informational purposes. Users should review.
	**Menu Reference** Indicates menu navigation instructions. **Example**: Insert➔Tables➔Quick Tables➔Save Selection to Gallery
	**External Hyperlink** This symbol indicates a hyperlink to an external document or website. **Example**: Murata  Click on the text to open the external link.
	**Internal Hyperlink** This symbol indicates a hyperlink within the document. **Example**: Scope  Click on the text to open the link.
`Console input/output or code snippet`	**Console I/O or Code Snippet** This text ***Style*** denotes console input/output or a code snippet.
`# Console I/O comment` `// Code snippet comment`	**Console I/O or Code Snippet Comment** This text ***Style*** denotes a console input/output or code snippet comment. • Console I/O comment (preceded by "#") is for informational purposes only and does not denote actual console input/output. • Code Snippet comment (preceded by "//") may exist in the original code.

1 Scope

This application note covers HW development and provides how to design the schematic and layout, and reference RF performance. Refer to Type 1XA Datasheet for module specification.

2 Module Introduction

This section describes the module features and has the hardware block diagram.

2.1 Features

- IEEE 802.11a/b/g/n/ac WLAN 2x2 MIMO, RSDB (Real Simultaneous Dual Band) + Bluetooth 5.2 combo module with Infineon CYW54591
- Small size LGA package with resin molding and metal shielding.
- PCIe Interface for WLAN
- Interface support for Bluetooth is Host Controller Interface (HCI)
- MAC address and BD address are stored in OTP

2.2 Hardware Block Diagram

Figure 1 , **Figure 2** show the block diagram.

Figure 1: Block Diagram – Type1XA for the Two – antenna configuration

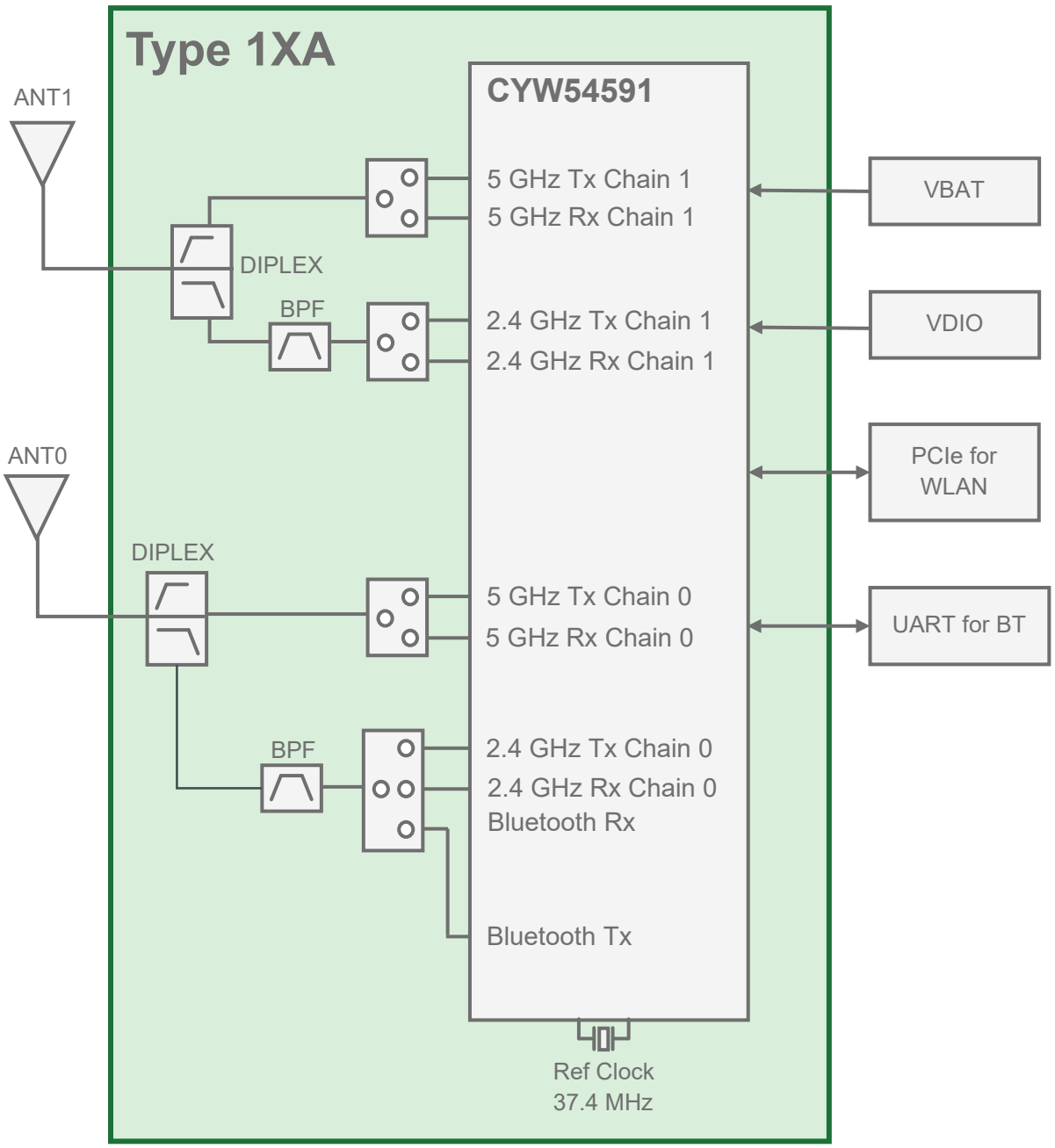
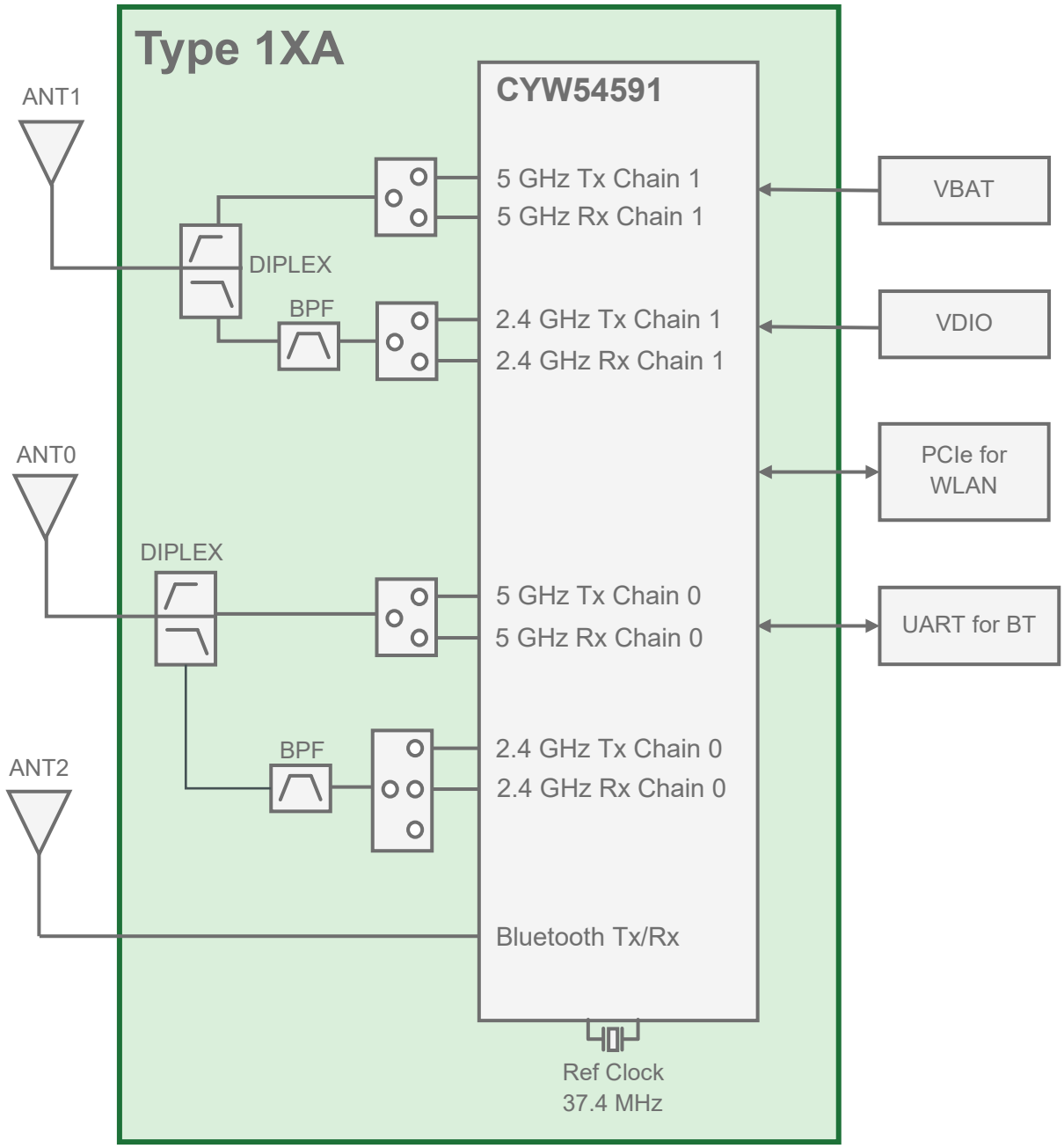


Figure 2: Block Diagram – Type1XA for the Three – antenna configuration



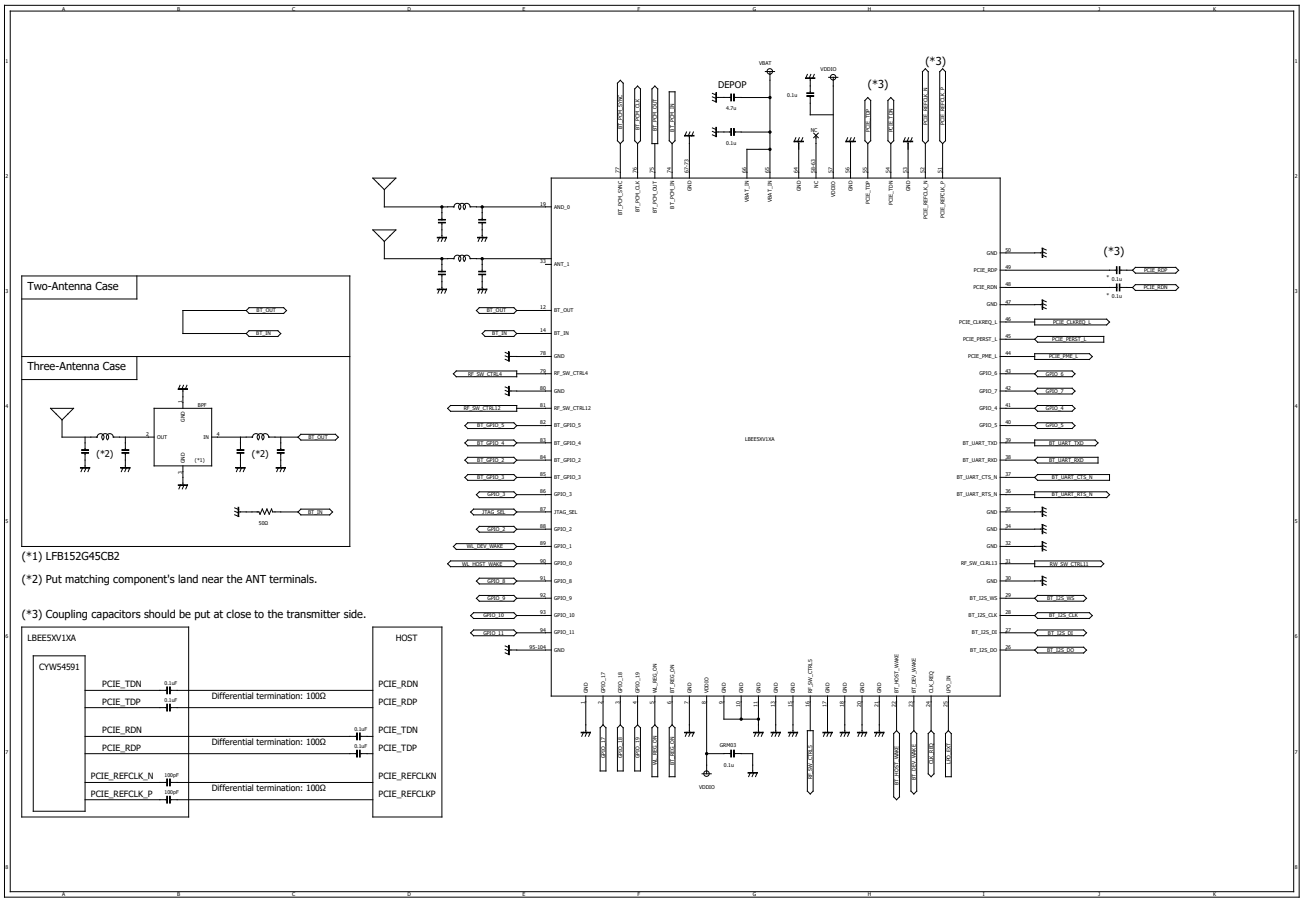
3 Reference Design

This section describes the circuit design and antenna information.

3.1 Reference Circuit

Figure 3 shows the reference design.

Figure 3: Reference Design



3.2 Requirements for High-Speed Digital Signals

- **PCIe:** TxP/N, RxP/N and CLKP/N signals should be differential 100 Ω impedance. DC blockers is necessary on RXP/N.

3.3 Requirements for Unused Signals

Any pull-up/down is not necessary (floating) for GPIO [0..19] if these signals are not used.

3.4 Module Footprint Design

Refer to dimensions in the Type 1XA Datasheet. The DXF File of module footprint is provided via website.

3.5 Recommended Antenna

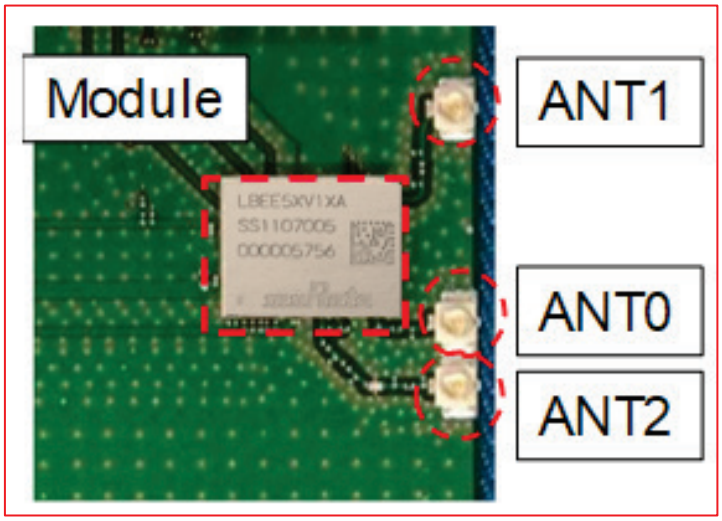
This module is certified with an antenna solution by regulatory certification body. To use Murata's regulatory certification, any user must follow below instructions.

3.5.1 PCB Type Di-pole Antenna with the Co-axial Connector

- Any users must use recommended antennas is showed in **Table 2**. However, user can use any equivalent type antenna with less antenna gain than antenna gain of recommended antennas for US and EU under approval of Class I Permissive Change by Murata.
- Any users must copy RF trace to U.FL/MHF connector from the trace layout file provided by Murata; adhering to below guidelines on:
  - Trace width accuracy within +/- 0.25 mm.
  - Stack height between GND layer and RF trace of 230 ~ 240 um (Exclude inaccuracy of PCB).
  - Passive component location matching Murata design.
  - Necessary "Keep out" area around U.FL/MHF connector.

Figure 4 shows the module antenna.

Figure 4: Module Antenna



3.5.2 Antenna Design and Configuration

Table 2 shows the list of certified antenna.

Table 2: Certified Antenna List

No.	Type	P/N	Form Factor	Type	Gain (dBi)	
					2.4 GHz	5GHz
1	Molex	146153	u.FL/flexible	dipole	3.2	4.25
2	Molex	146187	u.FL/flexible	dipole	3.4	4.75

An example of a Class I permissive change capable antenna is shown in **Table 3**.

Table 3: An example of Class I Permissive Change Capable Antenna

P/N	Vendor	Form factor	Type	2.4 GHz Gain	5 GHz Gain	Cable options
WT32D1-KX	Unictron	U.FL/PCB	Di-pole	3.0 dBi	4.0 dBi	119 mm (H2B1WD1A3B0200)

- Please perform the antenna design that followed the specifications of the antenna.
- About the signal line between an antenna and a module
  - It is a 50 Ω line design.
  - Fine tuning of return loss etc. can be performed using a matching network.
  - It is required to check "Class1 change" and "Class2 change" which the authorities define then.
- The concrete contents of a check are the following three points:
  - It is the same type as the antenna type of antenna specifications.
  - An antenna gain is lower than a gain given in antenna specifications.
  - The emission level is not getting worse.

Figure 5, Figure 6, **Figure 7,** and **Figure 8** and shows the overall design of the EVB used for the test and the antennas.

Figure 5: Antenna Test EVB - Overall Design

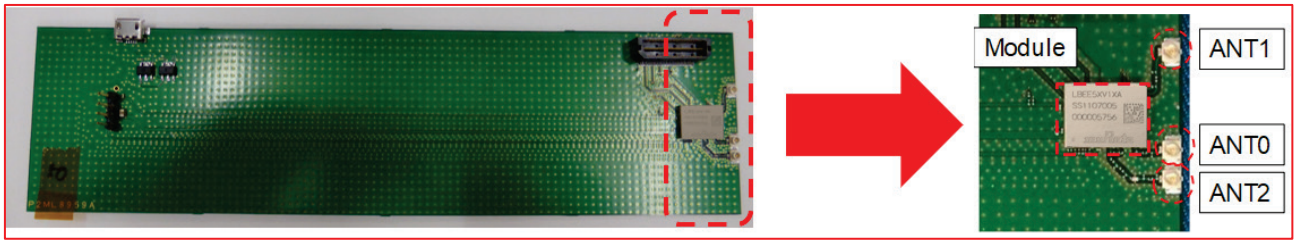
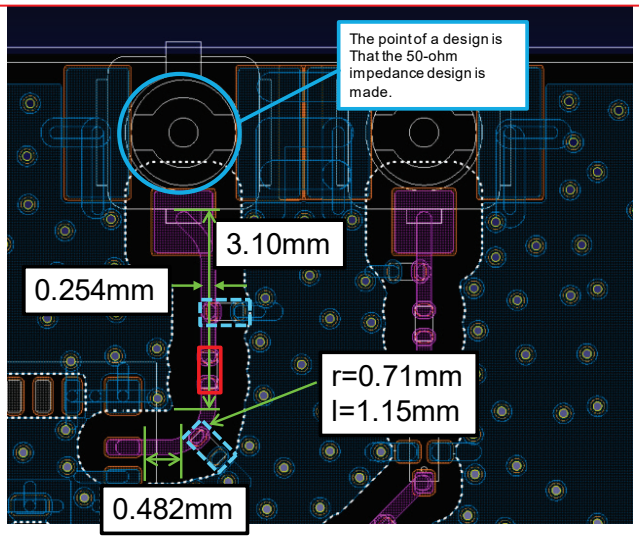


Figure 6: ANT0 Antenna Design



Note)
DNI: Do Not Insert
r: Line radius
l: Line length

Figure 7: ANT1 Antenna Design

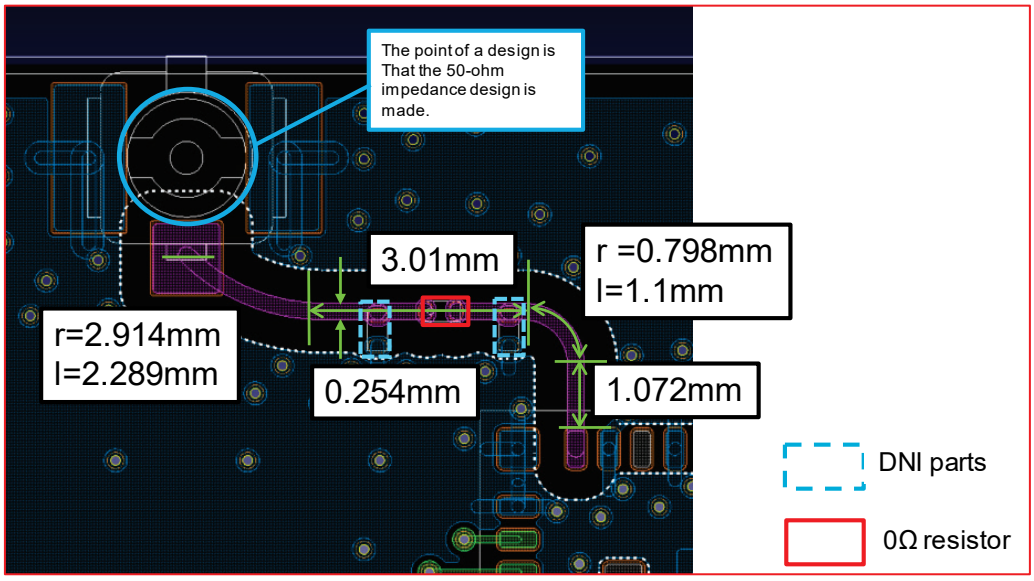
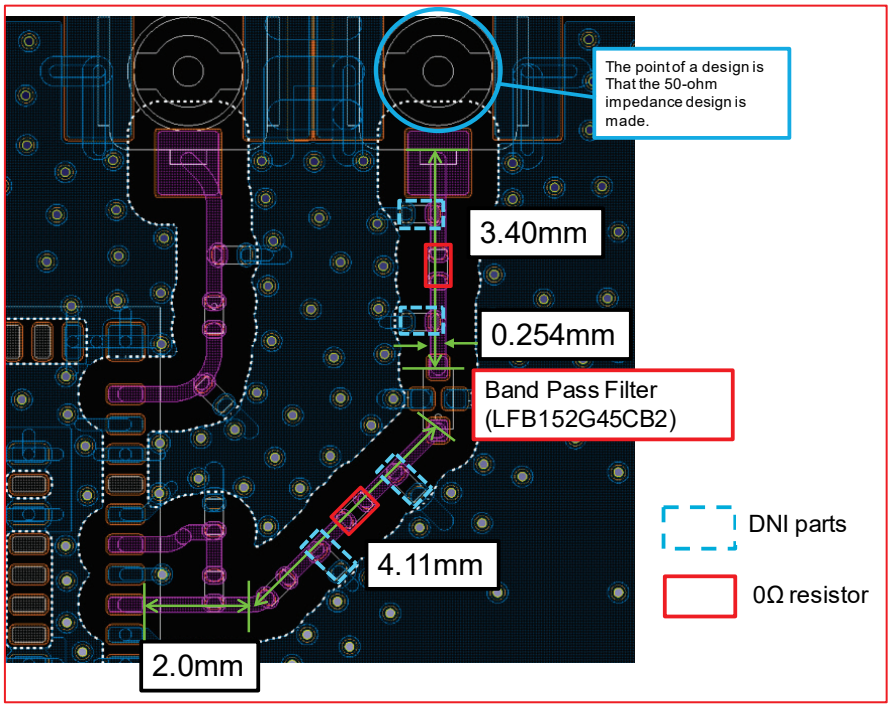


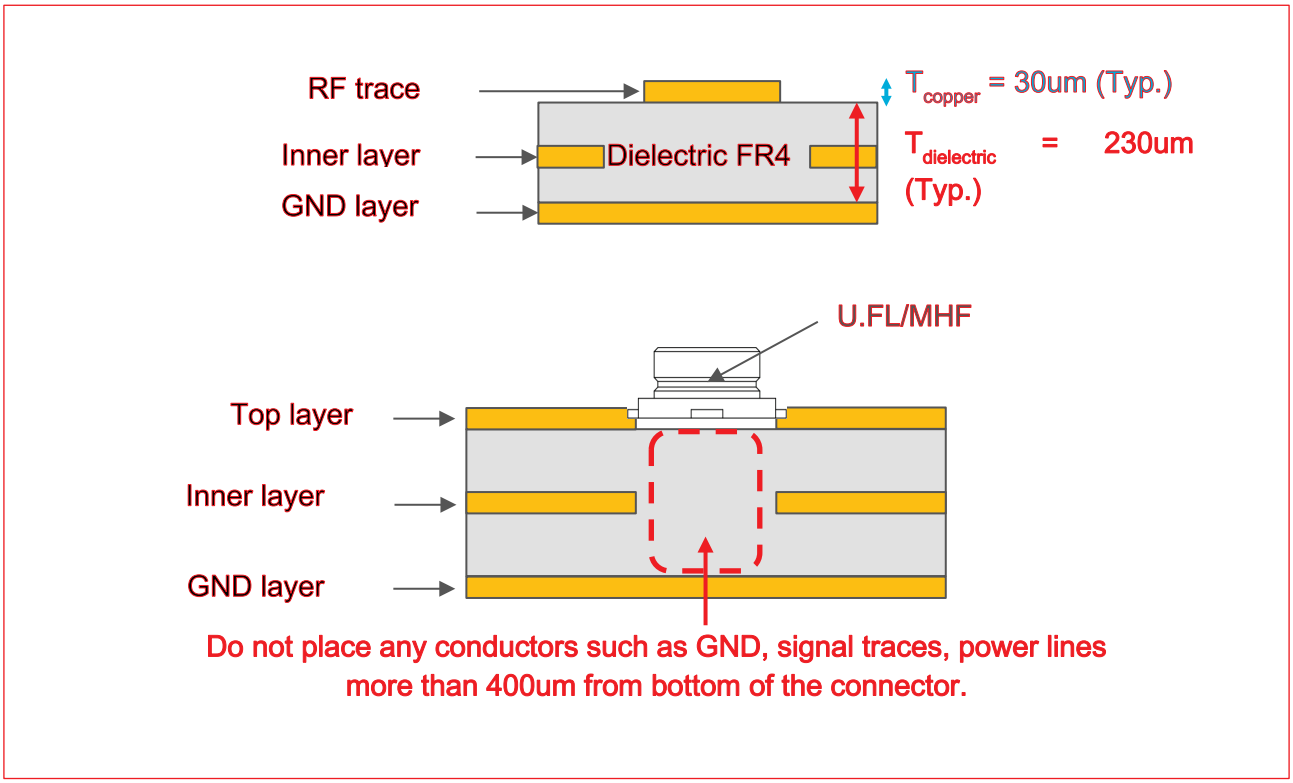
Figure 8: ANT2 Antenna Design



3.5.3 PCB Stack-up

Figure 9 shows the PCB stack-up design.

Figure 9: PCB Stack-up



4 Setup Configuration Files

To enable Murata's regulatory certification, below configuration file shall be loaded initially. Murata will provide configuration files via Murata GitHub. For more regulatory information, refer to section 11 of Linux User Guide.

4.1 WLAN Configuration Files

The files listed in **Table 4** shall be used to satisfy regulatory requirements if users want to use Murata regulatory certification.

Table 4: WLAN Configuration Files - Linux

Names	Configuration Files
WLAN configuration file	cyfmac54591-pcie.1XA.txt
WLAN regulatory configuration file	cyfmac54591-pcie.clm_blob

The following country codes are defined in "cyfmac54591-pcie.clm_blob".

- **US:** United States of America
- **CA:** Canada
- **DE:** Europe
- **JP:** Japan

4.2 Bluetooth Configuration Files

Bluetooth Tx power configuration is included in HCD file which if firmware of Infineon's chipset.

Please use the appropriate hcd file from the following according your antenna configuration. The files listed in **Table 5** shall be used to satisfy regulatory requirements if user wants to use Murata regulatory certification.

Table 5: Bluetooth Configuration Files - Linux

Names	Antenna Configuration	Configuration Files
Bluetooth configuration files	Shared Bluetooth Antenna	BCM4359D0_004.001.016.0241.0275.1XA.sAnt.hcd
	Dedicated Bluetooth Antenna	BCM4359D0_004.001.016.0241.0274.1XA.dAnt.hcd

5 Reference Performance Data

This section describes the typical Rx minimum sensitivity level for WLAN at 2.4 GHz and 5 GHz and Bluetooth and typical Tx/Rx current consumption at various power levels.

5.1 Typical Rx Minimum Sensitivity Level (at Module Antenna port)

This section describes the typical Rx minimum sensitivy level at module antenna port for WLAN and Bluetooth.

5.1.1 WLAN

This section describes the WLAN power levels at 2.4 GHz, 5 GHz, and for Bluetooth.

Test Configuration:

- Power supply: VBAT=3.3V, VDDIO = 1.8V
- Host IF: PCIe
- Nvram file: cyfmac54591-pcie.1XA.txt

Refer to WLAN configuration file. **Table 6** shows minimum sensitivity level at 2.4 MHz.

Table 6: Rx Minimum Sensitivity Level - 2.4 MHz

Frequency in MHz	Rx Minimum Sensitivity Level in dBm		
	11b	11g	11n
	11 Mbps	54 Mbps	MCS7
2412	-89	-76	-74
2442	-89	-76	-74
2472	-89	-76	-74

Table 7 shows the minimum sensitivity level at 5 MHz for various WLAN standards.

Table 7: Rx Minimum Sensitivity Level in dBm - 5 MHz

Frequency in MHz	Rx Minimum Sensitivity Level in dBm		
	11a	11n (HT20)	11ac (VHT20)
	54 Mbps	MCS7	MCS8
5180	-76	-74	-69
5500	-76	-74	-70
5825	-75	-73	-69

Frequency in MHz	Rx Minimum Sensitivity Level in dBm	
	11n (HT40)	11ac (VHT40)
	MCS7	MCS9
5190	-71	-65
5510	-71	-65
5795	-70	-64

Frequency in MHz	Rx Minimum Sensitivity Level in dBm
	11ac (VHT80)
	MCS9
5210	-62
5530	-62
5775	-61

5.1.2 Bluetooth

Test Configurations:

- Power supply: VBAT = 3.3V, VDDIO = 1.8V
- Host IF: UART
- HCD file: BCM4359D0_004.001.016.0241.0275.1XA.sAnt.hcd
  Refer to Bluetooth configuration files

Table 8 describes the Bluetooth sensitivity level parameters.

Table 8: Bluetooth Sensitivity Level Parameters

Frequency in MHz	Rx Minimum Sensitivity Level in dBm				
	DH5	2DH5	3DH5	LE 1M	LE 2M
2402	-91	-92	-87	-99	-96
2441	-91	-93	-88	-99	-96
2480	-91	-91	-88	-99	-96

5.2 Typical Tx/Rx Current Consumption

This section describes the typical Tx/Rx current consumption at single and maximum input and output at different power levels.

5.2.1 Typical WLAN Current Consumption

Test Configurations:

- Power supply: VBAT = 3.3V, VDDIO = 1.8V
- Host IF: PCIe
- Nvram file: cyfmac54591-pcie.1XA.txt
- Current definition: Shown in **Figure 10**.

Figure 10: WLAN Test Current Configurations

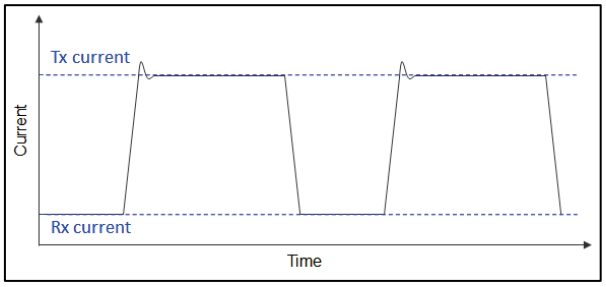


Table 9 describes the typical WLAN current consumption test parameters at 2.4 MHz (SISO).

Table 9: Typical WLAN Current Consumption Test Parameters at 2.4 GHz - SISO

Mode	Data Rate	Setting Tx Power (dBm)	Current in mA			
			Ant0		Ant1	
			Tx	Rx	Tx	Rx
11b	1 Mbps	17	350	100	390	110
11g	6 Mbps	17	350	100	370	110
11n	MCS0	17	350	100	380	110

Table 10 describes the typical WLAN current consumption test parameters at 5 GHz (SISO).

Table 10: Typical WLAN Current Consumption Test Parameters at 5 GHz - SISO

Mode	Data Rate	Setting Tx Power (dBm)	Current in mA			
			Ant0		Ant1	
			Tx	Rx	Tx	Rx
11a	1 Mbps	15	390	105	440	135
11n	MCS0	15	390	105	440	135
11ac	MCS0	15	390	105	430	135

Table 11 describes the typical WLAN current consumption test parameters at 2.4 GHz (MIMO).

Table 11: Typical WLAN Current Consumption Test Parameters at 2.4 GHz - MIMO

Mode	Data Rate	Setting Tx Power (dBm)	Current in mA	
			Tx	Rx
11n	MCS8	17	650	135

Table 12 describes the typical WLAN Current Consumption test parameters at 5 GHz (MIMO).

Table 12: Typical WLAN Current Consumption Test Parameters at 5 GHz - MIMO

Mode	Data Rate	Setting Tx Power (dBm)	Current in mA	
			Tx	Rx
11n	MCS8	15	740	160
11ac	MCS0	15	740	160

5.2.2 Bluetooth

Test Configurations:

- Power supply: VBAT=3.3V, VDDIO=1.8V
- Host IF: UART
- HCD file: BCM4359D0_004.001.016.0241.0275.1XA.sAnt.hcd
- Current definition: The current Bluetooth definition is shown in **Figure 11**.

Figure 11: Bluetooth Test Current Configuration

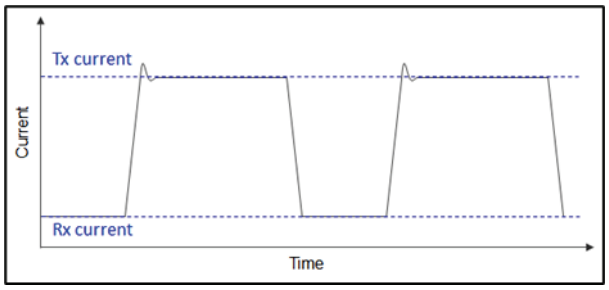


Table 13 describes the parameters for typical Bluetooth current test configuration.

Table 13: Typical Bluetooth Current Test Configuration Parameters

Mode	Setting Tx Power (dBm)	Current in mA	
		Tx	Rx
BR (1DH5)	11	51	16
EDR (3DH5)	7	40	16
1LE	3	32	16
2LE	3	32	17

5.3 IEEE Power Save Current Consumption

This section describes the IEEE power save current consumption for WLAN test configurations and parameters.

5.3.1 WLAN

Test Configurations:

- Power Supply: VBAT = 3.3V, VDDIO = 1.8V
- Host IF: PCIe
- BT_REG_ON: OFF
- Driver version: FMAC (Zigra)
- FW version: 13.35.173
- Platform: BRIX
- Access Point: ASUS RT-AX6000

Table 14 describes the test parameters for IEEE power save current consumption.

Table 14: IEEE Power Save Current Consumption Test Parameters

Band	Mode	Current in mA
2.4 GHz	IEEE Power Save: DTIM1	3.39
	IEEE Power Save: DTIM3	1.13
	IEEE Power Save: DTIM5	0.68
5 GHz	IEEE Power Save: DTIM1	2.96
	IEEE Power Save: DTIM3	0.99
	IEEE Power Save: DTIM5	0.59

5.3.2 BT Sleep Mode Current Consumption

Test Configurations:

- Power supply: VBAT = 3.3V, VDDIO = 1.8V
- Host IF: UART
- HCD file: BCM4359D0_004.001.016.0241.0275.1XA.sAnt.hcd
- WL_REG_ON: OFF

Table 15 describes the Bluetooth sleep mode current consumption test parameters.

Table 15: Bluetooth Sleep Mode Current Consumption Test Parameters

Mode	Current Consumption in uA
Deep Sleep (BT Only)	3
Advertise 1s	160
BLE Scan 1.28s	173
BT Page Scan 1.28s	151
BT Page & Inquiry Scan 1.28s	43
LE Link Master 1s	21

5.4 Throughput

This section describes the throughout conditions and parameters.

5.4.1 Typical Throughput

Test Configurations:

- Power supply: VBAT = 3.3V, VDDIO = 1.8V
- Host IF: PCIe
- DUT: Murata Type1XA M.2 EVB (LBEE5XV1XA-EVB)
  - WLAN Driver: FMAC (Baragon)
  - FW version: 13.35.225 (r728326 CY)
- Platform: MCIMX8MQuad-EVK
  - Linux Kernel version: 4.14.78
- Access Point: ASUS RT-AX6000
- UDP commands: Bit rate was set at more than 20% of observed correspondingTCP throughput.
  - Sample UDP command: iperf3 <server-ip-addr> -u -b <20%-of-TCP>M -P1 -t 60

Table 16 describes the test parameters for typical throughput.

Table 16: Typical Throughput Test Parameters

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
2.4 GHz 11n HT20 SISO	58	55	63	61
2.4 GHz 11n HT20 MIMO	111	115	130	124

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
5 GHz 11ac VHT80 SISO	325	362	361	385
5 GHz 11ac VHT80 MIMO	520	597	630	656

5.4.2 RSDB Throughput

Test Configurations:

- Power supply: VBAT=3.3V, VDIO=1.8V
- Host IF: PCIe
- DUT: Murata Type1XA M.2 EVB (LBEE5XV1XA-EVB)
  - WLAN Driver: FMAC (Baragon)
  - FW version: 13.35.225 (r728326 CY)
- Platform: MCIMX8MQuad-EVK
  - Linux Kernel version: 4.14.78
- Access Point: ASUS RT-AX6000

Table 17 describes the AP (2.4Ghz) – STA (5 GHz) configurations.

Table 17: AP (2.4 GHz) – STA (5 GHz) Configuration

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
AP 2.4 Ghz/HT20 (11n)	57	52	69	64
STA 5 Ghz/VH80	232	329	269	383

Table 18 describes the AP (2.4 GHz) – AP (5 GHz) configurations.

Table 18: AP (2.4 GHz) – AP (5 GHz) Configuration

Mode	TCP Throughput in Mbps		UDP Throughput in Mbps	
	Tx	Rx	Tx	Rx
AP 2.4 Ghz / HT20 (11n)	60	58	64	64
STA 5 Ghz/VH80	197	299	281	377

6 References

Table 19 reviews all the key reference documents that the user may like to refer to.

Table 19: Reference Table

Support Site	Notes
Murata Type 1XA Module Datasheet	Murata Type 1XA module datasheet (type1xa.pdf)
Murata Type 1XA Module Footprint	Murata Type 1XA module footprint (type1xa_module_footprint_topview.dxf)
Murata GitHub	Murata GitHub Link
Linux WLAN Configuration	Murata GitHub link for Linux NVRAM file for 1XA
Linux WLAN Regulatory Configuration	Murata GitHub link for Linux CLM_BLOB file for 1XA
Linux Bluetooth Configuration	Murata GitHub link for Linux HCD files for 1XA
Linux User Guide	Murata Linux User Guide for Infineon modules (Murata Wi-Fi & BT (IFX) Solution for i.MX Linux User Guide.pdf).

In case Murata website does not have the updated document, please refer to the Connectivity Module page on the Murata Community Forum. This contains a pinned post with all the updated documents.

7 Technical Support Contacts

Table 20 lists all the support resources available for the Murata Wi-Fi/BT solution.

Table 20: List of Support Resources

Support Site	Notes
Murata Community Forum	**Primary support point for technical queries.** This is an open forum for all customers. Registration is required.
Murata i.MX Landing Page	No login credentials required. Murata documentation covering hardware, software, testing, etc. is provided here.
Murata uSD-M.2 Adapter Landing Page	Landing page for uSD-M.2 Adapter. In conjunction with Murata i.MX Landing Page, this should provide the user with comprehensive getting started documentation.
Murata Module Landing Page	No login credentials required. Murata documentation covering all Infineon-based Wi-Fi/BT modules is provided here.

Revision History

Revision	Date	Section	Change Description
1.0	June 7, 2021		First issue
2.0	Feb. 22, 2022	Front Page	Updated Module Picture
3.0	June 15, 2022	Front Page 2.2 Hardware Block Diagram 5.1 Typical Tx output power level (at module antenna port) 5.1.1 5GHz SISO/1SS 5.1.1 MIMO/2SS 5.1.1 2.4GHz SISO/1SS 5.3.2 Bluetooth	• Added Module Picture • Block Diagram • Adding condition of Power table (US, Canada, EU and JPN) • Updating table format • Revising HCD file name • Revising HCD file name • Revising HCD file name • RSDB Throughput
4.0	July 1, 2022	4.0 Setup configuration files 5.0 Reference performance data	• Revising HCD file name • Revising Power table
5.0	Jan 13, 2023		• Converted to new template
6.0	Sep 12, 2023	3.5.2 Antenna Design and Confguratin	• Added an example of C1PC antenna list
7.0	Mar 8, 2024	2.2 Hardware Block Diagram 3.1 Reference Circuit	• Separate 2-ANT/3-ANT configuration • Added PCIe Interface detail