

# Ameba D WiFi MP FLOW V10

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This document is intended for the software engineer's reference and provides detailed programming information. Though every effort has been made to ensure that this document is current and accurate, more information may have become available subsequent to the production of this guide.

## **Revision History**

Revision	Date	Changes	Author
Ver 01	2018/08/14	First release	Winnita
Ver 02	2018/10/31	<ol> <li>Add ADC Test and GPIO Test</li> <li>Define target power</li> </ol>	Winnita
Ver 03	2019/01/03	Revise 5G target power	Alan
Ver 04	2019/03/01	Add mac address content	Alan
Ver 05	2019/03/29	Revise target power	Alan
Ver 06	2019/06/26	Modify Calibrated Crystal Cap. Flow	Winnita
Ver 07	2019/07/19	Add WiFi/BT Interface Switch	Winnita
Ver 08	2019/09/09	Revise 5G target power	Winnita
Ver 09	2020/03/13	Add a note in 3.5 Write Data	Winnita
Ver 10	2024/11/13	Modify WL TX CCK calibration method	Winnita

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## 1. Overview

This document is used to introduce WiFi calibration Flow of AmebaD series chip for Mass Production. Customers can build up their own MP software easily with just following step-by-step guidance of this document. Realtek also cooperates with instrument vendors during chip development stage, so customers can inquire MP software support from instrument vendors.

AmebaD series chip includes following IC part numbers and here lists its relative connectivity interface and its memory type,

1. RTL8720D/RTL8721D/RTL8722D: Support basic peripheral interface with external flash.

In order to correctly design your hardware and properly apply AmebaD series chip on your platform, please do provide following information to your Realtek local sales and Technical Support Team,

- 1. Memory requirements, such as PSRAM or flash size are required.
- 2. Connectivity interface requirement, such as USB/SDIO interface.
- 3. Special GPIO requirement, such as wake trigger pin from deep sleep state, ADC, etc.
- 4. Antenna configuration, such as one or two antenna and diversity required or not.

Realtek Technical Support Team will depend on above information, and then provide following document or design kit to assist customers on hardware design,

- 1. IC Datasheet
- 2. Hard Design Kit (HDK) or suitable recommendation
- 3. Calibration Data Content (flash/ non-volatile memory) Specification
- 4. Calibration Data Content (flash/ non-volatile memory) MAP file
- 5. MP API (customer can use this API to develop their own software tool for mass production)
- 6. MP calibration Flow

Emphasize again, different hardware configurations have to match up different MAP file, so customers do have to contact Realtek Technical Support team to obtain correct MAP file to match up your hardware design.

## 2. Test Platform

The calibration flow described in following section is based on WiFi one-box tester, such as Agilent N4010A or LitePoint IQFlex, etc.

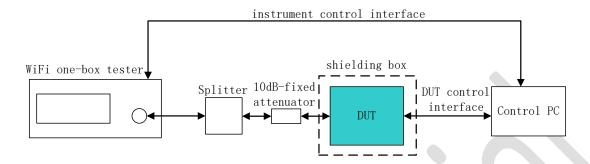


Figure 1: Brief diagram about test environment setup of DUT

Note the 10dB-fixed attenuator has to set as close as possible to DUT since it will reduce the mismatch effect between DUT and the environment.

## 3. WiFi MP Flow

Below diagram shows a global view of mass production flow, please refer to following sub-section to get detailed description for each step.

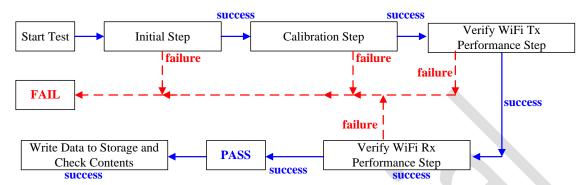


Figure 2: Brief diagram about MP flow

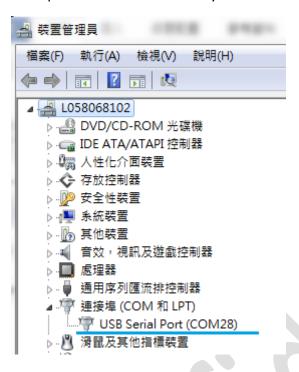
Note: Customers are suggested to read image file and program it to flash of the Ameba-D module before MP flow. Relevant application program is illustrated in

RTL8721D\_AN\_PART4\_image\_tool\_20180801\_1536.docx

# 3.1 Environment Setup

First you need to check comport show up.

COM port number is based on your environment.



# 3.2 WiFi Initial Step

The relative control commands about initializing WiFi DUT is in the released UI sample code.

The AT command "ATWP=1" can enable WiFi, and use "ATWP=0" to disable.

Please check the following message. The message "The driver is for MP" indicates this is a MP driver. MP driver is used to calibrate WiFi data.

```
#ATWP=1
[ATWP]: _AT_WLAN_POWER_[ON]
Initializing WIFI ...
RTL8195A[Driver]: The driver is for MP
WIFI initialized
[MEM] After do cmd, available heap 25968
```

And below commands controls WiFi DUT enter or exit MP(Mass Production) test mode.

iwpriv mp\_start

iwpriv mp\_stop

```
#iwpriv mp_start
[MEM] After do cmd, available heap 69776
```

This command is recommended before calibration:

iwpriv mp\_pwrctldm stop

The reason is that if the DUT has already been PG, the dynamic mechanism will be activated, this may lead to the calibration with unexpected results.

# 3.3 I/O Test Step

Ameba MP API supports IO connection tests for module fabrication. All the peripheral functions are well tested in Realtek mass production testing procedure.

If customers have specified test requirement for GPIO function used for your module or system design, please contact Realtek Support Team.

#### 3.3.1 ADC Test

For the Ameba-D module, the ADC\_CH0  $\sim$  ADC\_CH7 are fed with 0  $\sim$  3.3V voltage level and read the sample value. The sample value should be within tolerated error. When fed with GND, the value should be approach 0x100. When fed with 3.3V, CH0 $\sim$ CH6 would return a value approach 0xFFF, and CH7(VBAT) would return a value approach 0x0B20.

The AT command "ATSA=1" can read ADC\_CH1 value, use "ATSA=2" to read ADC\_CH2, and use "ATSA=3" to read ADC\_CH3.

The following output is the ADC value.

```
#ATSA=1

[ATSA]: _AT_SYSTEM_ADC_TEST_
[ATSA] A1 = 0x0827

[MEM] After do cmd, available heap 37432

#ATSA=2

[ATSA]: _AT_SYSTEM_ADC_TEST_
[ATSA] A2 = 0x0827

[MEM] After do cmd, available heap 37432
```

#### Note:

For RTL8721D module, test ADC CH0~ADC CH7.

#### 3.3.2 GPIO Test

For the RTK module Ameba-D, module pin PAO ~ PA31, PBO~PB11 and PB24~PB31 are fed with OV and 3.3V from the testing equipment. These GPIOs are configured as input mode and read the input value. Check the input logic values are same as the equipment output levels.

The AT command "ATSG=xy" can read the number y of GPIO port x.

For example, the command "ATSG=C1" can read GPIOC\_1, and use "ATSG=B2" to read GPIOB\_2.

The following output is the testing equipment voltage level.

```
#ATSG=C1

[ATSG]: _AT_SYSTEM_GPIO_TEST_
[ATSG] C1 = 1

[MEM] After do cmd, available heap 37432

# ATSG=B2

[ATSG]: _AT_SYSTEM_GPIO_TEST_
[ATSG] B2 = 0

[MEM] After do cmd, available heap 37432
```

#### Note:

For Ameba-D module, PB\_12~PB\_17 or PB\_18~PB\_23 are not allowed to be tested when code running on flash.

# 3.4 Calibration Step

This step includes 2 sub-steps as shown in Figure 3.

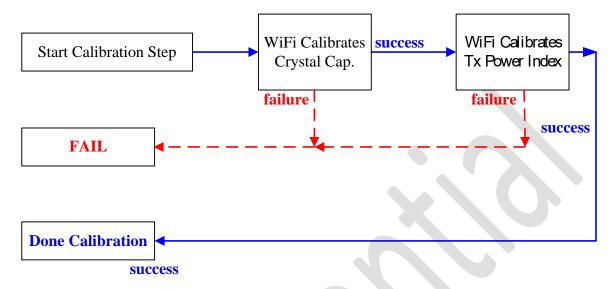


Figure 3: Brief diagram about calibration step

## 3.3.1 WiFi Calibrates Crystal Cap

## 3.3.1.1 EFuse definition about Crystal Cap

First, take a look at calibration data content about setting of Crystal Cap. Normal driver will load this value in initial step. So this value must be well-calibrated and filled on correct calibration data location.

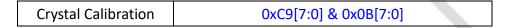


Table 1: Crystal calibration offset in eFuse

## 3.3.1.2 Calibrated Crystal Cap. Flow

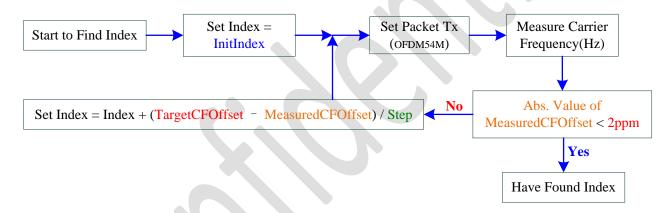


Figure 4: Finding Crystal Cap. Index Flow

Measurement environment: room temperature 25 degree

InitIndex: the default value is 0x40. Index range is 0x0 to 0x7F.

MeasuredCFOffset: Carrier frequency measured by instrument - Ideal Carrier Frequency Target range Abs. Value of 2ppm in 2.4GHz band is about 10KHz(±5KHz).

\*TargetCFOffset: generally is 0~-5ppm ppm, The reason for minus ppm was the frequency deviation could be under 15ppm at high temperature 80 degree environment.

Step: This value is dependent of different module dominated by external capacitor beside the crystal, so it needs to modify easily in initial file of test program. Usually, the value is about -2 ~ - 3 KHz by experience. The minus symbol means that the crystal cap. index and carrier frequency is negative-dependent (The larger index is relative to minor carrier frequency).

The command is shown as below:

#### Step 1:

iwpriv mp\_ant\_tx a
iwpriv mp\_bandwidth 40M=0,shortGI=0
iwpriv mp\_channel 7
iwpriv mp\_rate 108
iwpriv mp\_txpower patha=42,pathb=0
iwpriv mp\_phypara xcap=64
iwpriv mp\_ctx background,pkt

#### Step 2:

You can measure Frequency Error(ppm) Freq\_Err. If Freq\_Erris is between  $\pm 2$ ppm, you found this value (index\_cry\_ok) correctly. If Freq\_Erris is not between  $\pm 2$ ppm, you caught use algorithm as below to find next index\_cry\_next until you find Freq\_Err between  $\pm 2$ ppm.

$${\rm index\_cry\_next=Index\_cry-} \ \frac{Freq \ \_Err \times 2442}{2500}$$

ex: We set Index\_cry =64, measure Freq\_Err = -23.49ppm,

The next index is index\_cry\_next= 32- 
$$\frac{(-23.49) \times 2442}{2500} = 87$$

step3: The index\_cry\_next must be **rounded the number to the integer**, and use command to update index as follows:

iwpriv mp\_phypara xcap=index\_cry\_next
ex: iwpriv mp\_phypara xcap=87

Repeat Step2, Step3 until find Freq\_Erris correctly and note down Index\_cry\_ok.

Stop Tx command is as below:

iwpriv mp\_ctx stop

## 3.3.2 WiFi Calibrates Tx Power Index

## 3.3.2.1 EFuse definition about Tx power index and thermal meter

First, take a look at eFuse content about setting of RF Tx gain index. Normal driver will load bellow Tx gain setting for each channel group or each PHY data rate. So these Tx gain setting must be well-calibrated and filled on correct eFuse location.

The 0x2B default value was 0x02 for all channels. But the customer also can measured OFDM&HT20 to calculate diff value on CH7 (recommend).

	Power Index Location in EFuse of Antenna A							
2G Band								
	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6		
	CH1 – CH2	CH3 – CH5	CH6 – CH8	CH9 - CH11	CH12- CH13	CH14		
MCS7 B40	0x26[7:0]	0x27[7:0]	0x28[7:0]	0x29[7:0]	0x2A[7:0]			
ССК	0x20[7:0]	0x21[7:0]	0x22[7:0]	0x23[7:0]	0x24[7:0]	0x25[7:0]		
5G Band								
	Group 7	Group 8	Group 9	Group 10				
	CH36-40	CH44-48	CH52-56	CH60-64				
MCS7 B40	0x32[7:0]	0x33[7:0]	0x34[7:0]	0x35[7:0]				
	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16		
	CH100-104	CH108-112	CH116-120	CH124-128	CH132-136	CH140-144		
MCS7 B40	0x36[7:0]	0x37[7:0]	0x38[7:0]	0x39[7:0]	0x3A[7:0]	0x3B[7:0]		
	Group 17	Group 18	Group 19	Group 20				
	CH149-153	CH157 -161	CH165-169	CH173-177				
MCS7 B40	0x3C[7:0]	0x3D[7:0]	0x3E[7:0]	0x3F[7:0]				

	Power Difference Location in EFuse of Path A				
2C Dand	54M-1T to MCS7-B40	0x2B[3:0]			
2G Band	MCS7-B20 to MCS7-B40	0x2B[7:4]			
CC David	54M-1T to MCS7-B40	0x40[3:0]			
5G Band	MCS7-B20 to MCS7-B40	0x40[7:4]			

Thermal meter	0xCA[7:0]
---------------	-----------

Table 2: Tx gain index and thermal meter offset in eFuse

# 3.3.2.2 Define target power

## According to

- (1) EMI/EMC regulatory
- (2) IEEE TX EVM / Spectrum Mask requirement
- (3) The method was interpolation power index for un-calibration channel group.

Then you can define your target power for each channel group and also each PHY data rate. The recommended target power is listed below and assumes all channel have the same target power for each PHY data rate.

Data	a Rate	MCS7-B40	MCS7-B20	54M	CCK
Target Power 2G	3.3V power supply	16dBm	16dBm	17dBm	18dBm
Target Fower 2G	1.8V power supply	10dBm	10dBm	11dBm	12dBm
Towart Poyyar 5C	3.3V power supply	13dBm	13dBm	14dBm	
Target Power 5G	1.8V power supply	8dBm	8dBm	9dBm	

Table 3: The recommended target power (DPD on)

#### 3.3.2.3 Tx calibration flow

Theoretically, we need to measure all value defined above in OTP to calibrate the Tx power level. But since it needs too much time, we only measure several channels with MCS7-B40 signal and CCK-11M signal, and figure out the other non-measured value by some easy mathematics method.

Usually, the recommended measured channels are listed below:

	2G Band	d	2	2G	5G B	and 1	5G P	and2	5G B	and2	5G P	and4
	(CCK)		Band(	MCS7)	30 B	anui	30 B	anuz	3G B	ands	30 B	anu4
СН4	CH10	CH14	CH4	CH10	CH38	CH46	CH54	CH62	CH102	CH142	CH151	CH175

Table 4: The recommended measured channel for Tx power calibration

The flow is shown as below:

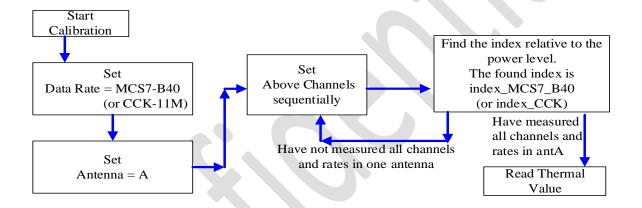


Figure 5: Tx calibration flow

Each finding index flow is shown as below:

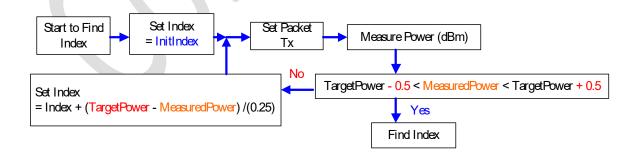


Figure 6: Finding index flow

While finding Index\_MCS7\_B40, the Init Index is defined by user or programmer and target power is MCS7-B40 target power level defined before.

After finding all Index\_MCS7\_B40, use these values to get all Tx gain index in each channel set by interpolation. As 2G channels for example, if the measured index in CH4 is 41 and the measured index in CH10 is 43, all 2G group MCS7-B40 index is shown as below:

Group 1	Group 2	Group 3	Group 4	Group 5
40	41	42	42	44
(Calculated by	(Massured)	(Calculated by	43 (Measured)	(Calculated by
Interpolation)	(Measured)	Interpolation)	(ivicasureu)	Interpolation)

Table 5: The example of finding MCS7 index in 2G band by interpolation

We have measured all groups of 5G band 1 and 5G band 2, so just only use the interpolation for 5G band 3 and 5G band4.

Similarly, all group CCK index is shown as below:

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
44 (Calculated by Interpolation)	45 (Measured)	46 (Calculated by Interpolation)	47 (Measured)	48 (Calculated by Interpolation)	49 (Measured)

Table 6: The example of finding index in 2G band by interpolation

The all power difference values are between +7 and -8. The value  $0x0 \sim 0x7$  in eFuse means  $0 \sim +7$  and the value  $0x8 \sim 0xF$  in eFuse means -8  $\sim$  -1. The +1 power difference will plus 0.5dB power theoretically, so we calculate all power difference by the defined target power. We take Table 7 as an example, the 2G power difference is shown as below:

MCS7-B20 to MCS7-B40	$(MCS7-B20\_Tatget\_Power - MCS7-B40\_Tatget\_Power)x2$ $= ((13-13) x2) = 0$
54M-1T to MCS7-B40	$(54M\_Tatget\_Power - MCS7-B40\_Tatget\_Power)x2$ = $((14-13) x2) = 2$

Table 7: The example of finding power difference

## 3.3.2.4 Read Thermal Meter

Normal driver will load thermal meter to do power tracking. So this value must be filled on correct calibration data location. Use MP command as below to get thermal meter value:

iwpriv mp\_ther

```
#<mark>iwpriv mp_ther</mark>
Private Message: <mark>24</mark>
[MEM] After do cmd, available heap 25968
```

# 3.5 Write Data to Storage and Check Contents

Allocate 512 bytes of memory space on your local PC and then load default map file to this memory space. (UCHAR calibration\_data[512]) Write board-dependent information into respective calibration data offset, this information include MAC address, calibrated Tx index, Thermal Meter, and so on.

The eFuse content about setting of WiFi MAC address is as following table.

WiFi MAC address	11Ah~11Fh	
------------------	-----------	--

Table 8: WiFi MAC address offset in eFuse

Use the MP command:

"iwpriv config\_set wmap,offset,data"

Note: Please reference document AN0004 Realtek mp user guide.pdf

to send 16 bytes calibration data content to on-chip Calibration data area, therefore 512 bytes contents need to do above command 512/16=32 times. If you want rewrite new contents, you can use above command again.

#### Note:

This command is only effective above 2.5V power supply. So if you want to write the "1.8V" efuse data, please storage them first and then write them into efuse at 3.3V power supply.

After above step, you should use below MP command to read partial contents,

"iwpriv config\_get rmap,offset,count"

or use below MP command to get full contents

"iwpriv config\_get realmap"

Note: Please reference document AN0004 Realtek mp user guide.pdf

to check the written contents are all correct or not.

# 3.6 Verify Tx Performance Step

This step includes 1 sub-step as shown in Figure 7:

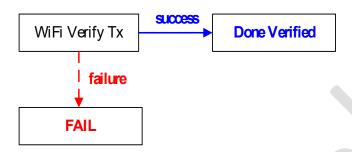


Figure 7: Verify Tx Performance Flow

# 3.6.1 WiFi Verify Tx Performance

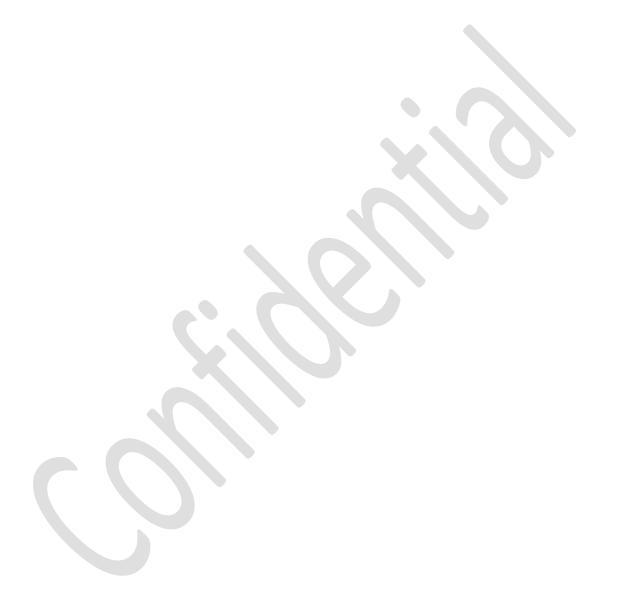
Use the calibrated index in previous step and measure Tx power, EVM, frequency offset and LO leakage to check Tx performance is ok or not. The recommended test items are listed below:

Data Rate	Antenna	Channel	Item	V 1	Criterion																		
				3.3V	Typical: 16dBm	Acceptable																	
			Power	1.8V	Typical: 10dBm	Range: +1/- 1.5dB																	
MCS7-B40	Antenna A	СН6	EVM		< -28dB	1.500																	
			Freq. Err.		±15ppm																		
			Leakage		< -20dBtotal																		
			Mask		IEEE spec. define	ed																	
				3.3V	Typical: 16dBm	Acceptable																	
			Power	1.8V	Typical: 10dBm	Range: +1/-																	
					1.0 V	Typicai: Toubin	1.5dB																
MCS7-B20	Antenna A	CH1	CH1	tenna A CH1	EVM	< -28dB																	
																			Freq. Err.		±15ppm		
													Leakage	< -20dBtotal									
			Mask		IEEE spec. define	ed																	
		СН7	Power	3.3V	Typical: 17dBm	Acceptable																	
OFDM	Antenna A			1 0 17	Typical:	Range: +1/-																	
54M	4M Antenna A CIII		ан Сп/			1.8V	11dBm	1.5dB															
			EVM		< -25dB																		

			Freq. Err.		±15ppm		
			Leakage		<-15dBtotal		
			Mask		IEEE spec. define	ed	
		A CH13	Power	3.3V	Typical: 18dBm	Acceptable	
				1 017	Typical: 12dPm	Range: +1/-	
CCV 11M	Antonno A		CIII2		1.8V	Typical: 12dBm	1.5dB
CCK IIW	CCK 11M Antenna A		EVM	< 8%			
			Freq. Err.	±15ppm			
			Mask		IEEE spec. define	ed	

	MCS7-B40 Antenna A CH38 CH54 CH102 CH151	CH38	Power	3.3V 1.8V	Typical: 13dBm  Typical: 8dBm	Acceptable Range: +1/-					
MCS7-B40		Antenna A CH54 CH102	Antenna A CH54 CH102 CH151	CH54 CH102	CH54 CH102	CH54 CH102	CH54 CH102	ntenna A CH54 CH102	EVM Freq. Err. Leakage Mask		<-28dB ±15ppm <-20dBtotal IEEE spec. define
			Iviask	3.3V	_						
	MCS7-B20 Antenna A	CH48 CH64 CH144 CH177	Power	1.8V	Typical: 13dBm  Typical: 8dBm	Acceptable Range: +1/- 1.5dB					
MCS7-B20			EVM	<-28dB							
			Freq. Err.	±15ppm							
			Leakage	< -20dBtotal							
			Mask	IEEE spec. defined							
				3.3V	Typical: 14dBm	Acceptable					
OFDM Antenn		CH44 CH60 CH120 CH165	Power	1.8V	Typical: 9dBm	Range: +1/- 1.5dB					
	Antenna A		EVM	<-25dB							
54M	34111		Freq. Err.	±15ppm							
		CH103	Leakage		< -15dBtotal						
			Mask		IEEE spec. define	ed					

Table 9: The recommended test items of WiFi Tx



# 3.7 Verify Rx Performance Step

This step includes 1 sub-step as shown in Figure 8:

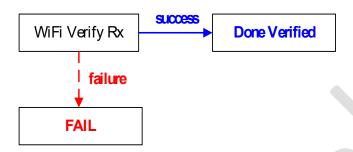


Figure 8: Verify Rx Performance Flow

# 3.7.1 iFi Verify Rx Performance

Measure the DUT Rx sensitivity to check Rx performance is ok or not. The recommended test items are listed below:

Data Rate	Channel	Item	Sensitivity Criteria
MCS7-B40	СН6		< -64dBm
MCS7-B20	CH1	Samaitivity	< -67dBm
OFDM 54M	СН7	Sensitivity	< -71dBm
CCK 11M	CH13		< -82dBm

Data Rate	Channel	Item	Sensitivity Criteria
MCS7-B40	CH118		< -64dBm
MCS7-B20	CH44	Sensitivity	< -67dBm
OFDM 54M	CH100		< -71dBm

Table 10: The recommended test items of WiFi Rx

# 4. WiFi/BT Interface Switch

The ATM2 series command can switch WiFi or BT MP test mode. Customers should follow this list by steps to do WiFi & BT Mass Production.

No	Steps	Commands/Descriptions	Remark
1	MP start	iwpriv mp_start	
2	WiFi Calibration & Verification	iwpriv commands	Reference doc: AN0004 Realtek low power wi-fi mp user guide.
3	Switch to Bluetooth	ATM2=bt_power,on ATM2=gnt_bt,bt ATM2=bridge	X/(O)
4	Open BT Uart interface		Reference doc: MP tool User guide for Realtek.
5	BLE- Tx calibration (gain k)	\ C	Sample code path:
6	Read BT thermal meter value	Refer to the sample codes in Realtek Bluetooth MP	RealeasePackage\NewBTMP\Realtek Bluetooth MP Kit Setup
7	BLE- Tx verification	Kit Setup Package	Package\RTLBTAPP\SampleCode\MPRtlB luetoothSample
8	Close BT Uart interface		Note: keep the tx gain k value and thermal value
9	Switch to Wifi	ATM2=bridge,close ATM2=gnt_bt,wifi	
10	Write efuse	iwpriv commands	Reference doc: Realtek Ameba-D calibration data spec.  * Write WiFi calibration data+MAC address  * Write BT calibration data+MAC address.
11	MP stop	iwpriv mp_stop	

Table 11: WiFi & BT Mass Production flow