泰芯半导体
TaiXin Semiconductor

TaiXin AH Performance Testing Method

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Revision History

Date	Version	Revision Notes	Reviser
2024-03-12	V2.3	Modified the methods for sensitivity testing and real-world channel testing.	WY
2024-01-11	V2.2	Revised the explanation for sensitivity testing.	WY
2023-09-03	V2.1	Added method explanations for real-world channel testing.	WY
2023-06-12	V2.0	Added instrument-based test items.	WY
2022-07-24	V1.2.2	Corrected typographical errors.	WY
2022-02-18	V1.2.1	Updated the logo.	XYJ
2021-07-22	V1.2	Added explanations for sensitivity testing.	WY
2021-07-03	V1.1	Added explanations for interoperability testing in test mode; Added explanations for board noise floor testing;	WY
2020-11-10	V1.0	Initial version	WY

Table of Contents

1. Overview

This document describes how to test the Tx/Rx performance of the AH module on the solution board, either with or without testing equipment. The test results can be served as a basis for improving the solution board's performance.

2. Test Preparation

2.1. Serial Port Settings

Configure the serial port as shown in Figure 2-1.

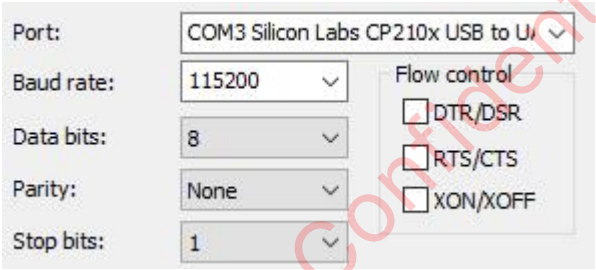

Figure 2-1 Serial Port Parameter Configuration

Additionally, please ensure that the "New Line Mode" is selected; otherwise, AT commands cannot be entered.

To test if the serial port is functioning correctly, input AT+, and the following output should be displayed:

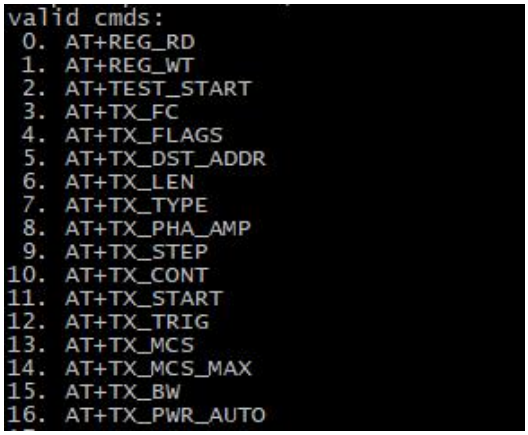

Figure 2-2 Echo of AT+ Input

If this output is not displayed, it indicates an incorrect serial port input, and you should

contact our FAE for assistance.

2.2. Serial Commands Introduction

1) Enter/Exit Test Mode
   at+test_start=1 or 0
   Upon entering test mode, it defaults to Rx mode;

   Note that this command is not saved after power-down.

2) Set Center Frequency
   at+lo_freq=908000
   The unit is kHz, 908000 means 908M, 921500 means 921.5M;

   Note that this command is not saved after power-down.

3) Set Bandwidth
   at+bss_bw=8 or 4 or 2 or 1
   Supports 4 bandwidths: 8M, 4M, 2M, 1M. The recommended setting value is consistent with the actual situation of the solution.

   Note that this command is saved after power-down, remember to restore it after modification.

4) Enter/Exit Tx Mode
   at+tx_start=1 or 0
   Note that this command is not saved after power-down.

5) Set MAC Address
   at+mac_addr=0
   Set mac_addr to 0 when doing Rx tests in test mode;

   Note that this command is not saved after power-down.

6) at+tx_mcs=255 or any value from 0~7
   By default, tx_mcs=255, which means automatic MCS switching based on channel conditions; setting it to any value from 0~7 fixes the value to that MCS;

   In test mode, when the value is 255, mcs7 is used for transmission. For Tx/Rx testing, set mcs=1 to avoid incorrect test results due to mcs7 failing to decode when Rx performance is poor.

   This command is saved after power-down. Ensure to restore MCS to 255 after testing to avoid fixing it to MCS1, which can affect real-world scenarios.

7) Set Channel List
at+chan_list=9080, 9160, 9240
This command sets the channel list to use, in units of 100kHz. 9080 means 908M; set according to the actual situation of the solution;

Note that this command is saved after power-down, remember to restore it after testing.

8) Start Background Noise Scanning
at+acs_start=1
This command starts the automatic background noise scan, displaying the minimum (min), average (avg), and maximum (max) values of background noise (bgr, backgroundrssi) for each channel;

Note that this command is not saved after power-off.

3. Test Items

3.1. Tests Based on Instrumentation

3.1.1. Tx Cable Single Tone Test

1. At+test_start=1 // Enter test mode
2. At+lo_freq=915000 /* Example frequency set to 915M, suggested to cover the working frequency band's upper and lower limits */
3. At+tx_start=1 // Enable Tx
4. at+tx_type=S /* S means single tone, which should emit a -500kHz signal by default, N means Normal (modulated signal) */
5. at+tx_cont=1 /* Continuous transmission; to modify Tx parameters, exit continuous transmission first */

3.1.2. Tx Cable Modulated Signal Test

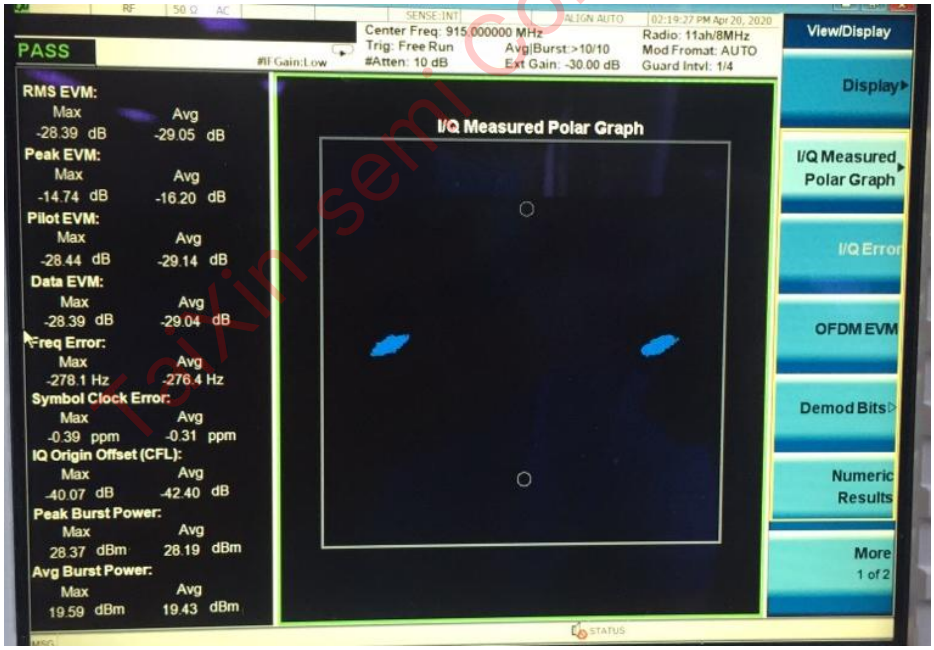

Figure 3-1 Modulated Signal Test (Spectrum Analyzer N9020 with AH license)

- Test Commands:

1. At+test_start=1 // Enter test mode
2. At+bss_bw=8 // Set bss_bw, default is 8 M, can also be 2/4 M
3. At+lo_freq=915000 /* Example frequency set to 915M, suggested to cover the

working frequency band's upper and lower limits */

4. At+tx_pwr_super=1 // Enable super power, outputs 25dbm at mcs0, 20dbm at mcs7
5. At+tx_mcs=0 // Set tx-mcs, test mcs0 and mcs7
6. At+tx_start=1 // Enable Tx

- Spectrum Analyzer Operation:

1. Press mode to select WLAN;
2. Press input, compensate -31db (due to 30db attenuator and approximately 1db cable loss);
3. Press mode setup to select 11ah sub-mode;
4. Set frequency center to match DUT's lo_freq;
5. Select modulation analysis for the test item, set search time to 50ms in measure setup/advance (default value too small, constellation diagram will flicker).

Notes:

1. Ensure the spectrum analyzer is connected to an attenuator (30db) to avoid damage;
2. Observe printout to check if chip temperature is high, indicating poor heat dissipation.

3.1.3. Rx Cable Sensitivity Test

- Test Commands:

1. At+test_start=1 // Enter test mode
2. At+bss_bw=8 // Set bss_bw, default is 8M, can also be 2/4M;
3. At+lo_freq=908000 /* Example frequency set to 908M, must cover all channels of the working frequency band */
4. At+tx_start=0 // Disable Tx test mode, default is off

- Signal Source Operation (E4438C with AH license):

1. Connect PC to signal source via Ethernet, check signal source IP in utility options, connect to it via WLAN software;
2. Load AH configuration file, contact TaiXin FAE for it;
3. Set packet interval to not less than 1ms, configure frequency, transmit power (initially -40dbm), bw, mcs, etc., and download to signal source;
4. Record the number of received packets as the signal source packet count per cycle after DUT successfully receives packets;
5. Press local key to exit remote mode, adjust output power, reduce power until received packets are 90% of signal source packets (due to errors and packet loss), observe rssi and evm; sensitivity is usually around -81dbm for 8M mcs7, and -95dbm for 8M mcs0; investigate if actual values significantly differ from expected values;
6. Change test frequency to cover all channels of the working frequency band.

3.1.4. Rx Over-the-Air Sensitivity Test

Place DUT (with antenna) in a shielded box, connect signal source via cable to another antenna inside the shielded box. Use the sensitivity test method to check for anomalies in sensitivity across various frequency points within the operating band. Ensure that the DUT's antenna setup matches its actual usage to obtain results that closely reflect real-world performance.

3.1.5. Using Test Box Instead of Instruments

If instruments are unavailable, use the AH test box for cable or over-the-air performance testing, following the test box manual and previous instrument-based test methods.

The test box can also be used as a golden device, controlled via serial port for Tx-Rx testing (described in the following sections).

Note the test box includes approximately 48db attenuation (documentation and box labels may vary, actual value is about 48db).

3.2. Non-Instrument-Based Test Items

3.2.1. Tx-Rx Interoperability Test

In the absence of AH-specific test instruments, two solution boards can be used for Tx-Rx testing to troubleshoot Tx and Rx performance issues.

Ensure the Rx side is functioning correctly when testing the Tx side, and vice versa.
When connecting Tx and Rx boards via RF cable, it's recommended to include a 50db attenuator to prevent excessive signal reception, which could lead to inaccurate test results.
If both Tx and Rx boards are using antennas, keep them at least 1 meter apart to avoid excessive signal reception.

- Tx Side Test Command Sequence:

1. at+test_start=1 // Enter test mode
2. at+lo_freq=908000 /* Example frequency 908M, adjust based on actual AH module supported frequency */
3. at+bss_bw=8 // Example bandwidth 8M, adjust based on actual usage
4. at+mac_addr=0 // Clear MAC address
5. at+tx_start=1 // Enable Tx, enter Tx mode
6. at+tx_mcs=1 // Set mcs=1

- Rx Side Test Command Sequence:

1. at+test_start=1 // Enter test mode
2. at+lo_freq=908000 /* Example frequency 908M, adjust based on actual module supported frequency */
3. at+bss_bw=8 // Example bandwidth 8M, adjust based on actual usage
4. at+mac_addr=0 // Clear MAC address

- Result Analysis:

1) If both Tx and Rx sides are functioning correctly, the output should be as shown in Figures 3-2a and 3-2b.

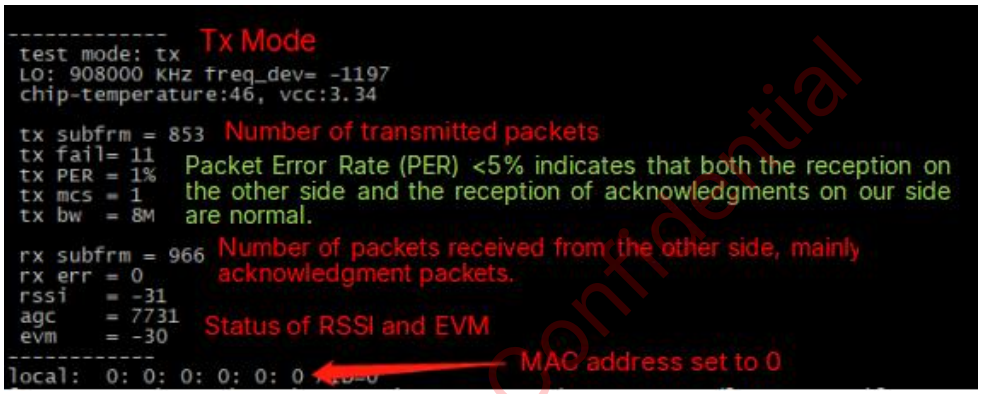

Figure 3-2(a) Tx Output When Both Tx and Rx are Normal

Figure 3-2(b) Rx Output When Both Tx and Rx are Normal

2) If the Rx side receives few packets, the Tx side might not be transmitting correctly.
3) If the Rx side receives packets normally but the Tx side receives few response packets, the Rx side might not be transmitting correctly.
4) If one side's transmission is confirmed to be fine but the other side's RSSI and EVM are poor, the receiving performance of the problematic side may be faulty.

3.2.2. Sensitivity Test

The receiver's sensitivity can be tested using the Tx-Rx interoperability method, with the help of a test box, a variable attenuator, and a shielded box (without a shielded box, interference may cause inaccurate sensitivity tests; if a variable attenuator is unavailable, adjust the test box's transmit power).

For sensitivity testing, first set the test box to Tx mode (placed outside the shielded box) and the DUT to Rx mode (placed inside the shielded box). Adjust the DUT's RSSI to around -40dBm and record the packet count over one print cycle (it should be correct under normal conditions). Increase the attenuation and note the RSSI value at which the correct packet count (received packets - erroneous packets) drops to 90% of the previously recorded count with strong signal. Observe RSSI and EVM (ignore the PER of the test box, which is due to the DUT not returning ACK). Figure 3-3 shows the cable sensitivity test values for the AH module.

For prototypes, you can test over-the-air sensitivity directly. Connect the test box to the shielded box via cable, and the internal antenna radiates the test box's signal to the DUT. Over-the-air sensitivity is typically several dB worse than cable sensitivity; if the degradation is too significant, troubleshoot and optimize the hardware design. Test all candidate channels.

Test frequency point 900MHz

BW MCS	1M	2M	4M	8M
0	-106	-103	-99	-96
1	-103	-100	-97	-94
2	-102	-99	-96	-93
3	-99	-96	-93	-90
4	-96	-93	-90	-87
5	-94	-90	-87	-83
6	-93	-89	-86	-82
7	-91	-87	-84	-81
10	-108	-	-	-

Figure 3-3 Cable Sensitivity Test Values for AH Module

If a variable attenuator is not available, reduce the test signal by adjusting the test box's internal Tx power levels. Use at+tx_pwr_max=5 or 4 or 3 to make coarse adjustments (level 4 is 15dB lower than level 5, and level 3 is 15dB lower than level 4), then fine-tune with at+txpower=6~20 (step=1, valid for levels 5/4/3). If the signal is still too strong, add a fixed attenuator.

Also, consider the frequency characteristics of the prototype antenna. Use the test box's default transmit power (tx_pwr_max=5, at+txpower=20)to send packets, traverse all candidate channels, and check the RSSI consistency of each channel on the prototype. If the

consistency is not good, some frequency RSSIs are much smaller, which may lead to communication anomalies.

3.2.3. Background Noise Scanning

Use the command at+acs_start=1 to scan for background noise (bgr) caused by the solution board's EMI.

Typically, an antenna is used for bgr scanning because it can receive EMI noise from the solution board, whereas RF cables shield against EMI noise, making the results appear better than they would with an antenna.

During testing, avoid external interference sources such as base station interference or other boards. Using a shielded box is preferable.

Enter at+acs_start=1 to see the serial port output as shown in Figure 3-4.

The Channel list will undergo a full scan for all frequency points, with the number of scans per frequency determined by bandwidth (e.g., 8M bandwidth scans 8 times, 4M bandwidth scans 4 times, etc.).

The bgr scan results display min/avg/max columns. Focus on the avg value, followed by the max.

For 8M bandwidth, a bgr-avg of <-90 is acceptable; if >-90, consider hardware EMI rectification. For 4M, subtract 3dB from the 8M standard (i.e., bgr-avg <-93 is acceptable; if >-93, consider rectification). For 2M, subtract 6dB from the 8M standard (i.e., bgr-avg <-96 is acceptable; if >-96, consider rectification). For 1M, subtract 9dB from the 8M standard (i.e., bgr-avg <-99 is acceptable; if >-99, consider rectification).

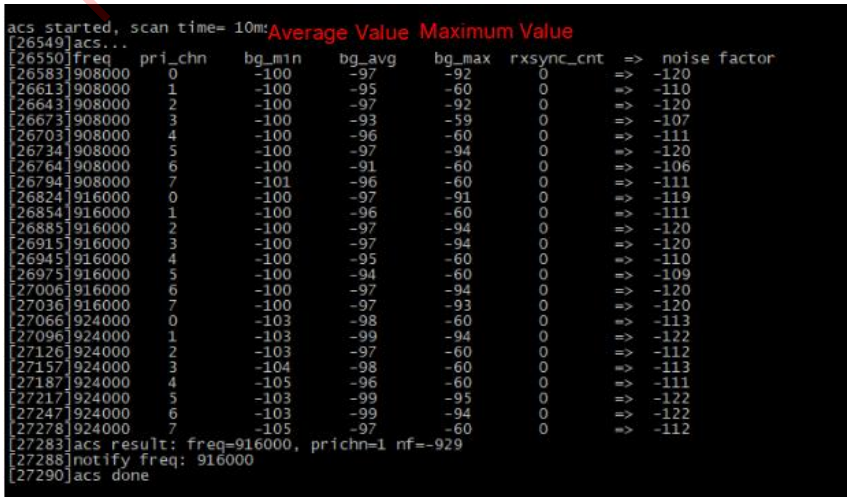

Figure 3-4 The ACS Scan Results

For example, an EMI issue with a solution board might be illustrated by the different frequency sweep results when the screen is on versus off, as shown in Figures 3-5a and 3-5b.

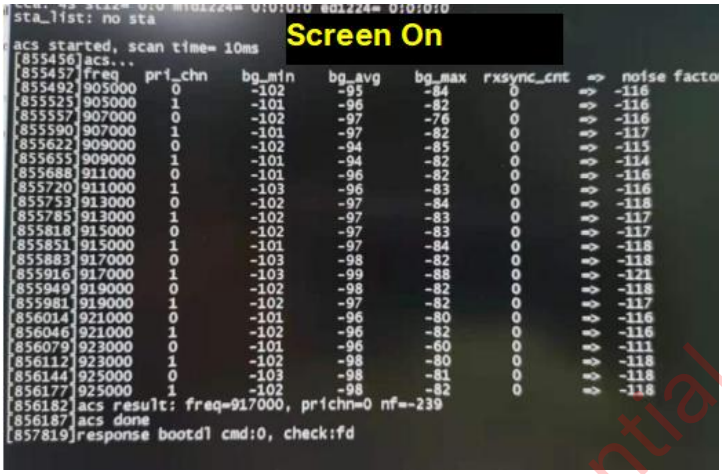

Figure 3-5(a) The Frequency Sweep with The Screen On

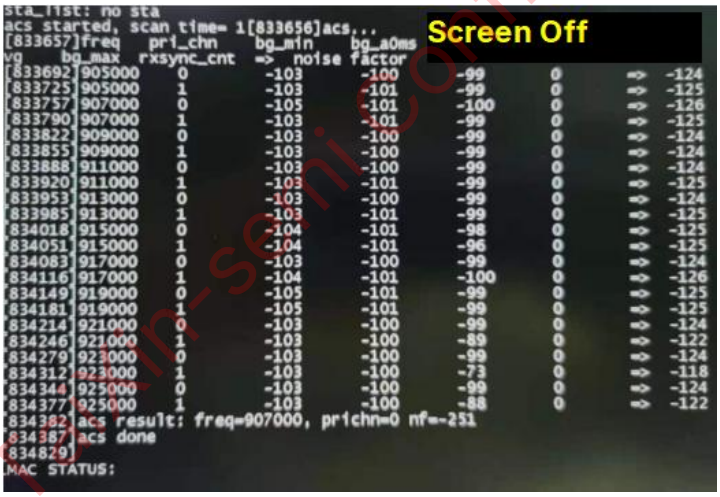

Figure 3-5(b) The Frequency Sweep with The Screen Off.

In this case, the bgr-avg values do not differ significantly between screen on and off, but the bgr-max values differ by nearly 15dB, which correlates with a 15dB difference in Rx sensitivity measured by instruments. Thus, it's recommended to identify and mitigate the EMI source when the screen is on.

3.2.4. Channel Performance Testing

Testing background noise within a shielded box uses the AH module's test mode. This mode might not fully reflect the actual noise floor of the system since the host controller interfaces

aren't fully operational, and some EMI from the host controller may only appear during normal operation. Therefore, consider testing each channel under real conditions to ensure they operate correctly. Since this test is difficult to conduct in a shielded environment, first ensure there is no significant interference in the surroundings.

The general approach is to set up at the required distance for the solution, which doesn't need to be extreme but should be far enough that the signal is not too strong (e.g., around -70dBm RSSI). Assess each channel's performance using metrics such as video smoothness or application-level packet loss rate to determine if each channel can operate normally. If some channels work well and others have noticeable issues, further analysis is required to identify whether the problem is due to external noise or board-level EMI. If the issue is board-level EMI and can be mitigated, do so to maximize the number of usable channels. If not, consider removing the problematic channel from the chan_list (ensure consistency between the AP and STA chan_list, and remove bad channels from both).

Below is a method for manually switching channels in a normal setup to test each channel using a few AT+ commands:

1) **AT+CS_EN=0:** Disable automatic channel switching to prevent it from affecting the manual switching test results.

2) **AT+CS_NUM=xxx:** Manually set the channel switching frequency point, using 700MHz as a reference. For example, to set the frequency to 906MHz, set it to 206; for 922MHz, set it to 222, with 1MHz steps (due to protocol constraints of 8-bit representation). After setting CS_NUM, the AP will coordinate with the STA to switch to the corresponding frequency point after CS_CNT cycles.

3) **AT+CS_CNT=10:** Manually set the countdown beacon cycles for channel switching (default is 10), after which the AP and STA will switch to the frequency set in CS_NUM, maintaining the connection.

These commands should be set on the AP side. Once set, you'll see successful channel switching in the logs. Then, observe if the image lags to determine channel performance.