Mini5 UWB development board

User Manual

Version 1.1

Content

1 Introduction to the YCHIOT Positioning Development Kit 4

1.1 Introduction to the UWB Mini 5 series modules 4

1.2 Glossary of technical terms 6

2 YCHIOT UWB practical project application 8

2.1 What can UWB Mini5 be used for? 8

2.2 What are the advantages and disadvantages of mainstream indoor positioning technologies? 8

3 Q&A on frequently asked technical questions 10

3.1 principle 10

3.2 use 10

3.3 exploitation 11

4 UWB MINI5 POSITIONING KIT TEST INSTRUCTIONS 13

4.1 Anchor AT command function configuration and setting 13

4.2 3 Anchor +1 Tag Test (scenario 1 - Indoor Positioning) 13

4.3 1 anchor + 3 tag test (scenario 2 – electronic fence altert) 16

5 Firmware updates 17

5.1 Mini5 firmware update 17

6 Raw data viewing 18

6.1 View raw data through the serial port 18

6.2 View raw data via USB 18

6.3 View raw data via an external Bluetooth module or Raspberry Pi 19

7 Communication data format with RTLS and secondary development........21

7.1 Introduction to RTLS host computer 21

7.2 RTLS host computer interface.. 22

7.3 TOF Report Message 25

7.4 Log Files 25

7.5 Principles and calculation methods of trilateration.. 26

8 UWB product development..29

8.1 Data calibration method 29

8.2 The impact of occlusion on indoor positioning UWB... 30

9 AT instruction set 31

10 Document Management Information Sheet 33

1 Introduction to the YCHIOT Positioning Development Kit

1.1 Introduction to the UWB Mini 5 series modules

1.1.1 Overview of the UWB Mini 5 series

The UWB Mini5 module uses STM32G070RBT6 microcontroller as the main control chip. Peripheral circuits include: DWM1000 module, power module, LED indication module, reset circuit, etc.

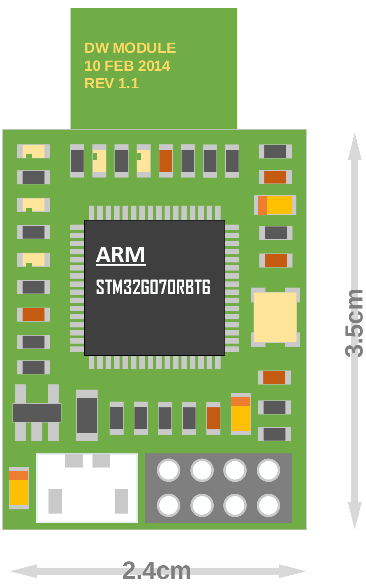


Figure 13.1.1 Front view of UWB Mini5

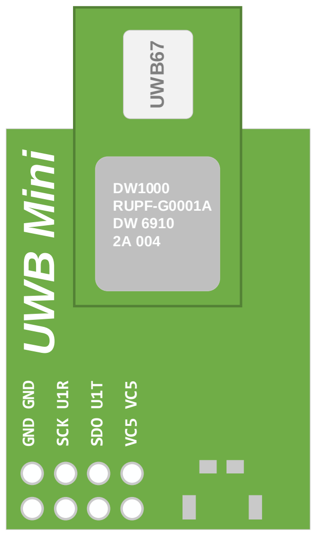
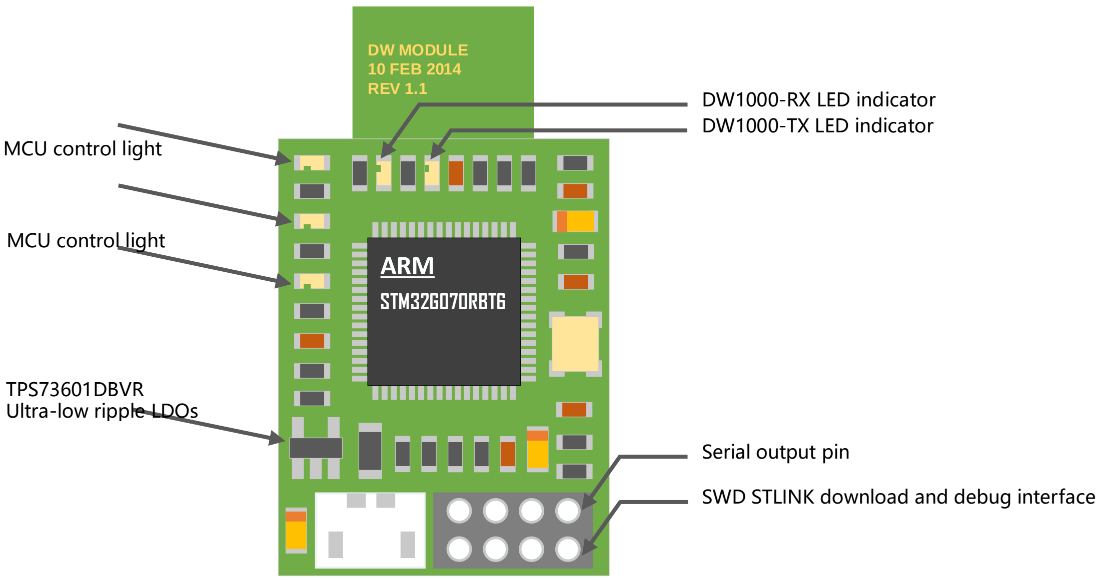


Figure 13.1.2 Rear view of UWB Mini5



1.1.2 UWB Mini 5 hardware parameters

Table 13.2 UWB Mini5 hardware parameters

Basic parameters		Wireless parameters	
PCB process	4-layer board - epoxy	Communication rate	110 kbit/s, 850 kbit/s, 6.8 Mbit/s
Power supply interface	micro-USB(5.0V) / Binding post	Operating frequency	3.5 GHz ~ 6.5 GHz (see Section 1.3.2).
Communication interface	micro-USB (5.0V) / Serial (3.3V TTL).	Work channel	6 (See Section 1.3.2).
Download the interface	SWD (VCC SDIO SCK GND)	Transmit power	-35dbm/MHZ ~ -62dbm/MHZ can be programmed
Main controller	STM32G070RBT6(64pin)	Maximum package length	1023 bytes
External crystal oscillator	8Mhz	Communication distance	30m for Mini5-CA and 80m for Mini5-SMA
PCB size	35mm * 24mm	Data jitter	The typical ± is 10cm, and the general occlusion ± 30cm

1.1.3 UWB Mini 5 supports frequency bands

UWB transmit power is less than WIFI and there should be no personal injury. From the DW1000 datasheet, it can be seen that the currently supported channels are only within the range of frequency bands that can be used by Channel5 and Channel7 in China.

Table 1.33 UWB IEEE802.15.4-2011 DWM1000 supported UWB channels

UWB channel UWB Channel	Center Frequency (MHz) Centre Frequency	Frequency Band (MHz) Band	Bandwidth (MHz) Bandwidth
1	3494.4	3244.8 – 3744	499.2
2	3993.6	3744 – 4243.2	499.2
3	4492.8	4243.2 – 4742.4	499.2
4	3993.6	3328 – 4659.2	1331.2*
5	6489.6	6240 – 6739.2	499.2
7	6489.6	5980.3 – 6998.9	1081.6*

Note: The maximum receive bandwidth of the DWM1000 is about 900MHz

1.1.4 UWB Mini 5 Channel 2 Measured Spectrum

Connecting the UWB Mini 5 antenna to the spectrum analyzer FSL6 (Rohde & Schwarz) yielded a Channel 2 center frequency of 4 GHz and a maximum gain of -49.96 dBm, as shown in the figure below.

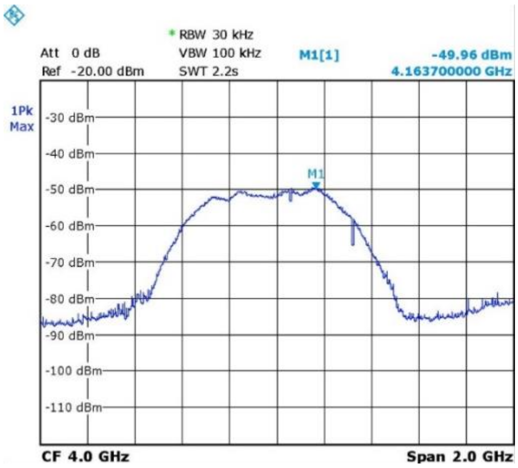


Figure 1.3.3 UWB Mini 5 transmit power test

1.2 Glossary of technical terms

Table 1.4 Abbreviations of technical terms

Shorthand	Full name in English	meaning
ANCHOR		A anchor, also known as a beacon anchor, is a node that has obtained location coordinates in advance by other means
DW1000		A chip from Decawave
DWM1000		A module from Decawave
IC	integrated circuit	chip
PHY	physical layer	Physical layer
PSR	preamble symbol repetitions	The leading symbol is repeated
RTLS	real time location system	Real-time location system
TAG		tag
TDOA	time difference of arrival	TDOA positioning is a method of positioning using time differences. By measuring the time it takes for the signal to reach the monitoring station, the distance of the signal source can be determined.
TOA	time of arrival	TOA positioning is a method that directly uses the arrival time of the signal for positioning.
TOF	time of flight	The TOF time-of-flight ranging method mainly

		uses the time of flight of the signal to and from two asynchronous transceivers (or reflected surfaces) to measure the distance between nodes.
TWR	two-way ranging	The bidirectional ranging method, i.e. two asynchronous transceivers (Transceiver) can obtain the ranging value.
UWB	ultra-wide band	UWB (Ultra Wideband) is a carrier-less communication technology that uses non-sine wave narrow pulses in the nanosecond to picosecond order to transmit data.

2 YCHIOT UWB practical project application

2.1 What can UWB Mini5 be used for?

According to the needs provided by customers and the actual application situation, after a series of technical return visits, UWB Mini5 indoor positioning products have been applied in the following application scenarios: such as airport halls, exhibition halls, warehouses, supermarkets, libraries, underground parking lots, mines and other environments. The specific scenarios are as follows:

- smart luggage, smart stroller;
- factory container and cargo positioning;
- Help visitors find the appropriate attractions and public facilities in the playground;
- supermarket personnel positioning;
- Helping visitors to understand exhibits and view exhibitions more effectively in museums;
- Positioning of mine personnel and the working condition of the roadheader;

2.2 What are the advantages and disadvantages of mainstream indoor positioning technologies?

In recent years, some technology giants, including Google, Microsoft, Apple, Broadcom, etc., as well as some world-famous universities, have been researching indoor positioning technology. According to the research and investigation of domestic and foreign literature, Bluetooth, wireless radio frequency, etc., have been widely used in indoor positioning in offices, homes, factories and other scenarios. The advantages and disadvantages of mainstream indoor positioning technologies at home and abroad are shown in the following table:

Table 22 Advantages and disadvantages of mainstream indoor positioning technology at home and abroad

Indoor positioning technology	merit	shortcoming
Ultrasonic positioning technology	High precision and simple structure.	It is greatly affected by the multipath effect and non-line-of-sight propagation, and at the same time, it requires a large amount of

		investment in underlying hardware facilities, and the cost is too high.
Bluetooth location technology/ibeacon	The equipment is small in size, easy to integrate, and easy to popularize.	For complex space environments, the stability of the Bluetooth system is slightly poor, and it is greatly interfered by noise signals.
Radio Frequency Identification (RFID) technology	The size of the logo is relatively small, and the cost is relatively low.	It has a short range of functions, does not have communication capabilities, and is not easy to integrate into other systems.
UWB ultra-bandwidth technology	Strong penetration, low power consumption, good anti-multipath effect, high security, low system complexity, and can provide accurate positioning accuracy.	It will have a certain impact when encountering shelters, metals, etc., and the price is slightly expensive, and there is still some distance from large-scale production.
SLAM technology	Create a map in a completely unknown environment under the condition of its own uncertain position, and use the map for autonomous positioning and navigation.	The amount of image data is huge, and the equipment is very expensive, which is suitable for research and not suitable for mass production.

3 Q&A on frequently asked technical questions

3.1 principle

3.1.1 What is the ranging principle of UWB?

In the two-way-time of flight (TW-TOF) method, each module generates an independent timestamp from the start-up. Module A's transmitter transmitsa request pulse signal at T a1 on its timestamp, and module B transmits a responsive signal at Tb2, which is received by module A at its own timestamp Ta2. At one time, it was possible to calculate the flight time of the pulse signal between the two modules, and thus determine the flight distance S.

S = Cx[(T a2-Ta1)-(Tb2-Tb1)] (C is the speed of light).

3.1.2 How does UWB positioning work?

1) Distance = Speed of light * Time difference / 2;XY plane, 3 circles, able to determine a point;
2) XYZ space, 4 circles, able to determine a spatial point;

3.2 use

3.2.1 Can this module measure distance through walls?

Answer: Penetrating the wall will cause signal blockage, resulting in ranging failure. This is determined by the principle of UWB positioning. Small obstacles, such as tables and chairs, do not have a great impact on the accuracy of positioning.

3.2.2 Is there anything I should pay attention to when installing this module?

Keep the module at least 1m away from obstacles such as walls and tables. Otherwise, the location data will not be accurate. Try not to get obscured around the antenna. The anchor is best placed on a tripod and **more than 2 meters above the ground**.

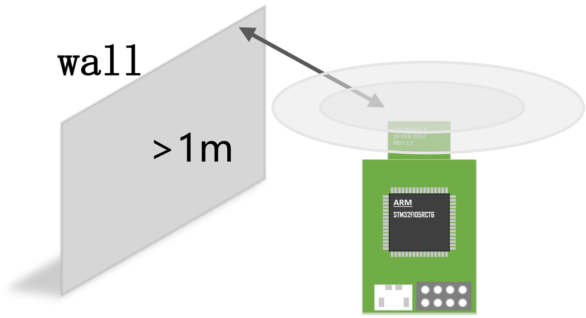


Figure 3.2.2 Precautions for installing anchor tags

3.2.3 Why does the anchor heat up when in use?

A: There will be a fever, which is normal. However, it will not burn out the module, so please feel free to use it.

3.2.4 Can the mini-map of the host computer be customized?

A: It can be customized, PNG format import is supported, and it can be drawn with Microsoft Office Visio .

3.3 exploitation

3.3.1 What are the main sources of error in TOF and TDOF ranging?

1) Signal impairment. The ranging information for indoor positioning is based on the assumption that the distance is measured in the case of line-of-sight, and if there is non-line-of-sight, such as an obstacle in the middle or through reflection, it will cause the reception time to become longer, and the measured distance will become larger.
2) The anchor coordinates are incorrect. The coordinates of the tag are relative to the coordinates of the anchor Anchor, if the coordinates of the anchor itself are wrong, then our positioning data is meaningless.
3) Clock synchronization error. Each anchor will have a slight gap in their clocks, but if the gap is 1ns, there will be an error of 30 centimeters, so if we can synchronize the time of all anchors in the system, we can further improve the positioning accuracy.

3.3.2 Are there any good books and websites for UWB development that I can

refer to?

1) "Wireless Positioning System", Electronic Industry Press, Liang Jiuzhen
2) DWM1000 Hardware Vendors (Forum): https://forum.qorvo.com/c/ultra-wideband/5
3) Kickstarter Crowdfunding Projects: https://www.pozyx.io/
4) Indoor Positioning Map: https://navigine.com/andhttps://github.com/Navigine/

4 UWB MINI5 POSITIONING KIT TEST INSTRUCTIONS

A UWB positioning system is composed of at least four units, that is, 3 anchors + 1 tag, the anchor can be selected as Mini5-SMA/Mini5-CA development board, and the tag can be selected as Mini5-SMA/Mini5-CA development board, which can be mixed. Thereafter, tags and anchors can be purchased to expand the number of tags and quantities in the system. The number of anchors and tags that can be supported depends on the firmware version purchased.

4.1 Anchor AT command function configuration and setting

The default configuration has been written from the factory and does not need to be modified. For modifications, please refer to Chapter 9 AT Instruction Set.

4.2 3 Anchor +1 Tag Test (scenario 1 - Indoor Positioning)

1) Hardware platform to build networking
2) Install the CH340 driver.
3) The A0 anchor is directly connected to USB;
4) DecaRangeRTLS.exe opening the host computer software, if the figure 4.2.2 appears, there may be the following reasons:
   - The installation of the virtual serial port driver failed, and the software could not find *COMx*;
   - USB is not connected on the hardware; The Micro-USB cable does not support communication or uses a damaged Micro-USB cable;

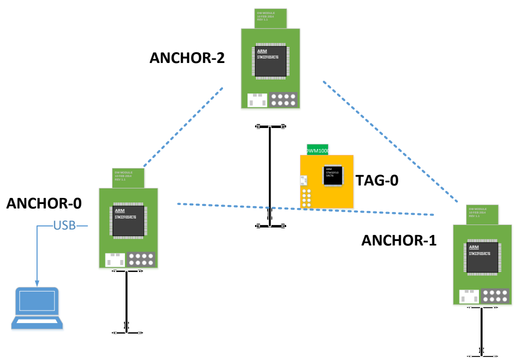


Figure 4.2.1 Schematic diagram of the positioning system 3 anchor + 1 tag

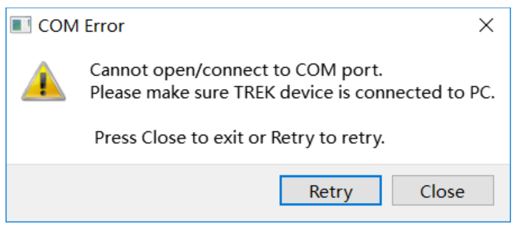


Figure 4.2.2 The host computer cannot communicate

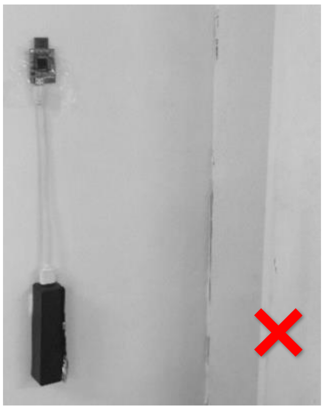
Note 1: Most Win7 users can't open the host computer, but you can see DecaRangeRTLS.exe background process, encounter this problem (currently can't solve the problem), please try it on a different computer;

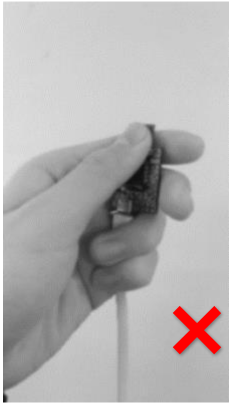
Note 2: Some high-resolution screen users (2K screen or 4K screen users) will have the problem of incomplete text display on the host computer, and can be displayed by adjusting the separator;

5) All tags are powered by power banks;
6) A1/A2 anchor is powered by power bank;
7) Precautions for product placement
8) The placement of anchors and tags directly affects the accuracy of positioning. Here are a few common mistakes:


Place the module near the metal


Place the module flat on the desktop


Glue the module to the wall


Hold the antenna in your hand

The correct installation method is shown in the figure below:



1) Operating software

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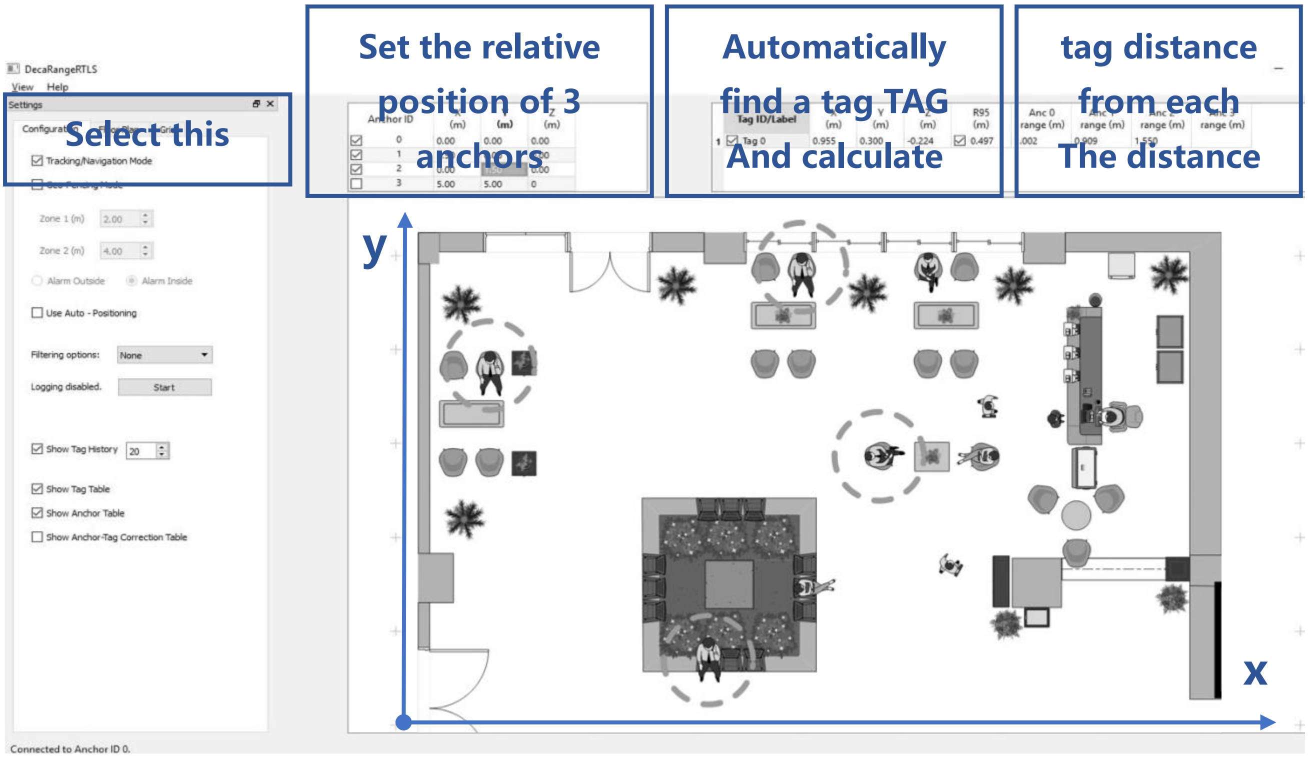


2) For a larger positioning system, it is best to need four anchors.

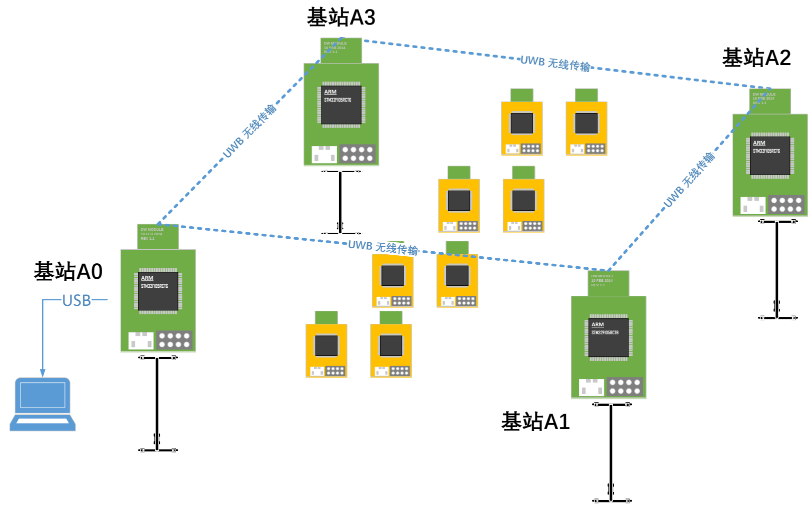


Figure 4.23. Schematic diagram of positioning 4 anchor + multi-tag hardware platform

4.3 1 anchor + 3 tag test (scenario 2 – electronic fence altert)

1) hardware networking;
2) Install the serial port driver (same as above);
3) A0 Connect to a computer via USB (same as above);
4) Open the host computer software DecaRangeRTLS.exe (Same as above);
5) All tags are powered by a power bank;
6) Note: If there is only one tag (1 tag for 1 anchor), the test can also be carried out in this mode, but the whole system can only be run if there is a anchor A0. I won't repeat it below.
7) Operating software: Set to Geo-Fencing Mode

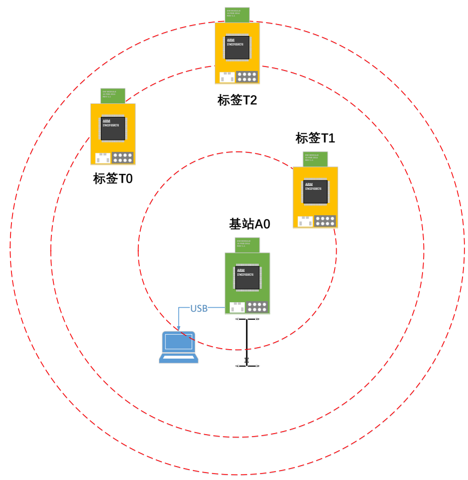
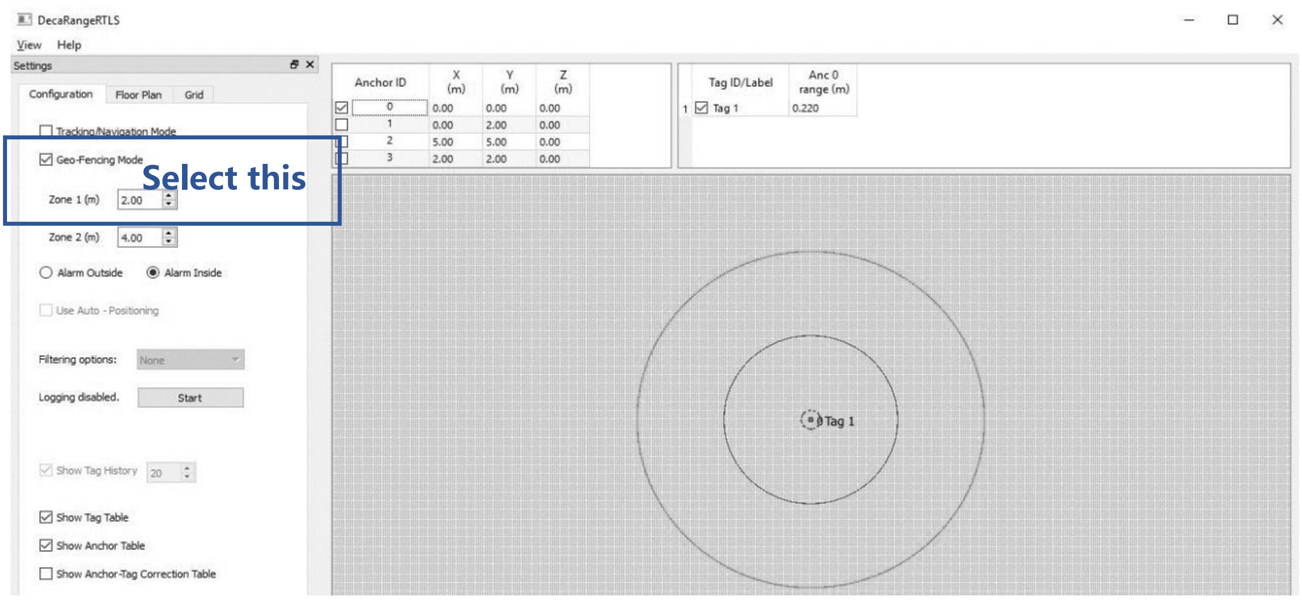


Figure 4.3 Schematic diagram of over-range alarm 1 anchor + 3 tag hardware platform



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5 Firmware updates

5.1 Mini5 firmware update

5.1.1 STLINK is connected to the Mini 5 hardware

If you need to upgrade or modify the firmware of UWB Mini5, you need to use STLINK to update the firmware, as shown in the following figure.

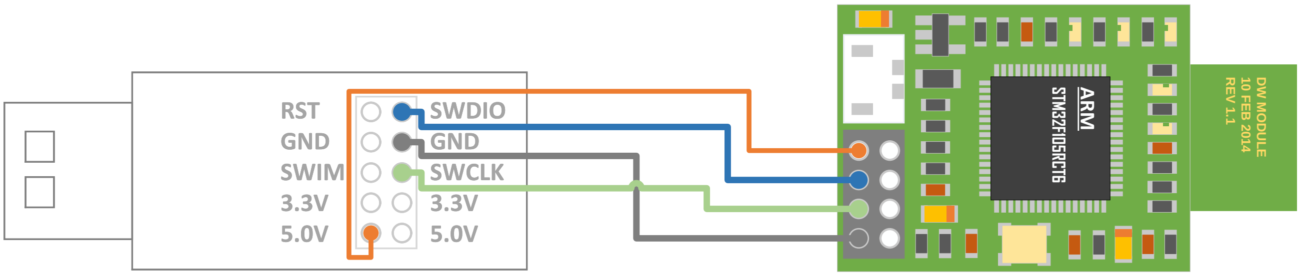


Figure 51 How to wire STLINK V2 Downloader with Mini5 hardware

5.1.2 STLINK DOWNLOAD SETTINGS

Please refer to the manual AP03-UWB module firmware update.
Document download address: https://www.ychiot.com/documents/

6 Raw data viewing

6.1 View raw data through the serial port

If the data is received through the serial port, set the baud rate to 115200bps, the data bit is 8 bits, the stop bit is 1 bit, and there is no check bit. According to Figure 5.2 connection, open the XCOM serial port debugging assistant on the computer, and you can observe TOF Report Message Data stream.

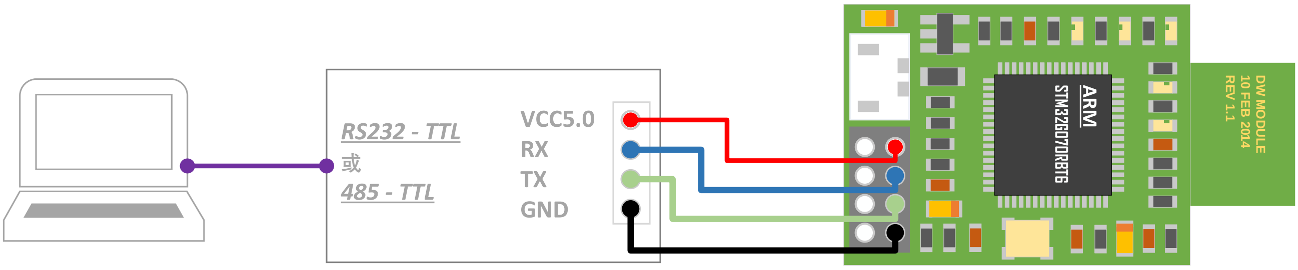


Figure 6.1 UWB Mini 5 module is connected to TTL to RS232 module or TTL to 485 module

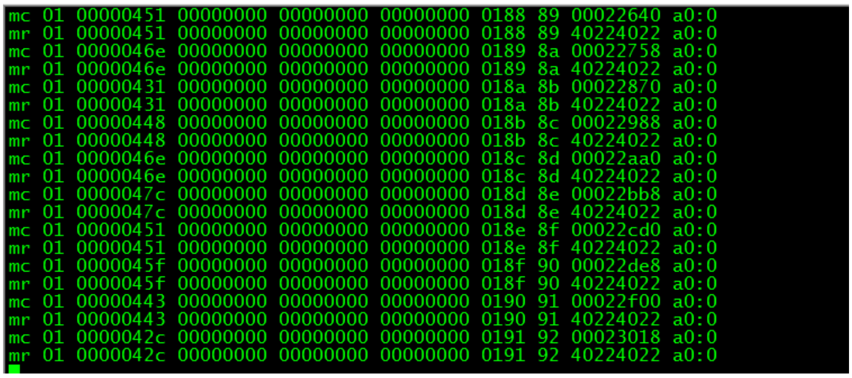


Figure 6.2 Data received by the serial port debugging assistant

6.2 View raw data via USB

If the data is received through the serial port, set the baud rate to 460800bps, the data bit is 8 bits, the stop bit is 1 bit, and there is no check bit. According to Figure 5.2 connection, open the XCOM serial port debugging assistant on the computer, and you can observe TOF Report Message Data stream.

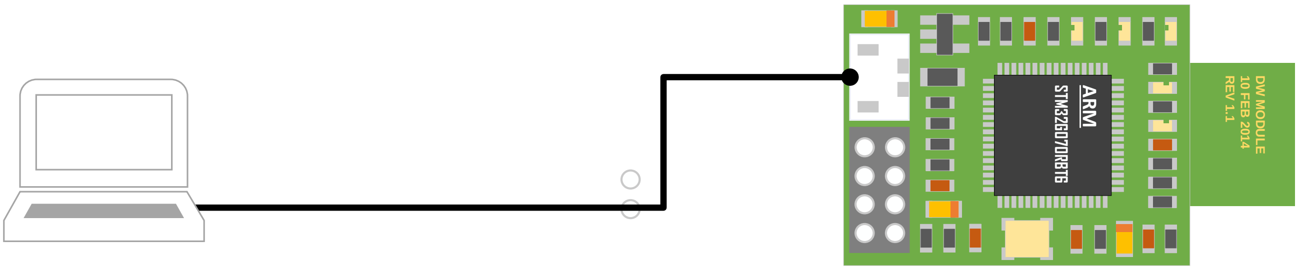


Figure 6.3 UWB Mini 5 module is directly connected to USB

```
mc 01 00000451 00000000 00000000 00000000 0188 89 00022640 a0:0
mr 01 00000451 00000000 00000000 00000000 0188 89 40224022 a0:0
mc 01 0000046e 00000000 00000000 00000000 0189 8a 00022758 a0:0
mr 01 0000046e 00000000 00000000 00000000 0189 8a 40224022 a0:0
mc 01 00000431 00000000 00000000 00000000 018a 8b 00022870 a0:0
mr 01 00000431 00000000 00000000 00000000 018a 8b 40224022 a0:0
mc 01 00000448 00000000 00000000 00000000 018b 8c 00022988 a0:0
mr 01 00000448 00000000 00000000 00000000 018b 8c 40224022 a0:0
mc 01 0000046e 00000000 00000000 00000000 018c 8d 00022aa0 a0:0
mr 01 0000046e 00000000 00000000 00000000 018c 8d 40224022 a0:0
mc 01 0000047c 00000000 00000000 00000000 018d 8e 00022bb8 a0:0
mr 01 0000047c 00000000 00000000 00000000 018d 8e 40224022 a0:0
mc 01 00000451 00000000 00000000 00000000 018e 8f 00022cd0 a0:0
mr 01 00000451 00000000 00000000 00000000 018e 8f 40224022 a0:0
mc 01 0000045f 00000000 00000000 00000000 018f 90 00022de8 a0:0
mr 01 0000045f 00000000 00000000 00000000 018f 90 40224022 a0:0
mc 01 00000443 00000000 00000000 00000000 0190 91 00022f00 a0:0
mr 01 00000443 00000000 00000000 00000000 0190 91 40224022 a0:0
mc 01 0000042c 00000000 00000000 00000000 0191 92 00023018 a0:0
mr 01 0000042c 00000000 00000000 00000000 0191 92 40224022 a0:0
```

Figure 6.4 Data received by the serial port debugging assistant

6.3 View raw data via an external Bluetooth module or Raspberry Pi

UWB Mini 5 can be connected to an external BLE 4.0 or above serial Bluetooth module, which can realize the data viewing of Android phones and Apple mobile phones.

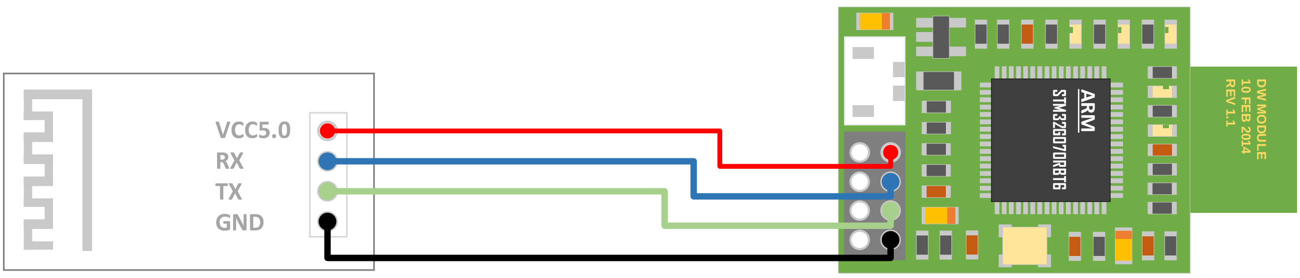


Figure 65 The UWB Mini 5 module is connected to the Bluetooth module

Raspberry Pi or Arduino is a development board with a TTL level of 5V, and when connected to a UWB module, **a current limiting resistor of 27R~51R needs to be connected in series.**

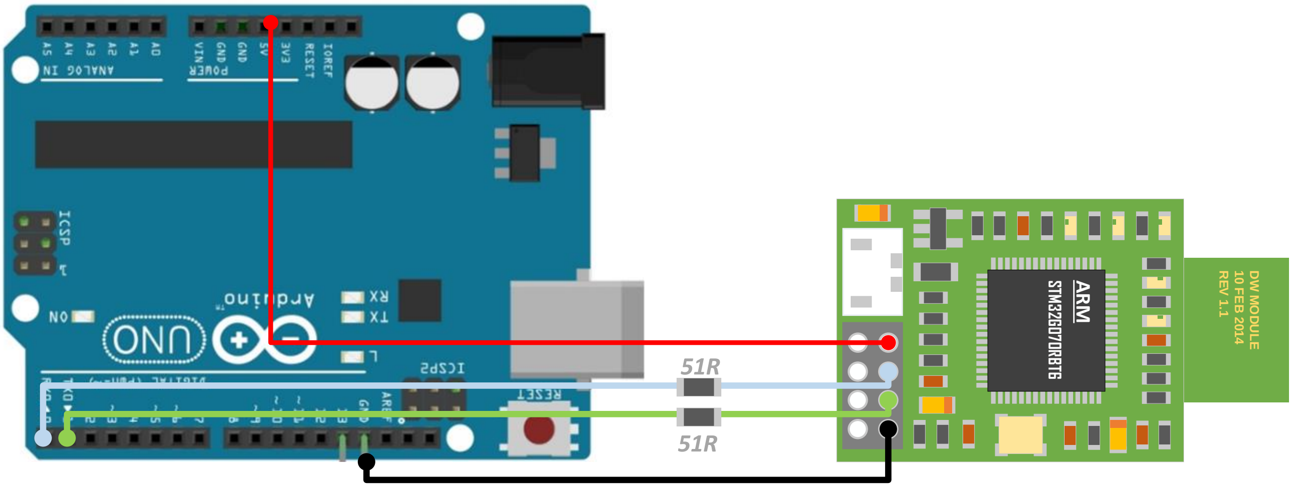


Figure 66 UWB Mini 5 module is connected to a microcontroller (Arduino).

7 Communication data format with RTLS and secondary development

7.1 Introduction to RTLS host computer

This section introduces the use of PC host computers. This host computer software uses *QT 5.9.0 MinGM* is written in C++. Qt is a cross-platform C++ graphical user interface application development framework developed by Wonder Technology in 1991. It can be used to develop both GUI and non-GUI programs, such as console tools and servers. Qt is an object-oriented framework that uses special code generation extensions (called meta-object compilers) as well as some macros that are easily extensible and allow component programming. In April 2014, Qt Creator 3.1.0, a cross-platform integrated development environment, was officially released, which realized full support for iOS, added plug-ins such as WinRT and Beautifier, abandoned GDB debugging support without Python interface, integrated Clang-based C/C++ code modules, and made adjustments to Android support, so as to achieve full support for iOS, Android, and WP.

The main functions realized by this host computer are:

1) Establish a connection with the virtual COM port of the UWB module;
2) Read the TOF report message from the UWB module;
3) a list of anchors, in which the actual location of the anchors can be set;
4) Tag list, which can show the distance of the tag from the anchor and the location of the tag (XYZ coordinates);
5) Map display, support custom import of a PNG format map, can achieve zoom and coordinate fine-tuning;
6) other parameter settings;

7.2 RTLS host computer interface

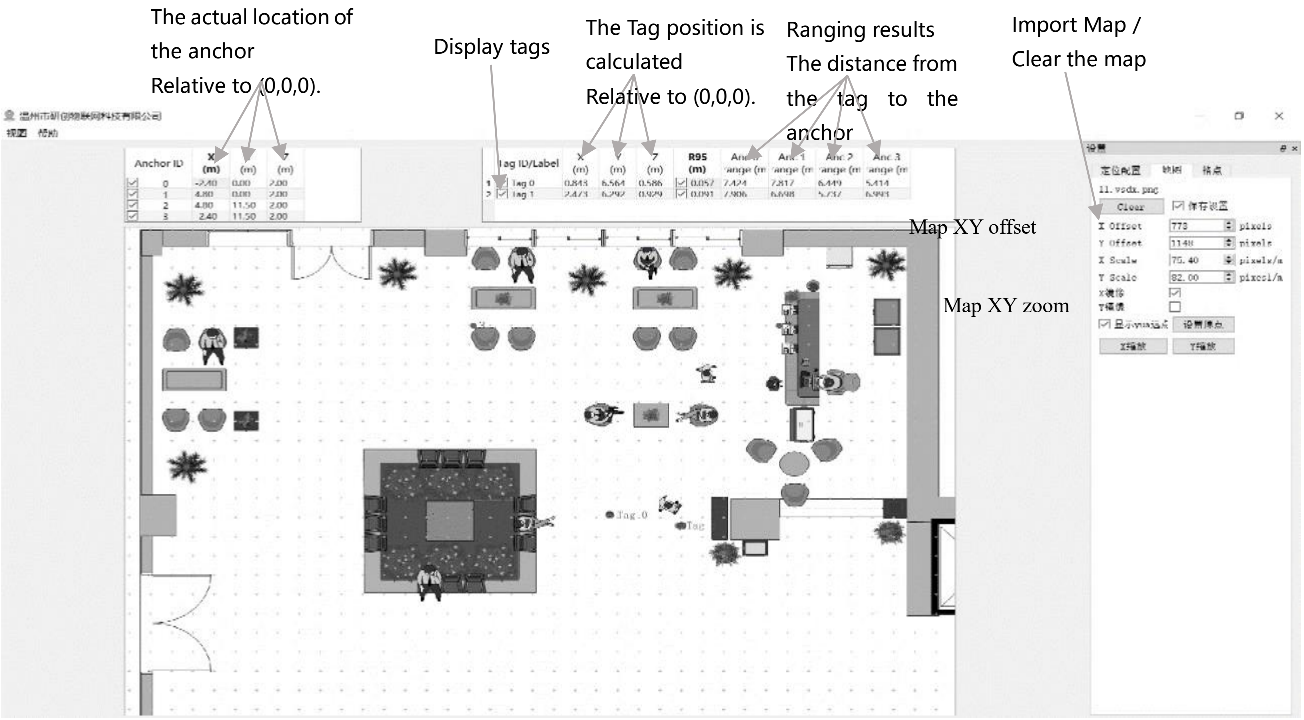


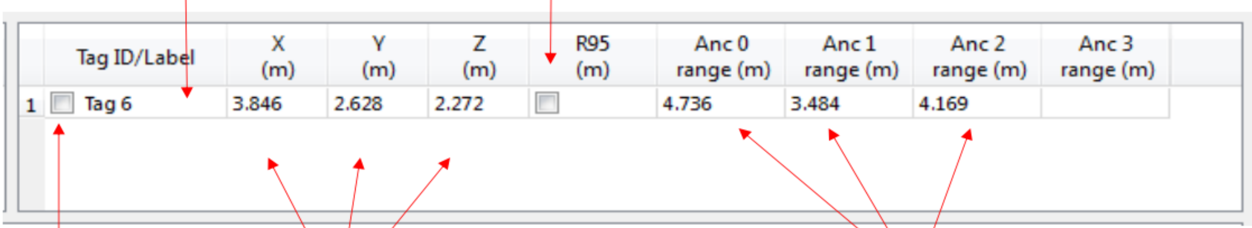
Figure 6.2.1 RTLS host computer interface

◆ Graphics

- Tag and Anchor Tables

The tag table contains the tag ID, ranging information, and positioning coordinates.

Double-click the Tag tag to modify the R95 statistical variable



	Tag ID/Label	X (m)	Y (m)	Z (m)	R95 (m)	Anc 0 range (m)	Anc 1 range (m)	Anc 2 range (m)	Anc 3 range (m)
1	☐ Tag 6	3.846	2.628	2.272	☐	4.736	3.484	4.169	

Whether or not to display the Tag Lable Tag solved location The ranging value from the module (tag-anchor distance).

Figure 6.22 Tag Table

- R95 Statistical Variable References:

https://baike.baidu.com/item/%E7%BD%AE%E4%BF%A1%E5%8C%BA%E9%97%B4/7442583?fr=aladdin

- The position of the tag solution is calculated according to the distance between the tag and the anchor, and the specific solution method is described in Section 7.5

	Anchor ID	X (m)	Y (m)	Z (m)
☑	0	0.00	0.00	3.00
☑	1	6.00	0.00	3.00
☑	2	0.00	4.00	3.00
☐	3	5.00	5.00	3.00

Figure 6.2.3 Anchor Table

Anchor Tables contain the ID of the anchor anchor and the location information of the anchor.

◆ Status Bar

The status bar in the lower left corner reads as follows:

- "DecaRangeRTLS Anchor/Tag ID Mode" – Open the software and the COM port is successfully connected
- "Connected to Anchor/Tag/Listener ID" – The tag/anchor is connected and receiving TOF data
- "No location solution" – The software cannot solve the coordinates based on the ranging data
- "Open error" – The software failed to open the virtual serial port

◆ View Settings

The view settings consist of three tables: configuration, floorplan, and grid.

- Configuration Table

name	description
Tracking/Navigation Mode	Positioning mode
Geo-Fencing Mode	Out-of-range alarm mode
Zone1	Scope 1

Zone2	Scope 2
Alarm Outside/Inside	Alarm outside the circle/inside the circle
Show Tag History (N)	Displays the last N historical points
Show Tag Table	Tag Table is displayed
Show Anchor Table	The Anchor Table is displayed
Auto Positioning	Auto-positioning mode, in which the anchor position does not need to be set, is carried out
Filtering	Set up data filtering
Logging	Whether to generate logs

- Grid Table

name	description
Width	Width, in meters
Height	Height, in meters
show	Whether to display grid points

- Floor Plan tab

name	description
Open	Open a map and import the software
X offset	In pixels in the X direction, pan the map
Y offset	In pixels in the Y direction, pan the map
X scale	In the X direction, in pixels, zoom the map
Y scale	In pixels in the Y direction, zoom the map
Flip X	The X-axis is the axis of symmetry, and mirroring is performed
Flip Y	The Y axis is the axis of symmetry, and mirroring is performed
show	Whether to display the origin
Set Origin	Set the origin
X Scale button	Clicking this button will bring up a widget that measures the distance on the map, enters the actual distance, and sets the zoom value of X
Y Scale button	Clicking this button will bring up a widget that measures the distance on the map, enters the actual distance, and sets the

	zoom value of Y

7.3 TOF Report Message

Open any serial port debugging assistant, no need to set parameters such as baud rate, you can observe that the anchor A0 transmits data to the USB of the PC through the USB virtual serial port in the following format:

```
mc 0f 00000663 000005a3 00000512 000004cb 095f c1 00024c24 a0:0
MID MASK      RANGE0          RANGE1           RANGE2       RANGE3       NRANGES  RSEQ        DEBUG      aT:A
```

Table 6.3.1 TOF data format table

content	function
MID	mc stands for tag-anchor distance (optimized and corrected data for positioning tags)
MASK	Indicates which messages are valid for RANGE0, RANGE1, RANGE2, RANGE3; For example, MASK=7 (0000 0111) means that RANGE0, RANGE1, RANGE2 are all valid
RANGE0	Indicates the distance from tag x to anchor 0 in mm
RANGE1	Indicates the distance from tag x to anchor 1 in mm
RANGE2	Indicates the distance from tag x to anchor 2 in mm
RANGE3	Indicates the distance from tag x to anchor 3 in mm
NRANGES	Unit Raw Range count value (will add up)
RSEQ	Range sequence number count value (will accumulate over and over again)
DEBUG	If MID=ma, it represents the TX/RX antenna delay
aT:A	T is the tag ID and A is the anchor ID The ID mentioned here is just a short ID, and the full ID is a 64 bit ID

7.4 Log Files

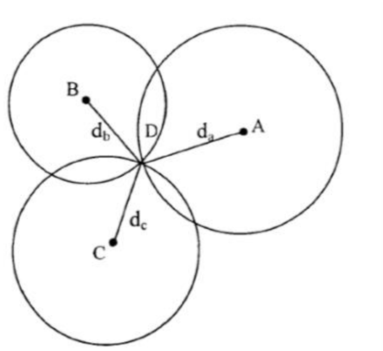
When using the host computer, click "Start", and in the Log folder, a log file in yyyymmdd_hhmmssRTLS_log.txt text format will be generated, which means as follows:

Table 6.4.1 Meanings of log files

Log content	meaning
T:151734568:DecaRangeRTLS:LogFile:Ver. 2.10 TREK:Conf:Anchor0:1:Chan2	15:17, 34s, 568ms, version V2.10, currently connected to A0, 6.8M, Channel 2
T:151734600:AP:0:-2.4:0:0 T:151734600:AP:1:4.8:0:0 T:151734600:AP:2:4.8:11.5:0 T:151734600:AP:3:-2.4:11.5:0	15:17, 34 sec, 600ms, Anchor Position 0 (X, Y, Z).
T:151734614:RR:0:0:8808:8808:147:27185 T:151734614:RR:0:1:9174:9174:147:27185 T:151734614:RR:0:2:5668:5668:147:27185 T:151734614:RR:0:3:4815:4815:147:27185	RR: Range Report: TagID: AnchorID: Reported Range: Corrected Range: Sequence# : Range Number
T:151734614:LE:0:2627:146:[0.743669,7.9919,-1.89245]:8794:9160:5687:4773	LE: Location Estimate: TagID: LE Count: Sequence #:[x,y,z]: Range to A0: Range to A1: Range to A2: Range to A3:
T:151734614:TS:0 avx:0.786397 avy:8.00351 avz:-1.93044 r95:0.0732666	TS: Tag Statistics: TagID: Average X: Average Y: Average Z

7.5 Principles and calculation methods of trilateration

7.5.1 Theoretical basis of trilateration based on UWB ranging



The principle of trilateration is shown in the figure on the right, with three nodes A, B, and C as the center of the circle, and the coordinates are, the three circumferences intersect at one point D, the intersection point D is the moving node, A, B, and C are the reference nodes, and the distances between A, B, and C and the intersection point D are „。 respectively Suppose the coordinates of the intersection point D are ((X_a, Y_a), (X_b, Y_b), (X_c, Y_c) $d_a d_b d_c$X, Y).

$$\begin{cases} \sqrt{(X-X_a)^2+(Y-Y_a)^2}=d_a \\ \sqrt{(X-X_b)^2+(Y-Y_b)^2}=d_b \\ \sqrt{(X-X_c)^2+(Y-Y_c)^2}=d_c \end{cases} \qquad (6.5.1)$$

From Eq. 7.5.1, the coordinates of the intersection D can be obtained:

$$\begin{pmatrix} X \\ Y \end{pmatrix} = \begin{pmatrix} 2(X_a - X_c) & 2(Y_a - Y_c) \\ 2(X_b - X_c) & 2(Y_b - Y_c) \end{pmatrix}^{-1} \begin{pmatrix} X_a^2 - X_c^2 + Y_a^2 - Y_c^2 + d_c^2 - d_a^2 \\ X_a^2 - X_c^2 + Y_b^2 - Y_c^2 + d_c^2 - d_b^2 \end{pmatrix} \qquad (6.5.2)$$

The defect of trilateration is that because the hardware and power consumption of each node are not the same, the measured distance cannot be an ideal value, so that the above three circles may not just intersect at one point, but in practice, they must intersect in a small area, so there is a certain error in the (X, Y) coordinate value calculated by this method. In this way, a certain algorithm is needed to estimate a relatively ideal position as the optimal solution for the coordinates of the current moving node.

7.5.2 Trilateration Function

In the trilateration.cpp file, the function of GetLocation() is to calculate the best solution (unit: m) of the tag by passing in the coordinates (unit: m) of the anchor and the distance (unit: mm) from each anchor to the tag.

As mentioned in the previous section, because the measured distance cannot be an ideal value, the above three circles may not just meet at one point, so when the anchor A0/A1/A2 is working, from a mathematical point of view, there will be 2 solutions; When A0/A1/A2/A3 is working, there must be an optimal solution. A3 is the auxiliary anchor, and after A0/A1/A2 completes a Trilateration algorithm, two solutions are obtained, and the solution closest to the A3 sphere is taken as the optimal solution.

Note: trilateration.cpp file is the source code of the PC side, and the kit with more than 4 tags for 4 anchors is provided free of charge.

7.5.3 Why is the Z-axis less accurate than the X-axis and Y-axis?

As shown in the figure, A0/A1/A2 is 3 anchors, T0 is the tag, LA0T0 LA1T0 LA2T0 is the distance from each anchor to the tag. In the case of completely accurate ranging, the calculated Tag coordinate should be at T0, however, since the actual measured value LA0T0 LA1T0 LA2T0 may be on the large side, the solved position is at T0'. Because A0/A1/A2 are all in *the xoy* plane, most of the ranging errors will be accumulated on the z-axis, resulting in jitter of the z-axis data.

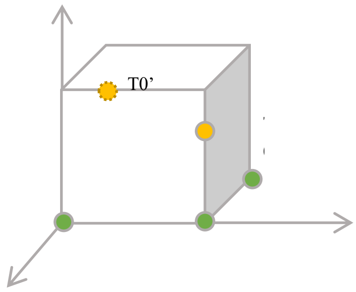


Figure 7.5.3 Schematic diagram of Z-axis data error

8 UWB product development

8.1 Data calibration method

Some customers reported that the measured value of the UWB module is always larger than the actual distance; Some users have reported that the UWB module measurements are smaller than the actual distance, what is going on? This is due to the fact that the environment of the site we use is different, and it is disturbed by factors such as latitude and longitude, air quality, environmental obstacles, altitude, etc., so in the process of productization, the module must be calibrated.

In general, calibration only needs to be performed once in the field, and the correction coefficient is obtained through the ranging of 1 Anchor and 1 Tag, and it is not necessary to calibrate each Anchor and Tag.

Using Microsoft Excel software, data fitting is performed and fitting formulas are generated. There are many fitting formulas, the simplest being linear equations.

UWB测量距离	实际距离（米尺测量）
1390.00	1000.00
2550.00	2000.00
3540.00	3000.00
4660.00	4000.00
5570.00	5000.00
6780.00	6000.00
7670.00	7000.00
8620.00	8000.00
9750.00	9000.00
10750.00	10000.00
11740.00	11000.00
12770.00	12000.00
13650.00	13000.00
14650.00	14000.00
15780.00	15000.00
16750.00	16000.00
17650.00	17000.00
18660.00	18000.00
19780.00	19000.00
20460.00	20000.00
21550.00	21000.00
22600.00	22000.00
23600.00	23000.00
24610.00	24000.00
25660.00	25000.00
26800.00	26000.00

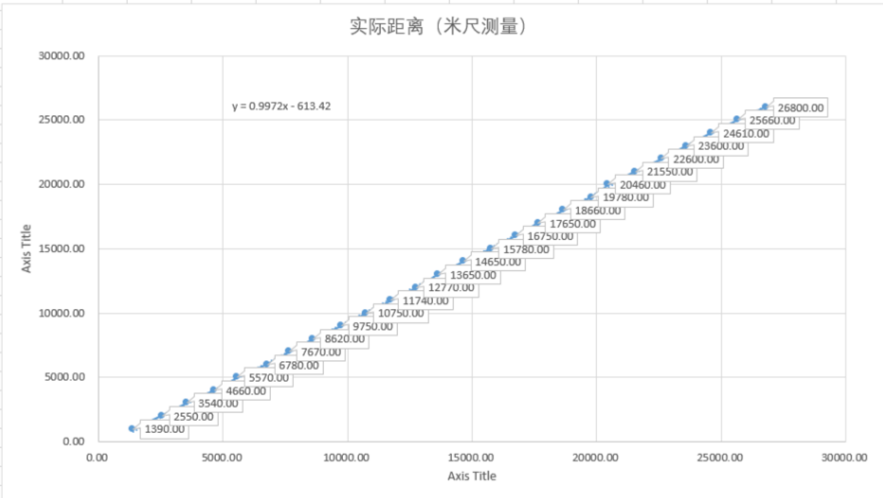


Figure 8.1 Mini5 calibration EXCEL table

There are instancegetidist_mm (0), instancegetidist_mm (1), instancegetidist_mm (2), instancegetidist_mm (3) of the four variables, and each distance needs to be substituted into the calibration formula just calculated. In the main.c function, the original program is:

```
n = sprintf((char*)&usbVCOMout[0], "mc %02x %08x %08x %08x %08x %04x %02x %08x %c%d:%d\r\n",
valid, instancegetidist_mm(0), instancegetidist_mm(1),
instancegetidist_mm(2), instancegetidist_mm(3),
l, r, rangeTime,
(instance_mode == TAG)?' t':'a', taddr, aaddr);
```

Amend it to read:

```
n = sprintf((char*)&usbVCOMout[0], "mc %02x %08x %08x %08x %08x %04x %02x %08x %c%d:%d\r\n",
     valid, (int)((instancegetidist_mm(0)*0.9972)-613.42), (int) ((instancegetidist_mm(1)*0.9972)-613.42),
            (int) ((instancegetidist_mm(2)*0.9972)-613.42), (int) ((instancegetidist_mm(3)*0.9972)-613.42),
l, r, rangeTime,
(instance_mode == TAG)?' t':'a', taddr, aaddr);
```

To recompile the software, you only need to download the program to the UWB module connected to the computer, and you don't need to download every module. With data correction, the UWB module measures the distance values with a very high degree of accuracy.

8.2 The impact of occlusion on indoor positioning UWB

The impact of occlusion on UWB positioning can be divided into the following scenarios:

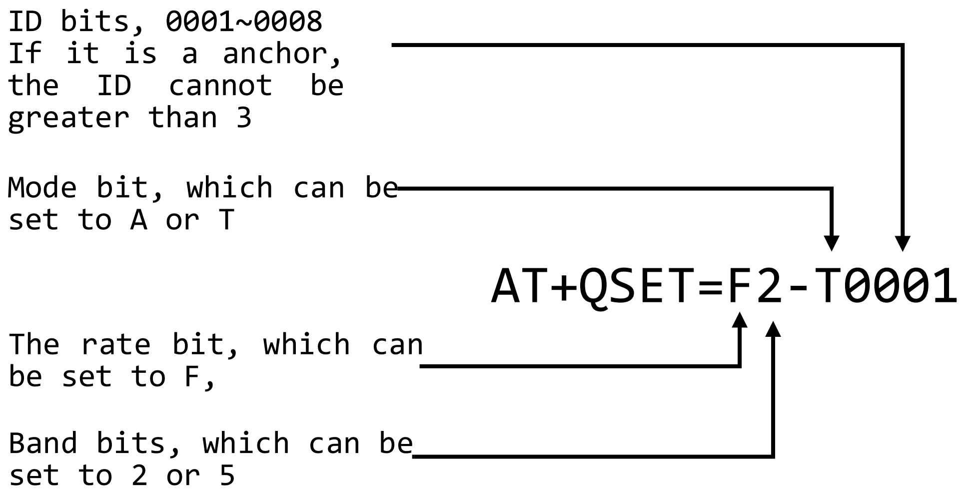
1) Solid wall: This occlusion of the solid wall will make the UWB signal attenuation by 60-70% and the positioning accuracy error increase by about 30 cm.
2) Steel plate: Steel absorbs UWB pulse signals very badly, which will make UWB unable to locate.
3) Glass: Glass occlusion does not have much effect on UWB positioning accuracy.
4) Wood or cardboard: Generally, wood or cardboard with a thickness of about 10 cm does not have much impact on the positioning accuracy of UWB.
5) Telephone poles or trees: When the poles or written shields are blocked, it is necessary to see the distance between them from the anchor or the tag, and whether the relative distance between the anchor and the tag is very small, for example, the distance between the anchor and the positioning tag is 50 meters, and the pole or tree is just in the middle of the two, 25 meters, this kind of shielding has no great impact, such as the distance from the anchor or the tag is very close to less than 1 meter, the impact is great.

9 AT instruction set

The PC initiates the command	type	meaning	The UWB module answers
AT+INF?	Query commands	Print the UWB configuration information	Returns the configuration information
AT+STAR	Control commands	The module restarts	OK+STAR
AT+RSET	Control commands	Module Flash erase, and restart	OK+REST
AT+QSET=xx-xxx	Control commands	Quickly set the transmission rate, frequency band, mode and ID (see below)	OK+QSET=xx-xxxxx

Note: All commands must end with a carriage return.

9.1.1 How it's set up



9.1.2 illustrate

Example 1: If the module is set as a anchor, with a transmission rate of 6.8M, channel 2, and an address of 0, then AT+QSET=F2-A0000 should be sent

Example 2: If the module is set to a tag, 6.8M transmission rate, channel 5, and address is 1, then AT+QSET=F5-T0001 should be sent

Note: The address of the anchor can only be 0000/0001/0002/0003, and more than 4 anchors are not supported for the time being. The default rate is 6.8M, channel 2, and in one system, the transmission rate and frequency band of the anchor and tag should be consistent.

9.1.3 The module is configured by default

Table 91.3 AT+QSET module default configuration command

module	directives
Anchor A0	AT+QSET=F2-A0000
Anchor A1	AT+QSET=F2-A0001
Anchor A2	AT+QSET=F2-A0002
Anchor A3	AT+QSET=F2-A0003
Tag T1	AT+QSET=F2-T0001
Tag T2	AT+QSET=F2-T0002
Tag T3	AT+QSET=F2-T0003
Tag T4	AT+QSET=F2-T0004
Tag T5	AT+QSET=F2-T0005
Tag T6	AT+QSET=F2-T0006
Tag T7	AT+QSET=F2-T0007
Tag T8	AT+QSET=F2-T0008

9.1.4 AT+SPED system positioning rate setting

The instruction is applicable to the anchor, the anchor receives this instruction, can control and adjust the sending speed of the field tag, the default value of the maximum number of tags is 8, the sending time of each tag is 10ms, under normal circumstances, the parameter does not need to be modified.

	Command header	MAX_TAG_NUM Maximum number of tags (unit: units)	separator	TAG_SLOTTIME Assign the elapsed time (unit: ms) for 1 tag
byte	[0]-[7]	[8]-[10]	[11]	[12]-[15]
example	AT+SPED=	008	-	0010
meaning		The system has a maximum of 8 tags	separator	

The period in which the anchor polls all tags is Tround, and the formula for Tround is as follows:

$$Tround = (MAX\_TAG\_NUM) * TAG\_SLOTTIME = 8 * 10 = 80ms$$

10 Document Management Information Sheet

Subject	YCHIOT UWB Mini5 User Manual
version	V1.1
Refer to the documentation	dw1000-datasheet-v2.08 dwm1000-datasheet-v1.3 evk1000_user_manual_v1.11 trek1000_user_manual_v1.04
Creation time	2022/01/01
Created by	Lynn
Latest release date	2022/01/01

Modifier	Date	Documentation change history
Lynn	2022/01/01	V1.0 Product Instruction Manual
Lynn	2022/12/01	V1.1 Some parameter errors have been corrected