YCHIOT UWB

Development board

UWB_DWM3000EVK

User Guide

Version 1.0.1

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1 Introduction to YCHIOT Positioning Development Kit

1.1 UWB DWM3000EVK introduction

1.1.1 DWM3000EVK series overview

UWB DWM3000EVK is composed of DWM3000EVB development board and NUCLEO-STM32F429ZIT6 development board. Peripheral circuits include: Ethernet module, power supply module, LED indicator module, reset circuit, etc.

Figure 1.1 DWM3000EVK Development Kit

1.1.2 UWB hardware parameters

Table 1.3.2 UWB DWM3000EVK hardware parameters

Basic parameters		Wireless parameters	
PCB Craft	4-layer board-epoxy resin	Communication rate	850 kbit/s, 6.8 Mbit/s
Power	micro-USB(5.0V)	working frequency	6.0 GHz ~ 9.0 GHz
Communication Interface	micro-USB(5.0V)	Work channel	Channel 5, channel 9
Download interface	STLINK-V2	Transmit power	-35dbm/MHZ ~ -62dbm/MHZ

Main controller	STM32F429ZIT6	Maximum package length	1023 byte
External crystal	8Mhz	Communication distance	Around 30m

1.2 Glossary

Table 1.4 Meanings of abbreviations of professional terms

Shorthand	English full name	Meaning
ANCHOR		A anchor, also called a beacon anchor, refers to a node that obtains position coordinates in advance by other means
DW3000		A chip from Decawave
DWM3000		A module from Decawave
IC	integrated circuit	chip
PHY	physical layer	Physical layer
PSR	preamble symbol repetitions	Duplicate leading symbol
RTLS	real time location system	Real time positioning system
TAG		Tag
TDOA	time difference of arrival	TDOA positioning is a method of positioning using time difference. By measuring the time when the signal arrives at the monitoring station, the distance to the signal source can be determined.
TOA	time of arrival	TOA positioning is a method that directly uses signal arrival time for positioning.
TOF	time of flight	TOF time-of-flight ranging method, it mainly uses the flight time between two asynchronous transceivers (Transceiver) (or reflected surface) to

		measure the distance between nodes.
TX	transmit	transmit
TWR	two-way ranging	Two-way ranging method, that is, two asynchronous transceivers (Transceiver) can obtain the ranging value.
UWB	ultra-wide band	UWB (Ultra Wideband) is a non-carrier communication technology that uses non-sine wave narrow pulses from nanoseconds to picoseconds to transmit data.

2 YCHIOT UWB actual project application scene

2.1 What scenarios can UWB DWM3000EVK be used in?

According to the needs of customers and actual application conditions, after a series of technical return visits, UWB DWM3000EVK indoor positioning products have been applied in the following application scenarios: such as airport halls, exhibition halls, warehouses, supermarkets, libraries, underground parking lots, mines, etc. . The specific situation is as follows:

- Smart luggage, smart children's car;
- Factory container and cargo positioning;
- Help visitors find corresponding attractions and public facilities in the playground;
- Supermarket personnel positioning;
- Help visitors to understand exhibit information and watch exhibitions more effectively in the museum;
- Positioning of mine personnel and working conditions of road headers;

2.2 Advantages and disadvantages of mainstream indoor positioning technology at home and abroad?

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

Table 2.2 Advantages and disadvantages of mainstream indoor positioning technologies at home and abroad

Indoor positioning technology	advantage	shortcoming
Ultrasonic positioning technology	High precision and simple structure	It is greatly affected by multipath effects and non-line-of-sight propagation. At the

		same time, a large amount of investment in the underlying hardware facilities is required, and the cost is too high.
Bluetooth positioning technology / ibeacon	The equipment is small in size, easy to integrate, and easy to popularize.	For the complex space environment, the stability of the Bluetooth system is slightly worse, and it is greatly interfered by noise signals.
Radio Frequency Identification Technology	The size of the logo is relatively small and the cost is relatively low	The operating distance is short, it has no communication capability, and it is not easy to integrate into other systems.
UWB technology	Strong penetration, low power consumption, good anti-multipath effect, high safety, low system complexity, and can provide precise positioning accuracy	It will have a certain impact if it encounters obstructions, metals, etc., the price is slightly more expensive, and there is still a distance from mass production.
SLAM	Under the condition of uncertain position, create a map in a completely unknown environment, and use the map for autonomous positioning and navigation at the same time.	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 Frequently asked technical questions

3.1 Principle

3.1.1 What is the ranging principle of UWB?

Two way-time of flight (TW-TOF, two way-time of flight) each module will generate an independent time stamp from the start. The transmitter of module A transmits a requested pulse signal at Ta1 of its time stamp, and module B transmits a responsive signal at time Tb2, which is received by module A at time Ta2 of its own time stamp. Once, the flight time of the pulse signal between two modules can be calculated to determine the flight distance S.

S=Cx[(Ta2-Ta1)-(Tb2-Tb1)] (C is the speed of light)

3.1.2 What is the principle of UWB positioning?

1) Distance = speed of light * time difference / 2; XY plane, 3 circles can determine a point;
2) XYZ space, 4 circles can determine a space point;

3.2 Use

3.2.1 Can this module measure distance through walls?

答: Passing through walls will cause signal isolation and cause ranging failure. This is determined by the principle of UWB positioning. Small obstacles, such as tables, chairs, etc., have little effect on the accuracy of positioning.

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

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

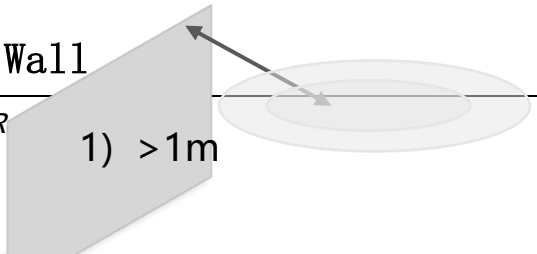


Figure 3.2.2 Precautions for the installation of anchor tags

3.2.3 Why does the anchor heat up when it is in use?

Answer: There will be fever, which is normal. But it will not burn the module, please rest assured to use.

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

Answer: It can be customized, supports PNG format import, and can be drawn with Microsoft Office Visio.

3.3 Development

3.3.1 Why this module recommends USB virtual serial port output?

Answer: The baud rate of the serial port is generally 115200bps. The A0 anchor will receive all the distance values of "anchor-tag" and "anchor-anchor", and the positioning data will be updated at least 20 times per second. As the number of tags increases, the data The amount is amazing. Through calculation, the serial port 115200bps = 14400 byte/s = 14kb/s, but the USB can reach the maximum 4Mb/s. In summary, choose the virtual serial port. Of course, when the number of tags is small, the serial port can be used to output data. This module provides USART1 output。

3.3.2 What are the main sources of errors in TOF and TDOF ranging?

1) Signal impairment. The distance measurement information for indoor positioning is the distance measured under the condition of line-of-sight. If the distance is not line-of-sight, such as obstacles in the middle or arrival through reflection, it will cause the receiving time to become longer, and the measured distance will be Get bigger.

2) The anchor coordinates are wrong. 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's clock will have a slight gap, but if the gap is 1ns, there will be an error of 30 cm, so if we can synchronize the time of all anchors in the system, the positioning accuracy can be further improved.

3.3.3 Are there any good books and websites for UWB development?

1) "Wireless Positioning System", Publishing House of Electronics Industry, Liang Jiuzhen
2) DWM1000 hardware supplier: http://www.decawave.com/
3) Kickstarter crowdfunding project: https://www.pozyx.io/
4) Indoor location map: https://navigine.com/ and https://github.com/Navigine/

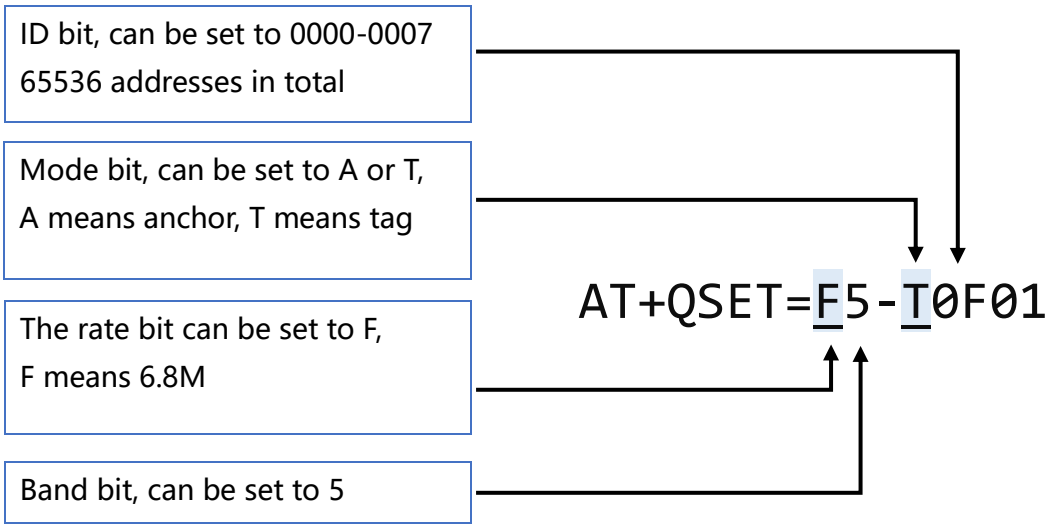
4 UWB DWM3000EVK positioning kit test instructions

A UWB positioning system consists of at least four units, that is, 3 anchors + 1 tag. The anchor can be selected as the DWM3000EVK series development board, and the tag can be selected as the DWM3000EVK series development board. After that, tags and anchors can be purchased to achieve the expansion of the tags and quantity of the system. The specific 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 in the factory, no need to modify. If you need to modify, please refer to:

4.1.1 Setting method



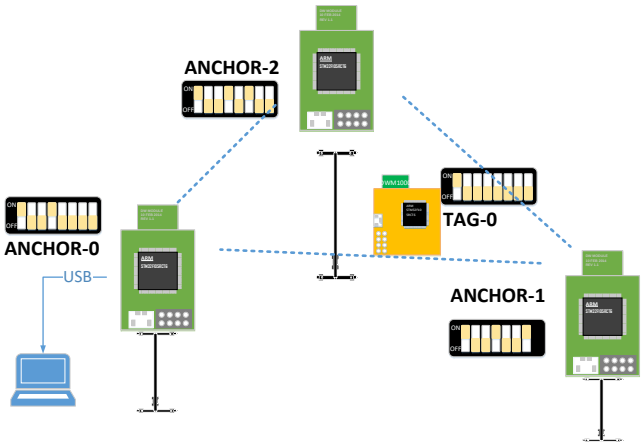
4.1.2 For example

Example: Set the module to tag, 6.8M transmission rate, channel 5, address is No. 7, then AT+QSET=F5-T0007 should be sent

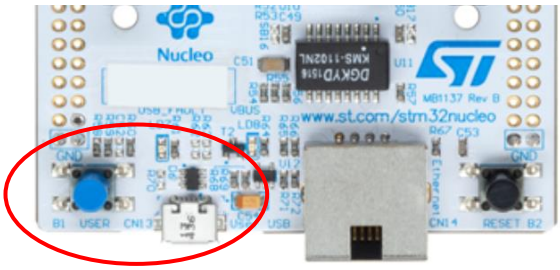
Note: The address of the anchor can only be 0/1/2/3, and currently does not support more than 4 anchors (If you need to connect more anchors, please contact us) ; the default rate is 6.8M, channel 5, in a system, the transmission rate and frequency band of the anchor and the tag should be required be consistent.

4.2 3 anchors + 1 tag test (scenario 1 -indoor positioning)

1) The hardware platform builds a network. Install the development board on the bracket.



2) Install the virtual serial port driver VCP1.4.0. For this operation step, please refer to the operation video in our WeChat official account.(link)
3) The A0 anchor is directly connected to the USB for power supply, and the USB port can also be used for data communication;



4) Open the host computer software DecaRangeRTLS.exe, if it appears as shown in Figure 4.2.2, there may be the following reasons:
   - The virtual serial port driver installation fails, and the software cannot find COMx;
   - The USB is not connected to the hardware; the Micro-USB cable does not support communication or a damaged Micro-USB cable is used;

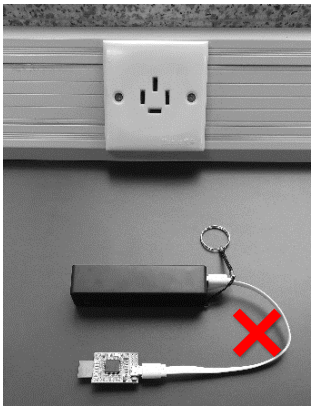
   Note 1: Most Win7 users cannot open the upper computer, but you can see the DecaRangeRTLS.exe background process. If you encounter this problem (currently unable to solve the problem), please try another computer;

   Note 2: Some high score screen users (2K screen or 4K screen users) will have the problem of incomplete text display on the host computer, which can be displayed

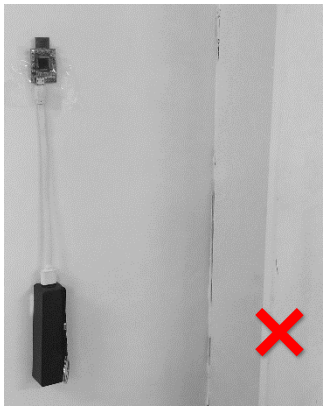
by adjusting the separator;

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

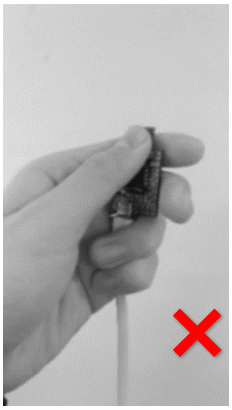
Place the module near metal



Place the module flat on the desktop



Glue the module to the wall



Hold the antenna

The correct installation method is shown in the figure below:

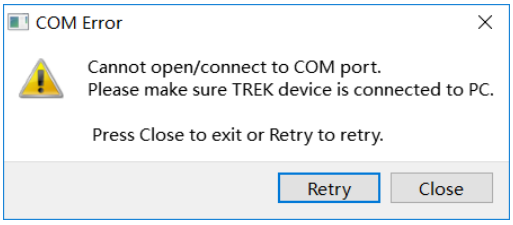
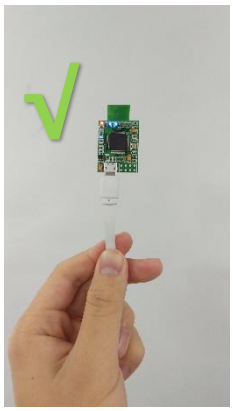
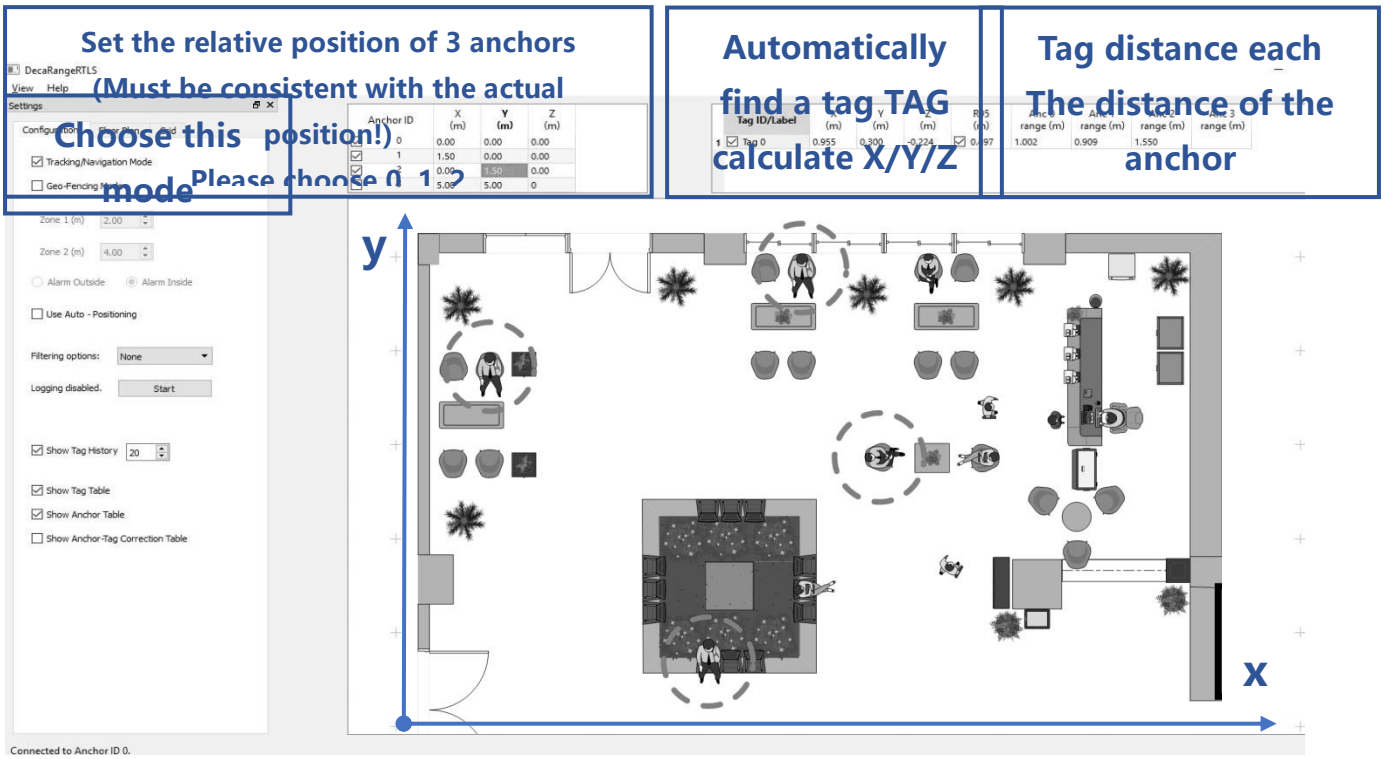


Figure 4.2.2 The host computer cannot communicate



1) Operating software



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

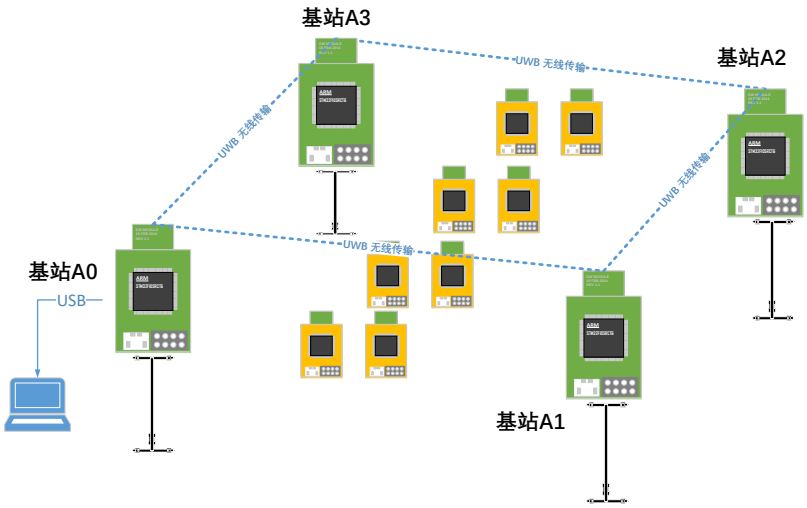


Figure 4.2.3 Schematic diagram of positioning 4 anchors + multi-tag hardware platform

4.3 Anchor +3 tags test (Scenario 2-over range alarm)

1) Hardware networking;
2) Install virtual serial port driver (same as above);
3) A0 connects to the computer via USB (same as above);
4) Open the upper computer software DecaRangeRTLS.exe (same as above);
5) All tags are powered by mobile power;
6) Note: If there is only 1 tag (1 anchor and 1 tag), the test can also be performed in this mode, but the entire system must have anchor A0 to operate. I won't repeat them below.
7) Operating software: set to Geo-Fencing Mode

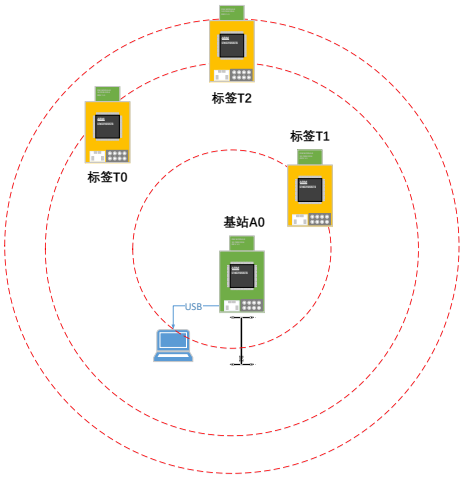
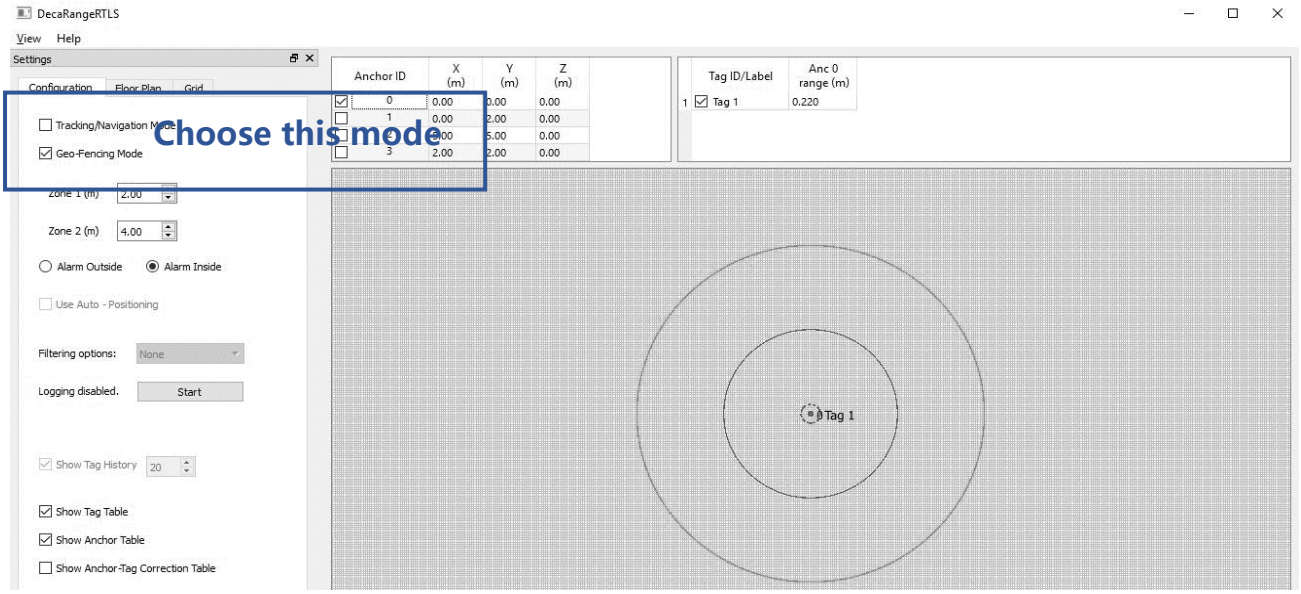


Figure 4.3 Schematic diagram of over-range alarm 1 anchor + 3 tags hardware platform



5 UWB DWM3000EVK module secondary development

5.1 DWM3000EVK firmware update

5.1.1 STLINK and Mini 4 hardware connection

If you need to upgrade or modify the firmware of UWB DWM3000EVK, you need to use STLINK to update its firmware. The downloader has been integrated on the development board. You can connect the USB cable to the port shown in the figure to update the firmware. For more information, please refer to the manual ST manual stm32 Getting Started with Nucleo Software Development Tools

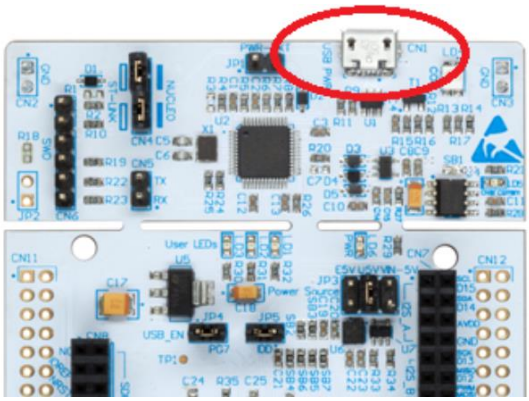


Figure 5.1 DWM3000EVK hardware wiring method

5.1.2 STLINK download settings

Please refer to the manual ap12-UWBPRO_YCHIOT_ device firmware upgrade, and related operation videos in this folder。

5.2 Various analysis of DWM3000EVK virtual serial port output data

Set the baud rate to 115200bps, 8 data bits, 1 stop bit, and no parity bit. Connect the USB port to the computer according to Figure 5.2.1, and open the XCOM serial debugging assistant on the computer，then you can observe the data flow of ATOF Report Message.

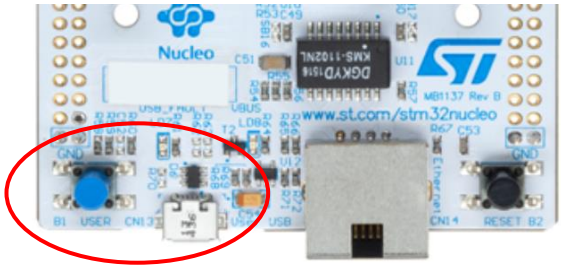


Figure 5.2.1 STM32 USB virtual serial port

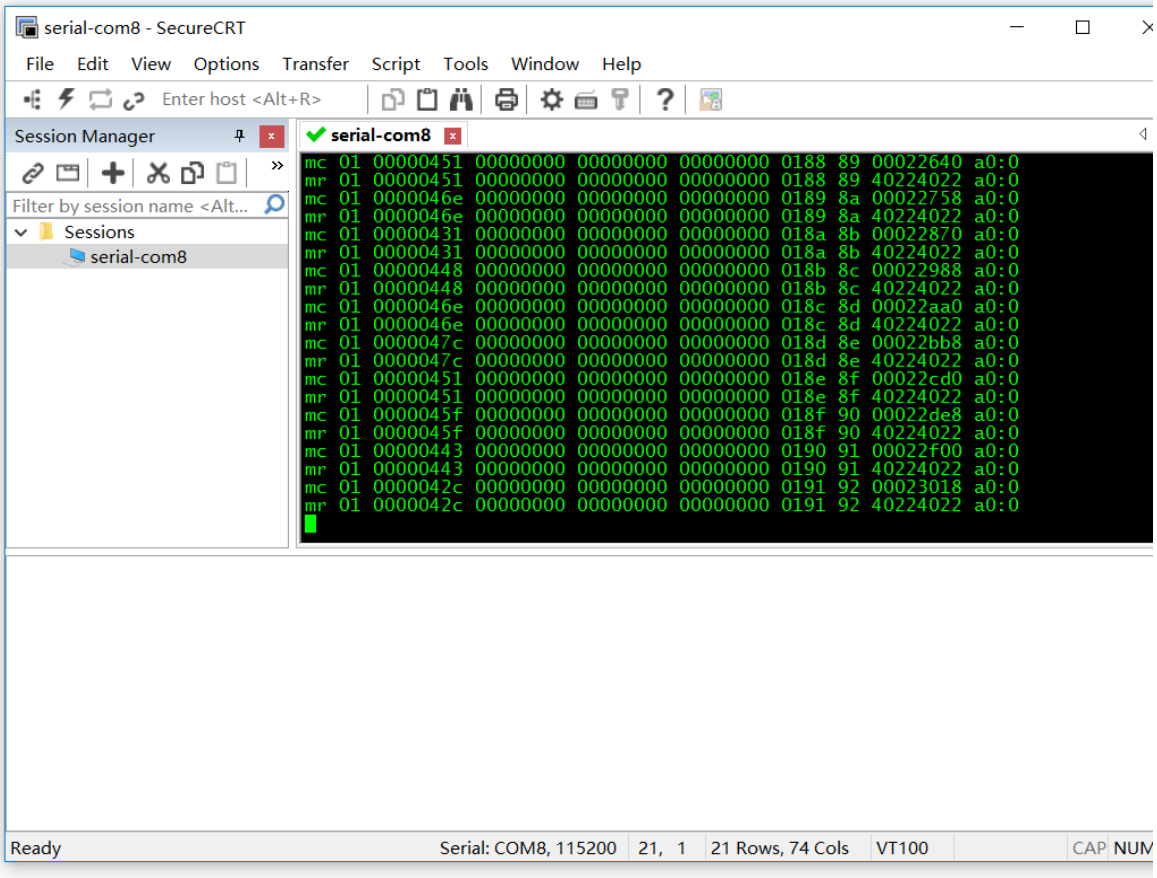
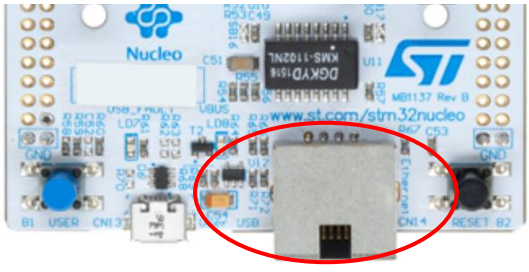


Figure 5.2.2 Screenshot of STM32 USB virtual serial port data content

Format content, see section 6.3 of this document.

5.3 Anchor output data into the network solution

The STM32F429ZIT6 development board comes with an Ethernet port implemented by LAN8742A, which can drive the Ethernet port to transmit data to the network. This part has not been developed, and the customer can study it by himself.



6 PC host computer communication data format and secondary development

6.1 Introduction to RTLS host computer

This chapter introduces the use of PC upper computer. The host computer software is developed using QT 5.7.0 MinGM, and the programming language is C++. Qt is a cross-platform C++ graphical user interface application development framework developed by Trolltech in 1991. It can develop GUI programs as well as 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) and some macros, which are easy to extend and allow component programming. In April 2014, the cross-platform integrated development environment Qt Creator 3.1.0 was officially released, which realized full support for iOS, added WinRT, Beautifier and other plug-ins, abandoned GDB debugging support without Python interface, and integrated Clang-based C /C++ code module, and made adjustments to Android support. So far, it has realized full support for iOS, Android, 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 TOF report message from UWB module;
3) Anchor list, in which the actual placement position of the anchor can be set;
4) Tag list, the list can display 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, which can realize zoom and coordinate fine-tuning;
6) Other parameter settings;

6.2 RTLS host computer interface

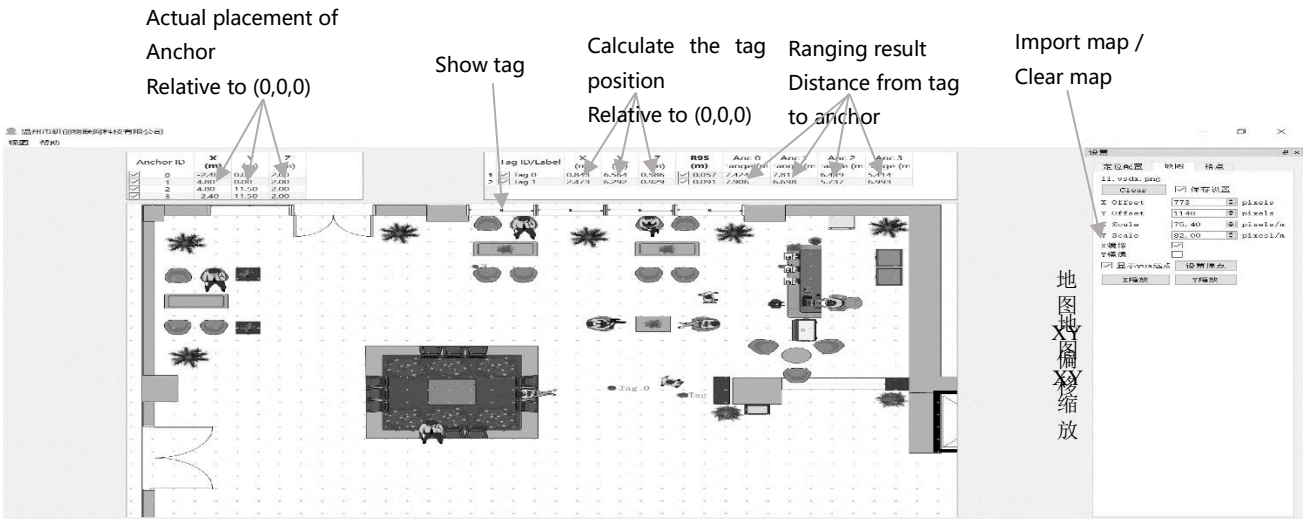


Figure 6.2.1 RTLS host computer interface

◆ Graphics

- Tag and Anchor Tables

Tag Table contains Tag ID, ranging information, and positioning coordinates.

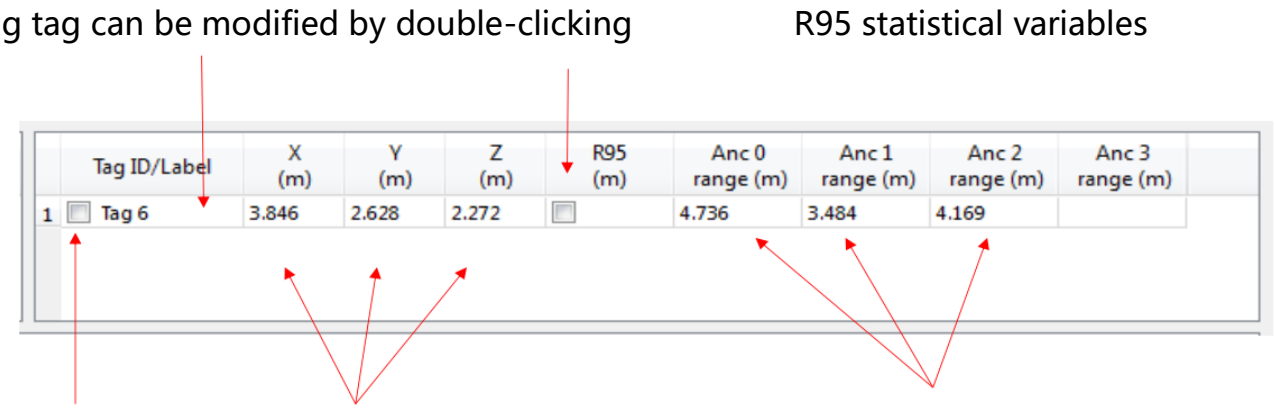


Figure 6.2.2 Tag Table

- R95 statistical variables reference materials: 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 based on the tag-anchor distance,

and the specific solution method is shown 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 contains the ID of the anchor, the location information of the anchor.

◆ Status Bar

The content displayed in the status bar in the lower left corner is 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 calculate the coordinates based on the ranging data
- "Open error" –The software failed to open the virtual serial port

◆ View Settings

View settings include three tables: configuration, floorplan 和 grid。

- Configuration Table

Name	Description
Tracking/Navigation Mode	Positioning mode
Geo-Fencing Mode	Over-range alarm mode
Zone1	Range 1
Zone2	Range 2
Alarm Outside/Inside	Alarm outside/in the circle
Show Tag History (N)	Display the most recent N historical points
Show Tag Table	Show Tag Table
Show Anchor Table	Show Anchor Table

Auto Positioning	Automatic positioning mode, in this mode, the anchor location does not need to be set
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 show grid

- Floor Plan tab

Name	Description
Open	Open a map and import it into the software
X offset	Shift the map in pixels in the X direction
Y offset	Shift the map in pixels in the Y direction
X scale	Zoom the map in pixels in the X direction
Y scale	Zoom the map in pixels in the Y direction
Flip X	The X axis is the axis of symmetry, mirroring
Flip Y	The Y axis is the axis of symmetry, mirroring
show	Whether to show the origin
Set Origin	Set origin
X Scale button	Click this button to generate a small tool to measure the distance on the map, enter the actual distance, and set the zoom value of X
Y Scale button	Click this button to generate a small tool for measuring the distance on the map, enter the actual distance, and set the Y zoom value

6.3 TOF Report Message

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

USB virtual serial port is as follows:

```
1. mr 0f 000005a4 000004c8 00000436 000003f9 0958 c0 40424042 a0:0
2. ma 07 00000000 0000085c 00000659 000006b7 095b 26 00024bed a0:0
3. 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	Message ID, there are three types, namely mr, mc, ma
MASK	mc stands for tag-anchor distance (optimized and corrected data, used to locate tags)
RANGE0	Indicates which messages of RANGE0, RANGE1, RANGE2, RANGE3 are valid;
RANGE1	For example: MASK=7 (0000 0111) means RANGE0, RANGE1, RANGE2 are all valid
RANGE2	If MID = mc, it means the distance from tag x to anchor 0, unit: mm
RANGE3	If MID = mc, it means the distance from tag x to anchor 1, unit: mm
NRANGES	If MID = mc, it means the distance from tag x to anchor 2, unit: mm
RSEQ	If MID = mc, it means the distance from tag x to anchor 3, unit: mm
DEBUG	Unit raw range count value (will continue to accumulate)
aT:A	range sequence number count value (will continue to accumulate)

6.4 Log Files

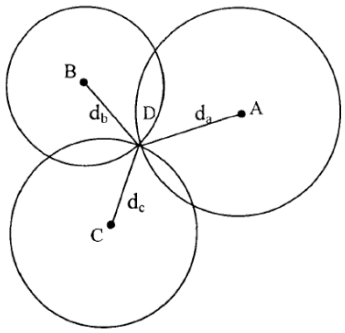
When using the host computer, click "Start", under the Log folder, a log file in text format yyyymmdd_hhmmssRTLS_log.txt will be generated, with the following meanings:

Table 6.4.1 Corresponding meaning of Log file

Log content	Meaning

T:151734568:DecaRangeRTLS:LogFile:Ver. 2.10 TREK:Conf:Anchor0:1:Chan2	15:17, 34 seconds, 568ms, version number 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 seconds, 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

6.5 Trilateration Principle and calculation method of trilateral measurement



6.5.1 The Theoretical Basis of Trilateral Measurement Method Based on UWB Ranging

The principle of the trilateral measurement method is shown in the figure on the right. The circle is made with three nodes A, B, and C as the center. The coordinates are (X_a, Y_a), (X_b, Y_b), (X_c, Y_c), these three The circle intersects at a point D, the intersection D is the mobile node, A, B, and C are the reference nodes, and the distances between A, B, C and the intersection D are d_a, d_b, and d_c, respectively. Suppose the coordinates of intersection D are (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 equation 7.5.1, the coordinates of intersection D can be obtained as:

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

The defect of the trilateral measurement method is: because the hardware and power consumption of each node are not the same, the measured distance cannot be an ideal value, which results in the three circles above not necessarily intersecting at one point. In practice, it must be Intersect in a small area, so the (X, Y) coordinate value calculated by this method has a certain error. In this way, a certain algorithm is needed to estimate a relatively ideal position as the optimal solution for the coordinates of the current mobile node.

6.5.2 Trilateration Function

In the trilateration.cpp file, the function implemented by the GetLocation() function is: the coordinates of the incoming anchor (unit: m) and the distance from each anchor to the tag (unit: mm), and the calculation of the Tag's Best Solution (unit: m).
As mentioned in the previous section, because the measured distance cannot be an ideal value, the three circles above may not be exactly at one point. Therefore, when the anchor A0/A1/A2 is working, from a mathematical point of view, There are 2 solutions; when there is A0/A1/A2/A3 working, there must be an optimal solution. A3 serves as an auxiliary anchor. After A0/A1/A2 completes a Trilateration algorithm, two solutions are obtained, and the solution closest to the sphere of A3 is taken as the optimal solution.
Note: The trilateration.cpp file is the source code of the PC, a kit with 4 anchors and 4 tags or more, provided free of charge。

6.5.3 Why the accuracy of the Z axis is worse than that of the X axis and Y axis?

As shown in the figure, A0/A1/A2 are 3 anchors, T0 is a tag, and LA0T0 LA1T0 LA2T0 represents the distance from each anchor to the tag. When the distance measurement is completely accurate, the calculated Tag coordinates should be at T0. However, since the actual measured value LA0T0 LA1T0 LA2T0 may be too large, the calculated position is at T0’ . Because A0/A1/A2 are in the xoy plane, most of the errors in ranging will be accumulated on the z-axis, causing the jitter of the z-axis data.

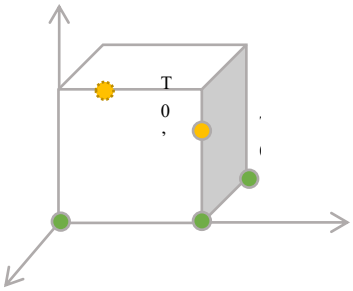


Figure 6.5.3 Schematic diagram of Z-axis data error

7 Document Management Information Form

Subject	YCHIOT UWB_DWM3000EVK User Manual
Version	V1.0
Reference documents	DW3000 User Manual DW3000 Datasheet Production Tests for DW3000-Based Products Guide_for_bulding_API_Examples
Creation time	2021/10/1
founder	Lynn
Latest release date	2021/10/1

Adjusted By	Date	Document change record
Lynn	2021/10/1	V1.0 Product Instruction Manual
Formores	2021/10/21	V1.0.1 English version released