Use of ISP1907-AOA-DK AoA Demo Kit

Application Note AN210401

Introduction

Scope

This document describes the contents of the Insight SiP AoA Demo kit and explains how it can be used to make preliminary assessments of BLE 5.1 AoA functionality with ISP1907 modules.

Contents

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1. Documents

1.1. Bluetooth SiG

AoA is defined in the latest core specification that can be found on the Bluetooth SIG site. This includes direction finding AoA and AoD options:
https://www.bluetooth.com/specifications/specs/core-specification/

A document describing AoA is also available:
https://www.bluetooth.com/wp-content/uploads/Files/developer/1903_RDF_Technical_Overview_FINAL.pdf

1.2. Nordic Semiconductor

Device hardware specifications for nRF52811 and nRF52833 can be found on Nordic Infocenter:
https://infocenter.nordicsemi.com/index.jsp

The following White Paper addresses the fundamental issues of AoA/AoD:
nWP036 - Direction Finding

1.3. Insight SiP

AN210401 – This application Note
ISP1907 Module Datasheet
ISP1907-AoA Datasheet

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2. Development Status of AoA

Angle of Arrival and Angle of Departure techniques have been specified by the Bluetooth SiG in BLE 5.1. Nordic Semiconductor has introduced several chipsets that support this feature of the BLE specification from a hardware standpoint. These devices have the capability of generating the BLE constant tone extension and are capable of measuring IQ values, and hence relative phase, of incoming BLE packets with the constant tone extension.

Insight SiP has added 2 ultra-miniature SiP modules that use Nordic Semiconductor BLE5.1 chipsets to its portfolio. These modules are ISP1907LL (nRF52811 chipset) and ISP1907HT (nRF52833 chipset). These modules are fully certified for Bluetooth SiG and for use in USA, Canada, Korea, Japan and Europe.

Currently the direction-finding attributes of these modules are not fully supported by BLE certified firmware from Nordic Semiconductor. Release, by Nordic Semiconductor, of a BLE SIG compatible firmware release with associated source codes is expected during the course of 2021. This will be based on nRFConnect SDK running a custom Zephyr RTOS, and will become available to all customers.

In the interim period, prior to full release of nRFConnect SDK version with AoA capability, Insight SiP has prepared an AoA demonstrator with proprietary firmware from Nordic Semiconductor. This demonstrator is available with pre-programmed code that cannot be modified at present.

A soon as Nordic Semiconductor officially releases the nRFConnect SDK with AoA features the customer will be able to create his own tag firmware and adapt the AoA anchor to his specific needs.

3. Installation & Setup

To use the AoA Demonstrator the following software should be obtained and installed.

Nordic Semiconductor nRFConnect with AoA extension. The standard version of nRFConnect for desktop should be downloaded and installed on a PC from Nordic Infocenter:
https://www.nordicsemi.com/Software-and-Tools/Development-Tools/nRF-Connect-for-desktop

In order to obtain the custom direction finder viewer add-on it is necessary to request the files from Nordic Semiconductor Devzone by creating a private support ticket with the indication that the add-on is required for use with ISP1907-AoA-DK. The devzone has the following address:
https://devzone.nordicsemi.com/

To access data from the AoA antenna a serial terminal should be available on the PC. A suitable terminal is RealTerm that can be downloaded at the following address:
https://sourceforge.net/projects/realterm/

Insight SiP has a Python-based application that requires a Python IDE to be installed on the PC. A suitable Python IDE “Spyder” can be obtained through Ananconda.

Anaconda can be downloaded at the following address:
https://www.anaconda.com/products/individual

Once Ananconda has been installed Spyder is available and can be launched directly from the Ananconda interface.

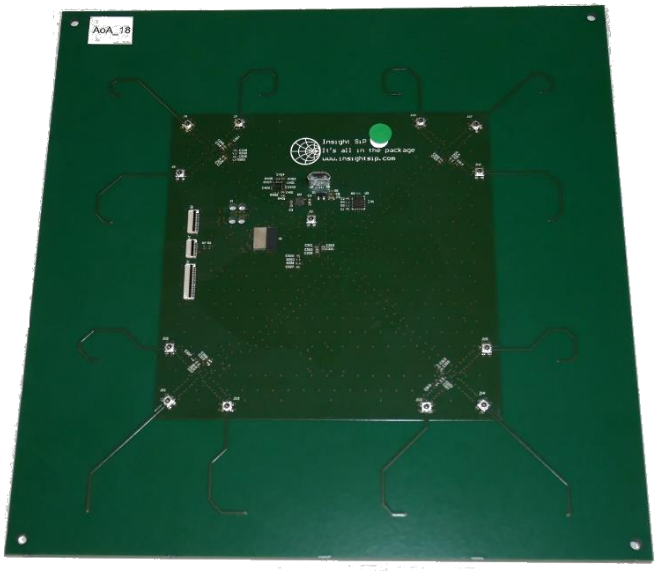
4. Hardware Description

The hardware consists of a custom receiving antenna array and a Sensor Board that sends regular BLE packets with BLE5.1 Constant Tone Extension.

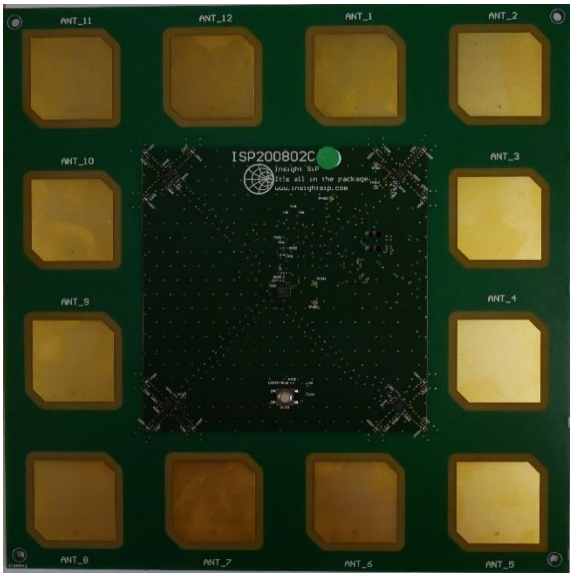
4.1. ISP200802 AoA Antenna Array

The custom antenna array has 12 patch antennas placed around the periphery of a 200 x 200 mm PCB. The antennas are connected via a 12-way switch to ISP1907-HT BLE module. The module is connected sequentially to each of the antennas whilst the incoming signal from a BLE tag is transmitting the BLE5.1 Constant Tone Extension. The module decodes the IQ values of the incoming signal and computes the phase differences between the 12 antennas. These phase differences are used to estimate the Angle of Arrival of the incoming BLE packet.

For operation, the USB cable should be connected to the AoA Antenna and to a PC.



Rear side of AoA Antenna



Front side of Antenna

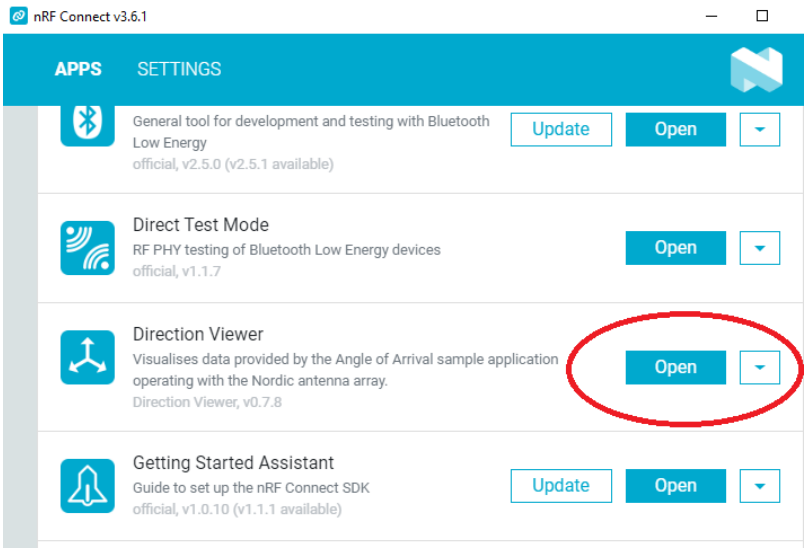
4.2. ISP1980 Sensor Board

The custom sensor board uses an ISP1907-LL module to transmit advertising packets with the Constant Tone Extension. These packets are used by the AoA Antenna to determine the angle of arrival. In order to use the board a CR2032 Battery (not included in kit) should be inserted into the battery holder.

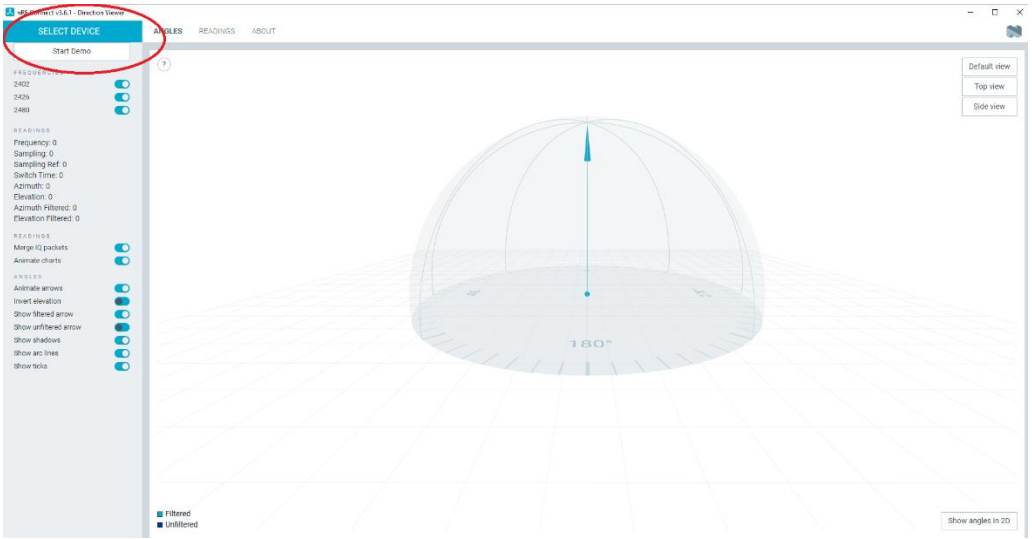
5. Angle of Arrival Demonstration

5.1. nRF Connect Direction Finder Application

To use the nRF Connect Direction Viewer App (available from Nordic Semi through private ticket on Nordic devzone) connect the AoA antenna to a PC and start nRFConnect.

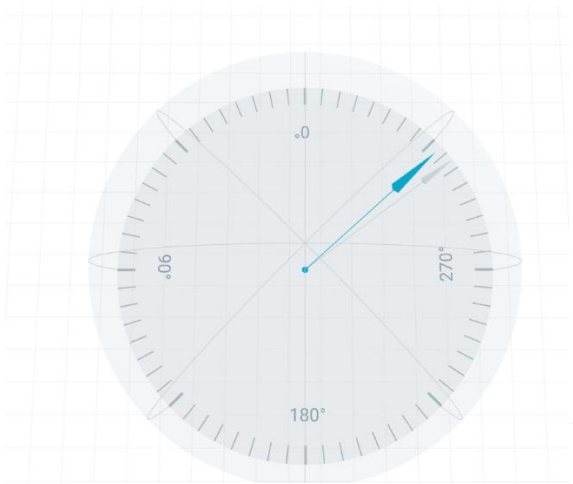


Open the Direction Viewer

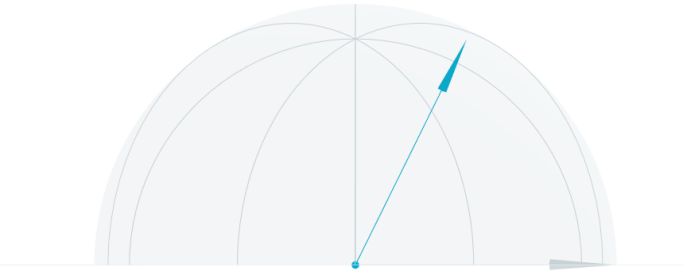


Select the device:

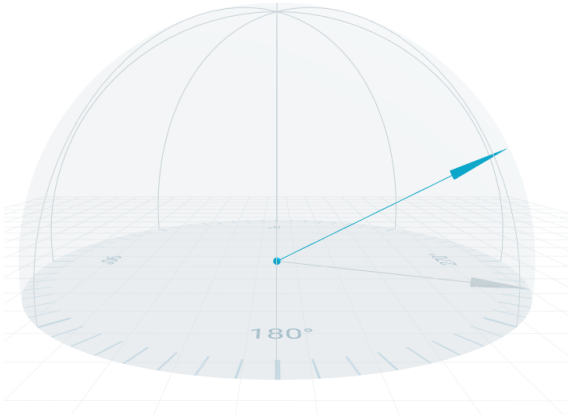
Start Reading:



Top View



Side View



3D View

Various options may be selected to visualize data from one or more of the advertising channels, to see the effect of filtering on results.

5.2. Insight SIP Python Application

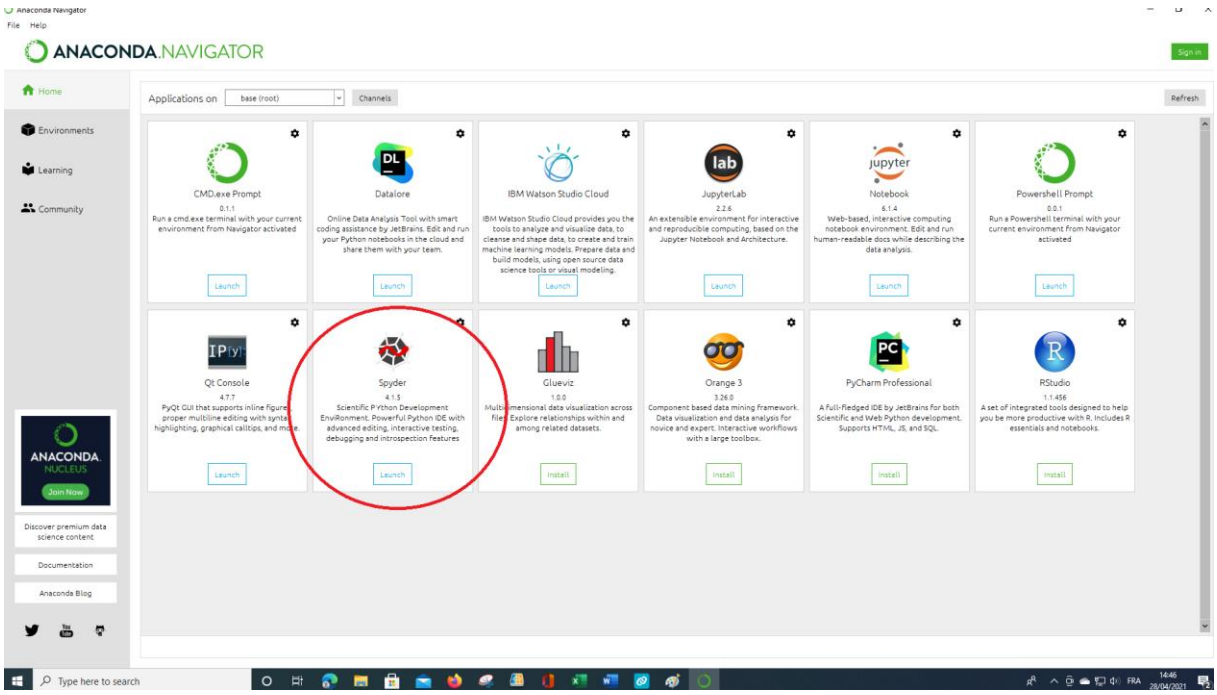
The Python Application is provided on Insight SiP Github at the following address:
https://github.com/insightsip/Python-AoA-Demo

The Python application provides an alternative visualization of the AoA results. This application processes the Angle of Arrival obtained by the antenna and estimates the position of the tag on a 2D grid assuming that the antenna is a known height above the tag “plane”.

To run the python application the following python files should be opened using Spyder (or alternative Python IDE):

- aoa_demo.py
- aoa_gui.py
- aoa_locator.py

Anaconda interface to launch Spyder:



The following Python modules must be installed using Spyder for the first use of the program:

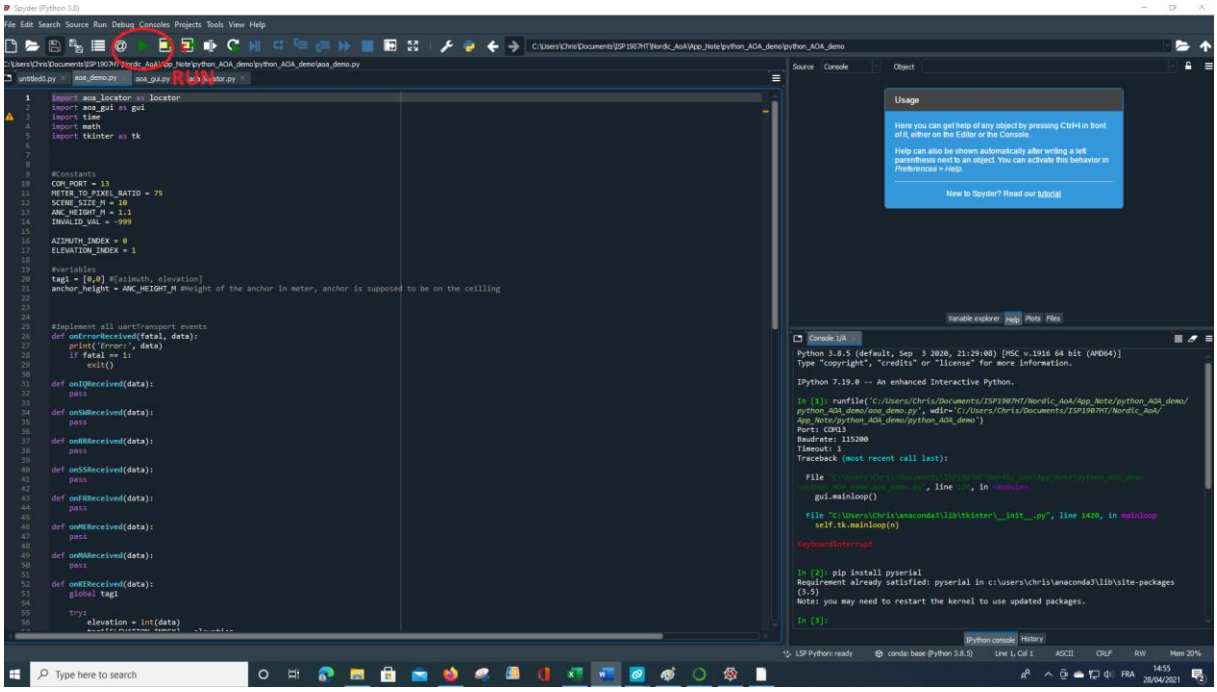
- pyserial
- parse
- event-notifier

This can be done by the commands *pip install pyserial*, *pip install parse*, *pip install event-notifier* on the command line of Spyder as indicated in this example:

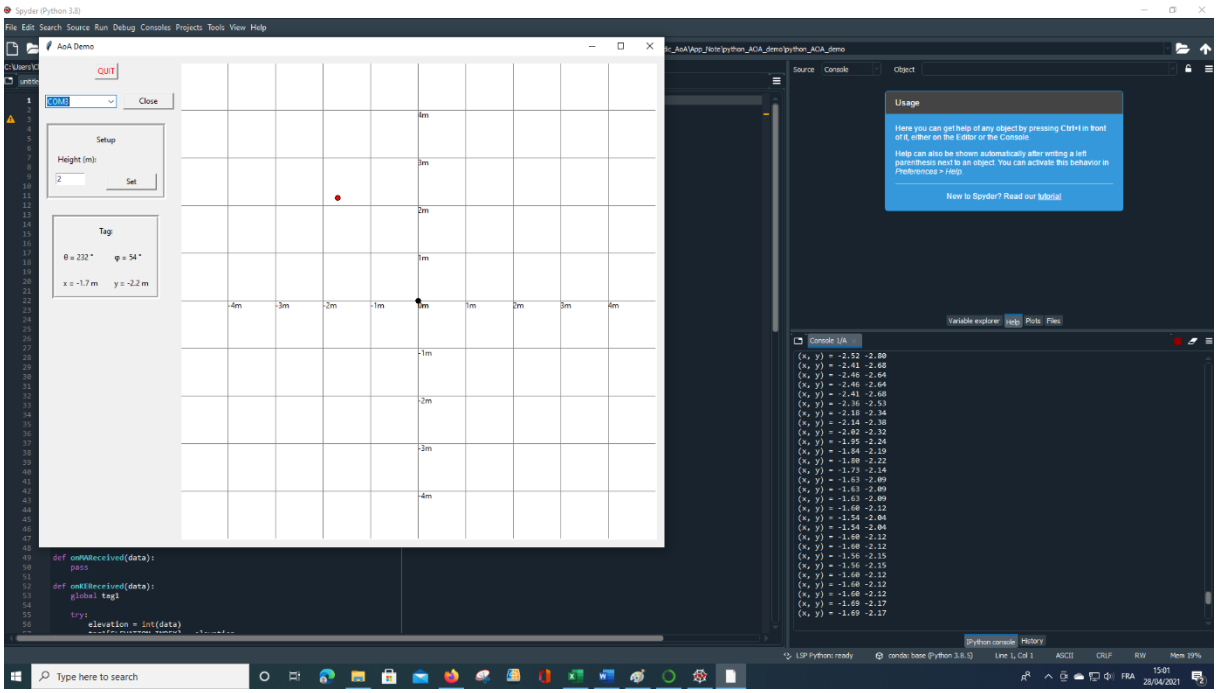
```
In [2]: pip install pyserial
Requirement already satisfied: pyserial in c:\users\chris\anaconda3\lib\site-packages
(3.5)
Note: you may need to restart the kernel to use updated packages.

In [3]:
```

If the module is already installed the message will indicate that this is the case.

Open *aoa_demo.py* and launch:



The following pane will open:



- Select the Com port that is in use and Open it (make sure that the port is not open in another application such as nRF Connect Direction Viewer)
- Set the height of the anchor relative to the tag plane.

The X Y coordinates of the tag will be displayed both visually and as X,Y values. The angular coordinates of the angle of arrival are also indicated in φ, θ format.

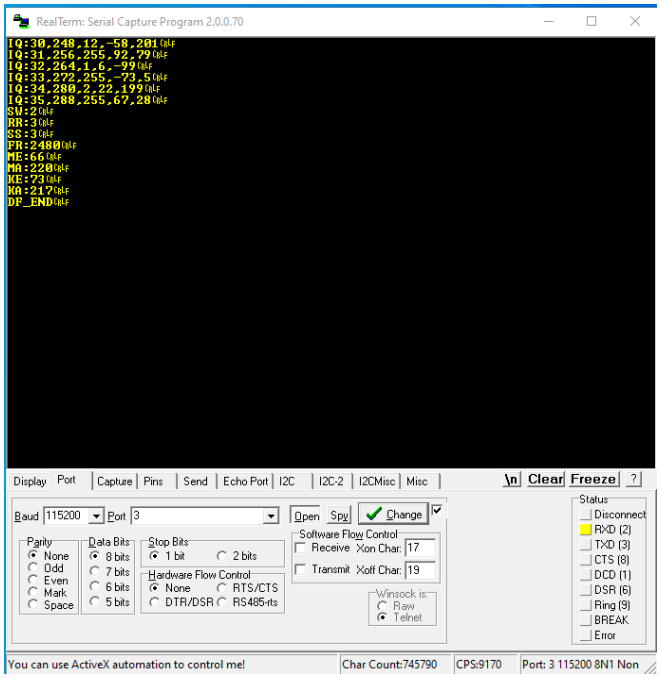
The python log also indicates the X Y coordinates as they vary over time.

5.3. Obtention of Raw Data using RealTerm

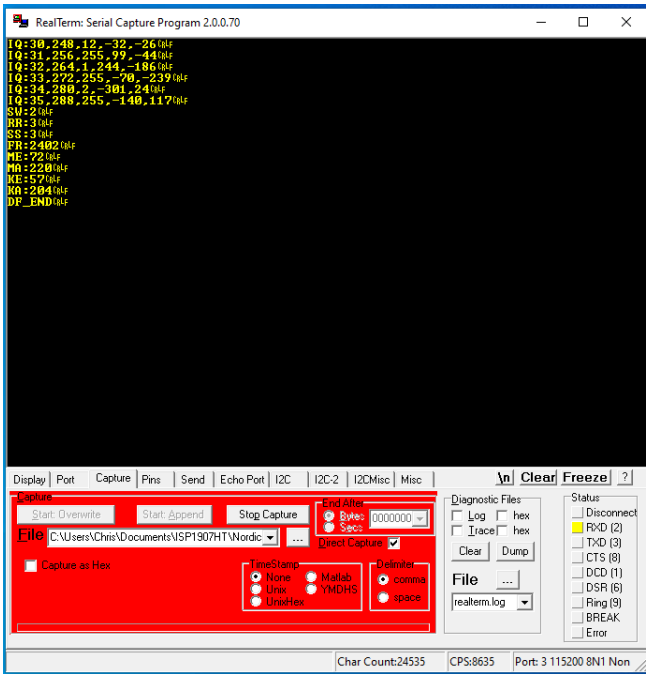
The data that is output from the AoA Antenna may be captured directly by connecting a serial monitor to the appropriate COM PORT.

- Launch RealTerm and set Baud Rate to 115200
- Select Port
- Open Port

Raw Data from the antenna can be visualized directly or captured in a file for analysis.



Raw Data



Capture to file

The captured file is made up of data sections between DF_BEGIN and DF_END for each measurement as shown below:

```
DF_BEGIN
IQ:0,0,11,-17,-204
IQ:1,8,11,-195,-32
IQ:2,16,11,-61,186
IQ:3,24,11,174,89
IQ:4,32,11,128,-148
IQ:5,40,11,-125,-149
IQ:6,48,11,-170,95
IQ:7,56,11,64,174
IQ:8,72,12,245,-5
IQ:9,80,255,18,-217
IQ:10,88,1,-315,-125
IQ:11,96,255,-147,189
IQ:12,104,2,259,128
IQ:13,112,255,141,-187
IQ:14,120,10,-253,-215
IQ:15,128,255,-277,-72
IQ:16,136,3,-241,-333
IQ:17,144,255,-450,-221
IQ:18,152,9,-555,-149
IQ:19,160,255,-362,293
IQ:20,168,4,12,230
IQ:21,176,255,-44,57
IQ:22,184,8,-537,55
IQ:23,192,255,-255,178
IQ:24,200,7,-128,-349
IQ:25,208,255,-238,-118
IQ:26,216,6,9,-102
IQ:27,224,255,-33,118
IQ:28,232,5,205,422
IQ:29,240,255,352,195
IQ:30,248,12,153,207
IQ:31,256,255,183,-94
IQ:32,264,1,-100,-314
IQ:33,272,255,-236,6
IQ:34,280,2,69,287
IQ:35,288,255,157,30
SW:2 switch spacing
RR:3 sample spacing ref
SS:3 sample spacing
FR:2480 frequency
ME:16 Raw Elevation from this packet
MA:170 Raw Azimuth from this packet
KE:52 Filtered Elevation using previous packets
KA:200 Filtered Azimuth using previous packets
DF_END
```

8 samples from ref Antenna
Used to measure frequency offset
between tag and anchor

28 samples used to
calculate angle of
arrival

system parameters

raw data

filtered data

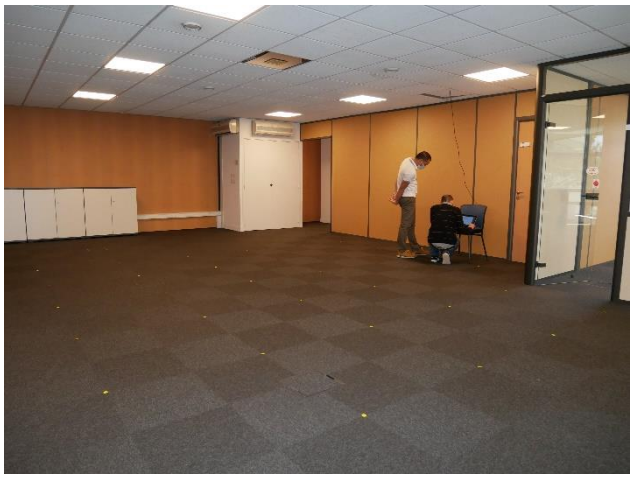
The calculations that have been used to estimate the angle of arrival are proprietary to Nordic Semiconductor. The resulting angles (elevation and azimuth), both in filtered and raw format can be used to create an alternative visualization scheme.

5.4. ISP System Test

At Insight SiP tests were carried out in a large room with the anchor positioned in the place of a ceiling tile as shown in the photo below:

The Insight SiP Python demo was used and results were compared to actual position of the tag in the room.

The room was marked with yellow dots every 1m:



Comparisons between actual and measured results were made with the tag placed on the floor. The results showed a positioning accuracy of better than 0.5m for positions in which the elevation angle was greater than 45°.

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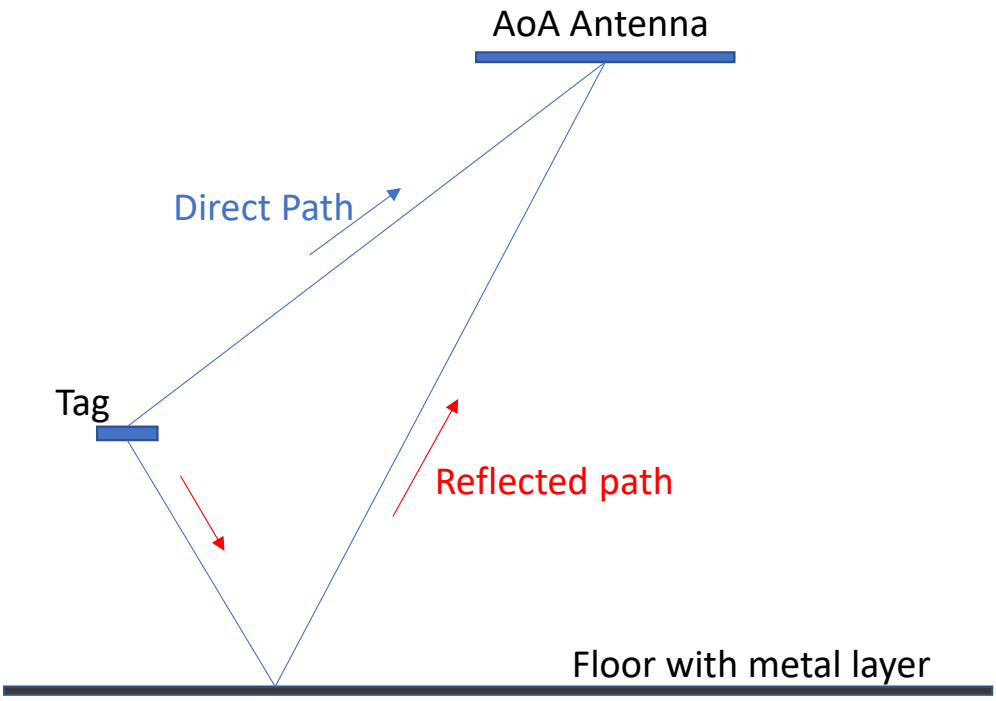
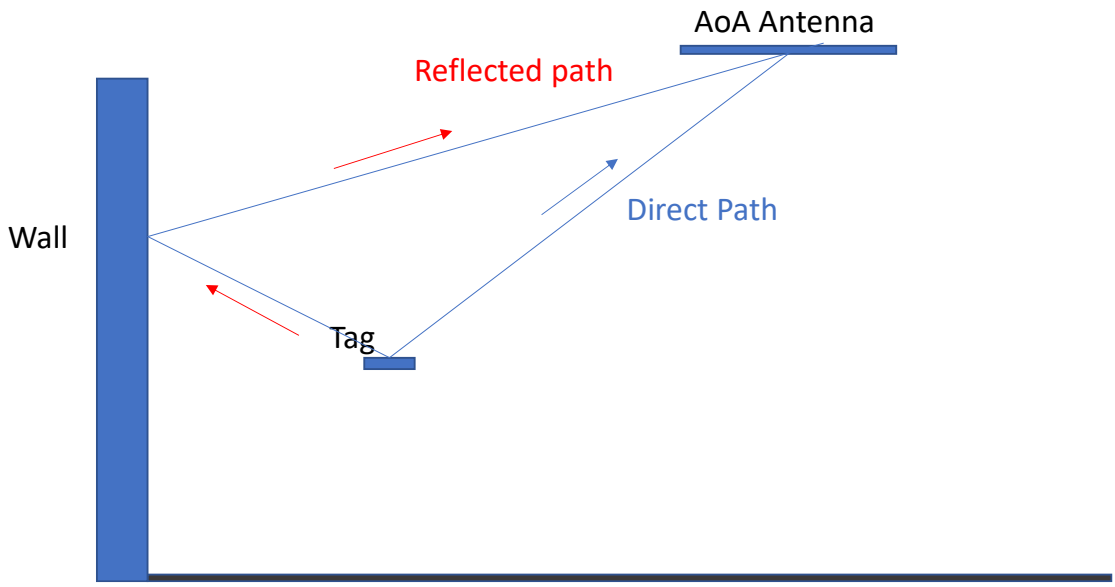
Due to the geometry and the relative angular precision for greater elevation angles the positional error increases significantly with elevation angles less than 45°.

Multipath effects can be seen in certain situations in which a reflected signal gives rise to a false estimate of the position:

- A metal floor will reflect the BLE signal and create an angle of arrival for part of the signal with a greater elevation than the direct path:



- A wall will have the opposite effect and will reflect the BLE signal to create a lower elevation than that of the direct path:



During deployment of a complete AoA system the position of the AoA Antenna is crucial in obtaining optimum positional information. Combining two or more AoA Antennas will help to eliminate potential errors indicated above.

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