

# 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.

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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/

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A document describing AoA is also available: <u>https://www.bluetooth.com/wp-content/uploads/Files/developer/1903\_RDF\_Technical\_Overview\_FINAL.pdf</u>

#### 1.2. Nordic Semiconductor

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

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

#### 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.

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#### 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: <u>https://www.nordicsemi.com/Software-and-Tools/Development-Tools/nRF-Connect-for-desktop</u>

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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: <u>https://devzone.nordicsemi.com/</u>

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.

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#### 4. Hardware Description

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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

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#### 4.2. ISP1980 Sensor Board

May 7, 2021

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.



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#### 5. Angle of Arrival Demonstration

#### 5.1. nRF Connect Direction Finder Application

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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.

🙆 nRF Connect v	3.6.1	-	
APPS	SETTINGS	l l	
8	General tool for development and testing with Bluetooth Update Low Energy official, v2.5.0 (v2.5.1 available)	Open	-
<b>?</b> .	Direct Test Mode RF PHY testing of Bluetooth Low Energy devices official, v1.1.7	Open	•
2	Direction Viewer Visualises data provided by the Angle of Arrival sample application operating with the Nordic antenna array. Direction Viewer, v0.7.8	Open	$\overline{)}$
	Getting Started Assistant   Guide to set up the nRF Connect SDK   official, v1.0.10 (v1.1.1 available)	Open	•

#### Open the Direction Viewer





Select the device:



Top View

Side View

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SP1907-AoA-Demo

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

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### Anaconda interface to launch Spyder:

	Applications on base (root)	~ Channels				
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ng	0	<b>E</b>	Ö	lab	jupyter	0
	CMD.exe Prompt	Datalore	IBM Watson Studio Cloud	JupyterLab	Notebook	Powershell Prompt
unity	0.1.1 Run a cmd.exe terminal with your current environment from Navigator activated	Online Data Analysis Tool with smart coding assistance by JetBrains. Edit and run your Python notebooks in the cloud and share them with your team.	IBM Watson Studio Cloud provides you the tools to analyze and visualize data, to cleanse and shape data, to create and train machine learning models. Prepare data and build models, using open source data	22.6 An extensible environment for interactive and reproducible computing, based on the Jupyter Notebook and Architecture.	6.1.4 Web-based, interactive computing notebook environment. Edit and run human-readable docs while describing the data analysis.	0.0.1 Run a Powershell terminal with your current environment from Navigator activated
	Leunch	Leunch	science tools or visual modeling.	Launch	Launch	Leunch
	¢ IPtyl:	*		*	PC *	R
	Qt Console	Spyder	Glueviz	Orange 3	PyCharm Professional	RStudio
)	4.7.7 PyQt CUI that supports inline Figure proper multiline editing with synta highlighting, graphical calltips, and more	4.1.5 Scientific Python Development EnviRonment, Powerful Python IDE with advanced editing, interactive testing, debugging and introspection Features	1.0.0 Multi-mensional data visualization across file: Explore relationships within and among related datasets.	3.26.0 Component based data mining framework. Data visualization and data analysis for novice and expert. Interactive workflows with a large toolbox.	A full-Fledged IDE by JetBrains for both Scientific and Web Python development. Supports HTML, JS, and SQL	1.1.456 A set of integrated tools designed to help you be more productive with R. Includes R essentials and notebooks.
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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:



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



Open *aoa\_demo.py* and launch:

Souder (Puthon 3.8)

File Edit 1	ieurch Source Run Debug Consoles Projects Tools View Help	
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56	elevation - int(data)	In (3):
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The following pane will open:



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- 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  $\varphi$ ,  $\theta$  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

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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	8 s Usi bet	amples from ref Antenna ed to measure frequency offset tween tag and anchor
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		28 samples used to calculate angle of arrival
SW:2 switch spacing RR:3 sample spacing ref SS:3 sample spacing		system parameters
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 F END		

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:



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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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