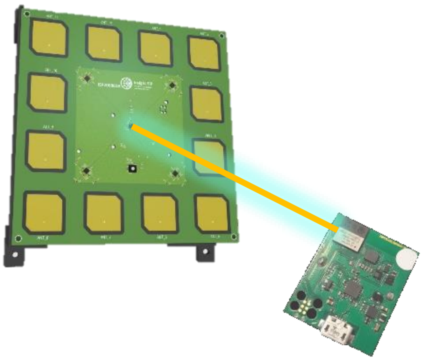
ISP1907-AOA-DK

Application note AN210105

AoA Evaluation with ISP1907-AOA-DK Demo Kit



Introduction

Scope

This document describes the AoA (Angle of Arrival) performance that can be achieved with Insight SiP AoA Development kit based on ISP1907 modules.

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Document Revision History

Revision	Date	Ref	Change Description
R0	21/01/2021	jf pg	Initial release
R1	07/05/2021	jf pg	Typo error correction
R2	09/06/2022	pd pg	Document layout update

1. Introduction

1.1. Direction Finding

Bluetooth latest addition (Bluetooth 5.1) introduces a new type of localization: direction finding. Until now the only mean of positioning using BLE was by measuring the signal strength of a signal (RSSI). The direction finding works by measuring the phase of a signal through an antenna array.

Bluetooth 5.1 introduces 2 methods of direction finding:

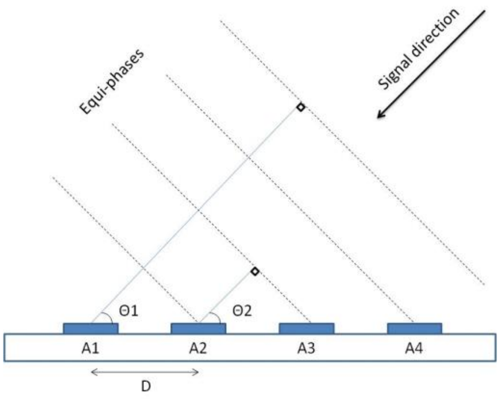
- Angle of Arrival (AoA): Here the transmitter is a simple single antenna device, and the receiver has a multi antenna array and must switch to different antennas during the reception. As such the transmitter is a low-cost mobile device whereas the receiver is anchored in a fixed location.

- Angle of Departure (AoD): Here the role is inversed: the mobile device is the receiver, and the transmitter has the antenna array.

This document will focus on the AoA method.

1.2. Theory

The transmitter sends a BLE signal that will travel at the speed of light in all directions. This signal will eventually reach the receiver antenna array. The signal will arrive at the antennas at a different time; it will first arrive at the closest antenna to the transmitter, then to the second closest etc… Thus, each antenna will see the signal with a different phase.



Knowing the phase difference between the antennas it is easy to find the angle of arrival:

$$\theta = \cos^{-1} \varphi\lambda/2\pi D$$

With: φ the phase difference, λ the wavelength and D the distance between 2 adjacent antennas.

2. Hardware

2.1. Design Choices

Antenna Array

We used a 12-antenna rectangular array derived from the Nordic Semi reference design. This design allows 2 angles to be determined: azimuth and elevation.

MCU

The board is designed to work with an ISP1907-HT containing an nRF52833. This module fully supports BLE 5.1 direction finding i.e it is capable of generating/receiving the CTE and controlling the antenna switches. The CTE (Constant Tone Extension) is the fixed frequency signal which is sampled in magnitude and phase for each antenna.

2.2. Antenna Array Description

MCU

The MCU is an ISP1907-HT.

Supply power & USB

Power supply comes from the USB. Then it is converted to 3V using a DCDC, the 3V supplies the ISP1907-HT and the switch. The USB lines are connected to the nRF52833 to allow communication with a PC through a virtual COM port.

RF Switch & lines

There are 5 RF switches on the board. One of them is central and distributes the signal to the 4 others which are located at each corner. Each “corner” switch distributes the signal to 3 antennas.

The switch used in this design is the PE42442 from pSemi. It is a SP4T with a fast switching time of 255ns. The switch loads the ports that are disconnected with 50 Ohms so that all the antennas have a terminating impedance of 50 Ohm. For a multi-patch antenna this is vital to ensure that adjacent patches do not interfere poorly with the patch that is receiving at a particular instant in time.

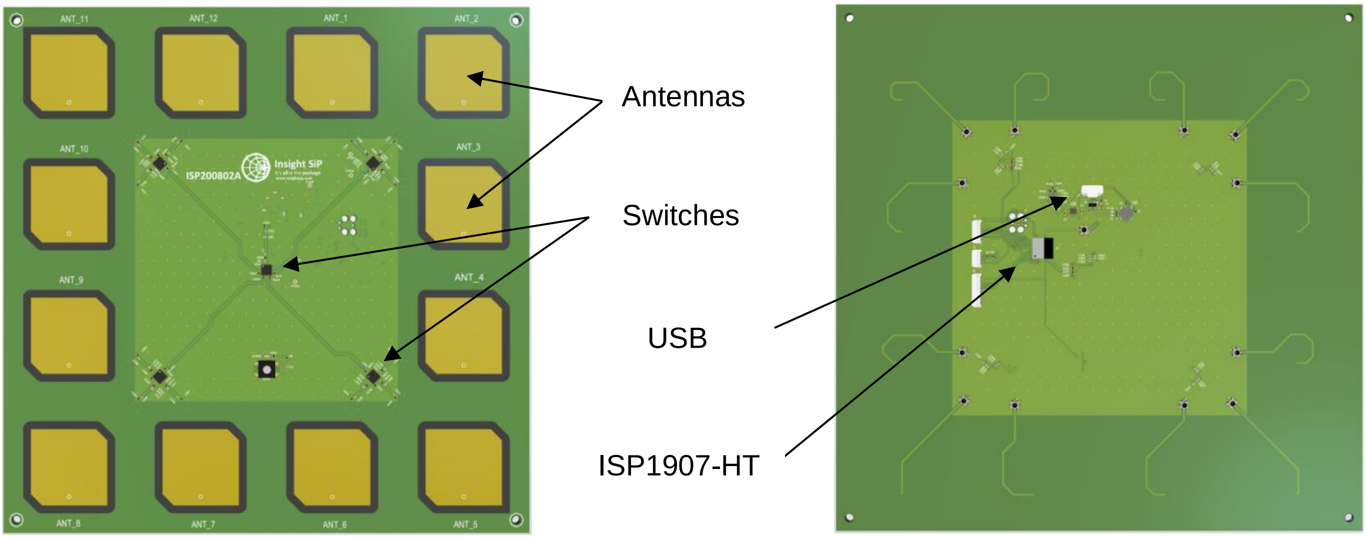
The Insight SiP version of the AoA antenna has been re-adjusted to ensure that the physical length of the sum of all transmission lines between the ISP1907HT module and the individual antennas is constant to within a fraction of a mm.

Special coaxial switch connectors were placed in each path between the feed structure and the antenna feed and at the input to the BLE module to be able to characterize the overall electrical line lengths.

RF Antennas

The RF antennas and their feed structure were re-designed to ensure that the feed structure does not impact antenna gain and performance and to ensure that all the feed lines have the same length. The PCB structure was altered so that the main antenna ground is on layer L2, with antenna feed on bottom layer, thereby separating the feed from the antenna.

In the Nordic implementation the main ground was on bottom layer with the feed between the antenna and ground on L2. Coupling between the feed lines and the antenna created highly non-uniform antenna amplitude and phase response.



Array Antenna Top View *Array Antenna Bottom View*

2.3. Transmitter Description

The transmitter is based on the ISP1880 self-contained sensor board using an ISP1907LL module that can send transmit pulses with the CTE.

3. Software

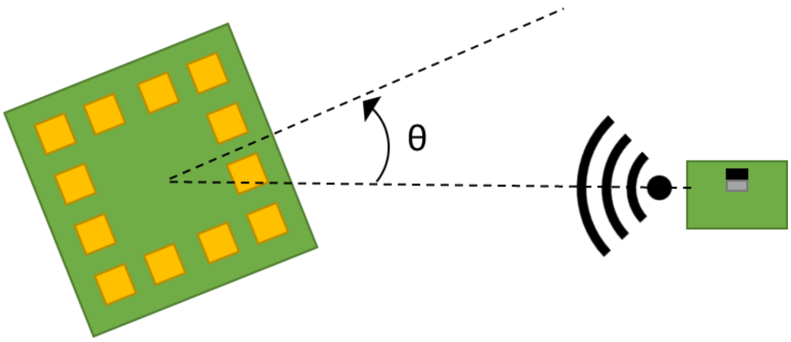
We are using the reference software provided by Nordic Semi.

4. Tests & Results

4.1. Azimuth accuracy

Setup

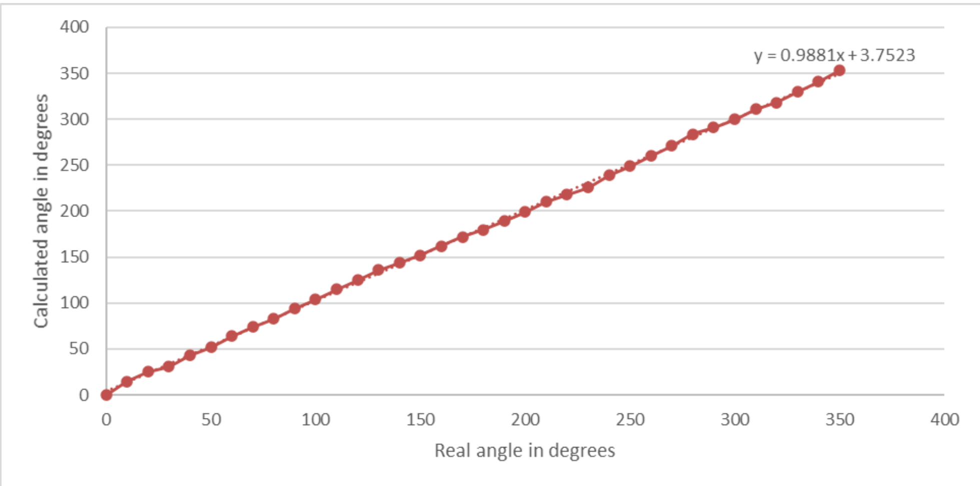
The anchor (12-antenna board) is put on a rotating support, antenna-side facing up. A tag (ISP1907-LL beaconing CTE every 100ms) is placed at a height of around 2m in order to have an elevation angle of around 50°.



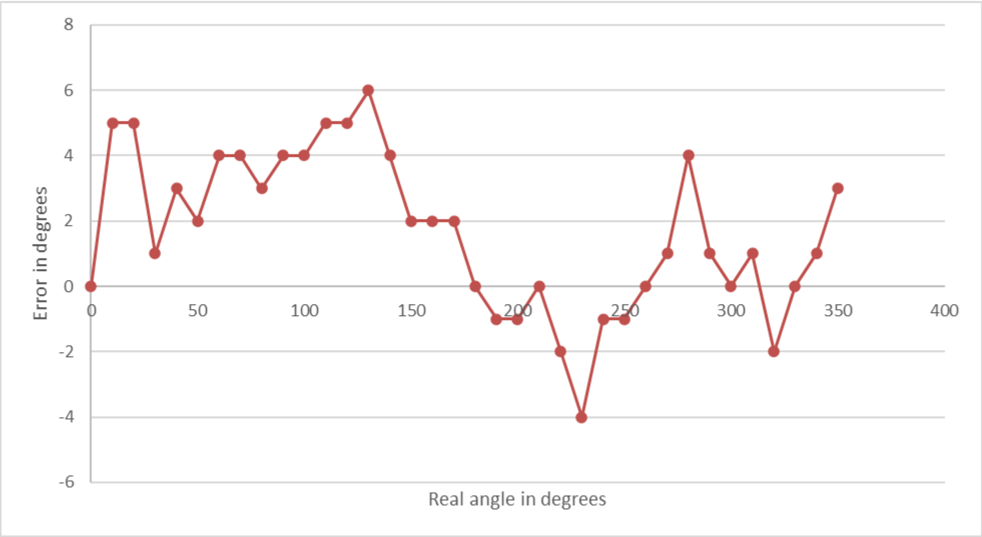
Azimuth setup

The anchor board is turned from 0 to 360° in 10° steps. The real angle is given by the rotating support. The results from the AOA calculation are retrieved on a serial terminal.

Results



Azimuth results



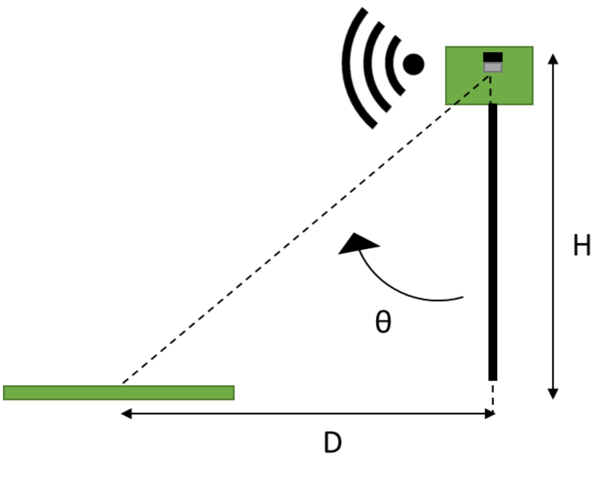
Azimuth error

All results are located between +/- 5°.

4.2. Elevation accuracy

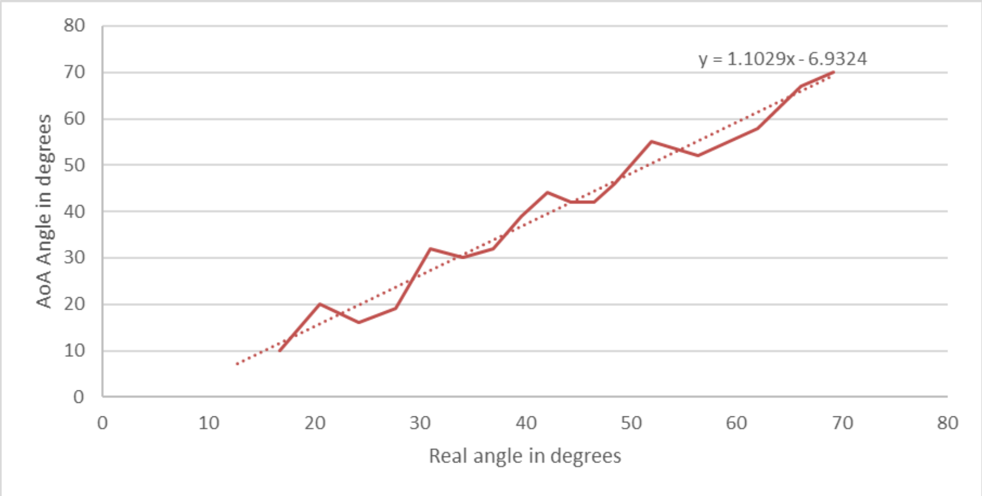
Setup

The anchor (12-antenna board) is put on a fixed support, antenna-side facing up and a t a height of 0.77m. A tag (ISP1907-LL beaconing CTE every 100ms) is placed at a height of around 2.1m. The distance between the tag and the anchor varies from 0 to 4m in order to have an elevation angle variation of 0 to 72°.

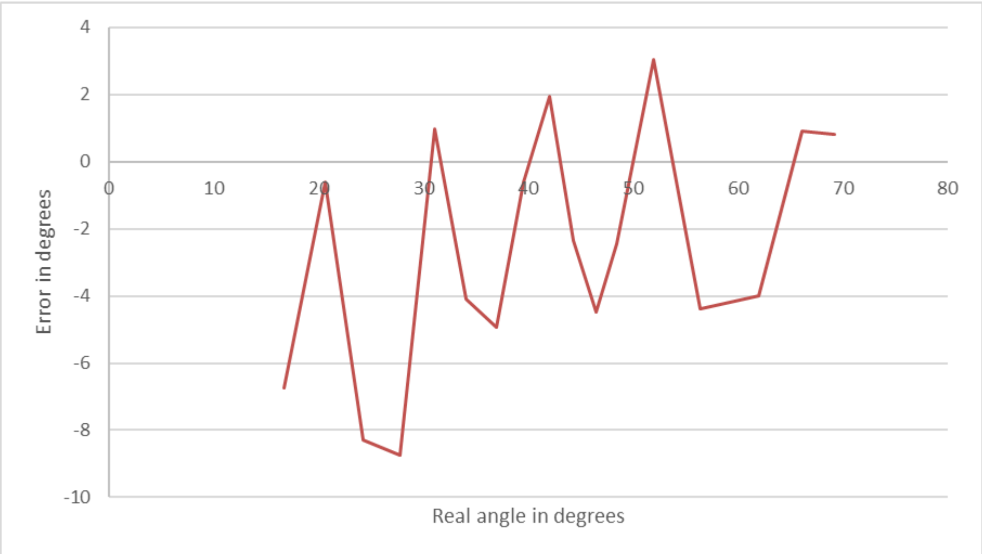


Elevation setup

Results



Elevation angle results



Elevation angle error

Except some outliers, most of results are located between +/- 5°.

5. Conclusion

The accuracy is around 10 degrees for both azimuth and elevation angles.

Assuming the system is used for location in a room where the anchor is placed on the ceiling at 3m height, 10° would represent an accuracy of 0.5 to 1m.

Notes:
(i) All these tests were performed in a closed area with possible interference with other Bluetooth devices. These results show the robustness of the system.
(ii) All samples are already processed by a FIR filter in the software.