Motorola Model: MD1005G
FCC ID: IHDT56XL1

Thermal Sensor Measurement Report

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2. Summary

This document provides the test results characterizing the thermal proximity sensors co-located with the mm-wave array modules of the 5G mm-wave Mod mobile device model MD1005G. The test method and test results are presented. More detailed operation of the sensor system and test plan detail are discussed in the long-term confidential documents "5G Mod Thermal Sensor Test Plan" and "5G Mod Device Description and Power Management Scheme."

3. Detector Test Procedure

Since the thermal sensors are responsive to body heat, the basic test uses a flat phantom filled with water maintained at nominal human skin temperature of 33 degrees C. Tests are also performed with the thermal target at temperatures of 30 C and 40 C. The device under test is mounted on a support that can hold it at the desired test orientation and test distance (7 cm is used as example in illustrations below), and the device on its mount is then slid under the heated phantom, while the control software is monitored to determine if/when the sensor is triggered. The basic setup is illustrated in figure 4-1.

Note that all tests are performed with the 5G Mod attached to the host phone device.

The sensors are designed for detection of normal human surface temperature. From literature search, this is nominally considered as 33C. To account for variation in human surface temperature due to e.g. elevated body temperature or greater or lesser biological cooling capacity, the wider range of temperatures from 30C to 40C were tested for worst-case. It was found that 30C was usually worst-case, so this temperature was used for the reported data. It is possible for the surface temperature to be lower than 30C in environments that are colder than nominal room temperature; however, since both environment temperature and surface temperature reduce together in these cases, the design of the thermal sensor and detection algorithm provide similar operation in these cases.

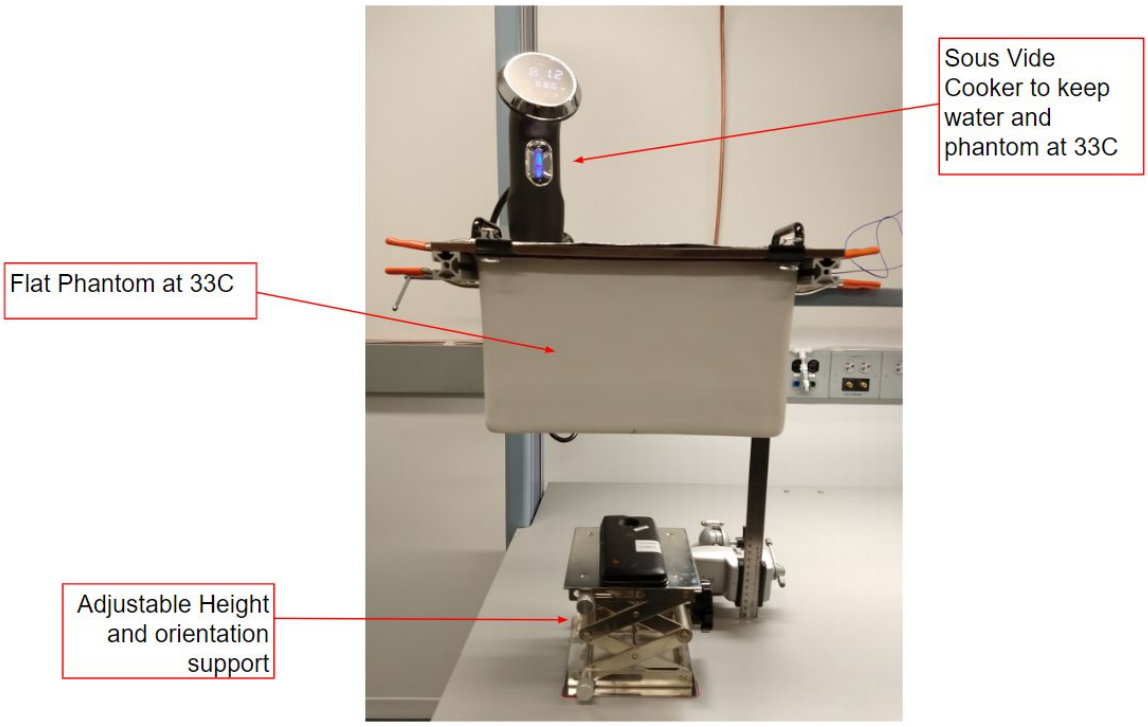

Figure 4-1: Thermal test setup.

The general procedure for testing is as follows:

1. Adjust the height and/or angle of the 5G Mod on the platform
2. Place the platform w/ the 5G Mod away from the Flat Phantom
3. Move the platform w/ 5G Mod under the center of Flat Phantom
4. Check the sensor state

Using the back-facing array module and sensor as example, the test procedure is shown diagrammatically below (the device support is omitted from view for clarity). A test distance of 7 cm is shown as example.

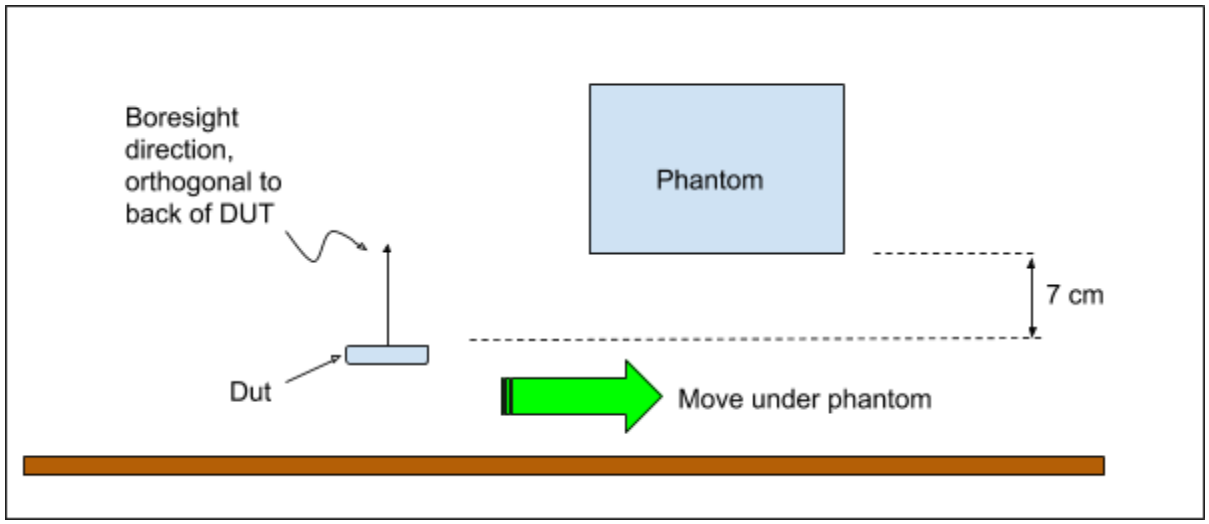

Figure 4-2: Illustration of test procedure, using back sensor at 7 cm for illustration.

This basic test procedure was applied at multiple spacings, in 1 cm increments, starting from a large spacing and reducing to a small spacing, and starting from a small spacing, and increasing to a large spacing. In this way the minimum detection distance was established for each module, and any hysteresis effects were taken into account. Steps of 1 cm were employed, rather than smaller steps of 3 or 1 mm as are commonly used to test capacitive proximity sensors, because of the much larger operational range of the thermal sensor. Note that using a larger step size of 1 cm produces a more conservative result, i.e. the smallest detection distance so found is equal to or less than that which would be found if using smaller step sizes like 1 mm.

Additionally, the test procedure was followed at a close distance of 5 mm from the device, to establish the extents of the angular cone of detection of each sensor, which was used to establish the measurement inclusion and exclusion zones in those measurement planes. Testing at this close spacing (corresponding to the actual measurement planes) is a more conservative means of establishing these characteristics of the sensor.

4. Measured Results

Results for minimum sensor response distance and angular response within specifically the 5 mm test separation distance relevant to MPE characterization are presented here. Figure 5-1 below shows the reference numbers for the sensors (four sensors on the device, one co-located with each mm-wave antenna array module), and the global coordinate system for reference.

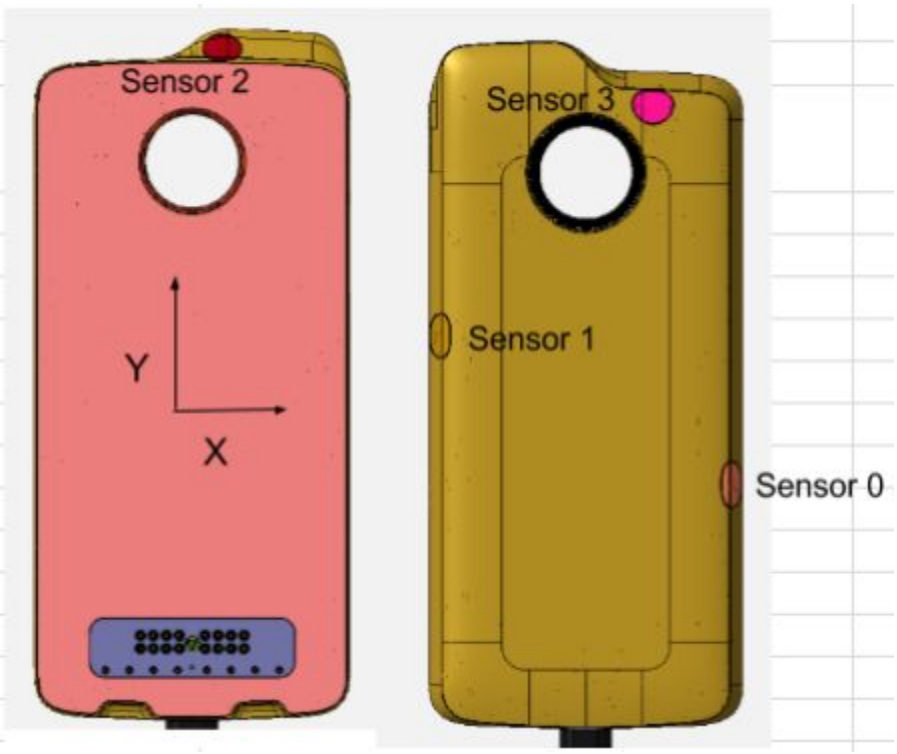

Figure 5-1: Reference numbers for sensors and the coordinate system.

4.1. Minimum Response Distance

The minimum response distance of each sensor was tested at the temperature extremes of 30C and 40C. The distance test is performed on-axis, in the broadside direction from the sensor and its associated mm-wave antenna array module, i.e. along a line orthogonal to the flat housing surface over the sensor. Testing was performed starting at large distance and reducing the distance until the sensor triggered, and starting at a small distance and increasing until the sensor released, to determine any hysteresis effects. The test results are presented as distance graphs in figure 5.1-1 below. Note that the sensor has effectively no hysteresis, i.e. trigger distance is the same as release distance.

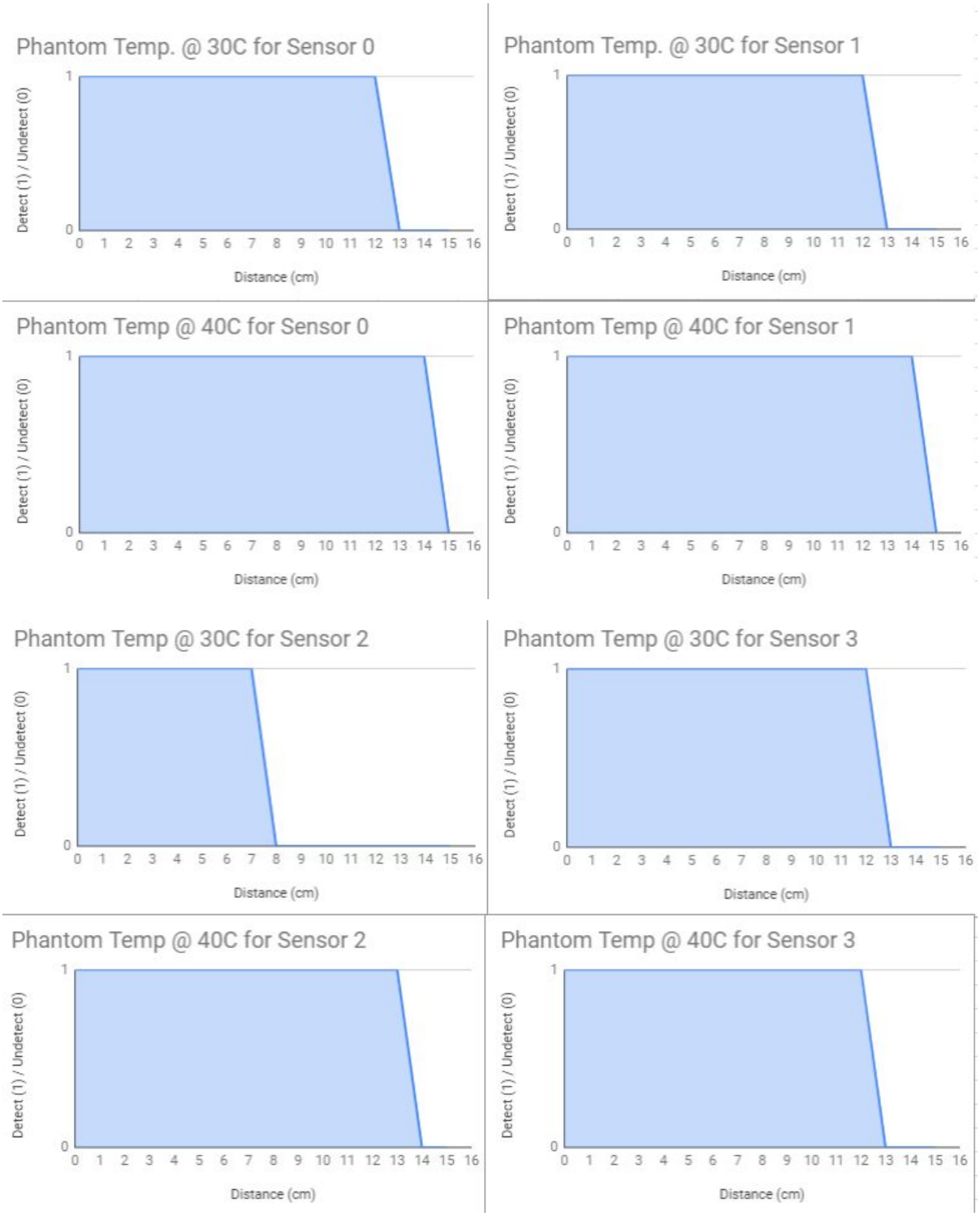

Figure 5.1-1: Trigger/Release distance test results.

The resulting minimum response distance results are tabulated in the table below.

Detect			
Phantom Temp @ 30C			
Unit 1 N5GV260099 w/ Phone	Location of sensor (eg, Bot Right, Top Left)	Y-Axis (in cm)	X-Axis (in cm)
Sensor 0	Right Side	12	12
Sensor 1	Left Side	12	12
Sensor 2	Top Front	7	7
Sensor 3	Top Rear	12	12

Undetect			
Phantom Temp @ 30C			
Unit 1 N5GV260099 w/ Phone	Location of sensor (eg, Bot Right, Top Left)	Y-Axis (in cm)	X-Axis (in cm)
Sensor 0	Right Side	13	13
Sensor 1	Left Side	13	13
Sensor 2	Top Front	8	8
Sensor 3	Top Rear	13	13

Phantom Temp @ 40C			
Unit 1 N5GV260099 w/ Phone	Location of sensor (eg, Bot Right, Top Left)	Y-Axis (in cm)	X-Axis (in cm)
Sensor 0	Right Side	14	14
Sensor 1	Left Side	14	14
Sensor 2	Top Front	13	13
Sensor 3	Top Rear	15	15

Phantom Temp @ 40C			
Unit 1 N5GV260099 w/ Phone	Location of sensor (eg, Bot Right, Top Left)	Y-Axis (in cm)	X-Axis (in cm)
Sensor 0	Right Side	15	15
Sensor 1	Left Side	15	15
Sensor 2	Top Front	14	14
Sensor 3	Top Rear	16	16

4.2. Angular Response at 5 mm Test Separation Distance

In addition to measuring the minimum response distance of the sensors, their angular response (detection cone) in a plane 5 mm in front of each sensor was also measured. These data are used to inform the detection regions employed in generating the final simulation and measurement planes as described in the document "Bolt PD Simulation and Measurement Report." These are established by approaching the thermal target at a 5 mm spacing, from each of four cardinal directions (+X, +Y, -X, -Y) in that plane, while monitoring sensor response.

These tests were performed at the worst-case temperature of 30C.

The results are presented graphically in the following plots, where the horizontal axis represents the displacement in the plane along the cardinal direction indicated in each plot. The angles calculated from these data and shown on the plots are thus the angles of response, relative the flat plane tangent to the housing surface in front of the sensor.

Note that these measurements are presented in the local coordinate system centered on the housing surface in front of each sensor and in the plane of tangency with the housing surface at that point. As such, the Y-axis in all cases (except sensor 2) corresponds to the global coordinate system's Y-axis as shown in figure 5-1. For sensors 2 and 3 (front and back surfaces), the local X-axis also corresponds to that in the global coordinate system in figure 5-1. But for the angled side sensors 0 and 1, the local X-axis shown in these plots would actually angle into or out of the page of figure 5-1, respectively, such that they are parallel to the respective tangency plane as described for each of those sensors. For the front sensor, the local Y-axis is titled about 12.5 with respect to global coordinate system's Y-axis as shown in figure 5-1 to make it parallel to the tangency plane of the front sensor.

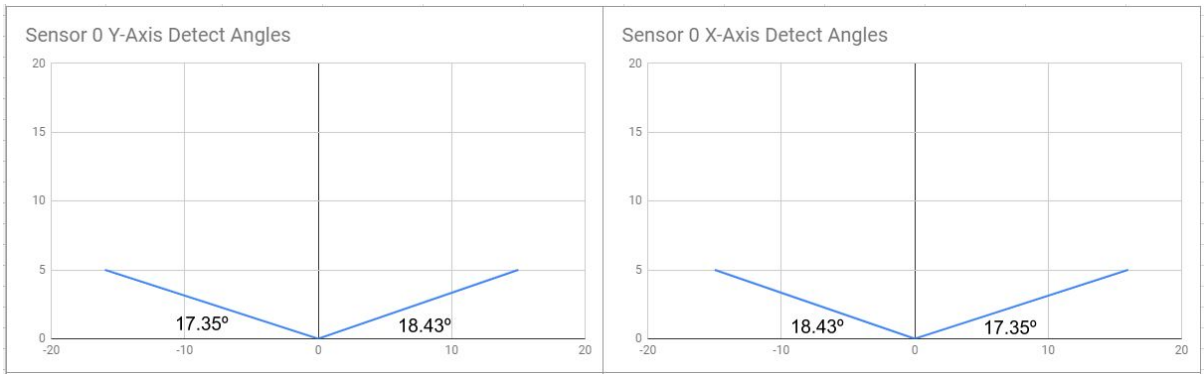

Figure 5.2-1(a): Measured angular responses of Sensor 0 at the 5 mm test separation distance.

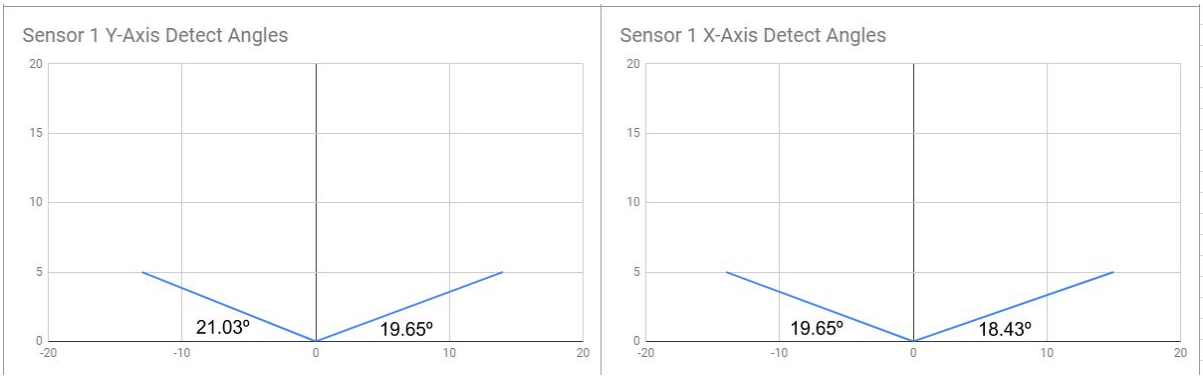

Figure 5.2-1(b): Measured angular responses of Sensor 1 at the 5 mm test separation distance.

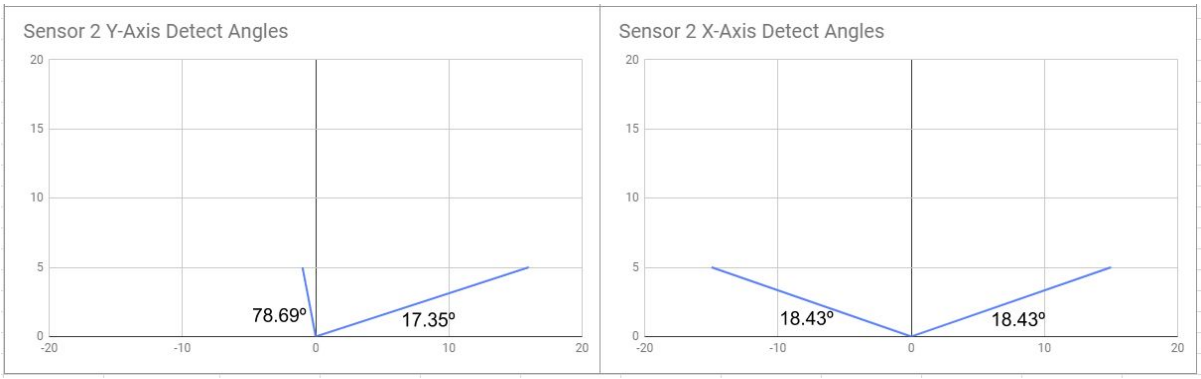

Figure 5.2-1(c): Measured angular responses of Sensor 2 at the 5 mm test separation distance.

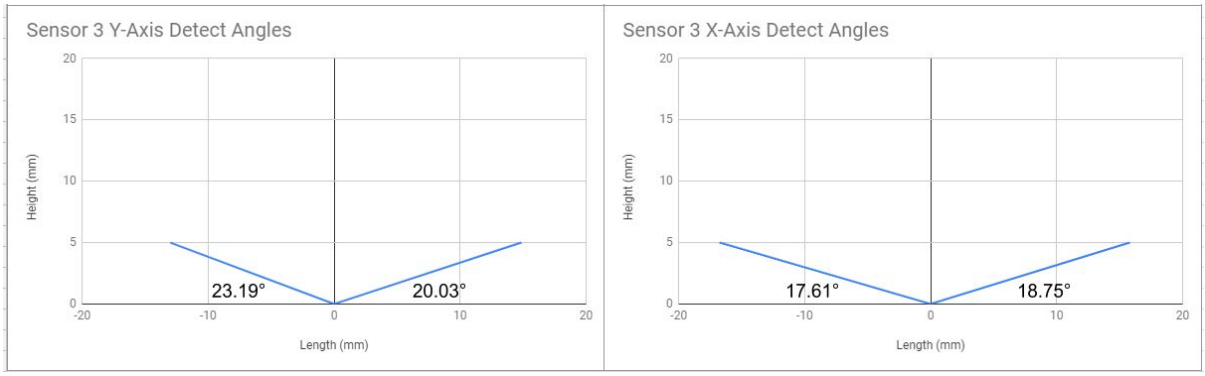

Figure 5.2-1(d): Measured angular responses of Sensor 3 at the 5 mm test separation distance.

These angular results are summarized in the table below:

Amb. Temp.: 20C Obj. Temp. 30C		Y-Axis (At 5mm)		X-Axis (At 5mm)	
Unit 1 N5GV260099 w/ Phone	Location of sensor (eg, Bot Right, Top Left)	-Y (Deg)	+Y (Deg)	-X (Deg)	+X (Deg)
Sensor 0	Right Side	17.4	18.4	18.4	17.4
Sensor 1	Left Side	21.0	19.7	19.7	18.4
Sensor 2	Top Front	78.7	17.4	18.4	18.4
Sensor 3	Top Rear	23.2	20.0	17.6	18.8

5. References

[1] none