EQUIPMENT : Portable Tablet Computer

Brand Name : Lenovo

MODEL NAME : Lenovo YB1-X90L

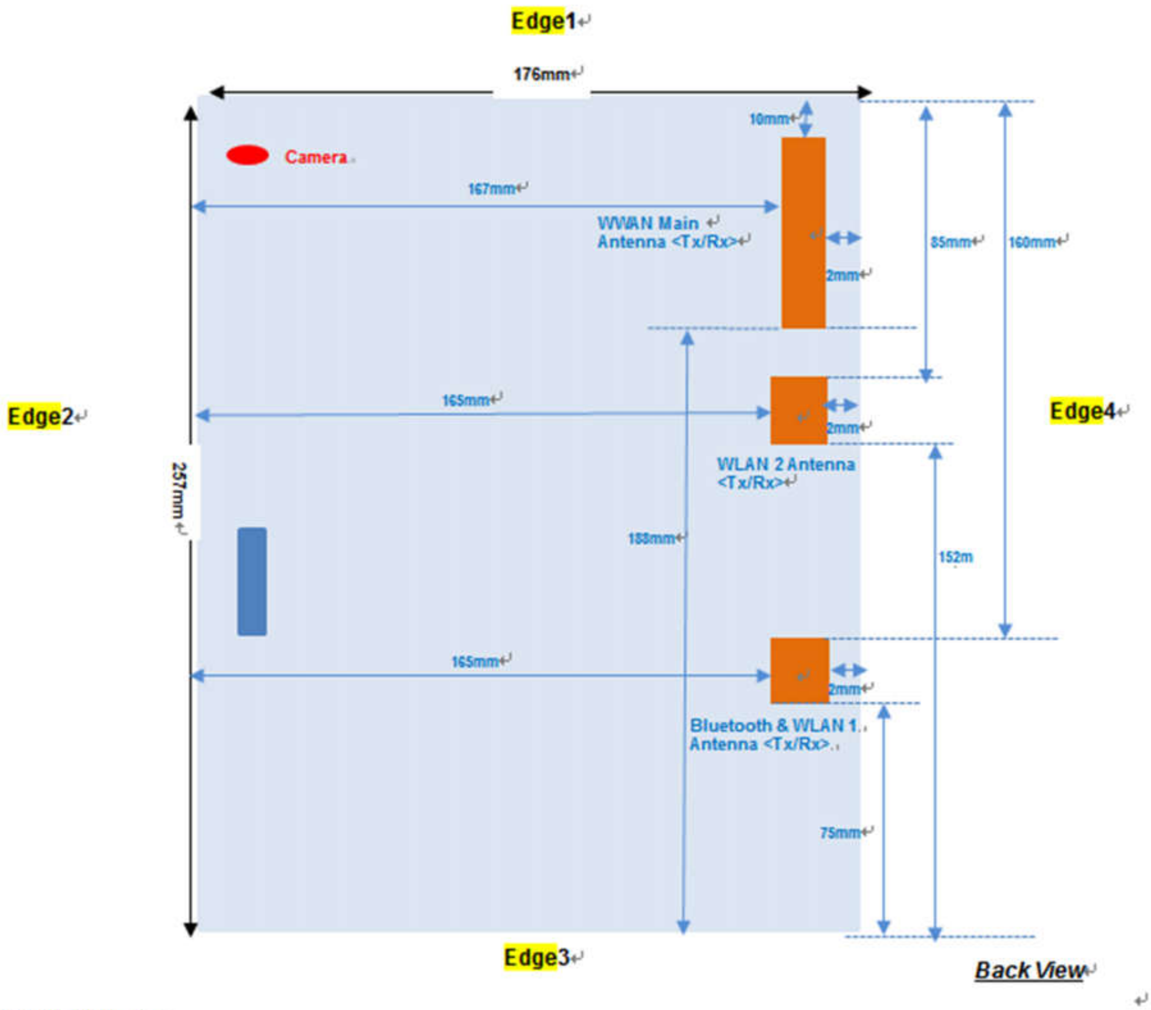
FCC ID : O57YB1X90L

– Technical Description of Power Reduction through Proximity Sensor

Table of Contents

1. EUT Antenna Placement

This is a Portable Tablet Computer, model name Lenovo YB1-X90L.
The antenna location and the EUT dimension is shown in the following diagram.



Diagonal: 308 mm

2. KDB 616217 D04v01r02 Section 6 Guideline/Requirement

Item	Description	Result
1	WWAN Antenna located in the corner of the tablet	No.
2	Power reduction for SAR compliance:	Only Proximity Sensor Triggered power reduction
3	Proximity sensor triggering distance	
3a	KDB 616217 D04v01r01 6.2 procedures to test trigger distance,	Detail in section 4
3b	KDB 616217 D04v01r01 6.4 procedures to verify tablet tilt angle influence	Detail in section 4
3c	The minimum trigger distance obtained in (a), (b) is defined as the trigger distance	Bottom Face: 18 mm Edge4: 16 mm
4	Proximity sensor coverage area	
4a	KDB 616217 D04v01r01 6.3 procedures are followed.	Yes. Detail in section 5
4b	The SAR peaks are enclosed with the sensor coverage area.	Yes. Detail in section 5
5	SAR testing to verify compliance of the mechanism	
5a	0cm SAR testing with EUT transmitting full RF power in reduced power mode	Yes.
5b	KDB 616217 D04v01r01 6.2)11), additional SAR testing with EUT transmitting full RF power in normal power mode, at the separation of "trigger distance -1mm", or less.	Full power SAR testing was performed at the distance smaller than the trigger distance; the test separation distance was used also for sensor coverage testing. Bottom Face: 17 mm [Note 1] Edge4: 15 mm [Note 1]

Note 1: Per KDB 616217 D04v01r02 footnote 26at page 13:
Depending on the antenna and sensor offset, if a test separation distance smaller than that determined by the triggering distance procedures can extend the coverage area to include the peak SAR location, a smaller test separation distance may be considered to avoid additional SAR tests

3. Power Reduction Theory

Proximity Sensor chipset Description

The device fully integrated, touch sensing capacitive sensor. It uses a ProxSense™ charge transfer capacitive acquisition method that is capable of near range proximity detection. The device offers a state of the art capacitive sensing engine with an embedded sampling capacitor and voltage regulator allowing the overall solution cost to be reduced and improving system immunity in noisy environments. It can target a detection range up to 20 cm thanks to the electrode parasitic capacitance compensation (EPCC) feature. The EPCC automatically compensates ground parasitic capacitance sources (such as ground planes, printed circuit board tacks, and large metal objects) which significantly reduce the proximity detection range.

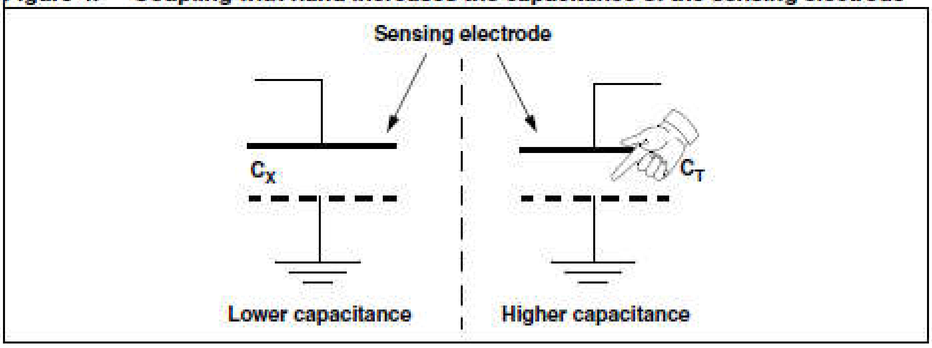
The application fields or typical functions with proximity features are various and include: on/off switches, replacement/enhancement, home buttons, backlighting feature on proximity for user interfaces, wakeup or control function on proximity, find-in-the-dark for lighting equipment, and companion device for battery saving in portable equipment.

The device has been designed to be used in applications where proximity is required and touch conditions can prevail for an extended period of time which may result in uncompensated drift in conventional capacitive sensors. Therefore, a process called DYCAL is implemented.

Capacitive sensing overview

A capacitance exists between any reference point and ground as long as they are electrically isolated. If this reference point is a sensing electrode, it can help to think of it as a capacitor. The positive electrode of the capacitor is the sensing electrode, and the negative electrode is formed by the surrounding area (virtual ground reference in Figure 4).

Figure 4. Coupling with hand increases the capacitance of the sensing electrode



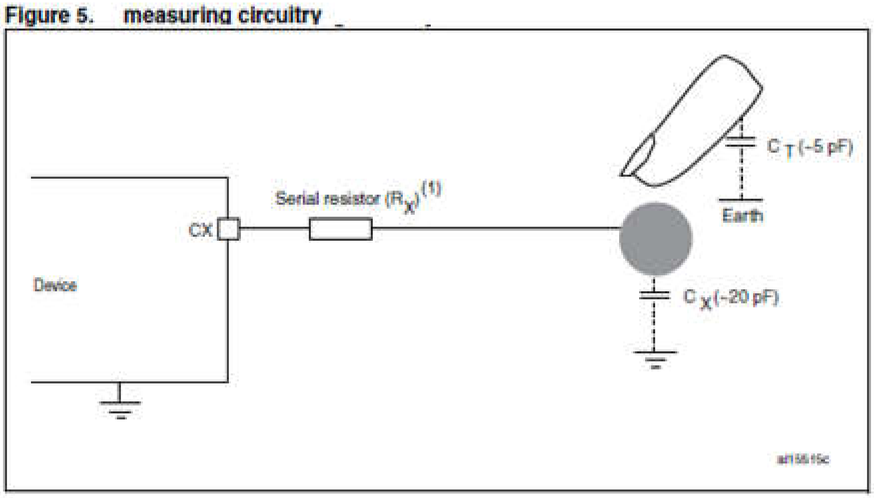
When a conductive object is brought into proximity of the sensing electrode, coupling appears between them, and the capacitance of the sensing electrode relative to ground increases. For example, a human hand raises the capacitance of the sensing electrode as it approaches it. Touching the dielectric panel that protects the electrode increases its capacitance significantly.

Charge-transfer acquisition principle

To measure changes in the electrode capacitance, device employ bursts of charge-transfer cycles.

The measuring circuitry is connected to the C_X pin. It is composed of a serial resistor R_X plus the sensing electrode itself of equivalent capacitance C_X (see Figure 5). The sensing electrode can be made of any electrically conductive material, such as copper on PCBs, or transparent conductive material like Indium Tin Oxide (ITO) deposited on glass or Plexiglas. The dielectric panel usually provides a high degree of isolation to prevent electrostatic discharge (ESD) from reaching the STM8T touch sensing controller. Connecting the serial resistor (R_X) to the C_X pin improves ESD immunity even more.

Figure 5. measuring circuitry



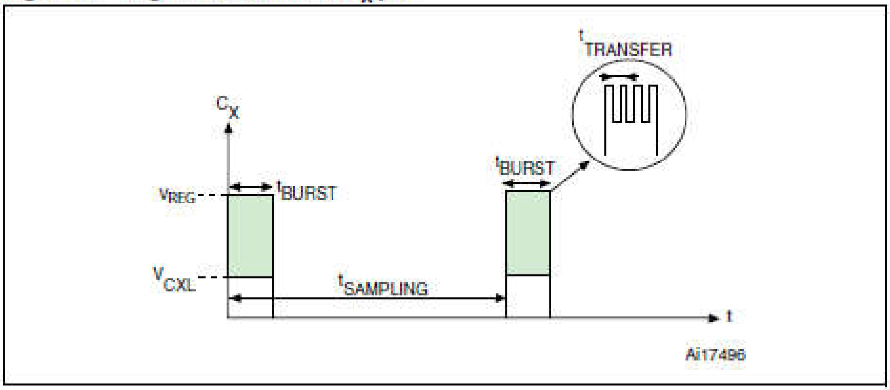
1. R_X must be placed as close as possible to the device.

The principle of charge transfer is to charge the electrode capacitance (C_X) using a stable power supply. When C_X is fully charged, part of the accumulated charge is transferred from C_X to an internal sampling capacitance, referred to as C_S. The transfer cycle is repeated until the voltage across the sampling capacitor C_S reaches the end of acquisition reference voltage (V_{TRIP}). The change in the electrode capacitance, caused by the presence or absence of the human body, is detected by measuring the number of transfer cycles composing a burst (see Figure 6).

Throughout this document the following naming conventions apply:

- The charge transfer period ($t_{TRANSFER}$) refers to the charging of C_X and the subsequent transfer of the charge to C_S.
- The burst cycle duration (t_{BURST}) is the time required to charge C_S to V_{TRIP}. The burst count is the number of charge transfer periods ($t_{TRANSFER}$) during one t_{BURST} cycle.
- The sampling period ($t_{SAMPLING}$) is the acquisition rate.

Figure 6. Signal monitored on C_X pin



Internal sampling capacitor

To reduce the application cost and increase the device flexibility, the features several internal sampling capacitors to fit a wide range of applications. The sampling interval is 9 msec.

Electrode parasitic capacitance compensation (EPCC)

The implementation of an electrode pad in a system always induces parasitic capacitances through tracks and surrounding components. The electrode parasitic capacitance is the residual capacitance between electrode and ground when no finger is present.

The EPCC is an internal hardware circuitry that compensates part of the electrode parasitic capacitance to improve the capacitive sensing channel sensitivity.

Detection and release thresholds

During the detection operation, after calibration is over, the device switches between three operating states: *no detection*, *proximity detection*, and *touch detection*. The switch between these states is driven by the difference between the signal and the reference.

The system goes from *no detection* to *proximity detection* state when the (reference - signal) is higher than the proximity threshold (PTh). In this state, the ECS is halted and the reference is frozen.

The system goes from *no detection* or *proximity detection* state to *touch detection* state when the (reference - signal) is higher than the touch threshold (TTh). When this happens, the reference value is changed to reflect the touch state after the delay t_{DYCAL_T}. This process is called dynamic calibration (DYCAL).

The system goes from the *touch detection* to *no detection* state when the (signal - reference) goes above the release threshold (RTh). At this point, another DYCAL occurs for the reference to represent the untouched state again.

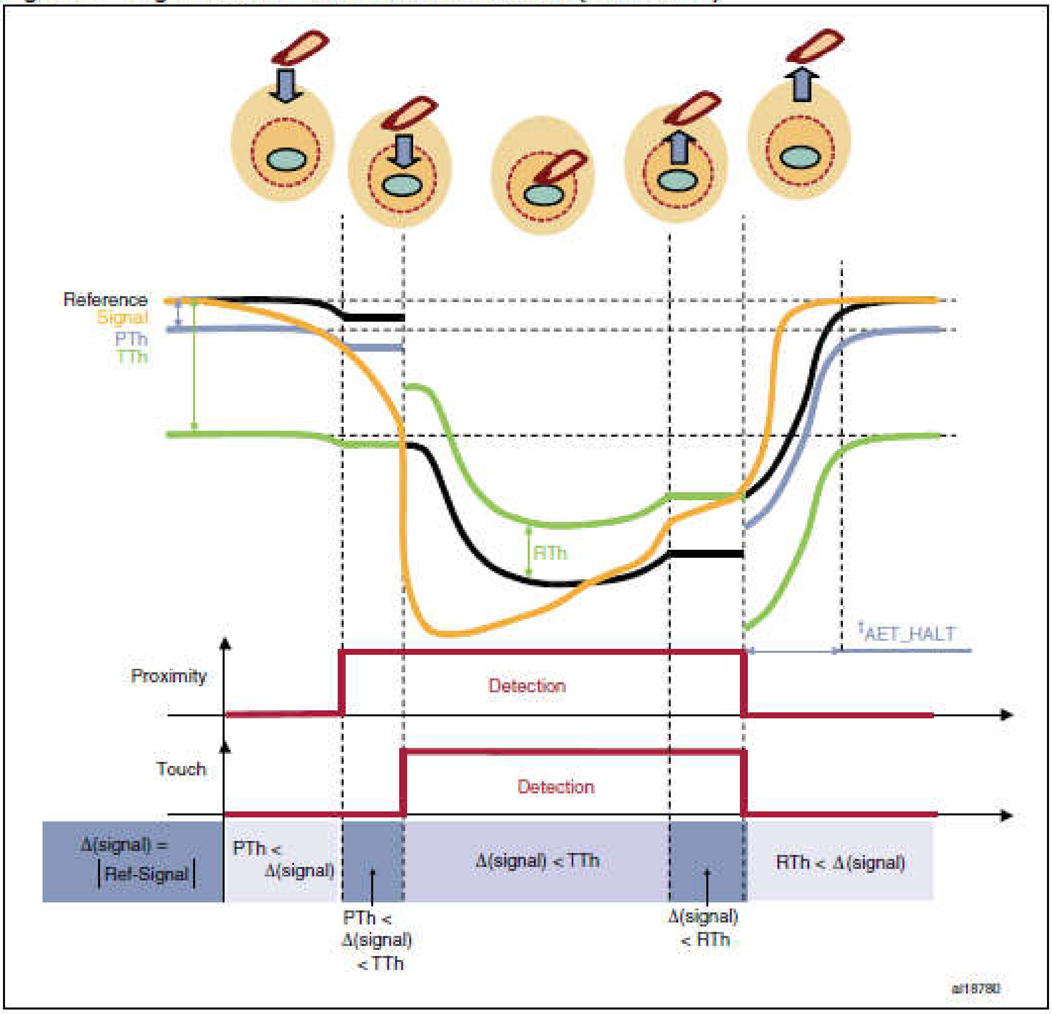
For higher flexibility, several proximity and touch detection thresholds are available and independently selectable through option byte: one PTh and one TTh.

- The touch thresholds allow the touch sensitivity to be adapted to the panel thickness and the electrode sensitivity.
- The proximity thresholds allow the device to adapt to various surroundings and to tune the detection distance.

The release threshold is a ratio of the touch threshold noted (TTh). TTh is selected by the “touch detection threshold” option bits. The ratio is selected by the “release threshold ratio” option bits.

A time filtering, similar to the debouncing of the mechanical switches, is applied to avoid noise induced detections.
Figure 8 simplifies the proximity and touch detection event according to the signal variation "Δ (signal)". The Δ (signal) is the absolute value of the reference minus the signal

Figure 8. Signal reference and detection threshold (not detailed)

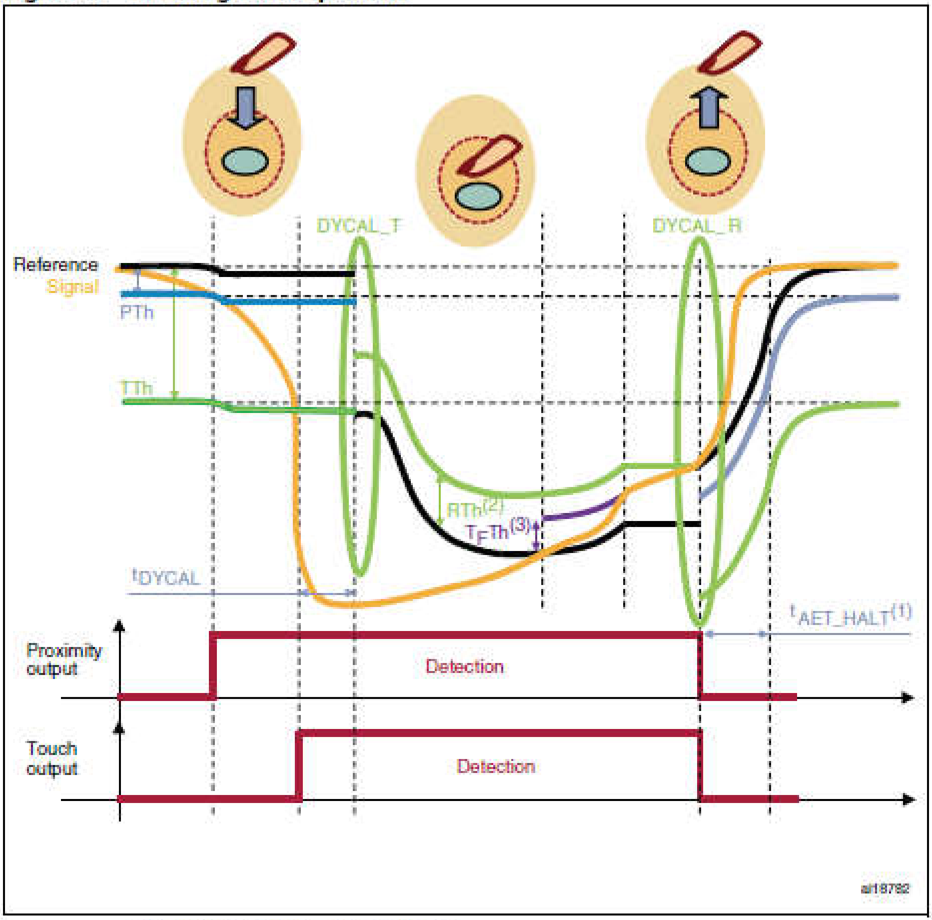


1. t_{AET_HALT} = AET HALT period after end of detection.

Dynamic calibration (DYCAL)

The device DYCAL process is based on a dynamic threshold and reference management which allows tracking of slow environmental changes even when the sensor is in touch state. A low threshold is used to detect the proximity of an object, with a higher threshold for touch detection. DYCAL is performed when a touch condition is detected for longer than a certain period (t_{DYCAL_T}). When a release condition occurs, the DYCAL operation is performed instantaneously. Figure 9 represents the DYCAL operation for the touch event (DYCAL_T) and for the release event (DYCAL_R).
After the DYCAL_R event, the AET process is frozen for a t_{AET_HALT} delay.

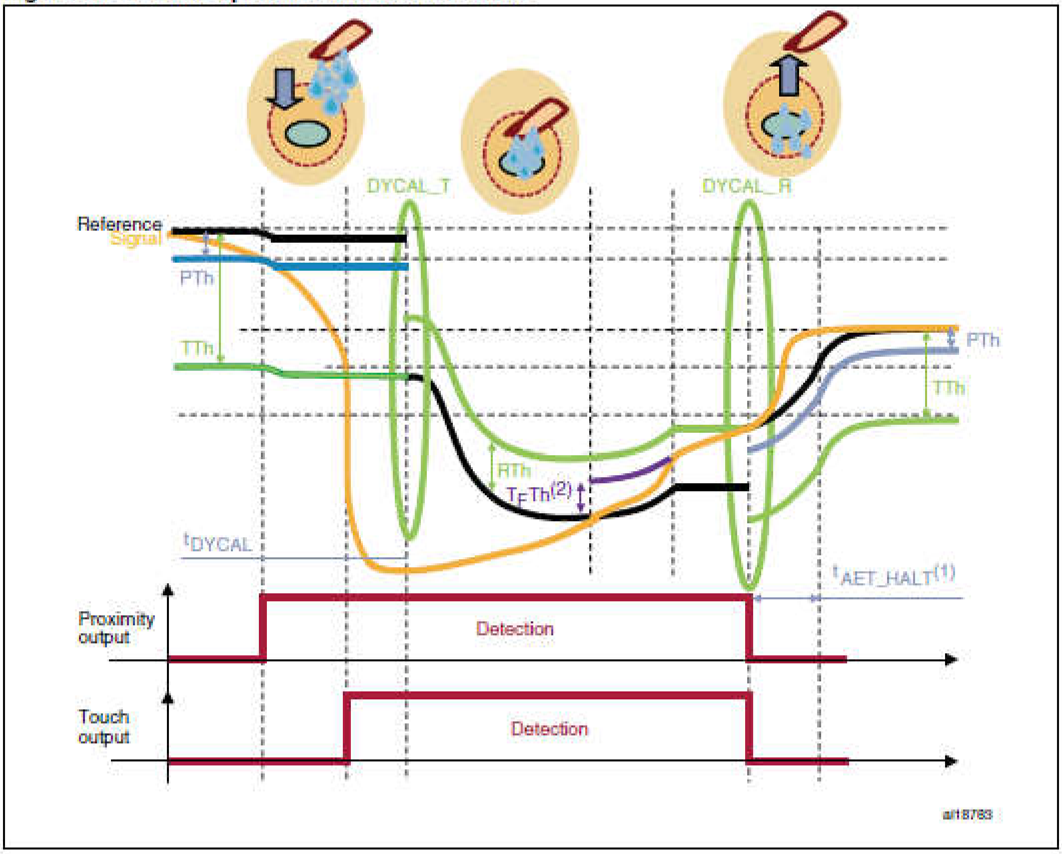
Figure 9. DYCAL general operation



1. t_{AET_HALT} = AET HALT period after end of detection.
2. The release threshold (RTh) is a ratio of the the touch threshold (TTh). TTh is selected by the "touch detection threshold" option bits (TTh). The ratio is selected by the "release threshold ratio" option bits.
3. T_FTh = Touch freeze threshold. Please refer to *Table 17: General capacitive sensing characteristics* and *Figure 12: IIR filter formula* for the T_FTh description.
4. In touch condition, the ECS allows the reference to adapt a slow signal variation change.

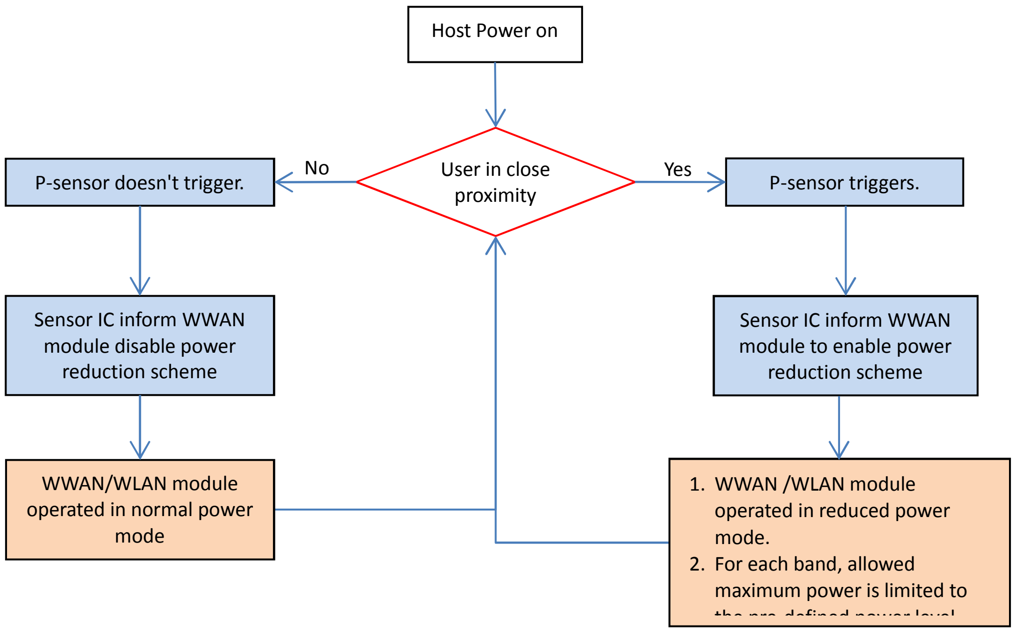
Figure 10 is an example of how the system behaves with a water residue when it is managed by DYCAL.

Figure 10. DYCAL operation with water residue



1. t_{AET_HALT} = AET HALT period after end of detection.
2. T_FTh = Touch freeze threshold. Please refer to *Table 17: General capacitive sensing characteristics* and *Figure 12: IIR filter formula* for the T_FTh description.

Power Reduction Block Diagram



Remark:

1. The sensor IC samples every 9 msec, a debouncing filter mechanism will detect few consecutive triggering status, and will update the sensor IC output status every 60 msec.
2. The reduced power is enabled through a look-up table on the WWAN/WLAN module. Once the P-sensor is triggered the Sensor IC will send an active signal to inform WWAN module to enable power reduction scheme.

Target Power reduction applied for each wireless mode and orientation

Exposure Position / wireless mode	Bottom Face[1]	Edge 1	Edge 2	Edge 3	Edge 4[1]
GSM850 GPRS (GMSK 1 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 GPRS (GMSK 2 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 GPRS (GMSK 3 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 GPRS (GMSK 4 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 EDGE (8PSK 1 Tx slot) - MCS5	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 EDGE (8PSK 2 Tx slot) - MCS5	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 EDGE (8PSK 3 Tx slot) - MCS5	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM850 EDGE (8PSK 4 Tx slot) - MCS5	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM1900 GPRS (GMSK 1 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM1900 GPRS (GMSK 2 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM1900 GPRS (GMSK 3 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM1900 GPRS (GMSK 4 Tx slot) - CS1	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM1900 EDGE (8PSK 1 Tx slot) - MCS5	6.0 dB	0 dB	0 dB	0 dB	6.0 dB
GSM1900 EDGE (8PSK 2 Tx slot) - MCS5	6.5 dB	0 dB	0 dB	0 dB	6.5 dB
GSM1900 EDGE (8PSK 3 Tx slot) - MCS5	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
GSM1900 EDGE (8PSK 4 Tx slot) - MCS5	7.0 dB	0 dB	0 dB	0 dB	7.0 dB
WCDMA Band V	4.5 dB	0 dB	0 dB	0 dB	4.5 dB
WCDMA Band II	9.5 dB	0 dB	0 dB	0 dB	9.5 dB
WCDMA Band IV	10.5 dB	0 dB	0 dB	0 dB	10.5 dB
LTE Band 2	10.0 dB	0 dB	0 dB	0 dB	10.0 dB
LTE Band 4	10.0 dB	0 dB	0 dB	0 dB	10.0 dB
LTE Band 5	4.5 dB	0 dB	0 dB	0 dB	4.5 dB
LTE Band 7	11.5 dB	0 dB	0 dB	0 dB	11.5 dB
LTE Band 12	5.0 dB	0 dB	0 dB	0 dB	5.0 dB
LTE Band 17	5.0 dB	0 dB	0 dB	0 dB	5.0 dB
LTE Band 25	10.0 dB	0 dB	0 dB	0 dB	10.0 dB
LTE Band 38	9.5 dB	0 dB	0 dB	0 dB	9.5 dB

Exposure Position / wireless mode	Bottom Face[1]	Edge 1	Edge 2	Edge 3	Edge 4[1]
WLAN2.4GHz Ant1	16.0 dB	0 dB	0 dB	0 dB	16.0 dB
WLAN2.4GHz Ant2	12.0 dB	0 dB	0 dB	0 dB	12.0 dB
WLAN2.4GHz Ant1+2	5.5 dB	0 dB	0 dB	0 dB	5.5 dB
WLAN5.2GHz Ant1	6.0 dB	0 dB	0 dB	0 dB	6.0 dB
WLAN5.2GHz Ant2	9.5 dB	0 dB	0 dB	0 dB	9.5 dB
WLAN5.2GHz Ant1+2	12.5 dB	0 dB	0 dB	0 dB	12.5 dB
WLAN5.3GHz Ant1	5.0 dB	0 dB	0 dB	0 dB	5.0 dB
WLAN5.3GHz Ant2	10.0 dB	0 dB	0 dB	0 dB	10.0 dB
WLAN5.3GHz Ant1+2	13.0 dB	0 dB	0 dB	0 dB	13.0 dB
WLAN5.5GHz Ant1	5.0 dB	0 dB	0 dB	0 dB	5.0 dB
WLAN5.5GHz Ant2	9.0 dB	0 dB	0 dB	0 dB	9.0 dB
WLAN5.5GHz Ant1+2	13.5 dB	0 dB	0 dB	0 dB	13.5 dB
WLAN5.8GHz Ant1	4.0 dB	0 dB	0 dB	0 dB	4.0 dB
WLAN5.8GHz Ant2	9.5 dB	0 dB	0 dB	0 dB	9.5 dB
WLAN5.8GHz Ant1+2	12.5 dB	0 dB	0 dB	0 dB	12.5 dB

Remark:

1. (1): Reduced maximum limit applied by activation of proximity sensor.
2. Power reduction triggered via proximity sensor is implemented for SAR compliance when users approach the device. The power reduction level is a single fixed level for each frequency band.
3. Power reduction is not applicable for Bluetooth.
4. Power reduction is enabled solely upon a proximity sensor trigger event, at the user-EUT distance equal or smaller than the trigger distance. The power reduction is of the highest priority of this device, and will not be overridden by the request of the base station (ex: poor RSSI, etc.), and will be overridden by any other event (ex: low battery, AC-plugged, etc.) or any user intervention. There is no software setting or any 3rd party software can disable the mechanism.

4. Trigger distance testing

4.1. Measurement Procedure

<Sensor Trigger distance testing – Bottom Face>:

1. Set the transmitter to operate at its normal maximum output power.
2. Place the entire Bottom Face of the tablet below a flat phantom filled with tissue-equivalent medium required for the test frequency range, For this device, tissue-simulating liquid for 1900MHz SAR measurement was filled for trigger distance and sensor coverage area testing and positioned at least 20 mm away the flat phantom.
3. Gradually move the device in 3 mm steps toward the flat phantom in the perpendicular direction, until the sensor triggers.
4. Move the device 5 mm back from the flat phantom and then again move the device toward the phantom in 1 mm steps until it touches the phantom. Make sure the power stays reduced after the device past the triggering point.
5. Record the distance between EUT and the flat phantom, when the proximity sensor starts to be triggered.
6. Place EUT Bottom Face contacted with the flat phantom. Gradually Move the device in 3 mm steps away from the flat phantom in the perpendicular direction, until the sensor stop triggering.
7. Move the device 5 mm toward the flat phantom and then again move the device away from the phantom in 1 mm steps until it is at least 20 mm away from the phantom and return to the normal maximum power level.
8. Record the distance between EUT and the flat phantom, when proximity sensor starts to be NOT triggered.

<Sensor Trigger distance testing – Edge4>:

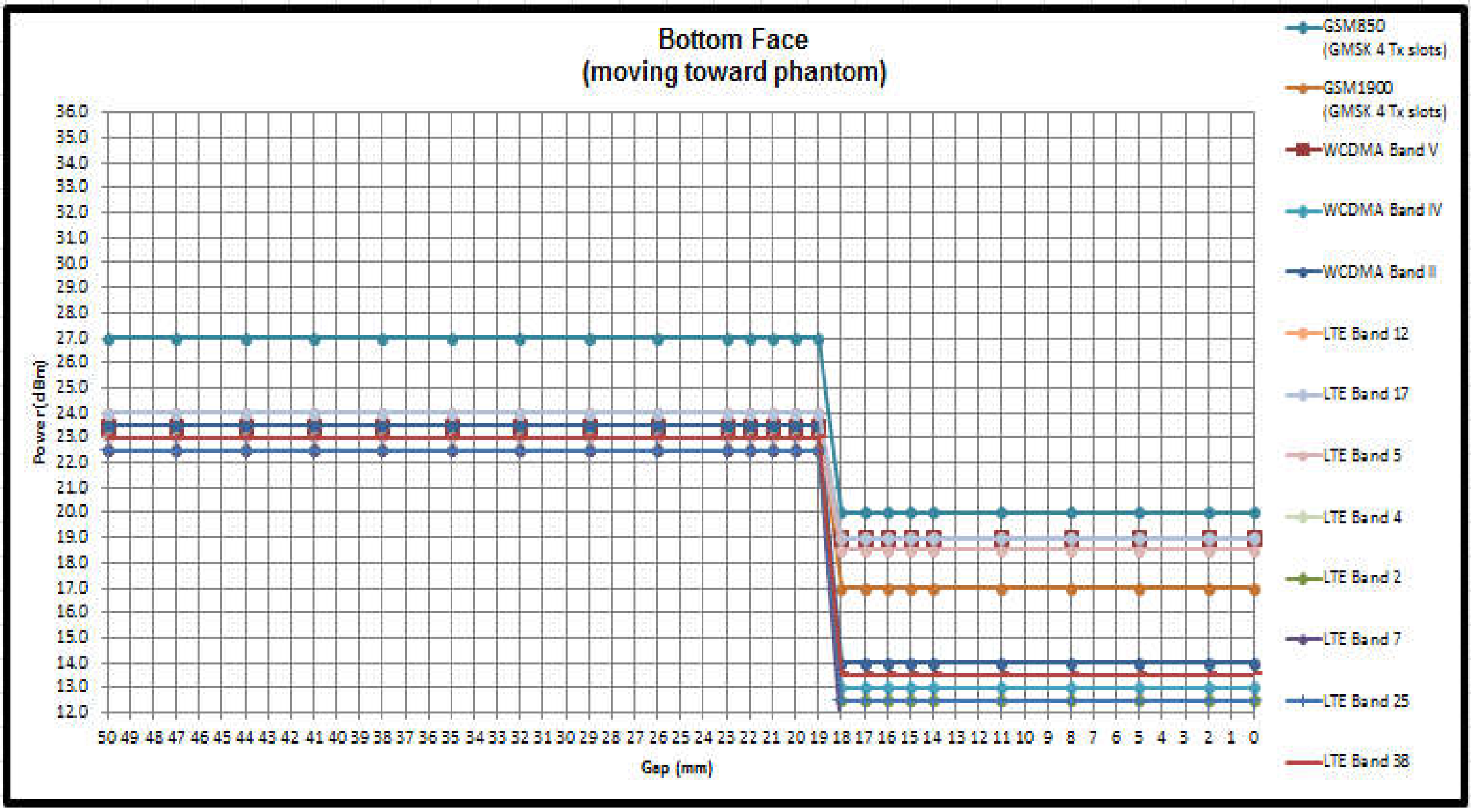
1. Set the transmitter to operate at its normal maximum output power.
2. Place the entire Edge1 of the tablet below a flat phantom filled with tissue-equivalent medium required for the test frequency range, and positioned at least 20 mm away the flat phantom.
3. Gradually move the device in 3 mm steps toward the flat phantom in perpendicular direction, until the sensor triggers.
4. Move the device 5 mm back from the flat phantom and then again move the device toward the phantom in 1 mm steps until it touches the phantom. Make sure the power stays reduced after the device past the triggering point.
5. Record the distance between EUT and the flat phantom, when proximity sensor starts to be triggered.
6. Place EUT Edge1 contacted with the flat phantom Gradually Move the device in 3 mm steps away from the flat phantom in perpendicular direction, until the sensor stop triggering.
7. Move the device 5 mm toward the flat phantom and then again move the device away from the phantom in 1 mm steps until it is at least 20 mm away from the phantom and return to the normal maximum power level.
8. Record the distance between EUT and the flat phantom, when proximity sensor starts to be NOT triggered.

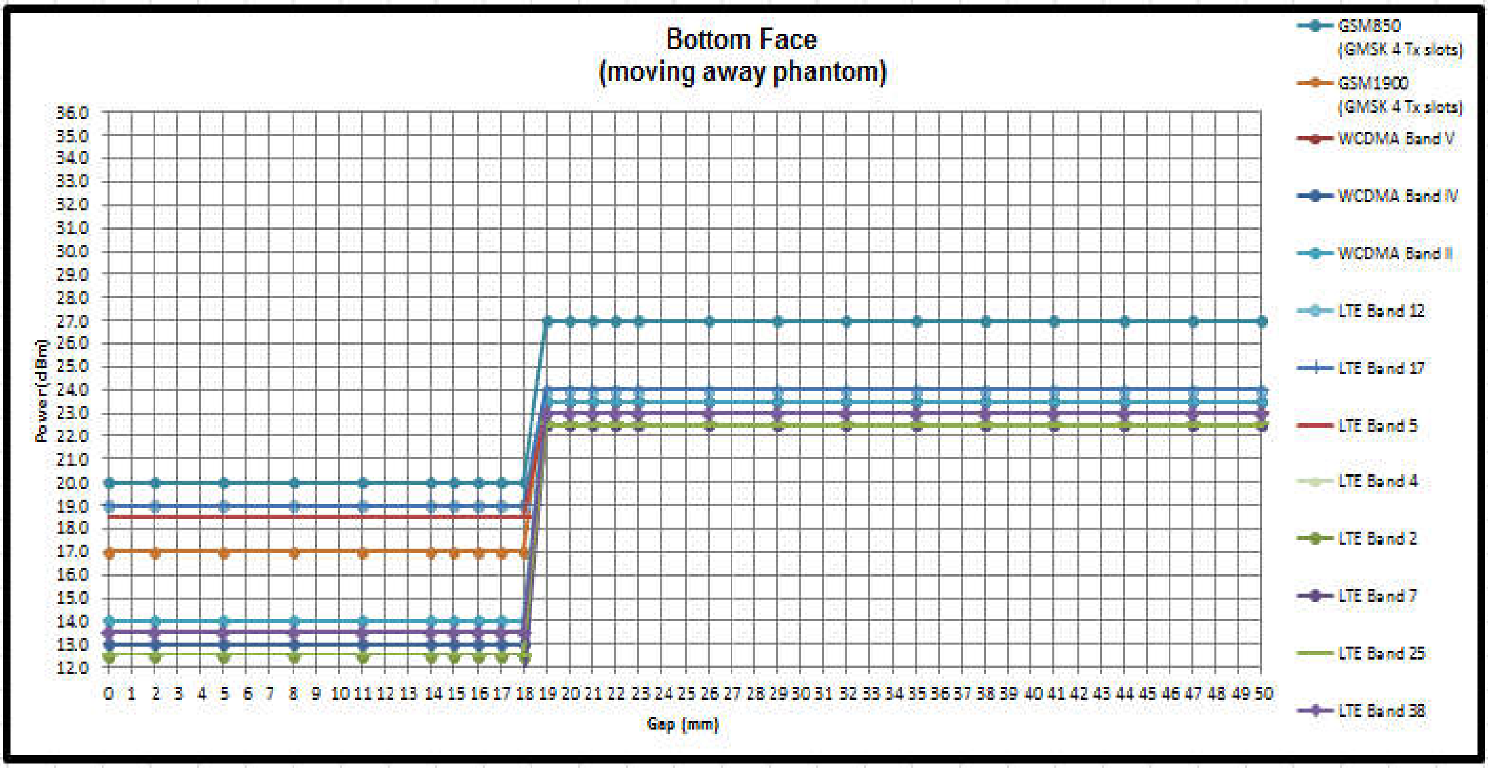
<Procedures for determining tablet tilt angle influences to proximity sensor triggering>

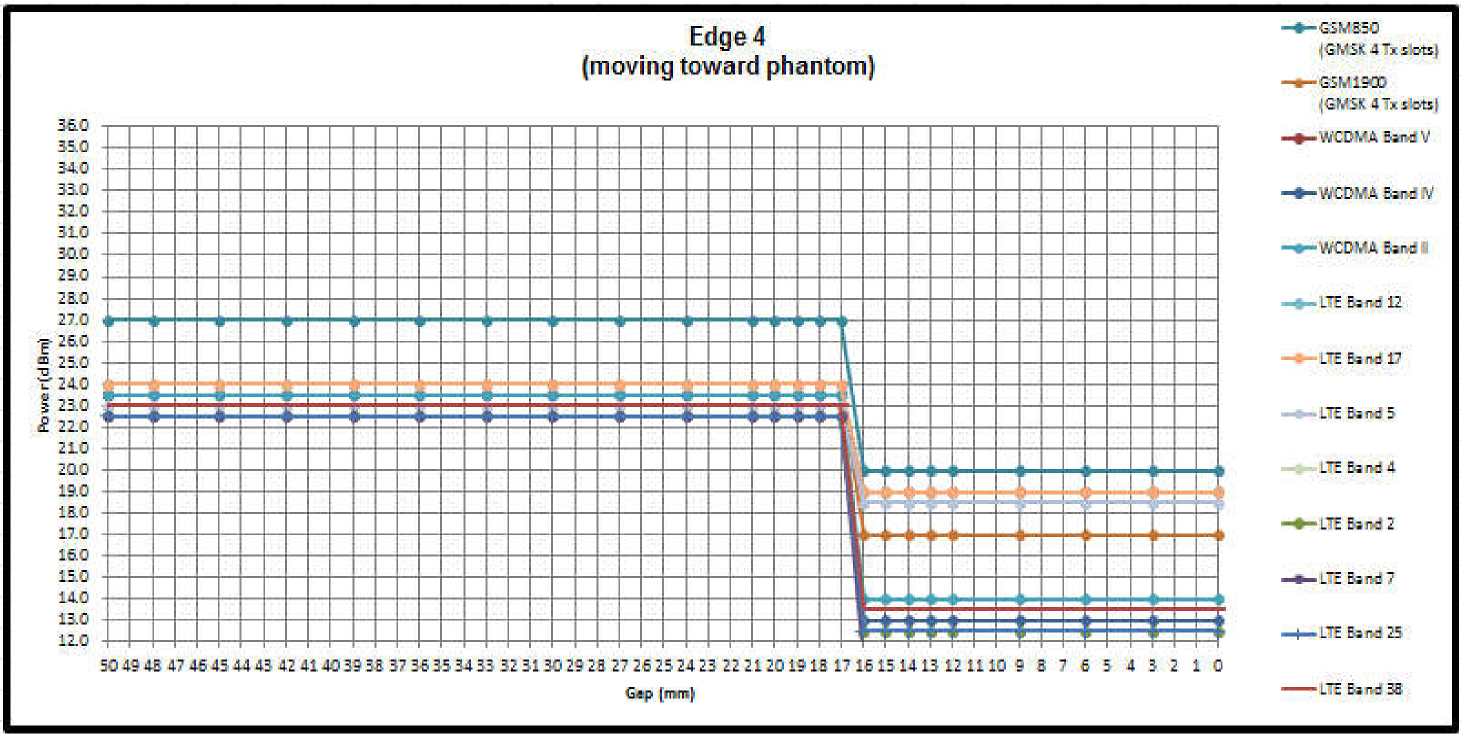
The procedures below quoted from KDB 616217 D04 6.4, are followed.

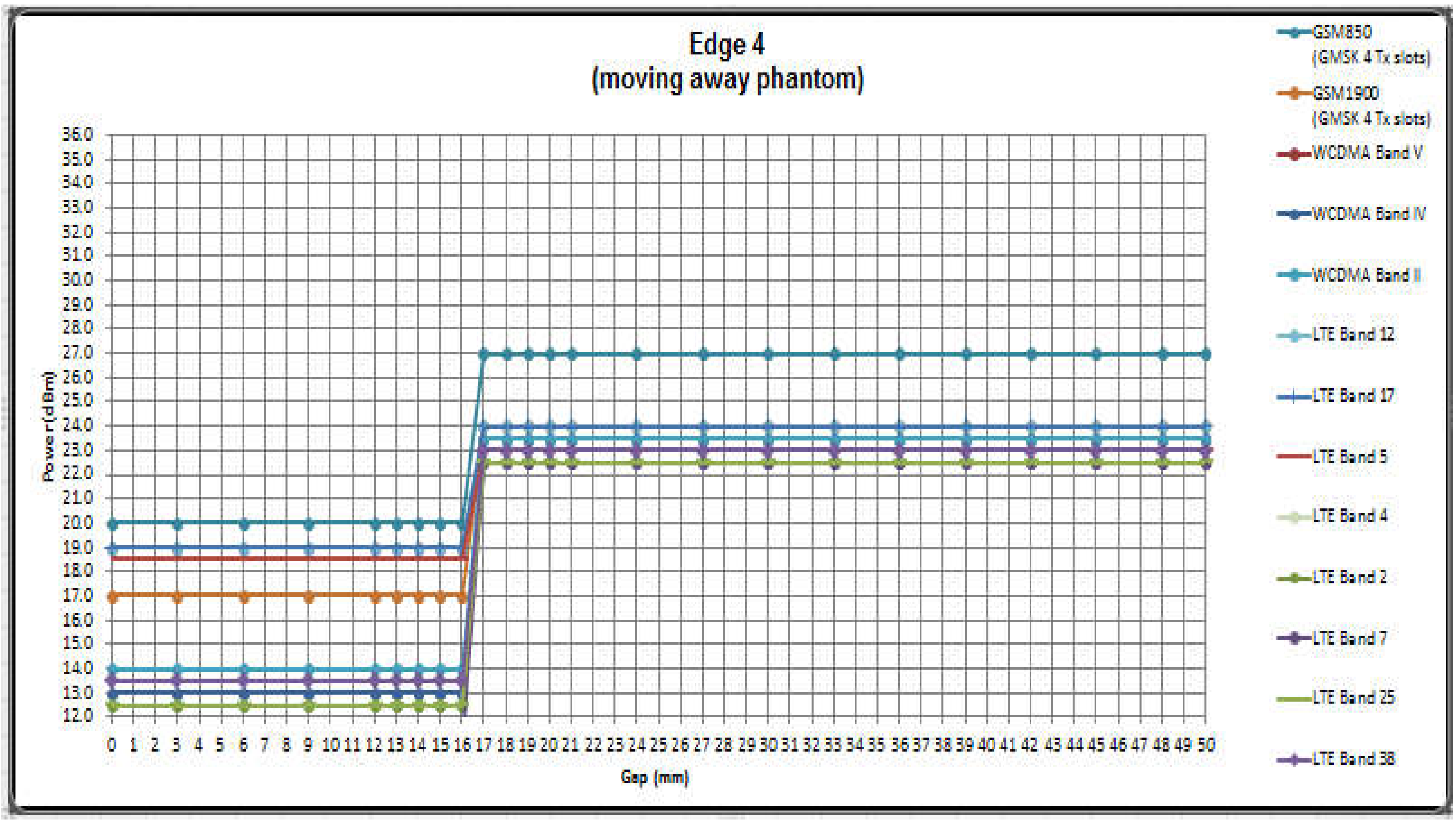
1. The influence of table tilt angles to proximity sensor triggering is determined by positioning each tablet edge that contains a transmitting antenna, perpendicular to the flat phantom, at the smallest sensor triggering test distance determined in sections 6.2 and 6.3 by rotating the tablet around the edge in ≤ 10° increments until the tablet is ±45° or more from the vertical position at 0°.
2. If sensor triggering is released and normal maximum output power is restored within the ±45° range, the procedures in step 1) should be repeated by reducing the tablet to phantom separation distance by 1 mm until the proximity sensor no longer releases triggering, and maximum output power remains in the reduced mode.
3. The smallest separation distance determined in steps 1) and 2), minus 1 mm, is the sensor triggering distance for tablet tilt coverage. The smallest separation distance determined in sections 6.2, 6.3 and 6.4 minus 1 mm should be used in the SAR measurements.

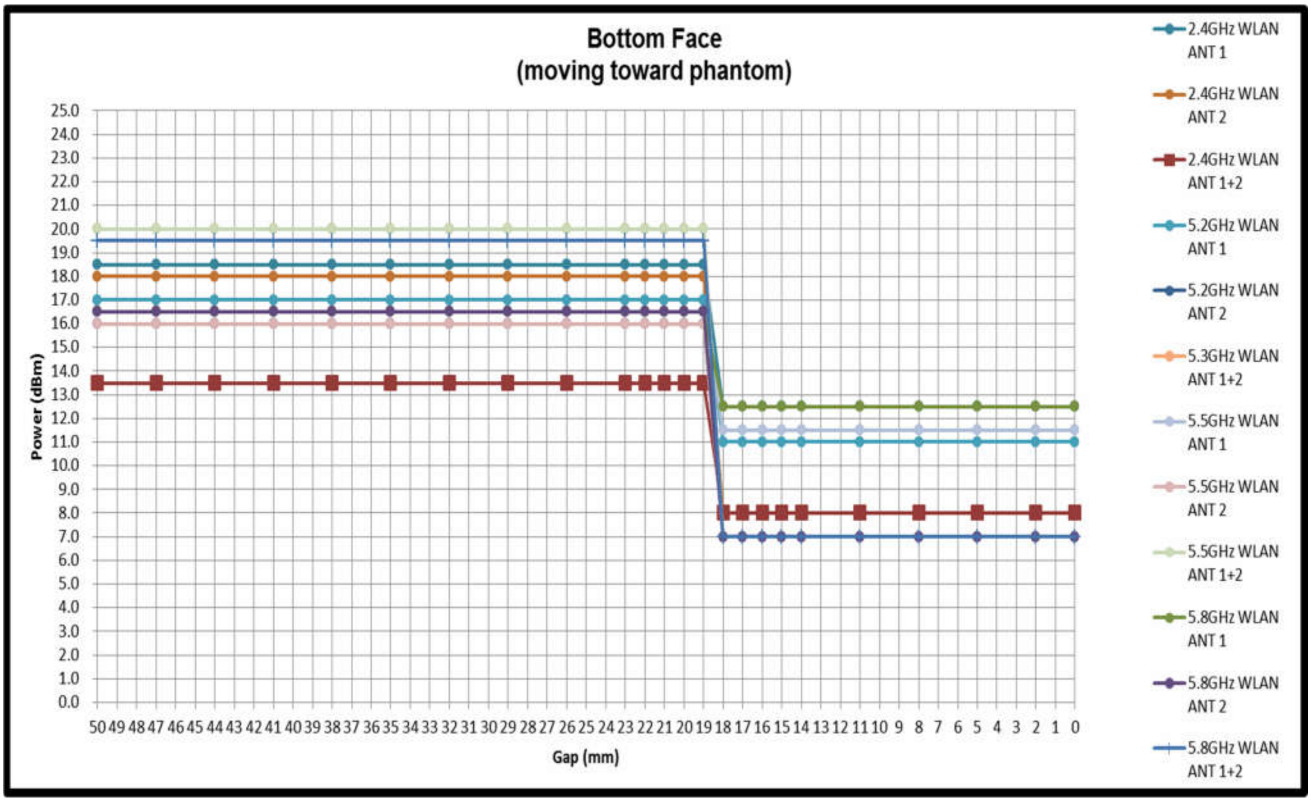
4.2. Power Measurement during Sensor Trigger distance testing

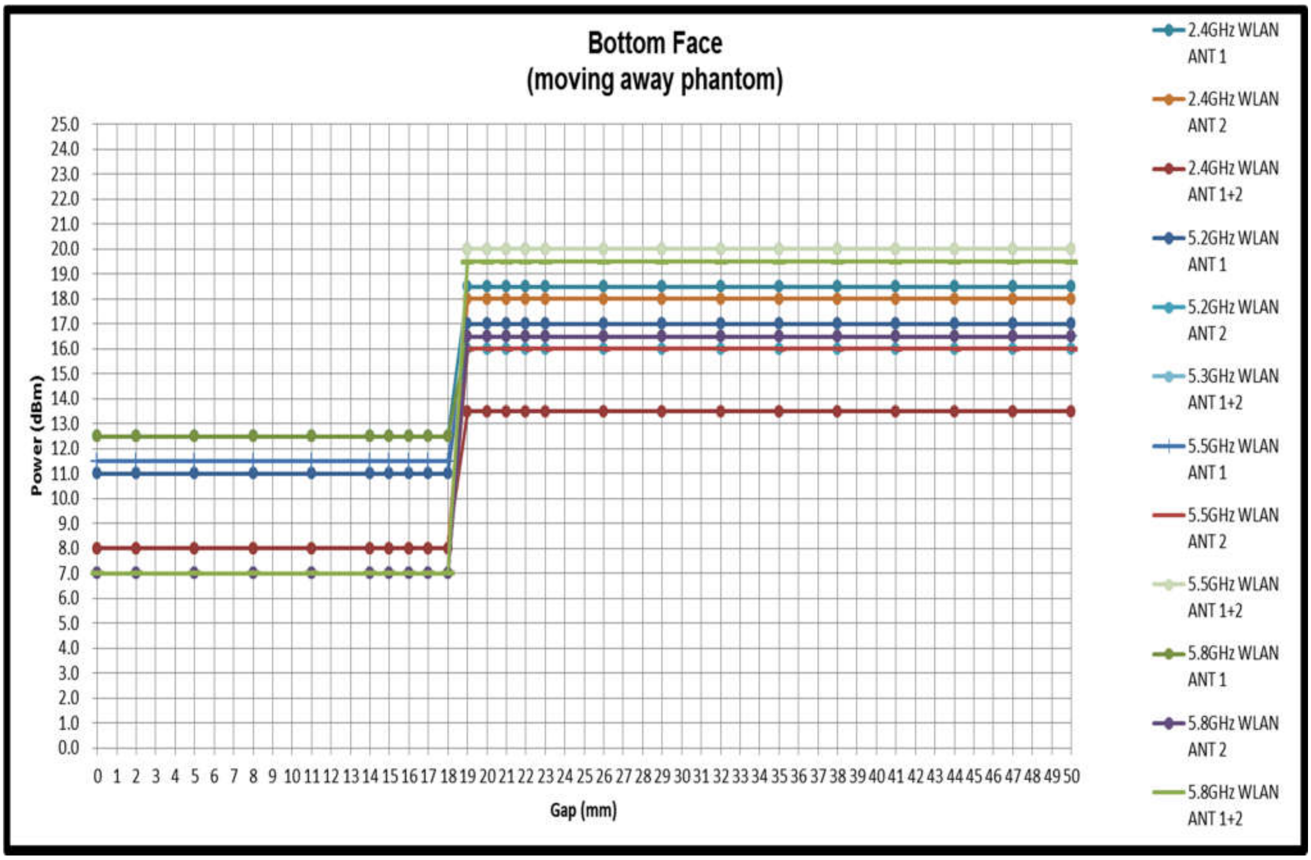


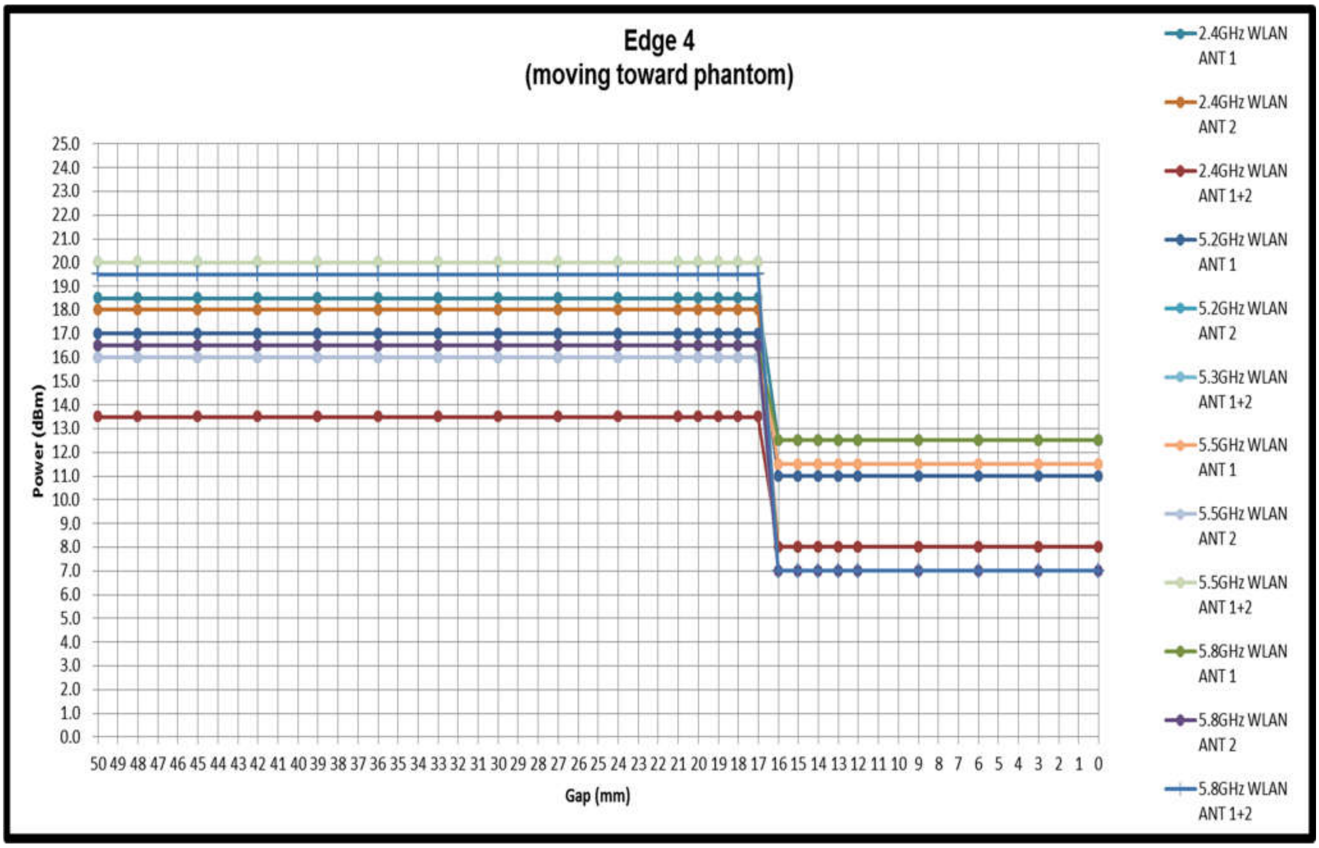


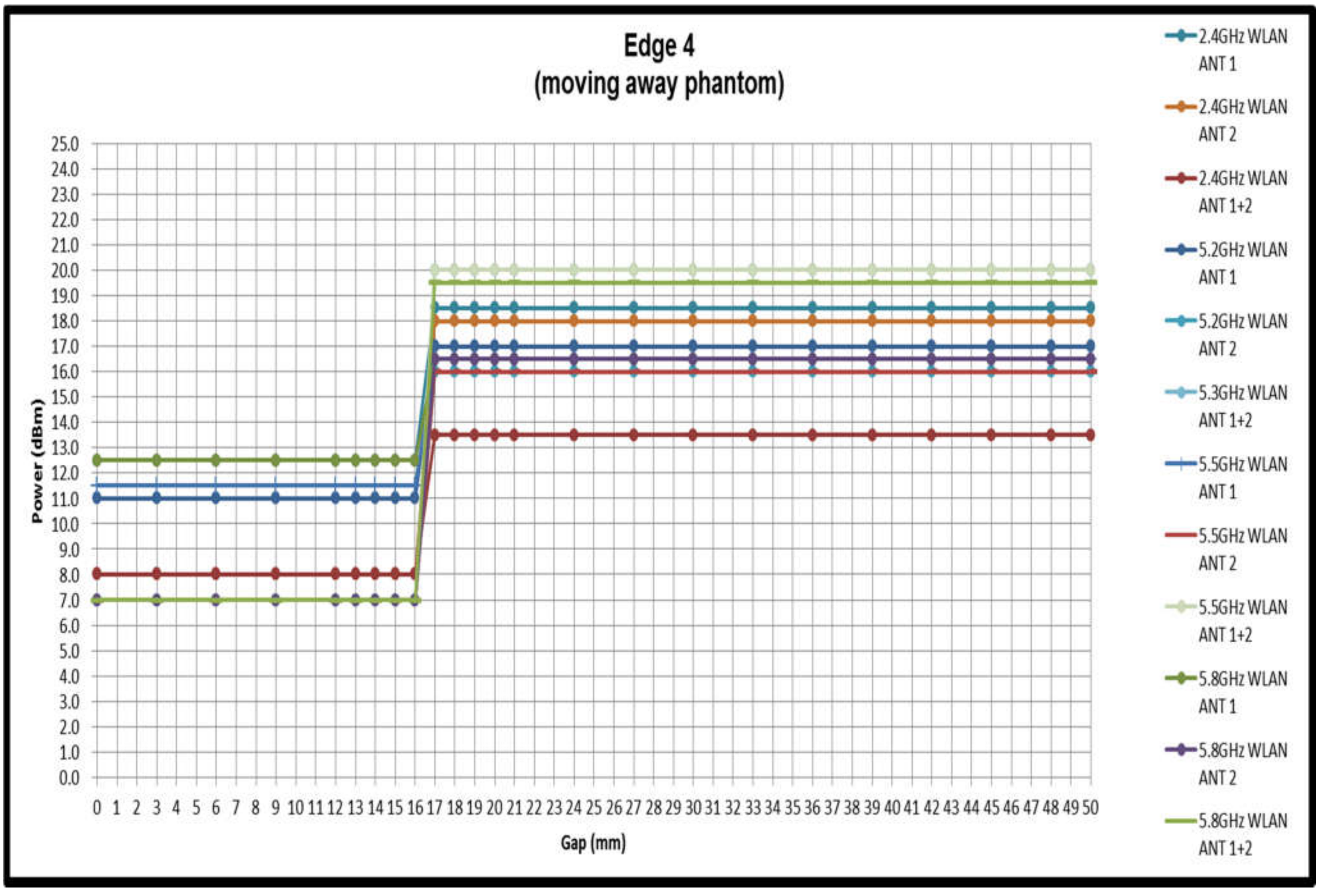

Edge 4
(moving toward phantom)
Power (dBm)
Gap (mm)
GSM850 (GMSK 4 Tx slots)
GSM1900 (GMSK 4 Tx slots)
WCDMA Band V
WCDMA Band IV
WCDMA Band II
LTE Band 12
LTE Band 17
LTE Band 5
LTE Band 4
LTE Band 2
LTE Band 7
LTE Band 25
LTE Band 38


Edge 4
(moving away phantom)
Power (dBm)
Gap (mm)
GSM850 (GMSK 4 Tx slots)
GSM1900 (GMSK 4 Tx slots)
WCDMA Band V
WCDMA Band IV
WCDMA Band II
LTE Band 12
LTE Band 17
LTE Band 5
LTE Band 4
LTE Band 2
LTE Band 7
LTE Band 25
LTE Band 38


Bottom Face
(moving toward phantom)
Power (dBm)
Gap (mm)
2.4GHz WLAN ANT 1
2.4GHz WLAN ANT 2
2.4GHz WLAN ANT 1+2
5.2GHz WLAN ANT 1
5.2GHz WLAN ANT 2
5.3GHz WLAN ANT 1+2
5.5GHz WLAN ANT 1
5.5GHz WLAN ANT 2
5.5GHz WLAN ANT 1+2
5.8GHz WLAN ANT 1
5.8GHz WLAN ANT 2
5.8GHz WLAN ANT 1+2


Bottom Face
(moving away phantom)
Power (dBm)
Gap (mm)
2.4GHz WLAN ANT 1
2.4GHz WLAN ANT 2
2.4GHz WLAN ANT 1+2
5.2GHz WLAN ANT 1
5.2GHz WLAN ANT 2
5.3GHz WLAN ANT 1+2
5.5GHz WLAN ANT 1
5.5GHz WLAN ANT 2
5.5GHz WLAN ANT 1+2
5.8GHz WLAN ANT 1
5.8GHz WLAN ANT 2
5.8GHz WLAN ANT 1+2


Edge 4
(moving toward phantom)
Power (dBm)
Gap (mm)
2.4GHz WLAN ANT 1
2.4GHz WLAN ANT 2
2.4GHz WLAN ANT 1+2
5.2GHz WLAN ANT 1
5.2GHz WLAN ANT 2
5.3GHz WLAN ANT 1+2
5.5GHz WLAN ANT 1
5.5GHz WLAN ANT 2
5.5GHz WLAN ANT 1+2
5.8GHz WLAN ANT 1
5.8GHz WLAN ANT 2
5.8GHz WLAN ANT 1+2



Edge 4
(moving away phantom)
Power (dBm)
Gap (mm)
2.4GHz WLAN ANT 1
2.4GHz WLAN ANT 2
2.4GHz WLAN ANT 1+2
5.2GHz WLAN ANT 1
5.2GHz WLAN ANT 2
5.3GHz WLAN ANT 1+2
5.5GHz WLAN ANT 1
5.5GHz WLAN ANT 2
5.5GHz WLAN ANT 1+2
5.8GHz WLAN ANT 1
5.8GHz WLAN ANT 2
5.8GHz WLAN ANT 1+2

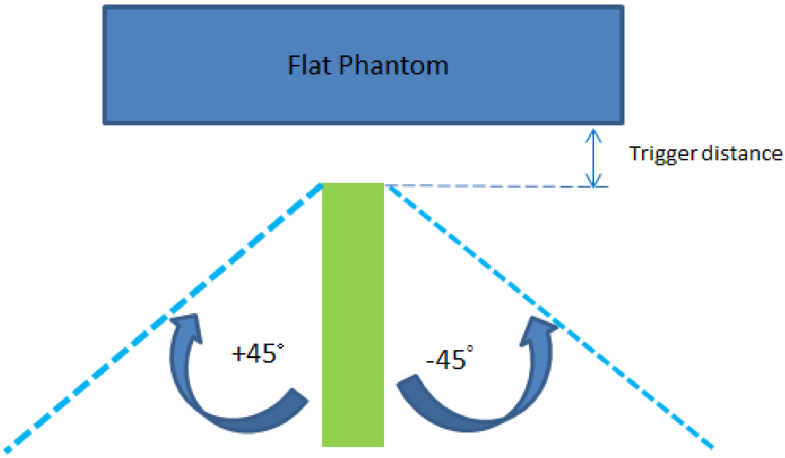
Summary

Proximity sensor triggering distances

Proximity Sensor Trigger Distance (mm)		
Position	Bottom Face	Edge 4
Minimum	18	16

<Tablet tilt angle influences to proximity sensor triggering>

1. The influence of table tilt angles to proximity sensor triggering is determined by positioning each tablet edge that contains a transmitting antenna, perpendicular to the flat phantom, set the 16mm separation for Edge 4 for tablet tilt coverage.
2. Rotating the tablet around the edge next to the phantom in ≤ 10° increments until the tablet is ± 45° from the vertical position at 0°, and the maximum output power remains in the reduced mode.



Proximity Sensor Tilt angle assessment

The Sensor Trigger Distance (mm)	
Position	Edge 4
Minimum	16

Remark:

1. KDB 616217 D04v01r02 footnote 26 at page 13: Depending on the antenna and sensor offset, if a test separation distance smaller than that determined by the triggering distance procedures can extend the coverage area to include the peak SAR location, a smaller test separation distance may be considered to avoid additional SAR tests
2. For verification of compliance of power reduction scheme, FCC requests to test SAR with EUT full power, at a conservative trigger distance. To have a smaller test separation distance in sensor coverage area, SAR testing distance is chosen smaller than trigger distance as follows:
   - Bottom Face: 17 mm
   - Edge4: 15 mm

5. Sensor Coverage Area Testing

<Procedures for determining proximity sensor triggering coverage – Not required for this device>

In KDB 616217 section 6.3, if a sensor is spatially offset from the antenna(s), it is necessary to verify sensor triggering for conditions where the antenna is next to the user but the sensor is laterally further away to ensure sensor coverage is sufficient for reducing the power to maintain compliance. For p-sensor coverage testing, the device is moved and "along the direction of maximum antenna and sensor offset".

The below figure of this device, the sensor pad is integrated into the WWAN antenna and covers it; there is no trigger condition where the antenna is next to the user; therefore proximity sensor coverage testing is not required.