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Cohda Wireless MK5 OBU Specification

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Change Log

Version	Date	Comments
1.0	22/04/2016	Initial issue
1.1	07/07/2016	Updates and corrections for new MK5CB options
1.2	07/02/2017	Change to i.MX6 Dual Lite and 1GB Configuration. Corrections in 4.2/4.4/4.5
1.3	29/03/2017	Removal of i.MX6 Solo and 512 MB options.
1.4	4/05/2017	HSM now standard
1.5	17/10/2017	Updated product label, added FCC statement. Changed PCB dimension from 120cm to 130cm.
1.6	31/10/2017	Added RCM compliance statement.

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1 Introduction

This document presents the specification of the **CohdaWireless** MK5 DSRC On-Board Unit (OBU). The MK5 is designed to provide a compact platform for the deployment of advanced connected vehicle applications and protocol stacks which can exploit the significant performance of the u-blox THEO-P1 module in mobile environments.

The MK5 OBU provides:

- Single or Dual channel **CohdaWireless** IEEE 802.11p radio
- IEEE 1609 and ETSI TC-ITS protocol stacks, including security functions
- Advanced vehicle positioning system, including
    - Advanced GNSS positioning system
    - Optional Dead Reckoning (DR) using vehicle sensors via CAN bus or VIC inputs
- High performance application processor for execution of ITS and safety applications
    - NXP i.MX6 Dual Lite processor at 800MHz
    - 1GB DDR memory
    - 4 GB Flash
    - Linux operating system
- Interfaces
    - Ethernet (IPv4/IPv6 networking)
    - USB 2.0 high-speed, on-the-go (host/peripheral)
    - High speed CAN bus interface on VIC connector
    - Audio
    - microSD card slot
- Optional future interface support via on-board expansion connector
    - Serial Console
    - HDMI
    - Audio line-out
    - USB
    - SPI
    - GPIO
- Hardware security services necessary to support the IEEE 1609.2 and ETSI TS 102 940 standards utilising the SmartMX Hardware Security Module
- Automotive operating temperature range (-40°C to +85°C PCB ambient temperature)

The MK5 OBU is designed for mounting in vehicles, running DSRC applications. For outdoor applications Cohda has designed the Road Side Unit (RSU). Both devices are based on the same MK5 carrier board.

2 Functional Specification

An overview of the hardware architecture of the MK5 is presented in below. The MK5 has two major functional components, the u-blox THEO-P1 module (implemented by the RF Front-End, NXP TEF5100 RF IC and NXP SAF5100 DSP), and the Application Processor sub-system (i.MX6 and GNSS Carrier Board).

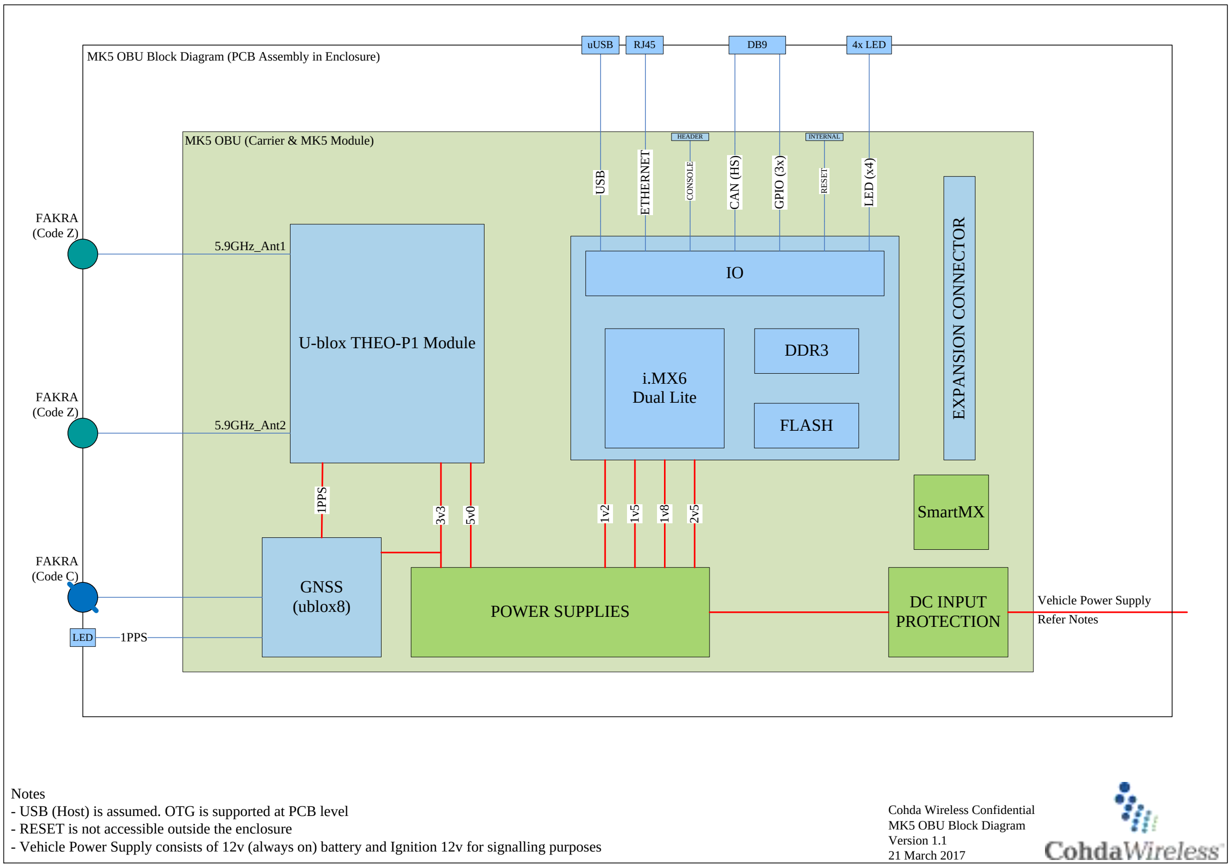

Figure 1 - MK5 Assembly Block Diagram shown inside an OBU

The Application Processor runs the Linux operating system and intelligent transport systems (ITS) application software. From a connected vehicle application perspective, the MK5 provides a suite of services which are outlined in Figure 2. This figure provides a functional outline of the MK5 system, as viewed by ITS applications. The MK5 runs an embedded Linux based on Ubuntu 14.04 LTS. The Kernel version is 3.10.17. The ITS stack and applications are implemented as Linux device drivers and application software. Non-volatile (flash memory) storage is accessible via standard Linux file-systems, and user interface devices are accessed via standard Linux APIs.

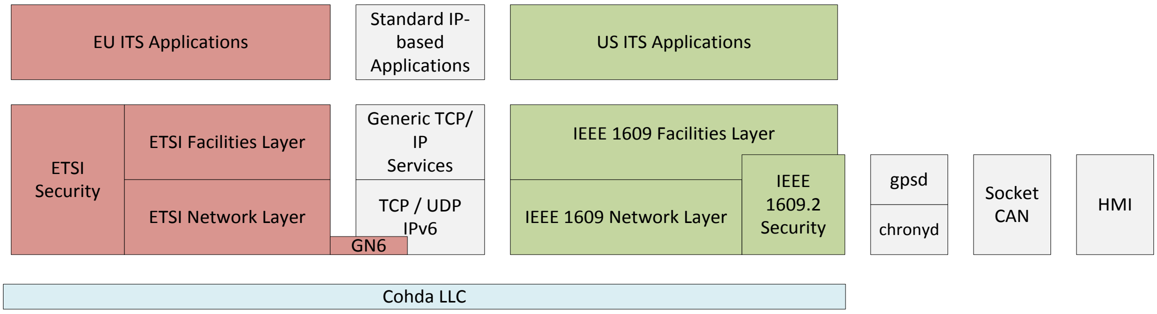

Figure 2 – MK5 SW Block Diagram

2.1 CohdaWireless DSRC Radio

The mobility radio is made up of distinct components; RF, PHY and MAC which are described below.

2.1.1 CohdaWireless PHY

The **CohdaWireless** PHY is a full IEEE 802.11p compliant physical layer radio transceiver (PHY) which employs the Cohda Wireless advanced mobility receiver algorithms. The PHY RF front-end can provide multiple radio configurations, allowing the MK5 Carrier Board to implement single or dual radio DSRC systems. The RF sub-system provides separate antenna ports for 5GHz bands via FAKRA connectors. In the dual-radio configuration, the **CohdaWireless** PHY effectively operates as two independent PHY modules, each operating on a different radio channel concurrently.

The **CohdaWireless** PHY provides 2-antenna diversity transmission and reception for optimum radio performance. A summary of the operating modes and functionality of the **CohdaWireless** PHY are as follows:

- Single-channel mode (1 or 2 antenna diversity operation).
- Dual-channel mode (1 antenna per channel), 2 independent IEEE 802.11p radios operating on different radio channels.
- 10MHz (DSRC) channel bandwidth modes.
- Dual 5.x GHz RF paths (5.18 GHz to 5.93 GHz)
- Transmit mask meeting IEEE 802.11p Class C (5GHz band).
- IEEE 802.11p enhanced adjacent channel receiver performance.
- Transmit antenna cyclic delay diversity (2 antenna operation only).
- Transmit power control (0.5dB steps).
- Fast mode changes for synchronised channel switching systems.

2.1.2 CohdaWireless MAC

The **CohdaWireless** MAC implements a full IEEE 802.11p compliant MAC layer, for 1 or 2 independent radio channels. The MAC runs on the ARM processor of the NXP SAF5100.

The **CohdaWireless** MAC provides fast, time-synchronised channel switching functionality. It also provides support for multiple queue sets, allowing packets to be queued while the PHY/MAC is operating on another channel.
The MAC provides the following operating modes:

- Simple single radio channel operation.
- Single radio, time-synchronised multi-channel operation
    - Channel switching between 2 channels with independent sets of transmit queues.
- Dual-radio, multi-channel operation
    - Independent MAC/PHY entities operating concurrently on different radio channels.
    - Optional coordination between channels to avoid self-interference when operating on close radio channels.
- Dual radio time synchronised multichannel operation.
    - As above, plus one of the radios optionally performs channel switching between 2 channels with independent sets of transmit queues

The **CohdaWireless** MAC provides full IEEE 802.11p support. Full support for MAC time-synchronisation is also provided utilising the time information and 1PPS signal from the GNSS receiver.

Other features of the MAC include:

- Radio channel measurements
    - Channel utilisation (ratio of channel busy time to measurement duration)
    - Channel active ratio (proportion of time that the radio is tuned to the SCH or CCH, respectively)
    - Per-channel statistics (number of packets successfully transmitted, number of packets that failed to transmit, number of packets successfully received, and number of packets received in error. Broken down according to broadcast, multicast, and unicast packets)
    - Received signal and noise power levels

2.2 MK5 Application Processor

The MK5 application processor provides software processing resources for connected vehicle applications. In order to implement such applications, the MK5 processor provides a number of services shown in the functional description diagram presented in Figure 2. The application processor runs an embedded Ubuntu 14.04 LTS with the Linux kernel 3.10.17 as operating system, providing a flexible environment for running multiple applications.

2.2.1 Processor

The MK5 Application Processor is an NXP i.MX6 Dual Lite processor, providing the processing power for the ITS applications. There is also a wide selection of services available to applications.

2.2.2 Communication Services

The MK5 system provides a range of communication services for ITS applications. All communication services are integrated within the Linux networking system. The following network protocols are provided by the MK5 platform:

- IPv6, IPv4 (Linux networking stack)
- IEEE1609.3 WSMP and WME management (Cohda WAVE networking services)
- ETSI TC-ITS G5, GN, GN6 & BTP (Cohda TC-ITS networking services)

These communication protocols are available to operate over the following communication interfaces available on the MK5 board:

- 10/100Mbps Ethernet
- USB 2.0

2.2.2.1 Ethernet

MK5 provides a 100Mbps Ethernet interface (10BASE-T/100BASE-TX) which can be used as part of an application or alternatively used for debugging purposes or remote status and control. The Ethernet interface is supported by Linux Ethernet device drivers, providing full IPv4/IPv6 over-Ethernet networking functionality.

2.2.3 Peripheral Interface Services

General purpose interface services are provided to allow interconnection with external peripheral devices and systems.

2.2.3.1 USB-OTG

A USB 2.0 on-the-go (OTG) port is available on the MK5 OBU and is supported by Linux USB host and peripheral device driver APIs.

2.2.3.2 Serial Console (optional)

The MK5 OBU provides an optional serial port upgrade via the expansion connector through which the primary operating system console is available. This port is used primarily for system development and debug operations, but may also be used by applications if required. It is presented using RS-232 level signals and polarity.

2.2.4 Timing and Positioning Services

The MK5 OBU manages both timing and positioning services via the use of an on-board u-blox8 GNSS receiver. To assist with positioning during GNSS outages or poor GNSS radio conditions (due to environments such as urban canyons), the MK5 Carrier Board can be upgraded with alternative hardware to introduce dead-reckoning (DR). The DR will be supported in future by the selection of a u-blox GNSS receiver that supports DR. The DR solution makes use of any combination of the following sensors:

- Odometer pulses (VIC or CAN)
- Single wheel tick or an “averaged” multiple wheel tick (VIC or CAN)
- FWD/REV switch (VIC or CAN)
- Steering angle (CAN bus)

2.2.5 Vehicle Interface Services

The Controller Area Network (CAN) bus is used to interface to the vehicles on-board computer in order to access the vehicle’s dynamic information. The interface operates at bit rates up to 1 Mbit/s. Both standard (CAN 2.0 A) and extended (CAN 2.0 B) frame formats are supported.

MK5 provides a CAN bus interface for accessing vehicle sensor information, supporting data rates of up to 1Mbit/sec. Access to vehicle data from the CAN bus is available to user applications. The MK5 supports CAN bus writes from applications.

In addition, the MK5 provides inputs for sensing odometer pulses and forward/reverse direction on the Vehicle Interface Connector.

2.2.6 Data Storage Services

MK5 provides 4GB non-volatile data storage services using on-board eMMC and standard Linux file systems.

2.2.6.1 Embedded File-System

The MK5 includes an embedded flash memory based file-system which is used for the storage of system firmware and small amounts of user application data.

2.2.6.2 General File-System

The MK5 system provides a general file-system in the form of a removable microSD card. This file-system can be used for any storage task an application may require, including the ability to log real-time data. The MK5 system includes device drivers for the microSD card.

2.2.7 Ancillary Services

The MK5 software environment also provides access to System time (UTC).

The MK5 also provides power on self-test operations with the facility to log faults to the embedded file system and report faults via LEDs.

2.2.8 LED Indicators

The MK5 Carrier Board has a range of LED signals available. The bi-colour on-board LED's are configured to provide the following visible status updates:

- FLT LED (SAF5100) (Back)
- PWR LED (i.MX6) (Back)
- 1PPS LED (GNSS Receiver) (Back)
- LED4 (Ethernet link status) (Front)
- LED5 (Ethernet activity) (Front)

The FLT and PWR LEDs will operate at boot similar to previous generations of Cohda radios. These indicate the various boot stages and operations as before but may be changed under SW control at a later stage to indicate other information. Default state for these two LEDs immediately after power up or reset is Red for FLT LED and green blinking for PWR LED.

LED3, GNSS, is used autonomously to indicate the GNSS module status. It will be off at boot. The LED will display green once the antenna power source is started. It will show red 1 Hz pulses as soon as a valid GNSS signal is received.

The 2 Ethernet LEDs are signalling the link status and activity of the Ethernet interface
The left Ethernet LED is the activity LED, the right LED is the link status.

3 Interface Specification

This section specifies the interfaces provided by the MK5 Carrier Board. The same Carrier Board is utilised in the OBU and the RSU. Unless specified, all connectors are mounted near the edge and are thus easily accessible when box mounted.

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Figure 3 – Board Layout (RF Side)

Figure 4 – Board Layout (Digital Connector Side)

3.1 Physical

The MK5 Carrier Board is a rectangular card with dimensions 85 mm wide by 130 mm long. Figure 5 shows the physical dimensions, including the mounting hole locations (marked in blue). It should be noted that the PCB is 84mm wide but has 6 x 0.5mm nubs on the sides to allow a snug fit to the OBU case which is 85mm wide. The PCB snap off points may also occupy space on the sides. See Figure 4 – Board Layout (Digital Connector Side)
Figure 6 presents the connector heights for the highest components on either side of the PCB.

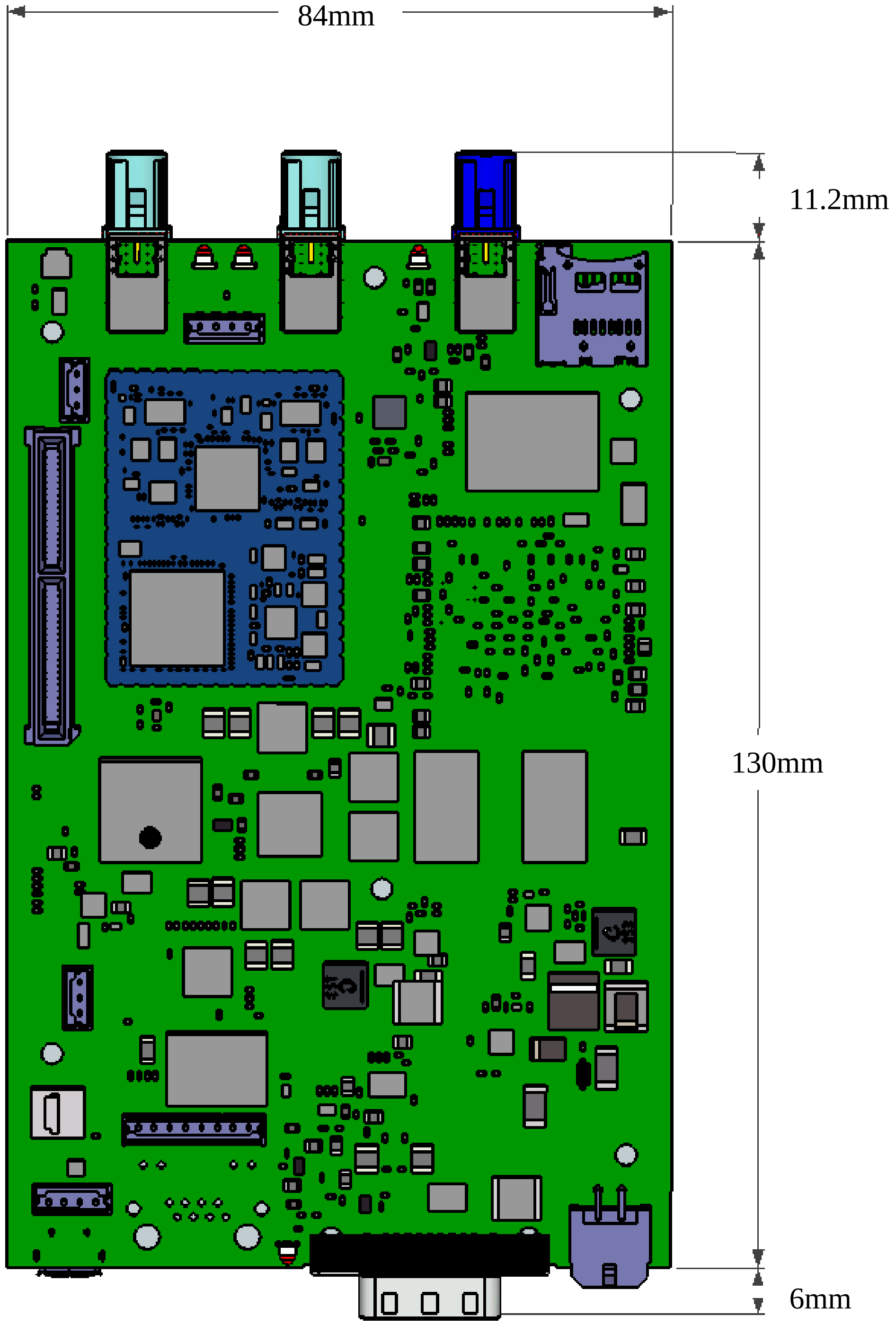


Figure 5 - PCB Dimensions with mounting hole locations

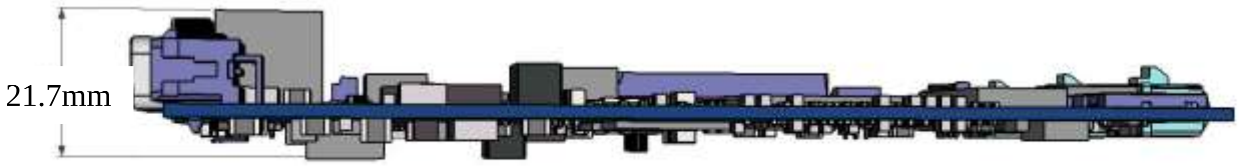


Figure 6 - Side view with maximum connector heights

The height requirement is distributed with the board requiring 10 mm clearance below and 20mm clearance above. The board is designed to dissipate heat from underneath and thus should be coupled to a box or a base-plate via thermal pad material. The following enclosures are available for the MK5:

- Extruded aluminium OBU (On-Board Unit) enclosure
  - Low profile with no expansion options (EXL)
  - Higher profile with some expansion options included (EXH)
- NEMA4 Compliant (Rugged Roadside Unit (RSU))

The NEMA2 OBU complies with public transport requirements:

- MIL-STD-810G, Test Method 514.6, Procedure I, Category 4
- Material handling TIA/EIA SP-4231 Drop Shock Section 3.3.5, Mobile and Portable tests.

3.2 Power Connector

The Power Connector is a Molex Micro-fit 3.0 4 pin connector (43045-0400, with mating receptacle 043025-0400). It provides a 7VDC to 36VDC supply input. The pin-out of the power connector is provided in Table 1.

Table 1 - Power Connector Pinout

Pin	Use
1	GND (KL31) *System ground.*
2	12VIN (KL30) *System power supply input (7 to 36VDC).*
3	GND (KL31) *System ground.*
4	12VIN (KL30) *System power supply input (7 to 36VDC).*

3.3 Radio 5GHz Antenna Connectors

The Ant1 and Ant2 connectors provide connectivity to the two 5GHz band diversity antennas. Each connector is a 50 Ohm, Edge mount - male/plug, Key Code Z FAKRA (6GHz) connector.

IMPORTANT: Before applying power, antennas or terminators must be placed on both 5GHz antenna connectors. Otherwise the internal PAs (Power Amplifiers) might be damaged.

3.4 GPS Antenna Connector

Ant3 is a 50 Ohm, Edge mount - male/plug, Key Code C FAKRA connector. This connector provides the GPS RF Antenna Input Interface. The Interface shall provide power to an Active GPS antenna, supplying a +4.7V, 50mA (max) supply.

3.5 Vehicle Interface Connector

The Vehicle Interface Connector provides connectivity to vehicle or external system devices. The Vehicle Interface Connector is a DE-9M connector containing a single high-speed CAN interface and three 12V-tolerant general purpose digital inputs. The general purpose inputs can be used for vehicle sensors such as odometer pulses and/or reverse direction indicators.

Table 2 - Vehicle Interface Connector Pinout

Pin	Use
Shell	*GND*
1	VIC-GPIN0 *12V General Purpose Signal Input*
2	CAN0-L *CAN0 Interface (high-speed) low signal*
3	GND *System ground*
4	-
5	VIC-GPIN1 *12V General Purpose Signal Input*
6	VIC-GPIN2 *12V General Purpose Signal Input*
7	CAN0-H *CAN0 Interface (high-speed) high signal*
8	-
9	+12V out *System power supply, 100mA (max)*

The VIC_GPINx pins are designed to allow interface to vehicle 12V based systems. There is a default load option which has these pins pulled high to pin 9 with 10k to allow the use of simple NO switches. In normal operation these can be driven by a 12V rail. Switching threshold is between 2.5V and 4.0V over the full temperature range. Ensure when driving these lines that they are less than 1V or greater than 6V to ensure proper level detection. The fusing on the 12V pin 9 is a self-resetting 100mA fuse.

The CAN0 interface in the OBU has no terminating resistors mounted. These must be provided externally if required (normally 120Ω across the CANH/CANL lines at both ends of the bus for a net 60Ω). The default speed for this interface is 500kbps.

3.6 USB-OTG Connector

The USB-OTG Connector is a micro-AB USB connector, providing a USB 2.0 On-The-Go (OTG) interface (up to 480Mbps operation). Being an OTG interface, either a peripheral or host USB device can be connected to this interface. When operating as a host this port provides the USB +5V Vbus supply with 500mA current limiting.

3.7 Ethernet Connector

The Ethernet Connector provides an RJ45 10BASE-T/100BASE Ethernet port. This connector includes integrated link and activity indicator LEDs.

3.8 microSD Card Socket

The microSD card socket accepts microSD flash cards to provide an external flash-based file system for the MK5. The interface supports either 1 bit or 4 bit transfers. microSD cards up to 64GB are supported.

3.9 Indicator LEDs

- Refer Section 2.2.8 LED Indicators

3.10 Reset Switch

The MK5CB provides a push-button reset switch on units configured with this which provides a full system-reset of the unit. This switch is right-angle mounted, allowing access through the back-wall of an enclosure. The system reset line is also available on the expansion connector.

4 Performance Specification

This section provides the performance specification of the radio, application processor and positioning sub-systems of the MK5 OBU.

4.1 DSRC Radio

4.1.1 Receive Sensitivity

The receive sensitivity of the u-blox THEO-P1 is presented in Table 3 for single and dual receive antennas, operating at 5.9GHz in DSRC 10MHz bandwidth mode. The packet error rate (PER) is less than 10% at a PSDU length of 1,000 octets for these input levels. The receive sensitivity is measured with a signal input directly to the antenna ports at room temperature (+25°C).

Table 3 - u-blox THEO-P1 Receive Sensitivity

	Channel	No Multipath [dBm]		Highway NLoS [dBm]	
	Number of Antennas	1	2	1	2
Rate ID	*MCS*	Typical *(Min)*	Typical *(Min)*	Typical *(Min)*	Typical *(Min)*
11	1/2 BPSK	-98 (-96)	-99 (-97)	-95 (-92)	-97 (-95)
15	3/4 BPSK	-96 (-93)	-98 (-96)	-92 (-89)	-95 (-93)
10	1/2 QPSK	-95 (-92)	-97 (-95)	-88 (-85)	-92 (-90)
14	3/4 QPSK	-93 (-90)	-95 (-93)	-86 (-83)	-89 (-87)
9	1/2 16QAM	-90 (-87)	-92 (-90)	-85 (-82)	-88 (-86)
13	3/4 16QAM	-86 (-83)	-88 (-86)	-82 (-79)	-85 (-86)
8	2/3 64QAM	-82 (-79)	-84 (-82)	na	na
12	3/4 64QAM	-80 (-77)	-83 (-81)	na	na

Table 4 - u-blox THEO-P1 Receive Sensitivity over temperature (10% PER)

MCS	Receive sensitivity against PCB ambient temperature [dBm]		
	-40°C	25°C	85°C
1/2 BPSK	-101	-98	-97
3/4 BPSK	-98	-96	-95
1/2 QPSK	-98	-95	-95
3/4 QPSK	-95	-93	-92
1/2 16QAM	-92	-90	-89
3/4 16QAM	-89	-86	-86
2/3 64QAM	-84	-82	-81
3/4 64QAM	-82	-80	-79

The Highway NLoS channel parameters used to obtain the values in Table 3 are captured in Table 5 below.

Table 5 - Highway NLoS channel parameters

Tap #	Relative Power [dB]	Delay [ns]	Doppler Frequency [Hz]
0	0	0	0
1	-2	200	689
2	-5	433	-492

Tap #	Relative Power [dB]	Delay [ns]	Doppler Frequency [Hz]
3	-7	700	886

This channel was used in the RF testing at the third ETSI Plugtest (CMS3).

Each tap is faded using Pure Doppler, but the second antenna has a Doppler increased by 11Hz, which prevents phase synchronization of the channels. The Rx Power listed in Table 3 refers to the power of Tap 0.

The values presented are typical values, measured at +25°C. Typical measured results for +25°C are shown in Figure 7 and Figure 8, and the sensitivity plots for -40°C and +85°C PCB ambient are presented in Figure 9 – Figure 12.

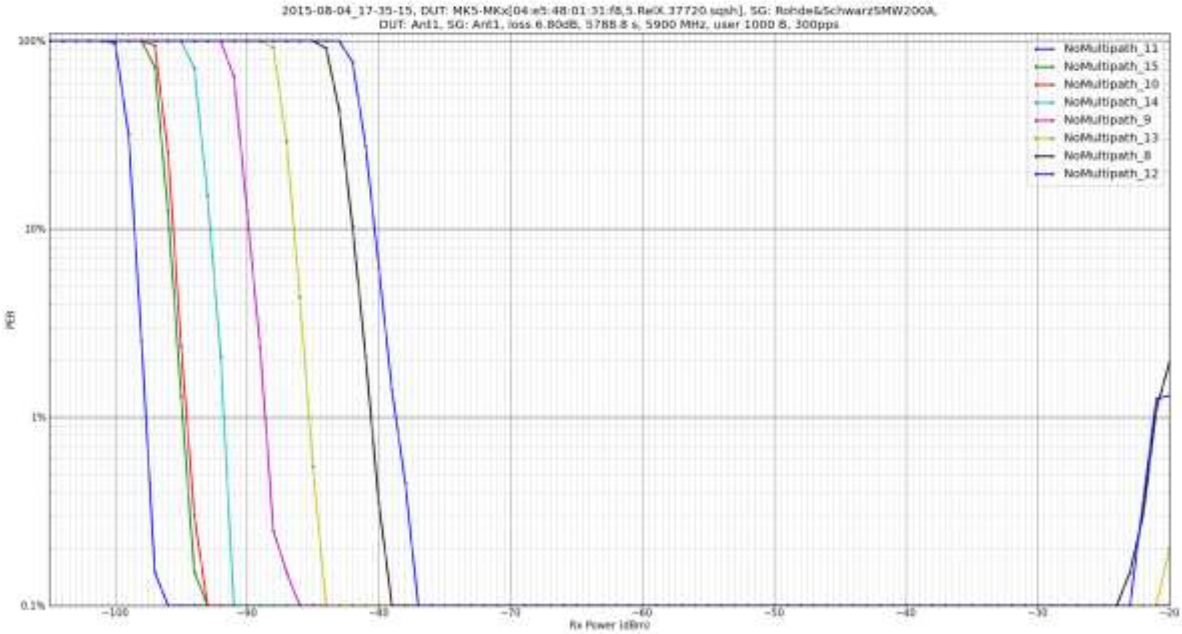


Figure 7 - Receiver sensitivity for Antenna 1 (No RF multipath, +25°C PCB Ambient)

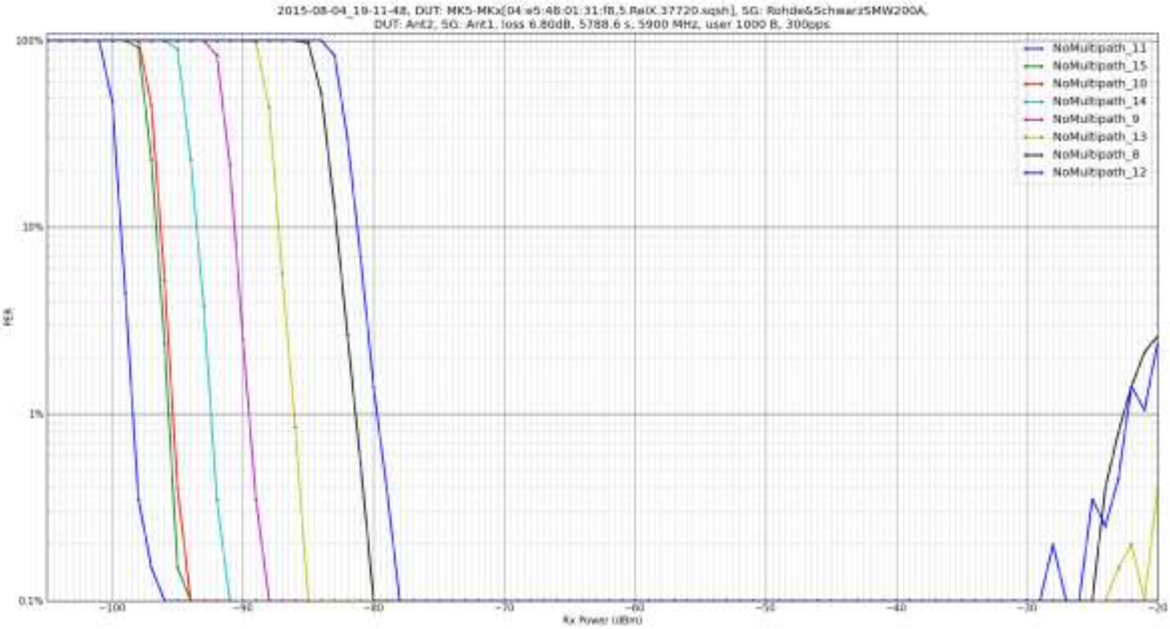


Figure 8 - Receiver sensitivity for Antenna 2 (No RF multipath, +25°C PCB Ambient)

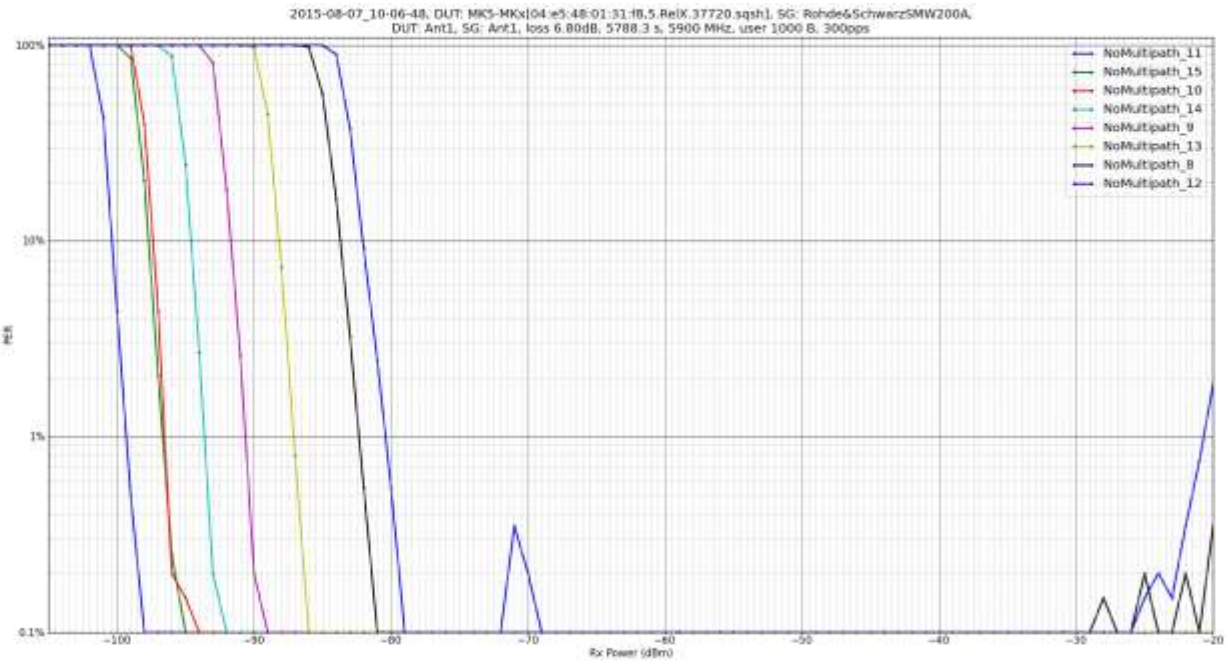


Figure 9 - Receiver sensitivity for Antenna 1 (No RF multipath, -40°C PCB Ambient)

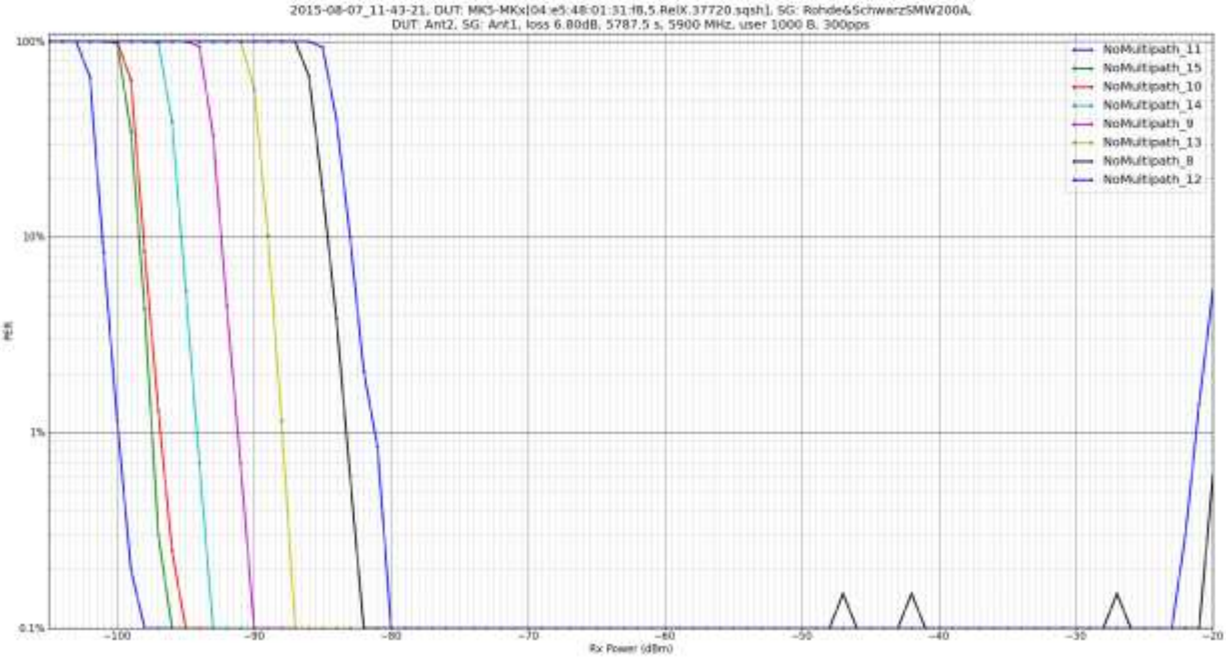


Figure 10 - Receiver sensitivity for Antenna 2 (No RF multipath, -40°C PCB Ambient)

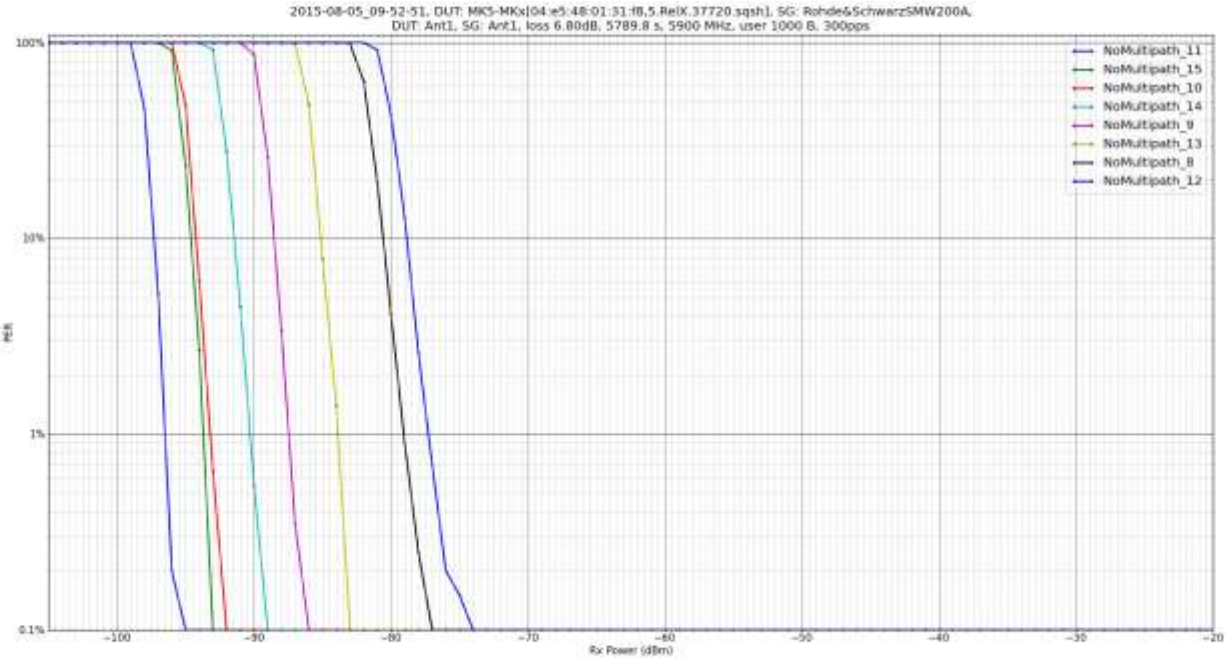


Figure 11 - Receiver sensitivity for Antenna 1 (No RF multipath, +85°C PCB Ambient)

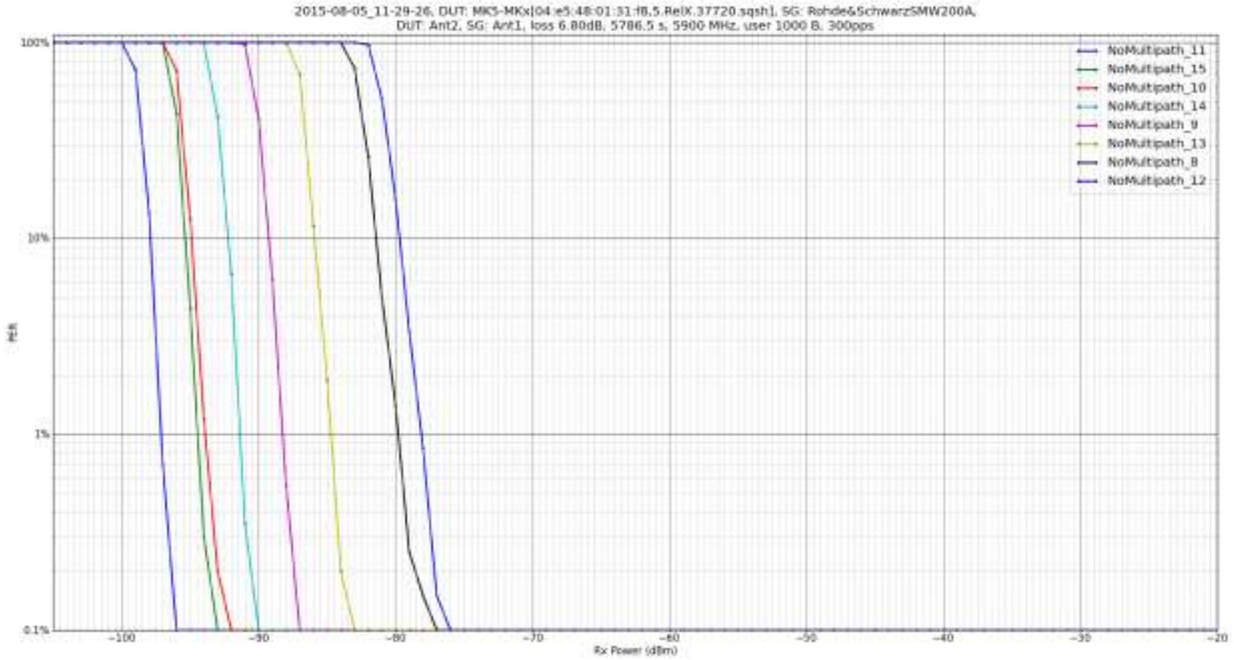


Figure 12 - Receiver sensitivity for Antenna 2 (No RF multipath, +85°C PCB Ambient)

4.1.2 Receiver Maximum Input Level

The receiver maximum operating input level is -20dBm (the PER may exceed 10% for input levels above this value).
The input level should not exceed 0dBm to avoid damage.

4.1.3 Transmitter Specifications

Table 6 outlines the transmitter specifications common to all operating modes of the u-blox THEO-P1.

Table 6 - General Transmitter Specification

Specification	Performance
Output centre frequency and symbol clock tolerance.	±10ppm
Transmitter spectral flatness	< ±2dB in all bandwidth and modulation modes
Transmitter centre frequency leakage	-15dB or better
Transmit power control step-size.	0.5dB
Transmit power control accuracy	±2dB over temperature

4.1.4 Power Level and Spectral Mask

The u-blox THEO-P1 maximum output power and spectral mask characteristics are outlined in Table 7. This specification applies to each of the two 5GHz antenna ports available (Ant1 and Ant2) and targets the entire temperature range. Measured results for the u-blox THEO-P1 are presented in Figure 13 and Figure 14. Figure 15 and Figure 16 presents typical Out-of-Band unwanted emission results for the u-blox THEO-P1.

Table 7 - u-blox THEO-P1 5GHz Radio Transmitter Specifications

Specification	Performance
Maximum Transmit Power	+23dBm per antenna port (+26dBm effective transmit power in 2-antenna transmit mode)
Minimum Transmit Power	-10dBm
Transmit power control	0.5dB steps monotonically increasing/decreasing
EVM	per IEEE802.11-2007 (clause 17.3.9.6.3)
Spectral Mask	Targets DSRC class C, • 5.0 MHz, -26dBc • 5.5 MHz, -32dBc • 10 MHz, -40dBc • 15 MHz, -50dBc
Out of Band Emissions	Target ETSI emission mask [EN 302 571] as per Table 8
Supported channels	5GHz: 168-184

Table 8 - Transmitter unwanted emission limits from 1GHz to 18GHz outside the 5GHz ITS frequency bands

Frequency Range	Res BW [MHz]	Maximum Power (EIRP) [dBm]
1 GHz < f < 5,795 GHz	1	-30
5,795 GHz < f < 5,815 GHz	1	-40
5,815 GHz < f < 5,850 GHz	1	-40
5,850 GHz < f < 5,855 GHz	1	-30
5,925 GHz < f < 5,965 GHz	1	-40
5,965 GHz < f < 18 GHz	1	-30

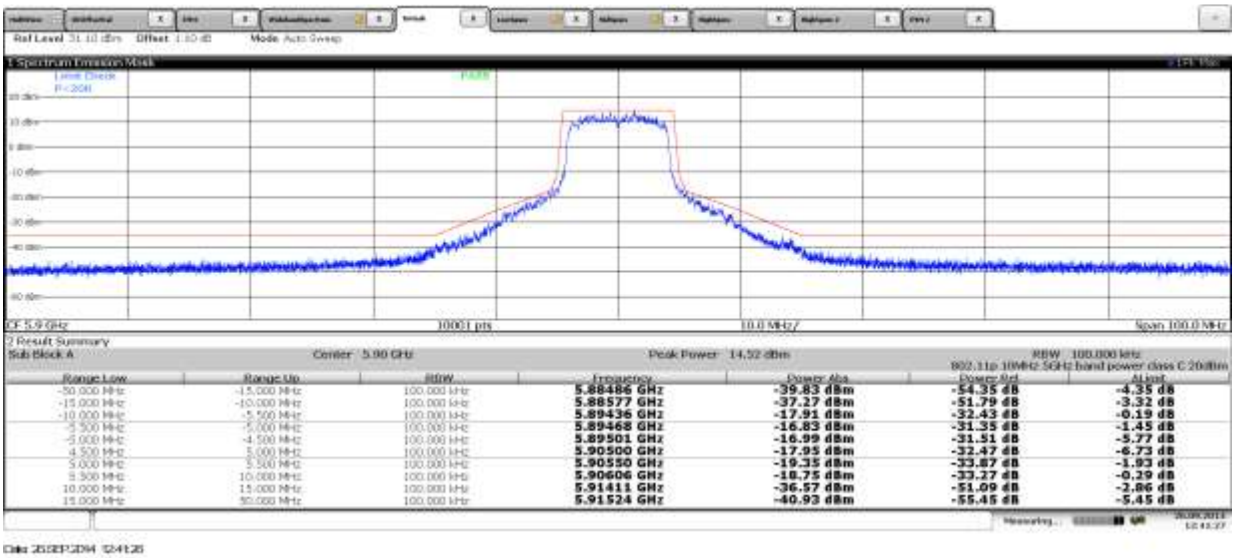


Figure 13 - u-blox THEO-P1Class-C Transmission Mask

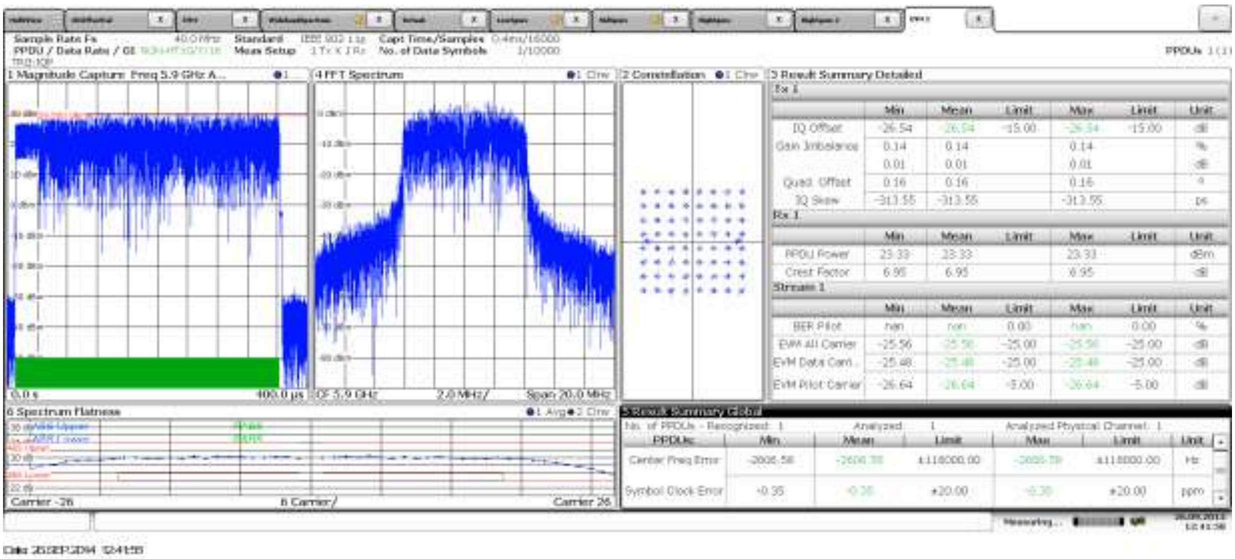


Figure 14 - u-blox THEO-P1 EVM and Transmit Power

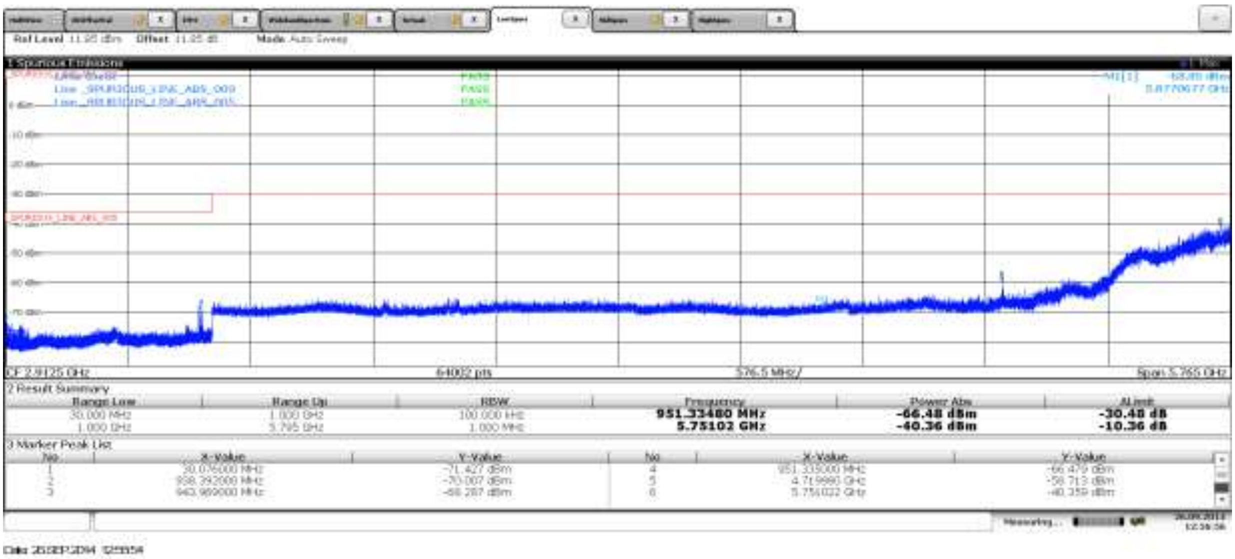


Figure 15 - u-blox THEO-P1 Out-of-Band emission mask (Below DSRC)

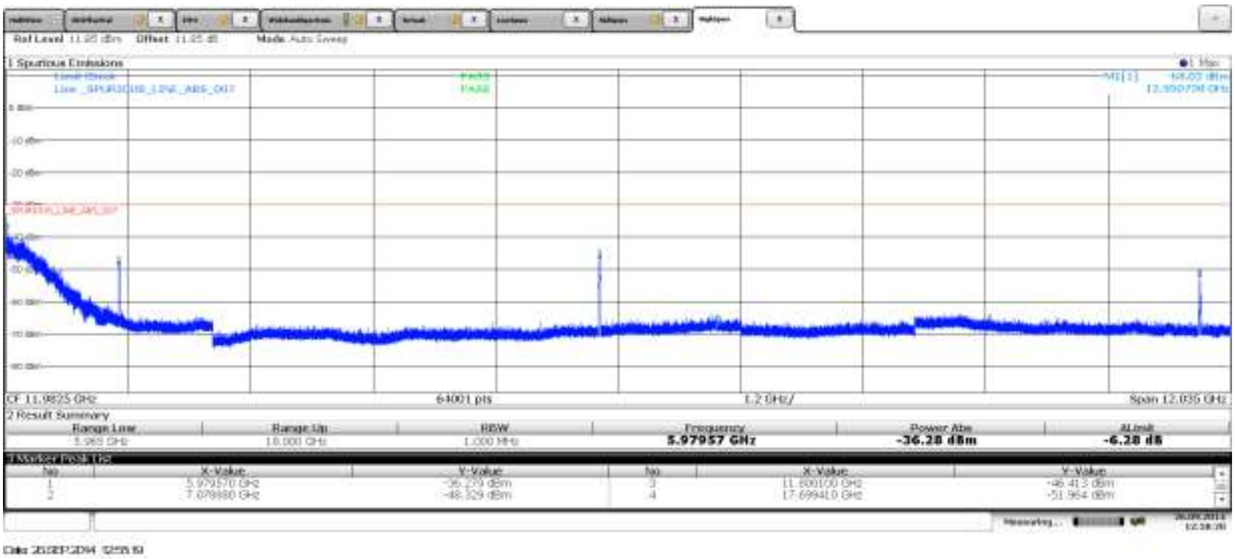


Figure 16 - u-blox THEO-P1 Out-of-Band emission mask (Above DSRC)

4.1.5 Adjacent Channel Rejection

The adjacent channel rejection of a u-blox THEO-P1is measured by setting the desired signal strength 3dB above the receive sensitivity specified in Table 18-14 of the IEEE802.11-2012 standard, (refer Table 9), and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 octets. The power difference between the interfering and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel is a conformant OFDM signal, meeting the DSRC Class C mask, unsynchronized with the signal in the channel under test. The receive sensitivity values are measured with a signal input directly to the Antenna Ports. Measured results for the u-blox THEO-P1adjacent channel rejection, together with the target nACR values obtained from the IEEE802.11-2012 standard, are provided in Table 9.

Table 9 - Adjacent Channel Rejection (ACR)

Modulation	Target ACR [dB]	Target opt. enh. ACR [dB]	MK5 Typical ACR [dB]
½ BPSK	16	28	37
¾ BPSK	15	27	33
½ QPSK	13	25	35
¾ QPSK	11	23	29
½ 16QAM	8	20	29
¾ 16QAM	4	16	25
⅔ 64QAM	0	12	22
¾ 64QAM	-1	11	20

4.1.6 Non-Adjacent Channel Rejection

The non-adjacent channel rejection of a u-blox THEO-P1 is measured by setting the desired signal's strength 3dB above the rate-dependent sensitivity specified in Table 18-14 of the IEEE802.11-2012, and raising the power of the interfering signal until a 10% PER occurs for a PSDU length of 1000 octets. The power difference between the interfering and the desired channel is the corresponding nonadjacent channel rejection. The interfering signal in the non-adjacent channel is a conformant OFDM signal, targeting the DSRC Class C mask, unsynchronized with the signal in the channel under test. The receive sensitivity values are measured with a signal input directly to the Antenna Ports. Measured results for the u-blox THEO-P1 non-adjacent channel rejection, together with the target nACR values obtained from the IEEE802.11-2012 standard, are provided in Table 10.

Table 10 - Non-Adjacent Channel Rejection (nACR)

Modulation	Target nACR [dB]	Target opt. enh. nACR [dB]	Typical nACR [dB]
½ BPSK	32	42	51
¾ BPSK	31	41	48
½ QPSK	29	39	48
¾ QPSK	27	37	45
½ 16QAM	24	34	42
¾ 16QAM	20	30	38
⅔ 64QAM	16	26	34
¾ 64QAM	15	25	32

4.1.7 Return Loss

The return loss on all RF ports is no more than -10dB.

4.1.8 Power Measurements

All receiver power measurements made by the u-blox THEO-P1 (e.g. RSSI) is accurate to ±2dB over the range of -95dBm to -20dBm and over the operating temperature range.

4.2 Application Processor

4.2.1 Main Processor

The application processor is an NXP i.MX6 Dual Lite CPU operating at 800MHz with 1GB SDRAM and 4GB eMMC flash memory, running embedded Ubuntu 14.04 LTS with Linux Kernel 3.10.17.

The processor includes an on-chip watchdog timer and a real-time clock.

4.3 Positioning

4.3.1 GNSS Receiver

The MK5 employs an advanced u-blox8 GNSS receiver with concurrent support for GPS and Galileo or GLONASS constellations. The GPS receiver provides best in class tracking and navigation performance in difficult urban canyon environments. The MK5 provides position fixes at rates of up to 10 fixes/sec. Default configuration is GPS and GLONASS with 5 fixes/sec

Table 11 - GPS Receiver Performance

Performance Parameter	Condition	Performance
Acquisition	Cold Start	≤ 29 s
	Aided Start	≤ 3 s
	Hot Start	≤ 1 s
Sensitivity	Tracking and Navigation	-165dBm
	Cold Start	-148dBm
Horizontal Accuracy		< 2.5m (maximum; all conditions considered)
Timing accuracy		30ns

4.4 Environmental

The MK5 operates (with graceful degradation) from -40°C to +85°C PCB temperature, 5 to 95% RH non condensing.

The IMX6 core Si operates to +110 C before the operating system shuts down to protect systems from long term thermal degradation of lifetime and reliability. The IMX6 Automotive grade part used is capable of 125 C Si operations but with reduced lifetime. The system should operate with ambient temperatures up to +95 C but with reduced reliability of operation and thus it is not recommended to operate above +85 C.

The MK5 OBU is designed to withstand typical automotive vibration and operate over a humidity range of 5% to 95%, non-condensing.

4.5 ESD & EMC

The MK5 interfaces are designed to withstand a touch discharge of ±15kV (150Ohm, 150pF).
The MK5 is designed to comply with radiated emissions in accordance with FCC Part 95 and FCC Part 15B.

4.6 Power Supply

The supply to the main board can be applied via an external adaptor to support the above requirements. This adaptor should supply a clean 7V to 36V supply.
Depending on the application the typical power consumption is 5 to 6W with a maximum of 8W.

The MK5 is designed to be connected to an automotive 12V battery. The power input is valid over a voltage range of 7V to 36V. If the power supply voltage drops below 7V the MK5 will shut down, and re-boot once the input voltage returns to normal operating levels. There is overvoltage protection for transients above 36V as well as reverse voltage protection. If power is continually applied above +36 V the unit will reset automatically continuously as the protection FET will be limited by its operating temperature. For reliable operation over full temperature range ensure the input voltage range is typically a few volts within the stated range on average i.e. 9 to 34 V.

5 MK5 OBU Enclosure

The inside of the enclosure is arranged such that there is thermal coupling between the warmer components on the PCB and the metal enclosure by way of customised heat spreaders mounted to dedicated heat spreader screw-holes.

The enclosure supports the following connector interfaces

- 12V (Typical) Power Supply. Operational from 7V to 36V
- 3x FAKRA RF connectors (1x GNSS and 2x DSRC connectors)
- DE-9M connector (for CAN and VIC GPIO's)
- Micro AB USB
- 10/100 Ethernet RJ45
- 5 x Dual LED
- microSD slot
- 3.5mm Audio Jack

The enclosure is designed to the following guidelines

- Internal heat spreader
- Extruded Aluminium
- Blue anodized finish
- External operating temperature range of -40°C to +65°C
- IP52

6 Enclosure Outline

The 3D design of the MK5 enclosure is presented in Figure 17.

Figure 17 – 3D view of the OBU MK5 enclosure

The front and rear view of the OBU enclosure is presented in Figure 18, Figure 19.
Figure 20 shows the side view of the OBU enclosure.

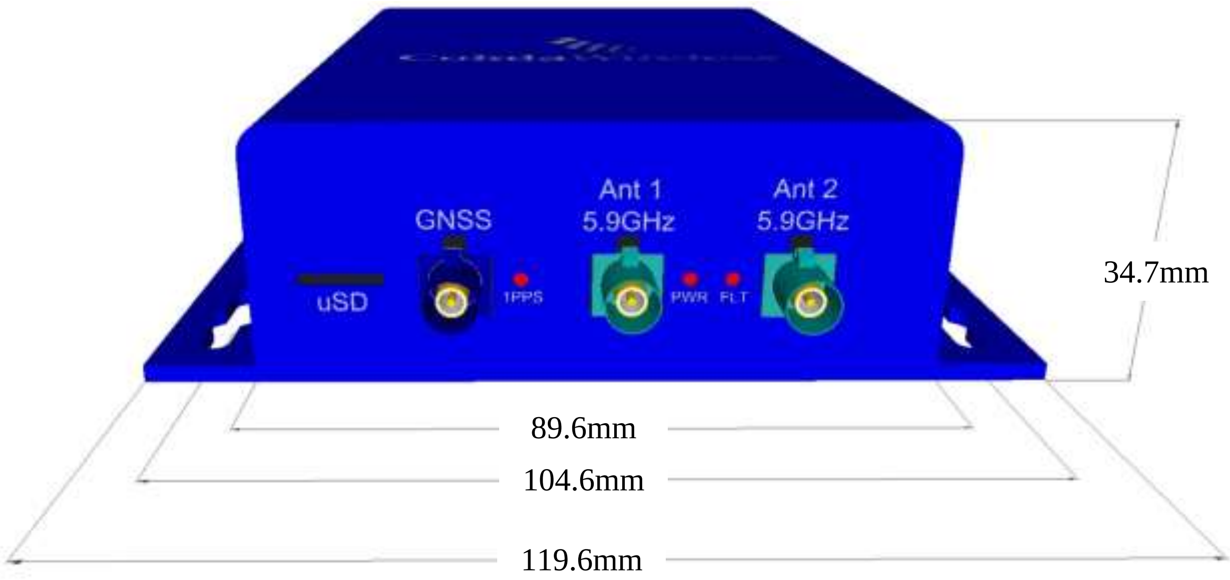


Figure 18 – RF End of the MK5 enclosure

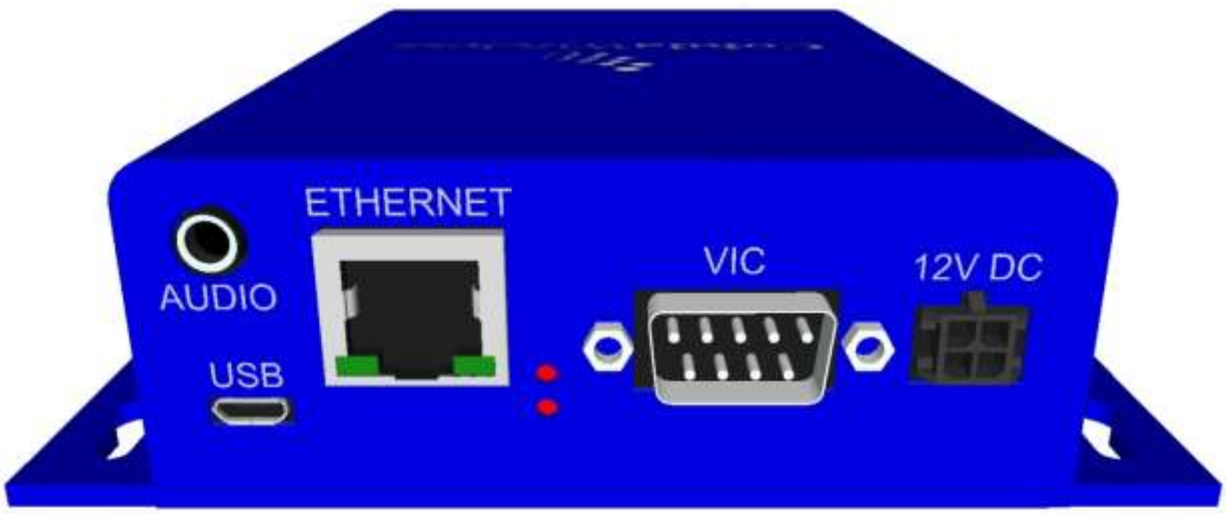


Figure 19 - Rear view (Digital End) of the OBU enclosure

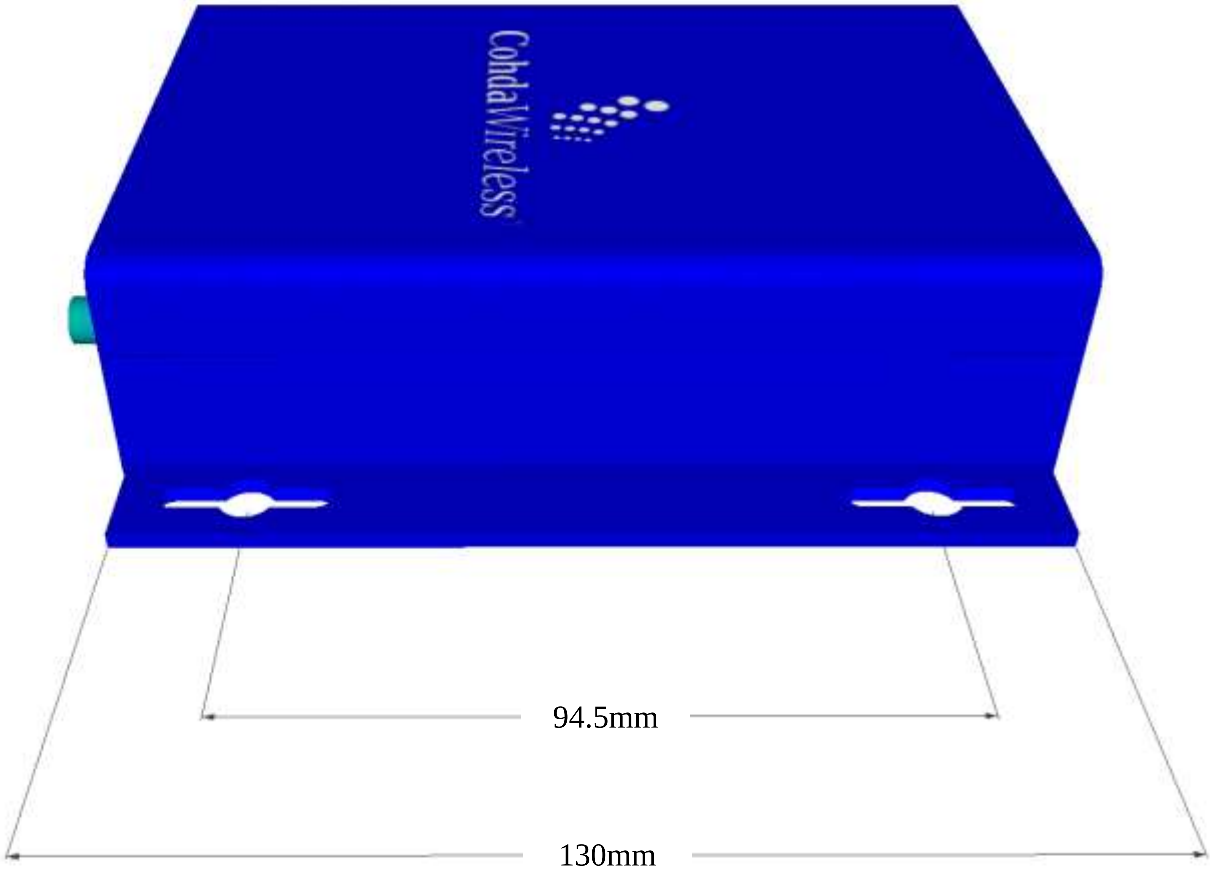


Figure 20 - Side view of the OBU enclosure

The enclosure is based on an off-the-shelf extrusion with customized mounting holes, length and a blue anodized finish.
The end-plate holes will support the following interfaces:

- Power Supply
  - Molex 0430450400 Micro-Fit 3.0™ or equivalent connector
- Multi-pin Digital Interface
  - DE-9M (Standard)
- USB
  - Micro AB USB
- Ethernet
  - RJ45
- Opening for internal LEDs
- RF Connectors
  - 1x FAKRA Code C
  - 2x FAKRA Code Z
- Slot opening for microSD Card
- 3.5mm Audio Jack

The top of the enclosure presents the Cohda Wireless logo and the base of the enclosure has a 30mm x 40mm cleared area for regulatory (e.g. FCC) and Cohda's Serial Number markings. The serial number is the MAC address of the Ethernet interface.

7 Approval and Compliance

7.1 FCC compliance

Federal Communications Commission (FCC) Compliance Statement

This device complies with Part 15 of the FCC Rules. Operation is Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

FCC Caution: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

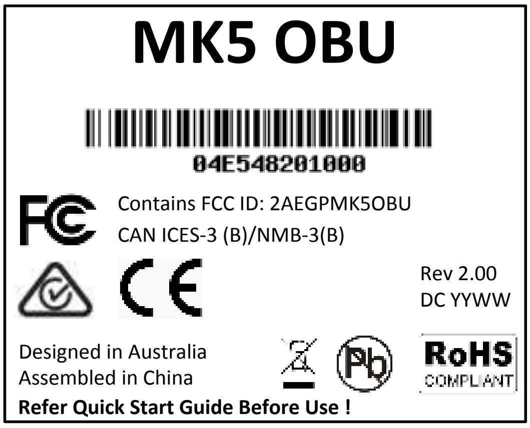
Federal Communications Commission (FCC) Interference Statement

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment to an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help

7.1.1 FCC and Product Label

Following is a copy of MK5 OBU product label.



7.2 Innovation, Science and Economic Development (ISED) Canada

The MK5 OBU complies with ISED's ICES-003.

Innovation, Science and Economic Development Canada ICES-003 Compliance Label:
CAN ICES-3 (B)/NMB-3(B)

7.3 CE

The MK5 OBU complies to Radio Equipment Directive 2014/53/EU. A copy of the Declaration of conformity is available on request.

The equipment operates within CE limit with following conditions:

- External Filter Cable Part Number – CWP-ASRYA-FLTR-WW00101
- An external DSRC Antenna with Gain less than or equal to 4dBi.
- CW provided Radio Firmware and ETSI Stack is used with Release number > 14

7.4 Regulatory Compliance Mark (RCM)

The MK5 OBU meets the requirements of AS/NZS 4268:2017 SRD operating under LIPD class license 40 – Telecommand and Telemetry 1W EIRP on channels 164,166,168,170,172 and 174 only (5815-5875 MHz). Maximum Tx power for dual antenna is +22dBm assuming +5dBi antenna and 2.0dB external cable loss. Under the operational scenario above the user is required to ensure that more than 20cm separation between the antenna and person while operating to comply with AS/2772.2:2016 general public exposure requirements.
Other combinations of LIPD class license, power, antenna and frequency used may be possible at your own risk.

As these channels are shared with other radio users interference may be possible.

7.5 Others

The MK5 OBU is RoHS and Lead-Free compliant. It complies with the "Directive 2011/65/EU of the European Parliament and the Council on the Restriction of Use of certain Hazardous Substances in Electrical and Electronic Equipment" (RoHS).

Signed for and on behalf of:

Adelaide	2017-10-31	F. Cure, Chief Engineer	
Place of Issue	Date of Issue	Name,function	signature