



User Manual



SkyHopper Pro
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Confidential

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This device complies with Part 15 of FCC rules. 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.

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This equipment has been approved for mobile applications where the equipment should be used at distances greater than 20cm from the human body (with the Exception of hands, wrists, feet and ankles). Operation at distances less than 20 cm is strictly prohibited.

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1 Abbreviation List

| Abbreviation | Syntax |
|-----------------|--|
| BPS | Bits Per Second |
| BW | Bandwidth |
| CEP | Circular Error Probable (Accuracy) |
| CINR | Carrier to Interference and Noise Ratio (Signal to Noise Ratio) |
| CPLD | Complex Programmable Logic Device |
| CRC | Cyclic Redundancy Code |
| dB | Decibel |
| dBm | Power ratio in decibels of the measured power referenced to one milliwatt |
| CDD | Cyclic Delay Diversity |
| Controller Unit | A SkyHopper Pro Unit, In PTP setup, which acts as an endpoint communication unit. Typically a Ground Unit. |
| CTC | Convolutional Turbo Code |
| DC | Direct Current |
| EMI | Electromagnetic Interference |
| ETH | Ethernet |
| ETSI | European Telecommunication Standard Institute |
| FAE | Field Application Engineer |
| FCC | Federal Communications Commission |
| FEC | Forward Error Correction |
| FFT | Fast Fourier Transform |
| Freq. | Frequency |
| FW | Firmware |
| GHz | Gigahertz |
| GPS | Global Positioning System |
| HD | High Definition (Video) |
| HW | Hardware |
| ID | Identification (Number) |
| IP | Internet Protocol |
| LAN | Local Area Network |
| LAT | Latitude |
| LED | Light Emitting Diode |

| | |
|-------------|---|
| LON | Longitude |
| LOS | Line-Of-Sight |
| mW | Milliwatt |
| MHz | Mega Hertz |
| MIMO | Multiple-In-Multiple-Out |
| MRC | Maximal Ratio Combining |
| N.C. | Not Connected |
| OEM | Original Equipment Manufacturer |
| OFDM | Orthogonal Frequency Division Modulation |
| OS | Operating System |
| PC | Personal Computer |
| PPS | Pulse Per Second |
| PTP | Point-To-Point |
| PTMP | Point-To-Multipoint |
| QAM | Quadrature Amplitude Modulation |
| QPSK | Quadrature Phase Shift Keying (modulation) |
| Remote Unit | A SkyHopper Pro unit, in PTP setup, which acts as an end point communication unit that distributes clocks in the system. Typically the Aerial Unit. |
| RF | Radio Frequency |
| RMS | Root Mean Square (Average) |
| RSSI | Receiver Signal Strength Indication |
| Rx | Receive |
| SBAS | Satellite Based Augmentation System |
| SDR | Software Defined Radio |
| SW | Software |
| TDD | Time Division Duplexing |
| TDMA | Time Division Multiple Access |
| Tx | Transmit |
| UAV | Unmanned Aerial Vehicle |
| UGV | Unmanned Ground Vehicle |
| VLAN | Virtual LAN |
| VPN | Virtual Private Network |

Table 1: Abbreviation List

2 Overview

The SkyHopper PRO offers a bi-directional Data Link specifically designed for commercial and industrial drones, and provides the best solution for fleet management and autonomous UAV systems. By employing leading wireless technologies, SkyHopper PRO delivers long range and Non-Line of Sight (N-LOS) communication that supports broadcast, multicast and unicast transmission modes.

SkyHopper PRO supports Point-to-Point and Point-to-Multipoint communication, thereby enabling various modes of operation such as communication for multi-drone operations and drone communication to multiple ground units and viewers (receivers).

An additional benefit of your SkyHopper Pro is that it offers Control, Telemetry and Payload all in one RF channel. No need for separate solutions for each, no need for excess items to weigh down your drone.

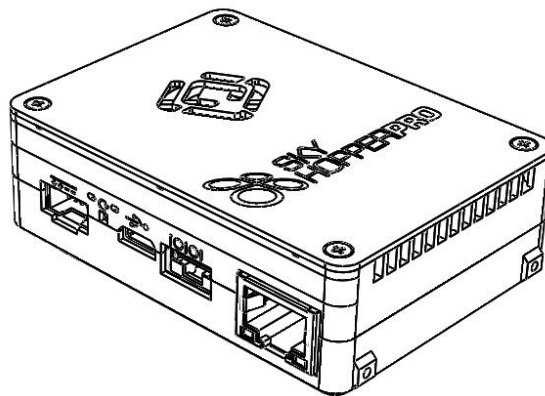


Figure 1: SkyHopper Pro

2.1 Network Topologies and Applications

2.1.1 Point-to-Point (PTP)

A Point-to-Point system includes 2 units, with the bandwidth ratio between the two units configurable according to the application. It can be symmetric when a full duplex communication is required (50% to each unit) or asymmetric up to 10% to one unit (Controller or Remote Unit) and 90% to the other unit (i.e. drone/robot that transmits video to the ground/controller unit and that controls the camera).

Example for an asymmetric link: 6Mbps configuration, where 10% of available BW is allocated for uplink and 90% is allocated for downlink.

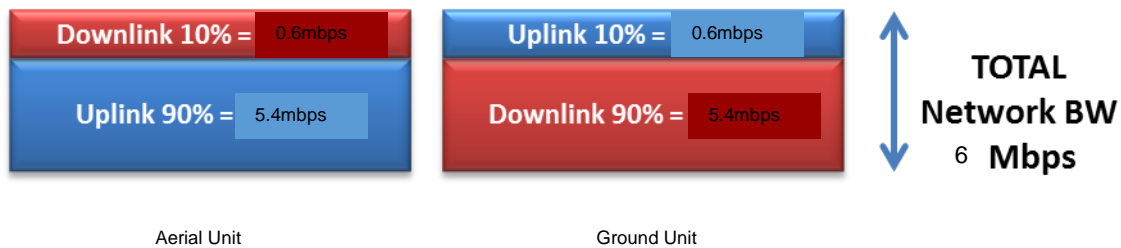


Figure 2: Asymmetric Link Configuration

2.2 SkyHopper Pro Main Features

SkyHopper Pro offers the following features to take your drone to new levels:

- Tremendous transmission range that exceeds 5km line-of-sight
- Relay operation for extending long range line-of-sight and overcoming dead spots in urban or industrial areas
- Non-line-of-sight (NLOS) communication by using a proprietary technology to provide a robust and clear radio signal
- Allows for a number of control stations with the same functionality to control the same drone simultaneously with seamless handover between control stations
- Supports drone communication to multiple control stations and an unlimited number of viewers (receivers)
- Real-time full HD wirelessly over the air at a Glass-to-Glass low latency via an IP camera through an Ethernet connection
- Robust security and encryption mechanisms to protect your data from potential cyberattacks
- Software Defined Radio (SDR) mobile technology
- MIMO antenna processing technologies
- Scalable solution from a Point-to-Point to a Point-to-Multipoint network with relays
- High mobility with continuous transmissions up to 800km/h
- Mobile broadband network
- Small physical dimensions and very lightweight (105 gr) (portable device)
- Low power consumption (less than 10W)
- Plug-and-play installation
- Battery operated

2.3 Packets supported by the SkyHopper Pro network

The SkyHopper Pro physical link supports Ethernet (IEEE 802.3) which includes:

1. Ethernet, VLAN Services, VPN and any other Protocol over IP.
2. Real-time applications using RT Protocols such as: Voice, Video, Data
3. Broadcast, Multicast, Unicast

Any Ethernet packet received by the unit's Ethernet port is encapsulated internally with a standard frame for transmitting via the Data Link to the remote unit. The remote unit recovers the original Ethernet packet and forwards it to the Ethernet port.



NOTE – The unit is similar to Ethernet layer 1 (physical layer), which makes integration with your equipment nothing more than connecting the Ethernet cable.

3 Physical Description

3.1 Front View Connectors

RF1: Antenna 1 Connector, MMCX/F 50 Ohm

RF2: Antenna 2 Connector, MMCX/F 50 Ohm

GPS: GPS Antenna Connector, MMCX/F

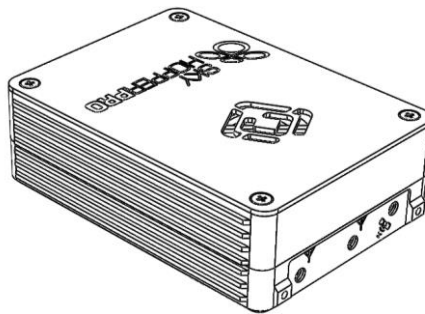


Figure 3: SkyHopper Pro Front View

3.2 Unit Cables: Type & Usage

Ethernet: Standard RJ45 connector

Serial (IOIO):

Molex - 502380-0600

RS232 / 1PPS connector

Power:

ZE - ZER-04V-S

Power connectors utilizing 7-14.5VDC



CAUTION – When SkyHopper Pro is carried by a person, environment temperature should not exceed 45°C (113°F)



NOTE – Information about the connectors' pin assignments are available in Appendix C – Connectors Pinout

LED: SkyHopper Pro's LEDs indicate power on, data transmission and link status.

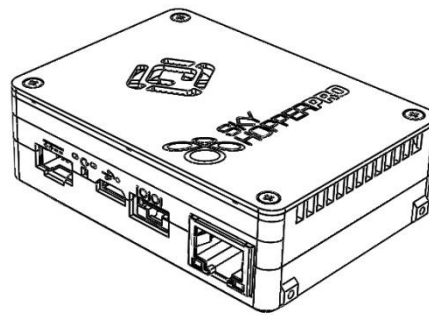


Figure 4: SkyHopper Pro Connector Side view

4 Mechanical Specifications

The SkyHopper Pro unit is lightweight and has small form-factor.

| Dimensions | [HxWxD] (mm) | [HxWxD] (inch) | Weight (gr) | Weight (oz.) |
|------------|--------------|-----------------|-------------|--------------|
| | 26 x 54 x 74 | 1.0 x 2.1 x 2.9 | 105 | 3.7 |

Table 2: SkyHopper Pro Mechanical Specifications

5 Technical Specifications

5.1 Radio and Modem Specifications

5.1.1 Frequency bands available:

- 2.4GHz unlicensed band

Note: This product is configured to operate within the FCC or CE limitations based on the country of ordering. It is configured within the 2.4 ISM frequency band. Mobilicom takes no responsibility should you choose to take and/or operate this product outside of FCC or CE limits and/or in a country that does not comply with FCC or CE regulations. Please note that SkyHopper specifications vary based on FCC or CE regulations.

5.1.2 Antennas

Various standard antennas can be supported using an MMCX/M connector. Some antennas with a different connector (such as SMA) can be used with an adaptor or adaptor cable. The Ground Unit has a mounting kit supplied with an MMCX to SMA connecting cable and SMA/M antennas.

5.1.3 RF Characteristics

- Peak output power: 2 x 0.5W per channel
- Average output power: 2 x 100mW per channel (23dBm)
- Noise Figure: 5dBm
- Transmission Power Control Range: 50dB in 1dB steps
- Radio Access Method: OFDM - TDMA
- Configuration & Diversity Support: 2X2 MIMO with MRC(RX) and CDD(TX)
- Frequency Resolution: 0.25MHz
- Channel bandwidth: Configurable 4.2/8.4MHz
- FFT Supported: 512
- Guard band: 64 sub-carriers on each side
- Total subcarriers used per symbol: 384
- Data carriers used: 336
- Pilot carriers used: 48
- Sub carrier spacing: 13KHz for 5MHz bandwidth with 5msec frame
- Modulations: QPSK
- FEC methods: CTC
- FEC Ratios: $\frac{3}{4}$, $\frac{1}{2}$, $\frac{1}{4}$
- Error Detection: CRC32
- Full TDD asymmetrical duplexing
- Flexible ratio from 1:1 to 1:9 in PTP
- Resolution of 1% between all units in multi-unit networks.



NOTE – The wide configurable power control range enables transmitting in low Tx power when not needed, thereby reducing power consumption.

5.2 Power Specifications

SkyHopper Pro is designed to be battery operated (DC) with low power consumption. Its design allows for multiple battery cell configurations (different voltages).

| Power - LF10WBRB-4P | |
|-------------------------------|---|
| DC Voltage (Battery Operated) | 7-14.5VDC |
| Power Consumption | 8 Watts average use Up to 12 Watts depending on the operational scenario (TX:RX Ratio) |

Table 3: SkyHopper Pro Power Specifications

5.3 Environmental Specifications

SkyHopper Pro is designed to meet international EMI, Radio & Environmental Standards, such as wireless ETSI & FCC etc.

| Environmental | | |
|-------------------|---------------|---------------|
| Temperature Range | Operating | Storage |
| | -10°C to 40°C | -50°C to 85°C |
| Humidity | 5 to 95% | |

Table 4: SkyHopper Pro Environmental Specifications

5.4 Embedded GPS Characteristics

SkyHopper Pro has a built-in GPS receiver. In a PTP network configuration it is used for location information only (which can be operated by the customer via the SkyHopper API). In a Multi-Unit network, it is used for synchronization and can also be used by the customer for location purposes. SkyHopper Pro uses active GPS antennas. The power for the active antenna is provided by the unit via the regular GPS MMCX connector.

| Item | Description |
|-----------------|----------------------|
| Receiver Type | GPS L1 C/A code |
| Accuracy | Position 2.5 m CEP |
| | SBAS 2.0 m CEP |
| Acquisition | Cold start: 27 s |
| | Aided start: < 3 s |
| | Hot start: 1 s |
| Sensitivity | Tracking: -161 dBm |
| | Cold start: -147 dBm |
| | Hit start: -156 dBm |
| Timing Accuracy | RMS 30 ns |
| | 99% < 60 ns |
| | Granularity 21 ns |

Table 5: Embedded GPS Characteristics of SkyHopper Pro

6 TDMA

Time Division Multiple Access (TDMA) is a channel access method for shared medium networks. It allows several units to share the same frequency channel by dividing the signal into different time slots. The units transmit and receive on the same frequency in a synchronized manner. Every unit transmits in its own dedicated time slots. On the other time slots said unit receives the transmission sent by the other units that are members of the same network (which are also transmitting on their own dedicated slots).

TDMA requires a synchronization system. The system is synchronized internally, externally or via GPS (synchronization varies between topologies and method used).

The SkyHopper Pro unit uses TDMA regardless of the application type, PTP or PTMP.

7 PTP (Point-to-Point)

A PTP network is a radio link between 2 SkyHopper Pro units. The configuration (frequency and profile) of both units must be the same with only one difference - one unit is configured as a Remote Unit while the other unit is configured as a Controller Unit.

The Remote Unit works with its internal clock and synchronizes the Controller Unit. After power-up, the Remote Unit starts transmitting regardless of link status. The Controller Unit however, does not transmit and stays in Rx mode, trying to acquire synchronization by finding a preamble (synchronization pattern). As soon as the Controller Unit recognizes the pattern, it starts to transmit according to its allocated time slot.

The transmission bandwidth ratio is predefined as part of the profile configuration. It can be symmetric when full duplex communications are required (50% to each unit) or asymmetric up to 10% to one unit (remote or controller) and 90% to the other unit.

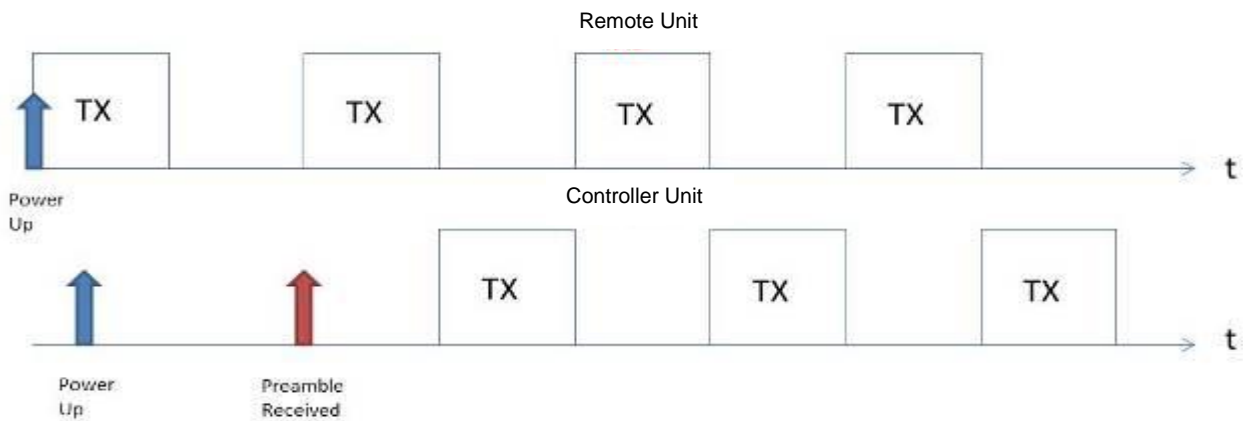


Figure 5: Transmit frames of the remote unit and controller unit from Power Up

Note: A viewer unit acts like a Controller unit but with one major change, it does not transmit and only receives.

7.1 PTP Link Step-by-Step Configuration

In order to build a PTP link, two SkyHopper Pro units are required. One unit acts as a remote unit, while the other as a controller unit.

1. Connect antennas to RF1 and RF2 connectors, and power up the unit.



CAUTION – Powering up a unit without connecting the antennas can cause irreparable damage to the unit.

2. Connect the unit to a PC using a standard Ethernet Cat 5 cable.
3. Set static IP in the 192.168.131.xxx subnet (**For more information, see the Web GUI Instructional Manual**).
4. Using the Web GUI: Open a web browser installed on your PC / laptop (Chrome, Firefox, Internet Explorer, etc.) and input in the address line: 192.168.131.241. That should connect you to the Web GUI interface, as shown on Figure 6:

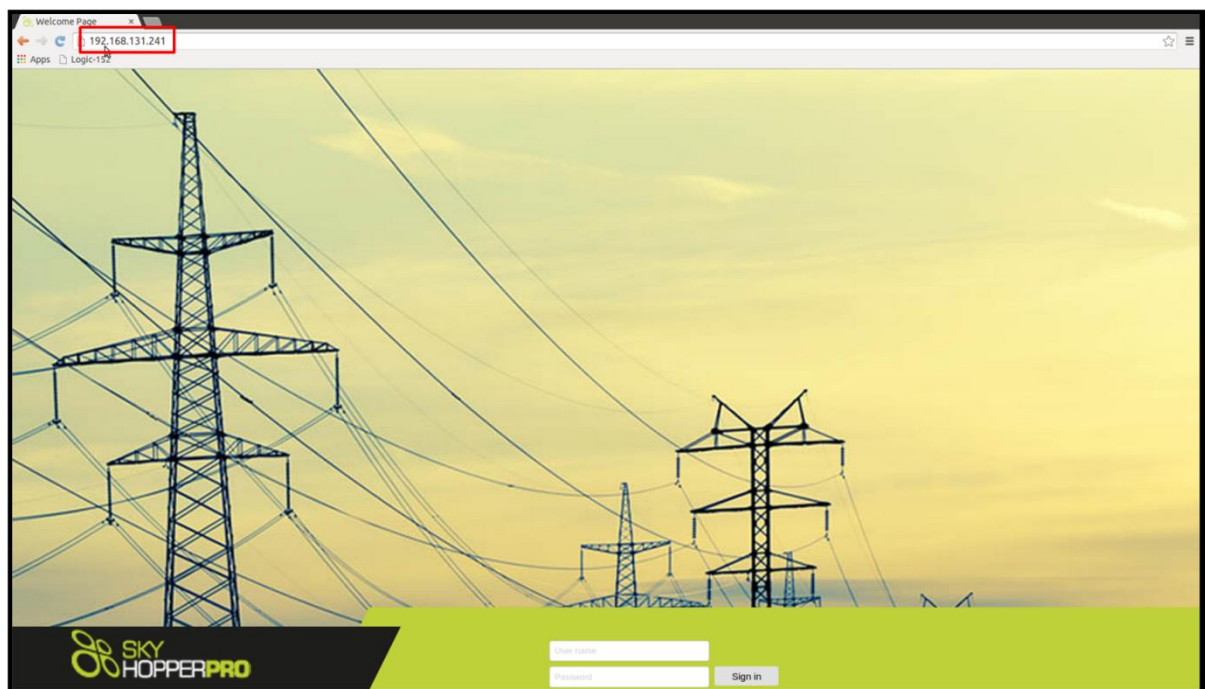


Figure 6: Web GUI main screen

5. To change the frequency to the required frequency, click on “Advanced Configuration” (third tab on the left corner) and on the “Frequency” line and write the desired frequency within the frequency range set in your unit.
6. Set the profile as required (RF bandwidth, bitrate and ratio) and click on the “Apply” button as shown on Figure 7. The unit will reboot.
7. Repeat stages 1-4 with the 2nd unit.



Figure 7: Web GUI “Advanced configuration” screen



NOTE – A PTP setup requires 2 SkyHopper Pro units configured with same frequency and profile.



NOTE – Frequency Hopping is currently not supported and has been disabled from the Web GUI.

7.2 SkyHopper Pro LED indicator

By following the LED on the unit, the power and link status can be monitored. It is described as follows:

1) ACTV LED:

- a) Off – Power Down
- b) On - Booting Up
- c) Slow Blinking – Remote unit is transmitting, controller unit receiving (P2P search)
- d) Fast Blinking – Air Link is up

2) DATA LED

- a) Off – No Ethernet detected
- b) On – Ethernet Cable is connected to a working device on host – No Data
- c) Slow Blink – Error (synced to ACTV LED)
- d) Fast Blink – Tx & Rx Air Traffic active

Should there be an error in your SkyHopper Pro unit, both the ACTV and DATA LEDs will be simultaneously slow blinking.

Link status, CINR, RSSI, throughput and unit log information is available in the Web GUI, which can be found online at www.skyhopper.biz/prosupport.

9 Installation and Setup

9.1 Package Contents

Aerial Unit

| Item | Quantity |
|-----------------------------|----------|
| SkyHopper Pro Aerial Unit | 1 |
| 2dBi Antenna MMCX | 2 |
| Power Cable | 1 |
| Telemetry Serial Data Cable | 1 |
| Ethernet Cable | 1 |

Ground Unit

| Item | Quantity |
|-----------------------------|----------|
| SkyHopper Pro Ground Unit | 1 |
| 2dBi Antenna SMA | 2 |
| Power Cable | 1 |
| Telemetry Serial Data Cable | 1 |
| Ethernet Cable | 1 |
| SMA to MMCX RF Cable | 2 |
| Bracket Mount | 1 |
| Bracket Screws | 3 |
| Tripod Knob | 1 |

9.2 Connecting the Antennas

Antennas for installation vary in size, shape, requirements and mounting methods. The antennas should be as close to the SkyHopper Pro as possible and can be connected to it directly.

Cables should be chosen according to their attenuation (lower attenuation gives better results) and flexibility (according to the path they pass through). Each cable should have an MMCX Male connector on the SkyHopper Pro end, and a connector matching the antenna's connector on the other.

9.3 Connecting the Power

SkyHopper Pro has a dual power feed enabling hot-swap battery replacement during operation.



CAUTION – Powering up a SkyHopper Pro without connecting the antennas can cause irreparable damage to the unit.

Appendix A - Specifications

| Radio and Modem | |
|----------------------|--|
| Frequency | 2.4GHz (ISM) 900MHz (ISM) - Optional 5.8GHz (ISM) - Optional |
| Antenna's Connectors | MMCX (X2) |
| TX Power Control | 50dB |
| RX Dynamic Range | 70dB |
| Sensitivity | Max -101dBm |
| Radio Access Method | OFDM - TDMA |
| Duplexing | TDD |
| Configuration | MIMO 2X2 |
| Channel BW | 4.2MHz / 8.4MHz |
| Frequency Resolution | 0.25MHz |
| Diversity Support | TX & RX Diversity |
| FFT Supported | 512 32 – 2048 upon request |
| FEC method | Turbo Code |
| Modulations | QPSK |
| Throughput | Configurable up to 6 Mbps |
| Synchronization | 1PPS sync input |
| Encryption | AES-128 bit |

| Environmental | | |
|-------------------------------------|---|---------------|
| Temperature Range | Operating | Storage |
| | -10°C to 40°C | -50°C to 85°C |
| Humidity | 5 to 95% | |
| Interfaces | | |
| Data | Ethernet, RS232 | |
| Full Ethernet Protocol Transparency | IP, TCP, UDP, RTP, HTTP Broadcast, Multicast, Unicast Ethernet, VLAN, VPN | |
| Serial Data | RS232 | |
| USB | Optional | |

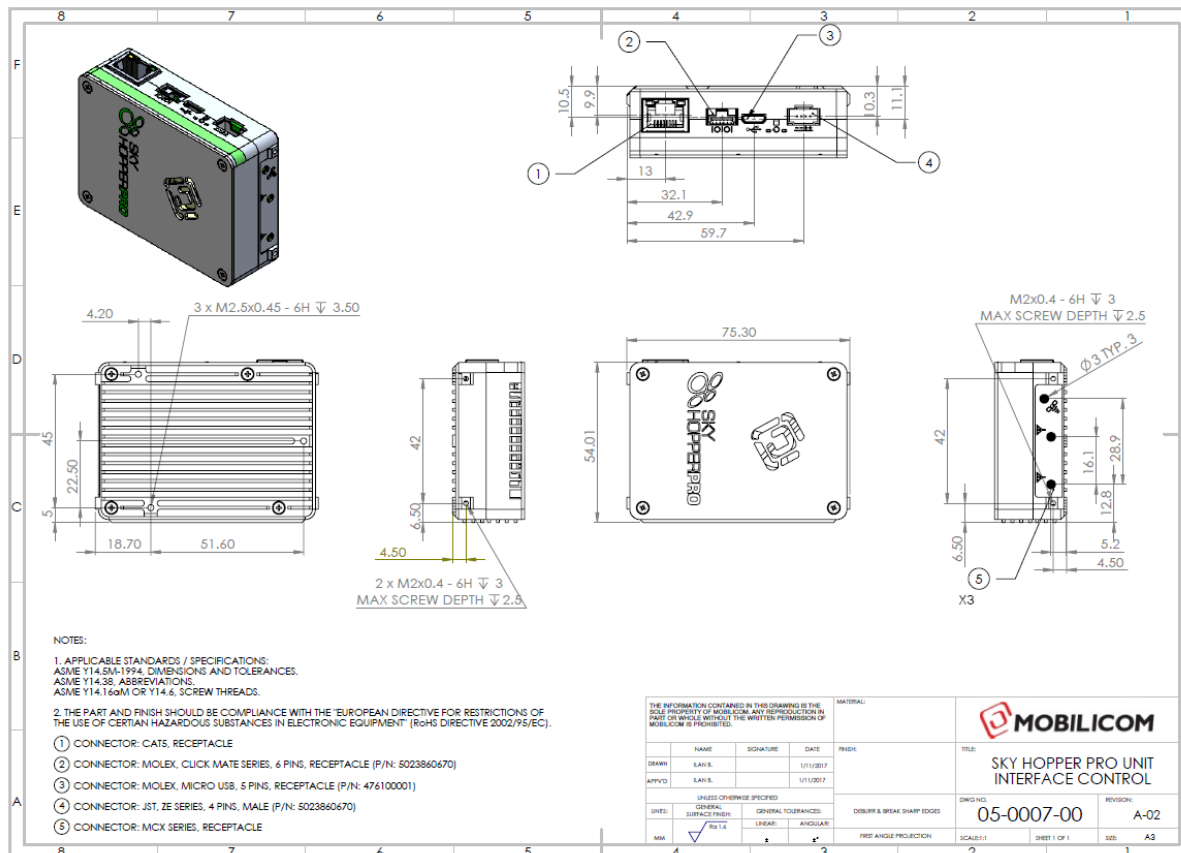
| Dimensions | [HxWxD] mm | [HxWxD] inch |
|-------------------|-------------------|---------------------|
| Embedded Package | 26 x 54 x 74 | 1.0 x 2.1 x 2.9 |
| Weight | Grams | Ounce |
| Embedded Package | 105 gr. | 3.7 oz. |

| Power | |
|-------------------------------|-----------------------------|
| DC Voltage (Battery Operated) | 7-14.5V DC |
| Power Consumption | Up to 12 Watt 8W Average |

| Configuration and Management | |
|-------------------------------------|---------------------------|
| Unit Monitoring Application | Web-Based Application |
| Program Interface | API, Code Lib. (Optional) |

| Integrated Options | |
|---------------------------|---|
| Video Encoder/Decoder | H.264 very low latency HD/SD Video Formats up to: 1920x1080p |
| Video Inputs / Outputs | Micro HDMI (Input/Output) Analog (Input) |
| Audio Inputs / Outputs | Embedded Audio over HDMI, Analog |

Appendix B - Mechanical Drawings



Appendix C – Connectors’ Pinout

1. RS-232/1PPS

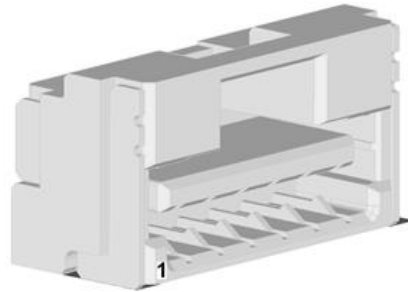


Figure 8: RS232/1PPS connector (IOIOI) (SkyHopper Pro side)

| SkyHopper Pro Housing P/N: 502380-0600 Pins P/N: 502381-0000 | Name | Description |
|---|-----------|-------------|
| 1 | N/A | |
| 2 | RS232 out | D9 Pin 2 |
| 3 | N/A | |
| 4 | RS232 in | D9 Pin 3 |
| 5 | GND | |
| 6 | 1PPS In | |

Table 6: RS232/1PPS connector pinout (IOIOI)

2. Power Cable

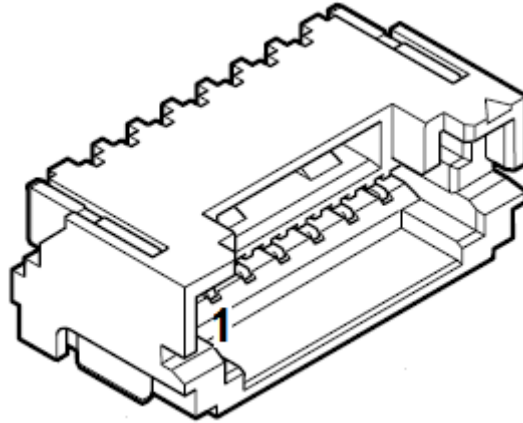


Figure 9: Power connector (SkyHopper Pro side)

| SkyHopper Pro Housing P/N: ZER-04V-S, Pins P/N: SZE-002T-P0.3 | Description |
|---|--------------------|
| 1 | GND (-VDC) |
| 2 | GND (-VDC) |
| 3 | Vin+ (+VDC) |
| 4 | Vin+ (+VDC) |

Table 7: PWR Connector Type and Pin Mapping

Appendix D – Setting up a Pixhawk based system

In this section we will describe how to setup a network for a drone using a Pixhawk flight controller.

The Pixhawk flight controller uses a UART interface and runs the MAVlink protocol over it. SkyHopper Pro has an RS232 interface which is similar in its word structure to RS232 but there is a difference in the voltage levels.

1. SkyHopper Setup

The first stage is to setup the SkyHopper link to enable the UART interface on the link. The configuration should be setup on both units (Remote/Aerial and Controller/Ground).

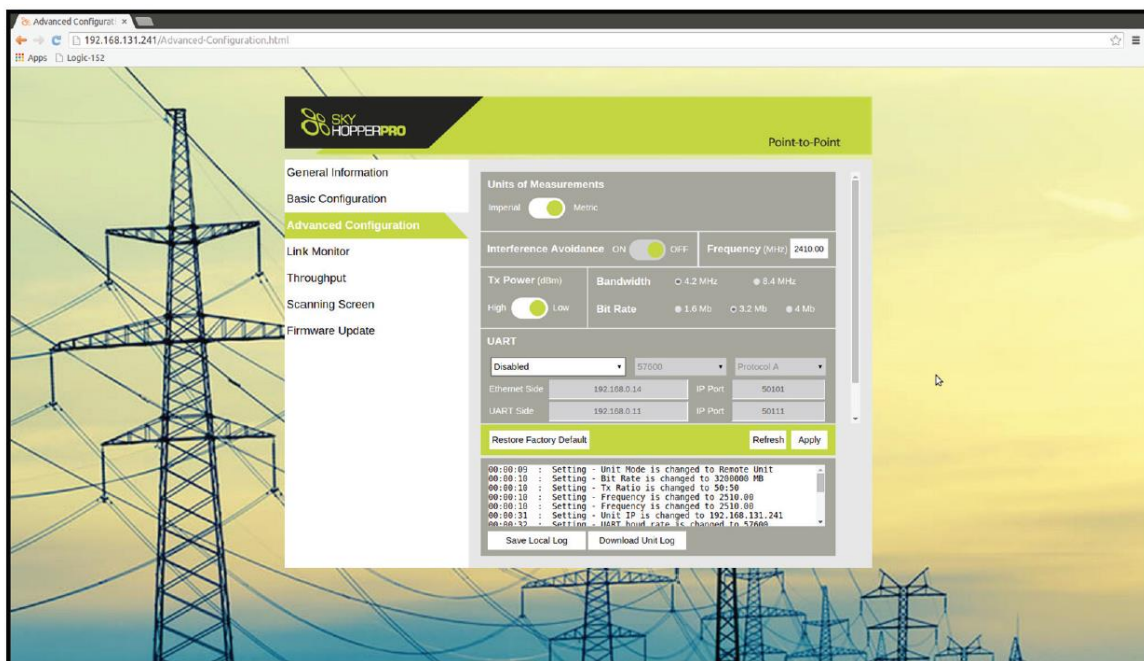


Figure 10: Web GUI advanced configuration

In the advanced configuration screen:

1. Go to the UART section
2. Enable the UART and choose UART-to-UART
3. Setup the Baud rate to 57600
4. Choose protocol C
5. Reboot the unit
6. Repeat on both Remote and Controller units

2. Physical connection

After the units are configured, the Pixhawk flight controller should be connected to the unit.

On the remote (Aerial) unit Use the Pixhawk adapter accessory which can be purchased on our website and connect it to the serial cable provided with the SkyHopper Pro unit. Connect the adapter to the Pixhawk flight controller and the serial cable to the unit.

On the controller (Ground) unit, connect the D-Type/9-pin accessory adapter to the serial cable supplied and connect the cable to the unit. If the Tablet/PC has a serial port, connect it directly, if not, a USB-RS232 adapter should be used.

3. UART to Ethernet

There is an option to configure the system to work with a UART-to-Ethernet configuration, which eliminates the use of the serial cable on the Ground Unit.

Please refer to the UART-to-Ethernet Connection Guide online at www.skyhopper.biz/prosupport.

Appendix E –Troubleshooting

| Symptom | Possible Cause | Action Needed |
|---|--|---|
| LED is off | Not connected to power source or battery is empty | <ol style="list-style-type: none"> 1. Verify power cable properly connected to the SkyHopper Pro PWR connector. 2. Verify that the battery or power supply is connected to the SkyHopper Pro power cable and to a power outlet. 3. Replace the battery or check the outlet. 4. Replace the power cable. |
| LED light is always on | PTP – Unit is in boot mode | <p>PTP</p> <ol style="list-style-type: none"> 1. Check the power source 2. Reboot the SkyHopper Pro. |
| Cannot connect to SkyHopper Pro using Web GUI | <ol style="list-style-type: none"> 1. The PC isn't configured with a correct static IP 2. Unit isn't powered up 3. Ethernet cable isn't connected or data cable is damaged 4. Firewall is blocking traffic 5. ETH port set to "auto negotiation off" with 1GE 6. Trying to connect to remote unit when link is down. | <ol style="list-style-type: none"> 1. Verify your PC is set with a static IP in the subnet of 192.168.131.xxx. 2. Check that the ETH port is set to "auto negotiation on". 3. Verify the unit is powered up. 4. Verify that the PC ETH port status isn't unplugged or disabled. 5. Disable the PC firewall. 6. Verify ETH cable is connected to the PCs ETH port and to the SkyHopper Pro MAIN connector. <p>If needed: replace cables.</p> <ol style="list-style-type: none"> 7. Ping the unit. 8. Try to connect to the local unit and verify link is up. |
| No link between SkyHopper Pro units | <ol style="list-style-type: none"> 1. Configuration isn't the same on all of the SkyHopper Pro units. 2. PTP – both units set as VC or both as Node. 3. The units aren't within reception range. | <ol style="list-style-type: none"> 1. Connect to each unit and verify they have the same configuration. 2. PTP -Verify 1 unit is set as a VC and the other as a Node. MPTMP - verify each transmitting unit has a different unit ID. 3. Verify that TX power is set to the maximum. 4. Verify the antennas fit the Frequency used (antenna spec). |
| Data with high delay and disconnecting data | Trying to send a higher amount of data than the allocated bandwidth sent to the unit. | <ol style="list-style-type: none"> 1. Verify that the data bandwidth sent to the unit from the connected device(s) does not exceed the allocated bandwidth (in its configuration). 2. Decrease the data received by the data source or change the allocated bandwidth via the Web GUI. |

Technical Support Inquiries

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