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**Foreword**

This document will outline a recommendation on a possible guidance computer and inertial measurement unit to be used in the on the UAV for the ZEPHYR 2012 project. The guidance computer will control the airborne segment of the Zephyr system, while the inertial measurement unit will determine the kinematic state vector. Both components will be required to be light weight, cheap, and consume little power.

In this document different computers and inertial measurement units will be analysed, this includes discussing both the advantages and disadvantages. After analysing the different types of sensors the appropriate sensors will be selected for the guidance, navigation and control subsystem of the ZEPHYR 2012 project.

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**Definitions**

|  |  |
| --- | --- |
| QUT | Queensland University of Technology |
| TS | Trade Study |
| UAV | Unmanned Aerial Vehicle |
| GNC | Guidance, Navigation and Control |
| Circumnavigation | Flying around the disaster zone. |
| Detect  Obstacles  RD  IMU | To discover or determine the presence of something whether it be a wall, table or person.  The walls, floor or ceiling.  Reference Document  Inertial Measurement Unit |
| GC | Guidance Computer |
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# Introduction

The guidance computer (GC) is the brains of the blimp. On it runs the autopilot, which determines where to go (guidance), and how to get there (control). It also retrieves where the blimp is (navigation) by asking the inertial measurement unit.

The inertial measurement unit is a component which determines both the position and attitude of the blimp by integrating the accelerations detected. This requires three accelerometers, to determine the linear acceleration, and gyroscopes, to determine the angular velocity. Alternatively, magnetometers can be used to determine attitude instead of integrating the gyros; however, magnetometers tend to not be very accurate, especially indoors and around metallic objects. Often a combination of the two is used to determine attitude.

## Scope

In this document various types of sensors that can be used on the UAV will be compared, investigating the strengths and limits of the sensors. Finally a recommended sensor will be presented to be selected for the UAV.

## Background

This is the same for everyone. Just copy this into your’s.

Student teams from ENB354 are required to design, build, test and demonstrate a dirigible search and rescue platform for ARCAA. The blimp is required to navigate autonomously around a disaster zone and seek and identify survivors. If required, the blimp must be able to deliver a rescue package to a stranded survivor. The platform is controlled via a remote ground control station, where platform telemetry and imagery is displayed, and operator commands are issued. Further information on the project can be found on the project brief document which can be found on ENB354’s university database.

# Reference Documents

## QUT Avionics Documents

|  |  |  |
| --- | --- | --- |
| RD/1 | Customer Needs Document | The ZEPHYR Project Indoor Search & Rescue 2012 |
| RD/2 | ZEPH4-PMP-2012-0001 | ZEPHYR 2012, System Requirements |

## Non-QUT Documents

Reference your websites, books, ect. Anything that you used directly or where the product are from Do proper referencing styles too. Like IEEE or Harvard

# Background Research

This is where your background research goes.

To help prevent collisions with walls, the floor or the ceiling the Navigation and Guidance system must know how close these obstacles are in relation to the airborne segment. This is the job of the Proximity Control and Collision Avoidance subsystem (PA). This subsystem works by using sensors which send a signal from their position on the airframe out into the surrounding area. If an obstacle is in the path of the airborne segment the signal from the sensors will be bounced back and received by the sensors. The sensors will then inform the Guidance, Navigation and Control subsystem (GNC) that there is an obstacle in the path of the blimp and the distance to that obstacle. The Guidance, Navigation and Control subsystem will then be able to take appropriate action to avoid this obstacle.

## Types of Sensors

There are three main types of active proximity sensors, ultrasonic, infrared and lasers or also referred to as optical sensors (RD/3).

### Ultrasonic Sensors

An ultrasonic sensor sends an ultra sound wave and measures the echo signal from surroundings or obstacles that bounce of that signal. Some factors that can affect the performance of these sensors are, surface roughness of objects that’s the sensor is measuring has to be greater than the frequency or else the object will just act as a mirror deflecting the signal and not returning it. Multiple reflections of the ultrasound waves can easily result in an error and also soft materials like curtains or pillows tend to observe the ultrasound wave and therefore go undetected. If more than one sensor is used, crosstalk between multiple sensors can often result in signal overlapping and error in measurements (RD/3).

### Laser Sensors

These types of sensors are the most precise and accurate sensors, they also have the longest range that they can operate at. This system uses a laser to send out a pulse of waves and then it collects it back using a mirror and a diode to detect the wave. After the wave is detected the time of travel is measured and the distance is calculated (RD/3). However this type of sensor due to the optics is usually heavy and also uses substantial amount of power.

### Infrared Sensors

Infrared sensors are typically used to detect nearby objects. This type of system operates in a very similar manner to the above two systems; however there is no time factor in this sensor. This system uses triangulation to achieve its solution (RD/3). These sensors are typically light in weight and consume small amount of power.

# Collision Avoidance and Proximity Control Requirements

List the requirements that affect your subsystem

The requirements for this subsystem are the followings (RD/2):

Table 3-1 2012 ZEPHYR Group 4 Collision Avoidance and Proximity Control Requirements

|  |  |
| --- | --- |
| Subsystem Requirements | Description |
| Functional Requirements | |
| REQ-21 | The airborne segment shall detect obstacles in its path before the airborne segment collides with the obstacles. |
| REQ-22 | The airborne segment shall avoid detected obstacles. |
| Performance Requirements | |
| REQ-44 | When operating in the circumnavigation task the minimum distance between the airborne segment and the closest wall shall be no greater than 1 metre. |

If the potential sensors cannot meet these requirements then the sensors cannot be used for the project.

# Criteria

List the criteria that you will be using to compare your different options.

The trade study will provide a recommendation for an adequate proximity and sensor solution to the ZEPHYR 2012 project. A variety of sensors will be compared and evaluated against a set of standards and criteria that need to be met to ensure the success of the subsystem and the project.

## Sensors Assessment Criteria

There are four different criteria that the sensors will be assed against. These criteria will be separately weighted depending on their importance towards the success of the project. Each sensor will receive a score for each criterion. The score given to each criterion will be ranging from one to five. A score of one will be awarded when the sensor does not meet the criterion and therefore not suitable; whist a score of five is awarded when the sensor is very suitable. Any sensor receiving a score of one in any of the criteria will not be considered for implementation in this subsystem.

The four criteria are:

### Range

The range of the sensor is a very important criterion as it refers directly back to REQ-44. Therefore the sensor shall be able to detect objects within 1 meter of the sensor. Since this is a requirement of the subsystem, sensors will only be awarded a grade of 1 or 5 for this criterion. A grade of 1 stands for the sensor not meeting the required range and a grade of 5 stands for it meeting the required range. This criterion is worth 30% of the final score. Remember to add this

### Cost

This criterion evaluates the cost of purchasing 5 sensors, 4 to be used in the project and a spare sensor in case of a damage caused to one of the other sensors. This criterion will also include the shipping costs if applicable. The scoring method for this criterion is shown in Table 4-1 and it is worth 30% of the final score.

### Weight

Weight plays a vital role in this project, as it is very important to keep the weight of the subsystems to a minimum so that the UAV can fly with no problems. This criterion evaluates the weight of each sensor individually and will receive a grade according to the scoring method which is shown in Table 4-1. This criterion is worth 30% of the final score.

### Availability

Availability of the sensors is also important as in a case of a crash the system needs to be up and running again in a reasonably short period of time. The scoring method for this criterion is shown in Table 4-1 and it is worth 10% of the final score.

## Sensors Criteria Table

In this table all of the above criteria is summarised and it will be used to analyse each sensors separately.

Table 4-1 Sensors Criteria Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 5 | 4 | 3 | 2 | 1 | Weighted Score |
| **Range**  Weighting: 0.3 | Within 1m | - | - | - | Outside 1m |  |
| **Cost**  Weighting: 0.3 | Under $100 | Between $100 and $200 | Between $200 and $500 | Between $500 and $1000 | Over $1000 |  |
| **Weight**  Weighting: 0.3 | Under 5g | Between 5g and 10g | Between 10g and 20g | Between 20g and 40g | Over 40g |  |
| **Availability** Weighting: 0.1 | In Brisbane | In QLD | In Australia | Over seas | Not available |  |
|  | | | | | Total 🡺 |  |

# Sensor 1: Devantech SRF02

Describe the first product available that you would consider using.



Figure 5: Devantech SRF02

## Range

The Devantech SRF02 has a cited range of 16cm to 6m, which will easily satisfy REQ-44.

## Cost

The Devantech SRF02 will cost $20.95 per unit and therefore 5 of them will cost $104.75 and shipping is $6.30. Therefore the total cost will come down to $111.05.

## Weight

The Devantech SRF02 has a weight of 4.6g.

## Availability

The Devantech SRF02 is available within Australia and can be ordered from robotgear.com which is based in Perth.

## Summary

The Devantech SRF02 has a cited range of 16cm to 6m, satisfying range requirements. It is light weight and small in size, It also a good price tag. Consequently, the Devantech SRF02 would be a very susceptible choice for the project.

Table 5-1 Devantech SRF02 Criteria Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 5 | 4 | 3 | 2 | 1 | Weighted Score |
| **Range**  Weighting: 0.3 | Within 1m | - | - | - | Outside 1m | 1.5 |
| **Cost**  Weighting: 0.3 | Under $100 | Between $100 and $200 | Between $200 and $500 | Between $500 and $1000 | Over $1000 | 1.2 |
| **Weight**  Weighting: 0.3 | Under 5g | Between 5g and 10g | Between 10g and 20g | Between 20g and 40g | Over 40g | 1.5 |
| **Availability** Weighting: 0.1 | In Brisbane | In QLD | In Australia | Over seas | Not available | 0.3 |
|  | | | | | Total 🡺 | 4.5 |

# Sensor 2: DT10-N10B5

The 2nd product that you might use



Figure 6: DT10-N10B5

## Range

The DT10-N10B5 has a quoted range of 50mm – 500mm, which will easily satisfy REQ-44. This is a laser equipped sensor which means a very high accuracy and precision when providing readings.

## Cost

The DT10-N10B5 is a very expansive piece of equipment costing at just above $500.00 per sensor and there for 5 of them will cost over $2500.00 without the shipping price which is obviously over the budget

## Weight

The DT10-N10B5 also has a large weight associated with it. The DT10-N10B5 has optical components inside which gives it a weight of 40g.

## Availability

The sensor is only available outside Australia.

## Summary

The DT10-N10B5 has a great range and accuracy however the cost and weight of the sensor is above what this subsystem is allocated.

Table 6-1 DT10-N10B5 Criteria Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 5 | 4 | 3 | 2 | 1 | Weighted Score |
| **Range**  Weighting: 0.3 | Within 1m | - | - | - | Outside 1m | 1.5 |
| **Cost**  Weighting: 0.3 | Under $100 | Between $100 and $200 | Between $200 and $500 | Between $500 and $1000 | Over $1000 | 0.3 |
| **Weight**  Weighting: 0.3 | Under 5g | Between 5g and 10g | Between 10g and 20g | Between 20g and 40g | Over 40g | 0.3 |
| **Availability** Weighting: 0.1 | In Brisbane | In QLD | In Australia | Over seas | Not available | 0.2 |
|  | | | | | Total 🡺 | 2.3 |

# Sensor 3: SHARP GP2Y0A02YK0F

The 3rd product that you might use

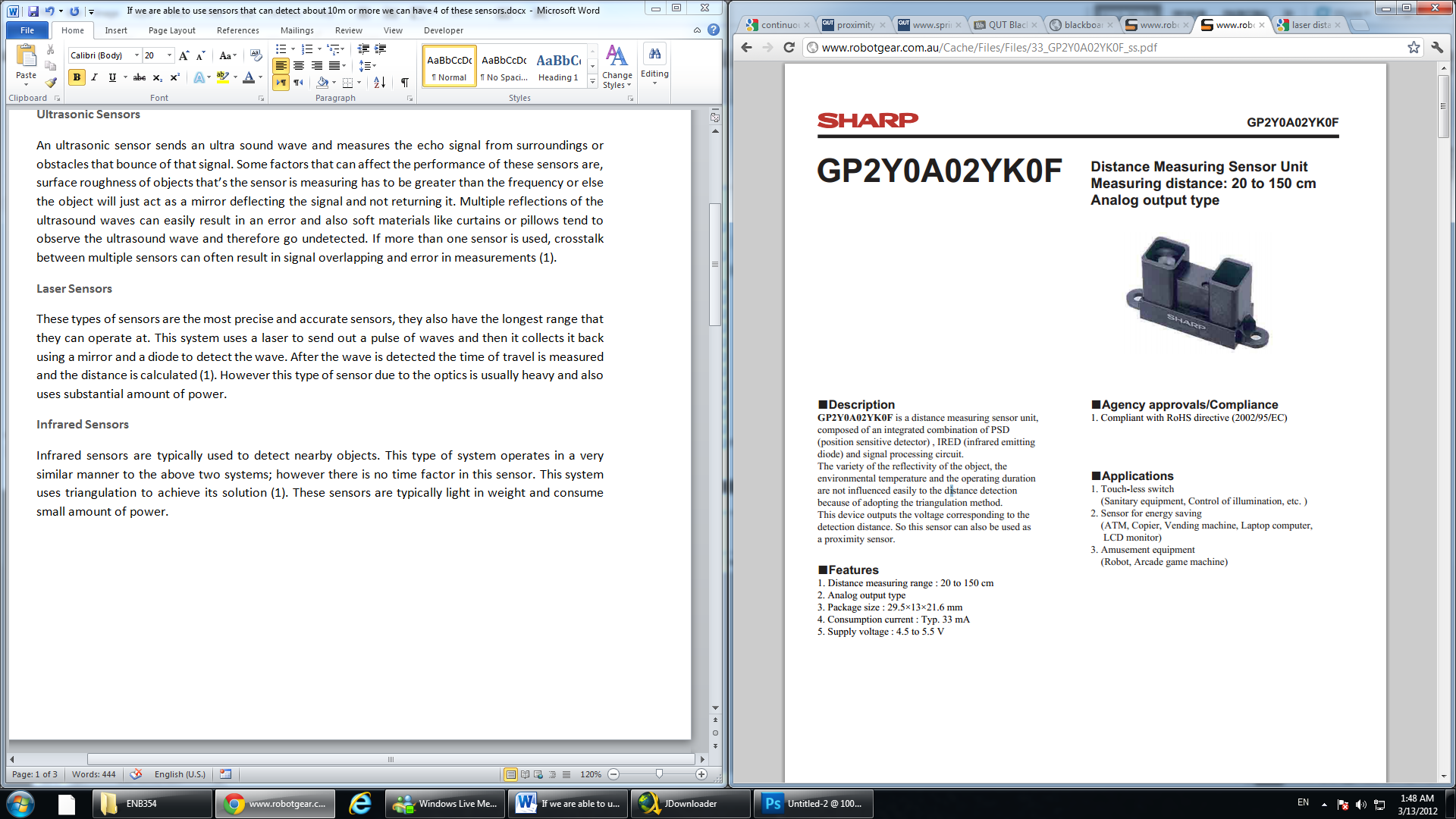


Figure 7: SHARP GP2Y0A02YK0F

## Range

The SHARP GP2Y0A02YK0F has a cited range of 30cm to 150cm which will satisfy REQ-44. This is an IR sensor which is reasonably accurate.

## Cost

The SHARP GP2Y0A02YK0F will cost $14.95 per unit and therefore 5 of them will cost $74.75 and shipping is $6.30. Therefore the total cost will come down to $81.05.

## Weight

The SHARP GP2Y0A02YK0F has a weight of 4.8g.

## Availability

The Devantech SRF02 is available within Australia and can be ordered from robotgear.com which is based in Perth.

## Summary

The SHARP GP2Y0A02YK0F is a common choice for robotics projects, and that is due to its reasonable price and accuracy. Another factor that makes this sensor a good choice for the UAV project would be its light weight and small size.

Table 7-1 SHARP GP2Y0A02YK0F Criteria Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 5 | 4 | 3 | 2 | 1 | Weighted Score |
| **Range**  Weighting: 0.3 | Within 1m | - | - | - | Outside 1m | 1.5 |
| **Cost**  Weighting: 0.3 | Under $100 | Between $100 and $200 | Between $200 and $500 | Between $500 and $1000 | Over $1000 | 1.5 |
| **Weight**  Weighting: 0.3 | Under 5g | Between 5g and 10g | Between 10g and 20g | Between 20g and 40g | Over 40g | 1.5 |
| **Availability** Weighting: 0.1 | In Brisbane | In QLD | In Australia | Over seas | Not available | 0.3 |
|  | | | | | Total 🡺 | 4.8 |

# Sensor 4: Aerocomm AC4790-200M

The 4th product that you might use

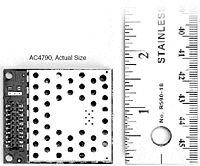


Figure 8: Aerocomm AC4790-200M

## Range

The Aerocomm AC4790-200M modem has a quoted range of up to 6.4km, which falls short of the telecommunications range requirement of 7km.

## Availability

The Aerocomm AC4790-200M is available within Australia, distributed by Mouser. Depending on mode of post, there could be up to a two week postage delay.

## Cost

The complete Aerocomm AC4790-200M development kit costs $270 exclusive of postage costs. This is significantly less than the previous three modems.

## C-Tick Australia

The Microhard MHX920A is C-Tick certified, hence its availability within Australia.

## Summary

The Aerocomm AC4790-200 radio modem is unlike previous radio modems, in that each module is a transceiver that uses peer to peer architecture. The AC4790-200 also uses FHSS agility, but isn’t available within Australia. Furthermore, the Aerocomm AC47900 only contains an RS485 interface, and thus an adapter would be required to interface with the autopilot (See Appendix D). Although the modem is very small and lightweight, it only has a range of 6.4km, falling short of the mandatory requirement of a 7km telemetry range.

Table 8-1 Aerocomm AC4790-200M Criteria Table

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 5 | 4 | 3 | 2 | 1 | Weighted Score |
| **Range**  Weighting: 0.3 | Over 7km | - | - | - | Under 7km | 0.3 |
| **Availability**  Weighting: 0.2 | Available within QUT | Available Within Australia | - | Available only Overseas | Not Available | 0.8 |
| **Cost (Kit)**  Weighting: 0.3 | Under $100 | Between $100 and $200 | Between $200 and $500 | Between $500 and $1000 | Over $1000 | 0.9 |
| **C-Tick Australia**  Weighting: 0.2 | Yes | - | - | - | No | 1.0 |
|  | | | | | Total 🡺 | 3.0 |

# Conclusions

Add a conclusion stating which is the best option and show how all the options scored on the table.

Although the Aercomm AC4790 is C-tick approved and available from overseas suppliers, it cannot be considered viable as it doesn’t meet the mandatory range requirements. The Digi XBee Pro 868 modem cannot be considered viable either, as it was too expensive and not C-tick certified. Thus, only the Maxstream 9xtream and Microhard MHX920A modems can be considered for use. Although the Maxstream satisfies all interface, range and budget requirements, the fact that there are already Microhard MHX920A modems available to SRUAV free of charge largely influenced the evaluation matrix. By using the MHX920A modems, all telecommunications telemetry link requirements will be satisfied and more room will be available in the team budget for other equipment.

Table 9 – Evaluation of Modems

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Critera** | | | |  |
| **Modem** | **Range**  Max score: 1.5 | **Availability**  Max score: 1.0 | **Cost**  Max score: 1.5 | **C-Tick Australia**  Max score: 1.0 | **Score** |
| Microhard MHX920A | 1.5 | 1.0 | 1.5 | 1.0 | 5.0 |
| Digi 9xStream | 1.5 | 0.8 | 0.9 | 1.0 | 4.2 |
| Digi XBee 868 | 1.5 | 0.4 | 0.9 | 0.2 | 3.0 |
| Aerocomm AC4790-200M | 0.3 | 0.8 | 0.9 | 1.0 | 3.0 |

# Recommendations

Finally and briefly state which product will be used

It is recommended that the Microhard MHX920A radio modem set is to be used on the SRUAV Project as it has extensive range, is available within QUT, is supplied for free and passes the Australian regulations. Previous teams have been successful in implementing these modems, and keeping this configuration from previous years will free up room in the budget for other subsystems.

# Appendices

Add any appropriate appendicies that will help/backup your research and trade study

## Appendix A: Digi XBee Pro 868 MHz Brief Specifications

|  |  |
| --- | --- |
| Frequency Band | 868MHz |
| RF Baud Rate | 24Kbps |
| Range | Up to 80km (depending on antenna and environment) |
| Supply Voltage | 3.3V |
| Weight | 23g |
| Dimensions | 22mm×33mm×3mm |
| Antenna Options | Chip antenna, ¼ monopole whip antenna or a U.F.L antenna connector |
| Interface Options | RS232 |
| Cost (Kit) | $460.38 |
| C-Tick Australia | No |

For more Specifications, see RD/4.

## Appendix B: Digi 9xStream Brief Specifications

|  |  |
| --- | --- |
| Frequency Band | 915MHz – 928MHz |
| RF Baud Rate | 10Kbps |
| Range | Up to 32km (depending on antenna and environment) |
| Supply Voltage | 5.5V |
| Weight | 24g |
| Dimensions | 40.6mm×71.8mm×8.9mm |
| Antenna Options | 2.1 dB dipole antenna, RPSMA, MMCX, or Wire Antenna |
| Interface Options | RS232 and RS485 capabilities |
| Cost (Kit) | $490 |
| C-Tick Australia | Yes |

For more detailed Specifications, see RD/5.

## Appendix C: Microhard MHX920A Brief Specifications

|  |  |
| --- | --- |
| Frequency Band | 915MHz – 928MHz |
| RF Baud Rate | 300bps to 230.4Kbps |
| Range | Up to 100km (depending on antenna and environment) |
| Supply Voltage | 4V to 5.5V |
| Weight | 55g |
| Dimensions | 89mm x 53.4mm x 17.8mm |
| Antenna Options | Any antenna with an MCX connector |
| Interface Options | RS232, RS485 |
| Cost (Kit) | Free (supplied from previous projects) |
| C-Tick Australia | Yes |

For more detailed Specifications, see RD/6.

## Appendix D: Microhard MHX920A Brief Specifications

|  |  |
| --- | --- |
| Frequency Band | 915MHz – 928MHz |
| RF Baud Rate | up to 76.8Kbps |
| Range | Up to 6.4km (depending on antenna and environment) |
| Supply Voltage | 3.3V to 5.5V |
| Weight | 20g |
| Dimensions | 42 x 48 x 5mm |
| Antenna Options | Any antenna with an MMCX connector |
| Interface Options | RS485 |
| Cost (Kit) | $270 (not including shipping costs) |
| C-Tick Australia | Yes |

For more detailed specifications, see RD/7.