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|-------------------------------------------------------|---------------------------------------------|-----------------------------------|
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### Abbreviations

| Abbreviation | Description                                 |
|--------------|---------------------------------------------|
| RCM          | Raydio Communications Module                |
| GW           | Gateway                                     |
| HC           | Handheld Controller                         |
| SOF          | Start Of Frame                              |
| EOF          | End Of Frame                                |
| RFIC         | Radio Frequency Integrated Circuit          |
| REAP         | Raymarine to Ember Application Protocol     |
| UART         | Universal Asynchronous Receiver Transmitter |
| SPI          | Serial Peripheral Interface™                |

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## **1 Purpose**

The purpose of this document is to outline Raymarine's Embedded Wireless Networking Technology.

Raymarine are developing four products. They are:

1. BASE
2. S1000 (Autopilot)
3. S100 (Autopilot Controller)
4. SMART CONTROLLER

As such these developments can be grouped by into two distinct, and quite different wireless categories. These are:

1. GW - Gateway
2. HC - Handheld Controller

The following Sections consider an overview of the products, the RF technology used and the distinction between Gateway & Handheld Controller.

## **2 Product Overview**

### **2.1 Base**

The Base is a Gateway.

It may be used in conjunction with the S100 or the Smart Controller.

Its function is to act as bridge between a wired communication system (SeaTalk™) and wireless products for the transfer of data and commands. For example, it will be capable of transferring control information to a wired Autopilot and vessel information such as Boat Speed, Wind Direction, etc.,.

### **2.2 S1000**

The S1000 is a Gateway.

It will be used in conjunction with the S100.

Its function is a Wirelessly Controlled Autopilot. It uses a combination of GPS and vessel attitude to maintain the vessel on a pre-determined course.

### **2.3 S100**

The S100 is a Handheld Controller.

It may be used in conjunction with the S1000 or the Base.

Its function is control both the S1000 and existing wired Autopilots available via the Base. There is only one Autopilot per system. The S100 issues commands to the Autopilot that

change its mode of operation. For example, from Standby to Auto and vice versa, course changes, etc... It also displays the current Autopilot status.

## 2.4 Smart Controller

The Smart Controller is a Handheld Controller.

It will be used in conjunction with the Base

Its function is to control a wired Autopilot as well as displaying vessel data that is available on the wired system to which the Base is attached. It issues commands to the Autopilot that change the mode of the Autopilot. For example, from Standby to Auto and vice versa, course changes, etc... It also displays the current Autopilot status. It also gathers vessel data such as Alarms, Boat Speed, and Water Depth etc,.

## 2.5 Product Matrix

These four products will be combined with ancillary equipment in three packages. This defines the three applications for Notified Body Opinion under the R&TTE Directive.

**Product Matrix**

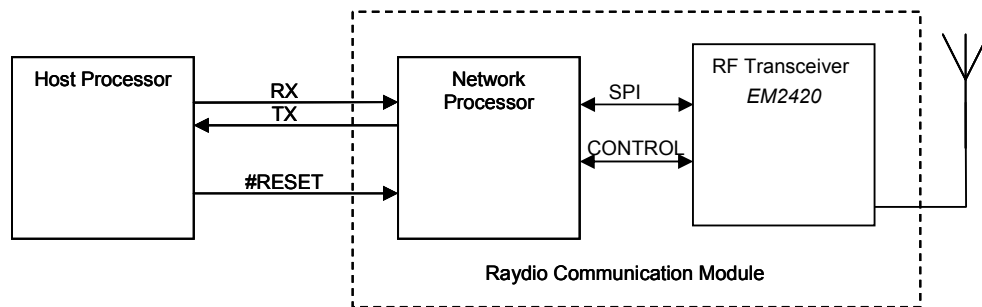
| System | Smart Controller | S100 | S1000 | Base | Pump | Fitting Kit |
|--------|------------------|------|-------|------|------|-------------|
| E15023 | X                |      |       | X    |      |             |
| E12169 |                  | X    | X     |      | X    | X           |
| E15024 |                  | X    |       | X    |      |             |

### 3 Hardware Overview

This Section provides a general overview of the hardware implementation for both the Gateway and the Handheld Controller.

#### 3.1 System Block Diagram

The illustration below is a block diagram for the solution.



The Raydio Communication Module (RCM) is based upon Ember's EM2420 2.45GHz RF transceiver connected to an ATMEGA64 microprocessor, the Network Processor. This Network Processor runs EmberStack - Ember's networking embedded wireless networking solution.

#### 3.2 Implementation

This solution is based upon IEEE 802.15.4. It uses Ember's EM2420 integrated solution ([www.ember.com](http://www.ember.com)) and Embernet, Ember's networking software.

##### **Key Features**

- 2400 – 2483.5 MHz Range
  - 16 channels from 2405MHz to 2480MHz @ 5MHz intervals
  - Fixed channel operation – No channel hopping
- Direct Sequence Spread Spectrum
- 0dBm (nom) output power
- –90dBm (nom) receiver sensitivity
- Point-to-point and mesh networking capability

### 3.3 Application

The application of this solution follows the rules below.

#### 3.3.1 Rule 1 – Data on Request

This RF system is not a broadcast system. Data must be requested using the PID request mechanism for the following reasons:

1. Reduced power consumption
2. Reduced on-air time
3. To avoid synchronisation problems

Typically a Handheld Controller will request data and stay awake until it has received the requested data (these being battery powered nodes).

The Gateway services the Handheld Controller requests. Since it is a powered node it can stay awake, permanently listening for requests and incoming data.

#### 3.3.2 Rule 2 – Frame usage

Data is sent in 91-byte data frames. For optimum performance the frame is used to transport multiple data entries.

#### 3.3.3 Rule 3 – Periodicity

Data will be requested no more than once a second. The exception to this rule is when an immediate response is required that would otherwise have an immediate impact on the functionality of the product / system. For example, changing Autopilot mode would be considered as being acceptable.

### 3.4 Gateway (GW)

The GW is an always-powered device, which will serve requests initiated by Handheld Controllers. This design uses PCB mounted antenna. Its role is to interact with the SeaTalk™ bus caching data locally, in order to speed up remote transactions. Since the GW is always powered it will be used as a relay / routing device. The embedded software running on the network processor of the GW performs the following functions:

1. Control the EM2420 RFIC
2. Perform networking functions required by EmberNet
3. Act as protocol gateway, passing data through to the host using the REAP protocol via a UART.
4. Provide a means of indicating registration activity
5. Manage and maintain all 'binding' information
6. The primary role of the Host Processor is to provide product functionality and not RF networking capability

Details for each of these functions are as follows.

#### 3.4.1 EM2420 Control

The software is responsible for all interactions between the network processor and the EM2420 RFIC. The software performs power-on configuration of the EM2420, upper-level MAC functions, SPI communications, and other necessary services.

#### 3.4.2 EmberNet Networking

The software implements the EmberNet stack. It performs all basic messaging services including origination, acknowledgement, and forwarding. It supports acknowledged transmissions, route discovery / maintenance, device discovery, and network diagnostics.

#### 3.4.3 Pass Through to the Host Processor

For communication between the network processor and the host microcontroller a simple protocol, known as Raymarine to Ember Application Protocol (REAP) will be established. In general this protocol simply takes advantage of the existing Raymarine protocol definition.

### 3.5 Handheld Controller (HC)

The HC is a highly power conscious device which will be asleep most of the time in order to preserve power. This design uses an inverted 'F' tracked antenna. It will initiate communication on the network and stay awake long enough to hear responses. It will primarily perform 'set and get' operations on the gateway to which it is bound. The embedded software running on the networking microprocessor of HC performs the following functions:

1. Control the EM2420 RFIC
2. Perform networking functions required by EmberNet
3. Act as protocol gateway, passing data through to the host using the REAP protocol via a UART.
4. Minimize power consumption
5. Get and Set operations performed on a 1 second interval
6. Operations that would affect the functionality of the product
7. The primary role of the Host Processor is to provide product functionality and not RF networking capability

Details for each of these functions are as follows.

#### 3.5.1 EM2420 Control

The software is responsible for all interactions between the network processor and the EM2420 RFIC. The software performs power-on configuration of the EM2420, upper-level MAC functions, SPI communications, and other necessary services.

#### 3.5.2 EmberNet Networking

The software implements the EmberNet stack. It performs all basic messaging services including origination, and acknowledgement. It supports "best effort" and connection-based messaging, route discovery / maintenance, device discovery, and network diagnostics. In order to minimize power consumption, routing and repeating functionality will be disabled on the HC device.

#### 3.5.3 Pass Through to the Host Processor

For communication between the network processor and the host processor a simple protocol, known as Raymarine to Ember Application Protocol (REAP) will be established. In general this protocol simply takes advantage of the existing Raymarine protocol definition.

#### 3.5.4 Power Consumption

In order to achieve the aggressive battery life, expected from the HC, the network processor must be extremely power conscious. This will mean turning off any unused peripherals on the network processor, as well as structuring the code in such a manner that it sleeps as often as possible, and changing the time base prescaler to maximize asleep time.

In effect, the network processor software should be kept as autonomous as possible from the host. The host will only be able to wake the network processor by an external interrupt. The goal will then be to execute the command issued by the host in as short a time as possible, in order to sleep again.

In order to further minimize power consumption, the network processor will be called upon, using specially formed commands to execute repetitive tasks, for the host. This will allow the host to stay asleep, while the network processor wakes and performs the tasks, the host will be notified of task results as well as if an error occurs.

## 4 Summary

### Outline Summary of Raymarine's Wireless Products

| Product Name        | Smart Controller                                                       | S100                                                                | S1000                                                               | Base                                                                |
|---------------------|------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|
| Alias               | SMART CONTROLLER                                                       | FOB                                                                 | ELP                                                                 | BASE-STATION                                                        |
| Part #              | A18105                                                                 | A18104                                                              | A18107                                                              | A18106                                                              |
| RF Category         | HC                                                                     | HC                                                                  | GW                                                                  | GW                                                                  |
| Schematic Reference | 4593-002 Issue P                                                       | 4593-004 Issue r                                                    | 4590-002 Issue L                                                    | 4619-003 Issue u                                                    |
| PCB Reference       | 3015-358 Issue E                                                       | 3015-359 Issue D                                                    | 3015-344 Issue E                                                    | 3015-364 Issue D                                                    |
| Output Power        | Nominally 1mW (0dBm)                                                   | Nominally 1mW (0dBm)                                                | Nominally 1mW (0dBm)                                                | Nominally 1mW (0dBm)                                                |
| Frequency           | ANY CHANNEL<br>16 CHANNELS FROM 2405MHz TO 2480MHz @ 5MHz INTERVALS    | ANY CHANNEL<br>16 CHANNELS FROM 2405MHz TO 2480MHz @ 5MHz INTERVALS | ANY CHANNEL<br>16 CHANNELS FROM 2405MHz TO 2480MHz @ 5MHz INTERVALS | ANY CHANNEL<br>16 CHANNELS FROM 2405MHz TO 2480MHz @ 5MHz INTERVALS |
| Bandwidth           | 2MHz                                                                   | 2MHz                                                                | 2MHz                                                                | 2MHz                                                                |
| RF Protocol         | IEEE 802.15.4<br>CSMA-CA                                               | IEEE 802.15.4<br>CSMA-CA                                            | IEEE 802.15.4<br>CSMA-CA                                            | IEEE 802.15.4<br>CSMA-CA                                            |
| Modulation          | DSSS<br>FIXED CHANNEL<br>NO CHANNEL HOPPING                            | DSSS<br>FIXED CHANNEL<br>NO CHANNEL HOPPING                         | DSSS<br>FIXED CHANNEL<br>NO CHANNEL HOPPING                         | DSSS<br>FIXED CHANNEL<br>NO CHANNEL HOPPING                         |
| Duty Cycle          | 4%                                                                     | 4%                                                                  | 4%                                                                  | 4%                                                                  |
| Antenna             | PCB INVERTED 'F'                                                       | PCB INVERTED 'F'                                                    | PCB MOUNTED ANTENNA 1/4λ                                            | PCB MOUNTED ANTENNA 1/4λ                                            |
| Power Source        | INTERNAL RECHARGEABLE BATTERY<br>EXTERNAL POWER SOURCE (SHIPS BATTERY) | INTERNAL DISPOSABLE BATTERY                                         | EXTERNAL POWER SOURCE (SHIPS BATTERY)                               | EXTERNAL POWER SOURCE (SHIPS BATTERY)                               |
| Default Channel     | 4                                                                      | 4                                                                   | 4                                                                   | 4                                                                   |