LPARD Manual Control Analysis per R003

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This document attempts to outline how the manual mode and control of the LPARD system will work. It outlines the technical aspects and minimum requirements of the system and attempts to highlight and solve any problems that may be encountered when a future group implements the system, since the control loop will not be closed this year. It is divided into three sections that explain what frequency was picked and why, the technical aspects of the transmitter and receiver and finally how the boat switches to manual mode and how it should behave in this mode.

Frequency Conflicts and F.C.C Regulations

The FCC provides several frequencies for use with remote controlled systems. These frequency bands are outlined below and their advantages and disadvantages discussed.

The 27 MHz frequency band does not require a license and provides room for six channels. There are no usage restrictions except that the 6th channel is shared with CB radios. The effect of this channel sharing would most likely be negligible due to the decreased popularity in CB radio. However it is still a factor that must be taken into account as the purpose of the river droid is to make environmental measurements easier to make in a larger range of locations. Therefore, restricting the locations to areas with no CB radios is undesirable. There is also the possibility of interference between other RC devices on the same frequency.

The 50 MHz frequency band is specifically allocated for amateur radio operators and requires an Amateur Radio License as outlined in the FCC Rules & Regulations Part 97. There are 10 channels available within the frequency band. However, because one of the river droid’s main goals is to increase the ease of river measurements, requiring the operator to register for a license is undesirable and should be avoided if possible. Again, there is also the possibility of interference between other RC devices on the same frequency.

The 72 MHz frequency band has a total of 50 channels available (channels 11-60) generally divided into sub-bands of 10 channels for use with each control device. These however are only available for model aircraft and therefore are not applicable to this application.

The 75 MHz band has 30 channels allocated to it (channels 61-90) also sub-divided into sub-bands of 10 channels. This band is allocated only for surface systems. The channels use frequencies ranging from 75.410 –75.990 MHz. Often only even or
odd channels are used to avoid interference between channels. This range does not require any form of licensing. Once again, there is also the possibility of interference between other RC devices on the same frequency.

The 2.4 GHz Spread Spectrum is another frequency allocated by the FCC. This frequency solves many of the interference problems faced by other frequency bands. By using an algorithm to jump along the spectrum the chances of any two signals attempting to use the same frequency at any one time are vastly reduced. The small wavelengths also mean much shorter antennas which have obvious benefits. There are several disadvantages, though. The XBee transceivers run at the same frequency. Although the spread spectrum in theory should handle this, the proximity of the high gain antennas means there would be some spectrum coupling and saturation of the frequency. The short wave lengths of the spectrum also require there to be a line of sight between the transmitter and the receiver. It also means the signal is more likely to be reflected or absorbed by certain objects. The spectrum-coupling problem can be overcome by orienting the receivers in a certain way. The design of the boat hull can also minimize shapes that may reflect the signal. 2.4 GHz systems are generally much more expensive than alternative frequencies which may or may not be a problem.

From the analysis above RC controllers that operate in the 75 MHz band are the most desirable and should be used if possible. The 27 MHz band should be used if for whatever reason the 75 MHz band is unavailable. The 2.4 GHz band can be considered as a viable frequency if the other two cannot be used. Although the spectrum coupling problem can be overcome the line-of-sight issue cannot which is a major disadvantage. Because the main XBee link requires line of sight it is desirable for the backup system to not require line of sight. Therefore the 2.4 GHz frequency should only be used if the others absolutely cannot.

**Transceiver Specifications**

The RC transceiver will have to be capable of transmitting at least 3 channels, for forward and reverse, rotation, and one for turning manual mode on and off. The transmitter therefore requires a toggle switch for manual mode activation. Generally more channels will probably be preferred. Extra channels could be used for strafing left and right, increased throttle control, and possibly a position hold option to allow semi-autonomous control. These options will require up to 6 channels which is generally the upper limit of the number of channels 75 MHz transceivers are capable operating with. 75 MHz receivers require an antenna length of 50 cm which must be taken into account when designing the structure of boat. On average 75 MHz receivers have a range of 150 meters. However receivers with a range of 300 meters are also available for relatively cheap thus meeting our distance requirements. Receivers with a failsafe mechanism are also available and should be used if possible. This allows the receiver to be programmed to output certain values in case of a loss of signal. For instance this could automatically put the
boat into freeze mode if the manual control signal drops out.

To summarize the specifications are:
- 3-6 channels
- Toggle switch on transmitter
- 300 meters range
- 50 cm receiver side antenna
- Built-in failsafe

**Basic Operation of Manual Mode**

Manual mode can only be turned on or off through the use of the RC controller as opposed to using the GUI or both. This is both desirable and necessary, and it is easy to switch between the two. It is desirable as it means the boat can still be controlled in case of a complete system failure or any loss of the main 2.4 GHz wireless link. It is necessary due to the nature of the manual mode activation through the RC controller. Manual mode is activated through a toggle switch on the RC controller. When the toggle is switched on one of the channels on the RC link is activated and remains activated until it is switched off. This notifies the processor on the boat that we are in manual mode instructing it to ignore any navigation related messages from the XBee link until manual mode is switched off. This means its impractical to allow the GUI to change in and out of manual mode. An example of where this method would fail is if the RC controller switched manual mode on and then the GUI attempted to turn manual mode off. The RC controller cannot be informed of this change and therefore the toggle will still be in the on position and the ‘on’ channel still activated. This puts the controller and the GUI and boat out of sync creating both a technical problem to overcome as well as creating confusion for the end user.

The channels from the RC receiver are routed into the Ardupilot which has a port especially designed for RC receivers. When the ‘on’ channel is activated the Arduino is notified and one of the built in interrupts is called. The Arduino ignores the main link’s navigational instructions and instead processes the channel inputs and directs the motors and servos accordingly. It also should notify the shore station that it has been place in manual mode through the XBee link. Only once the ‘on’ channel has been quiet for a certain amount of time (to avoid false off signals incase of brief signal dropouts) does the system again return to automatic mode. The system automatically returns to ‘Freeze Mode’ and should notify the shore side GUI that manual mode has been turned off.
For a possible implementation of manual control, the boat circuitry is powered through the RC receiver channels connected to ArduPilot Mega or through the ESC connected through the throttle out channel on the ArduPilot Mega board. If the boat is not powered through the RC receiver in this way, it could also be powered through a pin on the ArduPilot Mega board itself, in the same way it is being powered in our current implementation. The board also has a resettable fuse between the power input and the rest of the board which trips if the current through it exceeds 500mA. If a future system design implemented RC control, this fail-safe fuse would protect the circuitry from burning out while allowing the use of high current servos. The image below shows the possible RC power connections to the ArduPilot.

For RC setup, first connect the RC receiver to the ArduPilot Mega. Use female-to-female servo extension cables if necessary. An RC controller with enough channels to control each element of movement is necessary for the design. In this case we are concerned with RC boat movement, so there should be a channel for throttle and a channel to control the rudder. As previously described, there should also be a channel for switching manual mode on/off. These channels should each be connected to an input on the Mega board.
A possible controller to use in this design is the FrySky CT-6B 2.4GHz 6 Channel Transmitter Remote Controller (Model: CAM80912 for around $50). Originally intended for the use of RC airplanes, this controller contains six channels which we may possibly need as previously described and operates in the 2.4GHz band as required. One of these channels should also be designated for manual mode on/off. As for the receiver, the design could use the Spektrum AR6110 DSM2 Microlite 6-Channel Park Flyer Rx, Air. This is available for around $45. Images of the transmitter and receiver are shown below.

Software for manual control would simply need to check if the system is in manual or autonomous mode. If it is in autonomous mode, the receiver should then know not to accept any more commands from the transmitter. While in manual mode however, the software will allow the receiver to accept commands from the controller. These modes can be easily changed on the transmitter with the manual mode channel. Finally, below is a possible schematic of the boat design with manual control.