Chapter 3

Mechanical Design

3.1 Control Requirements

In order to design the frame, all the functional requirements are to be defined. In our project sufficient actuation for the control and the degrees of freedom are considered.

3.1.1 Yaw Control

Bird tails have an aerodynamic surface in the horizontal plane which are treated to their effects on yaw stability. Rudders are used to control the yaw movement of the tail. Birds have the wings of very small aspect ratio which are similar to the values of bird tails in order to identify features which are significant for the aerodynamic yawing moment. It is seen that there are yawing moments of certain magnitude for this aspect ratio region. The lift coefficient which also exerts an influence helps in the treatment of yaw stability.

3.1.2 Pitch Control

Pitch is controlled by using some complex techniques like by using the elevators. By changing the angle of the elevators will help in controlling the movement of airplane up or down. So, if the elevators go down the airplane will go down and it goes up the airplane will go up. So, if the aircraft pitches forward it will move forward as well due to the thrust being slightly non-vertical. Usually at the rear of aircraft controls the aircraft's pitch, and therefore the angle of attack and the lift of the wing. They may be the only pitch control surface currently present they are usually located at the front of an aircraft or integrated into a rear also called a slab elevator.

3.1.3 Roll Control

The three lines which are running through an airplane will intersect at right angles to each other at the centre of gravity of an aircraft. The rotation around the front and back axis is called as roll, the ailerons control the roll of an aircraft. The two ailerons move in the opposite directions i.e. up and down, which decreases the lift on one wing and increases on the other. This results in the aircraft to move left or right. In order to turn the aircraft, the ailerons are tilted in the desired direction.

3.2 Components Used

3.2.1 Brushless DC motors:

Brushless motors are inherently more complex than brushed motors because they rely on electronic commutator sensors to sense the position of the rotor. Brushless motor coils are activated in sequence by an electronic speed controller on cue from the signals being transmitted from the rotor position sensors. Similarly, to brushed motors, brushless motors still utilize the reliable mechanics of repelling magnetic poles but houses the magnets at the edge of the stationary casing of the motor.

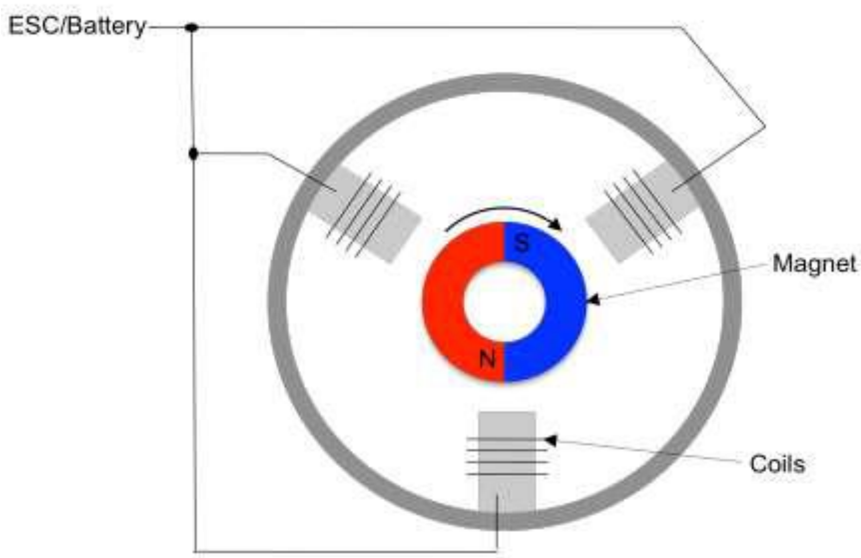

Fig : BLDC Motor

Brushless motors are measured by Kilo Volt (Kv) ratings, which indicates the motors maximum rotational speed for a given input voltage. The motors shaft rotation generates back EMF, the term used to describe the buildup of voltage on the windings. Back EMF gradually reduces the effect the voltage has on the windings, resulting in the EMF eventually matching the voltage being applied and the motor reaches its maximum rotational speed. Brushless motors have some favorable characteristics over brushed motors such as the reduced winding friction within the motor because of the removal of physically interacting brushes and commutators. Having said that the brushless motor does have pros and cons that need to be identified as problematic or acceptable for the chosen application.

3.2.2 Batteries:

Lightweight batteries suitable for ornithopters are identified as the lithium polymer (lipo) variety. Lipo batteries are the most recent addition to the battery family and benefit from a steady discharge of voltage and higher average voltage when compared to older nickel-metal hydride and nickel cadmium batteries. Batteries are required to be sized to voltage consumption of motors and their charge capacity can be measured in milliamp hours (mAh). A particular safety concern regarding a battery mounted to an ornithopter is the possibility for damage to occur from a crash landing, battery instruction manuals clearly stress that puncturing battery cells will release toxic chemicals and create a viable fire hazard. Manuals also state that the voltages applied to the battery during re-charging cycles should be monitored and voltage overcharging or discharging will impair the lifespan of the battery.

3.2.3 Servos:

A servo is basically a small electric motor that responds to control inputs by applying torque to a shaft connected to an output arm in order to rotate it in a very calculated manner. Firstly, gears are fabricated form plastic or metal depending on their intended use. Plastic gears are suitable for smaller models requiring less powerful servos to manipulate control surfaces under less stress whereas metal gears are suited to servos mounted on models weighing over 2.5kg. Secondly, brushed motors make a re-appearance for use in servos as they are robust and can be obtained at low costs. The iron armature at the core of the motor can be problematic when a servo with extremely fast responses to control inputs are required because of the inertial/momentum forces of a heavy material. The feedback potentiometer is an ingenious component mounted to a small circuit board in the servo casing that can determine the position of the output arm by using a variable resistor to create a voltage to determine the precise location. This is an important act that has to be carried out so that the user can manipulate the output arm in the desired manner during all phases of the operation. Finally, amplifiers are digital microcontrollers that control the torque, speed and accuracy of the servo.

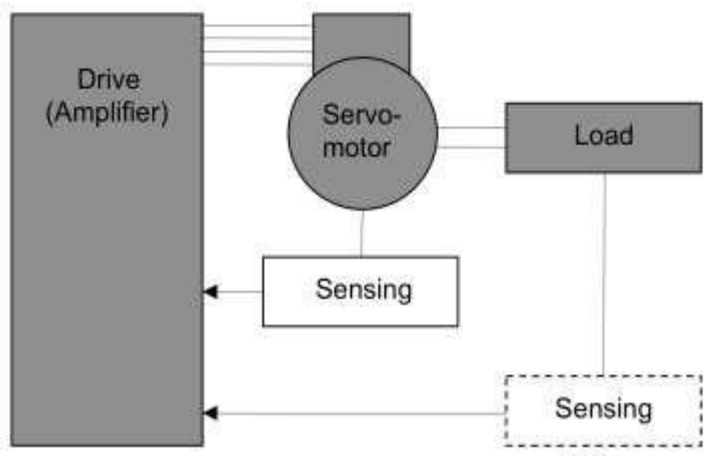

Fig Basic Servos mechanism

3.2.4 ESC

Electronic speed controls are a vital safeguard against damaging electrical motors by regulating motor rotation speeds. ESCs are often defined as standalone units or are married to the remote-control receiver. Brushless motors use the back EMF to sense rotary position whereas brushed motors tend to rely on Hall Effect or optical sensors. ESCs are programmed by the user to define required voltage cut-off values, acceleration rates and rotational direction. In order to provide voltage to an ESC a battery is required, this supply of voltage is regulated by the ESC and passes through to the motor.

3.2.5 Transmitters and Receivers:

Crucially, UAVs must be capable of being controlled when in flight; otherwise their possible applications become null and void. The pilot remotely controls modern UAVs such as scale aero planes, helicopters and ornithopters using a hand held transmitter that communicates with a receiver mounted onboard the vehicle. To ensure signal reliability, range, power and stability the 27 MHz technology is preferred. 27MHz systems rely on piezoelectric materials, often referred to as crystals, which create an electrical signal at a precise frequency, via the vibration of the crystal, to transmit frequencies on a MHz band. Each remote control system requires the same frequency rated crystal to be installed on the transmitter and the receiver so that they can communicate with one another; this also restricts interference from other remote control systems that may be in the same vicinity, for example, two 35.100 MHz crystals, one in the receiver and one in the transmitter, will not be interfered with by a different set of crystals operating on a frequency of 35.150 MHz Crystals, typically fabricated from quartz, are available in a wide range of frequencies resulting in a low probability of interference where large concentrations of remote control operations occur.

3.3 Design

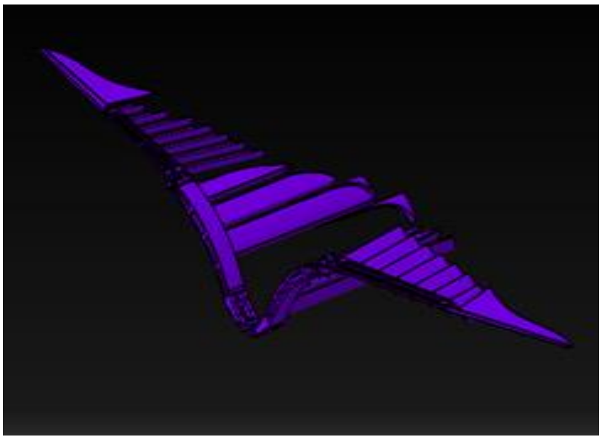

Fig: Fixed Wings

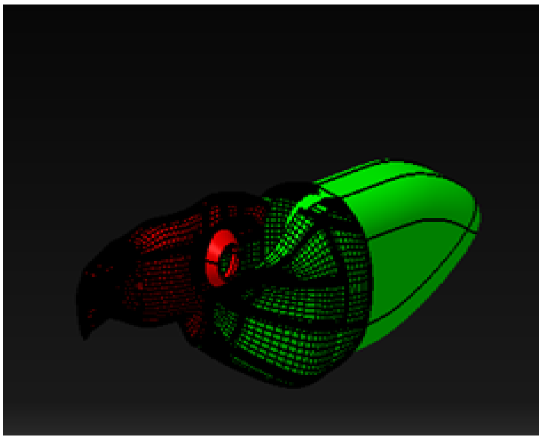

Fig: Body

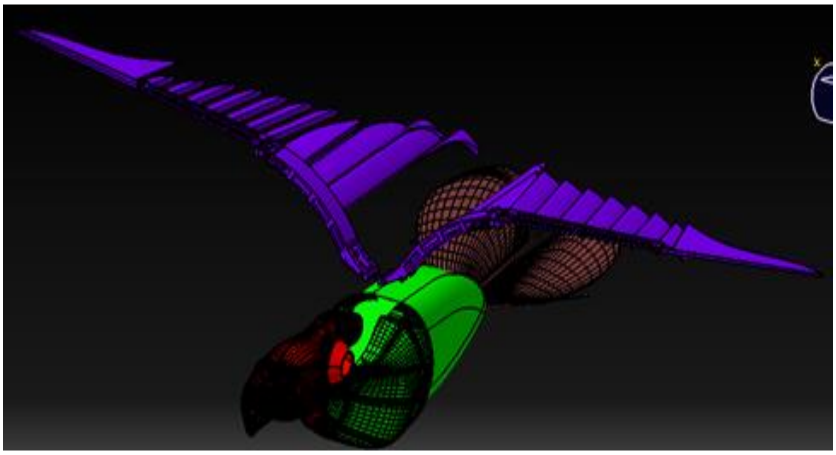

Fig: Complete Model

Chapter 4

Methodology

4.1 Mechanics of Bird:

One of the natural examples of flapping flight is bird. For the birds, the feather on their wing s are instrumental in their achieving flight, both the prolusion and the efficient aerodynamics. Primary and secondary feathers are the two sets of feathers on a bird's wing. The birds consist of hard bones which have got primary feathers and are found on the hand section. Flight will be impossible without the primary feathers. The inner wings are present on the secondary arm which are responsible for lift. The bird is able to enjoy much freedom of movement during flight because of the wing's ability to have its shape altered, which is the result of each feather functioning independently. During flapping flight, the inner wing is primarily responsible for providing the necessary lift whilst the hand section provides thrust the inner part of a bird's wing remains and acts as an aero foil and are relatively stationary, producing lift and drag. On the backstroke, which is the power stroke, the primary feathers are linked together to produce a near perfect aero foil. Since the outer part of the wing is more mobile, it can be twisted so that the wing points into the airstream; as with all aero foils, forces are generated and maximum thrust and minimum drag is obtained in addition to lift. On the upstroke, the primary concern is to reduce drag. This is achieved through different mechanisms for different species of birds. Also, on the smaller birds, the primary feathers are separated, allowing air to pass through and thus considerably reducing drag. For the larger birds or small but long-winged birds, their wings are typically either flexed or partially closed on the upstroke.

4.2 Kinematics of Wing:

The flapping wing motion ornithopters and entomopters can have three basic motion with respect to the axis based on the kinematics motion of wing and mechanism of force generation

a) Flapping, which is up and down plunge motion of the wing. Flapping produces the majority of the birds or insect's power and has the highest degree of freedom.

b) Flapping is the pitching motion of wing and can vary along the span length.

c) Lead-Lag is used in plane lateral movement of wing.

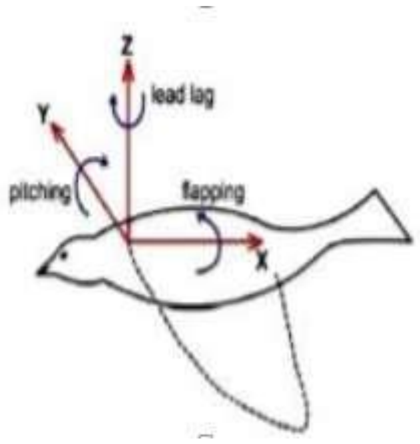

Fig: Kinematics of wing

4.3 Fixed wing methodology

i. The controls on a bird inspired fixed wing airplane are pretty much the same as on a real airplane.
ii. There are four major controls in a bird inspired fixed aircraft:

1. Throttle:

a. This affects the speed of the airplane.
b. This also affects the climbing and descending speed.
c. Applying more or less throttle will cause the airplane to descend or climb faster and also effect take-off and landing.
d. This mechanism in which the flow of the fluid is managed by using constriction and obstruction.

2. Elevators
a. These control something called "The Pitch" of the airplane.

b. Changing the angle of these elevators will control whether the airplane goes up or down.
c. If the elevators go down the airplane will go down and if the elevators go up the airplane will go up.
d. These are usually present at the tail part of a bird.

3. Ailerons:

a. Ailerons control the roll of an airplane.
b. These are not on all aircraft.
c. And they are not needed, many RC airplanes work just fine without them.
d. There are actually a pair of ailerons present which are interconnected so that if one is moving downwards the other starts moving upwards.
e. These are usually present at the wing tip of a bird.
f. Some of the types of ailerons are- single acting, wing tip, Fries ,differential etc.

4. Rudder**:**

a. The rudder controls the Yaw of the airplane.
b. This is what turns it to the left or right.
c. It is the primary control system for the steering of the aircraft.
d. It is usually attached to the tail part of a bird.

Chapter 5

Control system model

5.1 Signals

In order to provide some insight into the way the control system was integrated, the components are discussed briefly.

5.1.1 Control Signals

A frequency or pulse of electricity or light that indicates a control command as it travels over a network, a computer channel or wireless. In the world of data communications, control signals typically move the same path as the data either as separate packets or contained within the data packets. The type of control signal used in this project is basically of a radio control (RC).

5.1.1.1 Radio controller (RC)

Radio control often abbreviated as rc is used to control a device with the use of the radio signals. Radio control is used to control of model vehicles.

5.1.1.2 Radio controlled models

The first common use of radio controls in models started in the early 1950s with single-channel self-built equipment; commercial equipment came later. The invention of transistors has greatly reduced the requirements of the batteries, since the current requirements at low voltage were greatly reduced and the high voltage battery was eliminated. In both tube and early transistor sets the model's control surfaces were usually operated by an electromagnetic escapement controlling the stored energy in a rubber-band loop, allowing simple on/off rudder control and sometimes other functions such as motor speed.

5.1.1.2.1 Design

RC electronics have basically three important elements. The transmitter is the controller. Transmitter must have stick control, triggers, switches, buttons and dials at the user's finger tips. The receiver is mounted or placed in the model which receives and processes the signal from the transmitter, translating it into signals that are sent to the servos and speed controllers. The number of servo motors used in a model determines the number of channels the radio must provide.

Typically, the transmitter modifies all the channels into a single pulse – positioned modulated radio signal. The receiver demodulates and DE modifies the radio signal and translate it to another kind of pulse-width modulated signal employed by all the standard RC servos and controllers.

5.1.1.3 Rc controller

The Rc controller used in this project is of 6channel with a specification of 2.4ghz afhds 2a signal operation with a power of 20db.

T6A 2.4GHz system is an entry level transmitter offering the reliability of 2.4GHz signal technology and a twin receiver antenna and with 6 channels. This transmitter requires a PC to modify any of the channel variables including mixing and servo reversing. Requires 8 AA batteries.

Crucially, UAVs must be capable of being controlled when in flight; otherwise their possible applications become null and void. The pilot remotely controls modern UAVs such as scale aero planes, helicopters and ornithopters using a hand held transmitter that communicates with a receiver mounted onboard the vehicle. To ensure signal reliability, range, power and stability the 27 MHz technology is preferred. 27MHz systems rely on piezoelectric materials, often referred to as crystals, which create an electrical signal at a precise frequency, via the vibration of the crystal, to transmit frequencies on a MHz band. Each remote control system requires the same frequency rated crystal to be installed on the transmitter and the receiver so that they can communicate with one another; this also restricts interference from other remote control systems that may be in the same vicinity, for example, two 35.100 MHz crystals, one in the receiver and one in the transmitter, will not be interfered with by a different set of crystals operating on a frequency of 35.150 MHz Crystals, typically fabricated from quartz, are available in a wide range of frequencies resulting in a low probability of interference where large concentrations of remote control operations occur.

Fig 6 channel rc controller

5.1.2 Electrical system

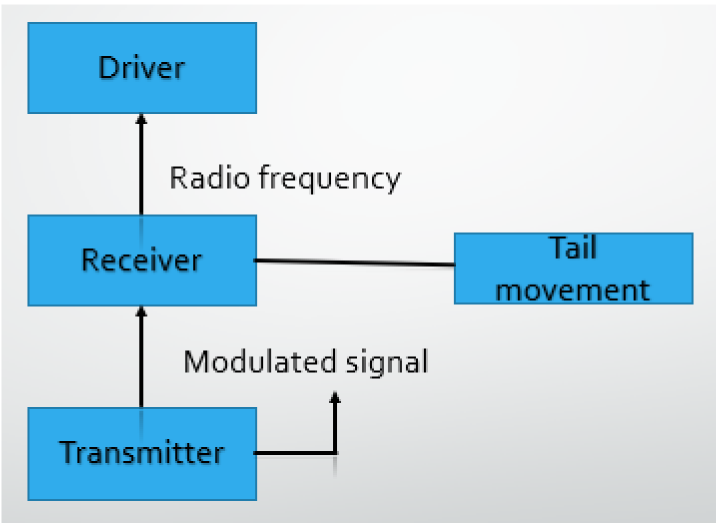

Fig Electrical control system

The above figure indicates the electrical block diagram of a control system. Here the function of the transmitter is to generate or develop a radio frequency of alternating current, which is applied to the antenna. The frequency of the modulated signal will be of 27MHz. The transmitter transmits a modulated or a amplified signal of frequency 27MHz which is received by the receiver having the same frequency. Thus receiver senses the signals sent by the transmitter and helps in the movement of the tail part. The signals from the receiver is passed to the driver in the form of a radio frequency signals and the driver performs based on the requirement.

5.1.2 Mechanical block diagram

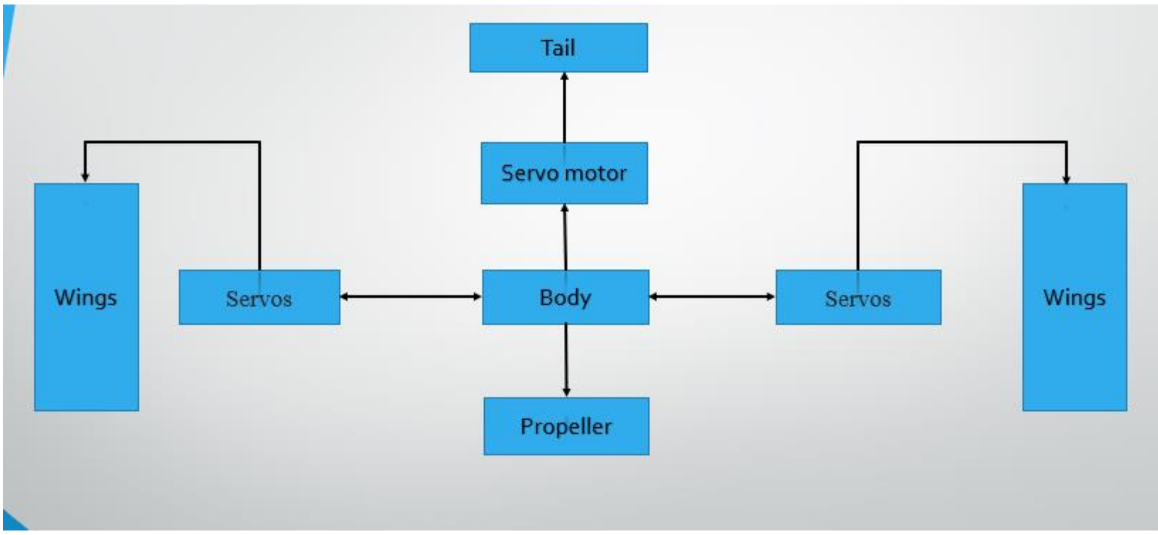

Fig mechanical block diagram

The main body of the bird is connected to two reciprocating systems along with servo motor and along with a main BLDC motor. The body is connected to the two-reciprocating system through an axle. The main body of the system is connected to the servos with the capacity of 4V to 6V which helps in the movement of the propeller. Basically, the UAV performs based on four parts and those are throttle, elevators, ailerons and rudders. The increase and decrease in the speed of the throttle is controlled by the help of servo motor in turn connected to the propeller. The movement of the tail is employed by the servo motor which has got both turning of 3 degree each in clockwise and anticlockwise direction.

5.2 Control calculations

Motor:

KV=1100V, Minimum ESC Specification=18A (But 20A preferred)

Current capacity: 12A/60S

Max current to lift should be greater than 12A, so 20A is preferable.

Time of flight and compatibility:

Max Current draw/motor=12A

Total current required=12*1=12

Assuming Factor of safety=1.3 => 12*1.3=15.6A

Cases for battery selection:

Case 1: 1000mAH=> 15.6/1=15.6c

Case 2: 2200mAH=>15.6/2.2=7.09c

Therefore 2200mAH 3S 30c/60c which gives 11.1V-75g (weight)

Esc selection:

Motor draws 12A so it’s better to select the proper ESC

Current discharge having FOS being considered (assume FOS =1.3)

12*1.3=15.6A, so 20A is preferable.

Expected duration of flight:

We have [capacity of battery/current drawn] =1/12*60

=5min

Motor compatibility check:

Total theoretical weight=580g

Considering acceleration and inertial margin factor of 2

Assuming required thrust/lift=2w

=2*580

=1160g

The motor gives a peak lift of=1800g

Total lift=1800*1(number of motors being used) =>1800g

Therefore 1800g>1160g so hence the selected motor is compatible with our requirements.

Chapter 6

Discussion and Future Work

6.1.1 Summary of achievements

We were able to achieve flight for about 5 min, and it covered a area of about 500m in circumference and 50ft high.

6.1.2 Choice of platform

The major task in our project was to choose the platform to base our design. We looked at some of the sources which were discussed in the literature review. So we took an eagle as a reference for the design of the UAV, all the dimensions were calculated by using the formulas and are implemented in the project.

6.1.3 Mechanical Design

In order to develop a working model, a full model of the bird the frame and the components were constructed by using CATIA. The detailed drawings of the bird was considered. And the biggest problem arrived was to keep the weight as less as possible. We went with a fixed wing UAV as we were not able to achieve flight by using flapping wings.

6.1.4 Mechanical Construction

The frame of the bird was manufactured in the workshop and was assembled with all the components. The frame had a higher degree of toughness and controllability.

6.1.5 Controller design and turning

The Rc controller used in this project is of 6 channel with a specification of 2.4ghz afhds 2a signal operation with a power of 20db Which is used to control the flight of the bird by throttling and helps the bird to move left or right by using the rudders which are fixed at the wing.

6.1.6 Control Implementation

UAVs must be capable of being controlled when in flight otherwise their possible applications become null and void. The pilot remotely controls modern UAVs such as scale aero planes, helicopters and ornithopters using a hand held transmitter that communicates with a receiver mounted onboard the vehicle. To ensure signal reliability, range, power and stability the 27 MHz technology is preferred.

6.2 Future Tasks

6.2.1