# Remote Antenna Mount Controller (RAMC)

## 1. INTRODUCTION

We, team RAR, have identified a need within the telecommunications industry for a wireless remote controlled antenna mount with the capability to adjust antenna tilt and azimuth (3 axis of rotation) and aim to rectify this.

As students in the senior design class (EECE 401), we are particularly enthusiastic about the opportunity to participate in the engineering design and implementation process. As you indicated during class, our goal is to develop an innovative idea for our senior design project. We anticipate that our idea will meet your expectations.

This correspondence outlines the complete scope of our work, including background information, problem description, design requirements, current state of the art, proposed solution, alternative solutions, timeline and budget, project team, and conclusion.

## 2. BACKGROUND

Wireless communication systems often utilize "cell" technology, where a base station or other transceiver is dedicated to a specific geographic area. Thus, to provide complete coverage over an entire metropolitan area or geographic region, base stations must be installed at frequent and regular intervals. Moreover, since communication base stations require an antenna system to transmit and receive information to and from a wireless user, the antenna often needs to be placed where there are no obstructions that will interfere with its operation such as a water tank, the roof of a building, a tower, or a mast. Such conspicuous installation is required because a direct line of sight between antennae and communication devices is preferred.

Antennas associated with communications systems may sometimes require adjustments after installation to accommodate new structures, additional base stations, or changing electromagnetic interference. Currently, it is common in the telecommunications industry for technicians to manually adjust the positions of the antennas either via a knob on the antenna (for antenna tilt) or one on the antenna mount (for azimuth (degree) orientation). **See Fig.1**. Such manual adjustments often require technicians to climb high structures to access the antennas.

## 3. PROBLEM DESCRIPTION

Such manual adjustments as described above can be dangerous and often inconvenient. They also require more man-power to be added to the maintenance team (in the form of a technician) resulting in higher maintenance costs. We believe that these issues can be eliminated by automating the adjustment process. We propose an antenna mount which can be remotely and wirelessly adjusted using a simple terminal, even from the convenience of an employee’s desk.

Ultimately, we would like a design that has a control range of 50 to 100 feet. Since our design is a prototype, for a complete marketable product, this would translate to an ideal range of about 5 miles. Once completed, an additional improvement for our design would be for the system to be able to store preferable positions of the antenna so that the antenna could be restored to these positions after any deviations have occurred (for example, the occurrence of a storm). Our solution will integrate mechanics, circuitry and software to make the antenna adjustment simple for the user. Our idea, if implemented, would expedite the antenna adjustment process, thus making improvements in signal quality easier to achieve. It would also reduce the man-power, the need for potentially hazardous situations (climbing high towers, etc), and the associated costs required to maintain cell sites.

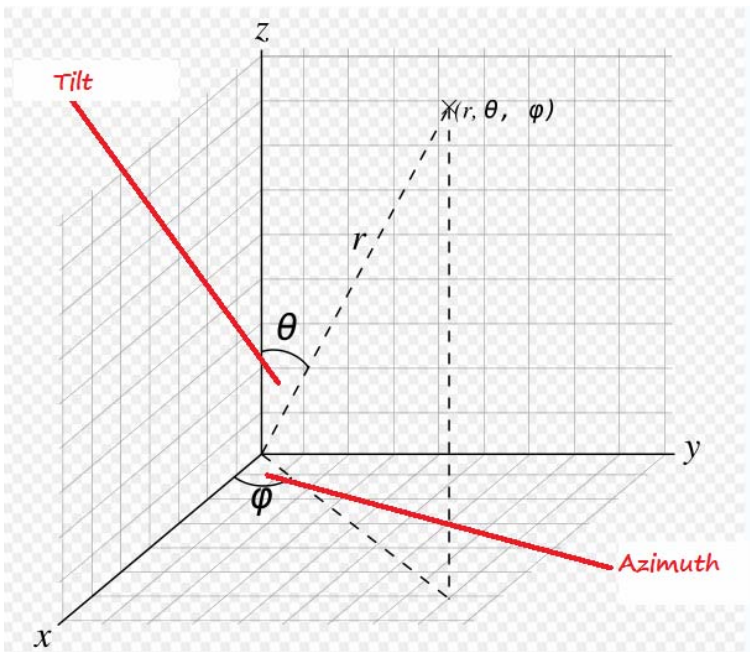



***Fig.1 Spherical coordinate system showing azimuth and tilt***

DESIGN REQUIREMENTS

Our system will be an antenna mount controller that takes inputs from a user and wirelessly adjusts the azimuth and tilt of antennae accordingly. We determined some criteria to judge the performance of our system. Some of these include a response time of less than one minute, a fail rate not exceeding ten percent, a response time not exceeding half a second and a speed of at least one revolution per minute (1rpm).

We also created constraints on the dimensions and weight of our system. The transmitter and receiver should each weigh at most twenty pounds (20lbs) and have maximum dimensions of

35cm by 40cm by 10cm (specifying the length, width, and height respectively). The weight and dimensions of the motors we will be using will be determined by our motor sizing equations.

The specifications and functionality of this project require compliance with some regulations and standards. Some of these include Section 15.247 of the FCC Unlicensed Radio Frequency Emissions Regulations, the IEEE 802.15.4-2006 for low-rate wireless personal area networks, and the National Electric Safety Code. Our design will also be environmentally friendly. The system should not interfere with surrounding devices and the transmitter receiver mechanism can be recycled and reused in other radio transmission products. The details of these environmental regulations and standards and how they apply to our project are detailed in the Environmental Issues and Regulations as well as the Standards sections of our proposal.

The power requirements for our system will be low. The devices we expect to consume power will be our transmitter and receiver, motors, and microprocessors. The transmitter and receiver will require at most 0.54W (12 Volts, 45mA).

The interface for such a system will include a user terminal with a display for monitoring adjustments. We also plan to design a sturdy system that we expect to last up to five years and we foresee an annual maintenance schedule required.

We have completed a few steps of the design process already. By December 1st, we were expected to have researched pertinent background information and developed a preferred solution to our design. The next benchmark is January 30th, when we will commence implementation of the proposed solution.

Our total budget for this project will be one thousand, six hundred and fifty US dollars. A detailed break-down can be seen in the budget section of this proposal.

## 4. CURRENT STATE OF THE ART

### RFS Antenna mounting Hardware and Accessories

RFS introduced a new universal mount applicable to most panel antennas and available in multiple upgradable configurations including mechanical down tilt mount with azimuth adjustment. A standard cluster mount is also described allowing users to fix 3 panel antennas around a pole. To correctly adjust both azimuth and elevation (down tilt), RFS has developed a special tool called the CELaligner. The CELaligner is a dual functional tool for alignment of panel antennas. It can be used for adjusting both the elevation (down tilt) and the azimuth of the antenna. The CELaligner is supplied in a handy carrying bag, to wear over the shoulder, when climbing an antenna mast or tower.

### Adjustable antenna mount with rotatable antenna brackets for PCS and other antennas: US Patent 6222504

US patent 6222504 by Oby, Lawrence comprises an antenna mount including at least a first anchoring portion having an open region formed there through wherein the open region is sized to accommodate a mounting structure such as a pole, mast, or other such structure. The antenna mount may include a locking device configured to releasably secure the antenna mount about a mounting structure disposed within the open region of the first anchoring portion. The locking device may comprise a first locking structure adjustably coupled to the anchoring portion, the first locking structure adjustable from a first position peripherally located with respect to a centerline of the open region to a second position adjacent the periphery of the open region, the first locking structure configured to releasably engage a mounting structure accommodated within the open region when the first locking structure is at the second position. The antenna mount also includes an antenna bracket comprising a first wall having an antenna engaging face and a second wall having a first face rotatably engaged to the first anchoring portion. An antenna mount as herein described thus provides an antenna mount suitable for installation on a variety of variously sized and configured mounting structures while allowing simple variable azimuth adjustment of patch or panel type antennas mounted to the antenna brackets.

**Adjustable antenna mount: US Patent 4563687**

US patent 4563687 by Eric Berger discloses an antenna mount includes a mounting plate which holds an antenna such as a microwave horn. The mounting plate is connected by a hinge to a base plate. The angle of the mounting plate with respect to the base plate is controlled by an adjustable brace extending between the antenna mounting plate and a bracket, allowing adjustment of elevation. The base plate is pivotally mounted on a mechanical ground allowing independent adjustment of azimuth.

The above mentioned arts all allow the adjustment of azimuth of antennae; however, all adjustments available are mechanical. There are some arts that implement azimuth adjustments wirelessly such as:

**Philips SDW1850/17 Antenna Remote-Controlled Rotor**

This system is a remote Programmable Antenna Rotator. It can stores 12 different locations for easy access and includes a 3-device programmable remote that controls antenna; however, this system only allows for azimuth adjustments; that is, it only allows for one axis of rotation, $\varphi$ in the spherical coordinate system (See Figure 1)

**Sell Indoor Antenna with remote control l rotating function TNY-009**

This remote controlled antenna made by Zhejiang Longyou Xinxidi Electronics Co., Ltd. has a remote controlled range of 6 meters. The remote controls the antenna which doesn’t have a mount. Also, only the azimuth of the antenna can be adjusted.

As discussed, although these systems allow for remote antenna adjustments, neither of them performs both tasks of allowing 3-axis of rotation for the antenna (azimuth and tilt adjustments) and storing preferred positions.

FUNCTIONAL REQUIREMENTS

This is an antenna mount that provides support for panel antennae and allows for the remote adjustment of azimuth and tilt, while storing default high-signal-strength positions for the antennae at a range of 50 to 100 feet.

## 5. ENGINEERING APPROACH

As previously stated, it is our objective to provide an automated module that provides support for antennae, and allows adequate control over elevation and azimuth with remote command signaling and control. In addition, it is an objective of the solution to provide a means to store some orientations or positions of the antenna in memory so that the antenna can automatically be restored to these default positions after any deviations have occurred. Here, we take a further look at the design implementation and constraints.

### Proposed Solution

We intend to have a module, consisting of a controller and a transmitter. The controller takes an analog input from the user, which is converted into corresponding digital signals, and eventually sent out by the transmitter. A receiver decodes the transmitted signal, causing the rotors on the mount to move, which changes the antenna configuration to that specified by the user. The wireless communication will be achieved via Frequency Modulation (FM) of Radio Frequency (RF) signals.

We intend to use microprocessors to perform the signal processing.

One option we are considering is to use FPGAs (Field Programmable Gate Arrays) as the module for the user interface, transmitter and receiver. FPGAs can be used to process signals and transmit them wirelessly (Digital Signal Processing [DSP]) using a board such as the Chipcon CC2420DBK development board/demonstration board kit. The CC2420DBK Demonstration Board Kit includes two CC2420DB Demonstration Boards. Each board comes equipped with an Atmel Altmega128L AVR microcontroller, 32 kilo bytes of external RAM, a PCB antenna, a joystick, and buttons and LED's that can be used to implement a visual user application interface. Each board also transmits/receives RF at a 2.4GHz frequency band.

Another option would be to use a PIC (Peripheral Interface Controller) as our microprocessor and to use a receiver, transmitter pair for our communication to and from the antenna.

**Schematics for proposed solution**

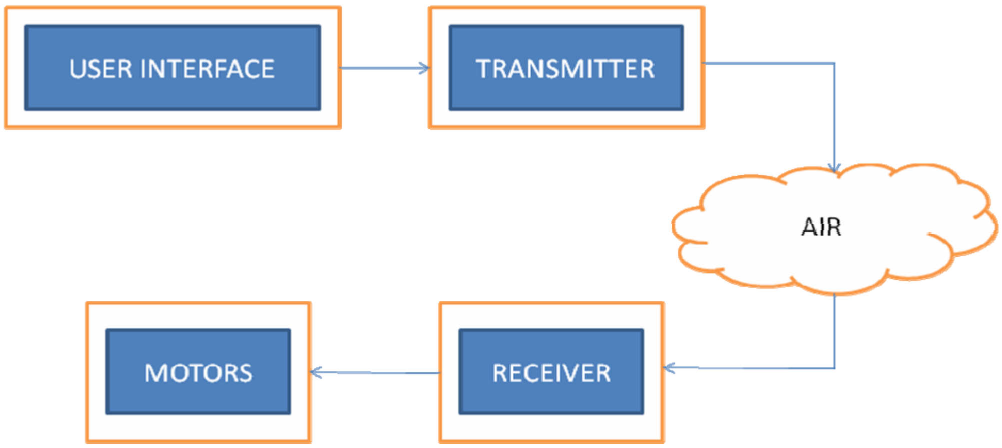



***Fig.2 Top Level Block Diagram***

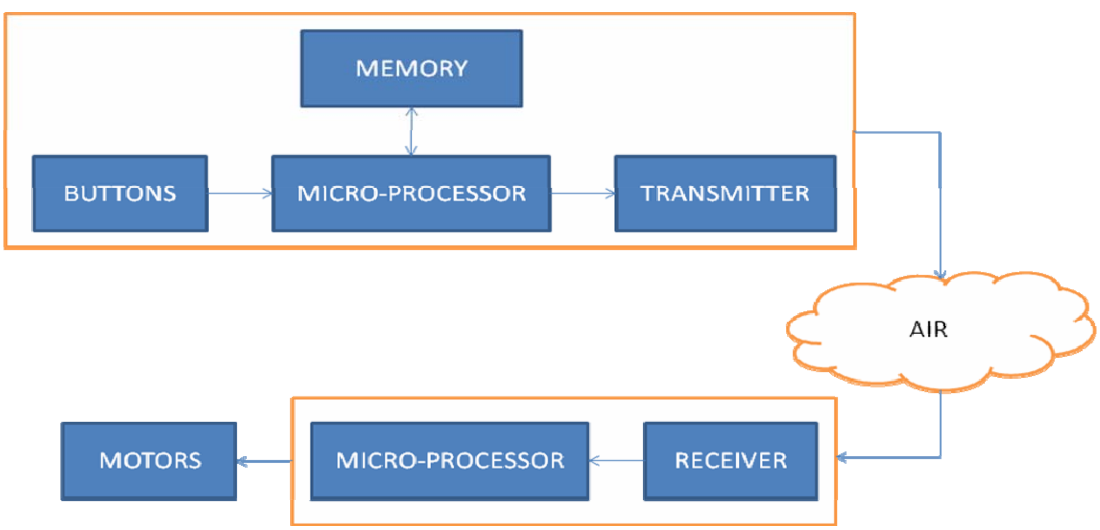



***Fig.3 Second Level Block Diagram***

A brief description of the RAMC system operation is as follows: Directional instructions are entered using buttons on the user interface. The micro-processor then performs several operations on these instructions. The micro-processor encodes them into a format that can be transmitted wirelessly via the antenna using Frequency modulation. The micro-processor can also store different positions of the antenna based on user preference in a memory unit attached to it. On the other end of this system is the receiver. Once the signals arrive at the receiver, they are sent to a micro-processor, which then decodes them into control commands for the servo-motors. **See Fig.2 and Fig.3**

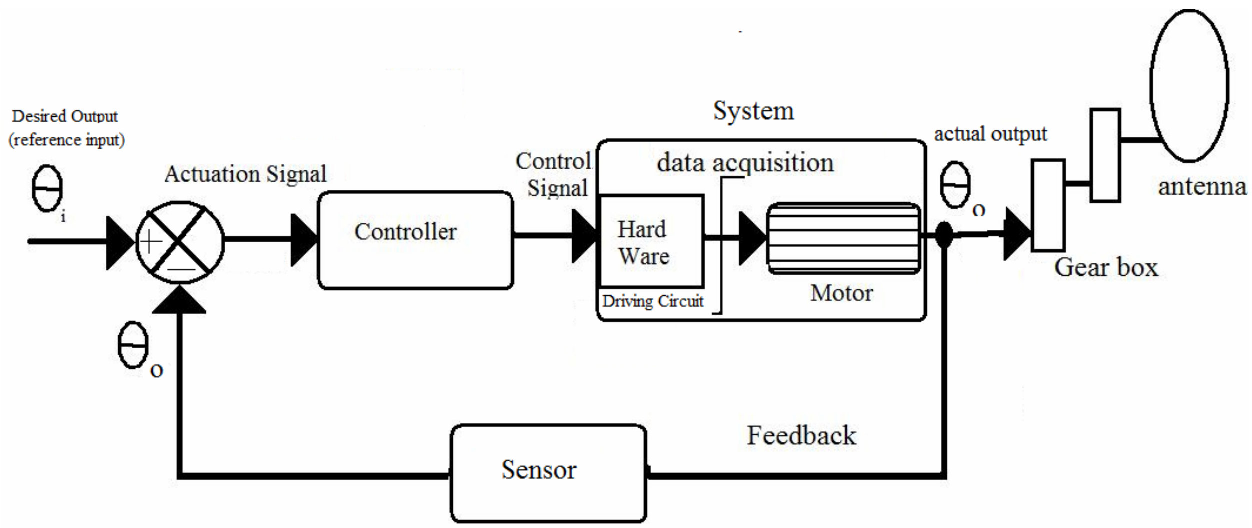



***Fig.4 Closed Feedback Loop for motor position control***

For this project we shall utilize servomotors. These motors use error-sensing closed feedback to correct the position control achieved **See Fig.4**. This closed feedback loop functions as follows: The desired output serves as the reference input. This input is passed through a controller which sends out instructions, to the plant to determine what actions the plant should take to approach the desired output. The plant output information is fed through a sensor. The error difference, between the desired output and the actual output is fed back to the input and the process repeats until the error difference is very low.

The closed loop transfer function of the system is

H(s) = [Se(s) C(s)]/ 1+[Se(s)Sy(s)C(s)]

where
Sy(s) = Fourier transform of the System
C(s) = Fourier transform of the Controller
Se(s) = Fourier transform of the Sensor

Special considerations

**Minimizing Interference:** To avoid interference, the band of frequencies used in transmission should be as far away as possible from that received/ transmitted by the antenna on the mount. For a fully marketable product, licensed companies could use different frequency bands associated with other transmission technologies. For instance, a company using both iDEN and

CDMA technologies could use CDMA frequency bands for RAMC on sites utilizing iDEN antennas and iDEN frequency bands for RAMC on sites utilizing CDMA. This would ensure minimum interference.
We suggest that consumers using RAMC purchase their own licensed frequency bands to ensure that the system does not interfere with any frequencies used by other devices in the surrounding area.

**Cable wrap-around:** Although our system will be able to make 360 degree adjustments to the antenna, the system will be designed such that the actual mount will not make 360 degrees sweeping motions. This is to avoid cable wrap-around that could cause antenna dismount.

**Motor Sizing:** To enable us to size our motors, we need to determine application requirements (including torque and speed requirements). The following equations enable us to obtain these values:

Torque (lb-ft) = Radius (ft) x Force(lb)

Speed (RPM) = v (ft/min) / (2pi x radius(ft))

Power (HP) = Torque (lb-ft) x Speed (RPM) /5252
Using these parameters as specifications, we will be able to choose the servomotor we need for the project.

**Prototype:** For our current implementation we will not be utilizing an actual antenna. This is because the weight of an actual antenna will require motors with greater torque and power output according to estimates from our motor-sizing equations. These motors are more expensive than our current budget allows. Also, the price of an actual antenna would drive up the cost of our project.

**Housing:** Most of our system components will be housed in the same housing created for the antenna equipment (such as base station radios). The parts of our system that need to be on the antenna mount, such as the motors, will need to be weather-proofed. To weather-proof our system, we are considering many options that include the use of a heat-shrink, or a weather-proof encasing that we will purchase.

**Position tracker:** We intend to make use of sensors to confirm position adjustments of the antenna. A few well-positioned sensors will ensure the accuracy of our confirmations. There are several systems we are considering to achieve this such as an infra-red transceiver module, a laser beam, or other low cost trigger circuit mechanisms.

## Alternative Solutions

Alternative Transmission techniques considered include:

**AM**

Advantage: We will be working with lower frequencies and therefore will have less attenuation
Disadvantages: Demodulation of AM signals is not always as good as in FM and we will need a larger antenna which is more expensive

**Wi-Fi**
Advantage: Unlicensed radio spectrums and does not require regulatory approval.
Disadvantages: Expensive, may require software programming, and is susceptible to internet connectivity issues

**Bluetooth**
Advantages: Utilizes less power and therefore is more cost effective. It also causes less interference to the mounted antenna
Disadvantage: Limited range

Alternative user interfaces and transmitters include:

**Computer Controlled transmitter and user interface:** A computer can be used to control a transmitter to send out signals using a 1MH oscillator and an RS232. This requires creating a computer GUI in addition to the project. It also increases the costs of production as the cost of a computer has to be taken into account.

**Play Station Pad for user interface:** A PlayStation pad (or any other game console pad) is connected to a microprocessor to accept input. This requires a thorough understanding of the pin configuration of the pad. This would also imply limiting the consumer base as such a user interface would probably appeal more to young people that like playing video games.

**Knowledge and Coursework to be used in Project:**
This project will be using a lot of concepts in such courses as Linear Controls, for controlling motor movements; Microcontrollers, for programming the integrated circuits we will be using; Electromagnetic Theory, for the transmission of RF signals; Signal Processing for converting signal from analog to digital and vice versa as well as filtering input signals.

**Knowledge to be learned for the solution:**
Some of the knowledge that we will need in implementing our design includes concepts we are yet to master. For this project we will have to do some research to understand Linear Controls concepts as well as understanding how to use such simulation tools as ModelSim, DSpace and Simulink.

Our project is unique because it provides new and exciting features for existing technology which we showed in the current state of the arts above.

## ENVIRONMENTAL ISSUES AND REGULATIONS

### Pollution

Pollution due to electrical waste is a prominent environmental issue. The waste is hideous, abundant, and toxic. IEEE 1680 regulation for Environmental Assessment restricts the amount of hazardous substances (RoHS) used to make personal computers and electronics. The standard specifically limits the levels of cadmium, mercury, lead, hexavalent chromium, flame retardants and plasticizers, polyvinyl chloride, and chlorinated plastics. Product specification sheets now commonly include information regarding RoHS compliance; therefore we must verity that our products are in compliance so that they do not contribute to toxic waste.

### Electromagnetic Radiation

Our design will emit electromagnetic waves, which have the potential to be harmful to the environment and human life. The International Electro-technical Commission (IEC) Regulation TC106 outlines standards for the assessment of human expose to electric, magnetic, and electromagnetic Fields. TC106 is an international standard, and the United States is a participating country. The standard covers the frequency range from 0 to 300 GHz. Safety factors are expressed in terms of the specific absorption rate or incident power density. Specific safe practices are outlined in the standard and our group will abide by these regulations for our health and the health of those who will be witness to our technology.

FCC §§1.1310 outlines the same regulations as IEC TC106, except for the Radio Frequency range. Our design emits radiofrequency signals, so we must take note of the safety constraints. The maximum permissible exposure limits are detailed in the table below with the highlighted row applying specifically to this project.

| Frequency range (MHz) | Electric field strength (V/m) | Magnetic field strength (A/m) | Power density (mW/cm\2\) | Averaging time (minutes) |
|---|---|---|---|---|
| **(A) Limits for Occupational/Controlled Exposures** | | | | |
| 0.3-3.0 | 614 | 1.63 | *(100) | 6 |
| 3.0-30 | 1842/f | 4.89/f | *($900/f^2$) | 6 |
| 30-300 | 61.4 | 0.163 | 1 | 6 |
| 300-1500 | --- | --- | f/300 | 6 |
| **1500-100,000** | **---** | **---** | **5** | **6** |
| **(B) Limits for General Population/Uncontrolled Exposure** | | | | |
| 0.3-1.34 | 614 | 1.63 | *(100) | 30 |
| 1.34-30 | 824/f | 2.19/f | *($180/f^2$) | 30 |
| 30-300 | 27.5 | 0.073 | 0.2 | 30 |
| 300-1500 | --- | --- | f/1500 | 30 |
| 1500-100,000 | --- | -- | 1 | 30 |
| f = frequency in MHz<br>* = Plane-wave equivalent power density | | | | |

*Figure 5. Limits for Maximum Possible Exposure*

**The table above has been provided by the W5YI group*

## STANDARDS

### <u>IEEE 802.15.4-2006: for low-rate wireless personal area networks</u>

In building the prototype of our system we will need to wirelessly transmit and receive data using a low date transfer rate, and low cost personal area network. This standard serves the importance of achieving extremely low manufacturing and operation costs and technological simplicity, without sacrificing flexibility or generality in WPAN (Wireless Personal Area Networks).

It also ensures that such devices include power management functions such as link quality and energy detection and use Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocols. This means that a station wishing to transmit has to first listen to the channel for a predetermined amount of time so as to check for any activity on the channel. If the channel is sensed "idle" then the station is permitted to transmit. If the channel is sensed as "busy" the station has to defer its transmission. It also specifies three frequency bands that must be used; 868-868.8 MHz, 902-928 MHz, and 2400-2483.5 MHz.

Our project is in compliance of this standard as our transceiver operates in the 2400-2483.5 MHz frequency bandwidth and the manufacturer specifies the product as IEEE 802.15.4-2006 compliant.

### <u>Unlicensed Broadcasting: FCC CFR 47 part 15</u>

The project complies with Part 15 of FCC CFR regulations which covers all electronic equipment that generate RF energy whether intentionally, unintentionally or incidentally

## 5. TASKS AND DELIVERABLES

The tasks remaining to be completed include completing a revised and/or a final draft of our project proposal. We have an ongoing obligation to further analyze the engineering problem at hand while continuing to explore our solution and alternative solutions.  This analysis involves conducting in-depth research on antenna theory and control theory and also an investigation into the parts and the simulation software we will use.  As the details in our project become more specific, we will determine if the parts we use comply with different federal regulations, how we will physically construct our design, and how we will simulate our design before we begin construction. In the spring semester, we will begin building the remote antenna mount controller. Throughout the entire design process, we will have periodic meetings with faculty members to ensure that we are taking the best approach.  All this will lead up to the final presentation and prototype demonstration on ECE day.

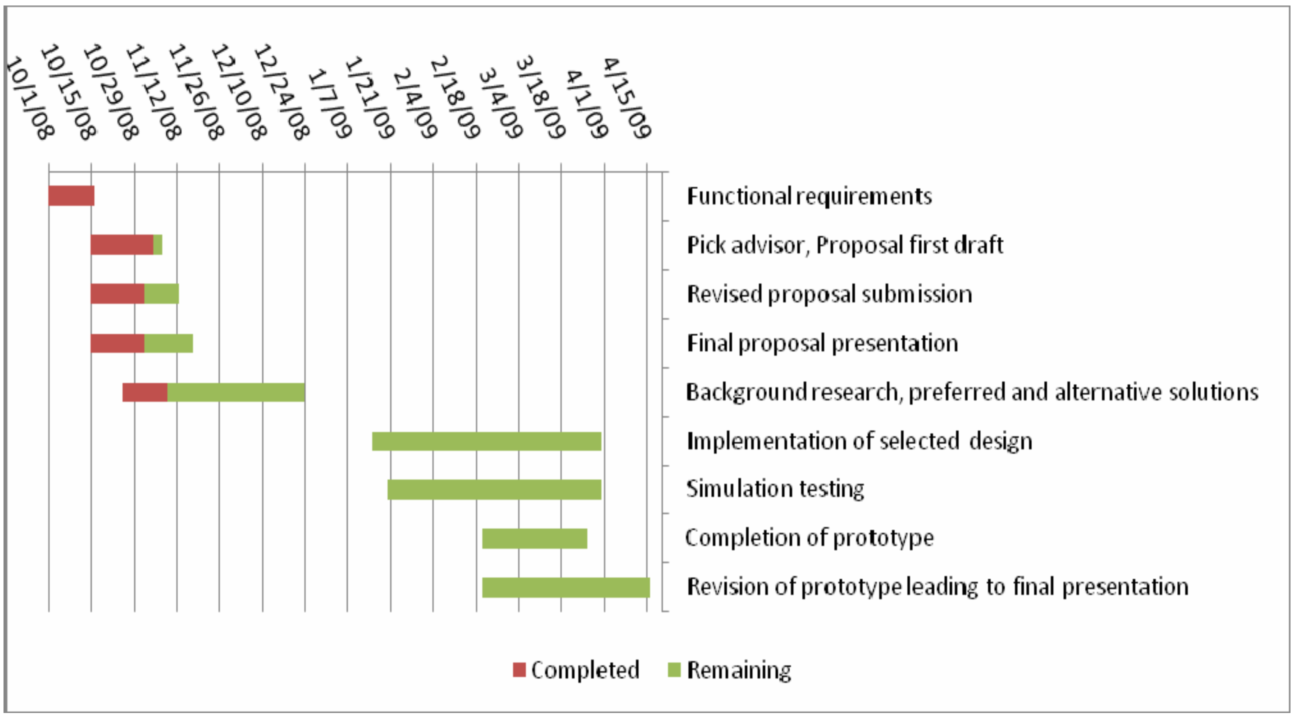
We expect to deliver a functioning prototype and a schematic for our design.  The prototype will demonstrate the remote antenna controller's capability. We will also maintain careful records documenting the evolution of the design to facilitate replication of the design.

## 6. PROJECT MANAGEMENT

### Budget

| | |
|---|---|
| Cost of 1 servomotor (4 @ $150/per): | $600 |
| Cost of FPGA package (2 FPGA boards): | $500 |
| Mount | $100 |
| Position tracker system (sensors) | $50 |
| Weather-proof casing | $50 |
| Antenna Prototype | $50 |
| Miscellaneous: | $300 |
| Total: | $1650 |

### Timeline




## SENIOR DESIGN PROJECT TEAM

The prospective project team includes: Tolu Akinyosoye, Omolade Salawu, Iverson Bell, and Cyril Acholo. The group worked with Dr. Mihai Dimian, an assistant professor at Howard

University, in 2008 on a preliminary senior design project that was presented and demonstrated in the 2008 Senior Design symposium. With Dr. Dimian's help, we have assembled a team of senior electrical engineering and computer engineering students, each bringing an array of creative ideas and experiences. Particularly, our group also boasts a member who has telecommunications industry experience! The team has harmony, synergy, and a level of compatibility that can yield rewarding results.

## 7. CONCLUSION

The remote antenna mount controller is revolutionary because it diminishes the risk of dangerous and inconvenient manual antenna adjustments. Furthermore, the antenna mount controller allows the system's user to store preferable antenna positions and return to previously stored positions. These advantages will make improvements in signal quality easier to attain, launching antenna mount adjustment technology into a future of convenience.

In fulfillment of the requirements for completing our Senior Design course, we look forward to the opportunity to provide such an automated module that will allow adequate control over tilt and azimuth with remote command signaling and control while also storing default positions.
Our proposed solution employs the use of microprocessors and FPGA boards, and some programming logic to send directional commands in the form of RF signals to servo-motors using frequency modulation. We researched alternative methods of implementation, such as Bluetooth transmission, and documented some respective advantages and disadvantages. The design of this project will require us to apply the knowledge we have gained from classes such as Elecromagnetic theory and Digital Systems design, and by its completion, to have mastered Linear controls and the use of Simulink (a simulation tool). We have compiled a detailed documentation of the requirements and specifications for our proposed design, and have ensured compliance with the standards of the respective regulatory bodies. At a total cost of $1500, we feel our design is relatively inexpensive for a prototype.

## 8. **REFERENCES**


- 2004-8 PatentStorm LLC < PatentStorm.com >
- Senior Design 1 course material <www.hirstbrook.com>
- National Electrical Safety Code
- MIT Digital Systems Design Lab <mit.edu/6.111>
- F.C.C C.F.R § 15.247 (2008): FCC Unlicensed Radio Frequency (RF) Emission regulations
- Texas Instruments Low Power RF ICs: CC2420DBK Demonstration Board Kit: <focus.ti.com/docs/toolsw/folders/print/cc2420dbk.html>
- IEEE Standards Association: IEEE 802.15.4-2006

- NCRP Report No. 86 "Biological Effects and Exposure Criteria for Radio Frequency Electro-magnetic Fields," ISBN 0-913392-80-4. National Council on Radiation Protection and Measurements

- Electronic Product Environmental Assessment Tool, The Green Electronics Council <http://www.greenelectronicscouncil.org/epeat/about.htm>

- W5YI, Resources for Commercial and Amateur radio, Part 1 : Sec. 1.1310 “Radiofrequency radiation exposure limits” < http://www.w5yi.org/page.php?id=231>

**APPENDIX**

| | | |
|---|---|---|
| <br>**Cyril Acholo**<br>**Tolu Akinyosoye**<br>**Iverson Bell**<br>**Omolade Salawu** | REQUIREMENT LIST<br>for<br>*RAMC*<br>*(Remote Antenna Mount Controller)* | **1st Version: 10/20/2008** |
| **UPDATED** | **REQUIREMENTS** | **SOURCES** |
| | *Overall Function: This is an antenna mount controller that takes inputs from a user and wirelessly adjusts the azimuth and tilt of antennae accordingly, while storing default positions for the antennae.* | |
| 10/20/2008 | **PERFORMANCE**<br>• Response time should not exceed 1minute<br>• The speed should be no less than 1 revolution per minute<br>• Fail rate should not exceed 60seconds<br>• Should have a response time not greater than 0.5secs | |
| 10/20/2008 | **SAFETY AND COMPLIANCE**<br>The module must be in compliance of the following safety standards:<br>• National Electric Safety Code (IEEE NEC, IEEE NSEC)<br>• Section 15.247 of the FCC Unlicensed radio Frequency emissions regulations<br>• NCRP Report No. 86 "Biological Effects and Exposure Criteria for Radio Frequency Electro-magnetic Fields," ISBN 0-913392-80-4. National Council on Radiation Protection and Measurements | |
| 11/14/2008 | • IEC 664-1 Specification for Hazardous voltage limitations | |
| 10/20/2008 | • IEEE 802.15.4-2006: for low-rate wireless personal area networks | |
| 10/20/2008 | **SIZE/WEIGHT**<br>• Transmitter: 20pounds, 35cm X 40cm X 10cm<br>• Receiver: 20pounds, 35cm X 40cm X 10cm | |

<table>
<tr><td></td><td><ul><li>Motors: As determined by our motor sizing algorithm</li></ul>COST<ul><li>$1600</li></ul></td><td></td></tr>
<tr><td>10/20/2008</td><td>MAINTENACE<ul><li>The Receiver will be placed in the same housing as the antenna base station radios to reduce maintenance costs.</li><li>The system should be checked annually</li></ul></td><td></td></tr>
<tr><td>10/20/2008</td><td>POWER<ul><li>Transmitter: 0.54W (12 Volts, 45mA)</li><li>Receiver: 0.54W (12 Volts, 45mA)</li><li>Motors: as determined by our motor sizing algorithm</li><li>Microprocessor and related components: 0.1W</li></ul></td><td></td></tr>
<tr><td>10/20/2008</td><td>ENVIRONMENT<ul><li>The RAMC should not interfere with surrounding devices</li><li>Upon completion of its lifespan, the RAMC components can be applied to alternative uses such as an AM receiver</li><li>The RAMC components are easily replaceable, and this contributes to reduced E-waste</li></ul></td><td></td></tr>
<tr><td>10/20/2008</td><td>INTERFACES<ul><li>The RAMC should have a user terminal with display for monitoring adjustments (Keypad and/or GUI showing the amount of degrees moved in each direction)</li></ul></td><td></td></tr>
<tr><td>10/20/2008</td><td>TIMELINE AND SCHEDULE<ul><li>Develop a clear set of functional requirements by October 15th, 2008</li><li>Research pertinent background information, and develop a preferred solution by December 1st, 2008</li><li>Develop alternative solutions by December 1st, 2008</li><li>Commence implementation of proposed solution by January 30th, 2009</li></ul></td><td></td></tr>
<tr><td></td><td>LIFESPAN<ul><li>The RAMC should last for up to five(5) years</li></ul></td><td></td></tr>
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