SWAMPSAT ANTENNA SYSTEM

By

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To my wife who inspires everyday; to my colleagues and friends who believe in me; and to my family especially my girls (Koda, Kenai, & Roxy) who always ♡ me and are there for me

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Abstract of Thesis Presented to the Graduate School
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SWAMPSAT ANTENNA SYSTEM

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SwampSat, the first CubeSat mission of the University of Florida, is an on-orbit technology demonstrator of a compact three-axis attitude control system capable of rapid retargeting and precision pointing (R2P2). This thesis addresses the design and test of the SwampSat antenna system. Various antenna configurations, antenna materials, packaging and deployment techniques feasible for SwampSat operation were surveyed. Based on the survey, a dipole antenna design was adopted for SwampSat.

The SwampSat antenna system consists of two modules which integrate the structural and electrical components in a non-intrusive manner. The antenna system modules are developed to support an assembly process which can be performed independently and then interfaced to the SwampSat structural frame and electrical components. A burn-wire deployment mechanism has been designed for each module. Prototypes of the antenna system have been fabricated and tested and the final flight design is presented. The antenna system will undergo further field and deployment tests to mitigate any failure modes.

CHAPTER 1
INTRODUCTION

> "The art of engineering is to take a bright idea and with money, personnel, materials, and the proper regard for the environment produce something the public wants at a price it can afford to pay" - Source Unknown

1.1 Research Motivation

The current United States administration has defined science education and training as the target areas for the next generation [10]. At the state level, the Governor's Commission on the Future for Space stated, "Florida's residents from Key West to Pensacola must embrace the statewide importance of the aerospace industry, as it benefits more than just the communities along the Space Coast. Beyond our borders, the nation and the world must learn to see Florida as more than just a launch site but also a home for manufacturing and assembly of rockets, satellites, and aircraft and for the research and innovation that underpins all of these industries" [11]. Internationally, European and Asian nations have already implemented an educational system that emphasizes science and technology, and their recent successes and advances in space exploration and technology development may be a direct consequence of it.

Since traditional satellites are expensive and are designed to accommodate sophisticated and redundant systems for operations, they are not appropriate for educational purposes [5]. The emerging CubeSat program, however, offers students educational opportunities through access to space with acceptable risks and affordable costs. The CubeSat program provides a knowledge-based platform for students and collaborators to assemble and to venture into the space frontier. The standard 1U CubeSat form factor, a 10 centimeter cube, poses challenges to innovate technology intended to utilize commercially available parts to obtain rapid results.

Due to their limited size, computational resources, and power generation capabilities, CubeSats offer the unique ability to provide technology research and development as well as educational opportunities. In addition to more universities joining the research

initiative, the recent interest of government agencies and commercial industries have expanded the possibilities of the CubeSat community [21].

The CubeSat concept embraces the idea that small satellites complement traditional satellites and offer the community improvements in cost and schedule which cannot be achieved by the traditional satellites. The 3U Poly Pico-satellite Orbital Deployer (P-POD) is a certified container which holds up to three 1U CubeSats. P-PODs can be integrated to various launch vehicles worldwide as secondary payloads thus offering additional access to space. CubeSats are currently scalable in 1/2 U increments up to 3U, however, several multi-pod configurations are under development which could support additional configurations (e.g., 6U, 12U) [20].

The University of Florida (UF) is developing a CubeSat to demonstrate a miniaturized attitude control system for pico- and nano-satellite applications. The scope of this thesis is the antenna system selection, integration, and deployment mechanism for the University of Florida CubeSat known as the SwampSat.

1.2 CubeSat Background and Heritage

CubeSats have become a growing trend worldwide in university pico- and nano-satellite research programs. The CubeSat concept was authored jointly by California Polytechnic State University (Cal Poly - San Luis Obispo) and Stanford University, and is quickly becoming a standard for small satellites in the pico- and nano-satellite classifications [16]. Small satellites are classified as pico-, nano-, micro-, and mini-satellites based on nominal mass and dimension [2]. The initial focus behind the CubeSat program was to allow universities to engage and train students by providing affordable access to space. Commercial-Off-The-Shelf (COTS) components and miniaturization of satellite technology have enabled successful CubeSat missions to date.

An emerging market opportunity has become evident as the space industry embraces the concept of CubeSats. Entities such as the National Science Foundation (NSF) [12], the National Reconnaissance Office (NRO) [8], and National Aeronautics and Space

Administration (NASA) [3] have invested in supporting the development of CubeSat technologies. NSF's space-weather and atmospheric research department sponsored two university affiliated 3U CubeSat missions in 2008 plans to continue the program for years to come. Additionally, the NSF is also supporting the Advanced Space Technologies Research and Engineering Center (ASTREC), which is a Industry/University Collaborative Research Center (I/UCRC) hosted by the University of Florida and North Carolina State University aiming to enhance the utility of small satellites through focused technology and research [9]. The NRO's Innovative Experiment Initiative (IEI) Broad Agency Announcement (BAA) acknowledged the need for advances in several critical small satellite subsystems. As a result, the NRO established a CubeSat office called Q_bX to monitor and develop pico-and nano-satellite technologies for improved satellite systems.

CubeSats provide universities a means to train students for the workforce and allow academia to solve innovative problems while providing students with project management skills related to space systems. A potential outcome will be the transformation of CubeSats from educational "toys" to technology demonstrators. Additionally, since CubeSats can have relatively rapid development cycles and quick turnaround as compared to traditional satellites, business opportunities for them are being developed. However, to truly realize such business opportunities, appropriate standards and continued expansion of the infrastructure (i.e., secondary payloads,multi-pod configurations, and flexible launch opportunities) is necessary.

1.3 SwampSat

SwampSat is a 1U CubeSat currently under development at the University of Florida [6]. The SwampSat EDU is shown in Fig. 1-1.

SwampSat's primary objective is to demonstrate a compact three-axis attitude control system (comprised of a pyramidal cluster of single gimbaled control moment gyroscopes) to rapid retarget and precision point (R2P2) pico-and-nano satellites [18].

Figure 1-1. SwampSat engineering development unit (EDU)

1.4 CubeSat Communications

The communication subsystem provides the critical link between the satellite and the users on the ground. CubeSats currently use radio-communication systems in the Very High Frequency (VHF), Ultra High Frequency (UHF), S and X amateur radio bands. The ability of the CubeSat community to utilize the existing amateur radio community has expanded the mission operations profile for university CubeSats. Radio frequency (RF) techniques are commonly implemented in CubeSat missions due to their omnidirectional characteristics, frequency selection, and worldwide tracking capabilities.

CubeSats currently lack the attitude sensors and actuators to precisely point and maintain their desired orientations. Thus directional instrumentation such as high gain antennas are not yet feasible. A directional antenna could improve the antenna gains for CubeSats and increase the achievable data rates significantly beyond what is currently available.

As developments in attitude sensors and actuators mature, CubeSat communications will improve. An increase in the pointing capabilities will directly impact on the gain of the antenna. A major challenge in CubeSat communications is to address increasing the

data rate transfer. Directional antennas would maximize the throughput for CubeSat operations reducing the dependency on memory stored for telemetry analysis which is very limited. One such methodology to increase CubeSat communications is by implementing a small satellite sensor network which would distribute various processes across several CubeSats in a constellation which in turn would expand the utility of CubeSat communications. But the satellite link to link network would still require radio frequency antenna systems to command and track from the ground [17].

Due to the CubeSats being inserted in the Low Earth Orbit (LEO), they have higher orbital velocities and thus need precision pointing and retargeting to compensate. Which in turn requires coupling R2P2 with a highly directional (i.e. optical) communications instrument which have been proposed but need to be further researched and developed for CubeSat missions [7].

1.5 Thesis Outline

This thesis is organized as follows. Chapter 1 provides an introduction of the benefits of a CubeSat program (e.g. as an educational tool) for developing science and technology as well as introduce SwampSat, the first UF CubeSat project.

Chapter 2 explores common antenna configurations and materials and the design tradeoffs for the antenna selected. A survey of existing CubeSat antenna systems was performed and used to finalize the SwampSat antenna system design.

Chapter 3 details the designs of the SwampSat antenna system.

Chapter 4 details the testing of the antenna deployment and supporting communication hardware for verifying the effectiveness of the antenna system design.

Chapter 5 discusses the logistics of communications for tracking and operating SwampSat.

Chapter 6 presents the conclusion.

CHAPTER 2
SURVEY FOR SWAMPSAT ANTENNA

2.1 Survey of Antenna Configurations

Miniaturization of antennas for electronic devices and computers have become a growing interest in the antenna field [4]. A large emphasis of the current antenna manufacturers is to focus on small but smart antennas (i.e., for small electronics such as cell phones, laptops, handheld devices). However, these smart antennas require a base station or existing network to establish a communications link since long range communications is not desired. In addition, fundamental mechanical limitations, which hinder the free-space wavelength to an antenna element must be designed, presents a challenge. Space-based in particular CubeSat communications require communication signals to travel long distances while to still penetrate through the atmosphere with minimal losses. The following survey and selection of the available antenna configurations is critical to the success of SwampSat.

The SwampSat antenna configuration was selected keeping in mind these mechanical and electrical factors:

- Packaging
- Rigidity
- Acceptable Gain
- Sufficient Bandwidth

A brief description of available antenna concepts is provided below to motivate the antenna selection process which is explained in the next sections.

2.1.1 Parabolic Reflectors

A parabolic reflector is a reflective device to collect or project radio waves. Parabolic reflectors transform an incoming plane wave traveling along an axis into a spherical wave converging towards a focus. A spherical wave generated by a point source placed in the focus is transformed into a plane wave propagating as a collimated beam along this axis.

The construction of a parabolic reflector ,though, is not feasible for SwampSat due to volume constraints.

2.1.2 Dipole

A dipole antenna consists of a center-fed point which splits into two elements for transmitting or receiving radio frequency energy. The current amplitude on a dipole antenna decreases uniformly from maximum at the center-fed point to minimum of zero at the element ends. Dipole antennas center-fed points are commonly implemented in CubeSats due to ease of their packaging and deployment characteristics. The length of the dipole antenna is directly related to the operational frequencies so the antenna lengths can be determined based on the desired frequency. The gain of a dipole antenna is approximately 2.14 dBi and the radiation resistance approximately is 73 Ω.

The dipole antenna configuration is an appropriate choice for SwampSat.

2.1.3 Monopole

A monopole antenna is a type of radio antenna formed by replacing one half of a dipole antenna with a ground plane normal to the remaining half. If the ground plane is large enough, the monopole behaves exactly like a dipole, as if its reflection in the ground plane formed the missing half of the dipole. However, a monopole has a gain of approximately 5.1 dBi and the radiation resistance is approximately 36.5 Ω, which is less.

The monopole antenna is appropriate but is not selected for SwampSat due to lower obtainable gain as compared to a dipole.

2.1.4 Helical

A helical antenna is an antenna consisting of a conducting wire wound in the form of a helix. In most cases, helical antennas are mounted over a ground plane. The far field radiation pattern is similar to an electrically short dipole or monopole. The radiation is directed perpendicular on the axis of the helix, and adjusting the diameter of each ring and the turn space between each helical coil allows for circular polarization. Helical antennas have a predictable pattern, gain, and impedance over a wide frequency range.

The directionality depends on the quantity of helical coil windings. As the length of the antenna increases so does the gain.

The helical antenna is not feasible for SwampSat due to volume constraints.

2.1.5 Microstrip and Patch

A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate. This substrate with a continuous metal layer is bonded to the opposite side of the substrate which forms a ground plane.

CubeSats have not utilized many patch antenna designs due to the challenges of miniaturization and parameter specifications. Hence, the microstrip and patch antenna is not feasible for the selected SwampSat frequencies. [13].

2.1.6 Horn

The horn's dimension and shape, placement of the reflector, and reflector's dimension and shape alter the beam pattern. Horn antennas are typically implemented as feed elements for large radio astronomy, satellite tracking, and communication dishes. Horn antenna is a common element of phased arrays and serves as a universal standard for calibration and gain measurements of high-gain antennas [4].

The horn antenna is not feasible for SwampSat due to volume constraints.

2.2 Antenna Configuration Selection

Selecting the horn, helical, and parabolic reflector for a SwampSat antenna system is not feasible as the packaging difficulties cannot be accommodated on SwampSat's structural design. The frequencies allocated for the SwampSat mission are within the 2 meter band and 70 centimeter band making patch antennas not applicable for SwampSat. Utilization of higher frequencies would decrease the dimensions of the patch antenna which could be embedded within the SwampSat structure. However, patch antennas were also eliminated from the design because of the constraints on the available frequency range.

The antenna configurations defined in the previous section are compared in Table 2-1. Additionally, a survey of operational CubeSat communication systems including their transceiver specifications, transmit frequencies, modulations, antenna types, power outputs, and data downloads are compiled in Ref. [15]. Monopoles and dipoles dominate the CubeSat antenna configurations while few patch antennas have been implemented.

As a result, the dipole antenna is selected.

Table 2-1. Pros and cons on antenna configurations survey for SwampSat

Antenna Type	Pros	Cons
Parabolic Reflector	high gain	packaging, deployment alignment, highly directional
Dipole	omnidirectionality frequency dependent, packaging	low gain
Monopole	omnidirectionality, frequency dependent	low gain,
Helical	high gain, circular polarization, simple constructio	packaging and deployment deployable volume
Microstrip/Patch	narrowband, small size, no deployment, frequency dependent	low gain
Horn	high gain, simple construction	packaging difficulties, joints, highly directional

2.3 Dipole Antenna Design Tradeoffs

As the length of the antenna decreases, its frequency, and hence its wavelength increases. Equation 2–1 describes this relationship where $\frac{\lambda}{4}$ is the length of a single element of a half-wave dipole, c is the speed of light, η is the wavelength of a dipole antenna. For SwampSat, the transmit and receive frequencies are 437.385 MHz and 145.980 MHz, respectively, resulting in a transmit antenna of length 34.3 cm and a receive antenna of length 103 cm.

$$\frac{\lambda}{4} = \frac{c}{4\eta} \tag{2–1}$$

2.4 Survey for SwampSat Antenna Material

Several characteristics were considered during the material selection for the SwampSat antenna dipole elements. The material needed to be elastic in order to fit inside the CubeSat constraints when stowed, yet unfold into its nominal length when deployed. Additionally, fabrication (including the ability to solder) factored into the selection of the final flight antenna material. Two materials were considered and are discussed below.

2.4.1 Nitinol

Nitinol is a nickel titanium alloy which is known for its shape memory characteristics. Nitinol wires have flown on several CubeSats [15]. However, an increased bandwidth is desired for SwampSat thus requiring nitinol strips rather than nitinol wires. Furthermore, care must be taken to fabricate nitinol elements and solder connections to nitinol.

Nitinol was not selected for SwampSat due to the difficulty in packaging and the additional fabrication challenges.

2.4.2 Tape Spring Steel

Tape spring steel is a common antenna material utilized on several CubeSat missions due to its ability to be packaged in a confined volume yet deploy to its desired length when released. Additionally, spring steel fabrication is a straight-forward process that can be easily accomplished in the moot laboratory. Solderable connections require that the coating be removed from the material (assuming the material was obtained from a commercially available tape rule). Any necessary holes for mounting and deployment in the antenna elements can be fabricated in-house.

The tape spring steel was selected for the SwampSat due to the factors above.

CHAPTER 3
SWAMPSAT ANTENNA SYSTEM DESIGN

The SwampSat antenna system is designed for ease of integration to the flight hardware to accomplish successful antenna storage, deployment and operation. The antenna system is mechanically integrated into the SwampSat structure and it electrically interfaces to the SwampSat communication board (for transmitting and receiving) and the SwampSat flight computer board (for deployment). The structural and electrical impact of the SwampSat antenna system is addressed in the design. The antenna system consists of two modules: a transmit module and a receive module. The SwampSat layout identifying the faces and deployed antennas is shown in Fig. 3-1 and relevant components are identified in Table 3-1. Overall, the antenna system design goals are:

- Modular design
- Ease of integration with SwampSat system
- Minimal mass

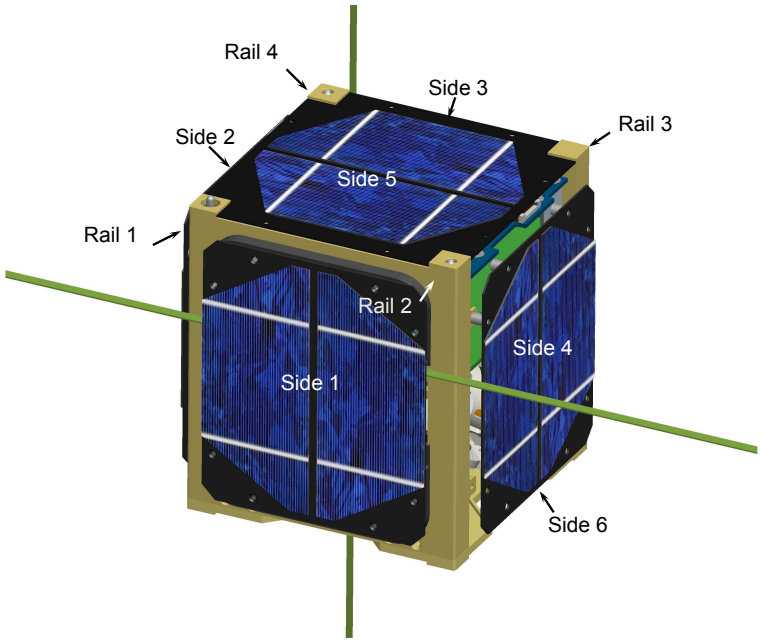

Figure 3-1. SwampSat layout with crossed dipole antennas

Table 3-1. Side components involved in determining antenna system layout

Side	Component
1	Composite panel
	Receive antenna
	Solar cells
	Sun sensor
2	Composite panel
	USB connector
	Remove-Before-Flight pin
	Motor controller board
	Solar cells
	Sun sensor
3	Composite panel
	Transmit antenna
	Magnet coil
	Solar cells
	Sun sensor
4	Composite panel
	Magnet coil
	J-Tag connector
	Motor controller board
	Solar cells
	Sun sensor
5	Composite panel
	Magnet coil
	Solar cells
	Sun sensor
6	CMG base plate
	Sun sensor

Figures 3-2 and 3-3 show, respectively, the section of structural aluminum frame and composite panel, between which the antenna system is sandwiched. Figure 3-2 also shows one of the SwampSat faces with screw holes to which the antenna system module is attached.

The antenna system consists of two different delrin plate designs for the transmit and receive dipole antenna elements. The modules are mounted on opposite sides to avoid any collision of the antenna elements during simultaneous deployment as shown in Fig. 3-1. The transmit and receive antenna lengths and corresponding frequencies are shown in

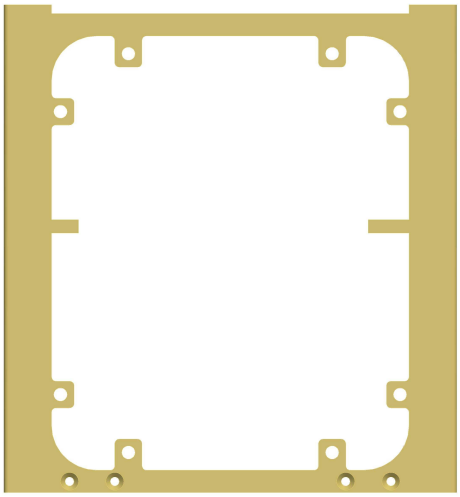

Figure 3-2. Section of the aluminum frame for mounting composite panels

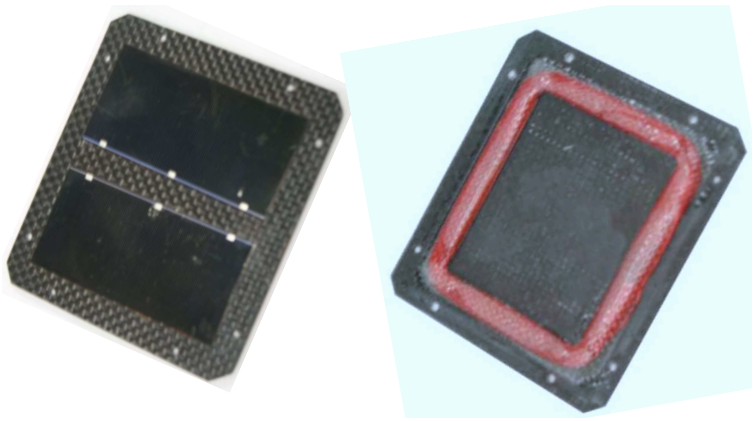

Figure 3-3. Composite panel (front and back views)

Table 3-2 and are based on Eq. 2–1. To accommodate the differences in antenna lengths, two separate antenna systems were required, both of which are fabricated from delrin.

Table 3-2. Theoretical half-wavelength dipole lengths and operating frequencies

	Total Length	Frequency
Transmit Antenna	34.3 cm	437.385 MHz
Receive Antenna	103 cm	145.980 MHz

3.1 Transmit Antenna System Module

As shown in Table 3-1, side 3 of SwampSat houses the transmit antenna and a magnet coil. The transmit antenna system is sandwiched between the CubeSat structure

shown in 3-1 and the composite panel shown in Fig. 3-3 and must accommodate the thickness of the magnet coil on the back of the composite panel.

The delrin plate for the transmit antenna elements is shown in Fig. 3-4. To avoid electrically shorting the antenna, a raised edge that interfaces with the aluminum structural plate is provided; no edge is required for the side that interfaces with the composite panel since shortage is not possible through contact.

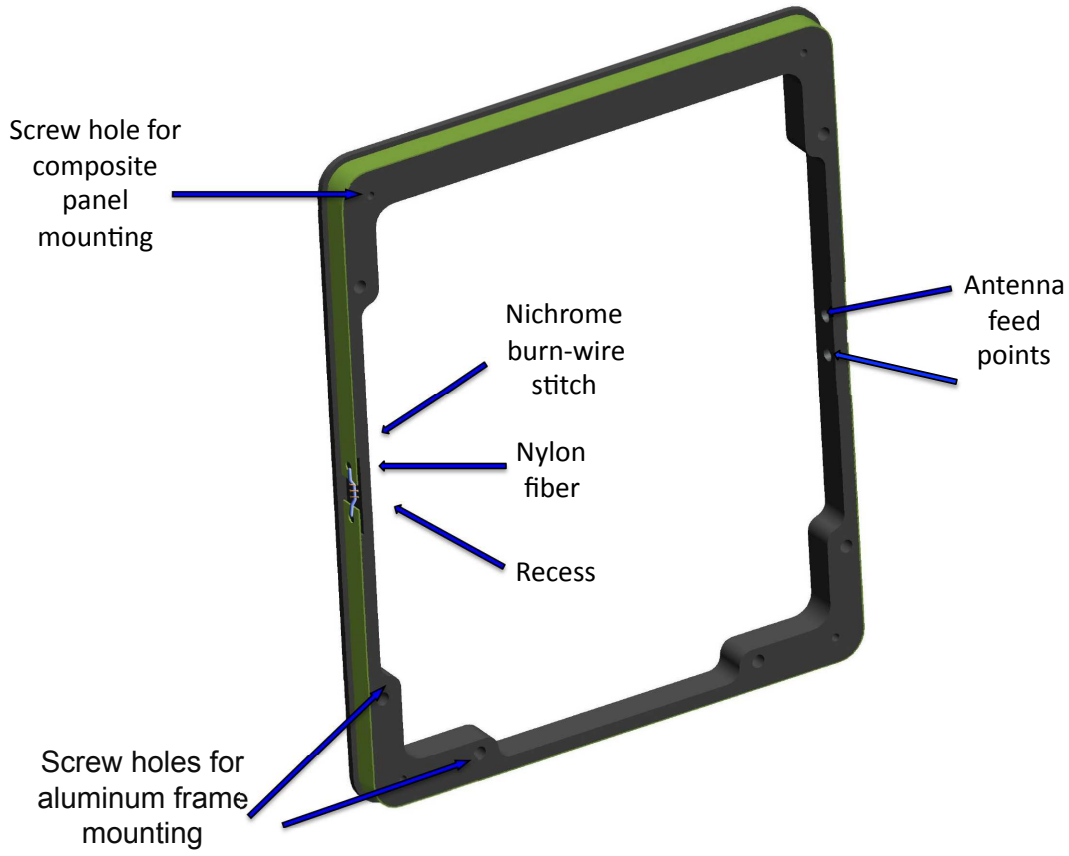

Figure 3-4. Transmit antenna system module

The antenna is wrapped inside a groove created by the composite panel and the back edge on the delrin plate. A nylon fiber (in blue) routes between the hole at each tip of the transmit antenna elements and restrains them from deploying. A recess in the delrin

plate is designed to accommodate the insertion of the nylon fiber across the delrin plate to allow for sufficient room for the assembly of the deployment mechanism and six holes are in the plate for the "three-stitches" of nichrome filament (in orange) which the nylon fiber passes through. The transmit antenna deployment mechanism resides on the middle of rail 3 (see Fig. 3-1). The nichrome filament is activated by a switch on the flight computer, which when activated heats the nichrome filament and severs the nylon fiber deploying each dipole receive element simultaneously into their flight configuration for operation.

3.2 Receive Antenna System Module

The receive dipole antenna elements are mounted on a delrin plate as indicated by Fig. 3-5. A separate design is necessary since the length of each element of the receive dipole is longer than the perimeter of the delrin plate. In this design, the antenna is coiled and stored inside the cavity. A nylon fiber (in blue) routes between the flap restraints (in yellow) on either side of the delrin plate. The flap restraints are free to rotate about a pin slotted in the pivot hole. A recess in the delrin plate is designed to accommodate the insertion of the flap restraint end and to allow sufficient room to route the nylon fiber placed in tension. The deployment mechanism , "three-stitches" of nichrome filament in the middle of the delrin plate, is indicated in Fig. 3-5. Tests were performed to ensure proper contact between the nylon wire and nichrome stitches throughout the burn process. The same stitch and burn technique is implemented as on the transmit antenna system module.

The electrical components and interfaces for the antenna system are described in the next section.

3.3 Electrical Components and Interfaces

The electrical components and interfaces for the antenna system integrate to the Stensat transceiver board and the SwampSat Flight Computer (SFC430) board.

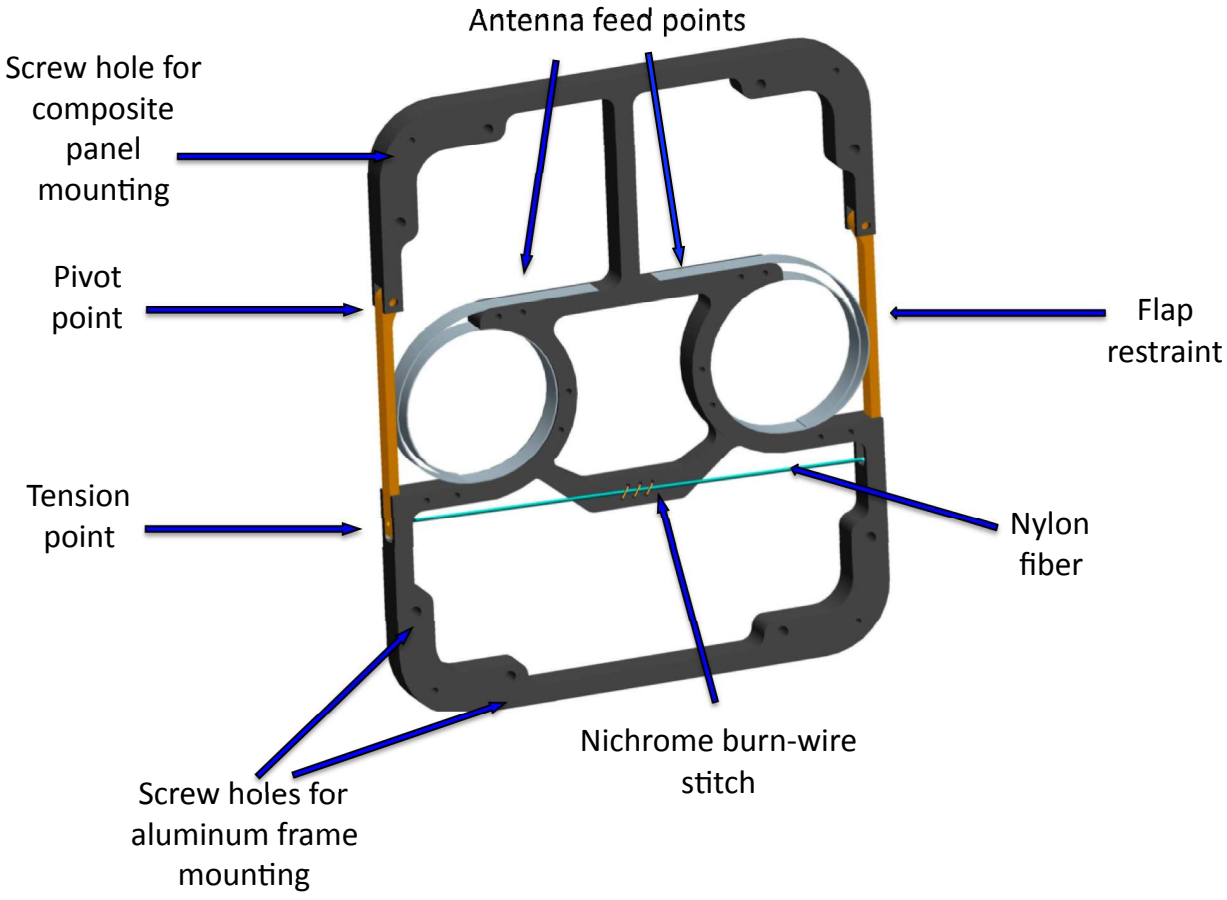

Figure 3-5. Receive antenna system module

3.3.1 Stensat Transceiver

A COTS communications board was purchased for SwampSat from Stensat Inc. The Stensat transceiver board has flight heritage and has flown on several CubeSat missions [15]. Table 3-3 includes the transceivers specification.

A SubMiniature version A (SMA) connector is utilized for the Stensat transceiver's transmit and receive antenna jacks as seen in Fig. 3-6. A coaxial cable with an SMA

plug fits onto the Stensat transceiver's antenna jacks for a connection to the antenna feed points. The antenna feed point end of the coaxial cable is pig-tailed as indicated in Fig. 3-7 and is routed to the transmit and receive antenna feed points where the antenna connector assembly resides.

Table 3-3. Stensat transceiver specifications

Parameter	Specification
Bandwidth	30 kHz
Nominal Power	1 watt
Transmit Frequency	437.385 MHz
Receive Frequency	145.980 MHz
Transmit Baud Rate + Modulation	1200 baud + AFSK
Receive Baud Rate + Modulation	1200 baud + AFSK
Transmit Baud Rate + Modulation	9600 baud + FSK
Packet Protocol	AX.25

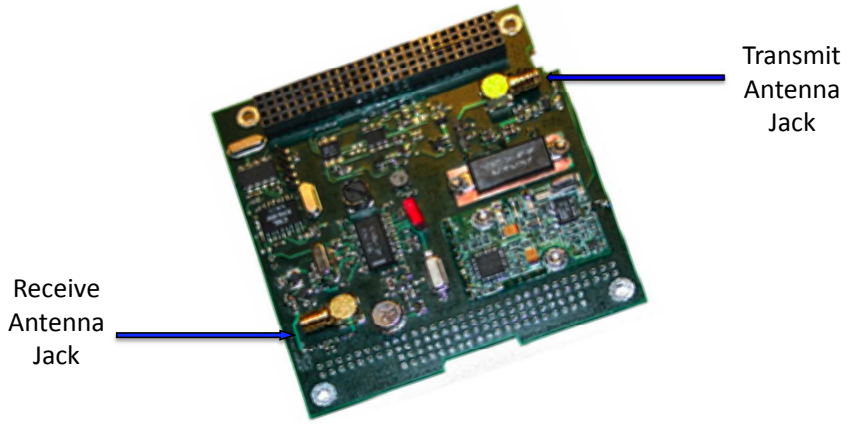

Figure 3-6. Stensat transceiver

Figure 3-7. Pig-tailed coaxial cable for testing

Figure 3-8 shows a drawing of the antenna connector assembly. The transmit and receive antenna system modules have the same antenna connector assembly. However, the

length of the cable is different between the transmit and receive antenna as dictated by the locations of the antenna jacks on the Stensat transceiver and the antenna connector assemblies on the transmit and receive antenna system modules, respectively.

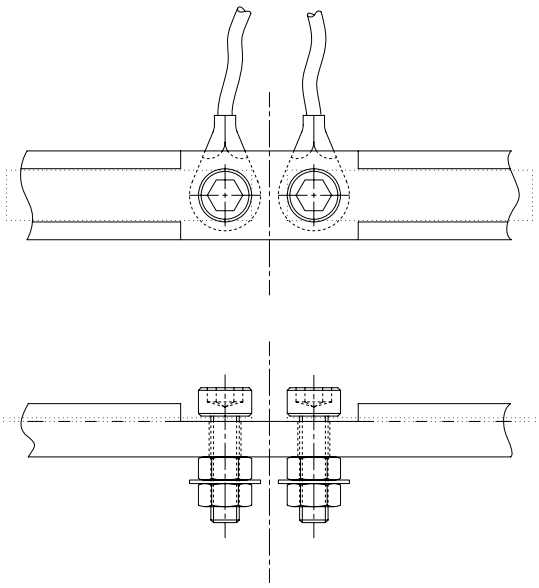

Figure 3-8. Drawing of the antenna connector assembly

3.3.2 SwampSat Flight Computer

The circuitry necessary to activate the deployment mechanism is located on the SwampSat Flight Computer board. To activate the deployment device (i.e., the nichrome filament), a load switch which is a power distribution integrated circuit is used.

The load switch implemented on SwampSat was selected due to its low-voltage operation, low-current consumption, fast timing responses, small footprint, and ease of use. This load switch has a slew rate control which when the device is turned on, the current fed to the load switch is gradually supplied to prevent a sudden surge of electricity reducing any damage possible to other SwampSat components. Load switch performance tests are provided in chapter 4 and the appendix.

The antenna deployment test process is documented in the appendix. It includes a description of the circuitry necessary for testing the load switch and also characterizing the severing (i.e., melting) of the nylon filament to deploy the dipole antenna elements.

3.3.3 Short Circuit Protection

The major motivation for implementing delrin on the antenna system modules is directly related to its non-conductive properties. The delrin plates provide a boundary so that the antennas do not short circuit with the surrounding aluminum frame.

While the current design of the antenna module using delrin should address the concerns of short circuitry of the antenna system, additional procedures were considered. Two of these are presented. First, coating of the antenna with a non-conductive powder coat was considered but quickly eliminated due to the potential for outgassing of the powder. The second option considered was to encapsulate the antenna element with a non-conductive kapton film. This was not pursued but is an option to consider should it be needed.

3.4 SwampSat Antenna System Mass Budget

The antenna system mass budget is in Table 3-4. The overall mass of the antenna system is 35.2 grams. Based on the the density of the delrin, the mass of the delrin transmit plate is estimated at 8 grams and that of the receive plate at 13 grams. The mass of the transmit dipole antenna is 1.8 grams and the mass of the receive dipole antenna is 5.4 grams. The mass of the fasteners necessary to mount the delrin plate and composite panel to the aluminum frame is estimated at 2 grams. The mass of the coaxial cables to interface the Stensat transceiver and the dipole antennas is estimated at 5 grams.

3.5 SwampSat Antenna System Assembly Process

A step-by-step process must be followed to ensure proper assembly of the antenna modules to the satellite cube. Each module is individually assembled before integrating to the satellite; i.e., the antenna and deployment mechanism (burn-wire) are assembled to the delrin plate. Once the modules are assembled, the appropriate electrical connections

Table 3-4. Antenna system mass estimated budget

Component	Mass
Delrin transmit plate	8 grams
Delrin receive plate	13 grams
Transmit dipole antenna	1.8 grams
Receive dipole antenna	5.4 grams
Fasteners	2 grams
Coaxial cables	5 grams

are made and the assembly is then interfaced to its respective face of the cube structure as shown in Figs. 3-1 and 3-9. Finally, the composite panels are then attached to complete the assembly.

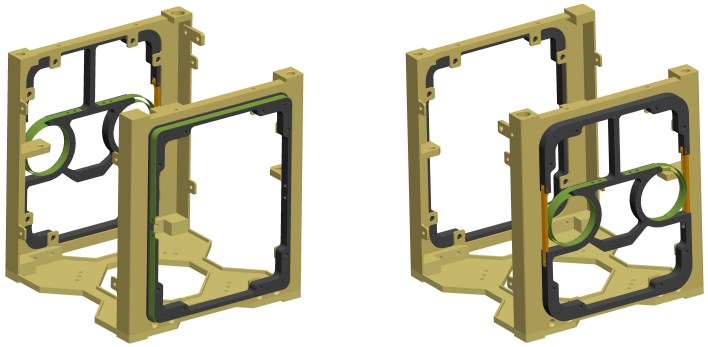

Figure 3-9. View of the transmit and receive antenna modules integrated to SwampSat

CHAPTER 4
ANTENNA SYSTEM TESTING

The antenna system testing is comprised of several tests to mitigate the failure modes for operation.

4.1 Antenna Deployment Experiments

Several antenna deployment tests were conducted to validate the nichrome burn-wire mechanism. In these experiments, the load switch was integrated to various burn wire configurations to emulate the deployment and to develop specifications for the deployment time. The details of the experimental apparatus used in these deployment are provided in the appendix. A high speed camera was utilized to capture the deployment sequence to observe the behavior of SwampSat and motivate further analysis for flight deployment and operation.

The results indicate that a supply current of 500 mA is sufficient to sever the nylon fiber with the nichrome burn-wire technique. The time required to completely burn the nylon filament at room conditions is approximately 1 second; vacuum tests are planned in order to characterize the performance in space. Further testing is required for the actual flight hardware components since the final design is based on the delrin frame which was not available at the time these deployment tests were conducted.

4.2 Impedance Matching and Antenna Tuning

Antennas behave differently in free space than they do in the vicinity of a conductive material. The CubeSat structure is made of aluminum and when the antenna is mounted on the structure, the structure behaves as a part of the antenna. This alters the expected properties of the required length of the dipole antennas and the classical equations still hold. It is imperative to tune the properties with the antenna mounted in its final orientation on the flight hardware. Antenna impedance has to be matched with the transmission line and in turn transmission line impedance has to be matched with the Stensat transmitter impedance for efficiency and loss reduction. This is required for

maximum power transfer from transmitter to free space and minimize transmission line reflection. The nominal impedance of a dipole antenna is 73Ω while the Stensat transceiver is 50Ω.

Equation 2–1 is ideal and assumes the electron velocity in the antenna material to be equal to the speed of light. This is not the case for spring steel. A factor of 0.9 is required to compensate for the finite speed of electrons in spring steel. The antennas behave differently due to the aluminum chassis as its proximity affects the resident electrons. The 0.9 factor is compensated such that Eq. 2–1 is still valid.

The procedures to perform impedance matching are documented in the appendix and need to be performed on the flight hardware when it becomes available.

4.3 Stensat Transceiver Testing and Antenna System Field Testing

The Stensat transceiver was tested to ensure that proper transmission and reception could be established. The CubeSat Kit development board was utilized in conducting this experiment. Prototype dipole antennas were connected to the antenna jacks on Stensat transceiver and tested with portable AX.25 packet radios and also the ground station equipment. Software was written to establish I^2C protocol between the Stensat transceiver and the flight processor and demonstrate telemetry transmission.

Initial testing was performed on the bandwidth and emissions of the Stensat transceiver at Timco Engineering, a local company which provides Federal Commissions Committee (FCC) certification for RF communication devices. The procedure and results of these tests are in the appendix.

Once the flight hardware is assembled, Electrical Magnetic Interference (EMI) tests will be performed at Timco Engineering on all SwampSat electronics to ensure no spurious transmissions as several launch guidelines require secondary payloads to not interfere with primary payloads.

Figure 4-1 shows the anechoic chamber at Timco Engineering which will be utilized to conduct these tests.

Figure 4-1. Anechoic chamber for RF emission testing

CHAPTER 5
COMMUNICATION LOGISTICS

5.1 Frequency Coordination and Allocation

The antennas system was designed to satisfy the frequencies allocated to SwampSat by the International Amateur Radio Union (IARU). The University of Florida applied to the IARU for its frequency coordination in December 2006 and on January 14, 2007 was granted an uplink frequency of 145.980 MHz and a downlink frequency of 437.385 MHz.

The University of Florida is submitting notification and updates to the IARU and Federal Communications Committee (FCC) to satisfy Rules and Regulations sub part C, special operations, (Part 97.207 sub paragraph g) as adopted on May 31, 1989.

Additionally, the SwampSat callsign (WG4SAT) has been assigned by the FCC. The primary ground station and mission control room is in the W4DFU radio station affiliated with the student organization known as the Gator Amateur Radio Club (GARC) [1].

5.1.1 Uplink and Downlink Specifications

The uplink and downlink communications use the AX.25 amateur radio protocol. The AX.25 protocol allows up to 200 characters per packet. Only text, punctuation, and numerical ASCII characters are permitted. The uplink (GNES to SwampSat) will operate in the Very High Frequency (VHF) band at the carrier frequency of 145.980 MHz. The Audio Frequency-Shift Keying (AFSK) modulation scheme is utilized, allowing for a 1200 baud receive data rate at SwampSat. The downlink (SwampSat to GNES) will operate in the Ultra High Frequency (UHF) at a carrier frequency of 437.385 MHz. The transmitter can operate in two modes: 1200 baud AFSK and 9600 baud Frequency-Shift Keying (FSK). The transmitter consumes approximately 1 watt of power while active.

5.2 SwampSat Link Budget

A communications link budget is necessary to ensure that a link can be established between the satellite and the ground, and to calculate the margins which are acceptable. The SwampSat link budget was developed using the available spreadsheet adopted by the

IARU and the Amateur Radio Satellite Corporation (AMSAT) [14]. Table 5-1 shows the results of the link budget.

Table 5-1. SwampSat link budget analysis

Item	Symbol	Units	Data
Receive Frequency	η_{RX}	MHz	145.980
Transmit Frequency	η_{TX}	MHz	437.385
Transmitter Power	P_{TX}	Watts	1
Transmitter Power	P_{TX}	dBW	0
SwampSat Antenna Gain	G_t	dBi	2.2
SwampSat Pointing Loss	Pl	dB	.1
SwampSat Polarization Loss	e_r	dB	.23
SwampSat Equiv. Isotropic Radiated Power	EIRP	dBW	2.1
GNES Power	P_{RX}	Watts	100
GNES Power	P_{RX}	dBW	2
GNES Antenna Gain	G_{RX}	dBi	12.8
GNES Pointing Loss	Pl	dB	.3
GNES Antenna Polarization Loss	e_r	dB	.23
GNES Pointing Loss	Pl	dB	.3
GNES Link Margin	-	dB	46.7
SwampSat Link Margin	-	dB	25.7

5.3 Mission Control Room

The SwampSat antenna system is designed to establish the communications link between the mission operations team on the ground and SwampSat. The mission control room for SwampSat is located inside the radio station owned by the Gator Amateur Radio Club. A 2 meter VHF uplink and 70 centimeter UHF downlink is achieved via two right handed circularly polarized Yagi antennas. The antennas perform satellite tracking through azimuth and elevation rotors. Uplink commands and telemetry downlinking is accomplished through the digital communications software. The satellite equipment shown in Figs. 5-1 and 5-2 is referred to as the Gator Nation Earth Station (GNES). The GNES hardware and software components are listed in Table 5-2.

5.4 Mission Operations Center

The Mission Operations Center (MOC) is utilized for coordinating satellite contacts and analyzing telemetry (see Fig. 5-3). The facility uses tracking software which is

identical that used in the mission control room. The purpose of the MOC is to make mission decisions based on computer simulations and telemetry analysis. The MOC also provides non-FCC licensed team members and collaborators the opportunity to participate in SwampSat activities. It should be noted that only FCC licensed technicians are allowed to command and operate the GNES equipment. Plans are being developed to upgrade GNES and the MOC to make them compatible with other national and international ground station networks [22].

5.5 GENSO

The Global Educational Network for Satellite Operations (GENSO) is an initiative by the European Space Agency's Educational Department initiated in 2006 that interconnects a worldwide network of ground stations via internet enabled software. The main focus is to provide an increased coverage for tracking and operating educational satellites and educational missions. Since CubeSats are operating in Low Earth Orbit (LEO), they have increased orbital speeds and decreased swath coverages compared to satellites in higher altitudes. Therefore, a limited communications window over a single ground station poses a challenge to CubeSat mission operators to acquire knowledge and behavior of their respective CubeSats. GENSO is coordinating with distributed institutions and amateur radio ground operators worldwide to increase the coverage available. A GENSO-compliant spacecraft has a set priority and other restrictions as to which ground station shall operate at a given time. The University of Florida's GNES has submitted a request to join and have been invited to participate in the limited software release in the fourth quarter of 2009 [19].

Figure 5-1. GNES workstation inside the mission control room

Figure 5-2. GNES UHF and VHF antennas

Table 5-2. Gator Nation Earth Station (GNES) hardware and software components

Hardware	
	iCOM 910H dual band transceiver
	Kantronics KPC-9612 TNC
	Yaesu G-5500 Rotor controller
	GS-232B rotor control interface
	Mirage KP-2 downlink preamplier
	Hy-Gain UB-7030SAT UHF Yagi antenna
	Hy-Gain 216S VHF Yagi antenna
Sotftware	
	SatPC32
	Orbitron
	WinAOS
	WinListen
	WiSPDDE
	Satellite ToolKit

Figure 5-3. Mission Operations Center (MOC) display

CHAPTER 6
CONCLUSION

6.1 Conclusion

SwampSat is a technology demonstrator of a highly integrated and innovative satellite system following the CubeSat standard. The antenna system described in this thesis represent an appropriate solution for the SwampSat communication requirements.

Based on this design, flight hardware is being procured for final assembly and test of the integrated SwampSat.

APPENDIX: SWAMPSAT ANTENNA SYSTEM DOCUMENTATION

Subsystem: Communications		Document No.: 09/A1/TD/05/05	Part No.
Begin: 03/27/09	End: 03/27/09	Tested By: Dante @ NEB185A	Test No.: 1

Objective

To test burn wire techniques to deploy packaged antennas and conduct various experiments to verify the deployment mechanism

Material Required:

Fig. 1 SwampSat EDU

Fig. 2 Antenna Deployment Push Button Box

Fig. 3 Nichrome Filament

Fig. 4: Load Switches

Fig. 5: Nylon Fiber

Fig. 6: Power Supply

Fig. 7: PVC Quarter-Round Guides

Figure 8: Nitinol Transmit and Receive Dipole Antenna Elements

Special Instructions

The SwampSat flight computer board supplies 3.3 V to the load switch implemented for the antenna deployments. Fig. 2 was constructed with two load switches within and the necessary resistors to implement the manual switch and reset the load switch. The yellow button indicated

in Fig.2 is the manual switch to activate and de-activate the current supplied to the burn wire which is representative if similar circuitry on the SwampSat flight computer. Figure 9 shows the circuitry for the antenna deployment box.

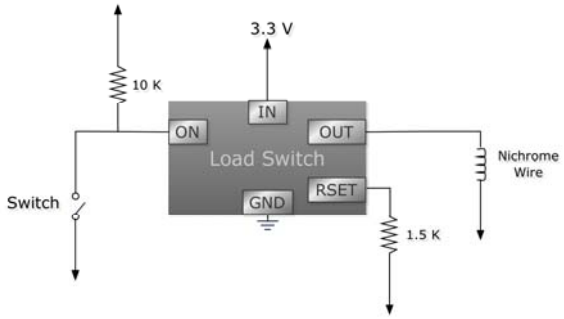

Fig. 9 Antenna Deployment Box Circuit Diagram

Procedure

This procedure was applied to both transmit and receive dipole antennas. The antennas mounted with the two holes to the delrin antenna mount on the CubeSat frame and the single hole to package the antenna elements.

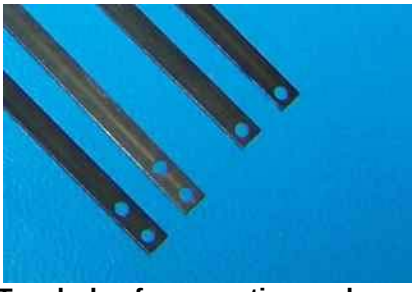

Fig. 10 Two holes for mounting and one for packaging

Step 1) Wind the antenna around the groove between the composite panel and edge of the satellite's chassis shown in Fig. 11-14. Figure 7 is mounted to the CubeSat as shown in Fig. 11.

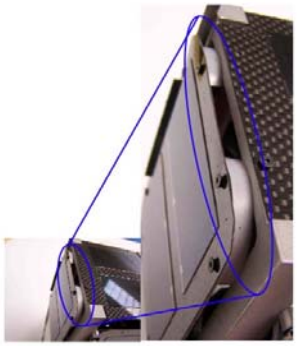

Fig. 11 Groove featuring quarter-round guides

Subsystem: Communications		Document No.: 09/A1/TD/05/05	Part No.
Begin: 03/27/09	End: 03/27/09	Tested By: Dante @ NEB185A	Test No.: 1

Step 2) Apply tension with your fingers when wrapping around the quarter-round guides to ensure the antenna is flush. No part of the antenna should protrude out beyond the composite face as illustrated in the following Figs 12-14. Use the nylon filament in Fig. 5 to package the antennas in tension.

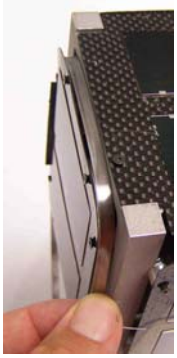

Fig. 12 Antenna in Groove

Fig. 13 Flush from the top view

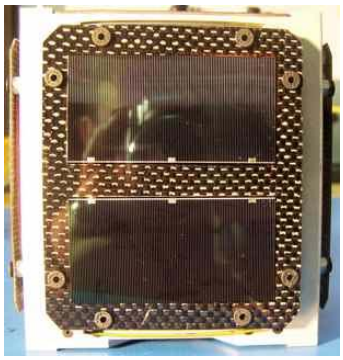

Fig 14. Flush from the side

Step 3) The composite panel edge (shown in the Fig. 15 with the blue line) must be flush with the edge of the Cube frame (shown in red) to ensure the antenna deploys and does not collide with any protrusion of the composite panel edge.

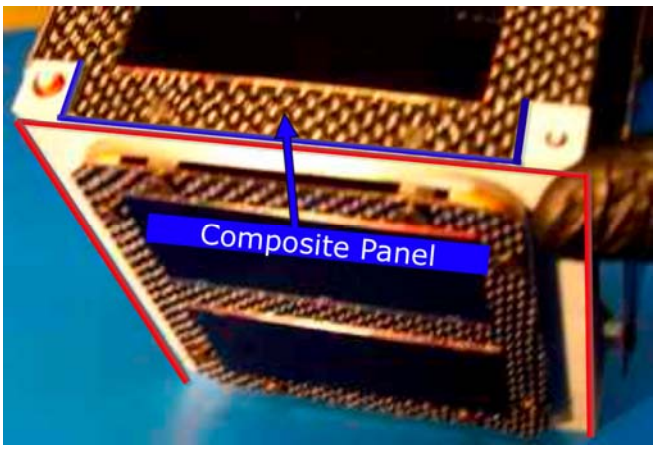

Fig. 15 Flush Edge

Step 4) The total length of the nichrome filament must be kept as short as possible to keep the resistance low. Standard gauge wires can be used to extend the nichrome filament connection to the circuitry. This is required to generate sufficient current at a voltage of 3.3 volts. The nichrome filament is coiled around the nylon fiber which is restraining the antennas from deploying.

Step 5) The coils on both the antennas have been connected to the load switch parallel because the load switch has the capability to supply sufficient current for both the coils.

Step 6) When all the preparation is complete, push the yellow button on the deployment box can activate the load switch. Stay clear of the antennas deploying to prevent any injuries. When the load switch is activated, the nichrome filament will heat to melt the nylon fibers to ultimately deploy the antennas into their dipole configurations (see Figs. 16 and 17).

Subsystem: Communications		Document No.: 09/A1/TD/05/05	Part No.
Begin: 03/27/09	End: 03/27/09	Tested By: Dante @ NEB185A	Test No.: 1

Test Data

Setup was completed and tests were carried out multiple times. A current of 500 mA was sufficient burn through the nylon fibers to deploy the antennas. This is a safe estimate with 300 mA enough to barely melt the nylon fibers. Thus it turns out to be around 1 A for both nichrome wire. The switch has to be activated for around 4- 5 seconds to make sure the nylon is melted, but further tests need to be conducted inside a vacuum. The nichrome burn wire has a distinctively red glow when initiated.

Results

Satisfactory results were obtained with respect to the electronics set up. The current limiting resistor required was around 6.8 kΩ (limited to 1 A) in the deployment circuitry. The switch/ON pin has 10 kΩ pull-up resistor since there is no internal pull up. The pin is active low.

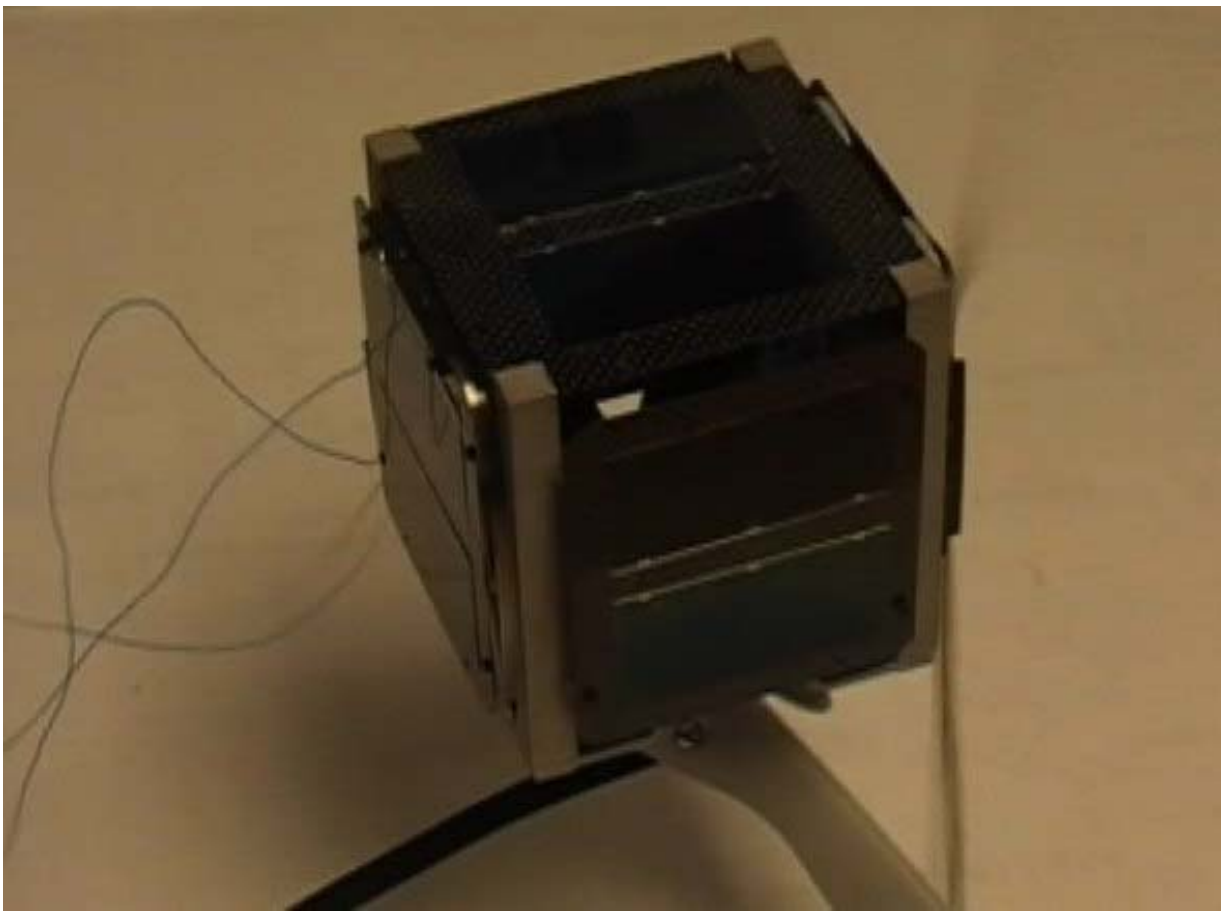

Figure 16 Deployed transmit antenna

Subsystem: Communications		Document No.: 09/A1/TD/05/05	Part No.
Begin: 03/27/09	End: 03/27/09	Tested By: Dante @ NEB185A	Test No.: 1

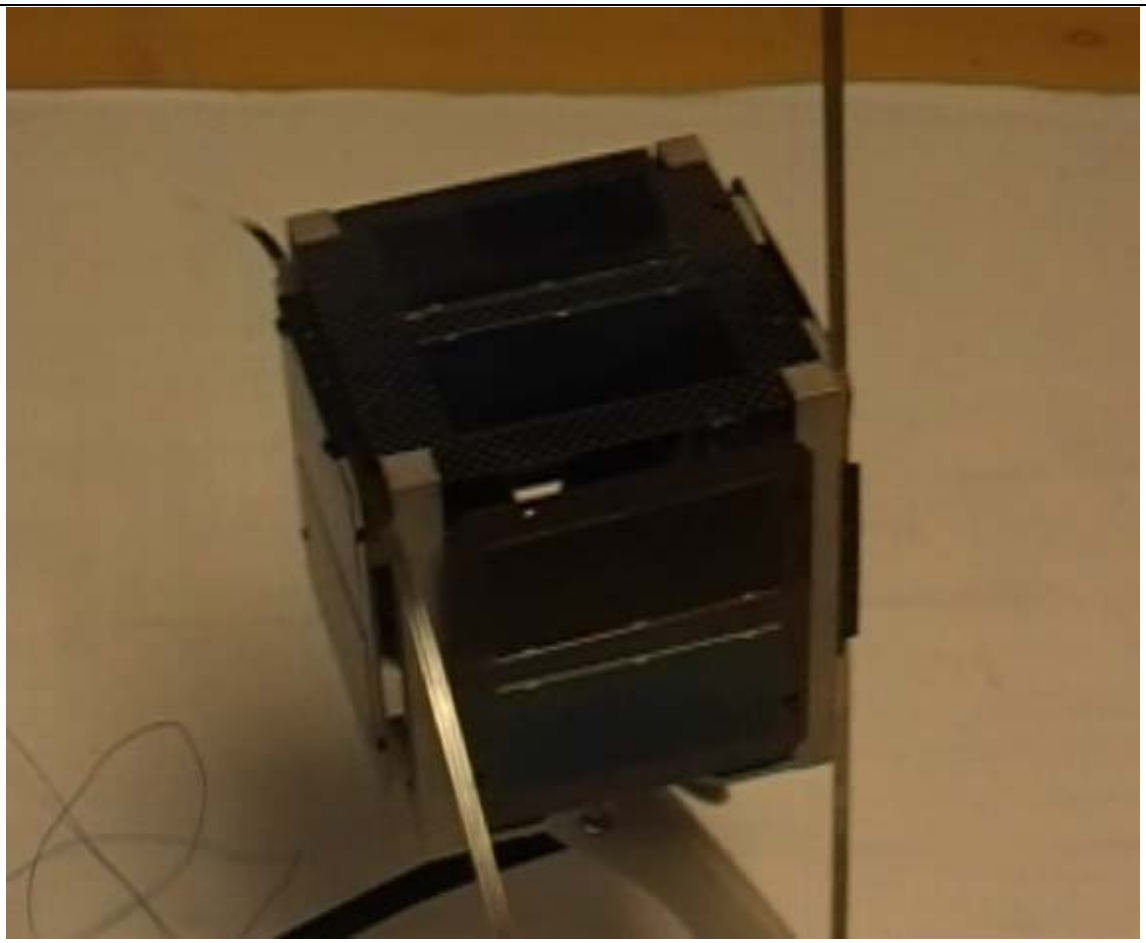

Figure 17 Deployed receive antenna

Subsystem: Communications		Document Number: 09/A1/TD/03/01	Part No.
Begin: 6/29/09	**End:** 6/29/09	**Tested By:** Dante @ Brain Institute, AMRIS RF Lab, Rm LG 100	**Test No.:** N/A

Objective

To match the impedance for the dipole antenna (73 Ω) and radio (50 Ω) and effectively tune the antennas to the appropriate frequencies. Also to figure out the resonant frequency of the dipole transmit and receive.

Materials Required

The SwampSat EDU in Fig. 1 tested throughout this document precedes the one mentioned in this thesis. The flight design presented in this thesis is still relevant because the antenna mounts are constructed out of a delrin plate as seen in Fig 3.

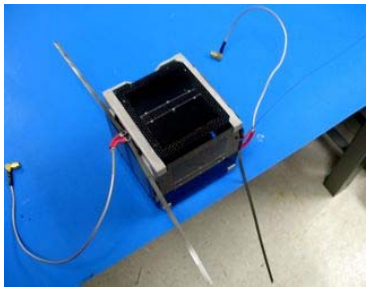

Fig. 1 SwampSat EDU

Fig. 2 Network Analyzer

Fig. 3 Delrin antenna mount and antenna connector prototype

Fig. 4 Short Circuit Cap

Fig. 5 SMA-to-BNC Connectors

Fig. 6 50 Ω termination

Test Personnel

Permission granted by: Barbara Beck
Dante Buckley
Sushant Kadimdivan
Timothy Bowen

Subsystem: Communications		Document Number: 09/A1/TD/03/01	Part No.
Begin: 6/29/09	End: 6/29/09	Tested By: Dante @ Brain Institute, AMRIS RF Lab, Rm LG 100	Test No.: N/A

Special Instructions

Due to the imperfections in the integration of the EDU and the delrin antenna mount (shown in Fig. 7), a contact between the antenna element and a mounting screw to the EDU frame creates a short circuit. As a result, the screws, which mount the delrin to the aluminum frame, had to be removed for this test.

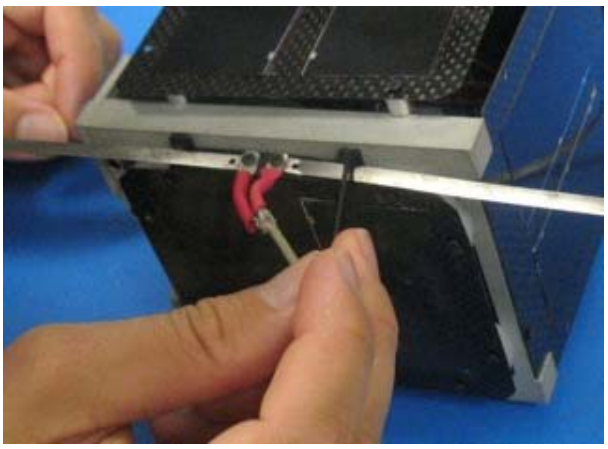

Fig. 7 EDU and Delrin Antenna Mount

Familiarity of the Smith Chart is helpful when performing this antenna test (see Fig. 8). The Smith Chart can be used to represent many parameters including impedances, admittances, reflection coefficients, scattering parameters, noise figure circles, constant, gain contours, and regions for unconditional stability.

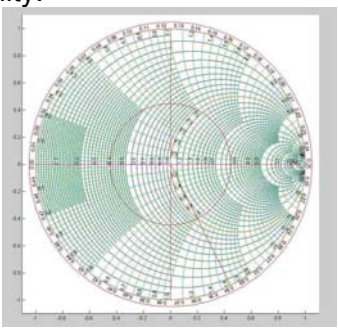

Fig. 8 Smith Chart

Theory:

The frequency of operation of an antenna is set by the length of the antenna elements.
For a half wave dipole the total antenna length is equal to the half wavelength of the desired operating frequency. The dipole is said to be resonant at that frequency. In other words the antenna impedance does not have any imaginary part at the frequency of resonance. This document illustrates the procedure to find out the resonant frequency of the antennas.

Subsystem: Communications		Document Number: 09/A1/TD/03/01	Part No.
Begin: 6/29/09	End: 6/29/09	Tested By: Dante @ Brain Institute, AMRIS RF Lab, Rm LG 100	Test No.: N/A

Procedure

The network analyzer has a female BNC connector at the reflection-test port. The coaxial cable, which plugs onto the Stensat transceiver antenna jack, is routed outside the EDU for these tests for convenience as shown in Fig 1. Hence an appropriate converter from a male SMA to a female BNC should be used as seen in Fig. 4. If necessary, use an extension cable to connect the antenna to the network analyzer. This is to make sure that the antenna is kept sufficiently away from the network analyzer metal chassis, so that interference is mitigated.
Every time the network analyzer is booted up or when the operating frequency spectrum is changed, it has to be calibrated. The steps to be followed for the same have been illustrated below. A perfect short and a perfect load (50 Ω) termination, shown respectively in Figs. 5 and 6, are needed to perform the calibration.
Calibration of the network Analyzer-

a. Start the network analyzer and set the center frequency and span of the frequency spectrum to be analyzed. This can be done by hitting the center button on the network analyzer front panel (stimulus subsection) followed by keying in the desired frequency from the keypad. The same should be performed for setting the span with the “span” key.
b. Next, press “CAL” button.
c. Press “Calibrate Menu”.
d. Press “Reflection Port 1”.
e. Keep the Reflection Port unconnected.
f. Press “Open Female”.
g. Press “Done”.
h. Repeat the steps (e through g) for the short and 50 Ω, but with perfect short and perfect load terminations at the reflection-test port respectively. The gender of the termination is “male” for the short and perfect load terminations.

Fig. 9 50 Ω termination

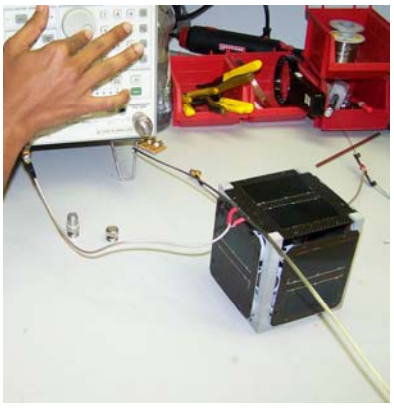

Fig. 10 Antenna Impedance Testing

Testing the Resonant Frequency

1. Calibrate the network analyzer for a center frequency of 440 MHz and a total span of 800MHz which the effective spectrum displayed on the network analyzer screen is 40MHz to 840MHz. This gives a range where both transmit and receive antennas can be

analyzed with the same calibration. This range can be reduced to increase the resolution and focus at either the 2m band or the 70 cm band.

2. Press the “Format” key on the display sub-section of the network analyzer. From the options displayed on the right side of the display, select “linear display”.”Smith Chart” can be selected from the format menu if desired.
3. Connect the antenna, if not already connected. The plot of the reflected power at different frequencies will be seen on the display. The frequency which has the least power reflected has the least impedance mismatch and is the resonant frequency. The antenna may have a resonance at multiple harmonics. The fundamental will usually show the lowest dip on the plot as seen in Fig. 13.

Fig. 13 Transmit Frequency Spike

Fig.14 Smith Chart Reading

Both receive and transmit antennas were tested for their resonant frequencies and the results are shown in the table below. Since the EDU chassis is made of metal, it modifies the near-field distribution of the antenna. Hence, two readings were recorded, one with the antenna mounted on top of the chassis and the other sufficiently away from the metal chassis.

Observations:

Table 1 and Table 2 respectively show the observed resonant frequency for the antenna in free space. The extension cable assisted in moving the antenna elements as far so that taking it any farther did not make any difference in the impedance plots on the network analyzer.

Table 1 Antenna in free-space (away from EDU)

	Length (cm)	Observed Resonant Freq. (MHz)	Calculated Resonant Freq.* (MHz)
Receive	25.4	270	295
Transmit	16.4	393	457

*Velocity propagation factor for steel has not been considered while calculating theoretical frequency of resonance.

Subsystem: Communications		**Document Number:** 09/A1/TD/03/01	**Part No.**
Begin: 6/29/09	**End:** 6/29/09	**Tested By:** Dante @ Brain Institute, AMRIS RF Lab, Rm LG 100	**Test No.:** N/A

Table 2 Antenna tested on the derlin mount on the EDU

	Dipole Element Length (cm)	Observed Resonant Freq. (MHz)	Calculated Resonant Freq.* (MHz)
Receive	25.4	297	295
Transmit	16.4	439	457

*Velocity propagation factor for steel has not been considered while calculating theoretical frequency of resonance.

RESULTS:

The results show that placing the antenna to the EDU structure tends to increase the resonant frequency. Hence, all further antenna tuning especially as flight hardware becomes available should be matched so the antenna elements can be altered. Also it is seen in Table 2 that when placed on the EDU, the transmit antenna is tuned approximately at 439MHz, which is the desired resonant transmit frequency of 437.385 which is sufficiently tuned and the transmit dipole length seems to be accurate with respect to the current EDU. However, the receive antennas performed for this test were not tuned appropriately. The receive antenna has to be tuned to the 2m band (~145 MHz). The receive dipole antenna tested here was approximately half length of the antenna length design presented. The results of the test seem accurate since the antenna increases by half then the frequency decreases by half. It can be noted that halving the frequency results in 148.5 MHz which is about 3.5 MHz away from the theoretical value needed for the receive antenna dipole.

One of the other important observations is noticing the narrowness of the valley on the network analyzer plots. If the valley representing the region of least reflection is wider, the bandwidth is wider. The reduction of the antenna width may provide enough bandwidth to handle the telemetry on SwampSat. Further tests will be conducted to address this situation. Packaging, mass reduction, and operation will need to be addressed in reducing the Also, one more important observation is that when placed near the EDU, the measured frequency of resonance corresponds more closely to the ideally-calculated frequency, i.e. neglecting the velocity propagation factor of the antenna material. This provides us with an empirical formula for calculating the frequency of resonance when mounted on the EDU.

Empirical formula: $\lambda/4 = c / (4^* \eta)$ [2-1]

where:
c = speed of light
η = operating frequency
λ/4 = dipole antenna length

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Objective

To measure the transmission bandwidth of the Stensat transceiver for the SwampSat communications subsystem

Material Required:

Fig.1 Spectrum Analyzer

Fig. 2 CubeSat Development Board with Stensat Transceiver

Fig. 3 Kenwood Dual Band Handheld Transceiver (HT)

Test Personnel

Permission granted by: Mario de Aranzeta, Timco Engineering

Dante Buckley
Shawn Allgeier
Victor Robles

Special Instructions

The transceiver should always be operated with a load attached (e.g. an antenna, dummy load, or measuring device). Operating the transmitter without a load produces unnecessary wear.

Procedure

The Stensat transceiver characterization was performed at Timco Engineering, a local company in Newberry, FL that performs FCC certifications for RF devices.

1. Setup the Stensat Transceiver and CubeSat Development board for operation in Fig. 2. Use the Kenwood HT to confirm that the transmitter is operating. The HT can be connected to a computer with terminal software (e.g. Hyperterminal) to verify that the data is successfully modulated / demodulated, and that the signal is therefore representative of the transmitter's intended output.

2. Connect the Stensat transceiver terminals (SMA connector) into the spectrum analyzer (Fig 1) using a SMA connector.

3. When setup is complete utilize the spectrum analyzer to sweep the frequency spectrum and measure the spectral density, spurious emission levels, and emitted power.

Test Data

The bandwidth of the emitted signal was measured for levels of -3 dB, -20 dB, -60 dB at a signal rate of 1200 baud, with the carrier (437.385 MHz) referenced as 0 dB. Plots of the measured bandwidths are shown in (Fig. 2, Fig. 4, Fig. 6). The measure values for bandwidth are listed in Table 1. Note that -60 dB lies within the noise level of the measurement equipment. The measurement values for spurious harmonic emission are listed in Table 2.

Results:

Table 1: Bandwidth Measurements

dB	Bandwidth
-3	12.4 KHz
-20	23.6 KHz
-60	800 KHz

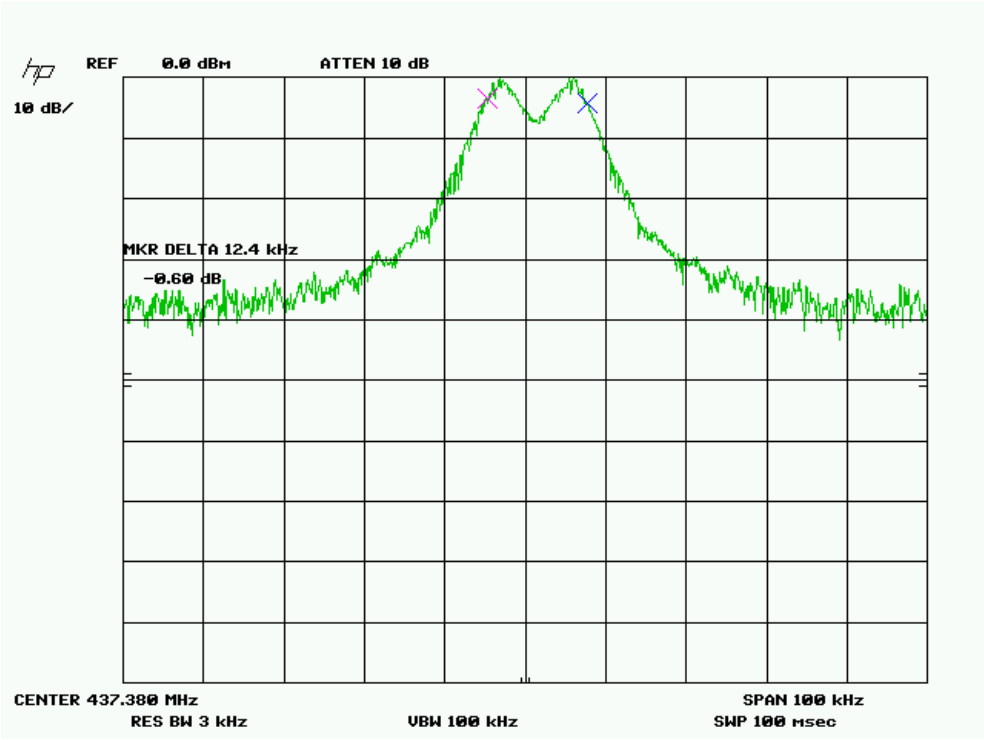

Figure 1: -3 dB Bandwidth Measurement

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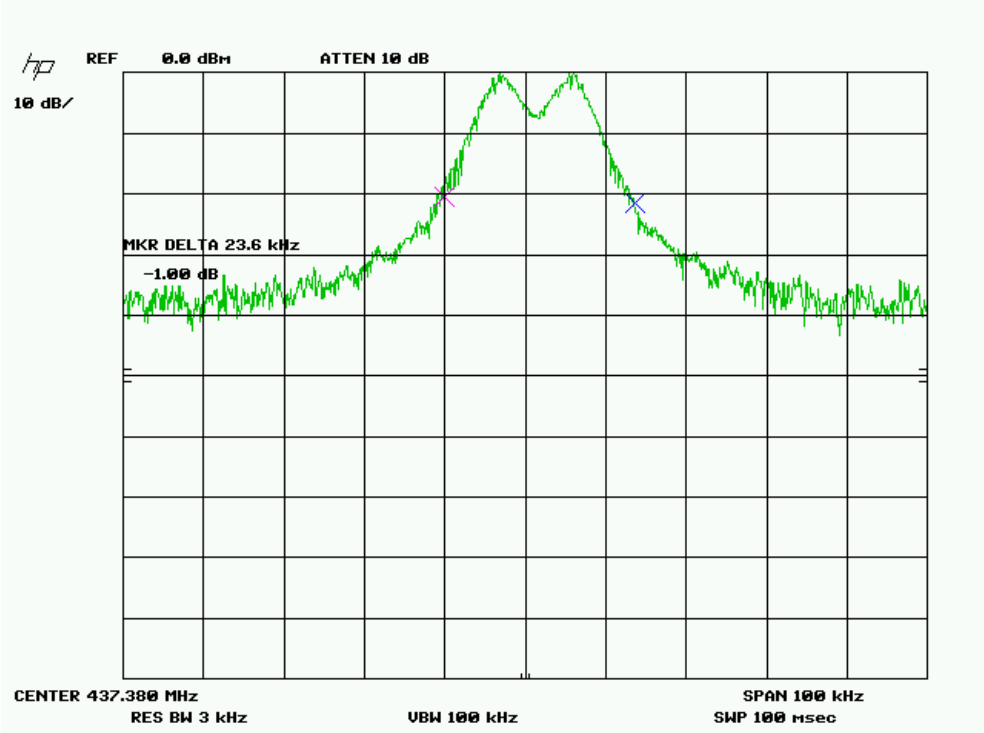

Figure 2: -20 dB Bandwidth Measurement

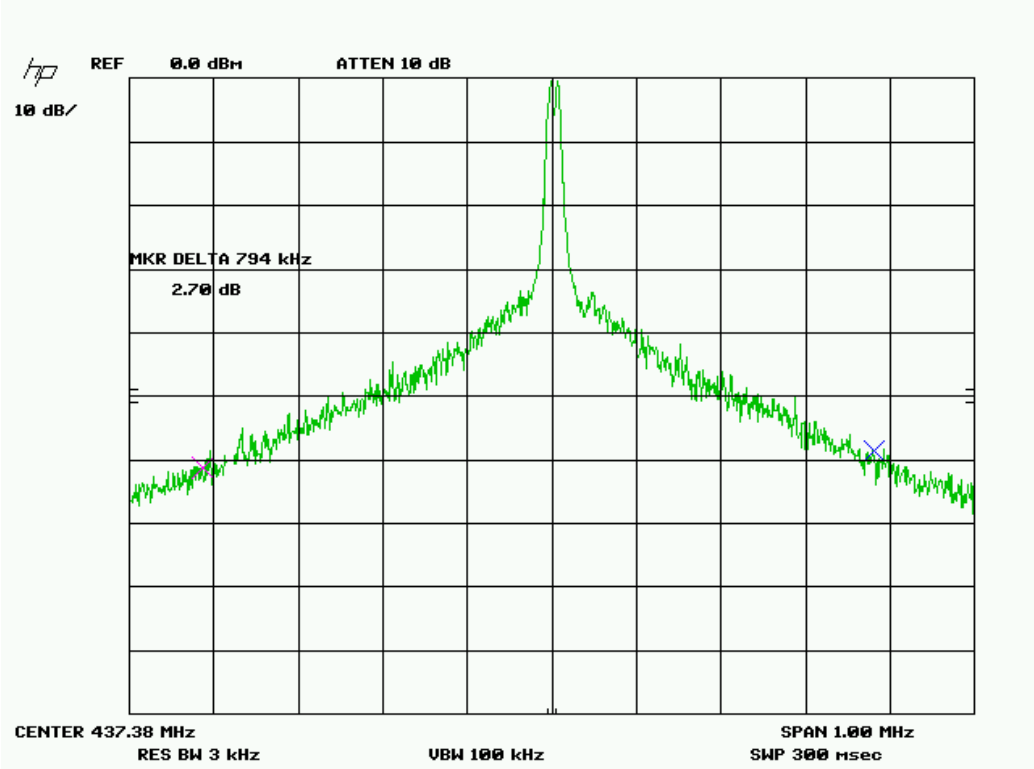

Figure 3: -60 dB Bandwidth Measurement

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Table 2: Harmonic Levels

Harmonic	dBc
1st (437 MHz)	0
2nd (874 MHz)	- 55
3rd (1,312 MHz)	- 63
4th (1,749 MHz)	> -86
5th (2,186 MHz)	> -86

The measured power delivered to the antenna terminals of the Stensat transmitter is 1.047 W (+30.2 dBm).

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BIOGRAPHICAL SKETCH

Dante Augustus Buckley was born in December of 1982 in Cincinnati, Ohio. He grew up in Cincinnati until 1991. Between 1991 and 1998, he and his family moved between Montgomery Alabama to Charleston South Carolina and Omaha Nebraska and finally resides in the state of Florida. Growing up, he was an active athlete playing baseball, basketball, football, and his favorite sport soccer. Dante is a high school graduate at Bishop Moore High School in Orlando, FL in 2001 and was a member of the 2000 State Championship soccer team. Dante met his wife-to-be at Bishop Moore. Dante became a United States Soccer Federation (USSF) referee in 1997 and is currently an aspiring State 5 USSF referee, a Florida High School Athletics Association (FHSAA) high school official, and also a National Collegiate Athletic Association (NCAA) soccer official. Additionally, Dante supports the local soccer community as a referee liaison and referee league and tournament assignor.

Dante was accepted into the University of Florida's College of Engineering in 2001. He is credited for co-founding the University of Florida's Small Satellite Design Club (SSDC) in 2005 after being selected to compete in the Frank J. Redd student competition at the 19th Annual USU/AIAA Small Satellite Conference in Logan, Utah. Dante is accountable for leading the Gator Amateur Radio Club effort by soliciting funds and technical input to upgrade the W4DFU radio station establishing the Gator Nation Earth Station. Dante became a FCC certified technician with the call-sign, KI4LDJ. Dante is the current SSDC President. SSDC's primary goal is to establish a permanent small satellite program on campus. Through Dante's leadership, SSDC focused its efforts towards winning the Annual Florida University Satellite Design competition sponsored by the Florida Space Grant Consortium and Space Florida doing so in 2008 and 2009. Dante is also credited for establishing and coordinating the Annual CubeSat Appreciation Day, which focuses a single day to create awareness of the UF and CubeSat community in high

hopes to establishing and participating in an educational outreach program CubeSats, which in return just may inspire the next generation of scientists and engineers.

Dante received his Bachelors in Science (B.S.) in Aerospace Engineering in 2006 and continued his satellite research with the Space Systems Group advised by Professor Norman Fitz-Coy. The Space System Group provides technical support to the CubeSat mission known as SwampSat. In November 2008, ASTREC, the Advanced Space Technologies Research and Engineering Center was established focusing on a paradigm to transform pico- and nano-satellite technologies for increased utility in on-orbit capabilities. Dante received his Masters of Science (M.S.) from the University of Florida in the summer of 2009. Dante plans to continue his studies at the University of Florida in pursuit of a career in the emerging small satellite sector.

Dante married his better half, Taryn Rivera, on June 28, 2008 at St. James Cathedral in Orlando, FL. Dante coaches and volunteers at Girls Place Inc. to spend time with his wife, Taryn. Taryn is the Athletic Director at Girls Place Inc. formerly known as Girls Club of Alachua County, a local non-profit organization dedicated to empowering girls of all racial, religious and economic backgrounds to grow confident, strong, and independent in order to thrive in the world around them. Dante and Taryn currently reside in Gainesville, but enjoy to travel and visit with friends and family frequently.