Microwave Reception Experiment

MRE II

MICROWAVE RECPECTION EXPERIMENT
CHARACTERIZATION OF THE 40-60 GHz BAND

Design Package

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1. ABSTRACT

MRE II, the Microwave Reception Experiment, focuses on characterizing the microwave background at stratospheric altitude in the frequency band between 55 and 65GHz via a high altitude student balloon payload that will fly for nearly 19.5 hours and reach a maximum of roughly 38.2 kilometers. MRE II is designed to use the latest passive microwave reception technology on the smallest scale ever attempted to capture and analyze these waves. The payload has to be designed to withstand a 10g vertical and two 5g horizontal shocks and provide ample thermal and vibration protection to ensure proper operation and the survival of all of the electronic equipment on board. MRE II must do this with a limited budget, weight limit of 20 kilograms, limited construction area, and 75 watt power budget.

2. SCIENTIFIC OBJECTIVES

When MRE II is fully constructed, it will be able to see, measure, process, and analyze microwaves that line in the V-Band from 55 to 65 GHz. There are relatively few sources of microwave radiation at the cruise altitude of 38.2 kilometers. These sources are:

- The cosmic microwave background
- Atmospheric emission lines (primarily oxygen, ozone, and water vapor)
- Atmospheric continuum emission
- Diffuse galactic continuum (free-free and synchrotron emission)
- Galactic line emission (primarily CO lines, but there are others)

Figure 3.1 shows the above mentioned sources as a function of the antenna temperature.

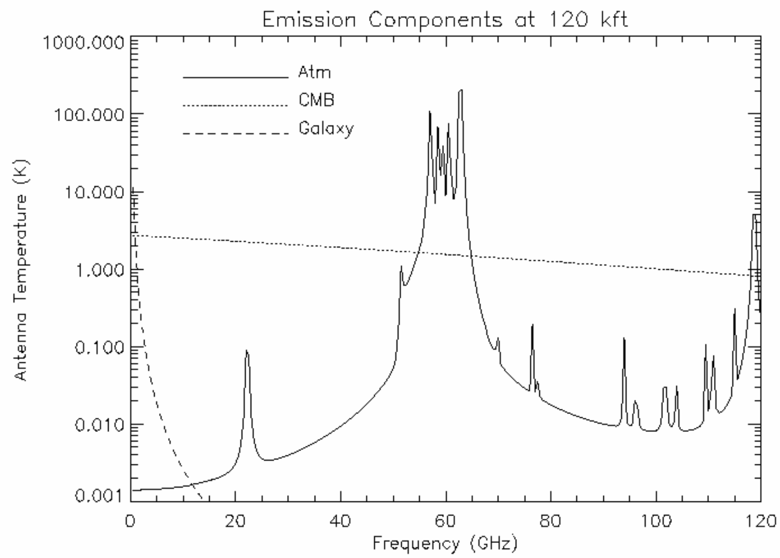

Figure 3.1: Microwave Emission Spectra Expected at Cruise Altitude,
Courtesy of Alan Kogut, Senior Engineer, WMAP

From Figure 3.1, the cosmic microwave background has a blackbody spectrum at 2.725 K. Except for the bright atmospheric lines it will be the dominant source at 120,000 feet. The atmospheric radiation is generally fainter than the CMB except for the complex of oxygen and ozone lines near 60 GHz. Galactic continuum emission spectra is negligible above a few GHz, while the Galactic line emission is fainter still. Calculations performed during the initial stages verified this and even showed that solar radiation will not adversely affect the operation of the receiver equipment. These calculations can be seen in Appendix A.

The primary area of interest for MRE II will be the center frequency band on the chart (55-65 GHz as stated above). At these frequencies, atmospheric emission lines will dominate. The atmospheric lines are pretty narrow at these frequencies, requiring the designed receiver to have at least 1 GHz of spectral resolution to see anything of significance. Anything broader will lump the complex of lines near 60 GHz into one big bump when processed. The data collected from this experiment would be used as design data for a future cryogenically cooled receiver that would be able to see with precision the CMB.

3. Flight Information

4.1 INTRODUCTION

The most important information that is utilized for designing the systems incorporated for MRE II is the flight information. The vibration analysis requires the horizontal wind data to determine the frequencies of oscillation due to vortex shedding. The thermal analysis requires property data to determine the heat lost during the flight and the heat load on the heaters. It is therefore critical to have all of this data centralized and available for both of these analyzes. This section will explain how the data was obtained and show the most critical properties and data in various figures. Appendix B gives the equations for the data as well as plots for all of the data on the worksheet entitled “Flight Profile for HASP Flight Based on U.S. Standard Atmosphere, 1976”.

4.2 PROVIDED FLIGHT DATA

The data obtained from HASP and used for analysis purposes was from the previous year's flight (2007).HASP provided little in the way of flight data though. On the HASP website, HASP only has listed the altitude for a given time. The altitude data is very limited; the times vary greatly between altitude readings. The previous year's flight data showed that the balloon was in the air for 19.04 hours. The takeoff altitude was 1270 kilometers. The last altitude given by HASP was 13.58 kilometers; this was far short of the actual landing altitude. Therefore, the last altitude was lowered to roughly 3.54 kilometers, which extended the flight time to just over 19.3 hours. The original flight data is given in Appendix B on the worksheet "HASP Flight Data." The flight data was data was linearized to help simplify the different analyzes performed. Linear equations best represented the flight profile. The flight profile from the developed equations is given below in Figure 4.1.

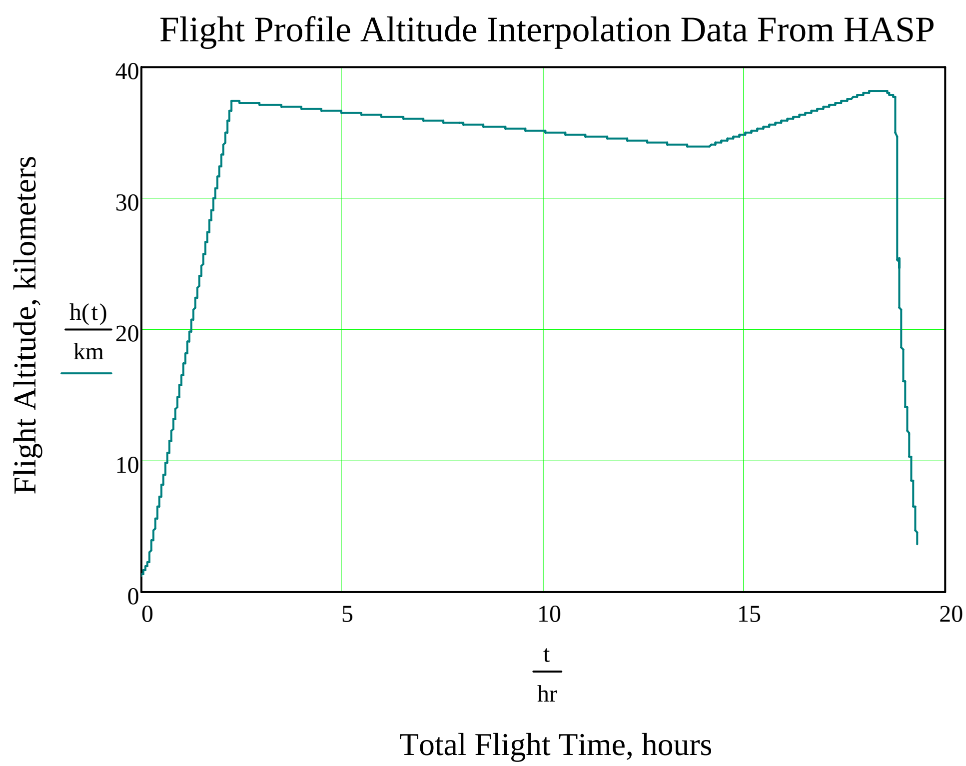

Figure 4.1: Flight Profile Data from HASP Flight 2007

4.3 WIND DATA AND VERTICAL BALLOON VELOCITY DATA

The vertical velocity of the balloon and the wind data are the most important pieces of data used in the design of the payload. The wind data is used to determine the frequencies of oscillation for the vibration analysis. The wind data and the balloon velocity are used for determining the convective heat transfer of the payload. The vertical wind data is simply taken from rate of change of the altitude data.

The [horizontal] wind data is taken from two different sources. The first source is rocket sounding data of the wind profile above the Pacific Missile Range in California in 1960 (Appendix L, High Altitude Wind Data from Meteorological Rockets). This data was used from 15 kilometers to the maximum altitude of the flight. The wind data for lower altitudes was taken from real time laser ranging data above White Sands, New

Mexico. This data was available from the NOAA Profiler Network and provide in Appendix L ("Lower Altitude Wind Data for White Sands, New Mexico from NOAA Profiler Network"). The data is averaged (12 hours).

The wind and velocity data are linearized and defined as functions of the altitude. A plot of the wind and velocity as a function of the total flight time is given below in Figure 4.2. Vi is the horizontal wind, and Vj is the balloon speed.

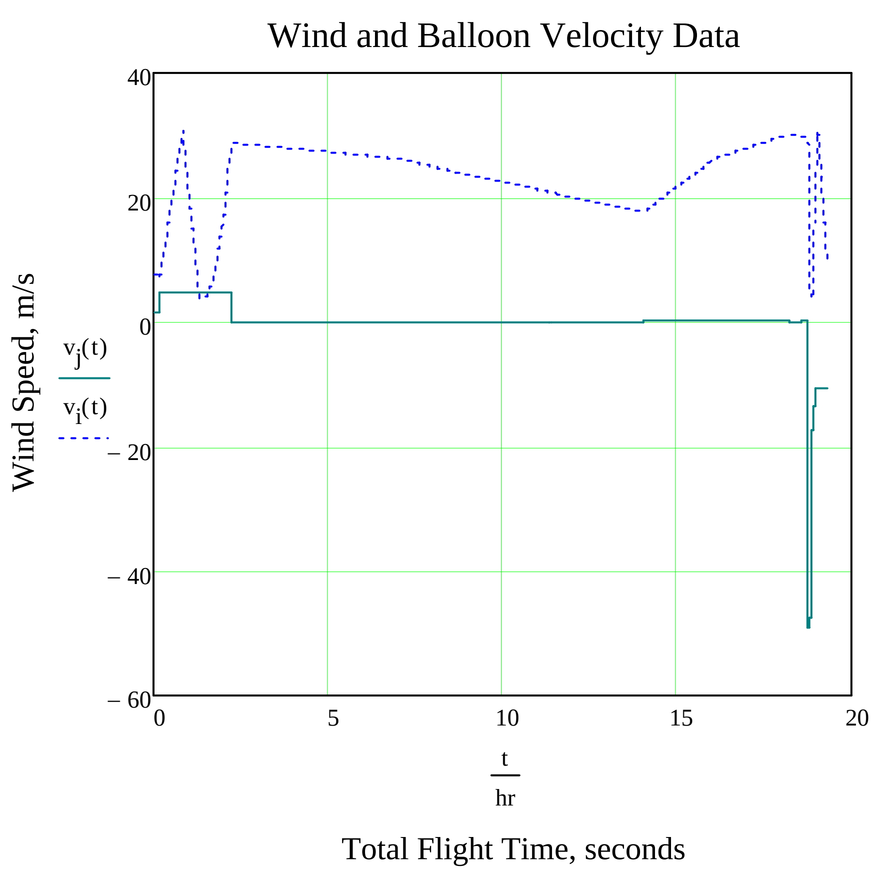

Figure 4.2: Wind and Balloon Velocity Data given as a Function of Time

4.3 AIR PROPERTY DATA

The air property data is important for the thermal analysis because the equations that govern heat transfer require the temperature, thermal conductivity, dynamic viscosity, pressure, and density of the air at all of the particular points of the flight. All of this data is taken from the 1976 US Standard Atmosphere. The 1976 air standard data was available from open source Matlab code which is available in Appendix B. The air property data was outputted from the code as a function of altitude. This data was then taken and fitted either with linear equations (temperature, thermal conductivity, and dynamic viscosity) or exponential equations (pressure, density). All figures of this data are presented in Appendix B.

4. Payload Structural Design and Construction

5.1 INTRODUCTION

The MRE II payload structure must be designed to the criteria given by HASP. The payload also has to be large enough to enclosure and protect sensitive microwave reception equipment and processing equipment. The payload has to survive the harsh environment during flight and shock that occurs at landing. The MRE II payload structure consists of the following assemblies which will be described in detail later in this section: payload shell assembly, antenna enclosure, insulation panels, and support structure. This section describes in detail the structural requirements that these assemblies must meet outlined by HASP, materials selected for construction, design of each part, and the construction of the payload assembly. Detailed part and assembly drawings with proper dimensioning and fabrication notes are provided in Appendix C. The HASP requirements for the design are given in Appendix L ("HASP Interface Manual Version 2/08/08").

5.2 DESIGN REQUIREMENTS

As stated before in the objectives, the payload is one of four 20 kilogram large class student payloads on the balloon system. All components must be included in the weight budget except the mounting plate. The large payload must fit within the large payload mounting plate mounting area. The diagram for the large mounting plate is given below in Figure 5.1.

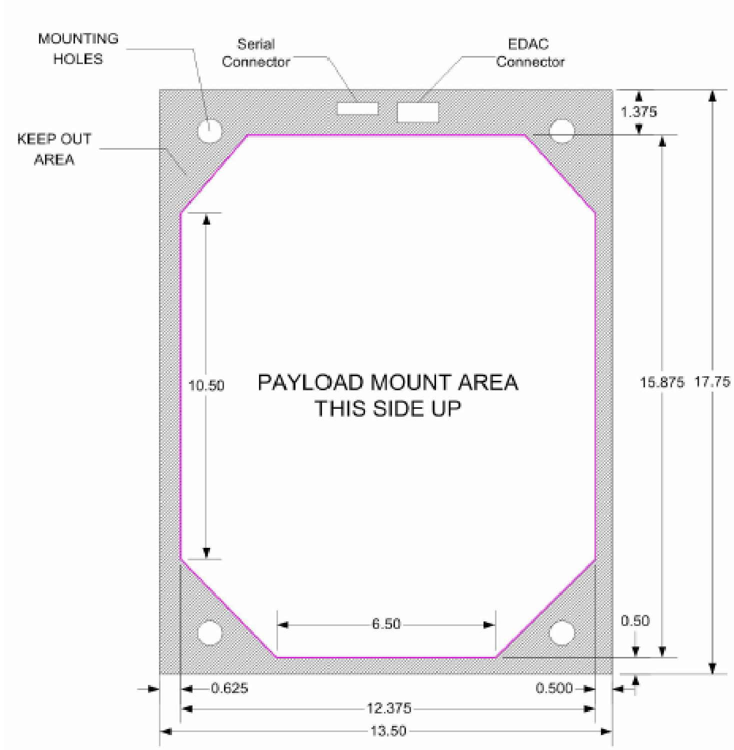

Figure 5.1: Large Payload Mounting Plate

The mounting plate allows for an octagon shaped design with overall square dimensions of 12 3/8 inches by 15 7/8 inches. No overhang is allowed into the shaded area below two inches. The payload cannot be taller than one foot, although exceptions are allowed. MRE II exceeds the height requirements by 2 7/16 inches. This extra distance is necessary for the antenna to have a clear view of the sky and for all of the equipment to fit inside. HASP also dictates that the payload structure must be able to withstand a 10g vertical shock and two 5g vertical shocks.

5.3 MATERIALS OF CONSTRUCTION

The materials for this project have been selected to withstand the physical requirements given in the initial project overview. The materials have been selected and sized with a factor of safety in order to safely survive the given conditions. Most of the material selection and sizing have come from decisions based on general commercial and industrial practices.

5.3a ALUMINUM

The payload structure solely consists of Aluminum alloys. This decision rests on the fact that Aluminum alloys are the most cost effective option for strong, light weight, structures. Aluminum also makes no ductile-brittle transition at sub-zero temperatures, meaning there will be little to no loss of strength during the flight. Aluminum alloys are also readily available in many compositions from most metal suppliers. This payload structure consists of the following Aluminum alloy compositions: 3003, 5052, and 6061. A list of the Aluminum alloys, sizes, and mechanical data selected for this project are shown in Table 5-1, below.

Table 5-1: Selected Alloys, Sizes, and Mechanical Data

Gauge	Aluminum Alloy	Specification Code	Temper	Yield Strength (ksi)	Ultimate Tensile Strength (ksi)
0.0625"	3003	AMS-QQ-A-250/2	H14	21	22
0.0250"	3003	AMS-QQ-A-250/2	H14	21	22
0.1250"	5052	ASTM B209-07	H32	28	33
0.1250"	6061		T4	16	30

The mechanical data shown in the table above supports certain design decisions made in this project. The 3003-H14, available in coil, plate, and sheet is often used in sheet metal work. It is corrosion resistant and has excellent formability. The 3003 alloy was used for the pieces which are simply coverings or barriers from the environment. The 5052-H32 alloy is also available in coil, plate, and sheet. It maintains a high fatigue strength which makes it a good choice for structures with excessive vibration. It is also corrosion resistant and has excellent formability. The parts which are considered structural pieces are made of the 5052 alloy, except for the internal extruded angle member. The internal vertical support columns are made from extruded 6061 Aluminum alloy. This alloy can be extruded to form continuous shapes. This is the reason it was selected for the vertical support columns. It is also capable of being welded without excessive deformation due to heat.

5.3b EXPANDED POLYSTYRENE

The insulation material selected for this project is expanded polystyrene. It is essentially STYROFOAM board. EPS, expanded polystyrene, is a solid plastic which is blown into foam using a blowing agent. It consists of 90-95% polystyrene and 5-10% gaseous blowing agent. The board is placed along the inside surface of the walls and top of the payload. This board will also give the payload shell some damping effect from wind vibration on the outside of the payload. EPS has nominal strength properties that are best utilized when they are in compression. The strength properties of EPS are sufficient for the overall design of the payload. EPS is more important from a design standpoint thermally as it is an excellent insulator and will help keep the heat in and reduce the heat load on the heaters. It is formable by cutting and shaving with a razor knife. It can be purchased in different sizes. This project used the 1” expanded polystyrene board.

5.3c FASTENERS

The selection of metal fasteners involved the issues of weight, function, and cost. The first decision was to select a readily available carbon steel bolt and nut to rigidly attach the structural parts to one another. Aluminum bolts were not selected despite their potential weight saving benefits because their strength would not have been enough to safely secure the payload together. Grade 5 5/16” and #6 bolts were used. The 5/16” bolts are either 3/4” or 9/16” long (depending on their location) hex head bolt with accompanying nut. The Grade 5 bolts are made of medium carbon steel. These bolts have yield strengths of 85 ksi, well above any expected stress developed (see the stress analysis section for verification of this). The #6 bolts (.138” diameter) are used to fasten the top to the sides and are used in this role as opposed to rivets so the top can easily be taken off repeatedly. Using rivets would require drilling them out each time the top was taken off. These bolts are not structural. Figure 5-2 is a picture of the 5/16” bolt used in this project.

Figure 5-2: 5/16” dia., 0.75” long bolt

The decision for the attachment of the sheet metal to the structural parts (corners) led to the implementation of metal pop-rivets. The use of rivets in general minimizes weight when compared to using bolts in this situation. There are a total of 176 rivets, and that many bolts, undoubtedly steel, would weigh at least three times as much. Aluminum pop rivets where used instead of stainless steel pop rivets. The stainless steel rivets are much stronger but also much heavier. The high strength was not need for this application as the sides and ends are not load bearing members. The 3003 aluminum sheet metal, which makes up the outer payload shell covering, required a large number of rivets to attach it to the structural supports. The light weight and low cost of the aluminum rivets sealed the decision. However, the sizing of the rivets required some thought. The project needed a rivet that would securely attach the sides and ends to the corners. Therefore, the decision was made to use a 1/8" diameter rivet with a 1/8" grip length. This grip length was a critical dimension. If the grip length is too large, the rivet would not compress the mating materials together. However, if it is too small, the rivet would fall short of the required length to grip the two mating materials. Figure 5-3 displays a pop-rivet before and after it has been compressed using a pop-rivet gun.

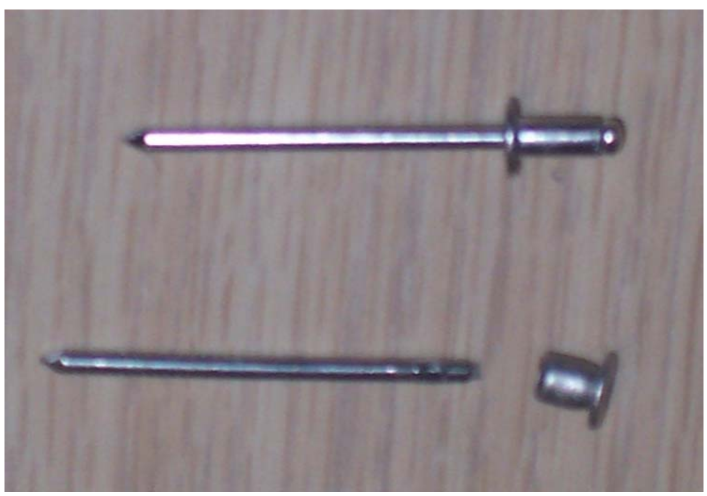

Figure 5-3: Pop-rivet before and after use.

Glue is used in the construction of the antenna enclosure and for securing it to the payload. The type of glue used here is Gorilla Glue. When Gorilla Glue dries, to looks very much like Styrofoam and can be worked the same. Gorilla Glue is very hard, though. Because Gorilla Glue dries like foam, it is unaffected by temperature extremes (this was verified two years ago on the MRE project). These two properties, plus the fact that Gorilla Glues anything to anything, make Gorilla Glue the perfect adhesive for this project. Gorilla Glue is not used on any structural parts. The material data sheet is given in Appendix D.

5.4 PAYLOAD SHELL ASSEMBLY

The Payload Shell assembly is really no more than a glorified box to house electronic equipment in. The payload shell consists of the following parts: long corner, short corner, side panels, long end panel, short end panel, top, top frame, base brackets, and top brackets.

5.4a LONG AND SHORT CORNERS

The both the long corner and short corner (of which there are two each) are the main structural load bearing components of the payload shell. These pieces have to be robust in order to handle the shock received at impact. Both corners are made of 1/8" Aluminum 5052-H32 that spans the whole corner area allowed by the mounting plate. Each corner has three faces; the two short faces are bent at 45 degrees from the longest face inward. Both of these short faces are 1.025 inches long. The third, as stated previously, spans the whole corner, and its length depends on the allowable mounting area for the corner. Each corner is also 12 1/16" high. The extra 1/16" is used to recess the piece into the mounting plate to create a seal to limit air entering the payload and to reduce vibration. Each corner has a 5/16" bolt hole drilled into it 2 9/16" from its base on the longest side to allow them to be secured to the base plate. The bolt is placed at this height because no overhang is allowed lower than 2" above the base plate. The two short sides have twenty two equally space 1/8" holes for rivets that are used to secure the side panels to the assembly. Two additional holes at the top of the corners are bolt holes used to help secure the top the rest of the assembly.

5.4c SIDE AND END PANELS

The sides and end panels help tie the shell assembly together. While these pieces do not carry any load, they are necessary to solidify the structure for stability and to close the system thermally. Each panel is made of .025" thick Aluminum 3003-H14. Each piece is 12 1/16" tall, with the 1/16" to minimize vibration as before via recession in the mounting plate. The length of the side panels are the same, but the ends vary because of the mounting plate restriction. Both the ends and the two side panels are secured to the corners with 1/8" rivets.

5.4d BASE AND TOP BRACKETS

The four base brackets used in the shell assembly are to secure the entire shell assembly to the mounting plate, while the four top brackets secure the top and top frame to the corners. The base brackets are made from 1/8" thick Aluminum 5052-H32. The base brackets are unequal legs 3" by 1" with 5/16" holes for bolts placed centered at 2.5" on the long leg and ½" on the short leg. The top brackets are one inch equal leg angles 1/8" thick made from Aluminum 6061-T4. The top brackets are brazed to the corners 1/8" from the top of the corners to allow the top frame to sit flush. 5/16" bolt holes are placed 3/8" from the ends for securing the top and top frame to the assembly.

5.4e TOP FRAME

The most complex piece of the entire payload, the top frame had to be cut out via a water jet. The top frame also is a major load bearing piece as it will have to absorb a large amount of stress due to the reaction of the payload to the impact. The top frame is made from 1/8” Aluminum 5052. The top frame is modeled after the allowable mounting area, but with two exceptions. First, the frame is made to fit inside the sides and corners, so it is .025” shorter on the each side and end and 1/8” shorter in the corners than the allowable area. Second, the top frame is offset inward an additional 1/16” to allow for any issues that may arise in the manufacturing of the parts. The top frame consists of a 1” outer rim where holes for mounting to the top brackets and cut-outs to allow the tie-in of the side and end insulating panels are located. In the center area, the frame has various cut-outs to allow for the top insulating panel to tie-in to the frame. The panels are tied-in to the shell to help create a good thermal seal. Also, one of the cut-outs in the center area (located by the bar that runs into one of the corners) allows the antenna to protrude from the inner cavity of the shell. This cut-out measures approximately 3.75” by 5”. The main reason for all of the cut-outs is not for tying in insulation to the frame; rather, the cut-outs are a weight saving measure as over 65% of the original frame was removed. These cut-outs have the adverse effect of creating multiple stress risers, though, and are thoroughly analyzed in the stress analysis performed. Please refer to the next section of the report for this data.

5.4f TOP

The last piece of the shell assembly, the top is made from .025” thick Aluminum 3003-H14. The top’s primary function is to finalize the thermal seal on the box. Its secondary application is to completely solidify the structure to help reduce vibration. The top is the same overall size as the allowable mounting area with a one inch overhang all the way around. This overhang is bent flush with the sides and corners. The overhang is used to create a better thermal seal and to secure the top to the sides and corners of the payload. This is accomplished with #6 bolts. The top is secured to the top frame with 5/16" bolts. The top also has a cut-out for the antenna the same size as the cut-out is on the top frame.

5.5 ANTENNA ENCLOSURE ASSEMBLY

The antenna enclosure assembly is the next major assembly of the payload. The antenna enclosure, constructed from 3/16" foam core, consists of seven different parts: back, base, cover, Mylar viewing pane, right side panel, left side panel, and top. The assembly is 2 7/16" tall, 4.75" wide, and 6" long. The base has a cut-out area that is the same as the top frame's and top. The cover also has a cut-out area that measures 4.25" wide by 2.94" long. The Mylar viewing pane fits over the cover and is secured via Gorilla Glue. The viewing pane is made from Mylar because it allows the light (radiation) to enter the antenna enclosure without distorting the microwaves. The side panels, top, and back are just solid pieces of foam core cut to fit and tie the assembly together. The assembly is glued together with Gorilla Glue. It is not stress tested as it is a noncritical assembly.

5.6 INSULATING PANEL ASSEMBLY

The insulating panel assembly helps control the heat transfer in and out of the interior of the shell assembly. The assembly also adds strength to the overall structure as it will be in a continuous state of compression due to the panels acting as columns for the top frame. The insulating panels are made from one inch thick expanded polystyrene insulation. There are seven parts that make up the insulating panel assembly: top, sides (2), short end, long end, short corner (2), and long corner (2). The insulating panels are made to fit securely and tight inside the payload shell assembly.

The insulating panel assembly has no appreciable gap between it and the sides of the shell assembly (>.01”). The only variance from this is the 1/8” indentation on the end and side panels to allow for proper clearance for the rivets. The sides and ends are 11 7/8” tall with 1/8” extensions that fit into the top frame. These extensions help to structurally tie the insulating panels to the payload shell and aid in sealing thermally the cavity from the outside environment. The corners have a 3”x1” section removed from the bottom to allow access to the base brackets when assembled. The corners are only 10” tall allow access to the top brackets. The top insulating panel has an overall thickness of 1” with several 1/8” recessions to allow the top frame to sit flush in it. The top insulation panel also has a 3.75” by 5” cut-out to allow for the antenna to protrude through to the top. The top insulation panel has 1” long “fingers” that recess into the side and end panels for a secure fit.

5.7 SUPPORT STRUCTURE ASSEMBLY

The support structure holds and secures all of the electronic equipment (microwave reception, processing, and data storage) within the payload. This fact alone makes the support structure a critically stressed and vibrated assembly. Both of these analyzes are seen later in the report. The support structure has four major components: angled support columns (4), platform tie-ins (12), sensor platform, and platform. Unfortunately, the support structure is to be considered an “incomplete” design. This is due to the lack of equipment specifications from the unavailability of funds. The equipment specifications could only be provided with money available to purchase the equipment, and as of this time, has yet to be accomplished. Therefore, the design of this structure is based on the limited equipment specifications made available from Millimeter Wave’s website (all of the equipment specifications are given in Appendix F).

The support columns are 1/8” thick 1” equal leg angles made from Aluminum 6061-T4. The columns are recessed into the mounting plate 1/16” to reduce vibration. The columns are secured to the mounting plate via four of the platform tie-ins with 5/16” bolts. The platform tie-ins are to be brazed or welded to the columns to eliminate any holes into the columns that might weaken the structure. The platform tie-ins are 1/8” thick 1” by 1” and made from Aluminum 5052-H32. The platform tie-ins are also used to secure the sensor platform and platform to the structure. The platforms are bolted to the tie-ins with 5/16” bolts. The sensor platform measures 7.5” by 11” and will sit nearly flush with the top of the columns. How flush or not the sensor platform sits will depend on actual the equipment specifications. The platform will sit lower on the structure and hold the processing and data storage equipment. The platform has the same overall dimensions as the sensor platform but also has an inch added to each end and 7/8” to each side. These extensions are added so a wide range of sizes on processing units (possibly a computer motherboard) could be used. Both the sensor platform and platform are manufactured from 1/16” Aluminum 3003-H14.

5. Thermal Design

6.1 INTRODUCTION

MRE II was established to characterize the noise that occurs in the 55-65 GHz range. In order to acquire this data, very sensitive receiver equipment will be used. The components that comprise the receiver require different operational temperatures which range from -50°C to 50°C. This posed a problem since the temperature during the flight, which will go up 38,000 meters, can reach below -50°C. Thus a thermal system had to be designed and built that can keep the payload's inner temperature within optimal operating range for all the components contained.

6.2 DESIGN CONSTRAINTS

The payload design had size, shape, weight, and power constraints that also affect the design of the thermal system. The thermal system had to be small enough to fit inside the payload yet still have enough room for the receiving equipment. The amount of power that runs the system either has to be supplied separately from the main system or be low enough that the same power source can be used to power the main equipment and heating system without any negative repercussions. The weight of the heaters had to be miniscule to allow enough weight in the budget to support the payload's structure and receiver equipment. The heaters also have to be able to produce enough heat to actually keep the box from falling below desired internal temperatures. Some of the constraints posed by the project were easily solved, while others took time to get around. All of the constraints had to be addressed if the project was going to work.

6.3 HEATER DESIGN

The first issue addressed during the design was the type of heater that would be used for the project. Two types of heating elements were considered: a polymer coated power resistor that can be custom made to cover the interior walls of the payload and a power resistor. The first resistor considered was suggested by Dr. Chandra. He had personally used this style of resistors for some of his research, and was a favored choice for the project. It solved the spacing and weight constraints that needed to be addressed. Figure 6.1 displays the flat polymer heater.

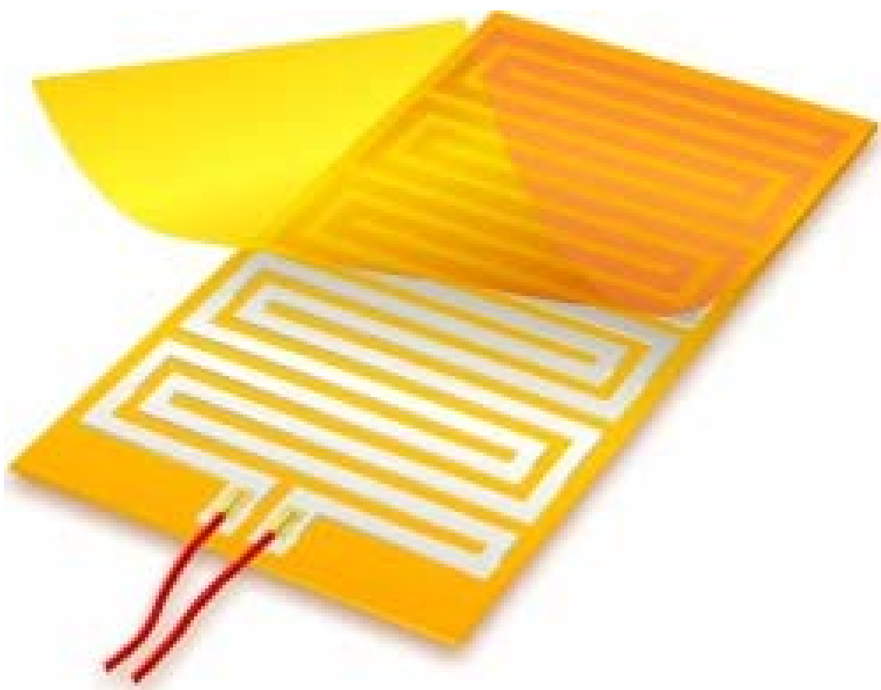

Figure 6.1: Flat Resistive Heater from Minco

The manufacturer was contacted and it was discovered that the amount of energy that would be needed to drive such a system would be infeasible with our space, weight, and power limitations. The latter heating element was a power resistor. Power resistors were used by some of the team members in the past for a similar project and they worked better than expected on that project. Figure 6.2 displays the power resistor.

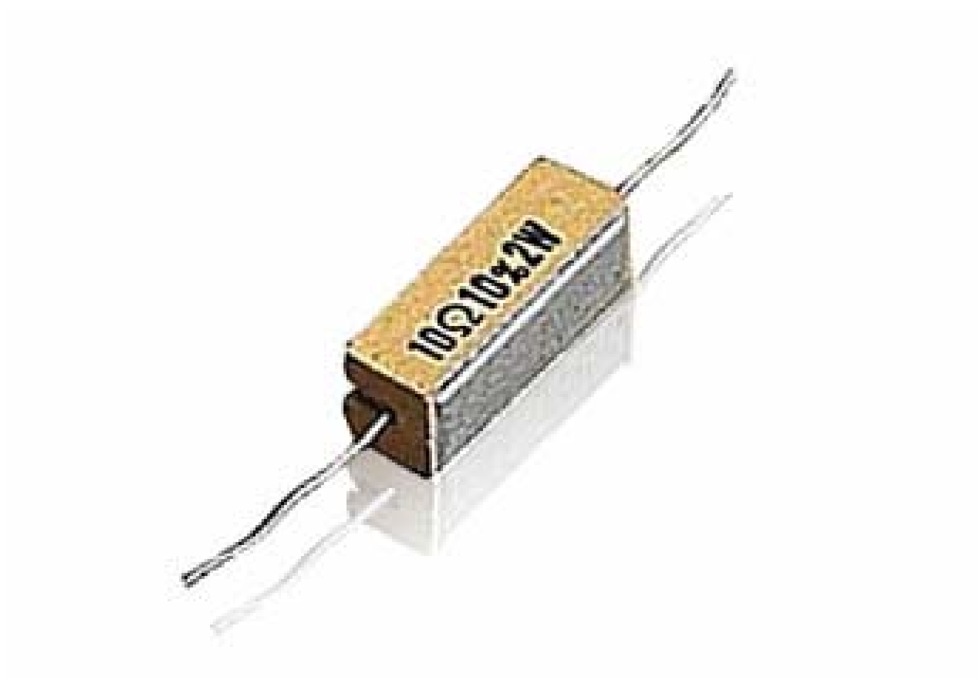

Figure 6.2: Wirewound Power Resistor from Radioshack

The payload for this experiment is much larger than any previous payloads built by some of the members, in order to accommodate this four times the amount of heaters will be used. In order to accommodate power usage two sets of 50 ohm power resistors will start at 15°C and cut off at 27°C. Those two sets are called the primary resistor set. The secondary resistor set, with resistances of 12 ohm each, will start at 10°C and cut off at 20°C which reduces the amount of energy that is necessary to the thermal system.

6.4 POWER SUPPLY

The thermal system will be powered by D sized lithium ion batteries that are used for military projects going into the atmosphere. Figure 6.3 displays the military grade D batteries used for the project.

Figure 6.3: LS 33600C Saft D Batteries

The primary system will use 6 of these batteries in series, and the secondary will use 3 series. The secondary system will use fewer batteries since the secondary system is not expected to run as long as the primary system. The primary system however is designed to run for the whole flight time just in case such a scenario was to occur. The power output from these batteries is acquired from Ohm's Law which allows for the life of the batteries to be determined as well. Those equations are displayed in the Appendix F "Battery Life Calculations."

6.5 THERMAL SYSTEM CONTROLLER

A Basic Stamp microcontroller was used as the controller for starting and stopping the thermal system. The Basic Stamp will have an eprom of 16kb, which will store the temperature data that it records during testing and flight, which will further validate the effectiveness of the heating system. Figure 6.4 displays the basic stamp board that will be used to control the system.

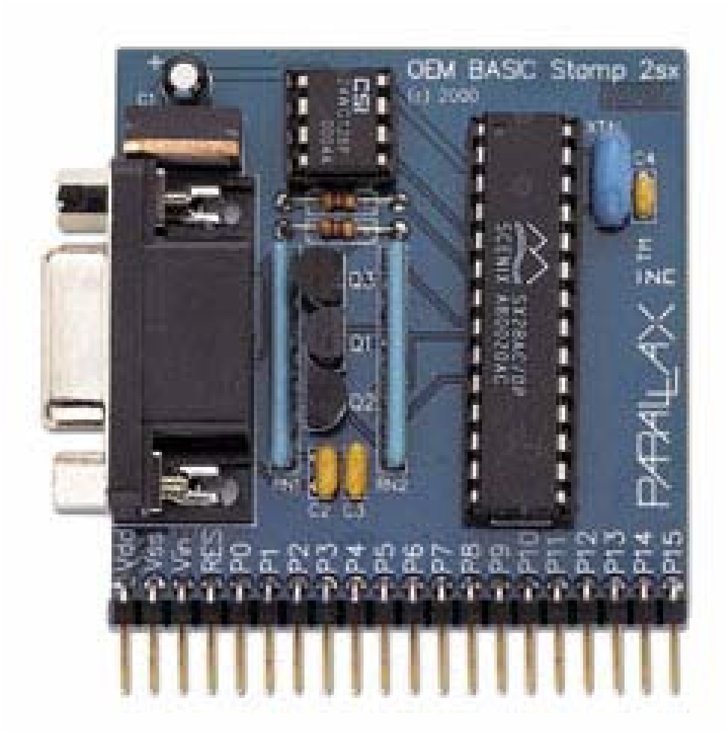

Figure 6.4: Basic Stamp Board

The Basic Stamp board will be powered by two 9 volt batteries in parallel, which will be of the same military quality as the D sized batteries. Figure 6.5 displays 9v batteries.

Figure 6.5: Military Grade 9 Volt Batteries from Saft

6.6 TEMPERATURE SENSORS

Two temperature sensors will be used. In the event that one of the sensors fails, the system can continue to operate. The temperature sensors will be kept in the center of the payload near the receiving equipment. Figure 6.6 displays the temperature sensor used.

Figure 6.6: AD590KF IC thermal sensors

6.7 INSULATION

Due to the constraint on power, space, and weight, the payload needed another way to either conserve or amplify the energy used. Insulation was the lightest, cheapest, and most efficient way to improve the payload’s heat retention without adding more heaters or dramatically increasing weight. Expanded Polystyrene was the type of insulation chosen due to its light weight and its thermal resistance. Figure 6.7 displays the payload with the polystyrene insulation arranged around the interior of the box.

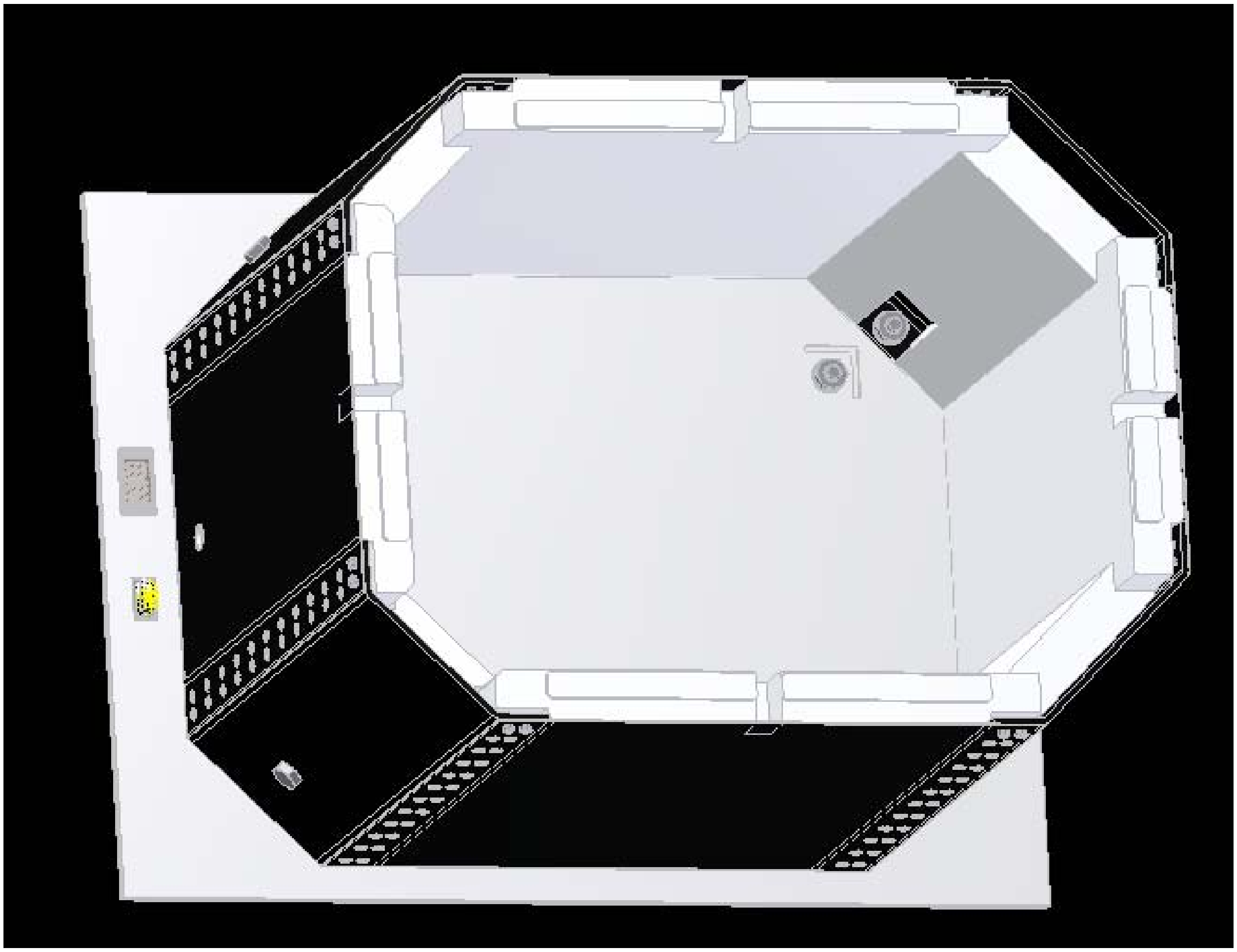

Figure 6.7: Payload with Insulation

6.8 SYSTEM PROGRAM DESIGN

With the heating element design finished, the program that will run the system was created. The Basic Stamp program's main objective is to check the temperature reading given from the two temperature sensors in the center of the box and record it every 20 seconds. If the temperature readout from the temperature sensor falls below 15°C it will divert voltage, using a transistor, to the primary heating system until the temperature sensor reaches above 27°C. If the primary heating system cannot keep the boxes temperature from dropping, then the temperature sensor will send a signal to the basic stamp to start the secondary system when the temperature is below 10°C.

The secondary system will shut off at 20°C. This program is written in pbasic and is mirrored from the pbasic code used in the LaACES project two years ago. Basic Stamp code has to also be written to extract the data recorded from the EEprom to a computer. This code was modified from the LaAces project as well. Both of these codes are given in Appendix F.

6. Microwave Radiometer Design

7.1 INTRODUCTION

The project requires a radiometer capable of detecting microwave radiation in the gigahertz frequency range. A radiometer is fundamentally a very sensitive calibrated receiver for measuring electromagnetic noise emitted by the environment. The equipment to be used in the design must conform to size and weight constraints set forth by HASP. The design described below was chosen due to its price and size of equipment.

7.2 DESIGN

The chosen design for the receiver is shown below in Figure 7.1. The schematic was acquired from Millimeter Wave. Millimeter Wave was the chosen company to provide the equipment for the receiver due to the price and experience of staff.

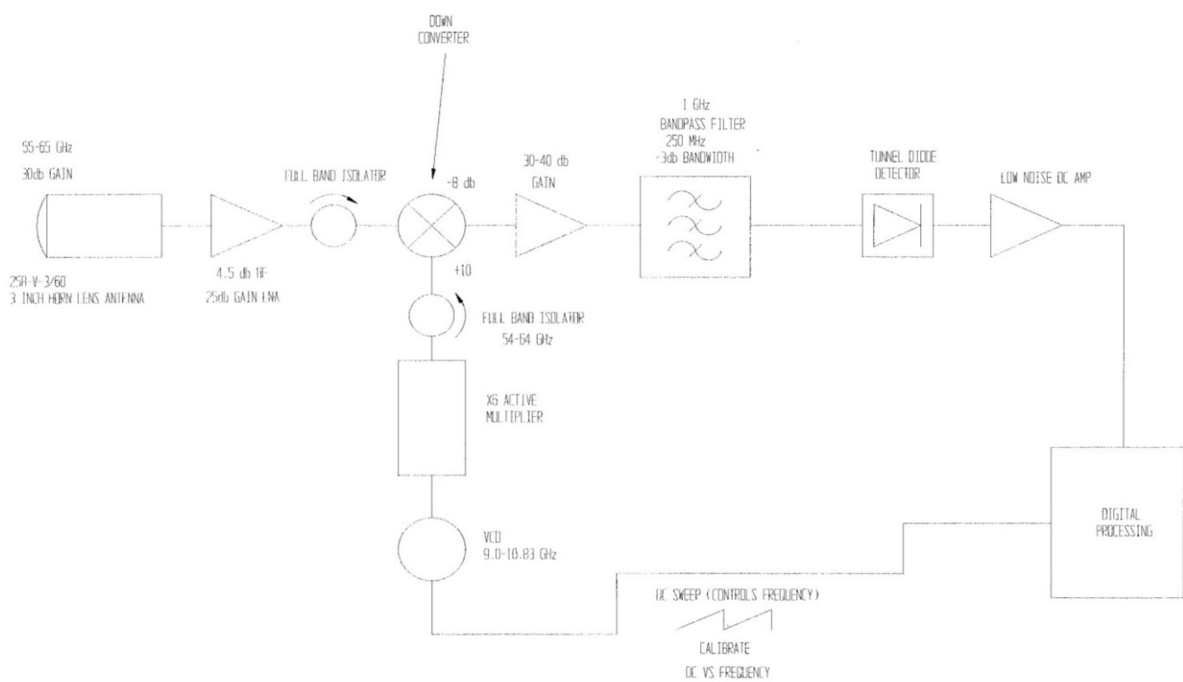

Figure 7-1: Millimeter 55-65 GHz Radiometer Schematic

7.3 EQUIPMENT SPECIFICATIONS

Figure 7-1gives schematically the layout of the equipment. The equipment used in this design are: Horn Lens Antenna, Low Noise Amplifier, Mixer, Voltage Controlled Oscillator, Multiplier, Band Pass Filter, and Detector. All of the specifications of the equipment listed above are given in Appendix G.

7.3a HORN LENS ANTENNA

The antenna used in this design is a three inch horn lens antenna. It is designed to provide 30 decibels of gain to intensify the signal. The horn design was chosen due to its frequent use in reception of microwave radiation and its affordability.

7.3b LOW NOISE AMPLIFIER

A Low Noise Amplifier (LNA) is implemented immediately after the antenna to reduce noise and amplify the desired signal (55-65GHz). It reduces noise by filtering out frequencies not desired for measurement. The LNA provides an amplification of 25 decibels. It also introduces an amount of noise estimated to be approximately 4.5 decibels.

7.3c MIXER AND BANDPASS FILTER

The mixer is used as a down converter to decrease the intensity of the signal to a frequency that the processing system can handle. The mixer accepts two signals (one from the antenna and the other generated by an oscillator) and as a result gives out two different signals. One of the resulting signals has a frequency that is the sum of the frequencies of the two incoming signals. The other output signal is one with a frequency resulting from the difference of the frequencies of the incoming signals. In our design the difference will result in a signal with a frequency of 1GHz. This is the output signal desired for this project. To select this signal, the mixer is followed by a bandpass filter designed to only accept a signal with a frequency of 1GHz.

7.3d VOLTAGE CONTROLLED OSCILLATOR

The mixer requires a generated signal in the range of 54 to 64 GHz. To create this signal, the receiver uses a voltage controlled oscillator (VCO).The VCO outputs signals with different frequencies. Since the frequencies of the output signals are smaller than desired, the output from the oscillator is sent to a multiplier to raise the frequencies to the desired range. These signals are then sent to the mixer to be combined with the signal from the antenna.

7.3e OUTPUT

The signal from the mixer is passed through a filter which only allows signals with approximately a 1GHz frequency. This filters out much of the noise introduced from the mixer. The remaining signal is picked up by a tunnel diode detector. The detector then measures the amount of power in the signal.

7. Data Acquisition Design

8.1 INTRODUCTION

From the radiometer, the signal after mixing and amplification will be at an IF frequency of 1 GHz. This frequency is accepted into a detector that will process and convert the signal into peak voltage levels. The signal is then converted into a digital waveform which will be processed and stored by the digital equipment. A flow diagram depicting this process is shown below in Figure 8.1.

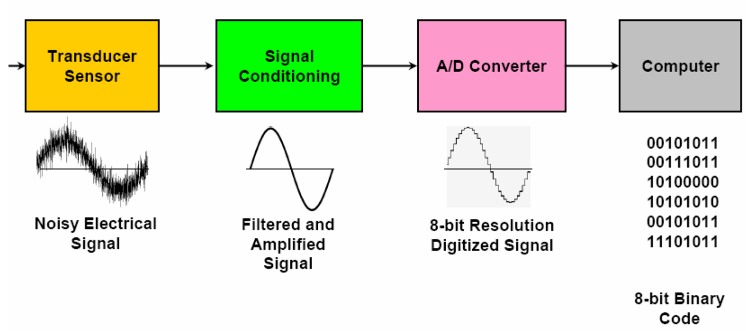

Figure 8.1: Process Flow Diagram for Data Acquisition System

Also key to the data acquisition system is the Sawtooth Waveform Generator that controls the VCO discussed in the previous section. The SWG helps the voltage level for the VCO and, via the use of a clock and timing circuit, indicates the frequency of the incoming signal.

8.2 EQUIPMENT

The data acquisition system uses six major components to accomplish its task. These components are: Detector, Analog to Digital Converter, Microcontroller, and Data Storage.

8.2a DETECTOR

After the signals are received and filtered from the radiometer, the LTC5507, a temperature-compensated Schottky diode peak detector and buffer amplifier detector, converts the .85 GHz to 1.15 GHz IF frequency to analog peak voltage signals. The LTC5507 integrates several functions to provide RF power detection over frequencies up to 1000MHz. These functions include an internally compensated buffer amplifier, an RF Schottky diode peak detector, and level shift amplifier to convert the RF signal to DC. A delay circuit is included to avoid voltage transients at VOUT when coming out of shutdown. A gain compression circuit is also included to extend the detector dynamic range. An electrical diagram of the detector is shown below in Figure 8.2

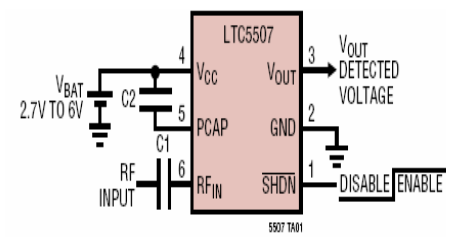

Figure 8.2: LTC5507 Schottky Tunnel Diode Detector

The internal RF Schottky diode peak detector and level shift amplifier converts the RF input signal to a low frequency signal. The frequency range of the RF pin is typically up to 1000 MHz. The specified detector has excellent operation over a wide range of input powers. The Schottky detector is biased at about 70mA. The hold capacitor is external for this system.

The gain compression circuit changes the feedback ratio as the RF peak-detected input voltage increases above 60mV. Below 60mV, the DC voltage gain from the peak detector to the buffer output is 4. Above 140mV, the DC voltage gain is reduced to 0.75. The compression expands the low power detector range due to higher gain. The gain compression circuit is seen schematically below in Figure 8.3.

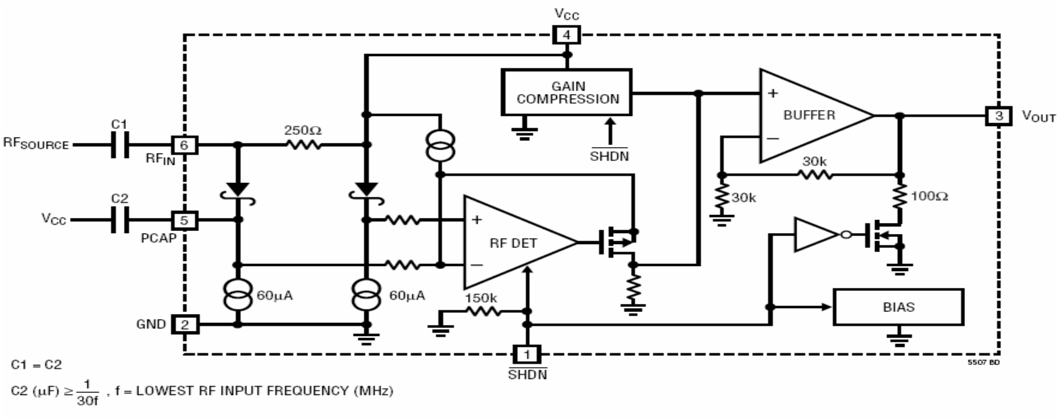

Figure 8.3: Gain Compression Circuit Schematic

The RF input power (dBm) can be converted into watts by solving for P_1 using P_0 equal to 1mW for reference. This is expressed mathematically via Equation 8.1.

RF Input Power, dBm: $$L_{\mathrm{dB}} = 10\log_{10}\left(\frac{P_1}{P_0}\right)$$ Equation 8.1

From Equation 8.1, the system will be able to receive signal power levels ranging between -34dbm and 14 dbm. This equates to power levels from $4*10^7$ W to .25 W. The voltage output of the system will be determined from Equation 8.2.

Voltage Output from Detector, Volts: $$Voltage = \sqrt{Power * 50\Omega}$$ Equation 8.2

Using Equation 8.2, the voltage output from the detector is between .0045 V and 1.12 V. Under the given thermal operating conditions, this detector should operate with a high amount of accuracy. Typical detector characteristics can be seen below in Figure 8.4.

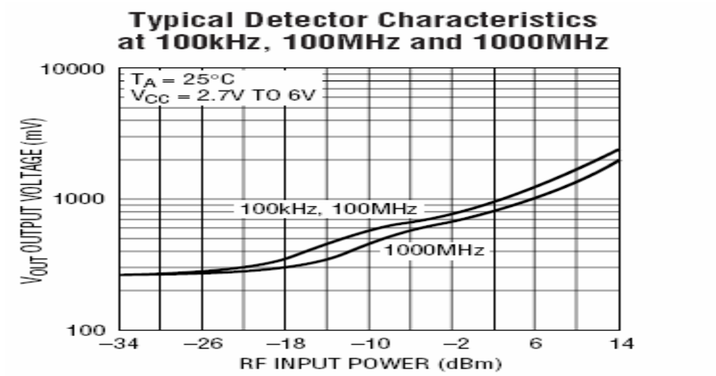

Figure 8.4: Typical Detector Characteristics

8.2b A/D CONVERTER

The power levels from the incoming signals into the system will be used to calculate the Power vs. Frequency graph in order to depict a correlation of background radiation at these specified frequencies. Error in the power response at each time interval is minimized by reducing the sampling rate. Data must sampled over two microsecond intervals to have a substantial amount of data for the ranges that are proposed. The data will then be digitized using an 8-bit A/D converter that will be sampled and held at the given rate. A schematic diagram of the A/D converter is given below in Figure 8.5.

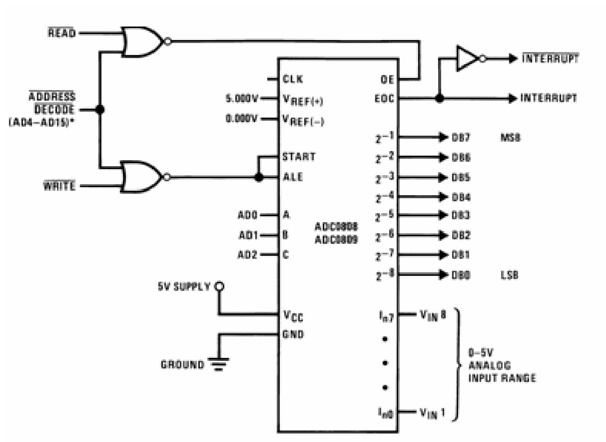

Figure 8.5: 8 Bit A/D Converter Schematic Diagram

8.2d MICROCONTROLLER AND DATA STORAGE

All of this data will be recorded and stored onboard by using a memory chip. The data will also be down-linked so real-time operating conditions of the system will be known. The signals from the radiometer will have to be signal conditioned and digitized.

The microprocessor will be used to multiplex the incoming 8-bit signals to designated data storage spaces at a given clock speed. The Rabbit 3000 is used in this application because of its data storage capabilities (20-bit address with 1 Mb of data addressing and a 16-bit data bus) and its acceptable range of environmental operating conditions. The data will be stored on a 1MB EEProm memory chip on the digital processing board interfaced with the Rabbit 3000. Before each read, the program that will run the software will check itself and shut down if there is not enough free space to avoid data overwrite. The Rabbit 3000 can be below in Figure 8.6.

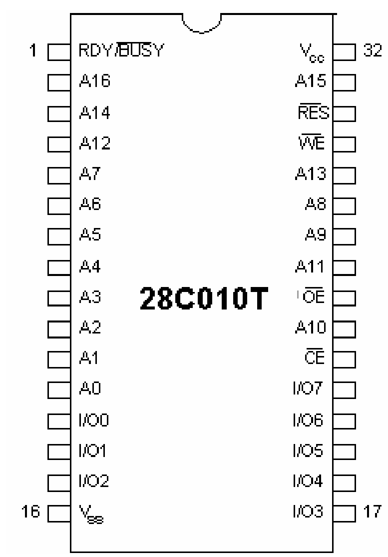

Figure 8.6: Rabbit 3000 Microcontroller

8.3 SAWTHOOTH VOLTAGE REGULATOR

The processing board will not only control the sampling, data storage, and telemetry of the system, it will also control the Voltage Controlled Oscillator (VCO) that will be used to sweep the range of frequencies. A sawtooth wave generator can be built using a simple 555 timer IC and a transistor as shown in the circuit diagram below in Figure 8.7.

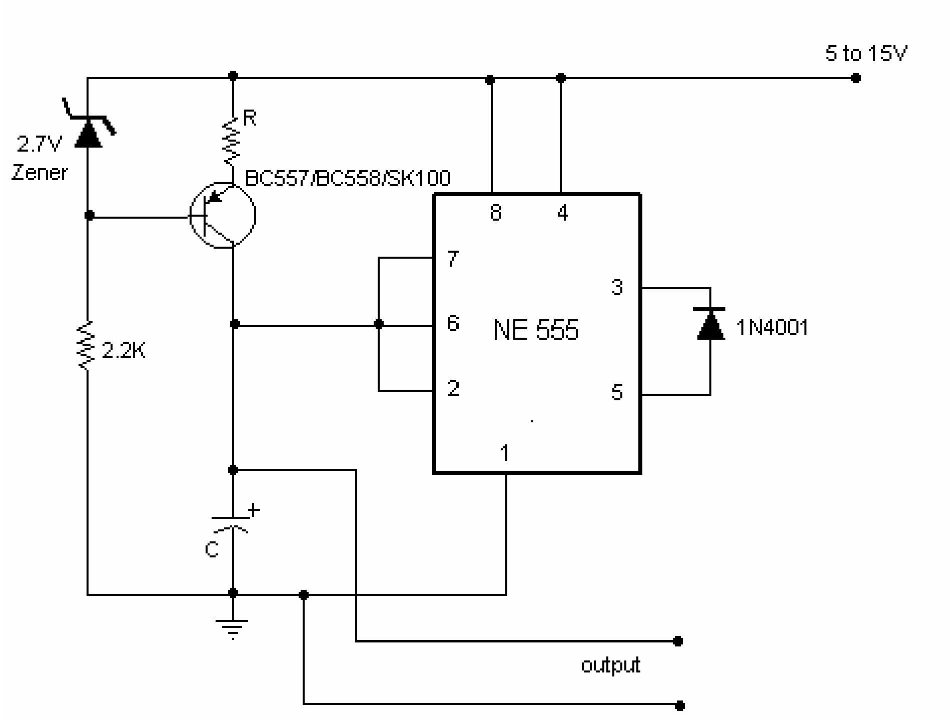

Figure 8-7: Sawtooth Waveform Generator

The SWG can be explained in the following manner. The part of the circuit consisting of the capacitor, transistor, zener diode, and the resistors form a constant current source that charges the capacitor. The voltage across it is zero, causing the internal comparators inside the 555 connected to pin 2 causes to go high and the internal transistor to open. The capacitor starts charging to the supply voltage. As it charges, to a point above two-thirds of the supply voltage, the 555's output goes low and shorts the capacitor to ground and discharges. Again the 555's output goes high when the voltage across C drops below a third the supply. Hence the capacitor charges and discharges between two-thirds and a third the supply voltage. Note that the output is taken across the capacitor. The 1N4001 diode makes the voltage across the capacitor go to ground level. The frequency of the circuit is given by Equation 8.3.

Frequency, Hz: f = (Vcc-2.7)/(R*C*Vpp) Equation 8.3

where: Vcc= Supply voltage.
Vpp= Peak to peak voltage of the output required.

Choosing the proper R, C, Vpp, and Vcc values will enable the system to get the required frequency. Choosing $f = \frac{V_{cc} - 2.7V}{R \times C \times V_{PP}} = \frac{15^{+} - 2.7}{10k\Omega \times 330\mu F \times 25} = .088485$ Hz.

This means that the period that it goes from origin to peak is 11 seconds. This will enable the SWG to produce a range of 5-10 Volts with an interval of 1 s/V. The SWG is represented using Matlab. The code for the SWG is given in Appendix H. Figure 8.8 shows the output of the SWG.

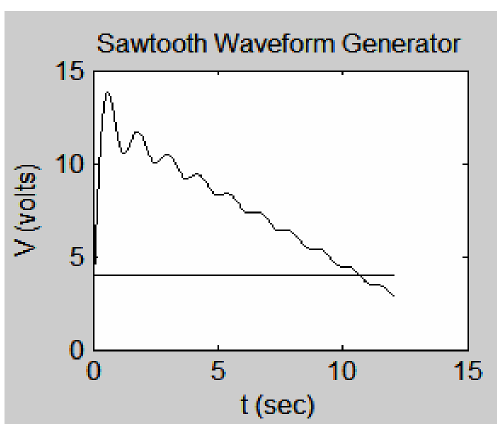

Figure 8.8: Output from Sawtooth Waveform Generator

This graph displays the discharge peak voltage that the capacitor will perform at and its period of performance. Since the system needed a minimum of 5 Volts and a maximum of 10 Volts for the Sawtooth Generator to operate correctly at a period of 11 seconds, this design reflects the expected projection.

8.4 SYSTEM POWER DESIGN

The EDAC 516 connector supplies the payload with 30 volts DC and 2.5 amps and has the grounding connections for all of the systems. By utilizing correctly sized resistors, the system can have its recommended supply of voltage to each component. The leads of the SWG will give an output between 5 and 10 volts that will control the VCO. Figure 8.9 shows the power supply diagram for the system.

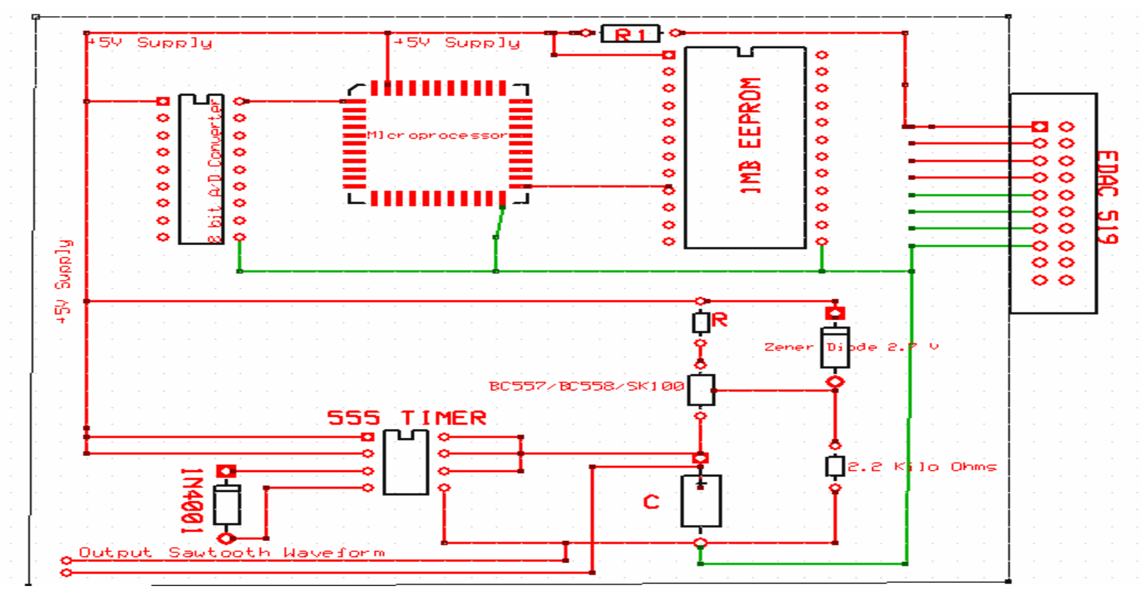

Figure 8-9: Power Supply Diagram

8.5 POST FLIGHT OPERATIONS

After the flight has ended the data will be retrieved via serial port connection and by running a program to print out the stored data onto the debug screen. The data will then be copied into Excel. The data will be in the form of power levels versus time. The

Excel program will be used to calculate the power levels from the data and construct the graphs of power versus altitude and the power versus frequency. The Excel program will also contain the frequency/time data of the SWG. The data will be time-stamped using Central Standard Time. The data will be correlated to determine the frequency of the incoming signals as a function of the time and altitude obtained from the HASP GPS.

9. Stress Analysis

9.1 INTRODUCTION

The stress analysis is performed as verification that all designed structures will not fail due to any loads applied to them. The HASP project guidelines dictate that any structure must be able to withstand a 10 g vertical shock as well as two 5 g horizontal shocks. These loads are to be expected whenever the gondola lands. The project has two main structures of interest for analysis: the payload shell and support structure. For the structure to pass the stress analysis, the structure must have a minimum overall safety factor of between 1.15 and 1.25, which is the acceptable range for aerospace applications.

9.2 SOFTWARE

The analysis is performed using the FEA software Algor. Algor takes a CAD model, Inventor in the case of this project, and processes it into three dimensional matrices which can then be combined to determine the maximum stresses given a specified load. Algor requires that the loads, material, size of mesh, and type of mesh be specified before an analysis can be performed. The user defined loads on a part or assembly can take many forms, but this analysis looks at shock loads, which is interpreted by Algor as a static load (i.e. very short duration). Algor also has a very wide selection of materials that can be selected for a part. Selection of a material is important because Algor takes the material properties and uses them to solve the load matrices. Mesh size specifies the size of the load matrix. The smaller the mesh, the larger this matrix becomes and the longer the analysis will take to process. The type of mesh depends on whether or not the part or assembly is 2 or 3-D. Tetrahedron is the recommended mesh style for three dimensional objects because it tends to better describe mathematically what the part or assembly is.

9.3 PAYLOAD SHELL ANALYSIS

The payload shell, as described earlier in the payload design section, consists of four 1/8 inch corners with walls with a thickness of .025 inches. The corners are mounted to the mounting plate with four 1x3x1/8 inch brackets. The payload shell is tied together at the top by the top frame with four 1x1x1/8 inch brackets. The top covers this frame and overhangs the sides of the payload. The corners, top frame, and base brackets were specified as Aluminum 5052-H32. The top brackets were specified as Aluminum 6061-T4. The PVC base was specified as fluorinated ethylene propylene. This was because Algor did not have PVC in the material libraries, and FEP was chosen due to its similar strength properties. Before meshing occurred, all bolts and rivets were removed from the assembly. This is because Algor tends not to handle these items very well in the processing (mesh) stage, especially with large models such as this. Also, all of the .025 side panels and top were removed from the model. Originally, these were going to be included in the analysis, but Algor could not process the mesh with these items included in the model, though all of the sides meshed on their own. The top, however, refused to mesh altogether for no apparent reason. Removing these items does not take away from the legitimacy of this analysis, though. The sides and top were not designed to be load bearing; only the corners were designed to withstand the shock that would be experienced upon landing.

The shell was processed to a 67% mesh. This mesh was used because it did not have any water tightness issues (meaning that if you could take the part and fill it with water it would not leak), and it was the convergent mesh for the stress output. The output is given both graphically and in pdf form (this is given in Appendix B). The stress data for the payload shell can be seen graphically below in Figure 9.1.

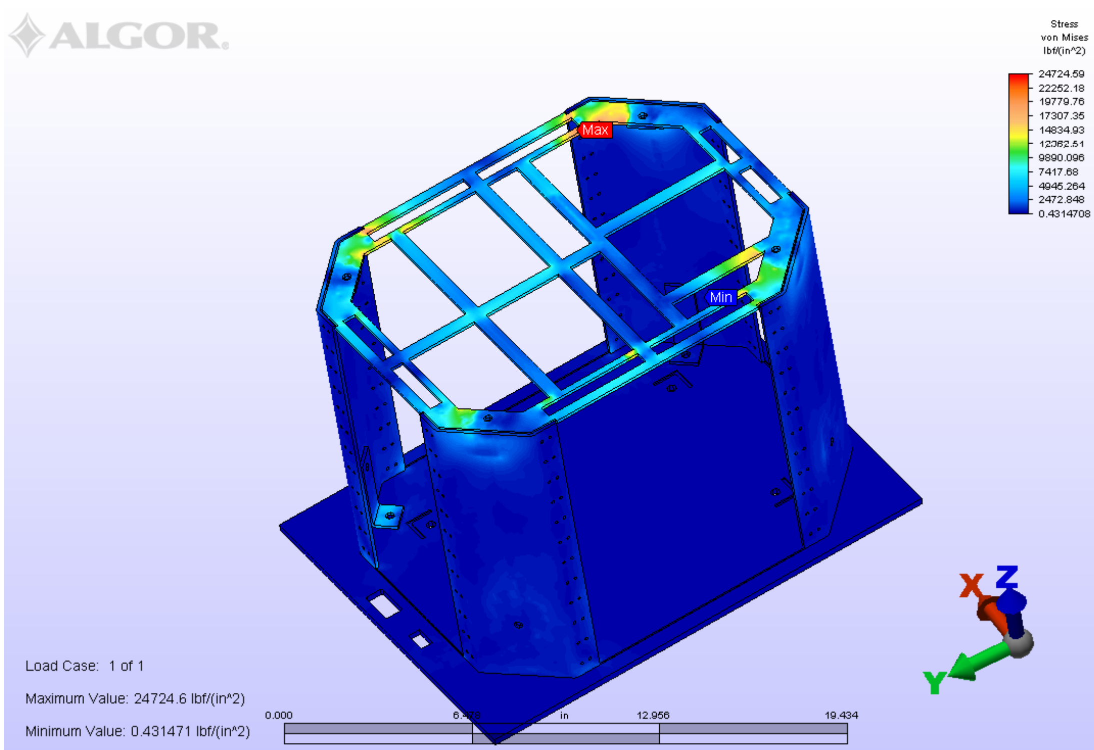

Figure 9.1: Stress Data for Payload Shell

From the figure, the maximum stress obtained is 24.57 ksi. The maximum stress (and largest stresses for the system in general) occurs on the top frame. This is due to stress risers present from the cutouts made in the frame for the insulation. Also, intuitively, the maximum stress should occur on the top plate because this is where impact load will be resisted. The stresses observed on the top plate would primarily be due to bending resulting from the impact. The maximum stress observed is below the yield strength of the Aluminum Alloy (5052) of 29 ksi. This gives a safety factor of 1.18. This is within the acceptable range of safety for aerospace applications, so the structure passes the stress analysis.

9.4 SUPPORT STRUCTURE ANALYSIS

The support structure, as described earlier in the payload design section, consists of four aluminum 1”x1”x1/8” columns with two platforms. These platforms are secured to the columns by 1” square brackets, or platform tie-ins. These tie-ins are welded to the columns. The columns are specified as Aluminum 6061-T4. The platforms are specified as Aluminum 3003-H14, while the tie-ins are specified as Aluminum 5052-H32. All the bolts of the support structure were removed so Algor could handle the analysis. Unlike the analysis of the Payload Shell, the PVC base was not included. This was because Algor could not process the matrices with it in it. The PVC base has no real load applied, though, as determined by the analysis performed on the Payload shell (.4 psi).

Like the Payload Shell, the mesh that converged and had no water tightness issues was 67%. The output is given both graphically and in pdf form (this is given in Appendix H). The stress data for the payload shell can be seen graphically below in Figure 9.2.

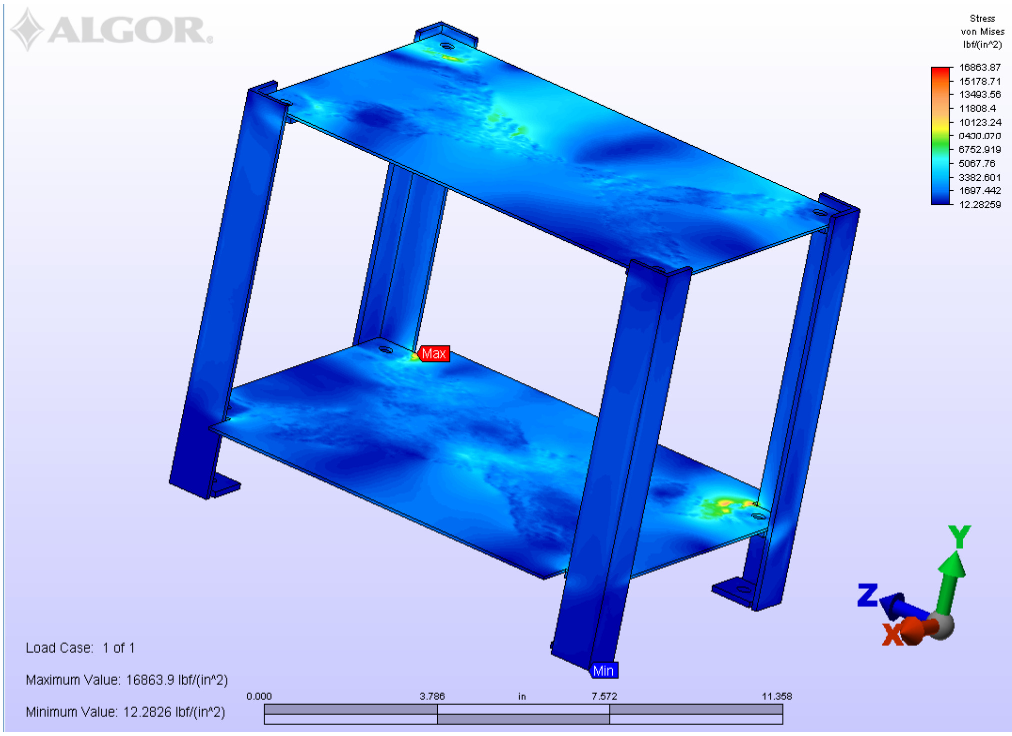

Figure 9.2: Stress Data for Support Structure

From the figure, the maximum stress obtained is 16.8 ksi. The maximum stress (and largest stresses for the system in general) occurs on the first platform around the platform tie-ins. This occurs because upon impact the platforms will experience buckling, especially around the tie-ins. This effect is clearly visible in Figure 9.2 as eddies in the platforms. The maximum stress observed is below the yield strength of the Aluminum Alloy (3003) of 24 ksi. This gives a safety factor of 1.42. This is actually above the acceptable range of safety for aerospace applications, so the structure passes the stress analysis.

10. Vibration Analysis

A major concern for any operation using electrical equipment is vibration. Vibration is highly detrimental because it can induce noise to the system that can wreak havoc on an incoming signal. Vibration can also damage the equipment if the frequencies of oscillation reach the natural frequencies of the equipment or the structure that the equipment is sitting on. Whenever a natural frequency is reached, resonance occurs. Resonance creates large amplitudes of oscillation and, if not quickly passed, will rip structures and equipment apart. Therefore, a vibration analysis is important for two reasons: 1) to determine the noise that will be induced to a system so it can be accounted for and possibly canceled out by prefiltering or 2) to determine the natural frequencies and the frequencies of oscillation to properly design structures and equipment to avoid resonance. The analysis performed here is concerned about the gondola that the balloon payload will sit upon and the support structure that the radiometer and processing equipment will sit upon.

The support structure is analyzed as a two degree of freedom system with base excitation. This base excitation is present from two sources: the oscillation induced by gondola and the wind hitting the sides of the payload. The focus on the analysis for the support structure is on the modes and natural frequencies of the structure. The natural frequencies will be used to check and see if resonance is reached. There will be two natural frequencies because the system has two degrees of freedom because the number of natural frequencies of oscillation is proportional to the degrees of freedom. The modes will show the relationship between the motions of each platform. The structure is made of four aluminum columns with two platforms for electrical equipment to mount to. Each of these columns is analyzed as cantilever beams with an end load applied to determine their respective stiffness as seen in Figure 10.1.

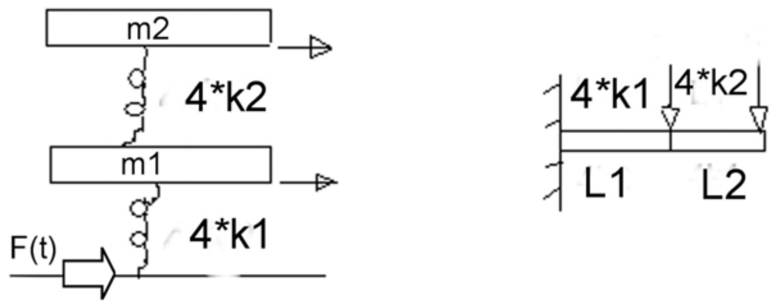

Figure 10.1: System Diagram of Support Structure Depicting Cantilever Assumption

These end loads are the platforms and the equipment. As the columns are considered in parallel, their stiffnesses are additive. The MathCAD worksheet, “Frequencies and Modes of The Support Structure,” shows this in Appendix I. To determine the modes and frequencies of the support structure, the forcing function (base excitation) need not be known or applied at this time. Performing the analysis requires the differential equations describing the motion of the platforms. These equations are presented in the MathCAD worksheet “Frequencies and Modes of The Support Structure” in Appendix I. The analysis is performed using Matlab. The code takes the combined eigenvector of the mass and stiffness matrices and outputs the displacement and velocity matrices. Using these matrices, the natural frequencies and modes can be extracted. An explanation on how this is done along with a copy of the code (NaturalFrequencies.m) can be found in Appendix I. The results of this analysis are displayed below in Table 10.1.

Table 10.1: Natural Frequencies and Modes for Support Structure		
1st Natural Frequency	714.4	rad/s
2nd Natural Frequency	14,135	rad/s
1st Modes	1	
	1.004	
2nd Modes	1	
	-1.48	

The first natural frequency is mid range and could pose a problem for resonance. The second natural frequency is high and should never be excited, but both of these will be checked when the analysis is performed for the gondola. The first mode shows that the first platform will move at the same rate as itself and at 1.004 times the rate of the second platform in the same direction. The second mode shows that the second platform will move at the same rate as itself and at -1.48 times the rate of the first platform but in the opposite direction. Both of these solutions are valid and possible, but which of the modes would occur would be unknown until data from the flight were taken and compared.

The gondola is important for the system analysis because it will provide the excitation for the support structure. The gondola is excited by the wind present at the different layers of the atmosphere throughout the flight profile. The wind data is taken from two sources: rocket sounding data taken from the 1960’s in California (see Appendix M: Technical Data for the paper detailing this) and from real time wind data taken using lasers in White Sands, NM (also seen in Appendix M). The horizontal wind velocity derived from these data sources is shown below in Figure 10.2.

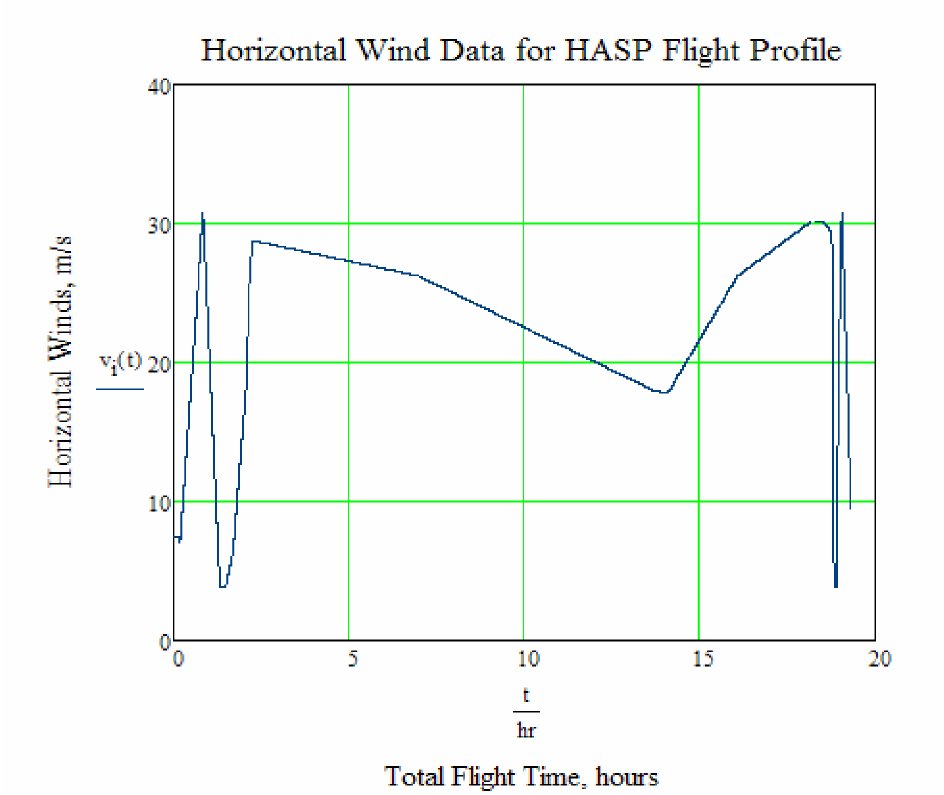

Figure 10.2: Horizontal Wind Data for HASP Flight Profile

The gondola experiences fluid-induced vibration due to vortex shedding. This analysis is possible because the gondola can be considered a blunt body (cube) present in a flow stream (atmospheric winds).This analysis requires that the mass of the gondola be known as well as the size, moment of inertia, Modulus of Elasticity, hydraulic diameter, and characteristic Strouhal number. Since there is no data given by HASP on the gondola other than the total weight (2000 lb), the actual size of the gondola was assumed to be an four foot cube (validity of this assumption can be checked in NASA's "National Scientific Balloon Facility Recommendations for Gondola Design: April 1, 1986" presented in Appendix M). The gondola is also assumed to be constructed of mostly Aluminum. Both the moment of inertia as well as the hydraulic diameter is easily determined from the assumed dimensions of the gondola. The Strouhal number is a characteristic quantity that relates the velocity of the flow the frequency of oscillation that is constant for a wide range of flow regimes (i.e. wide range of Reynolds numbers). For a cube, the Strouhal number is given as .143 from Applied Scientific. This analysis will give the natural frequency of the gondola, as well as the velocity required to induce resonance. The actual frequencies of oscillation can also be determined from the analysis. The worksheet “Vibration Analysis of The Gondola for HASP,” which details this analysis, can be seen in Appendix I. From the analysis, the natural frequency as well as the exciting velocity can be seen below in Table 10.2.

Table 10.2: Gondola Fluid-Induced Vibration Analysis

Natural Frequency	27968.87	rad/s
Excitation Velocity	37.95	km/s

Notice how high the natural frequency of the gondola is as well as the magnitude of the excitation velocity. The maximum wind reached during the flight is only about 30.8 m/s; therefore, it can be said with very high confidence that resonance will never occur for the gondola. Figure 10.3 displays the frequencies of oscillation for the gondola as well as the payload itself.

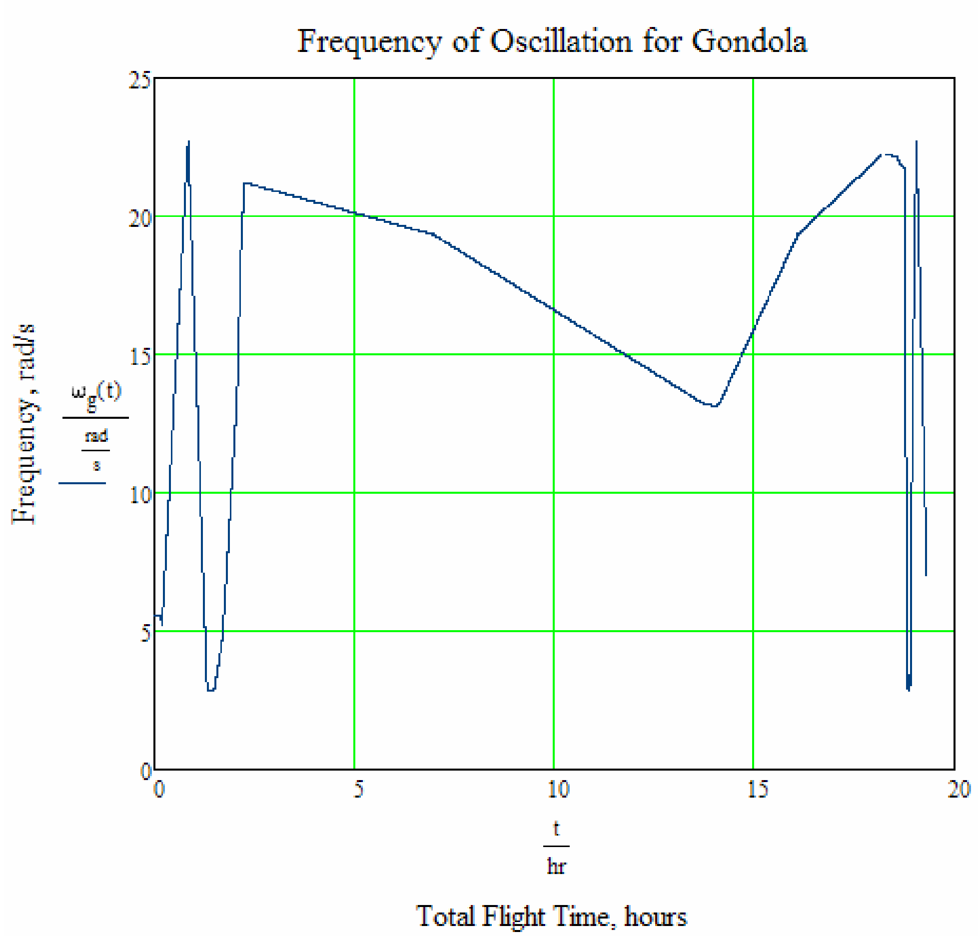

Figure 10.3: Frequency of Oscillation for Gondola

This figure shows that the maximum amplitude of oscillation is only 22.7 rad/s, well below the natural frequencies of both the gondola and support structure. Vibration is therefore a trivial structural problem for the balloon payload as resonance will never be reached. As for the electronics, the noise induced by vibration of the system is only at maximum 3.6 Hz, well below the range of interest for this experiment (55-65 GHz), so vibration should not be a major component of the total noise.

11. Thermal Simulation

11.1 INTRODUCTION

Understanding how the thermal system acts under flight conditions and environment is pivotal in making a solid design. A flight simulation is used to determine how air property changes affect the payload's temperature and how those same property changes affect the efficiency of the heating system. More detailed information on this simulation is given in "Flight Information" earlier in the report as well as in Appendix B. The main point of this simulation is to determine the center temperature of the payload at any given point so the load on the designed heating system can be verified and proved sufficient. Detailed calculations of the thermal simulation explained within this section are given in Appendix J.

11.2 ASSUMPTIONS

Since the temperature inside the payload is the main point of interest for the simulation, the temperature on the outside of the wall and the temperature of the air must be known. The air temperature is known at all elevations but the outside temperature of the payload is not. Due to crucial information for the project being unknown, assumptions had to be made in order for the simulation to work. A previous balloon project under the auspices of LaACES collected data on air temperature with respect to a payload's wall temperature. That data was made into an equation, and an assumption was made that the same difference in air temperature to outer wall of payload temperature was the same for both projects. The heat transfer rate is considered constant throughout the payload.

11.3 CALCULATIONS

With the information collected, thermal equations can be set up to begin the simulation. To determine the center temperature, the method of nodal analysis was used. Every major surface, except for the base, was selected to be a node, totaling nine. As stated earlier, the heat transfer from each node is assumed to be constant from the air to the inside of the box. The properties of the air were used to determine the heat transfer between the outside of the payload to the outer wall.

11.3a REYNOLDS NUMBER

The Reynolds number is necessary to determine which equation must be used to find the convection coefficient. Equation 11.1 is the Reynolds number.

Reynolds Number: $$Re_s(t) := \frac{\rho(t) \cdot u_m(t) \cdot D_{Hs}}{\mu(t)}$$ Equation 11.1

A graph of each Reynolds number is displayed in Figure 11.1.

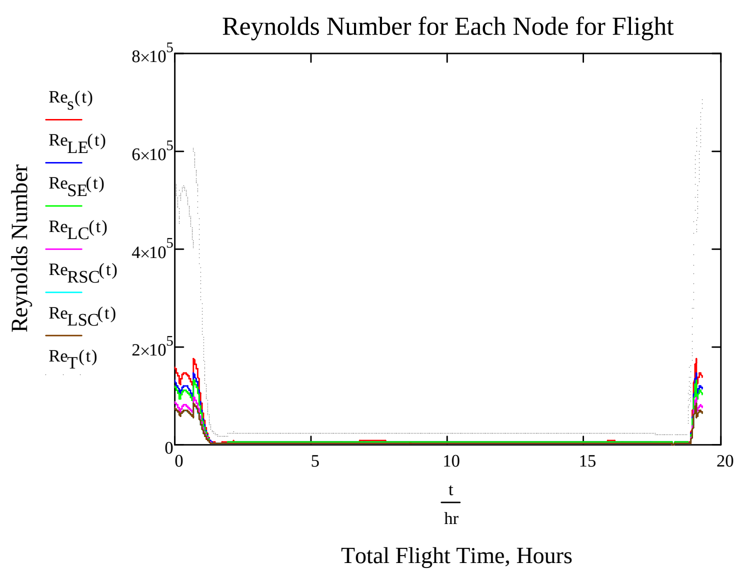

Figure 11.1: Reynolds Number of Each Nine Nodes

11.3b NUSSELT NUMBER

The heat transfer between the outside air and outer wall temperature is used to determine the inner wall temperature at each node. Based off of Figure 11.1, most of the nodes are under laminar flow conditions (Re < 5*10^5) for the entire flight and will use the same equation to determine the convection coefficient. The top, however, experiences turbulent flow conditions (Re ≥ 5*10^5) for certain periods of the flight. A logical if statement was made for the Nusselt Number of the top plate to accommodate the changes occurring for the Reynolds number, which is shown in Equation 11. 2.

Nusselt Number:

$$Nu_T(t) := \begin{cases} 0.664 \cdot Re_T(t)^{\frac{1}{2}} \cdot Pr^{\frac{1}{3}} & \text{if } Re_T(t) < 5 \cdot 10^5 \\ Re_T(t) \cdot Pr^{\frac{1}{3}} \cdot \left(.037 \cdot Re_T(t)^{-.2} - 871 \cdot Re_T(t)^{-1}\right) & \text{if } Re_T(t) \geq 5 \cdot 10^5 \end{cases}$$

Equation 11.2

11.3c CONVECTIVE HEAT TRANSFER

The Nusselt Number is necessary to determine the convection heat transfer coefficient coefficient. The convection coefficient is then used to determine the heat transfer rate which is shown in Equation 11.3.

Convective Heat Transfer, W: $q_s(t) := -h_s(t) \cdot A_s \cdot \left(T_w(t) - T_\infty(t)\right)$ Equation 11.3

11.3d INNER WALL TEMPERATURE

The heat transfer rate between the outside air and the outside wall of the payload is assumed to be the same between the outside wall and the inside wall. The inside wall temperature is found by using the outside wall temperature, thermal conductivity of the insulation and structure, and the thickness of the insulation and structure. This is done for all nine nodes. Equation 11.4 displays the equation to acquire the inside temperature for the side node.

Inner Wall Temperature, K: $$T_{iws}(t) := -q_s(t)\cdot\left(\frac{th_{sI}}{k_{al}\cdot A_{al}} + \frac{th_{sAl}}{k_p\cdot A_p}\right) + T_w(t)$$ Equation 11.4

Each node should have a different inner wall temperature due to the differences in area and insulation thickness, but should be relatively close to one another. Figure 11.2 displays all the inner wall temperatures from all nine nodes.

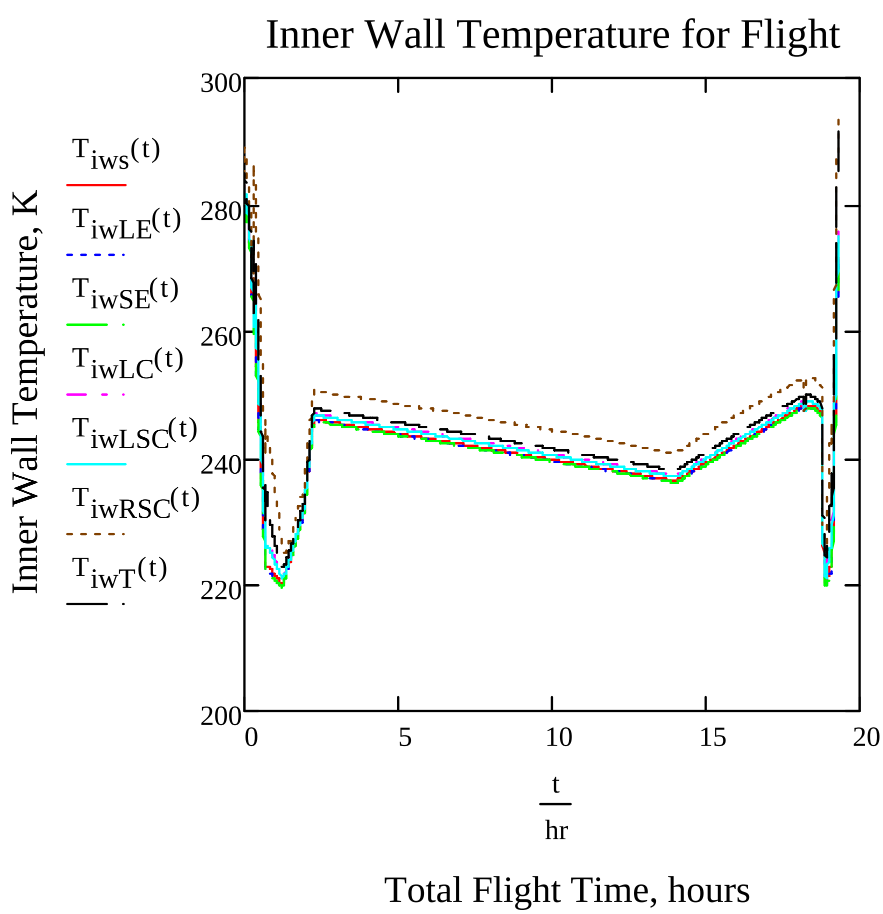

Figure 11.2: Inner Wall Temperature for Each Node

11.3e CENTER TEMPERATURE PRE-HEATER

Each of the inner wall node temperatures were then added together based on their distance to the center of the payload to determine the payload's center temperature. The nodal analysis equation used is displayed in Equation 11.5.

Nodal Equation, K:

$$T_c(t) := \frac{x_1(t) + x_2(t) + x_3(t) + x_4(t) + x_5(t) + x_6(t) + x_7(t)}{y_1 + y_2 + y_3 + y_4 + y_5 + y_6 + y_7}$$

Equation 11.5

The Nodal equation is quite large so variables had to be made for each node's inner wall temperature and distance. These variables are represented in Equation 11.5 as $x_1(t)$, $x_2(t)$, and so on. Since the outer wall temperature was assumed to be the same as another flight project, the outer wall temperature is iterated with the inner wall temperature in order to acquire a new outer wall temperature with increased accuracy. The iteration is shown in Equation 11.6.

Iterated Outer Wall Temperature, K:

$$T_{xws}(t) := \frac{T_\infty(t)\cdot h_s(t)\cdot A_s + \left(\frac{k_{al}\cdot A_{al}}{th_{sI}} + \frac{k_p\cdot A_p}{th_{sAl}}\right)\cdot\left(T_{iws}(t)\right)}{\left(\frac{k_{al}\cdot A_{al}}{th_{sI}}\right) + \left(\frac{k_p\cdot A_p}{th_{sAl}}\right) + \left(h_s(t)\cdot A_s\right)}$$

Equation 11.6

This new outer wall temperature is used to determine a new heat transfer rate and inner wall temperature. The new inner wall temperature will undergo nodal analysis in order to acquire the center wall temperature. Figure 11.3 compares the original center payload temperature with the center payload temperature acquired through the iteration of the outer wall temperature.

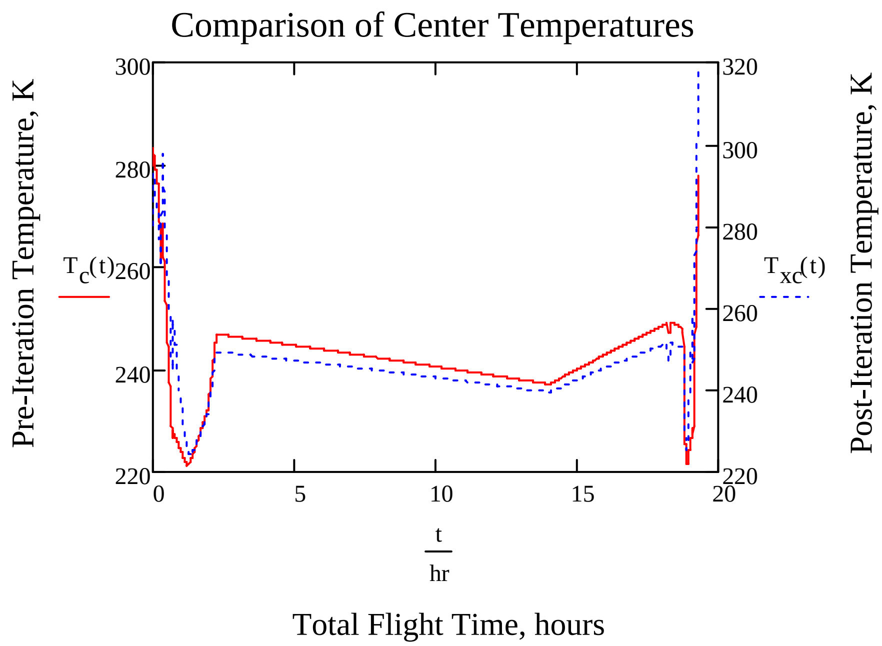

Figure 11.3: Comparison of Center Temperatures

11.4 HEATER SIMULATION

The amount of energy that is given off from the power resistors was determined from Ohm's Law. An alternate way to determine how much energy the resistors give off during operation is to find the heat transfer rate of the power resistors from radiation. The radiation heat transfer equations are used due to air low density at higher elevations, which makes convection heat transfer negligible. In order to determine the heat transfer rate from radiation, the shape factor is needed. The shape factor requires the radiosity of each piece of equipment to determine its radiation rate. Equation 11.7 displays radiosity, and Equation 11.8 displays the shape factor equation.

Radiosity, W/m^2: $$J = E_b - \frac{q \cdot (1 - \varepsilon)}{\varepsilon \cdot A}$$ Equation 11.7

Shape Factor: $$F_{12}(t) := \frac{P_s}{A_1 \cdot \left(J_1 - J_2(t)\right)}$$ Equation 11.8

The shape factor is then used to determine the heat transfer rate it takes for the thermal system to heat up center of the payload. Equation 11.9 shows this equation.

Heat Transfer Rate for Heaters, W: $$q_{nets}(t) := \frac{\sigma \cdot A_1 \cdot \left(T_1^{\,4} - T_2(t)^4\right)}{\left[\frac{A_1 + A_2 - 2 \cdot A_1 \cdot F_{12}(t)}{A_2 - A_1 \cdot \left(F_{12}(t)\right)^2}\right] + \left(\frac{1}{\varepsilon_1} - 1\right) + \left(\frac{1}{\varepsilon_2} - 1\right)}$$ Equation 11.9

The heat transfer rate for the heaters is used to determine how long it takes for the system to heat up to the cut off temperature. The heat transfer rate from the heat lost through the system is used to determine how long it takes for the interior of the payload to cool down to the start-up temperature for the heater system. The heater simulation determines the internal temperature of the box when both heaters kick on and off at the same time. The stagger system that the final system will have is not simulated in this simulation due to logistical errors that occur in the simulation. The start-up temperature for the simulated system is 10°C and the cut off temperature is 27°C. Figure 11.4 displays the internal temperature of the payload with the heaters running.

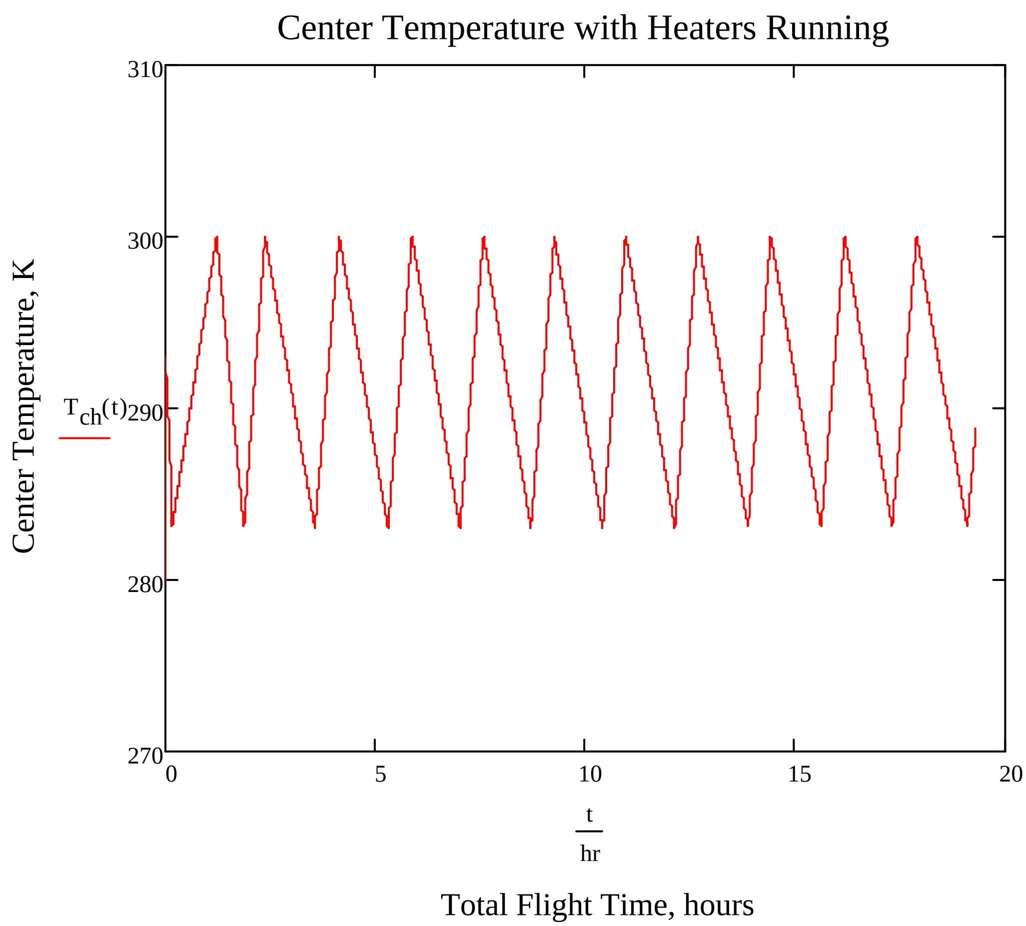

Figure 11.4: Internal Temperature with Heaters

11.5 CONCLUSION

As Figure 11.4 shows, the payload's internal temperature is kept within the optimal operating temperature throughout the whole flight. An assumption made during the simulation was that the air velocity is not subject to change during the flight. During a real flight, fluctuations in the winds will occur. To simulate these possible variations, the air velocity is reduced and increased by 25% and the center temperature is recalculated. Figure 11.5 displays the 25% reduced internal wall temperature and Figure 11.6 displays the 25% increased internal wall temperature. Even with these variations, the system still performs to the required specifications. Real-time testing will still have to be performed to verify the analysis given here. At the time of this writing, the equipment for testing was on order.

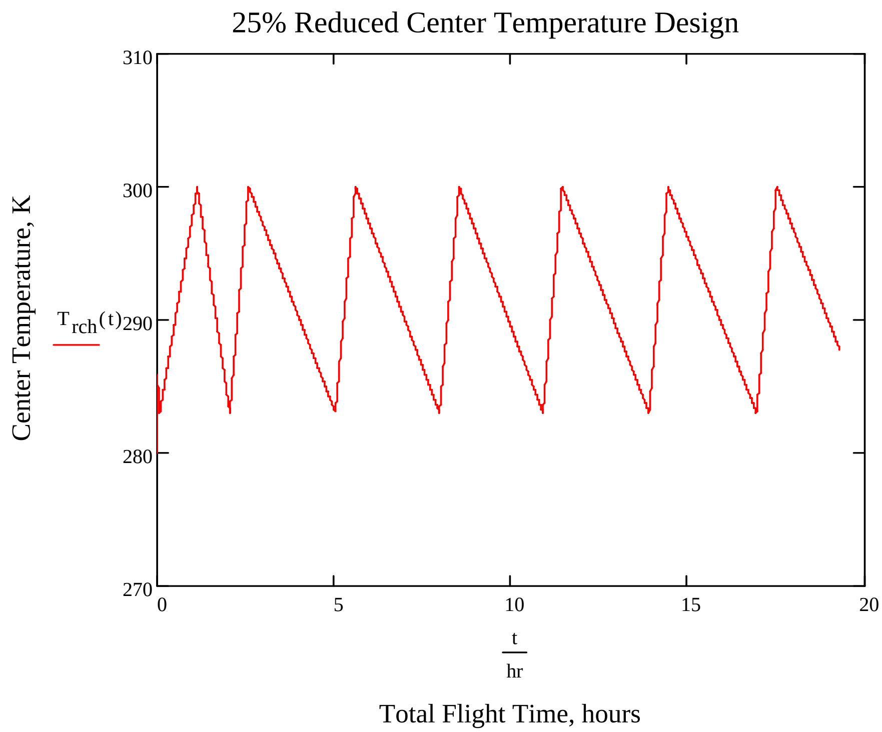

Figure 11.5: 25% Wind Reduced Internal Wall Temperature

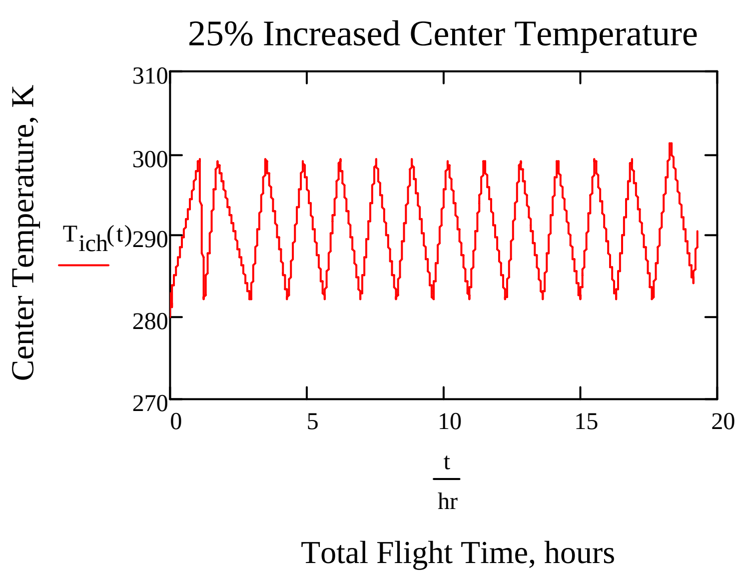

Figure 11.6: 25% Wind Increased Internal Wall Temperature

12. Receiver Simulation

12.1 INTRODUCTION

Simulations are provided to investigate the feasibility and utility of the project's design. MATLAB along with Simulink were used to demonstrate the results from each piece of equipment in the receiver. Using this program, useful predictions can be made regarding the response of the equipment. Shown below in Figure 12.1 is the model created in Simulink for the simulation. The MATLAB code used to create the graphs in this section can be found in the appendix.

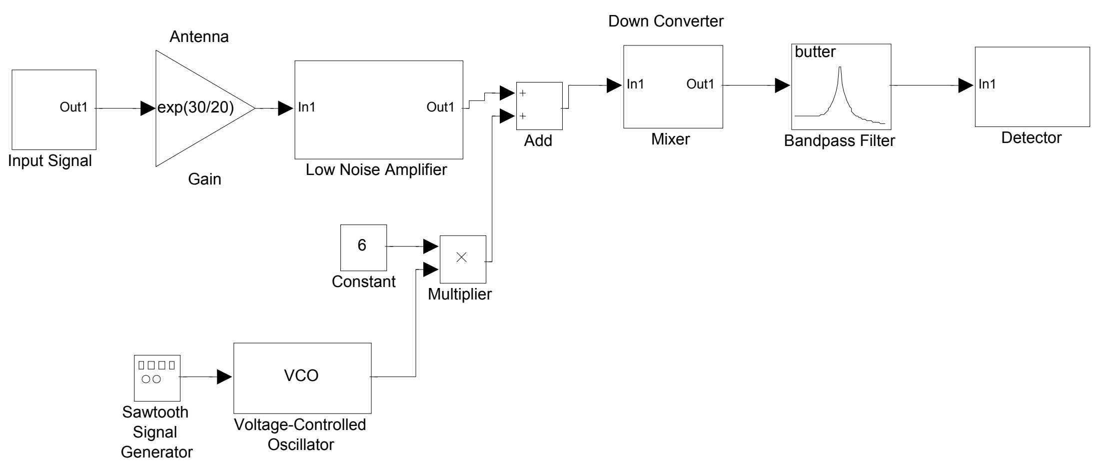

Figure 12.1: Simulink Model of Microwave Radiometer

12.2 SIMULATION

To begin the simulation, a signal was created that appears as white noise. This was created by using the MATLAB random normal number generator (randn). The noise generated appears in the figure below. Figure 12-2 show the input signal as it is measured in temperature (Kelvin). Figure 12-3 shows the input after temperature has been converted to voltage.

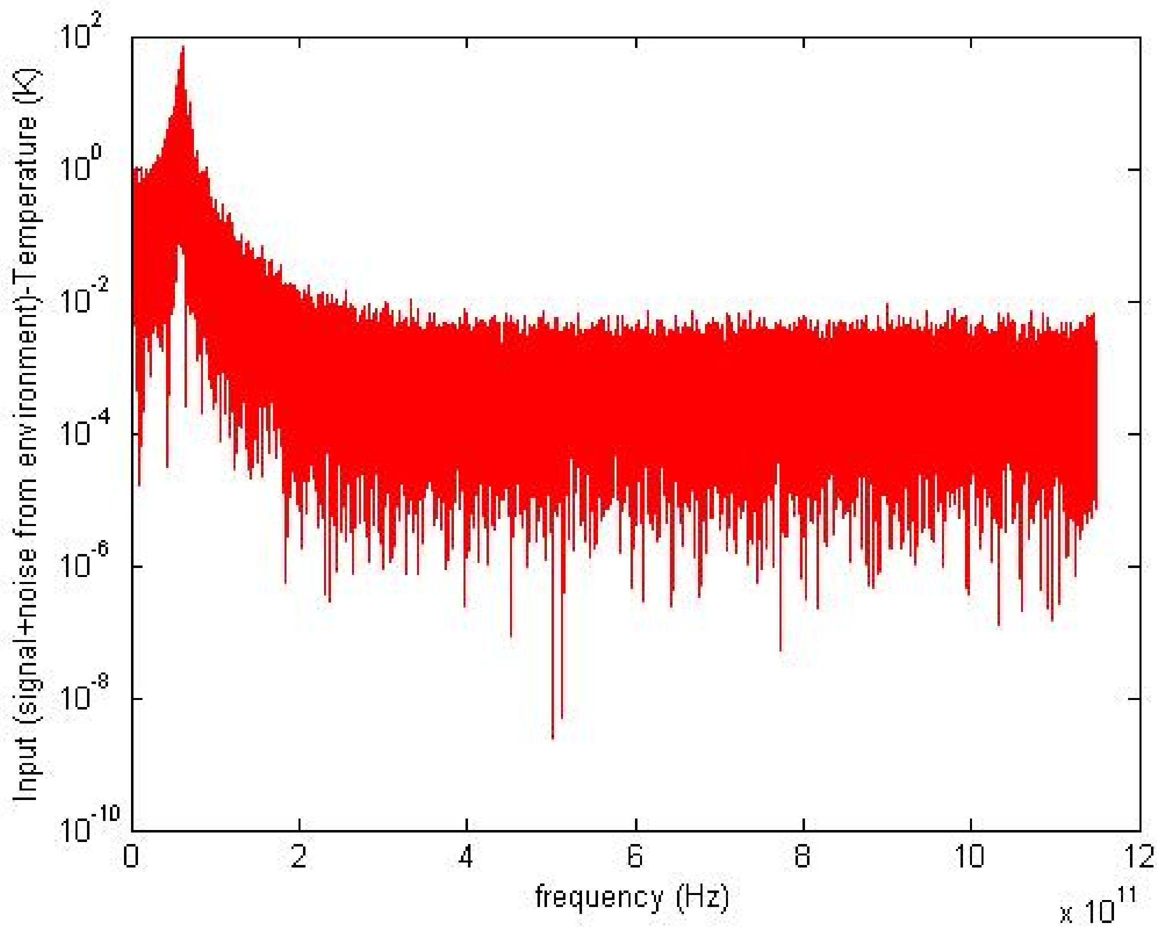

Figure 12-2: Radiometer Input Signal

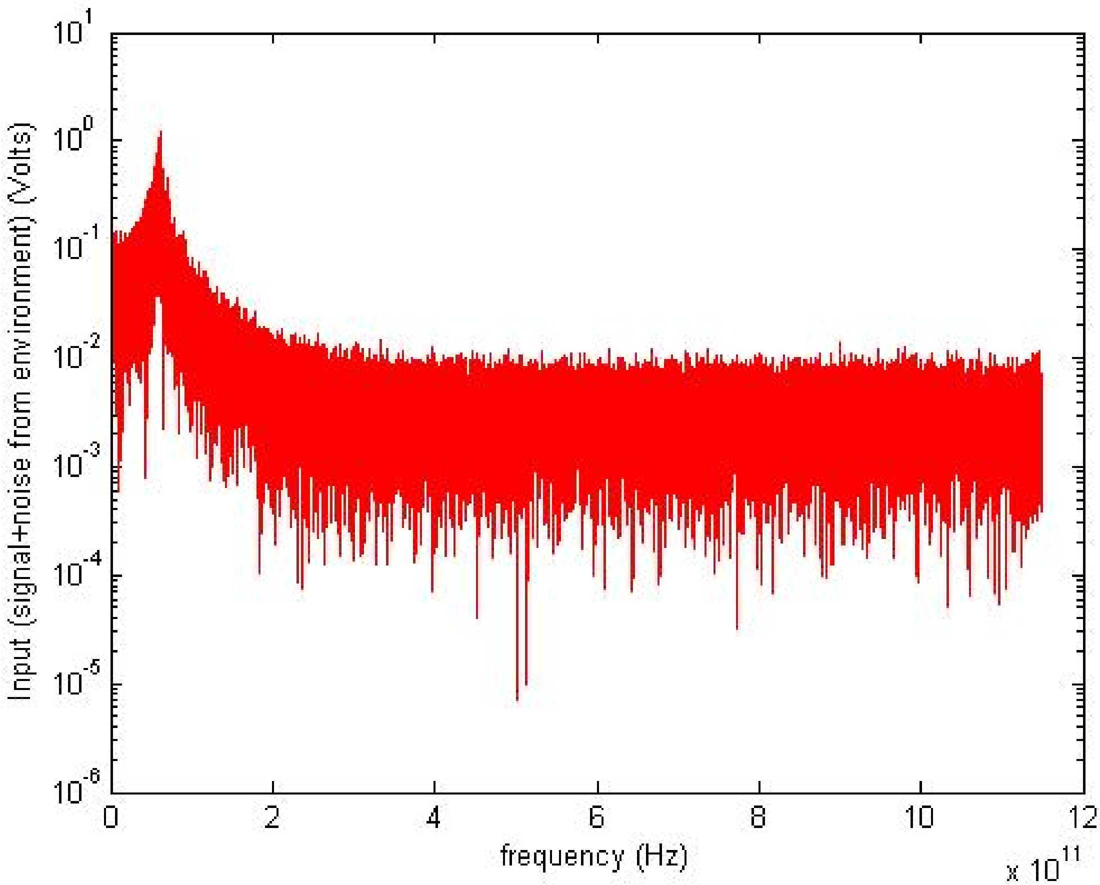

Figure 12-3: Radiometer Input Signal

The graphs below represent the final output from the radiometer. It shows the intensity detected at different frequencies. Figure 12-4 show the detected signal output in Watts. Figure 12-5 shows the output as temperature in Kelvin.

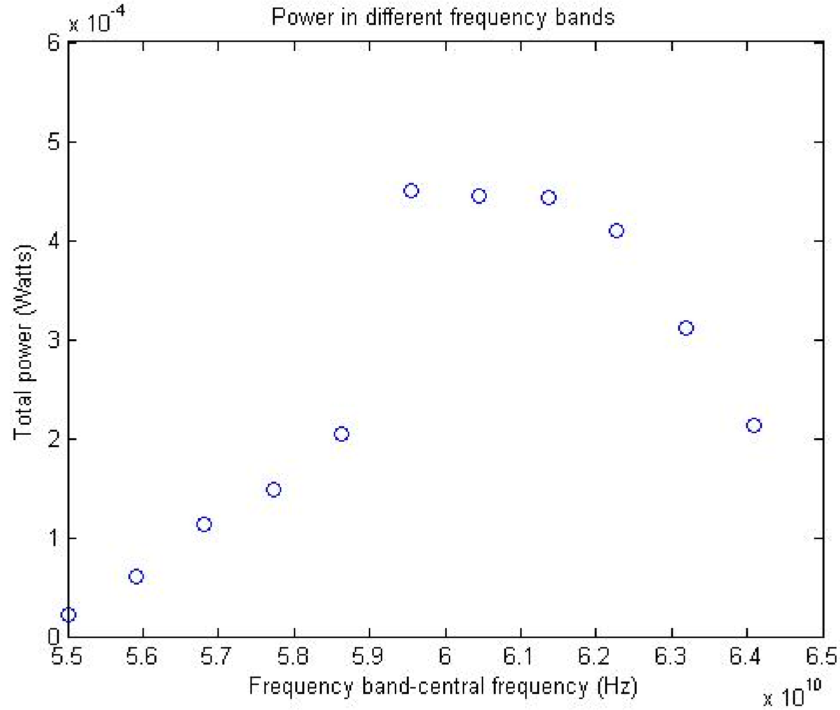

Figure 12-4: Output from Radiometer

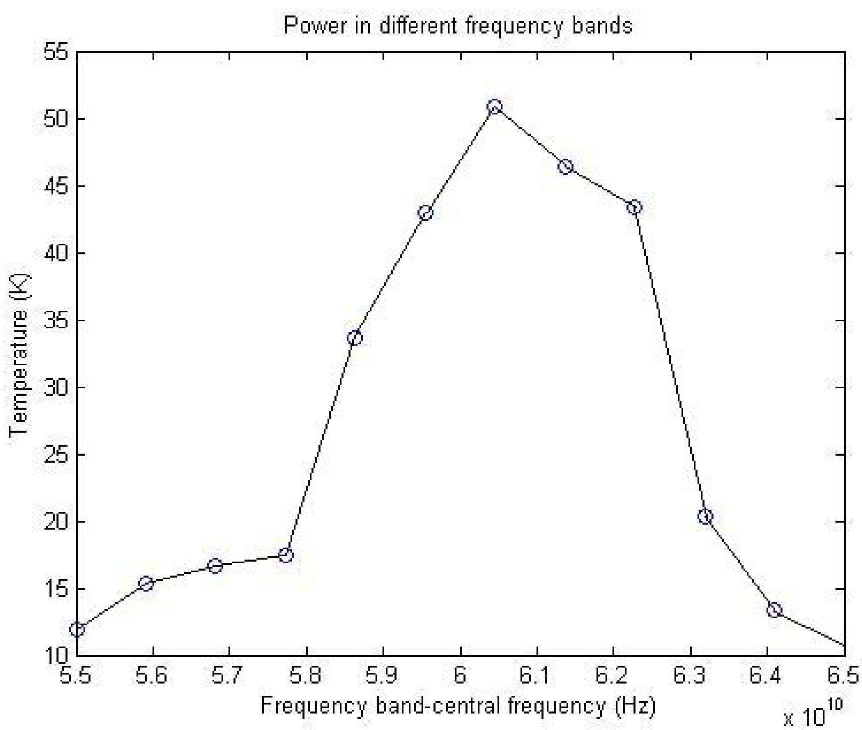

Figure 12-5: Output from Radiometer

The graph below (Figure 12-6) was achieved during the calibration of the equipment. This figure shows that measuring the temperature of the input signal and the signal that enters the detector yields the same result. This is desired to demonstrate that the receiver is not changing the intensity of the signal as it is being filtered.

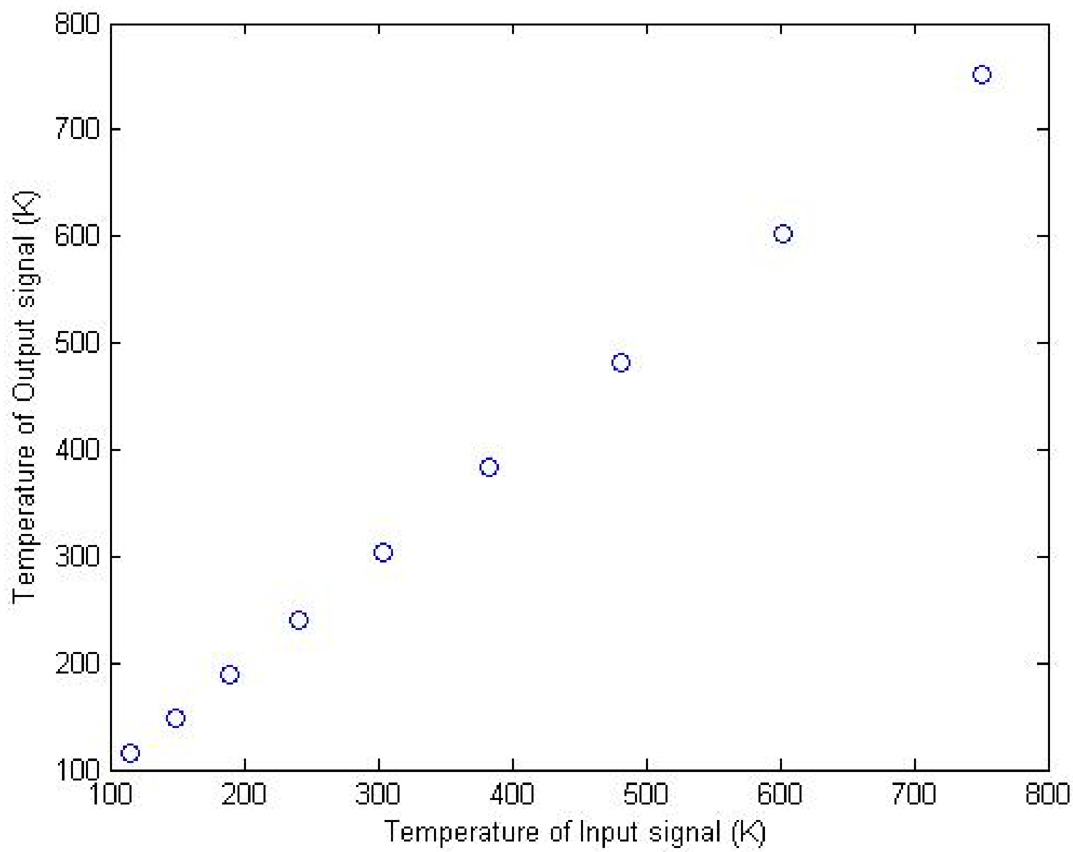

Figure 12-6: Equipment Calibration

13. Digital Processing Simulation

13.1 INTRODUCTION

The digital processing design was simulated using Simulink. Simulink provides an environment for multi-domain simulation and model-based design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries. One can design, simulate, implement, and test a variety of time-varying systems, including communications, controls, and signal processing.

13.2 SIMULATION

The block diagram in Figure 13.1 shows the simulation based on the detector output of the communication system and the digitizing equipment of the signal. After the signal is detected, it will have noise due to the environment and internal apperturing. As the signal flows it will be amplified and filtered so that the analog to digital converter will have a substantial signal to convert. By using the Fourier Spectrum Scope, we are able to detect the power level at which the incoming signal refers to in this simulation.

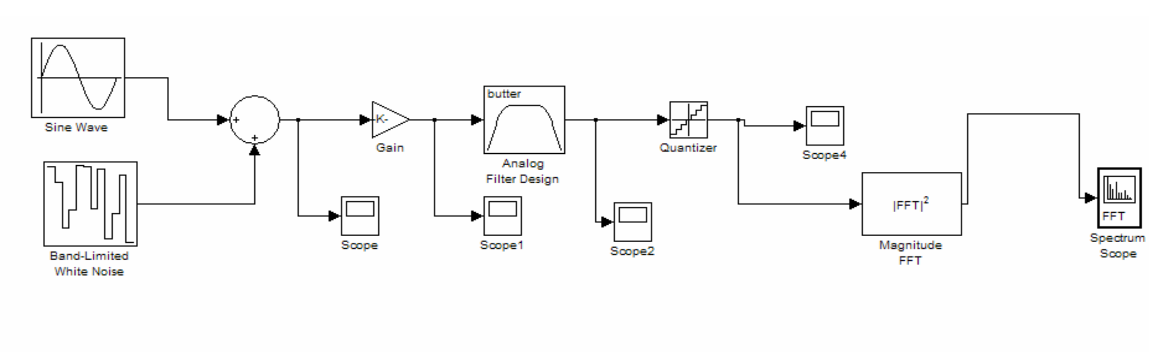

Figure 13.1: Block Diagram of Digital Processing System

The noise was calculated to have a power of .05dB and this relates to volatile movement at 120kft and the transformation of the signal from RF to analog before buffering and amplifying. The detector output signal is seen below in Figure 13.2.

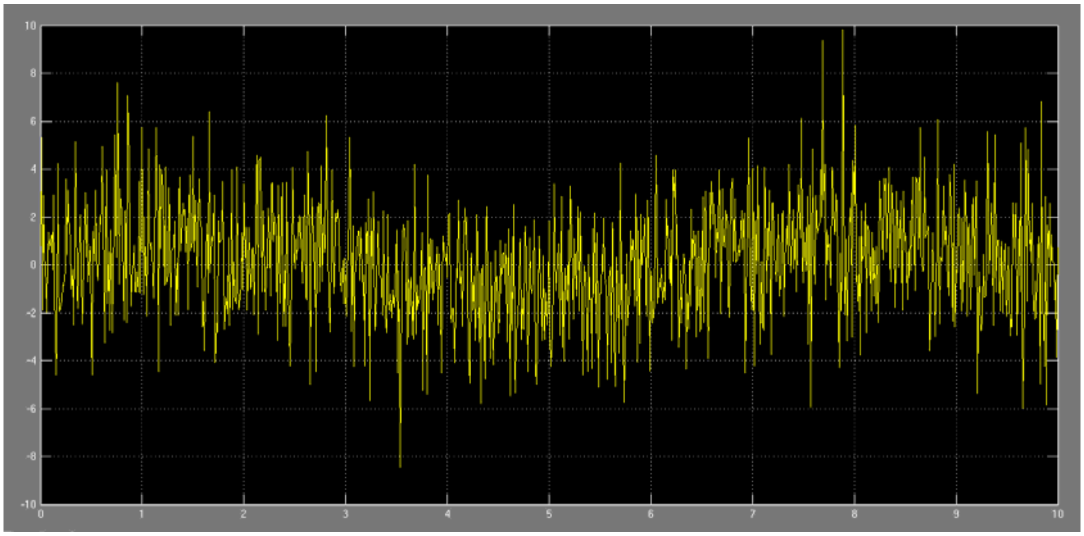

Figure 13.2: Detector Output Signal

After the noisy waveform is amplified with a 30dB gain op-amp, the signal to noise ratio is established and calculated to be 29dB. This is seen in Figure 13.3.

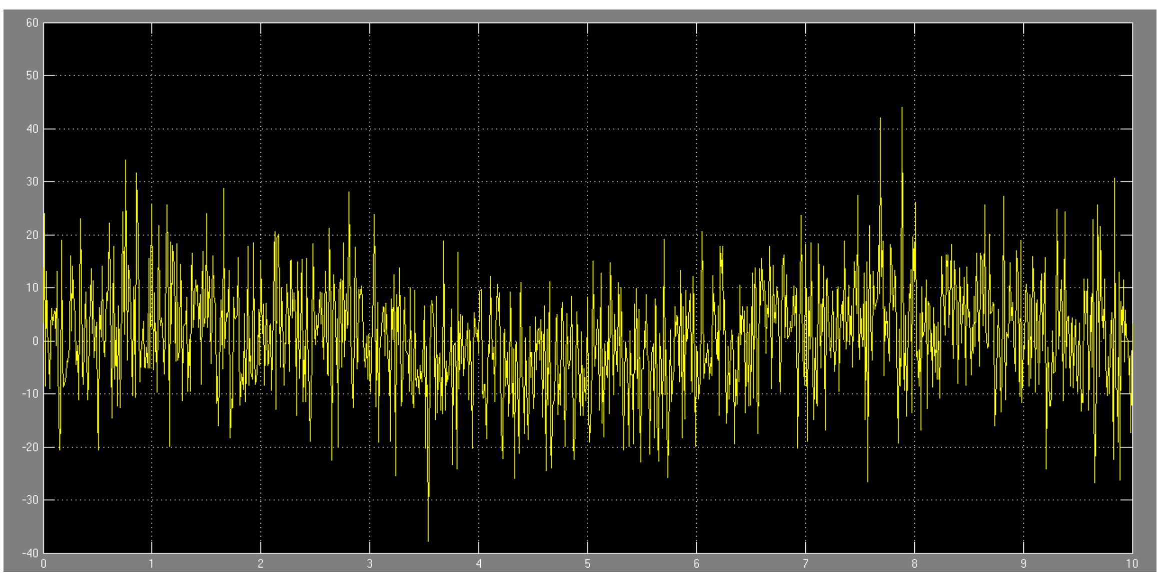

Figure 13.3: DC Amplifier Signal Output

The signal is then filtered using a Bandpass Buttersworth 2nd Order Filter. As detailed in the Figure 13.4, involving environmental and internal component factors, there is a significant response to harmonics in the system that relates to distortion in the signal. The average peak is available by further analyzing the power spectrum in this graph.

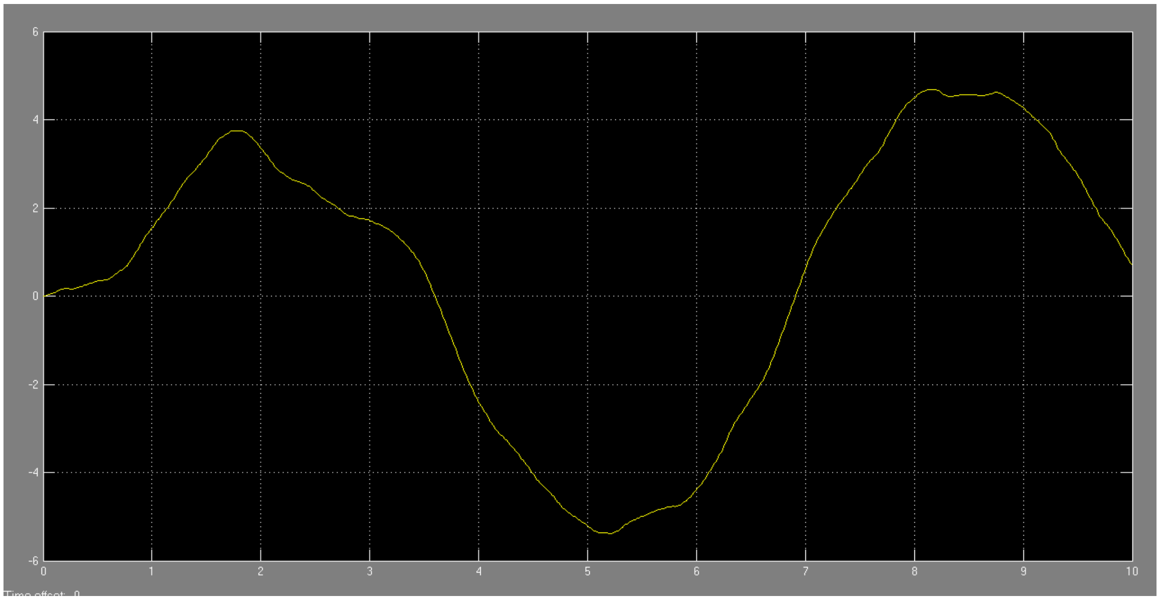

Figure 13.4 Bandpass Filter Signal

After the signal has been received, amplified, and filtered, the signal can then be sampled and digitized for storage purposes. Each of the different quantized levels refer to a specific discrete value which is then stored to the on-board memory chip in 8-bit binary code. This is seen in Figure 13.5.

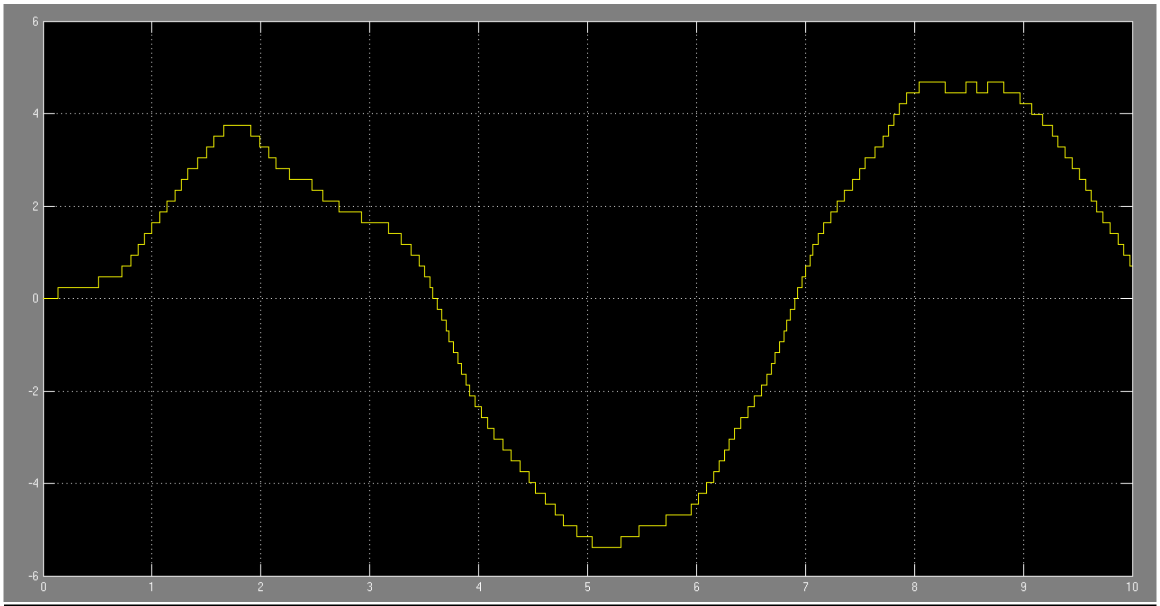

Figure 13.5: Digitized Signal from A/D Converter

The Fourier Transform of the incoming processed signals will output the power spectrum over their given sampled frequency. In this simulation, the Fourier Scope gives a -40 dB which equals .0001 W. The detector will be able to operate at that level. This is seen in Figure 13.6

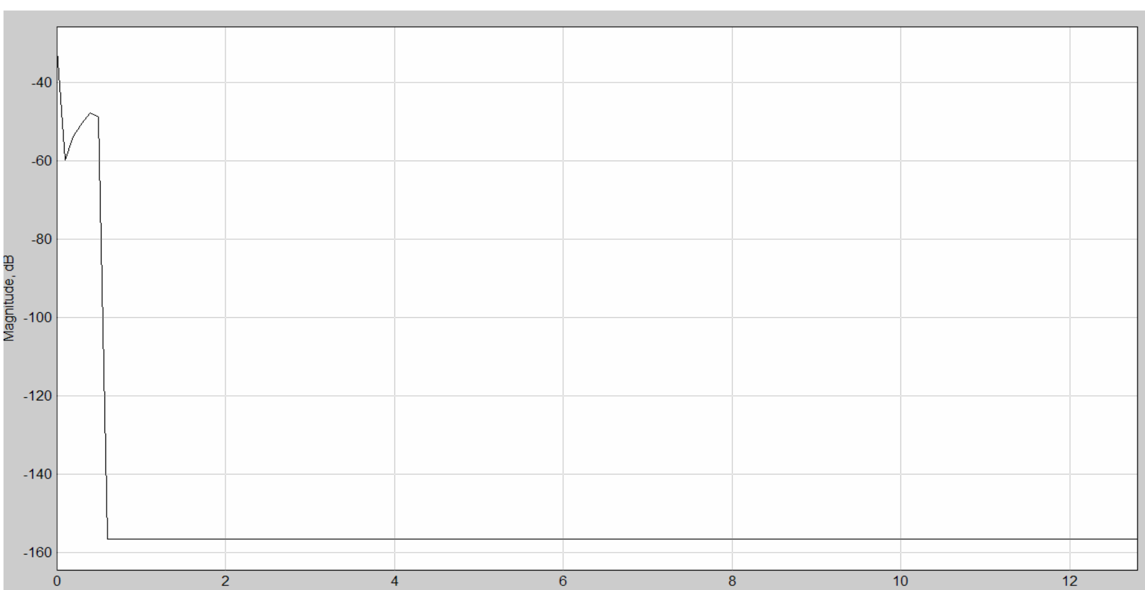

Figure 13.6: Final Power Output

APPENDIX A: Proof of Viability Calculations

APPENDIX B: Flight Information

APPENDIX C: Mechanical Drawings

APPENDIX D: Material Specifications

1. Aluminum Material Specifications

ALUMINUM & STAINLESS
101 THRU-WAY PARK
BROUSSARD, LA 70518
Phone: 337 837-4381 Fax: 337 837-5439
M.T.R. COVER SHEET
02/19/2008

Customer Name : OILQUIP
Address :
City, State Zip :
Attention :
Phone Number : 1 337 433-3601
Reference Number :

Control Number : 501508
Queued By : NORA GATES
Page Number : 1
Total Pages : 5
Fax Number : 1 337 439-4808

THE INFORMATION YOU REQUESTED IS ATTACHED.
THANK YOU FOR YOUR BUSINESS !

HEAT NUMBER	CUSTOMER PO #	PRODUCT
466738	S81664	5052S/125/32
999771	S81664	3003S/025/14

02/19/2008 From: ALUMINUM & STAINLESS To: OILQUIP
ITEM #:1 TAG # : NAME :
PO # :S81664 :
B/L # :156110

466738

ALCAN ROLLED PRODUCTS

ALCAN

Accredited Nadcap Materials Testing Laboratory

CERTIFIED TEST REPORT

RAVENSWOOD WV 26164 USA

SHIP TO: ALUMINUM & STAINLESS, 101 THRUWAY PARK, BROUSSARD LA 70510

SOLD TO: ALUMINUM & STAINLESS, 101 THRUWAY PARK, BROUSSARD LA 70510

ALUM&STAIN G11801 4330 INCLUSION SERIAL#: 20080206G11801 PAGE 1 OF 2

CUSTOMER PURCHASE ORDER NO.: 113-9944				ALCAN ORDER NO.: 102-102785		
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ITEM ORDERED: RAVENSWOOD DISTRIBUTOR SPEC FLAT SHEET		MILL				
CUSTOMER SPECIFICATION: ASTM B209-07						
		SHIP NUMBER: 162958		DATE SHIPPED: 02/06/08		
WEIGHT SHIPPED: 10,653	NO. OF PIECES: 195	GOVT. CONTRACT NO.:				

CERTIFICATION

"ALCAN Rolled Products hereby certifies that metal shipped under this order has been inspected and found in conformance with the requirements of the applicable specifications as indicated herein. Any warranty is limited to that shown on ALCAN Rolled Products' standard General Terms and Conditions of Sales. Test records are on file subject to examination."

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Rt 2 South, Century Road
P.O. BOX 68
RAVENSWOOD, WV 26164 USA

LaDonna B. Smith
LaDonna B. Smith - Quality Manager

LOT NUMBER	TEST DIRECTION	NO. OF TESTS	ULTIMATE STRENGTH KSI MIN	ULTIMATE STRENGTH KSI MAX	YIELD STRENGTH KSI MIN	YIELD STRENGTH KSI MAX	ELONGATION % MIN	ELONGATION % MAX	MIN	MAX
466738			***** H32				*****			
	L	2	33.0	33.0	28.7	29.0	9.5	10.0		

5052/.125/32
.125 x 48 x 96

5210
T- 5217

CHEM COMP	SILICON MIN	SILICON MAX	IRON MIN	IRON MAX	COPPER MIN	COPPER MAX	MANGANESE MIN	MANGANESE MAX	MAGNESIUM MIN	MAGNESIUM MAX	CHROMIUM MIN	CHROMIUM MAX	ZINC MIN	ZINC MAX	TITANIUM MIN	TITANIUM MAX	OTHER
SEE ACTUAL CHEMICAL COMPOSITION																	

ALUMINUM REMAINDER

Alcan 9944

02/19/2008 From: ALUMINUM & STAINLESS To: OILQUIP
ITEM #:1 TAG # : NAME :
PO # :S81664 :
B/L # :156110

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Accredited Nadcap Materials Testing Laboratory

CERTIFIED TEST REPORT

RAVENSWOOD, WV 26164 USA

Sold to: ALUMINUM & STAINLESS, 101 THRUWAY PARK, BROUSSARD LA 70510

Ship to: ALUMINUM & STAINLESS, 101 THRUWAY PARK, BROUSSARD LA 70510

ALUM&STAIN G11801 4330 INCLUSION SERIAL#: 20080206G11801 PAGE 2 OF 2

113-9944			102-102785		
5052	00	H32	.12500	48.000	96.000
RAVENSWOOD DISTRIBUTOR					
SPEC FLAT SHEET	MILL				
ASTM B209-07					
	162958		02/06/08		
10,653	195				

CERTIFICATION

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Rt 2 South, Century Road
P.O. BOX 68
RAVENSWOOD, WV 26164 USA

LaDonna B. Smith

							MIN	MAX

ACTUAL CHEMICAL COMPOSITION

466738 C SI= 0.17 FE= 0.19 CU= 0.05 MN= 0.05 MG= 2.66
CR= 0.20 ZN= 0.04
OTHERS-EACH: .05 MAX. OTHERS TOTAL: .15 MAX. AL REMAINDER

THIS TEST REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY OR AUTHORIZED QUALITY DELEGATE.
THE RECORDING OF FALSE, FICTITIOUS, OR FRAUDULENT STATEMENTS OR ENTRIES ON THE CERTIFICATE MAY BE PUNISHED AS A FELONY UNDER FEDERAL LAW.

CHEMISTRY BY OES: ARKSPARK

CHEMISTRIES REPORTED IN PERCENTAGE BY WEIGHT.

WHEN FRACTURE TOUGHNESS TEST REQUIRED, TESTED PER ASTM E399.

WHEN TENSILE TEST REQUIRED, TESTED PER ASTM E8; B557.

Tensile not tested in accordance with NADCAP

"END OF CERTIFICATION"

SILICON		IRON		COPPER		MANGANESE		MAGNESIUM		CHROMIUM		ZINC		TITANIUM	
MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX

SEE ACTUAL CHEMICAL COMPOSITION

02/19/2008 From: ALUMINUM & STAINLESS To: OILQUIP
ITEM #:3 TAG # : NAME :
PO # :S81664 :
B/L # :156110

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CERTIFIED TEST REPORT

RAVENSWOOD, WV 26164 USA

RELIANCE - PHOENIX METALS
4685 BUFORD HIGHWAY
NORCROSS GA
30071

PHOENIX METALS CO.
P.O. BOX 805
NORCROSS GA
30091

PHOENIX 025802 1502 INCLUSION SERIAL#: 20070316025802 PAGE 2 OF 2

CUSTOMER PURCHASE ORDER NO. & ITEM — ALCAN ORDER NO. 052-620777

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161128 / 3003	00	H14	.02500	48.000	.000

ITEM ORDERED: SPEC COIL NON HT MILL

CUSTOMER SPECIFICATION: AMS-QQ-A-250/2

PART NUMBER	B/L NUMBER	DATE SHIPPED
	025800	03/16/07

WEIGHT SHIPPED	NO. OF PIECES	GOVT. CONTRACT NO.
8,056	1	

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LOT NUMBER	TEST DIRECTION	NO. OF TESTS	ULTIMATE STRENGTH K.S.I. MIN.	MAX.	YIELD STRENGTH K.S.I. MIN.	MAX.	ELONGATION % MIN.	MAX	MIN	MAX

ACTUAL CHEMICAL COMPOSITION

999771 C SI= 0.49 FE= 0.60 CU= 0.11 MN= 1.10 ZN= 0.03
OTHERS-EACH: .05 MAX. OTHERS TOTAL: .15 MAX. AL REMAINDER

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CHEMISTRY BY OES: ARKSPARK

CHEMISTRIES REPORTED IN PERCENTAGE BY WEIGHT.

WHEN FRACTURE TOUGHNESS TEST REQUIRED, TESTED PER ASTM E399.

WHEN TENSILE TEST REQUIRED, TESTED PER ASTM E8; B557.

Tensile not tested in accordance with NADCAP

"END OF CERTIFICATION"

CHEM COMP

ALLOY	SILICON MIN.	MAX.	IRON MIN.	MAX.	COPPER MIN.	MAX.	MANGANESE MIN.	MAX.	MAGNESIUM MIN.	MAX.	CHROMIUM MIN.	MAX.	ZINC MIN.	MAX.	TITANIUM MIN.	MAX.	OTHERS EACH MAX.	TOTAL MAX.
SEE ACTUAL CHEMICAL COMPOSITION																		

ALUMINUM REMAINDER

P-800-1550 (1/05)

02/19/2008 From: ALUMINUM & STAINLESS To: OILQUIP
ITEM #:3 TAG # : NAME :
PO # :S81664 :
B/L # :156110

03/27/2007 15:09 2058415797 PHOENIX METALS BHAM PAGE 03/03
03/27/2007 15:39 678-258-7004 CARBON STEEL DEPT PAGE 02/02

ALCAN ROLLED PRODUCTS — ALCAN — Accredited Nadcap Materials Testing Laboratory

CERTIFIED TEST REPORT

RAVENSWOOD, WV 26164 USA

RELIANCE - PHOENIX METALS
4685 BUFORD HIGHWAY
NORCROSS GA
30071

PHOENIX METALS CO.
P.O. BOX 805
NORCROSS GA
30091

PHOENIX 025802 1502. INCLUSION SERIAL#: 20070316025802 PAGE 1 OF 2

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ITEM ORDERED: SPEC COIL NON HT MILL						
CUSTOMER SPECIFICATION: AMS-QQ-A-250/2						
PART NUMBER		B/L NUMBER: 025800		DATE SHIPPED: 03/16/07		
WEIGHT SHIPPED: 8,056	NO. OF PIECES: 1	GOVT. CONTRACT NO.				

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RAVENSWOOD, WV 26164 USA

LaDonna B. Smith
LaDonna B. Smith - Quality Manager

LOT NUMBER	TEST DIRECTION	NO. OF TESTS	ULTIMATE STRENGTH K.S.I. MIN.	MAX.	YIELD STRENGTH K.S.I. MIN.	MAX.	ELONGATION % MIN.	MAX.	MIN	MAX
999771			***** H14				*****			
	L	2	23.7	24.4	21.9	22.1	13.5	15.0		

ALL LOTS ON THIS CERTIFICATION ALSO CONFORM TO THE FOLLOWING REQUIREMENTS

ALSO CONFORMS TO ASTM B209 AND AMS 4008

CHEM COMP	ALLOY	SILICON MIN.	MAX.	IRON MIN.	MAX.	COPPER MIN.	MAX.	MANGANESE MIN.	MAX.	MAGNESIUM MIN.	MAX.	CHROMIUM MIN.	MAX.	ZINC MIN.	MAX.	TITANIUM MIN.	MAX.	OTHERS EACH MAX.	TOTAL MAX.
	SEE ACTUAL CHEMICAL COMPOSITION																		

ALUMINUM REMAINDER

P-460-1120 (1/06)

999771

3003S/.025/14
.0250x48x120

Phoenix Metals 8022
44592

2. Gorilla Glue Material Specifications

Material Safety Data Sheet

Data prepared: January 26, 2007 Data revised: 1st edition

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND THE COMPANY

Product Name: New Stronger-Faster Gorilla Glue®

Product Type: Polyurethane adhesive for wood and wood substrates

Distributor: The Gorilla Glue Company
4550 Red Bank Expressway
Cincinnati, OH 45227
Tel: (513) 271-3300
Fax: (513) 527-3742
Emergency: During business hours: The Gorilla Glue Company: (800) 966-3458.
Outside business hours: Prosar International Poison Center: (800) 420-7186.

2. COMPOSITION/INFORMATION ON INGREDIENTS

Chemical name	CAS No.	% content
Urethane prepolymer	trade secret	40-50
Polymeric MDI*	9016-87-9	50-60

*Polymeric MDI is a mixture of 4,4'-Diphenylmethane-diisocyanate, isomers and homologues.

3. HAZARDS IDENTIFICATION

Harmful by inhalation. Irritating to eyes, respiratory system and skin. May cause sensitization by inhalation and skin contact.

4. FIRST AID MEASURES

Inhalation If aerosol or vapour is inhaled in high concentrations: Move affected individual to fresh air and keep him warm, let him rest. If there is difficulty in breathing, call a doctor.

Eye contact Flush eyes for at least 10 minutes while holding eyelids open. Contact a doctor.

Skin contact Remove contaminated clothes immediately, and wash skin with a cleanser based on polyethylene glycol or with plenty of warm water and soap. Consult a doctor in the event of a skin reaction.

Ingestion Product is not intended to be ingested or eaten. If this product is ingested, severe irritation of the gastrointestinal tract may occur, and should be treated symptomatically. Do not induce the patient or animal to vomit. Call a doctor, ambulance or seek veterinarian assistance immediately.

5. FIRE FIGHTING MEASURES

Upper flammable limit (UFL): Not determined

Lower flammable limit (LFL): Not determined

NFPA: Health – 3, Flammability – 1, Reactivity – 1

HMIS: Health – 3, Flammability – 1, Reactivity – 1

General fire hazards

Down-wind personnel must be evacuated. Do not reseal contaminated containers; a chemical reaction generating carbon dioxide gas pressure may occur resulting in rupture of the container. Dense smoke is emitted when product is burned without sufficient oxygen. When using water spray, boil-over may occur when product temperature reaches the boiling point of water, and the reaction forming carbon dioxide will accelerate. MDI vapour and other gases may be generated by thermal decomposition.

Special hazards in fire

In case of fire, formation of carbon monoxide, carbon dioxide, nitrogen oxide, isocyanate vapour, and traces of hydrogen cyanide is possible.

Extinguishing Media

Carbon dioxide, dry powder, and foam. In cases of large scale fires, alcohol-resistant foams are preferred. If water is used, it should be used in very large quantities. The reaction between water and isocyanate may be vigorous.

Required special protective equipment for fire-fighters

Fire fighters should wear full-face, self-contained breathing apparatus and impervious protective clothing. Fire fighters should avoid inhaling any combustion products.

6. ACCIDENTAL RELEASE MEASURES

Personal precautions

Wear full-protective clothing and respiratory protection as required maintaining exposures during clean-up below the applicable exposure limits.

Environmental precautions

Do not discharge spillage into drains.

Clean-up procedures

Remove mechanically; cover remainders with wet absorbent material (e. g. sand, earth, sawdust). After approx. one hour transfer to waste container and do not seal (evolution of CO_2). Keep damp in a safe ventilated area for several days.

7. HANDLING AND STORAGE

Handling

Avoid contact with skin and eye. Do not smoke, eat and drink at the work-place.

Ventilation: If vapour or mist is generated during processing or use, local exhaust ventilation should be provided to maintain exposures below the applicable limits.

Personal protection: see Section 8.

Storage

Keep product away from sources of alcohols, amines, or other materials that react with isocyanates. Avoid prolonged heating above 160°C/320°F. Store the product in tightly closed containers in a well-ventilated place and in accordance with national regulations. Keep out of reach of children.

8. EXPOSURE CONTROLS/ PERSONAL PROTECTION

For exposure controls see Section 15.

Component exposure limits

Name	CAS no.	Type	ppm	mg/m³
4,4'-Diphenylmethane diisocyanate	101-68-8	OSHA PEL	0.02	0.2
		ACGIH (TLV-TWA)	0.005	

Personal protection equipment

General	Wear suitable protective clothing, protective gloves and protective goggles/mask.
Suitable materials for safety gloves	Natural rubber/natural latex – NR (>= 0.5 mm) Polychloroprene – CR (>= 0.5mm) Nitrile rubber – NBR (>= 0.35mm) Butyl rubber – IIR (>= 0.5 mm) Fluorinated rubber – FKM (>= 0.4 mm)

Personal protection equipment (continued)

Respiratory protection	Required in insufficiendy ventilated working areas and during spraying. An air-fed mask, or for short periods of work, a combination of charcoal filter and particulate filter is recommended.
Eyes protection	Chemical goggles or full face shields are recommended. An eyewash fountain and safety shower should be available in the work area. Contact lenses should not be worn when working with this product.
Skin protection	Wear special gloves and working clothes to avoid skin irritation or sensitization. Depending on operation, chemical resistant boots, overshoes, and apron may also be required. Suitable materials for clothing: Polyethylene/ethylene vinyl alcohol laminates (PE/VAL) has been reported as an effective material of construction for chemical protective clothing for MDI.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical form. . . . . Liquid
Color . . . . Dark-Brown
Odor . . . . Earthy, musty
Boiling point . . . . >300°C
Flash point . . . . >250°C
Vapour pressure. . . . . <0,00001 mbar at 20° C (diphenyl-methane-diisocyanate)
Specific gravity . . . . Approx. 1,14 g/cm³ at 20° C
Viscosity . . . . 4,000 – 7,000 mPa.s at 25°C (Brookfield sp. 6/20 rpm)
Solubility in water . . . . . . reacts
Percent VOC 0%

10. STABILITY AND REACTIVITY

Stability

The product is stable under the recommended handling and storage conditions (see section 7).

Hazardous decomposition products

By exposure to high temperature, hazardous decomposition products may develop, such as isocyanate vapour and mist, carbon dioxide, carbon monoxide, nitrogen oxide, and traces of hydrogen cyanide.

Hazardous reaction

Exothermic reaction with amines and alcohols; reacts with water forming heat, CO_2, and insoluble polyurea. The combined effect of CO_2 and heat can produce enough pressure to rupture a closed container.

11. TOXICOLOGICAL INFORMATION

Acute Toxicity	LD_{50} oral, rat: > 5000 mg/kg Skin and mucous membrane compatibility, rabbit: Skin 8 hour's exposure – slight reddening. Eyes – moderate reddening and slight swelling.
Inhalation	Over-exposure may cause irritating effects on nose throat and respiratory tract.
Skin contact	Prolonged or repeated contact may result in tanning and irritating effects.
Eye contact	Over-exposure may cause irritating effects on eyes.

12. ECOLOGICAL INFORMATION

Do not allow the product to escape into waters, wastewater or soil.

Biodegradability	0% after 28 days
Acute fish toxicity	LC0 > 1,000 mg/l (96 hrs.)
Toxicity for daphnia	EC 50 > 1,000 mg/l (24 hrs.)
Acute bacteria toxicity	EC 50 > 100 mg/l (3 hrs.)

13. DISPOSAL CONSIDERATIONS

The product remnants are classified as chemical waste. Dispose of waste according to Local, State, Federal, and Provincial Environmental Regulations.

14. TRANSPORTATION INFORMATION

This preparation is not classified dangerous according to international transport regulations ADR/RID/IMDG/IATA.

Other information: This product is not dangerous cargo. Irritating to skin and mucous membranes. Keep separated from foodstuffs.

15. REGULATION INFORMATION

This product and its components are listed on the TSCA 8(b) inventory.

Symbol

Hazard designation	Xn – Harmful.
Contains	4,4'- Diphenylmethane diisocyanate (MDI), isomere.
R-phrases	R20 – Harmful by inhalation. R36/37/38 – Irritating to eyes, respiratory system and skin. R42/43 – May cause sensitization by inhalation and skin contact.
S-phrases	S23 – Do not breathe gas/fumes/vapour/spray. S36/37 – Wear suitable protective clothing and gloves. S45 – In case of accident or if you feel unwell, seek medical advice immediately. (show the label where possible).

Any existing national regulations on the handling of isocyanates must be observed.

16. OTHER INFORMATION

The information herein is presented in good faith and believed to be accurate as of the effective date given. However, no warranty, expressed or implied, is given. It is the buyer's responsibility to ensure that its activities comply with Federal, State or Provincial, and Local laws.

The Gorilla Glue Company does not test on animals, nor do we require our suppliers to test on animals. Any information provided in this MSDS is based on existing scientific testing of the various raw materials, and is not commissioned by this Company.

Date 01/26/2007

Safety Data Sheet for New Stronger-Faster Gorilla Glue

APPENDIX E: Thermal Design

2. Heater Control Program

This program allows the heater system to switch on and off. It is written in pbasic and used with the Basic Stamp.

```
' {$STAMP BS2p}
' {$PBASIC 2.5}
ch0Bits VAR Byte
ch1Bits VAR Byte
'Channel addresses for ADC0834
'Each must begin with a '1' bit
ch0 CON %1100
ch1 CON %1110
ch2 CON %1101
ch3 CON %1111
Addr VAR Word
looop VAR Word
ch1Addr VAR Word
ch2Addr VAR Word
'The number of bytes each channel will be allocated
'in EEPROM
maxMem CON 12000         '3/4 of 16Kbytes of memory
sec VAR Byte
secR CON $81 'Command to read from seconds register of RTC
secW CON $80 'Command to write to seconds register of RTC
CtrlW CON $8E 'Command to write to control register of RTC
Clear CON $00
HEAT PIN 0
SDA PIN 8
SDATA PIN 10
SCLK PIN 11
RST PIN 12
ADCIO PIN 13
CLK PIN 14
CS PIN 15

'******************
'* Initialization *
'******************
sec = 0
'Clear write protect on RTC so that clock can be set
'and clear seconds to 0.
'HIGH RST
'SHIFTOUT SDATA, SCLK, LSBFIRST, [CtrlW, Clear, secW, Clear]
'LOW RST
DEBUG CLS
HIGH LED1
LOW HEAT
'Main Section of Code ********************
FOR looop = 0 TO 19                'loop 360 times
PAUSE 20000                      'twenty second pause
NEXT                          'end for loop
```

```
FOR Addr = 0 TO maxMem
REVERSE LED1
PAUSE 3886
  'GOSUB Check_Clock
  'IF sec.LOWNIB >= 3 THEN
  '  GOSUB ADC_Data
  '  GOSUB Write_Data
  '  GOSUB Reset_CLock
  'END if
  GOSUB ADC_Data
  GOSUB Write_Data
  GOSUB Display
  IF ch0Bits <= 127.92 THEN    'Turn on at 127.92~15 C'
    HIGH HEAT
  ELSEIF ch0Bits >= 163.93 THEN     'Turn off at 163.93~27 C'
    LOW HEAT
  ENDIF
NEXT
  IF ch1Bits <= 85.42 THEN    'Turn on at 85.42~10 C'
    HIGH HEAT
  ELSEIF ch1Bits >= 121.43 THEN     'Turn off at 121.43~20 C'
    LOW HEAT
  ENDIF
NEXT
DEBUG "Done"
END

Check_Clock:
  HIGH RST
  SHIFTOUT SDATA, SCLK, LSBFIRST, [secR]
  SHIFTIN SDATA, SCLK, LSBPRE, [sec]
  LOW RST

ADC_Data:
  HIGH CS
  LOW CS
  SHIFTOUT ADCIO, CLK, MSBFIRST, [ch0] 'Read Ch0
  SHIFTIN ADCIO, CLK, MSBPOST, [ch0Bits]
  HIGH CS
  LOW CS
  SHIFTOUT ADCIO, CLK, MSBFIRST, [ch1] 'Read Ch1
  SHIFTIN ADCIO, CLK, MSBPOST, [ch1Bits]
  HIGH CS
  LOW CS
RETURN

Write_Data:
  I2COUT SDA, $A0, Addr.HIGHBYTE \Addr.LOWBYTE, [ch0Bits]
  PAUSE 5 'Wait for write cycle to complete
  ch1Addr = Addr + maxMem 'maxMem acts as an offset to the ch1 memory space
  I2COUT SDA, $A0, ch1Addr.HIGHBYTE \ch1Addr.LOWBYTE, [ch1Bits]
RETURN

Reset_Clock:
  HIGH RST
  SHIFTOUT SDATA, SCLK, LSBFIRST, [secW, Clear]
```

```
  LOW RST
RETURN

Display:
  DEBUG HOME
  DEBUG "Ch0: ", DEC ch0Bits, CR
  DEBUG "Ch1: ", DEC ch1Bits, CR
  DEBUG "Count: ", DEC Addr
RETURN
```

3. Data Retrieval Program

This code shows the data retrieval system used to extract the thermal data on the EEprom of the Basic Stamp. The code is written in pbasic.

```
' {$STAMP BS2p}
' {$PBASIC 2.5}
'
'

' Main Program Variables

 SECONDS CON $
 MINUTES CON $
 HOURS   CON $
 DMONTH  CON $25
 MONTH   CON $4
 DWEEK   CON $3
 YEAR    CON $08

 SDA   PIN 8     'I2C SDA pin
 SCL   PIN SDA+1

 addr    VAR    Word
 value   VAR    Byte
 result  VAR    Byte
 check   VAR    Word

 SECOND VAR Byte
 MINUTE VAR Byte
 HOUR   VAR Byte

 Delay          VAR Byte(3)
 Time_Elapsed   VAR Byte(3)
 Min_Time       VAR Byte(3)
 Max_Time       VAR Byte(3)

 GMtube         VAR Byte(2)

 Sampling_Time CON 20000

 ' Initiate Variables

 Delay(0) = $0
 Delay(1) = $0
 Delay(2) = $0
```

```
  Time_Elapsed(0) = $16
  Time_Elapsed(1) = $0
  Time_Elapsed(2) = $0

  Min_Time(0) = HOURS + Delay(0)
  Min_Time(1) = MINUTES + Delay(1)
  Min_Time(2) = SECONDS + Delay(2)

  Max_Time(0) = Min_Time(0) + Time_Elapsed(0)
  Max_Time(1) = Min_Time(1) + Time_Elapsed(1)
  Max_Time(2) = Min_Time(2) + Time_Elapsed(2)


' Clock Set Up Variables

  C_SEC     CON 0
  C_MINUTE  CON 1
  C_HOUR    CON 2
  CONTROL   CON 7
  TRICKLE   CON 8
  BURST     CON 31

  rtc   PIN 10
  sdat  PIN 11
  sclk  PIN 12

 'DATA for SETTING the Real time clock

  DATE_TIME DATA SECONDS, MINUTES, HOURS, DMONTH, MONTH, DWEEK, YEAR
    'NOTE DATE_TIME is made of the sec, min, hr, day of month, month, day of week, &
year.

  ADR VAR Byte
  VAL VAR Byte

Set_Real_Time_Clock:

   LOW rtc
   LOW sclk
   HIGH rtc  ' bring /RST high while SCLK is low

   SHIFTOUT sdat, sclk, LSBFIRST, [$80 | (CONTROL<<1) \8]
   SHIFTOUT sdat, sclk, LSBFIRST, [$00\8]

   LOW rtc  ' bring /RST low to terminate

' Now write the date and time, one byte at a time.
```

```
  FOR ADR=0 TO 6
    READ DATE_TIME+ADR, VAL  ' fetch value from EEPROM
    GOSUB _Put_Time
  NEXT

' set the write protect bit

  LOW rtc
  LOW sclk
  HIGH rtc  ' bring /RST high while SCLK is low

  SHIFTOUT sdat, sclk, LSBFIRST, [$80 | (CONTROL<<1) \8]
  SHIFTOUT sdat, sclk, LSBFIRST, [$80\8] ' 1 in most sign bit

  LOW rtc  ' bring /RST low to terminate

Public_Main:

  DEBUG "Program has begun working.", CR
  addr = 0
  GOSUB _Check_Empty_Slot
  GOSUB _Check_Min_Time

  Main_Loop:

    GOSUB _Get_N_Save_GM_One
    IF (addr<=$0) THEN
      END
    ENDIF
    GOSUB _Get_N_Save_GM_Two
    IF (addr<=$0)THEN
      END
    ENDIF
    PAUSE 1000 'wait for a second

    IF (addr>=$7fff) THEN
      'DEBUG "Program has stopped working."
      END
    ENDIF

  GOTO Main_Loop

' Now, Retrieve_Time displays the time in HH:MM:SS format
Retrieve_Time:

  ADR = C_HOUR
  GOSUB _GET_TIME
```

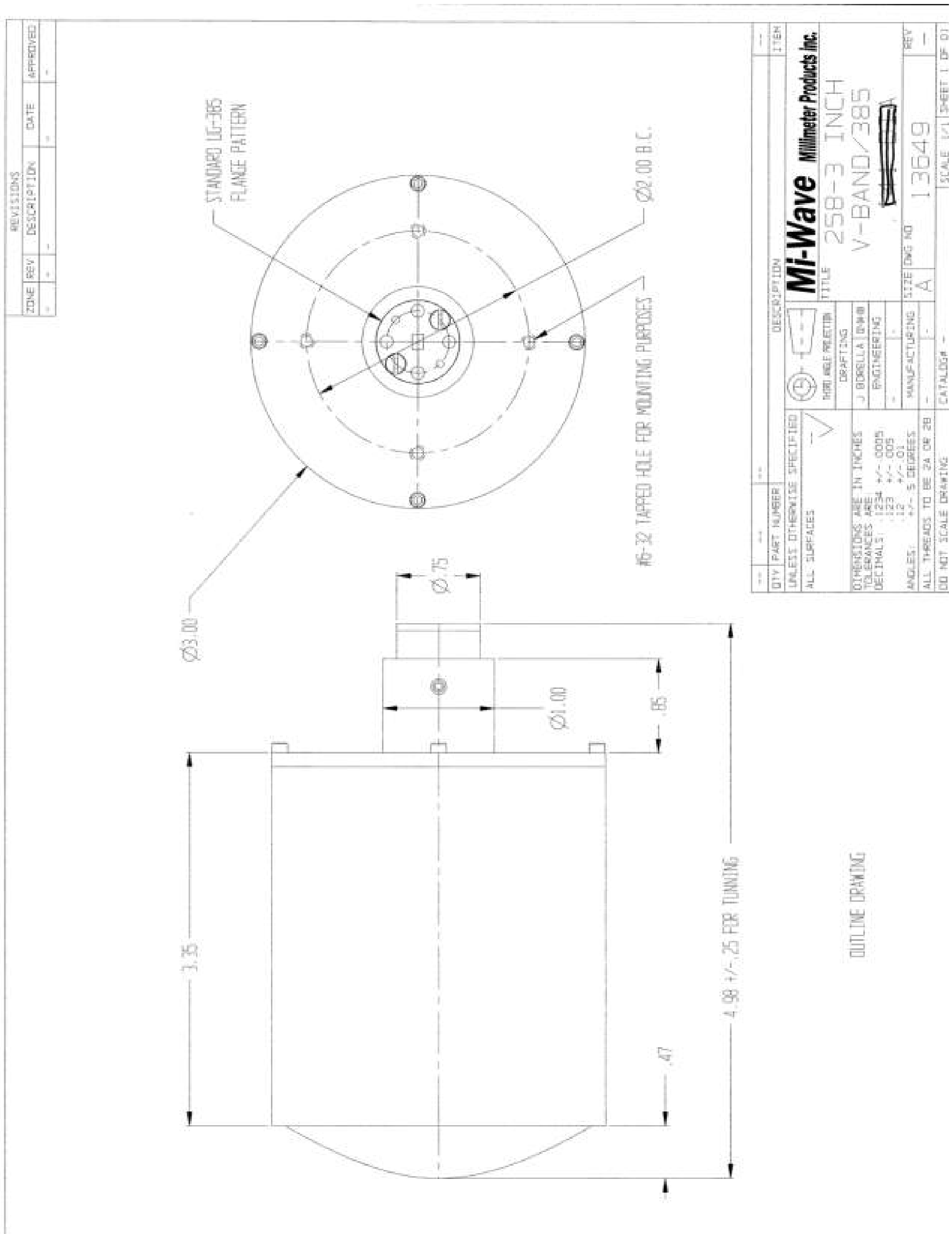
```
  HOUR = VAL

  ADR = C_MINUTE
  GOSUB _GET_TIME
  MINUTE = VAL

  ADR = C_SEC
  GOSUB _GET_TIME
  SECOND = VAL

  RETURN

_Put_Time:

  LOW rtc
  LOW sclk
  HIGH rtc 'bring /RST high while SCLK is low

  SHIFTOUT sdat, sclk, LSBFIRST, [$80 | (ADR<<1)\8] 'command byte
  SHIFTOUT sdat, sclk, LSBFIRST, [VAL\8]

  LOW rtc 'terminate the sequence

  RETURN

_Get_Time:

  LOW rtc
  LOW sclk
  HIGH rtc 'bring /RST high while SCLK is low

  SHIFTOUT sdat, sclk, LSBFIRST, [$81 | (ADR<<1)\8] 'command
  SHIFTIN sdat, sclk, LSBPRE, [VAL\8]

  LOW rtc

  RETURN

_Check_Min_Time:

  GOSUB Retrieve_Time
  IF
((HOUR*3600)+(MINUTE*60)+SECOND)>=((Min_Time(0)*3600)+(Min_Time(1)*60)+Min_Time
(2)) THEN
    RETURN
  ELSE
    GOTO _Check_Min_Time
  ENDIF
```

```
_Check_Empty_Slot:

  I2CIN SDA, $A1, addr.HIGHBYTE\addr.LOWBYTE, [STR result\1]
  IF (result<=$0) THEN
    'Return
  ELSE
    addr = addr+8
    IF (addr <= $0) THEN
      'DEBUG "Program Stopped"
      END
    ENDIF
    GOTO _Check_Empty_Slot
  ENDIF
  RETURN

_Get_N_Save_GM_One:

  'DEBUG "GM Tube One Sampling", CR
  COUNT 2, Sampling_Time, GMtube(0)
  GOSUB Retrieve_Time
  I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [HOUR]
  PAUSE 5
  'DEBUG HEX2 HOUR, ":"
  addr = addr+1
  I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [MINUTE]
  PAUSE 5
  'DEBUG HEX2 MINUTE, ":"
  addr = addr+1
  I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [SECOND]
  PAUSE 5
  'DEBUG HEX2 SECOND, " "
  addr = addr+1
  I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [GMtube(0)]
  PAUSE 5
  'DEBUG DEC GMtube(0), " counts for GM Tube #1 ", CR
  addr = addr+1
  RETURN

_Get_N_Save_GM_Two:

  'DEBUG "GM Tube Two Sampling", CR
  COUNT 6, Sampling_Time, GMtube(1)
  GOSUB Retrieve_Time
  I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [HOUR]
  PAUSE 5
  'DEBUG HEX2 HOUR, ":"
  addr = addr+1
```

```
I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [MINUTE]
PAUSE 5
'DEBUG HEX2 MINUTE, ":"
addr = addr+1
I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [SECOND]
PAUSE 5
'DEBUG HEX2 SECOND, " "
addr = addr+1
I2COUT SDA, $A0, addr.HIGHBYTE\addr.LOWBYTE, [GMtube(1)]
PAUSE 5
'DEBUG DEC GMtube(1), " counts for GM Tube #2 ", CR
addr = addr+1
        RETURN
```

APPENDIX F: Receiver Equipment

1. Horns Lens Antenna Schematic



2. Horn Lens Antenna

258 Series Horn Lens Antennas

Features

- Low Sidelobes
- Wide Bandwidths
- No Aperture Blockage
- Symetrical E and H Plane Beamwidths

Description 258 Series Horn Lens Antennas

Mi-Waves' 258 series horn lens antenna consists of a circular scalar feel horn illuminating a plano-convex lens. Housed in either aluminum or plastic, these horn lens antennas provide a high efficiency beam with equal E and H plane amplitude patterns.

The 258 series antenna are available from 12.4 to 170 GHz in standard sizes of 3, 6, 9, and 12 inch lens apertures. Other custom sizes and configurations are available, please consult *Mi-Wave* for further information.

Ordering Information

258 __ – X XXX

- XXX: Specify Circular Size (See Appendix J)
- X: Specify Size (In Inches)
- __: Specify Frequency

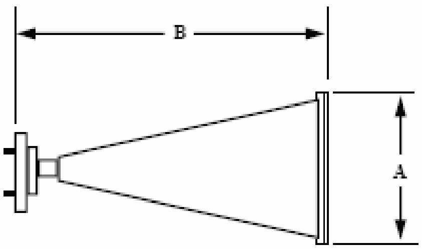
Applications

Radioastronomy
Surveillance Equipment
Communication Systems

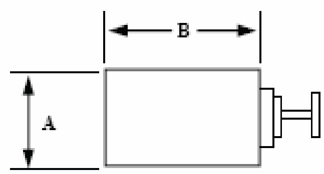
Mi-Wave
Millimeter Wave Products Inc.
www.miwv.com
2200 Tall Pines Drive, Suite 100
Largo, FL 33771
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

258 Series Horn Lens Antennas

Outline of 6, 9, 12"



Outline of 3,"



Please Note: Final dimensions are subject to variations from the tabulated data due to tuning, focusing, and mechanical tolerances.

Dimensional Specifications

Model No.	Effective Diameter (Inches)	A in	A mm	B in	B mm
258KU	-12	14.0	356	21.0	533
258K	-9	11.0	279	15.7	399
258K	-12	14.0	356	19.5	495
258A	-3	4.1	104	8.30	210
258A	-6	7.6	193	11.1	282
258A	-9	11.0	279	14.0	356
258A	-12	14.0	356	18.2	462
258B, U	-3	4.1	104	8.3	210
258B, U	-6	7.60	193	10.6	269
258B, U	-9	11.0	279	14.0	356
258B, U	-12	14.0	356	17.7	450
258V, E, W	-3	4.2	107	6.0	152
258V, E, W	-6	7.6	193	9.6	244
258V, E, W	-9	11.0	279	13.0	330
258V, E, W	-12	14.0	356	16.7	424

Typical Electrical Specifications

Frequency	12.4 to 140 GHz
Sizes	3, 6, 19, 12
Sidelobes	25dB (typical)
VSWR	1.2:1 (typical)
Cross Polarization	25dB (typical)

Mi-Wave
Millimeter Wave Products, Inc.
www.miwv.com
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

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3. H-Plane Bend

670, 671, 672, & 675 Series H-Plane Bends

Features

- Available from 12.4 to 220 GHz
- Additional Radius and Angle Bends by Special Order
- Smooth Precision Bends Minimize Energy Reflections

Description 670, 671, 672 & 675 Series Bends

Mi-Waves' 670, 671, 672 and 675 series H-plane bends are sections of high-precision waveguide accurately shaped to either 30° (671), 45° (675), 60° (672), or 90° (670). Special angles, radii, and configurations for particular application can be developed on special order. All H-plane bends are available from 12.4 to 320 GHz.

Ordering Information

___-___/ ___

Specify Flange (See Appendix A)

Specify RF Band Designator

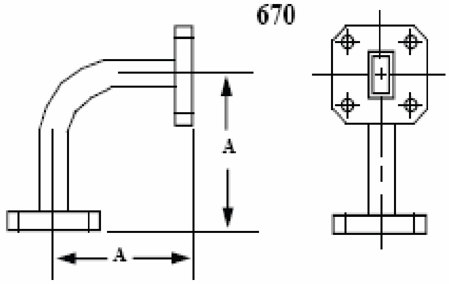
Specify Series (670, 671, 672 or 675)

Applications

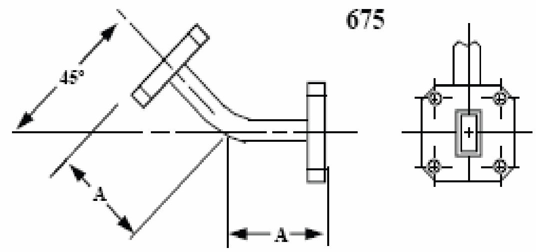
The H-plane bends series provide accurate offsets and directional changes in waveguide transmission lines for test and developmental applications. Manufactured to rigid specifications, these transmission line components provide minimum detrimental effects on the overall system VSWR.

Mi-Wave
Millimeter Wave Products Inc.
www.miwv.com
2200 Tall Pines Drive, Suite 100
Largo, FL 33771
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

670, 671, 672, & 675 Series H-Plane Bends



660	90°
661	30°
662	60°
665	45°



Dimensional Specifications

Model	A		Weight
Number	in	mm	(oz)
670Ku, 671Ku, 672Ku	1.80	45.7	2.7
670K, 671K, 672K	1.50	38.1	2.7
670A, 671A, 672A	1.50	38.1	2.5
670B, 671B, 672B	1.50	38.1	2.3
670U, 671U, 672U	1.50	38.1	2.2
670V, 671V, 672V	1.00	25.4	1.7
670E, 671E, 672E	1.00	25.4	1.6
670W, 671W, 672W	1.00	25.4	1.5
670F, 671F, 672F	1.00	25.4	1.1
670D, 671D, 672D	1.00	25.4	0.8
670G, 671G, 672G	1.00	25.4	0.8
675Ku	1.80	45.7	2.4
675K	1.50	38.1	2.4
675A	1.50	38.1	2.5
675B	1.50	38.1	2.3
675U	1.50	38.1	2.2
675V	1.00	25.4	1.7
675E	1.00	25.4	1.6
675W	1.00	25.4	1.5
675F	1.00	25.4	1.1
675D	1.00	25.4	0.8
675G	1.00	25.4	0.8

Technical Specifications

Model	Frequency Band BBand	
Number	(GHz)	VSWR
670Ku, 671Ku, 672Ku, 675Ku 665Ku	12.4 - 18.0	1.10
670K, 671K, 672K, 675K	18.0 - 26.5	1.10
670A, 671A, 672A, 675A	26.5 - 40.0	1.10
670B, 671B, 672B, 675B	33.0 - 50.0	1.10
670U, 671U, 672U, 675U	40.0 - 60.0	1.12
670V, 671V, 672V, 675V	50.0 - 75.0	1.12
670E, 671E, 672E, 675E	60.0 - 90.0	1.12
670W, 671W, 672W, 675W	75.0 - 110.0	1.15
670F, 671F, 672F, 675F	90.0 - 140.0	1.15
670D, 671D, 672D, 675D	110.0 - 170.0	1.15
670G, 671G, 672G, 675G	140.0 - 220.0	1.15

4. Low Noise Amplifier

955 Series Amplifiers

Features

- Low Noise
- High Gain
- Full Bandwidths
- High 1 db Comp. Points
- Wide Varity of Frequency Ranges
- 2 GHz to 140 GHz

Description 955 Series Amplifiers

Mi-Waves' 955 series microwave and millimeter wave amplifiers offer a wide variety of frequency ranges, bandwidths, gain and power outputs. Low Noise versions are now available. Frequencies from 2 GHz to 140 GHz. Low cost production designs to meet the demanding needs of communications are also now available. High Power Outputs in the Millimeter Wave Frequencies up to +43 dbm. Please consult Mi-Wave for technical specifications and outline drawings

Ordering Information

955 __-__/__

- Specify Flange (See Appendix A)
- Specify Frequency (44 GHz)
- Specify RF Band Designator (K, A, B)

Mi-Wave
Millimeter Wave Products Inc.
www.miwv.com
2200 Tall Pines Drive, Suite 100
Largo, FL 33771
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

955 Series Amplifiers

Technical Specifications

Frequency Ranges 2 to 140 GHz

Gain 10 to 60 db

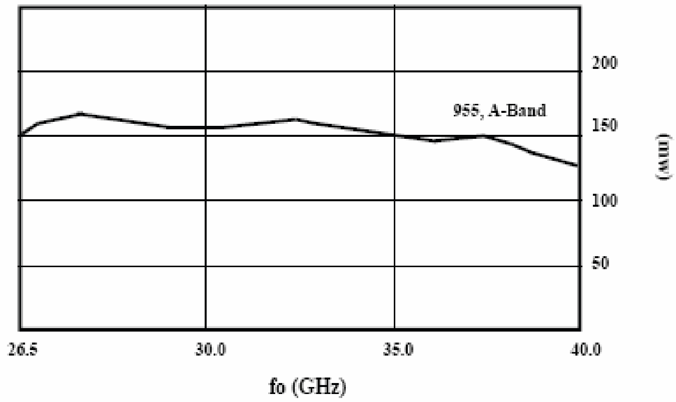
Noise Figures 0.6 db

+43 dbm power outputs

Coaxial and waveguide interfaces

1. Please Consult Mi-Wave with your technical requirements.

Typical Output Power
Ka Band Instrumentation Amplifier
RF input -20 dBm



Mi-Wave
Millimeter Wave Products, Inc.
www.miwv.com
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

5. Full Waveguide Band Isolator

115 Series Full Waveguide Band Isolators

Features

- Low Insertion Loss
- Full Waveguide Band
- Lightweight and Compact Design
- Excellent Isolation Across the Band
- Faraday Rotation Principle of Operation

Description 115 Series Isolators

Mi-Waves' 115 series isolators use the Faraday principle of rotation in a broadband dielectric waveguide design to achieve high isolation across full waveguide bands. These isolators are available in standard waveguide sizes from 18.0 to 110 GHz.

High-quality ferrite material is used in these isolators, and the magnetic field is produced by an integral Alnico V permanent magnet. To ensure maximum reproducibility and performance, a combination of precise machining operations and refined assembly techniques is used.

Applications

Designed for full waveguide band operation, the 115 series isolator is used in swept frequency applications. These components provide a high degree of isolation between signal sources and mismatched loads by attenuating the reflected signals. The insertion loss in the forward direction is minimized to allow for the full available power from the signal source-isolator combination. Typical applications for these broadband isolators include laboratory setups as well as millimeter wave test sets and EW / ELINT hardware.

Ordering Information

115 __ / __

Specify Flange (See Appendix A)

Specify RF Band Designator

WARNING

Sensitive ferromagnetic devices are susceptible to the effects of stray magnetic fields and the presence of other ferrous components. These isolators should be kept at least two inches from all possible sources of interference.

Mi-Wave

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www.miwv.com

2200 Tall Pines Drive, Suite 100

Largo, FL 33771

Tel. (727) 536-0033 Fax. (727) 536-0012

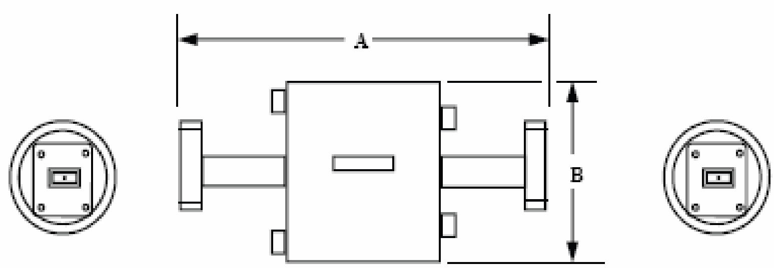
E: sales@miwv.com

115 Series Full Waveguide Band Isolators

Technical Specifications

Model Number	115K	115A	115B	115U	115V	115E	115W
Frequency Band (GHz)	18.0-26.5	26.5-40.0	33.0-50.0	40.0-60.0	50.0-75.0	60.0-90.0	75.0-110.0
Isolation (dB) Typ.	25	25	25	25	25	25	25
Insertion Loss (dB) Typ.	1.0	1.0	1.3	1.5	1.6	1.9	2.2
VSWR Max.	1.30	1.30	1.30	1.30	1.35	1.35	1.40
Power Handling (Watts Max.)	2.0	2.0	1.5	1.5	1.0	1.0	1.0
Waveguide Size	WR-42	WR-28	WR-22	WR-19	WR-15	WR-12	WR-10
Waveguide Flange[1]	UG-595/U (54-4-001)	UG-599/U (54-4-003)	UG-383/U (67-2-006)	UG-383/U (67-2-008)	UG-385/U (67-2-008)	UG-387/U (67-2-009)	UG387/U-M (67-2-010)

1. Optional flanges are available: UG-381/U (67B-005), *Mi-Wave* 719, and *Mi-Wave* 720.
   Please consult *Mi-Wave* for further information.



Dimensional Specifications

Model No.	A		B	
	in	mm	in	mm
115K	4.34	110.2	1.25	31.8
115A	3.38	85.9	1.25	31.8
115B	2.69	68.3	1.25	31.8
115U	2.56	65.2	1.25	31.8
115V	2.56	65.2	0.88	22.2
115E	2.56	64.9	0.88	22.2
115W	2.44	61.9	0.88	22.2

Mi-Wave
Millimeter Wave Products, Inc.
www.miwv.com
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

6. Electronically Tuned Gunn Oscillator

840 Series Electronically Tuned Gunn Oscillators

Features

- Low Noise
- High Reliability
- 12.4 to 110 GHz
- Electronic Tuning

Ordering Information

840 __-__ /__ /__

- Specify Flange (See Appendix A)
- Specify Center Frequency
- Specify Output Power
- Specify RF Band Designator (Ku, K, A, B, U, V, E, W)

Description 840 Series Oscillators

Mi-Waves' 840 series electronically tuned gunn oscillators have been designed to be used where a frequency agile millimeter source is required. This source can be used as a modulated transmitter or local oscillator. This 840 series gunn oscillator can provide up to 500 MHz of electronic tuning with power outputs of up to 250 milliwatts. Frequency stabilities of 100 KHz / ° C can be provided.

Applications

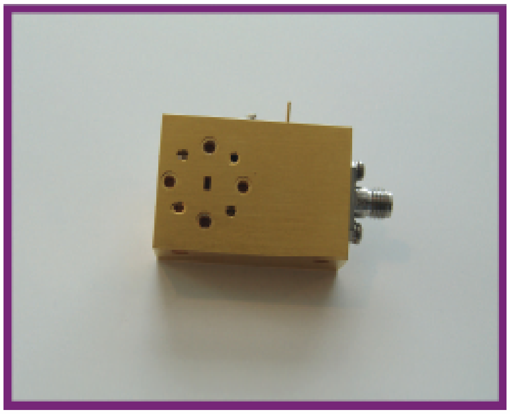
Radar
Swept Sources
Telecommunication Systems

Technical Specifications

Model No.	Frequency Band (GHz)	Power Output (up to mw)	Electronic Tuning (MHz)	Mech. Tuning	Freq. Stability MHz / ° C
840Ku	12.4 - 18.0	250	100	250	.30
840K	18.0 - 26.5	250	125	250	.50
840A	26.5 - 40.0	200	140	250	.70
840B	33.0 - 50.0	200	175	300	.90
840U	40.0 - 60.0	150	200	300	1.10
840V	50.0 - 75.0	100	200	400	2.2
840E	60.0 - 90.0	75	225	500	2.6
840W	75.0 - 110.0	50	250	500	3.5

Mi-Wave
Millimeter Wave Products Inc.
www.miwv.com
2200 Tall Pines Drive, Suite 100
Largo, FL 33771
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

938 Series Active & Passive Broadband Multipliers



Features

- Operation thru 140 GHz
- X2, X3, X4, X6 Multiplication
- High Efficiency
- 10° Percent to 100 Percent Bandwidth's

Description 938 Series Multipliers

Mi-Wave's 938 series frequency multipliers offer broad-band, high efficiency designs that can be used to generate millimeter wave frequencies from lower frequency microwave sources. The Passive Designs use GaAs varactor diodes mounted on a fin line design provides for minimal circuit losses and optimal harmonic generation. An SMA female input connector is available up to an input frequency of 50 GHz.

X2, X3, and most X4 multipliers use only a single multiplier stage. The 938 series multipliers are designed for input power levels from 30 mW to 100 mW. The multipliers are optimized for specific power levels in this range for an input dynamic range of 3 to 4 dB. These units are used for LO sources, frequency extension of synthesizers, and CW transmitters. Options such as isolators and filters can be supplied for many specialized applications. Please consult *Mi-Wave* for further

Operating Specifications

Input VSWR (Typ.)......................	2:1
Harmonic Rejection......................	-20 dBc
Operating Temperature..................	0 to + 60° C
Storage Temperature......................	-55° C to + 125° C

Ordering Information

938 ___/___

Specify Output Band (Ku, K, A, B, U, V, E, W, F, D, G)

Specify Input Band (X, Ku, K, A, B, U, V, E, W)

Please be sure to specify:

- Input Power
- Input Flange
- Output Power
- Output Flange

Mi-Wave
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www.miwv.com
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Largo, FL 33771
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E: sales@miwv.com

8. Harmonic Mixer

920 Series Harmonic Mixers

Features

- Full Waveguide Band Coverage
- Extends the Useful Frequency Range of Spectrum Analyzers

Ordering Information

920 __ / __ / __ (Without Diplexer)

IF Band Designator
02: 10-110 MHz
05: 100-600 MHz
09: 100-1000 MHz
10: 1000-2000 MHz

LO Band Designator
S: 2-4 GHz
C: 4-8 GHz
X: 8-12 GHz
Ku: 12-18 GHz

Specify RF Frequency Designator
(A, B, U, V, E, W, F)

Optional IF amplifiers are available. Please consult *Mi-Wave* for further information.

Description 920 Series Harmonic Mixers

Mi-Wave's 920 series harmonic mixers are used to downconvert millimeter wave signals using a Schottky barrier mixer diode. Measurements can be made by mixing the harmonic of the LO with the desired RF signal and observing the resulting IF.

The 920 series is designed for applications where a Diplexer is not required.

Operating Specifications

RF Input Power....................	+15 dBm, Max.
LO Input Power....................	+18 dBm, Max.
Storage Temperature............	-55° C to +125° C
Operating Temperature........	0° C to +60° C
Bias Requirements:	
Diode..........................	-0.7 Vdc @ 5 mA

Mi-Wave
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www.miwv.com
2200 Tall Pines Drive, Suite 100
Largo, FL 33771
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

9. Band Pass Filters

460 Series Band Pass Filters

Features

- Low Cost
- Low VSWR
- Narrow Bandwidths
- High Rejection Levels
- Low in-Band Insertion

Description 460 Series Band Pass Filters

Mi-Wave's 460 series band pass filter is primarily used for narrow band applications. Pass bands are typically from 1% to 4%. This design is well suited for frequency diplexers used in communication systems or any application where narrow bandwidths are required. Insertion losses are typically in the 0.8 dB to 2.0dB area depending upon rejection levels. The 460 series band pass filter can be designed from 12.4 to 60 GHz.

Please consult *Mi-Wave* for further dimensions and specific technical data.

Ordering Information

460 __ – __ / __

Specify Flange (See Appendix A)

Specify Center Frequency

Specify RF Band Designator

Applications

Side Band Filters
Frequency Diplexers
Telecommunications Systems

Mi-Wave
Millimeter Wave Products Inc.
www.miwv.com
2200 Tall Pines Drive, Suite 100
Largo, FL 33771
Tel. (727) 536-0033 Fax. (727) 536-0012
E: sales@miwv.com

APPENDIX G: Digital Design

1. Sawtooth Waveform Generator Code

This Matlab code demonstrates the Sawtooth Waveform Generator.

```
t = 0:.01:12;
x=.25;
p=2.5;
w=20;
y = p + w*sin(x*t)/pi; % The fundamental frequency
figure(1)
subplot(2,2,1), plot(t,y, 'k')
title('Sawtooth: first harmonic')
xlabel('t (sec)')
ylabel('V (volts)')
axis;

y = p + w*sin(x*t)/pi + w*sin(x*2*t)/(2*pi);
figure(2)
subplot(2,2,2), plot(t,y, 'k')
title('Sawtooth: first two harmonics')
xlabel('t (sec)')
ylabel('V (volts)')
% The first five harmonics:
y1 = p+w*sin(x*t)/pi+w*sin(x*2*t)/(2*pi)+w*sin(x*3*t)/(3*pi);
y = y1 + w*sin(x*4*t)/(4*pi)+w*sin(x*5*t)/(5*pi);
figure (3)
subplot(2,2,3), plot(t,y, 'k')
title('Sawtooth: first five harmonics')
xlabel('t (sec)')
ylabel('V (volts)')
% The first ten harmonics:
y1 = p+w*sin(x*t)/pi+w*sin(x*2*t)/(2*pi)+w*sin(x*3*t)/(3*pi);
y2 = y1+w*sin(x*4*t)/(4*pi)+w*sin(x*5*t)/(5*pi)+w*sin(x*6*t)/(6*pi);
y3 = y2+w*sin(x*7*t)/(7*pi)+w*sin(x*8*t)/(8*pi)+w*sin(x*9*t)/(9*pi);
y = y3+w*sin(x*10*t)/(10*pi);
figure(4)


subplot(2,2,4), plot(t,y, 'k')
title('Sawtooth Waveform Generator')
xlabel('t (sec)')
ylabel('V (volts)')
hold on
r=4
plot(t, r, 'k')

%The first fifteen harmonics
```

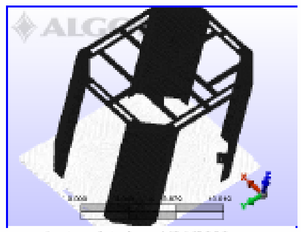
```
y1 = p+w*sin(x*t)/pi+w*sin(x*2*t)/(2*pi)+w*sin(x*3*t)/(3*pi);
y2 = y1+w*sin(x*4*t)/(4*pi)+w*sin(x*5*t)/(5*pi)+w*sin(x*6*t)/(6*pi);
y3 = y2+w*sin(x*7*t)/(7*pi)+w*sin(x*8*t)/(8*pi)+w*sin(x*9*t)/(9*pi);
y4 = y3+w*sin(x*10*t)/(10*pi)+w*sin(x*11*t)/(11*pi)+w*sin(x*12*t)/(12*pi);
y = y4+w*sin(x*13*t)/(13*pi)+w*sin(x*14*t)/(14*pi)+w*sin(x*15*t)/(15*pi);
figure(5)


subplot(2,2,4), plot(t,y, 'k')
title('Sawtooth Waveform Generator')
xlabel('t (sec)')
ylabel('V (volts)')
hold on
r=4
plot(t, r, 'k')

%The first twenty harmonics

y1 = p+w*sin(x*t)/pi+w*sin(x*2*t)/(2*pi)+w*sin(x*3*t)/(3*pi);
y2 = y1+w*sin(x*4*t)/(4*pi)+w*sin(x*5*t)/(5*pi)+w*sin(x*6*t)/(6*pi);
y3 = y2+w*sin(x*7*t)/(7*pi)+w*sin(x*8*t)/(8*pi)+w*sin(x*9*t)/(9*pi);
y4 = y3+w*sin(x*10*t)/(10*pi)+w*sin(x*11*t)/(11*pi)+w*sin(x*12*t)/(12*pi);
y5 = y4+w*sin(x*13*t)/(13*pi)+w*sin(x*14*t)/(14*pi)+w*sin(x*15*t)/(15*pi);
y6 = y5+w*sin(x*16*t)/(16*pi)+w*sin(x*17*t)/(17*pi)+w*sin(x*18*t)/(18*pi);
y = y6+w*sin(x*19*t)/(19*pi)+w*sin(x*20*t)/(20*pi);
figure(6)


subplot(2,2,4), plot(t,y, 'k')
title('Sawtooth Waveform Generator')
xlabel('t (sec)')
ylabel('V (volts)')
hold on
r=4
plot(t, r, 'k')
```

APPENDIX H: Stress Analysis

1. Payload Shell Stress Analysis

ALGOR®

Design Analysis



Last updated on 4/24/2008.

Project reviewed on 4/24/2008.

Summary

Model Information

Analysis Type - Static Stress with Linear Material Models
Units - English (in) - (lbf, in, s, deg F, deg F, V, ohm, A, in*lbf)
Model location - C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\Payload Assembly w-o Sensors v2.fem
Design scenario description -

Analysis Parameters Information

Load Case Multipliers

Static Stress with Linear Material Models may have multiple load cases. This allows a model to be analyzed with multiple loads while solving the equations a single time. The following is a list of load case multipliers that were analyzed with this model.

Load Case	Pressure/Surface Forces	Acceleration/Gravity	Displaced Boundary	Thermal	Voltage
1	1	1	0	0	0

Gravity Information

The following lists the values used if acceleration or gravity was included in the analysis. The Acceleration/Gravity direction multiplier is multiplied by the Acceleration Due To Body Force which is then multiplied by the Acceleration/Gravity load case multiplier.

Acceleration Due To Body Force = 386.4 in/sÂ²

Acceleration/Gravity X Multiplier	Acceleration/Gravity Y Multiplier	Acceleration/Gravity Z Multiplier
5	5	10

Multiphysics Information

Default Nodal Temperature	0 Â°F
Source of Nodal Temperature	None
Time step from Heat Transfer Analysis	Last

Processor Information

Type of Solver	Sparse
Disable Calculation and Output of Strains	No
Calculate Reaction Forces	Yes
Invoke Banded Solver	Yes
Avoid Bandwidth Minimization	No
Stop After Stiffness Calculations	No
Displacement Data in Output File	No
Stress Data in Output File	Yes
Equation Numbers Data in Output File	No
Element Input Data in Output File	No
Nodal Input Data in Output File	No
Centrifugal Load Data in Output File	No

Part Information

Part ID	Part Name	Element Type	Material Name
1	PVC Base:2	Brick	Plastic- FEP (Molded/Extruded)
2	Long Corner:1	Brick	Aluminum 5052-H32
3	Base Bracket:1	Brick	Aluminum 5052-H32
4	Long Corner:1	Brick	Aluminum 5052-H32
5	Base Bracket:1	Brick	Aluminum 5052-H32
6	Short Corner:1	Brick	Aluminum 5052-H32
7	Base Bracket:1	Brick	Aluminum 5052-H32
8	Short Corner:1	Brick	Aluminum 5052-H32
9	Base Bracket:1	Brick	Aluminum 5052-H32
10	Top Bracket:1	Brick	Aluminum 6061-T4; 6061-T451
11	Top Bracket:3	Brick	Aluminum 6061-T4; 6061-T451
12	Top Bracket:4	Brick	Aluminum 6061-T4; 6061-T451
13	Top Bracket:5	Brick	Aluminum 6061-T4; 6061-T451
14	Top Frame:1	Brick	Aluminum 5052-H32

Element Properties used for:

- PVC Base:2
- Long Corner:1
- Base Bracket:1
- Long Corner:1
- Base Bracket:1
- Short Corner:1
- Base Bracket:1
- Short Corner:1
- Base Bracket:1
- Top Bracket:1
- Top Bracket:3
- Top Bracket:4
- Top Bracket:5
- Top Frame:1

Element Type	Brick
Compatibility	Not Enforced
Integration Order	2nd Order
Stress Free Reference Temperature	0 Â°F

Material Information

Plastic- FEP (Molded/Extruded) -Brick

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\20.02\matlibs\algormat.mlb
Date Last Updated	2004/09/30-16:00:00
Material Description	Fluorinated Ethylene Propylene
Mass Density	.201e-3 lbf*s^2/in/inÂ³
Modulus of Elasticity	70000 lbf/inÂ²
Poisson's Ratio	.48
Shear Modulus of Elasticity	23649 lbf/inÂ²
Thermal Coefficient of Expansion	5.22e-5 1/Â°F

Aluminum 5052-H32 -Brick

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\20.02\matlibs\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.00025078 lbf*s^2/in/inÂ³
Modulus of Elasticity	10196000 lbf/inÂ²
Poisson's Ratio	0.33
Shear Modulus of Elasticity	3756500 lbf/inÂ²
Thermal Coefficient of Expansion	0.000013222 1/Â°F

Aluminum 6061-T4; 6061-T451 -Brick

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\20.02\matlibs\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.00025265 lbf*s^2/in/inÂ³
Modulus of Elasticity	9993200 lbf/inÂ²
Poisson's Ratio	0.33

Shear Modulus of Elasticity	3771000 lbf/inÂ²
Thermal Coefficient of Expansion	0.000013111 1/Â°F

Processor Output

Processor Summary

```
 ALGOR (R) Static Stress with Linear Material Models
 Version 20.01.00.0024-WIN 26-APR-2007
 Copyright (c) 2007, ALGOR, Inc. All rights reserved.

 **** Memory Dynamically Allocated = 1024066 KB (requested 1257288 KB)
-------------------------------------------------
                       DATE: MARCH 12, 2008
                       TIME: 05:18 PM
                INPUT MODEL: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Pay

            PROGRAM VERSION: 2001000024
            alg.dll VERSION: 2002010036
       agsdb_ar.dll VERSION: 1800000000
      algconfig.dll VERSION: 2002000064
       algsolve.exe VERSION: 2000000463
       amgsolve.exe VERSION:  330000000

-------------------------------------------------

      Structural

1**** CONTROL INFORMATION

      number of node points          (NUMNP)    =          99646
      number of element types        (NELTYP)   =             14
      number of load cases           (LL)       =              1
      number of frequencies          (NF)       =              0
      analysis type code             (NDYN)     =              0
      equations per block            (KEQB)     =              0
      bandwidth minimization flag    (MINBND)   =              0
      gravitational constant         (GRAV)     =     3.8640E+02
      number of equations            (NEQ)      =         298938

 **** PRINT OF NODAL DATA SUPPRESSED
 **** PRINT OF EQUATION NUMBERS SUPPRESSED
 **** Hard disk file size information for processor:

      Available hard disk space on current drive =  80105.953 megabytes

      Gravity direction vector =  5.0000E+00  5.0000E+00  1.0000E+01

1**** ELEMENT LOAD MULTIPLIERS

      load case      case A     case B     case C     case D     case E
      ---------    ---------- ---------- ---------- ---------- ----------

          1         1.000E+00  1.000E+00  0.000E+00  0.000E+00  0.000E+00

 **** Invoking Parallel BCSLIB-EXT Sparse Solver ...

 **** Symbolic Assembling Using the Row-Hits Matrix Profile ...
 **** Assembled in One Block.
 **** Real Sparse Matrix Assembly ...

1**** STIFFNESS MATRIX PARAMETERS

      minimum non-zero diagonal element =           1.0174E+03
      maximum diagonal element          =           7.1114E+07
      maximum/minimum                   =           6.9895E+04
      average diagonal element          =           8.5173E+05

      the minimum is found at equation 468: node=156 Tz
      the maximum is found at equation 294455: node=98152 Ty

      in the upper off-diagonal matrix:
      number of entries in the profile  = 33968940
      number of symbolic nonzero entries= 8231046
      number of real nonzero entries    = 8231042
 **** Sparse Matrix Assembled in One Block
 **** Load case 1
 **** 60.8% of available memory is allocated for the sparse solver
         memory required for the in-core solving:      861996 kbs
     memory required for the out-of-core solving:      126912 kbs
                    memory currently allocated:      611970 kbs
 **** End Sparse Solver Solution


              Reaction Sums and Maxima for Load Case       1

      Sum of applied forces
         X-Force      Y-Force      Z-Force     X-Moment     Y-Moment     Z-Moment
      4.4210E+01   4.4210E+01   8.8419E+01   0.0000E+00   0.0000E+00   0.0000E+00
```

Weight and Center of Gravity Analysis

The weight and center of gravity analysis output file (C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\Payload Assembly w-o Sensors v2.ds_data\1\ds.WCG) was not found.

Meshing Results

Part 1 <PVC Base:2>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	26255

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	52811
Volume	59.073587 in^3
Total elements	80860

	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	36167	20251	2125	22317
Volume %	12.42	15.08	2.42	70.09
Max. length ratio	169.9	33.1	8.8	16.9
Avg. length ratio	4.1	3.1	2.5	2
Avg. aspect ratio	1.2	1.3	1.1	1
Unconstrained aspect ratio	3.8	3.5	1.6	1.5

Log File

```
----------------------------------------------------

    SOLID MESH GENERATION BEFORE ANALYSIS

----------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 1
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 80860  ( 36167,  20251,  2125,  22317 )
    Volume (4,5,6,8 noded %): 59.073587 (  12.42,   15.08,    2.42,   70.09 )
    Number of nodes: 52811
    Length ratios (avg)      4.1,      3.1,      2.5,      2.0
    Length ratios (max)    169.9,     33.1,      8.8,     16.9
    Aspect ratio: unconstrained (   3.8,    3.5,    1.6,    1.5 )
```

Weight and Center of Gravity Analysis

The weight and center of gravity analysis output file (C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\Payload Assembly w-o Sensors v2.ds_data\1\ds.WCG) was not found.

Meshing Results

Part 1 <PVC Base:2>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	26255

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	52811
Volume	59.073587 in^3
Total elements	80860

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	36167	20251	2125	22317
Volume %	12.42	15.08	2.42	70.09
Max. length ratio	169.9	33.1	8.8	16.9
Avg. length ratio	4.1	3.1	2.5	2
Avg. aspect ratio	1.2	1.3	1.1	1
Unconstrained aspect ratio	3.8	3.5	1.6	1.5

Log File

```
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    SOLID MESH GENERATION BEFORE ANALYSIS

----------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:

    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:

    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:

    Meshing only surface defined by part 1

    Generating bricks, wedges, pyramids and tetrahedra elements

    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:

    Elements built (4,5,6,8 noded): 80860  ( 36167, 20251, 2125, 22317 )

    Volume (4,5,6,8 noded %): 59.073587 (  12.42,  15.08,   2.42,  70.09 )

    Number of nodes: 52811

    Length ratios (avg)     4.1,     3.1,     2.5,     2.0

    Length ratios (max)   169.9,    33.1,     8.8,    16.9

    Aspect ratio: unconstrained (   3.8,   3.5,   1.6,   1.5 )
```

```
Average aspect ratios:      (   1.2,    1.3,    1.1,    1.0 )
Total used memory:  117.92 MB
Number of restarts:   0
Elapsed time: 2 minutes 23 seconds
```

Part 2 <Long Corner:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	10165

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	12606
Volume	8.9959 in^3
Total elements	10252

	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	4037	1799	548	3868
Volume %	3.71	4.92	3.72	87.65
Max. length ratio	108	13.2	3.3	3.6
Avg. length ratio	5.7	3.9	2.1	1.2
Avg. aspect ratio	1.3	1.4	1.1	1
Unconstrained aspect ratio	3.8	3.7	1.2	1.1

Log File

```
-----------------------------------------------------------

    GENERATING SOLID MESH FOR ANOTHER PART

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PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\NRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\NRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -rw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\NRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 2
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 10252  ( 4037, 1799, 548, 3868 )
    Volume (4,5,6,8 noded %): 8.995900 (   3.71,    4.92,    3.72,   87.65 )
    Number of nodes: 12606
    Length ratios (avg)     5.7,      3.9,      2.1,      1.2
    Length ratios (max)   108.0,     13.2,      3.3,      3.6
    Aspect ratio: unconstrained (   3.8,    3.7,    1.2,    1.1 )
    Average aspect ratios:      (   1.3,    1.4,    1.1,    1.0 )
    Total used memory:   50.89 MB
```

```
Number of restarts:   0
Elapsed time: 0 minutes 27 seconds
```

Part 3 <Base Bracket:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	538

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	579
Volume	0.45604 in^3
Total elements	241

	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	6	11	11	213
Volume %	0.16	0.9	2.47	96.47
Max. length ratio	10.5	4.5	1.7	3.2
Avg. length ratio	5.1	2.7	1.3	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	1.5	1.6	1.1	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

--------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 3
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 241  ( 6, 11, 11, 213 )
    Volume (4,5,6,8 noded %): 0.456040 (   0.16,   0.90,   2.47,  96.47 )
    Number of nodes: 579
    Length ratios (avg)     5.1,     2.7,     1.3,     1.2
    Length ratios (max)    10.5,     4.5,     1.7,     3.2
    Aspect ratio: unconstrained (   1.5,   1.6,   1.1,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   12.26 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 1 seconds
```

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	538

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	589
Volume	0.45604 in^3
Total elements	241

	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	6	11	11	213
Volume %	0.16	0.9	2.47	96.47
Max. length ratio	10.5	4.5	1.7	3.2
Avg. length ratio	5.1	2.7	1.3	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	1.5	1.6	1.1	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

-----------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -nw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 5
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 241  ( 6, 11, 11, 213 )
    Volume (4,5,6,8 noded %): 0.456040 (   0.16,   0.90,   2.47,  96.47 )
    Number of nodes: 589
    Length ratios (avg)     5.1,     2.7,     1.3,     1.2
    Length ratios (max)    10.5,     4.5,     1.7,     3.2
    Aspect ratio: unconstrained (   1.5,   1.6,   1.1,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   12.31 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 2 seconds
```

Part 6 <Short Corner:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	9229

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	11374
Volume	7.929715 in^3
Total elements	9052

	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	3370	1656	601	3425
Volume %	3.55	4.86	4.76	86.83
Max. length ratio	99.5	25.1	3.3	3.3
Avg. length ratio	5.3	3.8	2	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	3.9	3.6	1.2	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

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PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 6
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 9052  ( 3370, 1656, 601, 3425 )
    Volume (4,5,6,8 noded %): 7.929715 (   3.55,    4.86,    4.76,   86.83 )
    Number of nodes: 11374
    Length ratios (avg)     5.3,      3.8,      2.0,      1.2
    Length ratios (max)    99.5,     25.1,      3.3,      3.3
    Aspect ratio: unconstrained (   3.9,   3.6,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   47.28 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 25 seconds
```

Part 7 <Base Bracket:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh

Final mesh size	0.129125 in
Elements created	538

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	590
Volume	0.45604 in^3
Total elements	241

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	6	11	11	213
Volume %	0.16	0.9	2.47	96.47
Max. length ratio	10.5	4.5	1.7	3.2
Avg. length ratio	5.1	2.7	1.3	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	1.5	1.6	1.1	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

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PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 7
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 241  ( 6, 11, 11, 213 )
    Volume (4,5,6,8 noded %): 0.456040 (   0.16,   0.90,   2.47,  96.47 )
    Number of nodes: 590
    Length ratios (avg)     5.1,     2.7,     1.3,     1.2
    Length ratios (max)    10.5,     4.5,     1.7,     3.2
    Aspect ratio: unconstrained (   1.5,   1.6,   1.1,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   12.34 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 2 seconds
```

Part 8 <Short Corner:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in

Elements created	9229

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	11407
Volume	7.929715 in^3
Total elements	9139

	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	3451	1658	612	3418
Volume %	3.6	4.85	4.86	86.7
Max. length ratio	99.5	25.1	3.3	3.3
Avg. length ratio	5.3	3.8	2	1.2
Avg. aspect ratio	1.3	1.4	1.1	1
Unconstrained aspect ratio	3.9	3.7	1.2	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

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PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 0
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 9139  ( 3451, 1658, 612, 3418 )
    Volume (4,5,6,8 noded %): 7.929715 (   3.60,   4.85,   4.86,  86.70 )
    Number of nodes: 11407
    Length ratios (avg)     5.3,     3.8,     2.0,     1.2
    Length ratios (max)    99.5,    25.1,     3.3,     3.3
    Aspect ratio: unconstrained (   3.9,   3.7,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.4,   1.1,   1.0 )
    Total used memory:   47.31 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 24 seconds
```

Part 9 <Base Bracket:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	538

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	602
Volume	0.45604 in^3
Total elements	241

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	6	11	11	213
Volume %	0.16	0.9	2.47	96.47
Max. length ratio	10.5	4.5	1.7	3.2
Avg. length ratio	5.1	2.7	1.3	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	1.5	1.6	1.1	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

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PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MKE II Payload Updated 2-15\Payload Shell\Large Assemblies'
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MKE II Payload Updated 2-15\Payload Shell\Large Assemblies'

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MKE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 9
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements

FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 241  ( 6, 11, 11, 213 )
    Volume (4,5,6,8 noded %): 0.456040 (   0.16,   0.90,   2.47,  96.47 )
    Number of nodes: 602
    Length ratios (avg)     5.1,     2.7,     1.3,     1.2
    Length ratios (max)    10.5,     4.5,     1.7,     3.2
    Aspect ratio: unconstrained (   1.5,   1.6,   1.1,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   12.37 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 2 seconds
```

Part 10 <Top Bracket:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	278

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	355
Volume	0.227806 in^3
Total elements	378

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	178	88	39	73
Volume %	9.62	11.37	16.54	62.46
Max. length ratio	83.9	8.3	3.8	1.8
Avg. length ratio	6.7	3.2	1.8	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	3.6	1.7	1.2	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

--------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 10
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 378  ( 178, 88, 39, 73 )
    Volume (4,5,6,8 noded %): 0.227806 (   9.62,  11.37,  16.54,  62.46 )
    Number of nodes: 355
    Length ratios (avg)     6.7,     3.2,     1.8,     1.2
    Length ratios (max)    83.9,     8.3,     3.8,     1.8
    Aspect ratio: unconstrained (   3.6,   1.7,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   11.30 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 1 seconds
```

Part 11 <Top Bracket:3>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	278

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra

Watertight	Yes
Mesh has microholes	No
Total nodes	359
Volume	0.227806 in^3
Total elements	387

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	180	100	38	69
Volume %	9.89	14.76	16.2	59.2
Max. length ratio	52.9	12.9	3.8	1.8
Avg. length ratio	6.6	3.4	1.8	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	2.9	2	1.2	1.1

Log File

```
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    GENERATING SOLID MESH FOR ANOTHER PART

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PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -zw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 11
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 387  ( 180, 100, 38, 69 )
    Volume (4,5,6,8 noded %): 0.227806 (   9.89,  14.76,  16.20,  59.20 )
    Number of nodes: 359
    Length ratios (avg)     6.6,     3.4,     1.8,     1.2
    Length ratios (max)    52.9,    12.9,     3.8,     1.8
    Aspect ratio: unconstrained (   2.9,   2.0,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   11.39 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 2 seconds
```

Part 12 <Top Bracket:4>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	278

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes

Mesh has microholes	No
Total nodes	345
Volume	0.227733 in^3
Total elements	370

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	170	87	39	74
Volume %	8.91	11.31	17.59	62.23
Max. length ratio	82.3	13	3.3	2.2
Avg. length ratio	7.4	3.5	1.9	1.2
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	3.6	2	1.2	1.1

Log File

```
----------------------------------------------------------------

    GENERATING SOLID MESH FOR ANOTHER PART

----------------------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 12
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 370  ( 170, 87, 39, 74 )
    Volume (4,5,6,8 noded %): 0.227733 (   8.91,   11.31,   17.59,   62.23 )
    Number of nodes: 345
    Length ratios (avg)      7.4,      3.5,      1.9,      1.2
    Length ratios (max)     82.3,     13.0,      3.3,      2.2
    Aspect ratio: unconstrained (   3.6,   2.0,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   11.35 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 1 seconds
```

Part 13 <Top Bracket:5>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	278

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No

Total nodes	356
Volume	0.227797 in^3
Total elements	411

	Tetrahedra	Pyramids	Wedges	Bricks
Elements	205	97	37	72
Volume %	11.17	12.69	15.69	60.43
Max. length ratio	80.1	8.4	3.3	2.2
Avg. length ratio	6.3	3.5	1.9	1.3
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	3.5	1.7	1.2	1.1

Log File

```
------------------------------------------------

    GENERATING SOLID MESH FOR ANOTHER PART

------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -o=1 -sw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 13
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 411  ( 205, 97, 37, 72 )
    Volume (4,5,6,8 noded %): 0.227797 (  11.17,  12.69,  15.69,  60.43 )
    Number of nodes: 356
    Length ratios (avg)     6.3,     3.5,     1.9,     1.3
    Length ratios (max)    80.1,     8.4,     3.3,     2.2
    Aspect ratio: unconstrained (   3.5,   1.7,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   11.40 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 2 seconds
```

Part 14 <Top Frame:1>

Status: the part successfully meshed.

Surface Mesh Statistics

Mesh operation	Solid mesh
Final mesh size	0.129125 in
Elements created	8923

Solid Mesh Statistics

Mesh type	Mix of bricks, wedges, pyramids and tetrahedra
Watertight	Yes
Mesh has microholes	No
Total nodes	10267

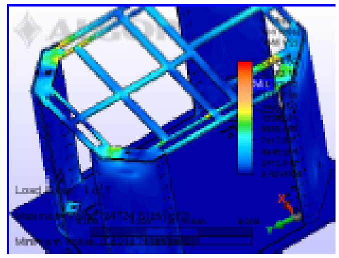
Volume	7.305009 in^3			
Total elements	7051			
	Tetrahedra	**Pyramids**	**Wedges**	**Bricks**
Elements	2496	1268	187	3100
Volume %	3.85	4.86	2.53	88.76
Max. length ratio	65.4	71.2	3.4	3.1
Avg. length ratio	5.7	3.6	1.9	1.1
Avg. aspect ratio	1.3	1.3	1.1	1
Unconstrained aspect ratio	3.1	3.3	1.2	1.1

Log File

```
-----------------------------------------------------

    GENERATING SOLID MESH FOR ANOTHER PART

-----------------------------------------------------

PROGRAM WILL USE THE FOLLOWING FILES:
    Input:  C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\
    Output: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Payload Shell\Large Assemblies\

COMMAND LINE:
    C:\Program Files\ALGOR\20.02\SolidX.exe -b=0 -c=1 -zw=2 C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payl

TYPE OF OPERATION:
    Meshing only surface defined by part 14
    Generating bricks, wedges, pyramids and tetrahedra elements
    Automatically minimizing aspect ratio of solid elements


FINAL STATISTICS:
    Elements built (4,5,6,8 noded): 7051  ( 2496, 1268, 187, 3100 )
    Volume (4,5,6,8 noded %): 7.305009 (   3.85,   4.86,   2.53,  88.76 )
    Number of nodes: 10267
    Length ratios (avg)     5.7,     3.6,     1.9,     1.1
    Length ratios (max)    65.4,    71.2,     3.4,     3.1
    Aspect ratio: unconstrained (   3.1,   3.3,   1.2,   1.1 )
    Average aspect ratios:      (   1.3,   1.3,   1.1,   1.0 )
    Total used memory:   46.53 MB
    Number of restarts:   0
    Elapsed time: 0 minutes 11 seconds
```

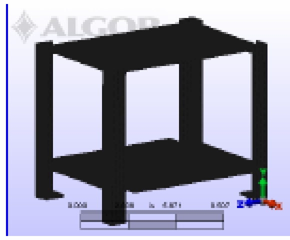
Superview Presentation Images

Stress



2. Support Structure Stress Output

Design Analysis



Last updated on 3/19/2008.

Project reviewed on 3/19/2008.

Summary

Model Information

Analysis Type - Static Stress with Linear Material Models
Units - English (in) - (lbf, in, s, deg F, deg F, V, ohm, A, in*lbf)
Model location - C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Sensor & Component Support Structure\Support Structure.fem
Design scenario description -

Analysis Parameters Information

Load Case Multipliers

Static Stress with Linear Material Models may have multiple load cases. This allows a model to be analyzed with multiple loads while solving the equations a single time. The following is a list of load case multipliers that were analyzed with this model.

Load Case	Pressure/Surface Forces	Acceleration/Gravity	Displaced Boundary	Thermal	Voltage
1	1	1	0	0	0

Gravity Information

The following lists the values used if acceleration or gravity was included in the analysis. The Acceleration/Gravity direction multiplier is multiplied by the Acceleration Due To Body Force which is then multiplied by the Acceleration/Gravity load case multiplier.

Acceleration Due To Body Force = 386.4 in/sÂ²

Acceleration/Gravity X Multiplier	Acceleration/Gravity Y Multiplier	Acceleration/Gravity Z Multiplier
5	10	5

Multiphysics Information

Default Nodal Temperature	0 Â°F
Source of Nodal Temperature	None
Time step from Heat Transfer Analysis	Last

Processor Information

Type of Solver	Sparse
Disable Calculation and Output of Strains	No
Calculate Reaction Forces	Yes
Invoke Banded Solver	Yes
Avoid Bandwidth Minimization	No
Stop After Stiffness Calculations	No
Displacement Data in Output File	No
Stress Data in Output File	Yes
Equation Numbers Data in Output File	No
Element Input Data in Output File	No
Nodal Input Data in Output File	No
Centrifugal Load Data in Output File	No

Part Information

Part ID	Part Name	Element Type	Material Name
1	1. Beam For Support Structure:1	Brick	Aluminum 6061-T4; 6061-T451
2	1. Beam For Support Structure:2	Brick	Aluminum 6061-T4; 6061-T451
3	1. Beam For Support Structure:3	Brick	Aluminum 6061-T4; 6061-T451
4	1. Beam For Support Structure:4	Brick	Aluminum 6061-T4; 6061-T451
5	Platform Tie-ins:1	Brick	Aluminum 5052-H32
6	Platform Tie-ins:2	Brick	Aluminum 5052-H32
7	Platform Tie-ins:3	Brick	Aluminum 5052-H32
8	Platform Tie-ins:4	Brick	Aluminum 5052-H32
9	Sensor Platform:1	Brick	Aluminum Alloy 3003-H14
10	Platform Tie-ins:5	Brick	Aluminum 5052-H32
11	Platform Tie-ins:6	Brick	Aluminum 5052-H32
12	Platform Tie-ins:7	Brick	Aluminum 5052-H32
13	Platform Tie-ins:8	Brick	Aluminum 5052-H32
14	Platform Tie-ins:9	Brick	Aluminum 5052-H32
15	Platform Tie-ins:10	Brick	Aluminum 5052-H32
16	Platform Tie-ins:11	Brick	Aluminum 5052-H32
17	Platform Tie-ins:12	Brick	Aluminum 5052-H32
18	Sensor Platform:2	Brick	Aluminum Alloy 3003-H14

Element Properties used for:

- L Beam For Support Structure:1
- L Beam For Support Structure:2
- L Beam For Support Structure:3
- L Beam For Support Structure:4
- Platform Tie-ins:1
- Platform Tie-ins:2
- Platform Tie-ins:3
- Platform Tie-ins:4
- Sensor Platform:1
- Platform Tie-ins:5
- Platform Tie-ins:6
- Platform Tie-ins:7
- Platform Tie-ins:8
- Platform Tie-ins:9
- Platform Tie-ins:10
- Platform Tie-ins:11
- Platform Tie-ins:12
- Sensor Platform:2

Element Type	Brick
Compatibility	Not Enforced
Integration Order	2nd Order
Stress Free Reference Temperature	0 Â°F

Material Information

Aluminum 6061-T4; 6061-T451 -Brick

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\20.02\matlib\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.00025265 lbf*s^2/in/inÂ^3
Modulus of Elasticity	9993200 lbf/inÂ^2
Poisson's Ratio	0.33
Shear Modulus of Elasticity	3771000 lbf/inÂ^2
Thermal Coefficient of Expansion	0.000013111 1/Â°F

Aluminum 5052-H32 -Brick

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\20.02\matlib\algormat.mlb
Date Last Updated	2004/10/28-16:02:00
Material Description	None
Mass Density	0.00025078 lbf*s^2/in/inÂ^3
Modulus of Elasticity	10196000 lbf/inÂ^2
Poisson's Ratio	0.33
Shear Modulus of Elasticity	3756500 lbf/inÂ^2
Thermal Coefficient of Expansion	0.000013222 1/Â°F

Aluminum Alloy 3003-H14 -Brick

Material Model	Standard
Material Source	ALGOR Material Library
Material Source File	C:\Program Files\ALGOR\20.02\matlib\algormat.mlb
Date Last Updated	2004/09/30-16:00:00
Material Description	None
Mass Density	2.56211e-4 lbf*s^2/in/inÂ^3
Modulus of Elasticity	10.0e6 lbf/inÂ^2
Poisson's Ratio	.38
Shear Modulus of Elasticity	3.63e6 lbf/inÂ^2
Thermal Coefficient of Expansion	12.9e-6 1/Â°F

Processor Output

Processor Summary

```
 ALGOR (R) Static Stress with Linear Material Models
 Version 20.01.00.0024-WIN 26-APR-2007
 Copyright (c) 2007, ALGOR, Inc. All rights reserved.

 **** Memory Dynamically Allocated = 1047740 KB
-------------------------------------------------
                      DATE: MARCH 19, 2008
                      TIME: 10:20 AM
               INPUT MODEL: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Sensor & Comp

          PROGRAM VERSION: 2001000024
              alg.dll VERSION: 2002010036
        agsdb_ar.dll VERSION: 1000000000
      algconfig.dll VERSION: 2002000064
        algsolve.exe VERSION: 2000000463
        ampsolve.exe VERSION:  330000000

-------------------------------------------------

      Structural

1**** CONTROL INFORMATION

      number of node points          (NUMNP)   =        163254
      number of element types        (NELTYP)  =            10
      number of load cases           (LL)      =             1
      number of frequencies          (NF)      =             0
      analysis type code             (NDYN)    =             0
      equations per block            (NEQB)    =             0
      bandwidth minimization flag    (MINBND)  =             0
      gravitational constant         (GRAV)    =    3.8640E+02
      number of equations            (NEQ)     =        489762

 **** PRINT OF NODAL DATA SUPPRESSED
 **** PRINT OF EQUATION NUMBERS SUPPRESSED
 **** Hard disk file size information for processor:

      Available hard disk space on current drive =  79959.570 megabytes

      Gravity direction vector =  5.0000E+00  1.0000E+01  5.0000E+00

1**** ELEMENT LOAD MULTIPLIERS

      load case      case A     case B     case C     case D     case E
      ---------    ---------- ---------- ---------- ---------- ----------

          1        1.000E+00  1.000E+00  0.000E+00  0.000E+00  0.000E+00

 **** Invoking Parallel BCSLIB-EXT Sparse Solver ...

 **** Symbolic Assembling Using the Row-Hits Matrix Profile ...
 **** Assembled in One Block.
 **** Real Sparse Matrix Assembly ...

1**** STIFFNESS MATRIX PARAMETERS

      minimum non-zero diagonal element =           1.3166E+05
      maximum diagonal element          =           6.8367E+07
      maximum/minimum                   =           5.1926E+02
      average diagonal element          =           9.8115E+05

      the minimum is found at equation 54878: node=18293 Ty
      the maximum is found at equation 463621: node=154541 Tx

      in the upper off-diagonal matrix:
      number of entries in the profile  = 43093086
      number of symbolic nonzero entries= 13956795
      number of real nonzero entries    = 13956795
 **** Sparse Matrix Assembled in One Block
 **** Load case 1
 **** ****% of available memory is allocated for the sparse solver
         memory required for the in-core solving:     1369293 Kbs
     memory required for the out-of-core solving:      206119 Kbs
                     memory currently allocated:      306518 Kbs
 **** End Sparse Solver Solution


              Reaction Sums and Maxima for Load Case       1

      Sum of applied forces
         X-Force     Y-Force     Z-Force    X-Moment    Y-Moment    Z-Moment
      1.0268E+01  2.0537E+01  1.0268E+01  0.0000E+00  0.0000E+00  0.0000E+00

      Sum of reactions
         X-Force     Y-Force     Z-Force    X-Moment    Y-Moment    Z-Moment
     -2.8990E+01  1.7034E+01 -9.4317E+00  0.0000E+00  0.0000E+00  0.0000E+00

      Sum of residuals
         X-Force     Y-Force     Z-Force    X-Moment    Y-Moment    Z-Moment
     -1.8721E+01  3.7571E+01  8.3678E-01  0.0000E+00  0.0000E+00  0.0000E+00

      Sum of unfixed direction residuals
         X-Force     Y-Force     Z-Force    X-Moment    Y-Moment    Z-Moment
     -1.8721E+01  3.7571E+01  8.3678E-01  0.0000E+00  0.0000E+00  0.0000E+00

      Largest applied forces and moments
            Node        Node        Node        Node        Node        Node
         X-Force     Y-Force     Z-Force    X-Moment    Y-Moment    Z-Moment
          157483      157483      157483           0           0           0
      2.7400E-04  5.4801E-04  2.7400E-04  0.0000E+00  0.0000E+00  0.0000E+00

      Largest nodal reactions
            Node        Node        Node        Node        Node        Node
         X-Force     Y-Force     Z-Force    X-Moment    Y-Moment    Z-Moment
          154541      153709      154541           0           0           0
     -1.8523E+00 -4.2206E+00 -3.8370E+00  0.0000E+00  0.0000E+00  0.0000E+00

      Largest nodal residuals
            Node        Node        Node        Node        Node        Node
```

```
     X-Force      Y-Force      Z-Force     X-Moment     Y-Moment     Z-Moment
      154541       153709       154541            0            0            0
 -1.8523E+00  -4.2206E+00  -3.0370E+00  0.0000E+00  0.0000E+00  0.0000E+00

  Largest unfixed direction residuals
        Node         Node         Node         Node         Node         Node
     X-Force      Y-Force      Z-Force     X-Moment     Y-Moment     Z-Moment
      154541       153709       154541            0            0            0
 -1.8523E+00  -4.2206E+00  -3.0370E+00  0.0000E+00  0.0000E+00  0.0000E+00


1**** TEMPORARY FILE STORAGE (MEGABYTES)
      ----------------------------------
       UNIT NO.  7 :       3.767
       UNIT NO.  8 :       5.606
       UNIT NO.  9 :       0.000
       UNIT NO. 10 :       0.000
       UNIT NO. 11 :       0.001
       UNIT NO. 12 :       3.737
       UNIT NO. 13 :       3.767
       UNIT NO. 14 :       0.000
       UNIT NO. 15 :       0.000
       UNIT NO. 17 :       0.000
       UNIT NO. 51 :      19.771
       UNIT NO. 52 :     549.067
       UNIT NO. 54 :       1.060
       UNIT NO. 55 :      51.373
       UNIT NO. 56 :     102.745
       UNIT NO. 58 :       3.737
       UNIT NO. 59 :       0.000

       TOTAL       :     746.230 Megabytes
```

Processor Log

```
ALGOR (R) Static Stress with Linear Material Models
Version 20.01.00.0024-WIN 26-APR-2007
Copyright (c) 2007, ALGOR, Inc. All rights reserved.

Structural
 163254   18    1    0  0 0
**** Linear stress analysis
**** Memory Dynamically Allocated = 1047740 KB

     Options executed are:

     NONLIN
     DOTS
     STRAIN
     SPARSE
     SUPCHF
     SUPELM
     SUPNOD
     REAC
     ENOR


     processing ...

**** OPENING TEMPORARY FILES
     NDTN = 0

                  DATE: MARCH 19, 2008
                  TIME: 10:20 AM
           INPUT MODEL: C:\Documents and Settings\Raymond\My Documents\My Docs\Capstone\Drawings & Schematics\MRE II Payload Updated 2-15\Sensor & Comp

         PROGRAM VERSION: 2001000024
         alg.dll VERSION: 2002010036
     agsdb_ar.dll VERSION: 1000000000
    algconfig.dll VERSION: 2002000064
     algsolve.exe VERSION: 2000000463
     amgsolve.exe VERSION:  330000000

**** BEGIN NODAL DATA INPUT
     163254 NODES
       150000 (91.%) nodes
       140000 (85.%) nodes
       130000 (79.%) nodes
       120000 (73.%) nodes
       110000 (67.%) nodes
       100000 (61.%) nodes
        90000 (55.%) nodes
        80000 (49.%) nodes
        70000 (43.%) nodes
        60000 (37.%) nodes
        50000 (30.%) nodes
        40000 (24.%) nodes
        30000 (18.%) nodes
        20000 (12.%) nodes
        10000 ( 6.%) nodes
            0 ( 0.%) nodes

     489762 DOFS
**** END   NODAL DATA INPUT
**** BEGIN TYPE-8 data INPUT
     PART 1 CONTAINING 8331 ELEMENTS
         3000 (36.%) elements
            0 ( 0.%) elements

**** end TYPE-8 data INPUT
**** BEGIN TYPE-8 data INPUT
     PART 2 CONTAINING 8331 ELEMENTS
         7000 (84.%) elements
         6000 (72.%) elements
         5000 (60.%) elements
         4000 (48.%) elements
         3000 (36.%) elements
         2000 (24.%) elements
         1000 (12.%) elements
            0 ( 0.%) elements

**** end TYPE-8 data INPUT
**** BEGIN TYPE-8 data INPUT
     PART 3 CONTAINING 8331 ELEMENTS
```

APPENDIX I: Vibration Analysis

APPENDIX J: Thermal Simulation

APPENDIX K: Receiver Simulation

1. Receiver Simulation Code

This code simulates what the receiver will see and how it will handle it.

```
%SIMULATION OF RADIOMETER
%simple design
%Single frequency detector
%with Local Oscillator
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear
%SIMULATION PARAMETERS
%simulate analog data
%we use high sampling rate
fsamp=23*10^11; % 100 Giga sampling frequency (about 10 time higher than highest
frequency
%that we want to detect
Temp=3; %temperature of noise in Kelvin
kb=1.38*10^-23;% m^2 kg/s^2 K boltzmann constanst

%TIME SEQUENCE
%for longer simulation time we could do a for loop and save just the
%heterodyned and downsampled data points
T=4*10^-8;%simulation time
dt=1/fsamp; %sampling time
Npoints=round(T/dt);%data points in our simulation
t=linspace(0,T,Npoints);%time sequence

%NOISE
%we simulate the noise inital as white noise (real noise is more complicated)
%kb--> Boltzman constant
Noise_Energy=kb*Temp;
R=300;%antenna impedance - constant resistor in Ohms to simulate response of
antenna to EM radiation
deltaf=10*10^9;%bandwidth over which the measurament is being made
Noise_Amp=sqrt(4*Noise_Energy*fsamp/2*R);%amplitude proportional to square root of
energy (up to constant)
noise=Noise_Amp*randn(1,Npoints);% random noise generator to simulate white noise
noise_CMB=sqrt(4*(kb*3)*fsamp/2*R)*randn(1,Npoints);%cosmic background
%we need to convert this into voltage V
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Nf=10;%number of frequencies that we are looking up
 minf=55*10^9;%minimum f
 maxf=65*10^9;%max f
 range=maxf-minf;
 df=range/Nf;
```

```
 signal=zeros(1,Npoints);
 nfft=Npoints;

%freq dependent noise
 fnoise=linspace(0,fsamp,Npoints);% frequency noise range
 fpeak=60*10^9%peak of noise Oxygen line
 gamma=2*10^10;
 fcurve=100*fpeak*gamma./( abs(fnoise.^2-fpeak^2) +gamma^2 );
 noise_fft=fft(noise);
 noise_fft1=noise_fft.*fcurve;
 figure(22)
 semilogy(fnoise,real(noise_fft1),'r-')

 noise=real(ifft(noise_fft1))+noise_CMB;

Ac=3;% initial amplitude signal
n=7;% determines the power law dependency of the strength of the signal
%as a function of frequency (test with different values)

Sig=0;
if Sig==0
    Ac=1;
    n=0;
end

for i=1:Nf

%SIGNAL
%sinusoidal signal at given frequency in the radiometer range
f1=minf+df*(i-1);% in Hz, signal frequency
omega1=2*pi*f1;% angular frequency rad/sec

A=Ac*Noise_Amp*(f1/minf)^n % amplitude of signal, smaller than noise
signal1=A*sin(omega1*t);% sinusoidal signal at given frequency
signal=signal1+signal;% signal plus noise
Const=1/4/fsamp*2/R;
Tsig(i)=A^2*Const/kb;
A1(i)=A;
end

data=noise;
nfft=Npoints;
[PP1,FF1]=psd(data,nfft,fsamp);
figure(1)
semilogy(FF1,sqrt(PP1*300),'r-')
xlabel('frequency (Hz)')
```

```
ylabel('Input (signal+noise from environment) (Volts)')

PP1T=PP1/sqrt(fsamp/2)*Const/kb*300;
figure(2)
semilogy(FF1,PP1T,'r-')
xlabel('frequency (Hz)')
ylabel('Input (signal+noise from environment)-Temperature (K) ')

for i=1:Nf
f1=minf+df*(i-1);
%spectrum of original data
nfft=Npoints;

%ANTENNA block 1
%3 inch horn antenna
% we simulate the antenna as a linear gain
% specifications from Mi-Wave: 30 db gain
%55-65 GHz
Gain_Antenna=30; %decibel
data1=data*exp(Gain_Antenna/20);%conversion from power to amplitude
% data after antenna gain

%LNA (Low Noise Amplifier) block 2
%we simulate the LNA as a linear gain + Noise Figure (added white noise)
%specificatios from Mi-Wave
Gain_LNA=25;% decibel
NF=4.5;% decibel (internal noise)
noise_factor=exp(4.5/20)*Noise_Amp*randn(1,Npoints);
data2=data1*exp(Gain_LNA/20);%+noise_factor; % data after LNA

%BAND PASS FILTER block 3
%we use butterworth filter to create a band pass between
%55 and 65 Giga Hertz
N=5;%order of filter will be 2 times N
w_Nyq=fsamp/2; % Nyquist frequency
w_low=55*10^9/w_Nyq;% low frequency cutoff
w_high=65*10^9/w_Nyq;% high frequency cutoff
wn=[w_low w_high];
[b,a]=butter(N,wn); %filter coefficients
data3=filter(b,a,data2); %filtered data


%CHECKING POWER SPECTRUM OF DATA
%DEMODULATION (MIXER through reference frequency)
%in this step we demodulate we signal (heterodyning) to a smaller frequency
%through mixing the data with a sine wave that is given by a stable
```

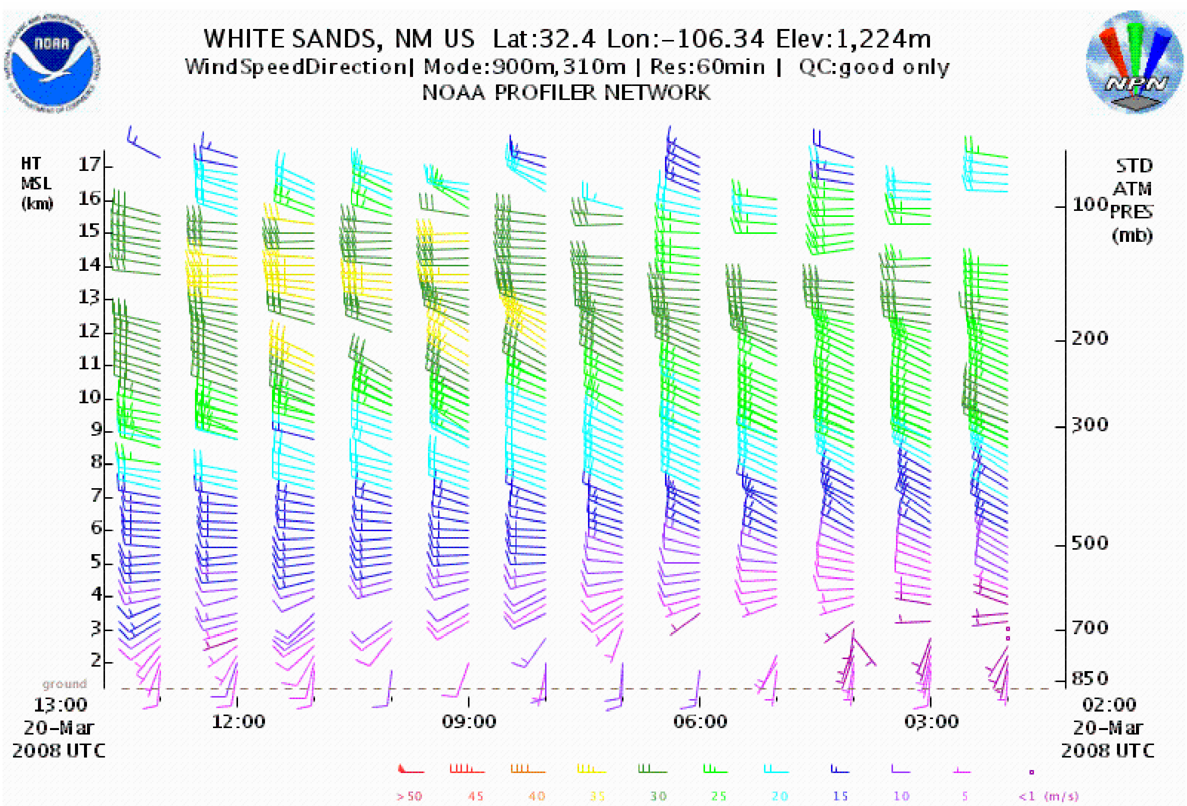
```
%oscillator. The Intermediate Frequency (IF) is chosen to give a final
%bandwith of 1GHz
%mathematically mixing is simply multiplying by a sine wave with a
%frequency=IF, in fact sine(a)*sin(b)=1/2*cos(a-b)-cos(a+b)
%we then filter away the higher frequency and keep the lower one
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
IF=(f1-1*10^9);%we shift the highest frequency we want to detect to 1 GHz
%to have a final bandwidth of 1 GHz
data4=data3.*sin(2*pi*IF*t);%this is a demodulation done by the detector
%GAIN after filter
GainIF=20; %decibel
data5=data4*exp(GainIF/20);%conversion from power to amplitude
% data5 data after IF Gain

%FILTERING after DEMODULATION
%we use Bandpass to eliminate anything above 2GHz
N=2;%order of filter will be 2 times N
w_Nyq=fsamp/2; % Nyquist frequency
w_low=100*10^6/w_Nyq;% low frequency cutoff 100 MegaHz
w_high=2*10^9/w_Nyq;% high frequency cutoff 1 GigaHz
wn=[w_low w_high];
[b,a]=butter(N,wn); %filter coefficients
data6=filter(b,a,data5); %filtered data


%DETECTOR
%square detector: ouptut in Volts (Amplitude) is linearly proportional to
%the input in Power (Energy/time or Amplitude^2/time)
%Millimiter Wave Product Model 950 A: Video Sensitivity 800 mV/mW
V1=data6;


Power1=V1.^2; % in Watts (we need to normalize this) so the quantities are right
PmW=10^-3; % Reference Power: 1 milliwatts
dbm=10*log10(Power1/PmW); %conversion to dbm
Vout_milli=800*Power1/PmW;% conversion to MilliVolts according to square law
data7=sqrt(Vout_milli);

[P_final,F_final]=psd(data6,nfft,fsamp);

%we need to convert this first into Energy then into Temperature

i2=find(F_final<1.2*10^9 & F_final>150*10^6);
i3=find(F_final<1.5*10^9 & F_final>500*10^6);

IF1(i)=IF;
```

```
Pmax=max(P_final(i2));
kb1=kb;

if Sig==0
   ijh=find(FF1<1.2*10^9+IF & FF1>150*10^6+IF);
   Pmax=mean(P_final(i2));
   A1(i)=sqrt(mean( PP1T(ijh) ) );
   Const=1;
   kb1=1;
end


%this is an attempt to convert to Tempature, more work needed
norm1=Pmax/(A1(i)^2*Const);
P_E=P_final/norm1;
P_T=P_E/kb1;


P_T_max(i)=max(P_T(i2));
Psum(i)=sum(P_final(i2))/sqrt(deltaf/2);% total power over the bandwidth
PsumT(i)=sum(P_T(i2));%total temperature over bandwith

figure(10)
semilogy(F_final(i2)+IF,P_T(i2),'r-o')
ylabel('Temperature (K)')
xlabel('Frequency Hz')
title('Final output sweeping through frequencies with increased P proportional to f^{  n}')
hold on
pause(0.01)
end
hold off

figure(11)
plot(Tsig(2:length(Tsig)),P_T_max(2:length(Tsig)),'o')
xlabel('Temperature of Input signal (K)')
ylabel('Temperature of Output signal (K)')

figure(12)
plot(IF1(2:length(IF1)),Psum(2:length(IF1)),'o')
xlabel('Frequency band-central frequency (Hz)')
ylabel('Total power (Watts)')
title('Power in different frequency bands, with bandwidth of 2 GHz')

figure(13)
semilogy(fnoise,fcurve)
```

```
figure(14)
plot(IF1(2:length(IF1)),PsumT(2:length(IF1))*sqrt(deltaf/fsamp*2),'o')
xlabel('Frequency band-central frequency (Hz)')
ylabel('Total power (K)')
title('Power in different frequency bands, with bandwidth of 2 GHz')
```

APPENDIX L: Technical Data

2. Lower Altitude Wind Data for White Sands, New Mexico from NOAA Profiler Network



This diagram shows the wind velocities for a twelve hour time period above White Sands, New Mexico on March 20, 2008. This data was averaged for twelve hours between the altitudes of 1224 meters and 15 kilometers.