1 Introduction

The Alaska Student Rocket Project (ASRP) at the University of Alaska Fairbanks participates in the design and launching of sounding rockets from Poker Flat Research Range. A necessary subsystem for a sounding rocket is the telemetry downlink, which provides communications from the rocket to the ground station. Another subsystem, which is not necessary but provides valuable positioning information, is the Global Positioning System (GPS) receiver. A vital component to both these subsystems is their antennas. One possible antenna that can be used on a sounding rocket is an antenna constructed using microstrip.

In previous ASRP missions, the rocket used a linearly polarized antenna, while the ground station antenna was circularly polarized. The use of a circularly polarized ground station antenna ensured that the telemetry signal was received despite the orientation of the linearly polarized sounding rocket antenna. However, the polarization mismatch between the linearly and circularly polarized antennas resulted in a 3 dB loss in received signal strength. It is the intent of this paper to determine whether the performance of a circularly polarized microstrip antenna, on a sounding rocket, justifies its more complicated design.

The size of the rocket, its maximum altitude, and flight path are determined by various factors, which range from the planned science requirements to the mechanical specifications. Previous rockets launched by ASRP have had diameters of 4 to 8 inches and reached altitudes as high as 80 km. The diameters of future ASRP payloads are expected to be 6, 8, or 14-inches.

This paper will investigate the design and performance of microstrip antennas for both the telemetry and GPS subsystems for 6, 8, and 14-inch rocket diameters. Since circularly polarized antennas provide less polarization loss but are much more difficult to design than linearly polarized antennas, the design of circularly polarized microstrip antennas will be the focus of this paper. However, for the purpose of comparison, the design and performance of a linearly polarized antenna will also be presented. The designs will be based on simplified models and fullwave CAD programs. The accuracy of the designs will be verified by designing, fabricating, and testing a telemetry antenna for the 14-inch diameter cylinder.

1.1 Antenna Requirements

1.1.1 Telemetry Antenna

The onboard transmitter is restricted to operate at one of the twelve telemetry channels within the frequency range of 2 to 3 GHz. The center frequency of each channel is specified by NASA's Sounding Rocket Program Handbook [1]. As seen in table 1.1, four of these channels have bandwidths of 16 MHz and eight have bandwidths of 3 MHz.

The rocket-borne transmitter for the Student Rocket Project 4 (SRP-4) was initially planned to operate at a center frequency of 2.21551 GHz and an output power of 21 dBm [2]. However, after this report was completed, the operating frequency was changed to 2.218 GHz. The link budget for SRP-4's telemetry system requires the transmitting antenna to have a minimum gain of –8 dB, assuming that the loss between the transmitter and antenna is 0.5 dB. A summary of the relevant link budget parameters used in this report is listed in table 1.2.

Table 1.1. Telemetry frequency channels used at Poker Flat Research Range.

Center Frequency (MHz)	**Channel Bandwidth** (MHz)	**Center Frequency** (MHz)	**Channel Bandwidth** (MHz)
2215.5	16	2259.5	3
2235.5	16	2265.5	3
2241.5	3	2269.5	3
2246.5	3	2276.5	3
2251.5	3	2279.5	16
2255.5	3	2295.5	16

Table 1.2. Telemetry link budget parameters.

Center Frequency	2.21551 MHz
Transmitting Power	21 dBm
Minimum Transmitting Antenna Gain	-8 dB
Cable Loss	0.5 dB

1.1.2 GPS Antenna

The Global Positioning System is a constellation of 24 satellites at an altitude of 20,200 km. The standard positioning signal, consisting of the 50 kHz navigation signal modulated by a Coarse/Acquisition (C/A) code, is transmitted on the GPS's L1 carrier. The L1 signal is centered at 1575.42 MHz, has a bandwidth of 2.046 MHz, and is transmitted right-hand circularly polarized. The transmitted signal power ensures a minimum signal power of –160 dBW at the earth's surface. A summary of these specifications is shown in table 1.3 [3].

Table 1.3. GPS L1-band frequency characteristics.

Coding	C/A
Center Frequency	1575.42 MHz
RF Bandwidth	2.046 MHz
Signal Polarization	RHC
Received Signal Strength at Earth's Surface	-160 dBW

The receiving antenna for the L1 signal is generally low gain and right-hand circularly polarized [4]. In order to receive the required number of GPS satellite signals, the pattern must be omnidirectional and have a broad beamwidth. A microstrip patch antenna is well suited for these requirements because it has broad beamwidth and can receive circularly polarized signals.

1.2 Sounding Rocket Antenna using Microstrip

Microstrip antennas meet the requirements for both the telemetry and GPS antennas discussed previously. There are many advantages that encourage the use microstrip antennas for sounding rockets, including low profile, lightweight, conformal shapes, and relatively low fabrication cost. Additionally, circularly polarized waves can be fabricated using simple geometries and more easily than compared to other types of antennas. And lastly, they can be fabricated easily using the existing equipment in UAF's electrical engineering department. The main limitation of microstrip antennas is their narrow bandwidth, which is typically 1 to 5%. Table 1.4 summarizes the advantages and disadvantages of microstrip antennas.

Table 1.4. Advantages and disadvantages of microstrip antennas.

Advantages	Disadvantages
Thin profile	Narrow Bandwidth
Lightweight	Moderate efficiency
Inexpensive and simple to manufacture	Dielectric losses
Unidirectional radiation pattern	Surface wave losses
Conformal	Spurious radiation from feed network
Linear or circular polarization	Variability of substrate permittivity
Amenable to feed networks	Temperature dependence of permittivity
Accurate numerical analysis	Effects of superstrates
	Mutual couplings