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The Design of a PocketQube Satellite Communication System

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Nomenclature

Variables and functions

V	Voltage
I	Current
R	Resistance

Acronyms and abbreviations

GS	GroundStation
PQ	PocketQube
LEO	Low earth orbit
LOS	Line-of-sight

Abstract

English

The English abstract.

Afrikaans

Die Afrikaanse uittreksel.

1. Introduction

This project aims to design and implement a wireless communication system for a miniaturised satellite called a PocketQube (PQ). The PocketQube standard was created to define physical and electronic requirements for so-called ”nano satellites”. The goal of this is to allow for easy integration of various sub-modules into one physical enclosure. One common use-case of these satellites is to collect sensory information from the atmosphere. These can either be placed into orbit, are attached to a *high-altitude balloons* (e.g. a large, helium balloon). In this project, such a balloon will been provided by the department, and a communication system for this satellite balloon will be designed.

This project consists of the design of three sub-systems. The communication system to be designed will involve both a tracking ground station (GS), as well as a PQ ’unit’. The general idea is that the GS will mechanically track the PQ while it communicates with it, enabling realtime data transmission and telemetry. An existing two-axis antenna mount has been provided for the GS, which a newly-designed PCB will be placed into. The GS will mechanically the balloon, allowing bi-directional wireless communication. The PQ unit should conform to the PQ standard and fit inside a provided housing. The third sub-system is the integration of a proprietary Radiosonde (atmospheric telemetry device) into the newly-designed communication system.

Literature will be consulted in order to investigate the various design approaches and decisions. Since the project focuses on system design and integration, a number of components and sub-modules will ultimately be combined to form the final system. Different electronic components and their specifications will be compared based on gathered project requirements. This will require trade-offs to be made, since the system design is limited in time, cost, form-factor and several other factors. This report documents the trade-offs and decisions made, with the goal of being of use to future designers of similar systems.

2. Problem Definition

2.1 Overview

The requirements for this project are defined by analysing general, currently existing balloon-satellite systems, as well as taking into account the planned launch that this specific PocketQube will be used in, as shown in Figure 2.1. Generally, high-altitude balloons can drift to a height as much as 30 km above sea level [1].

For this project, the balloon is planned to be released from around Saldanha Bay (Western Cape, South Africa), where it will travel a maximum distance of around 200 km towards the Cederberg and land furthest in Worcester. From Cape Town, this is a maximum straight line distance of around 115 km. At a height of 30 km, a line-of-sight (LOS) calculator reveals that the horizon is around 600 km, meaning that the antenna could theoretically be placed on sea level. Further, the earth's curvature is found to be negligible at this distance, meaning pythagoras can be used to calculate an LOS of 120 km. Lastly, it should be noted that high-altitude balloons generally remain air-bound for a few hours.

2.2 Requirements

The general requirement of the system is that continuous, wireless communication should be established between the ground station and the balloon for this path. From this information, slightly more specific requirements can be listed:

1. Continuous, wireless communication should be maintained between the GS and the PQ.
2. The line-of-site distance between the GS and PQ should be no less than 120 km for the new protocol. However, for compatibility with the existing proprietary Radiosonde system (iMet-54 + iMet-3100M), a slant range of 250 km will be designed for [2].
3. The PQ unit should remain online (using battery power) for at least 3 hours.
4. The GS should utilize power from a vehicle's 12V battery.

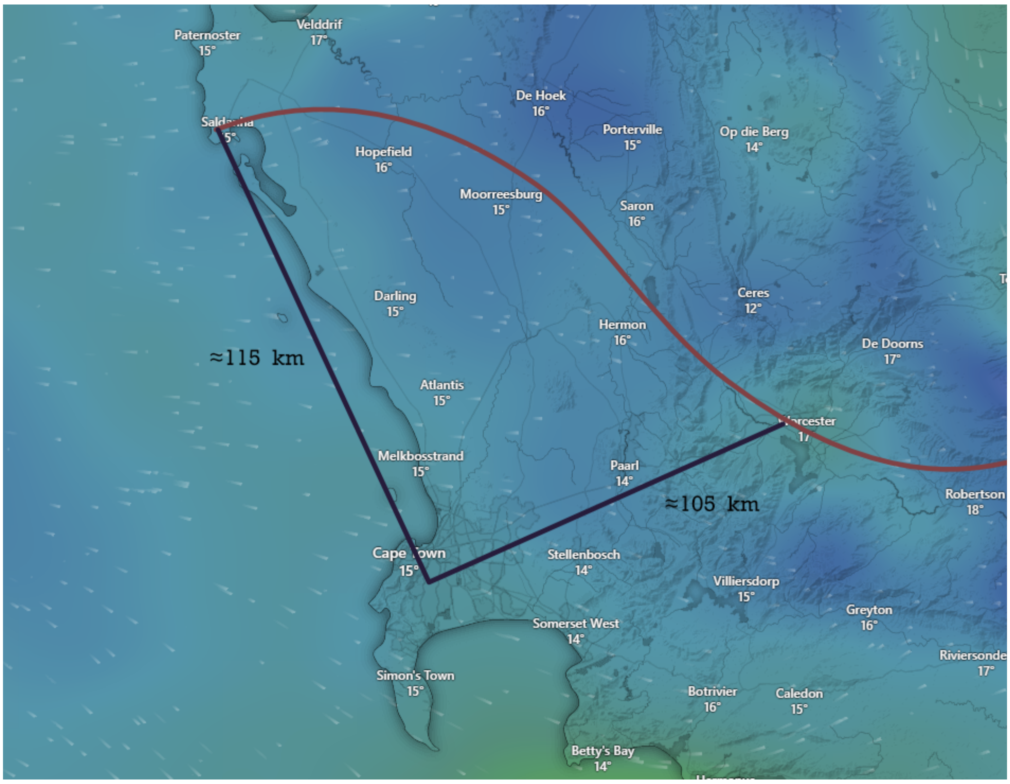

Figure 2.1: Balloon Path and Distances

2.3 Expansions

Although these are the minimum requirements for the Saldanha launch, choices could be made such that the communication system is more general-purpose, and can potentially be used for low earth orbit (LEO) applications as well. In this case, the orbital height is between 160 km and 1000 km [3], and the curvature of the earth must be taken into account. At an LEO height of 160 km, an LOS distance of 1400 km is required, and at 1000 km, an LOS distance of around 3500 km is required. As the project progresses, if supporting such a distance will not significantly increase the time, complexity or cost of the system, it could be added as an expansion to the project.

3. Background

3.1 PocketQube

The

4. Conclusion

The conclusion

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[2] "Intermet," https://intermet.co/wp-content/uploads/iMet-3100M-403MHz-Military-Antenna-Receiver-5.pdf, [Accessed 12-08-2023].

[3] "Types of orbits — esa.int," https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits#:~:text=Low%20Earth%20orbit%20(LEO),-A%20low%20Earth&text=It%20is%20normally%20at%20an,very%20far%20above%20Earth's%20surface., [Accessed 12-08-2023].

A. Appendix A

A.1 Project Planning Schedule

Week 01 (24/07 to 30/07): Problem formulation; requirements gathering Week 02 (31/07 to 06/08): Initial research; component selection Week 03 (07/08 to 13/08): System-level design; initial system layout; components ordered Week 04 (14/08 to 20/08): PCB design without traces; initial circuit design Week 05 (21/08 to 27/08): Component prototyping; Full circuit design; antenna design; Week 06 (28/08 to 03/09): Mechanical design; Custom protocol investigation; PCB design with traces Week 07 (04/09 to 10/09): (Test week) Week 08 (11/09 to 17/09): Initial build Week 09 (18/09 to 24/09): Software design; initial testing Week 10 (25/09 to 01/10): Software design; debugging Week 11 (02/10 to 08/10): Reporting Week 12 (09/10 to 15/10): Design improvement Week 13 (16/10 to 22/10): Testing Week 14 (23/10 to 29/10): Reporting Week 15 (30/10 to 05/11):