BEng Aerospace Project

Interim Report

Identifying the position of small airborne vehicle by using radio technology

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# Introduction, aims and objectives

## Introduction

Radio positioning is an ancient method for navigation compared to state of art global navigation satellite system (GNSS). However, in the past 2 hundred years of aviation, radio was proven a reliable way achieving navigation. Meanwhile, radio navigation is continuously evolving itself to meet contemporary requirements of modern aviation, and it is playing a more important role as one of the alternative methods when GNSS is malfunction. This project focus on a compatible solution bridging the VOR (Very High Frequency Omnidirectional Range)/TACAN (Tactical Air Control and Navigation) like system and GNSS system. In this study, VOR-like signal will be implemented with a GNSS signal generator, which is generated by using MATLAB and GPS toolbox. During the project, two different implementations will be examined in the further stages of study, which involved some lab works.

In the meantime, theories of two implementations are roughly developed. First evaluation will exam the phase modulation on a simulated GPS signal. And second evaluation will testify an alerted higher frequency VOR-like signal and transmit it in the different time with simulated GPS signal.

The final test will be carried out with a fixed transmitter and a receiver installed on a moving vehicle.

## Aims

This project aims to achieve a standalone prototype system of radio positioning.

## Objectives

1.The principle of the navigation theory related to combination of time and known position should be proved by using MATLAB

2.The algorithm of solving equation of time and location difference should be explored and examined with MATLAB

3.Ground station signal including time and location source should be determined

4.The system receiver prototype can be implemented into real time system or relevant simulation environment

5.The deliverable / prototype system shall include real hardware where possible, which may include creation of a PCB for both the drone and ground station

6.The produced system will be subject to a field test

7.Target Requirement: to obtain the flying speed of the aircraft

8.Target Requirement: to achieve the accuracy of 100m

9.Target Requirement: coverage range of 1km minimum

# Literature review work progress to date

The history of radio navigation can be traced back to late 19th century before the first world war, and before people started using radio, they had already used compass and stars for thousands years. However, the radio is a game changer which overcame major difficulty of the old navigation method.

The first ever radio relative system was radio direction finder, which is tuned to the certain station’s frequency and then using antenna to point at the direction. Next, it can determine the bearing of the station, which enable aircraft or ships drive towards the station. By listening two stations, the captains and pilots are able to draw a intersection of two radio station on the map and determine its own position. However, it requires a rather long antenna to provide better angle information, which is not practical for small aircraft. In later development, ADF was a great progress, which benefits from modern electronics such as transistor. It works with NDB which stands for non-directional beacon. It uses phase comparison technic to determine the bearing of the aircraft.

VOR was evolved from ADF and NDB, and it features better accuracy and a voice channel, which is used to identify the station. It consists of 3 parts, the first one is the voice, and the second is a continuous signal transmitted from the omnidirectional antenna as the reference signal and the third is a signal rotating at 30Hz and the signal was changed in phase corresponding to the direction it faced. By comparing the difference of the phases from two received signal, a bearing can be worked out easily. It has an advanced version named TACAN, which implies higher frequency and more division of phases.

Due to the limitation of this project, the study does not include hyperbolic navigation system due to the performance issue. Since the most hyperbolic system worked at low frequency in trade of wide coverage, their precision is much lower than the required specification of this project.

Beam system like Adcock by Macaroni known as LFR (Low Frequency Range) is also a good idea of navigation, however, it uses a beam to navigate the object facing the beam direction, and it requires that the object remains in the coverage of the beam. Therefore, considering the project is to know a position of aircrafts, the Adcock system has little value in it. Though, it was used as ILS (Instrumental Landing System), it was fully manual operative by listening to Morse code.

GPS is the best system in term of both precision and feasibility. It remains the most popular choice for navigation since it was operated. Meanwhile, there were many system, as mentioned above, dying or died because of widely usage of GPS. GPS was the system designed and operated by USAF (United State Air Force), and its huge military potential was well recognized by US military, therefore, the system had two different ranging mode for civil uses and military uses. The civil code, however, is less accurate compared with military code. It works with simple logic, by using trigonometry. GPS system has multiple satellites on low earth orbits, which were well designed, to guarantee that at the most surface area of earth, there will be at least 4 satellite can be found above the sky. It was so well designed that in most time, there were actually more than 4, which provides a potential opportunity to increase the accuracy. The algorithm relays on 3 known satellite position and signal’s time of arrival. An extra satellite is needed for time reference in case of wave propagation error. By knowing the time taken during the propagation, the distance can be worked out, then combine three of worked out distance, a matrix can be introduced to provide multiple solutions, whereas only one of them is the correct positon. Furthermore, the result need to be transfer from polar form into panel form and should be projected on the map with coordinates provided.

Pseudolites application implies simulating satellite signal with a ground or aerial station, which can be deployed to GPS’ blind zone. It has a huge potential in war or special circumstance like mining or cave exploring. Therefore, it is a good objective for this project.

# Current status of the work

1. Review of previous systems as mentioned above.
2. Research the usage of RLT-SDR to analyse GPS signal and VOR signal
3. 3 Phases of prototyping
   1. Transmitter design and signal simulation
   2. Upgraded signal simulation
   3. Upgraded Transmitter design
   4. Receiver design
   5. System Summary and practical implementation
4. Block diagram of proposed system
5. Learning GPS signal and algorithms
6. Generate Pseudolites signal to verify the algorithms

# Self-review

The overall progress is matching with scheduled, however the significant difficulty on the practical lab work was delayed due to lack of knowledge.

# Project management

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| • Define project equipment  • plan of deliverable content  • Plan for lab works  • Finishing the interim report  • Combing the algorithms with system  • Prototyping of models on the hardware platform  • Researching Hardware  • Developing algorithms  • Modelling of the system  • Radio fundamental studies  • Literature research |
| **Tasks to be completed in semester 2** |
| |  | | --- | | * Implement system on PCB | | * Oral presentation preparation | | * Demodulation using the development board | | * Prototyping on hardware | | * Final Report | | * Field Test | | * Test running through the Prototyping | | * Keep Prototyping of models (MATLAB & Simulink) | | * Combing algorithms with systems | |