# Introduction

Crash-Sat is in need of a way to detect AGL altitude without pre-flight ground calibration or communication with a ground station. Altitude needs to be accurate within +/- 5 meters and operate without GPS. A radar altimeter design will be investigated as a potential means of altitude sensing. The trade study for this is kept elsewhere, but is summarized with the following options and rationale.

* Barometric altitude – Requires premature calibration with ground pressure, and liftoff site may drastically vary in altitude from landing site. The time of flight can be long enough that ground pressure changes, resulting in poor accuracy and user convenience.
* GPS altitude – Requirements deny GPS measurements for any purpose that directly involves mission success. Relative altitude is accurate, but uncalibrated AGL altitude is based on geode accuracy, which is low.
* LIDAR – Ultimate range must be at least 1 km, and no such lidar altimeter exists with acceptable volume and price
* Sonar – Same problems as LIDAR
* Ground station triangulation – Transmitting any data except mission abort data is not allowed under crash sat requirements.
* Camera and sensor fusion with another option – Could be a possible alternative to explore, but visible light cameras require there to be no clouds and exceptional image processing and analysis.

Through methods of sensor fusion including velocity sensors, accelerometers, relative distance measurements, and more, the altitude can be determined with very high accuracy. A very reliable and direct AGL measurement is needed at minimum for this method to work. With the added sensors for sensor fusion we can feasibly relax the necessary sample rate needed for a radar altimeter. As such, no minimum sample rate is yet known. Possibly only 1 accurate measurement would be needed at any height for this method to work.

This document stands to track major updates and definitions of how a Continuous Wave Frequency Modulated (CWFM) and Pulse Wave (PW) altitude radar might work in a package size and price small enough for a UAV. This document will ONLY be dedicated to a radar altimeter measurement, and any design of sensor fusion algorithms will be limited to hypothetical and conceptual.

# Design

Two types of radar measurements for distance detection are common in the industry. These are continuous wave and pulse wave. A continuous wave radar is able to use a constantly emitted signal to measure time phase shift and/or doppler effect due to distance and velocity, respectively. Continuous wave radar is usually frequency modulated, thus the name, Continuous Wave Frequency Modulated (CWFM). Pulse wave radar instead sends a single pulse, or “ping” to the target for distance measurement, and the signal eventually returns back to the sender. The time difference from sent versus received is related to the speed of light and thus a distance measurement can be made.

CWFM is very popular for short range measurements as short as a few feet, but is functional for many kilometers as well. Pulse wave radar is more popular for long distance measurements. It is for this reason that attention will be given to the CWFM radar first.

Diagram

Description automatically generated

**Figure 1: Basic simulation and design of CWFM radar.**

The basic premise for my radar will use a dual frequency instead of a chirp frequency signal. Chirp frequency variation allows for both distance and speed measurements, but I can acquire speed with other methods. Distance is determined by phase shift so I can use a dual set of frequencies and avoid the complication of accurately controlling frequency. Figure 1 shows a frequency domain simulation of the current design. This frequency domain simulation does not take transient effects into account which will be analyzed later. The carrier waveform is expected to be 2.4 GHz or 5 GHz in the ISM band, and attention will be given to FCC class rating and compatibility.

The carrier wave will vary by 10 kHz. A voltage controlled oscillator is used to generate the transmitted frequency which will be released by some currently undetermined antenna. The transmitted frequency will bounce off the ground and travel back with some shifted frequency due to the doppler effect. For the expected speeds of Crash-Sat (<100 m/s) the doppler shift will be at most a couple hundred Hz. This is why the high and low frequency differ by 10 kHz. Because 10 kHz is very distinguishable from a couple hundred Hz in our analog filtering and analysis. After the transmitted frequency scatters off the ground and returns to the sensor, the RX antenna will see a very attenuated and possibly noisy signal. The simulation assumes the returned signal is clean and amplified. Sufficient circuitry must be used to clean and amplify the received signal without causing further time delay or by creating a consistent delay which can be compensated for.

The above equation is very important. It is the physical relationship of multiplying (or “mixing”) two signals together. Signal 1 has frequency f1 while signal 2 has frequency f2. If you multiply the two waveforms together you get a fourier series composed of 2 new waveforms. These two new waveforms will have frequencies equal to f1+f2 and |f1-f2|. i.e. the new signal will be composed of the sum and difference of both input signals.