UAV-Assisted Flight Inspection using Lightweight SDRs

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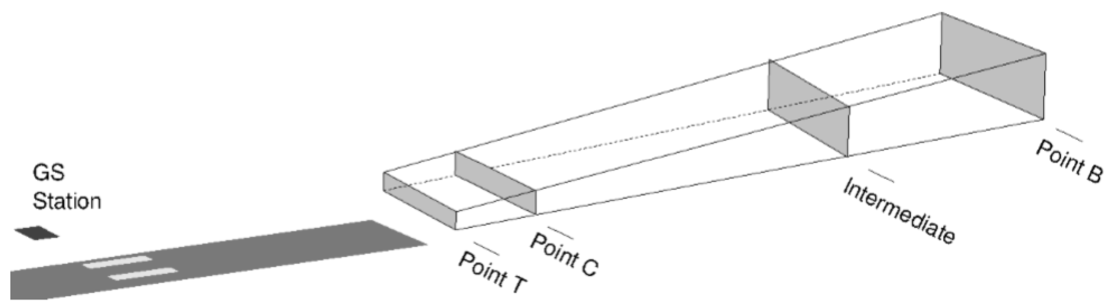
Video bio: https://drive.google.com/file/d/1ORdUcVD2d-bAkQ1Xp-7MnsK4OCzpweL3/view?usp=sharing

Introduction

Flight inspection using unmanned aerial vehicles (UAV) is a complementary method to the recent manned flight missions. The conventional method of inspection is through manned aircraft maneuvers in the inspected area [1]. Using drones allows hovering for relatively long durations over the inspected regions.

The work presented in this poster is part of the project that aims at measuring the instrumentation landing system (ILS) signals in zone 3. The inspection process relates signal power levels to a 3D grid in the inspected zone. ILS Zone 3 extends from the runway threshold to 3500 ft. away from the runway. From the localizer (LOC), the zone occupies $\pm\ 3^o$ lateral degrees around the centerline. The vertical region in guided by commissioned glideslope (G/S) angle. The data that is inspected in the course of this paper is the difference in depth of modulation (DDM). The value of the DDM informs the aircraft about its position relative to the runway while taking off or landing.

As shown in the figure below, point T is the threshold plane. Point C is where the commissioned glide-path is 100 ft above he ground, point B is 3500ft away from the runway. Point I is an intermediate point between C and B.



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Background

Navigation aid systems, such as ILS, are periodically inspected to ensure their functionality and accuracy[2]. One of the early attempts to use UAVs for flight inspection is described in [3] and further optimization was proposed in [4].

SDR is a programmable communication system makes the development process flexible and easy. The signal processing is done on a general purpose processor, rather than a dedicated embedded system.

Research hypotheses

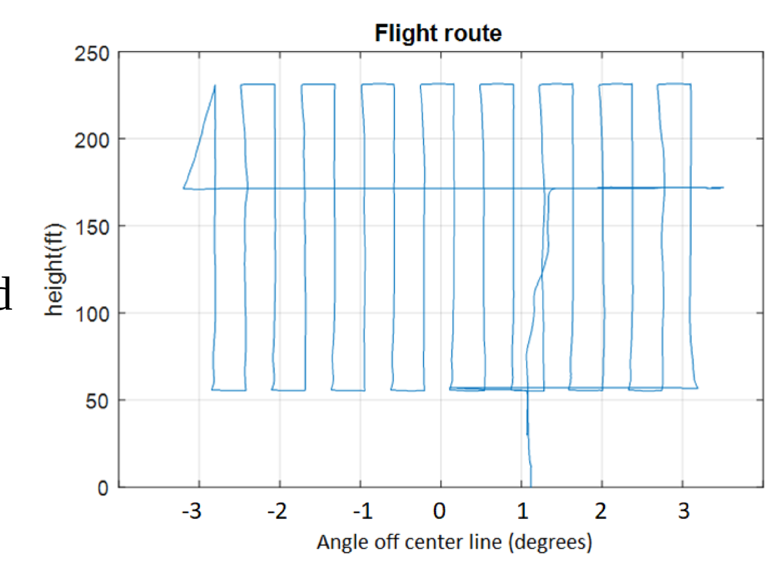
The lightweight inspection system is composed of a software defined radio (SDR) that captures the signal in the localizer and glide slope bands. A real-time code is instantly calculating the DDM values. The raw-signal is also recorded for offline analysis and debugging for receiver impairments. The SDRs are controlled by an off-shelf portable computer e.g. raspberry pi, and the whole setup is the payload attached to the mission UAV. On top of that, different ways of visualization are to be investigated.

Methods

The team at Oklahoma University is ultimately developing a calibrated SDR for the inspection purpose. The equipment developed in this study is for development and testing until that radio is available.

A lightweight prototype was developed using Ettus B200 mini USRPs. One USRP was dedicated to record the localizer band and the other recorded the glideslope band. The 2 bands are separated by around 200MHz, which made it difficult to capture both with the same SDR. The ILS signal is captured with a dipole antenna designed to receive both of the bands. The signal is divided by a splitter before it goes to the USRPs

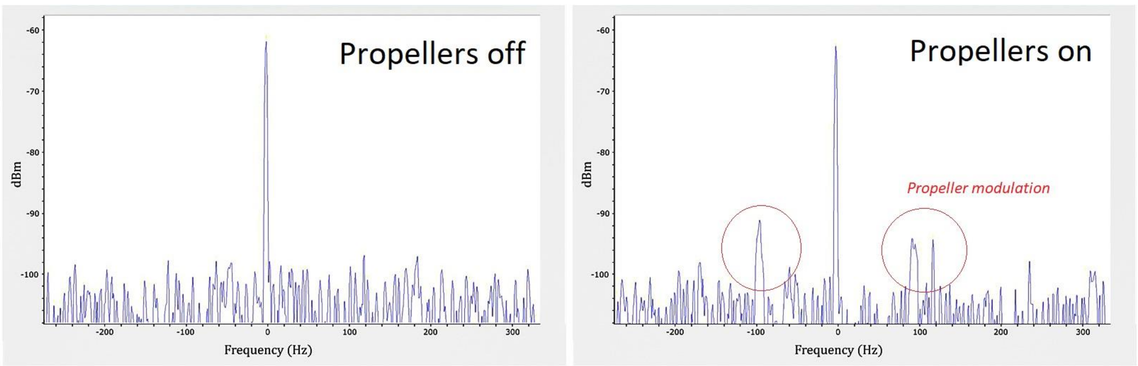
The output of the USRPs are connected to a raspberry pi device through USB3 ports. The whole setup is attached to the bottom of the UAV. The signal is real-time processed time stamped and recorded using Gnuradio blocks. The position information is captured by the UAV navigation system.



The test flight path took a zig-zag shape a shown below. For the presented experiment the runway at Stillwater regional airport was parallel to the longitude lines. So, the drone was moving laterally in a plane orthogonal to the runway. The UAV moved from longitude: from -97.0878 to -97.0862, which corresponded to angles $\pm 6^o$ off the centerline. The covered heights are: from 50 ft to 230 ft. The aim of this test flight is to collect data enough to create a cross section DDM map in the ILS zone 3.

Challenges

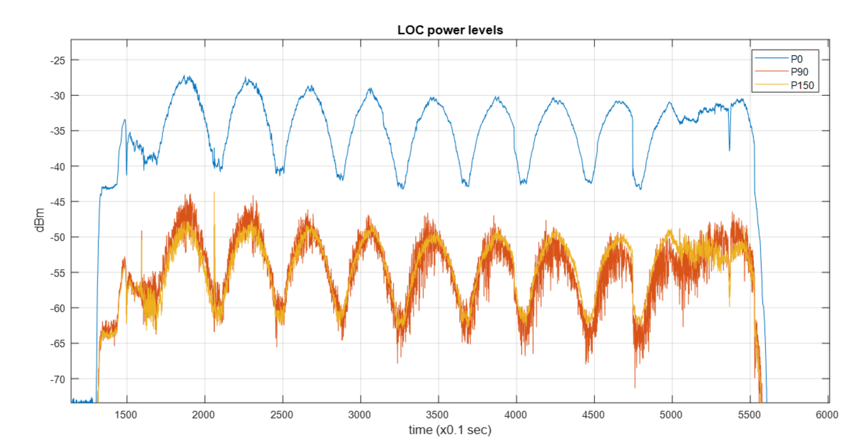
The main challenges faced during the measurement and testing phase are:
1- Electromagnetic interference EMI from the drone circuitry
2- Fading effect from the landing gear of the drone
3- Propeller modulation affected by the rotation of the propeller blades. Which adds a Doppler spread in the frequency domain.
The figure below shows the spread of a single tone signal occupying the 100Hz frequency, which degrades the ILS received signal.

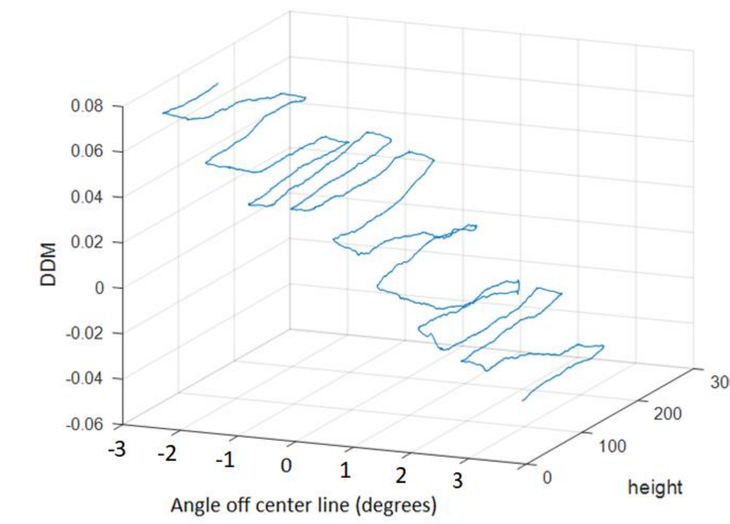


The aforementioned challenges are resolved as follows:
1- To avoid EMI effects, the receive antenna is positioned far away from the circuitry of the UAV by using a 3D printed mount.
2- The received signal showed 3dB improvement by raising the landing gear.
3. Different propellers are being investigated. This is an ongoing research.

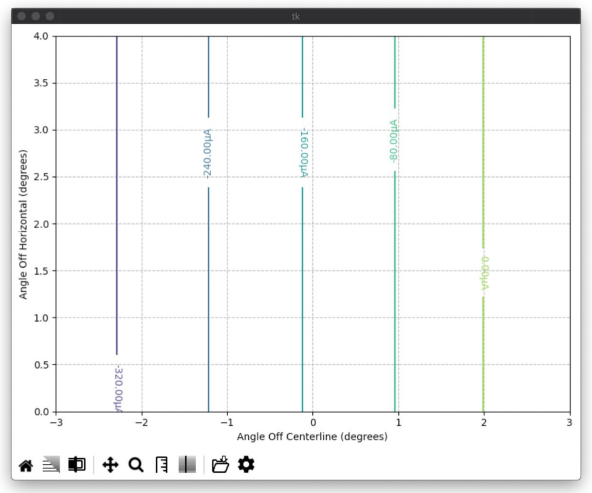
Results

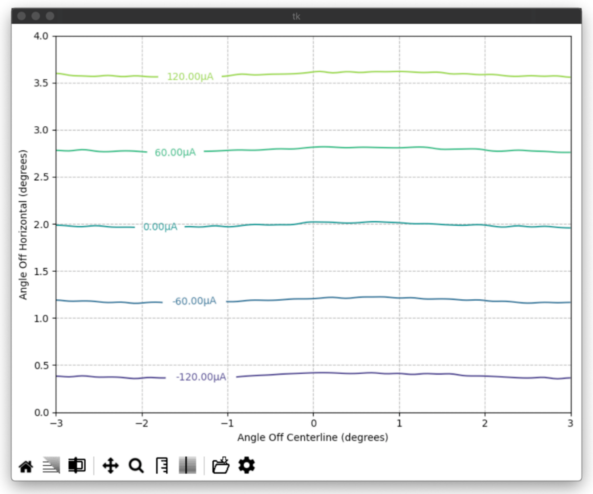
The results of the flights are shown in the section. The figures below show the LOC power levels for the carrier, 90 Hz and 150Hz components of the signal across the flight path. The DDM values are calculated and plotted with respect to that path. It shows gradient of the DDM values of the localizer across the inspected plane.



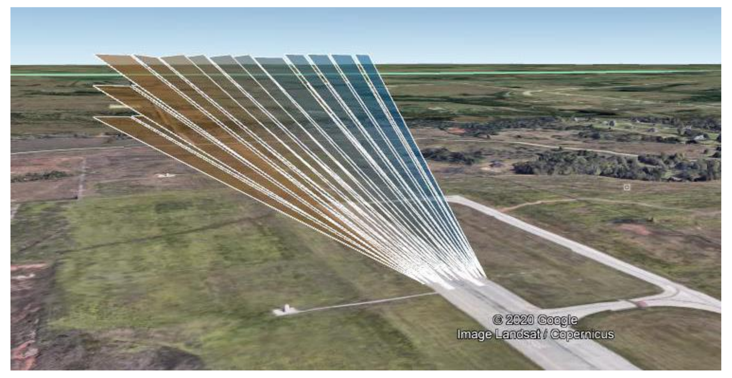


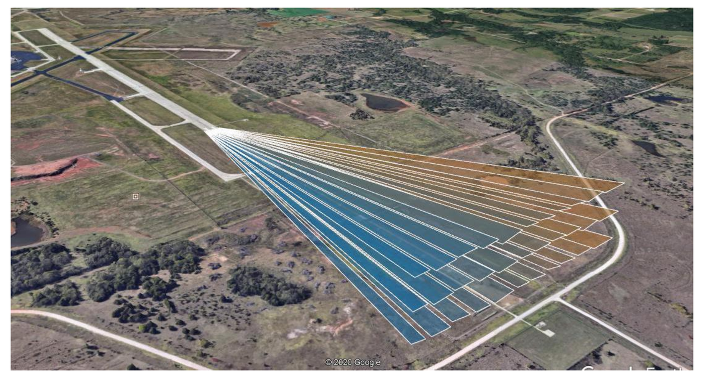
The data of the G/S were extracted as well (power levels not plotted here). The LOC and G/S data were interpolated over the inspected region via a visualization software. The software was developed to convert the raw data to the results in the figures below.





Finally, a 3D visualization software is being developed to export the LOC and G/S DDM gradients as .kml files that can be viewed by google earth, as shown in the below demo.





Conclusion

This study presents the work done on the development of an SDR base lightweight inspection system. The challenges of EMI, landing gear fading and propeller modulation were mentioned. The resolution of the challenges was discussed. The flight test route and the resultant power levels and DDM values were shown. Finally, 2D and 3D visualization software are being developed.

References

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