Ultra-Light Weight ILS/VOR Receiver for Flight Inspection

Center of Excellence for Technical Training & Human Performance

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Intro/Background

The goal of this project is to develop an ILS receiver system based on software-defined radio (SDR) technology, and to achieve the smallest size, weight, and power consumption as is required for the payloads of small unmanned aerial systems (UASs). The concept of operation, as shown in the Fig.1, involves a UAS flying different patterns within specific runway zones. The UAS uses the onboard ILS receiver to record the signal I/Q data, process them, and provide flight inspection data and plots to the FAA users.

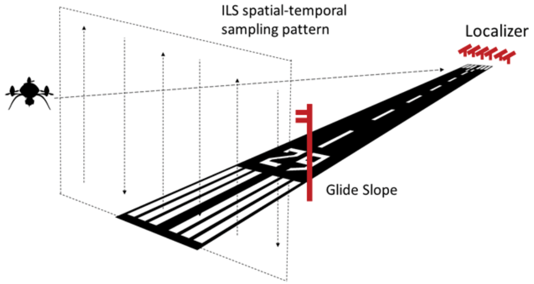

FIG1: Concept of Operation of using ultra-lightweight ILS/VOR receiver for flight inspection

Methods

We started our receiver engineering design in November 2019. FIG2 shows the hardware system architecture. It contains the wideband antenna, front-end RF channel, and parallel dual radio channels, which are important for simultaneous VOR/LOC and GS receiver channel operations. The radio channels, ADC data sampling, and MCU/Data interface are provided with a single SDR circuit. A backend embeded PC then captures the I/Q data stream from the SDR, performs signal processing, and stores the results.

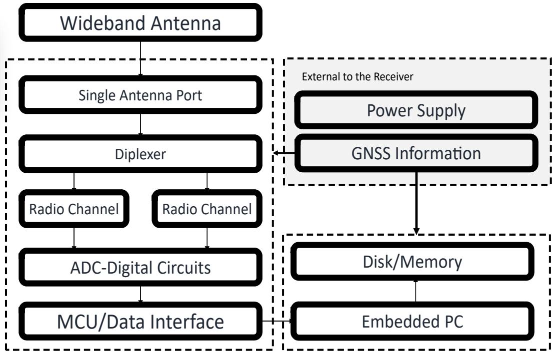

FIG2: The hardware architecture of the lightweight ILS recever.

The software system of the receiver contains digital down-conversion, calibration, filtering, spectrum analysis, and receiver product calculations. The receiver products include modulation depth (MD), Difference Depth of Modulation (DDM), and other information. The software and algorithms are mainly implemented in MATLAB, however, we are testing a Python version, aimed at achiving real-timeprocessing onboard. A main portion of the project is testing the receiver performance in the lab.

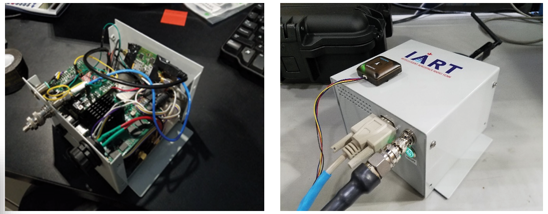

FIG 3: Actual receiver hardware built, integrated and being tested. LEFT: interior, RIGHT: closed enclousure

Much of our effort has been focused on laboratory tests and verifications of the receiver data output performance. We generated statistical records of long term results compared to truth values set from instrumentation. Our current test data shows we are able to achieve an accuracy for modulation depth of 0.004%, and total error (Mean Squared Error) and STD (standard deviation) for DDM estimation better than 0.002 for both localizer and glide slope. These results are very encouraging and have met, or exceeded the requireents of the ICAO and related standards. More lab tests are still ongoing at this stage.

Results

Specification Parameters	State of the Art	Our Objective
Size/Dimension	About 12 inches by 5 inches	5.5 by 5.5 by 3.5 inches
Weight (ILS receiver)	3 to 10 lbs	1.5 to 2 lbs
Power consumption	NA	5 watts max
Receiver technology	Customized	Open source GNU/SDR, 14-bit ADC
Receiver channels	Simultaneous LOC/GS/VOR	Simultaneous LOC/GS, plus VOR
Flight inspection product update rate	10 Hz	10 Hz
Internal signal sampling rate	NA	Up to 3 MSPS, much lower in normal operation
Data Products	Simultaneous analysis of dual-frequency LOC and capture-effect GS	Simultaneous analysis of dual-frequency LOC and capture-effect GS, combined DDM
Standard compliance	ICAO DOC 8071	ICAO DOC 8071 FAA-96E01B1
Raw data output DDM estimation errors	0.005 to 0.01	0.001 to 0.005 (lab tests)
Filtered output DDM estimation errors	0.001 to 0.005	< 0.001 (lab tests)
Cost	>$10,000	About $1000

TABLE 1: Summary of the achieved receiver specifications compared to state of the art

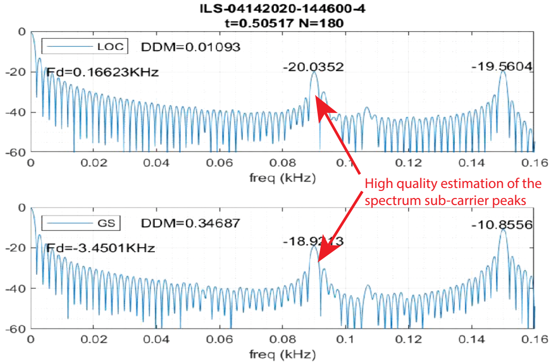

FIG 5: Power Spectral Density (PSD) estimation of the I/Q signal samples collected, This example has 0.5 sec of samplign duration from an actual flight test. In both lab and flight tests, there are thousands of such data segments for each test.

The preliminay flight test was done through collaboration with the OSU team. The key portions of the ILS receiver output show very good matching with theoretical expectations based on the GPS flight log data. The initial flight test is a verification of the functionality, especially for the handling of dual-frequency ILS signals. More flight tests are being scheduled again with the OSU team, including the support of user interface developments.

Conclusion/Impact

FEDERAL AVIATION ADMINISTRATION

S&T Impacts: The project has demonstrated the initial success of using SDR as the core of an ultra-lightweight ILS/VOR flight inspection receiver.
Operational Impacts: A new way of flight inspection operation based on the SDR-based receiver and small UAS will have significant impact on the operations, leading to reduced labor and cost, faster and more efficient facility inspection report, and new way of training flight inspection personel.

REFERENCES

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