Development of a Hardware Accelerated Radio Direction Finder for Drone Remote Controls

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Drones have become increasingly popular in recent years and so has their risk to enter into critical flight restricted zones, such as airports. To help mitigate this risk, a radio direction finder is being developed, which locates signals from within the 2.4GHz and 5.8GHz ISM bands. The research leading to these results was supported by the Swiss Center for Robotics and Drones of the Department of Defence, Civil Protection and Sport at armasuisse S+T under project No. 043-01.

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Introduction

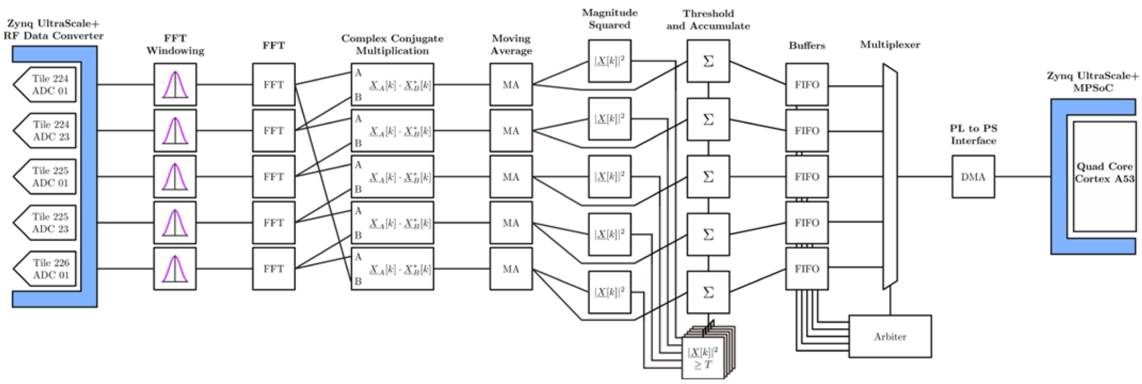
Drone remote controls nowadays use digital modulation schemes in conjunction with frequency-hopped spread spectrum (FHSS) to avoid channel interferences with other remote controls. These signals are usually located in the 2.4GHz ISM band and span over 80MHz. Some drones also incorporate a downlink for video (digital or analog) and telemetry data. Those are transmitted in the 5.8GHz ISM band in most cases, with a bandwidth between 6MHz to 40MHz. To process signals with bandwidths this large, a powerful software defined radio (SDR) is required. For this reason, the Xilinx ZCU111 is being used. The goal is to preprocess the large number of samples (5 x 128MHz after decimation) within the FPGA, so that the direction estimation can be done within the CPU of the ZCU111 without dropping any samples. In addition, an RF frontend will be developed to increase the sensitivity and frequency range of the receiver.

Concept and goals

The correlative phase interferometer is a robust and precise direction finder. It measures the phase difference between the antennas of a uniform circular array and compares them to a look-up table (LUT), that is being generated via measurements beforehand. The acquired samples are transformed into the frequency domain via an FFT in the FPGA. This has the advantage that multiple transmitters can be detected. To reduce the data throughput, each detected channel can be numerically integrated after the calculation of the phase difference in the frequency domain. This results in a data bandwidth in the range of kHz instead of MHz. To receive both 2.4GHz and 5.8GHz signals an RF fronted is incorporated. Each band features its own receiver, so that their sensitivity can be optimised.

Results

A digital signal processing chain was developed for the FPGA of the ZCU111, that can render the raw samples in into more compact phase differences for the direction estimation within its CPU. In the best-case scenario, it possible to reduce the throughput from 128MHz to 15.625kHz. The RF frontend was dimensioned to be as sensitive as possible, while keeping the noise figure as low as possible. Additionally, a sensor array, comprised of a GNSS receiver, accelerometer, gyroscope and compass, was included to get an absolute angle of arrival (AoA). A second PCB was developed, that interfaces with the RF fronted, to ease the measurement of its receivers.



Digital signal processing chain