COE TTHP Fourth Annual Technical Webinar Meeting

Ultra-Light Weight VOR/ILS Receiver

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Center of Excellence for Technical Training & Human Performance

Supporting Existing FAA Missions Through Safe UAS Flight Operations

Existing UAS-based Flight Inspection Solutions

Automation and unmanned operation is an important trend for future human-machine training and interaction, since it will greatly reduce cost and labor.

Canard Drones (Europe): https://canarddrones.com/portfolio/ils-inspection/
“in some scenarios we have achieved a difference of under 0.03º in measuring an Glideslope angle, or 0.04º measuring a localizer width. To provide a reference, the tolerance for a GS angle is +/-0.12º for a CAT III ILS and the tolerance for a LOC width can be approximately +/-0.35º for a CAT III ILS (the tolerance depends on the length of the runway).”

Herve Demule and Klaus Theipen, (**Skyguide, Rohde&Schwarz**),
Using UAV multicopters as an extension of ILS ground measurements:
This innovative idea has already become reality in Switzerland, IFIS 2018, paper#0024,
(R&S EVSF1000 - 95 mm by 177 mm by 360 mm, 3.7 kg (8.2 lbs))

3DS airport inspection effort:
https://interdrone.com/news/surveying-mapping/airport-turns-to-drones-for-construction/

Investigation of SDR (Software-Defined Radio) Solution

	Name	Frequency Range	Max bandwidth (MHz)	RX (bits)	Sampling Rate (MSPS)	Freq. Accuracy (ppm)	Host Interface	FPGA	Base price (US$)
1	ADALM-PLUTO	325 MHz – 3.8 GHz/ 70 MHz – 6 GHz	20	12	61.44	25	USB 2.0, Ethernet	Xilinx Zynq Z-7010	148
2	AD-FMCOMMS3-EBZ (2x2)	70 MHz – 6 GHz	54	12	61.44	15	FMC		750
3	AD-FMCOMMS4-EBZ (1x1)	70 MHz – 6 GHz	54	12	61.44	15	FMC		399
4	AD-FMCOMMS5-EBZ (4x4)	70 MHz – 6 GHz	54	12	61.44	15	FMC		1,125
5	AirSpy R2	24 – 1700 MHz	10 MHz	12	10/80	0.5	USB	none	169
6	bladeRF 2.0 micro	47 MHz – 6 GHz	56MHz	12	61.44		USB 3.0 SuperSpeed	Altera Cyclone V	480
7	HackRF One	1 MHz – 6 GHz	20 MHz	8	8 -20	20	USB 2.0		299
8	LimeSDR (2x2)	100 kHz – 3.8 GHz	61.44 MHz	12	61.44	2.5	USB 3.0, PCIe	Altera Cyclone IV	299(USB) 799(PCIe)
9	LimeSDR-Mini	10 MHz – 3.5 GHz	30.72 MHz	12	30.72	2.5	USB 3.0, PCIe	Altera MAX 10	159
10	RTL-SDR V3 Dongle	0.5 – 1766 MHz	Up to 3.2 MHz	8	2.4 - 3.2	1	USB		21.95-25.5
11	SDRplay: RSPduo	1kHz – 2 GHz	10 MHz	14	10.66	0.5	USB	none	279
12	Sidekiq Z2	70MHz – 6GHz	Up to 50 MHz	12	61.44	1	MiniPCIe	Xilinx Zynq 7010	5,000
13	SignalHound	1Hz – 4.4 GHz	5MHz			1	USB		1,119
14	USRP B200	70 MHz – 6 GHz	56 MHz	12	56	2	USB 3.0	Xilinx Spartan 6 XC6SLX75	675
15	USRP B210	70 MHz – 6 GHz	56 MHz	12	56	2	USB 3.0	Xilinx Spartan 6 XC6SLX150	1,259
16	USRP N200	DC – 6 GHz	Up to 40 MHz	14	25/ 50	2.5	Gigabit Ethernet	Xilinx Spartan 3A-DSP 1800	1,775
17	USRP N210	DC – 6 GHz	Up to 40 MHz	14	25/50	2.5	Gigabit Ethernet	Xilinx Spartan 3A-DSP 3400	2,011
18	USRP X300	DC – 6 GHz	Up to 120 MHz	14	200	2.5 / 0.02	GbE, 10 GbE, PCIe	Xilinx XC7K325T	4,557
19	USRP E310	70MHz – 6 GHz	Up to 56 MHz	12	61.44	2	Gigabit Ethernet	Xilinx Zynq 7020	3,164
20	XTRX Pro	30 – 3700 MHz	120 MHz	12	120	0.1	mini PCIe	Xilinx Artix7 50T	599

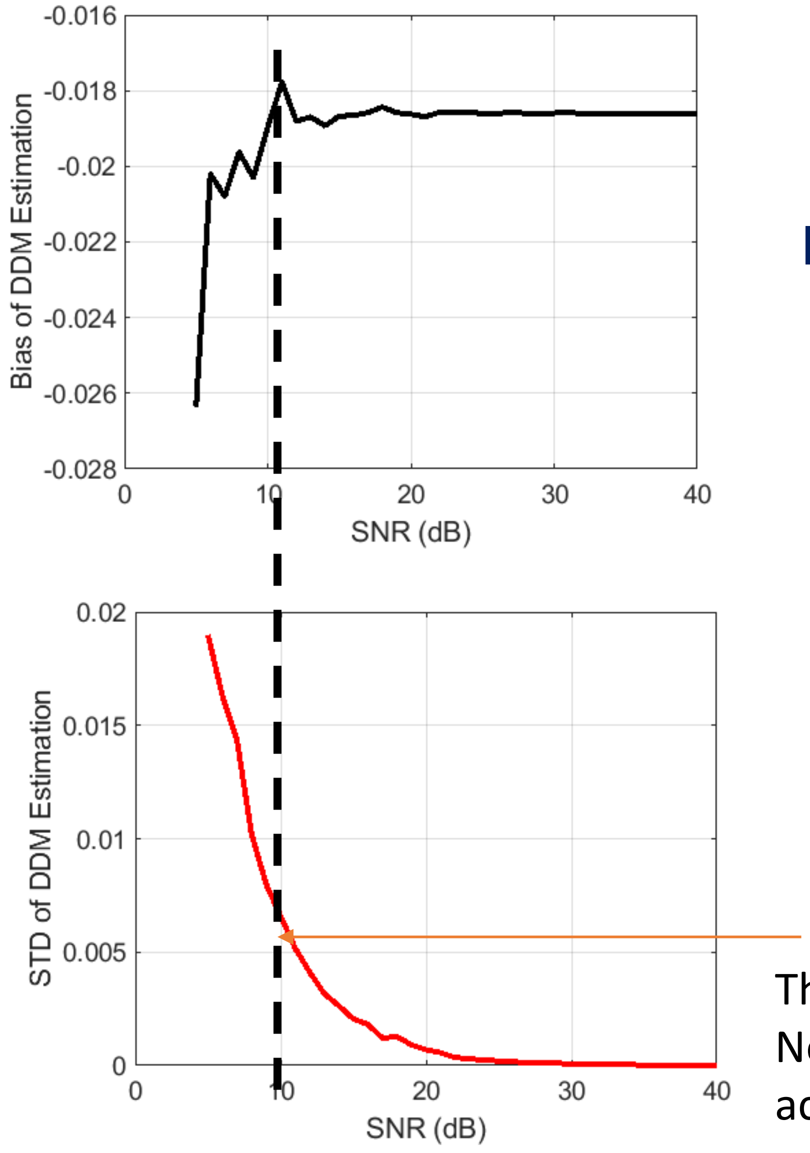
Challenges and Objectives

ICAO (DOC 8071) has strict requirements on accuracy, availability and repeatability as flight inspection receiver

VOR: Test data indicates that 99.94% of the time a VOR system has less than **±0.35° of error**. Internal monitoring of a VOR station will shut it down, or change over to a standby system if the station error exceeds some limit.

ILS: There are many parameters to test but the most important one is DDM. Goal: At different SNR levels, using a lab-based ILS signal generator, with actual DDM in range [0.000 0.300], the mean absolute error (MAE) of DDM estimation is in range of **± 0.005**.
Expect the standard deviation or uncertainty to achieve **level of 0.001**.
(This is a “rough” goal but should be a good starting point, again there are many other parameters to be tested according to Doc 8071 requirements)

Note: R&S previous ILS tests using drones claim 0.1 to 0.3 µA accuracies achieved.
1µA = 0.01° for a distance of 4 000 m (13 000 ft) between the localizer antenna and the threshold, and 1µA = 0.005° for a glide path angle of 3 degrees.



Bias and Accuracy of DDM Estimation For ILS with respect to SNR

The simulation tests are run based on the preliminary DDM computation algorithm (ICAO)

We recommend **15- 20 dB SNR** for the carrier Frequencies for the ILS receiver system design And UAS-operation scenarios

The basic algorithm
Needs 12 dB SNR to
achieve the requirement

Lab Test Environment

Lab test follows FAA-96E01B1 VOR/ILS Receiver procedure

Lab test has resumed since May 22

Rev.1 of The ILS Receiver Hardware and System

Backup GPS receiver for lab test

UAS onboard
Power and data

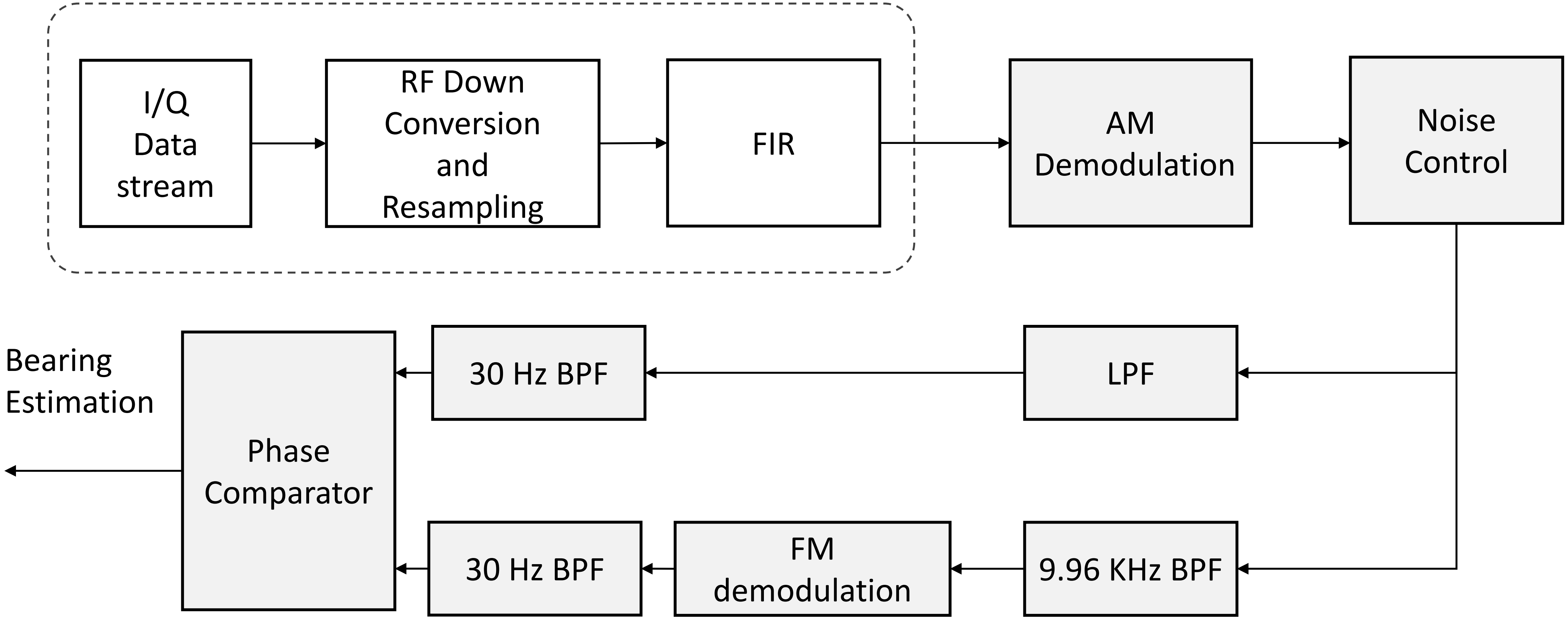
VOR/ILS
Dual-band
antenna input

Size/Dimension	**5.5 by 5.5 by 3.5 inches**
Weight (total weight of the box shown in Figure)	1.6 lbs
Data storage	Up to 128 GB SD card
SDR channels	Simultaneous LOC and GS
SDR sampling	1.5 MSPS each channel, 16-bit sample as integers
Data Products	Support real-time VOR/ILS receiver product outputs with up to 10 Hz update rate Support Dual frequency LOC, and capture-effect GS for combined DDM measurements

Prototype unit cost: About $1000

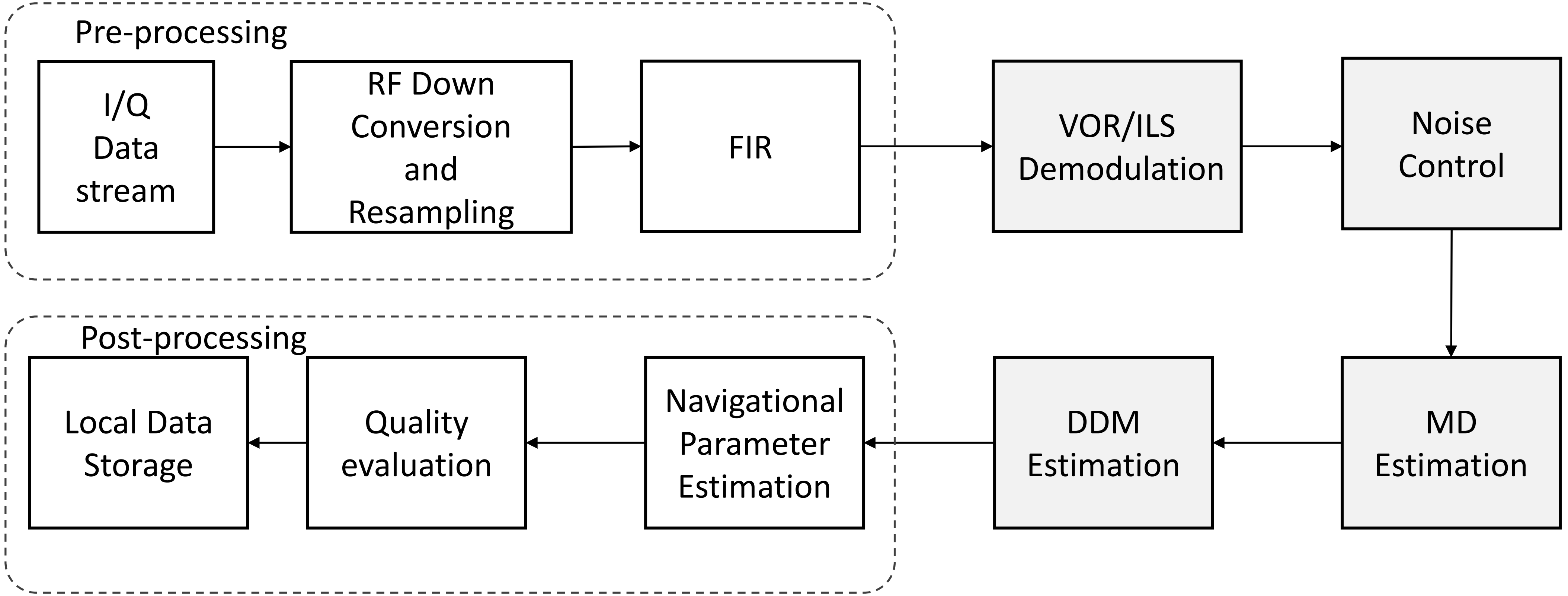
Real-Time Processing Algorithms and Implementation

VOR Channel



Real-Time Processing Algorithms and Implementation

ILS Channel



Current Project Status and Next Steps

Initial lab test of receiver prototypes show ILS DDM accuracy (uncertainty) meet the basic ICAO requirements, further tests are needed.

Further lab tests are needed for short sampling period (0.1 sec), following FAA recommended test procedures for real-time performance.

Initial flight test in April jointly with OSU team, verified basic capability of processing course/clearance signals. Planning further tests at local airports

VOR receiver functionality is still in lab-test/MATLAB tests

Real-time implementation using Python is ongoing

Current Project Status and Next Steps

Receiver prototype Box#2 (and bug fix in software): (within Summer 20)

New ground and flight tests at airports (Summer 20)

Initial release of real-time implementation (Fall 20)

Final real-time software verification (Fall 20)

FAA/ICAO initial verification data (Fall 20)

Questions?

For more information, please contact Dr. Rockee Zhang at rockee@ou.edu.