National Aviation University of Ukraine
Air Navigation Systems Department

Interrogation rate measurements of Distance measuring equipment in air navigation system

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Ostroumov Ivan, Ph.D.
Associate professor of
Air Navigation System Department

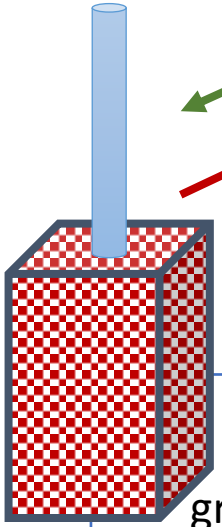
Kuzmenko Nataliia, Ph.D.
Senior researcher

Distance measuring equipment

DME
Interrogator

Interrogation pulse-pairs signal

Ground station replies after a fixed delay



DME
ground station

$$R = \frac{1}{2} c(t - \tau)$$

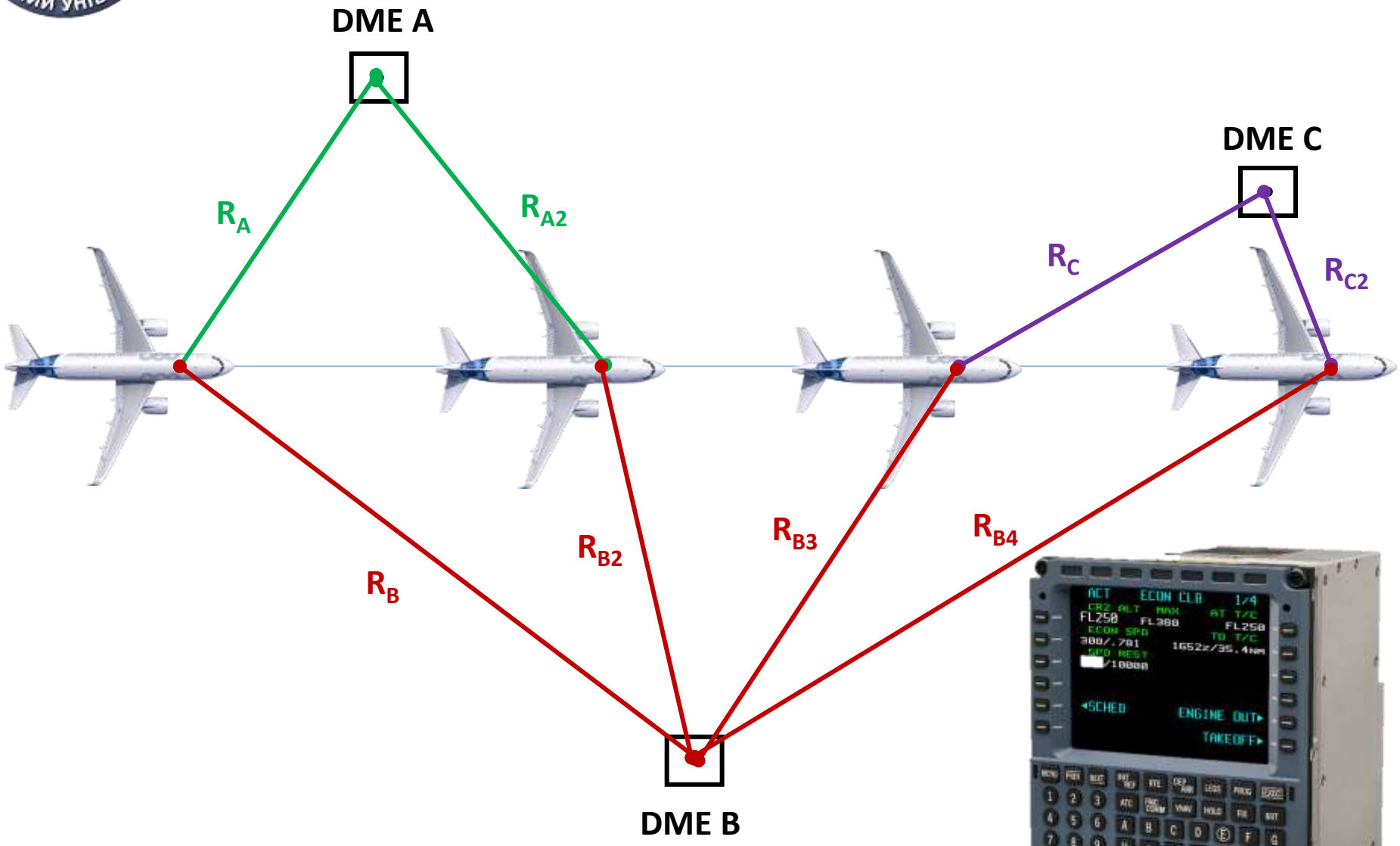
where

t – time of radio signal propagation

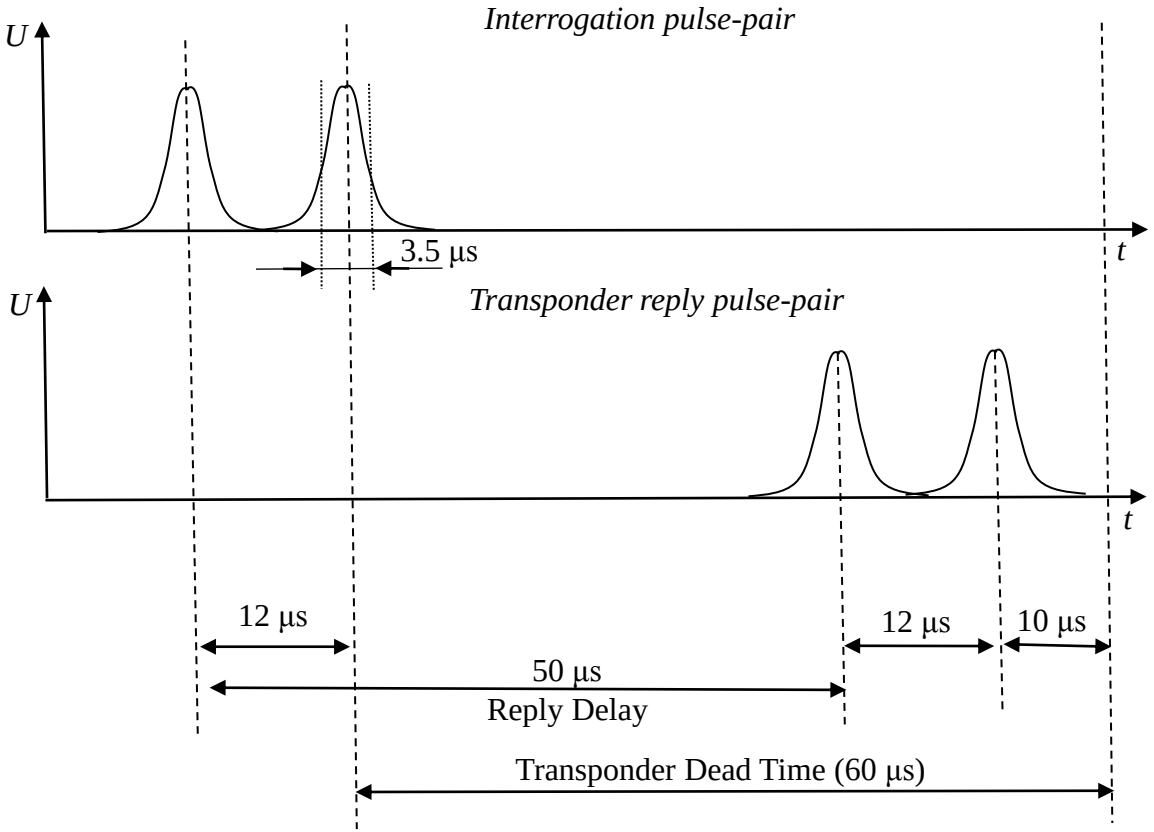
τ – delay in DME ground station

$c=3\times10^8$m/s

Airplane navigation by DME/DME

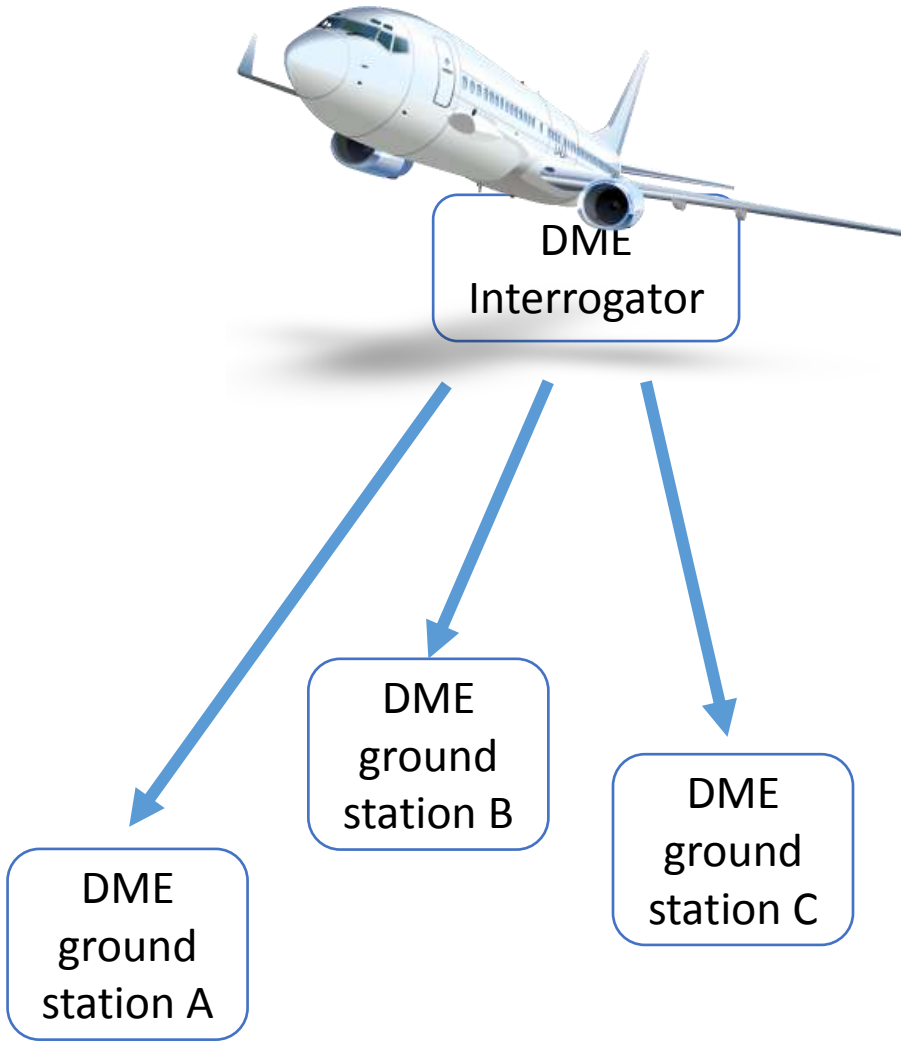


Navigation signals



Interrogation Repetition Frequency

No	Interrogator mode	Maximal number of interrogation per second
1	Tracking	30
2	Search	40
3	Airplane on the ground	5
4	Initial approach mode track	16
5	Final approach mode track	40



DME Types

Ground stations classification

T (Terminal)

From 1000 feet (305 m) AGL up to and including 12,000 feet (3,658 m) AGL at radial distances out to 25 nm (46 km).

L (Low Altitude)

From 1000 feet (305 m) AGL up to and including 18,000 feet (5,486 m) AGL at radial distances out to 40 nm (74 km).

H (High Altitude)

From 1000 feet (305 m) AGL up to and including 14,500 feet (4,420 m) AGL at radial distances out to 40 nm (74 km).

From 14,500 feet (4,420 m) AGL up to and including 60,000 feet (18,288 m) at radial distances out to 100 nm (185 km).

From 18,000 feet (5,486 m) AGL up to and· including 45,000 feet (13,716 m) at radial distances out to 130 nm (241 km).

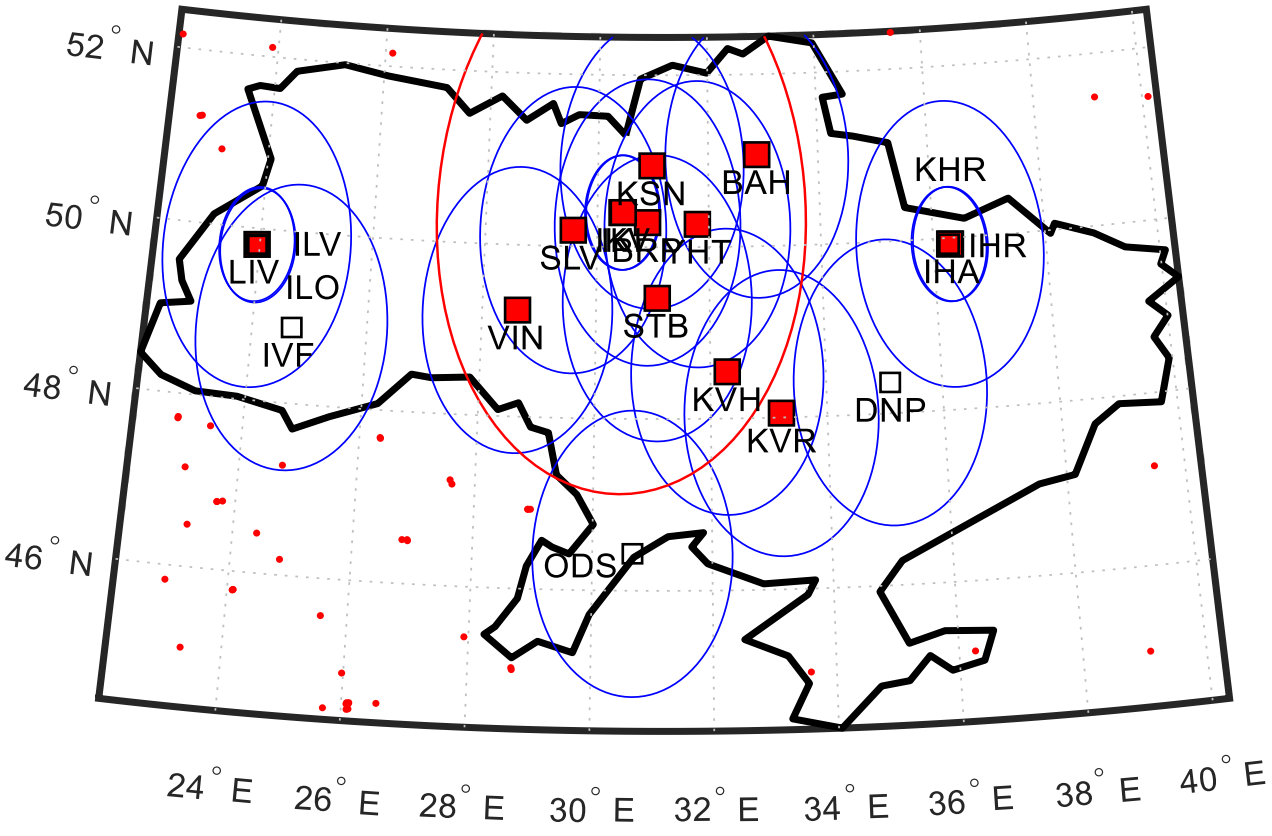
AGL – Above Ground Level

FAA AC 00-31A

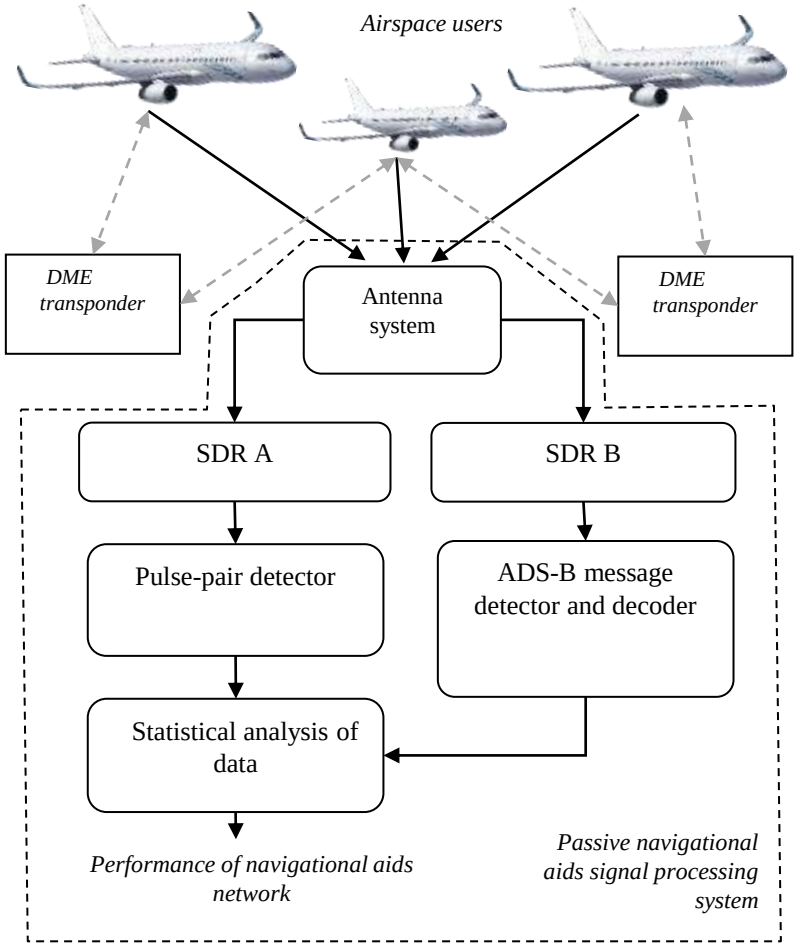
Ukranian navigational aids network

Navigational aids network includes 4167 DME and TACAN transponders over the globe.
Ukrainian navigational aids network includes

- 12 DMEs (BAH, IHA, IHR, IKI, IKV, KSN, KVR, ILO, ILV, STB, VIN, YHT)
- 8 VOR/DMEs (BRP, DNP, IVF, KHR, KVH, LIV, ODS, SLV)

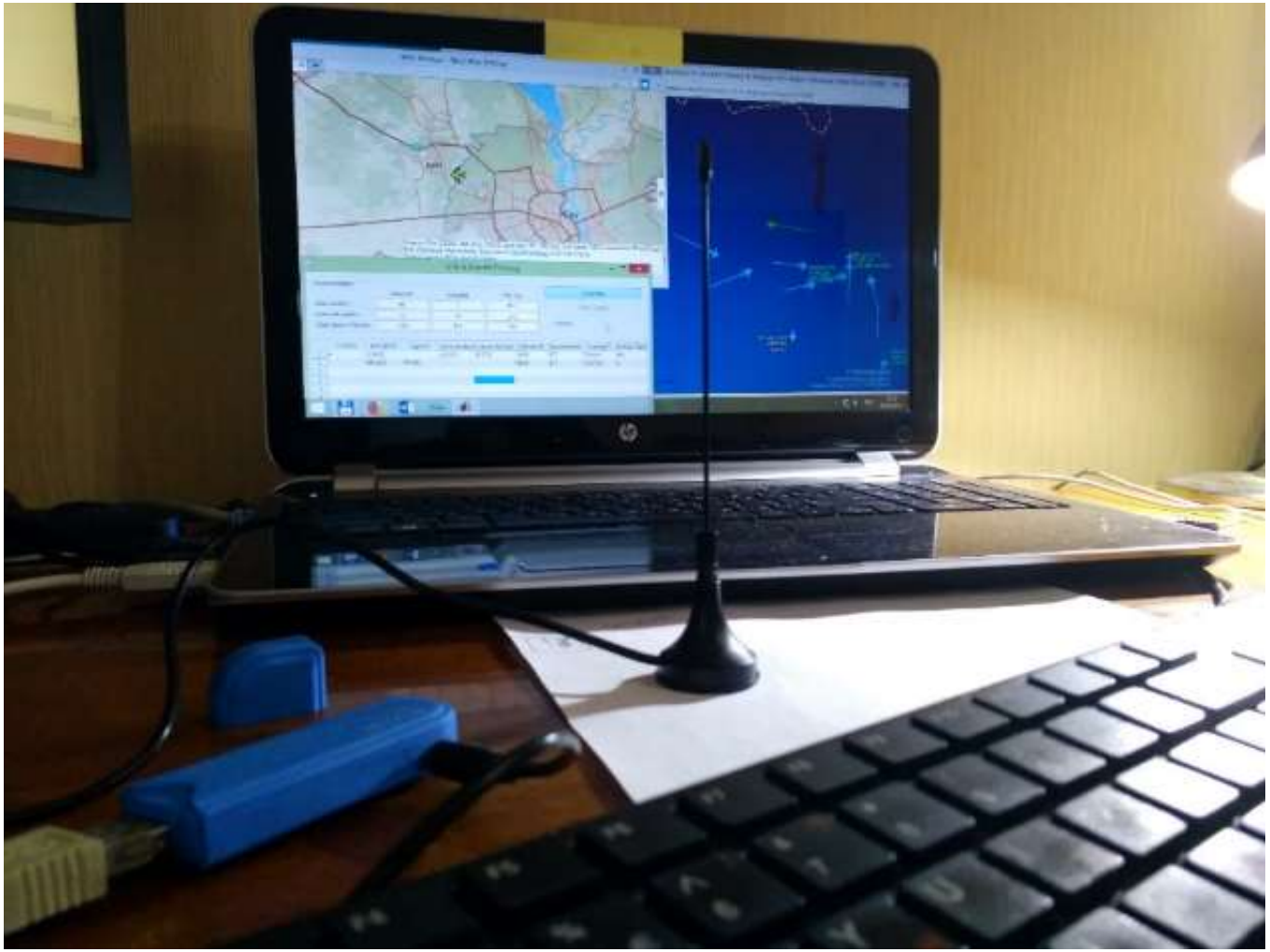


Interrogation rate measurement



- independent system for passive navigational aids signal receiving and processing in order to analyze network performance in real-time with current air traffic capacity.
- two SDRs based on RTL2832U chipset.
- omnidirectional antenna system for the UHF frequency band.
- SDRs support 3.2 M measurements per second which is enough for signal processing at the microsecond level.

Interrogation rate measurement



Performance estimation

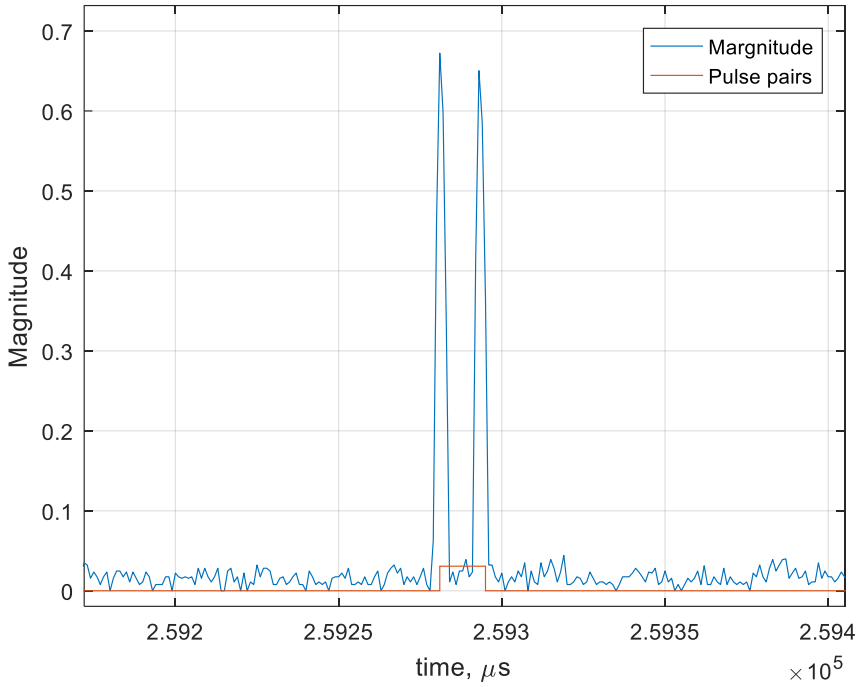


Fig. 9.1. DME interrogation pulse-pair (“BRP”)

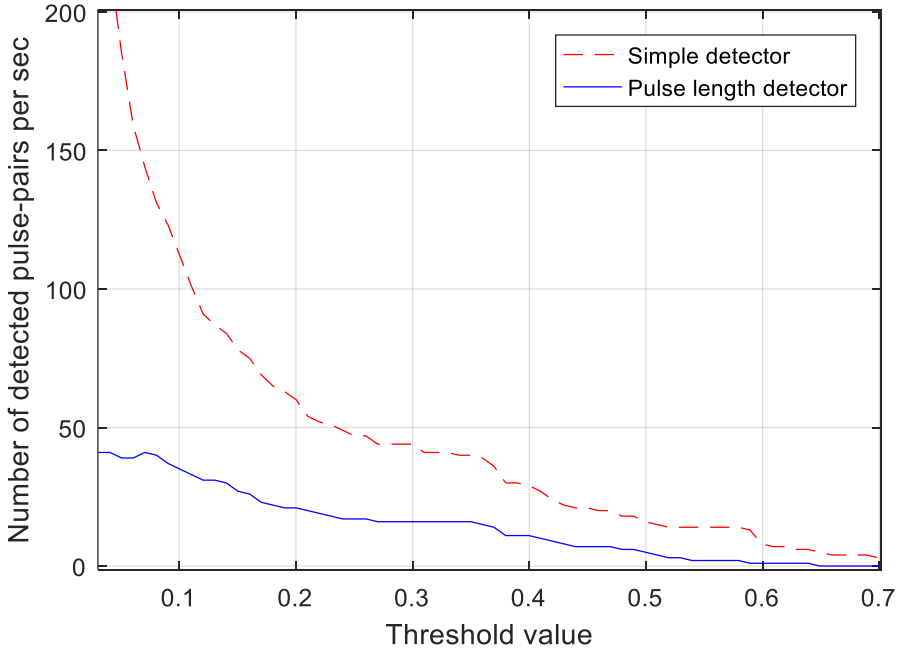
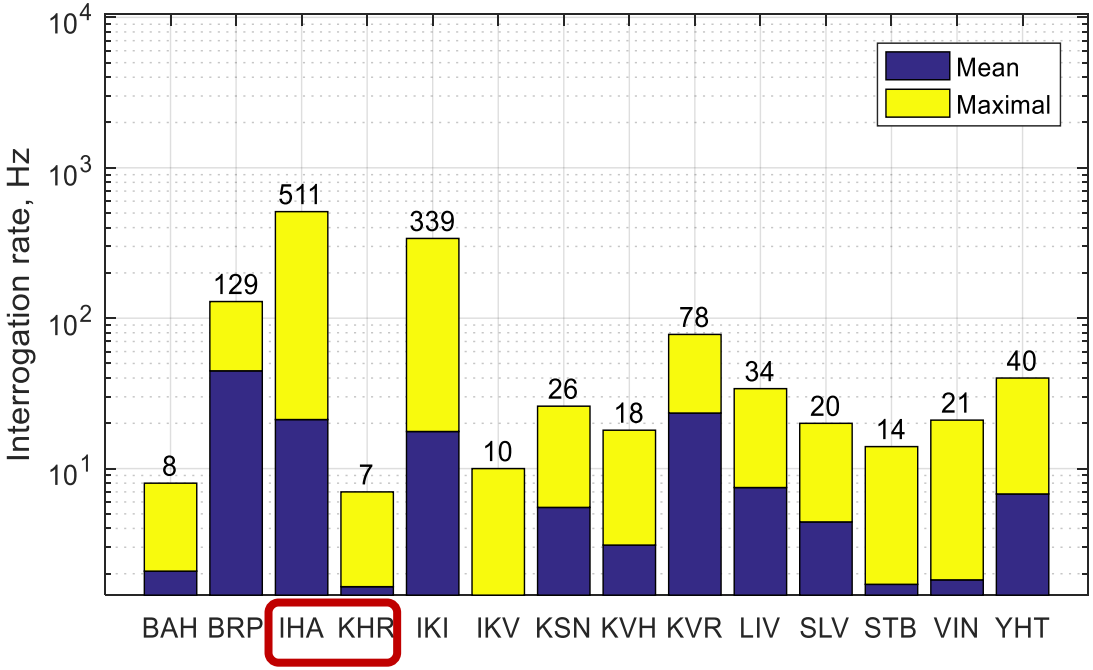


Fig. 9.2. Performance of interrogation pulse-pair detector

Interrogation rate of Ukrainian navigational aids network

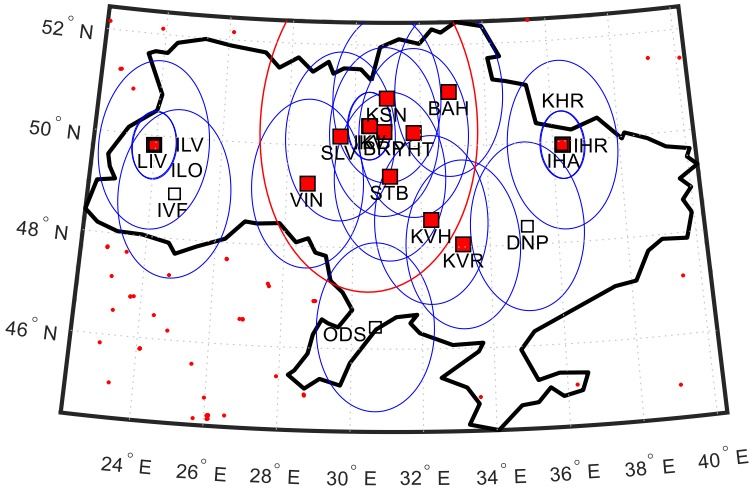


DMEs “IHA”, “KHR”, and “LIV” can not be reached by airplanes within SDR operational volume. Presence of interrogations of unreachable DME transponders is result of wrong manual settings of on-board DME equipment or faults in operational algorithms of FMS.

- Experiment duration: 1000 s
- Up to seven airplanes located within the operational range and detected by ADS-B receiver.

There are only two DMEs that have increased interrogation rate higher than 300 Hz (“IHA”, “IKI”), that are result of their frequent usage in SID/STAR during airplane operation at low altitude.

Other DMEs in the navigational aids network have approximately low load between 7 and 129 Hz.

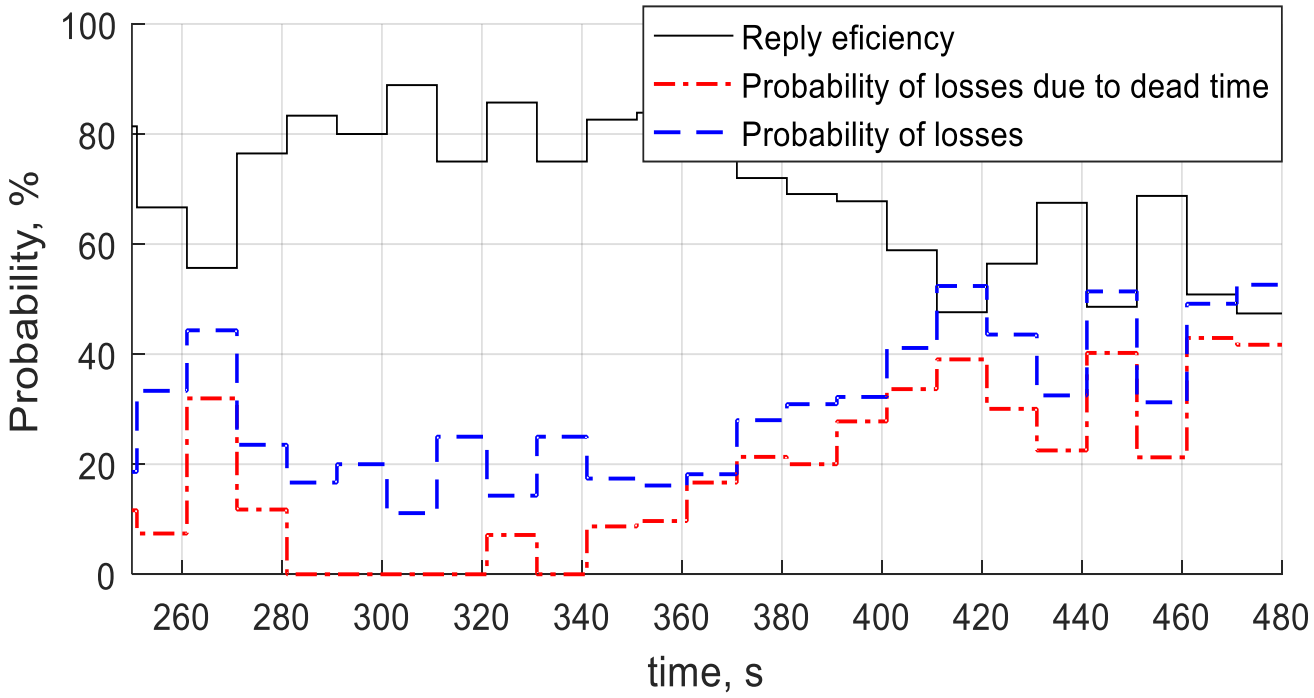


Reply efficiency and loses for “BRP” DME

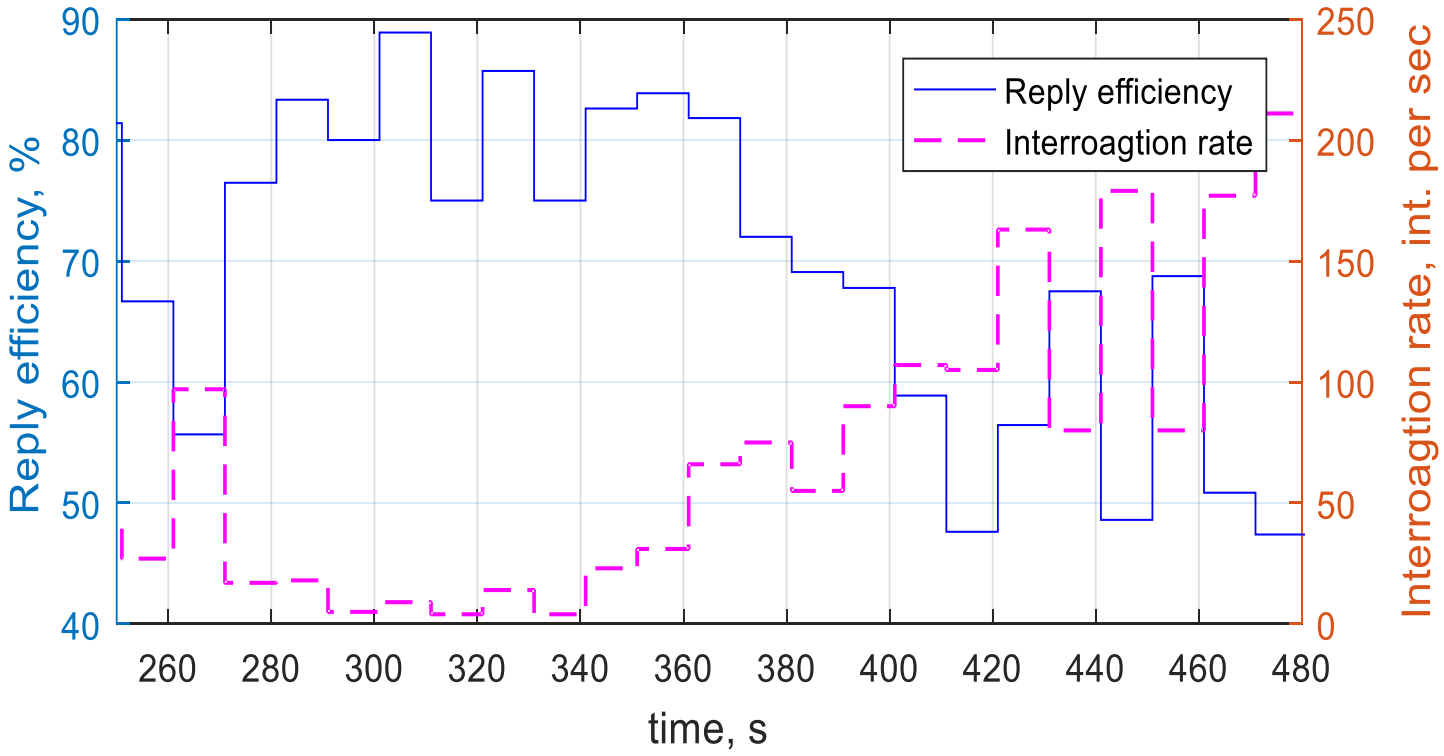
Reply efficiency can be estimated from measured data:

$$P_{RE} = 1 - \frac{N - N_{PP} - N_{dt}}{N},$$

where N is a total number of interrogations from rough detector; N_{PP} is a number detected pulse-pairs; N_{dt} is a number of pulse-pairs placed at the dead time of DME transponder.



Reply efficiency in comparison to interrogation rate for “BRP” DME



Conclusions

In research, we demonstrate the possibility to use passive data processing station, based on software defined radios for navigational aids performance monitoring. Results of experimental data processing indicate that on-board interrogators mostly use DMEs located within their service volume. Thus, in experiment the data in interrogation channels of 14 DMEs were obtained during search by each interrogation channel of all Ukrainian navigational aids. Outcome of experiment indicates presence of airplanes with wrong settings of on-board interrogators. Three DMEs “IHA”, “KHR”, and “LIV” have been tuned with no possibility for measurement. It indicates an issue of on-board selection algorithm operation, that should be solved in order to guarantee enough navigational data for safe airplane operation.

Developed low-cost passive ground station can be implemented for independent capacity estimation of navigational aids network. Obtained results can be improved by increasing the number of passive stations around the whole investigated territory.