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AIR NAVIGATION SYSTEMS DEPARTMENT



QUEUING MODEL OF DISTANCE MEASURING EQUIPMENT FOR CAPACITY ESTIMATION

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1. Distance Measuring Equipment



DME Interrogator

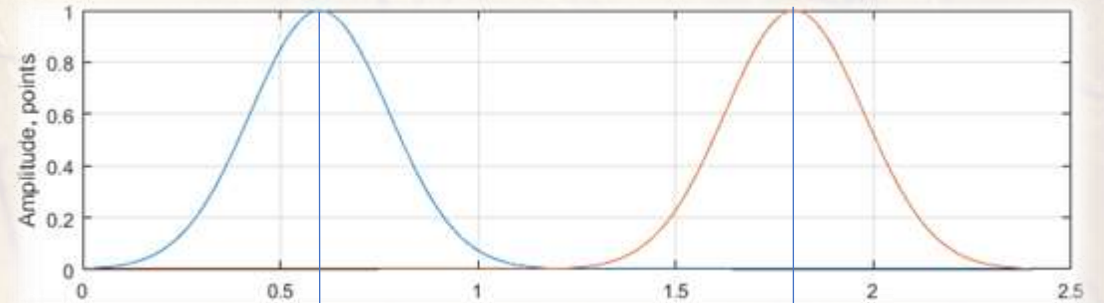
Interrogation pulse-pairs signal at F1



DME ground station

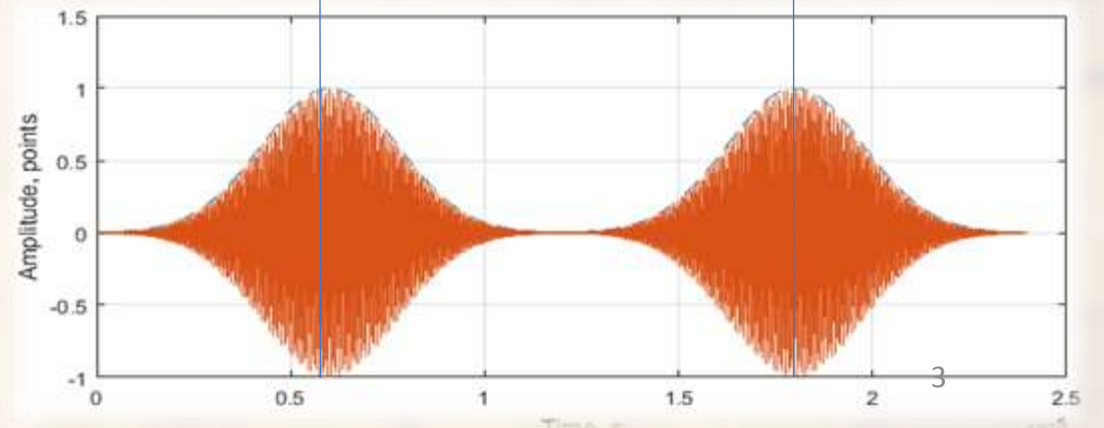
Ground station replies after a fixed delay at F2
 $F2 = F1 \pm 63\text{MHz offset}$

Pulses are specified to have a Gaussian envelope

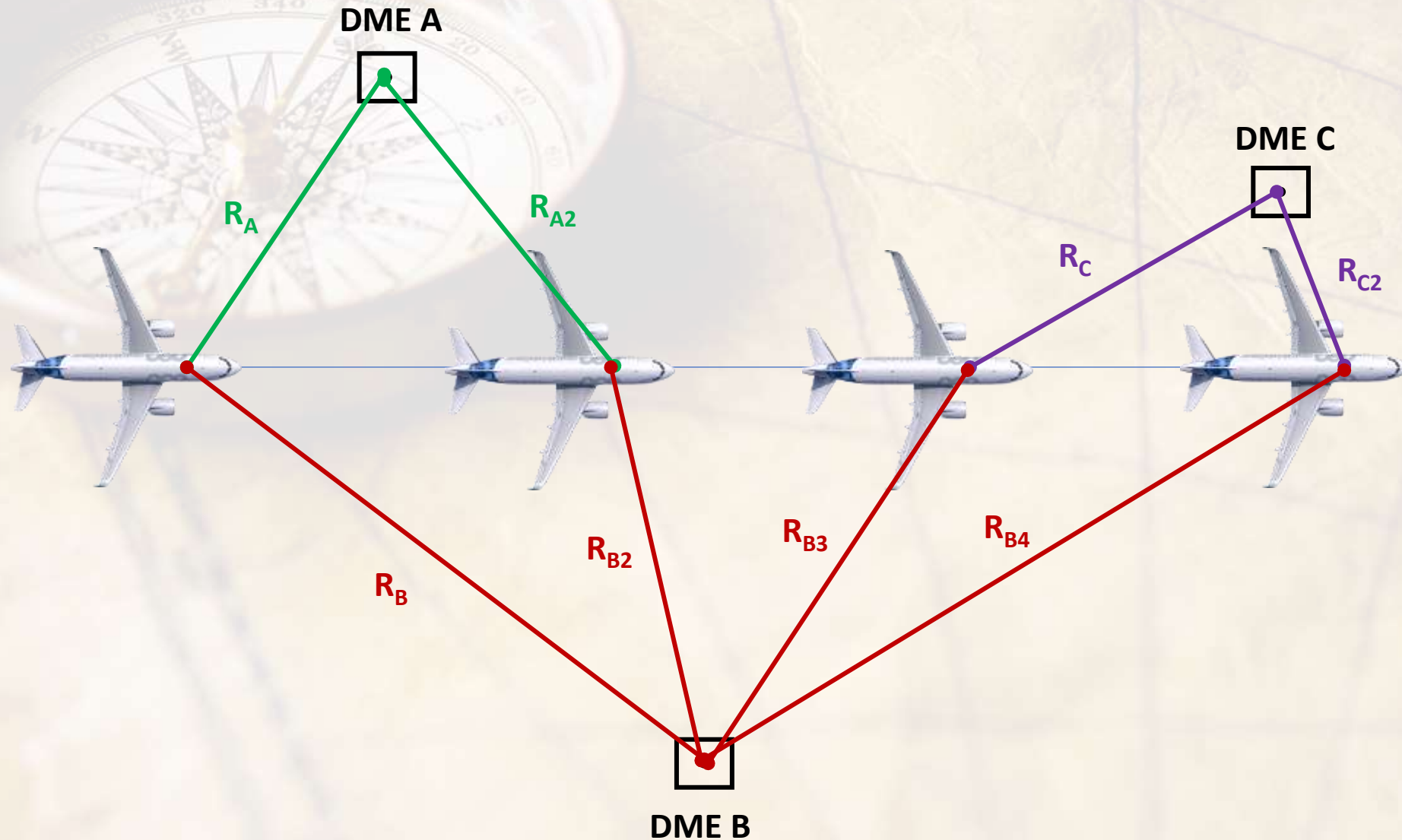


12 μs (X channel)

36 μs (Y channel)



2. Airplane navigation by DME



3. Ukrainian navigation aids network

12 DME: BAH, IHA, IHR, IKI, IKV, KSN, KVR, ILO, ILV, STB, VIN, YHT

8 VOR / DME: BRP, DNP, IVF, KHR, KVH, LIV, ODS, SLV

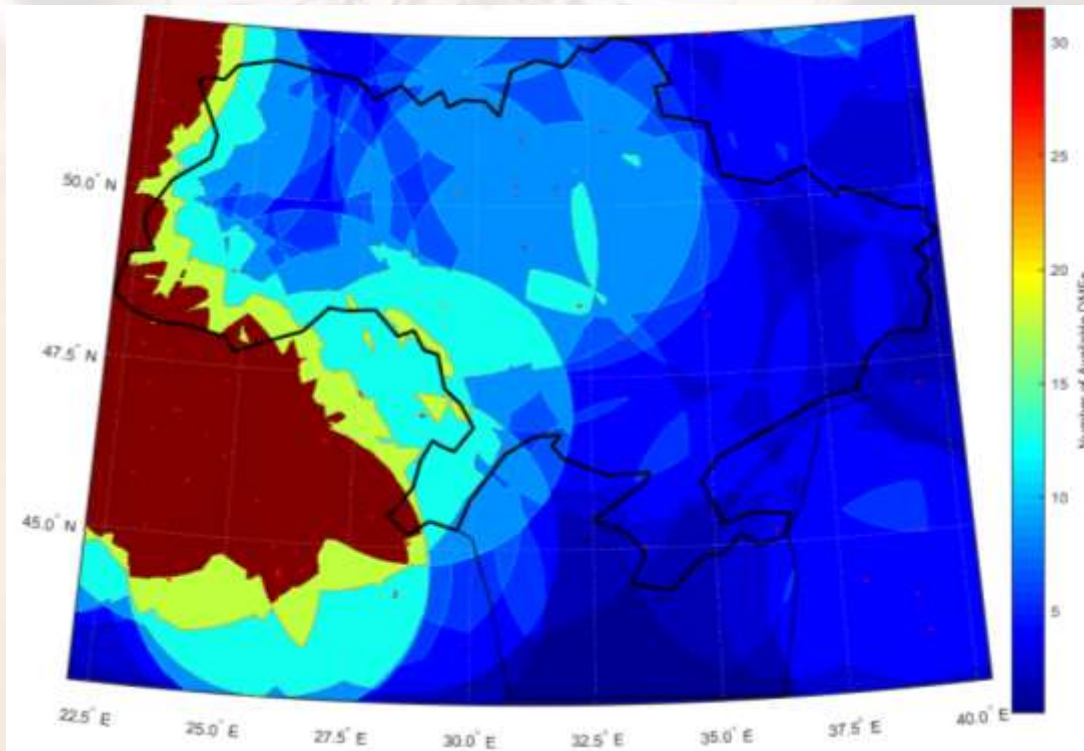


Fig. 5.1. Amount of available DME

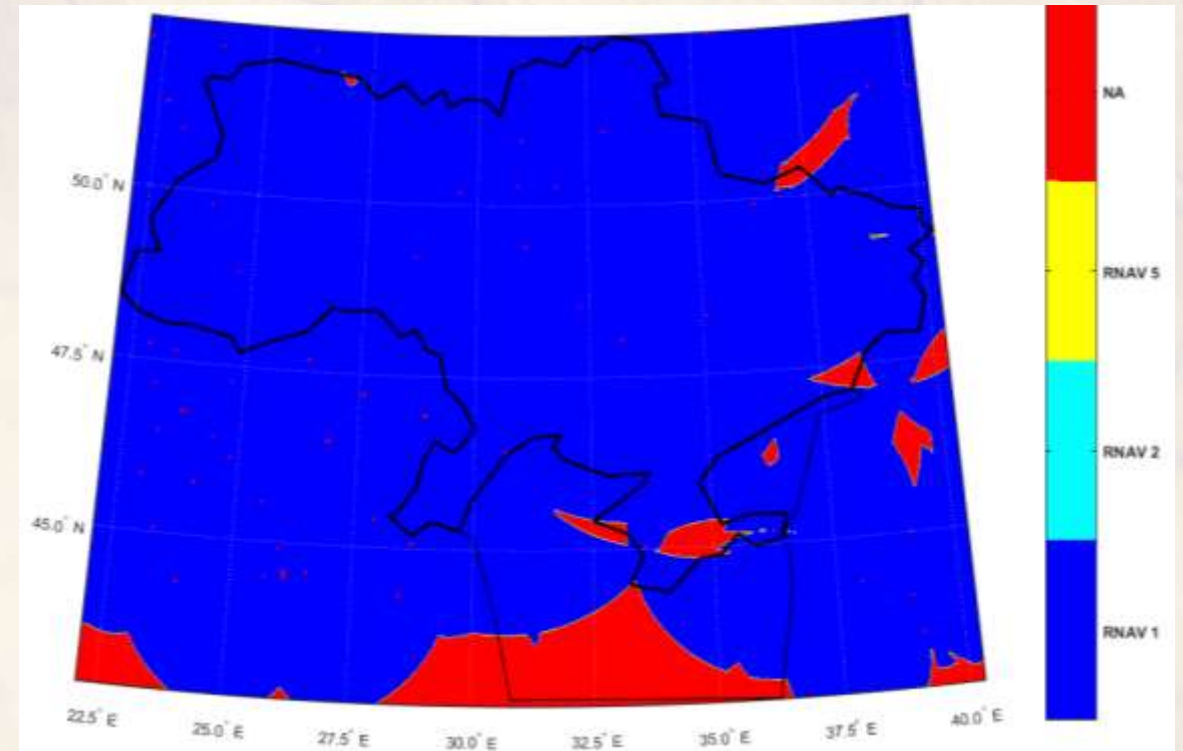
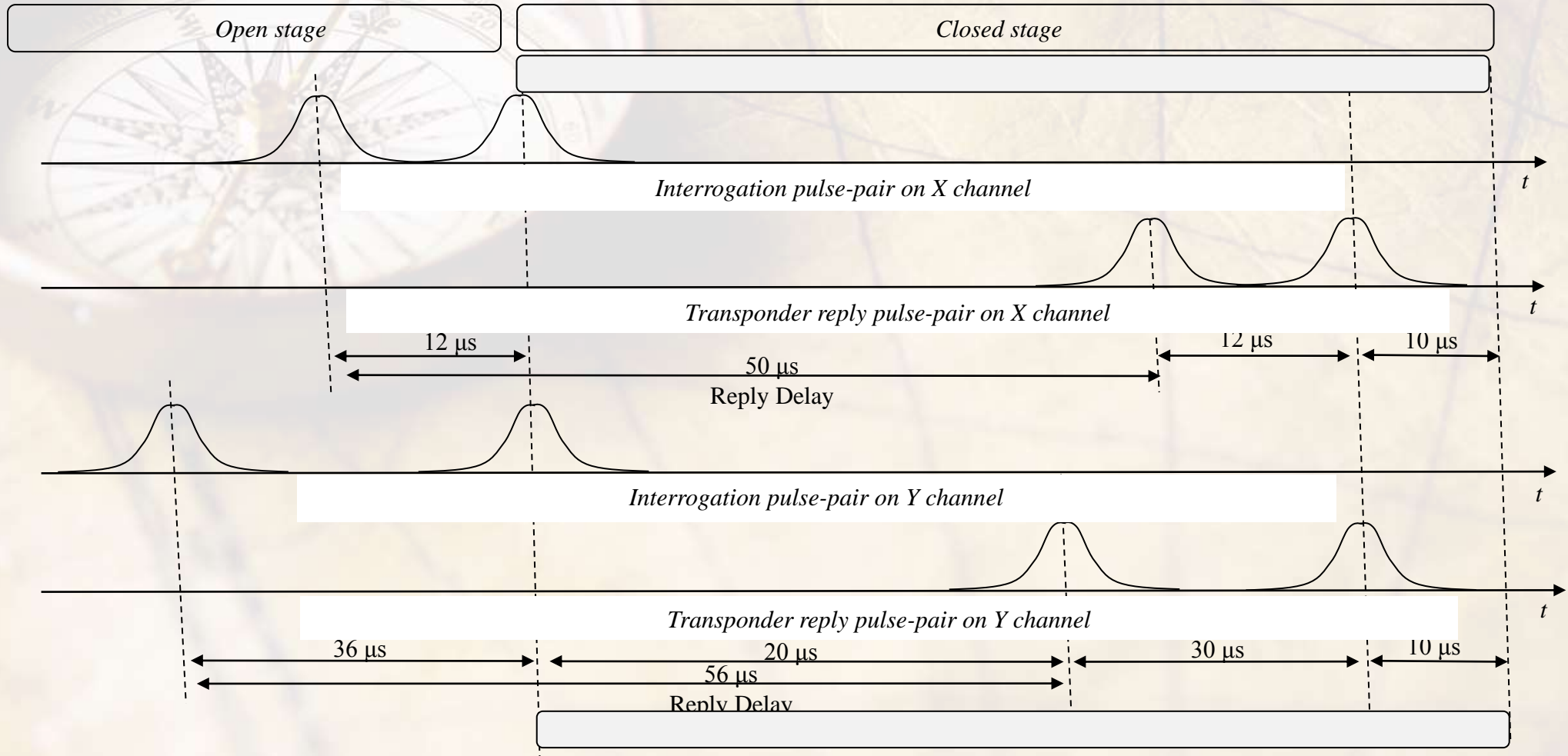


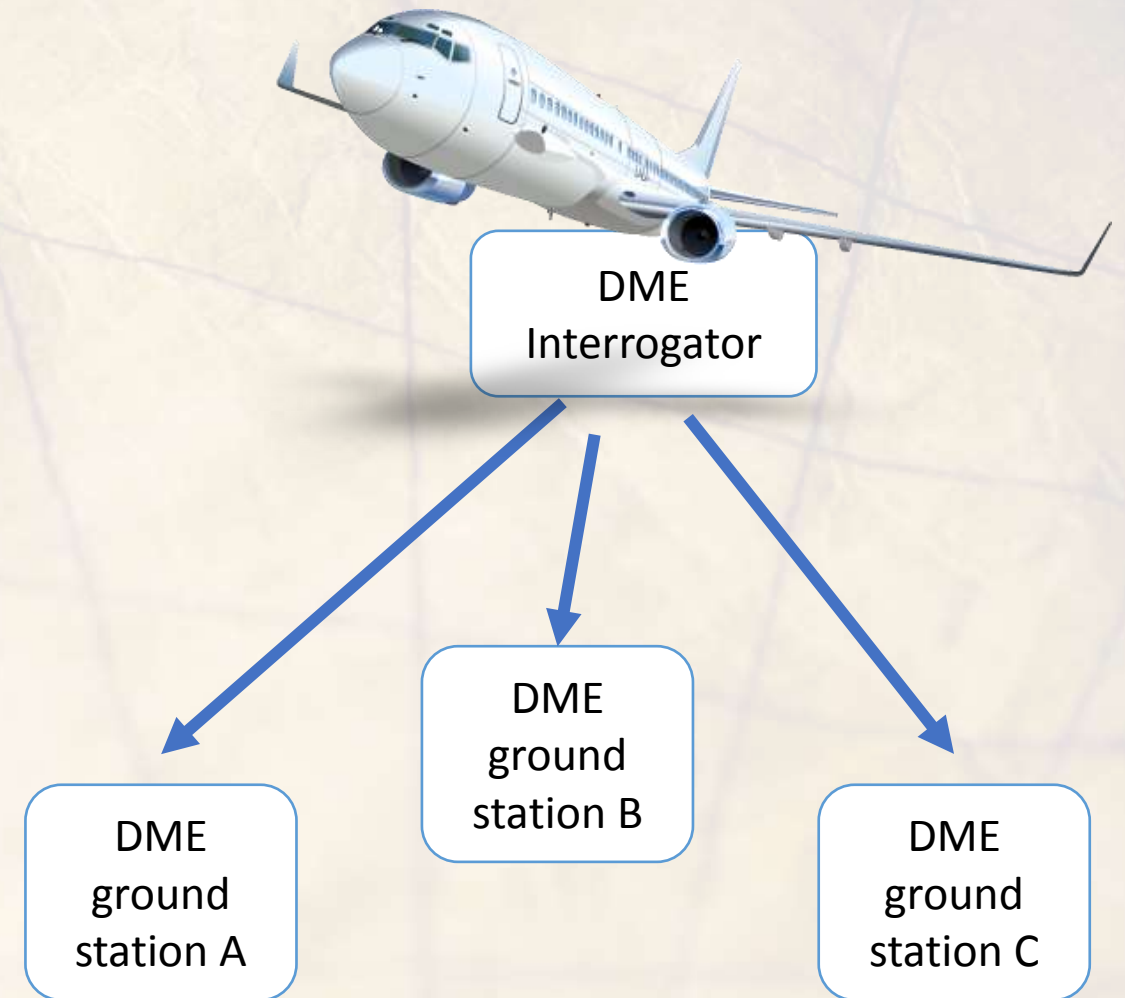
Fig. 5.3. RNAV areas

4. Problem Statement



5. 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



6. Queuing model of DME

Distance measuring cycle can be represented as a simple markovian queuing model:

$$0=PQ,$$

$$1=PE,$$

where 0 is a vector of zeros $[0, 0]$;

$P=[p_0, p_1]$ is a steady state probability vector;

Q is a rate transition matrix,

$E=[1,1]$ is a vector of ones.

The open stage indicates transponder readiness to perform measuring service.

DME transponder is in the closed stage during processing interrogation query or closed for dead time ($60 \mu\text{s}$ for X channel).

An average rate of interrogation λ changes a transponder state from open to closed and μ is a service rate comes back system to open stage.

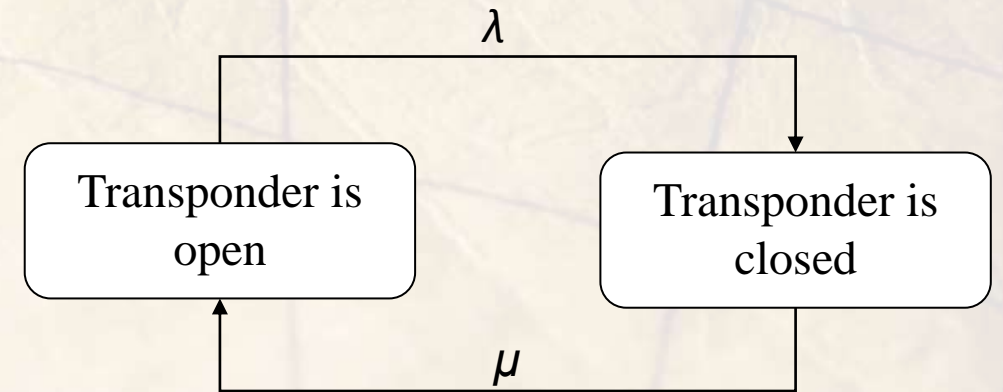


Fig. 8.1. Rate transition diagram for distance measuring transponder

6.1 Performance estimation

The state probability vector can be estimated by Erlang's loss formula:

$$p_0 = \frac{\mu}{\lambda + \mu};$$
$$p_1 = \frac{\lambda}{\mu + \lambda}.$$

An average number of successfully process interrogations called absolute bandwidth on transponder:

$$A = \lambda p_0.$$

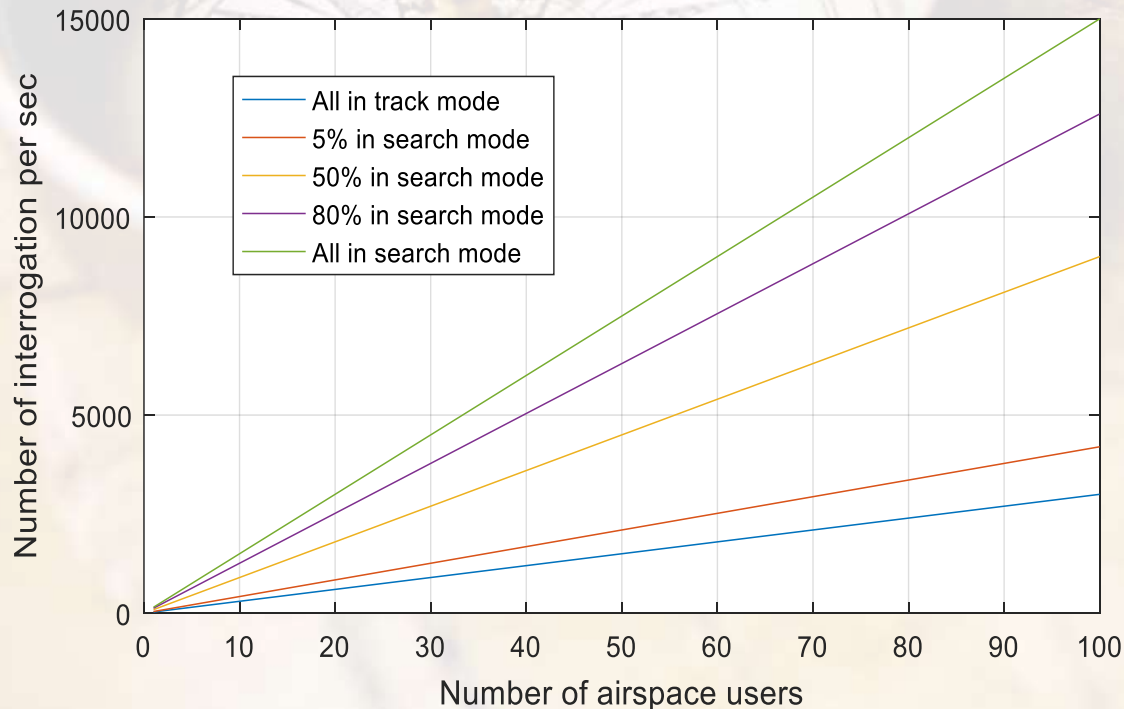
An offered load of transponder L is a measure of total load on the system:

$$L = \lambda / \mu.$$

7. Numerical demonstration

Statistical analysis of DME interrogations indicates that 95 % of airspace users using DME is in track mode and 5% are in search mode.

The average number of interrogations in relation to the number of airspace users is represented in figure for interrogators only in tracking mode, 5% in search mode, 50% in search mode, 80% in search mode, and for all interrogation in search mode.



7. Results of numerical demonstration

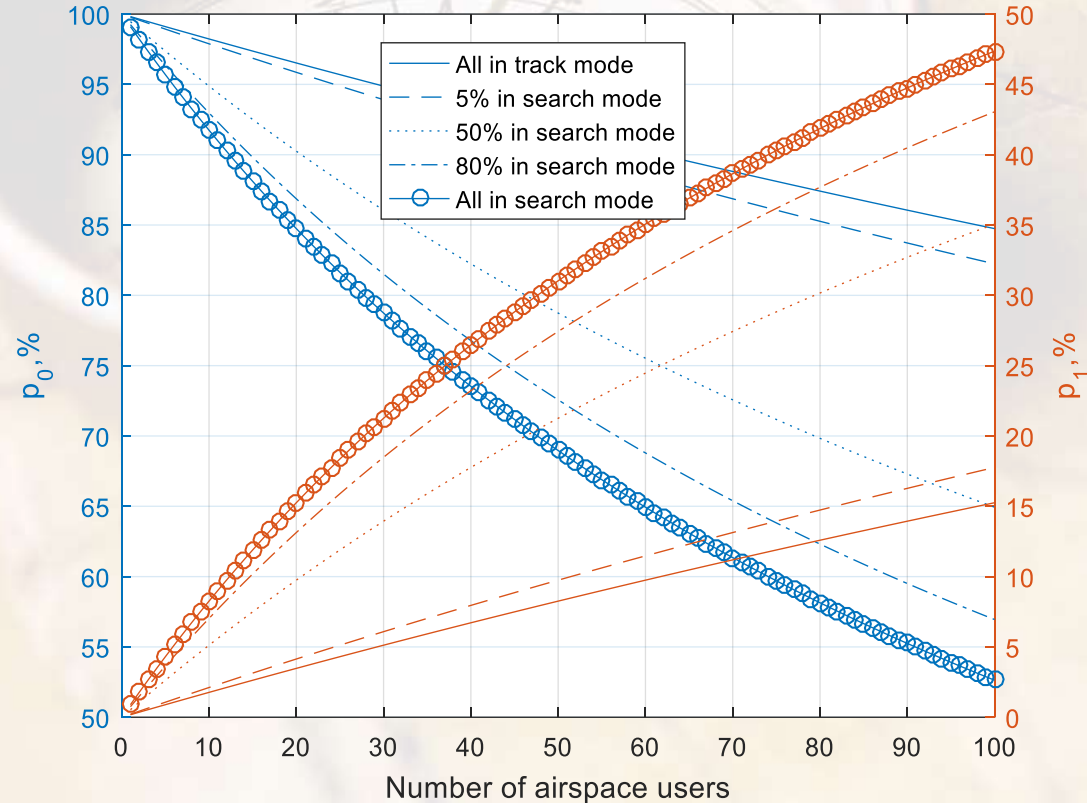


Fig.4. Components of the state probability vector

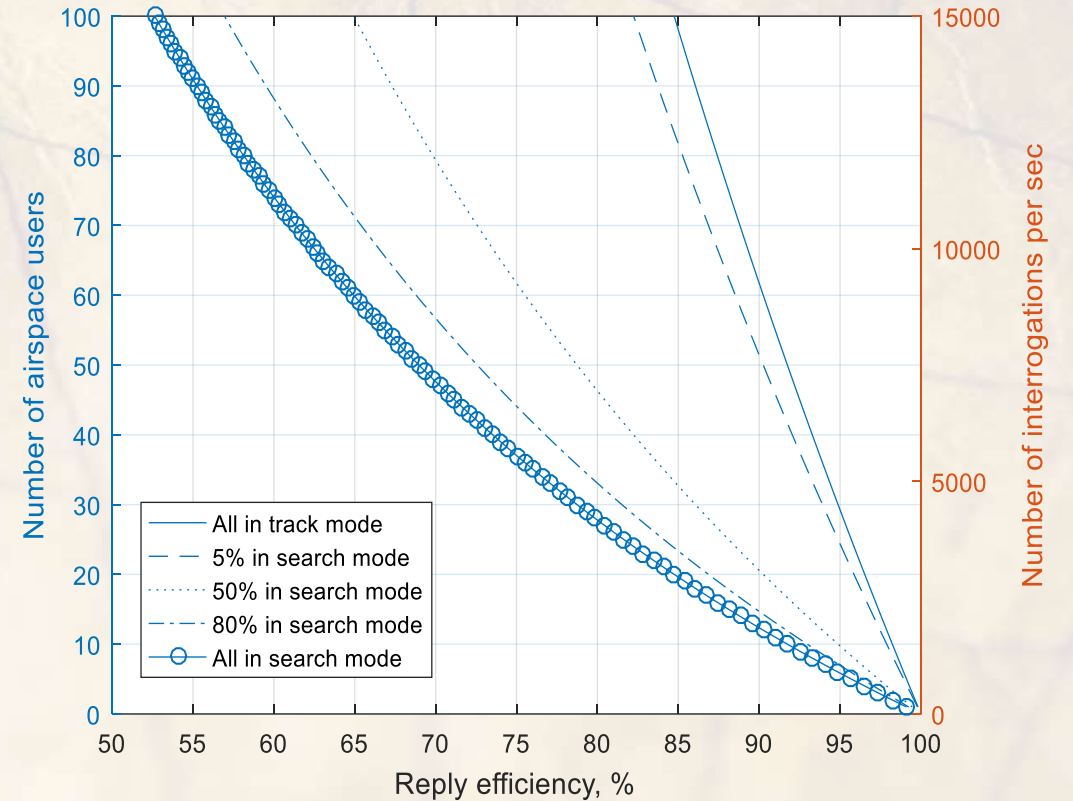


Fig.5. Reply efficiency

7. Results of numerical demonstration

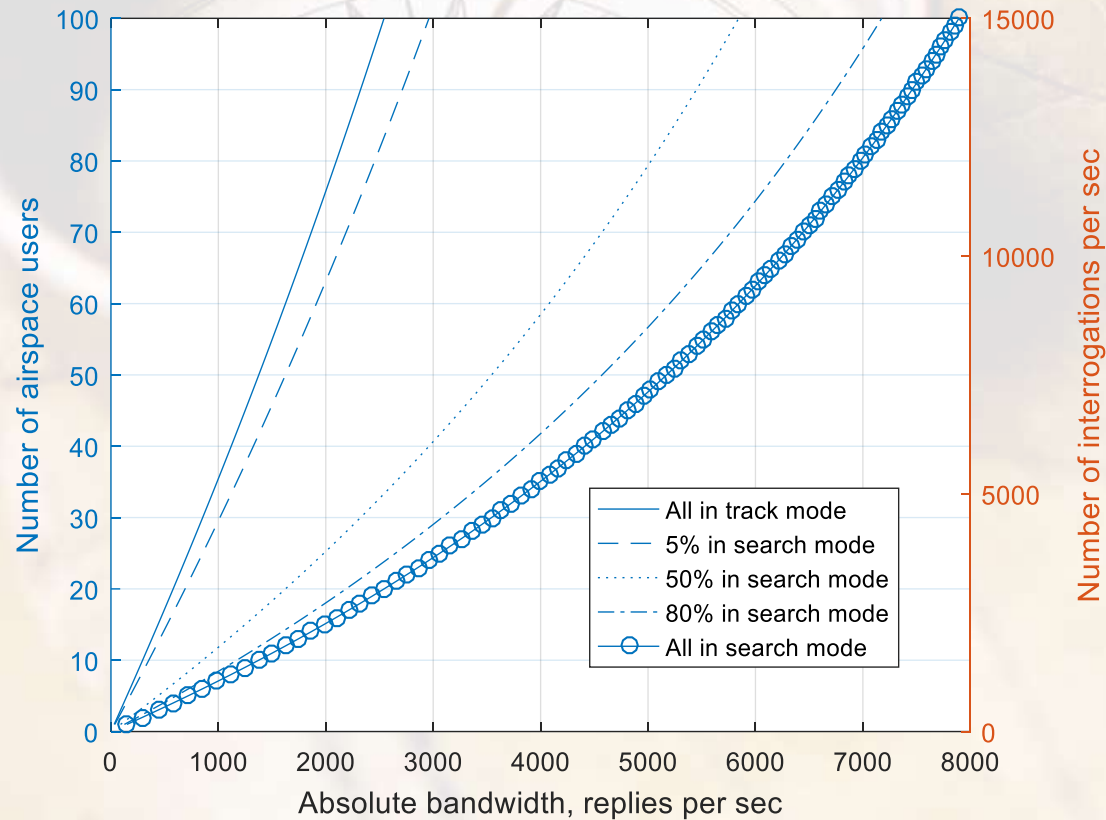


Fig.6. Absolute bandwidth on transponder

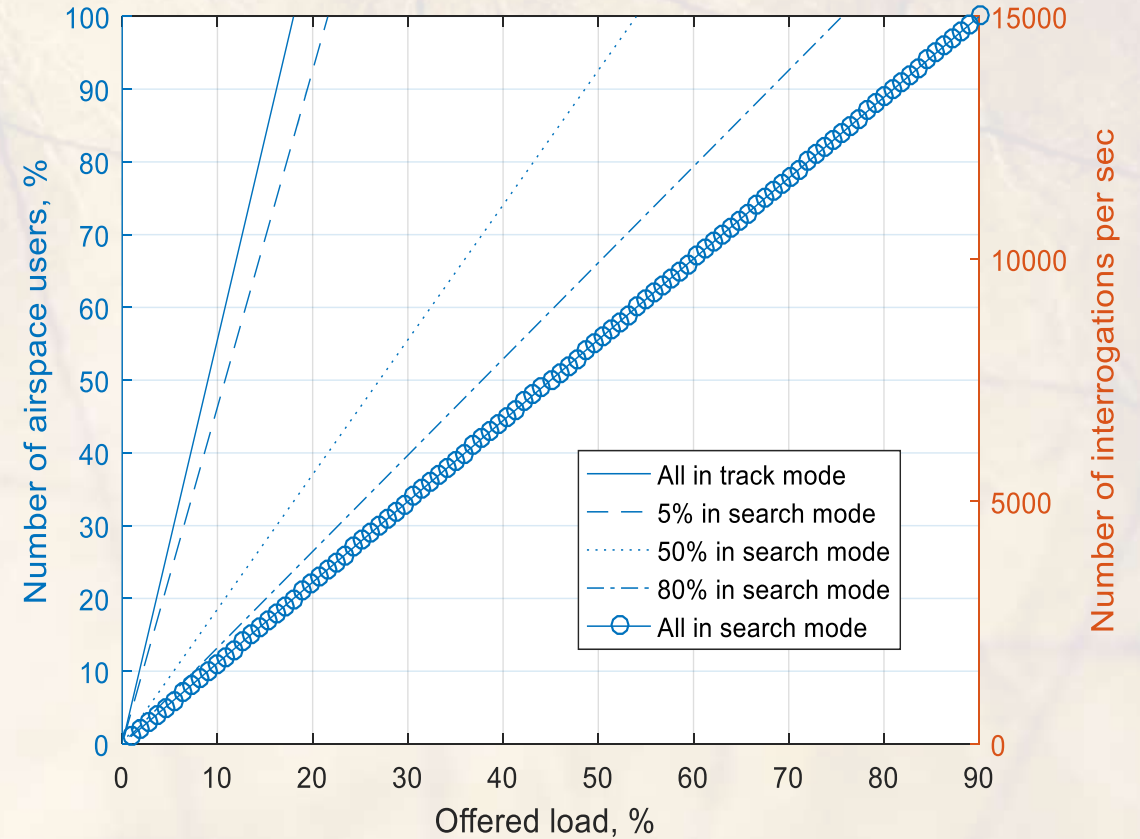


Fig.7. Offered load of DME transponder

CONCLUSION

The results obtained are important for estimation capacity limits in a maximal number of navigational aid users in different interrogation modes that can be served and to prevent system overload from a safety point of view. That is extremely important in conditions of continuously increasing capacity of air traffic flow.

The proposed queuing model of DME as a simple analytical model can be applied in the tasks of navigational aids network performance estimation within a specific volume of airspace, which can reduce total computation time in comparison with statistical simulation.



A vintage-style compass with a white face and a metal casing is positioned in the upper left corner. The compass face shows cardinal directions (N, S, E, W) and degree markings. The needle is pointing towards the top right. The compass is placed on a yellowed, aged map with a faint grid pattern. The background is a soft, light yellow color.

Thank you for attention, questions?