



**National Aviation University of Ukraine**  
Air Navigation Systems Department

# Identification of Distance Measuring Equipment interrogations

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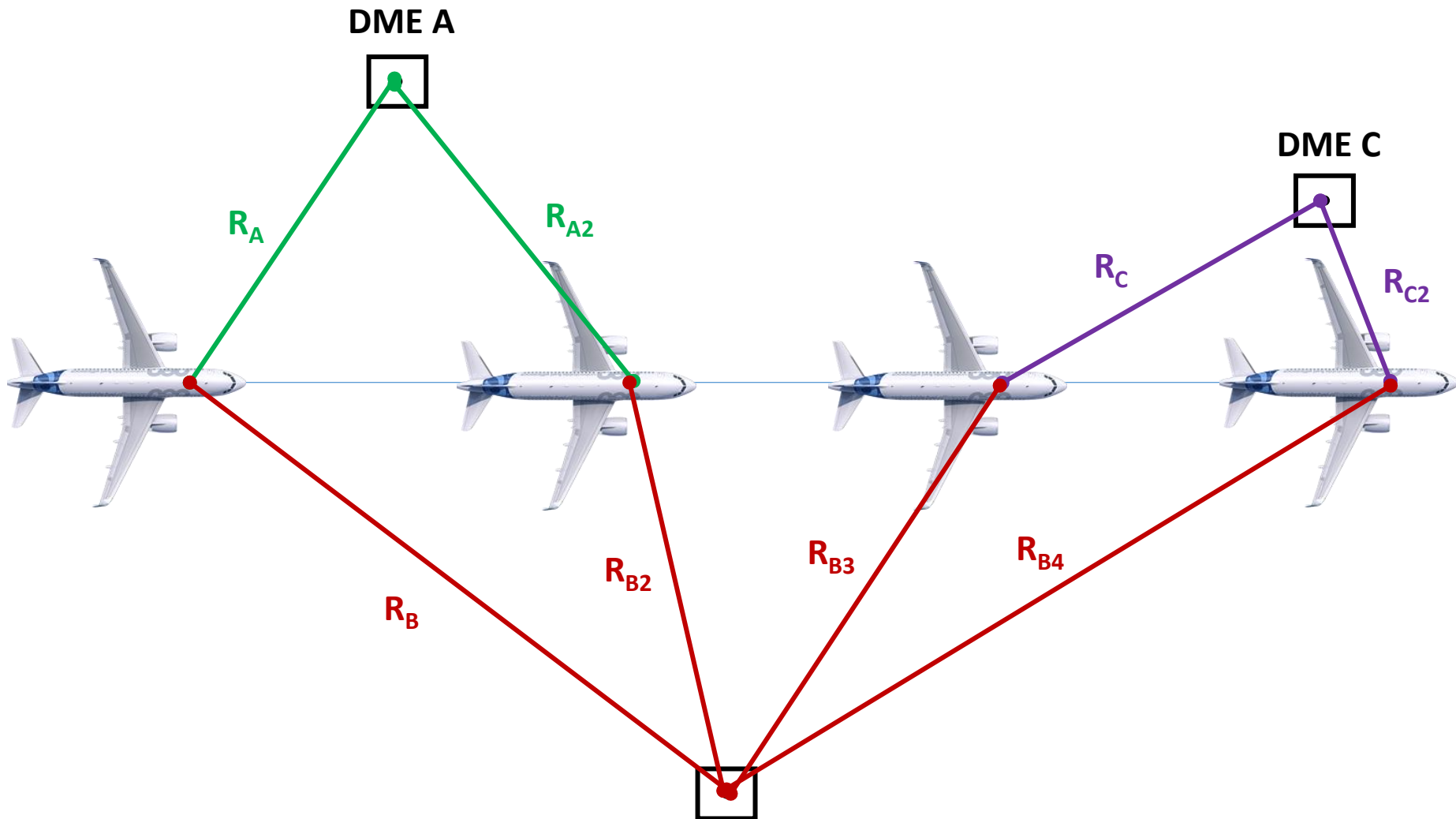


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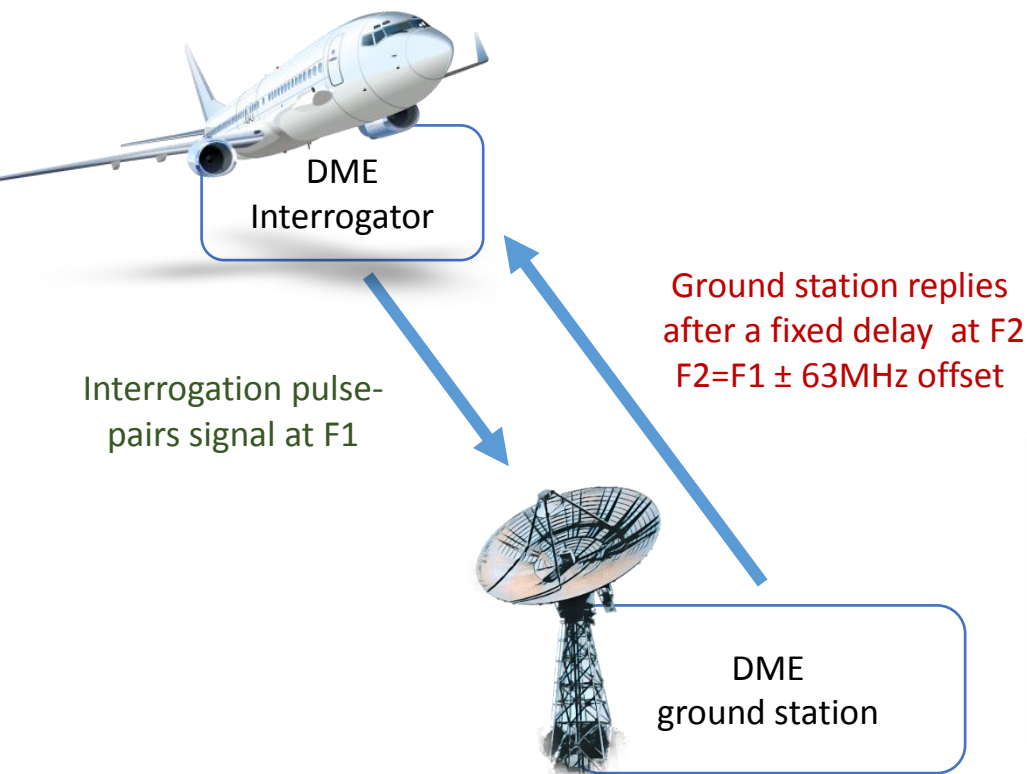


# Distance Measuring Equipment

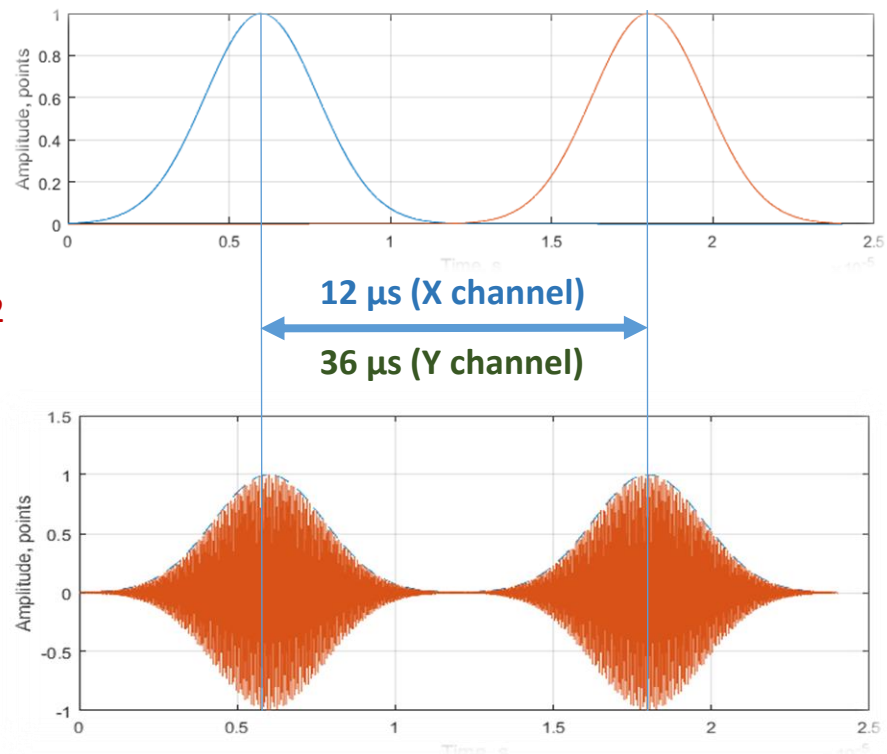




# Distance Measuring Equipment



Pulses are specified to have a Gaussian envelope



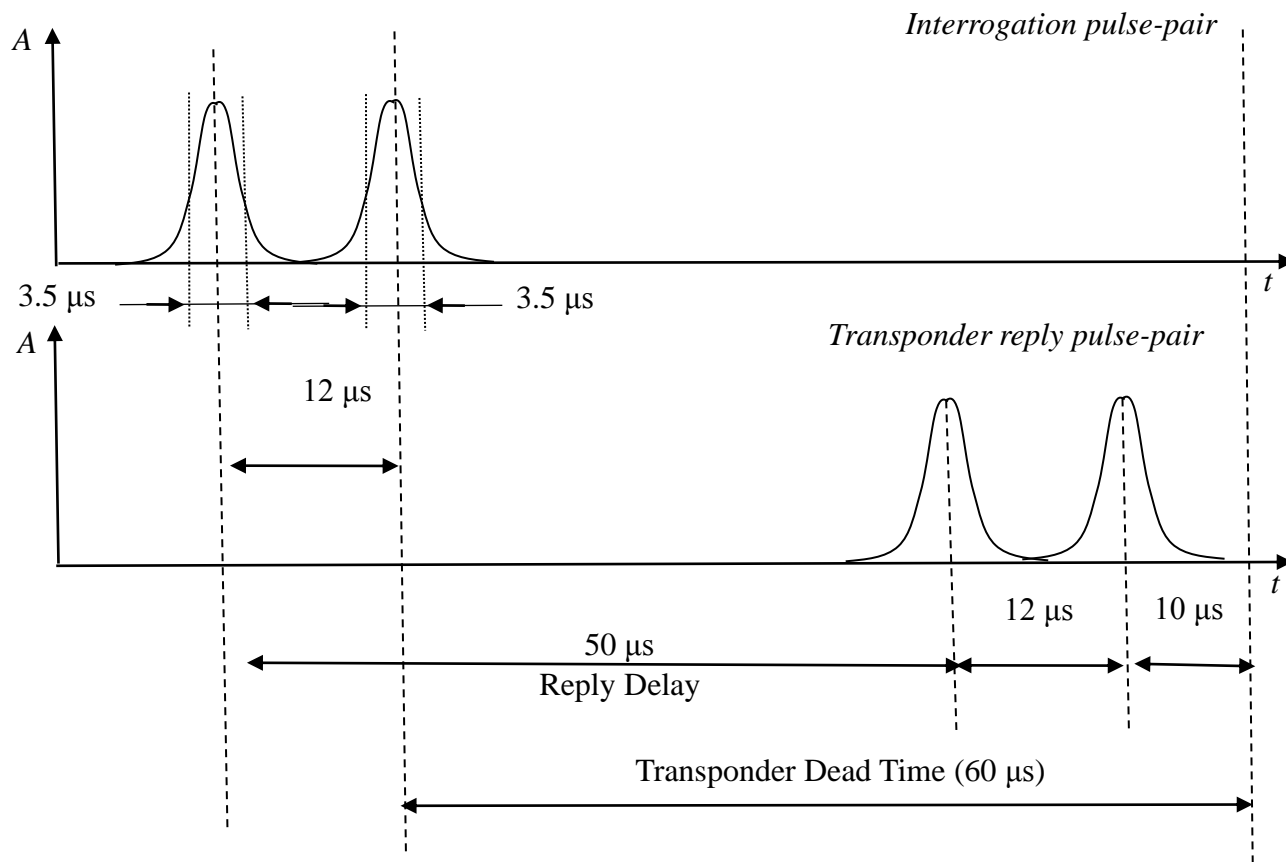


# Distance Measuring Equipment

- UHF
- frequency range of 960 and 1215 MHz
- 1 MHz spacing
- interrogator transmits an amplitude-modulated navigational signal at a carrier frequency
- DME navigation signal includes pulse-pairs.
- Each pulse has a Gaussian envelope with  $3.5 \mu\text{s}$  ( $\pm 0.5 \mu\text{s}$ ) length.
- Two pulses are grouped in pulse-pair with space in  $12 \mu\text{s}$  ( $\pm 0.25 \mu\text{s}$ ) for X channel and  $36 \mu\text{s}$  ( $\pm 0.25 \mu\text{s}$ ) for Y channel.
- DME transponder generates a reply pulse-pair
- time delay in  $50 \mu\text{s}$
- collocated radio frequency which is  $\pm 63 \text{ MHz}$  from interrogation frequency.



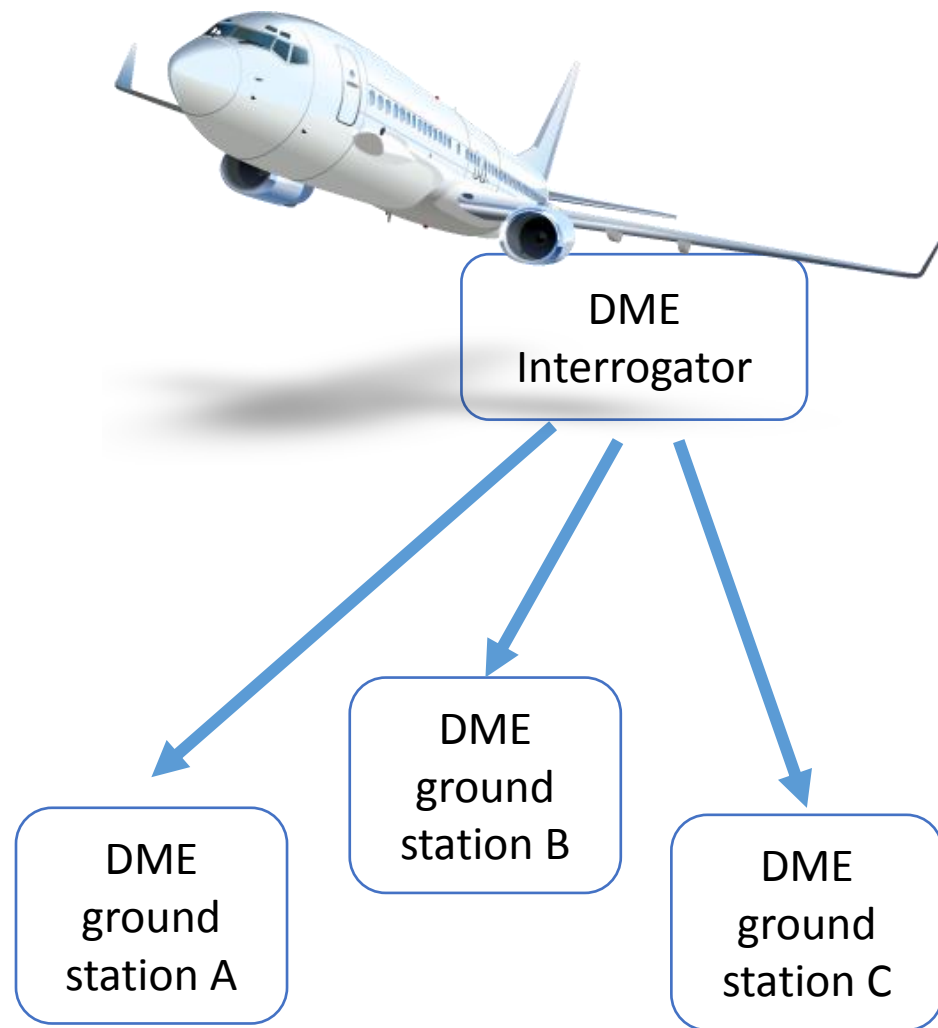
# DME interrogation and reply signals





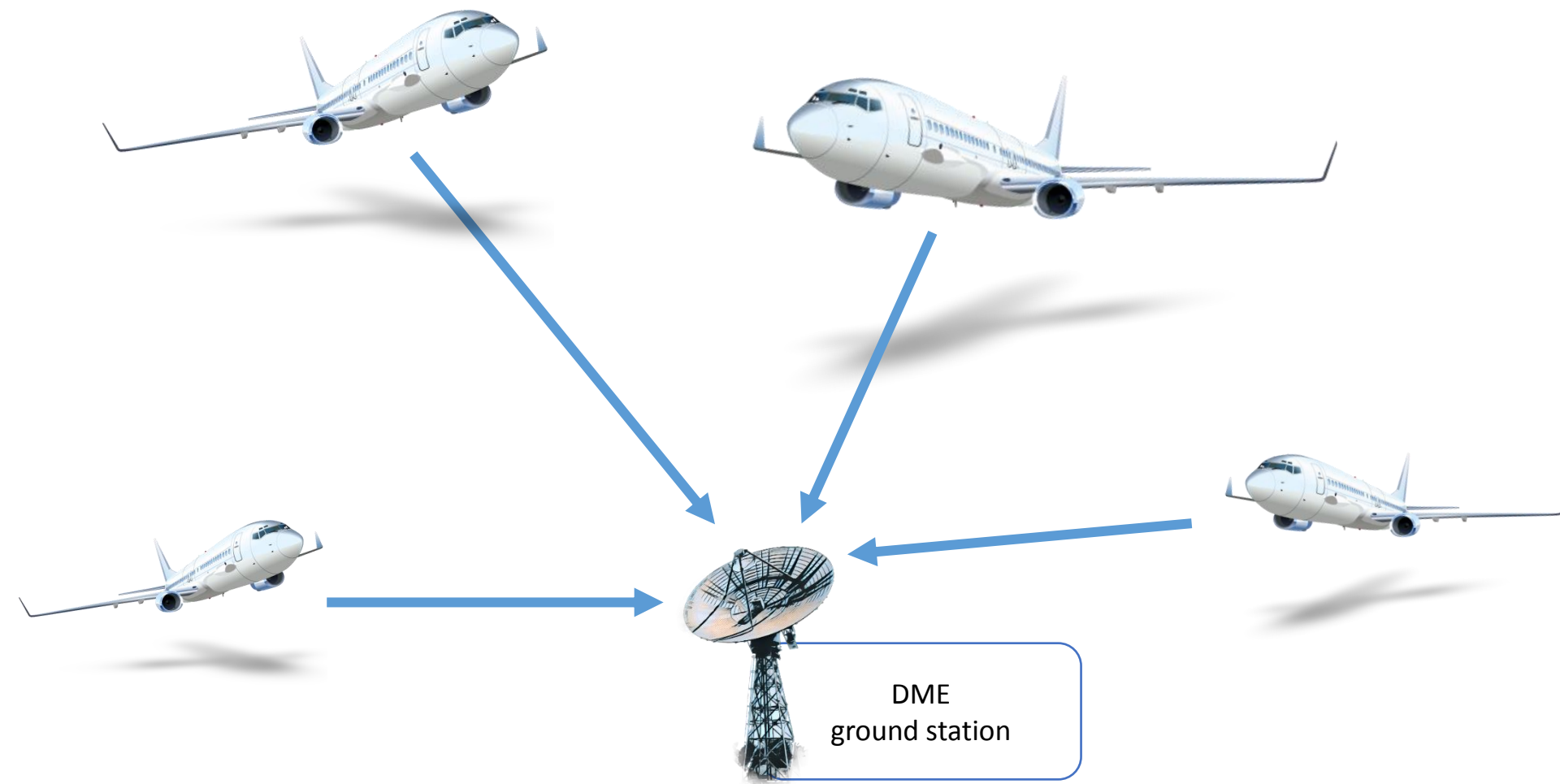
# Interrogation Repetition Frequency

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



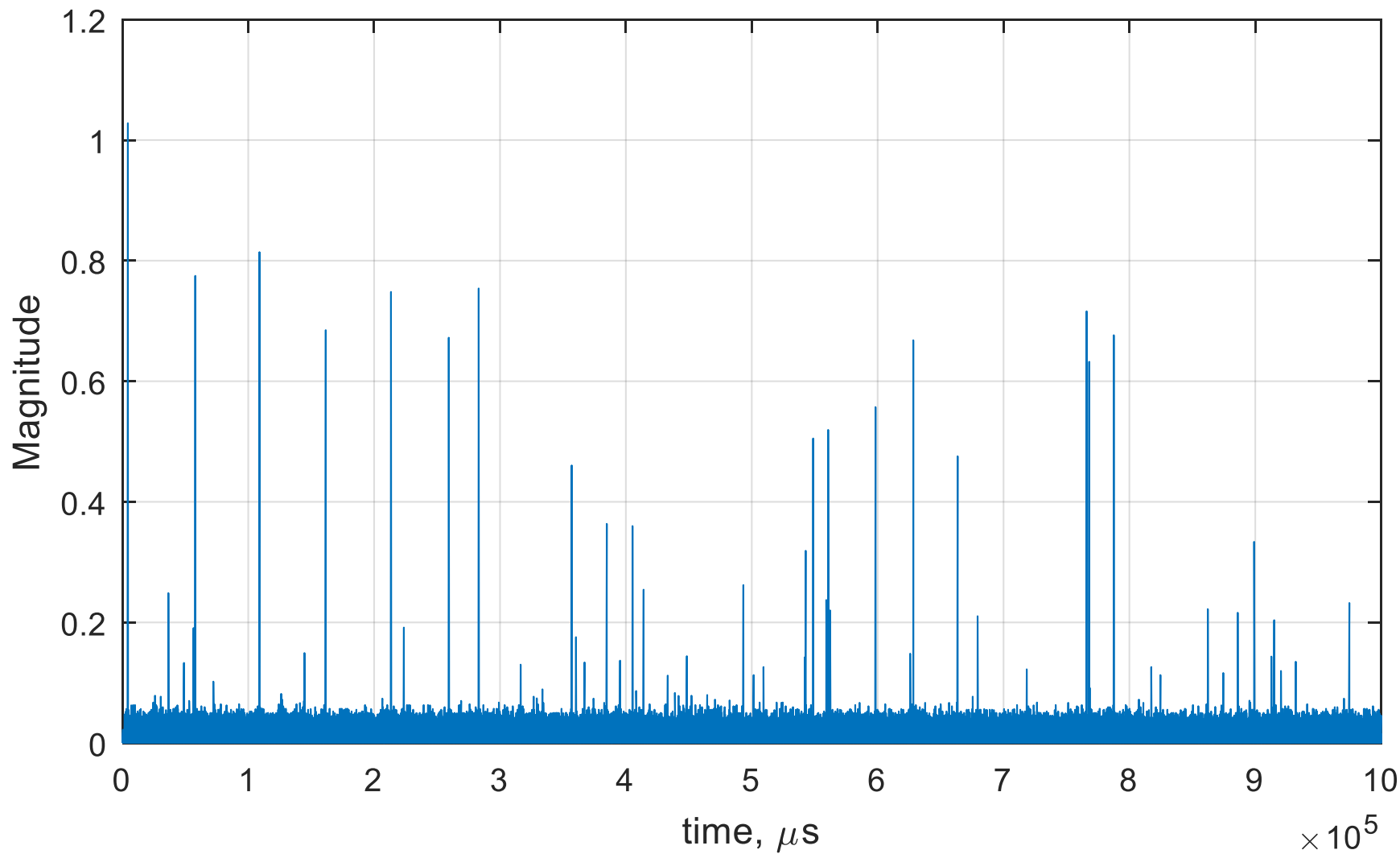


# DME



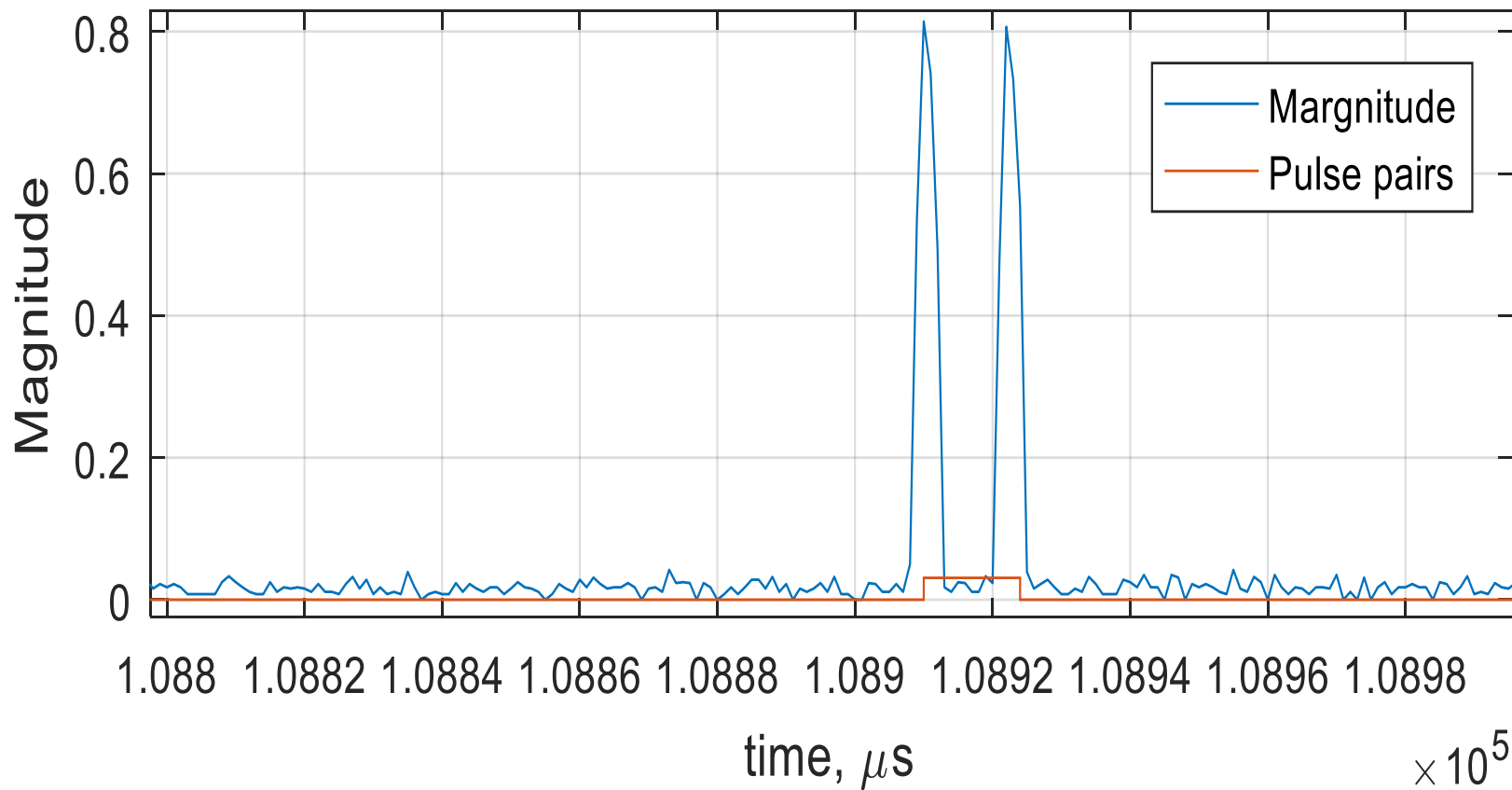


## Magnitude of signal in interrogation frequency of "BRP" DME





## Interrogation pulse-pair of “BRP” DME

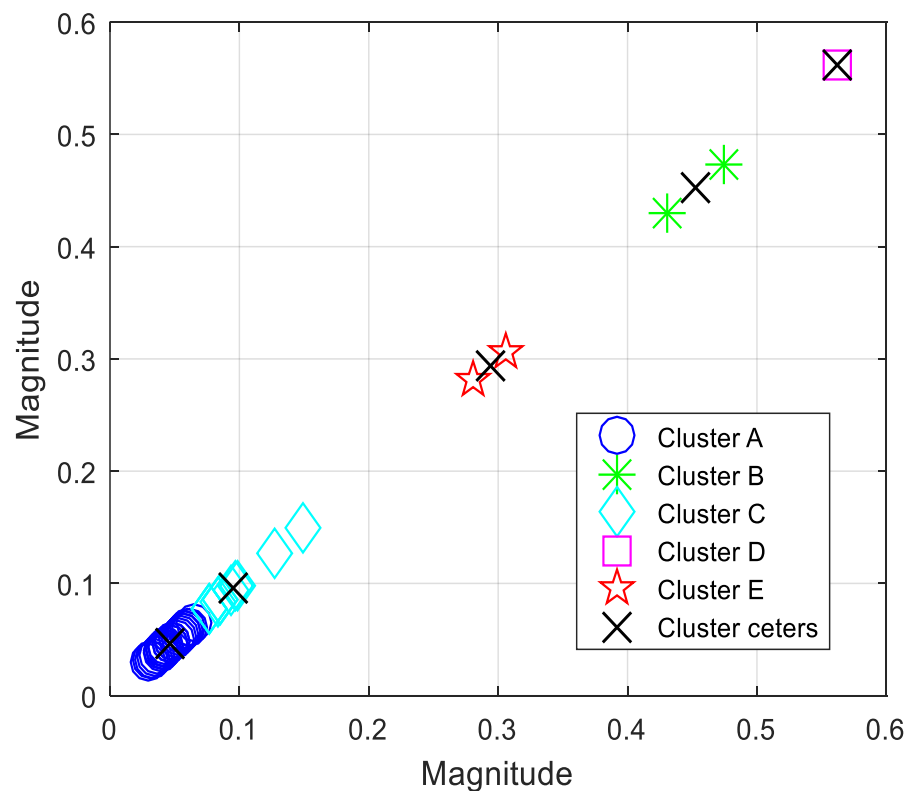
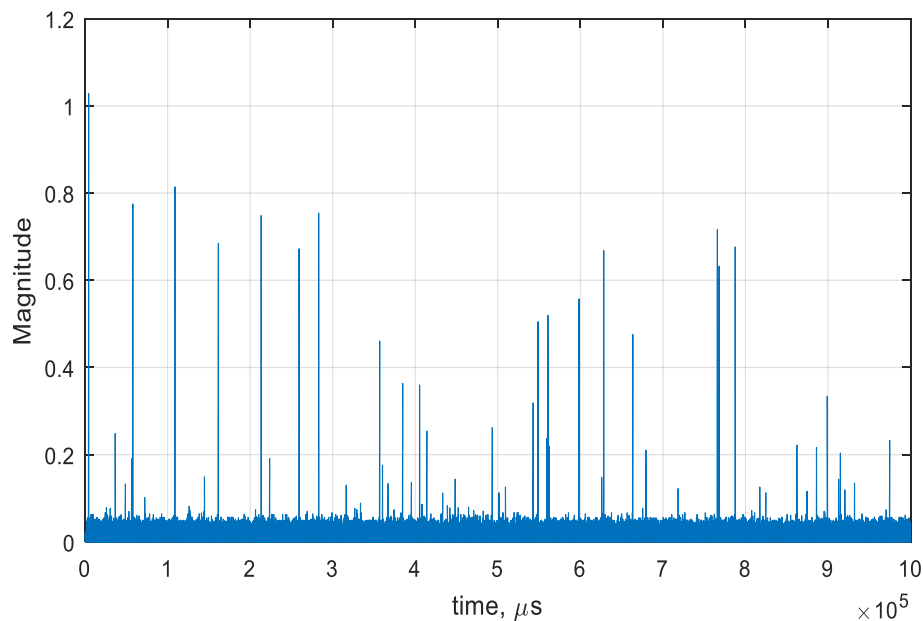


channel “X106” of DME “BRP”



# CLUSTERIZATION

- Magnitude of signal
- 1 sec timeframe for data drilling
- usage of K-means algorithm due to low computation time
- within a 1 sec timeframe the 41 interrogations were detected





# INTERROGATION CLASSIFICATION

- Probabilistic classifier based on maximum of posterior probability
- Each cluster is connected to particular CPDF

$$\rho_k(x) = \frac{1}{\sigma_k \sqrt{2\pi}} \exp\left(-\frac{(x - \mu_k)^2}{2\sigma_k^2}\right)$$

where  $\mu_k$  is mean value;  $\sigma_k$  is standard deviation;  $k$  is a cluster identification number.

Mean values of CPDF is equal to cluster centers. Standard deviation of each cluster is selected to guarantee 99% confidence band to meet cluster boundary:

$$\sigma_k = 0.3(3) \max(\mu_k - x_k),$$

where  $x_k$  is matrix of amplitude connected with cluster  $k$ .

A posterior probability

$$q_k(x) = \frac{p_k \rho_k(x)}{\sum_{i=1}^k p_i \rho_i(x)}.$$

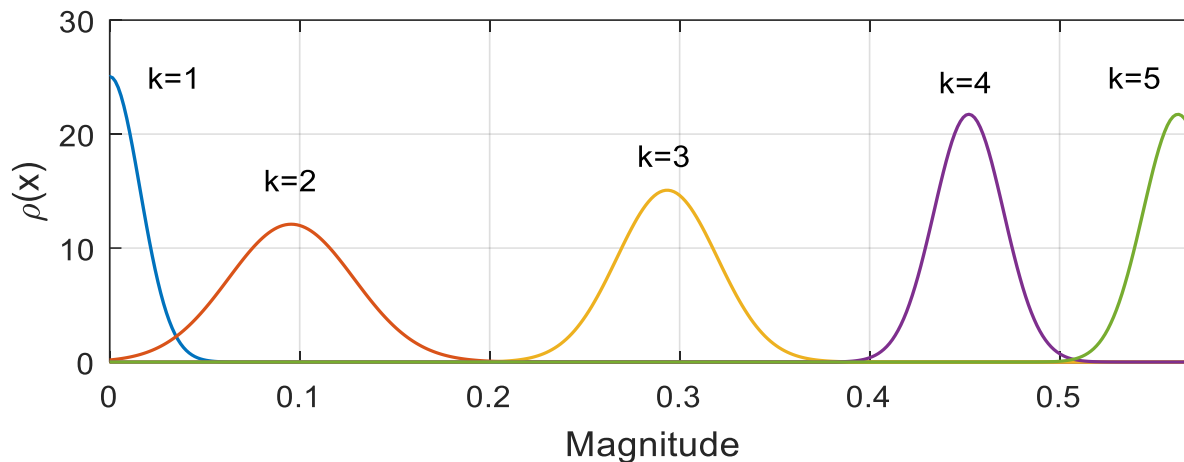
Interrogation identification is based on maximum of posterior probability:

$$P = \max(q_k(x)).$$

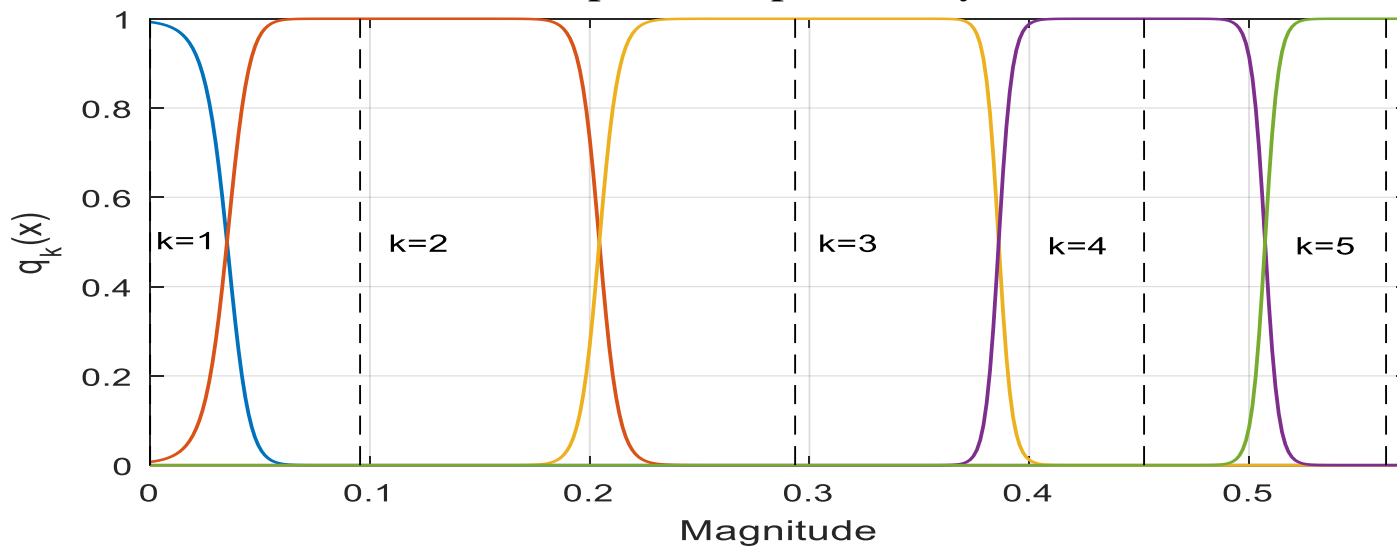


# posterior probability for five clusters

CPDF for input cluster data

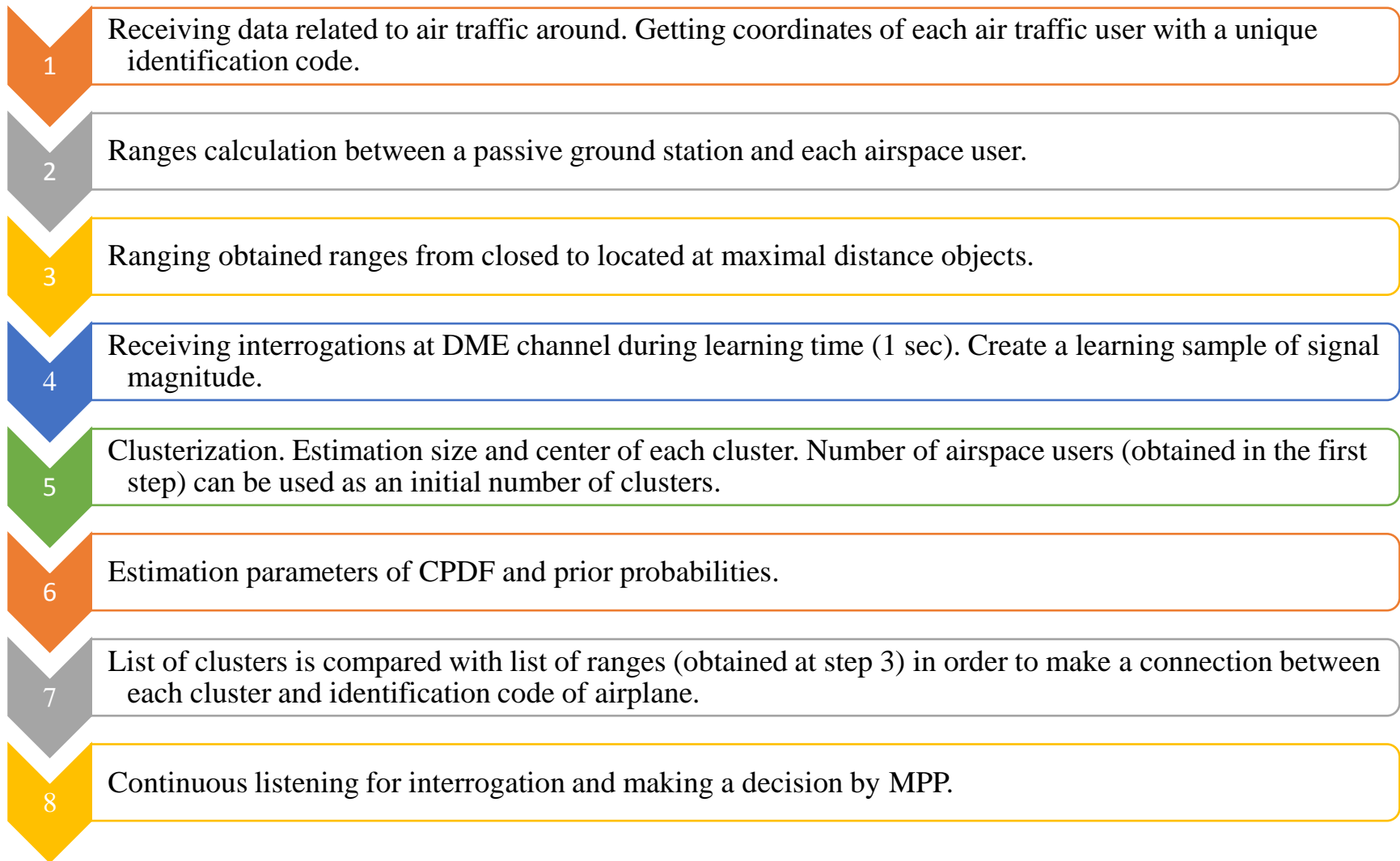


Distribution of posterior probability for five clusters





## DME interrogation identification algorithm





# CONCLUSION

- In the study, an algorithm of DME interrogation identification is proposed. Identification is based on signal magnitude value and known distances to airspace users. Unfortunately, application time between pulse-pairs criteria did not provide sufficient resolution due to the non-synchronized pulse-pairs series. Thus, method based on signal amplitude is only one possible solution for interrogation identification.
- Proposed algorithm gives a decision based on the assumption of all airspace users use service of particular navigational aid. In order to minimize influence of misdetection, we propose to increase learning time based on air traffic behavior.
- Proposed algorithm helps to estimate a quantity of delivered air navigation service for a particular airspace user. Obtained statistical data is used to monitor the overall performance of all navigational aids network in order to improve air navigation service quality.

## Contacts

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