Features of the implementation of a streaming data exchange system in a spatially distributed system of small-sized radar stations

Sergey A. Nenashev[1], Anton A. Sentsov[1], Vadim A. Nenashev[1]
[1]St.-Petersburg State University of Aerospace Instrumentation
Saint-Petersburg, Russia
nenashev.va@yandex.ru

Abstract — **This paper examines the features of implementing intensive exchange of streaming data in a spatially distributed system of small-sized airborne radars integrated into a network that provides control, communication and integrated data processing. Effective use of information requires the concepts of a conceptual model of specialized radio channels that prevent unauthorized interference in the operation of the system and ensure high requirements for reliability, capacity, range, information transmission speed, noise immunity and noise immunity.**

The features of presentation, storage, masking and compression of streaming information (due to its large volume) are also considered, taking into account the specifics of its formation in an intermediate radio relay station and the characteristics of the observed areas and objects during its transmission to the processing and control point, where decisions are made that allow solve problems of an operational nature.

When solving scientific research problems, the methodology for constructing multi-position onboard radar systems, the theory of high-resolution frame transmission, using special masking and compression algorithms without significant loss of useful information based on the use of a matrix apparatus, as well as methods that ensure the distribution of calculation of streaming data, were used.

Keywords — **data exchange system, radar data flow, presentation and transformation of information, small-sized airborne radar stations, spatially distributed system, small aircraft.**

I. INTRODUCTION

As small aircraft technology advances, the standout aircraft today are autonomous devices that are connected to a network and capable of flying along a predetermined route with minimal operator intervention.

The technology of combining several small aircraft into an intergroup group is especially important [1] when the capabilities of one small aircraft are insufficient due to its limitations associated with mass payload, flow time, limited energy capabilities, etc. In special cases when solving an operational problem is required, for example, in conditions of limited time when monitoring a large area in the event of natural disasters.

Therefore, to solve such operational problems, it is advisable to develop a concept within which to organize the unification of assets into an interacting group of several small aircraft interconnected by a single network that ensures exchange (through “small aviation-ground”, “small aviation-small aviation”), management and processing of streaming data.

The distributed system of a small aircraft, the structure of which is shown in Fig. 1, receives streaming information from several boards, observed observation zones from different angles, which allows complex processing of this data to solve mapping and classification problems. objects with the required accuracy and completeness.

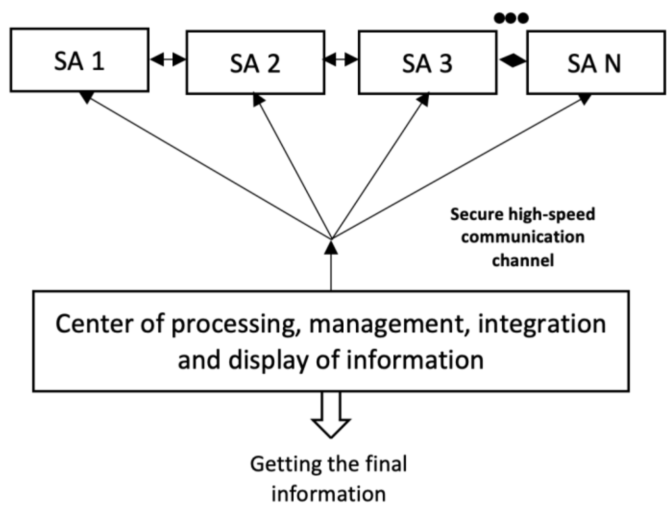


Fig. 1. Structure of the network for exchanging, managing and processing sweat data (draw arrows between small aircraft)

Thus, the urgent task of introducing the concept of group spatially distributed interaction of a small aircraft, the positions of which are combined into a single high-speed network of exchange, control and integrated processing of streaming information [2].

According to the introduced concept of group interaction, this main unified network should study the collection of data streams from spatially dispersed radar information devices, data on small aircraft for the purpose of their further analysis for the implementation of operational and high-precision monitoring of the surrounding space, water surface, earth surface and other environments, when it is necessary [3]. To implement this concept, it is necessary to determine approaches to building such spatially distributed systems consisting of small aircraft capable of operating in real time.

II. Features of the implementation of a data exchange system of small-sized airbone radar

The implementation of a spatially distributed system of small-sized airborne radar stations interacting in a group requires the development of specialized protocols for the exchange of streaming data between its elements. Such a specialized streaming data exchange protocol, on the one hand, should define the concept of interaction between elements of a spatially distributed system and, at the same time, give the system such properties as adaptability, efficiency, and also ensure the quality of transmitted information. These properties are interconnected, but each of them has its own characteristics. Adaptability is determined by the ability of the system to change its operating algorithms depending on external conditions (the number of ground objects, communication channels between on-board radar stations, computing power) to ensure efficiency and quality of processing. Efficiency is characterized by the time it takes to bring information to the consumer. Quality is characterized by the detail, accuracy and completeness of the generated data on the observed territories and ground objects.

To implement these properties in a system for exchanging streaming data between communication equipment of small-sized airborne radar stations of a spatially distributed system [4], it is necessary to consider:

- issues of presentation, formation and transformation of streaming information transmitted on the network;

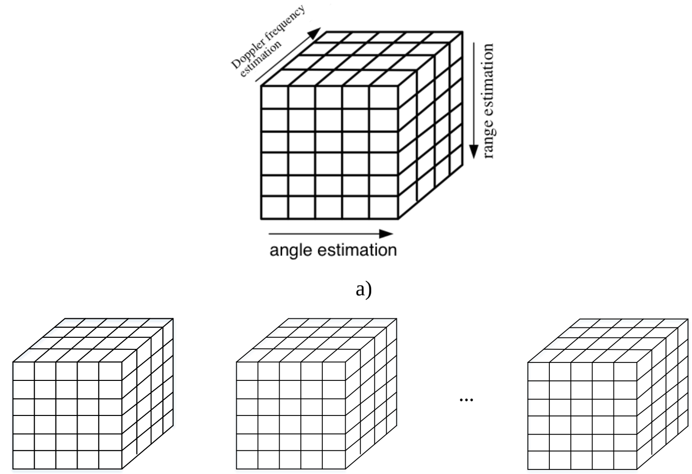
- architecture options for building a data exchange system;

- features of stream conversion for the purpose of noise immunity and their restoration.

Thus, it is necessary to find a balance between the limitations of the throughput of exchange channels, the performance of on-board computing facilities and the required quality of the result of complex processing of streaming data.

III. Features of representation, formation and conversion of radar frame streams into a spatially distributedsystem for intensive exchange

To implement such distributed systems, it is necessary first of all to determine the type of information collected and generated on board from radar devices on board small aircraft. In the case of small-scale airborne radar measurements, this is information that forms a stream of high-resolution radar frames or the production of radar images generated by the antenna aperture synthesis method. So basically it is an image that is a matrix structure or a flow of such a structure [1, 4]. That is, echoes that appear as data cubes, as shown in Fig. 2, as a result of processing, the radar information or the flow of radar frames is reduced.



b)

Fig. 2. Radar data cube (a) flow of cubes (b)

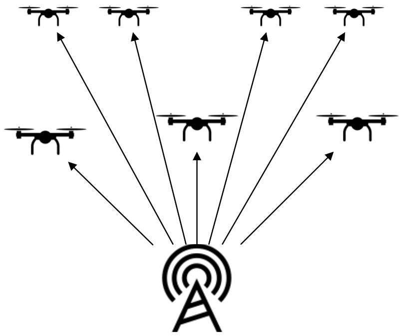
Currently, streaming data processing is used in a variety of areas of human activity. Of particular interest are large sweat data, in the form of generated streams of high-resolution radar frames with a high repetition rate. Today, such streaming digital visual information is increasingly used in aviation monitoring of the earth's surface for the purposes of environmental reconnaissance, assessing the condition of agricultural land objects and territories, as well as in search and rescue operations carried out from a group of small aircraft.

In such operational spatially distributed systems, great attention should be paid not only to algorithms for the formation of radar frames and their complex stream processing, but also to methods of presentation, transformation, storage, compression, and recovery of information, including in the event of destructive influences on it, in order to reduce the load via a channel of intensive exchange during transmission between communication equipment of small aircraft [4-6].

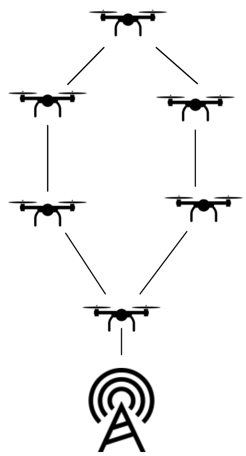
That is, in spatially distributed systems between the detection of the positions of small aircraft, as well as between the ground control station for complex processing, it is necessary to ensure intensive and continuous exchange of streams of radar frames. However, before transmission, these input data are transformed in such a way as to reduce the load on the communication channels so that the volume of control data is influential, especially in the case of the small aircraft-to-ground channel.

IV. Architecture optinions for bulding a streaming data exchange system

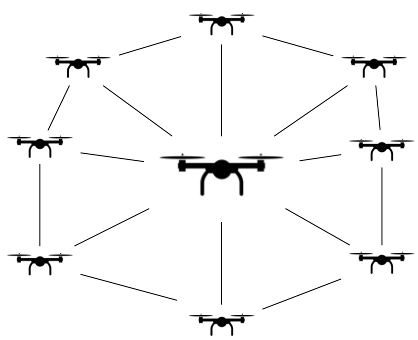
A spatially distributed system, consisting of several small aircraft, can be organized in the following options (see Fig. 3) network implementation: centralized network, decentralized network, distributed network.



a) Centralized network



b) Decentralized network



c) Distributed network

Fig. 3. Architecture of the streaming data exchange system

In a centralized system, all useful information from a distributed group of small aircraft is transmitted to the ground, where it is comprehensively processed and a decision is made to update the flight task or that the task has been successfully completed. It is known that this classic wireless method of transmitting information via radio communication channels has many disadvantages: the need to license frequencies and their shortage, noise of the communication channel, their high congestion, as well as the low security of this communication option [5].

In a decentralized system, small aircraft interact at different levels to achieve system goals and exchange information to jointly complete tasks and make group decisions.

This architecture has increased flexibility/scalability: since decentralized networks do not have a single point of failure, they can continue to operate even if the main hub fails or is taken offline. In addition, such networks are easily scalable because they have the ability to add more subscribers to the network to increase its computing performance if necessary, and network maintenance usually does not require a complete network shutdown.

However, there are inherent coordination problems in this architecture due to the fact that the main nodes in a decentralized work network may not independently interact with other larger organizations, which can be classified as international organizations with restrictions and classes with difficulties in managing collective tasks and their implementation.

Distributed network architecture is similar to decentralized network architecture in the sense that it abandons a single center for decision-making and complex data processing in favor of multiple on-board points of a spatially distributed system.

When discussing the relative merits of different network architectures, it is important to remember that no one configuration is superior to any other in all environments. However, to implement group interaction of small aircraft, a distributed network is preferable. Because distributed networks do not have a central server or a separate set of master nodes, the burden of data processing is shifted to subscribers throughout the network, while all users are given equal access to the data.

Therefore, the decision-making process in a distributed network typically involves individual nodes voting to move to a new state, and the final behavior of the system changes according to the aggregate results of the decisions that each individual node votes on. All forms of distributed decision making involve individual network components interacting with each other to achieve a common goal.

In addition, well-known methods and technologies for noise-free and high-speed data transmission over wireless communication channels between groups of young children with the integration of intelligent network management based on hidden and fog computing technologies for mobile sensor networks at the level of structure, nodes, protocols and software communications. This will improve the computing performance of on-board unmanned aircraft systems in order to ensure their autonomy [7-9].

In addition, first of all, the device on board the radar research studies the ranking of the importance of a ground object, for the purpose of its high-quality comprehensive processing (for example, individual zones of radar frames are considered). An automated control system for a distributed surveillance system must itself generate important parameters from the general flow of useful information. This will save network and computing resources and provide the distributed complex processing process with such qualities as flexibility and adaptability.

Thus, the transmission of useful information (a stream of radar frames or a separate selected fragment of a ground object) in the “small flying object-ground”, “small flying object-small flying object” channels must be controlled by the process. That is, it is carried out in such a way that the requirements for data transmission speed, reliability, and quality are acceptable in the changing conditions of the development of groups of small flying objects united in a network.

This primarily includes the issues of converting information generated on board into such a noise-resistant form without loss of quality, in the case of severe restrictions imposed on the network in the current conditions.

V. Implementation of the Process of Converting and Restoring Radar Stream Fremes

One of the effective methods for protective coding of visual streaming information is the two-way matrix transformation method. This method is based on methods using orthogonal matrices of different structures and corresponding matrix operations.

This matrix transformation of digital streaming information is carried out at the moment it enters the communication channel. There, each radar frame of the stream is subjected to matrix transformations in order to hide useful information. At the output, at the receiving end, operations are carried out to restore the original frame [10-13].

This process in a distributed computer is symmetrical. That is, on the front side there is a spectacular direct transformation, on the receiving side there is a reverse one, symmetrical to the direct transformation. Transformation refers to the transformation procedure, and reverse refers to restoration.

When transmitting visual information over a communication channel, there are many factors that create interference. Therefore, it is worth considering possible options for increasing noise immunity, increasing transmission speed and maintaining frame quality. For this purpose, the image uses various destructive influences (adding noise, interference, frequency, filtering, impact, etc.) in streaming data exchange channels.

The original image (P) is created in the communication channel and is represented as a two-dimensional array. Then the image fragments (X) are processed by multiplying by the transformation matrix (M) and by it, only transposed (M^T) on the other side. Various destructive influences of different sizes and quantities can occur on the communication channel. A two-way transformation occurs, as a result of which the matrix fragments are mixed and the frame becomes transformed (Y), and after passing through the communication channel, the transmitted information can be transformed (Y+Z). The process of frame restoration (P') occurs through an inverse transformation, where the converted and transmitted frame (Y+Z) with the presence of a destructive effect is multiplied by the inverse matrix (M) and its transpose (MT). The frame at the receiving end becomes restored and corresponds to the original one, without application or destructive influences. That is, a matrix transformation that almost completely eliminates the destructive influences that constantly occur in the communication channel.

With the help of two-way conversion on the transmitting side and restoration on the receiving side, these destructive influences are distributed throughout the entire frame of the stream. This leads to the almost complete elimination of the destructive effect due to its distribution over the entire surface of the frame [14-15].

If the destructive effect is located at the junction of frame segments and matrices of the appropriate size that carry out the transformation, then it is more likely to remain and will not be able to be evenly distributed over the entire surface of the frame, so the size of the matrix should be taken into account when implementing these operations. Also, the quality of the reconstructed frames depends on the size of the destructive transformation itself and the transformation matrix, which is involved in the direct two-way transformation and restoration of the stream frames, so these factors should also be taken into account together [16-17].

Thus, the process of converting and restoring radar frame streams is implemented in real time, displaying the number of each frame, its resolution, the type and dimension of the included matrices, metric estimates of the quality, quantity and size of destructive impacts.

VI. Conclusion

This paper describes the principles and features of the implementation of a streaming data exchange system in a spatially distributed system of small-sized airborne radar stations. The issues of presentation, formation and transformation of streaming information transmitted on the network were considered. Options for architectures for constructing a streaming data exchange system are considered.

The feasibility of using a distributed scheme is the most promising and provides reflection from the points of view of practical application for solving problems of implementing a data processing system in spatially distributed systems.

The features of matrix transformation and restoration of flow frames are considered for the purpose of its noise immunity in channels of intensive exchange between small flying vehicles.

Thus, by summarizing these results, it is possible to develop practical recommendations for the implementation of hardware consisting of an interacting group of small flying children, and thus enable the transmission and complex processing of streams of radar frames.

VII. Acknowledgments

The reported study was funded by a grant of Russian Science Foundation (project № 22-79-00303).

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