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# APPROACH TO THE ORGANIZATION OF JOINT INTEROPERABILITY RADIO NETWORKS BUILT USING DMR VHF RADIO STATIONS OF DIFFERENT FREQUENCY BANDS

*The article examines the essence of problematic issues regarding the compatibility of standard digital radio communication equipment with the use of trunking communication equipment "Mototrbo" manufactured by "Motorola Solutions" of the DMR standard when organizing joint radio networks of interaction between units of different power structures within one military formation.*

*For example, the units of the National Guard of Ukraine (hereinafter - NGU) are predominantly armed with radio equipment operating in the UHF frequency range, while the units of the Armed Forces of Ukraine (hereinafter - AF of Ukraine) use radio equipment of the same type, but in the VHF range. Accordingly, the radio equipment cannot be considered compatible in terms of such a technical indicator as the range of operating radio frequencies, which creates problems when trying to unite the specified units into a single information space.*

*Ways to solve them are revealed and an alternative approach to solving the problem is proposed for consideration, namely: the use of a radio gateway, which is built on two radio stations manufactured by Motorola Solutions of different ranges. In this case, the radio stations are connected to each other in an appropriate way through an accessory port on the radio station housing. Each of the radio stations is programmed with a configuration file of the corresponding unit with channels at the frequencies of its range and keys to the confidentiality parameters. Voice information is relayed between the radio networks of two interacting units via a radio gateway automatically, by group method.*

*The authors believe that providing the Defense Forces of Ukraine with radio gateways (with the appropriate equipment) as standard means of radio communication for the interaction of units can help in the operational solution of a wide range of communication tasks.*

***Keywords:*** *state security; weapons and military equipment; control systems; communication facilities; single infocommunication space; radio communication systems; radio communication facilities compatibility.*

**Statement of the problem.** In response to the armed aggression of the Russian Federation against Ukraine and in order to restore the state's territorial integrity, various components of Ukraine's Defense Forces have been mobilized. These include the Armed Forces of Ukraine (AFU), the National Guard of Ukraine (NGU), the State Border Guard Service (SBGSU), the Security Service of Ukraine (SSU), the National Police of Ukraine (NPU), the State Emergency Service of Ukraine (SESU), the Main Directorate of Intelligence of the Ministry of Defense of Ukraine (HUR MO), the Foreign Intelligence Service of Ukraine (FISU), as well as volunteer formations of territorial communities.

During joint combat operations involving units subordinated to different government agencies, difficulties often arise in ensuring effective information exchange and coordinated actions. The core issue lies in the use of incompatible communication equipment operating on different frequency bands or utilizing different data transmission protocols. As a result, it becomes impossible to quickly establish secure and stable communication between units, which, in turn, reduces the overall responsiveness of command and control.

All components of Ukraine's security and defense sector rely on radio communications in their operational activities. Radio communication plays a critical role in enabling command and control in complex combat environments, especially when commanders (or headquarters) and their subordinate units are on the move. Given the use of maneuver warfare tactics by Ukraine's Defense Forces, radio communication is considered the primary – and in many cases, the only – means of control at the tactical level.

Moreover, successful combat operations require the use of a unified information space composed of interoperable systems capable of ensuring secure information exchange.

At the stages of planning and organizing radio communications for interaction between units of different branches of the Defense Forces of Ukraine, compatibility issues often arise when attempting to integrate standard-issue radio equipment into shared radio networks. This is primarily due to the different operating frequency ranges of "Mototrbo" trunked communication equipment, manufactured by Motorola Solutions and based on the DMR standard, which are used by different security and defense agencies in Ukraine. For instance, NGU units are predominantly equipped with radios operating in the UHF frequency band, while AFU units typically use similar equipment but in the VHF frequency range. Consequently, these radio devices are incompatible with respect to such a technical parameter as operating frequency range — that is, the frequency band within which the radio station functions. As a result, the integration of such units into a single information space becomes problematic.

The use of radio systems operating in different frequency bands across Ukraine's Defense Forces can be attributed to a combination of historical, technical, functional, and security-related factors.

Typically, interoperability between units equipped with incompatible radio communication devices is addressed by providing the subordinate unit's commander with one (or occasionally several) radios from the senior command's reserve. Alternatively, if the subordinate unit possesses individual radios compatible with the senior command's frequency range, the issue is resolved by supplying appropriate configuration files for programming the devices. Neighboring units (to the left, right, or rear) often establish interoperability through the exchange of individual radios with pre-programmed channels and confidentiality keys between commanders or headquarters. We refer to this approach as the radio exchange method.

However, this method does not allow for direct information exchange between users of two separate radio networks without the participation of commanders. In other words, the speed of communication between units is limited by the commanders' ability to verbally relay information from one network to another.

Thus, the process of integrating units equipped with radios operating in different frequency bands into a unified information space of Ukraine's Defense Forces requires greater attention and the development of more effective solutions.

**Analysis of recent scientific research and publications.** The shared use of information within a unified information space provides commanders and headquarters at all levels with significant advantages during the planning and conduct of operations (combat actions). It enhances situational awareness, command and control of troops (forces) and weaponry. Such an approach enables the Defense Forces of Ukraine to leverage the benefits of adopting and implementing information technologies.

The effective conduct of operations by the Defense Forces of Ukraine depends on the interoperability of communication and information systems, allowing commanders at all levels to exercise efficient control

over the deployed troops (forces). The levels of standardization, in ascending order, include: compatibility, interchangeability, and commonality.

The procedure for organizing interaction among the components of Ukraine's Security and Defense Sector via radio communication means is governed by the relevant instructions issued by the senior commander [1].

The primary goal of developing the communication system of the Defense Forces of Ukraine is to create a unified information and telecommunications environment based on the implementation of modern information and telecommunication technologies, information exchange protocols, complexes, systems, and special-purpose communication means. This will enable the exchange of all types of information between management bodies and control points (at all levels) with appropriate bandwidth, reliability, and trustworthiness [2].

The main tasks of communication are:

– ensuring timely reception and transmission of combat command signals;

– ensuring information exchange with higher headquarters and subordinate units under any operational conditions;

– ensuring timely reception and transmission of warning signals about the immediate threat of enemy use of weapons of mass destruction, alerts about aerial threats, radioactive, chemical, and biological contamination;

– ensuring information exchange between cooperating units;

– transmitting orders and receiving reports related to the support of combat operations of the troops.

To successfully accomplish the aforementioned tasks, tactical-level communication must meet a range of requirements, the most critical of which are timeliness, reliability, and security of all types of information transmission. Timeliness, in particular, is defined by the time required to establish communication and the speed of information exchange \[3]. VHF radio networks of modern radio devices are organized according to the operating modes supported by these radios \[4].

However, fundamental guiding documents regulating combat organization and communication do not contain information on methods for integrating frequency-incompatible radio communication systems into common radio networks (or a unified information space) [5, 6].

Domestic scientific literature highlights basic principles for improving the communication system of the Defense Forces of Ukraine and creating a unified information and telecommunication environment, including analyses of such systems' capabilities [7–9]. Additionally, methods to enhance the efficiency and responsiveness of information exchange, based on NATO countries' experience, have been proposed for implementation in National Guard units [10]. Nonetheless, solutions addressing communication equipment interoperability are not considered.

Current open-access NATO sources [11–14], which regulate the organization of communication among units during combat, focus solely on planning interaction by using standard systems that are assumed, by default, to be technically interoperable. Constraints related to shortages in available communication equipment are neither addressed nor considered, implicitly assumed to be sufficient.

It can be concluded that existing guiding documents and scientific achievements lack a unified approach for planning and organizing radio communication interoperability between units of various components of the Defense Forces of Ukraine and for resolving the compatibility issues of standard radio communication equipment when attempting to integrate them into a common radio network.

Based on practical experience, the essence of these issues lies in the fact that the use of Motorola Solutions' "Mototrbo" trunked communication equipment by the Defense Forces of Ukraine is a temporary, widespread, rapid, and relatively inexpensive method of transitioning to modern digital communication means. A primary drawback of this equipment is its operation only on fixed frequencies within a relatively narrow frequency band, resulting in low resistance to reconnaissance and electronic warfare (EW) countermeasures. In other words, it is incapable of effectively countering the adverse effects of enemy signals intelligence and electronic warfare.

Currently, the Defense Forces of Ukraine are gradually transitioning to modern communication standards, particularly NATO STANAG. Key roles in this process are attributed to military communication systems such as those produced by Harris, Aselsan, and Elbit. Efforts are underway to establish unified interoperability standards, conduct joint exercises, develop standardized command and communication procedures, and create a shared information space for the exchange of intelligence and tactical data.

**The purpose of the article** is to justify and implement an approach to the organization of joint interaction radio networks, constructed using DMR-standard VHF radios of different frequency bands, with the aim of improving the efficiency of information exchange processes between units of various components of the Defense Forces of Ukraine.

**Presentation of the Main Material.** An alternative approach to solving the above-mentioned problem is the use of a "radio gateway", built using two Motorola Solutions radios operating in different frequency bands, such as the DM4600 (DM4601) models. These radios are interconnected via their accessory ports located on the radio housings. Each radio is programmed with the configuration file of its respective unit, including channels within its operational frequency range and associated privacy parameters.

Voice information is relayed between the radio networks of the two interacting units automatically via the radio gateway, using a group communication method.

As a result, the efficiency of information exchange between units is enhanced due to the capability of simultaneous circular notification of correspondents operating both within the same frequency band and those in the joint interaction network. Furthermore, each correspondent can selectively communicate with any other within the shared radio network, in the presence of all participants.

Using a radio gateway enables units to perform the following communication tasks:

1. Ensuring communication for coordination on local radio channels (including networks for mutual unit interaction), based on the scheme: "VHF radios – radio gateway – UHF radios", enabling interaction between adjacent units (see Fig. 1).

2. Ensuring command and control (or circular alerting regarding various threats) of subordinate units (including attached forces) operating within the coverage area of the radio communication system deployed in the area of responsibility of a given force grouping, following the scheme: "main VHF radio – VHF repeater network – radio gateway – UHF radios".

This scheme also enables the organization of functional interaction radio networks by branches of the armed forces. For example, it becomes feasible to establish a dedicated interaction network for tank units. Similarly, radio networks may be organized for reconnaissance units, engineering troops, artillery, air defense forces, and others (see Fig. 2).

3. Integration of radio users located within the coverage areas of two repeaters operating in different frequency bands into a unified interaction radio network, according to the scheme: "VHF radios – VHF repeater network – radio gateway – UHF repeater network – UHF radios" (see Fig. 3).

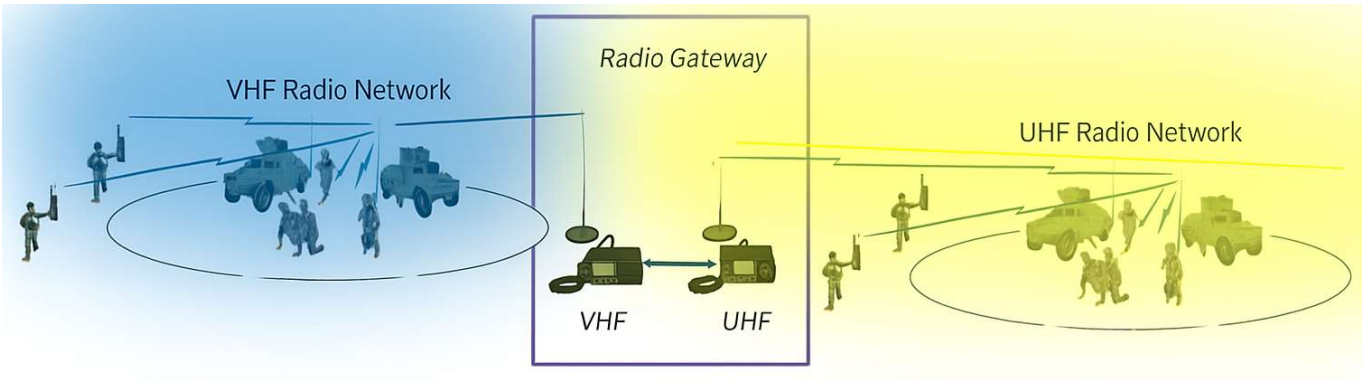


Figure 1. Ensuring interaction communication over local radio channels using the scheme: "VHF radios – radio gateway – UHF radios" between adjacent units.Source: developed by the authors.

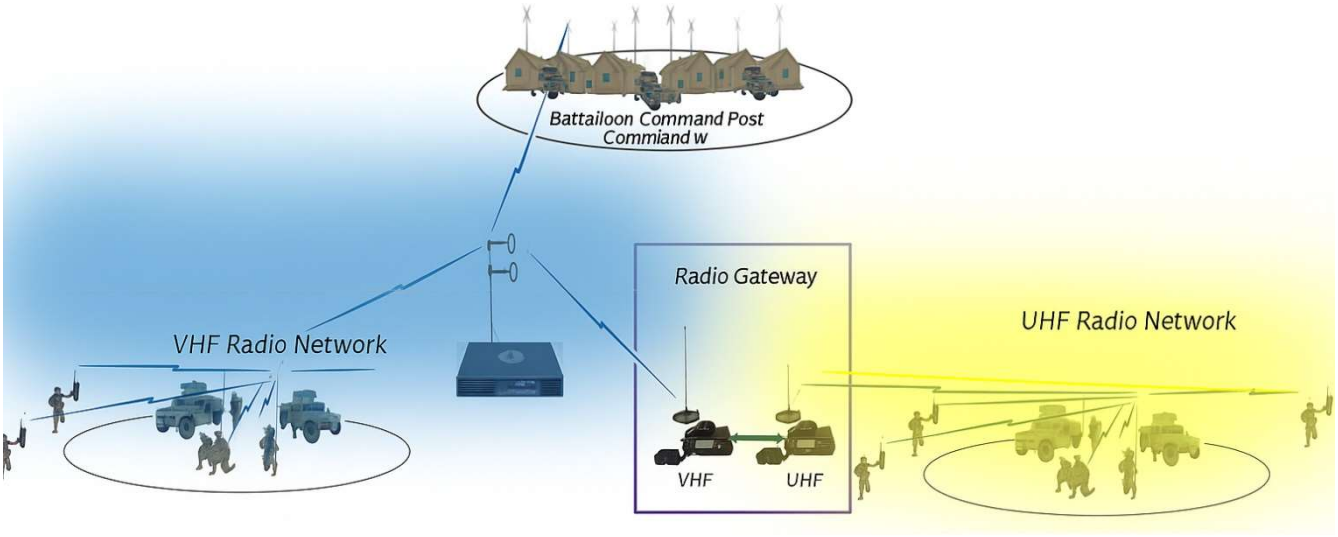


Figure 2. Branch-specific interaction radio networks using the scheme:
"Main VHF radio – VHF repeater network – radio gateway – UHF radios"

*Source: developed by the authors*

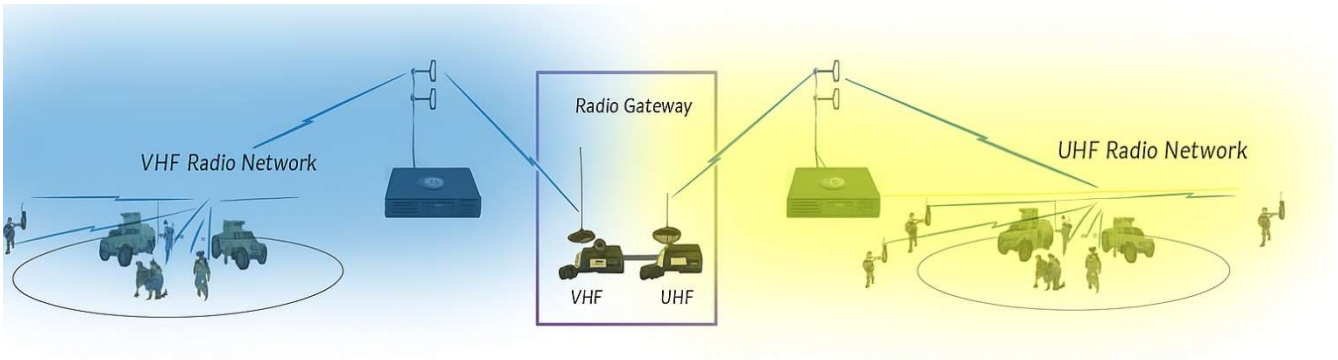


Figure 3. Integration of users within the coverage areas of two repeaters operating in different frequency bands into a joint interaction radio network using the scheme:
"VHF radios – VHF repeater network – radio gateway – UHF repeater network – UHF radio"

*Source: developed by the authors*

4. Flexibility in the use of existing repeater networks of different frequency bands by units operating within the area of responsibility of a force grouping, within the coverage area of these networks (following the scheme: "main VHF radio – radio gateway – VHF repeater network – UHF radios") (Fig. 4).

5. Extension of VHF radio communication coverage for units operating outside the effective range of existing network repeaters by establishing automatic relay points at the edge of the coverage zone. These points utilize a radio gateway installed on a mobile platform, additionally equipped with antenna-mast systems (including directional antennas) and autonomous power supply units (following the scheme: "main radio – repeater network – radio gateway – unit's local radio network"). The radio gateway may employ radios operating in either different or identical frequency bands. (Fig. 5).

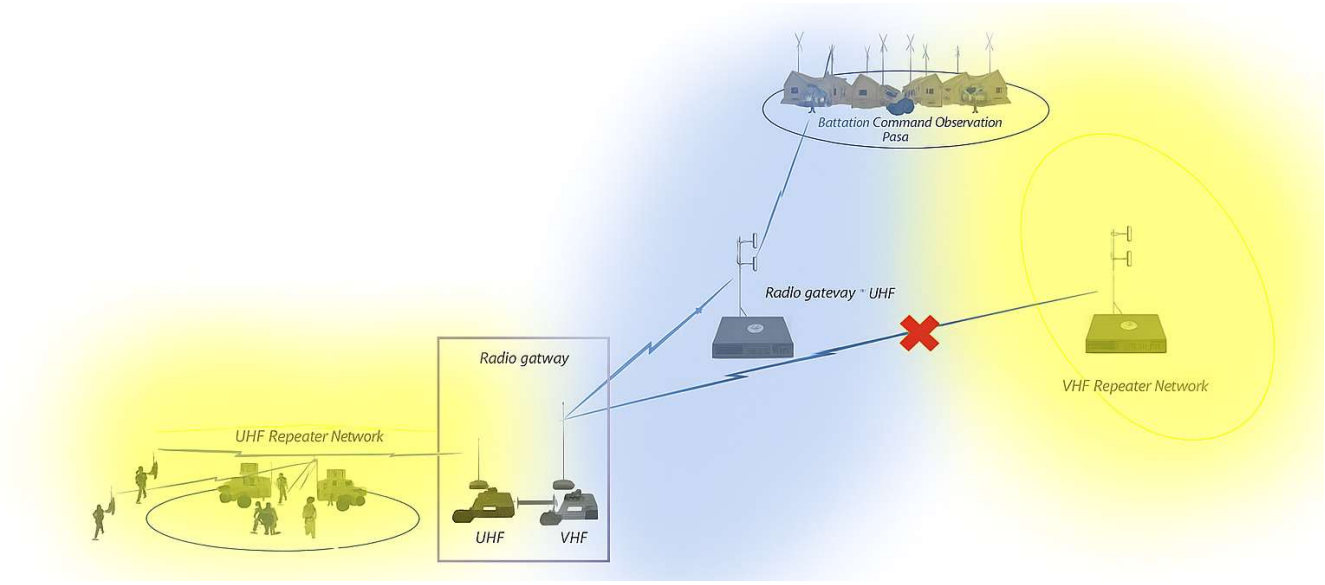


Figure 4. Flexibility in the use of active repeaters of different frequency bands by units deployed within the area of responsibility of a force grouping, following the scheme:
"VHF radios – VHF repeater network – radio gateway – UHF repeater network – UHF radio"

*Source: developed by the authors*

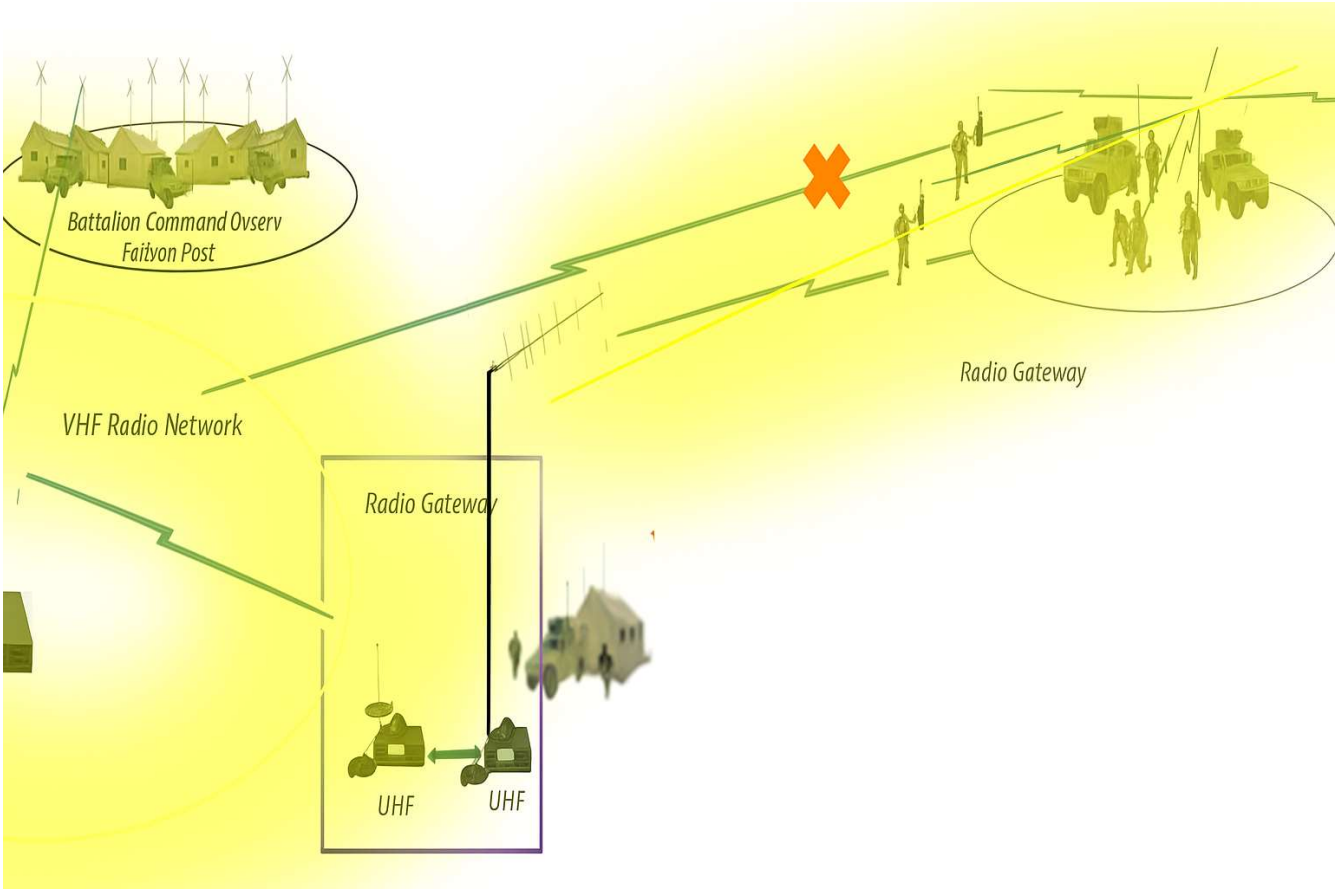


Figure 5. Extension of VHF radio communication coverage for units located outside the coverage area of existing repeaters by establishing automatic relay points at the edge of the coverage zone according to the scheme: "main radio station – repeater network – radio gateway – unit's local radio network on a local channel".

*Source: developed by the authors*

The majority of the aforementioned tasks can be addressed without using radio gateways, relying solely on standard repeaters operating across different frequency bands by integrating them into a common network via the IP-SITE CONNECT mode. However, this solution requires unified management of confidentiality parameters and timing (which may be lacking) to rework the configuration files of various units, ensuring their alignment to uniform security and privacy settings. Additionally, it is necessary to account for the time, resources, and personnel availability required for reprogramming all radio equipment.

The drawbacks of organizing interaction through a radio gateway include its inability to automatically relay short text messages and to establish voice connections between two radio stations in the “individual subscriber call” mode.

**Conclusions and Prospects for Further Research**. The method of employing a radio gateway is not new and was previously used solely as a means to unite correspondents of different repeaters into a common radio network to expand the radio coverage area. Subsequently, this method was abandoned in favor of the more efficient IP-SITE CONNECT mode, which requires mandatory departmental management of confidentiality parameters in radio station settings.

Therefore, the approach of using a radio gateway can be recommended to the command authorities of the National Guard units for organizing joint interaction radio networks built using VHF DMR standard radios operating across different frequency bands, as it is more effective than the method of radio station exchange. This will help solve the problem of communication equipment compatibility during the execution of primary communication tasks.

Prospects for further research include analyzing the optimal composition of components for a universal radio gateway as a standard interaction tool for units and developing guidelines for its use.

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