# БОЙОВЕ ЗАСТОСУВАННЯ ОВТ

# COMBAT EMPLOYMENT OF WEAPONS AND MILITARY EQUIPMENT

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## THE METHOD AND MEANS OF INSTALLING RADAR MEASURING DEVICES ON ARTILLERY SYSTEMS FOR THE PARAMETERS OF AMMUNITION MOTION

*During combat operations, striking the enemy at maximum range with artillery systems plays a key role. The effectiveness of such strikes depends significantly on the quality of comprehensive firing preparations and its component part—ballistic firing preparations The accuracy of ballistic firing preparations significantly depends on the technical parameters of the radar measuring device for artillery ammunition movement parameters and the methods of its application. Such measuring devices are usually installed next to the gun, which increases the time required for their deployment and leads to significant errors in measuring the current flight speed of the projectile. We have demonstrated that the highest accuracy of the measuring device is achieved when it is installed directly on the guns of artillery systems. Such installation requires the development of standardized mounting devices and the use of special shock absorbers to reduce the negative impact of external mechanical influences on the operation of the radar measuring device. We have shown that when the measuring device is installed on guns, the main influences are shock and vibration loads transmitted to each element of the measuring device. The vibrations caused can be resonant in nature. Resonance causes particularly large deformations, which are accompanied by large mechanical loads and can lead to the destruction of both individual elements and the radar measuring device as a whole. It has been determined that the most universal and effective way to overcome the effects of shocks and vibrations is to isolate the measuring device from the gun using a system of shock absorbers that are structurally combined within a shock-absorbing platform. It is advisable to attach such a platform to the recoil devices of the guns. In order to minimize the number of structural elements of the fastening devices, an analysis was carried out of the possible locations for installing the measuring device on the most common artillery systems in service with the artillery units of the Ground Forces of the Armed Forces of Ukraine. The following towed and self-propelled guns were selected for the study: D20, D30, 2S1, 2S3.*

***Keywords:*** *ballistic preparation of fire, radar device for measuring parameters of artillery ammunition movement, shock-absorbing platform, fastening devices.*

### Statement of the problem

Significant changes in the nature of combat operations require changes in the tactics of artillery units. With each new military conflict, the dispersion of military formations increases and the relevance of the autonomous use of individual artillery units to destroy enemy manpower and equipment grows. The introduction of automated fire control systems, the increasing intellectualization of automated guidance and fire control systems [1], and the optimization of software for automated workstations of battery-division-brigade officials in the management of artillery units' firepower ensure increased maneuverability of artillery units, allowing them to quickly complete fire missions, leave their firing positions in a timely manner, and avoid enemy artillery counterattacks.

When firing from closed firing positions, the most effective method of fire damage to the enemy is the method of complete preparation for firing. When firing at long ranges, the effectiveness of the method mainly depends on the quality of meteorological and ballistic preparation measures. The main task of ballistic preparation of fire (BPF) is to determine the total deviation of the initial velocity of ammunition from the tabulated values.

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## Analysis of recent studies and publications

Despite the fact that various methods and means of measuring projectile velocity are currently known, radar artillery ballistic stations (ABS) have been used since the 1970s to measure the initial velocity of projectiles [2].

The development of ABS in advanced countries is taking place under several programs. For example, the program to modernize the British AS90 Braveheart 155 mm self-propelled howitzer involves equipping it with an ABS integrated into the LINAPS (Laser Inertial Automatic Pointing System) by the British company Baye Systems [3].

Russia has developed a unified automated ABS (UAABS) called "Rampa," which provides ballistic firing preparation and performs tasks related to determining the initial velocity of projectiles (mines) with a rate of fire of up to 20 rounds per minute. The caliber of projectiles (mines) ranges from 20 mm to 240 mm, with an initial velocity of 100 m/s to 2000 m/s. The UAABS can be located both on firing systems and on a tripod near these systems. In terms of its characteristics, the UABS is on par with the best global models in this class, and even surpasses them in terms of functionality (it calculates the total deviation of the actual initial velocity of shells from its tabulated value, as well as the correction in the aiming) [4].

The artillery units of the Ground Forces of the Ukrainian Armed Forces (UAF) are equipped with the ABS-1M, which was developed and adopted in the 1970s. It has an extremely low level of automation and is obsolete because it does not have a digital communication interface with the automated control system [5].

Among domestic developers of artillery ammunition velocity measuring devices, it is worth noting the experimental models developed at the Lviv Scientific Research Radio Engineering Institute [6] and the holding company Ukrspetstechnika [7]. However, these companies did not proceed to serial production and delivery of ABS to the military.

Among foreign manufacturers whose products have been adopted by the artillery units of the Armed Forces of Ukraine it is worth noting the ABS SL-520PE from the Danish company Weibel [8].

Other means of measuring the velocity of ammunition are analyzed in [9].

All ABS systems are based on a radar motion parameter measuring device (RMPMD) for shells and mines in certain areas of movement. The effectiveness of the RMPMD depends on how it is installed relative to the line of fire, how the current velocity of the projectile (mine) is measured, and how these measured values are converted to the muzzle diameter of the artillery gun barrel. Almost all of the listed ABS are located next to the gun, which causes errors in speed estimation when the measuring base is placed at a short distance from the muzzle of the artillery gun barrel.

Thus, with regard to BPF, there is a discrepancy between existing scientific and methodological approaches to optimizing the structure of RMPMD for artillery ammunition and the lack of technical justification for the method of its installation relative to the gun for high-precision measurement of the initial velocity of ammunition.

**The purpose of the article** is to justify the feasibility of installing the RMPMDs directly on artillery guns, standardizing the means of their attachment to the existing fleet of artillery systems, and minimizing the impact of external mechanical factors (EMF) on its operation.

## Presentation of the main material

The initial velocity of the projectile can be determined according to the expression

$$V_0 = \Delta V(D) + V_{cep}$$

$$V_{cep} = \frac{L}{t_v} = \frac{(D_2 - D_1)}{t_v} \qquad (1)$$

where $V_0$ is the initial velocity of the projectile; $D_1$, $D_2$ are the distances from the muzzle to the beginning and end of the measuring base; Vave is the average velocity of the projectile within the measuring base of length $L$; *ΔV(D)=104id2x/2mΔD(V)* is the decrease in the velocity of the ammunition when it flies a distance $D$ from the muzzle of the gun to the middle of the measuring base; i – projectile shape coefficient; d – ammunition caliber; m – ammunition mass; *mΔD(V)* – function of range dependence on projectile velocity, whose value for the Siatchi law [10].

From expression (1), it can be seen that the highest accuracy of the $V_0$ estimate occurs at minimum distances from the muzzle of the barrel, namely at a measuring base located at a distance of up to 25 m from the muzzle of the barrel.

In accordance with the Rules of Shooting and Fire Control, the standard ABS, which is based on the RMPMD, is located at a distance of 6 m on the line of the gun trunnions (Fig. 1) [11].

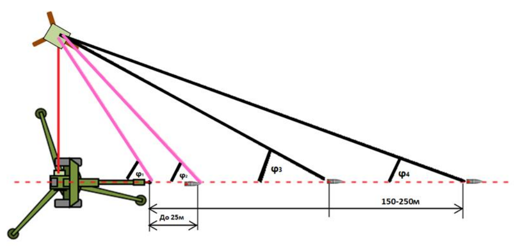



*Fig. 1.* **Standard installation of RMPMD**

The Doppler frequency of the signal reflected from the projectile depends on its velocity and is determined by the formula [12]:

$$F_d = \frac{2V}{\lambda} \times \cos\varphi_{1(2)} \qquad (2)$$

From Fig. 1 and formula (2), it can be seen that the uncertainty of angle $\varphi_{1(2)}$ when placing the measuring base in the muzzle area of the barrel leads to a corresponding uncertainty in the Doppler value of the reflected signal frequency and, accordingly, to an error in determining the initial velocity of the projectile. Therefore, to reduce this error, a method is proposed for installing the RMPMD on the gun and aligning the axis of the receiving-transmitting antenna's directional pattern with the line of fire. The essence of the method is schematically shown in Fig. 2.

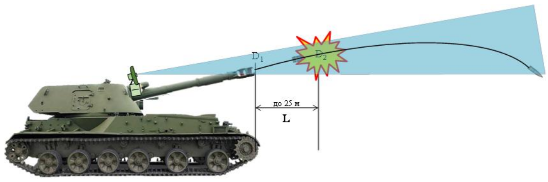



*Fig. 2.* **Schematic diagram of the installation of the RMPMD on a gun**

Fig. 2 shows that when the directional pattern of the RMPMD transceiver antennas is aligned with the line of fire, the observation angle φ=0 and the error in determining the initial velocity of the projectile, caused by its uncertainty, is absent.

This method of installing the RMPMD requires the development of means for attaching it to all types of guns in service with the artillery units of the Armed Forces of Ukraine, while minimizing the range of components and using means to minimize the impact of the EMF on the stability and strength of the RMPMD and the accuracy of its operation.

When installing RMPMD on guns, the main EMF are impact and vibration loads transmitted to each RMPMD element. The vibrations caused may be resonant in nature. Resonance causes particularly large deformations, which are accompanied by high mechanical loads and can lead to the destruction of the element and the RMPMD as a whole.

Impact and vibration resistance can be increased by creating and applying special means of isolating RMPMD elements from external mechanical factors that arise at the points of their installation on artillery systems.

The most universal and effective way to combat the effects of shocks and vibrations is to isolate the RPR from the EMF using a system of shock absorbers that are structurally combined within the shock absorption platform (SAP). This method of protection has general methodological recommendations for its implementation [13-17]. However, the practice of designing absorption platforms necessitates their maximum unification to ensure the effectiveness / cost criterion requirements are met.

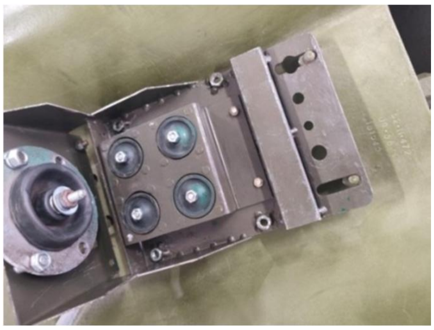
The practical implementation of the scheme for installing RMPMD on guns is related to the design of recoil devices (RD) for towed and self-propelled guns and requires an individual approach in each case.

In order to minimize the number of structural elements of the mounting devices, an analysis was conducted of the possible installation locations for the RMPMD on the most common artillery systems in service with the artillery units of the Ukrainian Armed Forces. The following towed and self-propelled guns were selected for the study: D20, D30, 2S1, 2S3.

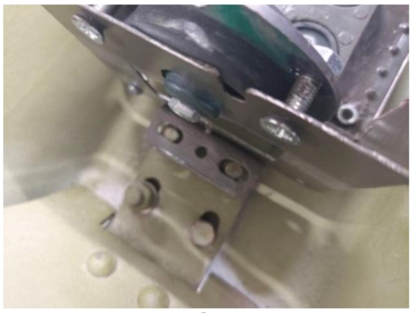
Based on the results of the analysis of possible installation locations on the selected guns, a SAP mounting bracket, which is installed on the recoil device RD casing of the D20 towed gun was selected as the base structure. The casing mounting is shown in Fig. 3.

*Fig. 3.* **Casing mounting on the recoil device casing of the D20 gun**

The mounting bracket of SAP for installation with screws for the fastening of the cover of the D20 towed gun recoil device is shown in Fig. 4. A special feature of the SAP is that the axis of the most powerful shock absorber is located parallel to the longitudinal axis of the gun barrel, along which the greatest shock loads act.



*a*



*b*

*Fig. 4.* **Bracket from shock absorption platform (SAP) for installation with mounting bolts of the fastening of the D20 towed gun recoil device:**

*a* – mounting with front bolts,
*b* – mounting with rear bolts

A mounting bracket has been developed to mount the RMPMD on the D30 trailer gun, which complements the one discussed above. The external appearance of this bracket is shown in Fig. 5a, and its integration with the bracket for the D20 gun is shown in Fig. 5b. The mounting of the SAP on the D30 gun is shown in Fig. 5c, and the RMPMD mounted on the gun is shown in Fig. 5d.

A bracket has been developed for mounting the SAP with RMPMD on self-propelled guns 2S1 and 2S3, as shown in Fig. 6. Its distinctive feature is the coupling of the SAP mounting locations with the corresponding design features of the bracket for the D20 towed gun.

*a*

*b*

*c*

*d*

*Fig. 5.* **Installation of the RMPMD on the D30 gun**

*Fig. 6.* **Bracket for mounting RMPMD with SAP on self-propelled guns 2S1, 2S3**

The alignment of the bracket for self-propelled guns 2S1 and 2S3 with the bracket for the D20 towed gun is shown in Fig. 7.

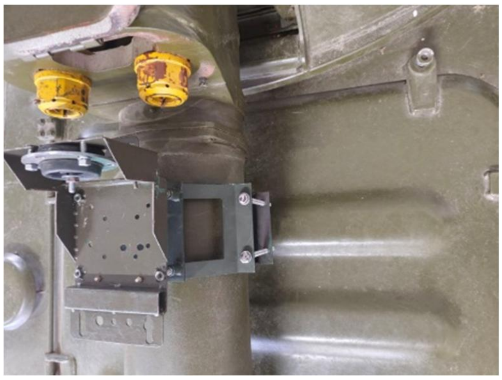


*Fig. 7.* **Alignment of brackets for self-propelled guns 2S1, 2S3 with a bracket for a towed gun D20**

The installation of the RMPMD on the RD of the 2S1 and 2S3 self-propelled guns is shown in Fig. 8.

*a*

*b*

*Fig. 8.* **Installation of RMPMD on self-propelled guns:** *a* – 2S1, *b* – 2S3

## Conclusions

1. We have substantiated the method for installing a radar motion parameter measuring device (RMPMD) on artillery guns.

2. Within the framework of a unified methodological approach, we have considered the design features of the unification of means for installing RMPMD artillery ammunition on D20 and D30 towed guns and 2S1 and 2S3 self-propelled guns, which, thanks to inter-system unification, have a minimum of unique components.

3. A shock absorption platform (SAP) has been developed for installing RMPMD on D20 and D30 towed guns and 2S1 and 2S3 self-propelled guns.

4. Further research involves the development of a software hardware complex for studying shock and vibration loads at the installation sites of the RMPMD on artillery guns and conducting experimental studies to assess the numerical characteristics of these loads before and after AP in order to optimize it and ensure the shock and vibration resistance and strength of the RMPMD when installed on artillery systems.

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## МЕТОД І ЗАСОБИ ВСТАНОВЛЕННЯ РАДІОЛОКАЦІЙНИХ ВИМІРЮВАЧІВ ПАРАМЕТРІВ РУХУ БОЄПРИПАСІВ НА ГАРМАТАХ АРТИЛЕРІЙСЬКИХ СИСТЕМ

А.О. Дзюба, Ю.І. Бударецький

*Під час ведення бойових дій ключову роль відіграє вогневе ураження противника на максимальних дуальностях засобами артилерійських систем. Ефективність такого ураження суттєво залежить від якості повної підготовки стрільби і її складової – балістичної підготовки стрільби. Точність балістичної підготовки стрільби суттєво залежить від технічних параметрів радіолокаційного вимірювача параметрів руху боєприпасів артилерійських систем і методів його застосування. Найбільша точність такого вимірювача досягається при його встановленні безпосередньо на гарматах артилерійських систем.*

***Ключові слова:*** *балістична підготовка стрільби, радіолокаційний вимірювач параметрів руху артилерійських боєприпасів, амортизаційна платформа, засоби кріплення.*