PROBLEMY MECHATRONIKI
UZBROJENIE, LOTNICTWO, INŻYNIERIA BEZPIECZEŃSTWA

ISSN 2081-5891

12, 2 (44), 2021, 55-62

PROBLEMS OF MECHATRONICS
ARMAMENT, AVIATION, SAFETY ENGINEERING

Concept of Short-Range Radar and Counter-Projectile for Detecting and Countering Armour-Piercing Projectiles

Adam RUTKOWSKI[1], Adam KAWALEC[1*]
Józef JARZEMSKI[2]

[1]Military University of Technology,
2 Sylwestra Kaliskiego Str., 00-908 Warsaw, Poland
[2]Military Institute of Armament Technology,
7 Prymasa St. Wyszyńskiego Str.,05-220 Zielonka, Poland
[*]Corresponding author's e-mail address and ORCID:
adam.kawalec@wat.edu.pl; https://orcid.org/0000-0003-3930-7504

Received by the editorial staff on 10 November 2020
The reviewed and verified version was received on 1 June 2021

DOI 10.5604/01.3001.0014.9337

Abstract. During warfare and acts of terrorism an extreme threat to vehicles and other high-value assets comes from armour-piercing projectiles. Under these conditions, defence systems should include devices capable of rapid detection of these threats. Defence assets should also be provided with counter-projectile systems capable of destroying incoming armour-piercing projectiles at a safe distance from the asset to be protected. This paper describes the concept of a system comprising of a lightweight short-range radar and a counter-projectile for countering armour-piercing projectiles. The purpose of the radar is to monitor the environment and search for incoming armour-piercing projectiles. When an armour-piercing projectile is detected in a designated monitoring area, an automatic command is given for the counter-projectile launcher to be fired.

The counter-projectile deployed can be equipped with a single or multi-sensor detection head unit and an explosive payload module, both being the primary components of the warhead. When the signal analysis blocks interfaced with the detection head determine that the armour-piercing projectile to be struck down is in the target position in relation to the counter-projectile deployed, they automatically command the explosive payload module to detonate. The components of the system concept were tested in proving ground conditions. The successful results of these tests confirmed the validity of the solutions initially adopted and the execution of the individual systems.
Keywords: electronics, armour-piercing projectile, counter-projectile, radar

1. INTRODUCTION

Various types of armour are used to protect vehicles and other assets from armour-piercing armament. The different versions of armour are characterised by their different structures and the variety of materials used. This in turn affects the effectiveness of specific armour type versions. Another means of defence against armour-piercing projectiles is anti-projectile systems [1]. An advanced version of counter-projectiles are the so-called "smart" counter-projectiles used to counter armour-piercing projectiles which feature sensors and rapid analysis systems to enable selection of the optimum conditions for neutralisation of the threat to be countered (which is an armour-piercing missile). By design, a counter-projectile should attempt to neutralise an armour-piercing projectile at a safe distance from the asset it is to protect. The small dimensions of an armour-piercing projectile mean that its effective RCS (*Radar Cross Section*) is relatively small [2, 3]. This in turn affects the potential detection and range of detection by the radar of the active defence system [4] and by the microwave sensor [5] that may be installed in the counter-projectile. The shape and dimensions of the armour-piercing projectile also determine the choice of method used to neutralise it. In turn, the flight velocity of an armour-piercing projectile, especially at the stage of approach to the target, affects the time required for the signal analysis blocks and the payload, which the counter-projectile should feature, to act effectively.

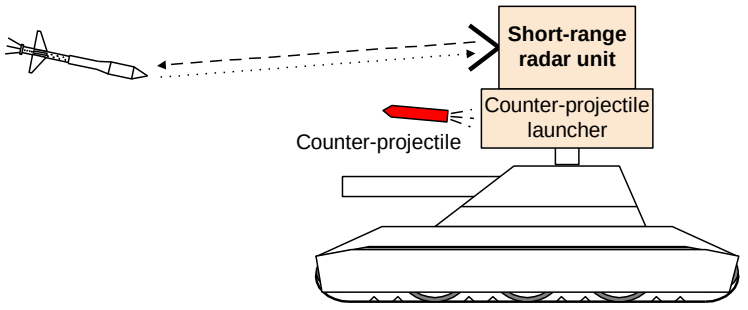

Fig. 1.1. Image of the short-range radar and counter-projectile launcher in vehicle defence system

Fig. 1.1 shows a vehicle defence system countering armour-piercing projectiles, comprising a short-range radar (SRR) and a counter-projectile deployed from a miniature launcher.

During a combat mission, the onboard radar monitors the environment around the vehicle. When an object is detected, the radar checks whether it is an armour-piercing projectile underway to strike the protected asset. If the identification is positive, the radar switches to tracking of the object. When the armour-piercing projectile approaches the protected asset at a distance deemed to be a threat, the counter-projectile is launched towards it. Once launched, the counter-projectile strikes the armour-piercing projectile by a direct hit or by fragmentation and blast wave from the detonated explosive payload module of the counter-projectile.

2. THE CONCEPT OF THE COUNTER-PROJECTILE

The counter-projectile launched from the defence system should counter the incoming armour-piercing projectile and, at the same time, it should pose a minimum threat to the protected asset (a vehicle, for example) and the friendly infantry or high-value infrastructure in the vicinity of the protected asset. In order to meet these expectations, the counter-projectile should affect the incoming armour-piercing projectile (by detonation of the explosive payload of the counter-projectile) at a sufficiently close distance to the armour-piercing projectile for it to be struck down at the greatest possible distance from the protected asset and the friendly forces or high-value infrastructure. In addition, the striking range of the counter-projectile warhead should be as short as possible while remaining highly effective in destroying threats in the immediate vicinity of the counter-projectile. These conditions impose two primary requirements to be met:

- An incoming armour-piercing projectile must be detected as soon as possible, which means it being at a distance where it is possible to estimate its basic parameters and to make a credible hypothesis that the counter-projectile's target is a threat located in the detection sector of the defence system;
- The counter-projectile launched towards an attacking armour-piercing projectile should be characterised by intelligence, understood as the capability to automatically detonate the explosive payload module only if the object detected in the vicinity of the counter-projectile is identified as a threat to the protected asset - i.e. being an armour-piercing projectile moving directly towards the protected asset - and the destruction of the threat by detonation of the payload should only occur at a moment when the armour-piercing missile can be struck down effectively with a method preselected by automatic controls or the defence system operator.

Figure 2.1 shows a diagram of the concept of an unguided counter-projectile, with a warhead which is equipped with multi-sensor detection systems to enable independent detection of armour-piercing projectiles thereby discerning them as such from among other objects the counter-projectile will be passing by in flight. The sensor channels of the warhead can use electromagnetic radiation in the microwave range, thermal radiation and acoustic signals for detection.

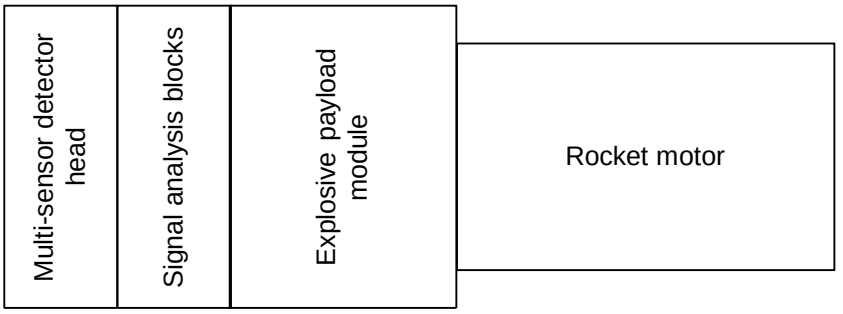

Fig. 2.1. Concept of the general counter-projectile structure

Based on information from the multi-sensor detection head, the signal analysis blocks formulate and output commands to detonate the explosive payload module at the moment when the armour-piercing projectile can be expected to be effectively neutralised. Effective neutralisation of an armour-piercing projectile is understood to mean:

- The extent of damage inflicted to the armour-piercing projectile or the change in the angle of its impact on the protected asset is sufficient enough that the armour-piercing projectile cannot penetrate the wall/armour of the asset;
- A deflection of the trajectory of the armour-piercing projectile by which the projectile misses the protected asset or hits the ground at a safe distance from the protected asset.

3. CONCEPT OF THE SHORT-RANGE RADAR FOR DETECTION OF THREATS AND LAUNCHING OF COUNTER-PROJECTILES

A general diagram of a short-range radar (SRR) concept for detection and countering armour-piercing projectiles is shown in Fig. 3.1.

The basic functional links of the radar version include: the antenna system, the microwave blocks, the low frequency blocks, the digital processing blocks, the counter-projectile launch control systems and the synchronisation systems. The whole unit is managed by a control computer with dedicated software.

The microwave channels output probing signals and receive the radar echos, followed by conversion of the echos into low-frequency analogue signals. The digital processing blocks convert the analogue signals into a digital form.

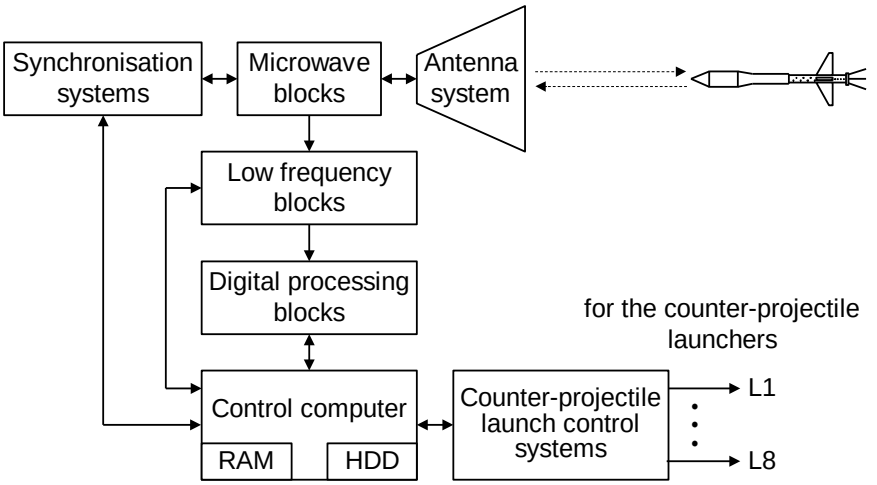

Fig. 3.1. Block diagram of the short-range radar concept for the counter-projectile defence system

The digital forms of the signals are used by the radar control computer to determine the current positions of incoming armour-piercing projectiles. When an armour-piercing projectile comes within a dangerous distance from the protected asset, the radar-controlled computer commands the launcher to deploy the counter-projectile. This command, via the launch control system, is sent to the counter-projectile launcher. In practical terms, the radar will be able to work with one or more (for example, 8) counter-projectile launchers. The results of radar environment monitoring and the commands output to launch the counter-projectile will be able to be recorded in RAM and permanently on a HDD.

4. EXPERIMENTAL RESULTS

The test versions of the component assemblies of the concept presented of the counter-projectile defence system were tested at a proving ground. A short-range radar unit was monitoring the environment. When a detected object had the characteristics matching an armour-piercing projectile and subsequently entered a zone deemed to be dangerous to the protected asset, the analysis procedures implemented in the radar-controlled computer solved and output the command to launch the counter-projectile. This command was relayed to the counter-projectile launcher via the launch control systems module.

As soon as the sensors of the counter-projectile in flight indicated that it was approaching the armour-piercing projectile, at a predetermined distance they commanded the explosive payload module to detonate.

Fig. 4.1. Automatically launched counter-projectile (see right) and the armour-piercing projectile (see left) in flight (on an intercept course)

The counter-projectile launched automatically by the short-range radar model and the armour-piercing projectile to be neutralised are shown approaching one another in Fig. 4.1.

5. CONCLUSION

The components discussed of the counter-projectile defence system were positively verified in real conditions of a proving ground. The results obtained indicated that there is a real capability of the domestic industry to build an automatic system for protection of assets against armour-piercing projectiles of various types, including armour-piercing sub-projectile penetrators. As the field tests of the basic components demonstrated, the short-range radar according to the concept presented had the ability to monitor the flight not only an armour-piercing projectile but also of the counter-projectile. It is therefore reasonable both to continue work on various types of counter-projectile and to work on a system in which the detonation of the counter-projectile payload would be effected in a command system, i.e. on a command sent from the radar, which had previously determined to launch the counter-projectile. These two solutions are not mutually exclusive and can effectively complement each other.

FUNDING

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

[1] Meyer J. Tom. 1988. „Active Protective Systems", *Armour*, May-June, 1998.

[2] Pizzillo J. Thomas. 2005. *RCS Measurements and High-Range Resolutions Profiles of Three RPGs at Ka-Band*. Army Research Laboratory, Adelphi, MD 20783-1145, ARL-TR-3511.

[3] Stratton R. Susan, Robert L. Bender. 2006. *Radar Cross-Section (RCS) Measurements of a Dismount with Rocket Propelled Grenade (RPG) Launcher at Ka-Band*. Army Research Laboratory, Aberden Proving Ground, MD 21005, ARL-TR-3855.

[4] "WindGuard Radar ELM-2133" http://www.iai.co.il/sip_storage/FILES/8/38048.pdf (11.07.2018r.)

[5] Stavis Gus, (Wayne, N.J.). 1986. *Sensor for Anti-Tank Projectile*. United States Patent, Patent No.: 4,614,317.

Koncepcja radaru bliskiego zasięgu oraz antypocisku do wykrywania i zwalczania pocisków przeciwpancernych

Adam RUTKOWSKI[1], Adam KAWALEC[1],
Józef JARZEMSKI[2]

[1]*Wojskowa Akademia Techniczna,*
ul. gen. Sylwestra Kaliskiego 2, 00-908 Warszawa,
[2]*Wojskowy Instytut Techniczny Uzbrojenia,*
ul. Prymasa Stefana Wyszyńskiego 7, 05-220 Zielonka

Streszczenie. W działaniach bojowych oraz podczas aktów terrorystycznych bardzo dużym zagrożeniem dla pojazdów i innych ważnych obiektów są ataki przy użyciu pocisków przeciwpancernych. W takich warunkach systemy obrony powinny dysponować, między innymi, urządzeniami zdolnymi do szybkiego wykrycia zbliżającego się zagrożenia. Systemy obrony powinny być wyposażone również w antypociski mogące zniszczyć nadlatujący pocisk przeciwpancerny w bezpiecznej odległości od chronionego obiektu. W pracy opisano koncepcję zestawu składającego się z lekkiego radaru bliskiego zasięgu oraz antypocisku do zwalczania pocisków przeciwpancernych. Zadaniem radaru jest obserwacja przestrzeni i poszukiwanie atakujących pocisków przeciwpancernych. Gdy wykryty pocisk przeciwpancerny znajdzie się w przewidzianej strefie wówczas automatycznie zostaje wydana komenda do odpalenia antypocisku. Wystrzelony antypocisk może być wyposażony, między innymi, w jedno- lub wielo-sensorową głowicę detekcyjną oraz moduł wybuchowy będące głównymi elementami głowicy bojowej. W chwili, gdy bloki analizy sygnałów współpracujące z głowicą detekcyjną stwierdzą, iż zwalczany pocisk przeciwpancerny znalazł się w zakładanym położeniu względem antypocisku, wówczas automatycznie wydają komendę do detonacji modułu wybuchowego. Elementy koncepcji zestawu zostały zbadane w warunkach poligonowych. Pomyślne wyniki tych badań potwierdziły poprawność wstępnie przyjętych rozwiązań oraz wykonania poszczególnych układów.
Słowa kluczowe: elektronika, pocisk przeciwpancerny, antypocisk, radar