Technical science and innovation

Volume 2022 | Issue 4 Article 4

12-31-2022

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Recommended Citation
Solonar, A S.; Khmarski, P A.; Mukhammedov, B M.; and Tuganov, G Sh (2022) "ANALYSIS OF METHODS OF CONSTRUCTION AND APPLICATION OF MODERN ANTI-RADAR MISSILES," *Technical science and innovation*: Vol. 2022: Iss. 4, Article 4.
DOI: https://doi.org/10.51346/tstu-01.22.4-77-0202
Available at: https://btstu.researchcommons.org/journal/vol2022/iss4/4

ANALYSIS OF METHODS OF CONSTRUCTION AND APPLICATION OF MODERN ANTI-RADAR MISSILES

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Abstract*: The analysis of methods of construction and application of modern anti-radar missiles (ARM) is carried out. The analysis allowed us to identify the most distinctive features of ARM such as: high flight speed (600-1200 m/s), limited launch range, different flight paths and it is oriented towards the attacked radar, small effective distribution surface (ESR), due to a sharp increase in the weight and size characteristics of the homing head of the homing head outside the frequency range (from 0.5 to 40 GHz), radio electronic means of the ARM are not created, the large range and high speed of tuning the operating frequency of the receiver of the homing head make it inefficient to use frequency jumps in electronic means, modern ARM has an autonomous inertial guidance system, corrected from the NAVSTAR (Navigation Satellites providing Time And Range) satellite radio navigation system via a GPS (Global positioning system) receiver which are physical prerequisites for their effective selection. The findings obtained during the analysis will be used in the development of a device for selecting an anti-radar missile aimed at a surveillance radar, as well as for taking effective measures to protect electronic equipment from them.*

Keywords*: Anti-radar missile, radar, ARM flight paths, effective reflection surface, radar homing head, inertial navigation system, tactical applications, Accuracy of fire.*

INTRODUCTION. Analysis of armed conflicts in Vietnam (1965-1973), Libya (1982), Iraq (1991, 1998, 2003), Yugoslavia (1999), Nagorno-Karabakh (2020), and other smaller conflicts [1-8] show that without the use of technical means and organizational measures of protection from high-precision weapons (HPW), the losses of the Air Force and air defense forces already in the first massive missile and aviation strike can amount to 25... 30%, and in the first two or three days of offensive operations - up to 90-95%. So, for example, in Iraq (1991, 1998, 2003), Yugoslavia (1999), anti-radar missiles in combination with electronic jamming (EJ) were widely used for fire destruction of air defense weapons (air defense). In this connection, the issue of protecting various military radars from ARM is relevant. Considering that one of the main methods of protecting the radar from ARM implies its temporary shutdown, which is not always possible during the reflection of an enemy air strike. This method of protection against ARM can be effective only in case of timely detection of a missile launched by radar, and for its implementation, first of all, there is a natural need for a detailed study of the combat capabilities and methods of using ARM. Therefore, the primary task is to analyze the method of constructing and using modern anti-radar missiles of foreign countries, which is what this article is devoted to.

The main part. Currently, there are anti-radar missiles with an inertial navigation system (INS), corrected from the NAVSTAR global satellite radio navigation system (SRNS) via a GPS receiver, which ensures high accuracy of pointing the ARM at the target, even with its prolonged (30 ...100s) shutdown. The main tactical and technical characteristics of the above-mentioned ARMs are given in

Table 1

The main tactical and technical characteristics of the ARM

Name Specifications	Characteristic values for ARM				
	HARM (AMG-88 B, C)	Martel (AS-37) (ARMAT)	Tacit Rainbow (AGM-136A)	ALARM	Delilah (Star-1)
Developer country	USA	France	USA	UK.	Israel
Year of adoption	1983	1970	1991	1991	2003
Dimensions of the rocket: length, m diameter, m wingspan, m	 4,16 0,25 1,12	 4,2 0,4 1,2	 2,54 0,686 1,56	 4,24 0,22 0,72	 2,71 0,33 1,15
Starting weight, kg	364,5	535	575	265	190
Launch range, km	7…80	15…130	4…90	10…45(90)	100…250
Launch height, km	0,15…15	0.15…16	0,1…6	0,1…6	0,1…6
Average speed, flight, m/s	660	700	300	500	300
Engine type	SFJE	SFJE	SFJE	SFJE	SFJE
Dive angle on the REM, deg	10…60	20…50	20…60	10…90	20…60
Accuracy of fire , m	7…9	7…9	5…6	5…9	5…6
Carrier aircraft ARM	F-15,F-16, F/A-18, Tornado-EGR, EA-6B	Jaguar, Nimrod, Harrier, Mirage-2000	B-52, F-111, A-6	Tornado-EGR, Sea Harrier, верт. Lynx	F-15,F-16, Вертолеты UH-60A, SH-60B

In the USA, on the basis of the AIM-9C Sidewinder aircraft guided missile (AGM), a cheap short-range (up to 10 km) SideARM (AGM-122) has been developed, designed to arm army aviation helicopters and attack unmanned aerial vehicles (UAVs) [9]. The main ARM of foreign countries are: HARM (AMG-88A, B, C), Tacit Rainbow (AGM-136A) (USA), Martel (AS-37) (France), ARMAT (France, UK), ALARM (UK), Delilah (Star-1) (Israel), BARB (South Africa) [10]. Distinctive features of modern ARM are:

-in addition to the passive radar homing head (HH), an active radar HH of the millimeter wavelength range and a television HH of the ranges of 8...14 microns have been introduced;

-the layout of the ARM according to a wingless aerodynamic scheme, with folding rudders in the tail of the rocket;

-equipping the rocket with a ramjet engine that provides its flight speed up to 1300 m / s;

-the possibility of re-targeting the ARM in flight to another radio-electronic means (REM)- target;

-availability of broadband homing head;

-combined guidance system (radar, thermal imaging, television, inertial).

MATERIAL AND METHODS. ARM has no fundamental differences from other types of homing missiles and consists of a glider that combines three main compartments: hardware, propulsion and warhead.

In the hardware compartment there is a homing head (HH), a digital processor and other electronic components of the missile guidance and control systems that carry out the output of the ARM to the radiating REM- target. The ARM hardware compartment is closed in front by a radio-transparent fairing, which is, as a rule, a paraboloid of rotation with a blunted nose. This shape of the fairing makes it possible to obtain acceptable characteristics of radar HH with the lowest aerodynamic drag of the rocket head. Most ARMs are equipped with a passive radar homing head (PRHH).

The passive radar homing head is the most important element of the ARM. It consists of an antenna system, receiver, direction finder, gyro-stabilized platform and selectors.

The HH is designed to solve the following tasks [9]:

- bearing of the REM- target regardless of the direction of its main radiation relative to the carrier aircraft ARM;
- autonomous search for REM- targets by direction, carrier frequency, repetition period and pulse duration;
- selection of signals selected for the destruction of the REM- target by the carrier frequency, as well as by the repetition period, duration and amplitude of the pulses;
- repeated search and capture of REM- target signals when they disappear;
- issuing extrapolated angular coordinates (and their derivatives) of the position of the target REM to the ARM control system with a short-term loss of signals from the radar (prolongation).

The GPS ARM uses passive monopulse radar direction finders, which provide:

-the bearing of radar signals and the output of signals of its angular position relative to the longitudinal axis of the rocket to the missile control system;

- output of the angular velocity of rotation of the radar line of sight to the missile control system;
- the issuance of signals about auto-interception and angular coordinates of the radar in the equipment of the carrier aircraft ARM.

The principle of operation of a monopulse direction finder is that information about the direction to the target is obtained by comparing the amplitudes or phases of radar signals simultaneously present in several channels of the direction finder. Depending on the circuit implementation, monopulse direction finders are divided into amplitude, phase and amplitude-phase direction finders. Amplitude-type direction finders were used in the Shrike (AMG-45) type ARM (Fig. 1) and Standart ARM (AGM-88) (Fig. 2). In modern ARM, amplitude direction finders in their pure form are not used.

In modern ARM, two types of direction finders are most used [11]:

-monopulse phase-phase type direction finders with phase comparison at an intermediate frequency;

-monopulse direction finder of amplitude-phase type with total-difference processing at high frequency.

Fig 1 ARM Shrike (AMG-45)

Fig 2 Standard ARM (AGM-88)

Monopulse direction finders of the amplitude-phase type with total-difference processing at high frequency have found the greatest use in the HH ARM, Direction finders of this type are used in HARM (AGM-88B, C), ALARM and Martel (AS-37) type ARM.

The advantages of direction finders of this type are:

- the ability to obtain independent information about the radar target simultaneously by the amplitude and phase ratios of the received signals, which increases the resolution in angular coordinates;
- for the bearing of the target in two planes, it is necessary to have only two angular channels and a total total channel;
- errors related to the imbalance of channel characteristics are random, which allows them to be determined by the results of mathematical modeling;
- the ability to determine the range to the radar target, which increases the selection capabilities and guidance accuracy.

The disadvantages of such direction finders are [10]:

- the random error caused by the internal noise of the HH receiver is twice as high as in phase-type direction finders with total difference processing;
- to compensate for internal errors in the direction finder channels, the use of complex circuit design solutions is required;
- the accuracy of the radar target direction finding in the phase channel is sharply reduced when using a frequency-modulated signal with a high frequency deviation;
- the accuracy of bearing in the amplitude channel decreases when processing a frequency-modulated signal due to the appearance of parasitic amplitude modulation of the error signal.

However, in order to ensure the operation of the direction finders of the RHH in the conditions of an intense radar field of air defense in the absence of electronic reconnaissance systems on ARM carrier aircraft, the principles of functioning should be laid down in the schemes and design of radar HH, ensuring:

- bearing of the radar target regardless of the direction of its main radiation;
- autonomous search for radar targets by direction and carrier frequency, as well as by pulse repetition period;
- selection of signals of the selected radar target;
- repeated search and capture of radar target signals when they disappear;
- output of signals of the angular position of the radar target and the angular rotation speed of the line of sight of the target "from memory" with a short-term loss of signals (prolongation).

To increase the noise protection, as well as the selection of signals from the selected radar target, the following selectors are used in the RHH ARM:

- by carrier frequency;
- by pulse repetition period;
- by pulse duration;
- at the moment of receipt of pulses;
- by pulse amplitude;
- by angular coordinates.

The carrier frequency selector can usually have a resolution of (2...4) MHz- for pulsed radars or (0.2....0.5) MHz - for continuous quasi-continuous radars. Currently, the weight and size limitations do not allow parallel multi-frequency reception and analysis of signals to be implemented in the RHH. A compromise solution to meet the requirements for frequency selectivity and search capabilities in the PRR is achieved by the fact that several carrier frequency search modes are implemented in the GPS receiver:

-broadband search mode in the range of 200...300 MHz without stopping (while the sensitivity of the RHH receiver decreases by 2...4 orders of magnitude);

-swiping, i.e. scanning with a narrow band at a speed of 500 MHz within a certain frequency range (up to 1000 MHz);

-search with a stop after detecting the radar target signal. Further tracking of the target by frequency should be provided from any search mode.

The pulse repetition period selector has a resolution of 20....50 microseconds. The selector sets strobing pulses during which the receiver of the RHH ARM are open. The repetition period and duration of the selective strobe pulses are set in such a way as to ensure the selection of target pulses, taking into account the possibility of wobbling them over the follow-up period.

The pulse duration selector can have a resolution of about 0.1 microseconds. It provides reception of signals from the radar target only within the open time gate of a given duration. The duration of the time gate is set in advance, based on the estimated duration of the pulses of the target being hit.

The selector at the moment of receipt of pulses is used to isolate the signal from the target in the presence of "interfering" pulses from distracting transmitters or re-reflected pulses from the earth (water surface). This selector provides an analysis of the number of non-overlapping pulses that have been selected by the repetition period and pulse duration, and the choice is accompanied by the homing head of the first, second or third pulse.

At the same time, in order to suppress interfering reflection from the underlying surface, further angular tracking of the detected radar pulse signal can be carried out along its leading edge (the so-called cutting-off mode of the leading edge of the pulse). The pulse signal amplitude selector allows you to select one of the non-overlapping pulse signals for further processing. The resolution of the amplitude selector is usually 1...2 dB.

Selector by angular coordinates selection of targets by angular coordinates is carried out by schematic methods (angular selector). In promising ARMS (for example, of the HARM type (AMG-88D, E), when the signal disappears in the RHH, the missile is guided to the target using an inertial guidance system corrected from the satellite radio navigation system NAVSTAR in the initial and middle sections of the flight path, with the transition to homing from an active millimeter-range radar RHH or infrared RHH in the final section. The listed principles ensure the noise immunity and autonomy of the operation of the homing head of the ARM.

Analysis of the characteristics of the RHH ARM shows:

-the operating wavelength range of the RHH ARM lies in the range from 0.5 to 40 GHz, (wavelength cm). Outside of this, the frequency range of the REM ARM is not created, because, at frequencies less than 0.5 GHz, the weight and size characteristics of the RHH ARM as a whole sharply increase. At the same time, the accuracy of direction finding decreases from 0.08 to 1.5°, and at frequencies above 40 GHz, the range of the ARM is sharply reduced due to the large attenuation of millimeter radio waves in the atmosphere, especially in bad weather conditions;

-the large range and high speed of adjustment of the operating frequency of the GPS receiver make it ineffective to use frequency jumps in the REM, since this does not lead to a significant increase in the errors of pointing the ARM at the target REM due to the presence in the ARM either an autonomous inertial guidance system corrected from the satellite radio navigation system NAVSTAR via the GPS receiver, or a prolongator of the flight path of the ARM;

-the small (0.2... 4 MHz) bandwidth of the RHH receiver ensures its high frequency resolution, which allows you to select the desired radar in a complex electronic environment.

ARM as an object of observation. Anti-radar missiles as objects of observation are significantly different from aircraft.

Their transverse and longitudinal dimensions are 3-5 times smaller than the size of the fighter, the geometric shapes are simpler, the dimensions of the main local reflectors are commensurate with the length of the decimeter and near-meter radar ranges. Table 3. shows the effective scattering surfaces (ESR) for different radar wavelengths and angles of their location relative to the longitudinal axis of the ARM.

Table 3

Type ARM	The angle of the location ARM, deg	ESR value for wavelengths			
		□=3 sm	□=10 sm	□=40 sm	□=200 sm
HARM	±15	0,06	0,07	0,08	1,8
	±45	0,04	0,07	0,08	2,0
Martel (AS-37) ARMAT	±15	0,25	0,3	0,3	1,4
	±45	0,2	0,25	0,3	3,8
ALARM	±15	0,06	0,07	0,08	1,2
	±45	0,05	0,06	0,08	1,5
Tacit Rainbow	±15	0,11-0,15	0,11-0,15	0,15-0,2	1,0-01,5
	±45	0,04-0,09	0,04-0,09	0,06-0,1	1,0-1,5

When attacking ground (surface) REM targets, the ARM can have the following typical flight paths (Fig.3) [11-15]:

- flight along a ballistic (curve 1) or semi-ballistic (curve 2) trajectory with a given casting height (up to 40 km) and a dive angle to the target in the range from 10 to 80°;
- gentle dive over the entire flight section of the PRR at angles of 10...20° (curve 3);
- horizontal flight at low altitudes of 100...500 m with a "slide" maneuver at a range of 10...15 km from the target RES and switching to a dive at angles of 20...60° (curve 4);
- horizontal flight at medium and high altitudes with a transition in the final section of the trajectory into a dive at angles of 10 ...60° (curve 5);
- horizontal flight at low and medium altitudes, with a sharp climb (when the REM is turned off) with a slow descent by parachute, followed by a dive at angles up to 90 degrees after the RES is turned on (ARM ALARM, curve 6).

Methods of application of ARM**.** According to the experience of military operations in local wars, the following tactical methods of using PRR can be distinguished [13-15]:

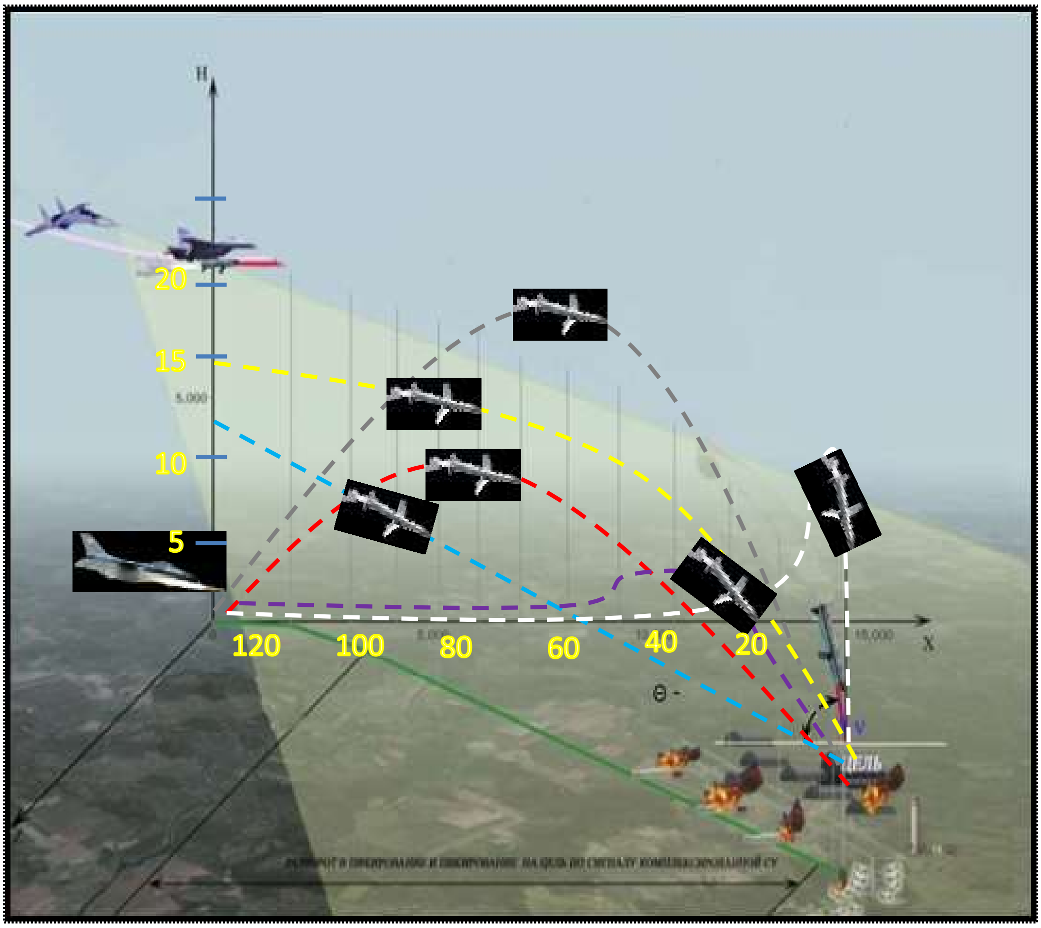


Fig 3. Typical flight paths of the ARM

The use of ARM from low and extremely low altitudes under the cover of reflections from local objects (Fig. 4). According to the experience of local wars, more than 70% of ARMs were used from low and extremely low altitudes, since this tactic ensures the surprise use of ARMs.

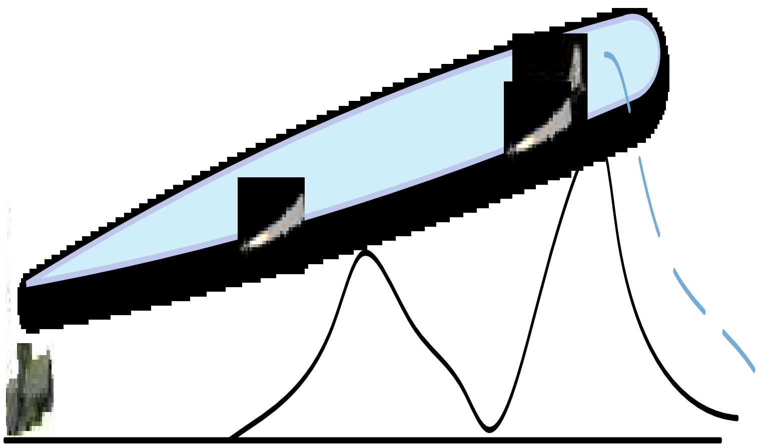


Fig 4. The use of ARM from low altitudes under the cover of reflections from local objects

When ARM is used during the day in the sector of ±10 º ... 20 º relative to the direction to the sun, the use of optical means of monitoring the target on the air defense system becomes impossible and the air defense system is forced to track the carrier aircraft of the radar channel (Fig. 5).

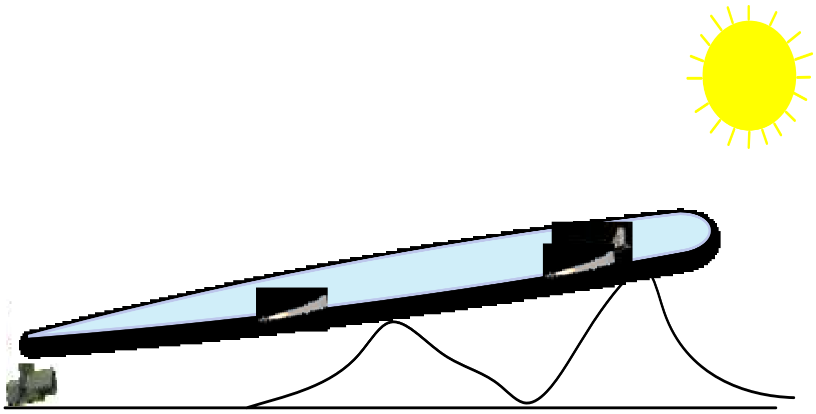


Fig 5. Application of PRR at night and from the side of the sun

The use of ARM under the cover of passive interference (Fig. 6).

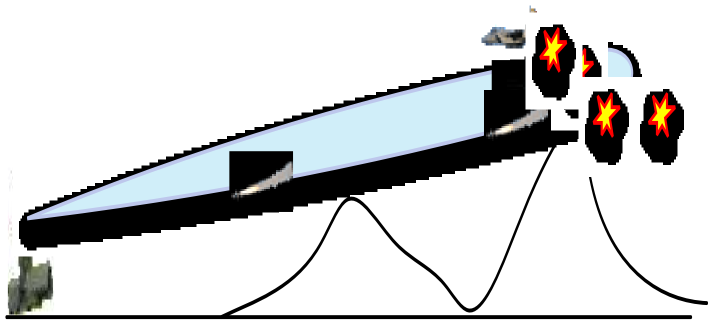


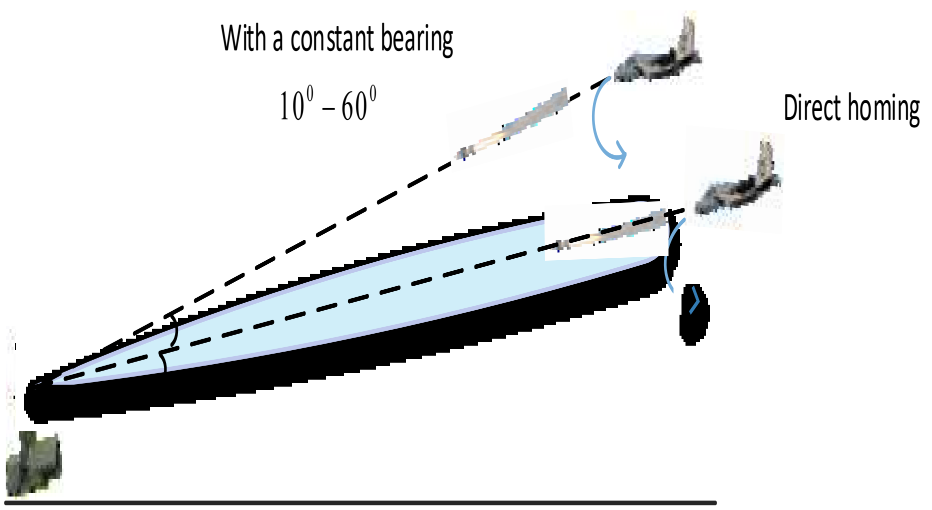
Fig 6. The ARM carrier aircraft is moving ahead of the passive interference cloud

This tactical technique is similar to the technique of using ARM from low altitudes under the cover of reflections from local objects, only in it the role of reflections from "locals" is played by reflections from clouds of dipole interference. Due to this, the range of ARM application from medium heights is significantly increased.

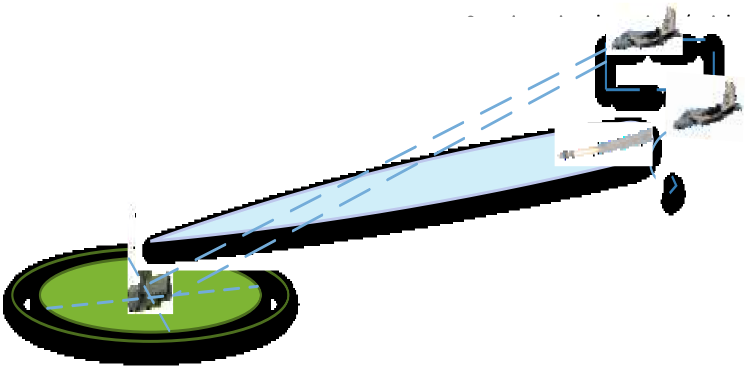
Methods of combat use of ARM distinguish:

-by the guidance method (Figure 7). - by flight mode (Figure 8).

-semi-active homing (with "illumination" of the object of impact");

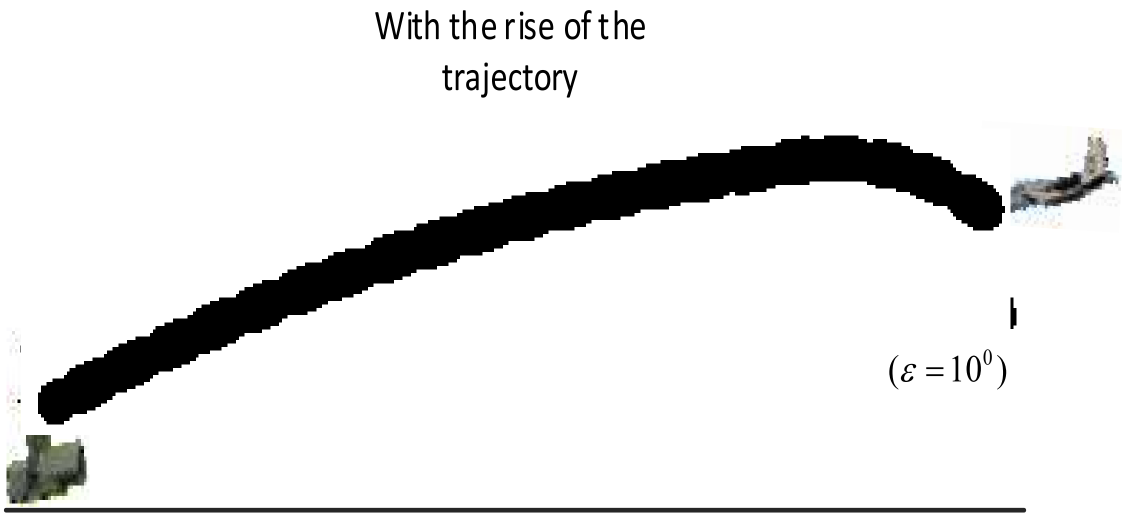


a)

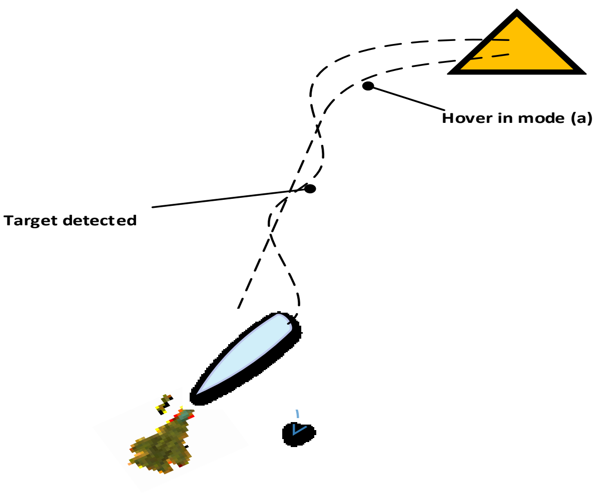


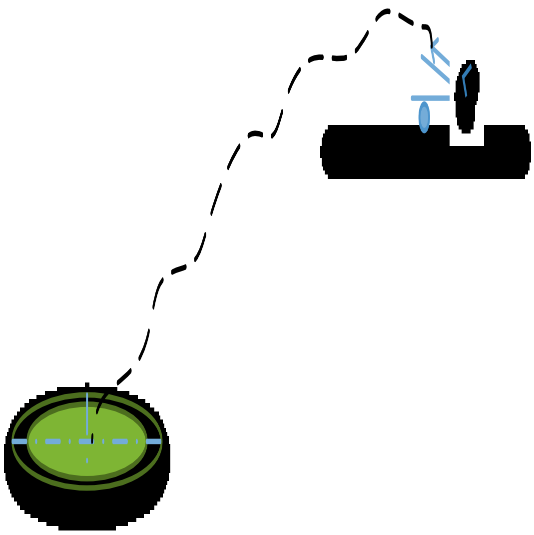
b)

Fig 7. Methods of combat use of high–precision weapons: a) passive homing (by radiation of the object of impact);



a)





b) **c)**

Fig 8. Flight modes of high-precision weapons:

a – directly on a given (detected) target;

b – along a given route with a goal search

c – for a given destination on the route (cruis)

CONCLUSION. The analysis of the characteristics of well-known modern ARMs based on open sources allowed us to identify their most distinctive features, which are physical prerequisites for effective selection (selection against the background of other objects):

1. Anti–radar missiles are small-sized targets with a small effective scattering area of $\square_{ARM}$ (for the centimeter and decimeter range, $\square_{ARM}$ is from 0.06 to 0.2 m^2).

2. At the moment of separation of the ARM and the carrier, the radial acceleration of the ARM is much greater than the radial acceleration of the carrier. The radial velocity of the ARM is also usually greater than the radial velocity of the carrier. The trajectory of the ARM is most often oriented towards the attacked radar (the heading angle of the missile relative to the radar is approximately 0^0).

3. The flight speed of the ARM V_{ARM} is in the range from 600 to 1200 m/s, which is significantly more than most modern aerodynamic aircraft. The ARM is characterized by a limited start-up range $D_{START\ UP}$. – no more than 200 km, which is due to the limited supply of rocket fuel on board.

4. In the final section of the ARM trajectory, large dive angles are characteristic – from 10^0 to 60^0. The flight path of the ARM is made in three possible ways (directly on the radar, along the route to the radar and along the route with the search for the radar).

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THE MOST COMMON SOURCES OF EMERGENCIES AND THEIR RESPONSE

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Abstract: *Humanity, entering the XXI st century, can choose and analyze cold wars, modern attacks, various catastrophes and other problems of past centuries. Based on this, this article, on civil protection from an emergency situation of a man-made nature, provides continuous communication and will provide an opportunity to navigate a possible situation. The article presents various ways to eliminate man-made emergencies.*
Keywords*: Emergencies, weapons, man-made, danger, catastrophe, safety, fire, explosion, accident, local, liquidation, utility system, evacuation*

INTRODUCTION: At all stages of its development, a person is closely connected with the outside world. He is more and more aware of the problems that arise when living in a highly industrial society. Dangerous human intervention in nature has increased dramatically and now threatens to become a global danger to humanity. Almost every day in various parts of our planet, emergency situations emergency occurs this is a system of disasters, catastrophes, regular accidents, acts of terrorism and the most common emergency of a man-made nature caused by the collapse of buildings, highways, caused by design flaws and various natural disasters (earthquakes, floods, collapses); Emergencies at public utilities - accidents at power stations, sewage treatment plants, water supply.

The most common sources of man-made emergencies are fires and explosions that occur:

- at the objects of production, storage and processing of flammable, combustible and explosive substances;
- on transport;
- in buildings and structures for residential, social and cultural purposes.
- at industrial facilities;
- in mines, mine workings, subways;

Prevention and liquidation of emergency situations:

Emergency Prevention: this is a set of measures taken in advance and aimed at minimizing the risk of emergencies as much as possible, as well as preserving people's health, reducing damage to the environment and material losses in case of their occurrence.