www.czasopisma.pan.pl PAN www.journals.pan.pl

INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2021, VOL. 67, NO. 1, PP. 43-48
Manuscript received May 22, 2020; revised January, 2021. DOI: 10.24425/ijet.2021.135942

# Mobility of Radars on the Today's Battlefield

Stanisław Czeszejko

***Abstract*—In this article the author makes an attempt to characterize the main factor – mobility – which is to be taken into consideration while designing the ground radar component (passive and active radars) of the Air Defense systems in order to enable them to operate on the contemporary battlefield. He presents the latest theoretical views on the relationship between the usage of anti-radiation missiles and the mobility of the passive and active radars as the key ability to protect them against such weapons. In particular the author emphasizes that the anti-radiation missiles present nowadays the biggest threat for the effective Air Defense systems, which are today characterized by a high complexity degree. He also stresses the need to combine the radars, both passive and active, into one system allowing for the streamlining of their work parameters and thus ensuring their complex usage. The gaining of those capabilities shall guarantee that the parameters of the air surveillance radar area can be defined effectively.**

***Keywords*—radar, radiolocation, air defense system, survive to operate on the battlefield, mobility, anti-radiation missile**

## I. Mobility

MANEUVERABILITY (sample definitions)[1] – 1. capacity of a vehicle or a ship, to perform a movement in terrain in military or naval tactics; or 2. ability of the troops to perform fast redeployment. In case of operating the radars, mobility should be understood as the ability to:

- efficient folding of all the construction elements of the radar in order to be able to transport the equipment in one piece and to leave the combat position quickly, moving to a secure distance, avoiding thus destruction or damage caused by weapons;
- efficient radar troops redeployment aiming at effective air target detection by keeping the ability to survive to operate.

## II. Main Threat – Anti-Radiation Missile (ARM)

Table I presents the simplified data concerning the velocity, range and flight time of the chosen anti-radiation missiles. Another important parameter of the anti-radiation missiles is the missile target accuracy and destruction range done by the warhead exploding – significant in the context of the radar's survival on the battlefield.

In the 1960s and at the beginning of the 1970s the ARMs possessed destruction range of 15 m (AGM-45 SHRIKE), of 20 m (Ch-58), of 50 m (Ch-28 and Ch-28M), and even of 150 m (AGM-78 STANDARD-ARM). However, the missile target accuracy of ARMs is known and at that time amounted to about 15-20 m (AGM-78 STANDARD-ARM) and about 5 m (Ch-28, Ch-28M, Ch-58).

At the end of 1970s and in the 1980s, the missile target accuracy of ARMs amounted to about 5-8 m (Ch-15P, Ch-31P[2], Ch-58U), or to 7-9 m (AGM-88 HARM), while their destruction range had not changed.

In the 1990s the missile target accuracy of ARMs did not undergo any significant changes and amounted to about 5-8 m (Ch-58E, Ch-58EM) or to 6 m (AGM-88C HARM).

The destruction ranges of ARMs from the first decade of the 21$^{st}$ century did not differ from their predecessors (being just another version of the basic ARMs), but the missile target accuracy of ARMs improved radically due to applying the GPS in the guidance systems (German ARMIGER, British ALARM, American AGM-88E AARGM) and their target accuracy is less than 1 meter ($\leq$ 1 m).

## III. Experiences

During the 1995 Balkan conflict campaign, during the, when the major role was played by the precision guided weapon, NATO planes were equipped with ARMs, too. In the NATO air campaign conducted by NATO code named *Deliberate Force*, the NATO forces used American Air Force ARMs of the AGM-88 HARM type and of the first version. Using these missiles was aimed at the destruction of the integrated Air Defense System by conducting SEAD missions (Suppression of Enemy Air Defenses).

During the 1999 period of this conflict ALARM, AGM-88B HARM and AGM-88C HARM missiles were launched over Serbia and Kosovo, but they were not able to do serious damage to the extremely mobile Yugoslavian air-defense forces. Only about 115-130 of the ground targets emitting electromagnetic radiation were eliminated, which proves the high efficiency of the Yugoslavian forces' operations, i.e. high discipline level concerning the limited time of radars' radiation (up to 10 seconds) and the high mobility of the forces (constant changing the positions of the anti-aircraft weapons).

The NATO official reports state that the efficiency of the HARM missiles was 3%-6.6%[3], depending on the operation's phase [7]. Since then, the development of weapons encompassed ARM too, but the experiences mentioned above prove the effective way of defending against these assets.

S. Czeszejko is with the General Command Polish Armed Forces, Warsaw, Poland (e-mail: staszejko@poczta.onet.pl).

[1] https://sjp.pwn.pl/sjp/

[2] According to several sources, the target accuracy of this particular missile amount to just 0.25 m (http:/johncool.host.sk/CH-31P.htm).

[3] W. Klembowski, J. Miłosz, T. Rutkowski, J. Wiśniewski, *Środki ochrony radaru przed rakietami naprowadzającymi się na emisję radarową*, 43 Konferencja Naukowo-Techniczna Radiolokacji, Rynia, 15-16.11.2011 r., s. 22.

TABLE I
ANTI-RADIATION MISSILES – PARAMETERS (N.D.A. – NO DATA AVAILABLE).

| **Missile type** | Ch-15P | Alarm | Ch-32P [Ch-22MP] | Ch-31PD / Ch-31PM | Ch-58USzE / Ch-58USzKE | Armiger | AGM-88 D Harm Block 6 / AGM-88 E AARGM |
|---|---|---|---|---|---|---|---|
| **Country** | USSR | Great Britain | USSR | Russia | Russia | Germany | USA |
| **Year of implementation** | 1988 | 1991 | 1995 | 2002 / 2005 | n.d.a. / 2007 | 2008 | 2003 / 2009 |
| **Flight speed [m/s]** | 1.000 -1.100 max. 1.700 | 320 max. 695 | 1.190 | 600-700 max. 1.000 / max. 1.170 | 450-600 max. 1.166 | - max. 1.020 | 680 max. 2.040 |
| **Minimum range [km]** | 40 | 8 | n.d.a. | 15 / n.d.a. | 10-12 | n.d.a. | n.d.a. |
| **Minimum flight time [s]** | 40-36 min. 23 | 25 min. 11 | - | 25-21 min. 15 / - | 26-16 min. 8 | - | - |
| **Maximum range [km]** | 150 | 45-93 | 700 | 180-250 / n.d.a. | 245 | 200 | 180 / 110 |
| **Maximum flight time [s]** | 150-136 min. 88 | 140-290 min. 64 | 588 | 257-416 min. 180 / - | 544-408 min. 210 | - min. 196 | 264 / 161 min. 88 / 53 |

## IV. TIME OF OPERATING ON A RADAR PICKET

The operating time of a radar on a radar picket should be limited to a minimum, like in case of the Yugoslavian conflict the time of the electromagnetic radiation of a radar has to be limited to 10 seconds.

In battle conditions a radar's antenna must rotate in a full circle (360°) at least once. In case of mid- and long-range radars produced in Poland, the time of scanning the full circle differs from 2.5 s to 10 s [11], which can be reduced only by means of sector operation (electromagnetic radiation). Just to be safe, regardless the situation development, the operating time of a radar transmitter on a radar picket has to be obligatorily limited to 10 s, which has already been checked in practice and confirmed during the Balkan conflict. The total time of folding[4] the radar consists of fractional phases: folding of the antenna, lifting the stabilizing supports, disconnecting and throwing away the cables along with the light pipes.

In order to radically shorten the process of radar folding, it is necessary to construct each mobile radar as a single vehicle, as well as equip it with the following automated mechanisms: quick antenna folding (among others absorbing the energy of the quickly folding antenna), lifting the stabilizing supports (immediately after the antenna folding), disconnecting and throwing away the cables and light pipes (they are all located in one place as a multi-pipe "fast-junction"). Thus, it shall be possible to move the radar quickly away for a distance allowing the radar to survive, despite being hit by splinters coming from the explosion of an anti-radiation missile. The starting and driving of the radar away must be performed automatically. The vehicle should be equipped with electric gear wheels, while the electric engine should be characterized by high torque and started by an automatic electric signal.

Summing up, on the basis of the available technologies, it is possible to reduce the time of the radar remaining on a radar picket even to less than 60 seconds (one minute): about 10 s of electromagnetic radiation, about 20 s for radar folding, about 30 s for a drive of more or less 40 m (with the speed of about 5 km/h, i.e. about 1.4 m/s).

[4] At the moment, the shortest time needed for folding a radar produced in Poland (NUR-21, NUR-22) is 5 minutes.

## V. MOBILITY AND THE RADAR PARAMETERS

One of the uppermost coefficient for radars (and the mobility) is the general dependence existing between: range of the electromagnetic wavelength and power of the transmitter; and weight and dimensions of the radar's antenna and weight and dimensions of the radar's platform (secondary dependence – equation 1, fig. 1).

$$W_{AP} = f(F_{EM}, P_T) \tag{1}$$

$W_{AP}$ – weight and dimensions of the radar's antenna and weight and dimensions of the radar's platform.
$F_{EM}$ – range of the electromagnetic wavelength.
$P_T$ – power of the transmitter.

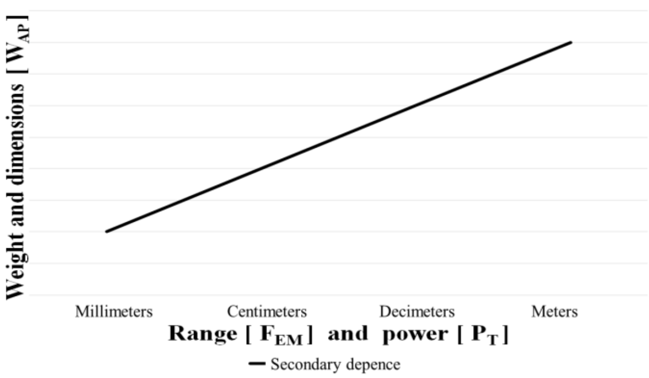


Fig. 1: Secondary dependence – range of the electromagnetic wavelength and power of the transmitter & weight and dimensions of the radar's antenna and weight and dimensions of the radar's platform

This dependence points to the fact, that in spite of increasing weight and dimensions of the radar's (depending on the range of the electromagnetic wavelength and power of the transmitter), it is necessary to keep the correct values of the mobility coefficient for all types of radars.

It means exactly that in the context of construction each radar has to possess the possibility of quick folding and changing the combat picket, which is the most important condition for the radars to survive to operate.

It is commonly known that on the today's battlefield destroying the object basically consists of two phases:

- detecting – when the sensor or man transfers the information about the detected object to the commanding post, where it becomes priority and the completed information about the object is transferred to active combat systems with the order to attack it;
- attack – when after receiving the order to attack the active combat systems make use of the appropriate assets, attacking and eventually destroying or disarming the object.

In case when the object does not have active defense (after seizure of the combat picket), on the opposite side of the barricade functioning of every object on the today's battlefield is basically divided into three phases:

- work – when the object has to complete the mission;
- folding – when the object does folding of all own parts and completely prepares to leave the combat picket;
- movement – when the object has to conduct the movement at the safety distance, applying the camouflage and confusing the active combat assets of the enemy.

In order to establish the possibility of estimating how to avoid the destruction of the attacked object, and to have the possibility to compare this kind of attribute between different objects, it is necessary to establish the coefficient, which allows for this kind of estimation and comparison.

Taking into consideration the data above we can lay down the mathematic formula, naming it "mobility coefficient":

$$M = \frac{(T_D + T_A)}{(T_W + T_F + T_M)} \qquad (2)$$

M – mobility coefficient.
$T_D$ – the detection time of the object by the enemy [s].
$T_A$ – the attack time on the object, conducted by the enemy [s].
$T_W$ – the work time of the object, attacked by the enemy on a picket [s].
$T_F$ – the folding time of the object [s].
$T_M$ – the movement time of the object [s].

Magnitude of mobility coefficient should be always equal or larger than magnitude one ($M \geq 1$), otherwise the attacked object is in danger of being destroyed.

In case of radars the mathematic formula can be used directly (calculated coefficient M will then have very low values), but because of the number of the additional peculiar factors, this formula has to be adapted to the conditions of functioning of the existing radars.

Because of the large quantity of combat assets, with which the enemy can destroy the radars, it is necessary to establish the reference times (point of reference / frame of reference; benchmark) for the radars, which shall determine the theoretical operational requirements defined for the radars on the today's battlefield.

The theoretical operational requirements are the point of reference for the possibilities of the active combat assets dedicated to destruction of the radars.

The new form of the mathematic formula, dedicated to mobility of the radars, will have the following form:

$$M_{RR} = \frac{(T_{DR} + T_{AR})}{(T_{WR} + T_{FR} + T_{MR})} \qquad (3)$$

$M_{RR}$ – reference mobility coefficient of the radar.
$T_{DR}$ – detection time of the radar by the enemy [s].
$T_{AR}$ – time attack on the radar conducted by the enemy [s].
$T_{WR}$ – acknowledged theoretical reference time of the radar's work (radiation – electromagnetic emission), radar attacked by enemy on a radar picket [s].
$T_{FR}$ – acknowledged theoretical reference time of the radar's folding [s].
$T_{MR}$ – acknowledged theoretical reference time of the radar's platform movement [s].

Desired magnitude of reference mobility coefficient of the radar ($M_{RR}$) will be equal or larger than the magnitude one ($M_{RR} \geq 1$), and its scale is comparable with the universal mobility coefficient of the radar (M).

In case when $M_{RR} < 1$, the attacked radar will be in danger of being destroyed.

Since most used radars were constructed many years or even decades ago, at the same time some of the recently and nowadays manufactured radars are constructed on the basis of a structural idea descended from the time of the "cold war", an additional multiplier (assumed numerical coefficient) must be applied, allowing for producing the result the radar's current mobility coefficient ($M_R$), calculated as a number approximated to one.

This kind of calculating (correction by multiplier) is necessary only for assuring better clarity of the coefficient and the possibility of comparing the mobility of the existing radars, which in most cases are exposed to being destroyed already in the first period of armed conflict.

Only the next form of the mathematic formula, dedicated to the current mobility of the radar, provides us with the comparative possibility (main formula – equation 4, Table II, fig. 2)]:

$$M_R = \frac{(T_{WR} + T_{FR} + T_{MR}) \cdot 10^2}{(T_W + T_F + T_M)} \qquad (4)$$

$M_R$ – current mobility coefficient of the radar.
$T_{WR}$ – acknowledged theoretical reference time (point of reference / frame of reference; benchmark) of the radar's work (radiation – electromagnetic emission) attacked radar on a radar picket (assumed for now about 10 s) [s].
$T_{FR}$ – acknowledged theoretical reference time (point of reference / frame of reference; benchmark) of the radar's folding (assumed for now about 20 s) [s].
$T_{MR}$ – acknowledged theoretical reference time (point of reference / frame of reference; benchmark) of the radar's platform movement (assumed for now about 30 s for a drive of more or less 40 m with the speed of about 5 km/h, i.e. about 1.4 m/s) [s].

$10^2$ – multiplier[5] (weighting factor), depend of the technology advancement and difference between: acknowledged theoretical reference times (point of reference / frame of reference; benchmark) of the radar's and the real times: work, folding and movement of the radar's (assumed for now 100).

$T_W$ – real time of the radar's work (radiation – electromagnetic emission) attacked radar on a radar picket) [s].

$T_F$ – real time of the radar's folding of attacked radar [s].

$T_M$ – real time of the attacked radar's platform movement on a safety distance [s].

TABLE II
Current mobility coefficient of the radar – $M_R$ (where: $T_\Sigma = T_W + T_F + T_M$).

| $T_\Sigma$ | 5 min. (0,083 h) | 10 min. (0,1 h) | 20 min. (0,33 h) | 30 min. (0,5 h) | 60 min. (1 h) | 1,5 h | 2 h | 2,5 h | 3 h | 4 h | 5 h |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **$M_R$** | 1,5 | 0,79 | 0,41 | 0,27 | 0,14 | 0,09 | 0,07 | 0,055 | 0,046 | 0,034 | 0,03 |

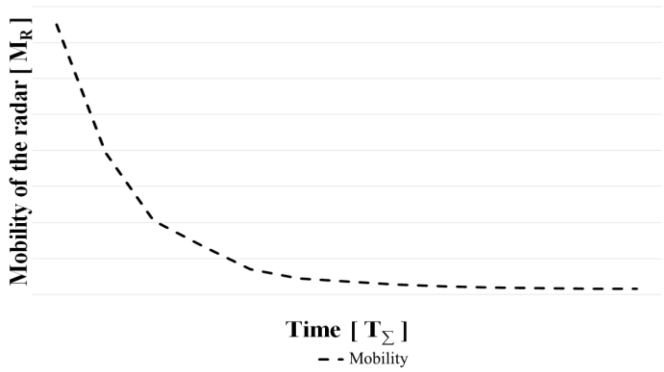

Fig 2: Major dependence – time (real time of the radar's work, folding and real time of the radar's platform movement) & mobility of the radar ($M_R$)

Acknowledged reference times (point of reference / frame of reference; benchmark) are connected with the theoretical assumption, that on the basis of the available technologies, it is possible to reduce the time of the radar remaining on a radar picket even to less than 60 seconds (one minute): about 10 s of electromagnetic radiation, about 20 s for radar folding, about 30 s for a drive of more or less 40 m (with the speed of about 5 km/h, i.e. about 1.4 m/s).
Theoretical reference times (point of reference / frame of reference; benchmark) connected with the radar's (work, folding and movement) result directly from the active weapon systems reaction caused by the radar's radiation, i.e. the time range between the detection of electromagnetic radiation until the moment of hitting into (the destruction of) the radar by the fire assets.
On the today's battlefield almost all the destruction systems work automatically, the result being the high requirements for the radars time of work, folding and movement.
By applying the high-defined operational requirements for the radars we protect them against destruction systems, they work automatically, semi-automatically and non-automatically too (manually operated).

## VI. ACTIVE RADARS

Because of the high value of an active radar (receiver, data processing, computer and transmitter), in order to survive, the radar has to be lightly armored. The armoring has to be mounted not only on the main parts of the radar, as it is in case of some existing radars (for example NUR-21, NUR-22, Pirhanna 740 – Giraffe). Also, it has to be mounted on the sensitive components of antenna (radiant elements and folding machinery), as well as on the stabilizing supports. The antenna should be protected continuously during operating – the armoring should be as lightweight as possible and located at the rear side of the antenna, lifting and rotating together with it while operating in combat.
Having detected an anti-radiation missile, the antenna must be automatically turned with its armored side towards the nearing missile. In the moment of explosion splinters of the missile exploding a few meters above the ground will hit the armor, leaving the antenna protected, regardless of its type. The antenna can be protected by means of lighter materials (Kevlar, composites with ceramic antiballistic layers, reactive armor, armors of the Chobham type[6]). The best solution would be ultimately to hide the antenna inside the armored vehicle so that the antenna armor itself would shield it from above.

## VII. PASSIVE RADARS

In the case of a passive radar, where the receiver is separated from the transmitter, the whole part of radar with the receiver inside needs extremely good protection (receiver, data processing, computer and transmitter, etc.). In most cases, the present solutions of the passive radar constructions rely on exploitation radiation emitted from foreign transmitters, based mostly on these used by the enemies. Nevertheless, in this instance it should be expected, that an interruption in detecting the air objects on the ground is possible, since our troops do not have control about the reclosure of the enemies transmitters.

[5] Acknowledged coefficient allowing for producing the result the radar's current mobility coefficient ($M_R$), calculated as a number approximated to one.

[6] Source: http://www.mt.com.pl/pociski-przeciwpancerne-i-pancerze

The concept of using transmitters belonging to the enemy for our own purposes should remain the major method of using our own passive radars.

However, in order to entirely control the development of situation on the today's battlefield, including the possibility to conduct military operations predictable to our own troops and to anticipate in advance movement of our troops, it is necessary to have own transmitters dedicated to own passive radars. In military use of the passive radars our troops cannot leave anything to chance, because one of the keys to win a conducted battle is to impose one's will on the opponent.

Considering that we construct one passive radar consisting of two components – two distinct devices located on two separate platforms – it gives us enormous possibilities of influencing the future military tactic by means of correct construction of this passive radar. The receiver with others important devices (the best is in this case is the wire communication) can be effectively hidden and camouflaged, because this particular part of the radar does not emit any electromagnetic radiation (or just minimal and directional in case of using the directional radio communication used to transmit the collected radar data concerning the air objects).

In case of the passive radar transmitter one must take into account that as an electromagnetic radiation active device, it is going to be a regular target of attacks by the enemy. Therefore, the transmitter has to be located on a very mobile platform and the whole device has to be as lightweight as possible, and have the ability to move efficiently in the terrain. As it was indicated before, the time of electromagnetic radiation has to be limited to minimum.

The solution guaranteeing the long-lasting electromagnetic radiation useful for the work of the passive radar receiver is to possess a large number of mobile transmitter platforms. This makes it able to provide continuity of the air targets detection by radars. Continual movement of the mobile transmitter platforms in the terrain and their electromagnetic radiation emitted during short stops, ensures military control of the airspace for needs of the Air Defense system.

## VIII. "Continuity of tracking" and "the information continuity" – comparison

On today's battlefield, "continuity of tracking" the air objects by the active elements of the radar surveillance system is not possible. It results from the fact that contemporary battlefield (battle space) is still strongly saturated with assets of destruction. Such stability of tracking can be nowadays provided only by passive assets (e.g. Passive Coherent Locator – PCL), which, however, requires constant electromagnetic emission of some other sources of radiation.

Radiation of the active elements of the radar surveillance system allowing them to survive, must be restricted to a minimum – and represent a compromise between the ability of "non-continuous tracking" of the air objects and maneuvering performed by the active elements. This only shall allow for keeping the ability to accomplish the principal task – which is detection of the air objects.

Consecutive turning on the active elements of the radar surveillance system (the so-called "flash") shall permit to keep "the information continuity" concerning the air object of the opponent, but it is not the same as "continuity of tracking" each of these objects. The first one is required only in the phase of fighting this object, when it is necessary to distribute the targets among one's own warfare assets and to direct them towards the assigned targets. In case of warfare assets equipped with their own guidance systems it is enough just to direct them preliminarily in such a way allowing their guidance systems for interception of the allotted target.

Therefore, during the phase of detection, observation and evaluation of the tactical operations of the adversary, it is enough to provide "the information continuity" concerning the opponent's air objects. It is not equivalent with the undisturbed "continuity of tracking" each of the enemy's objects, which – nowadays – can be provided only by passive radars, requiring, however, constant emission of the electromagnetic radiation from other sources. To guarantee such continuity, the passive radars must have the possibility of receiving a very wide spectrum of electromagnetic emission (frequency) emitted by all possible sources (e.g. radiolocation, radio communication, navigation systems etc.). Each of them must be equipped with broadband receiver or a proper number of devices must be equipped with receivers tuned to individual frequency sub-bands.

As a result, it is a priority to establish a proper compromise between the survivability of the radar surveillance system and its ability to keep "continuity of information" concerning the opponent's air objects or of tracking them. Taking into account the possibilities of the modern warfare assets, like detecting and self-guiding towards the targets, achieving such a compromise is possible, requiring just proper theoretical basis.

## IX. Mobility of radars

According to the dependences shown on the figures, which result from the laws of physics and experiences concerning construction of the radars, the most lightweight and the most mobile will be the transmitters of the passive radars (or the complete active radars), constructed with transmitters using who use the shortest range of electromagnetic wavelength (millimeter and centimeter radio waves). Transmitters using the electromagnetic wavelength of longest range (decimeters and meters radio waves) are going to have respectively larger weight and dimensions.

Therefore, because of the movement efficiency in the terrain, the most mobile complete active radars or the transmitters of passive radars should be directed towards the enemy as near as possible. But further away from the FLOT (Forward Line of Own Troops) less moveable radars can be used. It is confirmed by the data included in table I, which presents the flight time from the firing moment until reaching the target which emits electromagnetic radiation for every type of ARM, along with their ranges.

## X. Conclusions

Conclusions concerning the construction of modern radars:

– while constructing radars one must take into consideration all the factors, which influence their mobility;
– in order to keep control over the continuity of the air target detection with usage of the passive radars, it is necessary to construct and possess one's own transmitters for the passive

radars, located on separate and very mobile platforms;
- because of the construction aspects, the passive radars provide greater potential of effective tactical usage of them on the today's battlefield than the active radars;
- due to lower mobility and higher value of the active radars as a whole (transmitter and receiver in one device), active radars should to be lightly armored;
- passive radars do not need armor, because they have separated receiver and transmitter, which are used at different locations (the receiver and transmitter are mounted on two distinct platforms);
- to reduce the time of folding the radar and leaving the combat position (picket) with the active radars and transmitters of the passive radars is the absolute necessity on the today's battlefield.

## XI. System requirements

The next step to construct the modern radar reconnaissance subsystem meeting the needs of the Air Defense System is the functional combining of all radars one owns (active and passive) in one system, whose work is effectively controlled. In order to perform such a complicated function, it has already been recognized as necessary to construct universal radar control consoles (standardized), as well as to design new radars, which would be universal within the NATO in the context of standardized control.

The most important requirements concerning a modern radar surveillance subsystem of Air Defense System include the following:
- very high mobility of active radars and transmitters of passive radars;
- the limited time of radars' radiation on the combat position (picket), with short time of electromagnetically emission up to 10-12 seconds;
- high survivability of the active radars, resulting, among others, to light armoring;
- detecting all types of air objects;
- supporting the tactical and operational situation analysis with the aid of "intelligent" software;
- full cooperation with other surveillance and command systems;
- possibility of controlling the radar from different levels (fully flexible operation).

Meeting these requirements ensures the possibility to shape dynamically the radar surveillance zone parameters.

## XII. Summing-up

Course of last military conflicts proved that the existing radar surveillance systems of the Air Defense system has very little chance of surviving the first phase of a military conflict, not to mention surviving its whole duration, which was proved by the few recent ones. These experiences motivate to seek new solutions in this field, which would be resistant to the destructive effects of the modern combat assets.

## References

[1] Czeszejko S., *Anti-Radiation Missiles vs. Radars*, Intl Journal of Electronics and Telecommunications, 2013, vol. 59, No. 3, pp. 287-293, DOI: 10.2478/eletel-2013-0034.

[2] Czeszejko S., *Radar and its Survival to Operate on the Today's Battlefield*, Signal Processing Symposium SPS-2013, Jachranka k. Zegrza, DVD, IEEE Catalog Number: CFP1356U-DVD, IEEE Operations Center, 445 Hoes Lane, Piscataway, NJ 08854, 2013 r., ISBN 978-1-4673-6318-1.

[3] Czeszejko S., *Radar surveillance in the electronic environment of the 21st century*, 15th International Radar Symposium IRS-2014, Gdańsk, ISBN 978-83-931525-3-7.

[4] Czeszejko S., *Pociski przeciwradiolokacyjne – rozwój i ich stan obecny*, Obronność, AON, Warszawa, 2015, nr 1.

[5] Czeszejko S., *Wymagania operacyjne wobec współczesnych radarów systemu obrony powietrznej*, Obronność, AON, Warszawa, 2015, nr 1.

[6] Emami M., Jafargholi A., Marvasti F., Moghadam M. H. S., *Progress In Electromagnetics Research*, Article: *New Anti-Arm technique by using random phase and amplitude active decoys*, K. N. Toosi & Sharif University of Technology, Iran, 2008.

[7] Klembowski W., Miłosz J., Rutkowski T., Wiśniewski J., *Środki ochrony radaru przed rakietami naprowadzającymi się na emisję radarową*, 43 Konferencja Naukowo-Techniczna Radiolokacji, Rynia, 15-16.11.2011 r.

[8] Maślanka S., *Zabójcy radarów*, Przegląd Sił Powietrznych, nr 12 (018), Redakcja Wojskowa, Warszawa, 2008.

[9] Nayebi M. M., Norouzi Y., Hejazi S. F., *LPI Signal Detection Methods*, 15th International Radar Symposium IRS-2014, Gdańsk, 16-18.06.2014 r., Sharif University of Technology, Iran.

[10] Ptaszyński M., *AGM-88 Harm – samonaprowadzający się pocisk przeciwradiolokacyjny*, Lotnictwo nr 1, Warszawa, 2011.

[11] Zespół Oficerów Szefostwa WRt SP, *Stacje radiolokacyjne Wojsk Radiotechnicznych Sił Powietrznych - informator*, ZW SP, Warszawa, 2009.