DOI: https://doi.org/10.12700/btsz.2025.7.2.25

ASPECTS OF OBJECTS AND FACILITIES INTERFERING WITH SURVEILLANCE

OBJEKTUMOK, LÉTESÍTMÉNYEK LÉGTÉRFELDERÍTÉST ZAVARÓ ASPEKTUSAI

BRAUN András[1] – PETŐ Richárd[2]

Abstract

In Hungary, military installations equipped with radars can be found in several settlements in different parts of the country. These radars can reveal azimuth, distance and altitude of detected air targets. In the course of the study, besides the operation and application of radars, the general rules of their installation and terrain requirements are described. Separately, the RAT-31DL three-dimensional radar is shown, which has a fixed location, but a mobile transportable version, the RAT-31DL/M has also become available. However, regardless of whether the radars in question are mobile or fixed, they must comply with almost the same rules and terrain requirements in order to create a clear and acceptable air situational picture.

Keywords

Object, RAT-31DL Radar, Airspace Reconnaissance, Military Technology

Abstract

Magyarország több településén, az ország különböző pontjain, található radarokkal felszerelt katonai létesítmény. Ezen radarok különböző oldalszögeken, különböző magasságokon és távolságokon képesek a légi célokat felderíteni. A tanulmány során ismertetésre kerül a radarok működése és alkalmazása mellett azok telepítési helyeinek általános szabályai, terep követelményei. Külön szemléltetésre kerül a RAT-31DL három dimenziós radar, mely nagyrészt fix települési hellyel rendelkezik, ugyanakkor az idők során a mobil, szállítható verziója, a RAT-31DL/M is megjelent. Mindazonáltal, attól függetlenül, hogy a kérdéses radarok mobil vagy fix településűek szinte ugyanazon szabályoknak és terep követelményeknek kell eleget tenniük a tiszta és elfogadható légihelyzetkép felderítése érdekében.

Keywords

Objektum, RAT-31DL Radar, Légtérfelderítés, Haditechnika

1 braun.andras92@stud.uni-obuda.hu | ORCID: 0009-0008-3958-5751 | PhD Student, Doctoral School on Safety and Security Sciences Óbuda University | Doktorandusz hallgató, Óbudai Egyetem Biztonságtudományi Doktori Iskola

2 peto.richard@bgk.uni-obuda.hu | ORCID: 0000-0002-6757-0863 | Adjunct professor, Óbuda University Bánki Donát Faculty of Mechanical and Safety Engineering, Egyetemi adjunktus, Óbudai Egyetem Bánki Donát Gépész és Biztonságtechnikai Mérnöki Kar

INTRODUCTION

When installing radars and their associated communication equipment, be it civil or military use, the requirements for the installation site must primarily take into account the usability of the given equipment. Including its operational properties, communication capabilities, and other requirements. Of course, health and nature consideration aspects must also be taken into account, but from the point of view of utilizing the effectiveness of the devices, the most important thing is to provide a clear line of sight, i.e. a free radio horizon. In general, the installation rules prescribed for structures and objects to be installed in the vicinity of the radar serve environmental and health purposes as well. Therefore, if a tall structure, residential building or multi-storey house cannot be built in the immediate vicinity of the radar. This prohibition is not only intended to maintain detection or communication capabilities, but also to protect the environment and health of the people living there. Compared to the installation location of radars, in the direction or in the directions on which the objects listed above are located, a significant decrease in capability, usability may occur or may occur if some basic rules regarding the installation of the objects are not observed. In order to maintain the usability of civil and military radars and related communications technical devices, as well as to preserve the reconnaissance and communication capabilities required for these equipment, it is necessary to preserve their environment in the state in which it was deployed. [1]

OPERATION AND SUB-OPERATION OF RADARS

„Radar, as a radio detection and determining tool, became widely used in the Second World War. The radar detects the target with the help of radio waves and plots the spatial position of objects like a map. Radio waves travel through smoke, clouds, fog, even walls, they can see excellently even on objects impenetrable to light. The antenna emits radio waves and then waits for reflected waves from the target. It radiates several signals simultaneously to scan in as many directions as possible in a short time, while the antenna rotates continuously. The pulses emitted by the radars must be timed so that there is time for the signal already sent to return before the next pulse is sent by the antenna. From the reflected signal, the distance of a target can be measured, and in different radars, its height can also be measured.

Radio locators are classified as:

- By operation: continuous or pulsed.
- Used by wavelength: meter, decimeter, millimeter wavelength.
- By primary task: tracking, searching.
- By installation location: ship, ground, aircraft, etc.

The basic elements of active radars are the antenna and power line system, indicator, transceiver, antenna control system, as well as power source. Passive radars do not have transmitting equipment. Continuous radars are suitable for determining the radial velocity of the selected target using the Doppler effect. The Doppler effect is a change in wave frequency and thus wavelength due to the fact that the wave source and observer move relative to each other. The high-frequency energy radiated into the air by the antenna, produced by the transmitter, travels at a speed of $3x10^8$ m/s. Then the signal reflected from a

target or target is picked up by the receiving antenna, amplified by the receiver, and then transmitted to the indicator screen, where it is transformed into visible information.

Application of radio location in civilian life:

- In industry: research and fault positioning, monitoring.
- In meteorology: determining coordinates, measuring wind speed and forecasting the weather, observing cloud migration.
- In transport: search and control of ground, water and aircraft vehicles, determination of speed and other coordinates, possible prevention of accidents.
- In agriculture: crop estimation.

Application of radio location in the army:

- Recognition and distraction.
- Target detection, target tracking, target identification and fire control, target interception.
- Control of aircraft take-off and landing, determination of target coordinates and orientation to enemy targets.
- Remote control by command, depth measurement and entry into port, guidance of missiles and torpedoes." [2, pp. 2-3.]

RAT-31 DL three-dimensional radar

"The RAT-31 DL[3] is a long-range three-dimensional radar that provides surveillance and reconnaissance over aircraft. State-of-the-art radar system operated in military air defense. Its antenna is a phased array of broadband dipoles and has a detection range of 470 km. The radar provides survivability as well as versatile operational flexibility against various enemy disturbances. Full solid-state, remotely controllable, transmitting power 84 kW, D/L band 1215-1400 MHz, IFF[4] system Mode 4 and Mode S and Mode 5. In some cases, it can also be used by air traffic control. It enables early warning and situational recognition for the timely use of weapon systems in addition to air surveillance. Its feature is to map the electromagnetic environment for ECM[5] and clutters[6] , to more reliably detect flying aircraft within radar detection range, and to determine spatial coordinates, distance, azimuth and altitude.

The RAT-31 DL radar has all the modern data processing capabilities such as adaptive disturbance maps and all modern interference suppression techniques for known land objects. Its angular rotation is mechanical, while the angular height of the main beam is electronically determined on a phase-controlled principle, i.e. with phase shifters. The antenna surface of the radar is tilted back by about 10° in order to achieve the lowest possible radar beam angle value. Over time, they created the DL/M version of the RAT-31, a mobile,

3 RAT31-DL - Italian-made three-dimensional reconnaissance radar

4 IFF – Identification Friend or Foe, a radio recognition system designed for command and control. It allows military and civil air traffic control systems to identify aircraft, vehicles or forces as friends and determine their direction and distance from the interrogatory.

5 ECM – Electronic Countermeasure.

6 Clutter – Confusion, distraction.

transportable version of this state-of-the-art three-dimensional radar system. They are almost identical in parameters and properties, the biggest difference is in mobility." [2, pp. 3-4.]

GENERAL RULES AND TERRAIN REQUIREMENTS

The objects and facilities listed below, depending on the distance and height of their location relative to the electromagnetic center line of the antenna of the radar station, greatly negatively affect or even completely impair the basic detection properties of the radar equipment examined or affected:

- taller buildings, structures,
- high-power electrical transformers,
- high-voltage lines,
- electrical wiring and their supporting columns,
- wind farms, wind farms,
- high-frequency or microwave towers, repeater stations,
- plant populations, forests.

By following the general rules, detection capabilities of the currently installed, already operating radio technology and radar equipment, and in the case of military radars, their operational capabilities and the communication coverage of the associated radio communication devices can be preserved. General rules:

- The directional characteristics of the radio-locator (radar) antenna are shaped by the terrain conditions of the settlement location.
- The degree of influence of the terrain depends on the altitude of the radar antenna above the surrounding terrain or landmarks.
- The formation of the antenna beam is influenced by unevenness of the terrain (protrusions), which create a so-called cover angle[7] in the direction of free propagation of electromagnetic energy. The part of the space behind the cover angle remains unirradiated, so the signals reflected from that part of the space cannot be detected, i.e. so-called dead zones or blind spots are formed for the radar.
- Depending on the intensity of the energy reflected from different sections of the terrain, moving away from the antenna of the radar station, the area forming the antenna characteristics can be divided into two main parts. These areas are near space (0-1000 m) and far space, outside a radius of 1000 meters measured from radar.
- In order to ensure the tactical capabilities of radio locator stations, the so-called cover angles closed by the radio horizon and local landmarks should not exceed 20 arcminutes in any direction. At cover angles greater than 20 arcminutes, the detection distance specified in the radio-locator station pedigree will be significantly reduced, and the ability to detect and track devices flying at low altitude in that direction will be degraded or, in worse cases, may disappear.

7 Cover angle – The angle between the tangent drawn to a feature at a height other than the horizontal and the antenna plane. [minutes]

- An ideal settlement location can be considered a settlement site on the prevailing elevation with negative angles of cover. [3] [4]

Radar Near Space (0-1000 m) terrain requirements

When assessing terrain, both natural and artificial landmarks and structures should be taken into account. The radar near-space (0-1000 m) has the most significant influence on the formation of the radar vertical plane antenna radiation diagram.

- The height of the settlement, radar is close to the area, the height of its unevenness, including topography and artificial structures and buildings, within a radius of 1000 meters measured from the antenna, must not exceed the height of the antenna platform.
- A dense forest located at or close to the height of the radar antenna greatly reduces the detection distance, therefore, within a radius of 1000 meters around the settlement site, dense vegetation that rises above the antenna platform should not be.
- Artificial structures extending or located at radar antenna height, such as buildings, radio transmission or relay towers, TV transmitters or repeater towers, radiotelephone masts and other antenna poles. Masts and other high points such as wind farms, wind farms and observation towers may not be built.
- The radar station must be installed at a minimum distance of 1000 meters from densely populated areas. It is forbidden to build any structure in the etheric radius of the radar already installed, whatever its material or consistency, for any purpose or use - reaching above the radar platform1000 m.
- It is forbidden to construct any building or structure with a roof of metal construction or a total roof surface exceeding 50 square meters in the vicinity of the radar platform within a radius of 1000 meters, the roof of which exceeds half the height of the radar platform.
- Within a radius of 1000 meters of the radar, there must be no tall reinforced concrete and brick structures, buildings with metal roofs, metal masts, bridge structures, high-voltage transmission lines, or wired communication or telecommunications lines or cables that reach beyond the height of the radar platform.[4] [5]

Radar Far Space (outside a radius of 1000 meters from radar) terrain requirements

The design of the radar detection diagram is basically determined by the angles of cover of landmarks in the distant space. In connection with the above, Figure 1 below illustrates the limitations of building structures around radars.

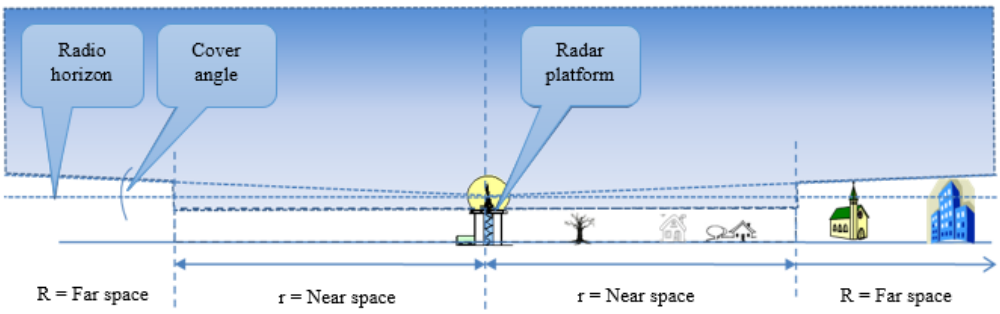

Figure 1: Illustration of radar detection, Near space, Far space, author's edit

The licensing of the construction plans of various structures and objects is approved by the competent authority. The authority may approve the construction and design documentation of the structure based on the height and distance from the radar of the structure to be constructed. The distance and height of the object to be constructed from the radar determines whether or not a building permit can be issued for the construction of the object. The administration is obliged to examine, on the basis of the submitted plans, whether the structure to be constructed corresponds to the radar cover angle or not, using the following mathematical relationship. In the distance of the radar, i.e. beyond the radius of 1000 m from the radar, only structures may be built which satisfy the values given by the following relationship. [5] [6]

$$R_{object} = 3605 * \sqrt{H_{object\,[m]}}\ [m]$$

R_{object}: The distance of the object or structure to be built from the radar, expressed in meters as the crow flies, where the result is obtained in meters after the calculation is completed.

H_{object}: The height of the highest point of the object or structure to be built expressed in meters, the data must be expressed in meters.

Figure 2 below depicts, with the help of two red marker lines, based on the coordinates of their intersections, that objects or structures up to 30 meters high can be built at a distance of 20 km from the radar.

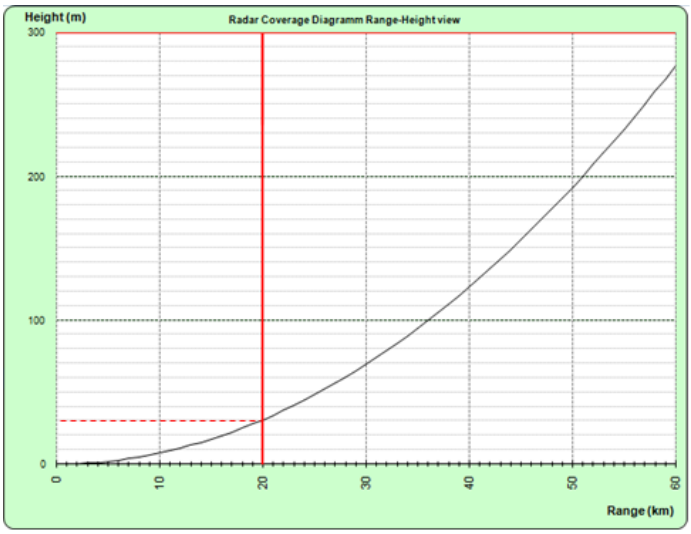

Figure 2: Radar coverage chart, distance-altitude view, author's edit

REQUIREMENTS FOR SETTLEMENT SITES

When choosing a settlement location, it should be taken into account that the terrain conditions of the settlement location play a key role in the development of the directional characteristics of the radar station. The dimensions of the terrain that affect the directional characteristics depend on the height of the radar station's antenna above the terrain, the operating frequency, and the antenna's angle of location. The location of the radar station must first be selected on a map, followed by a visual inspection of the terrain. The best possible

settlement place is straight open ground with a radius of 800-1000 meters. It is not always possible to find such a settlement place, therefore, in each case, it is necessary to choose a place suitable for the combat task of the radar station to be solved.

Near Space (0-1000 m) has the most significant influence on the design of the vertical plane radiation diagram. When assessing the zone of the presumed settlement site, the following shall be taken into account:

- disparities in settlement location must not exceed 3 m within a radius of 100 m from the antenna and 6 m within a radius of 1000 m,
- a uniform slope or rise of the terrain significantly affects the formation of vertical characteristics,
- if the settlement site has a uniform slope at some angle, the radiation diagram is inclined towards the ground at approximately the same angle in a vertical plane and has deeper incidences, the angle of slope must not exceed 2°,
- if the settlement site rises uniformly at a small angle, then the radiation diagram rises by the same angle in a vertical plane, as a result of which the detection distance decreases, the angle of rise should not exceed 0,5°,
- dense forest greatly reduces the detection distance, therefore the settlement site should be chosen at least 1000 meters from the forest, some trees and thickets do not affect the characteristics of the radar station,
- on mountainous terrain, where the choice of settlement site is difficult, the radar station should be located primarily on a plateau with a flat area with a radius of 500-1000 meters, if necessary, it can also be located on a slope or at the foot of the mountain,
- if the radar station is to be installed near built-up areas, it shall be at least 1000 m from built-up areas, and if there are buildings with high metal roofs in built-up areas, at least 2000 m,
- the water surface is advantageous for the development of direction characteristics, increases the range, therefore it is advisable to choose the settlement location on an island, cliff, sloping sea or river bank, in case of a river wider than 400 meters, so that the water surface falls into the main sector and the radar station is no more than 100 meters from the shoreline.

When choosing a place for settlement, it is also necessary to evaluate the surface of the remote zone. In order to increase the range, the cover angle shall not exceed 15'. The choice of settlement place should begin with the study of the map. Designating some possible settlement sites, it is necessary to evaluate the remote zone of each settlement site as follows:

- draw a vertical section of the terrain from the assumed settlement point, especially in critical directions,
- for each direction, the profile of the terrain must be edited in a Cartesian coordinate, where the distance from the antenna is applied to the abscissa axis, the height is applied to the ordinate axis, the resulting points are connected by a continuous line,
- using terrain sections, the settlement location should be evaluated in terms of covering angles and local landmarks on the basis of the above considerations,

- choosing the two or three best of the indicated places of settlement, you need to go out to the site to evaluate and study the nearby zone.

If at different side angles the slope and ascent angles of the terrain are different, then the settlement site should be divided into sectors with homogeneous terrain. If the settlement site has more than two or three sectors with homogeneous terrain, it is not suitable. When assessing the settlement site, access roads, drinking water supply, mains feeding, communications and radar station camouflage against air and ground surveillance shall be taken into account. Within a radius of 100 meters of the selected settlement site, there should be no high reinforced concrete and brick structures, buildings with metal roofs, metal masts, bridge structures, high-voltage power lines, multi-wire news lines. For the placement of cars and trailers, it is advisable to designate a place with hard ground. [4] [5] [6]

SUMMARY

When installing radars, whether for civilian or military purposes, the most important aspect is to ensure the operability and efficiency of the devices. To this end, a location should be chosen which guarantees a free radio horizon and helps to establish and maintain a clear air situational picture. When choosing a site, it is necessary to take into account the detection and communication capabilities of radars, as well as environmental and sanitary regulations. The latter aspects not only serve to protect the environment and human health, but also contribute to optimizing the operation of the radar. The impact of structures and landmarks is extremely important in the vicinity of radars. Taller structures, electrical equipment, wind farms and dense vegetation can significantly reduce radar's range and detection capability. To avoid them, in close space with a radius of 1000 meters, landmarks and structures that rise above the antenna platform cannot be placed. Also, in distance space (beyond 1000 meters), the height and distance of objects from radar are limited according to strict rules. Terrain conditions are also decisive in determining radar directional characteristics. In uneven terrain, the cover angle increases, which can lead to blind spots, reducing radar's ability to detect. Ideally, radars should be installed at prevailing heights with negative cover angles. If this is not possible, the unevenness and gradient/ascent angles of the terrain must be strictly controlled. Unevenness of terrain within a radius of 1000 m should not exceed the height of the antenna, dense forests and tall buildings should be avoided. The location of the radar installation must first be marked on a map, and then checked on the ground, taking into account accessibility, power supply and camouflage options. When choosing a site, priority is given to proper preparation of the environment for optimal radar operation. This includes assessing terrain conditions in near and far zones, minimizing coverage angles, as well as limiting objects in the radar environment. Overall, choosing the right installation site is key to ensuring long-term effective radar operation and minimizing environmental impact.

REFERENCES

[1] BEREK L. – BEREK L. – RAJNAI Z., *A tudományos kutatás folyamata és módszerei*. Óbudai Egyetem, 2022. [Online] https://oda.uni-obuda.hu/handle/20.500.14044/25308

[2] BRAUN A., *Szélerőművek hatása a radarokra*. Biztonságtudományi Szemle, Vol 6, No 3, pp. 59-69, 2024. [Online] https://biztonsagtudomanyi.szemle.uni-obuda.hu/index.php/home/article/view/482
[3] EUROCONTROL, *Guidelines on Assessing the Potential Impact of Wind Turbines on Surveillance Sensors*, 2014. [Online] https://www.eurocontrol.int/publication/eurocontrol-guidelines-assessing-potential-impact-wind-turbines-surveillance-sensors
[4] WOODFORD, C., *Radar*, 2015. [Online] https://www.explainthatstuff.com/radar.html
[5] BARTON D. K – LEONOV S. A., *Radar technology encyclopedia*. Artech House, Boston, Mass., 1997. [Online] https://us.artechhouse.com/Radar-Technology-Encyclopedia-P594.aspx
[6] SELLER R., *Radarmérés alapjai*. Nemzeti Közszolgálati Egyetem, 2016. [Online] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://vik.wiki/images/2/27/Radarmeres_alapjai.pdf