The structure of the construction of a radar receiver for over-the-horizon detection

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Abstract. The article provides information on the tasks of the over-the-horizon detection system, provides brief information on over-the-horizon radars of Russia. The foreign experience of building over-the-horizon detection systems is analyzed. The needs and options for constructing the receiving part of radars are shown, such as: placing equipment under the antenna pole, collecting equipment in the center, distributing equipment in containers along the antenna canvas. It is necessary to continue work in this direction.

1 Introduction

The continuous radar zone of the country's territory is necessary for the organization and conduct of intelligence for the actions of the air-space attack of the enemy in peacetime, opening the moment of starting the strike of the enemy at the beginning of the war and ensuring the information management and target designation of fire defense measures when conducting hostilities to reflect the strike of the enemy.

An important role in this is played by early warning tools, such as Over-The-Horizon Radars (OTHR). The tasks assigned to them are unique, their solution to other means is difficult, and in some cases, it is impossible primarily due to the range of action - up to 3000 km. They have the opportunity to detect aerial facilities of various classes, including aircraft performed by Stealth technologies, helicopters, strategic unmanned aerial vehicles, winged rockets, as well as hypersonic aircraft. OTHR is able to make a daily detection and accompaniment of about 10,000 air objects, and both at altitudes up to 100 km and low-fat targets at the earth or the surface of the sea.

2 OTHR in USSR/Russia

2.1 DUGA-2 (USSR)

The first experimental OTHR "DUGA-N" appeared in the USSR in the early 60s in the city of Nikolaev. And then two combat OTHR 5N32 "DUGA" was built - one near Chernobyl (in the early 70s), the other in the Komsomolsk-on-Amur region (in the early 80s) [1]. They were sent to North America from different sides of the globe and according to the plan should be

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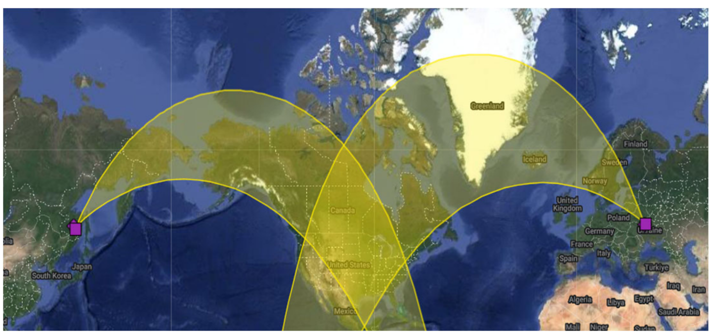
included in the missile defence warning system. Two OTHR "DUGA", duplicating each other, controlled the entire territory of the United States and extensive adjacent spaces (Figure 1). Here and further zones of the OTHR are shown conditionally. On the idea of the creators, they had to detect the launches of ballistic missiles at the very surface of the Earth to increase the time to make a response solution. Due to the multiple reflection of the signal from the ionosphere and the surface of the Earth, the range of their action reached 6000 km.

a)



b)

Fig. 1. Reception antennas OTHR 5N32 "DUGA" (a) and viewing area (b).

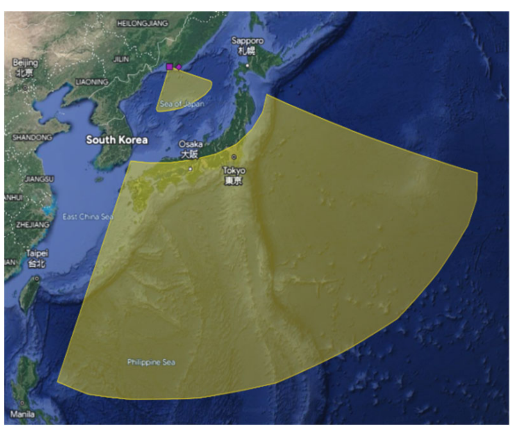
With a large range of action, such "multi-comma" OTHR had a significant drawback - the lack of opportunity to accurately determine the coordinates of the goals [2]. Ionospheres irregular perturbations, weakly studied at that time made additional distortions to work, and their compensation was not yet worked out. Radars 5N32 developed and began to erect until the experimental work of the experimental station of the DUGA-N. Also significant problems of the work of OTHR created powerful ionospheric research emitting systems that created nonlinear effects in the ionosphere. Such systems were established in the United States on Alaska (HIPAS and HAARP) and in Puerto Rico (near the Arecibo Observatory), in Norway near the town of Tromsø (EISCAT) and on the Spitsbergen archipelago (SPEAR). Similar scientific projects were carried out in our country: Uranium-1 ionospheric Observatory 5 km from Zmeiyev Kharkiv region, the Radiotechnical System "Horizon" near Dushanbe, a multifunctional radiocomplex "Sura" near the city of Vasilsursk Nizhny Novgorod region. The "DUGA" radar was not adopted, the work of DUGA-1 near Chernobyl was stopped on April 26, 1986 in connection with the accident at the Chernobyl, and the DUGA-2 near Komsomolsk-on-Amur was removed from the duty on November 14, 1989 in connection with a change in the international situation, it is later closed and dismantled.

Antennas Radar "DUGA" are built on the principle of phased array antenna system. Since one antenna could not block such a wide frequency band, the entire range is broken into two subbands, and the antenna grids are also supplied two: a low-frequency antenna with a height of the mast 150 meters, length 500 meters and a high-frequency antenna about 250 meters long and up to 100 meters in height.

2.2 Volna (Russia)

The second Over-the-Horizon system is already much more perfect, the station GP-120 "Volna" was erected in the Far East near the city of Nakhodka. The purpose of the radar is the control of the surface and air situation in the near 200-mile zone of the surface beam and radar intelligence in the far zone to 3000 km spatial beam (Figure 2). The radar operates using one ionospheric jump, which made it possible to increase the accuracy of the target data obtained compared to the possibilities of the stations of the previous generation. Developments began in 1982, and already in 1986 on the radar began to conduct experiments on the detection of surface facilities and in 1992 the station interpreted to combat duty. Throughout this time, the equipment was improved and upgraded. In the radar "Volna" antennas consists of 256 antenna masts, 35 meters high and 1200 meters aperture.

a)



b)

Fig. 2. Reception antennas OTHR GP-120 "Volna" (a) and a review area (b).

2.3 Kontayner (Russia)

The continuation of the Over-the-Horizon systems in Russia is OTHR 29B6 "Container" (Figure 3), which is considered the development of the "Wave" radar. Unlike the predecessor in the radar "Container" of only 144 masts 34 meters high and aperture of 1300 meters. The start of development dates back to 1995, the exit to the air and the start of the tests, which began in 2002, ended in 2013 by the production of the radar "Container" on pilot duty. The gained experience of the overseas detection and modernization of the equipment allowed the radar on December 1, 2018 to enter public tests that the station in 2019 successfully passed. According to the Department of Information and Mass Communications of the Ministry of Defense on December 1, 2019, the "Container" radar radar station interpreted on combat duty [3].

a)

b)

Fig. 3. Reception antennas OTHR "Container" (a) and review area (b).

"Container" is made according to the Bistatic System: the radar has two antenna fields - transmitting and receiving. It is intended for tracking the air situation in the area of responsibility, opening the nature of the actions of combat aviation, alerts on the start of the air attack and the transfer of the necessary information of air defense for interception of air targets. The task of the locator includes: detection, support and classification of aerodynamic aircraft (aircraft); tracking the daily activities of military and civil aviation; detection of potentially dangerous purposes; detection of mass and group takeoff of aviation; opening of the transfer of combat aviation; determination of the trajectory parameters of individual purposes and transfer to consumers; opening of aviation dispersal on spare airfields.

3 OTHR of the world

At the same time, it is advisable to consider unique in kind of foreign contradictional radar. Countries such as United States of America, Australia, France, Russia, and China, are also observed in the UK and China, the greatest success in mastering the technologies of the Ultrasonic detection [4]. Affordable open information on the overseas systems of foreign states allows us to conclude that the UK radar and China show standard characteristics: a detection range from 1000 to 3000 km in the azimuthal sector 60 ° in azimuth in the range of operating frequencies 5 ... 30 MHz. Despite the long-term experience of the United States, according to the available information, the system of the overseas detection of this country did not find wide use. At the moment, radars are known: MADRE (Magnetic-Drum Radar Equipment), WARF (Wide Aperture Research Facility), AN/FPS-95, AN/FPS-112 are dismantled due to moral and hardware obsolescence, the Conus system consisting of two locator nodes An / FPS-118 is also either dismantled or (according to another information) is canned. Rothr continues to work, built on the basis of AN / TPS-71 radar. Against the background of this, the attention of OTHR France and Australia deserves attention.

3.1 JORN (Australia)

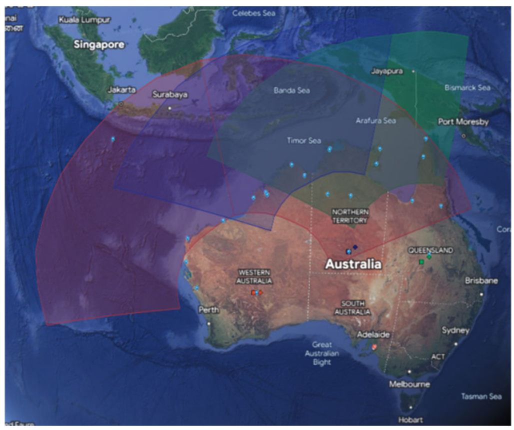
The development of the first experimental sample of the OTHR project of the JINDALEE began in 1974 [5]. For two years (1976-1978), research works were conducted on the radar. Immediately after that, work began to create a serial radar. As a result, the first data appeared in 1982, then in 1983 the first ship was discovered, and in 1984, the first capture and air target wiring. In 1986, it was decided to create a JORN system, the basis of which are two new radar. Currently, the JORN system includes two active radar stations in Queensland and Western Australia, the coordination center in South Australia, seven transponders, twelve ionosonda. Radar in Alice Springs with its own system of vertical and inclined ionosonda is used for scientific purposes, however, can be used as a third system radar. By the way, such a construction of the JORN system makes it possible to increase the accuracy of determining the target coordinates due to the adjustment under the current geophysical situation. The main distinguishing feature of the Australian radar is the size of the azimuthal sector of the review - 90 °! This is achieved due to the special design of the antenna canvase of the receiving part: the double row of 250 vertical monopoles with a height of 5.5 meters is achieved, the appleure of 3 km allows you to form a radiation diagram in a wide range with high accuracy (Figure 4).

3.2 NOSTRADAMUS (France)

A completely unique radar created in France in the 1990s and called "NOSTRADAMUS" (Nouveau Systeme Transhorizon Decametrique Appliquant Les Methodes Utilisees Dans Studio). [6] The development of this radar was preceded by the creation of Studio Peng station in 1968, and the first experiments on the return-inclined sounding of the ionosphere in France are dating back 1961.

OTHR "NOSTRADAMUS" refers to the monostatic type of radar, operates in the frequency range of 6-20 MHz and has a circular overview for azimuth. To implement the review sector at 360 °, the receiving-transmitting antenna grille is implemented as a star from three shoulders with a length of 400m and 80m wide, located at an angle of 120 degrees. Such a review sector is convenient for France due to its size and geographic location - the center of Europe. The location of the Nostradamus antenna and the area of responsibility are shown in Figure 5.

a)



b)

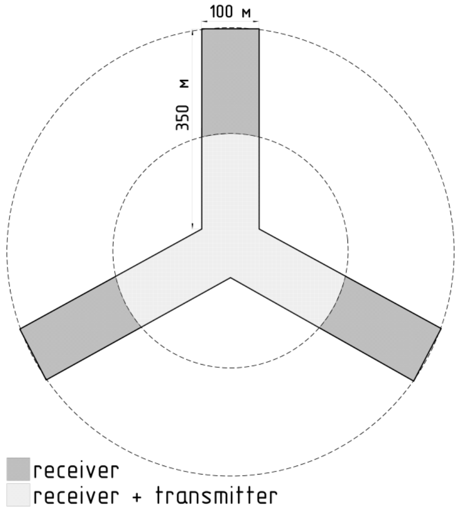
Fig. 4. Reception Antennas System OTH JORN (a) and viewing area (b).

4 Antenna Formation for Over-The-Horizon Radar

A standard embodiment of the receiving phased antenna array is the placement of several hundred elementary monopoles on the length of a more kilometer along the line, perpendicular to the direction of the signal radiation. The exception is the above-mentioned headlights of the French system, which provides a circular review of azimuth. Obviously, to ensure a circular review it is possible to build an antenna canvas by placing the simplest vibrators in a circle. This is how the phased antenna grille of the return-inclined sounding station "KRUG" is implemented - auxiliary station for the "DUGA" radar [7]. This placement of the antenna modules allows you to direct the bottom of 360 ° in azimuth.

Depending on the tasks solved, the appearance of the receiving complex is formed, including the antenna-feeder device. Application in the Digital Digital Digital Digital Diagram of the Focallery of the receiving tract requires use in the structure of constructing a radar of a large number of rendered reception devices and primary processing of radar information coming from the receiving antenna.

At the same time, the use of such devices located along the antenna leaf of a length of more than 1 km dictates the need to apply the pairing equipment, which should synchronize the operation of the separated receivers, remove the data and enter them for subsequent processing on the computing devices of the product receiving complex. In addition, such equipment should provide station synchronization and temporary binding of the transmitting and receiving complexes of the product.



a)

b)

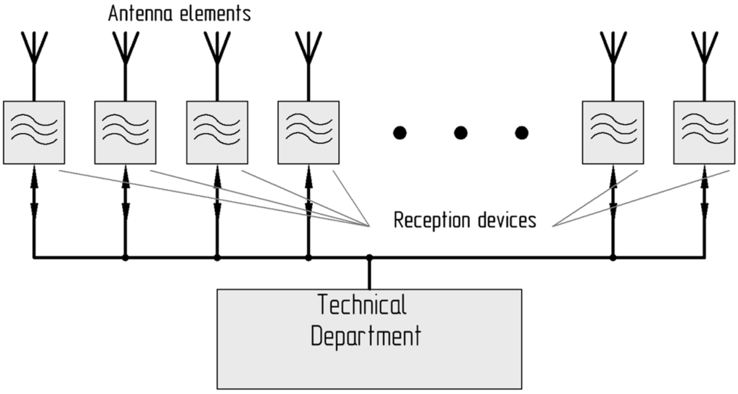
Fig. 5. Construction of the Nostradamus radar antenna (a) and the review area (b).

The antenna feeder device consists of several dozen separate receiving channels, including a mast with an elementary horizontal vibrator and the corresponding base receiver, the information from which is collected in the command center. Thus, the general structure of the receiving channel is as follows: Antenna Mast - receiver - control center.

4.1 Placement of Equipment under the Antenna

Obviously, one option is to install the hardware compactly under each antenna mast (Figure 6) [8]. This decision was applied in the JINDALEE Australian Radar, which is part of the JORN system. Such a solution leads to a number of restrictions: it is necessary to separately serve each receiving element, spare parts, tools and accessories are stored separately. The biggest problem in this case becomes synchronization and calibration of each receiving channel. For these purposes, you need to create accurate optical communication systems and synchronization. This eliminates the RF cables, which leads to an increase in the power of the transmitted calibration signal, and increases the accuracy of synchronization, and the final cost increases.

a)



b)

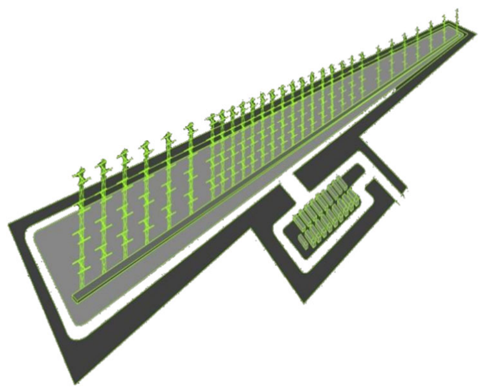
Fig. 6. Example of building receiving equipment.

A separate question that requires attention is the observance of the temperature modes of the equipment. In the climatic conditions of Australia, this task, apparently, is solved by installing fans, in the case of the implementation of such an option in Russia, it will be necessary to supplement the thermal installation, which increases the dimensions and the complexity of a separate receiving element.

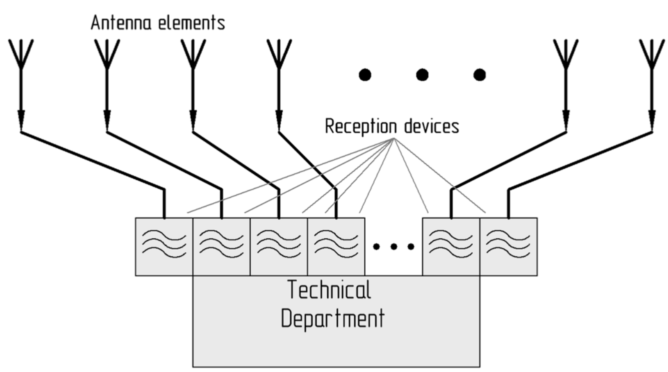
A similar option is implemented on French radar Nostradamus. Here the equipment is placed directly under the antenna elements in the tunnel, which facilitates the solution of the set of tasks: compliance with the temperature mode of the equipment, quick access and convenience of service at any time of day and year, phasing the antenna cables.

4.2 Placement of Equipment in the Center

Another option is to place all the equipment in the same room in the center of the antenna canvase (Figure 7). This is a classic solution for most radars, including an experienced option "Container" - radar 29B6. Of the advantages it should be noted the factor of the proximity of all functional equipment, service and repair efficiency, the lack of need to pull the kilometer control and synchronization cables. In stationary buildings there is no problem of compliance with temperature modes and storing spare inventory accessories. However, all this is outweighted by one disadvantage - the complexity of phasing more than a hundred reception cables from the antenna, the length of which is also up to 1 km. In the case of a relatively small opening antenna (as, for example, in 5H32 DUGA), this option is optimal. DUGA antennas consist of two liters (250 and 450 meters), the reception equipment is concentrated in the center of each.



a)



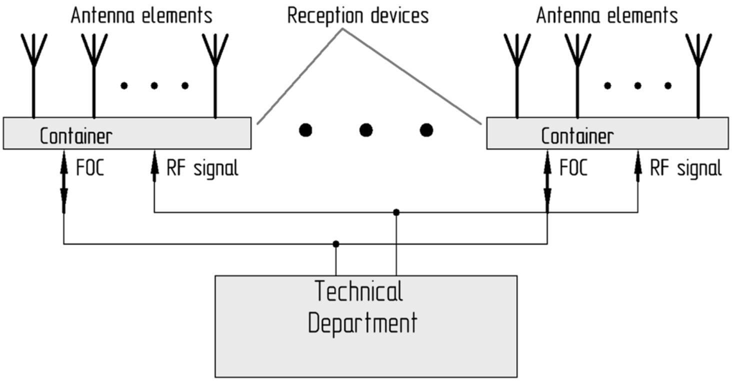
b)

Fig. 7. Example of building receiving equipment.

4.3 Placement of Equipment along the Antenna

According to the authors, the optimal option in this case is the placement of computing adopted equipment in containers directly near the antenna canvase (Figure 8). Such a solution is convenient for a number of reasons. First, the equipment placed in containers is more convenient to customize and maintain, it is also logical to store spare parts, tools and accessories. Secondly, in containers it is easier to maintain the operating temperature, combining the air conditioner and the heat gun depending on the conditions. Thirdly, such a solution reduces the length of cables that come from antenna to a receiving device, which in turn increases the sensitivity of the equipment and reduces the phase difference between the receiving channels. Such a solution improves the quality of the focus of the receiving antenna. However, it is necessary to solve the task of managing and synchronizing equipment in containers.

a)



b)

Fig. 8. Example of building receiving equipment.

5 Conclusion

The main disadvantage of OTHR is considered to be the low accuracy of determining the parameters of the target, while the main purpose of the contrary detection is the very fact of the existence of a goal [5]. Despite this, the contradictional radar showed their effectiveness in the early warning system. Based on the geographical conditions of the country, in different ways implement their overseas systems. Located in the center of Europe, the French radar Nostradamus controls the situation by 360 ° in azimuth. The Australian JORN system distant from most countries is interested in controlling the air and surface situation in the direction of Asia, each radar of this JINDALEE system is able to change the receiving focus diagram in the azimuth of 90°.

The application in the OTHR digital formation of the focus pattern of the receiving path requires use in the structure of building a radar of a large number of rendered reception devices and primary processing of radar information coming from the receiving antenna. At the same time, the use of such devices located along the antenna leaf of a length of about 1 km, dictates the need to use the conjugation equipment, which should synchronize the operation of the separated receivers, remove the data and enter them for subsequent processing on the computing devices of the receiving complex of the product. In addition, such equipment provides station synchronization and temporary binding of the transmitting and receiving complexes of the product.

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