Academicus Journal of Research
ISSN (E): 3054-3371
Volume 1, Issue 4, April, 2026
Website: https://researchiapress.com

PURPOSE, COMPOSITION AND CHARACTERISTICS OF A TYPICAL ANTENNA SYSTEM

Utkir Djurayev
4th-Year Cadet, Military Aviation Institute of the University of National Security and Defense of the Republic of Uzbekistan

Abstract

This article examines the fundamental principles of operation and the key parameters of antennas used in radar systems. It describes the functions of an antenna as a device for transmitting and receiving radio waves, as well as its role in ensuring effective formation and control of signal directivity. Particular attention is given to important antenna characteristics such as the shape and size of the radiation pattern and the mechanisms for beam steering.

The operating principle of the Hertzian dipole is discussed, along with its radiation pattern and the challenges associated with forming a narrow beam. The paper also addresses the technical features of radar antenna systems, including their dimensions, operating wavelength range, the shape and width of the main lobe of the radiation pattern, scanning speed, and the functioning of phased array antennas.

It is emphasized that different types of radar systems employ different wavelength ranges and radiation pattern characteristics to achieve maximum efficiency under various conditions. The conclusion highlights methods of interference mitigation and the role of antennas in protection against active jamming.

Keywords: Antenna System (AS); Radio waves; Receiving and transmitting antenna; Hertzian dipole; Radiation pattern (RP); Narrow beam; Effective antenna aperture; Operating wavelength range; Phased Array Antenna (PAA); Scanning speed; Interference and countermeasures; Surface-to-air missile systems (SAM systems); Electromagnetic waves (EMW); Mechanical and electronic scanning; Main lobe; Side lobes and back lobes.

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Introduction

Antenna systems (AS) play a key role in modern radar systems, providing both the transmission and reception of electromagnetic waves. These systems include not only the antennas themselves but also auxiliary equipment for controlling signal directivity.

The process of forming and controlling the directivity of radio waves is based on the principles of radiation and reception, which directly depend on the antenna design. It is essential that the antenna ensures precise beam control, minimizing the impact of interference and increasing the detection range of objects. The role of the antenna radiation pattern (RP) in this process is critical, as it determines how energy is distributed over different angles.

To create highly efficient antenna systems capable of operating under complex conditions, various parameters are taken into account, such as antenna size, the shape and beamwidth of the radiation pattern, as well as the ability to rapidly steer the beam. Successful implementation of these requirements is necessary to maintain the mobility and reliability of radar systems, which is particularly important for military and defense applications.

MAIN PART

1. Purpose and Composition of a Typical Antenna System

An antenna system (AS), which typically includes both receiving and transmitting antennas as well as beam-steering equipment, is intended for forming the directional characteristics of signals during transmission and reception, as well as for controlling their spatial orientation. Antenna systems commonly also include waveguide paths that connect the transmitter and receiver [1].

An antenna (from the Latin antenna - mast, yard) is a device designed for the transmission or reception of radio waves. A transmitting antenna converts electromagnetic oscillations supplied to it into radio waves that are radiated into space, while a receiving antenna, conversely, captures incident radio waves and converts them into oscillations that are subsequently processed by the receiver [4].

The operating principle of an antenna is based on the phenomenon of radiation-the conversion of high-frequency alternating current energy into the energy of propagating electromagnetic waves.

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The path along which a radio wave propagates depends on the shape and dimensions of the radiating antenna. The simplest example of an antenna system is the Hertzian dipole.

The Hertzian dipole (Fig. 1.1) consists of two conductors extending in opposite directions from the point where the energy source is connected. To ensure efficient radiation of the radio signal, the distance from the end of one conductor to the end of the other must be equal to half the wavelength of the emitted or received electromagnetic oscillation. The radiation pattern of a half-wave dipole has a toroidal shape-often described as a "doughnut" (Fig. 1.2) [2].

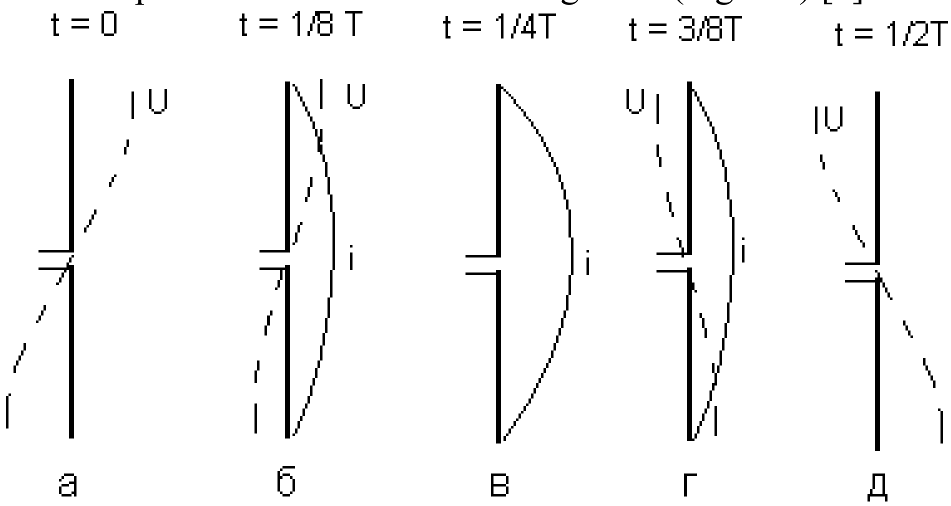

Fig. 1.1. Hertzian Dipole (Half-Wave Dipole)

The task of forming a narrow beam in the radiation pattern (RP) consists in creating a plane wavefront for the emitted electromagnetic wave (EM wave). The phase front of a wave is the set of points at which the wave has the same phase.

The area of a planar antenna or the surface bounded by the edge of an antenna reflector is called the antenna aperture. The radiating aperture of an antenna is defined as the surface over which the electromagnetic field is in phase, resulting in the formation of nearly plane waves. This surface is located at a distance equal to several wavelengths from the antenna itself and lies within the geometrical aperture area. Such an area is referred to as the effective aperture of the antenna and is denoted as Seff [8].

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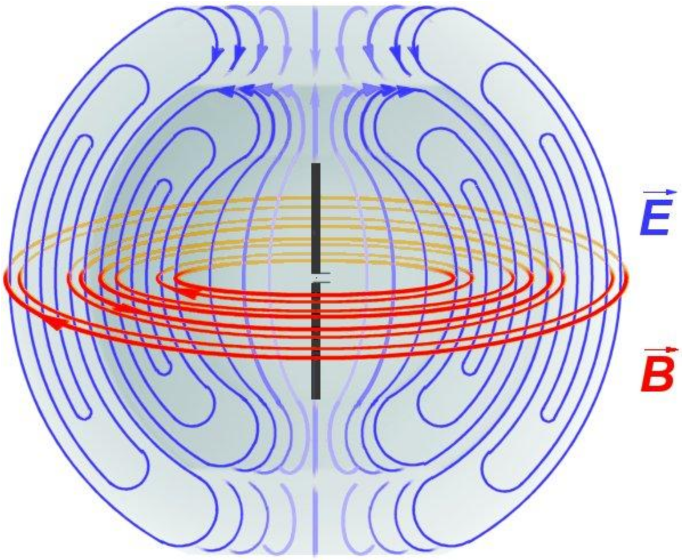

Fig. 1.2. Radiation Pattern of a Half-Wave Dipole

In general, the larger the geometrical dimensions of the antenna aperture and the greater the number of wavelengths that fit within its cross-section, the narrower the antenna radiation pattern can be, all other conditions being equal. This also leads to a dependence of antenna dimensions on the wavelength range. For example, to achieve the same beamwidth, a radar antenna operating at a wavelength of 3 meters must be 100 times larger than a radar antenna operating at a wavelength of 3 centimeters.

2. Technical Characteristics of the Antenna

The technical characteristics of radar antenna systems include several key parameters:

- mass and overall dimensions;
- operating wavelength range;
- radiation pattern shape and main lobe beamwidth;
- beam repositioning time, i.e., the achievable scanning speed;
- for phased array antennas (PAA), an additional parameter is the angular width of the operational sector within which the beam can be steered without degradation of the radiation pattern quality [3].

The antenna system of a radar is one of the largest and heaviest components of the overall structure. For example, the antenna system of a fire-control radar may

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have a total aperture area exceeding 10 m². Therefore, to ensure system mobility, radar designs often incorporate the capability to fold or stow the antenna system. Regarding the operating wavelength range, radar systems intended for low-altitude detection and fire control typically use the centimeter-wave band. Radar systems designed for medium- and high-altitude operation use the decimeter-wave band.

The antenna radiation pattern is a graphical representation of the distribution of power levels radiated by an antenna at equal distances from it in various directions within a given plane passing through the antenna's center or axis (Fig. 2.1).

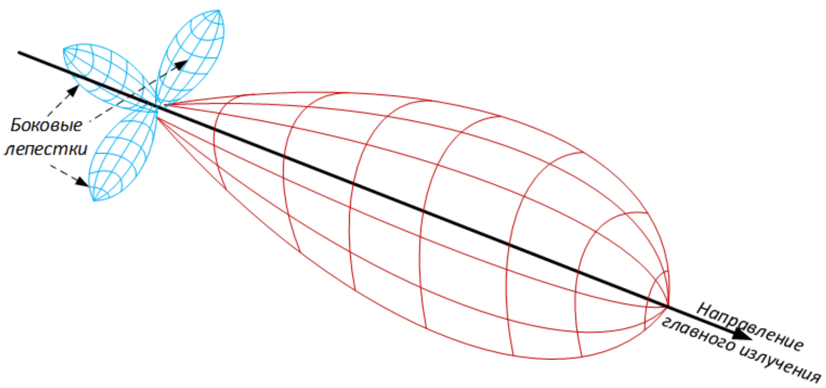

Fig. 2.1. Radiation Pattern Shape

All radar antennas are capable of providing a beamwidth on the order of 1 degree. However, it should be taken into account that, in addition to the main lobe of the radiation pattern (RP), all antennas also exhibit side lobes and back (or background) lobes. The level of the side lobes is typically 30-40 dB (i.e., 1,000–10,000 times) lower than that of the main lobe.

The shape of the main lobe can also vary. For accurate determination of two angular coordinates at long ranges, a pencil-beam radiation pattern is preferred. Conversely, for simultaneous coverage of all elevation angles at a given azimuth, it is preferable to use a radiation pattern that is narrow in azimuth and wide in elevation-for example, a fan-shaped or cosecant-squared pattern (Fig. 2.2) [8].

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Fig. 2.2. Radiation Pattern Cross-Sections in the Elevation Plane

Accounting for the shape of the radiation pattern (RP) is important because only the main lobe is capable of detecting weak target signals, whereas high-power interference signals can be received not only through the main lobe but also through the side and back (background) lobes. In this case, an interference signal received via a side lobe, due to its high power (70–80 dB greater than the target signal), can hinder target detection in the main lobe. The operation of onboard countermeasure systems against active jamming is based precisely on the principle of interference entering through the side lobes, particularly in systems employing mutual protection modes.

For surveillance radars, an important parameter is the scanning speed, which directly determines the update rate of airspace information. This speed typically ranges from 6 to 25 revolutions per minute for different types of radars included in surface-to-air missile (SAM) systems. In addition to mechanical circular scanning, phased array antennas (PAA) can employ electronic beam steering, which significantly enhances system capabilities. For modern fire-control radars, circular scanning is becoming less relevant. Instead, a key parameter is the beam switching time from one target to another within the operational sector, the angular width of which may exceed 100 degrees [7].

Conclusion

Antenna systems (AS) are an integral part of radar systems, ensuring high-precision transmission and reception of radio waves. The most critical parameters of antenna systems are the shape and beamwidth of the radiation pattern, which determine the effectiveness of target detection and beam control. The radiation

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pattern plays a key role in minimizing interference, as side and back lobes can significantly degrade signal quality.

The use of phased array antennas and high-speed scanning significantly improves radar performance, expanding capabilities for airspace monitoring and increasing system responsiveness. For different types of radar systems, optimal wavelength ranges are selected, which directly affect antenna design and its ability to operate efficiently under various conditions.

Thus, radar antenna systems are essential components that determine not only the accuracy of target detection but also the effectiveness of interference protection systems. The development and improvement of these systems significantly enhance their mobility, functionality, and resistance to interference, which is especially important in military and defense applications.

References

1. Petrov, V. S. Fundamentals of Radio Engineering and Radar Systems. Moscow: Energiya, 2015.
2. Shevchenko, A. V. Radar Systems and Their Components. Saint Petersburg: BHV-Petersburg, 2018.
3. Golubev, I. I., Cherkasov, V. L. Radar Antenna Systems. Moscow: Radio i Svyaz, 2017.
4. Kuznetsov, A. N. Theory of Antennas and Antenna Systems. Moscow: Vysshaya Shkola, 2016.
5. Emelyanov, P. S. Fundamentals of Antenna and Antenna System Design. Novosibirsk: Nauka, 2019.
6. Bondarev, Yu. I. Fundamentals of Radar. Moscow: IKT, 2020.
7. Solovyov, A. S. Antennas and Antenna Systems. Moscow: Tekhnosfera, 2014.
8. Makhov, V. V. Antennas and Their Use in Radar Systems. Moscow: Sovetskoe Radio, 2013.