D. Klyuev
Group 25RPh112
Tyumen State University
Institute of Physics and Chemistry
A. Yusupova
Tyumen State University
Department of Foreign languages and
Intercultural Professional Communication of Science
Senior Lecturer
Д.С. Клюев
студент группы 25РФ112
Тюменский государственный университет ИФиХ
А.А. Юсупова
Тюменский государственный университет
Кафедра иностранных языков и
межкультурной профессиональной коммуникации
естественнонаучных направлений
старший преподаватель

RADAR

РАДИОЛОКАЦИОННАЯ СИСТЕМА

Radar is an object-detection system which uses radio waves to determine the range, altitude, direction, or speed of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. The radar dish or antenna transmits pulses of radio waves or microwaves which bounce off any object in their path. The object returns a tiny part of the wave's energy to a dish or antenna which is usually located at the same site as the transmitter.

Radar was developed in secret in nations across the world just before and during World War II. The term RADAR was coined in 1941 by the United States Navy as an acronym for radio detection and ranging. The term radar has since entered English and other languages as the common noun radar, losing all capitalization.

The modern uses of radar are highly diverse, including air traffic control, radar astronomy, air-defense systems, antimissile systems; marine radars to locate landmarks and other ships; aircraft anticollision systems; ocean surveillance systems, outer space surveillance and rendezvous systems; meteorological precipitation monitoring; altimetry and flight control systems; guided missile target locating systems; and ground-penetrating radar for geological observations. High tech radar systems are associated with digital signal processing and are capable of extracting objects from very high noise levels.

Other systems similar to radar have been used in other parts of the electromagnetic spectrum. One example is "lidar", which uses visible light from lasers rather than radio waves.

The information provided by radar includes the bearing and range (and therefore position) of the object from the radar scanner. It is thus used in many different fields where the need for such positioning is crucial. The first use of radar was for military purposes: to locate air, ground and sea targets. This evolved in the civilian field into applications for aircraft, ships, and roads.

In aviation, aircraft are equipped with radar devices that warn of obstacles in or approaching their path and give accurate altitude readings. The first commercial device fitted to aircraft was a 1938 Bell Lab unit on some United Air Lines aircraft. They can land in fog at airports equipped with radar-assisted ground-controlled approach systems, in which the plane's flight is observed on radar screens while operators radio landing directions to the pilot.

Marine radars are used to measure the bearing and distance of ships to prevent collision with other ships, to navigate and to fix their position at sea when within range of shore or other fixed references such as islands, buoys, and lightships. In port or in harbour, vessel traffic service radar systems are used to monitor and regulate ship movements in busy waters. Police forces use radar guns to monitor vehicle speeds on the roads.

Meteorologists use radar to monitor precipitation. It has become the primary tool for short-term weather forecasting and to watch for severe weather such as thunderstorms, tornadoes, winter storms, precipitation types, etc. Geologists use specialised ground-penetrating radars to map the composition of the Earth's crust.

A radar system has a transmitter that emits radio waves called radar signals in predetermined directions. When these come into contact with an object they are usually reflected or scattered in many directions. Radar signals are reflected especially well by materials of considerable electrical conductivity—especially by most metals, by seawater, by wet land, and by wetlands. Some of these make the use of radar altimeters possible. The radar signals that are reflected back towards the transmitter are the desirable ones that make radar work. If the object is moving either closer or farther away, there is a slight change in the frequency of the radio waves, caused by the Doppler effect.

Radar receivers are usually, but not always, in the same location as the transmitter. Although the reflected radar signals captured by the receiving antenna are usually very weak, these signals can be strengthened by electronic amplifiers. More sophisticated methods of signal processing are also used in order to recover useful radar signals.

The weak absorption of radio waves by the medium through which it passes is what enables radar sets to detect objects at relatively long ranges—ranges at which other electromagnetic wavelengths, such as visible light, infrared light, and ultraviolet light, are too strongly attenuated. Such things as fog, clouds, rain, falling snow, and sleet that block visible light are usually transparent to radio waves. Certain radio frequencies that are absorbed or scattered by water vapor, raindrops, or atmospheric gases (especially oxygen) are avoided in designing radars except when detection of these is intended.

Electromagnetic waves reflect (scatter) from any large change in the dielectric constant or diamagnetic constants. This means that a solid object in air or a vacuum, or other significant change in atomic density between the object and what is surrounding it, will usually scatter radar (radio) waves. This is particularly true for electrically conductive materials, such as metal and carbon fiber, making radar well suited to the detection of aircraft and ships. Radar absorbing material, containing resistive and sometimes magnetic substances, is used on military vehicles to reduce radar reflection.

Radar waves scatter in a variety of ways depending on the size (wavelength) of the radio wave and the shape of the target. If the wavelength is much shorter than the target's size, the wave will bounce off in a way similar to the way light is reflected by a mirror. If the wavelength is much longer than the size of the target, the target may not be visible because of poor reflection. Low Frequency radar technology is dependent on resonances for detection, but not identification, of targets. This is described by Rayleigh scattering, an effect that creates the Earth's blue sky and red sunsets. When the two length scales are comparable, there may be resonances. Early radars used very long wavelengths that were larger than the targets and received a vague signal, whereas some modern systems use shorter wavelengths (a few centimeters or shorter) that can image objects as small as a loaf of bread.

Short radio waves reflect from curves and corners, in a way similar to glint from a rounded piece of glass. The most reflective targets for short wavelengths have 90° angles between the reflective surfaces. A structure consisting of three flat surfaces meeting at a single corner, like the corner on a box, will reflect waves entering its opening directly back at the source. These so-called corner reflectors are commonly used as radar reflectors to make otherwise difficult-to-detect objects easier to detect and are often found on boats in order to improve their detection in a rescue situation and to reduce collisions. For similar reasons, objects attempting to avoid detection will angle their surfaces in a way to eliminate inside corners and avoid surfaces and edges perpendicular to likely detection directions, which leads to "odd" looking stealth aircraft. These precautions do not completely eliminate reflection because of diffraction, especially at longer wavelengths. Half wavelength long wires or strips of conducting material, such as chaff, are very reflective but do not direct the scattered energy back toward the source. The extent to which an object reflects or scatters radio waves is called its radar cross section.

Polarization

In the transmitted radar signal, the electric field is perpendicular to the direction of propagation, and this direction of the electric field is the polarization of the wave. Radars use horizontal, vertical, linear and circular polarization to detect different types of reflections. For example, circular polarization is used to minimize the interference caused by rain. Linear polarization returns usually indicate metal surfaces. Random polarization returns usually indicate a fractal surface, such as rocks or soil, and are used by navigation radars.

Limiting factors

Beam path and range

The radar beam would follow a linear path in vacuum, but it really follows a somewhat curved path in the atmosphere because of the variation of the refractive index of air, that is the radar horizon. Even when the beam is emitted parallel to the ground, it will rise above it as the Earth curvature sinks below the horizon. Furthermore, the signal is attenuated by the medium it crosses, and the beam disperses.

The maximum range of a conventional radar can be limited by a number of factors:

Line of sight, which depends on height above ground.

The maximum non-ambiguous range which is determined by the pulse repetition frequency. The maximum non-ambiguous range is the distance the pulse could travel and return before the next pulse is emitted.

Radar sensitivity and power of the return signal as computed in the radar equation. This includes factors such as environmentals and the size (or radar cross section) of the target.

Noise

Signal noise is an internal source of random variations in the signal, which is generated by all electronic components. Noise typically appears as random variations superimposed on the desired echo signal received in the radar receiver. The lower the power of the desired signal, the more difficult it is to discern it from the noise. Noise figure is a measure of the noise produced by a receiver compared to an ideal receiver, and this needs to be minimized.

Noise is also generated by external sources, most importantly the natural thermal radiation of the background scene surrounding the target of interest. In modern radar systems, the internal noise is typically about equal to or lower than the external scene noise. An exception is if the radar is aimed upwards at clear sky, where the scene is so "cold" that it generates very little thermal noise. The thermal noise is given by kB T B, where T is temperature, B is bandwidth (post matched filter) and kB is Boltzman's constant. There is an appealing intuitive interpretation of this relationship in a radar. Matched filtering allows us to compress the entire energy received from a target into a single bin (be it a range, Doppler, elevation, or azimuth bin). On the surface it would appear then that within a fixed interval of time one could obtain perfect, error free, detection. To do this one simply compresses all energy into an infinitesimal time slice. What limits this approach in the real world is that, while time is arbitrarily divisible, current is not. The quanta of electrical energy is an electron, and so the best one can do is match filter all energy into a single electron.

Interference

Radar systems must overcome unwanted signals in order to focus only on the actual targets of interest. These unwanted signals may originate from internal and external sources, both passive and active. The ability of the radar system to overcome these unwanted signals defines its signal-to-noise ratio (SNR). SNR is defined as the ratio of a signal power to the noise power within the desired signal.

In less technical terms, SNR compares the level of a desired signal (such as targets) to the level of background noise. The higher a system's SNR, the better it is in isolating actual targets from the surrounding noise signals.

Clutter

Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators. Such targets include natural objects such as ground, sea, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), atmospheric turbulence, and other atmospheric effects, such as ionosphere reflections, meteor trails, and three body scatter spike. Clutter may also be returned from man-made objects such as buildings and, intentionally, by radar countermeasures such as chaff.

Some clutter may also be caused by a long radar waveguide between the radar transceiver and the antenna. In a typical plan position indicator (PPI) radar with a rotating antenna, this will usually be seen as a "sun" or "sunburst" in the centre of the display as the receiver responds to echoes from dust particles and misguided RF in the waveguide. Adjusting the timing between when the transmitter sends a pulse and when the receiver stage is enabled will generally reduce the sunburst without affecting the accuracy of the range, since most sunburst is caused by a diffused transmit pulse reflected before it leaves the antenna. Clutter is considered a passive interference source, since it only appears in response to radar signals sent by the radar.

There are several methods of detecting and neutralizing clutter. Many of these methods rely on the fact that clutter tends to appear static between radar scans. Therefore, when comparing subsequent scan echoes, desirable targets will appear to move, and all stationary echoes can be eliminated. Sea clutter can be reduced by using horizontal polarization, while rain is reduced with circular polarization (note that meteorological radars wish for the opposite effect, therefore using linear polarization to detect precipitation). Other methods attempt to increase the signal-to-clutter ratio.

The most effective clutter reduction technique is pulse-Doppler radar. Doppler separates clutter from aircraft and spacecraft using a frequency spectrum, so individual signals can be separated from multiple reflectors located in the same volume using velocity differences. This requires a coherent transmitter. Another technique is moving target indicator that subtracts the receive signal from two successive pulses using phase to reduce signals from slow moving objects. This can be adapted for systems that lack a coherent transmitter, such as time-domain pulse-amplitude radar.

Constant False Alarm Rate, a form of Automatic Gain Control (AGC), is a method relying on the fact that clutter returns far outnumber echoes from targets of interest. The receiver's gain is automatically adjusted to maintain a constant level of overall visible clutter. While this does not help detect targets masked by stronger surrounding clutter, it does help to distinguish strong target sources. In the past, radar AGC was electronically controlled and affected the gain of the entire radar receiver. As radars evolved, AGC became computer-software controlled and affected the gain with greater granularity in specific detection cells.

Radar multipath echoes from a target cause ghosts to appear.

Clutter may also originate from multipath echoes from valid targets caused by ground reflection, atmospheric ducting or ionospheric reflection/refraction (e.g. Anomalous propagation). This clutter type is especially bothersome since it appears to move and behave like other normal (point) targets of interest. In a typical scenario, an aircraft echo is reflected from the ground below, appearing to the receiver as an identical target below the correct one. The radar may try to unify the targets, reporting the target at an incorrect height, or eliminating it on the basis of jitter or a physical impossibility. These problems can be overcome by incorporating a ground map of the radar's surroundings and eliminating all echoes which appear to originate below ground or above a certain height. In newer Air Traffic Control radar equipment, algorithms are used to identify the false targets by comparing the current pulse returns, to those adjacent, as well as calculating return improbabilities.

REFERENCES:

1. The Radar Pages. [Электронный ресурс]. – Режим доступа: http://www.radarpages.co.uk/index.htm.
2. Wikipedia. [Электронный ресурс]. – Режим доступа: http://en.wikipedia.org/wiki/Radar