

Abstract

A satellite is an object which has been placed into orbit by human endeavor. Such objects are sometimes called artificial satellites to distinguish them from natural satellites such as the Moon. Antennas are another part of satellite communication subsystem. In fact the antennas on board the satellite serve as an interface between the Earth stations on the ground and various satellite sub-systems during operations. Antennas receive the uplink signal and transmit to downlink signals. In addition they provide single link for the satellite telemetry, command and ranging systems which in conjunction with attitude control subsystem provides beacon tracking signals for precise pointing of the antenna towards the Earth coverage areas. The design of satellite antenna is conditioned by the required coverage. It should be remembered that antennas are the one of the key elements in a satellite communication system since their gain values directly determine the amount of received power.

Types of antenna system use in satellite communication

Parabolic antenna

Horn Antenna

Helical antenna

Phased array

Applications

Broadcasting

Navel Usages

Space probe communication

Weather research usages

Introduction

A satellite is an object which has been placed into orbit by human endeavor. Such objects are sometimes called artificial satellites to distinguish them from natural satellites such as the Moon.

A full size model of the Earth observation satellite ERS 2



History of artificial satellites:

The first artificial satellite was Sputnik 1, launched by the Soviet Union on 4 October 1957, and initiating the Soviet Sputnik program, with Sergei Korolev as chief designer and Kerim Kerimov as his assistant. This in turn triggered the Space Race between the Soviet Union and the United States.

Sputnik 1 helped to identify the density of high atmospheric layers through measurement of its orbital change and provided data on radio-signal distribution in the ionosphere. Because the satellite's body was filled with pressurized nitrogen, *Sputnik 1* also provided the first opportunity for meteoroid detection, as a loss of internal pressure due to meteoroid penetration of the outer surface would have been evident in the temperature data sent back to Earth. The unanticipated announcement of *Sputnik 1*'s success precipitated the Sputnik crisis in the United States and ignited the so-called Space Race within the Cold War. *Sputnik 2* was launched on November 3, 1957 and carried the first living passenger into orbit, a dog named Laika.

In May, 1946, Project RAND had released the Preliminary Design of an Experimental World-Circling Spaceship, which stated, "A satellite vehicle with appropriate instrumentation can be expected to be one of the most potent scientific tools of the Twentieth Century. The United States had been considering launching orbital satellites since 1945 under the Bureau of Aeronautics of the United States Navy. The United States Air Force's Project RAND eventually released the above report, but did not believe that the satellite was a potential military weapon; rather, they considered it to be a tool for science, politics, and propaganda. In 1954, the Secretary of Defense stated, "I know of no American satellite program."

On July 29, 1955, the White House announced that the U.S. intended to launch satellites by the spring of 1958. This became known as Project Vanguard. On July 31, the Soviets announced that they intended to launch a satellite by the fall of 1957.

Following pressure by the American Rocket Society, the National Science Foundation, and the International Geophysical Year, military interest picked up and in early 1955 the Air Force and Navy were working on Project Orbiter, which involved using a Jupiter C rocket to launch a satellite. The project succeeded, and Explorer 1 became the United States' first satellite on January 31, 1958.

In June 1961, three-and-a-half years after the launch of Sputnik 1, the Air Force used resources of the United States Space Surveillance Network to catalog 115 Earth-orbiting satellites.

The largest artificial satellite currently orbiting the Earth is the International Space Station.

Antenna System

Antennas are another part of satellite communication subsystem. In fact the antennas on board the satellite serve as an interface between the Earth stations on the ground and various satellite sub-systems during operations. Antennas receive the uplink signal and transmit to downlink signals. In addition they provide single link for the satellite telemetry, command and ranging systems which in conjunction with attitude control subsystem provides beacon tracking signals for precise pointing of the antenna towards the Earth coverage areas. The design of satellite antenna is conditioned by the required coverage. It should be remembered that antennas are the one of the key elements in a satellite communication system since their gain values directly determine the amount of received power.

Some Basic things

Bandwidth, Beamwidth, and Polarization

Bandwidth, beamwidth, and polarization are three important terms dealing respectively with the operating frequency range, the degree of concentration or the radiation pattern, and the space orientation of the radiated waves.

Bandwidth

The term bandwidth refers to the range of frequencies the antenna will reflect effectively; i.e., the antenna will *perform satisfactorily* throughout its size of frequencies. When the antenna power drops to $\frac{1}{2}$ (3 dB), the upper and lower extremities of these frequencies have been reached and the antenna no longer *perform satisfactorily*.

Antennas that operate over a wide frequency range and still maintain satisfactory performance must have compensating circuits switched into the system to maintain impedance matching, thus ensuring no deterioration of the transmitted signals.

Beamwidth

The *beamwidth* of an antenna is described as the angles created by comparing the half-power points (3 dB) on the main radiation lobe to its maximum power point. In an example, the *beam angle* is 30°, which is the sum of the two angles created at the points where the *field strength* drops to 0.707 of the maximum voltage at the center of the lobe. (These points are known as the half-power points.)

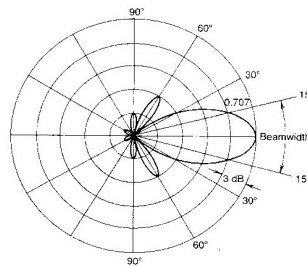


FIGURE 9-9 Beamwidth.

Polarization

Polarization of an antenna refers to the direction in space of the *E* field (electric vector) portion of the electromagnetic wave being radiated by the transmitting system. Low-frequency antennas are usually vertically polarized because of ground effect (reflected waves, etc.) and physical construction methods. High-frequency antennas are generally horizontally polarized.

Types of antenna system

1. Parabolic antenna

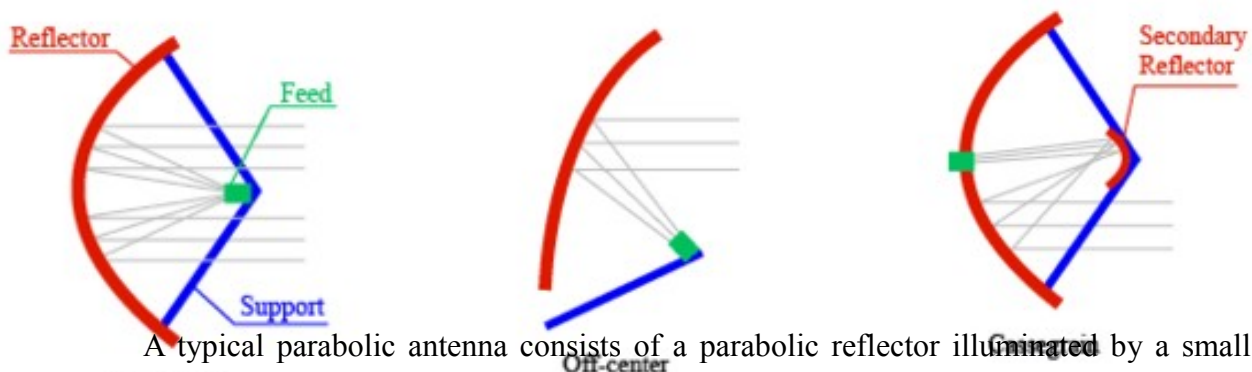


A parabolic antenna for Erdfunkstelle Raisting, the biggest facility for satellite communication in the world, based in Raisting, Bavaria, Germany.

A **parabolic antenna** is a high-gain reflector antenna used for radio, television and data communications, and also for radiolocation (RADAR), on the UHF and SHF parts of the electromagnetic spectrum. The relatively short wavelength of electromagnetic (radio) energy at these frequencies allows reasonably sized reflectors to exhibit the very desirable highly directional response for both receiving and transmitting.

With the advent of TVRO and DBS satellite television, the parabolic antenna became a ubiquitous feature of urban, suburban, and even rural, landscapes. Extensive terrestrial microwave links, such as those between cellphone base stations, and wireless WAN/LAN applications have also proliferated this antenna type. Earlier applications included ground-based and airborne radar and radio astronomy. The largest "dish" antenna in the world is the Arecibo Observatory's radio telescope at Arecibo, Puerto Rico, but, for beam-steering reasons, it is actually a spherical, rather than parabolic, reflector.

Design: Main types of parabolic antennas



A typical parabolic antenna consists of a parabolic reflector illuminated by a small feed antenna.

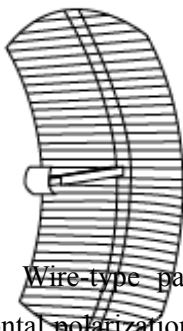
The reflector is a metallic surface formed into a paraboloid of revolution and (usually) truncated in a circular rim that forms the diameter of the antenna. This paraboloid possesses a

distinct focal point by virtue of having the reflective property of parabolas in that a point light source at this focus produces a parallel light beam aligned with the axis of revolution.

The feed antenna is placed at the reflector focus. This antenna is typically a low-gain type such as a half-wave dipole or a small waveguide horn. In more complex designs, such as the Cassegrain antenna, a sub-reflector is used to direct the energy into the parabolic reflector from a feed antenna located away from the primary focal point. The feed antenna is connected to the associated radio-frequency (RF) transmitting or receiving equipment by means of a coaxial cable

Applying the formula to the 25-meter-diameter antennas used by the VLA and VLBA radio telescopes at a wavelength of 21 cm (1.42 GHz, a common radio astronomy frequency) yields an approximate maximum gain of 140,000 times or about 50 dBi (decibels above the isotropic level).

Structure:



Wire-type parabolic antenna (Wi-Fi / WLAN antenna at 2,4Ghz). Oriented to provide horizontal polarization: the reflector wires and the feed element are both horizontal. This antenna has a greater extent in the vertical plane and hence, a narrower beamwidth in that plane. The feed element has a wider beam in the vertical direction than the horizontal and hence matches the reflector by illuminating it fully.

The reflector dish can be solid, mesh or wire in construction and it can be either fully circular or somewhat rectangular depending on the radiation pattern of the feeding element. Solid antennas have more ideal characteristics but are troublesome because of weight and high wind load. Mesh and wire types weigh less, are easier to construct and have nearly ideal characteristics if the holes or gaps are kept under 1/10 of the wavelength.

More exotic types include the off-set parabolic antenna, Gregorian and Cassegrain types. In the off-set, the feed element is still located at the focal point, which because of the angles utilized, is usually located below the reflector so that the feed element and support do not interfere with the main beam. This also allows for easier maintenance of the feed, but is usually only found in smaller antennas.

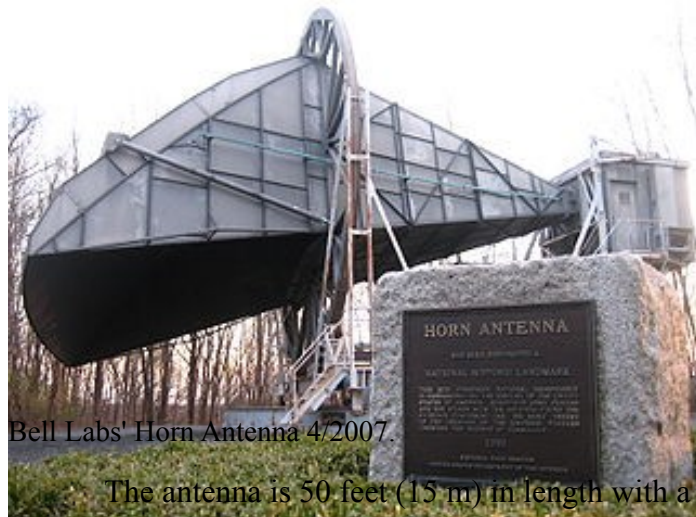
The Gregorian and Cassegrain types, sometimes generically referred to as "dual optics" antennas, utilize a secondary reflector, or "sub-reflector", allowing for better control over the colimated beam as well as allowing the antenna feed system to be more compact. These antennas are usually much larger where prime focus and off-set construction are not as practical. The feed element is usually located in a "feed horn" which protrudes out from the main reflector. This setup is used when the feed element is bulky or heavy such as when it contains a pre-amplifier or even the actual receiver or transmitter. Parabolic antenna theory closely follows optics theory. So a Gregorian antenna can be identified by the fact that it uses a concave sub-reflector, while a Cassegrain antenna uses a convex sub-reflector.

2. Horn Antenna

The **Horn Antenna**, at Bell Telephone Laboratories in Holmdel, New Jersey, is listed as a National Historic Landmark because of its association with the research work of two radio astronomers, Arno Penzias and Robert Wilson.^[1] In 1965 while using the Horn Antenna, Penzias and Wilson stumbled on the microwave background radiation that permeates the universe. Cosmologists quickly realized that Penzias and Wilson had made the most important discovery in modern astronomy since Edwin Hubble demonstrated in the 1920s that the universe was expanding. This discovery provided the evidence that confirmed George Gamow's and Abbe Georges Lemaitre's "Big Bang" theory of the creation of the universe and forever changed the science of cosmology — the study of the history of the universe — from a field for unlimited theoretical speculation into a subject disciplined by direct observation. In 1978 Penzias and Wilson received the Nobel Prize for Physics for their momentous discovery.

Description

The Horn Antenna at Bell Telephone Laboratories in Holmdel, New Jersey, was constructed in 1959 to support Project Echo—the National Aeronautics and Space Administration's passive communications satellite project.



Bell Labs' Horn Antenna 4/2007.

The antenna is 50 feet (15 m) in length with a radiating aperture of 20 by 20 feet (6 by 6 m) and is made of aluminum. The antenna's elevation wheel is 30 feet (10 m) in diameter and supports the weight of the structure by means of rollers mounted on a base frame. All axial or thrust loads are taken by a large ball bearing at the apex end of the horn. The horn continues through this bearing into the equipment cab. The ability to locate receiver equipment at the apex of the horn, thus eliminating the noise contribution of a connecting line, is an important feature of the antenna. A radiometer for measuring the intensity of radiant energy is found in the equipment cab.

The triangular base frame of the antenna is made from structural steel. It rotates on wheels about a center pintle ball bearing on a track 30 feet (10 m) in diameter. The track consists of stress-relieved, planed steel plates which are individually adjusted to produce a track flat to about 1/64 inch (0.4 mm). The faces of the wheels are cone-shaped to minimize sliding friction. A tangential force of 100 pounds force (400 N) is sufficient to start the antenna in motion.

To permit the antenna beam to be directed to any part of the sky, the antenna is mounted with the axis of the horn horizontal. Rotation about this axis affords tracking in elevation while the entire assembly is rotated about a vertical axis for tracking in the azimuth.

With the exception of the steel base frame, which was made by a local steel company, the antenna was fabricated and assembled by the Holmdel Laboratory shops under the direction of Mr. H. W. Anderson, who also collaborated on the design. Assistance in the design was also given by Messrs. R. O'Regan and S. A. Darby. Construction of the antenna was completed under the direction of Mr. A. B. Crawford from Freehold Borough, New Jersey.

When not in use, the antenna azimuth sprocket drive is disengaged, thus permitting the structure to "weathervane" and seek a position of minimum wind resistance. The antenna

was designed to withstand winds of 100 miles per hour (160 km/h) and the entire structure weighs 18 tons.

The Horn Antenna combines several ideal characteristics: it is extremely broad-band, has calculable aperture efficiency, and the back and sidelobes are so minimal that scarcely any thermal energy is picked up from the ground. Consequently it is an ideal radio telescope for accurate measurements of low levels of weak background radiation.

A plastic clapboarded utility shed 10 by 20 feet (3 by 6 m), with two windows, a double door and a sheet metal roof, is located next to the Horn Antenna. This structure houses equipment and controls for the Horn Antenna and is included as a part of the designation of U.S. National Historic Landmark.

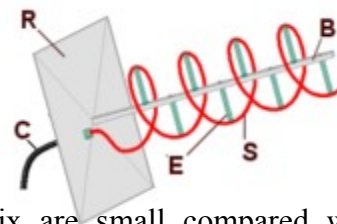
3. Helical antenna



Helical antenna for WLAN communication, working frequency app. 2.4 GHz

A **helical antenna** is an antenna consisting of a conducting wire wound in the form of a helix. In most cases, helical antennas are mounted over a ground plane. Helical antennas can operate in one of two principal modes: normal (broadside) mode or axial (or endfire) mode.

B: Central_Support,
C: Coaxial_Cable,
E: Spacers/Supports_for_the_Helix,
R: Reflector/Base,
S: Helical Aerial Element



In the *normal mode*, the dimensions of the helix are small compared with the wavelength. The far field radiation pattern is similar to an electrically short dipole or monopole. These antennas tend to be inefficient radiators and are typically used for mobile communications where reduced size is a critical factor. A Tesla coil secondary coil is also an example.

In the *axial mode*, the helix dimensions are at or above the wavelength of operation. The antenna then falls under the class of waveguide antennas, and produces true circular

polarization. These antennas are best suited for animal tracking and space communication, where the orientation of the sender and receiver cannot be easily controlled, or where the polarization of the signal may change. Antenna size makes them unwieldy for low frequency operation, so they are commonly employed only at frequencies ranging from VHF up to microwave.

Axial-mode helical antennas can have either a clockwise (right-handed) or counter-clockwise (left-handed) polarization. Helical antennas can receive signals with any type of linear polarization, such as horizontal or vertical polarization, but clockwise polarised antennas suffer a severe gain loss when receiving counter-clockwise signals, and vice versa.

Helical antennas are composed of a single driven element S which is coiled in a helix. In axial-mode operation, the winding sense of the coil determines its polarization, while the space between the coils (app. $0.25 \times \text{wavelength}$) and the diameter of the coils (app. $1/3$ of the wavelength) determine its wavelength. The length of the coil determines how directional the antenna will be and its gain; longer antennas will be more sensitive in the direction in which they point. A reflector R is almost always used to increase the sensitivity, or gain, in one direction (away from the reflector)

4. Phased array

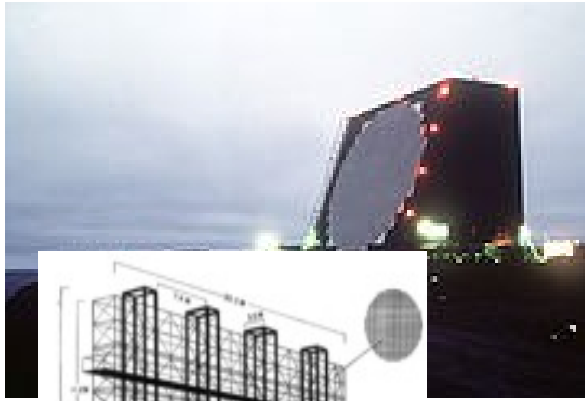


Cobra Dane Fylingdales

PAVE PAWS
phased array radar in Alaska



RAF



Mammut phased array radar WW II

In wave theory, a **phased array** is a group of antennas in which the relative phases of the respective signals feeding the antennas are varied in such a way that the effective radiation pattern of the array is reinforced in a desired direction and suppressed in undesired directions. This technology was originally developed by Nobel Laureate Luis Alvarez during World War II as a rapidly-steerable radar system for "ground-controlled approach", a system to aid in the landing of airplanes in England. GEMA in Germany built at the same time the PESA Mammut 1. It was later adapted for radio astronomy, leading to Physics Nobel Prizes for Antony Hewish and Martin Ryle after several large phased arrays were developed at the University of Cambridge. The design is also used in radar, and is generalized in interferometric radio antennas. Recently, DARPA researchers announced a 16 element phased array integrated with all necessary circuits to send at 30-50 GHz on a single silicon chip for military purposes.

An **antenna array** is a multiple of active antennas coupled to a common source or load to produce a directive radiation pattern. Usually the spatial relationship also contributes to the directivity of the antenna. Use of the term "active antennas" is intended to describe elements whose energy output is modified due to the presence of a source of energy in the element (other than the mere signal energy which passes through the circuit) or an element in which the energy output from a source of energy is controlled by the signal input.

Applications

The relative amplitudes of — and constructive and destructive interference effects among — the signals radiated by the individual antennas determine the effective radiation pattern of the array. A phased array may be used to point a fixed radiation pattern, or to scan rapidly in azimuth or elevation. Simultaneous electrical scanning in both azimuth and elevation was first demonstrated in a phased array antenna at Hughes Aircraft Company, Culver City, CA, in 1957 (see Joseph Spradley, "A Volumetric Electrically Scanned Two-

Dimensional Microwave Antenna Array,” IRE National Convention Record, Part I - Antennas and Propagation; Microwaves, New York: The Institute of Radio Engineers, 1958, 204-212). When phased arrays are used in sonar, it is called beamforming.

The phased array is used for instance in optical communication as a wavelength-selective splitter.

For information about active as well as passive phased array radars, see also active electronically scanned array.

1. Broadcasting

In broadcast engineering, phased arrays are required to be used by many AM broadcast radio stations to enhance signal strength and therefore coverage in the city of license, while minimizing interference to other areas. Due to the differences between daytime and nighttime ionospheric propagation at mediumwave frequencies, it is common for AM broadcast stations to change between day (groundwave) and night (skywave) radiation patterns by switching the phase and power levels supplied to the individual antenna elements (mast radiators) daily at sunrise and sunset. More modest phased array longwire antenna systems may be employed by private radio enthusiasts to receive longwave, mediumwave (AM) and shortwave radio broadcasts from great distances.

On VHF, phased arrays are used extensively for FM broadcasting. These greatly increase the antenna gain, magnifying the emitted RF energy toward the horizon, which in turn greatly increases a station's broadcast range. In these situations, the distance to each element from the transmitter is identical, or is one (or other integer) wavelength apart. Phasing the array such that the lower elements are slightly delayed (by making the distance to them longer) causes a downward beam tilt, which is very useful if the antenna is quite high on a radio tower.

Other phasing adjustments can increase the downward radiation in the far field without tilting the main lobe, creating null fill to compensate for extremely high mountaintop locations, or decrease it in the near field, to prevent excessive exposure to those workers or even nearby homeowners on the ground. The latter effect is also achieved by half-wave spacing – inserting additional elements halfway between existing elements with full-wave spacing. This phasing achieves roughly the same horizontal gain as the full-wave spacing; that is, a five-element full-wave-spaced array equals a nine- or ten-element half-wave-spaced array.

2. Naval usage



Port and starboard octagonal panels are the phased array radar, AN/SPY-1D, on the *USS Mason* (DDG-87).

Phased array radar systems are also used by warships of several navies including the Chinese, Japanese, Norwegian, Spanish, Korean and United States' navies in the Aegis combat system. Phased array radars allow a warship to use one radar system for surface detection and tracking (finding ships), air detection and tracking (finding aircraft and missiles) and missile uplink capabilities. Prior to using these systems, each surface-to-air missile in flight required a dedicated fire-control radar, which meant that ships could only engage a small number of simultaneous targets. Phased array systems can be used to control missiles during the mid-course phase of the missile's flight. During the terminal portion of the flight, continuous-wave fire control directors provide the final guidance to the target. Because the radar beam is electronically steered, phased array systems can direct radar beams fast enough to maintain a fire control quality track on many targets simultaneously while also controlling several in-flight missiles. The AN/SPY-1 phased array radar, part of the Aegis combat system deployed on modern U.S. cruisers and destroyers, "is able to perform search, track and missile guidance functions simultaneously with a capability of over 100 targets." Likewise, the Thales Herakles phased array multi-function radar onboard the Formidable class frigates of the Republic of Singapore Navy has a track capacity of 200 targets and is able to achieve automatic target detection, confirmation and track initiation in a single scan, while simultaneously providing mid-course guidance updates to the MBDA Aster missiles launched from the ship. The German Navy and the Dutch Navy have developed the Active Phased Array Radar System (APAR).



Active Phased Array Radar mounted on top of Sachsen class frigate F220 *Hamburg's* superstructure of the German Navy.

3. Space probe communication

The MESSENGER spacecraft is a mission to the planet Mercury (arrival 18 March 2011). This spacecraft is the first deep-space mission to use a phased-array antenna for communications. The radiating elements are linearly-polarized, slotted waveguides. The antenna, which uses the X band, uses 26 radiative elements but can gracefully downgrade.

4. Weather research usage



AN/SPY-1A radar installation at NSSL, Norman, OK.

The round dome primarily provides weather protection.

The National Severe Storms Laboratory has been using a SPY-1A phased array antenna, provided by the US Navy, for weather research at its Norman, Oklahoma facility since April 23, 2003. It is hoped that research will lead to a better understanding of thunderstorms and tornadoes, eventually leading to increased warning times and enhanced prediction of tornadoes. Project participants include the National Severe Storms Laboratory and National Weather Service Radar Operations Center, Lockheed Martin, United States Navy, University of Oklahoma School of Meteorology and School of Electrical and Computer Engineering, Oklahoma State Regents for Higher Education, the Federal Aviation Administration, and Basic Commerce and Industries. The project includes research and development, future technology transfer and potential deployment of the system throughout the United States. It is expected to take 10 to 15 years to complete and initial construction was approximately \$25 million.

Conclusion

An *antenna* is a structure—generally metallic and sometimes very complex designed to provide an efficient coupling between space and the output of a transmitter or the input to a receiver. Like a transmission line, an antenna is a device with distributed constants, so that current, voltage and impedance all vary from one point to the next one along it. This factor must be taken into account when considering important antenna properties. such as impedance, gain and shape of radiation pattern.

Thus artificial satellites are become the very important thing not only for the Science and research purpose but also in our day to day life.

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