The Horn Antenna in Radio Astronomy
(A History and Use)

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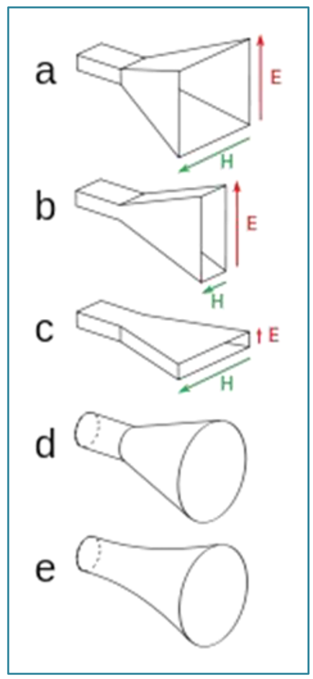
Abstract

A horn antenna or microwave horn is an antenna that consists of a flaring metal waveguide shaped like a horn to direct radio waves in a beam. Horns are widely used as antennas at UHF and microwave frequencies, above 300 MHz. An advantage of horn antennas is that since they have no resonant elements, they can operate over a wide range of frequencies, a wide bandwidth.

Horn History

One of the first horn antennas was constructed in 1897 by Indian radio researcher Jagadish Chandra Bose in his pioneering experiments with microwaves. In the 1930s the first experimental research (Southworth and Barrow, 1936) and theoretical analysis (Barrow and Chu, 1939) of horns as antennas was done.[6] The development of radar in World War 2 stimulated horn research to design feed horns for radar antennas. The corrugated horn invented by Kay in 1962 has become widely used as a feed horn for microwave antennas such as satellite dishes and radio telescopes.[6]



Horn Descriptions

Pyramidal horn (a, right) – a horn antenna with the horn in the shape of a four-sided pyramid, with a rectangular cross section.

Sectoral horn – A pyramidal horn with only one pair of sides flared and the other pair parallel. It produces a fan-shaped beam, which is narrow in the plane of the flared sides, but wide in the plane of the narrow sides. These types are often used as feed horns for wide search radar antennas.

> **E-plane horn (b)** – A sectoral horn flared in the direction of the electric or E-field in the waveguide.
> **H-plane horn (c)** – A sectoral horn flared in the direction of the magnetic or H-field in the waveguide.

Conical horn (d) – A horn in the shape of a cone, with a circular cross section. They are used with cylindrical waveguides.

Exponential horn (e) – A horn with curved sides, in which the separation of the sides increases as an exponential function of length. Also called a scalar horn, they can have pyramidal or conical cross sections.

These horns have minimum internal reflections, and almost constant impedance and other characteristics over a wide frequency range. They are used in applications requiring high performance, such as feed horns for communication satellite antennas and radio telescopes.

Corrugated horn – A horn with parallel slots or grooves, small compared with a wavelength, covering the inside surface of the horn, transverse to the axis. Corrugated horns have wider bandwidth and smaller side lobes and cross-polarization, and are widely used as feed horns for satellite dishes and radio telescopes.

Ridged horn – A pyramidal horn with ridges or fins attached to the inside of the horn, extending down the center of the sides. The fins lower the cutoff frequency, increasing the antenna's bandwidth.

Septum horn – A horn which is divided into several sub horns by metal partitions (septum's) inside, attached to opposite walls.

Aperture-limited horn – a long narrow horn, long enough so the phase error is a negligible fraction of a wavelength, so it essentially radiates a plane wave. It has an aperture efficiency of 1.0 so it gives the maximum gain and minimum beamwidth for a given aperture size. The gain is not affected by the length but only limited by diffraction at the aperture. [10] Used as feed horns in radio telescopes and other high-resolution antennas.

The Discovery of Hydrogen Radio emission by Ewen and Purcell

In 1950, "Doc" Ewen was working 40 hours a week designing and building apparatus for the new cyclotron at Harvard. In addition, during nights and weekends, he was working on completing a doctorate in physics by building a receiver to detect the 21 cm line of neutral hydrogen, supervised by Purcell.

This horn antenna, now displayed in front of the Jansky Lab at NRAO in Green Bank, WV, was used by Harold Ewen and Edward Purcell, then at the Lyman Laboratory of Harvard University, in the first detection of the 21 cm emission from neutral hydrogen in the Milky Way. The emission was first detected on March 25, 1951.

		
Original Photo at Harvard	**Actual Horn at NRAO. Green Bank, West Virginia (Friend, Kerry Smith)**	**H.I. ("Doc") Ewen pictured with his horn on the occasion of a visit to NRAO-Green Bank May 22, 2001. He had not seen his horn antenna since 1956!**

	
21 cm Horn built by Clint Jeffries in Australia	**21 cm Horn built by Jeff Lichtman**

Penzias & Wilson (1965, ApJ, 142, 419) showed that the zenith antenna temperature of the Bell Labs horn was 3.5 K higher at 4 GHz than expected—the first detection of the cosmic microwave background radiation.

Horn Antenna — Holmdel, New Jersey.
Horn Antenna, circa 1960.
(Photo Credit: Bell Labs)

Period: 1964-1965
Builder: Mr. A. B. Crawford

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.

The antenna is 50 feet in length with a radiating aperture of 20 x 20 feet and is made of aluminum. The antenna's elevation wheel is 30 feet 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 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. The faces of the wheels are cone-shaped to minimize sliding friction. A tangential force of 100 pounds 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, 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 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 side lobes 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 x 20 feet, with two windows, a double door and a sheet metal roof, is found next to the Horn Antenna. This structure houses equipment and controls for the Horn Antenna.

Little Big Horn

A Calibration Horn Antenna, nicknamed the “Little Big Horn,” was built by John Findlay in Green Bank in 1959 at the same time that our first large telescope, the 85-foot dish Tatel, came online.

As its name implies, the 120-foot long horn antenna was used to gather data that could be used to compare with observations made by the big dish telescopes. In particular, this horn measured the intensity of radio waves coming from the sky's strongest non-solar radio source, Cassiopeia A.

The Calibration Horn was built on a 30-degree hillside in order for it to aim at this source as it rose up the sky. For 50 minutes every day, radio waves from Cas A would pour into the 13-foot x 17.5-foot opening of this horn and be tapered to the 3-inch x 6-inch feed to enter the L-band (21-cm wavelength tuned) receiver. A chart recorder kept record of the quality of the signal.

The Calibration Horn measured a total power output for Cas A, and thus provided astronomers with a standard reference point on the sky against which they could measure other hydrogen sources.

The Sugar Scoop

A 4-foot parabolic horn reflector antenna, which received radiation on a wavelength of 3 cm, stuck out of the side of the Nutbin, research lab. It was called the "Sugar Scoop," and it helped astronomers gather information about man-made radio interference on the site.

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I would like to thank all those who contributed information on the following sites.

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