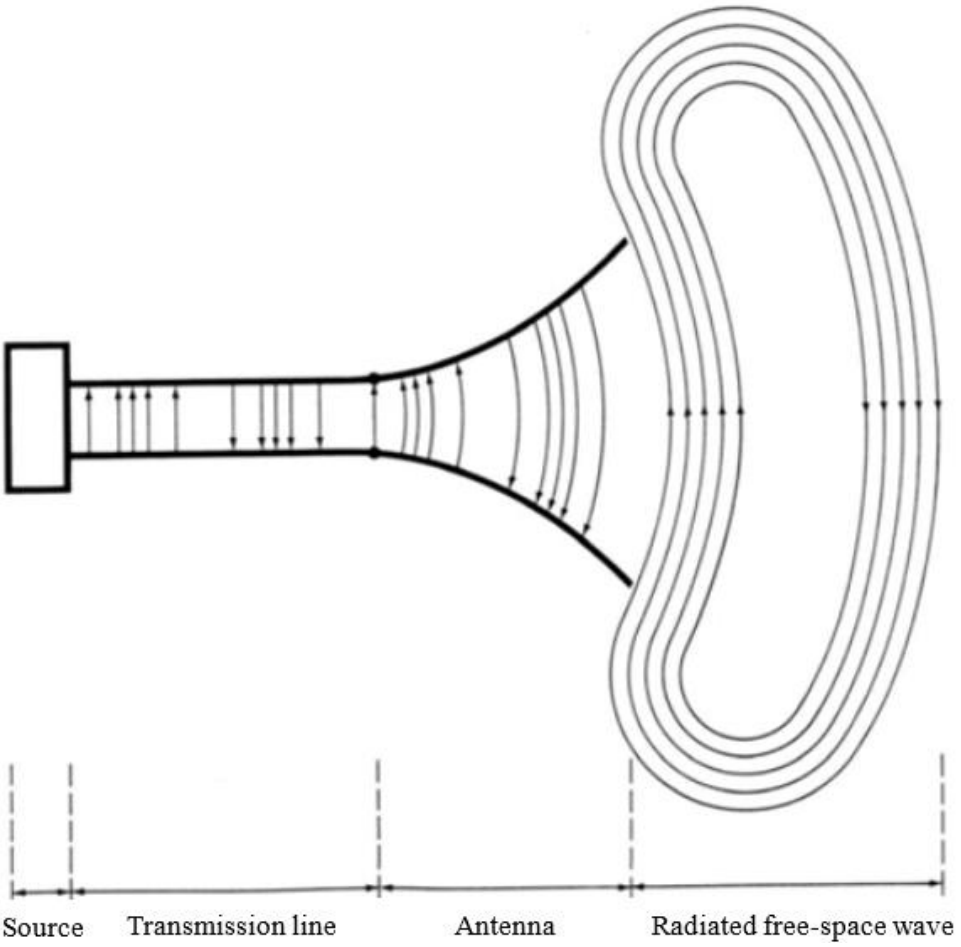
Definition and circuit theory description: -

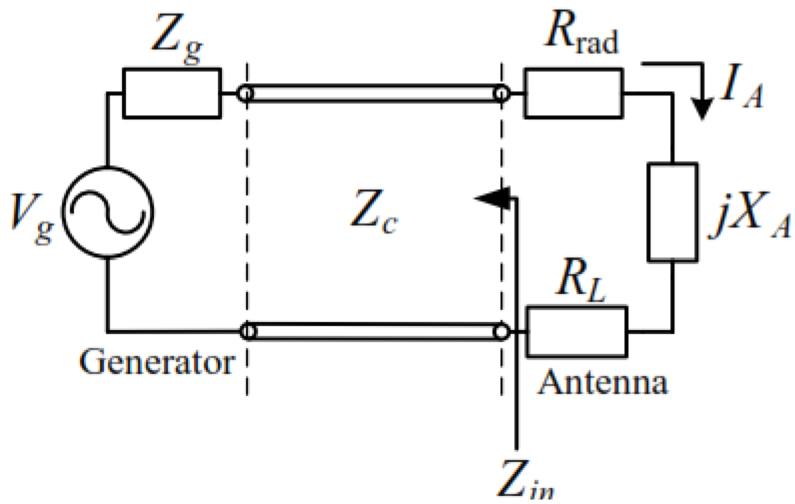
An antenna is defining as a metallic device (rod or wire) for radiating or receiving electromagnetic waves. In other words, the antenna is transitional structure between free-space and guiding device as shown in the figure below. Just as in humans the ears are the transducers that convert acoustic waves into electrochemical impulses.

The antenna is the transition between a guiding device (transmission line, waveguide) and free space (or another usually unbounded medium). Its main purpose is ***to convert the energy of a guided wave into the energy of a free space wave (or vice versa) as efficiently as possible, while at the same time the radiated power has a certain desired pattern of distribution in space***.



The equivalent circuit of an antenna; -

a) transmission-line Thevenin equivalent circuit of a radiating (transmitting) antenna



V_g - voltage-source generator (transmitter);

Z_g - impedance of the generator (transmitter);

Z_c - impedance of the transmission lines;

R_{rad} - radiation resistance (related to the radiated power as

$P_{rad} = I_A^2 \times R_{rad}$)

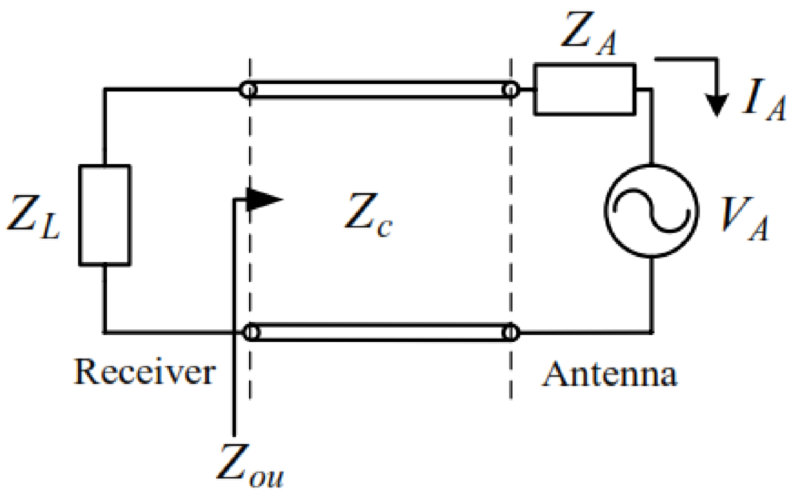
R_L - loss resistance (related to conduction and dielectric losses);

jX_A - antenna reactance.

The antenna impedance is ($Z_A = (R_{rad} + R_L) + jX_A$)

One of the most important issues in the design of high-power transmission systems are the matching of the antenna to the transmission line (TL) and the generator. Matching is specified most often in terms of voltage standing wave ratio (VSWR). Standing waves are to be avoided because they may cause arching or discharge in the TL. The resistive/dielectric losses are undesirable, too. They decrease the efficiency of the antenna.

b) transmission-line Thevenin equivalent circuit of a receiving antenna

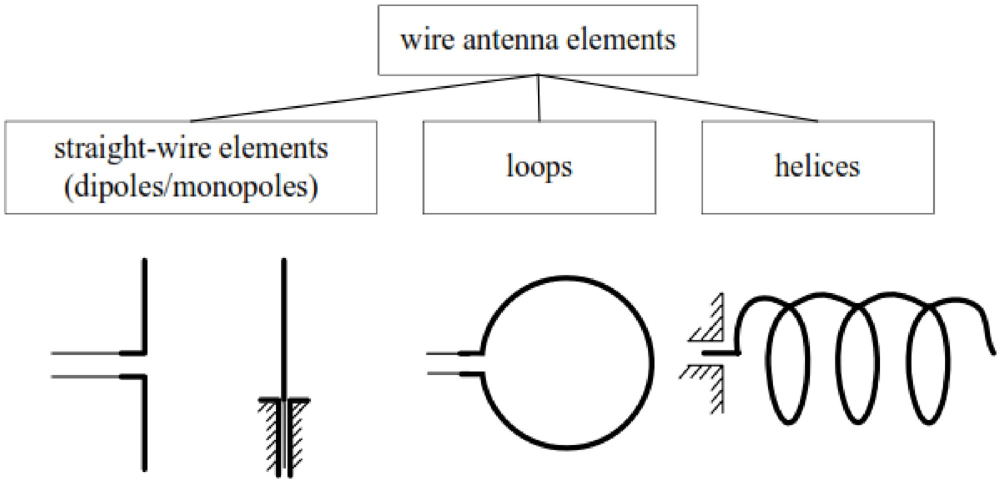


The antenna is a critical component in a wireless communication system. A good design of the antenna can relax system requirements and improve its overall performance.

General review of antenna geometries: -

1) Single-element radiators

a) Wire radiators (single-element)



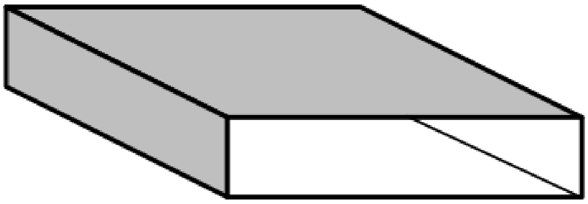
Wire antennas are simple to make but their dimensions are commensurable with the wavelength. This limits the frequency range of their applicability (at most 1-2 GHz). At low frequencies, these antennas become increasingly large.

b) Aperture antennas (single element)

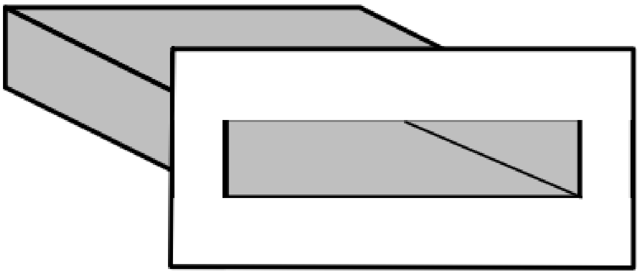
Aperture antennas were developed before and during the WW2 together with the emerging waveguide technology. Waveguide transmission lines were primarily developed to transfer high power microwave EM signals (centimeter wavelengths), generated by powerful microwave sources such as magnetrons and klystrons. These types of antennas are preferable in the frequency range from 1 to 20 GHz.

(a) pyramidal horn

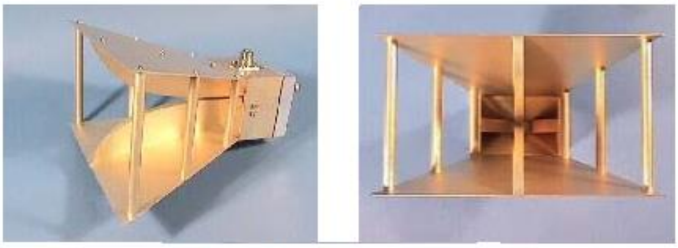
(b) conical horn



or



(c) open rectangular waveguide

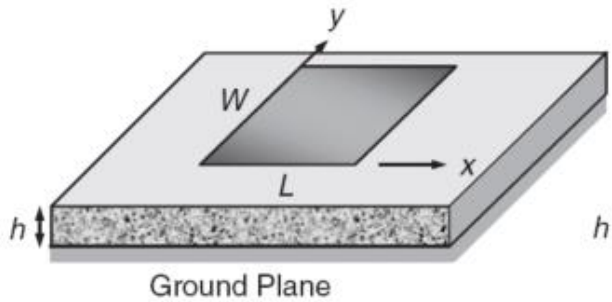


(d) double-ridge horns

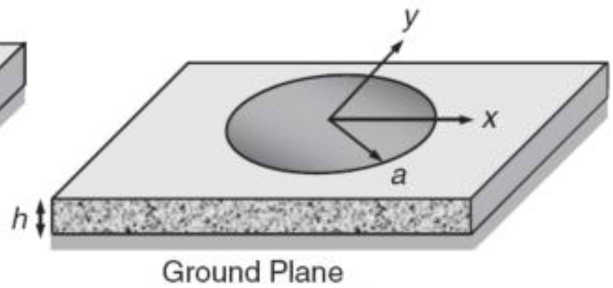
(e) quad-ridge horns

c) Printed antennas

The patch antennas consist of a metallic patch etched on a dielectric substrate, which has a grounded metallic plane at the opposite side. They are developed in the beginning of 1970s. There is great variety of geometries and ways of excitation. Modern integrated antennas often use multi-layer designs with a feed coupled to the radiator electro-magnetically (no galvanic contact).



rectangular patch

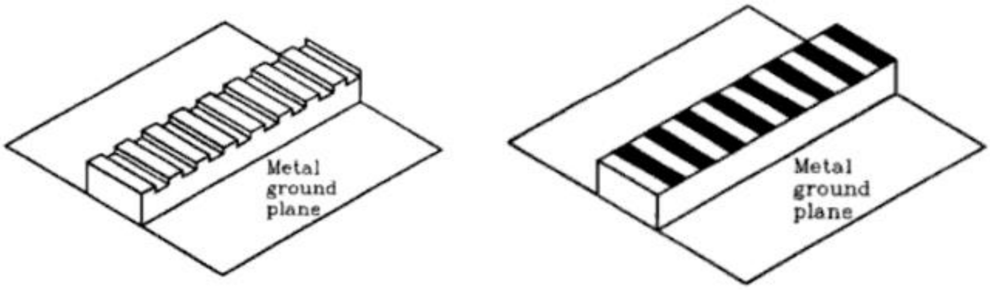


circular patch


printed dipole

d) Leaky-wave antennas

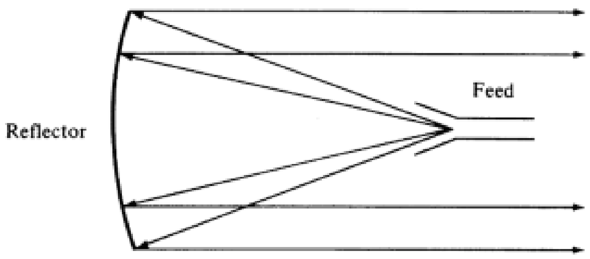
These are antennas derived from millimeter-wave (mm-wave) guides, such as dielectric guides, microstrip lines, coplanar and slot lines. They are developed for applications at frequencies > 30 GHz, infrared frequencies included. Periodical discontinuities are introduced at the end of the guide that lead to substantial radiation leakage (radiation from the dielectric surface). These are traveling-wave antennas.



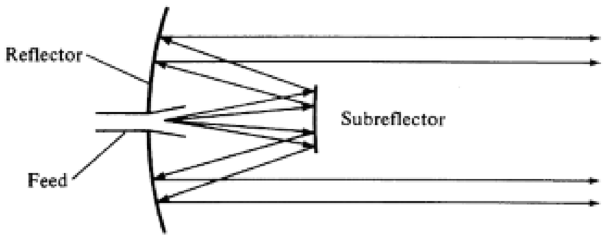
Dielectric-image guides with gratings

e) Reflector antennas

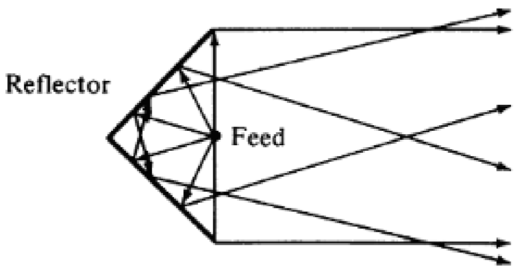
A reflector is used to concentrate the EM energy in a focal point where the receiver/feed is located. Optical astronomers have long known that a parabolic cylinder mirror transforms rays from a line source on its focal line into a bundle of parallel rays. Reflectors are usually parabolic. A parabolic cylinder reflector was first used for radio waves by Hertz in 1888. Sometimes, corner reflectors are used. Reflector antennas have very high gain and directivity. Typical applications: radio telescopes, satellite communications. They are not easy to fabricate and, in their conventional technology, they are rather heavy. They are not mechanically robust.



parabolic reflector with front feed



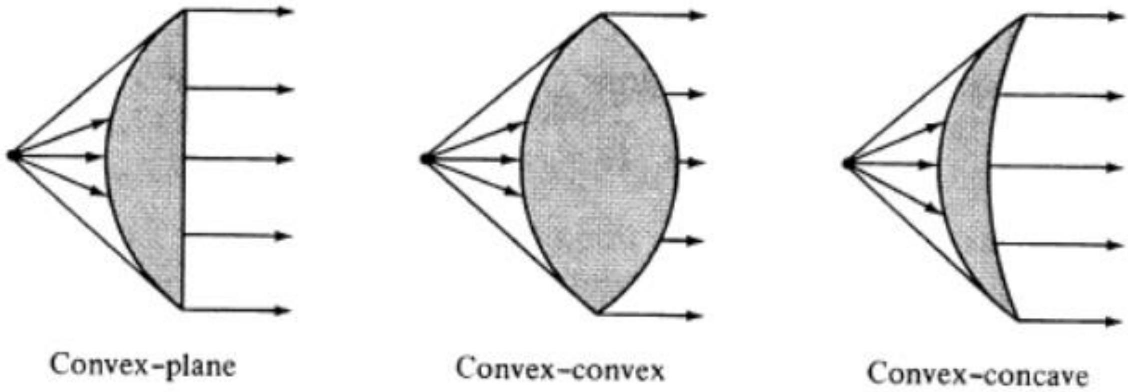
Parabolic reflector with cassegrain feed



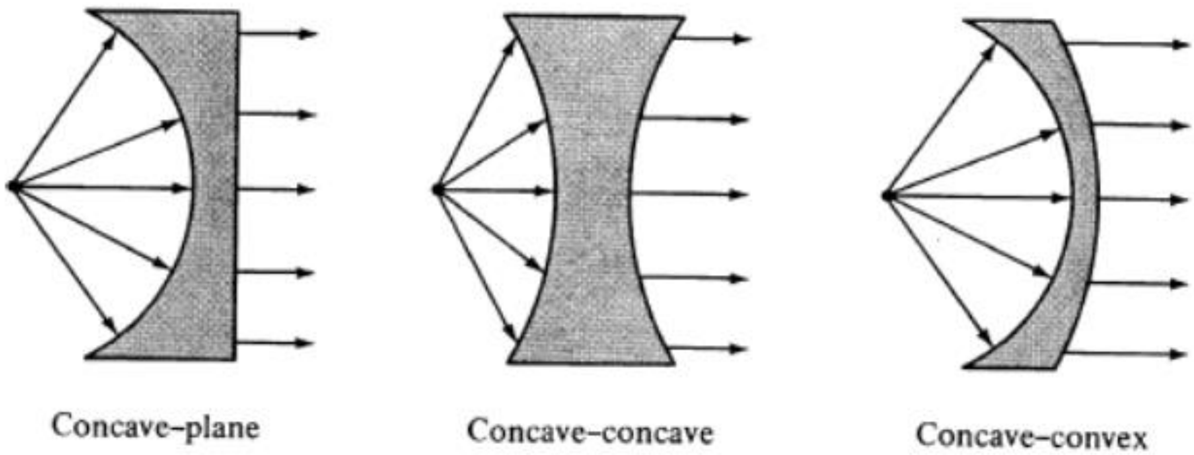
Corner reflector

f) Lens antennas

Lenses play a similar role to that of reflectors in reflector antennas. They collimate divergent energy into more or less plane EM wave. Lenses are often preferred to reflectors at higher frequencies (f > 100 GHz). They are classified according to their shape and the material they are made of.



Lens antennas with index of refraction $n > 1$



Lens antennas with index of refraction $n < 1$

2) Antenna arrays

Antenna arrays consist of multiple (usually identical) radiating elements. Arranging the radiating elements in arrays allows achieving unique radiation characteristics, which cannot be obtained through a single element. The careful choice and control of the phase shift and the amplitude of the signal fed to each element allows the change of the radiation pattern electronically – electronic scanning. Such arrays are called phased arrays.