# Transmission line

A transmission line is a system of conductors that transfers electrical signals from one place to another. The rising and falling of the waves moves the buoy-like structure creating mechanical energy which is converted into electricity and transmitted to shore over a submerged transmission line.

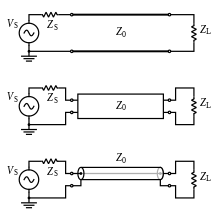
In [electrical engineering](https://en.wikipedia.org/wiki/Electrical_engineering), a **transmission line** is a specialized cable or other structure designed to conduct [electromagnetic waves](https://en.wikipedia.org/wiki/Electromagnetic_wave) in a contained manner. The term applies when the conductors are long enough that the [wave](https://en.wikipedia.org/wiki/Wave) nature of the transmission must be taken into account. This applies especially to [radio-frequency engineering](https://en.wikipedia.org/wiki/Radio-frequency_engineering) because the short [wavelengths](https://en.wikipedia.org/wiki/Wavelength) mean that wave phenomena arise over very short distances (this can be as short as millimetres depending on frequency). However, the [theory of transmission lines](https://en.wikipedia.org/wiki/Telegrapher%27s_equations) was historically developed to explain phenomena on very long [telegraph](https://en.wikipedia.org/wiki/Electrical_telegraph) lines, especially [submarine telegraph cables](https://en.wikipedia.org/wiki/Submarine_telegraph_cable).

Transmission lines are used for purposes such as connecting [radio transmitters](https://en.wikipedia.org/wiki/Transmitter) and [receivers](https://en.wikipedia.org/wiki/Radio_receiver) with their [antennas](https://en.wikipedia.org/wiki/Antenna_(radio)) (they are then called [feed lines](https://en.wikipedia.org/wiki/Feed_line) or feeders), distributing [cable television](https://en.wikipedia.org/wiki/Cable_television) signals, [trunklines](https://en.wikipedia.org/wiki/Trunking) routing calls between telephone switching centres, computer network connections and high speed computer [data buses](https://en.wikipedia.org/wiki/Bus_(computing)). RF engineers commonly use short pieces of transmission line, usually in the form of printed [planar transmission lines](https://en.wikipedia.org/wiki/Planar_transmission_line), arranged in certain patterns to build circuits such as [filters](https://en.wikipedia.org/wiki/Distributed-element_filter). These circuits, known as [distributed-element circuits](https://en.wikipedia.org/wiki/Distributed-element_circuit), are an alternative to traditional circuits using discrete [capacitors](https://en.wikipedia.org/wiki/Capacitor) and [inductors](https://en.wikipedia.org/wiki/Inductor).

# History

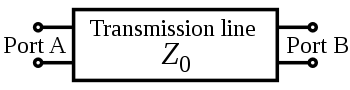
Mathematical analysis of the behaviour of electrical transmission lines grew out of the work of [James Clerk Maxwell](https://en.wikipedia.org/wiki/James_Clerk_Maxwell), [Lord Kelvin](https://en.wikipedia.org/wiki/Lord_Kelvin), and [Oliver Heaviside](https://en.wikipedia.org/wiki/Oliver_Heaviside). In 1855, Lord Kelvin formulated a diffusion model of the current in a submarine cable. The model correctly predicted the poor performance of the 1858 trans-Atlantic [submarine telegraph cable](https://en.wikipedia.org/wiki/Submarine_communications_cable). In 1885, Heaviside published the first papers that described his analysis of propagation in cables and the modern form of the [telegrapher's equations](https://en.wikipedia.org/wiki/Telegrapher%27s_equations).[[7]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-7)

## The four terminal model

[](https://en.wikipedia.org/wiki/File:Transmission_line_symbols.svg)

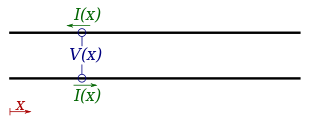
Variations on the [schematic](https://en.wikipedia.org/wiki/Electronic_schematic) [electronic symbol](https://en.wikipedia.org/wiki/Electronic_symbol) for a transmission line.

For the purposes of analysis, an electrical transmission line can be modelled as a [two-port network](https://en.wikipedia.org/wiki/Two-port_network) (also called a quadripole), as follows:

[](https://en.wikipedia.org/wiki/File:Transmission_line_4_port.svg)

In the simplest case, the network is assumed to be linear (i.e. the [complex](https://en.wikipedia.org/wiki/Complex_number) voltage across either port is proportional to the complex current flowing into it when there are no reflections), and the two ports are assumed to be interchangeable. If the transmission line is uniform along its length, then its behaviour is largely described by a single parameter called the [*characteristic impedance*](https://en.wikipedia.org/wiki/Characteristic_impedance), symbol Z0. This is the ratio of the complex voltage of a given wave to the complex current of the same wave at any point on the line. Typical values of Z0 are 50 or 75 [ohms](https://en.wikipedia.org/wiki/Ohm_(unit)) for a [coaxial cable](https://en.wikipedia.org/wiki/Coaxial_cable), about 100 ohms for a twisted pair of wires, and about 300 ohms for a common type of untwisted pair used in radio transmission.

When sending power down a transmission line, it is usually desirable that as much power as possible will be absorbed by the load and as little as possible will be reflected back to the source. This can be ensured by making the load impedance equal to Z0, in which case the transmission line is said to be [*matched*](https://en.wikipedia.org/wiki/Impedance_matching).

[](https://en.wikipedia.org/wiki/File:TransmissionLineDefinitions.svg)

A transmission line is drawn as two black wires. At a distance *x* into the line, there is current *I(x)* travelling through each wire, and there is a voltage difference *V(x)* between the wires. If the current and voltage come from a single wave (with no reflection), then *V*(*x*) / *I*(*x*) = *Z*0, where *Z*0 is the [*characteristic impedance*](https://en.wikipedia.org/wiki/Characteristic_impedance) of the line.

Some of the power that is fed into a transmission line is lost because of its resistance. This effect is called *ohmic* or *resistive* loss (see [ohmic heating](https://en.wikipedia.org/wiki/Ohmic_heating)). At high frequencies, another effect called *dielectric loss* becomes significant, adding to the losses caused by resistance. Dielectric loss is caused when the insulating material inside the transmission line absorbs energy from the alternating electric field and converts it to [heat](https://en.wikipedia.org/wiki/Heat) (see [dielectric heating](https://en.wikipedia.org/wiki/Dielectric_heating)). The transmission line is modelled with a resistance (R) and inductance (L) in series with a capacitance (C) and conductance (G) in parallel. The resistance and conductance contribute to the loss in a transmission line.

The total loss of power in a transmission line is often specified in [decibels](https://en.wikipedia.org/wiki/Decibels) per [metre](https://en.wikipedia.org/wiki/Metre) (dB/m), and usually depends on the frequency of the signal. The manufacturer often supplies a chart showing the loss in dB/m at a range of frequencies. A loss of 3 dB corresponds approximately to a halving of the power.

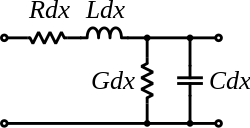
High-frequency transmission lines can be defined as those designed to carry electromagnetic waves whose [wavelengths](https://en.wikipedia.org/wiki/Wavelength) are shorter than or comparable to the length of the line. Under these conditions, the approximations useful for calculations at lower frequencies are no longer accurate. This often occurs with [radio](https://en.wikipedia.org/wiki/Radio), [microwave](https://en.wikipedia.org/wiki/Microwave) and [optical](https://en.wikipedia.org/wiki/Light) signals, [metal mesh optical filters](https://en.wikipedia.org/wiki/Metal_mesh_optical_filters), and with the signals found in high-speed [digital circuits](https://en.wikipedia.org/wiki/Digital_circuit).

# Telegrapher's equations

*Main article:*[*Telegrapher's equations*](https://en.wikipedia.org/wiki/Telegrapher%27s_equations)

*See also:*[*Reflections on copper lines*](https://en.wikipedia.org/wiki/Reflections_on_copper_lines)

The **telegrapher's equations** (or just **telegraph equations**) are a pair of linear differential equations which describe the [voltage](https://en.wikipedia.org/wiki/Voltage) (*{\displaystyle V}V*) and [current](https://en.wikipedia.org/wiki/Electric_current) (*{\displaystyle I}I*) on an electrical transmission line with distance and time. They were developed by [Oliver Heaviside](https://en.wikipedia.org/wiki/Oliver_Heaviside) who created the *transmission line model*, and are based on [Maxwell's equations](https://en.wikipedia.org/wiki/Maxwell%27s_equations).

[](https://en.wikipedia.org/wiki/File:Transmission_line_element.svg)

Schematic representation of the elementary component of a transmission line.

The transmission line model is an example of the [distributed-element model](https://en.wikipedia.org/wiki/Distributed-element_model). It represents the transmission line as an infinite series of two-port elementary components, each representing an infinitesimally short segment of the transmission line:

* The distributed resistance {\displaystyle R}*R* of the conductors is represented by a series resistor (expressed in [ohms](https://en.wikipedia.org/wiki/Ohm) per unit length).
* The distributed inductance {\displaystyle L}*L* (due to the [magnetic field](https://en.wikipedia.org/wiki/Magnetic_field) around the wires, [self-inductance](https://en.wikipedia.org/wiki/Self-inductance), etc.) is represented by a series [inductor](https://en.wikipedia.org/wiki/Inductor) (in [henries](https://en.wikipedia.org/wiki/Henry_(unit)" \o "Henry (unit)) per unit length).
* The capacitance {\displaystyle C}*C* between the two conductors is represented by a [shunt](https://en.wikipedia.org/wiki/Shunt_(electrical)) [capacitor](https://en.wikipedia.org/wiki/Capacitor) (in [farads](https://en.wikipedia.org/wiki/Farad) per unit length).
* The [conductance](https://en.wikipedia.org/wiki/Electric_conductance) {\displaystyle G}*G* of the dielectric material separating the two conductors is represented by a shunt resistor between the signal wire and the return wire (in [siemens](https://en.wikipedia.org/wiki/Siemens_(unit)) per unit length).

The model consists of an *infinite series* of the elements shown in the figure, and the values of the components are specified *per unit length* so the picture of the component can be misleading*. R{\displaystyle R},L{\displaystyle L},C* {\displaystyle C}, and {\displaystyle G}*G* may also be functions of frequency. An alternative notation is to use  *R{\displaystyle R},L{\displaystyle L},C* {\displaystyle C}, and {\displaystyle G}*G* {\displaystyle R'} {\displaystyle C'} {\displaystyle G'}to emphasize that the values are derivatives with respect to length. These quantities can also be known as the [primary line constants](https://en.wikipedia.org/wiki/Primary_line_constants) to distinguish from the secondary line constants derived from them, these being the [propagation constant](https://en.wikipedia.org/wiki/Propagation_constant), [attenuation constant](https://en.wikipedia.org/wiki/Attenuation_constant) and [phase constant](https://en.wikipedia.org/wiki/Phase_constant).

The line voltage *V* {\displaystyle V(x)}(*X* ) and the current *I (X )*{\displaystyle I(x)} can be expressed in the frequency domain as

# Practical

### Coaxial cable

*Main article:*[*coaxial cable*](https://en.wikipedia.org/wiki/Coaxial_cable)

Coaxial lines confine virtually all of the electromagnetic wave to the area inside the cable. Coaxial lines can therefore be bent and twisted (subject to limits) without negative effects, and they can be strapped to conductive supports without inducing unwanted currents in them. In radio-frequency applications up to a few gigahertz, the wave propagates in the [transverse](https://en.wikipedia.org/wiki/Transverse_wave) electric and magnetic mode (TEM) only, which means that the electric and magnetic fields are both perpendicular to the direction of propagation (the electric field is radial, and the magnetic field is circumferential). However, at frequencies for which the wavelength (in the dielectric) is significantly shorter than the circumference of the cable other [transverse modes](https://en.wikipedia.org/wiki/Transverse_mode) can propagate. These modes are classified into two groups, transverse electric (TE) and transverse magnetic (TM) [waveguide](https://en.wikipedia.org/wiki/Waveguide) modes. When more than one mode can exist, bends and other irregularities in the cable geometry can cause power to be transferred from one mode to another.

The most common use for coaxial cables is for television and other signals with bandwidth of multiple megahertz. In the middle 20th century they carried [long distance telephone](https://en.wikipedia.org/wiki/Long_distance_telephone) connections.

### Planar lines

*Main article:*[*Planar transmission line*](https://en.wikipedia.org/wiki/Planar_transmission_line)

Planar transmission lines are transmission lines with [conductors](https://en.wikipedia.org/wiki/Electrical_conductor), or in some cases dielectric strips, that are flat, ribbon-shaped lines. They are used to interconnect components on [printed circuits](https://en.wikipedia.org/wiki/Printed_circuit) and [integrated circuits](https://en.wikipedia.org/wiki/Integrated_circuit) working at microwave frequencies because the planar type fits in well with the manufacturing methods for these components. Several forms of planar transmission lines exist.

#### Microstrip

[](https://en.wikipedia.org/wiki/File:Solec_Kujawski_longwave_antenna_feeder.jpg)

A type of transmission line called a *cage line*, used for high power, low frequency applications. It functions similarly to a large coaxial cable. This example is the antenna [feed line](https://en.wikipedia.org/wiki/Feed_line) for a [longwave](https://en.wikipedia.org/wiki/Longwave) radio transmitter in [Poland](https://en.wikipedia.org/wiki/Poland), which operates at a frequency of 225 kHz and a power of 1200 kW.

*Main article:*[*microstrip*](https://en.wikipedia.org/wiki/Microstrip)

A microstrip circuit uses a thin flat conductor which is [parallel](https://en.wikipedia.org/wiki/Parallel_(geometry)) to a [ground plane](https://en.wikipedia.org/wiki/Ground_plane). Microstrip can be made by having a strip of copper on one side of a [printed circuit board](https://en.wikipedia.org/wiki/Printed_circuit_board) (PCB) or ceramic substrate while the other side is a continuous ground plane. The width of the strip, the thickness of the insulating layer (PCB or ceramic) and the [dielectric constant](https://en.wikipedia.org/wiki/Dielectric_constant) of the insulating layer determine the characteristic impedance. Microstrip is an open structure whereas coaxial cable is a closed structure.

#### Stripline

*Main article: [Stripline](https://en.wikipedia.org/wiki/Stripline" \o "Stripline)*

A stripline circuit uses a flat strip of metal which is sandwiched between two parallel ground planes. The insulating material of the substrate forms a dielectric. The width of the strip, the thickness of the substrate and the relative permittivity of the substrate determine the characteristic impedance of the strip which is a transmission line.

#### Coplanar waveguide

*Main article:*[*Coplanar waveguide*](https://en.wikipedia.org/wiki/Coplanar_waveguide)

A coplanar waveguide consists of a center strip and two adjacent outer conductors, all three of them flat structures that are deposited onto the same insulating substrate and thus are located in the same plane ("coplanar"). The width of the center conductor, the distance between inner and outer conductors, and the relative permittivity of the substrate determine the characteristic impedance of the coplanar transmission line.

### Balanced lines

*Main article:*[*Balanced line*](https://en.wikipedia.org/wiki/Balanced_line)

A balanced line is a transmission line consisting of two conductors of the same type, and equal impedance to ground and other circuits. There are many formats of balanced lines, amongst the most common are twisted pair, star quad and twin-lead.

#### Twisted pair

*Main article:*[*Twisted pair*](https://en.wikipedia.org/wiki/Twisted_pair)

Twisted pairs are commonly used for terrestrial [telephone](https://en.wikipedia.org/wiki/Telephone) communications. In such cables, many pairs are grouped together in a single cable, from two to several thousand.[[8]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-8) The format is also used for data network distribution inside buildings, but the cable is more expensive because the transmission line parameters are tightly controlled.

#### Star quad

*Main article:*[*Star quad cable*](https://en.wikipedia.org/wiki/Star_quad_cable)

Star quad is a four-conductor cable in which all four conductors are twisted together around the cable axis. It is sometimes used for two circuits, such as [4-wire](https://en.wikipedia.org/wiki/4-wire) telephony and other telecommunications applications. In this configuration each pair uses two non-adjacent conductors. Other times it is used for a single, [balanced line](https://en.wikipedia.org/wiki/Balanced_line), such as audio applications and [2-wire](https://en.wikipedia.org/wiki/2-wire) telephony. In this configuration two non-adjacent conductors are terminated together at both ends of the cable, and the other two conductors are also terminated together.

When used for two circuits, crosstalk is reduced relative to cables with two separate twisted pairs.

When used for a single, [balanced line](https://en.wikipedia.org/wiki/Balanced_line), magnetic interference picked up by the cable arrives as a virtually perfect common mode signal, which is easily removed by coupling transformers.

The combined benefits of twisting, balanced signalling, and quadrupole pattern give outstanding noise immunity, especially advantageous for low signal level applications such as microphone cables, even when installed very close to a power cable.[[9]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-9)[[10]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-10)[[11]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-11)[[12]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-12)[[13]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-13) The disadvantage is that star quad, in combining two conductors, typically has double the capacitance of similar two-conductor twisted and shielded audio cable. High capacitance causes increasing distortion and greater loss of high frequencies as distance increases.[[14]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-14)[[15]](https://en.wikipedia.org/wiki/Transmission_line#cite_note-15)

#### Twin-lead

*Main article:*[*Twin-lead*](https://en.wikipedia.org/wiki/Twin-lead)

Twin-lead consists of a pair of conductors held apart by a continuous insulator. By holding the conductors a known distance apart, the geometry is fixed and the line characteristics are reliably consistent. It is lower loss than coaxial cable because the characteristic impedance of twin-lead is generally higher than coaxial cable, leading to lower resistive losses due to the reduced current. However, it is more susceptible to interference.

#### Lecher lines

*Main article:*[*Lecher lines*](https://en.wikipedia.org/wiki/Lecher_lines)

Lecher lines are a form of parallel conductor that can be used at [UHF](https://en.wikipedia.org/wiki/Ultra_high_frequency) for creating resonant circuits. They are a convenient practical format that fills the gap between [lumped](https://en.wikipedia.org/wiki/Lumped-element_model) components (used at [HF](https://en.wikipedia.org/wiki/High_frequency)/[VHF](https://en.wikipedia.org/wiki/VHF)) and [resonant cavities](https://en.wikipedia.org/wiki/Resonant_cavity) (used at [UHF](https://en.wikipedia.org/wiki/Ultra_high_frequency)/[SHF](https://en.wikipedia.org/wiki/Super_high_frequency)).

### Single-wire line

[Unbalanced lines](https://en.wikipedia.org/wiki/Unbalanced_line) were formerly much used for telegraph transmission, but this form of communication has now fallen into disuse. Cables are similar to twisted pair in that many cores are bundled into the same cable but only one conductor is provided per circuit and there is no twisting. All the circuits on the same route use a common path for the return current (earth return). There is a [power transmission](https://en.wikipedia.org/wiki/Electric_power_transmission) version of [single-wire earth return](https://en.wikipedia.org/wiki/Single-wire_earth_return) in use in many locations.

# IMPORTANCE

The lines that carry radio waves from the radio transmitter to the antenna are known as transmission lines; their purpose is to convey radio-frequency energy with minimum heating and radiation loss. Heating losses are reduced by conductors of adequate size. Only the outer layers of the conductor carry radio-frequency current.

Amplifiers may be classified in a number of different ways: according to bandwidth (narrow or wide); frequency range (audio, intermediate, or [radio](https://www.britannica.com/topic/radio) frequency); or output [parameter](https://www.merriam-webster.com/dictionary/parameter) requirement (voltage or power).

Wide-band radio-frequency amplifiers are not needed for audio signals unless a frequency-modulated system is used. Amplitude-modulated signals for sound [broadcasting](https://www.britannica.com/technology/broadcasting) should have a radio-frequency bandwidth of ±10 kilohertz though on medium waves it is often limited to ±5 kilohertz (total bandwidth of 10 kilohertz). High-quality frequency-modulated audio needs a bandwidth of about ±100 kilohertz.

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Audio-frequency amplifiers present few design problems, and negative feedback of the output into the input can overcome [distortion](https://www.britannica.com/technology/distortion-communications) problems. Radio-frequency amplifiers, which can be tuned, suffer from variation of selectivity (ability to separate [adjacent](https://www.merriam-webster.com/dictionary/adjacent) stations) and gain (amplification) over the tuning range. Selectivity tends to broaden and gain to increase as capacitance is decreased, and instability can be troublesome at the highest tuning frequency. Intermediate-frequency amplifiers do not suffer from these defects since the tuning frequency is fixed.

The main problem with radio-frequency amplifiers in receivers is the possibility of cross modulation—that is, the mixing of two information channels, which can occur if an undesired modulated signal enters the radio-frequency input together with the desired signal.

## [Antennas](https://www.britannica.com/technology/antenna-electronics)

The [antenna](https://www.britannica.com/dictionary/antenna) is an essential part of a radio transmission and reception system. Its purpose at the transmitter is to project electromagnetic energy into space and at the [receiver](https://www.britannica.com/technology/receiver) to extract energy from the travelling [electromagnetic wave](https://www.britannica.com/science/electromagnetic-radiation) produced from the transmitter antenna.

The size of the antenna relative to the wavelength of the electromagnetic radiation is important. The wavelength of medium waves is about 300 metres (1,000 feet), and a vertical transmitting mast or self-supporting tower 150 to 210 metres (490 to 690 feet) high may be used with a high-power transmitter (200 kilowatts or more). An equally tall receiving antenna would be ideal but impractical. A vertical rod or suspended wire about six metres (20 feet) long is a workable solution. If the transmitting antenna is vertical, the receiving antenna must also be vertical; if the former is horizontal the receiving antenna must be horizontal. This rule applies at all radio frequencies except shortwaves because the plane of their [electromagnetic field](https://www.britannica.com/science/electromagnetic-field) can be twisted in its passage through the ionosphere, and a vertical shortwave antenna may pick up a good signal from a horizontal [transmitting](https://www.britannica.com/dictionary/transmitting) antenna. The antenna system becomes progressively smaller as the transmitting frequency is increased, and at ultrahigh frequencies (300 megahertz or more) the individual antenna may be only about 50 centimetres (20 inches) long.

For normal amplitude-modulated broadcasting, the receiver antenna may be composed of a fairly short coil of wire wound on a powdered iron or ferrite core. This type of design permits adequate signal pickup with a very small antenna which may be located in a small space, a necessity for small, battery-operated portable receivers.

Antennas may have their directional characteristics modified by employing multiple elements. Thus an antenna may be omnidirectional (transmitting in all directions) horizontally but narrowly beamed vertically, or it may be bidirectional (transmitting in two directions) in a figure eight pattern with two main directions of energy projection at 180°. It may be unidirectional, having energy projected to one side, or the energy may be concentrated in a relatively narrow beam both horizontally and vertically.

In point-to-point communication, as from one network centre to another, highly directional antennas are used. Local broadcasting uses an omnidirectional antenna, radiating equally in all directions, except in such special cases as a coastal location or proximity to a neighbouring transmitter.

Broadcasting planned to serve distant areas, employing shortwaves and depending on reflection from the ionosphere, normally uses a relatively narrow [beam](https://www.britannica.com/dictionary/beam) of energy projected skyward at an angle from 5° to 10° to the horizontal. A reflecting curtain is placed behind the antenna to prevent loss of energy in the reverse direction. The beam is divergent (spreads out) so that after two or three reflections between ionosphere and Earth it covers a relatively large area.

# CONCEPTS OF SELECTIVITY AND SENSITIVITY

Radio-frequency communication requires the receiver to reject all but the desired signal. Were the number of frequency channels equal to the demand, each channel could be given its correct width in the tuning stages of a receiver. Thus, for audio broadcasting each carrier channel should be 20 kilohertz wide to [accommodate](https://www.britannica.com/dictionary/accommodate) both side bands, and each transmission carrier should be 20 kilohertz, separated from those on either side. In much of the world, the medium-wave and shortwave bands are in such demand that transmitters must share the same channel and channels thus must overlap. Though efforts have been made to arrange sharing by geographically separated transmitters, the congestion has forced receiver manufacturers to reduce the receiver bandwidth to about eight kilohertz (±four kilohertz).

Very-high-frequency transmissions can generally be received at full bandwidth because their signals are confined to line of sight and are, in effect, local-station signals to the receiver. Frequency-modulated transmissions must be received on full bandwidth (about 200 kilohertz) if serious distortion is to be [avoided](https://www.britannica.com/dictionary/avoided) on loud programs.

Receiver sensitivity is the ability of a receiver to pick up weak signals. Though a communication receiver should always have a high sensitivity, there is a maximum determined by the noise generated inside the receiver itself. Little value is gained by increasing sensitivity if noise at the receiver output is already considerable and comparable with desired signal output. Normally, radio broadcasting systems operate with the signal voltage at least 10 to 50 times greater than the noise. To take full advantage of high sensitivity, receiving [antennas](https://www.britannica.com/dictionary/antennas) for communications links are usually located in an area where there is little man-made noise. A receiver intended only for local-station reception can have a much lower sensitivity than a shortwave receiver intended for picking up signals from the other side of the world.

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## [Antennas](https://www.britannica.com/technology/antenna-electronics)

The [antenna](https://www.britannica.com/dictionary/antenna) is an essential part of a radio transmission and reception system. Its purpose at the transmitter is to project electromagnetic energy into space and at the [receiver](https://www.britannica.com/technology/receiver) to extract energy from the travelling [electromagnetic wave](https://www.britannica.com/science/electromagnetic-radiation) produced from the transmitter antenna.

The size of the antenna relative to the wavelength of the electromagnetic radiation is important. The wavelength of medium waves is about 300 metres (1,000 feet), and a vertical transmitting mast or self-supporting tower 150 to 210 metres (490 to 690 feet) high may be used with a high-power transmitter (200 kilowatts or more). An equally tall receiving antenna would be ideal but impractical. A vertical rod or suspended wire about six metres (20 feet) long is a workable solution. If the transmitting antenna is vertical, the receiving antenna must also be vertical; if the former is horizontal the receiving antenna must be horizontal. This rule applies at all radio frequencies except shortwaves because the plane of their [electromagnetic field](https://www.britannica.com/science/electromagnetic-field) can be twisted in its passage through the ionosphere, and a vertical shortwave antenna may pick up a good signal from a horizontal [transmitting](https://www.britannica.com/dictionary/transmitting) antenna. The antenna system becomes progressively smaller as the transmitting frequency is increased, and at ultrahigh frequencies (300 megahertz or more) the individual antenna may be only about 50 centimetres (20 inches) long.

For normal amplitude-modulated broadcasting, the receiver antenna may be composed of a fairly short coil of wire wound on a powdered iron or ferrite core. This type of design permits adequate signal pickup with a very small antenna which may be located in a small space, a necessity for small, battery-operated portable receivers.

Antennas may have their directional characteristics modified by employing multiple elements. Thus an antenna may be omnidirectional (transmitting in all directions) horizontally but narrowly beamed vertically, or it may be bidirectional (transmitting in two directions) in a figure eight pattern with two main directions of energy projection at 180°. It may be unidirectional, having energy projected to one side, or the energy may be concentrated in a relatively narrow beam both horizontally and vertically.

In point-to-point communication, as from one network centre to another, highly directional antennas are used. Local broadcasting uses an omnidirectional antenna, radiating equally in all directions, except in such special cases as a coastal location or proximity to a neighbouring transmitter.

Broadcasting planned to serve distant areas, employing shortwaves and depending on reflection from the ionosphere, normally uses a relatively narrow [beam](https://www.britannica.com/dictionary/beam) of energy projected skyward at an angle from 5° to 10° to the horizontal. A reflecting curtain is placed behind the antenna to prevent loss of energy in the reverse direction. The beam is divergent (spreads out) so that after two or three reflections between ionosphere and Earth it covers a relatively large area.

## [Transmission lines](https://www.britannica.com/technology/transmission-line)

The lines that carry radio waves from the radio transmitter to the antenna are known as transmission lines; their purpose is to convey radio-frequency energy with minimum heating and radiation loss. Heating losses are reduced by conductors of adequate size. Only the outer layers of the conductor carry radio-frequency current.

## Concepts of selectivity and sensitivity

Radio-frequency communication requires the receiver to reject all but the desired signal. Were the number of frequency channels equal to the demand, each channel could be given its correct width in the tuning stages of a receiver. Thus, for audio broadcasting each carrier channel should be 20 kilohertz wide to [accommodate](https://www.britannica.com/dictionary/accommodate) both side bands, and each transmission carrier should be 20 kilohertz, separated from those on either side. In much of the world, the medium-wave and shortwave bands are in such demand that transmitters must share the same channel and channels thus must overlap. Though efforts have been made to arrange sharing by geographically separated transmitters, the congestion has forced receiver manufacturers to reduce the receiver bandwidth to about eight kilohertz (±four kilohertz).

Very-high-frequency transmissions can generally be received at full bandwidth because their signals are confined to line of sight and are, in effect, local-station signals to the receiver. Frequency-modulated transmissions must be received on full bandwidth (about 200 kilohertz) if serious distortion is to be [avoided](https://www.britannica.com/dictionary/avoided) on loud programs.

Receiver sensitivity is the ability of a receiver to pick up weak signals. Though a communication receiver should always have a high sensitivity, there is a maximum determined by the noise generated inside the receiver itself. Little value is gained by increasing sensitivity if noise at the receiver output is already considerable and comparable with desired signal output. Normally, radio broadcasting systems operate with the signal voltage at least 10 to 50 times greater than the noise. To take full advantage of high sensitivity, receiving [antennas](https://www.britannica.com/dictionary/antennas) for communications links are usually located in an area where there is little man-made noise. A receiver intended only for local-station reception can have a much lower sensitivity than a shortwave receiver intended for picking up signals from the other side of the world.

# Effects of the Physical Presence of Transmission Lines

The physical presence of transmission lines can have an effect on wildlife. These potential effects include long-term changes to habitat, bird strikes, access issues, noise effects and associated avoidance behaviour, and electric and magnetic fields.



Two key concepts are associated with the long-term presence of transmission line rights-of-way in wildlife habitat: edge effect and habitat fragmentation. While the mixture of habitats created by rights-of-way can allow greater density and diversity of wildlife to be present, transmission lines may also produce a negative edge effect for some species which require large, undisturbed habitat. Rights-of-way can create an edge effect, which refers to the border between different types of habitat and it is regarded as an important component of wildlife habitat. Vegetation composition changes in the newly created edge because plant species that do well in high light conditions become more widespread and abundant while interior species not accustomed to higher light intensity are eliminated. Changes to habitat composition will also change habitat quality for plants and animals which can have a positive,

negative or neutral effect depending on the species7.

Habitat fragmentation refers to plant communities that have become divided or isolated. Individual transmission line projects may fragment the landscape by dividing large blocks of forested habitat into smaller blocks which can result in a decline in species within the remaining forests. The northern spotted owl is one example of a raptor dependant on old growth forest that is negatively affected by fragmentation8. Woodland caribou, which require large tracts of relatively undisturbed habitat may also be negatively affected by any habitat fragmentation effects caused by transmission line rights-of-way9. Manitoba Hydro continues to be involved in ongoing caribou-related studies including conducting aerial surveys and radio collaring of woodland caribou.



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