EARTH SEGMENT

Earth segment of a Satellite Communication System consists of transmit earth station and receive earth station.

E.g. TVRO System (TV Receive only).
- Ku band (12 GHz) used for Direct Broadcast Satellite (DBS) Service.
- Dish antenna is used to receive C-band (4 GHz).

RECEIVE ONLY Home TV SYSTEMS:

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Block Diagram of Home terminal for DBS-TV systems:
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Outdoor Unit:
- LNB
- Lower Noise Block
- 950-1450 MHz

Indoor Unit:
- FM demodulator
- IF (70 MHz)
- Tuning filter
- Converter
- Amplifier
- Tunable Oscillator
- Channel selection & display

Satellite Receiver

To TV
The Home Receiver Outdoor Unit (OOU):

* Black diagram of OOU (out door unit).

* At any DBS location, there are cluster of satellites.
  60 cm dish at 12 GHz is sufficient for the cluster.
  
  → Hughes DBS-1 Satellite launched on 18.12.1993
     (101.2° W longitude).
  
  → Hughes DBS-2 Satellite launched on 3.8.1994
     (100.8° W longitude).
  
  → Hughes DBS-3 Satellite launched on 3.6.1994
     (100.8° W longitude).

* Parabolic reflector antenna is used as the receiving antenna.

* Horn antenna is mounted at the focus.

* Diameter of the reflector is 3 meter for 4 GHz.
  
  * Increase in diameter will increase the gain.

* The high gain antenna is not necessary for DBS.
  
  Because DBS operate at a much higher EIRP.

  The gain reduction is,

  \[ \frac{P_{\text{out}}}{P_{\text{in}}} = e \]
The isotropic power gain of an antenna is proportional to \( \frac{D^2}{A^2} \).

\( D \) - Diameter of an antenna.

When \( D \) is increased, gain is also increased.

* The downlink frequency band is 12.2 to 12.7 GHz.
  It can accommodate 32 channels (each channel - 24 MHz wide).

* The polarizer is switched to the desired polarization from the indoor control unit. The channels are alternately polarized left-hand circular (LHC) and right-hand circular (RHC) to reduce interference. This is known as polarization interleaving.

* Low Noise Block (LNB) consists of LNA and converter.

* LNB is used to provide the gain and then it converts the signal to a lower frequency range. Its range is 950 - 1450 MHz.

* The coaxial cable is used to carry dc power to the outdoor unit.

* Low Noise Amplified Signal is given to the cable input.
The Home Receiver Indoor Unit (IDU):

* 950 - 1450 MHz Signal is applied to the Indoor unit. This signal is amplified and given to tracking filter block. It is used to select the desired channel.

* By polarization interleaving, half the 32 channels present at the input side of the indoor unit.

* The selected channel is down converted and intermediate frequency is fixed (10 MHz). Then it is demodulated.

In,

- DVB TV - Frequency modulation is used
- Conventional TV - VSSB is used

* 12.2 - 12.7 GHz frequency band is down converted to 950 - 1450 MHz frequency. Each transponder maintains its 24 MHz BW.

* This IDU unit capable of receiving any of the 32 transponders. In this, 16 transponders are available for single polarization.

* Center frequency of the transponder is OQPSK modulated by the bit stream.

* The output of the tuner is connected with the demodulation block. Here, Carrier is demodulated and OQPSK modulation is converted to bit stream.
* The demultiplexer block is used to separate the individual programs.
* These programs are stored in memory for further processing.
* We can view the pay-per-view list and connect through modem to the service provider. It is used for the purpose of billing.

The Home Receiver Indoor Unit (IDU)

Block Diagram.
**MASTER ANTENNA TV SYSTEM (MATV)**

* MATV is used to provide reception of DBS TV channels to the user group.
* It consists of one outdoor unit and various indoor units. Each user can independently access all the channels.
* In MATV, separate LNA/c (Low Noise Amplifier) converter is required for LHC (Left Hand Circular) and RHC (Right Hand Circular) polarization.
* Large antenna is needed to get good SNR.

![Diagram of MATV System](image)
**COMMUNITY ANTENNA TV SYSTEM**

* CATV consists of one outdoor unit and separate feeds for each sense of polarization.

* CATV System

```
+---------------------------------+------------------+
| 5                  3              1 |           |
| 2                  4              6 |           |
| Combiner Block     | To Cable         |
|                   |                  |
```

* Separate receivers are not provided. All the carriers are demodulated in a general receiver filter system.
* The channels are then combined by using combiner block.
* The combined signal is a multiplexed signal which is transmitted through the cable to the users.
* In remote areas, cable distribution system is not installed.
* Here, the signal is retransmitted from a low power VHF TV transmitter.
**TRANSMITTER AND RECEIVER**

The transmitter, receiver, antenna, tracking and pointing forms the major subsystem for an earth station.

**Transmitter**

* In transmitter, the signal to be transmitted is converted to uplink frequency with proper encoding and modulation.
* It is then amplified and directed to the appropriate polarization of the antenna feed.
* For a large earth station, there will be many transmitters as well as receivers multiplexed together onto one antenna to provide channelized communication through a satellite transponder.
* As the earth station requires the transmission of microwave power, they use high power amplifiers such as TWTs and multichip klystrons.
* When compared to klystrons, TWTs allow high power over a wide BW.
* When there are several HPA working, their output may be combined through band pass filters and circulators.
* The modulation is performed at 70 MHz IF which is then upconverted.
* The configuration for HPA to be employed depend on the number of carriers to be transmitted and whether there are FSS or TDM signals.
* The most common configuration employ one HPA for each transponder to be used.
* The reliability is the most important requirement in Satellite Communication.
* The equipments in transmitter always employ some sort of redundancy configuration with automatic switch over.
* In the event of failure the redundancy configuration comes into work.

Transmitter Block Diagram.

Receiver:
* The receiver of an earth station employs mainly low noise Amplifier (LNA), down converters, demodulation, decoder and baseband signal treatment equipments.
* In the receiver chain of the earth station, the weak signal from the satellite are accepted by the same feed that carries the transmitter output.
* These two signals which differ in power by several orders of magnitude are kept separate in frequency domain as they are assigned to uplink and downlink bands.
* The diplexers are used to enhance the separation in the frequency domain.
* The noise consideration is also an important factor for the design requirement of downlink.

![Block Diagram of Earth Station Receiver]

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**EC6004 Satellite Communication**

Unit III

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[www.studentsfocus.com](http://www.studentsfocus.com)
* The receiver should have first stage with very low and sufficiently high gain.
* The large earth stations require very low noise amplifiers.
* For this reason, the Cryogenically cooled, parametric amplifiers are widely used, with liquid helium cooling at 4°K above absolute zero to achieve temperatures of 20 to 40°K at 14GHz.
* The receiver system also have some sort of redundancy configuration.
* The LNA used in earth stations usually cover the 50MHz fixed service band at 4GHz and 750MHz at 11GHz.
Equivalent Isotropically Radiated Power (EIRP)

In radio communication systems, equivalent isotropically radiated power (EIRP) or, alternatively, effective isotropically radiated power \( P_{EIRP} \) is the amount of power that a theoretical isotropic antenna (which evenly distributes power in all directions) would emit to produce the peak power density observed in the direction of maximum antenna gain. EIRP can take into account the losses in transmission line and connectors and includes the gain of the antenna. The EIRP is often stated in terms of decibels over a reference power emitted by an isotropic radiator with an equivalent signal strength. The EIRP allows comparisons between different emitters regardless of type, size or form. From the EIRP, and with knowledge of a real antenna’s gain, it is possible to calculate real power and field strength values.

\[
EIRP = P_T - L_c + G_a
\]

where \( EIRP \) and \( P_T \) (output power of transmitter) are in dBm, cable losses \( (L_c) \) is in dB, and antenna gain \( (G_a) \) is expressed in dBi, relative to a (theoretical) isotropic reference antenna.

This example uses dBm, although it is also common to see dBW.

Decibels are a convenient way to express the ratio between two quantities. dBm uses a reference of 1 mW and dBW uses a reference of 1 W.

\[
dBm = 10 \log \left( \frac{\text{power out}}{1 \text{ mW}} \right)
\]

and

\[
dBW = 10 \log \left( \frac{\text{power out}}{1 \text{ W}} \right)
\]

A transmission output of 50 W is the same as 17 dBW or 47 dBm.

\[
16.9807 \text{ dBW} = 10 \log \left( \frac{50 \text{ W}}{1 \text{ W}} \right)
\]

The EIRP is used to estimate the service area of the transmitter, and to coordinate transmitters on the same frequency so that their coverage areas do not overlap.

In built-up areas, regulations may restrict the EIRP of a transmitter to prevent exposure of personnel to high power electromagnetic fields, however EIRP is normally restricted to minimise interference to services on similar frequencies.
Antenna Gain:

Gain is a parameter which measures the degree of directivity of the antenna's radiation pattern. A high-gain antenna will preferentially radiate in a particular direction. Specifically, the antenna gain, or power gain of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in the direction of its maximum output, at an arbitrary distance, divided by the intensity radiated at the same distance by a hypothetical isotropic antenna.

The gain of an antenna is a passive phenomenon - power is not added by the antenna, but simply redistributed to provide more radiated power in a certain direction than would be transmitted by an isotropic antenna. An antenna designer must take into account the application for the antenna when determining the gain. High-gain antennas have the advantage of longer range and better signal quality, but must be aimed carefully in a particular direction. Low-gain antennas have shorter range, but the orientation of the antenna is relatively inconsequential. For example, a dish antenna on a spacecraft is a high-gain device that must be pointed at the planet to be effective, whereas a typical Wi-Fi antenna in a laptop computer is low-gain, and as long as the base station is within range, the antenna can be in any orientation in space. It makes sense to improve horizontal range at the expense of reception above or below the antenna.[12]

In practice, the half-wave dipole is taken as a reference instead of the isotropic radiator. The gain is then given in dBi (decibels over dipole):

NOTE: 0 dBi = 2.15 dBd. It is vital in expressing gain values that the reference point be included. Failure to do so can lead to confusion and error.
Transmitter and Receiver Antenna:

An antenna (or aerial) is an electrical device which converts electric power into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver. In transmission, a radio transmitter supplies an oscillating radio frequency electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce a tiny voltage at its terminals, that is applied to a receiver to be amplified.

Antennas are essential components of all equipment that uses radio. They are used in systems such as radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, and satellite communications, as well as other devices such as garage door openers, wireless microphones, Bluetooth enabled devices, wireless computer networks, baby monitors, and RFID tags on merchandise.

Typically an antenna consists of an arrangement of metallic conductors (elements), electrically connected (often through a transmission line) to the receiver or transmitter. An oscillating current of electrons forced through the antenna by a transmitter will create an oscillating magnetic field around the antenna elements, while the charge of the electrons also creates an oscillating electric field along the elements. These time-varying fields, when created in the proper proportions, radiate away from the antenna into space as a moving transverse electromagnetic field wave. Conversely, during reception, the oscillating electric and magnetic fields of an incoming radio wave exert force on the electrons in the antenna elements, causing them to move back and forth, creating oscillating currents in the antenna.

Antennas may also include reflective or directive elements or surfaces not connected to the transmitter or receiver, such as parasitic elements, parabolic reflectors or horns, which serve to direct the radio waves into a beam or other desired radiation pattern. Antennas can be designed to transmit or receive radio waves in all directions equally (omni directional antennas), or transmit them in a beam in a particular direction, and receive from that one direction only (directional or high gain antennas).

Basic Antenna Models

Typical US multiband TV antenna (aerial)

There are many variations of antennas. Below are a few basic models. More can be found in Category:Radio frequency antenna types.

- The isotropic radiator is a purely theoretical antenna that radiates equally in all directions. It is considered to be a point in space with no dimensions and no mass. This antenna cannot physically exist, but is useful as a theoretical model for comparison with all other antennas.
Most antennas' gains are measured with reference to an isotropic radiator, and are rated in dBi (decibels with respect to an isotropic radiator).

- The dipole antenna is simply two wires pointed in opposite directions arranged either horizontally or vertically, with one end of each wire connected to the radio and the other end hanging free in space. Since this is the simplest practical antenna, it is also used as a reference model for other antennas; gain with respect to a dipole is labeled as dBi. Generally, the dipole is considered to be omnidirectional in the plane perpendicular to the axis of the antenna, but it has deep nulls in the directions of the axis. Variations of the dipole include the folded dipole, the half wave antenna, the ground plane antenna, the whip, and the J-pole.

- The Yagi-Uda antenna is a directional variation of the dipole with parasitic elements added which are functionality similar to adding a reflector and lenses (directors) to focus a filament light bulb.

- The random wire antenna is simply a very long (at least one quarter wavelength wire with one end connected to the radio and the other in free space, arranged in any way most convenient for the space available. Folding will reduce effectiveness and make theoretical analysis extremely difficult. The added length helps more than the folding typically hurts.) Typically, a random wire antenna will also require an antenna tuner, as it might have a random impedance that varies non-linearly with frequency.

- The horn antenna is used where high gain is needed, the wavelength is short (microwave) and space is not an issue. Horns can be narrow band or wide band, depending on their shape. A horn can be built for any frequency, but horns for lower frequencies are typically impractical. Horns are also frequently used as reference antennas.

- The parabolic antenna consists of an active element at the focus of a parabolic reflector to reflect the waves into a plane wave. Like the horn it is used for high gain, microwave applications, such as satellite dishes.

- The patch antenna consists mainly of a square conductor mounted over a ground plane. Another example of a planar antenna is the tapered slot antenna (TSA), as the Vivaldi antenna.

**Practical Antennas:**

"Rabbit ears" set-top antenna

Although any circuit can radiate if driven with a signal of high enough frequency, most practical antennas are specially designed to radiate efficiently at a particular frequency. An example of an inefficient antenna is the simple Hertzian dipole antenna, which radiates over a wide range of
frequencies and is useful for its small size. A more efficient variation of this is the half-wave dipole, which radiates with high efficiency when the signal wavelength is twice the electrical length of the antenna.

One of the goals of antenna design is to minimize the reactance of the device so that it appears as a resistive load. An "antenna inherent reactance" includes not only the distributed reactance of the active antenna but also the natural reactance due to its location and surroundings (as for example, the capacity relation inherent in the position of the active antenna relative to ground). Reactance can be eliminated by operating the antenna at its resonant frequency, when its capacitive and inductive reactances are equal and opposite, resulting in a net zero reactive current. If this is not possible, compensating inductors or capacitors can instead be added to the antenna to cancel its reactance as far as the source is concerned.

Once the reactance has been eliminated, what remains is a pure resistance, which is the sum of two parts: the ohmic resistance of the conductors, and the radiation resistance. Power absorbed by the ohmic resistance becomes waste heat, and that absorbed by the radiation resistance becomes radiated electromagnetic energy. The greater the ratio of radiation resistance to ohmic resistance, the more efficient the antenna.

**Effect of Ground**

Antennas are typically used in an environment where other objects are present that may have an effect on their performance. Height above ground has a very significant effect on the radiation pattern of some antenna types.

At frequencies used in antennas, the ground behaves mainly as a dielectric. The conductivity of ground at these frequencies is negligible. When an electromagnetic wave arrives at the surface of an object, two waves are created: one enters the dielectric and the other is reflected. If the object is a conductor, the transmitted wave is negligible and the reflected wave has almost the same amplitude as the incident one. When the object is a dielectric, the fraction reflected depends (among other things) on the angle of incidence. When the angle of incidence is small (that is, the wave arrives almost perpendicularly) most of the energy traverses the surface and very little is reflected. When the angle of incidence is near 90° (grazing incidence) almost all the wave is reflected.

Most of the electromagnetic waves emitted by an antenna to the ground below the antenna at moderate (say < 60°) angles of incidence enter the earth and are absorbed (lost). But waves emitted to the ground at grazing angles, far from the antenna, are almost totally reflected. At grazing angles, the ground behaves as a mirror. Quality of reflection depends on the nature of the surface. When the irregularities of the surface are smaller than the wavelength, reflection is good.
The wave reflected by earth can be considered as emitted by the image antenna. This means that the receptor "sees" the real antenna and, under the ground, the image of the antenna reflected by the ground. If the ground has irregularities, the image will appear fuzzy.

If the receiver is placed at some height above the ground, waves reflected by ground will travel a little longer distance to arrive to the receiver than direct waves. The distance will be the same only if the receiver is close to ground.

In the drawing at right, the angle has been drawn far bigger than in reality. The distance between the antenna and its image is $\theta$.

The situation is a bit more complex because the reflection of electromagnetic waves depends on the polarization of the incident wave. As the refractive index of the ground (average value $\approx 2$) is bigger than the refractive index of the air ($\approx 1$), the direction of the component of the electric field parallel to the ground inverts at the reflection. This is equivalent to a phase shift of $\pi$ radians or $180^\circ$. The vertical component of the electric field reflects without changing direction. This sign inversion of the parallel component and the non-inversion of the perpendicular component would also happen if the ground were a good electrical conductor.

The vertical component of the current reflects without changing sign. The horizontal component reverses sign at reflection.

This means that a receiving antenna "sees" the image antenna with the current in the same direction if the antenna is vertical or with the current inverted if the antenna is horizontal.

For a vertically polarized emission antenna the far electric field of the electromagnetic wave produced by the direct ray plus the reflected ray is:

$$|E_\perp| = 2 |E_{01}| \cos \left( \frac{\text{refractive index}}{2} \sin \theta \right)$$

The sign inversion for the parallel field case just changes a cosine to a sine:

$$|E_\parallel| = 2 |E_{01}| \sin \left( \frac{\text{refractive index}}{2} \sin \theta \right)$$

In these two equations:

- $E_{01}$ is the electrical field radiated by the antenna if there were no ground.
- $\frac{k}{\lambda}$ is the wave number.
- $\lambda$ is the wave length.
• $d$ is the distance between antenna and its image (twice the height of the center of the antenna).

Radiation patterns of antennas and their images reflected by the ground. At left the polarization is vertical and there is always a maximum for $\theta=0$. If the polarization is horizontal as at right, there is always a zero for $\theta=0$.

For emitting and receiving antennas situated near the ground (in a building or on a mast) far from each other, distances traveled by direct and reflected rays are nearly the same. There is no induced phase shift. If the emission is polarized vertically, the two fields (direct and reflected) add and there is maximum of received signal. If the emission is polarized horizontally, the two signals subtract and the received signal is minimum. This is depicted in the image at right. In the case of vertical polarization, there is always a maximum at earth level (left pattern). For horizontal polarization, there is always a minimum at earth level. Note that in these drawings the ground is considered as a perfect mirror, even for low angles of incidence. In these drawings, the distance between the antenna and its image is just a few wavelengths. For greater distances, the number of lobes increases.

Note that the situation is different—and more complex—if reflections in the ionosphere occur. This happens over very long distances (thousands of kilometers). There is not a direct ray but several reflected rays that add with different phase shifts.

This is the reason why almost all public address radio emissions have vertical polarization. As public users are near ground, horizontal polarized emissions would be poorly received. Observe household and automobile radio receivers. They all have vertical antennas or horizontal ferrite antennas for vertical polarized emissions. In cases where the receiving antenna must work in any position, as in mobile phones, the emitter and receivers in base stations use circular polarized electromagnetic waves.

Classical (analog) television emissions are an exception. They are almost always horizontally polarized, because the presence of buildings makes it unlikely that a good emitter antenna image will appear. However, these same buildings reflect the electromagnetic waves and can create ghost images. Using horizontal polarization, reflections are attenuated because of the low reflection of electromagnetic waves whose magnetic field is parallel to the dielectric surface near the Brewster's angle. Vertically polarized analog television has been used in some rural areas. In digital terrestrial television reflections are less intrusive, due to the inherent robustness of digital signalling and built-in error correction.
Antenna Systems TVRO:

Television receive-only, TVRO, big ugly dish (BUD), is a term used in North America to refer to the reception of satellite television from FSS-type satellites, generally on C-band analog free-to-air and unconnected to a commercial DBS provider. TVRO systems rely on feeds being transmitted unencrypted and using open-standards, which heavily contrasts to DBS systems in the region.

The term is rarely used in recent times due to the general move towards pay television and subscription-based DBS services like DirecTV, Dish Network, Bell TV, and Sky TV, although it is still sometimes used to refer to receiving digital TV “backhaul” feeds from FSS-type satellites.

TVRO was once the sole, and later the main means of consumer satellite reception in the United States, until the mid-1990s and the arrival of services such as Prime Star, USSB, DirecTV, and Dish Network. While these services are at least theoretically based on open standards (DVB-S, MPEG-2, MPEG-4), the majority of services are encrypted and require proprietary decoder hardware.

Reception of free-to-air satellite signals, generally K band Digital Video Broadcasting, for home viewing is still common in Europe, India and Australia, although the TVRO nomenclature was never used there.

Free-to-air satellite signals are also very common in the People’s Republic of China, as many rural locations cannot receive cable television and solely rely on satellites to deliver television signals to individual homes.

A C-band dish (often given as BUD, for “big ugly dish”) is a colloquial name for a TVRO satellite dish used to receive satellite television signals from FSS-type satellites on the microwave C band. BUDs are usually 6½ to 12 feet or two to 3.5 meters in diameter, and have been a source of much consternation (even local zoning disputes) due to their perception as an eyesore. Neighborhoods with restrictive covenants usually prohibit this size of dish, except where such restrictions are illegal.

Popularity:

BUDs were most popular in rural areas, beyond the broadcast range of most local TV stations. The mountainous terrain of West Virginia, for example, makes reception of over-the-air television broadcasts (especially in the higher UHF frequencies) very difficult. From the 1970s to the early 1990s DBS systems weren’t available, and cable TV systems of the time only carried a few channels, resulting in a boom in sales of BUDs in the area, which led to the systems being termed the "West Virginia state flower". The term was regional, known mostly to
those living in West Virginia and surrounding areas. Support for BUDs dried up when strong encryption was introduced around 1994. Many long-disconnected BUDs still occupy their original spot. Due to the number of systems in existence, their lack of usefulness, and because many people consider them an eyesore, used BUDs can be purchased for very little money.

**Current Use:**
There are over 150 channels for people who want to receive subscription channels on a C-band dish via Motorola's 4DTV equipment via two vendors Satellite Receivers Ltd (SRL) and Skyvision.

The dishes themselves can be modified to receive free-to-air and DBS signals. The stock LNBFs fitted to typical BUDs will usually need to be replaced with one of a lower noise temperature to receive digital broadcasts. With a suitable replacement LNBF (provided there is no warping of the reflector) a BUD can be used to receive free-to-air (FTA) and DBS signals. Several companies market LNBFs, LNBFs, and adaptor collars for big-dish systems. For receiving FTA signals the replacement should be capable of dual C/Ka reception with linear polarization, for DBS it will need a high band K_a LNBF using circular polarization. Older mesh dishes with perforations larger than 5mm are inefficient at K_a frequencies, because the smaller wavelengths will pass through them. Solid fiberglass dishes usually contain metal mesh with large-diameter perforations as a reflector and are usually unsuitable for anything other than C band.

Large dishes have higher antenna gain, which can be an advantage when used with DBS signals such as Dish Network and DirecTV, virtually eliminating rain fade. Restored dishes fitted with block up converters can be used to transmit signals as well. BUDs can still be seen at antenna farms for these reasons, so that video and backhauls can be sent to and from the TV network with which a station is affiliated, without interruption due to inclement weather. BUDs are also still useful for picking-up weak signals at the edge of a satellite's broadcast "footprint" — the area at which a particular satellite is aimed. For this reason, BUDs are helpful in places like Alaska, or parts of the Caribbean.

**Modern Equivalent:**
Large parabolic antennas similar to BUDs are still in production by companies such as Fortec Star and Standard Antenna Manufacturing Inc.. New dishes differ in their construction and materials. New mesh dishes have much smaller perforations and solid dishes are now made with steel instead of fiberglass. New systems usually include a universal LNBF which is switched electronically between horizontal and vertical polarization, obviating the need for a failure-prone polarotor. As a complete system they have a much lower noise temperature than old BUDs, and are generally better for digital K_a reception. The prices on these dishes have fallen dramatically.
MATV

MATV stands for Master Antenna Television. MATV systems allow multiple receivers (TV & FM) to receive signals from a single (Master) antenna, as opposed to individual antennas for each receiver. MATV systems are separated into two portions, the ‘Head End’ and the ‘Distribution System’. When these two portions are planned and engineered using suitable MATV equipment and the appropriate installation techniques, signals will be distributed without loss of signal quality. Any signal passing through system components, including the cable, will be attenuated (i.e., have its level diminished). The level of this attenuation is important, as it will be a factor in signal quality. Signal quality within the system is related to signal level, system noise and headroom. The system needs to maintain a low noise level and a high signal level. However, the signal must not be too high, as this can overdrive the equipment. In order to simplify MATV design, the relationship between noise and signal levels is measured (in Decibels).

Decibels

The signal level received on a television antenna is measured in microvolts. Calculations in microvolts are difficult, therefore MATV calculations are carried out in decibels. Decibels are added and subtracted, as opposed to being multiplied and divided. The decibel is 1/10 of a bel and is derived from a formula originally used by telephone engineers. The decibel indicates how many times greater or smaller a quantity is from a pre-established reference level. The relationship between dB levels is logarithmic, not linear. Therefore 40 dB is not twice as much as 20 dB, for example:

- 10 dB = 3.2 x reference level
- 20 dB = 10 x reference level
- 30 dB = 32 x reference level
- 40 dB = 100 x reference level
- 50 dB = 316 x reference level

In the MATV industry, the zero reference level is 1,000 microvolts measured across 75 Ohms of impedance. The reference level determines that a minimum signal of 1,000 microvolts is required to produce an acceptable picture. The dB figure is represented as dBmV (a reference to 1 millivolt), or dBµV (a reference to 1 microvolt). MATV amplifier gains, cable losses, insertion losses and isolation values are all expressed in dB. To determine the output signal level and any system losses, decibels are added and subtracted. The minimum signal for a good quality, noise-free picture is typically stated as -6dBmV although most televisions will work well with signals as small as -6dBmV. Working to the 0dBmV level will provide a tolerance to slight signal variations. The signal level fed into a television should be kept below 20dBmV. Equipment is critical to maintain the maximum bandwidth.

For audio and video signals to be transmitted using only a portion of the available bandwidth, they are modulated onto carrier signals within a fixed bandwidth. In Australia, the standard bandwidth is 7MHz, this is known as a channel. If TVs or VCRs are tuned to a particular channel, it is not tuned into a single frequency, but a 7MHz band from which the audio and video information is retrieved. For analogue transmission in Australia the vision carrier is 1.25MHz above the lower frequency for a given channel’s bandwidth, with the primary audio approximately 5.5MHz above that. The secondary audio is approximately 24KHz above the primary audio.
The MATV Head End
The Head End of a MATV system usually consists of an antenna which receives broadcast signals, processing equipment to filter the signals and a distribution amplifier to amplify the signals to compensate for distribution losses. Antennas, amplifiers, taps, filters and attenuators are used in this portion of the system.

The MATV Antenna
The quality of TV reception can be no better than the quality of the signal from the antenna. It is therefore vital to select the correct antenna for the intended location. Antenna manufacturers produce geographic maps detailing preferred antenna types based on the geographic location. In addition, professional antenna installers carry test equipment to optimise antenna placement and orientation. The quality and strength of any signal received is determined by the following:-
• Proximity to the transmission tower.
• Power of the transmitter.
• Quality of the transmission.
• Line of sight to the transmission tower.
• Weather conditions.
• Interference from power lines.
• Directional characteristics and orientation of the antenna.
• Level of gain of the antenna.

Antenna Selection
The antenna installation should provide at least 60 dB or 0dBmV of picture signal per channel at the amplifier input. In strong signal areas this will be relatively easy to obtain. In weak signal areas a larger antenna with a high gain will usually be necessary. It may also be necessary to “stack” two or more antennas. Stacking two antennas will provide an additional 3 dB of gain above the gain of a single antenna. Although a pre-amplifier may be used, stacking before pre amplification is preferable, as it delivers a cleaner signal to the system. Antenna directivity is important. Directivity is a measure of how well an antenna will reject signals from any direction other than the front. The front-to-back ratio is one way of measuring an antenna’s directivity. This is the ratio of the amount of signal received by the front of the antenna to the amount of signal received by the rear. A highly directional antenna will generally have a high front-to-back ratio.

SIGNAL SURVEY
Determining signal levels is one of the most important steps in Head-End design and a signal survey before installing the system will avoid many potential problems. An antenna, several sections of mast, a field strength meter and a portable colour TV is the equipment required for a signal survey. The field strength meter measures the amount of signal received on each channel. Carefully selected antennas can also do much to overcome certain types of interference. The portable TV allows the quality of the signal received on each channel to be determined.
 Masthead Amplifiers
In weak signal areas, it is often necessary to amplify the signal before the distribution amplifier. This will ensure a signal of sufficient strength and acceptable quality. This is achieved using a Masterhead Amplifier. It is important to choose a Masterhead Amplifier with a low noise figure. The noise figure of the Masterhead Amplifier establishes the noise figure of the entire system, therefore the amplifier should always increase the signal more than it increases the noise.

MATV Distribution
A well-designed distribution system is necessary to guarantee an adequate signal at every receiver connected to the system. The distribution of MATV is the role of a combination of splitters and taps. Splitters and taps provide a predetermined signal level and maintain the correct impedance to each of the outputs. Calculation of losses associated with splitters, drop taps and cable are required. Each outlet has a defined amount of signal level required, and there is a recommendation for maximum cable runs. Splitters and taps provide the same signal quality to each outlet, as long as design recommendations are adhered to. If there is a poor signal received from the antenna, this same poor signal will be output to each of the TV outlets. To guarantee a good signal at each of the TV outlets, a good quality signal needs to be received at the antenna.

ATTENUATORS
As there are many signals received by an antenna, there may be a wide variation in signal levels. In order to ensure the same picture quality on all channels, the signal levels may require equalisation to prevent the stronger signals from overriding the weaker ones. Equalisation is achieved by using attenuators, which reduce the incoming stronger signals by a specified amount. Attenuators can be either fixed or variable. They are either designed for one specific attenuation level, or they are switchable so that the signals can be reduced in increments to the required level. Attenuators reduce all signals that pass through by the same amount. Therefore, frequencies that need reducing need to be separated from the rest of the signals so that only the stronger signals are reduced.

AMPLIFIERS
Amplifiers increase the strength of signals received to a level greater than the losses in the distribution system. The amplifier gain determines the level of signal increase, which should be high enough to provide an acceptable signal level to all televisions in the system. Although an amplifier’s gain is important, the output capability is just as important. The amplifier’s specifications should be checked to ensure that the output level is sufficient to feed the system and that the strength of the input signal plus the gain of the amplifier doesn’t exceed the amplifiers rated output capability. Exceeding the output capability will result in over loading, cross modulation distortion, and overall signal deterioration.
CATV
Cable television is a system of distributing television programs to subscribers via radio frequency (RF) signals transmitted through coaxial cables or light pulses through fiber-optic cables. This contrasts with traditional broadcast television (terrestrial television) in which the television signal is transmitted over the air by radio waves and received by a television antenna attached to the television. FM radio programming, high-speed Internet, telephone service, and similar non-television services may also be provided through these cables.

The abbreviation CATV is often used for cable television. It originally stood for Community Access Television or Community Antenna Television, from cable television's origins in 1948: in areas where over-the-air reception was limited by distance from transmitters or mountainous terrain, large "community antennas" were constructed, and cable was run from them to individual homes. The origins of cable broadcasting are even older as radio programming was distributed by cable in some European cities as far back as 1924.

Receiving Cable Television:
In order to receive cable television at a given location, cable distribution lines must be available on the local utility poles or underground utility lines. Coaxial cable brings the signal to the customer's building through a service drop, an overhead or underground cable. If the subscriber's building does not have a cable service drop, the cable company will install one. The standard cable used in the U.S. is RG-6, which has a 75 ohm impedance, and connects with a type F connector. The cable company's portion of the wiring usually ends at a distribution box on the building exterior, and built-in cable wiring in the walls usually distributes the signal to jacks in different rooms to which televisions are connected. Multiple cables to different rooms are split off the incoming cable with a small device called a splitter.

There are two standards for cable television; older analog cable, and newer digital cable which is capable of carrying high definition signals used by newer digital HDTV televisions. Many cable companies have upgraded to digital cable in the last 5 years. To receive digital cable, most TVs require a digital television adapter (set-top box or cable converter box) from the cable company. A cable from the jack in the wall is attached to the input of the box, and an output cable from the box is attached to the "Antenna In" or "RF In" connector on the back of the television. Different converter boxes are required for newer digital HDTV TVs and older legacy analog televisions. The box must be "activated" by a signal from the cable company before use.

Most American television sets are "cable-ready" and have a television tuner capable of receiving older analog cable TV. The cable from the wall is attached directly to the "Antenna In" connector on the back of the television.

Operation
In the most common system, multiple television channels (as many as 500) are distributed to subscriber residences through a coaxial cable, which comes from a trunkline supported on utility poles originating at the cable company's local distribution facility, called the headend. Multiple
channels are transmitted through the cable by a technique called frequency division multiplexing. At the headend, each television channel is translated to a different frequency. By giving each channel a different frequency "slot" on the cable the separate television signals do not interfere. At the subscriber's residence, either the subscriber's television or a set-top box provided by the cable company translates the desired channel back to its original frequency (baseband), and it is displayed on the screen. Due to widespread cable theft in earlier analog systems, in modern digital cable systems the signals are encrypted, and the set-top box must be activated by an activation code sent by the cable company before it will function, which is only sent after the subscriber signs up. There are also usually "upstream" channels on the cable, to send data from the customer box to the cable headend, for advanced features such as requesting pay-per-view shows, cable internet access, and cable telephone service. The "downstream" channels occupy a band of frequencies from approximately 50 MHz to 1 GHz, while the "upstream" channels occupy frequencies of 5 to 42 MHz. Subscribers pay with a monthly fee. Subscribers can choose from several levels of service, with "premium" packages including more channels but costing more.

At the local headend, the feed signals from the individual television channels are received by dish antennas from communication satellites. Additional local channels, such as local broadcast television stations, educational channels from local colleges, and community access channels devoted to local governments (PEG channels) are usually included on the cable. Commercial advertisements for local business are also inserted in the programming at the headend (the individual channels, which are distributed nationally, also have their own nationally oriented commercials).

**Hybrid fiber coaxial systems**

Modern cable systems are large, with a single network and headend often serving an entire metropolitan area or county. Most systems use hybrid fiber coaxial (HFC) distribution; this means the trunklines that carry the signal from the headend to local neighborhoods are optical fiber to provide greater bandwidth and also extra capacity for future expansion. At the headend the radio frequency electrical signal carrying all the channels is modulated on a light beam and sent through the fiber. The fiber trunkline goes to several distribution hubs, from which multiple fibers fan out to carry the signal to boxes called optical nodes in local communities. At the optical node, the light beam from the fiber is translated back to an electrical signal and carried by coaxial cable distribution lines on utility poles, from which cables branch out to subscriber residences.

**Cable Television deployments**

It is mostly available in North America, Europe, Australia and East Asia, and less so in South America and the Middle East. Cable TV has had little success in Africa, as it is not cost-effective to lay cables in sparsely populated areas. So-called "wireless cable" or microwave-based systems are used instead.