Television Technology

Michaela Keegan

First Edition, 2012

ISBN 978-81-323-3108-7

Published by:
Research World
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

Table of Contents

Chapter 1

Technology of Television

The **technology of television** has changed since its early days using a mechanical system invented by Paul Gottlieb Nipkow in 1884.

Elements of a television system

The elements of a simple broadcast television system are:

- An image source. This is the electrical signal representing the visual image, and may be from a camera in the case of live images, a video tape recorder for playback of recorded images, or a film chain-telecine-flying spot scanner for transmission of motion pictures (films).
- A sound source. This is an electrical signal from a microphone or from the audio output of a video tape recorder or motion picture film scanner.
- A transmitter, which generates radio signals (radio waves) and encodes them with picture and sound information.
- An antenna coupled to the output of the transmitter for broadcasting the encoded signals.
- An antenna to receive the broadcast signals.
- A receiver (also called a tuner), which decodes the picture and sound information from the broadcast signals, and whose input is coupled to the antenna.
- A display device, which turns the electrical signals into visual images.
- An audio amplifier and loudspeaker, which turns electrical signals into sound waves (speech, music, and other sounds) to accompany the images.

Practical television systems include equipment for selecting different image sources, mixing images from several sources at once, insertion of pre-recorded video signals, synchronizing signals from many sources, and direct image generation by computer for such purposes as station identification. The facility for housing such equipment, as well as providing space for stages, sets, offices, etc., is called a television studio, and may be located many miles from the transmitter. Communication from the studio to the transmitter is accomplished via a dedicated cable or radio system.

Television signals were originally transmitted exclusively via land-based transmitters. The quality of reception varied greatly, dependent in large part on the location and type of receiving antenna. This led to the proliferation of large rooftop antennas to improve reception in the 1960s, replacing set-top dipole or "rabbit ears" antennas, which however remained popular. Antenna rotors, set-top controlled servo motors to which the mast of the antenna is mounted, to enable rotating the antenna such that it points to the desired transmitter, would also become popular.

In most cities today, cable television providers deliver signals over coaxial or fiber-optic cables for a fee. Signals can also be delivered by radio from satellites in geosynchronous orbit and received by parabolic dish antennas, which are comparatively large for analog signals, but much smaller for digital. Like cable providers, satellite television providers also require a fee, often less than cable systems. The affordability and convenience of digital satellite reception has led to the proliferation of small dish antennas outside many houses and apartments.

Digital systems may be inserted anywhere in the chain to provide better image transmission quality, reduction in transmission bandwidth, special effects, or security of transmission from reception by non-subscribers. A home today might have the choice of receiving analog or HDTV over the air, analog or digital cable with HDTV from a cable television company over coaxial cable, or even from the phone company over fiber optic lines. On the road, television can be received by pocket sized televisions, recorded on tape or digital media players, or played back on wireless phones (mobile or "cell" phones) over a high-speed or "broadband" internet connection.

Display technology

Digital video equipment in an edit suite

Thanks to the advances in display technology, there are now several kinds of video displays used in modern TV sets:

- **CRT** (cathode-ray tube): The most common screens were direct-view CRTs for up to roughly 100 cm (40 inch) (in 4:3 ratio) and 115 cm (45 inch) (in 16:9 ratio) diagonals. These are the least expensive, and are a refined technology that can still provide the best overall picture quality value. As they do not have a fixed native resolution, they are capable of displaying sources with different resolutions at the best possible image quality. The frame rate or refresh rate of a typical NTSC format CRT TV is 29.97 Hz, and for the PAL format, 25 Hz, both are scanned with two fields per frame in an interlaced fashion. A typical NTSC broadcast signal's visible portion has an equivalent resolution of about 640x480 pixels. It actually could be slightly higher than that, but the vertical blanking interval (VBI), allows other signals to be carried along with the broadcast.
- **Rear Projection** (**RPTV**): Most very large screen TVs (up to 254 cm (100 inch) and beyond) use projection technology. Three types of projection systems are used in projection TVs: CRT-based, LCD-based, and DLP (reflective micromirror chip) -based, D-ILA and LCOS-based. Projection television has been commercially available since the 1970s, but at that time could not match the

image sharpness of the CRT; current models are vastly improved, and offer a cost-effective large-screen display.
    - A variation is a **video projector**, using similar technology, which projects onto a screen. This is often referred to as "front projection".

- **Flat panel** (LCD or plasma): Modern advances have brought flat panels to TV that use active matrix LCD or plasma display technology. Flat panel LCDs and plasma displays are as little as 25.4 mm (1 inch) thick and can be hung on a wall like a picture or put over a pedestal. Some models can also be used as computer monitors.
- **LED** technology has become one of the choices for outdoor video and stadium uses, since the advent of bright LEDs and driver circuits. LEDs enable scalable ultra-large flat panel video displays that other technologies may never be able to match in performance.

Each has its pros and cons. Flat panel LCD and plasma displays have a wide viewing angle (around 178 degrees) so they may best suited for a home theatre with a wide seating arrangement. Rear projection screens do not perform well in daylight or well-lit rooms and so are only suited to darker viewing areas.

Terminology for televisions

Pixel resolution is the number of pixels of one row on a given screen. Before the year 2000 *horizontal lines of resolution* was the standard method of measurement for analog video. For example, a VHS VCR might be described as having 250 lines of resolution as measured across a circle circumscribed in the center of the screen (approximately 440 pixels edge-to-edge).

A typical resolution of 720×480 and 720x576 means that the television display has 720 pixels across and 480 or 576 pixels on the vertical axis. The higher the resolution on a specified display the sharper the image. Contrast ratio is a measurement of the range between the lightest and darkest points on the screen.

The higher the contrast ratio, the better looking picture there is in terms of richness, deepness, and shadow detail. The brightness of a picture measures how vibrant and impacting the colors are. Measured in cd / m^2 equivalent to the amount of candles required to power the image.

On the other hand, the so-called *brightness* and *contrast* adjustment controls on televisions and monitors are traditionally used to control different aspects of the picture display. The brightness control shifts the black level, affecting the image intensity or brightness, while the contrast control adjusts the contrast range of the image.

Transmission band

There are various bands on which televisions operate depending upon the country. The VHF and UHF signals in bands III to V are generally used. Lower frequencies do not have enough bandwidth available for television. Although the BBC initially used Band I VHF at 45 MHz, this frequency is (in the UK) no longer in use for this purpose. Band II is used for FM radio transmissions. Higher frequencies behave more like light and do not penetrate buildings or travel around obstructions well enough to be used in a conventional broadcast TV system, so they are generally only used for MMDS and satellite television, which uses frequencies from 2 to 12 GHz. TV systems in most countries relay the video as an AM (amplitude-modulation) signal and the sound as an FM (frequency-modulation) signal. An exception is France, where the sound is AM.

Aspect ratios

Aspect ratio refers to the ratio of the horizontal to vertical measurements of a television's picture. Mechanically scanned television as first demonstrated by John Logie Baird in 1926 used a 7:3 vertical aspect ratio, oriented for the head and shoulders of a single person in close-up.

Most of the early electronic TV systems, from the mid-1930s onward, shared the same aspect ratio of 4:3 which was chosen to match the Academy Ratio used in cinema films at the time. This ratio was also square enough to be conveniently viewed on round cathode-ray tubes (CRTs), which were all that could be produced given the manufacturing technology of the time. (Today's CRT technology allows the manufacture of much wider tubes, and the flat-screen technologies which are becoming steadily more popular have no technical aspect ratio limitations at all.) The BBC's television service used a more squarish 5:4 ratio from 1936 to 3 April 1950, when it too switched to a 4:3 ratio. This did not present significant problems, as most sets at the time used round tubes which were easily adjusted to the 4:3 ratio when the transmissions changed.

A Samsung LE26R41BD HDTV

In the early 1950s, movie studios moved towards widescreen aspect ratios such as CinemaScope in an effort to distance their product from television. Although this was initially just a gimmick, widescreen is still the format of choice today and 4:3 aspect ratio movies are rare.

Yet the various television systems were not originally designed to be compatible with film at all. Traditional, narrow-screen movies are projected onto a television camera either so that the top of the screens line up to show facial features, or, for films with subtitles, the bottoms. What this means is that filmed newspapers or long captions filling the screen for explanation are cut off at each end. Similarly, while the frame rate of sound films is 24 per second, the screen scanning rate of the NTSC is 29.97 Hz (per second), which requires a complex scanning schedule. That of PAL and SECAM are 50 Hz, which means that films are shortened (and the sound is offkey) by scanning each frame twice for 25 per second.

The switch to digital television systems has been used as an opportunity to change the standard television picture format from the old ratio of 4:3 (1.33:1) to an aspect ratio of 16:9 (approximately 1.78:1). This enables TV to get closer to the aspect ratio of modern widescreen movies, which range from 1.66:1 through 1.85:1 to 2.35:1. There are two methods for transporting widescreen content, the most common of which uses what is

called anamorphic widescreen format. This format is very similar to the technique used to fit a widescreen movie frame inside a 1.33:1 35 mm film frame. The image is compressed horizontally when recorded, then expanded again when played back. The anamorphic widescreen 16:9 format was first introduced via European PALplus television broadcasts and then later on "widescreen" Laser Discs and DVDs; the ATSC HDTV system uses straight widescreen format, no horizontal compression or expansion is used.

Recently "widescreen" has spread from television to computing where both desktop and laptop computers are commonly equipped with widescreen displays. There are some complaints about distortions of movie picture ratio due to some DVD playback software not taking account of aspect ratios; but this may subside as the DVD playback software matures. Furthermore, computer and laptop widescreen displays are in the 16:10 aspect ratio both physically in size and in pixel counts, and not in 16:9 of consumer televisions, leading to further complexity. This was a result of widescreen computer display engineers' assumption that people viewing 16:9 content on their computer would prefer that an area of the screen be reserved for playback controls, subtitles or their Taskbar, as opposed to viewing content full-screen.

Aspect ratio incompatibility

The television industry's changing of aspect ratios is not without difficulties, and can present a considerable problem.

Displaying a widescreen aspect (rectangular) image on a conventional aspect (square or 4:3) display can be shown:

- in "letterbox" format, with black horizontal bars at the top and bottom
- with part of the image being cropped, usually the extreme left and right of the image being cut off (or in "pan and scan", parts selected by an operator or a viewer)
- with the image horizontally compressed

A conventional aspect (square or 4:3) image on a widescreen aspect (rectangular with longer horizon) display can be shown:

- in "pillar box" format, with black vertical bars to the left and right
- with upper and lower portions of the image cut off (or in "tilt and scan", parts selected by an operator)
- with the image vertically compressed

A common compromise is to shoot or create material at an aspect ratio of 14:9, and to lose some image at each side for 4:3 presentation, and some image at top and bottom for 16:9 presentation. In recent years, the cinematographic process known as Super 35 (championed by James Cameron) has been used to film a number of major movies such as *Titanic*, *Legally Blonde*, *Austin Powers*, and *Crouching Tiger, Hidden Dragon*. This process results in a camera-negative which can then be used to create both wide-screen

theatrical prints, and standard "full screen" releases for television/VHS/DVD which avoid the need for either "letterboxing" or the severe loss of information caused by conventional "pan-and-scan" cropping.

The end of analog television broadcasting

NTSC

In North America, the basic signal standards since 1941 have been compatible enough that even the oldest monochrome televisions can still receive color broadcasts in 2007. However, the United States Congress has passed a law which requires the cessation of all conventional television broadcast signals by February 2009. If the law is not changed again, then after that date all NTSC standard televisions, with analog-only tuners, will go dark unless fitted with digital ATSC tuners, and the spectrum previously occupied by those analog channels will be auctioned off by the United States' Federal Communications Commission for other uses. The analog cut-off date has been changed by Congress in the past.

PAL and SECAM

PAL and SECAM are expected not to be broadcast in Europe and Eurasia by the mid-2020s. PAL-M may have a similar decommissioning timeline.

The European Union has recommended its members to have closed down analogue terrestrial television by 2012. Luxembourg and the Netherlands had already completed their closedowns in 2006, and Finland and Sweden closed down their analogue broadcasts in 2007. Meanwhile, some countries may have difficulties making the 2012 deadline.

Britain started its programme of switching off analogue transmitters in October 2007. At 2am on Wednesday 17 October 2007 the BBC2 transmitter covering the Whitehaven and Copeland areas (NW England) was turned off. The remaining four analogue channels cease broadcasting in the region on Wednesday 14 November. The original five channels will then only be available in digital form, alongside some 15 additional free to air channels.

Television add-ons

The television was the first consumer mass market for video displays. Today there are many television add-ons including video game consoles, VCRs, Set-top boxes for Cable, Satellite and DVB-T compliant Digital Television reception, DVD players, or Digital Video Recorders (including personal video recorders, PVRs). The add-on market continues to grow as new technologies are developed. Computers, the internet, and even pocket devices such as the iPod provide other ways to consume video content.

New developments

- 3D television
- Ambilight
- Broadcast flag
- CableCARD
- Digital Light Processing (DLP)
- Digital Rights Management (DRM)
- Digital television (DTV)
- Digital Video Recorders (DVR)
- Direct Broadcast Satellite TV (DBS)
- DVD and HD DVD standards
- Blu-ray Disc
- Flat panel display
- Flicker-free (100 Hz or 120 Hz, depending on country)
- High Definition TV (HDTV)
- High-Definition Multimedia Interface (HDMI)
- IPTV also known as Internet television (IPTV)
- Laser TV display technology
- Liquid crystal display television (LCD)
- Mirror TV
- OLED TV - Roll up TV (using organic light-emitting diodes)
- P2PTV
- Pay-per-view
- Personal video recorders (PVR)
- Picture-in-picture (PiP)
- Pixelplus
- Placeshifting
- Plasma display
- Remote controls
- Surface-conduction electron-emitter display (SED) display technology
- The Slingbox
- Time shifting
- Video on-demand (VOD)
- Ultra High Definition Television (UHDTV)
- Web TV

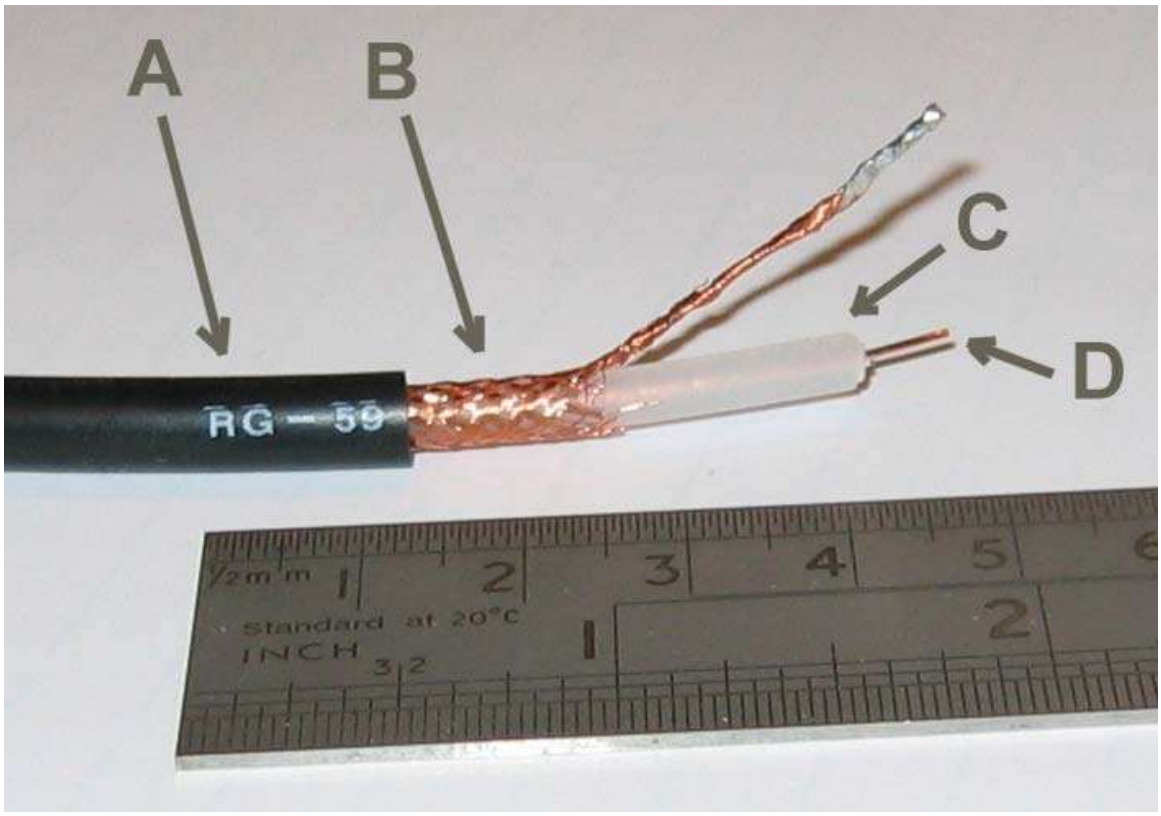
A long screen television in Korea.

Exterior designs

In the early days of television, cabinets were made of wood grain (often simulated particularly in the later years), however, they went out of style in the 1980s. Up until the late 1970s, console TV/Hi Fi's were common. These were large (about 6' wide by 4' high) wooden cabinets containing a television, speakers, radio and a turntable.

Chapter 2

Cable Television



Coaxial cable is often used to transmit **cable television** into a residence.

Cable television is a system of providing television to consumers via radio frequency signals transmitted to televisions through coaxial cables or Digital light pulses though fixed optical fibers located on the subscriber's property, much like the over-the-air method used in traditional television broadcasting (via radio waves) in which a television antenna is required. FM radio programming, high-speed Internet, telephony, and similar

non-television services may also be provided. The major difference is the change of radio frequency signals used and optical connections to the subscriber property.

The abbreviation **CATV** is often used to mean "Cable TV". It originally stood for **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.

It is most commonplace in North America, Europe, Australia and East Asia, though it is present in many other countries, mainly 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.

Cable television deployments

Asia & Australia

Australia

Cable television began in the early 1990s in Australia. Several companies appeared including FOXTEL, Galaxy TV, OPTUS TV, Selectv and Austar offering services to homes across the major states of Australia. Services to Tasmania and the Northern Territory took longer to start, not until the mid 2000's when the digital satellite pay television service had picked up momentum and was beginning to be used for metropolitan installs and not just rural installs. As FOXTEL and Austar subscribers continued to rise, Galaxy TV ended their services, while Selectv has become a Greek dedicated Satellite service. OPTUS TV in 2011 will cease their services.

Philippines

“NUVUE”, the first cable television system, was set up in Baguio City spearheaded by American expatriate Russel Swartley in 1969. Popularity of CATV started in the 1980s after the Marcos administration. Cable giant SkyCable started in 1992. Cable providers have grown, and these some examples are Global Destiny, Cablelink, and some regional cable providers. In 2007, SkyCable introduced the DigiBox, a cable TV set-top box that provides a digital television (DTV) signal for higher video quality and prevents illegal cable TV connections. In 2008, SkyCable also broadcast the 37th Ryder Cup in HDTV. In 2009, SkyCable became the first cable TV service provider in the Philippines to broadcast the UAAP Games in HDTV via the new SkyHD Cable TV service.

Mongolia

There are several cable TV providers in Mongolia. The main three are "SuperVision", "Hiimori" and "Sansar CATV". All three cover approximately 15 national channels and

40 foreign channels, such as CNN, BBC, and NHK. "Sansar" has biggest network in Ulaanbaatar. SuperVision is the first digital cable television in Mongolia and other CATVs are planning to launch digital cable television with CA systems.

Maldives

There are only two cable TV operators in the country. As the population of the Maldives is separated across around 200 inhabited islands, there is a cable TV operator for nearly every island. MediaNet Pvt. Ltd. is the country's largest cable TV operator (providing only analog service, although digital service has been announced. MediaNet is a Male-based cable TV operator that provides cable and MMDS service to five islands near Male. MediaNet holds a distribution license for 75 channels and distributes channels to nearly all the operators of the country. In Maldives, cable TV subscribers can get most premium channels available in Asia.

All channels are required to obtain an exhibition license from Department of Information after each channel is classified at **National Bureau of Classification (NBC)**. NBC gives the highest classification for every channel after contents of each channel are examined for a week. Cable TV classification ratings are as follows:

- **G** - General viewing for all ages.
- **PG** - Parental Guidance is required.
- **12+** - For viewers aged 12 and above.
- **15+** - For viewers aged 15 and above.
- **18+** - For viewers aged 18 and above.
- **18+R** - For viewers aged 18 and above.

Channels with an **18+R** classification rating contains content that may affect an individual directly or indirectly. Viewers discretion is advised.

Latin America

Panamá

Panamanian company Rexa started Cable TV deployment in 1983. Rexa's successor, Cableonda, was dominant throughout the 1990s, but as the customer base expanded, other companies entered the market. Since 2000 several companies compete for the Panamanian market, such as CTV, Cable Onda, Cablevision, Cable and Wireless, and others. Cable Onda is the largest. The penetration of CableTV in Panamá is at 40%.

Dominican Republic

Cable television in the Dominican Republic is provided by a variety of companies. These companies offer both English and Spanish language television, plus a range of channels in other languages, high definition channels, pay-per-view movies and events, sports packages and premium movie channels such as HBO, Playboy TV, Cinecanal, etc. Also, the channels are from not only the Dominican Republic, but also the United States and Europe. In the Dominican Republic television spectrum, there are 46 VHF, UHF, and free-to-air channels. The free of charge channels programming consists mainly of locally produced entertainment shows, news, and comedy shows; and foreign sit-coms, soap operas, movies, cartoons, and sports programs.

The main service provider in the Dominican Republic is Telecable from Tricom. Aster is concentrated in Santo Domingo, but is expanding its service throughout the Dominican Republic. There are also new companies using new technologies that are expanding quickly such as Claro TV (IPTV), Wind Telecom (MMDS) and SKY (Satellite TV).

Europe

Ireland

Cable television is the most common system for distributing multi-channel television in Ireland. With more than 40 year of history and extensive networks of both wired and "wireless" cable, Ireland is amongst the most cabled countries in Europe. Forty percent of Irish homes received cable television in September 2006. The figure dropped slightly in the early years of the 21st century due to the increased popularity of satellite reception, notably Sky, but has stabilized recently.

In the Republic of Ireland, UPC Ireland is by far the largest cable and MMDS operator, owning all of the state's MMDS licenses and almost all of the state's cable TV operators. UPC offers analogue and digital cable television services in cities and towns throughout the country (with the exception of Cork, where the network is digital-only). It offers MMDS services in rural areas. In areas previously served by NTL, the network is digital-only, while Chorus areas still have both analogue and digital services. Other than UPC, the only other operator providing analogue and digital cable is Casey Cablevision, which operates in Dungarvan, County Waterford. There also exists a small number of analogue-only cable networks such as the Longford service Crossan Cable.

United Kingdom

When the infant BBC Television service was started in 1932, Rediffusion, which had supplied cable radio services since 1928, started providing "Pipe TV" to its customers who had difficulties tuning into the weak TV broadcast signal.

Suspended during World War II, the BBC service was re-established in June 1946, and had only one transmitter, at Alexandra Palace, which served the London area. From the

end of 1949, new transmitters were steadily opened to serve other major conurbations, and then smaller areas of population. The areas on the fringes of the transmitter coverage provided an opportunity for Rediffusion and other commercial companies to expand cable systems to enlarge the viewing audience for the one BBC television channel which then existed. The first was in Gloucester in 1950 and the process gathered pace over the next few years, especially after a second television channel, ITV, was launched in 1955 to compete with BBC. By the late 1970s, two and a half million British homes received their television service via cable.

By law, these cable systems were restricted to the relay of the public broadcast channels, which meant that as the transmitter network became more comprehensive, the incentive to subscribe to cable was reduced and they began to lose customers. In 1982, a radical liberalization of the law on cable was proposed by the Information Technology Advisory Panel , for the sake of promoting a new generation of broadband cable systems leading to the wired society After setting up and receiving the conclusions of the Hunt Inquiry into Cable Expansion and Broadcasting Policy, the Government decided to proceed with liberalization and two pieces of legislation: the Cable and Broadcasting Act and the Telecommunications Act, were enacted in 1984.

The result was that cable systems were permitted to carry as many new television channels as they liked, as well as providing a telephone service and interactive services of many kinds (as since made familiar by the Internet). To maintain the momentum of the perceived commercial interest in this new investment opportunity, in 1983, the Government itself granted eleven interim franchises for new broadband systems each covering a community of up to around 100,000 homes, but the competitive franchising process was otherwise left to the new regulatory body, the Cable Authority, which took on its powers from January 1, 1985.

The franchising process proceeded steadily, but the actual construction of new systems was slow, as doubts about an adequate payback from the substantial investment persisted. By the end of 1990 almost 15 million homes had been included in franchised areas, but only 828,000 of these had been passed by broadband cable and only 149,000 were actually subscribing. Thereafter, however, construction accelerated and take-up steadily improved.

The first new television channels launched for carriage on cable systems (going live in March 1984) were Sky Channel, Screensport, Music Box and TEN - the Movie Channel. Others followed, some were merged or closed down, but the range expanded. A similar flux was seen among the operators of cable systems: franchises were granted to a host of different companies, but a process of consolidation saw the growth of large multiple system operators, until by the early 2000s, virtually the whole industry was in the hands of two companies, NTL and Telewest.

In 2005, it was announced that NTL and Telewest would merge, after a period of co-operation in the preceding few years. This merger was completed on March 3, 2006, with the company being named **ntl Incorporated**. For the time being, the two brand names

and services were marketed separately. However, following NTL's acquisition of Virgin Mobile, the NTL and Telewest services were rebranded *Virgin Media* on February 8, 2007, creating a single cable operator covering more than 95% of the UK cable market.

There are a small number of other surviving cable television companies in the UK outside of NTL including WightCable (Isle of Wight) and Smallworld (Ayrshire, Carlisle and Lancashire).

Cable TV faces intense competition from British Sky Broadcasting's Sky satellite television service. Most channels are carried on both platforms. However, cable often lacks "interactive" features (e.g. text services, and extra video-screens), especially on BSkyB owned channels, and the satellite platform lacks services requiring high degrees of two-way communication, such as true video on demand.

However, subscription-funded digital terrestrial television proved less of a competitive threat. The first system, ITV Digital, went into liquidation in 2002. Top Up TV later replaced it; however, this service is shrinking as the DVB-T multiplex owners are finding free-to-air broadcasting more profitable.

Another potential source of competition in the future will be TV over broadband internet connections; this is known as IPTV. Some IPTV services are currently available in London, while services operated in Hull ceased in April 2006. As the speed and availability of broadband connections increase, more TV content can be delivered using protocols such as IPTV. However, its impact on the market is yet to be measured, as is consumer attitude toward watching TV programs on computers instead of television sets. At the end of 2006, BT (the UK's former state owned monopoly phone company) started offering BT Vision, which combines the digital free-to-air standard Freeview through an aerial, and on-demand IPTV, delivered over a BT Broadband connection through the Vision set-top box (BT have chosen to deploy Microsoft's Mediaroom platform for this.)

North America

Canada

In 1949, Broadcast Relay Service began negotiations for the implementation of what was to be the first large scale cable TV system in North America. The development of the system relied on reaching agreement with Quebec Hydro-Electric Commission to utilise their existing network of power poles supplying power to the Montreal Metro area. Initial discussions began with a meeting with Montreal City Council on June 21, 1949. After many months if negotiation agreement was reached between Hydro Quebec and Rediffusion on February 28, 1950 for an initial 5 year period. The Rediffusion cable system was operational in 1952 and eventually supplied 80,000 homes in Montreal Quebec. Cable television in Canada began in 1952 with community antenna connections in Vancouver and London, Ontario; which city is first is not clear. Initially, the systems brought American stations to viewers in Canada who had no Canadian stations to watch;

broadcast television, though begun late in 1952 in Toronto and Montreal, did not reach a majority of cities until 1954.

In time, cable television was widely established to carry available Canadian stations as well as import American stations, which constituted the vast majority of signals on systems (usually only one or two Canadian stations, while some systems had duplicate or even triplicate coverage of American networks). During the 1970s, a growing number of Canadian stations pushed American channels off the systems, forcing several to expand beyond the original 12-channel system configurations. At the same time, the advent of fibre-optic technology enabled companies to extend their systems to nearby towns and villages that by themselves were not viable cable television markets.

USA

Fee structure

The industry strongly lobbies against federal "family tier" and "a la carte cable television" bills which would provide consumers the option of purchasing individual channels rather than a broad tier of programming, sometimes consisting of channels which are not desired by various subscriber segments. These anti-consumer issues continue to garner attention from state governments, Congress and U.S. Federal Communications Commission (FCC) Chairman Kevin Martin. What's more, the argument calling for an adjustment to the manner in which cable is distributed was reaffirmed in January 2010 when cable subscribers throughout Connecticut, New Jersey, and New York found themselves in the middle of a contentious battle over an increase in subscriber fees paid to the media company Scripps Networks Interactive by cable provider Cablevision. The parties' contract expired December 31, 2009, and as they were unable to reach a mutual agreement beforehand regarding the amount paid for each cable subscriber, Scripps pulled two of its television channels, HGTV and Food Network, from the Cablevision channel lineup on January 1, 2010 at 12:01AM as the 2010s had arrived.

Other cable-based services

Coaxial cables are capable of bi-directional carriage of signals as well as the transmission of large amounts of data. Cable television signals use only a portion of the bandwidth available over coaxial lines. This leaves plenty of space available for other digital services such as cable internet, cable telephony and wireless services, using both unlicensed and licensed spectrum.

Broadband Internet is achieved over coaxial cable by using cable modems to convert the network data into a type of digital signal that can be transferred over coaxial cable. One problem with some cable systems is the older amplifiers placed along the cable routes are unidirectional thus in order to allow for uploading of data the customer would need to use an analog telephone modem to provide for the upstream connection. This limited the upstream speed to 31.2k and prevented the always-on convenience broadband internet typically provides. Many large cable systems have upgraded or are upgrading their

equipment to allow for bi-directional signals, thus allowing for greater upload speed and always-on convenience, though these upgrades are expensive.

In North America, Australia and Europe many cable operators have already introduced cable telephone service, which operates just like existing fixed line operators. This service involves installing a special telephone interface at the customer's premises that converts the analog signals from the customer's in-home wiring into a digital signal, which is then sent on the local loop (replacing the analog last mile, or POTS) to the company's switching center, where it is connected to the PSTN. The biggest obstacle to cable telephone service is the need for nearly 100% reliable service for emergency calls. One of the standards available for digital cable telephony, PacketCable, seems to be the most promising and able to work with the Quality of Service demands of traditional analog POTS service. The biggest advantage to digital cable telephone service is similar to the advantage of digital cable TV, namely that data can be compressed, resulting in much less bandwidth used than a dedicated analog circuit-switched service. Other advantages include better voice quality and integration to a VoIP network providing cheap or unlimited nationwide and international calling. Note that in many cases, digital cable telephone service is separate from cable modem service being offered by many cable companies and does not rely on IP traffic or the Internet.

Beginning in 2004 in the United States, the traditional cable television providers and traditional telecommunication companies increasingly compete in providing voice, video and data services to residences. The combination of TV, telephone and Internet access is commonly called **triple play** regardless of whether CATV or telcos offer it.

More recently, several US cable operators have begun offering wireless services to their subscribers. Most notably was the September 2008 launch of Optimum Wi-Fi by Cablevision. This service is made available, at no additional cost, to Optimum Broadband subscribers, and is available at over 14,000 locations across Long Island, NY, parts of NJ and CT. Cablevision has reported a double digit reduction in subscriber churn since launching Optimum Wi-Fi, even as Verizon has rolled out FiOS, a competitive residential broadband service in the Cablevision footprint. Other Tier 1 cable operators, including Comcast, have announced trials of a similar service in sections of the US Northeast.

History and beginnings of Cable TV-originated live programs

During the 1980's, mandated regulations not unlike public access created the beginning of the Cable-originated live TV program that evolved into what we know today in 2011 where many cable networks provide live cable-only broadcasts of many varieties, cable-only produced movies, and mini-series. Various live local programs with local interests were rapidly being created all over the United States in most major markets in the early 1980's. One of the first was with the local ATC broadcasting station in Columbus, Ohio, the company being based in Colorado at the time, where, in 1982, at the age of 16, while still in high school, Richard Sillman was one of if not the youngest Cable TV Director in the US of these live on-air Cable TV programs.

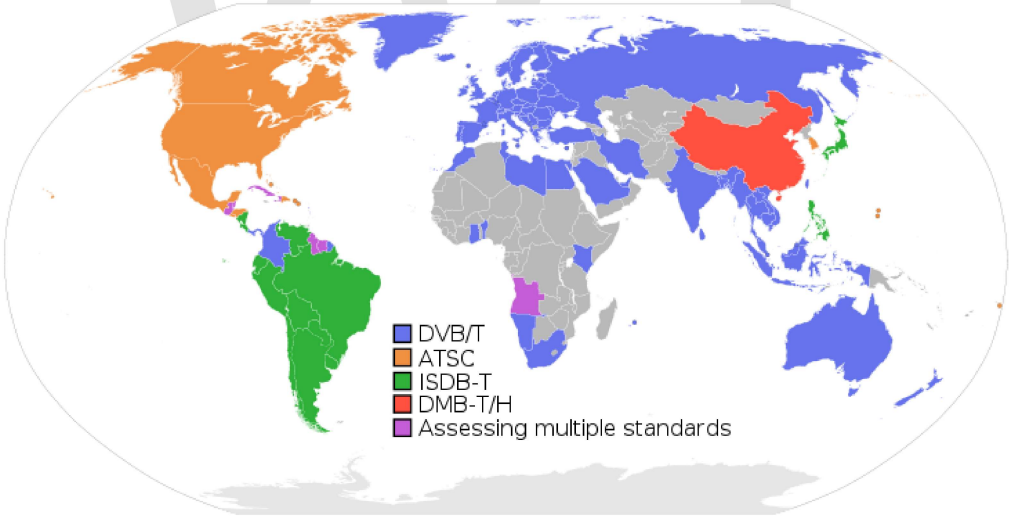
With the development of the internet, by the late 1990's and early 2000, much of that regulation had been replaced where newer industry technologies developed, offering viewers alternate choices for local events and programming leading to what is today, that being Digital Cable, Internet, and Phone being offered to consumers, bundled, by 2010.

Chapter 3

Digital Television

Digital television (**DTV**) is the transmission of audio and video by digital signals, in contrast to the analog signals used by analog TV. Many countries are replacing over-the-air broadcast analog television with digital television to allow other uses of the radio spectrum formerly used for analog TV broadcast.

Technical information



Digital terrestrial television broadcasting systems by country

Formats and bandwidth

Digital television supports many different picture formats defined by the combination of size, aspect ratio (width to height ratio) and interlacing. With digital terrestrial television broadcasting, the range of formats can be broadly divided into two categories: HDTV and

SDTV. These terms by themselves are not very precise, and many subtle intermediate cases exist.

High-definition television (HDTV), one of several different formats that can be transmitted over DTV, uses different formats, amongst which: 1280 × 720 pixels in progressive scan mode (abbreviated *720p*) or 1920 × 1080 pixels in interlace mode (*1080i*). Each of these utilizes a 16:9 aspect ratio. (Some televisions are capable of receiving an HD resolution of 1920 × 1080 at a 60 Hz progressive scan frame rate — known as 1080p.) HDTV cannot be transmitted over current analog channels.

Standard definition TV (SDTV), by comparison, may use one of several different formats taking the form of various aspect ratios depending on the technology used in the country of broadcast. For 4:3 aspect-ratio broadcasts, the 640 × 480 format is used in NTSC countries, while 720 × 576 is used in PAL countries. For 16:9 broadcasts, the 704 × 480 format is used in NTSC countries, while 720 × 576 is used in PAL countries. However, broadcasters may choose to reduce these resolutions to save bandwidth (e.g., many DVB-T channels in the United Kingdom use a horizontal resolution of 544 or 704 pixels per line).

Each commercial terrestrial DTV channel in North America is permitted to be broadcast at a data rate up to 19 megabits per second, or 2.375 megabytes per second. However, the broadcaster does not need to use this entire bandwidth for just one broadcast channel. Instead the broadcast can be subdivided across several video subchannels (aka feeds) of varying quality and compression rates, including non-video datacasting services that allow one-way high-bandwidth streaming of data to computers.

A broadcaster may opt to use a standard-definition digital signal instead of an HDTV signal, because current convention allows the bandwidth of a DTV channel (or "multiplex") to be subdivided into multiple subchannels (similar to what most FM stations offer with HD Radio), providing multiple feeds of entirely different programming on the same channel. This ability to provide either a single HDTV feed or multiple lower-resolution feeds is often referred to as distributing one's "bit budget" or multicasting. This can sometimes be arranged automatically, using a statistical multiplexer (or "stat-mux"). With some implementations, image resolution may be less directly limited by bandwidth; for example in DVB-T, broadcasters can choose from several different modulation schemes, giving them the option to reduce the transmission bitrate and make reception easier for more distant or mobile viewers.

Reception

There are a number of different ways to receive digital television. One of the oldest means of receiving DTV (and TV in general) is using an antenna (known as an *aerial* in some countries). This way is known as Digital Terrestrial Television (DTT). With DTT, viewers are limited to whatever channels the antenna picks up. Signal quality will also vary.

Other ways have been devised to receive digital television. Among the most familiar to people are digital cable and digital satellite. In some countries where transmissions of TV signals are normally achieved by microwaves, digital MMDS is used. Other standards, such as DMB and DVB-H, have been devised to allow handheld devices such as mobile phones to receive TV signals. Another way is IPTV, that is receiving TV via Internet Protocol, relying on DSL or optical cable line. Finally, an alternative way is to receive digital TV signals via the open Internet. For example, there is P2P (peer-to-peer) Internet television software that can be used to watch TV on a computer.

Some signals carry encryption and specify use conditions (such as "may not be recorded" or "may not be viewed on displays larger than 1 m in diagonal measure") backed up with the force of law under the WIPO Copyright Treaty and national legislation implementing it, such as the U.S. Digital Millennium Copyright Act. Access to encrypted channels can be controlled by a removable smart card, for example via the Common Interface (DVB-CI) standard for Europe and via Point Of Deployment (POD) for IS or named differently CableCard.

Protection parameters for terrestrial DTV broadcasting

Digital television signals must not interfere with each other, and they must also coexist with analog television until it is phased out. The following table gives allowable signal-to-noise and signal-to-interference ratios for various interference scenarios. This table is a crucial regulatory tool for controlling the placement and power levels of stations. Digital TV is more tolerant of interference than analog TV, and this is the reason a smaller range of channels can carry an all-digital set of television stations.

System Parameters (protection ratios)	Canada	USA	EBU [9, 12] ITU-mode M3	Japan & Brazil [36, 37]
C/N for AWGN Channel	+19.5 dB (16.5 dB)	+15.19 dB	+19.3 dB	+19.2 dB
Co-Channel DTV into Analog TV	+33.8 dB	+34.44 dB	+34 ~ 37 dB	+38 dB
Co-Channel Analog TV into DTV	+7.2 dB	+1.81 dB	+4 dB	+4 dB
Co-Channel DTV into DTV	+19.5 dB (16.5 dB)	+15.27 dB	+19 dB	+19 dB
Lower Adjacent Channel DTV into Analog TV	−16 dB	−17.43 dB	−5 ~ −11 dB	−6 dB
Upper Adjacent Channel DTV into Analog TV	−12 dB	−11.95 dB	−1 ~ −10	−5 dB
Lower Adjacent Channel Analog	−48 dB	−47.33	−34 ~ −37 dB	−35 dB

TV into DTV		dB		
Upper Adjacent Channel Analog TV into DTV	−49 dB	−48.71 dB	−38 ~ −36 dB	−37 dB
Lower Adjacent Channel DTV into DTV	−27 dB	−28 dB	−30 dB	−28 dB
Upper Adjacent Channel DTV into DTV	−27 dB	−26 dB	−30 dB	−29 dB

Interaction

Interaction happens between the TV watcher and the DTV system. It can be understood in different ways, depending on which part of the DTV system is concerned. It can also be an interaction with the STB only (to tune to another TV channel or to browse the EPG).

Modern DTV systems are able to provide interaction between the end-user and the broadcaster through the use of a return path. With the exceptions of coaxial and fiber optic cable, which can be bidirectional, a dialup modem, Internet connection, or other method is typically used for the return path with unidirectional networks such as satellite or antenna broadcast.

In addition to not needing a separate return path, cable also has the advantage of a communication channel localized to a neighborhood rather than a city (terrestrial) or an even larger area (satellite). This provides enough customizable bandwidth to allow true video on demand.

1-segment broadcasting

1seg (1-segment) is a special form of ISDB. Each channel is further divided into 13 segments. The 12 segments of them are allocated for HDTV and remaining segment, the 13th, is used for narrowband receivers such as mobile television or cell phone.

Conversion from analog to digital

DTV has several advantages over analog TV, the most significant being that digital channels take up less bandwidth, and the bandwidth needs are continuously variable, at a corresponding reduction in image quality depending on the level of compression as well as the resolution of the transmitted image. This means that digital broadcasters can provide more digital channels in the same space, provide high-definition television service, or provide other non-television services such as multimedia or interactivity. DTV also permits special services such as multiplexing (more than one program on the same channel), electronic program guides and additional languages (spoken or subtitled). The sale of non-television services may provide an additional revenue source.

Digital signals react differently to interference than analog signals. For example, common problems with analog television include ghosting of images, noise from weak signals, and many other potential problems which degrade the quality of the image and sound, although the program material may still be watchable. With digital television, the audio and video must be synchronized digitally, so reception of the digital signal must be very nearly complete; otherwise, neither audio nor video will be usable. Short of this complete failure, "blocky" video is seen when the digital signal experiences interference.

Effect on existing analog technology

Analog switch-off would render a non-digital television obsolete unless it is connected to an external digital tuner. An external converter box can be added to non-digital televisions to receive the new digital signals. Several of these devices have already been introduced, with availability on the increase. In the United States, a government-sponsored coupon was available to offset the cost of an external converter box. Analog switch-off (of full-power stations) took place on June 12, 2009 in the United States and is scheduled for August 31, 2011 in Canada, July 24, 2011 in Japan, by 2012 in the United Kingdom and Ireland, by 2013 in Australia and by 2015 in the Philippines and Uruguay.

Environmental issues

The adoption of a broadcast standard incompatible with existing analog receivers has created the problem of large numbers of analog receivers being discarded during digital television transition. An estimated 99 million unused analog TV receivers are currently in storage in the US alone and, while some obsolete receivers are being retrofitted with converters, many more are simply dumped in landfills where they represent a source of toxic metals such as lead as well as lesser amounts of materials such as barium, cadmium and chromium.

While the glass in cathode ray tubes contains an average of 3.62 kilograms (8.0 lb) of lead (amount varies from 1.08 lb to 11.28 lb, depending on screen size but the lead is "stable and immobile") which can have long-term negative effects on the environment if dumped as landfill, the glass envelope can be recycled at suitably-equipped facilities. Other portions of the receiver may be subject to disposal as hazardous material.

Local restrictions on disposal of these materials vary widely; in some cases second-hand stores have refused to accept working color television receivers for resale due to the increasing costs of disposing of unsold TV's. Those thrift stores which are still accepting donated TV's have reported significant increases in good-condition working used television receivers abandoned by viewers who often expect them not to work after digital transition.

In Michigan, one recycler has estimated that as many as one household in four will dispose of or recycle a TV set in the next year. The digital television transition, migration to high-definition television receivers and the replacement of CRTs with flatscreens are all factors in the increasing number of discarded analog CRT-based television receivers.

Technical limitations

Compression artifacts and allocated bandwidth

DTV images have some picture defects that are not present on analog television or motion picture cinema, because of present-day limitations of bandwidth and compression algorithms such as MPEG-2. This defect is sometimes referred to as "mosquito noise".

Because of the way the human visual system works, defects in an image that are localized to particular features of the image or that come and go are more perceptible than defects that are uniform and constant. However, the DTV system is designed to take advantage of other limitations of the human visual system to help mask these flaws, e.g. by allowing more compression artifacts during fast motion where the eye cannot track and resolve them as easily and, conversely, minimizing artifacts in still backgrounds that may be closely examined in a scene (since time allows).

Effects of poor reception

Changes in signal reception from factors such as degrading antenna connections or changing weather conditions may gradually reduce the quality of analog TV. The nature of digital TV results in a perfectly-decodable video initially, until the receiving equipment starts picking up interference that overpowers the desired signal or if the signal is too weak to decode. Some equipment will show a garbled picture with significant damage, while other devices may go directly from perfectly-decodable video to no video at all or lock up. This phenomenon is known as the digital cliff effect.

For remote locations, distant channels that, as analog signals, were previously usable in a snowy and degraded state may, as digital signals, be perfectly decodable or may become completely unavailable. In areas where transmitting antennas are located on mountains, viewers who are too close to the transmitter may find reception difficult or impossible because the strongest part of the broadcast signal passes above them. The use of higher frequencies will add to these problems, especially in cases where a clear line-of-sight from the receiving antenna to the transmitter is not available.

Multi-path interference is a much more significant problem for DTV than for analog TV and affects reception, particularly when using simple antennas such as rabbit ears. This is perceived as ghosting with analog broadcasts, but this same problem manifests itself in a different way with DTV. Multi-path can be worse for DTV under high signal conditions. If the problem is severe enough, multi-path can be perceived by the viewer as a spotty loss of audio or picture freezing and pixelation.

Dynamic multipath interference, in which the delay and magnitude of reflections are rapidly changing, is particularly problematic for digital reception. While this just produces moving and changing ghost images for analog TV, it can render a digital signal impossible to decode. The 8VSB-based standards in use in North American ATSC

broadcasts are particularly vulnerable to problems from dynamic multipath; this has the potential to severely limit mobile or portable use of digital television receivers.

Chapter 4

High-Definition Television

High-definition television (or **HDTV**) refers to video having resolution substantially higher than traditional television systems (standard-definition TV, or SDTV, or SD). HDTV has one or two million pixels per frame, roughly five times that of SD. Early HDTV broadcasting used analog techniques, but today HDTV is digitally broadcast using video compression.

Some personal video recorders (PVRs) with hard disk storage but without high-definition tuners are described as "HD", for "Hard Disk", which can be a cause of confusion.

History of high-definition television

The term *high definition* once described a series of television systems originating from the late 1930s; however, these systems were only high definition when compared to earlier systems that were based on mechanical systems as few as 30 lines of resolution.

The British high definition TV service started trials in August 1936 and a regular service in November 1936 using both the (mechanical) Baird 240 line and (electronic) Marconi-EMI 405 line (377i) systems. The Baird system was discontinued in February 1937. In 1938 France followed with their own 441 line system, variants of which were also used by a number of other countries. The US NTSC system joined in 1941. In 1949 France introduced an even higher resolution standard at 819 lines (768i), a system that would be high definition even by today's standards, but it was monochrome only. All of these systems used interlacing and a 4:3 aspect ratio except the 240 line system which was progressive (actually described at the time by the technically correct term 'sequential') and the 405 line system which started as 5:4 and later changed to 4:3. The 405 line system adopted the (at that time) revolutionary idea of interlaced scanning to overcome the flicker problem of the 240 line with its 25 Hz frame rate. The 240 line system could

have doubled its frame rate but this would have meant that the transmitted signal would have doubled in bandwidth, an unacceptable option.

Color broadcasts started at similarly higher resolutions, first with the US NTSC color system in 1953, which was compatible with the earlier B&W systems and therefore had the same 525 lines (480i) of resolution. European standards did not follow until the 1960s, when the PAL and SECAM colour systems were added to the monochrome 625 line (576i) broadcasts.

Since the formal adoption of Digital Video Broadcasting's (DVB) widescreen HDTV transmission modes in the early 2000s the 525-line NTSC (and PAL-M) systems as well as the European 625-line PAL and SECAM systems are now regarded as *standard definition* television systems. In Australia, the 625-line digital progressive system (with 576 active lines) is officially recognized as high definition.

Analog systems

In 1949, France started its transmissions with an 819 lines system (768i). It was monochrome only, it was used only on VHF for the first French TV channel, and it was discontinued in 1985.

In 1958, the Soviet Union developed *Transformator* (Russian: Трансформатор, *Transformer*), the first high-resolution (definition) television system capable of producing an image composed of 1,125 lines of resolution aimed at providing teleconferencing for military command. It was a research project and the system was never deployed in the military or broadcasting.

In 1979, the Japanese state broadcaster NHK first developed consumer high-definition television with a 5:3 display aspect ratio. The system, known as Hi-Vision or MUSE after its Multiple sub-Nyquist sampling encoding for encoding the signal, required about twice the bandwidth of the existing NTSC system but provided about four times the resolution (1080i/1125 lines). Satellite test broadcasts started in 1989, with regular testing starting in 1991 and regular broadcasting of BS-9ch commenced on 25 November 1994, which featured commercial and NHK programming.

In 1981, the MUSE system was demonstrated for the first time in the United States, using the same 5:3 aspect ratio as the Japanese system. Upon visiting a demonstration of MUSE in Washington, US President Ronald Reagan was most impressed and officially declared it "a matter of national interest" to introduce HDTV to the USA.

Several systems were proposed as the new standard for the USA, including the Japanese MUSE system, but all were rejected by the FCC because of their higher bandwidth requirements. At this time, the number of television channels was growing rapidly and bandwidth was already a problem. A new standard had to be more efficient, needing less bandwidth for HDTV than the existing NTSC.

Demise of analog HD systems

The limited standardization of analogue HDTV in the 1990s did not lead to global HDTV adoption as technical and economic reasons at the time did not permit HDTV to use bandwidths greater than normal television.

Early HDTV commercial experiments such as NHK's MUSE required over four times the bandwidth of a standard-definition broadcast -- and HD-MAC was not much better. Despite efforts made to reduce analog HDTV to about 2x the bandwidth of SDTV these television formats were still only distributable by satellite.

In addition, recording and reproducing an HDTV signal was a significant technical challenge in the early years of HDTV. Japan remained the only country with successful public broadcast analog HDTV, with seven broadcasters sharing a single channel. Digital HDTV broadcasting started in 2000 in Japan, and the analog service ended in the early hours of 1 October 2007.

Rise of digital compression

Since 1972, International Telecommunication Union's radio telecommunications sector (ITU-R) has been working on creating a global recommendation for Analogue HDTV. These recommendations however did not fit in the broadcasting bands which could reach home users. The standardization of MPEG-1 in 1993 also led to the acceptance of recommendations ITU-R BT.709. In anticipation of these standards the Digital Video Broadcasting (DVB) organisation was formed, an alliance of broadcasters, consumer electronics manufacturers and regulatory bodies. The DVB develops and agrees on specifications which are formally standardised by ETSI.

DVB created first the standard for DVB-S digital satellite TV, DVB-C digital cable TV and DVB-T digital terrestrial TV. These broadcasting systems can be used for both SDTV and HDTV. In the USA the Grand Alliance proposed ATSC as the new standard for SDTV and HDTV. Both ATSC and DVB were based on the MPEG-2 standard. The DVB-S2 standard is based on the newer and more efficient H.264/MPEG-4 AVC compression standards. Common for all DVB standards is the use of highly efficient modulation techniques for further reducing bandwidth, and foremost for reducing receiver-hardware and antenna requirements.

In 1983, the International Telecommunication Union's radio telecommunications sector (ITU-R) set up a working party (IWP11/6) with the aim of setting a single international HDTV standard. One of the thornier issues concerned a suitable frame/field refresh rate, the world already having split into two camps, 25/50 Hz and 30/60 Hz, related by reasons of picture stability to the frequency of their main electrical supplies.

The IWP11/6 working party considered many views and through the 1980s served to encourage development in a number of video digital processing areas, not least conversion between the two main frame/field rates using motion vectors, which led to

further developments in other areas. While a comprehensive HDTV standard was not in the end established, agreement on the aspect ratio was achieved.

Initially the existing 5:3 aspect ratio had been the main candidate but, due to the influence of widescreen cinema, the aspect ratio 16:9 (1.78) eventually emerged as being a reasonable compromise between 5:3 (1.67) and the common 1.85 widescreen cinema format. (Bob Morris explained that the 16:9 ratio was chosen as being the geometric mean of 4:3, Academy ratio, and 2.4:1, the widest cinema format in common use, in order to minimize wasted screen space when displaying content with a variety of aspect ratios.)

An aspect ratio of 16:9 was duly agreed at the first meeting of the IWP11/6 working party at the BBC's Research and Development establishment in Kingswood Warren. The resulting ITU-R Recommendation ITU-R BT.709-2 ("Rec. 709") includes the 16:9 aspect ratio, a specified colorimetry, and the scan modes 1080i (1,080 actively interlaced lines of resolution) and 1080p (1,080 progressively scanned lines). The current Freeview HD trials use MBAFF, which contains both progressive and interlaced content in the same encoding.

It also includes the alternative 1440×1152 HDMAC scan format. (According to some reports, a mooted 750-ine (720p) format (720 progressively scanned lines) was viewed by some at the ITU as an enhanced television format rather than a true HDTV format, and so was not included, although 1920×1080i and 1280×720p systems for a range of frame and field rates were defined by several US SMPTE standards.)

Inaugural HDTV broadcast in the United States

HDTV technology was introduced in the United States in the 1990s by the Digital HDTV Grand Alliance, a group of television companies and MIT. Field testing of HDTV at 199 sites in the United States was completed August 14, 1994. The first public HDTV broadcast in the United States occurred on July 23, 1996 when the Raleigh, North Carolina television station WRAL-HD began broadcasting from the existing tower of WRAL-TV south-east of Raleigh, winning a race to be first with the HD Model Station in Washington, D.C., which began broadcasting July 31, 1996 with the callsign WHD-TV, based out of the facilities of NBC owned and operated station WRC-TV. The American Advanced Television Systems Committee (ATSC) HDTV system had its public launch on October 29, 1998, during the live coverage of astronaut John Glenn's return mission to space on board the Space Shuttle *Discovery*. The signal was transmitted coast-to-coast, and was seen by the public in science centers, and other public theaters specially equipped to receive and display the broadcast.

European HDTV broadcasts

Although HDTV broadcasts had been demonstrated in Europe since the early 1990s, the first regular broadcasts started on January 1, 2004 when the Belgian company Euro1080 launched the HD1 channel with the traditional Vienna New Year's Concert. Test

transmissions had been active since the IBC exhibition in September 2003, but the New Year's Day broadcast marked the official start of the HD1 channel, and the start of HDTV in Europe.

Euro1080, a division of the Belgian TV services company Alfacam, broadcast HDTV channels to break the pan-European stalemate of "no HD broadcasts mean no HD TVs bought means no HD broadcasts..." and kick-start HDTV interest in Europe. The HD1 channel was initially free-to-air and mainly comprised sporting, dramatic, musical and other cultural events broadcast with a multi-lingual soundtrack on a rolling schedule of 4 or 5 hours per day.

These first European HDTV broadcasts used the 1080i format with MPEG-2 compression on a DVB-S signal from SES Astra's 1H satellite. Euro1080 transmissions later changed to MPEG-4/AVC compression on a DVB-S2 signal in line with subsequent broadcast channels in Europe.

The first Russian HDTV broadcast commenced in 2007 by NTV Plus, followed by Platform HD in 2008. Both companies broadcast via satellite using MPEG-4/AVC video compression.

In December 2009 the UK became the first European country to deploy high definition content on digital terrestrial television (branded as Freeview) using the new DVB-T2 transmission standard as specified in the Digital TV Group (DTG) D-Book.

The Freeview HD service currently contains 4 HD channels and is now rolling out region by region across the UK in accordance with the digital switchover process. Some transmitters such as the Crystal Palace and Emley Moor transmitters are broadcasting the Freeview HD service ahead of the digital switchover by means of a temporary, low-power pre-DSO multiplex.

Notation

HDTV broadcast systems are identified with three major parameters:

- **Frame size** in pixels is defined as *number of horizontal pixels × number of vertical pixels*, for example *1280 × 720* or *1920 × 1080*. Often the number of horizontal pixels is implied from context and is omitted, as in the case of *720p* and *1080p*.
- **Scanning system** is identified with the letter ***p*** for progressive scanning or ***i*** for interlaced scanning.
- **Frame rate** is identified as number of video frames per second. For interlaced systems an alternative form of specifying number of fields per second is often used.

If all three parameters are used, they are specified in the following form: *[frame size][scanning system][frame or field rate]* or *[frame size]/[frame or field rate][scanning*

system]. Often, frame size or frame rate can be dropped if its value is implied from context. In this case the remaining numeric parameter is specified first, followed by the scanning system.

For example, *1920×1080p25* identifies progressive scanning format with 25 frames per second, each frame being 1,920 pixels wide and 1,080 pixels high. The *1080i25* or *1080i50* notation identifies interlaced scanning format with 25 frames (50 fields) per second, each frame being 1,920 pixels wide and 1,080 pixels high. The *1080i30* or *1080i60* notation identifies interlaced scanning format with 30 frames (60 fields) per second, each frame being 1,920 pixels wide and 1,080 pixels high. The *720p60* notation identifies progressive scanning format with 60 frames per second, each frame being 720 pixels high; 1,280 pixels horizontally are implied.

50 Hz systems support three scanning rates: 25i, 25p and 50p. 60 Hz systems support a much wider set of frame rates: 23.976p, 24p, 29.97i/59.94i, 29.97p, 30p, 59.94p and 60p. In the days of standard definition television, the fractional rates were often rounded up to whole numbers, e.g. 23.976p was often called 24p, or 59.94i was often called 60i. 60 Hz high definition television supports both fractional and slightly different integer rates, therefore strict usage of notation is required to avoid ambiguity. Nevertheless, 29.97i/59.94i is almost universally called 60i, likewise 23.976p is called 24p.

For commercial naming of a product, the frame rate is often dropped and is implied from context (e.g., a *1080i television set*). A frame rate can also be specified without a resolution. For example, 24p means 24 progressive scan frames per second, and 50i means 25 interlaced frames per second.

There is no standard for HDTV color support. Until recently the color of each pixel was regulated by three 8-bit color values, each representing the level of red, blue, and green which defined a pixel color. Together the 24 total bits defining color yielded just under 17 million possible pixel colors. Recently some manufacturers have produced systems that can employ 10 bits for each color (30 bits total) which provides for a palette of 1 billion colors, saying that this provides a much richer picture, but there is no agreed way to specify that a piece of equipment supports this feature.

Most HDTV systems support resolutions and frame rates defined either in the ATSC table 3, or in EBU specification. The most common are noted below.

High-definition display resolutions

Video format supported [image resolution]	Native resolution [inherent resolution] (W×H)	Pixels		Aspect ratio (W:H)		Description
		Actual	Advertised (Mpixel)	Image	Pixel	
720p 1280×720	1024×768 XGA	786,432	0.8	4:3	4:3	Typically a PC resolution (XGA);

							also a native resolution on many entry-level plasma displays with non-square pixels.
	1280×720	921,600	0.9		16:9	1:1	Standard HDTV resolution and a typical PC resolution (WXGA), frequently used by high-end video projectors; also used for 750-line video, as defined in SMPTE 296M, ATSC A/53, ITU-R BT.1543.
	1366×768 WXGA	1,049,088	1.0		683:384 (approx. 16:9)	1:1	A typical PC resolution (WXGA); also used by many **HD ready** TV displays based on LCD technology.
1080p/1080i 1920×1080	1920×1080	2,073,600	2.1		16:9	1:1	Standard HDTV resolution, used by *Full HD* and **HD ready 1080p** TV displays such as high-end LCD, Plasma and rear projection TVs, and a typical PC resolution (lower than WUXGA); also used for 1125-line video, as defined in SMPTE 274M, ATSC A/53, ITU-R BT.709;

Video format supported	Screen resolution (W×H)	Pixels		Aspect ratio (W:H)		Description
		Actual	Advertised (Mpixel)	Image	Pixel	
720p 1780×956	1780×956 Clean Aperture	876,096	0.9	16:9	1:1	Used for 750-line video with faster artifact/overscan

						compensation, as defined in SMPTE 296M.
1080p 1920×1080	1888×1062 Clean aperture	2,005,056	2.0	16:9	1:1	Used for 1125-line video with faster artifact/overscan compensation, as defined in SMPTE 274M.
1080i 1920×1080	1440×1080 HDCAM/HDV	1,555,200	1.6	16:9	4:3	Used for anamorphic 1125-line video in the HDCAM and HDV formats introduced by Sony and defined (also as a luminance subsampling matrix) in SMPTE D11.

Standard frame or field rates

- 23.976 Hz (film-looking frame rate compatible with NTSC clock speed standards)
- 24 Hz (international film and ATSC high definition material)
- 25 Hz (PAL, SECAM film, standard definition, and high definition material)
- 29.97 Hz (NTSC standard definition material)
- 50 Hz (PAL & SECAM high definition material)
- 59.94 Hz (ATSC high definition material)
- 60 Hz (ATSC high definition material)
- 120 Hz (ATSC high definition material)

At a minimum, HDTV has twice the linear resolution of standard-definition television (SDTV), thus showing greater detail than either analog television or regular DVD. The technical standards for broadcasting HDTV also handle the 16:9 aspect ratio images without using letterboxing or anamorphic stretching, thus increasing the effective image resolution.

The optimum format for a broadcast depends upon the type of videographic recording medium used and the image's characteristics. The field and frame rate should match the source and the resolution. A very high resolution source may require more bandwidth than available in order to be transmitted without loss of fidelity. The lossy compression that is used in all digital HDTV storage and transmission systems will distort the received picture, when compared to the uncompressed source.

There is a wide spread confusion of using terms like PAL or SECAM or NTSC relating to HD material. PAL, SECAM, NTSC are only standard definition standards, not HD. There is no specific technical reason to keep 25 Hz as HD frame rate in a former PAL country (except in case of a need of compatibility with both HD and standard definition television systems).

Types of media

Standard 35mm photographic film used for cinema projection has higher resolution than HDTV systems, and is exposed and projected at a rate of 24 frames per second. To be shown on standard television, in PAL-system countries, cinema film is scanned at the TV rate of 25 frames per second, causing an acceleration of 4.1 percent, which is generally considered acceptable. In NTSC-system countries, the TV scan rate of 30 frames per second would cause a perceptible acceleration if the same were attempted, and the necessary correction is performed by a technique called 3:2 Pulldown: Over each successive pair of film frames, one is held for three video fields (1/20 of a second) and the next is held for two video fields (1/30 of a second), giving a total time for the two frames of 1/12 of a second and thus achieving the correct average film frame rate.

Non-cinematic HDTV video recordings intended for broadcast are typically recorded either in 720p or 1080i format as determined by the broadcaster. 720p is commonly used for Internet distribution of high-definition video, because most computer monitors operate in progressive-scan mode. 720p also imposes less strenuous storage and decoding requirements compared to both 1080i and 1080p. 1080p is usually used for Blu-ray Disc.

Contemporary systems

Besides an HD-ready television set, other equipment may be needed to view HD television. In the US, Cable-ready TV sets can display HD content without using an external box. They have a QAM tuner built-in and/or a card slot for inserting a CableCARD.

High-definition image sources include terrestrial broadcast, direct broadcast satellite, digital cable, IPTV, the high definition Blu-ray video disc (BD), internet downloads, the Blu-ray disc compatible Sony PlayStation 3 video game console (PS3), and the Microsoft Xbox 360 video game console.

Recording and compression

HDTV can be recorded to D-VHS (Digital-VHS or Data-VHS), W-VHS (analog only), to an HDTV-capable digital video recorder (for example DirecTV's high-definition Digital video recorder, Sky HD's set-top box, Dish Network's VIP 622 or VIP 722 high-definition Digital video recorder receivers, or TiVo's Series 3 or HD recorders), or an HDTV-ready HTPC. Some cable boxes are capable of receiving or recording two or more broadcasts at a time in HDTV format, and HDTV programming, some free, some for a fee, can be played back with the cable company's on-demand feature.

The massive amount of data storage required to archive uncompressed streams meant that inexpensive uncompressed storage options were not available in the consumer market until recently. In 2008 the Hauppauge 1212 Personal Video Recorder was introduced. This device accepts HD content through component video inputs and stores the content in an uncompressed MPEG transport stream (.ts) file or Blu-ray format .m2ts file on the

hard drive or DVD burner of a computer connected to the PVR through a USB 2.0 interface.

Realtime MPEG-2 compression of an uncompressed digital HDTV signal is prohibitively expensive for the consumer market at this time, but should become inexpensive within several years (although this is more relevant for consumer HD camcorders than recording HDTV). Analog tape recorders with bandwidth capable of recording analog HD signals such as W-VHS recorders are no longer produced for the consumer market and are both expensive and scarce in the secondary market.

In the United States, as part of the FCC's *plug and play* agreement, cable companies are required to provide customers who rent HD set-top boxes with a set-top box with "functional" Firewire (IEEE 1394) upon request. None of the direct broadcast satellite providers have offered this feature on any of their supported boxes, but some cable TV companies have. As of July 2004, boxes are not included in the FCC mandate. This content is protected by encryption known as 5C. This encryption can prevent duplication of content or simply limit the number of copies permitted, thus effectively denying most if not all fair use of the content.

Chapter 5

Satellite Television

Satellite television is television delivered by the means of communications satellite and received by an outdoor antenna, usually a parabolic mirror generally referred to as a satellite dish, and as far as household usage is concerned, a satellite receiver either in the form of an external set-top box or a satellite tuner module built into a TV set. Satellite TV tuners are also available as a card or a USB stick to be attached to a personal computer. In many areas of the world satellite television provides a wide range of channels and services, often to areas that are not serviced by terrestrial or cable providers.

Direct broadcast satellite television comes to the general public in two distinct flavors - analog and digital. This necessitates either having an analog satellite receiver or a digital satellite receiver. Analog satellite television is being replaced by digital satellite television and the latter is becoming available in a better quality known as high-definition television.

History

The first satellite television signal was relayed from Europe to the Telstar satellite over North America in 1962. The first geosynchronous communication satellite, Syncom 2, was launched in 1963. The world's first commercial communication satellite, called Intelsat I (nicknamed Early Bird), was launched into synchronous orbit on April 6, 1965. The first national network of satellite television, called Orbita, was created in Soviet Union in 1967, and was based on the principle of using the highly elliptical Molniya satellite for re-broadcasting and delivering of TV signal to ground downlink stations. The first domestic North American satellite to carry television was Canada’s geostationary Anik 1, which was launched in 1972. ATS-6, the world's first experimental educational and Direct Broadcast Satellite, was launched in 1974. The first Soviet geostationary satellite to carry Direct-To-Home television, called Ekran, was launched in 1976.

Technology

Satellites used for television signals are generally in either naturally highly elliptical (with inclination of +/-63.4 degrees and orbital period of about 12 hours, also known as Molniya orbit) or geostationary orbit 37,000 km (22,300 miles) above the earth's equator.

Satellite television, like other communications relayed by satellite, starts with a transmitting antenna located at an uplink facility. Uplink satellite dishes are very large, as much as 9 to 12 meters (30 to 40 feet) in diameter. The increased diameter results in more accurate aiming and increased signal strength at the satellite. The uplink dish is pointed toward a specific satellite and the uplinked signals are transmitted within a specific frequency range, so as to be received by one of the transponders tuned to that frequency range aboard that satellite. The transponder 'retransmits' the signals back to Earth but at a different frequency band (a process known as translation, used to avoid interference with the uplink signal), typically in the C-band (4–8 GHz) or K_u-band (12–18 GHz) or both. The leg of the signal path from the satellite to the receiving Earth station is called the downlink.

A typical satellite has up to 32 transponders for Ku-band and up to 24 for a C-band only satellite, or more for hybrid satellites. Typical transponders each have a bandwidth between 27 MHz and 50 MHz. Each geo-stationary C-band satellite needs to be spaced 2 degrees from the next satellite (to avoid interference). For K_u the spacing can be 1 degree. This means that there is an upper limit of 360/2 = 180 geostationary C-band satellites and 360/1 = 360 geostationary K_u-band satellites. C-band transmission is susceptible to terrestrial interference while K_u-band transmission is affected by rain (as water is an excellent absorber of microwaves at this particular frequency). The latter is even more adversely effected by ice crystals in thunder clouds.

Last not least, there will be a sun outage when the sun lines up directly behind the geostationary satellite the reception antenna is pointing to. This will happen twice a year at around midday for a two-week period and affects both the C-band and the K_u-band. The line-up swamps out all reception for a few minutes due to the sun emitting microwaves on the same frequencies used by the satellite's transponders. This happens in the spring and in the fall.

The downlinked satellite signal, quite weak after traveling the great distance, is collected by a parabolic receiving dish, which reflects the weak signal to the dish's focal point. Mounted on brackets at the dish's focal point is a device called a feedhorn. This feedhorn is essentially the flared front-end of a section of waveguide that gathers the signals at or near the focal point and 'conducts' them to a probe or pickup connected to a low-noise block downconverter or LNB. The LNB amplifies the relatively weak signals, filters the block of frequencies in which the satellite TV signals are transmitted, and converts the block of frequencies to a lower frequency range in the L-band range. The evolution of LNBs was one of necessity and invention.

The original C-Band satellite TV systems used a Low Noise Amplifier connected to the feedhorn at the focal point of the dish. The amplified signal was then fed via very expensive and sometimes 50 ohm impedance gas filled hardline coaxial cable to an indoor receiver or, in other designs, fed to a downconverter (a mixer and a voltage tuned oscillator with some filter circuitry) for downconversion to an intermediate frequency. The channel selection was controlled, typically by a voltage tuned oscillator with the tuning voltage being fed via a separate cable to the headend. But this design evolved.

Designs for microstrip based converters for Amateur Radio frequencies were adapted for the 4 GHz C-Band. Central to these designs was concept of block downconversion of a range of frequencies to a lower, and technologically more easily handled block of frequencies (intermediate frequency).

The advantages of using an LNB are that cheaper cable could be used to connect the indoor receiver with the satellite TV dish and LNB, and that the technology for handling the signal at L-Band and UHF was far cheaper than that for handling the signal at C-Band frequencies. The shift to cheaper technology from the 50 Ohm impedance cable and N-Connectors of the early C-Band systems to the cheaper 75 Ohm technology and F-Connectors allowed the early satellite TV receivers to use, what were in reality, modified UHF TV tuners which selected the satellite television channel for down conversion to another lower intermediate frequency centered on 70 MHz where it was demodulated. This shift allowed the satellite television DTH industry to change from being a largely hobbyist one where receivers were built in low numbers and complete systems were expensive (costing thousands of Dollars) to a far more commercial one of mass production.

Direct broadcast satellite dishes are fitted with an LNBF, which integrates the feedhorn with the LNB.

In the United States, service providers use the intermediate frequency ranges of 950-2150 MHz to carry the signal to the receiver. This allows for transmission of UHF band signals along the same span of coaxial wire at the same time. In some applications, (DirecTV AU9-S and AT-9) ranges the lower B-Band and upper 2250-3000 MHz, are used. Newer LNBFs in use by DirecTV referred to as SWM, use a more limited frequency range of 950-1800 MHz.

The satellite receiver or Set-top box demodulates and converts the signals to the desired form (outputs for television, audio, data, etc.). Sometimes, the receiver includes the capability to unscramble or decrypt the received signal; the receiver is then called an Integrated receiver/decoder or IRD. The cable connecting the receiver to the LNBF or LNB should be of the low loss type RG-6, quad shield RG-6 or RG-11, etc. RG-59 is not recommended for this application as it is not technically designed to carry frequencies above 950 MHz, but will work in many circumstances, depending on the quality of the coaxial wire.

A practical problem relating to satellite home reception is that basically an LNB can only handle a single receiver. This is due to the fact that the LNB is mapping two different polarizations - horizontal and vertical - and in the case of the K-band two different reception bands - lower and upper - to one and the same frequency band on the cable. Depending on which frequency a transponder is transmitting at and on what polarization it is using, the satellite receiver has to switch the LNB into one of four different modes in order to receive a specific desired program on a specific transponder. This is handled by the receiver using the DiSEqC protocol to control the LNB mode. If several satellite receivers are to be attached to a single dish a so-called multiswitch will have to be used in conjunction with a special type of LNB. There are also LNBs available with a multiswitch already integrated. This problem becomes more complicated when several receivers are to use several dishes (or several LNBs mounted in a single dish) pointing to different satellites.

Standards

Analog television distributed via satellite is usually sent scrambled or unscrambled in NTSC, PAL, or SECAM television broadcast standards. The analog signal is frequency modulated and is converted from an FM signal to what is referred to as baseband. This baseband comprises the video signal and the audio subcarrier(s). The audio subcarrier is further demodulated to provide a raw audio signal.

If the signal is a digitized television signal or multiplex of signals, it is typically QPSK.

In general, digital television, including that transmitted via satellites, are generally based on open standards such as MPEG and DVB-S or ISDB-S.

The conditional access encryption/scrambling methods include BISS, Conax, Digicipher, Irdeto, Nagravision, PowerVu, Viaccess, Videocipher, and VideoGuard. Many conditional access systems have been compromised.

Categories of usage

There are three primary types of satellite television usage: reception direct by the viewer, reception by local television affiliates, or reception by headends for distribution across terrestrial cable systems.

Direct to the viewer reception includes direct broadcast satellite or DBS and television receive-only or TVRO, both used for homes and businesses including hotels, etc.

Direct broadcast via satellite

Direct broadcast satellite, (DBS) also known as "Direct-To-Home" can either refer to the communications satellites themselves that deliver DBS service or the actual television service. DBS systems are commonly referred to as "mini-dish" systems. DBS uses the upper portion of the K_u band, as well as portions of the K_a band.

Modified DBS systems can also run on C-band satellites and have been used by some networks in the past to get around legislation by some countries against reception of K_u-band transmissions.

Most of the DBS systems use the DVB-S standard for transmission. With Pay-TV services, the datastream is encrypted and requires proprietary reception equipment. While the underlying reception technology is similar, the Pay-TV technology is proprietary, often consisting of a Conditional Access Module and smart card.

This measure assures satellite television providers that only authorised, paying subscribers have access to Pay TV content but at the same time can allow free-to-air (FTA) channels to be viewed even by the people with standard equipment (DBS receivers without the Conditional Access Modules) available in the market.

Television receive-only

The term Television receive-only, or TVRO, arose during the early days of satellite television reception to differentiate it from commercial satellite television uplink and downlink operations (transmit and receive). This was before there was a DTH satellite television broadcast industry. Satellite television channels at that time were intended to be used by cable television networks rather than received by home viewers. Satellite TV receiver systems were largely constructed by hobbyists and engineers. In 1978 Microcomm, a small company founded by radio amateur and microwave engineer H. Paul Shuch, introduced the first commercial home satellite TV receiver. These early TVRO systems operated mainly on the C band frequencies and the dishes required were large; typically over 3 meters (10 ft) in diameter. Consequently TVRO is often referred to as "big dish" or "Big Ugly Dish" (BUD) satellite television.

TVRO systems are designed to receive analog and digital satellite feeds of both television or audio from both C-band and K_u-band transponders on FSS-type satellites. The higher frequency K_u-band systems tend to be Direct To Home systems and can use a smaller dish antenna because of the higher power transmissions and greater antenna gain.

TVRO systems tend to use larger rather than smaller satellite dish antennas, since it is more likely that the owner of a TVRO system would have a C-band-only setup rather than a K_u band-only setup. Additional receiver boxes allow for different types of digital satellite signal reception, such as DVB/MPEG-2 and 4DTV.

The narrow beam width of a normal parabolic satellite antenna means it can only receive signals from a single satellite at a time. Simulsat or the Vertex-RSI TORUS, is a quasi-parabolic satellite earthstation antenna that is capable of receiving satellite transmissions from 35 or more C- and K_u-band satellites simultaneously.

Direct to Home television

Many satellite TV customers in developed television markets get their programming through a direct broadcast satellite (DBS) provider. The provider selects programs and broadcasts them to subscribers as a set package. Basically, the provider's goal is to bring dozens or even hundreds of channels to the customers television in a form that approximates the competition from Cable TV. Unlike earlier programming, the provider's broadcast is completely digital, which means it has high picture and stereo sound quality. Early satellite television services broadcast in C-band - radio in the 3.7 GigaHertz (GHz) to 4.2 GHz frequency range. Digital broadcast satellite transmits programming in the K_u frequency range (10 GHz to 14 GHz).

Programming sources are simply the channels that provide programming for broadcast. The provider (the DTH platform) doesn't create original programming itself. The broadcast center is the central hub of the system. At the broadcast center, the television provider receives signals from various programming sources, compresses these signals using digital compression (encryption if necessary), and sends a broadcast signal to the proper satellite.

Chapter 6

Interactive Television

Digital TV set-top box

Interactive television (generally known as **ITV** or sometimes as **iTV** when used as branding) describes a number of techniques that allow viewers to interact with television content as they view it.

Definitions of interactive television

Interactive television represents a continuum from low interactivity (TV on/off, volume, changing channels) to moderate interactivity (simple movies on demand without player controls) and high interactivity in which, for example, an audience member affects the program being watched. The most obvious example of this would be any kind of real-time voting on the screen, in which audience votes create decisions that are reflected in how the show continues. A return path to the program provider is not necessary to have an interactive program experience. Once a movie is downloaded for example, controls may all be local. The link was needed to download the program, but texts and software which can be executed locally at the set-top box or IRD (Integrated Receiver Decoder) may occur automatically, once the viewer enters the channel.

Return path

To be truly interactive, the viewer must be able to alter the viewing experience (e.g. choose which angle to watch a football match), or return information to the broadcaster.

This "return path," return channel or "back channel" can be by telephone, mobile SMS (text messages), radio, digital subscriber lines (ADSL) or cable.

Cable TV viewers receive their programs via a cable, and in the integrated cable return path enabled platforms, they use the same cable as a return path.

Satellite viewers (mostly) return information to the broadcaster via their regular telephone lines. They are charged for this service on their regular telephone bill. An Internet connection via ADSL, or other, data communications technology, is also being increasingly used.

Interactive TV can also be delivered via a terrestrial aerial (Digital Terrestrial TV such as 'Freeview' in the UK). In this case, there is often no 'return path' as such - so data cannot be sent back to the broadcaster (so you could not, for instance, vote on a TV show, or order a product sample) . However, interactivity is still possible as there is still the opportunity to interact with an application which is broadcast and downloaded to the set-top box (so you could still choose camera angles, play games etc.).

Increasingly the return path is becoming a broadband IP connection, and some hybrid receivers are now capable of displaying video from either the IP connection or from traditional tuners. Some devices are now dedicated to displaying video only from the IP channel, which has given rise to IPTV - Internet Protocol Television. The rise of the "broadband return path" has given new relevance to Interactive TV, as it opens up the need to interact with Video on Demand servers, advertisers, and web site operators.

Forms of interaction

The term "interactive television" is used to refer to a variety of rather different kinds of interactivity (both as to usage and as to technology), and this can lead to considerable misunderstanding. At least three very different levels are important:

Interactivity with a TV set

The simplest, **Interactivity with a TV set** is already very common, starting with the use of the remote control to enable channel surfing behaviors, and evolving to include video-on-demand, VCR-like pause, rewind, and fast forward, and DVRs, commercial skipping and the like. It does not change any content or its inherent linearity, only how users control the viewing of that content. DVRs allow users to time shift content in a way that is impractical with VHS. Though this form of interactive TV is not insignificant, critics claim that saying that using a remote control to turn TV sets on and off makes television interactive is like saying turning the pages of a book makes the book interactive. In the not too distant future, the questioning of what is real interaction with the TV will be difficult. Panasonic already has face recognition technology implemented its prototype Panasonic Life Wall. The Life Wall is literally a wall in your house that doubles as a screen. Panasonic uses their face recognition technology to follow the viewer around the room, adjusting its screen size according to the viewers distance from the wall. Its goal is to give the viewer the best seat in the house, regardless of location. The concept was released at Panasonic Consumer Electronics Show in 2008. Its anticipated release date is unknown, but it can be assumed technology like this will not remain hidden for long.

Interactivity with TV program content

Screenshot of a OpenTV program browser set-top box resident software

Screenshot of a OpenTV email browser set-top box resident software

In its deepest sense, **Interactivity with TV program content** is the one that is "interactive TV", but it is also the most challenging to produce. This is the idea that the program, itself, might change based on viewer input. Advanced forms, which still have uncertain prospect for becoming mainstream, include dramas where viewers get to choose or influence plot details and endings.

- As an example, in Accidental Lovers viewers can send mobile text messages to the broadcast and the plot transforms on the basis of the keywords picked from the messages.
- Global Television Network offers a multi-monitor interactive game for Big Brother 8 (US) "'In The House'" which allows viewers to predict who will win each competition, who's going home, as well as answering trivia questions and instant recall challenges throughout the live show. Viewers login to the Global website to play, with no downloads required.
- Another kind of example of interactive content is the Hugo game on Television where viewers called the production studio, and were allowed to control the game character in real time using telephone buttons by studio personnel, similar to The Price is Right.
- Another example is the Clickvision Interactive Perception Panel used on news programmes in Britain, a kind of instant clap-o-meter run over the telephone.

Simpler forms, which are enjoying some success, include programs that directly incorporate polls, questions, comments, and other forms of (virtual) audience response back into the show. There is much debate as to how effective and popular this kind of truly interactive TV can be. It seems likely that some forms of it will be popular, but that

viewing of pre-defined content, with a scripted narrative arc, will remain a major part of the TV experience indefinitely. The United States lags far behind the rest of the developed world in its deployment of interactive television. This is a direct response to the fact that commercial television in the U.S. is not controlled by the government, whereas the vast majority of other countries' television systems are controlled by the government. These "centrally planned" television systems are made interactive by fiat, whereas in the U.S., only some members of the Public Broadcasting System has this capability.

Commercial broadcasters and other content providers serving the US market are constrained from adopting advanced interactive technologies because they must serve the desires of their customers, earn a level of return on investment for their investors, and are dependent on the penetration of interactive technology into viewers' homes. In association with many factors such as

- requirements for backward compatibility of TV content formats, form factors and Customer Premise Equipment (CPE)
- the 'cable monopoly' laws that are in force in many communities served by cable TV operators
- consumer acceptance of the pricing structure for new TV-delivered services. Over the air (broadcasted) TV is FREE in the US, free of taxes or usage fees.
- proprietary coding of set top boxes by cable operators and box manufacturers
- the ability to implement 'return path' interaction in rural areas that have low, or no technology infrastructure
- the competition from Internet-based content and service providers for the consumers' attention and budget
- and many other technical and business road blocks

Interactivity with TV-related content

The least understood, **Interactivity with TV related content** may have most promise to alter how we watch TV over the next decade. Examples include getting more information about what is on the TV, weather, sports, movies, news, or the like.

Similar (and most likely to pay the bills), is getting more information about what is being advertised, and the ability to buy it—this is called "**tcommerce**" (short for "**television commerce**"). Partial steps in this direction are already becoming a mass phenomenon, as Web sites and mobile phone services coordinate with TV programs (note: this type of interactive TV is currently being called "participation TV" and GSN and TBS are proponents of it). This kind of multitasking is already happening on large scale—but there is currently little or no automated support for relating that secondary interaction to what is on the TV compared to other forms of interactive TV. Others argue that this is more a "web-enhanced" television viewing than interactive TV. In the coming months and years, there will be no need to have both a computer and a TV set for interactive television as the interactive content will be built into the system via the next generation of set-top boxes. However, set-top-boxes have yet to get a strong foothold in American

households as price (pay per service pricing model) and lack of interactive content have failed to justify their cost.

Many think of interactive TV primarily in terms of "one-screen" forms that involve interaction on the TV screen, using the remote control, but there is another significant form of interactive TV that makes use of Two-Screen Solutions, such as NanoGaming . In this case, the second screen is typically a PC (personal computer) connected to a Web site application. Web applications may be synchronized with the TV broadcast, or be regular websites that provide supplementary content to the live broadcast, either in the form of information, or as interactive game or program. Some two-screen applications allow for interaction from a mobile device (phone or PDA), that run "in synch" with the show.

Such services are sometimes called "**Enhanced TV**," but this term is in decline, being seen as anachronistic and misused occasionally. (Note: "Enhanced TV" originated in the mid-late 1990s as a term that some hoped would replace the umbrella term of "interactive TV" due to the negative associations "interactive TV" carried because of the way companies and the news media over-hyped its potential in the early 90's.)

Notable Two-Screen Solutions have been offered for specific popular programs by many US broadcast TV networks. Today, two-screen interactive TV is called either 2-screen (for short) or "**Synchronized TV**" and is widely deployed around the US by national broadcasters with the help of technology offerings from certain companies.

One-screen interactive TV generally requires special support in the set-top box, but Two-Screen Solutions, synchronized interactive TV applications generally do not, relying instead on Internet or mobile phone servers to coordinate with the TV and are most often free to the user. Developments from 2006 onwards indicate that the mobile phone can be used for seamless authentication through Bluetooth, explicit authentication through Near Field Communication. Through such an authentication it will be possible to provide personalised services to the mobile phone.

Interactive TV services

Notable interactive TV services are:

- ActiveVideo Networks (formerly known as ICTV) - Pioneers in interactive TV and creators of ActiveVideo: A cloud-based interactive TV platform built on current web and television standards. The network-centric approach provides for the bulk of application and video processing to be done in the cloud, and delivers a standard MPEG stream to virtually any digital set-top box, web-connected TV or media device.
- T-commerce - Is a commerce transaction through the set top box return path connection.
- BBC Red Button

- BrightlineiTV Partners - The top 200 national television advertisers work with BrightlineiTV to drive a two way dialogue with consumers off of an advertisers .30 second commercial. Their database includes nearly 175 iTV campaigns for leading brands like Unilever, Burger King, JP Morgan Chase, Tylenol, and Fortune Brands. They work with the satellite, cable, telco's and other platforms to reach 81 million US households. They are experts in how people watch TV today and how consumers interact with advertisers television offers.
- Ensequence - Provides solutions that enable programmers, advertisers and distributors to create and deploy interactive TV experiences that increase programming ratings, advertising response and audience reach. The company mitigates the technical complexities of interactive TV implementation and enables its customers to quickly and affordably deliver a high volume of robust interactive TV experiences across cable, satellite and IPTV.
- TiVo
- ATVEF - 'Advanced Television Enhancement Forum' is a group of companies that are set up to create HTML based TV products and services. ATVEF's work has resulted in an Enhanced Content Specification which makes it possible for developers to create their content once and have it display properly on any compliant receiver.
- MSN TV - MSN TV supplies computerless Internet access. It requires a set-top box that sells for $100 to $200, with a monthly access fee.
- Philips Net TV - solution to view Internet content designed for TV; directly integrated inside the TV set. No extra subscription costs or hardware costs involved.
- Interactive TV purchasing system An Interactive TV purchasing system was introduced in 1994 in France. The system was using a regular TV set connected together with a regular antenna and the Internet for feedback. A demo has shown the possibility of immediate purchasing, interactively with displayed contents.

User interaction

Interactive TV is often described by clever marketing gurus as "lean back" interaction, as users are typically relaxing in the living room environment with a remote control in one hand. This is a very simplistic definition of interactive television that is less and less descriptive of interactive television services that are in various stages of market introduction. This is in contrast to the similarly slick marketing devised descriptor of personal computer-oriented "lean forward" experience of a keyboard, mouse and monitor. This description is becoming more distracting than useful as video game users, for example, don't lean forward while they are playing video games on their television sets, a precursor to interactive TV. A more useful mechanism for categorizing the differences between PC and TV based user interaction is by measuring the distance the user is from the Device. Typically a TV viewer is "leaning back" in their sofa, using only a Remote Control as a means of interaction. While a PC user is 2 ft or 3 ft from his high resolution screen using a mouse and keyboard. The demands of distance, and user input devices, requires the application's look and feel to be designed differently. Thus Interactive TV applications are often designed for the "10ft user experience" while PC applications and

web pages are designed for the "3ft user experience". This style of interface design rather than the "lean back or lean forward" model is what truly distinguishes Interactive TV from the web or PC. However even this mechanism is changing because there is at least one web-based service which allows you to watch internet television on a PC with a wireless remote control.

In the case of Two-Screen Solutions Interactive TV, the distinctions of "lean-back" and "lean-forward" interaction become more and more indistinguishable. There has been a growing proclivity to media multitasking, in which multiple media devices are used simultaneously (especially among younger viewers). This has increased interest in two-screen services, and is creating a new level of multitasking in interactive TV. In addition, video is now ubiquitous on the web, so research can now be done to see if there is anything left to the notion of "lean back" "versus" "lean forward" uses of interactive television.

For one-screen services, interactivity is supplied by the manipulation of the API of the particular software installed on a set-top box, referred to as 'middleware' due to its intermediary position in the operating environment. Software programs are broadcast to the set-top box in a 'carousel'.

On UK DTT (Freeview uses ETSI based MHEG-5), and Sky's DTH platform uses ETSI based WTVML in DVB-MHP systems and for OCAP, this is a DSM-CC Object Carousel.

The set-top box can then load and execute the application. In the UK this is typically done by a viewer pressing a "trigger" button on their remote control (e.g. the red button, as in "press red").

Interactive TV Sites have the requirement to deliver interactivity directly from internet servers, and therefore need the set-top box's middleware to support some sort of TV Browser, content translation system or content rendering system. Middleware examples like Liberate are based on a version of HTML/JavaScript and have rendering capabilities built in, while others such as OpenTV and DVB-MHP can load microbrowsers and applications to deliver content from TV Sites. In October 2008, the ITU's J.201 paper on interoperability of TV Sites recommended authoring using ETSI WTVML to achieve interoperability by allowing dynamic TV Site to be automatically translated into various TV dialects of HTML/JavaScript, while maintaining compatibility with middlewares such as MHP and OpenTV via native WTVML microbrowsers.

Typically the distribution system for Standard Definition digital TV is based on the MPEG-2 specification, while High Definition distribution is likely to be based on the MPEG-4 meaning that the delivery of HD often requires a new device or set-top box, which typically are then also able to decode Internet Video via broadband return paths.

Interactive television projects

Some interactive television projects are consumer electronics boxes which provide set-top interactivity, while other projects are supplied by the cable television companies (or multiple system operator, or MSO) as a system-wide solution. Even other, newer, approaches integrate the interactive functionality in the TV, thus negating the need for a separate box. Some examples of interactive television include:

- MSOs
  - Cox Communications (US)
  - Time Warner (US)
  - Comcast (US)
  - Cablevision (US)
- Previous MSO trials or demos
  - TELE TV from Bell Atlantic, Nynex, Pac Tel, CAA (US) - no longer in operation
  - Full Service Network from Time Warner (US) - no longer in operation
  - GTE mainStreet (US) a former product of GTE, also provided over select Continental Cablevision and Daniels cable television systems.
  - Smartbox from TV Cabo, Novabase and Microsoft (PT) - this no longer in operation, although some of the equipment is still used for the digital TV service. This was the pioneer project.
- Consumer electronics solutions
  - TiVo
  - ReplayTV
  - UltimateTV
  - Miniweb
  - Microsoft Windows XP Media Center
  - Philips Net TV
- Two-Screen Solutions, or "enhanced TV" solutions
- Hospitality & healthcare solutions
  - LodgeNet
  - Miracle TV Corp.: Tru2Way and IPTV Centralized and Stand Alone solutions.

Mobile phone interaction with the STB and the TV

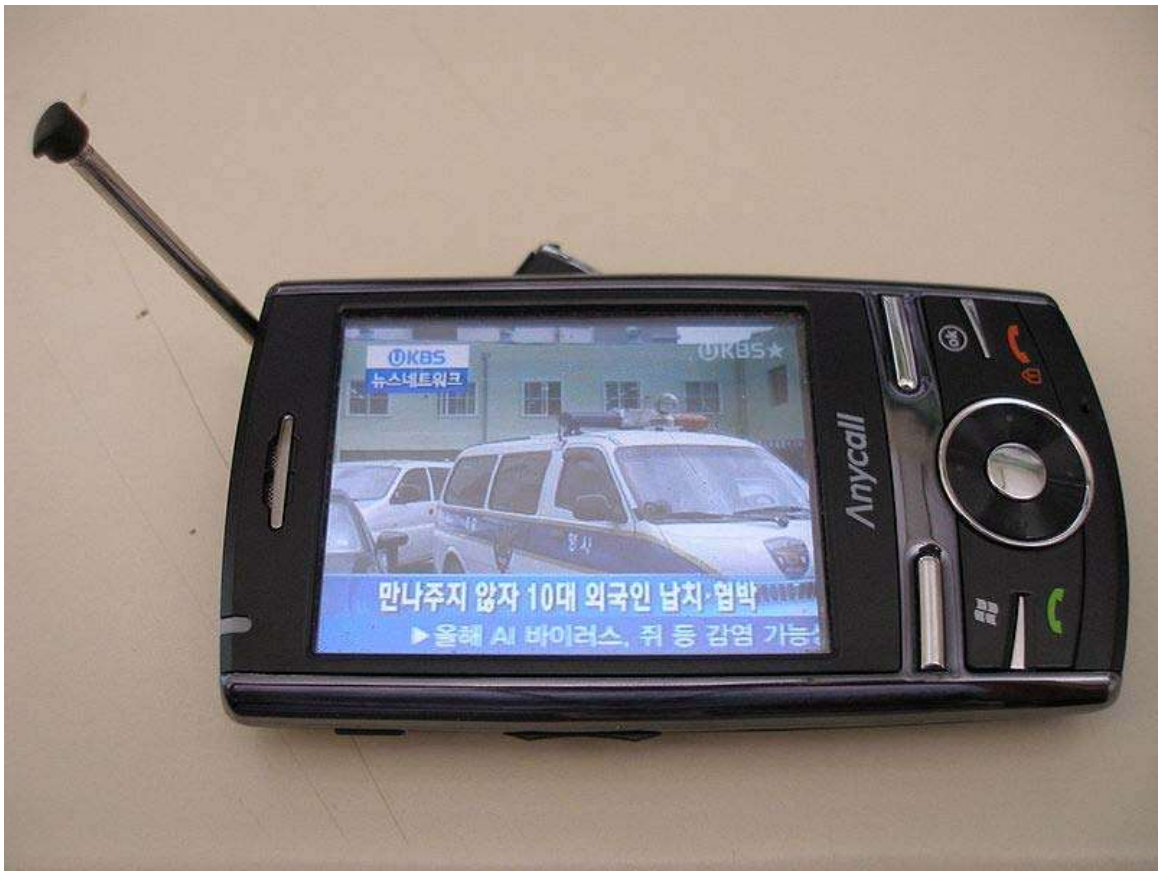
- ITEA WellCom Project using Bluetooth and NFC for authentication, pairing and seamless service access

Interactive Video and Data Services

IVDS is a wireless implementation of interactive TV, it utilizes part of the VHF TV frequency spectrum (218–219 MHz).

Chapter 7

Mobile Television



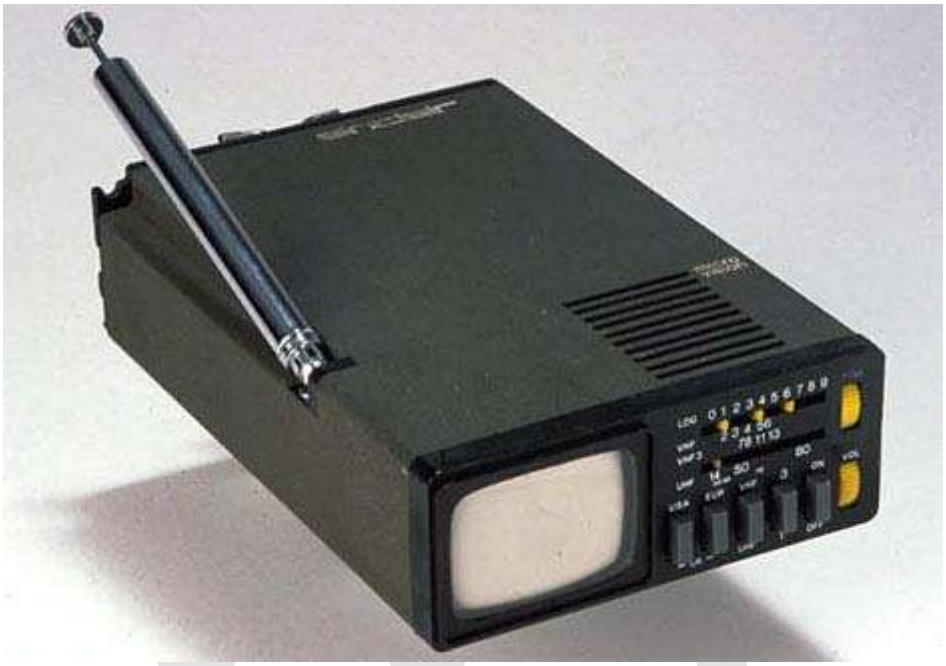
DMB in South Korea

Mobile television usually means television watched on a small handheld device. It may be a pay TV service broadcast on mobile phone networks or received free-to-air via terrestrial television stations from either regular broadcast or a special mobile TV transmission format. Some mobile televisions can also download television shows from

the internet, including recorded TV programs and podcasts which are downloaded and stored on the mobile device for later viewing.

The first pocket sized mobile television was sold to the public by Clive Sinclair in January 1977. It was called the Microvision or the MTV-1. It had a 2in CRT screen and was also the first television which could pick up signals in various countries.

History



The MTV-1 was the world's first pocket sized television. Sold first in 1977, this device was uniquely small for a CRT-based television while having better features than most regular sized TVs.

The first televisions small enough to fit inside a pocket, the MTV-1 or (Microvision), were made available to the public by Clive Sinclair in January 1977. They had a 2in CRT screen and were also the first televisions which could receive signals in various countries. It measured 102x159x41mm and was sold for less than £100 in the UK and for around $400 in the US. The project took over ten years to develop and was funded by around £1.6 million in British Government grants.

Mobile TV is one of the features provided by many 3G phones. In 2005, South Korea became the first country in the world to have mobile TV when it started satellite DMB (S-DMB) and terrestrial DMB (T-DMB) services on May 1 and December 1, respectively. Today, South Korea and Japan are at the forefront of this developing sector. Mobile TV services were launched by the operator CSL in Hong Kong, March 2006, on the 3G network. BT in the United Kingdom was the among the first companies outside South Korea to launch Mobile TV in September 2006, although the service was abandoned less than a year later. The same happened to "MFD Mobiles Fernsehen

Deutschland", who launched their DMB-based service June 2006 in Germany, and stopped it in April 2008. Also in June 2006, mobile operator 3 in Italy (part of Hutchison Whampoa) launched their mobile TV service, but opposed to their counterpart in Germany this was based on DVB-H. Sprint started offering the service in February 2006 and was the first US carrier to offer the service. In the US Verizon Wireless and more recently AT&T are offering the service.

Overview

Mobile TV is a service which allows cell phone owners to watch television on their phones from a service provider. Television data can be obtained either through an existing cellular network or a propriety network.

In South Korea, mobile TV is largely divided into satellite DMB (S-DMB) and terrestrial DMB (T-DMB). Although S-DMB initially had more content, T-DMB has gained much wider popularity because it is free and included as a feature in most mobile handsets sold in the country today.

Mobile TV is also available for consumers in India. BSNL introduced this feature for its eastern and north-eastern regions of India. In 2007, it also launched a mobile TV application called "isee". Today, isee is available not only in the four BSNL zones but also to other networks across India (except Reliance and TATA Indicom CDMA services).

Challenges

- **Device Manufacturer's challenges**

1. Power consumption: Battery technology for mobile portable devices may be stuck in a race condition. Improved battery life can be used up by the upgraded mobile content and enhanced functions. However, dashtop mobile devices can also be powered by a 12-volt vehicle battery, however vehicle batteries are not a sustainable source of power for mobile devices.

2. Memory: To support the high buffer requirements of mobile TV. Current memory capabilities available will not be suited for long hours of mobile TV viewing. Furthermore, potential future applications like peer-to-peer video sharing in mobile phones and consumer broadcasting would definitely add to the increasing memory requirements. The existing P2P algorithms won't be enough for mobile devices, necessitating the advent of mobile P2P algorithms. There is one start-up technology that claims patentability on its mobile P2P, but has not drawn attention from device manufacturers yet.

3. User interface design: A large number of mobile phones do not support mobile TV; users have to purchase new handsets with improved LCD display and user interface that support mobile TV. This new design has to appeal to the end-users and increase the

clarity of images without making the handset very bulky. The wider LCD touchscreens will be preferred by end-users and iPhone's popularity in the United States is part of the compelling evidence.

4. Processing power: Device manufacturers should improve the processing power significantly to support a MIPS intensive application like mobile TV.

- **Content Provider's challenges**

The mobile TV industry opens up a new market for the content specifically tailored for mobile TVs. These could include making new mobisodes –mobile episodes of popular shows which are relatively shorter in length (3 to 5 minutes), modifying the content to suit mobile TV.

Digital TV

North America

Mobile TV and mobile digital radio has been a challenge in North America, in part, because of the decision of the U.S. Federal Communications Commission (FCC) to use proprietary systems instead of the principles of network neutrality. This sometimes leads to vendor lock-in by mobile phone companies and manufacturers. The FCC chose the ATSC system for digital TV which, with the choice of 8VSB modulation, makes mobile reception difficult, because it is heavily prone to multipath interference (which changes rapidly in a mobile reception environment). ATSC-M/H was developed to allow for mobile reception, riding within each TV station's regular MPEG transport stream, and using heavy error correction to compensate for poor signals, while taking space out of the "bit budget" for each station's other digital subchannels and/or HDTV. In comparison with DVB-T, there is no hierarchical modulation to allow for LDTV reception, however, the use of MPEG-4 Scalable Video Coding coding in ATSC-M/H allows for scalable resolutions and frame rates. As of 2009, chipsets for ATSC-M/H were not yet in any consumer electronics devices, but early products using chipsets by LG and Samsung were shown at the 2010 CES and NAB Conferences. The FCC also chose HD Radio which, although it uses COFDM and has reasonable mobile reception, does not have provisions for mobile TV as DAB-T has with DMB-T and is incompatible even with neighboring Canada, where the Canadian Radio-television and Telecommunications Commission (CRTC) already chose DAB in the L band. Satellite radio is also proprietary with no choice made by the FCC regarding the system. MediaFLO, which also uses COFDM, is broadcast on UHF TV channel 55, but like satellite TV is encrypted and controlled by conditional access (provided via the cellular network). Also, it must be purchased as pay TV for a limited number of cellphones which must have AT&T Mobility or Verizon Wireless phone service.

Broadcast mobile DTV development

While MediaFLO uses the TV spectrum and MobiTV used cell phone networks, "mobile DTV" (ATSC-M/H) uses the digital TV spectrum. At the National Association of Broadcasters (NAB) show in April 2007 in Las Vegas, the ATSC and 8VSB methods for delivering mobile DTV were shown. A-VSB (Advanced VSB), from Samsung and Rohde & Schwarz, was shown at the previous year's show. In 2007, LG, whose Zenith Electronics came up with 8VSB, introduced (with Harris Group) its Mobile-Pedestrian-Handheld (MPH) system. As the broadcast networks began making their content available online, mobile DTV meant stations would have another way to compete. Sinclair Broadcast Group tested A-VSB in fall 2006, and its KVCW and KVMY were participating in the mobile DTV product demonstrations at the NAB show. A-VSB had worked in buses at the 2007 Consumer Electronics Show. ION Media Networks started a test station on channel 38, which was to be used for digital LPTV, to use for a single-frequency network (SFN). In some areas, more than one TV transmitter would be needed to cover all areas. Mobile DTV could have been used at that time because it would not affect HDTV reception. A single standard, however, had to be developed. At the Consumer Electronics Show in January 2009, the first prototype devices from LG and other manufacturers were demonstrated, including receivers for cars from Kenwood, Visteon and Delphi. It was announced that 63 stations in 22 markets would debut the service in 2009. Gannett Broadcasting president David Lougee pointed out that many of those attending the inauguration of Barack Obama would likely hear him but not see him; had the new technology been in place, this would not have been a problem. In April 2009, the Open Mobile Video Coalition, made up of over 800 broadcast stations, selected four test stations: Gannett's WATL and ION's WPXA-TV in Atlanta, and Fisher Communications' KOMO-TV and Belo's KONG-TV in Seattle. WPXA had begun mobile DTV broadcasting on April 1. The others would start in May. Later in 2009, ION said it was making available HDTV, standard definition and Mobile DTV streams using its affiliates in New York City and Washington, D.C. The "triple-play" concept was part of an effort to create a Mobile DTV standard. At the time, only those with prototype receivers could pick up the streams. ION Chairman and CEO Brandon Burgess said mobile DTV lets stations "think beyond the living room and bring live television and real time information to consumers wherever they may be." The Advanced Television Systems Committee started work on mobile DTV standards in May 2007, and manufacturers and sellers worked quickly to make the new technology a reality. The OMVC persuaded LG and Samsung to work together starting in May 2008 so that differing systems (possibly a self-destructing format war) would not delay or kill the technology. Early in July 2009, the ATSC Technology and Standards Group approved the ATSC-M/H standard for mobile DTV which all members green-lighted October 15. The public could be using the new devices by 2010, though watching TV on cell phones seemed unlikely in the near future since telephone manufacturers did not yet include that capability. The technology was expected to be used for polls and even voting. By the end of the year, the ATSC and the Consumer Electronics Association began identifying products meeting the standard with "MDTV".

Paul Karpowicz, NAB Television Board chairman and president of Meredith Broadcast Group, said

This milestone ushers in the new era of digital television broadcasting, giving local TV stations and networks new opportunities to reach viewers on the go. This will introduce the power of local broadcasting to a new generation of viewers and provide all-important emergency alert, local news and other programming to consumers across the nation.

Later in July, the first multi-station tests began in Washington, D.C., while single stations in New York City and Raleigh, North Carolina already offered mobile DTV. The OMVC chose Atlanta's WATL and Seattle's KONG as "model stations" where product testing could take place. 70 stations in 28 media markets planned streams by the end of 2009. The Washington test would involve WPXW-TV, WUSA, WDCA, WRC-TV, WHUT-TV, WNUV in Baltimore, and WNVT, a part of MHz Networks, a multicasting service. All of the stations would have two of more channels each, with "electronic service guide and alert data" among the services. 20 sellers of equipment would use these stations to test using the existing standard, but testing the final standard would come later, and tests by the public would happen in 2010, when many more devices would be ready. Obviously, manufacturing large numbers of the devices could not take place without the final standard. LG, however, began mass-producing chips in June. ION technology vice president Brett Jenkins said, "We're really at a stage like the initial launch of DTV back in 1998. There are almost going to be more transmitters transmitting mobile than receive devices on the market, and that's probably what you'll see for the next six to nine months." Devices would eventually include USB dongles, netbooks, portable DVD players and in-car displays. White House officials and members of Congress saw the triple-play concept in an ION demonstration on July 28, 2009 in conjunction with the OMVC. Another demonstration took place October 16, 2009 with journalists, industry executives and broadcasters riding around Washington, D.C. in a bus with prototype devices. Included were those who would be testing the devices in the Washington and Baltimore markets in January 2010. On August 7, 2009, BlackBerry service began on six TV stations--WISH-TV in Indianapolis; WAVY-TV in Hampton Roads, Virginia; KRQE in Albuquerque, New Mexico; WANE-TV in Fort Wayne, Indiana; WALA-TV in Mobile, Alabama; and KXAN-TV in Austin, Texas. 27 other stations will eventually offer the service, and LIN TV, which developed the BlackBerry service, has an iPhone application planned. By October, 30 stations were airing mobile DTV signals, and that number was expected to be 50 by year-end. Also in the same month, FCC chair Julius Genachowski announced efforts to increase the amount of spectrum available to wireless services. Also in August, WTVE and Axcera began testing a single-frequency network (SFN) with multiple transmitters using the new mobile standard. The RNN affiliate in Reading, Pennsylvania had used this concept since 2007. Richard Mertz of Cavell, Mertz & Associates says VHF won't work as well for mobile DTV because a 15-inch antenna or some other solution would be required, although he has heard from people who had no problems. An amplified antenna or higher power for the transmitting station would likely be needed, as well as repeater stations where terrain is a problem. Lougee, whose company planned testing in its 19 markets in 2010, said the chip designs with the new devices made targeted advertising possible. In December 2009, Concept Enterprises

introduced the first Mobile DTV tuner for automobiles. Unlike earlier units, this one will provide a clear picture without pixilation in a fast-moving vehicle, using an LG M/H chip and a one-inch roof-mounted antenna. No subscription wil be required. Also in December, the Consumer Electronics Association hosted a "plugfest" in Washington, D.C. to allow manufacturers to test various devices. More than 15 companies, and engineers from different countries, tested four transmission systems, 12 receiver systems, and four software types. On December 1, News Corp. chairman Rupert Murdoch said mobile DTV would be important to the future of all journalism, and he planned to offer TV and possibly newspaper content in this way. At the January 2010 Consumer Electronics Show, NAB head Gordon H. Smith disputed the idea that broadcasting's days were numbered, calling mobile DTV the proof over-the-air television would continue its popularity. He said people would use cell phones and other devices to watch, and broadcast technology would be the best way to do this. Wireless broadband, which some wanted to replace broadcasting, would not be able to handle the demand for video services. ION's Burgess showed off one of the first iPhones capable of receiving mobile DTV, while ION's Jenkins showed an LG Maze and a Valups Tivit; the latter sends signals to the iPod Touch and will soon work with the Google Nexus. Sinclair Broadcast Group director of advanced technology Mark Aitken said the mobile DTV concept of multiple transmitters would help free up spectrum for wireless broadband in rural areas but not large cities. He also explained to the FCC that mobile DTV was the best method for sending out live video to those using cell phones and similar devices. The OMVC's Mobile DTV Consumer Showcase began May 3, 2010 and lasted all summer. Nine stations planned to send out 20 programs, including local and network shows as well as cable programs, to Samsung Moment phones. Dell Netbooks and Valups Tivits also received programming. On September 23, 2010, Media General began its first MDTV service at WCMH-TV in Columbus, Ohio, and a month later had plans to do the same at WFLA-TV in the Tampa Bay area. However, viewers still had few choices for using the service, and they needed to be made aware the service existed.

On November 19, 2010, a joint venture known as the Mobile Content Venture announced plans to improve the capabilities of TV stations in 20 markets representing 40 percent of the United States population by the end of 2011.

Mobile TV standards

Terrestrial

- DVB-H (Digital Video Broadcasting - Handheld) - Europe, Asia
- ATSC-M/H (ATSC Mobile/Handheld) - North America
- T-DMB (Terrestrial Digital Mulitmedia Broadcast) - South Korea
- 1seg (One Segment) - Mobile TV system on ISDB-T
- MediaFLO - launched in US, trialled in UK and Germany
- DMB-T/H - China and Hong Kong
- DAB-IP (Digital Audio Broadcast) - UK
- iMB (Integrated Mobile Broadcast, 3GPP MBMS)

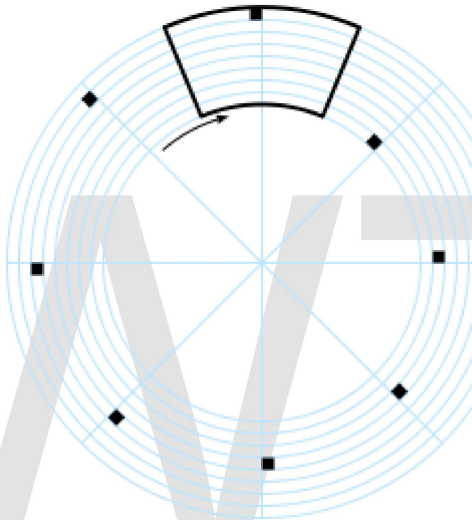
Satellite

- DVB-SH (Digital Video Broadcasting - Satellite for Handhelds)
- S-DMB (Satellite Digital Multimedia Broadcast) - South Korea
- CMMB (China Mobile Multimedia Broadcasting) - China

The European Union adopted DVB-H/DVB-SH over other versions of the technology in 2008.

Chapter 8

Mechanical Television



This schematic shows the circular paths traced by the holes in a Nipkow disk.

Mechanical television (also called **televisor**) was a television system that used mechanical or electromechanical devices to capture and display images. However, the images themselves were usually transmitted electronically and via radio waves. The reason for the dual nature of mechanical television lay in the history of technology. The earliest mechanical television components originated with 19th century inventors, with 20th century inventors later adding electronic components as they were created. Mechanical systems were used in television broadcasting from 1925 to 1939, overlapping the all-electronic era by three years.

Mechanical television in history

The essential mechanical component usually consisted of a Nipkow disk, which has a series of holes in a spiral pattern. In the camera, the disk had a light-detecting device, usually a photoelectric cell, behind it. In the reproducer (the display), a modulated light source, usually used a neon tube, replacing the light detector. As each hole flew by, it produced a scan line. An AM radio wave or closed circuit then carried the scan line to the TV reproducer.

Facsimile transmission of still photographs employed some of the principles of mechanical television as early as the 19th century. For instance, Shelford Bidwell demonstrated such a system in 1881. For decades, earlier systems had pioneered scanning in the transmission of type and line art. Photographic transmission was a greater challenge due to the selenium in early photoelectric cells having very low sensitivities. Scanning a photograph at a resolution suitable for newspaper reproduction could take several minutes. With silhouette or duotone still images, instantaneous transmission was possible by 1909.

Baird-like modern televisor image of replica "Stooky Bill" puppet head similar to the one used by J. L. Baird in his early TV experiments. His images would probably have been of comparable quality.

American inventor Charles Francis Jenkins developed mechanical television systems in the 1920s and early 1930s. In 1923, Jenkins transmitted the first moving silhouette images, and on June 13, 1925 publicly demonstrated synchronized transmission of images and sound. Over 400 patents were issued to Jenkins, including 75 devoted to mechanical television alone. In the 1920s, the Japanese electrical scientist Yasujiro Niwa invented a simple device for phototelegraphic transmission through cable and later via radio.

Mechanical television transmitting a live, moving image in tone gradations (grayscale images) was demonstrated by British inventor John Logie Baird on January 26, 1926, at his laboratory in London. Unlike later electronic systems with several hundred lines of resolution, Baird's vertically scanned image, using a scanning disk embedded with a double spiral of lenses, had only 30 lines, just enough to reproduce a recognizable human face.

Ulises Armand Sanabria was the builder and engineer of WCFL, the first mechanical television station to go on the air in Chicago on June 12, 1928. By sending the sound signal to station WIBO and the video signal on WCFL, he was the first to transmit sound and picture simultaneously on the same wave band on May 19, 1929. Several US universities established and maintained mechanical television stations from 1930 to 1939.

Because only a limited number of holes could be made in the disks, and disks beyond a certain diameter became impractical, image resolution on mechanical television broadcasts was relatively low, ranging from about 30 lines up to 120 or so. Nevertheless, the image quality of 30-line transmissions steadily improved with technical advances, and by 1933 the UK broadcasts using the Baird system were remarkably clear. A few systems ranging into the 200-line region also went on the air. Two of these were the 180-line system that Compagnie des Compteurs (CDC) installed in Paris in 1935, and the 180-line system that Peck Television started in 1935 at station VE9AK in Montreal.

Instead of a Nipkow disk, mechanical television could also use several other technologies. Other arrangements often made use of a rotating drum, either with holes or with a series of mirrors on it.

Flying spot scanners

Another scanning method was the "flying spot." The flying spot developed as a remedy for the low sensitivity that photoelectric cells had at the time. A bright, narrow beam of light would shine through the holes of a Nipkow disk. This light would then illuminate the television subject, standing in a darkened studio.

Whipping back and forth and up and down, the spot of light would complete sixteen or more scans per second. The light would reflect back to not one, but a bank of photoelectric cells. The combined signals of these cells gave a strong picture. Like mechanical television itself, flying spot technology grew out of phototelegraphy (facsimile). This scanning method began in the 19th century.

The BBC television service used the flying spot method until 1935. German television used flying spot methods as late as 1938. This year was by far not the end of flying spot scanner technology. The German inventor Manfred von Ardenne designed a flying spot scanner with a CRT as the light source. In the 1950s, DuMont marketed Vitascan, an entire flying-spot color studio system. Today, graphic scanners still use this scanning method. The flying spot method has two disadvantages:

- Actors must perform in near darkness;
- Flying spot cameras tend to work unreliably outdoors in daylight.

A note about outdoor telecasts with a flying spot scanner: In 1928, Ray Kell from the United States' General Electric proved that flying spot scanners could work outdoors. The scanning light source must be brighter than other incident illumination.

Kell was the engineer who ran a 24-line camera that telecast pictures of New York governor Al Smith. Smith was accepting the Democratic nomination for presidency. As Smith stood outside the capital in Albany, Kell managed to send usable pictures to his associate Bedford at station WGY, which was broadcasting Smith's speech. The rehearsal went well, but then the real event began. The newsreel cameramen switched on their floodlights.

Unfortunately for Kell, his scanner only had a 1 kW lamp inside it. The floodlights threw much more light on Governor Smith. These floods simply overwhelmed Kell's image. In fact, the floods made the unscanned part of the image as bright as the scanned part. Kell's photocells couldn't pick up reflections off Smith from the AC scanning beam. Instead, the photocells only detected the flat, DC light from the floodlamps.

The effect is very similar to extreme overexposure in a still camera: The scene disappears, and the camera records a flat, bright light. Use the camera in favorable conditions, though, and the picture comes out fine. Similarly, Kell proved that outdoors in favorable conditions, his scanner worked fine.

Mechanical television with large pictures

A few mechanical TV systems could produce images several feet wide and of comparable quality to the cathode ray tube (CRT) televisions that were to follow. CRT technology at that time was limited to small, low-brightness screens. One such system was developed by Ulises Armand Sanabria in Chicago. By 1934, Sanabria demonstrated a projection system which had a 30-foot image.

Perhaps the best mechanical televisions of the 1930s used the Scophony system, which could produce images of more than 400 lines and display them on screens at least 9×12 feet (2.8×3.7 m) in size (at least a few models of this type were actually produced).

The Scophony system used multiple drums rotating at fairly high speed to create the images. One using a 441-line American standard of the day had a small drum rotating at

39,690 rpm (a second slower drum moved at just a few hundred rpm). Today, DLP mechanical TV technology from Texas Instruments far outstrips the capabilities of the Scophony system.

Aspect ratios for different purposes

Some mechanical equipment scanned lines vertically rather than horizontally, as in modern TVs. An example of this method is the Baird 30-line system. Baird's British system created a picture in the shape of a very narrow, vertical rectangle.

This shape created a portrait image, instead of the landscape orientation that is common today. The position of a framing mask before the Nipkow disk determines the scan line orientation. Placement of the framing mask at the left or right side of the disk gives vertical scan lines. Placement at the top or bottom of the disk gives horizontal scan lines.

Baird's earliest television images had very low definition. These images could only show one person clearly. For this reason, a vertical, portrait image made more sense to Baird than a horizontal, landscape image. Baird chose a shape three units wide by seven high. Actually this shape is only about half as wide as a traditional portrait. You can imagine this shape this way: A typical doorway also has the proportions three by seven.

Instead of entertainment television, Baird might have had point-to-point communication in mind. Another television system followed that reasoning. The 1927 system developed by Herbert E. Ives at AT&T's Bell Laboratories was a large-screen television system and the most advanced television of its day. The Ives 50-line system also produced a vertical "portrait" picture. Since AT&T intended to use television for telephony, the vertical shape was logical: phone calls are usually conversations between just two people. A picturephone system would depict one person on each side of the line.

Meanwhile, in the US, Germany and elsewhere, other inventors planned to use television for entertainment purposes. These inventors began with square or landscape pictures. (For example, consider the television systems of these men: Ernst Alexanderson, Frank Conrad, Charles Francis Jenkins, William Peck and Ulises Armand Sanabria.) These inventors realized that television is about relationships between people. From the very beginning, these inventors allowed picture space for two-shots. Soon, images increased to 60 lines or more. The camera could easily photograph several people at once. Then even Baird switched his picture mask to a horizontal image. Baird's "zone television" is an early example of rethinking his extremely narrow screen format. For entertainment and most other purposes, even today, landscape remains the more practical shape.

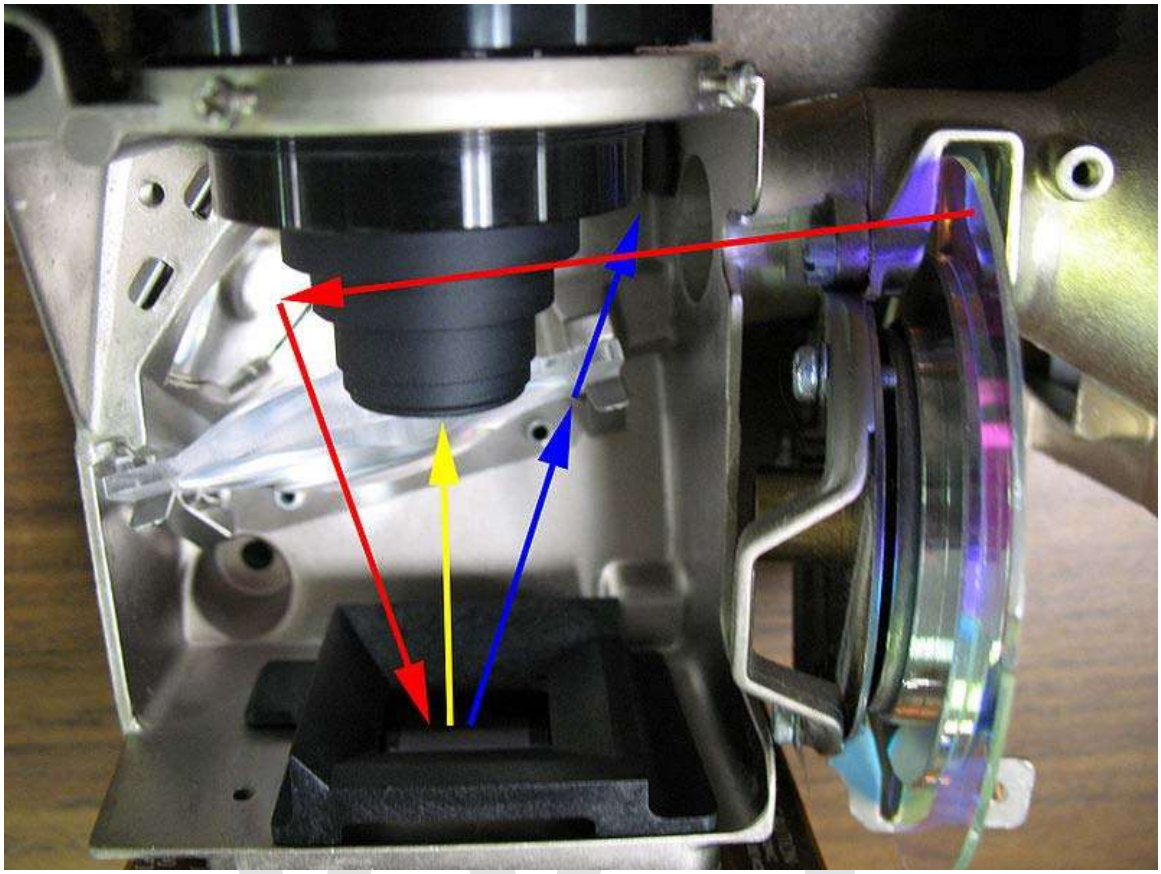
Rise of electronic television

The advancement of all-electronic television (including image dissectors and other camera tubes and cathode ray tubes for the reproducer) marked the beginning of the end for mechanical systems as the dominant form of television. Mechanical TV usually only produced small images. It was the main type of TV until the 1930s.

All-electronic television, first demonstrated in September 1927 in San Francisco by Philo Farnsworth, and then publicly by Farnsworth at the Franklin Institute in Philadelphia in 1934, was rapidly overtaking mechanical television. Farnsworth's system was first used for broadcasting in 1936, reaching 400 to more than 600 lines with fast field scan rates, along with competing systems by Philco and DuMont Laboratories. The last mechanical television broadcasts ended in 1939 at stations run by a handful of public universities in the United States. In 1939, RCA paid Farnsworth $1 million for his patents after ten years of litigation, and RCA began demonstrating all-electronic television at the 1939 World's Fair in New York City.

Color mechanical television

Modern colour televisor. A test card (the famous test card F) can just be seen through the lens on the right.



Color wheel in a modern single-chip Digital Light Processing projector.

Mechanical television returned to the United States as a method of painting colors over a monochrome CRT. The CBS color television system of Peter Goldmark used such technology in 1940. John Baird's 1928 color television experiments had inspired Goldmark's more advanced field-sequential color system. In Goldmark's system, stations transmit color saturation values electronically. Yet mechanical methods also come into play. At the transmitting camera, a mechanical disc filters hues (colors) from reflected studio lighting. At the receiver, a synchronized disc paints the same hues over the CRT. As the viewer watches pictures through the color disc, the pictures appear in full color.

Of course, simultaneous color systems superseded the CBS-Goldmark system. Yet mechanical color methods continued to find uses. Early color sets were very expensive, over $1,000 in the money of the time. Inexpensive adapters allowed owners of black-and-white, NTSC television sets to receive color telecasts. The most prominent of these adapters is Col-R-Tel, a 1955 NTSC to field-sequential converter. This system operates at NTSC scanning rates, but uses a disc like the obsolete CBS system had. The disc converts the black-and-white set to a field-sequential set. Meanwhile, Col-R-Tel electronics recover NTSC color signals and sequence them for disc reproduction. The electronics also synchronize the disc to the NTSC system. In Col-R-Tel, the electronics provide the saturation values (chroma). These electronics cause chroma values to

superimpose over brightness (luminance)changes of the picture. The disc paints the hues (color) over the picture.

A few years after Col-R-Tel, Apollo moon missions also adopted field-sequential techniques. The lunar color cameras all had color wheels. These Westinghouse and later RCA cameras sent field-sequential color television pictures to earth. The earth receiving stations included mechanical equipment that converted these pictures to standard television formats.

Today, some Digital Light Processing (DLP) projectors still use color filter wheels.

Recording

In the days of commercial mechanical television transmissions, a system of recording images (but not sound) was developed, using a modified gramophone recorder. Marketed as "Phonovision", this system, which was never fully perfected, proved to be complicated to use as well as quite expensive, yet managed to preserve a number of early broadcast images that would otherwise have been lost. Scottish computer engineer Donald F. McLean has painstakingly reconstructed the analogue playback technology required to view these recordings, and has given lectures and presentations on his collection of mechanical television recordings made between 1925 and 1933.

Among the discs in Dr. McLean's collection are a number of test recordings made by television pioneer John Logie Baird himself. One disc, dated "28th March 1928" and marked with the title "Miss Pounsford", shows several minutes of a woman's face in what appears to be very animated conversation. In 1993, the woman was identified by relatives as Mabel Pounsford, and her brief appearance on the disc is one of the earliest known video recordings of a human being.

Recent uses of mechanical television

Since the 1970s, some amateur radio enthusiasts have experimented with mechanical systems. The early light source of a neon lamp has now been replaced with super-bright LEDs. There is some interest in creating these systems for narrow-bandwidth television, which would allow a small moving image to fit into a channel less than 40 kHz wide (modern TV systems usually have a channel about 6 MHz wide, 150 times larger). Also associated with this is slow-scan TV, although that typically uses electronic systems.

The re-emergence of mechanical TV techniques

Today, a mechanical system of a sort has seen moderate popularity. Digital Light Processing (DLP) projectors use an array of tiny (16 μm^2) electrostatically-actuated mirrors selectively reflecting a light source to create an image. Many low-end DLP systems also use a color wheel to provide a sequential color image, a common feature of many early color television systems before the shadow mask CRT provided a practical method for producing a simultaneous color image.

Another place where high-quality imagery is produced by opto-mechanics is the laser printer, where a small rotating mirror is used to deflect a modulated laser beam in one axis while the motion of the photoconductor provides the motion in the other axis. A modification of such a system using high power lasers is used in laser video projectors, with resolutions as high as 1024 lines and each line containing >1500 points. Such systems produce, arguably, the best quality video images. They are used, for instance, in planetariums.

The closest modern systems to the original mechanical scan camera is the long wave infrared cameras used in military applications such as giving fighter pilots night vision. These cameras use a high sensitivity infrared photo receptor (usually cooled to increase sensitivity), but instead of disks of lenses, these systems use rotating prisms to provide a 525 or 625 line standard video output. The optical parts are made from germanium, because glass is opaque at the wavelengths involved. These cameras have found a new role in sporting events where they are able to show (for example) where a ball has struck a bat.

Laser lighting display techniques are combined with computer emulation in the LaserMAME project. It is a vector-based system, unlike the raster displays thus-far described. Laser light reflected from computer-controlled mirrors traces out images generated by classic arcade software which is executed by a specially modified version of the MAME emulation software.

Television Machine with 4 LED – Strips

Chapter 9

Enhanced-Definition Television

Enhanced-definition television, **extended-definition television**, or **EDTV** is a United States Consumer Electronics Association (CEA) marketing shorthand term for certain digital television (DTV) formats and devices. Specifically, this term defines formats that deliver a picture that is superior to that of standard-definition television (SDTV), but not as detailed as high-definition television (HDTV).

The term refers to devices capable of displaying 480 or 576-line signals in progressive scan (commonly referred to as "480p (NTSC)" and "576p (PAL)" respectively) as opposed to interlaced scanning, commonly referred to as "480i (NTSC)" or "576i (PAL)". High-motion is optional for EDTV.

In other countries the outlook may be different. For example, in Australia the 1080i digital TV system is officially recognised as high definition. In the United Kingdom, all HD broadcasts regardless of the platform used are broadcast at 1080i.

Connectivity

As EDTV signals require more bandwidth than is feasible with SDTV connection standards, such as composite video or S-Video, higher bandwidth media must be used to accommodate the additional data transfer. To achieve EDTV, consumer electronic devices such as a progressive scan DVD player or modern video game console must be connected through at least a component video cable (typically using 3 RCA cables for video), a VGA connector, or a DVI or HDMI connector. For over-the-air television broadcasts, EDTV content uses the same connectors as HDTV.

Broadcast and displays

EDTV broadcasts use less digital bandwidth than HDTV, so TV stations can broadcast several EDTV stations at once. Like SDTV, EDTV signals are broadcast with non-square

pixels. Because the same number of horizontal pixels are used in 4:3 and 16:9 broadcasts, the 16:9 mode is sometimes referred to as anamorphic widescreen. Most EDTV displays use square pixels, yielding a resolution of 852×480. However since no broadcasts use this pixel count, such displays always scale anything they display. (The only sources of 852×480 video are internet downloads, such as from iTunes, and some video games). When Plasma EDTVs were common, viewers found that while the TVs were not theoretically HD, downscaled HD signals looked far better than DVDs on such TVs. Unlike 1080i and SDTV formats, plasma displays can show EDTV signals without the need to de-interlace them first. This can result in a reduction of motion artifacts.

DVDs

The progressive output of a DVD player can be considered the baseline for EDTV. Movies shot at 24 frames per second (fps) are often encoded onto a DVD at 24 fps progressive, and most DVD players do the 2:2 or 3:2 pulldown conversion internally before feeding the output to (usually) an interlaced display, or here, a progressive 576p or 480p.

The progressive 24 fps DVD will have a unifying effect on PAL and NTSC, just as film does, perhaps needing conversion of the number of lines but without a conflict between field and frame rate. The player converts the video to the more conventional video formats on the fly, by simply repeating each field. For PAL , by repeating each frame twice with a corresponding interlace, and for NTSC (by repeating some 480p frames 2 times and others 3 times (3:2 pulldown), to make 24fps material play at 30fps, or 60 *fields* per second).

On an EDTV display, or on HDTVs in 480p mode, DVD players can display progressive disc content without needing to convert it to interlaced format. Various signal processing tricks are then used to fake progressive scan, and the quality of this depends on how good the upconversion process is.

Blu-ray Disc and HD DVD formats can encode all EDTV forms - but because HDTV is a primary selling point of Blu-ray/HD DVD discs, to date, this has been used only on certain bonus content.

Gaming

The video resolution of video game consoles reached EDTV specifications starting with the Sega Saturn, with NiGHTS into Dreams..., Christmas NiGHTS, Panzer Dragoon II Zwei, and High Velocity being the only supported games. The Dreamcast expanded on this, becoming the first mainstream console with a VGA output, supporting EDTV. The PlayStation 2, Nintendo GameCube, Xbox and Wii are also EDTV compatible with a component connection. The Xbox 360 can output 480p via YPbPr component, VGA and HDMI (newer models only) cables. The PlayStation 3 also outputs in 480p (NTSC) and 576p (PAL) via its HDMI, component video(Y/Pr/Pb), and RGB connections. Also, some

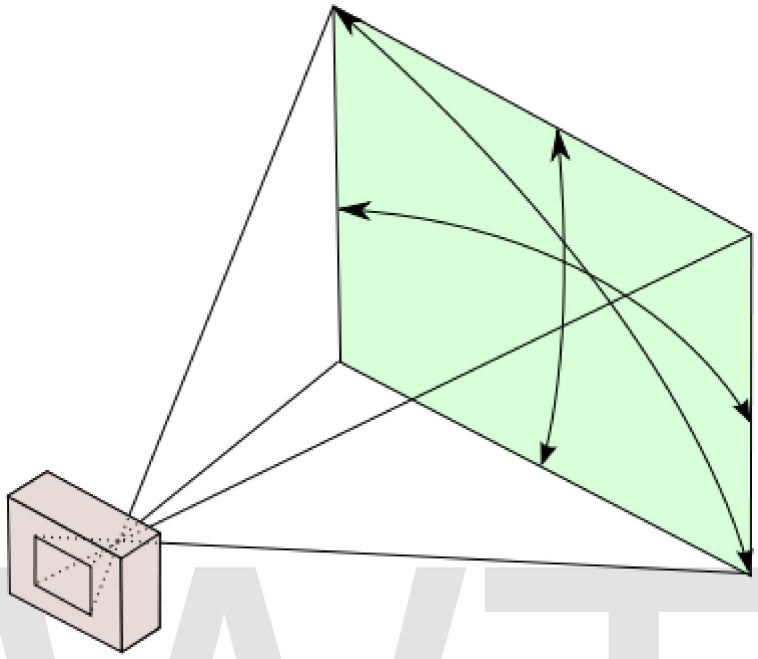
consumer devices, such as a video game console, typically use a horizontal resolution of 640 square pixels when outputting an EDTV signal, which is already a 4:3 format.

Chapter 10

Large-Screen Television Technology

Large-screen television technology developed rapidly in the late 1990s and 2000s. Various thin screen technologies are being developed, but only the liquid crystal display (LCD), plasma display (PDP) and Digital Light Processing (DLP) were released on the public market. These technologies have almost completely displaced cathode ray tubes (CRT) in television sales, due to the necessary bulkiness of the cathode ray tubes. However, just released technologies like organic light-emitting diode (OLED) and not-yet released technologies like surface-conduction electron-emitter display (SED) or field emission display (FED) are making their way to replace the first flat screen technologies in picture quality. The diagonal screen size of a CRT television is limited to about 40 inches because of the size requirements of the cathode ray tube, which fires a beam of electrons onto the screen, creating a viewable image. A larger screen size requires a longer tube, making a CRT television with a large screen (50 to 80 inches) unrealistic because of size. The aforementioned technologies can produce large-screen televisions that are much thinner.

Viewing distances



Horizontal, vertical and diagonal field of view

Before deciding on a particular display technology size, it's very important to calculate at what distances it's going to be viewed from. As the display size increases so does the ideal viewing distance. As a rule of thumb, the viewing distance should be roughly two to three times the screen size for standard definition (SD) displays.

Screen size (in)	Viewing distance (ft)	Viewing distance (m)
15–26	5–8	1.5-2.4
26–32	8–11.5	2.4-3.5
32–42	11.5–13	3.5-4
42–55	>13	>4

Display specifications

The following are important factors for evaluating television displays:

- Display size: This refers to the diagonal length of the display.
- Display resolution: This refers to the number of pixels in each dimension on a display. In general a higher resolution will yield a clearer, sharper image.
- Dot pitch: This measures the size of an individual pixel, which includes the length of the subpixels and distances between subpixels. It can be measured as the horizontal or diagonal length of a pixel. A smaller dot pitch generally results in

sharper images because there are more pixels in a given area. In the case of CRT based displays, pixels are not equivalent to the phosphor dots, as they are to the pixel triads in LC displays. Projection displays that use 3 monochrome CRTs do not have a dot structure, so this specification does not apply.

- Response time: This is the time it takes for the display to respond to a given input. For an LC display it is defined as the total time it takes for a pixel to transition from black to white, and then white to black. A display with slow response times displaying moving pictures may result in blurring and distortion. Displays with fast response times can make better transitions in displaying moving objects without unwanted image artefacts.
- Brightness: This is the amount of light emitted from the display. It is sometimes synonymous with the term *luminance*, which is defined as the amount of light per area and is measured in SI units as candela per square meter.
- Contrast ratio: This is defined as the ratio of the luminance of the brightest color to the luminance of the darkest color on the display. High contrast ratios are desirable but the method of measurement varies greatly. It can be measured with the display isolated from its environment or with the lighting of the room being accounted for. Static contrast ratio is measured on a static image at some instant in time. Dynamic contrast ratio is measured on the image over a period of time. Manufacturers can market either static or dynamic contrast ratio depending on which one is higher.
- Aspect ratio: This is the ratio of the display width to the display height. The aspect ratio of a traditional television is 4:3, which is being discontinued, the television industry is currently changing to the 16:9 ratio typically used by large-screen, high-definition televisions.
- Viewing angle: This is the maximum angle at which the display can be viewed with acceptable quality. The angle is measured from one direction to the opposite direction of the display, such that the maximum viewing angle is 180 degrees. Outside of this angle the viewer will see a distorted version of the image being displayed. The definition of what is acceptable quality for the image can be different among manufacturers and display types. Many manufacturers define this as the point at which the luminance is half of the maximum luminance. Some manufacturers define it based on contrast ratio and look at the angle at which a certain contrast ratio is realized.
- Color reproduction/gamut: This is the range of colors that the display can accurately represent.

Display technologies

LCD television

A pixel on an LCD consists of multiple layers of components: two polarizing filters, two glass plates with electrodes, and liquid crystal molecules. The liquid crystals are sandwiched between the glass plates and are in direct contact with the electrodes. The two polarizing filters are the outer layers in this structure. The polarity of one of these filters is oriented horizontally, while the polarity of the other filter is oriented vertically.

The electrodes are treated with a layer of polymer to control the alignment of liquid crystal molecules in a particular direction. These rod-like molecules are arranged to match the horizontal orientation on one side and the vertical orientation on the other, giving the molecules a twisted, helical structure. Twisted nematic liquid crystals are naturally twisted, and are commonly used for LCD's because they react predictably to temperature variation and electric current.

When the liquid crystals are in its natural state, light passing through the first filter will be rotated (in terms of polarity) by the twisted molecule structure, which allows the light to pass through the second filter. When voltage is applied across the electrodes, the liquid crystal structure is untwisted to an extent determined by the amount of voltage. An extremely large voltage will cause the molecules to untwist completely, such that the polarity of any light passing through will not be rotated and will instead be perpendicular to the filter polarity. This filter will block the passage of light because of the difference in polarity orientation, and the resulting pixel will be black. The amount of light allowed to pass through at each pixel can be controlled by varying the corresponding voltage accordingly. In a color LCD each pixel consists of a red, green, and blue subpixel, which requires appropriate color filters in addition to the components mentioned previously. Each subpixel can be controlled individually to display a large range of possible colors for a particular pixel.

The electrodes on one side of the LCD are arranged in columns, while the electrodes on the other side are arranged in rows, forming a large matrix that controls every pixel. Each pixel is designated a unique row-column combination, and the pixel can be accessed by the control circuits using this combination. These circuits send charge down the appropriate row and column, effectively applying a voltage across the electrodes at a given pixel. Simple LCD's such as those on digital watches can operate on what is called a passive-matrix structure, in which each pixel is addressed one at a time. This results in extremely slow response times and poor voltage control. A voltage applied to one pixel can cause the liquid crystals at surrounding pixels to untwist undesirably, resulting in fuzziness and poor contrast in this area of the image. LCD's with high resolutions, such as large-screen LCD televisions, require an active-matrix structure. This structure is a matrix of thin-film transistors, each corresponding to one pixel on the display. The switching ability of the transistors allows each pixel to be accessed individually and precisely, without affecting nearby pixels. Each transistor also acts as a capacitor while leaking very little current, so it can effectively store the charge while the display is being refreshed.

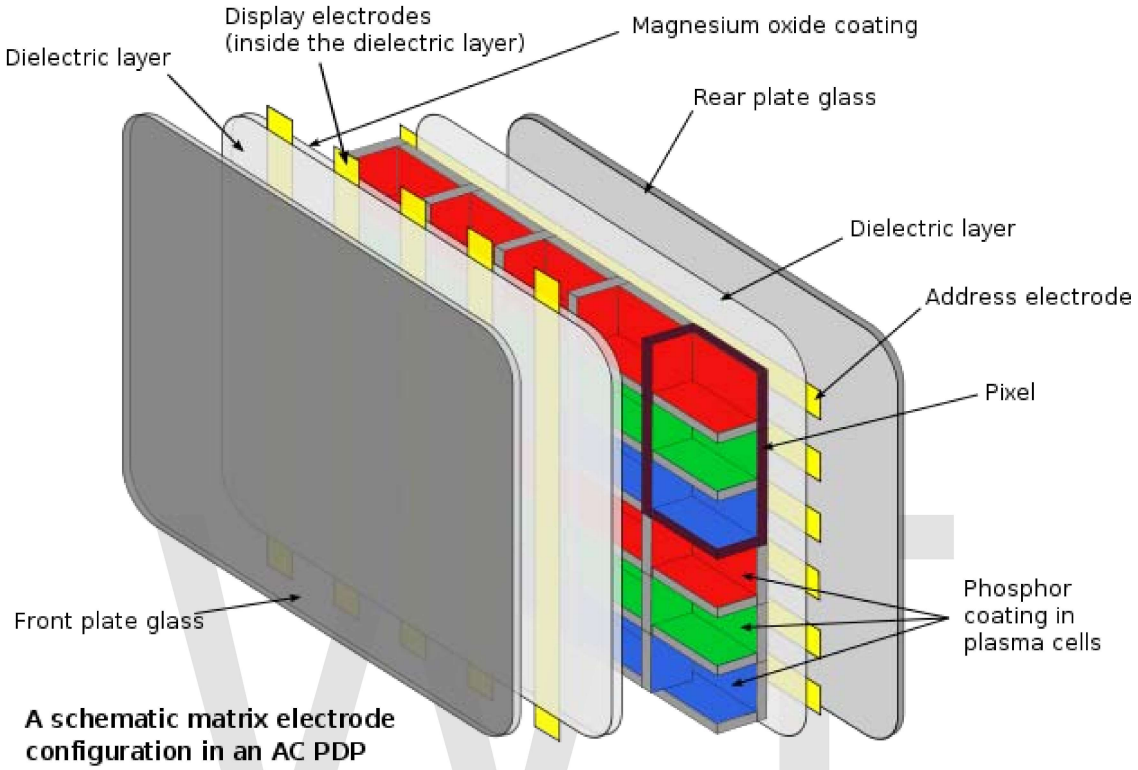
The following are types of LC display technologies:

- Twisted Nematic (TN): This type of display is the most common and makes use of twisted nematic-phase crystals, which have a natural helical structure and can be untwisted by an applied voltage to allow light to pass through. These displays have low production costs and fast response times but also limited viewing angles, and many have a limited color gamut that cannot take full advantage of advanced graphics cards. These limitations are due to variation in the angles of

the liquid crystal molecules at different depths, restricting the angles at which light can leave the pixel.

- In-Plane Switching (IPS): Unlike the electrode arrangement in traditional TN displays, the two electrodes corresponding to a pixel are both on the same glass plate and are parallel to each other. The liquid crystal molecules do not form a helical structure and instead are also parallel to each other. In its natural or "off" state, the molecule structure is arranged parallel to the glass plates and electrodes. Because the twisted molecule structure is not used in an IPS display, the angle at which light leaves a pixel is not as restricted, and therefore viewing angles and color reproduction are much improved compared to those of TN displays. However, IPS displays have slower response times. IPS displays also initially suffered from poor contrast ratios but has been significantly improved with the development of Advanced Super IPS (AS - IPS).
- Multi-Domain Vertical Alignment (MVA): In this type of display the liquid crystals are naturally arranged perpendicular to the glass plates but can be rotated to control light passing through. There are also pyramid-like protrusions in the glass substrates to control the rotation of the liquid crystals such that the light is channeled at an angle with the glass plate. This technology results in wide viewing angles while boasting good contrast ratios and faster response times than those of TN and IPS displays. The major drawback is a reduction in brightness.
- Patterned Vertical Alignment (PVA): This type of display is a variation of MVA and performs very similarly, but with much higher contrast ratios

Plasma display



Composition of plasma display panel

A plasma display is made up of many thousands of gas-filled cells that are sandwiched in between two glass plates, two sets of electrodes, dielectric material, and protective layers. The address electrodes are arranged vertically between the rear glass plate and a protective layer. This structure sits behind the cells in the rear of the display, with the protective layer in direct contact with the cells. On the front side of the display there are horizontal display electrodes that sit in between a magnesium-oxide (MgO) protective layer and an insulating dielectric layer. The MgO layer is in direct contact with the cells and the dielectric layer is in direct contact with the front glass plate. The horizontal and vertical electrodes form a grid from which each individual cell can be accessed. Each individual cell is walled off from surrounding cells so that activity in one cell does not affect another. The cell structure is similar to a honeycomb structure except with rectangular cells.

To illuminate a particular cell, the electrodes that intersect at the cell are charged by control circuitry and electric current flows through the cell, stimulating the gas (typically xenon and neon) atoms inside the cell. These ionized gas atoms, or plasmas, then release ultraviolet photons that interact with a phosphor material on the inside wall of the cell. The phosphor atoms are stimulated and electrons jump to higher energy levels. When

these electrons return to is natural state energy is released in the form of visible light. Every pixel on the display is made up of three subpixel cells. One subpixel cell is coated with red phosphor, another is coated with green phosphor, and the third cell is coated with blue phosphor. Light emitted from the subpixel cells is blended together to create an overall color for the pixel. The control circuitry can manipulate the intensity of light emitted from each cell, and therefore can produce a large spectrum of colors. Light from each cell can be controlled and changed rapidly to produce a high-quality moving picture.

Projection television

A projection television uses a projector to create a small image from a video signal and magnify this image onto a viewable screen. The projector uses a bright beam of light and a lens system to project the image to a much larger size. A front-projection television uses a projector that is separate from the screen which could be a suitably-prepared wall, and the projector is placed in front of the screen. The setup of a rear-projection television is in some ways similar to that of a traditional television, the projector is contained inside the television box and projects the image from behind the screen.

Rear-projection television

56 inch DLP rear projection tv

The following are different types of rear-projection televisions, which differ based on the type of projector and how the image (before projection) is created:

- CRT rear-projection television: Small cathode ray tubes create the image in the same manner that a traditional CRT television does, which is by firing a beam of electrons onto a phosphor-coated screen and then the image is projected to a large screen. This is done to overcome the limit of size of cathode ray tube which is about 40 inches which is the maximum size a normal CRT television set (see image). The cathode ray tubes can be arranged in various ways. One arrangement is to use one tube and three phosphor (red, green, blue) coatings. Alternatively, one black-and-white tube can be used with a spinning color wheel. A third option is to use three CRT's, one for red, green, and blue.
- LCD rear-projection television: A lamp transmits light through a small LCD chip made up of individual pixels to create an image. The LCD projector uses mirrors to take the light and create three separate red, green, and blue beams, which are then passed through three separate LCD panels. The liquid crystals are manipulated using electric current to control the amount of light passing through. The lens system takes the three color beams and projects the image.
- DLP rear-projection television: A DLP projector creates an image using a digital micromirror device (DMD chip), which on its surface contains a large matrix of microscopic mirrors, each corresponding to one pixel in an image. Each mirror can be rotated to reflect light such that the pixel appears bright, or the mirror can be rotated to direct light elsewhere and make the pixel appear dark. The mirror is made of aluminum and is rotated on an axle hinge. There are electrodes on both sides of the hinge controlling the rotation of the mirror using electrostatic attraction. The electrodes are connected to an SRAM cell located under each pixel, and charges from the SRAM cell drive the movement of the mirrors. Color is added to the image-creation process either through a spinning color wheel (used with a single-chip projector) or a three-chip (red, green, blue) projector. The color wheel is placed between the lamp light source and the DMD chip such that the light passing through is colored and then reflected off a mirror to determine the level of darkness. A color wheel consists of a red, green, and blue sector, as well as a fourth sector to either control brightness or include a fourth color. This spinning color wheel in the single-chip arrangement can be replaced by red, green, and blue light-emitting diodes (LED). The three-chip projector uses a prism to split up the light into three beams (red, green, blue), each directed towards its own DMD chip. The outputs of the three DMD chips are recombined and then projected.

Laser Phosphor Display

In this newest television technology, first unveiled in June 2010 at InfoComm, the image is provided by the use of lasers, which are located on the back of the television, reflected off a rapidly moving bank of mirrors to excite pixels on the television screen in a similar way to cathode ray tubes. The mirrors reflect the lasers across the screen and so produce the necessary number of image lines. The small layers of phosphors inside of the glass

emit red, green or blue light when excited by a soft UV laser. This technology produces brilliant, high quality images on very large resolutions.

The laser can be varied in intensity or completely turned on or off without a problem, which means that a dark display would need less power to project its images. Unlike most other imaging technologies, the LPD images have no motion blur or flicker.

According to Prysm, the brightness and color range of the LPD exceeds LCD and LED technologies. It also has a viewing angle of almost 180˚. Its frequency lies near the 240 Hz and it has a 1.6 mm dot pitch. Both of these aspects exceed the current technologies such as LED.

The technology is also very easy to assemble as all components, including the phosphors, mirrors and lasers are widely available. This makes development time short.

LPD is said to be eco-friendly throughout its manufacture. As well as greatly reduced power consumption, does not contain toxic components, has no consumables and generates little heat.

Comparison of television display technologies

LCD

Advantages

- Slim profile
- Lighter and less bulky than rear-projection televisions
- Is less susceptible to burn-in: Burn-in refers to the television displaying a permanent ghost-like image due to constant, prolonged display of the image. Light-emitting phosphors lose their luminosity over time and, when frequently used, the low-luminosity areas become permanently visible.
- LCDs reflect very little light, allowing them to maintain contrast levels in well-lit rooms and not be affected by glare.
- Slightly lower power usage than equivalent sized Plasma displays.
- Can be wall-mounted.

Disadvantages

- Poor black level: Some light passes through even when liquid crystals completely untwist, so the best black color that can be achieved is varying shades of dark gray, resulting in worse contrast ratios and detail in the image
- Narrower viewing angles than competing technologies. It is nearly impossible to use an LCD without some image warping occurring.
- LCDs rely heavily on thin-film transistors, which are easily damaged, resulting in a defective pixel. The number of defective pixels at which the LCD is determined to be unusable varies. LCDs currently have a rejection rate of about 50% but this

is improving. A larger screen size requires more transistors, which increases the chances of yielding a defective LCD. Technology advancements are slowly easing this problem.
- Typically have slower response times than Plasmas, which can cause ghosting and blurring during the display of fast-moving images. This is also improving by increasing the refresh rate of LCD displays

Plasma display

Advantages

- Slim profile
- Can be wall mounted
- Lighter and less bulky than rear-projection televisions
- Achieves better and accurate color reproduction than LCDs (68 billion (2^{36}) versus 16.7 million (2^{24}))
- Produces deep, true blacks allowing for superior contrast ratios (up to 1:1,000,000)
- Far wider viewing angles than those of LCD (up to 178°), images do not suffer from degradation at high angles unlike LCD's
- Absence of motion blur, because of very high refresh rates and faster response times (up to 0.001 milliseconds) make plasmas ideal for fast motion video (films or sports viewing)

Disadvantages

- Susceptible to Screen burn-in and image retention (however, newer models have built-in technologies to prevent this such as pixel shifting)
- Phosphors lose luminosity over time, resulting in gradual decline of absolute image brightness (newer models are less susceptible to this, having lifespans exceeding 60,000 hours, far longer than older CRT technology)
- Generally do not come in sizes smaller than 32 inches
- Susceptible to reflection glare in bright rooms
- High power consumption
- Heavier than LCDs due to the requirement of a glass screen to hold the gases
- Damage to the glass screen can be permanent and far more difficult to repair than an LCD

Projection television

Front-projection television

Advantages

- Significantly cheaper than flat-panel counterparts
- Front-projection picture quality approaches that of movie theater

- Front-projection televisions take up very little space because a projector screen is extremely slim, and even a suitably-prepared wall can be used
- Display size can be extremely large, typically limited by room height.

Disadvantages

- Front-projection more difficult to set up because projector is separate and must be placed in front of the screen, typically on the ceiling
- Lamp may need to be replaced after heavy usage
- Image brightness is an issue, may require darkened room.

Rear-projection television

Advantages

- Significantly cheaper than flat-panel counterparts
- Projectors that are not phosphor-based (LCD/DLP) are not susceptible to burn-in
- Rear-projection is not subject to glare

Disadvantages

- Rear-projection televisions are much bulkier than flat-panel televisions
- Lamp may need to be replaced after heavy usage
- Rear-projection has smaller viewing angles than those of flat-panel displays

Comparison of different types of rear-projection televisions

CRT projector

Advantages

- Achieves excellent black level and contrast ratio
- Achieves excellent color reproduction
- CRTs have generally very long lifetimes
- Greater viewing angles than those of LCDs

Disadvantages

- Heavy and large, especially depth-wise
- If one CRT fails the other two should be replaced as well to maintain color and brightness balance
- Susceptible to burn-in because CRT is phosphor-based
- Needs to be 'converged' about every year
- Has focus problems

LCD projector

Advantages

- Smaller than CRT projectors
- LCD chip can be easily repaired or replaced
- Is not susceptible to burn-in

Disadvantages

- The Screen-door effect: Individual pixels may be visible on the large screen, giving the appearance that the viewer is looking through a screen door.
- Possibility of defective pixels
- Poor black level: Some light passes through even when liquid crystals completely untwist, so the best black color that can be achieved is a very dark gray, resulting in worse contrast ratios and detail in the image. Some newer models use an adjustable iris to help offset this.
- Not as slim as DLP projection television
- Uses lamps for light, lamps may need to be replaced
- Fixed number of pixels, other resolutions need to be scaled to fit this
- Limited viewing angles

DLP projector

Advantages

- Slimmest of all types of projection televisions
- Achieves excellent black level and contrast ratio
- DMD chip can be easily repaired or replaced
- Is not susceptible to burn-in
- Better viewing angles than those of CRT projectors
- Image brightness only decreases due to the age of the lamp
- defective pixels are rare
- Does not experience the screen-door effect

Disadvantages

- Uses lamps for light, lamps need to be replaced on average once every year and a half to two years. Current models with LED lamps reduce or eliminate this. Estimated lifetime of LED lamps is over 100,000 hours.
- Fixed number of pixels, other resolutions need to be scaled to fit this. This is a limitation only when compared with CRT displays.
- The Rainbow Effect: This is an unwanted visual artifact that is described as flashes of colored light seen when the viewer looks across the display from one side to the other. This artifact is unique to single-chip DLP projectors. The Rainbow Effect is significant only in DLP displays that use a single white lamp

with a "color wheel" that is synchronized with the display of red, green and blue components. LED illumination systems that use discrete red, green and blue LEDs in concert with the display of red, green and blue components at high frequency reduce, or altogether eliminate, the Rainbow effect.

Chapter 11

Color Television

Title card for NBC, promoting their broadcast "in RCA color".

Color television is the technology and practices associated with television's transmission of moving images in color.

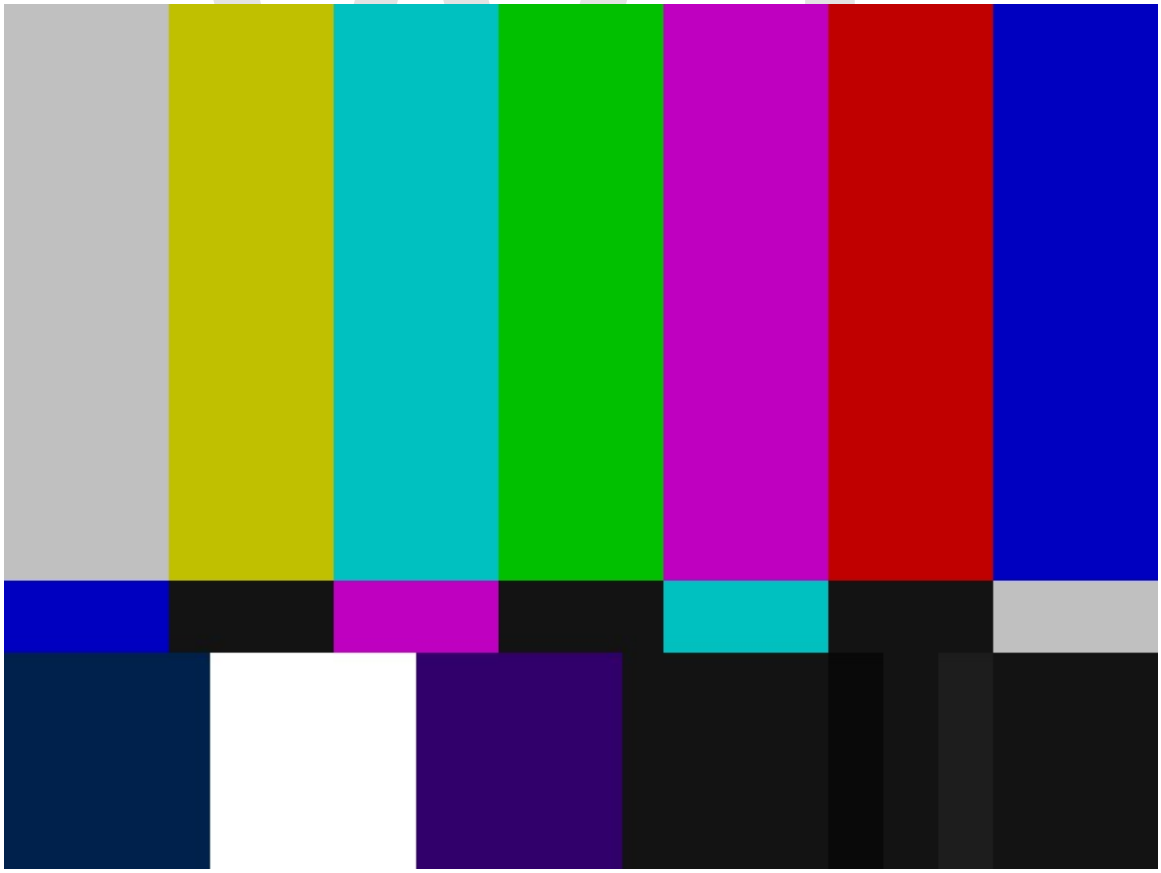
In its most basic form, a color broadcast can be created by broadcasting three monochrome images, one each in the three colors of red, green and blue (RGB). When displayed together or in fast succession, these images will blend together to produce a single color as seen by the viewer.

One of the great technical challenges of introducing color broadcasting was the desire to reduce the high bandwidth, three times that of the existing black-and-white (B&W) standards, into something more acceptable that would not use up most of the available radio spectrum. After considerable research, the NTSC introduced a system that encoded the color information separately from the brightness, and greatly reduced the resolution of the color information in order to conserve bandwidth. The brightness image remained

compatible with existing B&W television sets, at slightly reduced resolution, while color televisions could decode the extra information in the signal and produce a limited-color display. The higher resolution B&W and lower resolution color images combine in the eye to produce a seemingly high resolution color image. The NTSC standard represents a major technical achievement.

Although introduced in the U.S. in the 1950s, only a few years after black and white televisions had been standardized there, high prices and lack of broadcast material greatly slowed its acceptance in the marketplace. It was not until the late 1960s that color sets started selling in large numbers, due in some part to the introduction of GE's Porta-Color set in 1966.

By the 1970s color sets had become standard, with all-color broadcasts becoming common. Color broadcasting in Europe was not standardized on the PAL format until the 1960s, and broadcasts did not start until 1967. By this point many of the technical problems in the early sets had been worked out, and the spread of color sets in Europe was fairly rapid. Most major markets in North America and Europe were all color by the mid-1970s, and by the 1980s B&W sets had been pushed into niche markets, notably low-power uses, small portable sets, or use as monitor screens in lower-cost consumer equipment and in the television industry.



Color bars used in a test pattern, sometimes used when no program material is available.

Development

The human eye's detection system in the retina consists primarily of two types of light detectors, rod cells that capture light, dark, and shapes/figures, and the cone cells that detect color. A typical retina contains 120 million rods and 4.5 million to 6 million cones, which are divided among three groups that are sensitive to red, green and blue light. This means that the eye has far more resolution in contrast, or "luminance", than in color. However, post-processing in the optic nerve and other portions of the human visual system combine the information from the rods and cones to re-create what appears to be a high-resolution color image.

The eye has limited bandwidth to the rest of the visual system, estimated at just under 8 Mbit/s. This manifests itself in a number of ways, but the most important in terms of producing moving images is the way that a series of still images displayed in quick succession will appear to be continuous smooth motion. This illusion starts to work at about 16 fps, and common motion pictures use 24 fps. Television, using power from the electrical grid, tunes its rate in order to avoid interference with the alternating current being supplied – in North America, some Central and South American countires, Taiwan, Korea, part of Japan, the Philippines and a few other countries this is 60 fields per second to match the 60 Hz power, while in most other countries it is 50 fields per second to match the 50 Hz power.

Early television

Experiments in television systems using radio broadcasts date to the 19th century, but it was not until the 20th century that advances in electronics and light detectors made development practical. A key problem was the need to convert a 2D image into a "1D" radio signal; some form of image scanning was needed to make this work. Early systems generally used a device known as a "Nipkow disk", which was a spinning disk with a series of holes punched in it that caused a spot to scan across and down the image. A single photodetector behind the disk captured the image brightness at any given spot, which was converted into a radio signal and broadcast. A similar disk was used at the receiver side, with a light source behind the disk instead of a detector.

A number of such systems were used experimentally starting as early as the 1920s, the best-known being John Logie Baird's system that was broadcast for a time in Britain. In spite of these early successes, all mechanical television systems shared a number of serious problems. Being mechanically driven, even slight differences in syncing between the signal and disk motor resulted in major image distortion. Another problem was that the image was captured in a roughly rectangular area of the disk, covering only a small portion of its face; making a larger display required increasingly unwieldy disks. Additionally, the resolution of the system was limited by the number of holes that could be punched into the disk, which was normally under 100, although there are rare examples with as many as 200 holes in them.

It was clear to a number of developers that a completely electronic scanning system would be superior, and that the scanning could be achieved in a vacuum tube via electrostatic or magnetic means. Converting this concept into a usable system took years of development and several independent advances. The two key advances were Philo Farnsworth's electronic scanning system, and Vladimir Zworykin's Iconoscope camera. The Iconoscope, based on Kálmán Tihanyi's early patents, superseded the Farnsworth-system. With these systems, the BBC began regularly scheduled black and white television broadcasts in 1936, but these were shut down again with the start of World War II in 1939. In 1941 the first NTSC meetings produced a single standard for US broadcasts. US television broadcasts began in earnest in the immediate post-war era, and by 1950 there were 6 million televisions in the United States.

All-mechanical color

The basic idea of using three monochrome images to produce a color image had been experimented with almost as soon as black and white televisions had first been built.

Among the earliest published proposals for television was one by Maurice Le Blanc in 1880 for a color system, including the first mentions in television literature of line and frame scanning, although he gave no practical details. Polish inventor Jan Szczepanik patented a color television system in 1897, using a selenium photoelectric cell at the transmitter and an electromagnet controlling an oscillating mirror and a moving prism at the receiver. But his system contained no means of analyzing the spectrum of colors at the transmitting end, and could not have worked as he described it. Hovannes Adamian worked on color television as early as 1907.

John Logie Baird demonstrated **the world's first color transmission** on July 3, 1928, using scanning discs at the transmitting and receiving ends with three spirals of apertures, each spiral with filters of a different primary color; and three light sources at the receiving end, with a commutator to alternate their illumination. Baird also made the **world's first color broadcast** on February 4, 1938, sending a mechanically scanned 120-line image from Baird's Crystal Palace studios to a projection screen at London's Dominion Theatre.

Mechanically scanned color television was demonstrated by Bell Laboratories in June 1929 using three complete systems of photoelectric cells, amplifiers, glow-tubes, and color filters, with a series of mirrors to superimpose the red, green, and blue images into one full color image.

Hybrid systems

As was the case with black and white television, an electronic means of scanning would be superior to the mechanical systems like Baird's. The obvious solution on the broadcast end would be to use three conventional Iconoscopes with colored filters in front of them to produce an RGB signal. Using three separate tubes each looking at the same scene would produce slight differences in parallax between the frames, so in practice a single

lens was used with a mirror or prism system to separate the colors for the separate tubes. Each tube captured a complete frame and the signal was converted into radio in a fashion essentially identical to the existing black and white systems.

The problem with this approach was there was no simple way to re-combine them on the receiver end. If each image was sent at the same time on different frequencies, the images would have to be "stacked" somehow on the display, in real time. The simplest way to do this would be to reverse the system used in the camera; arrange three separate black and white displays behind colored filters and then optically combine their images using mirrors or prisms onto a suitable screen, like frosted glass. RCA built just such a system in order to present the first electronically scanned color television demonstration on February 5, 1940, privately shown to members of the US Fedferal Communications Commission at the RCA plant in Camden, New Jersey. This system, however, suffered from the twin problems of costing at least three times as much as a conventional black and white set, as well as having very dim images, the result of the fairly low illumination given off by tubes of the era. Projection system of this sort would become common decades later, however, with improvements in technology.

Another solution would be to use a single screen, but break it up into a pattern of closely spaced colored phosphors instead of an even coating of white. Three receivers would be used, each sending its output to a separate electron gun, aimed at its colored phosphor. Although obvious, this solution was not practical. The electron guns used in B&W televisions had limited resolution, and if one wanted to retain the resolution of existing B&W displays, the guns would have to focus on individual dots three times smaller. This was beyond the state of the art at the time.

Instead, a number of hybrid solutions were developed that combined a conventional black and white display with a colored disk or mirror. In these systems the three colored images were sent one after each other, in either complete frames in the "field-sequential color system", or for each line in the "line-sequential" system. In both cases a colored filter was rotated in front of the display in sync with the broadcast. Since three separate images were being sent in sequence, if they used existing B&W radio signaling standards they would have an effective refresh rate of only 20 fields, or 10 frames, a second, well into the region where flicker would become visible. In order to avoid this, these systems increased the frame rate considerably, making the signal incompatible with existing black and white standards.

The first practical example of this sort of system was again pioneered by John Logie Baird. In 1940 he publicly demonstrated a color television combining a traditional black-and-white display with a rotating colored disk. This device was very "deep", but was later improved with a mirror folding the light path into an entirely practical device resembling a large conventional console. However, Baird was not happy with the design, and as early as 1944 had commented to a British government committee that a fully electronic device would be better.

In 1939, Hungarian engineer Peter Carl Goldmark introduced an electro-mechanical system while at CBS, which contained an Iconoscope sensor. The CBS field-sequential color system was partly mechanical, with a disc made of red, blue, and green filters spinning inside the television camera at 1,200 rpm, and a similar disc spinning in synchronization in front of the cathode ray tube inside the receiver set. The system was first demonstrated to the Federal Communications Commission (FCC) on August 29, 1940, and shown to the press on September 4.

CBS began experimental color field tests using film as early as August 28, 1940, and live cameras by November 12. NBC (owned by RCA) made its first field test of color television on February 20, 1941. CBS began daily color field tests on June 1, 1941. These color systems were not compatible with existing black and white television sets, and as no color television sets were available to the public at this time, viewership of the color field tests was limited to RCA and CBS engineers and the invited press. The War Production Board halted the manufacture of television and radio equipment for civilian use from April 22, 1942 to August 20, 1945, limiting any opportunity to introduce color television to the general public.

Fully electronic

As early as 1940, Baird had started work on a fully-electronic system he called the "Telechrome". Early Telechrome devices used two electron guns aimed at either side of a phosphor plate. The phosphor was patterned so the electrons from the guns only fell on one side of the patterning or the other. Using cyan and magenta phosphors, a reasonable limited-color image could be obtained. He also demonstrated the same system using monochrome signals to produce a 3D image (called "stereoscopic" at the time). A demonstration on 16 August 1944 was the first example of a practical color television system. Work on the Telechrome continued and plans were made to introduce a three-gun version for full color. However, Baird's untimely death in 1946 ended development of the Telechrome system.

Similar concepts were common through the 1940s and 50s, differing primarily in the way they re-combined the colors generated by the three guns. The Geer tube was similar to Baird's concept, but used small pyramids with the phosphors deposited on their outside faces, instead of Baird's 3D patterning on a flat surface. The Penetron used three layers of phosphor on top of each other and increased the power of the beam to reach the upper layers when drawing those colors. The Chromatron used a set of focusing wires to select the colored phosphors arranged in vertical stripes on the tube.

FCC color

In the immediate post-war era the Federal Communications Commission (FCC) was inundated with requests to set up new television stations. Worrying about congestion of the limited number of channels available, the FCC put a moratorium on all new licenses until 1948 while considering the problem. A solution was immediately forthcoming; rapid development of radio receiver electronics during the war had opened a wide band of

higher frequencies to practical use, and the FCC set aside a large section of these new UHF bands for television broadcast. At the time B&W broadcasting was still in its infancy in the U.S., and the FCC started to look at ways of using this newly available bandwidth for color broadcasts. Since no existing television would be able to tune in these stations, they were free to pick an incompatible system and allow the older VHF channels to die off over time.

The FCC called for technical demonstrations of color systems in 1948, and the "Joint Technical Advisory Committee" (JTAC) was formed to study them. CBS displayed improved versions of its original design, now using a single 6-MHz channel (like the existing B&W signals) at 144 fields per second and 405 lines of resolution. Color Television Inc. demonstrated its line-sequential system, while Philco demonstrated a dot-sequential system based on its "Apple" tube technology. Of the entrants, the CBS system was by far the best-developed, and won head-to-head testing every time.

While the meetings were taking place it was widely known within the industry that RCA was working on a dot-sequential system that was compatible with existing B&W broadcasts, but RCA declined to demonstrate it during the first series of meetings. Just before the JTAC presented its findings, on August 25, 1949, RCA broke its silence and introduced its system as well. The JTAC still recommended the CBS system, and after the resolution of an ensuing RCA lawsuit, color broadcasts using the CBS system started on June 25, 1951. By this point the market had changed dramatically; when color was first being considered in 1948 there were fewer than a million television sets in the U.S., but by 1951 there were well over 10 million. The idea that the VHF band could be allowed to "die" was no longer practical.

During its campaign for FCC approval, CBS gave the first demonstrations of color television to the general public, showing an hour of color programs daily Mondays through Saturdays, beginning January 12, 1950, and running for the remainder of the month, over WOIC in Washington, D.C., where the programs could be viewed on eight 16-inch color receivers in a public building. Due to high public demand, the broadcasts were resumed February 13–21, with several evening programs added. CBS initiated a limited schedule of color broadcasts from its New York station WCBS-TV Mondays to Saturdays beginning November 14, 1950, making ten color receivers available for the viewing public. All were broadcast using the single color camera that CBS owned. The New York broadcasts were extended by coaxial cable to Philadelphia's WCAU-TV beginning December 13, and to Chicago on January 10, making them the first network color broadcasts.

After a series of hearings beginning in September 1949, the FCC found the RCA and CTI systems fraught with technical problems, inaccurate color reproduction, and expensive equipment, and so formally approved the CBS system as the U.S. color broadcasting standard on October 11, 1950. An unsuccessful lawsuit by RCA delayed the first commercial network broadcast in color until June 25, 1951, when a musical variety special titled simply *Premiere* was shown over a network of five East Coast CBS affiliates. Viewership was again extremely limited: the program could not be seen on

black and white sets, and *Variety* estimated that only thirty prototype color receivers were available in the New York area. Regular color broadcasts began that same week with the daytime series *The World Is Yours* and *Modern Homemakers*.

While the CBS color broadcasting schedule gradually expanded to twelve hours per week (but never into prime time), and the color network expanded to eleven affiliates as far west as Chicago, its commercial success was doomed by the lack of color receivers necessary to watch the programs, the refusal of television manufacturers to create adapter mechanisms for their existing black and white sets, and the unwillingness of advertisers to sponsor broadcasts seen by almost no one. CBS had bought a television manufacturer in April, and in September 1951, production began on the only CBS-Columbia color television model, with the first color sets reaching retail stores on September 28. But it was too little, too late. Only 200 sets had been shipped, and only 100 sold, when CBS discontinued its color television system on October 20, 1951, ostensibly by request of the National Production Authority for the duration of the Korean War, and bought back all the CBS color sets it could to prevent lawsuits by disappointed customers. RCA chairman David Sarnoff later charged that the NPA's order had come "out of a situation artificially created by one company to solve its own perplexing problems" because CBS had been unsuccessful in its color venture.

Compatible color

While the FCC was holding its JTAC meetings, development was taking place on a number of systems allowing true simultaneous color broadcasts, "dot-sequential color systems". Unlike the hybrid systems, dot-sequential televisions used a signal very similar to existing B&W broadcasts, with the intensity of every dot on the screen being sent in succession.

In 1938 Georges Valensi demonstrated an encoding scheme that would allow color broadcasts to be encoded so they could be picked up on existing B&W sets as well. In his system the output of the three camera tubes were re-combined to produce a single "luminance" value that was very similar to a B&W signal and could be broadcast on the existing VHF frequencies. The color information was encoded in a separate "chrominance" signal, consisting of two separate signals, the original blue signal minus the luminance (B'–Y'), and red-luma (R'–Y'). These signals could then be broadcast separately on a different frequency; a B&W set would tune in only the luminance signal on the VHF band, while color televisions would tune in both the luminance and chrominance on two different frequencies, and apply the reverse transforms to retrieve the original RGB signal. The downside to this approach is that it required a major boost in bandwidth use, something the FCC was interested in avoiding.

RCA used Valensi's concept as the basis of all of its developments, believing it to be the only proper solution to the broadcast problem. However, RCA's early sets using mirrors and other projection systems all suffered from image and color quality problems, and were easily bested by CBS's hybrid system. But solutions to these problems were in the pipeline, and RCA in particular was investing massive sums (later estimated at $100

million) to develop a usable dot-sequential tube. RCA was beaten to the punch by the Geer tube, which used three B&W tubes aimed at different faces of colored pyramids to produce a color image. All-electronic systems included the Chromatron, Penetron and "Apple" tube that were being developed by various companies. While investigating all of these, RCA's teams quickly started focusing on the shadow mask system.

In July 1938 the shadow mask color television was patented by Werner Flechsig (1900–1970) in Germany, and was demonstrated at the International radio exhibition Berlin in 1939. Most CRT color televisions used today are based on this technology. His solution to the problem of focusing the electron guns on the tiny colored dots was one of brute-force; a metal sheet with holes punched in it allowed the beams to reach the screen only when they were properly aligned over the dots. Three separate guns were aimed at the holes from slightly different angles. and when their beams passed through the holes the angles caused them to separate again and hit the individual spots a short distance away on the back of the screen. The downside to this approach was that the mask cut off the vast majority of the beam energy, allowing it to hit the screen only 15% of the time, requiring a massive increase in beam power to produce acceptable image brightness.

In spite of these problems in both the broadcast and display systems, RCA pressed ahead with development and was ready for a second assault on the standards by 1950.

Second NTSC

The possibility of a compatible color broadcast system was so compelling that the NTSC decided to re-form, and held a second series of meetings starting in January 1950. Having only recently selected the CBS system, the FCC heavily opposed the NTSC's efforts. One of the FCC Commissioners, R. F. Jones, went so far as to assert that the engineers testifying in favor of a compatible system were "in a conspiracy against the public interest".

Unlike the FCC approach where a standard was simply selected from the existing candidates, the NTSC would produce a board that was considerably more pro-active in development.

Starting before CBS color even got on the air, the U.S. television industry, represented by the National Television System Committee, worked in 1950–1953 to develop a color system that was compatible with existing black and white sets and would pass FCC quality standards, with RCA developing the hardware elements. RCA first made publicly announced field tests of the dot sequential color system over its New York station WNBT in July 1951. When CBS testified before Congress in March 1953 that it had no further plans for its own color system, the National Production Authority dropped its ban on the manufacture of color television receivers, and the path was open for the NTSC to submit its petition for FCC approval in July 1953, which was granted on December 17. The first publicly announced network demonstration of a program using the NTSC "compatible color" system was an episode of NBC's *Kukla, Fran and Ollie* on August 30, 1953, although it was viewable in color only at the network's headquarters. The first network

broadcast to go out over the air in NTSC color was a performance of the opera *Carmen* on October 31, 1953.

Adoption

North America

United States

NBC made the first coast-to-coast color broadcast when it telecast the Tournament of Roses Parade on January 1, 1954, with public demonstrations given across the United States on prototype color receivers by manufacturers RCA, General Electric, Philco, Raytheon, Hallicrafters, Hoffman, Pacific Mercury and others. A color model from Westinghouse ($1,295, or $10.6 thousand in today's dollars) became available in the New York area on February 28, 1954 and is generally agreed to be the first production receiver using NTSC color offered to the public; a less expensive color model from RCA reached dealers in April 1954. Television's first prime time network color series was *The Marriage*, a situation comedy broadcast live by NBC in the summer of 1954. NBC's anthology series *Ford Theatre* became the first network color filmed series that October.

Early color telecasts could be preserved only on the black and white kinescope process introduced in 1947. It wasn't until September 1956 that NBC began using color film to time-delay and preserve some of its live color telecasts. Ampex introduced a color videotape recorder in 1958, which NBC used to tape *An Evening With Fred Astaire,* the oldest surviving network color videotape.

Several syndicated shows had episodes filmed in color during the 1950s, including *The Cisco Kid*, *The Lone Ranger*, *My Friend Flicka*, and *Adventures of Superman*. The first two were carried by some stations equipped for color telecasts well before NBC began its regular weekly color dramas in 1959, beginning with the Western series *Bonanza*.

NBC was at the forefront of color programming because its parent company RCA manufactured the most successful line of color sets in the 1950s, and by 1959 RCA was the only remaining major manufacturer of color sets. CBS and ABC, which were not affiliated with set manufacturers, and were not eager to promote their competitor's product, dragged their feet into color. CBS ceased all regular color programming between 1960 and 1965 (including at least one of their shows, *The Lucy Show*, which was filmed in color, beginning in 1963, but continued to be telecast in black and white through the end of the 1964-65 season), while ABC delayed its first color series until 1962. The DuMont network, although it did have a television-manufacturing parent company, was in financial decline by 1954 and was dissolved two years later. Thus the relatively small amount of network color programming, combined with the high cost of color television sets, meant that as late as 1964 only 3.1 percent of television households in the U.S. had a color set. NBC provided the catalyst for rapid color expansion by announcing that its prime time schedule for fall 1965 would be almost entirely in color. ABC and CBS joined the bandwagon and over half of their prime-time programming also was in color that

season. All three broadcast networks were airing full color prime time schedules by the 1966–67 broadcast season, and ABC aired its last new black and white daytime programming in December 1967. But the number of color television sets sold in the U.S. did not exceed black and white sales until 1972, which was also the first year that more than fifty percent of television households in the U.S. had a color set. This was also the year that "in color" notices before color television programs ended, due to the rise in color television set sales, and color programming having become the norm.

Color broadcasting in Hawaii started in September 1965, and in Alaska a year later.

Cuba

Cuba in 1958 became the second country in the world to introduce color television broadcasting, with Havana's Channel 12 using the NTSC standard and RCA equipment. But the color transmissions ended when broadcasting stations were seized in the Cuban Revolution in 1959, and did not return until 1975, using equipment acquired from Japan's NEC Corporation, and SECAM equipment from the Soviet Union, adapted for the NTSC standard.

Mexico

In Mexico, Guillermo González Camarena invented an early color television transmission system. He received patents for color television systems in 1942 (U.S. Patent 2,296,019), 1960 and 1962. The 1942 patent (filed in Mexico on August 19, 1940) was for a synchronized color filter wheel adapter for monochrome television, similar to the field sequential color receiver demonstrated by Baird in England in July 1939 and by CBS in the United States in August 1940.

On August 31, 1946 González Camarena sent his first color transmission from his lab in the offices of The Mexican League of Radio Experiments at Lucerna St. #1, in Mexico City. The video signal was transmitted at a frequency of 115 MHz. and the audio in the 40 metre band. He obtained authorization to make the first publicly announced color broadcast in Mexico, on February 8, 1963, of the program *Paraíso Infantil* on Mexico City's XHGC-TV, using the NTSC system which had by now been adopted as the standard for color programming.

A field-sequential color television system similar to his Tricolor system was used in NASA's Voyager mission in 1979, to take pictures and video of Jupiter.

Europe

European color television was developed somewhat later and was hindered by a continuing division (and nationalistic bias) on technical standards. Having decided to adopt a higher-definition 625-line system for monochrome transmissions, with a lower frame rate but with a higher overall bandwidth, Europeans could not directly adopt the U.S. color standard. This was widely perceived as inadequate anyway because of its hue

error problems, which became particularly acute with the introduction of videotape recorders in the late 1950s. There was also less urgency, since there were fewer commercial motivations, European television broadcasters being predominantly state-owned at the time.

As a consequence, although work on various color encoding systems started already in the 1950s, with the first SECAM patent being registered in 1956, many years had passed when the first broadcasts actually started in 1967. Unsatisfied with the performance of NTSC and of initial SECAM implementations, the Germans unveiled PAL (phase alternating line) in 1963, technically similar to NTSC but borrowing some ideas from SECAM. The French continued with SECAM, notably involving Russians in the development.

The first full-specification PAL receivers ("PAL-D") relied on a precision ultrasonic glass delay line, which in the early days was estimated would make up about a third of the cost of the receiver. PAL stood for Phase Alternated Line. It was basically a 625-line version of NTSC, with phase inversion of alternate numbered scan lines. Therefore, for example, a HUE or TINT (phase) error on line 22 would be offset be an opposite HUE or TINT error on line 23. The two phase errors would cancel each other in the optical presentation interpreted by the human eye. The TINT control required by NTSC was therefore obviated. Other color encoding systems had already been proposed which would overcome the tint problems of NTSC using such a delay line, but PAL was unique in that an economy receiver (known as "PAL-S" for "simple PAL") could also be built *without* using a delay line, with a performance no worse than, and in most cases better than an equivalent NTSC model.

SECAM did not require such precision for its delay line, and could use much cheaper magnetostrictive metal types. Ironically, by the time PAL broadcasts commenced in 1967, advances in glassmaking techniques had dropped the cost of precision PAL delay lines so much that hardly any simple-PAL receivers were built commercially, and virtually all SECAM receivers used the same type of delay line as PAL receivers. By the end of the 20th century, glass delay lines had been completely replaced by all-electronic equivalents.

The first regular color broadcasts in Europe were by the United Kingdom's BBC2 beginning on July 1, 1967 (PAL). West Germany's first broadcast occurred in August (PAL), followed by France in October (SECAM). Norway, Sweden, Finland, Belgium, the Netherlands, Austria, East Germany, Czechoslovakia and Hungary all started regular color broadcasts before the end of 1969.

The PAL system spread through most of Western Europe and on into the territories of the old British, Portuguese, Belgian, Dutch, Austro-Hungarian, Ottoman and Chinese Empires.

In Italy there were debates to adopt a national color television system, the *ISA*, developed by Indesit, but that idea was scrapped. As a result, Italy was one of the last European

countries to officially adopt the PAL system in 1977, after long technical experimentation.

France, Luxembourg and most of the Eastern Bloc along with their overseas territories opted for SECAM. SECAM was a popular choice in countries with a lot of hilly terrain, and technologically backward countries with a very large installed base of monochrome equipment, since the greater ruggedness of the SECAM signal could cope much better with poorly maintained equipment. However for many countries the decision was more down to politics than technical merit.

A drawback of SECAM for production is that, unlike PAL or NTSC, certain post-production operations of encoded SECAM signals are not really possible without a significant drop in quality. As an example, a simple fade to black is trivial in NTSC and PAL: you just reduce the signal level until it is zero. However, in SECAM the color difference signals, which are frequency modulated, need first to be decoded to e.g. RGB, then the fade-to-black is applied, and finally the resulting signal is re-encoded into SECAM. Because of this, much SECAM video editing was actually done using PAL equipment, then the resultant signal was converted to SECAM. Another drawback of SECAM is that comb filtering, allowing better color separation, is not possible in TV receivers. This wasn't, however, much of a drawback in the early days of SECAM as such filters didn't become readily available in high-end TV sets before the 1990's.

The first regular color broadcasts in SECAM were started on October 1, 1967, on France's Second Channel (ORTF 2e chaîne). In France and the UK color broadcasts were made on UHF frequencies, the VHF band being used for legacy black and white, 405 lines in UK or 819 lines in France, till the beginning of the eighties. Countries elsewhere that were already broadcasting 625-line monochrome on VHF and UHF, simply transmitted color programmes on the same channels.

Some British television programmes, particularly those made by or for ITC Entertainment, were shot on color film before the introduction of color television to the UK, for the purpose of sales to US networks. The first British show to be made in color was the drama series *The Adventures of Sir Lancelot* (1956–57), which was initially made in black and white but later shot in color for sale to the NBC network in the United States. Other British color television programmes include *Stingray* (1964–1965), which was the first British TV show to filmed entirely in color, *Thunderbirds* (1965–1966) and *Captain Scarlet and the Mysterons* (1967–1968). However, other UK series, such as *Doctor Who* (1963–89; 2005–present) didn't begin color production until later, with the first color *Doctor Who* episodes not airing until 1970.

Asia and the Pacific

In Japan, NHK introduced color television, using a variation of the NTSC system (called NTSC-J), on September 10, 1960, making the first country in Asia to introduce color television. The Philippines (1966) and Taiwan (1969) also adopted the NTSC system. Other countries in the region instead used the PAL system, starting with Australia (1967,

but not fully implemented until 1975), and then Hong Kong (1970), China (1971), New Zealand (1973), Singapore (1974), Thailand (1975) and Indonesia (1978), with India not introducing it until 1982. South Korea did not introduce color (using NTSC) until 1980, although it was already manufacturing color television sets for export.

Middle East

Nearly all of the countries in the Middle East use PAL. The first country in the Middle East to introduce color television was Iraq in 1967. Saudi Arabia, the United Arab Emirates, Kuwait, Bahrain, and Qatar followed in the mid-1970s, but Israel, Lebanon and Cyprus continued to broadcast in black and white until the early 1980s.

Africa

The first color television service in Africa was introduced on the Tanzanian island of Zanzibar, in 1973, using PAL. At the time, South Africa did not have a television service at all, owing to opposition from the apartheid regime, but in 1976, one was finally launched. Nigeria adopted PAL for color transmissions in 1974 in the then Benue Plateau state in the north central region of the country, but countries such as Ghana and Zimbabwe continued with black and white until 1984.

South America

In contrast to most other countries in the Americas, which had adopted NTSC, Brazil began broadcasting in color in PAL-M. Its first transmission was on February 19, 1972. However Ecuador was the first South American country to receive color TV, using NTSC. It transmission was on November 5, 1973. Some countries in South America, including Argentina, Chile, Colombia, Uruguay, Peru and Venezuela, continued to broadcast in black and white until the late 1970s.

Color standards

There are three main analog television standards in use around the world, PAL (Phase Alternating Line), NTSC (National Television System Committee) and SECAM (Séquentiel Couleur à Mémoire—Sequential Color with Memory).

The system used in North America is NTSC. Western Europe, Australia, and Eastern South America use PAL. Eastern Europe used SECAM, but switched to PAL after the change of the political regimes there. France still uses SECAM. Generally, a device (such as a television) can only read or display video encoded to a standard which the device is designed to support; otherwise, the source must be converted (such as when European programs are broadcast in North America or vice versa). Because a tint control is unnecessary in PAL, NTSC has jokingly been said to stand for *Never Twice the Same Color.*

This table illustrates the differences:

	NTSC M	PAL B,G,H	PAL I	PAL N	PAL M	SECAM B,G,H	SECAM D,K,K',L
Lines/Fields	525/60	625/50	625/50	625/50	525/60	625/50	625/50
Horizontal Frequency	15.734 kHz	15.625 kHz	15.625 kHz	15.625 kHz	15.750 kHz	15.625 kHz	15.625 kHz
Vertical Frequency	60 Hz	50 Hz	50 Hz	50 Hz	60 Hz	50 Hz	50 Hz
Color Subcarrier Frequency	3.579545 MHz	4.43361875 MHz	4.43361875 MHz	3.582056 MHz	3.575611 MHz		
Video Bandwidth	4.2 MHz	5.0 MHz	5.5 MHz	4.2 MHz	4.2 MHz	5.0 MHz	6.0 MHz
Sound Carrier	4.5 MHz	5.5 MHz	5.9996 MHz	4.5 MHz	4.5 MHz	5.5 MHz	6.5 MHz

Digital television broadcasting standards, such as ATSC, DVB-T, and DVB-T2, have superseded these analog transmission standards in many countries.