HIGH-DEFINITION TV IN THE U.S.

Bruce Montag, Technology Strategist

Dell launched its first liquid crystal display (LCD) TVs in Fall 2003. Designed as multifunction devices, they can serve equally well as high-end PC displays or as stand-alone TVs. These LCD TVs are particularly well suited for viewing high-definition television (HDTV) programming because of their wide aspect ratio.

HDTV programming is increasing in the U.S. due to the Telecommunications Act of 1996, which requires that all "terrestrial" (that is, broadcast "over the air") TV stations convert from conventional analog to digital broadcast. The current deadline set by the FCC is the end of 2006. Of the 1,500 or so terrestrial TV stations in the U.S., approximately 1,000 have a digital channel on the air. Most are transmitting some HDTV programming on these channels. The National Association of Broadcasters (NAB) website maintains a list of these digital TV (DTV) stations at **www.nab.org/newsroom/issues/digitaltv**. In addition to over-the-air broadcasts, satellite and cable TV companies offer HDTV programming in their higher-tier subscription packages.

During the transition to digital television, there are a number of things to consider when buying an HDTV set. In this white paper, we focus on HDTV in the U.S. We define HDTV and compare it to traditional analog TV. We describe at a high level how HDTV works and identify the equipment you need to watch HDTV programming. We also compare the different digital TV technologies and conclude with features that improve the HDTV viewing experience.

What is HDTV?

HDTV is the highest-quality digital TV format. The Advanced Television Systems Committee (ATSC) defined this new TV format to be a significant improvement over the legacy National Television Standards Committee (NTSC) conventional format that has been in existence for over 50 years. Key improvements are in the areas of TV transmission method, resolution, aspect ratio, color, and audio.

Improved Transmission Method

ATSC programming is broadcast digitally and uses a better modulation scheme than conventional analog NTSC broadcasts. "Modulation" refers to how the audio and video is encoded onto a radio frequency (RF) carrier signal. ATSC transmits a digital signal containing MPEG-2 compressed video and multichannel AC-3 audio streams. In contrast, NTSC transmits raw analog video and audio signals. This difference applies whether the transmission medium is terrestrial broadcast or delivered via cable or satellite TV. The improved ATSC modulation method, combined with digital signaling, means that HDTV signals are less susceptible than NTSC signals to transmission interference that causes noise effects such as "ghosting" or "snow." The result is much better picture quality with HDTV.

Higher Resolution

HDTV provides a more detailed picture than NTSC by increasing the number of pixels in the format. Pixels are individual addressable picture elements, arranged in rows and columns, that together form the TV's picture. Each pixel is made up of individual color elements called subpixels. These subpixels contain the red, green, and blue color information that produces a pixel's overall color at any point in time. The NTSC format is 640 horizontal lines of pixels by 480 vertical lines of pixels and a 4:3 aspect ratio. ATSC improves on this resolution by providing a range of formats up to 1080 lines of resolution, and by widening the aspect ratio to 16:9. The ATSC formats enable a wider TV screen than NTSC, and provide for a more theater-like experience at home due to the 6x increase in the number of pixels displayed.

Wider Aspect Ratio

The arrangement of rows and columns determines a TV's aspect ratio, which is the ratio between the number of pixels per row and the number of pixels per column. NTSC TVs have a 4:3 aspect ratio. An HDTV's 16:9 aspect ratio enables a wider field of view than NTSC TVs. Scene elements that are "off screen" when captured by an NTSC camera (such as the first baseman during a double play in a baseball game) are now viewable with HDTV.

Better Color

Color performance refers to the ability of a TV to accurately display all possible colors in the incoming video signal. ATSC formats can transmit and display more vivid and distinguishable colors. (See discussion of color later in this paper.)

Dolby Digital 5.1 Surround Sound

NTSC transmissions include basic analog stereo audio in conjunction with the video signal. ATSC improves on this by providing multichannel digital audio transmission based on Dolby Digital 5.1 surround sound. This enables an HDTV to function as a home theater, driving two front speakers, two rear speakers, a center channel, and a subwoofer. Each speaker has its own unique signal coded in the AC-3 format, which is the same approach as that used on DVD movie discs.

ATSC Formats

When creating the HDTV specification, the ATSC defined a range of formats that encompass standard-definition TV (SDTV) and high-definition formats. SDTV refers to a digital television format with quality that is equivalent to conventional analog NTSC.

The ATSC format-naming convention is based on the number of lines of resolution, followed by a letter that indicates whether the scan type is "interlaced" or "progressive." (See sidebar, "Interlaced vs. Progressive Signaling.") ATSC formats that are interlaced are indicated by an "i" after the format name. ATSC formats that are progressive scan are indicated by a "p" after the format name.

Standard-definition ATSC formats (or SDTV) are based on 480 lines of resolution, like NTSC, but provide for both interlaced and progressive scan transmission. High-definition formats range from 720 to 1080 lines of resolution. The four most common ATSC formats are summarized in Table 1.

ATSC Format	Resolution	Progressive/ Interlaced	Analog/ Digital	Aspect Ratio
480i (SDTV)*	640 x 480	Interlaced	Digital	4:3
480p (EDTV)	704 x 480	Progressive	Digital	16:9
720p (HDTV)	1280 x 720	Progressive	Digital	16:9
1080i (HDTV)	1920 x 1080	Interlaced	Digital	16:9

*The terms, "480i," "SDTV," and "NTSC" are often used interchangeably.

Table 1. ATSC TV Formats

HDTVs are required to be able to display all of these formats. However, the picture quality of each format on a particular TV is based on its deinterlacing and scaling capabilities, as well as its native resolution. (See sidebar, "What is 'native resolution'?" for a discussion of native resolution and scaling.)

Broadcasters vary in which formats they have chosen to adopt for their digital programming. For instance, ABC has chosen 720p for their HD broadcasts, Fox is currently transmitting 480p but migrating to 720p, and NBC and CBS have selected 1080i.

Interlaced vs. Progressive Signaling

NTSC and ATSC signals are limited to 6 MHz of broadcasting bandwidth. Since its inception in the 1950s, NTSC signaling has used "interlacing" to conserve bandwidth. The NTSC signal is composed of approximately 480 active horizontal scan lines, which make up one frame or screenful of video. Using interlacing, each frame is displayed on the screen in two passes. During the first pass, the odd-numbered lines are drawn in a 1/60th of a second scan sequence. During the second pass, the even-numbered lines are drawn in another 1/60th of a second scan sequence. A complete picture is drawn 30 times per second. In this way, only half of the scan lines are transmitted at a time. Traditional cathode ray tube (CRT) TVs are interlaced displays. Interlacing can introduce defects in the picture, especially when there is rapid movement in the scene.

In contrast, progressive scan transmits the entire frame of pixels in one scan sequence, similar to how PCs render to their displays. The resulting picture can be superior to that produced via interlaced scan. HDTVs that are based on fixed-pixel digital display technologies such as LCD and plasma use progressive, rather than interlaced scanning. Many DVD players now commonly support progressive video output over a component video connection to produce a better picture.

What is "native resolution"?

An HDTV based on a digital display technology such as LCD, plasma, or microdisplay for projection, is a "fixed-pixel" display. This means that, unlike a CRT, it is hard-wired to display an optimal "native resolution" and must "scale" the incoming video to display full screen at any other resolution. For example, a multifunction monitor/LCD TV may have a native resolution of 1280 x 768 (WXGA). This means that the TV can display 768 horizontal scan lines that are 1280 pixels long. This resolution allows the TV to be compatible with PC video timings, but requires that a scaling engine be included in the display to scale incoming TV content in 480i (NTSC), 480p, 720p, or 1080i formats to fit the native display resolution.

How Does HDTV Work?

Figure 1 shows the logical components of HDTV program reception and their functions. The three main components are HDTV programming, a receiver,[1] and the HDTV display.

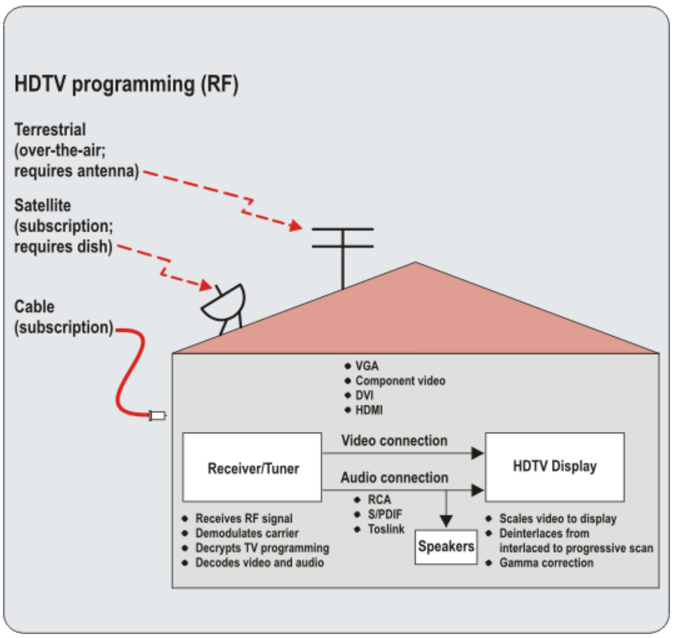


Figure 1. Components of HDTV

HDTV Programming

HDTV programming is either broadcast over the air or transmitted by a cable or satellite TV provider. RF signalling is used and the content is compressed using MPEG2 and AC-3 compression. Content from cable or satellite TV companies is also encrypted.

> **Is "Digital Cable" the Same as HDTV?**
>
> In addition to conventional analog programming and HDTV, cable companies offer "digital cable." Digital cable is sometimes confused with HDTV. For digital cable programming, digital technology is used to compress analog video signals, so that more programming can be transmitted in the bandwidth typically required for one analog program. In contrast, HDTV programming is higher-resolution and can only be displayed on a digital TV capable of displaying HDTV. HDTV via cable companies is referred to as "high-definition cable."

Receiver

At its destination, an ATSC-compliant receiver demodulates the signal to "tune in" the particular channel to be viewed. In the case of a subscription service, the receiver then decrypts the program stream using a decryption key that is stored in the set-top box or on a smart card that is inserted into the set-top box. The receiver then decodes the MPEG-2 video and AC-3 audio streams for output. ATSC-compliant receivers can decode all ATSC TV formats.

The ATSC-compliant receiver may be integrated into a HDTV set, which enables the set to receive over-the-air digital broadcasts. All that is required to view HDTV with this type of TV is an antenna. In some cases, an indoor antenna may be sufficient; in many, an outdoor antenna is required. Most HDTV broadcasts are in the UHF band, and can be received by a standard UHF TV antenna. The type of antenna required depends on local conditions such as the strength of HDTV signals and the local topography. The website **www.antennaweb.org** provides guidance on the most-suitable antenna for receiving HDTV programming over the air in your local area. The antenna connects to the TV through a threaded coaxial connector, known as an "F" connector on the back of the set.

TVs that do not include an ATSC receiver, but can display ATSC formats delivered over a video connection are called "HDTV Ready." These TVs require an external receiver component to view HDTV programming. This receiver may be installed in a PC, provided in the form of a set-top box by a cable or satellite company, or included with the TV as a separate component.

Audio/Video Connections

The audio and video connections between an HDTV and other consumer electronics devices, including receivers, are an important consideration for HDTV usage. HDTVs require video connections that can support the high resolutions of ATSC formats. High-definition video connections available today include the component video, video graphics array (VGA), Digital Visual Interface (DVI), and High Definition Multimedia Interface (HDMI).

- **Component Video** — A component video connection can be either analog or digital, and consists of three separate cables, one each for red, green, and blue color components. The analog version is referred to as "YPbPr," and the digital version, "YCbCr." Component video delivers higher-quality

1. In addition to HDTV receiver, this device may be referred to as an HDTV tuner, decoder, converter, or digital set-top box.

video than a composite video or S-video connection. Most DVD players, set-top boxes, and HDTVs have at least one set of component video connections.

- **VGA** — VGA is the traditional PC analog display interface and is commonly available on multifunction displays that can be used either as a PC monitor or as a TV. A VGA connection supports both ATSC high-definition formats (720p and 1080i), but the graphics driver on the PC must support the ATSC timings in addition to standard PC display timings.
- **DVI** — DVI is a digital interface for sending pixel data to flat-panel displays, but it has been adopted in some TVs and set-top boxes because of copy protection requirements. Unlike VGA, DVI includes an optional means of protecting the transmitted video content using the High-Bandwidth Digital Copy Protection (HDCP) protocol.
- **HDMI** — HDMI is an emerging connection that is based on the same fundamental technology as DVI. However, HDMI has a smaller connector than DVI and includes multichannel audio capability. Unlike DVI and the other video connections, HDMI does not require a separate audio connection to the TV.

The stereo audio connections used with component video, DVI, and VGA display connections are RCA-style analog audio jacks with a white plug for the left channel and a red plug for the right channel. HDTV receivers can include digital audio outputs for connecting to a separate audio amplifier for surround sound. Digital audio connections include the Sony-Philips Digital Interface (S/PDIF) and the Toslink optical connector. These connections can carry compressed multichannel surround sound in several formats including Dolby 5.1 and Digital Theater Systems (DTS).

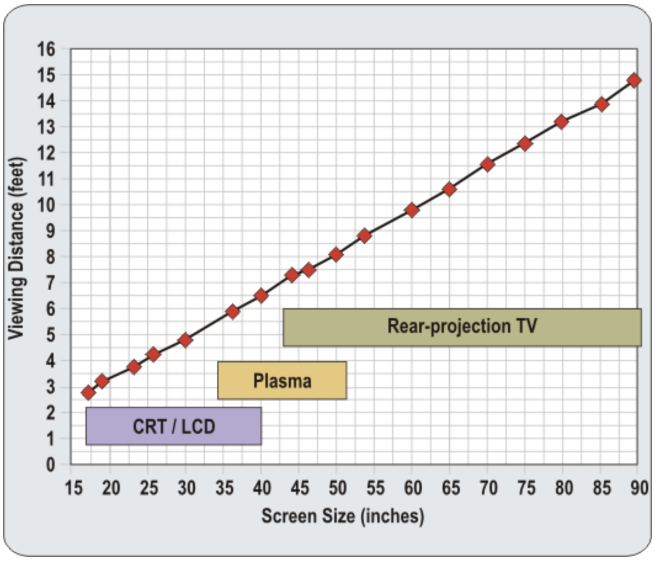
Display

If required, the display electronics deinterlaces and scales the incoming ATSC video format to fit the native resolution of the display. Alternatively, this conversion may be performed by the set-top box. For example, 1080i programming must be deinterlaced and scaled to display on a fixed-pixel 1280 x 768 HDTV display. The quality of the deinterlacing and scaling engines is an important determinant of picture quality, and this feature set is commonly called out by TV manufacturers to differentiate their products. Advanced deinterlacing techniques include "3:2 pull down" for converting feature film content for TV display.

HDTV Set Technology

There are four basic types of HDTV technologies: "direct-view" (as opposed to "rear-projection") CRT, LCD, plasma, and rear-projection displays. Each has strengths and weaknesses, as well as typical screen sizes. When choosing between HDTV sets, first decide which screen size is appropriate for your room. Not only must it fit in your room, but the screen size determines how far the HDTV set should be placed from the viewer. If your room is too small to accommodate the optimal "viewing distance" for a 90-inch screen, the viewing experience will be compromised.

Figure 2 estimates the optimal viewing distance for various HDTV screen sizes.



Note: Because of their higher resolutions, the optimal viewing distances of HDTV displays are closer than those of NTSC displays.

Figure 2. HDTV Optimal Viewing Distances

Another consideration when selecting screen size is the difference in screen height between a traditional TV and an HDTV with the same published screen size. Screen size is measured diagonally from corner to corner. Because HDTVs have a wider aspect ratio, a 19-inch HDTV will have a smaller screen height than a 19-inch TV with traditional 4:3 aspect ratio. The equivalent HDTV screen size (in picture height) is approximately 23 inches.

Once you've chosen screen size, look at the overall size, particularly depth, and weight of the HDTV set to be sure that it will fit in the planned location. These decisions will narrow your options to a few technologies that you can compare on performance and cost.

Direct-View CRT HDTVs

This HDTV uses the same CRT technology used in traditional CRT computer monitors, but with additional circuitry. CRT technology creates pixels by scanning a beam of electrons horizontally and vertically across a layer of phosphors on the inside of the picture tube. When “excited” by the passing electron beam, the phosphor pattern will “glow” temporarily through an aperture grille or mask to produce individual pixels. The intensity of each pixel's color is regulated by the number of electrons that strike the phosphor. A CRT HDTV has a wide viewing angle and provides (arguably) the best color, but is not as bright as other types of displays. It also has the best video-response performance. However, its bulky size and heavy weight are big drawbacks. The largest CRT TVs made today are around 40 inches. They weigh approximately 300 pounds and are more than 2 feet deep. As screen size increases, so does the weight and bulk of the TV. Just as CRTs are giving way to flat-panel monitors for PC's, CRT-based HDTVs are being displaced by thinner and more-compact HDTVs.

Plasma HDTVs

Plasma displays carry forward some of the performance advantages of CRTs, but have a slimmer form factor. With plasma technology, each subpixel consists of a cell containing a mixture of gases. When current is applied across the cell, the gas is ionized into plasma, and the plasma begins emitting photons. Like a CRT, the photons excite a phosphor layer on the inside surface of the display screen, producing a visible pixel at the cell location. However, unlike a CRT, the pixel intensity cannot be directly regulated. Rather, the cell is switched on and off rapidly to create color intensity that can be detected by the viewer.

Plasma HDTVs are more expensive than the other technologies, but they have better video response and better color performance than LCDs. Plasma has several drawbacks, though, that are being addressed by TV manufacturers. The first is a shorter life than that of LCD or CRT HDTV. The color performance of plasma technology may degrade over time. In addition, like CRTs that also use phosphors, a static image displayed on the screen for a long time can leave a faint image “burned in” on the screen. This damage can be permanent. Plasma TVs also have high energy consumption and generate more heat than the other technologies. Finally, their resolution is more limited than LCD technology due to the minimum size in which plasma cells can be manufactured. For this reason, plasma HDTV screen sizes tend to be limited to a range of 37 to 55 inches.

LCD HDTVs

LCD technology allows thin and light form factors and high-definition resolutions at more affordable prices than plasma. LCD HDTVs also have a longer life and do not suffer from “burn in.” LCD technology creates pixels by casting light, generated by one or more fluorescent bulbs or “back lights,” through a grid of cells that are sandwiched between polarized glass sheets. Each cell is filled with liquid crystal material. When a current is applied to the cell, the crystal material changes shape, which affects the amount of light that is passed through the cell. In this way, the relative brightness of each pixel is adjusted. The light that passes through each subpixel cell is directed through a color filter, producing a viewable pixel on the TV. The advantages of LCDs include high brightness, contrast, and resolution for sizes ranging from 17 to 40 inches. A drawback of LCD technology is that it has traditionally had slower video response time than other display technologies. This response time is improving with continuing advances in liquid crystal materials and associated control schemes.

Rear-Projection HDTVs

CRT technology has been used in rear projection TVs for a long time, but emerging microdisplay projection technologies—LCD, Digital Light Processing (DLP), and Liquid Crystal on Silicon (LCoS)—are enabling thinner and more streamlined form factors that are approaching 6–7 inches deep. Designed for large-screen viewing environments, typical rear-projection HDTVs have screens that range from approximately 42 to 90 inches.

CRT Rear Projection

These HDTVs commonly feature three CRTs, one for each color, to deliver sufficient brightness. The outputs from each CRT are "converged" by a series of mirrors to yield one picture to the viewer. Projection CRT TVs tend to be larger (in depth) and heavier than the emerging microdisplay projection TVs. In addition, due to the reduced brightness of CRTs, the viewing angle is sometimes constrained, requiring the viewer to be positioned directly in front of the TV.

Microdisplay Rear Projection

DLP, LCoS, and LCD rear-projection TVs create pixels by separating light from a high-intensity lamp into red, green, and blue colors, and projecting each color across or through a tiny microdisplay. Color separation can be achieved by rapidly spinning a color filter wheel or prism in front of the lamp, or by using a fixed-color filter similar to LCDs. The microdisplay adjusts how much light is reflected or passed through at each pixel location. The resulting light pattern is projected against the inside surface of the TV to form the picture. The lamp, color splitter, and projection optics are referred to as a light engine. The light-engine technologies used in DLP, LCoS, and LCD can be key differentiators between TVs with the same microdisplay. Some larger rear-projection TVs may include up to three microdisplay panels.

- **DLP** — DLP technology relies on a grid of micromirrors. There is one mirror for each pixel location and each mirror can be tilted very rapidly. Tilting one way allows light to reflect toward the screen, while tilting another way allows the light to be absorbed. The color shade of each pixel is controlled through a dithering technique that varies the amount of time each pixel reflects light to the screen. DLP TVs are known for their very high contrast.
- **LCoS** — LCoS technology creates pixels by covering a reflective silicon chip with crystal material arranged in a grid pattern. Like direct-view LCDs, the orientation of the crystals is controlled by applying current to control the amount of light that is reflected from the chip's surface at each pixel location. The reflected light is then magnified and focused on the inside surface of the TV to form the picture.
- **LCD** — LCD projection TVs operate similarly to direct-view LCDs, except that a more-powerful lamp is used, and the light transmitted through the LCD panel is magnified and focused to form the projected image.

Beyond the scope of this paper is an additional HDTV technology used in large specially designed home theaters. Front-projection HDTVs use the same basic technology as rear-projection TVs, but consist of a ceiling-mounted HDTV projector and a separate screen. Rather than focusing light from each pixel on the inside surface of a TV, the light is projected outward to the screen, which is typically 90 inches or more.

Why do some HDTVs look better than others?

Picture performance and how it is achieved is one of the most important areas of consideration for HDTV display technologies. Manufacturers often provide performance information describing the brightness, contrast, color, and response times of their TVs.

Brightness

A TV's brightness is the amount of light produced across the display surface, and is expressed in candelas per square meter (cd/m^2). In the U.S. this is also called a "nit." Computer displays are typically in the 150- to 300-nit range, while most TVs are brighter, in the 400- to 500-nit range. A brighter TV is easier to view in a room with a lot of sunlight, and can reproduce colors across a wider range.

The brightness capability of front projectors is described differently. Projector brightness is expressed in "lumens," which is a measure of light produced through an angle, rather than across a surface. Home theater projectors that produce less than 1,000 lumens may require a darkened room for acceptable viewing, while projectors that produce more than 1,500 lumens should be viewable at typical home-lighting levels.

Contrast Ratio

Contrast is the difference in perceived brightness between light and dark areas of a TV's picture. This brightness difference is expressed as a contrast ratio. The higher the contrast ratio, the more discernible fine details and color shading will be in the picture. HDTVs with contrast ratios below 400:1 may make it hard to pick out fine color details, and the darker areas of a scene may appear washed out. Under bright ambient lighting, contrast ratios above 1000:1 produce a better viewing experience with good color separation.

Color

Color reproduction is an important part of TV performance. TV transmission standards such as NTSC and ATSC define “color gamuts,” which express the range of colors that can be recorded and displayed by broadcast equipment. Manufacturers will often specify the color performance of a TV as a percentage of one of these color gamut definitions. For example, a TV that can produce the entire range of colors defined by the NTSC standard is said to have a “100% NTSC color gamut,” while a TV that has a limited range may be specified with a “72% NTSC color gamut.” The range of colors that make up the gamut are defined by chromaticity coordinates for the maximum red, green, and blue values. Figure 3 shows the HDTV color gamut.

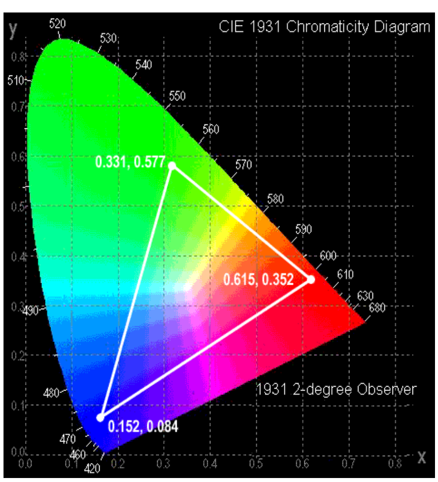


Figure 3. HDTV Color Gamut Plotted on a CIE 1931 Chromaticity Diagram

Another factor in determining color performance is the “color depth” of the TV. Color depth governs the number of discrete colors per pixel that the TV can display. For example, a TV with a color depth of 24 bits per pixel can display 16.7 million discrete colors. The higher the color depth, the greater number of distinct colors that can be displayed.

Response Time

Another factor commonly used to indicate TV picture performance is pixel response time, which is the time required for a pixel to transition from one color to another. A TV that refreshes its picture at 60 Hz requires that each pixel change colors within 1/60th of a second (16.6 milliseconds) or faster. For fast-moving content such as sports, a slow pixel response time may result in motion artifacts caused by color changes that occur too slowly. LCDs in notebook PCs and multifunction displays that serve as PC monitors and HDTVs typically have a pixel response time of 25 ms. Desktop flat-panel monitors are now achieving 16 ms. Most stand-alone HDTVs designed for living rooms are able to respond even quicker, with color-to-color switching times faster than 16 ms.

Figure 4 compares key attributes of the four HDTV technologies discussed in this paper.

		Good	Better	Best
Characteristics	Thin	CRT	RPTV	Plasma, LCD
	Light	RPTV	CRT	Plasma, LCD
	Power Used	Plasma	RPTV, CRT	LCD
Performance	Brightness	Plasma	RPTV, CRT	LCD
	Contrast	Plasma	CRT, RPTV	LCD
	Resolution	Plasma	CRT, RPTV	LCD
	Response Time	LCD	RPTV, CRT	Plasma
	Reliability	Plasma	RPTV, CRT	LCD
	Color	LCD	RPTV	CRT, Plasma

CRT, LCD — Size: 17” - 40”
Plasma — Size: 37” - 55”
RPTV — Size: 42” - 90”

Figure 4. Comparison of HDTV Technologies

HDTV Recording and Copy Protection

HDTV programming cannot effectively be recorded using existing removable media because of the massive amounts of data involved. HDTV is transmitted at 19 Mbps, which requires approximately 6 GB of storage for 1 hour of programming. Currently, there is no removable storage medium other than digital VHS (D-VHS) tape, including DVD-Video, that can accommodate a feature-length HDTV film. HDTV cannot be recorded with a standard analog VCR.

HDTV programming can be internally recorded to a hard drive and there are set-top box solutions that include a hard drive for local HDTV recording. However, due to copy protection provisions for the video connection commonly used on HDTV receivers, HDTV output video cannot be recorded using a video capture device such as a VCR. HDTV connections commonly use HDCP to encrypt the video data, while component video connections commonly include Macrovision to prevent external video capture.

Blu-ray Disc

An emerging removable storage medium called Blu-ray Disc will provide a solution to the removable media storage problem. A Blu-ray Disc is a higher-capacity, rewritable optical disc that will accommodate more than two hours of HDTV or 12 hours of standard video. A Blu-ray Disc will also support content protection, enabling HDTV recording. The Blu-ray Disc specification is currently being finalized, but solutions are not expected until the second half of 2005.

Conclusion

HDTV is a revolutionary improvement over the analog NTSC format that has predominated since the 1950s. The new ATSC high-definition formats provide higher resolution and, thus, more detailed scenes, better color, and surround-sound audio. Digital programming is increasingly available in the U.S. via local over-the-air broadcasts or through cable and satellite subscription services. Digital TV set technology improvements parallel the growth of HDTV programming. Mirroring the trend in computer displays, bulky and heavy CRT-based TVs are being displaced by TVs based on the latest digital display technologies. These HDTV sets offer high resolutions, great picture quality, and lightweight, sleek form factors.

Dell currently offers 17-, 23-, and 30-inch HDTV-Ready multifunction LCD TVs. Each integrates a wide-aspect flat-panel monitor and NTSC receiver into one device that can be used to watch HDTV programming or as a PC monitor. The addition of a separate set-top box from a subscription cable or satellite service provides digital TV programming. For more information on Dell™ TVs, see **www.dell.com**.