Chapter

1

The March to Digital Television

1.1 What Is Digital Television?

DTV, or digital television, is a "ready or not, here it comes" proposition. This is true not only for consumers but also for television professionals. Part of the universal confusion surrounding DTV is that it represents different things to different people. To most consumers DTV means sharper pictures and *extremely* expensive receivers. To most broadcasters it means uncertainty and large capital outlays with very little initial return on investment. Even people in the electronics industry think DTV means only compressed bit streams. However, digital television is not entirely new. It has been serving niche markets in the television universe for more than 20 years. Anyone who subscribes to Direct TV ™ or to one of the other broadcast satellite services has already been receiving DTV. The set-top box that decodes the digital signal from the satellite receiver feeds a television signal that is usable by your current set. Some cable companies now have digital channels on their systems. Again, you need a set-top box to receive these signals. The set-top box will become much more prevalent in the next few years because boxes that receive local DTV signals and convert them to signals your current set can display will become available. Digital television is nothing new to most television engineers.

1.1.1 National Television System Committee (NTSC)

First, a few additional terms and a little history are necessary to an understanding of DTV. NTSC, which is the television format that broadcasters transmit today, was the acronym for the National Television System Committee. The committee was formed by the Federal Communications Commission (FCC) back in the 1940s, and its purpose was to decide on the technical attributes of the television signal. An inside joke among broadcasters, especially our European counterparts (who use a different and, what many claim, a better standard), is that NTSC means "never twice the same color." The NTSC originally specified how black-and-white video, with its accompanying audio or sound, would be transmitted over the airwaves. Later, the committee was reconvened to determine how color information could be added to the signal. NTSC is also called *analog television* by some.

NTSC is considered a *standard-definition* (SD) television signal. Many other signals, including many DTV signals, are also SD television. Confused? You're not alone. Many equate DTV with *high-definition* (HD) television only. This is understandable because DTV grew out of the initial Japanese development of HD. In the early 1970s a number of Japanese organizations started experimenting with analog HD television. We should expand upon analog versus digital television at this point. *Analog television* (digital television will be introduced in Sec. 1.2.3) is a signal that is continuous in nature, with a varying voltage whose value indicates the picture's brightness and whether it is time to start a new scan line or a whole new picture (Fig. 1.1).

Later, when color was added, an additional frequency was embedded into this varying voltage. Its amplitude indicated how saturated the color was, and its phase determined the color (Fig. 1.2).

The problem with this approach is that the television receivers and processing equipment used in television stations can't completely separate the color signal from the black-and-white picture. You see the result when a gray tweed suit on someone develops a rainbow pattern. To eliminate this problem, some *videotape machines* (VTRs) are used in professional television applications that keep the chroma, or color information, separate from the luminance, or black-and-white information. This is what is known as *component television*. But before it can be broadcast to your home, the chroma and luminance must be recombined. This is called *composite television*. NTSC is analog composite television. Early Japanese HD was analog component television, but with a lot more picture information than the television we are used to.

1.1.2 Advisory Committee on Advanced Television Service (ACATS)

In the early 1980s the head of engineering at one of the major U.S. networks claimed that the Japanese had invented HD television to spark a rise in TV set sales, which had flattened out at the time. The Japanese kept plugging away. In 1987, 58 broadcasting organizations petitioned the FCC to initiate proceedings to explore the issues arising from the possible introduction of advanced television technologies. The broadcasters were concerned about the possible impact that HD might have on them. At the time, it was believed that high-definition television (HDTV) could not be broadcast in a standard television channel, which is 6 MHz wide. The FCC created the Advisory Committee on Advanced Television Service, known as ACATS. Its mandate was to determine the form that HDTV should take. Initially, ACATS was only looking at analog high-definition television. At one time there were 23 analog

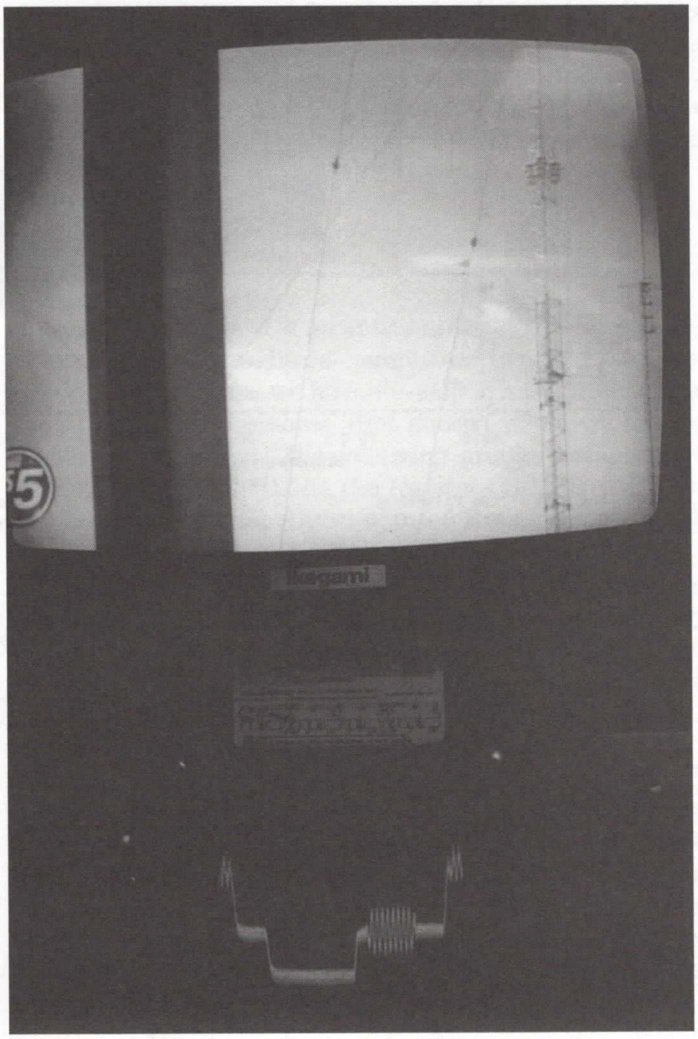
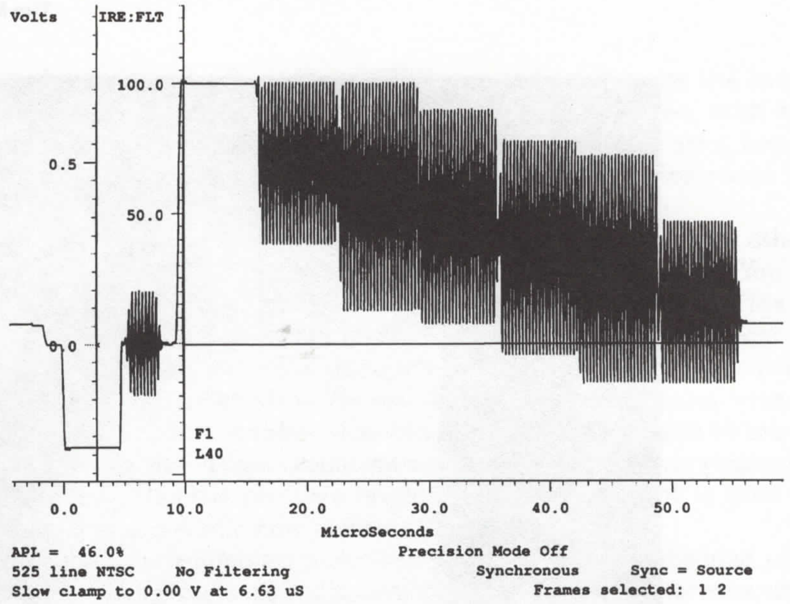


Figure 1.1 An NTSC signal is displayed on a video monitor that can be time-shifted to show the horizontal blanking interval. Below the video monitor is a waveform monitor that is displaying the varying voltages that occur during the horizontal interval.

proposals on the table, and the technology was heavily dominated by the Japanese. In 1990 U.S. and European concerns performed an "end run" around the Japanese and their analog HDTV. Four digital television transmission systems were proposed by consortiums consisting of AT&T (now Lucent), Sarnoff Research Center (formerly RCA's research lab), General Instrument, Massachusetts Institute of Technology (MIT), Philips, Thomson, and Zenith. ACATS decided that the new U.S. television transmission system would be digital. The Japanese were out. However, in 1993 ACATS tested the



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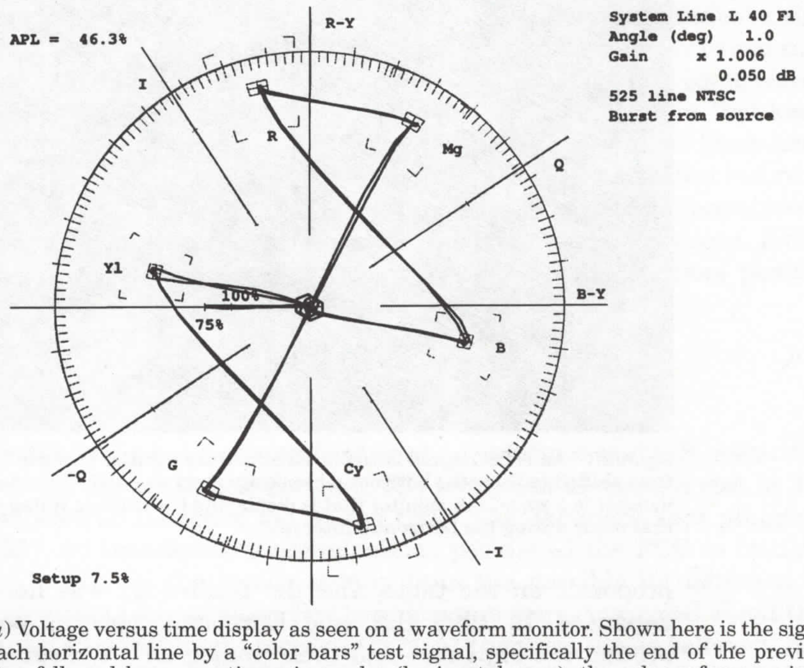

(*b*)

Figure 1.2 (*a*) Voltage versus time display as seen on a waveform monitor. Shown here is the signal generated each horizontal line by a "color bars" test signal, specifically the end of the previous horizontal line followed by a negative-going pulse (horizontal sync), the color reference signal (color burst), and then the video. Notice that the first part of the video is simply a straight line. This is the "white" bar in the test signal. The rest of the signal is additional bars of various color hues and saturation along with descending values of luminance. (*b*) Vectorscope display. This device filters out only color information and represents the color energy (voltage) in a vector display. This device displays color saturation and hue. The phase of the color signal determines the color or hue. The farther away the signal is from the center, the greater the color energy or saturation. The horizontal spike to the left is the color reference signal, which is also known as the color burst. This reference signal occurs at the beginning of every horizontal line.

competing systems and found no clear winner, so it asked the competing parties to work together and compromise to create a system that used the best attributes of each proponent. The competitors came together and became known in the industry as the Grand Alliance. They developed the new television transmission scheme, which the FCC eventually accepted, and which we call DTV.

1.1.3 Joint Committee on Intersociety Coordination (JCIC)

However, no standard is an entity unto itself. There were—and are—a number of international standards committees involved with the creation of the DTV system. Just because we have developed a transmission standard that televises digital data into the home, that doesn't mean we have decided how that data should be organized. The following groups became involved: the Electronics Industry Association (EIA), the Institute of Electrical and Electronics Engineers (IEEE), the National Association of Broadcasters (NAB), the National Cable Television Association (NCTA), and the Society of Motion Picture and Television Engineers (SMPTE). An intergroup coordination committee was formed and was called, what else, the Joint Committee on Intersociety Coordination (JCIC). This body, which would advise the FCC as to their members' interest and concerns, created the Advanced Television System Committee (ATSC). The ATSC split itself into six specialized areas of interest, with the goal of nailing down a complete system. The system for turning video pictures into data streams was taken to another totally separate group, the Motion Pictures Expert Group (MPEG). The system that MPEG developed has been accepted as an international standard by the International Standards Organization (ISO), but more on MPEG later. The system for taking audio and creating a data stream was a system created by Dolby Labs, and it is called AC-3. Wrapping the various data streams into one complete data stream was also taken from MPEG, with slight modifications. ATSC adopted the Grand Alliance transmission system for getting the digital data to the home.

1.2 SDTV versus HDTV

Before advanced television turned into a digital system, it was thought that two television channels would be needed to broadcast HD—one channel for the SD signal and the second channel to carry the extra information needed for high definition. When the digital approach was adopted with the MPEG system included, it became apparent that one HD program could be transmitted in a television channel. Soon engineers inside the television industry began to realize how expensive it was going to be to add a DTV channel while still operating an old NTSC channel. In addition, to make matters worse, HD equipment is much more expensive than SD equipment. There would be few viewers during the first few years, which would mean a dearth of advertising revenue.

Sentiment began to grow to *not* use all the data bits for a single HD picture, but instead to divide the bit stream up and send multiple SD pictures. This is currently not sitting too well with Congress because many of the members thought the country was getting HD as DTV. There are many issues within the television industry now that border on being philosophical, and they quickly become almost religious discussions when broached. HD versus SD is one of those issues. Many claim that HD will not be needed in newscasts and, in fact, many news anchors would not want more facial details sent into their viewers homes. Many professional studio cameras actually have circuitry that softens the details of skin tones. Technical arguments have been made that most studios do not have sets with enough spatial content to warrant HD inside. Most experts agree that HD shines when used for sporting events or just about anywhere outdoors. Another area where it stands out is when viewing a movie or program that was originally made on 35-mm film. Television production people with film backgrounds still claim that 35 mm is the best method of capturing HD pictures. In 1997, 70 percent of prime-time programming for CBS was shot on film. CBS has said that 16-mm film conversion to HD doesn't work. However, television production people with video backgrounds counter that if what is being shot is going to end up on television, then a television camera is the best acquisition tool. This is another of those philosophical arguments.

There are those who argue that no one can prove what program stream in the DTV signal is the most important. Are multiple SD educational programs on an educational station less important than one HD educational program? Is one football game in HD better than letting the viewer watch the same game and choosing between multiple SD angles? Is an SD program with supplemental data less worthy than the same program in HD without any additional data? We have already mentioned the SD versus HD debate, but in Sec. 1.2.5 we will begin to define what constitutes an SD and a HD picture.

1.2.1 Multimedia

Some in the computer industry are now developing multimedia presentations called *tele-presence*. Tele-presence sends multiple video and audio streams that allow the viewer to interact with the story and to actually select alternate viewing locations or, in some cases, to actually select a different story line. Terms like "freedom," "location" or "position," and "gravity" are used to define the viewers' interaction with the presentation. The amount of gravity means how much or how little freedom the viewer has or, in other words, how tied the viewer is to a particular view or position. A panoramic show that allows the viewer to change view direction but not location or position has a single story line with high gravity on position and low gravity on viewpoint. Traditional television is simply a single story line with gravity so high that the viewer can only view from the perspective broadcast to them. Shows which allow full freedom have low gravity for both position and viewpoint. Shows which broadcast multiple camera angles or views have high gravity with multiple story lines. Although this technology was initially used in software applications like games and virtual tours, it is intended for use on DVD discs and over the Internet. With DTV able to send multiple data streams it could find a home with DTV.

1.2.2 Studio quality

As mentioned earlier, the NTSC television you watch now is SD. The FCC has mandated that each DTV channel must contain at least one SD program equal in quality to today's single NTSC channel. Many would flinch at that thought. Most people have never seen what the NTSC signal looks like before it leaves the television station. More recently, newcomers that see NTSC inside the station have asked if the picture they are viewing is HDTV. "Studio" quality NTSC is actually not too bad. In most cases it shouldn't be. In this day of $200 VCRs, $600 camcorders, and $100 receivers, television stations can still spend $40,000 for VTRs, $100,000 for studio cameras, and $10,000 for video monitors. Why so high? Ever hear the saying that "20 percent of something usually requires 80 percent of the resources"? The same holds true for professional television equipment. In order to get significantly better performance than that provided by your home equipment, a significant engineering effort is needed for products that sell very few units. Why bother with such high quality? Besides the fact that many advertisers demand it, every time a video signal passes through a cable or piece of equipment, it is slightly degraded. It is not uncommon for a particular program to experience many trips on and off videotape, plus a couple of satellite and microwave hops, along with additional passage through switching and processing equipment on its way to the television station's transmitter, each time taking a slight hit in quality.

1.2.3 Digital's lineage

Because of continual quality degradation, many television stations have started their migration to digital technology. It can be safely said that, today, no NTSC video reaches your home that hasn't been "digital" at some point in its life. Over 20 years ago the processing equipment in VTRs converted analog video that came off the tape into digital data for processing. The subsystem of the VTR that did this was known as a *time-base corrector* (TBC). The digitally processed video was then converted back to analog at the output. The technology in the TBC was expanded to allow video signals arriving from outside the television station, such as the networks (ABC, CBS, Fox, NBC, UPN, WB, etc.), to be synchronized to all the video in the station. Video that is not locked in phase to each other can't be mixed together or have locally produced graphics laid over it. Next, the technology was expanded to create systems that allow full-screen video to be shrunk back and flown around the screen, or raster. Separate shots of a news anchor or a reporter in the field are done using these techniques. Now, some professional VTRs and cameras can internally process the video and audio as digital data. Most television stations have these digital "islands," which are pockets of digital equipment surrounded by analog equipment. However, few facilities are shipping the video, and even fewer the audio, around the television station as digital data.

The main advantage of making video and audio into digital data streams is that once the analog video and audio become what are essentially number sequences, they will not be degraded at all, unless something in the system is broken. The quality will remain the same. However, the problem has been that, up until now, the digital video had to be converted back to analog to be transmitted. What the DTV revolution is bringing to the broadcaster that is totally new is digital techniques for transmission. These techniques are sorely needed because it is the trip from the broadcaster's antenna to your home, either straight from the antenna to yours or via a detour through a cable system, that causes the most grief. The NTSC pictures that some think are HD when viewed at the television station will surely not be mistaken for HD by the time they get to your TV receiver. Noisy pictures, ghosting (multiple images), and interference from other sources are the most common complaints. Once again, many people who see SD on a DTV receiver think they are looking at HD.

1.2.4 Cliff effect

Like all things digital, it generally either works or doesn't. What this means is that digital signals are usable right up to a point where they stop working altogether. There is no warning or gradual degradation, no increase in visible symptoms; it just quits. Component digital video (some bits describe black-and-white values and some describe chroma values) can be sent down a coax only so far before losses overcome the signal and render it unusable. Generally, SD digital video can travel approximately 1000 ft down high-quality coax before the signal is degraded to a point where it can't be received without errors occurring. Errors occur when the receiving device can no longer decode all digital bits correctly. When errors start, adding only another 20 ft of coax will usually render the signal totally unusable. DTV broadcasting has the same steep rise in error rates. Those testing DTV have witnessed the received DTV signal going from perfectly fine to unusable over a distance as small as 300 ft as you reach the edge of a television station's service area. Of course, if you go behind a hill or a building, just like NTSC, it could get a lot worse in a few feet. Signal strength, the amount of radio frequency (RF) energy available at a receiving antenna, can vary in strength by over a 3000:1 ratio. That means that some people close to the station's antenna might receive a signal 3000 times as strong as someone out near the edge of a television station's reception area. Another dramatic way to describe the cliff's slope is that once you are at the edge, a change in the signal as small as 0.07, or 7 percent, can cause the signal to go from usable to unusable. The good news is that DTV appears to be very robust. We have seen a number of cases where the NTSC signal is not watchable, while the DTV signal is still perfect (Fig. 1.3).