3 Audio and Video Technology

Quick Facts

- Bandwidth of an FM channel: 200 kilohertz
- Bandwidth of a digital television channel: 6 megahertz
- First high-definition TV broadcasts: 1998
- Cost of 51-inch digital HDTV projection TV, 1999: $5,000
- Cost of 51-inch digital HDTV projection TV, 2006: $1,699
- Percent of dads hoping for a consumer electronics gift on Father's Day, 2006: 42

Watching TV and listening to radio are the easiest things in the world to do. Just twist that dial, flip that switch, or punch that button and poof: Vivid sounds and picturesque images are yours (unless, of course, you're watching a test pattern). Surfing the Internet requires a bit more interactive work, but not too much. The ease with which we command TV and radio reception hides the incredibly difficult problems and complex technical processes involved in moving sound and pictures from their source to you. This chapter attempts to demystify the magic of radio and TV technology. We describe how the process works and, more important, why it matters. In many ways understanding the technology behind electronic media helps you understand their history, legal status, social and political power, and future.

BASIC PRINCIPLES OF MEDIA TECHNOLOGY

It's helpful to begin a discussion of technical aspects of radio and TV with some basic principles.

Facsimile Technology

All modes of mass communication are based on the process of **facsimile** technology. That is, sounds from a speaker and pictures on a TV screen are merely representations, or facsimiles, of their original form. We all learn and practice facsimile technology at an early age. Did you ever use a pencil or crayon to trace the outline of your hand on a sheet of blank paper? That's an example of facsimile technology. Having one's face covered by plaster of Paris for a mask or sculpture is facsimile technology; so are having your picture taken and photocopying a friend's lecture notes.

In general, the more faithful the reproduction or facsimile is to the original, the greater is its **fidelity.** High-fidelity audio, or hi-fi, is a close approximation of the original speech or music it represents. And a videocassette recorder marketed as high fidelity boasts better picture quality than a VCR without hi-fi (known as H-Q, to distinguish video high fidelity from its audio counterpart). Indeed, much of the technical development of radio and TV has been a search for better fidelity: finding better and better ways to make facsimiles of the original sounds or images. Today's developments in digital technology are yet another example of our quest for higher-fidelity pictures and sound.

The second point about facsimile technology is that in creating their facsimiles, radio and TV are not limited to plaster of Paris, crayon, oils, or even photographic chemicals and film. Instead, unseen elements such as radio waves, beams of light, and digital bits and bytes are utilized in the process. Although you cannot put your hands on a radio wave as you can a photo in your wallet, it is every bit as much there. The history of radio and TV is directly linked to the discovery and use of these invisible "resources," from Marconi's early radio experiments in the 1890s to the newest forms of audio and video digital transmissions of today.

In the technical discussion that follows, bear in mind that the engineer's goal in radio, TV, and cable is to create the best possible facsimile of our original sound or image, to transport that image without losing too much fidelity (known as signal loss), and to re-create that sound or image as closely as possible to its original form. Today, engineers use both analog and digital systems to transport images and sounds, but more and more we are switching to digital transmission.

Transduction

Another basic concept is **transduction,** the process of changing one form of energy into another. When the telephone operator says "the number is 555-2796" and you write it down on a sheet of notepaper, you have transduced the message. Similarly, when you slip on your earbuds and turn on an iPod while you stroll through the mall, you are transducing—although some around you will surely wonder what you're listening to.

Why does this matter? Well, getting a sound or picture from a TV studio or concert hall to your home usually involves at least three or four transductions. At each phase loss of fidelity is possible and must be controlled. With our current system of broadcasting, it is possible that with each phase the whole process may break down into **noise**—unwanted interference—rendering the communication impossible. Although breakdowns due to transduction rarely occur, they do happen. Technicians were embarrassed when the sound went out during the 1976 presidential debate between Gerald Ford and Jimmy Carter. Closer to home, a VCR with dirty heads can make a Tchaikovsky ballet look like a snowy outtake from *The Ring.*

Today, the United States is in the midst of a digital revolution. In fact the DVD player has become the fastest-selling consumer electronics device of the decade. And television stations are converting over to a digital television (DTV) system that includes high-definition transmission and surround sound. New radio systems, including satellite radio and digital HD radio stations, are providing greatly improved fidelity with reduced noise. Today it's common to see digital televisions and radios side by side with standard broadcast receivers on store shelves, but more and more digital technology is replacing analog equipment.

Television and radio signals begin as physical energy, commonly referred to as light waves or sound waves. When you hear a bird chirping in a tree, your brain directly perceives the event by processing the sound waves that enter your ears and vibrate your eardrums. You see the bird as your brain processes the reflections of light that have entered the eye and fallen on the retina. This is direct experience: no transduction, no signal loss; true high fidelity. To experience the bird's chirping on radio, however, the following translations or transductions occur.

As we stand there with a microphone attached to a digital recorder, the bird's song is first changed into mechanical energy. Inside a dynamic microphone, the various sound wave pressures cause a small coil to vibrate back and forth in a magnetic field. This sets up in the coil a weak electrical current that reproduces the pattern of the original sound waves. Next, this current is fed into a digital converter and held in the recorder's memory for a fraction of a second while the signal is sampled, or, in other words, converted into a series of digital bits and bytes. Thus the bird's song is translated into patterns of zeros and ones as the sound has been converted into a series of digital samples. How well the transduction occurs is based on the quality of our facsimile. In other words, the higher the sample rate, the higher the quality of the recording. Next, we'll write that sampled information into a file (like a .WAV or .MP3 file) and then store it for playback later. Our digital recorder might store the sound file on a small flash drive or a miniature hard drive.

Now we have a facsimile of the chirping, stored as a series of digital bits in an electronic file. Next, we need to transduce that sound file into electrical energy. When we hit the play button on our recorder, it transfers the stored *bi*nary digi*ts* (bits) back into the recorder's memory. From there the data are sent to a digital-to-analog converter that reads the data files and converts them back into electrical energy pulses. The amplifier detects the pulses, boosts them, and sends them to the output jack. And as stereo buffs know, the quality of our facsimile is now based on the quality and bandwidth of our amplifier. We are now halfway to hearing the chirp through the radio.

Next, we transduce the electrical energy into electromagnetic energy. At the radio station we feed the amplified sound from the recorder to the transmitter. Here the signal is superimposed, or "piggybacked," onto the radio wave (channel) assigned to that station through a process called modulation (examined in detail later). The fidelity of the signal is based on the station's power, its location, its channel, its bandwidth, and all sorts of other factors.

At home we turn on the radio and tune to the appropriate channel. Our antenna detects the signal and begins to reverse the transduction process. The electromagnetic energy is conducted from the antenna to the radio's circuits where it is transduced into electrical impulses as it enters the detector; then it is filtered and sent to the radio's amplifier. Next, the amplified signal vibrates the diaphragm of the radio's loudspeaker. At long last it is transduced back into its original form, physical energy, as we hear the chirp in the form of vibrations on our tympanic membrane (eardrum). Note the many transductions in this process.

What's the point of all this? Why does the transduction process matter?

Signal and Noise: Analog versus Digital

First, the recording example we discussed took a sound and converted into a digital file. Digital technology has many advantages over older analog recording techniques. Assuming that the original sound was faithfully sampled and properly stored, then the quality of the sound will always be the same as long as the integrity of the digital file is kept intact. You can make many copies of the sound file and they'll all sound as good as the original. This is one of the real benefits of digital technology: consistent sonic quality.

However, imagine if we tried to record the bird chirping using a handheld cassette recorder. The analog recording and playback process would be quite different. In analog audio, the bird chirping goes through many translations, with the possibility (and likelihood) of losing some information or adding some unnecessary data at each phase. (Ever notice that cassettes have some noise called *hiss* mixed in with the audio?) It's rather like playing the game "telephone," where several people whisper a simple message in turn. By the time the message gets to the last person, a lot of the original information has dropped out and some irrelevant information has crept in. In electronic terminology, losing information in the transduction process is known as signal loss, and the unwanted interference is known as noise. Now you can understand a term found in many advertisements for stereos: the **signal-to-noise ratio.** In common terms, this is a numerical representation of the amount of "pure" picture (in video) or sound information (in audio) when compared to the unwanted noise acquired during the transduction process. The higher the signal-to-noise ratio, the higher the fidelity; the lower the ratio, the "noisier" the sound or picture. Digital technology produces much higher signal-to-noise ratios (and better sound and pictures) than analog technology.

Analog and Digital Signals: The Real Lowdown

How information is converted from one form of energy to another is an important aspect of transduction. Until the 1990s, broadcast transmissions utilized analog signals. This means that to change the energy from physical to electrical impulses, an "analogy" to the original sound or image replaced the matter itself. It sounds tricky, but the concept is really pretty simple. By their nature, analog transmissions and recordings are subject to a great deal of signal loss and noise. They merely represent the original signal, itself a major limitation since the transmissions can never include all the information present in the original sound or picture. And analog signals tend to decay over time and space. Think of older snapshots you've taken: Over time photographs blur, tear, and fade.

Most of the excitement in broadcasting, home audio, and video today concerns digital recording and transmission: Rather than creating an analog to the original sound or picture, the signal itself is transduced into digital form. Each element of the audio or video signal is converted into its digital equivalent—that is, a series of numbers—using a binary code. A binary code is one with only two values, such as "on-off," "yes-no," "open-shut," or 0 and 1. Computers use strings of binary codes, called *bytes* (digital words comprised of bits of information), to process information. In digital recording, each sound is a unique sequence of binary numbers: 0101 (binary for the number 10), 1110 (the number 14), 10011 (the number 19), and so on. The digital words used for recording audio are quite long. They comprise information about the frequency (pitch) and the amplitude (loudness) of each sound in the recording.

To record a picture or music, the signal is electronically sampled and converted into strings of digital bytes. It could be stored in digital form on a flash drive, or your computer's hard drive, on a CD or a DVD, but let's assume that we want to store the information on a CD. When we want to record information on a CD, we send digital pulses to a laser (*l*ight *a*mplification by *s*timulated *e*mission *r*adiation). The blank CD is made up of a light-sensitive layer protected by clear plastic. As it turns at a high speed and as pulses are sent to the CD burner, the laser beam alters the light-sensitive CD layer. The laser burns a pattern of reflective and nonreflective areas that correspond to the zeros and ones in our binary files.

In the playback process the digital information on a CD is transduced by a beam of laser light, the same way the bar codes on your groceries are at the supermarket checkout. There are no needles, no friction, no wear, no scratches. More important, if the sampling rate is high enough, there is virtually no opportunity to introduce noise. When the signal is transmitted and played back, what we hear through the speakers is a virtual duplicate of the original signal with very high fidelity and excellent signal-to-noise ratio, meaning it is virtually noise-free.

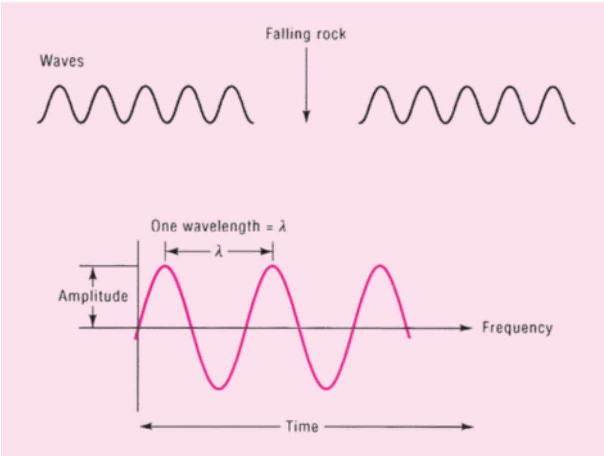
A frequent topic of this text is the transition from analog to digital. Radio, TV, cable, and recording have all moved to digital means of production. As a result, they are merging with the computer and newer wireless digital devices. This phenomenon has received its own industry buzzword: **convergence.**

Oscillation and the Waveform

Another basic principle to both audio and video signal processing is the concept of **oscillation.** Recall that we hear sounds and see images as variations, fluctuations, or vibrations detected by our ears and eyes and interpreted by our brain. Remember too that every vibration has a unique signature or "footprint"; every sound and image has its own characteristics. How well we see, how acutely we hear, and how well we can re-create these signals as sounds and pictures depend on our ability to identify, store, and re-create those vibrations. In electronic terms, the vibration of air produced by our mouths, the instruments we play, and objects in our natural environment, as well as the vibration of light

Figure 3–1

Principle of Oscillation and the Common Waveform



that accounts for every color and image our eyes can see, is known as oscillation. The footprint or image of an oscillation we use to visualize the presence of the invisible is known as its **waveform.** Figure 3–1 demonstrates the phenomenon of oscillation and the common waveform.

The most common way we can visualize oscillation is by dropping a small rock into a pail of water. You know that the result will be a series of circles or waves, radiating outward from the spot where the rock fell, until dissipating some distance from the center (depending on the size of the bucket and the height from which we drop the rock). All audio and video signals produce a pattern like this, except that they are invisible to the naked eye. However, while we can't see the patterns with the naked eye, by using the appropriate electronic equipment (such as an oscilloscope and a waveform monitor), we can detect them, use them, even create them ourselves.

Frequency and Amplitude

A major way in which we describe a wave is by its **frequency,** the number of waves that pass a given point in a given time. Originally measured in cycles per second (cps), frequency is more commonly measured now in **hertz (Hz),** in homage to early radio pioneer Heinrich Hertz.

In our example with the rock, depicted in Figure 3–1, the frequency is simply the number of waves that pass a given point in a single second. Note also from the bottom of Figure 3–1 that the distance between two corresponding points on a wave is called the **wavelength.** Also note that frequency and wavelength are inversely related. High frequency means a short wavelength; low frequency means a long wavelength. In the early days of radio, U.S. stations were classified by their wavelengths. Today we identify them by their frequencies.

A wave may also be described by its height or depth, from its normal position before the rock is dropped to the crest created by the splash. This is known as its **amplitude.** When choosing a section of beach to swim in, families with small children are likely to select those with slow, low, undulating waves—waves of low amplitude or, to use a radio term, long waves. Surfers will select a wild stretch of shoreline with frequent, mammoth-sized (high-amplitude) waves capable of picking the swimmer up and depositing her anywhere on the beach. In radio terms, these are the high-frequency short waves.

What's the significance of all this? For one thing, this is precisely how radio and TV work. As we examine in detail later, local radio stations wish to blanket their area with a strong local or regional signal. That's why AM signals use medium-length waves. International broadcasters like the BBC and Radio Moscow seek to spread the word about their countries around the globe. Hence they use short waves to hopscotch around the world. The services of these and other shortwave broadcasters are traced in detail in Chapter 14.

Frequency Response

Consider a final point about oscillation and the waveform. How well we can record and play back music or pictures depends on the range of frequencies that our radio or recorder is capable of receiving or reproducing. This is known as the unit's **frequency response.** A radio set that can only reproduce frequencies below 10,000 cycles and above 1,000 cycles will simply exclude very low and very high sounds. At the same time, a receiver with the best speakers, with a frequency response from 20 to 20,000 hertz, will be able to reproduce all the sounds the human ear can hear. It's the difference between hearing a symphony orchestra on a good stereo or through the tiny speaker on your cell phone. This is critical since the history of the popular arts is directly linked to the frequency response of the prevailing methods of signal processing.

In the recording industry the early success of banjo-playing minstrel-type performers, who frequently whistled in their acts, was in large part due to their audibility on 78-rpm records of limited, mainly high-frequency capability. Early recording stars such as Al Jolson, Rudy Vallee, and Eddie Cantor fall into this class. Similarly, in retrospect, Elvis Presley's limited tonal range seems to have directly fit the limitations of the cheaply produced 45-rpm record popular in the 1950s, which was meant to be heard on a teenager's much-abused "personal" record player (certainly not on dad's hi-fi in the den). In fact, early rock-and-roll record producers frequently listened to the final mix of a song on small car speakers instead of big studio monitors! Is it any surprise that the orchestrations, sound collages, and other experimentations ushered in by the Beatles' *Sergeant Pepper's Lonely Hearts Club Band,* the Beach Boys' *Pet Sounds,* and other groups in the late 1960s were aided by the developments of high-fidelity studio recording and FM stereo broadcasting? Today the complexities and acoustic calisthenics of rap and hip-hop performers (such as Busta Rhymes and Black Eyed Peas) are made possible by the extended range of frequencies available with new audio components, such as digital recording consoles and CD players.

STEPS IN SIGNAL PROCESSING

Having mastered the basics of media technology, let's turn to how it's actually done. All electronic signals—radio, TV, cable, satellite, and computer—follow the identical path from their inception to our consumption. These steps are depicted in Figure 3–2.

Figure 3–2

Steps in Signal Processing

(1) Signal generation

(2) Amplification and processing

(3) Transmission

(4) Reception

(5) Storage and retrieval

STEP 1: SIGNAL GENERATION

This step involves the creation of the necessary oscillations, or detectable vibrations of electrical energy, which correspond to the frequencies of their original counterparts in nature. In plain language, signal generation involves getting the sound vibrations into a microphone, or the bits and bytes onto a CD, a DVD, or an MP3 player.

Audio Signal Generation

Sound signals are generated by two main transduction processes: mechanical and electronic. Mechanical methods, like microphones, phonograph records, and tape recorders, have been in use for many years. Records and tapes have been largely replaced by digital electronics, such as CDs, DVDs, and MP3 players. First, let's briefly review how mechanical methods work.

Mechanical Methods Mechanical generation uses facsimile technology to create an analog of the original signals (by now you should be able to understand that technical-sounding sentence). That is, mechanical means are used to translate sound waves into a physical form, one you can hold in your hand, like a phonograph record or an audiocassette.

Inside the microphone One place where speech or music is mechanically re-created to produce electrical signals is inside a microphone. There are three basic types of microphones: dynamic, velocity, and condenser. Each produces the waveforms required for transmission in a different manner.

In a dynamic microphone a diaphragm is suspended over a electromagnet. In the center of the microphone is a coil of electrical wire, called a *voice coil.* Sound pressure vibrates the diaphragm, which moves the voice coil up and down between the magnetic poles. This movement induces an electrical pattern in the mike wire analogous to the frequency of the entering sound. Thanks to durable and rugged design similar to a sturdy kettle drum and good frequency response with voices and most music, dynamic mikes are frequently utilized in radio and TV productions, particularly news gathering.

There are other types of microphones that use different principles. For example, velocity microphones, also known as ribbon microphones, replace the voice coil with a thin metal ribbon. There is no diaphragm; the oscillations of the ribbon suspended

Issues: Are Cell Phones Changing Our Lifestyles for the Better?

We live in an interconnected world. Certainly the evening news shows us that world events have intertwined our lives with the lives of others from around the globe. But beyond the ramifications of the global media, perhaps no other device is doing more to change our culture than the cell phone.

According to a poll conducted by the Pew Research Center, the cell phone has become the most important communication device available for many under the age of 25. Some of the implications are undeniable, some amusing and some disturbing. For example, more than one in four users admit that they talk on the phone when driving and do not always drive as safely as a result.

The Pew study provides a detailed picture of how cell phones are being used in everyday life. Many say that the device has changed their lives in some ways. Youth are more likely to use their phones to make spontaneous calls when they have free time or when they want to kill time. (They're also more likely to get sticker shock at the end of the month when the bill comes.) A third of all youth say they cannot live without their cell phones, compared with only 18 percent of the general population. Interestingly, people under 29 are not always truthful about where they are when they're on the phone.

In an interview with the Associated Press, one college student from Tennessee said that he used his phone to do everything: talk, play video games, and use as an MP3 player. Almost 90 percent of all people polled said that they've encountered annoying people using cell phones, conversely only 8 percent said that they had ever been rude talking on their cell phone.

between the electromagnetic poles produce the necessary electric signals. Velocity mikes produce a lush sound and were very common in the "golden age" of radio. (You can see one on David Letterman's desk on *Late Night*.)

Condenser microphones use an electrical device known as a capacitor to produce electronic equivalents of sound pressure waves. The capacitor is comprised of two electrically charged plates. The pattern of electricity in the plate (its amplitude and frequency) varies in relation to its distance from its stationary backplate. That distance is affected by the pressure of the incoming sound waves. While this might seem complex, the process is quite similar to the workings of your own ear. Without touching the volume knob on a portable stereo, you can vary its loudness simply by moving the headphones closer to or farther from your eardrums.

Inside the phonograph record and tape recorder Phonograph records now seem archaic, but they were an important means of mechanical transduction of audio signals. Because they've been around for more than a century and are an important part of broadcast history, we're going to spend a moment discussing them. In recorded music, the sounds produced by musicians and singers are transduced into cuts made on each side of the central groove on the record (this is probably why songs on an album are known as "cuts" in the popular music business). This process is known as *lateral cut recording*. As the turntable rotates, the stylus (needle) vibrates laterally as it follows the record groove, creating the vibrations corresponding to the original words and music.

Early 1900s record reproduction ranged from 200 hertz (G below middle C, for you musicians) to around 1,500 hertz (second G above middle C), making the sound tinny, but a typical high-fidelity LP record ranges over nine octaves, from 50 to 15,000 hertz, which pretty much includes most of the sounds that are produced by voice and musical instruments.

Another way we begin sound signal processing is by converting sounds into electromagnetic pulses or "blips" on a piece of audiotape. Under a microscope, a piece of audiotape can be seen as a concentration of millions of metallic particles suspended in a plastic base. When a small electrical signal is fed into the recording circuit, an electromagnetic field is emitted by the tape head. As the tape passes the head, its microscopic metal filings are charged (arranged magnetically) into an exact replica of the electrical patterns moving through the tape head. We have now created an analog signal, just like the grooves on a record or the oscillations in a microphone. Playing back is simply the reverse of the recording process. The signals recorded on tape induce a magnetic field in the playback head, which is then amplified and sent to speakers.

The tiny electret condenser is the preferred microphone in TV news due to its small size and rugged design.

Professional audio recording facilities use tape that is 1 or 2 inches wide, capable of recording 8, 16, and even 24 or 48 separate sets of signals on one piece of tape. Consequently, such machines are known as multitrack recorders. Broadcast stations use ¼ inch wide tape recording in stereo.

For many years radio stations also used audiotape cartridge players, or "carts," for their music, commercials, and station identifications. These machines use a special tape cartridge with only one reel. The tape winds past the heads and back onto itself. This allows for the musical selections to arrive quickly at their original starting point (in radio jargon, they are fast-cued).

Cassette tape recorders use a miniaturized reel-to-reel configuration enclosed in a small plastic housing. Because of their small size and portability they were popular with news reporters. The tape is only ⅜ inch wide, and, as we all know from our home and car stereos, the tape can be recorded and played back on both sides. Thus there are up to four tracks of information crunched onto the small tape area. This is why cassette stereo units produce some noise and hiss and why the better ones allow for noise-reduction options (such as Dolby B and Dolby C).

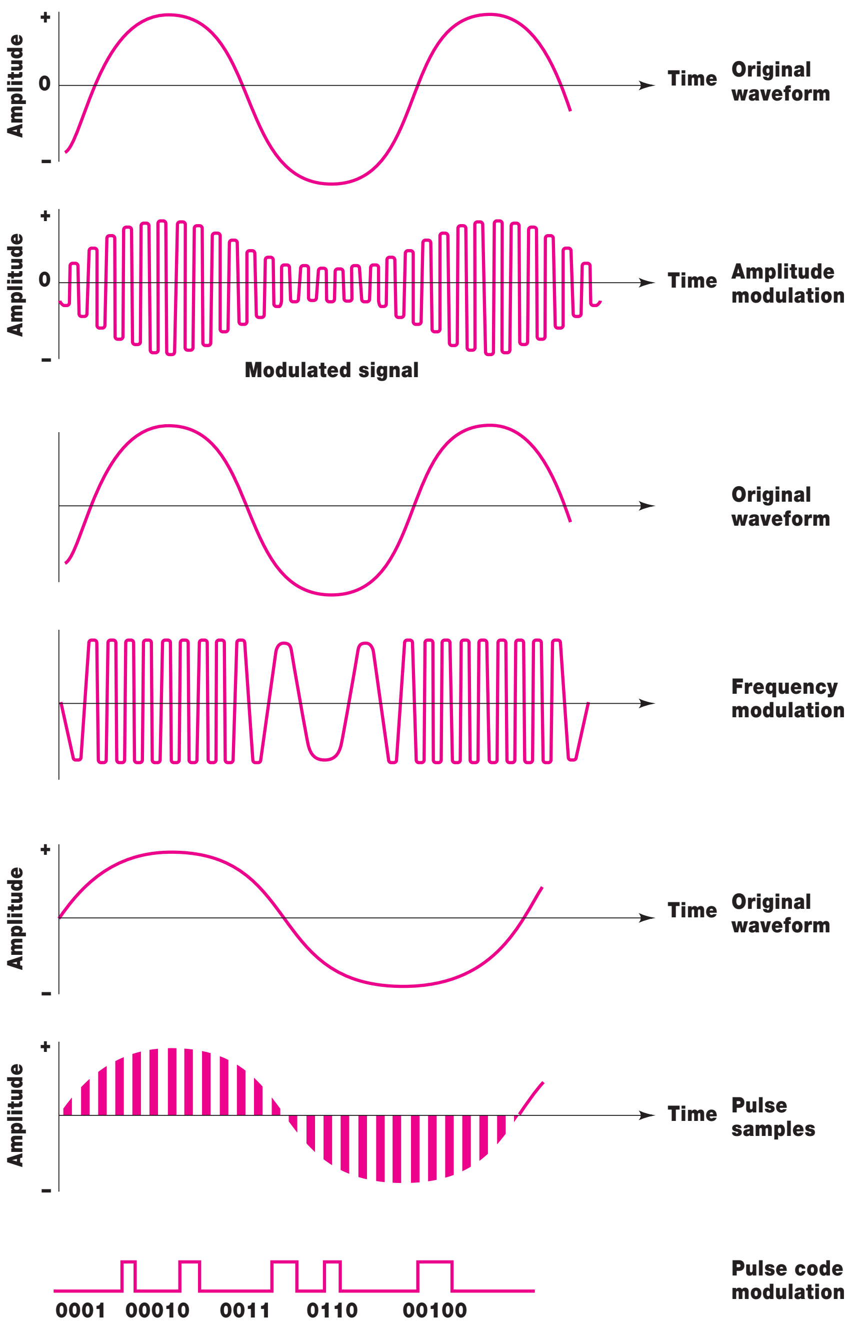
Why is it useful to know how phonographs and tape recording works? A basic understanding of audio technology adds much to our study of the radio industry. Our entire broadcast history was preserved on records, audio-, and videotape. These older analog technologies are frequently referred to as "legacy" devices, and you may still see them in radio and television stations.

Digital Electronics As a trip to the nearest electronics store confirms, there has been a revolution in audio in recent years. Recordings and magnetic tapes have given way to compact discs (CDs), audio DVDs, MP3 players, and the minidisc (MD).

Digital audio was made possible by the development of a new means of signal generation, known as **pulse code modulation** (PCM). This and other modulation methods are seen in Figure 3–3. At the top of the figure is the original waveform: the shape of the original sound we seek to record and reproduce. Let's say for this example, it's the sound of a guitar string being plucked. Below the waveform is its shape, transduced into an AM signal. Like a surfer on a wave, its new shape is a series of peaks and valleys, or changes in amplitude. In essence, the amplitude of the carrier changes with the variations of the plucked guitar string. Below that is the same waveform transduced into an FM signal. Now the message is in the form of a series of changes in the number of times it occurs over a period of time (in this case let's say in 1 second)—that is, its frequency. At the bottom is the waveform translated into a digital signal. By sampling the amplitude of the wave many thousands of times each second (by turning a laser beam on and off

Figure 3–3

Modulation Methods



and measuring the length of the light beam at each interval), a digital version of the wave could be produced. This process is called pulse code modulation.

Foremost, unlike an analog signal, a digital wave is virtually constant—it is the identical shape on recording, on transmission, going into the amplifier, and coming out of the speakers. Second, unlike tapes and standard phonograph records, if the digital device can "read" the file successfully, all the original information will be preserved and the original sounds will be reproduced in a noise-free environment.

CDs As we mentioned previously, the information on a compact disc (CD) is carried beneath the protective acrylic coating in a polycarbonate base. In the base is a series of pits and flats. The pits vary in length in precise correspondence to the waveforms they represent. The flats represent no waveforms: utter silence. As the disc rotates, a laser beam is focused on the disc. Like a mirror, when the beam "sees" a pit, it reflects back a light wave that contains data about the original sound wave. Now, using a digital-to-analog converter and other electronics, the data are collected and transduced into an electrical signal through amplifiers and into speakers. The result is a clean, nearly perfect sound. In technical terms, the frequency response for CDs ranges from 20 to 20,000 hertz (remember, the best LP record ranges from 50 to 15,000 hertz), and CDs have a signal-to-noise ratio of 90 decibels (compared with about 60 decibels for records), the common measure of the intensity of sound, which is pretty darn good.

Unlike with records and tapes, there is no friction or wear. Discs are comparatively immune from damage in routine handling and storage, but they can

Ethics: Negativland—Digital Artists or Rip-Off Artists?

Digital sampling techniques allow virtually any sound or image to be reproduced and rerecorded, thereby raising a critical ethical dilemma. Is it ethical to borrow musical phrases from one song and then combine them with pieces of other songs without the original copyright owner's permission? Most performers and musicians argue that their work should be protected from such digital manipulation. Others argue that the technology has created a new art form. Composers should be free to use sounds and images from other works to create new ones, especially those that use the expropriated images for comedic or satirical purposes.

Negativland is one of those groups of new "composers." The "band," if you can call it that, exists by purloining the work of other artists and turning compilations of those bits of work into their own songs. Their albums make use of hundreds of digital samples—from familiar rock guitar riffs to snippets of conversations from TV talk shows to slogans and jingles from radio and TV advertisements. The results are mixed (pun intended), but when it works, the effect can be insightful and interesting.

Negativland spent nearly 25 years as part of San Francisco's vibrant underground, running a free-form radio show on Berkeley's edgy KPFA-FM. Things changed when the Irish supergroup U2 sued Negativland over the release of an album titled *U2,* which included a vicious parody of the supergroup's "I Still Haven't Found What I'm Looking For." The lawsuit has been detailed by Negativland in their book entitled *The Story of the Letter U and the Numeral 2.* Issues related to fair-use statutes in U.S. copyright law have been a concern for the group, and they have consistently advocated for reforms.

Never ones to shy away from issues related to modern culture, their CD *Dispepsi* made use of samples of dozens of soft drink ads to satirize the leading cola companies. Apparently Coke and Pepsi are too busy with their "Cola Wars," and have thus far failed to file suit.

Negativland caused quite a stir in late 1998 with the release of its CD with the not-so-clever title of *Over the Edge Volume 3—The Weatherman's Dumb Stupid Come-Out Line.* According to the band's co-leader Mark Hosler, five CD-pressing plants refused to manufacture the disc, apparently under pressure from the Recording Industry Association of America, and Disctronics, a plant in Texas, said it was refusing to make the CD since it might contain unauthorized sound clips.

In 2005 the group issued *No Business,* a CD/book that manipulates trademarked icons like Mickey Mouse, SpongeBob, Batman, and Starbucks. Still, despite mixed reviews from critics, the group performed a shortened version for the Duke University Conference on the Public Domain. Don Joyce, co-founder of the band, has said that *No Business* is certainly illegal with packaging that has a variety of trademark infringements all over it. Today's digital technology makes it easy to capture and manipulate the works of others. The question is whether groups like Negativland should be able to bend the law to make social statements about it. What do you think?

become scratched. With proper care, they should never warp, unwind, or jam in the player, and they cannot get accidentally erased.

Writable compact discs (CD-Rs), developed for the computer industry, have become standard features today on home computers and have the added ability to record audio signals. As peer-to-peer file sharing became popular on the Internet, CD-Rs came into their own. CD-Rs have helped popularize the MP3 format, which we'll discuss in a moment.

Digital versatile discs and Super Audio CDs Digital versatile discs (DVDs) have become remarkably popular since their introduction in 1997. Most people think of DVDs for playback of movies, and prerecorded discs are capable of reproducing from one to six channels of audio or Dolby 5.1 surround sound (a theaterlike, multichannel sound experience). This makes it possible to playback movies encoded with Digital Theater Sound (DTS). However, a new audio format, DVD-A, has been established that allows multichannel audio playback and fidelity greater than the current CD format.

Fidelity greater than CDs? Some audiophiles claim that CDs are incapable of producing harmonics above the range of human hearing and that the sampling rate for CDs is inadequate, imparting a coarse, almost clinical sound. The new DVD-A format allows a wider band of frequencies to be recorded and with greater fidelity, 24-bit recording as opposed to 16 bits as currently used on CD (remember the bigger the digital word—24 bits as opposed to 16—the more data about the original signal is recorded). DVD-A discs are not compatible with older DVD players, and they won't play back on a standard CD player.

Super Audio CD (SACD) is another new format that has been developed in recent years. Like DVD-A discs, SACDs promise the highest-quality sound format, and they use a brand-new audio technology called Direct Stream Digital (DSD) encoding. Unlike DVD-A, CDs, and other digital technologies, SACDs do not use pulse code modulation. Instead, these new CDs use 1-bit sampling at amazingly high sample rates (more than 2.8 million samples per second). Some experts claim this new sampling technology gives SACDs a more realistic sound quality.

SACDs, like DVD audio discs, are capable of playing back DTS 5.1 multichannel sound. SACDs were invented by Sony and Philips, the two companies that originally invented the CD. While it's too early to tell whether there will be widespread acceptance of the new audio format in the consumer marketplace, new high-definition (HD) radio may use these technologies to broadcast surround sound and multichannel audio.

Moving Picture Experts Group—Audio Layer III (MP3)
MP3 is the name for a recording compression technology that grew for file sharing and exchange on the Internet. It has quickly spread from college campuses to home audio systems. MP3 uses compression technology to eliminate inaudible frequencies as a way of shrinking the file size of an audio recording. This compression scheme, which made it possible to share audio files via the Internet, grew to be very popular by the year 2000. Compression technology makes it possible to squeeze thousands of songs onto tiny MP3 players. Today, many DVD players and personal CDs can play back the MP3 format. MP3 files come in a variety of quality standards, but the highest-quality MP3s (such as Apple's iTunes files) nearly equal the sound of CDs.

Some broadcasting stations have encoded music on computer drives using MP3 technology. The result is that it is possible to store hundreds of hours of music on several large computer hard drives. Today most stations use computers for music playback since special programs allow the program director to order music selections in accordance with the station's format.

Minidisc In 1993, Sony introduced a compact digital replacement for cassettes called the **minidisc (MD).** The minidisc is about 2½ inches in diameter, just about one-quarter the size of a standard CD. Designed mainly as walkabout stereos, the MD eliminates the problem many portable CD players have had: skipping as a result of laser mistracking. MDs can record up to 74 minutes of music, and HD-MD discs can record up to 13 hours on one disc. Some minidisc machines can also read out text (liner notes, song titles, and so on), and they can be reused for recording numerous times. Like MP3s, minidiscs use compression technology for recording and playback.

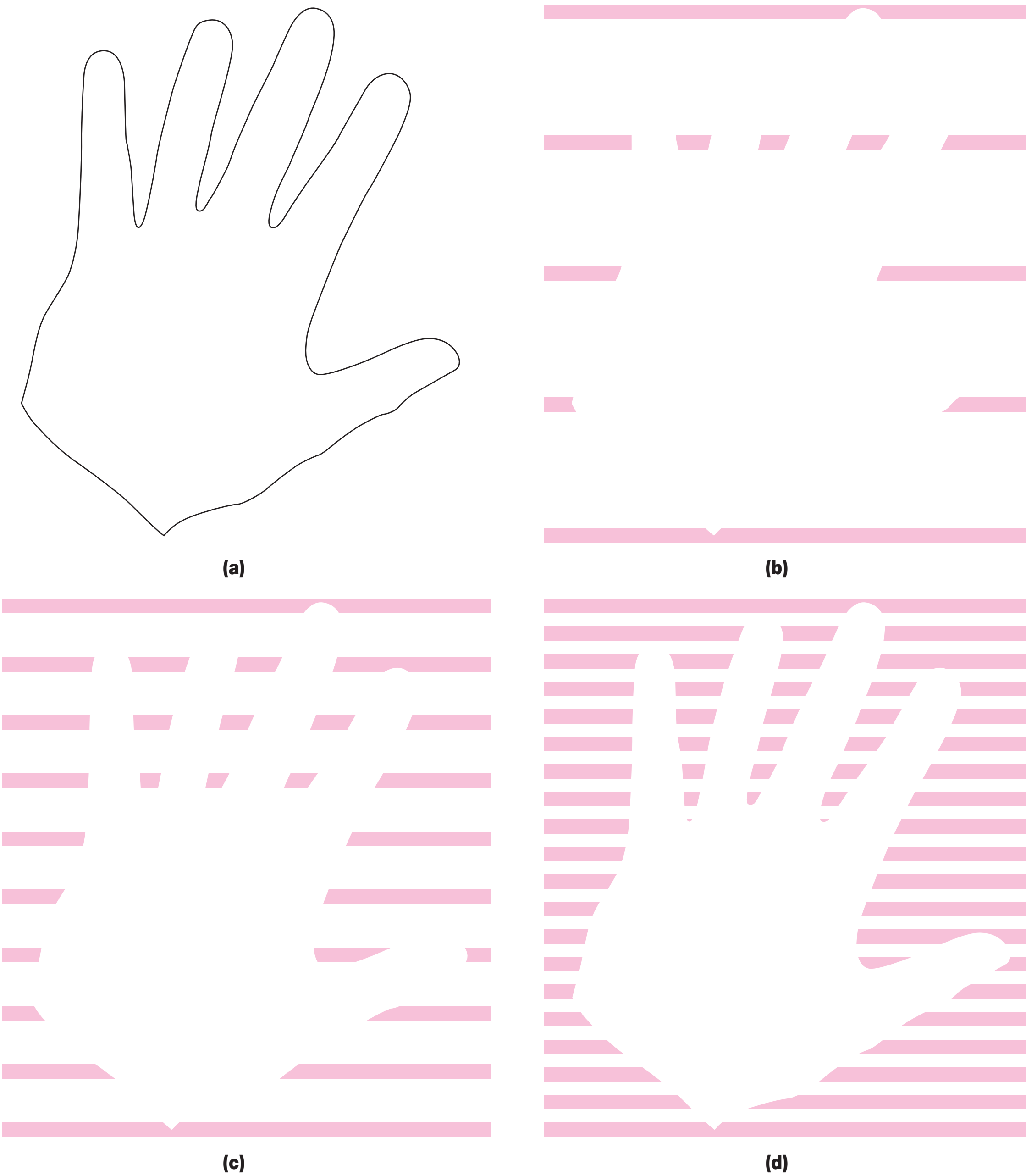
While minidiscs have become fairly common in broadcasting stations as substitutes for analog cart machines and for radio news gathering, the minidisc has never really been accepted in the home marketplace.

Video Signal Generation

Television's ability to transmit images is based on the technology of scanning. The TV camera scans each element of a scene line by line; the picture tube

Figure 3–4

Examples of Scanning



in your TV set retraces the scene. Earlier in the chapter we said tracing the outline of your hand is a way to create a facsimile representation of the hand on the sheet of paper, like the illustration in Figure 3–4(*a*). Let's change the game a little bit. Instead of drawing one continuous line, suppose we trace the hand by using a series of five parallel lines, as depicted in Figure 3–4(*b*). We move the crayon straight across. We lift it when it encounters the hand and return it to the paper when it passes by a "hand" area. The result is the rough facsimile of the hand in Figure 3–4(*b*). Now, let's use 10 lines instead of 5.

This tracing will provide a fairly good representation of the hand, as in Figure 3–4(*c*). Just for fun, let's alternate the tracing by doing every odd-numbered line first, then each even-numbered line. After two passes, top to bottom, the result is Figure 3–4(*d*). In this exercise we have actually demonstrated the workings of TV technology.

When done invisibly by the TV camera, the tracing process is called *scanning*. The process of alternating lines is known as the *interlace method*. And the process of replicating the scan on the picture tube to produce the image at home is known as *retracing*. The process originates in the TV camera and is re-created at home on the picture tube.

The Importance of Scanning At this point you may feel saturated by needless technical information. Actually there are excellent reasons why this information is critical to understanding modern telecommunications.

Standardization First is the issue of standards. There are a number of different television systems, and the number of lines utilized in the scanning process varies throughout the world. The United States now has several different standards for television. Our analog system uses a 525-line system adopted in 1941 by a group known as NTSC (National Television Systems Committee). The complete picture consists of a composite of two separate scans or **fields,** each consisting of 262½ horizontal scanning lines. The two fields combine to form a single picture, called the **frame.** In the United States, the AC power system we use oscillates at 60 hertz. Thus, our TV system uses a 60-hertz scanning rate. Since two fields are needed to produce one frame, 30 complete pictures are produced every second.

Much of European TV uses a system known as PAL (for phase alternating lines), adopted several years after the U.S. system. Based on the AC power available there, European TV uses a shorter scanning rate (50 hertz), but with more scanning lines (625). Many Americans are startled to see how clear European TV is; that's due to the fact that it has 100 more lines of resolution. However, European television is subject to some flicker, since the two picture fields are refreshed fewer times per second. France and Russia use yet a third system.

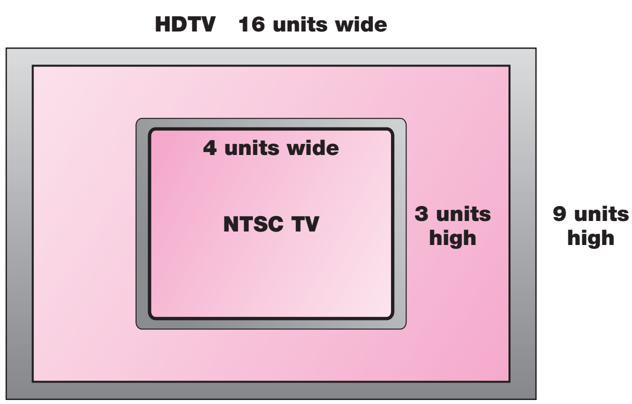
Beyond better picture quality, the issue of standardization involves a lot of other important matters. Televisions and VCRs produced for one system will not work on the other. The same is true for prerecorded videotapes; you can't bring a tape recorded in the United States to Europe and expect it to play.

Digital television and high-definition television The scanning process is also directly involved in many of the newest technical innovations occurring in television today. Digital television (DTV) is the new standard being adopted by television stations around the country. DTV is actually a multiple-standard system that was devised through the collaboration of broadcasters and set manufacturers. There are 18 different formats that can be transmitted, but essentially most new DTV televisions convert them into either standard definition or high definition. **High-definition television (HDTV)** is the moniker for digital television utilizing either 720 or 1,080 scanning lines, producing an image rivaling 35-millimeter film in quality. But the new digital television system can transmit a *scalable* picture. That means that the quality of the transmission can be varied from 480 lines to 1,080 lines of resolution. DTV can also change the aspect ratio (the ratio of screen width to screen height) of conventional TV. In standard TV the screen is 4 units wide and 3 units high. In wide-screen, the ratio is 16:9 (16 units wide and 9 units high), much like the frames of a motion picture (see Figure 3–5). Television stations are able to change the resolution of the picture and the width of the screen to meet the needs of the programs transmitted.

As we trace in the "Television Today" chapter (Chapter 5), TV stations, networks, cable, and satellite systems are in the process of converting from the

Figure 3–5

The new wide-screen TV sets have an aspect ratio of 16:9 compared to an aspect ratio of 4:3 for tradional sets. The new aspect ratio is closer to the dimensions of a theater screen.



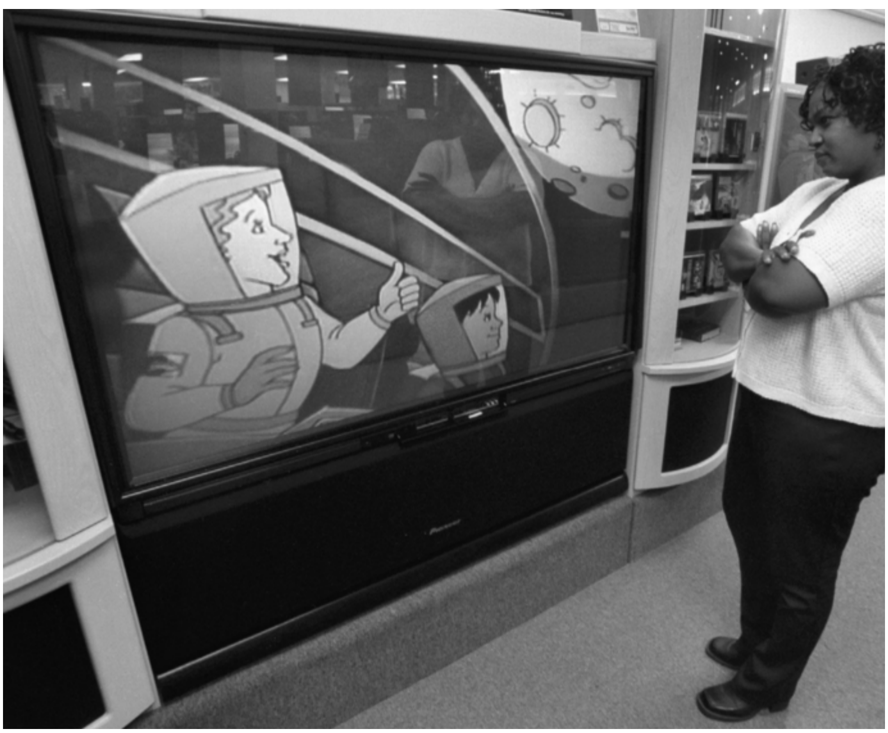
60-year-old 525-line system to the new digital system. Many TV stations across the nation have already begun the transition to DTV. NFL games, the *Tonight Show*, *24*, *CSI*, and many prime-time TV shows are already being transmitted in the digital format. Mark your calendars: The FCC has called for a complete transition to DTV by February 17, 2009.

The switch to DTV is actually quite complex and involves three standards for resolution (number of lines), several sets of frames, and two scanning methods. The new DTV sets are able to tune in TV signals using 480, 720, and 1,080 lines, all of which have much higher fidelity than traditional analog 525 NTSC (because there's less noise in the picture). And the picture can be scanned in 24, 30, or 60 frames per second. Finally, the new TV signals can be sent every other line (the traditional interlace method) or line by line—an alternative scanning method known as progressive scan, which most computers use.

So what difference does this make? Plenty. Using 480 lines (and only a portion of the channel allocation) allows TV stations to *multicast;* that is, they can send more than one program over the same channel allocation at the same time but not in high definition. One station might actually transmit as many as four or five different programs on one 6-megahertz television channel. Broadcast TV is touting this multicasting feature so it can compete more successfully with its cable competitors, which have made multiple versions of their channels available for some years now (like ESPN, ESPN2, and ESPNews). A local television station could start its own all-local news program service, for instance, and still broadcast the network program feed on the same channel. And using the progressive scan method brings TV much closer to the computer business, which has used progressive scan on its monitors for years now. Some large, flat-screen displays would be able to be used for both progressive scan television and computer images.

Beyond the picture quality, DTV is capable of broadcasting in surround sound and could also provide the home user with a data stream information channel, providing both picture and interactivity. And consider this: Now that the new TV system can use progressive scanning and is a digital signal, it may be possible to marry the home computer and the home entertainment center into one unit in the future.

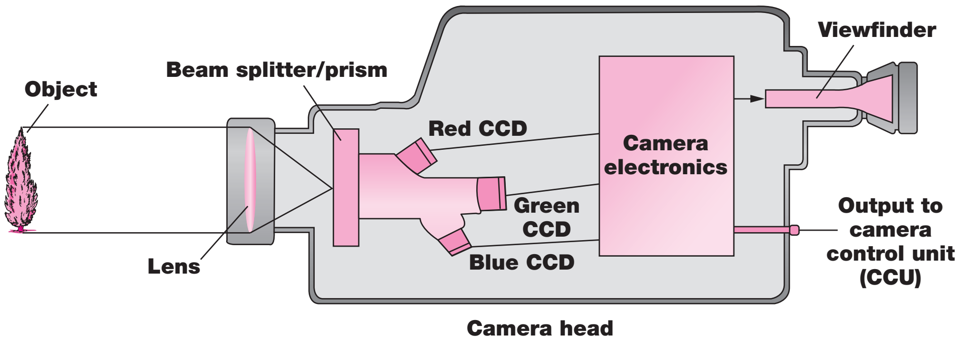
Closed captioning Closed captioning is a technology that uses the blanking period between scans (called the *vertical blanking interval*) to send additional



Wide-screen (16:9) HDTV sets are now becoming more commonplace in the home.

Figure 3–6

Inside the TV Camera



information with the TV signal. Appropriate decoders provide captions for deaf viewers or specialty text services, such as news capsules or stock market reports, to specially equipped TV sets.

Inside the Camera: Pickup Device We already know that the purpose of scanning is to transduce physical light into electronic signals. The process occurs inside the TV camera, as depicted in Figure 3–6.

The first step in creating TV is the collection of an image by a lens. Inside the TV camera the image is captured by a beam splitter and prism that break down the image into the primary colors of red, green, and blue. Attached to the prism are light-sensitive wafers called *charge-coupled devices (CCDs).* Each of the red, green, and blue chips can sample 1 million picture elements in a manner not unlike the way a printing press uses dots to produce a color newspaper photo. The CCDs rasterize the red, green, and blue components of the picture by turning them into rows of individual dots that we call *pixels.* Here's how it works: When light passes through the beam splitter and hits the red (or blue or green) chip, it creates a charge that's proportional to the amount of light that strikes it. Each point that becomes charged becomes a pixel of information. Combining circuits in the camera overlay the red, green, and blue information to produce a full-color picture. These signals are extremely weak and need to be amplified by the camera electronics. A black line is added after each horizontal line and after each complete scan to allow the image to burn into our retina. These are known as the blanking pulses. The signal that exits the camera thus contains two sets of information: picture information plus blanking. At the camera control unit (CCU) or in the switcher, a third signal (sync) is added. The synchronization pulse enables the output of two or more cameras and other video sources to be mixed together and allows all the scanning processes to take place at the same time, from camera to receiver.

In analog television, the complete TV picture of red, green, and blue scan lines, picture plus blanking plus sync, is known as the *composite video signal.* Digital television and DVDs frequently provide separate outputs of the color channel signals, known as *component video.* This provides better picture fidelity.

STEP 2: SIGNAL AMPLIFICATION AND PROCESSING

Now, we've successfully transduced sounds and pictures into electronic analog or digital signals. The next step is to boost those signals so that they can be transported from one place to another and to mix them with other sounds and images so we can hear more than one musical instrument or see a great football catch from many different angles. In engineering terms, we're talking about signal amplification, mixing, and processing.

Audio Amplification and Signal Processing

An **amplifier** is a device that boosts an electrical signal. Typically, in electrical circuitry the voltage or current of an input is increased by drawing on an external power source (such as a battery or an AC or DC transformer) to produce a more powerful output signal. Devices to perform this function range from the original vacuum tubes like De Forest's audion (which made radio and sound movies practical in the 1920s), to transistors (which emerged in the 1950s to enable manufacturers to reduce the size of radios and TVs), and finally to integrated circuits in the 1970s (which permitted "microelectronics").

Modern amplifiers may perform functions beyond increasing the power of the sound (or video) source. An **equalizer** is a special kind of amplifier that is frequency-dependent. This means that it can work to boost or reduce a specified range of frequencies while leaving others unaffected. Equalization, referred to as EQ by sound engineers and music trendies, enables a sound signal to be fine-tuned for its best tonal quality. For example, equalizers can be used to make bass (between 60 and 250 hertz) sound more fat, thin, or "boomy." An equalizer can also be used to boost vocal sections out of the "soup" of an orchestrated passage and even to isolate, diminish, or remove poor-sounding sections or mistakes in vocals or music. Once limited to expensive studios, EQ is now available in many home and car stereo systems. In fact, a tiny iPod has several equalization settings on it allowing you to change the tonal balance of the playback.

Rock bands may use amplification circuitry that allows for electronic special effects to be added. These include reverberation, which is simply an echolike effect. Special amplifiers can create all sorts of effects, from echoes to "sing-along" doubling or tripling. They can even create artificial choruses and deep echo chambers. Other devices are available to play tricks on audio signals. Phasers (not the kind used by Kirk and Spock) and distortion boxes on guitars (for example) manipulate the phase relationship between frequencies to create fuzz tones, pitch changers, or other effects. Today computers can be manipulated to record sounds backward and to speed up or slow down recordings. In the 1950s and 1960s it was common practice for radio stations to use speeded-up recorders to rerecord popular songs so that they played more quickly, allowing for more commercial and promotion time.

Mixing Consoles and Control Boards The next link in the audio production chain is the audio console, which combines sound sources into a single signal. In radio and TV stations the console is generally referred to as an *audio board.* In recording studios and motion picture sound studios, it is commonly known as the *mixing console.* Regardless of its name, the console is the central nervous system of the audio

Modern radio production boards use slide faders to control audio levels from various input sources.

facility. Today consoles are likely to be either analog or digital. It is the place where all audio signals are inputted, selected, controlled, mixed, combined, and routed for recording or broadcast transmission. Let's examine each of these phases individually.

The first function of the board is to accept (input) sound sources. A major-market radio station may have several computers for playing back music and commercial messages, several CD players or digital cart machines, and perhaps five or more microphones spread among several studios but capable of being interconnected. A recording studio is even more complex.

The board usually consists of a number of sliding faders that control the sound level. Ten-, 12-, and 24-input boards are common. Some inputs correspond to one and only one sound device. Others use select switches and routing devices to allow for a single input to control as many as four or five different sound signals.

Each input is controlled by a sliding bar called a *fader.* By using the fader, the board operator can adjust the sound level of each studio input. More elaborate boards allow for equalization and special effects to be controlled at this stage as well. Consoles also allow for each source to be measured or metered and for the outputs of various signals to be amplified similarly.

Sitting at one location, the audio person can combine and compose the overall sound of a performance, which is called the *mix.* All the various audio sources are combined together, sometimes in a single (monaural) mix for AM radio but more commonly in a two-channel (stereo) mix where the different instruments are placed left, right, or in the middle of the sound field. Today a five- or six-channel mix may be done for a surround sound high-definition program or a movie soundtrack. The resulting mixes are recorded on a computer using special audio recording software or broadcast live to viewers and listeners at home.

Desktop Audio As you might have guessed, today's high-memory, fast computers can perform the same audio tricks as can the largest, most sophisticated mixing consoles. With a microphone, a sound card, and a fast hard drive, many home computers can be turned into fully functional sound studios. In fact, computers are probably the most common recording device in radio and television today.

The result is a revolution in audio signal processing. Many radio executives have converted their stations into "tapeless" radio stations, where the announcing, music, amplification, and mixing are done on a desktop computer.

One company, Radio Computing Services (RCS) of Scarsdale, New York, calls its desktop system Master Control and touts it as the "paperless, tapeless, all-digital studio." In its system, all audio signals—jingles, commercials, musical selections, even telephone calls from listeners—are stored on computer hard drives. There are no tape machines, CDs, or turntables. In essence, an entire radio station is converted into a network of desktop computers. The jock doesn't even have to be in the same city as the radio station since the system can send and receive the voice tracks as sound files over the Internet.

Video Amplification and Processing

You're watching a live newscast, but before the TV signal travels from the camera to the transmitter, several things happen. First, the electrical signal is amplified—increased in electrical intensity—and carried along a wire to a monitor, within a video control room where it is viewed by the director and other production personnel. In most TV programs the cameras and other video input sources (tape machines, video servers, computers, the graphics generator, and so on) are mixed together before they are transmitted. The **switcher,** a device used for mixing TV signals, is probably the first thing a visitor to a TV control room notices. The advanced models are impressive-looking devices consisting of several rows of buttons and numerous levers. A television director uses a switcher to put the desired picture on the air. If camera 3 shows what the director wants to see, then pushing the appropriate button on the switcher puts camera 3 on the air. If video server 4 has the desired instant replay, then pushing another button puts it on the air.

The switcher also lets the director choose the appropriate transition from one video source to another. Simply punching another button generates what's known as a *cut*—an instantaneous switch from one picture to another. By using a fader bar the director can dissolve from one picture to another or fade an image to or from black.

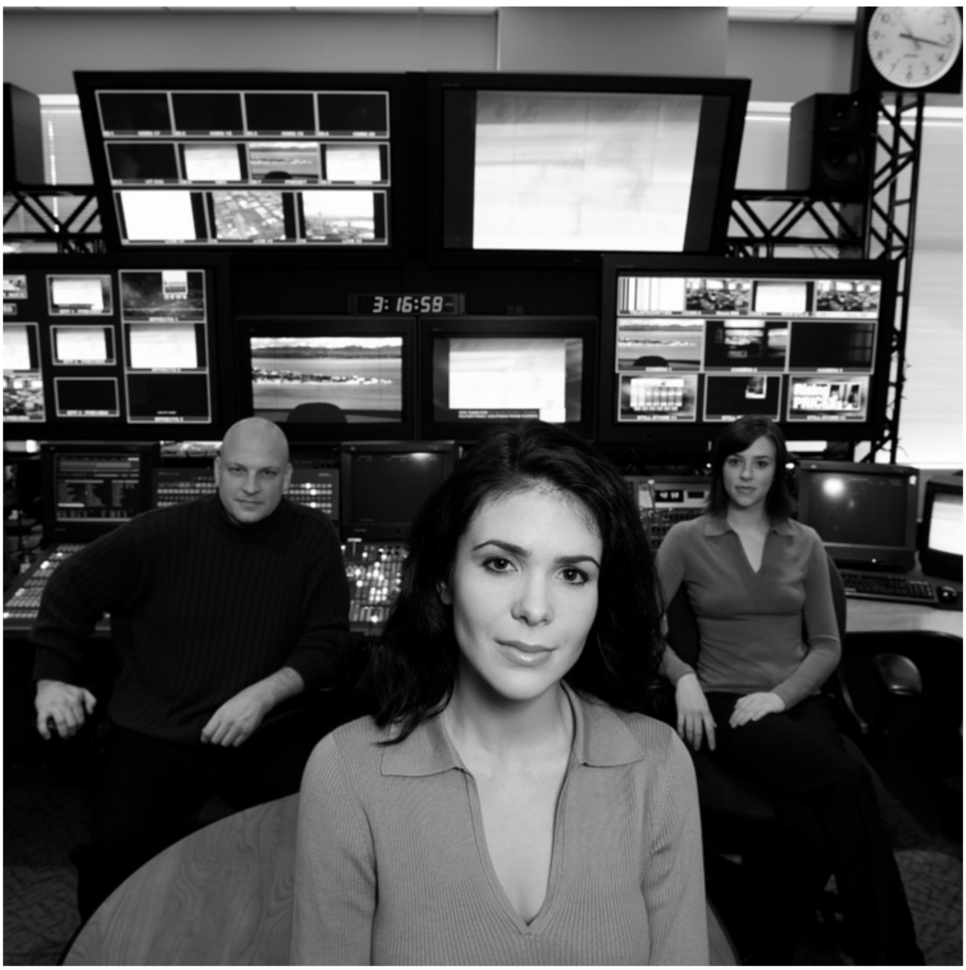
If a special-effects generator is added, a host of other transitions is possible. One picture can wipe out another horizontally, vertically, or in many other patterns. A split screen with two or more persons sharing the screen at the same time is possible, as is **keying,** an effect in which one video signal is electronically cut out or keyed into another. The most common use of this process is **chromakey.** A specific color (usually blue or green) drops out of one picture and another picture is seen everywhere that color appeared in the original picture. Weathercasters, for example, usually perform in front of a blue background, which is replaced by keyed-in weather maps or other graphics. (Performers must be careful not to wear clothing that is the same color as the chromakey blue, or they will appear transparent on screen.)

Digital Video Effects As might be expected, digital technology has had an immense impact on video processing. Each TV signal can be converted into a series of binary code numbers that can be manipulated and then reconverted back into a TV signal. There are numerous types of digital video effects, or DVE, in industry parlance. They include freeze-framing, shrinking images in size and positioning them anywhere on the screen (as happens when an anchor talks to a field reporter and both pictures are kept on screen), stretching or rotating a video picture, producing a mirror image, and wrapping the picture into a cylindrical shape.

Desktop Video Until the late 1980s, generating video special effects required large, expensive processing equipment. Only a few big-city TV stations and production centers had the capability to produce digital video (DV).

In the early 1990s computer companies merged the video signal with the personal computer. As if to underscore the low cost and simplicity of these new technologies, one common setup was known as a "video toaster."

Today, the digital revolution is in full swing. Video can even be produced on powerful laptop computers; Apple Computer's Final Cut Pro and Avid's Express



Video inputs are mixed together in the television control room.

Events: Webcams, Phone Cams, and the View of the Real World

As soon as the Web became popular, an interesting voyeuristic technology took off: the webcam. The concept was simple. You simply hooked a video camera to your computer and streamed the output directly to the Web.

Soon a number of sites took off showing people living their lives in front of the camera. Some sites were free, and others, ones with more prurient views, charged a fee. Since their invention webcams have become part of the Internet world, allowing us views into exotic as well as fairly mundane places. WebCam Central allows you to search by category or location or choose random sites. You might find a webcam showing a view of the great pyramids or another illuminating a computer lab at some university, a view of Sydney's Harbor or the view of a mall's foodcourt in Newark, New Jersey (really). Amazing webcams allows you to search by continent. (There are actually seven webcams for Antarctica!)

Finally, technology has allowed us to make the webcam mobile. Suncam TV broadcasts live views from an SUV in Florida, even during hurricanes. As mobile technology improves, it's likely we'll see more webcams and phone cams showing us more of the world. Some of it is bound to be mundane, but some of it will provide us with unique views.

software provide professional video editing capabilities in systems that interact with DV camcorders and other production devices. Advances in high-speed, high-capacity hard disks and DVD drives allow the storage and retrieval of still and moving images. Other software can be used to produce dazzling titles and graphics. As a result, the kind of spectacular visuals once reserved for music videos with huge budgets, or for the promotional messages of the major networks, can now be produced by anyone with a broadcast-quality camcorder linked to a PC.

STEP 3: SIGNAL TRANSMISSION

We've now succeeded in selecting sounds and pictures, changing them from physical energy into electronic signals, and amplifying and mixing them. The next step is to take them from point A to point B. Broadcasting is really the process of signal transmission. As we read in the history chapter, the modern age of broadcasting began when scientists and inventors became able to do this over the air, without wires. Ironically, as we move comfortably into the new century, we are now trying to do it all over again by wire (over cable and the Internet) and by wireless (using wireless local area networks to mobile devices). But let's not get ahead of the story.

Audio Transmission

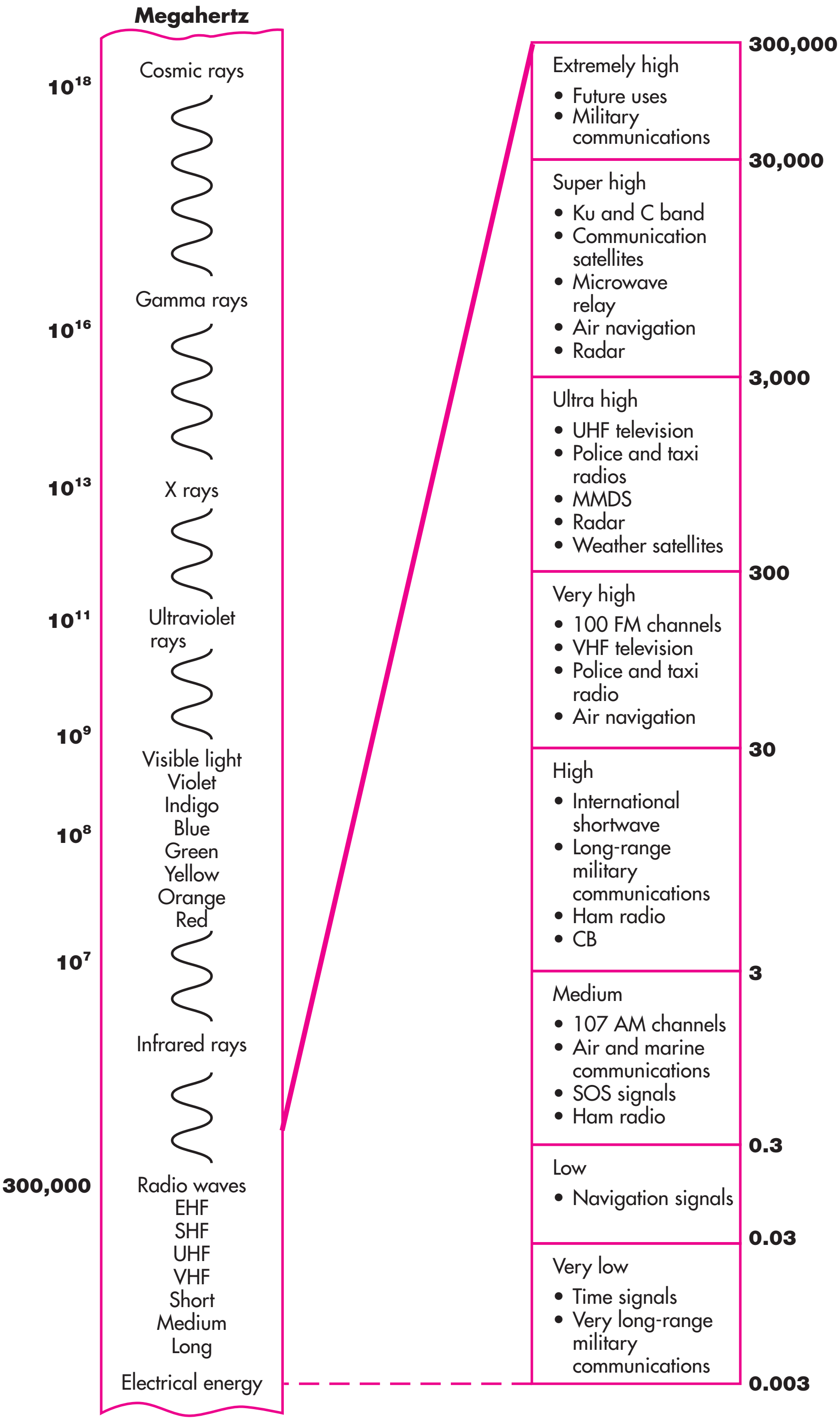
As Chapter 1 described in detail, the radio pioneers found that electrical signals created by human beings could be transported across space so that buttons pushed here could cause a buzz over there. They soon replaced signals and buzzes with a voice at both ends.

The Electromagnetic Spectrum This magical process was made possible by the discovery and use of the **electromagnetic spectrum,** the electromagnetic radiation present throughout the universe. Figure 3–7 is a chart of the spectrum. A fundamental component of our physical environment, electromagnetic radiation is traveling around and through us at all times. We can see some of it (the narrow band of frequencies corresponding to visible light and color, or the "heat waves" that radiate off a parking lot in the summertime). But most of the spectrum is invisible to the naked eye and must be detected by human-made devices (like radio and TV receivers).

In the past century we have learned how to superimpose, or "piggyback," our own electronic signals on the electromagnetic waves that exist in nature, a process known as **modulation.** This is done by generating a signal that is a replica of the natural wave. This signal, produced by a radio station on its assigned frequency, is called a **carrier wave.** It is "heard" on our radios as the silence that comes just before the station signs on in the morning or after the national anthem at sign-off. The radio signal is created by varying the carrier wave slightly, in correspondence with the frequencies of the signals we mean to transmit. Our tuner, tuned to the precise middle of the carrier, interprets these oscillations and reproduces them as sounds in the speaker system. If this process seems hopelessly complex, consider this metaphor. Suppose there is a natural rock formation in the shape of a bridge. Adding a bed of concrete atop the formation,

Figure 3–7

The Electromagnetic Spectrum



we have propagated a carrier wave. When we ride a car across the bridge, we have superimposed a signal, or modulated the carrier wave.

Radio Frequencies Only a small part of the electromagnetic spectrum is utilized for AM and FM broadcasting and related transmissions. This range spans from long waves of very low frequency to extremely short waves of relatively high frequency. In general, the higher one goes in the spectrum, the more sophisticated the electronics needed in the modulation process. Unlike AM and FM, new satellite radios use very high frequencies beamed from a geostationary satellite to your car or home. Pretty amazing.

Each new development in electronic media has taken us higher in the spectrum. Radio broadcasting began toward the low end of the spectrum, in the area ranging from 0.3 to 3 megahertz (mega = million), a region known as the medium waves. Included in this region is the range of 550 to 1,605 kilohertz (kilo = thousand), which is the range of the AM radio dial. In fact, in many countries AM is still referred to as the medium-wave (MW) band.

The high frequencies (which, with satellite and infrared communications, actually aren't so high anymore) range from 3 to 30 megahertz. These waves are utilized for long-range military communications, CB, and ham radio. Since high-frequency waves can be used to transmit signals over greater distances than can medium waves, this part of the spectrum has been used for over 50 years by international shortwave stations such as the BBC and the Voice of America. The shortwave band on a radio is sometimes labeled HF, for high frequencies.

The next group of radio waves used for telecommunications applications is the very high frequencies, or the VHF band. VHF ranges from 30 to 300 megahertz. Television stations operating on channels 2 to 13, FM radio stations, police radios, and airline navigation systems are located in this band.

Above the VHF channels are the ultra-high frequencies, or the UHF band, spanning the region from 300 to 3,000 megahertz. This part of the spectrum is used for TV stations 14 to 83, including most of the new digital TV stations, police and taxi mobile radios, radar, and weather satellites. In addition, it is UHF radiation that is modulated to cook our food in microwave ovens.

Much of recent telecommunications development has occurred in the next two radio bands: super-high frequencies (SHF) and extremely high frequencies (EHF). SHF spans from 3,000 to 30,000 megahertz and EHF from 30,000 to 300,000 megahertz. Commercial satellites—which deliver pay cable channels, superstations, advertiser-supported cable networks, and satellite news—emanate from these bands, as do new developments in digital audio broadcasting, military radar, and air navigation.

Spectrum Management Keeping track of all these uses of the electromagnetic spectrum is difficult and requires substantial domestic and international regulation, a process known as *spectrum management.* In the United States, decisions regarding which services operate in which regions of the spectrum, and at what operating power, are handled primarily by the Federal Communications Commission (FCC) and, to a lesser extent, the National Telecommunications Information Administration (NTIA). Here's how broadcast radio and TV service is administered in the United States.

Radio channel classifications At the latest count more than 13,700 radio stations were on the air in the United States. Yet there are only 117 AM channels and 100 FM channels. How is this possible? The answer is spectrum management. By controlling operating hours, power, antenna height and design, and other factors, the FCC squeezes all radio stations into the 217 channels. If you can imagine 13,700 cars competing for 200 parking spaces (kind of like the first day of classes), you have a sense of the task at hand.

- *AM channels and classifications*. The 117 AM channels are divided into three main types: 60 are clear channels, 51 are regional channels, and the remaining 6 are local channels. Here's how the system works: The clear channels are frequencies that have been designated by international agreements for primary use by high-powered stations. Such stations use ground waves in daytime and sky waves at night to reach a wide geographic area, often thousands of miles. The United States has priority on 45 clear channels. Stations on these frequencies include some of our oldest and strongest. Class A stations, like WABC in New York at 770 kilohertz, WJR in Detroit at 610 kilohertz, KFI (640 kilohertz) in Los Angeles, and KMOX (1120 kilohertz) in St. Louis, have the exclusive right to the clear channel after sunset. They operate at high power, from 10,000 to 50,000 watts. Class B stations use either clear channel or regional channel frequencies, but many must operate at reduced power at night to avoid interference. Their power outputs range from 5 to 50 kilowatts. Class C stations are designated as local stations. Ranging in power from 250 to 1,000 watts, Class C's must share channels with numerous other stations. To do this they generally use directional antennas and strategic placement to blanket their main population areas. Over 2,000 Class C stations share six local channels. These stations are mostly at the right or top end of the dial (above 1,230 kilohertz).

- *FM channels and classifications.* In 1945 the FCC set aside the region from 88 to 108 megahertz for FM. This allowed room for 100 channels, each 200 kilohertz wide. This means that when your FM radio is tuned to 97.3 the station is actually radiating a signal oscillating from 97.2 to 97.4 megahertz. Of the 100 channels, 80 were set aside for commercial use. The remaining 20 channels, located from 88 to 92 megahertz, were reserved for educational and noncommercial stations.

To facilitate the development of commercial FM, the FCC divided the United States into three regions. Zone I includes the most densely populated area of the United States: the Northeast. Zone I-A covers the southern California region. The rest of the country composes Zone II. FM stations also use A, B, and C designations. Class A FM stations operate in all zones, Class B's in Zone I, and Class C's only in Zone II.

Each class is defined by its effective radiated power (ERP), the amount of power it is permitted to use. Class C FMs are the medium's most powerful. They can transmit up to 100,000 watts (ERP). They may erect transmitters with a maximum height above average terrain (HAAT) of 600 meters. Class B's can generate up to 50,000 watts ERP at 150 meters HAAT, and Class A's are authorized to a maximum of 3,000 watts ERP at 100 meters HAAT. Unlike AM radio, both FM and television signals must have a line of sight in order to be received. As a result, the height of the transmitter above average terrain is an important consideration for how far the signal will travel. At maximum power and antenna height, Class C's can cover about 60 miles, Class B's about 30, and Class A's up to 15. In January 2000, the FCC created a new low-power service, limiting stations to a maximum of 100 watts ERP with an antenna height of 30 meters HAAT. These new low-power stations have a coverage radius of approximately 3.5 miles and are available only as a noncommercial service.

Sidebands and subcarriers The bandwidth of FM (200 kilohertz) allows these stations to transmit more than one signal on their channel. Such signals use the area above and below the station's carrier frequency, known as the *sideband.* The most common use of the sideband is to disseminate separate signals for the left and right channel to broadcast stereo. This is called **multiplexing.** If you have an old FM stereo receiver, it may be labeled "FM multiplex."

FM station operators may use additional spectrum space to send multiplex signals, which can be tuned only by specially designed receivers. To do this, stations apply to the FCC for a subsidiary communications authorization (SCA). Such services include the "background" music one hears in malls and elevators, a Talking Book service for the blind, telephone paging, data transmission, and special radio services for doctors, lawyers, and some others.

Although technically the process is not the same, AM stations can use their carrier waves for other purposes as well. Many AM stations transmit a subaudible tone used in utility load management. A subscriber, such as a business, rents a special receiver. During peak electric use hours the station transmits a tone that turns off the subscriber's appliances. When the peak load period is over, another subaudible tone turns them back on.

Digital radio In 2003, a new hybrid digital radio was approved for general broadcasting. Digital AM and FM radio transmissions are encoded within the sidebands of the radio channel. These new services allow a radio station to send entirely different analog and digital programs to listeners. And because the program is digital, like CDs, it is unaffected by static and other problems that plague analog transmission. Digital AM broadcasts will be closer to full fidelity than current analog AM signals and digital FM will be equal to satellite radio–quality broadcasts. Both AM and FM digital broadcasts will be able to show data information such as song titles and artists. This will allow local broadcasters to compete more effectively with satellite radio.

Video Transmission

As might be expected, the TV signal, with its complex set of information (including picture, sound, color, blanking, and synchronization signals), requires enormous amounts of space in the electromagnetic spectrum. More than any other reason, this explains why there are over 13,000 radio stations but only about 1,700 TV stations on air in the United States.

The Television Channel Each TV station, both analog and digital, requires a bandwidth of 6 megahertz. This is equivalent to enough space for 30 FM radio stations and 600 AM stations!

The NTSC system was perfected in the 1930s and 1940s when amplitude modulation (AM) techniques were considered state-of-the-art. For this reason it was decided to transmit the TV picture information via AM. Two-thirds, or 4 megahertz, of the TV bandwidth is used for picture information. Interestingly enough, interlace scanning was chosen as a way to conserve bandwidth. The sound signal is essentially a full-range FM, or frequency-modulated, signal, oscillating at 25 kilohertz above and below its center (carrier) frequency. The remainder of the video channel is occupied by protective guard bands that keep the various encoded signals from interfering with one another.

TV Allocations The complexity of the TV signal and its vast need for space caused the FCC in the 1940s and 1950s to assign it a place higher in the electromagnetic spectrum than any that had been utilized in prior years.

Channels 2 to 13 are located in the **very high frequency (VHF)** portion of the spectrum, the area ranging from 54 to 216 megahertz. Interestingly, a sizable portion of the VHF band is not used for TV purposes. The area between channels 6 and 7 includes the space for all FM radio stations as well as aircraft-control tower communication, amateur or "ham" radio, and business and government applications.

Channels 14 to 83 lie in the **ultra-high frequency (UHF)** portion of the band, the region between 470 and 890 megahertz. There is another gap, this time between channels 13 and 14, which is reserved for government communications.

VHF stations 2 through 6 can achieve excellent coverage transmitting at a maximum of 100 kilowatts. Channels 7 to 13 require power up to a ceiling of 316 kilowatts. However, channels 14 and above need power up to 5,000 kilowatts to generate an acceptable signal (the UHF maximum is 10,000 kilowatts). In addition, more sophisticated antenna arrays are required. So viewers often have difficulty locating UHF stations on their dial, and, once stations are located, tuning and maintaining a clear signal can also be problematic. The FCC's freeze on new stations from 1948 to 1952 (discussed in Chapter 1) also hurt UHF's development. The existing stations were all VHFs and had established loyal audiences before UHF even got started.

For these technical and historical reasons VHF stations have tended to travel "first class" in the TV business, while UHF properties have typically been relegated to the "coach" section.

From NTSC to ATSC: Digital TV Channels The end is near for analog! In 2006, Congress told the FCC to finalize its plans for the transition from analog to digital television broadcasting. Previously, each existing TV station had been given a second UHF channel, 6 megahertz wide, to use for its new digital broadcasts, and most broadcasters are now broadcasting in both analog and DTV. The new digital channel allocations are 2 through 36 and 38 through 51. Once the conversion takes place, the old remaining TV channels 52 through 69 will be auctioned for other purposes.

The transmissions standards that we discussed earlier in this chapter were set by an industry group—the Advanced Television Standards Committee (ATSC)—in the mid-1990s. (For engineering and computer fans, the standard uses the MPEG-2 video compression format and the 8-VSB modulation format.) To speed the transition to DTV, the FCC mandated that all new televisions manufactured after March 1, 2007, must be able to receive digital television signals, even if the television is standard-definition TV. In addition, a timetable was set for TV stations to move from analog to digital. Congress set February 18, 2009, as the deadline when all full-power television stations will cease broadcasting an analog signal; however, low-power television stations will be converted to digital transmission at a later date.

Satellite Transmission

A common sight on lawns, homes, and businesses is the satellite dish, which has become an important means of radio and television transmission. These dishes are all pointed up to the sky to one or more of the dozens of communications satellites in orbit about 22,000 miles above the earth. These satellites are launched into an orbit that moves at the same rate as the earth rotates, a technique known as **geosynchronous orbit.** For all intents and purposes, the satellites are "parked" in their unique orbital slots.

Satellite Terminology Satellite technology has introduced a new vocabulary into telecommunications. Because of the complexity of their operations, the amount of information they carry, and the power needed to send a signal through the earth's atmosphere and back, satellites operate in the **super-high frequency (SHF)** portion of the electromagnetic spectrum. Technically speaking a satellite is a *transponder.* Satellites receive their signals from a ground station, which is called an *uplink.* The satellite then amplifies the signal and rebroadcasts it to a downlink (like a TV station or cable head-end) or in the case of DBS to a home receiver. Just as new developments led radio and TV to move up the spectrum, the same has happened in satellite communications. The first geosynchronous satellites were assigned to the area ranging roughly from 4 to 6 gigahertz (gHz, or billions of cycles) in an area known as the *C band.* Newer, more-powerful satellites operate from 12 to 14 gigahertz, a region known as the *Ku band.*

Direct Broadcast Satellite The year 1994 saw the launch of a new form of communications, known as **direct broadcast satellite (DBS).** DBS makes use of higher-powered satellites with a much larger footprint than traditional C- and Ku-band "birds" (as satellites are sometimes called). In addition, rather than needing a 3-meter dish (the size you see in some backyards), DBS receivers are only 18 inches wide. They can be made to work successfully on a rooftop or window ledge, much like the TV aerials of yesteryear.

DBS satellites use MPEG-2 and MPEG-4 compression to send signals to home receivers. Data rates are fairly high, enabling a home to have several receivers tuned to different channels simultaneously.

Marketed by such firms as DirecTV and The Dish Network, DBS has enjoyed widespread consumer acceptance. Today DBS reaches one in four TV households. One of the newest wrinkles in DBS technology is the use of spot beams to deliver local television channels to satellite viewers. Newer DBS systems can receive signals from several satellites simultaneously, making reception of both standard-definition and high-definition signals possible.

Digital Audio Broadcasting If we can get direct satellite-to-home TV, why can't we also get direct satellite-to-car radio? Well, we can. **Digital audio broadcasting (DAB)** combines the technique of digital compression (advanced audio compression, or AAC), which made MP3 audio practical and popular, with super-high-frequency transmission (such as that used for satellites and microwaves). The result is CD-quality sound from a home or car radio without the need for records, tapes, discs, or your local radio station.

Modern computers can function as digital workstations.

In 1997, the FCC auctioned off part of the spectrum to two companies, and five years later they began beaming digital audio to cars and homes. XM and Sirius Radio transmit all-digital radio services to subscribers across America, and both services offer nearly 150 channels of unique programming and traffic information. XM beams its signals to customers from two geosynchronous satellites (appropriately named *Rock* and *Roll*), while Sirius uses three satellites that rotate in an elliptical orbit. The satellites transmit in the 2.3 gigahertz digital audio radio service (DARS) band. A small car-phone-sized antenna that fits unobtrusively on the roof of an automobile is used to receive the services.

Back to the Future: The Return to Wired Communications

As we traced in Chapter 1, the modern era of broadcasting began with the liberation of the telegraph by Marconi's wireless. Ironically, a century later, much of the change in contemporary telecommunications is due to the return to prominence of wired communications. This trend is led by the phenomenal growth of cable television and the rise of the Internet.

Cable Transmission Shortly after World War II a new type of cable, called *coaxial cable,* was developed to support the burgeoning telephone industry. In addition to handling thousands of simultaneous telephone conversations, this cable was soon found to be an excellent conduit for disseminating TV signals. Since then, cable TV has become an increasingly widespread and important means of TV signal carriage.

Coaxial cable, or "coax" for short, consists of two electronic conductors. At the center is a copper wire shielded by a protective insulator called the *dielectric.* Outside the dielectric is a wire mesh, typically made of copper or aluminum. This conductor is shielded by a durable plastic coating, the outer body of the cable. This design gives the cable some special properties. The shielding keeps the signals within a confined space, reducing the electrical interference common in normal wiring (like that in household appliances) and extends the cable's life. Coaxial cable can also carry its own power source, which allows signals to travel comparatively long distances with little signal loss or noise.

Over the years, as the materials used to make coaxial cable improved, the number of TV signals transmittable by cable increased. In the 1950s cable TV systems could carry only three to five TV signals. Transistorized components and new cable materials raised cable channel capacity to 12 channels. The cable explosion in the 1970s came about as further technical refinements allowed cable systems to carry as many as 60 TV channels, as well as a range of other services (FM radio to data, text, and so on).

As you can see, local cable operators can exert a kind of media power that broadcasters cannot. Within certain limits (see Chapter 5), they—not the FCC—can control where a given TV station is placed on the cable. In addition, cable systems can reuse their own frequencies simply by installing two cables side by side. Moreover, a cable company can construct a system that allows communication from the receiver to the headend, enabling two-way, or interactive, communication. Newly introduced digital cable uses digital compression techniques to increase the channel capability of coaxial cable even more, making on-demand, pay-TV options and multiple programming sources (HBO1, ESPN2, etc.) a reality. Digital cable systems boast more than 200-channel capacity, although the technology is capable of providing even more channels in the future.

Another advantage of cable is addressability, the ability of a cable system to send a program to some houses that request it and to not send it to those that don't. Addressability is important in the development of pay-per-view TV, where only a portion of subscribers are willing to pay extra to watch a recent movie or sports event.

This flexibility accounts for cable's great expansion in recent years. Originally a source of improved reception of only three or four nearby TV stations, the cable has become a broadband source of local and regional broadcast stations, distant superstations, sports, movies, and other special-interest channels to more than two-thirds of the nation. The introduction of high-speed cable modems allowed cable to offer high-bandwidth Internet service in addition to cable programming, and now many cable systems are offering bundled telephone service (Voice over Internet Protocol, or VoIP).

For nearly half a century, two different wires connected most homes, for communications purposes. The common "twisted pair" brought telephone calls into and out of the home. The "coax" connected subscribing households to a cable television company. However, both telephone companies and cable systems are now installing a new kind of cable that allows the telephone companies to provide video service and the cable companies to handle telephone calls. Battle lines are forming due to this new means of video signal distribution.

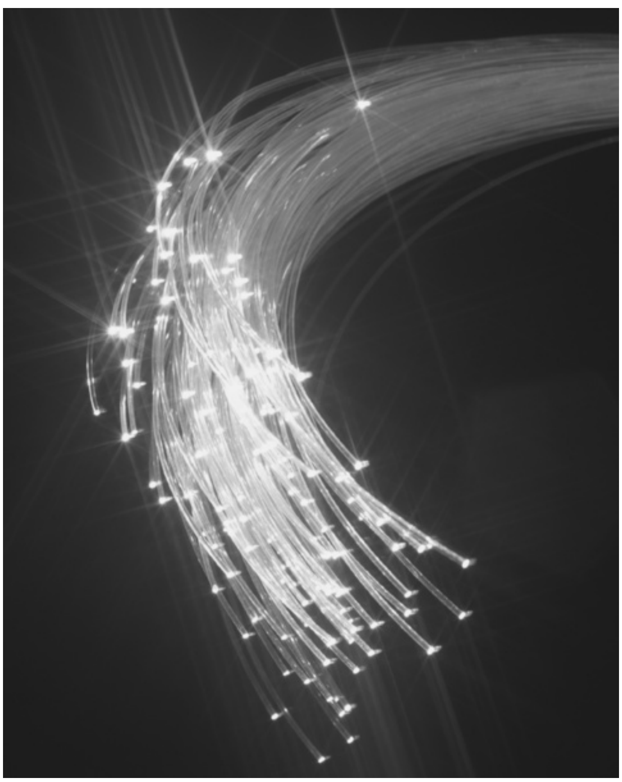
Fiber Optics Fiber-optic cable is a kind of "wireless wire." Instead of the copper and aluminum elements found in coaxial cable, fiber-optic cable contains strands of flexible glass.

Fiber-optic technology makes use of digital communications. That is, the electrical signals normally transmitted through conventional wire are converted into light pulses transmitted by a laser light source. These on-off (binary) pulses are decoded at the receiving source by a photodiode, a small, light-sensitive device. The process is similar to the way DVDs produce high-quality pictures and sound.

Fiber-optic cable has excellent potential in its applications to telecommunications. Electrical interference is nonexistent since there is no real electricity in the wire. Fiber is thinner and more flexible than coax, and perhaps most important, the bandwidth is virtually limitless. On the downside, amplifying fiber-optic signals is hard to do, as is connecting and switching fiber-optic transmissions.

Fiber-optic technology is at the center of the struggle now emerging between the telephone and cable industries. Regional telephone companies are replacing their copper wires with fiber optics and have announced their intentions to offer video services in competition with cable. Cable companies have also been busy installing fiber in their operations. The benefits of fiber over the traditional copper cable are significant: clearer video and audio, low maintenance costs, and a virtually unlimited capacity for video and Internet services.

The pure, noise-free digital signal passing through the fiber connection into the home can be a telephone call, a radio show, a modem connection to the Internet, or a TV program. It should not be a surprise to the reader, then, that TV, cable, and telephone companies are in the process of entering each other's businesses to one degree or another.



A fiber-optic bundle. Eventually fiber optics will replace the copper wires that now carry TV and telephone signals.

STEP 4: SIGNAL RECEPTION

We've now modulated, amplified, mixed, and transmitted an audio or a video signal. The next step is reception: capturing that signal on a receiving device, such as a radio or TV set. As you might expect, the once-simple task of tuning a radio or dialing in a TV station has become quite complex. Just think of how many different remote control devices you own, or how many different entertainment boxes are connected to your TV set. Let's trace trends in some common audiovisual reception devices.

Radio Receivers

AM (MW) Band Receivers The location of AM radio in the medium-wave part of the spectrum has several advantages. Long telescopic antennas are normally not needed, and a good signal may be received even when the radio is in motion. This makes AM ideal for car radios. AM radios can take almost any form, from microscopic transistor versions to large tabletop models. At night AM signals can travel hundreds of miles. While good reception should only be a matter of moving the receiver slightly for best tuning, the sad fact is that most AM radios are fairly inferior in design, making the radios sound worse than they should.

In addition, consider some of the disadvantages associated with AM: A check of the spectrum chart shows that the MW band is precariously close to the bandwidth of electrical energy. Thus AM radios are prone to interference and noise, heard mostly as static. In cars, energy produced by engines and electrical systems can often be heard on AM. At home, one can "hear" vacuum cleaners, lights turned on and off, and so forth. Buzzing and whining are often present as a result of carrier wave interactions with other AM stations. These distractions make AM difficult for serious listening.

Another limitation of AM reception has to do with its limited frequency response. As you know, AM stations generate signals in a bandwidth only 10,000 hertz wide. Recall that the human ear can hear a bandwidth about twice that. As a result, you may have noticed that AM sounds somewhat thinner or tinnier than FM (with a 15,000-hertz response). AM is best suited to speech and music of limited orchestration. Hence news/talk and sports tend to be popular AM formats; however, new high-definition digital AM transmission may bring quality music back to AM in the future.

FM Receivers The evolution of the FM receiver has followed an interesting path. From the beginning, the noise-free dynamic range of FM made it a natural element for the hi-fi enthusiast's home audio system. Thus many early FM tuners that had to be plugged into Dad's hi-fi system in the den. However, when FM stereo boomed in the late 1960s, consumers demanded FM in forms they had become familiar with in AM: in cars, transistor radios, table models, and so on. Thus most radios manufactured after 1970 were capable of both AM and FM reception. As a result, FM moved from an "add-on accessory" to the most important part of the radio receiver.

Since the FM signal requires a line of sight from transmitter to receiver, there are some potential pitfalls in signal reception. First, FM normally requires a long antenna, in the shape of a telescoping rod or a wire. The antenna needs to be directed for best results. FM signals tend to be blocked by buildings or moving objects with signals fading in and out in rural areas or in dense, city environments. Reception can also be improved by attaching the radio antenna to a TV antenna and in some areas by hooking the receiver to the cable TV system.

Moreover, multipath distortion is commonly experienced in cars when a station's signal is reflected off buildings or tall objects. Unlike the AM signal, this type of signal distortion is seldom heard as static. Instead, the distortion manifests itself as a blurring of the sound, sibilance, or a brittle sound. To solve this problem, the FM antenna needs to be redirected to minimize multipath.

Multiband Receivers Today virtually all radios offer both AM and FM bands. Recently the National Association of Broadcasters began pushing digital terrestrial radio, and we are beginning to see AM/FM HD radios being marketed by several manufacturers. Other receivers can monitor channels used by police and fire services, and some radios feature a weather band, capable of tuning in to the nearest government weather station. Weather radios can automatically turn themselves on to announce a weather alert and are very popular in the Midwest, where residents are subject to tornado warnings. Also popular are radios with "TV sound": These allow listeners to keep up with "soaps" and sports while at the beach or at work. Finally, many car radios are now being made with satellite reception capability in addition to AM and FM.

"Smart Radios"—Radio Broadcast Data Systems Digital technology makes possible a new generation of "smart" FM radio receivers. Using their subcarrier frequencies, FM stations can send information signals to the receivers. On such radio sets, a small display can provide a readout of the station's dial location, call letters, format, and even the name of the program.

These new smart radios are known as **radio broadcast data systems (RBDS).** Advertisers are excited by one new feature called "coupon radio," which allows the listener to record information from the RBDS screen (such as a secret password) and use that information when making a purchase.

Satellite Radios Most automotive radio manufacturers now offer either XM or Sirius radios as options. As we noted in earlier chapters, satellite radio has about 13 million listeners and is growing. New models of satellite receivers can be used in boom boxes and in the home, extending the usefulness of the two services. XM has even introduced a satellite radio/MP3 player that allows the user to download favorite channels and then play them back on a music player about the size of an iPod.

TV Receivers

Improvements in our media devices usually are confined to making the items either grossly large or incredibly minute. For example, consider the contrast in radios between nearly piano-sized boom boxes and personal stereos custom-fit to the human ear canal. Changes in size and shape head the list of new developments in TV as the industry embraces HDTV.

Large-Screen TV In the early 1970s wall-sized TV screens began appearing in bars, nightclubs, and conference facilities. Today they are slowly creeping into the home video environment.

Large-screen TVs come in two main types. The first is the projection TV systems that beam the red, green, and blue elements that compose the color signal through special tubes to a reflecting screen suspended at a distance from the video unit. This is the type of system most commonly seen in sports bars.

The second type of large-screen TV that is rapidly gaining in popularity is the slim wall-mounted TV. These TVs are either plasma or LCD televisions. Unlike standard TVs, which are bulky and heavy, LCD or plasma TVs may be only a few inches thick, but they can produce startlingly excellent-quality pictures with extremely high resolution and vivid color. Both LCD and plasma TVs can act as computer monitors because they accept both digital and analog inputs. While they are way cool, they're also pricey.

Plasma screens are illuminated using tiny red, green, and blue fluorescent lights to form the image. Just like a standard television, the plasma display varies in intensity of color and brightness; however, plasma screens are made of thousands of tiny fluorescent lights that vary in proportion to the picture being displayed. Each fluorescent element is a plasma, a gas made from charged ions and negatively charged particles (electrons). When a signal is applied, the ions and electrons collide, releasing energy in the form of light.

Liquid crystal displays (LCDs) are different yet! Two thin membranes hold millions of liquid crystals in place, and as electric signals pass through the membranes, the liquid crystals interpret the signal as in either an ON or OFF state. In an ON state, they allow light to pass through them, and fluorescent tubes behind the membranes illuminate the image corresponding to the electrical signal.

Small-Screen TV For some TV enthusiasts smaller is better. These folks like to take the TV with them to the ball game, the beach, the office, or elsewhere. To satisfy this demand, manufacturers have introduced the visual equivalent of Sony's revolutionary Walkman radio design. Sony and its competitors, Casio and other Japanese manufacturers, have merged microprocessor technology and display expertise to produce smaller and smaller TV sets.

A couple of major problems have hindered the diffusion of this technology. For one thing, the screens are so small, they tend to produce very low light levels. Hence they can get drowned out by bright sunlight (a big limitation if you're at a day baseball game or the beach). Another fault is inherent in the medium: Unlike radio, a TV must be watched (at least some of the time) to be enjoyed. For obvious reasons the Watchman thus has limited success.

However, small DVD players have become popular additions to family minivans. Personal viewing screens are mounted behind the front console or on the ceiling, allowing families to watch their favorite movies while traveling along the highway. Also, portable DVD players are very popular with teenagers and frequent air travelers. These small players usually have a 7- or 8-inch screen and can play several DVDs on one battery charge.

Digital TV Sets How many times have you tried to watch two or three TV programs simultaneously? Using a remote control or nimble fingers, you flip continuously from one to the other—playing a sort of TV musical chairs—and end up missing the important parts of all programs. Well, if you're an inveterate flipper (like the authors), the digital receiver is for you. The integrated microchips that make tubeless cameras and micro-TVs practical have made it possible for the TV screen to display more than one channel at a time. The technique is known as *picture-in-picture (PIP).*

Digital TVs also perform other electronic tricks. Suppose, when watching a baseball game, you decide to try to see the catcher's signs to the pitcher. Zoom allows you to fill the entire picture with just one small detail you would like to see, in this case the catcher's hands. To really get the sign, you can stop the picture momentarily, a technique known as *freeze frame.*

New midsized LCD screens are making an impact as well. These sets can be used for computers or as televisions. Perhaps one of the most striking aspects of LCDs is that they're only a few inches wide and can be easily mounted on your wall. LCDs come tailored for the 16-by-9 format, meaning you can watch TV or DVD movies in the wide-screen format, as they were meant to be viewed. Not all LCD televisions are high definition; however, some LCD TVs are called EDTV (meaning enhanced television). New sets by Sharp and Samsung come in sizes up to 40 inches wide, and some can actually display a split screen, half television and half computer. LCD prices have dropped dramatically in the last two years. The price ranges for LCD TVs start at $500.

STEP 5: STORAGE AND RETRIEVAL

The final step in audio and video technology is the storage and retrieval of sounds and moving images. As we all know, old programs never die: They live on forever in reruns. Some of the great growth industries in mass media in recent years are based on improved means of storing and accessing images, including the video store, nostalgic TV networks like Nick at Night, TV Land, and, yes, the Nostalgia Network. In fact, one of the benefits of the World Wide Web is that the content of all the memory of all the computers connected to the Internet is accessible to any single user. Increasingly, that content includes sounds and pictures, not merely text. Yet, not too long ago (in the 1940s and 1950s), radio and TV programs were still "live," as recording methods were noisy and inefficient. Even today, the complex signals involved in speech, music, motion pictures, and TV tax the storage and processing capacity of even the fastest microcomputers, so we're still a bit away from dialing up on our PC any movie ever made. Let's see where things stand with respect to radio and TV storage and retrieval.

Audio Storage

Phonograph Recording The old standby, the phonograph record, has been around since the turn of the century. From that time, the sizes and speeds have been changed, but the basic design has remained consistent. Today, the most common record format is the 33⅓ revolutions per minute (rpm), 12-inch, high-fidelity recording. Few new records are issued each year, but many people still have record libraries.

Magnetic Tape Recording The development of magnetic tape recording was revolutionary for both radio and TV. Unlike earlier recording methods, such as disc and wire recordings, magnetic tape was of very high fidelity. For all intents and purposes, radio and TV programs recorded on magnetic tape sounded just like they were "live." Tape recorders became the heart and soul of radio and TV operations.

Digital technology has all but replaced analog magnetic tape as the recording media of choice in broadcasting. However, some high-quality cassette recorders are still used by radio reporters to record meetings and to do interviews in the field.

While most manufacturers have pretty much abandoned production of analog tape recorders, many musicians and audio engineers prefer their rich, full sound when compared with the crisp, clean sound of digital recordings. Thus, reel-to-reel and cassette audio recorders promise to remain in use in recording studios for some time to come.

Video Storage

Magnetic Video Recording As we stated in Chapter 2, the videotape recorder (VTR) made its network debut with *The CBS Evening News with Douglas Edwards* on November 30, 1956. But it hardly resembled today's tabletop VCR. (Pardon us as we romp through a brief Jurassic tape history.) For nearly 20 years, TV's tape machines were the size of a refrigerator-freezer and required four hands (two people) to operate them. The reels of tape, as big as 35-mm film canisters, were 2 inches across (thus, these were called 2-inch recordings). But they produced excellent, long-lasting copies of TV programs.

The next revolution in videotape recording was started by the Japanese. At the forefront of the emerging field of microelectronics, Sony technicians, in the late 1960s, perfected a means of storing the complex video signal on narrower tape, moving at slower speeds.

The idea was to stretch the magnetic tape around the revolving recording head so that there was virtually continuous contact between the tape and the recording head. For an analogy, imagine that instead of taking a single piece of chalk to one blackboard at the head of the class, your instructor had a piece of chalk in each hand and foot and was surrounded by a huge cylindrical blackboard. This technique became known as helical-scan tape recording, since the heads are positioned obliquely to the tape and the lines of picture information produced on the tape form the shape of a helix.

The birth of a standard: ¾-inch VTR The helical-scan recorder had many advantages. Tape width shrank from 2 inches to ¾ inch, which had financial as well as technical advantages. The tape could be packaged in a protective case; thus the videocassette became popular. Most important, the size of the tape recorder shrank. In the early 1970s it became practical to send cameras and recorders into the field for coverage of breaking news and live sporting events. Although a number of helical-scan recorders had been introduced, by 1975 the industry had standardized. The 2-inch machine gave way to the ¾ -inch VTR.

The VTR was soon a fixture in TV production. After its introduction, recorders became small, portable, and usually dependable. Editing from one machine to another became easy, especially with the development of computer-assisted editing equipment. And the entire field of broadcast news changed: The era of electronic news gathering, or ENG, was launched.

Home video In 1976 Sony introduced its first Betamax videocassette recorder (priced at a hefty $1,200); today the $49 home VCR has become the centerpiece of a revolution in the way we view TV.

The key was the development of high-density recording. Basically, the difference between broadcast-quality ¾-inch VTR and the ½-inch system introduced in the late 1970s is that the new system eliminated guard bands on the videotape, providing more room to store the picture signal on a reel of magnetic tape. Essentially, the VCR sacrificed some picture quality for smaller, lighter, and cheaper recorders with longer recording times. Clearly, the compromise was worth it: By 2002, more than 93 million U.S. homes (about 90 percent of all households) had acquired VCRs.

Initially there were two competing varieties of ½-inch helical-scan VCRs. Sony and its licensees used the Beta format; machines produced by Panasonic, JVC, and other manufacturers used VHS. For 10 years, a debate raged about which system was best; however, in the interim the American consumer had decided on the standard. Since more prerecorded tapes were available in the VHS format, by the mid-1980s the home market had more or less standardized in the VHS format.

Beta videotape didn't die off, however. A high-fidelity version, Beta-SP, became a vital part of professional TV production. At home, ½-inch tape was shrunk even further, into a compact version of VHS (VHS-C) and another popular Sony format, only 8 millimeters wide for small handheld camcorders.

Digital Video Recording It should come as no surprise that the digital revolution sweeping the audio industry soon spread to television recording. The first wave of digital video recording was the appearance in the early 1990s of digital videotape. Today, many TV studios boast camera and editing systems that utilize digital videotape. Sony's system is easy to spot: Its equipment uses the DV prefix to denote digital videotape. DVC-Pro is the line of machines in widest distribution.

In a way, digital videotape is a hybrid recording system, combining the analog system of putting images on magnetic tape with the new digital sampling techniques. With the increasing processing and storage capacity of today's computers, it's possible to go all-digital. Why have tape at all? Why not store all the TV sounds and images on a computer server or a DVD or Blu-Ray recorder? More and more TV facilities, from CNN International to large-station newsrooms, have no VCRs in sight. Systems like Final Cut Pro and Avid Express have moved TV news and entertainment programming production from linear editing suites to nonlinear desktop computer consoles.

Digital Versatile Disc (DVD) and DVD Recording The DVD playback format has become enormously popular since its introduction. Movie studios put extra features on DVDs and frequently release new movies on DVDs first, since the cost to produce DVDs is lower than videotape. It is no wonder that DVD recorders have being introduced into the marketplace by consumer electronics manufacturers. The recording devices are capable of better picture resolution than VCRs and provide a stable storage environment too. Videotape can become old and brittle over time, but DVDs should last forever (provided the format is not made obsolete by some other technical advance).

Recently two new competing DVD formats have been introduced, and the real performance benefit is that they can record and play back HD (high-definition) content. One system is called HD-DVD (logically), and the other is called Blu-ray Disc (BD), so called because it uses a blue laser.

Both formats promise huge storage capacity (for both the playback of HD movies and as storage

Issues: Pirates Threaten World Commerce! But Is It Really Illegal?

No, that's not a newspaper headline from the eighteenth century. It's a modern, global problem. Today's digital technology and the widespread popularity of VCRs, audiotape recorders, and now recordable CDs have made illegal copying of music, movies, and recordings a worldwide growth industry. To make matters worse, some of the illegal activity may actually be . . . well, almost legit. According to Ken Hansen of Canada's Royal Canadian Mounted Police, organized crime is getting involved in these activities because it is seen as a low-risk, high-reward activity.

It is common today for illegal copies of first-run movies to be available on DVD from street-corner vendors, whose wares may also include audiotapes and CDs, and fake name-brand cosmetics or leather goods. In fact, in Russia, illegal DVDs of popular movies like *Spider-Man 2* were available on the street within a few days after its theatrical release! The economic impact of this phenomenon is staggering. The Justice Department puts losses of intellectual property in the $250 billion range.

Illegal copies are being made and sold all over the world. In the United States, the Recording Industry Association of America (RIAA) and record companies won a major victory over Napster and Grokster, but new peer-to-peer file-sharing programs have replaced the defunct file-sharing services.

In Hong Kong, customs inspectors smashed a pirate recording factory in the To Kwa Wan district that had been producing more than 40,000 video discs each day. All the seized discs contained illegal copies of American movies, some still in the theaters. In Britain the Federation against Copyright Theft (FACT) shut down a major bootlegging ring at one of London's largest open-air markets. While these individual raids make headlines, thousands more pirated CDs and DVDs, particularly from mainland China and Russia, escape detection. And it's a big problem. Some estimate that 300 million pirated DVDs were produced in Russia alone in 2005.

In what may be a groundbreaking precedent, some entrepreneurs have taken advantage of Russian law and created an illegal music downloading service that may be legal. Allofmp3.com is a Russian online music store with a fancy Web site (in both English and Russian), offering music downloads for as little as 7 cents. *Pet Sounds,* the Beach Boys' masterpiece album, is offered for $1.11! In contrast, iTunes Music Store charges $9.99 for the same album. The company says that it's in compliance with Russian copyright, governed by the Russian Mulitmedia and Internet Society and general laws, which unlike the U.S. regulations do not cover individual downloading of music files. But here in the United States, Allofmp3.com is at the top of the office of the government's list of the world's most notorious piracy markets. There is a fierce debate going on currently between record companies and Allofmp3.com. The British Phonographic Industry (BPI) has won approval to serve proceedings against the Web site, and U.S. trade negotiators have warned Russia that the Web site could jeopardize Russia's entry in the World Trade Organization. According to Russia's 1933 copyright law companies that collect royalties for use of foreign artistic works are not obligated to pass them on to the International Confederation of Societies of Authors and Composers. At the moment, it seems perfectly legal to use this illegitimate music service.

devices for the next generation of computers). Still it is not clear which technology consumers will embrace. Microsoft has said it will incorporate HD-DVDs as an accessory, while Sony will add Blu-ray technology to PlayStation 3 consoles. At this time (2006) Blu-ray has more studios promising HD movie releases, but it also a more expensive technology. While the initial sets are priced high: $500 for HD-DVD and $1,000 for Blu-ray, consumer electronics become more affordable over time.

Digital Video Recorder (DVR) The DVR is a video recorder that uses a computer hard drive as the main storage device. The recorder, marketed under such trade names as TiVo and Replay, connects to your cable box and telephone. It has the ability to record and play back television shows via a remote control, but its ability does not stop there. The TiVo is essentially a set-top computer that collects information about what television shows are on and when. You can tell the device what you like, and it will record programs for you. For example, you could program the TiVo to record every episode of *House* for an entire season. And because the machine allows instant record and playback access, you could skip through the commercials on a program or pause live TV. (Skipping

The digital versatile disc player is rapidly replacing the VCR.

through commercials gives some advertising executives pause to embrace this technology.) While TiVo and Replay both require a monthly fee to get access to the program guides, penetration has been rising since their introduction in 1999, particularly among DBS homes where the satellite companies have been packaging them with the service. However, the real growth has been in the cable arena, where cable companies are now marketing generic DVRs built into cable set-top boxes. While DVR penetration was only about 12 percent of all U.S. households (in 2006), some researchers predict that number will rise to 30 percent penetration by 2010. Some analysts wonder what the impact of DVR usage will be on American television viewing habits.

WEBCASTING: AUDIO AND VIDEO STREAMING

We close this section on audio and video technology with a technique that's blurring the lines between computers, TV sets, and radio receivers. The technique, called **streaming,** allows sounds and moving pictures to be transmitted on the World Wide Web and other computer networks. It allows these complex, high-memory transmissions to travel on high-speed cable modems or digital subscriber line (DSL) connections and even on slower, comparatively low-capacity bandwidths, such as 56K modems.

Streaming audio and video makes use of two nifty shortcuts called **buffering** and **compression.** To put a complex radio or TV signal on the Web, the signal is first "shrunk" and then transmitted in a much simpler form, using techniques of digital compression. Essentially, the complex signal is sampled, and redundant, nonessential information is stripped away, to be added back later (in decompression).

MP3 audio streams from SHOUTcast.com and RealAudio streams from NPR.org are just two examples of real-time feeds over high-bandwidth cable and DSL modems. CNN.com, ABC, NBC, and FOX are now podcasting prime-time programming using iTunes technology. Even so, music and moving video images are sometimes still too complex to transmit in real time over narrow bandwidths, like telephone lines. The solution is to stop playback for a short time so the computer hard drive can store the necessary information. It then begins playback, all the time replenishing the drive with new, incoming signals. This technique is called buffering.

Playing sounds and moving images on the Web requires special software. Featuring brand names like Quicktime, RealAudio, RealVideo, Shockwave, and Windows Media Player, these programs allow desktop computers to become more like radio and TV receivers. The software display controls are similar to a radio or TV set (with tuning buttons and volume controls). There are now literally hundreds of audio channels and radio and TV stations that can be heard and seen on any computer hooked to the Net (so long as it has a sound card, speakers, and the appropriate media player software).

The success of Apple's iPod has spawned new technology and new terminology over the past few years. The iTunes Music Store allows users to download daily or weekly news and entertainment shows. Individuals can post their own programs on podcasting Web sites, and new software programs like iLife have made the creation of personal audio and video programs extremely easy. We discuss this in greater detail in Chapter 6.

SUMMARY

- Broadcasting, cable, and new media make use of facsimile technology, reproducing sound and sight in other forms. The better the correspondence between the facsimile and the original, the higher the fidelity.
- Transduction involves changing energy from one form to another; it is at the heart of audio and video technology. Transduction can be analog—the transformed energy resembles the original—or digital—the original is transformed into a series of numbers.
- Audio and video signal processing follow five main steps: signal generation, amplification and processing, transmission, reception, and storage/retrieval.
- *Signal generation.* Audio signals are generated mechanically, by using microphones and turntables; electromagnetically, by using tape recorders; and digitally, by using laser optics. Television signal generation involves the electronic line-by-line scanning of an image. An electron beam scans each element of a picture, and the image is then retraced in the TV receiver.
- *Amplification and processing.* Audio and video signals are amplified and mixed by using audio consoles and video switchers. Today's digital technology enables sophisticated signal processing and a variety of special effects.
- *Transmission.* Radio waves occupy a portion of the electromagnetic spectrum. AM radio channels are classified into clear, regional, and local channels. FM stations are classified according to power and antenna height. The wide bandwidth of an FM channel allows for stereo broadcasting and other nonbroadcast services. There are two types of digital radio: satellite-based and terrestrial radio, encoded within the AM and FM signals. The traditional systems of transmitting a TV signal are (1) over-the-air broadcasting utilizing electromagnetic radiation on channels located in the VHF and UHF portions of the spectrum and (2) by wire through a cable system using coaxial cable that can carry more than 100 channels of programming. New distribution technologies include fiber optics, satellite transmissions, and digital distribution using computer networks.

  Television and radio are moving to new forms of digital distribution. On the TV side, the FCC has mandated a switch to digital high-definition television by 2009. That process is currently under way at the nation's TV stations and networks.
- *Signal reception.* Radio receivers pull in AM, FM, and other signals, in monaural or stereo. New digital multiband receivers are becoming more prevalent. In TV, large- and small-screen receivers have attained record sales in recent years, abetted by new digital capabilities and "smart" remote control devices.
- *Storage and retrieval.* New technology is reshaping audio and video storage and retrieval. Phonograph records, compact discs, and videotapes are being supplemented and may ultimately be replaced by digital storage media, such as recordable CDs, digital versatile discs (DVDs), and high-capacity disk drives on computers. A comparatively new phenomenon, audio and video streaming, permits radio and TV stations to send their complex signals onto the Internet. Today, any home computer with a sound card, a CD-ROM drive, and a microphone can produce and distribute its own radio and TV programs. The impact of this development on traditional radio, TV, and cable is unclear.

KEY TERMS

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SUGGESTIONS FOR FURTHER READING

Austerberry, D. (2004). *The technology of video and audio streaming* (2nd ed.). Amsterdam: Focal Press.

Bertram, H. N. (1994). *Theory of magnetic recording*. New York: Cambridge University Press.

Cicora, W.; Farmer, J.; Large, D.; & Adams, M. (2003). *Modern cable television technology* (2nd ed.). San Francisco: Morgan Kaufman.

DeSonne, M., ed. (1996). *International DTH/DBS.* Washington, DC: National Association of Broadcasters.

Luther, A. (1997). *Principles of digital audio & video.* Norwood, NJ: Artech House.

Menin, E. (2002). *The streaming media handbook.* Englewood Cliffs, NJ: Prentice Hall.

Hausman, C.; Benoit, P.; Messere, F.; & O'Donnell, L. (2007). *Modern radio production* (7th ed.). Belmont, CA: Wadsworth.

O'Leary, S. (2000). *Understanding digital terrestrial broadcasting.* Boston: Artech House.

Paulsen, K. (1998). *Video & media servers: Technology and applications.* Woburn, UK: Butterworth-Heinemann.

Persson, C. (1999). *Guide to HDTV systems.* Clifton Park, NY: Delmar.

Pohlmann, K. C. (1992). *The compact disc: Handbook of theory and use* (2nd ed.). Madison, WI: A-R Editions.

Robin, M., & Poulin, M. (2000). *Digital television fundamentals.* New York: McGraw-Hill.

Weise, M., & Weynand, D. (2004). *How video works.* Amsterdam: Focal Press.

Whitaker, J. (2001). *DTV: The revolution in digital video.* New York: McGraw-Hill.

Zettl, H. (2003). *Video basics 4.* Belmont, CA: Wadsworth.

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