Show Bookmarks

Excerpt from

Introduction to Telecommunications

Preview

The following is a sample excerpt from a study unit in the Telecommunications Technician program. The sample has been converted into the Adobe Acrobat format.

The word *telecommunications* literally means "communicating at a distance." Exactly what type of communication is this? Well, the distance can be as short as the width of a room, or as long as the distance between continents. The communication can take place over a length of copper wire, or span the globe traveling through undersea cables, microwave stations, and earth-orbiting satellites.

The nature of communications can be simple, such as a casual conversation between friends on the telephone. Or, it can be very complex and crucial to the economic stability of a major corporation. An example of such a critical communication would be the encoded and compressed digital information that confirms an international, multimillion-dollar electronic transfer of funds.

The study unit on which this excerpt is based provides an introduction to the fascinating technology behind distance communication. In this excerpt, you'll learn about the different mediums used to carry data.

After reading through the following material, feel free to take the sample exam based on the excerpt.

Contents

Introduction to Telecommunications

WHAT IS TELECOMMUNICATIONS?

Think back over the week that has just passed. Chances are, sometime during this week you've done at least one of the following things:

- Used a telephone
- Watched TV or listened to the radio
- Used an automatic teller machine (ATM)
- Paid for a purchase using a credit card
- Used a personal computer to read E-mail

Every day, millions of people engage in activities such as these without a second thought. Many millions also use fax machines, talk on cellular telephones, and take part in teleconferences with voice and video (Figure 1). Each of these activities (and many more) depends on our ability to transmit enormous amounts of information over great distances in a very small amount of time. That's what telecommunications is all about.

In this study unit excerpt, we'll introduce you to the fascinating world of telecommunications. We'll also discuss some of the technology that's used to transmit information, and the vocabulary that's used to describe it.

FIGURE 1—A few of the many different activities that use telecommunications are shown here. As shown in (A) and (B), the most common use of telecommunications is the telephone and cell phone. Funds transfers at ATM machines (C) and international banks (D) also require telecommunications connections.

Communicating at a Distance

The literal meaning of the term *telecommunications* is "communicating at a distance." Telecommunications applications touch our lives in familiar ways every day as we use the telephone, listen to the radio, or watch television. Making a credit card purchase, using an automatic teller machine, and cashing a personal check also involve communicating at a distance. The newest and most rapidly growing telecommunications activity is connecting personal computers to online services that access the Internet.

The telecommunications industry started when Alexander Graham Bell invented the telephone back in 1875. At the time, Bell's invention for transmitting the human voice from one point to another seemed revolutionary. Visionary that he was, Bell could hardly have imagined how his invention would evolve. The simple telephone, and the advanced technology that has developed from it, has become the backbone of the telecommunications industry.

After the telephone was invented, it took more than forty years before it could be used to make a call across the country. The electrical impulses that carried the voice from one telephone to another traveled over copper wires laboriously strung across countless thousands of telephone poles. It was a marvel of the day, but quite crude by today's standards (Figure 2). Nevertheless, the science of telecommunications had been born and the world would never be the same.

FIGURE 2—In its day, this telephone was considered to be state-of-the-art.

Today, the human voice is still transmitted over copper wires, but it can also be transmitted in other ways. Furthermore, the human voice isn't the only kind of data that's transmitted. Every day, new types of communications are established that involve data transmissions between computers and other electronic devices. In the near future, it's probable that the voice transmissions that started with Bell will represent the minority of the communications that flow over our telecommunications networks.

Data Transmission

The transmission of data is what telecommunications is all about. The data being transmitted can be a human voice speaking on the telephone, a television picture broadcasting over the airwaves, or encrypted data authorizing a credit transaction. The telecommunications network doesn't care what type of data is being transmitted. Generally speaking, it will handle all data in exactly the same manner.

Let's look at a few everyday examples of data transmissions. Suppose that an American tourist traveling in Hong Kong uses her credit card to make a purchase. Authorizing the credit will require two-way data communications from the point of purchase in Hong Kong to her bank in New York, half a world away. The data flows through copper wires, undersea cables, land-based microwave relay links, and satellites that are orbiting in space. The purchase is authorized, and the entire transaction is completed in just five seconds.

In another example, suppose that a telecommunications technology student uses his personal computer to log onto the Internet. He then enters the term "telecommunications" into a search program. Within seconds, the system identifies more than 50,000 documents that contain the keyword. The documents are actually stored in thousands of different computers located all over the world. With a few keystrokes, the student selects a document, and it appears on his screen ready to be printed out.

We tend to take these everyday activities for granted and forget that complex technology is required to make them possible. Scores of trained telecommunications technicians are needed to install, support, and maintain the vast network of technology that makes transactions such as these possible. At one time, only scientists had access to computers, laser technology, and digital data transmission. Now, these technologies have all advanced to the point where they're available to everyone, and people use them as routinely as they pick up the phone to order a pizza. More than ever before, our society depends on complex data transmissions for ordinary daily living.

Now that you understand how data transmissions are used and why they're so important, let's take a closer look at how information is actually transmitted. When you speak on a telephone, the sounds of your voice are converted into an electrical signal that represents the volume and tone (the frequency) of your voice. This signal is called an analogy or "analog" of the actual voice. This *analog signal* can be represented by a *waveform* as shown in Figure 3A. As the loudness of your voice goes up and down, the signal waveform also goes up and down. The spacing of the waves represents the tone or frequency of your voice. In electronics, the frequency is measured in hertz, a term you'll learn much more about later.

Analog data transmission was used almost exclusively up until the decade of the sixties. At that time, the computer began to be a factor in electronic communications. Over the next twenty years, computer technology advanced at an explosive rate. Computers got progressively smaller, faster, more reliable, and cheaper. The computer chip became a reality, and digital communications began to replace analog as the mode of choice in many telecommunications applications.

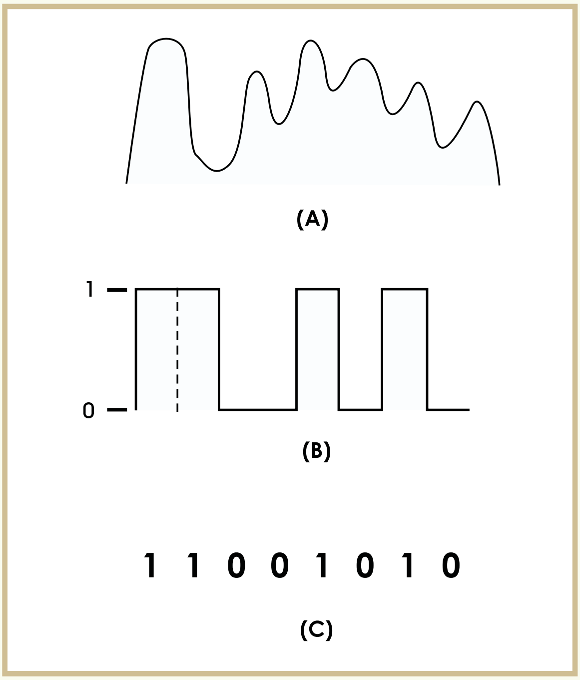
Computers speak a language of their own—a digital language. In a digital transmission, a signal is actually represented as a series of numbers. For example, the amplitude of a voice signal might be represented by numbers from 1 to 10, with 10 being the highest amplitude (a shout) and 1 being the lowest (a whisper). The frequency or tone of the signal could also be represented by numbers. The number 10 might represent a frequency of 4,000 hertz, and the number 1 might represent a frequency of 30 hertz. Numbers in between 1 and 10 would represent corresponding amplitudes between the whisper and the shout, and frequencies in the range between 30 hertz and 4,000 hertz. These varying numbers are used to form a digital signal with bars of varying heights. Figure 3B shows how the human voice characteristics of tone and volume can be translated into a digital signal.

Thus, an original voice signal can be represented by a series of numbers that stands for tone and volume, as well as by an analog signal. However, one more factor must be discussed before you understand how all this relates to digital communications.

Computers, as we've already stated, speak a language of their own. This language is digital and is represented *by only two digits*: one and zero. These ones and zeros can be manipulated inside the machine by switches. When a switch is closed, it represents a one; when the switch is open, it represents a zero. Using only ones and zeros in this way greatly simplifies the hardware inside the computer.

The ones and zeros can represent any number by using the conventions of a *binary numbering system* instead of the decimal system we're accustomed to. So, in order to be understood by a computer, the numerical values in a digital signal must be converted to binary values. The digital signal shown in Figure 3B can therefore be represented by a binary sequence, as shown in Figure 3C. Binary numbering systems will be explained in more detail in later study units. For now, it's enough to understand that any decimal number can be represented by a binary sequence.

FIGURE 3—An analog signal representing a human voice is shown in (A). This same analog signal can be converted to a digital signal, as shown in (B), and then to a binary number sequence, as shown in (C).



Here are two important ideas you should understand from this discussion. First, any kind of data or information can be represented in either analog or digital form. Second, the characteristics of data or information can be represented by the amplitude and frequency of an analog signal or by numbers in a digital signal.

Now that you know that data can be converted to an analog or digital format, you're ready to explore how data can be transmitted.

HOW IS DATA TRANSMITTED?

Three basic elements are required for a telecommunications link—a transmitter, a transmission medium, and a receiver (Figure 4). The *transmitter* and the *receiver* are any type of device (such as telephones, fax machines, computer modems, and so on) that are designed to send and receive data. The transmission medium is the information path that will carry the data. Let's begin our examination of data transmission by taking a closer look at transmission mediums.

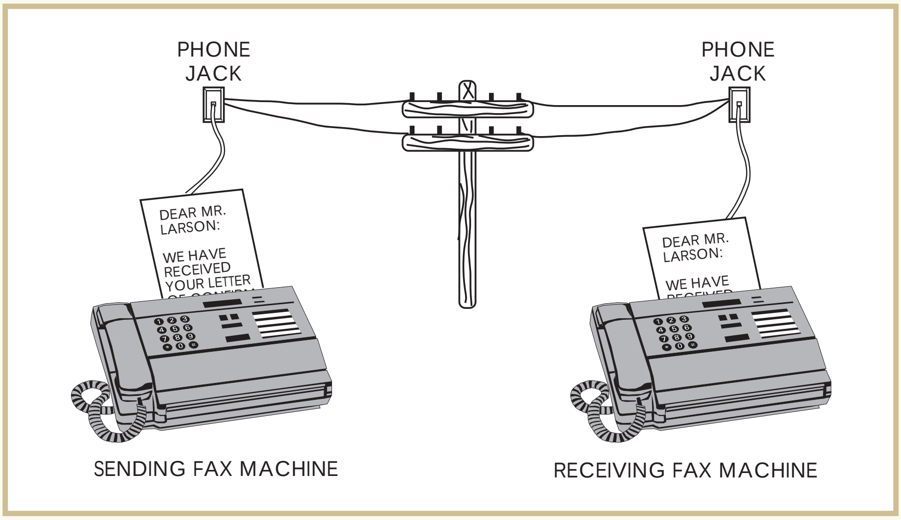


FIGURE 4—A telecommunications link requires a transmitter, a transmission medium, and a receiver. In the example shown here, the transmitter is the sending fax machine, the receiver is the receiving fax machine, and the transmission mediums are the copper wire and fiber-optic cable in the telephone lines between.

Transmission Mediums

Converting data (such as a human voice) into some kind of an electrical signal is the first step in transmitting data. The electrical impulses may represent the voice in either digital or analog form. The form of the data often dictates the transmission medium that will be used to carry the signal from the point of origin to the point of reception.

Data signals need to be converted to analog or digital form so that they can be handled by some kind of transmission medium. When we convert data to digital or analog form, we actually convert it to an electrical signal that can be transmitted over the various information paths that circle the globe. On the receiving end of the path, equipment such as a telephone or television converts the signals back into the data that originally produced it—a television picture or a human voice, for example. The information paths or mediums that data flows over are called *transmission mediums*. Without a transmission medium, a voice could only be transmitted as far as a shout can be heard.

Modern telecommunications technology uses three different transmission mediums—copper wiring, electromagnetic waves, and fiber-optic cable. Each of these mediums can carry both analog and digital signals. Each has certain advantages and disadvantages, depending on the application in which it's used. In practical telecommunications networks, you'll see all three mediums used on one information path.

Copper wiring is the oldest and most familiar means of conveying data (Figure 5). Despite numerous innovations and improvements to existing technologies, more copper wire is carrying data today than ever before. However, even though the use of copper wiring is growing, the *overall percentage* of data carried by copper wiring is diminishing.

FIGURE 5—Copper cable is one of the oldest means of conveying electrical signals. Braided copper cables like these are used as service entrance lines and in industrial applications.

Ordinary copper conductors are the medium of choice in many telecommunications applications, particularly where the links cover short distances. Data is often transmitted over copper conductors in the form of analog signals. For example, local telephone conversations are analog electrical impulses that travel over copper wires.

Electromagnetic waves carry signals through the airspace, whether that airspace is within the earth's atmosphere or outside the atmosphere in the vacuum of space. Conventional radio waves, or electromagnetic radiation, travel within the earth's atmosphere, while satellite communications travel through space to satellites in orbit.

Fiber-optic cable is made up of many tiny strands of glass fiber that are bundled together and protected by an outer covering (Figure 6). You may think of the strands as being "light pipes." That is, beams of light are directed into one end of the cable and then transmitted along the length of the cable. The beams follow any twists or turns that the cable makes. Analog or digital signals can be placed on the light beam and transmitted along the length of the cable, just as they can with copper wiring.

FIGURE 6—A fiber-optic cable is made up of a bundle of thin glass strands like those shown here.

Bandwidth

At this point, you may be wondering why we would go to all the trouble of using fiber-optic cable and light beams to transmit data when copper wiring seems to do the job much more simply. The fact is, each transmission medium has certain advantages in terms of cost and suitability to the application at hand.

One of the important factors that will affect the selection of a transmission medium is bandwidth. *Bandwidth* is a term that's used to describe the information-carrying capacity of a given medium. For example, a 3-inch-diameter water pipe can carry many more gallons per minute than a 1-inch-diameter pipe. In a similar way, some telecommunications links are capable of carrying much more information per unit time than others. When we're talking about transmission mediums, the greater the bandwidth, the more data the medium can carry per unit time.

Information density and *data transmission per unit time* are other expressions that mean the same thing as bandwidth. The greater the information density, the greater the bandwidth of a medium. In a typical telephone application, fiber-optic cable can carry thousands of times more information than copper. Thus, fiber-optic cable has a greater bandwidth than copper cable. For this reason (and others that we'll explore later in the program), fiber-optic cable is rapidly replacing copper wire in many data communications applications.

Bandwidth is measured differently in analog links than in digital links. In an analog link, the bandwidth is determined by the *range of frequencies* that the medium will effectively transmit. If an analog link can carry signals in the frequency range of zero to 4,000 cycles per second, it's said to have a bandwidth of 4,000 cycles per second. A bandwidth of 4,000 cycles per second is equal to 4,000 hertz, or 4 kilohertz. You may be familiar with the term *cycle.* It refers to how quickly a signal or power source (like the alternating current that comes from an outlet in your house) changes. In your studies of AC electricity, you'll learn much about this term. A *hertz* is a unit of measure that's defined as one cycle per second. The prefix "kilo" means "one thousand," so 1 kilohertz is equal to 1,000 hertz. Kilohertz is a shorter term that's more convenient to use, so we'll use this term throughout the remainder of your program.

In contrast, digital data links define bandwidth using the term *bits per second*. The word *bit* is derived from the term *binary digit*, and it refers to the ones and zeros of a digital signal. Recall that in a digital link, characteristics such as the amplitude and frequency of a signal are represented by ones and zeros. It makes sense that the more rapidly we can transmit the ones and zeros, the more information we can convey in a given time period.

The bandwidth of practical analog and digital data links is typically in the range of hundreds or even thousands of kilohertz. You'll often see the prefixes *mega* (meaning one million) and *giga* (meaning one billion) used in bandwidth specifications.

One final area of discussion in the context of bandwidth is the electromagnetic spectrum, as shown in Figure 7. By looking at the figure, you can see that the human eye responds to only a very small fraction of the electromagnetic spectrum. We can't begin to imagine what our world would look like through eyes that could see this entire spectrum. Certainly, it would be very different from the one we see now.

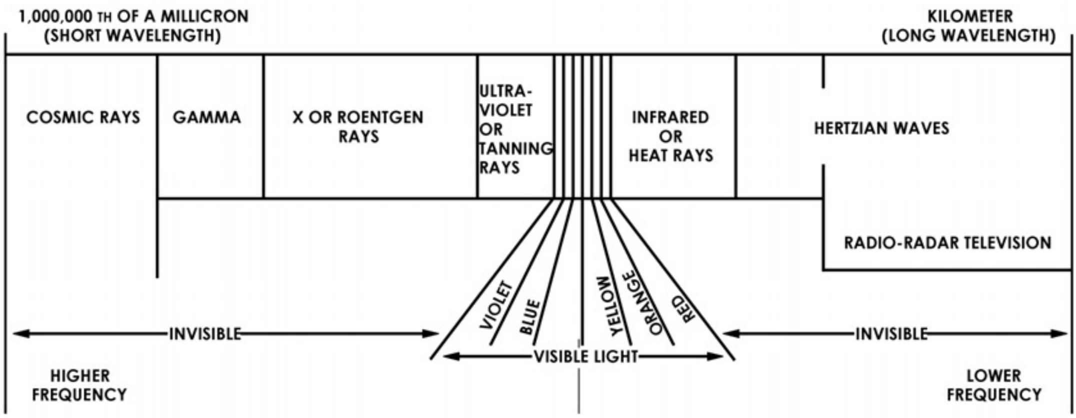


FIGURE 7—This chart shows the electromagnetic spectrum.

As a rule, the higher the frequency that's used in a communications link, the greater the theoretical bandwidth becomes. Therefore, it's desirable to use the highest frequencies possible in a system where band width is an important consideration.

Microwave Stations

Microwave antennas are a familiar site along our highways and atop the tallest buildings in our cities. Very high-frequency signals are used in microwave transmissions. The signals are transmitted by one station and picked up by another in a sort of "chain," allowing a signal to be transmitted over great distances.

High-frequency microwave signals behave very much like visible light. They can be focused by a reflector, such as a parabolic dish. They can also be focused by a reflector, such as the parabolic dish of a dish antenna. Thus, because the signals can be blocked by obstructions, the transmitting and receiving stations must be within "line of sight" of each other (Figure 8).

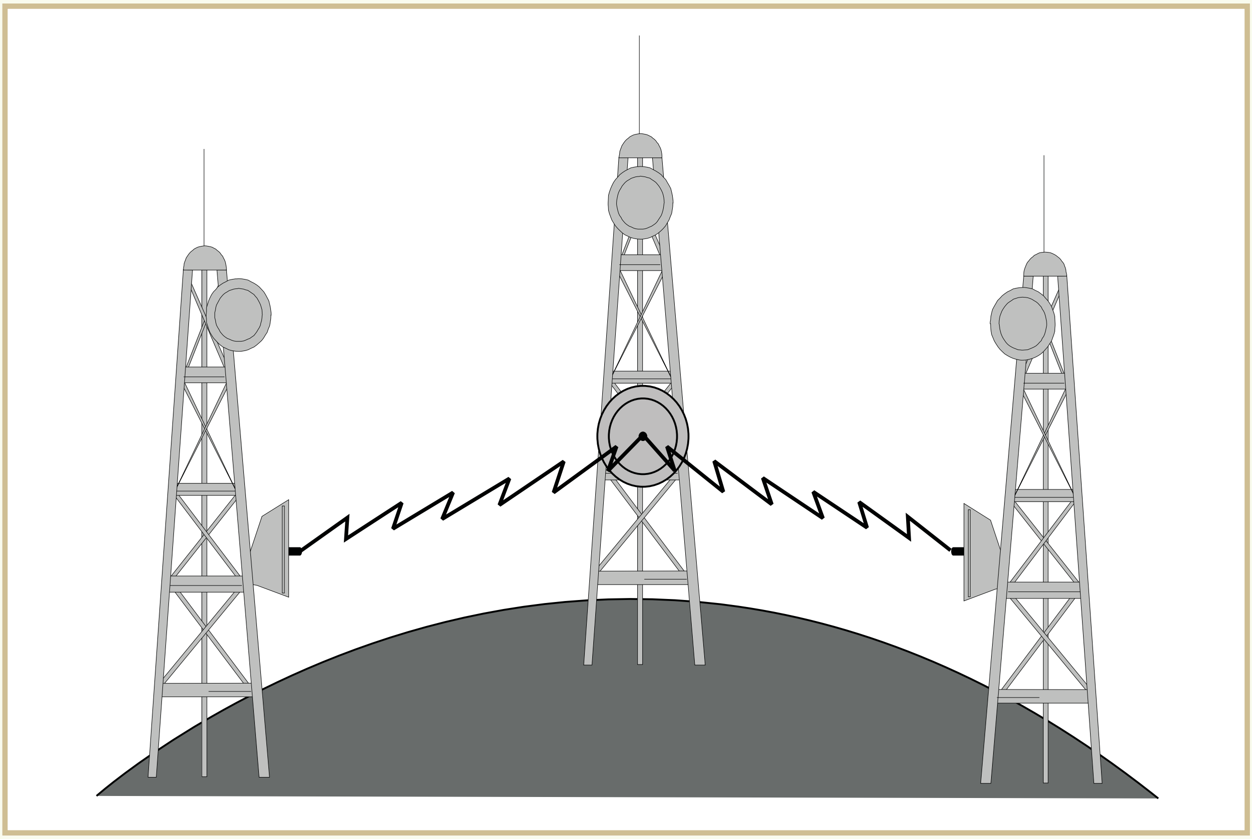


FIGURE 8—Microwave transmitting and receiving stations must be located within "line of sight" of each other to prevent the link from being broken.

Microwave signals can be transmitted over great distances through the use of relay stations. *Relay stations* or *repeaters* are used to route microwave signals around man-made and natural obstructions. Stations on top of buildings and mountains simply amplify and retransmit or "repeat" the signals they receive. Microwave transmission links such as these carry network television broadcasts, as well as long-distance telephone communications. Huge distances can be spanned by mounting repeater stations in high towers or on top of mountains, where the unobstructed line of site is greatest (Figure 9).

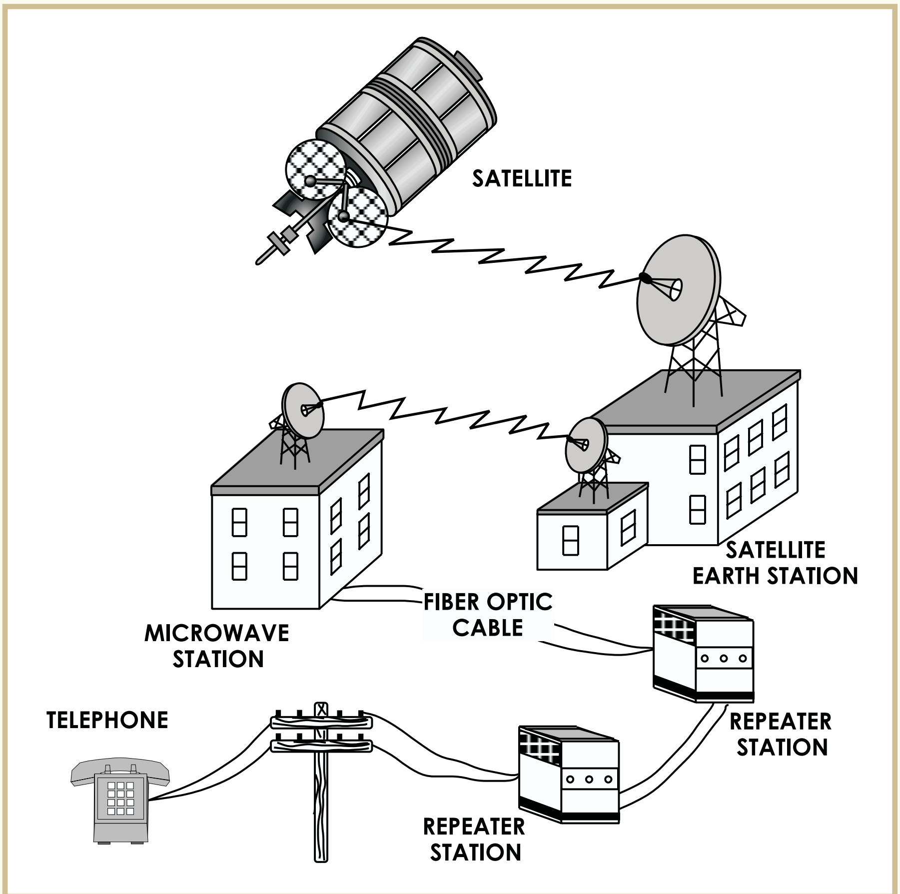


FIGURE 9—Relay stations or repeaters are used to route microwave signals around both man-made and natural obstructions. The stations are often located on towers or on the tops of tall buildings.

Satellites

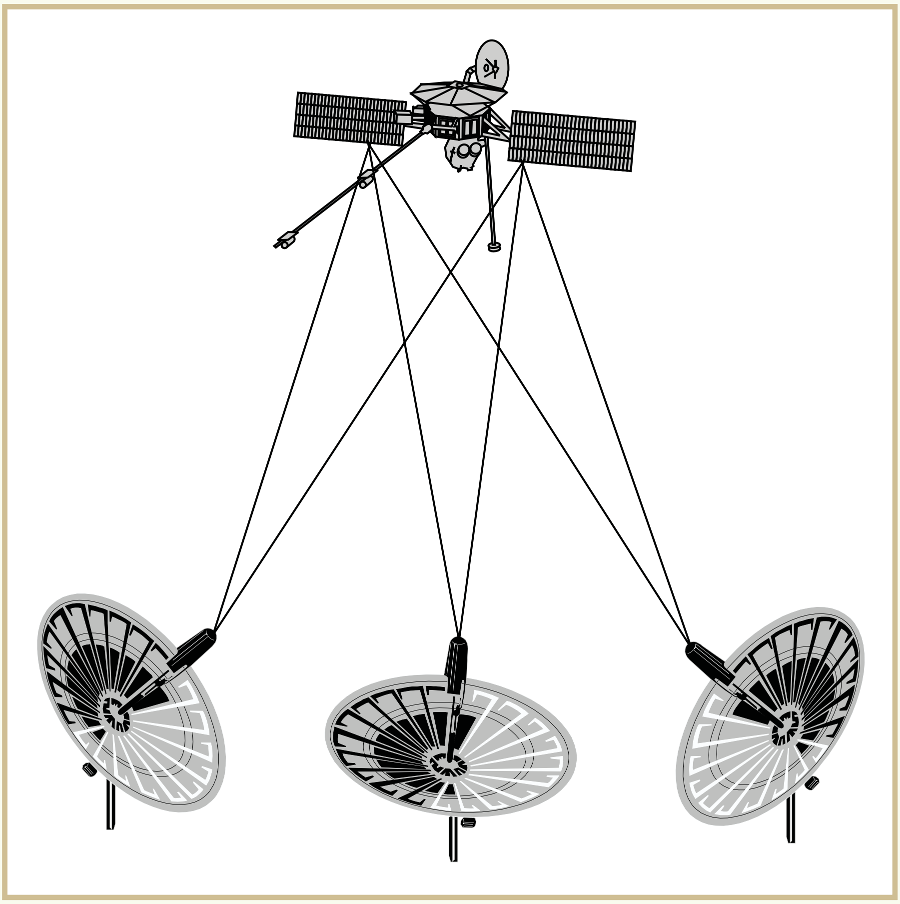
Many years ago, all intercontinental data communications took place through undersea cables. The first undersea cable was laid all the way back in 1858. After more than a year of heartbreaking failures, a message from Queen Victoria was finally successfully transmitted over the cable. The signal at the receiving end of the cable was so weak that it pushed the receivers to the limit of their capabilities, even though they were sophisticated for their time. The message had to be retransmitted repeatedly because of missing text, and the 90-word message from the queen ultimately took more than 16 hours to complete.

Today, although undersea cables are still used, they're rapidly being replaced by satellites. Hundreds of thousands of different data transmissions can all pass simultaneously through a single satellite. The messages travel at the speed of light, and the error rate is infinitesimally small.

The space program is responsible for much of the progress in satellite technology. Placing satellites in known orbits around the earth has made it possible to transmit data over the entire globe in a matter of seconds. The location of these communication satellites is so precisely known that they can be used to measure the "drift" of continents on the earth's surface to within a few inches. This indicates the incredible precision of this technology.

Telecommunications satellites fall into two major categories—passive and active. *Passive satellites* reflect the signals that are directed to them without altering the signals in any way (Figure 10). Passive satellites are reflectors that are placed high above the earth—they merely echo the signals that are transmitted to them. An earth station beams microwave electromagnetic energy at the passive satellite, and the satellite reflects it like a mirror to some other point on the earth's surface. Passive satellites are useful for producing reliable long-range communications over rough terrain, or to overcome the line-of-sight limitations that are produced by the curvature of the earth.

FIGURE 10—Passive satellites reflect the signals that are transmitted to them without altering them in any way.



Passive satellites are inexpensive and reliable due to their inherent simplicity. However, because passive satellites reflect signals that may already have traveled thousands of miles, very powerful transmitters and supersensitive receivers must be used with them to ensure that the data makes the journey without any distortions.

In contrast, *active satellites* amplify the signals that are transmitted to them and then retransmit the signals at a much higher power level (Figure 11). Active satellites are much more sophisticated than passive satellites. An active satellite will capture and "wash" a signal to eliminate any interference it may have picked up before retransmitting it back to earth. The satellite may also greatly amplify the signal before retransmission to ensure that a clean, high-level signal will be available to the hundreds (or even thousands) of earth stations that will receive it.

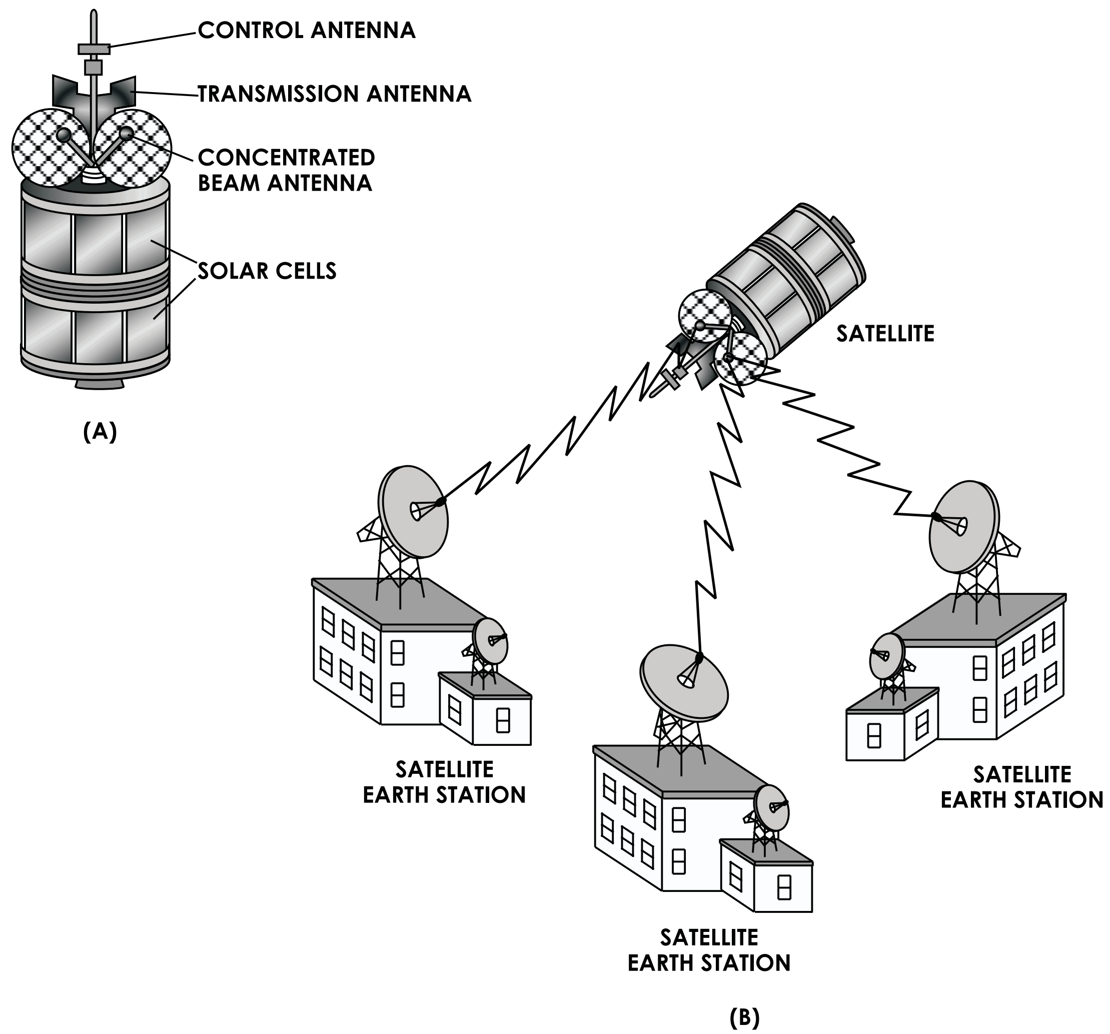


FIGURE 11—An active satellite (A) eliminates interference from the signals that are transmitted to it, amplifies the signals, and retransmits them back to earth (B).

Lasers

Back in the spring of 1962, after months of experiments, a scientist in an obscure laboratory made some electrical connections to a length of ruby rod, and then turned on the power. A moment later, the most intense red light ever seen on earth was generated. This was the birth of the laser.

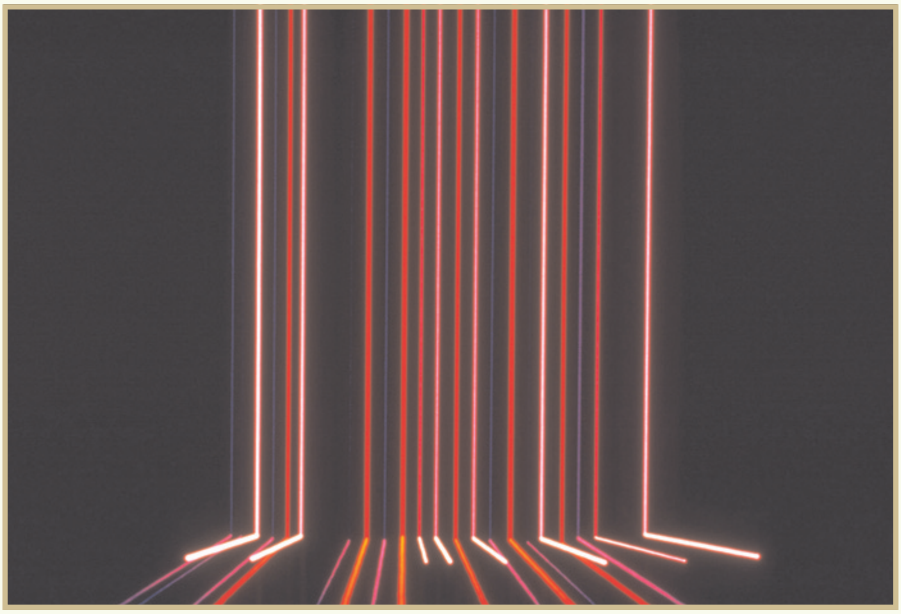
The term *laser* is an acronym that stands for *light amplification by stimulated emission of radiation*. This lengthy expression describes the action that makes the laser work. For our purposes here, it isn't important to understand precisely what this expression means. It's enough to know that a laser is a source of intense, highly focused light. Laser light is a very special kind of light that has important applications to data communications.

Laser-generated light has several characteristics that make it easy to control and an ideal medium for data transmission. First of all, laser light is *monochromatic*. The prefix "mono" means "one," and the root word "chrom" means "color." Thus, the term "monochromatic" means "one color." Laser light is made up of just one color of light that occupies a single frequency in the electromagnetic spectrum. In contrast, light from incandescent lightbulbs, fluorescent lamps, and the sun actually consist of many different colors that cover a broad range of frequencies in the visible spectrum. If sunlight is focused through a glass prism, you can see that "white" light is actually made up of red, orange, yellow, green, blue, indigo, and violet colors. Because laser light is just one color, it's easier to control for data transmission applications.

Another characteristic that's peculiar to laser-generated light is *coherence*. A coherent light source has special properties that make it possible to focus it into an extremely tight beam (Figure 12). Ordinary light can't be focused as tightly. Even with the most carefully designed reflector, ordinary light will spread apart as the distance from the source increases. In contrast, a laser beam won't spread apart very much, even over very long distances. For example, if a laser beam was projected onto the moon's surface (a quarter of a million miles away), it would illuminate a circle only one mile in diameter. This example illustrates just how tightly a laser can be focused and controlled.

A laser could be used for data transmission directly through the atmosphere. However, it would be very vulnerable to interruption—even more so than microwave energy. Unlike the electromagnetic energy from microwave stations, laser light would be obstructed by rain, snow, or fog. For this reason, lasers typically supply the light source to send data through a fiber-optic cable. Here, the light is unimpeded, and may be bent to follow the path over which the cable is routed.

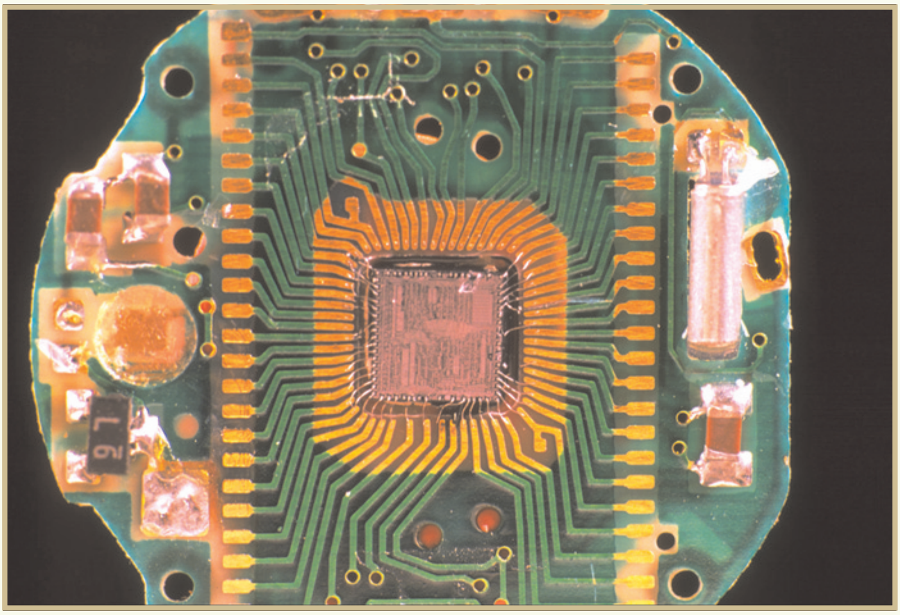
FIGURE 12—Laser light is monochromatic and can be focused into a very tight beam.



Microprocessors

No single development has had a greater impact on telecommunications technology than the microprocessor. A *microprocessor* is a computer processor that's contained on a single, tiny integrated circuit chip (Figure 13). At one time, computers were huge—they filled entire rooms and were incredibly expensive to produce. Now, similar equipment fits on a desktop and is available at a price every consumer can afford.

FIGURE 13—A typical microprocessor is shown here under magnification. These tiny computer chips are incredibly powerful.



It has been said today that computer performance rates double every 18 months, and costs drop 30 percent. The tiny microprocessor made this revolution possible. If automotive technology had progressed at the same rate as computer technology, today we would be able to buy a luxury automobile that would travel at the speed of sound, get about 600 miles to a thimble full of gasoline, and sell for about $2!