COMMUNICATIONS TECHNOLOGY—A FORECAST OF CHANGE (PART I)*

ROSCOE L. BARROW† AND DANIEL J. MANELLI‡

INTRODUCTION

Man's first footstep upon the moon was witnessed by hundreds of millions of people throughout the world. Across the lunar distance, television brought this epoch-making event into the home and made all mankind participants. The moon walk itself would not have been possible without the phenomenal progress in communications technology. A communications center on earth planned, tracked, and directed Apollo XI throughout its mission.

In the wake of the moon walk, many leaders have observed that a nation which placed man on the moon should be able to solve earthly problems. The major impediment to solving earthly problems is the lack of a consensus in society that priority should be accorded, and resources allocated, to the solution of such problems. One lesson of the space program is that when our citizens become intellectually involved in the solution of a problem the consensus necessary to see a proposed solution through can be maintained. Someone has observed that human history is becoming more and more a race between education and catastrophe. Thus, society's problems grow more complex, and the time for decision shortens. Some think that solution of certain crucial problems has been delayed for so long that the race between education and catastrophe has been lost. Fortunately, the current explosion in communications technology may provide another opportunity to win the race.

Our country has undergone commercial, industrial, and financial revolutions. Our people have felt the impact of the internal combustion engine, the locomotive, the automobile, the aeroplane, and nuclear energy. But these inventions created mere ripples compared with the tidal wave which the new communications technology is generating. New energy sources increase man's wealth. Faster means of transportation give man mobility and bring him into contact with new ideas. But

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† B.S. 1935, Illinois Institute of Technology; J.D. 1938, Northwestern University. Wald Professor of Law and former Dean, University of Cincinnati College of Law; Director, Network Study Staff, FCC, 1955-57; Consultant, Office of Commissioners, FCC, 1961-63; Moderator, Hearings on the Fairness Doctrine, Special Subcommittee on Investigations, House Committee on Interstate and Foreign Commerce, 1968. Research by Professor Barrow incident to this article was supported by a grant by the Walter E. Meyer Research Institute of Law.

‡ B.S. 1957, LL.B. 1962, University of Notre Dame. Attorney, Federal Trade Commission, 1962-65; Legal Counsel, Office of State Technical Services, U.S. Department of Commerce, 1966-67; Staff Attorney, Special Subcommittee on Investigations, House Committee on Interstate and Foreign Commerce, since 1967. The views herein expressed by Mr. Manelli do not necessarily represent the opinion of any member of the Special Subcommittee on Investigations, House Committee on Interstate and Foreign Commerce, or its staff.

the new forms of electronic communications focus directly upon the mind of man. The citizen's personal information environment is undergoing a great transformation. Through electronic communications, all the great libraries in the world can be channeled into one massive pool of information. The computer can organize this information. Data processing and information storage and retrieval systems can extract the information relevant to any problem. Over-the-air and cable systems of communication can bring this information into the home. The great increase in the available information and the devices for systematizing its use will accelerate the rate of change in man's culture and sociopolitical concepts beyond present capacity of prediction. In this way the individual can be aided to conduct himself maturely in society and can be encouraged to participate in solving the crucial problems of his time. Through informed participation in decision-making, a person may contribute to the consensus necessary to support solutions to our crucial problems. Moreover, business and the professions will use the new technology to provide greater service at less expense. A doctor will be able to send by facsimile transmission a cardiogram to a national center for diagnosis. A lawyer will be able to extract from a legal data bank all the precedents for his case. Banking, shopping, and credit card supervision can be conducted largely through telecommunications. Government records of land liens and other secured transactions can be kept current through data storage and retrieval systems. Newspapers and mail can be delivered by facsimile and video recording units. Through satellite broadcasting the storehouse of information can be made worldwide.

The innovations in communications technology may render anachronistic some of our timeworn approaches to broadcasting and its regulation. Care should be exercised lest the potential service of the new communications technology be limited unduly by protectionism toward the established components of broadcasting. This article describes the nature of the radio spectrum and significant innovations in the telecommunications media, considers major public interest goals which should be served by the media, and suggests guidelines for more effective use of the media in achieving these goals.

I

THE NATURE OF THE RADIO SPECTRUM

Man's awareness of the electromagnetic spectrum has existed for only a century.¹ In 1864, a British physicist, James Clark Maxwell, hypothesized the existence of a

¹The historical and technical treatment contained in this section has been drawn from a number of sources, including *Electromagnetic Radiation*, 10 ENCYC. AMERICANA 201b (Int'l ed. 1969); *Radio*, 23 *id.* at 121; *Television*, 26 *id.* at 399; I. ASIMOV, *THE NEW INTELLIGENT MAN'S GUIDE TO SCIENCE* (1965); 1966-68 FCC ANN. REPS.; FCC Information Bulletin Nos. 2-B, 3-G, 14-G, 15-G; PRESIDENT'S TASK FORCE ON COMMUNICATIONS POLICY, FINAL REPORT ch. 8 (1968); FCC, REPORT OF THE ADVISORY COMMITTEE FOR THE LAND MOBILE RADIO SERVICES (1967); TELECOMMUNICATIONS SCIENCE PANEL, ELECTROMAGNETIC SPECTRUM UTILIZATION—THE SILENT CRISIS (1966); REFERENCE DATA FOR ENGINEERS

continuous spectrum of electromagnetic radiations travelling through space as light does. In 1888, Heinrich Hertz detected radio waves emanating from an oscillating electric current. This discovery proclaimed that electronic communication could be broadcast over the air and need not be limited to wire. Guglielmo Marconi increased the range of transmission and reception by grounding one side of the transmitter and the receiver and attaching the other side of the circuit to an antenna. Thus, in 1901, Marconi sent signals across the Atlantic. This radio telegraphy was soon used in ship-to-ship and ship-to-shore communications. Radio telegraphy sends and receives impulses of controlled duration which, on the basis of the Morse or other code, are translated into messages. Radio telephony, the transmission and reception of sound, including the human voice, awaited a more sophisticated development. In 1906, this was supplied by the American physicist, Reginald Fessenden. Fessenden developed the technique of "modulation" of a radio wave so that it could be varied in strength or amplitude and thereby mimic sound waves. This is the basis of the system used today in standard, AM (amplitude modulation) broadcasting. Another giant stride was taken in 1907 when the American physicist, Lee DeForest, invented the radio tube, or triode, thereby making possible the amplification of radio waves.

Broadcasts by amplitude modulation were subject to static or interference from random amplitude modulation of noise sources, such as sunspot activity. In 1935, the American inventor, Edwin Armstrong, solved this problem by substituting frequency modulation for amplitude modulation. Under this system, amplitude remains constant and the frequency is varied to impose sound patterns on the radio wave.

The first successful device for transmitting a picture by radio wave was the iconoscope, which was invented in 1923 by a Russian-born American citizen, Vladimir Zworykin. Working independently, the American inventor, Philo T. Farnsworth, in 1930 patented a competing electronic television system. Television employs amplitude modulation in transmitting the picture and frequency modulation in transmitting the sound. While the technology necessary for commercial television was available in the thirties, World War II delayed its development. After 1937, newspapers could be transmitted by radio and received by a facsimile process.

This note on the development of electronic communication is a reminder that its history is brief and that the full force of the telecommunications media upon civilization is still to come.

Electromagnetic radiation is radiant energy resulting from acceleration of an electron or other charged particle. Some well known forms of electromagnetic radia-

(Sams 5th ed. 1968); H. HICKEY & W. VILLINES, *ELEMENTS OF ELECTRONICS* (2d ed. 1961); R. OLDFIELD, *RADIO-TELEVISION & BASIC ELECTRONICS* (2d ed. 1960); M. UPTON, *ELECTRONICS FOR EVERYONE* (2d ed. 1959); G. WILCOX, *BASIC ELECTRONICS* (1960); S. DAVIS, *THE LAW OF RADIO COMMUNICATION* (1927); HOUSE SELECT COMM. ON SMALL BUSINESS, *THE ALLOCATION OF RADIO FREQUENCY AND ITS EFFECT ON SMALL BUSINESS*, H.R. DOC. NO. 1978, 91st Cong., 1st Sess. (1968).

tion are light, radio waves, x-rays, infrared (heat) radiation, ultraviolet radiation, and gamma rays. Electromagnetic waves possess different wavelengths and frequencies, the frequency and wavelength being inversely proportionate so that as the frequency increases the wave length decreases. As to any electromagnetic wave, if the frequency is multiplied by the wavelength the product is the speed of light.² The relationship between various regions of the electromagnetic spectrum can be roughly illustrated by Figure 1.

FIGURE 1
THE ELECTROMAGNETIC SPECTRUM

The wavelengths within this spectrum vary from trillionths of an inch for gamma rays to thousands of feet for low frequency radio waves. Electromagnetic energy travels from its source in wave form. The distance between the peaks of maximum energy, or between the nodes of minimum energy, is the wavelength. The progression of a wave from one peak to the next completes one cycle of the wave. The rapidity with which a wave completes its cycle is the frequency, expressed in cycles per second. The term *hertz*,³ which is synonymous with "cycles per second," has recently come into use. Although radio waves may be described by wavelength as well as frequency,⁴ usually they are designated by frequency. The electromagnetic spectrum is so vast that it is helpful to employ the terms *kilohertz* (KHz), which means 1000 cycles per second; *megahertz* (MHz), 1000 kilohertz; *gigahertz* (GHz), 1000 megahertz; and *terrahertz* (THz), 1000 gigahertz.

The portion of the electromagnetic spectrum currently used for over-the-air radio-TV broadcasting is very small. The radio spectrum ranges from ten kilohertz (10,000 cycles per second) to three terrahertz (3,000,000,000,000 cycles per second). Only forty gigahertz are allocated internationally, although frequencies as high as

² This relation is expressed by the following equation:

$$\lambda = \frac{300,000,000}{f}$$

λ equals wavelength, and f equals frequency. 300,000,000 is the speed of light expressed in meters. Thus, for a wave having a frequency of 20 KHz, the wave length is 15,000 meters, or approximately 9.3 miles:

$$\frac{300,000,000 \text{ meters per second}}{20,000 \text{ cycles per second}} = 15,000 \text{ meters}$$

³ The term *hertz* honors the pioneer investigator of radio waves, Heinrich Hertz.

⁴ See note 2 *supra*.

300 gigahertz are used from time to time for experimental purposes.⁵ Physical existence of the electromagnetic spectrum does not mean that it is usable either technologically or economically. The higher the frequency the more delicate and sophisticated the technology must be in order to use the frequency effectively. Also, the propagation characteristics change as the frequency changes so that some uses may be served only in relatively low frequencies. More of the electromagnetic spectrum can be opened for exploitation when the technology has provided equipment which can be operated efficiently at these frequencies. At the other end of the spectrum, frequencies below ten kilohertz have not proved practical for radio communications.

The following shows the convenient designations used to describe the radio spectrum:

Below 30 kilohertz.....	Very Low Frequency (VLF)
30 to 300 kilohertz.....	Low Frequency (LF)
300 kilohertz to 3 megahertz.....	Medium Frequency (MF)
3 to 30 megahertz.....	High Frequency (HF)
30 to 300 megahertz.....	Very High Frequency (VHF)
300 to 3,000 megahertz.....	Ultra High Frequency (UHF)
3 to 30 gigahertz.....	Super High Frequency (SHF)
30 to 300 gigahertz.....	Extremely High Frequency (EHF)

The propagation characteristics of radio waves vary with the frequency. This affects the use of the frequency band and the type of equipment required. The lower frequencies have the ability to follow the curve of the earth; that is, they produce "ground waves." They have the disadvantage of requiring large antenna installations and ground facilities.

These low frequencies are useful for long-range, high-power communications, radio beacons for ships and aircraft, intercontinental radio telegraph stations, and naval command systems requiring the longest possible day and night range. The radio spectrum from ten to 540 kilohertz is largely devoted to these uses. The considerable cost of the installations and the elaborate antenna arrays needed are not critical drawbacks in these applications.

In the 540 kilohertz to twenty-five megahertz band, the significant change in propagation characteristics lies in the fact that as the frequencies increase the radio waves tend to depart from the curvature of the earth and, whether directed skyward or naturally moving in that direction, they are reflected by the ionosphere twenty-five to 155 miles above the earth back to the earth's surface again. This reflective characteristic renders these frequencies, particularly in the 1600 kilohertz to twenty-five megahertz range, useful for long-distance radio telegraph, radiophone communication between ships at sea and planes in the air, and international broadcasting. The reflective quality of the ionosphere varies with the time of day and the seasons

⁵ Levin, *The Radio Spectrum Resource*, 11 J. LAW & ECON. 433, 438 (1968).

of the year. Accordingly, if continuous point-to-point service is necessary, more than one frequency is assigned to a transmitter.

Above the twenty-five megahertz range, another important propagation characteristic occurs. These frequencies pierce the ionosphere and are not reflected to earth. Accordingly, long-distance broadcasting is not feasible in this frequency band. Moreover, as the frequencies increase, surface objects absorb the waves at a progressively higher rate. Buildings and hills absorb signals at 200 megahertz, and foliage does so at 400 megahertz. In the higher frequencies even rain produces attenuation of the signal.

The twenty-five to 900 megahertz range includes the frequencies over which FM radio, VHF television, and much of UHF television is broadcast. Land mobile communications, some radar, and various safety and special services are allocated frequencies in this band. The short wavelengths characteristic of this portion of the spectrum make practical the use of compact receiving equipment. Also, extraneous noise levels are low, facilitating broadcasting. However, as the radio waves in this frequency band are not reflected by the ionosphere, high broadcasting towers or micro-relay facilities are necessary if substantial ground range is desired.

The 900 megahertz to forty gigahertz part of the spectrum takes in the upper portion of the UHF band, the entire SHF band, and the lowest portion of the EHF band. Above one gigahertz (a wavelength of thirty centimeters) a clean line of sight is necessary for transmitting. It is used for radio navigation, common carrier microwave, satellite communication, and many other specialized radio services. At these frequencies, radio waves take on some characteristics of light waves, and can then be directed much in the manner of optical direction of light waves, using directional antennas instead of lenses. The lack of atmospheric interference at these frequencies, and their greater bandwidth, make them suitable for high volume data and voice transmissions, although rain interference does occur.

Low-frequency radio waves with a "ground wave" propagation characteristic are subject to "attenuation," or loss of signal strength due to a variety of factors. For a given distance and power input, the lower the frequency the stronger the signal. The nature of the terrain over which the signal passes affects the amount of attenuation. This is illustrated by the data in Table 1 showing the number of miles a signal of equal field strength is delivered by one kilowatt of power from an antenna at ground level. While the 100 kilohertz and one megahertz waves have roughly comparable field strength over salt water, over hilly terrain the one megahertz wave suffers ninety per cent attenuation. The ten megahertz wave is practically nonexistent over hilly terrain.

In the case of "sky waves," attenuation is more complex. The attenuation is determined by such factors as the length of the signal path through space, the angle at which the signal strikes the ionosphere, the degree of ionization, which varies with the season and the time of day, the latitude of the signal path, and the level

TABLE 1
MAXIMUM DISTANCE OF EQUAL-FIELD-STRENGTH SIGNAL AS A FUNCTION OF TERRAIN,
AT ONE KILOWATT POWER
(DISTANCE IN MILES)

Frequency	Salt Water	Flat, moist ground	Hilly, dry terrain
100 kilohertz.....	160	150	110
1 megahertz.....	130	40	11
10 megahertz.....	76	4.7	1.9

of sunspot activity. Sky-wave reflection will not occur if the signal is projected directly overhead from the transmitter. However, if the signal is directed at an oblique angle, it will be reflected. Reflection of sky waves is more efficient at night than during the day. This accounts for the familiar phenomenon of increased range of standard broadcast stations at night.

Interference between radio signals occurs when two or more transmitters broadcast on the same frequency at the same time. The coexisting radio waves have the same frequency and wavelength, and the transmitters have impressed different modulation patterns upon the signals. The receiver is unable to distinguish between the two signals and receives both with resulting bedlam. Interference between radio signals necessitated the Radio Act of 1927⁶ and the regulation of broadcasting. Two transmitters can share the same frequency without interference if there is sufficient geographical separation between the transmitters, the power of one transmitter is too low to send a signal to the territory in which the other transmitter is operating, the antenna height is limited, or the hours of operation are limited. The FCC uses all these methods of regulation to prevent interference between broadcast signals.

Also, interference may be caused by broadcasts of two stations on adjacent channels, unless the frequencies assigned to the two stations have a bandwidth sufficiently wide to isolate the two signals from each other. Although each radio station is assigned a specific frequency and wavelength, radio waves cannot be so precisely controlled as to radiate precisely on one specific frequency. Moreover, the process of amplitude modulation distorts the frequency. The channel width or band of a standard AM broadcast station is ten kilohertz. Thus, if a station is assigned to a frequency of 565 kilohertz, the channel which the broadcaster is authorized to occupy is from 560 to 570 kilohertz. This bandwidth provides isolation from interference by signals broadcast in adjacent channels.

While the standard AM radio channel is allotted a bandwidth of ten kilohertz, an FM radio channel is allotted a bandwidth of 200 kilohertz. The greater bandwidth for FM is necessary because frequency modulation, as distinguished from

⁶ 44 Stat. 1170. See *National Broadcasting Co. v. United States*, 319 U.S. 190 (1943); *United States v. Zenith Radio Corp.*, 12 F.2d 614 (N.D. Ill. 1926).

amplitude modulation, utilizes a range of several frequencies. Accordingly, both the spectrum requirement for the FM signal and the isolation from interference with signals on adjacent FM stations require a much greater bandwidth.

While the bandwidth occupied by an FM radio station seems great when compared with the bandwidth occupied by an AM radio station, it is small when compared with the bandwidth of a single television channel. A single television station is given a bandwidth of six megahertz. This is almost six times as much channel space as is occupied by the entire standard AM broadcast band. A television transmission is composed of a video signal and an audio signal, which is frequency modulated and the equivalent of an FM radio station channel. Tremendous information must be transmitted to a receiver to enable it to reproduce a picture with figures in motion.

Transmitting a moving image by television is vastly more complicated than transmitting the human voice by AM or FM. To reproduce the human voice it is only necessary to modulate the amplitude or frequency of the radio wave by impressing upon it a pattern which mimics the sound pattern being transmitted. In order to broadcast a picture by television, it is necessary to separate the picture into minute component parts and to modulate the carrier radio wave so as to transmit these parts in rapid succession. The television receiver reconstructs the picture by reassembling the parts. In the United States, a television picture is formed of 525 horizontal lines, called a "frame." If ten or more frames per second are reproduced upon a screen, the human eye interprets these separate related pictures to be moving figures. The standard motion picture film speed is twenty-four frames per second. In the United States, television transmission is at the rate of thirty frames per second. The television picture is "painted" by a rapid scanning point of light which traces horizontal lines.

To avoid the sensation of flickering of the picture, such as we associate with the old-time movies, a system of interlace scanning is used. Instead of painting the 525 lines in order from top to bottom, the scanning beam skips every other line and when the bottom of the screen is reached returns to the top of the screen and paints the omitted lines. Each of the two scans is called a "field," and two fields comprise a single frame. This rapid rate of scanning eliminates the sensation of flicker. The beam in the television receiver must be synchronized with the scanning beam in the television camera so that both begin each line, field, and frame together. This is accomplished by the use of a "sync pulse" which signals the scanning beam to start a new line or frame. A "blanking pulse"—to switch off the beam as it moves into position for a new line or frame—is also necessary. As the beam traces each line in turn, the light and dark characteristics for that particular line are controlled by the intensity with which the beam is made to fire against the phosphor-coated face of the television tube. The scanning beam traverses 15,750 lines per second in order to paint the standard thirty frames per second. The high volume of

information which must be transmitted to carry out these operations accounts for the wide bandwidth allocated to television channels.

In color television, the brightness of the picture is transmitted in the same manner, described above, that a black and white (monochrome) television picture is transmitted. The color component is transmitted simultaneously on a sub-carrier frequency located between the visual and audio frequencies contained within the standard six megahertz channel. Instead of a single scanning beam, such as is used in black and white television, in color television there are three scanning beams, one each for red, green, and blue color. By varying the intensity of one or more of these three scanning beams, the basic colors can be reproduced on the picture tube.

In 1941, commercial television was approved, and eighteen channels were assigned in the band extending from fifty to 294 megahertz.⁷ Development of commercial television was delayed by the freeze on station and set production during World War II. In 1944, the FCC initiated a general allocation proceeding to determine the needs of nongovernmental services for frequencies. The industry was sharply divided on the place in the spectrum which should be assigned to television, some contending that it should be placed in the UHF band and others urging that, because the existing equipment was satisfactory for VHF and substantial experimentation would be necessary to develop equipment providing comparable service in the UHF band, television should go forward in the VHF.⁸ The FCC decided that initially television would be assigned the VHF band and ultimately moved to the UHF band. In 1945, the FCC held a hearing for assignment of the VHF channels to 140 metropolitan areas.⁹ Again the industry divided over the question of moving television to the UHF band. However, the FCC decided to continue the assignment of the VHF band to television. In 1952, the FCC issued its Sixth Report,¹⁰ in which it retained the VHF band for television and added seventy channels in the UHF band, from 300 to 3000 megahertz.

Although the FCC authorized television in the UHF band, the conditions necessary to its development were not available.¹¹ The VHF stations were located in the major markets, were served by the three major networks, and had strong audience and advertising support. By contrast, UHF broadcasters were caught in an unbreakable chain of circumstances. Sets in the hands of viewers were not wired to receive UHF signals, and substantial cost was involved in wiring the set and

⁷ HOUSE COMM. ON INTERSTATE AND FOREIGN COMMERCE, NETWORK BROADCASTING, H.R. REP. NO. 1297, 85th Cong., 2d Sess. 17-18 (1958).

⁸ *Id.* at 18-19.

⁹ *Id.* at 19-20.

¹⁰ Amendment of Section 3.606 of the Commission's Rules and Regulations; Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television Broadcast Service; Utilization of Frequencies in the Band 470 to 890 Mcs for Television Broadcasting (Sixth Report and Order), Nos. 8736, 8795, 9175, & 8796, 17 Fed. Reg. 3905 (F.C.C., filed May 1, 1952).

¹¹ NETWORK BROADCASTING, *supra* note 7, at 31-33.

providing an antenna. Moreover, the viewer was not strongly motivated to alter the set because the program service of UHF stations was of poor quality. A program service of high quality was not available because network service was unavailable, television programming is costly, advertisers were unwilling to advertise over UHF stations because viewers were few, and the UHF broadcasters could not attract viewers because their sets were not wired to receive the UHF signal.

The obvious answer to the problem was to require that all TV receivers shipped in interstate commerce be wired to receive all channels. However, the FCC maintained that it lacked authority to require all-channel receivers, and the Congress, until recently, did not see fit to require them. Accordingly, numerous pioneer UHF television entrepreneurs failed, and wiser businessmen delayed entering the field. Finally, the All-Channel Receiver Act of 1964¹² was enacted. This legislation requires that all receivers shipped in interstate commerce be equipped to receive UHF as well as VHF signals. It will be several years before most of the receivers in use are all-channel receivers. Until all-channel set saturation occurs, UHF stations will continue to suffer great economic disadvantage.

The UHF channels, in addition, have technological disadvantages in comparison with VHF channels. While all television channels have a bandwidth of six megahertz, the higher the frequency the more readily is the signal absorbed by terrain and buildings. The established components of the broadcasting industry are well served in the VHF band, and there has not been great demand for progress in developing sending and receiving apparatus for use in the UHF band which will render UHF television comparable in quality with VHF television. Accordingly, the UHF broadcasters are generally not able to compete with the VHF licensees.

Networks transmit programming to affiliated stations by coaxial cable and microwave relay towers.¹³ These facilities are provided by the American Telephone & Telegraph Company (AT&T) and the associated Bell System companies. Tariffs and charges are subject to FCC regulation and may not be "unreasonable" or "unduly discriminatory."

Microwave relay operates in the portion of the radio spectrum extending into the gigahertz range. In the upper range, these frequencies approach the propagation characteristics of light. There is no ground-wave or sky-wave characteristic, and transmission must be by clear line of sight. The microwaves are susceptible to

¹² 47 U.S.C. § 303(s) (1964). The U.S. television channel allocations are as follows:

<i>Channel No.</i>	<i>Band</i>	<i>Frequency (MHz)</i>
2-4	VHF (30-300 MHz)	54-72
5-6	"	76-88
7-13	"	174-216
14-83	UHF (300-3000 MHz)	470-890

¹³ H.R. REP. NO. 1297, *supra* note 7, at 50-52.

optical-like focusing through the use of directional antennas. Hence, the microwaves can be beamed from one relay tower to the next. The towers are placed at intervals of about thirty miles so that the horizon does not absorb the signal. The power requirement for microwave transmission is low, less than one watt transmitter power being sufficient to send a signal from one tower to the next. The output of any transmitter cannot be made to confine itself to exactly the assigned frequency. The outgoing signal will involve frequencies of plus and minus four to six per cent of the assigned frequency. In the very high frequencies, such as are found in the microwave range, this can involve a wide swath of frequencies, which results in a signal of wide bandwidth. This wide bandwidth can be utilized to increase the amount of information which can be carried via microwave. Microwave is used to transmit a wide variety of information such as voice, telegraph, teletype, facsimile, digital data, and television. By multiplexing, many different types of information can be transmitted simultaneously on a single microwave relay channel.

For some time, the American Broadcasting Company (ABC) has sought permission to establish a network-owned system of satellites in outer space for transmission of network service, and now the Columbia Broadcasting Company (CBS) and the National Broadcasting Company (NBC) have joined ABC in proposing a space satellite consortium to counter AT&T in network interconnection.¹⁴ Any such development would require an accommodation of the interests of AT&T and Comsat.¹⁵ Comsat favors a single, international space satellite communications system.

It is anticipated that future technological developments will enable society to make a much more extensive and intensive use of the electromagnetic spectrum for communications. As noted above, only a small portion of the electromagnetic spectrum is in use today. More extensive use awaits the development of more sophisticated hardware, capable of carrying information in the highest frequencies. Meanwhile, the usable portion of the electromagnetic spectrum is being more intensively used. One example of this is microwave relay, discussed above. Another is the "splitting" of bands through use of more expensive, sensitive equipment which reduces the required bandwidth.¹⁶ In recent years, there has been a trend of thinking toward removal of electronic communications, including radio-TV, from over-the-air broadcasting to cable systems. Cable-TV has technologically developed to the point where thirty or more channels may now be made available to the home, and in the future systems including sixty or more channels may well be available.¹⁷ While the use of cable-TV should be encouraged in the interest of maximum in-

¹⁴ BROADCASTING, Oct. 20, 1969, at 80.

¹⁵ Comsat, the Communications Satellite Corporation, was established by the Communications Satellite Act of 1962, 47 U.S.C. §§ 701-44 (1964), to develop a global communications network. See pp. 221-23 *infra*.

¹⁶ Levin, *supra* note 5, at 441-42.

¹⁷ Cable television is described at pp. 238-43 *infra*.

formation and opinion sources, it should be borne in mind that the potential capacity of over-the-air electronic communications is great, and only a small portion of this capacity is now being used by means of a technology that is still in its infancy.

II

TECHNOLOGICAL INNOVATIONS IN ELECTRONIC COMMUNICATIONS

In the preceding section dealing with the nature of the radio spectrum, the manner in which AM, FM, and television are transmitted over the air and by coaxial cable was described. In this section, technological innovations which provide opportunities for more extensive and intensive use of the radio spectrum and for competing systems of electronic communications are described.

A. Space Satellite Communication

The communications satellite introduces a new and revolutionary capability for both point-to-point and mass communications on a worldwide scale. The cost of using cable, both submarine and land, and microwave relay varies in proportion to the distance covered. However, the cost of space satellite communication is nearly independent of distance. From its station 22,300 miles above the surface of the earth, a synchronous, apparently stationary¹⁸ satellite has approximately forty per cent of the surface of the earth constantly in view. A transmission directed up to it from any point on this vast surface can be relayed back down to any other point.¹⁹ Three such satellites, spaced along the Equator over the Atlantic, Pacific, and Indian Oceans, provide a global communications network. Operating at microwave frequencies, the satellites can transmit simultaneously vast amounts of information, including facsimile, voice, data, and television.

The satellite introduces a third dimension into the existing communications technology. Like the airplane's ability to free transportation from the confines of surface travel, the satellite can overleap the terrestrial communications cable and microwave highways. Emerging nations in remote portions of the world, through the construction of an earth station, may become full participants in the global communications network.

It is the satellite's unique spatial relationship with the earth, rather than any unique electronic features, which accounts for its great capabilities. Electronically, the communications satellite resembles, both in its use and function, the terrestrial microwave tower—its electronic circuitry (or "plumbing" as it is termed in the industry) is essentially the same as a microwave relay tower, and it is, in effect, a microwave tower in orbit.²⁰ Transmission to and from the satellite is carried out

¹⁸ See p. 217 *infra*.

¹⁹ The transmission to the sending earth-station and its retransmission to the receiving station (except in the case of direct satellite broadcast) require additional terrestrial facilities.

²⁰ Even the intercontinental service performed by satellites could theoretically be performed by micro-

in the four and six gigahertz bands, respectively. Signals transmitted by microwave relay travel in a straight line. Each tower must be in line of sight with the next one in the chain, and the usual "hop" is twenty-five to thirty miles. By contrast, the synchronous satellite is in line of sight for approximately forty per cent of the earth's surface.

As the microwave transmissions from the satellite do not follow the curvature of the earth, its range depends upon the altitude of its orbit. The speed of the satellite's rotation is also dependent on the height of the orbit. The higher the orbit, the slower the satellite needs to move to maintain that orbit. At an altitude of 1075 miles, for example, a satellite would circle the earth in two hours. As the height of the orbit is increased, the gravitational pull of the earth is lessened, requiring less speed to maintain position in orbit.²¹ At an altitude of 22,300 miles, the satellite completes an orbit every twenty-four hours. A satellite placed in such an orbit, and in the same plane as the equator, appears to remain motionless in the sky because its speed of 7,000 miles per hour is synchronized with the rotation of the earth. Only at an altitude of 22,300 miles and in the plane of the equator, can a satellite remain in a stationary position.²² Hence, the number of synchronous satellites which can be placed in a geostationary or synchronous orbit without signal interference is limited. The extent of available "parking spaces" is discussed below.

Early experimental satellites were placed in relatively low-level orbits. The higher orbiting speed of such satellites caused them to roam over one country after another as they circled the earth. The ability to communicate from one ground station to another via satellite requires that both stations be simultaneously in sight of the satellite. When the movement of a low- or medium-orbit (random-tracking) satellite causes it to sink below the horizon of either of the ground stations, communication with it is no longer possible. Transmission must be broken off or continued by means of a different satellite. These low or medium-level orbits have the further disadvantages, for communication purposes, of limited range and the necessity for elaborate tracking facilities. The tracking facilities required for such satellites must be capable of ascertaining their position at any given moment. Computers are commonly utilized to predict these movements. The synchronous, rather than the random-tracking satellite, is the most practical satellite for communications, except in far northern latitudes.²³

wave towers carried aboard ship. These ships, however, would have to be spaced over the ocean at thirty mile intervals.

²¹ See A. CLARKE, *THE PROMISE OF SPACE* 49-79 (1968); W. VON BRAUN & F. ORDWAY, *HISTORY OF ROCKETRY AND SPACE TRAVEL* (1967).

²² 1966 COMSAT ANN. REP. 4.

²³ See PANEL 10 OF THE SUMMER STUDY ON SPACE APPLICATIONS, DIVISION OF ENGINEERING, NATIONAL RESEARCH COUNCIL FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, *USEFUL APPLICATIONS OF EARTH-ORIENTED SATELLITES—BROADCASTING*, reprinted in *Hearings on Satellite Broadcasting—Foreign Policy Implications Before the Subcomm. on National Security Policy and Scientific Developments of the House Comm. on Foreign Affairs*, 91st Cong., 1st Sess. 230 (1969) [hereinafter cited as *Foreign Policy-Satellite Hearings*]. See also Silberman, *The Little Bird That Casts a Big Shadow*, *FORTUNE*, Feb. 1968,

At the time of the passage of the 1962 Communications Satellite Act,²⁴ it was assumed that communications satellites of the synchronous-orbit type were still far in the future.²⁵ The system envisaged at that time was an elaborate series of Telstar-type, low-altitude satellites. A large number of these would be required, spaced out so that at least one would be above the horizon at any given point. The original \$200 million capitalization of the Comsat Corporation reflected the anticipated expense of such a system, with its requisite ground stations and tracking facilities. However, the much less expensive synchronous system was perfected considerably in advance of expectations.²⁶

Launching of satellites is usually conducted in an eastward direction so as to obtain the advantage of the earth's rotational speed. This imparts an extra 1000 miles per hour to the orbital speed of the satellite. A variety of launch vehicles are available which are capable of placing various payloads into geostationary orbit. These range from the Thor-Delta, capable of up to 575 pounds delivered to orbit, through the Atlas-Centaur (1650 pounds), to the Titan 3C-Centaur (6500 pounds).²⁷ Still greater lifting power is available if needed, ultimately including the Saturn 5, capable of lifting 100,000 pounds into a synchronous orbit. Such huge lifting power as is available with the Saturn 5 will probably not be needed in the near future. The orbital weights of presently used satellites, including the forthcoming Intelsat IV series, are easily within the range of a smaller and less expensive booster. The Intelsat I (Early Bird) had a final orbital weight of only seventy-six pounds; Intelsat II was 150 pounds; and Intelsat III, the most advanced communications satellite in use, weighs 240 pounds. The Intelsat IV, which is to be launched during 1971 and 1972, will have a final orbital weight of 1200 pounds.²⁸

The technique for injection of a satellite into synchronous orbit involves the initial establishment of a temporary "transfer" orbit. This is an elongated elliptical orbit with its high point, or apogee, at about 23,000 miles and its low point, or perigee, at 195 miles. As the satellite is placed into this orbit, it is spun about its

at 108, 110. The USSR's Molniya Satellites, which provide domestic communications service to the Soviet Union, make use of a 63.5° prograde (*i.e.*, moving in the same direction as the earth's rotation) elliptical orbit. This orbit is nonsynchronous and requires the use of several satellites and a comparatively complex earth terminal system. However, this system does have certain advantages for use by the Soviet Union. It permits better coverage of far northern latitudes and is easier to launch from the available sites in the Soviet Union. See *Foreign Policy-Satellite Hearings*, *supra*, at 21, 231.

In addition, nonsynchronous orbits are extremely useful, and often necessary, for meteorological, scientific, and military reconnaissance satellites. For the latter purpose, the polar orbit, which allows the satellites to pass periodically over the entire surface of the earth, is especially valuable.

²⁴ Communications Satellite Act of 1962, 47 U.S.C. §§ 701-44 (1964).

²⁵ See PRESIDENT'S TASK FORCE ON COMMUNICATIONS POLICY, FINAL REPORT ch. 3, at 11, ch. 5, at 3-4 (1968). See also Silberman, *supra* note 23, at 110; Lessing, *Cinderella in the Sky*, *FORTUNE*, Oct. 1967, at 130, reprinted in 21 *FED. COM. B.J.* 92, 102 (1967).

²⁶ This has resulted in Comsat's showing what one writer has termed an "embarrassing surfeit" of cash. See Lessing, *supra* note 25. Comsat's 1968 annual report lists total assets of \$246.4 million, of which \$132.3 million is in cash and temporary cash investments.

²⁷ *Foreign Policy-Satellite Hearings*, *supra* note 23, at 287.

²⁸ 1968 COMSAT ANN. REP. 15.

own axis for stabilization. This simplifies the thermal design of the satellite, since it keeps any one side from being excessively heated by the sun. As the satellite reaches the high point of its transfer orbit, a brief firing of its rocket engine in a horizontal direction relative to the earth's surface causes it to assume a circular geostationary orbit. Once in orbit, the satellite is subject to various forces which tend to push it away from its station. Gravitational anomalies in the earth cause the satellite to drift in their direction along the line of the equator, much like a ball-bearing rolling down a very shallow incline. The positioning rockets of the satellite are periodically activated to bring it back on station. Station-keeping is a precise operation, since the rocket engines must be pulsed to match the spinning motion of the satellite.

Satellite transmissions make use of the same four to six gigahertz microwave band as is used by the terrestrial microwave system. Interference with terrestrial signals is theoretically possible, but its likelihood is minimized by a number of factors. The power for the satellite is derived from solar cells of limited output. The satellite puts out a relatively weak signal and requires a large antenna to receive it. These antennas are approximately ninety feet in diameter. Therefore, the satellite's signal is unlikely to be picked up by the comparatively small antenna of a microwave tower. Each tower operates on a line-of-sight with the next one in the chain, with an angle of reception of about one degree. For this reason, the satellite, in order to cause interference to the tower (assuming a satellite with sufficient power to do so) would have to be in a position just above the horizon so as to "look" directly into the tower. However, a development of more powerful satellites in the future may raise a possibility of interference between the satellite and terrestrial microwave systems.

The use of microwave frequencies by satellites accounts for many of their capabilities. The broadband characteristics of these frequencies enable the satellite to handle an enormous volume of communications simultaneously. Also there are considerable miniaturization advantages. The geostationary satellite avoids the main disadvantage of microwave, the necessity for line-of-sight transmission, having over one-third of the surface of the globe in sight. One disadvantage in the use of microwave for satellites is the relatively high "free space loss" in signal strength experienced by high frequencies. However, this is partially compensated for by the greater antenna gain obtainable with high frequencies.²⁹

The outer limit of a satellite's coverage is defined by the circumference of the circular area on the earth's surface from which the satellite can be seen. At the center of this area of coverage, the satellite will appear directly overhead. At the

²⁹ "Antenna gain" refers to the efficiency of a directional antenna as compared to a nondirectional antenna (isotropic radiator). The value varies with the design of the particular antenna but is greater for high frequencies. Directional antennas are used to shape the signal into a narrow beam, thus concentrating radiated power over the desired area of reception. See also HOUSE COMM. ON GOVERNMENT OPERATIONS, GOVERNMENT USE OF SATELLITE COMMUNICATIONS—1968, H.R. REP. No. 1836, 90th Cong., 2d Sess. 9 (1968).

outer limit of this area, the satellite will be just above the horizon. While reception has been reported at an elevation of only 1.5 degrees, the generally accepted minimum beam angle is five degrees.

As more and more satellites are launched, the question of available orbital positions, or "parking spaces," will become important. There are two critical factors to the definition of a synchronous orbit: The critical altitude must be achieved; and the orbit must run parallel to the equator, that is, the inclination of the orbit to the plane of the equator must be zero. If this last requirement is not met, the satellite will not remain motionless relative to the earth. Rather, it will travel back and forth in a north-south direction. If this movement is substantial, the use of steerable antennas will be required to track the satellite, and the zone of its coverage will vary from hour to hour. Because of these limitations on the altitude and inclination of the synchronous orbit, only a finite number are available. Furthermore, some of these are more desirable than others depending upon the area to be served. At present, the number of satellites which can satisfactorily be accommodated in synchronous orbit around the equator is not definitely known. Fortunately, the number appears to be fairly large.³⁰

A satellite can transmit all forms of communication, including telephone, telegraph, data and facsimile, and television. However, the capacity, or bandwidth, necessary to transmit these different forms of communication varies widely. The bandwidth necessary to carry one long-distance telephone call in both directions is termed a "voice circuit." Data transmission requires substantially less bandwidth than a voice circuit. It requires about 240 to 300 voice circuits to transmit one television signal. The Intelsat III series of satellites has a capacity of 1200 voice circuits, but only four television channels. Thus, if one television program is carried, 300 voice circuits are eliminated from its potential capacity for the duration of the program.³¹

Since the requisite size and complexity of the ground receiving equipment diminishes as the effective radiating power (ERP) of the satellite is increased, it is possible to conceive of a satellite with sufficient power to be received by an ordinary television set. This type of "direct broadcast" satellite is not presently available. It has been variously estimated that such a system could be developed in five to ten years.³² In time, it will be technically feasible to launch a satellite capable of transmitting a dozen color channels to unmodified television sets, using ordinary rabbit-ear antennas and located inside concrete buildings in downtown urban areas. However, such a satellite would require hundreds of kilowatts of

³⁰ See *Foreign Policy-Satellite Hearings*, *supra* note 23, at 19, 38-39.

³¹ See *Hearings on Military Communications—1968 Before the Military Operations Subcomm. of the House Comm. on Government Operations*, 90th Cong. 2d Sess. 27 (1968). The following analogy is helpful in understanding this point: "Picture the satellite or cable as an interstate highway. Data transmission is like a scooter along the side of the road. Telephone calls are like a Volkswagen. TV is like a whole fleet of Mack Trucks." 26 CONG. Q. 534 (March 15, 1968).

³² *Foreign Policy-Satellite Hearings*, *supra* note 23, at 47, 119, 164, 203.

power and would be of such great weight that it could be placed into orbit only by a Saturn 5 launch vehicle at an estimated cost of \$200 million per launch.³³ At this high cost, it is unlikely that this system will be used for direct satellite-to-home broadcasting. However, with simple modifications to existing television sets, a much less powerful satellite would provide direct satellite-to-home television. For example, specially designed outdoor antennas and preamplifiers would drastically reduce the size and power of the satellite required for direct broadcast. The cost of such additions to the conventional television receiver has been estimated at only about \$100 per set.³⁴ AT&T has stated recently that a communications satellite can be launched at a cost of thirteen million dollars.³⁵

A further reduction in the size of the direct broadcast satellite could be achieved if the television picture were to be transmitted by means of FM rather than AM modulation. FM has the advantage of requiring much less radiated power than AM to produce the same quality picture.³⁶ Two factors will probably preclude the use of FM transmission. The use of FM modulation would require approximately ten times as much bandwidth, or spectrum space, as AM requires.³⁷ More importantly, all existing television receivers in this country are built to receive the visual signal on AM.

A television broadcast satellite need not be direct satellite-to-home broadcast. Two other types of systems are available. These are termed "community broadcast" and "distribution" systems. By "community broadcast" is meant a system whereby the satellite signal would be picked up by roof-mounted antennas in the three to ten meter size range. While these would be of impractical size and cost for home use, they would present no problems for use by educational television, commercial television, or cable television systems. The use of such receiving equipment permits a much smaller satellite to be used. One weighing under 1,000 pounds could, it is estimated, provide six channels.³⁸ Distribution of the signal to individual receivers could then be carried out via closed circuit or cable. The "distribution" system requires a still smaller satellite and correspondingly larger ground facilities. The principal use for such a system would be commercial TV distribution in the same manner as microwave links accomplish this today. The signals would be received and rebroadcast by regular television stations or via cable.³⁹

The Communications Satellite Act of 1962⁴⁰ set up the Communications Satellite Corporation (Comsat)⁴¹ as a unique instrument to promote the establishment of a

³³ Satellite Broadcasting, an address by W. L. Pritchard, Director, Comsat Laboratories (AIAA 5th Annual Convention, Oct. 22, 1968). See also *Foreign Policy-Satellite Hearings*, *supra* note 23, at 11.

³⁴ W. L. Pritchard, *supra* note 33.

³⁵ N.Y. Times, Oct. 23, 1969, at 83.

³⁶ See *Foreign Policy-Satellite Hearings*, *supra* note 23, at 10, 264.

³⁷ *Id.* at 10.

³⁸ *Id.* at 273.

³⁹ *Id.*

⁴⁰ Communications Satellite Act of 1962, 47 U.S.C. §§ 701-44 (1964).

⁴¹ *Id.* §§ 701(c), 731.

global communications network. In 1964, the International Telecommunications Satellite Consortium (Intelsat) was formed. Intelsat owns the present global satellite system, with Comsat serving as satellite manager as well as being the representative of the United States in the consortium. Each country which has signed the international agreement has an ownership interest in the system proportionate to its investment. As of October 1969, there were seventy member nations in Intelsat.

Table 2 shows the ownership quotas for a selected number of Intelsat member nations.⁴² The major investment of the United States in the research and development leading up to a practical communications satellite, and its provision of launch-

TABLE 2
REPRESENTATIVE INTELSAT OWNERSHIP QUOTAS

Country	Quota (Per Cent)
Australia.....	02.390993
Brazil.....	01.413399
Canada.....	03.260445
France.....	05.303657
Germany.....	05.303657
India.....	00.471133
Israel.....	00.568841
Italy.....	01.912794
Japan.....	01.738904
The Netherlands.....	00.869452
Philippines.....	00.492590
United Arab Republic.....	00.316899
United Kingdom.....	07.303396
United States (Comsat).....	53.036570

ing facilities, is reflected in its predominant ownership share of over fifty-three per cent. By way of comparison, the second largest ownership share, that of the United Kingdom, is only 7.3 per cent. The policy-making body for Intelsat is the Interim Communications Satellite Committee (ICSC). Representation on the ICSC is assigned to member nations having ownership quotas of 1.5 per cent or more. Countries with less than 1.5 per cent ownership can associate with others so as to obtain the requisite total and place a representative on the ICSC. Voting is weighted according to shares. By agreement, Comsat's share can never drop below 50.6 per cent.

A simple majority does not determine the issue in major policy matters, including design of the satellite system and contract expenditures of more than \$500,000. Such policy-making decisions require Comsat's voting strength plus 12.5 per cent or, if that formula fails to produce a result within two months, Comsat's vote plus 8.5 per cent.⁴³ Comsat, therefore, needs at least the votes of Great

⁴² 1968 COMSAT ANN. REP.

⁴³ Agreement with Other Governments Establishing Interim Arrangements for a Global Commercial Communications Satellite System, Aug. 20, 1964, [1964] 15 U.S.T. 1705, T.I.A.S. No. 5446; see Trooboff, *INTELSAT: Approaches to the Renegotiation*, 9 HARV. INT'L L.J. 1 (1968); Johnson, *Inter-*

Britain and one other country, or some larger combination of countries, to carry a major decision.

The interim agreements under which Intelsat was formed are being renegotiated at present. At issue is the continued pre-eminence of the United States in its role of satellite manager and majority owner. Some member nations have been reported as desiring a more nearly equal division of ownership and policy-making authority. Also at issue is whether the USSR will agree to join Intelsat. While the USSR has been welcomed to membership, the Soviet Union has indicated that its participation is dependent upon significant changes being made in the organization.⁴⁴

Satellites in the Intelsat system are designated by their series and with individual numbers. Their capabilities are shown in Table 3.⁴⁵ At present, the global satellite system is concentrated over the Atlantic, Pacific, and Indian Oceans. Over the Atlantic there is one Intelsat III and one Intelsat II, both of which are in use. The Intelsat I (Early Bird) is also in orbit over the Atlantic. Although presently shut off,

TABLE 3
INTELSAT CAPABILITIES

Item	Intelsat I Early Bird	Intelsat II	Intelsat III	Intelsat IV ¹
Diameter, inches.....	28.4	56.0	56.0	93.0
Height, inches (overall).....	47.1	51.0	78.0	193.0
Weight, pounds (in orbit).....	85	190	322	1,200
Design lifetime (years).....	1½	3	5	7
Total 2-way telephone circuits ² , or.....	240	240	1,200	5,000 to ³ 8,000
TV channels ⁴	1	1	4	12

¹Parameters estimated.

²When using standard earth stations having 85-to-79 foot diameter antennas.

³Depending on type modulation, number of carriers per repeater, and antenna beam width used.

⁴In lieu of telephone circuits.

the Intelsat I is capable of being activated if needed, as in fact it was during the recent malfunction of the Intelsat III.⁴⁶ A single Intelsat III is in use over the Indian Ocean. Another Intelsat III and an Intelsat II are in use over the Pacific, with one inactive Intelsat II in orbit as a reserve.

The only nation, apart from the United States and the USSR, to launch its own satellite with its own equipment is France.⁴⁷ The Japanese appear on the verge of

national Co-operation in Satellite Communications Systems, in AMERICAN SOC'Y OF INT'L LAW, 1967 PROCEEDINGS 24.

⁴⁴Trooboff, *supra* note 43, at 75-81; *Foreign Policy-Satellite Hearings*, *supra* note 23, at 97; Washington Post, Mar. 10, 1969, § A, at 6, col. 1. In 1968, the Soviet delegate to the United Nations circulated a proposal for its own global satellite system, Intersputnik. See *Foreign Policy-Satellite Hearings*, *supra* note 23, at 99, 194; TIME, Sept. 6, 1968, at 85.

⁴⁵Reproduced from SIXTH ANNUAL REPORT ON COMMUNICATIONS SATELLITE ACT OF 1962, H.R. DOC. No. 91-61, 91st Cong., 1st Sess. 9 (1969).

⁴⁶Wall Street Journal, July 3, 1969, at 7; *id.*, July 7, 1969, at 9.

⁴⁷*Foreign Policy-Satellite Hearings*, *supra* note 23, at 20.

doing so, despite the recent failure of their fourth launching attempt.⁴⁸ Some nations have launched their own satellites while contracting with NASA to provide the launch equipment. A group of European nations have organized the European Launcher Development Organization (ELDO) for the development of a vehicle similar to the Thor or Atlas.⁴⁹ France and Germany are developing a satellite system, called "*symphonie*," which is intended to provide regional TV distribution and multichannel telephone service for those two countries. The Canadian government also has a similar system under development.

Communication by space satellite provides the opportunity for great increase in information to the people of the world. By satellite, electronic data and information centers throughout the world can be connected into a single reservoir of information. Satellite transmission can make this information available to the peoples of the undeveloped countries, contributing greatly to their cultural, economic, and social development. Direct satellite-to-home broadcasting could have a great impact on the present system of over-the-air television provided by local stations. The implications of satellite broadcasting for future progress and existing regulatory approaches is great.

B. The Laser Beam

A new technology utilizing the visible light range of frequencies has grown up around the unique capabilities of the laser beam. A laser beam is composed of light waves so firmly parallel in their path that they can traverse enormous distances without diffusing substantially. In 1962, a laser beam was directed to the surface of the moon. After traversing the lunar distance of a quarter million miles, the beam had spread to a diameter of only two miles. The focusing characteristic of laser beams has been used to advantage in clinical techniques, including surgery. For example, a laser beam can be converged within a few thousandths of an inch inside the human eye. Laser beams have many industrial applications, such as machining integrated circuits, cutting ceramic substrates, fabricating semiconductors, and welding transistors and other electronic component parts.⁵⁰

Laser beams, like radio waves, can be modulated to transmit information. Moreover the quantity of information which can be transmitted by such beams is astounding. In 1965, the information broadcast by New York's seven television channels was transmitted across a room on a single pencil-thin beam of laser light.

Laser beams can be transmitted both over the air and through closed systems. For the latter, an internally silvered pipe or laser tube is used. It has been estimated

⁴⁸ Washington Post, Sept. 23, 1969, § A, at 19.

⁴⁹ *Foreign Policy-Satellite Hearings*, *supra* note 23, at 20.

⁵⁰ 1969 IEEE INTERNATIONAL CONVENTION DIGEST 144-51 (1969).

that a laser tube having a diameter of one inch has the capacity to carry one hundred million voice channels.⁵¹

C. The Computer-Communications Complex

It was difficult in the 1860s to predict the consequences of Maxwell's equations hypothesizing the existence of the electromagnetic spectrum. It is equally difficult in the 1970s to predict the impact of the invention of the electronic digital computer. In this technological age, the computer is becoming a necessity of life. Less than twenty years after its introduction it has become indispensable for the conduct of our government and national defense. It is rapidly becoming indispensable for the operation of commercial and financial institutions. The time is not far off when the ordinary citizen will use the computer, as he now uses the telephone, in his daily life.

The developing communications technology provides an opportunity to improve greatly man's information environment. However, the volume of information can inundate us and prevent orderly use of the information unless a commensurate system of selecting and channelling information is utilized. The computer satisfies this need for selection and organizing of information on the part of the individual.

The growth of the computer industry has been phenomenal. Its popular beginning was in 1951 when the first "Univac" was delivered to the Bureau of the Census.⁵² Now, less than twenty years later, it is being confidently predicted that the computer industry, including design, manufacturing, programming, and servicing, will soon constitute the world's leading industrial occupation.⁵³

In 1968, the number of computers in use was 60,000, with an additional 25,000 on order.⁵⁴ Over the network of the domestic telephone, the volume of data transmission—the "voice" of the computer—is rising rapidly. The chairman of the board of AT&T has predicted that by 1970 the volume of data transmitted over the lines of the Bell System would exceed the volume of voice transmission.⁵⁵ The computer has become a means of communication indispensable to message and circuit switching.⁵⁶ Were it not for the conversion of the switching operations of

⁵¹ Johnson, *New Technology: Its Effect on Use and Management of the Radio Spectrum*, 1967 WASH. U.L.Q. 521, 537 (1967).

⁵² S. THOMAS, *COMPUTERS: THEIR HISTORY, PRESENT APPLICATIONS, AND FUTURE* 73 (1965).

⁵³ *Id.* at 9.

⁵⁴ Response of the Department of Justice at 6, *Regulatory and Policy Problems Presented by the Interdependence of Computer and Communication Services and Facilities*, No. 16979 (F.C.C.) [hereinafter cited as FCC Computer Inquiry].

⁵⁵ See D. PARKHILL, *THE CHALLENGE OF THE COMPUTER UTILITY* 50 (1966).

⁵⁶ "Message switching" refers to the process whereby the common carrier transmits a set message over its facilities, as is the case with the public message telegram service. The charge is based on the number of words or amount of information sent. The transmission typically calls for store-and-forward functions, wherein the complete message is recorded and held until a suitable circuit for transmission becomes available. "Circuit switching" refers to the provision of an open channel for the user's exclusive utilization, such as the public telephone service. The carrier's charge is based on the length of time the circuit is used rather than on the amount of information conveyed.

the domestic telephone network to automation-computer control, it has been estimated that every woman in the nation would be needed as a telephone operator.⁵⁷

The computer has become an indispensable component of the communications industry. This was recognized by the Federal Communications Commission in 1966 when it announced an inquiry to determine the applicability of the Federal Communications Act of 1934 to computer services.⁵⁸ Of course, the computer has important uses for science and business, apart from its communications function.

A computer can be utilized on an "in-house" or a time-shared basis. "In-house" refers to a computer which is used only on the premises in which it is housed, with no provision for utilizing it, via communications links, from remote locations. In the time-shared use, to be described below, a single computer is utilized by many different users who are not located at the computer site. The "in-house" use is less significant to the widespread utilization of the computer than is the remote access, time-sharing system now coming into use under the term "computer utility."⁵⁹ Such application, which makes a central computer available for simultaneous use by a large number of remote users, requires suitable communications to link the user with the computer system.

Computers are of two principal types, the analog and the digital. The analog computer is built to meet specific needs and is used primarily in scientific and engineering applications. It has the ability, through the manipulation of electric potentials or other quantities, to simulate exceedingly complex systems. An analog computer may be thought of as an elaborate electronic equivalent of the slide rule or thermometer. On the slide rule, numerical quantities are represented by differing lengths. The quantities can be compared, and mathematical operations performed upon them by comparison of the lengths which are analogous to them. In the same way, a thermometer can measure temperature by means of containing a measure, the trapped mercury in the glass tube, which will behave analogously to the temperature. However, rather than measure just one quantity, such as temperature, the analog computer can evaluate systems with great numbers of variables. For example, an engineer can study the behavior of a jet-plane design in flight under various conditions of temperature, altitude, speed, and load, without the expense and risk of building and flying the design.⁶⁰

⁵⁷ THOMAS, *supra* note 52, at 33-34.

⁵⁸ FCC Computer Inquiry, *supra* note 54, Notice of Inquiry, 7 F.C.C.2d 11 (1966). See Smith, *The Interdependence of Computer and Communications Services and Facilities: A Question of Federal Regulation*, 117 U. PA. L. REV. 829 (1969); COMPUTER COMMUNICATIONS SYMPOSIUM (Gruenberger ed. 1967).

⁵⁹ The use of this term has been criticized by some because of its implication—by analogy to public utilities—of the need for government regulation. H. BARNETT, *THE FUTURE OF THE COMPUTER UTILITY* 15 (1967). While increasing in importance, time-shared computers now account for only a small percentage of all computers in use.

⁶⁰ See generally COLE, *INTRODUCTION TO COMPUTING* 9 (1969); H.R. REP. No. 802, 89th Cong., 1st Sess. 7 (1965).

Since the analog computer must work by manipulating electronic potentials, or other electrical quantities, its accuracy is only as good as the components it contains. While these are relatively accurate, errors can be cascaded and cumulative over the course of complex operations. The analog computer's special function, then, is to provide an electronic model that can be used for experimentation and study of complex systems containing many variables. It is not suited for the solution of high precision mathematical problems or data retrieval. Computers of the analog type make up only a small percentage of those now in use.⁶¹

The word "computer" as used today is practically synonymous with the electronic "digital" computer. The digital computer works in numerical code. It is capable of dealing with any information, quantity, or concept which can be reduced to a symbolic representation or code. It can remember instructions of great complexity, recall a desired item of information from an immense hoard of stored items in its memory, and exercise a form of logic by automatically taking specific alternate courses of action depending on the outcome of a particular operation. All this it does at incredibly high speed.⁶² The speed of operation of the digital computer has increased impressively during the short history of the computer. At one time, internal computer speeds were measured in thousandths of a second. Now they are measured in millionths and billionths of a second. Computer designers have brought computer speed close to the speed of an electric current through a circuit, that is, almost the speed of light. In a billionth of a second, a signal cannot be sent further than one foot.⁶³ Therefore, to increase the speed of operation it is necessary to reduce the size of the computer, thus shortening the signal's path. Miniaturization is rapidly taking place, aided by the advances in transistorized, solid-state circuitry.

Unlike the analog computer, the digital computer does not need to manipulate electric values over wide ranges to achieve its results. The digital computer, operating in code, need only be able to recognize whether a given circuit is "on" or "off." In order to permit the digital computer to perform mathematical calculations and follow programming instructions, the code need only use this modest ability to recognize two states of a circuit. This is done with the binary code, a numerical system which makes use of only two digits.

In order to understand the binary system, it is helpful to review briefly the familiar decimal system. Man's reliance upon external means of computation at a relatively late period resulted in his mastering a system based on his ten fingers. Today our numerical system is based on units of ten. Ten different digits, from zero to nine, are used to express any quantity, no matter how large. Since there is no single digit greater than 9, we must reuse digits in order to express higher

⁶¹ H.R. REP. NO. 802, 89th Cong., 1st Sess. 7 (1965).

⁶² See THOMAS, *supra* note 52, at 76-87; J. HARGREAVES, *COMPUTERS AND THE CHANGING WORLD* 1-26 (1967).

⁶³ THOMAS, *supra* note 52, at 106.

numbers. This is carried out by placing the digit one place to the left to indicate that it now represents a quantity ten times as great. This process is repeated for higher numbers, with each shift to the left representing a multiplication by ten. In the number 624 for example, the right hand digit represents four units, the digit to the left of it represents twenty units (two times ten), and the left hand digit represents six hundred (six times ten times ten). In recent years, our students in the elementary grades have been taught comparative numerical base systems such as "base seven."

While the decimal system is practical for the human mind, it is not an efficient system for a computer which uses two-state devices or circuits rather than ten-state ones. Also the rules of addition and multiplication are much simpler in the binary than in the decimal system. Replacing the ten digits of the decimal system, the binary system has only two digits: 0 and 1. A circuit in the "off" condition represents 0; in the "on" position, it represents 1. In the decimal system, we utilize all the available digits from 0 to 9 and then begin to reuse them by displacing them one position to the left. The same procedure is used in the binary system. However, after we have reached 1 we are already out of digits. To write the number two, we displace the digit one place to the left, thus doubling its value just as the same operation in the decimal system increases the value tenfold. To illustrate, the number one looks the same in both the decimal and the binary system:

$$\begin{array}{ccc} \textit{Decimal} & & \textit{Binary} \\ 1 & = & 1 \end{array}$$

To write the number two, we use the appropriate digit in the decimal system. In the binary system we displace the digit 1 one place to the left, thus doubling its value to two. The resulting empty space on the right is indicated by zero:

$$\begin{array}{ccc} 2 & = & 10 \end{array}$$

To write three we again use the appropriate digit in the decimal system. In the binary system, 1 is added to the above figure for two:

$$\begin{array}{ccc} 3 & = & 11 \end{array}$$

To write four, a single digit is again available in the decimal system. In binary, we again move the digit one place to the left, doubling its value from two to four:

$$\begin{array}{ccc} 4 & = & 100 \end{array}$$

The following equivalents further illustrate the relationship between decimal and binary numbers:

$$\begin{array}{ccc} 5 & & 101 \\ 6 & & 110 \\ 7 & & 111 \\ 8 & & 1000 \end{array}$$

9	1001
10	1010
20	10100
100	1100100

One disadvantage to the binary system is the large number of digits needed to express numbers. The binary number for one hundred requires the same number of digits as the decimal system used for one million. Although this method of expressing quantities may seem cumbersome to man, it presents no problem for the computer, which can operate in millionths and billionths of a second.⁶⁴

The binary code may be thought of as the language of the computer. The basic unit of data transmission to and from the computer is the "bit" (*binary digit*). The computer expresses all quantities, concepts, values, and other data in bits. This output can be made to operate various terminal devices, such as an electric typewriter, so as to render it intelligible.⁶⁵

The computer's speed of operation is such that it is feasible for a large number of remote users, connected with suitable communications links, to make use of the unit simultaneously. This is called a "time-shared" system. The response times are so short as to give each user the impression that he has sole possession of the system. As more efficient central computers are coming into use, the unit costs for computation are diminishing. This is resulting in the communications costs becoming the principal economic limitation on the extension of shared computer service to remote users.⁶⁶

Computer linkages are commonly by telephone line, broadband cable, or microwave. Satellite linkage is also possible. The communication channel used for data transmission, be it telephone line, cable, or microwave, can be compared with a pipeline. It has limitations, just as the pipeline, on the capacity it can handle in a given unit of time. In the pipeline, this is determined in part by the diameter of the pipe, its length, and the friction of the pipe-walls. In a similar manner, the

⁶⁴ The rules for binary addition are much simpler than those for decimal addition:

$$\begin{aligned} 0 + 0 &= 0 \\ 0 + 1 &= 1 \\ 1 + 0 &= 1 \\ 1 + 1 &= 10 \end{aligned}$$

That is, if two different digits are added together the result is 1. If similar digits are added, the result is 0. But if the digits are both 1's, the machine must carry 1 to form the binary number of two (10). For binary multiplication:

$$\begin{aligned} 0 \times 0 &= 0 \\ 0 \times 1 &= 0 \\ 1 \times 0 &= 0 \\ 1 \times 1 &= 1 \end{aligned}$$

That is, if either digit, is 0, the result is 0; if neither is 0, the result is 1.

⁶⁵ See BARNETT, *supra* note 59, at 46.

⁶⁶ FCC Computer Inquiry (Notice of Inquiry), *supra* note 58, at para. 19; Response of the Department of Justice at 1, FCC Computer Inquiry, *supra* note 54.

amount of data which can pass through a communications link is restricted by its bandwidth ("diameter") and transmission losses ("friction"). The flow of data through a communications link is measured in bits-per-second.

The most easily available connection system is the telephone line. The public voice network can be used for data transmission, but it is limited in its bandwidth and transmission quality. No more than 2000 bits per second may be transmitted over this network.⁶⁷ With sufficient bandwidth, available through such communications links as microwave, transmission speeds of 1.5 million bits per second are attainable.

Depending on the user's requirements, communications links can be obtained in various bandwidths from the Western Union Company or AT&T. These bandwidths can be divided into narrowband and broadband. Any frequency up to and including four kilohertz is defined as narrowband. A four kilohertz bandwidth is also referred to as a "full voice" circuit. Broadband is defined as anything above four kilohertz in bandwidth. If the narrowband capacity of 2000 bits per second is sufficient for the user's purpose, he need only place a telephone call in the usual manner, and, provided he has the necessary terminal equipment, the computer at the other end of the telephone can talk at the rate of 1500 words per minute.⁶⁸

The terminal is the instrument by which data is supplied to (input terminal) or is received from (output terminal) the computer system. Terminal equipment can include a variety of devices. One of the most popular for commercial use is the interrogating typewriter. It can be used as both an input and an output device and has the advantage of providing a permanent record of the data supplied to and received from the computer. Other terminals include card readers and punches, paper tape readers and punches, chart or print readers, magnetic tape devices, plotters, and various cathode-ray-tube displays. Written material can be read by a suitably equipped computer or printed by it at high speeds. Also, the touch-tone telephone can enter digital information into the system by means of its buttons. Computers cannot respond to voice inquiries, but, through programmed audio response by recorded message, they can "answer back."⁶⁹

The process by which one computer can serve a large number of remote users simultaneously with such speed as to give each the illusion that he is in sole control of the system is quite complex.⁷⁰ Its operation can be analogized to a chess master playing a score of games simultaneously. Before one opponent has had time to react to the master's move and respond with one of his own, the master is back with him, thus giving the illusion that the master is playing only with him.

To insure that no user's program is neglected in favor of another, the time-shared computer has a timer which allocates time segments, usually measured in milli-

⁶⁷ BARNETT, *supra* note 59, at 46.

⁶⁸ THOMAS, *supra* note 52, at 33.

⁶⁹ BARNETT, *supra* note 59, at 53.

⁷⁰ *Id.* at 33 *et seq.*

seconds, to each user. When that time has expired, the program is interrupted and placed at the end of the line of waiting users; the next program is then brought into action.⁷¹ Thus, the "waiting time" is averaged over all those who are making use of the machine at any particular moment. If the computer simply performed the programs all the way through on a "first come, first served" basis, the last users in line might notice a perceptible delay.

The above discussion has reference to what is termed a "real-time" computer. This is a computer which produces the desired data concurrently, within a matter of seconds or minutes, to the reception of the incoming data. This allows the user to react to the information and put further questions to the computer, based on previous answers. In contrast to real-time computers, "batch-processing" computers respond after a sizeable time delay, such as hours or days. Typically, these computers accumulate data for a period of time in order to arrive at an economic volume for processing. Time-shared computers are typically real-time systems.

It is impossible to list exhaustively the applications of computers. Computers have been used to analyze traffic-flow patterns, automobile manufacturing processes, electronic circuit problems, and airline flight plans. In the area of data retrieval, computers can supply stock market quotations or the precise location of a given railroad car from among thousands in motion over a track system extending thousands of miles. Computers owned by the Weather Bureau can produce forecasts as far as 100 days in advance in five-minute increments, and automatically draw weather maps, plotting highs and lows, by means of a computer-controlled writing pen.⁷² Computers can track the orbits of all the satellites and "space junk" now circling the globe, a not inconsiderable service for anyone planning to launch a new manned rocket.⁷³

There are many down-to-earth applications of the computer to the needs of the ordinary citizen. Money and the conventional bank check may pass from the scene as a result of the computer. The bank would become a service operation for its depositors. Bills would be sent to the bank for payment directly from the individual's account with the bank's computer noting the debit. The depositor could be spared the necessity of collecting his paycheck, as well as paying his bills. His employer's computer need only notify the bank to credit his account with the amount of his wage.⁷⁴ A further development of this concept has been described as follows:

⁷¹ *Id.* at 40.

⁷² See THOMAS, *supra* note 52, at 39.

⁷³ At a recent count, the North American Defense Command (NORAD) was tracking, with the aid of computers, 1744 objects, less than fifty of which are functioning space satellites. The remainder are abandoned spaceships, burned out or exploded rockets, and silenced satellites. See Washington Daily News, Sept. 29, 1969, at 9.

⁷⁴ THOMAS, *supra* note 52, at 17.

Suppose, for example, that businesses of all sizes have simple terminals linking them electronically to a central information exchange. Then each business can make instantaneous credit checks and offer its customers the convenience of universal credit cards. These cards, referred to by some as "money keys," together with the simple terminals and information exchange, can all but eliminate the need for currency, checks, cash registers, sales slips, and making change. When the card is inserted in the terminal and the amount of the purchase keyed in, a record of the transaction is produced centrally and the customer's balance is updated. A signal is transmitted to the terminal from the central exchange if the customer's balance is not adequate for the sale. Positive credits to the customer's account, such as payroll payments, benefits, dividends, and gifts are entered in a similar way. Periodic account statements are figured automatically and delivered to customers, perhaps directly to a private terminal for some, or by postal service for others.⁷⁵

As computers become more widely utilized, the consumer may not need to visit the store. He may be able to make his selection at home over his television receiver. He might wish to study a prospective purchase by inquiring of a computer utility regarding the average price of a particular product in his area, the results of any government testing of the product, and any allegations of false advertising involving it.

As noted below in the discussions of electronic video recording and cable television, the communications technology which will ultimately enable the individual citizen to abandon his role as a passive spectator is rapidly becoming available. Each individual will become an active seeker of information and entertainment and a participant in the process of self-government. The computer will be available, and ultimately will be necessary, as an aid in exercising man's new freedom of choice. By reference to the computer, each citizen can specify exactly what type of service, information, or program he desires. In response, the computer can inform him of the availability of those offerings which seem to meet his specifications. This proliferation of computer services available to the ordinary citizen is not far off.

The implications for misuse of such a powerful instrument as the computer are unsettling. The danger of invasion of the individual's privacy seems to be the most pressing in point of time. Computers may soon be the repository not only of trade secrets and customer lists, but of many other types of information including tax returns, credit information, criminal records, and medical histories. As more and more of this data accumulates in the permanent memories of business and government computers, it will become increasingly important to safeguard the privacy of individuals from inadvertent intrusions as well as the incursions of overzealous government agents and others who may have access to the computers. Without adequate safeguards, the computer could quickly become an instrument of repression:

⁷⁵ Greenberger, *Banking and the Information Utility*, COMPUTERS AND AUTOMATION, April 1965, quoted in PARKHILL, *supra* note 55, at 157.

It requires no surfeit of extrasensory perception to see some of the dangers that might face us if certain capabilities of the computer utility were to be misdirected. Together, the various data files of the different networks—medical, educational, financial, legal, law enforcement, etc.—could contain a complete record from birth until death of even the most private affairs of everyone. In the absence of adequate controls, there are obviously enormous possibilities for industrial espionage and even blackmail in such a situation. Worse still are the possibilities for political repression inherent in a system in which one could not purchase so much as a stick of chewing gum without immediately revealing one's identity and whereabouts to the central computer. There is an uncomfortable aura of "1984" in all this.⁷⁶

The FCC recognized the potential invasion of privacy by the computer when it announced its computer inquiry,⁷⁷ and this issue has been the subject of congressional hearings.⁷⁸ The solution to this problem may require cryptographic computer techniques in the case of privately operated computer systems. While it will be relatively easy to design government computer memories that are closed to unauthorized inquiries, it will be difficult to insure that such authorization is not abused or is not granted improperly.

Of course, the implications of the computer reach far beyond the relationship it bears to telecommunications, but the resolution of the social problems raised by the computer the use of the computer in solving other social problems will involve communications techniques.

D. Electronic Television Recording

In this section, the term "electronic television recording" (ETR) is used to describe any system for recording television for home playback. This can be accomplished in a number of ways, as will be described below. Regardless of the details of the technology used, the advent of ETR will endow the television set with a new versatility; it will be capable of being more responsive to the individual taste and interests of its owner. Freed from the present necessity of choosing from among the available selections at a given time from the networks or his local station, the viewer will be able to select from new program sources. He will also be able, with certain ETR systems, to record regular programming for later playback at a more convenient time, and as often as he may wish.

A problem in developing a suitable ETR system for home use is the great amount of electronic information required to enable a television receiver to reconstruct a complete picture thirty times per second. As already described in this article, this

⁷⁶ PARKHILL, *supra* note 55, at 167.

⁷⁷ FCC Computer Inquiry (Notice of Inquiry), *supra* note 58, paras. 22-24.

⁷⁸ SUBCOMM. OF THE HOUSE COMM. ON GOVERNMENT OPERATIONS, 89TH CONG., 2D SESS., THE COMPUTER AND THE INVASION OF PRIVACY (Comm. Print 1966); SUBCOMM. ON ADMINISTRATIVE PRACTICE AND PROCEDURE OF THE SENATE JUDICIARY COMM., 90TH CONG., 1ST SESS., COMPUTER PRIVACY (Comm. Print 1967); *see* 82 HARV. L. REV. 400 (1968).

requires a much greater volume of information than is needed for the mere reproduction of sound.⁷⁹

For example, the familiar tape recorder can adequately duplicate the human voice by means of a quarter inch tape moving at one and seven-eighths inches per second past the playback head. In the high fidelity reproduction of music, with its complex harmonics and greater tonal range, a tape speed of seven inches per second is needed for adequate reproduction.

By contrast, the typical video tape equipment used in television studios utilizes magnetic tape which is two inches wide and moves at fifteen inches per second. From every standpoint, including size, cost, and complexity, such professional equipment is obviously impractical for home use. Smaller versions of this magnetic tape video recording equipment, making use of half-inch tape, have been available for some years. Size and cost considerations, however, have thus far prevented their widespread utilization for home entertainment.

If a system for reproducing pre-recorded television in the home is to be practical, it must be compatible with existing television receivers, marketed at a reasonable price, and miniaturized to a size in keeping with home furniture. These requirements may have been met in a number of ETR systems which will begin coming on the market in 1970.

The Electronic Video Recording (EVR) system developed by CBS laboratories makes use of film and an optical scanning device, rather than magnetic tape. The EVR player converts the optical images on the film to electronic signals which are fed to the antenna terminals of a conventional television set. This electronic information is then retranslated into a television image in the same manner as with an over-the-air signal. The Selecta-Vision system, developed by RCA, makes use of inexpensive clear vinyl tape to store the television picture. By means of a new technology combining a laser beam with a series of holograms (optical interference patterns) impressed on the tape, the recorded television signal can be reproduced and fed into the receiver. The Sony Corporation of Tokyo has joined this competition by announcing the introduction in late 1971 of an ETR device making use of magnetic tape.

The announced prospective costs of these ETR units range from \$350 to \$795.⁸⁰ These prices may be expected to decrease when economies of volume production are achieved. Eventually the ETR system may be incorporated as an integral part of the television set. Another development which may be readily anticipated is the perfecting of a camera device enabling the individual to produce his own programs, "electronic home movies," for viewing on his television set.

⁷⁹ See pp. 212-13 *supra*.

⁸⁰ TV DIGEST, Aug. 26, 1969, at 4, 8; BROADCASTING, Oct. 6, 1969, at 57, Oct. 13, 1969, at 75, Nov. 24, 1969, at 82; NEWSWEEK, Oct. 13, 1969, at 102; VARIETY, Oct. 1, 1969, at 1.

Once an individual home is equipped with ETR, it may be used in a number of ways. It may be used simply as a means of delayed viewing of regular programs, or to view pre-recorded material produced and distributed much in the manner as presently done with phonograph records and stereo tapes. Aside from making the television set a more versatile and flexible instrument for the individual, this second use of ETR offers a new outlet for the creative talents and efforts of artists, actors, programmers, and so forth.

Unlike cable and satellite television, the EVR technology appears to be entering the communications market place unattended by controversy and unfettered by regulatory control. Nevertheless, extensive use of ETR equipment for pre-recorded programs would result in diminished use of television sets to receive the regularly scheduled commercial programming and possible diversion of some talent from program production for so-called "free" commercial television to independent program production for electronic home movie exhibition.

The FCC has not indicated that electronic television recording should be subject to regulation.⁸¹ However, the FCC has imposed stringent limitations on subscription television stations for pay television and potential siphoning of talent from "free" television to pay television.⁸² As electronic television recording does not utilize programming broadcast over the air, it seems unlikely that it would be subject to regulation by the FCC. However, in the case of cable-TV transmitting solely by cable, the FCC has exercised jurisdiction and the Supreme Court has approved.⁸³ Accordingly, it is possible that if the impact of electronic television recording on commercial broadcasting should become substantial, some effort might be made to extend the FCC's protection of commercial broadcasting by regulation of ETR.

E. Subscription Television

There is no significant new technology which relates to subscription television (STV). Subscription television may be broadcast over the air or by cable. Hence, the transmitting and receiving equipment is that used for commercial broadcasting. In order that its programs may be received only by subscribers, the signals are broad-

⁸¹ In *Hearings on H.R. 12435 Before the Subcomm. on Communications and Power of the House Comm. on Interstate and Foreign Commerce*, 90th Cong., 1st Sess. 183 (1967), the following colloquy took place:

Mr. BROYHILL: "Would the FCC want to exercise jurisdiction over [EVR]? Would this not be a siphoning off of audience?"

Mr. HYDE [then Chairman of the FCC]: "Neither this committee nor the FCC is concerned. . . . True, this replay device would use your TV set but it would be like playing a program on your TV set in the same way you would play a record on your high-fidelity set."

⁸² Amendment of Part 73 of the Commission's Rules and Regulations (Radio Broadcast Services) to provide for Subscription Television Service, No. 11279, 10 P & F RADIO REG. 2d 1617 (F.C.C., 1967) [hereinafter cited as Subscription Television Service].

⁸³ Second Report and Order on CATV, 2 F.C.C.2d 725 (1966); 47 C.F.R. § 74.1101 (1966); *United States v. Southwestern Cable Co.*, 390 U.S. 157 (1968).

cast in a "scrambled" form, and an attachment to the conventional television receiver in the home decodes the scrambled signals into a television picture. The "unscrambling" device is rented by the subscriber. In the Hartford subscription television trial, the decoder was installed for a fee of ten dollars, a rental fee of \$3.25 per month for the decoder was charged, and service calls were without additional charge.⁸⁴ A weekly schedule was sent to subscribers, and the charge for each program was listed therein. Subscribers wishing to view a particular program set the prescribed code number in the decoder, and the video picture was unscrambled. Each program viewed and its price were recorded on a tape. Each month the subscriber mailed this tape together with a check for the charges for the programs viewed and the monthly rental fee to the broadcaster of the subscription television service.

The institutional components necessary for subscription television are three. A licensee of a television station must broadcast the programs over the air. Program production and distribution sources are necessary to supply programming. A local franchise organization, if the licensed broadcaster does not perform such function, must scramble the programs of the station, install, maintain, and service the unscrambling devices, collect fees from subscribers, and disburse funds to the participating components.⁸⁵

Subscription television could be provided over cable, either as a separate subscription television service or as a part of the service of cable television.⁸⁶ Cable television systems could either originate subscription television programs, transmitting them over one or more cable channels, or transmit subscription television programs over the air or capture signals broadcast over the air by others and transmit them by cable to subscribers. A cable television system can unscramble subscription television signals and transmit the decoded television signal on its cable as in the case of other cable television signals. However, the FCC prohibits cable television from including subscription television in its service. A minor exception is that on a case-by-case basis the Commission will consider whether it should approve a joint arrangement between a subscription television broadcaster and a cable television service for carriage by the cable television operator of subscription television broadcasts solely in the grade B (picture quality) contour of the service of the station.⁸⁷ The FCC has prohibited, for all practical purposes, inclusion of subscription television in the cable television service because of concern that cable television may be transformed into subscription television.⁸⁸

Throughout its consideration of subscription television, the FCC has exhibited a deep concern that subscription television would impair the service of advertiser-

⁸⁴ Subscription Television Service, *supra* note 82, at app. B.

⁸⁵ *Id.* para. 115.

⁸⁶ *Id.* para. 306.

⁸⁷ *Id.* paras. 309-10.

⁸⁸ *Id.* para. 304.

financed television,⁸⁹ divert viewers from conventional commercial television, and siphon programs and talent from advertiser-financed television to subscription television.⁹⁰ In part, this is articulated in terms of the inability of a large percentage of television viewers to pay the subscription television fees. Accordingly, the FCC has limited subscription television to major markets where ample commercial television service is available.⁹¹ Thus, subscription television will only be approved if there are five or more commercial television stations serving the community, and even then only one station may provide subscription television service.⁹² Other significant limitations are that feature films released only within the past two years may be shown on subscription television,⁹³ and sports events may not be shown if they were regularly televised over commercial television in the community during the past two years.⁹⁴ The Commission has stated,

We have, through limiting STV operations to five-station markets and to one station in those markets, and through limiting the kind of programming the STV stations may broadcast . . . , taken sufficient steps at this time to protect the existing TV structure.⁹⁵

Just why the FCC thought it necessary to place such stringent limitations on subscription television is not clear. In 1955, the FCC authorized experimental subscription television in Hartford, Connecticut. This test area was then observed for the value of subscription television's program supplement and its impact on conventional commercial television. Thirteen years later, the FCC authorized subscription television on the limited basis described above. After this lengthy experimental period, subscription television penetration was only three quarters of one per cent of the television homes in the test area.⁹⁶ Moreover, after this thirteen-year experiment, the Commission stated that ". . . the programming of a single over-the-air operation at Hartford . . . cannot form the basis for completely certain predictions

⁸⁹ Advertising-financed television is popularly called "free" television. The FCC has demonstrated concern that subscription television would impair "free" television in quality and quantity. Commercial television is "free" only in the sense that there is no direct charge to the viewer, as in the case of subscription television or, as it is popularly called, "pay-TV." Just as an advertiser must pay for capital equipment, labor, and raw materials, he must also pay for the advertisement, program, and time period when he presents his product to the public via commercial television. By attracting the customers of small business concerns which cannot afford to advertise nationally, a national advertiser on commercial television may increase sales and reduce cost through volume production and distribution. The phenomenal pattern of mergers among business institutions in recent years has been brought about in substantial part by the necessity of advertising on nationwide television networks in order to compete in the marketing of mass consumer goods and the inability of medium-sized companies to advertise over network television.

⁹⁰ Subscription Television Service, *supra* note 82, paras. 77-114.

⁹¹ *Id.* para. 75.

⁹² 47 C.F.R. § 73.642(a)(3) (1968).

⁹³ Subscription Television Service, *supra* note 82, paras. 86-87.

⁹⁴ *Id.* paras. 87-94.

⁹⁵ *Id.* para. 199.

⁹⁶ *Id.* para. 64.

about the programming that would be shown if nation-wide STV were authorized."⁹⁷ Of course, such a conclusion should have been clear from the beginning. The experience of the many UHF stations, which could not get off the ground for lack of a program source which was competitive with VHF, should have made it obvious that the experiment with *one* subscription television station would not lay a basis for predicting the future capacity of subscription television. However, such information as was gained from this experience—for example, the fact that saturation was less than one percent—suggests that subscription television could have been approved without the limitations imposed by the Commission.

F. Cable Television

Cable television, alias community antenna television (CATV), began for the purpose of serving people in communities which did not receive over-the-air television⁹⁸ and has become the potential complete telecommunications system.⁹⁹ By linking space satellites, radio, television, facsimile, telephone, teletype, telemetry, computers, data storage and retrieval systems, and other communications hardware in a complete cable-to-home communications system, it is possible to place each person in contact with his full information environment and to allow each person to contribute information to the storehouse of knowledge.

Cable television had its inception in 1949.¹⁰⁰ By mid-1968, approximately 2,000 cable television systems were operating or under construction.¹⁰¹ These systems were capable of carrying their own programs, in addition to signals received from regular television stations. Initially, cable television served communities lacking television service or receiving a signal of poor quality. An antenna was placed on a mountain or tall tower, and the signal was picked up, amplified, and transmitted via cable to the viewer's home. Later, microwave relay also was used to bring the signal from the point of origination or capture to the distribution point in the community served. At the distribution center, connection is made with coaxial cable or other wire-distribution lines. Usually, the distribution cable is supported by telephone or electric utility poles, the cable television system paying a rental for the use of the poles. In some cases, the cable is laid beneath city streets, an easement being obtained from the city; in other cases it may be necessary for the cable television system to erect poles for the cable. The signals are amplified at the central distribution point,

⁹⁷ *Id.* para. 48.

⁹⁸ 1968 FCC ANN. REP. 78.

⁹⁹ See PRESIDENT'S TASK FORCE ON COMMUNICATIONS POLICY, FINAL REPORT (1968) [hereinafter cited as TASK FORCE REPORT]; Comments of Jansky and Bailey, Broadcast Television Department, Atlantic Research Corporation, Amendment of Part 74, Subpart K, of the Commission's Rules and Regulations Relative to Community Antenna Television Systems, No. 18397 (F.C.C., filed Apr. 30, 1969); CATV Via Satellite, a presentation by Comsat before the National Cable Television Association, San Francisco, June 23, 1969.

¹⁰⁰ For a description of cable television, see L'Heureux, *The CATV Industry—Its History, Nature and Scope*, 2-3 TV & COMMUNICATIONS MAG., 1965-66.

¹⁰¹ 1969 BROADCASTING YEARBOOK 16.

and, depending upon the length of the cable and other conditions, further amplification of the signal may be necessary along the line. The systems now being installed usually are twelve-channel systems. However, twenty-channel systems are technically feasible at slightly greater cost,¹⁰² and some such systems have been installed.¹⁰³ The multiple purpose cable can carry simultaneously as many signals as there are channels, using different frequencies.

At home, the cable is attached directly to the television receiver. The viewer, as with the selection of conventional over-the-air broadcasting channels, turns the dial to select the channel carrying the program desired. More than three and a half million homes in the United States are receiving cable television service.¹⁰⁴ Cable television revenues for 1969 are estimated to be \$300 million.¹⁰⁵ As of 1965, the average subscriber was paying approximately sixty dollars per year for cable television service, in addition to the initial installation fee.¹⁰⁶

The "wired city" concept of cable television has received much attention during the past two years.¹⁰⁷ This concept has been strongly opposed by the existing structure of broadcasting.¹⁰⁸ The President's Task Force on Communications Policy concluded that cable television was the most promising avenue to diversity¹⁰⁹ but recommended that a policy be adopted of encouraging the growth of both over-the-air broadcasting and cable television.¹¹⁰

The principal difference between the "wired city"¹¹¹ cable television system and other cable television systems is that programs which are imported from outside the community to be served are carried by cable or microwave relay exclusively. Hence, over-the-air frequencies which otherwise might be used for this purpose can be reallocated to other spectrum uses. From the local distribution center, a coaxial cable is extended throughout the community. The cable provides at least twenty television channels of the conventional six-megahertz bandwidth. The sub-

¹⁰² TASK FORCE REPORT, *supra* note 99, ch. 7, at 36.

¹⁰³ 1969 BROADCASTING YEARBOOK 20.

¹⁰⁴ *Id.*

¹⁰⁵ *Id.*

¹⁰⁶ 1968 FCC ANN. REP. 79.

¹⁰⁷ Barnett & Greenberg, *A Proposal for Wired City Television*, 1968 WASH. U.L.Q. 1; DIMLING, McCABE, & SCHMIEDEKNECHT, IDENTIFICATION AND ANALYSIS OF THE ALTERNATIVES FOR ACHIEVING GREATER TELEVISION PROGRAM DIVERSITY IN THE UNITED STATES (report prepared by Spindletop Research, Inc., for the President's Task Force on Communications Policy, 1968).

¹⁰⁸ HERMAN W. LAND ASSOCIATES, INC., TELEVISION AND THE WIRED CITY—A STUDY OF THE IMPLICATIONS OF A CHANGE IN THE MODE OF TRANSMISSION (commissioned by the National Ass'n of Broadcasters for the President's Task Force on Communications Policy, 1968); Cox, *CATV: Why Is It So Complicated?*, TELEVISION AGE, March 24, 1969, at 110. A staff agreement between the National Association of Broadcasters and the National Cable Television Association recognized the "constant conflict between the two industries" and sought to resolve the conflict by agreement. See Resolution adopted by the National Cable Television Association Board of Directors, May 28, 1969. However, the Board of Directors of the National Association of Broadcasters did not approve this joint staff agreement.

¹⁰⁹ TASK FORCE REPORT, *supra* note 99, ch. 7, at 9.

¹¹⁰ *Id.* at 10.

¹¹¹ DIMLING *et al.*, *supra* note 107, app. D, 2-5.

scriber can connect any number of television sets to the entrance cable. The desired program can be selected by a channel switch or dial on the television receiver as it is done today. Such system is capable of carrying to the subscriber the conventional network and local television programs, subscription television (pay-TV), and various information services, such as marketing, banking, and shopping.

Using a single cable of sufficient bandwidth, or two of narrower bandwidth, the subscriber may be provided with switched, custom two-way service,¹¹² with both "input" programs and "output" from the home or office. Thus, the subscriber can select programs from libraries and view them at the time he wishes and receive home newspapers or selected facsimile as well as television and other fixed services. The output from the home or office can include audio and visual communication among all subscribers; facsimile transmission from the home; audio and visual responses to input of shopping, banking, and other information services; audio, visual, and facsimile charts and data for remote medical diagnostic service; and other similar personal and professional information.

A modification of the one and two-cable systems is the switched, single coaxial cable and telephone pair.¹¹³ Under this system, a single broadband coaxial cable is used for the input information, and a narrowband and telephone pair are used for output. The output is limited to direction to the local switching office as to changes in input sources, dialing the program library for selection of programs, and voice responses to input information such as shopping.

An interesting variation from the above described systems is the British re-diffusion cable television system.¹¹⁴ This system provides six television and six sound (FM) channels. The television channels have a six-megahertz bandwidth. There is a single distribution cable which is shielded against external interference. The cable carries a pair of wires for each of the six television channels and a pair of wires for each of the voice channels. The twelve pairs of wires are attached to the television receiver. In lieu of a television tuner for selection of channels, a switch is used to connect the amplifier to the channel carrying the desired program. As the tuner represents almost one-third of the cost of the television receiver, the British system provides an opportunity to reduce the cost of television sets. However, a disadvantage of the British system is the large cable required. If a cable for twenty channels were manufactured, it would, of course, be even larger.

To be contrasted with the "wired city" concept of cable television is the short-hop microwave distribution system.¹¹⁵ The transmitter operates on a frequency of eighteen gigahertz. Dish-design receiving antennas are placed at line-of-sight locations within twenty miles of the transmitter. In cities, the receiving equipment is located on tall skyscrapers, and the distribution cable feeds into the apartments of

¹¹² *Id.*, app. D, 17-21.

¹¹³ *Id.*, app. D, at 21.

¹¹⁴ Comments of Jansky & Bailey, *supra* note 99.

¹¹⁵ DIMLING *et al.*, *supra* note 107, app. D, 7.

subscribers. In small communities, the receiver is mounted on a tower, and the signal is fed by cable to individual homes. The Teleprompter Corporation has been granted a license by the FCC to use the eighteen gigahertz spectrum for a short-hop microwave distribution system in New York City. This system is compatible with both current cable television equipment and current television receivers. Presently, this system is being produced with a capacity of twelve channels. However, equipment is in the design stage which will accommodate thirty-six channels. The system saves the high cost of underground ducts in large cities, and in rural areas and between communities it avoids dead cable runs.

The cost of the above described cable television systems varies. However, the cost of any of these systems is reasonable in relation to the volume of services provided and the comparative cost of television receivers. Moreover, the cost factor in determining the type of cable television system may have been rendered insubstantial by the new rules relating to cable television which were adopted by the FCC on October 24, 1969.¹¹⁶ These rules provide that cable television may carry commercials at natural time breaks. Also, the new rules require that cable television systems having more than 3,500 subscribers must originate programming to a significant extent, beginning January 1, 1971. The new rules may well lead to a cable television "network" program service. In turn, this could provide substantial national advertising revenue to cable television systems and a reduction in or discontinuance of regular payment of fees for much of the service.

Initially, the FCC determined that it lacked jurisdiction to regulate cable television.¹¹⁷ Later, this opinion changed, the FCC first determining that it had jurisdiction of cable television which utilizes microwave relay¹¹⁸ and then extending its jurisdiction to cable television utilizing cable exclusively.¹¹⁹ The authority of the FCC to regulate cable television not using over-the-air facilities has been approved by the Supreme Court.¹²⁰ In its rules,¹²¹ the FCC imposed three significant restrictions on cable television. Cable television was required to carry the signals of television stations operating in the area served by the cable television system. Cable television could not duplicate the programming of a local station on the day that it was broadcast over the air. Except upon special waiver by the FCC, cable television systems in the 100 largest metropolitan areas could not import signals from distant

¹¹⁶ Amendment of Part 74, Subpart K, of the Commission's Rules and Regulations Relative to Community Antenna Television Systems, 34 Fed. Reg. 17651, No. 18397 (F.C.C., Oct. 24, 1969).

¹¹⁷ CATV and TV Repeater Services, 26 F.C.C. 402 (1959). For a comprehensive review of the FCC's regulatory treatment of cable television, see *Hearings on H.R. 7715 Before the House Subcomm. on Communications and Power*, 89th Cong., 1st Sess. 121 *et seq.* (1965) and *Hearings on H.R. 12914, H.R. 13286, and H.R. 14201 Before the House Comm. on Interstate and Foreign Commerce*, 89th Cong., 2d Sess. 115 *et seq.* (1966).

¹¹⁸ *Carter Mountain Transmission Corp. v. FCC*, 321 F.2d 359 (D.C. Cir. 1963); First Report and Order on CATV, 38 F.C.C. 683 (1965).

¹¹⁹ Second Report and Order on CATV, 2 F.C.C.2d 725 (1966).

¹²⁰ *United States v. Southwestern Cable Co.*, 390 U.S. 157 (1968).

¹²¹ 47 C.F.R. § 74.1101 *et seq.* (1966).

stations into the prime area served by cable television. In 1968, the FCC issued a further notice of proposed rulemaking concerning cable television.¹²² In this notice, the FCC proposed division of television viewers for purposes of cable television regulation into three groups: viewers within thirty-five miles of a major television market; viewers within thirty-five miles of a minor television market; and viewers who are outside of either of these zones.¹²³ The Commission proposed that, as to cable television systems within thirty-five miles of the main post office of the 153 cities located in the 100 largest television markets, the systems could carry only local television signals unless the cable television system obtained consent of the distant television station to retransmit the signal by cable, such consent being obtained on a program basis.¹²⁴ Moreover, in ninety-one of the largest 100 markets, where grade B signals of two major markets overlap, cable television could carry only the local television signals of the nearer city unless consent to retransmit were obtained.¹²⁵ In the case of cable television systems operating within a thirty-five mile radius of communities smaller than the 153 major markets but which have a television station, the system is permitted to carry the local station and enough additional signals to provide the three network services, one independent station service, and educational stations. However, additional signals could be carried only if consent to retransmit were obtained. As to cable television not operating within thirty-five miles of a community having a television station, cable television is permitted by the FCC to carry distant signals to its full capacity, but the following priorities must be observed: first, stations having a complete network service; second, stations having partial network service; third, independent stations; and fourth, educational television stations.

The foregoing restrictions upon operations of cable television systems were prompted in part by protectionism toward the existing network and over-the-air commercial broadcasting system, which the FCC deems in the public interest. Also, the restrictions appear to have been prompted in part by reaction to the Supreme Court's decision holding that cable television systems are not required to pay copyright royalties on programs broadcast by network services and local broadcasters and captured from the air.¹²⁶ The center of conflict between networks and their affiliated local commercial broadcasters on the one hand and cable television on the other has been the capture of broadcast signals of conventional broadcasting stations and retransmission of these programs via cable to the homes of subscribers. In the staff agreement between the National Association of Broadcasters and the National Cable Television Association,¹²⁷ the cable television group recognized that it should

¹²² Amendment of Part 74, Subpart K, of the Commission's Rules and Regulations Relative to Community Antenna Television Systems (Notice of Proposed Rule Making), 15 F.C.C.2d 417 (1968).

¹²³ *Id.* at 428 *et seq.*

¹²⁴ *Id.* at 436.

¹²⁵ *Id.* at 436.

¹²⁶ *Fortnightly Corp. v. United Artists Television, Inc.*, 392 U.S. 390 (1968).

¹²⁷ Authorities cited note 108, *supra*.

pay reasonable copyright fees for programs broadcast by conventional broadcasting stations. The most recent rules of the FCC¹²⁸ point cable television in the direction of developing its own programming and network services, thus rendering cable television less reliant upon capture of signals of conventional broadcasters. Among the public interest goals to which the FCC has given greatest emphasis has been diversity of programming to serve the great variety of needs, tastes, and desires of listeners and viewers. The recent rules appear to have been prompted in part by the FCC's policy of promoting this diversity.

The development of cable television has been retarded by the FCC's restrictive rules. Cable television is capable of bringing into many homes radio and television signals of higher quality than those currently received. In addition, cable television can provide a great variety of additional services. The opportunity through cable television to bring the individual into contact with his information environment and to give him greater participation in decision making introduces a new communications goal having the highest societal value. Cable television can contribute greatly to other public-service areas by providing communications for police, fire, and defense. The channel capability can accommodate instructional programs for schools and industry. Data retrieval for a variety of purposes is possible. Thus, cable television can not only increase the variety of programming but also provide many communications services which are essential to the individual's information, participation, and convenience in modern life. Cable television should not be retarded by restrictive rules which do not serve the over-all public interest. The Communications Act of 1934 contains a mandate that the FCC shall "[s]tudy new uses for radio, provide for experimental uses of frequencies, and generally encourage the larger and more effective use of radio in the public interest."¹²⁹ Observance of this mandate requires that in the accommodation of a new development in communications, such as cable television, the FCC's protectionism of established components of the industry should not be extended further than necessary to serve the greater public interest in receiving the benefits that both the new and the old technologies can offer.

CONCLUSION TO PART I

In Part I of this article, the nature of the radio spectrum and the significant components of the old and new technologies in communications have been described. In Part II of the article, the public-interest goals of a self-governing society in communications will be articulated, the extent of achievement of these goals by the existing communications technology will be evaluated, the potential for greater achievement of these goals through innovations in communications technology will be discussed, and guidelines for accommodation of the old and new technologies in service of the over-all public interest will be suggested.

¹²⁸ BROADCASTING, Oct. 27, 1969, at 10.

¹²⁹ Communications Act of 1934, 47 U.S.C. § 303(g) (1964).