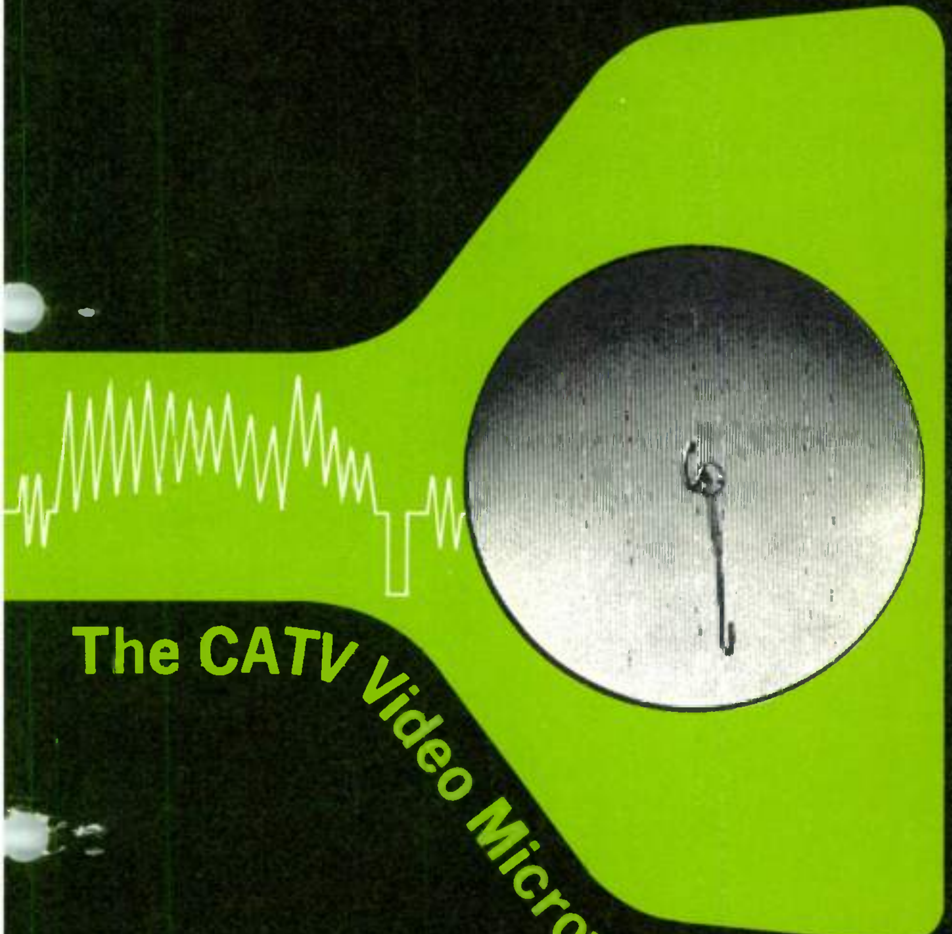
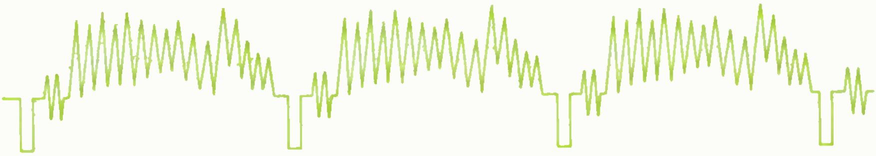
The Lenkurt

FEBRUARY 1971

DEMODULATOR



The CATV Video Microwave Link



From its beginning as a tiny measure of light picked up by a TV camera and changed into electrical energy, to the time it is viewed on the screen, the television signal undergoes a complex adventure on its journey from broadcast transmitter to television receiver.

The television signal leaves the broadcast transmitter as composite video information modulated on an RF (radio frequency) carrier. This composite signal contains the video (picture signals), sound, color, blanking, and synchronizing information necessary to materialize a picture on the television screen (Figure 1). If the path between the transmitter and receiver is straight and unobstructed, viewers will enjoy a good picture with few complications ever arising. However, if TV viewers live in an area where irregular terrain or sheer distance blocks reception of television signals, some means of making television reception available in that area is necessary. Since the distance a television signal travels after it leaves the broadcast transmitter is generally limited to a line-of-sight characteristic, reception is confined to a relatively small geographical area. One method of extending TV programs to viewers in remote areas is by use of a microwave CATV (Community Antenna Television) system (Figure 2). In this type of system, an off-the-air pickup of the television signal is made at a "head end" station. Here the signal is amplified and processed to produce a TV baseband signal which is essentially a duplicate of the original TV baseband signal that went into the input of the distant broadcast transmitter. This signal is then relayed by a series of line-of-site repeaters to the remote area.

The types of microwave repeaters, their methods of operation, their appropriateness in certain systems, and their overall performance in a multihop video microwave link constitute some aspects of a CATV system that are discussed in this article.

A system of line-of-sight repeaters which amplify the incoming microwave signal and send it on its directed path comprises the major part of a video microwave system. One of the most important considerations in the planning of a microwave installation is choice of equipment which will accommodate future growth expectations and at the same time provide satisfactory video information at the initial terminal point.

The microwave repeater performs two important functions. The first of these functions is to amplify the incoming signal sufficiently so that it may reach the next repeater. The amplified output signal may be anywhere from 55 to 105 dB greater in power than the incoming signal. Secondly, the repeater must convert the incoming signal to a different frequency so that in transmission the outgoing signal does not interfere with the

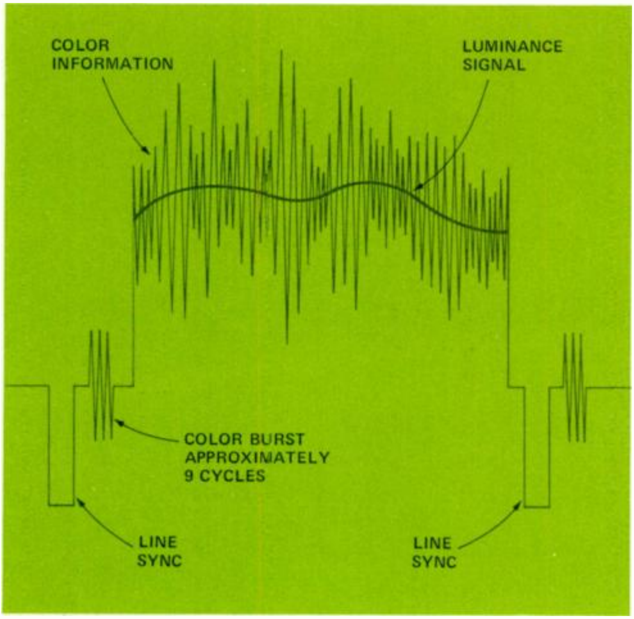


Figure 1. The composite video signal. The color burst is transmitted during the blanking pulse to serve as a phase reference for the color information which modulates the basic video or luminance signal.

incoming signal; interference usually being due to limitations on antenna front-to-back ratios and foreground reflections. Most CATV microwave systems operate in the CARS (Community Antenna Relay Service) band. In the CARS band the frequency shift is usually 25 MHz or some mutliple of it.

There are three types of microwave repeaters – baseband, IF heterodyne, and RF heterodyne (Figure 3). Video microwave systems use the first two types almost exclusively. Each has advantages and disadvantages which must be considered when planning a video microwave system. Generally the choice of repeaters is based on the distance the microwave signal must travel.

Baseband Repeaters

Baseband or remodulating type of radio equipment is usually employed when designing systems of two hundred miles or less. The baseband consists of the composite video signal, program channels, and supervisory signals that are used to modulate a particular carrier. In a baseband repeater the incoming microwave signal is mixed to produce an intermediate frequency; this is then amplified, demodulated, and amplified again at the original baseband frequency. Lastly, the signal is remodulated and transmitted at the microwave frequency. The baseband repeater is generally used only in short haul applications because each time the video signal is modulated or demodulated, a certain amount of distortion is generated due to nonlinearities in the conversion from amplitude variations to frequency variations.

Since the incoming signal is demodulated to its baseband frequency at each repeater, it is possible to make

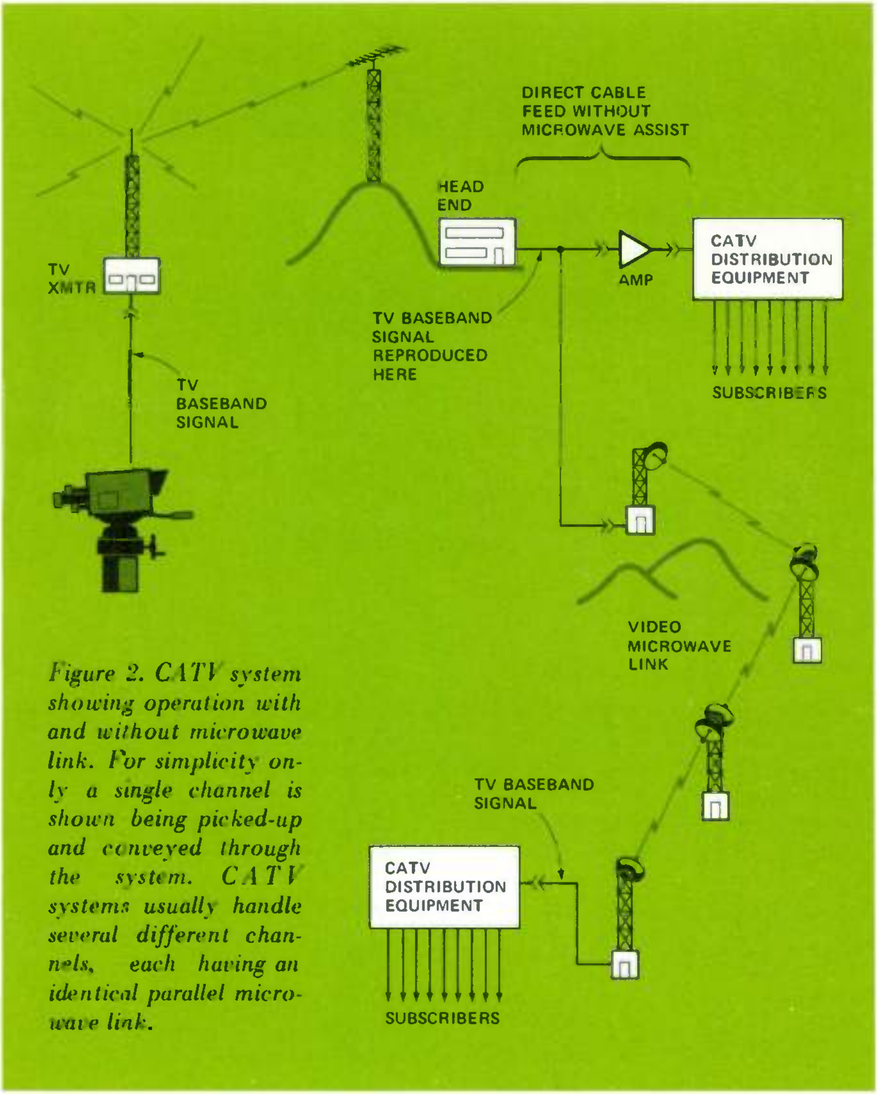


Figure 2. CATV system showing operation with and without microwave link. For simplicity only a single channel is shown being picked-up and conveyed through the system. CATV systems usually handle several different channels, each having an identical parallel microwave link.

television signals available for reception anywhere along the main backbone route. This convenient availability of baseband signals at each repeater is one of the advantages of a baseband system.

Although ten hops in tandem are usually the maximum length considered for baseband type equipment, GTE Lenkurt 76C microwave equipment was successfully used in a 17 hop system, providing low enough distortion in both differential phase (phase variation) and differential gain (gain variation), to permit a color projection on a 30 foot (9.2 meters) by 40 foot

(12.2 meters) screen at EXPO '67 in Montreal.

IF Heterodyne Repeaters

In the IF heterodyne repeater, amplification is performed at the intermediate-frequency stage without going through the demodulation and remodulation process required in the baseband repeater. The incoming signal is first heterodyned to the IF stage. This process involves mixing the incoming signal with a constant signal provided by a local oscillator. The result is two frequencies equal to the sum and difference of the first two, each containing identical information. At this point the difference frequency is amplified, then passed through an up-converter to be translated to the outgoing microwave frequency. The elimination of the demodulation and remodulation process gives improved noise performance since distortion is kept to a minimum. Other advantages of heterodyne repeaters over baseband repeaters are less maintenance, better baseband level stability, higher power output, and greater distance between hops. The greatest limitation of a heterodyne repeater is its cost. Because of its more sophisticated components which include a traveling-wave tube and associated power supply requirements, the cost of the heterodyne repeater is higher than that of the baseband repeater.

In the heterodyne system, the baseband is not as readily available at each repeater station as it is in the baseband repeater although it may be easily acquired by adding a 70-MHz discriminator. In the discriminator, the baseband is separated from the incoming frequency-modulated carrier wave by changing modulations in terms of frequency variations into amplitude variations. The low distortion of IF heterodyne repeaters makes it possible to carry video information over great distances without any appreciable degradation of the picture at the terminal point.

Composite systems utilizing a mixture of both IF heterodyne and baseband repeaters are often used. In a composite system, the heterodyne repeater may form the backbone route of the system while baseband repeaters are used on short side legs to provide local television reception along the route. In some systems, IF heterodyne repeaters are combined with baseband terminals as an economic compromise. The main purpose of these systems is to combine the low costs of the baseband repeater with the low distortion of the heterodyne repeater.

RF Heterodyne Repeaters

Although RF heterodyne repeaters are not presently used in video microwave links, they are mentioned here as a point of interest and to acknowledge their existence. All solid state RF repeaters (though not rated as video capable) are "state of the art" at 2 GHz, and not readily available above this frequency.

The RF heterodyne repeater provides amplification directly at the incoming microwave frequencies. The incoming microwave signal is first amplified, then heterodyned with a signal at the shift frequency to produce an output at the desired microwave output frequency. This latter is then filtered and amplified for transmission over the next hop. The prohibitive cost of the RF heterodyne repeater makes it a seldom used item. This high expense manifests itself in the form of providing gain at microwave frequencies, producing filters selective at microwave frequencies, and provision of adequate limiting, automatic gain control and delay distortion correction — all necessary, all expensive.

Overall Performance

Published industry standards are available as guide lines for calculating overall color video performance*. EIA has established a standard of 0.6 dB as maximum differential gain and ±1.5 degrees as maximum differential phase that should exist in an overall system. These standards are established relative to the maximum gain at 50% APL (average picture level). Actual performance measurements taken at an operating microwave installation may show performance to be within these tolerances. For example, in a 6-hop IF heterodyne system, the total differential gain may be 0.3 dB and the total differential phase may measure 0.4 degrees. A 6-hop baseband system has shown measurements of 0.5 dB for differential gain and 1.0 degrees for differential phase.

Other factors to consider in calculating overall video performance are frequency response and signal-to-noise ratios. Frequency response roll-off on the baseband system has a tendency to accumulate at a predictable rate; roll-off being the gradual increase in attenutation as frequency is varied in either direction beyond the flat protion of the frequency response curve. This attenuation rate can be reduced by utilizing correctional amplitude equalizers as required, thus tailoring individual hop frequency response.

In an IF heterodyne system, amplitude response and group delay accumulations tend to have an unfavorable bearing on the video performance. However, by using 70-MHz parabolic and slope equalizers on a periodic basis, a system will show considerably improved video characteristics.

*EIA (Electronic Industries Association) standard RS-250-A.

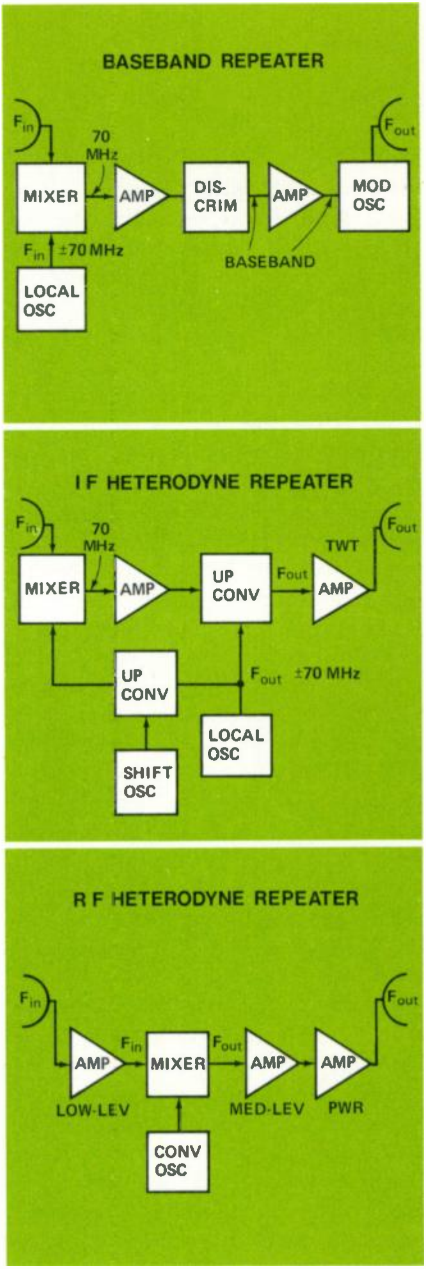


Figure 3. Microwave repeaters are classified by whether they provide amplification at baseband frequency, intermediate frequency, or radio frequency.

Signal-to-noise measurements should be made using weighting networks. In a weighting network an artificial factor is inserted into the measurement to compensate for conditions which, during normal use of a device, would otherwise differ from the conditions during measurement. These conditions are subjective in nature and can be assigned a degradation factor based on their relative effect. For example, background noise measurements may be weighted by applying factors or inserting networks that reduce measured values in inverse ratio to the interfering effect. The essential function of a weighting network is to make the measurement parameters reflect as accurately as possible the degree of annoyance to an average viewer or user. For example, an interfering tone or noise in the higher parts of the video baseband will usually cause less degradation to a viewer than a tone or noise of the same power in the lower portions of the baseband. The weighting network is designed to compensate for these subjective effects, which have been determined by actual trial and error tests on many subjects. Bell laboratories evolved a color TV weighting curve that would apply to various transmission media and which has since been adopted by EIA. Signal-to-noise ratios (peak-to-peak video to RMS noise) of 75 dB per microwave path are normal, and would allow 100 hops before a 55-dB signal-to-noise ratio was attained. An outage level of 33-dB signal-to-noise ratio was adopted by the EIA committee.

In addition to the electronics design problems in a microwave system, there are wave propagation considerations such as path attenuation between two points under free-space conditions, atmospheric and ground effects on propagation, and reflection and refraction effects on the microwave path. Losses due to these effects may sometimes be forecast with some degree of accuracy but loss data due to atmospheric effects for a particular area may be realized only by survey measurements in that area.

Still more considerations in planning a television microwave system include antenna design to be used, location of towers, routine maintenance, adequate temperature controlled housing for equipment, continuous power supply requirements, back-up equipment with automatic switching devices, and security of equipment. Only when these requirements have been completed is there a source of television signals available at the terminal station.

It is at the terminal station that signals are brought to proper levels and remodulated to VHF and UHF frequencies. At this point the microwave link is complete. Signals are conveyed to viewers by means of private distribution systems, usually by means of a cable television system.

Planning, engineering, and even some solid intuition are all necessary for the successful realization of a microwave system that brings daily television programs to home, school, and business.

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JANUARY 1971

communications and the environment

Proper application of today's communication technology can bring people together and improve the atmosphere in which they live.

Environment includes not only geographic features, but also the people and the subsequent culture of an area. Present communication links can be expanded for environmental channels — voice and video channels for education and exchange of ideas, as well as data channels for earth resources management. This expansion can be realized by utilizing today's communications technology.

Remote data collection and centralized computer analysis of the data can provide an efficient means of measuring, analyzing, and correcting environmental pollution. By providing more channels of communication, more opportunities for expression of ideas through dialogue would be available. These communication channels can be provided by increased two-way video, voice, and data communication.

Pollution Control

Although it is not physically or financially feasible to establish manned laboratories in every geographic location where pollution is most likely to occur, it is possible, by means of a network of unmanned data collection stations, to sample the surroundings and transmit information on air, earth, and water conditions to a central processing laboratory for analysis. In this way, computer technology and remote data acquisition can contribute to pollution control.

Prototype pollution monitoring systems are presently in operation. What look like ordinary navigation buoys are really ocean pollutant detectors. Instrumented buoys, anchored in oceans and inland waterways are equipped with sensor systems and automatic data handling equipment. These unattended buoys are able to measure and transmit such data as water and air temperature, wind speed and direction, and barometric pressure. Such systems are being designed for low-power consumption and long-life expectancy which should provide easily-maintained, low-cost environmental monitoring. A network of ocean monitoring buoys, or stations can communicate with a central processor either over a direct microwave link or via satellite relay links (see Figure 1).

Another pollution detection device now under development employs a patrol aircraft that measures the changes in microwave radiation from the surface of the water (see Figure 2); thereby, determining what the pollutant is — oil or gas — and how thick the spill is.

Similar tests can also be made on the atmosphere to detect air pollution. The proper transmission links permit measurement at many remote locations and processing at one location. Depending upon the results of the analyzed data, the proper corrective

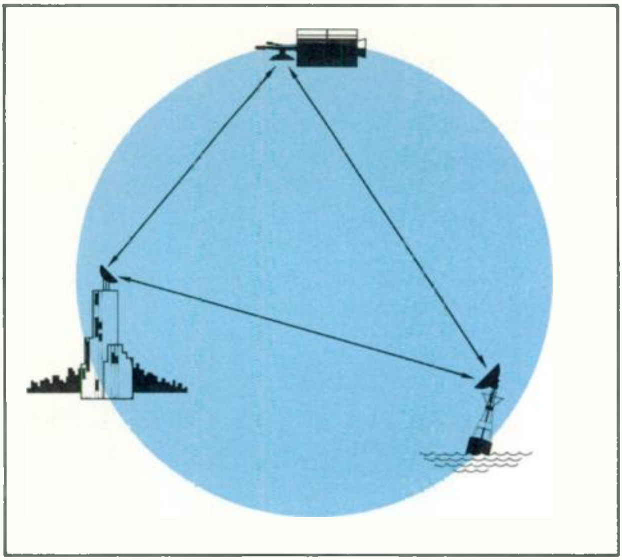


Figure 1. Satellite relay techniques are used to monitor natural resources when a direct microwave link is not practical or feasible.

actions can be transmitted by the central processor for the particular pollution location.

Information can be transmitted from the data collection points to a central processor by microwave techniques. For getting information from the remote data collection points, satellites seem to offer a convenient means. In some cases, depending upon the type of data being collected, the satellite may be able to actually gather the raw data and transmit it directly to the central processor without a surface-collection system.

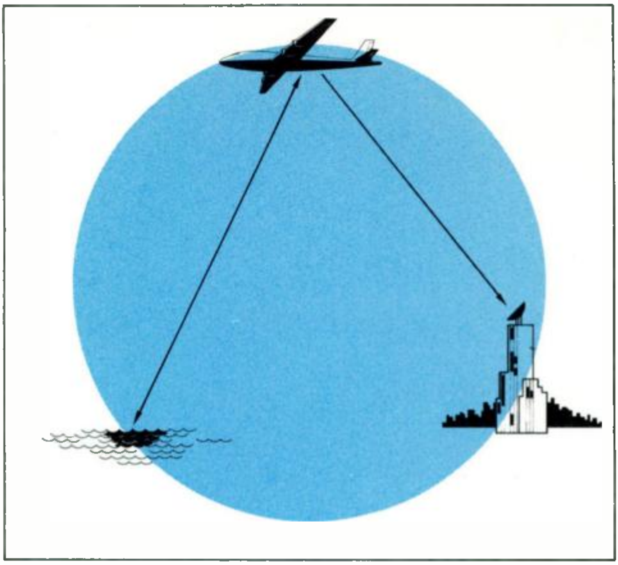
Satellite Network

A network of satellites and surface-probing sensor systems may be used to study natural resources. In addition to the oceans and air, this network can take inventory of what, where, and how well forests and crops are growing, and the condition of the soil and its ability to be put to work; thus permitting regional, national, or global predictions of crop yields, livestock inventory, and patterns of fire, insect, and disease damage. Information about stream and river flow, excess surface water, pollution, and glacial action can be studied in order to plan better irrigation and flood control systems, develop and maintain water resources, and control erosion.

Air pollution is generally correlated with population distribution and geographic features that can be studied with satellite mapping techniques. Detailed maps of the earth's features can be used for planning land use, urban development, and transportation facilities. Aerial data collection can also be used to map ocean currents, ice, and other navigational hazards. Fish and other marine biology of interest, as well as pollutants, can be studied for the seafood industry, shipping, and marine ecology.

Surface-collection relay satellites and remote-sensing satellites, along with non-satellite remote sensing devices — including sounding rockets, balloons, aircraft, buoys, and ground-based platforms — are capable of transmitting the gathered information

Figure 2. Airborne systems detect petroleum spills in the ocean and transmit the information to a central office for cleanup operations.



to a central computer. The computer's role in this overall environmental management system is that of soothsayer – if, for example, a decision were made to irrigate thousands of square miles of desert to create a new agricultural area, the computer could predict such things as the plan's effect on: climate, population, water resources, and international trade.

In order to manage world resources effectively, adequate information must be available. Information has for centuries been gathered by man on the surface of the earth. In recent times, aerial observations have broadened the field of view, the amount, and the usefulness of the information. With the mass acquisition of data and sophisticated computer processing, it may be possible to stem the tide of diminishing resources, and pollution of the existing resources.

Human Environment

Solving the problems of an area's pollution and diminishing natural resources will do little to improve the total environment, if the people in the area are unable to communicate and clear up differences. These differences often represent a widening gap between expectations, and reality. In an affluent society, we expect more, and better communications are raising these expectations. Through proper education and exchange of ideas it is possible to bring expectations in line with reality.

The areas of communication offered to bring expectations closer to reality include: education, community expression, cultural enrichment, and politics. Some specific services offered include: home library service, facsimile, delivery of mail, crime detection and prevention, remote data acquisition and central processing, educational television, remote participation at conferences, and armchair shopping.

Expanded Services

These new services can be divided into two classes: one-way transmission with no interaction between transmitter and receiver; and two-way trans-

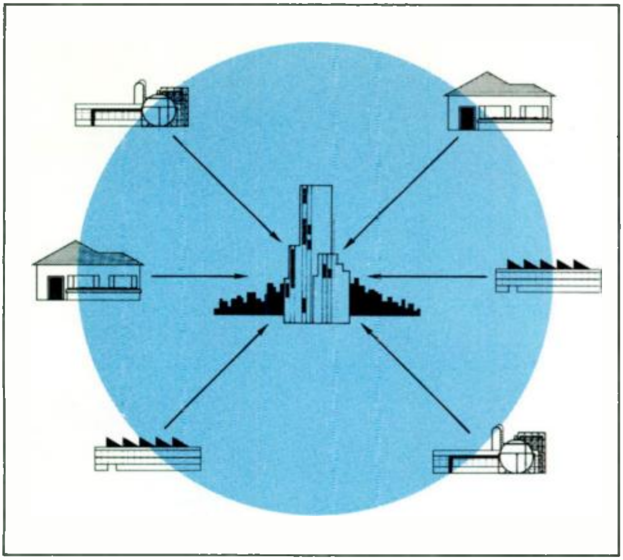


Figure 3. Utility meter-reading employs one-way transmission from many subscribers to one central office.

mission where there is a transmitter and receiver on both ends which provides the opportunity for interaction and response.

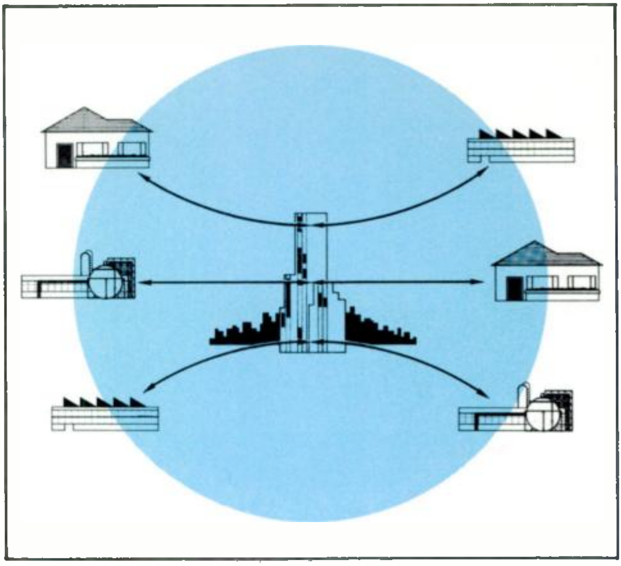
Utility meter-reading is one-way transmission from many subscribers to a central office where the information is processed (see Figure 3). The gathered data from each subscriber is sent through a central processing unit for charge computation. The actual billing could be included in the processing, which would make meter-reading a two-way transmission process. But, it is more likely that billing will continue to use a centralized mail distribution system, since it would not be economical for utilities to operate their own video or data transmission system.

Facsimile (the art of sending pictures or other printed material) is a form of one-way transmission in that there is no interaction between the transmitter and receiver, but both terminals are transmitter/receivers. As technology advances, it may eventually become economical to bring facsimile into the home for such things as home library service and newspaper distribution – if a printed copy of the transmitted image is desired. The transmission of color is possible as demonstrated by color television, but a color facsimile printout device needs to be perfected. Law enforcement agencies are using black and white facsimile printers to speed information across the country for crime detection and prevention. The addition of color would offer improved image recognition.

If printed copy is not needed a video system like television provides readable, although not permanent, written material. The information is read directly off the screen and when finished, the viewer terminates the signal. Cable television, with local programming, could provide channels to bring these services – library and newspaper – into the home. Videophone service could also bring these visual images into the home.

Mail transmission and distribution, as well as video-phone, is a two-way transmission service that could use

Figure 4. Mail transmission and distribution, as well as video-phone, uses a switched network.



the same transmission and distribution plan that is presently used for telephone service. That is, a switched network where an individual sends his message through a central office which redirects the message to the receiver (see Figure 4). With mail transmission and distribution, the service need not be completed at the same time; therefore, delaying the interaction or response. This delay would provide for more efficient use of the transmission channels – transmitting mail in non-peak hours. Mail transmission and distribution will not eliminate the letter carrier, but it can relieve the letter carrier of over 75% of his load without transmitting actual correspondence – personal, business, and government letters – over the air or through a cable. The receiver for such a system could be either a facsimile printer or a video screen depending upon whether printed copy is needed for future use. Another plan gives the sender a choice of transmission modes – instantaneous transmission over telegraph lines to the receiving "post office" where a letter carrier would deliver the message or letter "posting" common today where the original document is "hand" carried to its destination.

Totally automated system monitoring is a two-way system using programmed transmitter/receiver terminals. This is essentially the same technique used for natural resource control, but also used for monitoring other remote systems. Remote data access and central processing also includes time-sharing computer service. As the complexity and cost of these terminals is reduced, more people will take advantage of the benefits offered.

Educational television and remote conference participation are similar to video-phone with instantaneous voice and video communication. Where these services differ from video-phone is that there is a central transmitter/receiver and many remote transmitter/receivers that interact with the central unit (see Figure 5). Using such a service, government officials have direct contact with their constituents. This service has the greatest potential

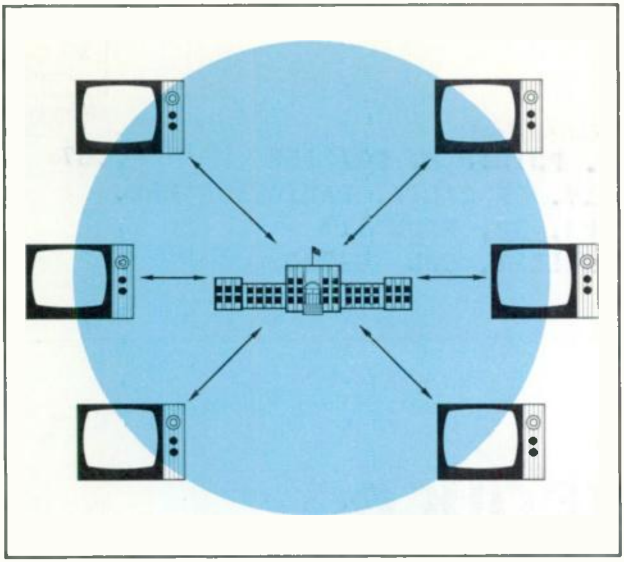


Figure 5. There is two-way communication between one central location and many remote subscribers for educational television and remote conference participation.

for bringing people together because it is possible to clear up any misunderstandings that might arise before they have a chance to cause dissention in the ranks. This service could put expectations and reality into proper perspective. Communities can express themselves over a two-way voice/video channel so the public has the opportunity to know the full story and to express their approval or objection. And, educational television provides the means for educating large masses in one geographic region or select groups scattered over several regions. Increased educational facilities provide the means to close the gap between expectations and reality.

New Direction

Expanded means of communication have the potential to provide a more efficient society with an informed public living in a healthy, plentiful environment. Presently, the possibilities are practically unlimited, but so are the possibilities for this expansion getting out of control. If the best interests of the public are to be realized, the most efficient and most economical systems must be put into effect. None of these expanded services will be totally adopted unless present costs can be substantially reduced. Technology has developed these services, economics will dictate their future.

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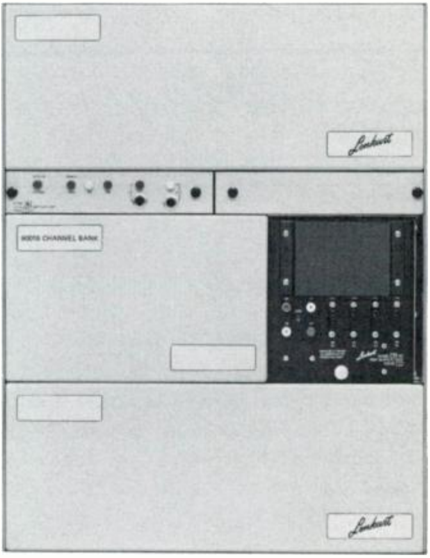

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