

Experiments With Picturephone Service

Visitors to the New York World's Fair are holding novel telephone conversations. While they talk they can see each other on the television screens of an experimental system designed at Bell Laboratories.

THE COMMUNICATIONS DEVICE that transmits a television picture and a telephone conversation simultaneously is a familiar prop of science fiction movies and stories. As fiction the device is an entertaining novelty. An operating Picturephone service, however, would represent a new dimension in telephony because it would add the inestimable quality of an in-person conversation to an ordinary telephone call. In addition, such a service could have important new uses. It could, for example, improve communication for people with hearing defects by allowing them to lip read or use sign language or writing slates. It could be used to show the shape of objects that are hard to describe. All of its uses, however, depend on the characteristics and capabilities of a complete system.

Basic to the design of any communications system is detailed information on what its potential customers will need and want from it. In fact, the customers' needs largely determine the fundamental technical and economic requirements of the system. For instance, the quality of

a television picture determines the required bandwidth of the system. Thus it is essential to know what uses a customer will consider most important and what quality of picture will best serve these uses. It is essential to know what features a customer will want in a Picturephone set and what controls he will need to activate them. It is also important to know the frequency with which a customer will use the system, the periods of the day during which he will use it, and the durations of his conversations. On the answers to such questions, systems engineers can base realistic assumptions about what compromise a customer would make if he had to choose between a system's features, its performance, and its cost.

This kind of information can be compiled in a program of studies and experiments. A vital part of the program consists of observing how people use and react to experimental systems complete with station sets, transmission facilities, and switching facilities. Fortunately, many devices and techniques in present technology are readily adaptable to Picturephone systems. Solid-

state electronics makes possible Picturephone sets that are small and highly reliable, that operate on low power, and that produce good pictures without studio lighting. Also, new transmission techniques such as high-speed PCM should make it possible to eventually provide a large number of broadband channels economically.

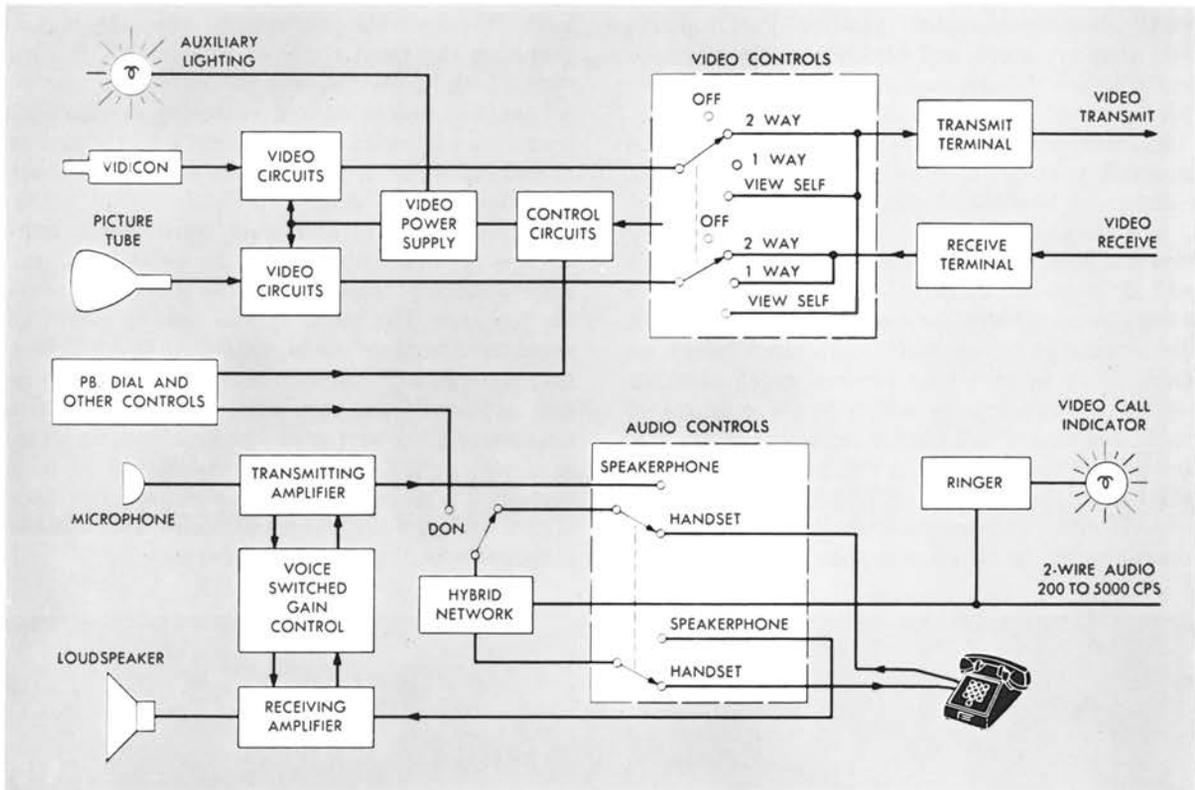
For the past two months, an experimental system has been operating between the Murray Hill and Holmdel laboratories. A number of Picturephone sets, divided between the two locations, are connected by ordinary unshielded telephone cable pairs to switching centers which are connected by two trunks which are a mixture of cable and radio. Bell Laboratories engineers taking part in the experiment will use this system in their daily business for several months. A second experimental Picturephone system was put into operation at the Bell System pavilion of the New

York World's Fair this month. (See the photograph on the front cover of this issue.) It consists of eight station sets in individual booths. All sets are connected to a switching system that permits a visitor to call an attendant or a visitor at another station. This system also serves a set at Disneyland in Anaheim, Calif.

Before these systems were constructed, temporary requirements had to be established for their picture parameters, performance, and service features. The problem was how to arrive at requirements that would reflect what customers may want in a Picturephone system before there was any experience with such a system. The telephone was a known factor, the accompanying picture was not. The problem was solved in part through the design of a variable-parameter television system that can generate millions of different sets of picture parameters.



L. A. Meacham, at Holmdel, holds a Picturephone conversation with the author at Murray Hill.



A schematic representation of the Picturephone set that is shown in the photograph on page 115. This shows the arrangements for both television and telephone switching and for signaling as well as the Picturephone set controls. With the view self feature, a customer can center his own image on the screen.

This unique system is part of a special laboratory that is set up to carry out subjective tests on television pictures. The laboratory consists of two television studios and a control room containing two variable-parameter systems. Each system (see the diagram on page 117) contains a camera, a control panel, transmission path filters, and two television receivers. Each has a dual set of controls—called “red” and “green” parameters—which can be used to prepare two different sequences of pictures. A subject can view the red parameter pictures while a second set is being prepared with the green parameters. By throwing a switch, the operator of the system can change immediately from one set of pictures to the other to facilitate pair comparison and other subjective measurements.

The system is variable over ranges of the various parameters listed in the table on page 117. Contrast, brightness, and spot wobble (a technique of softening a picture that has too prominent a line structure) also can be varied over wide ranges. The viewing conditions in the studio also can be altered. For example, the studio

lighting system can be used to produce a wide range of spatial and spectral effects. This flexibility has great value in studies of such problems as glare, picture tube surface treatment to reduce washout from ambient light, and color and the reflection of background materials. Because the transmission path of the system is quite free of impairments, known amounts of signal impairments can be introduced in order to determine tolerable levels of noise, interference, and echoes for various picture standards.

Experiments performed in a laboratory of this type may vary from quite straightforward ones to the most complex multi-variable ones; their design is a large subject in itself. Very simple tests can be made just to acquire a “feeling” for television pictures of unusual composition. For instance, it is difficult even to speculate about the merits of five-to-one interlacing until one actually views pictures that use it. Another simple experiment was performed to determine the optimal band shaping, or roll-off characteristic, for a band 24 db down at 500 kc. For this experiment, subjects viewed a television picture while

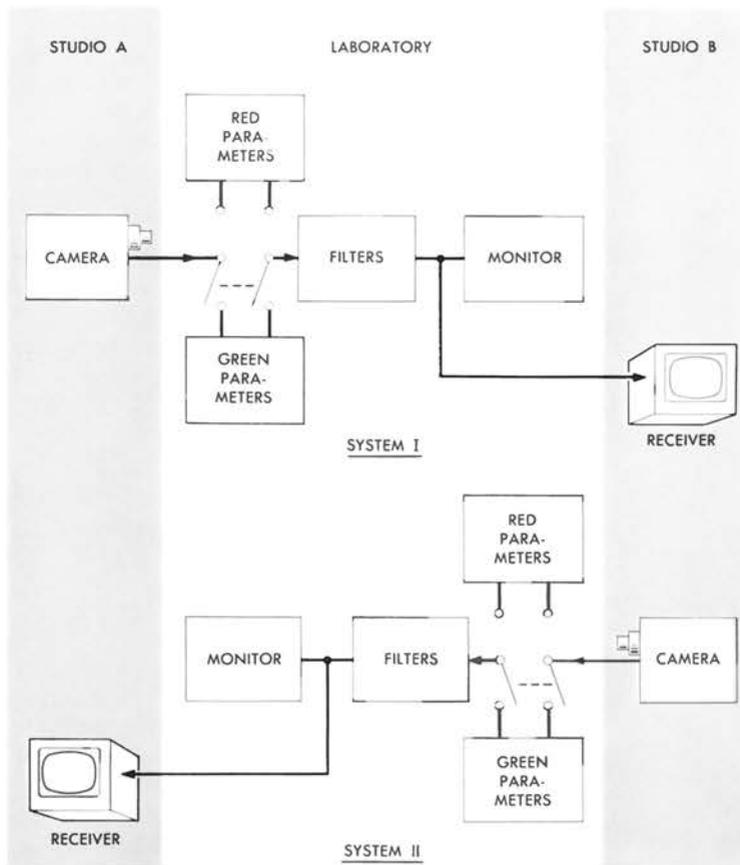
adjusting the roll-off as they wished, and judged the quality of the picture at the different adjustments. These tests resulted in the selection of a roll-off of 30 db per octave as the best compromise between ringing (for sharp cut-offs) and loss of horizontal resolution (for gradual cut-offs).

The experimental Picturephone systems were developed around picture parameters tentatively selected on the basis of information gained with the variable-parameter system. The table on page 118 lists the major picture parameters selected for the system. Of these, the most important is bandwidth. Although it is much less than the four megacycles of broadcast television, it provides a very acceptable head and shoulders view of a person if the other parameters are carefully chosen. It is also instrumental in achieving system economy because it simplifies using base-band transmission over ordinary telephone cable pairs for customer loops. Another advantage is that this bandwidth is free of interference from the radio broadcast band of 550 kilocycles to 1500 kilocycles.

The general objectives of the station set design included an attractively styled set small enough to be used on a desk top or table top and with a small number of controls so that it would be easy to use. It also had to be low in power consumption and heat dissipation, reliable, and stable in its performance. These requirements were satisfied through a design that uses solid-state devices exclusively except for the pickup and display tubes.

The station set (see the drawing on page 116) consists of three equipment packages: a display unit, a control unit, and a power supply. The first two are in reach of the user, the third is out of sight. The largest package is the display unit which contains a cathode-ray picture tube, a vidicon camera, the scanning, synchronization and other video circuits, and a loudspeaker. The control unit contains a telephone handset, a speakerphone, and a set of TOUCH-TONE® push-buttons.

One object of the experiment is to observe the relative use given to the handset and the speakerphone. The audio line connects through relays to the Picturephone switching system as well as to the standard telephone switching system so that both services are provided on the same instrument. The user controls the system with the pushbuttons and dials calls with the TOUCH-TONE telephone set. There are pushbuttons to select either of two modes of viewing: one-way video in which the user receives an incoming picture but does not transmit his own, and two-way



The variable parameter television system is contained in a laboratory which consists of two studios for viewing and a control room where the design of the pictures is determined.

RANGE OF THE VARIABLE PARAMETER TELEVISION SYSTEM	
Picture size	12 to 280 square inches
Aspect ratio	3:4 to 4:3
Frame rate	15 to 75
Interlace ratio	1:1 (no interlace) to 8:1
Lines per frame	50 to 1024
Bandwidth	1/8, 1/4, 1/2, 1, 2, 4, and 7 mc

video. Another pushbutton controls a "self-view" feature that allows the user to see himself on his own viewing screen. This feature helps him to position himself with respect to the focus and field-of-view of the camera lens. A lamp is provided for use if room lighting is poor. It can be switched on and off manually, or be set to light automatically when the set is turned on.

Novel circuits used in the station set make important contributions to economy. An example is the semirandom transmitter synchronization with locked 2:1 interlace. This circuit combines the high quality interlacing of picture lines that broadcast television enjoys with the circuit economy of the method known as "random interlace". (See box on page 120.)

The experimental system at Bell Laboratories is connected to the regular telephone switching systems at Murray Hill and at Holmdel. The audio lines from the Picturephone sets are connected directly to a crossbar switching system; the video lines are connected to a separate crossbar switch which is slaved to the audio crossbar switch. Since the video line is on four-wire operation, each connection has a reversing relay to insure that a camera always is connected to a receiver. The switching systems have TOUCH-TONE registers that permit simultaneous reception of signals from two customers. Up to six conversations can be carried on simultaneously.

When a call is placed, the transmit terminal receives an unbalanced composite video signal from the Picturephone set, amplifies it, and launches a balanced baseband signal onto a telephone cable pair. The receiver terminal amplifies this signal, equalizes it according to the attenua-

tion shape of the cable pair, and sends an unbalanced signal to the receiver circuits of the Picturephone set.

A telephone pair used as a Picturephone system loop or trunk can have no loading coils or buildout devices. In addition, if the bridged taps fall in a range of lengths that may cause echoes they must be removed or terminated. Finally, these trunks must be equalized. This is done very simply: First a 10 kilocycle sinusoidal signal is sent from the switching system to the station set where the flat gain is adjusted to produce a standard level. Then a 100 kilocycle signal is sent out and measured and a combination of four networks is selected to bring this level into the desired signal range.

The two trunks between Murray Hill and Holmdel, a distance of about 25 miles, are flat to 500 kilocycles. The switching system in the Holmdel Laboratory is about 3 miles from the radio transmitter on Crawford Hill. To span this distance, an experimental baseband transmission system was designed around the requirements of an exchange area Picturephone system trunk. Its main element is a balanced amplifier-equalizer very similar to the one used in the receiving end of the video loops. The amplifiers are mounted in manholes about a mile apart and receive power from each end. The signaling and audio line of a trunk is frequency multiplexed with the video signal at the radio transmitter.

One of the methods used to gather data on the system is a telemetry connection between the Picturephone sets and the computation centers at Murray Hill and Holmdel. Extra contacts on the control unit relays in the station sets are wired over cables to the computation center. Data over these lines causes cards in the computation center to be punched as a record of a change of state for any station set. Cards are punched when:

- A telephone begins to ring or stops ringing.
- A Picturephone begins to ring or stops ringing.
- The main station goes off-hook when it has been idle, or goes on-hook after completing a call.

The following modes of using the station sets also are recorded by card punching:

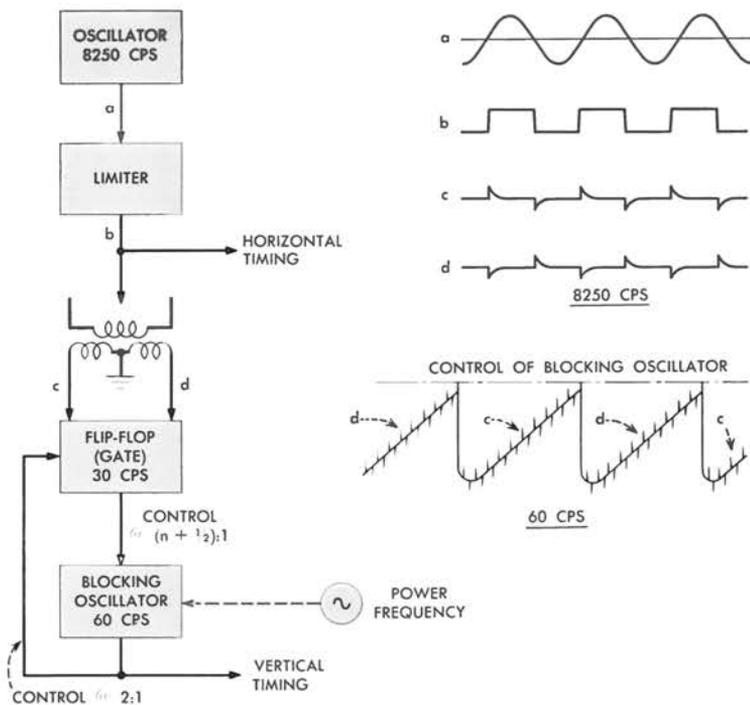
- Whether the call is a Picturephone call or a telephone call.
- Whether the speakerphone or the handset is used.

PICTUREPHONE SYSTEM MAJOR PICTURE PARAMETERS

Bandwidth	About 500 kc
Frame rate	30 per second, 2:1 interlace
Lines per frame	275
Picture size	4 $\frac{3}{8}$ inches wide, 5 $\frac{3}{4}$ inches high
Viewing distance	36 inches



The variable-parameter television system laboratory. R. H. Rosasco, at the control panel, adjusts picture parameters which the author, A. D. Hall, in the viewing room, judges them according to standards of clarity, brightness, etc.



Operating principle of the semirandom transmitter synchronization circuit. The waveform (a) is transformed to the pulse train (b). Pips of (c) and (d) then appear alternately and are presented to the flip-flop.

In broadcast television cameras the vertical and horizontal sweep frequencies are derived from an oscillator followed by a frequency divider chain. Interlace is achieved by locking the vertical oscillator to the 60 cps power source and synchronizing it with an exact submultiple of the horizontal oscillator. Some closed circuit systems use "random interlace" in which the two oscillators run independently, but this requires very stable oscillators. In the picture-phone set the two oscillators are coupled so that although their average frequencies are independent, the ratio between their periods is always exactly n (an integer) $+ 1/2$.

The drawing on this page shows how it works. A free-running oscillator at approximately 8250 cps controls the horizontal synchronization. The sinusoidal output of the oscillator is applied to a symmetrical extreme limiter and the resulting square wave is differentiated and balanced to ground through a low-inductance pulse transformer. Pips of a single polarity in one waveform are produced alternately with pips of the same polarity in a second waveform. Both waveforms, gated through a flip-flop circuit to a common lead, are used to control the blocking oscillator so that its average frequency is held exactly equal to that of the power system (60 cps). The 60 cps pulses from the locking oscillator control the flip-flop circuit at a 2:1 ratio, giving it a frequency of 30 cps. The pips from the two waveforms do not determine the mean frequency of the oscillator, but they do control the exact time of each of its triggered wavefronts. Since the train of pips to the blocking oscillator is changed 180 degrees in phase at each period of the oscillator, every period is accurately timed to be just $n + 1/2$ cycles of the square wave at the limiter.

- Whether two-way or one-way video is used.
- Whether or not the self-viewing feature is used.
- Whether the lamp is on or off or arranged to light automatically.

The punched cards record the date of any of these actions and its time of day to the nearest millisecond. This exact record will facilitate correlation of all the punched cards periodically. By comparing cards from both locations, it is possible to study the use of the service in detail.

Rounding out this part of the experimental program, a digital computer has been programmed to accept the cards from the telemetry system and to derive statistical information from them such as:

- The mean and standard deviation of the number of off-hooks a day.
- The mean and standard deviation of the number of uses of the various service features (view-self, one-way or two-way video, etc.)
- The mean and standard deviation of conversation time, ringing time, and signaling time.
- The mean and standard deviation of the percent of off-hook time in which the speaker-phone is used

The telemetry data will be analyzed weekly until the statistics become stabilized. It should then be possible to draw some conclusions concerning the learning effects experienced by the users of the system. Various circuit options will be introduced during the experiment and pertinent statistics collected to assess how they are used. Interviews with the users will complement the telemetry analysis. When the data from the analysis and the interviews become stabilized, the sample of users being studied can be changed.

A sample of the World's Fair visitors who use the Picturephone system will be asked for their initial reactions to it. Because a large number of people will have an opportunity to use this system, differing attitudes after one experience may be studied exhaustively. Viewing conditions may be changed to obtain an even wider range of first-use reactions.

Reactions to any communications system, however, will change markedly after a long period of daily use. This, of course, is a fact motivating the Murray Hill-Holmdel system. Between information gathered on both experimental systems, it will be possible to assess the response of several samples of users. Thus, the data from both systems should complement each other effectively.