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COMPUTER-PRODUCED MOVIES

By

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APPLICATION OF TIME-DIVERSITY to MULTI-LINK DATA TRANSMISSION

By

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THE RADIO CLUB OF AMERICA, INC.

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PROCEEDINGS OF THE RADIO CLUB OF AMERICA

Volume 41 December, 1965 No. 3

COMPUTER-PRODUCED MOVIES*

By

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An automatic, electronic microfilm recorder can plot points and draw lines at speeds many orders of magnitude faster than a human draftsman. This machine and the electronic computer which controls it promise to facilitate the production of animated movies for a wide range of educational and research purposes -- to the extent of making economically feasible some kinds of animated movies which heretofore have been prohibitively intricate, time-consuming and expensive to draw and film.

The microfilm recorder, reduced to its essentials, consists of a display tube, similar to a TV tube, but whose electron beam is controlled by signals, not from a broadcasting station, but from an electronic computer or a computer-written magnetic tape. Facing the display tube is a camera whose film advancement is also under automatic control. The commands which this assemblage understands are the simple instructions to advance the film, to display a spot of a certain brightness at specified coordinates of, typically, a 1024-by-1024 raster on the tube face, or to draw a straight line segment from one such point to another. Some displays, in addition, can "type" characters from a large but fixed alphabet by means of a shaped electron beam which has passed through the appropriate stencil of its alphabet mask; in some other displays, characters are drawn instead by automatic plotting of appropriate patterns of spots or line segments.

In spite of the simplicity of the machine's elementary operations, it can compose complicated pictures or series of pictures from a sufficiently large number of appropriately placed points and lines; it can draw and film these elements at speeds fast enough to make this not only a feasible but a desirable way to produce long series of such pictures. Current speeds for microfilm recorders lie in the range of 10,000 to 100,000 points, lines, or characters per second. This is fast enough to produce in a matter of seconds a television-quality image consisting of a fine mosaic of closely spaced spots, or fast enough to turn out simple line drawings at rates of several frames per second.

Still, asking the movie producer to specify the desired pictures in terms of elementary points and lines is out of the question -- this would usually be worse than his actually drawing the pictures outright. The producer would like instead to describe the pictures in more sweeping and powerful terms, such as "type such-and-such a title, center each line, give the letters shadows, now shoot 150 frames." The job of the computer, equipped with an appropriate program, would then be to deduce, from a few statements in the powerful language, the very large number of corresponding instructions for the microfilm recorder -- and thus actually to produce the pictures automatically.

Still another role of the computer may appear when the producer doesn't know in advance just what the desired sequence of pictures is -- for example in the case where he wants to describe the computer, in yet more abstract terms, a hypothetical situation and the laws which govern it. The job of the computer then is first to simulate the system, i.e., to follow its mathematical laws, which may require a great deal of computation, in order to determine its successive states. Then for each such state the computer calls upon its picture drawing facilities to "photograph" the hypothetical system.

I shall discuss in turn these two roles of the computer -- drafting and simulation -- citing examples of actual computer-produced movies and movie-making systems which my colleagues at

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** Member of the Computing Research Department of the Bell Telephone Laboratories. Presented before the Radio Club of America September 23, 1965.

Bell Telephone Laboratories and I have developed during the past three years. Three movies will be mentioned, all of which are available on loan from the Technical Information Libraries, Bell Labs., Murray Hill, N. J.; they were made by use of an IBM 7094 digital computer and a Stromberg-Carlson 4020 microfilm recorder.

The Computer as a High-Powered Drafting Machine

My own work in this area has concerned the development of a special programming language for animated movies, and necessarily the development of the corresponding computer program that "understands" this language and carries out the designated operations.[1] This language, called BEFLIX (for "Bell Flicks"), speaks of a picture as a large 252-by-184 array of spots each of which is represented in computer storage by a number from 0 to 7 indicating the intensity of light at that point. Pictures are built up and modified within the computer by appropriate manipulation of these numbers, and at the desired times these numbers are used to direct the microfilm recorder in displaying the entire array of 46,368 spots in order to expose one frame of film.

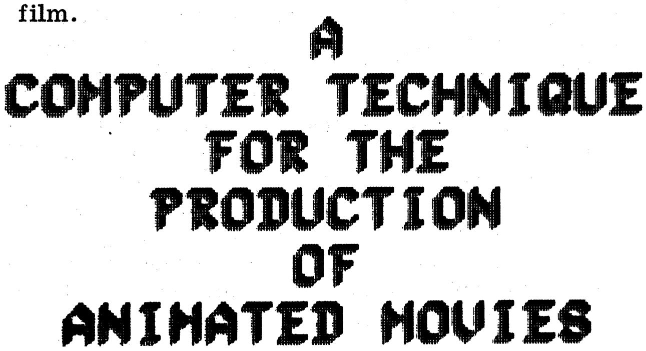

Fig. 1a. Title scene of a 17-minute movie about the BEFLIX movie language developed by the author and entirely produced by his process.

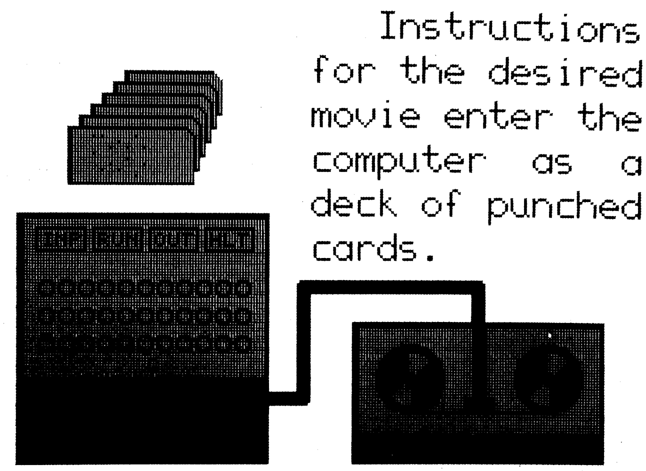

Fig. 1b. A scene from the movie, depicting the computer at the left and the tape on which it writes a spot-by-spot description of pictures. The scene is composed of a 252 by 184 array of variously shaded spots.

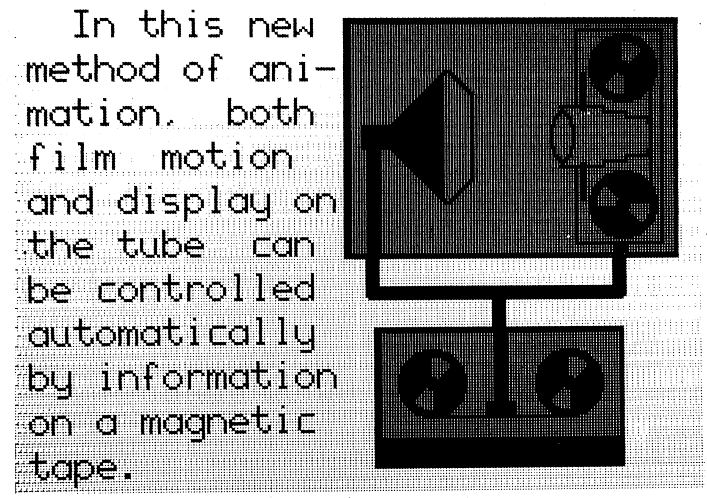

Fig. 1c. The magnetic tape at the bottom controls a microfilm printer with a display tube, upper center, and a camera, upper right. Another scene from the BEFLIX language movie.

Figures 1a through 1c are scenes from a movie which I have made by programming entirely in this language, a movie about the very process by which the film was made.[2] The first of these scenes is a more or less traditional title scene, but it was produced at a minimum of human effort because the computer movie program contains patterns for the letters (actually in several sizes and fonts) and operations for automatically centering lines of text. The effect of depth was achieved by drawing the title twice in black, with slight displacement between successive operations, and finally once in light grey. (It was not much harder to tell the computer to do it three times than to do it once, and the additional computation time involved was insignificant).

Some of the picture-drawing capabilities of the language are demonstrated by the second and the third scenes which, incidentally depict schematically the physical equipment involved. These two pictures were produced by instructions of the BEFLIX language such as those for drawing

[1] Knowlton, K.C., AFIPS Conference Proceedings, 25, pp67-87, 1964.

[2] Knowlton, K.C., "A Computer Technique for the Production of Animated Movies", 17-min. 16 mm black and white silent film. Available on loan from Technical Information Libraries, Bell Telephone Laboratories, Murray Hill, New Jersey

straight lines (consisting of dots in the BEFLIX system), or drawing arcs and other curves, or "painting" an area with a solid shade of grey, or copying contents of one area onto another, or shifting the contents of an area up, down, right, or left a specified number of raster positions. There are also operations for automatically filling a region that has been outlined by a specific shade of grey, for enlarging a part of a picture or a whole one, and for gradually dissolving one picture into another which has been drawn on an auxiliary "drawing board" within the computer.

In all, the language contains about 25 kinds of instructions, each of which is punched on an IBM card with appropriate parameters specifying just where and how the operation is to be performed, and how many movie frames are to be produced at intermediate stages of the operation. For example, the instruction for drawing a straight line requires the programmer to specify beginning and end points, width of line in raster units, shade of grey, and the speed at which the line is to be drawn, expressed as the number of raster units the line should advance between successive frames of the movie.

The BEFLIX language actually does not do much which cannot be done by normal methods. In many cases, however, drawings can be made with far less human effort than when drawn manually, especially drawings which exhibit symmetries or periodicities. In Fig. 1b for example, the 33 lights on the computer console were produced by giving instructions for drawing just one of them and in addition, a list of positions at which these instructions were to be performed. In fact, not even an explicit list of positions was given to the computer, but instead the rules for enumerating these positions.

Finally, a big payoff comes, for the movie programmer as for other programmers, with the accumulation of a library of subroutines pertaining to a specific area. The second movie on any topic is nearly half-finished when the first is done, in the sense that the basic subroutines for drawing and manipulating the picture elements involved - atoms or spacecraft or electronic circuit components - are already written and checked out. The movie programmer has at this point developed a higher and more powerful language designed for animating his own particular subject matter.

The economics of computer animation is, of course the fundamental question: it should now be a surprise to no one that a computer, given sufficiently detailed instructions, can create on a display tube any desired picture or series of pictures - the question is whether the man-given instructions can be sufficiently concise and whether the computer can determine and produce the display quickly enough to make this a desirable way to do animation. The answer is definitely yes, judging from the movie of Fig. 1. This is a 17 minute film, which is consequently about 25,000 frames long. However, if each sequence of identical frames is counted as a single picture, the number reduces to 3,000 unique pictures. Now these 3,000 pictures were actually produced by approximately 2,000 lines (or punched cards) of BEFLIX programming, which took two months of my time as the sole producer-programmer. The other major expense was 4 hours of 7094 computer time (2 hours for program checkout and two hours for "production" run).

Other incidental costs bring the total cost up to $600 per minute of film, which already falls at the lower edge of the range for manual animation of this quality and complexity; computer animation costs will undoubtedly go down with increasing size and speed of computers, with special-purpose peripheral equipment better suited to movie-making, and with further development of computer languages for the purpose. With efficiency improved only slightly from what we have now, it will also be feasible to improve the resolution of pictures and to do animation in color, both of which will require correspondingly more computation but only a slight increase, if any, in programming effort.

A large area of animation should, therefore, soon open up to the computer - particularly in educational areas like physics, chemistry, and mathematics, which have much to gain when their more-or-less traditional schematic diagrams can be brought to life by animation, at costs which do not overwhelm the usually hard-pressed educational budget.

This is not to say that all or most animation presently done by hand will eventually be done by computer. In fact, it is difficult to imagine at this point how one could formalize for the computer the rules for drawing familiar cartoon characters. Instead, it is the more schematic and geometric forms for which the computer will be used to advantage.

The Computer as a Simulator

Movie-making potential of the computer is further extended by taking advantage of the computer's ability to perform prodigious numerical calculations, such as may be involved in simulating hypothetical systems. It was one such simulation which led to a movie by R. E. Zajac, chrono-

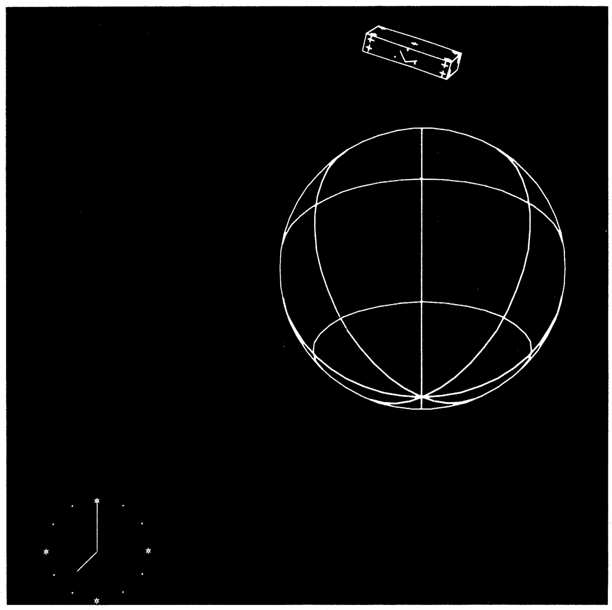

Fig. 2a. E. E. Zajac's computer produced satellite-orientation study. Satellite shown as rectangular box with + sign to identify sides. Computer drawn clock counts orbits.

logically the first of the three films under discussion, scenes of which appear in Fig. 2. [3,4]

The basic problem on which Zajac was working was one of celestial mechanics: given a certain mechanism for orientation and stabilization of a communications satellite with respect to the earth, and given certain initial conditions of insertion of the satellite into orbit, what is the satellite's resultant motion? The hypothetical satellite under investigation had a long axis, and it is represented by a domino-shaped box in the scenes shown. Orientation of the satellite, with one end eventually pointing constantly toward the earth, is achieved by the gravity-gradient torque - i.e. the torque resulting from the earth's gravity pulling ever so slightly harder on the end of the satellite which is nearer to the earth. This results in general in an oscillatory motion; damping of this oscillation is accomplished by two gyros mounted within the satellite, with axes free to swing through a prescribed range, but with viscous damping. [5]

The satellite's motion is described by complicated differential equations for which we have no solution in closed form. In such a situation, the applied mathematician usually resorts to numerical integration by computer, as Zajac did, to determine by iterative procedure the position, velocity, orientation and angular momentum of the satellite and its gyros for successive moments of time. But the resulting tabulation of these quantities, if such a listing had actually been produced, would have been difficult to interpret, even for the specialist in these affairs, and of no use to the layman. Instead, the results of the computation were automatically put out as a series of perspective drawings showing the computed positions of these objects as a function of time. The result is a movie which gives, to the specialist and layman alike, a much better feeling of the dynamics of the process than would the reams and reams of paper output.

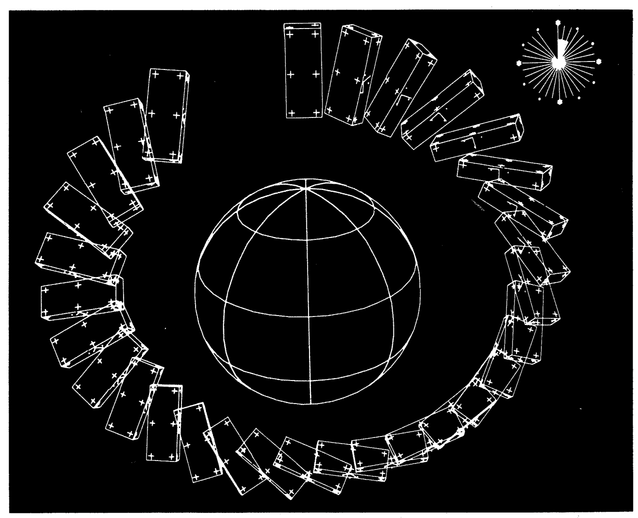

Fig. 2b. Several frames of Zajac's satellite movie combined, showing the earth with multiple exposures of satellite and clock.

One scene of Zajac's movie appears in Fig. 2a, showing the earth in the center and the satellite below it. Different faces of the satellite are identified by different numbers of '+' signs, and

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[3] Zajac, E.E., "Two-Gyro, Gravity Gradient Attitude Control System," 7-min. 16-mm. black and white silent film. Also available on loan from B.T.L.

[4] Zajac, E. E., Communications of Assn. for Comp. Machinery, 7, pp. 169-170, Mar.1964

[5] Lewis, J. A. and Zajac, E. E., BSTJ 43, No. 6, (Nov. 1964), pp. 2705-2765

the instantaneous positions of the gyro axes are indicated by the two additional line segments on the side of the box, the dots there representing stops which limit gyro motion. The clock in the upper right, also computer-drawn, counts orbits, with one "hour" of clock time equal to one orbit. Fig. 2b is a composite drawing showing the earth just once (it rotates in the movie), but with superimposed images of the satellite and clock from every fifth frame of a section of the film.

The pictures of Zajac's movie were produced not by means of a large-scale movie-making system but rather by special-purpose subroutines written specifically for drawing an earth, satellite and clock in the forms illustrated. The earth and sattelite subroutines produced perspective drawings by mathematically projecting lines from significant points of these objects back to a viewing point; places where these lines pierced an imaginary "picture plane" gave positions of the corresponding points in the picture. The clock was always drawn, in effect, directly on the picture plane. Finally, the computer instructed the microfilm recorder in constructing pictures, here composed of several dozen line segments and a few dots, as contrasted with BEFLEX pictures containing tens of thousands of dots.

Here, then, is an example of a movie that probably would not have been made without the automatic microfilm recorder. It is true that a few dozen manually produced line drawings on clear plastic "cels" would have sufficed for the earth and individual clock hands -- to be photographed, as is common in traditional animation, by stacking up several cels in appropriate relative positions to give many different composite pictures from a few drawings of individual objects or parts. Yet every frame of the movie would have required an individually drawn satellite, since the satellite and its gyros appear in so many different ways. The human draftsman would have to follow the results of the computer simulation, plotting and drawing the box with inhuman accuracy and perseverence, for thousands of such drawings in order to match the quality and quantity of a few minutes worth of output of the microfilm recorder.

A still further advantage in producing movies by computer is that the programmer is in effect composing many scenes or movies at once, since a slight but meaningful change in the computer program can yield a very different but useful movie. By changing the rules of display, for example, Zajac was able to produce views of the satellite such as that of Fig. 2c, which shows the same motion as Fig. 2b, but where the viewer imagines himself to be following closely behind the satellite in an orbitint reference frame. He was also able to investigate a wide range of orientation and stabilization mechanisms and a range of initial conditions of insertion into orbit, simply by adjusting the appropriate parameters and rerunning the program to produce another movie.

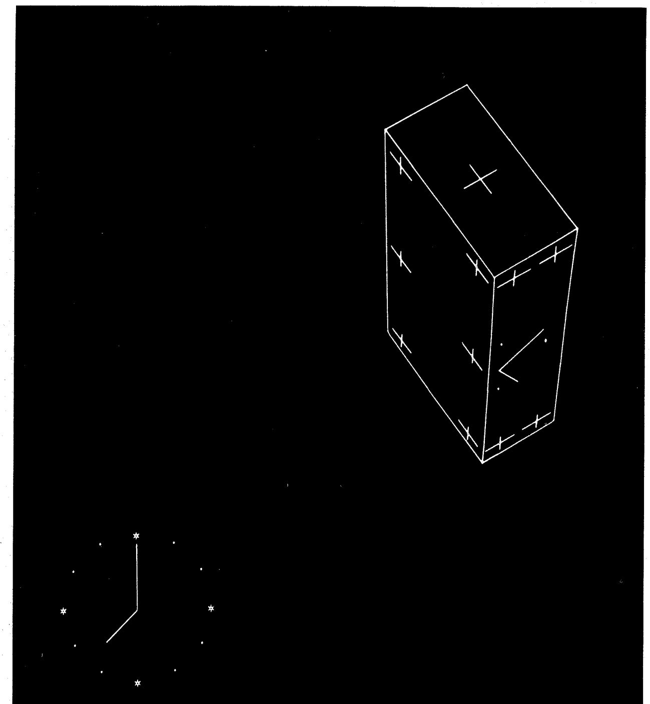

Fig. 2c. Another view of the motion shown in 2b. The frame of reference is moving with the satellite. Illustrates how a minor change in the program can yield a different but useful movie.

In this way many movies can be made where just one would have been made by usual techniques. This should please many people. Consider, for example, the educator making a movie on molecular structure, who may, understandably, be sensitive about the way atoms are portrayed. He should be happier about computer animation for two reasons: first, he himself or someone working very closely with him will be the programmer, thus avoiding a multi-level heirarchy of command with its inescapable communication problems. Secondly, if the first attempt does not produce the desired esthetic or pedagogical effect, then it is not at all out of the question, as it might be with manual animation, to make the appropriate change in rules and try again: the marginal cost of redoing a scene or an entire movie can be an order of magnitude less for computer animation. This is indeed a marvelous but formerly unthinkable luxury for the movie maker: the ability to actually view a large family of movies in search of the one or few that best serve the research or educational purpose at hand.

Computer-produced Movies in Education

Scenes from a movie strictly along educational lines appear in Fig. 3. This film, entitled "Force, Mass and Motion",[6] produced by F. W. Sinden, describes the motion of two bodies acting under Newton's law, f = ma, for a number of different central force laws and a range of initial velocities.

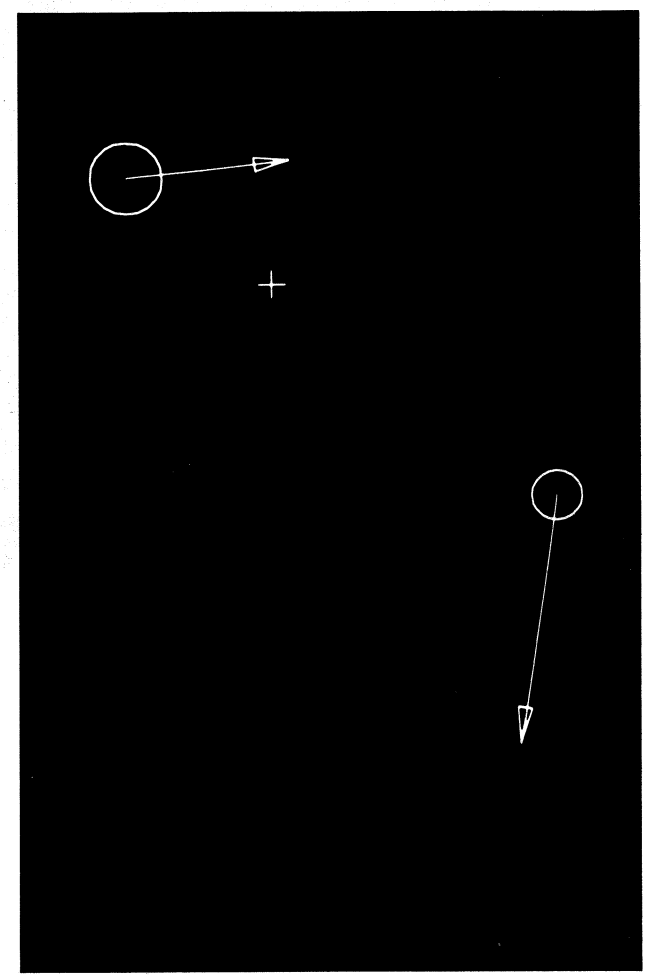

Fig. 3a. A scene from F. W. Sinden's computer produced movie, "Force, Mass and Motion," showing velocities imparted on two bodies acting under the inverse square law. Arrows show velocities imparted at time = 0.

For example, Fig. 3a depicts two bodies with different masses, as shown by different sized circles, about to be imparted at time t = 0 with velocities as shown by the arrows, and whose motion is to be governed by the inverse square (gravitational) law. The center of mass of the system is marked by a cross. The resultant motion of these bodies is the apparently complicated pair of paths traced out in the animated sequence, one frame of which is Fig. 3b. The film then views the same motion

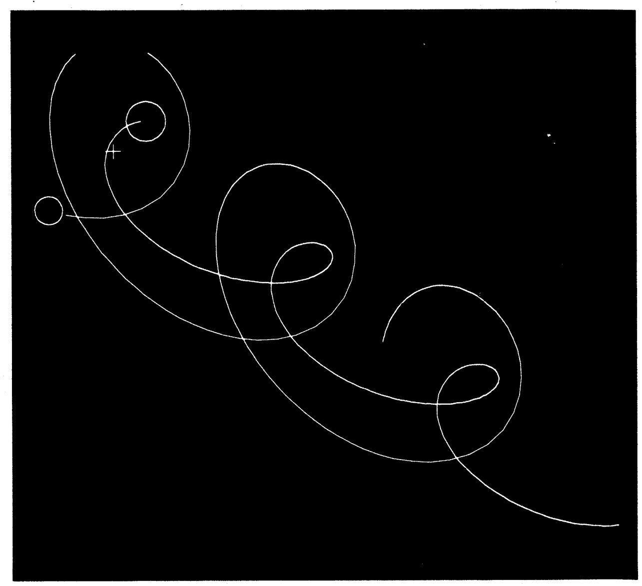

Fig. 3b. Bodies tracing paths resulting from initial conditions of Fig. 3a and gravitational force. Cross indicates center of mass of the system.

from a frame of reference in which the center of mass is fixed, demonstrating that the motion is simpler than it first appeared, as exhibited by the ellipses being traced out in Fig. 3c. Pictures of this film, as those of Zajac's, consist of straight lin line segments, drawn by special purpose subroutines for animating this particular subject matter.

Sinden's film contains many other scenes demonstrating motion under other central forces; those which vary as r^{-3}, r^{-1}, r^{3}, and r^{∞}. Fig. 3d, for example, shows two bodies tracing out their paths as determined by a force which varies as the cube of the separating distance. Arrows in the figure show instantaneous direction and magnitude of the force.

This 10 minute film as a whole is an elegant and esthetically beautiful lesson in physics: its total effect, I believe, cannot be matched by hours of hand-waving at a blackboard or with physically realizable demonstration equipment. (The world of the computer is in one sense the perfect physics

[6] Sinden, F. W., "Force, Mass and Motion", 10-min. black and white sound film. Likewise available on loan from B.T.L.

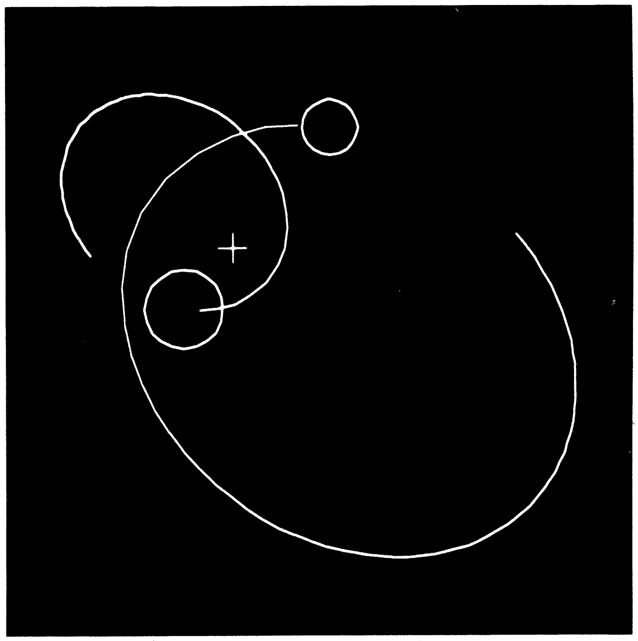

Fig. 3c. Same motion as Fig. 3b but viewed in a frame of reference moving with the center of the mass. Note paths are elipses with common force at center of mass.

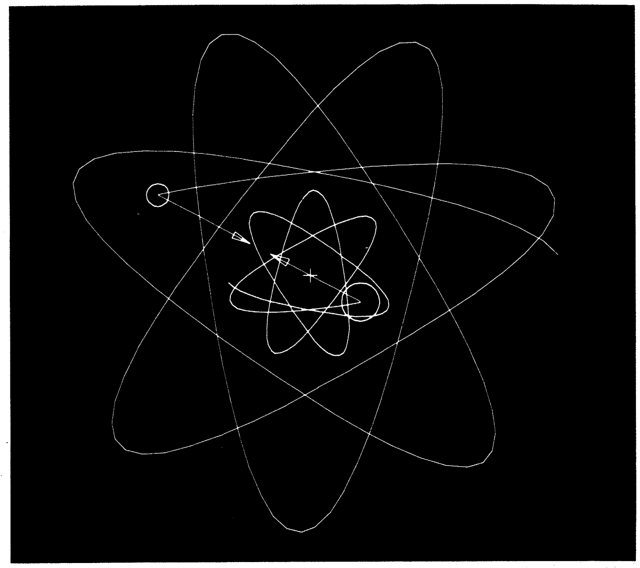

Fig. 3d. Two bodies acting under a force which varies as the cube of the separating distance. Arrows show instantaneous direction and magnitude of the force on each.

laboratory -- for the laws of physics can here be idealized or revised to degrees impossible to approximate with other teaching aids). And it is another film that probably would not have been made without the computer, for to achieve the same accuracy and smoothness of animation would have been all but impossible by normal means, whereas computer-animation was easy because the mathematical laws governing the situation portrayed were simple.

Summary

Automatic microfilm recorders can draw pictures at speeds orders of magnitude faster than a human draftsman. They are therefore ideally suited for the production of animated movies if they can be instructed by a digital computer whose job is to accept abstract or high-level descriptions of pictures or situations and to reduce them to elementary picture elements of points and lines. The movies and movie-making systems thus far developed do in fact demonstrate the feasibility of producing a wide variety of animated movies by these methods.

The electronic computer performs one, or sometimes two distinct jobs. In all cases it renders, in terms of points and lines, a series of pictures which have been described to it in a more powerful or abstract way. In addition, it is sometimes called upon to do a great deal of calculation in order to determine just what the picture or situation to be portrayed is, as a function of time. The latter job is usually called simulation of a hypothetical model and it is done by integrating differential equations or by otherwise following the mathematical laws which govern it. In both jobs the computer and electronic display hardware excel because of the speeds at which they work and hence because of the magnitude of the tasks they can undertake.

Thus, many research, demonstration and educational movies are only now becoming feasible to produce, because of the complexity of the subject matter being animated - such as three-dimensional vector fields, changing in time, as encountered in fluid dynamics and electrodynamics. The new machinery and display techniques enhance our picture-drawing capabilities so dramatically that they provide a qualitative as well as quantitive extension of the jobs that can now be done.

APPLICATION OF TIME-DIVERSITY

to

MULTI-LINK DATA TRANSMISSION

By

WALTER LYONS*

SUMMARY

A novel means for the reduction of errors in multi-link wireline, cable and microwave radio circuits is presented. Time diversity is applied to the data terminals with switching of paths in diversity determined by two assessment criteria. One is the distortion, the other parity. Error rate reduction of at least two orders is realized in this manner.

INTRODUCTION

A previous paper "Error Protection Via Time-Diversity,"[1] described the application of time diversity to point-to-point data circuits over various transmission media. The assessment means for diversity switching described utilized but one criterion, per cent bit distortion. These simple means are sufficient for a single link circuit where burst disturbances are associated with but one transmission path.

The particular problem concerning multi-link circuits is that bursts of errors occur in each link in a statistical manner which is independent for each link. However, in multi-link transmission circuits HF is seldom, if ever, employed and disturbances peculiar to this medium are not encountered.

Most multi-link circuits have very low broad band noise, that due to thermal effects (random noise). They are however, subject to natural disturbances, especially on open wirelines and over microwave circuits or severe man-made disturbances primarily due to switching transients, maintenance and supervisory devices (burst noise).

These burst type disturbances cause errors over the period of their duration when their amplitude is of the same order as the signal amplitude, regardless of the type of modulation employed.

METHODS

Most wireline and microwave systems can support the transmission of serial bit streams of the order of 1200 bits per second (bauds), binary keying, on a nominal 3KC voice channel. This figure may be doubled in cases where the transmission links are of sufficiently high grade as regards uniformity of delay and frequency-amplitude characteristics.

For the application of time-diversity, we would be limited to half these speeds since the data must be transmitted twice. The separation in time of the repeated bit stream required is determined from statistical studies of burst disturbance duration on the medium employed. As an example, if wirelines are used the delay between the real time and repeat information should be about 200 to 250 micro-seconds.[2] This will require a digital delay of 250 bits for 1200 baud traffic on transmission. In order to switch without error each diversity path, the real time signal must be delayed equally on reception in order that both signals be timed coherently at the point of selection. The delay at both terminals is maintained exactly by the use of flip-flops, one per bit delay. Thus, in the example we would use 250 flip-flops.

It may be noted that for high frequency point-to-point circuits the limiting keying speed is roughly

[1] Lyons, W., "Error Protection Via Time Diversity," Convention Record Xth National Communications Conference, October 1964, Utica, N.Y.

[2] Hughes Aircraft Co., Culver City, California, "Phone Line Digital Transmission Study, PB 159 953. Office of Technical Services, U. S. Department of Commerce, September, 1960

* Vice-President, Tele-Signal Corporation, Hicksville, New York.
Delivered before the National Telemetering Conference, Houston, Texas, April 14, 1965.

100 baud (bits per second) and the statistical maximum burst duration is approximately 1.5 seconds.[3] From this sample analysis 150 bits (flip-flops) delay was built into the Tele-Signal Model 163 Error Protection Terminal.[4] Over several long-haul HF circuits employing this equipment error reduction is extraordinarily high as compared with other commercially available apparatus for this purpose.

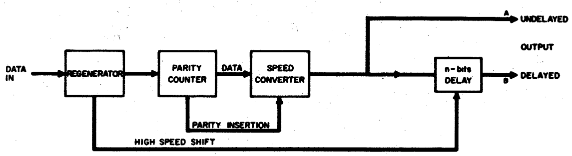

Fig. 1 - Transmitter Unit

FUNCTION

Time-diversity is particularly suitable for the reduction of bit errors since reception during periods of time variant disturbances is avoided. There is no interruption of traffic, however, because the other transmission of the same traffic is taken out of storage immediately upon detection of limiting distortion or parity error detection.

In preliminary tests, without parity assessment, over circuits using multiple relays, the majority of errors not caught were predominately single bit. Investigation disclosed that these were due to sporadic pulses of very short duration that occur between periods of noise bursts predominating. The inclusion of parity protection in the bit stream transmitted to effect diversity switching for a very short period, improved error reduction materially over link circuits.

A by-product of the inclusion of parity assessment affords a degree of privacy. This is because the parity bit may be placed in any arbitrary position in the bit stream and in other polarity.

Figure 1 is a functional block diagram of the PEP Transmitter Unit. The DC data input is regenerated and passed on to circuitry which counts the number of input bits and inserts a parity bit in every block of 9 information bits. The output from the speed converter is then divided into 2 paths, a real time output which has not been delayed and a delayed output which has been delayed by an appropriate number of bits. The delay is predetermined from the characteristics of the medium and translated into the number of flip-flops required to get this delay under the required speed of transmission. These outputs may be transmitted each over its individual tone channel or they may be time division multiplexed over a single tone.

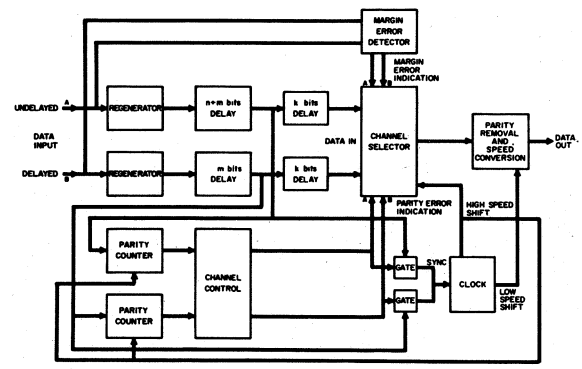

Fig. 2 - Receiver Unit

Figure 2 is a functional block diagram of the receiver unit. The real-time and delayed inputs which are usually low level DC derived from the tone channel receivers are regenerated and delayed in such manner that the same information from both channels is available at identically the same time at the input to the channel selector. Margin error detection is accomplished at the input before regeneration in order to have maximum assessment ability of the medium at any time. This detector then determines which channel will be selected for reception for the period of approximately n bits. The m bits delay is required to assure that the circuit selected is error free for the time required for assessment and selection. During the time that one channel or the other has been selected, parity assessment may indicate a sporadic error. This assessment is accomplished by examining both channels when the information from each is received synchronously. The k bits delay extends over a period of ten bits of transmission time in order to permit parity assessment before selecting the channel with the correct parity, only for the time of one ten bit block. The data output is a replica of the input bit stream of the transmitter of Figure 1.

Figure 3 is a sample record of transmission of page printing. Both records were taken simultaneously on printers connected to the output of the

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[3] Lyons, W., "Optimizing High Frequency Telegraph Transmission," Proceedings of the Radio Club of America 1964 No. 2 May, 1964 and IEEE Transactions on Communications Systems March, 1964.

[4] Minc, A., "Pulse Communication System," Application for U. S. Patent #312,527, September, 1963.

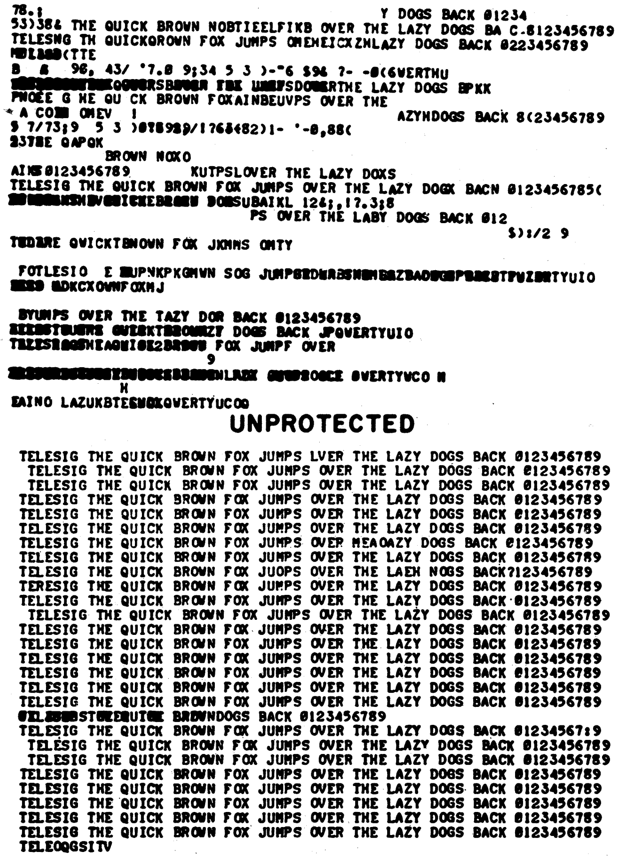

Fig. 3 - Protected and Unprotected Transmissions

PEP and to one of the channels before the application of time-diversity or parity assessment. The improvement in copy in this figure is quite dramatic and illustrates the power of this method for error protection. Statistically, several tests have shown that on an unprotected circuit having a character error rate of 1%, the application of PEP will result in an improvement of over two orders. We should expect a greater order of improvement for circuits with lower error rate when unprotected.

Figure 4 is a picture of the hardware required for a duplex terminal. The equipment mounts in a standard 19" rack and is 10-1/2" high (6 rack units).

CONCLUSION

The method for error reduction or protection disclosed, although only 45% in traffic efficiency, is probably more efficient than a highly redundant

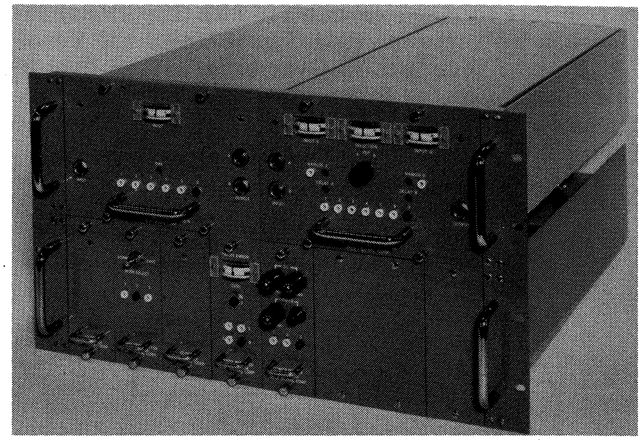

Fig. 4 - Duplex Time-Diversity Terminal

character coding scheme designed for the same degree of protection. Moreover, these latter types requiring character recognition, restrict the flexibility of simple bit stream transmission. The only restriction to the system described is that a transmission speed in bauds be integrally related unless a simple provision is incorporated for changing speed equally at both terminals. Character coding need not be accommodated.

Impulse noise is the major factor determining error performance of data modems on wireline, cable and microwave multi-link circuits, assuming the signal-to-random noise ratio exceeds 20db and the signalling speed is not so high that keying components lie outside the characteristic distortion-free bandwidth of the facility. Thus, avoiding transmission during periods of disturbance is the most effective solution to the problem - that afforded by time-diversity with adequate circuit assessment.

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ARMSTRONG FM CONTEST FOR 1965 COMPLETED

The 1965 Armstrong "FM" Awards contest has been completed and the judges selected by the Armstrong Memorial Research Foundation will soon announce winners and honorary certificate awards. This year's contest drew more entries in every category and a larger proportion of superior entries. The four categories for which FM broadcasting stations submitted tapes were music, news, public or community service and education. Awards were presented at the Engineers' Club on December 16th.

MEASUREMENTS'

"FAMOUS FIRSTS"

1939 MODEL 54 STANDARD SIGNAL GENERATOR—Frequency range of 100 Kc. to 20 Mc. The first commercial signal generator with built-in tuning motor.

MODEL 65-B STANDARD SIGNAL GENERATOR—This instrument replaced the Model 54 and incorporated many new features including an extended frequency range of 75 Kc. to 30 Mc.

1940 MODEL 58 UHF RADIO NOISE AND FIELD STRENGTH METER—With a frequency coverage from 15 Mc. to 150 Mc. This instrument filled a long wanted need for a field strength meter usable above 20 Mc.

MODEL 79-B PULSE GENERATOR—The first commercially-built pulse generator.

1941 MODEL 75 STANDARD SIGNAL GENERATOR—The first generator to meet the need for an instrument covering the I.F. and carrier ranges of high frequency receivers. Frequency range, 50 Mc. to 400 Mc.

1942 SPECIALIZED TEST EQUIPMENT FOR THE ARMED FORCES. WORLD WAR II.

1943 MODEL 84 STANDARD SIGNAL GENERATOR—A precision instrument in the frequency range from 300 Mc. to 1000 Mc. The first UHF signal generator to include a self-contained pulse modulator.

1944 MODEL 80 STANDARD SIGNAL GENERATOR—With an output metering system that was an innovation in the field of measuring equipment. This signal generator, with a frequency range of 2 Mc. to 400 Mc. replaced the Model 75 and has become a standard test instrument for many manufacturers of electronic equipment.

1945 MODEL 78-FM STANDARD SIGNAL GENERATOR—The first instrument to meet the demand for a moderately priced frequency modulated signal generator to cover the range of 86 Mc. to 108 Mc.

1946 MODEL 67 PEAK VOLTMETER—The first electronic peak voltmeter to be produced commercially. This new voltmeter overcame the limitations of copper oxide meters and electronic voltmeters of the r.m.s. type.

1947 MODEL 90 TELEVISION SIGNAL GENERATOR—The first commercial wideband, wide-range standard signal generator ever developed to meet the most exacting standards required for high definition television use.

1948 MODEL 59 MEGACYCLE METER—The familiar grid-dip meter, but its new design, wide frequency coverage of 2.2 Mc. to 420 Mc. and many other important features make it the first commercial instrument of its type to be suitable for laboratory use.

1949 MODEL 82 STANDARD SIGNAL GENERATOR—Providing the extremely wide frequency coverage of 20 cycles to 50 megacycles. An improved mutual inductance type attenuator used in conjunction with the 80 Kc. to 50 Mc. oscillator is one of the many new features.

1950 MODEL 111 CRYSTAL CALIBRATOR—A calibrator that not only provides a test signal of crystal-controlled frequency but also has a self-contained receiver of 2 microwatts sensitivity.

1951 MODEL 31 INTERMODULATION METER—With completely self-contained test signal generator, analyzer, voltmeter and power supply. Model 31 aids in obtaining peak performance from audio systems, AM and FM receivers and transmitters.

1952 MODEL 84 TV STANDARD SIGNAL GENERATOR—With a frequency range of 300-1000 Mc., this versatile new instrument is the first of its kind designed for the UHF television field.

1953 MODEL 59-UHF MEGACYCLE METER—With a frequency range of 420 to 940 megacycles, the first grid-dip meter to cover this range in a single band and to provide laboratory instrument performance.

1954 FM STANDARD SIGNAL GENERATOR. Designed originally for Military service. The commercial Model 95 is engineered to meet the rigid test requirements imposed on modern high quality electronic instruments. It provides frequency coverage between 50 Mc. and 400 Mc.

1955 RADIO INTERFERENCE MEASURING SET. An aperiodic noise meter useful to 1000 Mc.

1956 MODEL 505 STANDARD TEST SET FOR TRANSISTORS. A versatile transistor test set which facilitates the measurement of static and dynamic transistor parameters.

1957 RADIO FIELD STRENGTH AND INTERFERENCE MEASURING SET. A tuned radio interference and field strength set covering the frequency range of 150 Mc. to 1000 Mc.

1958 MODEL 560-FM STANDARD SIGNAL GENERATOR—First successful FM Signal Generator using solid state modulator.

1959 MODEL 700 FREQUENCY METER—A completely new concept of frequency measurement. An instrument capable of direct and continuous reading to one cycle in 25-1000 Mc range.

1960 MODEL 139 TEST OSCILLATOR—A compact, versatile, and portable instrument for rapid and accurate alignment of I.F. circuits in all types of radio receivers.

1961 MODEL 760 STANDARD FREQUENCY METER—An accurate, simple to operaate, direct read-out, portable instrument designed for servicing two-way mobile radio equipment.

MEASUREMENTS

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NEW FROM EDISON . . .
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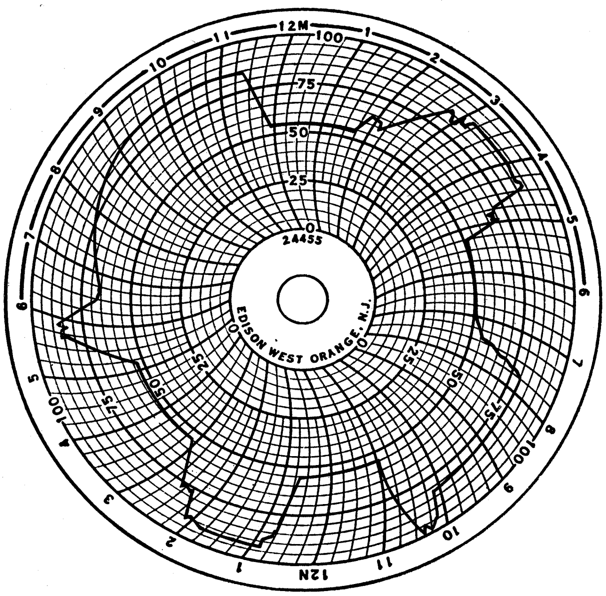

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Now you can take advantage of a new, economical means of recording any variable that can be converted to an electrical signal. Thanks to Omnicorder, you need no longer rely on meters or indicators, even where cost factors or space restrictions would ordinarily dictate the use of these instruments.

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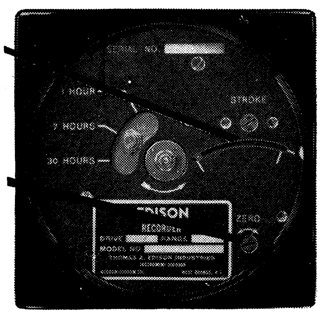
Omnicorder's simple, inexpensive construction assures dependable operation and a long, maintenance-free life. Four types of meter movements are available to measure a wide range of AC and DC electrical quantities, ranging from thermocouple outputs to currents as high as 100 amperes. No amplification is ever required, even for signals as low as 10 microamps.

For complete information on this rugged, maintenance-free Omnicorder, write for Catalog 3057.

Stylus operates through this slot. The measuring system is sealed off from any careless tampering.

Zero Set Screw: Adjustment is made when measuring system is not printing and when the circuit to be recorded is disconnected.



Thomas A. Edison Industries

INSTRUMENT DIVISION

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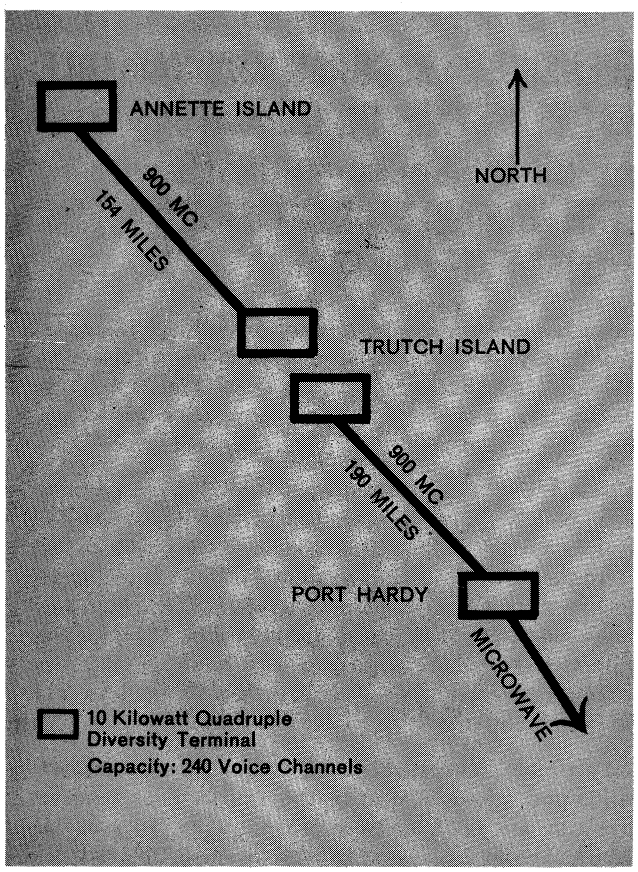
TROPO

CANADA

Province of British Columbia, Canada — focal point of a pioneering tropo scatter communications system connecting Alaska, British Columbia, and the Continental United States.

In creating this system, prime contractor Lenkurt Electric Company of Canada, Ltd., a GT&E subsidiary, selected internationally-proven tropo scatter radio relay equipment by REL.

Operated by the British Columbia Telephone Company and the Alaska Telephone Corporation, also GT&E subsidiaries, the privately financed system spans 344 miles in two giant leaps to provide a totally integrated commercial telecommunications network.



PHILIPPINES

Island of Luzon, Philippines — focal point of a tropospheric scatter system that provides a vital link in telecommunications between the Island Republic of the Philippines and the Continental United States.

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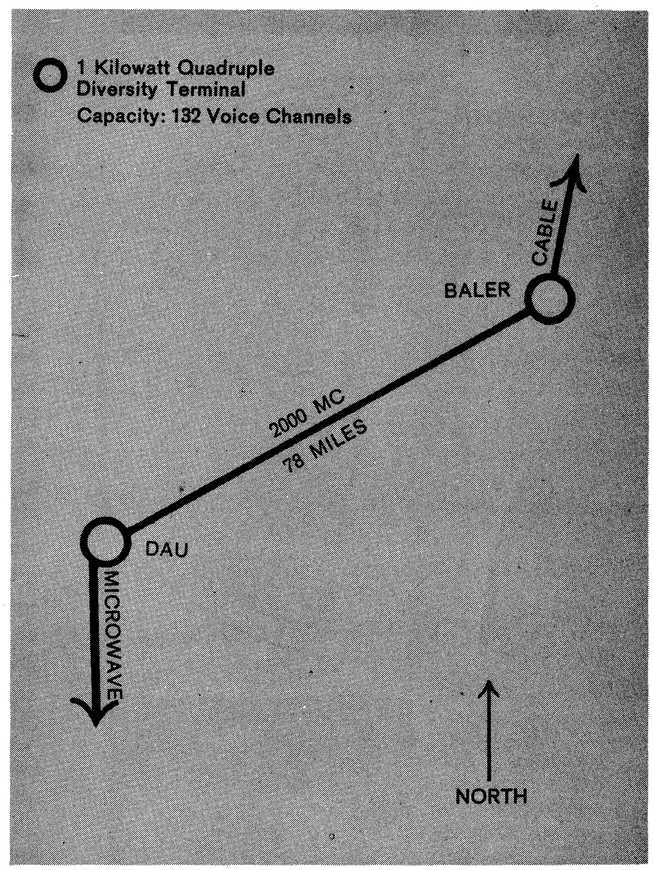

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