AMPEX

READOUT

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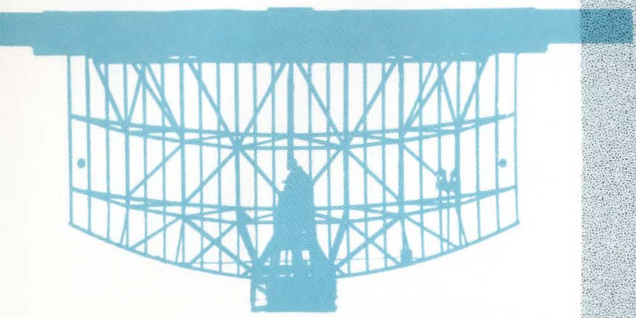
FAA RECORDS RADAR TO TEST AIRCRAFT TARGET AND WEATHER PROCESSING SYSTEMS

In the next decade, the FAA expects to see a tremendous increase in its air traffic control and flight service activities, as the entire aviation sector of our economy pushes ahead at an even faster rate than before. To help cope with its increased activities, new systems and refinements of existing systems are now under development. Here is the story of one such development, which tries to do something more than just talk about the weather.



THE FAA is developing a processing subsystem for radar data to help air traffic control personnel better identify aircraft during storms. Storm signals appear as noise on radar indicators, sometimes making it temporarily difficult to accurately identify and track signals from aircraft. In developing the system, two rotary head wideband recorders (Ampex FR-900 and FR-950) record radar data representing storm signatures and aircraft during different weather environments. In the near future, the program will be expanded to include some six sites around the country. This radar information is replayed as many times as required to set up a standard of comparison and identification in testing system components. Comparison hadn't been possible previously using live radar inputs because the data couldn't be repeated. Both routine and major storms are recorded.

RADAR PROCESSING SUB SYSTEM: Part of National Airspace System

At the National Aviation Facilities Experimental Center of the Federal Aviation Administration in Atlantic City, New Jersey, a program is under way to develop a radar digital processing subsystem for weather and aircraft data. This subsystem is part of the National Airspace System which will provide automated or semiautomated tracking and display of aircraft and radar weather clutter. Within a few years, it will be operational throughout the country to help handle the ever increasing volume of air traffic. Two types of Airspace Systems are being developed: en-route systems with a range of 200 miles, and terminal systems with a range of 60 miles.

One of the principle objectives of the data acquisition program at Atlantic City is to help air traffic control personnel more easily separate aircraft signals from radar weather clutter during all types of weather conditions.

Air traffic control specialist evaluating weather contours generated from recorded radar data.

FAA project engineer adjusting the two-channel Ampex FR-950 rotary head recorder.

STORM TYPES: Storm Signatures from Common and Infrequent Conditions

Storm data is made up of radar returns from ice and rain in the air. Each storm has a characteristic radar signature which shows direction and indicates approximate intensity in terms of the density of the hydrometeors. Previously, the FAA studied these storm signatures and their effect on aircraft signals in real time on conventional radar indicating devices, such as a plan position indicator (PPI).

Now, the experimental center records radar data during a variety of storms, ranging from common thunder showers to hurricanes, on Ampex FR-900 and FR-950 wideband rotary head instrumentation recorders. Soon, recordings will also be made at major airports to get typical heavy traffic data (such as Chicago, New York, Los Angeles, and San Francisco) plus Norman, Oklahoma, to get typical tornado and land storm data.

Storing the radar data on magnetic tape allows it to be recreated at a later time and studied as many times as necessary to extract all significant information. By this means it is hoped that a standard of comparison and identification can be established between the noise created by storms and the aircraft data. Storage of radar data is especially useful for infrequent storms like hurricanes, since the characteristic signature can be repeated at any time without waiting for another storm to reoccur.

The Center is building up a library of tapes covering all types of weather and signal conditions. Forthcoming field recordings will expand this library and its usefulness greatly. After the development phase, the Center will add new recordings to the library so that it can continuously evaluate and improve the processing system and techniques.

RADAR SIGNALS: Receiver Output, MTI and Beacon

Several types of radar data are commonly recorded: linear receiver output, logarithmic receiver output, moving target indicator, and beacon or aircraft identification signals. In situations where the Center wants to record more than one type at the same time, the two-channel FR-950 is used. Radar data is presented to the recorder in the form of detected video made up of low frequency clutter blocks and sharp rising pulses. The pulses may have a rise time as fast as 100 nanoseconds, and a repetition rate of up to 1500 pulses per second. The radar triggers are multiplexed as negative spikes while the radar video is positive going pulses. This permits full utilization of each wideband recording channel. During recording, input radar signals are paralleled into a standard PPI scope for monitoring.

To show the position of the radar antenna, output from the positional servo system and an azimuth pulse generator are multiplexed and recorded on the two auxiliary channels. A time code and voice cueing signal are also recorded on the auxiliary channels to aid in identifying specific activities on the tape.

DATA PROCESSING: Recorder Recreates Live Data for Repeated Analysis

To process the information, the output of the recorder is treated as if it were a live radar source. Storm data occurs essentially in a random manner with some degree of correlation, in contrast to aircraft signals which occur more uniformly. By statistical analysis of the recorded data, the FAA hopes to set up a data processing program which will allow a computer to supress a typical storm signal and allow an aircraft signal to be reproduced on the operational displays. The effect on the scope is to remove most conventional weather clutter depending on an adjustable threshhold level set into the system by the operator.

However, without the contour of the clutter to identify a storm area, an aircraft could be misdirected into a storm. Therefore, a contour outline of the storm clutter will be derived by the system and presented on the scope along with a visual indication of intensity. This could be shown either by an identifying symbol or the brightness of the contour line. The exact technique is being developed now by repeated replay of the library of radar data on tape. Parallel to this effort, the FAA is digitizing the analog video output for recording on digital tape in IBM compatible format. These tapes will be used in the analytical studies of radar signatures.

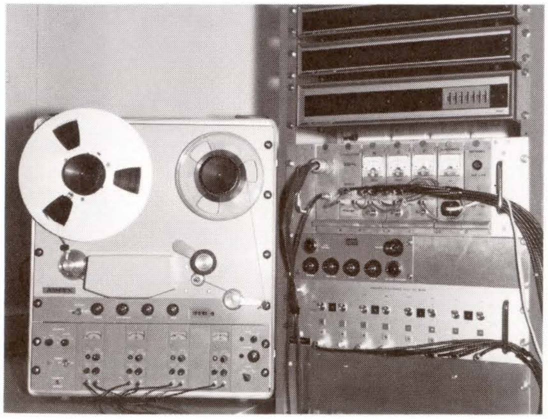
Single-channel Ampex FR-900 recorder, also used in this development.

MAGNETIC RECORDING ADVANTAGE: Recreating Live Data

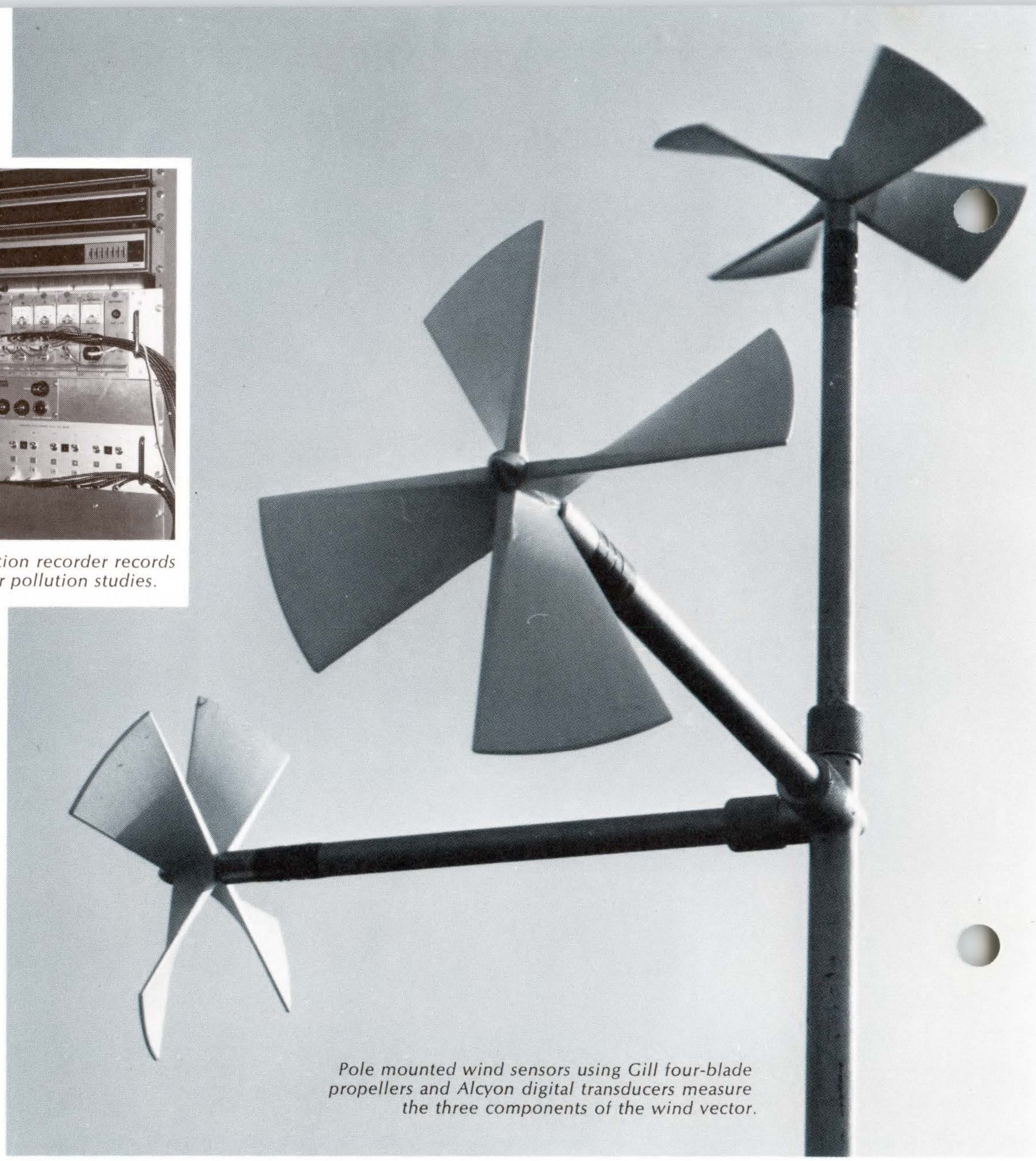
Probably the key advantage of magnetic recording in these applications is its ability to recreate the data exactly as it occurred as many times as necessary for complete evaluation of all system components. The FR-900 series records sinusoidal data up to 5.5 megahertz or 6 megahertz with the FR-900A or FR-950 and pulse data with a rise time as fast as 100 nanoseconds.

Related applications of wideband recording are airborne radar recording (using the airborne version of the FR-900 family), predetection recording by feeding the receiver intermediate frequency directly to the recorder, television recording at any scan rate (the recorder is synchronized internally so that it can accept signals of any scan rate singly or in any sequence), and digital recording up to 20 megabits per second and higher. ■

General view of FAA's Terminal Radar System, Model ASR-5.



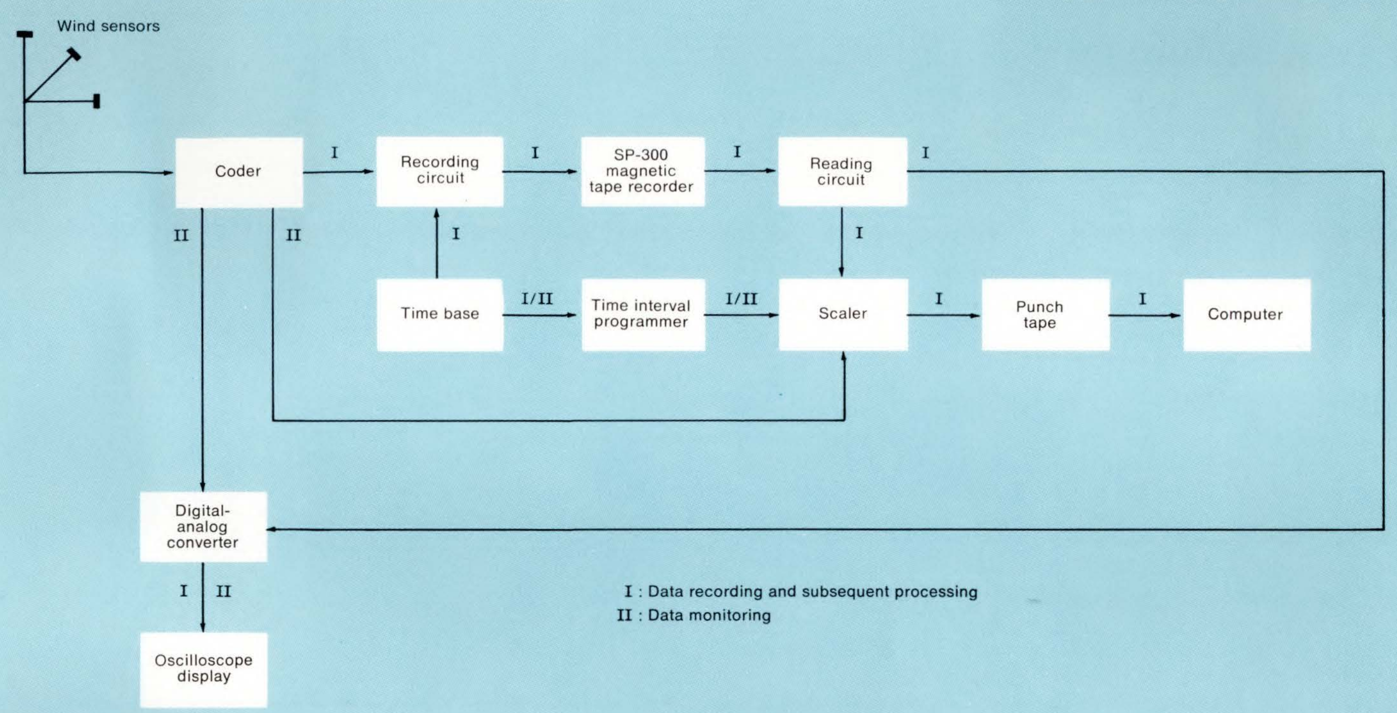
Ampex SP-300 four-track instrumentation recorder records and plays back digital data in Swiss air pollution studies.



Pole mounted wind sensors using Gill four-blade propellers and Alcyon digital transducers measure the three components of the wind vector.

The Swiss Meteorological Institute is measuring wind parameters to come up with an estimate of atmospheric diffusion patterns in air pollution studies.
Using a magnetic tape recorder (Ampex SP-300) the three components of the wind vector are recorded in digital form over periods of 15 hours. Then the data is played back at a higher speed to compress its time base and significantly speed up processing. Besides allowing this speed up of data, magnetic recording provides greater resolution than graphic recording and presents the data in electrical form so that automatic data processing can be done, rather than time consuming manual reduction.

Swiss Use Tape Recording in AIR POLLUTION Studies



Swiss Meteorological Institute, Air Pollution Section
NEZ Anemometric System Block Diagram

SWISS METEOROLOGICAL INSTITUTE: Air Pollution Section

In Payerne, Switzerland, the Air Pollution Section of the Swiss Meteorological Institute is carrying on a research project to estimate atmospheric diffusion parameters in air pollution studies. They are particularly interested in the drift and dispersion of pollutants in the exchange layer, which extends from the ground to about 1000 meters above the surface. From a statistical analysis of the three components of the wind vector, it will also be possible to make up a wind-field map covering about a 10-km radius, which will show the distribution of wind forces in that area.

DATA ACQUISITION: Digital Data Representing Wind Vector

To collect the original data, wind sensors using three Gill four-blade propellers, Alcyon opto-electronic digital transducers are used. This instrumentation measures north, —north or south, west, —west or east, up and —up or down. After some signal processing to control pulse polarity and shape, the data is presented to the recorder in the form of positive and negative pulses of ±5 volt amplitude, duration of 1 msec and repetition rate of 0 to 300 times/sec. The three vectors are recorded on three channels of the four-channel SP-300. On the fourth channel, a clock signal from a tuning fork is recorded in the form of 300Hz 1 msec, 5 volt pulses, Recording is done at 1⅞ in/sec. A normal data run lasts 15 hours. During recording, data is monitored by counting the pulses on three scalers over preselected time intervals.

A digital data recording method was chosen by the Swiss researchers because their data analysis is based on communications information theory and this is easier and more convenient to compute with digital data.

DATA ANALYSIS: Computer Processing

For data analysis, the tapes are played back at 15 in/sec which in conjunction with two other recorders compresses the time base (speeds up the data) by a factor of 200. Preliminary analysis is done using counters which give a pulse count from data samples of one second to one hour. This is punched into cards for a quick look and initial edit.

Then selected portions are processed in a digital computer which determines statistical moments and correlates fluctuating orthogonal wind components.

Besides the digital analysis, the SP-300 recorder also plays back tapes into a digital to analog converter. This output is displayed on an oscilloscope to perform more conventional vector analysis and determine the fluctuating path of the horizontal wind vector extremity. A camera photographs sequentially the vector on the oscilloscope for a visual record as reconstructed from the original data recorded in electrical form on magnetic tape. ■

Computer Simulations of Tape Recording

by J. C. Mallinson

INTRODUCTION

The basic head to tape configuration of tape recorders has remained unchanged in the last two decades. Nevertheless, by careful refinement of both head and tape technologies, the performance attained has been improved by a factor of more than ten. Most of this improvement has been achieved by purely empirical means but unfortunately the level of understanding of the basic processes involved and of the precise limiting factors in recording has until recently remained very poor.

The difficulties encountered in analyzing performance of a recorder are due to three factors, none of which may be ignored: 1) the extreme spatial non-uniformity of the record head fringing field, 2) the non-linearity of γFe_2O_3 magnetization versus field characteristic, and 3) the time varying nature of the signals being recorded. It transpires, however, that these difficulties can be overcome by the use of sufficiently detailed calculations such as may be employed in a computer simulation. Simulations of both unbiased sine wave recording (as employed in video machines), and unbiased square wave recording (as in digital machines) have been undertaken by the Ampex Research Department during the last couple of years. In both cases, the results compare well with experiment.

In this article, the general structure of the computer programs is outlined. Then some important results applicable to sine wave and square wave recording are discussed.

THE COMPUTER PROGRAMS

The magnetic coating of tape is divided into a sufficiently dense network of points, and the magnetic field history of each point is computed as it passes the record head. So far, about 400 such points per wavelength on the tape have proved to be adequate. The field history is computed by multiplying the record head field function by the input signal waveform (see Fig. 1). The descending magnitude field extrema are identified and then used to calculate the magnetization recorded at each point via a simplified model of the tape magnetization loops (see Fig. 2).

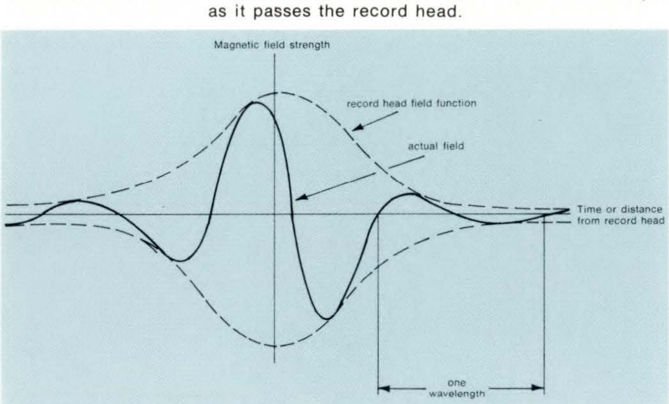
Because all subsequent physical processes are, to a very good approximation, linear operations on the recorded magnetization, it is permissible to continue the simulation by the method of harmonic analysis. Each harmonic is, therefore, subjected to a calculation of the demagnetization and reproduce head flux collecting processes, yielding, after differentiation, the harmonics of the output voltage. Finally, the output voltage waveform obtained by adding these harmonics is automatically plotted.

Apart from the input signal waveform, the simulation requires the specification of four geometrical and five magnetic parameters. The geometric parameters are the tape coating thickness, the head-to-tape spacing, the record gap length, and the reproduce gap length. The magnetic parameters are the record field magnitude, the threshold field for magnetizing the tape, the saturation field of the tape, the demagnetizing permeability of the tape, and the remagnetizing (recoil) permeability. It is possible, of course, to assign any value to these parameters. This facility is one of the significant advantages of having such computer simulations available, for it permits the rapid identification of the limiting parameters. Further, since the computer may be programmed to plot intermediate results, such as the recorded magnetization pattern before the demagnetization processes, it is also possible to determine the precise limiting mechanisms.

UNBIASED SINE WAVE RECORDING

One of the most debated phenomena in sine wave recording is that of "over-recording." At short wavelengths (0.1 mil) the output voltage shows a pronounced peak as the input current is increased (see Fig. 3). An optimum input current exists which is not the same for all wavelengths. This forces undesirable compromises upon the machine designer. It is clear that over-recording must be due to either the inability of the record head to magnetize the tape to high enough levels, or its inability to magnetize the tape in phase at all depths. Our computer simulations of this phenomenon have shown that in the case of well oriented tape the magnetization penetrates the tape adequately at all record current levels. However, the phase of the signals recorded deep

FIGURE 1. Longitudinal magnetic field experienced at a point in the tape as it passes the record head.



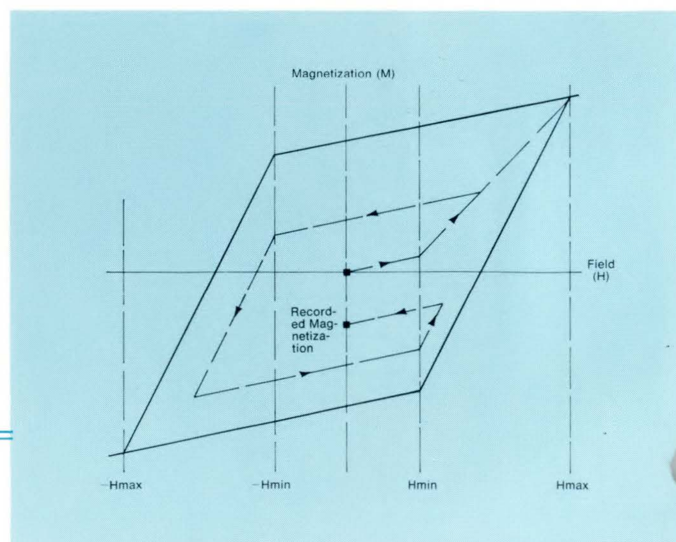


FIGURE 2. Simplified model of the tape magnetization versus field loops.

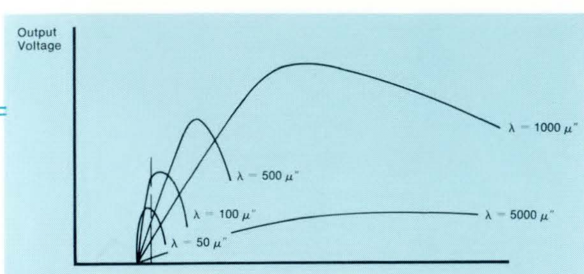


FIGURE 3. Output voltage versus record current for various wavelengths (λ).

in the tape can easily be 180° (or more) different from those in the surface layers.

This finding has important consequences. First, since the phasing problem is primarily related to the fringing field shape of the record head, it means that no improvements in the formulation, processing, coating or orienting processes of tape coatings of normal thickness (0.2 to 0.5 mil) can possibly eliminate over-recording. Second, the thinner the coating the less the possibility becomes of over-recording. For example, in thin plated media, where the coating thicknesses are only 0.05 mil, the setting of the input current level is not likely to be a critical adjustment.

UNBIASED SQUARE WAVE RECORDING

Normal IBM compatible digital recording is performed at about 1000 bits to the linear inch (bpi). Increases in bit density are usually accompanied by dramatic increases in the error rate. These errors arise from two sources: 1) temporary increases in head-to-tape spacing causing reductions in the replay signal amplitude, which are usually called dropouts, and 2) the overlapping of the signals from adjacent bits, termed pulse crowding. Since dropouts are due to purely mechanical factors (primarily dust and other surface contaminants), we have not studied them in great detail. The pulse crowding effects have, however, been the subject of many computer simulations.

In Fig. 4 is shown the excellent agreement obtained between the computed and experimental waveforms under conditions of acute pulse crowding. Here the basic bit density is 7500 bpi with flux reversals of 15,000 per inch. In all, there exist 12 digital transitions in one mil of track length. Not only are we able to simulate accurately this pulse crowding, but we can also trace precise origins. With the aid of the intermediate outputs available in our computer programs, we have been able to prove that the pulse crowding is a linear process providing only that the input current to the record head displays step transitions. That is, if the appropriate series of single transition ouptut pulses are added, the result is precisely the multi-transition ouput waveform. Such knowledge makes possible the exact analysis of the associated detection circuitry. As an immediate consequence of such studies (which were also performed on the computer), several new designs have evolved which should materially reduce the error rate at high bit densities.

FUTURE WORK

We will next attempt to simulate accurately ac biased sine wave recording as used in audio and instrumentation recorders. In these cases, the operating level is governed principally by the degree of third harmonic distortion permitted. Despite the fact that such distortion amounts (typically) to only a few per cent of the total signal amplitude, it is hoped that the computer simulations can be made sufficiently accurate to serve as a design tool.

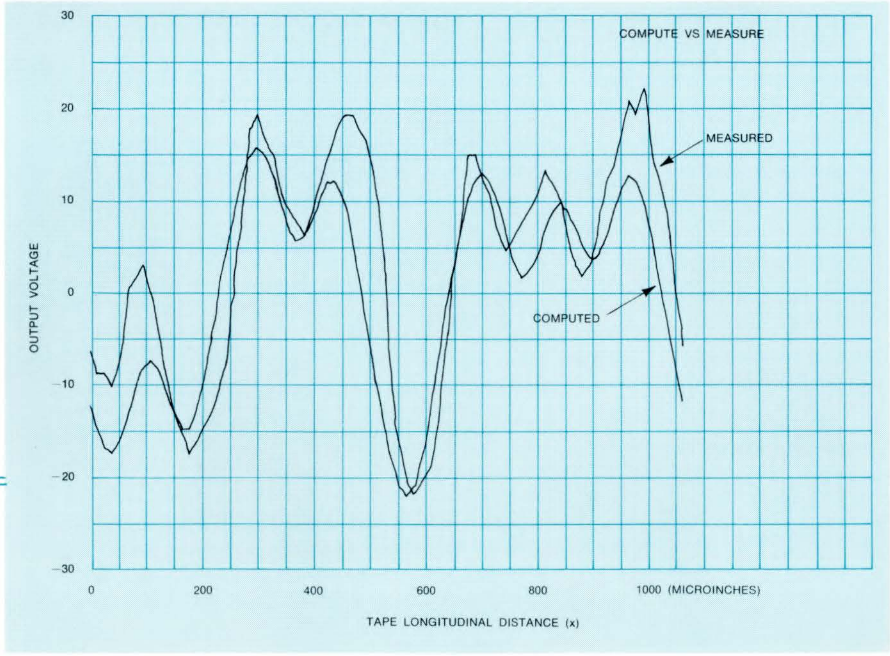
Further in the future, it seems likely that a series of studies aimed at optimizing the head-tape configuration for particular applications will be undertaken. For instance, it may be possible to find new record head designs which minimize the phase shift problems of the present types. Novel reproduce head techniques offer the possibility of minimizing the effects of pulse crowding. All of these topics can be evaluated and optimized more rapidly, accurately and at far less cost by computer simulations than by any other means.

CONCLUSIONS

Computer simulations of the unbiased recording process have been proven possible and of sufficient accuracy to be useful research and development tools. A typical computer simulation run, with automatic plotting, takes less than five minutes. If required, it is obvious that complete signal processing, recording, replay, and detection channels may be simulated with little additional difficulty. The technique offers unique advantages since the precise limiting factors can be singled out rapidly. There appears to be every reason to suppose that such simulations will contribute increasingly to our overall understanding of tape recording.

Reference: C. W. Steele and J. C. Mallinson, "A Computer Simulation of Unbiased Digital Recording," 1968, INTERMAG Conference, Paper 3.3.

FIGURE 4. Measured and computed digital waveforms under conditions of acute pulse crowding at 750 bpi. (frequency doubling coded word 10100110)



Four-car Department of Transportation train used for rail technology development program.

Railroads have been around for quite a long time and it looks as if they're going to be with us for some time to come. As Mark Twain ad libbed in one of his famous lecture tours: "The recent reports of my death have been greatly exaggerated."

Tape Rides the Rails

Enclosed in a weatherproof housing (foreground) an Ampex closed circuit television camera is used to monitor the pantograph at the center of the picture. Pantograph's motion is recorded on one of two on-board Ampex VR-7000 portable videotape recorders.

SUCCESS IN RAILROADING: Selling Transportation Services

The key to future railroad success is to sell transportation . . . not just railroad service. Modernization is important too. Increasingly, railroads today are using computers to control the expensive and time consuming operations of putting freight trains together, taking them apart and keeping track of where they are across the nation. A new system for automatic weighing of freight cars is in the offing. Automatic push button control of trains in freight yards is already in operation. A Videofile® Information System has just been installed by Ampex at Southern Pacific Company to automate filing and retrieval of freight waybills. Containerized shipments and piggyback trains are examples of the new systems approach to transportation that is quietly revolutionizing the railroad business.

In the area of passenger travel it may seem as if service is being phased out at every turn. This is certainly true for cross country runs. On the other hand, Europe's train service is all basically short range and remains pretty much intact. Using existing technology, the Trans-Europe Express delivers people from city center to city center in the relatively compact continent of Europe faster than air transport, with its airport buses, check in time, and actual flight time, can offer. In the United States this kind of train service can still be valid, as is shown by the development of the 110-mph train for service in the northeast corridor between New York and Washington. Impetus for studies leading to the 110-mph train comes from the Office of High Speed Ground Transportation of the U.S. Department of Transportation. This new train service between New York and Washington will cut running time from three hours and 35 minutes to two hours and 59 minutes. This speed plus direct-dial telephones, comfortable seating and ride, and good food is expected to win back air passengers. Service is scheduled to begin no later than early 1969.

DEPARTMENT OF TRANSPORTATION: 21-Mile Test Track

Key element in the rail technology development program is a 21-mile test track on the Penn Central line between Trenton and New Brunswick, New Jersey. Under Department of Transportation contract, Penn Central has upgraded the track to tighter tolerances and installed welded rails. Over this test track, the Department is running a four-car experimental train instrumented by Melpar Transportation Systems Center of Falls Church, Virginia, with several hundred thousand dollars worth of measuring devices. By taking measurements at various speeds from a few miles per hour up to 155 mph, Melpar engineers under direction of the Department of Transportation can plot the track conditions and ride comfort against speed. This enables them to find out exactly what the speed does to the position of the rails and how the rails move as the speed changes.

On one test car, track geometry is measured: gauge, alignment, and level of each rail, plus cross level rail separation, and warp or distortion of the plane of the two rails. Measurements are made by very sensitive capacitor probes installed on the wheel truck. These are proximity sensors which measure the electrical capacity of the air gap between the air sensor and the top of the rail. Previous sensors actually touched the rail. Proximity sensors cut out wear and abrasion, a particular problem at the 100 to 150-mph test speeds of this train, and eliminate mechanical linkages which can cause problems due to their own inertia.

A second test car has instrumentation to measure ride quality. Accelerometers and placement transducers measure the action of the wheel trucks and the acceleration within the

Two Ampex FR-1300 instrumentation recorders aboard high speed test train are used alternately for continuous data recording on long test runs. Over 100 different multiplexed measurements showing actual performance at high speeds are recorded on five data channels.

One of two Ampex VR-7000 portable videotape recorders aboard test train. Closed circuit cameras, each connected to one recorder, are located on the roof and step well to observe pantograph motion and wheel action.

to Test 110-mph Train

car body. Roll, pitch, and yaw, and the linear acceleration about three axes are measured. This gives a good picture of the actual ride comfort. Additional transducers measure the noise levels. In general, the ride becomes uncomfortable long before it becomes unsafe. At speeds of 150 mph, the ride on the test train is judged better than a conventional train going 60 to 80 mph on a standard roadbed. This car also has instrumentation which measures air pressure to show the differences in pressure as two trains pass each other or as a train enters a tunnel. One of the wheels on this car also has a temperature transducer to sense temperature changes at various speeds and during braking.

The third car measures arcing between the pantograph (the voltage pickup on top of the train) and the catenary (the pickup wire above the train). This is done by a coil wound around the pantograph cable which detects the radio frequency energy generated during the arc.

Some trackside instrumentation supplements the measurements taken in the train. These include the movement of the rail and ties to tell exactly what the track structure is doing and correlate with the measurements taken inside the car. An optical tracker has also been used at trackside to watch the movement of the catenary wire.

Another series of studies on the train are being carried on by the Bell System to test the mobile telephone service which will be one of the plus features of the new trains. Of particular interest to telephone engineers were tests to confirm successful operation during traverse of a tunnel in Baltimore.

MULTICHANNEL RECORDING: Correlation of Many Parameters

The key to analysis of these measurements is multichannel recording on magnetic tape which allows precise instantaneous correlation of data. This means that the speed of the train at very slow and very high speeds can be compared to show its effect on wheel motion, axles, couplings, track distortion, comfort factors, as well as the catenary and pantograph movement. By correlating track characteristics with the ride quality, it's possible to identify just which characteristics have the greatest effect on ride quality. It should be possible to isolate the affect of alignment, gauge, or cross level with ride quality at various speeds, which has never been done before.

In total, from 100 to 125 different parameters are being measured at the same time by the Department of Transportation. These are multiplexed in groups of 20 to 25 by five frequency multiplexers. The multiplexed signals are recorded on five tracks on one of two seven-track Ampex FR-1300 instrumentation recorders installed on a work bench in one of the test cars. Normally the test runs are made at speeds in excess of 100 mph over the 21-mile track for a data run of about 15 minutes. Recording at 30 ips, the FR-1300 will capture 24 minutes of data. In case the test run is for a longer period of time, the second FR-1300 is operated sequentially so that it begins when the first one is about to run out of tape. Five tracks are used for multiplexed data, two are used for timing information.

Data is analyzed at the Melpar plant in Virginia. A separate FR-1300 is used for playback for pass one analog-to-digital conversion. Then detailed analysis is done on selected portions by processing it with a computer.

ON BOARD VIDEOTAPE RECORDING: Provides Visual Correlation of Pantograph/Catenary Motion

Besides the data recording, a television camera, Ampex Model 322, mounted on the roof captures visually the movements of the pantograph and catenary, recording them on a VR-7000 videotape recorder located inside the train. Another 322 camera is mounted in one of the wheel wells where it picks up the movement of the wheels for visual observation of rail-wheel interaction. This camera output is recorded on a second on-board VR-7000. These recorders can play back the pictures in slow or stop motion to permit detailed study.

OTHER USES OF THE DATA: Simulated Computer Studies

Besides the operational studies being made by Melpar for the Department of Transportation, the Department has awarded over forty research and development contracts. Most of this work has to do with improvements of rails and roadbeds. The new rail structures can be of any type as long as the gauge and shape of the rail top is not changed. A study by Batelle Memorial Institute is developing a computer program to simulate track structures from the rails down to the under soil. Data collected by Melpar on magnetic tape in the test cars will be used to confirm that the computer testing is providing a good representation of the actual track action.

TRACK MAINTENANCE: Magnetic Recording and Computer Processing

One nagging problem in railroad operation is track maintenance. Rails and ties move out of position and alignment as heavy trains at increasingly higher speeds move over them. Recordings made routinely on magnetic tape can be run through a computer to produce printed reports that will tell track maintenance engineers how to program their maintenance. Track maintenance is directly related to safety because most derailments are caused by rail misalignment. The Department of Transportation hopes to show that a high speed test car with data recording on magnetic tape and high speed computer processing can speed up track maintenance, thus improving overall safety and lowering maintenance costs. ■

Scarborough College

Satellite of the University of Toronto

Built Around TV

TELEVISION, as an aid to education, has taken many forms. But unquestionably the most television-conscious instructional facility in the world is Scarborough College in suburban Toronto. Established in 1965 as one of two satellite campuses of the University of Toronto, Scarborough is set up to handle about 1500 students initially, and eventually students from the overflow at the main campus in the center of the city. The college is housed in a startingly modern building, on a beautiful 202-acre tree-studded site. The plant was designed by architect John Andrews, a faculty member at the University, who laid out an organic structure with liberal use of unfinished wood, aluminum and concrete. Its two wings ramble about a ravine-straddling location providing a sense of spaciousness yet privacy to its many sections.

If modern is the word for the structure, modern, too, is the word for the television communications system that the structure was built around. Probably no educational facility has made such a full commitment to televised instruction. The reasons for television at Scarborough may be common to many educational facilities throughout the world. The difference at Scarborough is the degree to which technology and teaching have been married together.

Basically, television was included from the outset in the design of Scarborough College because it helps promote first class teaching. In these times, when the shortage of teachers is critical, television's ability to present the information and attitude of highly qualified professors to a large number of students is a valuable tool to any educational organization. Television effectively spreads out the time and talents of these teachers giving them more time to work individually with students on a true teacher-student level. Television at Scarborough was never considered as simply a method of piping a lecture to overflow audiences in several different locations or storing it on magnetic tape for replay to later sections of the class. Rather each production is individually planned to obtain the best possible blend of good teaching and good presentation suited to the particular subject.

SUCCESSFUL ETV: Quality and Professionalism

Success in educational television, according to W. E. Beckel, Dean of Scarborough College, is based on three necessities: the highest quality organization and distribution, the highest quality viewing environment and the highest quality programming. He admits that these

take a hard-to-achieve blend of technology, artistry and scholarship.

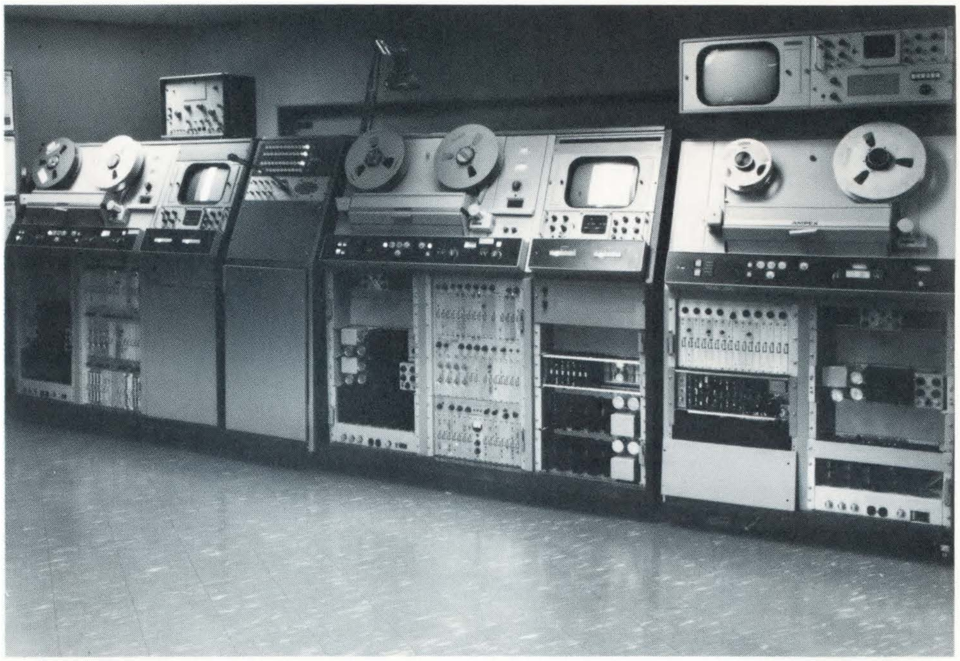
Besides its advantages in spreading the time and talents of teachers, Dean Beckel estimates that television teaching can work out to be more economical, too. His studies show that the break even point for the use of television in university instruction is about 200 to 250 students. Below that number television may not pay for itself over a period of time. Above that number, both the improved quality of instruction and the economics can fully justify television in university education.

At Scarborough, professional quality equipment matches the professionalism of the televised presentation and that of the teaching staff. Three high-band broadcast videotape recorders are used: two VR-2000 and one VR-1200. Audio recorders include one AG-350 and one Model 601 with an accompanying speaker amplifier.

In both the areas of production and distribution videotape recording plays an essential role at Scarborough. For the highest quality master recording, high-band quadruplex recorders, two VR-2000 and one VR-1100, produce lesson materials. For distribution, these recorders play back the material on a flexible schedule with the highest possible fidelity. Videotape recording simplifies production of lesson material. Scenes can be replayed and corrected immediately to be sure that the material has the right blend of good teaching and good presentation. Electronic editing simplifies production, because key to the high quality of presentation at Scarborough is the use of many inserted materials from different sources: films, slides, still pictures, videotape, and live camera, allowing these to be put together into a unified whole. Updating either picture or sound can easily be done so that the material can be kept always current. Once captured in recording form programming can be replayed repeatedly during the week to match the different class schedules of each of the courses.

FIRST AND SECOND YEAR:
Forty-five Percent of Instruction via TV

During his first two years at Scarborough a student could receive about 45 percent of his didactic course material via television. This concentration of televised instruction is made possible because of the large number of students taking certain basic subjects. As many as a thousand students could take first year English, Zoology, French, Chemistry, and Physics. As many as 500 could take Economics, Political Science, Sociology and History. Reaching this number of students with traditional teaching methods, given today's shortage of professors, cannot be done without sacrificing some learning.



Recorder room with three high-band videotape recorders, two Ampex VR-2000, and one VR-1200 provide the professionalism in recording equipment that goes hand in hand with Scarborough's high quality of presentation and educational approach.

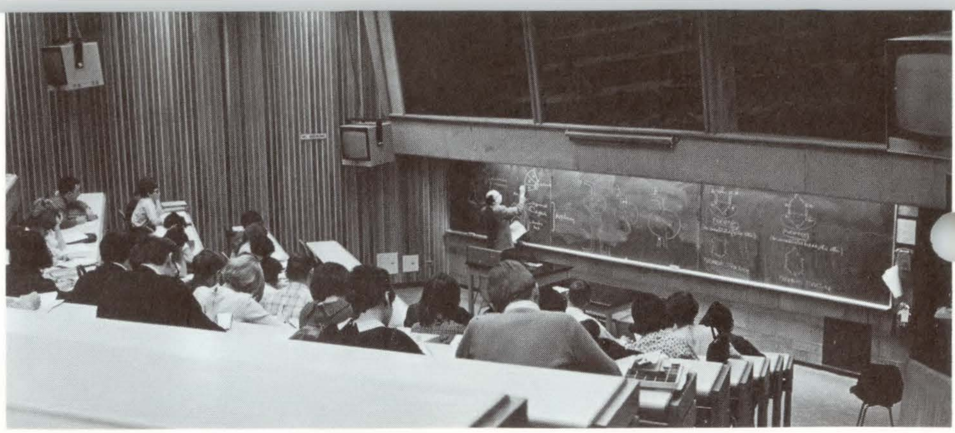
After the first two years, many of the class sections are smaller because students began to specialize. During these years, television's role is also important. It brings enrichment into the formal structure of the courses. Examples are materials produced for the humanities courses. Drama segments, usually performed by students with an explanation by the instructor, illustrate a point in each lecture. This area will receive considerable expansion now that much of the basic course material for the freshman and sophmore students is being completed.

INSTRUCTIONAL MATERIALS:
Lectures and Laboratory Demonstrations

Instructional material via television at Scarborough breaks into two main areas: lectures and laboratory demonstrations. Lecture series typically have forty to fifty units in subjects like Zoology, Sociology, English Literature, Physics, Mathematics, Geography, Psychology, Botany and Political Science. These lectures are broadcast several times during the course of each day into five lecture halls to reach all class sections.

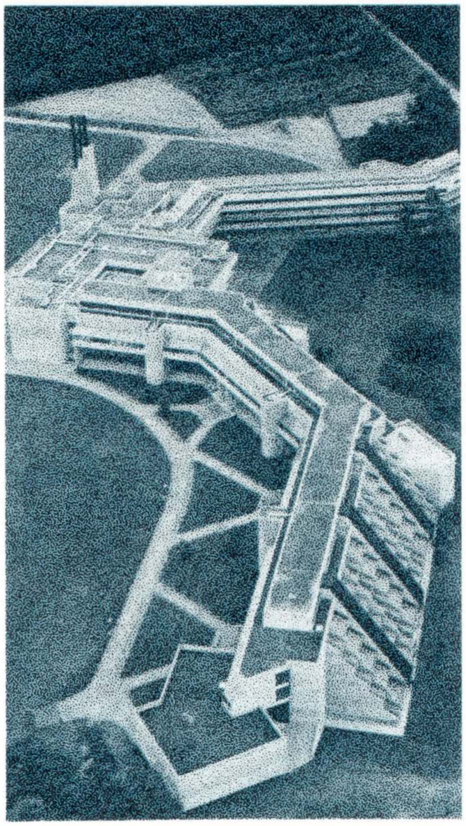
A lecture to be televised is often audio taped the previous year. Then a transcribed version is gone over line by line by the teacher and the television staff. Suggestions for many additional graphic materials, including slides, film, still photographs and live subject matter are added to improve the presentation

Control room for studio 1 (40 by 60 feet) where Scarborough College produces its extensive lecture series. It is easily the match of many commercial facilities. Audio control room at right includes an Ampex AG-440 recorder and Ampex 620 speaker amplifier.



Two hundred seat lecture auditorium at Scarborough College where five 25-inch television monitors give a front row seat to each student.

One of four science studios where Scarborough professors perform laboratory demonstrations for direct distribution or replay via videotape into the 30 laboratories, each seating 20 students.



and illustrate particular points. Decision as to what goes in and what is left out are entirely in the hands of the teacher. Production of lectures on videotape then begins, and continues throughout most of the school year, a few lectures being taped each week, or they may be done continuously during the summer.

This method of course preparation is estimated to take a minimum of three times as long as it would for a lecture that is delivered in the traditional way. For this reason, tapes are maintained for a period of three years, at the end of which each professor will normally remake the series. However, any time during the three year period he can update any part of it, either in the visual or sound portion. Especially important, the professor's class schedule is greatly reduced for the second and third years, so he can devote himself to working with the individual student, and his teaching fellows, lab demonstrators, etc.

The other general area at Scarborough covered by television is science demonstrations. This is a now commonly accepted method of using television for teaching. Laboratory demonstrations have three basic purposes. First, they present laboratory information to the students in the remote laboratories. Second, they allow microscopic close-ups to be presented to many students at the same time. Third, they allow the instructor to answer questions from past lectures during the first ten minutes, give short lab tests, etc.

Scarborough has some thirty science laboratories equipped with multiple television monitors. An instructor in one of the five specially designed laboratory studios performs an experiment with the students following it through step by step. Each student has a front row seat and a clear view of the experiment. No one is crowding around a small lab table. Everyone can hear perfectly. Some of these demonstrations are done live, some are recorded, particularly those involving dangerous, costly or self-destructive experiments.

TELEVISION STUDIOS:
One Large Studio, Four Science Studios

To be successful, educational television must be at least as good as commercial television. Studio facilities at Scarborough are easily the equal of any commercial facility. Studio 1 is a large studio about 45 by 45 feet. It includes a complete walkway/cableway grid for lighting, four 4½-inch Marconi image orthocon cameras and a wealth of background props and screens. The smaller studios are science laboratory demonstration units with overhead cameras on a flexible boom (GE Model TE-21). Three other vidicon cameras are also available in these studios for short lectures or blackboard explanations accompanying the demonstration.

The television staff usually produces an average of six new programs each week. Some of these are temporary programs done in the science laboratories which may be done live or recorded only on a helical scan recorder for limited repeats and erasure. Most production is done in the studios. Some work has been done by taking cameras into other rooms in the building using long cables. For example a special on library orientation was done in the library, and during the visit of a Canadian member of Parliament cameras were taken into one of the large auditoriums.

LECTURE HALLS AND CLASSROOMS:
Forty Receiving Sites

Some forty locations throughout the building can receive television programs from the control center. These include five lecture halls, thirty science laboratories, and five classrooms. Three of the lecture halls seat two hundred people and have five monitors in each, plus a six by eight foot screen for rear screen projection from movie, slide, or television projectors. The other two lecture theaters seat a hundred and forty-five people and have four television monitors each and two rear screens. The smaller classrooms include two 100-seat size with four monitors, and three 50-seat size with two monitors. The science laboratories seat twenty and have two monitors. In total, the college has seventy 23-inch Conrac television display monitors. Principally designed for science use, the laboratories, seating about 20 people each, have turned out to be very good for other subjects, too, and are widely used throughout the day and evening.

Switching from central control is done by a matrix network with 12 inputs, with room for expansion to 24: four videotape recorders, two telecine chains, the five studios and two off-the-air television tuners. Fifty locations can be connected simultaneously from these 12 inputs. ■

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Technical Information:
COMMENTS ON TELEVISION RESOLUTION

By Roger Hibbard

Resolution is a measure of the resolving capabilities of a television system. This term is also used in the optical, film and printing industries, although the definitions are quite different. It is the purpose here to present the accepted television resolution definition, point out the parameters which affect it, and to comment on the relationship to film resolution.

Television resolution is determined primarily by bandwidth, scan rates and aspect ratio. Television systems are generally designed to have equal horizontal and vertical resolution. The aspect ratio, which is the ratio of picture width to height, is 4:3 for U.S. broadcast and closed circuit television systems, and is quite generally used elsewhere.

HORIZONTAL RESOLUTION

Television horizontal resolution is defined as the maximum number of black and white vertical bars that can be resolved within a horizontal expanse of raster equal to one picture height.[1,2] Height equals 0.75 x picture width; therefore, with this aspect ratio, the horizontal resolution is the maximum number of black and white bars resolved within ¾ of the width of the television raster, which is equal to one picture height. Therefore, horizontal resolution is expressed in terms of *lines per picture height*. It is common in the industry to refer to resolution in terms of lines and to presuppose the remainder of the term.

Horizontal resolution is primarily determined by the bandwidth, the active line time and the aspect ratio. For instance, a slow-scan television system can give very high resolution using long periods for scanning and narrow channel bandwidth. If larger bandwidths are available, resolution can be increased vertically by increasing the line scan rate, and horizontally by use of the available channel bandwidth. Vertical resolution is not affected by bandwidth.

A useful factor for relating horizontal resolution to system bandwidth or vice versa is the Horizontal Resolution Factor.[3] For a television system with an aspect ratio of 4:3, the Horizontal Resolution Factor is defined as:

$HRF = \frac{3}{2} T$ (in lines per MHz), where T is the active horizontal line time (horizontal scan period minus horizontal blanking time)

The U.S. 525/60 television system has a Horizontal Resolution Factor of 80 lines per MHz. With a standard bandwidth of 4.2 MHz, the nominal resolution is 340 lines. The 675/60 closed circuit television system has a Horizontal Resolution Factor of 59 lines per MHz and generally requires a 7.5 MHz bandwidth to provide 440 lines horizontal resolution. The 945/60 closed circuit television system has a Horizontal Resolution Factor of 40.5 and requires 15 MHz to provide 615 lines horizontal resolution. The bandwidth referred to for the Horizontal Resolution Factor is the 3-dB bandwidth.

VERTICAL RESOLUTION

Television vertical resolution is defined as the maximum number of black *and* white horizontal bars that the system can resolve. It is also expressed in lines per picture height.

The vertical resolution of a television system is determined by the number of active horizontal lines per frame (the total line count minus the number of lines in vertical blanking). The actual vertical resolution (for an interlaced television system) equals the number of active lines per frame times 0.7, where 0.7 is the Kell factor. (The Kell factor is experimentally derived and represents the relationship between the total number of active scan lines per frame, and the actual resolving power determined in a visual manner.) The vertical resolution of the 525/60 television system can be determined by the following routine: consider that each field blanking period contains 20 inactive horizontal lines, and that there are two fields per frame; therefore, subtract 40 lines from the total line count of 525 and multiply the resulting number by 0.7. The results should show a vertical resolution of 340 lines for this system.

For a random interlace television system the Kell factor is not applicable, and the vertical resolution is equal to the number of active lines per frame.

RESOLUTION MEASUREMENT

Television resolution is normally measured visually while the system is reproducing a test pattern such as shown in Figure 1. The upper central group of black and white lines is the resolution wedge. The line thickness and spacing at the top of the wedge equals 200 lines per picture height when the camera scans the full test pattern. The bottom of the wedge presents a line spacing of 400 lines per picture height. The wedge immediately below gives a test range of 300 to 800 lines resolution. The resolution is determined by the point at which the wedge line pattern loses contrast, but the individual lines are still clearly discernible. In the test pattern shown, the television system resolution has been bandwidth limited to approximately 550 lines per picture height.

Resolution, as defined for television, does not directly correspond to resolution as it is defined for the optical, film and printing industries. Television resolution measurements refer to the maximum number of discernible black and white lines that can be resolved within the dimension of one picture height. Optical resolution is referred to in terms of cycles per millimeter, line pairs per millimeter, or lines per millimeter. Each of these interchangeable terms refers to pairs of lines and the resolution capability is generally accepted as the maximum number of line pairs per millimeter that can be visually resolved. Since television resolution is relative to picture height and optical resolution to the millimeter, no direct conversion factor exists.

The resolution of a television system is independent of the image or monitor screen size. The definition refers to the number of resolvable lines within the picture height, whatever that height may be.

1. D. Fink, *Television Engineering Handbook*, McGraw-Hill 1957, Ch. 1, p. 60.
2. RETMA, 1952.
3. D. Fink, Op. Cit., Ch. 1, p. 13.

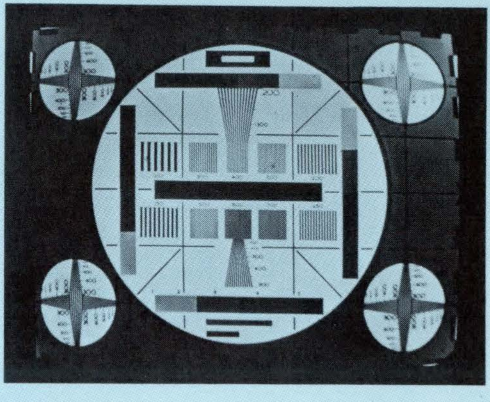

FIGURE 1. Typical test pattern used to measure resolution.

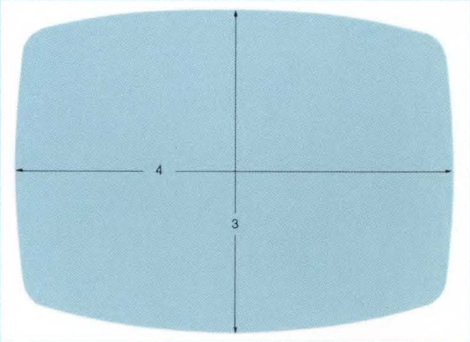

FIGURE 2. Television raster with a 4:3 aspect ratio. Height equals three-quarters of the width.

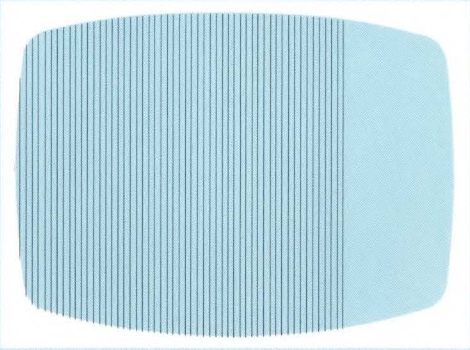

FIGURE 3. Horizontal resolution is the maximum number of black and white vertical bars that can be visually resolved within three-quarters of the width of the raster. It is expressed as lines per picture height, or more commonly, as lines.

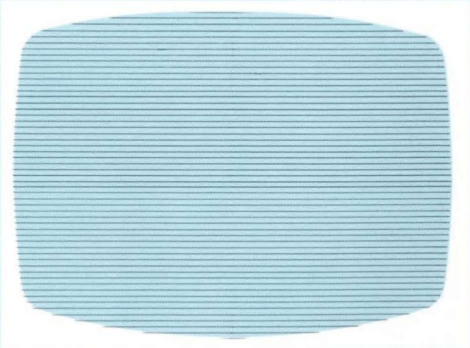

FIGURE 4. Vertical resolution is the maximum number of black and white horizontal lines that can be visually resolved. It is also expressed as lines per picture height or lines.

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