TECHNICAL PAPERS
Presented at the

NATIONAL ASSOCIATION NAB OF BROADCASTERS

Engineering Conference
March 25-28, 1973

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Luncheon Address—Dr. James Redmond

Director of Engineering
British Broadcasting Corporation
London, England

Oscar Wilde said that Britain and America were divided by a common language. As far as I know, he was no engineer, nor did he know much about broadcasting. But as he was good at paradoxes, he would probably have said that, so far as broadcasting is concerned, we are united by our very different methods.

Of course, I'm going to talk about broadcasting, but let me deal first with the common language. Some words need translation as they cross the Atlantic. But I'm sure it will be better if I speak my sort of English and leave you to do translation. So I give fair warning that when I say aerial, I shall mean antenna, but when I say gramophone—and I mean to say just that—I shall mean phonograph; when I say wire, I shall mean cable; and that if, by chance, I should say he's not a very decent sort of fellow, I shall mean the he's a son of a bitch. Right now we know where we are. I will start talking about broadcasting.

In Britain, as in the United States, they began over 50 years ago with radio. We celebrated our 50th anniversary last November, and in the various parts of the United Kingdom we have been celebrating it ever since. Scotland reached the anniversary of its own start earlier this month. Like you, we began radio as a regional affair. But we then became very centralized, and it's certainly within the last two years that we have developed truly local radio stations of the sort that you have always had.

Of course, geography has had a good deal to do with it. You're bigger than we are. The United Kingdom is about as big as New York State, Maine, Massachusetts, and Connecticut. On my atlas, that is the northeast corner of your country, less Vermont and Rhode Island. Another way of putting it is that the United Kingdom would go into Texas three times. I may add that it doesn't want to.

The distinguishing mark of our radio is that there is so little of it. I'm tempted to say little and good, but I don't want to get a reputation as a big head right at the beginning of this talk. We have four BBC radio networks covering the country, and these are streamed into pop, light music, serious music, and one network carrying news and other feature programs. We also have 20 BBC local radio stations, each with a service radius of between 15 and 25 miles. So compared with your domestic air, ours is quiet. We even have three hours in the 24, between 2:00 a.m. and 5:00 a.m., when there is no radio at all.

I will talk about money in a moment, but let me first complete the picture about radio. There is no commerical radio in the United Kingdom. Actually, there is a commercial station on the Isle of Man, but constitutionally the Isle of Man is not part of the United Kingdom. But the government introduced legislation a couple of years ago to permit the operation of some local radio stations financed by commercials and in competition with the BBC. Later this year the first stations will start operating, including two in London. One of these will be an all-news station of the kind that has become familiar in the United States. You will not expect me to give these competitors a plug, so I will leave it at that.

Turning back to BBC radio, some of it is on long wave, some on medium wave, and some on VHF FM, including stereo. We do not broadcast quadraphony, but we are watching with interest the work of your National Quadraphonic Radio Committee. We distribute our stereo sound using a PCM sound system developed within the BBC, which carries 13 high-quality sound channels on a standard television link.

I said the distinguishing mark of our radio was that there is so little of it. The same is true of television. In the United Kingdom only three television programs are available, even in the biggest cities. Of the three television networks, the first was started in 1936 by the BBC. I will say that again. The first was started in 1936 by the BBC. Yes, I have to confess that we beat you to it by three years. I'm sorry, but there it is; I cannot tell a lie. The second network was started in 1955 by a number of commercial companies coordinated by the Independent Television Authority. This is financed by advertising revenues, but there are no sponsored programs, only spot advertising. The third network was started by the BBC in 1964 and, like the first BBC network, is financed by licensed income. The two earlier channels, BBC One and commercial television, were started on 405 lines in the VHF band and reach 99 percent of the population.

The belief in the principle of universality is a politically powerful one in the United Kingdom, and great efforts are made by both the BBC and the commercial company to ensure that their programs are as widely received as possible. This means building some transmitters in remote, underpopulated areas, transmitters which cannot in any way be described as financially viable in terms of the income received either from additional licenses or, in the case of the commercial company, from additional advertising revenues. The two BBC networks carry the same programs through all parts of the country for about 90 percent of the time. Only about 10 percent is local programing. The bigger of the commercial companies do more individual programing, but also many of their programs are sold and exchanged between each other.

Because the first two networks occupied all the available frequencies in VHF, the third network, BBC Two, had to be started in UHF. Long before we started it in 1964, we had agreed within the European Broadcasting Union that all future networks in Europe would use 625 lines and 50 fields; and so BBC Two began on that standard. When it was time to colorize the first two programs, we decided that it would not be good enough to color them in their original forms in 405-line form. Instead, we duplicated them on 625 lines on UHF, the intention being to discontinue the 405-line VHF transmission when we had reached the same 99 percent population coverage on UHF. This is no small task. Thomas Bibden describes Britain as "a snug little island, a right little, tight little island." Even so, it means building about 500 stations, plus hundreds more very low-powered ones. And at our present rate of progress, these will not be completed until about the mid 1980s.

Our experience of UHF broadcasting is good. Of course, there are gaps in the coverage of stations in certain areas, and these gaps are to be filled in by low-power relay. An outdoor receiving aerial with rooftop heights is much more likely to be needed than in the case of VHF, but there is no great difficulty in sitting these aerials and in adjusting them for good reception, and they're smaller and better looking than their VHF counterparts.

We and the commercial companies also share UHF sites, so that only one receiving aerial is needed for each home. We're already serving over 90 percent of the population, with all three programs in color, and the sale of color sets is going well This is important for the BBC, since each color set license means an extra 12 dollars a year income to us.

That brings me to money. There is a simple answer to the question—how's the BBC financed?—and that's inadequately. I suppose it is—that is, a first cousin to Pope John's reply to the question—how many people work in the Vatican?—when he said about half of them. Anyway, our income is from licenses, and I mean license fees paid by viewers, not government handouts. The BBC is not part of government; it is completely independent, a fact that some governments don't care to be reminded of. But they do accept it, as an essential part of the democratic process.

There used to be separate radio and television licenses, but now all the radio is financed out of the television license. It is, in fact, a license to own and use a television set. Every now and again some joker writes and says, I hate the BBC programs and never watch them. I only watch the commercial programs, so why should I pay a license to the BBC? I should describe him as not a very decent fellow, but I should also go on to say that he is wrong. The license is not for watching BBC; it's for using a television set. That's all. Viewers pay 18 dollars a year for a black-and-white television license or 30 dollars a year for a color license. As a result of color licenses, BBC income has gone up from 230 million dollars three years ago to 300 million dollars today, and we expect it'll be 400 million dollars in another three years' time—a very useful increase in income. Four hundred million dollars a year may not sound much by your standards, but 400 million dollars without having to say "please" to a government or a sponsor or a rich foundation is not to be sneezed at. And the programs are not interruped by advertisements, which make them effective for people. They're good as well, of course.

Governments throughout the world find it difficult to leave broadcasting alone, and British governments are no exception. We've just had a government inquiry into the future of television. It has concluded that there are no realistic alternatives to broadcasting for at least the next decade and has recommended that the BBC and the commercial companies should concentrate on extending the three UHF color television networks to the rest of the country as quickly as possible.

The inquiry also concluded that direct broadcasting by satellite into the home is still some way off; that the introduction of video cassettes and other forms of recorded television for home viewing, which may well be successful in their own right, will no more affect the demand for television programs than the gramophone record has affected the growth of radio, and that the development of wire—I mean, cable—distribution of programs will be too costly and too slow to affect broadcasting, to any significant extent, in the next 10 to 15 years.

About 10 percent of the British viewers at present get their television programs off wire. Wire distribution began in the early days of radio when people in some densely built-up areas were offered good quality reception by wire directly into the home, and the only equipment they needed to buy was a loudspeaker. In the early days of television, wire distribution spread in roughly the same areas, because the networks already existed, particularly in areas like the Welsh mining valleys where houses are closely packed together and broadcast reception initially was poor. More recently, wire distribution has spread as an economical way of giving good color television reception in tall blocks of flats—I mean, apartments—and their immediate neighborhoods. In addition, some local authorities have banned aerials from the rooftops of the houses they build, and, as an alternative, they provide wire distribution and charge for it in the rents of the homes.

Wire, or cable, distribution companies are required to relay all three forms of United Kingdom television programing and are prohibited from originating or importing any other. The only exceptions are in six small areas which have recently been licensed to experiment in originating local programs, but which have been refused permission to finance them by carrying advertisements. The viewers will have to pay for the extra programs by an increased subscription fee, or the cable company will carry the extra cost during the experiment.

The existing wire distribution companies are now beginning to press for the right to originate their own programs. They have rechristened themselves cable television companies, and they now call the viewers consumers.

So how is cable television likely to develop in the United Kingdom? There is no complete television over the horizon, no distant signals, as there is in many parts of the United States. Across the horizon in Britain takes in French, Dutch, or Belgian television, and there is a language problem. If the cable operator provides alternatives to the programs broadcast in the U. K., he's got to buy or originate it. There is some interest in local television to provide programs of interest and significance to local communities, and there is some pressure for the "excess" type of program to give minority groups a chance to put their views across. The other programs proposed are similar to those proposed by cable operators in the United States—a video arts channel, a leisure-studies channel, a channel for programing by local authorities (as is the local television channel), a box office and sports channel, and a television repeats channel—all to be financed by subscription—and the shop window channel to be financed by advertising.

If cable television provides true alternatives, then certainly we in the BBC will not complain. That would be healthy competition which we can meet, as we have met competition from the commercial television companies. But, in fact, the cable lobby gives no indication of wanting that kind of competition. It seems to want their cake and eat it. They would like to continue as at present; that is, to receive the broadcaster's programs free and to sell them to their subscribers. We have no objection to that at the moment, because, by doing so, they're helping us to provide a good signal to the public. But, of course, if they continue to relay our programs and also offer their own in competition, we must change our attitude and, at the minimum, charge for our programs. Even if our Minister of Posts and Telecommunications, the equivalent of your FCC, tried to persuade us to be as altruistic as broadcasters are in this country and give our programs free to our competitors, our office and other contributors would not agree. They would expect an additional fee, and so would we. We're not such decent fellows as all that.

The British cable operators also talk of the virtues of unlimited choice of programs and so little of the costs. Thus, they have in mind the kind of vital statistics that seems to be so dear to the hearts of you citizens of this great continent. I have in mind those pictures we so often see on cable systems telling us the time, the temperature, air pressure, and humidity. I've never been able to understand the North American obsession with such transient information. In Britain we find that we can, if we care—and most of the time we don't care—to make a fair approximation of most of these factors as we go about our normal business.

Well, how should we react to cable television in the United Kingdom? And I may say we're watching what you're doing with a great deal of interest and with some trepidation. In Britain we have spectrum space for a fourth UHF television network, which could be started at any time. In the mid 1980s when we switch off the old 405-line system, there will be space for two more VHF networks. Thus, we could have six television networks of national coverage, or perhaps four national networks with a large number of local stations, if that was what was wanted at the time.

In about the same period, the mid 1980s, it should be possible, if we wish, thanks to American technology, to broadcast by satellite directly into a viewer's home another four or five programs, which would reach over 99 percent of the population instantly. This answers much of the criticism leveled by cable operators at broadcasting; namely, that the lack of frequencies limits the number of programs that can be provided. Even so, it behooves the broadcasting engineer to do all he can to make efficient use of this valuable commodity. In the BBC we have done, and are continuing to do, a great deal of work on bandwidth savings. We have developed sound in sync, which permits us to package the television sound within the television picture waveform. So far we use sound in sync only to distribute our programs through our transmitters and so save the cost of sound circuits. But eventually when we start new services, we shall broadcast the combined signal and so save bandwidth, enabling us to have more stations in the same band. We're also looking at ways and means of eliminating redundant information from the television picture, which, again, might permit us to reduce bandwidth and so squeeze in more stations.

We've also developed and will be bringing in for experimental use later this year a method of broadcasting information within the television waveform which can be stored in an add-on unit in the home and reproduced on the television screen whenever the viewer wants it. We call it feedback. It will provide up to 32 pages of information, in alpha and numeric form, on the television screen. I haven't any doubt at all that, if only as a friendly gesture to North American visitors, one of these pages will be devoted to telling of the time, temperature, air pressure, and so on. But the other 31 will provide news and information of any kind that can be presented on the television screen in the form of words and numbers. The system could be interconnected with the telephone or the cable service so that the viewer might dial up any additional information that these companies were willing to provide. Feedbacks will enable us to provide the kind of information, and much more of it, than can at present only be provided by cable television because of the scarcity of broadcast cameras. And because it can go out on existing transmitters at the same time as, and without interfering with, the normal programs, it can be made available overnight to over 90 percent of the population of the United Kingdom.

This, then, is where we've got to after 50 years of broadcasting in Britain. Broadcasting began as a result of the developments of the thermionic valve by Fleming and De Forest, then the cathode ray tube, then the iconoscope by Zwarkin of RCA, and the transistor by the famous Bell Laboratory team. I hope these great men feel that we have exploited their inventions well. But broadcasting isn't going to rest on its laurels after only 50 years, remarkable though these 50 years have been in the scale and scope of the development. The use of feedbacks, as far as we're concerned in the BBC, is only the latest runner from a stable which has produced all electronic standards—converters, sound and sync, and stereo sound. It takes us another stage along the road of digital techniques in television made possible by the great invention of the transistor and its race. There is much that still has to be done and can be done. It will very soon be possible for most television pictures to be recorded, edited, and processed in digital form with all the inherent high quality to which we're accustomed.

The future is bright and the BBC will be part of that future.

Opening of the Conference

Vincent T. Wasilewski
President, National Association of Broadcasters
Washington, D.C.

George Bartlett tells me I am such a friend of engineers because he knows I flunked out of engineering school before I went to law school. You know, each year at these NAB conventions, when some 7,000 or 8,000 people are involved in the broadcasting industry or hangers-on, I am always reminded by George Bartlett that the engineers are at the bottom of the whole thing, and I believe that sincerely. There is little doubt that the instruments of broadcasting, the audio and the visual inventions that make it possible, are in terms of their effect on our society the most influential innovations to appear in this century. A pretty good argument can be made that they are the most influential inventions in man's life history.

Thus, we are all assembled here because engineers have developed this means of communication in the first place, and we are here in such numbers because constant engineering improvements have increased the range and lowered the cost for both radio and television broadcasting and receiving equipment. This I think is the key, not merely the inventions but the improvements that so many of you are involved in constantly.

So, I am sure that I speak for NAB in toto when I say that we take pride in the feeling that these Engineering Conferences, which have been held over the years, have made a contribution to both aspects of broadcast engineering by providing a place where engineers can gather, discuss, and evaluate one another's ideas, where you can learn of new developments and improvements on the old ones.

I think you have a wonderful thing going here. Your meetings I know are always interesting. On behalf of NAB I welcome you to the 27th Annual NAB Engineering Conference. I hope you find it stimulating and productive, and hope that many ideas of continuing improvement in the technical side of our broadcasting system will be generated this year as they have in past years.

I know that I personally am deeply appreciative of George Bartlett's service to NAB. He is a most important element and a most important person, and his is a most important department at the NAB in the overall structure. He works with everybody there and is helpful to everybody, and without him there would be little that I would know about engineering. He also has the capability of explaining these complicated technical subjects to a layman in a very effective way, and I am sure that you share with me my deep feeling and gratitude toward him.

Thank you. Have a productive and most stimulating session.

NAB Engineering Advisory Committee Report

Benjamin Wolfe
Vice President for Engineering
Post-Newsweek Stations, Washington, D.C.

As chairman of the NAB Advisory Committee I would like to review some of the items that have been before our Committee for the past year and action taken thereon.

1. **OPERATOR REQUIREMENTS**—In June, 1972, in FCC Report No. 7784, operator requirements for radio broadcasting stations were eased. A clearer understanding of the entire scope of the new re-regulations by the FCC can be ascertained by ordering Part III, Volume 37 of the Federal Register, published first in June, 1972. The re-regulation has considerable depth and, to a great extent, is in keeping with the aspects of modern technology.

2. **TOWER DEICING**—In the area of tower deicing, no significant changes have taken place since June, 1972, and as soon as experiments are conducted, the technical results will be made available.

3. **OVERMODULATION**—This subject has been incorporated with the overall Part 73 revision program and at the moment no individual report on overmodulation is available.

4. **AUTOMATIC TRANSMITTER**—The automatic transmitter subcommittee has concluded its initial AM-FM report and its findings will be submitted to the FCC within the next 30 days.

5. **NAB ENGINEERING STANDARDS FOR GOOD ENGINEERING PRACTICE**—As the new FCC rules are developed, a publication devoted to recommended Engineering Standards of Good Practice must be developed, one that would guide the industry in implementing the new re-regulation criteria. A member of our Committee has suggested that the NAB be responsible for the development of such standards, which should be eventually adopted by the board.

6. **VISUAL AND AURAL CODING OF COMMERCIAL AND PROGRAM MATERIAL**—At the moment there is no report on the visual or aural coding of commercial and program material. There is also no report available on the aural STL operation in the 2110-2113 MHz band.

7. **CASSETTE RECORDING AND REPRODUCING STANDARDS**—The new NAB cassette recording and reproducing standards are now available in printed form. The committee has recommended that the NAB cartridge tape recording and reproducing standards, which were promulgated in April, 1964, be reviewed in light of recent technological advancements and that a standards subcommittee be appointed to undertake this activity.

8. **FCC-EIA QUADRAPHONIC COMMITTEE**—Your chairman can report that the FCC-EIA quadraphonic committee was extremely active and that in all

probability evaluation field tests of system concepts will be undertaken during 1973. The NAB staff was requested to follow this activity closely.

9. **SHARED TIME WITH WIRELESS MICROPHONES**—The proposal to share TV channels 7 to 13 with wireless microphones has been discussed. It was the consensus of the committee that additional spectrum space should be made available for this service and appropriate comments should be filed when this proceeding is issued for rule making.

This concludes my report. It also concludes two years of serving as the chairman of the NAB Engineering Advisory Committee. My sincere thanks to the committee members, without whom the progress recorded in the past two years would not have been possible. The committee members are as follows:

Walter G. Alliss, Jr.
Chief Engineer
KCRG & KCRG-TV
Cedar Rapids, Iowa

Albert H. Chismark
Director of Engineering
Broadcast Division, Meredith Corp.
Syracuse, N. Y.

Eugene R. Hill
Vice President, Engineering
Kaiser Broadcasting Corp.
Oakland, Calif.

Leslie S. Learned
Vice President for Engineering
Mutual Broadcasting System
New York, N. Y.

Richard T. Monroe
Vice President for Engineering
Westinghouse Broadcasting Co.
New York, N. Y.

James D. Parker
Staff Consultant, Telecommunications
CBS Television Network
New York, N. Y.

Royce LaVerne Pointer
Director, Broadcast Engineering
American Broadcasting Co.
New York, N. Y.

Lindsey G. Riddle
Vice President, Engineering
WDSU-TV, Inc.
New Orleans, Louisiana

William H. Trevarthen
Vice President, Operations & Engineering
National Broadcasting Co.
New York, N. Y.

Joint Committee for Intersociety Coordination Report

K. Blair Benson
Society of Motion Picture
and Television Engineers
Scarsdale, N. Y.

The JCIC represents the Electronic Industries Association, the Institute of Electrical and Electronic Engineers, the National Association of Television Broadcasters, the National Cable Television Association, and the Society of Motion Picture and Television Engineers. The Committee meets on call from any of the member organizations to cope with problems which may be considered worthy of joint action.

Presently there are three ad hoc committees which have been set up by JCIC to study a variety of problems in the television system. One of these, organized in 1968, is the Color Television Study Committee charged with the responsibility of pinpointing sources of variability in color reproduction as viewed on the home receiver. The second, which was organized last year, is the Committee on Television Broadcast Ancillary Signals. The third is charged with a study of the quality of television sound.

COLOR TELEVISION STUDY COMMITTEE

First, a review of the highlights of the Ad Hoc Color Television Study Committee activities since the last report to NAB at the 1971 Convention follows.

Colorimetry

Although the committee activities have continued to cover a broad range of subjects, particular emphasis has been placed upon the need for standard color measurement and alignment procedures for cameras and monitors. However, the work has been partially stymied by the question of what chromaticity parameters to use for camera-taking characteristics. The FCC Rules and Regulations for color broadcasting specify these in terms of picture tube phosphor values. On the other hand, there has been a movement under way to depart from these taking characteristics in order to accommodate the more restricted gamut of chromaticities provided by present-day phosphors. The principal argument raised in support of such a change has been that present-day phosphors, which provide the high brightness level demanded by the television viewer, cannot be produced with the NTSC-FCC chromaticity values.

The strongest support for a change in camera characteristics has come from the European Broadcasting Union and the Canadian Telecasting Practices Committee. The salient points of the EBU proposal are the following:

1. It may be desirable to modify the agreed-upon characteristics at a later date because of technical progress, i.e., new phosphors.
2. The spectral analysis characteristics of picture-signal sources should be unified on the basis of present phosphors.
3. The signal coding, i.e. the derivation of E'y and the color difference signals should continue to be based upon the FCC reference stimuli.

The EBU recommendations have been referred to the CCIR for consideration as an international standard.

In order to resolve the question, the color study committee set up a demonstration last year to determine the feasibility of modifying receiver and monitor characteristics by matrixing to compensate for differences in phosphors, rather than that of cameras. The demonstration was arranged for the Committee by RCA at Camden wherein pictures were viewed on two monitors with present-day phosphors, one of which was matrixed to simulate the NTSC-FCC reproducing chromaticities. Since several members of EIA committees concerned with receiver and phosphor characteristics were on hand to view the demonstration and to participate in the ensuing discussion, the meeting represented a total industry involvement.

The picture signals used for the demonstration were generated from a 3-channel camera using Plumbicon pickup tubes. Studio scenes illuminated by 3100K incandescent light were the subject matter. The camera colorimetry characteristics were trimmed with a matrix to reduce color errors to roughly one JND unit. Encoding of the signal was in accordance with FCC specifications.

Both monitors were adjusted to a white balance of D6500 at a reference highlight brightness of 25 foot-lamberts. The transfer characteristic of both monitors was equal to an exponent of 2.2. Hue and saturation were adjusted in the conventional manner for uniform brightness from the red, green, and blue phosphors when driven with a 75 percent color-bar signal and observed individually. The normal matrix was used in both monitors during these adjustments.

After adjustment, the special matrix which simulated color reproduction of the NTSC-FCC phosphor characteristics was switched in one monitor. It should be pointed out in this case, that the color errors were not zero because of the impracticability of matrixing linear signals, rather than nonlinear signals which are present in the monitor before the characteristic is modified by the picture tube gamma of 2.2. Nevertheless, the errors are reduced substantially, in fact, to nearly a 4-to-1 improvement.

The outcome of the demonstration was unanimous agreement among committee members and guests present that the FCC primaries should continue to be followed and that receiver and monitor manufacturers should be responsible for incorporation of the necessary corrections for any differences in phosphor characteristics. This position was referred to the CCIR in Geneva in July by the principal U.S. spokesman on television standards. At the same time, the EBU position was pressed hard by the delegate of the U. K. with support of EBU countries.

The U.S. position was a tenuous one because the U.S. CCIR Document 11-63/E, entitled "Colorimetry Standards in Color Television," expressed concurrence in principle with the EBU recommendation, with the qualification that no definite action should be taken until the matter was studied further. Nevertheless, as a result of the U.S. presentation, action on international standardization of new primaries was deferred, pending further study by the administrations participating in CCIR.

In order to assist the U.S. delegation, the SMPTE Colorimetry Subcommittee of the Television Committee will prepare a document to taken under consideration as support for the U.S. position at the plenary meeting of the CCIR in 1974. In the meantime, with this matter in hand as far as agreement in the U.S. is concerned, subcommittee work in the development of reference camera and monitor characteristics, as well as related measurement techniques, can proceed.

In regard to practical studio monitor setup procedures using the matrix for simulated NTSC phosphors, as was noted earlier in this paper, the monitor used in the demonstration in 1972 was set up with the standard NTSC matrix, using standard color bars. The special matrix was switched in for the demonstration. Thus, in order to avoid broadcasters having to acquire special color-bar generators which complement the new matrix, it will be necessary to provide a matrix switchable between the conventional characteristics and that which is suitable for present-day phosphors. At least one manufacturer of monitors has announced his intention of providing such a feature in all new production, as well as a suitable retrofit kit for monitors presently in use. Fortunately, it appears this can be done by merely switching a few fixed resistors—no active elements are required.

Receiver White Balance

An investigation of receiver color balance was conducted at Eastman Kodak with the cooperation of Motorola to determine if a viewer's tolerance to color variation differs for the usual receiver white balance of 9300K or for the warmer 6500K recommended for studio monitors and referenced in the FCC Rules and Regulations.

For the experiment, two good-quality television receivers balanced to 9300K and 6500K, respectively, were used for display of the picture material. Each receiver was equipped with the optimum matrix for its white balance.

In this case, the results showed that significantly more pictures are considered to be good or excellent when displayed on a receiver adjusted to 9300K white balance.

Color Film Characteristics

In 1969, extensive measurements were made by Eastman Kodak of density, and skin-tone hue and saturation, on several hundred samples of television films—programs, commericals, and news—supplied by the network. This survey was repeated with samples from 1972 programing. The preliminary findings are the following:

1. In general, program films made for television today have less color variations than were found in the earlier study.
2. Films made on the west coast are balanced noticeably "warmer" than those from the east coast.
3. Density of program films is closer to recommended values than commericals, the latter having lower or thinner highlight values.
4. Picture quality definitely decreases with decreasing highlight density.
5. There is a continuing tendency to use undesirable production practices in commercials.
6. Most news films are well within recommended ranges of density.

Telecine Camera Characteristics

Presently, a broad investigation of telecine characteristics is under way. A subcommittee under Mr. Zwick is gathering data on telecine operation as the first step in an investigation of the need for more precise alignment specifications and for standard telecine characteristics. A questionnaire distributed to stations asked the following questions:

1. Brand of equipment used.
2. Operating practices (automatic or nonautomatic).
3. Test used for balance, patterns, etc.
4. Use of image enhancement.
5. Type of maintenance.
6. General questions for improvements.

In essence, a wide variation in telecine characteristics has been found, even in a single station. A complete report on the findings will be published in the SMPTE Journal.

COMMITTEE ON TELEVISION BROADCAST ANCILLARY SIGNALS

In comments filed with the FCC in a rulemaking procedure, involving the addition of coded identification patterns to television commericals, the SMPTE pointed out the need for an overall study of the entire subject of special signals "piggybacked" on the television program signal. Such signals have been in use for many years, such as the vertical interval network transmission test signals, and "subliminal" audio tones intended to alert network affiliates to upcoming special program notices. A wide variety of other such special signals have been proposed, such as the Vertical Interval Reference (VIR) color signal. Many other proposals which have surfaced are of dubious technical feasibility, while still other proposals are mutually exclusive.

In view of the limited space available for such signals (the expression "valuable real estate" has become a common industry expression) the need for a sound technical evaluation of these and other possible signals, and the fact that the subject embraces all disciplines of the television broadcasting industry, the SMPTE announced, in the aforementioned comments to the FCC, its intention to call a meeting of the JCIC to deal with the problem. The possible applications suggested by the SMPTE were the following:

1. Network signaling for news breaks and special announcements.
2. Cueing to automatically start and stop equipment.
3. Continuous program log printout.
4. Unique identification of programs or commercials.
5. Program sound channel.
6. Emergency sound channel or second sound channel for non-English-speaking minorities.
7. Subtitles for the deaf or for non-English speaking minorities.
8. Automatic operation of cable television nonduplication switchers.
9. Emergency Action Notification alerting.
10. Automatic operation of preset video tape recorders in schools.
11. Data transmission, closed circuit or for broadcast.
12. Facsimile transmission, closed circuit or for broadcast.
13. Precise time and frequency dissemination.

A meeting of the JCIC was held on June 27, 1972 at which time it was decided to form an Ad Hoc committee to study the question, and the National Association of Broadcasters was designated as the logical JCIC member to oversee the project. Mr. George W. Bartlett of the NAB established the new committee, to be known as the JCIC Ad Hoc Committee on Television Broadcast Ancillary Signals, and formulated a basic 7-point charge to the committee. Mr. Robert A. O'Connor of the CBS Television Network was selected as chairman.

Three meetings of the Committee have been held to date and considerable progress has been made, particularly with respect to the first three points of the 7-point charge:

1. The Committee has examined existing and future uses of ancillary signals and has a reasonably complete feeling for overall requirements.
2. The Committee has established that program-related functions should bear a higher priority over nonprogram related functions.
3. The Committee has identified the following time and frequency domains of the television program signal as being technically possible for meeting ancillary signal requirements.
    a. The vertical blanking interval
    b. The horizontal blanking interval
    c. The program audio signal, using time- or frequency-diplexing techniques
    d. The program video signal using time- or frequency-diplexing techniques.

The remaining four points—admittedly the most difficult aspects of the study—deal with:

4. The development of an optimum overall plan to meet all requirements.
5. Establishment of guidelines for the testing and evaluation of new techniques.
6. Delegation to existing industry committees, as appropriate, the task of the evaluation of specific proposals.
7. A recommendation for an overall plan to the industry and to the FCC.

Toward this end, four working subgroups have been established to study in detail the four potential problem areas described previously:

Subject	Chairman
1. Vertical blanking interval	Robert Butler, NBC
2. Horizontal blanking interval	Carl Eilers, Zenith Radio
3. Program audio signal	Evans Wetmore, PBS
4. Program video signal	Robert Butler, NBC

Up to now, considerable activity has already taken place with respect to the vertical blanking interval—possibly the most useful "home" for ancillary signals—and many specific proposals are pending, or soon will be, at the FCC. They are:

1. A suggestion that radiated signals be permitted on all of line 17 rather than just the last 12 microseconds as currently permitted (Doc 18505).

2. A proposal to reserve line 19 of both fields for the exclusive use of the VIR signal, along with a corollary move of the remote control VITS to lines 17 and 18 (proposed EIA petition).

3. A request to include network identification among the permissible uses of vertical interval signals (4-network letter of February 28, 1973).

4. A proposal to transmit precise time and frequency signals, and other signals, on line 21 (NBS petition RM-2108).

Consistent with its charge, the Committee has under preparation a "Status Report No. 1" to the FCC and to the industry, expressing its opinion on these pending proposals.

TELEVISION SOUND STUDY COMMITTEE

The number of comments regarding shortcomings in television sound have become increasingly more frequent over the past two years. In fact, on two occasions at SMPTE meetings, the quality of television sound has come under severe criticism. At a joint AES—SMPTE meeting in San Francisco on April 18, 1972, the entire meeting was devoted to a discussion of "Television Sound—Why is it so bad? What can be done to improve it?" Later in April at the 111th Technical Conference in New York, Hartford Gunn, Jr., President of the Public Broadcasting Service, in his paper presentation entitled, "Engineering Objectives in Public Broadcasting," urged that action be instituted to improve the quality of television sound.

As a result of these and other comments, on November 28, 1972, a meeting of the JCIC was called by the SMPTE to review the problem and determine what industry action, if any, should be undertaken. Following a discussion of the various problems and questions raised at the meeting, those present agreed unanimously that an ad hoc committee under the JCIC should be formed to study the overall question.

Reflecting the agreement, and subject to the approval of the NAB and EIA who were not represented, a motion was passed to request the SMPTE to form an ad hoc group consisting of representatives from each of the five organizations, and any additional representatives (including NTC, FCC, and AES) deemed necessary to:

1. Examine the entire television system from the original production to the sound as heard in the home.
2. Determine the source of significant degradations in the receiver sound.
3. Assign to appropriate organizations specific questions for resolution.

The group will be known as the ad hoc Committee for Study of Television Sound. The SMPTE has assumed responsibility for administration of the committee and Daniel R. Wells of PBS has accepted the appointment of chairman. The first meeting will be held on April 11 at the SMPTE Conference in Chicago.

CONCLUSION

In summary, from the foregoing it is evident that the JCIC is providing a valuable service to the industry and to the television viewer by initiating and supporting technical studies which will result in a continuing improvement in picture and sound quality.

CBS Electronic News-Gathering Experience

Raymond D. Schneider
CBS Television Network
New York, N.Y.

For many years, television networks and broadcasters have covered news events exclusively with 16 mm motion picture cameras. With this system, after a news event has been photographed, the exposed film is hand-carried to the station, processed, edited, inserted in a telecine chain, and finally, broadcast.

The inevitable delays and costs associated with the traditional film process prompted CBS to seek an alternative. CBS has instituted the use of an alternative system which we refer to as "Electronic News Gathering."

In CBS' terms, Electronic News Gathering is defined as a system wherein a portable electronic color camera is used to gather news on a daily basis by either recording on video tape in the field or by transmitting by microwave directly to the news room.

CBS began regular daily network use of its video tape Electronic News-Gathering System in November 1971. Since then, several additional systems utilizing direct microwave transmission have been put into service. The objective of this paper is to describe those systems and to summarize our experiences with them.

TRADITIONAL PROBLEMS TO BE OVERCOME

The traditional film system has two obvious operating disadvantages. First, valuable time is required to process a film before it is put on the air, and second, the cost of the raw film stock, plus its processing, represents a significant expense. Note also that, not only does the processing delay the news from being put on the air, but also, and perhaps more importantly, it delays the home-base news editor from viewing and judging film content. Final editorial news judgments cannot be made until processing is complete.

With respect to costs, color film stock and processing expenses average approximately 11 cents per foot in most operations. This is approximately $3.60 per minute. CBS in its Washington news operation, alone, processed some 1,700,000 feet of color film in 1972. At 11 cents per foot this becomes a cost of $187,000.

Furthermore, when you realize that CBS maintains over 100 active film crews on a worldwide basis, these costs become large factors. The use of an electronic camera and a video tape recorder has seemed a promising way to overcome the film system's disadvantages.

Incidentally, a third important advantage for the electronic news-gathering system is that the sensitivity of the electronic camera as compared to the film camera should eventually make it possible to cover most news stories without the need for special lighting. Without lights and with small equipment, news coverage can become increasingly unobtrusive. CBS considers this to be one of the most important advantages of an all-electronic system.

FAVORABLE ELECTRONIC STATE OF-THE-ART CONDITIONS

To those of you who may already have had a chance to tour the exhibition halls of this 51st Annual NAB Convention, I'm sure that it will be apparent that evolutionary improvements and reductions in the size of electronic cameras and video tape equipment have reached the point where serious consideration can be given to using video tape for coverage of hard news. Lower-cost portable cameras are becoming available. Portable cameras having low light-level capabilities in the order of one footcandle are a reality. The time-base error correctors needed for accurately stabilizing relatively low-cost portable video tape recorders have been developed.

EQUIPMENT AVAILABLE FOR CBS' FIRST SYSTEMS

An early significant step along the road of color camera miniaturization was taken six years ago when CBS designed and developed the Minicam MK VI camera system. The Minicam was designed originally for the coverage of the political conventions in 1968. The Phillips Broadcast Equipment Company currently manufactures this camera under license to CBS, and is now marketing it as the PCP-90. Up until recently, the Minicam has been one of the few cameras of its type available, and indeed nearly all broadcasters who employ portable hand-held color cameras use the Minicam PCP-90.

Using an early Minicam and a VR 3000 portable video tape recorder, the first CBS electronic news-gathering system was put into daily network service at the CBS Washington plant approximately 2½ years ago, in November 1971.

CBS WASHINGTON CAMERA-VIDEO TAPE SYSTEM

Since 1971, the CBS Washington electronic news-gathering crew has been in service on a daily basis as an equal full-time adjunct to six regular film crews. During this period, the electronic news crew has provided an average of two to three stories per day, equaling the average rate of its film counterparts.

Tapes made in the field are carried by messenger to the 2020 M Street Studios where they are edited and put on the air. As expected, the video tape electronic news-gathering system has proven to be remarkably fast and effective.

We have put together a series of three film clips that illustrates "Typical Uses of the Electronic News System." (Film clips mentioned or referenced to in this manuscript were impossible to include in this printed text.) This first film is presented to show how the Minicam functions identically to its film counterpart. The video tape and film system "takes" are shown as they would be seen on the air. Both takes have been transferred by the CBS Laser Recorder to the projection film that you are watching.

The committee action being covered here was not put on the air. This is Subcommittee 5 of the House Judiciary Committee. The hearing is being conducted by Congressman Ridino of New Jersey. Attorney General Kleindienst is present to testify on the President's proposal for special revenue sharing for law enforcement.

The next two news clips provide an example of the speed of the electronic system. This is a pickup from Andrews Air Force Base of the return of the POWs. The plane was due to arrive at 3:30, but did not arrive until 4:30. The tape reached the studio by 5:30 and was edited, ready for air at 5:45. Had it been on film, it would have been a scramble to get it ready for the 6:30 evening news.

This next story shows Mr. Peter Flannigan as he emerged from a hearing at 6:15 p.m. The interview with Mr. Flannigan, a White House aide, following his testimony at the ITT hearing, was obtained with very little warning and took place at 6:15 in the evening in the Capitol Building in Washington. Taped on the spot, the recording was taken back to the CBS Washington plant and contributed as an insert in the Cronkite News at 6:40 p.m.

A film camera crew would scarcely be able to make such a tight deadline, and, in fact, none did. This example dramatizes the speed of response of the electronic system concept. The opposition, covering the same story with film cameras, failed to make the evening news.

An even faster electronic news-gathering system was put on line by CBS in October 1972.

WCAU-TV CAMERA-MICROWAVE SYSTEM

In October 1972, at WCAU-TV in Philadelphia, a mobile unit consisting of a PCP-90 camera and multiple-hop microwave equipment was placed in regular service. The support vehicle's microwave transmitter is a standard commercial product operating in the 2 GHz band. The receiver for this transmitter is located in an unmanned receiver site in a tall building in the center of the city. A repeater transmitter relays the signal from the city center to the television station where it may be processed for live broadcast or video tape recording. Standard commercial microwave equipment is used for the repeater system also.

However, where the camera must be operated remotely from the support vehicle in a live news-gathering assignment, a portable transmitter is provided with the camera in order to send the video signal back to the support vehicle. This additional microwave link is required, for example, where a news location is in a large office complex in the city.

On many occasions the real time transmissions back to the station are broadcast immediately. Where such complete immediacy is not required, the signal is recorded in a video tape recorder at the station, for editing and later broadcast.

It is interesting to note that even though a news story may not be broadcast live, a significant advantage to this microwave system remains, namely that senior studio-based news producers can see and judge news content immediately. Editorial news judgments can be made immediately. If, by logical extension, multiple microwave units are put in the field, editorial judgments can be made for all nearly simultaneously.

For those of you who may be saying to yourselves that daily microwave is too complicated, we offer the following film. This film was produced by WCAU-TV and was shot at a speed of one frame per second for effect. However, when you see this crew work (Dave Harvey and Jay Mathis), you will find that the speed and practicality with which the system operates is not an exaggerated claim.

This film shows the essential simplicity of handling the main components of the system on an assignment, and shows how a camera crew of two men accompanied by a newsman is entirely adequate for most assignments. An average of two to three stories are covered per day; setup times are typically no more than for a film crew.

Electronic news-gathering systems operating in the camera-microwave mode were put on the air early on CBS owned and operated stations: WCBS-TV, New York; WBBM-TV, Chicago; KMOX-TV, St. Louis and KNXT, Los Angeles. Each station is utilizing its system daily. This application of the system is suited best to the needs of regional service areas, and provides news coverage for a city community.

In the further development of the camera-microwave mode, we look for the availability of smaller and lighter microwave transmitter equipment, for both the camera-support vehicle and the support vehicle-repeater station links.

A major concern for the future of this type of electronic news-gathering system is the acute lack of spectrum space for point-to-point microwave systems in which the transmitter is highly mobile, and is quite likely to be located alongside a similar transmitter of another station's mobile unit. Multiple news units in any given city may well be impossible unless efforts are made to expand the broadcaster's allocation. The use of rf mikes is imperative for the full rf system. Interference-free space for rf mikes must be insured.

CONCLUSION

In 2½ years of operation, CBS has found its use of electronic news-gathering techniques to be exciting and practical. The systems have proven to be faster and more responsive than any daily system used in the past.

Although capital investment costs are as yet high, they have been found to be offset by lower operating costs. And in any event, as you will see from this NAB Convention, capital costs are being lowered by new technologies. And lastly, and not to be taken lightly, the promise of the sensitive electronic camera's low obtrusiveness is a major impending advance.

FCC/Industry Technical Panel

James D. Parker, Moderator
CBS Television Network
New York, N.Y.

Mr. Parker: Our distinguished members on the panel are:

Mr. Albert H. Chismark, Director of Engineering, Broadcast Division, Meredith Corporation, Syracuse, New York.

Mr. Robert Flanders, Vice President for Engineering, McGraw-Hill Broadcast Division, Indianapolis, Indiana.

Mr. Walter Alliss, Jr., Chief Engineer, Stations KCRG-AM/FM/TV, Cedar Rapids, Iowa.

Mr. Wallace E. Johnson, Chief, Broadcast Bureau, Federal Communications Commission.

Mr. Harold L. Kassens, Assistant Chief, Broadcast Bureau, Federal Communications Commission.

Mr. Harold G. Kelley, Assistant Chief, Broadcast Facilities Division, Broadcast Bureau, Federal Communications Commission.

As you know, the FCC/Industry Panel has been for the past several years one of the most, if not the most, popular session on the program. The intent of the Panel is to engage in an exchange of ideas and information through a series of questions and answers. I'm sure you are all familiar with this process from past get-togethers. So as not to waste any time, let's get right down to the business at hand. Throughout the audience there are a number of microphones that we hope you will use. Who has the first question?

Mr. Chismark: This was handed to me this afternoon. The question is: We operate a directional antenna via remote control and use lesser grade operators. The Rules require us to make a skeleton proof each year and file them with the renewal applications. And section 73-93E3 requires a partial proof the first year and skeleton proofs the next two years. These proofs are to be kept on file at the station. Now, the question is: Do we have to make two skeleton proofs the second and third years, one to be kept on file and the other to send in with the renewal? Can we submit the partial proof made the first year to use as one of the skeleton proofs?

Mr. Johnson: This action was the result of the petition for reconsideration filed by the NAB on the operator rules. When the Commission first came out with its Order, it stated you can now use third-class-licensed disc jockeys at DAs, but you must make a partial proof every year for three years, not the skeleton proof for normal remote control, but a partial proof which is the next level up.

On reconsideration, we decided to back down a little bit and compromise. And we ended up: The first year you do a partial proof and the next two years you do skeleton proofs. So these are the three that you submit with the renewal.

Mr. Kassens: I might say that the re-regulation program has opened up the whole question of directional antennas, how you prove that the antenna system has been maintained properly, and the initial proof is something that we're trying to study to try to take a new approach. Do we really need measurements? If we do need measurements, how many? I think you'll be seeing rulemaking quite soon, opening up the whole question of proof of performance as far as directionals are concerned.

Larry Taylor: I'd like to plead the plight of a small broadcast facility. In some of this re-regulation could we see different rules for different types of markets. For instance, suppose Mr. Chismark goes to his boss and says he needs ten thousand dollars to put the VIT package in, he may get a raised eyebrow, I get the roof raised. And the same thing, too, with a five day a week inspection with me being the only engineer, it's a good hour and a half for me to go up to the transmitter and back. For five days a week I've lost a whole day for any other kind of maintenance I could have done. So if there could be some kind of regulation that would separate us little guys from the big guys.

Mr. Parker: You raise a very tough question: Do you set your engineering standards depending upon how big or how small the station is? I think as engineers, hopefully, we'd all say no. You set the engineering standards and live by them. Admittedly, for the UHF, primarily, and the smaller stations, it's rough.

The industry wanted remote control for television. We were faced with a real problem. You mentioned the VIT problem. We think VIT is a great thing to tell you what the transmitters are doing. This is preliminary to what we hope will come on an automated TV transmitter. You know, on an automated TV transmitter you're going to have to have some use of the VIT signals. So this, we hope, is leading into automatic TV transmitters.

Admittedly, it's tough: but when you go out and buy your first D-Mod at five thousand dollars, it's tough, too. It's unfortunate, but I don't see how you distinguish your engineering standards and the size of the market on how much money you're making. It's unfortunate, but I think it's true.

Mr. Johnson: In the re-regulations, we're trying to recognize different size stations. We're having trouble in determining different size stations as it relates to engineering or technical problems. But we already have. And last week we came out with a notice on ascertainment in a nontechnical area of trying to determine whether the ascertainment procedure can be different depending on the size of the station, size of the market, and so forth. And we're also trying to do something in renewals, trying to come up with a short form renewal—a 1040, as we're calling it—for small-market and possibly for aural stations. But as far as the technical side is concerned, we're having some real problems. And if you have any suggestions at all as to how we can treat different size stations differently with the same type of a technical problem, we'd like to have you bring that in to us.

Jack Hughes: My question concerns the recent change in the rules regarding the visibility of transmitters in the 360-degree range and the ability to read the meters to the extent that you can actually determine where the pointer lies. And, gentlemen, I would like to have you view some of the modern transmitters on the exhibition floors here. And when you do, you will see that for years pointers on meters were a very parallax-type device, and the meter manufacturers have worked now for a number of years to make them nonparallax.

To do that, the hand presents a very low profile. And you will find some of the meters on some of the transmitters here are no longer pointers. The end of the hand does not have a pointer on it. The hand passes directly through the numerical scale; and when you view the hand directly, straight on, it presents its lowest profile. And at a distance of 15 feet, I defy anyone to locate the hand.

Now, when you stand in front of the meter, you can certainly take a tremendously accurate reading, because it makes you orient your head correctly. But when you stand back a distance, properly oriented, the hand becomes invisible.

Now, we've gone from having pointers that were thick and heavy that we could see at a distance down to this modern mechanism, which the transmitter manufacturers merely used—nice, well constructed, well designed meters that are available. They don't make meters. But this is quite a disturbing point to me because we have a rather large transmitter plant where we have AM, FM, and TV together, and it's impossible to crowd up the transmitters that have been standing there for some 20 years to reorient those in such a way that a man could observe the meters. And I don't frankly know what the language really means, what meters we were talking about. I'd like that question answered.

According to the rules we're really only talking about a single meter, a power meter. But it perhaps may be in the mind of the person who wrote that re-regulation—he may have been thinking in terms of looking at all the meters or, in particular, more than just the power meter.

I'd like that question answered. And really as a practical matter I can't see what purpose that would serve if the man could see the meter from his position, meaning sitting down, as opposed to the few seconds that it takes for him to rise to his feet should the occasion require. I really would like to know the philosophy behind having this capability and what possible motives were behind that, because I frankly don't understand.

Mr. Johnson: We thought we had solved this problem that we talked about last year where some of the stations had gotten violation notices because the operator had to turn around to see the meters. The Re-Regulation Task Force came up with this new rule that says you can turn around, and whirl as many times as you want to. You can stand up, you can lean over, you can do anything just so you can see the meters.

The basic concept we're trying to reach is that, sure, you have practical problems in how to construct the transmitter room and you run into difficulty in being able to see. But remember the operator on duty is supposed to know what's going on. He is responsible for keeping that transmitter within the limits.

We obviously do not require every transmitter operator to have 20-20 vision. And what we were intending was that where he was located he would be able to assure himself that the transmitter was within the limits specified in the rules. So we don't care about buffer voltage and things like that. It's the things you have to log that have to be within the limits. Those are the parameters we're worried about.

Now, the new meter you're talking about creates a new problem. We solved one and now we've got another one. The easy answer to that whole thing is, if we had an automatic transmitter we wouldn't have all these problems.

Mr. Prestholdt: Jack's point, I think, is a very well taken one. Perhaps, you have forgotten the fact that for many years we didn't have either of these two prohibitions written into the rules in terms of reading meters, either that one, the operator could see it without having his swivel neck working, or that he'd be able to read the meter from his operating position.

Many, many transmitter plants over the last 40, 50 years have been built where you could see the transmitter and you could see the meters; it was very rare, though, where the operator could actually read the meters and determine whether or not the thing was absolutely correct or appropriate from the operating position. The refinement of having him either be able to see or read the meter from a particular position has crept in only in the last decade.

I think it's almost universal that it's very difficult—if not impossible—to actually read accurately any one of the significant meters from the operating position. I don't really see any need for continuous surveillance at this time.

Voice: It seems to me that we get into a lot of nit-picking situations when the rules get too defined. Why couldn't the FCC use the approach: These are the standards you must maintain. How you do it is your business, but we're going to come around and look, and you'd better be maintaining them when we get there. And then leave the exact method of how the broadcaster gets that standard and keeps it up to the individual plant. And the rule only says "maintain this standard."

Mr. Johnson: Isn't it a question of philosophy here; what do you want from the government? What we were trying to do is to get away from very specific rules on this particular one that you've been talking about. We're trying to get away from telling you exactly where the operator had to be seated, what kind of eyesight he had to have, what distance he had to be from the meters, and so forth. What we're trying to do is to determine what the end result is that we're trying to achieve and then leave it up to you, give you some leeway on how you're going to achieve it. Well, what I'm hearing now is that you want more specific regulations on our part. And I'm not sure you really want that. I don't think we want that.

Voice: Why don't you allow extension meters?

Mr. Johnson: Fine. Great idea. But you run into a problem. And this comes back to the same thing we're talking about—seeing the transmitter.

How far is the extension? You can be reasonable and say, sure, you can see it on the other side of the room. Maybe you can't read it accurately so you put the meters up in front of you. But there are people in this business who would have extension meters to a transmitter 20 miles away, and remote control, then, is down the drain. And this is the problem you run into. Where do you draw the line and say you've gone too far; you can't see it; it's out of your control; therefore, you must have remote control, or it's close enough.

We took a real—what we thought—was a simple solution and said, well, if you see it you're close enough to it, and obviously people have problems with that.

Mr. Kassens: We were actually trying to simplify things in doing this. We've had a lot of questions through the years as to where the operator can sit. Can he sit around the corner from the transmitter? Can he sit down the hall? Can he sit in the next room, and so forth? We finally decided if he can see it, that's all the farther we're going to go. But automatic transmitters, I think, is the answer, and maybe we'll get to it someday.

Bill Draper: I've been through this battle with the viewing on several occasions; and in light of these new rules, now, I am curious as to how this affects the type of remote control system where you dial up readings and you only have, at any given time, one reading on your remote control unit which is, in our case, modulation. Now how does that affect it in that situation?

Mr. Chismark: Well, the rule says that you've got to be able to see the remote control equipment which means the guy can't be too far away. The dial can't be down at the other end of the building because, in effect, he's now lost control of the transmitter. That's the difficulty.

Mr. Draper: In the case here where you say he's got to be able to see the actual meter reading, where obviously he can't see but one reading at any given time.

Mr. Chismark: He's got to be close enough to be able to see that one.

Bill Strubey: We get in a hassle about this meter visibility thing every year. What would be the Commission's feeling toward relaxation of some of the remote control rules to allow me to remote control my transmitter for a distance of about 20 feet so I don't have to worry about the visibility thing?

Mr. Johnson: That's fine. Lots of people do it. That's an easy way out and we have gone so far as to say that if it's in the near vicinity you don't need the fail-safe requirements, and you don't need the raise-lower capability. You can apply for remote control and not have to worry about the visibility problem after that. It's a way to get around this extension meter thing.

The problem is some people can't apply for remote control because they got a DA and they don't want to go through the DA proof and all that sort of thing.

Voice: Regarding reading of meters, I've been operating a television station by remote control for six years now. And we've been logging, for example, our aural klystron. It's been the same at 1.24A and hasn't changed for six years.

I think this is probably the most absurd of the specific cases of meter readings, all of which are rather useless in comparison to the importance of monitoring the actual signal being broadcast by observing the picture monitor.

It seems to me from practical experience that worrying about how thick the vane is on a meter, or what pointer is on a meter, or how far away the meter is, is not really relevant to the most important aspect of watching the activity of the station.

I really wonder if it is necessary to continue monitoring plate current and plate voltage and even output power, and instead put emphasis on modulation quality.

Mr. Kelley: This might surprise you, but we're pretty much in agreement with the position you've just stated. If you have a klystron in the final, obviously there's no point in reading the collector current. The present rule doesn't recognize the existence of klystrons. So what we've been telling people is this: if you have a klystron, to satisfy the requirement for the aural transmitter, we will not enforce that rule insofar as reading the current of the final stage in the aural transmitter. We will not enforce that pending our re-regulation to recognize the existence of flash currents.

Voice: In the present remote control rules for television, if you have an alternate transmitter or if you have a means of maintaining 25 percent power in event of a failure, you can quote, "inspect your transmitter and calibrate your remote control once a week." In the absence of that provision, you must both inspect your transmitter and check the calibration of your remote control metering five days a week.

Now, what I'm contending is that the remote control equipment is going to be the same whether you have a single transmitter or an alternate transmitter giving you duplicate facilities. And what I'm asking is, do you see the possibility of distinguishing between calibration of remote control on one hand, and inspection of the transmitter on the other hand?

We have no quarrel with inspecting the transmitter five times a week, but we do wonder whether it's necessary to recalibrate or check calibration of remote control five times a week.

Mr. Chismark: I think the problem there is your definition of calibration. What you should be interested in, is that you're getting the correct readings at the remote control point. One of the purposes of the inspection is to make sure that what you are reading at the transmitter is the same thing that the guy down at the remote point is reading. This is, if you will, calibration. At least a check to make sure the meters are tracking. That's the important thing about calibration.

Voice: This I understand, but what I'm trying to make clear is the fact that stability of remote control gear, which goes directly to the question of whether what is read at the studio is the same as what is read at the transmitter, does not relate to whether you have duplicate transmitter facilities or an alternate transmitter. And yet the rules make it relate, perhaps by accident, but not—definitely not—based on technical facilities.

Mr. Kassens: Yes, we have the answer. They're really not related. This so-called calibration is just one of the things you do when you go to check the transmitter. The two have nothing to do with each other directly. What you're saying is that if you have the 20 percent availability, you only go to the transmitter once a week. If you don't have it, you've got to go up every day. And if you go up every day, why do I have to check the meters? The point is, it's something you ought to do while you're up there to make sure that they're tracking, because if they aren't tracking, you may have some problems, and hopefully you don't want any problems. The two are not related.

Voice: I would like to know if the Commission or the NAB is looking towards data to prove you don't have to inspect five days a week, and that once a week would be plenty on television remote control?

Mr. Johnson: We'll make a note for the Re-Regulation Task Force. What happened was that TV remote control came out, if you'll remember, last year right before the convention. And the Task Force started right after. You make a good point. Really, what we're looking for is some experience here. We're serious about our re-regulation. We haven't gotten into the television part of it yet, but we will. So some of these things have already brought up some good points. We'd appreciate it if you'd just drop us a line and tell us what problems you have and what you think should be done. And I can assure you we'll consider them at the time that we get to that particular part of the rule.

Mr. Chismark: I think Wally made a very good point there. For some reason or another there seems to be a widespread misunderstanding that this re-regulation relates only to radio. Actually, it's across the board. TV is included in it, so your TV comments are just as welcome.

Mr. Johnson: Everything in Part 73—AM, FM and TV.

Voice: I'd like to comment directly on the five day per week inspection requirements. Our experience with TV remote control has been rather extensive, being one of the first stations to go to that process. And our records show that a once-a-week inspection has been adequate and that no significant improvement in the reliability of the station operation would have occurred had we gone up five days per week instead of one. This is experience from the field. Of course, it's only one station. Perhaps my experience is not duplicated significantly enough among other stations to make it equitable to your rulemaking decisions.

But I am wondering in your consideration of making rules such as the five day a week inspection, if you had a chance, if your work arrangement allows you to go out in the field and find out for yourselves as a reporter might do for a newspaper, just what does happen when a station operates by remote control? Or are you limited, really, to us taking the initiative and sending in our hard letters about what we want?

Mr. Johnson: We urge you to send in your cards and letters. You can do it in a very informal way. You don't need to file a petition. But give us the benefit of your experience. And we're also sending out our Task Team on some of these things so when we get to that part of it we may send them out touring those control operations.

Voice: I have a question. Assuming that the rules didn't require any inspection at all, how often would you go, based upon your experience? Or would you go at all?

Mr. Johnson: I would stick with the once per week. I think that this was the original rule for UHF operation and that seems quite sensible from our experience.

Mr. Chismark: I'm not arguing. Please don't misunderstand. You make a good point. You said you had a lot of experience. We've had experiences the other way. Now, I won't say that it isn't a good thing or a bad thing, but UHF television being what it was, we've had some difficulties with some stations because of that sort of thing.

Now, a good reliable operation—and let's get right down to it—it's the attitudes that management and the engineering departments take, and not what the rules say, as to how good the station is going to run, and whether you need it one day a week or seven days a week.

Voice: Well, I think with the addition of the VIT signal to monitor the transmitter, that's been the best step forward. And it really shouldn't mitigate any five day a week inspection because you're not going to see what your transmitter is doing without having to read any meters.

Walter Alliss: As long as we're on remote control I have two submitted questions. One is: The Commission recently amended its rules to permit the operating and maintenance logs to be kept individually on the same sheet in one common log. The question states: Does this log apply to a station operated by remote control where the transmitter is in a different location?

Now, I presume what they mean here is, can the information attained at the transmitter be carried back to the studio facility and then entered into the main log?

Mr. Kassens: People seem to be having problems about a separate maintenance and operating log. And we said, be our guest, if you want to put them together, fine. That doesn't give us any problem.

The problem you'll run into is that if the first-class man in going up to the transmitter to make the inspection, how did he make the entries into the maintenance log if it's back at the studio? One way out, of course—if you do want to have a combined operating and maintenance log—would be for the chief, when he goes up, to make notes, everything he has to do up at the transmitter, and come back and enter it into the maintenance log. The only problem there is, I caution you, he's got to save that little piece of scratch paper and attach it to the log. And that's where you get into a little trouble.

Voice: How about relaying the information between the studio and transmitter on the telephone?

Mr. Kassens: It's a little way around. Two things: One of them is if the guy back at the other end of the phone is a third-class man, he can't do it. If he's a first-class man the other hitch is that the rule really says—73.112, I think it is—he has to have knowledge of the facts. And does he have knowledge of the facts? I suppose the lawyers could work on that one all the way up to the Supreme Court.

Mr. Parker: Well gentlemen, that's about all the time we have. Once again thank you for your participation and we will all look forward to our next get-together in Houston in 1974.

The Broadcast Cartridge Today

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The familiar NAB audio cartridge is now in use all over the world. Even the smallest broadcast facility is not considered complete without at least three cartridge tape players and 300 or 400 cartridges. The reasons for this popularity are many-fold. Cartridges are simple to use and permit a versatility of programing that would be difficult to duplicate by any other means.

Today's cartridge equipment comes in many sizes and capabilities. They all feature ease of operation and high reliability. Solid-state electronics has brought improved performance, reliability, and reduced size.

As the cartridge comes into use in more and more diversified applications, it is inevitable that some shortcomings of the system become increasingly more important. The broadcasting-oriented technical publications have recently been devoting a lot of attention to something called "the stereo phase problem." There has been little explanation as to the exact nature of the problem. The purpose of this discussion is to review in some detail the many aspects of the problem, and suggest some positive steps to reduce the effect to a minimum.

At Broadcast Electronics we have done a rather extensive investigation into the system aspects of stereo cartridge performance. Part of the work done has resulted in a new head-support tape-guide assembly which we are recommending to our stereo cartridge machine users. However, the study has revealed that the performance cannot be enhanced substantially with improved tape guidance alone. A great deal of improvement in the cartridge itself is required, if there is ever to be a standard of performance equivalent in reliability and stability to the monaural performance we have come to expect.

To begin with we should understand the basic stereo system requirements. As far as the electronics are concerned, stereo is simply two identical amplifier systems that drive two identical speakers. One of the design objectives is to make them separate but equal. To provide the proper stereo effect, the time relationship between the two channels must be maintained at all times, for all frequencies. Electrically the term for this is "phased" properly. Referring to the speakers in the system, if we desire to have the sound appear to come from the left, we supply signal to the left speaker only; similarly, for the sound to appear to come from the right side, we drive only the right speaker—so far no phase problem. If it is desired that the signal come from in between the two speakers, then both speakers are driven; but in order to provide the appearance of center information, both speakers must be pushing at the same time. To the listener, the subjective effect is that the sound originated in between the two source speakers. If the two speakers are not synchronized (phased), that is, if one pushes while the other pulls, the subjective effect of directionality is lost. Therefore, to maintain the desired stereo effect, the phase relationship of the two channels must be maintained as close to the original as possible.

To further complicate the problem, the broadcaster is required by law to transmit a monaural channel derived from the two stereo channels by electrically adding them together. The primary channel of the FM signal must be a channel which provides the total program content so that monaural receivers will still receive the entire program. A secondary subchannel is used to transmit the additional channel of information required for stereo.

How does all this relate to the stereo phase problem? Well, let's consider the tape recorder in this framework. Fig. 1 shows a piece of tape traveling across a tape head from left to right. There are two gaps in the head, track A and track B. Let's assume that there is a magnetic mark on the tape that will give us a pulse output when the mark crosses the head gap.

Referring to Fig. 2, the tape is still traveling from left to right, but there are two sets of gaps—A and B and A' and B'. The A', B' gaps are twisted about the head's axis. Let's assume that the angle of a plane passing through the gaps is 91 degrees with respect to the edge of the tape. This is an azimuth error of 1 degree.

If the mark travels across the gaps and an output amplitude vs time chart is drawn, the result is shown in Fig. 2. The output of the A and B tracks are exactly time

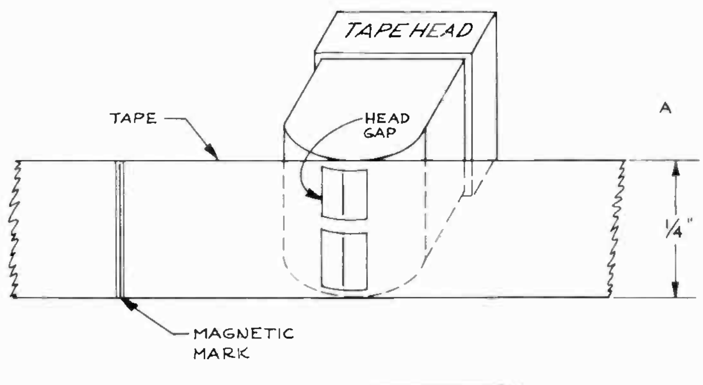


FIGURE 1

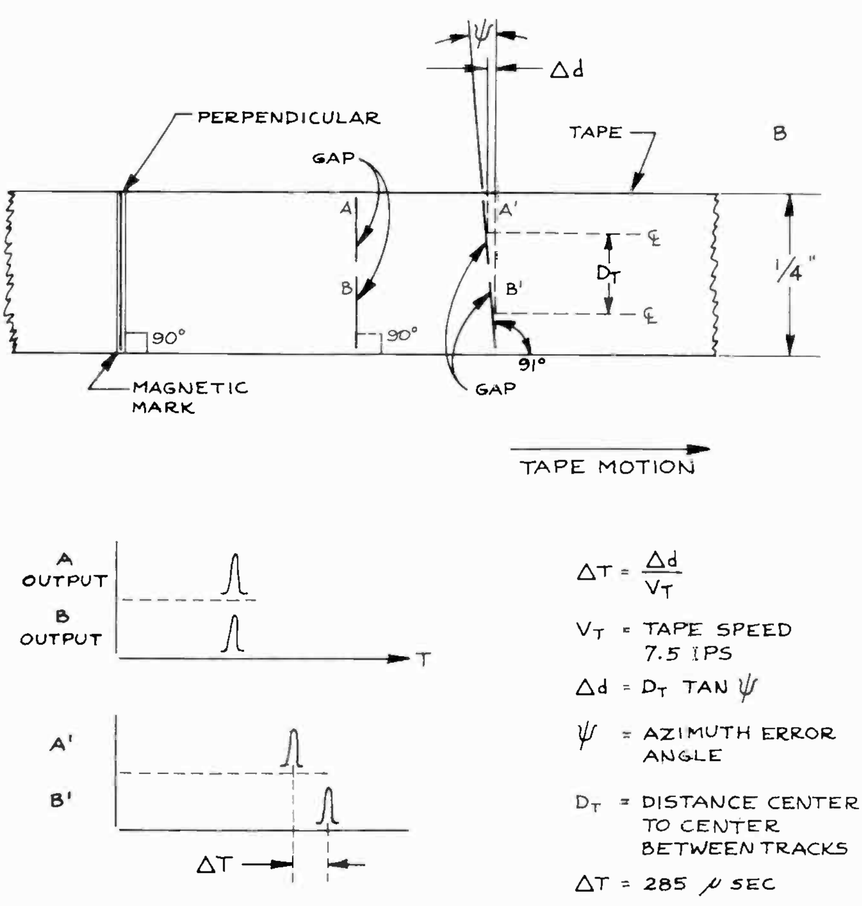
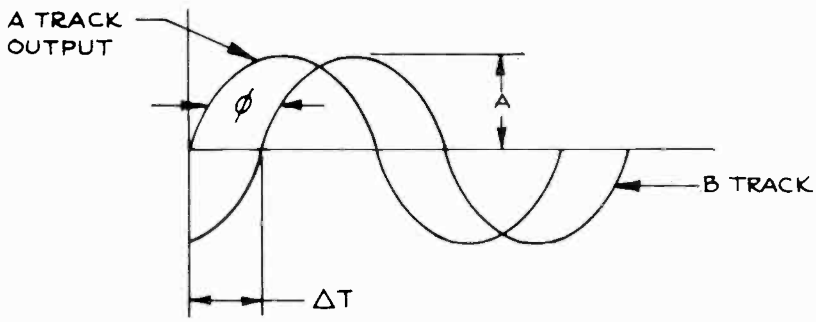


FIGURE 2



A TRACK + B TRACK = A SIN ωt + A SIN (ωt + ϕ)

= 2A COS $\frac{\phi}{2}$ (SIN ωt)

ϕ = 360° ΔT X f

FOR THE EXAMPLE GIVEN ABOVE THE SUMMED OUTPUT OF THE TWO TRACKS WILL BE -3 db AT 818 Hz

-6 db AT 1168 Hz

CANCELLATION @ 1.625 KHz

FIGURE 3

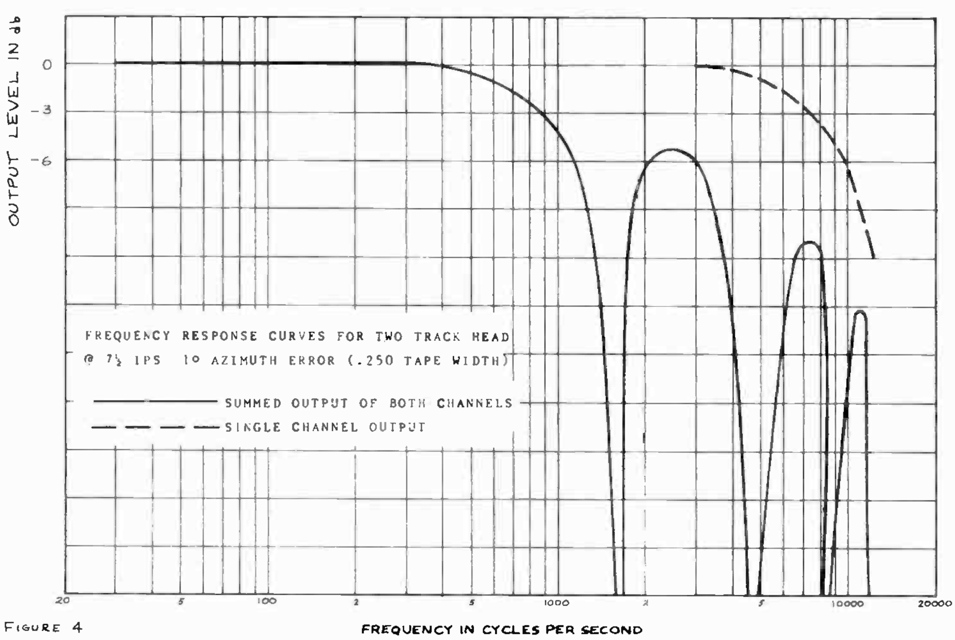


FIGURE 4

coincident. However, the output of A', B' are not coincident. The result of the azimuth misalignment is a time difference between the two tracks.

If, instead of our magnetic mark, we have recorded on the tape a sine wave in both channels, Fig. 3 is the result. The two sine waves are delayed by a time difference, dt, which may also be characterized by an angle ϕ, ϕ equals dt x 360 x f (f equals frequency in Hz).

If we assume that the outputs of these tape heads are to be broadcast in FM stereo, then the two signals must be added together to provide the main-channel signal. Figure 4 shows the resultant frequency response for this case of 1 degree of azimuth error. A complete loss of output is observed at 1600 Hz. For comparison, the 3 dB point for 1 degree of azimuth misalignment on one track only occurs at 7.5 kHz (dashed curve). The 3 dB point for the summed stereo output occurs at 800 Hz. At

1600 Hz, the signal is present; however, there is a phase reversal. The nulls in the output recur at increments of 3200 Hz.

As you can see, a small amount of error is devastating to the summed signal. This, of course, is a center-channel signal (where both channels are identical). However, this delay also totally destroys the stereo effect by changing the time relationship between the two channels.

Fortunately, this is a rather extreme example of what could happen in a stereo signal for a standard NAB 3-track cartridge machine in proper adjustment. Fig. 5 shows the relation of the relative output signal level versus azimuth adjustment angle.

The abscissa shows the angular difference of the head from the true perpendicular in minutes of arc. The ordinate shows the signal loss in dB with reference to a perfectly aligned head. The solid-line curve depicts the loss in output at 15 kHz for a single track of 0.043 inch width. With an angular displacement of 10 minutes of arc, a 1 dB loss is obtained. A 15-minute displacement causes a 3 dB loss.[2]

Contrast this curve against the 15 kHz output curve when it is summed with the output of the second channel of the stereo cartridge head (as shown by the dashed line). The same angular deflection which caused only one dB loss for a single channel now causes a complete cancellation of output. To maintain the output level of the summed channel at 15 kHz, the azimuth angle must be maintained to within 3 minutes of arc or less.

The third curve (dotted line) indicates the summed output at 5 kHz versus the azimuth angle. The rather surprising result is that the sensitivity to angular azimuth errors is approximately the same at 5 kHz for the composite output as the single head is at 15 kHz.

To look at the situation from another viewpoint, assume that the 15 kHz azimuth is adjusted to within 3 dB or 15 minutes of arc; Fig. 6 shows the resultant summed frequency response.

The main point is, it is not enough to peak the azimuth adjustment for the maximum 15 kHz output on one channel. The azimuth must be set to get zero phase difference between the two adjacent tracks. The summed main-channel frequency response performance is about three times as sensitive as a single track to azimuth alignment errors. This is the essential factor of the stereo phase problem.

It would seem that with the appropriate phase-measuring equipment and a well built head support assembly, the proper adjustment could be made quite easily and this would be the end of the problem. But the total problem is that we must maintain the azimuth adjustment with respect to the tape.

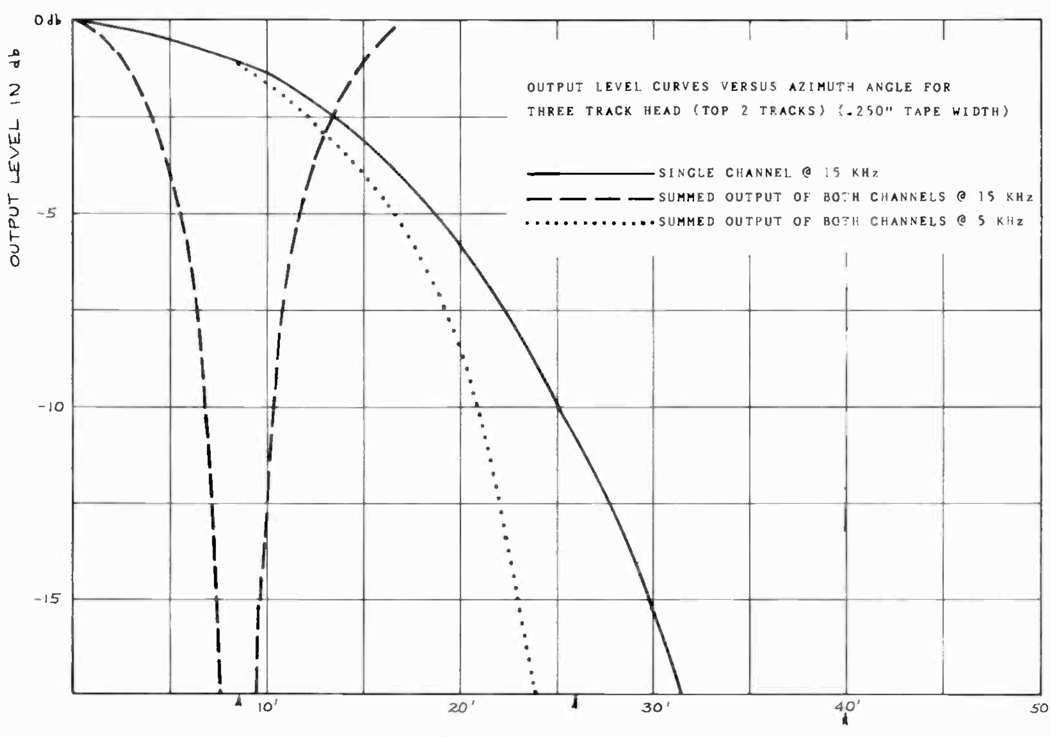


FIGURE 5

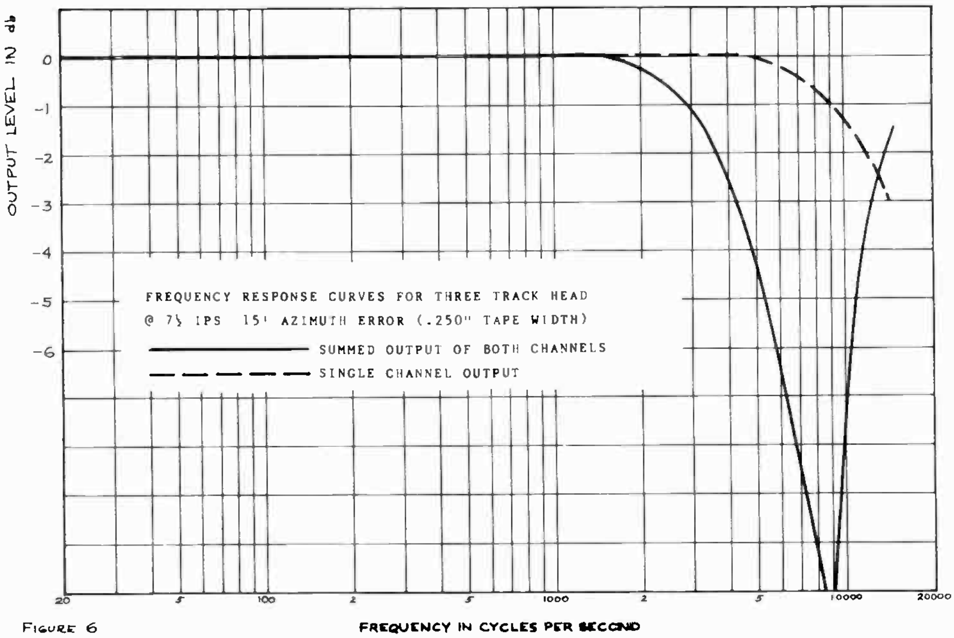


Figure 6

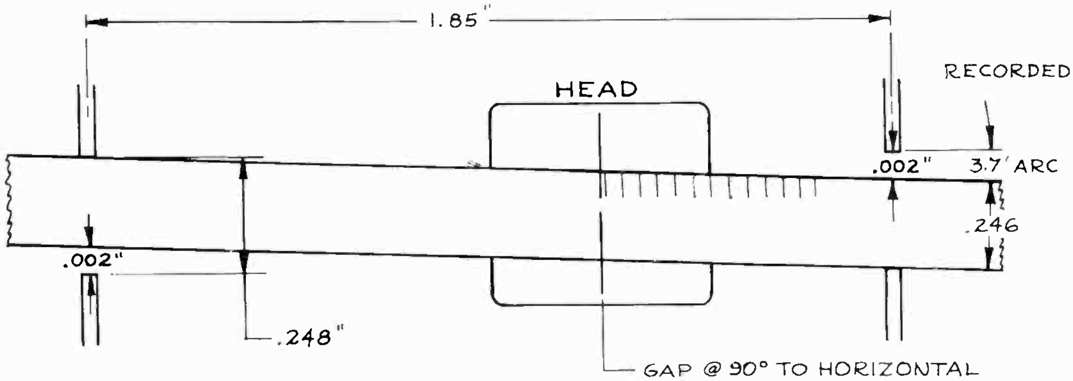
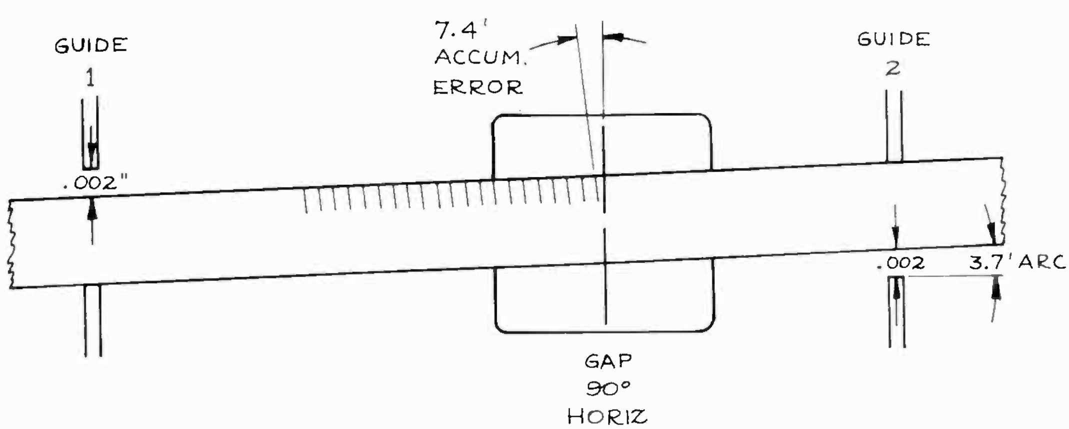


Figure 7



Let's examine the tape guidance situation. Fig. 7 shows the guides with the appropriate dimensions as required in a cartridge. The spacing shown is the maximum spacing that is available in a cartridge.

The tape has a width of 0.248 inch and a tolerance of plus or minus 0.004 inch. The guide may then have a minimum opening of 0.248 inch. If we assume that tape is in the middle of its width tolerance (0.246 inch), then there is a degree of uncertainty as to the exact position of the tape within the guide opening.

For instance, if the tape touches the bottom of the first guide and the top of the second guide, the tape is traveling at an angle of 3.7 minutes of arc with respect to the horizontal. If the tape is recorded while running in this way and then played back while the tape is touching the top of the first guide and the bottom of the second guide, then the azimuth error will have accumulated to a value of 7.5 minutes of arc, or a combined channel frequency response of 3 dB down at 8.6 kHz. This will occur even though the heads are perfectly aligned and haven't been moved.

In actual practice it is very difficult to construct and maintain a guide with an actual dimension of 0.248 inch, since if the tape actually is 0.248 inch it will scrape the guide and possibly cause damage to the tape. Hence, a tolerance of 0.001 inch larger is usually maintained. Therefore, if the tape is on the small side of its tolerance, then the total angle error could be as large as 18.6 minutes of arc. That results in a rolloff in the summed output beginning at 4 kHz.

As you can see, before we even set the head azimuth, there is a considerable uncertainty as to the tape tracking angle, which causes considerable deterioration in the stereo results.

To further add to our miseries, there is considerable uncertainty about effectiveness of the guides to steer the tape. A good way to verify this is to take a piece of paper and hold it tight by the ends, then try to bend it in the middle by pressing its edge against something. You will quickly observe that rather than bending in the middle the edge will only wrinkle. A similar effect occurs against tape guides if the tape is entering the guides at a different angle than normal.

This is especially prevalent in the NAB tape cartridge, since the tape is being pulled out of the center of the hub, up over the tape pack, and then down to the operating plane of the tape heads. See Fig. 8. To a large degree, the corner post in the cartridge determines the entry height of the tape into the head area. However, since the height and twist of the tape is being manipulated prior to the tape's contact with the corner post, there still may be skew in the tape which will not be completely removed by the corner post or the guides. In addition, the skew may not be stable because the exact bending angle of the tape is determined by the amount of back pressure offered by the tightness of the tape wind. In fact, it is this instability that is the most audible when listening to the mono FM channel. The high frequencies fade in and out as the skew angle changes.

When listening in stereo, the effect is not apparent. However, the subjective position of various parts of the signal will be found to move around unpredictably. The more serious listeners in your audience will definitely not care for this effect. When listening with stereo headphones it can be particularly disturbing.

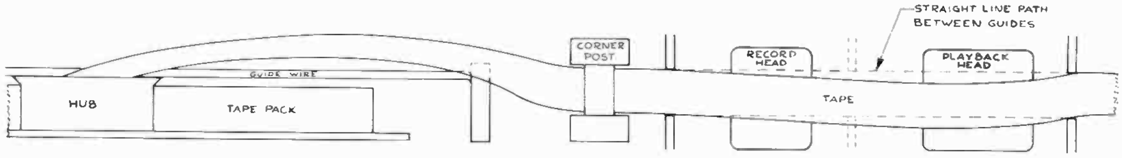
It has been found that not only are the errors apparent between different cartridges played back on different decks, but the same cartridge played on the same machine will not give consistent phase repeatability each time it is played.

Since all these factors apply equally well to a reel-to-reel tape recorder, why does it appear to be not as susceptible to the same type of inconsistency? The answer is that it is affected the same way; however, because of several inherent design factors the problem is minimal.

First, since the deck is not restricted in size, the tape guidance ends up to be quite simple (Fig. 9). Consider our previous example of two guides; but instead of being only 1.85 inches apart, they are placed six inches apart. The skew error has then been reduced by more than a third for the same tape and guide tolerance. In some of the larger professional recorders, the guides are eight to ten inches apart, thus reducing the possibility of skew error still more.

Another important factor which contributes to the skew angle stability is that the tape is handled in the same horizontal plane at all times. There is no twisting or turning of the tape to affect the angle of travel.

Since the cartridge size limits the guidance capability of the tape transport, there are quite definite limits on the amount of control that may be attained. Therefore, it appears necessary to consider possible modifications to the cartridge format to improve the performance. In the past couple of years, there has been considerable



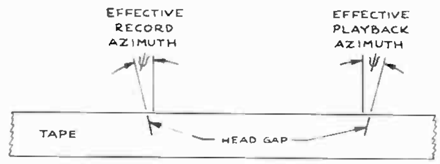
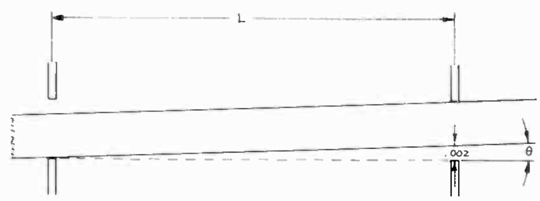


FIGURE 8



FOR L = 5"

θ = ARC TAN $\frac{.002}{6}$ = ARC TAN .00033 = 1.15'

FIGURE 9

FOR L = 10"

θ = ARC TAN $\frac{.002}{10}$ = ARC TAN .0002 = .75' ARC

work in this area. The primary effort has been to more tightly control the skewing angle when the tape enters the head area. Both Fidelipac and Marathon have come out with adjustable corner posts in their cartridges so that the user may adjust the tape entry height to the head area. Audiopak has revised their cartridge with a precision corner post to set the tape height and further control the tape skew with the addition of a guide ahead of the corner post.[3] A new entry to the cartridge field, Aristocart, has arranged the tape path in the cartridge so that the tape is allowed to assume its operating height (and so reduce skew) as far away from the heads as possible (Fig. 10). The tape is pulled from the pack and passes over a corner post at the rear of the cartridge. The tape then travels along the edge of the cartridge to a second corner post at the front of the cartridge. This allows approximately five inches of tape travel for the skew angle to stabilize. [4]

At Broadcast Electronics a testing program in conjunction with the new head bracket design has shown some interesting results, while verifying the extreme difficulty of controlling the phase repeatability.

With conventional cartridges, no amount of guidance in the tape window area of the cartridge could adequately control the tape. Phase aberrations as high as 90 degrees at 2 kHz (3 dB down) would occur with the same cartridge sample. With different samples of the same make cartridge, the results were even worse. About equal repeatability was found among cartridges of different makes.

The newer cartridges with the adjustable corner posts running with very carefully adjusted guides on the deck could provide phase repeatability between cartridges to less than 90 degrees at 4 kHz. With a single cartridge in the same machine, the repeatability was less than 45 degrees at 5 kHz.

The anti-skew type cartridge design could provide phase repeatability when interchanging cartridges to less than 45 degrees at 5 kHz. The repeatability with one cartridge was less than 45 degrees at 10 kHz.

In the design stage of our improved guidance assembly, a two-point guidance system was planned, similar to the diagram shown earlier. Since the shortest distance between two points is a straight line, this system would not be as sensitive to minor height variations between the guides as would a multiple-point guidance system. By experiment with most cartridges it was found that the tape was not traveling in a straight line between the two guides. It was, in fact, going in an arc (as shown in Fig. 8), due to the skewing problems mentioned earlier. The only way found to control it was to add a third guide between the heads. When testing the anti-skew type cartridge, this third guide was not found to be necessary.

Another item to emerge from our tests was the relative insensitivity of the heads' zentih adjustment. Several degrees of deflection from normal had no observable effect on the phase performance. That isn't to say that zenith can be ignored, since if it is incorrect the tape head wrap and contact pressure will vary, causing other problems. However, its effect on the tape skewing is minimal when compared to the other factors affecting this parameter.

Another consideration is tape speed. If the tape speed is doubled, the phase errors are cut in half for the same amount of mechanical error. Thus, where a 15-minute arc azimuth error causes an 8.5 kHz rolloff at 7.5 inches per second, the response rolloff would not begin until 17 kHz with the tape running at 15 inches per second.

Where does this leave you, the operator of stereo cartridge equipment, when it comes to maintaining an acceptable level of performance in your station?

First of all, if you are not prepared to have your people make some extra effort to maintain a high level of performance, and purchase the cartridges and equipment to do the job, forget it—don't use stereo cartridges.

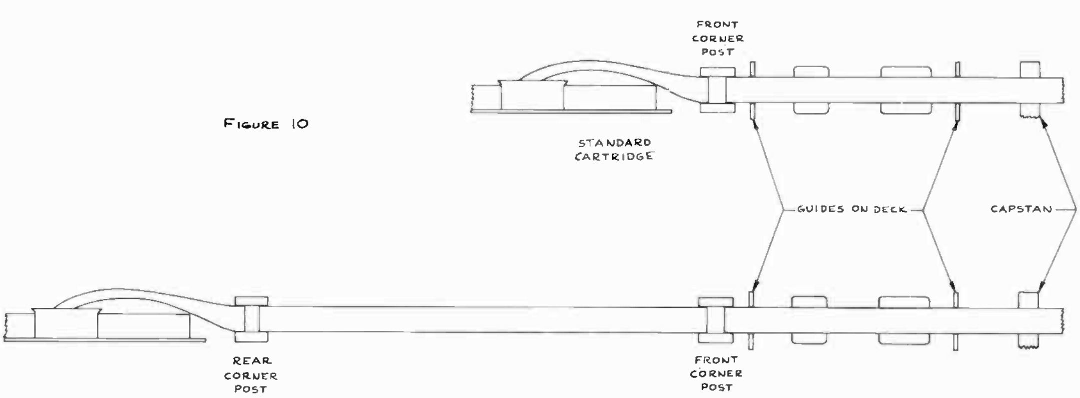
To begin to set up your system, you must have some method of establishing the proper head phasing setup.[5] Since there is no stereo head alignment standard available, it will be necessary to establish your own standard. Fig. 11 shows the basic procedure to follow.

Incidentally, there isn't a stereo standard tape available in the cartridge tape format for the same reasons that we have been discussing here; the inability to forecast the way the tape will ride across the heads. The tape itself can be made very accurately on a reel-to-reel machine.

This should be the method that you use to make your own cartridge phasing standard tape, using graphite lubricated tape. The recording should consist of alternate cuts of 500 and 5000 Hz. The reason for having the two frequencies is that the 5 kHz may give an indication of zero degrees phase difference, while in fact being 360 or 720 degrees out of phase. The 500 Hz will give an indication of this error. The major problem is to load the tape into a cartridge which will give you the most consistent results as compared to the other cartridges in use in your system. One method ensuring that the individual cartridge is not giving you misleading results is to make the tape long enough to wind several cartridges at the same time. Discard any cartridge that gives inconsistent results or that appears to be greatly different than the majority of others.

Once you have a basic standard, then it can be used to align the playback channel in the recorder. The record head may then be set up to match the alignment of the playback channel. Once again, several cartridges should be checked and the recording head aligned to give the best average alignment among all the different cartridges. In fact, if possible, all the cartridges to be put in service should be checked. Any that do not match should be discarded. Some of them may prove to be adjustable or repairable, but until the phase test has been passed, these cartridges should not be used. They will only cause trouble at some future time. Each cartridge should be removed from the deck and replayed several times to assure their performance.

FIGURE 10



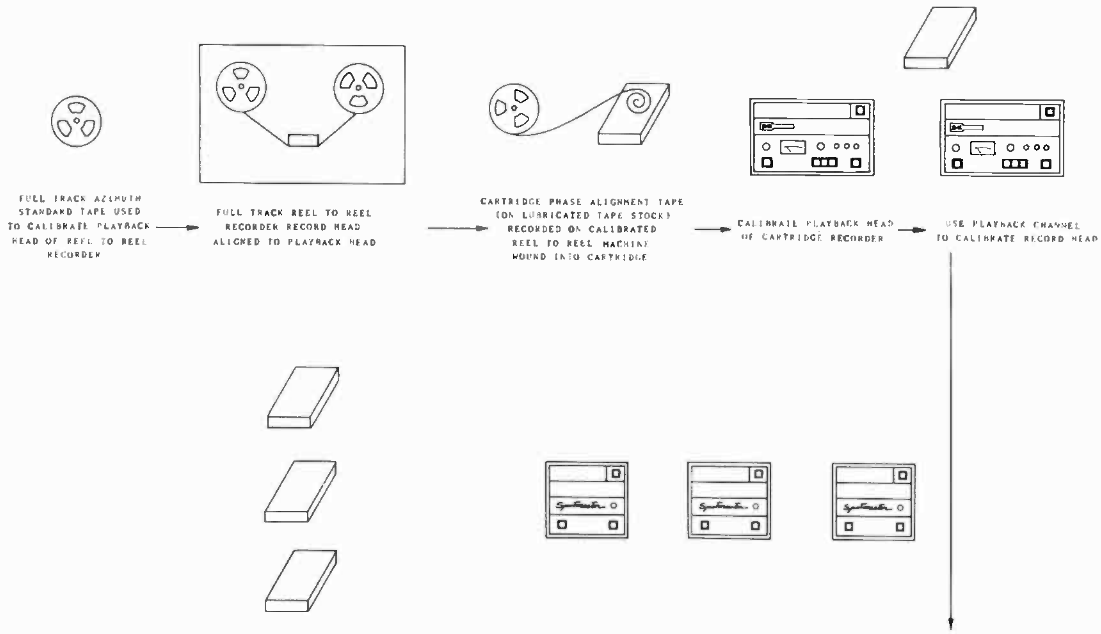


Figure 11 USE CARTRIDGES RECORDED ON CALIBRATED CARTRIDGE RECORDER TO CALIBRATE ALL PLAYBACK MACHINES TO BE USED.

The next step is to standardize the other cartridge tape players in the system using a tape recorded on the previously aligned recorder. Again, cross check each deck with several cartridges. The adjustment objective should be the most consistent performance with all the cartridges, rather than a perfect standard azimuth adjustment. It would be best practice to record all cartridges on one recorder. If this is not possible, the second recorder should be matched as closely as possible to the first recorder.

Prior to use on the air, all newly recorded cartridges should be played in monaural by summing the left and right channels to ascertain that the material does not have objectional phase shifts that could be heard by your listeners.

All cartridges should be inspected periodically to see that the tape does not have edge damage (due to worn tape), the pressure pads are in good condition, and that the cartridge case has not warped or cracked. In short, anything that you ever had trouble with in monaural goes double for stereo cartridges.

There are no guidelines for what is acceptable phase error, simply because this type of distortion has not been evaluated subjectively. It should be remembered that the amount of degradation depends a great deal on the frequency content of the material being reproduced. Thus, the same amount of distortion would not be as noticeable on a simple voice announcement as it would with music.

In conclusion, the monaural NAB cartridge has proved to be a workhorse which serves the broadcasting industry in many ways. Its ease of usage and convenience have permitted a sophistication in the programing that would not have been attained in any other way.

For use with stereo (and possibly for future 4-track), the present cartridge system has proved to have shortcomings which impair program quality. The basic system needs some improvements before it can attain the level of reliability that has been enjoyed in the monaural systems. If changes are to be effected in an expeditious manner, the broadcaster, through the NAB Standards Committee, should insist upon active reconsideration of the standards with particular emphasis on stereo performance.

Acknowledgments:

The author would like to express his appreciation to Mrs. Mary DeSimone for her help in preparing the illustrations for this presentation.

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Measuring and Adjusting the FM Stereo System

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Four general topics will be discussed. There will be a brief review of standard monophonic FM transmission. Remember that? That is where we attempt to transmit with reasonable fidelity only one signal. In addition, we will touch on stereo transmission, quadraphonic transmission, and system measurements.

MONOPHONIC TRANSMISSION

In the old days, two, maybe three years ago, FM broadcasters contented themselves with broadcasting a signal that ranged from 50 to 15,000 Hz with a signal-to-noise ratio greater than 60 dB and a harmonic distortion content that approached 1 percent. Many FM broadcast engineers still retain the fervent hope that some day they will reach that Shangri-La again. And with good reason. Measurements and problems with frequency response and noise were easily remedied compared with the problems of some of today's signal schemes.

STEREOPHONIC TRANSMISSION

Most of us have heard of the definitions used in the stereo industry. Fig. 1 shows a comparison of the bandwidth requirements of stereo and mono transmission. One of the important items to know regarding stereo signal transmission is definitions. The two originating signals are termed Left (L) and Right (R). They physically correspond to the left and right ear. Because of the requirement of monophonic compatibility, the stereo signal is frequency-division multiplexed as seen in Fig. 1. The L and R signals are added algebraically to form an L + R signal, which is termed the **main** channel by the FCC. The algebraic difference of the L and R signals produces an L — R signal. Since the L — R signal contains the same frequencies as the main-channel (L + R) signal, the L — R is translated to a higher frequency range through a process of modulation.

The particular modulation scheme used is termed **double sideband** (DSB). Because the DSB technique has a carrier that is not necessary, except to demodulate the signal or translate it back to the original band of frequencies; the carrier is suppressed. In the demodulation process, a new carrier must be inserted in order to translate the DSB frequencies to their original frequencies. So this may be accomplished accurately, a low-level **pilot carrier** is transmitted with the L — R information. The pilot carrier is generally exactly in phase and one-half the frequency of the DSB carrier. In the demodulation process, the pilot carrier is doubled in frequency with small phase adjustments performed on it. Absolute phase control is necessary to achieve low-distortion demodulation. The DSB L — R signal is termed the **subchannel** by the FCC. The pilot carrier is termed the **pilot subcarrier**. The entire signal including the main channel, pilot subcarrier, and subchannel is termed the baseband signal.

Figure 2a is a functional block diagram showing one method of generating the baseband signal. The L and R signals are injected into a matrix that mixes the signals, thereby creating the main (L + R) and sub (L — R) channels. The main is fed to a precision delay circuit. The purpose of this circuit is to delay the main signal the same amount the subsignal is delayed in the modulator. This is sometimes very difficult to achieve over the entire audio frequency range. The subchannel (L — R) signal is applied to a doubly balanced modulator which produces a double-sideband suppressed carrier signal centered at 38 kHz. A 38 kHz master oscillator output is simply divided by two to form the pilot subcarrier. The baseband is then created by summing the three signals in the proper amounts.

Figure 2b shows the reverse process. The baseband signal is fed into a low-pass filter which has a rather sharp cutoff characteristic. The output of this filter is the main-channel (L + R) signal. The baseband signal is also injected into a demodulator through a high-pass filter which rejects the pilot-subcarrier and main-channel signals. The output from the demodulator is the subchannel (L — R) signal which is passed through a low-pass filter to reject the 38 kHz component. The demodulator works exactly in the manner of the modulator, but with its carrier signal being derived from a frequency doubler fed by the 19 kHz pilot subcarrier. The frequency doubler generally consists of a simple full-wave rectifier circuit which when properly filtered will produce a sinusoidal wave at 38 kHz in exact phase with the 19 kHz pilot subcarrier. The main and subchannel signals are then injected into a matrix which produces the original L and R signals.

The system appears at first sight to be straightforward. However, as we shall see, a number of perplexing problems can creep into the process and degrade the final L and R signals.

Figure 3 shows the current FCC limits and specifications for the various stereo transmission parameters. Main carrier refers to the output of the transmitter under a no-modulation condition. It should be noted that each of the three components comprising the baseband signal contribute to the overall modulation of the main carrier. The FCC limits the modulation of an FM transmitter to 100 percent, referenced to a deviation of 75 kHz. Of that deviation, approximately 10 percent is devoted to the pilot subcarrier. The remaining 90 percent is shared by the main channel and the subchannel, each having a maximum of 45 percent modulation of the main carrier. This definition applies only when one input signal, either a left or right, is fed to the stereo generator. This is reasonable because if a single modulating signal is fed into the stereo L input, the output of the matrix would be L for both the main and subcarrier. Recall that the output of the subcarrier is fed to the doubly balanced modulator. The output of the modulator is shown in Fig. 4. The delay circuit output waveshape is also shown in Fig. 4. Section 73.322 of the FCC Rules, subparagraphs (l) and (m), state the peak amplitudes of these two signals shall be within plus or minus 3.5 percent of each other for all frequencies between 50 to 15,000 Hz. The phase difference between the dashed line shown in Fig. 4, which is part of the envelope of the subcarrier, and the main signal is limited to plus or minus 3 degrees over the same audio frequency

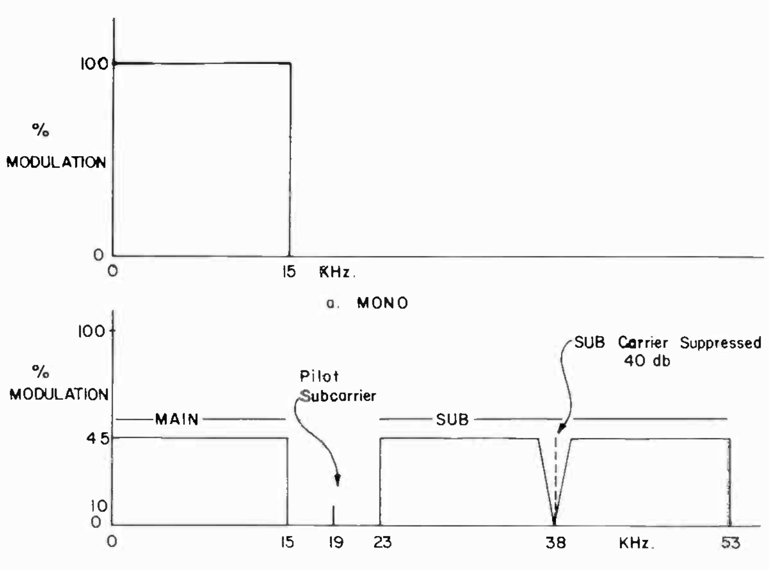


Figure 1. BASEBAND FREQUENCIES

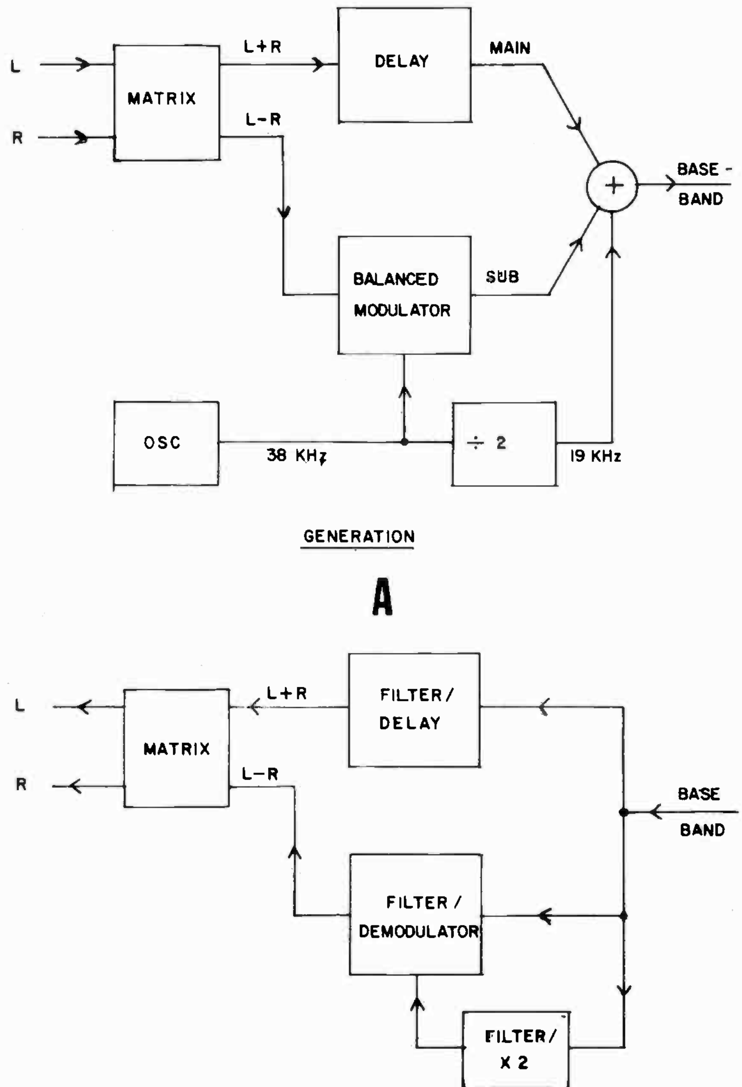


Figure 2

DEMODULATION

B

SUBJECT	LIMIT	REFERENCE
Main Carrier Frequency	± 2 KHz	Assigned Frequency
Pilot Carrier Frequency	± 2 Hz	19 KHz
Pilot Carrier Amplitude	± 1%	9% of Main Carrier Modulation
Stereo Subcarrier Frequency	± 4 Hz	38 KHz
Subcarrier Amplitude	-40 db	90% modulation
Sub to Main Crosstalk	-40 db	90% modulation
Main to Sub Crosstalk	-40 db	90% modulation
L to R Separation	-29.7 db	90% modulation
R to L Separation	-29.7 db	90% modulation

Figure 3

range. The FCC Rules then state that if the measured separation is greater than 29.7 dB in the audio frequency range, these two conditions will be considered to be met.

Since we must start measuring the system at some point, let us begin with the factors that create the most confusion. Two factors, main-into-sub and sub-into-main crosstalk, are required to be 40 dB below the level which modulates the main carrier to 90 percent. The implication is that the licensee's entire system must meet this requirement. However, in my opinion, it is virtually impossible to meet this requirement for the entire system. Figure 5 shows a universal crosstalk family of curves. This graph is simply the resultant, expressed in dB, of the difference between two sinusoidal waves which differ in amplitude and phase. The principal of the graph may be applied to main-into-sub crosstalk, sub-into-main crosstalk, L-into-R separation, and R-into-L separation.

The FCC in Section 73.322, paragraphs (n) and (o) of the Rules does not make clear how much of the stereo system is to be included in meeting the 40 dB main-into-sub and sub-into-main crosstalk requirements. Figure 5 shows that with no phase error the L and R signals may differ in amplitude by no more than 2 percent. This implies that, taken from the microphone input terminals through consoles, telephone lines, amplifiers, and the matrix in the stereo generator (see Fig. 2a), the L and R amplitudes must differ by no more than 2 percent. If a phase difference of 1 degree is introduced in the system, the maximum amplitude difference reduces to approximately 0.5 percent. Under these conditions the system would be required to have L and R amplitude characteristics matched to within plus or minus 0.04 dB for all frequencies within the audio range. Clearly, this is beyond the present state of the art. However, if the Rule applies only to the stereo generator (or the transmitter input), the requirements would then include the matrix shown in Fig. 2a. Under these circumstances the 73.322 (n) and (o) requirements are easily met.

In order to measure main and subchannel crosstalk, we must feed the transmitter directly from an oscillator. The left (L) and right (R) channels should be hardwired together in phase to eliminate any chance of amplitude or phase differences of the input signals. Since input signals wired in phase were specified above, the matrix output should be twice the input for the main channel and nearly zero output, or at least 40 dB down, for the subchannel if everything is working well. This should be measured in the subchannel or L — R position on the FM stereo station monitor. If the —40 dB figure is not met, a check for noise near the input or in the stereo generator should be performed. The null of the balanced modulator should also be checked. When the noise problems, if any, are cleared, then the L — R matrix may be adjusted. Phase and amplitude controls should be adjusted together to minimize main-into-subchannel crosstalk. Checks at different frequencies should be performed after the matrix is initially adjusted. Do not confuse the above adjustments with pilot carrier phase and amplitude adjustments. In the event that the matrix has no adjustments and you have found no noise, the manufacturer of the stereo generator and the station monitor should be consulted. Several station monitors have provisions for directly measuring the output of the stereo generator. This measurement should be performed to ascertain that the transmitter or the station monitor rf circuits are not at fault.

When the —40 dB main-into-subchannel crosstalk figure is reached for the entire audio frequency band, one channel of the transmitter input, either left or right, should be reversed or changed 180 degrees in phase. This has the effect of causing the sub-

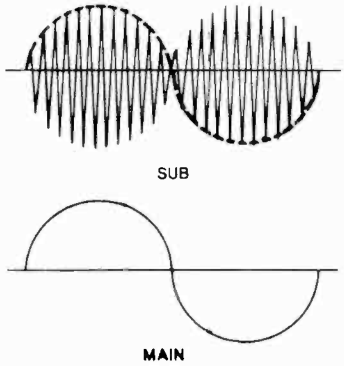
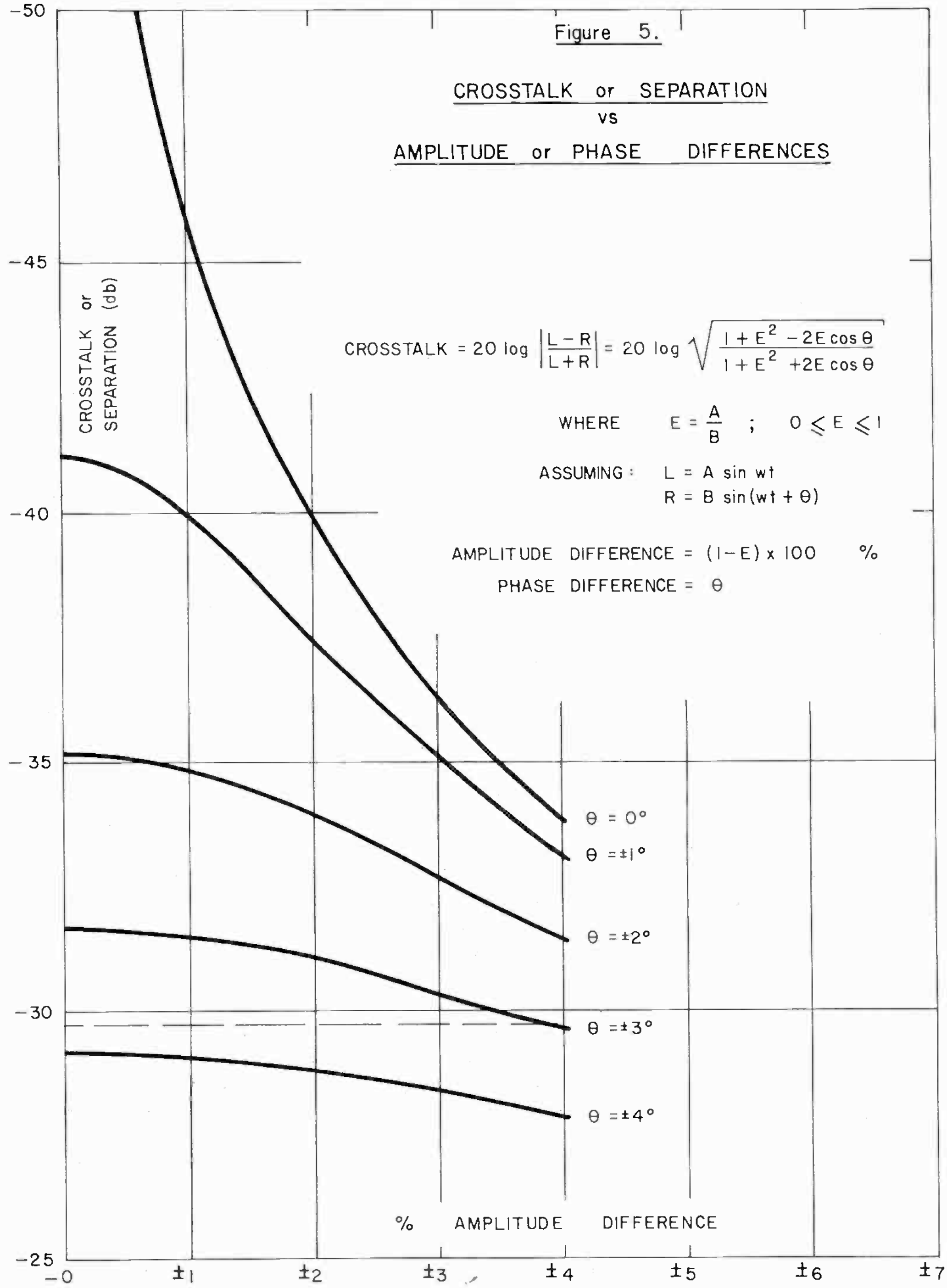


Figure 4.



carrier amplitude to increase to twice the value of either input level. The main channel should decrease to nearly zero, or at least to less than 40 dB below the level when the transmitter is modulated to 90 percent. Again, if —40 dB cannot be attained, noise and L + R phase and ampltiude adjustments should be performed. When the —40 dB level has been reached for all frequencies in the audio range, a second check should be made of the main-into-subchannel crosstalk. Chances are that this measurement is unaffected. However, if necessary, readjust the main-into-subchannel crosstalk and repeat the sub-into-main channel measurement until no further improvements can be gained. If both crosstalk measurements are within tolerance, you are ready to proceed with separation measurements.

At this time, with the oscillator hardwired to one channel of the transmitter input, adjustments of the main and subchannel amplitude and phase can be performed. Feed a signal directly into either the left or right channel input of the transmitter. With the station monitor looking at the opposite channel (i.e., if the oscillator feeds the left channel), measure the separation or how much signal is on that opposite channel. Adjust the main and subchannel phase and amplitude controls for a minimum reading. If under these conditions the separation limit cannot be met, the transmitter tuning and baseband frequency and phase response should be checked. Also, VSWR of the transmitting antenna and transmission line should be checked. If any of these factors are out of tolerance, amplitude or frequency response distortions could occur, causing such effects as different amplitudes between the main and subchannels. Phase differences between the main and subchannels could also be present.

Assuming that the —40 dB and 29.7 dB crosstalk requirements have been met for the audio frequency range, we can be assured that the stereo system has a possibility of meeting specifications. Reconnect the transmitter input lines and feed the oscillator into the amplifier (or limiter with the compression function disabled) immediately preceding the transmitter. A quick check of the main and subchannel crosstalk and L and R separation over the audio band will indicate any phase or amplitude problems in the amplifier. To adjust amplifier levels, hardwire the oscillator to both the L and R channel inputs of the amplifier, in phase. Monitor the subchannel on the station monitor. Adjust the amplifier gain controls for a minimum indication on the station monitor. This should be —40 dB or better. When the minimum is reached, the L and R channels of the amplifier are in balance. Recheck at several frequencies throughout the audio band. If the amplifier causes an out-of-tolerance condition at any frequency, it should be repaired before proceeding.

Each item in the system should receive the same treatment including telephone lines, console, and finally microphone inputs. When you reach the microphone inputs, you have "arrived." If all items are within tolerance, the final set of measurements will yield data required for the annual proof of performance regarding crosstalk and separation. In addition, you will have balanced all amplifiers.

Audio phasing problems will have been eliminated because in the course of the above measurements any phase reversals would show up as high subchannel readings with low main-channel readings—the opposite of what was desired.

Frequency response, distortion, and noise measurements are straightforward and need not be discussed in this paper. It is noteworthy, however, that in a stereo system the most critical demand on frequency response is not the flatness of response but the degree to which the frequency response of the left amplifier matches the frequency of response of the right amplifier. Frequency response, distortion, separation, and crosstalk measurements should be performed with de-emphasis in the station monitor.

QUADRAPHONIC CONSIDERATIONS

Most of us have read in the industry journals the fact that quadraphonic is here. Various systems are presently being proposed. In fact, from a broadcaster's viewpoint, the whole scene is ridiculous. Two basic quadraphonic schemes are being proposed. One is termed discrete and the other termed matrix. There is a third which is a combination of discrete and matrix.

Discrete quadraphonic is a method quite similar to the method of stereo transmission today. That is, four channels are matrixed into two signals. The two signals consist of combinations of the four channels termed left front (LF), right front (RF), left rear (LR) and right rear (RR). Discrete systems universally utilize a frequency-division multiplexing scheme which places a portion of the channel information in the superaudible frequency range from 20 to 70 kHz. Discrete systems then have two channels of information, each of which requires approximately a 70 kHz bandwidth. The broadcaster would find that attempting to transmit discrete quadraphonic would require all new equipment and special telephone circuits or STL modifications. In fact, the problems associated with equipment compatibility would be prohibitively expensive to overcome. Therefore, discrete quadraphonic to broadcasters is probably something we will only read about in audio magazines.

Matrix quadraphonic synthesizes two channels from four channels through a matrixing technique; that is, the combining of four channels by algebraically summing portions of each channel. One or more of the four channels could have special phase characteristics introduced before the summing or matrixing takes place. The principal advantage of the matrix method seems to be that the sum of the two synthesized channels yields a fairly good monophonic signal. In addition, individually the two synthesized channels display characteristics similar to the left and right channels in the stereo system. In other words, the matrix system of quadraphonic transmission is compatible with existing mono and stereo transmission standards. Baseband frequency requirements are also compatible.

Utilizing the matrix system, the broadcaster would require minimal expenditures to be able to transmit quadraphonic. If the broadcaster presently has a stereo system in good operating condition, quadraphonic would be a breeze. However, if the stereo system is on the borderline, the problems of quadraphonic will magnify with poor results likely. Broadcasters with stereo systems that do not meet the FCC minimums, and there are many, should not even consider quadraphonic transmission. Quadraphonic transmission system precision requirements are on the same order of magnitude as stereo requirements regarding crosstalk, frequency-response matching, and phase matching. Undesirable effects, such as sudden movements of the apparent location of the sound source, can be minimized only in a system that meets or exceeds minimum FCC specs for stereo FM broadcasting.

You have received the good news about matrix quadraphonic as it relates to the broadcaster; i.e., it should not represent much difficulty to a well operated station. Here is the bad news. At present there are nearly as many systems of matrix quadraphonic as there are recording manufacturers. Each claims his own to be superior. In the meantime, the broadcaster and consumer are sitting back watching with interest and awaiting settlement of the fight. Unfortunately, of the half dozen or so predominant matrix schemes, none are compatible with each other. A broadcaster would be taking an unnecessary risk to invest in any quadraphonic equipment utilizing any one or two of the matrix schemes being touted today. We should push, however, to get some standardization in the quadraphonic techniques.

The Evaluation and Correction of AM Transmitter Defficiencies

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Practically every AM broadcaster is aware of folktale-like stories which run about the industry concerning dire happenings with certain types of modulation: "There is this one announcer who overmodulates every time he opens his mouth," and "a certain version of an overture trips the plate breakers when the cannon roars at its finale."

Operational difficulties have been experienced at many radio stations with respect to correct maintenance of modulation peaks. Constant setting and resetting of the limiter output level suggests that either equipment instability exists or that the operators have widely varying opinions about modulation adjustment. Neither of these need be the actual case, especially where a correlation between program material type and modulation peaks has already become evident. One should consider these as strong indicators that transmitter delay-distortion and bandwidth limitations may be reducing peak limiter effectiveness.

Modulation settings are not only a focal point of operational concern, but very often a sore spot in labor relations. In many stations, observers will find ominous notes hanging on modulation controls attesting to an air of suspicious and distrust between employer and employee. "Hands Off" is a sort of proclamation of incompetence to be more or less openly opposed by those so proclaimed.

It is suggested that perhaps, due to the diverse characteristics of the industry, many equipment manufacturers have not successfully integrated their specialties into the real needs of the broadcaster. But, for whatever reason, it has been found that the equipment in present use often plays upon the deficiencies of companion units to the detriment of the entire system. In the particular case of AM peak control, delay distortion and bandwidth limitations of AM transmitters cause significant error in the modulation process. Carefully controlled waveshapes supplied to the input are modified within the transmitter and introduce a randomness in peak control.

PEAK LIMITERS

Since the earliest days of radio, broadcasters have sought various means of modulation improvement to reach ever larger audiences with a given transmitter facility. Over the years, this has progressed from the mere selection of announcers with superior articulation to the addition of a variety of devices to the audio chain. The peak limiter has always been the most important of all these devices. Classic examples of peak limiters offered an attack time of 100 microseconds or less and adjustable release times of 0.5 to 3 seconds. Often, the release times were made to vary with differing program content.

Newer answers to the peak-limiting problem have evolved in products which amount to a combination of peak-limiting devices in cascade. Today, several manufacturers supply devices which employ both a moderately rapid automatic gain control and diode clippers. Due to adjustment, the nonlinear action of the diodes is confined to program transients, with a degree dependent upon input drive. Typically, a good deal of flat-topping is evident. While these limiters sound extremely raw when

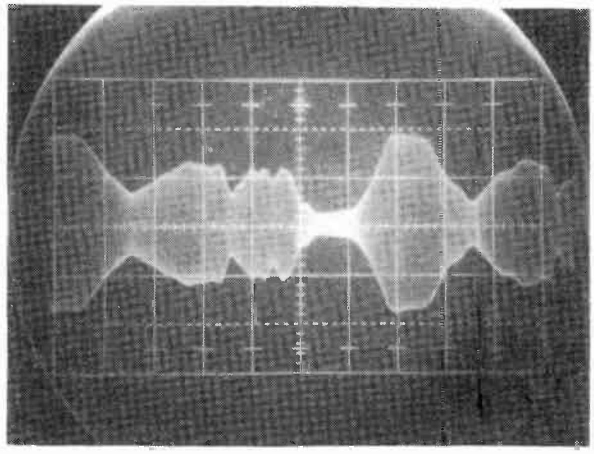

Fig. 1. Waveform showing tilted, clipped transients.

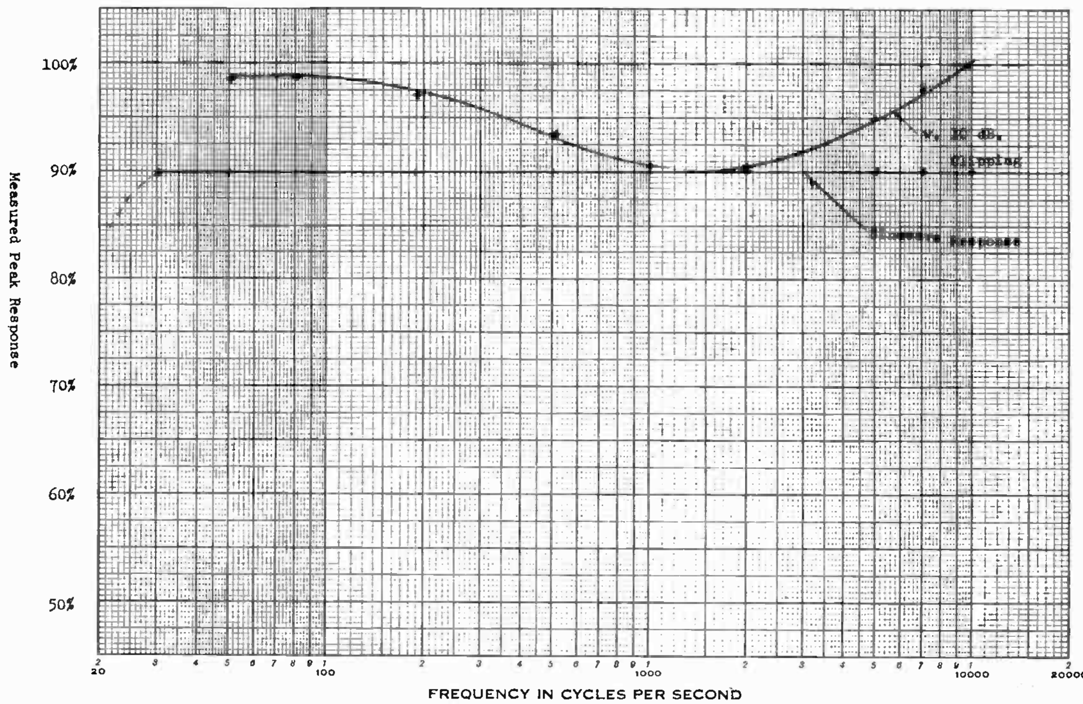

Fig. 2. Peak amplitude of limiter output.

overdriven, properly used they can produce a louder modulation without objectionable prolonged periods of distortion. As a result, the use of these devices has become extremely popular. The waveforms produced, although very adequately limited, pose far more difficult requirements to broadcast transmitters than are typically met, and many broadcasters may be setting average modulation low to compensate for defective transmitter response to clipped waveforms. Fig. 1 shows a typical off-the-air signal of a station employing a peak limiter of the type discussed. The sweep rate is 1 millisecond per centimeter.

TESTING THE PEAK LIMITER

As a convenient, although slightly imperfect, method to investigate the system response of an AM transmitter to these clipped transients, we can utilize the clipper diodes actually built into the peak-limiter device. To do this, it is necessary to deactivate the AGC portion. A sine wave is introduced at the limiter input and brought up to the threshold of limiting as noted by observation on an oscilloscope; then, an additional 10 dB of level is switched in at the signal generator. The resulting 10 dB of clipping is considered here to simulate a sudden program peak upon which the AGC system would not have time to act; only now, we have a steady-state condition which we can carefully examine.

Switching our additional 10 dB of level in and out of the circuit at various frequencies, examination is first made at the output of the limiter itself. Note carefully (a) at what relative amplitude the onset of clipping occurs, and (b) the change in peak level resulting from the additional 10 dB of drive. Figure 2 shows the change in peak level occurring at the limiter output. These observations can be best made on an oscilloscope which is known not to introduce any of its own problems into the measurement. The amplitude discrepancy expected within the limiter will probably be quite small, but check nonetheless, as problems have been encountered. It should be noted that most peak limiters perform very well at all frequencies. One very recent model produced 30 percent tilt at 50 Hz due to its own undercoupled amplifier stages. Tilt was corrected to less than 15 percent by heavily increased coupling capacitors. Units having no amplifiers after the clipper diodes are of best behavior.

TESTING THE AM TRANSMITTER

Let us assume that at this point we have convinced ourselves that the clipper diodes in the limiter are holding the peak amplitude of the signal applied to the transmitter to a tightly fixed level, and that the only result of shifting the drive level is the flattening of the sine wave into a square-wave shape. With an oscilloscope we can observe the wave envelope of the transmitter's AM modulation signal and read peak modulation directly from the station's modulation monitor. For the sake of convenience, let us start our test with a 100 Hz tone driving the clipper diodes 10 dB above the onset of clipping. Let us adjust the output level of the peak limiter to yield just under 100 percent peak modulation. We record this value, and also the peak modulation indicated when the additional 10 dB of drive is switched out. This procedure is repeated at various frequencies across the audio bandpass. Figure 3 illustrates test results using the same limiter as in Fig.2, now measured at the antenna common point. The conclusion must be that a large, ambiguous range of modulation settings is possible for program material, depending upon flat-topped content.

METERING INSERTION

Here again, the broadcaster is faced with the inconsistent situation of having equipment presented to him which meets FCC criteria but does not behave harmoniously in his station. The offensive device is the high-pass filter in the little black box provided to AM broadcasters for insertion of subaudible metering tones. Instructions usually call for placement of this device between limiter and transmitter. Beware if you do this.

Square-wave measurements on one commercially successful insertion unit showed a 70 percent upward shift in output peak level above the sine-wave reference at 100 Hz. This greatly adds to existing transmitter difficulties. There is an obvious systems cure for this problem. A broadcaster using such a device can usually separate the high-pass filter and move it up into the audio chain ahead of the limiter. Here, the filter's group delay cannot reshape carefully limited transient peak levels, while the actual metering insertion is still accomplished after limiting.

FUTURE AM TRANSMITTERS

Concentration has been placed on square-wave testing as a convenient (but not perfect) test signal for the clipped transients we wish to pass without distortion. Good square-wave response will bring landmark improvement to existing systems; however, the present broadcast approach of low-level clipping ultimately has impossible theoretical drawbacks. The reason is that when asymmetrical clipping occurs, due either to waveform or diode arrangement, a dc component is created. AC-coupled transmitters do not respond to the dc component causing peak levels of the opposite polarity to ride the crest of a resulting undershoot. By placing the peak-limiter diodes within the transmitter circuitry at a higher level, it is possible that many of the problems discussed could be averted. Another approach might be use of the pulse-duration-modulation method; however, dc coupling of the peak-limiting diodes to circuits within the transmitter would still have to be provided, ruling out the present approach of using a separate peak-limiter device.

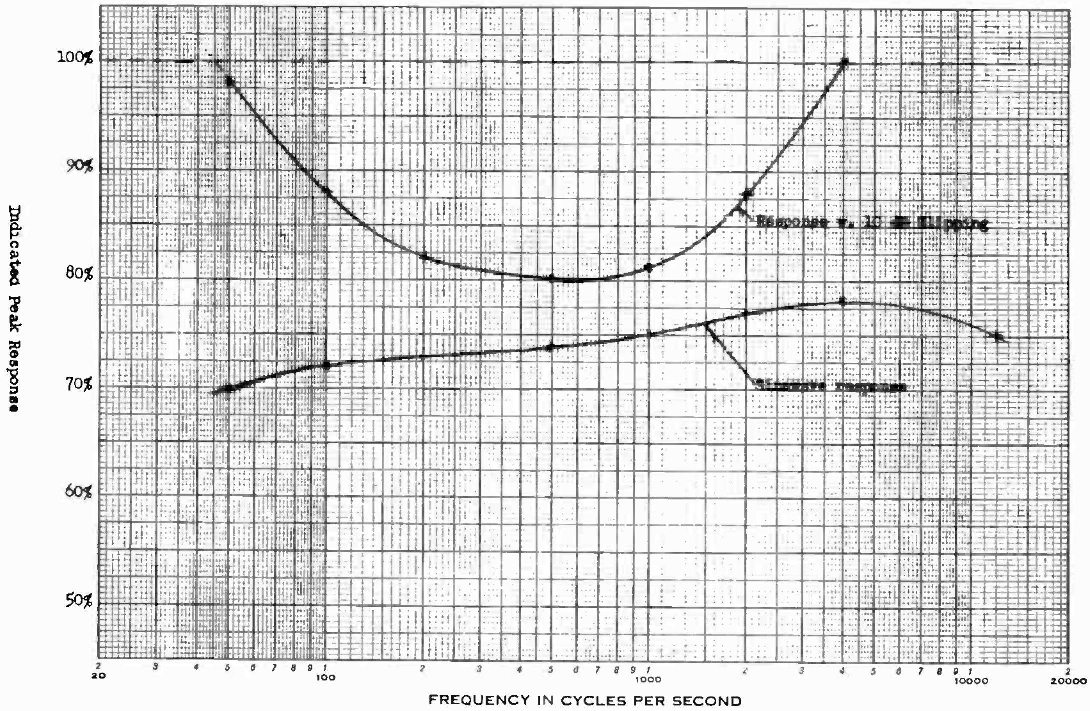

Fig. 3. Peak amplitude of limiter and transmitter.

CONCLUSION

A method has been suggested for evaluation of AM broadcast facilities by simulation of clipped transients. The AM broadcaster should be concerned about transmitter response to these clipped transients due to the possibility that they may force him to maintain too low a modulation setting, and that this setting will show variation with program content.

Although a square wave is applied by the clipper diodes at all frequencies, waveshapes finally modulated onto the carrier exhibit problems falling into two major categories: (a) At frequencies below mid-band, waveshapes take on increasing degrees of tilt. For example, a transmitter with a 3 dB point at 10 Hz will show 31.4 percent tilt at 100 Hz. It is obvious that phase shift, and not amplitude response, is the cause of this tilt, although a direct relationship exists between the two. (b) At frequencies above mid-band, overshoot and ringing are of concern. Components of a square wave fall at the fundamental and a sequence of odd harmonics, extending well out of the desired bandpass. The possibility exists that the transmitter may show considerable increase in modulation percentage where these modes are excited. If this becomes the controlling problem in setting station modulation, the modulation monitor may show heavy amounts of modulation, although it may be so far removed from the carrier frequency as to have little effect upon the listener with his radio of narrow bandpass.

The author wishes to give special thanks to Steve Larsen of WGMS for careful help and collaboration.

Amplitude Modulation — 1973

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Amplitude modulation is, perhaps, one of the oldest forms of information transmission in broadcasting, yet for many years, those connected with broadcasting were concerned only that the transmitter did modulate and sounded good. Concern was not placed on high peak modulation nor consistently high average-to-peak ratios. But as competition increased for radio audiences, it was realized that the higher the modulation averages, the more likely the audience was to hear the station in weak signal areas, in cars, or on transistor radios. As a result, averages and peaks of modulation went up. New equipment allowed higher modulation, but not many broadcasters were really breaking any modulation records.

Then, in late 1972, the Commission ruled that the present requirement for modulation to be limited only in the negative direction at 100 percent be amended to require that modulation in the positive direction also be limited, but to 125 percent. Now, the broadcasters had a limit. Just like a motorist on a superhighway with a posted speed limit of 70 miles per hour will tend to push that limit, whereas, if no limit were posted, he would probably drive at a comfortable speed, the broadcaster now wants to push the 125 percent positive peak limit whether he or his equipment is capable at that limit.

In the following, I will describe high peak modulation and its effects on the broadcast system, and present some of the techniques which may be employed to achieve and control higher and more consistent modulation averages. With these improved techniques, I will also describe methods of monitoring which may be employed to insure that the consistently high levels have no adverse affect on the broadcast system.

In a discussion of modulation, it might be enlightening and, perhaps, useful to begin with the derivation of amplitude modulation and its form with a periodic modulation signal. If we assume a carrier of:

$$\cos \omega_c t$$

and a modulating signal of:

$$\cos \omega_m t$$

which is a periodic signal with zero average value, and ω_m is much less than ω_c, the amplitude modulated carrier can be expressed,

$$f_c(t) = P\ (1 + m\cos \omega_m t\ )\ \cos \omega_c t$$

where P is carrier amplitude and $m\mathrm{Cos}\,\omega_m t$ is less than or equal to 1 for an undistorted signal.

By using the trigonometric sum and difference formulas, the previous expression now becomes:

$$P \cos \omega_c t + \frac{P}{2} m \cos\ (\omega_c + \omega_m)\ t$$

$$+ \frac{P}{2} m \cos\ (\omega_c - \omega_m\ )\ t$$

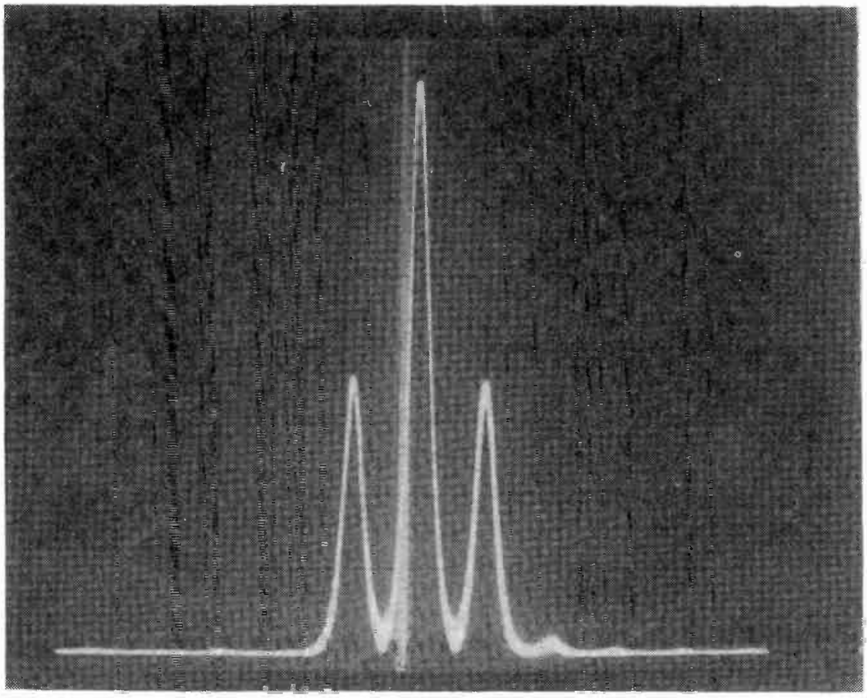


Fig. 1. Waveform showing relationship between carrier power and sideband power.

CONVENTIONAL HIGH LEVEL AM TRANSMITTER

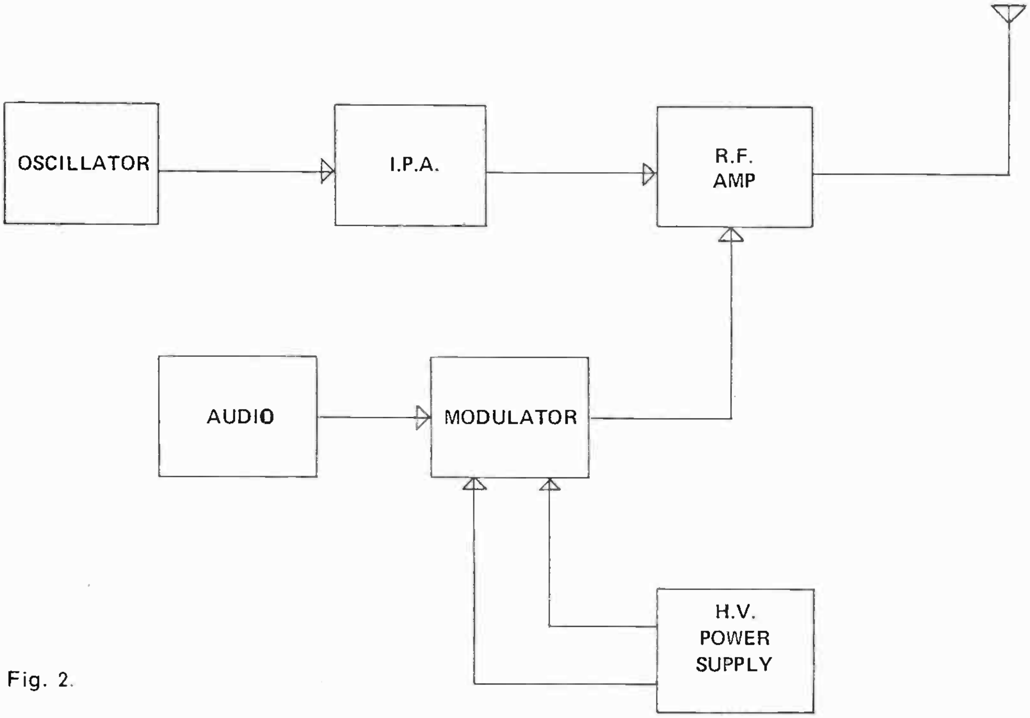


Fig. 2.

Examining the expression, it is apparent that a carrier is present at $\omega_c t$, plus side bands at $(\omega_c + \omega_m)t$ and $(\omega_c - \omega_m)t$. It is easily seen that the total average power in the sidebands is one-half that of the total carrier power at 100 percent modulation, as can be seen in Fig. 1.

The derivation shown above is for some type of periodic symmetric modulation, in this case a cosine function. The derivation works well, and many have approached modulation analysis from this point of view. In broadcasting, though, sine waves are not considered normal program (although, in some cases, it might help the ratings). The complex waveforms that are a part of the music and speech are asymmetrical and the transmission systems should be designed to handle this program, and processing equipment adjusted to provide the highest average-to-peak ratio while maintaining peak excursions at legal limits.

The transmitter is the method of delivering the audio from studio to the radio at home. As it is a method or a medium, the transmitter should have no affect on the signals put in to it, or, in other words, it should be transparent. No method of amplitude modulation, whether it be high-level, class B linear-amplifier, screen, class D, cathanode, phase-to-amplitude, or any other method in practice now, is totally transparent. If audio peaks go beyond the normal excursion, will the transmitter pass it? That is a question with which we must concern ourselves with on a discussion of high positive-peak modulation.

The majority of transmitters in use today employ a high-powered audio amplifier to modulate a class C rf amplifier. In most of these transmitters, a single high-voltage power supply is employed to power both the audio modulator and the rf amplifier. Figure 2 is a simplified block diagram of this type of transmitter. It is in this single high-voltage power supply that the peak modulation problems of the transmitter develop. For as the modulator is drawing increased current to follow the excursion of the peak, the rf amplifier is also demanding more current to supply the increased rf demand. In this type of conventional transmitter under 125 percent positive peak modulation, the instantaneous plate voltage can vary as much as 20 percent. As the voltage drops, so does the rf level and the modulated B+ from the modulator itself. What happens, then, is a rounding off of the peak excursion and carrier shift.

Now that I have mentioned it, and before proceeding, let us make certain we understand carrier shift. Carrier shift can be defined as a change in the average value of current produced by the carrier, whether modulated or not. This change can be measured by rectifying the carrier and measuring the average current (thanks to a meter movement) in a load, as can be noted in Fig. 3. Under symmetrical, ideal modulation, the value of the carrier decreases at the trough of modulation as much as it increases at the peak of modulation; therefore, there is no change in the average value of carrier.

Consider now a transmitter that is not capable of symmetrical modulation below 100 percent; that is, a transmitter that does not have sufficient rf to make the crest of modulation or one that does not have enough modulator power to close the carrier. In the first case, as the modulator calls for rf to supply the additional energy for the production of the crest, the rf runs out and the crest is rounded or flattened, as in Fig. 4. Assuming sufficient modulator power to close the carrier, the average value of carrier has decreased due to the fact that peak power was not attained. The result: negative carrier shift.

The second case is exactly opposite to the previous one. As there is sufficient rf to make the peak, but not enough modulator power to close the carrier, the average value of carrier has increased. The result: positive carrier shift, as can be noted in Fig. 5.

Now, passing either of these two signals through a low-pass filter, as in Fig. 6, we detect audio, but this audio is distorted because it is not identical to the modulating wave. Something has happened in the process of modulation that has affected the waveform; notice I said modulation and not carrier.

Perhaps carrier instability or shift is a misnomer. Assume a carrier in Fig. 7 and a modulator capable of modulating that carrier as much as desired. As modulation is increased, what happens to the carrier? Nothing. The carrier power is not unstable, nor does it shift, as is indicated in Fig. 8. Its only function in life is to move the audio spectra up to some frequency.

The origin of the specification for carrier shift is uncertain. Perhaps 35 years ago, when linear amplifiers were extensively used for broadcast transmitters, variations in the average power of the carrier indicated improper tuning of the linear amplifier, i.e., distorted modulation.

SIMPLIFIED CARRIER SHIFT DETECTOR

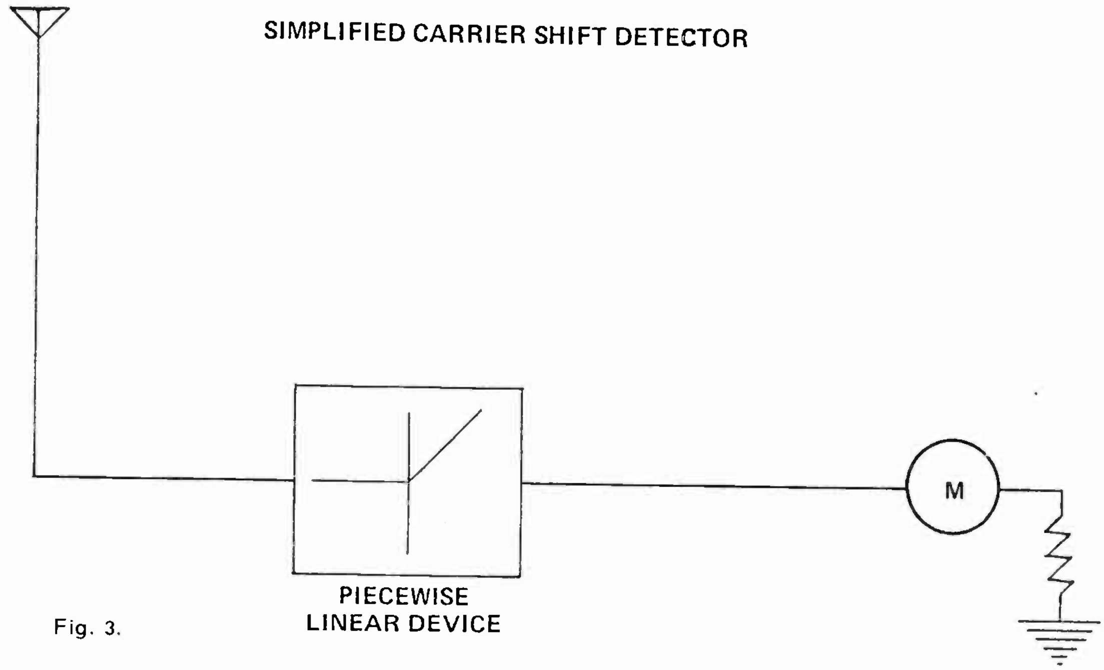
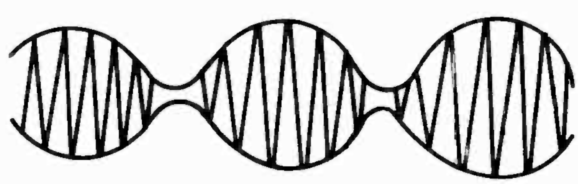


Fig. 3.

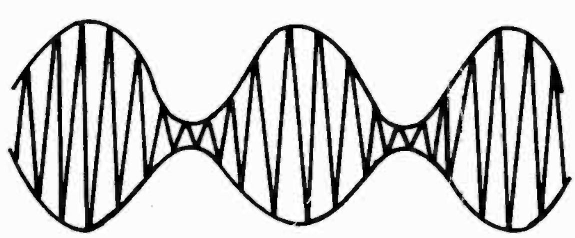
ASYMMETRICAL MODULATION LESS THAN 100%



NEGATIVE CARRIER SHIFT

Fig. 4.

ASYMMETRICAL MODULATION LESS THAN 100%



POSITIVE CARRIER SHIFT

Fig. 5.

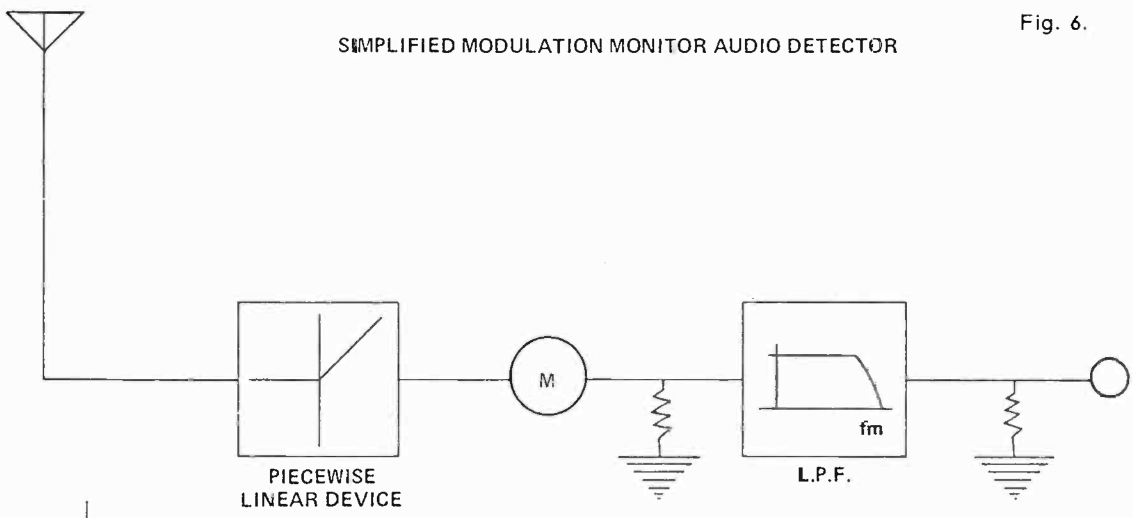
Even in our method for detecting carrier instability there are problems. The time constant of the piecewise linear detector, resistor load, and capacitor are not defined. The longer the time constant, the less sensitive to changes is the meter in measuring the average current produced by the carrier.

Another point that might be worth mentioning: What affect does this carrier instability or shift as defined have on the AM receiver? The process of detection strips away the carrier and throws it away. If an audio peak causes the transmitter to be severely modulated in the positive direction, and the carrier is caused to shift, by our definition, what happens? The receiver reproduces that audio peak in the manner that it left the studio. The average value of carrier current has no affect on the process of demodulation. Examining carrier instability from this point of view suggests that a specification on it limits the transparency of the broadcast system.

By our definition of carrier shift, that is, "a change in the average level of the modulated carrier as received," we must also state the modulating waveform is symmetric. At values less than 100 percent positive and negative modulation, an asymmetric waveform will, by not having a zero average value, produce carrier shift. If a symmetric waveform is applied to the transmitter, and the modulation process is linear up to 100 percent modulation, there is no carrier shift, as in Fig. 9.

Fig. 6.

SIMPLIFIED MODULATION MONITOR AUDIO DETECTOR



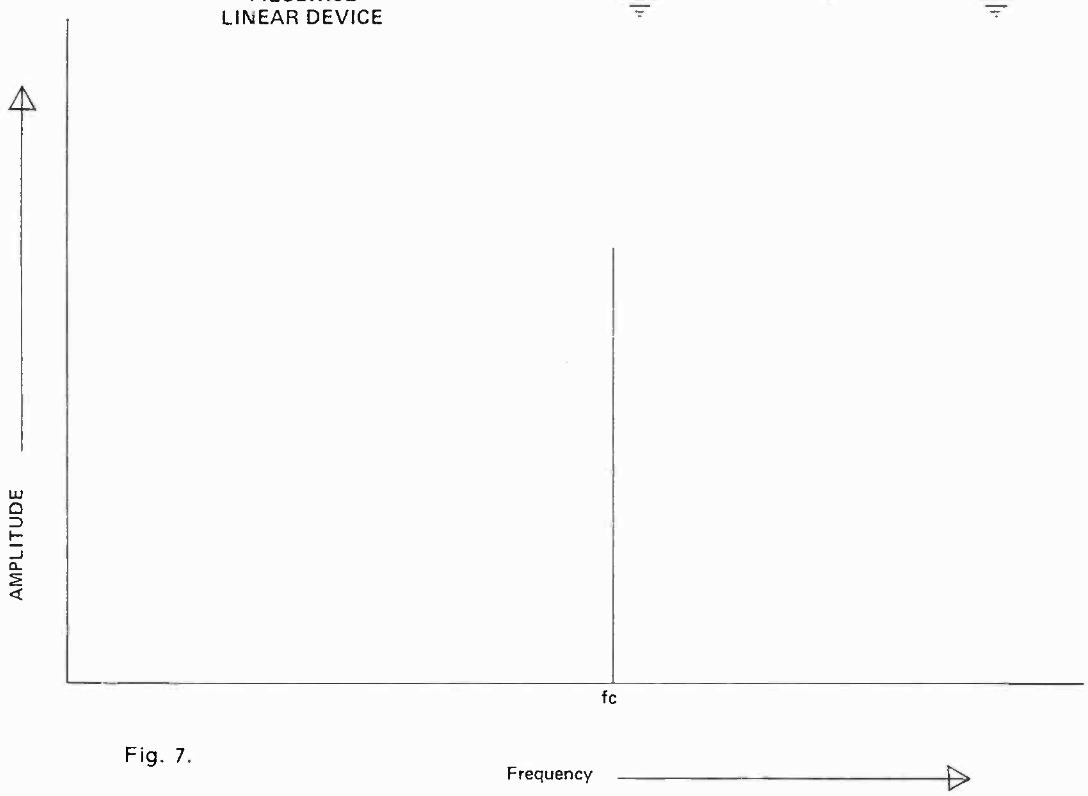


Fig. 7.

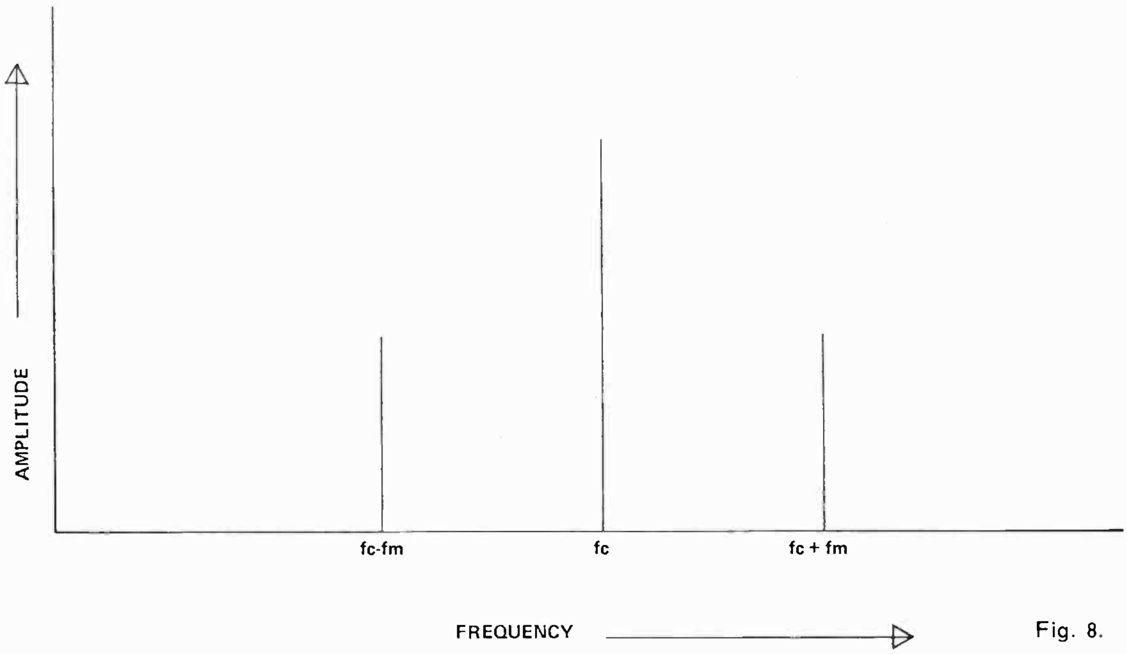


Fig. 8.

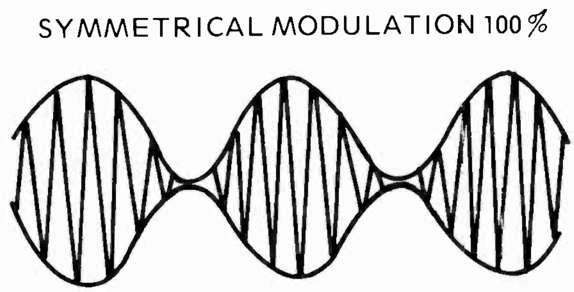


Fig. 9.

IMPROVED HIGH LEVEL AM TRANSMITTER

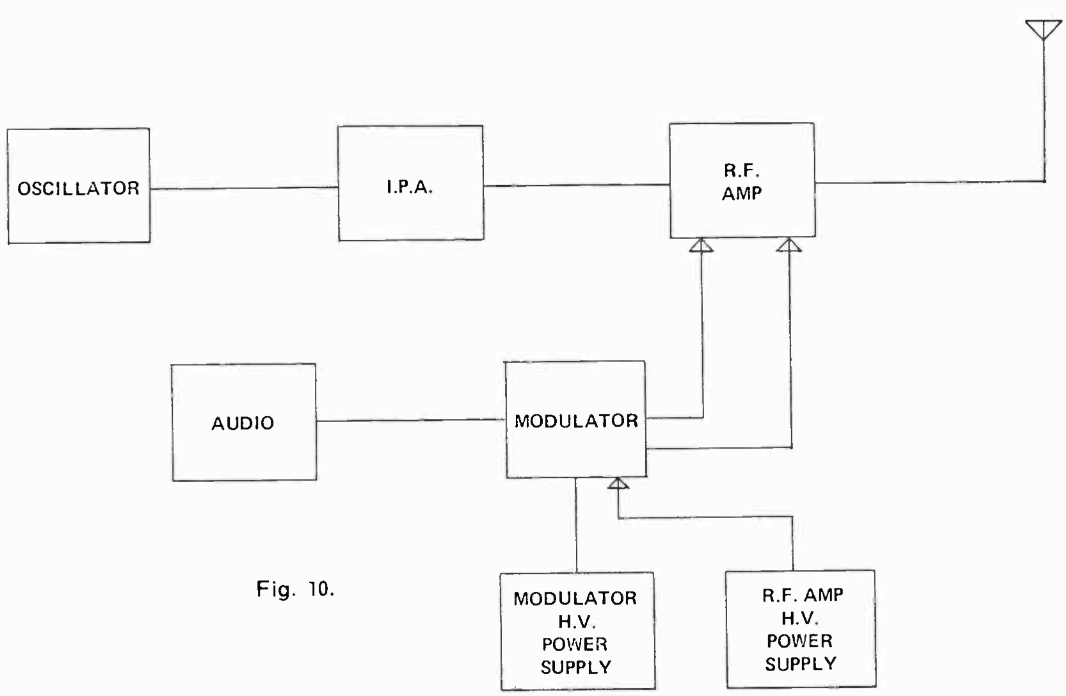


Fig. 10.

Assume a waveform that produces 125 percent positive peak and 100 percent negative peak modulation. Can this waveform be symmetric? I don't believe so. So now, how can we apply a limitation of carrier shift that is intended to be used with symmetric modulation?

What is needed is a test signal and a method of measuring the peak positive modulating capability of a transmitter. Hopefully, this measurement method could take over at 100 percent modulation, where sinusoidal distortion and carrier shift leave off. At ABC, we are working on such a signal and a measurement technique.

Figure 10 is a simplified block diagram of an improved high-level AM transmitter similar to one that ABC has in operation. Note that in this transmitter, the rf amplifier and the modulator are powered by separate power supplies. This allows both stages to act independently and not be tied to a common supply.

This approach to transmitters allows the previously used model of a carrier and modulated sidebands existing as a function of level and frequency of the modulating waveform. The only relationship existing between the carrier and the modulating frequency is the frequency translation from baseband.

In order to see how two different transmitters responded to high positive-peak modulation, a spectrum analyzer was utilized to look at a spectrum of both. Only one transmitter was capable of modulating in excess of 100 percent; the other transmitter had difficulty at the 100 percent level.

Complex audio in the form of top 40 music was applied to the transmitters with and without asymmetrical limiting. In order to make more consistent measurements, the audio was derived from a 10-second continuous loop. Measurements were endeavored to be taken at the exact portion of the program from which all the measurements were taken in an attempt to insure identical spectral content. The transmitters were applied to a dummy load, with identical characteristics as the main antenna.

Figure 11 is a spectrum of transmitter 1; that is, the transmitter not able to modulate highly, with no processing, but overmodulated to produce some peak information. The faint light line in the center of the photo is the center frequency reference as produced by the spectrum analyzer. Carrier amplitude is referenced to the top of the photo and was maintained at this point for all the photographs.

Note that the sidebands do not appear coherent. This is correct, as it requires the analyzer a finite amount of time to sweep the frequency range selected. This isn't a problem, however, as the sets of sidebands produced are identical; thus, we need concern ourselves only with one set. The lower sideband in this photo at one point has an amplitude of approximately 72 percent of that of the carrier, which corresponds to a peak of modulation of approximately 144 percent. In order to obtain the above peak

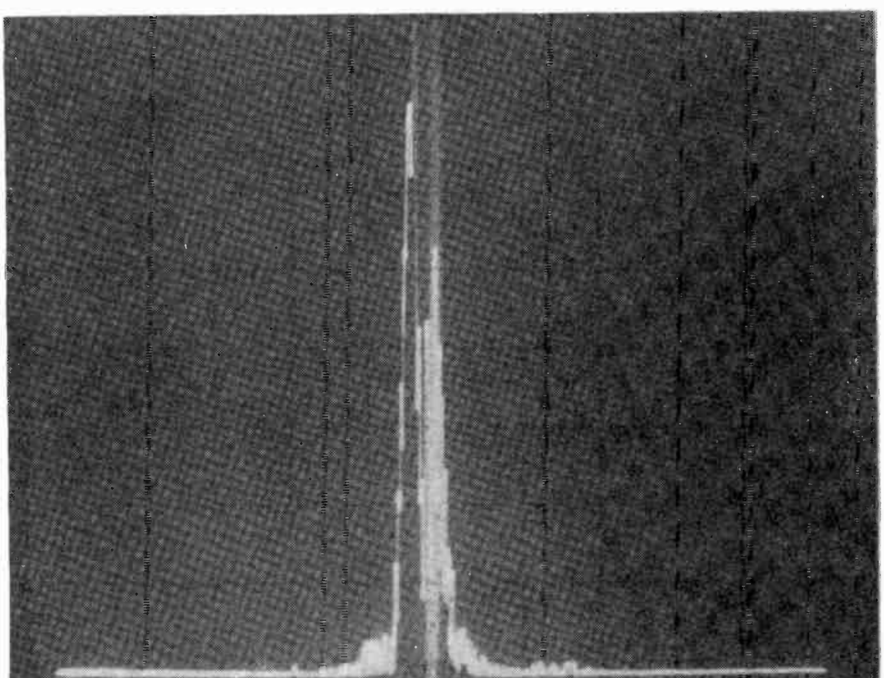


Fig. 11. Spectrum of transmitter 1.

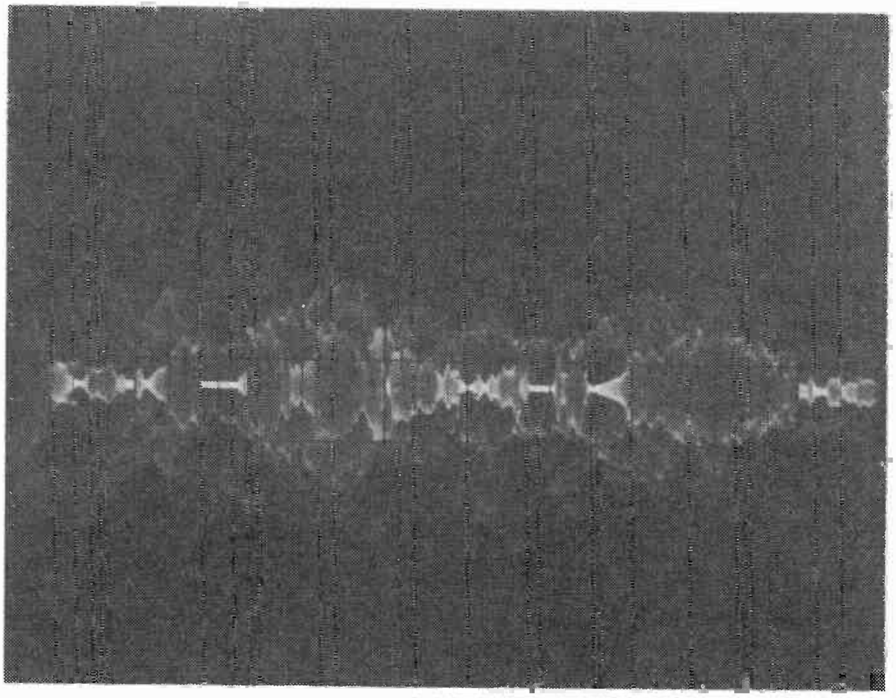


Fig. 12. Display showing severe overmodulation.

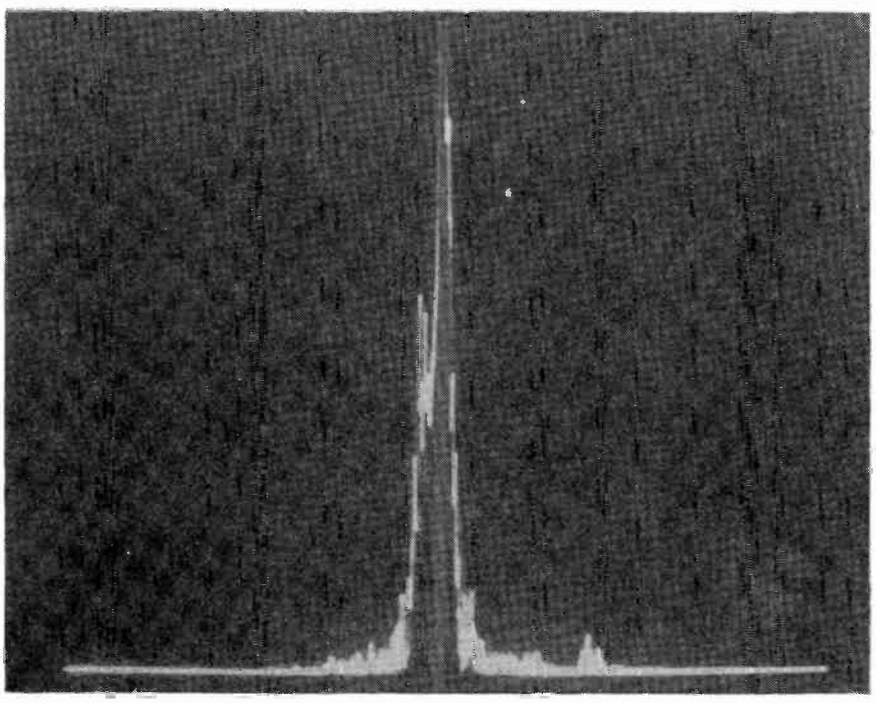


Fig. 13. Number 1 transmitter, asymmetrically processed.

percentage of modulation, the transmitter was severely overmodulated, as one can see in Fig. 12, which is an envelope or time-domain presentation of the modulated carrier. This photograph was triggered with the spectral display in Fig. 11. Notice the severe negative overmodulation; and, although it is not apparent from this photograph, the rounding and even flat-topping of the peaks of modulation, while this was happening, the modulation monitor, while indicating many negative peaks, was indicating high positive peaks. Were these peaks really there? Undoubtedly not, as the monitor was probably measuring the fundamentals and all other products of the complex waves.

Figure 13 is the display when the number 1 transmitter was asymmetrically processed. Notice the upper sideband, with a peak of approximately 70 percent of carrier. In this instance, however, severe negative modulation was not noticed, as the asymmetrical limiting tended to do its job.

Figure 14 is a spectrum of transmitter number 2 (the one that handles high positive-peak modulation) modulated by the same complex audio as was used in the preceding tests. Note in this photograph that the upper sideband has a peak of approximately 95 percent of carrier which corresponds to 195 percent positive peak modulation. No asymmetrical processing was used, and greater than 100 percent negative overmodulation was indicated by the modulation monitor at the time-domain display. I will say, however, that the carrier shift was horrendous; but, as I pointed out before, it is irrelevant. Whatever that assymetric peak of complex audio was, the transmitter passed it.

Figure 15 is the same transmitter as before, but this time asymmetrical limiting was employed. Note again the peak of about 95 percent carrier in the upper sideband. The spectrum also appears to be full and higher than in other photographs. I wish I could say that was true of asymmetrical processing. The full spectrum is undoubtedly due to the modulating signal at the instant the photograph was taken. The conditions of this photograph produced no negative overmodulation.

I believe the preceding photographs tend to show that the positive-peak-handling capability of a transmitter is important with complex waveforms. The transmitter becomes a transparent medium. Does this high-peak capability make one sound louder on the radio? Not really. As the speaker in the radio responds mostly to average level, it is the average level of all audio that will make one transmitter louder than another. Consequently, high average-to-peak levels must be maintained by some type of audio processing.

We at ABC employ two devices to process audio to the transmitter—an average-level-controlling device or AGC, and a limiting device or limiter. I don't propose to make statements about the setup of audio processing devices, as I imagine everyone has a different idea on what to do. I would like to, however, explain some ideas which we use when adjusting our processing equipment.

The AGC has one purpose in the chain and that is to improve the average level of program material. Basically, we use the AGC in a medium fast portion of attack and release times, on the order of tens of milliseconds for attack and hundreds of milliseconds for release. In this manner, we hope to have the gain of the amplifier change almost at an audio rate so that the program tends to become leveled in an average range of 7 dB. The AGC, however, won't catch the peaks of program or level changes that are beyond its dynamic range, so the limiter comes into play.

The limiter is of classic design, which up to a predetermined value, is basically a linear amplifier. After that point, however, any increase in input produces little or no increase in the output. The limiters we employ use a fast attack time on the order of microseconds and release times in the range of milliseconds. This combination of time constants allows the limiter to quickly do its work and then get out.

Another important feature of the limiter is its ability to see a highly negative asymmetric peak and flip it over. As I imagine you are all aware, the male voice has a content which is highly rich in negative peak information. Under these instances with normal processing, the male voice would be more likely to overmodulate the transmitter in the negative direction, which is limited to 100 percent, and not in the positive direction.

With conventional limiters, this audio would cause them to limit at 100 percent negative; and, since the amplitude of the negative is greater than the positive, the transmitter would not be fully modulated in the positive direction. By employing this flip-type of limiter, the high-amplitude negative peaks are inverted so that they go positive, and with the high positive-peak capability of the transmitter, the average value of the audio transmitted is increased.

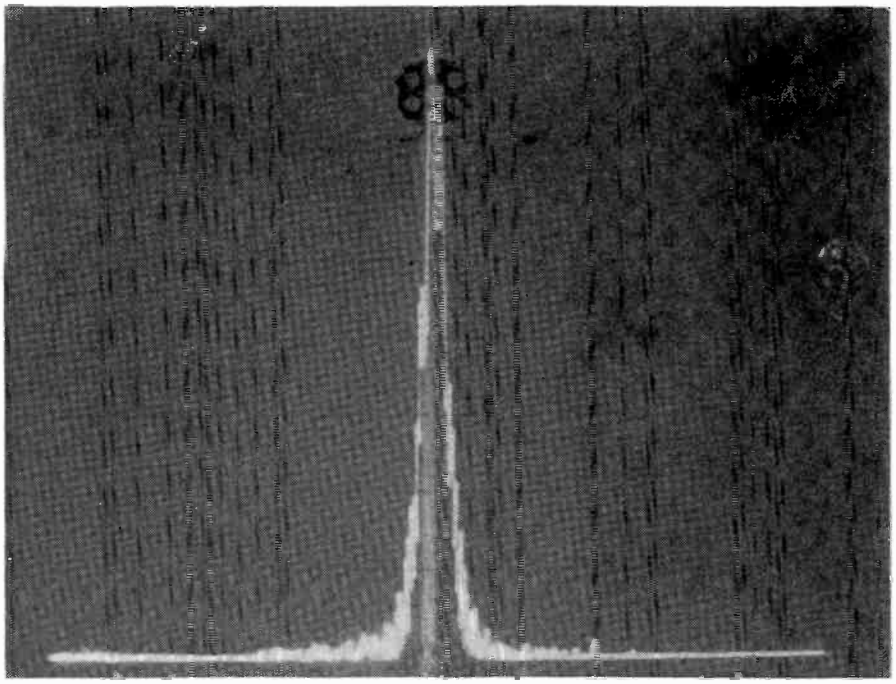


Fig. 14. Number 2 transmitter modulated by same complex wave.

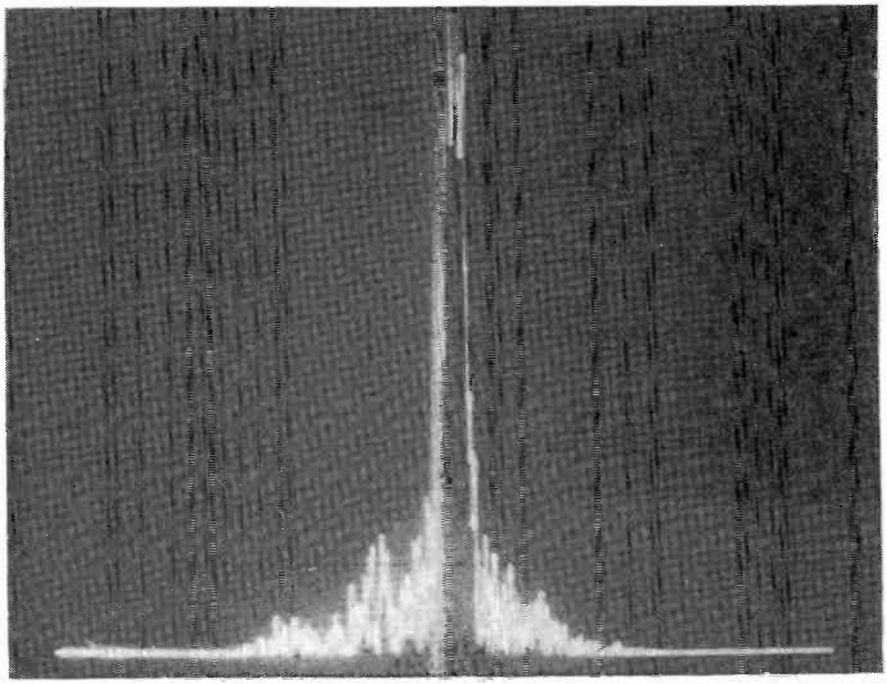


Fig. 15. Display showing effect of limiting.

As I mentioned before, the processing of audio is a personal approach in which one has to tune for the sound that he wants. It is this processing that will determine the amplitude modulation characteristics of the transmitter. But with some of the basics discussed here, and an awareness of what happens during that modulation process, perhaps your task of attaining that sound will be made more logical, and 1973 will be a very good year for AM.

The author wishes to extend his deepest appreciation to Fred Zellner and John Toth of the American Broadcasting Company's Engineering Department for the many hours of consultation they provided and without whose assistance this paper would not have been possible.

FM Translators

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and
Doug C. McDonell
Consulting Engineers
La Grange, Illinois

Whenever I hear a long and especially flowery introduction I am reminded of the words of D. L. Moody. He was once quoted as saying, after such an introduction: "Remember soft soap is still made of 50 percent lie." Those who know tell me that a successful talk, like our paper today, should be like the length of a lady's dress. That is, it should be long enough to cover the subject, but short enough to hold your attention.

FM translators (Fig. 1) have been legal now in the U.S. for about two and a half years, yet most station engineers and owners seem to be totally unaware of them or at best fail to grasp their real importance in the field of electronic communications. FM translators may well be the last gadget to come along that we as broadcasters can employ.

The FCC Rules, Parts 74, 1201-1284, cover the requirements for this FM service. Basically, there are two types of devices. They are referred to as translators and as boosters.

An FM translator has three important points or facts that set it apart from an FM booster. These are, first, the power level is restricted to either 1.0 or 10 watts. By power I am referring to the power output of the translator. Now, why the difference in power outputs? This is because Section 74.1235 of the FCC Rules says that those people lucky enough to locate their translators west of the Mississippi, except in Zone I-A, can operate with 10 watts. The rest of us are stuck with a 1.0 watt (Fig. 2). Keep in mind that these power levels are effective regardless of where the primary FM station may be located. For example, if you were to pick up station WRVB-FM in Madison, Wisconsin, and translate it from a point at Dubuque, Iowa, you could operate with 10 watts. If, however, you translated it from East Dubuque, Illinois, you could employ only 1.0 watt.

The second point one must recognize about translators is that their output frequency must be on one of the 20 class A channels. Please note that the input can be on a class A, a class B, a class C, or even an educational channel, except that educational translators can also be allocated to any of the educational channels 201 through 220.

There are four major points that distinguish an FM booster. First, the power is 10 watts regardless of which side of the Mississippi you locate; in other words, anywhere in the country. Second, the input and output frequencies must be the same. That is to say, there can be no changing of the frequency—no "translating." Next, they have to operate on the same channel as the primary station they are repeating. Possibly the choice of the word "repeater" would have been more descriptive than the word "booster" to represent this type of FM satellite. And lastly, these boosters must be located geographically within the theoretical 1.0 MV/M contour of the primary station.

Figure 3 shows the country as it is now divided with respect to 1.0 and 10 watts. Southern California is also limited to 1.0 watt. The Mississippi River is really an arbitrary boundary, not a geographically unique one. While we concur that the FCC must "draw the line" somewhere, a more logical division would fall along the zone

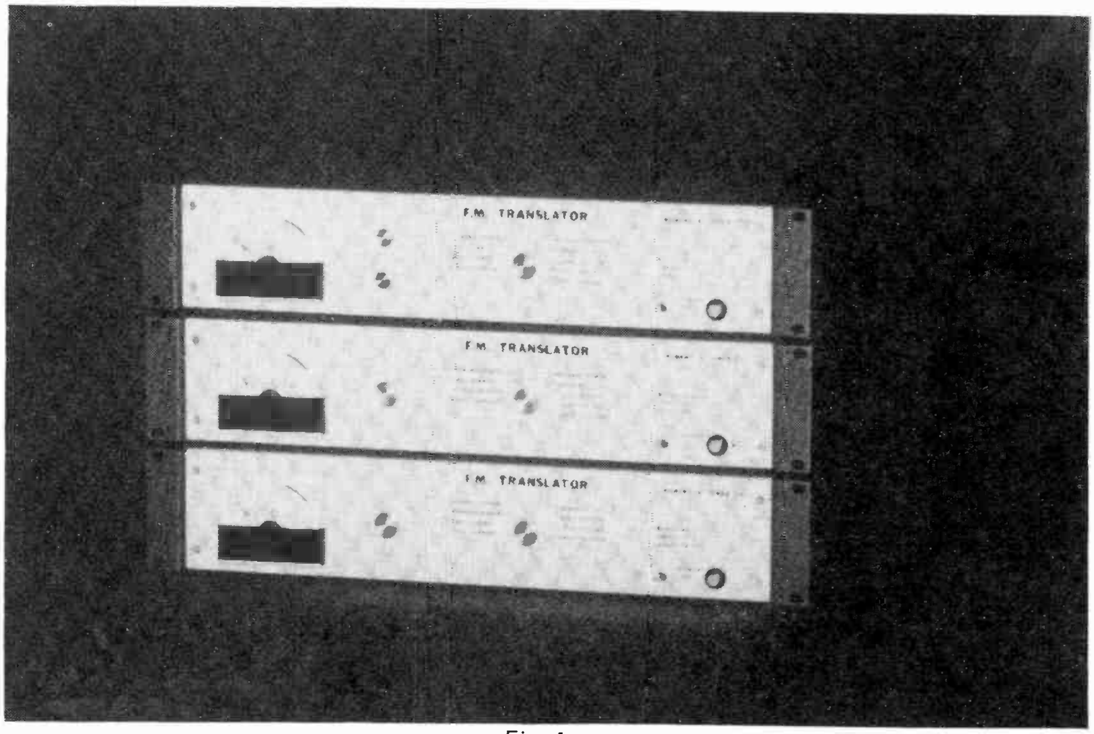

Fig. 1.

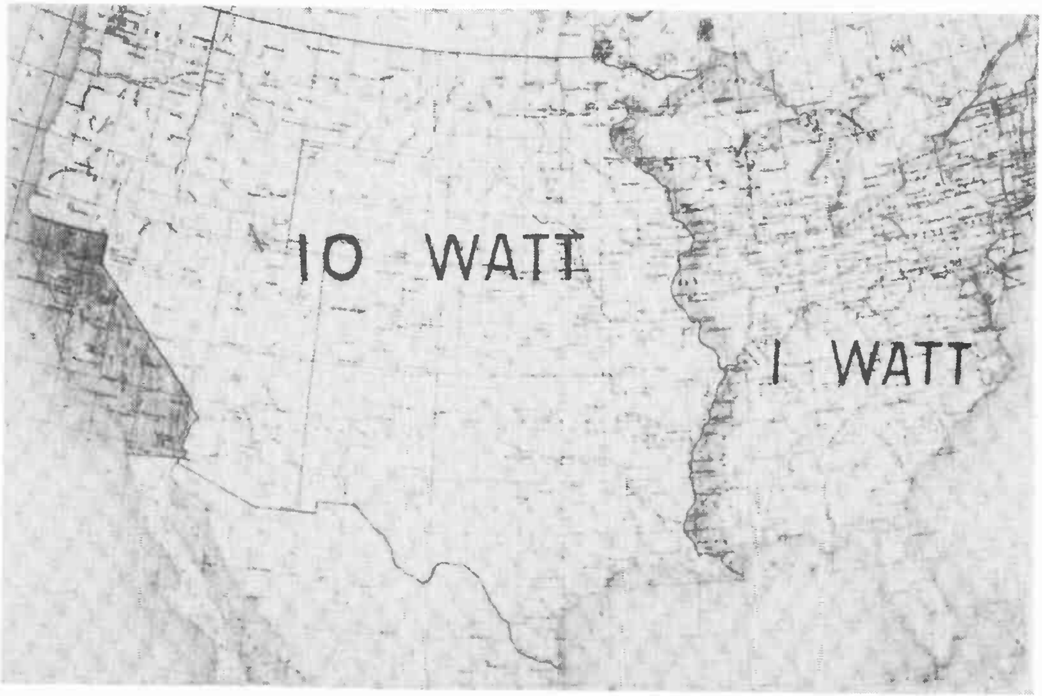

Fig. 2.

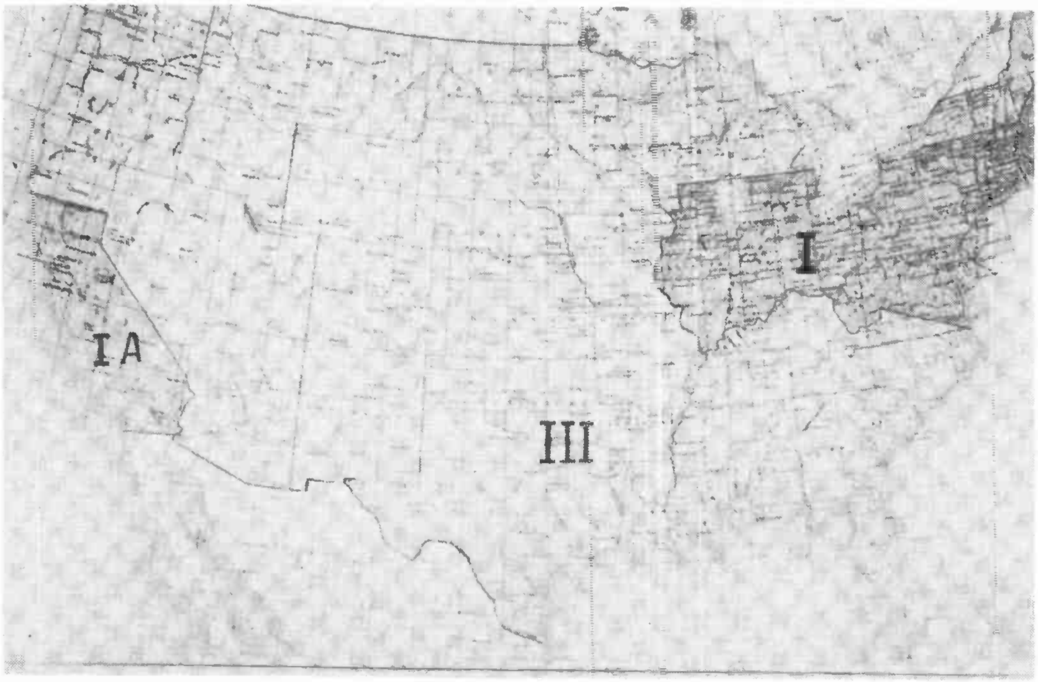
IA
I
III

Fig. 3.

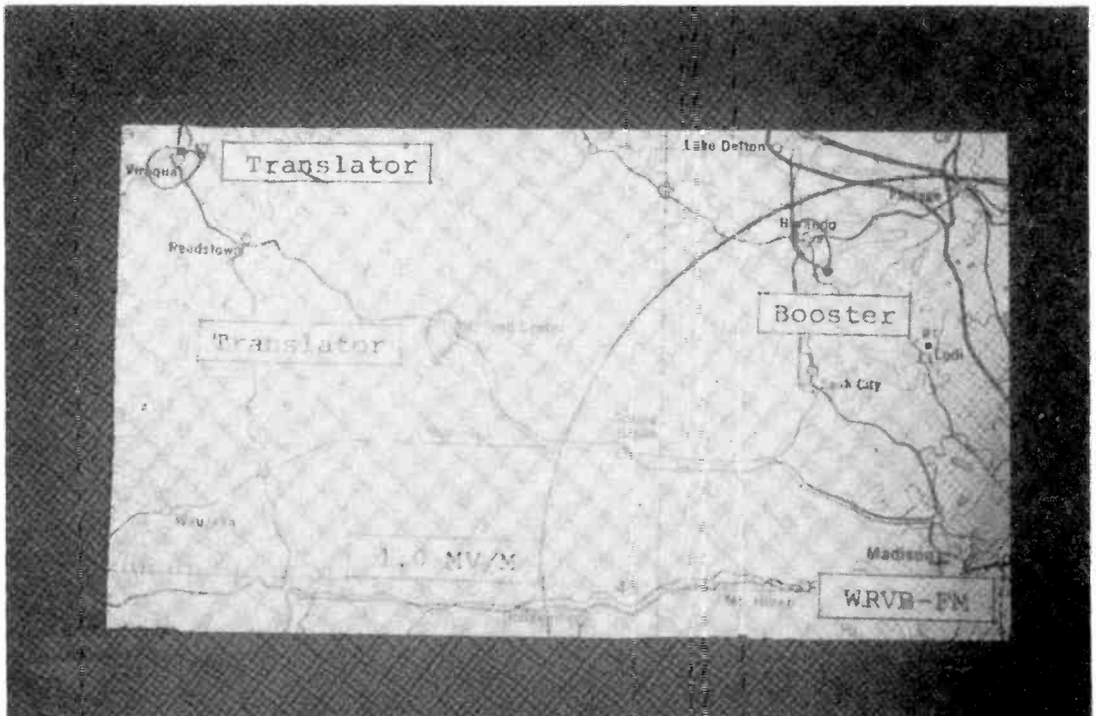
Translator
Lake Delton
Reedstown
Booster
Lodi
Translator
Madison
WRVB-FM

Fig. 4.

boundaries already established in Section 73.205 of the Rules. In fact, a petition is now pending to make such a change in the Rules.

The map in Fig. 4 shows a hypothetical allocation of two FM translators and one FM booster used to extend the coverage of FM station WRVB-FM. The two translators are located well beyond the 1.0 MV/M contour of the primary station, while the booster is within this same contour.

The reason for the coverage of each of these three satellites being drawn as a tear-drop shaped contour, instead of a circle, is because each FM satellite employs a highly directional antenna. In fact, such antennas are used both for receiving and for transmitting. By use of the antenna's gain, the ERP can be amplified up some ten times.

At this point, some may question why anybody would want to or even have to locate a booster within his 1.0 MV/M contour. Figure 5 depicts a situation where a booster would be helpful. Just to the north of Madison, Wisconsin, lie the Baraboo Hills. They effectively block off all FM reception from Madison area FM stations. A line-of-sight signal from WRVB-FM (a typical Madison station) would completely miss covering the City of Baraboo. If, however, an FM booster were installed on top of one of these hills, it could easily "fill-in" this city, insofar as service from WRVB-FM is concerned. I'm sure you are thinking of other cases where holes in existing FM stations' service area exist.

I think by now you can appreciate the differences between FM boosters and FM translators, and how each can be used in a different way to improve or extend the signal of a given FM station.

The proper antenna can take a 10-watt translator and make it as powerful as a 100-watt station—in the direction the antenna points. The FCC has not placed any restrictions on the type, the size, or the gain of the antennas we can use with these low-power devices. You do have to file with the FCC the type of antenna as well as its pattern.

Let me at this point give you a little history about FM translators and describe some of the installations of translators as well as a brief description of the units we supply to the industry. The first known such devices were installed ten years ago by Radio Lumiere, the radio voice of the West Indies Mission in Haiti (Fig. 6). Figure 7 shows the originator of FM translators, Rev. Dave Hartt. Where no telephone lines exist, FM relays are the only way to hook up several AM transmitter sites.

The first FM translator was authorized by the FCC a little over one year ago (W292AA) at Viroqua, Wisconsin. The 10-element yagis for the translator output were

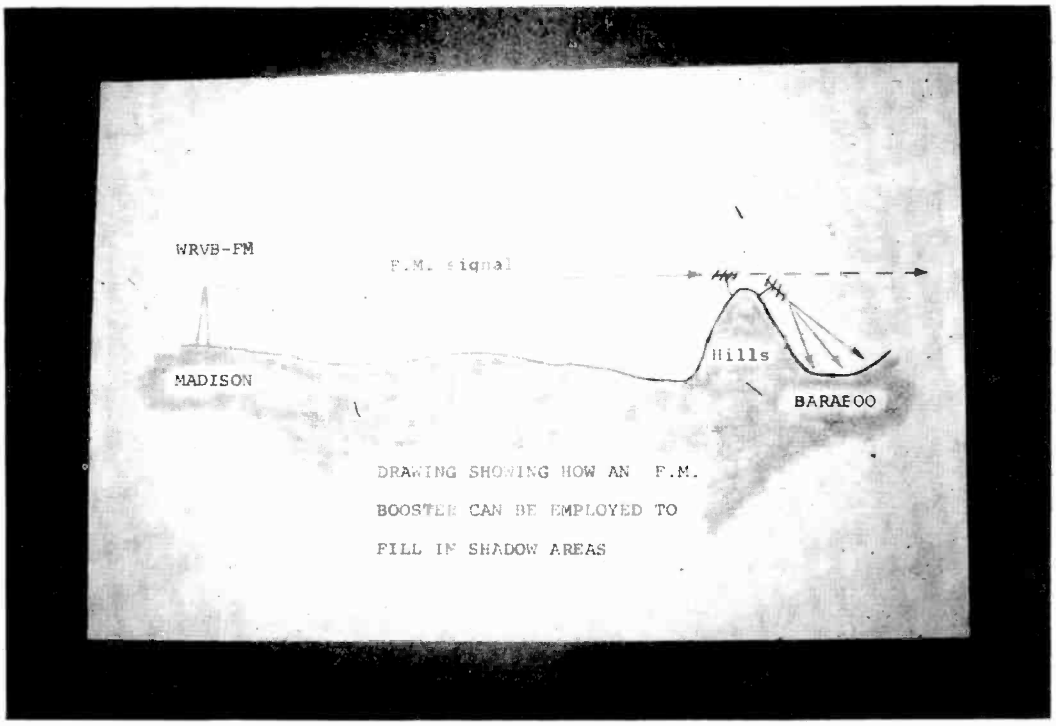

Fig. 5.

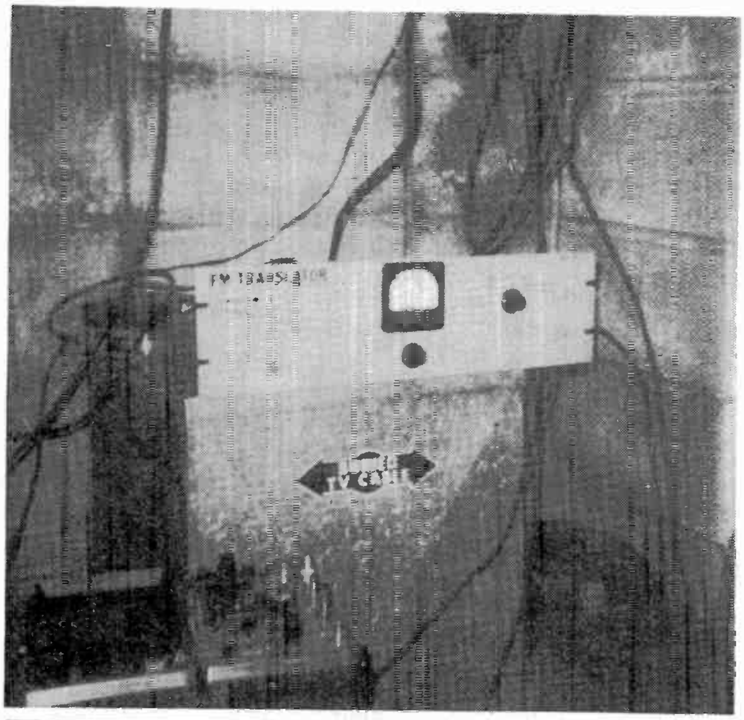

Fig. 6.

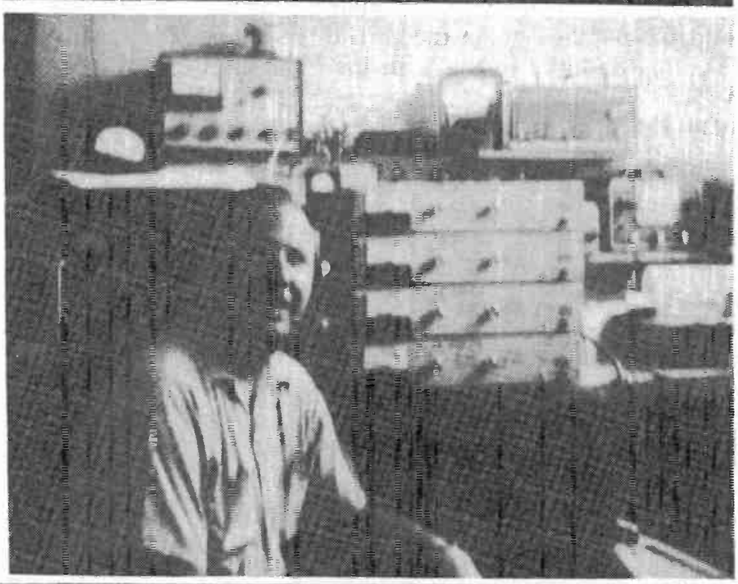

Fig. 7.

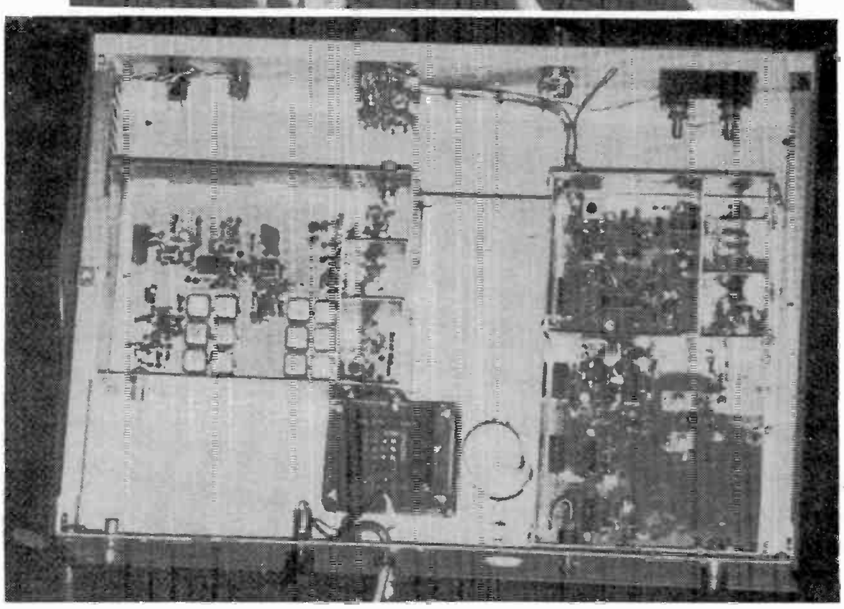

Fig. 8.

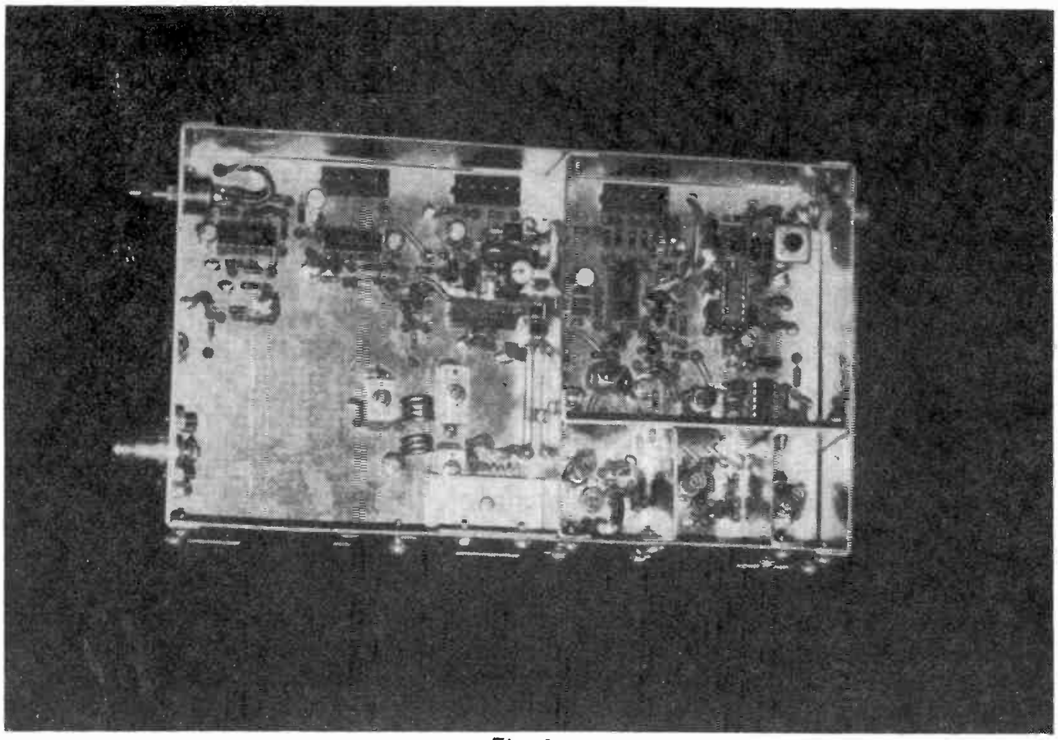

Fig. 9.

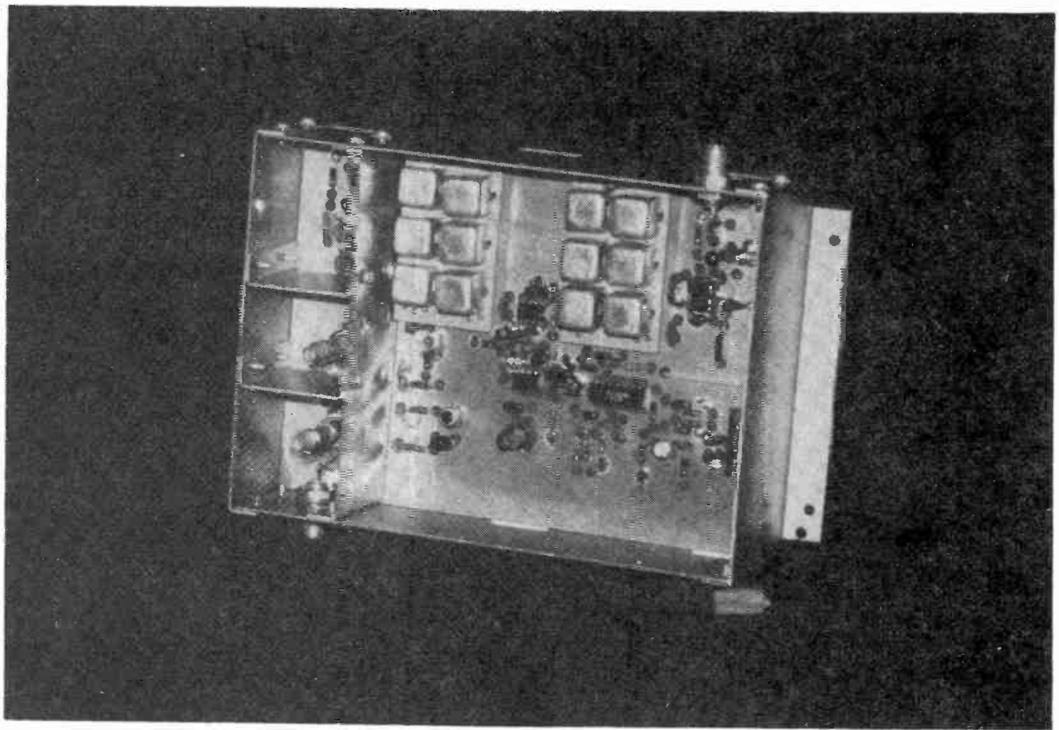

Fig. 10.

all mounted on the local CATV tower at Viroqua. W292AA repeats FM station WRVB-FM in Madison, Wisconsin.

Another installation also uses a CATV tower. This is W288AA at Iron Mountain, Michigan, which repeats WRVM from Suring, Wisconsin, about 60 miles away. This is one of the few FM translators that uses a four-by horizontal antenna. It may be of interest that on this same CATV tower is a 3000-watt FM station, WJNR-FM, operating 1.60 MHz lower in frequency. We have experienced no cross-modulation or overload problems at all.

A third installation is that of W261AA at Charlottesville, Virginia. Here, the primary station is WIVE-FM Ashland, Virginia, some 70 miles to the east. We were fortunate in finding a tall barn on a 900-foot hill just south of the city in which we installed the 5-element yagi antenna inside the wooden roof of the barn. This may not be quite as effective as one outside, but with the 900-foot advantage, we were able to put a good signal into all the city. The J-316 translator is mounted vertically between two beams. This way it was off the attic floor and would not collect dust.

To date, the FCC has received over 80 FM translator applications and there are some 35 on the air.

Figure 7 shows four of the units "talking" to each other. It is interesting to note that these 4.0-watt units do not interfere nor cause any cross-modulation to another, even in this close proximity. There is no limit in the number of FM translators you can own, nor on the distance one can relay a signal.

Figure 8 shows an inside view of a 1.0-watt translator. The receiver and transmitter are still in separate subchassis, but now we have them mounted in the same cabinet. The power supply is in the middle.

Figure 9 is a closeup view of the inside of a typical receiver module. As you can see, it is solid-state design all the way through, with individual shielding. The small cans are the preferential filter, a unique design employed only by the J-316 series.

The translator contains double-sided PC boards, solid-state design with nine ICs (Fig. 10). The unit has an output stability of better than 1 percent of power for any change of input signal and for a 10 percent change in source voltage.

The door has just begun to open on the use of FM translators. Now is the time for all smart FM broadcasters to jump on the bandwagon. Let me list the major advantages of FM translators:

A. There is no limit to the distance you can carry a given signal.
B. There is no limit to the number you can own.
C. The cost of a typical installation is less than $2,500.
D. No FCC logs are required.
E. No periodic visits are required by a technician.
F. And best of all, there are no FCC filing fees.

Thank you for this opportunity to share our thoughts and some of our clients' success with FM translators. We trust this has informed, encouraged, and even motivated you to apply for a translator or two of your own.

The New WGH Radio Broadcast Facilities

Joe Looper
Chief Engineer
Hampton Roads Broadcasting
Newport News, Virginia

WGH Radio, owned and operated by Hampton Roads Broadcasting Corporation, is based in Newport News, Virginia. WGH-AM is a 5000-watt regional station on 1310 kHz. The daytime facility operates at 5000 watts from its daytime nondirectional site and 5000 watts directional at night from a separate site. WGH-FM operates 24 hours per day from the daytime AM site with a power output of 74,000 watts, vertical and horizontal. WGH-AM radio has been on the air continuously since 1928. It went on the air as WNEW, call letters which I am sure you recognize. However, we had it first. In December of 1928, the call letters were changed to WGH, for World's Greatest Harbor, which in reality the Hampton Roads Harbor truly is.

Newport News is on the north bank of the James River where it empties into the famous Hampton Roads area. To the north, and adjoining Newport News, are the cities of Hampton, Yorktown, and Williamsburg. Those of you who have some background in history will immediately recognize that this area is the very heart of the founding of our country and contains many points of historic interest. On the south bank of the James River are the cities of Norfolk, Virginia Beach, Chesapeake, and Portsmouth. This large metropolitan area includes a population well in excess of one million people.

WGH has been engaged in a construction program since 1965 to improve its facilities to the point where it can adequately serve all of the people of this large area. The construction process, which started in 1965, was divided into several phases and I will cover these each individually and sum up this short discussion on some of the problems involved in operating a station that operates from five different locations in three cities. These locations are: 1. Main studio site in Hampton; 2. Norfolk studio site; 3. Night-time transmitter site in Hampton, Va; 4. Daytime AM and full-time FM site in Newport News; and 5. Microwave site in Norfolk.

Phase I of the construction started at our daytime boat harbor site in 1965. The shell of the building which was constructed in 1936 is all that remains of the original WGH. Everything else is completely new. The initial construction consisted of removing a 428-foot self-supporting tower which was put up in 1948 to support a TV and FM antenna.

The first order of business was the installation of a new ground system and tower. Since this site borders the ocean, advantage was taken of the conductivity of the sea water by installing an extremely heavy ground system. Twelve-inch copper strap was used for a firm foundation. All fencing around the tower was well grounded with copper strap and carried back to the main ground system. The 24-foot ground screen was installed and all joints were silver-soldered, due to the salt-water atmosphere.

The first order of business in the old building was removal of the existing hot-water system and the partitions which divided the building into six rooms. A new power distribution system was installed. This may seem somewhat antique in that it uses fuses rather than magnetic trip breakers, but this was done to increase the safety factor. All engineers working at either of our transmitter sites are instructed to turn off the breaker, remove the fuses, and put them into their pockets. This may seem extreme, but cases of electrocution are somewhat permanent.

The boat-harbor-site building is approximately one-fourth of a mile from the largest coal-loading piers on the east coast. All the air entering is double filtered to eliminate the coal-dust problem.

In 1967, a new RCA AM transmitter was installed. This unit has proved extremely reliable and is capable of extremely high levels of positive modulation. The transmitter feeds a switch panel which allows feeding the transmitter into a dummy load for testing purposes.

Our new 40 kW dual FM transmitter was placed on the air March 5 along with a new dual polarized antenna. The transmitter is operated at 26 kW, which allows a healthy safety factor. The advantage of this dual transmitter system is the ability to maintain an on-the-air signal in the case of failure of either of the transmitters and to allow maintenance without interrupting the signal. During the installation of this transmitter, the components were labeled by the engineers with their actual function, in addition to the part numbers. All relays, resistors, and components were labeled. This labeling cuts down troubleshooting time considerably, as many of the parts can be replaced without referring to the circuit diagram.

In 1969, a 90 kW diesel generator with automatic start and transfer was installed at this site to permit continuous operation in case of power failure. Sufficient fuel is stored underground to provide two weeks of continuous operation. I might add that WGH is the primary EBS station in this area.

Phase II of our construction program started in 1968. This consisted of moving our night-time 3-tower array from its original site at the studio location to a new site, which is approximately four miles farther up the Peninsula. The existing phasor was removed from service and a substitute home-made phasor was used in its place to allow rebuilding of the old unit. Twelve-inch copper straps were used to tie into the ground system. Here again, silver solder was used in all joints. The cable to the antenna was installed in fiber conduit so that it could be removed easily in case of any lightning damage.

A new technique for us was tried in the raising of the antennas at this site. Rather than setting up the bottom 50 feet or so and then gin-poling the rest of the tower up, it was decided to try to erect the towers in one piece, since they were only 190 feet. This was done successfully by preassembling the towers and attaching the guy wires on the ground. The tower was then picked up with a crane with a 15-foot boom. The entire operation, not including the crane assembly, took less than 10 minutes per tower. One luxury which management afforded us, which was not given to us at the old site, are concrete walkways to the dog houses. I'm sure many of you can appreciate these on rainy, muddy nights.

The building for this site was installed in 1968. It is a modern brick structure made to blend in with the homes in the immediate area. The first order of business was installing the power distribution panel and here again fuse boxes were used rather than breakers.

The phasor system was built by the staff engineers using components from the old RCA phasor. All coils were silver plated. Vacuum capacitors were substituted for the micas. This was a wise decision, in that in the last four years we have had no problems. In fact, as of this date, there have been no changes in the setting of the phasor controls since the setup in July of 1969, and it looks like they will remain in this position for some time to come.

This site is remotely operated; however, it can be operated locally. The daytime site can be remotely controlled from this site also. As it stands now, the station may be run from three different locations. It is licensed for control from two separate points. This site is also licensed to be used as an auxiliary daytime transmitter site; hence, we have the capability of using three separate transmitters in the daytime and two separate transmitters at night. There is a diesel generator at three of the sites. It is quite easy to understand why management would be upset if we were to lose any extended air time.

The night-time transmitter site has a fall-out facility with 3-foot thick concrete walls and a 12-inch thick steel reinforced roof. In this is a small studio which may be put on the air when any of the normal studios fail; hence, the night-time transmitter site is a complete facility. There is sufficient fuel here for three weeks' 24-hour a day use.

WGH started Phase III in 1970 by building modern studios in a very large shopping center in the middle of Norfolk's fastest growing area. The studios are open to the public and may be viewed from the mall of the shopping center. They have a studio reception area where we find a modern waiting area and windows from which the studio operation can be observed. The decor in the area is one of basic cream and red, and, as you can see, the interior decorator had a wild imagination. The conference room adjoins the main studio and is also utilized as a recording studio. The microphones may be controlled from the main studio or, if it is desired to have privacy in the conference room, the curtains may be drawn. This studio is used as a back-up studio or a production studio and utilizes glass copy boards over the consoles so that the operator may view into the windows in case there is any need for visual communication.

The production studio is equipped with two stereo recorders, three turntables, and two recording cartridge machines. Limiters and equalizers are also provided. News may also be originated from the Norfolk studios. This studio also has visual communications with the other studios. The main on-the-air studio, which is primarily used for AM, is a stereo facility. It may be used either for monaural or stereo.

Phase IV: WGH has always tried to keep its personalities before the public. In order to help do this, extensive use is made of a mobile studio which is used in both Norfolk and on the Peninsula. Since we cover an area of approximately 60 by 30 miles with active service, it is necessary to use two receivers for the trailer. For normal use, the signal from the trailer is directed back to the Newport News studios. When in the Norfolk area; the signal is directed back to the microwave site, atop the Sheraton Hotel one-quarter mile away. From here it is carried down to the studio for control purposes, backup to the microwave site, then carried back to the Newport News studio, some 17 air miles away. The use of two receiving sites enables us to cover this large area with our mobile studios.

Phase V consisted of the building of our new Newport News site. Many studios throughout the country were visited for ideas. The central control room, news studio, and production studios were located away from this complex for sound isolation and to prevent interference from normal operation.

The FM stereo studio is equipped with three stereo cartridge machines, three turntables, two microphones, and three reel-to-reel tape machines. There is remote control for all equipment including the automation and reel-to-reel recorders that are in a separate tape room. The equipment is kept out of the studio to prevent noise when starting a tape with an open microphone.

The reception area has several chairs in the waiting area and the window opening into the studios make them available for public viewing. The door opens on the right into the interview studio and the enclosed area in the rear is the entrance to the executive offices. The engineering shop at the studio facility is fairly small, since most of the equipment is maintained on location in the center areas. There is adequate equipment here for proofing and maintaining small items.

The main control rack is laid out as follows: The left control rack is for the AM studio processing gear and distribution amplifiers which carry all program sources to the various studios. The central rack contains FM audio processing gear, a studio transmitter link, a Hewlett Packard frequency counter, which is used for all station frequency checks. The oscilloscope in the center rack is hooked up to the left and right outputs of the FM monitor at all times, which gives a picture of all modulation and phasing problems on the FM signal. The right rack contains remote control metering and remote control equipment to both transmitter sites. The building monitor system, which carries AM and FM and Muzak audio to all of the 40 rooms in the building is in the lower right portion. Immediately in front of the control rack is a communication console which contains a two-way radio, an intercom, and recording facilities. The intercom is a voice-operated, hands-free system which allows communication between any of the 40-some rooms in the main studio building.

The AM control position is a stand-up operation which gives the operator freedom to move around. Ten cartridge playback cartridge tape machines are used, all remotely controlled. The cueing and on-the-air playback of the turntables is a two-step operation. The operator's steps are reduced from the conventional five or six to only two per record. The total time saved is considerable and the chance for error is practically nonexistent, since a record cannot be cued on the air. The small recording studio can be used for groups of five or six people. Larger groups are easily handled in our Norfolk facility, which will accommodate up to 15 people.

The news facility uses a conventional sit-down configuration. There are 12 inputs on each of the Ampex machines, which may be selected for playback during the newscast. The glass copy board is used to allow visual contact without having to move out of the chair of the operator in the next studio. Two typewriters are arranged in this studio to allow two people to use this room at one time. Two cartridge playbacks are also utilized, giving a total of five playbacks which may be used during the newscast.

The FM record library contains in excess of 20,000 recordings at the present time. Ours is basically a classical music format and only tapes and 12-inch recordings are used. The filing and logging for this studio is a full-time job. One of the three production studios in the main studio building is primarily used for mechanical dubbing or changing from tape to cartridge or improving commercials from outside sources. It can be used for a second voice in the adjoining studio which may be seen through the window in front of the console. The production studio is opposite the dubbing studio, which is used for the creative spots. The FM stereo production facility has full stereo spot and tape recording equipment and can also be used on the air as well.

The foregoing will give you an idea of our overall operation. The problems in a multi-site operation are many. Obviously, the lack of communication is the biggest problem in an operation of this type. Through the use of three separate microwave systems, this has been reduced to a minor problem. The diesel generators at three sites have eliminated most power problems. This station, as is any other station, has been built to fulfill a need for a specific purpose. The built-in redundancy of the multi-site operation has been a blessing as far as maintaining maximum air time. The problems of maintenance have expanded three-fold, however, and good preventive maintenance is a must to prevent the whole operation from turning to a can of worms. Needless to say, a short presentation of this nature can only scrape the surface. If any of you would care to visit our operation, we would be delighted to have you. Just call and let me know. Bring your family and let them spend some time in our historic area. You'll be glad you did.

Active I-F Group Delay Correction of Television Transmitters

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We are in an era of television broadcasting where both the viewer and the broadcaster are demanding better equipment for true life-like color television transmission. As we see this trend toward ever tightening specifications, we become more conscious of differential gain, differential phase, frequency response, group (or envelope) delay, and other critical performance parameters. It is the purpose of this paper to acquaint the reader with recent advances in group delay equalization techniques.

Group delay is a type of distortion where one signal frequency passes through a system in more or less "time" than another signal frequency. It is mathematically related to phase shift as:

$$Tg = \frac{d\emptyset}{dW}$$

If the phase shift is **linear** with frequency, as in a transmission line, the delay will be the same for all frequencies. If, however, the signal is passed through a high Q resonant circuit, such as a bandpass filter, the phase will be **nonlinear** with frequency. A "timing" difference will, therefore, result between signals the center and edge of the passband.

In television broadcast systems there are several sources of group delay. The transmitter must include filters to restrict the upper and lower sidebands. These are commonly known as vestigial sideband and video low-pass filters. The sound-notch filter in the receiver by economic necessity is equalized at the transmitter. The notch diplexer has a high Q reject filter centered 4.5 MHz above the visual carrier which must be equalized. Amplifier tuning and cable losses may also be significant if excessive frequency response rolloff occurs.

Low-frequency delay errors have a significant effect on the luminance signal, while high-frequency errors affect primarily the chrominance signal. With increased use of electronic character generators, it is imperative that the luminance component be given a second look. Let us assume that the 2T pulse is representative of the transitions encountered in electronic lettering. A study of the spectral response of a 2T pulse as shown in Fig. 1 indicates that most of the energy is below 2 MHz.

Figures 2 through 6 illustrate the importance of group delay for faithful pulse reproduction. Figure 2 shows pulses from a system with the frequency response rolled off sharply at 4.18 MHz but with flat delay. The pulses show a small amount of ringing due to the missing high frequencies. Figure 3 shows the same system but with 100 ns delay introduced at very low frequencies. This much low-frequency distortion is acceptable for FCC specifications. Figure 4 shows 100 ns delay centered at 1 MHz. Figure 5 shows 100 ns delay centered at 2 MHz. Figure 6 shows 100 ns delay centered at 3 MHz. The magnitude of distortion is now much less than before even though the

SPECTRAL DISTRIBUTION OF A 2T SINE SQUARED PULSE

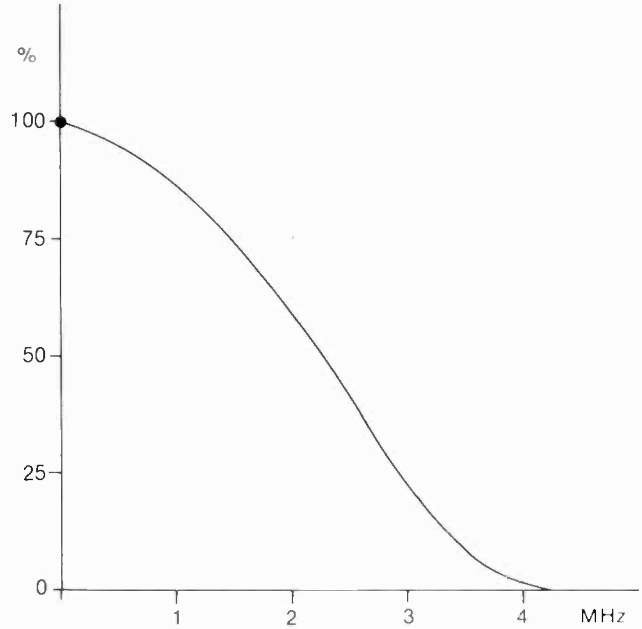


FIGURE 1

PULSE RESPONSE WITHOUT DELAY DISTORTION

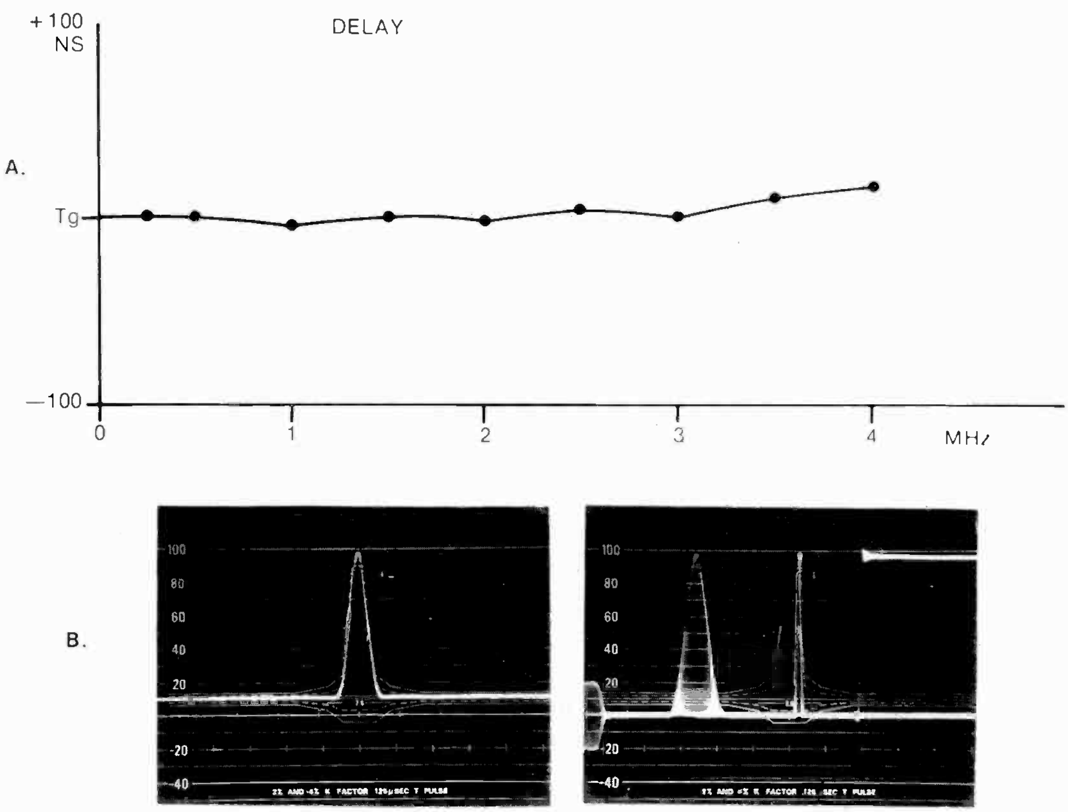


FIGURE 2

A. Delay Curve
B. Photo of 2T Pulse

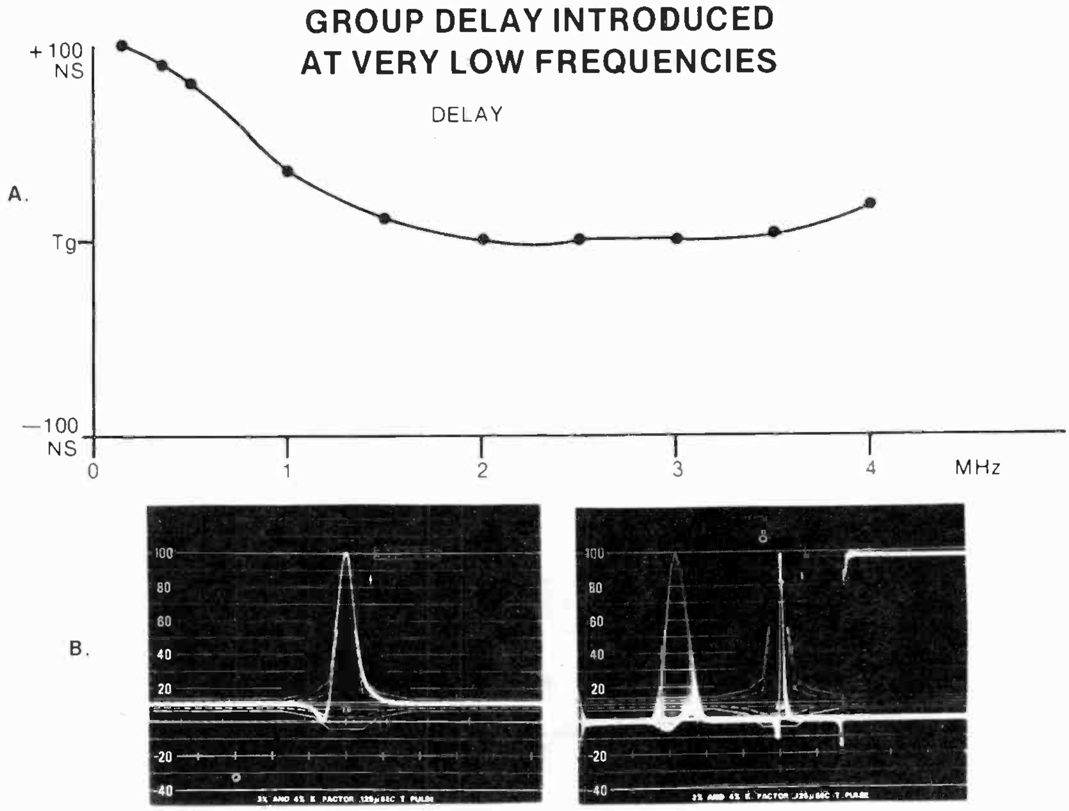


FIGURE 3

A. Delay Curve
B. Photo of 2T Pulse

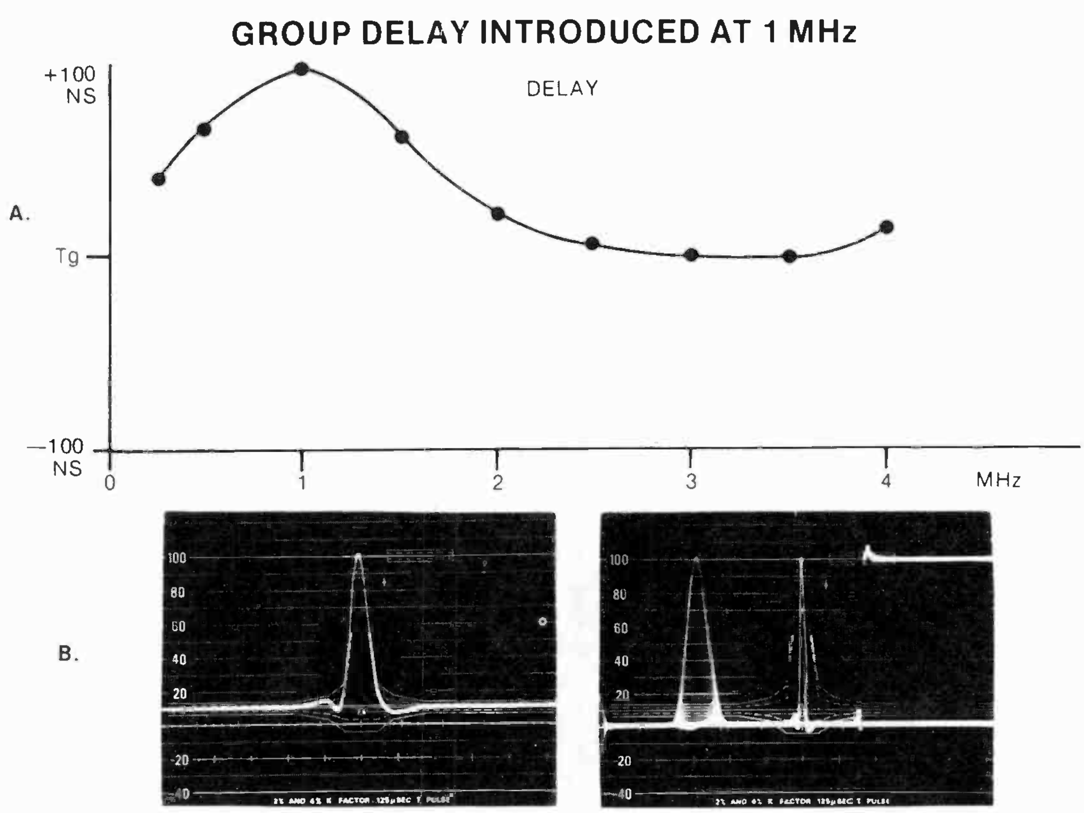


FIGURE 4

A. Delay Curve
B. Photo of 2T Pulse

GROUP DELAY INTRODUCED AT 2 MHz

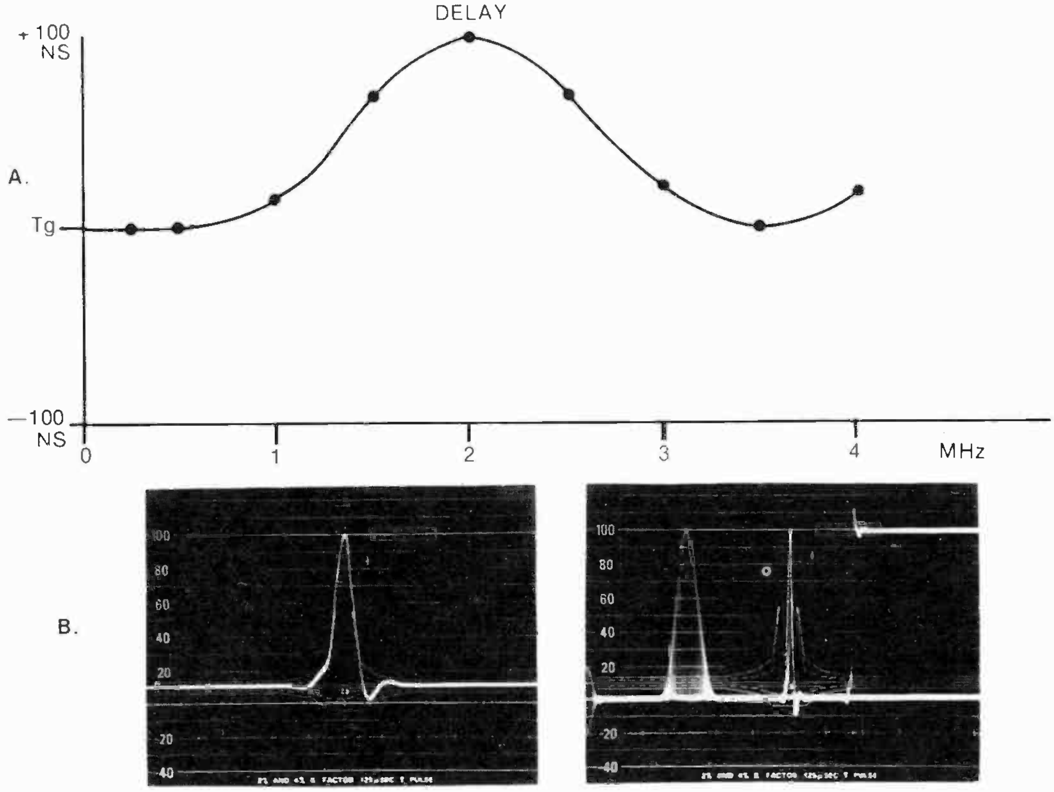


FIGURE 5

A. Delay Curve
B. Photo of 2T Pulse

GROUP DELAY INTRODUCED AT 3 MHz

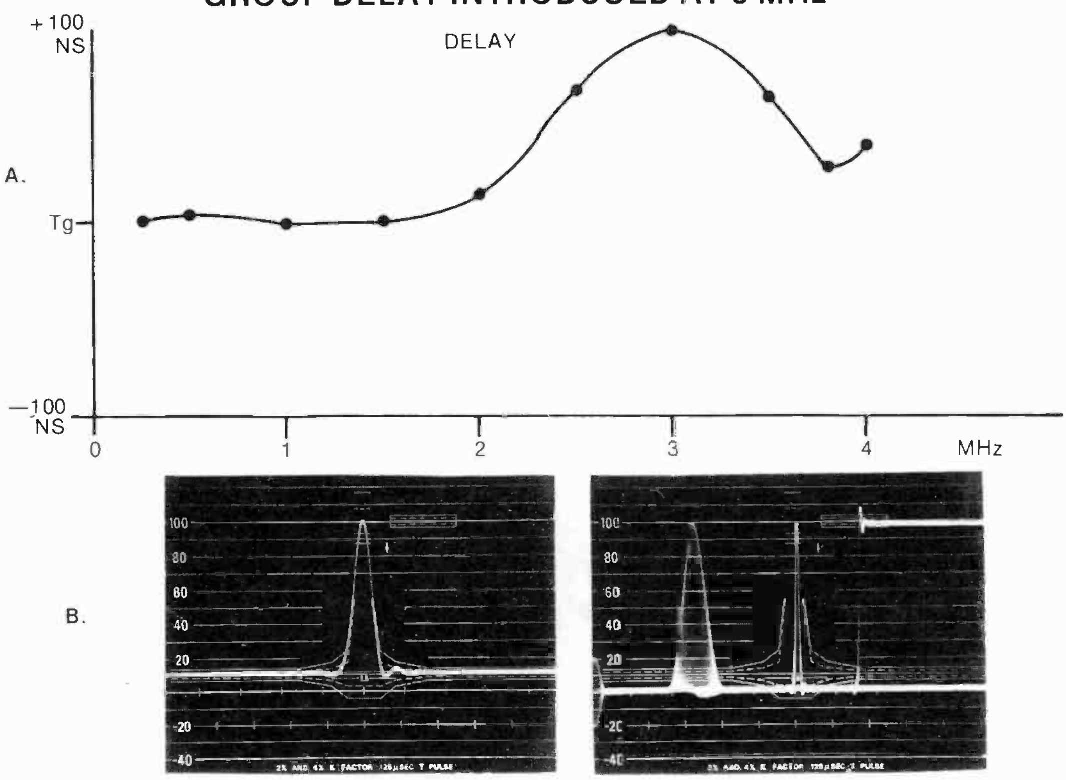


FIGURE 6

A. Delay Curve
B. Photo of 2T Pulse

group delay error is still 100 ns. Figure 7 shows 100 ns delay at 4 MHz. The pulse distortion is barely visible at this point, again suggesting that delay below 2 MHz be given careful consideration.

The vestigial sideband filter imposes group delay errors in the frequency region crucial to the 2T pulse and thus the luminance signal. Figure 8 shows the group delay curve for a typical VSB filter. The Nyquist filter in the receiver reduces the delay errors considerably due to the attenuation of the carrier and lower sideband. Even after demodulation, Fig. 9 illustrates that there is still sufficient group delay distortion to have a serious effect on the 2T pulse.

I-f modulation has brought with it a few new techniques. First the VSB filter. VSB filtering at i-f is just as valid as final frequency filtering, provided that all power amplifiers are highly linear or use i-f linearity correction to insure lower sideband cancellation. The VSB filter then becomes a low-power, low-cost bandpass filter to be switched in or out at will. Perhaps the most significant advantage is its higher percent bandwidth (being at a lower frequency). A wider bandwidth allows better control of bandpass shaping and better tuning stability.

I-f group delay compensation also has some distinct advantages. The VSB filter may be compensated by introducing group delay into the i-f passband as shown in Fig. 10. Video precorrection, by comparison, has limited capability since it attacks both the upper and lower sidebands simultaneously. I-f delay compensation has complete freedom to correct the upper or lower sideband as required. The group delay variation is thus minimized. The group delay ripple which remains is simply a function of the number of allpass networks used. Four allpasses are usually sufficient to hold the ripple at plus or minus 20 ns.

Figure 11 shows a 2T pulse of an i-f equalized transmitter operating at full power. Four allpass networks were used in this illustration.

The modulated 12.5T pulse provides an excellent test for chrominance-luminance timing errors. The spectral distribution of a 12.5T pulse is shown in Fig. 12. It can be seen that energy exists in comparatively narrow bands at the very low frequencies and at the color subcarrier. It should be kept in mind that measurements using the 12.5T pulse reflect only differences between chrominance and luminance and not the delay across the band.

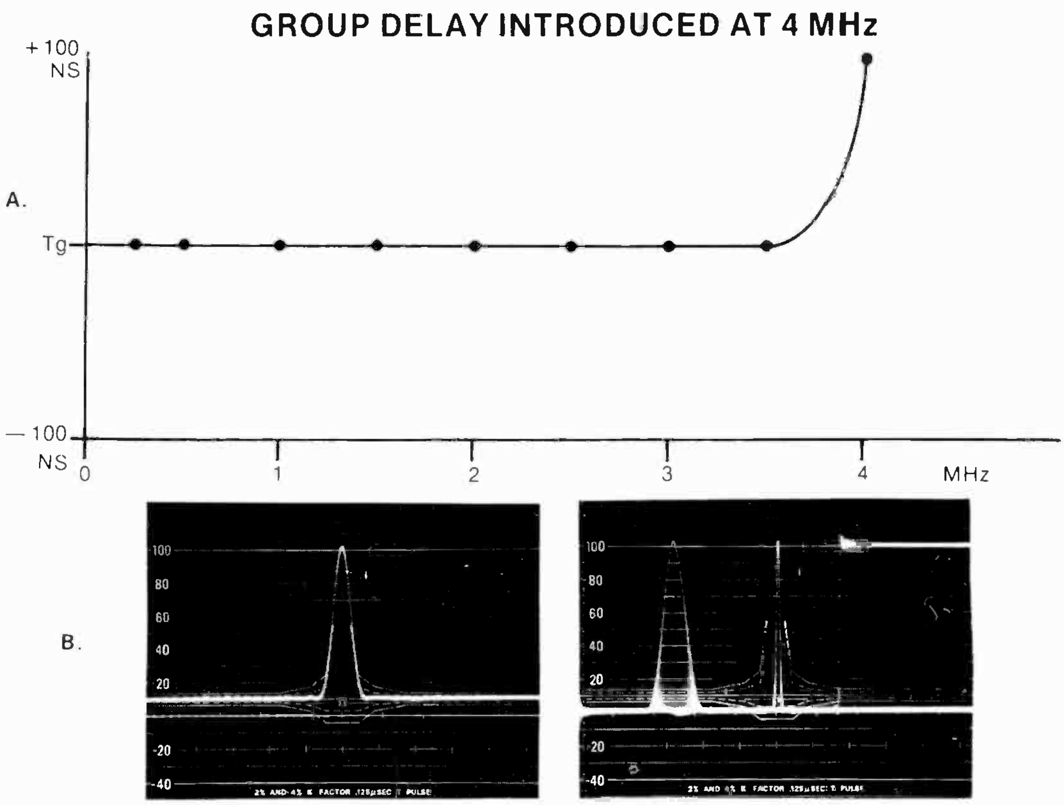


FIGURE 7

A. Delay Curve
B. Photo of 2T Pulse

GROUP DELAY OF A TYPICAL VSB FILTER

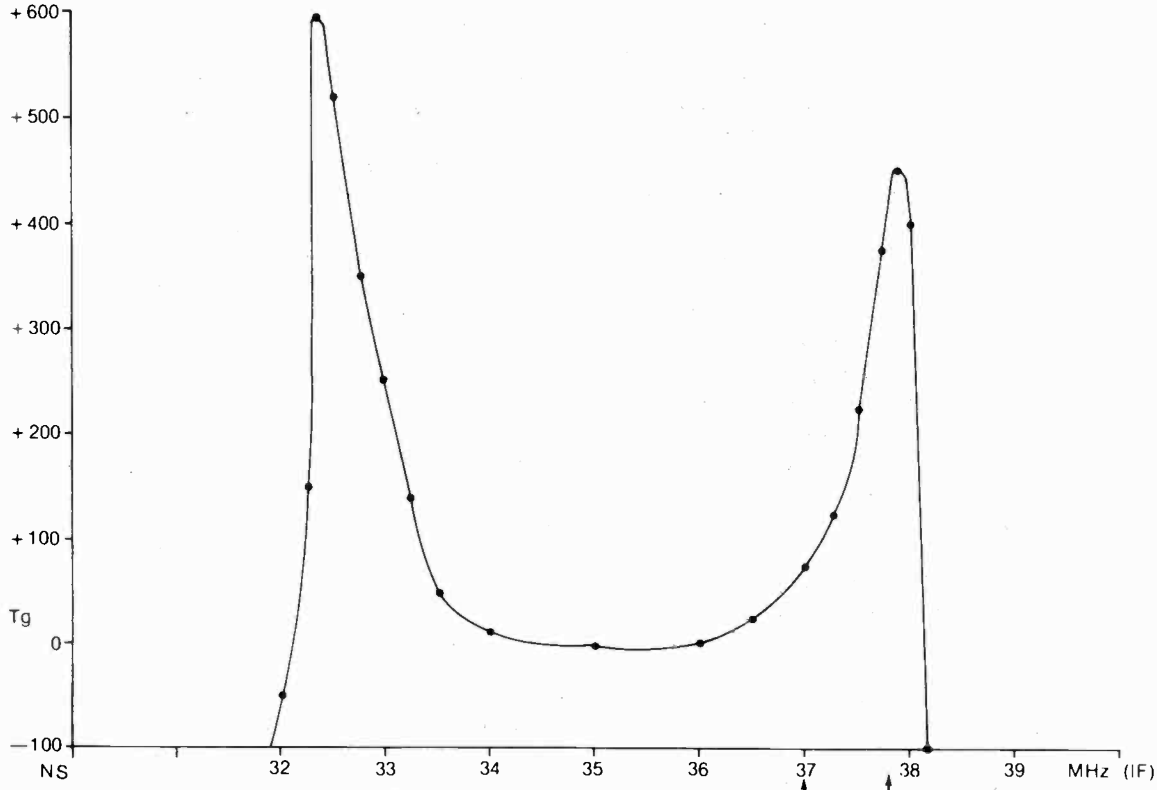


FIGURE 8

GROUP DELAY OF TYPICAL VSB FILTER AFTER DEMODULATION

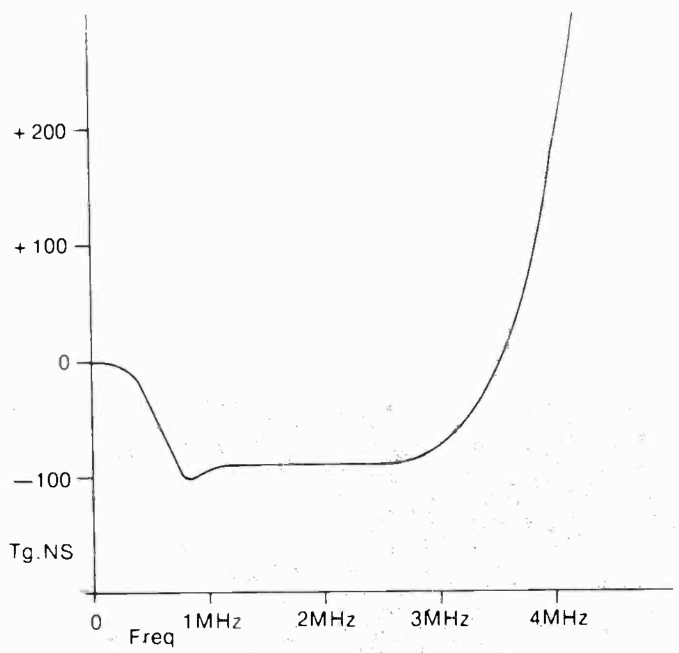


FIGURE 9

RELATIVE TUNING OF IF ALLPASS NETWORKS

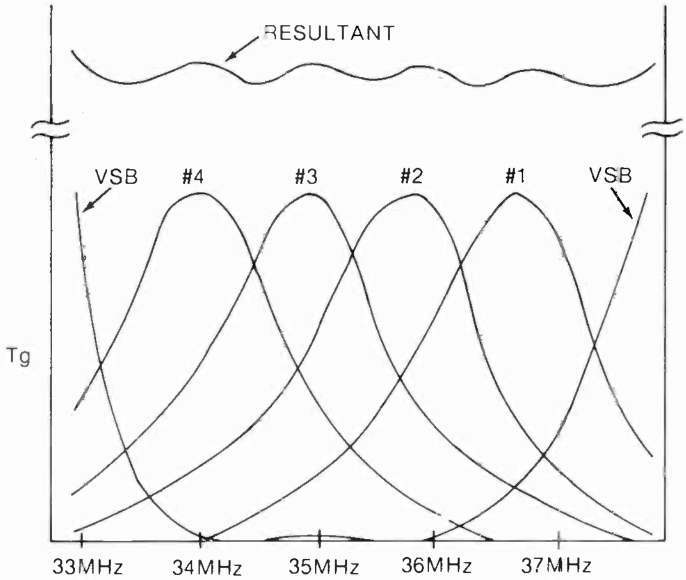
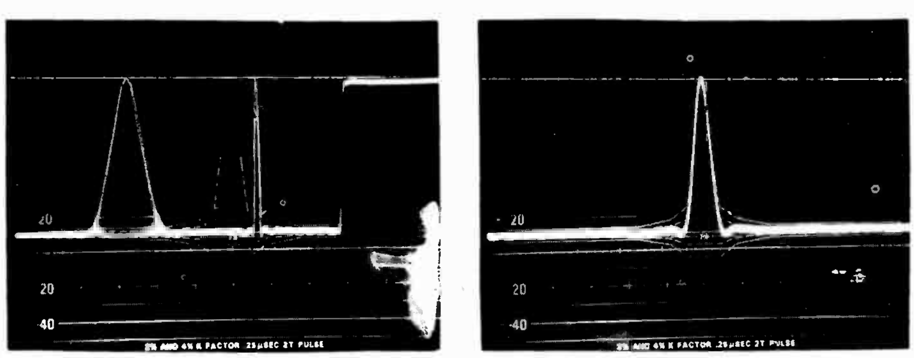


FIGURE 10

A. Group Delay of an IF Transmitter using four Allpass Sections for Equalization

B. Corresponding 2T Pulse



A.　　　B.

FIGURE 11

SPECTRAL DISTRIBUTION OF A MODULATED 12.5T SINE SQUARED PULSE

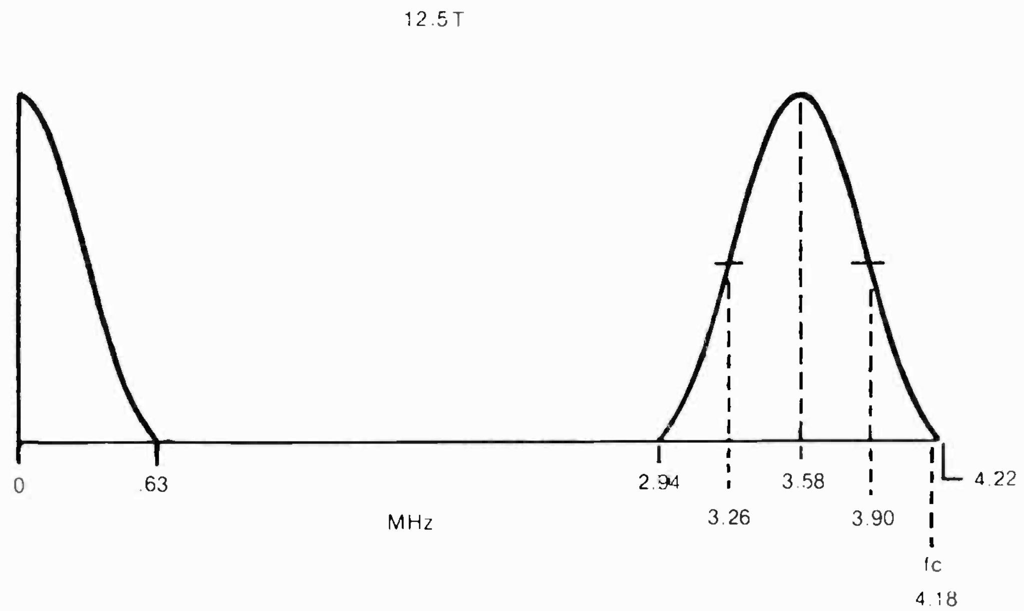


FIGURE 12

VECTOR DIAGRAM ILLUSTRATING QUADRATURE DISTORTION

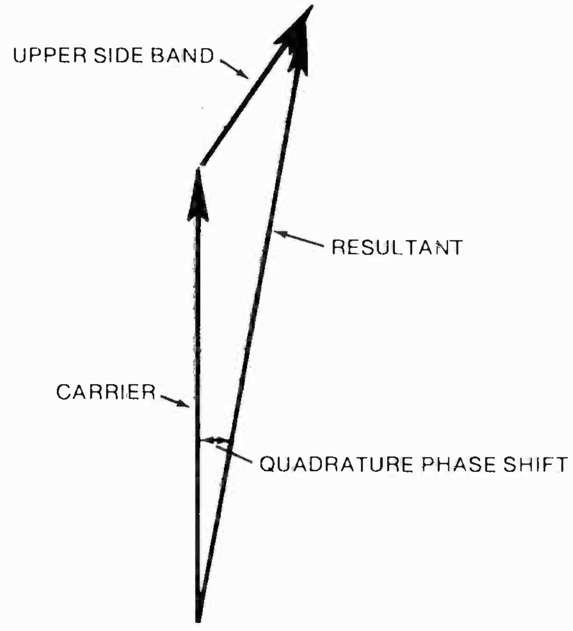


FIGURE 13

If the 2T pulse and the 12.5T pulse are reproduced faithfully, it may be assumed that a color television picture will be also. There are regions near 3 MHz and near 4 MHz where the pulses are comparatively insensitive. This is not serious, however, since little useful picture information exists in either area. This fact may be used to advantage if during adjustment the group delay is allowed to deviate from the ideal at 4.18 MHz while using the adjustment capability where it really counts, i.e., 0 to 2 MHz and at the color subcarrier.

When measuring transmitter performance using pulses, beware of two common pitfalls: quadrature distortion and nonlinear distortion. Quadrature distortion is inherent when envelope detectors are used in conjunction with vestigial sideband transmission. As illustrated by vectors in Fig. 13, quadrature distortion is an apparent phase shift of the carrier when energy exists on only one sideband. Some demodulators tune the i-f such that the carrier is 3 dB higher than normal to minimize the quadrature effect. A simple test for quadrature distortion is to reduce the pulse amplitude about 6 dB and see if the distortion shape and magnitude remain constant.

In pulse measurements it is assumed that the system under test has good linearity. If excessive differential gain, differential phase, or poor linearity exist, the test pulses may be distorted. System linearity may be checked by reducing the pulse amplitude 6 to 10 dB and moving the baseline to different picture levels. It is generally wise to make group delay adjustments at 50 percent APL with a low signal amplitude to minimize nonlinear and quadrature distortion.

Receiver equalization may be accomplished at video frequencies with no ill effects since the distortion relates only to the high video frequencies. It is important, however, to maintain flat low-frequency delay. Four allpass networks are needed to hold rigidly to the FCC predistortion curve. Figure 14 shows the approximate delay curves of a receiver equalizer.

Notch diplexer equalization is similar to receiver correction in that only the high video frequencies need compensation. A notch diplexer equalizer must be versatile to accommodate different notch diplexers. Amplitude response peaking is also needed with most notch diplexers.

THE ACTIVE ALLPASS NETWORK

By comparison, two commonly used passive allpass networks are shown in Fig. 15. It can be seen that frequency response, input impedance, output impedance, and group delay are all dependent upon the adjustment of each element. It is necessary to adjust all four components simultaneously to make tuning changes. More often, a system of selector switches and allpass networks are used. Each switch position represents a pretuned curve. One obvious disadvantage of this system is the lack of resolution between switch settings. The effects of low Q inductors and stray wiring capacitance make it very difficult to achieve broad frequency response with low ripple.

Figure 16 shows a simplified schematic of an active allpass network. Many circuit configurations may be used to achieve similar results. The input signal is split into two signal paths and processed separately. The lower signal maintains flat group delay and amplitude response. The upper signal passes through a series tuned circuit having the resonant frequency and circuit Q variable. The upper signal undergoes an amplitude response and group delay change much like a bandpass filter. The differential amplifier algebraically subtracts the two signals creating one with a flat amplitude response but group delay similar to the tuned input. The action of a conventional allpass network is thus duplicated. Note that the frequency and Q controls have assigned functions with little or no interaction with one another.

The active allpass network has greater flexibility than its predecessor. The Q control on the tuned circuit is used to determine the shape of the group delay curve as shown in Fig. 17. The frequency control is used to place the group delay where desired. A number of allpass networks are then stagger tuned across the passband using the frequency and Q controls on each allpass. The overall group delay variation is thereby minimized as illustrated in Fig. 10.

The variable phase and balance controls are related to the amplitude response. Nominally, a flat response is desired and may be achieved. It is possible, however, to correct other system deficiencies. The balance control normalizes the level between signal paths and may cause a peak or dip to occur in the frequency response at resonance. The phase control normalizes the phase between the two signal paths. It

APPROXIMATE TUNING CURVES FOR A RECEIVER EQUALIZER MADE UP OF 4 ALLPASS NETWORKS

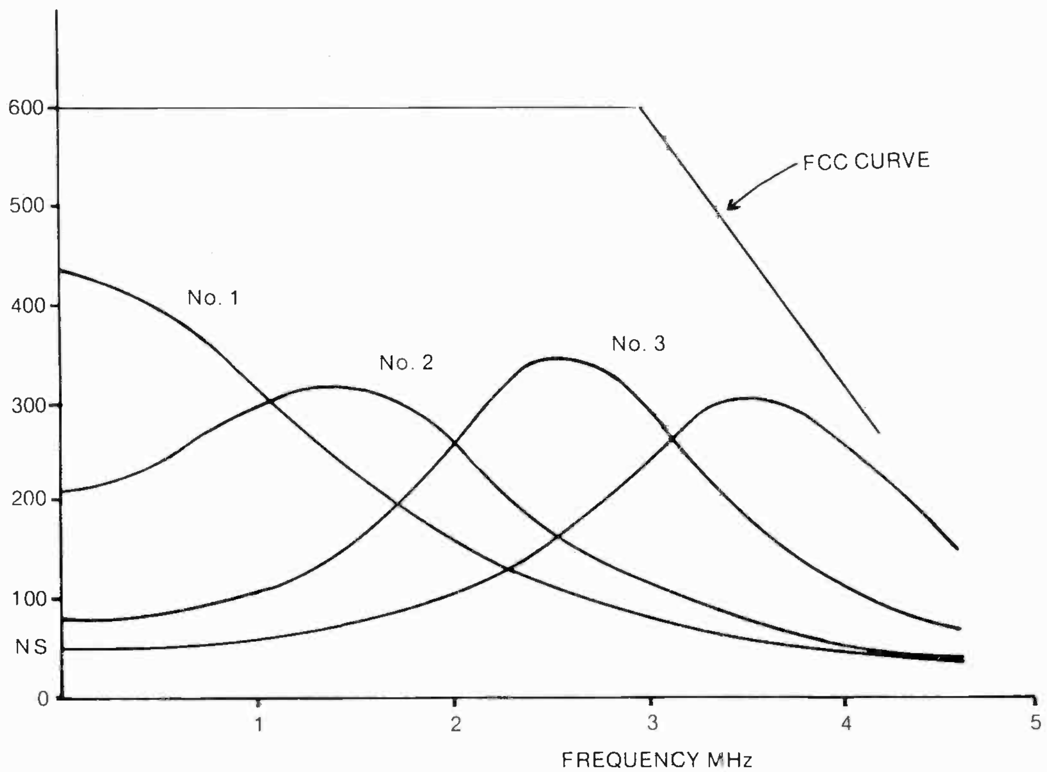
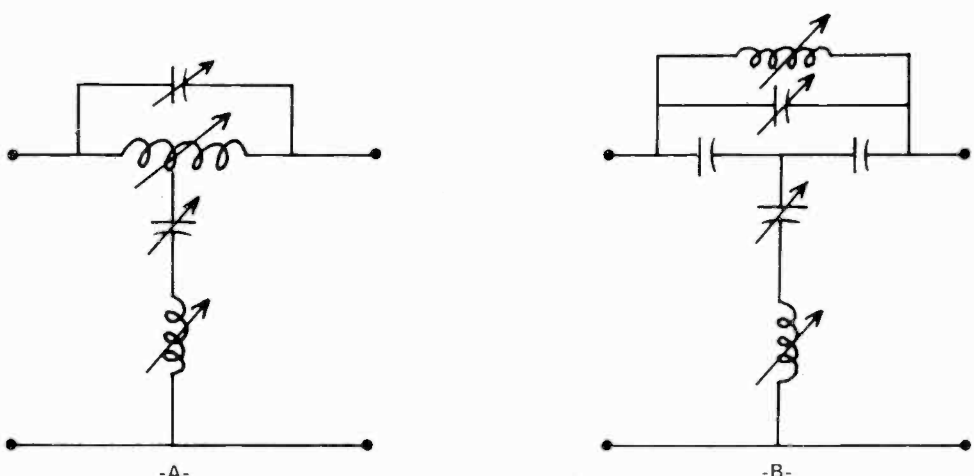


FIGURE 14

PASSIVE ALLPASS NETWORKS



A. Uses Tapped Transformer
B. Uses Split Capacitors

FIGURE 15

SIMPLIFIED DIAGRAM OF AN ACTIVE ALLPASS NETWORK

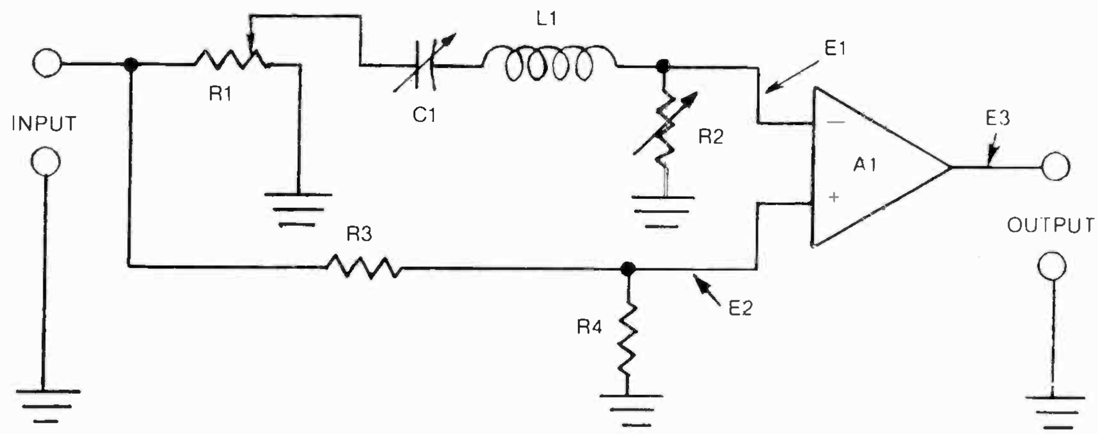


FIGURE 16

ILLUSTRATION OF FREQUENCY AND Q CONTROLS ON THE GROUP DELAY CURVE

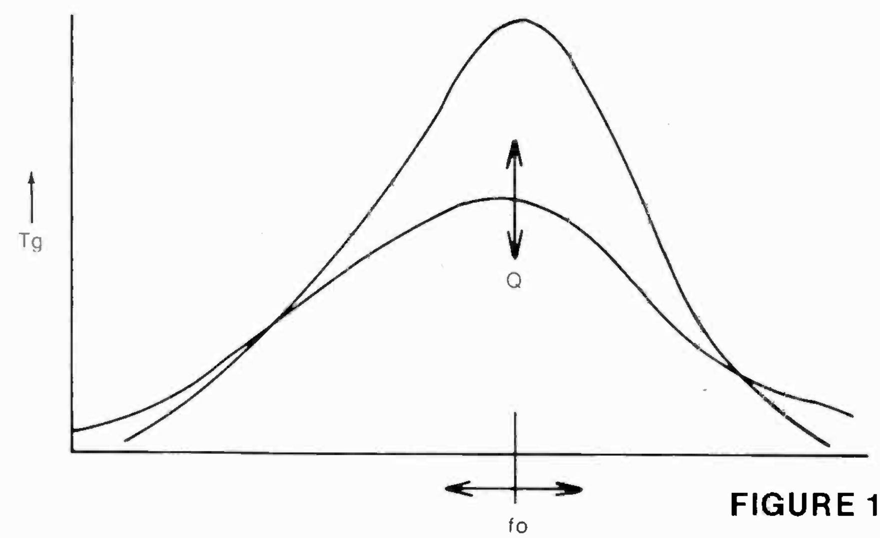
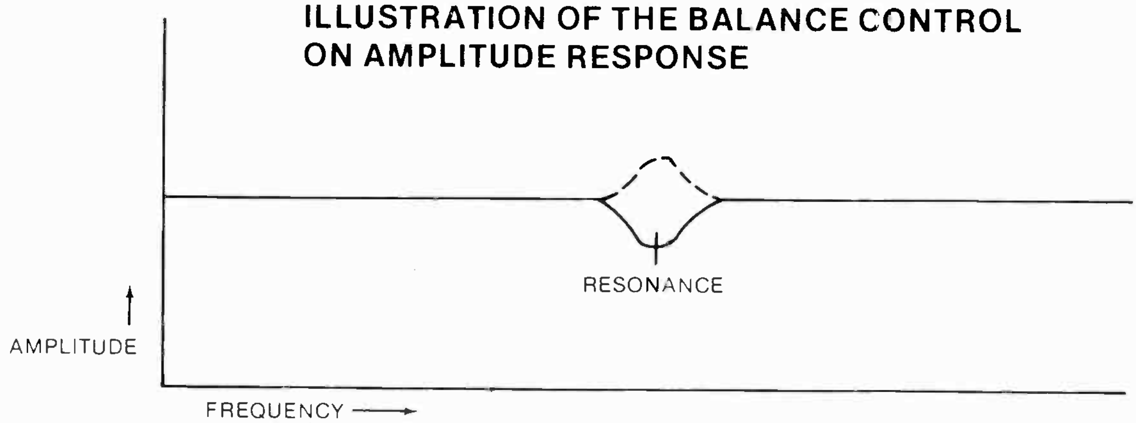


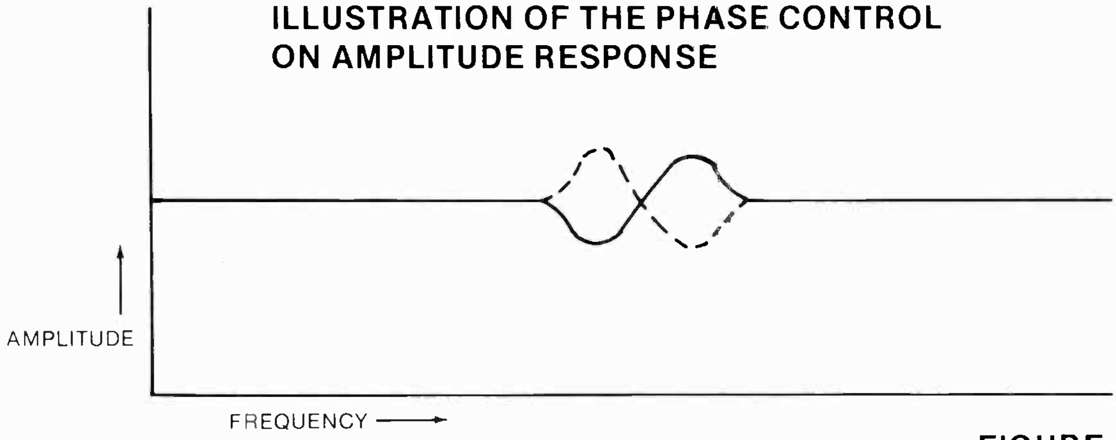
FIGURE 17

ILLUSTRATION OF THE BALANCE CONTROL ON AMPLITUDE RESPONSE



EFFECT OF "BAL" CONTROL ON AMPLITUDE RESPONSE

FIGURE 18



EFFECT OF "PHASE" CONTROL ON AMPLITUDE RESPONSE **FIGURE 19**

may be used to induce a positive or negative sine-wave shape to the frequency response.

It seems inevitable that with improved performance comes increased complexity. The active allpass is very simple to troubleshoot, however. By lifting the inductor of the resonant circuit, the entire network is simplified to a straightforward wideband amplifier. Troubleshooting is reduced to signal tracing and voltage measurement.

CONCLUSION

It is very important to equalize the low video frequencies accurately. Ghosting and loss of detail are evident if not equalized properly. The 2T pulse is representative of the luminance signal and, therefore, provides a good measure.

I-f group delay compensation is the best method known to minimize low-frequency delay errors. It may distinguish between the upper and lower sideband and apply the necessary correction to each.

Active allpass networks, whether i-f or video, provide much more flexibility in group delay adjustment. Amplitude response correction is also available if needed for other system deficiencies such as the notch diplexer.

TV Station Weather Radar—The Technical Considerations

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Technology Service Corporation
Santa Monica, California

TV stations frequently become interested in weather radar because of its potential as a "ratings builder" without the benefit of a thorough quantitative understanding of the capabilities and limitations of this equipment. This paper is written for the chief engineer and meterologist-weather forecaster. Factors which should be considered when planning a radar installation are discussed, including the difficult trade-offs which must be made between sensitivity, penetration, and resolution, all vs. rf wavelength. The empirical relationship between rain intensity and receiver signal level is described, along with some practical methods for estimating storm intensity by simple interpretation of the cathode-ray-tube display. The factors involved in antenna siting, electromagnetic interference, and personnel safety are also discussed.

In the early 1950s, radar equipment, originally developed during World War II, became available for commercial use. Specialized radars were developed for the airline industry to call the pilot's attention to weather cells which could cause uncomfortable and even dangerous turbulence. Marine radars were developed to help prevent collisions between ships at sea. The availability of surplus military radars, plus the mass production of airline and marine sets, brought the price of radar equipment to within reach of many TV stations, especially those located in areas of the country where the weather can be the news; e.g., the tornado belt of the south central states and the hurricane areas on the eastern and Gulf seaboards. As a result, dozens of TV stations are operating surplus military-, airline-, and marine-type weather radar and, thereby, providing a very useful weather reporting service to their viewers. Figure 1 shows a typical radar antenna installation. The purpose of this paper is to discuss the basic capabilities and limitations of this equipment and the effect of certain recent engineering improvements which have been made available. Installation considerations are also discussed.

WAVELENGTH CONSIDERATIONS

The four frequency bands below are commonly used in weather radars:

	Frequency Range	Wavelength
S band	1.5 — 3.7 GHz	($\lambda \approx 11$ cm)
C band	3.7 — 6.2 GHz	($\lambda \approx 6$ cm)
X band	6.2 — 10.9 GHz	($\lambda \approx 3.5$ cm)
K band	10.8 — 18.0 GHz	($\lambda \approx 2$ cm)

C band and X band have proven superior in large, high-speed aircraft and TV stations because of their ability to penetrate intervening rainfall and "see" the storms beyond. C band is superior to X band in this respect.

For a given size antenna, the higher frequencies produce sharper beams and, therefore, greater resolution. A high degree of resolution allows the radar to show

Fig. 1. Typical weather radar installation.

Table 1. Trade-offs vs frequency.

FREQUENCY	RESOLUTION	ATTENUATION	SENSITIVITY
Lower	Large Antenna Required (Higher Cost)	Little Attenuation Due to Intervening Rain (Can see the Storm behind the Storm)	Low Sensitivity (Sees light rainfall with difficulty)
↕	↕	↕	↕
Higher	Small Antenna Satisfactory (Lower Cost)	Greater Attenuation Due to Intervening Rain (Cannot see the Storm behind the Storm)	Higher Sensitivity (Sees light rainfall easily)

storm details such as tornado hooks and the individual cells within extended storm systems. Raindrops, the reflecting objects, are of a relatively uniform size and much smaller than the wavelength; therefore, a greater amount of radar energy is "back-scattered" for short wavelength signals than for long wavelengths. Thus, a high-frequency radar will be more sensitive and able to detect light rainfall and even snow. The representation in Table 1 shows the trade-offs vs. frequency for resolution, attenuation, and sensitivity.

Obviously, one cannot, without great investment, enjoy the best of all possibilities. For TV stations requiring wide area coverage, the higher-frequency bands, X and K, are less desirable because of the excessive attenuation which makes it difficult to detect heavy rainfall through even small amounts of intervening rain. S band, the lower of the available choice of frequencies, has negligible attenuation; however, the larger antenna and more powerful transmitter required to provide the required resolution and sensitivity frequently make this choice too expensive. Because of these considerations, C band is the most popular frequency for TV station weather radar. Several C band radars are in use today. The parameters listed below are typical of these systems.

	AIRLINE TYPE	GROUND TYPE
Transmitter power	60 kW	250 kW
Pulse width	2 microseconds	2 microseconds
PRF	400 pps	260 pps
Receiver bandwidth	1 MHz	0.4 MHz
Receiver sensitivity	—105 dBm	—108 dBm
Antenna diameter	30 inches	6-8 feet
Antenna gain	28 dB	38 dB or greater
Scan rate	90 deg per sec	0-30 deg per sec
Maximum display range	150 n. miles	250 n. miles

RANGE DETERMINATION

Figure 2 shows the capability of the first radar above for detecting distant rain falling at various rates. The performance of a weather radar is determined from the basic range equation modified to account for the unique back-scattering characteristics and resulting target cross section of hydrometeors, as raindrops, snowflakes, and hailstones are called. The equation has the form:

$$R^4 = \frac{P_t A_e c \tau}{32 \overline{P}_r} \sum_i \sigma_i$$

R = Maximum detection range
P_t = Transmitter peak power
A_e = Effective antenna aperture
c = Speed of light
τ = Pulse width
$\overline{P}_r$ = Average received power level
σ_i = Back-scatter cross section of a single hydrometeor

All the factors in the equation are straightforward except, perhaps, the summation. It represents the total back-scattering cross section of all the hydrometeors within the illumination volume of the radar transmitter pulse and is the result of a statistical process. Use of the equation is simplified by the graph of Fig. 3, which gives:

$$\sum_i \sigma_i$$

as a function or rainfall rate.

Use of this graph makes it quite easy to calculate, at least to the first approximation, the expected detection range of any weather radar against a storm of

Technology Service Corporation

MAXIMUM RANGE FOR CONTOURING AND DETECTION VS RAINFALL RATE FOR TYPICAL C-BAND TV STATION WEATHER RADAR

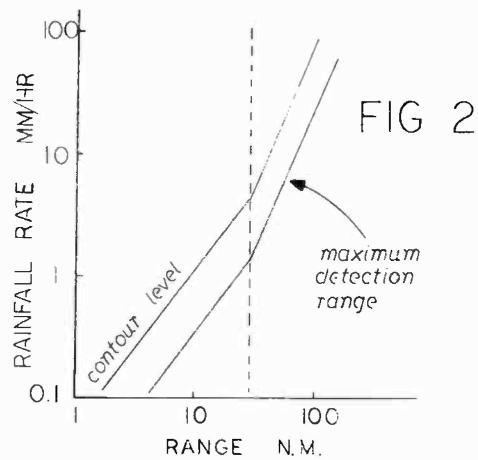

Fig. 2. Maximum range for contouring and detection vs rainfall rate for typical C-band TV station weather radar.

Technology Service Corporation

BACKSCATTERING CROSSECTION VS RAINFALL RATE

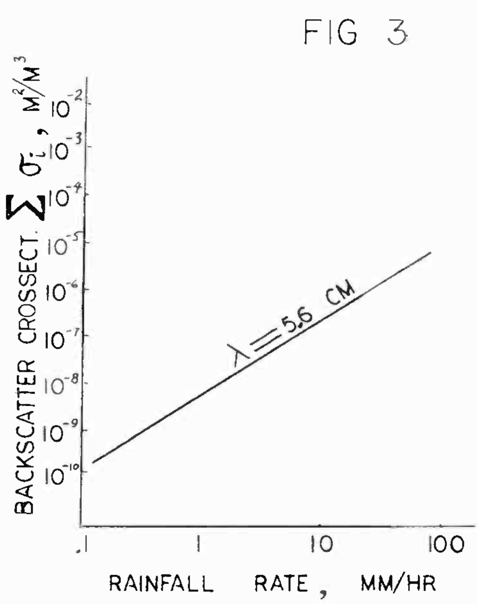

Fig. 3. Backscattering crossection vs rainfall rate.

given size and rain content, assuming that there is no intervening rain to attenuate the radar signal.

A factor to be kept in mind is that for large, beam-filling storms, the echo signal varies with the inverse square of range, whereas, for smaller, less than beam-filling targets, the relationship is closer to the inverse fourth power. The range at which the storm just fills the radar beam is indicated by the broken line in Fig. 2.

MEASURING RAINFALL RATE

Since the echo signal level from a storm is related to the number and size of the individual raindrops in the illuminated volume, one would expect to be able to use the radar to measure the rate at which rain is falling, say in inches or millimeters per hour. In large, typically S-band meteorological radars such as the WSR-57 used by the National Weather Service, rainfall rate is measured. In order to facilitate treatment of this problem, the reflectivity factor Z, is defined as:

$$Z = \sum_{i=1}^{N} D_i^6$$

where D_i is the diameter of the i^{th} raindrop in the illuminated volume. The radar reflectivity of a raindrop varies as the sixth power of diameter; therefore, Z is proportional to the received signal. It has been shown empirically that Z is related to rainfall rate by the equation:

$$Z = ar^b$$

The coefficient and exponent depend on the raindrop size distribution in the particular storm under consideration; however,

$$Z = 200\ r^{1.6}$$

is a widely accepted form of the equation. From this it can be seen that by measuring the amplitude of the returned signal in the radar receiver and relating it to Z, the associated rainfall rate can be deduced. This is usually done through use of a conversion graph similar to Fig. 4. In order to use this type of graph meaningfully, it is necessary that the radar be accurately calibrated. That is, the transmitter power, receiver sensitivity, etc., must be accurately known. In most television station radar, this is rarely the case and, as a result, any computation must be recognized as very approximate.

The curves of Fig. 4 are used in the following manner. Precision rf attenuators are inserted into the receiver front end until the echo signal from the particular range segment of the storm being observed has been reduced to the level of thermal noise as observed on an "A scope" (signal amplitude vs. range). It is convenient to stop the antenna scan with the beam pointing directly at the target of interest if this is possible. One then reads up the conversion graph to the amount of attenuation inserted and the rainfall rate in question is given by the left-hand ordinate. The ordinate on the right-hand side of the graph shows the Z factor.

ISO-ECHO CONTOUR

A limited, but more easily used, measure of rainfall rate is accomplished through use of the "iso-echo contour" feature provided on most weather radars. This technique does not require stopping the scan or use of an A scope.

In iso-echo receivers, the sensitivity is time-controlled (STC), usually by a square-law function in such a manner that the echo signal is independent of range for beam-filling targets. In practice, beam-filling targets are not encountered beyond say 50 or 100 miles (depending on antenna beamwidth). Consequently, the STC covers only that much of the display range sweep. Removing range as a factor in signal amplitude leaves the signal a function of target characteristic only; i.e., Z factor. A threshold level is established in the video amplifier and all signals above this level are inverted, causing the PPI display to show a black hole in storm cells, indicating that the rainfall in the "contoured" area exceeds the rate corresponding to the threshold setting. The iso-echo contour threshold is typically set at 10-15 mm per hour rainfall rate. Figure 5 shows normal and "contoured" PPI presentations.

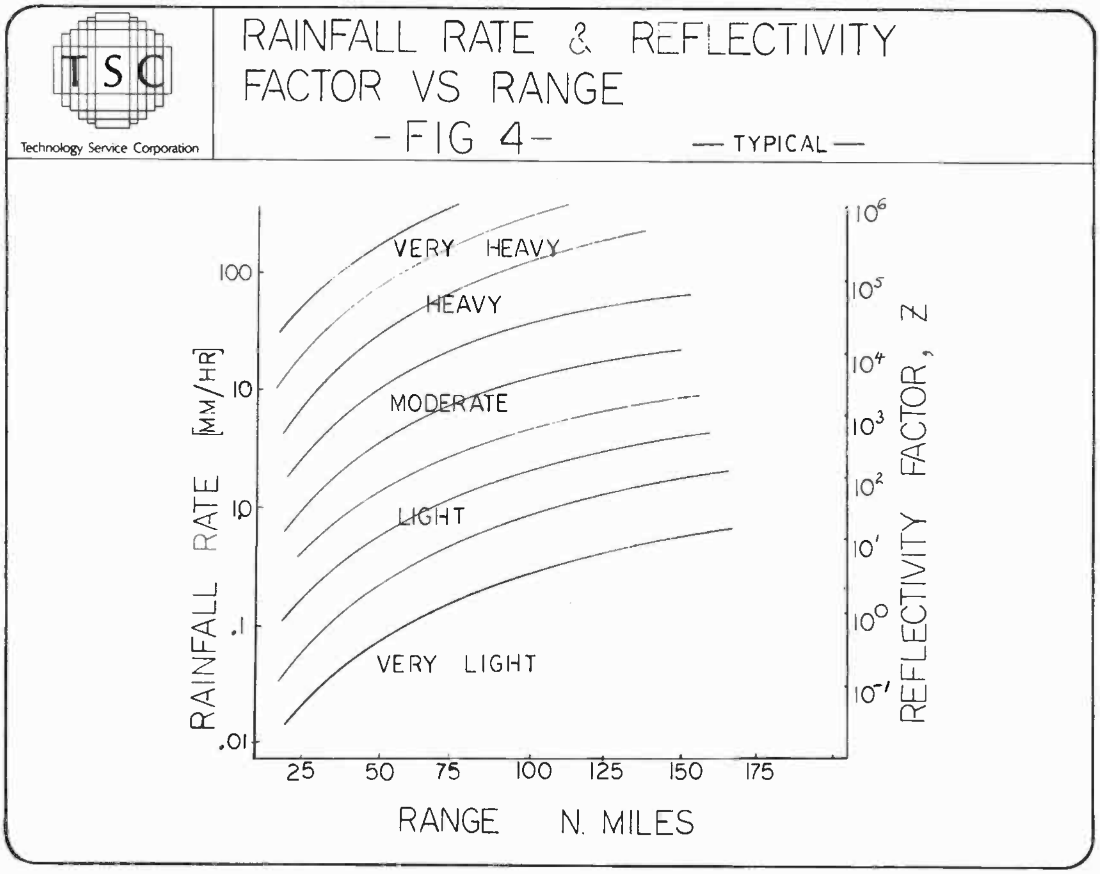

Fig. 4. Rainfall rate and reflectivity factor vs range.

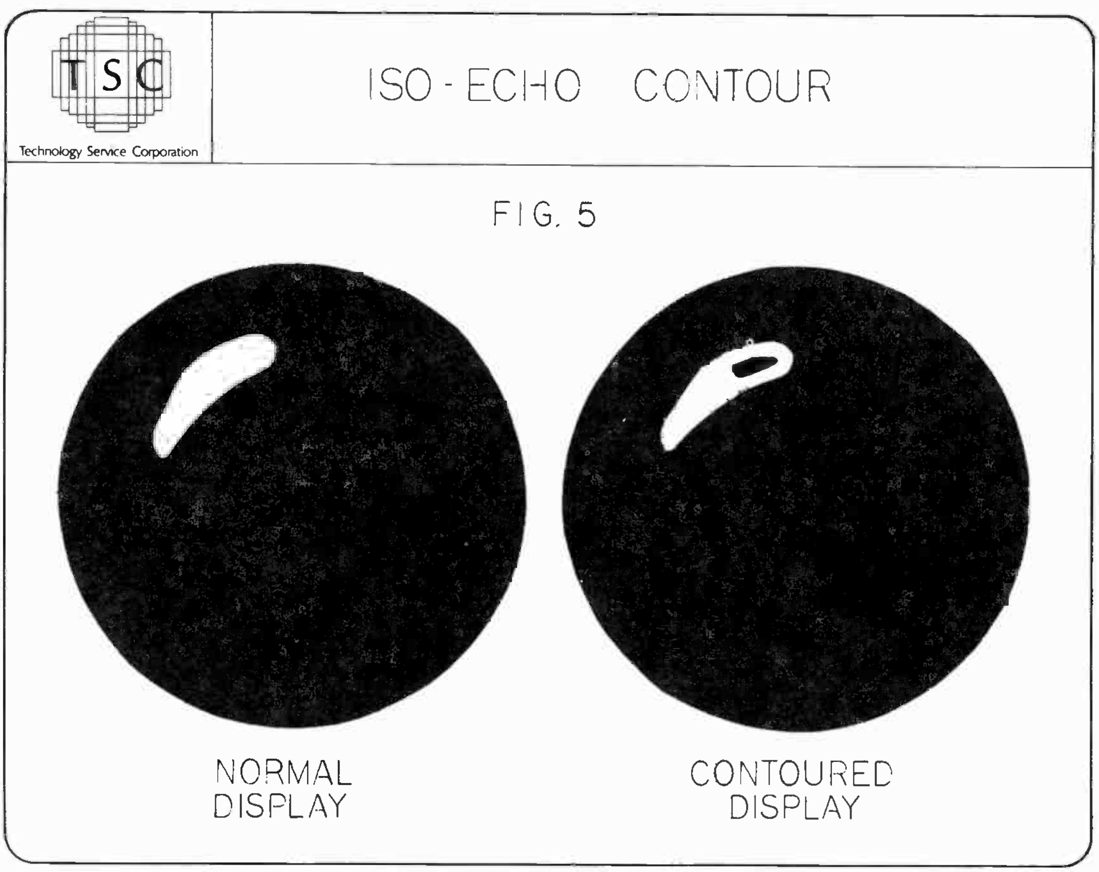

Fig. 5. ISO-Echo contour.

An interesting possibility for color equipped TV stations is to present contoured and normal echos in contrasting colors; e.g., green for normal echos and red for contoured ones. Since contouring is accomplished by a simple threshold comparison in the video channel, one can easily adapt the function to control color selection. This would make areas of heavy rainfall standout for clear recognition by any viewer.

LOCATING THE ANTENNA

There are several trade-offs which must be weighed in determining the optimum location (principally, height above ground) for the antenna. Chief among these are:

—Obstruction by nearby objects.
—Earth curvature effects.
—Ground clutter.
—Personnel hazard.

OBSTRUCTION BY NEARBY OBJECTS

This refers to nearby buildings, hills, and even the antenna-mounting structure when, for example, the antenna is mounted on a microwave tower. For the most part, the considerations are obvious; however, two comments are worthwhile. First, nearby buildings seem to always offer some transmissibility to the radar signal and, consequently, are rarely as troublesome as first supposed. Second, with respect to radar antennas mounted within or on the side of metal towers of the type typically used at TV stations, it has been found in several instances that very satisfactory performance can be obtained. This author would recommend covering the tower structure with a suitable thickness of microwave-absorbing material to reduce sidelobe generation and high VSWR due to strong reflected signals.

EARTH CURVATURE EFFECTS

For long-range weather detection, the radar beam is frequently set to an elevation angle that results in it being tangent or nearly tangent to the earth's surface. This setting positions the radar beam at its greatest usable angle of depression and, therefore, at ranges beyond the point of tangency determines the minimum height of weather targets in its field of view. Table 2 shows these minimum target altitudes for several antenna heights (neglecting refraction effects). It is clear from these figures that a highly elevated antenna position, such as a mountain peak or hilltop, is very helpful in allowing the radar to see low-altitude weather at the longer ranges. In general, there are three factors which influence, and in some instances determine, the height of the antenna. These are waveguide loss, ground clutter, and the need to locate the radar remotely from the studio.

For a radar antenna mounted at the 100-foot level of a tower, at least 100 feet of waveguide is usually required to connect the antenna with the radar receiver-transmitter unit, since it is not desirable to place the electronic units at such an inaccessible and exposed location. Typically, the two-way loss in 100 feet of C-band waveguide is in the order of 2 dB, which for long-range targets (inverse fourth power in the range equation) causes a reduction in detection range of approximately 0.5 dB or 12 percent. Thus, a 150-nautical-mile radar is permanently reduced at the outset to a 132-mile radar, a penalty that many TV stations will accept only reluctantly. The inducement to accept this penalty is the ability to see weather in the 12,000-15,000 foot altitude band at the maximum range. Referring to Fig. 2, it can be seen that at the maximum range of 150 nautical miles, a storm must be "very heavy" in order to be detected at all by the typical television station radar and that any loss in system sensitivity will likely result in important storms not being seen by the radar. For these reasons, long waveguide runs are to be avoided whenever possible.

GROUND CLUTTER

Ground clutter seems to be ever present in radar systems, and in TV station installations it is most severe at short ranges. This clutter is caused by both the main beam and especially the sidelobes striking the ground at large enough angles of in-

Table 2. Minimum beam elevation at distances indicated.

Antenna Height Above Ground	20 NM	50 NM	150 NM
-0-	264	1,562	14,872 ft.
100 ft.	39	939	12,533 ft.
2,500 ft.	—	—	5,177 ft.
5,000 ft.	—	—	2,627 ft.

cidence to cause detectable reflections; therefore, the condition gets worse with increasing antenna elevation. At large antenna elevation angles, as when operating on the shorter ranges, ground clutter due to the main beam is decreased.

Due to the increase in ground clutter with increasing antenna height above ground, there is very little to be gained by raising the antenna "tower distances" above flat ground. In contrast, however, there is much to be gained if the antenna can be located on a hill or mountain top several thousand feet above surrounding terrain. This, best of all possibilities, has a drawback in addition to the scarcity of suitable hilltops. Hilltops, when they can be found, are invariably out of town or on the edge of town, while the TV studio is usually downtown. In these cases, the station's transmitter is usually on the hilltop and a studio-transmitter microwave link is employed to send the TV signal from studio to transmitter. The radar picture requires a wideband link for transmission (in the order of several megahertz); consequently, something approximating a reverse STL is required in these cases. The only alternatives are to control the radar remotely by narrow-band signals or for transmitter site personnel to operate the radar. Frequently, transmitter sites are unattended and so the latter alternative is not possible. Remotely controlling the radar can be accomplished with signals sent over standard telephone lines. These signals must operate switching circuits at the radar to allow range-scale and contour-mode selection and analog circuits for setting the antenna elevation angle and the receiver gain. Of course, the disadvantage remains that the studio personnel cannot preview the radar picture before it is put on the air.

After all antenna location factors have been considered, the stations that install radar systems are most often those that can cover their market area by either mounting the radar antenna on the roof of the studio building or on a tower a few hundred feet or less from the station.

ELECTROMAGNETIC INTERFERENCE

Radar systems are vulnerable to electromagnetic interference from other nearby high-power transmitters. The most common source of interference is from other pulse radars, which appears as spiral, dotted tracks on the display screen, usually in the azimuth sector, pointing toward the offending transmitter. In severe cases, interference may enter the antenna sidelobes and produce "rabbit tracks" all around the screen. There are three methods which can be used to eliminate or reduce this interference:

—Operating one of the mutually interfering radars at a time.

—Increasing the frequency separation between the radars by selecting replacement magnetrons with displaced frequencies.

—In some cases, it is possible to rotate the plane of polarization of the radiated signal from one radar relative to the other by 90 degrees. This can be accomplished by replacing the waveguide feed section in the antenna with one containing a 90 degree twist.

Time-sharing radar equipment between two cooperating users is feasible under certain circumstances. When the two radars are operated by competing TV stations though, this is usually unacceptable.

Weather radars are designed to radiate a linearly polarized rf signal. There does not seem to be much difference in system performance between vertical and horizontal polarization. However, a radar designed to emit horizontally polarized waves will attenuate vertically polarized incoming signals by 10 to 20 dB. Here, then, is a method for reducing interference between two like polarized radars; one of them is converted to the orthogonal mode. The effectiveness of this technique in eliminating rabbit tracks will depend upon the intensity of the interfering signal. If the interfering signal is so strong that it is saturating the victim receiver, then this technique will probably not solve the problem. If, on the other hand, the interfering signals are of the same order of magnitude as normally displayed weather targets, polarization reversal will probably eliminate or greatly reduce interference tracks on the display.

EFFECT OF ANTENNA SIDE LOBES

It has already been pointed out that sidelobes in the antenna's vertical pattern can aggravate the ground-clutter situation in a weather radar. Sidelobe responses in the horizontal pattern can also cause trouble of a different kind. Three effects are worthy of mention:

—The creation of false targets.
—The elimination of real targets.
—Introduction of error into the iso-echo contour circuits.

When one of the sidelobes, such as the one indicated in Fig. 6, is scanned past an intense weather cell, it will, under certain conditions, generate a signal in the receiver, strong enough to paint a response on the display tube. The problem is that since the display sweep is synchronized to the antenna's main beam and the sidelobes are, by definition, angularly displaced relative to this reference (16 degrees in the case of Fig. 6), sidelobe targets appear offset from their true positions by the same amount. The sidelobes at plus or minus 90 degrees will cause false targets to appear a full quadrant away from their true position. The radar operator is usually unable to identify false targets as such and the average TV viewer never can. This effect can be minimized by decreasing the gain of the receiver so that weak targets are not detected by the sidelobes. Of course, this reduces the radar's sensitivity to weak returns from distant storms which may be of great interest.

A more obvious and certainly superior technique for eliminating false targets due to antenna sidelobes is to employ an antenna which has very low sidelobe responses. In the following paragraph, we will show that if the peak sidelobe responses of the antenna are kept more than 25 dB below the main-beam response, false targets can be virtually eliminated from the radar screen. At least one manufacturer of airline and TV station weather radar offers such an antenna which uses phased array techniques for beam formation (Reference 8.).

An important characteristic of weather targets is the very wide radar signal dynamic range which they produce. Reference to the Z-factor scale in Fig. 4 shows that the echo signal from heavy rainfall (200 mm per hour) is 50 dB greater than the signal from light rainfall (0.5 mm per hour). Imagine two weather cells in view of the radar as shown in Fig. 7. One of these cells is strong, containing rain falling at 200 mm per hour. The other represents light rainfall at 0.5 mm per hour. In order for the radar to accurately portray these cells, it must be able to detect the weak storm in its main beam while rejecting the intense cell from its sidelobes. These two storms reflect radar signals which differ by approximately 50 dB. Clearly, sidelobe responses must be, at least, 50 dB below the main beam. This calls for one-way sidelobes to be 25 dB down. If this condition is not met, then either the strong target will appear as a false target, due to the sidelobe response, or the weak target will not be detected in the main beam, depending on the setting of the receiver gain control.

Think now, back to the iso-echo contour function described earlier. Sensitivity time control is used to render the video signal level independent of range for beam-filling targets. If no errors are introduced, the video signal level after STC is a direct function of the rainfall rate in the storm being illuminated by the main beam. A threshold is established and video inversion at the threshold is used as a quantitative measure of rainfall rate. Antenna sidelobe responses introduce an error into this process which tends to make a storm cell look more intense than it really is. This is because the level of the video signal at a particular point in time is the sum of all echo energy at a given range, including any energy introduced through antenna sidelobes. The sidelobe responses can only add to the signal being developed by the main beam; therefore, the video signal tends to be amplified by this source of distortion. The total error in the rainfall rate measurement due to this effect is a function of the integrated effect of all sidelobe responses and, of course, to the rainfall rate distribution in the radar scan volume. An error of several dB is not unlikely under severe conditions.

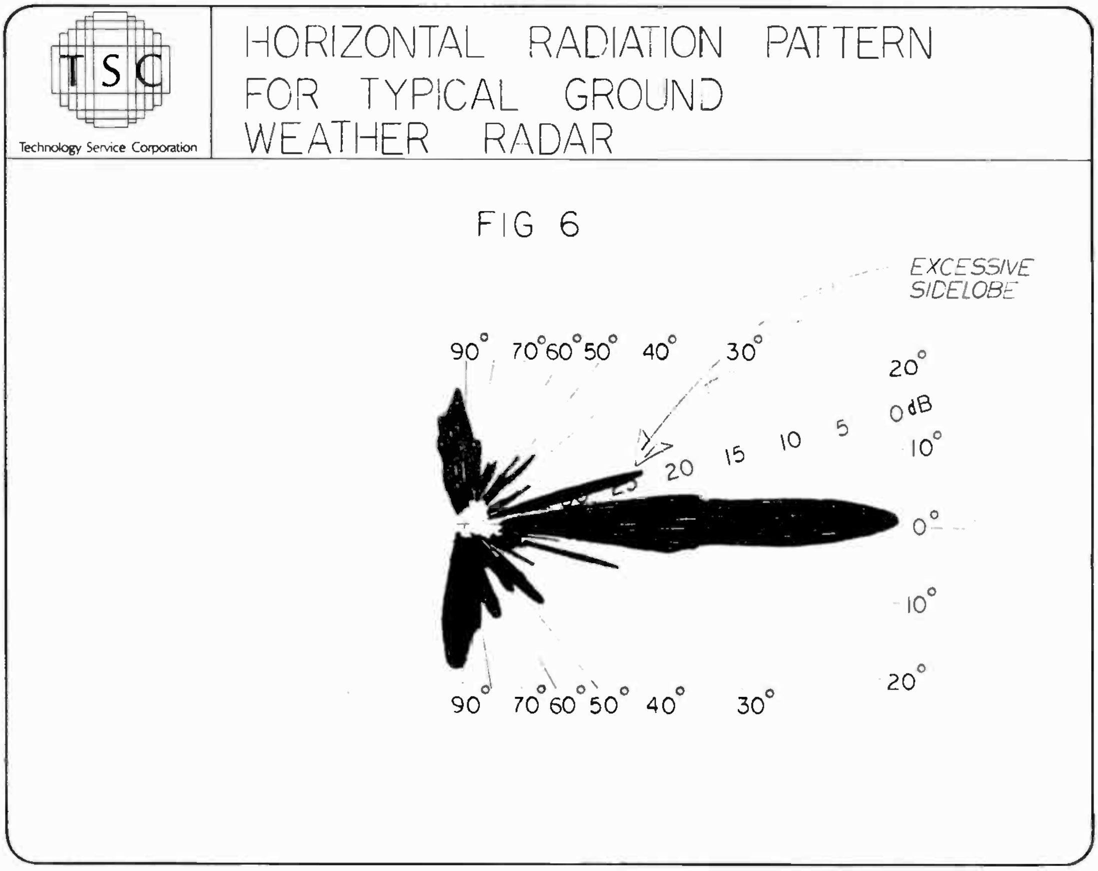

Fig. 6. Horizontal radiation pattern for typical ground weather radar.

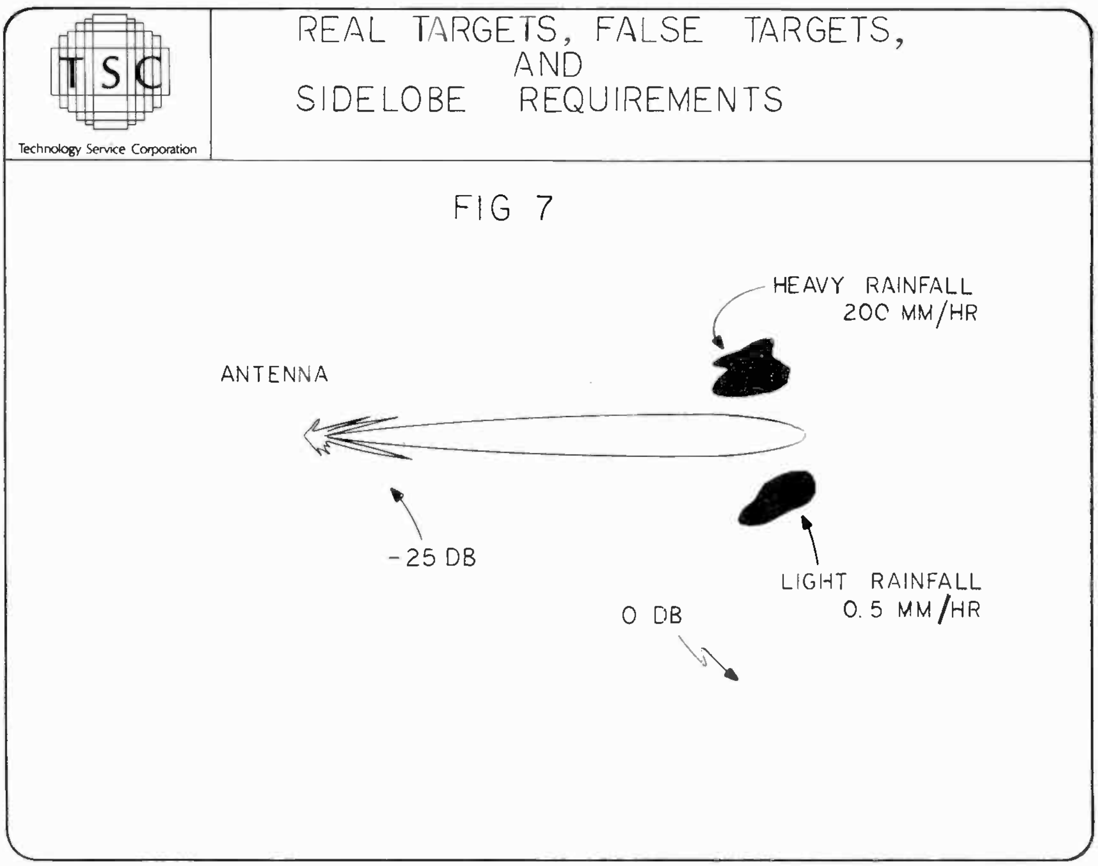

Fig. 7. Real targets, false targets, and sidelobe requirements.

PERSONNEL SAFETY

The intensity of radiation emitted by a typical weather radar antenna is sufficiently great that certain precautions should be taken to assure the safety of station personnel. The primary danger from high-power microwave sources is due to the heating which radiation induces in living tissue. The principle is the same as that utilized in microwave cooking. The eyes and internal organs are particularly delicate in this regard. Extensive research has been performed on this subject and it is generally agreed that radiation intensities below 10 milliwatts per square centimeter are not likely to be dangerous. The TV station manager or chief engineer, preferring to err on the safe side, would be well advised to prevent employees from absorbing more than one-tenth that figure. Except for certain anomalous behavior in the near-field of a parabolic antenna, power density decreases with distance. For the typical 60 kW, 0.0008 duty factor radar described earlier, the power density along the antenna's axis has reduced to 10 milliwatts per square centimeter at a distance of about 27 feet. The 1 milliwatt per square centimeter level is reached at approximately 90 feet. The heating effect of a scanning radar beam is reduced by the rotation of the beam. Therefore, these figures which do not take antenna rotation into account can be thought of as conservative and well on the safe side. For any particular radar system, the power-density characteristic should either be measured or calculated by the methods described in the reference. Any uncertainty should be resolved by consulting the manufacturer of the radar. The transmitter should always be turned off when people are required to work on or near the antenna. A further recommended precaution is to interlock the modulator with the antenna scan so that in the event of scan failure, the transmitter is automatically turned off.

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A Low-Cost TV Logging System

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The television logging system described in this paper evolved as a result of pursuing another goal—that of developing a low-cost system for slowing the pace of television programs so that their content could be analyzed more effectively. The unsatisfactory method then used was to expect an analyst to view a program when broadcast and, at the same time, prepare a complete and accurate abstract of its content. In the past, this method had been successful with entertainment shows because of the availability of scripts as a backup source of content. However, in complex news programs wherein a commentator introduces a rapid flow of information with voice-over filmed sequences, background visuals, and even an intentional or unintentional raised eyebrow, it became necessary for NBC to find a better system that would permit a more accurate and economical means of program content coding.

The obvious solution to the problem was to record the program and later play it back at a pace consistent with the data assimilation capability of the analyst. After briefly considering "audio-only" magnetic tape and film approaches, the ideal solution seemed to be a tape recording of both audio and video. Once the decision to tape was made, the question of which programs should be recorded arose. The first thought was to record news programs only. However, as the system began to take shape, it became irresistible to NBC management to have, in addition to news, a low-cost, accurate, easily accessible, complete source of "as broadcast" program content for entertainment shows, public affairs programs, and even commercials. These "complete" tapes would provide an invaluable aid to NBC in responding to the ever increasing inquiries by community, government, and commercial interests. The concept to record all NBC program output together with identifying date-time information (to permit accurate indexes) was thus formulated.

The NBC Stations Division recognized immediately that the essential elements for a new program logging system were at hand. If each day's video tapes were certified properly by operational personnel, these tapes could then qualify as a program log in accordance with FCC Rules and Regulations (Paragraph 73.669). Two such systems are presently installed and operating at NBC: one taping the TV Network since July 1972; and one taping the transmitted signal of New York Station WNBC-TV since February 1973.

THE RECORDING SYSTEM

The tape recording portion of the TV logging system has three principal elements:

The video tape recorder
The time-date generator
The recorder-monitor

The Video Tape Recorder

For several years, helical scan (or slant-track) video tape recorders have been used in a time-lapse mode to reproduce video at reduced frame rates. However, it has been only relatively recently that the growing market demand for closed-circuit television surveillance equipment has pressed manufacturers to equip low-cost tape recorders for the time-lapse mode of operation. Several good helical scan recorders so equipped are now available.

Figure 1 is a picture of one of them. In addition to recording in accordance with EIA-J format at the normal 7½ inch-per-second speed, this recorder will also record at approximately one-third inch-per-second. At this low speed, only one video frame is recorded every one-half second; therefore, a standard 7-inch reel of ½-inch video tape will record for a 24-hour period.

A closer view of the recorder control panel (Fig. 2) shows the function switch which allows an operator to select either the time-lapse or normal modes. All other operational controls normal to a tape recorder (play, fast-forward, rewind, pause, etc.) are solenoid-activated by the square, black pushbuttons seen at the lower right.

As sometimes happens in television, the video system worked effortlessly, but the audio was a source of problems from the outset. Because the application for which the recorder was originally adapted was that of surveillance, the audio at the one-third inch-per-second tape rate was not used to any great degree. The NBC application demanded at least intelligibility, and hopefully much better. The trade-off was, of course, between audio fidelity and tape speed. However, the plan to have one reel of tape to represent one day's TV programs was so compelling that several months' work with the manufacturer was expended in an effort to improve the audio quality to an acceptable level.

The first thing done was to exchange the record-playback head for one with a narrower gap. This, together with an equalization change, extended the frequency response from a high of about 1000 Hz to 1500 Hz—not quite good enough for the hi-fi enthusiast, but just adequate for speech intelligibility.

As so often occurs in the engineering world, this improvement exposed another problem—that of tape flutter. The correction of this class of problem usually means costly modification to the mechanics of the tape transport system. The initial look at

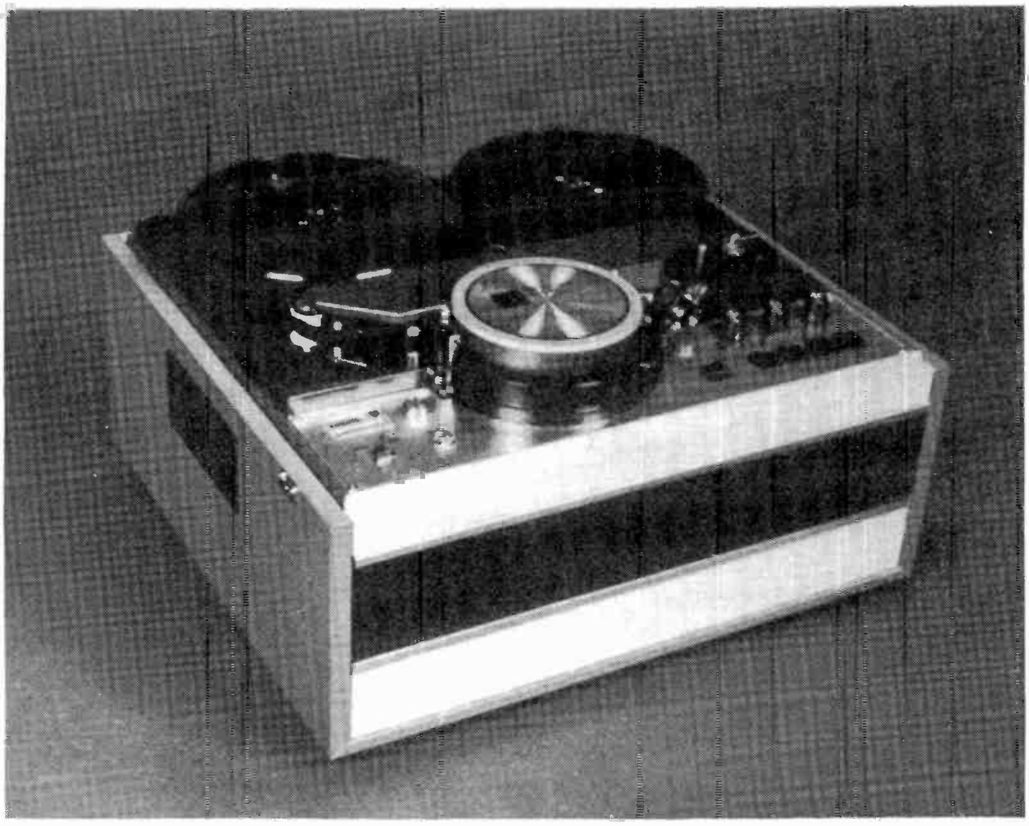

Fig. 1. Overall view of recorder.

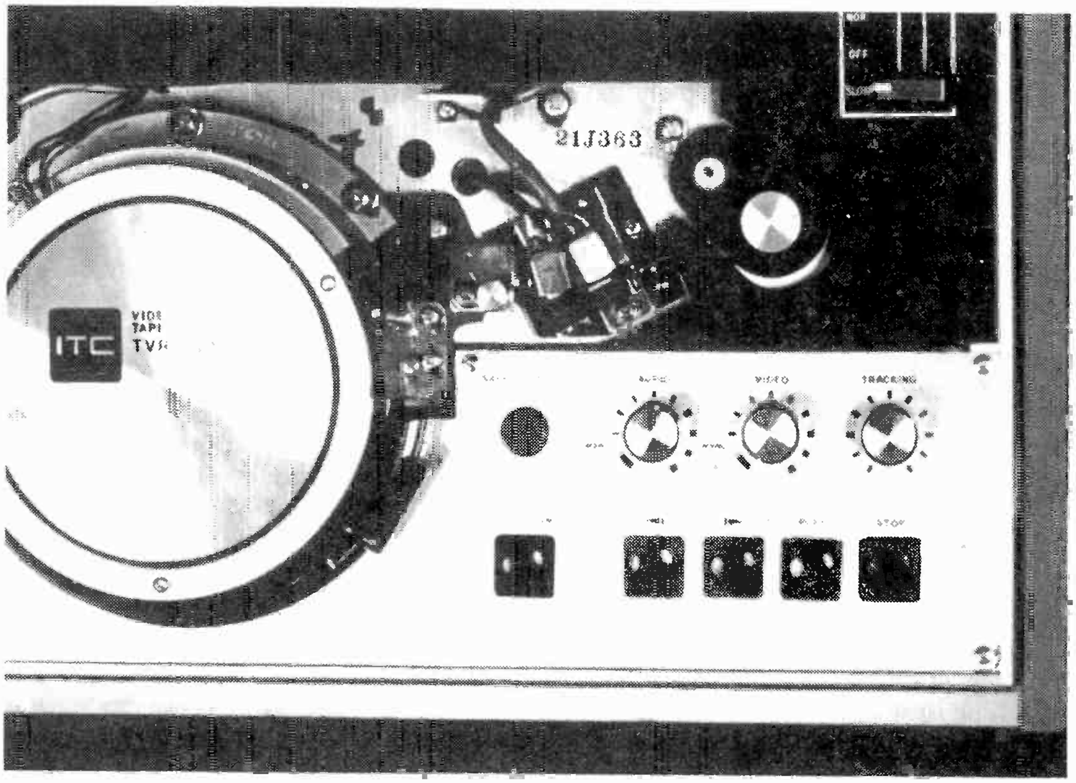

Fig. 2. Closeup of recorder showing audio head, pushbuttons, etc.

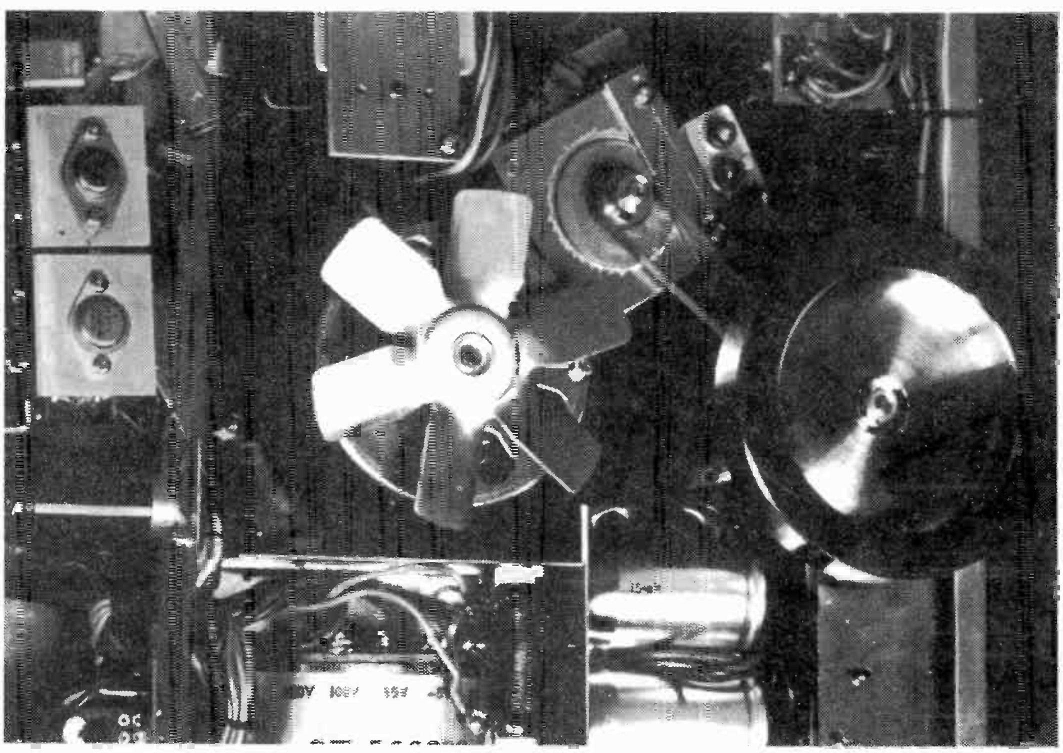

Fig. 3. Closeup view of recorder mechanism showing flywheel.

the high-density packaging of the recorder's four motors, solenoid control mechanisms, and transistor circuit boards, indicated little room for added stabilizing equipment. However, a closer look at the capstan-drive pulley disclosed that there may be just room enough for the smoothing mass of a flywheel. Figure 3 shows this flywheel as installed. It was successful in improving the flutter from an average 4 percent to 1½ percent peak-to-peak, which made a dramatic improvement in intelligibility. At this point, the video and audio quality was deemed acceptable to the NBC ad hoc committee functioning in this decision.

At the heart of any logging system is the identification of the date and time. The generator pictured in Fig. 4 accepts a composite video signal, adds to it the date, the time to the second, the station call-sign, and delivers two composite output signals. The only vendor modification required by NBC was the addition of a separate precision 60-Hz signal input to drive the digital clock as an alternate to the use of power-line frequency sampling. The pushbutton controls on the front panel are used to set the day and time. The station call-signs and the location of the alphanumerics on the raster are set at the factory.

Figure 5, a diagram of the record system, shows a television receiver-monitor in addition to the previously described slant-track recorder and time-date generator. For logging purposes, a sample of the station's transmitted signal is used to feed the system. This off-the-shelf TV receiver comes equipped with a multiconductor cable which connects it with the tape recorder and facilitates the exchange of audio and video signals between monitor and recorder. In this case, the record signals are fed externally to permit the date-time signal to be added to the video. However, during playback the cable is used.

Figure 6 shows the final recording installation, used in this instance to record daily TV Network programs, in the rack at the left. Note the two receivers and tape recorder plus the time-date generator barely visible at the very bottom of the rack. The extra recorder is used to provide a redundant, protective copy in case of system failure. However, there has been no such failure since this installation was made in mid-1972. The system has been in operation for over six months, and not even a tape head has been replaced.

THE PLAYBACK SYSTEM

One of the playback operating positions is shown in Fig. 7. NBC analysts find that tape playback is simple and convenient. The tape loading, threading, and operation is about as uncomplicated as that of an audio tape recorder.

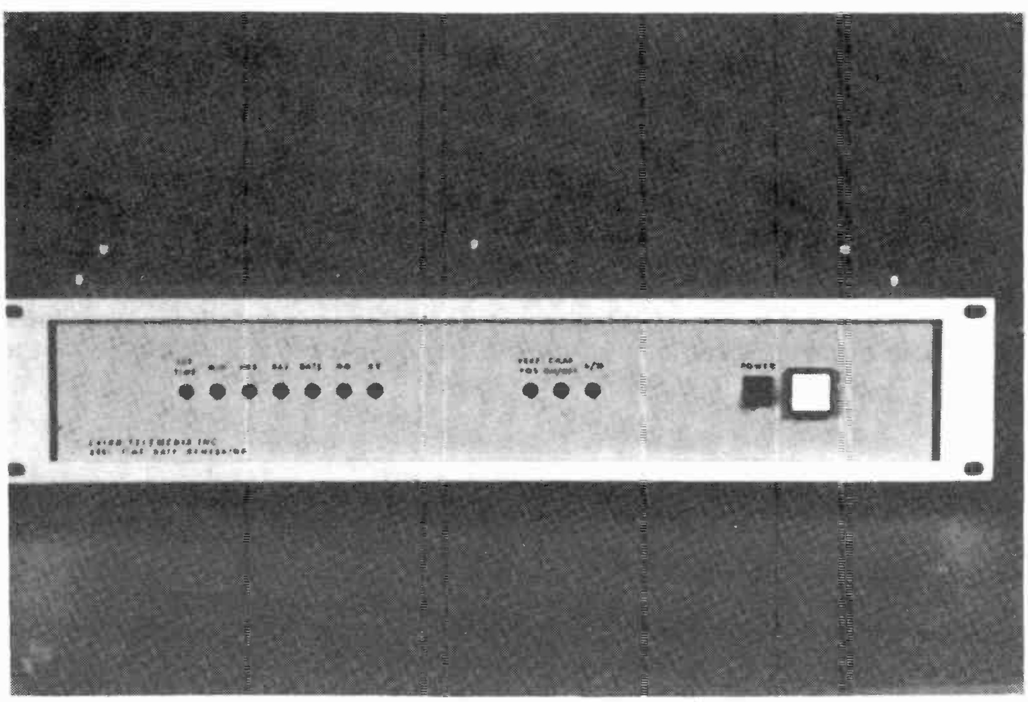

Fig. 4. View of time-date generator.

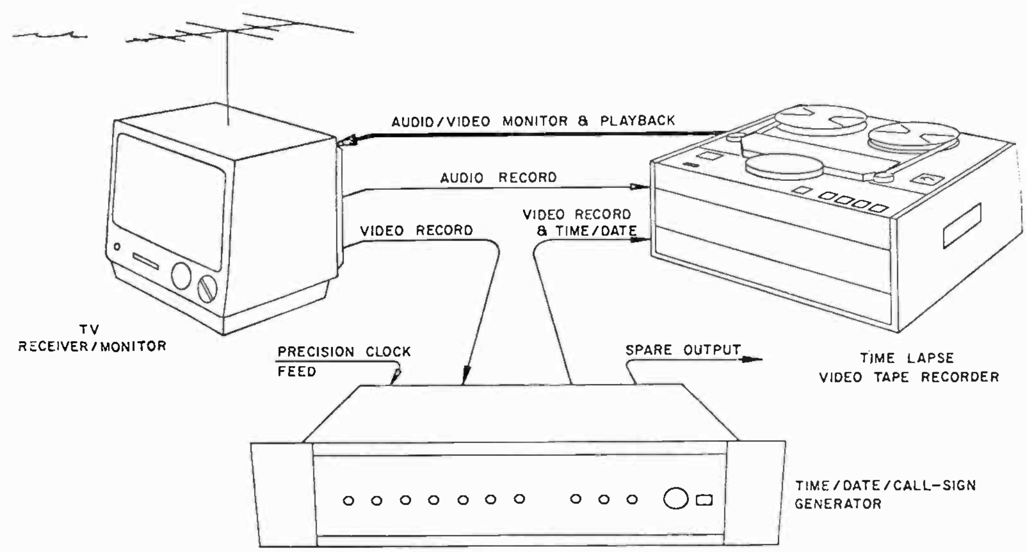

Fig. 5. Record system block diagram.

Figure 8 is a view of the monitor showing a picture of a typical NBC news show as it would appear to an analyst. Note the time, the NET designation for network, and the date at the top of the picture. When the program, recorded in time-lapse mode at 1/3 inch per second, is played back in the normal mode at 7 1/2 inches per second, the clock runs about 24 times faster. This feature is extremely useful in locating time-indexed programs rapidly. A whole day's recording can be viewed in less than one hour. Under these rapid-playback conditions the audio, of course, is meaningless.

One problem thought to be bothersome at the beginning of the project was the momentary breakup occurring between the ½-second picture sequences. The precise instant of breakup, frozen in Fig. 9, is caused by the playback head reading both video frames at the area of transition. It is unavoidable using this type recorder and must be "lived with." Once the analyst became accustomed to the discontinuity, it did not appear to cause undue eye fatigue as originally feared.

As an aid in optimizing the system for audio intelligibility, two additional steps were taken during playback. First, a set of comfortable headphones having a restricted frequency response was worn by the analyst. This helped filter out electrically and acoustically generated background noise. The second audio aid was the addition of an inexpensive audio equalizer used to match more closely the audio frequency response of the program to the hearing of the analyst.

In addition to having semi-permanent locations for tape playback positions, a portable unit (shown in Fig. 10) was developed that could be wheeled to offices throughout NBC when a need developed to consult program-log material. This particular unit happens to be equipped with a tape recorder of a different manufacturer than shown earlier. The control panel of this unit features an adjustment knob which allows a continuous adjustment of playback speed. This is helpful in locating specific time-indexed sequences.

NBC currently maintains a library of daily program tapes for both the Television Network and the New York Station, WNBC-TV. By mid-1973, the installation of these logging systems will be extended to include all NBC-operated stations. A portion of the Network library is shown in Fig. 11. This library is centrally located so that all NBC departments may have easy access to it.

COST

This presentation is entitled, "A **Low-Cost** TV Logging System, and the question can be anticipated—low-cost, compared to what? The chart of Fig. 12 summarizes the main costs to operate a minimum TV logging system using the type of equipment described during this presentation. It is assumed that recorders will be overhauled twice a year. The second recorder can be used both as a backup to the main recorder and as a playback system when required. Note the sensitivity of the total cost to the cost of video tape, even under the assumption that tape is recycled every three years.

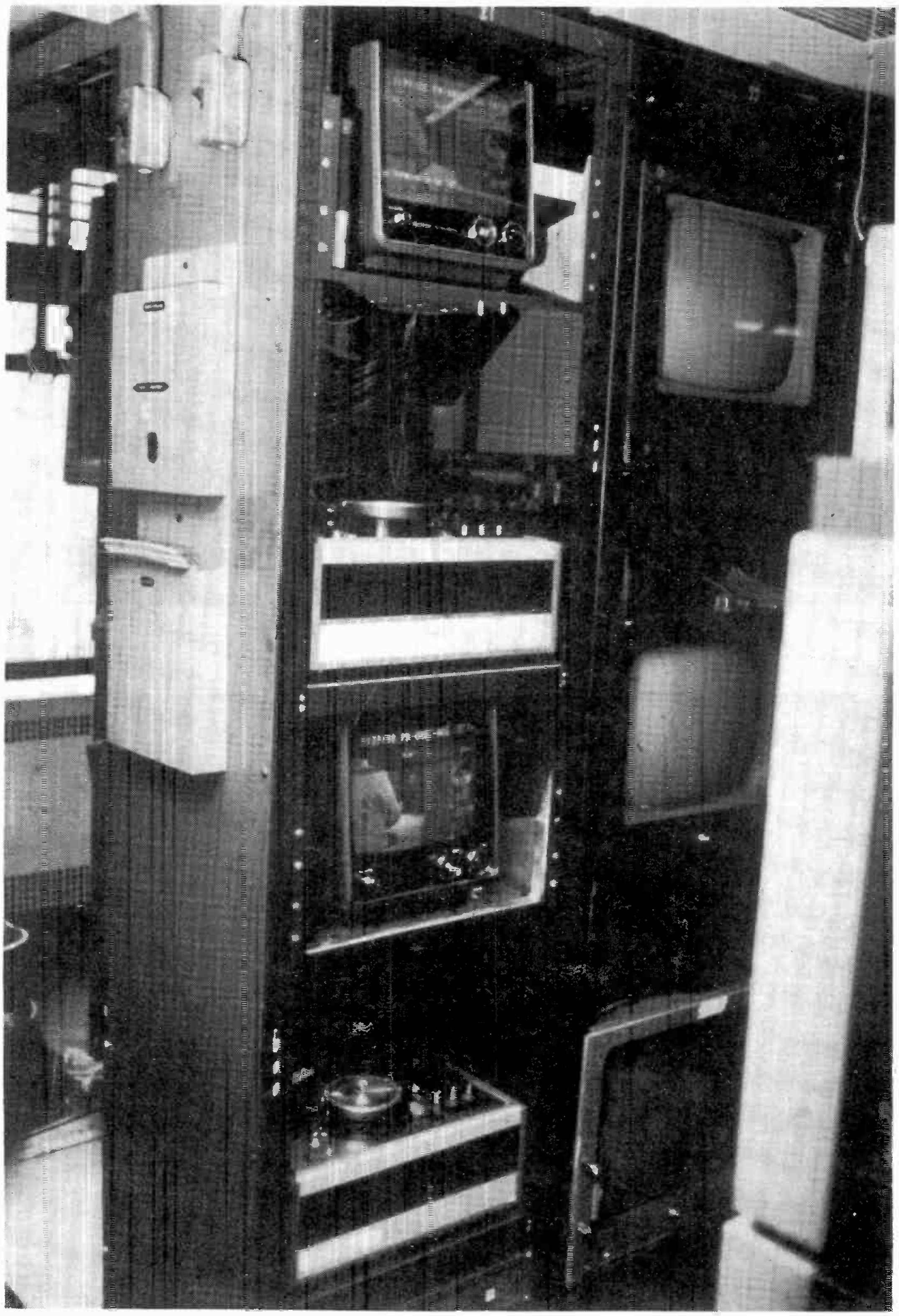

Fig. 6. Record system mounted in rack.

Fig. 7. Operator at playback desk (writing).

Fig. 8. Monitor view with time-date.

Fig. 9. Monitor view showing breakup.


Fig. 10. Portable playback cart.

Fig. 11. Tape library

TV LOGGING SYSTEM – COSTS

	$ Capital Cost	$ Annual Cost*
RECORD SYSTEM		
TIME LAPSE TAPE RECORDER	2,500	315
TIME-DATE GENERATOR	1,000	125
RECEIVER/MONITOR	240	30
MAINTENANCE (2 OVERHAULS/YEAR)		400
TAPE ($18 X 400 ÷ 3)		2,400
Subtotal		**3,270**
PLAYBACK SYSTEM		
TIME LAPSE TAPE RECORDER	2,500	315
RECEIVER/MONITOR	240	30
EQUALIZER & EARPHONES	160	20
MAINTENANCE		165
Subtotal		**530**
TOTAL ANNUAL COST		3,800

* 8 YEAR LIFE EQUIPMENT DEPRECIATION USED

Fig. 12. System cost.

TV LOGGING SYSTEM – COST COMPARISON

	$ Annual Cost
NEW LOGGING SYSTEM	
RECORD	870
PLAYBACK	530
TAPE	2,400
TOTAL	**3,800**
MANUAL LOGGING SYSTEM	
3½ LOG CLERKS ($8,000 SALARY)	28,000

Fig. 13. Summary cost comparison.

TV LOGGING SYSTEM – BENEFITS

- **OPERATING LOG AID**
- **AIRED COMMERCIAL VERIFICATION**
- **PROGRAM CONTENT ANALYSIS**
- **GENERAL REFERENCE**

Fig. 14. Benefits.

The number of log clerks required to maintain the program log will vary widely depending on the length of the broadcast day, the going pay rate for the log clerks, and the allocation of the clerk's time to other tasks. In any event, it is difficult to envision a requirement for less than 3½ clerks to cover the normal broadcast day as indicated. The salary and time allocation shown can be adjusted to reflect individual situations. The cost of tape is shown again in Fig. 13 because, in consideration of its sensitivity, stations may elect to record less than 24 hours per day or continue to use tapes beyond the three times indicated earlier.

A word of warning must be issued. Once the TV logging system is operational, and it becomes known that the station has time-coded tapes of the as-broadcast program day, the operating department will be besieged with tape requests for uses other than those normally associated with meeting FCC program logging needs. A few of these added benefits are shown in Fig. 14.

In conclusion, I would make the point that this logging system was the result of bringing together recent equipment developments that have evolved in a broad front in many allied fields. It is doubtful that such a system could have been assembled even a year or two ago without incurring costs much greater than those shown in this presentation. At NBC, this system will have paid for itself many times as a logging function only. However, the value of a data-bank of "as-broadcast" program material is beginning to be appreciated by a variety of NBC departments; and, these other uses of the recorded tapes may eventually become more important than their use as a program log.

Helical Scan Video Recorders for Broadcast Use Panel

Moderator: Edward H. Herlihy, Kaiser Broadcasting Corp.

Panel: Charles Anderson, Ampex Corp.
Keith Y. Reynolds, International Video Corp.
Stan Becker, Echo Science Corp.
C.R. Paulson, Television Microtime, Inc.

I think historically broadcasters in general have shied away from helical scan; it might be said anything other than the 2-inch quadraplex. Generally, in my own mind, this is probably due to quality problems and the interchange of varying standards. There are all kinds of formats in helical scan, 2-inch, 1-inch, length of the helix, so on and so forth. I think the other area is that most of the equipment manufacturers haven't directed their efforts directly towards us as broadcasters over the years. But times are changing.

Quadraplex prices are rising dramatically. It's very difficult to buy a standard quad tape machine for under $100,000 today. In the area of quadraplex cartridge machines, cassette machines, prices are even higher. And I've seen people going away from the exhibits at this convention shaking their heads about the prices.

The helical scan quality has improved. Manufacturers are directing their efforts towards the broadcasters. The interchange problem seems to be coming into focus. And we are beginning to see helical scan entering the broadcast field. One manufacturer told me that he had approximately 200 helical scan machines in broadcast stations on the air, not just for in-house viewing. So the question comes: Where is helical headed? And that's one of the things this panel will cover.

There's the cartridge-cassette concept. There are lower cost reel-to-reel machines available from several manufacturers. For electronic news gathering, in which I think there is a great deal of interest, it looks as though helical scan may be the answer. A low-cost color camera and a small backpack helical scan machine may bring news gathering down into the station in all market sizes.

The gentlemen on this panel represent all segments of the helical scan field. Each has different concepts, different ideas, and supplies different types of equipment. Each one of the gentlemen is going to make a 5-minute presentation.

Charles Anderson: Ampex's position is I think, a little unique in that we have about 19 years of helical experience as well as quad. The early experimentation, long before we introduced the machine here in 1956, involved a lot of experimentation with formats other than quad. So we've got 19 years of experience.

Now, we are also in a unique position that we offer equipment in both formats; therefore, we obviously feel there is a role for helical to definitely play. We feel that some of the smaller machines—the EIAJs, the Sonys—are making marvelous pictures. They've really done a magnificient job on these smaller machines.

But there's also a point that I feel very strongly about: If you asked of helical what you ask of quad—if you asked the same performance level, the same flexibility, the same features—you're going to have costs that come very close to a quad machine. For example, of the new machines that are being offered, all are priced above the $40,000 range, some of them are being offered above the $50,000 range—not $800, not $1300. The price is up there, if you're comparing apples with apples. And I do take issue with the statement that you can't buy a quad machine for much under

$100,000. The simple version of our VR-1200 can be had at a much, much lower figure than that.

The matter of broadcast news I think is of great interest to us all. I don't think there is really any format in existence that will do the job. We are supplying VR-3000s in the quad formats. People are using helical machines. They're talking about using Sony U-matics or EIAJ. I think it's a very muddied picture right now. People are experimenting. They're trying to establish a quality level which is acceptable. I hear a lot of comments about the poor quality of TV news film, yet I've seen some pretty good TV news film. I think we're in a shaking-down period, we're in a learning period that's going to go on for several years.

We do definitely need a small, compact camera. It won't do a lot of good to come out with the ultimate tape recorder until we have that camera. I've seen some startlingly good pictures out of some startlingly cheap cameras. Maybe we're close.

We definitely feel there's a very large role in helical—in the off-line situation for preview of program material, for editing. However, we feel very, very strongly that quad is still a very viable format, and there's a great deal that we can do in the years ahead to improve it. I've worked with quad now for almost 19 years, I can tell you every problem that ever existed in the silly thing; I'm sure every one of you can enumerate in great detail each and every problem that we've experienced. Many of you haven't worked with helical yet, and there are problems. It is no panacea. And I think that's the point that I'd like you to remember: there is no panacea in format. They all have their problems; they all have their advantages. And I think that good engineering and making the best use—well, let's put it this way—you have to make the best use of the trade-offs and, really, good engineering will prevail. Don't look for panaceas within the format.

Stan Becker: At Echo Science we take a fresh view of the problem. We felt that there were four items that you people were looking for—performance, reliability, interchangeability, and economics—economics of acquisition and economics of operation. When we viewed the market we found the spectrum of the quad on one side and the field-rate helical on the other side and felt that we just couldn't get the economics from the one side and the performance from the other side. So we went ahead on a different track; and that was segmented helical.

Now, I'm sure the first comment going through everyone's mind is, "Oh, God—not a new format." It was a real soul-searching decision. But the problem is basically one of buildability. In order to get the signal performance and the time-base stability required, you must have a certain writing speed. There are compromises that you can make. And there will be more compromises, and there will be in the future less compromises, too, as tapes get better and transducers get better. But for the present you must have a significant writing speed, and quad speed seems to be a good starting point. So we chose a writing speed of 1470 ips, which would enable us to work in high-band modulation standards.

The other aspect is the geometry of the recorded signal on the tape. If you want the writing speed, you'll either have to suffer very large diameters or write in a segmented format. So we chose to segment the helical scan, keeping our track length down to what we felt was an absolute maximum, being approximately 3½ inches. In this way we could guarantee good interchangeability, less problems with environment, problems with humidity, problems with making a tape in one area and playing it back in another area. So we've chosen a segmented helical format, one that writes at a high writing speed, and at a short track length.

We also felt that we wanted to produce a total package, one that you did not have to buy a lot of extras and accessories to make it work. The package is complete in the sense that you end up with broadcastable time-base stability, you end up with processed output reinserted burst and sync. With the single machine you end up with the total broadcast package achievable only by addressing the thing at a nonfield rate format. A helical format at field rate we felt could not match it. And quad has addressed itself to a much more sophisticated and a much more expensive line of thinking. We hope we've achieved this compromise between the two present established formats, whether it's field-rate helical or segmented quadraplex.

Keither Reynolds: IVC's approach from the very beginning was to design a machine which could be used for broadcast applications. Our original 800 recorder was designed with a single head, with a 5-meter bandwidth, and a good signal-to-noise ratio. We put the dropout, or the area where the head does not hit the tape, in the vertical interval, so that as time went on we could go through time-based records, processing amplifiers, and so on to produce a broadcast helical scan recorder.

About two years ago at NAB, we introduced the 900 series videotape recorder. And we have built about 500 of these machines—about 200 of them are used on the air at TV stations. The format that we have is the color format. It was conceived from the very beginning, because we knew that broadcasters were going color way back a few years ago; and they are used very successfully in several TV stations for various applications. Network delay is a very popular application. And as more and more people are using these, more and more color production is being done on the 1-inch helical scan video tape format.

We've taken a look at what you want and I've talked to many of you personally to find out what the future does bring with helical scan recorders. We intend to make quite a few more of these 900s, but at this show we also introduced the cartridge recorder with the same 1-inch IVC format. We will be able to play back commercials or full-length programs in a cartridge format. The original program material can be recorded on the reel-to-reel machine and then transferred to a cartridge very simply by removing the reel from the 900, putting a leader on it, putting it in the cartridge, and inserting it in the machine. Conversely, you could go the other way around, too, and record on the cartridge recorder, take it out, and put it on the reel-to-reel machine.

We mentioned a minute ago the aspect of news coverage with helical scan recorders. And the 900 is rather large. But the BCR 200 Recordak in our cartridge recorder is removable and is self-contained. That unit can be taken out of the recorder or a spare unit purchased, and it can go out into the field. It's only about 19 inches wide by 24 inches deep. Again, it's a cartridge format. The cartridge could be brought back to the TV station by motorcycle or whatever and put on the air very quickly if that's the requirement.

We've been dedicated to helical scan for the broadcaster for several years. We have a lot of equipment out there. Performance of the equipment—signal-to-noise—is 45 or 48 dB, depending on which tape you're using. We are very proud of our record, and we intend to continue with this type of product line and make it more modern as time goes on and make it exactly as you want it.

C.R. Paulson: Television Microtime is a wholly owned subsidiary of a company that's been in the delay line business for approximately 25 years, Anderson Laboratories in Springfield, Connecticut. TMI was organized approximately four years ago because we recognized that there was a market emerging to build time-base corrector equipment for sale within the broadcast industry. Approximately two years ago, we started showing to some of the companies in the industry a time-base corrector, which was designed to work specifically with broadcast VTRs. In this case, the definition of broadcast VTR is a 1-inch helical machine with sufficient servo-correcting ability that it's H-locked to station sync as well as to station vertical. So we have been addressing ourselves to the needs of the broadcaster since the company was organized.

There's an interesting change between last year's NAB and this year's NAB. Last year we introduced a time-base corrector, a Delta 44, interfaced to a 1-inch broadcast recorder. We had a booth with an Ampex 7900 in it and the time-base corrector resolving the jitter from the 7900 down to specifications acceptable to the broadcaster, plus or minus three nanoseconds of resolution. The interesting occurrence, time after time, was the look on the broadcaster's face as he walked by the booth, looked at the 7900, said, "That's a very nice picture, but that's not our format."

Things have changed, however, in this past year; and for the last six months our phones have been ringing and our mail has been loaded with inquiries specifically asking the question, "What can you do for us? We would like to do—" and then there can be any one of several descriptions of what they would like to do. But the drive of the broadcaster now is to get away from the constantly rising costs of production on the so-called broadcast format 2-inch quadraplex. He's intrigued by the cost of the ¾-inch cassette or the ½-inch EIAJ color format and wants to know what we can do about making that format broadcastable.

Knowing that this was going to be the trend, we came to the show this year with a time-base corrector. We have four operating time-base corrector systems interfaced with a 2-inch quadraplex, to a 1-inch IVC, to a 1-inch Ampex, to a ½-inch monochrome EIAJ, to a ½-inch color EIAJ, and a ¾-inch color cassette format. We're the time-base corrector store; we are very interested in seeing all of the companies present here, and any other tape recorder companies that can come into the business, introducing recorders which you find acceptable. We'll have a time-base corrector available to process the color or the black-and-white in a form that's acceptable to you. We're not trying to set standards or define definitions. We're here to try to do whatever the broadcaster wants in putting whatever recorder he selects on the air so that it meets his standards.

As you're well aware, there's an interesting departure as you get down to the ½-inch and ¾-inch color formats in that you are no longer recording direct color; you're recording heterodyne color. The color subcarrier is somewhere down below the luminous information on the tape. When it's recovered, the output of that recorder is a noncoherent or nonphase color. There's an oscillator inside the VTR that's running at some frequency around 358, and the sync frequency coming off the tape is phased to whatever the power line tells it to be in the cheapest of recorders and is jumping and jittering at some rate determined by the interchange problems, by the mechanical instabilities of the recorder, and by the amount of skew tension error. That's introduced both by tape dimensional changes and by the transport itself. So the problem of handling nonphase color is not one that can be solved very quickly.

One of the questions we're asked is, "Well, why don't you do something? You're not a VTR manufacturer, but why don't you do something to improve the technical performance of these cheapie recorders so that they'll be easier for us to use?" This is like putting a $10,000 tail on a $1,000 dog, however. We are making some modifications to improve the performance of the cheap recorder. The first of these is actually a development of Goldmar Communications Corporation, an automatic skew-tension corrector which has been written up fairly well in the press. We have a cassette and a ½-inch VTR with this automatic tension corrector device installed. That eliminates the need for the operator to constantly monitor skew tension as the tape is playing back and, therefore, simplifies one of the operating problems in the station.

Going beyond that, there's another possibility of converting a line-locked machine to a quasi V-lock so that the phase of the signal off the tape, rather than being locked to something commanded by the power line, is locked to station vertical. This will reduce the problem of harnessing the nonphase color to a substantial degree.

To make the Delta 44 product line acceptable to the broadcast industry and compatible with your needs, we are building accessories in two directions. Some of these accessories involve working on the video signal and literally having the time-base corrector chase the sync from the tape and resolve its jitter on a floating sync approach. The other approach is to provide within the recorder itself a means of converting it from line lock or V-lock up to H-lock and, therefore, move the sync, harness the sync, corral the sync, move the sync into the framework of your station's sync generator. We have interfaces to do either of these jobs working around the standard Delta 44. We invite you to come to the time-base corrector store so that you can see the 2-inch, the 1-inch IVC, the 1-inch Ampex, the ½-inch, and ¾-inch machines in operation and judge for yourselves whether the quality you see from those tape recorders is what you want to put on the air.

Herlihy: Gentlemen, you've heard from three manufacturers of helical scan recorders and one manufacturer of items to correct signals from machines already built. We are now ready for questions. There are three microphones in the center aisle. Please use them. And direct your questions either to the entire panel, they'll field them as best they can, or to individual manufacturers.

Mr. Paulson: I have another comment. From an academic standpoint there are some facts about the history of time-base corrector development that may help you understand why we are where we are and why you see so many different kinds of time-base correctors available to you. I was an employee of Ampex Corporation along with Charley back in the glory days 19 years ago, when NAB was turned on its ear one Sunday morning by the introduction of the quadraplex recorder. You, the broadcasters, were just overjoyed at the availability of this unit and immediately bought them in great quantities. RCA began to supply them almost immediately thereafter also.

Your first dissatisfaction was with the fact that you couldn't use the recorder as a picture source. You didn't like the skew tension errors or the scalloping and the quadrature errors that you saw in the head, so Ampex developed something called an Amtek (And I'll only use Ampex, since I was part of that history.) Amtek was the first of the boxes applied to do something about the signal off tape. That wasn't quite enough because you wanted to use the recorder as a picture source. So a box called Intersync was developed. Now Amtek and Intersync worked together. Then, you were very excited about going to color, so a heterodyne color scheme was developed. You were unhappy about that; therefore, a device that Ampex calls Colortek was developed, which relates the color to the station subcarrier. Then, you noticed that there was something called velocity error in the unit, so something called Velcomp was invented. And, of course, in the process of all this, Color Pro Amp had to be invented. So now you're talking about Amtek, Intersync, Colortek, Velcomp, and a Color Pro Amp as accessories that were all developed because you, the broadcaster, demanded them of the quad VTR manufacturer.

We have had the benefit of this 19 years of experience just watching what happened; therefore, our design approach recognizes that the broadcaster wants all of those functions in one box installed in the simplest possible way. So our time-base corrector store includes stand-alone velocity error correction devices or an integrated velocity error corrector that integrates with a time-base corrector or the time-base corrector standing alone or the accessories I mentioned previously.

Mike Wilhelm: Mike Wilhelm of Kessler Associates, Consulting Engineers. The question is directed to either Mr. Reynolds or Mr. Anderson, or both possibly. With respect to the unphased color that comes out of either the low-cost ½-inch and ¾-inch machines or the IVC 900 series without time-base correction, are you aware of any opinion by the FCC that the use of such unphased color is consistent with FCC regulations?

Mr. Reynolds: Our engineering staff has had conversations with the FCC in regard to the 900 without the time-base corrector, which is a heterodyne or burst-lock color system, and they have indicated that they'll issue no citations to people who use this type of device. However, to get the full bandwidth that most broadcasters I'm sure would like to have and direct color, the time-base corrector is recommended.

Mr. Wilhelm: Could I ask for a clarification? The matter of the Commission saying that they're not going to issue citations and the machine being in conformity to the rules appear to be two different things. Broadcasters inevitably want to have a piece of paper on the wall that says, yes, you can use it. Where can we get this piece of paper?

Mr. Reynolds: I guess by calling or writing to the FCC and finding out. We haven't pursued it any further, only to know that we were not in violation of what they said was right.

Mr. Wilhelm: Could you tell us who issued this opinion at the FCC?

Mr. Reynolds: I don't recall. Dee Porsio, our engineering vice president, talked with him. Mr. Porsio could probably answer that question better than I could.

Mr. Anderson: I'd like to comment on that. I doubt that you'll ever be able to get anyone at the FCC to prepare such a statement in writing as I doubt that you would get a police officer to say, "No, I won't arrest for going 70 in a 50-mile zone." He's not about to. I'll be very surprised. But I think one of the key things that Keith said in his statement is that when you do have nonphase color you do not have full bandwidth. And I think this has to be recognized. This is a major drawback. Actually, the picture looks pretty good.

Mr. Reynolds: And on the same subject we might also talk a little bit about the ½-inch and the ¾-inch and the fact that you do have quite poor bandwidth on those, too. It's doubtful in my mind that would be a broadcastable signal. Maybe legally it is, but as far as picture quality on the air. . .

Mr. Paulson: The standard for evaluation that I keep hearing about, "Is it as good on the home receiver as super 8 color film? If it's as good as that, we want to go to it." So that's the difference in standard or criterion that seems to exist between last year and this year. Now, in recognition of this, one of our approaches, knowing that nonphase color is broadcast, is a solution which locks the color information on the signal to the station's subcarrier. So we have nonphase color that's upside down from what you're used to, where the sync is locked to the sync generator but the color is rotating—the color vector is rotating. We've done the opposite, as you can see: our burst vector is locked to the station subcarrier and the sync is moving around at approximatly a 15,734 frequency, but plus-or-minus approximately a half a line, depending on the characteristics of the recorder that we happen to be using.

TV Automation Design Concept

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Recently, my company began installing a second series of Television Automated Packages to the CBC, particularly for use by a medium-sized TV installation. The purpose of this system is to operate the transmitter booth switcher, with control of all film islands, video tape machines, audio cartridge machines, and networks available to it. Automatic preview of next source, with continuous monitoring of upcoming events, is built in.

The purpose of this paper is not to discuss at great length the flowing beauty of this latest development by Richmond Hill Labs in the field of automation, but more to discuss the logical development of hardware that has allowed us to put together a very practical, low-cost system for on-air presentation use by the CBC. A look at the original automated switcher system supplied by RHL will serve as an introduction to this latest development.

The automated system originally installed in Moncton, New Brunswick, was built around a Data General NOVA computer with 4K memory, a punched-card reader, a custom-built keyboard, and a commercially available character generator. Interfacing was done completely by relays operating not only the video and audio crosspoints but also the machine control functions such as film start, video tape start, multiplexer, mirrors, etc.

A look here into the general technical concepts of the RHL approach to television automation would serve useful. An automated television system can be broken into two basic subsystems:

A. The video and audio switcher with a conventional manual control panel.

B. The automated control system which operates the switcher, when there is no one to operate the manual control panel.

The video-audio switcher, the first item, is straightforward in design and layout, with facilities to switch up to 15 input sources to preview, transmitter, ongoing network, and utility buses.

The second subsystem, the automated control, was designed and built independently of the video-audio switcher. This automated package in its entirety can be considered as operating in partnership with the master control operator. In reality, both the automation and the operator are capable of controlling the switcher—**in parallel** with one another. The electrical connection of the switcher to the computer is at the same point as the manual control panel. The switcher itself is unable to tell who pushed the button—the computer or the operator. In fact, it doesn't need to know, as long as the operator knows what the computer is doing, and vice versa.

Let us now dissect this computer-driven operator and examine its component parts. Every operator, to be human or machine, requires the following parts:

REQUIREMENT	HUMAN	MACHINE
DATA INPUT	PROGRAM LOG	PUNCHED CARDS
CONTROL OUTPUT	PUSHBUTTONS	RELAYS OR TRANSISTOR SWITCHES
TRAINING	EDUCATION	SOFTWARE
EXPERIENCE	HUMAN MEMORY	CORE MEMORY
STATUS	BRAIN	EVENT STORE AND DISPLAY
RULES	CLOCK	CLOCK

The component parts of an automation system, are, therefore:

(a) The computer with memory
(b) Clock and clock interface
(c) Data input device(s)
  1. Punched card reader
  2. Keyboard
  3. Cassette tape, etc.
(d) Switching interface
(e) Status display—alphanumeric video character generator
(f) Input interface for manual controls from the human operator, feedback from devices, etc.
(g) Software

The individual system components can be studied in detail:

DISPLAY

The alphanumeric video display is the main status monitor point of the system. It is composed of up to 20 lines of 40 characters each, each line displaying one complete "event." An event is defined as an "on-air" occurrence, usually a change of video and audio signal, with duration time, transition codes, and program identity entered. The top line of the display shows the event that is presently "on air," with entries reading from left to right as: Time of day (24-hour clock), time-to-go (counting down) until next event, video source, audio source, transition, film sound code (mag—opt), and program identity. Succeeding lines show the upcoming events with the same information.

KEYBOARD

A slightly modified typewriter-style keyboard is used for manual entry of events. It has extra keys fitted, for cursor control (HOME and four directional arrows) and tab keys (TIME, DUR, VIDEO, AUDIO TEXT). The remainder of the keyboard adheres to the usual typewriter key layout.

EVENT ENTRY

In Moncton, a punched-card reader is supplied; it reads standard IBM-style cards for data entry. Each card contains coding for one event, plus other billing and accounting coding not read by this computer. The computer will read cards as events are used up, in order to continuously refresh its event store.

A noise problem was encountered with this machine, of such an extent that it is impossible to leave it running continuously, on standby, due to the low noise requirement in a TV control room. A special circuit was developed and the card reader modified such that it starts up approximately 3 seconds ahead of "Take" time, and shuts off about 15 seconds later. This allows the computer to read a card when needed, but permits a quiet control room most of the time.

TODAY

The experience in Moncton served us well when building the CBC units for similar functions in Toronto and Edmonton. However, the actual hardware used varies somewhat. In particular, the punched-card reader, which is a source of constant noise and has the disadvantage of requiring a keypunch machine at the traffic department, is replaced by a digital cassette tape machine which employs common cassette tapes which are prepared in the traffic department by a similar tape machine and a conventional computer CRT terminal. The character generator in Moncton is replaced by a conventional, commercially available computer CRT terminal. This particular unit is built by Beehive Medical Electronics in Salt Lake City. It is modified considerably to permit the computer to operate directly with the unit and the keyboard to instruct the computer in such specific functions as tab keys for control of the cursor and special keys concerned with the display.

The overall final system as now installed in CBC Toronto and shortly in CBC Edmonton consists of a Data General Model 1220 jumbo chassis computer with 12K core memory permitting entry of a complete day's events in one loading session such that the operator has access to 500 on-air events ahead. These events, of course, are read in by the cassette tape machine, which is an integral part of the system. Interface to the computer is contained entirely inside the jumbo chassis of the unit and consists primarily of integrated circuits which eventually terminate in open-collector transistor driver stages which connect directly to the video and audio crosspoints. However, it was felt expedient that control of devices such as video tape, telecine, etc., be connected via relays, which are offered externally to the computer system immediately adjacent to the computer itself. These relays are also driven from open-collector transistor stages which are plugged into the main chassis of the computer.

The facility of being able to load all of the on-air events for one complete day's programing permits the operator more flexibility in his approach to editing, adding, or changing these effects. Certain pushbuttons on the control panel allow the display to go into the edit mode, which permits the operator to search through the event store 20 units at a time, until he finds the desired one where corrections or changes may be made.

The cassette tape also allows the easy addition of a logging function to the automation system. As the machine selected for this use is a dual unit, which consists of two tape transport systems sharing electronics, the sequence is such that the prepared tape is read from the transport on the left into the computer memory, and at the end of the day's programing the tape on the right is used as a log of the events as they occurred in the day with exact program times, alterations, and changes as they occurred. These cassette tapes are interchangeable with a similar dual unit in the traffic department which permits then a hard-copy printout of the log and the program schedule by a small inexpensive line printer. The computer program, the 'software,' has been considerably expanded to perform many and varied tasks that enlarge the system's scope to a great degree.

In addition to the normal tasks that a computer program is expected to do, that is, video switching, audio switching, event reading, and time code checking, this program has been expanded to preroll the appropriate video tape machines, telecine chains, etc., at their required times irrespective of intervening events such that video tape machines can not be inadvertently not rolled. Also, it will check that the computer has control of these devices at the 2-minute point before the expected on-air time. If the machine is not delegated at this time, an alarm circuit is activated and the Prevent Entry on the CRT display changes to reversed video. The operator then is warned that this event, although scheduled, will not be controlled by the computer and, as such, it is entirely possible that the machines or slide projectors will not start, change, etc.

The computer program is arranged to continuously read the time of day such that changing of the time standard, or updating the clock to WWV, is completely automatic. The master clock system delivers a PCD code for all six digits of the time. The computer interface is arranged to generate an interrupt to the computer program each time that this time code changes, that is, once per second. This is considered a tick of the clock and the computer program immediately reads the new time of day. It then, of course, has to check if it has any tasks to perform at this particular time of day and if it has, it does them.

Another feature of this computer software is the error-checking subroutines. If an attempt is made to enter invalid data, such as wrong times, nonexistent video or audio sources, or any other anomaly, the computer will flag the appropriate event with an asterisk in column 12 of the display and light a large Error lamp on the operator's console. If the invalid event goes uncorrected, the computer will refuse to act on it at its scheduled time but will go to black for this period. This is natural, since the computer can not presuppose anything at all—it must be instructed completely as to what to do under adverse situations.

All failure occupies the minds of many broadcasters when the talk turns to automation. This particular computer is fitted with a power failure monitor which senses an impending power failure and shuts itself down in an orderly manner. Upon restoration of power, the next tick of the clock causes the computer to read its new time of day and to update its events store to that point in its memory. Now this may be a matter of a couple of seconds, or maybe hours. Both eventualities are taken care of in this manner. However, due to the uncertain amount of time that the computer has been off the air, it comes up in a manual mode and must be re-energized in order to take control once more of the video switcher

SUMMARY

This paper has been an attempt to demonstrate how the simple automation system as built in 1970 has evolved to a rather sophisticated on-air presentation system as delivered in 1973, employing the latest hardware available from the computer industry interfaced to modern television techniques. Of course, the world's greatest television switcher, the RHL Series 2000, was employed for the video portion of this automation package with suitable excellent audio electronics by Ward-Beck Systems of Toronto.

An outgrowth of our experience in these TV automation systems is that we are presently engaged in building two very large automated systems for the CBC, employing similar hardware, but controlling a 50 x 9 audio-video routing switcher that feeds the ANIK domestic telecommunications satellite, and another system that completely controls the routing switchers, 10 AVR-1 video tape machines, machine control assignment, intercom, and pulse switching for complete control of program delay center feeding Canada's five time zones with program material at the proper time.

A Cartridge System for 16 mm Television Film

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Broadcasts Systems Div.
Radio Corporation of America
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Literally thousands of short pieces of 16 mm film on small reels or hubs are received by television stations in this country every year. Five hundred to a thousand or more of these films are played back every week by a typical TV station. At the outset of this project, the program logs of nine stations (one network, six U.S. TV stations, and two Australian stations) for a total of 44 days were analyzed to determine the distribution (by length duration) of the film segments used. The total number of segments used by four of the stations during a one-week period was 3174 of which 2842 or 89 percent fell in the duration period of 10 to 120 seconds. The numbers will vary from station-to-station, but the significant fact is that the percentage of short segments of film is high.

The short films are sometimes spliced together and handled on "commercial reels," but, in most instances, they are played back one reel at a time. All of this requires a great deal of handling for incoming inspection identification, cataloging, storage, retrieval for playback, etc. Also for playback, it must be loaded, threaded, cued, played, rewound, spliced, unspliced, etc.

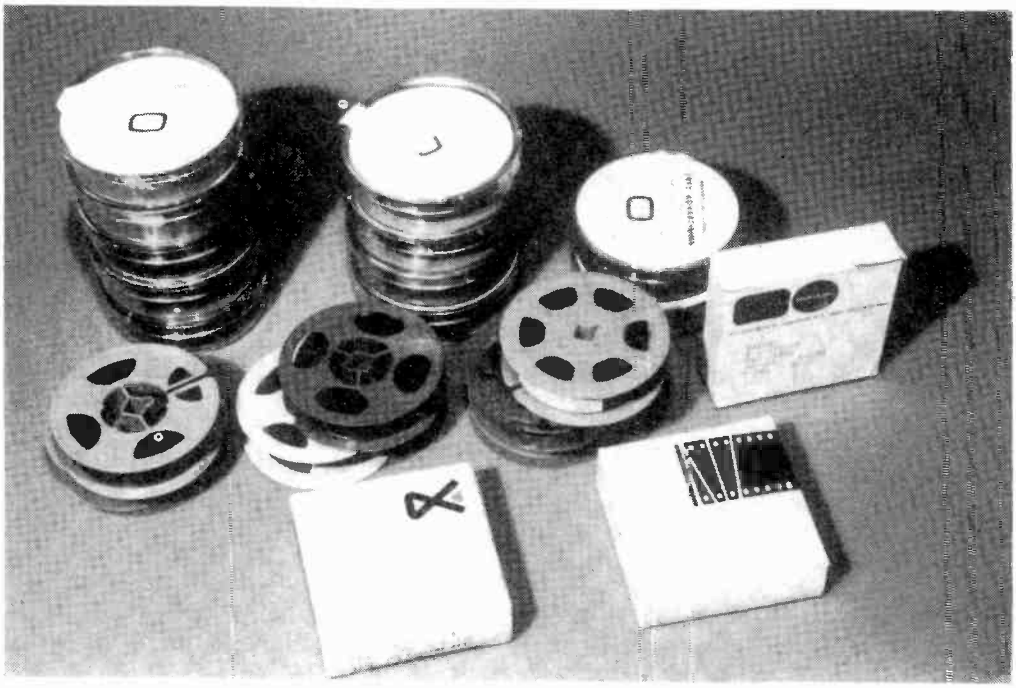
A cartridge-loading automatic film-handling projector is an obvious and very logical answer to this problem. RCA and Eastman Kodak subsequently undertook a joint-venture project to develop this 16 mm film cartridge system.

THE CARTRIDGE

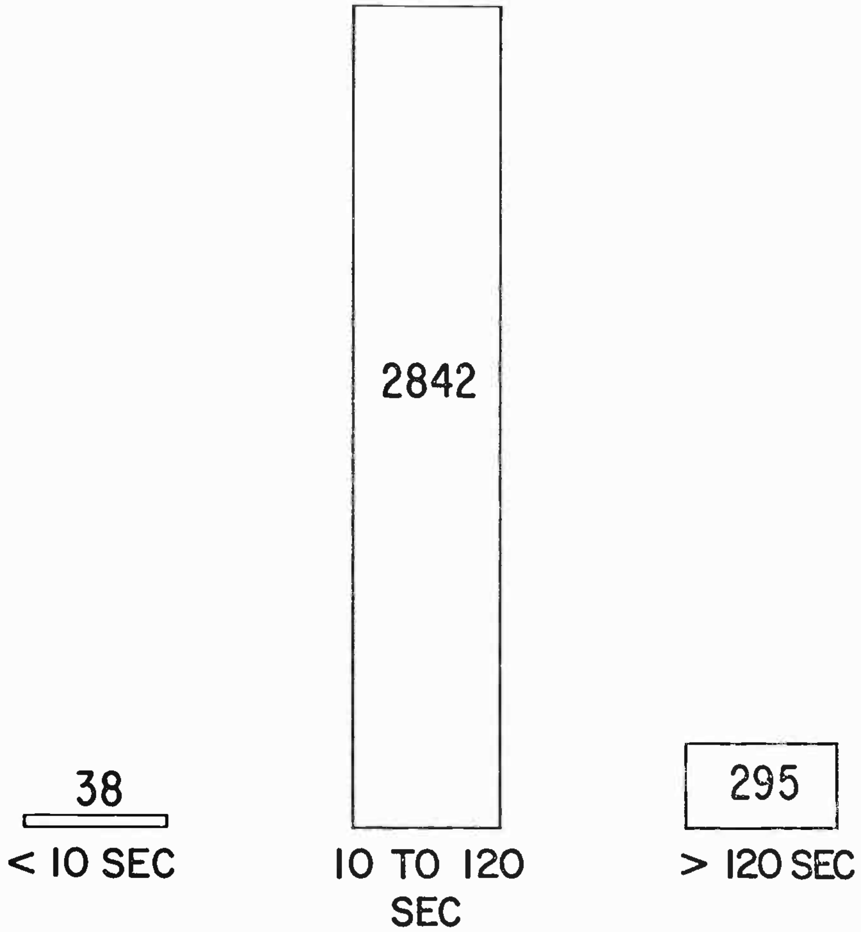
The cartridge concept is well established for rapid and convenient handling of film and tape media. Cartridge film for pictures and cartridge tape for sound have been widely used in the business and consumer fields, as has cartridge tape for sound in the radio broadcast field for some time. More recently, the cartridge concept is finding its way into TV broadcasting.

For this new system, a compatible 16 mm reel, and a plastic case which encloses it, has been designed specifically for the TV broadcast application. The new reel is compatible with currently used 16 mm reels and thus can be loaded on existing 16 mm reel-to-reel projectors. In addition, the film-loaded reel can be quickly placed in the cartridge case without the use of tools. Once loaded in the cartridge case, there is no further physical contact required for the usage life of the film.

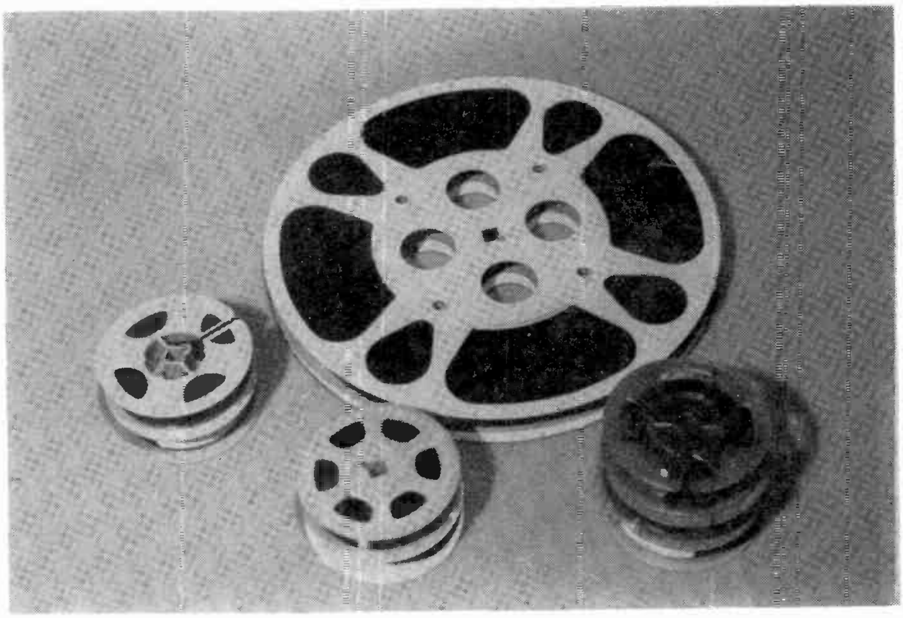
The reel, which is molded of an antistatic ABS plastic, has a larger than conventional hub diameter, solid flanges, plus a keying groove on one side and radial surface splines on the other for positive coupling in high-speed reeling. It conforms with present ANSI standards for projection reels. The capacity of the reel is 75 feet of 6 mil film; or, in other words, two minutes plus leader and trailer at a 25 frame projection rate. A preformed, stiff Mylar leader approximately 13.5 inches long is attached to the film for purposes of automatic threading in the projector. The presence of this leader as an outside wrap-around when the film is in the cartridge adds further protection to keep dirt from reaching the film. The stiff leader does not preclude threading the film on a reel-to-reel machine, since its width is the same as the 16 mm perforated film and it is sufficiently flexible that it will wind on a takeup reel quite readily.



Stacks of current commercial reels of film.

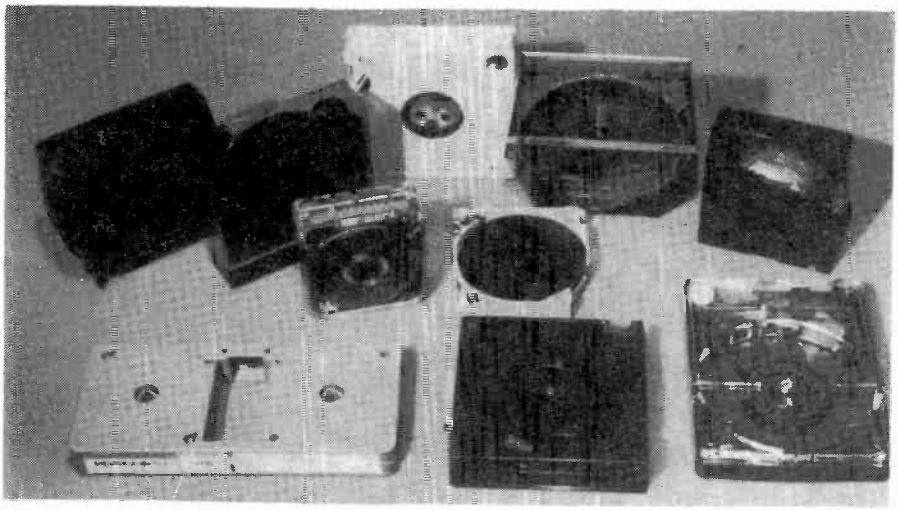


Four stations, 3174 film segments during one week.

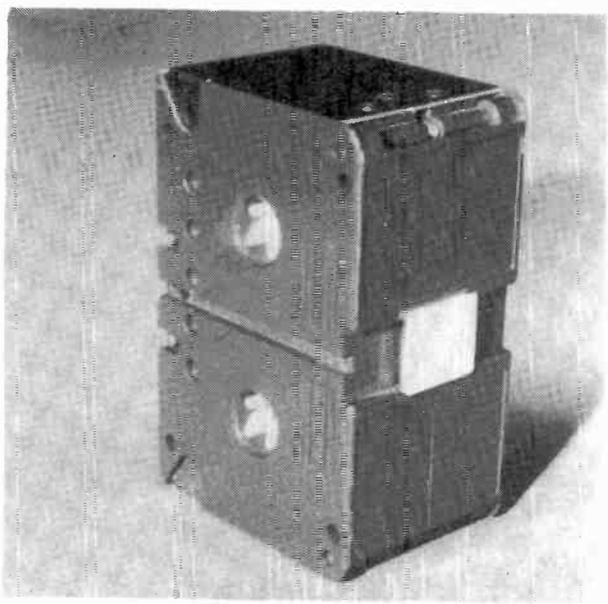


Several small commercial reels plus one large one (15 min.).

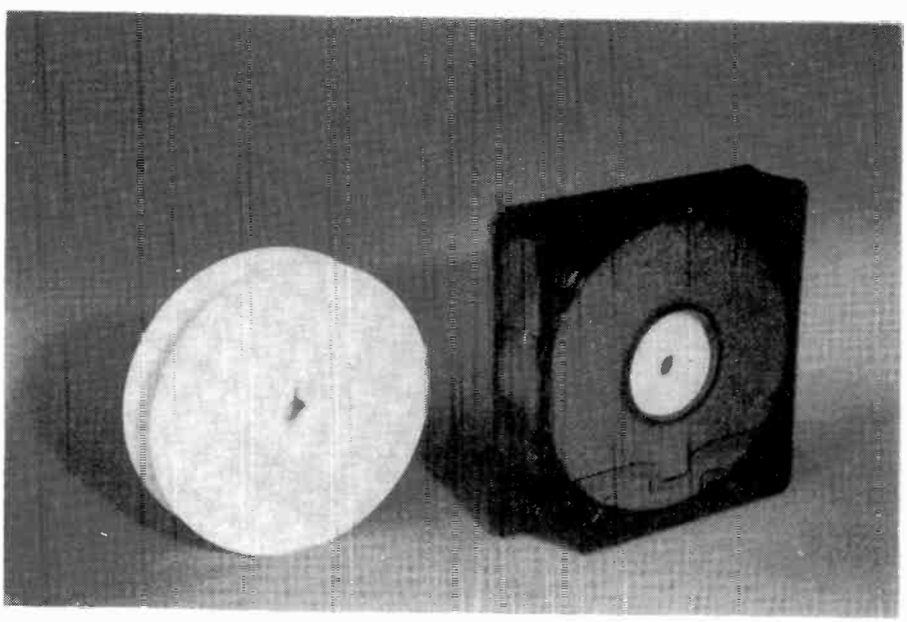
Overall shot of TCP-1624.



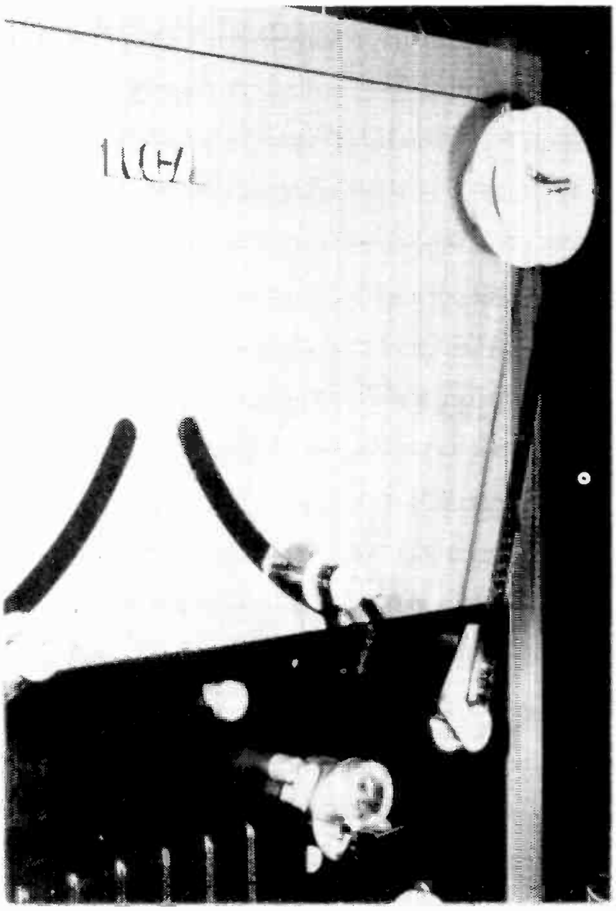
Super 8 film cartridge, Philips sound tape cassette, broadcast audio cartridge.



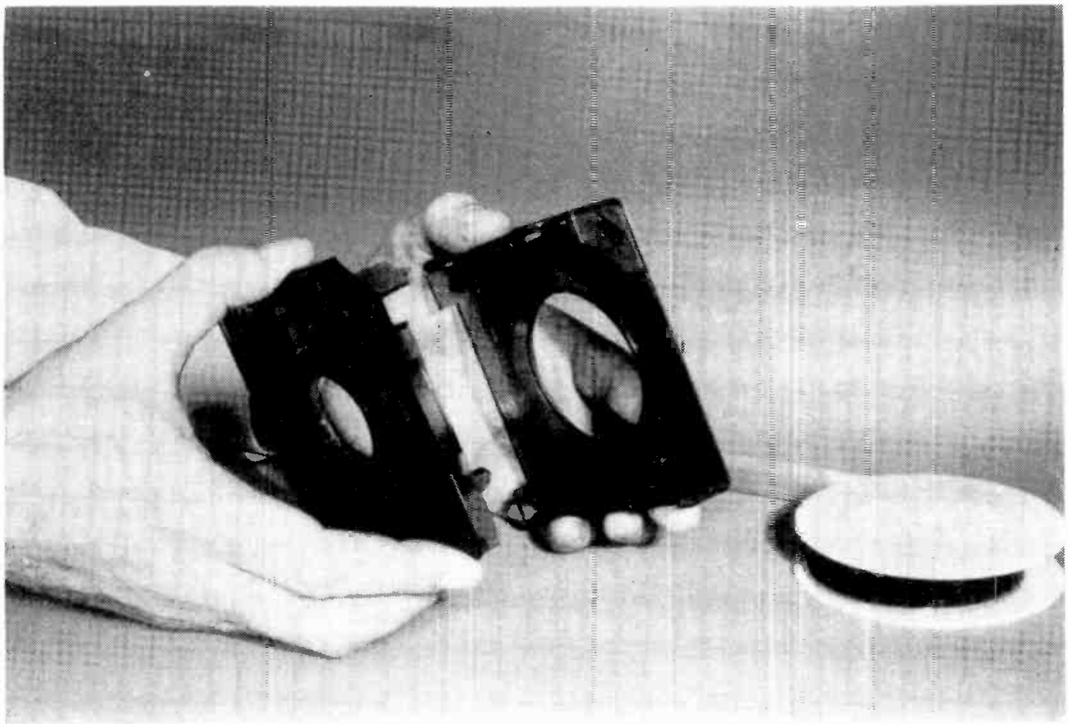
TCR-100 tape cartridge.



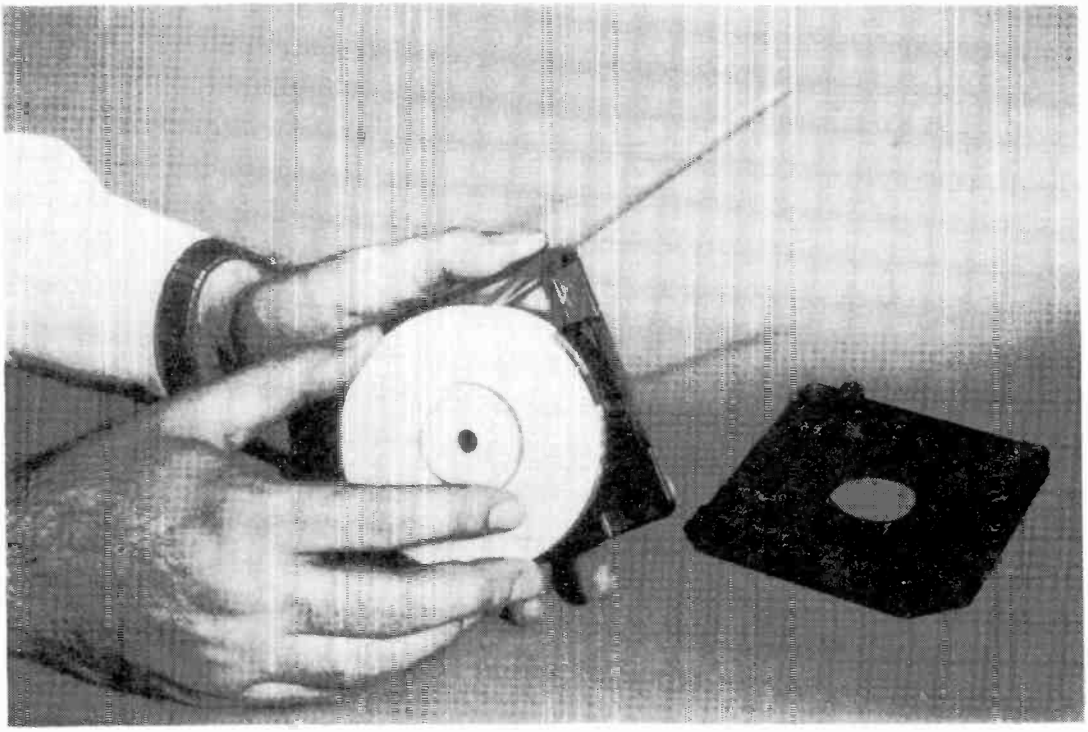
Cartridge in case on right; reel (and film) only on left.



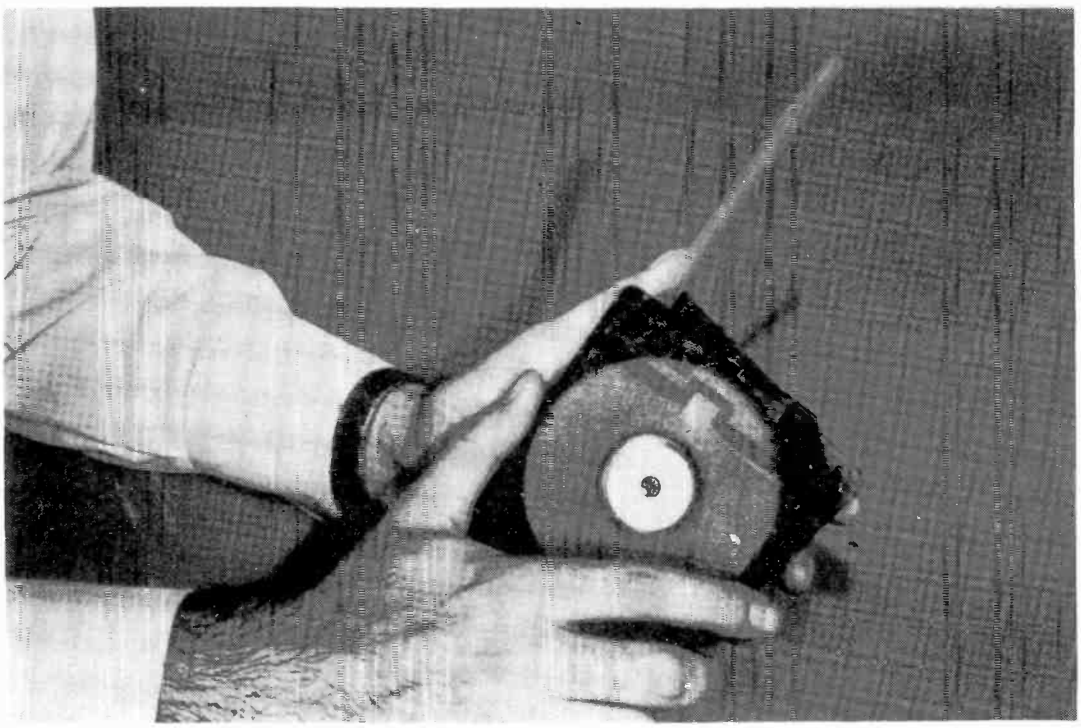
New reel on TP-66 with film threaded.



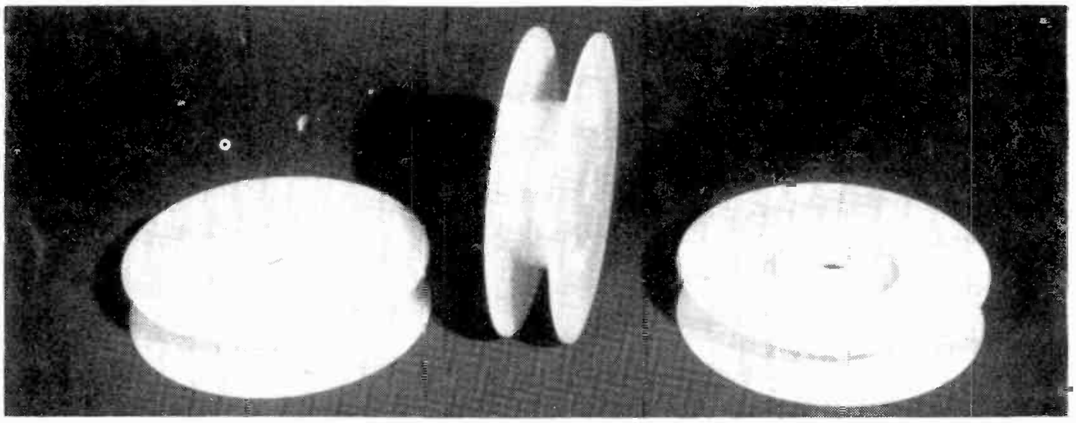
Cartridge case being opened, with film lying adjacent.



Reel placed in cartridge case.



Case being closed.



Three reels, different views.

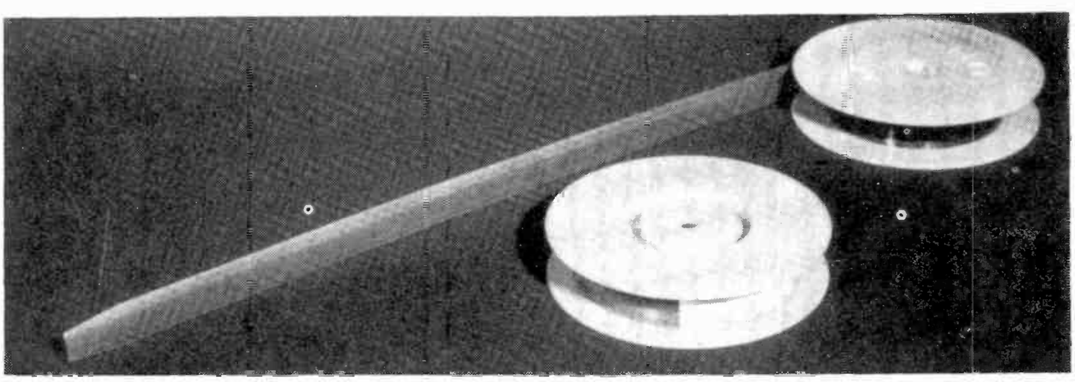
While the reel is designed for a maximum film program load of 2 minutes, it can, of course, contain any length of film down to 1 frame of program. However, it was designed for an anticipated minimum of 10 seconds of program material, which is slightly more than the maximum recycle time when a 2-minute cartridge is utilized in the projector. Thus, with the program segments ranging from 10 seconds to 2 minutes in duration, it is possible to intermix them in any manner and still provide a continuous picture output from the automatic projector. While it is possible to utilize thinner base film and contain a longer playing time on the reel, this would in turn increase the minimum playing time possible while retaining the intermix capability, since the rewind period for the maximum length of film establishes the minimum recycle time.

THE CARTRIDGE-LOADING PROJECTOR

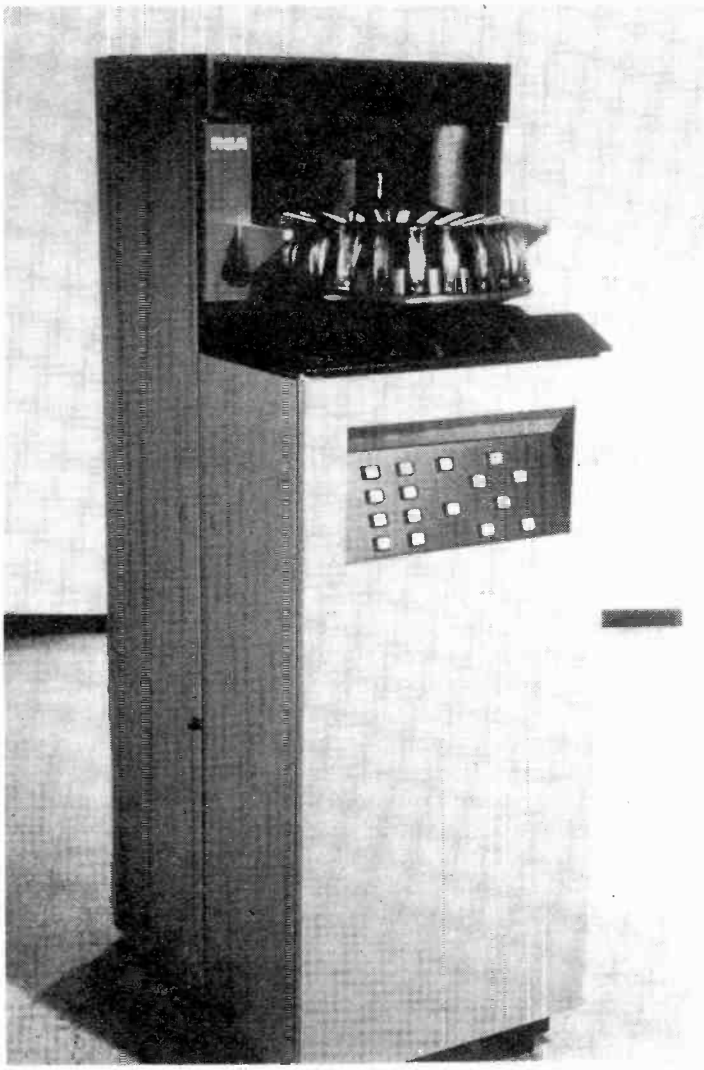
The film cartridges are loaded in a circular magazine which has a capacity of 24 cartridges. The magazine is removable from the projector, which makes it convenient to load either on or off the machine. The automatic projector, as illustrated, is designed to occupy the same position in a telecine island as a standard TV reel-to-reel projector such as a TP-6, TP-66, Eastman 285 or CT-500, etc. The projector is a 2-channel machine with internal optical multiplexing to combine the optical outputs into a single telecine island multiplexer input. The dual-transport design provides a continuous picture output from the projector with the sequential playback of the cartridges as loaded in the magazine. The projector is designed so that very excellent access to the cartridges in the magazine is available for rapid last-moment changes, if required, except for the two cartridges that are in the playing stations within the projector housing. Any intermix of program material between 10 seconds and 2 minutes is possible while retaining the continuous picture capability.

The projector contains the following functional subsystems:

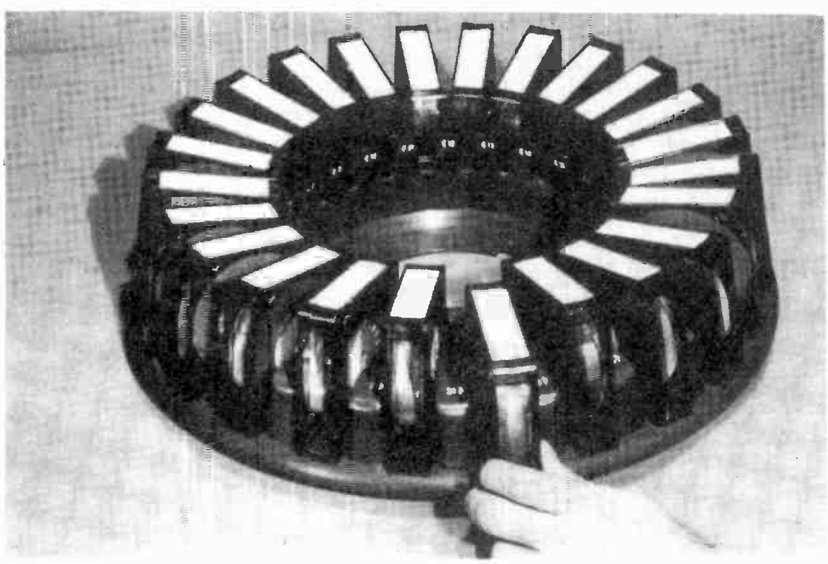
1. Magazine drive
2. Cartridge transfer and playback stations
3. Film transports



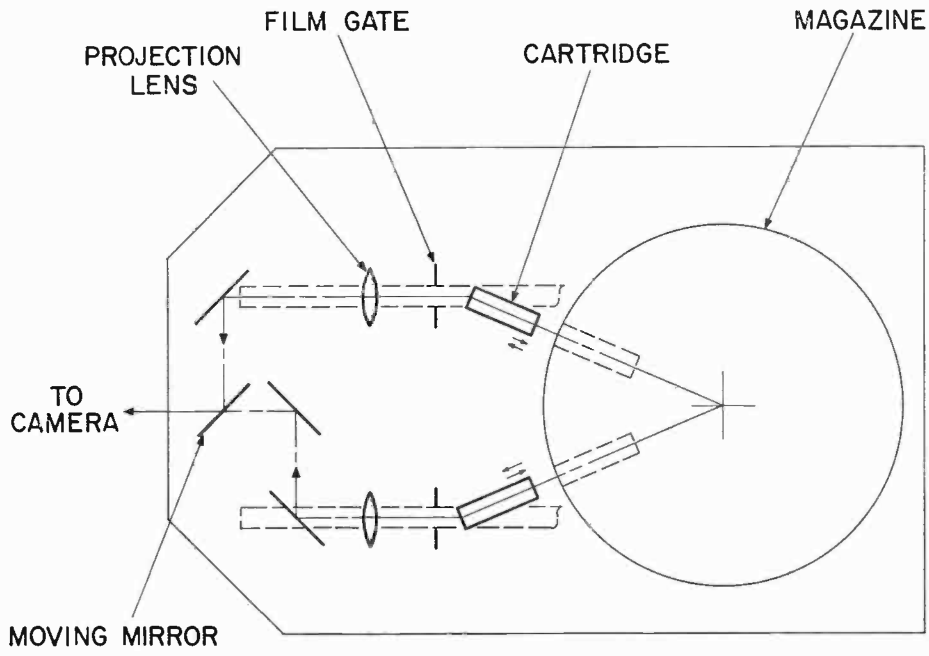
Two reels; one with some film and stiff leader extended, one with film and leader tightly wrapped.



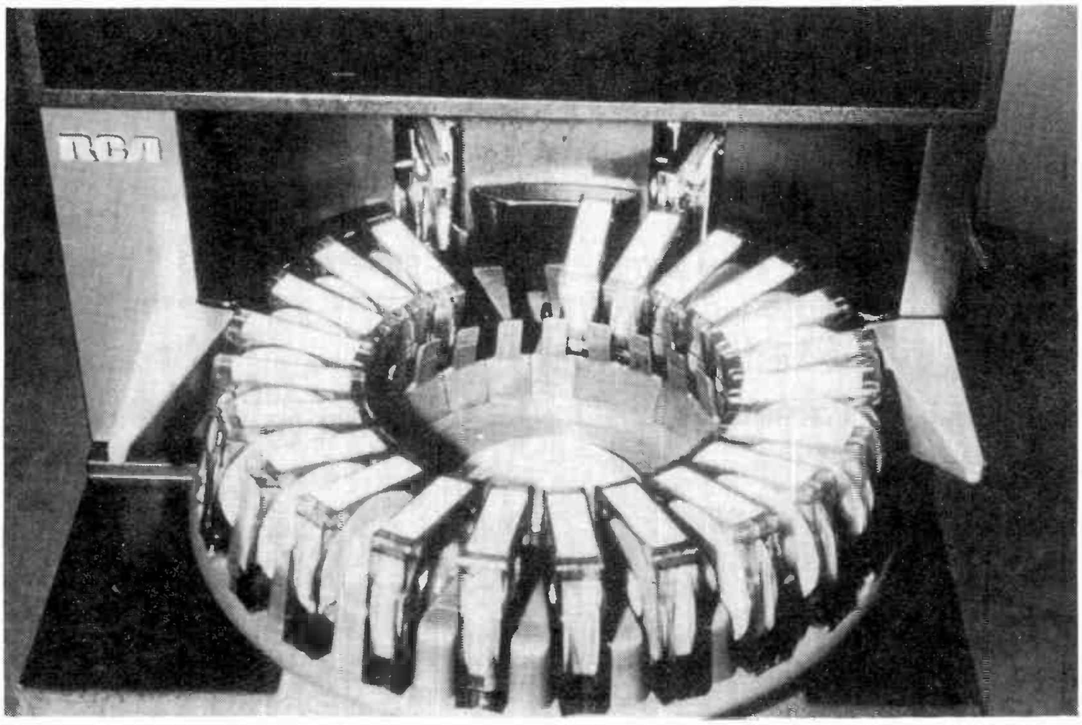
Overall view of TCP-1624.



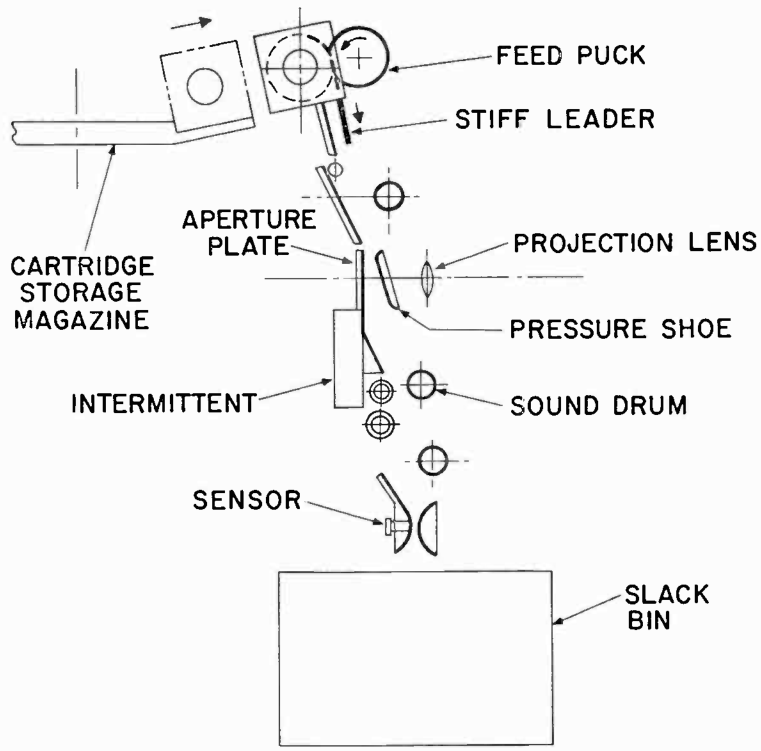
Show magazine with 23 cartridges loaded and 24th being inserted.



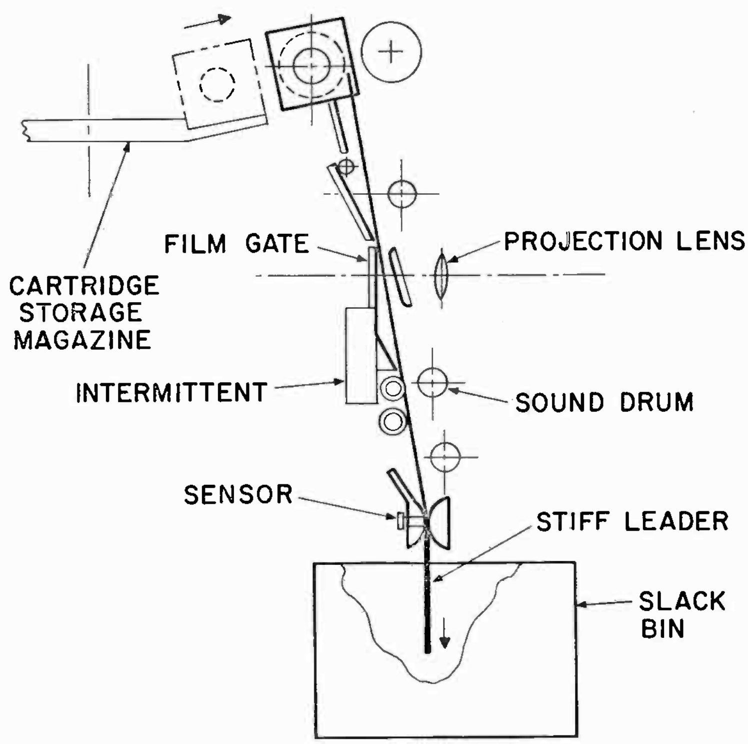
Top view showing twin optical path.



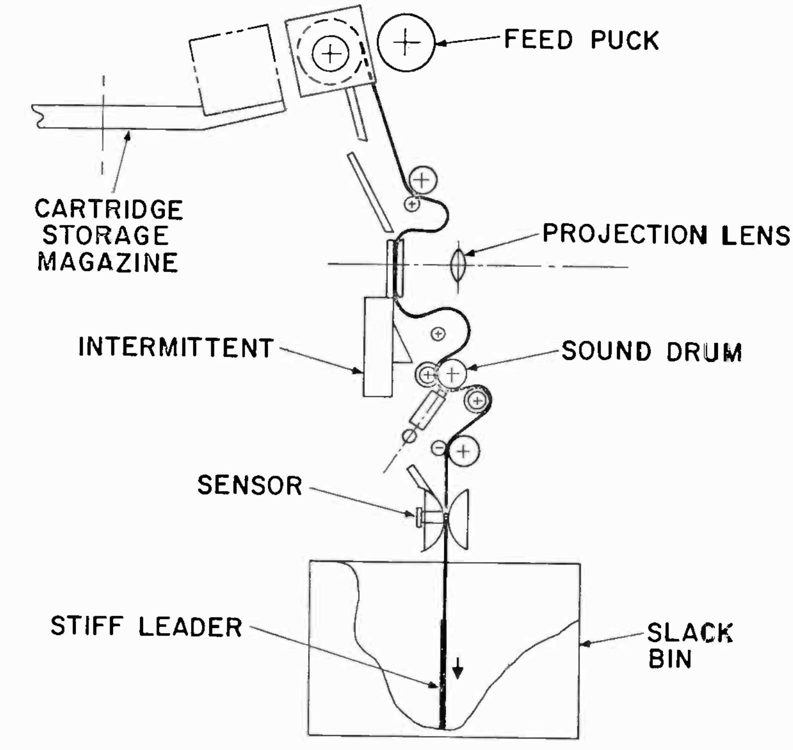
Closeup showing cartridge-loaded magazine on the projector with two cartridges in play stations.



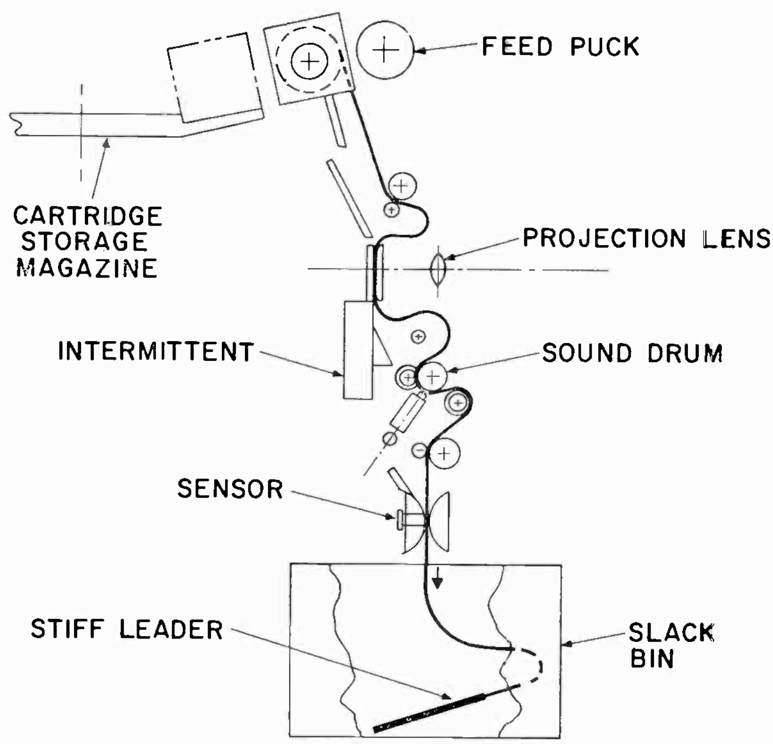
Projector film path in loading mode: cartridge in play station, leader just emerging from case, puck engaged.



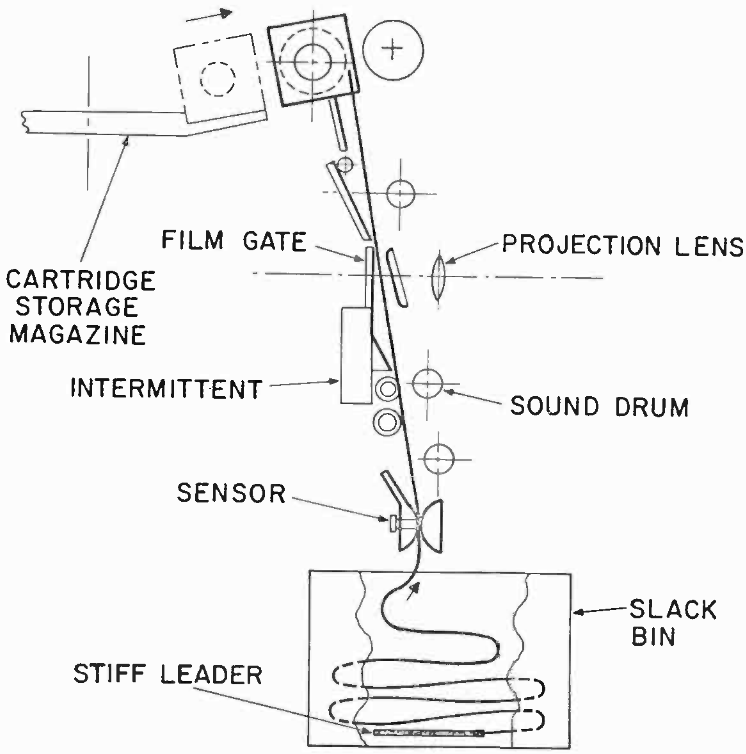
Same as above, except leader entering slack bin and the puck drive disengaged.



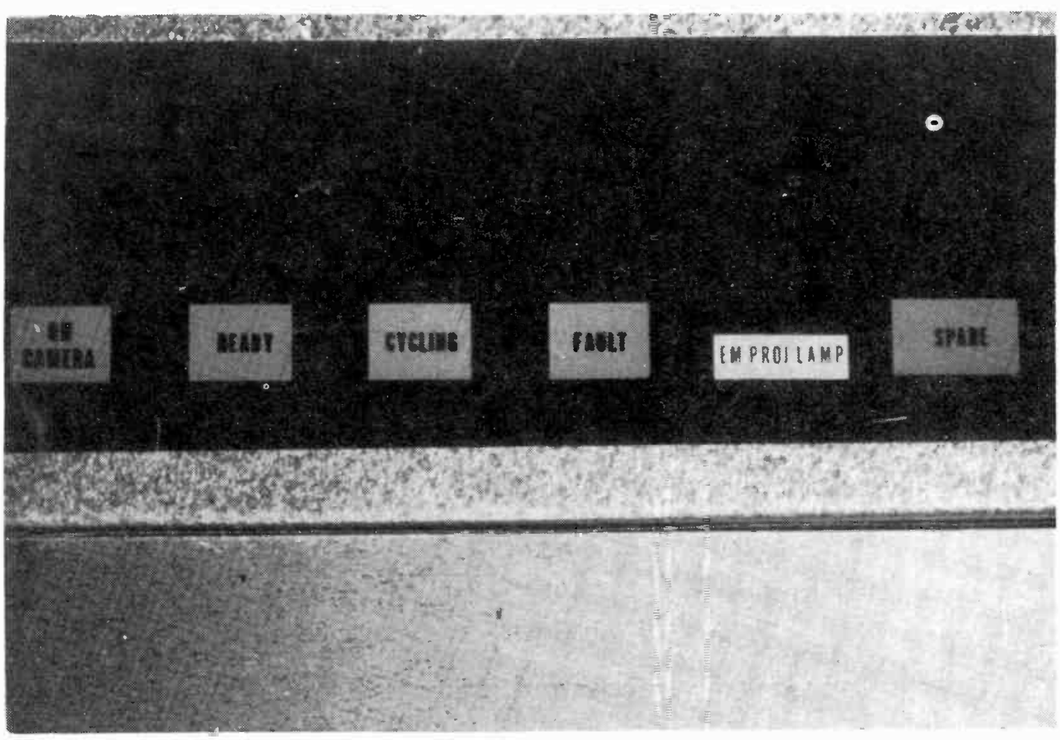
Film running path formed.



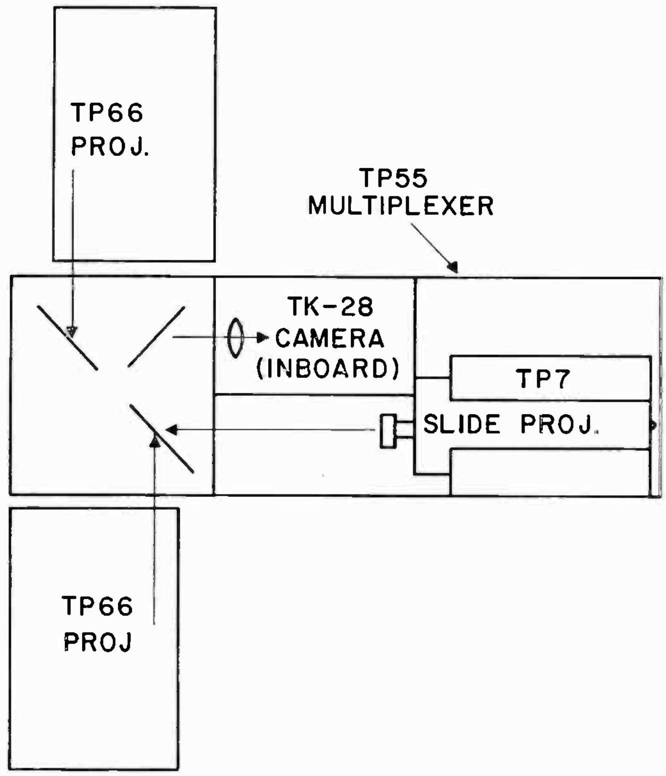
Film cued, some film in slack bin.



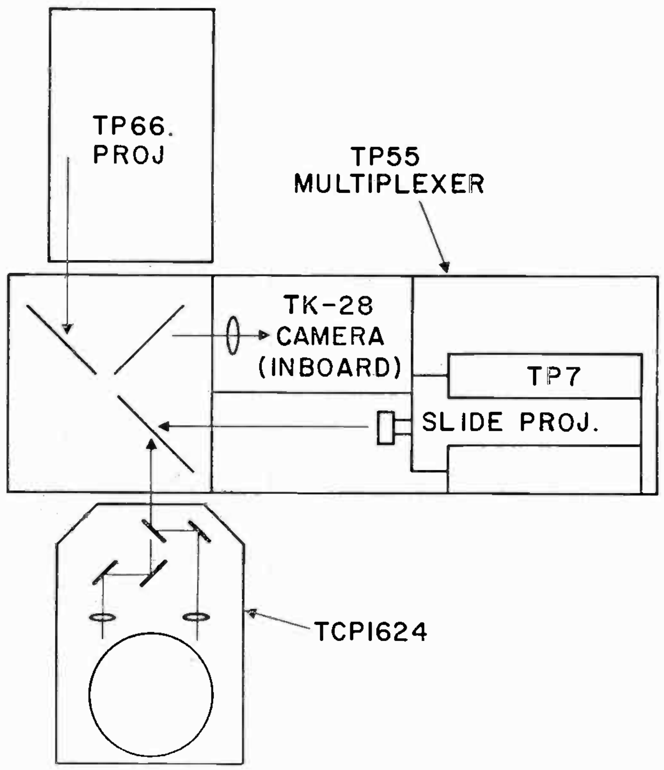
As the projector runs, film accumulates in slack bin (ready to rewind).



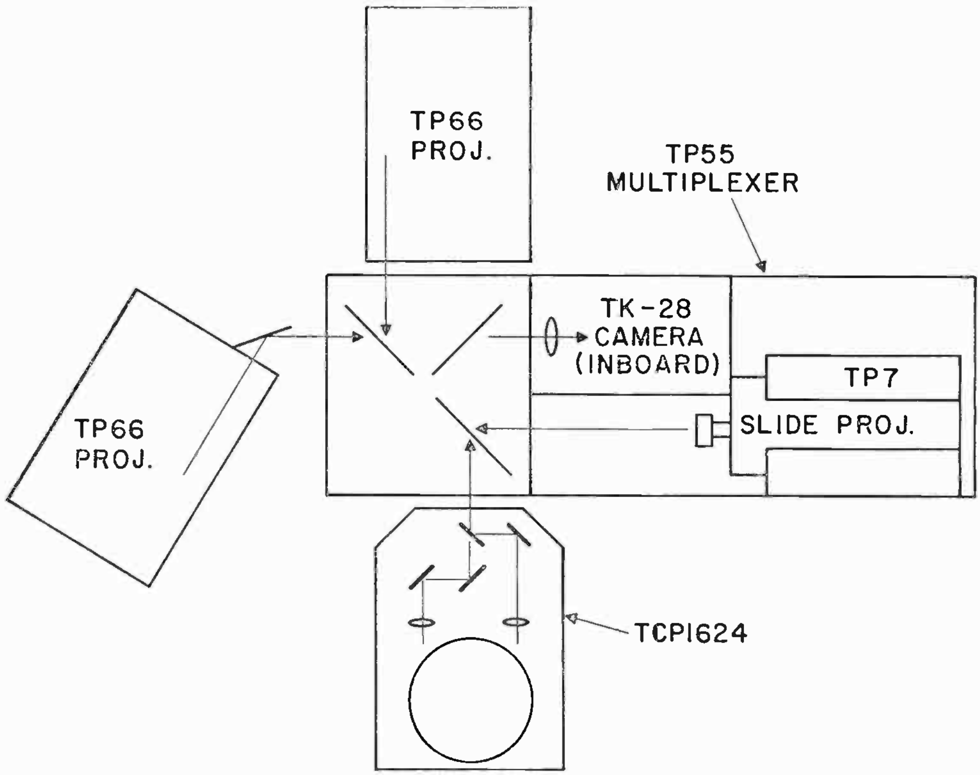
Status panel, lamp-change indicator lighted.



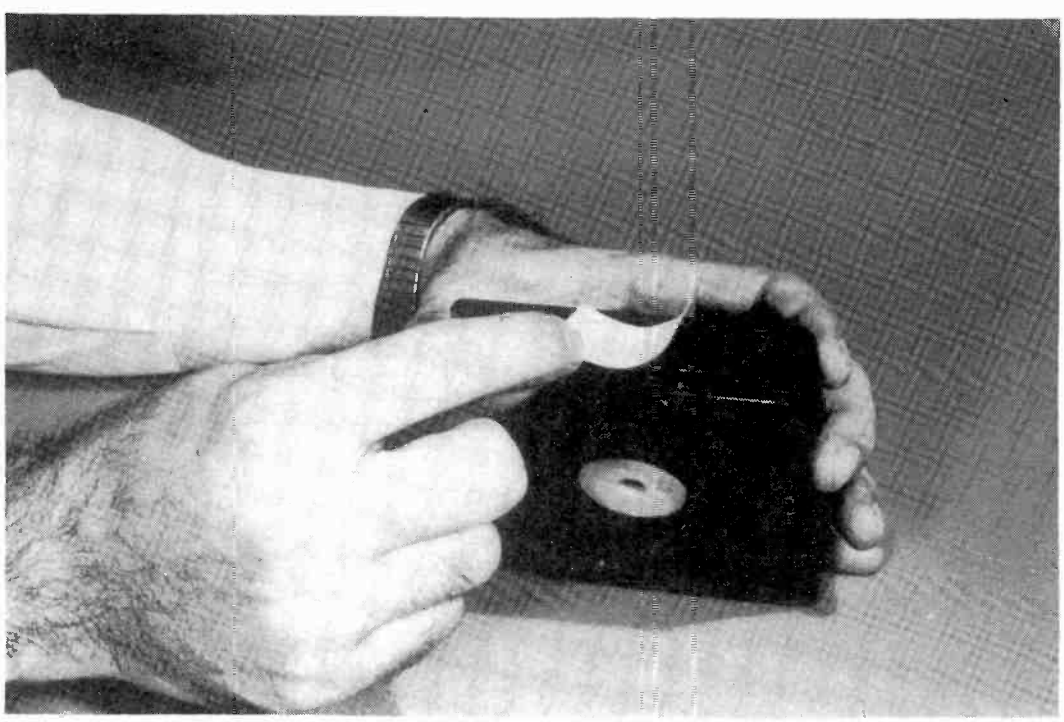
Telecine island including TK-28, TP-55B, TP-7, two TP-66s.



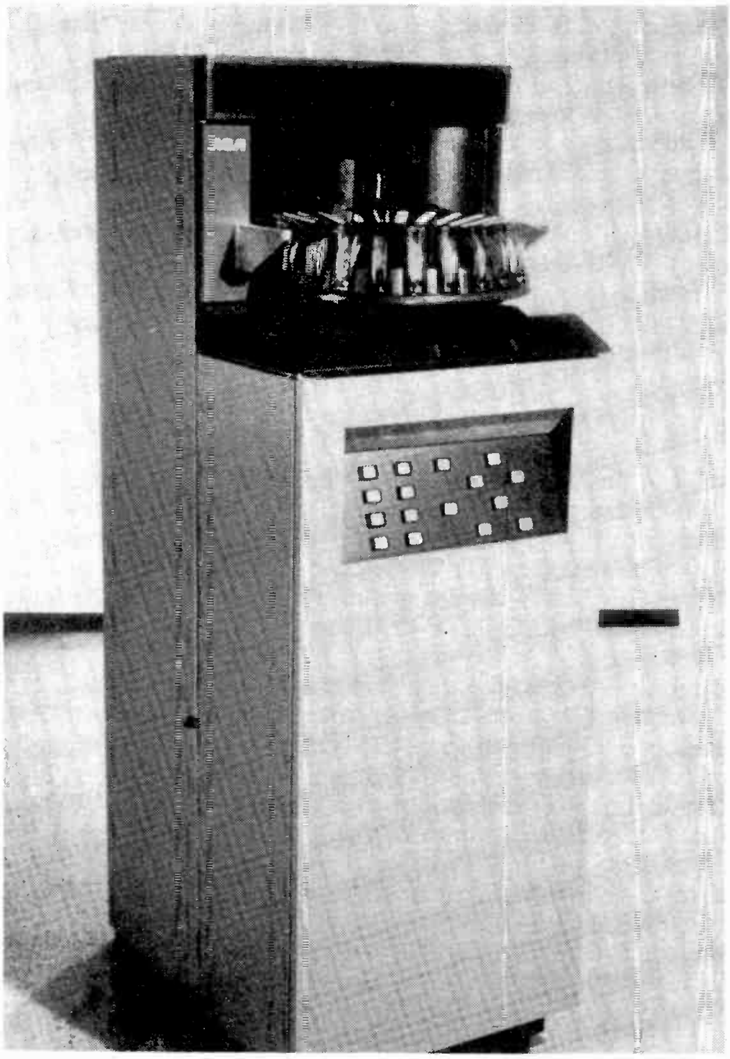
Telecine island including TK-28, TP-55B, TP-7, TP-66 , TCP-1624.



Telecine island including TK-28, TP-55B (internal mount) TP-7, TCP-1624, two TP-66s.



TFC-1 film cartridge with film load.



TCP-1624 in a film island.

4. Optical magnetic sound systems
5. Lamphouse and projection optics
6. Optical multiplexing
7. Power supply and systems
8. Control logic
9. Film takeup pin

Very briefly, the sequence of events in the operation of the automatic projector is as follows. The cartridge is transferred from the magazine to its playback station where a motor-driven puck drives the stiff leader vertically downward into and through the film transport loading path. The film path through the transport loading is an open, unimpeded chute with a strategically placed guide to channel the stiff leader through it and into a slack bin at the bottom of the machine. The slack bin serves as a receptacle to collect the film as it leaves the transport during playback. A proximity sensor detects the presence of the leader when it enters the slack bin and causes the film drive at the cartridge to stop. It also initiates the film threading cycle which starts at the lower sound sprocket and progressively establishes the film running path back toward the cartridge. Once this is accomplished, the film is run in at normal projection speed to a cue which stops it with the first "on air" frame in the gate. The film is now ready for an air playback on command. The same loading action occurs on the second transport with film cartridge 2. Thus, at the conclusion of the initial loading, both transports are brought to a film cued, ready state.

After cartridge 1 has played back, cartridge 2 is available for continuing picture output and the automatic cartridge change cycle for cartridge 1 is initiated. The film path first opens to the load state and the film is then rewound at high speed. When rewinding is completed, the cartridge is transferred back to its location in the magazine and cartridge 3 is transferred to the playback station, threaded, and cued to be ready for the next playback command. The maximum time required for the cycle from detection from the end of message cue on cartridge 1 to the cued and ready condition of cartridge 3 is less than 10 seconds.

As the film is running in at normal speed to the cued first frame position, the presence of magnetic sound track is sensed and the magnetic sound playback channel automatically selected. If a magnetic track is not detected, the sound channel remains in the optical playback mode. Both the sound exciter and the optical projection lamps have standby lamps as backup with automatic changeover mechanisms to shift them into service whenever the primary lamps fail. This changeover is displayed on the status readout panel of the projector to remind maintenance personnel that the primary lamp has failed.

THE TELECINE ISLAND SYSTEM

The TCP-1624 is designed to be another building block in the universal telecine island system which has been available in building-block form since the early 1950s. The output optical axis is 48 inches from the floor and it is designed to fit in existing telecine island systems such as the TK-26/TP-15, PE-240/EK Model 2, TK-27/TP-55, and the TK-28/TP-55B. It can be installed to project into the multiplexer input ports currently occupied by TP-6, TP-66, Eastman 275, 285, CT-500, etc., reel-to-reel 16 mm projectors.

A typical current telecine island as shown in the illustration will contain a TK-28, TP-55B, a TP-7 and two TP-66 reel-to-reel projectors. In such an installation, it is very simple to replace one TP-66 with the TCP-1624. If the deletion of one reel-to-reel 16 mm projector presents an operational problem, it is possible to add the TCP-1624 to a telecine island as in the next illustration so that in addition to the TK-28, TP-55B, TP-7, two TP-66s, the TCP-1624 is accommodated. Thus, the facility of two reel-to-reel projectors is retained.

This brief discussion has introduced a new, exciting tool for automatically handling short sigments of 16 mm film. The films are loaded, then stored and subsequently handled in cartridge form. The cartridges are played back automatically in a very versatile projector that can be used in existing color telecine islands.

Engineering Luncheon Address

Professor Richard D. Cupka
Purdue University
West Lafayette, Indiana

Ernest L. Adams: It gives me a great sense of pride to introduce our guest speaker. He is not only a man steeped in the hallowed hall traditions, but a man of practical experience in industry with a broad understanding of industry's needs and wants as they relate to industry and to the broadcast engineer. Richard D. Cupka is a professor in the department of Industrial Supervision, Purdue University, West Lafayette, Indiana. Prior to joining the Purdue faculty in 1965, Professor Cupka served as personnel manager for a large midwestern paper manufacturing firm and a personnel manager for a major food processing company. He is experienced in labor relations, employment, employee benefits, purchasing, wage salaries, and administration.

Professor Cupka received his Bachelor of Science Degree from Purdue University in 1962 and his Master of Science Degree from the same University in 1967.

To many of you in this room today, Professor Cupka is an old friend. He has been a champion of the broadcast engineer for nearly a decade, and was instrumental in structuring and developing the NAB Engineering Management Seminar each year at Purdue University. For those who have not made his acquaintance, I present to you Professor Richard D. Cupka.

Professor Cupka: Chairman Adams, distinguished guests, honored guest Mr. Ebel, NAB staff, ladies and gentlemen, and then last and least the Purdue Seminar grads.

I think one of the more disturbing things that has already happened to me so far, is that you probably noticed that when all of the distinguished guests were introduced at the head table, I was not among that list of distinguished guests.

I was just delighted a few weeks ago when I received a telephone call from George Bartlett asking that I come here today and spend a few minutes during this luncheon talking with you. In our management development activities at Purdue, we meet literally thousands of people as we deal with them, trying to help them improve and develop their management skills. And it's so seldom that we get an opportunity like this today to again see some of our ex-students, to renew old acquaintances, and it's personally quite comforting to me to see so many familiar faces here in our room.

Those of you who have attended one or more of the produced seminars very likely have an advantage over those persons in the room who did not attend, especially over those persons in the room who have not yet made any kind of a personal commitment to continue their education. When I talk about a continuance of their education I mean as it relates to their engineering expertise and their technical ability; as it relates to their managerial skills, the functions and the processes and accountabilities thereof; or as it relates simply to their total overall professional competency—not just as an engineer, but for what many of you are, managers of engineering.

So you went to college somewhere and you figure you've gotten your education. Why? But at this very moment there are young men and there are young women not only at Purdue, but at many other fine universities across the country, sitting in classes right now in their freshmen and their sophomore years, studying subjects which when you went to school were considered upperclassmen curriculum, or maybe even more appropriately only that stuff that the good seniors get.

Remember, too, as we think about continuing education, it's these young people, these young men and these young women who are going to be coming into broadcasting. These people have two and three more years of education ahead of them, and it's a little bit frightening to me as an educator as I think about my friends in broadcasting, specifically broadcast engineering, it's a little bit frightening to me to think that they, in their sophomore year, may have already caught up with you in your education.

Now, where does this put you then, when, say, for example, one of these young, eager, ambitious, very highly trained, more thoroughly educated, college grads come knocking at your boss's door looking for a job? Or where does it put you then when new technical innovations in your industry come to the attention of your boss, but from outside his own organization? Or what does it make you feel, Mr. Engineer, when someone is needed in your station's organization for the filling of a higher level management job but you aren't considered for it? How does it make you feel when you are not considered for that job because you're just not ready? Or because you're considered a little to shallow? Or because you're considered too technically oriented? Or because someone up there, whoever that is, thinks that you do not and cannot think broadly and with sufficient depth?

But then you've already been to college. Most of you have. Gentlemen, education isn't something that ends, as you well know, with the awarding of a high school diploma, or with the conferring of a college degree. That's only the beginning. And it's what you individually and personally then do that really counts. It's what you do to keep yourself abreast of that young, smart, intelligent, aggressive, and eager graduate coming out of our nation's leading schools. It's what you do to keep yourself aware and abreast of all the managerial and technical innovations that really counts. And in the final analysis, you gentlemen, individually, are the only ones who can really do anything about your continued growth, about your continued personal private development, and about your continued professional progress.

The title of my talk with you today is, "Are You In Step With Progress?"—"Keeping In Step With Progress." Are you really in step with progress? Think about that question. Not right now, but during the rest of this convention. And compared to many of the conventions that I have participated in, it's beautiful. Think about it for the rest of the convention. Think about that question of whether or not you are in step with progress for a week following this convention. And then I beg you—very deliberately—think about that question for every remaining day of your life. I'll speculate that at least one third of the gentlemen here will simply not give that question, ever again, a second thought. And they will continue to be out of step. Some of you will lose your jobs because of it. And those of you who do not lose your jobs because you do not think about keeping in step may by one reason or another be kept on the payroll. If you choose not to think about the question, well then your stations and their sounds and their pictures will be something less than they should and could be. And, you know, if I were a general manager I don't think I would tolerate that.

Now, on the other hand, for those of you who will be continuing to ponder that question of whether or not you are truly in step with progress, what types of things might you get involved in? What types of things might you want to learn about? Well, as I was preparing this talk, I asked myself that question and I tried to think back over the last eight seminars we've had at Purdue, and these are the things that came to mind.

What might you learn? Well, the first and the most obvious answer to that question, is, of course, engineering. And I got to thinking, well, not really. And this thought came to mind. Should we leave all of the learning and all of the study of the engineering sciences and the creative application thereto—thereof to the manufacturers? That would be the easiest way, wouldn't it? Because then you, as engineers, all you have to do is purchase and then maintain the product of their learned creativity and application. In that way you don't have to get involved with that kind of learning. We can leave that to the manufacturers.

Well, how about some learning in the area of sales? That question came to mind because of some of the things that have happened at Purdue over the last eight years. And then I thought, well, what the heck, a chief engineer or an engineering manager really shouldn't get involved in sales, should he? So we'll leave that learning to the sales man, the sales manager.

Well, then, how about some learning in the areas of finance or cash flows, station budgets, cost control? Not really. These things are sort of the daily weights of executives, aren't they? Besides it's hard for guys like you and me as engineers to find time for stuff like that when you're an engineer type, isn't it?

Well, let's forego that then and ask the question, well, how about learning something of marketing, production, labor relations, human relations, news, accounting, etc.? And some of the people that I put this question to at Purdue replied, "With all the engineering problems I've got, and with all the paper work I should be doing, there just isn't time to learn about all these things. I'll get to them some day, as soon as I get around to it." There's a special meaning there. And if you want to find out what "around to it" means, ask the graduating class of 1973.

The question again, are you really in step with progress? Think about it gentlemen, because, and here I quote an executive of the Carrier Corporation, whom I once heard speak—and this man said, "If you do not think about your future, you just may not have one."

In the February 1973 memo and instruction the NAEB reported that the Commission on Nontraditional Study had just completed its final report of a 2-year study on adults in continuing education. For those of you who may have seen this publication, you remember that of all the persons interviewed, the these were persons considered adults, between the ages of 18 and 60, none of whom were full-time students, about three-quarters of those persons interviewed said they wanted to continue their education. About half of them indicated thay they would prefer additional job career training. One-third of them had already gotten themselves motivated by one means or another, or for one purpose or another, to become actively involved in some form of continuing education. For example, evening classes, correspondence courses, seminars, conferences, on-the-job instruction, university programs, and workshops.

But the great bulk of these part-time students were not concerned with getting a degree or with going back to school to get another degree. They were, I suspect, simply trying to keep abreast or maybe even stay ahead of the constant demands of their ever-changing jobs. In fact, according to the C & S, there were only about 5½ percent of all of these people who even wanted to go back to college. They were career oriented.

Well, then if so many people want to become involved in continuing their personal growth and their personal career-oriented education, why then do they not do so? The answers that are most frequently offered to myself and my colleagues at Purdue in response to that question are quite varied. Most often, as I reflect back on them, they are uttered without ever really having been thought about. The brain was not put in gear before the mouth was.

For example, one of the more common and quick replies to the question of, well, why don't you get some education? Why don't you go back to a seminar or school and develop yourself? One of the most common replies is, it just costs too much.

Well, my personal comment to that, gentlemen, is that you cannot afford not to continue your education or your development. And besides, the excuse that it costs too much doesn't hold too much water with me anymore as I learn more and more about the cost-sharing systems that many of your employers make available to those people who will avail themselves of financial help.

Another common reply or an excuse to the question is, it would just take too much time away from my family and too much time away from so of the other things in life that I want to do. Well, let me speculate, gentlemen, that those of you who have fallen prey to this particular excuse, at some point in your future, you will have all the time you want to spend with your family, that is, until you can find another job to get yourself off the ranks of the unemployed.

Another frequent excuse is we just have so darn much work at the station that I just can't afford to take the time away from my engineering job. And, gentlemen, that's a killer concept. Because what it leads me to believe is that the person uttering this remark has not yet learned to manage his time, nor the time of his subordinates, nor his own job functions or theirs. And that, in all likelihood, the man is simply a poor, possibly incompetent, but technically qualified manager. And again, here too, if I were a general manager I don't think I would tolerate that.

Now, some of the Purdue grads here have used that very excuse in the past. But many of them have learned since that there are ways of motivating people to take home more work, and possibly even enjoy it. Thus, these managers have gained more time for a higher priority, more important personal activities, for example, their own self-development, their own progression, their own personal growth and personal professional improvement.

And then there's the classic of all excuses, which goes something like this, "All the studying and the learning in the world isn't really going to do me any good. I guess I'm just an engineer at heart. And all of the good jobs, like a general manager vacancy, are going to the boys from sales and marketing. I guess they just don't think engineers can be good executives capable of holding good jobs like that."

And you know what? The man that makes that kind of statement to me, he's right. He's dead right. And he's right when he as a chief engineer or a director of engineering hasn't significantly, personally, actively tried to learn to be more than just an engineer, and hasn't tried to broaden and develop himself to the point where he is worthy of consideration for the good jobs.

But then if I were a broadcast company president, I wouldn't take the time either to look at the typical engineering manager or chief engineer as potential for a spot on my executive staff. To the contrary, I would look to the man who is willing to stick his neck out like a salesman. I would look to that someone who is articulate and outspoken, like a salesman. I would want someone capable of growing, capable of progressing, capable of broad and indepth conceptual thinking abilities, like a salesman. I wouldn't think to look to the engineering department for a man of those characteristics and qualities unless, of course, someone in the engineering department showed me that he had those qualities. At that point in time, my friend, I most certainly guarantee you, you would spark some interest in me in looking at you as potential.

And, finally, there is the most frustrating of all excuses as to why men just like yourselves don't actively, systematically, and thoughtfully pursue their own self-development. And it goes something like this. I'm just too old. I had this said to me earlier here at the head table. I'm just too old and too set in my ways to learn something new. Anyway I can't keep up with all these new things coming along and all of the smart kids coming in. I guess I'm just over the hill.

I simply don't buy that kind of thinking. Age doesn't have that much effect on learning. It does affect physical performance but not that much on learning. But a desire to learn, or a lack thereof, most definitely and assuredly does affect learning.

Let me give you a couple of brief, quick examples here which, even though they are exceptional, they do point out what man's motivation and commitment can do to help him.

When I started out as a freshman at Purdue a few years ago, one of the first greenies that I had a chance to meet and talk with was another new freshman sitting right next to me in the auditorium during the opening session of freshman orientation week at Purdue. This freshman, however, was 72 years old. He had been forced to retire. And he had decided after laying around for awhile that he would continue his schooling.

By the way, the last schooling that he had or had gotten involved in just prior to enrolling as a freshman at Purdue was a 2-year noncredit course in biochemistry, which he had very successfully completed just prior to the year he enrolled at Purdue.

Incidentally, this 72-year-old man who can understand and comprehend and pass with distinction a 2-year noncredit course in biochemistry was a retired mailman. And his plans for the rest of his life were to become a management consultant. He graduated the same year I did, with a Bachelor's in hand, but unlike me, this 72-year-old duffer, who was over the hill, graduated with distinction and I didn't.

Now, another quick example, on the Purdue campus, right at this very moment, there's another older fellow and I wouldn't even attempt to guess his age. But this man has taken an educational leave of absence to further his education for career purposes. He is working at this very moment on five Master's degrees **simultaneously**. Sure, it's rough on him. But he'll make it and he'll have much more in the way of career potential to offer his present employer or to just about anybody else who would look at him. And I grant you, they will.

Let me close with this: Earlier, in his introduction of Mr. Ebel, George Bartlett said, "He is presently a member of the AMST Technical Committee and Board,"—now, think about these things this time through. Don't just hear them. Listen to them and think about them—"He is presently a member of the AMST Technical Committee and Board. He is Chairman of the CBS Affiliates Satellites Study Committee. He is Chairman of the Combined Networks Affiliates Satellite Study Committee. He is a member of the President's Frequency Management Advisory Council. He has participated in several international conferences. He is a member of numerous technical and professional societies, and is the author of many landmark publications in broadcasting. And on top of that, he's got a job, too." And as was said earlier in the introduction of Jim Ebel, "His intensive self-instruction has paid off, not only for himself and for his charming wife, but for the industry—the greatest benefactor."

All progress, all personal development is only a result. It is only a product of something else, and that something else is intensive self-instruction. Now, you can sit there and envy Jim Ebel all you like, but I have somewhat of a feeling about all of the thinking and all of the studying and all of the learning that this man has poured into himself. Most assuredly it hasn't all been easy. It hasn't always been fun or enjoyable, or always a satisfying experience to him. This I know for sure. But we are all honoring Jim Ebel as someone who is very special to be honored and respected by the members of his industry as an outstanding leader in that industry. And I personally will credit his current stature, prestige, and position to an awful lot of very trying, very hard, very time-consuming and often exasperating intensive self-instruction. Mr. Ebel, I commend you, in spite of the fact that you chose to leave Purdue.

Gentlemen, I poked at you enough for one sitting, so let me conclude my short talk here by asking you to remember this, and many of you have heard it before—today is the first day of the rest of your life. My urging to you at this point and time is: so use today, and use all of the remaining todays wisely. Keep yourself in step with progress. And remember this, too; think about your future so you will have one.

Digiplex, A Digital One-Line Machine Control System

Al Busch
Director of Engineering
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Bloomington, Indiana

Digiplex is the name we have given to the Sarkes Tarzian one-line machine-control system. This system allows a technical director at a remote control panel to operate a number of film islands and VTRs via only one communication channel. This channel is a balanced pair of conductors which originates at the control terminal panel and is looped through every VTR and film island terminal.

Before discussing how Digiplex functions, I would like to guide you through the installation at WETA here in Washington to give you an idea of what a Digiplex system looks like and what it can do. WETA has facilities for eight VTRs and five film islands to be controlled from any of four control positions via four communication lines.

Each VTR has an associated terminal which is connected to each of the four control terminal lines. On the front panel of each VTR terminal are four independent pushbuttons for delegating the VTR to any or all of the remote control panels. This multiple-control feature could result in operating economies. If, for example, a VTR has been delegated to two remote control panels, it may be started by a technical director at the first panel and that panel might be then deserted. The technical director could then go to the second control panel and, when the VTR output was no longer needed, turn the machine off from the second position.

The multiple control feature is optional, as is the status panel, which can be located at each control panel to advise each technical director as to which machines have been selected for control.

Each VTR terminal contains logic circuitry which recognizes the commands which are addressed to it and which provides dry contact closures for operating the machine. Each VTR terminal senses the status of the machine and returns tally information to the remote control position.

Each film island similarly has an associated terminal which has delegation, command, and tally functions identical to those of the VTR. However, the film-island terminal can control up to four machines and a multiplexer instead of just three machines as at WETA. It must respond to three separate addresses and accumulate tallies from three machines.

Each control panel at WETA has thumb wheels for the selection of three film islands and four VTRs. In effect, this is a double-delegation system in which the telecine operators make a bank of machines available to each control panel and the technical directors choose from among that bank which machines to control from each position on the control panel. Little or no oral communication between the control rooms and the machine rooms is needed. When a machine is selected at the control panel, at least one of the buttons is illuminated if the machine has been delegated to the panel. If not, all lights at the position stay off. If a delegated machine is selected but is put on local control at the machine, the tally lights blink as a warning to the technical director.

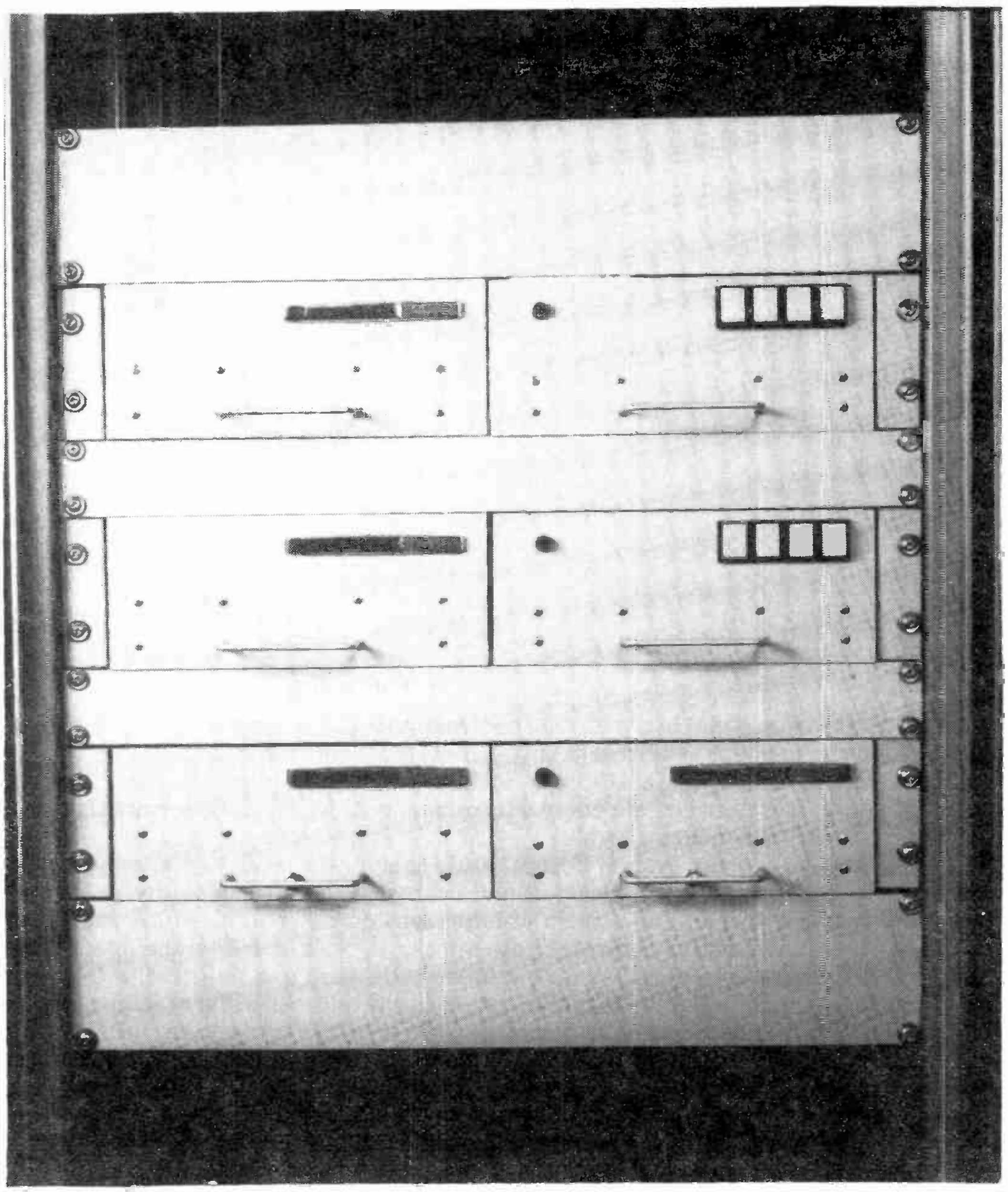
There are probably as many different requirements for machine control as there are stations. The number of machines can vary. WETA has five islands (one has a slide machine only) and eight VTRs. There is a total of 21 machines and three multiplexers under control; but, for operational simplicity, the machine selection at each position is made with a single 10-position thumb wheel. This application does not extend the Digiplex system, which can address 128 different locations.

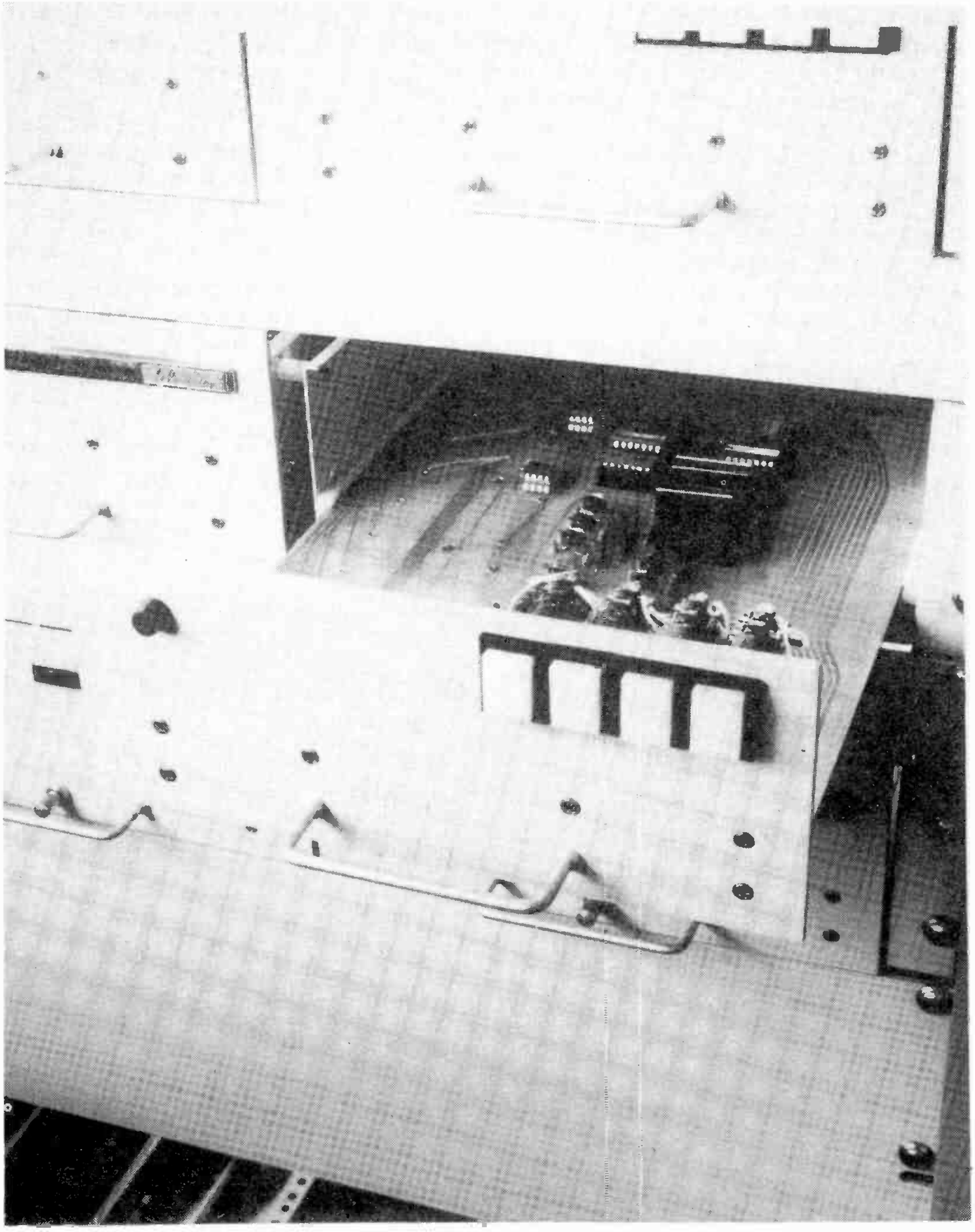
The number of required machine functions can vary from station to station. WETA chose four for each film projector and three for each VTR. Digiplex has facility for seven independent functions for each machine. For example, it can provide start, stop, forward, reverse, still, show, magnetic, optical, cue defeat, fast, and normal speed buttons for a film projector because these 11 functions are interrelated and have only seven independent functions. The remainder are toggle functions (eg. optical and magnetic).

A group roll pushbutton has been provided to allow simultaneous roll of selected machines. The TD has switches which he can use to select which of the machines he has under control and which should be part of this simultaneous roll.

WETA has three control rooms in operation and a fourth projected and provided for. Digiplex is unlimited as to the number of control panels. However, if the multiple control option is selected, eight is a practical limit.

There is no requirement that control panels be identical in size. Simultaneous control of every machine in the station could be provided at one panel, while at another only one machine could be selected at a time. And the functions to be con-



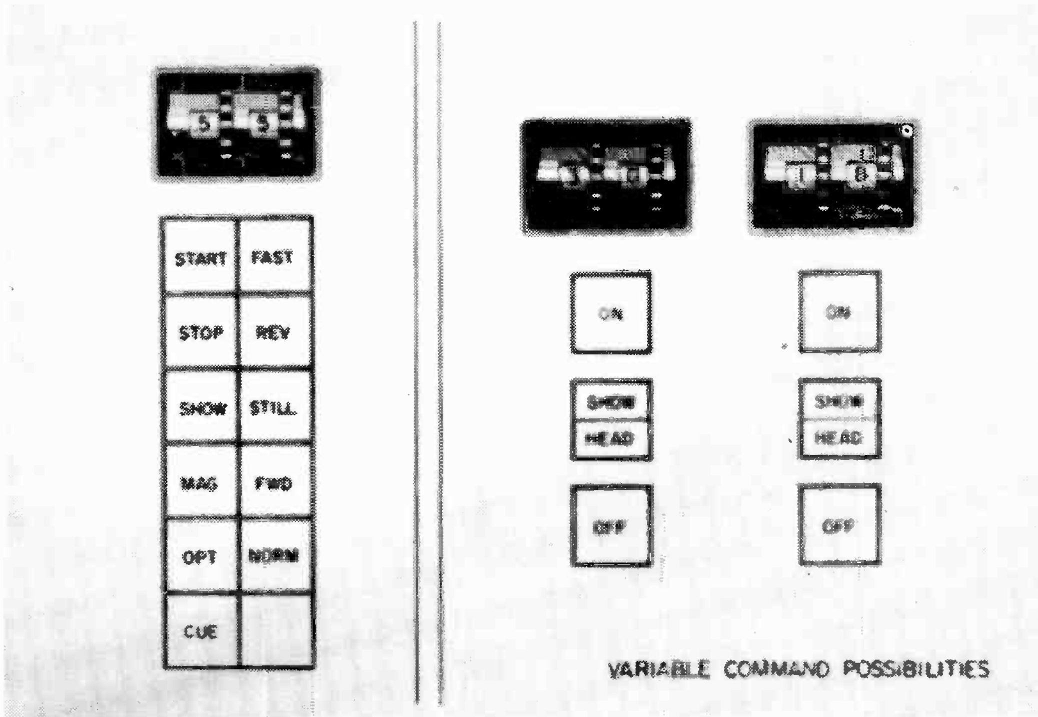


trolled can vary from panel to panel. One control panel could control nine functions of one machine and the next panel might only control three functions.

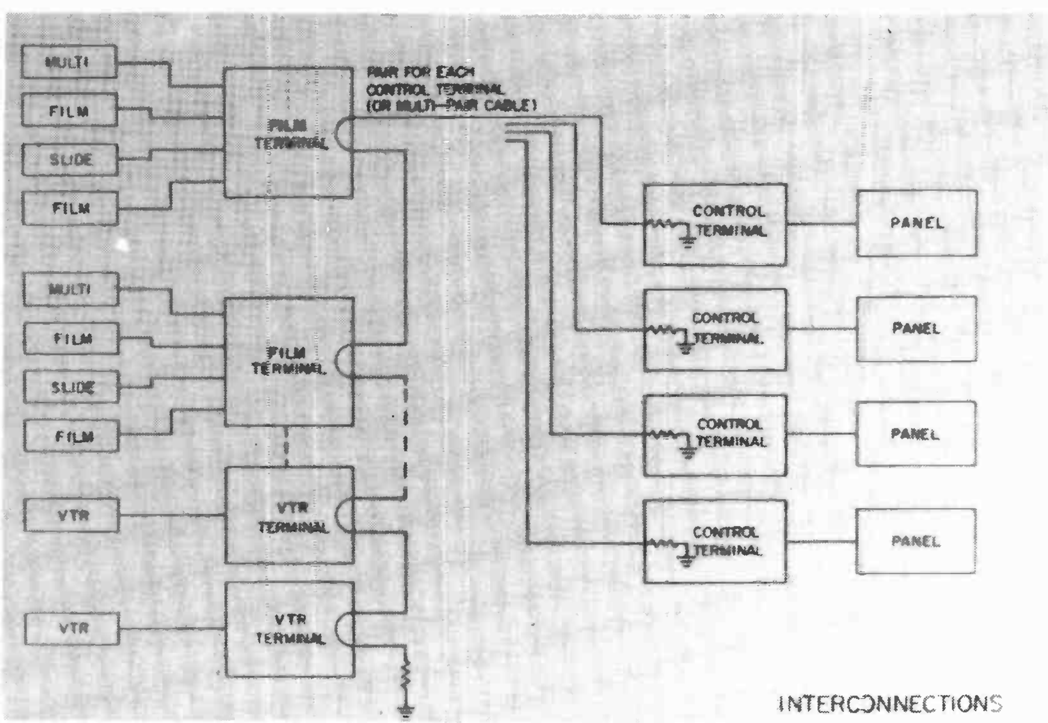
The interconnections of a Digiplex installation are simple. The four looping communication lines between the control terminals and the machine terminals could indeed be a single 8-conductor cable.

Let us now discuss the system design. Each machine is assigned a unique code which serves as the machine address. Each control terminal constantly generates and puts onto the common line a train of addresses corresponding to the machines which have been selected for control. These appear in serial form on the line. These code word addresses are spaced so that another code word can be fitted in between the addresses. When a machine terminal receives the address of its machine, or (in the case of a film island) of one of its machines, a code word representing the status of that machine is generated and placed on the common line immediately following the address word.

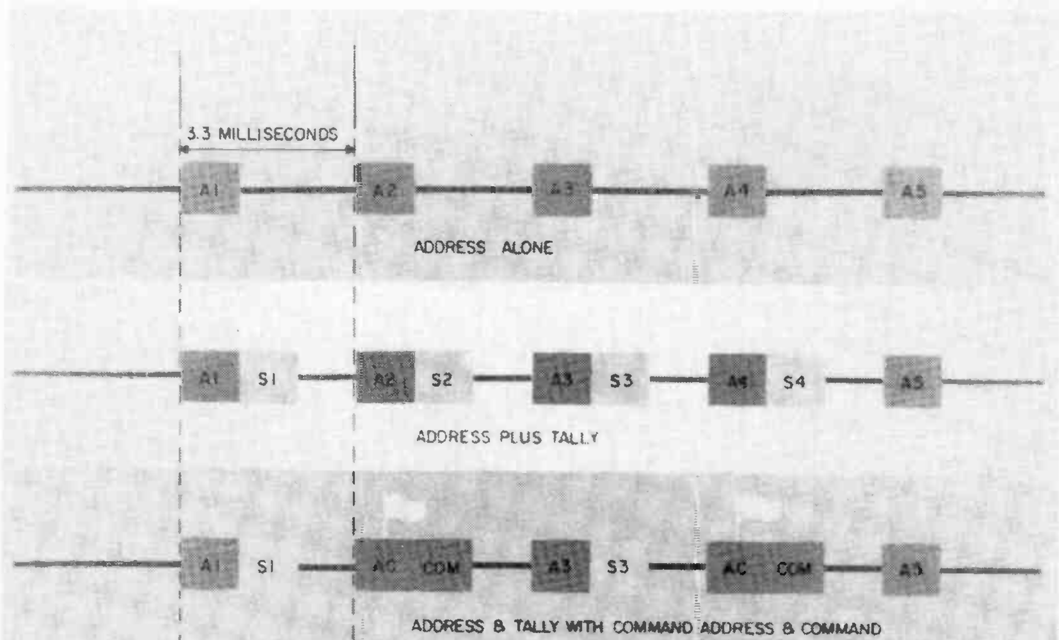
An address word and its status word take only 3.3 milliseconds. A control terminal, for example, with 13 machines under control would poll every machine and refresh its tally information once every 43 milliseconds.



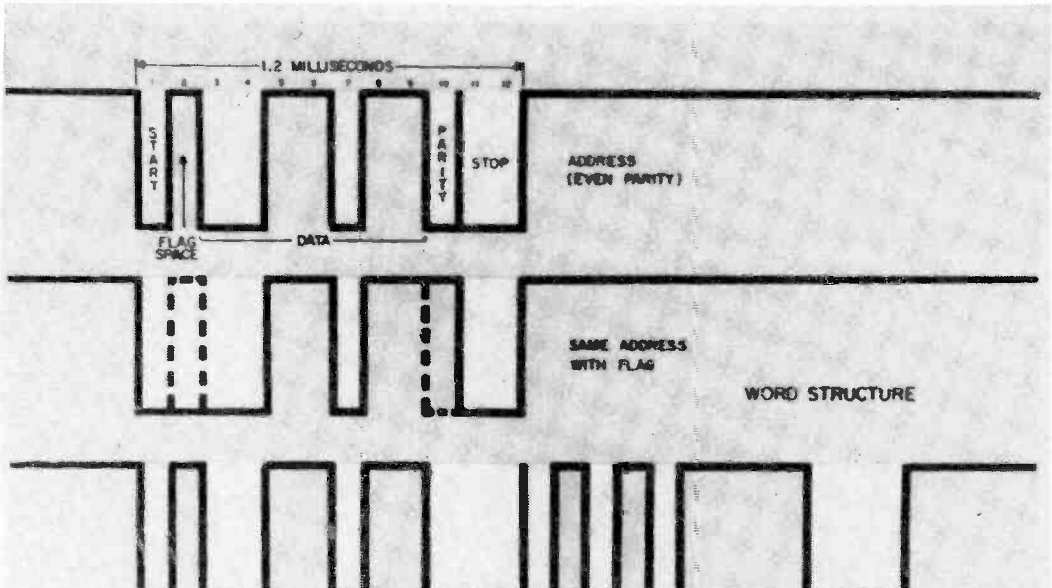
VARIABLE COMMAND POSSIBILITIES



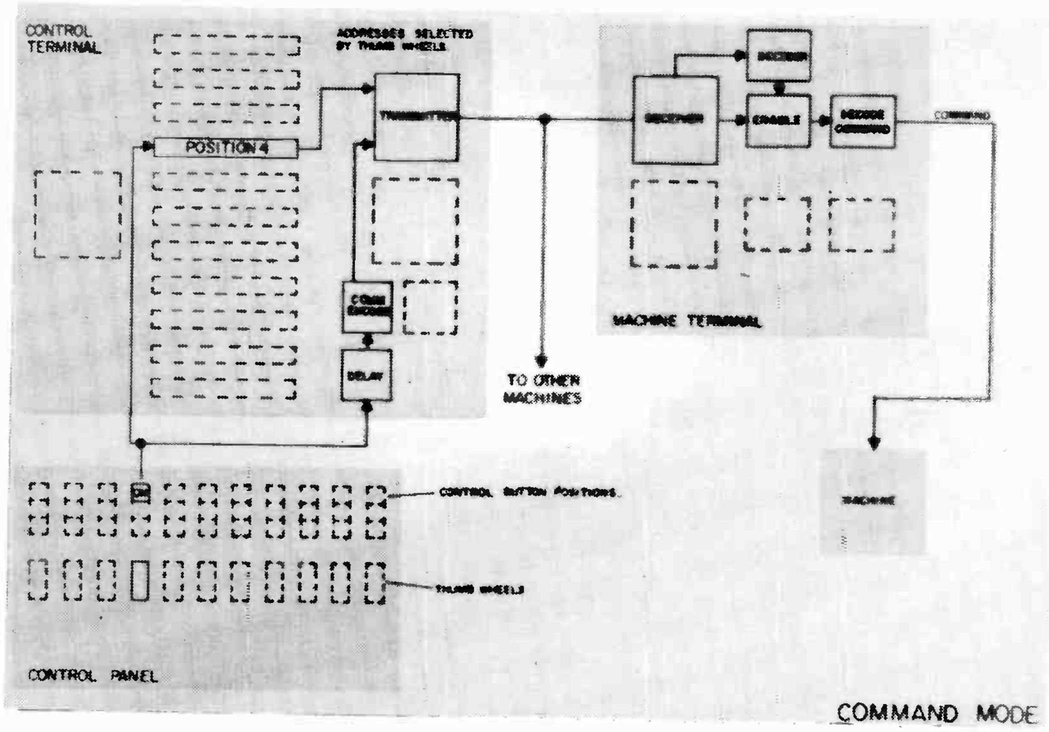
INTERCONNECTIONS

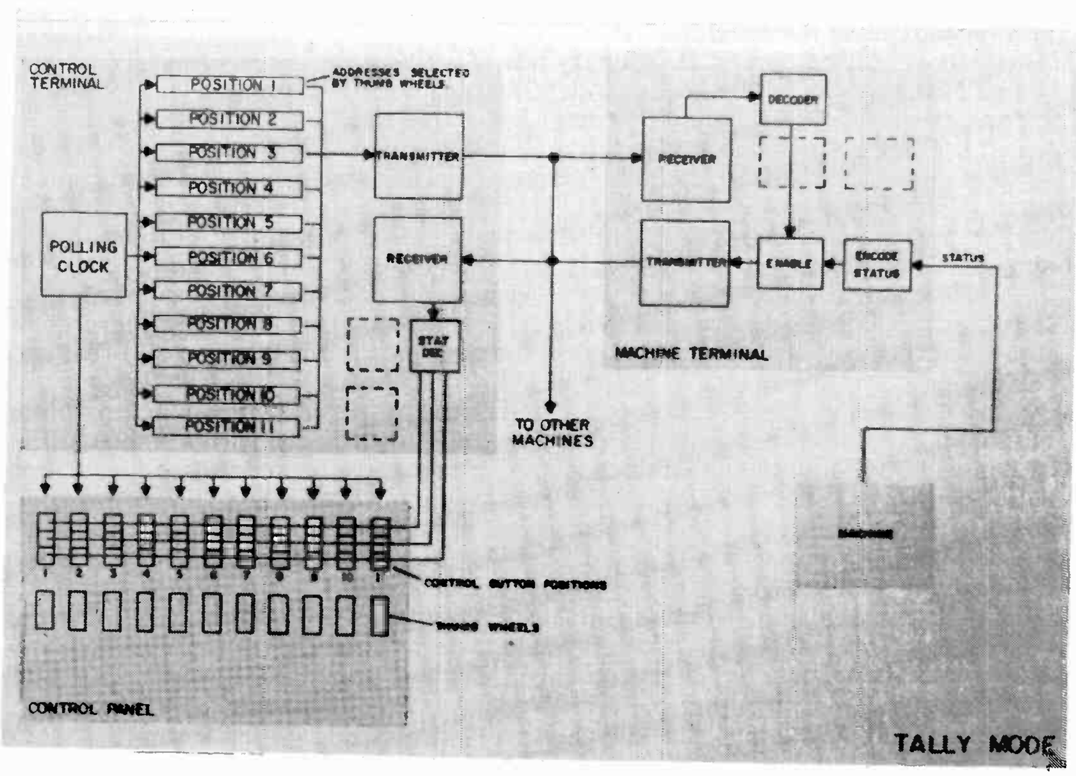


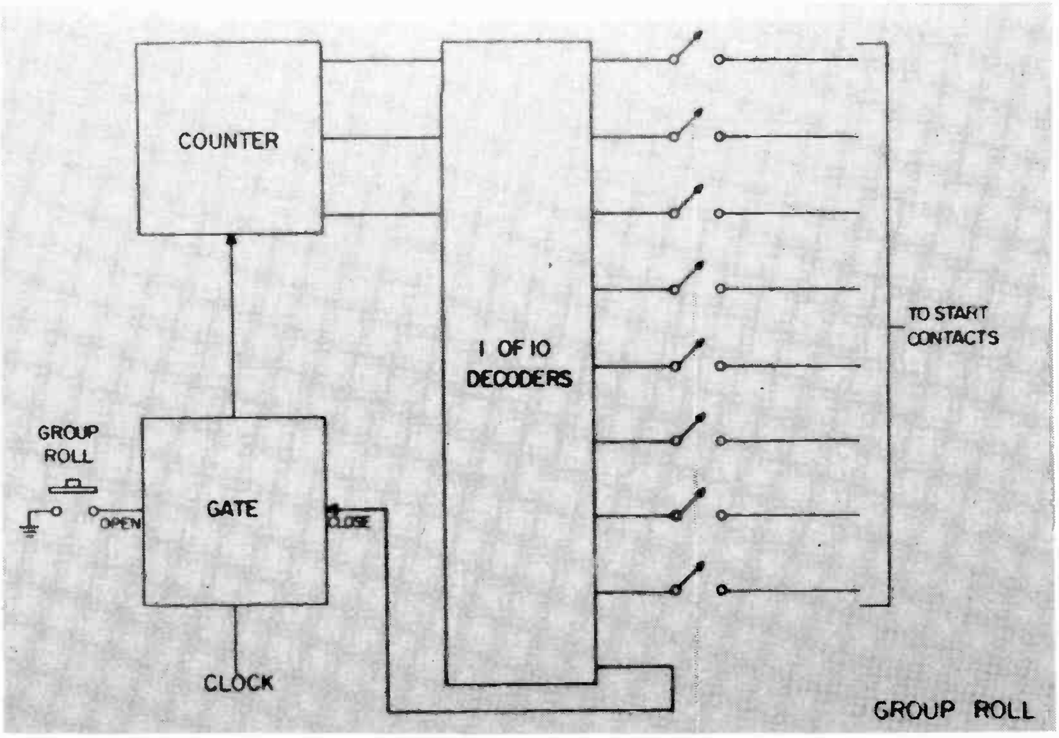
WORD TRAIN STRUCTURE



WORD STRUCTURE


CONTROL TERMINAL
POSITION 4
DELAY
TO OTHER MACHINES
MACHINE TERMINAL
CONTROL PANEL
COMMAND MODE


CONTROL TERMINAL
POSITION 1
ADDRESSES SELECTED BY THUMB WHEELS
POSITION 2
POSITION 3
POSITION 4
POSITION 5
POSITION 6
POSITION 7
POSITION 8
POSITION 9
POSITION 10
POSITION 11
POLLING CLOCK
TRANSMITTER
RECEIVER
DECODER
ENABLE
ENCODE STATUS
STATUS
STAT DEC
MACHINE TERMINAL
TO OTHER MACHINES
MACHINE
CONTROL BUTTON POSITIONS
THUMB WHEELS
CONTROL PANEL
TALLY MODE



When a command is issued by pushing a control button on the remote panel, the train of address words and status words continues; but every second address-status combination is replaced with an address-command combination generated at the control terminal. The command is received at the machine terminal and is decoded and used to present a dry contact closure for the machine status change desired. The address word associated with a command is modified by the addition of a "flag" so that it does not evoke a status response while a command word is on the line. A command appears at the machine terminal no later than 6.6 milliseconds after the control button depression. The modified tally information is returned not later than 86 milliseconds after the machine has changed status.

Each word is composed of 12 binary bits of which eight are used for signal purposes. Each bit lasts for about one tenth millisecond. For a command word, the first bit and the last two bits are "framing" bits, which are used by the decoders to recognize that a word exists. The second bit is used as a "flag" to signal when an address associated with a command appears. The next seven bits are used to generate one of 128 possible addresses. The tenth bit is a parity bit. The address is always presented in even parity and this bit is "high" whenever there is an odd number of "high" bits in positions two through nine.

The command word is identical in form with the address word, except that the flag bit is never used. A single high on bits three through nine is used to represent a command. The status word is identical to the address word in form, except that odd parity is used.

The circuitry of Digiplex can best be understood by considering the two operating modes—tally and command—separately. The tally mode is the normal mode of the equipment. The polling clock continuously steps from one machine address to another until all the machines selected by the control panel thumbwheels have been addressed. The polling cycle then repeats until interrupted by a command. The addresses are transmitted to all the machines in the station. The machine terminals compare the addresses with the assigned machine codes. When a correct address is received at a machine terminal, a status word is transmitted immediately following the address. This status word is received at the control panel terminal, decoded, and fed to control panel tally lights. The polling clock steps from one tally-light position to another in synchronism with the address steps. As the polling clock signal steps from position to position, it latches the tally lights with the updated status information from the addressed machine.

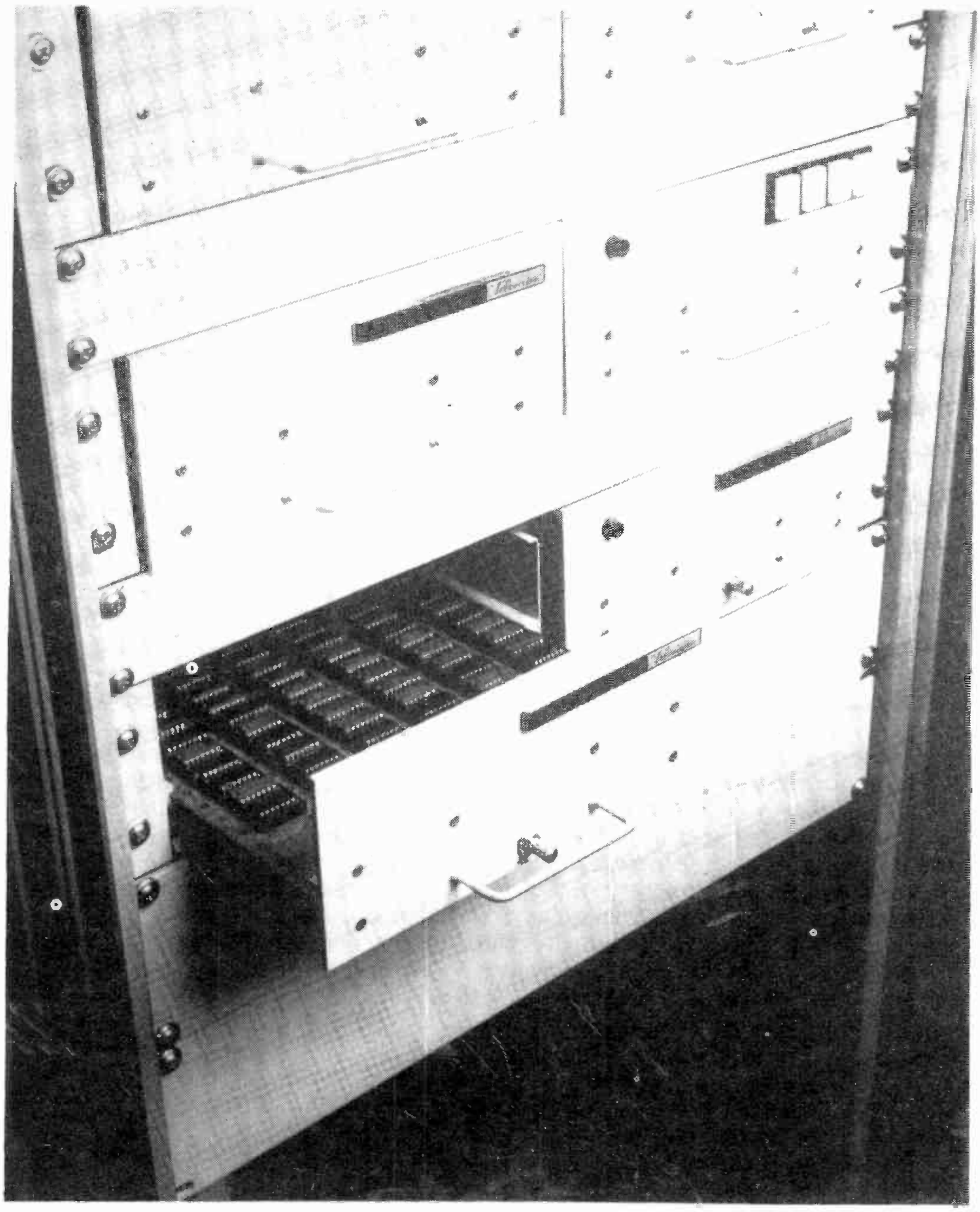
When a control panel pushbutton is activated, the polling clock is interrupted for 3.3 milliseconds and the address of the machine associated with the pushbutton is substituted for the polled address. In addition, a flag bit is added to the address to identify it as a command address. Immediately following the address, a command word is transmitted. This word occupies the position normally filled by the status word when Digiplex is in the tally mode.

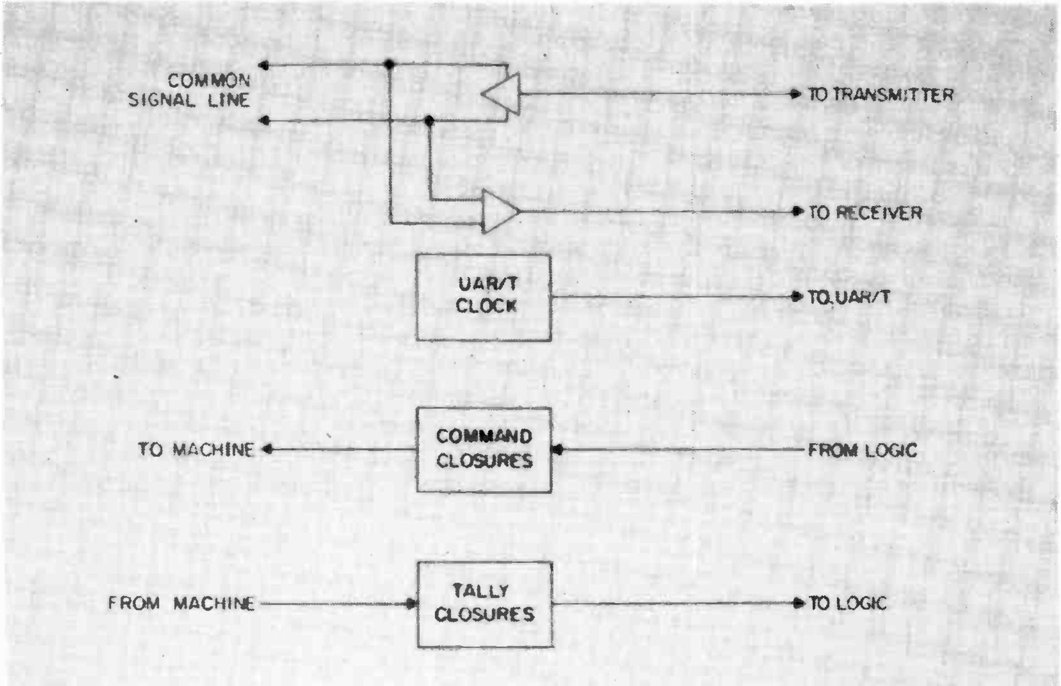
The machine terminal decodes the address word and, because of the presence of the flag bit, inhibits the tally return. The command word is received, decoded, and fed to the machine in the form of a dry contact closure.

Following the transmission of the command word, the system reverts to the tally mode. The interruptions to the tally mode continue to occur on alternate words until the control panel pushbutton is released.

The start pushbutton contacts of each VTR and each film projector can be connected via a switch at each position to a group roll circuit. This circuit applies a ground successively to each connected start contact if the group roll button has been depressed. The elapsed time required to command eight machines is 53 milliseconds.

The circuitry of Digiplex is almost entirely composed of integrated circuits. One special component is worthy of individual attention. This is an MOS digital code transmitter and receiver which has been developed for computer communication use.





INTERFACE

This single chip accepts logic signals in parallel form and transmits them in serial form. It checks and corrects parity. It receives signals in series form and presents them in parallel form, after having decoded the start and finish of each word, and checks and signals the parity status. Circuits are built into the chip which allow us to operate many receiver-transmitters without the use of a common clock. This chip, with its 15 decision circuits and six registers, makes possible the relatively simple logic circuitry used in Digiplex. The control terminal, for example, has only 71 chips, while the VTR terminal has 47.

An interface card at each terminal contains the circuitry for transferring the logic signals to and from the common balanced lines and for supplying clock signals and power. Balanced lines are used for signal transmission to gain noise immunity. If the terminal is a machine terminal, the interface card also contains the interfaces for controlling the machines and for receiving tallies.

There are no adjustments to be made anywhere in Digiplex. The control room cards are all identical, as are the VTR cards and the film island cards, except for the plug-in module which establishes the unique address. Service by substitution is simple; and, of course, because of the reliability of logic circuitry, service is not often needed.

The installation of a system is fast. The terminals mount into racks and the control panels are fitted into consoles or racks. Only one small cable is strung between the control rooms and the machine. The machines are prepared to accept closure commands and to return tally signals and the installation task is complete.

Once Digiplex is installed, the need for control-room-to-machine room intercommunication almost vanishes. As an exaggerated example, a single man could load and assign machines, walk to a control point, operate for a while, stroll to another control point for another stint of operating, wander back to the machine room to change tapes or film, and then go back to a control room. Or the common control line could be looped through a computer so that the machines would be automatically operated in accordance to a pre-established program.

Minicomputers for the Control of the Broadcast Transmitter System

William J. Clark
Vice-President, Engineering
RKO General Radio and Television

As recently as five years ago, closed-loop data acquisition and process control automation for broadcast transmitter facilities was virtually unheard of. At that time, however, some industries were well along the way toward almost complete plant automation. The result for some of these industries has been a striking improvement in operations cost effectiveness, and advances in production technology wholly automation-related. It is not unreasonable for the broadcaster to expect similar benefits. The modern minicomputer has made such systems practicable.

Automation of the broadcast transmitter plant can affect station operations in several ways. First of all, it can assist in achieving maximum quality and dependability for the broadcast signal. An automated system is able to continuously scan operating parameters, providing a much tighter watch on transmitter operations than can be achieved without this automated monitoring. It can also minimize the hazard of operator error by simplifying control functions and, in many cases, eliminating the need for direct emergency action by the operator. The mechanics of such things as changeover to standby equipment, in the event impaired signal quality is detected, can be made automatic and immediate.

Further consideration of the man-machine interface brings us to a second important point. Automation of the broadcast transmitter system should make possible a more effective use of skilled personnel. This is especially critical in some of the present large-market transmitter facilities. A large part of a transmitter staff's responsibilities has traditionally been the record-keeping chores and "crisis intervention." Both of these detract from staff productivity. They replace the skilled work of maintenance, design, and troubleshooting with a routine of record-keeping and button-pushing. In this day and age, it is difficult to justify the skilled electronics technicians necessary for air-chain maintenance and then use them as clerks.

Transmitter automation can improve the quality control of the broadcast signal and eliminate "busy work" for a technician's schedule. It can also expedite the maintenance work itself by providing more complete operating and maintenance records for the technician's use without increasing his workload. Data on component performance and expected life could be made available, as well as a tabulation and summary of the results of daily air-chain tests automatically initiated and recorded by the minicomputer system. It is also worth noting that during the majority of the broadcast day, a significant part of such a system's operating capacity will be available for routine housekeeping tasks such as working out maintenance and personnel schedules.

Perhaps the reason that control automation systems of this type did not appear in broadcasting simultaneously with automation systems for other industries can be seen from a comparative analysis of the systems involved. The profitability of the computer-based automation systems used for manufacturing is based upon their high throughput for repetitive functions and their capacity for fast-turnaround flexibility. The economics of broadcast facilities place primary emphasis, instead, on reliability and simplicity in a generally slower-paced, highly interactive real-time system. The minimum configuration with maximum dependability and efficiency in terms of the practical requirement of this application is required. The realities of broadcasting also bring into play a special set of acutely important man-machine interface considerations. Systems for this industry should be designed to be reliably operated, maintained, and even up-dated by a staff of minimal size which has no extensive special training on the system. New sophistication in system design is required to successfully meet the conflicting demands for both architectural and operational simplicity in a high-reliability, interactive, real-time system.

Control automation costs in general have dropped sharply, and the component hardware has attained a high degree of reliability in recent years. The price of minicomputer mainframes has plummeted from more than $20,000 in the late 60s to less than $2,000 today, and equally remarkable is the improvement in mini software efficiency. The sophistication of some minis has increased to the point that both savings in programing time and additional system design flexibility can be realized without leaving the "mini" price range.

Some time ago, with the prospect of continually rising engineering cost facing us, RKO General decided to implement minicomputer transmitter control systems. Of key importance to the success of this effort was the specification and implementation of transmitter system automation as rapidly and economically as this could be realistically accomplished. We found the standard devices available for the job incompatible with our goal of realizing full transmitter facility automation. Although there are on the market a variety of autologgers and other automation component packages, any of these devices which are not computer-based present obstacles to future implementation of the expanded system capability.

The systems that are in the final stages of implementation within RKO will provide for continuous monitoring and control of system operations as well as remote control and autologging. All of these systems are built from the same basic hardware configuration. They also use a standard in-house developed modular software package with minor individual additions for log headings and other station-specific information. The major differences among these units can best be described by reference to the four incremental phases specified in our original plan of automation system implementation.

Automated continuous monitoring, selectable-period autologging, and keyboard-initiated control of all automated monitoring operations is phase 1.

Open-loop and closed-loop automated remote control of the transmitter facility are phases 2 and 3, respecitvely.

Automated monitoring and testing of the air-chain performance is implemented in phase 4, the ultimate phase.

We now have a phase 1 system operational at WOR-TV. Phase 2 systems for both radio and television are in the final stage of development and will soon be installed. Phased implementation of a total-system design for facility automation has the advantage of a distributed capital outlay and an evolutionary development process.

Seven major components constitute the basic hardware configuration for these systems: a logger, a software input and system control unit, an analog-to-digital converter, modem facilities, a minicomputer, suitable test signal generators, and a waveform analyzer. A typical system would have two teletype or other type printers for its logger and control unit. The analog-to-digital converter is used to multiplex and convert the analog inputs to digital values with better than 1 percent accuracy. The signal generator and analyzer are programmable devices which insert test signals into the transmission system and compare the result against established system norms. The system uses either wire or microwave data links and a full duplex modem system. The heart of the system is, of course, the new breed of ninicomputer. These minis have the immediate capacity for input-output facility expansion far beyond even the requirements of envisioned multistation transmitter facility automation systems.

All operator-initiated actions, such as system calibration, are simple, efficient, one-man operations. The commands can be written for the system in a "TURN FILS (ON)...DELAY 25 SECS...TURN PLATES (ON)" language, and software data storage is streamlined so that modifications, such as changing a pair of parameter limits, involve only one data location in the software. The system's software is fully modular. Each successive phase is software implemented by adding a code block to the current system software in the computer's memory by extending pre-exisiting software rather than superceding it. Communications between the system and the operator are handled through keyboard-printer devices. In addition to logged readings, the system will output information in the form of automatically printed diagnostics and alarm reports. Additional sets of up-to-the minute log entries and a report of status information and nonlogged parameters can be produced on command. The commands which can be used to control the system are a concise form of the familiar broadcast terminology.

Some of the possible applications, particularly those which affect the automatic closed-loop control of the transmitter, may require coordination with and permission from the FCC. There is every indication that such permission, if required, will be forthcoming. After we have had a chance to acquire operational experience with these systems, we plan to acquaint the Commission with our efforts on a more formal basis.

For those of you who may be inclined to rush out and buy your own equipment to implement such systems, a note of caution. For most broadcast engineers, the technology and expertise required for computers will be a new experience. The successful implementation of a computer-based system will require considerable formal training and time. The most difficult portion of the entire developmental process will be the software. At a very early stage, you will have to very rigidly define your objectives and make a decision on whether to develop the software in-house or to purchase the services outside. There are pros and cons to both approaches. The ultimate decision should depend upon what your goal is. If it is for a one-time, nonrecurring control function development, there is no question that it should be done outside. If it is for a more extensive long-term development leading toward a more complete integration of automation into your plant, it virtually requires that the software be done in-house.

The typical software package for the basic control and monitoring functions that I have described will require, including files, up to 12,000 words of memory when finished. Of these, from 4,000 to 8,000 would have to be written for your specific application. It has been our experience to date that our software has cost us in excess of $10 per word. This, of course, for a finished, documented product. Needless to say, even for a small system, it is expensive. It has further been our experience that our original estimates as to the final cost of the system were low by a factor of at least two. In summary, if you plan to get into computers, project the worst possible case of cost and time, and then double your estimates.

At this point in time, we are optimistic about the value of these systems. It will, however, require at least another three to five years to know if our original assumptions regarding the value of such automation were correct. Should any of you have an interest in taking a closer look at our equipment at work, please feel free to contact me in New York.

A Chroma Level and Delay Corrector

Written by: Mr. D. J. Newport
Presented by: Fred C. Everett, Consulting Engineer

Now that the initial problems associated with generating and transmitting color TV have been largely overcome in those countries which led this important innovation in domestic communication, more effort is being placed upon improving the quality of the picture. Picture impairment can now be quantified both in engineering parlance (K ratings)[1] and program parlance (just noticeable difference ratings).[2]

Among the various sources of picture impairment, relative chroma level (r.c.l.) and relative chroma delay (r.c.d.), are clear candidates for attention, since r.c.l. inequality causes color saturation to depart from realism, and r.c.d. inequality causes colors to be misregistered either to the left or right of objects.[3]

This paper presents a practically oriented description of a new, low-cost equipment which can be installed permanently into the video route, and which provides a means by which r.c.l. and r.c.d. inequalities can be corrected during program time.

The operation and performance of this unit is briefly described in relation to a Code of Practice which has been announced recently by The British Independent Broadcasting Authority, and which is considered to be typical of the picture quality standard required by the majority of network authorities. This standard is the fairly obvious result of the cycle of events beginning with authorities and individuals contributing to the CCIR[4] committees, and ending with those authorities translating the collated recommendations emanating from CCIR into quality targets which are realistic, both in terms of the average capability of equipments and routes, and in the ability to measure the resulting performance. Figure 1 is a table extracted from the I.B.A. Technical Reference book (issued September, 1972), and it shows the limits which it recommends are maintained by the program companies for various conditions.

Modern television processing equipment and transmission routes do allow a high performance to be achieved, while measurement capability has kept pace.[5,6] However, there are many links in the chain leading to the point of radiation, and the preservation of signal fidelity throughout the ever-increasing program day at a typical origination station is an exacting task for the technical staff. Thus, there is an increasing need to shorten the loop between recognition that picture impairment exists and the correction of the fault. A station is judged not only upon the quality of its program content, but also upon the percentage of advertised program time which is maintained at, or better than, "definitely perceptible" on the 7-point scale. An increasing number of networks are introducing V.I.T. (vertical interval test, sometimes referred to as I.T.S.—insertion test signal) signals for monitoring the quality of routes.[7]

The equipment described here is designed to operate in conjunction with one of these signals to provide engineers, or program staff (depending upon station philosophy), with the means to correct for r.c.l. and r.c.d. inequalities immediately when they occur. The system employs the principle of addition and subtraction of echo pairs, a subject which has been extensively documented.[8,9,10]

The idea for the basic echo generation circuit was stimulated from consideration of the characteristics of camera phaseless aperture correctors, and involves the use of odd and even echo pairs similar to the passive circuits proposed by Mr. Coles of the British Post Office.[11] However, certain innovations have been incorporated, in order to provide features which would benefit the user, and at the same time ease the manufacture and testing of the unit.

Firstly, the hybrid transformers were replaced by active stages for signal division and collection. Secondly, dc control of the echo amplitudes was introduced so that remote control of the correction could be imposed. Finally, an automatic-manual bypass mode was included to ensure that the system reverts to copper-to-copper in the event of failure or loss of mains supply.

OPERATION OF GAIN CORRECTION CIRCUIT

Figure 2 shows the simplified gain correction circuit. The design centers around a delay line of electrical length equal to ¼ or ½ wavelength at the frequency at which maximum boost or cut is required, which can be either the NTSC or PAL subcarrier frequency (3.58 MHz or 4.43 MHz).

The video signal is applied to the delay line from a source impedance equal to the characteristic impedance of the delay line, and the far end of the delay line is left open-circuit. Let signal at delay line input equal:

$$\tfrac{1}{2} E_o \sin \omega t,$$

therefore, the signal at the delay line output equals:

$$E_o \sin\omega (t - T_1)$$

PARAMETER	DIRECT PATH	WORST PATH	VTR
2.2 NONLINEARITY DISTORTION			
(d) LUMINANCE SIGNAL			
1. LINE TIME NONLINEARITY	3%	5%	10%
(b) CHROMINANCE SIGNAL			
i TOTAL PHASE ERRORS	±2°	±5°	±6°
ii DIFFERENTIAL GAIN	±3%	±5%	±7%
(c) DYNAMIC GAIN			
i LUMINANCE	±1%	±2%	±1%
ii CHROMINANCE	±1%	±2%	±1%
iii SYNC	±1%	±2%	±1%
(d) TRANSIENT CRUSHING			
i LUMINANCE	2%	5%	2%
ii CHROMINANCE	2%	5%	2%
iii SYNC	2%	5%	2%
2.3 LINEAR DISTORTION			
2.3.1. WAVEFORM DISTORTION			
(d) 2T PULSE AND BAR			
i PULSE-TO-BAR RATIO	½% k	1% k	2%
ii 2T PULSE RESPONSE	½% k	1% k	2%
iii 2T BAR RESPONSE	½% k	1% k	2%
(b) 50 Hz SQUARE-WAVE RESPONSE	½% k	1% k	2%
(c) VLF RESPONSE			
i 1st OVERSHOOT	14%	25%	—
ii 2nd OVERSHOOT	7%	10%	—
(d) SYNC			
i OVERSHOOTS	5%	5%	5%
ii TILT	5%	5%	5%
2.3.2. LUMINANCE/CHROMINANCE INEQUALITIES			
(a) GAIN (LEVEL)	±3%	±4%	±6%
(b) DELAY	±20 ns	±40 ns	±40 ns
2.3.3. INPUT/OUTPUT IMPEDANCE			
(a) RETURN LOSS	−30 dB	—	—

FIG. 1. EXTRACTS FROM IBA TECHNICAL REFERENCE BOOK pps. 23-24.

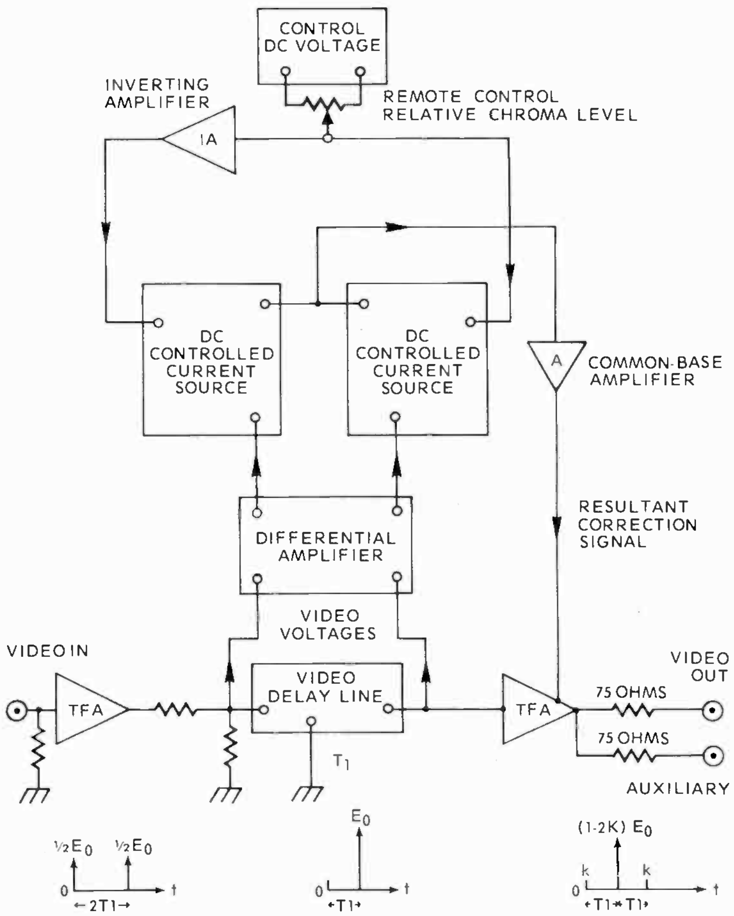


FIG. 2. SIMPLIFIED LEVEL CORRECTION CIRCUIT. (COURTESY MATTHEY PRINTED PRODUCTS, LTD.)

where T_1 equals the length of the delay line. Therefore, the signal at the delay line input due to reflection from an open-circuit delay line equals:

$$\tfrac{1}{2}\, Eo \sin \omega t + \tfrac{1}{2}\, Eo \sin\omega\, (t - 2T_1)$$

If this signal is subtracted from the signal at the end of the delay line in the differential amplifier, the result will be:

$$= Eo \sin\omega\, (t - T_1) - \tfrac{1}{2}\, Eo \sin\omega\, T_1 - \tfrac{1}{2}\, Eo \sin\omega\, (t - 2T_1). \qquad (1)$$

$$= Eo\, (1 - \mathrm{Cos}\ \omega T_1) \sin\omega\, (t - T_1).$$

The signal is converted to two differential currents in order that dc control may be applied to vary the proportion of the echo signal which is to be added to the main signal. This proportional echo signal is then added to the main signal in the thick-film amplifier via the common-base amplifier. If individual echoes of amplitude k are added, then the total echo added coincidentally with the main signal will be:

$$v_T = Eo \left[1 + 2k\, (1 - \mathrm{Cos}\ \omega T_1) \right] \sin\omega\, (t - T_1).$$

$$= Eo \left[1 + 4k\ \sin^2 \frac{\omega T_1}{2} \right] \sin(\omega t - \omega T_1).$$

thus the amplitude at subcarrier frequency will be:

$$= Eo\ \left(1 + 4k\ \sin^2 \frac{\omega T_1}{2}\right), \qquad (2)$$

while differentiation of the term ωT with ω confirms that group delay equals T_1 for all frequencies, and hence no delay inequality is introduced when correcting for gain inequality.

OPERATION OF DELAY CORRECTION CIRCUIT

Figure 3 shows the simplified delay correction circuit. Let the signal at the input to first delay line equal Eo sin ω t. Therefore, the signal at the output of the first delay line will be:

$$= \text{Eo} \sin \omega (t - T).$$

where T_2 equals the length of each delay line. The signal at the output of the second delay line equals

$$\text{Eo} \sin \omega (t - 2T_2) \qquad (1)$$

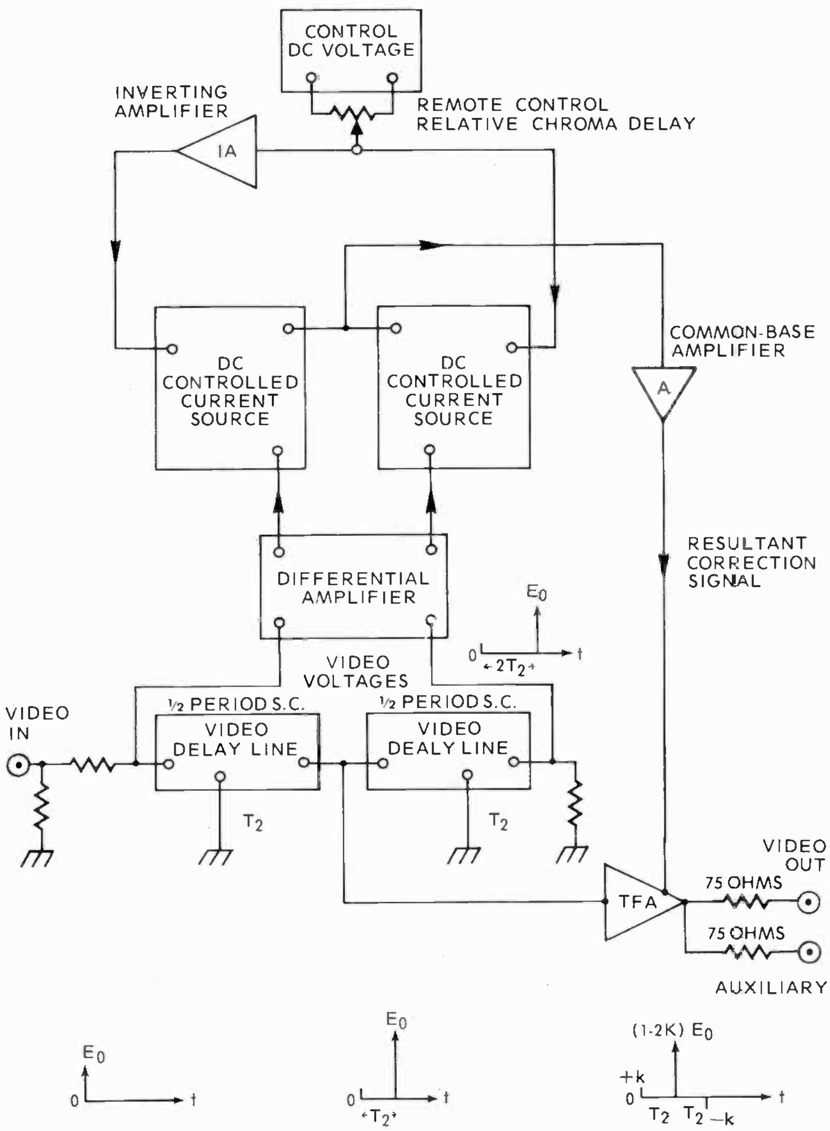


FIG. 3. SIMPLIFIED DELAY CORRECTION CIRCUIT. (COURTESY MATTHEY PRINTED PRODUCTS, LTD.)

The correction signal is obtained by subtracting the signal at the input of the first delay line from that emerging from the second delay line; i.e.,

$$= Eo \sin\omega\ (t - 2T_2) - Eo \sin\ \omega t. \qquad (2)$$

Again, ignoring the current conversion, a fraction (k) of this correction signal is added to the main signal in the thick-film amplifier.

Therefore,

$$v_T = Eo \left[\sin\omega\ (t - T_2) + k \left\{ \sin\omega\ (t - 2T_2) - \sin\omega t \right\} \right]$$

Now,

$$\sin\omega\ (t - 2T_2) - \sin\omega t = 2\cos\omega\ \frac{(2t - 2T_2)}{2} \sin\omega\ \frac{(-2T_2)}{2}$$

$$= -2 \sin\omega T_2 \cos\omega\ (t - T_2)$$

i.e.,

$$v_T = Eo \left[\sin\omega\ (t - T_2) - 2k \sin\omega T_2 \cos\omega\ (t - T_2) \right] \qquad (3)$$

Use:

$$a \cos\Theta + b \sin\Theta = \sqrt{a^2 + b^2} \left[\frac{a \operatorname{Cos}\Theta}{\sqrt{a^2 + b^2}} + \frac{b \sin\Theta}{\sqrt{a^2 + b^2}} \right]$$

Then,

$$v_T = Eo\ (1 + 4k^2 \sin^2\omega T_2)^{1/2} \left[\frac{\sin\omega\ (t - T_2)}{(1 + 4k^2 \sin^2\omega T_2)^{1/2}} - \frac{2k \sin\omega T_2 \cos\ (t - T_2)}{(1 + 4k^2 \sin^2\omega T_2)^{1/2}} \right]$$

Let

$$\frac{1}{(1 + 4k^2 \sin^2\omega T_2)^{1/2}} = \cos\phi \quad \text{and} \quad \frac{-2k \sin\omega T_2}{(1 + 4k^2 \sin^2\omega T_2)^{1/2}} = \sin\phi$$

Then,

$$v_T = Eo\ (1 + 4k^2 \sin^2\omega T_2)^{1/2} \left[\sin\ (t - T_2) \cos\phi + \cos\ (t - T_2) \sin\phi \right]$$

$$= Eo\ (1 + 4k^2 \sin^2\omega T_2)^{1/2} \sin \left[\omega\ (t - T_2) + \phi \right]$$

and

$$\phi = \sin^{-1} \left[\frac{-2k \sin\omega T_2}{(1 + 4k^2 \sin^2\omega T_2)^{1/2}} \right]$$

Thus,

$$v_T = Eo\ (1 + 4k^2 \sin^2\omega T_2)^{1/2} \sin \left\{ \omega\ (t - T_2) + \sin^{-1} \left[\frac{-2k \sin\omega T_2}{(1 + 4k^2 \sin^2\omega T_2)^{1/2}} \right] \right\} \qquad (4)$$

Differentiating the underlined term w.r.t. yields the group delay.
Use expression:

$$\frac{d}{dx}\sin^{-1} v = \frac{1}{\sqrt{1-v^2}} \cdot \frac{dv}{dx}$$

i.e.,

$$\frac{d(F)}{d\omega} = \frac{1}{\sqrt{1-\frac{(-2k\sin\omega T_2)^2}{1+4k^2\sin^2\omega T_2}}} \left\{ \begin{array}{l} (-2k\sin\omega T_2)(-\tfrac{1}{2})(1+4k^2\sin^2\omega T2)^{-\frac{3}{2}} \\ \cdots\cdots(4k^2.2.\sin\omega T_2\cos\omega T_2)(T_2) + \cdots\cdots \\ \cdots\cdots(1+4k^2\sin^2\omega T_2)^{-\frac{1}{2}}(\cos\omega T_2)(-2k)(T_2) \end{array} \right\}$$

$$= (1+4k^2\sin^2\omega T_2)^{\frac{1}{2}} \left\{ \begin{array}{l} \dfrac{(-2k\sin\omega T_2)(-\tfrac{1}{2})(4k^2.2.\sin\omega T_2)(\cos\omega T_2)(T_2)}{(1+4k^2\sin^2\omega T_2)(1+4k^2\sin^2\omega T_2)^{\frac{1}{2}}} + \cdots\cdots \\ \cdots\cdots\dfrac{(-2k\cos\omega T_2)(T_2)(1+4k^2\sin^2\omega T_2)}{(1+4k^2\sin^2\omega T_2)(1+4k^2\sin^2\omega T_2)^{\frac{1}{2}}} \end{array} \right\}$$

i.e.,

$$\frac{d(F)}{d\omega} = \frac{-2k\cos\omega T_2(T_2)}{1+4k^2\sin^2\omega T_2} \left\{ -4k^2\sin^2\omega T_2 + 1 + 4k^2\sin^2\omega T^2 \right\}$$

i.e., group delay equals:

$$\frac{-2k\cos\omega T_2(T_2)}{1+4k^2\sin^2\omega T_2} \qquad (5)$$

Group delay, therefore, varies cosinusoidally with frequency; and since T_2 was made equal to ½ wavelength at the subcarrier frequency, the maximum delay correction coincides with the first peak in this characteristic. It should be noted that the application of delay correction introduces a variation in gain, as contained in expression 4; i.e., amplitude varies as

$$Eo\,(1+4k^2\sin^2\omega T_2)^{\frac{1}{2}}$$

This ripple occurs at twice the periodicity of the delay excursion, but is zero at subcarrier when T_2 is made ½ wavelength at this frequency.

Thus, the correction of level and delay effected by a single echo pair in each case results in a fairly high degree of mutual exclusivity. The two are totally exclusive at the subcarrier frequency.

Linke and Coles make it clear that group delay remains essentially unaltered when operating the level correction over its full range of plus or minus 40 percent, while the maximum ripple in the amplitude (away from subcarrier) remains within + 0.778 dB when operating the delay correction over its full range of plus or minus 100 ns.

LINEAR DISTORTION

The equipment meets the essential requirement of nulling level and delay inequalities between two frequencies (taken as 4.43 MHz and 1 MHz for the 10T MOD PAL I.T.S.). However, it should be asked what happens outside these two frequencies. The answer is that it depends to a great extent on the nature of the distortion the equipment is being required to null, as will be seen from the following.

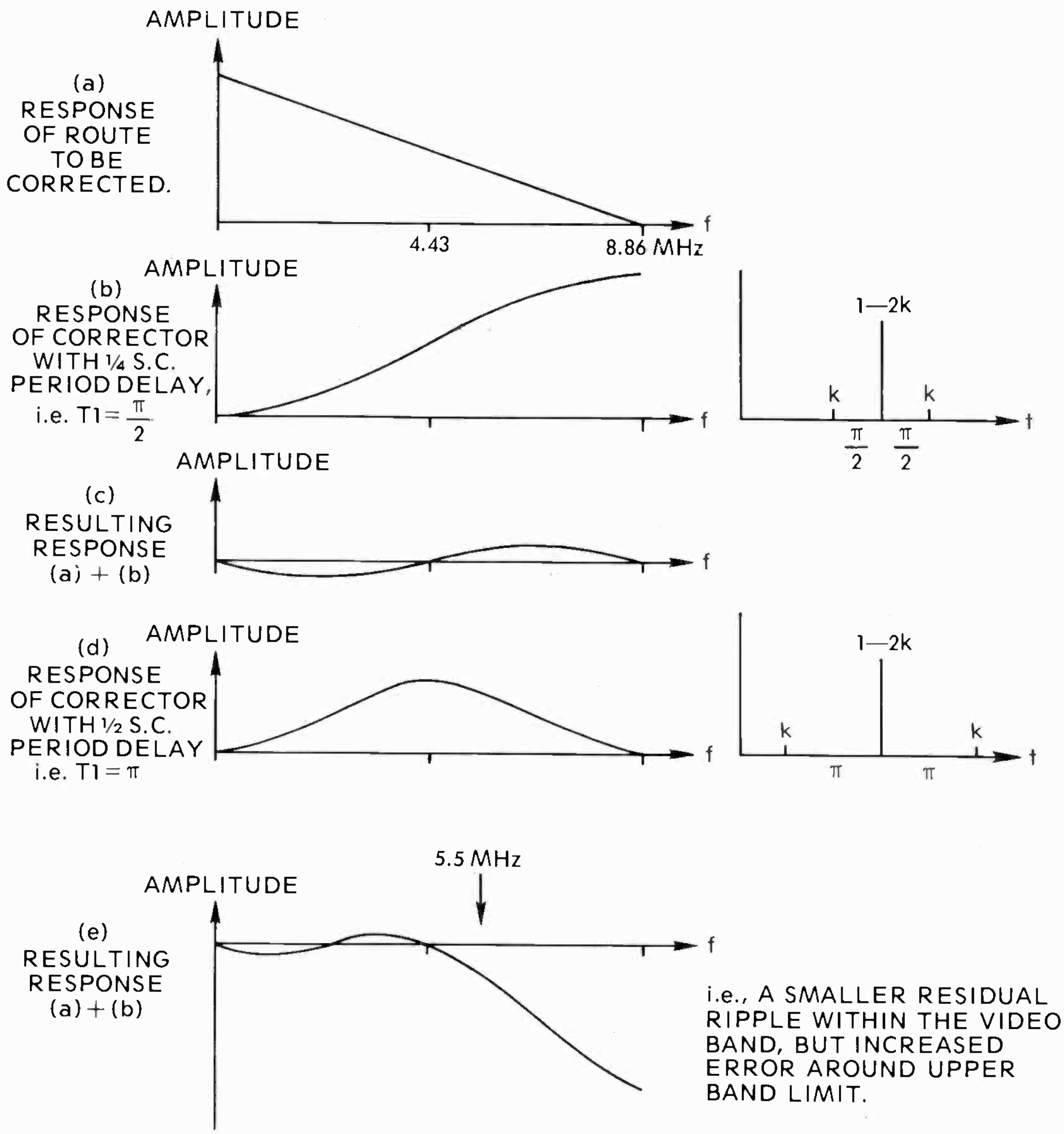


FIG. 4. CORRECTION OF LEVEL DISTORTION (PAL) (COURTESY MATTHEY PRINTED PRODUCTS LTD.)

(a) Level Correction

It is clear that unless the distortion in the route follows the same cosine law as the chroma corrector circuit, there will always be some ripple remaining within the overall video band after correction. Wheeler makes this clear, but it is not reckoned to be objectionable. Observation of the 2T pulse would reveal a change in amplitude. Figure 4 shows how the choice of T_1 can minimize residual ripple (so long as the type of distortion is known in advance).

Figure 4(a) shows the response of a fictitious route. For simplicity, a triangular amplitude response was selected, falling by α dB at 8.86 MHz. It will thus have fallen by $\alpha/2$ dB at 4.43 MHz.

Figure 4(b) shows the actual shape of the level corrector response when employing a delay line of time equal to ¼ period at the subcarrier frequency. As stated above, its shape is cosinusoidal, peaking at 8.86 MHz.

The time domain graph, adjacent to (b), indicates the relative position of the even echoes relative to the main signal. If the level control is set such that the echo amplitude k is sufficient to cause the corrector amplitude response to be $\alpha/2$ dB above its l.f. level at 4.43 MHz, then a signal distorted through route (a) will be equalized exactly at the chrominance subcarrier after passing through the corrector set to give (b) response. Since the reciprocal of (b) does not equal (a) at frequencies other than at zero, subcarrier, and twice subcarrier, there will be a residual ripple as shown in (c).

If the level corrector employs instead a delay line of time equal to ½ period at subcarrier, its response will again be cosinusoidal, but this time it will peak at 4.43 MHz as shown in Fig. 4 (d). The time domain graph adjacent shows the relative positions of the echoes relative to the main signal. If the level control is set such that the echo amplitude at k is sufficient to cause the corrector amplitude to be equal to $\alpha/2$ dB above its l.f. level at 4.43 MHz, then a signal distorted through route (a) will again be equalized exactly at the chrominance subcarrier after passing through the level corrector, but the residual ripple will clearly be different, as indicated in Fig. 4(e). The ripple amplitude will be smaller than in (c) for the important frequencies, i.e., those up to around subcarrier, but a larger amplitude deformation will be observed beyond the video band. No group delay distortion will be introduced when applying level correction.

(b) Delay Correction

As was shown above, T_2 has to be π at subcarrier in order to ensure that no r.c.l. variation is introduced during application of delay correction.

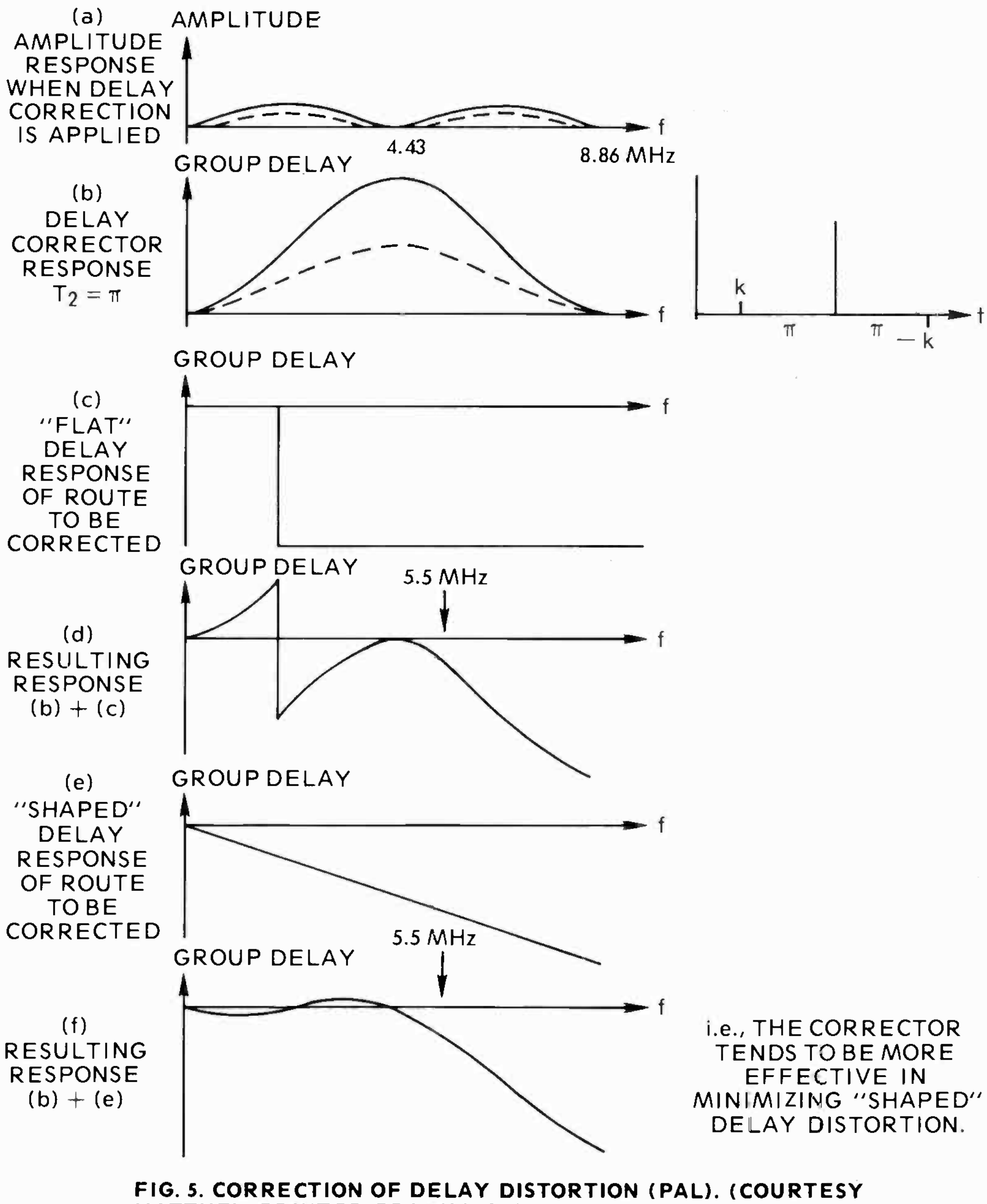


FIG. 5. CORRECTION OF DELAY DISTORTION (PAL). (COURTESY MATTHEY PRINTED PRODUCTS, LTD.)

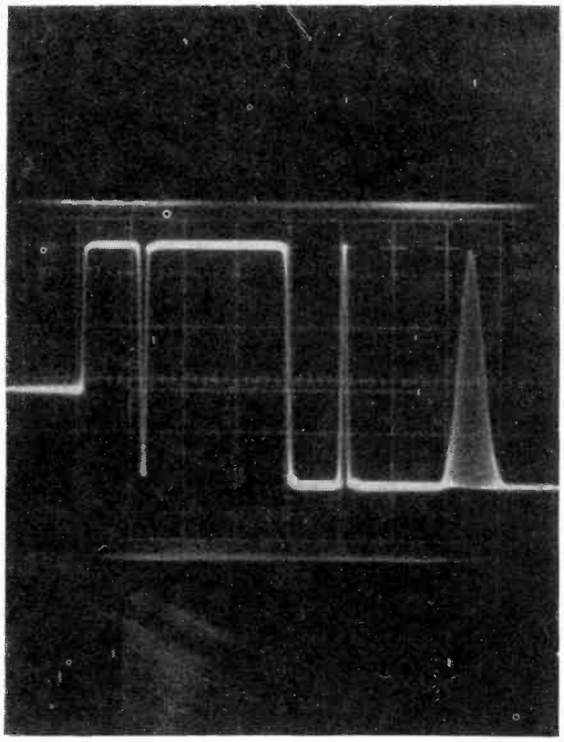


FIG. 6. 10T MOD AND 2T RESPONSE AT MINIMUM LEVEL SETTING.

It is probably safe to say that delay distortions will be unlikely to follow the cosine law in practice. Lessman observed two basic types of distortion which he termed "flat" and "shaped." An idea of the residual delay ripple from correction of these two types of distortion can be seen from Fig. 5.

As stated above, application of the delay correction will introduce a small amplitude ripple, and Fig. 5(a) shows how the amplitude response follows (b), the delay response (dotted curves illustrating mid-setting).

The time domain graph adjacent to (b) indicates the relative positions of the odd echoes (i.e., + k and — k) relative to the main signal.

Figure 5(c) shows the group delay response of a fictitious route which introduces "flat" delay distortion, extending from an arbitrarily chosen frequency. Let this error be $T_F$ns. Then, if the delay correction control is set such that the echo amplitude k is sufficient to cause the corrector delay response to be $T_F$ns relative to its l.f. value at 4.43 MHz, then a signal distorted through route (c) will be equalized exactly at chrominance subcarrier, after passing through the corrector set to give (b) response. Since the reciprocal of (c) does not equal (b) at frequencies other than at zero and subcarrier, there will be a residual ripple as shown in (d) but the important inequality, i.e., chrominance/luminance delay inequality, will be nulled.

Now, if the route to be corrected introduces "shaped" group delay distortion as indicated by the triangular response in (e), then again a correction setting can be chosen which will equalize the response exactly at the chrominance subcarrier, and the residual ripple will be as indicated in Fig. 5(f).

The effect of the residual delay ripple on the 2T pulse will be the appearance of asymmetric lobes, becoming a maximum at the extremities of the delay control.

Referring again to Fig. 5(a), no amplitude distortion will be incurred at the chrominance subcarrier, due to application of delay correction, while the amplitude ripple error away from the subcarrier is not reckoned to be objectionable.

Both level and delay corrector circuits can be cascaded, enabling correction of routes, which exhibit both group delay and level distortion, by setting delay and level controls while monitoring the 10T chrominance modulated pulse to obtain a flat envelope.

ACTUAL PERFORMANCE

Figure 6 is a photograph of the 10T MOD and 2T response at zero setting. Figure 7 is a photo of the 10T MOD and 2T response at the maximum level correction setting,

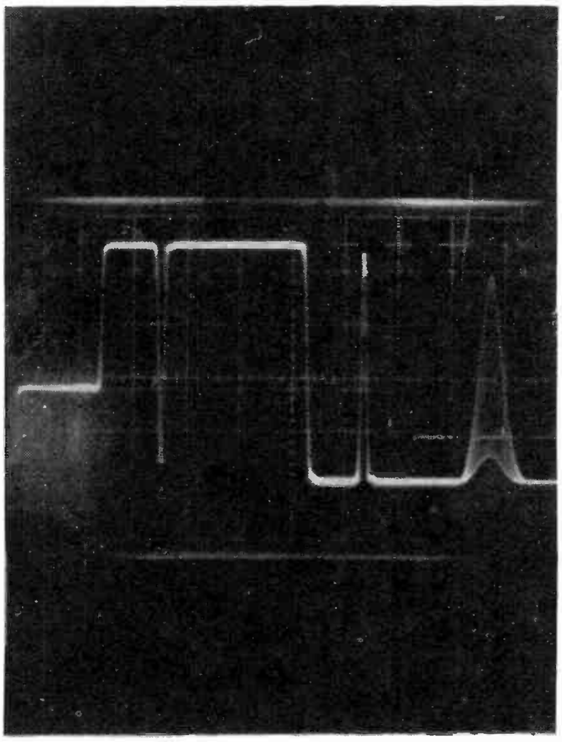


FIG. 7. 10T MOD AND 2T RESPONSE AT MAXIMUM LEVEL SETTING.

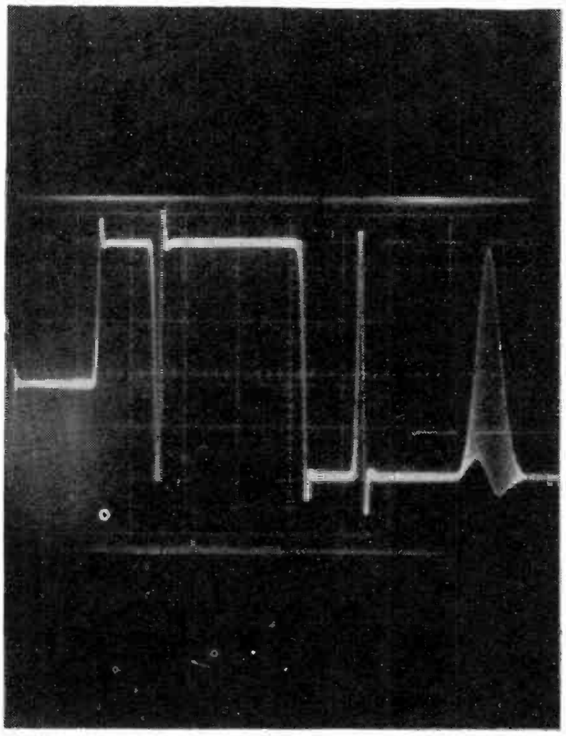


FIG. 8. MOD AND 2T RESPONSE AT MAXIMUM DELAY CORRECTION SETTING.

PARAMETER	CHROMA CORRECTOR	IBA— DIRECT PATH
RANGE OF OPERATION		
RCL CORRECTION	± 40 %	N.A.
RCD CORRECTION	± 100 ns	N.A.
NONLINEAR DISTORTION		
DIFFERENTIAL GAIN @ 90 % A.P.L.	0.2 %	± 3 %
DIFFERENTIAL PHASE @ 90 % A.P.L.	0.2	± 2
LINEAR DISTORTION		
2T PULSE-TO-BAR RATIO	~ 0.1 % K	½ % K
2T PULSE RESPONSE	~ 0.1 % K	½ % K
2T BAR RESPONSE	~ 0.25 % K	½ % K
50Hz SQUARE WAVE	~ 0.25 % K	½ % K
LUMINANCE/CHROMINANCE INEQUALITIES		
RCL AT CENTRAL SETTING	< ± 0.2 dB	± 3 % (= ± 0.3 dB)
RCD AT CENTRAL SETTING	< ± 10ns	± 20ns
INPUT/OUTPUT IMPEDANCE		
RETURN LOSS	> 30 dB	30 dB
T PULSE RESPONSE		CCIR REC 451 *
1st (NEG) LOBE	~ 2.8 %	12 %
2nd (POS) LOBE	~ 2.0 %	8 %

* LIMITS FOR 1 % K

FIG. 9. COMPARISON OF TYPICAL DATA FROM PRODUCTION CHROMA CORRECTOR UNITS WITH IBA LIMITS.

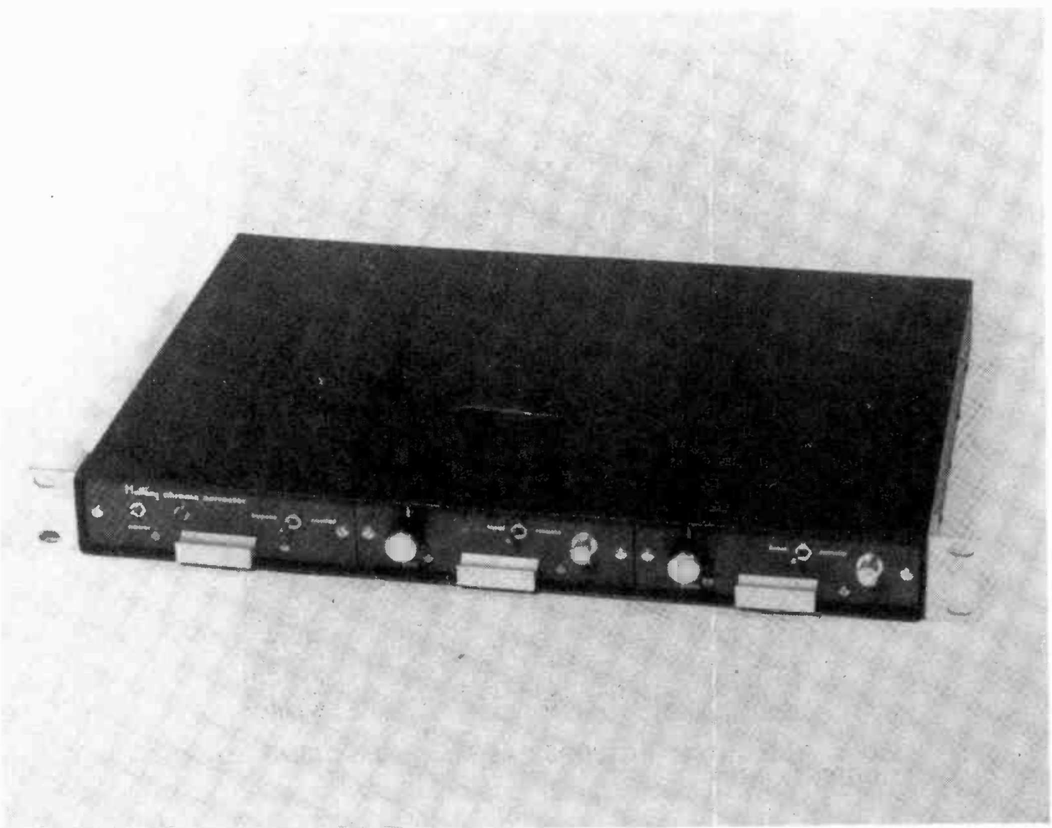


FIG. 10. MATTHEY CHROMA CORRECTOR.

while Fig. 8 is a photograph of the 10T MOD at 2T response at the maximum delay correction setting.

CONCLUSIONS

It is respected that the tolerances set by broadcasting companies are in general intended for controlling the quality of pictures transmitted from their studios. These limits, therefore, reflect the sum performance of all those individual equipments which make up a typical studio complex.

There are at present no national specifications for individual items of equipment built for television broadcasting systems. Where a company is supplying a complete studio package, then clearly the whole system can be designed, and its performance assessed, in relation to the broadcaster's overall limits. On the other hand, anyone supplying an individual item has to negotiate a specification.

Because of the known difficulty in determining allowable tolerances for individual items, broadcasting companies naturally err towards tight limits. Unfortunately, this can lead to problems in measurements, since the tolerances required at the studio level for some parameters verge on the limit of measurement sensitivity.

For example, the limit for 2T bar response is 0.5 percent k for a direct path, and this value is close to the best discrimination achievable, which is about 0.25 percent K, whereas the limit for, say, differential gain, being plus or minus 3 percent for a direct path, is 30 times the best discrimination achievable, which is about 0.1 percent. Thus, it is practically impossible to guarantee a limit of, say, 0.25 percent k for 2T bar, but a limit of plus or minus 0.5 percent differential gain is realistic.

Taking this into account, it will be seen from Fig. 9 that the chroma corrector maintains an acceptable overall performance, while providing the means to reduce quite large amounts of r.c.l. and r.c.d. distortion to almost negligible proportions.

The unit, as shown in Fig. 10 is contained within a 1¾-inch high standard 19-inch rack unit, and has been engineered to fulfill normal on-air central apparatus room requirements.

ACKNOWLEDGEMENTS

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Recent Advances in the Remote Control of TV Cameras

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Clearly, remote control of cameras is not essential to television. Equally, however, this is also true of many other things that are used in television studios. Remote control is an automation function and, therefore, merits consideration in attempting to minimize labor costs. The aim of the paper is to outline the present position and to introduce some of the new concepts. It starts, therefore, with a description of one or two areas where remote control has been successfully applied and continues with a more technical appreciation of the latest systems by comparison with earlier ones.

OUTLINE OF REMOTE CONTROL

As its name implies, remote control means that there is no operator behind the camera, which is moved around by servo systems. The function of the cameraman is taken over by someone in the control room, who may be doing other things as well, or controlling several cameras. For example, Figs. 1 and 2 are photographs of News Studio C in Norddeutscher Rundfunk in Hamburg, Germany. This station is responsible for the West German National News, which it originates from a 4-camera studio. A single operator controls all the camera channels together with lighting. He is responsible for the quality of all aspects of pictures originated in the studio. Figure 1 is a general view of the control area with the studio in the background, while Fig. 2 shows the control panel. From this the operator positions the cameras, adjusts the color balance and lens and organizes the sequence in which camera shots are to be used. All the information is stored in a core memory and is recalled either at random or from prerecorded sequences.

This system has a clear labor-saving benefit, even though many stations might consider that four cameras, with a supporting staff solely for the purpose, is excessive. This studio is used intensively if intermittently through the day and its economics seem attractive.

Remote control is primarily valuable in situations where the camera usage is fairly predictable, since much of the operation is based on preset shots. Some experiments have been made in making drama material, but while technically competent the technique suffers from the lack of a cameraman's ability to sense what is going on around him. Continuity, news, discussions, and similar material lend themselves to the use of remotely controlled cameras. This is doubly true in stations with computers used either as switchers, or as on-line controllers. The Hamburg control system has facilities for computer-operated selection of shots.

Figure 3 shows the control panel for one camera of a computer-operated system for BRT/ RTB in Brussels. The computer is again used as a switcher, selecting and cutting to the next shot. This system also has two other features which affect the application of this kind of equipment. Firstly, the controlled camera is mounted on an X-Y table and used for caption and rostrum work (Fig. 4). Secondly, the lighting for the camera is controlled from the same panel (and the settings retained in the same memory). In this system the lights are only turned on or off; but in systems being designed, amplitude outputs are used to control dimmer settings. This is not the same

Fig. 1. Wide-angle view of NDR studio. (Courtesy NDR Hamburg.)

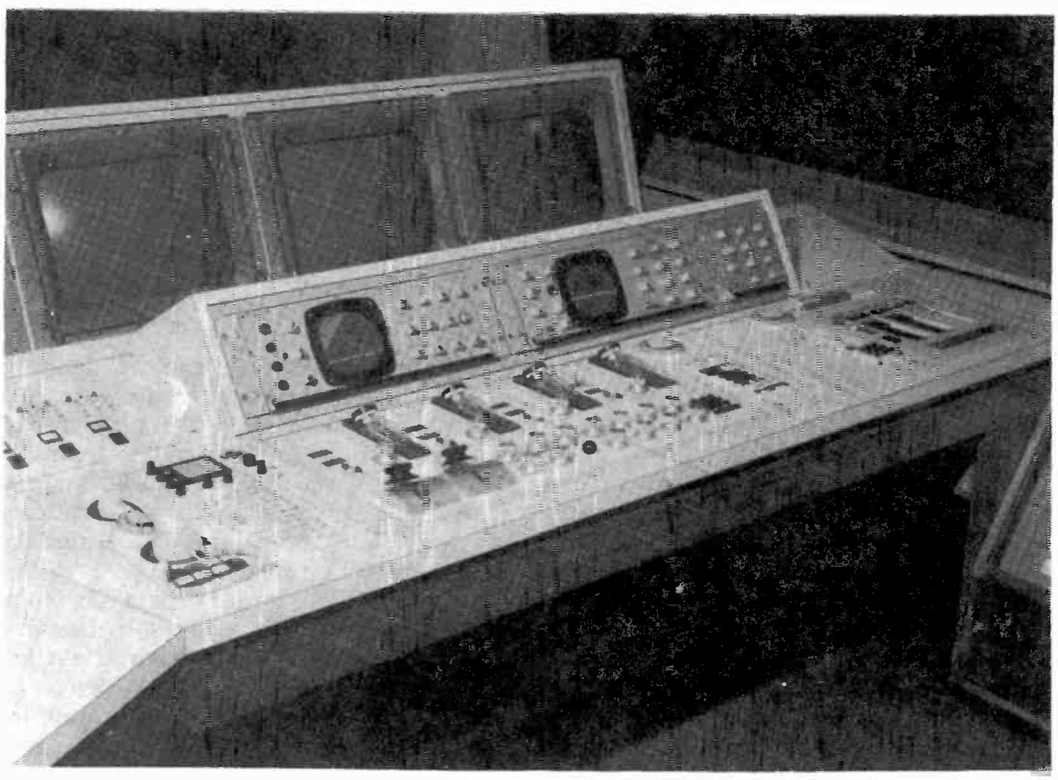

Fig. 2. Control panel of NDR studio. (Courtesy NDR Hamburg.)

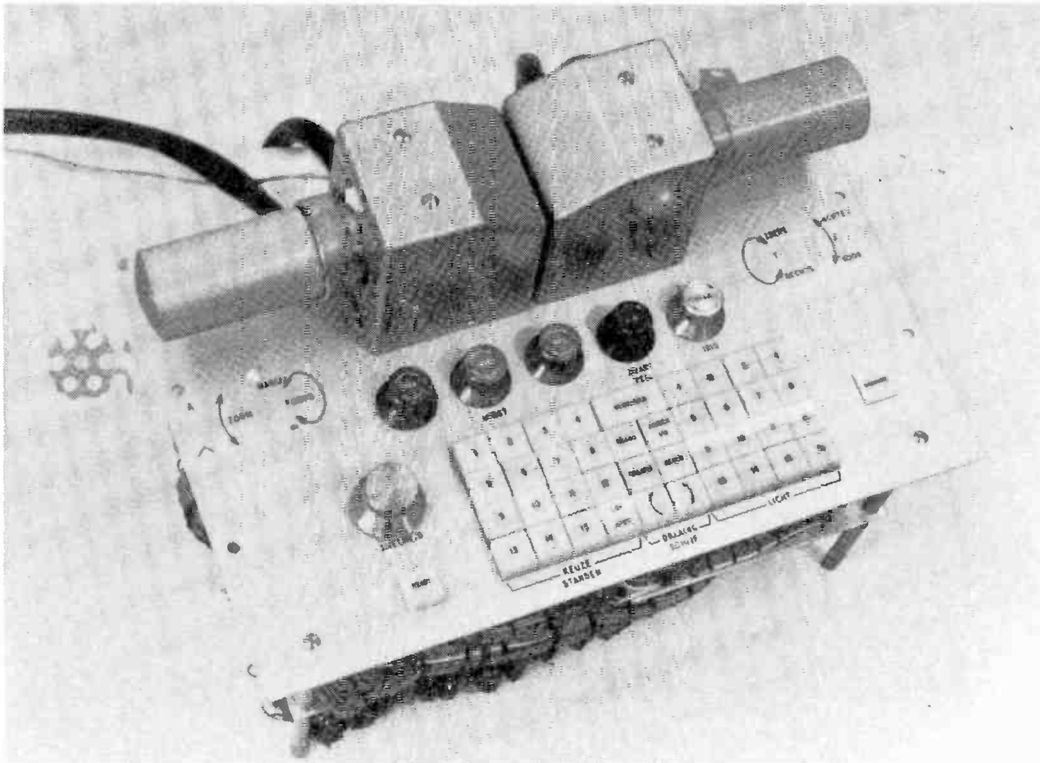

Fig. 3. Episcope (or X—Y Table) control panel. (Courtesy BRT/RTB Brussels.)

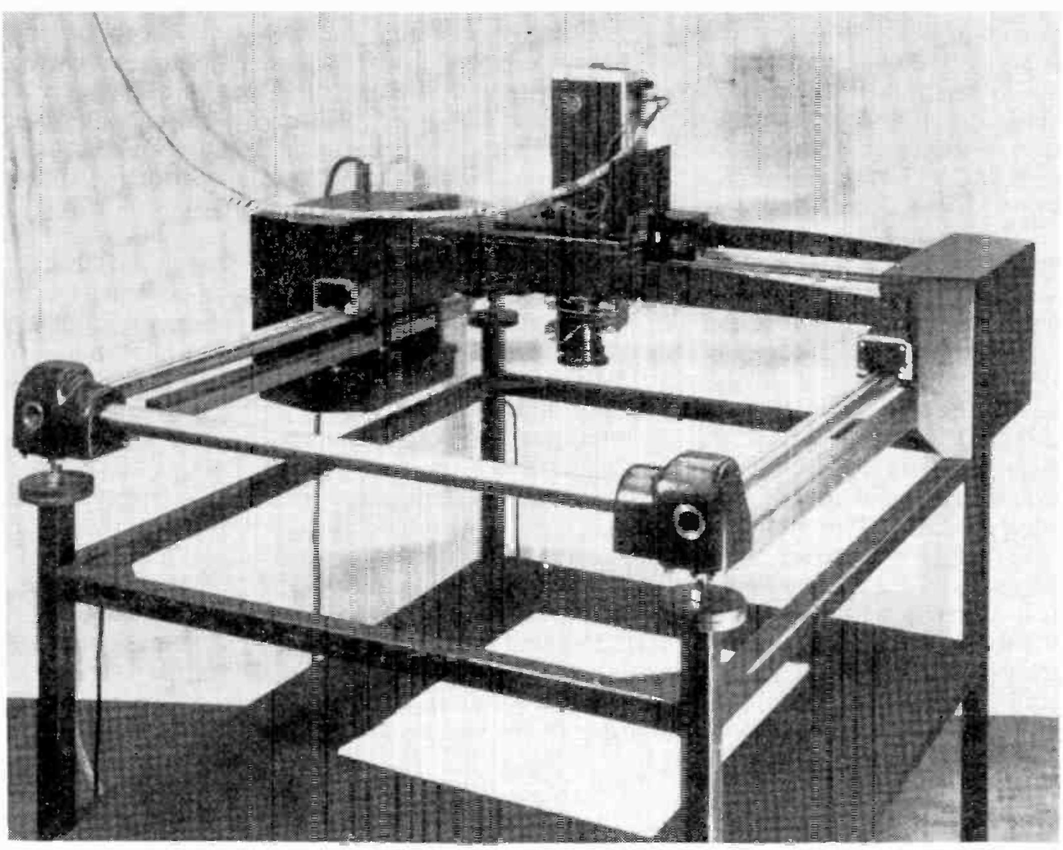

Fig. 4. Episcope (or X—Y Table) carrying a monochrome television camera. (The unit is designed to carry a studio color camera.) (Courtesy BRT/RTB Brussels.)

Fig. 5. College News remote controlled studio. (Courtesy BBC London.)

thing as a complete automated lighting system such as might be installed in a large drama studio or theatre. However, a few channels of dimmer control can be extremely valuable in conjunction with a remote system. Modern remote control systems, therefore, tend to offer a package of operating functions to align with a computerized switching system. It may be observed that many of the potential savings of automation can be dissipated if a significant number of studio operations have still to be done by men. Clearly, too, packaging a number of operations tends to improve the economics of each.

Completely unmanned studios represent another application of remote control in which the economic case is clear. These can be situated in parliaments, city halls, airports, or other places where interviews or presentations have to be organized in a hurry. In many parts of the world they also allow local participation on national networks without the cost of a manned studio. Figure 5 shows the studio end of a remote control link from the main BBC studios about three miles away. The studio beside the Houses of Parliament is controlled over a standard tariff S3 telephone line using a 2400 baud carrier. This system has full position, color, and studio test and adjustment facilities, but does not require shot or fade operation. This particular system has now been superseded by more flexible units with shot storage at the receiving end. This means a reduced dependence on line bandwidth to provide a satisfactorily sensitive and at the same time speedy control, since much of the necessary data can be held at the far end of the line and merely modified over the transmission lines. We are expecting to introduce this type of system at Montreux in the European Television Convention in conjunction with Philips. The remote control transmission is via the camera cable of an LDK 5 camera (which is the European equivalent of the PC 100). In this case, the effective data rate for the remote control system is very low (being of the order of 200 Hz) and only the remote shot storage permits satisfactory operation.

EQUIPMENT

As the application of remote control has diversified, so the equipment has altered. The original approach of storing shot information on potentiometers has given way initially to core memories, and most recently to semiconductor memories. Systems using these are being introduced this year and I propose to describe them in a little more detail. Unlike core systems which have a high basic cost and are economically justified only for multiple camera operations, the semiconductor memory systems are lower in cost than comparably sized potentiometer types with similar facilities. The solid-state switching and memory (if properly supported) should also be very significantly better in reliability terms. (Support is necessary because ordinary semiconductor memories are volatile; that is, they lose their contents if their power supply is interrupted for any reason. Since this is obviously undesirable if the data is wanted for a long period, it is normal to provide a backup, typically as in this case, a nickel cadmium rechargeable battery.

The problem with control in such a sophisticated environment as television is that users have strong feelings about how they want to operate and about what controls they need and how they should be arranged. Though we have made efforts at standardization, a single layout and set of facilities has not proved to be feasible. Part, therefore, of the motivation behind the new system is a desire to alter the problem of customizing from being a major engineering effort to one needing a software solution. The ideal is a panel laid out on a grid basis with a switch location at each grid intersection which can then be programed later to do what the customer wants. Another thing that is important in operation is that the user should be able to adjust a picture to get what he wants, then press a button to memorize the settings. All settings, therefore, are made using controls which add or subtract increments from what has already been set or recovered from the memory. These trim signals can either be retained or cancelled.

It is difficult to give any idea of the 'feel' of a control panel in a picture, but Fig. 6 is a diagram of a typical single camera panel. This panel can control a system with up to 99 shots and 5 functions. The lines indicate the grid structure which is the basis for the layout. The same type of layout can be adapted to control lighting dimmers or slide scanners or multi-camera systems. (Though usually several cameras only require one set of trim controls shared between them because the operator has only one pair of panels). Other trim controls can be added to operate more functions.

The controls are basic, a keyboard to select shot numbers (shown in the indicator windows) and a minimum of functional pushbuttons. Most of these are obvious: store, fade, and cut are analogous to the lighting controls (the length of time a fade is to take being set on the bottom right-hand control). Transfer is, however, an unusual one. Using it, one shot can be overwritten with another, a process of cross storing. This is useful if a series of shots are close together (eg as in Fig. 7, captions, sports results, and photographs on the board). The operator only has to line up on the board once,

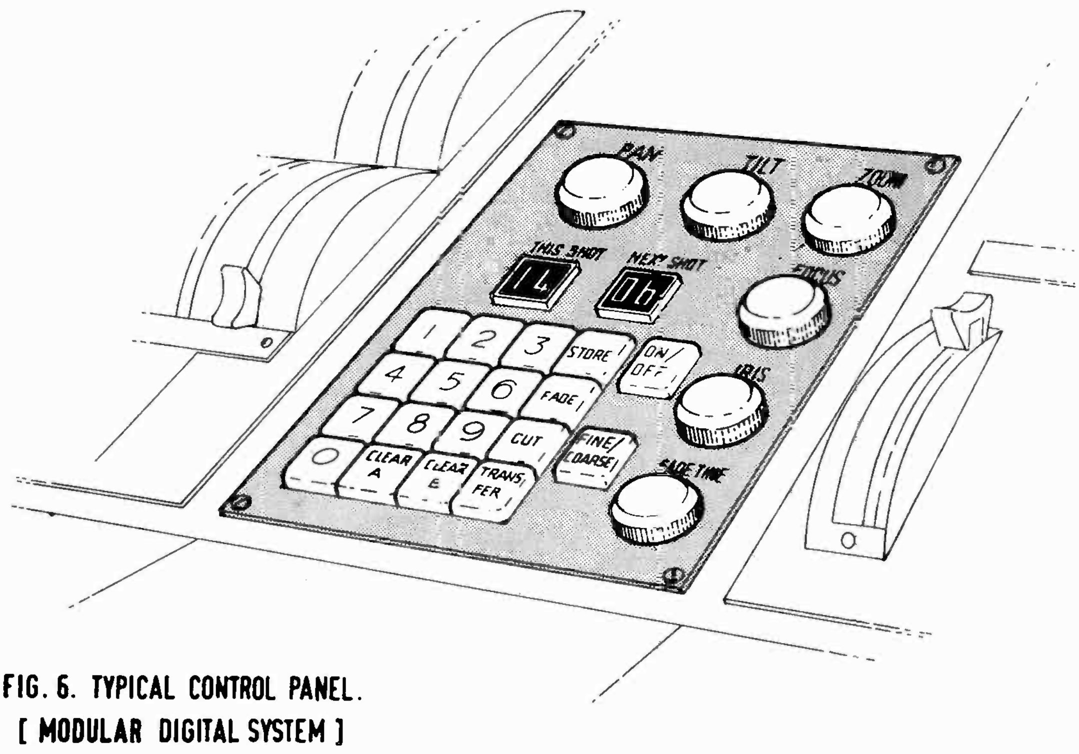

FIG. 6. TYPICAL CONTROL PANEL.
[MODULAR DIGITAL SYSTEM]

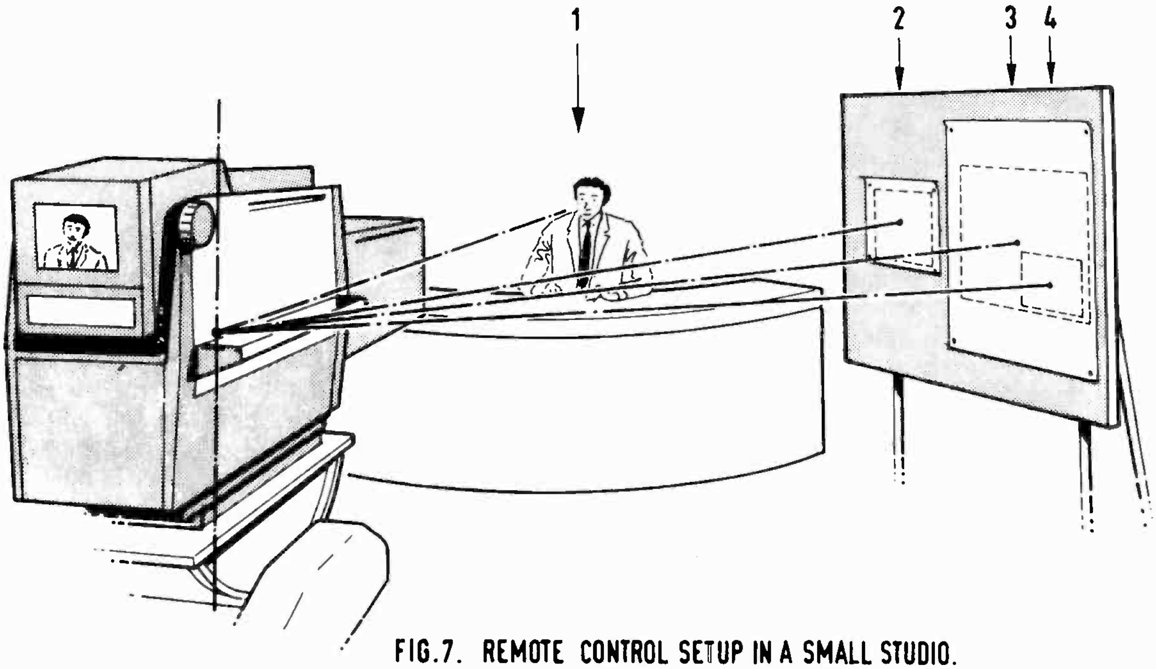

FIG.7. REMOTE CONTROL SETUP IN A SMALL STUDIO.

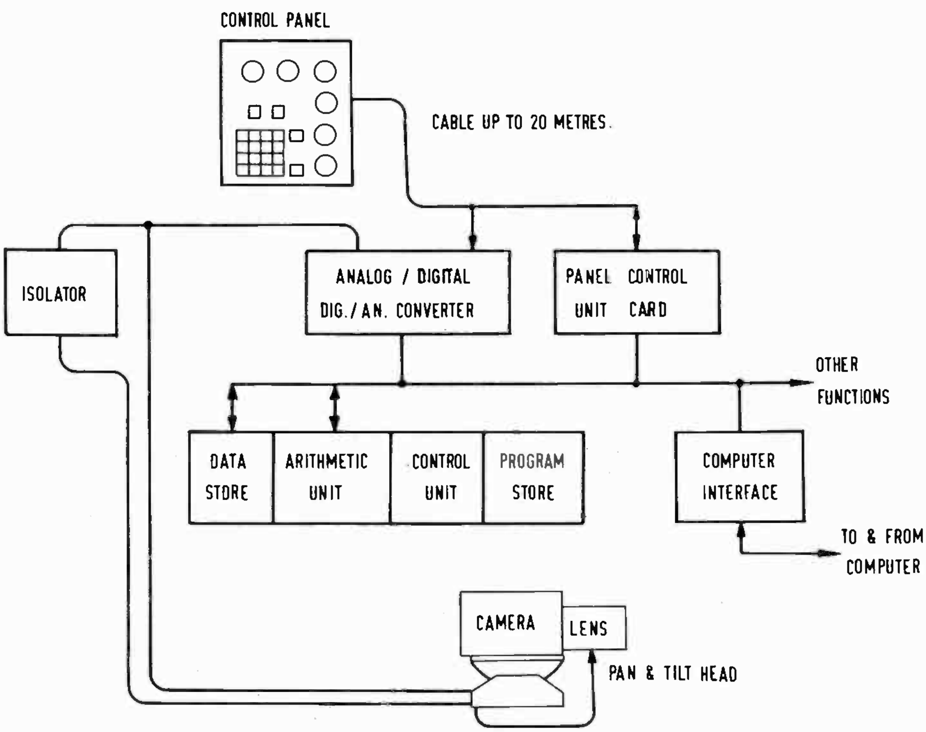

FIG. 8. TYPICAL SMALL REMOTE CONTROL SYSTEM WITH COMPUTER FACILITY.

then cross store, trim to get the individual pictures he wants and when satisfied, store again.

The fine-coarse control is an indication of the main technical problem with the digital control of television cameras. Because of the very narrow field of view of modern zoom lenses, performance, particularly of pan, is all important. For example, if a picture produced by a camera having a lens with a 3 degree field of view is shown on a 22-inch monitor, each inch across the monitor is equivalent to rather less than 10 minutes of arc. It is easily possible to see an uneven movement or instability which is 0.1 inch in magnitude. In other terms, this means a pan resolution of around 1 minute of arc. In practice, this means, in digital terms, resolutions of at worst one part in 2^{14} (16384), and stabilities a factor of three or four times better. Stability problems in particular mean that grounding is a problem, and we have found it necessary to isolate (using transformers or optical coupling, depending upon the interface) any functions which may involve uncertain ground paths. Fine-coarse control is needed to allow the operator to respond quickly to demands for big changes, but at the same time retain the ability to make a sensitive adjustment. Different users have strong views about the nature of such controls, whether they are purely positional or have rate operation, and whether all the controls should be worked on by one hand or both.

As has been indicated, the basic idea is to allow the user at least some freedom in choosing his own panel layout, as long as he conforms to a basic grid structure. To do this is impracticable with a normal hard-wired system and the only solution is a computer. Nothing as sophisticated as a normal central processor—even a micro version of one—is needed to operate a camera, or even a group of cameras. However, the calculator unit which is the core of the system (Fig. 8) is structured similarly to any other machine in general principles. As mentioned, it has a semiconductor data store which is maintained by a rechargeable battery when power is lost, while the program is stored in fusible link read-only memory integrated circuits. In principle these are arrays of diodes into which the program is built by literally blowing links in the circuitry by passing excessive (but controlled) current through them. While these confer all the flexibility associated with normal software, however, it is not possible to alter the program as simply as in a normal computer. It is not possible simply to run another paper tape through a reader and start again with a new method of operation. Reprograming in this case means replacing the existing circuits by new ones.

COMPUTER INTERFACES AND APPLICATIONS

Mention has already been made of systems where remote control systems are used in conjunction with computerized switching systems. In the main, the remotely controlled camera is treated by these as though it is a slide scanner. That is, the source is selected and a shot called; thereafter, the source can be switched on the air. In some systems the computer can initiate both a cut or a fade (though the speed at which the fade takes place is usually at the discretion of an operator).

Clearly, however, this is only a half-way stage and users are beginning to experiment with full on-line control of cameras. This means that very complex shots can be executed with nonlinear movements. (Experiments are in hand, however, to store and recover shots such as those generated by a man entering a studio, walking to a chair and sitting down). Other applications include such things as the control of the X-Y table shown earlier, on which drawings, graphs, and photographs can be laid out for showing on educational and other similar programs. In these the same information can be used and re-used so that sophisticated camera handling adds interest and variety to the program.

Interfacing to a computer is simple. The camera control system is similar to a rather slow external core store as far as the computer is concerned. (In general, data has to pass bidirectionally through the interface). Except when the head is directly on line, the data rates across the interface are very low.

Interfacing to telephone modems is equally simple from a technical point of view. This, again, has already been touched upon. Technically, the store unit has to be at the receiver end of the transmission, since one of the main purposes of such a system is to make satisfactory material over a narrow bandwidth line. The reduction in line bandwidth can be as high as a factor of ten (as noted before). This allows for other controls or other cameras over the same line and a major gain in system economics using a typical rented line.

CONCLUSION

This paper has described some recent developments in the remote control of television cameras. It will be apparent that significant changes are taking place in this field and it seems that, particularly in conjunction with computerized switching, these will continue at an increasing pace.

ACKNOWLEDGEMENTS

I should like to thank my fellow-workers for their help in the developments described over a period of years. I should like to thank NDR Hamburg, BRT/RTB Brussels, and the BBC London for their permission to use the illustrations.

Modernization of TV Station Production Facilities

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Updating the production facilities of an on-the-air television broadcasting station is too complex to be effective when performed piecemeal. An overall design is required for scheduling that avoids disrupting the ongoing operation while minimizing the time and cost to completion.

The advantages to be gained from plant modernization are the outgrowth of current solid-state and integrated circuit technology and recent experience with color operation and station automation. They include more reliable performance requiring less maintenance and warmup time, better space utilization, and better workspace layout. These benefits, coupled with remote control of transmitters and automation of master control, permit more effective utilization of the operating staff.

PRELIMINARY PLANNING

Station management is concerned with the overall budget requirements, time schedule, and advantages to be gained from a facilities modernization. It needs this information before it can meaningfully decide whether or not to commit funds and effort to the proposed project.

Plant Survey and Operations Personnel Interviews

The first phase of a modernization project entails developing the required information for station management's review. To this end, design targets that are tailored to the needs and operation of the station must be established. Because of geographic and market differences, as well as competitiveness within a given geographic market, rarely, if ever, do two broadcasting stations have identical facilities requirements. These requirements can be formulated after specific knowledge concerning the existing physical plant and operating technique has been obtained from plant surveys and discussions with key operating personnel.

Space Layout

The most dramatic advantages of plant modernization are seen in the floor plan layouts that are developed for the new facilities. Much less space is required for current equipment than in older, existing facilities utilizing vacuum-tube equipment. Advantage can be taken of space saved in a new layout, to arrange the working relationships and traffic flow of technical areas in a more effective manner. See Figs. 1, 2, and 3.

Studio control rooms. Studio control rooms are preferably located at the same level and (See Figs. 4 and 5) adjacent to their associated studios. This permits the easiest possible access to the set, cast, and production crews by the program director. The television studio control room is best designed to meet the needs of the program director—the person responsible for the end product—the program seen and heard on the home television receiver. It is desirable for the director to react directly with the

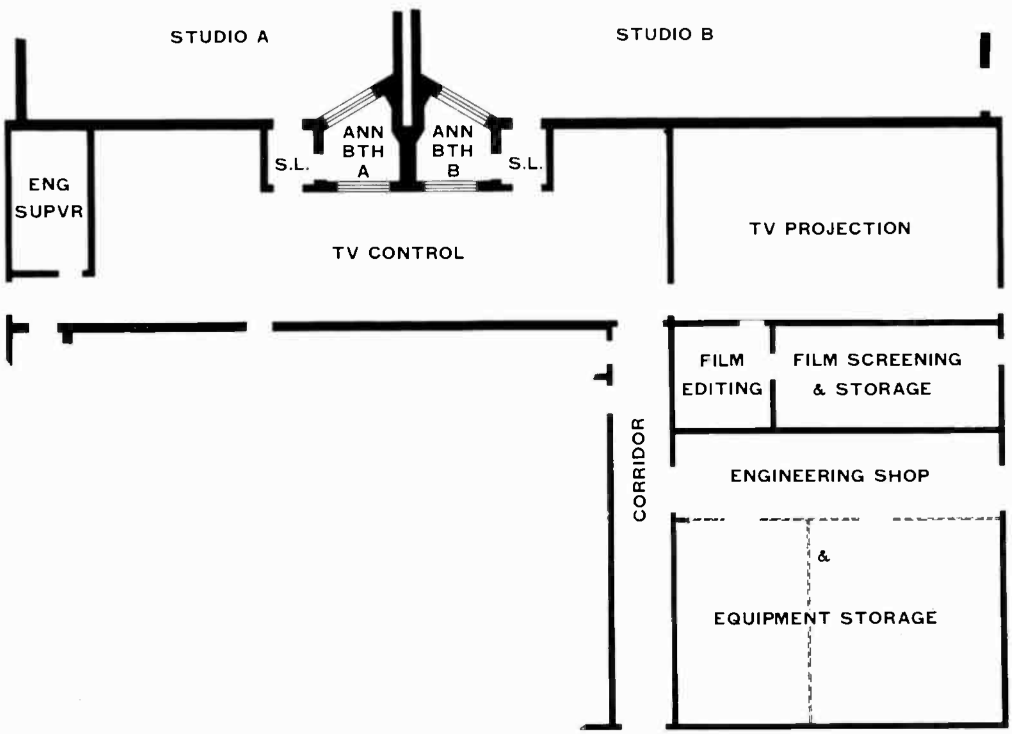
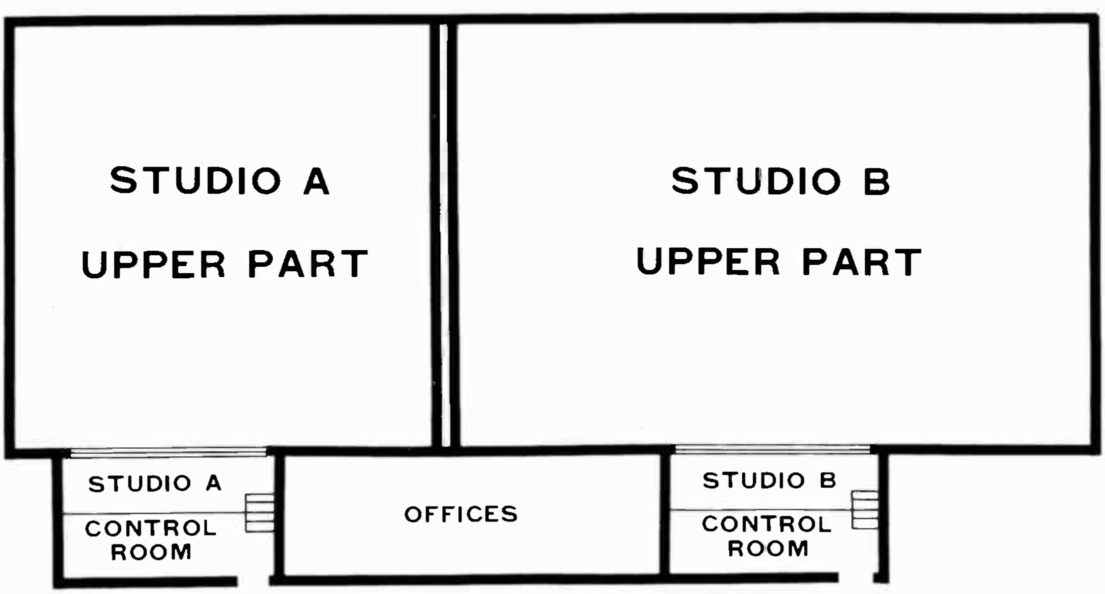


FIG 1



SECOND FLOOR

FIG 2

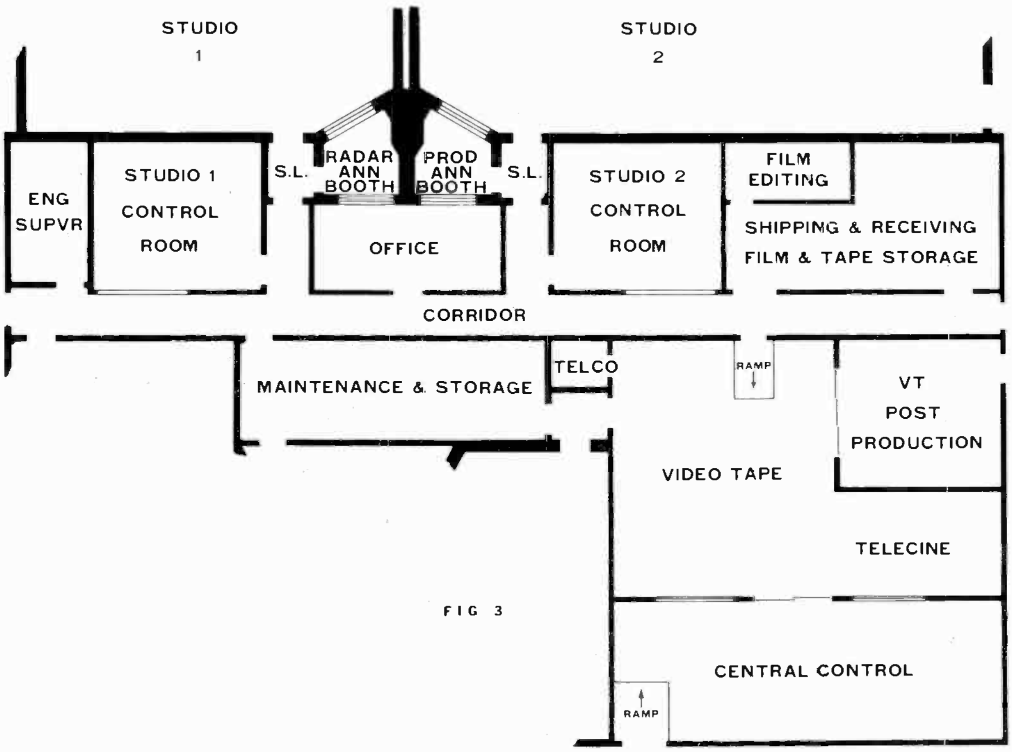


FIG 3

on-stage production group during rehearsal. It is not necessary, nor even desirable, for the program director to have a line-of-sight view from the control room to the stage. The program is best observed on a television monitor as it will be viewed by the audience. There are a large number of monitoring devices in a television control room that require a convenient line-of-sight relationship to the control-room staff. The more that must be considered for line-of-sight viewing, the more compromises must be made among them. Not requiring line-of-sight to the studio floor from the control room console permits a better layout to be achieved.

The configuration of the control room and the personnel in it varies greatly with the station's operating technique. At some stations, the program director has no responsibilities related to the technical operation and only directs the program staff. At other stations, the program director handles the program switcher, including fades and special effects, and in some cases, remote control of video tape and film chains. In all cases, a separate audio-control operator having at least visual contact with the program director is required. An acoustically isolated sound-control position is often requested. Some stations, however, prefer the audio operator to have direct voice contact with the program director and a sound-isolated position is not desirable. Video-control positions, too, vary in location with the operating style of the station. In

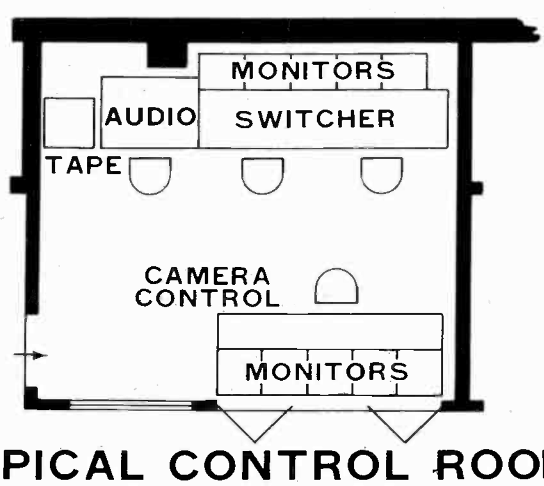


Fig. 4

TYPICAL CONTROL ROOM

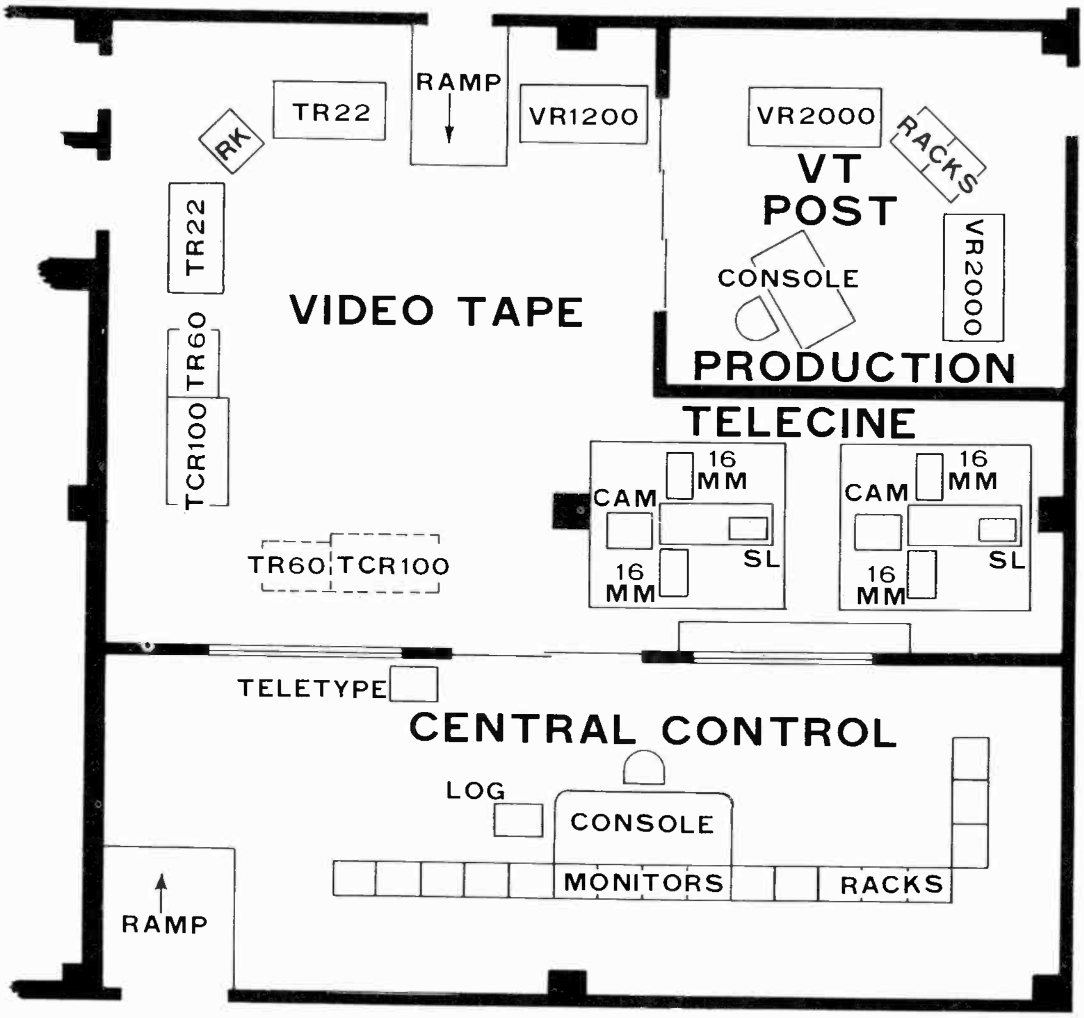


FIG 5

some, the program director wants direct contact by eye and voice with the video operators. In others, the video operators are preferred in an isolated location, free to perform setup functions and quality control away from the busy control room. If a lighting director is used and lighting can be remote controlled, it is advisable to have the lighting position adjacent to the video-control position, so that both groups can work closely with each other to achieve proper light and color balance. An announce booth can be associated with the control room if the station operation requires it.

Master Control. The last quality control and switching facility at the television station that both audio and video signals pass through before reaching the transmitter is called, variously, master control, central control, or transmission control. Recent advances in station automation have made this operation less hectic than it has traditionally been, requiring fewer operators and permitting it to do a limited amount of program production. Complex station breaks at times have required two operators, one for video and one for audio. Recent design master control switchers have combined audio and video switching with break-away audio that may operate independently of video. The break-away audio can have automatic fade transitions, automatic gain control, and machine control. The video position of the switcher similarly can have automatic transitions and special effects, as well as machine control with built-in preroll times. When all of these features are incorporated into a master control switcher, automatic control by means of a minicomputer is feasible. A manual override to the automation system permits single-camera news announcements and simple program inserts to be easily handled directly from a master control designed in this manner. The recent authorization of television transmitter remote control can be accommodated at a properly designed, automated master control with the appropriate monitors and logging facilities located within line of sight and hearing of the master control operator.

Video tape. The video tape area of a station should allow several distinctly different operations to take place simultaneously without interfering with each other. The highest priority is the on-air playback operation involving reel-to-reel and cartridge machines. This group of machines can be located in an open area permitting maximum accessibility to the operators. Recording, dubbing, and screening can be handled in the same area by the same group of machines. The disadvantage of the open video tape area is the noise generated by the machines. It is difficult to critically monitor the sound or to communicate by voice in the high ambient noise level. For critical requirements, such as post production editing, a more isolated environment is desirable. A suitable compromise for video tape areas is to have one area of open, accessible machines and another area with only two or three machines in acoustically isolated rooms that can be utilized for post production editing or critical viewing.

Telecine. The space requirements for telecine are simpler than for video tape. Although the film projectors are generally noisy, editing and critical viewing are not performed at the telecine machines, but in other spaces which can be remotely located. Telecine space may, therefore, be an open area, permitting easy access to all machines by the operators.

Block Diagrams

Block diagrams, or single line drawings showing the functional interrelationship of the plant system elements, are required to outline the proposed new facility's capabilities and components. This set of drawings can be prepared after the layout drawings have been developed sufficiently to establish the required area working relationships.

Audio and Video Systems. The audio and video block diagrams are developed simultaneously. Their combined output is the end product of the plant facility. The routing of audio and video signals through a plant were accomplished, in the earlier days of television, by patching. High-performance, reliable routing switchers are now available to perform that function, greatly simplifying the problem of flexibly assigning the proper signals throughout the plant. The remote control capability of a routing switcher aids the designer in permitting the assignment of signals either at the source or at the destination, depending on where it is better done.

At the studio control room, the audio console and video-switching system are the major production tools available. Their design requirements are determined by the kinds of productions that are expected of the studio facility. The more elaborate and sophisticated programs require more elaborate and sophisticated control-room equipment and capability. The same criterion applies to all the technical areas.

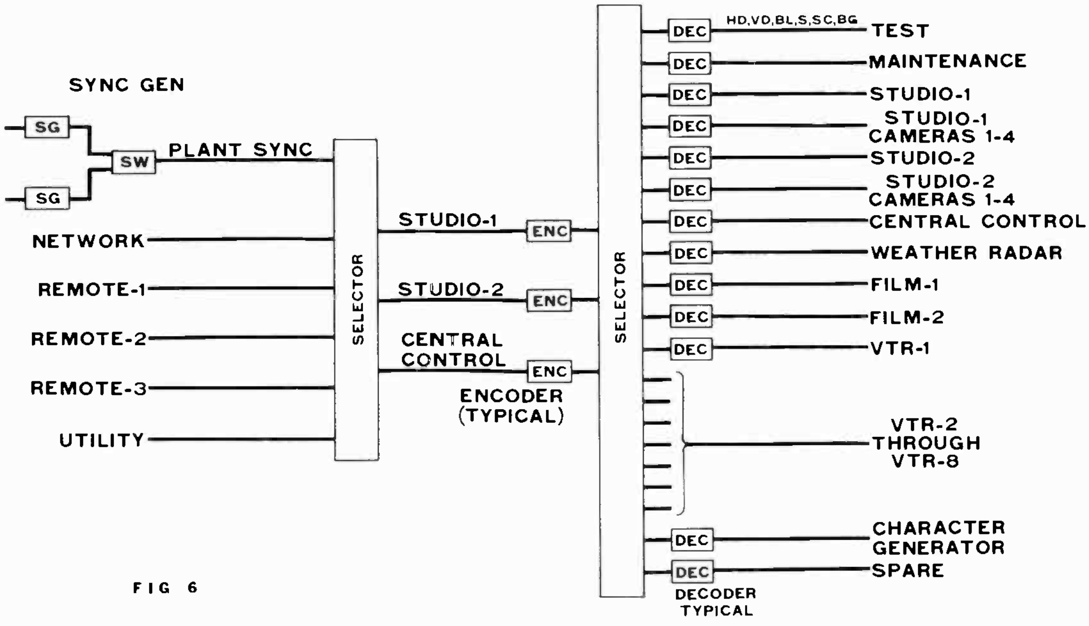


FIG 6

PLANT PULSE SYSTEM

Stations that are heavily film-oriented for their programing require telecine capability adequate to their needs. Many stations have shifted their emphasis from film to video tape in the past few years with the advent of video cartridge recorders and high-quality video tape recorders.

Pulse System. Pulse systems, once the most complex and unreliable component of a television facility, as a result of current technology are now the simplest and most stable. Rubidium-controlled frequency standards, highly stable crystal oscillators, digital circuitry utilizing integrated circuits and computer logic, and single-wire pulse distribution techniques have all blended to provide the change. Circuitry that required a full rack of equipment to provide the early vacuum tube sync generators is now available in a single integrated circuit chip.

The single-wire pulse distribution technique combined with the concept of providing each pulse-driven piece of equipment with its own complete pulse generator, wherein all pulses may be advanced or retarded, provide a flexible pulse system. The single-wire concept permits simple routing of timing signals through simple crosspoint switchers. Figure 6 shows a single pulse system utilizing these concepts. Every necessary timing requirement can be accommodated by such a system. Genlocking to plant sync or out-of-plant remotes, multiple re-entries by either individual pieces of equipment or entire studios, can be effected.

Intercom and Interphone System. Intercom or intercommunications systems in the technical plant utilize microphones and loudspeakers for communication. A 4-wire circuit is involved, containing no dc voltages except for control. Interphone is the communication facility utilizing telephone-type headsets and carbon microphones. A 2-wire circuit, with dc voltage on the audio circuits is involved.

Intercom and interphone are generally the last circuits to be designed, for they require the operation to be well defined before design can begin and the first to be required in working order, for they can be effectively used by the installation teams in setting up the plant. The technology of these systems is simple, but the execution of their installation is generally one of the most troublesome. Problems often arise with these facilities because they are operated by both technical and nontechnical personnel who have not been instructed on proper technique. The technology is so simple that it is assumed that everyone understands how to use it properly, which is never the case.

Current intercom systems for television use remote controlled switching or programable matrices. These matrices allow for the flexibility of station assignment that is so necessary to these systems. Each one must be custom-tailored to the station using it. It is also desirable and feasible to interconnect the interphone system with the intercom system. This permits studio floor personnel to communicate directly with personnel not normally wearing telephone headsets, and allows telephone lines external to the plant to be coupled into the communications system.

Control System—Machine Control. The block diagrams for control systems have been difficult to properly prepare and have not usually been drawn. It has sometimes been impossible to reduce the complex control circuitry into a single-line concept. The control system often had to be left to the specifications for its written description. With the advent of digital control systems, it is easier to prepare this drawing. Digital control systems can be single-wire systems allowing for single-wire distribution. The complexities of control are built into the digital coding, making the block diagram easy to conceptualize. Remote control capability for all pertinent equipment must exist before automation can be considered. Facilities updating should allow for remote control of all machine operation.

Tally Lights. Tally-light control is one of the subsystems that must be considered. Like intercom, it is left for design after all other elements of the system, including machine control, have been formulated. In general, tally control is routed by means of the same assignment as are pulses and machine control. Tally-light control routing does not follow the same assignment as audio and video.

Specifications

Block diagrams alone are not a sufficient description of a system. Performance specifications are additionally required to delineate the facilities of a television station. Performance specifications are a description of equipment parameters and requirements that do not needlessly limit the design. The more traditional equipment specifications are built around existing equipment and include the listing of one manufacturer "or equal." Performance specifications, when prepared in conjunction with block diagrams, are a thorough system description and are simple to prepare. The traditional equipment specification is heavily burdened with needless descriptive material in lieu of block diagrams and are restrictive of new and imaginative proposals.

Budget Estimate

Upon approval of the concepts and equipment outlined by system block diagrams and performance specifications, a budget estimate can be prepared for management consideration. A good budget estimate, prepared from these plans and specifications, should have an expected accuracy of plus 15 percent or minus 10 percent. There is more allowable leeway on the high side of budget estimating because an allowance should be made for errors of omission. The mistakes on budget estimates are usually items not apparent in early planning.

Time Schedule

The completion of plans and specifications also provides the basis for an estimate to be made for the required project time to completion. It is best to leave allowance, as in budget estimating, for unforeseen and unpredictable problems. It is the exception, rather than the rule, for ongoing project conditions to allow time to be gained. At the same time, allowing unreasonably long periods permits unnecessary inefficiency. A reasonable estimate can be made at this point, however, with the understanding that it is to be refined after all vendors have been selected and their delivery schedules known.

BID SUMISSION AND REVIEW — NEGOTIATION

When the preliminary planning has developed sufficiently to meet with management approval, the project is ready to be submitted to all appropriate vendors. Ideally, all interested vendors should be allowed to submit bids based on the prepared drawings and specifications. The bid review process, in such a case, is quite difficult, because judgments on suitability of the vendor's proposal, qualifications, and ability to perform must be part of the review. The various vendors equipment and cost effectiveness must also be evaluated in context of overall integration.

In some instances, there are requirements that bids go out on a selective basis to predetermined, qualified vendors and further, that the project be awarded to the lowest qualified bid. Actually, performance specifications are not appropriate to require low-bid acceptance because they are intentionally not restrictive. The more restrictive the vendor selection, however, the easier the bid review process. If all judgments on vendor suitability are made prior to accepting bids, their cost alone becomes a major determinant.

Often there are requirements for a turnkey installation that restrict the number of potential vendors. Not all vendors are equipped for that kind of proposal.

It is also quite appropriate to consider only one vendor, either on the basis of past satisfactory performance or some unique characteristic, and negotiate a bid with that vendor. The preliminary planning has included effective budget and time estimates and these can be the basis for negotiating with a reliable vendor. In such an instance, the negotiation process replaces the bid submission and review phase. The outcome of this stage is the selection of the vendors required to provide the necessary equipment.

BUILDING RENOVATION

Some degree of building renovation is required in facilities modernization. If it is minimal, a building contractor can be directed to execute the changes. In most cases, it is substantial, however, and the services of an architect should be obtained to design and supervise the required building project.

A set of building construction design targets detailing the building requirements essential for television stations should be prepared for the architect. Few architects are familiar with the many requirements that are unique to television stations. The sound-level and air-conditioning requirements for studios and work areas, control room and work area lighting requirements, studio lighting requirements, sound-lock requirements and special flooring are but a few of the special requirements that must be made known to the architect. The architect can usually prepare drawings based on these design targets, with the assistance of his consulting engineers, but frequently clarifications are required.

PERT / CPM

At this point, the detailed project schedule, Program Evaluation Review Technique or Critical Path Method, may be set up. This schedule details the various steps required for project completion. The combination of station operating requirements, building renovation, vendors' delivery schedules, and installation schedules must be spelled out for effective execution. The PERT/CPM drawing shows the complex relationships on a calendar basis and permits a day-by-day evaluation of project progress and problems.

When working within the shell of an existing building, facilities modernization is a "hop-scotch" operation. Areas must be cleared, renovated, and reoccupied without disrupting the on-going broadcast schedule. Some facilities must be installed overnight to accomplish this. Preplanning, as on PERT/CPM, is essential.

EQUIPMENT PROCUREMENT

Close liaison with equipment vendors is of great value to the vendor and to the station. Misunderstandings that are detrimental to both can be minimized or eliminated completely.

The first important check after an order has been placed is a review of the vendor's shop drawings just prior to release. Enough information is available at this time to permit a meaningful evaluation.

The next essential vendor contact is the equipment and system check at the manufacturer's plant prior to shipping. No equipment should leave the plant malfunctioning or not in accordance with specifications. Any problems noted are easier to correct at the manufacturer's plant, even if it entails delaying the project schedule until all is cleared. There is no assurance that problems left to be cleared at the job site will be handled expeditiously. Unpredictable job site problems are enough burden to any project; the predictable ones should be eliminated whenever possible.

The vendor's deliveries should be continuously checked with the PERT/CPM chart. Action can be taken if any discrepancies are noted. If unavoidable, the PERT/CPM should be changed to reflect delays, so that the chart realistically indicates the project status.

DETAILED SYSTEM DESIGN

Detailed system design can commence immediately after the vendors have been selected. Electrical contractor information will be required first. As part of this set of drawings, an effective grounding system should be detailed.

Interconnect wiring, interface equipment design and fabrication, and existing equipment and facilities modification must be undertaken concurrently so that the mesh is complete when equipment arrives. Although it tends to be underestimated, this phase of the project is probably the most tedious and time-consuming. It is also the phase that surfaces any unforseen technical problems.

ELECTRICAL CONTRACTOR

The electrical contractor can commence work before the building renovation is complete. It is best to have the electrical work completed, including all wireways and power installations, as soon as possible and certainly before any vendor's equipment arrives to be installed. Close liaison with the electrical contractor is required to minimize problems.

INSTALLATION

On-site installation supervision is a critical function. The actual physical installation may be executed by the vendor's personnel, station personnel, contractor installation personnel, or any combination of these. There should be no needless problems or delays if the project has proceeded as described herein. The preplanning, PERT/ CPM, and detail drawings should have surfaced any incongruities and necessary clarifications. There is always the problem of interpreting drawings and modifying plans in accordance with on-site job conditions. The final mesh of the entire project occurs during the installation, and the on-site engineering must be capable of coping with changes. Even though all equipment has been checked prior to installation, some faults will occur and time must be taken to clear up equipment malfunctions prior to cut-over.

The cut-over of facilities should proceed in the shortest possible time. One of the major goals of the entire effort is to permit the cut-over to the new facilities to occur smoothly.

FINAL CHECKOUT AND OPERATOR TRAINING

After all the new facilities have been installed and all equipment is operating, a proof of performance test can be run on the plant facilities. This test is to determine that the plant is indeed performing in accordance with its design specifications. Any deviation from these specifications must be corrected at this time. The final effort is the documentation of the plant facilities as built. All drawings and documents should be brought up to date, reflecting any last-minute changes required by the installation.

Operator familiarization and training can occur during the checkout period. Some familiarization could have been taking place during the installation period, but final training must await the completion of installation and checkout. The operators training should not be confused by equipment and system malfunctions. At this point, the project has been completed and the plant can be turned over to the operating group.