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the technical journal of the broadcast-communications industry

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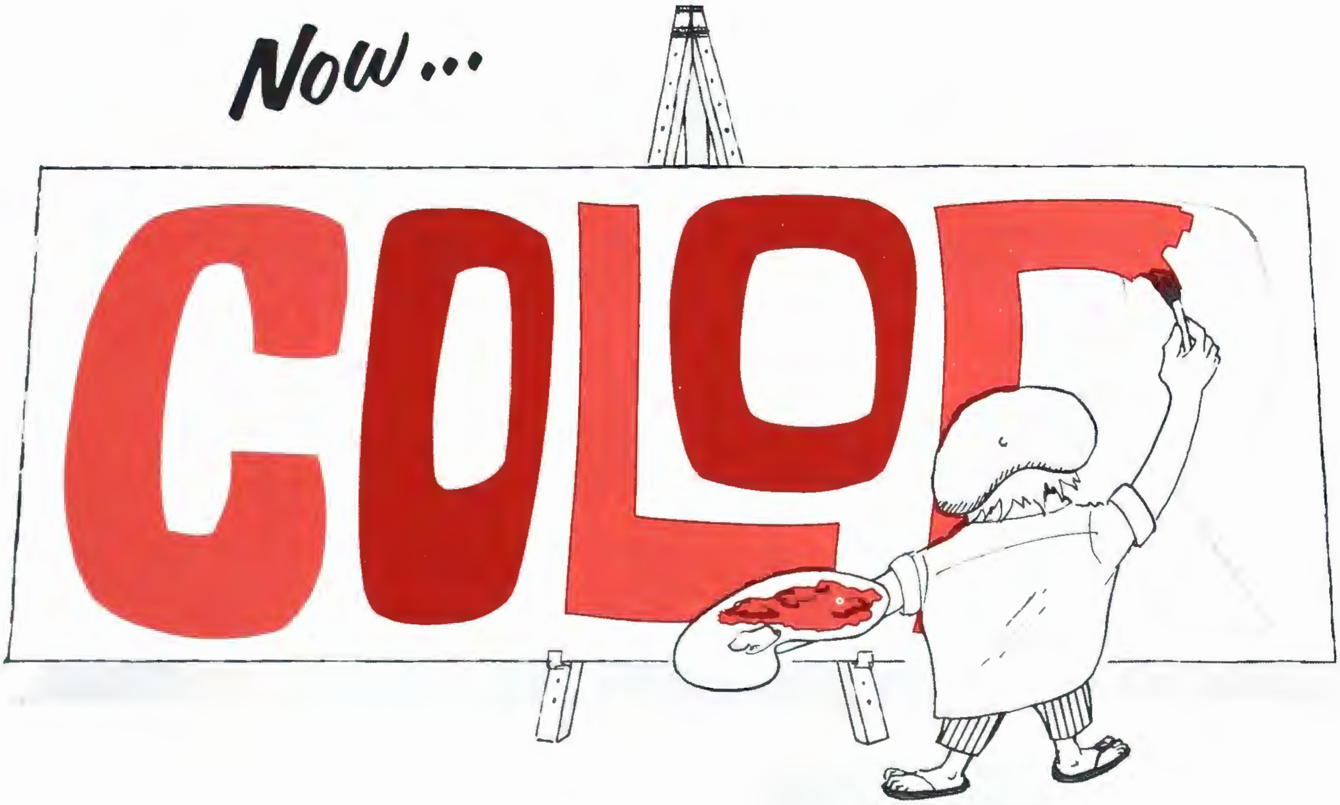

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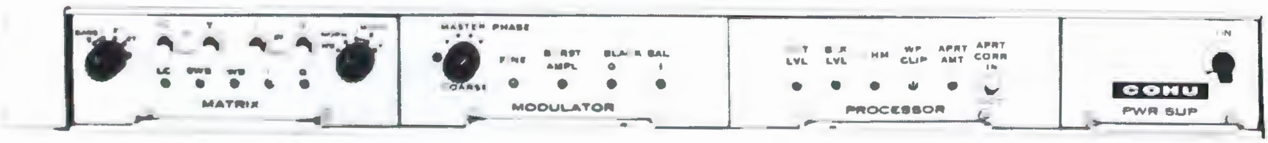

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Broadcast Engineering

Volume 9, No. 3 — March, 1967

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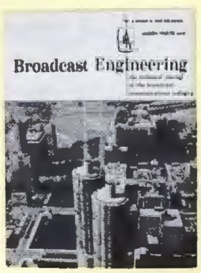
This aerial view shows part of downtown Chicago, which is of course the host city to the 1967 NAB Convention. Dominating the picture are the twin towers of Marina City and the antennas of WBKB (Channel 7) and WFLD (Channel 32). (Cover photo courtesy of United States Steel Corp.)



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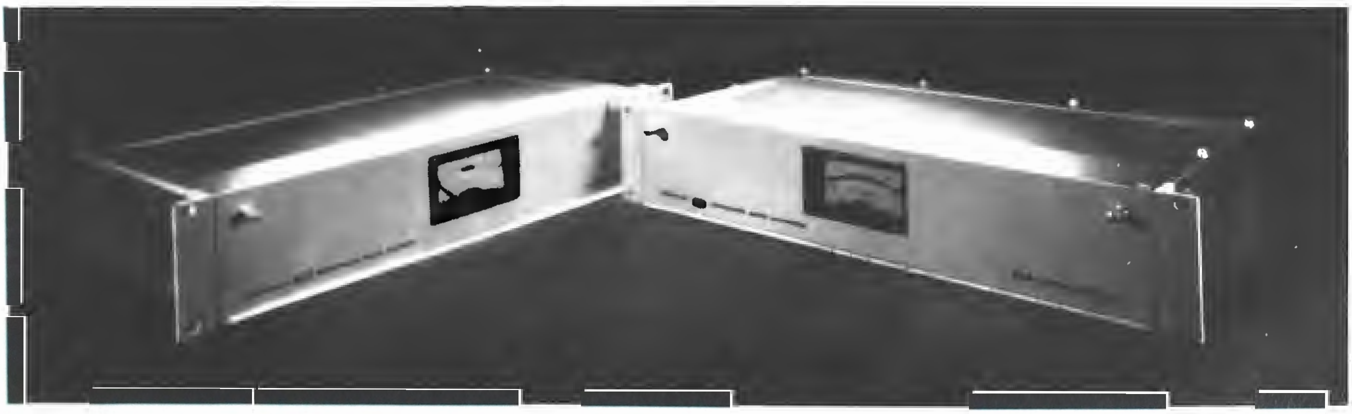

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LETTERS to the editor

DEAR EDITOR:

The article "Reducing Disc Playback Distortion" (November 1966 BROADCAST ENGINEERING, page 36) clearly illustrates the importance of proper maintenance of one of the most vital sources of programming in radio, the turntable pick-up cartridge. While the article is quite comprehensive, I believe it is in error on one point.

Regarding the identification of a high-impedance or low-impedance GE VR-II cartridge, the article states the high-impedance model can be identified by "brass-colored" shielding and the low-impedance model by "chrome-plated" shielding. However, it has been my experience that GE produced both models with the "chrome" shielding. The low-impedance VR-II cartridges I've encountered have always been encased in bright red plastic; all other units in a gray plastic body have always been high-impedance versions of the VR-II. Some of these high-impedance VR-II's do have a brass-colored shielding, but I believe it is the exception rather than the rule; it does not necessarily identify the cartridge impedance, as the red or gray plastic cartridge bodies clearly do.

WILLIAM A. KINGMAN
Chief Engineer
KTHO AM-FM
So. Lake Tahoe, Calif.

In the interest of maximum service to the reader, we inserted our cartridge indentification method in the article. It now seems that we erred. A check with General Electric verifies reader Kingman's observation.—Ed.

• *Please turn to page 10*

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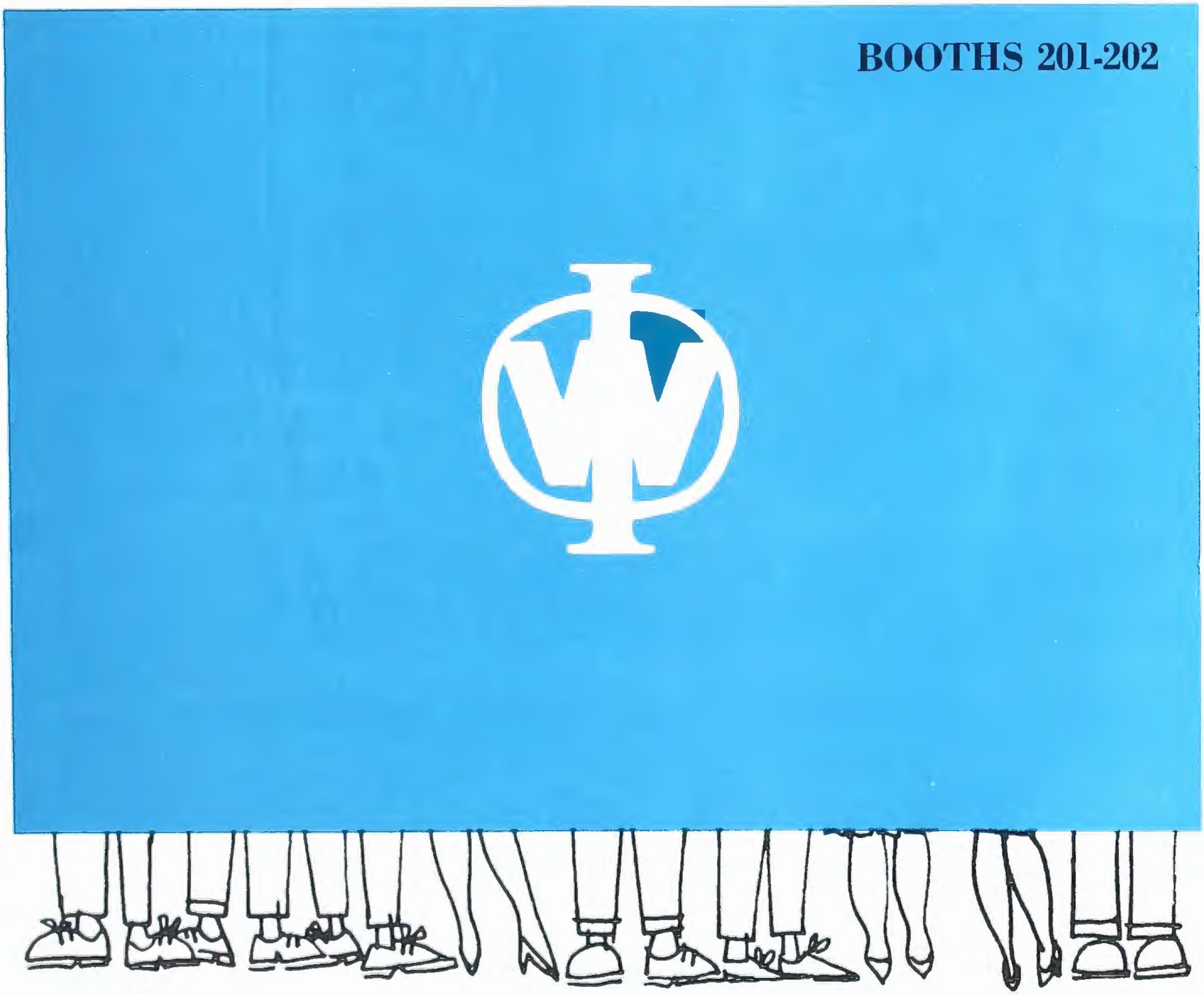

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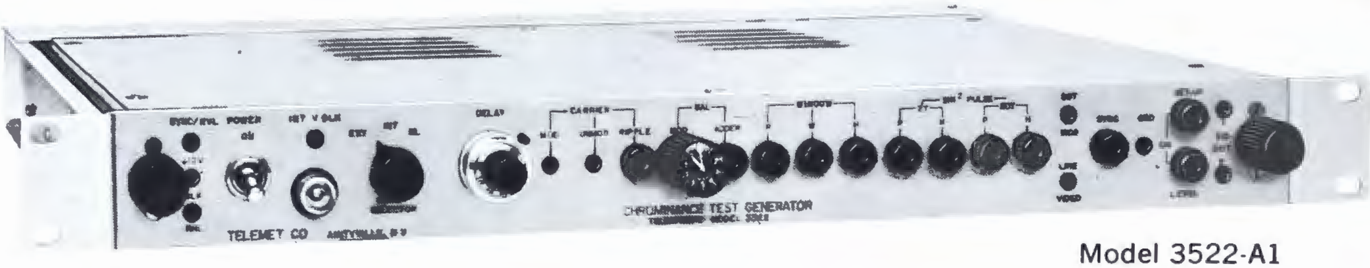

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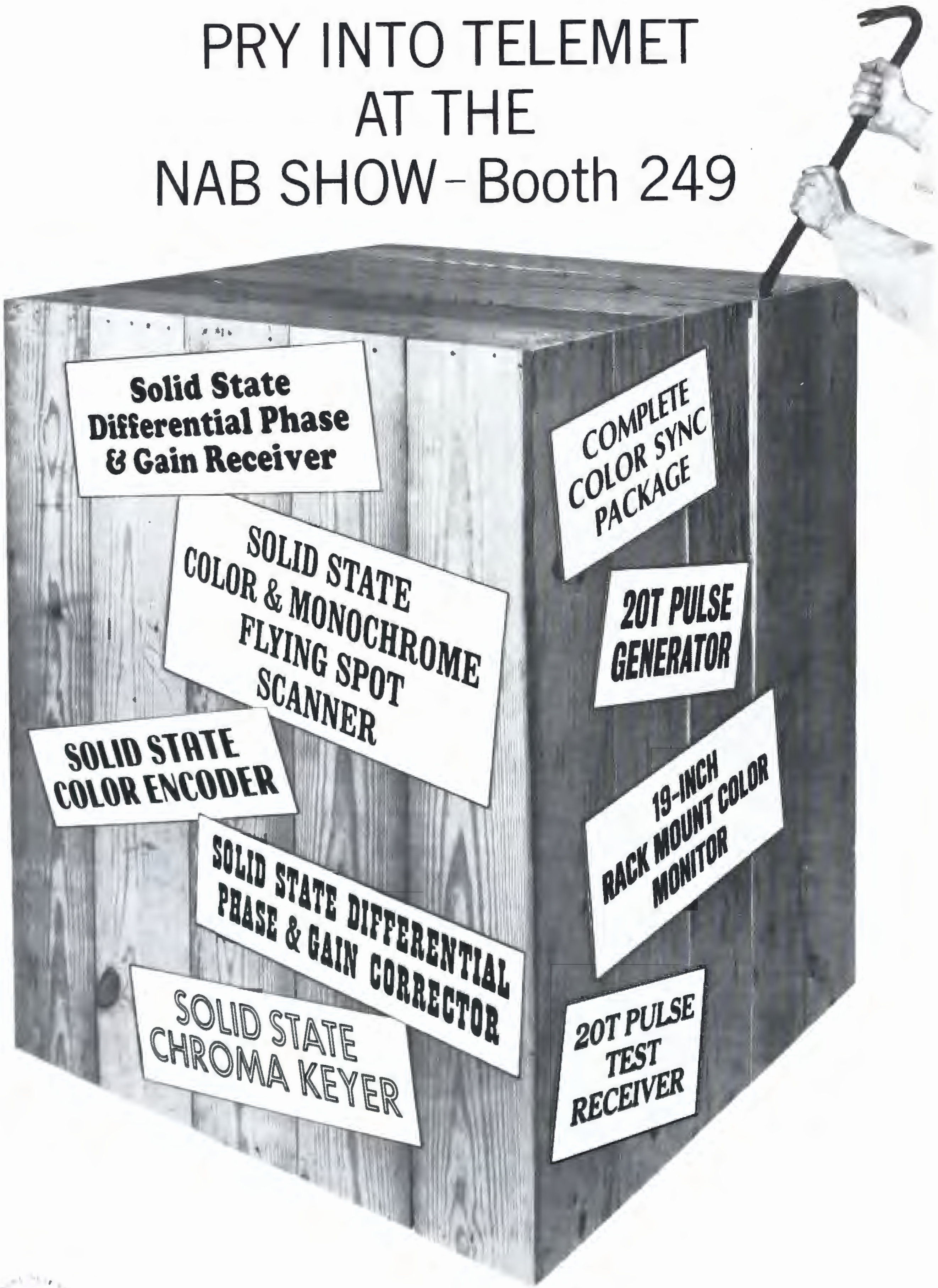

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Circle Item 7 on Tech Data Card

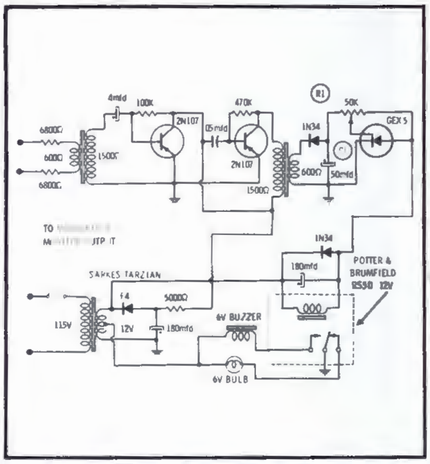
Letters *(Continued from page 6)*

DEAR EDITOR:

In my "Engineers' Exchange" item "Audio Dropout Alarm" (December 1966 BROADCAST ENGINEERING, page 38), I notice an error in the diagram. The relay should be fed 12 volts AC instead of a DC voltage. If DC is used, the unit will not turn off when audio is restored to the input.

MARSHALL ROYALTY
WKLO, Louisville, Kentucky

A corrected diagram appears below.—Ed.



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The 212T-1 control panel provides 28 inputs to 14 faders, 2 program output channels, and 2 10-watt monitor speaker outputs. The overall dimensions are 15¾" high by 24" wide.

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POWER SUPPLIES. Two power supplies are housed with the rack-mounted assembly. One power supply provides variable illumination for meters and push-button controls. Another provides powering for cards, attenuators, amplifiers, switches, and photoconductive cells.

Most studio audio requirements can be met by adapting the standard 212T-1 or 212T-2 Console through strapping options and minor wiring changes. Expansion and adaptation can be accomplished easily with additional space which the units provide for two extra preamplifier cards, two additional program amplifiers, and two unwired spare card receptacles.

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COMPRESSORS, LIMITERS, AND AUTOMATIC PROGRAM CONTROL

*by Robert H. Tanner**—

A discussion of the use of automatic devices to control audio gain.

Radio engineers have always been faced with the discrepancy between the dynamic range of normal audio programs and the range of levels a radio transmission system can accommodate. Much thought has been given to ways of solving this problem automatically. A related but actually quite different problem is the maximization of the service area of a radio transmitter by keeping the average modulation as high as possible. It is unfortunate that there appears to be a tendency to confuse these two problems, as well as their possible solutions, and to expect relatively simple equipment to carry out very sophisticated functions.

Signal-Modification Requirements

As a basis for examining the fundamentals of the situation, assume a "perfect" transmission system, which introduces no amplitude or frequency distortion, but which possesses upper and lower limits beyond which it is inadvisable to work. Now if the range between these two limits is less than the dynamic range of the program to be transmitted, it is necessary to make some change in the transmission. This change will make the reproduction differ from the original, unless an opposite change can be introduced at some point in the system past the "level bottleneck." The use of a compressing device at the sending end and an exactly corresponding expanding device at the receiver is perhaps the only really sound solution to the dynamic-range problem. Unfortunately, it is one which not only demands additional expense in the broadcast receiver, but also requires standardization of uniform operating characteristics throughout the industry. There is the further complication that the noise level of the average listening location may produce a "bottleneck" in the transmission path between the loudspeaker and the listening ear, and, therefore, after any possible location of the expander.

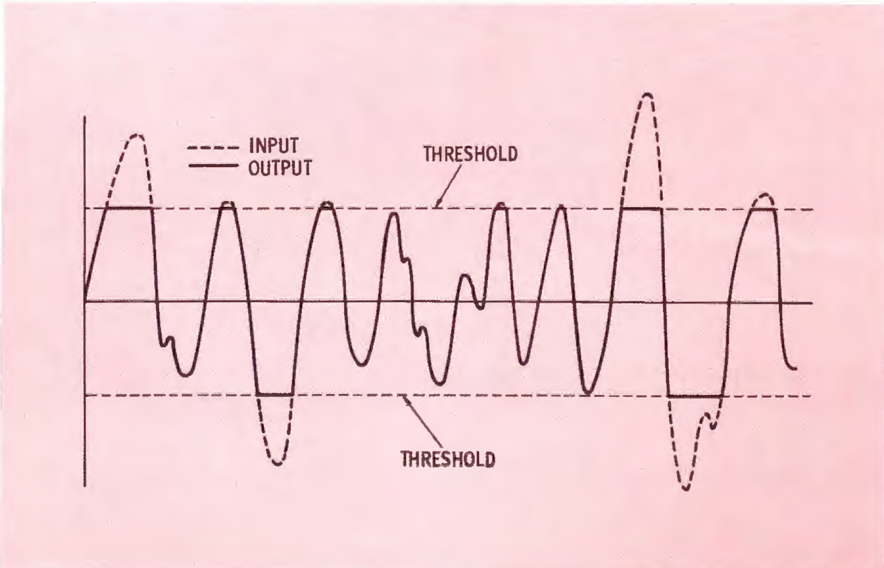

Fig. 1. Clipper controls peak signal level, but causes waveform distortion.

The inescapable conclusion is that, if the program is to be passed through the "level bottleneck," it must be modified in some way which will cause the reproduction to differ materially from the original. The next decision is what modification will result in the least change in the subjective effect on the listener. The answer to this leads at once into the deep waters of psychoacoustics. Loudness is not an absolute quantity, nor is the sensitivity of the human ear constant. If they were, nothing could mask the fact that the dynamic range of the program material must be reduced. However, it can be shown by experiment that the ear does not give full value to slow changes in level. With program material, rather than a steady tone, it is possible to vary the level slowly by as much as 10 dB before the listener detects a change. If the level changes are made in small steps, in time with the beats or bars of music, they can be camouflaged even more effectively. In these facts lies a possible solution to the main problem: If the program is increasing in level toward a peak outside the operating limits, or if a steady passage of music is to be followed by a sudden loud chord of unacceptable level, the gain of the system may be slowly reduced ahead of time, either steadily or in timed steps. Decreasing passages or sudden diminuendoes can be dealt with similarly by properly adjusted increases in gain. In this way, the subjective

*Manager, Microwave Laboratory, Northern Electric Co.

effect of the music will be virtually unchanged, and it will appear to have a dynamic range considerably greater than the system level range would allow.

The processes just described do not, of course, lend themselves to any simple form of automation. They can be performed quite adequately by a skilled human operator, if he is familiar with the music or is provided with a score. Alternatively, if the music can be recorded with full dynamic range (in itself not an easy feat), a chart of overall level might be made at the same time. A computer would then have little difficulty in making suitable level adjustments during a replay, if furnished with the correct subjective criteria.

Level-Control Devices

But all of this, while perhaps of interest to the purist or the student of psychoacoustics, is really of only academic interest to the radio-station engineer or the designer of the broadcast audio equipment. In broadcast applications, the need is for a comparatively simple electronic device either to reduce the dynamic range or to limit the maximum amplitude of program material, without introducing noticeable distortion.

As soon as ways of achieving these ends are considered, the time factor becomes of great importance. Because it is impractical or impossibly expensive to use any system which depends on foreknowledge of the future, the control system must be capable of fast initial action, since this is the closest practical approximation to an anticipative control. The limiting criteria governing just how fast this initial action should be will be discussed later. First, attention will be given to the speed of the succeeding action of the device, and the level or levels at which it comes into action.

If a device reduces the gain as soon as the instantaneous voltage of a waveform exceeds a certain level, but restores it to normal as soon as the instantaneous voltage falls below this threshold value, the device is normally called a "clipper" (Fig. 1). Such a device is highly effective in protecting, for example,

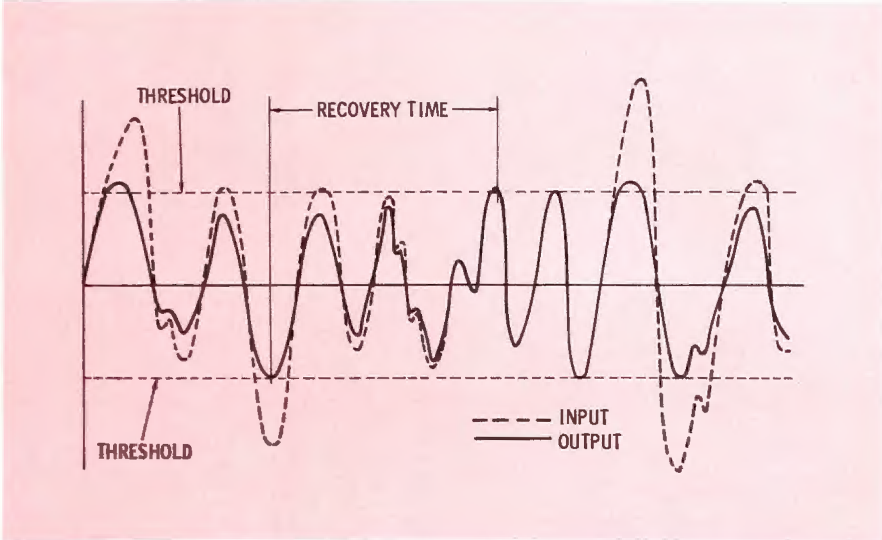

Fig. 2. Limiter reduces gain on peaks and restores it during recovery time.

a transmitter from a voltage overload, but it introduces into the signal amplitude distortions which are normally unacceptable for high-quality program transmission.

Another arrangement reduces the gain on receipt of a signal greater than a given threshold, but then only gradually restores it to normal over an appreciable time period. Such a device, arranged so that the gain reduction is virtually equal to the amount by which the signal would have exceeded the threshold, is a "limiter" (Fig. 2); it may have a recovery time ranging from a fraction of a second to several seconds. When used solely to protect a transmitter from occasional overloads, a limiter does not appreciably affect the dynamic range of the program material. However, if the recovery time is too long, objectionable level surges may be introduced into such material as music with heavy percussion. One method of reducing these effects is to arrange for the recovery time to be governed by the amount of overload so that a heavy pulse produces a fast recovery and a smaller pulse produces a slower recovery. Then the limiter acts more like a clipper for short, heavy overloads, which would otherwise tend to "punch holes" in the program.

A third configuration starts to work at a much lower level than either a clipper or a limiter, and the gain reduction is only a fraction (perhaps one half) of the excess of signal over threshold. For a gradually rising signal, the rate of rise, and thus the dynamic range, is reduced. However, if the recovery time is quite long, on actual music the device will tend to set the gain

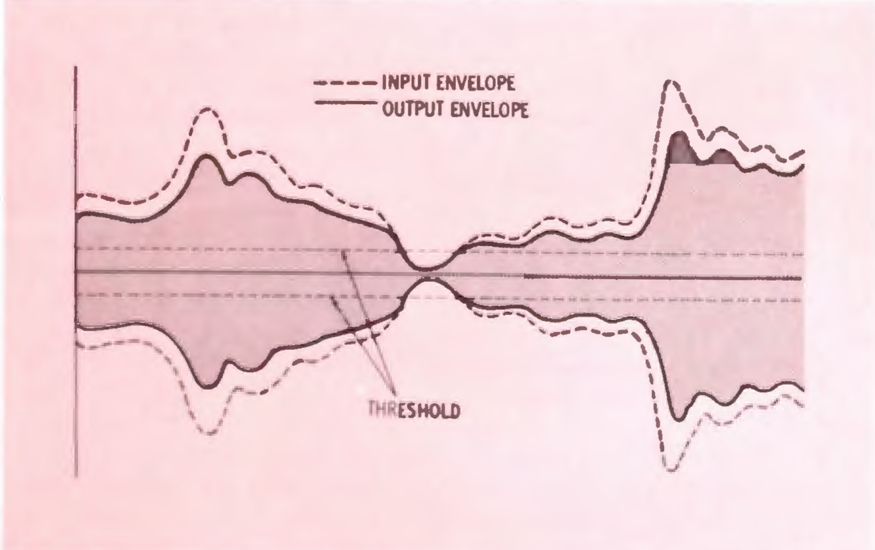

Fig. 3. Effect of compression on a signal; gain is maximum with no signal

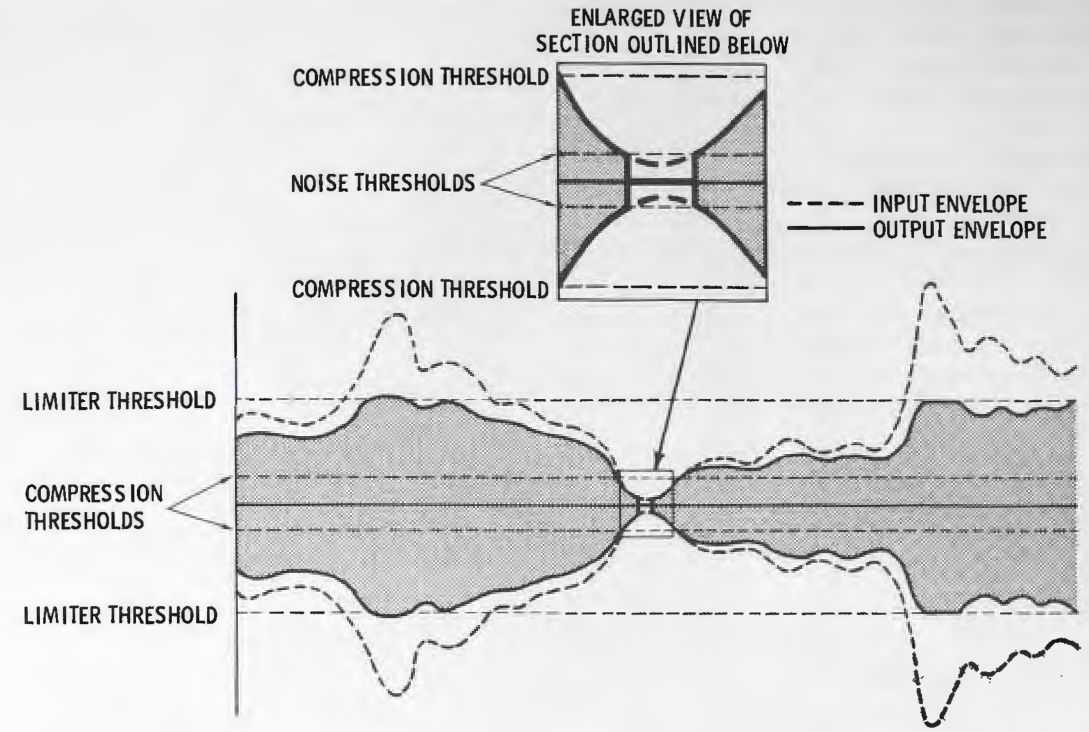

Fig. 4. Limiting, compression combined with gain reduction below noise threshold; all thresholds normally adjustable.

for complete phrases, within which the dynamic range will be maintained. The result is an approximation to the intelligent control mentioned at the beginning of this article. This device, in its simplest form, is called a "compressor" (Fig. 3). It has the disadvantage that the system gain is a maximum when there is no program, and any background noise therefore will be more obtrusive.

It was shown earlier that the functions of limiter and clipper can be combined. Similarly, it is possible to make a compressor which acts as a limiter (or even limiter-clipper) above a second threshold. In addition, the device may be arranged so that, below a given low signal input, the gain reduces rapidly so as to eliminate the accentuation of background noise (Fig. 4). At this degree of sophistication, especially when coupled with adjustable attack and recovery times, the simple terms compressor, limiter, and clipper are no longer fully descriptive. Equipment possessing these characteristics might be called a "program-controlled amplifier."

A few words about attack time were promised earlier. Here two criteria appear to be paramount: first, the sensitivity of the transmitter or other equipment in the chain to overload, and, second, the overload properties of the human ear. Obviously, if the transmitter can be kicked off by a 1-millisecond pulse of an amplitude within the capability of the driving amplifier, then the attack time of the control device should be shorter than 1 millisecond. In practice, however, the operation of normal protective devices is much slower than this, and it is the human ear which becomes the governing factor. Subjective experiments have shown that, in general terms, the ear does not detect distortions which last for less than 10 milliseconds. Thus an attack time of 5 milliseconds or less is sufficiently rapid to carry out the changes necessary, without such changes being audible.

The problem of recovery times is a much more complex one; it depends to a very great extent on the exact function which the program-controlled amplifier is intended to perform. In some cases, it becomes a completely subjective matter, and for this reason a choice of several suitable recovery-time values usually is provided.

It is usual to illustrate articles concerning clippers, limiters, and compressors with curves showing various relationships between input and output levels. These in fact tend to be misleading because they show an instantaneous picture of a characteristic which may be varying with time. In a properly designed program-controlled amplifier, the instantaneous input/output curve remains linear (unless clipping is introduced) and at 45° to the axes. However, its position shifts along the input axis as gain changes are made. This, incidentally, is analogous to the curve for a manually controlled attenuator.

Conclusion

In summary, the following is a list of functions which can be performed through automatic program control and. perhaps even more important, some of those which cannot.

1. A transmitter or any subsequent equipment can be protected from the effects of program overload lasting more than about 5 milliseconds (or less if necessary).
2. The overall dynamic range of a program can be reduced to within acceptable limits for radio transmission, while the short-term dynamic range of musical phrases or speech sen-

• *Please turn to page 107*

ANTENNA PATTERNS BY COMPUTER

by Robert A. Jones and Donald L. Markley***—A digital computer can relieve the engineer of the labor of repetitive computations in designing a directional array.

The design, adjustment, and maintenance of a directional broadcast antenna system involves many lengthy mathematical computations which, after calculation of the first radial bearing, are of little direct value in understanding the system under study. The computations, nevertheless, must be made. They are an excellent example of the kind of work a modern computer does best—many repetitions of straightforward and lengthy problems. Now that computers have become available in most areas at reasonable cost, it seems logical that engineers should employ them as an aid in this kind of "busy" work.

Using Digital Computers

Besides relieving the engineer of much relatively nonproductive work, the computer has two outstanding advantages: great speed and a high degree of accuracy. The authors have employed an IBM Model 1620 computer for work and investigation of computer possibilities. With this unit, a daytime, two-tower array can be completely calculated in about two minutes—approximately the time ordinarily required to remove a slide rule from its case and to sharpen a couple of pencils. The work, when completed, is done to eight-place accuracy.

For those concerned that the computer may eventually replace the chief engineer, there is little cause for worry because computers have a significant fault: they aren't very smart. In fact, they must be told, in a very specific way, everything they are to do. This may seem incongruous in view of the speed and accuracy with which they work, but it is true. A computer even has to be told when to stop working.

It was stated that a computer must be given detailed instructions in a very specific way. The instructions are called a "program" and are given in the exact sequence in which they are to be performed. It may seem surprising, but computer operators and programmers rarely have any knowledge of electronics or of the electronic and mechanical principles involved in computer operation. This is because it is possible to write the instructions contained in a computer program in a "language" which can be understood by the writer and the computer. Computer languages are quite similar to the basic spoken language. They have rather unique names such as FORTRAN, COBOL, and ALGOL. These are abbreviations for much longer names such as FORMula TRANslation (FORTRAN), COmmon Business Oriented Language (COBOL), and ALGOrithmic Language (ALGOL). For each specific type of computer, the manufacturer has developed a special program which then translates the "source" language (FORTRAN, etc.) into an "object" language which actually controls the circuitry and devices of the computer and its associated equipment.

In order to "program" a computer it is necessary to understand the problem which the computer is to solve and to select the language which is best suited to solve that particular problem. At this time two languages are in common usage; these are FORTRAN and COBOL. COBOL was developed especially for business usage, although FORTRAN is widely used for that purpose. FORTRAN is generally used for engineering and other mathematical applications. In order to program a computer it is necessary to "learn" the language to be employed. Learning a computer language is much like learning any language; there are rules of grammar and of spelling, and much memorizing must be done. The more one knows of the language, the greater will be the speed and facility with which he may "converse" with the com-

Operator, console are at left, card reader in rear, printer in foreground.

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**Consulting Engineer, Mapleton, Illinois.

puter. There are excellent texts available, including many published by computer manufacturers.

When the program has been written, using whatever language has been selected, it is fed into the data-processing system by means of punched cards or perforated paper tape. The output of the program will then appear in the form of punched cards, punched tape, magnetic tape, or material printed by typewriter or line printer.

Pattern Calculations

The authors elected to write their own program for a directional pattern employing KINGSTON FORTRAN II (a modification of the basic FORTRAN language). It was desired that the pattern be calculated in v/m at one mile at intervals of five degrees of azimuth and five degrees of elevation. The elevation calculations were limited to the zone between zero and sixty degrees vertical; these are the limits normally required by the FCC in support of nighttime directional applications. The calculations can be made with any number of towers in any physical or electrical configuration.

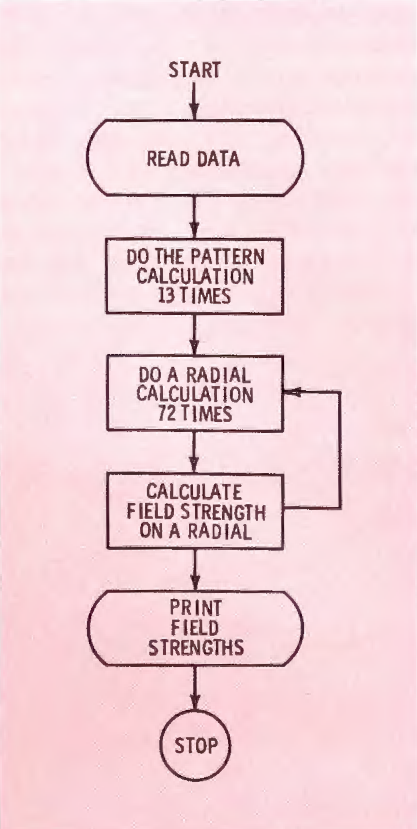

Fig. 1. Flow chart shows instructions given computer to solve the problem.

The basic equation solved by the computer was the generalized equation covering any directional antenna system:[1]

$$E = \sum_{k=1}^{k=n} E_k f_k(\theta) \angle \beta_k$$

where,

- E = the total effective field intensity vector at unit distance (P) for the antenna array with respect to the voltage-vector reference axis. This vector makes the angle β with respect to the axis.
- k = the kth tower in the directional antenna system.
- n = the total number of towers in the directional antenna array.
- E_k = the magnitude of the field intensity at unit distance in the horizontal plane produced by the kth tower acting alone.
- $f_k(\theta)$ = vertical radiation characteristic of the kth tower.
- θ = elevation angle of the observation point P measured up from the horizon in degrees.
- β_k = $S_k \cos\theta \cos(\phi_k - \phi) + \psi_k$ = phase relationship of the field intensity at the observation point P for the kth tower taken with respect to the voltage-vector reference axis.
- S_k = electrical length of spacing of the kth tower in the horizontal plane from the space reference point.
- ϕ_k = true horizontal azimuth, orientation of kth tower with respect to the space reference axis.
- ϕ = true horizontal azimuth angle of the direction to the observation point P.
- ψ_k = time phasing portion of β_k due to the electrical phase angle of the voltage (or current) in the kth tower taken with respect to the voltage-vector reference axis.

The basic equation was modified slightly to allow easier use in the digital computer, but the basic form of the equation remained unchanged. While shortcuts may be applied to some antenna systems, only a general equation will apply to all systems with any number of towers in any configuration. While the computer may have to work a little longer to do everything the hard way, the difference in time normally will be in the order of a few seconds.

All the information needed was fed into the computer from punched cards. This information concerned the system parameters and included field ratios for each tower as compared to the reference tower, the phase angle of each tower, the electrical spacing between towers, the space shift of each tower from the reference bearing, and the electrical height of each tower.

When the punched-card data has been fed into the computer, it then becomes a matter of minutes until the complete pattern has been calculated. The output pattern calculations serve as a check on any previous slide-rule calculations and provide printed-form support for the FCC application with eight-place accuracy. If the directional antenna pattern, as described by the computer, meets the coverage and protection requirements, you can feel confident in the mathematics. The probability of any error in the computer is almost negligible.

A "flowchart" (Fig. 1.) helps to show how a computer attacks a problem. An analogue to a flowchart might be a road map, in that it shows the route to follow from point "A" to point "B." The first step taken by the computer is to read the punched cards. The next instruction is to calculate the pattern thirteen times (once for each five degrees of elevation from zero to 60 degrees—only one computation is needed for a daytime pattern). The computer terminology for this instruction is an "execution statement" (in some places called a "do-loop"). An execution statement simply causes the computer to execute a series, or "loop," of operations a specified number of times (in this case, thirteen).

The second execution statement instructs the computer to calculate the signal strength for each five degrees of azimuth in each elevation plane. It is in this statement that the computer is told how the computations are to be performed. This may seem to be a backward ap-

[1] Smith, Carl E., *Theory and Design of Directional Antennas,* Cleveland Institute of Electronics, 1951, p. 2-1-23.

Table 1. Typical Computer Costs

IBM—1620 plus 1 Disk File	= $44.00 hour
IBM—082 Card Sorter	= $2.50/hour
IBM—026 Keypunch	= $3.60/hour
Programming for IBM—1620	= $7.50/hour
Senior staff consulting	= $15.00/hour
Cards (box of 2,000)	= $2.25
Printing paper (100 sets)	= $0.60

All prices include operator and first 1000 cards per hour and first 150 sets of paper per hour.

proach, but in writing the computer program it is necessary to think the problem back from the answer. Fig. 1 shows that the second execution statement requires that the calculation be made 72 times. Each calculation corresponds to five degrees of azimuth, or a total of 360 degrees.

When all calculations have been made by the computer, the program tells the machine to give the answer, or answers, in readable form. This is called the "print" statement. In addition, the print statement tells the computer how to print the information, *i.e.*, whether to print the data in rows, in columns, or in any other desired configuration. This instruction permits selection of the format which lends itself best to the analysis to be made. We chose to have the data printed in columns, since this would lend itself most easily to plotting polar patterns. Also, it is customary to have the data grouped by vertical planes. Fig. 2 shows a computer "readout" of a portion of the ground-plane data computed for a daytime array. The same data are shown in Fig. 3 in the customary polar graph.

At this point, the computer has finished its work, but it still waits for further instructions. It is necessary to tell the computer to stop, and this is done with a "stop" statement.

Other Computer Uses

There are other ways in which the computer can be used in the analysis and tuning of directional patterns. The authors have employed this program to help tune a six-tower array. Most engineers use some sort of vector analysis in the determination of which way to shift the various phase and current ratios. With relatively simple arrays (two or three towers), these vectors are easy to plot. With six or more towers, however, it can be appreciated that plotting them is not only more difficult, but very time consuming.

We were fortunate in that an adequate computer was nearby. Initially, we set all networks for the theoretical parameters, and then, by spot measurements, determined the degree of distortion from the theoretical pattern. Knowing the degree of distortion enabled us to feed data and certain variables into the computer. The computer then told us which parameter would most likely cause the distortion condition. At the same time, we supplied the computer with more than one set of values so as to have several tuning moves with which to try to correct the measured pattern.

We tried the moves suggested by the computer and found that we did achieve a better pattern shape. With the new measurements, we repeated the process and again made use of the computer suggestions. We do not wish to claim that the entire problem was solved by the computer; there were many sleepless nights, and much use was made of conventional two-way radio as the array came into adjustment. We do believe that the computer helped shorten the time required to complete the pattern adjustment.

Another area where we believe the computer can be helpful is in the analysis of pattern distortion caused by nearby reflective objects. It is easy to determine the distance in wavelengths from an array to any reflective source, the magnitude of field intensity from the array

FOR A VERTICAL ANGLE OF 0. THE FOLLOWING RESULTS ARE OBTAINED

HORIZONTAL ANGLE	STRENGTH (V/M)
5	.80608669
10	.80666347
15	.80747765
20	.80831403
25	.80888220
30	.80882752
35	.80774481
40	.80519566
45	.80072714
50	.79389355
55	.78427835
60	.77151692
65	.75531742
70	.73548031
75	.71191314
80	.68464123
85	.65381290
90	.61969772
95	.58268005
100	.54324554
105	.50196377
265	.58267997
270	.61969764
275	.65381282
280	.68464119
285	.71191306
290	.73548023
295	.75531742
300	.77151684
305	.78427835
310	.79389355
315	.80072714
320	.80519566
325	.80774485
330	.80882752
335	.80888220
340	.80831403
345	.80747765
350	.80666347
355	.80608669
360	.80587959

K= .4045

Fig. 2 Sample of computer print-out shows radiation values to eight places.

at that point, and the maximum reradiated field intensity (assuming that the reflective object is resonant). The mathematics involved with a simple two- or three-tower array and a single reflective object is not too time consuming. If, however, the reflecting source is a row of steel power-line towers (or some other multiple source) and the antenna array has four or five towers, use of a computer is indicated. With the computer, it could readily be determined in advance which towers or objects are capable of causing serious reflections and require detuning.

The area in which the computer can be used by consultants is in the design of directional antennas. As has been described, the final parameters can be fed into the computer as an accurate check. The computer also can be used to help arrive at these final values. Normally, in the design of a pattern, trouble is encountered at no more than one or two bearings. The normal process is to "cut and try" minor variations in parameters until the pattern fits. With this type of problem, it is customary to be concerned only with the effect the minor parameter variations will have at the two or three critical points. It is a relatively simple matter to program the computer to calculate only the bearings and elevations desired, and thus avoid the other lengthy computations.

The computer applied to an existing station would be most helpful in three main areas. First is the analysis of a mistuning which might occur. Second is the evaluation of any reflection or distortion that might result from new construction in the vicinity of the array. Third is help in plans for future power increases and/or increased hours of operation.

Conclusion

Typical costs are shown in Table 1. While this table reflects charges in our area, regional variations should not be excessive. Although the hourly rate for the computer itself is high, it should be remembered that computer operation is very fast; generally, it should be possible to run any antenna program in less than one hour. Usually, the highest net cost is for the program. We learned to write our own program and in this way avoided that cost altogether. It should also be remembered that a program, once written and debugged, can be used over and over again.

The value of the whole process can be summarized by emphasizing three points. First the pattern calculations have been performed in a small fraction of the time required with a slide rule or calculator. Second, the calculations have a much higher degree of accuracy than is possible with a slide rule (especially with the possibility of human error removed). Third, it is nice to know that a particular directional-antenna pattern has been computer proven before the Commission has a chance to disprove it with its computer.

At present, the authors are working on a program to design the array for any station based upon given maximum field-intensity limits and transmitter power. This is a much larger program and is further enlarged because it is difficult to give a computer the useful experience acquired by a design engineer through years of work with directional antennas. Results to date, however, appear promising. ▲

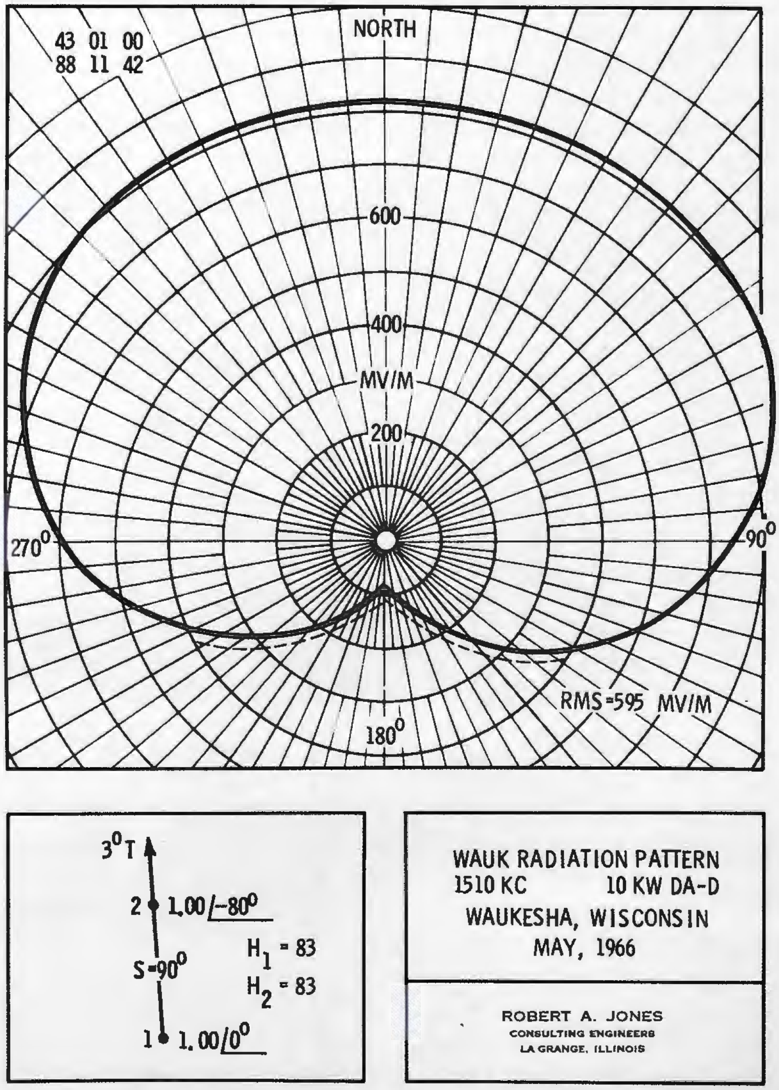

Fig. 3. Conventional plot of radiation figures shown in sample print-out.

DESIGN OF CLASS B AND C POWER AMPLIFIERS

by Joseph B. Sainton*—A detailed analysis of the methods and computations employed in the design of these amplifiers.

In the design of Class-B or -C power amplifiers, it is not always possible to consult a table of typical operating data for the type of tube to be used, since these data seldom match the conditions of electrode voltages and power output contemplated in the amplifier design. It is then necessary to refer to the characteristic curves of the tube in order to design the amplifier and to predict its performance. In other words, operating data for the amplifier must be determined from the curves. After all, this is the way the tube manufacturer compiled his data in the first place. The following is a simplified explanation of the design process. It will result in some useful rules of thumb derived from the more rigorous processes involved in a more exacting method.

Amplifier Efficiency

The first rule in the design of class-B or -C power amplifiers is that plate efficiency (designated η) be as high as possible; high efficiency is the primary reason for selecting these classes of operation in the first place. In order to achieve this efficiency, the AC components of plate current and voltage must be as high as possible; that is, the plate voltage must be allowed to fluctuate as widely as possible. This can be understood easily by considering a resistance-coupled class-A amplifier in a hypothetical case (Fig. 1.).

If one ampere of plate current flows through the plate load resistor of 1000 ohms, then the voltage drop is:

$$E = IR = 1.0 \times 1000 = 1000 \text{ volts}$$

The power supply voltage is 2000 volts, and with a current drain of one ampere, 2000 watts of power is delivered, since:

$$P = EI = 2000 \times 1.0 = 2000 \text{ watts}$$

All the power is given up as heat because no power is being taken from the amplifier. The heat is divided between that which heats the resistor and that which heats the plate of the tube (called plate dissipation). The heat from the resistor is the product of its voltage drop and the current through it. The resistor heat loss is therefore:

$$P = EI = 1000 \times 1.0 = 1000 \text{ watts}$$

Similarly, the plate dissipation is the product of plate voltage and current, or:

$$P = EI = 1000 \times 1.0 = 1000 \text{ watts}$$

So, of the 2000 watts delivered by the power supply, 1000 watts goes to heat the plate resistor and 1000 watts goes to heat the plate.

Fig. 2 is a hypothetical graph of the tube characteristics. Although this graph represents the familiar constant - plate - current characteristics, or constant-current charac-

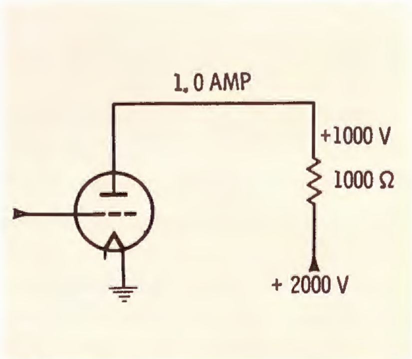

Fig. 1. Amplifier operation is shown in this partial resistance-coupled stage.

teristics, it has some curious properties. First, the plate-current lines fail to bend upward on the left, near the zero-plate-voltage region. Second, the plate-current lines are all evenly spaced from zero plate current up to I_b = 3.0 amperes. This is indeed a magical tube, one which will draw plate current at zero plate voltage; but it is only hypothetical in order to simplify the explanations.

Now suppose a sinusoidal voltage is applied to the grid in order to vary the plate current, and therefore the plate voltage. It was stated previously that the variations of plate voltage and current should be as large as possible for maximum efficiency. The widest plate voltage excursion would be from zero to the full supply voltage of 2000

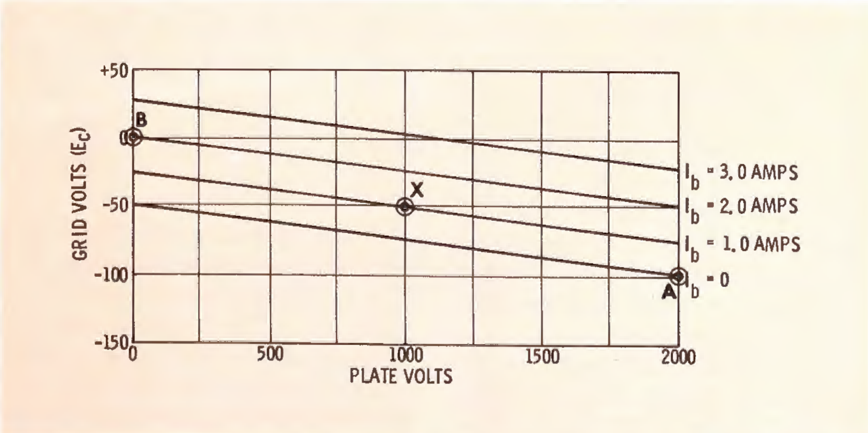

Fig. 2. Hypothetical constant-current curves are straight and evenly spaced.

*Principal Engineer,
Continental Electronics Mfg. Co.

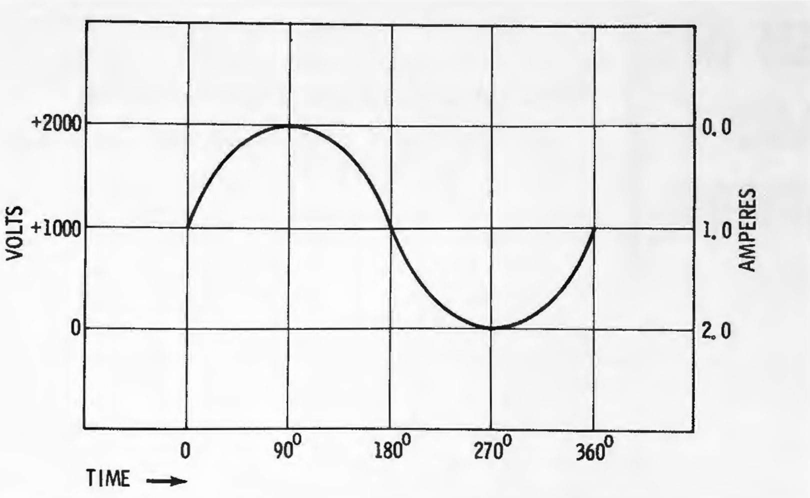

Fig. 3. Graph of plate voltage shows maximum swing for conditions assumed.

volts, and would appear as shown in Fig. 3.

Now it is necessary to determine what values of plate current through the 1000-ohm plate resistor would establish this condition. The quiescent condition (no signal on grid) at the start of the cycle is:

Plate current = 1.0 ampere
Plate voltage = 1000 volts

Ninety degrees later, the full supply voltage of 2000 volts is to appear at the plate. The only plate-current condition which will satisfy this is zero plate current (I_b). Under this condition, there will be no drop across the resistor, and the full 2000 volts will appear on the plate.

At the other peak of the cycle (270°), the plate voltage must be zero. This means the entire supply voltage of 2000 volts must be dropped across the 1000-ohm resistor. The plate current necessary to satisfy this condition is:

$$I = \frac{E}{R} = \frac{2000}{1000} = 2.0 \text{ amperes}$$

Now, if the known values are placed at these three points — that is, at quiescence, positive peak, and negative peak — on the hypothetical constant-current curves, several things can be learned about the performance of the amplifier.

First, the quiescent point is established on Fig. 2. The 1000-volt plate-voltage line intersects the 1.0-ampere plate-current line (these are the quiescent conditions) at point X.

Next, the positive peak is established. The conditions are:

Plate voltage = 2000 volts
Plate current = 0

These values determine Point A.

The conditions at negative peak are:

Plate voltage = 0
Plate current = 2.0 amperes

This is Point B.

From these steps, the following facts are learned. First, the bias voltage required to establish the quiescent condition is −50 volts, since point X is on a horizontal line that intersects the grid-voltage scale at −50 volts. Second, the grid-voltage excursion necessary to obtain $I_b = 0$ and $I_b = 2.0$ amperes is from grid voltage $E_c = -100$ to $E_c = 0$, respectively. A sinusoidal grid driving voltage of 100 volts peak-to-peak produces this variation. The voltage gain of the amplifier is therefore:

$$A = \frac{E_{out}}{E_{in}} = \frac{2000}{100} = 20$$

From this information, it is now possible to compute other data concerning the performance of the amplifier. First is the plate efficiency (designated η). In a class-A amplifier, the average (or DC) plate current does not change from a zero- to a maximum-signal condition. This may be seen when it is considered that in the zero-signal condition the plate current is (in this example) one ampere, and that in the maximum-signal condition it varies equally above and below one ampere in a symmetrical manner so that the average is still one ampere. The average plate voltage also varies symmetrically above and below 1000 volts so that the average plate voltage is 1000 volts. In other words, if a DC voltmeter were connected to the plate, it would indicate 1000 volts DC. Similarly, if a DC ammeter were placed in series with the plate, it would indicate one ampere. The plate input power is therefore:

$$P = EI = 1000 \times 1.0 = 1000 \text{ watts}$$

This is the plate input power all the time, signal or no signal. At zero signal, there is no output power from the plate, so the efficiency is:

$$\eta = \frac{\text{Power out}}{\text{Power in}} \times 100\% = \frac{0}{1000} \times 100 = 0$$

At maximum signal, however, the situation is different. There is an alternating voltage of 2000 volts peak-to-peak across the 1000-ohm plate resistor. The rms value of this voltage is:

$$E_{rms} = \frac{E_{p-p}}{2\sqrt{2}} = \frac{2000}{2.828} = 707 \text{ volts}$$

The AC power (heating power) delivered to the resistor is:

$$P = \frac{E^2}{R} = \frac{707^2}{1000} = \frac{500{,}000}{1000} = 500 \text{ watts}$$

Since this power is taken from the tube and the plate input power is still 1000 watts, the efficiency at maximum signal is:

$$\eta = \frac{\text{Power out}}{\text{Power in}} \times 100\ \%$$

$$= \frac{500}{1000} \times 100$$

$$= 50\%$$

Also, plate dissipation has decreased from 1000 watts to 500 watts because half of the 1000-watt plate input power is now delivered as AC heating power into the load resistor. The 2000-watt drain on the power supply is now divided in the following manner:

Plate Dissipation	=	500 watts
AC heat in resistor	=	500 watts
DC heat in resistor	=	1000 watts
		2000 watts

This is the reason why the maximum theoretical efficiency of a class-A amplifier is 50%. However, such efficiency could only be obtained by using a tube with the ideal features of the hypothetical type in this example.

At this point, it seems appropriate to explore briefly the more practical application of tubes in class-A service. Assume the grid driving voltage on the tube is reduced by one half to 50 volts peak to peak. Since the hypothetical tube is linear in operation, the alternating plate voltage will also be reduced to half, or 1000 volts peak to peak.

The power input to the amplifier remains constant at 1000 watts regardless of signal level, but the AC power delivered to the load resistor with only 1000 volts peak-to-peak is:

$$P = \frac{E_{rms}^2}{R}$$

$$= \frac{353^2}{1000}$$

$$= \frac{125{,}000}{1000}$$

$$= 125 \text{ watts}$$

The plate efficiency is:

$$\eta = \frac{\text{Power out}}{\text{Power in}} \times 100\%$$

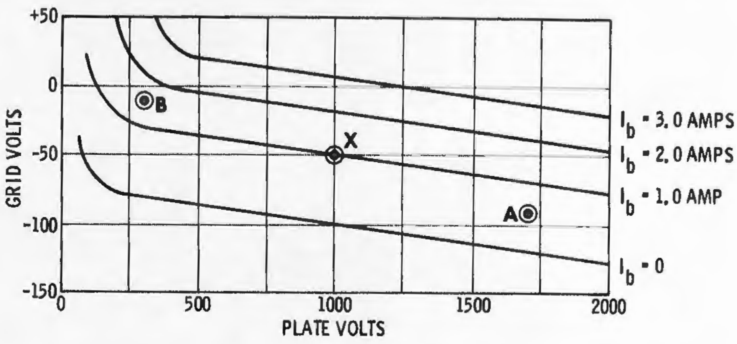

Fig. 4. Practical characteristic curves bend at left, are unevenly spaced.

$$= \frac{125}{1000} \times 100$$

$$= 12.5\%$$

This is closer to the actual efficiency usually encountered with class-A amplifiers. From this, it can be seen that the higher the plate-voltage swing is, the higher the efficiency is. In the class-A case, efficiency varies as the square of the plate swing; that is, doubling the swing results in a fourfold increase in efficiency, up to the theoretical limit of 50%. For class-B and -C operation, the efficiency still is affected by the plate swing, but in different proportions.

In practice, the constant-current curves of a typical triode appear as shown in Fig. 4. Note that the plate-current lines bend upward near zero plate voltage; this fact precludes the possibility of drawing plate current at zero plate voltage. Note also that the spacing between the zero- and one-ampere lines is greater than between other lines. These two features prevent swinging the plate voltage from zero to power-supply voltage and restrict operation to about 70% of that range. This is depicted by displacing points A and B only about 70% of the way toward E_{max} and E_{min}, respectively, from point X. With this plate swing (70% of E_{max}), efficiency in the class-A case is:

$$\eta = (.7)^2 \times \eta_{max}$$

$$= .49 \times 50\%$$

$$= 24.5\%$$

Class B and C Operation

Class-B and -C ampifiers are used when it is necessary to develop great amounts of power output. These amplifiers are capable of doing this at high plate efficiency, although efficiency is not part of their definitions. By definition, class-B and -C amplifiers conduct plate current for a half cycle or less of the driving voltage, and are driven into the region of positive grid voltage.

It would be impossible to operate a class-C amplifier in a resistance-coupled configuration, because the output voltage would not resemble the input voltage. In broadcast transmitter work, the input voltage is always considered to be a sine wave. This limits the use of class C amplifiers to frequencies at which a reasonably good resonant circuit can be employed in the plate circuit to restore the output waveform to a sine wave from the nonsinusoidal plate-current pulses. The case for Class B is different in that no narrow-band plate circuit is needed to eliminate harmonics, since the half-sinusoidal plate-current pulses can be put together in the plate circuit by using push-pull tubes and combining transformers.

A class-B amplifier is biased so that its "operating angle," or "plate conduction angle," is 180°; in other words, plate current flows for 180° of the electrical cycle. Class-C amplifiers are biased so that plate current flows for *less than* 180° of the cycle; an exact operating angle for Class C is not defined because there are many conditions of class-C operation. Before understanding the advantages and disadvantages of these many conditions, it is necessary to look more deeply into operating angle.

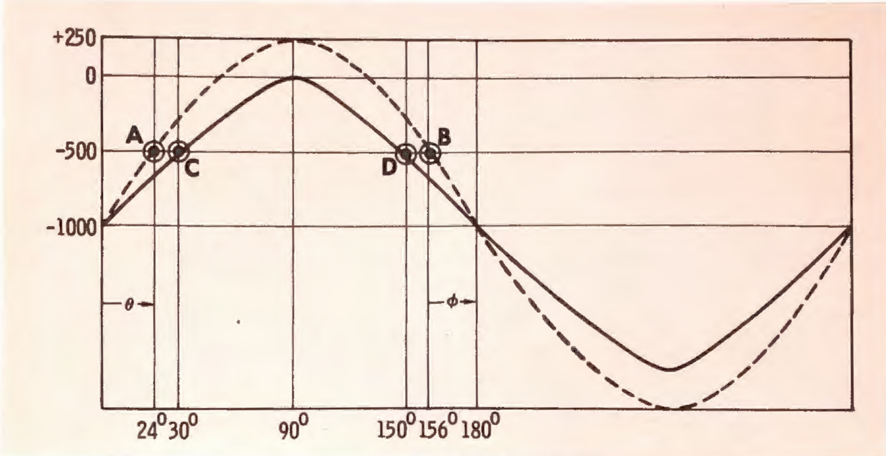

Fig. 5. Conduction angle depends on bias, cutoff voltage, signal amplitude.

It can be seen that a tube biased at cutoff will conduct for only half the driving-voltage cycle, regardless of the amplitude of the driving voltage. The reason is that the tube begins to draw current at the axis of symmetry of the driving wave, and regardless of how far the grid drive voltage goes positive, it goes the same amount negative. This is not true for class-C operation. When a class-C amplifier is biased at twice cutoff and the driving voltage drives it only to cutoff, the conduction angle is 0° because the tube never draws plate current. If the driving voltage is increased until plate current starts to flow, the operating angle is no longer zero, but some number of degrees. The new operating angle may be determined graphically, as shown by the following example.

It is found that cutoff bias for a particular power tube is −500 volts. In this application, the tube will be driven up to +250 volts. Bias is at twice cutoff, or −1000 volts. From the graphical representation in Fig. 5, it can be seen that the sinusoidal grid voltage wave (dash line) starts at the axis of symmetry at −1000 volts and goes positive to +250 volts, a total excursion of 1250 volts. At the point at which it crosses the −500-volt line (where conduction begins), it has traveled 500 of the total 1250 volts, or:

$$\frac{500}{1250} = .4 \text{ of the distance}$$

In order to determine the number of degrees during which the tube conducts, it is necessary to know how far the grid voltage wave has traversed across the horizontal, or time, scale. This can be determined most easily with the application of simple trigonometry. Because the curve is a sine wave, the number 0.4 is the numerical value of the sine of angle θ. The angle is therefore 23.5°, or about 24°. Since the waveform is symmetrical, point A (at which conduction begins) has the same relationship to 0° as Point B (at which conduction ends) has to 180°. The conduction angle is represented by the length of line segment AB and can be calculated from the formula:

$$C = 180° - (\theta + \phi)$$

where,

C = conduction angle

θ = angle from 0° to point conduction begins

ϕ = angle from point conduction ends at 180°

In this case:

$$C = 180° - (24° + 24°)$$
$$= 180° - 48°$$
$$= 132°$$

For a further study of the conduction angle, assume the drive voltage is reduced so that the positive peak goes only to 0 volts (solid curve in Fig. 5). Points C and D represent the beginning and ending of conduction; they are at −500 volts, or halfway up the voltage scale from −1000 volts to 0 volts. Thus sin θ and sin ϕ are each 0.5, and the two angles are each 30°. The conduction angle is therefore:

$$C = 180 - (30 + 30)$$
$$= 120°$$

From the preceding, it can be seen that the term "twice cutoff" means nothing so far as operating angle is concerned unless the positive amplitude of the sinusoidal grid driving voltage is known. Further, since operating angle is the important factor in determining class-C amplifier performance, the term "number - of - times-cutoff" cannot be used as a factor in any further computation.

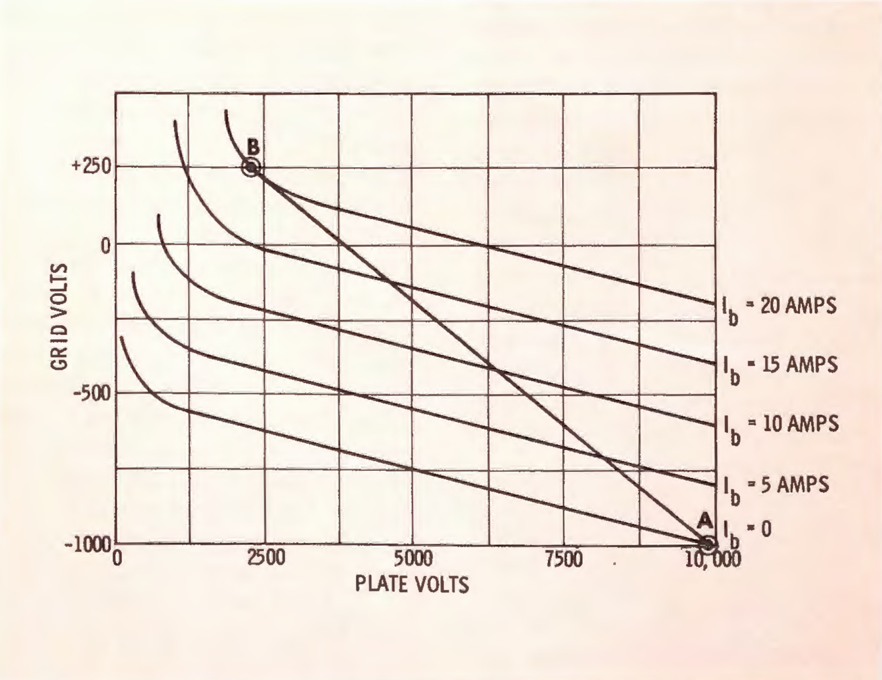

Fig. 6. Characteristic curves are used to predict the plate-circuit action.

Predicting Class-B Performance

It is well known that class-C amplifiers operate at higher plate efficiency than class-B amplifiers, and that class-B ampilfiers are more efficient than class-A amplifiers. The reasons may be found in the examination of what happens in the amplifier plate circuits and the relationships that exist between DC plate current and peak plate current. In this regard, it should be helpful to examine the design of a class-B RF amplifier and to explain the steps involved in predicting its performance.

A set of constant-current curves for the hypothetical design is shown in Fig. 6. This set of curves is quite similar in appearance to the "practical" set of curves shown previously for the class-A design, in that they bend upward in the region of low plate voltage. Note, however, that the voltage and current scales are quite different; that is, they denote higher values of current and voltage than do the class-A curves. This indicates the curves are for a high-power tube.

In the foregoing discussion of class-A and class-B amplifiers, the following points were made. A class-B amplifier is biased at cutoff and delivers high power output at high efficiency; in order for the amplifier to deliver high power, the grid must be driven positive in order for high plate current to be drawn; and high efficiency means swinging the plate voltage over the widest possible limits. With these facts in mind, the results of operating the tube of Fig. 6 at maximum power will be examined.

In the class-A design, it was useful to locate on the curves points which indicated the quiescent point and the positive and negative peaks of the input and output waves. The same thing can be done here, except that the application is different.

Refer to Fig. 7. First, notice that in the plate circuit there is no resistor across which the AC plate-voltage component can be applied, and which drops the B+ voltage to some value of quiescent plate voltage. Although there is no plate resistor, there is a *resistance* in the plate circuit across which the AC voltage will be applied. The amount of this resistance is determined by the actual value of resistor R and

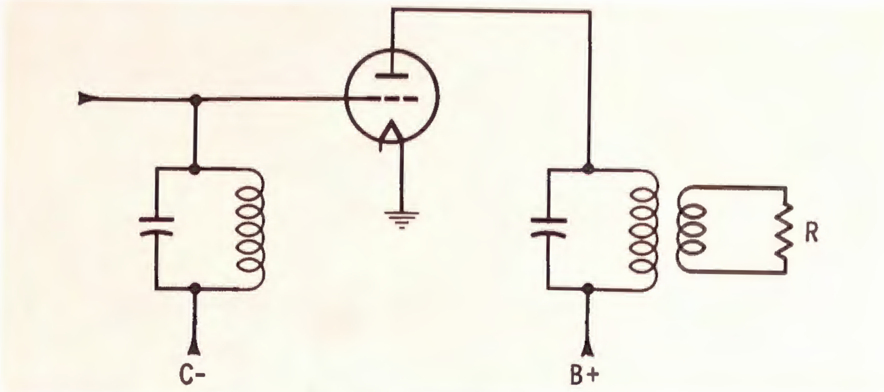

Fig. 7. Plate tank circuit fills in missing half of the RF voltage waveform.

the resistance transformation ratio of the coupled plate tank circuit. If the transformation ratio were 10 to 1 and the value of R were 100 ohms, the AC voltage would "see" a resistance of 1000 ohms in the plate lead.

A hasty examination of this circuit might lead to the conclusion that the output is a series of half-sine pulses, because the supply voltage is the quiescent plate voltage and the plate voltage cannot exceed the supply voltage. A more careful examination, however, will show this not to be the case.

For this example, a power-supply voltage of 10,000 volts DC will be employed. The plate-current pulses will appear as shown in Fig. 8A, because plate current can flow only on the positive half of each driving cycle. If a parallel resonant circuit has a sufficiently high Q, or ratio of circulating volt-amperes to output volt-amperes, it will continue to oscillate sinusoidally if excited occasionally by pulses related numerically to the natural, or resonant, frequency of the circuit. Therefore, the plate voltage wave will not be pulses like the plate-current pulses, but rather will appear as shown in Fig. 8C.

Note that the plate voltage wave is 180° out of phase with the grid voltage wave; that is, the grid wave

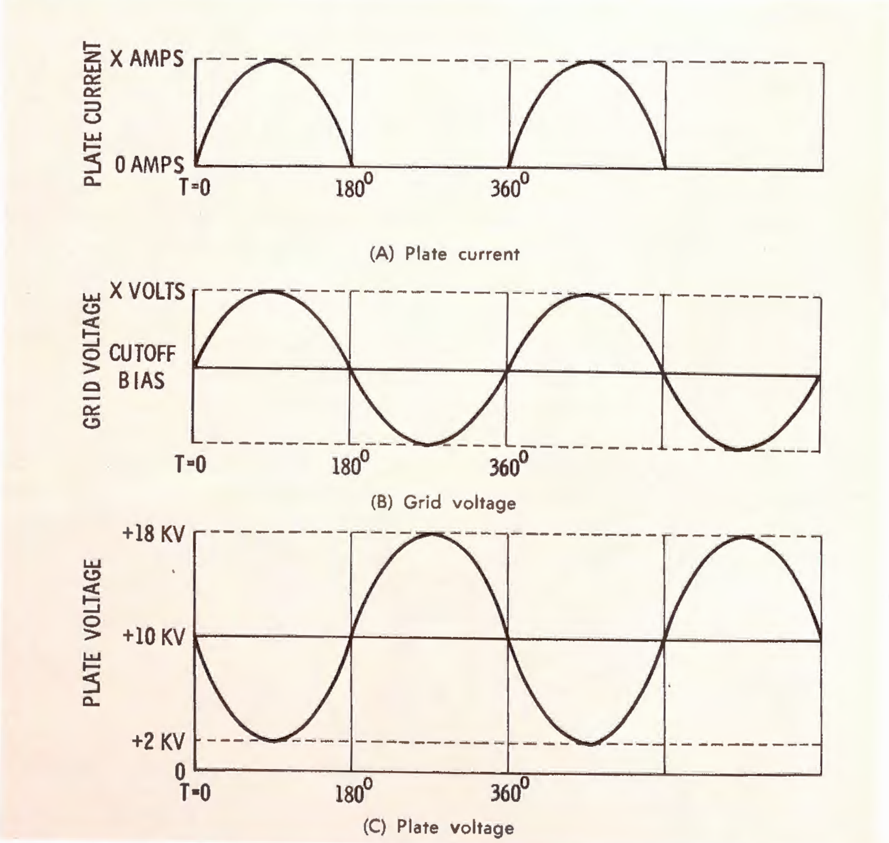

Fig. 8. Waveforms show relationships of voltage and current in RF amplifier.

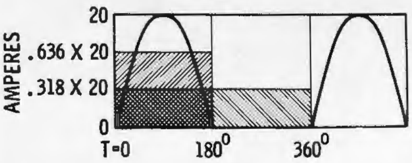

Fig. 9. Graphical determination of half-sine-pulse peak/average ratio.

goes positive at T = 0, but the plate voltage wave goes negative. In addition, the plate current increases as the plate voltage wave goes negative. One-half cycle after T = 0, the plate current is cut off and stays cut off for the next half cycle. During this time, from 180° to 360°, the flywheel effect of the resonant plate tank circuit keeps the plate voltage wave going upward until it reaches a point as equally displaced from the quiescent point as was the negative peak. Therefore, although the DC supply voltage is only 10 kv, the peak positive plate voltage rises to +18 kv (for the operating conditions assumed in Fig. 8) during the half cycle that plate current is cut off.

With this understanding, it is now possible to locate operating points on the constant-current curves of Fig. 6. First, cutoff bias is required for class-B operation. With a 10-kv plate voltage, −1000 volts of bias is required for zero plate current. This is point A. Next, point B must be located.

As was stated previously, the grid must be driven positive to obtain high power output, and the minimum instantaneous plate voltage must be low for good efficiency; in other words, the plate voltage "swing" must be large. Reasons also were given for avoiding the area where the plate-current lines bend upward. To meet these requirements, a maximum grid voltage of +250 volts is selected arbitrarily, and a point on the graph is selected such that the plate-current curves just begin to curve upward as they cross the line for +250 volts on the grid. This point is shown as "B" in Fig. 6. Point B can be seen to represent a plate current of 20 amperes and a plate voltage of 2000 volts.

These facts are now known:

DC plate voltage = 10,000 volts

Minimum plate voltage = 2000 volts

Peak plate swing = 8000 volts

Peak plate current = 20 amperes

Peak grid-voltage swing = 1250 volts
(This is the excursion from −1000 to + 250 volts.)

Operating angle = 180°

From these data it is now possible to determine such things as power output, efficiency, and AC plate current. The determination of DC plate current will be described first.

It has been found by methods of integral calculus that a half sine wave of current has an average value equal to $2/\pi$, or (in round figures) .636, times the peak value of the current. From this, the average current for the half cycle during which the tube conducts can be computed. During the next half cycle, the current is zero, so the average current for the full cycle is $\frac{1}{2} \times 2/\pi$, or .318, times the peak current. In the example, the peak current has been determined to be 20 amperes, so the average current is .318 × 20 = 6.36 amperes. These calculations are shown graphically in Fig. 9.

It should be pointed out that the preceding discussion is based on an ideal tube and that, in practice, instead of being perfect half sine waves, the pulses of plate current will appear as shown in Fig. 10. The curvature at the bottom of the pulse is caused by the nonlinearity of the plate-current curves in the region of zero plate current. The average current over a cycle for this pulse shape will be lower than $1/\pi$ times the peak current; this fact will be considered later.

Since the DC plate current is known to be 6.36 amperes, the plate input power can be determined in this manner:

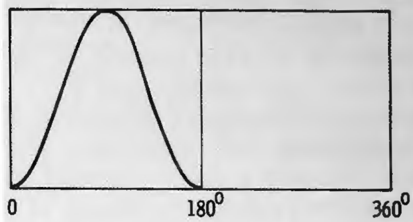

Fig. 10. In real amplifier, current pulses are not true half sine waves.

P input = DC plate voltage × average plate current

= 10,000 × 6.36

= 63,600 watts

To determine the useful power output, it is necessary to know the amplitude of the sinusoidal RF component of plate current. For true half-sine-wave pulses of plate current, mathematical analysis shows the RF component to have a peak amplitude equal to one-half the peak value of the pulses. Since the peak of the current pulse was 20 amperes, the peak value of the RF current is 20/2 = 10 amperes.

The peak plate voltage is already known to be 8000 volts. For a computation of the AC power output, the voltage and current values must be converted to rms terms:

E_{rms} = 8000 × .707

= 5700 volts rms

and

I_{rms} = 10 × .707

= 7.07 amperes rms

Power output is, therefore:

P = EI

= 5700 × 7.07

= 40,000 watts

Note that in these computations, both the voltage and current were multiplied by $1/\sqrt{2}$. A shortcut is


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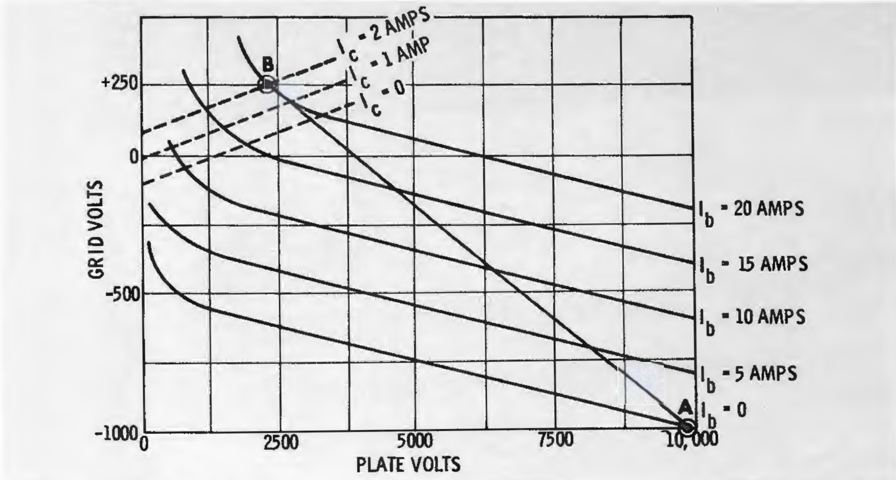


Fig. 11. Additional characeristic lines permit grid current to be evaluated.

therefore to multiply the peak current by the peak voltage and then multiply the result by $1/\sqrt{2} \times 1/\sqrt{2}$, which is the same as dividing the EI product by 2:

$$\frac{8000 \times 10}{2} = 40{,}000 \text{ watts}$$

Efficiency can now be calculated from the determined values of power input and power output:

$$\eta = \frac{\text{Power out}}{\text{power in}} \times 100\%$$

$$= \frac{40{,}000}{63{,}600} \times 100\%$$

$$= 62.8\%$$

The load resistance which must be seen by the plate of the tube is:

$$R = \frac{E}{I}$$

$$= \frac{5700}{7.07}$$

$$= 800 \text{ ohms}$$

The same result is obtained if peak values are used:

$$R = \frac{8000}{10}$$

$$= 800 \text{ ohms}$$

In the examination of class-A amplifiers, it was shown that the maximum theoretical efficiency is 50% when the plate swing is maximum, or, in the same context, when the minimum plate voltage is zero (which was shown to be impossible). In a similar way, a theoretical efficiency for class-B operation can be established.

For simplification, the peak plate current will be assumed to be 20 amperes. The plate-current lines will be assumed to be straight to the zero-plate-voltage line. These conditions now prevail:

Peak plate voltage = 10,000 volts

Peak plate current = 20 amperes

Peak sinusodial plate current = 10 amperes

DC power input (unchanged) = 63,600 watts

The RF power output is now:

$$\text{Power out} = \frac{10{,}000 \times 10}{2}$$

$$= 50{,}000 \text{ watts}$$

and the efficiency is:

$$\eta = \frac{50{,}000}{63{,}000} \times 100\%$$

$$= 78.5\%$$

A more rigorous mathematical analysis leads to the well-known expression for class-B efficiency, which is:

$$\eta = \frac{\pi}{4}\left(1 - \frac{E_{bmin}}{E_{DC}}\right)$$

With $E_{bmin} = 0$, the expression becomes:

$$\eta = \frac{\pi}{4} = .785$$

Using this formula as a double check on the example circuit results in:

$$\eta = \frac{\pi}{4}\left(1 - \frac{2000}{10{,}000}\right)$$

$$= .785\ (.8)$$

$$= .628$$

$$\%\ \eta = .628 \times 100$$

$$= 62.8\%$$

This expression shows that efficiency is directly proportional to plate swing — unlike the class-A case, in which it was proportional to the square of the plate swing.

All of this shows that by simple

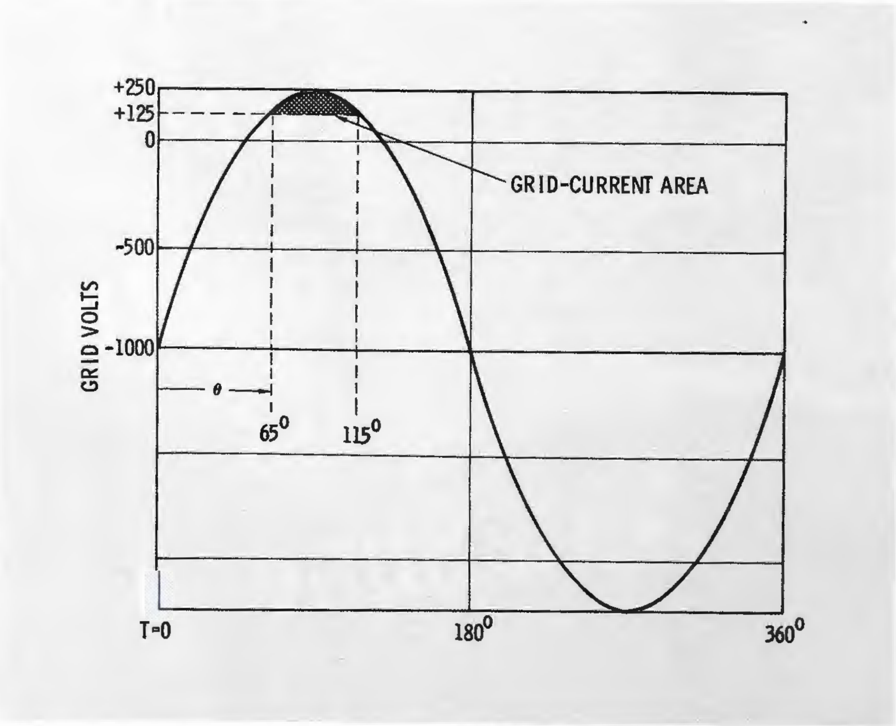
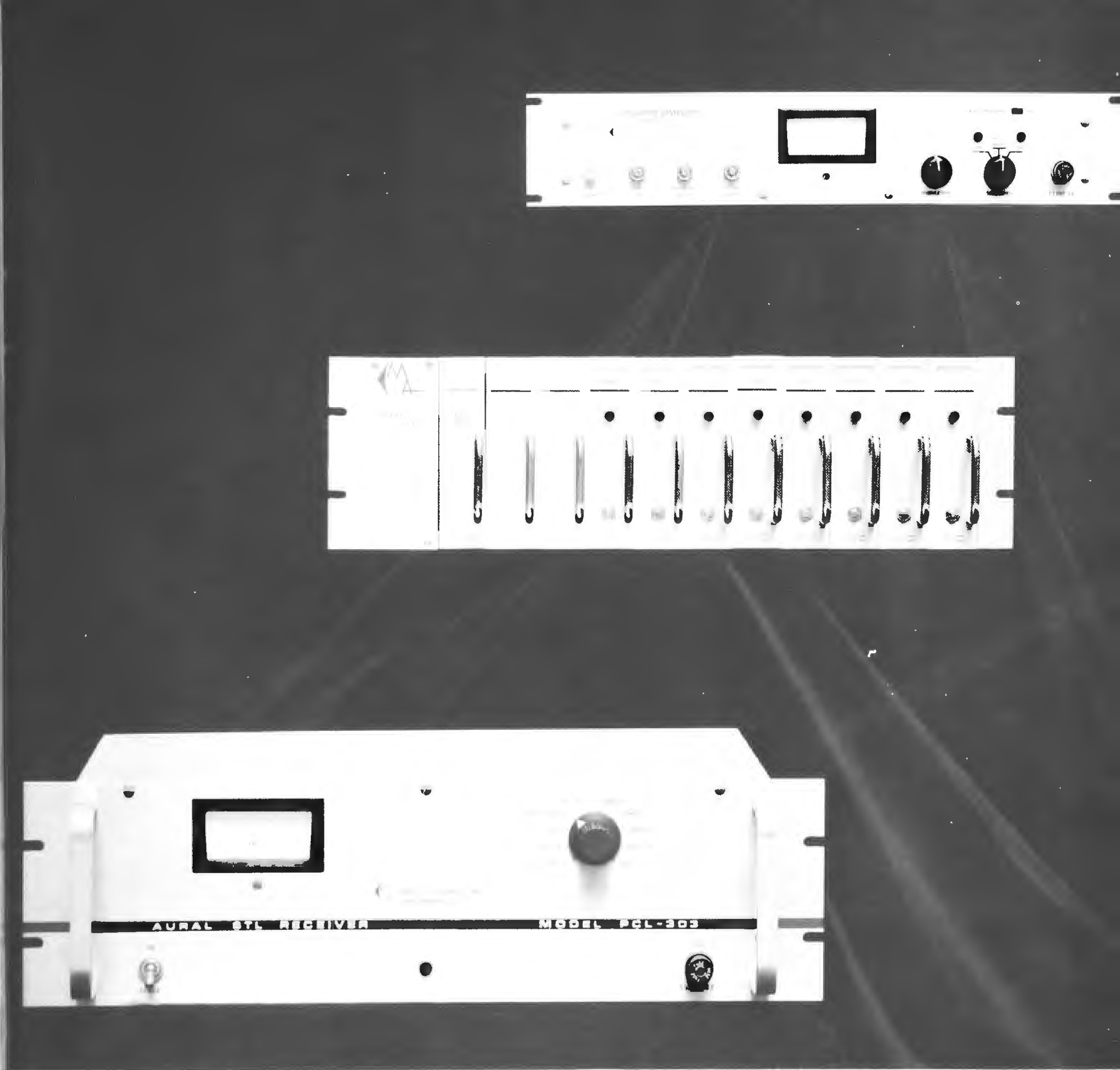


Fig. 12. Shaded area shows portion of cycle during which grid current flows.



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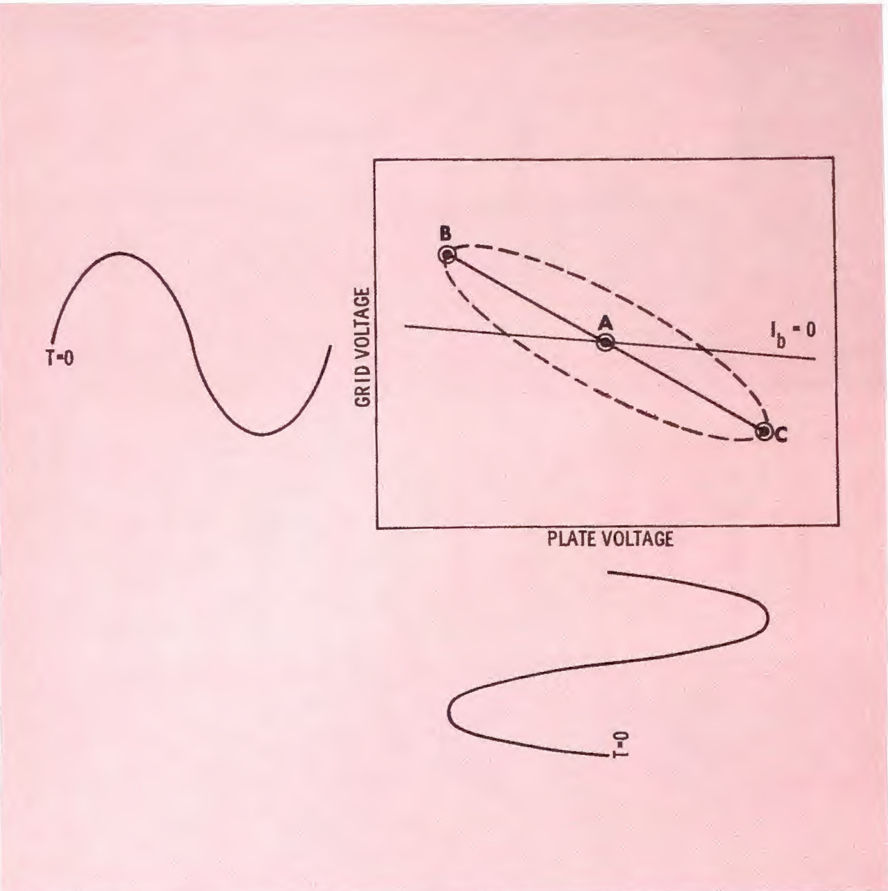

Fig. 13. Calculations assume input and output voltages are 180° out of phase.

application of known relationships between peak and average values, it is possible to predict the performance of an amplifier. At this point, however, nothing is known about the grid-circuit conditions. In the class-A grid, it was sufficient to establish the peak-to-peak grid voltage; in this case, other factors must be determined. Since the amplifier is being driven into the positive grid-voltage region, it is necessary to know the driving power required and DC grid current expected. These can be found by the same simple methods by which plate-circuit conditions were determined. First, some grid-current lines must be put on the characteristic curves. These were omitted previously for simplicity.

In determining DC plate current, it is necessary to know the relationship between peak and average current values. For a half-sine-wave pulse shape, this was found to be $1/\pi$. The pulse shape and the conduction angle were all the information needed. Similarly, the same information is sufficient to find the average, or DC, grid current. The grid pulse will be assumed to be sinusoidal, since to do otherwise would unduly complicate matters. The grid-current conduction angle is then quite simple to find.

In Fig. 11, it can be seen that the operating line (or load line, as it is sometimes called), intersects the zero grid-current line at a positive grid voltage of about +125 volts, and at the peak (point B), the grid current is two amperes. From this it is possible to scale the grid-current pulse on a graph (Fig. 12).

The grid voltage has gone to 1125/1250 = .9 of its peak amplitude at the time grid current begins to flow. Since the wave is sinusoidal, this is the numerical value of the sine of angle θ (the number of electrical degrees traversed across the time scale from T = 0). This angle is found to be 65°. Conduction will cease 65° short of 180°, or at 115°. The conduction angle is therefore 115° − 65° = 50°. For a 50° conduction angle, the peak current is 10.6 times the DC current. (This figure is derived by the same process used to determine the peak/average ratio for a half-sine-wave pulse).

From the tube curves, the peak grid current was found to be 2.0 amperes. The DC current is therefore:

$$I_{DO} = \frac{I_{peak}}{10.6}$$

$$= \frac{2.0}{10.6}$$

$$= .19 \text{ ampere}$$

Thus all one needs to know in order to compute tube performance are a few simple rules and relationships. The things which must be found on the constant-current curves are the peak currents and conduction angles, whether plate current, control-grid current, or screen-grid current is involved. It must, of course, be assumed the current pulses are chopped off the tops of sine waves in order for the relationships to hold. This is usually a fair assumption in practice, since a slightly flattened pulse introduces only a slight error into the computations. Ratios of peak to DC current for various conduction angles appear in Table 1 (page 36).

It has been found that, if the DC grid current is known, the driving power required can be computed from the formula:

Driving power = Peak grid volts × DC grid current

$$= 1250 \times .19$$

$$= 235 \text{ watts}$$

This driving power is dissipated as heat at the grid and in the bias resistor. The amount dissipated by the bias resistor is simply the product of DC bias voltage and DC grid current.

$$P = EI$$

$$= 1000 \times .19$$

$$= 190 \text{ watts}$$

Since the driving power is 235 watts, the grid dissipation is the difference, which is:

$$235 - 190 = 45 \text{ watts}$$

Now a complete set of operating data for the class-B amplifier has been developed. These results are based on an aribitrary choice of point B, but it is just as easy to se-

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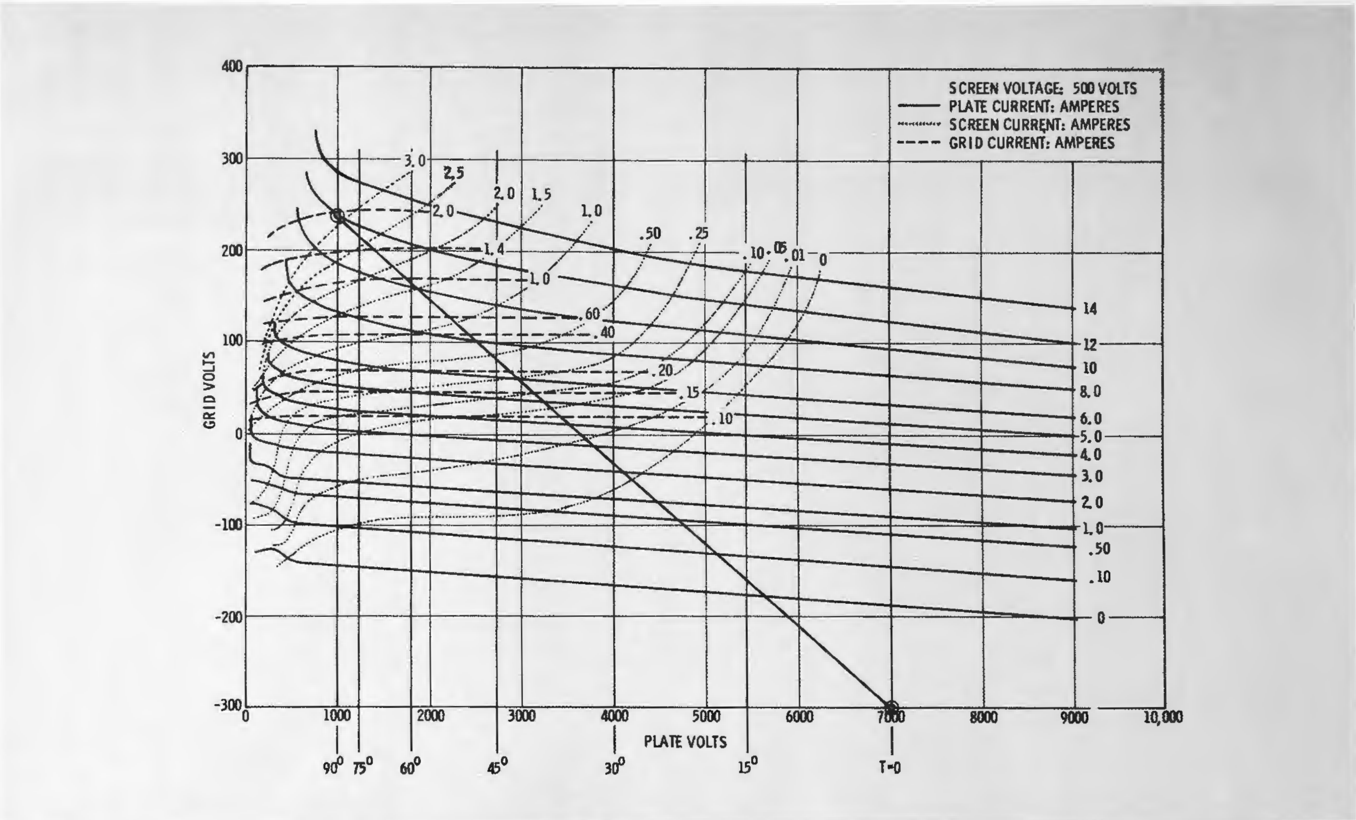

Fig. 14. Typical constant-current characteristics for plate, screen grid, and control grid of a transmitting tetrode.

lect some desired result and then find point B accordingly.

For instance, suppose 50,000 watts instead of 40,000 watts of output power is wanted. If the same plate swing is maintained, it is obvious that the peak plate current must be increased by driving the grid more positive and by decreasing the plate load resistance. If the plate voltage swing is still 8000 volts peak, the efficiency will remain at 62.8%. The plate input power will then be:

$$\text{Pwr} = \frac{1}{.628} \times 50{,}000$$

$$= 1.59 \times 50{,}000$$

$$= 79{,}500 \text{ watts}$$

Since the DC plate voltage is

Table 1. Peak-to-DC Current Ratios

Conduction Angle	Current Ratio I_{PK}/I_{DC}
180°	3.1:1
160°	3.5:1
140°	4:1
120°	4.6:1
100°	5.5:1
90°	6:1
80°	6.8:1
70°	7.8:1
60°	9:1
50°	10.6:1

still 10,000 volts, the DC plate current will be:

$$I = \frac{P}{E}$$

$$= \frac{79{,}500}{10{,}000}$$

$$= 7.95 \text{ amperes}$$

The required peak plate current will be:

$$I_{pk} = \pi \times I_{DC}$$

$$= 3.14 \times 7.95$$

$$= 25 \text{ amperes}$$

Now locate point B at the intersection of the 25-ampere plate-current line and the 2000-volt plate voltage line. Moving horizontally to the left, find the required value of positive grid voltage. After point B has been established, the rest of the work is done as previously outlined.

It was stated that in order for the relationships that have been discussed to hold true, it is assumed that the input and output signals are sine waves. There is one other requirement—they must be 180° out of phase. If they are not, the operating line will no longer be straight. Rather, it will become elliptical and render the preceding computations meaningless. This is easily understood when one considers that detuning the plate tank of an RF amplifier from resonance causes the DC plate current to increase even though the same grid drive is maintained. This is represented graphically in Fig. 13. The plate-current lines and voltage-scale values are omitted for clarity.

The load-line segment from A to B is the part that has been used in the preceding discussion. The part from A to C shows the positive increase of plate voltage during the half cycle when plate current is cut off (grid-voltage wave negative). The straight line B-C is analogous to the trace that would be presented on an oscilloscope if the grid and plate voltage waves were fed into the horizontal and vertical deflection plates 180° out of phase. If the phase of one were to be advanced or retarded relative to the other, the scope display would become elliptical, as shown by the dash lines. The load line would likewise become elliptical. This indicates that the plate load impedance is no longer purely resistive, but has become reactive; the previous computations would no longer be valid. Since an RF

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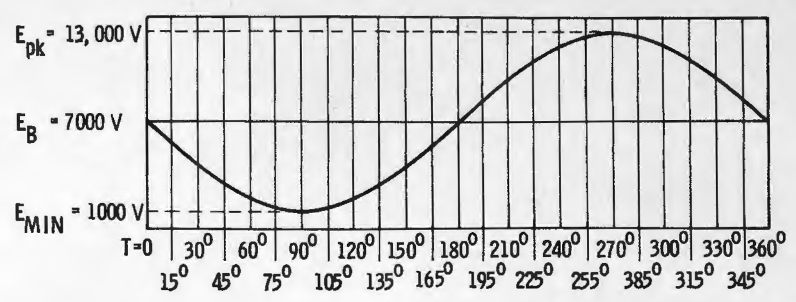


Fig. 15. Plate-voltage waveform divided into intervals for graphical analysis.

amplifier would never be operated into a detuned tank circuit, a 180° phase relationship can always be assumed. However, class B push-pull audio amplifiers sometimes encounter reactive plate loads at the higher audio frequencies. As a result, the load line turns into an ellipse, making it difficult to compute tube performance in that region.

Predicting Class-C Performance

The process of computing tube performance for class-C operation involves no more than has been done in the class-B example, except that the relationships between peak plate current, DC plate current, and peak sinusoidal, or fundamental, RF current take on different values, depending on conduction angle. The values shown in Table 1 will result in accuracy sufficient for most designs. If a greater degree of accuracy is desired, one may resort to a graphical integration of the actual current pulse shapes to be encountered in the tube type to be used. This is done by plotting the instantaneous plate-current values against time over a period of one cycle. These instantaneous values can then be averaged to give the DC component. The peak value of the sinusoidal current can be found by averaging the instantaneous values of current multiplied by twice the sine of the angle at which the instantaneous current is plotted. Some manufacturers of transmitting tubes have distributed transparent overlays which divide any length of load line (up to about 10 inches) into divisions corresponding to the sine (or cosine, if one begins 90° later) of 15° increments along the time scale. Without this tool, it is still a simple matter to lay off these points on the constant-current curves of the tube involved in the design. As an example, this graphical integration process will be carried out on the curves for a large transmitting tetrode (Fig. 14).

It is decided from desired objectives to use a DC plate voltage of 7000 volts and swing to a minimum instantaneous plate voltage of 1000 volts. The plate swing will then be 7000 − 1000 = 6000 volts peak, or 12,000 volts peak-to-peak. This waveform is shown in Fig. 15. Note that the time scale is divided into 24 divisions of 15° each for one full cycle.

Fig. 16 shows what a plot of plate current might look like over one cycle. Here again, the time scale is divided into twenty-four 15° increments. To integrate this current waveform, it is necessary to add the instantaneous currents at each of the 24 points in time and divide the sum by 24 to get the average value. Since the current is zero from 180° to 360°, it is sufficient to add the first 12 points and divide by 24. To simplify further, since the current at C equals the current at I, the current at D equals the current at H, etc., it is possible to sum up the currents at points A, B, C, D, E and F (F must be divided by two since it occurs only once) and divide by 12. The instantaneous current can be found on the constant-current curves. From the plot of plate voltage versus time, the voltage at T = 0 is 7000 volts; this is marked T = 0 on the 7000-volt plate-voltage line (Fig. 14). The voltage 15° later will be:

$$E_{15^\circ} = E_{DC} - \sin 15^\circ \times E_{pk}$$
$$= 7000 - .26 \times 6000$$
$$= 5440 \text{ volts}$$

At $T = 30^\circ$, $E = E_{DC} - \sin 30^\circ \times E_{pk}$
$$= 7000 - .5 \times 6000$$
$$= 4000 \text{ volts}$$

At $T = 45^\circ$, $E = E_{DC} - \sin 45^\circ \times E_{pk}$
$$= 7000 - .707 \times 6000$$
$$= 2750 \text{ volts}$$

At $T = 60^\circ$, $E = E_{DC} - \sin 60^\circ \times E_{pk}$
$$= 7000 - .866 \times 6000$$
$$= 1800 \text{ volts}$$

At $T = 75^\circ$, $E = E_{DC} - \sin 75^\circ \times E_{pk}$
$$= 7000 - .96 \times 6000$$
$$= 1240 \text{ volts}$$

At $T = 90^\circ$, $E = E_{DC} - \sin 90^\circ \times E_{pk}$
$$= 7000 - 6000$$
$$= 1000 \text{ volts}$$

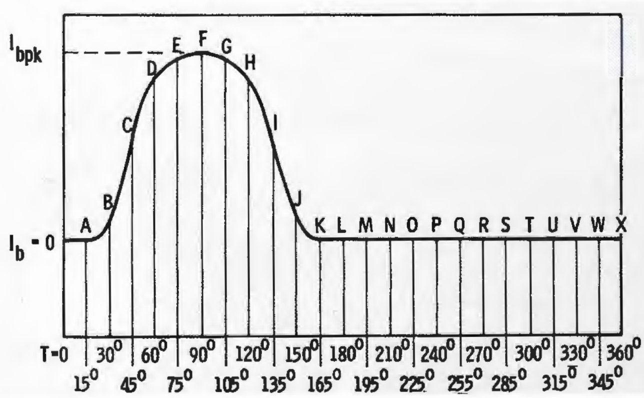


Fig. 16. Plate-current waveform need be examined only in conduction interval.

ACCURATE MEASUREMENT OF CHROMINANCE DELAY

*by Leo Lazarus**—Use of the 20T-pulse method in checking system performance is described.

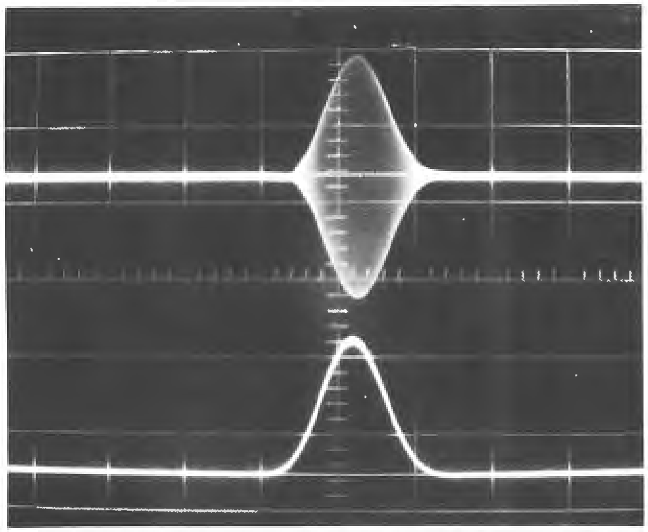


Fig. 1. Modulated (top) and unmodulated 20T waveforms.

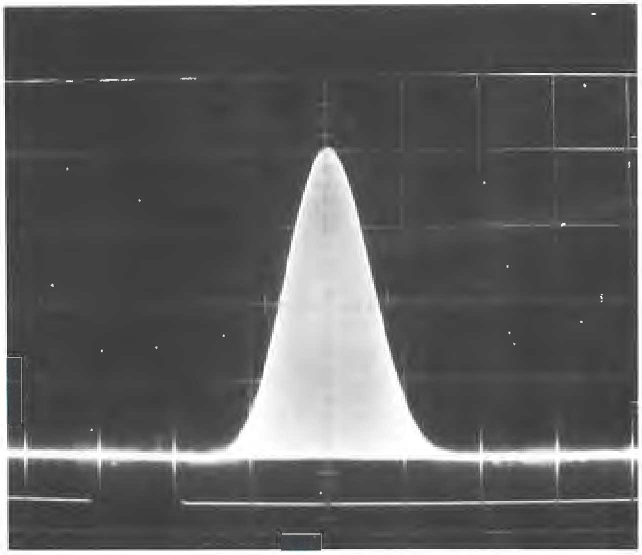


Fig. 2. Result of adding the waveforms shown in Fig. 1.

In transmission through a television system, chrominance signals are normally delayed with respect to luminance signals, and displacement of colo1 in the television picture results. Accurate means of measuring chrominance delay in order to stay within the FCC specified 50-nanosecond limit is needed, but up to now no satisfactory instrument for making such measurements has been available in the US to the average broadcaster.

20T-Pulse Technique

Based on a method using a 20T pulse, test instruments are now becoming available that are capable of measuring chrominance-versus-luminance delay to within 10 nanoseconds. The 20T-pulse method is an extension of the now familiar sine-squared pulse and bar testing techniques.[1] The 2T sine-squared pulse is a near approximation to the output waveform of a camera scanning a very thin vertical black line under average studio conditions. Since the energy of the 2T pulse is approximately zero at 4 MHz, and the spectra of the usual monochrome TV signals have a small amount of energy near the upper frequency limit of the video band, the 2T pulse is a fair representation of the details in a black-and-white television picture.

Color signals (appearing as modulated 3.58-MHz signals), on the other hand, have a high amount of energy at the upper end of the video band. Transmission distortions in this area are not indicated by the 2T pulse and bar test signal.

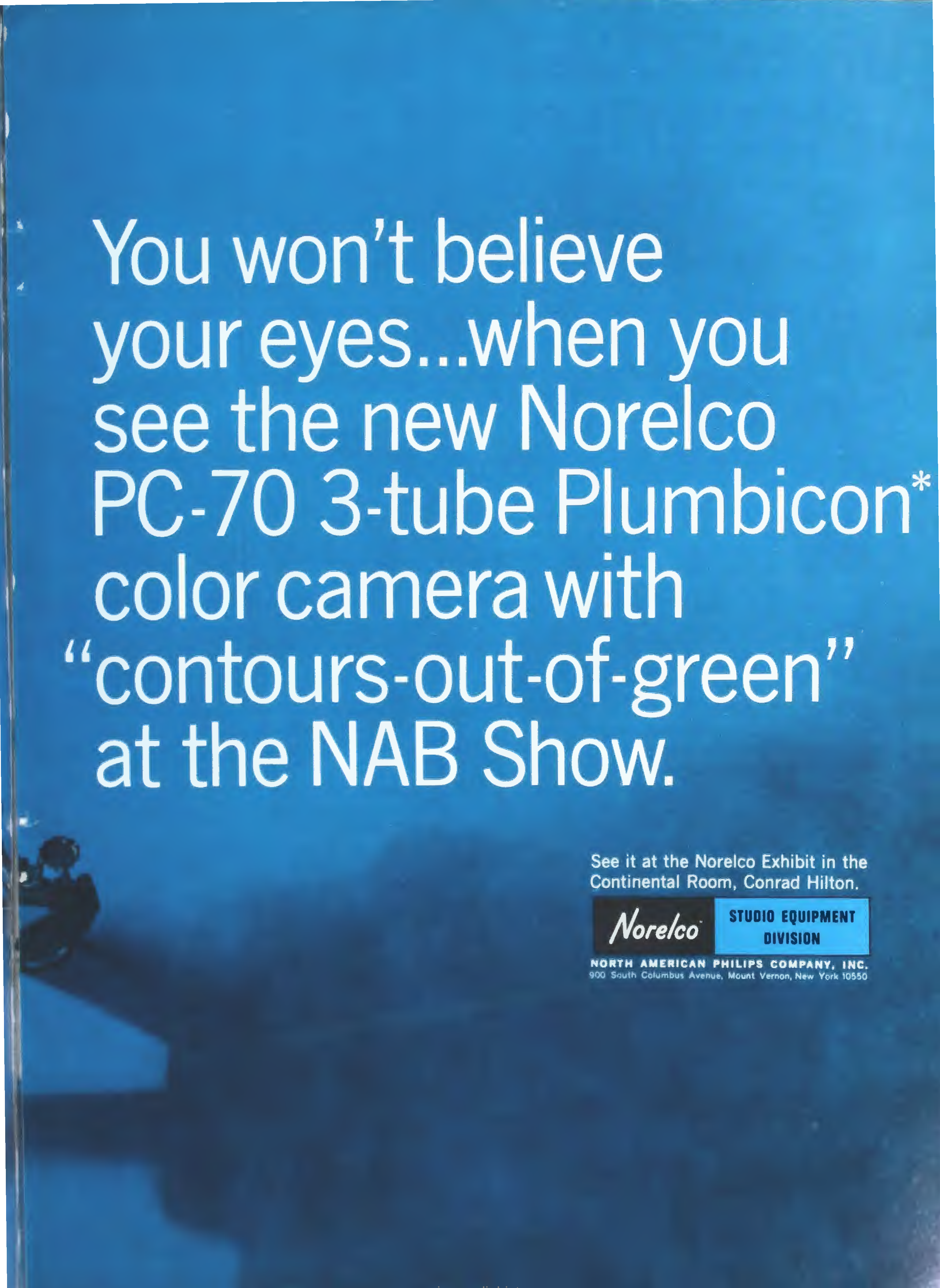
The T pulse has high energy at the upper end of the band, but its frequency components extend to twice the upper video-frequency limit. An ideal TV transmission system would act as a perfect 4.2-MHz lowpass filter; thus, the T pulse is subject to distortion whether or not the response of the transmission system is ideal.

An answer to the problem is to use a test waveform having frequency characteristics truly representative of

● *Please turn to page 78*

*Publications Supervisor, Telemet Company. Technical acknowledgement is made to A. Kwartiroff, Director of Engineering, and J. Abdulezer, Project Engineer.

°Trademark of N. V. Philips' Gloeilampenfabrieken of the Netherlands for television tubes.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Chrominance Delay

(Continued from page 43)

color signals. The effect of transmission equipment on such a test waveform would be similiar to the effect on the color signals, and distortion could be detected readily. A test waveform providing the required characteristics is formed by modulating a color subcarrier with a sin² pulse of the proper duration. The half-amplitude duration of this pulse must be such that the sum of the highest additive frequency components of the pulse and the color subcarrier do not exceed the upper video-frequency limit. Such a test waveform would be transmitted through an ideal transmission system without distortion; transmitting errors would distort the test signal in the same manner as they would a color TV signal.

Luminance-Chrominance Test Waveform

A color subcarrier modulated positively 100% by a 20T pulse and added linearly in the proper phase to an unmodulated 20T pulse provides a test waveform having the characteristics described. Fig. 1 is a dual-trace oscilloscope display of the modulated and unmodulated 20T pulses respectively. Fig. 2 is a display of the additive resultant: a 20T pulse filled out with the cycles of the 3.58-MHz subcarrier.

The half-amplitude duration of the 20T pulse is 2.5 microseconds, giving it an amplitude/frequency spectrum up to 10% of the video bandwidth (400 kHz in a 525-line system). Because the unmodulated 20T pulse is added to the modulated waveform, there are two spectral ranges of the test waveform: The spectrum of the unmodulated 20T pulse ranges from nearly zero up to 10% of the video bandwith (0 to 400 kHz); the 20T pulse modulated on a 3.58-MHz carrier occupies a frequency range extending 10% of the video bandwidth (400 kHz) above and below 3.58 MHz. Thus the spectra containing the main information of the luminance and chrominance channels are covered. Improper transmission response in either channel (low and high frequency respectively) is indicated by distortions of the envelope of the modulated 20T pulse.

Time-Difference Distortion

If no time differential is present, the signal components add linearly to give a straight line at blanking level; however, if delay inequality exists, the addition of the waveform components results in the bottom of the envelope not being straight. The shape of the envelope at blanking level assumes the shape of the time derivative of the original waveform—a sine wave at blanking level for a sine-squared test signal. The shape and amplitude of the upper envelope remains unchanged.

The sine-shaped lower envelopes of the modulated pulses in Figs. 3 and 4 expose a time differential between chrominance and luminance signals. (The narrow pulse leading the modulated pulse is ignored for this explanation; it is explained later.) Fig. 3 shows chrominance delayed with respect to luminance; Fig. 4, on the other hand, shows chrominance advance. The

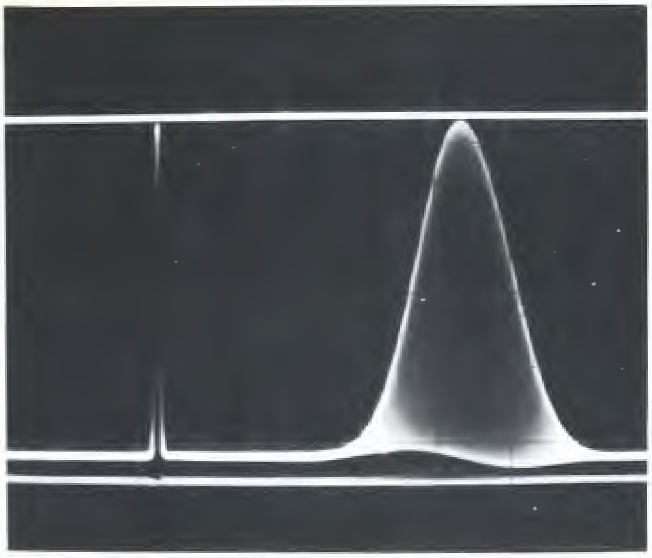

Fig. 3. Distorted base line indicates chrominance delay.

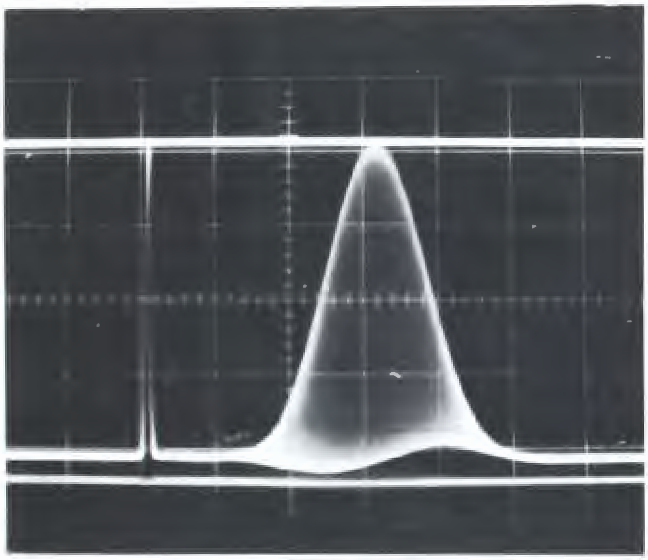

Fig 4 Different distortion shows chrominance advance.

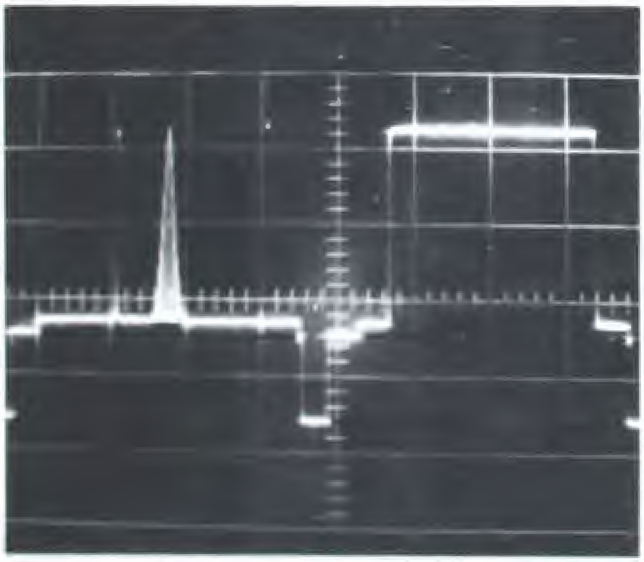

Fig. 5. Two lines contain waveforms for complete test

amplitude of the sine-shaped lower envelope is proportional to the amount of time differential.

Measuring Relative Delay

By relating the amplitude of the lower envelope to the fixed amplitude of the upper envelope, it is possible to calculate the delay of one spectral group with respect to the other. Another method is to introduce a known delay in opposition to the delay of the equipment under test so that the shape of the lower envelope is reduced to a straight line at blanking level.

A test instrument using the second method eliminates the need for mathematical calculations. An adjustable delay in the 3.58-MHz circuit, linked to a calibrated dial on the control panel, is introduced. When the distortion of the lower envelope is cancelled to a straight line, the amount of delay thus introduced is read out from the calibrated dial as the delay in the equipment under test.

Other Test Pulses

A complete test instrument of this nature should not neglect the other portions of the video spectrum. If a 2T sine-squared pulse and bar waveform are included in the test signal, distortions throughout all the video band can largely be detected. The 2T pulse covers the area of frequencies between the luminance and chrominance spectra; this pulse is shown leading the modulated 20T pulse in Figs. 3 and 4. A waveform generator can produce the test waveforms on two successive horizontal lines; on one line is the window, or bar, waveform, and on the other line are the 2T and modulated 20T pulses. Fig. 5 is an oscilloscope display of the two lines, and Fig. 6 is a block diagram showing how the complete signal is generated.

Conclusion

The 20T-pulse method can expose delay inequality between chrominance and luminance information in proportion to the amount of time difference. References 2 and 3 below provide studies of greater depth for those readers who wish to explore the full scope of the 20T pulse. This method of measuring the time differential, if employed in a properly calibrated test instrument, is more than accurate enough to ensure compliance with FCC specifications. Equipment to perform this test requires no radical departures from the methods already used to manufacture existing transmission test equipment; such instruments should therefore be within the means of the low-budget broadcaster. ▲

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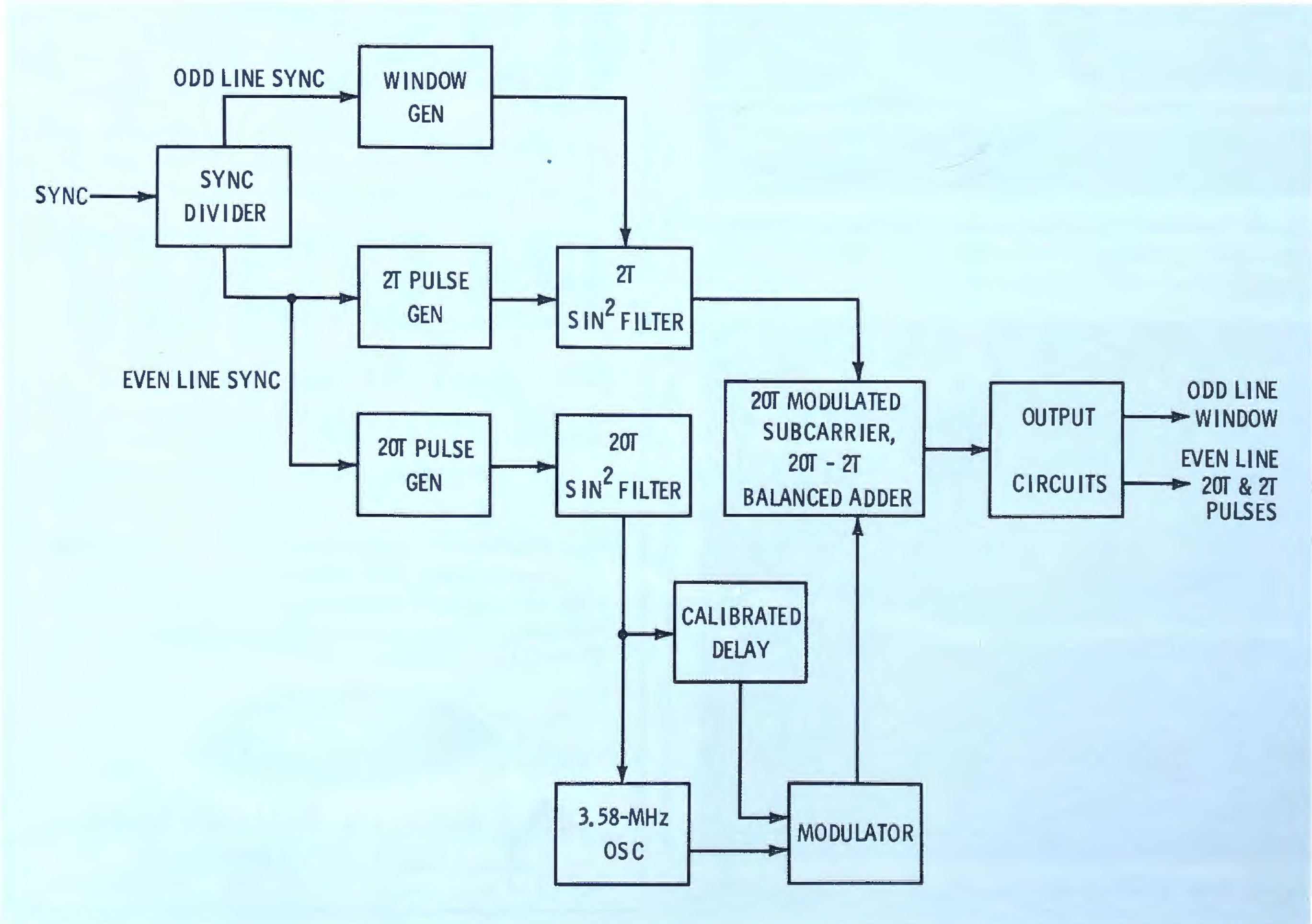
1. Finnegan, Patrick S., "Vertical Interval Test Signals," BROADCAST ENGINEERING, August 1966, page 20.
2. Wolf, Peter, "Modification of the Pulse-and-Bar Test Signal With Special Reference to Application in Color Television," *Journal of the Society of Motion Picture and Television Engineers*, January 1966, page 15.
3. Tanner, R.K.R., "Testing 625 Line Monochrome and Color Television Transmission Systems," Part 1, *Post Office Electrical Engineers Journal*, July 1965, page 132.

Fig. 6. Block diagram shows generation of test signals.



A LOW-COST STEREO CONVERSION

by *David L. Yerzley** —A small station need not be completely without stereo facilities.

Some time ago, the transmitting facilities of WVBR-FM were modernized with the installation of a new 1000-watt transmitter, a new transmission line, and a dual-polarized antenna. The new equipment was chosen with an eye toward the later addition of stereo, and when $1400 of the allocation for equipment remained after the installation, it was decided to proceed with the stereo conversion if it could be accomplished for $2000 or less.

The transmitting site could be converted for stereo simply by adding a stereo generator, a pair of matched amplifiers to drive the two transmitter inputs, and a second program line from the studios, matched in both amplitude and phase response to the line already in use for monophonic programming.

The Studio System

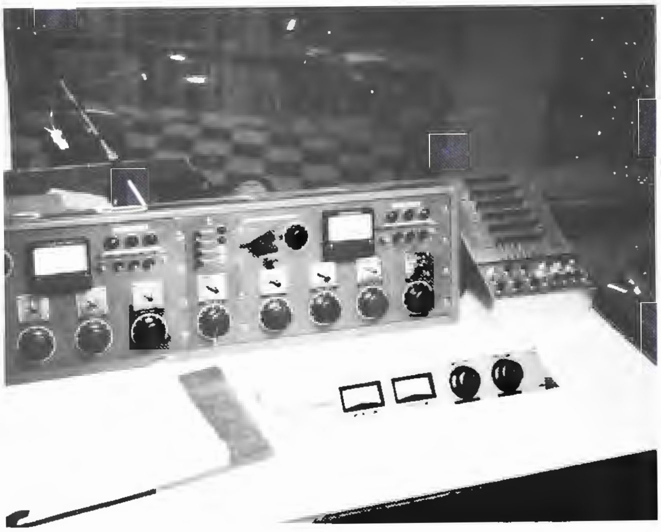
The studios, however, appeared to be a different matter. Our dual-channel, nine-input audio console was about ten years old and had been bulit from scratch by station personnel. Although the board was quite adequate for monophonic service, we decided it would be impractical to convert it for stereo use. This left two alternatives: Replace the board with a new stereo model, or add an auxiliary set of faders for stereo.

The first alternative was obviously impossible if we were to stay within the $2000 allotted for the conversion. Therefore, the methods of accomplishing the second alternative were investigated. Sources of audio used for our monophonic programming were one studio microphone, one cartridge machine, three reel-to-reel tape machines, and two turntables. It was not felt there was any need for a stereo announce microphone. The cartridge machine is used only for ID's and spots, and therefore it need not be stereo, either. Since our format is mostly classical and serious music, the primary source of our programming is the two turntables. The reel-to-reel machines are used only for breaks between records and special taped programs. Obviously, then, for our format it is of prime importance to have the capability to play stereo records, with stereo tape machines being of secondary importance.

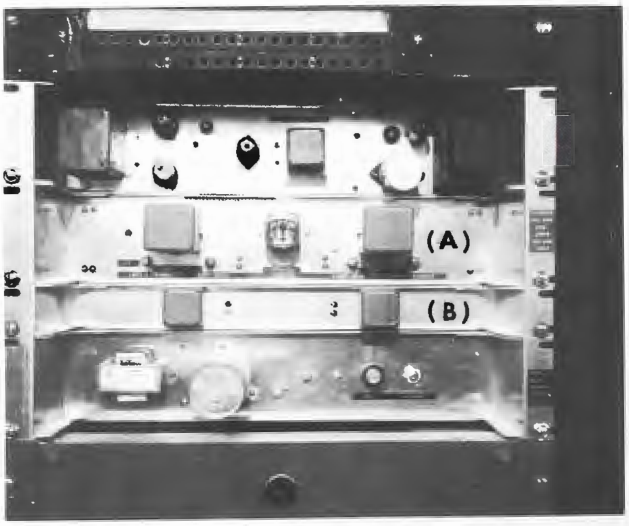
In our case, conversion of the two turntables was relatively easy and inexpensive, since we had been using stereo cartridges for some time. The two preamplifiers were combined in one turntable to provide identical left and right channels, and two spare preamplifiers which the station had on hand were installed in the other turntable. Conversion of the tape machines was investigated briefly; because we possessed one spare set of electronics, the first machine could be converted for only the price of stereo heads. The second and third machines would require purchase of both stereo heads and an extra set of electronics for each deck. Since even the heads for these machines are relatively expensive, we decided not to convert them at this time.

The net result is that we now have only two stereo sources to provide for, the two turntables. The announce microphone, the cartridge

*WVBR-FM, Ithaca, New York



Mode switches are at right, stereo mixer in foreground.



Transmitter input amplifiers (A) and transformers (B).

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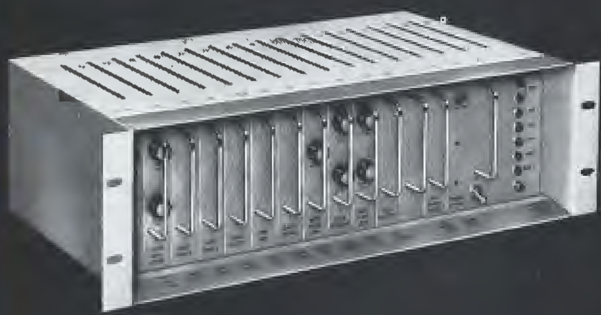

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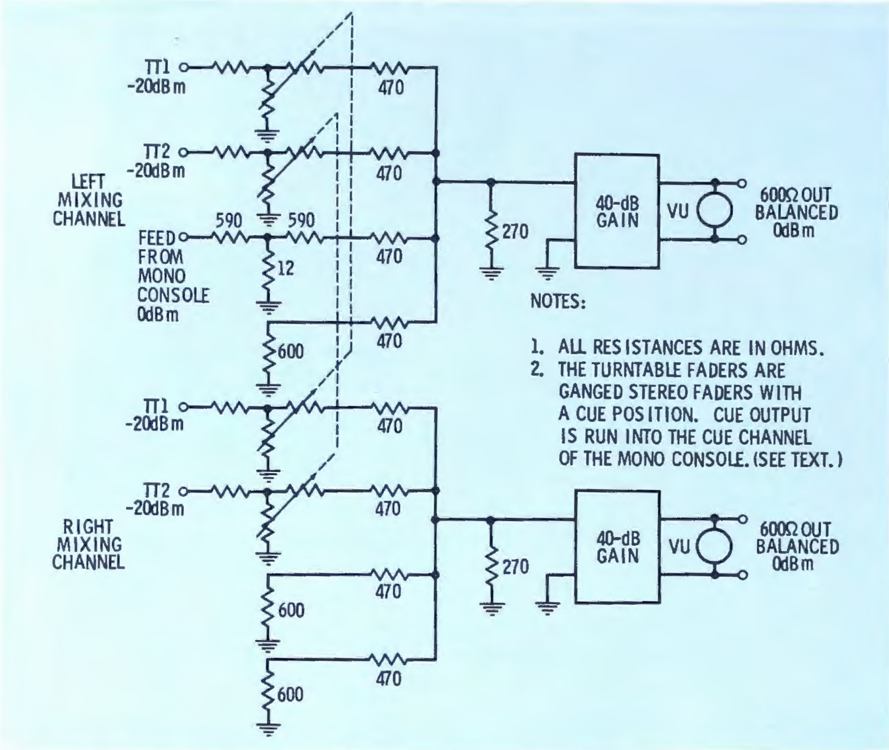

Fig. 1. Schematic shows use of stereo faders, dummy resistors in stereo mixer.

machine, and the three tape decks remain monophonic; during stereo programming they are aired through the left channel only. It seemed that the easiest and most practical way to do this was to construct two mixers, one for the left and the other for the right channel, using stereo faders for the stereo program sources.

The schematic of the stereo mixing board, as constructed, is shown in Fig. 1. The left-channel mixer combines programming from the microphone and tape sources and the left channels of the two turntables; the right channel simply mixes the right signals from the two turntables. It will be noticed that electrically this is a four-input board. Two of the inputs are the sections from the stereo turntable faders. The third left-channel input is a 40-dB pad, which accepts the output of the old monophonic console and attenuates it to mixing-bus level; in the right channel this is balanced by a 600-ohm resistor. The fourth input is a dummy in both channels. The mixer was built on a 24-inch rack panel to allow space for a third fader, which later may be added and wired into the mixing networks in place of the two 600-ohm resistors to accept a stereo tape machine.

A block diagram of the control room in the stereo mode is shown in Fig. 2. The existing mono board is used to control the levels of microphone and tape sources. The output of channel 2 of the mono board is fed into the left channel of the stereo board. The advantage of this arrangement is that channel 1 of the mono board may still be used for taping and production while the station is on the air in stereo. In the monophonic mode, all sources, including turntables, are controlled from the mono console.

Normal monitoring is done monophonically off the air. However, the monitor amplifiers in the mono console may be used to monitor the output of the control room in stereo by means of a simple patching arrangement. This, of course, could readily be wired in permanently, eliminating the need for patching, were it to prove desirable. No additional cost is involved because the only amplifiers required are the existing monitor amplifiers in the console.

We do not have provision to cue program material in stereo. The faders chosen do have stereo cue outputs; in our case, these outputs have been paralleled and fed into the cue circuit in the mono console. However, stereo cue could be provided by using the two monitor amplifiers built into the board in a manner similar to that described above for stereo program monitoring.

Mono/Stereo Switching

Switching between mono and stereo is accomplished with one pushbutton, which pulls in five relays, four at the studios and one at the transmitter. A schematic of the relay switching system at the studios is shown in Fig. 3. The following steps take place when the STEREO button is pushed:

1. The left and right outputs of the

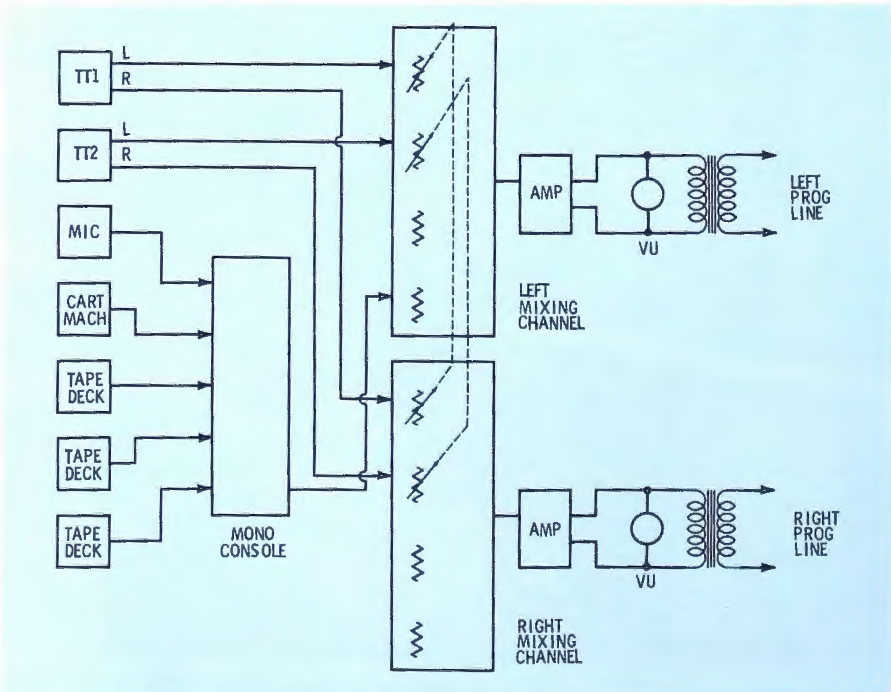

Fig. 2. Block diagram of the WVBR-FM control room when operating in stereo.

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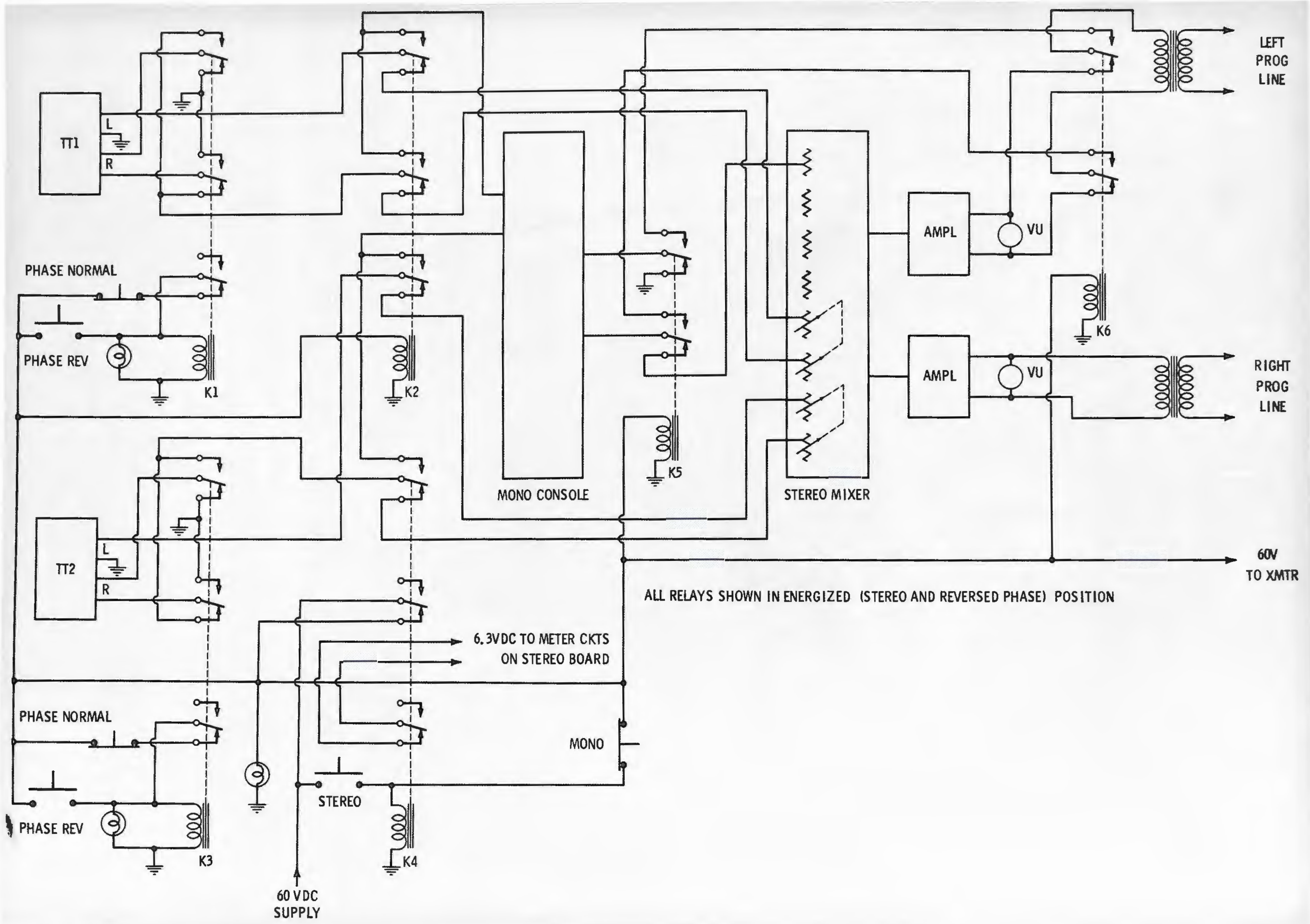

Fig. 3. Diagram shows use of relays for mono/stereo switching, and phase reversal of one channel from each turntable; mono sources are aired through left channel.

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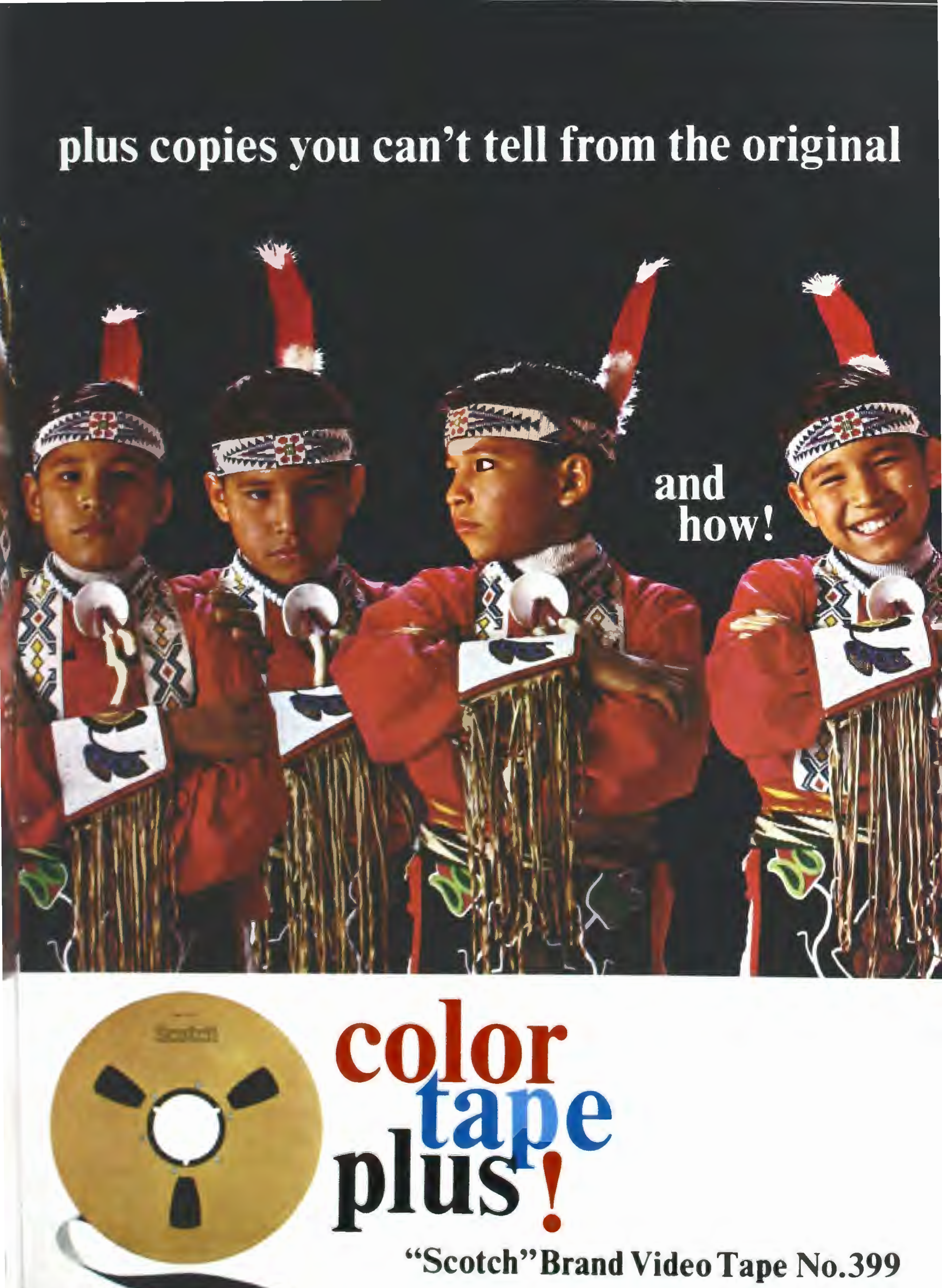
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two turntables, which are normally paralleled and fed to the turntable faders on the mono board, are split and switched to the proper faders in the stereo mixer.

2. The output of the mono board is switched from the left transmitter program line to a left-channel input of the stereo mixer.
3. The left line-amplifier output of the mixer is connected to the left transmitter program line. (The right line amplifier output is permanently connected to the right program line.)
4. At the transmitter (Fig. 4), the L − R subcarrier generator is energized, and the input of the right transmitter amplifier is switched from the left line to the right line.

Two other relays (K1 and K3) appear in Fig. 3. The need for these occurs because occasionally a stereo record has one of its channels recorded out of phase. If this is the case, although the listener equipped with a stereo system may not notice the defect, the mono listener definitely will. For this reason, provision is included to reverse the phase of one channel from each turntable. Our operators monitor all stereo transmissions in mono so that such a situation will be noticed and corrected as soon as possible.

We standardized on sealed 3-PDT plug-in relays for this installation (as well as for all other future relay applications at the station). Although we operate the relays from a 60-volt DC supply, we ordered relays with 115-volt AC coils, which will work on any DC voltage above about 20 volts and can also be used with 115 volts AC or 230 volts AC should the occasion arise.

Although our transmitter is located several miles from the studios and is remote controlled, the stereo switching is completely independent of the remote control. This was accomplished by using a third control pair. One conductor and ground are used to control the stereo switching relay at the transmitter; the other conductor is used with a ground return to run a remote overmodulation flasher at the studios from the modulation monitor at the transmitter site. (This third control pair had been installed for the flasher some months before work was begun on stereo—splitting the pair into two independent conductors provided a convenient solution to both the control and indicator problems.) The relay switching system was designed so that if relay power fails, the system reverts to the monophonic mode as the relays de-energize.

Transistorized plug-in modules were chosen for the two extra studio amplifiers and the transmitter driving amplifiers. The modules purchased have gain adjustable from about 35 dB to 43 dB, and good noise, distortion, and response figures. The input impedance is 10K unbalanced, and the output impedance is 600 ohms balanced. We built our own regulated power supplies for these amplifiers.

Cost of the Conversion

The approximate cost for the conversion was:

Stereo generator	$1200
Four plug-in amplifiers	180
Power supplies	50
Relays	50
Two VU meters	60
Two stereo faders	120
Wide-band detector	90
Misc. (wire, chassis, etc.)	50
Total	$1800

Stations that do not have two spare turntable preamps, as we did, would have to purchase one stereo preamp. The two old preamps can be used together in one turntable. Even if it is necessary to buy two stereo cartridges, the cost of conversion should not be increased by more than $300.

The remaining $200, which brings the total cost up to the original limit of $2000, was allotted for a stereo tuner and other audio equipment for monitoring the signal in stereo off the air. No test equipment not normally found in a well equipped monophonic station is required, other than the wide-band detector. An indication of stereo performance may be obtained by observing the composite stereo waveform with an oscilloscope at the output of the detector. A high-quality tuner may be used for this purpose by observing the waveform at the output of the discriminator. We use a tuner to check the measurements made with the wide-band detector.

[*Editor's Note: The stereo conversion described here makes no provision for a stereo modulation monitor because Rules for the type approval of these monitors had not been adopted at the time the conversion was made. In the future, allowance will have to be made for such a monitor. (See July 1966 "Late Bulletin from Washington.")*]

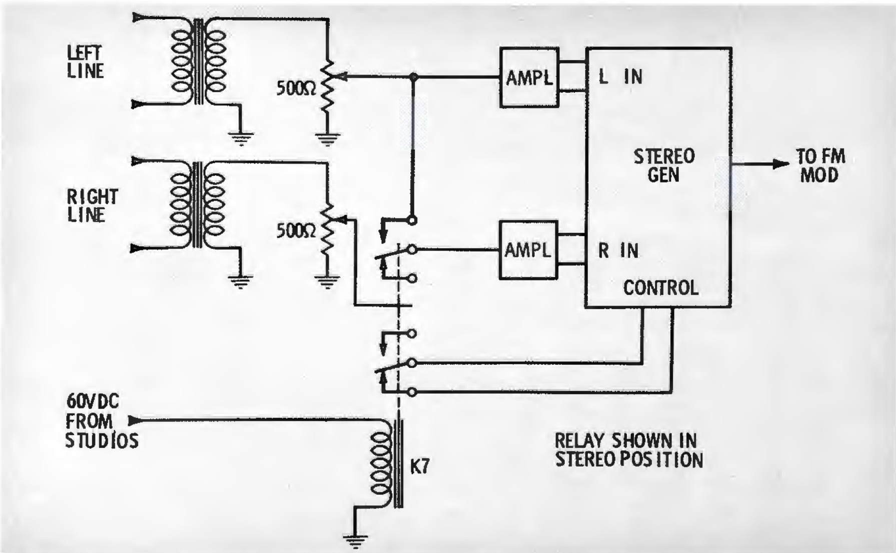

Fig. 4. Stereo/mono relays at transmitter are controlled over separate line.

Conclusion

The installation described is not intended to be a permanent one, but rather one which will allow us to transmit multiplexed stereo until we can afford the large expenditure associated with the purchase of a new stereo audio console and the complete rewiring of our studios. Although it is inexpensive, the system makes no compromises on the technical quality of the transmitted signal, and we are able to bring to our listeners the finest in stereo recordings. ▲

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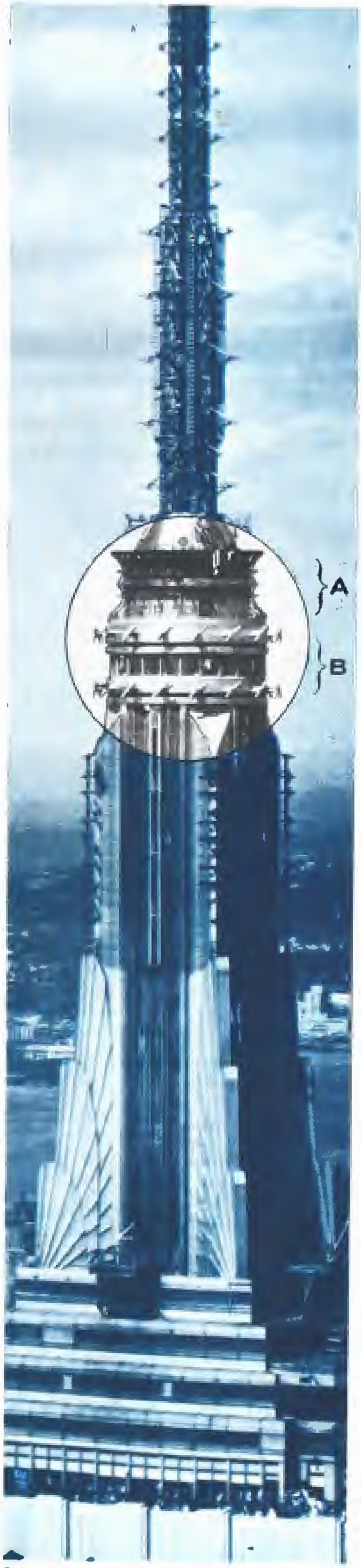

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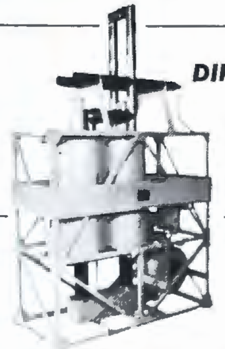

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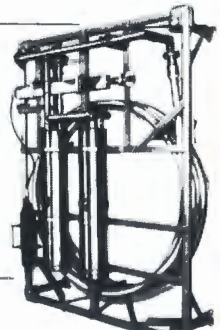

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by Howard T. Head

Increasing Concern Over Color-Kinescope Performance

Color-television receiver manufacturers and broadcasters are becoming increasingly concerned over the realization that current versions of color kinescopes have color response differing considerably from earlier tubes. The principal difficulty lies with the currently employed green phosphors, which produce a substantially less saturated green color than earlier phosphors.

The coordinates of the newer phosphors differ so substantially from the "standard" green, on which the NTSC color system is based, that different matrixes are required in studio monitors and home receivers to produce optimum color rendition. Even so, the range of colors which can be rendered is substantially reduced, and linear matrixing will not produce faithful colors under all conditions.

The problem is further complicated by the fact that the NTSC system is based on a reference white (illuminant C) of 6500° K. Typical studio illumination ranges from 2800° to 3200° K, and many receivers and monitors are matrixed to produce a reference white of 9300° K, corresponding approximately to a black-and-white kinescope. These problems are under study, and the Society of Motion Picture and Television Engineers (SMPTE) is considering setting up a special committee to see what can be done to improve the situation.

Tighter Station-ID Rules Proposed

The Commission has proposed to amend the Rules governing station identification announcements, promotional announcements, or other broadcast matter which might lead the audience to believe the station is assigned to a city other than that to which it is licensed. The Commission reports the receipt of various complaints charging that stations in suburban markets have attempted to identify themselves with the major nearby city to the detriment of the smaller community to which the station is assigned. Under the new Rules, this practice would be prohibited.

The Commission's proposal was sparked by a series of incidents some months ago involving a West Coast station; the station was fined substantially for the use of promotional material intended to lead listeners to believe that the station was actually assigned to a nearby large city.

Plans Advance for Tests of TV-Channel Sharing

The joint Government-Industry Committee for testing of sharing of television channels by the land mobile radio services has settled on Washington, D. C., as the area where such sharing will be tested on an experimental basis. Earlier plans for conducting the tests in the Los Angeles area (December 1966 Bulletin) fell through when the Commission ruled that testing within 250 miles of the Mexican Border would require the consent of the Mexican Government. To date, Mexican consent, although requested, has not been forthcoming even on an experimental basis.

The Washington tests, expected to commence this spring, will be conducted on various frequencies within the limits of Channel 6 (82-88 MHz). Three land mobile base stations on frequencies in the Channel-6 band will be operated at various locations in the metropolitan area. Measurement and observation teams will explore possible interference to the Channel-5 station in Washington, as well as Channel-6 stations in Philadelphia and Richmond, Virginia. Noncommercial educational FM stations in Washington in the 88-92 MHz band may also be affected.

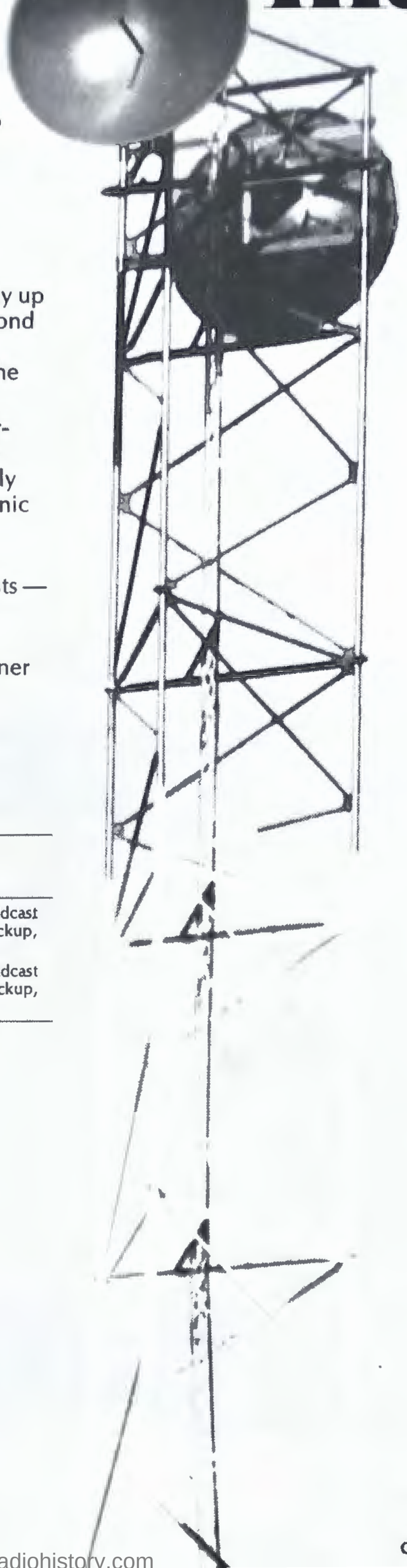
Proposals for regular land mobile operation on Channel 6 represent another potential threat to Channel-6 television reception, already plagued by growing interference from noncommercial educational FM stations in the lower part of the FM band (January 1967 Bulletin). In addition, frequency relationships involving the standard 41.25-MHz IF make Channel 6 color reception particularly susceptible to interfering beats.

Short Circuits

The Commission has refused to order CATV nonduplication protection in a New England city within the calculated Grade A contour of a television broadcast station -- the city is in rugged terrain and no actual off-the-air service is received from the broadcast station. . . A notice of inquiry has been adopted looking to regularization of translators for the FM broadcast service (July 1966 Bulletin). . . "Educasting," a system for using FM multiplex subcarrier channels for educational purposes, has been tested successfully by a Philadelphia FM station, and is now available on a regular basis (December 1965 Bulletin). . . TelePrompter has reported that the tests of broadband 18-gHz CATV relaying in New York were successful (October 1966 Bulletin), and has requested such operation nationwide on a regular basis. . . The National Association of Broadcasters will hold another engineering-management seminar this year at Purdue University (December 1966 Bulletin) -- past sessions have been oversubscribed.

Howard T. Head . . . in Washington

What's new in Reelsville, man?



One repeater of an intercity color TV relay system that uses no tubes, no filaments, no high voltages, no mechanical relays.

Microwave Associates' all-solid-state MA-2A relay system owned by WTWO Terre Haute, relays both NBC and ABC programming from Indianapolis to Danville to Reelsville to Farmersburg near Terre Haute through a single feed line antenna system. More than that. The antenna system was already up there, with conventional klystron equipment. But when the second network came aboard, it was add another tube system with antennas, or change over to a solid-state system diplexed into the existing antennas. WTWO opted for the new technology.

Color was one of the big reasons. In the MA-2A, the color-determining characteristics are controlled by highly stabile semiconductor devices and solid-state circuitry. The system is completely free of the drift and degradation that is associated with thermionic components.

Money was another reason. Paralleling the existing system with new tube equipment, new antennas, new feed lines, rigging costs — would have been expensive. More than they cared to spend for equipment some consider obsolete.

Reliability was still one more reason. Solid-state reliability. Sooner or later, tubes mean trouble. The ultimate solution is obvious. The MA-2A has no tubes.

What's new in Reelsville is also new at Rattlesnake Mountain, Washington; North Pole, New York; Bozrah, Connecticut and other famous places. Should it be near you?

Model	Band MHz	*Nominal RF Power	Nominal RCVR Noise Figure without preamp	Nominal RCVR Noise Figure with preamp	Allocation
MA-2A	1990-2110	2 watts	10 dB	5 dB	TV Auxiliary broadcast STL, remote TV pickup, intercity relay
MA-7A	6875-7125	.5 watt	12 dB	5.5 dB	TV Auxiliary broadcast STL, remote TV pickup, intercity relay

Also available at other frequencies in the 1300 to 2300 MHz band for international allocation requirements.

MICROWAVE ASSOCIATES
Burlington, Massachusetts
Offices: Burlington, Mass.; 9911 Inglewood Ave., Inglewood, Cal.
Hyde House, Edgware Rd., London NW9, England
Subsidiary: Microwave Associates, Ltd., Luton, Beds, England

Class B & C

(Continued from page 42)

The driving power is therefore:

$$P = E_{gpk} \times I_{GDC}$$
$$= 540 \times .31$$
$$= 168 \text{ watts}$$

The bias loss is:

$$P = E_{CDC} \times I_{CDC}$$
$$= 300 \times .31$$
$$= 93 \text{ watts}$$

The grid dissipation is:

$$P_{DISS} = P_{drive} - P_{bias}$$
$$= 168 - 93$$
$$= 75 \text{ watts}$$

This value is exactly the rated grid dissipation of the tube.

The conduction angle of the various electrode currents can be found by noting on the time scale the points at which conduction commences. For instance, plate current begins to flow at about 15° after T = 0, so its conduction angle is:

$$\theta = 180° - (2 \times 15°)$$
$$= 150°$$

Similarly, the screen current, which begins at about 30°, has a conduction angle of:

$$\theta = 180° - (2 \times 30°)$$
$$= 120°$$

Grid current begins at about 35°, so its conduction angle is:

$$\theta = 180° - (2 \times 35°)$$
$$= 110°$$

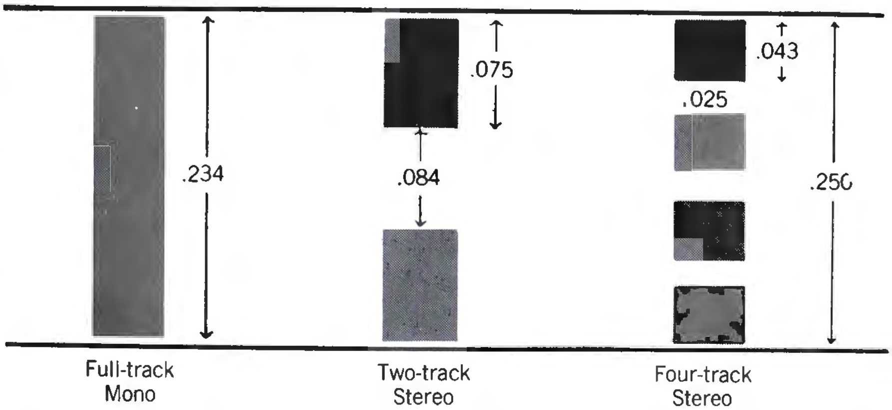
Conclusion

A thorough understanding of the reasoning behind the steps involved in these calculations will enable the designer to predict accurately the performance and requirements of any circuit involving vacuum tubes in these various classes of operation. This may expand into point-by-point analysis of modulated RF amplifiers, RF linear amplifiers, or different classes of audio amplifiers. ▲

Some plain talk from Kodak about tape:

The big squeeze—Multitrack Stereo

Remember the college fad a few years back—how many brawny brutes could be squeezed into a little car built for plain folks? For a while, it looked like a somewhat similar situation was about to take place in the tape-recording field—first monaural, then 2-track, then 4-track, and now even 8-track recording. Even though these developments continue at a fast clip, 4-track stereo is still the name of the game as far as high-fidelity applications are concerned. And very nice it sounds,

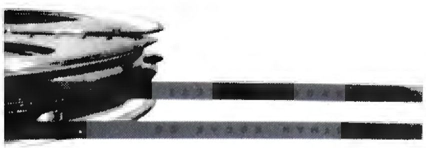


too, thanks to the precision built into modern heads. But you do have to watch yourself. Having double the information on a given length of tape means everything has to be just so—including the tape you use.

4-track star. The first thing to worry about in considering a tape for 4-track stereo is output. As you can see in the chart above, adequate separation must be maintained between each track to prevent cross-talk. And as the actual width of the recorded tracks drops down, the output per channel on the tape drops in proportion.

Thus, to make the most of what you can record, you need a tape with a high-powered oxide layer—one that's going to give you a high output with a good signal-to-noise ratio. KODAK Sound Recording Tape, Type 34A, fills the bill—gives you 125% more undistorted output than conventional general-purpose tapes. You get practically the same per-channel output on 4-track stereo with Type 34A that the other tapes would give you on 2-track! But there's more to recommend the use of Kodak tape.

Staying on the right track. Because everything gets smaller in proportion when you go to 4-track, dimensional precision becomes that much more important. Take a tape that suffers from a case of drunken slitting. (That's when the edges of the tape snake back and forth even though the width is constant.) It's not hard to see how this tape isn't going to "track" straight past the head. A slight case of this and you get alternating fluctuations in output on both channels. If the condition is bad enough, a poorly slit tape can cause your heads to drop out the signals completely, even pick up the signals on the tracks going the other way. Horrors! Lucky for you, you have nothing to worry about with Kodak tapes. We keep our tolerance to .001 inches. That's twice as close as industry standards. To make your life even easier, we also backprint all our tapes so you can always tell



whether a reel has been wound "head" or "tail" first. Simply note which comes first off the supply reel, the "E" of "EASTMAN" or the "O" of "CO"... and note it on the reel.

Kodak tapes—on DUROL and Polyester Bases—are available at most electronic, camera, and department stores. To get the most out of your tape system, send for free, 24-page "Plain Talk" booklet which covers the major aspects of tape performance.

EASTMAN KODAK COMPANY, Rochester, N.Y.

Circle Item 35 on Tech Data Card

NEWS OF THE INDUSTRY

INTERNATIONAL

TV Studio for Ethiopia

The **Ethiopian Television Service** has ordered from **Pye TVT Limited** a complete television studio, including image-orthicon cameras, monitors, and associated mixing equipment. The equipment is to be used in the new television center in Addis Ababa.

NATIONAL

ETV Survey

One Week of Educational Television, a special report released by the **Morse Communication Research Center** of **Brandeis University** and the **National Center for School and College Television,** shows that the nation's 115 ETV stations broadcast a total of 5688 hours during the survey week (April 17-23, 1966). This total represents a weekly average of 49 hours 27 minutes, an increase of seven hours a week as compared with the 1964 figures. In 1966, 39 stations broadcast on weekends; in 1964 only 16 stations broadcast on weekends.

Only 27% of all ETV programming was produced by stations at the local level in 1966, compared to 37% in 1964. Local production for school programs decreased from 50% of total school service in 1964 to 41% in 1966. National, regional, and state ETV agencies accounted for 53% of the total broadcast time in 1966, and for the first time, one of these agencies, National Educational Television, was the largest single source of ETV programs.

Other findings are:

Fifty-seven percent of all broad-

EIMAC has advanced power amplifiers for low power UHF-TV transmitters

These power amplifier tubes are electrostatically focused klystrons (ESFK). They need no magnets. Our entire ESFK family offers you the best power-to-weight ratio of any power amplifiers. That means when you use one of our new ESFK's in your next design, your UHF-TV transmitter will be smaller—and easier to maintain. And since these tubes are air-cooled, they need less heat dissipation equipment, so your transmitter is less expensive to operate.

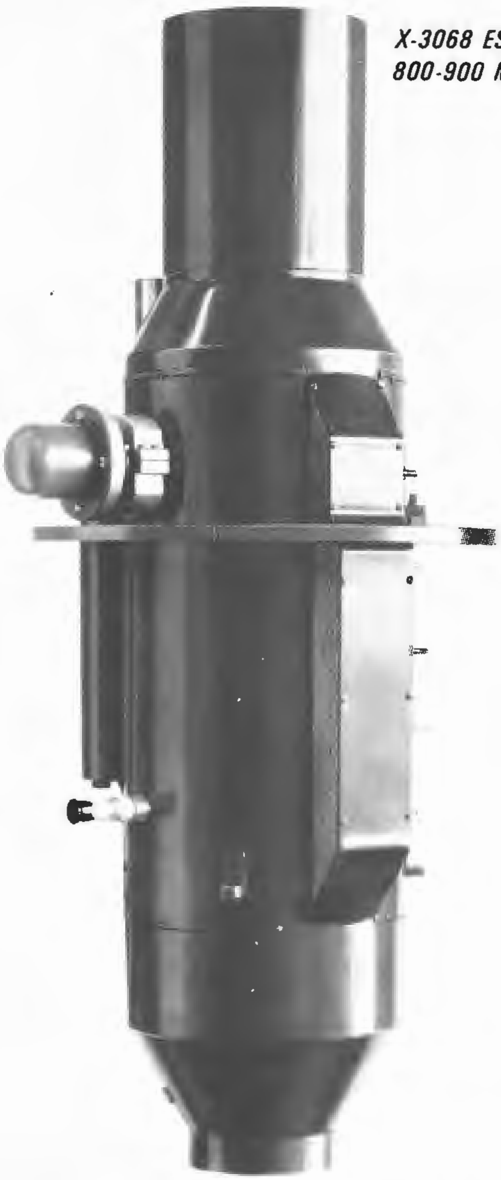
One example: the X-3068 amplifier. Note its 35 db gain with 36% beam power efficiency. At UHF frequencies, power outputs between 1 and 3 kilowatts are available.

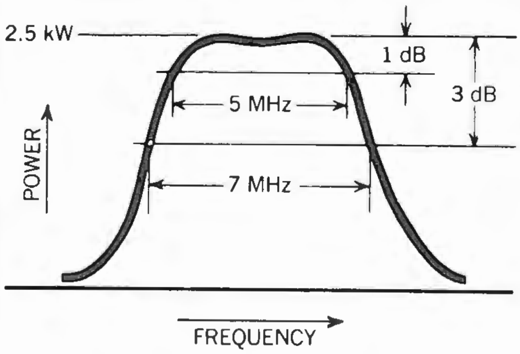
For S-band transmitter designs, check our X-3065. It offers 500 watts output yet weighs only 5 pounds and measures just 6 inches. And provides 30 to 40 db gain with efficiency between 35% and 45%; heat-sink or air-cooled.

We have spent more than ten years in advanced materials research, ceramic-to-metal technology, and beam focusing studies. To make an advanced power amplifier, it takes experience. You can count the number of experienced ESFK manufacturers on one finger.

EIMAC
Division of Varian
San Carlos, California 94070

X-3068 ESFK
800-900 MHz





RF OUTPUT POWER vs. FREQUENCY.
CAVITIES TUNED FOR BANDWIDTH.

DRIVING POWER	2 W
OUTPUT POWER	2.5 kW
GAIN	31 dB
1 dB BANDWIDTH	5 MHz
3 dB BANDWIDTH	7 MHz

See Varian at NAB 1967 — Booth 406
Circle Item 38 on Tech Data Card

casting was intended for the general evening audience.

Thirty-three percent of all programming was designed for school (kindergarten through the twelfth grade) use, a slight increase in service to the schools.

The Arts have replaced Science as ETV's major program concern and most-broadcast subject.

ETV broadcasters also offered more programming concerning public affairs and news, and more programming for children.

For the schools Science and Mathematics remained the most-broadcast subjects.

From 1964 to 1966, 28 new ETV stations began broadcasting, and 65 more ETV stations are in various stages of development. All but ten states now have at least one educational television station, and, with two exceptions, ETV is now serving the 25 most populous centers of the United States.

Of the 115 stations now on the air, 38 are licensed to communities, 33 to universities, 22 to states, 21 to school systems, and one to a municipal government. Sixty-six are VHF stations, and 49 are UHF stations.

Equipment Manufacturer Purchased

Bauer Electronics Corp. has been purchased by **Granger Associates,** and will operate as a wholly owned subsidiary of the purchasing company. Founded by Fritz Bauer in 1960, Bauer Electronics specializes in AM and FM transmitters and accessory equipment for the broadcast industry. To maintain continuity within the management, Mr. Bauer will continue engineering and manufacturing high-power AM transmitters. Chester M. Carr will remain general manager, and Paul E. Gregg will continue as sales manager.

Sells Interest in CATV Manufacturing Concern

Cox Broadcasting Corp. has sold its 50% interest in **Kaiser-Cox Corp.** to the **Kaiser Aerospace and Electronics Corp.,** which now assumes 100% ownership. A Cox official said the decision to withdraw from manufacturing CATV equipment was related to the desire of the company to concentrate management and financial resources in other fields. CBC expects to continue its program of expansion in CATV system operations.

Model 635A Dynamic Microphone $82.00 List. (Normal trade discounts apply.)

How can a microphone as good as the E-V Model 635 be made obsolete? By making it better! It wasn't easy. After all, professional sound engineers have depended on the 635 since 1947.

During this time, the 635 earned a reputation for toughness and dependability that was unrivalled by other omnidirectional dynamics. And internal changes through the years have kept the 635 well in the forefront of microphone design.

But now the time has come for an all new 635: the Electro-Voice Model 635A. It's slimmer, for easier hand-held use. Lighter, too. With a slip-in mount (or accessory snap-on Model 311 mount) for maximum versatility on desk or floor stands. The new, stronger steel case reduces hum pickup, and offers a matte, satin chromium finish perfect for films or TV.

The new 635A is totally new inside, too—and all for the best. A new four-stage filter keeps "pops" and wind noise out of the sound track, while guarding against dirt and moisture in the microphone, completely eliminating any need for external wind protection. Of course you still get high output (—55db) and smooth, crisp response. And you can still depend on the exclusive E-V Acoustalloy® diaphragm that is guaranteed against failure for life* (it's that tough)!

We expect to see plenty of the "old" 635's in daily use for years. But more and more, the new 635A will take over as the new standard. It's easy to find out why: just ask your E-V Professional Microphone distributor for a free demonstration in your studio. Or write us today for complete data. We'll be proud to tell you how much better the new Model 635A really is!

*The E-V Professional Microphone Guarantee: All E-V professional microphones are guaranteed UNCONDITIONALLY against malfunction for two years from date of purchase. Within this period, Electro-Voice will repair or replace, at no charge, any microphone exhibiting any malfunction, regardless of cause, including accidental abuse. In addition, all E-V microphones are GUARANTEED FOR LIFE against defects in the original workmanship and materials.

ELECTRO-VOICE, INC., Dept. 371V, 638 Cecil Street, Buchanan, Michigan 49107.

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SETTING NEW STANDARDS IN SOUND

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ORGANIZATIONS

NAB

The National Association of Broadcasters has noted with approval the Federal Communications Commission's proposal to let AM and FM radio stations with 10-kilowatt or higher power operate by remote control without first undergoing a 12-month, full-scale engineering study. In comments filed by General Counsel Douglas A. Anello, NAB said the proposed change would update FCC Rules and Regulations and reflect advances that have been made in transmitting equipment over the past 10 years.

The Association last July requested the proposed change in a petition filed with the FCC. The original petition stated that the full-scale performance study of transmitting equipment was an unnecessary burden on broadcasters because it required extra manpower to keep performance logs for complying with a rule outmoded by technological advances.

SMPTE

Arrangements chairmen for the 101st Technical Conference of the Society of Motion Picture and Television Engineers have been appointed by Conference vice-president E. B. (Mike) McGreal, Producers Service Corp., Hollywood. The semi-annual conference will be held April 16-21 at the New York Hilton Hotel.

General Arrangements Chairman is John J. Kowalak, vice-president, Movielab, Inc., New York City. Committees for conference arrangements and the chairmen are:

Hotel Arrangements: Robert J. Harrington, Andre Debrie, New York

Get-Together Luncheon: Fred J. Scobey, DeLuxe Laboratories, New York

Registration: Jack Asher, Lab-TV, New York

Entertainment: Saul Jeffee, Movielab, Inc., New York

Transportation: Irwin B. Freedman, Agfa-Gevaert, Inc., Teterboro, N. J.

Ladies Program: Irene Kowalak, Beatrice Jeffee, and Saul Jeffee, Movielab, Inc., New York

Publicity: D. W. Robinson, The 3-M Company, New York

Typical of the customized concept in Visual solid-state Video Switchers is this system installed at WHYY-TV, Philadelphia. Used for switching Channels 12 and 35 WHYY's Master Control Switcher incorporates preset 16-event store, audio-follow-video and audio breakaway facilities, independent switcher busses to five VTRs, program and preview feeds, full machine control, and audio-video monitoring and preview facilities.

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another key to better color

The key to Visual Electronics' unquestioned leadership in advance-design video switching systems is our belief that there is no such thing as a "packaged" switching system in today's complex color broadcasting operation. Instead, your system is *customized* to your exact requirements. Your *customized* system is completely solid-state, including FET (Field Effect Transistor) mixing and clamp circuitry of modular design — for long, minimum-maintenance operation, unlimited accessibility, and flexibility for future expansion. Regardless of the program complexity, the number of input sources and switchable feeds, or the previewing and monitoring facilities required . . . your *customized* solid-state Visual Video Switcher is designed to meet those needs!

the Blue Ribbon Line

Visit with Visual

- at the 1967 NAB Convention
- at the Visual Post-NAB Technical Seminar, April 6th.

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FIRST BY ANY STANDARD

Projection: Nicholas Mastrogiavanni, Pathe Laboratories, New York

Membership: Eli Drexler, Fuji Photo Film U.S.A., Inc., New York

Auditor: Peter Cardasis, Movielab, Inc., New York

During the papers program, papers will be presented in Education, Medicine, Laboratory Practices, Sound, Television, Projection and Theater Presentation, Space Technology, Instrumentation and High-Speed Photography, and Film and Television Studio Production Practices.

In addition to the papers program, the Conference will feature an equipment exhibit where some 90 booths of equipment will be on display.

NAEB

William G. Harley, president of the National Association of Educational Broadcasters, will make the

How would you shrink 180 feet of video cable into one foot?

Shrinking video cable into delay lines is really no great task. The real challenge is in maintaining bandwidth of video broadcast quality. Kappa Networks has met this challenge successfully through a new design approach which yields greater delay-bandwidth from fewer components.

Designed specifically for the video broadcast industry, Kappa Super-η (high efficiency) Delay Lines provide superior performance with the same number of components needed by conventional lines. Alternatively, if performance is held equal to that of conventional lines, Kappa Super-η need far fewer (up to 40% less) components. Consequently they can realize maximum reduction of size and cost where necessary, as well as greatest inherent reliability.

Finally, outstanding uniformity in performance is a marked feature of Kappa Super-η Video Delay Lines. This assures that prototypes are consistently typical of production quantities.

SPECIFICATIONS: KAPPA MODEL 10A503 SUPER-η DELAY LINE

ELECTRICAL

Delay:	260 nsec. ± 2% (replaces 180 ft. of cable)
Impedance:	75 ohms ± 2%
Insertion Loss:	1.5 db.
K Factor:	less than 0.25% for sin² "T" pulse
Cross Talk:	less than 46 db.

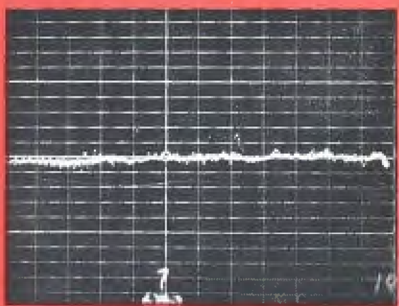
MECHANICAL

Size:	12″ x 7/8″ x 7/8″
Case Material:	Electro-tinned brass
Finish:	Mil-spec gray lacquer
Mounting:	(2) 6-32 threaded inserts
Price:	Under $100
Delivery:	4 weeks

AMPLITUDE

Amplitude Response Flat within 0.1 db to 12 MHZ
Ripple Within ± .02 db to 12 MHZ

GROUP DELAY



Group Delay Slope: Linear within ± 0.5 to 12 MHZ
Group Delay Ripple: Within ± 0.5% to 12 MHZ

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presentation for the United States at the Third International Conference on Educational Radio and Television in Paris, March 8-22. Hr. Harley will deliver the wind-up speech at the final plenary session of the Conference which will bring together representatives from more than eighty nations. The international meeting will be held under the auspices of the European Broadcasting Union, which has seven associate members in the United States. At a meeting of representatives of the EBU members, it was agreed that Mr. Harley should make the report. Other associate members of the EBU are: ABC, CBS, NBC, Time-Life Broadcast, Inc., National Educational Television, and U.S. Information Agency.

Mr. Harley also will coordinate the submission of filmed and taped programs which American broadcasting groups will send for the auditioning and screening sessions to be held at the Paris meeting.

Eight members of the NAEB have been elected to three-year terms on the Board of Directors. They are: Loren B. Stone, station manager, KCTS, Seattle, and Hartford Gunn, Jr., general manager, WGBH, Boston, representing the Educational Television Stations Division of NAEB; Will I. Lewis, director of broadcasting, WBUR-FM, Boston University, Boston, and Myron Curry, manager, KFJM, University of North Dakota, Grand Forks, representing the National Educational Radio Division; Dr. George Bair, educational director, South Carolina, TEV Commission, Columbia, and Hugh Green, TEMP project coordinator, radio-TV KUT-FM, University of Texas, Austin, representing the Instruction Division; Kenneth K. Jones, director of broadcasting, KFBS-FM, San Diego State College, San Diego, and Dr. Lee Dreyfus, University of Wisconsin, Madison, representing the Individual Membership Division.

Chairman of the NAEB full board is E. G. Burrows, manager of WUOM WVGR, The University of Michigan, Ann Arbor. Robert Schenkkan, general manager of KLRN Austin-San Antonio, is vice-chairman.

OBITUARY

Alexis "Alex" Badmaieff, 54, chief engineer, acoustics-tranducers at Altec Lansing, died suddenly on December 31. Born in Petrograd, Russia, Mr. Badmaieff came to the United States in 1922 and was naturalized in 1941. He was the holder of 27 patents in the fields of electronics, acoustics, optics, and mechanics. The author of many technical papers and articles for scientific journals and magazines, he recently coauthorized the book *How to Build Speaker Enclosures*.

During his career, Mr. Badmaieff did work for almost every major motion picture company in Hollywood. In 1950, he was nominated for an award by the Academy of Motion Picture Arts and Sciences for the original 150-pound magnetic sound recording channel developed for Paramount Pictures. During World Warr II, he contributed to improvements on the proximity fuse, certain control circuits for the Manhattan Project, a submarine depth-charge indicator, development and supervision of a pilot production run of nonmetallic land-mine detectors, and motion-picture recording and fast development processes.

Mr. Badmaieff joined Altec Lansing in 1952, after having served for many years in a consulting capacity. He was in charge of research, engineering, and quality control of all acoustical and transducer items and systems. ▲

Compressors

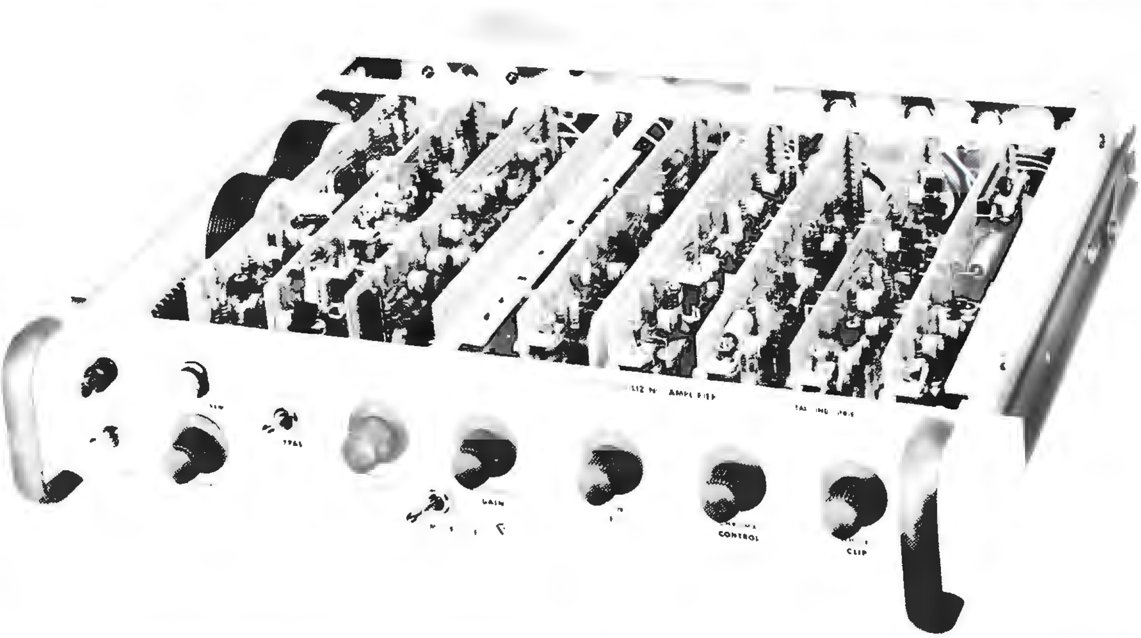
(Continued from page 20)

tences is maintained virtually unaltered.

3. The average modulation level of a transmission can be increased to give better signals in fringe areas, and thus an extension to the range of a station. In doing this, however, the dynamic range must inevitably be compressed still further, with a resulting "flatness" which will be appreciable on symphonic music, opera, etc., but probably will be tolerable on speech and popular music.
4. The equipment cannot (unless providing for recording and playback) foresee the future and compensate for an event before it happens. To this extent, its control of a musical program will always be inferior to that of an intelligent, trained human operator.
5. For most program purposes it is possible to obtain a reasonable control function which will be undetectable except to the most discriminating of listeners. ▲

OVER 200 STATIONS

NOW ENJOY THE BENEFITS OF OUR VI-500 SOLID STATE COLOR STAB AMP WITH AGC



THIS YEAR AGAIN AT THE NAB SHOW WE WILL NOT HAVE THE LARGEST EXHIBIT SPACE BECAUSE WE DON'T MAKE EVERYTHING. BUT WHAT WE DO MAKE IS VITAL FOR GOOD TELEVISION, AND NOW FOR THOSE WHO WANT EVERYTHING IN COLOR VIDEO PROCESSING, VITAL INDUSTRIES WILL DEMOSTRATE THE VI-1000 COLOR VIDEO PROCESSING AMPLIFIER. IT WILL PROVIDE:

- ★ REGENERATED PULSES. LIKE HAVING AN EIA SYNC GENERATOR WITH ADJUSTABLE PULSE LEVELS AND WIDTHS.
- ★ HIGH NOISE IMMUNITY IN CLAMPING.
- ★ MANUAL OR AUTOMATIC LUMINANCE LEVEL CONTROL.
- ★ MANUAL OR AUTOMATIC CHROMA LEVEL CONTROL.
- ★ REFORMED CLEAN BURST OR ALLOW ORGINAL BURST TO GO THROUGH.
- ★ PEDESTAL CONTROL TO ALLOW OPERATION AT A FIXED MINIMUM LEVEL TO COMPLY WITH FCC RULES.
- ★ INDEPENDENTLY ADJUSTABLE WHITE STRETCH, BLACK STRETCH AND WHITE CLIP.
- ★ SYNC PULSES AT OUTPUT IN ABSENCE OF INCOMING VIDEO.
- ★ MAXIMUM PROTECTION AGAINST FCC VIOLATION WHEN USED AT TRANSMITTER INPUTS.

THINK IT CAN'T BE DONE?

Let us show you

BOOTH 203 WEST HALL

NEVER BEFORE HAS SUCH A MODEST INVESTMENT DONE SO MUCH FOR THE TELEVISION BROADCASTER.

GOOD ENGINEERING IS VITAL

Write for complete information and specifications.

VITAL INDUSTRIES 3614 SOUTHWEST ARCHER ROAD GAINESVILLE, FLORIDA—PHONE (904) 378-1581

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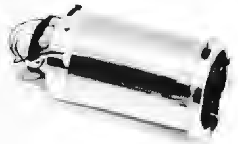
NEW PRODUCTS

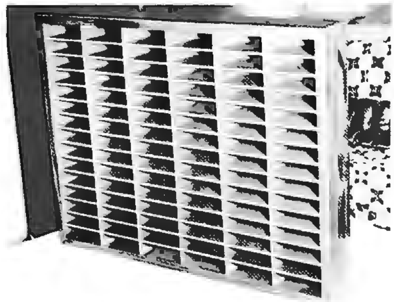
For further information about any item, circle the associated number on the Tech Data Card.



Deflection Assembly
(76)

A one-inch vidicon deflection assembly has been designed by **Lake Electronics, Inc.,** for use with all currently available vidicon tubes incorporating a basic 40-gauss field design. The component includes a yoke, a focus coil, and an alignment device. and offers full adjustment of individual components included within the assembly. Four insulated lead feed-throughs are provided for passage of lens remote-control leads from the face of the camera and deflection assembly to the rear of the assembly. A portion of the inside of the yoke has felt padding located directly under the area where the tube clamp, supplied with the assembly, is located. This padding provides a firm, nonabrasive clamping of the tube.

For mounting purposes, the threaded outside surface of the front mounting plate can support the entire assembly, yet provide a quick method of installation or replacement of the deflection unit within the camera.



Cartridge Rack
(77)

A rack for holding tape cartridges is being manufactured by **Broadcast Products Co.** The Model CR-90 rack holds 90 cartridges and measures 22" x 28" x 4". Features include walnut-Formica® finish and interlocking construction. Net price is $35.

New!

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Color - TV - Variogon 1:2,1/18 - 200

SCHNEIDER

announces

the completion of the

10 millionth lens*

*it is the new COLOR-TV-VARIOGON

f/2.1 from 18 to 200mm

for television color cameras

to be introduced and demonstrated at the NAB Show in Chicago

JOS. SCHNEIDER & CO. OPTISCHE WERKE BAD-KREUZNACH, GERMANY

Circle Item 55 on Tech Data Card

Audio Console

(78)

A fully transistorized program for studio or remote broadcast use is now available from **United Radio Industrial.** The unit contains dual turntable, tape, and microphone input channels and program, monitor, and cue outputs. Gain controls are provided for all input channels and for monitor, cue, and master volume. "Cue-on-off" switches allow for cueing either tapes or records during broadcasts. A VU meter and built-in speaker are included. Specifications include harmonic distortion of 0.5% or less, hum distortion 120 dBm down at microphone inputs, and frequency response from 40 Hz to 15 kHz ± 1½ dB. The unit is of modular construction for easier maintenance.

The price of the console is $495. The legs shown in the photo, which are designed to straddle dual turntables, are priced at $23.80.

Self-Contained Camera
(79)

A self-contained TV camera is being produced by **Cohu Electronics, Inc.** This closed-circuit camera, designated the 4100 series, has all-silicon solid-state circuitry and is available for use with a broadcast television receiver or a video monitor. Both camera installations use 75-ohm coaxial cable to connect the camera with the monitor or receiver.

Automatic adjustment of sensitivity is provided for unattended operation over an illumation range of greater than 5000:1 with highlight intensities as low as 10 foot lamberts. The camera housing is finished in mar-resistant vinyl-clad aluminum and measures 3-3/4" x 7" x 12". The entire camera weighs less than 6 pounds, including the 1" lens and vidicon. Any standard TV 16-mm "C"-mount lens may be used. The mounting base is tapped for standard 1 4-20 camera-tripod screws.

The price is $750, complete with vidicon and lens.

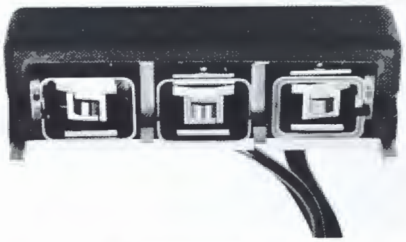
Circular Slide Rule

(80)

General Industrial Co. is now producing a small circular slide rule for engineers and other plant and office executives. It can be used to multiply, divide, and find proportions quickly; instructions are included.

The slide rule is free to engineers or executives who request it on a business letterhead to General Industrial Co., 1788J Montrose Avenue, Chicago, Illinois 60613. Requests should include the name of this magazine and the writer's zip code.

Persons who do not qualify as an engineer or other business executive may purchase the slide rule for 50 cents.



Replacement Heads

(81)

A line of professional erase, record, and reproduce heads for all Ampex recorders in the 300, 350, 400, 450, and 3100 Series is offered by **Minneapolis Magnetics, Inc**. They are available in both full- and half-track styles for machines using ¼" tape, and are designed for direct interchangeability, both mechanically and electrically.

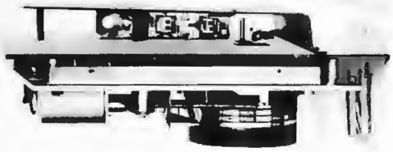
During manufacture, each half of the stack is aligned and balanced with its mating half by the use of two radius straps; then the entire assembly, except the pole face, is encapsulated to prevent alignment shift. The face is then lapped by the "Cross-Radial" process, which was developed to eliminate the need for a run-in period after the head is installed in the machine.

Heads can be installed by Minneapolis Magnetics, by some of its distributors, or by the purchaser. Individual heads are priced at $32, professional net.

New Tape-Deck Design

(82)

Several design improvements have been incorporated in the **Sparta** CH-5 tape-cartridge deck designed for multicartridge machines with four independent playback mechanisms. For reduced size, a direct capstan drive system is used. Regulation of the pinch-roller-to-capstan pressure



is done by movement of the capstan shaft rather than by angular variation of the pinch roller. This arrangement is to keep the roller and capstan always parallel and vertical to achieve uniform pressure across the width of the tape and more accurate alignment of these parts with the tape.

Insertion of the cartridge raises the pinch roller to "ready" by solenoid action. No other operator action is required. The "play" function is solenoid actuated, featuring a mechanical damper for quiet operation. The tape heads are protected because the cartridge is guided on all sides. The guide itself swings away when larger cartridges are used.

The CH-5 tape-deck mechanism contains a hysteresis synchronous motor with life-time-lubricated ball bearings.

VTR for CCTV Use

(83)

This solid-state video tape recorder system is designed primarily for the educational, business training, and industrial markets. The basic VTR system is made up of a recorder, a closed-circuit TV camera, and a 12-inch monitor (74 sq in. viewing area) Accessory equipment includes a microphone, tripod, connecting cable, and recording tape The system is available in two configurations, a "Tri Pack" consisting of three separate units each contained in a case for hand carrying, and a mobile console (illustrated) housed in a

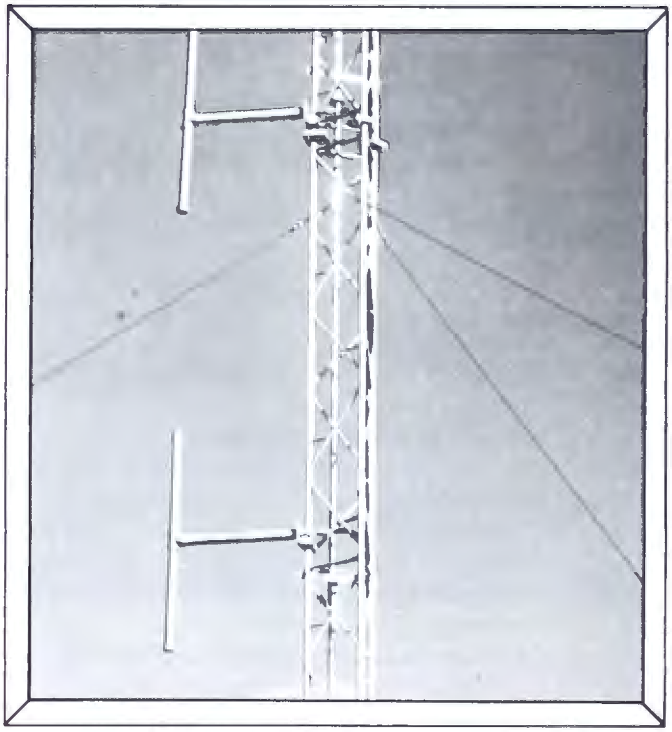
wooden cabinet finished in walnut-grain and light beige Textolite®.

The camera is all solid-state except for the vidicon; it is equipped with a crystal-controlled oscillator for improved picture stability. Camera resolution is approximately 500 lines when displayed on a standard video monitor.

The complete system, made by the **General Electric Co.,** has a suggested list price of $1695 for the portable 3-piece unit, and $1995 for the mobile console.

40,000-Watt FM Transmitter
(84)

Designed for the maximum-power Class C FM station utilizing both horizontal and vertical polarization, the **Gates Radio Co.** FM-40G consists of two 20-kw FM transmitters operating into a combiner. Single or dual exciters with automatic switchers are available as accessories. The unit is contained in three cabinets plus two power supplies which utilize solid-state rectifiers. The transmitter is fully FCC type approved. ▲



Expanded production facilities and increased volume capacity at our factory mean superior JAMPRO quality antennas can now be furnished at these new low prices. Save up to 42% on your FM antenna. Call Jampro today.

PRICES EFFECTIVE FEBRUARY 1, 1967

JAMPRO TYPE	No. of H. Bays	No. of V. Bays	NEW PRICE
J2B/2V	2	2	$2,075.
J4B/4V	4	4	$4,150.
J6B/6V	6	6	$6,500.
J8B/8V	8	8	$8,900.
J10B/10V	10	10	$11,100.

Prices apply to antennas having equal division of power to all bays.

For a complete list of prices and specifications, write or call Jampro Antenna Co., today!

- ANTENNAS MAY BE MOUNTED BACK to BACK or INTERPOSED to CONSERVE TOWER HEIGHT
- VSWR is better than 1.1 to 1 for ± 200 KC from carrier when properly installed.
- Antenna input connections are all 3⅛″ 50 ohms with EIA flanges.
- De-icers can be installed on **horizontal bays** at only $90 per bay. (250, 500, 1000 Watts)
- Prices are FOB Sacramento, Calif. and include suitable tower mounting hardware.

JAMPRO

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Circle Item 68 on Tech Data Card

Engineers' TECH DATA

ANTENNAS & TRANSMISSION LINES

100. ANDREWS TOWERS—Brochure details features of "quick-erect" tower.
101. FT. WORTH TOWER—Literature describes tropo-scatter antenna systems; fabrication and installation of towers; and passive reflectors, equipment buildings, and accessories.
102. MOSELEY ASSOCIATES—Bulletin 218 has as its subject Isocouplers designed to facilitate connection to remote-pickup or aural STL antennas mounted on ungrounded AM towers.

AUDIO EQUIPMENT

103. ATLAS SOUND—Catalog 566-67 lists public-address loudspeakers and microphone stands and accessories.
104. GATES—Large fold-out sheet "The Most Complete Line of Consoles From Gates" illustrates and gives specifications for ten console models.
105. KOSS—Two booklets give descriptions of Rek-O-Kut turntables and Koss personal listening products.
106. QUAM-NICHOLS—Catalog 66 contains information about line of loudspeakers for public-address, background music, and replacement use.
107. SPARTA—Product guide has illustrations, descriptions, and specifications of Model RA-5 two-channel, three-input remote broadcast amplifier/mixer.
108. STANFORD INTERNATIONAL—Catalog sheets are concerned with MB microphones and headphones, and Butoba professional portable tape recorder.
109. SWITCHCRAFT—Literature includes Audio Accessory Catalog A-401b, with data on audio mixers, speaker controls, couplers, adapters, selector switches, molded cable assemblies, and audio connectors; Bulletin 165 describes two pendant (cord) switches.
110. TELEX—Brochures and information sheet are about 300/600 Series and Teleset headphones; Magna-Twin Mark II headphone; Dynaset, Monoset, and Tele-Fi headphones; and replacement/optional accessories.

CATV EQUIPMENT

111. AMECO—Pacesetter series of CATV amplifiers and "Courier" multichannel CCTV transmission systems are subjects of two brochures.

COMPONENTS & MATERIALS

112. AUTOMATED MEASUREMENTS—Data sheet on remotely programmable coaxial switches is available.
113. CHERRY ELECTRICAL—Offer includes pocket selector guide for precision switches; brochures on crossbar-type selector switches, "Snap/Reed" switches, and "Feather-Touch" miniature switches; and short-form switch catalog.
114. DIALIGHT—Catalog Sheet L-202 tells about flashing indicator light that uses NE-2J high-brightness neon lamp.
115. MAGNECRAFT—"Designers' Handbook & Catalog of Reed and Mercury Wetted Contact Relays," Product Data Bulletin No. 665 on Class 22F relays, and Engineering Bulletin 465A on coaxial relays are offered.

116. MICROTRAN—34-page catalog of transformers and toroids also contains charts, graphs, applications, schematics, and notes for transformer specification.
117. NATIONAL SEMICONDUCTOR—Illustrated catalog describes more than 500 types of silicon transistors and integrated circuits.
118. SHALLCROSS—Black-and-white and two-color drawings are used in Catalog RS 100 of precision rotary switches.
119. STACO—Flyer gives descriptions of four bench-model variable autotransformers.
120. TECKNIT—Data Sheet EMC-061 provides specifications on 40 standard Teckcell ventilating panels designed to fit 19-inch and 24-inch EIA cabinets.
121. TROMPETER—Subjects of literature are precision connectors, coaxial video and data switching systems, patch panels and accessories, and low-noise twinaxial and triaxial cable.
122. UNIMAX—Condensed Catalog No. 123B gives information about snap-acting switches.

MICROWAVE EQUIPMENT

123. AIRTRON—16-page publication presents information on waveguide systems and components for microwave communication systems.
124. MICROLAB/FXR—1967 short-form catalog contains specifications, features, and prices of items from line of microwave products.

MISCELLANEOUS

125. AIR SPACE DEVICES—Brochure STC 5-65-10M is about SAF-T-CLIMB, for safety in climbing structures.
126. BRADY—Bulletin 405 describes fingertip-operated embossing machine that prints self-adhesive plastic labels for electronic parts and equipment.
127. DENSON—160-page Catalog 966-S1 lists new, used, and surplus electronic equipment.

MOBILE RADIO & COMMUNICATIONS

128. MOSLEY ELECTRONICS—1967 catalog lists line of Citizens-band antennas.

POWER DEVICES

129. HEVI-DUTY—Bulletin supplies data on line-voltage regulator using saturable-core reactor.
130. KATO—Four-page, four-color brochure shows high-voltage AC generators.

RECORDING & PLAYBACK EQUIPMENT

131. ALTEC LANSING—Short-form catalog BR6626 concerns broadcast and recording equipment; other literature is about rotary precision switches.
132. AUDIO DEVICES—1967 Audiotape catalog offers information on line of sound recording tape and accessories for professional use.
133. BROADCAST ELECTRONICS—Literature on SPOTMASTER tape-cartridge equipment gives specifications and price information on recorder/reproducer units, reproducer only, TEN SPOT multiple units, audio distribution amplifier, remote amplifiers, equalized turntable preamplifier, tape-cartridge winder, and cartridge racks.
134. VIKING OF MINNEAPOLIS—Two-color brochure describes Studio 96 professional tape transport and associated solid-state electronics.

REFERENCE MATERIAL & SCHOOLS

135. CLEVELAND INSTITUTE OF ELECTRONICS—Pocket-size plastic "Electronics Data Guide" includes formulas and tables for: frequency vs. wavelength, dB, length of antennas and color code.
136. HOWARD W. SAMS—Literature describes popular and informative technical publications; new 1967 catalog of technical books is included.
137. WEINSCHEL—Application Note No. 4 provides a description of the Dual Channel Insertion Loss Test Set, and contains block diagrams, operation procedures, and tables of equipment from various manufacturers.

TELEVISION EQUIPMENT

138. CANON—Catalog illustrates and gives specifications for industrial and broadcast TV lenses with fixed and variable focal lengths.
139. CLEVELAND ELECTRONICS—A 52-page quick-reference step-down die-cut catalog covers complete information on vidicon Plumbicon®, and image-orthicon deflection components.
140. COLORADO VIDEO—Data sheet tells about Model 120 thirty-channel "bar graph" generator.
141. COLORTRAN—ColorTran News, Issue No. 1, features application stories of interest to the motion picture and TV industries.
142. INTERNATIONAL NUCLEAR—Literature concerns TDA7 precision distribution amplifier and TVM2 transistorized video modulator.
143. KLIEGL BROS.—Offered is reprint of article "Lighting for the Plunge to Color," by Herbert R. More.
144. LAKE ELECTRONICS—Descriptive folder contains drawings and specifications of vidicon deflection components.
145. LIGHTING & ELECTRONICS—TV studio lighting layout request form is available.
146. METRO TEL—Descriptive sheet is about TV transmission line equalizers and delay lines.
147. TELEMATION—Literature describes TSG-2000 EIA sync generator for producing all required monochrome and or color waveforms for television broadcast transmission.
148. TELEMET—Sheets give information on Model 3508-C1 video transmission test signal generator and Model 3208-A1 dual video distribution amplifier.
149. VITAL—Information is for Model VI-10A video distribution amplifier and Model VI-20 pulse distribution amplifier.

TEST & MEASURING EQUIPMENT

150. BARKER & WILLIAMSON—Subjects of catalog sheet are Model 210 audio oscillator and Model 410 distortion analyzer.
151. [illegible]A—Catalog sheet covers AM frequency and modulation monitor.
152. DYNAIR—Bulletin No. 91A supplies information on Model TS-100B solid-state sideband analyzer for use in alignment of broadcast and CATV modulators.
153. WATERS—RF instrumentation equipment is listed in leaflet.

TRANSMITTERS & ASSOCIATED EQUIPMENT

154. BAUER—New product brochure describes Model 601 3000/5000 watt FM transmitter.
155. ENGLISH ELECTRIC—Technical description of Marconi 25-kw UHF transmitter type B7301 is available.
156. TELETRONIX—Specification sheets are for 10 kHz monitor, 250-watt to 10-kw FM transmitters, horizontal and vertical antennas, automatic leveling amplifier and other broadcast equipment.

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Advertising rates in the Classified Section are fifteen cents per word. Minimum charge is $2.00. Blind box number is 50 cents extra.

The classified columns are not open to the advertising of any broadcast equipment or supplies regularly produced by manufacturers unless the equipment is used and no longer owned by the manufacturer. Display advertising must be purchased in such cases.

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EQUIPMENT WANTED

EMPLOYMENT

EXPERIENCED CATV ENGINEER WANTED

System to begin construction. Located out of Pittsburg, Pa. Area.

Send Resume

BROADCAST ENGINEERING
Dept. 169 2-67-2t

PROJECT ENGINEERS

Project Engineers, all levels for challenging assignments in the design of audio, video & control facilities for color TV studios. BSEE and minimum of 2 years experience, preferably in broadcasting, required.

Location: CBS Headquarters Building, midtown Manhattan

Please send resume and salary requirments, to:

WILLIAM JR. REILLY, JR.
Personnel Dept.

COLUMBIA BROADCASTING SYSTEM, INC.
51 W 52 St., N.Y., N.Y. 10019
12-66-3t

RADIO ENGINEERS — Earn extra money part time. P/M Associates is national headquarters for contract engineering services. Many current openings for 1st class engineers. For full information write: Personnel Manager, P/M Associates, Inc., 203 Pond Street, Natick, Mass. 01760. 2-67-3t

TELEVISION ENGINEERS

We are interested in contacting Station Engineers capable of design or field engineering. Excellent opportunities in TV Development Engineering and Systems Engineering with Sarkes Tarzian, Inc., Broadcast Equipment Division.

TV station engineering experience required, BSEE or equivalent desirable. Send resume of experience, or call, Mr. Biagio Presti, Broadcast Equipment Division, Sarkes Tarzian, Inc., Bloomington, Indiana, Area Code 812, 332-7251.

Symbol of Excellence in Electronics

REPRESENTATIVES WANTED — Large established Eastern Manufacturer needs representatives for FCC TYPE ACCEPTED AM and FM broadcast transmitter line. Selected territories available throughout U.S. Established broadcast equipment representatives preferred, but will consider individuals in related areas of the broadcast field. Interested parties are requested to reply to Mr. L. K. Peetoom, American Electronic Labs, Inc., P.O. Box 552, Lansdale, Pa. 19446. 2-67-2t

Job Headquarters for all Radio and Television Engineers. Immediate openings exist in 9 western states and elsewhere for qualified engineer and technical personnel. All categories from trainees to experienced transmitter maintenance, chief, assistant chief, live color video maintenance and technical operations. Send us your complete resume now. The AMPS Agency, 3974 Wilshire Blvd., Los Angeles, California 90005. Telephone DU 8-3116.
By Broadcasters—For Broadcasters 11-66-tf

IMMEDIATE EMPLOYMENT — ENGINEER, background in video equipment maintenance. Good salary and fringe benefits. Contact Robert Schlorff, Mass Communciations, Wayne State University, Detroit, Michigan. 3-67-2t

WTOC-AM-FM-TV, Savannah, Georgia, has opening for first class engineer with experience. Reply by letter to Chief Engineer, WTOC, P.O. Box 858, Savannah, Georgia 31402. 2-67-3t

NEEDED IMMEDIATELY: experienced TV Broadcast Engineers with first phone for expanding staff of WTMJ-TV, Wisconsin's leading AM-FM-TV broadcast facility. Pioneers in color broadcasting. Presently operating from new studios with latest color equipment. Excellent pay and benefits when you work for this employee owned company. Call or write to Chief engineer, WTMJ-TV, Milwaukee. (414) 271-6000 2-67-2t

TELEVISION SYSTEM SPECIALISTS—Positions open on the Apollo Program with General Electric at Cape Kennedy, Fla. Duties include adequacy reviews of TV installations at the launch site, liaison work in support of operational TV systems used for check-out and launch of space vehicles, preparation of installation and test procedures for TV systems, support of design and system engineering on all Television installations. BS degree preferred, but not essential, or H.S. diploma with industrial training school or training courses desirable. 4 years industrial experience desirable with at least 1 year work involving television or communication systems. Write to: Mr. F. G. LaMotte, Apollo Support Dept., General Electric Co., Room 1180C, P.O. Box 2500, Daytona Beach, Fla. 32015. (An equal opportunity employer, M/F.) 3-67-1t

Young engineer looking for challenge of chief's position. You'll be working for a long established full-time nondirectional station in the Shenandoah Valley of Virginia. Position offers good starting salary, security, and fringe benefits. Theory, maintenance, technical, and practical ability a must. This is a long-term position, with a solid future for the man who earns it, in a settled, hard-working, friendly operation. Dept. 172 BROADCAST ENGINEERING. 3-67-1t

AUDIO COMMUNICATIONS SPECIALISTS—Work on the Apollo Program with General Electric at Cape Kennedy, Fla. The position involves working with operational intercommunication and paging systems required for checkout and launch of space vehicles, and includes launch readiness reviews, design modifications, and component analyses. BS degree preferred, or HS diploma with 4 years industrial experience including 1 year experience in communication and special audio systems. Write to: Mr. F. G. LaMotte, Apollo Support Dept., General Electric Co., Room 1180-C-1, P.O. Box 2500, Daytona Beach, Fla. 32015. (An equal opportunity employer. M/F.) 3-67-1t

WANTED: Technicians for closed circuit television-video tape-TV cameras—maintenance. Allstate Communications, 1200 West Chestnut Street, Union, New Jersey, 201-687-8810. 3-67-1t

TECHNICAL EDITOR-WRITER

Broadcast Engineering

has an immediate opening for a technical editor-writer. An FCC first-class radiotelephone license and five years of technical experience at broadcast stations are required. Writing or editing experience and/or one or more years of college are desirable.

Send resume and salary requirements to:

Personnel Director
Howard W. Sams & Co., Inc.
4300 West 62nd Street
Indianapolis, Indiana 46206

PERSONNEL

Broadcast Engineer, would like position in radio or television station within sixty miles of New York City. Can do some announcing. 24 years old; First Class license; Associate in Applied Science degree; experience in A.T. & T. microwave and carrier. Military experience with missile radar. Attending college evenings in N.Y.C. toward B.S.E.E. degree. Wish to make career in broadcasting and want job with some challenge. Ability unlimited. Dept. 173 Broadcast Engineering. 3-67-1t

TV ENGINEERING PLACEMENT ALL EMPLOYER PAID FEES

Check Area of Interest

- Director of Eng. ☐
- Xmtr supervisor ☐
- Studio supervisor ☐
- Xmtr technician ☐
- Studio technician ☐
- Video tape technician ☐
- Allied fields ☐
- Other ☐

Name ....
Address ....
Salary Desired ....

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System to begin construction. Located out of Pittsburg, Pa. Area.

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Dept. 169 2-67-2t

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Job Headquart vision Engineer in 9 western st ified engineer categories fron transmitter m chief, live col technical opera plete resume n Wilshire Blvd 90005. Telephon By Broadcaster

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Send resume and salary requirements to:

Personnel Director
Howard W. Sams & Co., Inc.
4300 West 62nd Street
Indianapolis, Indiana 46206

PERSONNEL

Broadcast Engineer, would like position in radio or television station within sixty miles of New York City. Can do some announcing. 24 years old; First Class license; Associate in Applied Science degree; experience in A.T. & T. microwave and carrier. Military experience with missile radar. Attending college evenings in N.Y.C. toward B.S.E.E. degree. Wish to make career in broadcasting and want job with some challenge. Ability unlimited. Dept. 173 Broadcast Engineering. 3-67-1t

TV ENGINEERING PLACEMENT
ALL EMPLOYER PAID FEES

Check Area of Interest

- Director of Eng. ☐
- Xmtr supervisor ☐
- Studio supervisor ☐
- Xmtr technician ☐
- Studio technician ☐
- Video tape technician ☐
- Allied fields ☐
- Other ☐

Name........................

Address........................

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Circle Item 73 on Tech Data Card

You have only *one opportunity* to plug in an RCA solid-state rectifier

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