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MARCH 1967/75 cents

Broadcast Engineering

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of the broadcast-
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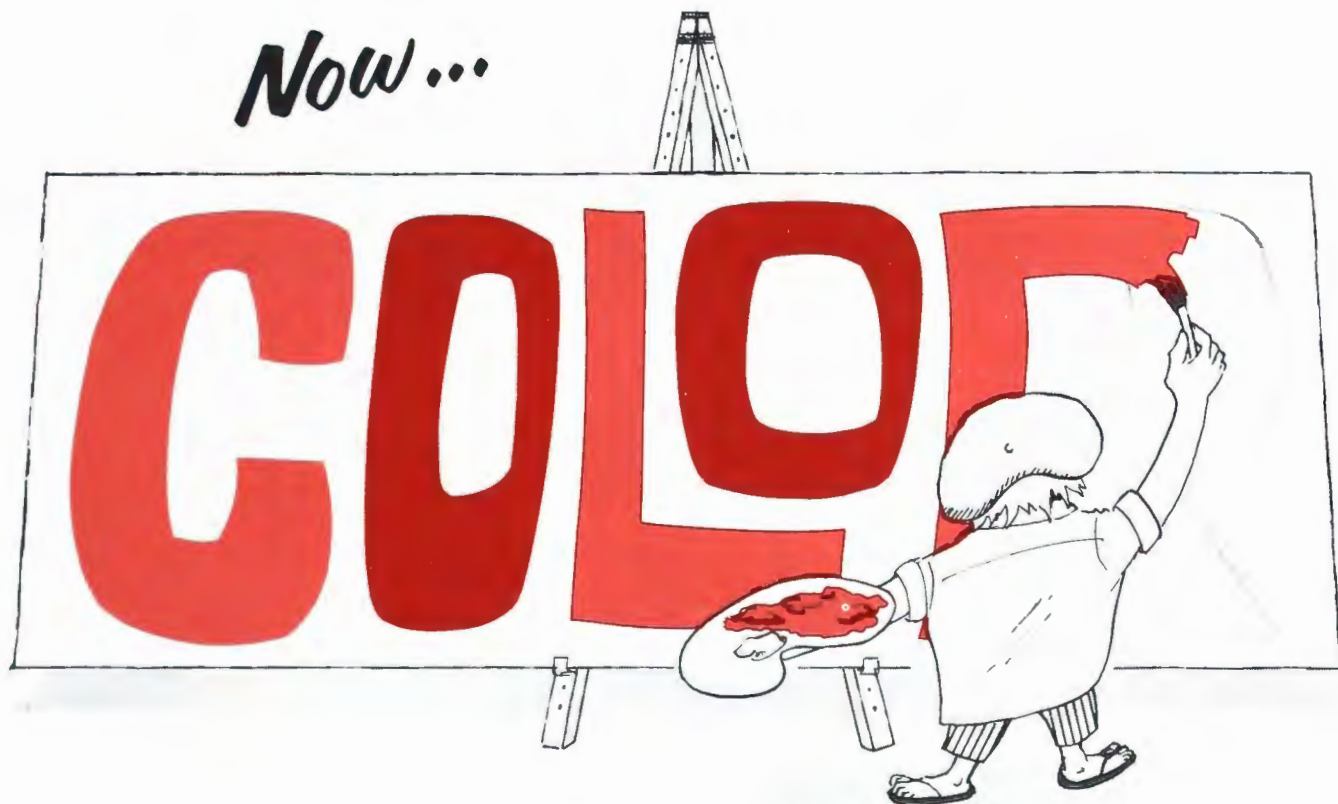
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the technical journal of the broadcast-communications industry



Broadcast Engineering

Volume 9, No. 3

March, 1967

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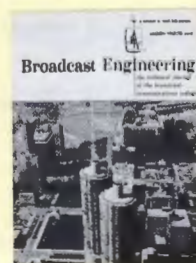
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This aerial view shows part of downtown Chicago, which is of course the host city to the 1967 NAB Convention. Dominating the picture are the twin towers of Marina City and the antennas of WBKB (Channel 7) and WFLD (Channel 32). (Cover photo courtesy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



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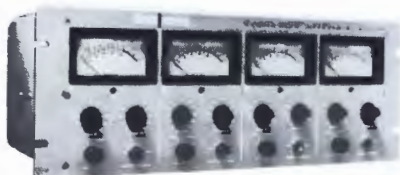


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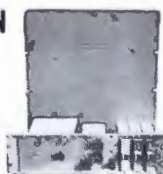


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Circle Item 4 on Tech Data Card

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 identification 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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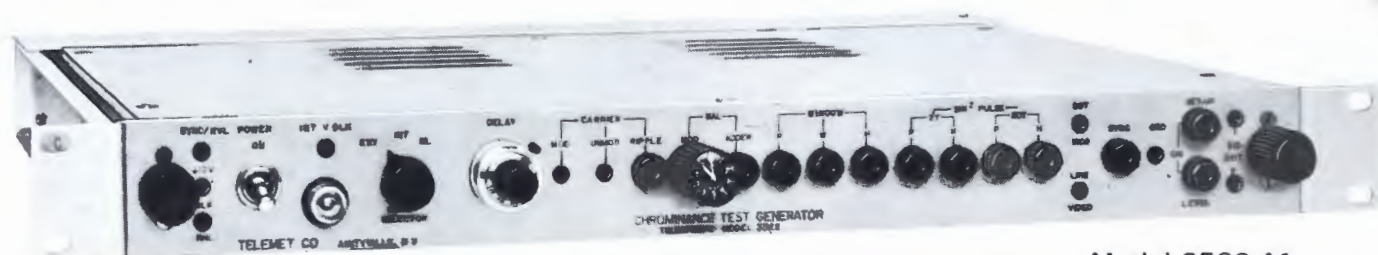
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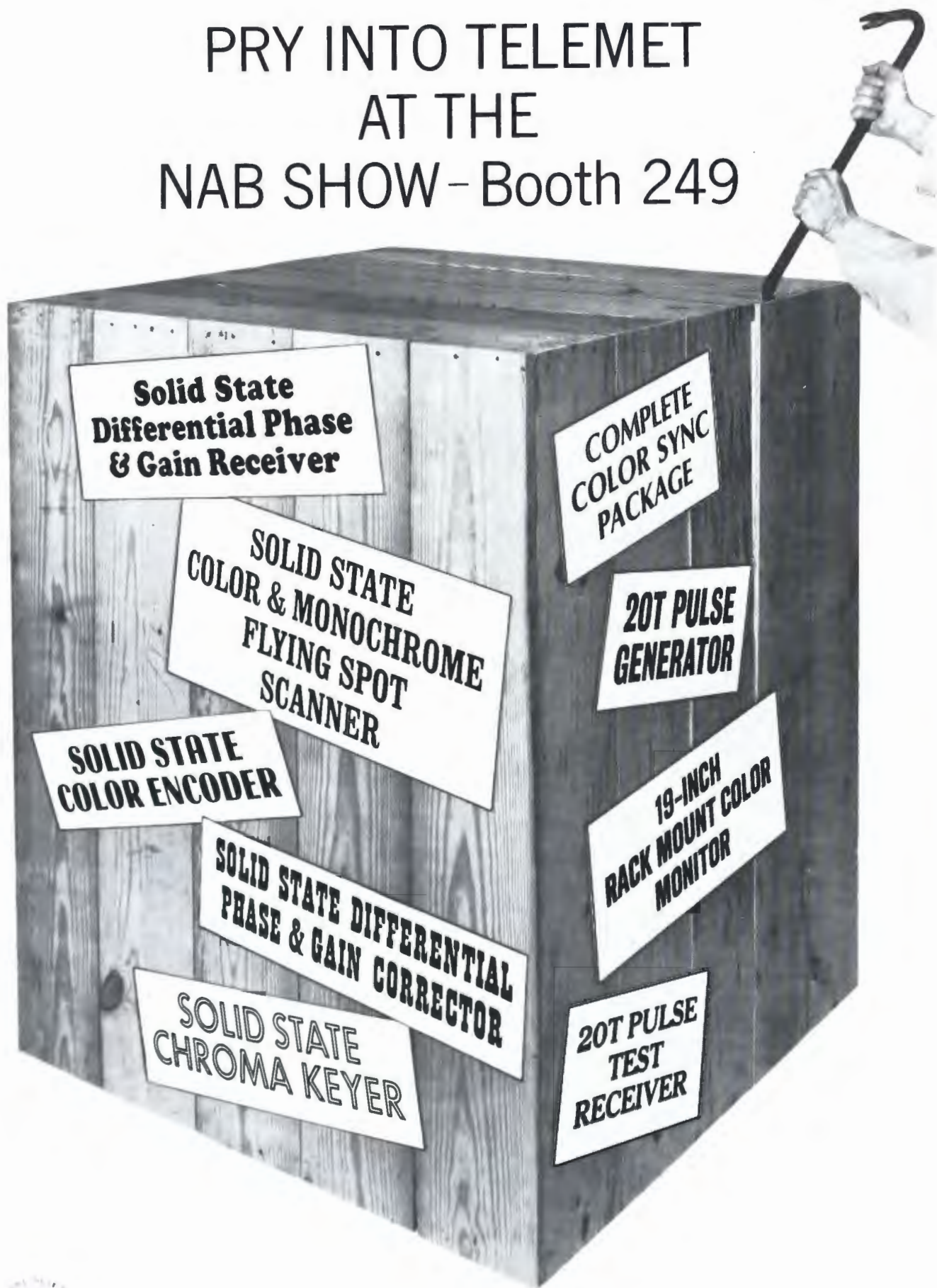


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March, 1967

A black and white cartoon illustration of a screaming, furry monster head. The head is round with a jagged, spiky outline. It has large, wide eyes with thick, dark eyelids and a large, dark, textured mouth that is open in a scream, showing sharp teeth. The monster has a long, thin, curled tail. The illustration is set against a background of a 3D box with the letters 'H' and 'A' on its top face.

Circle Item 8 on Tech Data Card

Letters *(Continued from page 6)*

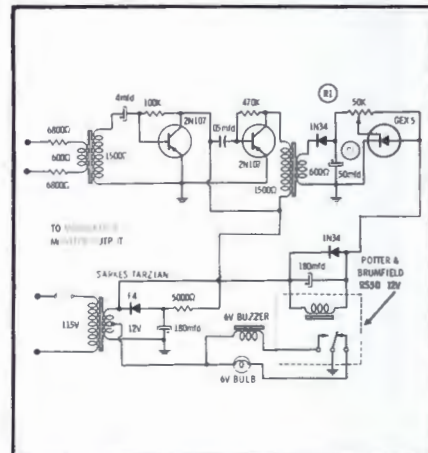
DEAR EDITOR:

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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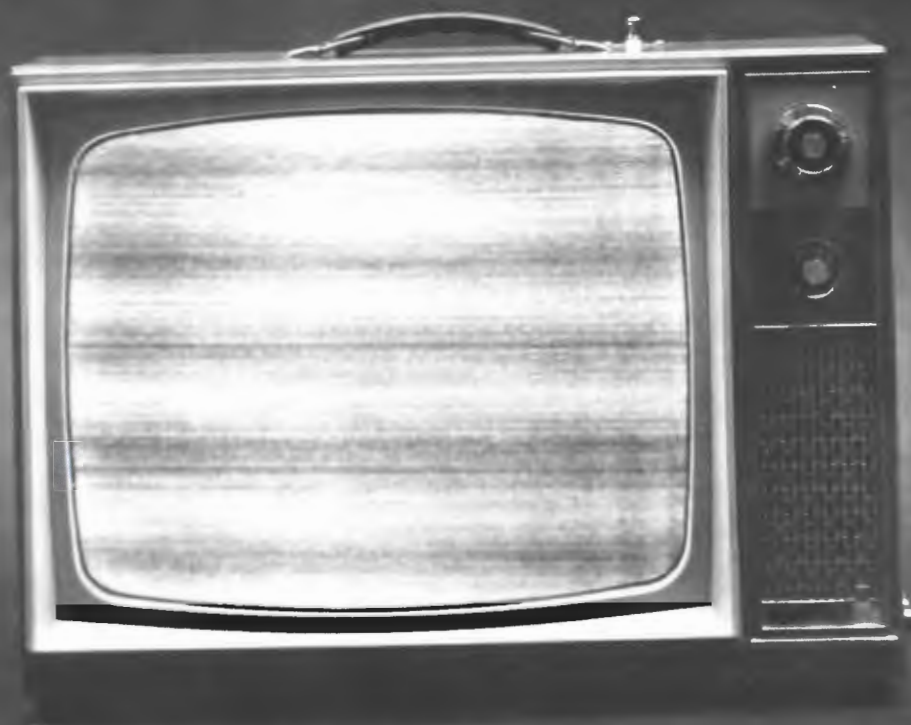
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It all comes down to this: when you're thinking about microwave transmission equipment for any application, think of Lenkurt. We'll show you how to improve your picture. Both TV and profit. Write or call Lenkurt Electric Co., Inc., San Carlos, California. Other offices in Atlanta, Chicago, Dallas, and New York City.

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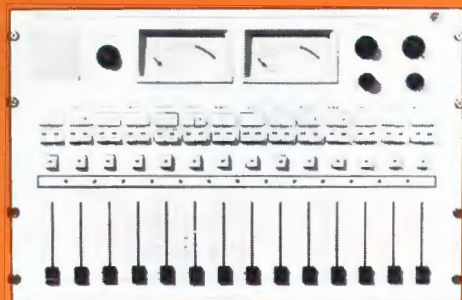
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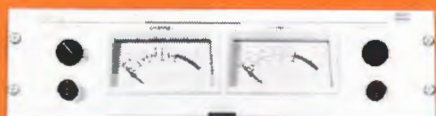
6-68

Circle Item 11 on Tech Data Card

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212T-1



212T-2

In 8 out of 10 cases
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CUSTOM console
requirements



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The 212T Audio Control Consoles consist basically of three units:

CONTROL PANELS. The control panel constitutes the difference between the two systems.

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 15 $\frac{3}{4}$ " high by 24" wide.

The 212T-2 control panel has 32 inputs to 16 faders. The panel is divided into two sections: The fader operating controls are mounted on a panel 10 $\frac{1}{2}$ " high by 19" wide: the

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RACK-MOUNTED ASSEMBLY. The assembly contains 16 pre-amplifier cards. Quantity and types of cards depend upon individual requirements. The assembly includes three program amplifier cards—one for cue and two for program channels. Two amplifiers are for speaker monitors; two switching cards select monitor inputs. The rack-mounted assemblies for the 212T-1 and 212T-2 are identical.

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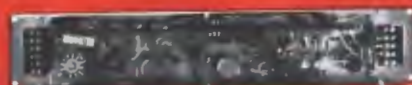


3KW FM



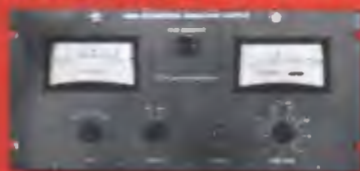
10KW FM

5C-1D MULTIPLEX SUBSIDIARY GENERATOR



The CCA 5C-1D is an inexpensive but reliable subsidiary generator which can be used with all modern FM transmitters to achieve a 2nd broadcast channel.

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A popular addition to the CCA product line is our FCC type approved AM modulation monitor. This instrument guarantees instantaneous evaluation of transmitter operation and is an essential tool for every broadcaster.

CCA transmitters offer a complete broadcast package including equipment supplied by government vendors such as towers, antenna transmission line and studio equipment. Contact your local CCA representative for a quotation.

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LA-1D Audio Limiter \$375.
AGC-1D AGC Audio Amplifier \$320.
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RFA-FM Remote FM RF Amplifier \$395.
RFA-AM Remote AM RF Amplifier \$425.
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MEMOREX

Circle Item 15 on Tech Data Card

March, 1967

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.

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

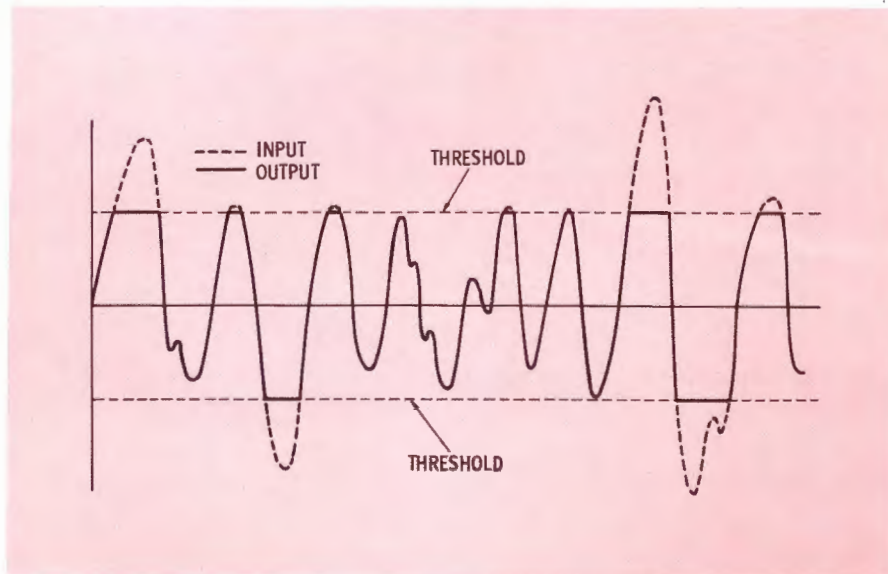


Fig. 1. Clipper controls peak signal level, but causes waveform distortion.

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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,

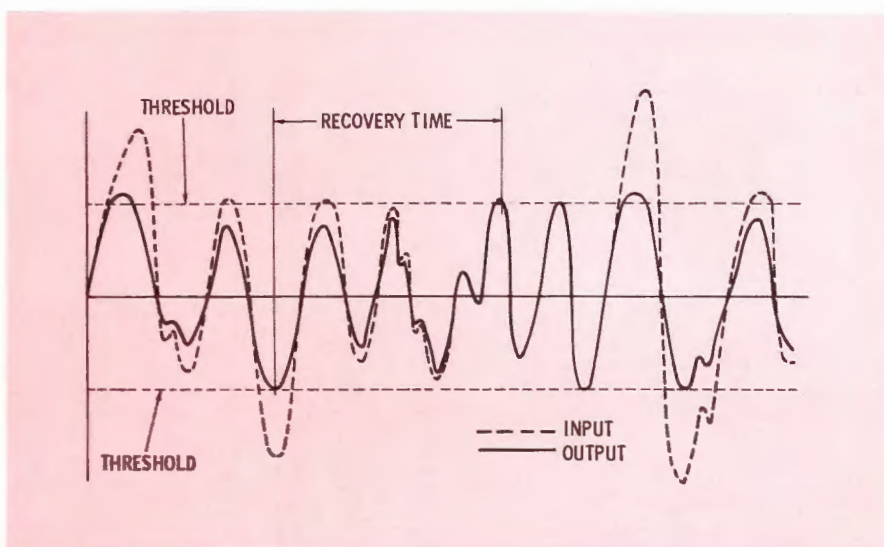


Fig. 2. Limiter reduces gain on peaks and restores it during recovery time.

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 in-

troduced 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

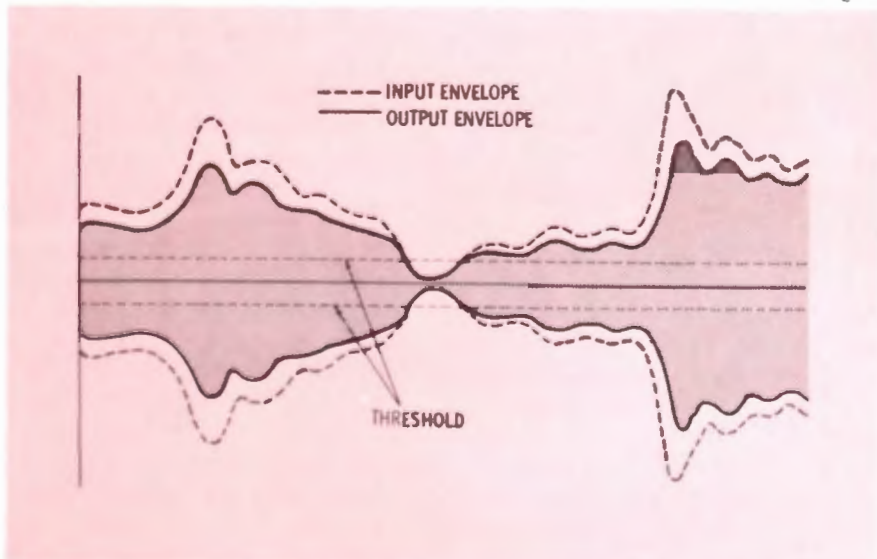


Fig. 3. Effect of compression on a signal gain is maximum with no signal

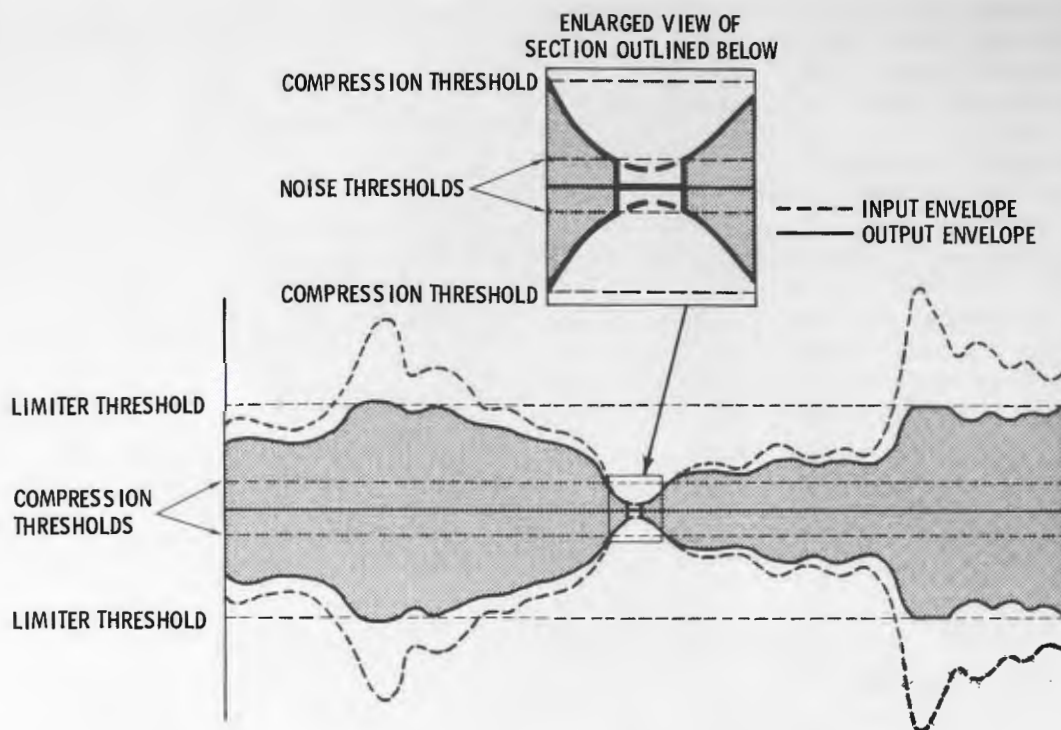


Fig. 4. Limiting, compression combined with gain reduction below noise threshold; all thresholds normally adjustable.

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 transmit-

ter 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 day-time, 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.

*Consulting Engineer, La Grange, Ill., and
BE Midwest Regional Editor

**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.

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 k th 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 k th tower acting alone.

$f_k(\theta)$ = vertical radiation characteristic of the k th tower.

θ = elevation angle of the observation point P measured up from the horizon in degrees.

$\beta_k = S_k \cos \theta \cos (\phi_k - \phi) + \psi_k$
= phase relationship of the field intensity at the observation point P for the k th tower taken with respect to the voltage-vector reference axis.

S_k = electrical length of spacing of the k th tower in the horizontal plane from the space reference point.

ϕ_k = true horizontal azimuth, orientation of k th 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 k th 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-

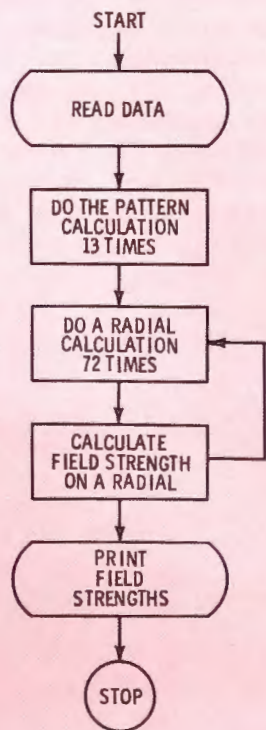


Fig. 1. Flow chart shows instructions given computer to solve the problem.

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 Key punch	= \$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 phases 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

$\kappa = .4045$

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 com-

puter 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 mat-

ter to program the computer to calculate only the bearings and elevations desired, and thus avoid the other lengthy computations.

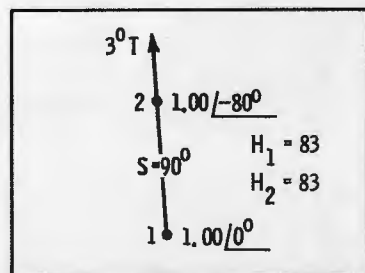
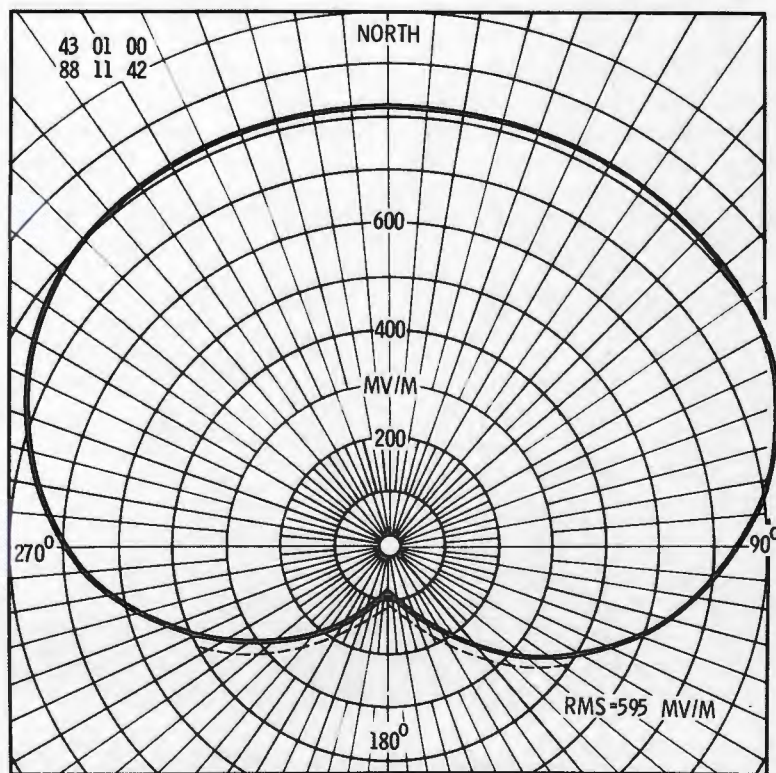
The computer applied to an existing station would be most helpful in three main areas. First is the analysis of a mistuning which might occur. Second is the evaluation of any reflection or distortion that might result from new construction in the vicinity of the array. Third is help in plans for future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



WAUK RADIATION PATTERN	
1510 KC	10 KW DA-D
WAUKESHA, WISCONSIN	
MAY, 1966	
ROBERT A. JONES	
CONSULTING ENGINEERS	
LA GRANGE, ILLINOIS	

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:

$$\begin{aligned} E &= IR \\ &= 1.0 \times 1000 \\ &= 1000 \text{ volts} \end{aligned}$$

The power supply voltage is 2000 volts, and with a current drain of

one ampere, 2000 watts of power is delivered, since:

$$\begin{aligned} P &= EI \\ &= 2000 \times 1.0 \\ &= 2000 \text{ watts} \end{aligned}$$

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:

$$\begin{aligned} P &= EI \\ &= 1000 \times 1.0 \\ &= 1000 \text{ watts} \end{aligned}$$

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

$$\begin{aligned} P &= EI \\ &= 1000 \times 1.0 \\ &= 1000 \text{ watts} \end{aligned}$$

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-

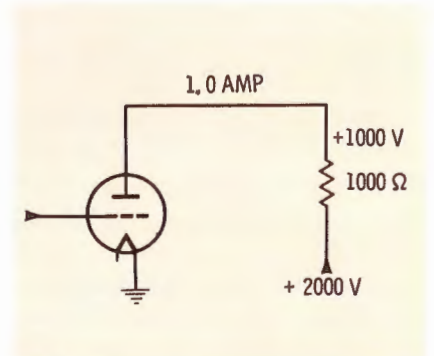


Fig. 1. Amplifier operation is shown in this partial resistance-coupled stage.

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

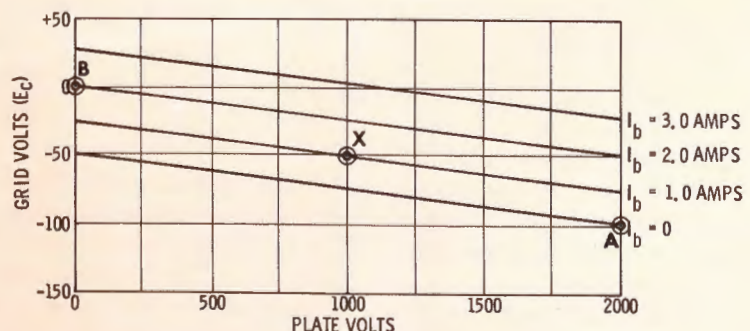


Fig. 2. Hypothetical constant-current curves are straight and evenly spaced.

*Principal Engineer,
Continental Electronics Mfg. Co.

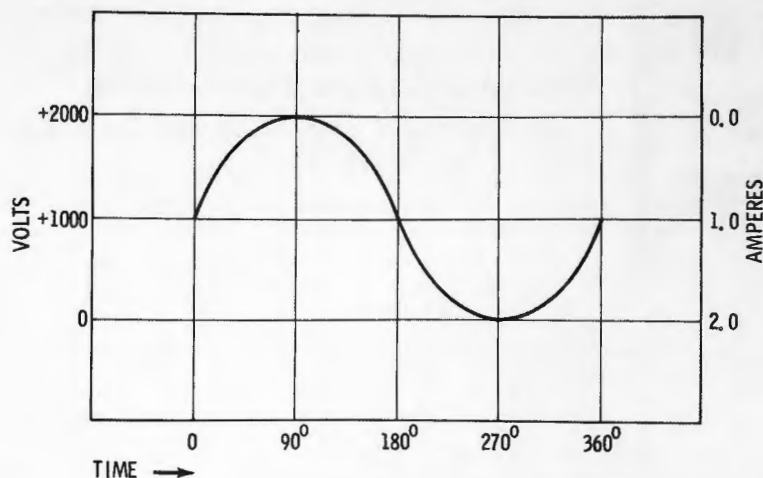


Fig. 3. Graph of plate voltage shows maximum swing for conditions assumed.

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:

$$\begin{aligned}\text{Plate current} &= 1.0 \text{ ampere} \\ \text{Plate voltage} &= 1000 \text{ volts}\end{aligned}$$

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:

$$\begin{aligned}I &= \frac{E}{R} \\ &= \frac{2000}{1000} \\ &= 2.0 \text{ amperes}\end{aligned}$$

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:

$$\begin{aligned}\text{Plate voltage} &= 2000 \text{ volts} \\ \text{Plate current} &= 0\end{aligned}$$

These values determine Point A.

The conditions at negative peak are:

$$\begin{aligned}\text{Plate voltage} &= 0 \\ \text{Plate current} &= 2.0 \text{ amperes}\end{aligned}$$

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:

$$\begin{aligned}A &= \frac{E_{out}}{E_{in}} \\ &= \frac{2000}{100} \\ &= 20\end{aligned}$$

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:

$$\begin{aligned}P &= EI \\ &= 1000 \times 1.0 \\ &= 1000 \text{ watts}\end{aligned}$$

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:

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

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:

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

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

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

Since this power is taken from the tube and the plate input power

is still 1000 watts, the efficiency at maximum signal is:

$$\begin{aligned}\eta &= \frac{\text{Power out}}{\text{Power in}} \times 100 \% \\ &= \frac{500}{1000} \times 100 \\ &= 50\%\end{aligned}$$

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:

$$\begin{aligned}\text{Plate Dissipation} &= 500 \text{ watts} \\ \text{AC heat in resistor} &= 500 \text{ watts} \\ \text{DC heat in resistor} &= \frac{1000 \text{ watts}}{2000 \text{ watts}}\end{aligned}$$

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:

$$\begin{aligned}P &= \frac{E_{\text{rms}}^2}{R} \\ &= \frac{353^2}{1000} \\ &= \frac{125,000}{1000} \\ &= 125 \text{ watts}\end{aligned}$$

The plate efficiency is:

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

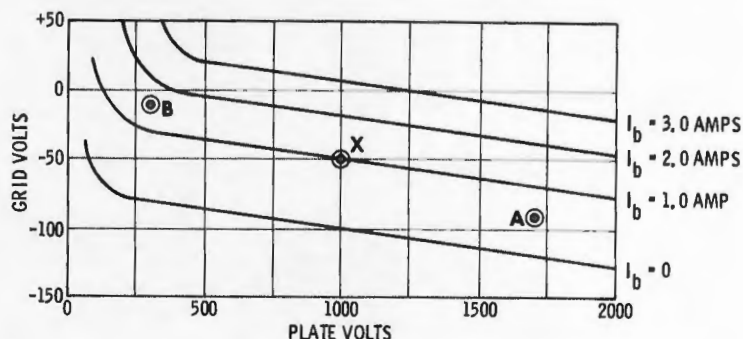


Fig. 4. Practical characteristic curves bend at left, are unevenly spaced.

$$\begin{aligned}&= \frac{125}{1000} \times 100 \\ &= 12.5\%\end{aligned}$$

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:

$$\begin{aligned}\eta &= (.7)^2 \times \eta_{\text{max}} \\ &= .49 \times 50\% \\ &= 24.5\%\end{aligned}$$

Class B and C Operation

Class-B and -C amplifiers 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.

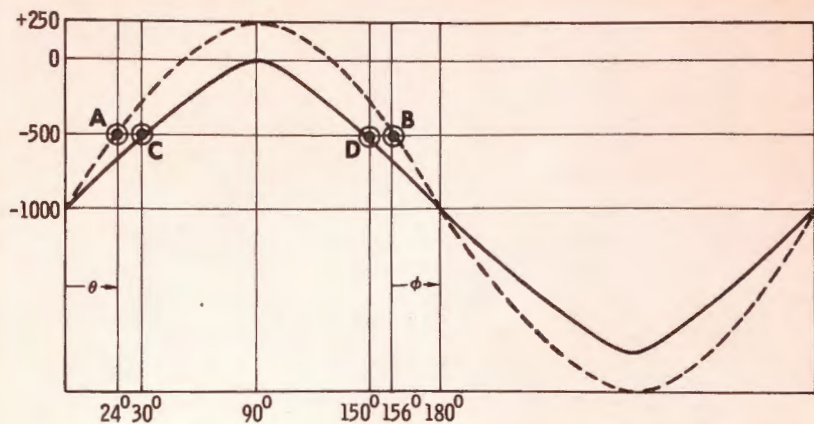


Fig. 5. Conduction angle depends on bias, cutoff voltage, signal amplitude.

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:

$$C = 180^\circ - (\theta + \phi)$$

where,

C = conduction angle

θ = angle from 0° to point conduction begins

ϕ = angle from point conduction ends at 180°

In this case:

$$\begin{aligned} C &= 180^\circ - (24^\circ + 24^\circ) \\ &= 180^\circ - 48^\circ \\ &= 132^\circ \end{aligned}$$

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 $\sin \theta$ and $\sin \phi$ are each 0.5, and the two angles are each 30°. The conduction angle is therefore:

$$\begin{aligned} C &= 180 - (30 + 30) \\ &= 120^\circ \end{aligned}$$

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.

Predicting Class-B Performance

It is well known that class-C am-

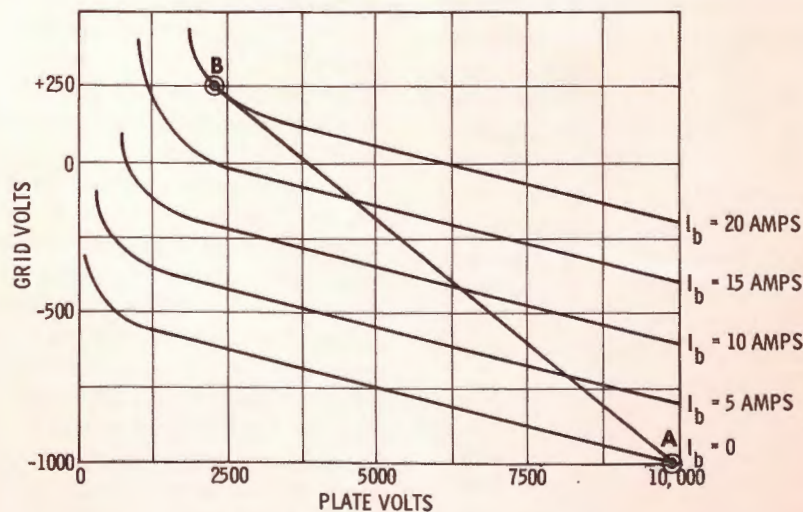


Fig. 6. Characteristic curves are used to predict the plate-circuit action.

plifiers operate at higher plate efficiency than class-B amplifiers, and that class-B amplifiers 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 cut-off 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

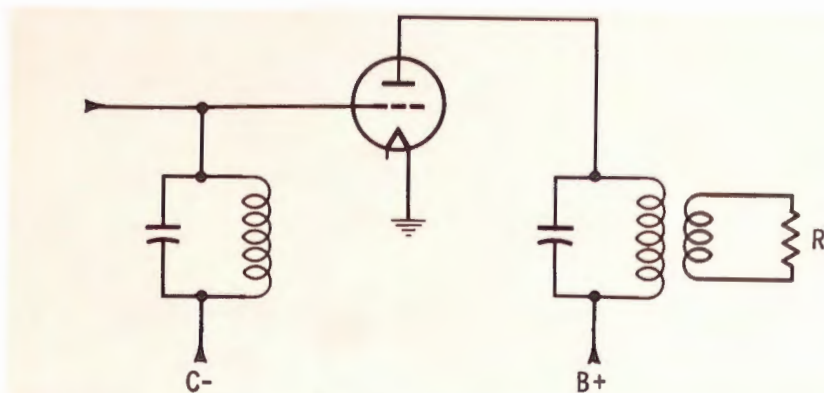


Fig. 7. Plate tank circuit fills in missing half of the RF voltage waveform.

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

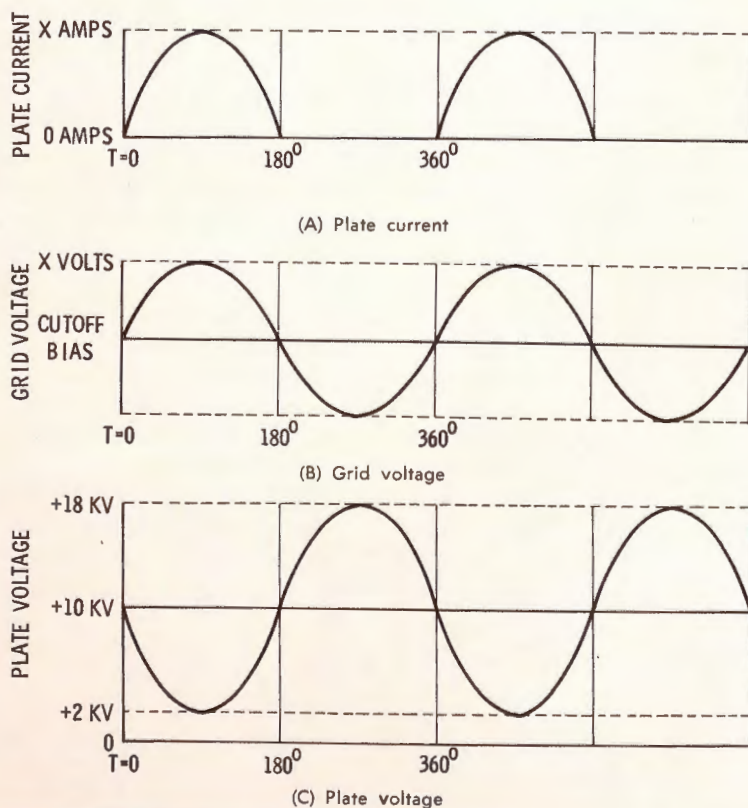


Fig. 8. Waveforms show relationships of voltage and current in RF amplifier.

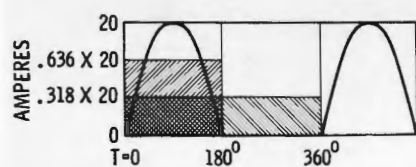


Fig. 9. Graphical determination of half-sine-pulse peak/average ratio.

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 $.318 \times 20 = 6.36$ 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

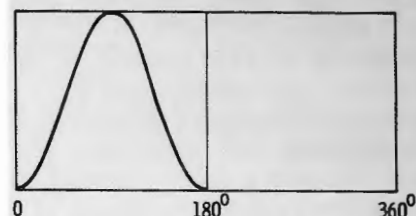


Fig. 10. In real amplifier, current pulses are not true half sine waves.

plate input power can be determined in this manner:

$$P_{\text{input}} = \text{DC plate voltage} \times \text{average plate current}$$

$$= 10,000 \times 6.36$$

$$= 63,600 \text{ watts}$$

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:

$$E_{\text{rms}} = 8000 \times .707$$

$$= 5700 \text{ volts rms}$$

and

$$I_{\text{rms}} = 10 \times .707$$

$$= 7.07 \text{ amperes rms}$$

Power output is, therefore:

$$P = EI$$

$$= 5700 \times 7.07$$

$$= 40,000 \text{ watts}$$

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

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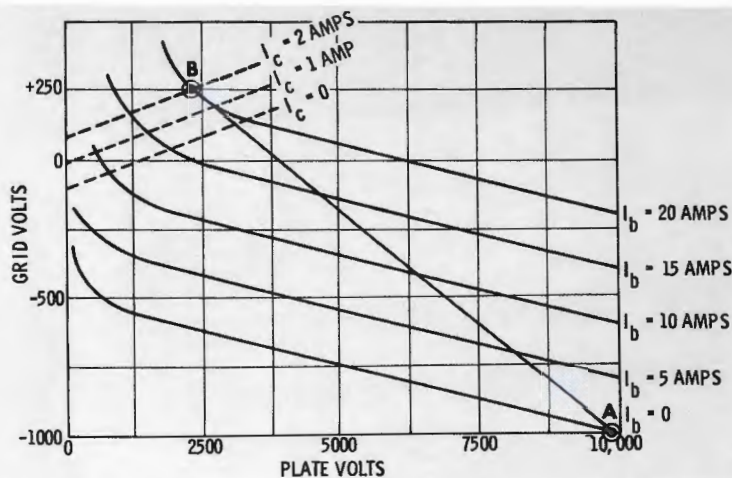


Fig. 11. Additional characteristic lines permit grid current to be evaluated.

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:

$$\begin{aligned} \eta &= \frac{\text{Power out}}{\text{power in}} \times 100\% \\ &= \frac{40,000}{63,600} \times 100\% \\ &= 62.8\% \end{aligned}$$

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

$$\begin{aligned} R &= \frac{E}{I} \\ &= \frac{5700}{7.07} \\ &= 800 \text{ ohms} \end{aligned}$$

The same result is obtained if peak values are used:

$$\begin{aligned} R &= \frac{8000}{10} \\ &= 800 \text{ ohms} \end{aligned}$$

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 impossi-

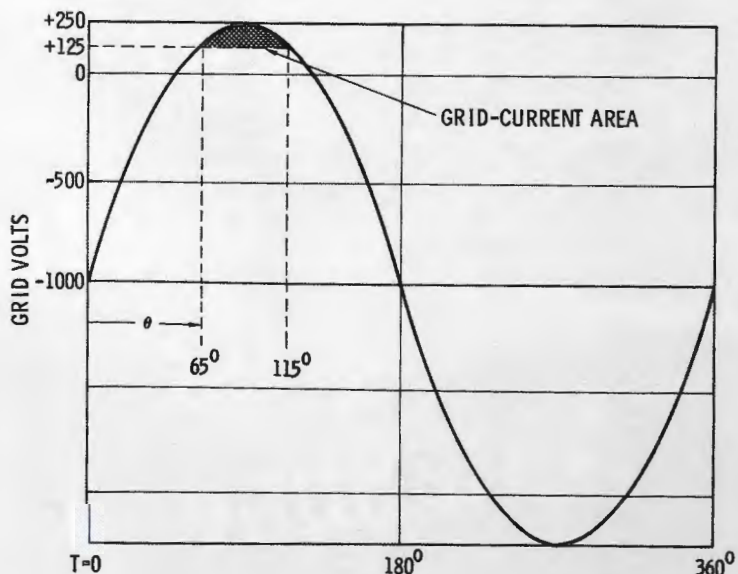


Fig. 12. Shaded area shows portion of cycle during which grid current flows.

ble). 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 sinusoidal plate current = 10 amperes

DC power input (unchanged) = 63,600 watts

The RF power output is now:

$$\begin{aligned} \text{Power out} &= \frac{10,000 \times 10}{2} \\ &= 50,000 \text{ watts} \end{aligned}$$

and the efficiency is:

$$\begin{aligned} \eta &= \frac{50,000}{63,600} \times 100\% \\ &= 78.5\% \end{aligned}$$

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:

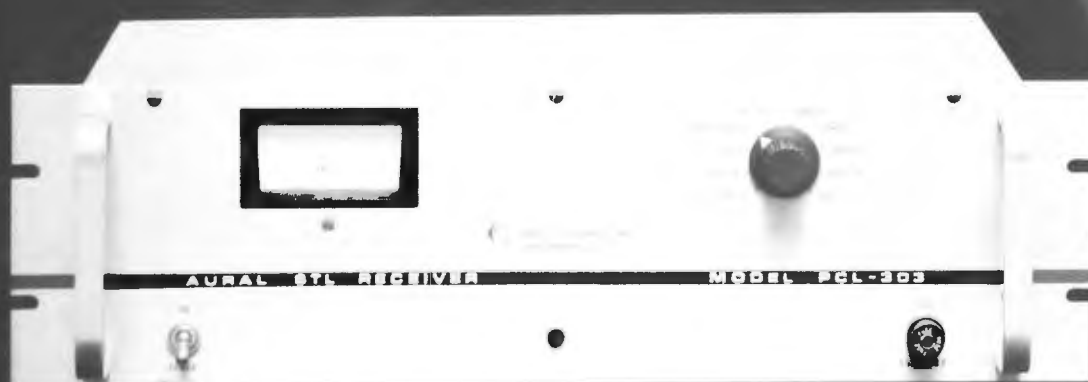
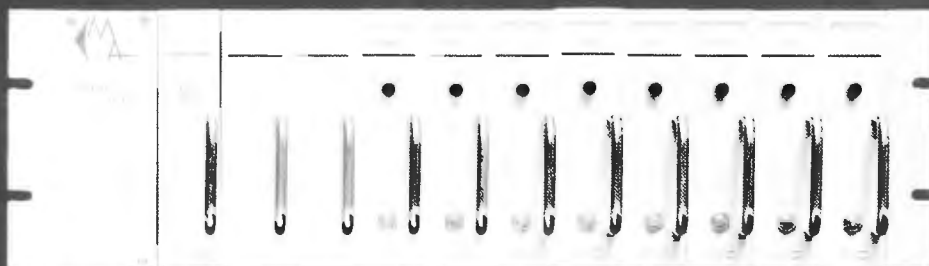
$$\eta = \frac{\pi}{4} = .785$$

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

$$\begin{aligned} \eta &= \frac{\pi}{4} \left(1 - \frac{2000}{10,000} \right) \\ &= .785 (.8) \\ &= .628 \\ \% \eta &= .628 \times 100 \\ &= 62.8\% \end{aligned}$$

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.

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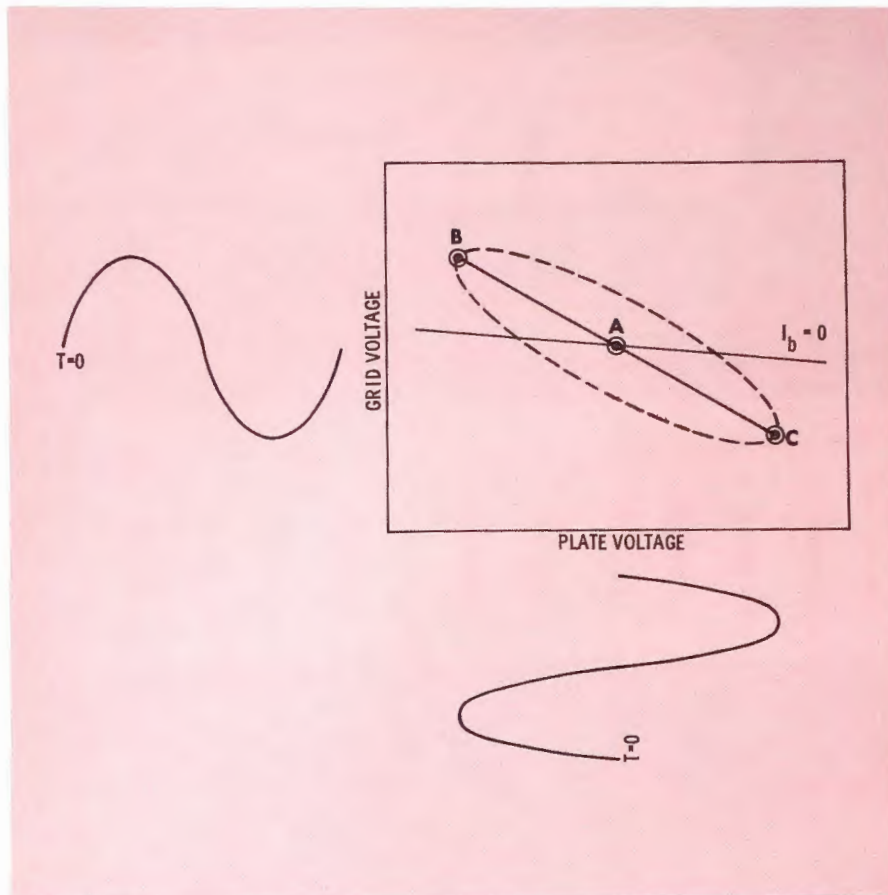


Fig. 13. Calculations assume input and output voltages are 180° out of phase.

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 $115^\circ - 65^\circ = 50^\circ$. 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:

$$\begin{aligned} I_{b0} &= \frac{I_{\text{peak}}}{10.6} \\ &= \frac{2.0}{10.6} \\ &= .19 \text{ ampere} \end{aligned}$$

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:

$$\begin{aligned} \text{Driving power} &= \text{Peak grid volts} \\ &\quad \times \text{DC grid current} \\ &= 1250 \times .19 \\ &= 235 \text{ watts} \end{aligned}$$

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.

$$\begin{aligned} P &= EI \\ &= 1000 \times .19 \\ &= 190 \text{ watts} \end{aligned}$$

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 arbitrary choice of point B, but it is just as easy to se-



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The black dropouts shown on the left are followed by a complete loss of color-lock in the direct color recovery equipment. Since these dropouts include horizontal sync and color burst, they cause transient color flashing not ordinarily attributed to the dropouts themselves. Even shallow dropouts can create a similar problem due to loss of side-band information.

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After compensation, note the precise color match and complete freedom from switching transients. Also, the dropout disturbance to the time correction unit has been eliminated. Proc amp and

servo stability are improved to such a degree that it is possible to play this tape in full intersync or pixloc mode.

In the compensated half of the photo, compare the replacement material with the original signal two scan lines above the dropout due to a *complete* frame being photographed. Try to find the 13 switching transients.



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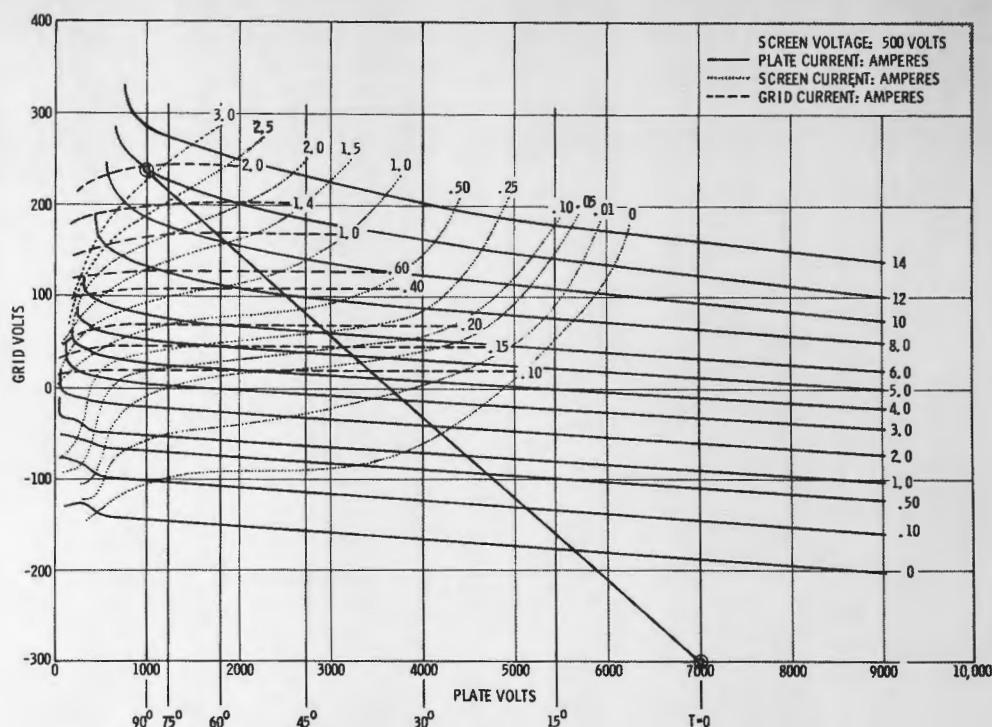


Fig. 14. Typical constant-current characteristics for plate, screen grid, and control grid of a transmitting tetrode.

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:

$$\begin{aligned} \text{Pwr} &= \frac{1}{.628} \times 50,000 \\ &= 1.59 \times 50,000 \\ &= 79,500 \text{ watts} \end{aligned}$$

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:

$$\begin{aligned} I &= \frac{P}{E} \\ &= \frac{79,500}{10,000} \\ &= 7.95 \text{ amperes} \end{aligned}$$

The required peak plate current will be:

$$\begin{aligned} I_{pk} &= \pi \times I_{dc} \\ &= 3.14 \times 7.95 \\ &= 25 \text{ amperes} \end{aligned}$$

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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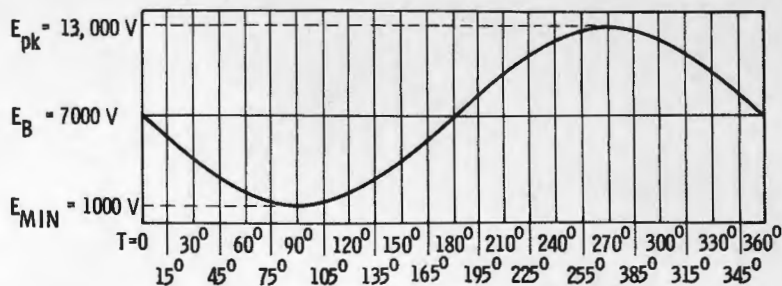


Fig. 15. Plate-voltage waveform divided into intervals for graphical analysis.

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.

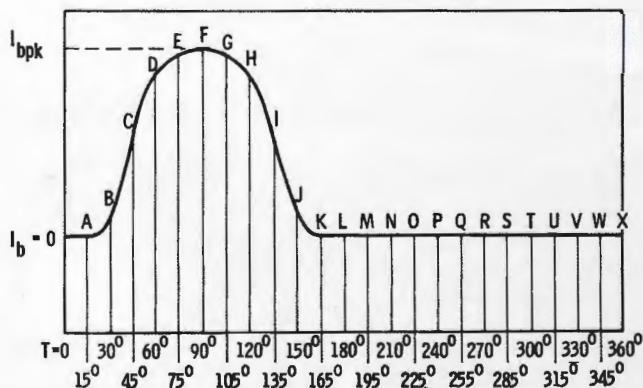


Fig. 16. Plate-current waveform need be examined only in conduction interval.

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:

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

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

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

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

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

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

ACCURATE MEASUREMENT OF CHROMINANCE DELAY

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

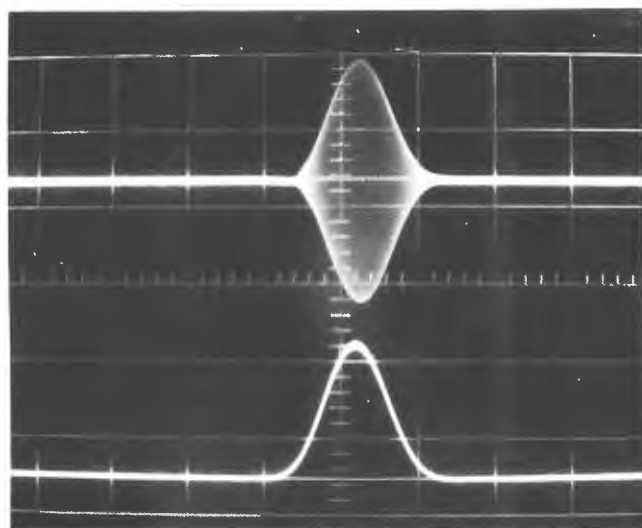


Fig. 1. Modulated (top) and unmodulated 20T waveforms.

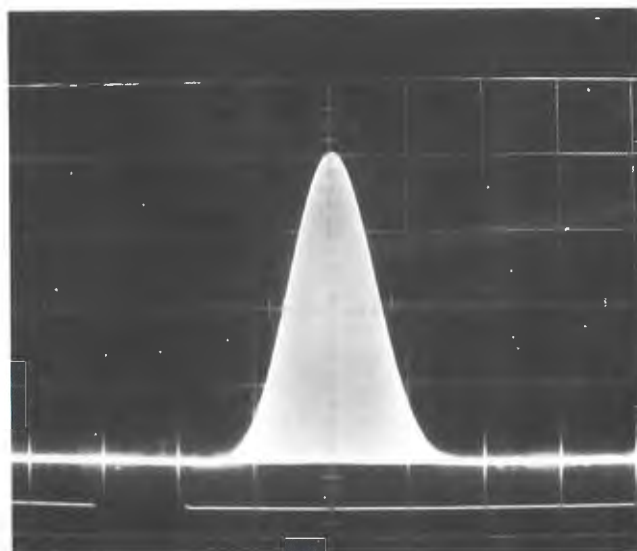


Fig. 2. Result of adding the waveforms shown in Fig. 1.

In transmission through a television system, chrominance signals are normally delayed with respect to luminance signals, and displacement of color 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 low-pass 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. Abdulazer, Project Engineer.



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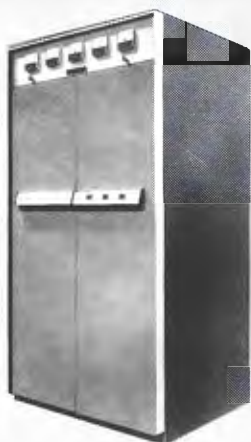
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Chrominance Delay

(Continued from page 43)

color signals. The effect of transmission equipment on such a test waveform would be similar 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 $\sin^2$ 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 bandwidth (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

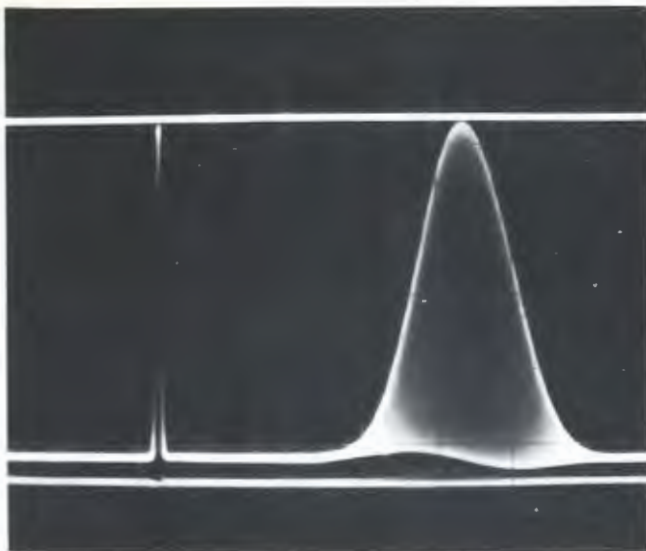


Fig. 3. Distorted base line indicates chrominance delay.

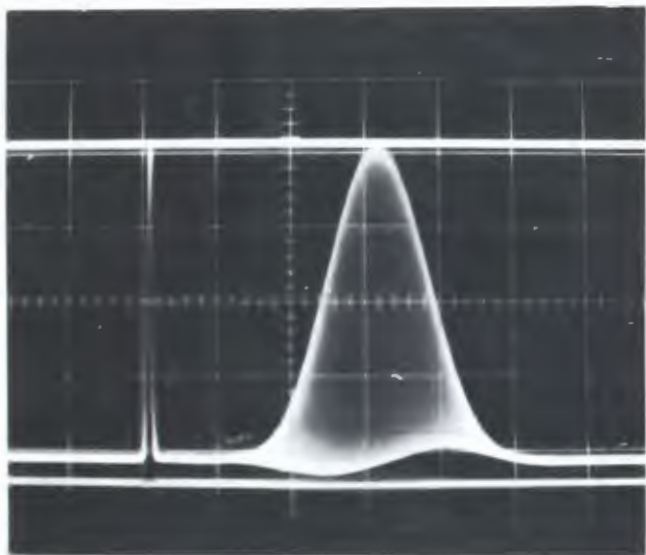


Fig. 4. Different distortion shows chrominance advance.

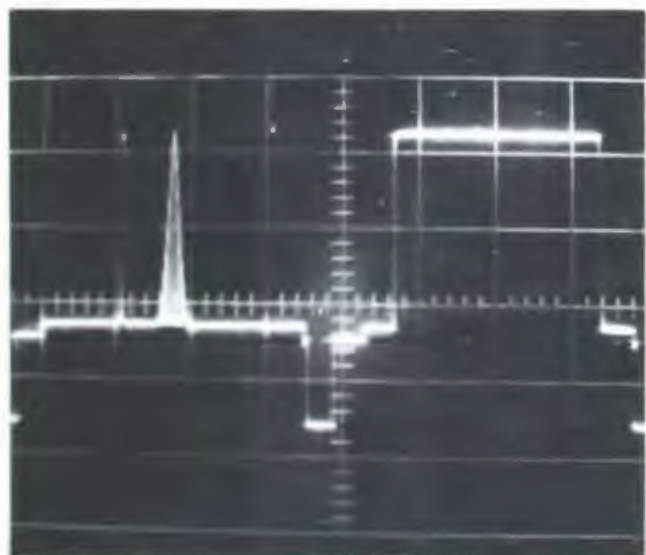
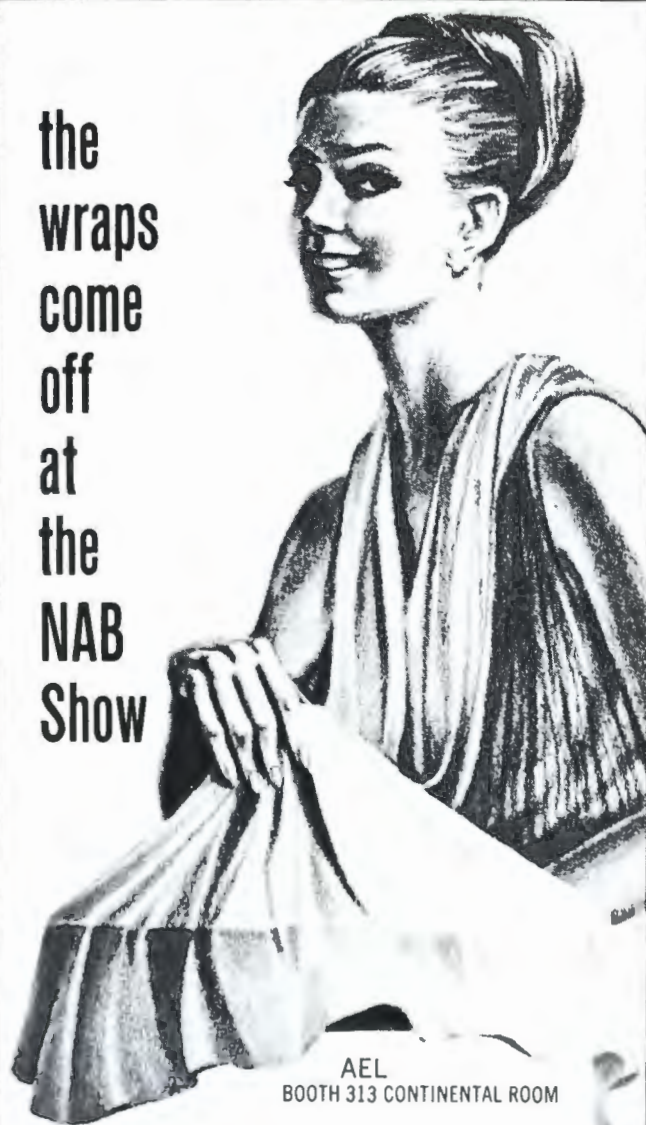


Fig. 5. Two lines contain waveforms for complete test

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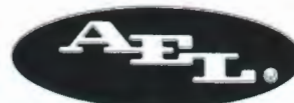
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amplitude of the sine-shaped lower envelope is proportional to the amount of time differential.

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.

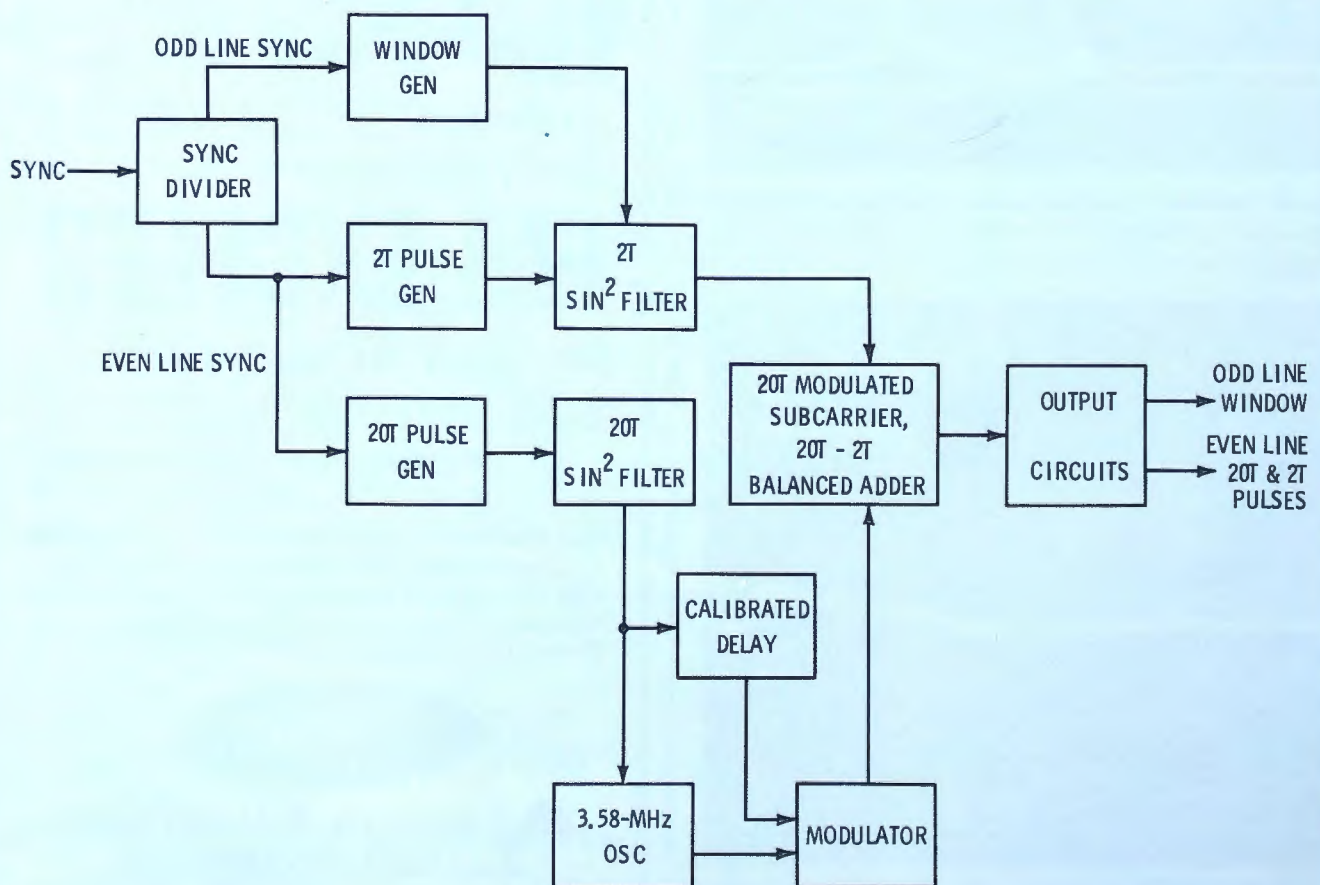
Conclusion

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.



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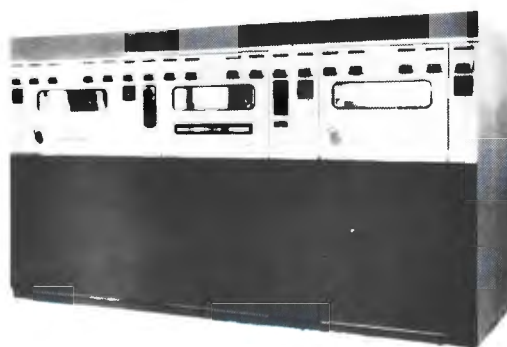
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A LOW-COST STEREO CONVERSION

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

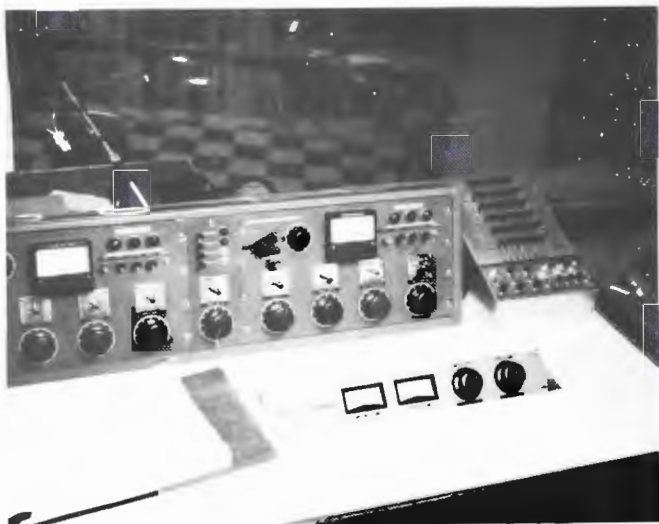
been built from scratch by station personnel. Although the board was quite adequate for monophonic service, we decided it would be impractical to convert it for stereo use. This left two alternatives: Replace the board with a new stereo model, or add an auxiliary set of faders for stereo.

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

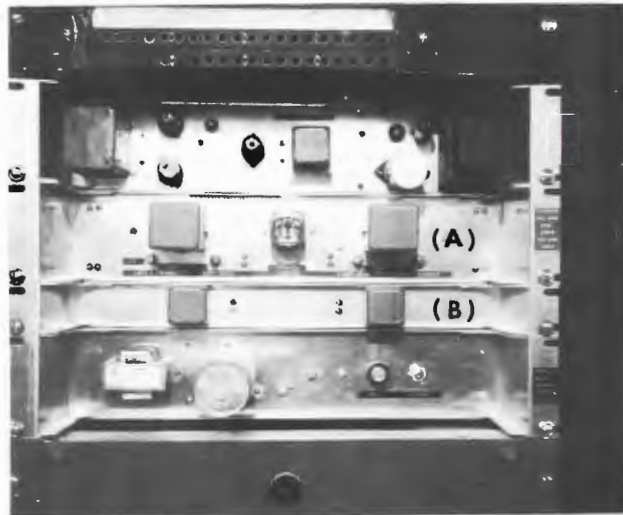
format it is of prime importance to have the capability to play stereo records, with stereo tape machines being of secondary importance.

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



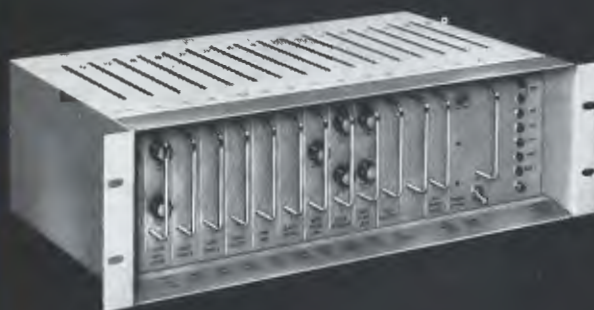
Mode switches are at right, stereo mixer in foreground.



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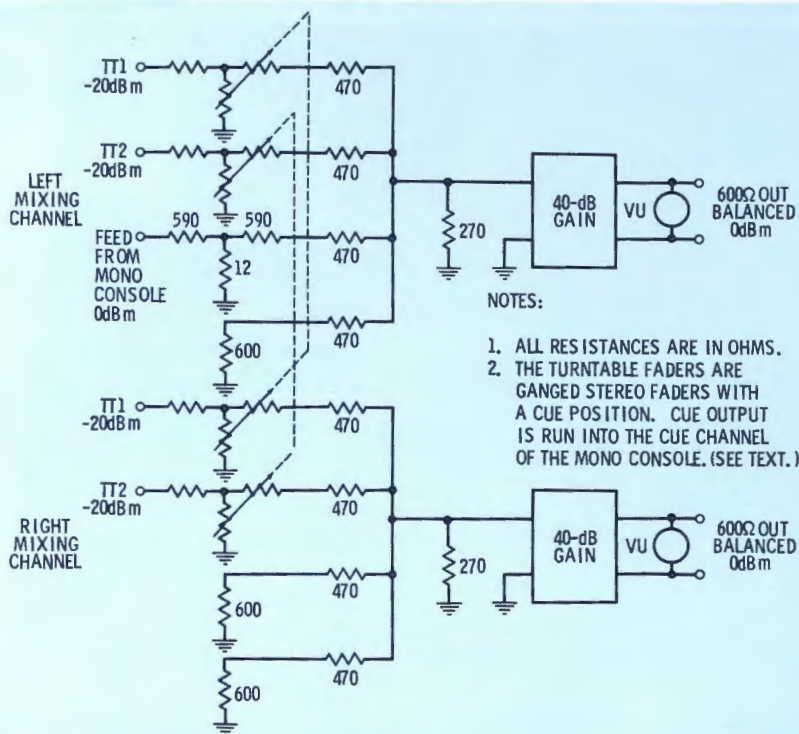


Fig. 1. Schematic shows use of stereo faders, dummy resistors in stereo mixer.

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

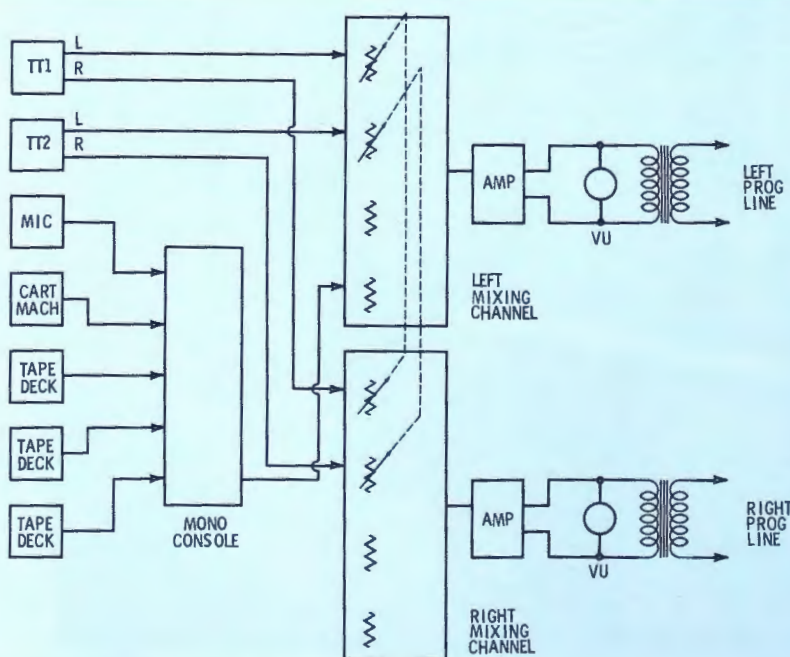


Fig. 2. Block diagram of the WVBR-FM control room when operating in stereo.



How to know you're buying the finest live-color camera.

It's not one single feature that makes the difference.

It's a unique combination of advanced design and operating characteristics that makes one live-color camera the finest in television today for both studio and remote operation. The General Electric PE-250.

Stated simply, here is the winning combination:

Advanced mechanical design—Circuit modules accessible during operation without extenders. Easy, flexible pickup tube replacement. Parallel and planar deflection assemblies for optimum match in all channels. Weighs less than 160 pounds, fully operational.

Advanced optical design—All optical elements mounted firmly to rigid, precise, machined optical bed. Iris control at both camera and control unit. Zoom lens range extenders installed in seconds.

Advanced electrical design—All-solid-state circuits with all-plug-in transistors. Simplified all-solid-state encoder. 20-position go/no-go test meter in camera. Total power input only 500 watts (camera—260W; monitoring—165W; encoder—75W). Subtractive monitoring for fast, precise registration.

Four-channel pickup—Four lead oxide pickup tubes ...the most modern tubes in the most accepted con-

figuration. Separate luminance channel for high resolution and high signal-to-noise ratio...without critical dependence on chrominance channel registration. Optimum chrominance and luminance performance without interaction.

Flexibility—Lightweight, compact, rugged design and low power demand make it ideal for both studio and remote use. Uses U.S. camera cable and connectors. Adjustable compensation for cable lengths up to 2000 feet, usable pictures even beyond 2000 feet. Long cable runs also facilitated by registration controls at the camera and calibration controls at the camera control unit.

Acceptance—Now originating programs for two of the three major U.S. networks and for leading group and independent stations throughout the country.

Availability—Excellent...backed by a record of dependable delivery on every order since introduction.

That's the combination that gives you the best performance in live-color television today. For the lowest price, too.

And when you see the brilliantly detailed, beautiful color pictures the PE-250 produces, you'll know you've found the right combination.

GE-43

Look for it at the NAB Show.

Visual Communication Products Department

GENERAL  ELECTRIC

Electronics Park, Syracuse, New York 13201



How to know you're buying the finest color-film camera.

Start with a film or slide like this.



The background color and texture, the modeling and tone of the flesh and hair and the high-contrast black and white stripes make it a tough, thorough system test.

The General Electric PE-240 color-film camera will

consistently reproduce it with sharp detail, striking color fidelity and unmatched stability.

And it's easy to see why. The PE-240 has automatic exposure and black level controls. Transistorized circuits. A simplified all-solid-state encoder. Master black level. Video reversal for negative black-and-white film. Circuit and performance similarity to the live-color PE-250 for simplified maintenance and smooth film inserts to your live shows.

And the right tube for the right job in all four channels. Luminance is supplied by a separate-mesh one-inch vidicon for high resolution without visible lag or flicker.

But judge for yourself. And use any film or slide you like.

The tougher the test, the easier it is to see why the PE-240 is the top-ranking color-film camera in television.

GE-43

See it in action at the NAB Show.

Visual Communication Products Department

GENERAL  ELECTRIC

Electronics Park, Syracuse, New York 13201

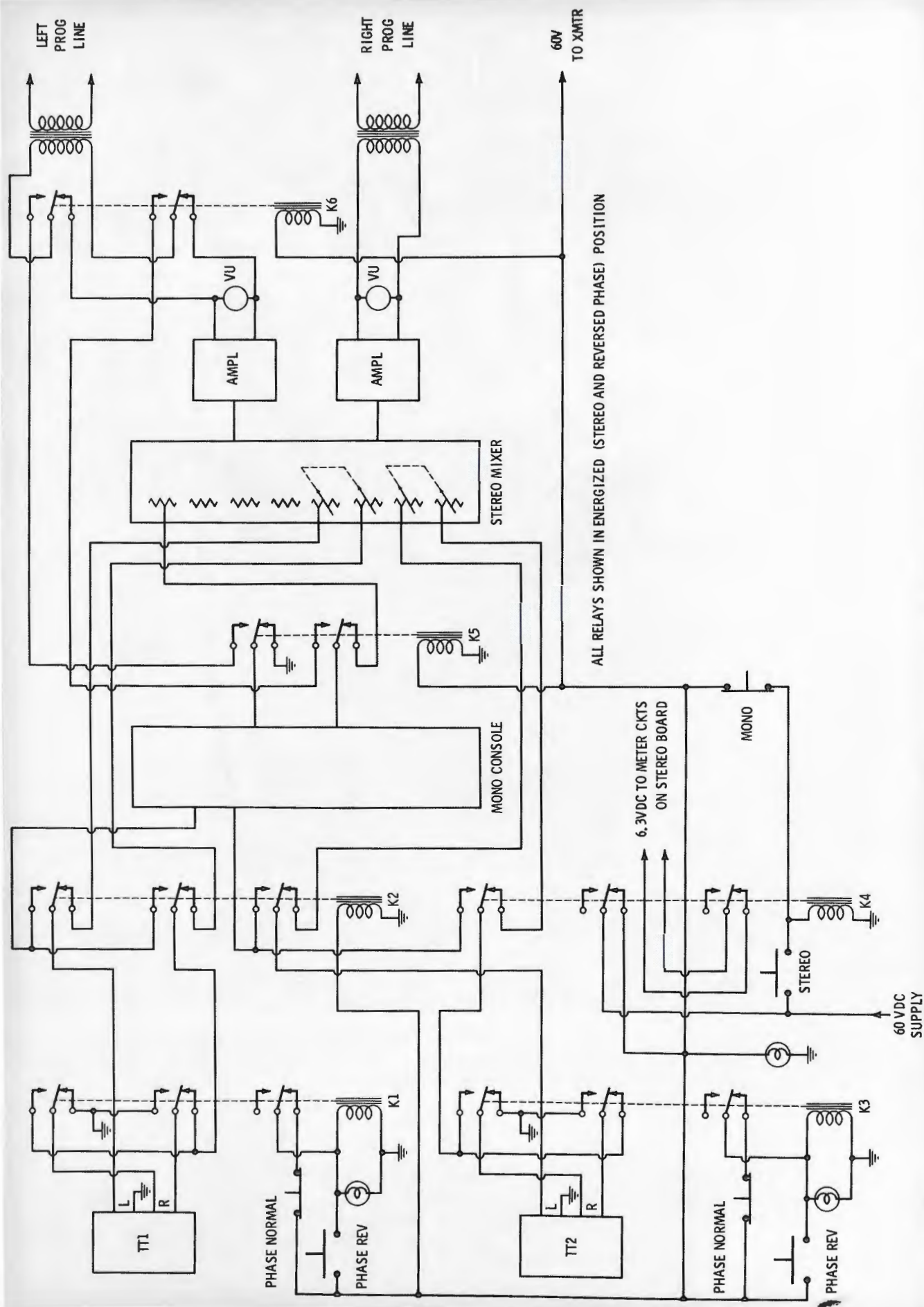


Fig. 3. Diagram shows use of relays for mono/stereo switching, and phase reversal of one channel from each turntable; mono sources are aired through left channel.

Livelier and truer colors...



Livelier, truer colors: Colors appear brighter, clearer, lifelike. Up to 5db better signal-to-noise ratio for multiple generation copies. New oxide, new binder, new coating technique make this possible.

Perfect copies: Create up to 4th generation duplicates that only the most experienced eye can distinguish from the master tape.

Stronger black and whites: Compatible high fidelity resolution with startling presence. Minimal background interference or blur. It's a picture that's truly alive!

Improved sound: Tape background noise is significantly reduced. New No. 399 gives you living sound to match the picture!

Total versatility: Can be used for both high-band and low-band recording. Recorders need no special adjustments or set-ups.

Cleaner running: Will not shed, block or rub-off. Leaves no oxide deposit on heads or guides. Assures better results—averages less than 15 dropouts per minute.

Longer life: Capable of three times the life of previous video tapes.

No visible indication of head to tape contact. Almost impossible to wear out. Virtually unlimited shelf life.

Field proven: Thoroughly tested and proven in actual broadcasting use by networks, local television stations and production studios.

Find out how Color Tape Plus can add an exciting new dimension to your programming. Write: Magnetic Products Division, 3M Co., St. Paul, Minnesota 55119.

Magnetic Products Division **3M**
THE 3M "BUTT-W" IS A REGISTERED TRADEMARK OF THE 3M COMPANY

plus copies you can't tell from the original



and
how!



color
tape
plus!

"Scotch" Brand Video Tape No.399

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.")]

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. ▲

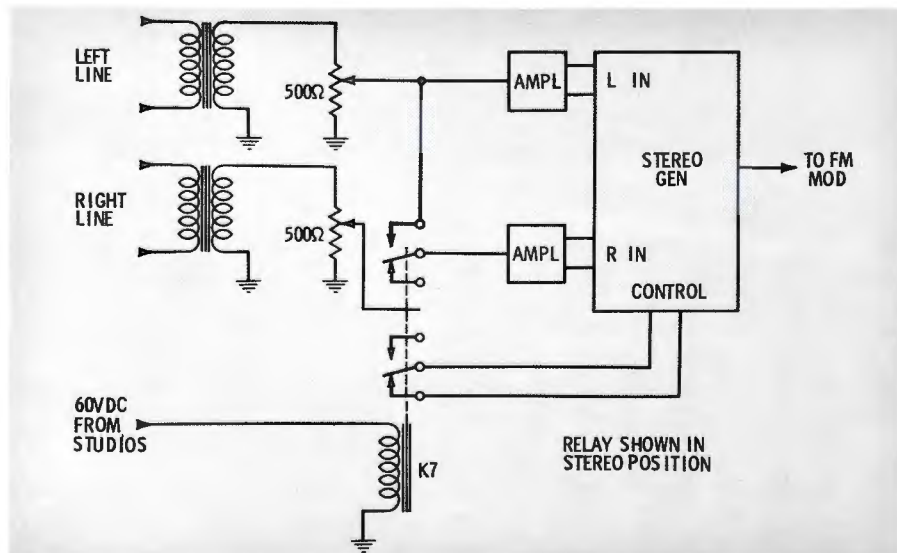


Fig. 4. Stereo/mono relays at transmitter are controlled over separate line.

AMCI BROADCAST EQUIPMENT for VHF and UHF-TV and FM



Directional VHF-TV
Transmitting Antenna

VHF-TV TRANSMITTING ANTENNAS

Mast or tower-corner mounted
DIRECTIONAL OR OMNIDIRECTIONAL
for Channels 5 to 13

Omnidirectional VHF-TV antennas with power gains up to 20. Directional VHF-TV antennas with power gains up to 36.

UHF-TV TRANSMITTING ANTENNAS

Mast, tower-corner, or truss-mounted
DIRECTIONAL OR OMNIDIRECTIONAL
for Channels 14 to 83

Omnidirectional UHF-TV antennas with power gains up to 50. Directional UHF-TV antennas with power gains up to 80.

FM TRANSMITTING ANTENNAS

Mast or tower-corner mounted
DIRECTIONAL OR OMNIDIRECTIONAL
For single or multi-station transmission.

SPECIAL PURPOSE ANTENNAS

Empire State Building Master FM Antenna: two rows of dipoles around 102nd floor observation level, duplexers within tower, and transmission line, designed, built, and installed in 1965, permit up to 17 FM stations to broadcast simultaneously from the same antenna.



Side-mounted
VHF-TV Transmitting
Antenna



Side-mounted
UHF-TV Transmitting
Antenna

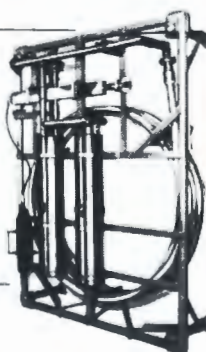
DIPLEXING FILTERS

Temperature compensated. Aural-to-visual and visual-to-aural rejection over 30 db. For use with transmitters up to 50 kw.



VESTIGIAL SIDE BAND FILTERS

Low insertion loss. Lower sideband of the color subcarrier frequency is attenuated 30 db. or more.



COAXIAL SWITCHES

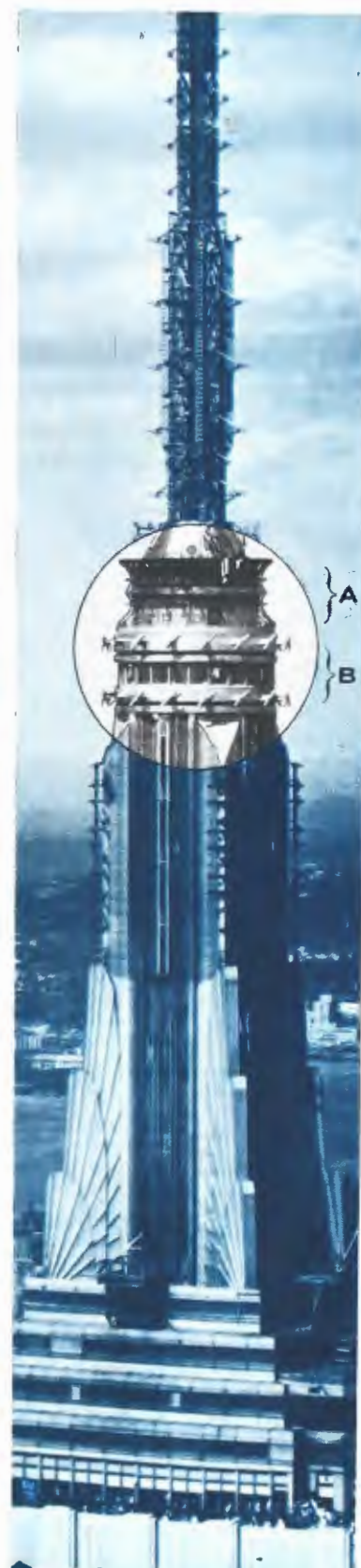
For 6 1/8" or 3 1/8", coaxial transmission lines.

SWR over a specified 100 mc band under 1.03, high peak power models under 1.06 over a specified 50 mc band. CW power rating equal to the mating transmission line.



OTHER PRODUCTS

- Standby Antennas
- Dipoles
- Power Dividers
- Hybrids
- Transfer Panels
- RF Terminations
- Impedance and Transfer Characteristic Plotters
- Variable Calibrated Attenuators
- Slotted Lines



Special-purpose Antennas:
a) antenna array for WOR-TV channel 9
b) Empire State Building master FM antenna



ALFORD

MANUFACTURING COMPANY

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Telephone: 617-729-8050

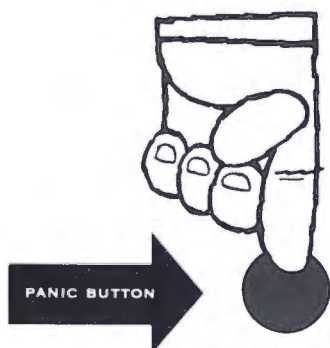
TWX: 710-348-1063

Cable Address: AMCIBOS

Circle Item 30 on Tech Data Card

March, 1967

YOU WON'T FIND A PANIC BUTTON ON A MAGNECORD!



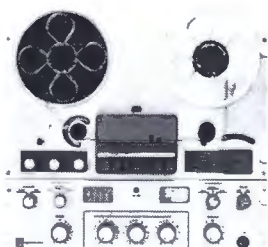
When Magnecord engineered a long list of safety factors into their professional line of tape recorder/reproducers . . . they engineered the emergencies out! A sturdy die-cast mainplate, supporting the transport in every model, insures precise location of internal parts under the roughest operating conditions. Rigid die-cast head mounts eliminate alignment problems. Professional quality hysteresis synchronous

capstan motor and individual reel drive motors are heavy duty models, and the capstan shaft assembly is re-inforced for extra strength and longer life.

While you are taping, safe-guard operating features protect your thinnest tapes. With Magnecord you get top-notch performance and superb fidelity to keep your taping facility operating at maximum capacity, even after years of constant use. Ask a broadcaster who uses one . . . Magnecords are built to take it!

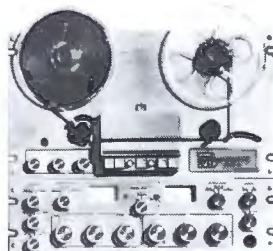
Write now for the full story on the complete line of durable quality Magnecord tape instruments.

Magnecord 8+ Reels now available from Audiotape®. See your local dealer.



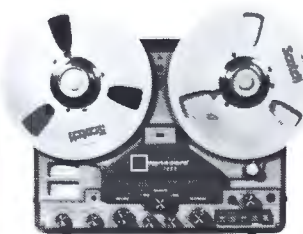
MAGNECORD MODEL 1021

Fully transistorized professional tape recorder/reproducer for monaural operation. For use in main or production control room.



MAGNECORD MODEL 1022

Fully transistorized professional tape recorder/reproducer two channel (stereo) for use in main or production control room.



MAGNECORD MODEL 1028

Professional quality 2 channel (stereo) tape recorder/reproducer for recording master tapes. (10½" reel capacity) Available in ½- or ¼-track.



MAGNECORD MODEL 1048

Professional 2 channel (stereo) recorder/reproducer for use in main studio, production studio or conference recording. (10½" reel capacity) Model 1048 is available in ½- or ¼-track.



Magnecord
DIVISION OF THE
TELEX CORPORATION
P. O. Box 1526 / Tulsa, Oklahoma 74101
MANUFACTURER OF TELEX HEADSETS
AND OTHER FINE ACOUSTIC DEVICES

March 1967

We interrupt this magazine to bring you...

Late Bulletin from Washington

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.

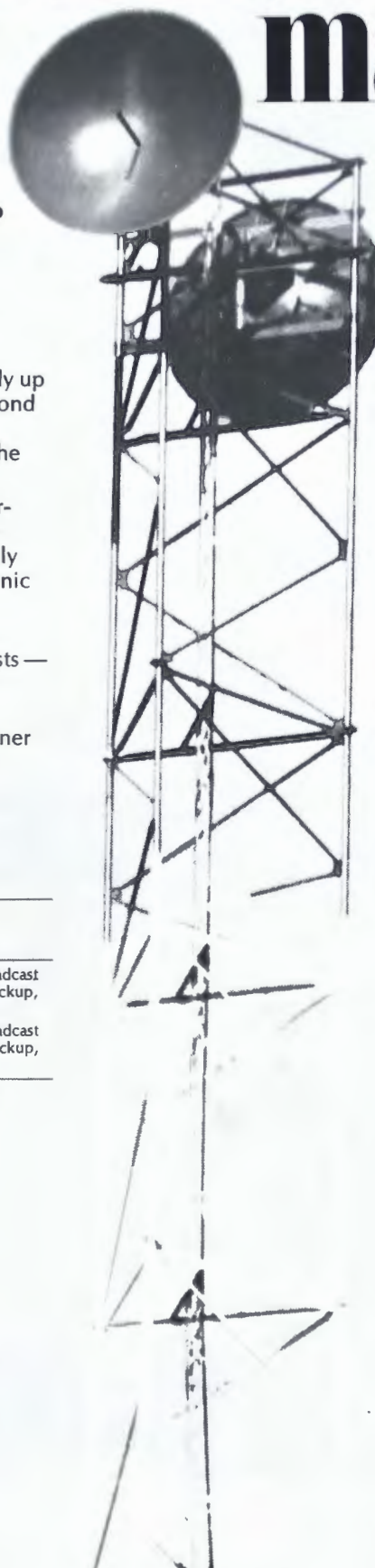
Money was another reason. Paralleling the existing system with new tube equipment, new antennas, new feed lines, rigging costs — would have been expensive. More than they cared to spend for equipment some consider obsolete.

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		Allocation
			without preamp	with preamp	
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

NEW!



Model
4N-1

WILKINSON

4-in-1

Portable Solid-State

1. FIELD INTENSITY METER
2. NULL DETECTOR
3. STANDARD SIGNAL GENERATOR
4. AM MONITOR RECEIVER

□ New Wilkinson Model 4N-1 all solid-state Field Meter combines all the features broadcast engineers have long been awaiting in a completely portable 12-pound unit. □ As a FIELD INTENSITY METER, the Wilkinson 4N-1 measures field strength with 3% accuracy and reduces measurement time. □ As a NULL DETECTOR, for use with a RF bridge to measure impedances, the Wilkinson 4N-1 eliminates the complexity of a multi-instrument AC test set-up. □ As a STANDARD SIGNAL GENERATOR, the Wilkinson 4N-1 is invaluable since its output accuracy of 3% from one microvolt to one volt is essential to many broadcast applications. □ As a MONITOR RECEIVER, the Wilkinson 4N-1 has sensitivity of 5 microvolts

nominal, permitting excellent off-air monitoring in extreme fringe areas. □ The frequency range of the complete Wilkinson 4N-1 is 535-1605 kc. □ The Wilkinson 4N-1 is powered by dependable nickel cadmium batteries, rechargeable from AC or an automobile source. Ease of operation is assured by simplicity of procedure, oversized controls and meter, built-in speaker and illuminated panel. The Wilkinson 4N-1 is packaged in a sturdy and attractive genuine cowhide case.



When case is closed, power is interlocked off.

For complete details write:

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ELECTRONICS, INC.

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TELEPHONE (215) 874-5236 874-5237

SEE US AT BOOTH 200A

NAB SHOW

Circle Item 33 on Tech Data Card

Class B & C

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:

(Continued from page 42)

$$\theta = 180^\circ - (2 \times 15^\circ)$$

$$= 150^\circ$$

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

$$\theta = 180^\circ - (2 \times 30^\circ)$$

$$= 120^\circ$$

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

$$\theta = 180^\circ - (2 \times 35^\circ)$$

$$= 110^\circ$$

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. ▲

IT'S NEW!

GIBRALTAR CRAB PEDESTAL

- Select Crab or Tricycle control with the flip of a lever.
- Micrometer gear-driven height adjustment.
- Brakes and/or cable guards optional.
- Accepts all Gibraltar heads directly; adapters available for others.



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NAB Show—Chicago

QUICK-SET

INCORPORATED



SKOKIE, ILL.

Complete descriptive literature
available on request.

PHONE 312/673-1200

Circle Item 34 on Tech Data Card

BROADCAST ENGINEERING

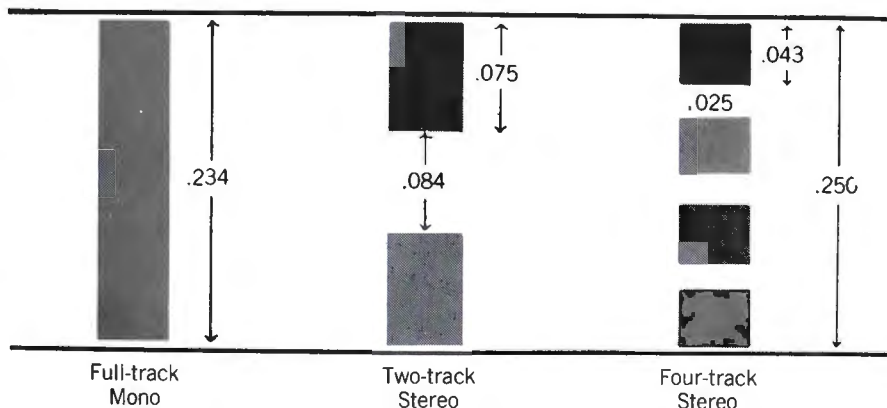
Some plain talk from Kodak about tape:

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,

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.

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



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

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

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



Leadership
PERFORMANCE



MODEL SX 724

ELECTRONIC ADVANCES

- ⊗ Performance as yet unequalled
- ⊗ Two years proven Solid State circuitry
- ⊗ Extremely low noise electronics
- ⊗ Etched circuit modules

TRANSPORT ACHIEVEMENTS

- ⊗ Patented Electro-Magnetic Brakes never need adjusting
- ⊗ Complete head accessibility
- ⊗ Precision Construction
- ⊗ Low Wow and Accurate Timing

THESE ARE
JUST A FEW OF THE
OUTSTANDING FEATURES
WHICH PROVIDE
THE ULTIMATE IN—

**QUALITY
DEPENDABILITY
PERFORMANCE**



MODEL SS822

Write to **Crown International**
Box 1000, Dept. BE-3
Elkhart, Indiana 46514

MADE ONLY IN AMERICA

Circle Item 36 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-



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Circle Item 37 on Tech Data Card

BROADCAST ENGINEERING

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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

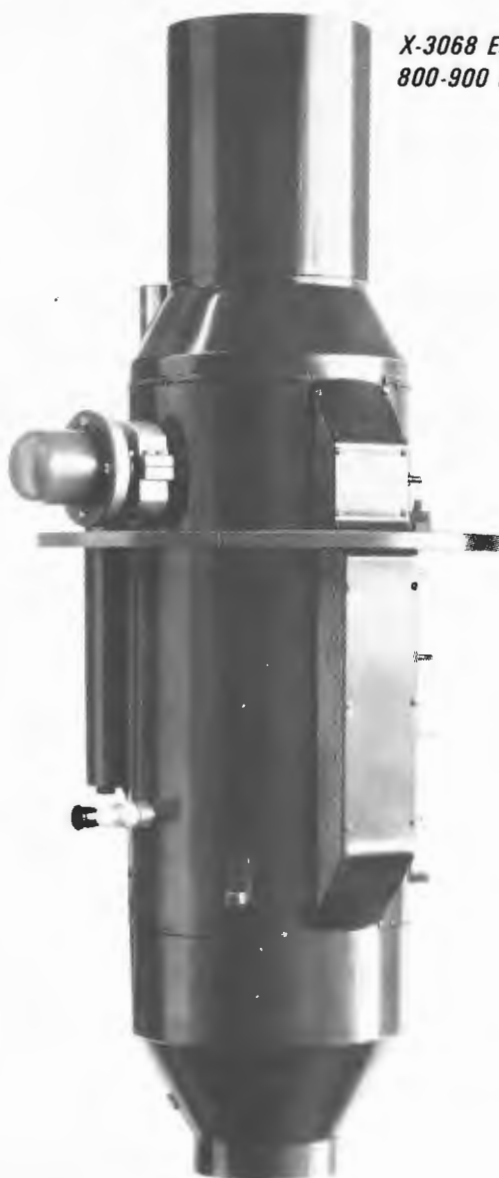
offers 500 watts output yet weighs only 5 pounds and measures just 6 inches. And provides 30 to 40 db gain with efficiency between 35% and 45%; heat-sink or air-cooled.

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.

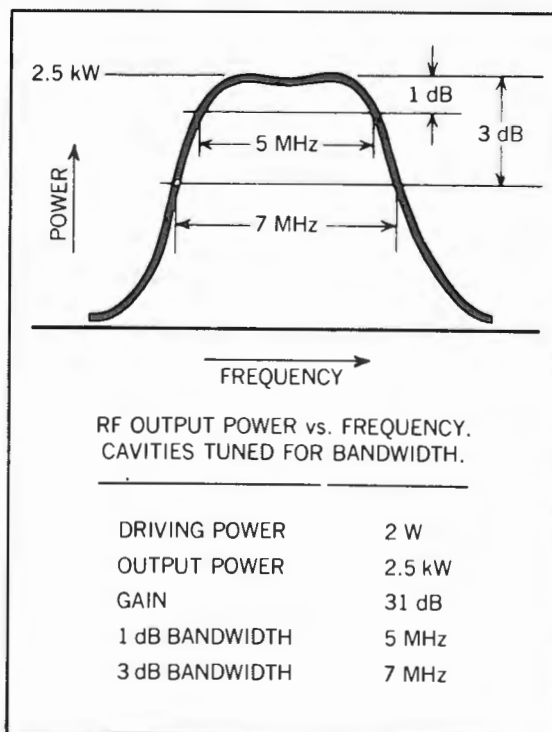
EIMAC

Division of Varian

San Carlos, California 94070



X-3068 ESFK
800-900 MHz



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

SUPERIOR TV-10* JACKS DO ALL THREE WITH PLUG-IN SPEED



TEST

PATCH

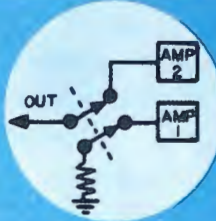
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TERMINATE



no circuit interruption, permanent or temporary set-ups

replace or couple modules in seconds including use of non-adjacent normalised jacks



1 operation patches 1 circuit, loads another

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Circle Item 39 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.

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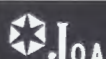
(b) replacement of minor parts

(c) VISIBLE SPLICE

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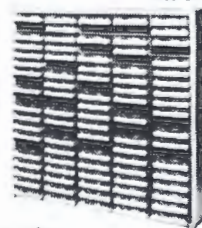
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Enjoy finger-tip convenience with RM-100 wall-mount wood racks. Store 100 cartridges in minimum space (modular construction permits table-top mounting as well); \$40.00 per rack. SPOTMASTER Lazy Susan revolving cartridge wire rack holds 200 cartridges. Price \$145.50. Extra rack sections available at \$12.90.

Write or wire for complete details.

Spotmaster

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Silver Spring, Maryland

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**This was the E-V Model 635.
It started a tradition
of excellence in
dynamic microphones.**



**This is the new
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It's better
in every way!**



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

E-V 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 re-

duces 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.

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Circle Item 44 on Tech Data Card

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.

SMPTÉ

Arrangements chairmen for the 101st Technical Conference of the

vision 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 Debie, New York

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

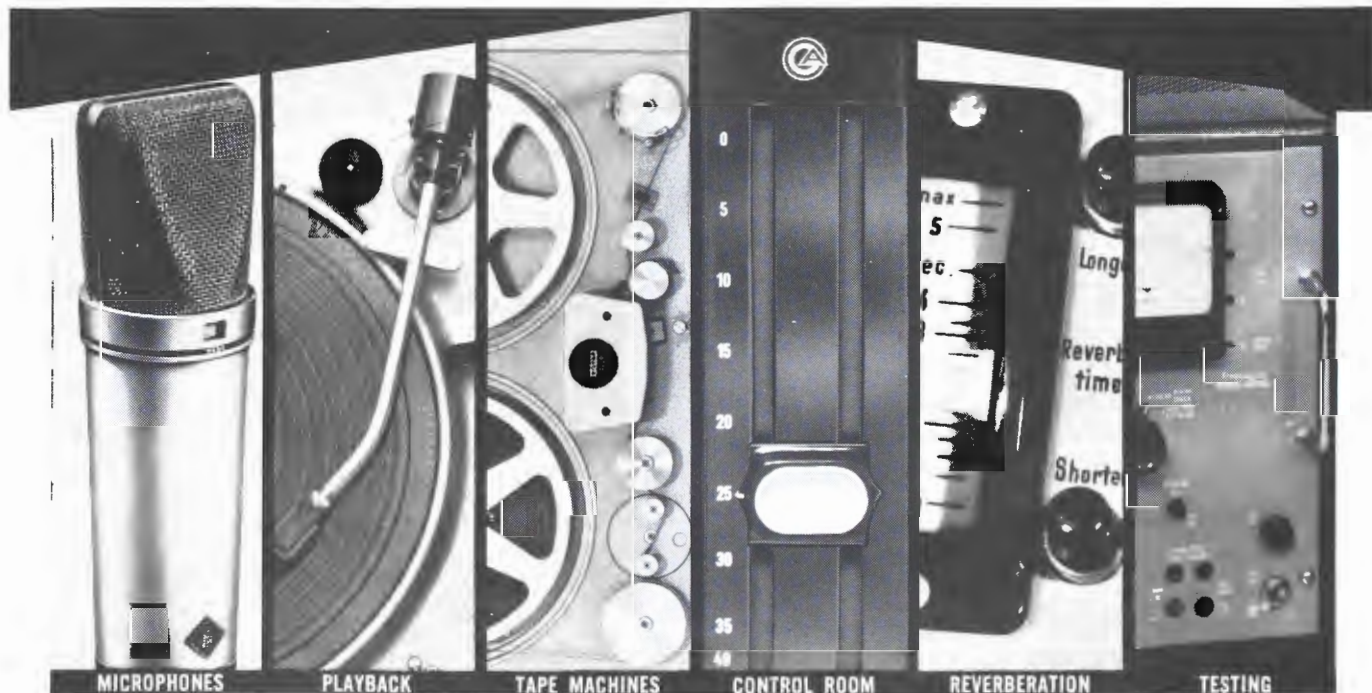
Registration: Jack Asher, Lab-TV, New York

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



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

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Circle Item 46 on Tech Data Card

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

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

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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.

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SPECIFICATIONS: KAPPA MODEL 10A503 SUPER-η DELAY LINE

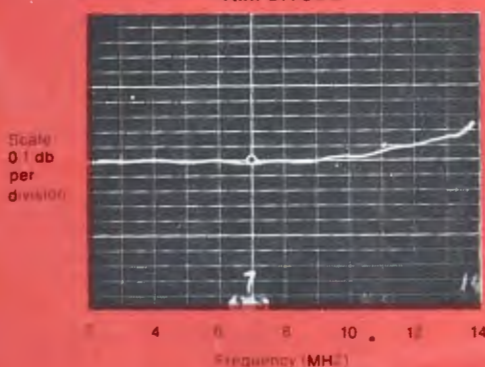
ELECTRICAL

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

MECHANICAL

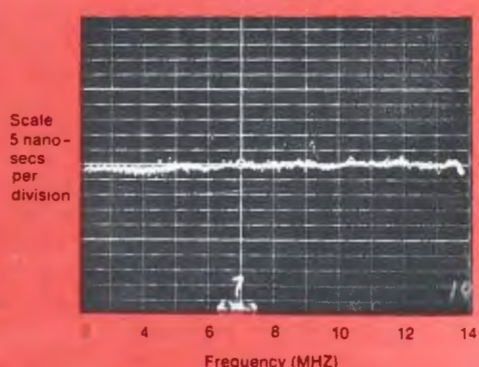
Size: 12" x 7/8" x 7/8"
Case Material: Electro-tinned brass
Finish: Mil-spec gray lacquer
Mounting: (2) 6-32 threaded inserts
Price: Under \$100
Delivery: 4 weeks

AMPLITUDE



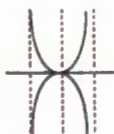
Amplitude Response: Flat within 0.1 db to 12 MHz
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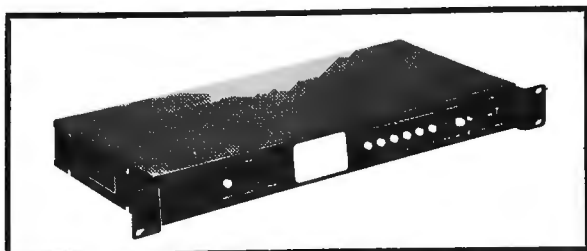
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The amplifiers distribute to six isolated outputs, permitting a substantial savings in space and cost; each input and output line has its own front panel test jack.

Both rack-mount and portable models are available with a "Sync Add" option, and the rack mount series also includes a remote gain version which may help you solve a perplexing cable routing problem. All models carry their own regulated AC to DC power supply.

PRICES: RACK-MOUNT SERIES — DAR-1 Standard, \$340.00; DAR-2 Sync Add, \$365.00; DAR-3 Remote Gain, \$395.00. PORTABLE SERIES — DAP-1 Standard, \$350.00; DAP-2 Sync Add, \$375.00; Rack-mount models are just 1 3/4" high. Portable units are 8" wide, 5 1/2" deep and 5" high.

For complete information and specifications, call or write:

APPLIED ELECTRO MECHANICS, INC.

2350 Duke Street
Alexandria, Virginia 22314
PHONE: (703) 548-2166



Circle Item 49 on Tech Data Card

presentation for the United States at the Third International Conference on Educational Radio and Television in Paris, March 8-22. Mr. 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-transducers 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 coauthored 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 War 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 feasible control function, which will be undetectable except to the most discriminating of listeners. ▲

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March, 1967



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- ★ 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.

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NEW PRODUCTS

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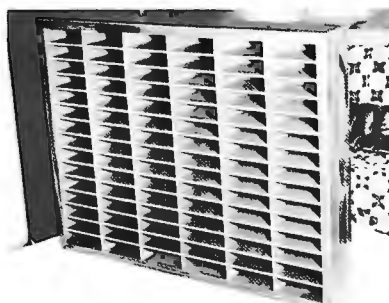


Deflection Assembly
(176)

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.

ed. 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.

VEGA WIRELESS MICROPHONES ALL NEW FROM VEGA!

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- Solid state
- Fully portable

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- Low cost capacitor microphones

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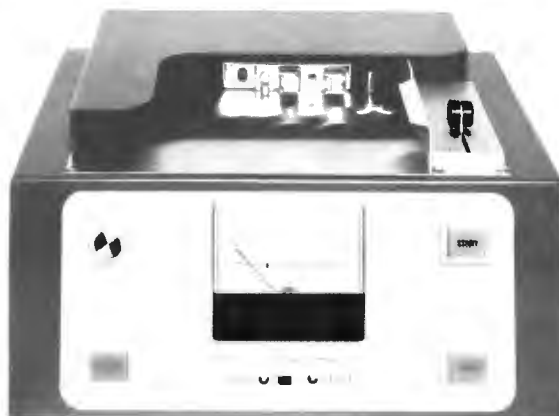


VEGA ELECTRONICS CORP.

1161 RICHARD AVENUE
SANTA CLARA, CALIF. 95050

Circle Item 54 on Tech Data Card

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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

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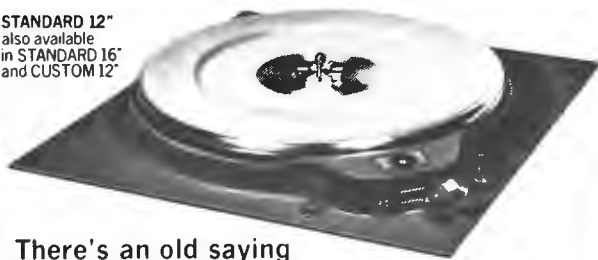


Audio Console
(78)

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 $\pm$ 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.

STANDARD 12"
also available
in STANDARD 16"
and CUSTOM 12"



There's an old saying
among radio engineers...

***"The only reason to change a QRK
is if you're tired of its color"****

That's the reputation for long, trouble-free service QRK Professional Turntables have gained in 21 years of spinning in stations around the world. Add to that reputation, "instant start" for accurate cueing plus the original "platter-dapter" that plays all discs with no need for pop-up gadgets — and you order QRK with confidence that your turntable troubles are over.

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Circle Item 57 on Tech Data Card

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TODAY WITH BELAR**

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SYSTEM**



The Belar ADD-ON MONITORING SYSTEM allows the broadcaster to fulfill his monitoring requirements as the needs arise. The basic unit is the FMM-1 Frequency and Modulation Monitor for monaural use, and when requirements call for SCA, add the plug in SCAM-1 SCA unit. And for stereo the FMS-1 Stereo unit completes the system.

Today's monitoring requirements make this system a must.

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Circle Item 56 on Tech Data Card

**THE
ADD-ON
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COMPLETE**

Pilot Frequency
38 KC Suppression
L + R Crosstalk
L - R Crosstalk
AM Noise or Inc. AM

The FMS-1 monitors and measures:

Total Modulation
L + R Modulation
L - R Modulation
Pilot Amplitude
Left or Right Channel

A stereo station must—the Belar FMS-1 monitors the 19 KC pilot frequency as well as all the modulation characteristics of FM stereo. The advanced solid-state circuitry guarantees that all FCC performance requirements for stereo monitors are exceeded so that precise, accurate proof-of-performance measurements can be made for the finest in stereo broadcasting.

TOTAL QUALITY CONTROL -
ANOTHER REASON WHY
CDC EQUIPMENT PERFORMS
FROM THE INSTANT
YOU TURN IT ON.



"Total" means just that. All our people, in engineering production and administration, are trained to be quality control conscious in their day-to-day operations. To this is added a complete understanding of station operation by our systems engineers, who will visit your studio if required. The result is that when your CDC equipment is installed, it just can't help fitting naturally into your station's operational environment. CDC video terminal equipment is crafted in Canada to your specifications and serviced in the United States by our own people.



CENTRAL DYNAMICS CORPORATION

HEAD OFFICE: 903 Main Street, Cambridge, Mass. 02139

Circle Item 58 on Tech Data Card



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 illumination 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

For only \$550 your old Ampex 300/350 will be up-to-date in 1982 with new Lang Record/Playback Electronics!



MODEL
LRP

CHECK THESE ADVANCED FEATURES:

- ALL SOLID STATE • COMPATIBLE WITH EXISTING HEADS • LOW NOISE • HIGH RELIABILITY • FRONT PANEL SWITCHING OF MIC. AND LINE • RECORD ALIGNMENT CONTROLS ON FRONT PANEL • PLUG-IN CONSTRUCTION
- BUILT-IN MICROPHONE PREAMPLIFIER • HIGH OUTPUT RECORD ELECTRONICS • LOW DISTORTION LINE AMPLIFIER • SAFE/RECORD SWITCH • MONITOR JACKS • COMPACT SIZE.

FREQUENCY RESPONSE:

- ± 2 db 30-18 KHZ at 15 ips
- ± 2 db 50-15 KHZ at 7 1/2 ips
- ± 2 db 50-7.5 KHZ at 3 3/4 ips

FOR COMPLETE DETAILS AND NEW LANG CATALOG WRITE...

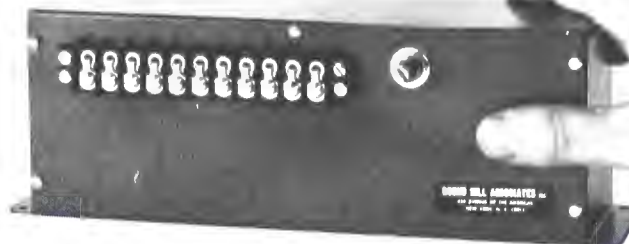
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507 FIFTH AVENUE, NEW YORK, N. Y. 10017

For all your audio needs — LOOK TO LANG!

Circle Item 60 on Tech Data Card

March, 1967

Model AA-200



SOLID STATE AUDIO AMPLIFIER

Frequency Response:

±1db, 20 to 20,000 cycles at 100MW

±2db, 20 to 35,000 cycles at 100MW

Harmonic Distortion:

Less than 1%, 20 to 20,000 cycles at 100MW

Less than 2%, 20 to 20,000 cycles at 200MW

Input:

50 to 150 ohms balanced (mu metal shielded, permalloy core transformer)

2,000 or 100,000 ohms unbalanced

Gain:

70db, 50 ohm input, 8 ohm load

65db, 2,000 ohm input, 8 ohm load

Output: 500 and 8 ohms

(grain oriented transformer)

Circuit: 7 transistors, 1 thermistor

Controls: Locking volume control

Connections: Barrier strip

Power Supply: 9 volts DC, 100 MA
(accessory power supply available — Round Hill Model PS-200)

Construction: Brown enameled steel case

Size: 9"L x 2 3/4"W x 3 1/4"H

Weight: 28 ounces

Price: **\$34⁵⁰** Including complete Technical Data and Schematic
Send check or money order — we pay postage.

ROUND HILL ASSOCIATES INC.

A MILO ELECTRONICS SUBSIDIARY

434 Avenue of the Americas, New York, N. Y. 10011

Model PS-200



SOLID STATE POWER SUPPLY

An all-transistor general purpose power supply, the Round Hill Model PS-200 is particularly suited for use in applications requiring a stable, well-filtered DC source. It employs Zener referenced voltage regulation, and delivers 9 volts DC at loads up to 200 MA with complete dead short protection. A locking screwdriver-adjusted programming potentiometer permits the output voltage to be adjusted over a one-volt range.

Input Voltage: 105-125 volts AC,
60 cycles, 5 watts

Regulation: Line + load 5 MV

Ripple: Under full load 10 MV, peak to peak

Output Voltage: 9 volts DC

(adjustable over 1 volt)

Maximum Load Current: 200 MA

Controls: Locking programming control

Connections: Barrier strip

Construction: Brown enameled steel case

Size: 9"L x 2 3/4"W x 3 1/4"H

Weight: 44 ounces

Price: **\$24⁵⁰** Including complete Technical Data and Schematic
Send check or money order — we pay postage.

ROUND HILL ASSOCIATES INC.

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434 Avenue of the Americas, New York, N. Y. 10011

Circle Item 59 on Tech Data Card

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)

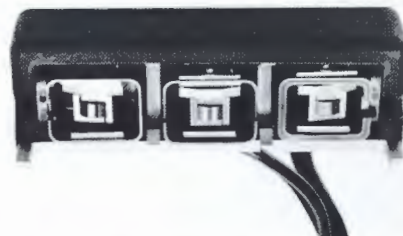
General Industrial Co. is now producing a small circular slide rule for engineers and other plant and office executives. It can be used to multiply, divide, and find proportions quickly; instructions are included.

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 1/4" 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



capable

There are really very few engineers who are capable in the designing of towers. A goodly number of them work for Dresser. These men know how to deal with the complexities of loading and other factors unique to each tower... they're truly capable in tower design.

capability

Just not every steel fabrication shop can build tower components. It takes a lot of special knowledge and skill to lay out, cut, drill, weld, and otherwise hold to the accuracy and safety margins towers must have. Dresser shop men have developed an unusual capability in fabricating tower steel.

DRESSER CRANE, HOIST & TOWER DIVISION

That's one of the most respected names in towers... DRESSER. It means capable engineers and shop capability ready to tackle just about any type of tower... commercial broadcast and communications, military and space program "specials," radar. When you think towers, think first of Dresser... then call or write us. Dresser Crane, Hoist & Tower Division, 877 Michigan Avenue, Columbus, Ohio 43215. Phone area 614, 299-2123. TWX 810-482-1743.

Circle Item 61 on Tech Data Card

"Arcturus" Catalog

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Since 1925

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ARCTURUS ELECTRONICS BE

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Circle Item 62 on Tech Data Card

BROADCAST ENGINEERING



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.



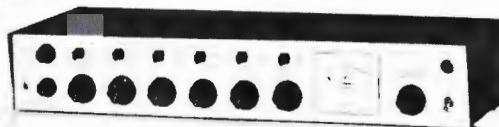
VTR for CCTV Use
(83)

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

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NOT A
CHEAPY!**

**KUSTOM
BROADCAST
CONSOLE**

**ONLY
\$495***



You, like other satisfied customers, will use words of praise like: "versatile"; "flexible"; "easy to use on remotes"; "great frequency response". But most you'll like the economy price. Fully transistorized. Six input channels. Built in speaker. Full volume control flexibility. Frequency response 40 Hz to 15 KHz. Distortion 0.5% or less. Sold with a full money back guarantee. Write today for full fact sheet.

*Price F.O.B. Portland. Legs as shown \$23.80 more.

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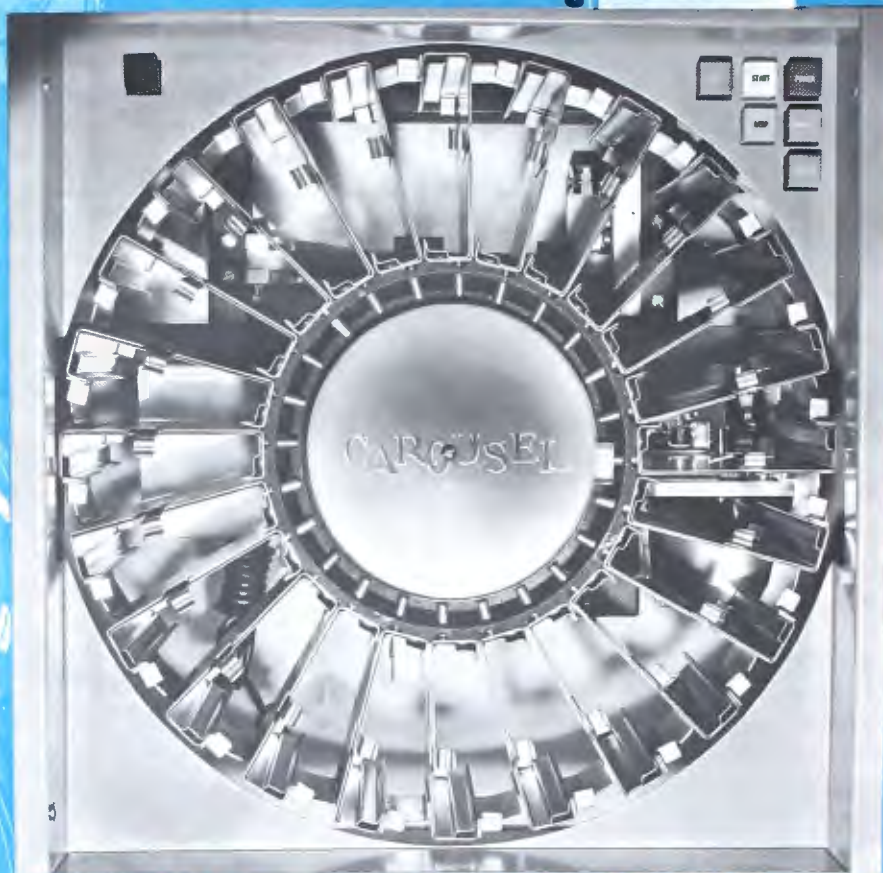
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WGBS
Miami, Florida

Schofer Electronics

CARTRIDGE TAPE EQUIPMENT



International Good Music

KBRO
Bremerton, Washington

The CAROUSEL

"MOST WIDELY USED AUTOMATIC CARTRIDGE PLAYER IN THE AUTOMATION FIELD"

Continental Electronics

FEATURES

- Precision machined aluminum castings . . . ball bearing, main drum shaft . . . Oilite bronze bushings at all wear points.
- Only 34 seconds for full rotation of drum—no delay between last and first cartridge.
- Full access random selector available.
- WEAR on cartridge MINIMIZED by cartridges being firmly and positively held in sliding carrier tray.
- Automatic cartridge clear back to prevent cartridge damage when drum is in motion.
- Only 19 1/4-inch panel space required for 24-cartridge Carousel . . . 3 Carousels fit standard rack.
- Full or partial load capability.
- MAXIMUM AZIMUTH REPEATABILITY—transport and heads stationary and mechanically fixed in relation to drum mechanism.

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1011-1013 West Washington St. Bloomington, Illinois 61701 Telephone 309-829-7115

MANUFACTURING ENGINEERS

www.americanradiohistory.com

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. ▲

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HAPPENING AT THE

MIRATEL

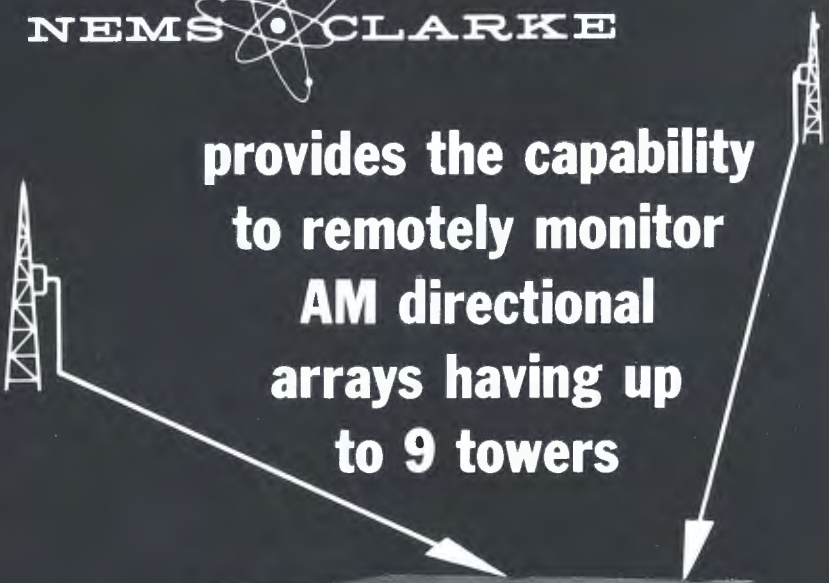
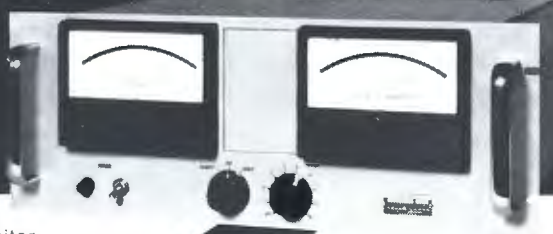
BOOTH

**MAKE BOOTH 219 A "MUST"
STOP — NAB CONVENTION
APRIL 2 to 5 — CHICAGO!**

Circle Item 67 on Tech Data Card
March, 1967



**provides the capability
to remotely monitor
AM directional
arrays having up
to 9 towers**

Model 112
Phase Monitor



Model 113
Remote Meter Panel

The Model 112 Phase Monitor is an advanced, all-solid-state unit which provides phase and current measurements of AM directional arrays having up to 9 towers. Easy-to-read panels provide phase readout of ± 1 degree accuracy with 0.5 degree resolution, and loop current readout with .5% repeatable accuracy. Automatic Day-Night switching of reference levels is also available. Phase angle and loop current outputs are provided for direct readout on a chart recorder or digital voltmeter, or can be fed over land lines for direct studio readout on the Nems-Clarke Model 113 Remote Meter Panel. The optional Model 113 unit contains duplicate phase and current meters.

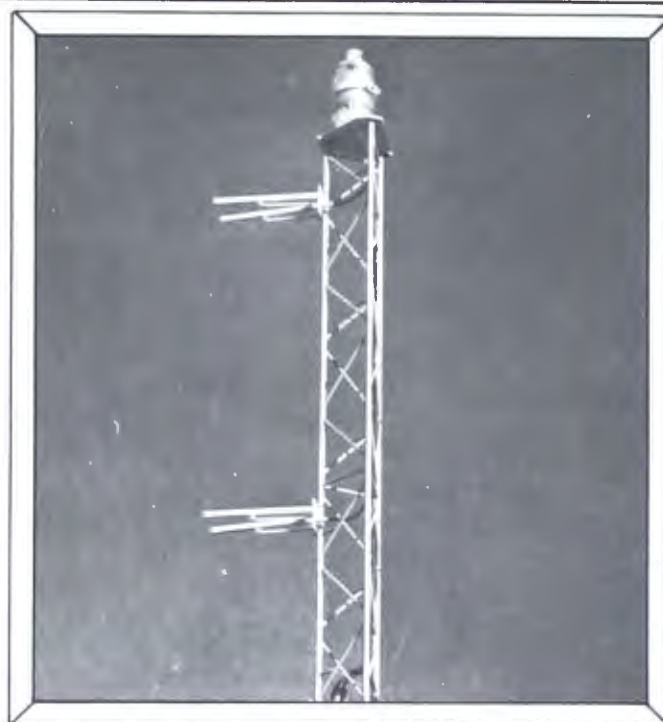
The Model 112 Phase Monitor is very simple to operate; easy to read; and incorporates all circuitry necessary to permit future adaptation to remote control. Silicon transistors are used throughout for high reliability, long life and excellent temperature stability. Panel meters are of the taut-band type to eliminate pointer binding, and have mirror scales to improve reading accuracy.

V-29

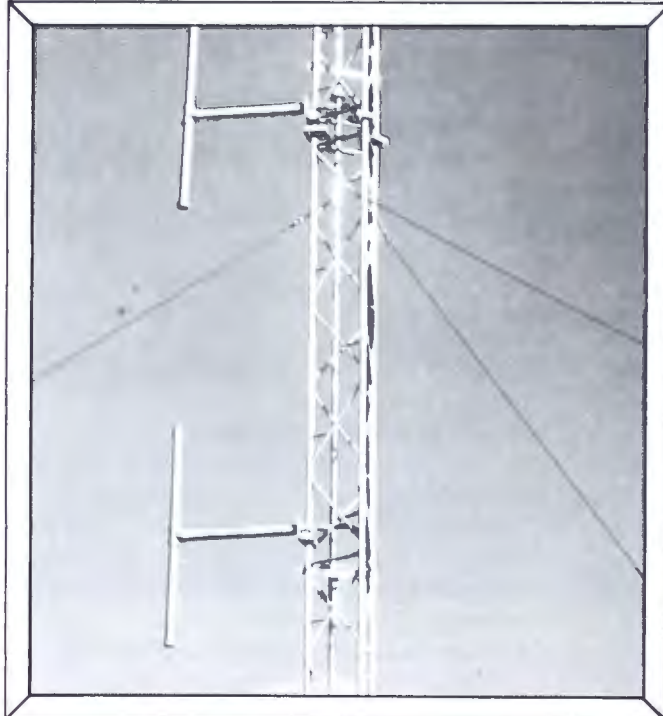
For further information, write or call:

Vitro ELECTRONICS

Producers of NEMS-CLARKE Equipment
A Division of Vitro Corporation of America
919 Jesup Blair Drive • Silver Spring, Maryland (301) 585-1000
Circle Item 66 on Tech Data Card



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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 $3\frac{1}{8}$ " 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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SACRAMENTO, CALIFORNIA

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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.

"Want a Good Job in Broadcasting?"



You'll Need a First Class FCC License."

Matt Stuczynski knows. He's the Senior Transmitter Operator of Radio Station WBOE. His story is typical of hundreds of men who have used Cleveland Institute Training as a springboard to success in Broadcasting. Here's what Matt says about Cleveland Institute:

"I give Cleveland Institute credit for my First Class FCC License. Even though I had only 6 weeks of high school algebra, CIE's AUTO-PROGRAMMED™ lessons really made electronics theory and fundamentals easy. After completing the CIE course, I took and passed the First Class Exam. I now have a good job in studio operation, transmitting, proof of performance, equipment servicing. Believe me, a Commercial FCC License is a 'must' for a career in Broadcasting."

If you want rapid advancement in broadcasting, the first step is a First Class FCC ticket with *your* name on it. And Cleveland Institute Home Study is a fast, economical way to get one. What's more, CIE backs their licensing programs with this money-back warranty:

"A CIE License Course will quickly prepare you for a First Class FCC License. If you complete the course but fail to pass the exam on *your first attempt*, CIE will refund all tuition."

With Cleveland Institute you get your First Class FCC License or your money back! Send coupon today for FREE book or write to Cleveland Institute of Electronics, 1776 E. 17th St., Dept. BE-35, Cleveland, Ohio 44114.

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BE-35



'BEST IN THE PATCH FIELD ...'

William E. Jaynes
Chief Engineer
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Hamilton, Ont., says:

"COTERM is my choice every time for its rugged dependability in helping to maintain a trouble-free board. Its excellence of construction makes it specially important in color operations. I don't hesitate to recommend it highly."

COTERM®

COTERM® provides the broadcast engineer with a new standard of dependability. With COTERM you have normal-through coaxial circuits without the use of patchcords. When the load side is patched the source is terminated automatically in the proper impedance.

Active circuits may be tested without signal interruption. COTERM is compact, permitting high density on the patch field — 22 jacks on the standard 19" x 1¾" panel.

COJAX® offers all the same advantages except self-termination of source when the load side is patched. All COTERM-COJAX accessories are compatible.



QUICK DISCONNECT CONNECTOR

The unique snap lock feature allows easy insertion and removal even in the densest patch field. Available for a wide range of coaxial cables and simple to attach with standard tools.

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at Booth 408 at the NAB Convention.

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Circle Item 70 on Tech Data Card

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

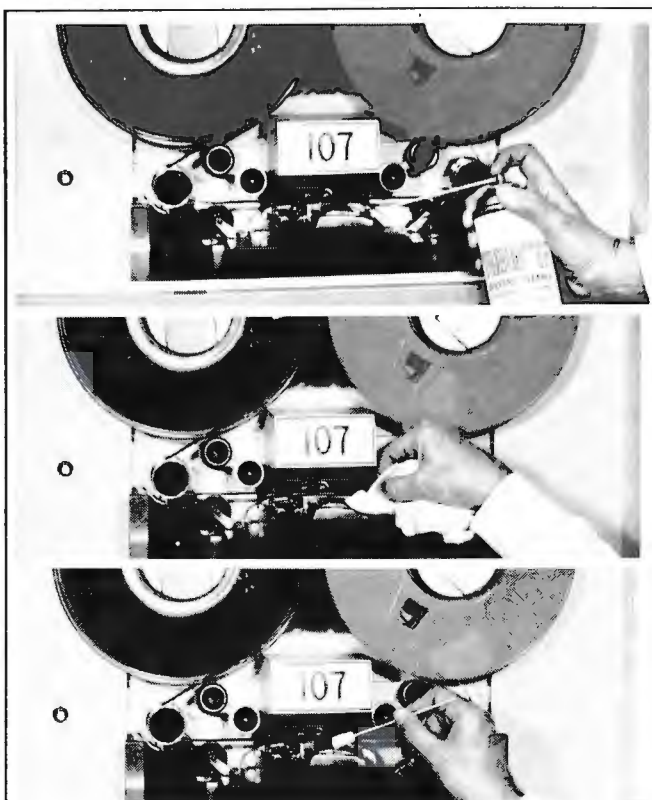
138. CANON—Catalog illustrates and gives specifications for industrial and broadcast TV lenses with fixed and variable focal lengths.
139. CLEVELAND ELECTRONICS—A 52-page quick-reference step-down die-cut catalog covers complete information on vidicon Plumbicon[®], and image-orthicon deflection components.
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 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. A—Catalog sheet covers AM frequency and modulation meter.
152. DYNAIR—Bulletin No. 91A supplies information on Model TS100B solid state signal analyzer for use in alignment of broadcast and CATV modulators.
153. WATERS—RF instrumentation equipment is listed in leaflet.

TRANSMITTERS & ASSOCIATED EQUIPMENT

154. BAUER—Newspaper advertisement describes Model 601 3000 watt FM transmitter.
155. ENGLISH ELECTRIC—Technical description of 150-watt 20-kw JHF transistor type B7301 is available.
156. TELETRONIX—Specification sheets are for 10-kw and 100-watt 10-kw FM transmitters, horizontal and vertical antenna automatic loading amplifier and three-band receiver.



Make tape heads, guides, capstans, 3 ways cleaner

FLUSH OUT oxide build-up, dust, grit, grease and oil quickly and efficiently with "FREON TF*" Aerosol Solvent Cleaner. Safe . . . even on operating equipment. Has excellent wetting . . . gets into tiniest openings to replace soils. Leaves essentially no residue. Packaged in 16 oz. aerosol spray cans with extension nozzle for hard to reach areas.

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Feeds line or distribution system. Low noise figure makes it suitable preamp or booster amplifier. Board mounted, all connections through single receptacle.

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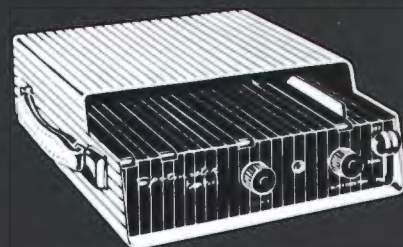
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Your time salesmen will wonder how they ever got along without it! Completely self-contained and self-powered, PortaPak I offers wide-range response, low distortion, plays all sized cartridges anywhere and anytime. It's solid state for rugged dependability and low battery drain, and recharges overnight from standard 115v ac line. Packaged in handsome stainless steel with a hinged lid for easy maintenance, PortaPak I weighs just 11½ lbs. Vinyl carrying case optional.

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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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Audio Equipment bought, sold, traded. Ampex, Fairchild, Crown, McIntosh, Viking. F. T. C. Brewer Company, 2400 West Hayes Street, Pensacola, Florida. 3-64-tf

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MARCH, 1967

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How to turn an ordinary color television set into a highly useful monitor for \$195.00.

Money-saving engineering ideas are what put International Nuclear in business. Pre-testing the ideas by in-station use is what guarantees you of the practicality of the ideas. Take the TVM2 Video Modulator pictured above, for example. This self-powered, printed circuit unit (completely transistorized) accepts

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

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Dept. 169 2-67-2t

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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.

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