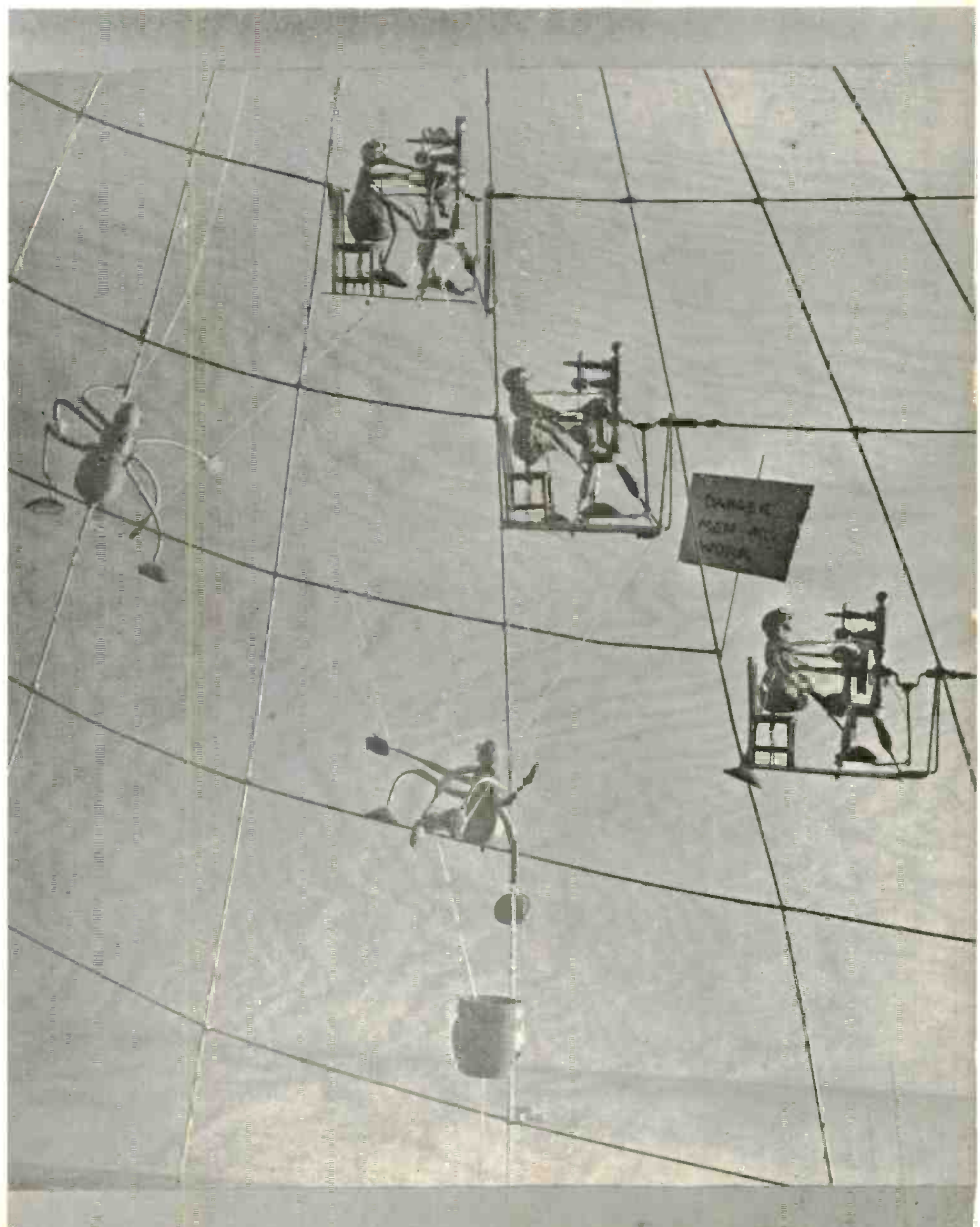
# COMMUNICATIONS

including

## TELEVISION ENGINEERING



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Editor

## CONTENTS FOR FEBRUARY

Cover Illustration: Miniature sets play an important part in television broadcasting. This video effect shows five little spiders spinning webs with spinning wheels. It was designed under the direction of Wm. C. Eddy, for a special NBC television broadcast.



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# WITH THE EDITORS

## TELEVISION ENGINEERING

DURING the past few months your editor has spent considerable time in the laboratories of many of the more progressive manufacturers, talking television and seeing television, in an honest effort to determine the present status of the art. Our findings have convinced us that an "on the fence" attitude should not exist in regards to television. Our answer is *Television Engineering*.

As far as the average engineer is concerned, commercial television is now a reality. While no commercial television station licenses have been granted by the Federal Communications Commission, a number of stations are on the air, others are under construction. There are television receivers already on the market and more will be placed on sale around the first of May in those localities where stations exist. It is anticipated that these receivers will sell within a reasonable price range. In addition, considerably more television test equipment will be made available at an early date.

While it is hardly expected that television networks comparable to our present broadcast setup will be built up during the next few months, the future of television seems to promise much. The problems faced by the television industry seem no more formidable than those that faced the radio industry in its early stages of development.

It seems to us that one of the major cost obstacles has been overcome with the announcement of a low-power television transmitter (see COMMUNICATIONS for December, 1938, p. 31). Since antenna height seems to be the limiting factor at ultra-high frequencies, such a transmitter could be used to good advantage in the smaller communities.

Unlike broadcasting, television programs cannot be transmitted from one station to another over specially equalized wire lines. The solution to this problem may well lie in the use of ultra-high-frequency guided-wave transmissions (around 4000 mc or higher) which employ hollow conductors or conductors filled with insulating material. Another, and a more probable solution, would seem to be the use of directional radio beams at frequencies in the vicinity of 4000 mc. Remarkable directivity can be easily accomplished at these frequencies through the use of electromagnetic horns. (Some interesting data on these horns appears elsewhere in this issue.) Since both of these developments are still in the laboratory stage, a more immediate solution might be accomplished through the medium of motion picture film.

Much could be written concerning the future of television, but it would be a wise man indeed who could predict anywhere near all of the ramifications of such a rapidly changing art. Our aim in *Television Engineering* is to keep you informed of the present trends and attempt to point the way towards future development.

## FCC REPORT

THE COMMITTEE of the Federal Communications Commission on "Proposed Rules Governing Standard Broadcast Stations and Standards of Good Engineering Practice" has recently released its preliminary report. This report is based upon the hearings held in June, 1938.

While the Committee's proposed changes in the rules have not yet been released, this preliminary report does discuss the factors upon which these rules will be based. It is interesting to note that this report is in line with the views expressed in this publication. (See article "Compromises in Allocation Engineering," by R. M. Wilmotte, p. 23, March, 1938, COMMUNICATIONS.) The Committee's discussion indicates that the recommended rules are likely to be a great deal more flexible . . . a change that is indeed gratifying.

Relative to licenses, the report states: "Based upon the evidence at the hearing concerning the present short term of license the Committee is of the opinion that many advantages can accrue to the public as well as to the industry if the term of license can be extended to at least one year." This recommendation seems quite logical since it would save a great deal of time for the broadcasters as well as the Commission.

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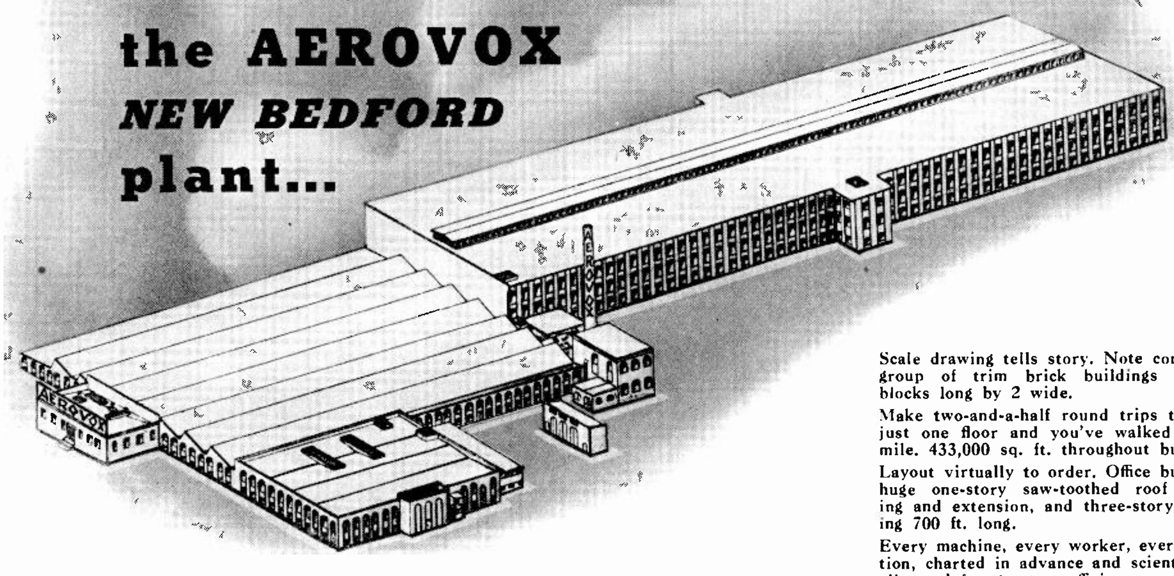

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COMMUNICATIONS

FOR FEBRUARY, 1939

# FREQUENCY CONTROLLED OSCILLATORS

By **SAMUEL SABAROFF**
WCAU BROADCASTING CO.

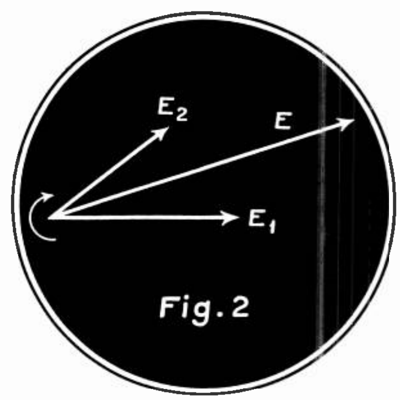
OSCILLATORS that are so controlled that they operate on some multiple or sub-multiple of a controlling frequency have been in use for many years. A general theoretical basis for the operation of such controlled oscillators, however, has not yet been completed, though the practical operation of these oscillators is well known. It is intended in this paper to present a general picture of the underlying operation of a controlled oscillator. The presentation will be from the physical point of view in the main, and will, it is felt, tend to unify and clarify the various concepts pertaining to controlled oscillators.

Consider first a controlled oscillator from the broad point of view. Since the oscillator is controlled, it must, of course, be oscillating at some frequency determined by the controlling frequency. If some parameter in the oscillator is varied, the oscillator frequency will not change for some range of values of this parameter and will drop out of control when the parameter lies outside this range of values.

Consider for the moment an uncontrolled oscillator. If some parameter of this oscillator is changed the frequency of oscillation will change. The only way in which the frequency can be returned to its former value is for some other parameter to change in such a manner as to exactly compensate for this shift in frequency.

Carrying this concept over to an oscillator that is controlled we see that a controlled oscillator can be considered to be one in which the effect of some change in a parameter is compensated for by an automatic change in some other parameter. The only effect of a controlling frequency, therefore, would be to set in motion the mechanism that makes automatic compensation possible.

In Fig. 1 is shown a block diagram of a controlled oscillator in which the various actions involved have been separated. The kind of oscillator being controlled is not specified. The frequency control is of the type in which a variation of some potential will cause a variation in some parameter of the oscillator, thus varying its frequency.




**Vector representation of controlling and oscillator voltages.**

The detector is of the type that will produce the difference frequency of the controlled and controlling frequencies down to zero frequency. A simple rectifier falls in this classification.

For the moment consider the situation when the oscillator and controlling frequencies are identical. Since these two signals are fed together into the detector, the output of this detector will be a function of their phase difference. The oscillator parameter that is controlled by the frequency control will also depend on the phase difference of the oscillator and controlling frequencies, since the output of the detector is fed into the frequency control.

In Fig. 2 the vector representations of the controlling and oscillator voltages are indicated by $E_1$ and $E_2$ respectively while $E$ is the resultant voltage applied to the detector. If the direction of rotation of the vectors be taken as clockwise then an increase of frequency of the oscillator will tend to increase the resultant voltage since their phase difference will decrease. If this oscillator frequency increase is not checked in some manner its voltage vector will overtake the controlling voltage vector and rotate with respect to it at a rate equal to their frequency difference.

For the purpose of illustration let us suppose that the frequency control is so adjusted that an increase in detector output will cause the oscillator frequency to decrease. It is evident therefore that if the vector relation of the oscillator and controlling voltages is such that an increase of the oscillator frequency causes an increase in detector output, thus causing the frequency control to decrease the oscillator frequency, a point of balance or stability will be reached in which the latter effect exactly compensates the former. The controlled and controlling frequencies are still identical except that a change of phase between them has occurred. This change of phase is that necessary to effect the compensatory parameter change through the medium of the detector and the frequency control. The range over which this compensation can take place is determined by the amplitude of the oscillator and controlling voltages, the type of detector and by the range of the frequency control.

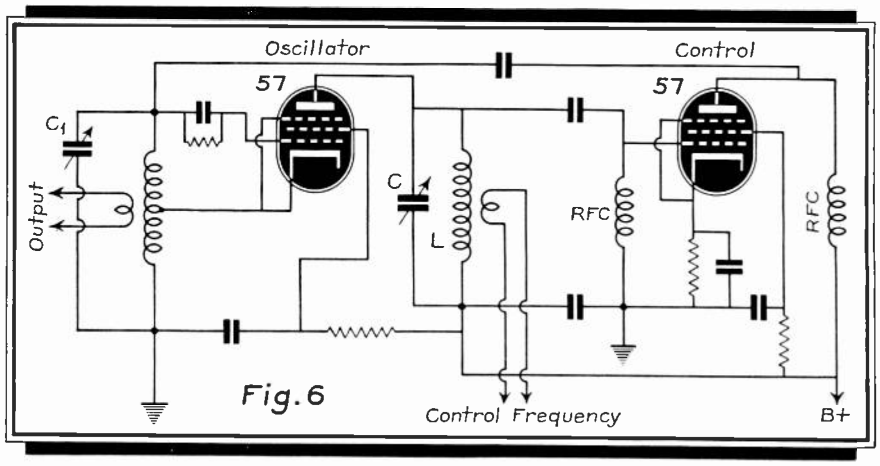
It is evident that proper compensation can take place only through a phase change of $\pi$ radians of the oscillator voltage with respect to the controlling voltage. A phase angle outside this region represents an unstable condition since in this case any change of oscillator frequency will result in a further change in the same direction. The effect of this instability is the rotation of the oscillator voltage vector into the region of stability.

We have thus far considered the situation when the controlled and controlling frequencies are identical. Let us now discuss the conditions under which control is secured when, at the start, these frequencies are different.

Let a parameter of the oscillator be capable of being manually varied so that its frequency can be made to pass through a region in which is located the controlling frequency. The output of the detector will be the difference frequency between the oscillator and controlling voltages. Since the output of the detector is fed into the frequency control, the oscillator will be frequency modulated by the difference frequency.

Now let the manually controlled oscillator parameter be varied so that the oscillator frequency approaches that of the controlling frequency. It is evident that the extreme value of the modulated oscillator frequency will reach that of the controlling frequency before that of the unmodulated oscillator and control will therefore be obtained when this occurs. The output of the detector will be a difference frequency reducing in value as the oscillator approaches the controlling frequency until control is secured with a sudden jump of the difference frequency to zero without passing through the intermediate values.

The frequency characteristic of the coupling arrangement between the detector and the frequency control will also determine the amplitude of the difference frequency that will be applied to the frequency control. Usually the coupling arrangement has a falling characteristic with increase in difference frequency. This manifests itself by a "holding effect" between the oscillator and the controlling frequency after control has been secured. When control has been obtained and the manually controlled oscillator parameter varied in some direction until control is lost, control will be regained only when this parameter is moved in the opposite direction to a point past that which control was lost.




**A simple circuit used for submultiplication.**

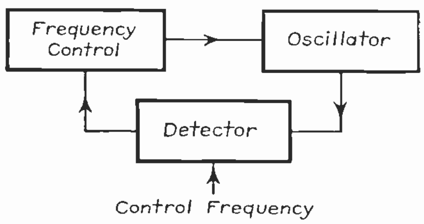



Fig. 1

**Block diagram of a controlled oscillator.**

It is a simple matter to extend what we have said to the control of the oscillator on some harmonic of its fundamental frequency. It is necessary to insert a harmonic generator between the oscillator and the detector as shown in Fig. 3, and then vary the frequency of the oscillator until a selected harmonic coincides with the controlling frequency. Control will then be obtained in exactly the same manner as on the fundamental frequency. However, the effect of the frequency control will be multiplied by the harmonic number and the phase change of the oscillator over the region of control will in general be $\pi$ radians divided by the harmonic number.

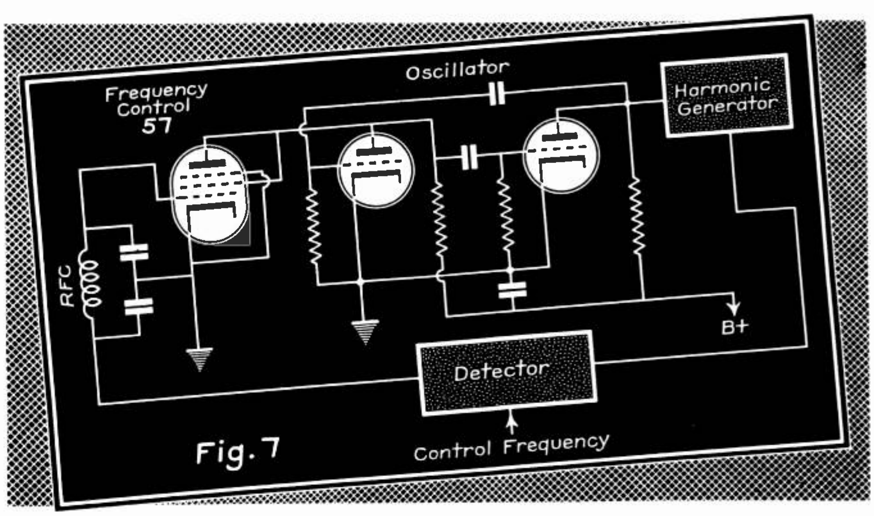
The "holding effect" mentioned in a previous paragraph will also become evident if a tuned circuit exists in the harmonic generator tuned to either the harmonic or oscillator frequency when control is established. After control has been obtained the frequency is constant so that the fixed tuned circuits have no effect on the limits of control, but when control is being established these tuned circuits will affect the point at which control is secured.

The block diagram of Fig. 3 is an exploded view of the various individual items that must generally comprise a controlled oscillator. It is possible, of course, that some or all of these items may be combined in a common circuit element.

In Fig. 4 is shown a practical arrangement in which all of the various items are separate circuit elements. The oscillator and detector are conventional and need not be considered in any detail. The harmonic generator is also self evident. The output circuit of the harmonic generator is tuned to the controlling frequency and coupled to the detector and to the source of controlling frequency as indicated.

There are many kinds of arrangements that could have been used as a frequency control.[1]* The type of frequency control indicated in Fig. 4 was used because of its simplicity. It is equivalent to a capacity in shunt to the LC circuit of the oscillator having a value approximately equal to $C/(1 + gR)$. g is the mutual conductance of the frequency control tube, R is around 400 ohms and C is large with

**An RC type of oscillator or multivibrator.**



respect to the cathode-to-ground capacity of the control tube. The range of frequency control is determined by the relation of C to $C_1$.

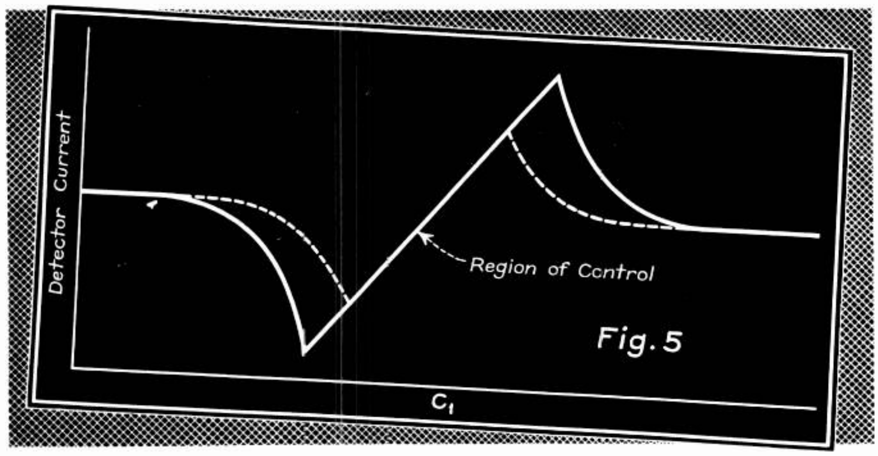
Everything that has been described till now can be verified in the circuit arrangement of Fig. 4.

The current in the detector is an interesting indication of control. The current change with respect to an oscillator parameter variation is like that shown in Fig. 5, control being obtained over the straight portion of the curve. The dotted portion of the curve indicates the current variation before control is secured.

The frequency range of the arrangement in Fig. 4 is very wide. With the use of acorn type tubes a submultiplication of ten to one with the controlling frequency in the neighborhood of sixty megacycles was relatively easily obtained.

It is possible to omit the harmonic generator and detector of Fig. 4 and obtain control by inserting the controlling frequency in the suppressor or screen circuit of the frequency control tube. The frequency control tube is thus acting also as a harmonic generator and detector. The amplitude of the controlling frequency becomes relatively large, however, for a comparable stable control ratio of submultiplication.

A simple circuit useful for a submultiplication ratio up to four or five is shown in Fig. 6. LC is tuned to the controlling frequency and should have as low a value of C as possible. Control is established by varying $C_1$ until a selected harmonic of the oscillator coincides with the controlling frequency. A headphone in the screen circuit of the control tube facilitates finding the point of control. Some adjustment of the voltages and the amount of controlling voltage is necessary for obtaining maximum stability as indicated by the amount of variation of $C_1$ necessary to lose control.




**Showing current change with respect to oscillator parameters.**

It is possible for an LC type of oscillator to perform all of the functions necessary for control as a submultiplier[2,3,4,5]. It is evident that in this case, detection, harmonic generation, and frequency control demands a non-linearity of the tube characteristic and at the same time the conditions for oscillation must be maintained. It is found that control is most easily secured when the L/C ratio is as high as possible.

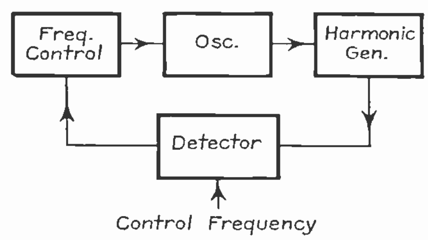



Fig. 3

**Controlled oscillators are comprised of above items.**

An LC type of oscillator is easily controlled on its fundamental frequency, however. In this case the problem of harmonic generation is absent. Also the tuned circuit is resonant to the controlling frequency so that its maximum effect is more easily obtained. However, the non-linearity of the tube characteristic is still essential for detection and frequency control. The problem of the control of an LC oscillator on its fundamental frequency in terms of the non-linearity of the tube characteristic was quite thoroughly investigated by Appleton[6].

The LC type of oscillator is not the only kind amenable to control in a circuit such as shown in Fig. 4. In Fig. 7 is shown an RC type of oscillator or multivibrator in which the frequency control tube constitutes a variable resistance controlled by the output of the detector. This circuit has somewhat of an advantage in the frequency range over which it is capable of operation, over that in Fig. 4, because of the greater range of frequency control of the frequency control tube.

The multivibrator type of oscillator has in itself the qualities necessary for submultiplication. The harmonic content is large and the frequency is quite sensitive to any change in the tube characteristics which is necessary for compensation over the region of control.

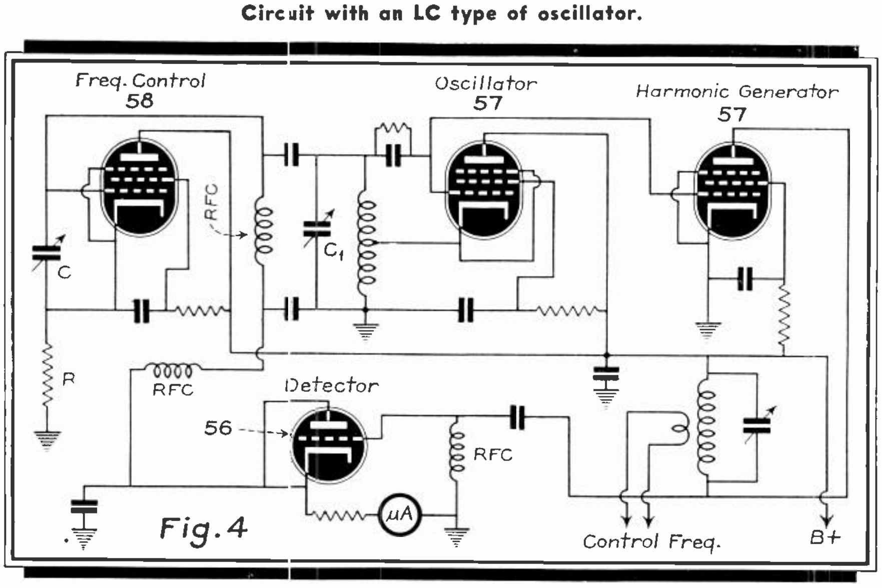
It is beyond the scope of this paper to indicate at any length the uses for which frequency controlled oscillators are suitable. A few of the possible applications will be mentioned, however.

The use of a submultiple generator for the generation of standard frequencies in a frequency measuring assembly is well known. A frequency controlled oscillator can also be used to bring a signal, the frequency of which is being measured, into a part of the spectrum

(*Continued on page* 50)

*See bibliography at end of article.—Editor.

**Circuit with an LC type of oscillator.**



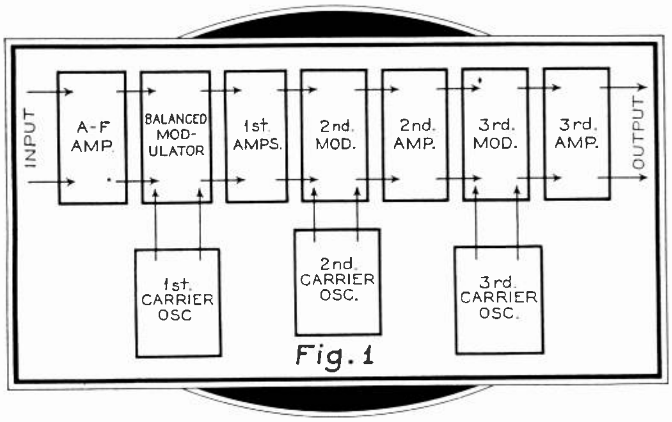


Fig. 1

# An Experimental SINGLE-SIDEBAND TRANSMITTER

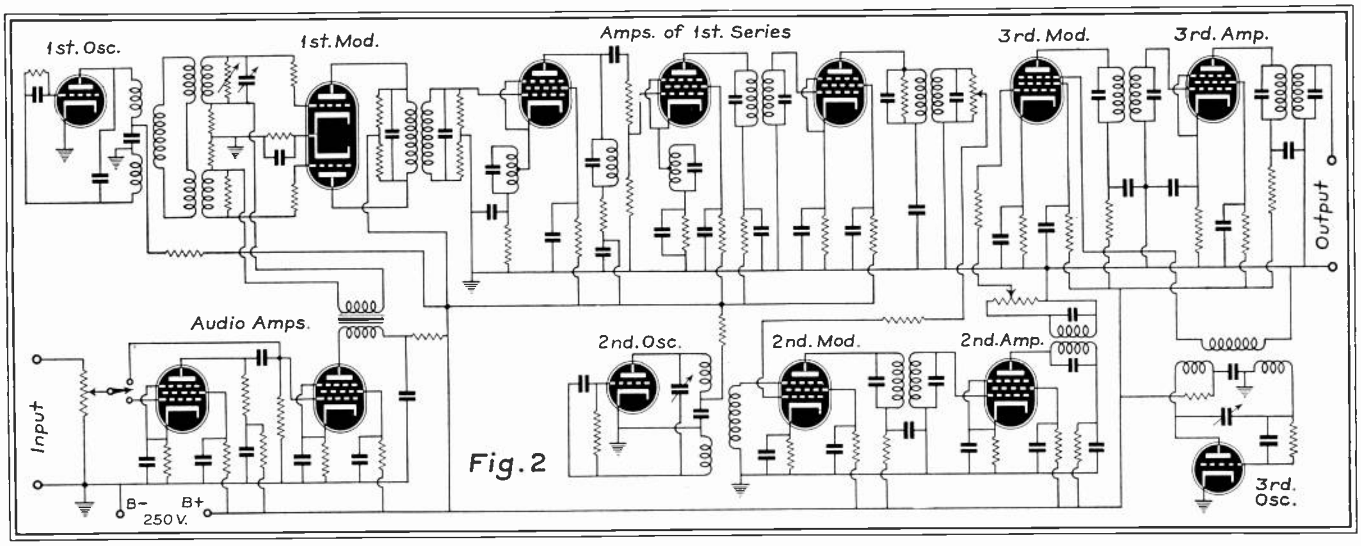


Fig. 2

THE GRADUALLY increasing importance of single-sideband systems in radio communication makes desirable laboratory apparatus that is suitable for general experimental purposes. Such equipment should be flexible, inexpensive, and so constructed as to be highly accessible. Following is a description of a unit which has been developed at Purdue University to meet the above requirements. It is capable of handling an audio-frequency band from approximately 100 to 8,500 cycles, employs no crystal filters, and is made up of standard radio receiver parts.

A block schematic of the transmitter is shown in Fig. 1. The first carrier has a frequency of 20 kilocycles; the second of 440 kilocycles, in order that standard i-f transformers might be used to pass the desired sideband; and the third can be adjusted so as to put the desired sideband anywhere in the long-wave amateur telephone band.

The circuit diagram of the complete unit is shown in Fig. 2. The output power is quite low, but is sufficient for experimental work in the laboratory. For use on the air it would be necessary to provide a linear amplifier to feed the antenna.

The most critical and troublesome part of the system is the first modulator and its associated filter-amplifiers. The overall frequency characteristic of these two units in cascade must be extremely steep on one side, so that the undesired sideband may be separated from the desired. Such a filter was developed without resort to the use of quartz crystals or magneto striction rods.

The circuit of the modulator proper is shown in Fig. 3.

A Type-6A6 tube works into a pair of coupled circuit filters which are shunted with resistance so as to pass a band 10-kilocycles wide. The frequency characteristics of the modulator are shown in Fig. 4, and it will be seen that there is considerable discrimination against audio frequencies which might

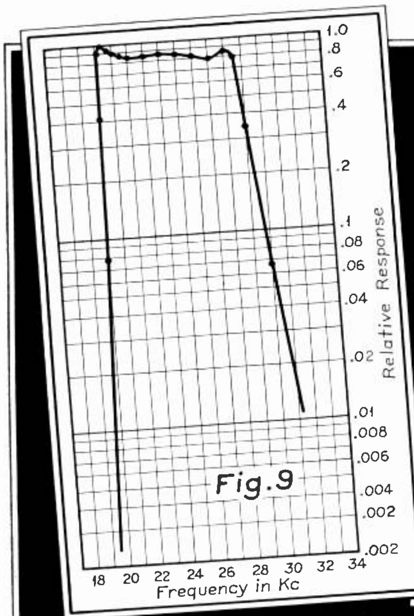


Fig. 9

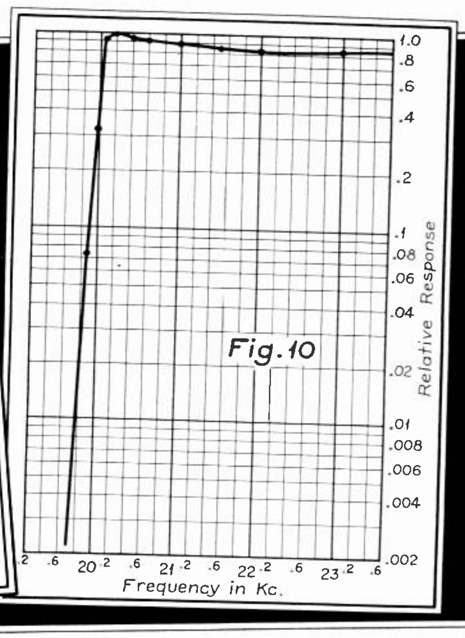


Fig. 10

**By C. B. AIKEN**
**& H. S. LOH**

leak through from the input, and there is also some discrimination against harmonics of frequencies in the neighborhood of 20 kilocycles. Of course a great deal more selectivity is necessary and is furnished by additional filters located in the following amplifiers.

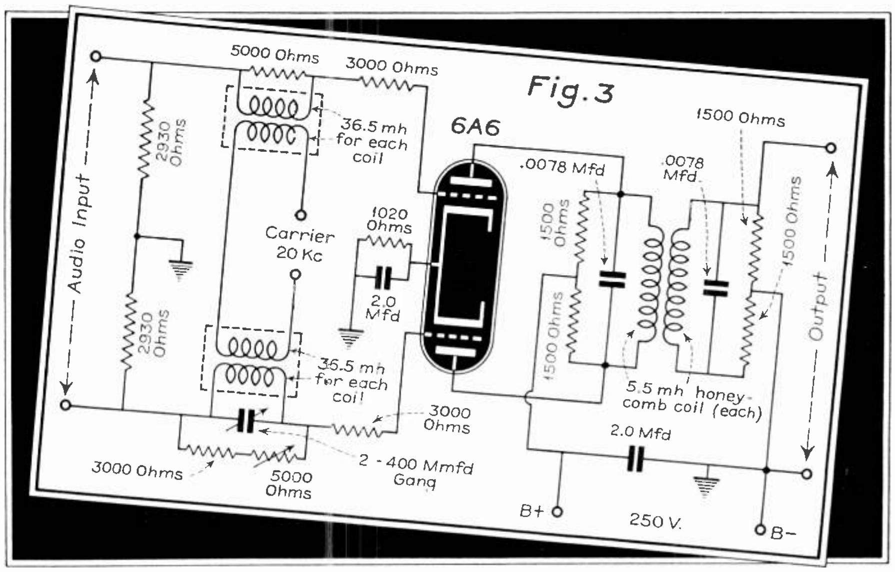
The constants of the elements in the grid circuit of the modulator have been chosen to give a linear modulation characteristic over a useful range. The overall performance of the unit is indicated by Fig. 5, which is a plot of 20-kilocycle output versus d-c input. The linearity of this characteristic shows that satisfactory modulation will be obtained when the d-c input is replaced by an audio frequency. No effort has been made to completely eliminate the carrier leak from the first modulator, since a small amount of carrier is useful as a pilot frequency.

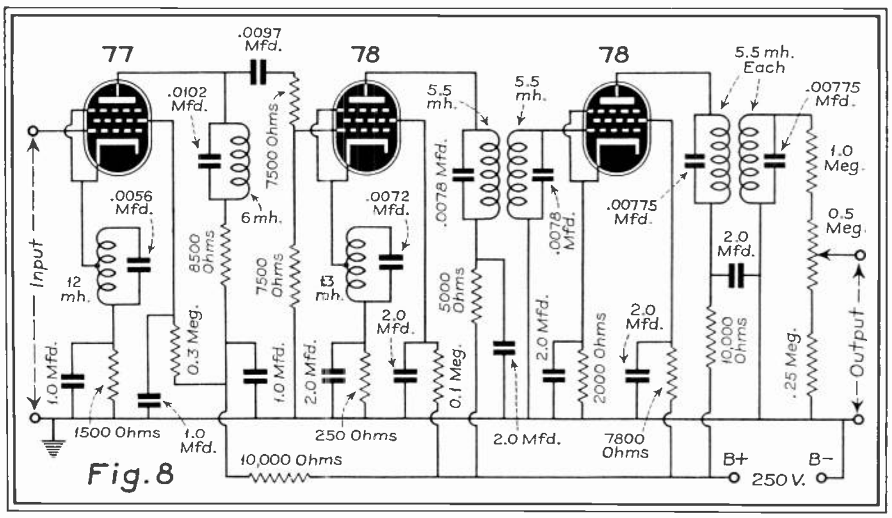
Following the modulator are stages of amplification incorporating coupling circuits that act as band-pass filters. The second and third stages each work into a pair of tuned coupled circuits while the first is designed to give added discrimination at the low-frequency side of the passed band. Fig. 6 shows the selectivity characteristic of the first pair of coupled circuits and Fig 7 shows that of the second pair. The curve of Fig. 6 is too peaked for use alone whereas that of Fig. 7 has a single peak which is not broad enough, but the two together give a satisfactory characteristic with large overall selectivity.

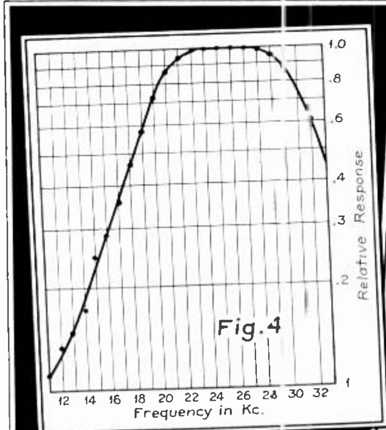
In order to increase the sharpness of the overall characteristic on the low-frequency side, the first and second stages of amplification are each provided with a high-Q tuned circuit in the cathode leg. This causes maximum degeneration at the resonant frequency of the circuit, and by properly adjusting the tap on each of these circuits a large reduction in amplification can be obtained over a narrow frequency band. Both circuits are tuned to near the low edge of the passed band and add tremendously to the discrimination against the unwanted sideband. This method of filtering has the great advantage that the rejector circuits are not coupled to the rest of the filter and can be independently adjusted.

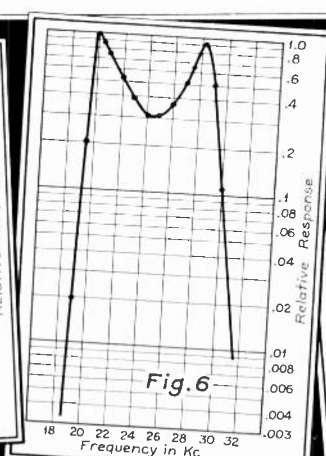
The circuit details of the three amplifiers are shown by Fig. 8. The overall selectivity of the modulated amplifier is indicated in Fig. 9 and it will be seen that the steepness of the lower side is really remarkable. Fig. 10 shows a portion of this characteristic on a larger

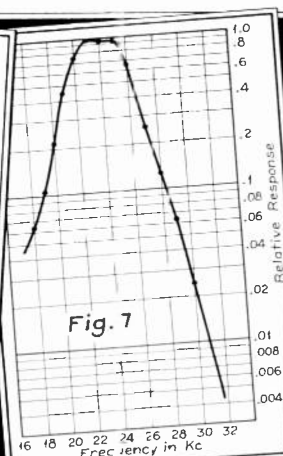
(*Continued on page* 49)

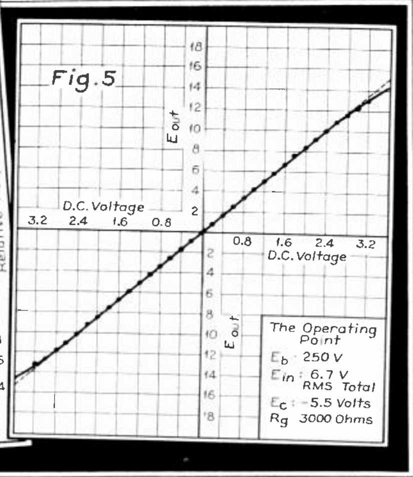


# INDUCTIVE TUNING

## Theory and Application

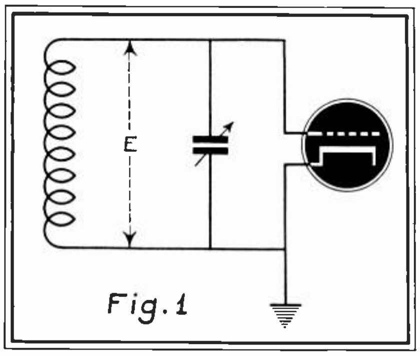
**By O. J. MORELOCK**

Radio Engineer

WESTON ELECTRICAL INSTRUMENT CORP.

THE METHOD of tuning radio-frequency circuits by variations in inductance is far from new. In fact, the earliest tuning device for commercial receivers was an adjustable inductance consisting of a cylindrical coil and a contactor sliding along the coil parallel to its axis. The contactor jumped from one turn to another and picked up the required inductance for the tuned circuit. Progressively, the so-called variocoupler was an elaboration of the earlier arrangement and included a tapped secondary winding along with the mutual coupling between the two coils. The variometer then appeared and following this came the double roller type of tuner involving a bare wire wound from an insulated roller onto a bare metallic roller for varying the inductance of the insulated coil.

Since then the variable condenser has taken the primary position in the field of tuned circuits. Although years of skillful development of the variable condenser as a tuned circuit component have brought many improvements in this device, there is still room for considerable improvement and economy in meeting stricter requirements for resonant circuits, especially in the high-frequency field. A new basic method of inductive tuning was described last year in the *I.R.E. Proceedings* for March, 1938, under the heading "A New System of Inductive Tuning". Since that time considerable development work has been undertaken* in adapting this principle to actual production devices, especially in the high-frequency tuning bands.




**Circuit for coupling to input of vacuum tube.**

*This work has been undertaken by the Weston Electrical Instrument Corp. under its licenses.

There are two basic advantages of the inductive tuning system over the condenser tuning system:

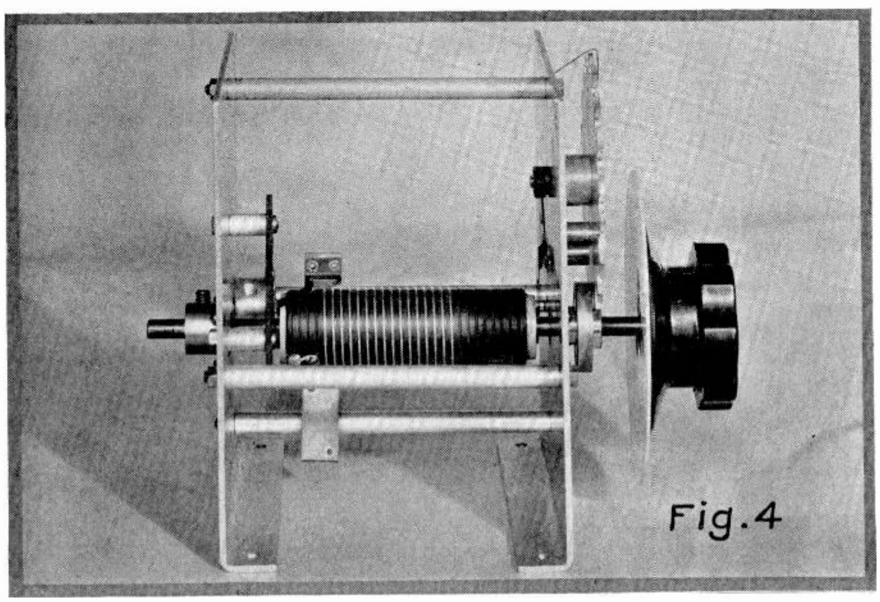
(1) Much broader frequency coverage is possible with the inductive tuning system. Frequency ratios of 7 or 8-to-1 can be obtained as against ratios of 3 or 3½-to-1 for condenser tuning systems. This has been verified in actual production devices.

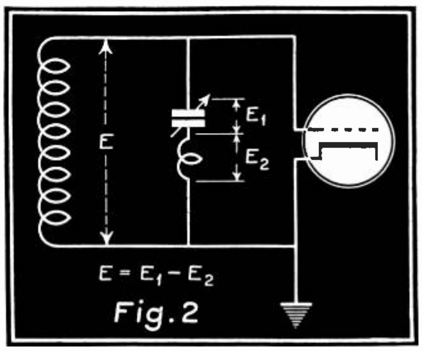
(2) Increased amplification and higher resonant-circuit voltages are available with the inductive system.

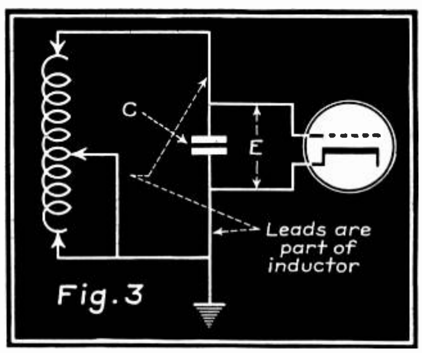
If a simple resonant circuit for coupling to the input of a vacuum tube is observed, theoretically the voltage across such a circuit would be equal to the induced voltage across the coil itself, or E in Fig. 1. This however, will be the case only if the circuit components are lumped in each section of the parallel circuit, i. e., L and C are pure inductors and capacitors respectively. In high-frequency work, it is well known that there is very appreciable inductance in a variable condenser and its connect-

(*Continued on page 42*)

**Fig. 2. Illustrating inductive drop across condenser. Fig. 3. Illustrating inductive tuning. Fig. 4. A continuously variable inductance tuning unit.**



# ELECTROMAGNETIC HORNS

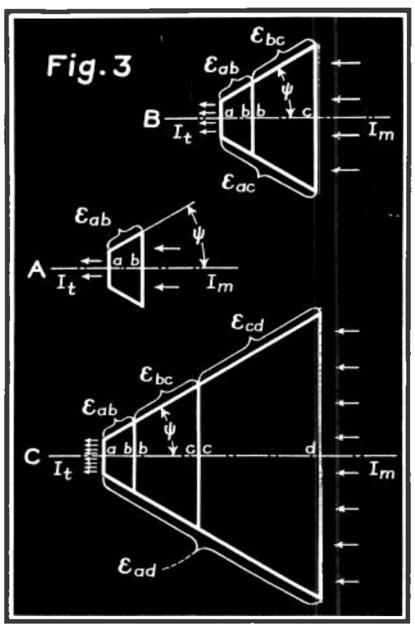
**By GROTE REBER**

ELECTROMAGNETIC resonance chambers have been discussed as sinks and sources of wave power[1]. When used in conjunction with a parabolic reflector the directional properties of the system are a function of the size of the opening in the chamber. Since the dimensions of the chamber are inversely proportional to frequency an increase in frequency will increase the resolving power (directivity) of the antenna system. To obtain comparable measurements at increased frequency may require an opening in the chamber larger than the diameter of the chamber. The way out of this mechanical dilemma is to use a horn with a mouth diameter of the size desired and a throat diameter to fit the chamber required. Such a device will act to compress the electromagnetic energy. Only conical horns are discussed in this paper.

### EQUIPMENT

The oscillator was a magnetron operating in transit time fashion; the radiator being merely the transmission-line shorting bar, 5/16″ long, acting as a point source of energy. The receiver consisted of a chamber with transverse cut-off frequency of 4170 mc. Using the notation of the previous paper[1]; D was adjusted to resonance by a plunger and A maintained equal to C. Fig. 1 shows the set up with a series of 2-to-1 horns in the background. For large cones another jig was built for the chamber so that the distance from the source to the mouth of the horn could be held at 7.5 times the mouth diameter of the horn. The chamber output was read on a microammeter and since the crystal closely approximated a current-squared rectifier the response data is the square-root of the current readings.

The arrangement shown is for taking the vertical characteristic of the space pattern. The dipole in the chamber is parallel to the vertical oscillator shorting bar. To obtain response as a function $\phi$ (angle $\phi$ between axis of horn and direction to source) the chamber is turned on a vertical axis through the center of the mouth of the horn. To get the horizontal pattern the magnetron is turned 90° making the radiator horizontal and perpendicular to the direction from the radiator to the chamber. Likewise the chamber is rotated 90° axially to make the dipole horizontal. The chamber and the horn are then turned on the same mechanical axis through the center of the mouth of the horn. In this case the axis is perpendicular instead of parallel to the electric field. Unless otherwise stated all data was taken at 4640 mc.




**Above: Horns with constant $\psi$, increasing $D_m/D_t$.**

**Below left: Apparatus for experiment; right: series of 3:1 horns; values of $\psi$ left to right 90, 75, 60, 45, 30, 20, 15, 12, 10, 8°.**

### RESPONSE

For a perfect horn the gain will be

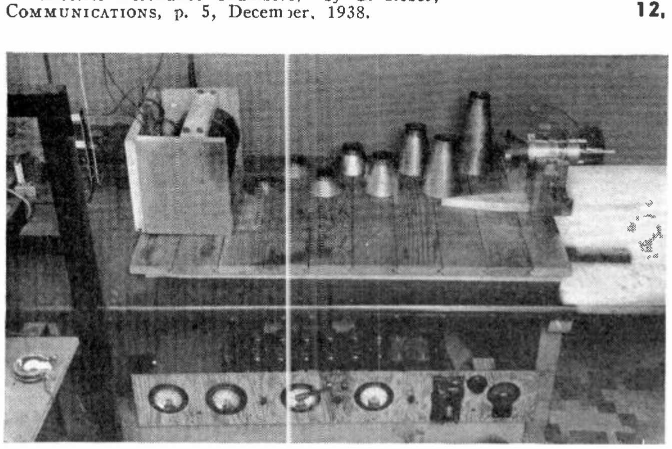
$$G = \sqrt{\frac{I_t}{I_m}} = \frac{D_m}{D_t} \quad \ldots\ldots\ldots (1)$$

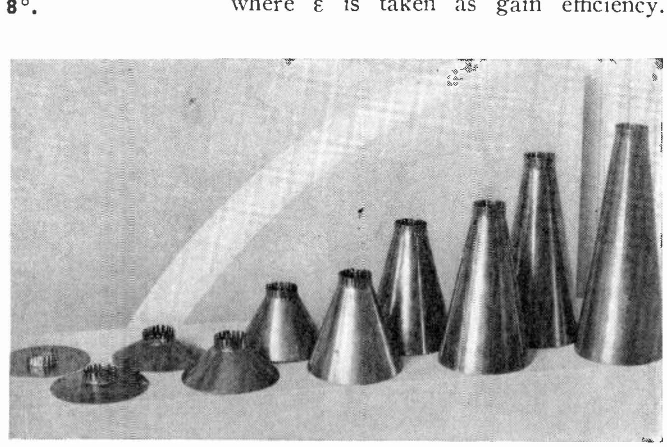
where I, D, m and t respectively denote intensity, diameter, mouth and throat. Actually some energy will be lost in the material of which the horn is constructed and some will be reflected back out. The taper of a horn may be defined by the angle an element of the surface makes with the axis. Call this angle $\psi$. If a series of horns, as shown in Fig. 2, are tested the effectiveness for $\psi = 90°$ will be zero and the efficiency will approach zero as $D_m/D_t$ increases indefinitely. For decreasing values of $\psi$ the efficiency will at first increase because less energy is reflected out. When $\psi$ is made very small the horn will become very long and the efficiency will again decrease due to losses in the material of fabrication. Actually this condition is not reached in the following tests because loss of energy in the material of the horn is very small compared to the loss of the energy due to reflection back out. The response will be

$$R = \varepsilon G \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where $\varepsilon$ is taken as gain efficiency.

[1] "Electric Resonance Chambers," by G. Reber, COMMUNICATIONS, p. 5, December, 1938.





ε must not be confused with energy efficiency as it is the square root of the latter. Further reference to the efficiency will always mean gain efficiency.

To obtain any given efficiency for increasing ratios of $D_m/D_t$ will require decreasing values of $\psi$. Consider a series of horns with fixed $\psi$ as shown in Fig. 3. Horn A will have an efficiency $\varepsilon_{ab}$ depending upon a, b and $\psi$. Horn B can be split up into two horns ab and bc. The efficiency will be $\varepsilon_{ac} = \varepsilon_{ab} \times \varepsilon_{bc}$. Similarly $\varepsilon_{ad} = \varepsilon_{ab} \times \varepsilon_{bc} \times \varepsilon_{cd}$, etc. Since all values of ε are less than unity the overall efficiency will decrease for horns with increasing $D_m/D_t$ ratios and fixed $\psi$. The correctness of this qualitative argument is born out by data of Fig. 4. Some data was taken using 7-to-1 and 10-to-1 cones for angles of $\psi$ between 20° and 45°. The 7-to-1 crossed 5-to-1 at $\psi = 20°$ while the 10-to-1 points fell consistently to the right and below the 5-to-1 curve. Unfortunately there seems to be no simple relationship between ε, $\psi$, mouth and throat diameters which is discernable from the data. $\varepsilon_{ab} > \varepsilon_{bc} > \varepsilon_{cd} \cdots$ where a, b, c, d, $\cdots$ have values 1, 2, 4, 8, $\cdots$. If the length, mouth and throat diameters of the horn are fixed the most efficient horn will have some curve similar to the solid line between the dotted lines of Fig. 5. The optimum curve could be determined if the efficiency function and its parameters could be set up accurately. The peculiar dip in the curves of Fig. 4 at $\psi = 20°$ is difficult to explain except as some type of systematic error, because the computed probable error is well within deviation from a smooth curve.

Theory developed for wave guides of rectangular cross-section[2] will apply in substance to wave guides of circular cross-section. It is predicted that for openings less than one wavelength the space pattern will not be greatly affected by the size of the opening. Also for equal dimensions of the opening in horizontal and vertical directions the vertical space pattern will be sharper than the horizontal. Previous work[1] with resonance chambers also has verified the above predictions. The theory also predicts that for large values of openings (in terms of wavelengths) the space pattern will sharpen up and minor maxima will appear at each side of the major maximum. Fig. 6 shows how the space pattern varies with $\psi$ for 2-to-1 cones. It is interesting to note that for less than 30° there is little change in sharpness similar to little change in gain as shown in Fig. 4. Inspection of the curves will show that the vertical space pattern can be closely approximated by

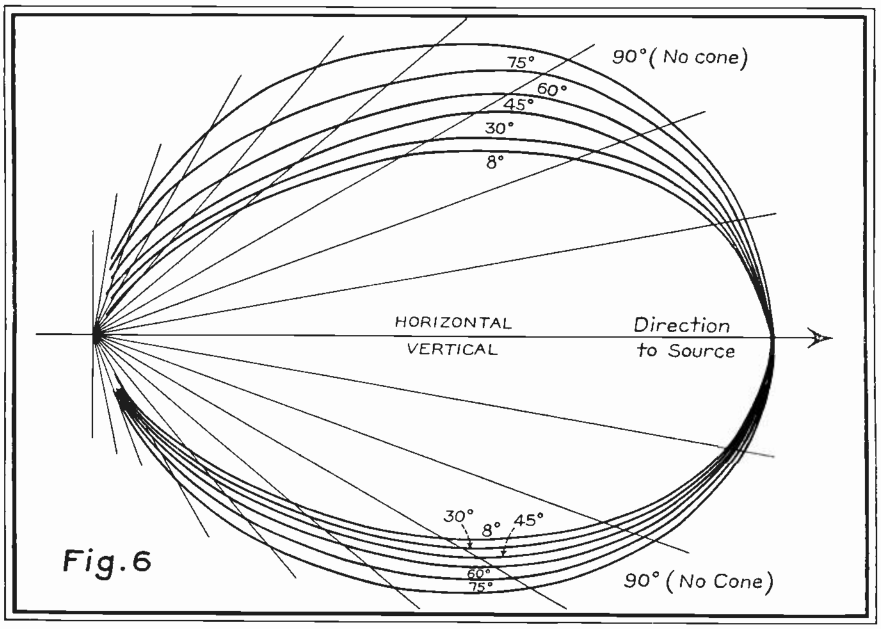
$$R = (\cos \phi)^v \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and the horizontal pattern by

$$R = (\cos \phi)^h \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

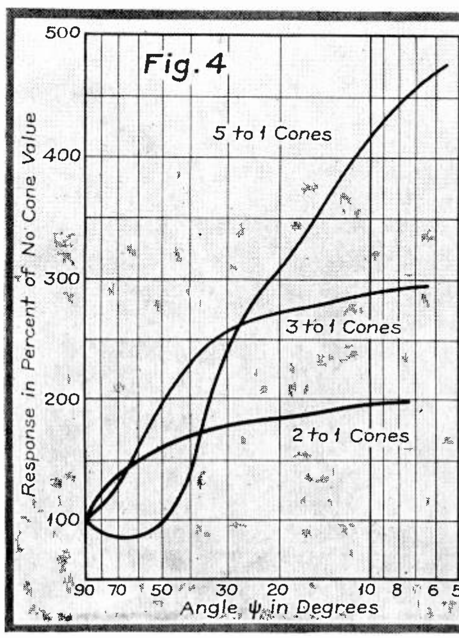
Values of h and v are given in Figs. 7-A and 7-B. v is greater than h for no cone values and while they both increase with $D_m$ the horizontal sharpness becomes greater than the vertical for small $\psi$ and large $D_m$. Minor maxima of approximately 10% response were found in horizontal pattern at $\phi = 45°$ to 50° for $\psi = 10°$ on 3:1 $D_m/D_t$. None was found in the vertical pattern. When testing 5:1 cones of $\psi = 15°$ the minor maxima were about 15% response and located at $\phi = 45°$ in the horizontal characteristic and $\phi = 35°$ in the vertical pattern. The angles of zero response were $\phi_h = 40°$ and $\phi_v = 28°$. These angles are between the axis of the cone (maximum response) and the zero response. Computation will show them to be in fair agreement with theory but here again strict comparison is not possible. The best method of defining quantitative sharpness depends upon the use to which the data is to be put. While the response curve departs markedly from equations (3) and (4) for very small response and large $D_m/D_t$ the nose of

[2] "Rectangular Hollow-Pipe Radiators," by Barrow and G. Reber, *Proc. IRE*, p. 1498, December, 1938.

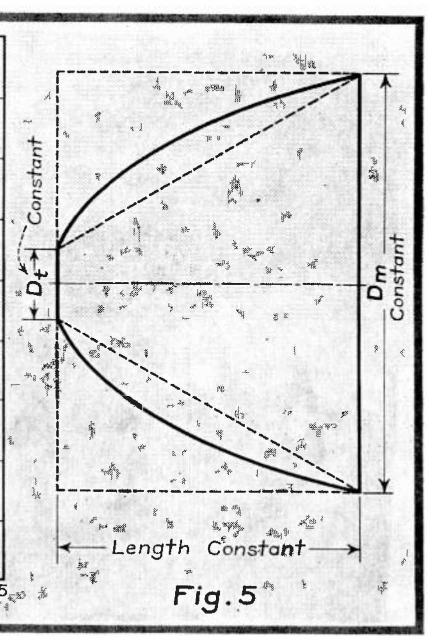



**Variation of space pattern with angle $\psi$ for 2:1 conical horns.**

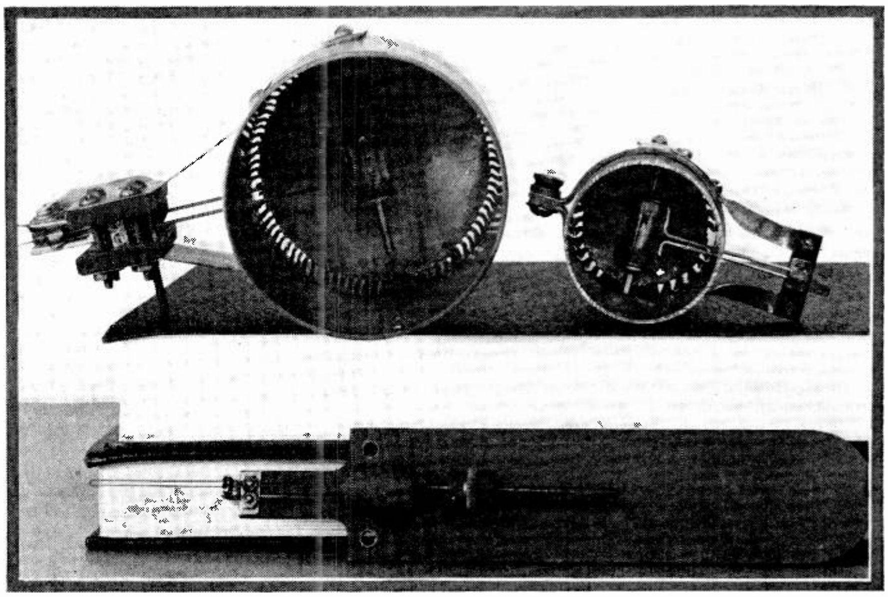
**Response as function of taper and mouth-to-throat diam. ratios.**




**Efficient curve for horn of fixed dimensions similar to solid line.**



the curve (from maximum to half maximum response, the region of most interest) still closely approximates these simple functions. They were chosen to make possible the analysis of reflector efficiency to be discussed later. The dotted lines of Figs. 7-A and 7-B indicate data that was taken but the pattern varied so greatly from eqns. (3) and (4) that no approximation was possible. The patterns were of multimaxima type with either a maximum or minimum (not zero) along the axis of the cone. Some data was taken on space pattern using 7:1 and 10:1 cones between $\psi = 20°$ and $\psi = 45°$. The value of v was in all cases below the 5:1 curve while h could not be evaluated as the space patterns were of the multi-maxima type. These results are in agreement with discussion under response and indicate that small values of $\psi$ are increasingly important as the ratio of $D_m/D_t$ increases. No spurious response could be detected in reverse or side directions at any time.

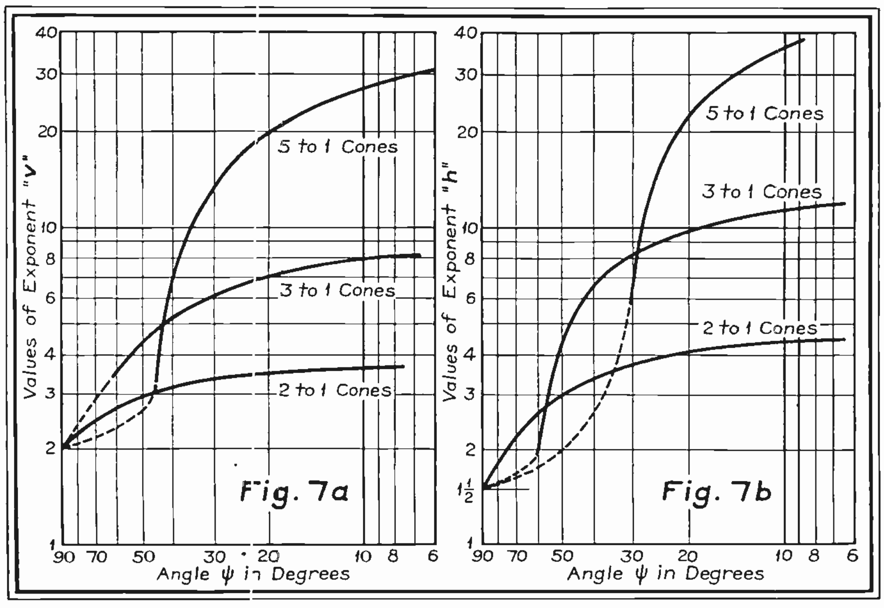


View of two chambers. One at left has transverse cutoff of 2305 mc; at right, 4170 mc. See wavemeter below.

## ADDENDA

Fig. 8 shows the internal view of chamber used in the previous paper at the left and that of this discussion at the right. The crystal holders are of the same size and construction. In the first case the obstruction caused by the crystal holder was negligible and the chamber was able to operate in the simple fashion described. In the second case the relative size of the crystal holder was four times as great, causing severe distortion of the field within the chamber. Actually it seemed to be a stop which effectively divided the chamber into two parts; the front tuning broadly as in the case of A = 100% C with the back part tuning sharply similar to condition of A = 30% C.

The first attempt to tune the chamber involved setting the plunger (distance D) to resonate for mode $\alpha$. Due to the above mentioned distortion of field D had to be less than the radius of crystal holder and true resonance became impossible. Moving the plunger back one wavelength (wavelength inside chamber; not free space wavelength) gave another resonance point; this time mode $\beta$. It seems this notation was not explained sufficiently in the first paper. The electric field in a chamber is similar to standing waves on a wire. The difference between modes $\alpha$, $\beta$, $\gamma$, etc., being merely a designation of the number of standing waves in chamber 1, 2, 3, etc. In all cases the type of excitation is transverse or $H_1$ as stated in the introduction. In the discussion of response it was erroneously stated that certain resonance points were merely minimum reactance points. All resonance points were zero reactance points. The fact that one produced greatest response indicated that was where strongest electric field occurred in the chamber.




Space pattern sharpness criterion as function of taper and mouth to throat diameter ratios.

Getting back to the small chamber used for this test of horns; all data was taken with the plunger set for mode $\beta$. Tests were made from 5100 mc down to 4190 mc and no change in the space pattern or gain of the horns could be found. At 4190 mc the wavelength had become long enough so that the plunger could be resonated in the mode $\alpha$ very close to the crystal holder. Here again the Q was 90 as in the case of mode $\beta$. Then the oscillator was set at 4150 mc and the plunger adjusted for output. The difference in operation was marked. At ½% above cutoff frequency the device exhibited all the characteristics of a sharply tuned resonance chamber. At ½% below cutoff it degenerated to merely a dipole with quarter wave reflecting plate. The field supplied to dipole being merely that due to leakage into the large front aperture. The space pattern broadened out, response dropped and adjustment of plunger became very broad. In this degenerate fashion some response could be obtained all the way down to 3440 mc.

•

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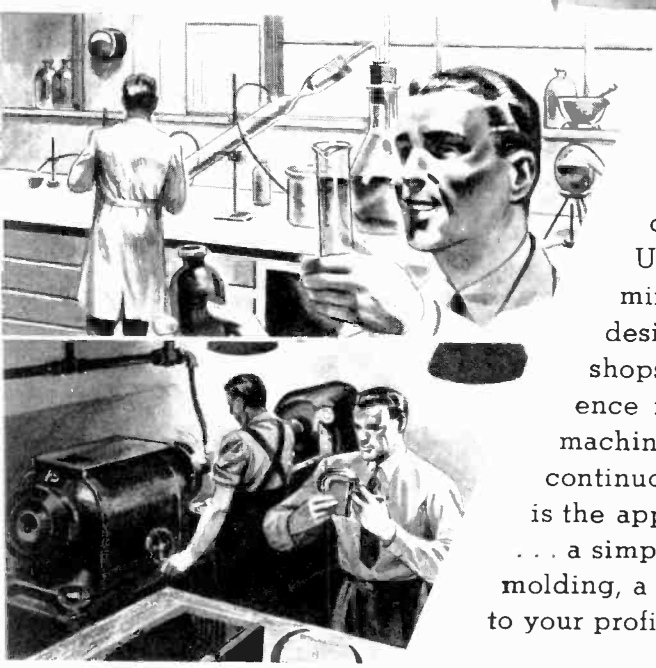

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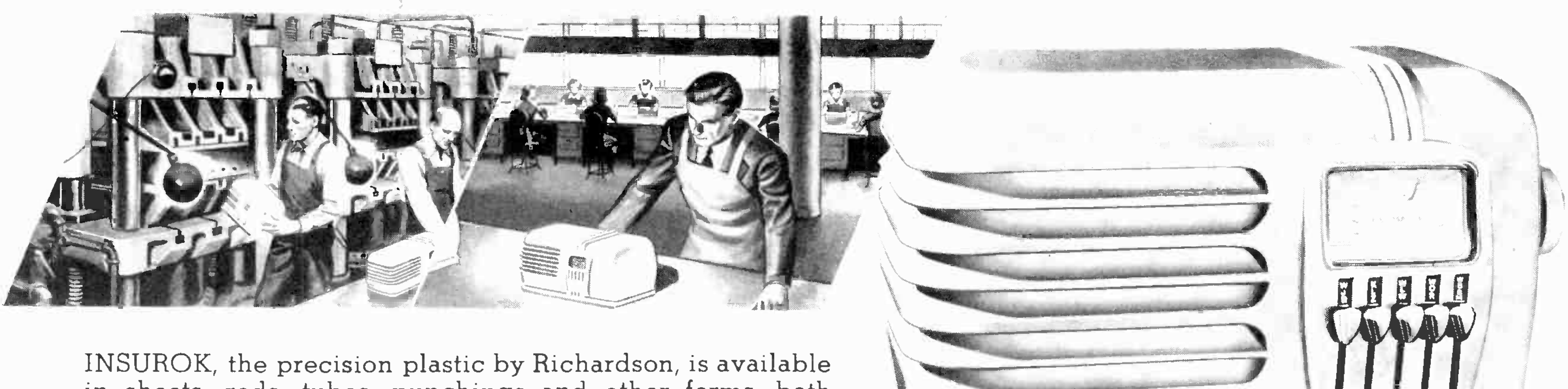

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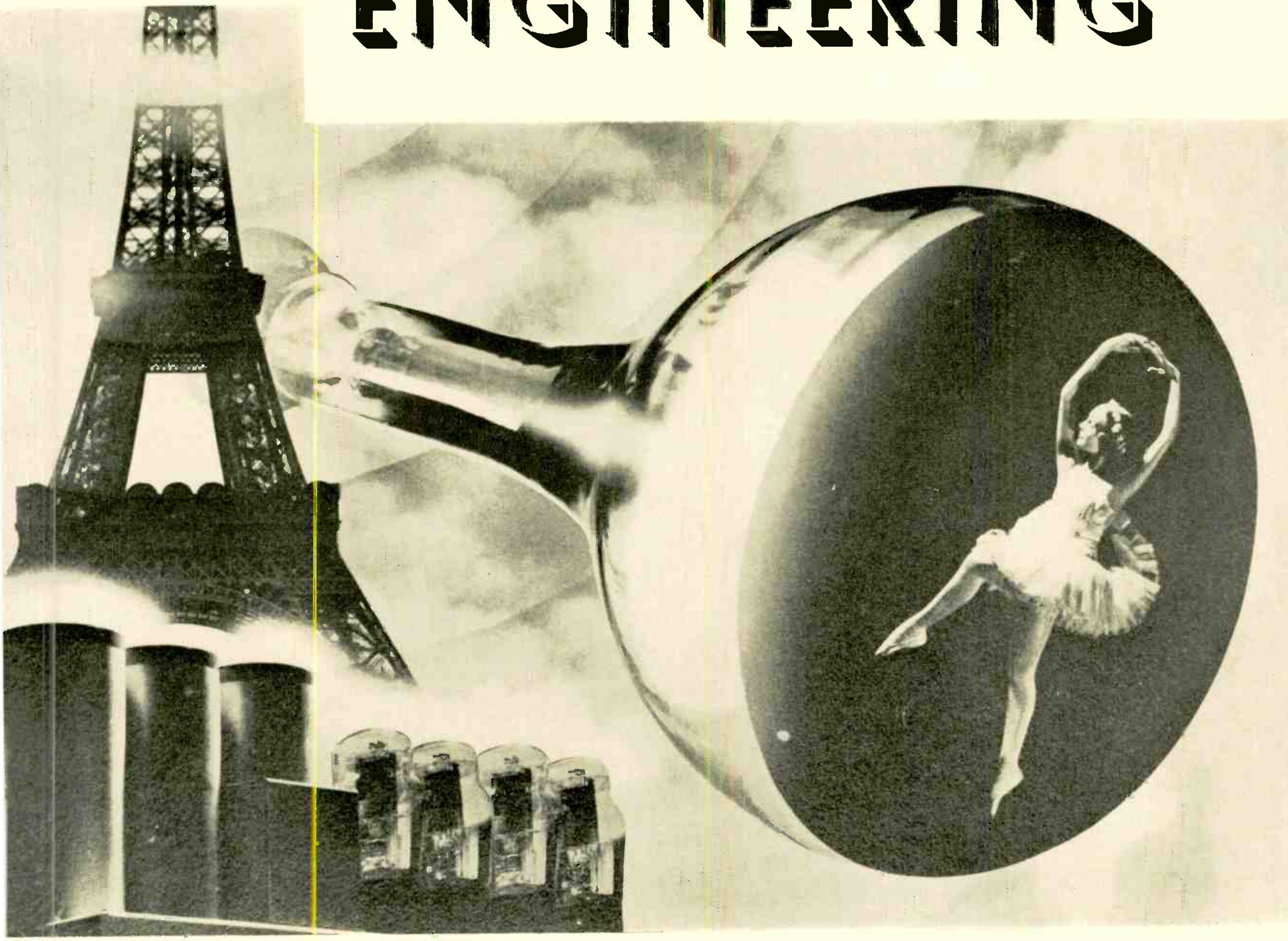


IN the belief that the industry needs one central source of unbiased technical information, we plan to make ***Television Engineering*** a permanent part of COMMUNICATIONS. Suggestions and criticisms will be welcomed.

TO the many engineers who through the giving of their time and knowledge have made available the material incorporated in this number—and to be included in the March and following issues—our thanks and appreciation.

# Television Economics

## Part I

**By Dr. ALFRED N. GOLDSMITH**

Consulting Industrial Engineer

#### INTRODUCTION

TELEVISION broadcasting technique has reached a stage of development which makes timely the following summarized recapitulation of television methods and the related analysis of the economic factors involved in television equipment, installation, and operation. The collected data are intended primarily for the planning engineer and cost estimator, as well as the supervising executive. They are intended as well to enable radio manufacturers, broadcasters, and a certain section of the public to judge the economic factors involved in television broadcasting and to take proper measures to develop and further that art.

The data given herein, even when numerical, must be regarded as approximate and in the nature of an outline. It is not practical within any reasonable space to list completely all cost factors or matters involving expense in a television system. Accordingly, the following data are not intended to be sufficiently detailed and explicit to serve as a full guide for design and construction, equipment being listed and technical data given primarily to enable anticipated difficulties to be appraised and resulting costs to be estimated. Detailed circuits are largely omitted. In a rapidly changing art like television, with speedy obsolescence, a practical and useful guide to detailed design is probably as undesirable as it is unproducible at present. Indeed it is well that individual preferences and selected solutions along different lines should be tried out by various organizations.

Although some planning assistance may be derived from the following, it is emphasized that a universal prescription for curing all television ills does not exist. The material here given will therefore more modestly aim at presenting a "road map" through a television system, while pointing out some of the economic pitfalls which beset the television exploiter, and at the same time furnishing him with a "bill of materials" covering all the important elements of the television system, their general characteristics, their interrelationships, and the economic factors to be considered.

Definite prices or price lists will be avoided. It is certain that the cost of a given device or service depends on numerous factors which are strictly individual in each instance. These include the type of organization which desires to use the device, the completeness

Dr. Alfred N. Goldsmith

and rigidity of the specifications governing the device, the special arrangements or relationships existing between the manufacturer and the user, the quantity scale on which the device is produced, the temporary or permanent installation of the device, the type of usage to which it will be subjected, the likely rate of simplification of the structure or general obsolescence of the device and last but not least the financial position and bargaining ability of the purchaser.

So far as practicable, the following data are concentrated on American practice in the television field and on electronic methods of television. Apparatus of other origin and types is included mainly where economic questions justify its mention.

#### A. RADIATION AND RADIATORS

##### A-1. Frequency and Propagation of Waves

The allocation of frequencies to any broadcasting service must be based on the side-band width, the necessary spacing between adjacent channels, and the required type of service as determined by the propagation characteristics of waves of the selected frequency. The decisions must be amply justified by experimental observations. In ordinary broadcasting the highest modulation frequency generally used is about 5 kc; the interchannel separation is 10 kc; the average carrier frequency about 1,000 kc, and the ratio of the first- and third-mentioned quantities is 0.005. It has been determined that, for adequate detail in the present state of the art, the television picture requires 441 lines, and that the avoidance of flicker requires the transmission of approximately 30 frames per second with interlaced scanning. This leads to the requirement of a side-band width of 3.5-4 mc for satisfactory picture reproduction. If one side band is transmitted completely and a 1-mc wide portion of the other side band is transmitted (with sharp cutoff of this latter side band at 1 mc from the carrier), about 5 mc are needed for the total television channel using this so-called "vestigial" side-band transmission. Accordingly it has been proposed that the television channels shall be 6-mc wide (including also the sound carrier and its side bands). The lowest frequency judged adequate for television is included in the band from 44 to 50 mc. The ratio of side-band width to video-carrier frequency for this band will then be 0.11 (as compared with 0.005 for sound broadcasting on a 1,000-kc carrier). It will readily be seen that the trend of television carrier frequencies on this basis would naturally be toward considerably higher frequencies provided other factors (absorption in urban areas, difficulty of generating high power at the higher frequency, and the like) did not intervene.

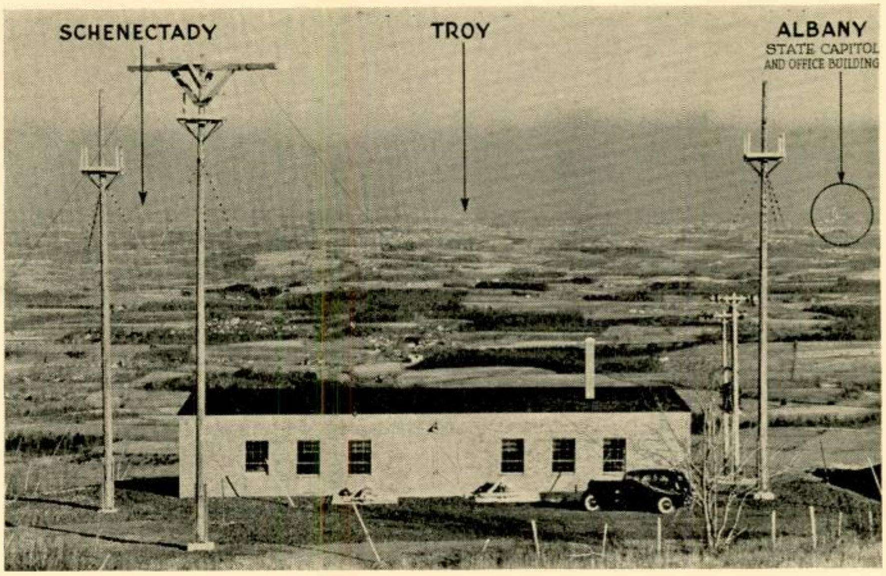
The spectrum of television transmissions differs markedly from that of sound broadcasting. The side bands extend from zero frequency to an ill-defined upper limit (which will be discussed later). When sequential scanning is used, the spectrum is not continuous but consists of grouped lines representing concentrations of energy around certain frequencies. It thus contains unoccupied portions which might be employed for other transmissions or services. Interlaced scanning, however, presents a different type of spectrum although one which also shows concentrations of energy at specific frequencies and groups of frequencies.

To determine the propagation characteristics of the ultra-high-frequency (uhf) waves, a signal-strength measuring equipment is required covering a range from approximately 10 microvolts per meter to between 10 and 100 millivolts per meter. Measurements have shown that the attenuation of the uhf waves over urban paths is high. Available data indicate that on 42 mc, there is an approximate 50-percent drop in signal strength for each 500 feet of path, the corresponding figure on 100 mc being each 200 feet of path.

This in itself complicates the service-range problem, but beyond the (optical) horizon there is also a very sharp diminution of signal which tends, using ordinary transmission methods, to limit the range rather abruptly. Available data indicate that beyond the horizon, at a frequency of 40 mc the attenuation varies approximately as the 3.6th power of the frequency, while at 100 mc it varies as the 5th power, and at 300 mc it varies as approximately the 8th power. Despite these unfavorable constants, the uhf transmissions correspond to extremely steady and high-grade channels within their normal service area and are considerably less susceptible to fading and the effects of atmospheric disturbances than are the medium-frequency broadcasting channels.

The service range of the television stations so far established is of the order of 30-50 miles. One European station claims a service range in various directions of 25-60 miles. However, this station has been occasionally received at distances between 220 and 500 miles whereas another European television station has been intermittently received at 180 miles. Still more astonishing, the first-mentioned station, operating on 41.5 and 46 mc, has been received (though only very occasionally) in America (with a signal strength up to 0.7 mv /m for the 45-mc transmission)! However, this required special receiving antennas either of the dipole or of the reversible rhombic type. Another station on the European continent has similarly been received. The fading on 45 mc was "stepwise"; on 41.5 mc the fading was far more rapid and irregular. Such frequencies are clearly at the lower boundary limit of utility for long-distance communication and have, in fact, even been received the long way around the world. At the higher uhf frequencies, such long-distance-reception effects will probably be still more limited or non-existent.

It is important, despite these occasional long-distance-reception records, to avoid reviving the fallacies of early broadcasting days relative to the claimed range of stations. In planning a service, the *useful* range of a station depends entirely on the stability of reception, the duration of such stable reception, and the frequency with which such stable reception occurs. From the economic viewpoint, station time can be sold only if an acceptable service lasting throughout the program period can be anticipated for a high percentage of the time.




**The 10-kw General Electric television station. Antennas left to right: receiving (studio programs), video, audio.**

No "ideal" frequency exists for broadcasting television under all circumstances. The selected frequency will be a compromise between absorption in the transmission path, steadiness of received signal, effects of atmospheric disturbances and of man-made interference, limitation of the "nuisance range" of the transmitter, and power available for radiation.

The Federal Communications Commission has assigned the following 7 channels for television communication: 44-50 mc; 50-56 mc; 66-72 mc; 78-84 mc; 84-90 mc; 96-102 mc, and 102-108 mc. The above frequencies have been arranged to reconcile conflicting claims of various groups, and are unlikely to be changed substantially until after they have been thoroughly tested over a period of years in actual service. It will be noted that an amateur band (56-60 mc) lies adjacent to one of these television channels and channels assigned to other services are interspersed between the television channels. In general, the lower-frequency channels are suitable for the larger cities and the higher-frequency channels for small cities and towns.

It will also be noted that certain of the above channels are directly adjacent and thus require maximum sharpness of side-band cutoff in the transmitter and sharp selectivity in the receiver.

The Commission has also tentatively allocated the following 12 channels to television: 156-162 mc; 162-168 mc; 180-186 mc; 186-192 mc; 204-210 mc; 210-216 mc; 236-240 mc; 240-246 mc; 258-264 mc; 264-270 mc; 282-288 mc, and 288-294 mc within which groups there are as well adjacent channels with no spacing between them.

While no regular television-relay frequency assignments have as yet been made, a frequency of 177 mc is experimentally used.

From the economic viewpoint, there is an urgent need for an early and systematic nation-wide allocation plan for television stations to enable the orderly placement and the assignments of frequencies to stations with the aim of avoiding inter-station interference. A conspicuous example of this need—and one presenting numerous allocation problems—is in the Atlantic Coast Section from Boston to Richmond. Stations at Boston, Bridgeport, New York, Philadelphia, Baltimore, Washington, and Richmond (with possible stations at Hartford, Wilmington, and Norfolk) present an interesting and somewhat pressing problem. The commercial development of television in this section, as well as in certain similar regions, should preferably await in part an orderly allocation plan.

#### A-2. Transmitting Antennas

It has been found that a received signal strength of about 1 mv /m is necessary in cities for satisfactory reception. If the transmitting antenna is about 1,000 feet above ground and the receiving antenna about 50 feet from the ground, the horizon is at approximately 50 miles from the transmitter. To produce the desired signal strength at the horizon is found to require about 30 kilowatts in the antenna—an amount of power which would be attainable with difficulty, if at all, by means of presently available uhf tubes in the television service. However, there are several favorable factors which may improve this situation. These include the lower noise level at the outskirts of cities in some cases, the probable increase in the available output of uhf tubes, and possible improvements in modulation and transmission methods.

The transmitter antenna obviously should be located at a substantial height ranging from several hundred feet to considerably over a thousand feet wherever possible. Its dimensions are small as compared to those of antennas used in the medium-frequency broadcasting service since the video wave-length is only a few meters. In general such antennas can be mounted on the tops of buildings or on towers or masts without undue difficulty. When located far above the streets or buildings in cities, these antennas must be provided with heating means for the removal of ice—a measure desirable in every case if continuous operation is necessary. In America, a horizontal polarization of the radiator wave has been selected as providing a better signal-to-noise ratio at the receiving station under most conditions. Horizontally the antenna system should be non-directional, but vertically it should have substantial directivity favoring the horizon and discriminating against the zenith. The types of antennas used at present include multiple dipoles, fed from a single transmission line, and radiating in a number of directions, and also the "melon" type of antenna. This consists of an ovoid body resting within and separated from a sort of "socket" or container, the contours of these metallic objects being carefully selected so that the distributed electrical constants are such as to permit efficient radiation over a wide band of frequencies, as is required by video modulation.

While great elevation of the antenna is desirable, a compromise must be carefully engineered in many instances. If the antenna is placed on the top of a skyscraper numerous costly problems such as long power-supply lines, floor reinforcement, electrical adaptation of the antenna to the building, and the like, are encountered. If towers or hills can be found near or within a city, they may present a desirable possibility as an antenna support. The location of the antenna in relation to the resulting absorption of the waves in reaching the major part of the audience should also be carefully analyzed prior to locating the station.

### B. TRANSMITTER TRANSMISSION LINES

In selecting the location for the transmitting equipment, careful consideration should be given to minimizing the transmission-line length, particularly in existing structures where such lines can sometimes be run only with considerable difficulty. Bends in the lines cause mechanical and electrical problems, and a straight run is desirable. Since power loss in the lines is to be anticipated, which loss continues throughout the operating life of the transmitter, the cost of placing the transmitting equipment in existing structures close to the antenna should be carefully balanced against the electrical losses otherwise resulting. In general, building alterations are costly, particularly if extensive reinforcement or passage through sections of the building used for other purposes becomes necessary.

The usual transmission line will be of conventional type, for example, of the coaxial-conductor type, and of dimensions suited to the voltages which are involved. The cost of the line will depend upon its size (diameter and length) which, again, will influence the electrical losses and termination difficulties in the transmission of a wide band of frequencies. Termination of such lines requires careful antenna and line design, as a unit. Electrically, simple installations result from the use of two transmission lines, one for the video transmitter and one for the audio transmitter.

### C. TRANSMITTING EQUIPMENT

#### C-1. Video Transmitters

Uhf transmitting tubes are a specialized product. The elements must be small; and the leads must be short and of sufficient capacity to carry the necessary uhf currents which, particularly in grid circuits, far exceed in proportion those on the lower frequencies. To reduce the electron-transit time and obtain efficient operation, the electron paths must be of limited length. The cathodes and other elements of such tubes are subjected to unusual bombardment, and means for removing and dissipating the resulting heat must be provided. For example, such materials as tungsten and tantalum are found suitable for filament and grid construction respectively. In general, the plates of these tubes are water-cooled in the higher powers. Uhf insulation presents problems in keeping the losses low and in withstanding the voltages generated in the tubes. The trend of uhf tubes is toward higher powers and greater efficiency, as well as toward successful operation at the higher frequencies in this band. However, both tubes and circuit equipment are usually more expensive per watt of output than at lower frequencies.

The requisite transmitter power can be determined only by knowledge of the antenna height, local absorption, desired service range, reception signal-strength standards, and existing noise levels at various distances from the transmitter. In general, a 1-kilowatt transmitter will serve for towns and small cities, particularly in the early stages of television development; while transmitters in the 7.5-10 kilowatt range are required for large cities under unfavorable conditions (with an approximate 30-mile service range).

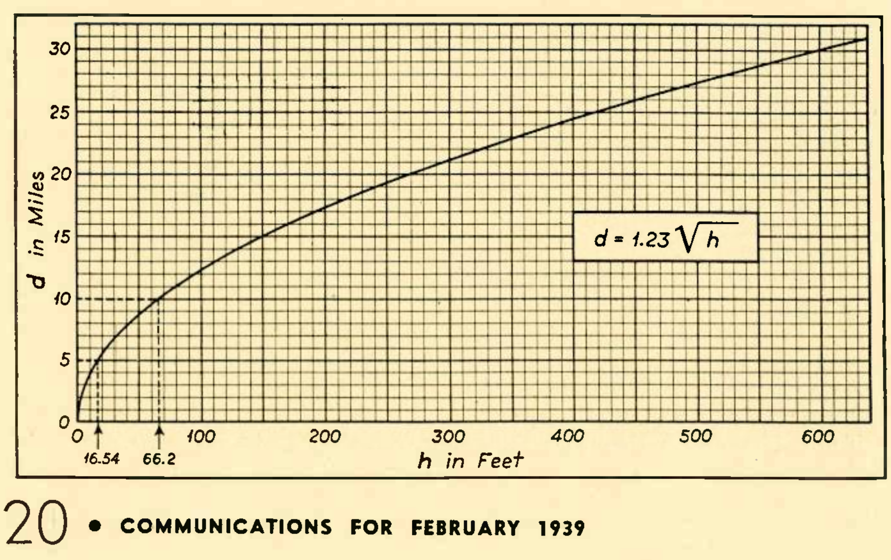
Since the gain per stage in the transmitter amplifier is approximately inversely proportional to the band width which must be passed, the efficiency of video transmitters is generally lower than of audio transmitters.

Inasmuch as an ideal insulator for uhf purposes, meeting all desirable specifications, is not available, the transmitter condensers present construction problems. The ready formation of standing waves in the transmitter circuits requires careful design consideration, particularly in connection with methods of supplying filament power.

In a commercially available 1-kilowatt video transmitter, the oscillator is either line-controlled or crystal-controlled in

(*Continued on page* 45)

**Approximate optical distance (d) at various antenna heights (h). For antenna 600 ft. above earth the horizon is approx. 30 miles.**



| Curve | K | Time for 50% Rise in Percent of Period | Period |
|---|---|---|---|
| A | 22.1 | 0.5 | 140 RC |
| B | 11.05 | 1.0 | 70 RC |
| C | 4.4 | 2.5 | 28 RC |
| D | 2.1 | 5.0 | 14 RC |
| E | 1.1 | 9.5 | 7 RC |
| F | 0.6 | 15.0 | 3.5 RC |

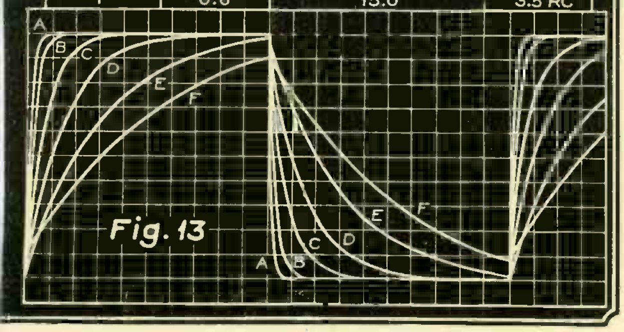



Fig. 13

# AMPLIFIER

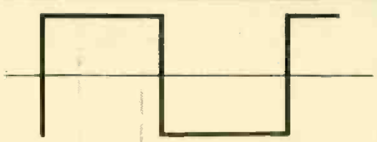
## By Means of


By
Gilbert Swift
RCA Manufacturing Co., Inc.
Camden


THE observation of the wave form of the output of an amplifier when a potential of square (or rectangular) wave form is applied to its input, provides a simple and rapid method for determining the transmission characteristics of the amplifier, since the frequency and phase characteristics of the amplifier can be deduced by proper interpretation of the output wave form. Thus, an amplifier which is provided with controls for adjusting its characteristics can be rapidly adjusted to provide the desired response by observing the output waves obtained by applying square waves of one or possibly two frequencies. The time required to make these adjustments by this method is thus the same as that used in taking one or two measurements of the many required by the usual point-by-point method.

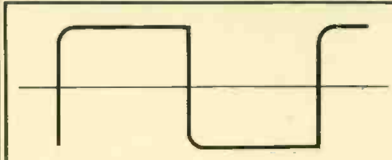
The particular output wave form which indicates proper adjustment of frequency and phase characteristics may be determined in either of two ways; one method is to observe the output of an amplifier which has previously been adjusted by the point-by-point method. The second, and generally more accurate, method consists of interpreting, qualitatively and quantitatively, the observed wave form in terms of the phase and frequency characteristics of the equipment under test. Before attempting to explain the interpretation of these wave forms a discussion of the basis for this method of testing, the relationship of the transient characteristic of a circuit to the response to square waves, will be of value.

The transient characteristic of a circuit is defined as the output which results from a suddenly applied voltage which thereafter remains constant. It can be shown that the response of a circuit to any type of input voltage is determined by its response to a suddenly applied voltage. The transient characteristic may be considered to be limited by two effects: the ability of the circuit to transmit high frequencies and the ability of the circuit to transmit low frequencies. The high-frequency transmission will determine the shape of the transient at, and for a short time after, the application of the input voltage while the low-frequency transmission will determine the value of the output voltage after a longer time has elapsed. Obviously, an amplifier which transmits down to and including zero cycles per second (d-c) will eventually reach some steady value of output voltage if the suddenly applied input is not removed, while an amplifier which does not transmit d-c must eventually return to zero output even if the input voltage remains connected.



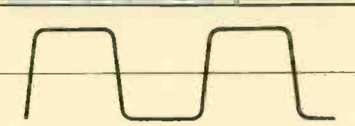
Constant Gain at all Frequencies. Highly Damped, Constant Delay.

Fig. 1



Some Attenuation of High Frequencies. Highly Damped, Excess Delay at High Frequencies.

Fig. 2



Higher Attenuation at High Frequencies. Highly Damped, Constant Delay.

Fig. 3

Most amplifiers will be found to have constant transmission (flat frequency characteristic with constant delay or phase proportional to frequency) over a wide band of frequencies lying between high and low-frequency regions where the transmission is impaired. If a succession of suddenly applied voltages, alternate impulses having opposite polarity is applied to such an amplifier, and the frequency of repetition lies within the band of frequencies for which the circuit gives constant transmission, the high-frequency transient effects will be present and the low-frequency effects eliminated. It can be seen that such a succession of impulses is a square wave. As the rate of repetition is lowered the low-frequency effects will become noticeable. If the frequency of repetition is increased the high-frequency effects will become more pronounced. The separation of effects is particularly useful in interpreting the response to square waves in terms of response to other wave forms and other characteristics of the circuit.

In most cases square waves of two frequencies will suffice to determine the complete performance of the equipment under test. One frequency should be

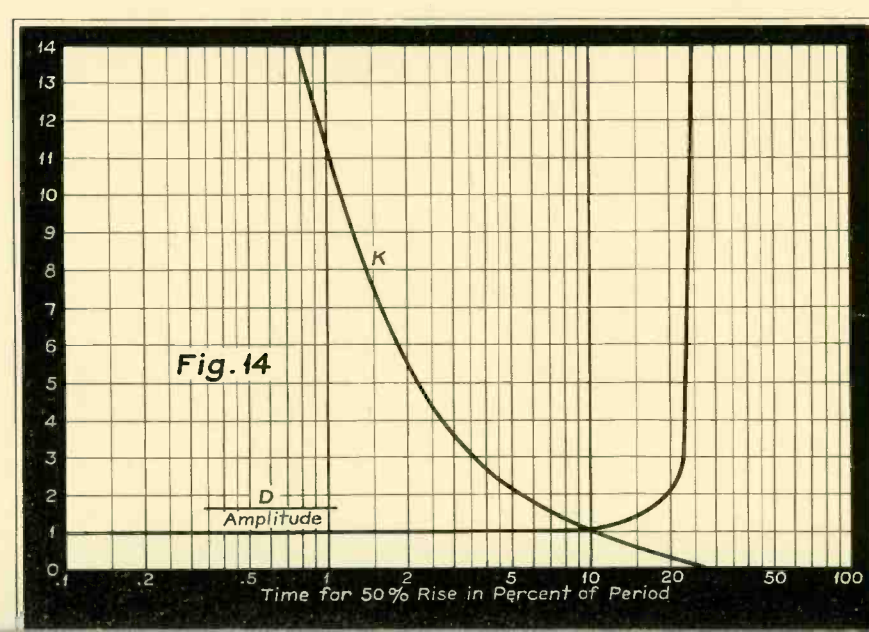
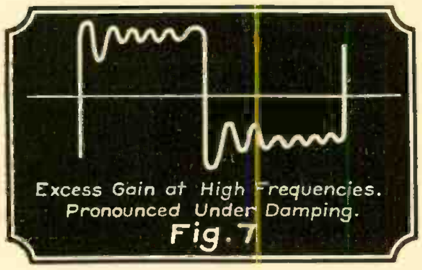



Fig. 14

# TESTING

## Square Waves

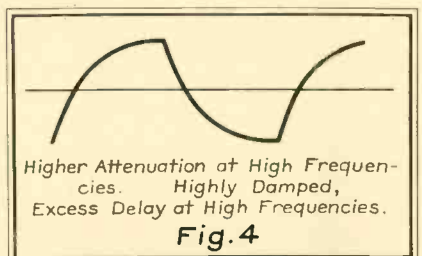


Excess Gain at High Frequencies. Pronounced Under Damping.
**Fig. 7**

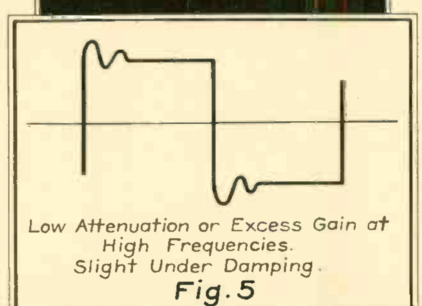
high enough to eliminate low-frequency effects completely while the other should be low enough to include them. In this way the results can be analyzed separately thus simplfying the process considerably. In circuits whose high and low-frequency regions of impaired transmission lie close together or overlap, the analysis becomes somewhat more complex.

### QUALITATIVE ANALYSIS

The output wave form obtained by the use of a square wave input of sufficiently high frequency to eliminate the effects of poor low-frequency transmission can be readily analyzed to secure qualitative information concerning the frequency characteristic, phase or delay characteristic, circuit damping and the response to other wave forms (See Figs. 1 to 8). Methods for quantitative analysis of this data and for the evaluation of circuit constants will be discussed later. In general, the time required for the wave to reach maximum value is dependent upon the frequency range, a rapid rise indicating that high frequencies are attenuated only slightly. The circuit damping is indicated by the shape at the top of the rise. A highly damped circuit will result in a wave which approaches its final maximum without any overshoot while underdamping will produce a train of oscillations after the initial rise. Multiplying the frequency of the input signal by the number of maxima which occur in one cycle will give an approximate value for the natural frequency of the circuit. Excess delay at the higher frequencies is indicated by rounding of two diagonally



Higher Attenuation at High Frequencies. Highly Damped, Excess Delay at High Frequencies.
**Fig. 4**



Low Attenuation or Excess Gain at High Frequencies. Slight Under Damping.
**Fig. 5**

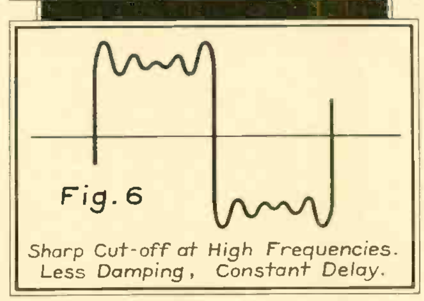


**Fig. 6**
Sharp Cut-off at High Frequencies. Less Damping, Constant Delay.

opposite corners of the wave, as shown in Fig. 2. A circuit in which the delay decreases from the normal value at high

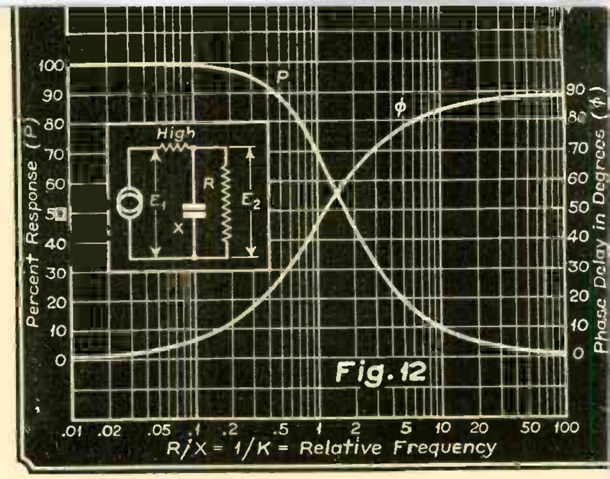



**Fig. 12**

frequencies will result in changes at the other two corners. Constant delay for all the transmitted frequencies is indicated by all four corners of the wave having the same shape.

Certain other characteristics of a circuit may be inferred from its response to square waves. An output wave form, having a train of oscillations, is always the result of a circuit whose frequency and delay characteristics contain sharp changes. The amplitude and duration of the wave train are measures of the sharpness of the high-frequency cut-off of the circuit, while the period of the oscillation gives a measure of the frequency at which the rapid change in the transmission characteristics occurs.

If the repetition rate of the square wave is lowered until it falls within the region of poor low-frequency transmission, a slightly different type of interpretation may be used to obtain other circuit characteristics. The high-frequency effects, rise time, overshoot and rounding of corners must be neglected if they are present to a noticeable degree, and only the average shape of the top of the wave considered. However, most circuits possess a sufficiently wide band of constant transmission that the high-frequency effects are negligible when a frequency low enough to show low-frequency deficiencies is used. The low-frequency effects most often encountered are those due to coupling capacitors between plate and grid of successive stages which cause the transient characteristic to delay exponentially after the initial rise. Typical wave forms obtained with this type of circuit and with a circuit having a rising low-frequency characteristic are shown in Figs. 9 to 11. Except for the fact that most circuits which do not transmit d-c have an appreciable change in their delay characteristics at a frequency higher than that at which a change in frequency characteristic becomes noticeable, no information as to the circuit performance at frequencies lower than the fundamental frequency of the square wave can be obtained. Where the relationship between the frequency and delay characteristics at low frequencies is known, the shape of the frequency

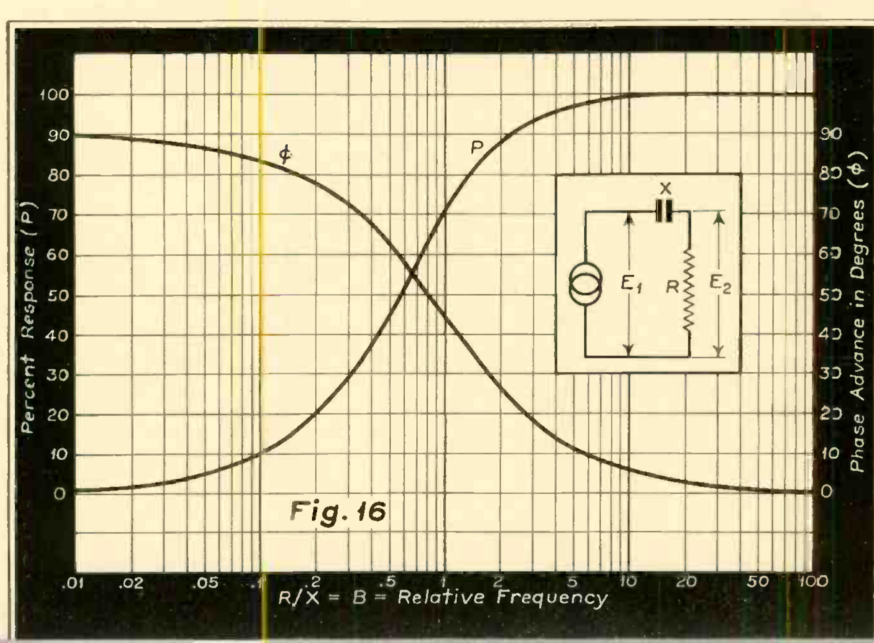



**Fig. 16**

characteristic may be inferred from the observed changes in delay.

### QUANTITATIVE ANALYSIS

As an aid to the quantitative determination of the frequency characteristic, phase or delay characteristic, circuit damping, natural period, circuit constants and other data from the response to square waves, a discussion of the harmonic analysis of such waves will be of value. A perfectly square wave, as shown in Fig. 1, may be shown to be composed of a fundamental frequency component together with all its odd-numbered harmonics, the amplitude of each harmonic component being inversely proportional to its harmonic number or frequency. The Fourier series which represents this wave is:

$$e = \frac{4E}{\pi} \sum_{n=1}^{n=\infty} \frac{1}{n} \sin n\left(\omega t + \phi\right)$$

(for all odd values of n)

or

$$e = \frac{4E}{\pi}\left[\sin\left(\omega t + \phi_1\right) + \frac{1}{3}\sin\left(3\omega t + 3\phi_1\right) + \frac{1}{5}\sin\left(5\omega t + 5\phi_1\right) + \cdots \frac{1}{n}\sin n\omega t\right] \qquad (1)$$

where E is the peak amplitude of the square wave. A graphical representation of this series is given in Fig. 23.

Obviously, a circuit which has a flat frequency characteristic and phase shift proportional to frequency (constant delay) will transmit all the above components perfectly, preserving the amplitude and phase relations of all the components. Hence, such an amplifier transmits a square wave without change of shape. Changes in the relative amplitude of some components or changes in their phase relations must result in the changes of the output wave shape. Terminating the above series abruptly at any finite term is equivalent to applying a square wave to an amplifier having a flat frequency characteristic and constant delay up to some finite frequency at which a sharp cut-off occurs. This will result in an output wave form similar to that shown in Fig. 6.

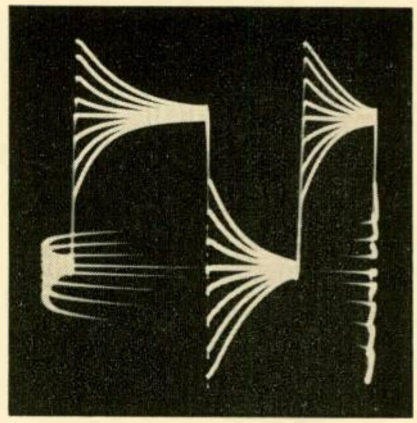
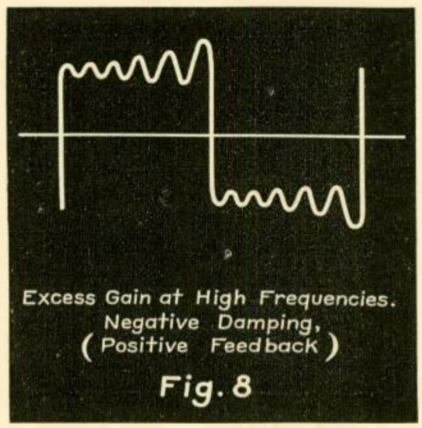


**Fig. 25. Adjustment using 10-kc square wave.**



Excess Gain at High Frequencies.
Negative Damping,
(Positive Feedback)
Fig. 8

A typical circuit in which the transmission changes more gradually is shown, with its characteristics, in Fig. 12. Output wave forms for square-wave input at several different frequencies are shown in Fig. 13. A harmonic analysis of this type of wave yields the following expressions for the amplitude and phase of any one component:

$$E_n = \frac{4D}{n\pi}\sqrt{1 - \frac{n^2}{k^2 + n^2}} \qquad (2)$$

$$\phi_n = \tan^{-1} - \frac{n}{k} \qquad (3)$$

Where

$E_n$ is the amplitude of any component
$\phi_n$ is the phase angle of any component
n is any odd-harmonic number
D is the final positive value which would be reached if the wave were non-recurrent
$2\pi k$ is the ratio of the time for one full cycle to the time required for 63.2 percent of the total rise to take place

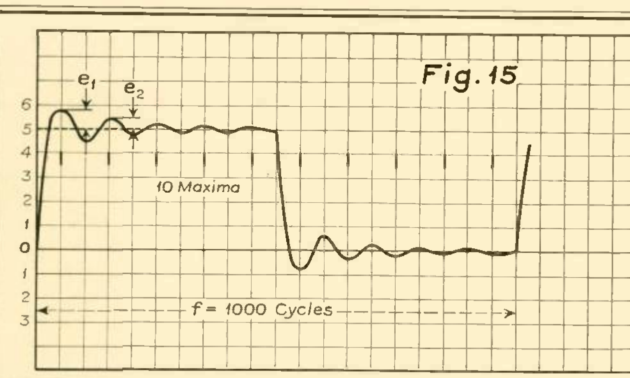
The amplitude and phase of any component of the perfectly square input wave are given by the expressions:

$$E_n = \frac{4E}{n\pi} \qquad (4)$$

and

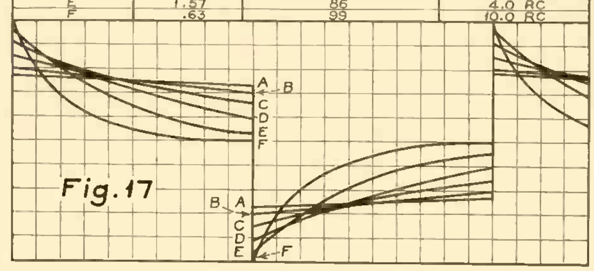
$$\phi_n = 0 \qquad (5)$$

The frequency characteristic of this circuit is obtained by dividing the expression for the amplitude of any component of the output by the expression for the amplitude of the input components.

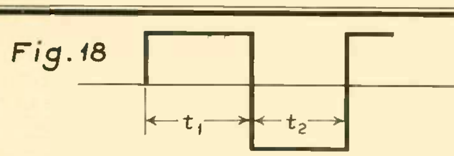




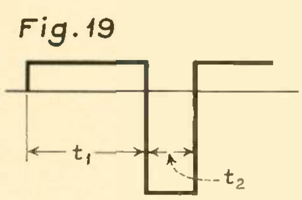
| Curve | B | Decay in % of Rise | Period = T |
|---|---|---|---|
| A | 31.4 | 10 | 0.2 RC |
| B | 15.7 | 19 | 0.4 RC |
| C | 6.28 | 40 | 1.0 RC |
| D | 3.14 | 63 | 2.0 RC |
| E | 1.57 | 86 | 4.0 RC |
| F | .63 | 99 | 10.0 RC |



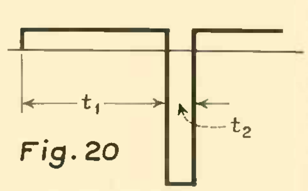




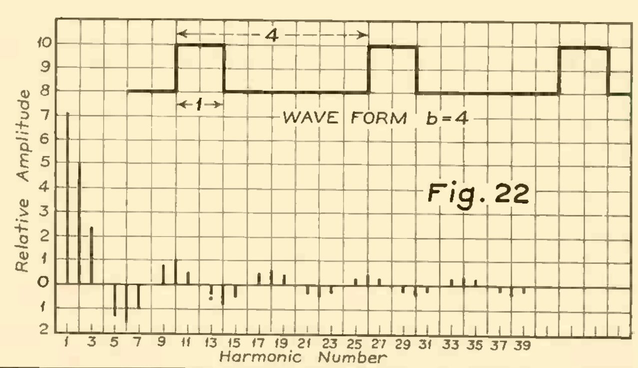












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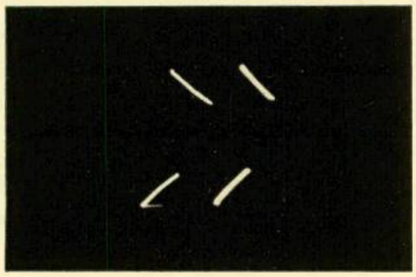


**Fig. 26. 30-cycle square wave applied to amplifier.**

Thus

$$\frac{E_n\,(\text{output})}{E_n\,(\text{input})} = \frac{D}{E}\sqrt{1-\frac{n^2}{k^2+n^2}} \quad (6)$$

Where $\frac{D}{E}$ represents the voltage gain which would be obtained with no capacitance in the circuit and the remaining part of the expression represents the ratio of the actual gain to this value.

The phase characteristic is obtained by subtracting the expression for the phase of any input component from the corresponding expression for the output components.

$$\phi_n\,(\text{output}) - \phi_n\,(\text{input}) = \tan^{-1} - \frac{n}{k} - 0 = \tan^{-1} - \frac{n}{k} \quad (7)$$

It will be seen that the frequency and phase characteristics can be plotted, if D and k are known, by evaluating the expressions:

$$\frac{D}{E}\sqrt{1-\frac{n^2}{k^2+n^2}} \quad \text{and} \quad \tan^{-1} - \frac{n}{k}$$

for various odd values of n from 1 to infinity. The frequency corresponding to $n = 1$ is the fundamental frequency of the square wave. A curve for evaluating D and k in terms of the observed amplitude and the time (in percent of one cycle) required for one half the total rise to take place is given in Fig. 14.

It will be noted that for a rise time of less than 5 percent of one cycle the value of D may be taken as the actual amplitude and that a close approximation for k is given by the expression:

$$k = \frac{11.05}{P}$$

Where P is the time required for one-half the total rise in percent of one cycle.

Obtaining values of D and k from the observed amplitude and rise time by means of the table and substituting in the expressions given above will give the frequency and phase characteristics shown in Fig. 12.

In general, the frequency characteristic of any circuit, for frequencies at and above the frequency of the square wave, can be obtained by dividing each term in the harmonic series which represents the output wave by the corresponding term of the series which represents the input wave. When the input can safely be assumed to be square this process takes the form of multiplying each term of the output series by n. The wave analysis may be performed by calculation, if an expression for the observed wave form can be obtained, or by graphical methods if an accurate graph of the wave can be plotted. Information on several methods of wave analysis will be found in standard engineering and mathematic texts. Calculation of the phase characteristic is similarly determined from the phase angles obtained from the wave analysis, correcting, if necessary, for any phase differences between various components of the input wave.

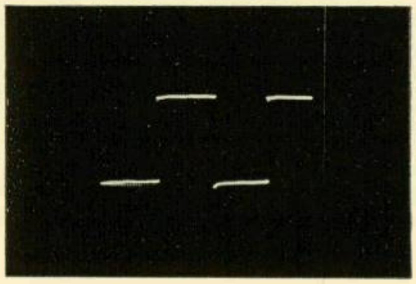


**Fig. 27. Proper adjustment of amplifier of Fig. 26.**

The values of certain circuit constants can usually be determined if the frequency characteristic is known. In the circuit shown in Fig. 12 the frequency at which $X_c = R$ is the frequency at which $n = k$, thus if either R or X is known the other can be calculated.

Circuit damping can be calculated from the circuit constants or, if the circuit is underdamped, from the following expression:

$$a = \delta f_n$$

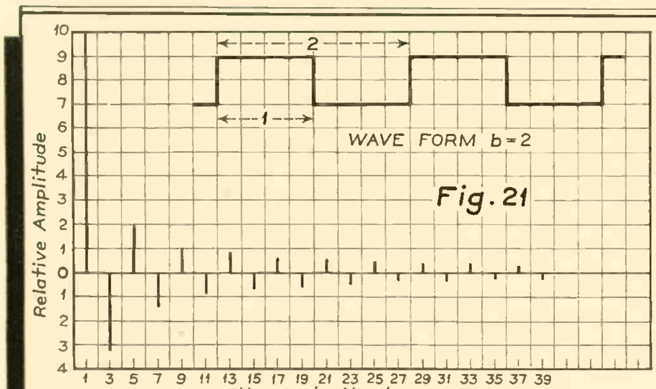
where a is the damping factor

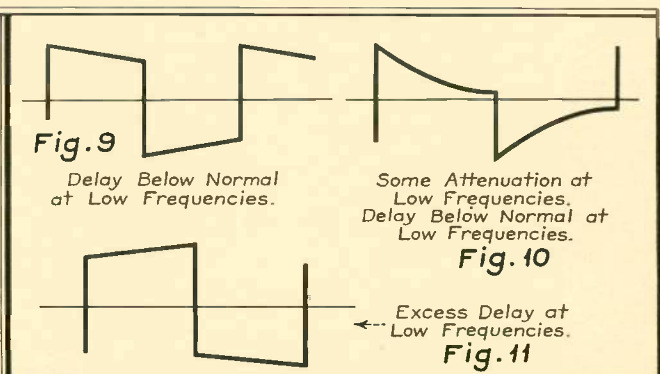
$\delta$ is the logarithmic decrement

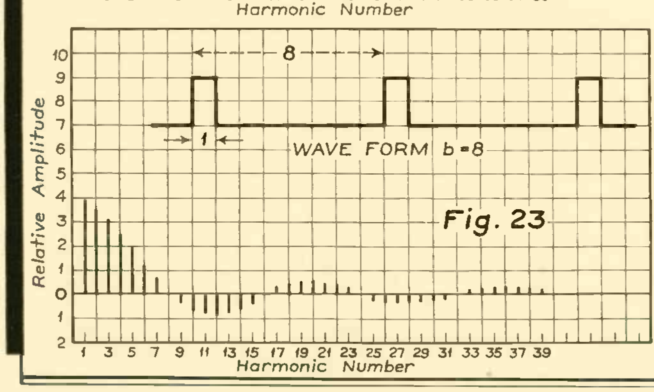
$f_n$ is the natural frequency.

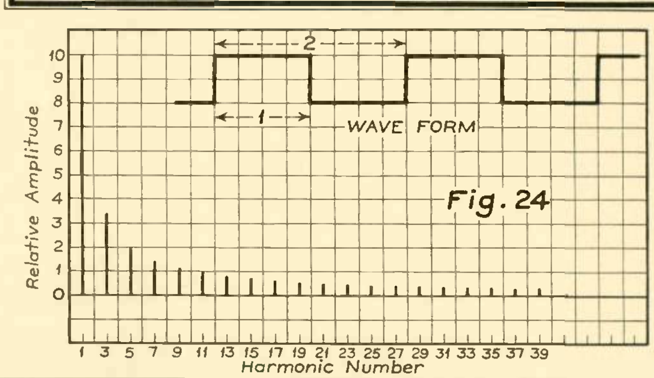
The natural frequency may be deter-

(*Continued on page 52*)



# TELEVISION STATION W2XAX

## Part II—Studio

**By PETER C. GOLDMARK**
Chief Television Engineer
COLUMBIA BROADCASTING SYSTEM, INC.

THE TELEVISION STUDIO of the Columbia Broadcasting System* is being completed in the Grand Central Station building on the third floor facing south, above the automobile ramp and extending the entire width of the building from east to west (Fig. 2). The studio is approximately 270 ft. long, 60 ft. wide and 45 ft. high.

As can be seen from Fig. 1, which is the schematic floor plan of the control room and studio, a space of about 1,400 sq. ft. is reserved for the master control room while the rest of the space remains unaltered during an experimental period when the exact dimensions and properties required of such a studio will be determined.

The master control room will serve a dual purpose: it will contain all electrical equipment needed for studio operations, such as master pulse generators, camera racks, line amplifiers, monitors, switching and relay circuits and audio equipment, at the same time, it will serve as production control room for the adjacent studio.

*Part I of this article, describing Columbia's television transmitter, appeared in the November, 1938, issue of COMMUNICATIONS, p. 7.—*Editor.*

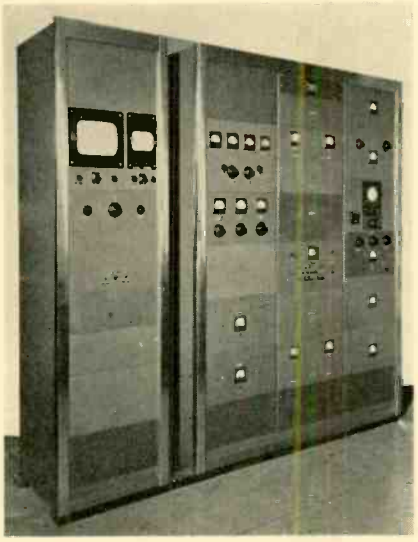


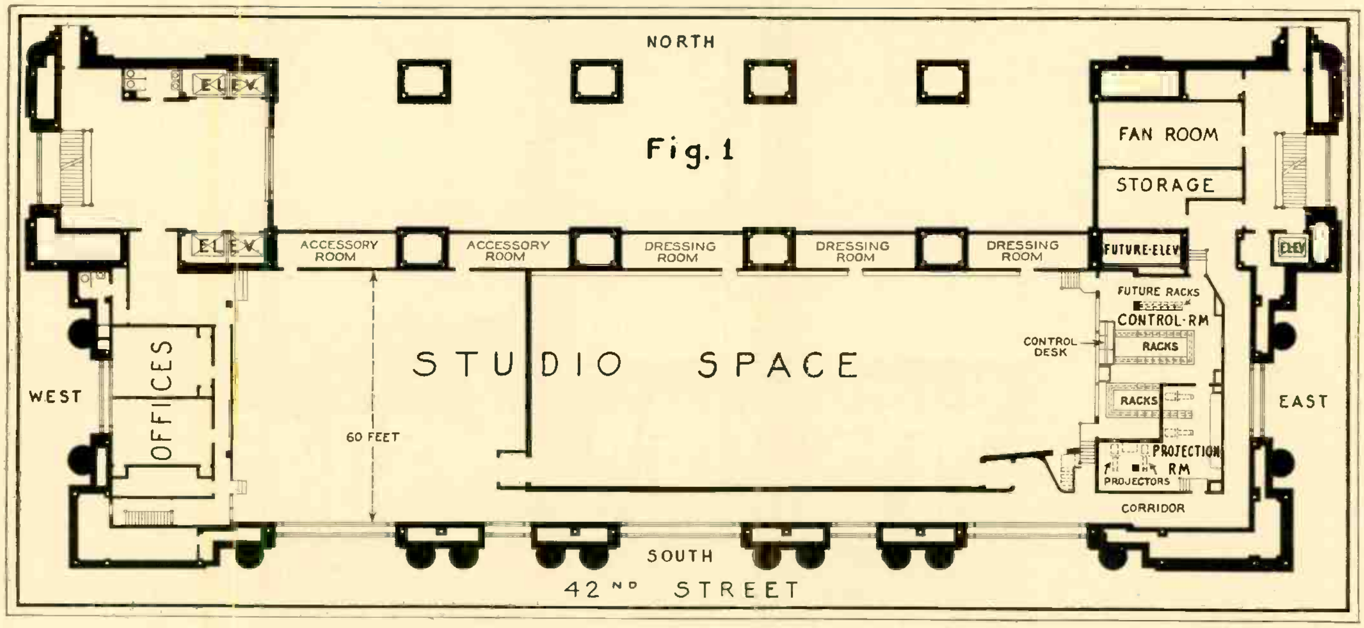
**Fig. 4. Amplifiers and monitors associated with film scanner.**

One section of the control room, as can be seen in Fig. 1, will be used for scanning motion picture film. In this space various types of film scanners with associated amplifiers, monitors, as well as film accessories, will be housed. From this fireproof space the film, running through intermittent projectors, is projected through a small window into the iconoscope camera located in the main control room. The projectors of continuous type, employing dissector tubes for pickup, operate entirely within the film scanning room. There will be a 35 mm. and a 16 mm. scanner of this type. Fig. 3 shows a 35 mm. scanner with pickup equipment and Fig. 4 the associated amplifiers and pulse generator, also the picture and waveshape monitors mounted on racks.

Fig. 5 represents a cross-section through the control room where three picture monitors are placed underneath the control room window in such a manner as to permit operators and producers to observe easily action in the studio or in the monitored picture. One monitor will show the studio scenes as seen by the camera that is not at the moment on the air and holds it in readiness to be switched into the circuit. The other two monitors show the air picture at different points in the circuits. Next to each picture monitor a waveshape monitor is provided which indicates relative amplitudes of picture, blanking and synchronizing signals.

There are several talkback circuits

**Schematic plan of the television control room and studio.**



between the studio, the control room and the telecine room. Each camera has one of these so that the producer in the control room may talk to the cameramen individually or to the studio at large.

As can be seen in Fig. 1 the layout of the master control room is such that in addition to the existing equipment, ample room has been provided for expansion. The control room floor is about 4 ft. above the studio floor. There are two doors connecting the control room with the studio. The video and audio control desks are in one line next to the double control room window.

The video control desk carries such equipment as fading controls, blanking, pedestal height controls and video signal amplitude controls. Either camera or film scanning channel can be switched to the line amplifiers or to any monitor instantaneously by means of push buttons, or can be faded gradually by means of fading controls. The latter are still undergoing tests in the laboratories and probably will not be installed until after the equipment has been put into operation.

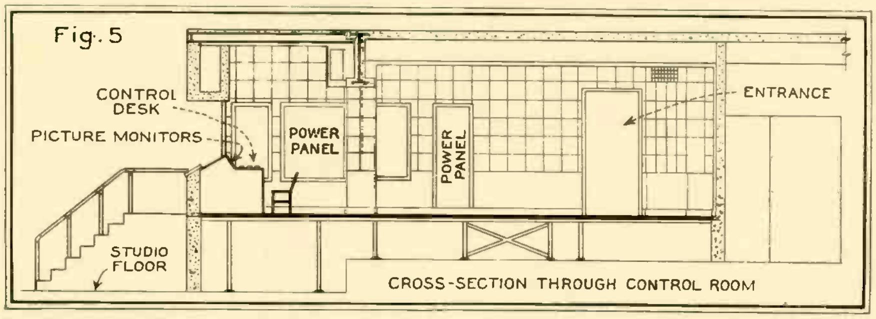
Other functions which can be controlled from the same desk are remote starters for the motion picture film scanners as well as their framing and phasing.

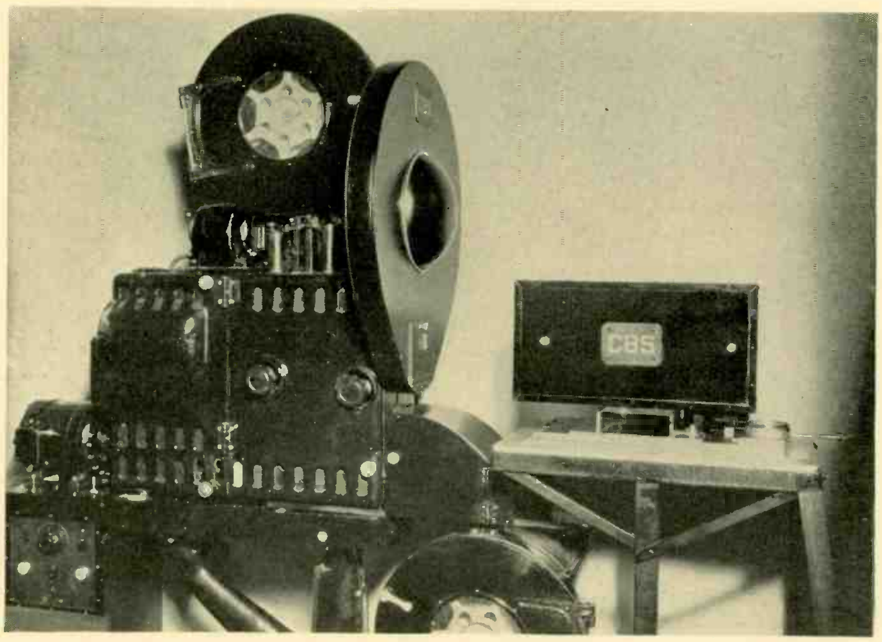
The camera outlets in the studio are mounted underneath the control room window where microphone and light outlets also are located. There is about 65 ft. of cable attached to each camera. If, however, it becomes desirable to move a camera beyond that distance, an additional 80 ft. of cable, which is ordinarily coiled up underneath the control room, can be used.

For the studio lighting there are available 200 kw of d-c and about 50 kw of a-c. It is planned to operate incandescent lamps on d-c for both key and spot lighting, and special gas discharge lamps on a-c connected in three phase in order to eliminate 60-cycle interference.

Fig. 6 is a view inside the studio before alterations were begun.

**Above: Fig. 2. Showing location of studios in Grand Central Station building. Below: Fig. 6. The studios before alterations.**




**Above: Cross-section of control room. Left: Fig. 3. The 35 mm scanner with pickup equipment.**

•

## NATIONAL UNION TELEVISION LAB

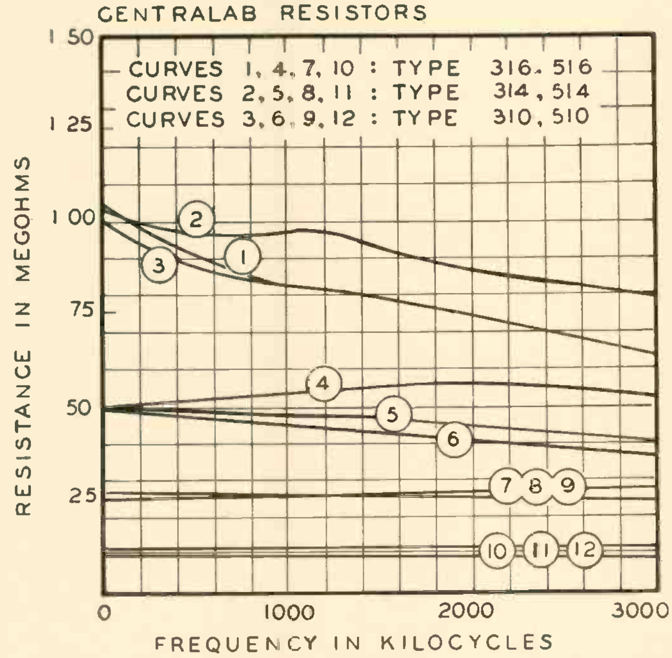
A TELEVISION testing laboratory has been launched by the National Union Radio Corporation to assist set manufacturers in the design and manufacture of their sight receivers.

(*Continued on page* 42)

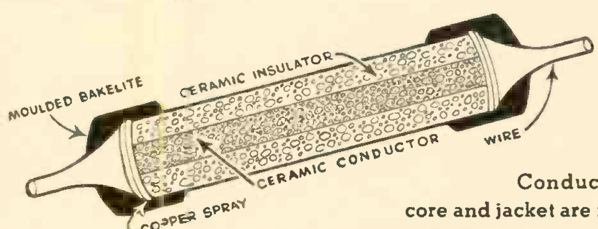
# Charting a future course

## RADIO FREQUENCY CHARACTERISTICS

CENTRALAB RESISTORS




**Cross-sectional sketch of Centralab Resistor**




Conducting core and jacket are fired together at 2500 degrees F. into a solid unit, hard and durable as stone, providing mechanical strength and protection against humidity.

Copper contact to the resistance material at the extreme ends only provides uniform resistance and load distribution over ENTIRE length. End contacts do not short circuit part of the resistance as in other types.

Because resistance is small in diameter and uniformly distributed for entire length, Centralab's specific resistance per unit length is low. The result is low noise level and constant value over a wide range of frequency and voltage.

**CENTRALAB • Division of Globe-Union Inc., Milwaukee**

## TELEVISION CIRCUITS

frequently require fixed resistors whose values remain uniform at high frequencies.

Centralab Fixed Resistors because of their relatively small cross section conductor area plot a comparatively flat resistance-frequency curve . . . as shown in the graph above.

In charting the future — in Television broadcast and reception, Centralab will continue to give satisfactory service . . . just as it is now doing with its performance record of more than 80,000,000 units in all parts of the world.

*Engineers send for Resistor Data Bulletin 647.*

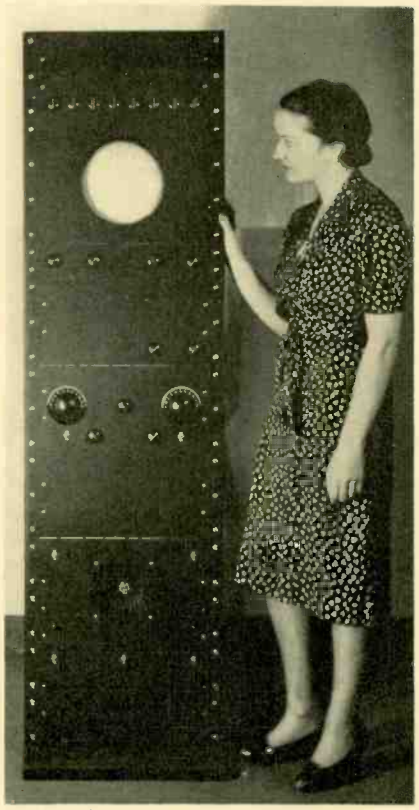
**SPECIFY CENTRALAB**

# Centralab CRL

★ FIXED RESISTORS ★

# Television Design

# Receiver Factors



Front view of the television receiver described in this article.

By WM. N. PERKINS

NATIONAL UNION RADIO CORP.

MUCH has been written in the past few years relative to the finer points involved in television receiver design. In fact, so much detailed material is available that it is, at first, very confusing to one attempting to obtain a general picture of the subject. It is almost superfluous to remark that there are many points of similarity between radio and television receivers, and equally so are there points of dissimilarity. Nevertheless, to those of us accustomed to thinking in terms of radio receivers, a comparsion, or contrast, of the unit similarities in the two receivers represents a natural method of orienting ourselves.

A representative radio receiver may be broken down into units encompassing the functions of: (1) r-f amplification, (2) frequency conversion, (3) intermediate-frequency amplification, (4) detection, (5) audio-frequency amplification, (6) sound reproduction.

A television receiver similarly divided into its functional units would include: (1) r-f amplification, (2) frequency conversion, (3) intermediate-frequency amplification, (4) detection, (5) video amplification, (6) sweep generation, (7) sweep synchronization, (8) optical reproduction.

Comparison between functional diagrams of the two receivers would indicate identity up to and including the fourth function; namely, detection. In fact, as audio-frequency amplification and video-frequency amplification are analogous, we may as well think of them as counterparts, even though the terms we use for them are different. The sound reproducer, or speaker, completes the functional chain of the radio receiver, and, of course, its functional counterpart in the modern television receiver is the cathode-ray tube. We would have, however, in our functional block diagram of a television receiver, two functions which have no counterparts in a radio receiver. These are the functions of deflection and synchronization.

However, even for those units of the two receivers having identical functions there exist enormously different performance characteristics. Broadly speaking, these characteristics are the ones describing transmission band width and transmission time.

The transmission band width necessary for television—three megacycles and upwards—is so vastly greater than that necessary for radio reception, that the problem involved in the attainment of band width is one of major proportions. In addition to the band-width problem, one is concerned with transmission time in a television receiver, while in a radio receiver this is an item which does not concern us.

In fact, this matter of time, being so intimately associated with our television system, might be thought of as the main distinguishing element between aural and visual transmission and reception. As the synthesis of the final picture is based on assembly of picture elements, in what one might call a chronological order, the merit or demerit of the final picture is in proportion to the ability, or lack of ability, with which we handle the time element.

If the several frequencies, involved in the reproduction of a single picture element, do not pass through our receiver in equal lengths of time, then the picture element, as we see it reproduced on the screen of the cathode-ray tube, is not a true representation of the original picture element in the studio. Obviously, what we desire to obtain is constant time of transmission for all frequencies involved in our picture. This requirement is met when we have linear phase shift with frequency, and in measuring departure from constant time of transmission we would measure the departure from linear phase shift.

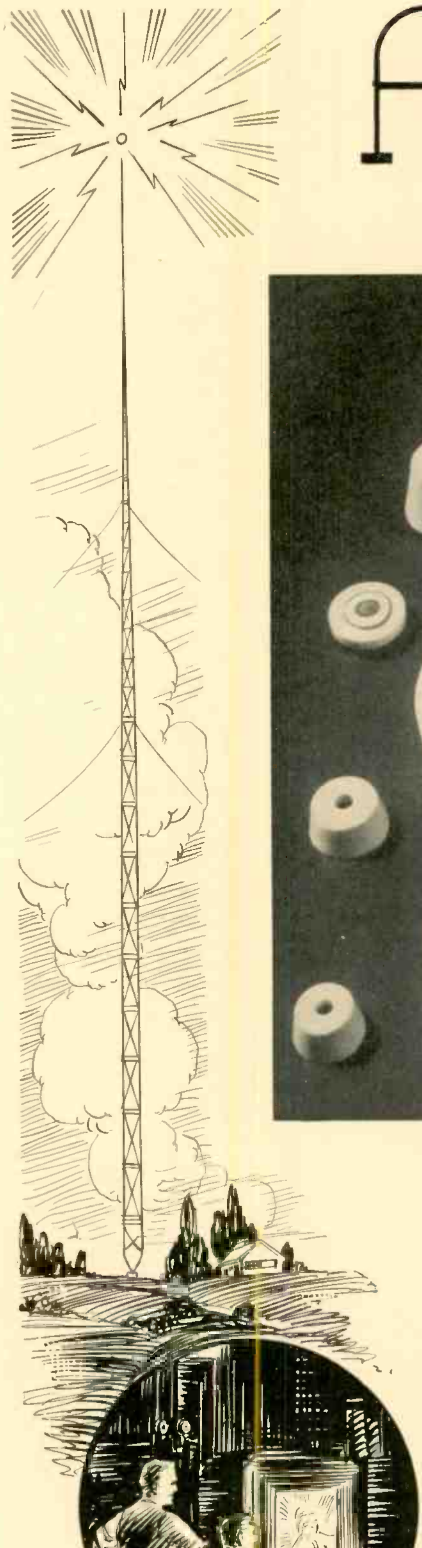
The R.M.A. has recently standardized on a particular type television signal and has recommended to the Federal Communications Commission this signal, together with certain other television transmission standards.[1] This signal makeup is based on a television system embracing 441 lines, 30 frames per second, 60 fields per second, interlaced two to one. The polarity of transmission shall be such that a decrease in initial light intensity shall cause an increase in radiated power and approximately 25% of the peak amplitude of the signal shall be devoted to synchronization. The aspect ratio of the picture shall be 4:3.

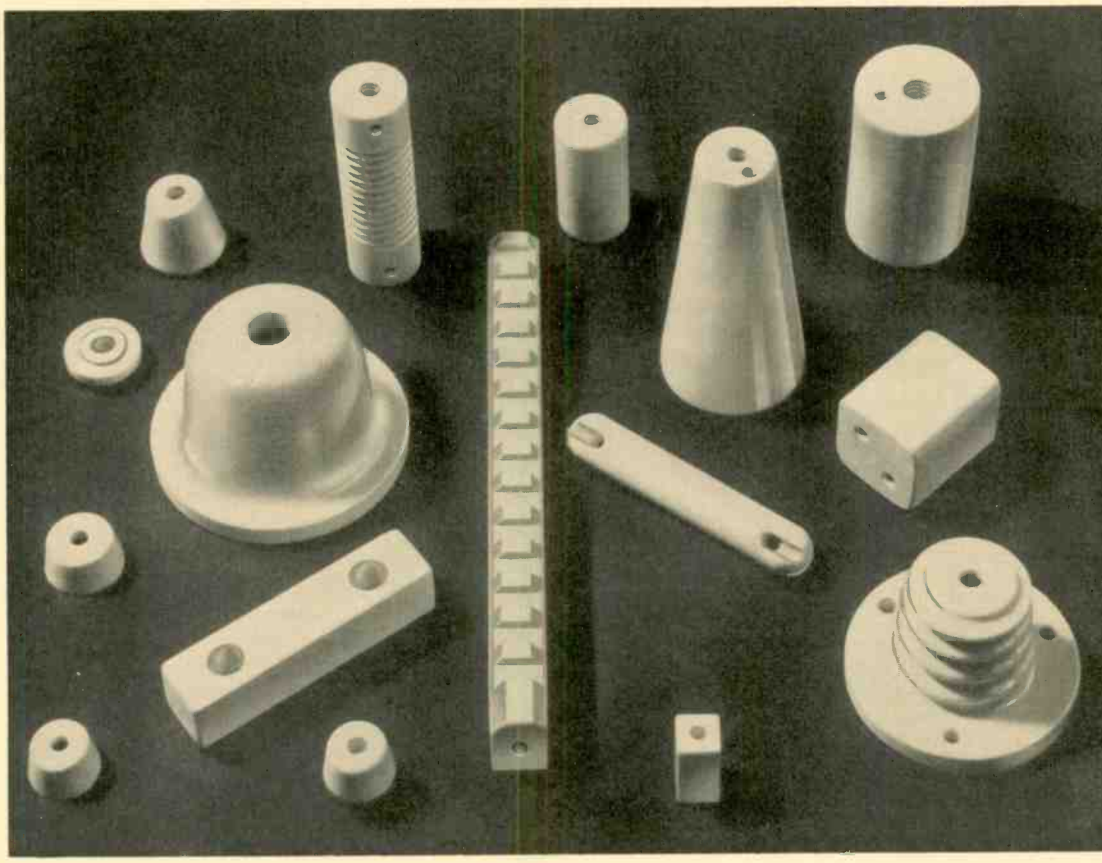
The signal as it arrives at a receiving antenna contains information which the receiver translates into light intensity variations—the video component—timing pulses for the vertical and horizontal deflection circuits—the synchronization signals—retrace the blanking—the pedestal and background control—the d-c component. This composite signal appearing at the 2nd detector then follows two courses. The signal in its entirety is applied to the input of the video amplifier, and after amplification, is applied to the control grid of the cathode-ray tube. Also, at the output of the 2nd detector, the composite signal is applied to a sync separation unit where the video signal component is removed. The remaining portion of the signal; namely, the sync pulses are then separated into vertical and horizontal pulses and applied to the vertical and horizontal deflection circuits.

So far, we have been considering television reception only in the broadest of

[1]See "Television Standards," by Albert F. Murray, p. 14, December, 1938, COMMUNICATIONS.

# ALSIMAG
## *for* TELEVISION





*SINCE the beginning of radio, we have kept in step with rapid advances by specializing in high frequency, low-loss insulation.*

NOW we are ready to supply insulation for the stringent television requirements. Space does not permit a detailed description of our many materials, but we are proud to state that we are producing Alsimag materials, perfectly vitrified, with power factors approaching pure quartz crystal at high and ultra-high frequencies.

*The Alsimag Property Chart will be sent upon request, giving complete information on our ceramic materials.*

**AMERICAN *Lava Corporation***

CHATTANOOGA, TENN.

**SALES OFFICES**

Boston New York Chicago Cleveland Philadelphia Los Angeles St. Louis Washington San Francisco terms. Becoming more specific, we might well discuss, to a certain degree of detail, some of the considerations of the various units that make up the receiver.

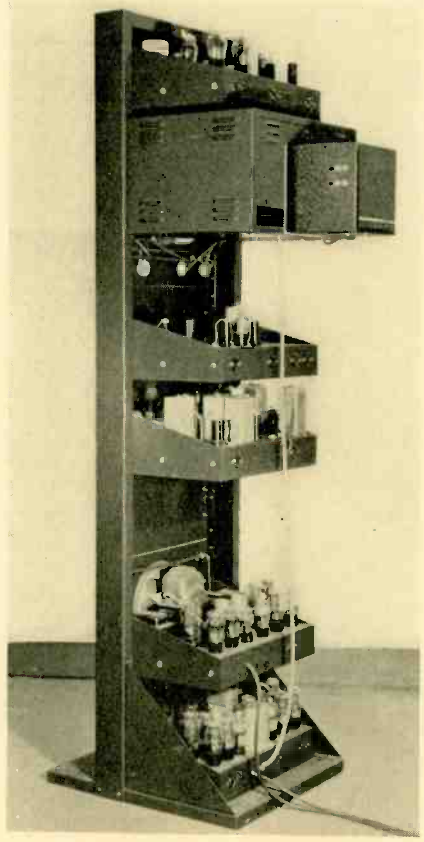
From the antenna to the grid of the frequency-converter tube, we must provide sufficient selectivity to insure against bad image response, as well as isolation between the antenna and the i-f amplifier. At the same time we must maintain a signal frequency band-pass characteristic between the antenna and the grid of the converter sufficient to pass upwards of four megacycles. As the television channel allocations are all in the ultra-short-wave spectrum, beginning at 44 megacycles and extending upwards in frequency, we have only recently had available tubes capable of giving any substantial gain at the television signal frequency. Two tuned circuits, heavily damped and stagger-tuned, have generally served in experimental receivers, between the antenna and grid of the frequency converter. In order to swamp out converter-tube noise, r-f amplification is desirable, and with the tubes now available sufficient gain is attainable at frequencies from 40 to 80 megacycles to make the inclusion of a radio-frequency amplifier stage worthwhile.

The frequency-converter tube, operating as it must into a relatively low plate-circuit load, and by its nature having lower conversion conductance than an equivalent tube has mutual conductance, cannot be expected to give gains of more than two to five. In this connection it is hardly necessary to state that pentagrid converters, of the type we use in broadcast receivers, do not serve very well at ultra-short waves. Not only is their conversion conductance so low as to almost preclude the possibility of obtaining any gain, but also their oscillator ability is low when considered in terms of ultra-short-wave performance. A high-mutual-conductance amplifier tube, operated as a biased detector, in conjunction with a separate local oscillator, is much better.

The i-f amplifier must provide the greatest portion of the gain, and must, of course, contribute the adjacent-channel selectivity. Incidentally, one of the adjacent channels is occupied by the accompanying sound signal, and so will be of essentially equal intensity with the picture signal at the input of the i-f amplifier.

In order to obtain the required band-pass characteristics of 3 or 4 megacycles, it is necessary to use a high intermediate frequency. That portion of the spectrum between 8 and 14 megacycles represents a reasonable compromise between the conflicting requirements of gain and band width. In order to obtain the necessary band width, heavily damped circuits, disposed in compensating arrangements, are called for. Under such circumstances, the load presented to the plate circuit of the amplifier tube is low—generally not more than two or possibly three thousand ohms—and as a result the gain per stage is relatively low, even when using very high-mutual-conductance tubes.

The second-detector considerations, very largely, revolve around the problem of eliminating the carrier frequency



**Receiver, bottom to top: power supplies, p-a, receivers, video amp., controls, c-r tube, sweep circuit.**

without mitigating against the higher video frequencies. The carrier is only three or four times greater in frequency than the highest video frequency, and so the simple expedient employed in broadcast receivers of placing a capacity in parallel with the load does not serve. Balancing out the carrier by means of push-pull detection, or the use of a low-pass filter composed of capacity and inductance between the detector and the video amplifier input, are means which do recommend themselves.

The video amplifier is, of course, nothing more nor less than an extremely wide frequency range resistance-coupled amplifier. It must amplify, without the introduction of appreciable departure from linear phase shift, a band of frequencies from 60 cycles per second to 3 or 4 megacycles per second. This amplifier, consisting of one or more stages, employs plate loads consisting of resistances, inductances, and capacities. The capacity is that unavoidable capacity introduced by the tube and the circuit wiring. At the higher frequencies, this unavoidable capacity reduces the gain and introduces an increasing phase angle because it represents a reactive shunt on the resistance load. Inductance is placed in series with the resistance load so as to compensate for the deleterious effects of the capacity. By proper proportioning of R, L and C, the amplifier may be made to have substantially flat gain and transmission-time characteristics up to the highest video frequency to be encountered.

Included in the video-amplifier chain between the detector and the cathode-ray tube must be some means for impressing the detector d-c component on the grid of the cathode-ray tube. This requirement is a result of the fact that the extremely low-frequency components of the signal represent the information governing the light intensity of the picture background. Direct coupling in the video amplifier may be employed to transmit this, essentially, d-c component, or the amplifier may of itself be capacity-coupled, with responsibility for background control assigned to some form of d-c restoration circuit. One form that such a circuit may take would be a diode rectifier operating on the blanking and synchronizing pulses, with the resulting current pulses being stored in a resistance-capacity load and thus serving to establish the operating bias of the cathode-ray tube. The time constant of the resistance-capacity load should be long enough so that the voltage across it may be constant between successive sync pulses, but not so long as to be unable to compensate for any low-frequency deficiency characteristic of the video amplifier.

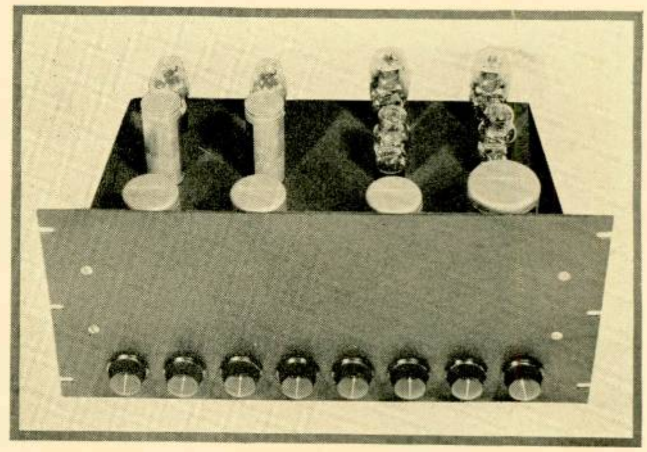
The synchronization and deflection system considerations fall into two groups; namely, timing and deflection linearity. Of course, deflection linearity is itself a matter of timing. The deflection, or sweep circuits, must be triggered off in very precise synchronization, if satisfactory interlace is to be achieved. The composite signal delivered by the second detector contains the sync pulses and video signal as well. In order to guard against random components of the video signal triggering the sweep circuits, the video must be removed. This removal can be effected by some type of amplitude-conscious "skimming" device. Utilization of the grid or plate circuit cut-off characteristic of a vacuum tube serves effectively here. The proper utilization of the vertical timing signal requires some modification of the signal before application to the vertical sweep circuit. This ver-

tical timing signal is preceded by six, and followed by six equalizing pulses. Their presence is dictated by the synchronization requirements of an odd-line interlaced picture. The pulse applied to the vertical sweep circuit may be the integrated energy of both the vertical sync pulse and the equalizing pulses occurring immediately before the vertical sync pulse. The pulse obtained by such integration exhibits remnants of the horizontal pulses, but their amplitude is considerably less than that of the vertical pulse proper and so are ineffective.

So far as the horizontal-sweep-circuit synchronization is concerned, only simple modification of the composite synchronization signal is needed. Some simple type of frequency-conscious device, effecting discrimination against low frequencies, will satisfactorily guard against any possibility of the vertical pulse interfering with the timing of the horizontal sweep circuit.

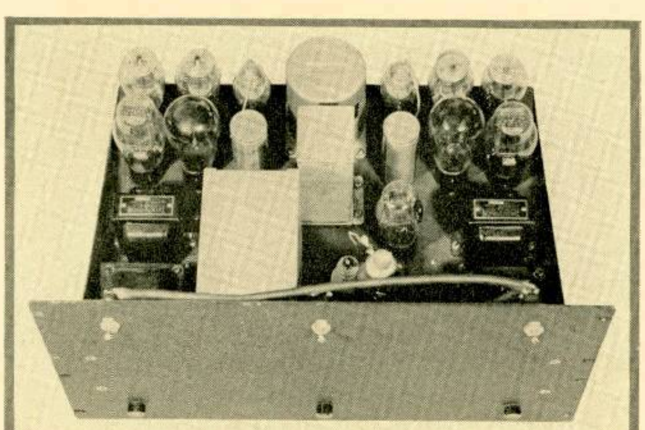
Deflection, or sweep-circuit linearity requirements, call for the production of saw-tooth voltage pulses, in the case of electrostatic deflection, or saw-tooth current pulses, in the case of magnetic deflection. Basically, the generation of the deflection forces for either electrostatic or magnetic deflection starts with the production of a saw-tooth voltage pulse, which is simply amplified and applied to the deflection plates of a cathode-ray tube, in the case of electrostatic deflection, or modified into a more or less rectangular voltage pulse for application to the deflecting coils for magnetic deflection.

The initial production of the saw-tooth voltage pulse generally makes use of the charging rate of a condenser supplied with charging current from an essentially constant-current source. Some form of discharge tube is utilized to remove the charge from the condenser and thus complete the saw-tooth pulse. The charging of the condenser produces that portion of the saw-tooth responsible for the forward sweep of the cathode-ray spot and the discharge tube in shorting the condenser produces that portion of the pulse accounting for the retrace sweep. Repetition rate of the charge and discharge cycle of the condenser must, of course, be ultimately governed by the incoming sync pulse. The tube which discharges the condenser variously takes the form of either a gas or a vacuum tube. If a vacuum tube, it is usually preceded by some form of blocking oscillator adjusted in timing to trigger off the discharge at approximately the proper rate for horizontal or vertical sweeping, as the case may be, even in the absence of sync pulses. The application of the sync pulse to this blocking oscillator acts to precisely adjust its timing. A gas tube, employed as the discharge tube, need not be preceded by a separate blocking oscillator, for the gas tube contains in itself a type of action which will repeat the charge and discharge action indefinitely.



**Vertical and horizontal magnetic sweep circuit of the transformer-coupled blocking oscillator type.**

If electrostatic deflection is to be employed, the saw-tooth voltage pulse, as has been said previously, may simply be amplified and applied to the deflection plates of the cathode-ray picture tube. For small picture tubes, operating at relatively low anode voltage, this represents no problem. For large tubes, requiring many hundreds of volts change on the deflection plates, it does present somewhat of a problem, particularly when it is recalled that the amplifier, in order to preserve the wave form of the horizontal saw-tooth pulse, must be designed to amplify frequencies to upwards of 150 kilocycles. Amplifier requirements for vertical deflection are more readily met, for an upper frequency range of only six or seven hundred cycles is required.



**Panel containing 6,000-volt power supply for cathode-ray tube, as well as two 300-volt regulated supplies and bias supplies.**

Magnetic deflection, as has previously been stated, calls for a saw-tooth current pulse through the deflecting coil, and this in turn means that the coil voltage must be rectangular. To achieve the required current wave form a high plate-resistance tube—a pentode—acting as a source of constant current, and having a saw-tooth voltage applied to its grid, suggests itself. Generally, such an arrangement is employed for feeding the horizontal deflection coils. The saw-tooth voltage necessary for the grid of this output tube is, of course, obtained from across the condenser and discharge tube. Vertical deflection current, because of the relatively large number of turns of the vertical coils, need not be so great in magnitude, and, furthermore, because of the much greater ratio of coil resistance to coil reactance, the wave form of the necessary coil voltage represents a compromise between saw-tooth and rectangular form. A small triode, supplied with saw-tooth grid voltage, and operating on a curved portion of its characteristic is generally employed as the vertical deflection output tube.

Design considerations of the cathode-ray tube proper, insofar as the television receiver designer is directly concerned, naturally revolve around utilization of some given design which the tube maker hopes is satisfactory. Broadly, the several designs available at the present time differ in regard to focus and deflection principles. There are both electrostatically as well as magnetically focussed tubes, and also tubes, some designed for electrostatic deflection, and others for magnetic deflection. At the present time, the majority of the small tubes employ electrostatic focus and electrostatic deflection, while most of the larger tubes are designed for elec-

(*Continued on page 47*)

# THE DUMONT TELEVISION SYSTEM*


**By THOMAS T. GOLDSMITH, Jr.**
ALLEN B. DUMONT LABORATORIES, INC.


THOUGH it will be unnecessary to dwell at great length upon general television principles, it may be advantageous to review briefly those fundamental factors common to electronic television of today. This new system, which will be described here, has many features in common with the foremost existing systems of today, and so it will be well to have clearly in mind the standard methods employed in television and from there it will be relatively simple to introduce the major new features of the DuMont system.

The pictures to be transmitted by television are focused optically on a photoelectric mosaic which is in turn scanned by a beam of electrons, converting the lights and shadows into corresponding electrical energy. These video signals are utilized to vary the electron current of the receiving cathode-ray tube whose beam is caused to follow an identical scanning pattern with that employed at the transmitting camera tube. In this manner the electrical energy is converted into the original lights and shadows. The picture is sent point-by-point consecutively, but at such an extremely rapid rate that the persistence of vision of the eye provides the pleasing illusion of perfect continuity even with moving objects. It is customary to use an associated sound channel to accompany the pictures.

The cathode-ray television systems which have received the most attention in England and this country in recent years are basically the same. Sweep circuits are employed at the transmitter, and by means of a complicated system of blanking pulses and synchronizing pulses superposed on the video signal from the transmitter, another set of sweep circuits at the receiving point is locked into synchronism with those sweeps at the transmitter. Remarkably good success has been had with this method, even when it comes to the use of the interlaced system of scanning. However, there may be limitations on the degree of interlace which can be obtained by this method of local sweeps with remote control, and receiving sets operating on signals from such a transmitter are seriously limited in their versatility of reception, requiring signals of a specific degree of definition, and sweep pulses to control practically a fixed number of lines or frames. This limit on the versatility of receiving sets has done much to prevent the commercial introduction of sets on the market because of fear of obsolescence with further development of the art. Also the necessity of sticking closely to these tentatively assumed standards of lines and fields has prohibited many experimenters from even considering the possibility of setting up less expensive low-definition equipment, adequate for studying other important phases of television.

It is thoroughly desirable that the very highest definition television be given primary research consideration, but at the same time if it is possible, provision should be made to allow lower definition experiments to be carried on and furthermore provide for expansion to even higher definition pictures than are now practical without having to make a complete sacrifice of much of the present equipment, especially at the receiving station. The following description will present a system which solves several of these problems.

The DuMont television system employs the actual transmission of the entire scanning signals for both horizontal and vertical deflection in addition to the conventional video-modulating signals and the associated audio-channel signals. The deflection signals are generated exclusively at the transmitting station and sent by means of a suitably

*Presented before the Thirteenth Annual Convention of the Institute of Radio Engineers, New York City, June, 1938.

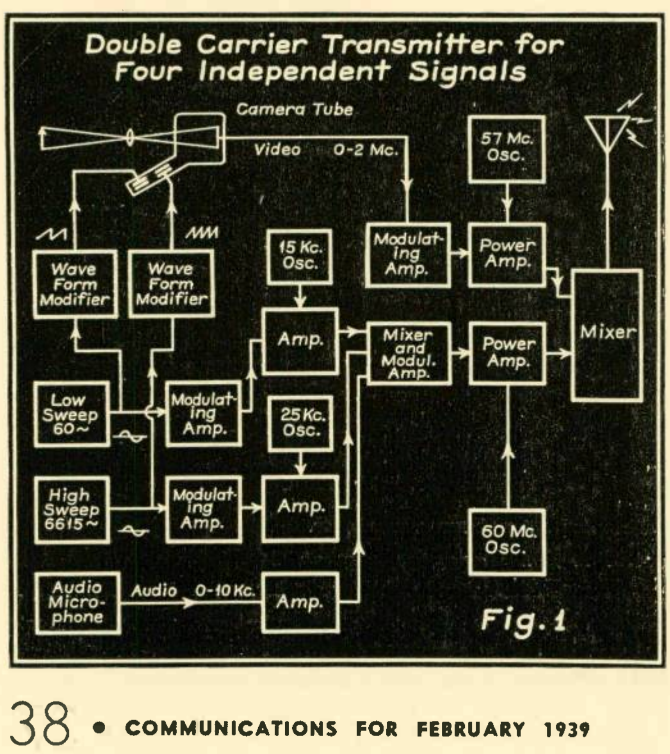


Fig. 1

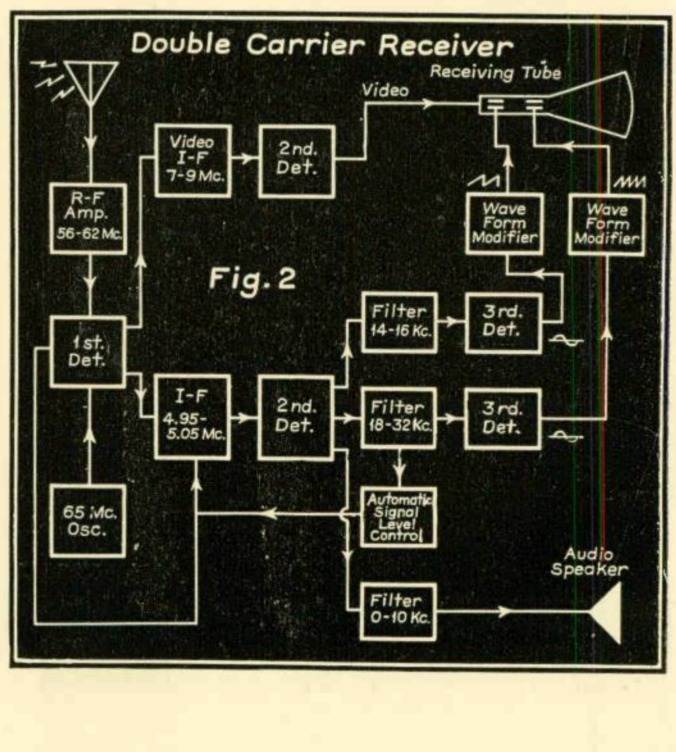
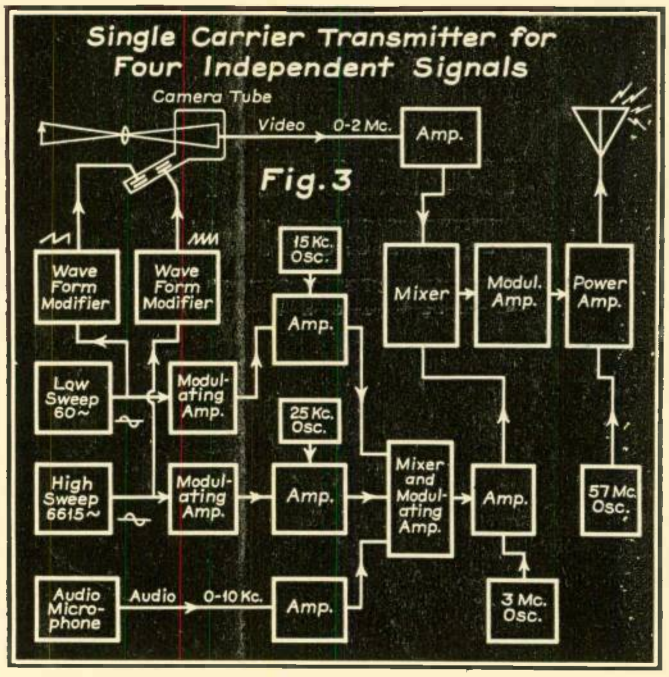
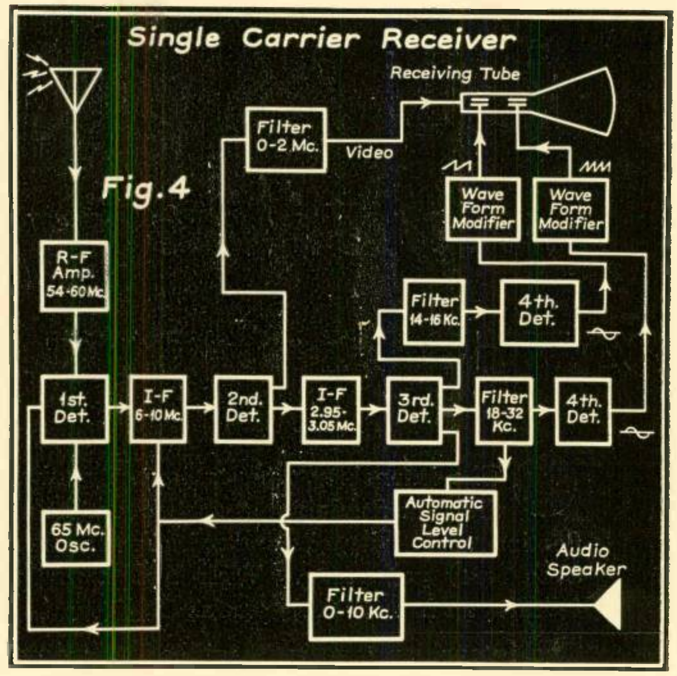


Fig. 2




designed carrier methods as independent signals to the receiver, thus simplifying the receiver considerably by making it unnecessary to employ local sweep oscillators at each receiver. Local synchronizing and sweep-frequency controls are unnecessary.

At first thought it may seem that the addition of these two sweep signals on two new channels seriously complicated the methods, but advantages result therefrom which more than offset the complication. It is ideal to construct receivers which are the simplest possible to operate. Furthermore it is highly desirable that they be as versatile as possible to allow for reception from numerous stations of differing degrees of definition. The complex equipment in any transmission system rightly belongs at the transmitter, leaving the receiver very simple to operate and free from critical circuits which require frequent attention. It may be seen presently how many of these advantages are possible when utilizing this new system.

In place of the conventional practice of having a set of sweep-generating oscillators at the transmitter controlled by synchronizing pulses, and having another set of sweep oscillators in each receiving unit, these synchronized by pulses sent out from the transmitter and carefully selected from the video signals by amplitude filters, this new Du-Mont system employs one carefully controlled set of sweep generators at the transmitting station, and then utilizes these sweep waveform voltages to modulate auxiliary carriers in the transmission system, enabling the actual sweep wave forms to be picked up at the receiver and there simply amplified to utilize directly for the scanning. In this way the receiver at once will follow even quite radical changes in the scanning raster. The problem of maintaining synchronization no longer exists as no synchronizing pulses are utilized at the receiver and there is no need for the complicated system of synchronizing pulses with their provision for causing the interlace of scanning. Two-to-one interlaced scanning has been achieved quite acceptably with the synchronizing pulse method although the receiving equipment is thereby complicated, but it is not very likely that higher interlace ratios can be employed by this method of remote control of oscillating circuits. On the other hand, when the sweep oscillators of the master transmitter of this new system have once been adjusted to the proper frequencies, interlace ratios of four or six are entirely practical, as the deflection circuits at the receiver are essentially connected directly with the transmitter oscillators and automatically remain in step with whatever system of scanning is being employed there.

The receiver has four signal channels, each of which is quite like ordinary radio channels, though employing unique frequency characteristics to be described presently in connection with the illustrative diagrams. These channels require no adjustment after installation other than proper tuning for satisfactory audio reception whereupon the remaining signal channels are at once in adjustment. There may, of course, be necessity for brilliance controls associated with the cathode-ray tube, but in general the set will not be much more complicated to operate than the average broadcast receiver.

A primary advantage to be realized with the system is the practical possibility of the use of four-to-one or even six-to-one interlace, still maintaining sixty fields or fractional scans per second in order to insure absence of flicker, but utilizing a correspondingly lower frame or picture repetition frequency, by means of which a great reduction in video signal band width is realized. Even including the extra bands necessary for the transmission of the independent sweep signals, the entire band necessary for a complete television transmission is reduced to one-half or less of the band width required for 441-line pictures utilizing the two-to-one interlace of today with the tentative line and field frequencies being used, all simply because of the reduction in the band width of video modulating signals.

The general system may best be illustrated by a specific example. In order to maintain simple frequency discriminating circuits, the sweep signals are transmitted in the form of sinusoidal wave shapes and are then modified to the rather conventional saw-tooth signals by means of a simple filter network at the receiver, and the cathode-ray tube is indicated employing electrostatic deflection which very readily follows changes in the scanning system since electrostatic deflection plates have practically no frequency discriminating characteristics.

Fig. 1 shows a double-carrier transmitter for the necessary four independent signals. This system utilizes two separate ultra-high-frequency carriers to transmit the signals. A single carrier alternative transmission system will also be described.

In Fig. 1 the two carriers are in adjacent ultra-high-frequency channels to facilitate dual handling at the receiver.

*(Continued on page 42)*

# DU MONT

## *Intensifier type*

## CATHODE-RAY TUBES

The intensifier type cathode-ray tube represents the first fundamental improvement affecting deflection sensitivity since the inception of these tubes over forty years ago. With this *exclusive* DuMont feature, an increase as great as 60% may be realized.

The intensifier type tube will effect many savings in television receiver designs, due to its increase in deflection sensitivity, lower modulation voltage requirements, and more economical filter requirements.

### Type 54-11-T—5" Tube

Not only does this Teletron (television-type cathode-ray tube) feature the intensifier electrode, but it incorporates several refinements in its gun structure for better focus and modulating characteristics. Instead of a reduction in pattern size of 50% which doubling the accelerating voltage would produce in the usual type tube, the voltage with use of the intensifier electrode reduces pattern size only 18%. BLACK and WHITE screen. Silver intensifier-electrode bands deposited on inside walls of glass blank.

### Type 94-11-T—9" Tube

Intensifier-electrode Teletron with improved focusing and modulating characteristics. Provides same sensitivity and image size advantages as smaller type. New DuMont egg-shaped blank provides increased strength of glass envelope, to counteract high vacuum and atmospheric pressure with a more than generous margin of safety. BLACK and WHITE screen.

### *Write for Data*

Bulletins 5-1 and 9-1 covering complete descriptions and characteristics of these intensifier-type tubes, sent on request. Other bulletins on tubes, oscillographs, electronic switch and television receivers available.

## 60%

## INCREASE IN DEFLECTION SENSITIVITY


Type 54-11-T—5" Intensifier-type cathode-ray tube or Teletron for television applications.


Type 94-11-T—9" Intensifier-type cathode-ray tube with new egg-shaped glass blank for maximum safety factor.

DUMONT

SO YOU SEE
AS WELL AS HEAR

ALLEN B. DU MONT LABORATORIES, INC.

PASSAIC NEW JERSEY

CABLE ADDRESS—WESPEXLIN, NEW YORK

VETERAN WIRELESS OPERATORS ASSOCIATION NEWS

W. J. McGONIGLE, President — RCA Building, 30 Rockefeller Plaza, New York, N. Y. — H. H. PARKER, Secretary

## MEDAL OF ACHIEVEMENT

IN REPLY to our letter informing him of the award of the first Marconi Memorial Gold Medal of Achievement to him for outstanding accomplishments in the communications field by a former radio operator, Mr. Sarnoff wrote: "I thank you, and through you the Board of Directors of the Veteran Wireless Operators Association, for the great honor tendered me. I accept with pleasure and Mrs. Sarnoff and I will be delighted to be present at the Fourteenth Annual Dinner-Cruise of the Veteran Wireless Operators Association on Saturday evening, February 11, 1939, at the Hotel Astor. We look forward with pleasure to seeing you on that occasion. With cordial greetings, Sincerely yours, (Signed) David Sarnoff."

## AWARDS

IN ADDITION to the award of our Marconi Memorial Gold Medal of Achievement to Mr. Sarnoff the following awards will also be made:

Silver Commemorative medals to Jack Binns, hero of the *Republic-Florida* disaster in 1909 and to Ted Haubner, hero of the *Arapahoe* in 1909 and the man who first used SOS as a signal of distress when that ship was in trouble off Cape Hatteras. In each case the Commemorative Medal is awarded to mark the Thirtieth Anniversary of the heroic incidents. Both recipients will be present to accept their awards and the proceedings will be carried by an NBC network. Captain Sealby, master of the *Republic* at the time of disaster, will be present and Captain Ruspini, master of the *Florida* at that time, has been invited to attend.

Marconi Memorial Scrolls of Honor will be awarded to: Patrick Chapman, hero of the flying boat Cavalier disaster in January of this year; Ernest Krenkel, hero of the Russion Ice-Floe party which remained aboard an ice-floe for over a year studying weather conditions, during all of which time Mr. Krenkel maintained daily contact with the outside world; Andrew Hamilton Radio Officer abroad the rescue ship *Esso Baytown* for his fine work in keeping the world informed of the rescue of the Cavalier's officers and passengers; Sergeant Morgan of the United States Army Signal Corps for his heroic work in Alaska during an epidemic and also for his outstanding work in keeping the world informed of the Post-Rogers flight disaster; Richard Stoddart, Radio Officer of the Hughes Round-the-World Flight who maintained continuous radio communication during the fastest round-the-world trip in history; Charles Hogger, Russian Radio Officer who received a medal from the Czarina of Russia about the time of the World War for his heroic radio work; Papas Theodorou, Radio Officer aboard a Greek freighter which broke in two and sank in mid-Atlantic, whose heroic efforts saved all the crew but himself. For further details of these awards consult our 1939 Year Book.

## HONORARY PRESIDENT

WE ARE PLEASED to announce the acceptance by Dr. Lee de Forest of the office of Honorary President in our Association. In accepting Dr. de Forest said: "Be assured that I greatly appreciate the high honor which the Board of Directors of the Veteran Wireless Operators Association has extended to me, the office of Honorary President of the Association. I accept this office with sincere gratification.

"Enclosed find draft of my message of greeting to the Association on the occasion of the Annual Dinner-Cruise in New York. February 11th.

"Wishing the Veteran Wireless Operators Association long life and continued usefulness, Very cordially yours, (Signed) Lee de Forest."

Dr. de Forest's message of greeting follows:

"Fellow Veterans, Pioneers in Wireless:

"It's great honor you have done me in electing me your Honorary President, a tribute which I value more than words can express.

"'Deep as first love,' sings the poet, Tennyson; and so deep, because first in my active life is the love I bear, and have borne for the past 36 years, for the Wireless Telegraph and for those fine fellow pioneers who labored with me to first launch over the Atlantic waves those mysterious ether waves.

"To me those boys, now grown gray (and so many gone, alas), remain always the young, bright, cheery optimists, willing and ready to make any sacrifice, face any danger, in the cause of that great Adventure, which we knew and enthusiastically, devotedly loved—as 'Wireless.' I can still hear Baskerville's delicious Southern accent as he pronounced it: 'Wahless.'

"Then there was Barnhart, my very first operator, and Pop Athern, Mac Horton (God bless them, if still alive)—Isbell, Pannill, 'Sunny Jim' Easton, Henry Hughes, Harry Brown, Marriott, Pickerill, Blaney, lovable, candid Harry Shoemaker, Midgley, dear A. Y. Tuel, George Lewis, pungent George Clark—and others too many to list separately, all in my own Organization (or its successor or allies). And outstanding in the then rival Company, Dave Sarnoff, Bill McGonigle, and Costigan, and others whom I didn't know personally, but had abundant reason to remember and cuss for honest QRM!

"Far indeed have the lengthening years travelled since those days, and far indeed has that primitive art as we beginners knew it developed into the magnificent network of Radio Communications which today enlaces the globe. Justly proud are we Veterans to have intimately witnessed this incredible advance, to have had active, personal hand in this development, matchless in all the annals of scientific progress. Because we deeply felt, away back there in the early years of this century, that the seas on which we were embarking were as boundless as they were uncharted; that mystery and strange allure and great Adventure beckoned us on.

"And so tonight to pause for a spell, to look back along the track we have sailed, to realize whence we embarked and over what majestic, albeit storm-tossed waters we have come, ever sailing, into the West and toward the Sunset—brings to us all a quiet joy, the satisfaction of duty faithfully performed, of work, often faulty, but on the whole well done—which is more valued than present ease or riches.

"The Annals of the Veteran Wireless Operators Association are glowing ones, bright-starred with names and deeds of heroic sacrifice. We have a Record which as high heritage we can pass on to our successors with deep satisfaction and pride, confident that this fine tradition will be carried on.

"Too soon, alas, will come the Dog Watch—too soon will sound: Eight Bells. So here's a toast, Me Hearties, to the V.W.O.A.!

"And from my heart—
"'73'
(Signed) Lee de Forest."

## "STORM"

BY THE WAY did any of you Wireless Heroes see the motion picture called the "Storm"? It was a WOW. Often, many of us wanted to sock the Skipper on the jaw but, somehow, at the moment, it never seemed to be the right thing to do.

## BOSTON DESPATCHES

AS A RESULT of the annual revolution the Boston forces are now under the command of R. F. Trop, Chairman, Massachusetts Radio and Telegraph School, 18 Boylston St.; Mark L. MacAdam, Vice-Chairman, Brockton Police Department; B. McCarthy, Secretary and Treasurer; Entertainment Committee; McAdam, Cowie of WEEI and James J. Green of the Brookline Police. Membership and By-Laws: Guy R. Entwistle, 18 Boylston Street, A. J. Prior of WJAR, Providence, and J. Loyall, RCA, Boston, Mass. Ways and Means Committee: J. A. Loyall, Chairman, Henri Jappe, 40 Corn Hill, and Ed. Tierney of the Cambridge Police.

The Boston forces under the energetic leadership of General Trop are expected to take Boston on the night of February 11th. The exact whereabouts seem known to the

(*Continued on page* 51)

## INDUCTIVE TUNING

(*Continued from page 12*)

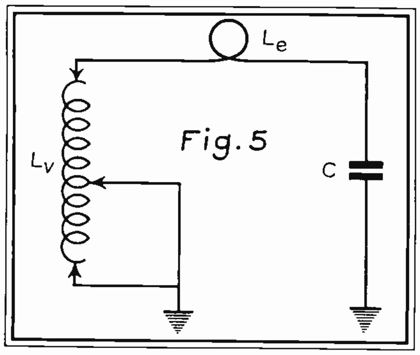
ing leads. The actual voltage E available at the input of the vacuum tube will, therefore, be reduced considerably by $E_2$, the inductive drop across the variable condenser and leads, as shown in Fig. 2. If, on the other hand, a variable-inductance device is used to resonate with a small highly stable fixed condenser designed for minimum inductance, considerably higher voltages would be available in a tuned circuit of this type. At the high-frequency end of the tuning range, the ratio of desired to undesired reactance is considerably increased. The input voltage to the vacuum tube would be available across the points shown in Fig. 3 wherein the inductance of the capacitive leg of the parallel circuit would be kept at an absolute minimum. An inductance-tuning device involving principles wherein high-gain circuits of this type are entirely practical at relatively high frequencies, is described in the following paragraphs.

### MECHANICAL DESIGN

The continuously variable inductance (CVI) system makes use of a rigid coil which rotates on its own axis driven by a direct or geared shaft. A contactor is constrained to slide directly along the length of the coil wire whenever the coil is rotated. This contactor is mounted in a small carriage which is allowed to slide along the axis of the coil and is moved in this direction by a small insulated pulley, grooved to follow the convolutions of the wire. When the coil is rotated for tuning, the carriage and likewise the contactor, is moved in a direction parallel to the coil axis, depending upon the direction of rotation. A rod, likewise parallel to the coil axis acts as the guide for the motion of the carriage. The carriage assembly itself is compressed between the guide rod and the coil form, maintaining a light pressure between the contactor and the wire on the coil.

The contactor itself takes the form of a small bifurcated phosphor bronze spring having two parallel nibs which ride on the outside diameter of the coil conductor. The contactor spring itself is not called upon to perform any mechanical function other than that of supplying the continuous contact at all times. The bifurcated contact spring greatly improves the contact reliability of this device and hence enables reduction in required pressure due to the double contacting arrangement. Any minute obstruction on the outside surface of the wire under conditions of single contact, might cause a break in the direct continuity but with the double contact arrangement such irregularities have little or no effect.

Grid and ground contacts are picked up at the opposite ends of the coil. The contactor itself operates at ground potential and determines by its position, the grounded or low-potential end of the tuned circuit. The unused portion of the coil is grounded at all times and the upper limit of tuning range is determined by the natural period of the unused portion of the coil when the contactor approaches the grid end. Voltage is




**Circuit of tuning system.**

picked up at the high potential or grid end of the inductor through a contactor mounted on a small insulating strip suitably spaced from the grounded end plate. This connects to an "end" or minimum inductance which, in turn, is connected into the resonant circuit in the regular manner. This end induct-

(*Continued on page 49*)

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## TELEVISION LAB

(*Continued from page 30*)

The testing laboratory, put in operation under the joint direction of W. M. Perkins and M. G. Nicholson, has been enlarged to accommodate the demands for its many services to television set manufacturers in the pioneer production stages of home video equipment. The television proving grounds are available to receiver firms desiring to gauge the efficiency of circuits and equipment. All facilities are gratis, being so provided by National Union as a contribution to the video art's development and advancement.

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## DUMONT TELEVISION

(*Continued from page 39*)

One carrier is modulated by the video signal alone, and the other one is modulated by the three remaining signals, the sweeps and the audio in distinct narrow channels. These three signals remain distinct from one another by the use of appropriate subcarriers.

The camera tube for converting the pictures into the so-called video signals may assume several conventional forms, though very promising results have been obtained with the use of a special type of photoelectric mosaic tube employing electrostatic deflection. This type of deflection is considerably more desirable where it is planned to vary the style of scanning raster. With certain types of scanning it will be desirable to provide black levels on the picture signals to eliminate undesirable portions of the return traces, but these blanking pulses need not be of greater height than just sufficient to cause extinction of the beam, for there is no need of their use for synchronizing pulses, with the complex amplitude and frequency filtering at the receiver. With such a video signal it is feasible to utilize full hundred percent modulation of the ultra-high-frequency carrier with efficient picture producing signal. It is unnecessary to sacrifice twenty to twenty-five percent of this very broad channel for the purpose of synchronizing pulses.

The sweep signal generators shown here provide sinusoidal wave shapes of 60 cycles per second and 6615 cycles per second respectively for the vertical and horizontal scanning. This type of signal is rather easily handled in selective-filter circuits, and can be modified by a simple resistance-capacitance rectifier network into the more conventional sawtooth waveform which is very efficient in accomplishing uniform coverage of the screen area.

It is necessary to provide a suitable and simple means of transmitting the sweep signals and the audio voltages independently. The low sweep is used to modulate the output of a 15-kilocycle oscillator. The high sweep in turn is used to modulate the output of a 25-kilocycle oscillator. The audio signals generated in a conventional manner by microphone supply the third channel which has a frequency band from 0 to 10 kilocycles. These three signals are combined and used to modulate the power output of a 60-megacycle carrier oscillator. The 57-megacycle carrier and the 60-megacycle carrier are subsequently fed to a radiating antenna system.

Fig. 2 shows the double-carrier receiver for use with this transmitting system. It accepts the antenna signals with a radio-frequency stage having a band pass of 56 to 62 megacycles. The first detector mixes this compound signal with the output of a local 65-megacycle oscillator, and delivers the signals to tuned intermediate-frequency circuits. The video second detector receives only those potentials intended to modulate the grid of the receiving cathode-ray tube. The other selectively tuned intermediate-frequency stage is followed by a second detector which delivers the three original signals through

tuned filters and third detectors in the cases of the sweeps and directly through a filter to the loudspeaker in the case of the sound signals. Simple waveform modifying networks deliver the deflecting voltages to the plates of the cathode-ray tube.

It can be seen that there are no critical local adjustments to be made to this receiver, after it is once lined up properly with regard to the filters. A single tuning control is sufficient for both channels. The problem of satisfactory automatic signal level control is easily solved since the output of the filter for the high-frequency sweep remains of constant signal strength and does not change at all as the picture subject matter varies. A circuit can be provided in the video output to obtain brightness regulation of the picture with changes in the d-c background level of the picture signal.

With these band-pass systems in the receiver it can readily be seen that small variations in the scanning signals are immediately followed by the beam in the receiving tube to maintain faithful picture reproduction. With a somewhat wider channel in each band, though keeping the same general principles, receiving sets may be produced having great flexibility as to the types of scanning signals they may accept, and consequently a high-fidelity receiver can also be employed without any change to observe the transmission from a low-definition experimental station so long as each station employs identical subcarriers and maintains uniform separation between its assigned carrier frequencies. All of the critical equipment is located at the transmitting station where it justly belongs, leaving the receiver simple to operate and inexpensive as contrasted with circuits containing complete sweep oscillators with their associated control features.

Fig. 3 presents an alternative method of transmitting the four necessary signals for this television system. It employs only one ultra-high-frequency carrier. The two sweep signals have their subcarriers as before and a mixer combines the two modulated subcarriers with the audio-channel signals. Now this composite signal is used to modulate an intermediate subcarrier of three megacycles which can then be suitably combined with the output of the video channel. Finally, the single ultra-high-frequency carrier is modulated and radiated. This method offers certain advantages regarding the ultra-high frequencies. Design of a single antenna system is simplified when it is not required to radiate two carriers as in the first method, but merely to radiate the one carrier with its somewhat broader modulation. Only one ultra-high-frequency power amplifier is required.

The receiver for this single-carrier system is shown in Fig. 4. It utilizes a conventional superheterodyne circuit through the second detector, except for the use of the broad band pass necessary for television reception. At this point a low-pass filter isolates the video signals and feeds them to the cathode-ray-tube grid. The band-pass intermediate-frequency stage selects the composite signals still superposed on the three-megacycle subcarrier which is then demodulated by the third detector. The respective filters further isolate the signals and deliver the sweep signals through the fourth detectors and the sound signals to the loudspeaker. Again the automatic-signal-level control is taken from the constant-amplitude source in the channel of the high sweep frequency.

The relative merits of these two transmission systems will be more fully revealed by further definite field tests of each system.

These illustrative figures which have been presented should clarify the major principles of the system, and now it is of interest to consider the important advantages of this system over other contemporary systems. Of major importance is the ability to transmit high-definition pictures with a reduced frequency band. This simplifies the requirements at both the transmitter and the receiver. It allows radio spectrum space for more television stations. It makes it possible to transmit signals on carrier frequencies with hundreds of miles range, though it is well understood that fading and phase errors become more ominous with increased transmission distance. With a six-megacycle peak-modulating frequency it is essential to use ultra-short-wave carriers in the region of sixty megacycles which are nearly limited to the optical horizon, but with the video peak frequencies halved, it is impossible to utilize carriers with a world-wide range.

It is important to point out here just how this video-frequency reduction is accomplished in this system without a sacrifice in definition. The system makes practical the use of interlace ratios as high as four and six. With the synchronizing-pulse method of controlling local oscillators at the receiver, this is very difficult if not absolutely unreliable. With proper equipment, the higher interlace patterns can be controlled at the transmitter, and the method herein described provides the identical scanning system at the receiving station. Let us illustrate what we mean by an interlace ratio of four by a specific example. To maintain freedom from apparent flicker it is satisfactory to utilize fractional scanning at the rate of sixty vertical traverses or fields per second. If the horizontal scanning frequency is accurately enough controlled, the scanning can be made to occur so that the entire system of lines is completed at a repetition rate of fifteen per second. The frame frequency is fifteen per second, providing fifteen completed pictures each second, yet the fractional scanning frequency is sufficiently high to maintain persistence of vision, and the frame frequency of fifteen is high enough to provide adequate continuity of motion of moving objects. By maintaining the field frequency of sixty and reducing the frame frequency to fifteen instead of thirty, as with the 441-line two-to-one interlaced pictures, the video frequency band is halved without sacrifice in either horizontal or vertical definition.

Use of single-side-band transmission is of course possible with this system which will reduce the required frequency band on the air to one-quarter of that of existing systems.

Another advantage of the DuMont system is the assurance of synchronism if signals are received at all. There is no local adjustment of auxiliary controls. Furthermore, the receivers are capable of responding to several scanning systems in turn from successive sending stations. This wide versatility of receiving equipment should do much to foster valuable experimentation in new phases of television.

In the spirit of true research it is realized that this system can only stand on the merits of results of extensive field trials which are under way. Our laboratory tests indicate that this system is entirely feasible, and preliminary tests over the air substantiate these conclusions.

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### TELEVISION ECONOMICS

(*Continued from page 20*)

the carrier-frequency-control circuits. The oscillator is followed by a group of buffer amplifiers and a final power amplifier. Modulation is accomplished during video transmission by connecting the grids of the power-amplifier tubes to the modulator plates. Present practice involves the insertion of the d-c component of the signal, corresponding to the average brightness of the picture, in the form of a variable carrier output. The modern transmitter is so arranged that it can be disassembled to carry it through buildings prior to reassembly. The by-passing of the power supply to video transmitters require particular attention, since very low impedance at video frequencies is desirable in the rectifier and filter circuits.

Transmitters meeting the presently proposed American standards require partial suppression of one side band, generally by means of a suitable filter in the output circuit.

The method of rating the transmitter, in view of the peculiarities of video transmission of the vestigial-side-band variety, will require general agreement. It is obviously not strictly comparable to that of audio transmitters.

In the selection of transmitter power, it is present practice to require a signal of about 1 mv /m at distances between 30 and 45 miles. The lower the carrier frequency, the greater the likely interference range of the transmitter, the more likely occasional "freak" ranges, and the greater the reception difficulties from atmospheric disturbances; on the other hand, the less the urban absorption and the greater the available output power.

The transmitter alone is not the major item in a television installation, since the camera chains for studio operation with their associated gear will cost several times as much as a small transmitter. The presently proposed American standards appear unlikely to be obsolesced rapidly unless unforeseen technical or commercial conditions arise.

### C-2. Audio Transmitters

Essentially the audio transmitter associated with a television broadcast is a conventional uhf sound-broadcasting transmitter. Experiments have been carried out to determine the extent to which electrical disturbances affect the picture and the sound for various radiated powers; and the necessary and available selectivity in receivers for picture and sound has been determined experimentally. As a result of such studies it has been found that the audio-transmitter power should be about the same as the video-transmitter power.

The audio transmitter will be of high fidelity, covering not only a wide frequency range (e.g., up to 15,000 cycles) but having low harmonic distortion (a few percent). Its overall utility will be determined in part by government policy in permitting, or not permitting, the use of the audio transmitter alone for commercial sound and facsimile broadcasting during hours when the video transmitter is not on the air (that is, when no television material is available).

Certain radical improvements in sound transmission and reception, not hitherto deemed practical on medium-frequency broadcasting, will become available on uhf sound broadcasting. These factors may lead to a relatively rapid obsolescence or required modification of the audio transmitters.

To permit tuning of the receiver to picture and sound by a single knob, the audio and video transmitters have a constant difference of frequency in each channel (4.5 mc at present). According to present practice, it would seem that adjacent channels for television must be made usable in some localities and that transmitter cutoff and receiver selectivity must be engineered with this requirement in mind. This emphasizes the fundamental fact that the economics of transmitter and receiver design depend in large measure on the frequency-allocation plan and regional assignments which may be adopted.

(*To be continued*)

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### TELEVISION RECEIVER

(*Continued from page* 36)

trostatic focus and magnetic deflection. Some of the larger European tubes employ magnetic focus and magnetic deflection, and American tube makers are at present examining the merits of this combination.

A brief description of an experimental television receiver, built by Mr. M. G. Nicholson and the author, may be of interest. The receiver in question was planned, not so much with the idea of constructing a receiver to be used for entertainment purposes, but rather to form the basis of an experimental study.

This receiver is so arranged that either single-dial or two-dial tuning may be used at will. That is to say, the sound and picture intermediate frequencies are selected so that the use of a common oscillator and first detector may be employed for tuning purposes, or at the flick of a switch a separate oscillator and first detector set-up may be cut in to allow independent tuning of either the picture or the sound receiver. The picture i-f was selected as starting at 10 megacycles and extending to 12.5 megacycles. The sound i-f was arranged to be approximately 8.25 megacycles. Thus when operating as a single-dial receiver, tuning in the sound program automatically adjusts the picture receiver to accept the picture carrier, two megacycles of the upper sideband and a portion of the lower sideband. When the picture and sound receivers are tuned independently, it is possible to select either the upper or lower sideband of the picture transmission, or make use of double-sideband reception without interfering with sound reception. The sound receiver proper consists of two stages of 8.25 megacycles, i-f amplification, diode second detection and diode avc action with one stage of a-f amplification, and then into a phase inverter and push-pull output stage. The bandpass of the sound receiver is approximately 100 kc, and consequently does not impose any extreme stability requirement on the oscillator.

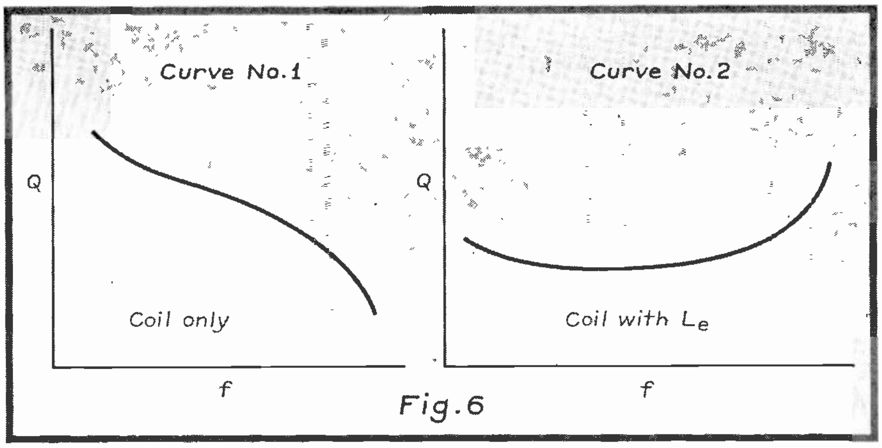
The picture i-f amplifier is a three-stage affair, making use of six tuned circuits, all-told. The converter tube plate operates into an i-f transformer having two over-coupled circuits, heavily damped, the output of this transformer feeding the grid of the first i-f amplifier tube. This i-f amplifier tube then operates into a single tuned stage, properly damped, and tuned so as to fill in the hollow of the first i-f transformer response characteristic. The plate of the second i-f amplifier tube operates into an i-f transformer made up of two over-coupled, heavily damped, tuned circuits which feed the grid of the third i-f amplifier tube. The plate circuit of the third i-f stage is a single tuned circuit, heavily damped, and tuned to fill in the hollow exhibited by the response curve of the preceding transformer. This last-tuned circuit feeds the grid of an 1851 operated as a biased detector. The plate circuit of the second detector incorporates a load resistance and low-pass filter which eliminates the i-f carrier frequency before the composite video signal is applied to the grids of the video amplifier and sync separation unit.

The video amplifier itself is a two-stage affair, designed to be flat in frequency response, and have negligible departure from linear phase shift, up to approximately 3.5 megacycles. An 1851 constitutes the first stage, and a 6V6G the second or output stage. The 6V6G is used in order to have sufficient output voltage to swing the grid of the cathode-ray tube over its entire modulation characteristic, which, in the case of a nine-inch tube, means approximately thirty volts peak to peak.

As the video amplifier is capacity-coupled, restoration of the d-c component of the signal is necessary and is accomplished at the grid of the cathode-ray tube by means of a half-wave rectifier operating on the blanking pulses of the signal.

The nine-inch tube employed is of the electrostatic focus, magnetic deflection type. Horizontal and vertical sweeps circuits employed follow conventional practice for magnetic deflection. That is to say, a vacuum-tube blocking oscillator, in conjunction with a vacuum discharge tube is employed for saw-tooth generation, and finally an otuput tube, functioning simultaneously as an amplifier and wave-form modifier, completes the unit.

The sync signal separation unit obtains the composite television signal directly from the second detector and first passes it through an amplifier to raise the level before impressing it on the grid of a "clipper" tube where the video component is removed. After clipping, the remaining signal is applied to the grids of two tubes—one operating as a horizontal pulse output tube and the other as a vertical pulse integrator output tube.




**Showing Q of coil with and without $L_e$.**

## INDUCTIVE TUNING

*(Continued from page 42)*

ance takes the form of a coil of heavy wire having a diameter of approximately ½" and from 1 to 7 turns depending upon the tuning range required. This coil is adjustable and is somewhat analagous to the trimming condenser used for the minimum capacity adjustment on a variable condenser. The end inductance is adjusted correctly for the high-frequency tracking and determines the high-frequency limit of the coil resonated with a fixed condenser.

The coil rotates on a copper shaft which connects to the coil end ring and to the ground contactor; and is maintained at ground potential. This shaft rotates in suitable insulated bearings so as to maintain a low noise level for high-frequency operation in receivers.

In multiple-section units, the shaft is cut to length depending upon the number of units required and each inductance section mounts between end plates directly on the shaft. With a single knob, a direct-drive mechanism is thus obtained with a multiplicity of full revolutions, depending upon the required coverage of the tuning unit. The units are adaptable to several types of dial mechanisms with a spiral dial calibra-

*(Continued on page 51)*

## SINGLE-SIDEBAND TRANSMITTER

*(Continued from page 11)*

scale and it is evident that the selectivity is sufficient to allow side frequencies to be separated if they are 100 cycles or more from the carrier. The suppression of the 100-cycle component in the unwanted sideband is about 22 db, while that of 200 cycles is approximately 44 db. The very sharp corner on this frequency characteristic is obtained by using a parallel resonant circuit in series with the plate coupling resistor of the first amplifier stage in Fig. 8. This circuit is tuned to resonance at the low edge of the passed band and greatly reduces the tendency of the characteristic to round off at this point.

The remaining stages of modulation and amplification are of conventional design and present no serious problems. The next carrier frequency at 440 kilocycles differs from the near edge of the desired sideband by 20 kilocycles, and consequently an ordinary i-f transformer will separate them quite easily. In the case of the last modulator, the carrier and the desired sideband differ by 440 kilocycles so that the separation is even more simple.

The stability of the first oscillator is of course a matter of great importance. However, if a gas-regulated power supply is used and only normal variations of room temperature are experienced, the drift in this frequency will ordinarily amount to only a few cycles in the course of a day's work. It can easily be adjusted to the proper value by unbalancing the modulator and measuring its output with a vacuum-tube voltmeter. The frequency is then varied until the response is down by about 8 db from that obtained when the frequency is tuned to the flat part of the passed band.

This transmitter has proved very satisfactory in the course of the tests made upon it during the development work. It is easy to adjust and operate and contains no elements that are either expensive, unusual, or troublesome in any way.

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## CONTROLLED OSCILLATOR

*(Continued from page 9)*

more suitable for accurate measurement.

A frequency controlled oscillator can be used to resupply carrier to a single or double-sideband transmission, provided a sufficient amount of carrier has been transmitted for proper control. It can be used also to detect frequency-modulated signals[7].

The action of a synchronous motor can be analyzed in terms similar to those in a frequency controlled oscillator. A method of making any rotating machine perform in a synchronous manner thus presents itself in which the synchronizing elements are almost entirely electronic.

In certain applications where the amplitudes of the oscillator and control-



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ling voltages are unsteady, the controlling functions can be rendered practically independent of amplitude by means of limiters. Frequency control will then be exercised entirely by phase difference.

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## VWOA NEWS


*(Continued from page 41)*


local police, but still undetermined at Staff Headquarters.

From all reports the Boston Doin's will be considerably BROADER in scope than New York, and/but, the EVENTS of the evening will not be as well covered.

Good luck, Boston, we are with you in Spirits.

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## INDUCTIVE TUNING


*(Continued from page 49)*


tion and with this arrangement a calibrated dial with markings extending over 5 or 6 feet of spiral length, may be used with the continuously variable inductance units. A stop mechanism mounted either on the back or front end plate is designed to allow free movement of the coils through a predetermined number of revolutions and in turn, this mechanism stops the coil rotation near the end of the winding. A novel stop mechanism and turn counter has been developed in conjunction with this device and this as well as other application problems, will be discussed in a second article to appear in future.

### ELECTRICAL CHARACTERISTICS

A typical circuit representing a variable-inductance fixed-capacitance arrangement is shown in Fig. 5. In this case the end or fixed inductance is repre-


*(Continued on page 54)*

## AMPLIFIER TESTING

*(Continued from page 26)*

mined by multiplying the frequency of the square wave by the number of full cycles of the oscillation which occur in one full period of the square wave. This number may or may not be fractional. The logarithmic decrement is defined as the logarithm of the ratio of any two successive maxima of the oscillatory wave train (measured from the average value of the wave train not from the average of the entire wave). The wave shown in Fig 15 yields the following data:

$f_n = 10\,f_1 = 10{,}000$ cycles

$\delta = \log\dfrac{e_1}{e_2} = \log 2 = .693$

the damping factor $a = \delta f_n = 6930$.

### LOW-FREQUENCY SQUARE WAVES

A typical circuit having deficient low-frequeny transmission is shown, with its characteristics, in Fig. 16. Output wave forms obtained with square-wave input at several different frequencies are shown in Fig. 17. The time constant ($R \times C$) of the circuit is obtainable directly from measurements of the output wave shape, the decay during any half period being given by the expression:

$$1 - \varepsilon^{-\frac{T}{2RC}}$$

Thus, if either R or C is known the value of the other may be readily obtained.

### NON-SYMMETRICAL SQUARE WAVES

The above discussion has been limited entirely to waves whose positive and negative portions occupy equal time intervals and are identical in shape. These waves contain only odd harmonics. Waves whose time intervals are unequal contain even as well as odd harmonics. The output wave shapes obtained with input waves of the types shown in Figs. 18, 19 and 20 will in most cases be similar to the wave shapes obtained by means of symmetrical waves. The shape of the output wave over the long interval $T_1$ being similar to that obtained by means of a symmetrical wave whose period is $2\,T_1$ while the shape over the short interval $T_2$ will be similar to that obtained by the use of a symmetrical wave whose period is $2\,T_2$. Thus, changing the positive and negative time intervals may be considered equivalent to using square waves of different frequencies at the same time.

Wave analyses of this type of wave will result in harmonic series similar to those shown in Figs. 21, 22 and 23.

The general expression for a rectangular wave is:

$$E = \sum_{n=1}^{n=\infty} E_n \cos\left(n\omega t + \phi_n\right)$$

$$E_n = \frac{4D}{n\pi}\sin\frac{n\pi}{b} \quad \text{where} \quad \phi_n = 0$$

and b is the ratio of the full period to the shorter duration. It can be seen that the amplitude of any harmonic whose number is an integral multiple of b will be zero, and that the successive groups of harmonics, lying between those whose amplitude is zero, are of opposite polarity (reversed in phase). These points are illustrated by Figs. 21, 22 and 23. The wave shown in Fig. 24 is square, having $b = 2$ and is identical with the wave shown in Fig. 21. In this special case, the phase of all the components can be made to coincide by choosing the origin at the beginning of the rise rather than at the center of the positive portion of the wave and by plotting sine components rather than cosines. In general, it will be found that most wave analyses can be considerably simplified by proper choice of origin.

Output waves which are symmetrical with respect to time but whose positive and negative half cycles are unsymmetrical indicate the presence of non-linear distortion in the circuit. This effect is not usually noticeable unless oscillations are present in the wave shape. Where the amplitude of the wave trains at top and bottom are unequal, some non-linear distortion is indicated. Oscillations on only one side of the wave is usually indicative of saturation or cut-off in the equipment under test.

### PRACTICAL APPLICATION

Square-wave testing has been used with considerable success in laboratory adjustments and in production tests on oscillographs and video amplifiers. In such applications the test personnel are instructed to set the compensating adjustments to secure a square-wave output. Fig. 25 is a composite oscillogram showing several output wave forms obtained during adjustment of the high-frequency compensation in an oscillograph amplifier. The final adjustment is shown by the square wave near the center of the range. For this particular test the frequency of the square wave was 10,000 cycles. Considerable accuracy is afforded by the use of the square-wave test since slight variations of the frequency characteristic make large changes in the ouput wave shape. This effect is particularly useful in adjusting the low-frequency compensation. Fig. 26 shows the output wave form obtained by applying 30-cycle square wave to an amplifier whose frequency characteristic was two percent low at 30 cycles. Proper adjustment of its low-frequency compensation resulted in the wave shown in Fig. 27.


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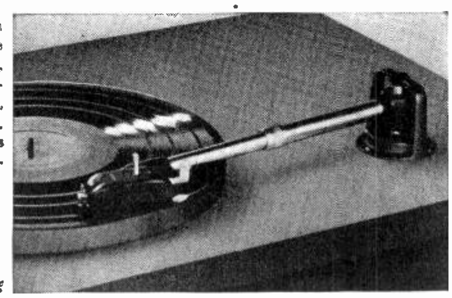

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# OVER THE TAPE . . .

## NEWS OF THE COMMUNICATIONS FIELD

### RCA PROMOTIONS

George K. Throckmorton, President of the RCA Manufacturing Company, announced that the Board of Directors has elected Frank B. Walker, Vice-President in charge of all record activities, and Thomas F. Joyce, Vice-President and Advertising Director.

At the same time, Mr. Throckmorton also announced the following major promotions and new assignments. Jay D. Cook has been made Manager of the International Division, in which all of the Company's activities in the export field, including its subsidiary companies in Canada, Argentina, Brazil, Chile, China, London and Australia have been consolidated.

David J. Finn, formerly Assistant Advertising Manager, has been elevated to the post of Advertising and Sales Promotion Manager. Edward W. Butler has been appointed Manager of the Radio & Victrola Division, in which his former duties in connection with small radios will be consolidated.

Paul C. Richardson, formerly Manager of the Radio & Victrola Division, will head a new Educational Sales Division. It will be the function of this division to coordinate and expand the sale of the Company's products to schools and other educational institutions, and to assist district and wholesale distributor organizations in planning their activities to cover this market.

The duties of Ellsworth C. Dent, as Educational Director, will remain unchanged. He will continue to determine and coordinate the development of the products needed for the school market, and to direct national sales promotional activities among educational institutions. In addition, he will be responsible for maintaining and extending contacts with educational organizations of all types; for coordinating the educational activities of the Company with those of associated RCA Companies; and will act as consultant on all activities directed at the school field.

### UTC EXPANDS

The United Transformer Corporation has expanded its facilities and has moved to a new and larger plant. The main offices, engineering division and manufacturing are at 150 Varick Street, New York, N. Y.

### GUTHMAN BULLETIN

An interesting bulletin has just been made available by Edwin I. Guthman & Co., Inc., 402 South Peoria St., Chicago, Illinois. It describes and gives technical specifications of a frequency meter-monitor, i-f transformers, antenna, r-f and oscillator coils, trimmer and padder condensers, etc.

### UNIVERSAL MICROPHONE BULLETIN

Universal Microphone Co. Ltd., of Inglewood, has issued a 1939 edition of its "Treatise on Practical Wax Recording", by E. K. Barnes. The new edition contains the identical illustrations and text of the earlier printing but it is printed in smaller type and in handy pocket size with the price reduced from 50c to 25c.

### UTAH DROPS PLANT PLAN

Continued increases in the volume of business prompted officials of the Utah Radio Products Company to enter negotiations for the purchase of a new plant several months ago. However, as agreement could not be reached as to the purchase price of the plant considered, the negotiations have been terminated. The company's directors believe that the improvements being planned for the plant now occupied will provide adequate facilities to meet the demands of increased volume.

### ELECTRO PRODUCTS BULLETIN

Electro Products Laboratories, 549 W. Randolph Street, Chicago, Illinois, have issued a catalog sheet, No. 1138, dealing with their 2 and 6-volt battery eliminators. To secure a copy of this bulletin, write to the above organization.

### WINCHARGER BULLETIN

The latest bulletin made available by Wincharger deals with their steel antenna towers. These towers are for use by commercial, broadcast, police and airport stations. To secure a copy of the bulletin, write to Wincharger Corporation, Sioux City, Iowa.

### INSULINE CATALOG

The 1938-9 catalog of the Insuline Corporation of America, 25 Park Place, N. Y., is now available. It contains 40 pages and describes the ICA line of receiving and transmitting parts and accessories.

### INDUCTIVE TUNING

*(Continued from page 51)*

sented by $L_e$ in the figure and connects directly in series with the fixed tuning capacitor. A sliding contactor is represented by the arrow and this in turn, maintains ground potential at the point indicated on the coil periphery. The use of the end inductance provides superior performance to an equivalent mechanically stopped off variable inductor. With the end inductance an increase in Q of the circuit is available with increase in frequency. Without this end inductance, the curve of Q versus frequency drops off at the high-frequency end. The improved performance with the end inductance will be noted by comparing curves 1 and 2 in Fig. 6.

The maximum frequency limit for any inductively-tuned circuit is determined by the natural period of the unused part of the variable coil. Absorption will take place if the circuit is tuned past this natural frequency, this being due to the mutual coupling between the used and unused parts of the variable coil; the natural frequency, of course, decreasing as the contactor approaches the high-frequency end of the tuning range. It is therefore considered essential to ground the unused end of the coil as this in turn, raises quite considerably the natural frequency of the unused portion. This is automatically taken care of by the ground contactor at the low-potential end of the coil.

There are two factors that account for the increased frequency coverage of the inductive tuner over that of the variable condenser

(1) The LC product of the inductively-tuned circuit may be reduced to a much smaller magnitude than in the case of the variable-condenser circuit, where the LC product minimum is limited by the minimum capacity of the variable condenser plus the capacity of the external circuit. This is especially true in high-frequency circuits where the minimum capacity of the variable condenser and leads is a large percentage of the total.

(2) By increasing the number of turns in the variable-inductance coil, the low-frequency end of the tuned circuit may be extended so long as the natural frequency of the unused part of the coil is above the operating range. Actual production devices have been manufactured with tuning ratios of 7 or 8-to-1 in the ultra-high-frequency bands. The continuously variable inductance unit shown in Fig. 4 actually consists of a coil and fixed capacitor covering a frequency spread from 22.5 to 150 megacycles in a single range with no band switching. This involves 16 complete dial rotations in a continuous band. There are already 2 or 3 applications of this system in actual equipments, which will appear shortly on the market. These will be discussed along with the application problems of the CVI devices in a second article to be published in the near future.

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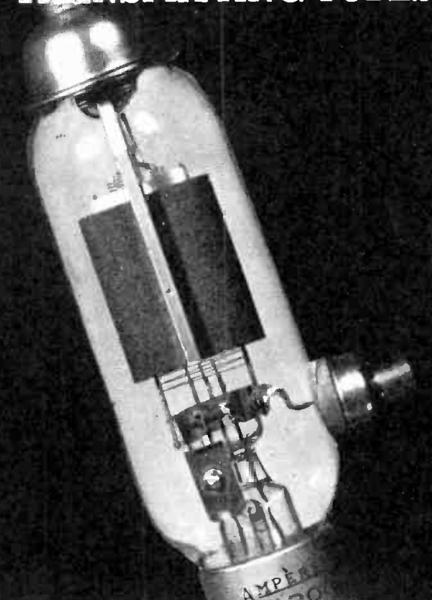

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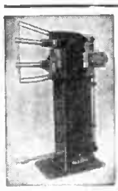

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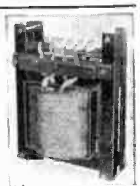

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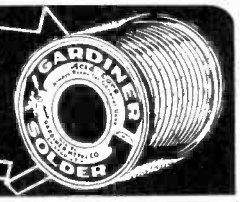


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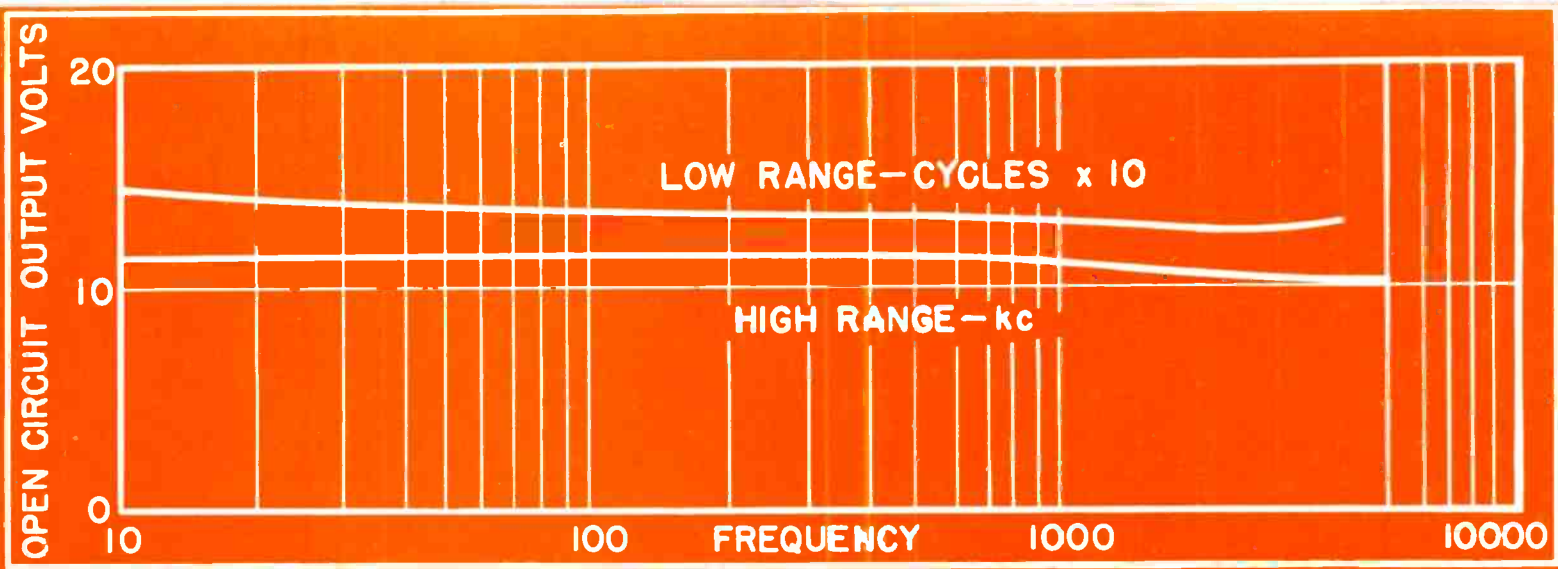


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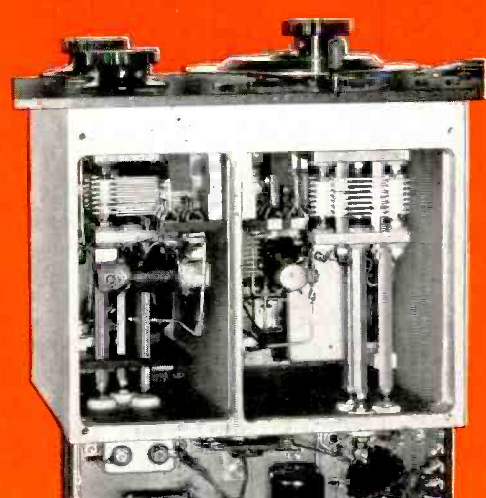

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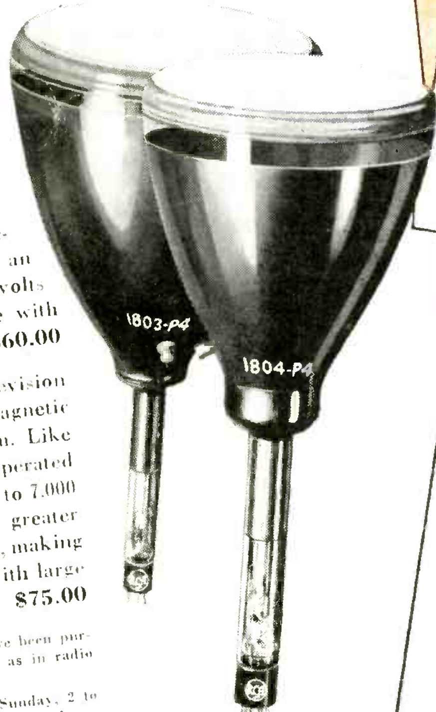


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