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"To promote the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering."

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THE INSTITUTION'S LIBRARY

Every engineer should be concerned with means of keeping himself *au fait* with literature published on his particular range of subjects.

Rapid advances in new developments, techniques and production methods used in radio and electronic engineering provide an increasing store of new information. It is, therefore, almost impossible for the individual to acquire and build up his own personal library and abstracting service.

One of the functions of such an Institution as our own is to provide that service and thus enable members to keep in touch with current developments. The Institution's Library has now reached a stage when it can be of great value to members seeking information on all aspects of their work.

Although the number of books available on loan is not as great as the Library Committee would wish, the range covered is comprehensive; in addition, over one hundred periodicals are received regularly and the Library is able to meet the majority of requests for assistance in obtaining technical papers. Through its membership of the Association of Special Libraries and Information Bureaux, which arranges inter-library loans, the Institution's Library is able to obtain any book or reference work which is not included in its catalogue.

Where it is not possible to obtain a certain paper on loan, or where a member wishes to have a copy for personal reference, the Library is able to provide photo-copies through the Science Museum and Patents Office Libraries, under the terms of the Royal Society Declaration on Fair Copying of Scientific Information. This service is of particular assistance to members overseas, whose access to local libraries may be limited and to whom the facilities of the Institution's lending Library cannot extend.

In addition to the textbooks and periodicals available in the Library, much useful technical information is to be found in reports, specifications, and manufacturers' announcements and catalogues. A selection of this type of material is filed in the Reference Library, and of particular importance are the British Standard Specifications on aspects of radio engineering.

During the past few years lists of papers and other publications on specific subjects have been compiled at the request of members, copies of which are filed and brought up to date at short notice. In this connection, mention should be made of the value of classified abstracts, such as the Institution's publication "Abstracts of *J.Brit.I.R.E.* Papers," the Radio Research Organization's "Abstracts and References," and "Science Abstracts." These are invaluable to the engineer whose time is limited to reading only a small proportion of the publications in the fields in which he is interested.

A further service for members is the inclusion in the Institution's *Journal* of selected abstracts of papers published in Commonwealth and European publications. These publications contain many useful papers which, because of their limited circulation in this country, might otherwise escape notice.

In its endeavours to build up the Library, the Institution has been severely hampered by lack of space; in particular, reading rooms and storage facilities are restricted. This aspect of the Institution's work will be one of the Council's main considerations in planning new housing arrangements; by supporting the Building Appeal, therefore, members will be helping to fulfil the object for which the Institution was founded—"the advancement of radio, electronics and kindred subjects by the exchange of information in these branches of engineering."

NOTICES

Obituary

The Council of the Institution has learnt with great regret of the recent death at the age of 47 of Norman Charles Robertson, C.M.G., M.B.E.

Mr. Robertson began his career in 1924 as an apprentice with the Sterling Telephone and Electric Company Ltd., and subsequently served on the engineering staff of Marconi's Wireless Telegraph Company Ltd., and as Chief of Test with Kolster Brandes Ltd. In 1930 he joined E. K. Cole Ltd. in the same capacity, and remained associated with this company until his death, holding successive posts as production manager, works manager, and deputy managing director. He was also a member of the Board of Ekco Electronics Ltd.

In 1944 Mr. Robertson was appointed a Member of the Most Excellent Order of the British Empire in recognition of his services during the war, and in 1954 he was awarded the C.M.G. for his services as Director-General of Electronic Production from 1951 to 1953. During this period, he was loaned by his Company to the Ministry of Supply, where he was responsible for co-ordinating the production of electronic equipment for the defence programme.

Elected to Membership of the Institution in 1952, Mr. Robertson served on the Committee of the Industrial Electronics Convention held by the Institution at Oxford in 1954, and was Chairman of the session on Nucleonic Instrumentation and Applications.

Professor G. W. O. Howe

The General Council has announced that Emeritus Professor George William O. Howe, D.Sc., LL.D., M.I.E.E., is to be elected an Honorary Member of the Institution in recognition of his work in the advancement and teaching of radio science.

Professor Howe, who was born in 1875, graduated from King's College, Newcastle-on-Tyne, and received his early industrial training with Siemens Bros., Woolwich, and Siemens-Schuckert, Berlin. Between 1903 and 1909 he held appointments as lecturer at Hull Technical College and Imperial College, London, subsequently becoming Assistant Professor of Electrical Engineering at Imperial College. After a short period in charge of the Electrical Measurements and Standards Section at the National Physical Laboratory, Professor Howe was in 1921 appointed James Watt Professor of Electrical Engineering at Glasgow University, a position which he held for twenty-five years; on his retirement in 1946, he was granted an Emeritus Professorship.

Professor Howe is well-known for his close association with the technical press; from 1920-2, he was Editor of *Radio Review*, and in 1926 he was appointed Technical Editor of *The Wireless Engineer*, a position which he held for nearly thirty years. He is the author of many papers on radio and electrical engineering subjects, and in 1924 gave the first Faraday Lecture of the Institution of Electrical Engineers. Members of the Brit.I.R.E. will recall that Professor Howe delivered the Inaugural Clerk Maxwell Memorial Lecture during the 1951 Convention held at Cambridge.

In February of this year the Faraday Medal was awarded to Professor Howe for "his pioneering work in the study and analysis of high-frequency oscillations. . . ." Other distinctions which he has gained include Honorary Doctorates of Science of Durham and Adelaide Universities, Honorary Doctorate of Laws of Glasgow University, and Fellowship of the American Institute of Radio Engineers. He is also a Director of the Mullard Radio Valve Company Limited.

Proposed New Section

A preliminary meeting is to be held on May 11th at the North Gloucestershire Technical College, Cheltenham, to discuss the formation of a new Section of the Institution based on Cheltenham and Malvern. It is proposed that, if the support given to this meeting is sufficient, a Section will be established which will hold a full programme of meetings in the 1956-7 session. Full details of the arrangements are being sent to members resident in the area, and further information may be obtained from Mr. J. D. Storer, A.M.Brit.I.R.E., 74 Bournside Road, Cheltenham.

Library Note

The Institution's Library requires a copy of *Electronic Engineering* for November 1955 to complete its set for binding. This issue is now out of print, and the Librarian would be grateful for any offers of copies in good condition.

PRESCRIBED-FUNCTION VIBRATION GENERATOR*

by

Professor Pierre M. Honnell, Ph.D.†

SUMMARY

An electromechanical system which produces vertical vibrations in the image of prescribed functional wave-forms is described and the mathematical theory of its operation derived. The advantage and usefulness of this device for theoretical researches and for routine testing, as compared to the common vibration generator producing sinusoidal motions, is indicated by actual examples of the response of vibration pick-ups to complex motions of prescribed waveform.

1. Introduction

The generation of vibrations for the testing of engineering structures and vibration measuring instruments undoubtedly had its origins in the science of seismology. Indeed, the production of sinusoidal motions for the testing of seismographs was well established at the turn of the century. It was then recognised that not only sinusoidal motions, but also more complicated motions such as those simulating an actual earthquake, would be highly advantageous for testing seismographs. To produce motions of prescribed functional waveform by purely mechanical means is difficult and at best not too satisfactory for many reasons. Nevertheless, attempts in this direction have often been undertaken, including very ingenious mechanical devices for the synthesis of a number of independent sinusoidal functions to produce one given recurrent wave. But such devices are stringently limited in frequency range, in purity of waveform, and furthermore generate intolerable noise levels.

Electronic technology has, however, completely revolutionized the whole picture. As is well known, electrical methods and in particular electronic methods, dominate most measuring techniques. It is not surprising, therefore, that the generation and measurement of prescribed mechanical motions should now depend almost entirely upon electronic methods.

The purpose of this paper is to describe a development in this direction: namely, an electromechanical transducer which generates not only sinusoidal displacements, but also displacements of prescribed functional form. In particular, square waves, triangular waves, and other recurrent waveforms of this character are closely approximated. Non-repetitive waveform vibrations can also be generated, such as a single pulse, or a displacement represented by $(\sin \omega t)/\omega t$, for example.

Naturally, this accomplishment depends in great measure upon the latest in technology in electronic amplifiers, and the techniques of feedback. The apparatus described herein, although constructed principally to test the theory of operation of the system, has actually proved to be extremely useful for the testing of many types of seismograph detectors, accelerometers and other vibration measuring instruments.

Accelerometers, vibration detectors, and similar devices, can be analysed in terms of their sinusoidal, steady-state response. However, this does not yield directly the response of these instruments to transient or arbitrary motions. Of course, computed responses of idealized devices to idealized transient inputs do serve as a theoretical guide to performance, but these require considerable calculation time and effort. Furthermore, the validity of such computations depends upon the extent of the simplifications and idealizations upon which they are based. It is clear, therefore, that there is finally no substitute for a laboratory determination of the actual response of physical accelerometers and vibrometers to specified transient motions. The prescribed-function vibration generator provides the means for determining the transient responses of vibration-measuring apparatus by *direct physical test.*

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* Manuscript received 22nd December 1955 (Paper No. 349).

† Department of Electrical Engineering, Washington University, Saint Louis 5, Missouri, U.S.A.

U.D.C. No. 621.373÷620.179.1.

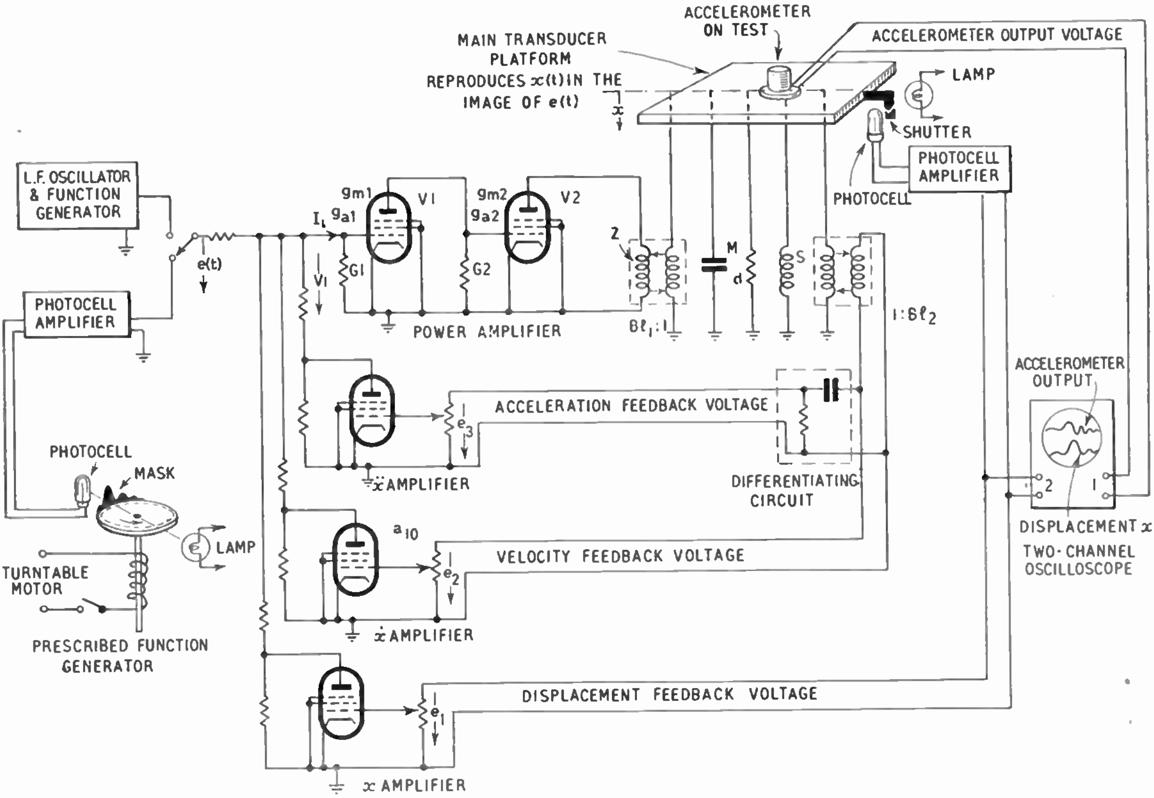

Fig. 1.—Simplified schematic of Prescribed-Function Vibration Generator System.

This is of great value in research and development of vibration-measuring apparatus.

Another field of application of the prescribed function vibration generator is in the testing of certain devices such as electronic tubes for their responses to vibrations. Clearly the sinusoidal testing for microphonics is useful, as are impact tests. However, a sharp wave front function (such as a square wave) recurring at a uniform rate is more advantageous as it provides for more satisfactory visual inspection on a cathode-ray oscilloscope. This corresponds to the square-wave testing of electrical circuits, a well-known technique in radio engineering circles.

Finally, the availability of motions of prescribed functional wave form will undoubtedly be useful in many fields of research. These may lie in the direction of optical phenomena, in chemical reactions, or in other physical researches on the basic properties of matter.

2. Description of the Prescribed-Function Vibration Generator

As mentioned at the outset, the vibration generator and associated apparatus as actually constructed do not represent optimum designs, for the system was built principally as a university laboratory device for test of the analysis. Nevertheless, experience gained from this model serves as a point of departure for improved physical designs.

As may be seen from the (simplified) schematic in Fig. 1, the prescribed-function vibration generator comprises several distinct parts, electronic and electromechanical, which in combination form an integrated system. In

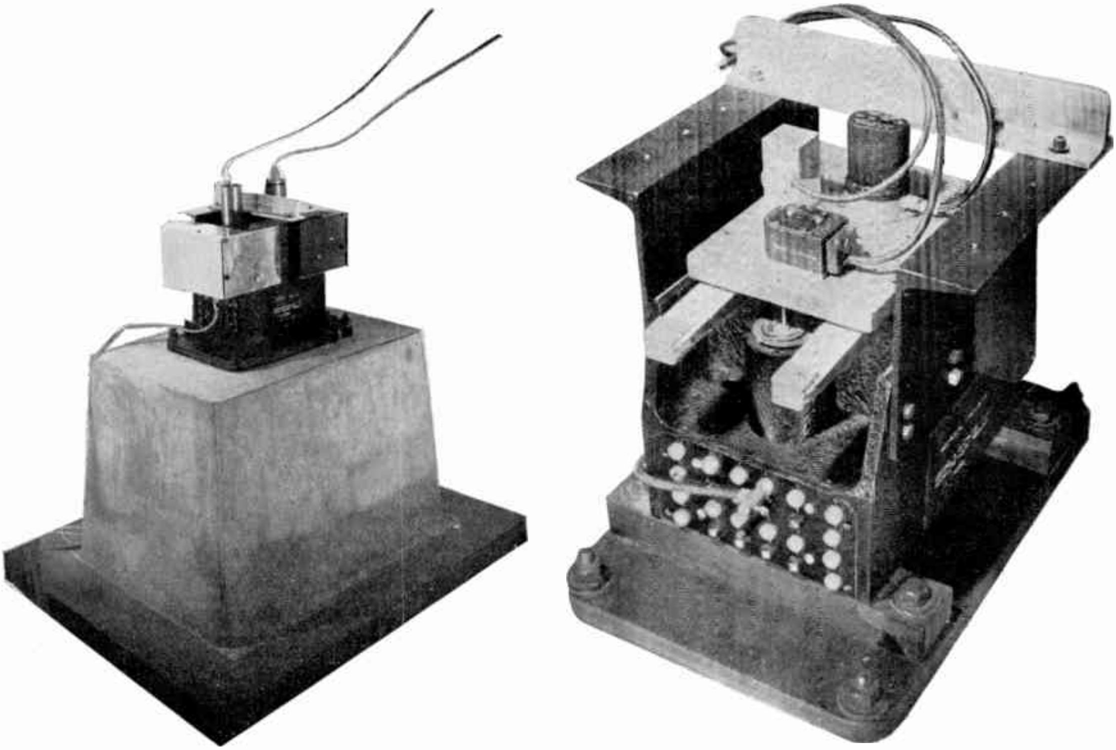

Fig. 2.—The electromechanical transducer mounted on pier and with covers removed.

other contexts, this would be described as a "servo" or "control" system.

2.1. *Electromechanical Transducer*

The principal electromechanical transducer (Fig. 2) executes the desired vertical motions. Its short and stubby design was evolved after some experience with a shaking table incorporating long supporting members which were found to resonate to such an extent that the platform motion was a highly erratic function of frequency, a wholly undesirable situation. As indicated by the phantom view in Fig. 3, the 15·5 by 21·5 cm moving platform of the transducer is supported on double cantilever springs which constrain it to substantially vertical motions, with maximum displacements of ±1·5 mm. The platform is coupled mechanically by a drive shaft to two 4,000-turn force coils. These force coils—energized by an electronic power amplifier—are immersed in magnetic fields of about 0·2 webers per square metre flux density. The air-gap magnetic fields are produced by stationary field coils each requiring 100 watts direct current power.

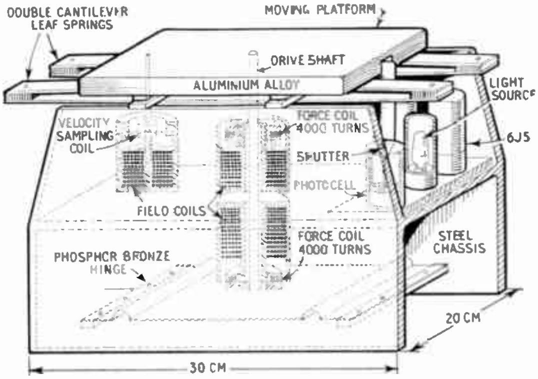

Fig. 3.—Phantom view of the electromechanical transducer.

Not only must the mechanical structure of the transducer be short and rigid as previously mentioned, but the chassis of the device must be rigidly fastened to a firm support of considerable mass. Otherwise, spurious modes of vibration are coupled into the moving system. This cannot be tolerated for motions requiring a plurality of discrete frequency components simultaneously, such as are present in recurrent waves, or continuous bands of frequencies as in transient functions.

Since bed-rock was not accessible as a support, a practicable substitute was found in a floating concrete pier, Fig. 4, to which the transducer chassis is firmly bolted. The mass of the concrete pier is estimated to be 0·5 metric ton and the sand base upon which it rests at 0·15 metric ton. The void within the concrete block is undesirable but was required to keep the floor loading within safe limits. The principal resonance of the mounting lies below 0·5 c/s, apparently a result of the elasticity of the floor beams. The arrangement has been found to be satisfactory for the stringent requirements of arbitrary-function transient studies, and has made feasible the operation of the transducer system in a third-floor laboratory.

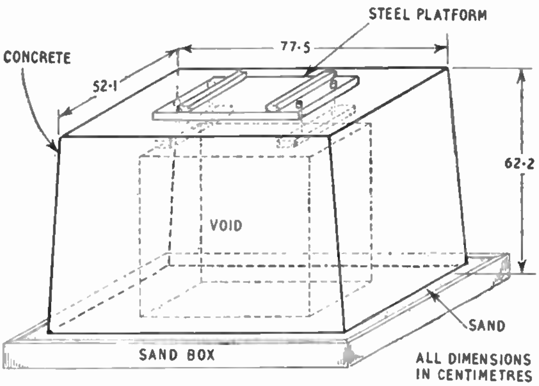

Fig. 4.—Details of floating concrete pier.

2.2. *Electronic Circuits*

The electronic components of the transducer system indicated in the simplified schematic in Fig. 1, actually include a push-pull, direct-coupled three-stage amplifier chain, together with three independent feedback links. The amplifier utilizes a pair of R.C.A. 6146 beam power valves in its output stage, class A operated at 400 volts supply with some 75 mA anode current through each valve. These valves energize the force coils of the transducer with varying currents in the image of the desired waveforms, thereby actuating the main transducer platform. Higher-powered valves would be helpful, especially to override ambient mechanical noise.

Of the three feedback circuits, one derives a voltage e_1 proportional to the displacement x of the platform, and is obtained by a photo-electric cell and light-shutter arrangement as shown in the illustrations. The second feedback circuit derives a voltage e_2 proportional to the platform velocity, or dx/dt; this voltage is obtained from a velocity sampling coil rigidly fastened to the moving platform and immersed in a stationary, constant, magnetic field in a separate field-coil arrangement. The third feedback voltage component e_3 is obtained from an RC-network differentiation of the velocity sampling voltage e_2. These three feedback voltages enable the overall performance of the system to be modified electronically such as to respond in the desired manner to arbitrary-wave signals, as is indicated in Section 3.

2.3. *Function Generators*

Two sources of electric signal functions are utilized. One is a low frequency function generator which furnishes sinusoidal, triangular and square waves. The second is a generator of arbitrarily prescribed waveforms of the photo-electric type. It employs masks cut to the desired wave-form which intercept a light beam focused on a photocell, thereby producing electromotive forces of the desired functional form. The resultant functional voltage waves are applied to the power amplifier input.

2.4. *Measuring Instruments*

Recording and observation of the actual motions of the moving platform of the vibration generator requires the usual array of oscillographs. Calibration is a special study in itself, and naturally requires valve voltmeters. Although not considered herein, the fundamental problem is clearly the conversion of minute displacements in fractions of millimetres to known and measurable voltages not only statically but also dynamically.

3. Analysis of the Vibration Generator System

A straightforward analysis of the actual ibration generator system shown in Fig. 1—ven though this is a stringently idealized ersion of the actual physical system—ecessitates the definition of a large number of lectromechanical parameters and variables. This has been done, and details of the derivation re given in the Appendix. A useful expression or present purposes relates the transducer teady-state system output displacement X to the lectrical signal input E. This relation reads:

$$X = \frac{k_0 E}{K_0 + K_1 p + K_2 p^2 + K_3 p^3} \quad \dots\dots\dots\dots\dots\dots (1)$$

n which

X is the rectilinear, alternating root-mean-square vertical platform displacement; that is, the motional output of the system.

E is the root-mean-square voltage signal applied to the transducer system input.

p is the angular frequency, here taken as $p = j\omega = j\,2\pi f$, where f is in cycles per second.

k_0, K_0, K_1, K_2, K_3 are involved expressions in terms of the system parameters: that is, the masses of the moving platform assembly and the accelerometer load; the spring stiffnesses; the resistances and inductances of the coils; the valve anode admittances and mutual conductances; etc.

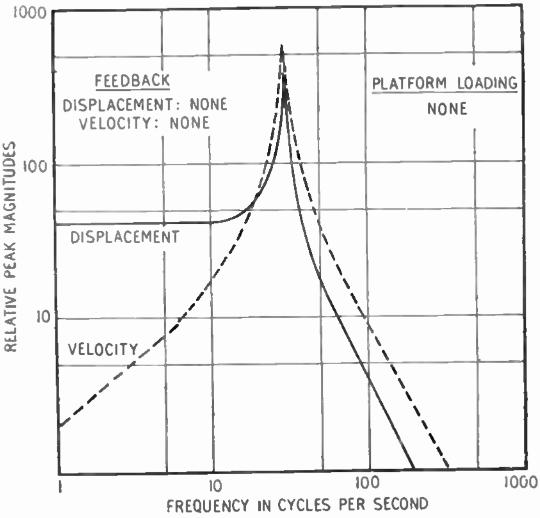

Fig. 5.—Vibration generator system response without feedback.

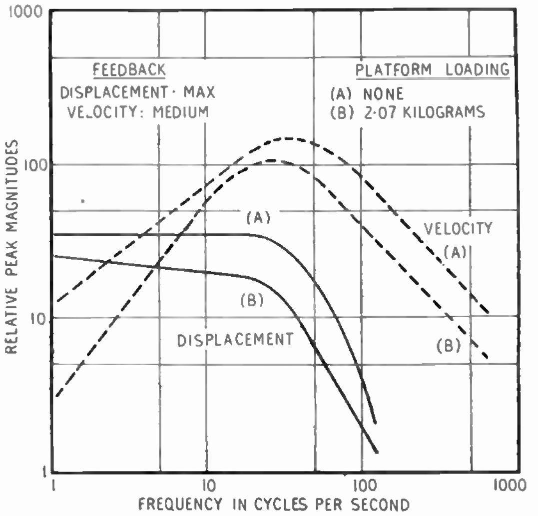

Fig. 6.—Vibration generator system response with displacement and velocity feedback, displacement mode.

The performance of the vibration generator system clearly depends upon the magnitudes of the coefficients in equation (1). Now in purely passive networks, a system function such as equation (1) can be altered only by changing the actual physical parameter magnitudes: that is, by purposely changing the resistances, inductances, stiffnesses, masses, flux densities, and the like, in the system. The response of such a system can therefore be altered only with some difficulty, often only in discrete steps.

3.1. *Influence of Feedback*

The use of electronic feedback avoids the limitations usually encountered in electromechanical systems. This is clear from equation (10) of the Appendix, which indicates that the coefficients K_0, K_1 and K_2 of equation (1) may be altered in magnitude and sign by merely changing the gains of the three feedback circuits e_1, e_2 and e_3 shown in Fig. 1.

Consider, for example, the response of the vibration generator to sinusoidal input E *without feedback*. This is shown in Fig. 5 which indicates the relative peak magnitudes of the sinusoidal platform displacement X—and the corresponding velocity $\dot{X}$—for a constant amplitude sinusoidal signal voltage E of frequency varying from 1 to 300 c/s. These response curves clearly show the pronounced peaks at about 28 c/s due to resonance of the mechanical parameters, and are representative of the usual electromechanical system behaviour.

In contrast, the performance of the transducer system with both displacement and velocity feedback of the proper magnitude and polarity is indicated in Fig. 6. *With feedback*, the displacement response X of the transducer system becomes substantially independent of frequency. This is indicated by the solid line (A) in Fig. 6 which is "flat" from zero to 25 c/s. Loading of the platform with about 2 kg—see curve (B)—does not substantially change the response, but does require some resetting of the feedback controls.

The feedback adjustments indicated lead to platform displacements in the image of the applied electric signal input voltage, and may be described as the "displacement mode" of operation of the vibration generator. In effect, this means that feedback has made K_0 the dominant term in the denominator of equation (1). Consequently, an approximate description of the system is given by

$$X \simeq \frac{k_0 E}{K_0} \qquad \text{..................(2)}$$

i.e., the platform of the generator moves in accordance with the electrical signal input. The approximation denoted by equation (2) is valid only for sufficiently slow motions, as is clear from the low-pass characteristic indicated in Fig. 6, since the response does drop off for frequencies above 25 c/s.

Experience indicates that eradication of the principal resonance peak at 28 c/s cannot satisfactorily be achieved except by means of feedback techniques. Introduction of damping by a shorted copper turn in a strong magnetic field has been found inadequate for the purpose.

3.2. *Performance*

The performance of the vibration generator is indicated by oscillograms of the actual motions which it can execute; for example, the response to triangular and square-wave as well as sinusoidal electric signals from the function generator. Fig. 7 displays three sets of oscillograms of the vibration generator output motions; in each set, the lower oscillogram represents the actual platform displacement, and the upper oscillogram the corresponding velocity.

The upper pair of oscillograms in Fig. 7 shows the sinusoidal displacement and velocity of the platform at a 10-c/s repetition rate. The centre pair shows the platform displacement and velocity for triangular-wave electric voltage signals. Finally, the lower pair of oscillograms in Fig. 7 displays the displacement and velocity of the platform for square-wave electric signals. These oscillograms indicate the nature of the available responses from the vibration generator more vividly than do the preceding steady-state response curves.

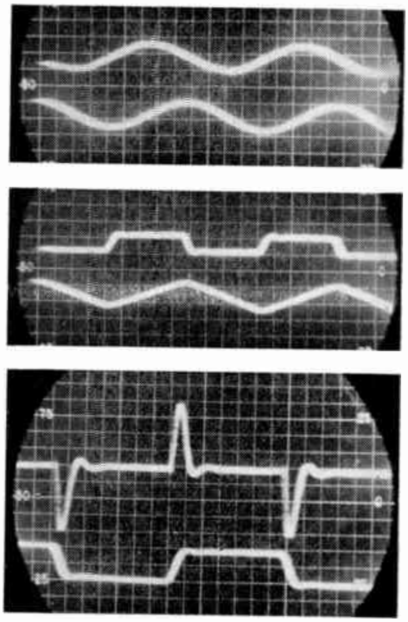

Fig. 7.—Oscillograms of output displacement and velocity of vibration generator at 10 c/s repetition rate.

Upper pair: sinusoidal signals.
Centre pair: triangular-wave signals.
Lower pair: square-wave signals.

Perhaps even more interesting are the results obtained with the prescribed function photoelectric generator. Fig. 8 exhibits vibration generator displacement (lower) and velocity (upper) oscillograms for the function $(\sin \omega t)/\omega t$. The electric control signal input for the vibration generator was obtained from the photoelectric generator using a mask cut to the function $(\sin \omega t)/\omega t$.

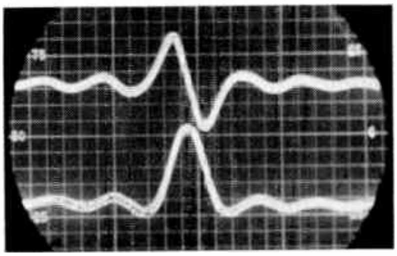

Fig. 8.—Oscillograms of output displacement and velocity of vibration generator system for (sinωt)/ ωt *electrical control signal.*

Upper oscillogram: platform velocity.

Lower oscillogram: platform displacement.

3.3. *Higher Modes*

By proper choice of the feedback path voltage gains and polarities, the K_1 coefficient may be made the dominant term in the denominator of equation (1). In that event, the following approximation expression may represent equation (1):

$$\dot{X} \simeq \frac{k_0}{K_1} E \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

where $\dot{X} = \mathrm{d}X/\mathrm{d}t$.

Under these conditions, the sinusoidal platform velocity response $\dot{X}$ is substantially uniform over the frequency range of 8 to 200 c/s, as indicated by the dashed curve in Fig. 9. This means that the transducer system velocity response is in the image of the applied electric signal voltage, as postulated by equation (3) for all motions with frequency components within the specified interval. These feedback adjustments lead to what may therefore be called the "velocity mode" of operation of the system. As is clear from Fig. 9, which is actually of finite "band-pass" type and not of infinite band-width as implied by equation (3), the velocity-mode of operation is obtained only for those functions whose principal frequency components lie within the given pass-band, such as periodic waveforms.

In theory—although this has not so far been exploited—higher modes of response could similarly be obtained by proper utilization of additional feedback channels from the transducer output motions to the input of the power amplifier. In this connection, it may be said that the acceleration feedback voltage e_3—although it definitely is effective—is not determinative in the present experimental design.

4. Application

The results of qualitative tests on a geophone may serve to indicate the potentialities of the Prescribed-Function Vibration Generator. The instrument mentioned is a type EVS Seismic Detector* of particularly rugged construction adapted to seismic exploration in the field. The detector weighs approximately one pound with case. It consists essentially of a coil wound on an aluminium former which is suspended by a spring arrangement allowing linear displacements. The springs also centre the coil in an annular air gap in which a high magnetic flux density is created by a permanent magnet. The free linear vibration frequency of the moving coil and spring combination is 30 c/s. The coil resistance is 200 Ω, and the electrical output is of course proportional to the relative velocity of the suspended coil and the case of the seismic detector.

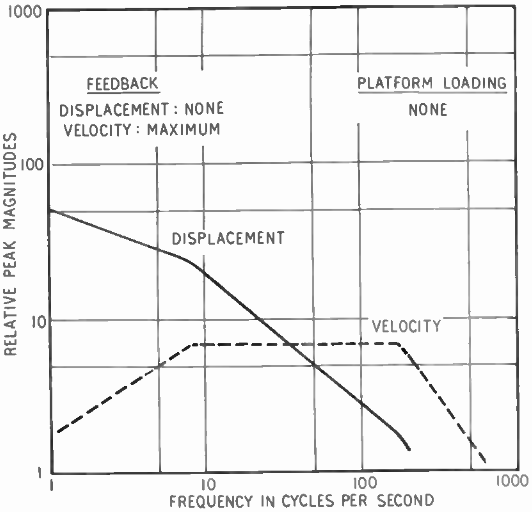

Fig. 9.—Vibration generator system response in velocity mode.

Typical normalized sinusoidal steady-state output voltage characteristics of the seismic detector for constant sinusoidal input vibration velocity are plotted in Fig. 10. The two curves indicate the relative effects of 500Ω and 125Ω

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* Electro-Technical Laboratories, Inc., Houston, Texas, U.S.A.

damping resistors shunting the detector output coil. These data were obtained by constant-amplitude sinusoidal voltages of varying frequency as the input signal to the Vibration Generator. Operating in the velocity mode, this results in a constant magnitude platform or output velocity for testing the seismic detector. Beyond the extreme limits of the flat pass-band of the vibration generator in this mode—that is, below 8 c/s and above 200 c/s, see Fig. 9—some adjustment of the amplitudes of control signal is necessarily required to maintain a constant velocity. The constancy of velocity of motion in this mode, within the pass-band, is a valuable property of the Vibration Generator in steady-state testing, as it minimizes continuous readjustment of the signal source amplitude otherwise required as the testing frequency is changed.

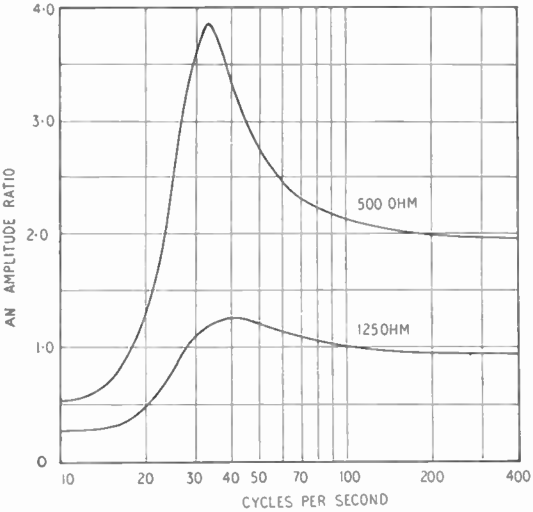

Fig. 10.—*Steady-state sinusoidal response of exploration seismic detector. Output voltage for constant velocity input vibrations, with* 125 *and* 500 Ω *damping resistor.*

4.1. *Square Wave Tests*

An example of non-sinusoidal testing is the response of the EVS seismic detector to square waves. This is indicated by the oscillograms in Fig. 11. In each pair of oscillograms, the lower curves represent the square-wave of displacement applied to the case of the seismic detector at a repetition rate of 5 c/s, while the upper curves show the detector output. The increased damping effect of the 125-Ω shunting resistor, compared to the 500-Ω resistor, is evident by comparison of the lower pair with the upper pair of oscillograms. This is a well-known phenomenon, here quickly and easily demonstrated by actual physical experiment.

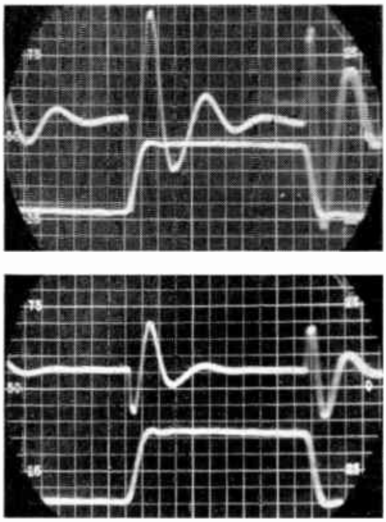

Fig. 11.—*Response of seismic detector to* 5 *c/s repetition rate square-waves of displacement.*
Upper pair: 500 Ω *damping resistor.*
Lower pair: 125 Ω *damping resistor.*

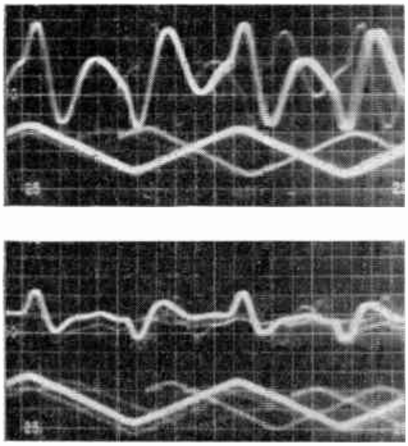

Fig. 12.—*Response of seismic detector to* 10-*c/s repetition rate triangular waves of displacement.*
Upper pair: 500 Ω *damping resistor.*
Lower pair: 125 Ω *damping resistor.*

4.2. *Triangular Wave Tests*

Not so well known, perhaps, are the results obtained with triangular waves of displacement applied to such an instrument. The response of the EVS seismic detector to triangular waves of 10 c/s repetition rate are shown in Fig. 12, partially obscured by the long-persistence afterglow of previous oscillations on the cathode-ray oscillograph screen. The beneficial effect of the increased damping upon the character of the seismic detector response, afforded by the 125-Ω shunting resistor as compared to the 500-Ω resistor, is clearly sustained. That is, the onsets of the changes in the direction of motion of the detector case are more clearly indicated by the record for the condition of higher damping.

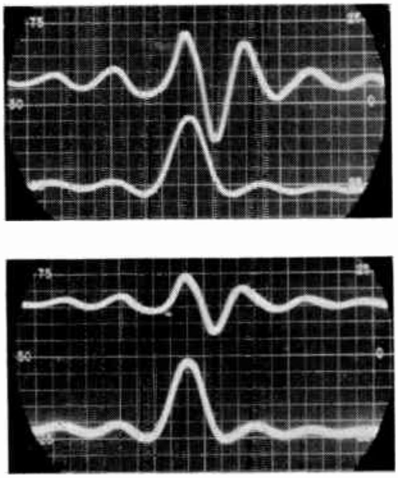

Fig. 13.—*Response of seismic detector to displacement function* (sin ωt)/ ωt.
Upper pair: 500 Ω *damping resistor.*
Lower pair: 125 Ω *damping resistor.*

4.3. (Sin ωt)/ ωt *Tests*

The response of the EVS detector to displacements prescribed by the function (sin ωt)/ ωt are exhibited in Fig. 13. The motion of the vibration generator platform is represented by the lower curves in each pair of oscillograms. This motion is the same displacement-time function illustrated in Fig. 8; in both cases, the time interval $2\pi / \omega = 2T$ of the function is of the order of 50 milliseconds. Once again, the condition of highest damping, the lower oscillogram pair, yields the more intelligible signal output from the detector.

5. Conclusions

The foregoing brief outline of results which are so easily obtainable with the vibration generator surely indicates the increased scope and utility of physical tests and experiments which may be performed with its aid.

Of course, the vibration generator is rather more complicated electronically than the simpler devices now commonly employed, which leads to the increased capabilities of the system. This also implies that greater care must be exercised in the design of the vibration generator to yield a stable system. Naturally, with multiple feedback paths, there easily develop tendencies of the electromechanical system to vibrate without control signals. That this natural tendency can be overcome, and the advantages of feedback techniques enjoyed, is demonstrated conclusively by the device described. In fact, demonstration of this very possibility was one of the reasons which lead to the actual construction of the Prescribed Function Vibration Generator.

6. Acknowledgment

It is a pleasure to acknowledge the important assistance of my former students, particularly Messrs. Alvin G. Bush, Jr., and Allen N. Wollscheidt. Finally, the support of Washington University, and in particular that of Dr. R. J. W. Koopman, has made possible the continued researches in this interesting and important domain of electromechanical networks.

7. Mathematical Appendix

To be tractable, the mathematical analysis of a complicated electromechanical system requires simplifications and idealizations. One extreme in this direction is a very approximate analysis in terms of so-called "block diagrams." The other extreme must naturally involve an intolerably large number of variables and include the effects of deviations from linearity.

A compromise includes the assumption of linearity and the reduction of the totality of separate parameters and variables to the minimum number consistent with clarity of representation of the phenomena. This middle course provides an understanding of the functioning of the electromechanical system and also acts as a guide in the actual design of the system.

7.1. *System Transfer Function*

The purpose of this section is to derive within the spirit of the previous paragraph the analytical relation between the electrical signal input and the resulting motion of the moving platform of the vibration generator. This is of fundamental importance not only for the solution to sinusoidal input signals, but is also required in the application of Fourier and Laplace transform methods, although these are not used here.

The point of departure for the analysis is the simplified network schematic shown in Fig. 1. The electromechanical network may be considered as a principal transmission channel from the electric function generator connected to the grid of the valve V1, through the power amplifier V2, and thence transduced to mechanical motion as the output x of the vibration generator. The net mechanical motion x is itself transduced to electrical signals and returned to the input tube V1 by three subsidiary paths: the displacement, velocity and acceleration voltages e_1, e_2, and e_3.

Since the feedback paths are coupled through unilateral valves, they may be opened temporarily and an analysis of the main transmission channel considered first. The feedback circuits are then closed and their contributions to the network operation determined so as to yield the desired transfer function.

The fixed *parameter* elements in the network, assumed as adjustable constants, are defined below and may be identified in Fig. 1.

Electromechanical Network Parameters

m	the total suspended mass of the transducer moving platform, force coils, etc.
M	the mass added to the system by the accelerometer or other device on test clamped to the moving platform
d	the total residual damping of the main transducer due to the motion of conducting metal in stray magnetic fields; air damping, and the like (of small magnitude)
s	the equivalent stiffness of the springs suspending the moving platform
Bl_1	the product of the constant air-gap flux density and the length of the force coil windings immersed therein
R	the total resistance of the force coils
L	the total inductance of the force coils
g_{m1}, g_{m2}	the transconductances of the power amplifier valves V1 and V2
g_{a1}, g_{a2}	the anode conductances of the power amplifier valves V1 and V2
G_1	the external grid-cathode coupling admittance of V1
G_2	the coupling admittance between the voltage and power amplifier valves V1 and V2
Bl_2	the product of the constant air-gap flux density and the length of the velocity sampling coil winding immersed therein
$k_0, k_1,$ k_2, k_3	coefficients relating the net input voltage to the grid of V1, and the control signal, displacement, velocity and acceleration feedback voltages

The electrical and mechanical *variables* may similarly be found in Fig. 1 and are defined below.

Electromechanical Network Variables

x	the rectilinear platform displacement, a dependent function of time
Dx	the rectilinear platform velocity, where $D = \mathrm{d}/\mathrm{d}t$
f	the externally applied mechanical force on the transducer platform (not shown in Fig. 1) and ultimately taken as zero
v_1	the electric input voltage to the amplifier tube V1
I_1	the electric current input to the grid coupling admittance G_1
$e(t)$	the signal voltage output of the electrical function generator, a prescribed function of time
e_1	the feedback voltage from the photo-electric transducer proportional to the platform displacement x
e_2	the feedback voltage from the velocity sampling transducer, proportional to the platform velocity Dx
e_3	the feedback voltage proportional to the platform acceleration D^2x

With the feedback paths opened, the relation between the electrical input variables v_1 and I_1 and the mechanical output variables Dx and f

may be expressed as the matrix product:

$$\begin{bmatrix} v_1 \\ I_1 \end{bmatrix} = [\mathrm{V1}] \cdot [\mathrm{V2}] \cdot [Z] \cdot [Bl_1] \cdot [Y] \cdot \begin{bmatrix} Dx \\ -f \end{bmatrix} \quad \ldots.(1)$$

in which the individual matrices are associated with the physical subnetworks of the transmission channel. These matrices are defined in the following manner:

Amplifier V1

$$[\mathrm{V1}] \equiv \begin{bmatrix} -g_{a1}/g_{m1} & -1/g_{m1} \\ -g_{a1}G_1/g_{m1} & -G_1/g_{m1} \end{bmatrix} \quad \ldots\ldots\ldots.(2)$$

Amplifier V2

$$[\mathrm{V2}] \equiv \begin{bmatrix} -g_{a2}/g_{m2} & -1/g_{m2} \\ -g_{a2}G_2/g_{m2} & -G_2/g_{m2} \end{bmatrix} \quad \ldots\ldots\ldots.(3)$$

Force transducer electrical parameters

$$[Z] \equiv \begin{bmatrix} 1 & R+LD \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \quad \ldots\ldots\ldots.(4)$$

Force transducer transformance

$$[Bl_1] \equiv \begin{bmatrix} Bl_1 & 0 \\ 0 & 1/Bl_1 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(5)$$

Transducer mechanical parameters including mass M of device on test

$$[Y] \equiv \begin{bmatrix} 1 & 0 \\ (m+M)D + d + (Bl_2)^2 G_{10} + s/D & 1 \end{bmatrix}$$

$$\equiv \begin{bmatrix} 1 & 0 \\ U & 1 \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots.(6)$$

Substituting equations (2) to (6) in equation (1) yields

$$\begin{bmatrix} v_1 \\ I_1 \end{bmatrix} = \frac{g_{a1} + G_2}{g_{m1}\, g_{m2}\, Bl_1} \cdot \begin{bmatrix} \left\{(Bl_1)^2 + UZ\right\} g_{a2} + U & 1 + Z\, g_{a2} \\ \left\{(Bl_1)^2 + UZ\right\} g_{a2}\, G_1 + U\, G_1 & G_1 + G_1\, Z\, g_{a2} \end{bmatrix} \times \begin{bmatrix} Dx \\ -f \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots.(7)$$

in which Z and U are defined by (4) and (6) respectively. This is the relation between the electrical input signal and the mechanical output of the principal transmission channel, exclusive of the contributions of the feedback connections.

The net voltage v_1 applied to the grid of the valve V1 *with* the feedback connections may be shown to be a linear function of four separate voltages. These are $e(t)$ derived from the electric signal function generator, and e_1, e_2, e_3 the voltages returned from the platform motion proportional to its displacement, velocity and acceleration. To simplify matters, this complicated relationship is written simply as

$$v_1 = k_0\, e(t) + k_1\, x + k_2\, Dx + k_3\, D^2 x, \quad \ldots\ldots(8)$$

a linear combination of all the voltages acting on the grid of V1. It should be noted that the coefficients k_1, k_2 and k_3 will vary in magnitude with the settings of the respective voltage dividers or feedback path gain settings; when the feedback contributions are zero, these coefficients are taken as zero. Also, they can change sign by reversing the connections of the feedback loops.

Assuming that the suspended mass of the accelerometer or other device on test is negligible in comparison with its base of mass M, and that there are no externally applied mechanical forces acting on the platform—that is, $f=0$—then equation (7) simplifies to read

$$v_1 = \frac{g_{a1} + G_2}{g_{m1}\, g_{m2}\, Bl_1} \times$$

$$\times \left[\left\{(Bl_1)^2 + U\, Z\right\} g_{a2} + U \right] Dx \; . \quad \ldots\ldots.(9)$$

Substituting into equation (9) the quantities represented by Z, U and v_1 obtained from equations (4), (6) and (8) respectively yields a differential equation which reads

$$(a_4)D^3x + (a_3\text{-}k_3)D^2x + (a_2\text{-}k_2)Dx + (a_1\text{-}k_1)x = k_0\, e(t) \quad \ldots\ldots\ldots(10)$$

where

$$a_4 = \frac{g_{a1} + G_2}{g_{m1}\, g_{m2}\, Bl_1} \left[g_{a2}\, (m+M)L \right]$$

$$a_3 = \frac{g_{a1} + G_2}{g_{m1}\, g_{m2}\, Bl_1} \Big[(m+M) + (m+M)R\, g_{a2} +$$

$$+ \left\{ (Bl_2)^2 G_{10} + d \right\} L\, g_{a2} \Big]$$

$$a_2 = \frac{g_{a1} + G_2}{g_{m1}\, g_{m2}\, Bl_1} \Big[d + (Bl_2)^2 G_{10} + (sL + dR) g_{a2} + + (Bl_2)^2 G_{10} R g_{a2} + (Bl_1)^2 g_{a2} \Big]$$

$$a_1 = \frac{g_{a1} + G_2}{g_{m1}\, g_{m2}\, Bl_1} \Big[s + sR g_{a2} \Big] \quad \ldots\ldots\ldots\ldots\ldots\ldots(11)$$

The differential equation (10) relates the electrical signal input $e(t)$ to the platform mechanical displacement x of the vibration generator. Hence, the operation of a multiple-loop feedback electromechanical network has effectively been expressed in terms of a linear differential equation.

Furthermore, the formulation of this equation is distinctly different from the common run of third-order linear differential equations arising from networks. It has coefficients which can easily be made to assume a large range of values, positive, zero, or negative. The order and character of the equation can therefore be changed at will merely by changing the gain settings and connections on the respective feedback controls; that is, the k_1, k_2 and k_3. Thus the response of the system to electrical control signals can be widely changed conveniently and easily.

For convenience, equation (10) may also be written as

$$K_3 D^3 x + K_2 D^2 x + K_1 D x + K_0 x = k_0 e(t) \quad \ldots(12)$$

with the obvious definitions of the coefficients as respectively equal to the respective terms in equation (10).

The flexibility of the network is not an unmixed blessing. For example, it is easy to obtain an unstable system. If K_1 becomes zero or negative (by proper connection of the velocity path feedback voltage) the network vibrates in a normal mode without provocation. This can become disastrous unless checked quickly, for under these conditions the platform oscillations readily become violent. On the other hand, a small amount of regenerative feedback is sometimes beneficial in steady-state testing.

The usual steady-state, or the "operational," transfer function is readily obtained from equation (12) and reads

$$X = \frac{k_0 E}{K_0 + K_1 p + K_2 p^2 + K_3 p^3} \quad \ldots\ldots\ldots\ldots\ldots\ldots(13)$$

where X and E are the steady-state magnitudes, or the "operational transforms," of the platform displacements and electric control signals respectively, and p is the angular frequency $j\omega$ or the frequency transform.

Finally, it may be noted that the coefficient K_3 in the equations above could also be made a function of a gain control knob, if an additional feedback voltage derived from the third derivative of the platform motion were also returned to the grid of V1. In the actual vibration generator as constructed this would probably not be useful, since the acceleration feedback voltage circuit itself has just noticeable effects. However, this does not mean that a system of superior physical design would not benefit from such additional feedback.

FROM ALEXANDRA PALACE TO CRYSTAL PALACE

The B.B.C's New London Television Station*

The change-over from Alexandra Palace to Crystal Palace as the B.B.C. Television Service's London Station, which took place on March 28th, may be said to span two decades of television development in Britain. Alexandra Palace closed down as a transmitting station twenty years after its opening on November 2nd, 1936. It was not until four years later that there was any other comparable television service.

Crystal Palace comes into use at a stage in the B.B.C. Television Service's history when there are thirteen television stations covering the country, and in addition three permanent television studios have been established in the regions. As the change-over is made it is worth noting that Alexandra Palace has rendered a service which represents its own tribute to the foresight and skill of British engineers. Since it was built the Alexandra Palace transmitter has never needed fundamental alteration. For comparison with the new transmitters, a photograph of the vision transmitter is shown in Fig. 1: its input to the aerial system is 17 kW, giving an e.r.p. of 34 kW.

When the original television service for the London area was being planned in 1935 one of the possible sites investigated for the transmitter was the Crystal Palace. At that time, however, little was known about the range which could be achieved with the frequencies on which the television service was to be operated or of the requirements for satisfactory reception of television signals and the Alexandra Palace site was chosen because it placed the transmitter nearer to the centre of the densely populated areas of Greater London and the Home Counties.

Experience has shown that a considerably greater service area can now be achieved and it was apparent when considering the replacement of the Alexandra Palace station that, given a suitable site further south, it would be possible to extend the service in Kent, Surrey and Sussex without introducing a corresponding loss in the North and North-east. At the same time the service area of the London station could be made to join up with the service areas of the adjoining stations at Sutton Coldfield and Rowridge, and later, Norwich.

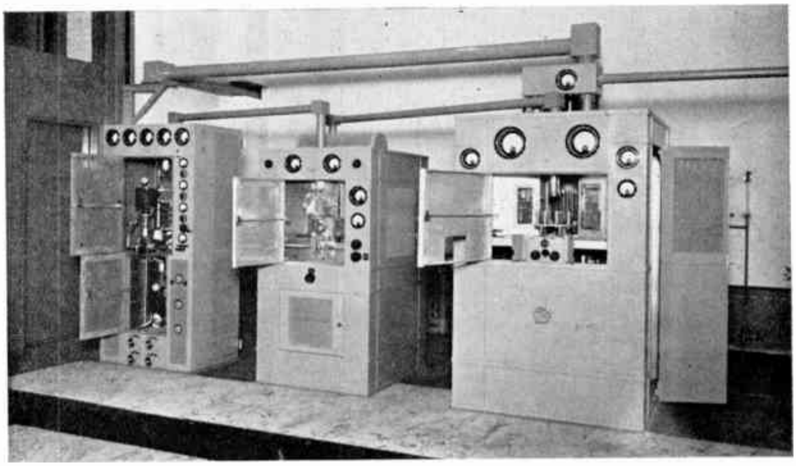

Fig. 1.—The original Marconi-E.M.I. vision transmitter which came into operation at Alexandra Palace twenty years ago.

Several possible sites for the new station were investigated and tested. An exhaustive field-strength survey showed that, by moving the London station to Crystal Palace, and by increasing the height of the aerial and the effective radiated power, it would be possible to bring more than a million additional people within the acceptable service area and to provide a stronger, and therefore more interference-free, signal for a great many more.

The new station uses the same frequencies as Alexandra Palace (vision 45 Mc/s and sound

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* Based on information supplied by the British Broadcasting Corporation and Marconi's Wireless Telegraph Company Ltd.
U.D.C. No. 621.397.71.

41·5 Mc/s), but a vestigial upper side-band characteristic has been adopted for the vision transmissions at at all post-war B.B.C. television stations.

The station is operating initially with an aerial on a temporary 250-ft. mast and an effective radiated power of 60 kW—about twice the power of the Alexandra Palace station. Eventually, using the permanent aerial system, the e.r.p. will be raised to 200 kW; it is permitted, under the Stockholm agreement, for it to be increased to a maximum of 500 kW.

The Station Buildings

The London County Council, in leasing a two-acre site to the Corporation, stipulated that the buildings were to be sunk beneath the Terrace so that the ground above the buildings would be available to the public as terrace and gardens. The general arrangement of the building can be seen in Fig. 2. The rooms at the front of the building have natural light, but the reminder of the building, including the transmitter hall, relies on artificial light and mechanical ventilation. All the engineering equipment, with the exception of the ventilating plant and feeder switching equipment on the upper floor, is on a single level. The buildings have been so planned that, if necessary in the future, they can be extended without causing interruption to the services.

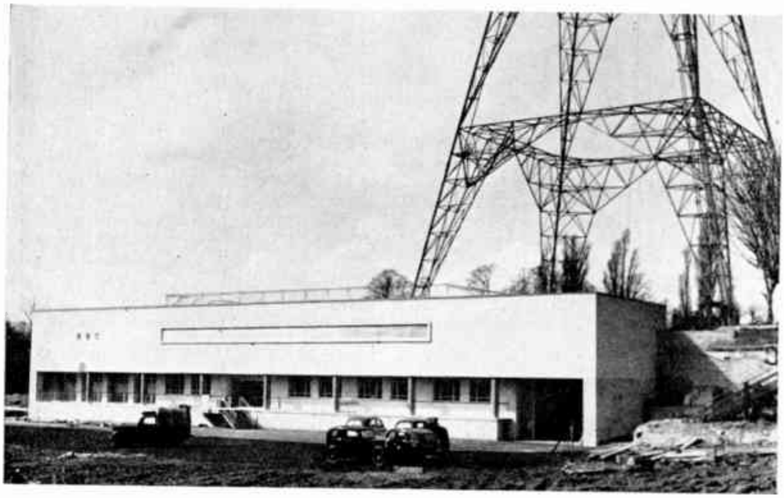

Fig. 2.—General view of the new London television station at Crystal Palace, taken during construction. The base of the main tower can be seen.

The Transmitter Hall and Description of the Transmitters

The main transmitter hall, shown in Fig. 3, contains two vision and two sound transmitters; the sound transmitters are on the left and the vision transmitters are on the right. The duplication of vision and sound transmitters and feeders and aerials, described later, has been devised for parallel operation which enables faulty units to be switched out and leave the station operating at half power. This is the first time that parallel operation of television transmitters has been carried out, although the v.h.f. transmitters at Wrotham are operated in this manner.* It obviates the need for separate stand-by transmitters.

The transmitter unit consists of five cubicles, the doors of which are all fitted with an electromechanical interlock system for the safeguarding of personnel. The extreme left-hand cubicle contains the three r.f. amplifier stages which serve to raise the drive input from 5 W to the final output power.

The first two of these stages are hard-driven Class C narrow band stages and consist of a QQV06-40 double tetrode driving four QY4-250 valves in push-pull pairs. Modulation is applied to the grid circuits of the final r.f. amplifier, which uses two CR.192 valves in push-pull, having triple-tuned anode circuits.

It will be noted that all the valves in the r.f. stages are tetrodes. This practice confers several advantages: the number of stages required is thereby much reduced, modulation at high output level is much easier to achieve, while problems of stabilization are reduced.

The second cubicle from the left contains the video amplifiers and associated circuits, together with the modulator and power supplies. The input signal from the control desk is fed to the input circuits of two units, namely a Clamp Pulse Generator and a Correction Unit.

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* "Inauguration of v.h.f.-f.m. service in Great Britain," *J. Brit.I.R.E.*, **15**, pp. 269-270, May 1955.

Fig. 3.—The Transmitter Hall at Crystal Palace; the Sound transmitters are on the left and the Vision transmitters on the right, with the Control Room in the background. The doors on each side lead to adjoining rooms from which the backs of the transmitters are accessible.

The Clamp Pulse Generator produces a clamping pulse designed to operate on the back porch. The amplitude of the pulse is 2 volts negative-going, and is applied to all the clamping circuits throughout the transmitter. It is derived from the input signal and will remain correctly timed even though that signal may contain considerable l.f. distortion, superimposed hum or noise pulses of up to 1·5 μ sec. duration.

The Correction Unit serves to give the necessary stretch to the synchronizing pulses, to clip them to standard level and to apply pre-correction for transmitter non-linearity. The output level is approximately 1·5 V to the next unit, a Pre-Amplifier. In this, the signal is increased to approximately 40 V. The black level is maintained in the pre-amplifier stages by d.c. restoration. A Final Clamping and Black Level Feedback Unit is incorporated to maintain a constant black level. A sample of the output signal in the aerial feeder is detected and clamped; the synchronizing pulses so derived are separated and delayed to coincide with the clamp pulses. They are then applied to the final clamp as correction pulses, the amount of correction being proportional to any change in amplitude of the detected synchronizing pulses.

The output from the final clamping stage is fed to a cathode follower whose output is directly connected to the cathode of the "shunt-regulated" final amplifier. In order to obtain a high input impedance the valves in this stage are tetrode-connected, with their screens stabilized with respect to their cathodes. As the reactive current demanded by the output capacitance is heavy, another valve (driven from the anode of the cathode follower) contributes part of the output at the higher frequencies; this improves linearity for full black to white swing up to the maximum video frequency. Negative feedback is derived from the output of the stage and applied to the grid of the amplifier.

A peak white limiter is incorporated to protect the final r.f. stage from being over-modulated. From the amplifier the signal is passed to a "shunt-regulated" cathode-follower stage, the regulator being in series with the cathode-follower stage and acting as its load.* The cathode-follower output is connected to the grid circuits of the final r.f. amplifier, where the variation of the negative grid potential of the two CR.192 valves due to modulation is of the order of 340 V.

H.t. and grid bias power supplies for the modulator stages are also contained in the second cubicle, while the other three cubicles contain filament and bias power supplies, and control circuits. The main power supply unit is installed in an adjacent room, and consists of a further four cubicles. All h.t. and bias supplies use metal rectifiers except for the auxiliary h.t., penultimate amplifier h.t. and final amplifier screen supply, for all of which xenon-filled rectifiers are used.

The centre frequency of the band-pass characteristic of the transmitter output circuit is offset from 45 Mc/s to 44 Mc/s to take advantage of the narrower bandwidth and hence

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* V. J. Cooper, "New amplifier techniques," *J.Brit.I.R.E.*, **12**, pp. 374-384, July 1952.

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the higher output power permitted by the vestigial sideband characteristic of the transmission. The transmitter tuned circuits are not relied on for any of the shaping of the unwanted upper sideband, as this is done by the two vestigial upper sideband filters into which the outputs of the two vision transmitters are fed. These filters are installed in cabinets in line with the vision transmitters.

The sound transmitters are Class B modulated in the final stage and are rated at 4½ kW carried output, but will operate at 3¾ kW to preserve the standard ratio of 4 to 1 between peak white vision and sound carrier power. The design is straightforward, but the use of 20 db of negative feedback over the a.f. chain keeps the distortion at less than 1 per cent. at 95 per cent. modulation, which is well up to modern transmitter standards. The sound transmitters are contained in a single line of cabinets whilst the vision transmitters have additional cabinets containing power supply equipment mounted behind them.

The phases of the pairs of vision and sound transmitters are compared at similar points near the inputs to the combining filters and monitored and adjusted to the correct values by the r.f. phasing equipment in the control room. It is found that very little phase drift occurs after the first ten minutes after switching on. The combining filters and aerial feeders are assumed to have a constant phase shift and check measurements made over a period have proved this to be a correct assumption. Video phasing, once set for the two transmitters, is unlikely to change.

Water-cooled test loads are provided for each transmitter. Thus any transmitter may be tested while the others are still operating.

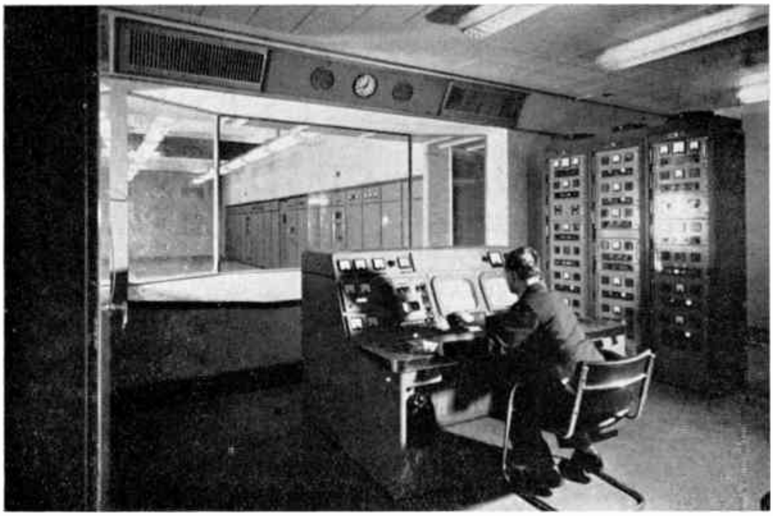


Fig. 4.—The Control Room, with a view of one bay of transmitters beyond, showing the control desk and the three racks containing the drive and phasing equipment.

Transmitter Control Room

The transmitter control room (Fig. 4) is situated at the end of the transmitter hall which can be viewed through sliding glass windows. From here the engineer on duty can see all the transmitters under his control. The control room contains, in addition to the main transmitter control desk, the duplicate drive and phasing equipment for the transmitters, the vision and sound programme input equipment, together with distribution amplifiers and a transparency scanner for the local generation of captions and test cards. Magnetic tape sound reproducers are also installed to provide locally generated announcements in case of emergency.

The four transmitters can be started from cold, and shut down, from the control desk. Two picture monitors and a waveform monitor are mounted on the sloping front of the desk. These normally display the input and output pictures and the output waveform but they can be switched, by push-button operated relays, to other points in the transmitter chain.

At the top of the control desk (Fig. 5) is an illuminated mimic diagram showing the arrangement of the transmitter and aerial feeder coaxial switches. For normal use, all the lamps on this diagram should be white, abnormal conditions being indicated by lamps of various colours.

A key switch panel is provided for selecting the input to be fed to the sound and vision transmitters; this may be the television programme, one of a variety of test patterns, or the output of the local caption scanner.

The main driving and phasing equipment is housed in three 7-ft. high cabinets. The comparator unit, however, is contained in a small die-cast instrument case and is mounted on a suitable panel near the transmitter outputs. The output phases of the two vision transmitters are compared, and any phase difference is removed by appropriately adjusting the phases of the r.f. inputs to the transmitters by means of the phasing equipment. Both transmitters are driven from a common crystal oscillator to ensure an identical radiated frequency in each case, instead of a crystal oscillator.

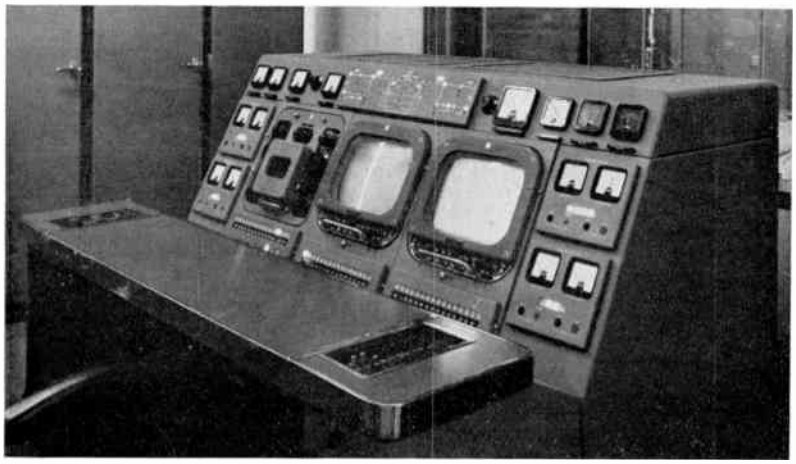


Fig. 5.—A close-up view of the main control desk for the vision and sound transmitters; the mimic diagram can be clearly seen and below it are the waveform monitor and two picture monitors.

The output from the oscillator is fed to a hybrid network to provide the two vision outputs. The phasing adjustments are carried out in two stages, the coarse adjustment by switching in lengths of coaxial cable, and the fine control by adjustment of variable capacitors. A capacitor is connected in each chain, the pair being arranged in opposition. Input and output amplifiers are provided in each chain, to act as buffer amplifier for the fine phasing circuit, and to make up for the losses. The actual phase difference is measured by the phase comparator unit, which is connected by means of coaxial cable to the output feeders of the transmitter. As it employs no tuned circuit or valves, it is most reliable and needs little or no attention.

The transmitter control room is acoustically treated to facilitate aural monitoring of the sound part of the transmission but adjacent to it there is in addition an acoustically treated quality-checking room equipped with vision and sound apparatus of high quality to enable critical sound monitoring to be carried out.

Transmitter Combining Filters and Feeder Switching

The outputs of the four transmitters are combined in the following way. The output from one sound transmitter is combined with the output of one vision transmitter, and the outputs of the other sound and vision transmitters are also combined. The two combining filters are located in cabinets which are set in line with the sound transmitters. Combining filters allow signals to be united without cross-modulation or mutual resistance between the two transmitters. Basically they are frequency discriminating devices based on the Maxwell bridge, and operate at an extremely low power loss. No critical matching is involved above that normally required for television purposes.

The feeders from the combining units are routed to the base of the aerial tower via a feeder switching room on an upper floor in which eight coaxial switches are provided to enable the transmitters and feeders to be interchanged in all possible combinations in the event of faults developing in the transmitters, feeders or aerial system. Under normal conditions the output of each combining unit is connected to one half of the aerial system. A mimic diagram mounted on the wall indicates the position of the various switches.

The feeder switching room also contains switchgear controlling the aircraft warning lights on the tower, the aerial de-icing equipment and the s.h.f. receiving equipment on the tower. De-hydrators are also provided to feed dry air under pressure to the aerial feeders so as to exclude moisture.

The Aerial System

The temporary aerial to be used initially consists of six dipoles mounted in two tiers on the three corners of a 250-ft. triangular stayed mast which is erected on the site of the old reservoir, adjacent to the permanent mast. This system is fed by six H.M.7 helical-membrane semi-flexible cables connected to extensions of the two 5 in. diameter feeders which will feed the final aerial system on the main tower. One group of three cables feeds the upper three dipoles and the other group the lower dipoles. Great care has been taken to keep the lengths of all cables and feeders electrically equal.

The partly completed permanent tower has at present a height of approximately 440 ft. but in its final form it will be 640 ft. high—it is already a notable landmark over a large part of South London. Preparations are in hand for erecting—by about July of this year—a four-stack temporary aerial near the top of the tower as it is at present. This will increase the effective height of the aerial from 200 to about 400 ft. and at the same time increase the effective radiated power from 60 kW to 120 kW.

Later, in 1957, when the tower is completed, a further four stacks of dipoles will be erected above the 440 ft. level and the e.r.p. will be further increased to 200 kW. Above the Band I aerial there will be space for two high gain Band III transmitting aerials.

Vision and Sound Programme Circuits to Crystal Palace

The vision signals reach Crystal Palace over duplicate 1 in. diameter co-axial cables rented by the B.B.C. from the G.P.O. Normally one of these cables carries the programme from Broadcasting House, a distance of 9 miles (14 km), with the other acting as a reserve. Either cable can, however, be used in the reverse direction from Crystal Palace to Broadcasting House. This provision has been included to cater for the feeding of outside broadcast programmes, received at Crystal Palace by radio link, to the other transmitters in the B.B.C.'s national network. The low attenuation of this type of cable enables the signals to be transmitted in either direction without intermediate repeater equipment which would have inevitably reduced the reliability and increased the running costs of the vision link. A carrier frequency of 15 Mc/s is used. The terminal equipment at each end of the link has been engineered by the Designs Department of the B.B.C. Engineering Division and is installed in the Lines Termination Room from where the vision and sound signals are passed to the Transmitter Control Room. Provision has been made for additional terminal equipment which will enable each cable to carry more than one programme simultaneously to cater for possible future developments. The associated sound programme reaches Crystal Palace over G.P.O. lines.

Test equipment is installed for carrying out routine performance measurements on the vision circuits to Broadcasting House.

S.H.F. Receiving Room

The s.h.f. receiving room for receiving vision signals from outside broadcast points is situated behind the control room. It will contain equipment for handling the signals to and from the s.h.f. paraboloids which are to be mounted at the 430 ft. level on the permanent tower, and also the remote-control mechanism used for turning them. Initially there will be four paraboloids although later the number may be increased. These aerials, which are intended for receiving radio link transmissions in the 4,400-4,800 Mc/s band from outside broadcast link transmitters, have a gain of 33 db and each paraboloid can be set to any desired bearing within an arc of 180 deg. with an accuracy of better than ±1 deg. The received signal from the aerials is fed by a system of waveguides and flexible coaxial feeders to receiving equipment mounted on the tower structure. It is then passed, at intermediate frequency, to the receiver room. Means are provided for remotely tuning the receivers.

Power Supplies

The power supply (at 11 kV) for the station is obtained from the London Electricity Board over two feeders connected to different networks so as to ensure continuity of supply in the event of a failure of either one. A 25-kVA automatic-starting diesel-alternator set is provided for use in the event of a complete mains failure. This is arranged to feed skeleton lighting throughout the building, the aircraft warning lights on the tower, and the outside broadcast link and coaxial cable termination equipment. This ensures that, when an outside broadcast is being received via the Crystal Palace radio link equipment, a failure of the public power supply in the district would not deprive the whole country of the programme.

PHONEVISION—AN EFFECTIVE METHOD FOR SUBSCRIPTION TELEVISION*

by

A. Leonard C. Webb,† and Alexander Ellett, Ph.D.‡

SUMMARY

A brief analysis of the economic problems of television shows a pressing need for an income supplementary to that which operators at present obtain from licence fees or advertising sponsorship. The subscription or home box-office method of obtaining this extra income is shown to be highly desirable, particularly in countries like Australia.

The operational objectives of a subscription television service are discussed and the operation of the Phonevision system is then described. Details are given of the video and sound coding and decoding methods.

Part I: by A. Leonard C. Webb

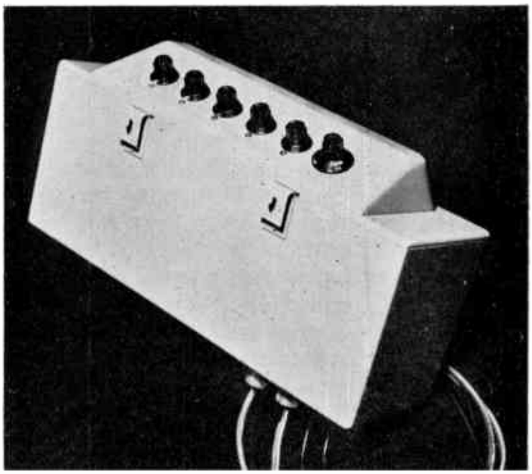
1. Introduction

Before exploring some of the technical aspects of subscription television, it is proposed to deal briefly with the general economies of television as a communications medium. Australia is fortunate in having available the experience gained by other countries, particularly the United States. This allows some important basic conclusions to be drawn.

(i) The cost of producing television programmes is extremely high, yet television devours talent and material at a faster rate than any other entertainment medium. The result is that in most countries the average quality of television programmes is very low.

(ii) Experience has shown, particularly in the U.S.A., that programme production must be carried out collectively by station networks. The facilities of these must be purchased as a group by the advertiser willing to sponsor a programme. Without network affiliation, a commercial television station can hardly exist.

(iii) Advertisers will use television as a medium only where it covers densely populated areas. In other sections of the country the sponsorship cost is too high. Rural television is almost inconceivable in any advertiser-supported system of television broadcasting.



The subscriber decoder developed for home use in unscrambling television pictures transmitted in the Phonevision aircode system. Information to be used in setting the dials is contained on programme cards obtained by post, purchased at a vending machine or received orally by telephone. The decoder is attached to the subscriber's television receiver.

(iv) As is evident in England, a Government sponsored television system faces the same problem of high costs, necessitating limitation of transmission hours.

(v) In the United States, advertisers last year paid $515,000,000 (£181,000,000) for television programme sponsorship. Despite this, high quality entertainment such as new films,

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† Rola Company (Aust.) Pty. Ltd., Richmond, Victoria.

‡ Zenith Radio Corporation, Chicago, U.S.A.

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popular legitimate theatre shows, opera, etc., are never seen on television. Most of the major sports events are restricted to closed circuit theatre television.

As a general summary of the foregoing observations, it can be stated that neither in England nor America is television being used to the full extent of its technical capabilities.

The problem is obviously economic in nature and results from the fact that neither government nor advertising sponsorship provides television with a base wide enough to permit healthy growth in its most desirable forms.

2. Subscription Television

As early as 1931, the Zenith Radio Corporation in the United States had foreseen this problem and consequently developed a new television broadcast system known as subscription television or pay-as-you-see television. This new system is not yet in commercial use. The Federal Communications Commission in the U.S.A. has begun to determine whether subscription television should be authorised in addition to the present system of advertiser-sponsored television. This is acknowledged to be the most important development in broadcasting now under study by the F.C.C.

Essentially, subscription television is a complementary service to either Government-operated or advertiser-sponsored television. It is a service which can contribute additional revenue of such magnitude as to bring to television, programmes from sources which are now closed to the medium.

We in Australia are fortunate in still being in the planning stages of our television service. We can still incorporate new thoughts and techniques. Subscription television holds out a very important promise to this new service and its possibilities should be carefully explored by all concerned.

In the opinion of the author, subscription television provides the answer to the problem of rural television services. It can provide multi-channel services in metropolitan areas and will set programme standards far higher than those possible under the conventional system of operation. In Australia, where communications are so vitally important, it will permit the rapid growth of television on a truly national scale. Technically, subscription television is entirely practical and has been thoroughly field tested.

Part II: by Alexander Ellett

1. Major Objectives

The development of Phonevision has been directed towards the accomplishment of the following objectives, considered by Zenith to be essential requirements, which any practical system of subscription television should satisfy.

(i) Picture and sound should be so effectively scrambled that a programme viewed and heard without unscrambling will be substantially unintelligible.

(ii) The system should be compatible, permitting use of the millions of receiving sets now in the hands of the public. There should be no impairment in the performance of the subscriber's set during the reception of a subscription programme when the unscrambling device is in use, or during the reception of non-toll programmes when that device is not used.

(iii) Use of the unscrambling device to clear up a scrambled programme should be practical only for subscribers who pay or commit themselves to pay for the programme viewed. Fees paid by subscribers should be accurately allocatable to programmes so that the income to an individual programme producer may reflect subscribers' acceptance and use of his programme.

(iv) Successful use of an unscrambling device other than that authorised by those who supply subscription programmes should be sufficiently difficult or costly to discourage any significant use of such devices.

(v) The system should be compatible with network operation and, in cases of overlapping coverage, should permit allocation of fees to the stations involved on the basis of their individual viewing audience.

If subscription programmes are to be receivable by existing television sets, it follows at once that such programmes must be transmitted over present channels.

An experimental commercial test of Phonevision was authorized by the Federal Communications Commission in 1951. During this test the picture was subjected to two-mode scrambling. "Mode" is the term used to indicate

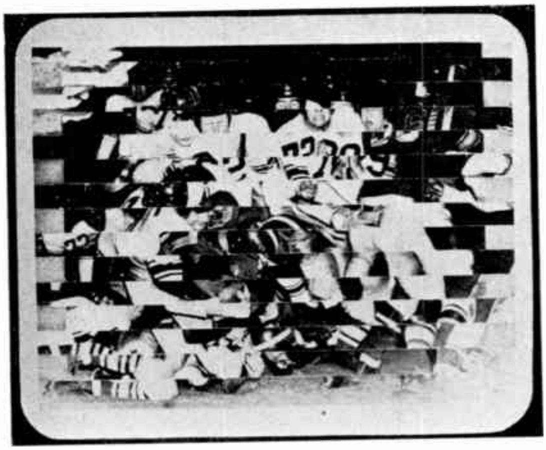

Fig. 1 (a).—*The scrambled image sent out by the Phonevision transmitter.*

(b)—*The same picture when the decoding information has been fed into the receiver circuits.*

a particular scrambling or distortion pattern of the picture. As an example, the distorted picture of Figure 1 (a) is obtained from that shown in Figure 1 (b) by shifting alternate groups of lines away from their correct positions.

From this test it was concluded that sound scrambling is essential to any acceptable system of subscription television. At the start of this test the picture was scrambled, but not the sound, and it was immediately apparent that the programme material so broadcast attracted a large audience whose members enjoyed the audio part of the programme as they would a radio broadcast.

Many of this audience also viewed the scrambled picture and, although they found its jitter annoying, they were able to derive enough picture information to make this a rather common practice. However, when the sound was coded and made unintelligible, this audience dropped to insignificant proportions.

In conducting the authorized test, it was also learned that too much information was available to non-subscribers from the video portion of the programme. Further study showed this to be particularly true of certain sports events. In boxing and in baseball, for example, many persons are able to follow the course of a match or game in spite of the type of picture scrambling used in this test.

Their success, of course, is a consequence of the simple character of scenes involving only two persons, or several persons usually well separated. Under such conditions figures are easily identified and the general course of events can be discerned through the movements of identifiable characters, though with some loss of finer points of the action.

Study of slightly more elaborate techniques of coding, employing three or four-mode scrambling instead of the two-mode scramble used in the test, showed little improvement. It became clear that some way must be found to break the picture up instead of simply displacing it as a physical whole.

The scrambling process finally adopted for Phonevision effectively cuts the picture horizontally into segments of sixteen lines each and displaces alternate segments by about 7 per cent. of the picture width in a horizontal direction. In addition, the divisions between segments randomly shift their position from field to field. This results in a satisfactory breakup of the picture, with little residual intelligibility.

2. Coding or Scrambling

The displacement of the lines of video in a given field is achieved by shifting the phase of such lines with respect to the horizontal synchronizing pulses, which remain perfectly regularly spaced. The phase shift is accomplished by a video delay line having approximately three micro-seconds of delay, in combination with a switch, so that the delay line may be effective or not depending upon the

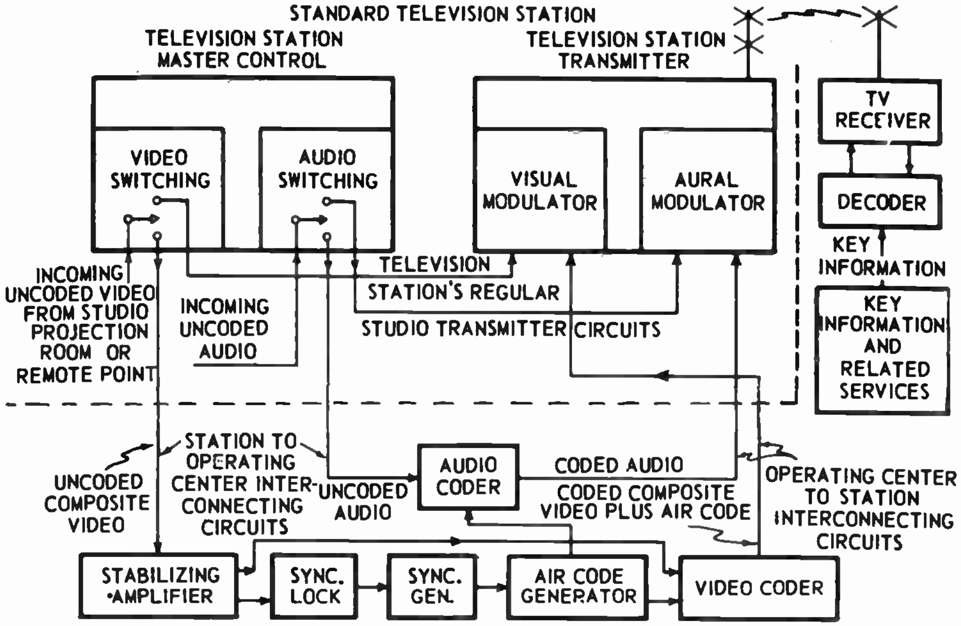

Fig. 2.—A simplified functional diagram of a Phonevision installation.

operating conditions of the switch. Thus, video information for a horizontal line may be sent in either of two phase conditions relative to the synchronizing pulses—delayed or undelayed.

The switch, which inserts or removes the delay, is controlled by a square wave having a period of thirty-two lines and a phase relative to the vertical synchronizing pulses which may be changed from field to field although it is held constant, phasewise, throughout any one image field. The effect thus produced is a shifting of the vertical positions of the jittered sixteen-line strips from field to field.

With a thirty-two line square wave, there are thirty-two possible phase positions of the strips, or thirty-two modes, and any field may be transmitted in any one of the thirty-two modes. Transitions from mode to mode are made during the vertical blank period under the control of decoding information transmitted during that period. Fig. 1 gives a limited illustration of this process, showing the coded picture and the same picture after decoding—for one phase condition of the switch-controlling square wave.

It must be kept in mind that Fig 1 (a) shows only a single scrambled field. The viewer sees in rapid succession fields in several of the thirty-two possible modes with the lines of division between the horizontally shifted portions at different places. Because of persistence of vision, this gives rise to a degree of confusion and unintelligibility which must be seen to be appreciated. No stationary picture can convey the full impression.

To reduce the intelligibility of the video further, even for simple scenes which are otherwise more difficult to scramble, it may be transmitted with black-and-white inverted, as in a photographic negative. Such inversion is readily introduced by a video inverting stage and another switch which permits use of that stage or not, as desired, for any programme interval. More complex subject matter, such as the ordinary motion picture, does not require this inversion.

Sound accompanying the picture is scrambled by changing its phase from time to time. Specifically, it undergoes a 180 degree phase shift of its wave-form in synchronism with the thirty-two line square wave which controls picture scrambling. Amplitude inversion at this rate makes sound unintelligible.

By this scrambling process the video and sound portions of both monochrome and N.T.S.C. colour are handled without difficulty.

3. Decoding

Fundamentally, decoding is the identical process employed to effect coding, but practised in a complementary sense. In its simplest form, a subscriber's decoder for unscrambling the video coding of Phonevision consists of a video delay line and switch, identical with those used for coding and operated upon by the same square wave, but in inverse phase. Of course, this pre-supposes the availability to subscribers of such a square wave.

Were that square wave to be transmitted as an unmasked radiation, there would be no security to the system; all decoders would be free to appropriate it to decode. Subscribers would require no additional information, and there would be no basis for assessing a subscription charge measured in terms of toll programmes viewed by the subscriber. Consequently, instead of transmitting the original square wave to subscribers for decoding purposes, a new square wave is generated in the decoder. This new square wave can be made similar to the coding square wave as to period and phase by properly using two sets of information: the *air code* and the *key information.*

The air code is transmitted as part of the composite video signal and is coded in that it is not a direct manifestation of the programme code; it must be read or interpreted to reveal its code message. Without the air code and the additional information required to decode or interpret the air code, the decoder will not function.

Thus, at one and the same time, the air code feature introduces the security required of a commercial system and lays a foundation for arriving at an equitable subscription charge predicated on the distribution of such additional information.

Only when the decoder has been set correctly will the air code be properly interpreted to control the decoder and produce a square wave having the necessary correlation with the coding square wave. The decoder is adjustable by means of dials, and the correct dial setting is called the key information. By suitable construction the decoders are individualized to subscribers so that the key information is unique to each subscriber and unusable by other subscribers.

Sound decoding is basically the same as video decoding, being the converse of the operation employed in coding. In particular, sound decoding is accomplished by a 180 degree phase reversal of the audio signal, from time to time, effected under control of the decoder square wave. Since this square wave is also properly correlated to that used for sound coding, decoding results.

3.1. *Decoder switching mechanism*

Apart from the normal controls of a television receiver, the dial-controlled switch-mechanism is the only portion of the Phonevision decoder operated by the subscriber. There are, altogether, six dials or knobs. Five of these are set to the digits received by the particular subscriber as key information for a given programme. The sixth, or operating knob, is used to choose the desired one of the permissible functions of the equipment.

These functions are: "normal television" and "reset," "P.V.-A" and "P.V.-B." In the "TV-RESET" position, the apparatus is adjusted to receive non-toll programmes and the switching mechanism is concurrently released preparatory to registering the key information therein to decode a subscription programme. Position "P.V.-A" is for the reception of Phonevision programmes transmitted with normal as contrasted with inverted video, while "P.V.-B" is for subscription programmes having inverted (negative) video.

The subscriber's key information may be placed in his hands by any of several means. That information is not only specific for a particular programme, but is also specific for the particular subscriber.

4. Phonevision System Installation

Figure 2 shows a simplified functional diagram of a Phonevision installation and associated facilities consisting of these main parts:

(*a*) A standard television station having a suitable source of uncoded video and audio which may be any programme production point, such as the television station's studios or projection room, remote pick-up points, networks, etc.

(*b*) The Phonevision service company's *operating centre* which codes or scrambles video and audio, generates air code information and computes and distributes key information to subscribers.

(*c*) Interconnecting links, which supply uncoded video and audio from a switch panel in

The composite video signal is applied to the stabilizing amplifier which supplies a non-composite video at an amplitude of 1·4 volts. In addition, stripped composite synchronizing pulses from the stabilizing amplifier are used to lock in the local synchronizing generator by means of a conventional commercial control unit such as a synchronizing signal-locking unit. Pulses formed by the synchronizing generator are made available by conventional techniques through the use of a synchronizing-pulse distribution amplifier.

When coding a colour signal, provision is made to apply the composite video to a burst controlled oscillator. The output phase-controlled 3·58 Mc/s sub-carrier is fed to a burst generator. This unit, when gated by means of a pulse during the horizontal blanking interval, reconstitutes the colour synchronizing burst, which is later re-added to the colour signal in the video coder. The burst controlled oscillator and burst generator are units which are in use in commercial colour equipment.

It has already been mentioned that provision is made to transmit video of either conventional or inverted polarity. The chosen polarity is maintained for an entire programme. The video inverter is driven by a 1·4 volt video signal stripped of synchronizing pulses. Composite blanking of proper configuration and polarity, obtained from the blanking pulse generator, is added to the video signal after inversion. The resulting output is applied to the video coder.

The 32-line coding square wave is generated in the units represented by blocks on the right-hand side of Fig. 4. These are the *air code generator* and the coding square-wave generator consisting of the *permuting selector* and the *mode determining circuit*. The phase of the 32-line square wave is determined by the coding pulses reaching the input of the coding square-wave generator. The proper combination of pulses is the result of the routing of air code pulses by the switching and permuting mechanism of the transmitter.

5.1.1. Generation of air code and mode determination

The first step in coding is the generation of the air code bursts. The air code consists of ten tone-bursts which are placed into a ten-line interval immediately following the post-equalizing pulses of the vertical blank interval. The duration of a burst is approximately equal to that of one horizontal line of video. A burst may have any one of six frequencies. The choice of tones, or frequencies, is a random selection of one of seven possibilities, namely, any one of six tones, or no tone at all. A typical air code group is shown in Fig. 5. In this particular instance, bursts of frequency of f_3 and f_6 are absent.

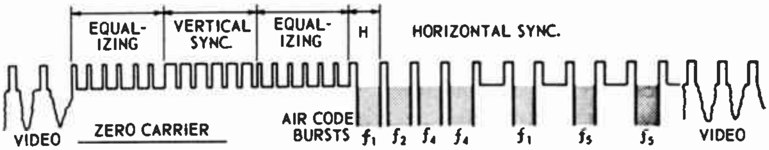

Fig. 5.—A typical air code group.

As already indicated, coding functions are under control of a 32-line square wave which is phase modulated under qualified control of the air code pulses. Specifically, the air code pulses are first applied to the switching and permuting mechanism which routes the particular bursts to the seven inputs of the mode determining circuits in accordance with the master programme code. Application of the air code to the mode determining circuit by this means, determines the unique instantaneous-phase condition of the 32-line square wave.

5.1.2. The video coder

The output of the video inverter, discussed earlier, is supplied as a signal to the video coder, where it is coded by use of a switch tube and a delay line. The switch tube, a beam deflection device, is actuated by means of the 32-line square wave so that video applied to the grid of this tube will become, at the stage output, either delayed or non-delayed in accordance with the phase of the square wave. Typical horizontal lines, one delayed and one non-delayed, are shown in Fig. 6.

It will be noted in this Figure that a narrow by-product segment of the video lines appears alternately on the right- or the left-hand side of the horizontal blank interval, depending on the phasing of the coded video. This segment shifts with the coding process, and cannot be used to transmit picture information.

This segment of the video, called the "jittered blank," is maintained at approximately average-video level.

Composite sychronizing pulses as well as the air code bursts are added to the coded video in the main video-coder chassis. The entire combination finally results in a composite video signal shown in Fig. 5.

When coding colour, a colour burst formed in the colour burst generator is re-added on the horizontal back porch. This addition also takes place in the coder chassis.

5.2. *Audio coding*

5.2.1. The sound coder

Sound is coded by reversing the polarity or phase of the sound, in synchronism with the picture scrambling. Whenever the picture is received in an undelayed mode, the sound is received in its initial or reference phase. When the picture is received in its delayed mode the sound is received in its corresponding inverted, or reversed, phase.

The basic rate of sound phase reversal is therefore determined by the same mode determining circuit that generates the square wave used to control picturing scrambling. The mode determining circuit provides a countdown of 32 from line rate and establishes a mean frequency of about 500 phase reversals per second. However, since the air code establishes 32 phase conditions of the square wave at a random rate, the positions of the phase reversals of the sound are modulated in the same random manner. A portion of a 100-c/s pure tone is shown in Fig. 7 (a). The same tone is shown in Fig. 7 (b) after scrambling.

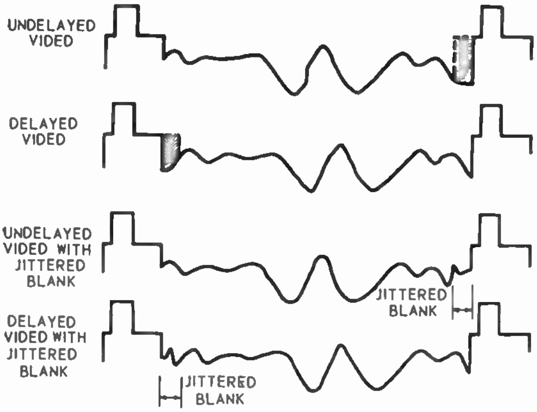

Fig. 6.—Typical delayed and non-delayed horizontal lines.

Inversion of the audio signal without resultant introduction of spurious signals requires the use of both a new tube, referred to as the sound switch tube, and a special technique of sampling.

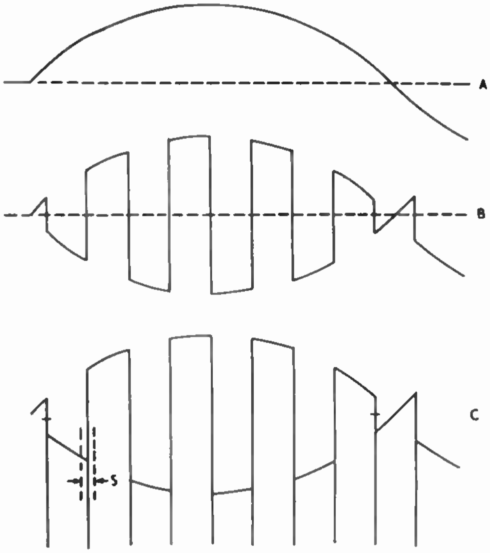

Fig. 7.—(a) Portion of 100-c/s pure tone; (b) same tone after scrambling; (c) output from switch tube.

Although the sound switch tube permits the selection of either of two opposite phases of the audio signal, hence providing the necessary coding inversion, it also produces transient signals during the times of phase reversal. The switching transients are of nearly constant amplitude, independent of sound-signal level; and they may vary between two and four microseconds in width, depending upon the particular audio switch tube and its switching-signal characteristics. The amplitude of the transients is equal to or slightly in excess of the peak amplitude of the audio signal. Fig. 7 (c) shows the output of the switch tube before sampling.

Removal of the switching transients from the output of the audio switch requires processing of the signal by the sampler. (See Fig. 3.) The sampler is a device that is controlled to become alternately conductive or non-conductive. During the time the sampler conducts, the sound-switch output appears unaltered at the next amplifier input. In the interval when the sampler is made non-conductive, the amplitude at its output is maintained at the level of the sound signal just prior to the time the sampler was rendered non-conductive.

The conducting and non-conducting intervals are of equal duration and are approximately eight microseconds long. The sampling frequency is four times the horizontal line-scanning frequency and since the coding interval is a 32-line countdown from this same frequency, the sampling and line frequencies are harmonically related. By properly phasing the sampling frequency, the "dwell-time" can be made coincident with the transient, or spike, produced by the sound switch.

Fig. 8.—Appearance of the signal during the interval marked "S" on Figure 7 (c).

Figure 8 shows the appearance of the signal during the interval marked "S" on Fig. 7 (c) after operation by the sampler. The dotted waveform shows the transient eliminated during the holding interval of the sampler.

A block diagram of the sound coder is shown in Fig. 9 and it is self-explanatory in view of the previous discussion.

5.2.2. The sub-carrier modulator

Now consider the result of coding a pure tone of the same frequency as the coding square wave. When the phase of the pure tone relative to the coding signal is such that phase reversal takes place at the zero-amplitude points of the sinusoidal signal, the coded tone will appear as in Fig. 10.

The dotted curves indicate the waveform before scrambling. A Fourier analysis of the coded tone reveals that it is made up of a unidirectional component, subsequently referred to as the d.c. term of the analysis, and of even harmonics of the tone frequency which decrease in amplitude as a function of their order.

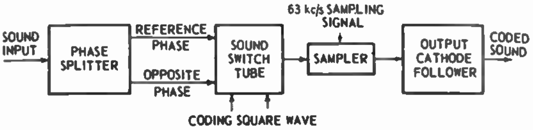

Fig. 9.—Block diagram of the sound coder.

If such a signal is conveyed to a decoder through a circuit incapable of transferring the d.c. component, for example a transformer or RC-coupling, the resulting waveform will appear as shown in Fig. 10 (a). The negative peak has an amplitude of 63 per cent. of the peak-to-peak excursion.

The decoder inverts the instantaneous amplitude of this signal at the time the negative peak is at its maximum value, producing the signal shown in Fig. 10 (b), a distorted version of the uncoded tone. This signal is composed of two components—the tone signal and a square wave, as shown in Fig. 10 (c). The square wave results from the omission of the d.c. component in the signal supplied to the decoder.

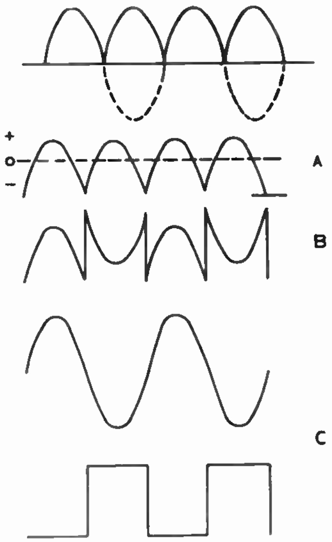

Fig. 10.—Sound coding waveforms.

The illustration is an extreme case, since the coding signal is not always so related but, as previously explained, is a phase-modulated square wave. However, very low modulation frequencies are generated by the coding process, and transmission of these is essential if substantially distortionless reception is to be achieved. Because the coupling circuits found in audio equipment at the receiver will not pass sufficiently low frequencies, an auxiliary device is used to convey that part of the coded-audio frequency spectrum not readily passed by the coupling networks.

A reciprocal coupling network, composed of time-constant sections equivalent to those of the coupling networks found in the path of the coded sound signal, provides the low-frequency modulating voltage for the auxiliary modulator. A subcarrier of twice the horizontal scanning frequency (31·5 kc/s) is used in a suppressed carrier modulator, modulated by these low frequencies. The decoding circuits can be arranged to reinsert automatically the information derived from this modulated subcarrier. The means by which this occurs will be discussed in connection with the sampling process of the decoder. A block diagram of the d.c.-subcarrier modulator is shown in Fig. 11.

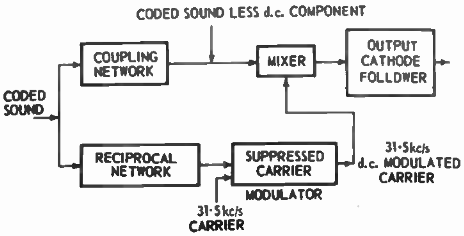

Fig. 11.—Block diagram of d.c. subcarrier modulator.

5.2.3. The f.m. sound modulator

The output from the subcarrier modulator is connected to the frequency-modulation sound modulator through a low-pass linear-phase filter, as in Fig. 12, which shows the block diagram of the sound-coding equipment.

The linear-phase filter transmits without attenuation all signal frequencies up to 45 kc/s. At higher frequencies such as 63 kc/s and above, the attenuation exceeds 35 decibels. This filter introduces a delay of twelve microseconds. The frequency-modulation modulator may be any type capable of modulation by frequencies of the coded-sound frequency spectrum lying between 16 c/s and 45 kc/s, and capable of centre-frequency control within the limits specified by the F.C.C.

Since the bandwidths of the transmitter and receiver sound circuits are much narrower than those of the corresponding video paths, greater delays are experienced by the sound signals. Since it is desirable that both sound and picture signals be decoded by the same square wave at the decoder, the sound-coding square wave must precede the picture-coding square wave at the coder.

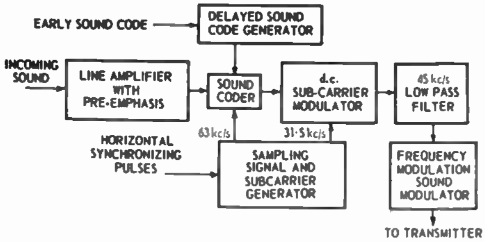

Fig. 12.—Sound coding delayed-square-wave-generator block diagram.

A sound square-wave generator having an adjustable delay provides the coder with the properly-advanced coding square-wave which preceded the picture-coding square wave by the required time difference.

The generator of the delayed square wave for sound coding (Fig. 12), receives an input coding square wave, which is identical in form to the picture-coding square-wave, but which precedes it by the time of one horizontal scan of the picture. A subsequent delay of 15 microseconds is introduced to equalize the overall delays of the sound and picture circuits. The output of the delayed-sound square-wave generator is identical in form with the picture coding square wave, but precedes it by 48 microseconds.

When the sound is coded as shown in Fig. 7 (b), full-amplitude transitions may occur. Subsequent pre-emphasis of high frequencies in the modulator circuits of the transmitter would require unnecessarily large bandwidths for transmission. To preclude such waste of the allowable transmission spectrum, pre-emphasis of the sound frequencies takes place before coding. In the decoder, de-emphasis takes place after decoding. Fig. 12 shows the placement of the pre-emphasis amplifier in the sound-coding equipment.

6. The Decoding System

6.1. *The decoder*

Figure 13, a simplified block diagram of the decoder installed on a subscriber's receiver, discloses the required connections at the television receiver. These may be made by means of socket adapters. The "PV-TV" switch indicated in this figure is so arranged that in the "TV" position the Phonevision decoder is completely by-passed, and the receiver is restored to its original condition. When the switch is in this position, the decoder can in no way affect the normal operation of the subscriber's television receiver. Obviously, the "PV" position of this switch connects the decoder functionally in the circuits of the receiver so that the signal circuits represented in Fig. 13 are completed and the decoder may unscramble a Phonevision broadcast.

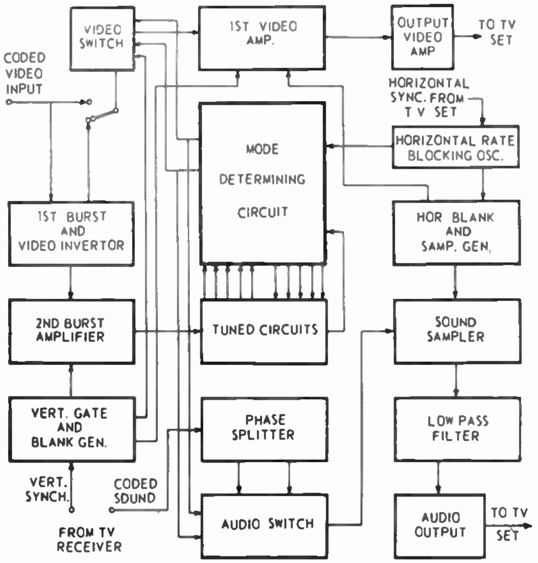

Fig. 13.—Block diagram of the decoder connected to the subscriber's television set.

Figure 14 is a block diagram of a Phonevision decoder. Video obtained from the receiver, usually at the grid or cathode of the picture tube, is applied to an input stage, which takes care of the dual functions of amplifying air code bursts and inverting the video when required.

The amplified air code bursts are applied to a burst separation stage where they are made available separately by means of tuned circuits. The individual bursts, once separated, are used to actuate gates which control horizontally timed trigger pulses. The controlled trigger pulses are then properly routed by the switching and permuting mechanism to inputs of the mode determining circuit in accordance with the key information.

A horizontal blocking oscillator, locked in by signals obtained from the horizontal drive circuits of the receiver, supplies these trigger pulses. Since the 32-to-1 countdown mode determining circuit is synchronized by the horizontal blocking oscillator, the square-wave transitions are kept well within the horizontal blanking interval.

The square wave from the mode determining circuit is applied to the video decoder which, operating on the output of the video inverter, provides unscrambling of the video.

Horizontal blanking is necessary at the receiver. Fig. 1 (a) shows a single field of a Phonevision signal. Decoding results in areas where video appears only half the time, as indicated by the shadings on the right-and left-hand sides of the picture. These flickering edges are blanked out.

Horizontal blanking pulses are generated in the decoder by means of a blocking oscillator locked in by horizontal pulses derived from the horizontal-sweep-circuit waveform of the television receiver. The output of the blank-forming blocking oscillator is a waveform having adequate timing and shaping for blanking the video signal in appropriate circuits in the video decoder.

Since, during the vertical retrace interval, the composite Phonevision signal is modulated below black level by the air code bursts, it is necessary to provide vertical blanking to prevent illumination of the picture tube during the retrace. Vertical blanking pulses are formed by a blocking oscillator which is synchronized with pulses derived from the vertical drive circuits of the receiver. The retrace blanking pulse is added at the switch tube as well as in the output video amplifier sections of the video decoder.

In addition to blanking, this vertical pulse gates the burst separation circuits, disabling them except during those intervals when bursts are expected. This improves the reliability of the separated and detected air code bursts by preventing erroneous registration by video frequency components close to those used in the air code bursts, and by eliminating noise except during the brief interval of the air code transmission.

6.2. *Decoding functions*

It was stated earlier that scrambling of video and audio is accomplished by shifting the phase of the video signal relative to the synchronizing pulses and by phase inversion of the audio. It will be remembered that introduction of video delay and of audio phase reversal is under control of the output of the mode determining circuit. To unscramble the video and audio it is merely necessary that video, not delayed at the transmitter, be delayed at the receiver and vice versa; and that phase reversal of the audio be properly synchronized with such reversals taking place at the transmitter.

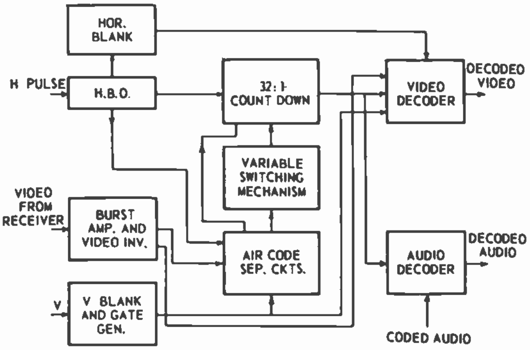

Fig. 14.—Functional block diagram of decoder.

We will now consider in more detail how these unscrambling operations are accomplished and how they are controlled by the air code in a decoder whose switching and permuting circuits have been set so that air code bursts are routed to their proper destinations.

Referring to the block diagram of the decoder (Fig. 13), video obtained from the receiver is applied to an input tube which serves two functions; as an amplifier for the air code burst frequencies and as an inversion stage for the video. Assume that the video has been removed from the cathode of the picture tube and that synchronizing pulses are positive-going. The video signals obtained from the receiver and the output of the inverter are applied to two contacts of a single-pole double-throw switch called the inversion switch. Selection of polarity of the video in accordance with the predetermined condition of transmission is here determined.

The video output of the first stage, which serves as an inverter for video, is naturally a wide-band circuit capable of amplifying the complete video signal. This stage has unity gain for video. A second function of this same stage is the amplification of the more limited portion of the spectrum containing the air code bursts. The burst output, having a limited bandwidth, drives a second burst amplifier. Sufficient burst gain is desired in the first stage to permit grid limiting in the second amplifier under all but the weakest signal conditions.

The second burst amplifier is also gated to permit amplification only during the time that the air code group is present. Generation of the gating pulse is provided in a vertical blocking oscillator which is synchronized with a signal derived from the vertical drive circuits of the receiver. The output of this vertical blocking oscillator stage is also used to supply a blanking pulse. This will be discussed later.

The anode load of the second burst amplifier consists of six individually tuned stages which serve as a separation filter for the six bursts constituting the air code group.

The separated air code pulses, after selection by the permuting mechanism, are used in driving the mode determining circuit of the decoder. Here a 32-line decoding square wave is formed in synchronism with the square wave generated in the coding equipment.

6.3. *Video decoding*

The 32-line square wave of the mode determining circuit is applied to the video switch tube, which is identical with that used in the coder. The delay line associated with the decoder deflection tube has the same electrical length as that used in the coder. Mode-determined switching of delay or non-delay into the video signal path is made opposite to the corresponding coding switchings, thereby consummating decoding of the video signal.

Since the output of the video switch tube stage is at a rather low level, two stages of amplification are used to obtain video of adequate amplitude and of proper phase for driving the picture tube.

The horizontal blanking waveform, the need of which has already been pointed out, is generated in a horizontal blocking-oscillator.

The desirability of independent phase-control, plus the demand for a side blanking pulse with relatively steep transitions, have made it desirable to include a separate blocking oscillator to supply this waveform. The pulse generated in the second blocking oscillator is applied to the first output video-amplifier where it inserts the blank into the composite video signal.

The vertical pulse used to gate the second burst amplifier is additionally applied to the video switch tube and also to the first output video-amplifier for the purpose of inserting vertical blanking.

6.4. *Sound decoding*

Figure 15 is a block diagram of the sound-decoding equipment required to reproduce the original audio signal without perceptible distortion.

The recovered coded-sound signal is taken from the frequency-modulation detector. At the input to the decoder, the bandwidth is restricted only by the characteristics of the tuned circuits preceding the detector.

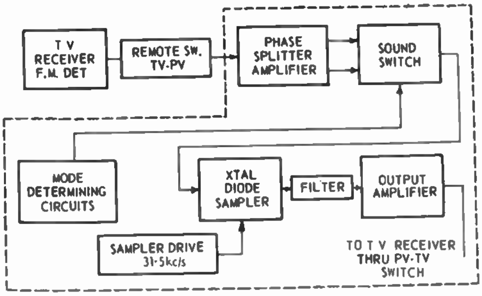

Fig. 15.—Block diagram of the sound decoder.

Equal outputs of opposing polarities are taken from the phase-splitter amplifier to the sound switch through the necessary coupling and balancing networks. As described in connection with sound coding, provision has been made to transmit the very-low-frequency components of the coded-audio signal by means of an auxiliary subcarrier. Therefore, all couplings to and from the phase splitter are of the capacitor-resistor type. This results in elimination of any unidirectional or d.c. output from the second detector as a result of intercarrier frequency-drift or frequency-modulation detector misalignment.

Selection of the proper one of the two phases from the phase-splitting amplifier is made by the sound switch under the control of the mode determining circuits. The output of the mode determining circuits follows the same transitions as the sound and picture-coding signal in the transmitter coding equipment.

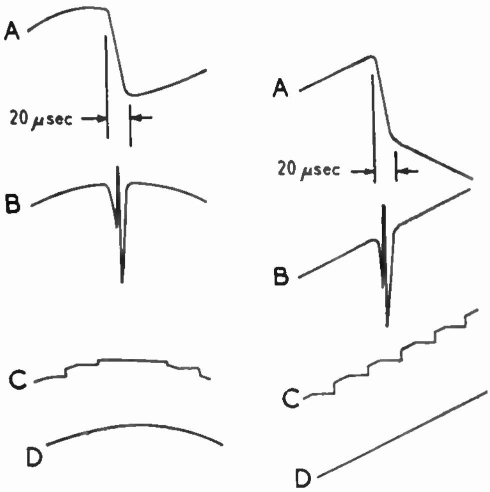

Fig. 16.—Two sets of waveforms prior to and afte decoding, after sampling, and after filtering.

Although the transition at the coder from one phase to the other can be made within two or three microseconds, a transient or spike of 20 microseconds maximum duration can result from the finite rise-time characteristics o transmission of the coded sound through limited-bandwidth circuits. Fig. 16 (a) illustrates a portion of the received coded signal prior t decoding and Fig. 16 (b) shows the result afte decoding.

To eliminate both the transient produced b the switch tube and the spike caused by banc limitation, a sampling technique is used whicl is similar to that at the transmitter, except fo the rate and duration of the relative conductin and non-conducting intervals.

The decoder sampler operates at a frequenc of 31·5 kc/s, or twice line-scanning rate, with conducting interval of one-third of a cycle o 10 microseconds, and with a non-conducting o "dwell-time" of two-thirds of a cycle or 2 microseconds. The output of the decode sampler is shown in Fig. 16 (c).

The sampler is followed by a low-pass m-derived filter. The output of the filter, which transmits all frequencies up to 15 kc/s, contains no evidence of the sampling action, as is shown in Fig. 16 (d). This unusually rapid cut-off characteristic is necessary, because the sampling is a modulation process which produces sum and difference frequencies of the input audio and sampling signals. The sampling frequency is suppressed or balanced out and does not appear in the output audio of the sampler, when an input signal is not present.

As an example, consider the input to the sampler to be a frequency of 14 kc/s. The sum frequency generated by the sampler is 14+31·5=45·5 kc/s, which would not contribute to the audible distortion of the tone. The difference frequency, 31·5 – 14=17·5 kc/s, would provide a measurable distortion component. If subsequent amplifiers should cause intermodulation distortion, it could result in a remodulation frequency of 17·5 – 14=3·5 kc/s, which is an easily audible tone.

Since the first-order difference-frequencies are eliminated by the filter, and thereby the possibility of subsequent remodulation, only the audio frequency spectrum signals are available at the output of the filter. The standard 75 μ sec. de-emphasis circuit follows the filter.

The difficulty encountered in transmitting the very-low-frequencies generated during the coding process, and a means for sending these by-products as an auxiliary signal, have been discussed in connection with sound coding. The method used to recover these components is best explained by means of a particular example, from which the general explanation will become obvious. Consider again the extreme case of a 500 c/s tone coded by a synchronous square wave phased to produce the maximum d.c. component. (See Fig 17a).

The dotted curves show the signal in the absence of the subcarrier. The d.c.-subcarrier modulator produces a continuous 31·5 kc/s signal of such amplitude that the resulting average value at the output of the coder mixer is zero, as illustrated.

At the output of the sound switch the signal appears as in Fig. 17 (b), and the enlarged section "Q", assuming ideal switching, shows that the phase of the 31·5 kc/s sub-carrier has been reversed. The dotted curve again shows the signal if the subcarrier were absent. Since the decoder sampler, operating at a regular rate of 31·5 kc/s. maintains the original phase, the sampled portion of the signal switches from the positive to the negative peaks of the subcarrier, thereby automatically reinserting the required square wave at this point to provide substantially distortionless decoding. In a similar manner, the other low-frequency components are re-introduced by the sampler.

An output amplifier follows the filter and de-emphasis network and is preceded by an adjustable gain-control in order to provide appropriate output-levels for various receivers.

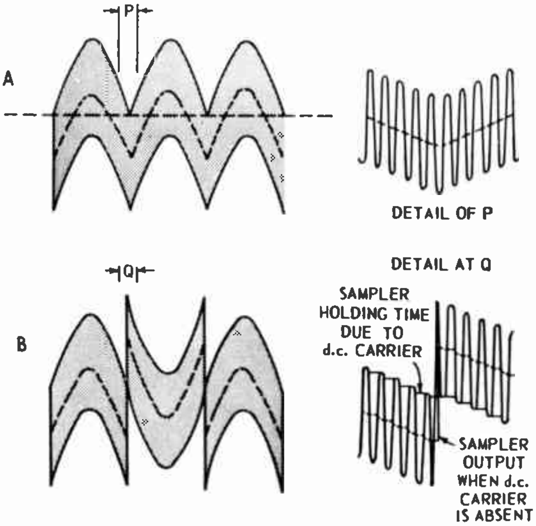

Fig. 17.—Coded and decoded sound with d.c. subcarrier.

7. Conclusion

It is evident that overseas television urgently needs an additional source of revenue to allow it to function economically and to expand to its fullest scope. The subscription or home box-office method appears the most logical way to acquire this extra income. In Australia in particular it would seem to be the only way in which television can be brought to areas beyond the capital cities.

The problems involved in providing a practical operating system have been completely solved in the Phonevision method of subscription television, in which electronic coding of both picture and sound prevents unauthorized reception of premium programmes, yet reserves to the subscriber the right to select either these or non-toll programmes as he wishes.

MIDDLESEX CONFERENCE ON ADVANCED TECHNOLOGY

Over one hundred representatives of industry and education, including the Institution's Education Officer, recently attended a Conference on Advanced Technology held by the Middlesex County Council.

Dr. Willis Jackson, F.R.S., the Director of Research and Education, Metropolitan-Vickers Electrical Company Limited, addressed the conference on "Industrial Applications of Nuclear Energy," emphasizing that the rate of development was not sufficiently fast to cover the "fuel gap." Dr. Jackson stated that the only limiting factor to this development was the supply of suitably qualified technologists.

The Chief Education Officer for Middlesex, Dr. C. E. Gurr, then discussed the provision of technological education in the county, particularly referring to the increasing population (now over two million) and the growth of the engineering industry. He stated that there were eight technical colleges in Middlesex which provided courses in advanced technology; three new colleges were planned, and in addition, the White Paper on technical education had made special mention of Acton Technical College where it was intended that the proportion of advanced work should be greatly increased. The Middlesex County Council was also hoping that other colleges, e.g. Southall and Enfield, would be able to extend their advanced courses.

The County was at present spending some £1·5 million on extensions to colleges, and the expenditure of a further £340,000 had been approved; it was estimated that the cost of the colleges planned for Harrow, Uxbridge, and Southgate would be in excess of £1·5 million.

Lastly, Mr. A. L. Stuchbery, Chief Technical Engineer to the Metal Box Co. Ltd., spoke on "Automation—Some of the Human Problems." He pointed out that automation, which he defined as "mechanization squared," had been in use ever since the Industrial Revolution, and was the natural development of mechanization. For example, there had been automation in the printing of newspapers since 1850. Another important point was that, out of a working population of 23 million, it was doubtful whether more than two million people would be affected by automation. Contrary to the belief that less people would be employed as a result in the manufacturing industries, it was found that automation brought with it an increase in the number of persons employed, though of a different type and category.

The Conference ended with a general discussion which indicated the very keen interest taken by local industry in the problems of technical education. One of the first subjects raised was that of sandwich courses, and of the most desirable length for the alternate periods of works and college training which make up these courses. The White Paper had suggested periods of six months, but colleges in the area had operated courses with alternate periods of two months; it had been found that this period gave greater continuity at works and college and also fitted in with the general curriculum of the colleges. There was a need to maintain the connection between the apprentice and the technical college either by evening class attendance during works training, or by making the alternate periods shorter; a period of only one week had been tried successfully by some colleges in other parts of the country.

There was also a definite need for the colleges to provide short courses for the mature and experienced technician and craftsman, to enable him to take his place in the developing field of automation.

All industrialists seemed to agree that there was an apparent drop in the standards of technical college and university students. In replying to this point, Dr. Gurr said that, although war-time conditions might be partly responsible, throughout the ages one generation had always criticized the moral and educational attainments of the next, and he felt that the loss of standard was not very real. The technique of teaching had now changed, and it was no longer the policy to cram factual information into children, but rather to teach them to be useful citizens, to think and to use their brains.

There was also some discussion on the development of regional technological education, and the consequent abolition of fees paid to other Councils for the training of students who wished to study outside their own county. A number of speakers appealed for an ending of the system whereby university grants were not available for the professional man, due to the imposition of what might be referred to as a "means test."

JOURNAL OF THE BRITISH INSTITUTION OF RADIO ENGINEERS

A METHOD OF DERIVING OVERALL NEGATIVE FEEDBACK VOLTAGE IN TRANSMITTERS *

by

D. Smart (Student) †

SUMMARY

The feedback voltage is derived from a resistor in the earth return of the power amplifier valve. The ease of frequency changing, greater linearity, reduced phase shift, drift, and cost of this system eliminate the disadvantages of conventional methods of deriving feedback voltage.

1. Introduction

It is an accepted fact in transmitter design procedure that Overall Negative Feedback, or as it is sometimes called, Envelope Feedback, can be used to obtain an improved performance or to cheapen a design for a given performance requirement. The main advantages to be gained are an improvement of the noise level, a reduction in harmonic distortion, and an improvement of the frequency response.

Most of the hum present in the output waveform of a transmitter is introduced by the power amplifier stage. By the use of push-pull output stages and negative feedback, modulators can be designed to have a very low noise level (> -60 db). No such easy remedy exists for the power amplifier stage, and the overall noise level is largely determined by the hum introduced by the power amplifier. Typical figures for overall noise levels are 45 db and 60 db below 100 per cent. modulation for communications and broadcast transmitters respectively.

In the power amplifier stage hum is introduced by the filament. Voltage hum due to the difference in potential across the filament can be minimized by centre-tapping the latter or its transformer. The main source of hum, however, is due to the magnetic field set up by the large filament current deflecting the electron beam within the valve. Means of overcoming this difficulty consist of using polyphase filament valves, not very easily obtainable, or using two valves in the power amplifier stage and outphasing their filament currents so that the hum modulation largely cancels out in the common load. Either of these expedients is expensive and solves only the noise level problems leaving distortion unaffected.

Insufficient emission on modulation peaks, insufficient r.f. grid drive and mismatching to the modulator, are all causes of distortion in the power amplifier. These effects can all be made small by careful design initially, but may be reintroduced as valves age, etc. Negative feedback affords a means of obtaining these results at the same time allowing for greater latitude in component tolerances.

The frequency response is affected by the power amplifier in so far as the tuned circuit of this stage introduces "sideband cutting," i.e. the higher modulating frequencies are attenuated due to too high a loaded Q of the tuned circuit. Also affecting the high frequency response is the effect of any r.f. decoupling capacitor in the anode circuit of the power amplifier. The foregoing points assume anode modulation, which is normally used in all except very high powered fixed frequency transmitters.

2. Disadvantages of Conventional System

The conventional way of deriving the feedback voltage is to rectify part of the modulated output by means of a linear detector. A tuned circuit inductively coupled to the tuned circuit of the power amplifier is necessary but introduces many disadvantages.

In broadcast transmitters where changes of carrier frequency are infrequent the added complication of having to retune an extra circuit is not great. However, the degree of non-linearity in the detector and the permissible amount of "sideband cutting" and consequent phase shift in the tuned circuit and coupling circuit to the detector are both very much

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† Formerly with Redifon, Ltd., London, S.W.18; now with Cinema-Television, Ltd., London, S.E.26.

U.D.C. No. 621.375.132:621.396.61.

reduced. This requires careful design of the feedback circuit.

In communications transmitters, frequent changes of frequency are necessary and the extra tuned circuits are a definite drawback. More than one tuned circuit is required to cover the large frequency ranges encountered. Thus some form of coil switching becomes necessary, adding to the cost of the transmitter.

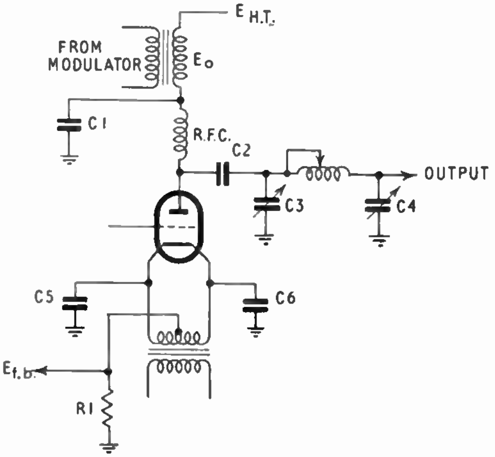


Fig. 1.—Circuit diagram of power amplifier.

The system to be described was tried by the author during an investigation into the noise level of some transmitters. Although very simple in principle it does not appear to have been used before.

3. Description of Circuit

As can be seen from Fig. 1 a resistor R1 is connected in series with the earth return lead of the power amplifier filament. Across it are developed a direct voltage due to the power amplifier mean anode current and an a.f. voltage due to the modulation plus hum etc. The r.f. current pulses are by-passed by C5 and C6. The a.f. voltage plus hum and noise is fed back to the modulator input. Note that no additional phase reversal occurs at the power amplifier. The d.c. component of the feedback voltage can be blocked by a capacitor or, if balanced feedback is required, transformer coupling could be used. If direct coupling is deemed necessary, i.e. for minimum phase shift in the feedback loop, the d.c. component could be used for biasing purposes if cathode injection of the feedback into the modulator chain is employed. In this way the required number of components is reduced to a minimum.

The advantages of this system over the orthodox detector system are apparent.

(*a*) It avoids the complication and expense of tuned circuits coupled to the anode tuned circuit.

(*b*) By avoiding the need for a detector it introduces no additional non-linearity into the feedback voltage. It is, furthermore, free from drifts such as would be caused by ageing of valves.

(*c*) The absence of tuned circuits in the feedback loop eliminates this source of phase shift and allows a larger degree of feedback to be applied for the same degree of stability.

(*d*) It does not require re-tuning every time the transmitter frequency is changed.

(*e*) It is far easier to calculate the feedback factor since coupled circuits and diode efficiencies are not involved.

4. Analysis of Circuit

A simple approximate method is to consider the power amplifier as a resistor: $R_L = E_{HT}/I_{DC}$ We can see that the circuit then becomes, as far as the modulator is concerned, a simple negative current feedback circuit, in which the feedback voltage is developed across a resistor in series with the load. The analysis of this circuit can therefore be carried out as follows:

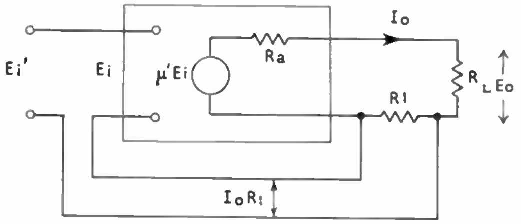


Fig. 2.—Schematic of modulator and feedback loop.

Referring to Fig. 2

Gain without feedback $= A = E_0/E_i$,

Gain with feedback $= A' = E_0/E_i'$.

By definition,

feedback factor $= A/A'$, or 20 log (A/A') db

$$\text{Hence, feedback factor} = \frac{A}{A'} = \frac{E_i'}{E_i} = \frac{E_i + I_0R_1}{E_i}$$

$$\text{since } E'_i = E_i + I_0R_1 \ldots\ldots\ldots\ldots (1)$$

$$\text{i.e. feedback factor} = 1 + \frac{\dfrac{E_0}{R_L} \cdot R_1}{E_i}$$

$$= 1 + A \cdot \frac{R_1}{R_L} \qquad \ldots\ldots\ldots(2)$$

Defining $\frac{R}{R_L} = -\beta$, we have $A/A' = 1 - A\beta$ ...(3)

R1 can be calculated as follows:—

Let us assume a transmitter of 2 kw output power, with an efficiency, η, of 75 per cent.:

$$\text{Then } P_{\text{in}} = P_{\text{out}} + P_{\text{anode}} \text{ or } P_{\text{out}} \times \frac{1}{\eta}$$

$$P_{\text{in}} = 2000 \times \frac{4}{3} = 2660 \text{ watts}$$

Assuming $E_{HT} = 4000$ volts,

$$\text{then } I_{DC} = \frac{2660}{4000} = 660 \text{ mA}$$

$$\text{and } R_L = \frac{4000}{660} \times 10^3 \simeq 6000 \text{ ohms}$$

A typical a.f. sensitivity figure is 200 mV for 100 per cent. modulation. The gain should therefore equal $4000 \times 10^3/200 = 20 \times 10^3$. However, if it is desired to have up to say 20 db of feedback, then the gain must be made 200×10^3 so that the sensitivity is 20 mV for 100 per cent. modulation.

$$\text{Since } 20 \log (A/A') = 20$$

$$A/A' = 10$$

From equation (2)

$$10 = 1 + \frac{R_1}{6000} \cdot 200 \times 10^3$$

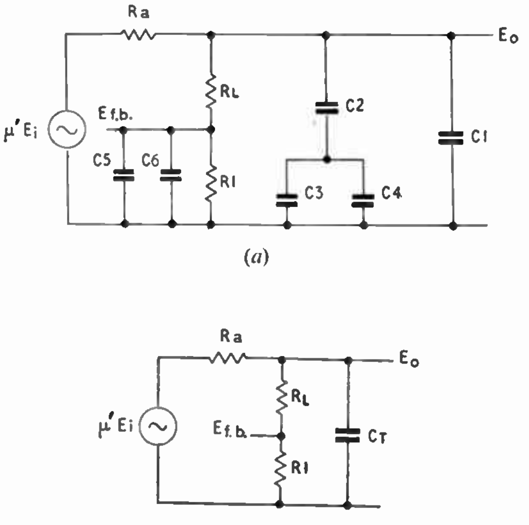
$$\text{Hence } R_1 = \frac{9 \times 6 \times 10^3}{200 \times 10^3} = 0{\cdot}27 \text{ ohms.}$$

The feedback voltage therefore equals

$$4000 \times \frac{0{\cdot}27}{6000} = 0{\cdot}18 \text{ volts.}$$

The above system was tried on transmitters with carrier frequencies ranging from 500 kc/s to 50 Mc/s and in every case proved entirely satisfactory.

Figures 3 (a) and (b) show the modulator equivalent circuit. The effect of C2, C3 and C4 is usually negligible compared to C1, but can be taken into account by suitably modifying C1 to C_T. The effect of C5 and C6 can be neglected as their reactance is large compared with R1, since it has been shown that a typical value of R1 is smaller than one ohm.



(*a*)

(*b*)

Fig. 3.—*(a) Equivalent circuit of modulator;*
(b) Simplified equivalent circuit at audio frequency.

It can thus be seen that E_{fb} is always in phase with E_0, i.e. no additional phase shift is introduced by the feedback path.

5. Conclusion

In all the cases tried, the transmitter had not been designed for feedback. The available gain in hand was therefore limited in most cases to about 6 db and this in turn limited the amount of feedback which could be applied. It was found however, that 6 db of feedback improved the noise level by this amount and reduced harmonic distortion by 50 per cent.

It would appear therefore, that if the necessity of using negative feedback was realized during the initial design, then far greater feedback factors could be employed and a greatly improved performance obtained without great difficulty.

APPLICANTS FOR MEMBERSHIP

New proposals were considered by the Membership Committee at a meeting held on March 27th, 1956, as follows: 29 proposals for direct election to Graduateship or higher grade of membership, and 41 proposals for transfer to Graduateship or higher grade of membership. In addition, 52 applications for Studentship registration were considered. This list also contains the names of seven applicants who have subsequently agreed to accept lower grades than those for which they originally applied.

The following are the names of those who have been properly proposed and appear qualified. In accordance with a resolution of Council and in the absence of any objections being lodged, these elections will be confirmed 14 days from the date of the circulation of this list. Any objections received will be submitted to the next meeting of the Council with whom the final decision rests.

Direct Election to Member

PEARD, Rear Admiral Kenyon Harry Terrell, R.N., C.B.E. *Woking.*
WIKKENHAUSER, Gustav, M.B.E. *Chigwell.*

Transfer from Associate Member to Member

WEBSTER, Edmund Ernest. *Ilford.*

Direct Election to Associate Member

COOPER, William Percival, M.B.E. *Aspley Guise.*
NEILL, Stanley Francis Mundy. *Potters Bar.*
SAXENA, Flg. Off. Shiva Dass, M.Sc., I.A.F. *Bangalore.*
SINGH, Sqdn. Ldr. Karnail. *Delhi.*
TAN SOO YANG, B.Sc. *Singapore.*

Transfer from Associate to Associate Member

DAVID, Thekekara Pylunny. *Insein, Burma.*
EDDOWES, Lieut.-Com. Harry A. L., R.N., B.Sc. *H.M.S. Newcastle.*
HUME, Captain Cyril Robert, M.B.E., R.E.M.E. *Bushey.*
MORRIS, Lionel Alfred Dodsworth. *Pontypridd.*

Transfer from Graduate to Associate Member

BHATTACHARYA, Abani Bhushan, M.Sc. *Calcutta.*
BUTTERY, Peter Joseph. *Klemzig, South Australia.*
CHORLEY, Francis Kenneth. *London, S.W.20.*
DATE, Vishnu Purushottam, B.Sc. *Jubbulpore.*
GRAY, Bertram Charles. *Hitchin.*
GREEN, Sydney William. *Stanmore.*
JONES, Harry Major. *Boreham Wood.*
KOVACS, Albert Frank. *London, N.19.*
LOGAN, Donald James. *Wellington, New Zealand.*

Transfer from Student to Associate Member

SASTRY, Kuruganti Venkateswara, B.A. *Madras.*
TALWALKAR, Krishnaji Balbhim. *Poona.*

Direct Election to Associate

DOUBELL, Lional Joseph. *London, S.W.19.*
HAYNES, Reginald Albert. *Garston, Herts.*
LIPSCHITZ, Gerhard Gad. *Haifa.*
PETERS, Hugh. *Bletchley.*
SELBY, Ronald. *London, S.W.12.*

Transfer from Student to Associate

CURTIS, Norman Ralph. *Bolden Colliery, Co. Durham.*

Direct Election to Graduate

BEWLEY, William. *High Wycombe.*
BROWN, Derek John Lee. *Liverpool.*
CRONIN, Thomas Francis. *London, S.E.18.*
EAGLESTONE, Reginald Fredrick. *London, S.E.14.*
HALLIWELL, Roy. *Yelverton.*
HINCHLIFFE, Philip. *Weston-Super-Mare.*
HURRELL, Frank Arthur. *Shoreham-by-Sea.*
LENT, Stuart James. *Tadworth.*
ROSENTHAL, Myron Martin, B.E. *Massapequa, New York.*
SALMON, Lieut. Christopher Leonard, R.N. *Malta, G.C.*
THURLOW, Anthony Lawrence. *Rayleigh.*
VOYSEY, Martin. *Ingatestone.*
WALKER, Ronald Slee. *Urmston.*
WILLETTS, Flt. Lt. Walter John, R.A.F. *Cyprus.*

Transfer from Student to Graduate

ADUR, Mohanrao Narayanrao. *Bombay.*
BRAUN, Simon. *Haifa.*
CHANDRA DUTT, Govindan, B.Sc. *Trivandrum.*
FARNWORTH, Geoffrey. *Cambridge.*
GRAHAME, Jackson. *Lusaka.*
GREGORY, Frederick Robert. *Newport, Mon.*
HALL, Capt. Wilfred Francis, R.E.M.E. *Crowthorne.*
HATTANGADI, Bansidhar Srinivas. *Gwalior.*
KUNJUVAREED, V. V., B.Sc.(Hons.) *Madras.*
MAHLAB, Ezra Salim. *Jerusalem.*
MARTIN, Arthur William. *London, N.4.*
SMITH, David Trevor, B.Sc. *Fleet.*
ZAFIROPOULOS, Peter. *Athens.*

STUDENTSHIP REGISTRATIONS

ADAMS, Terrance George Frederick, B.Sc. *Ruislip.*
ALLEN, George. *Plymouth.*
ASLAND, Greggar. *Bergen.*
BARBER, Anthony Richard. *Great Yarmouth.*
BARTOLO, Anthony J. *Malta, G.C.*
BAWA, Murari Lal, B.A. *Rohtak, Punjab.*
BOWN, Kenneth Albert. *London, N.2.*
BROADBENT, Kimball Scott. *Durban.*
BRONSTEIN, David. *Tel-Aviv.*
BROOKER, William Harry George. *Stevenage.*
CHADDA, Santosh Kumar, M.Sc., B.Sc. *Hardwar.*
CHANDRA, Jagdish. *London, W.C.2.*
CHATURVEDI, Naresh Chandra. *New Delhi.*
COLLINS, James Edward. *Barking.*
DAVIES, Jeffrey Nash. *Port Talbot.*
DORMAND, Keith. *Jersey.*
DU BARRY, James Joseph. *Dun Laoghaire, Eire.*
ELLIOTT, David. *Belper.*
GARDIKIS, Dimitrios. *Athens.*
GAZI, Yusuf Ahmet. *London, N.W.1.*
GILL, Ujagar Sing. *Singapore.*
HAIGH, Fred Ellison. *Grangemouth.*
HILL, Valentine Benjamin. *Newcastle-on-Tyne.*
HO CHUN FAI. *London, S.W.1.*
JAYAN, Kutty N. K. *Bombay.*
JESSANI, Mohan Choithram. *London, N.W.4.*
KARAMANOLIS, Ch. *Mitylene.*
KERWOOD, Mrs. Dilys Joyce. *Coventry.*
KING, John. *Ilford.*
KIRWAN, Patrick Noel. *Portstewart, Northern Ireland.*
KLIKOWICZ, Eugeniusz. *London, S.W.4.*
KOLLIOS, Spiros. *Corinthias.*
KOZIELEK, Charles. *London, N.16.*
LJONE, Olav. *London, S.W.1.*
LYSONS, John Michael Charles. *Chelmsford.*
McALLISTER, John Smillie. *London, W.5.*
McGREGOR, Donald Malcolm William. *London, W.7.*
MANOHAR LAL. London, *W.1.*
MEDROW, David Graham. *Staines.*
MITRA, Gobinda Lal. *Bangalore.*
NARAYANA MENON, Pottekkat. *Kottakal.*
OSBORN, James Phillip. *Carshalton, Surrey.*
PARSONS, Ronald. *London, S.E.2.*
PATTABIRAMAN, A. K. *Madras.*
PRAHALLADA RAO, B.S., B.Sc. *Bombay.*
PURI, Inder Krishnan, B.A., B.Sc.(Eng.). *Dortmund.*
RAINA, Santosh. *Nasik.*
RICHARDS, Kenneth John. *London, S.E.20.*
SERELEAS, Christos. *Athens.*
SHARMA, Kuldip Kumar. *Delhi.*
TARAK NATH MISRA, B.Sc. *Calcutta.*
YADAVA, Dalvir Singh. *Bangalore.*

TELEVISION BROADCASTING IN BAND III

I.T.A. Northern Region

The coverage map at the foot of the page shows approximately the areas in which reception of signals from the Independent Television Authority's television transmitters at Winter Hill and Emley Moor will be possible when these transmitters come into operation. It is expected that the Winter Hill transmitter will begin sending out programmes early in May 1956, followed by the Emley Moor transmitter in the late Autumn of 1956. Winter Hill will operate on Channel 9 and Emley Moor on Channel 10.

Most viewers in the primary service areas, shown as the inner unshaded zone, unless situated in specially unfavourable positions, will receive a satisfactory service. Within the shaded zones (secondary service areas) a substantial proportion of viewers will receive a satisfactory service, but there will be some local areas in which reception conditions will be poor. Outside the shaded zones, some favourably situated viewers will be able to obtain a reasonable service. In the central Pennine area, covering will be "patchy" and some places may have poor reception from one or both transmitters.

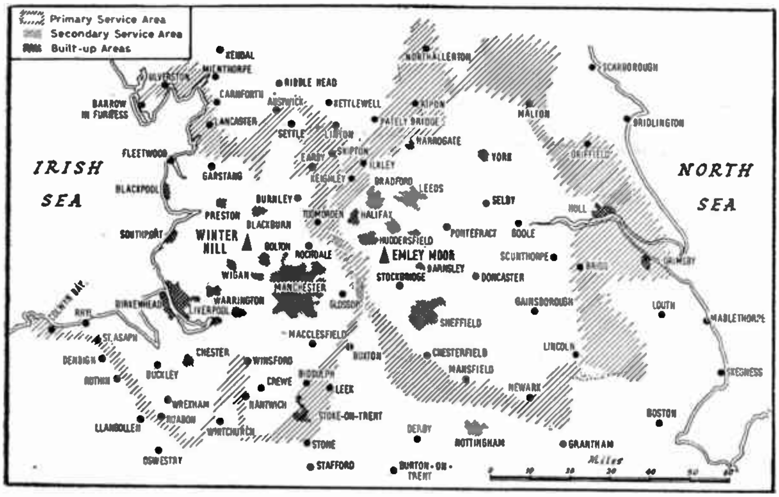
The population in the Northern Region is estimated as follows:

	Winter Hill	Emley Moor
Primary Service Area ..	6.55 m.	4.27 m.
Secondary Service Area ..	0.66 m.	0.65 m.
Total	7.21 m.	4.92 m.

The Winter Hill transmitter will have an effective radiated power of 100 kilowatts (approximately) and signals will be transmitted from a 16-stack high-gain omnidirectional aerial which will be carried on a 445-foot self-supporting tower. Work on levelling the site and excavating the foundations for the transmitter building and tower began in August 1955, and the technical section of the building is almost complete and the tower has been erected. Installation of the equipment and erection of the aerial system and domestic section of the building remain to be done, but completion of this last item mentioned will not affect the opening date.

The Emley Moor transmitter will have an effective radiated power of 200 kilowatts (approximately) maximum, transmitted from a 16-stack high-gain directional aerial which will be carried on a 445-foot self-supporting tower. This directional aerial has a semi-circular radiation pattern which will transmit maximum power in an easterly direction; the area covered thus extends about seventy miles to the East but only some ten miles to the West, so that overlapping of the service area with that of the Winter Hill transmitter is minimized. The site for the Emley Moor transmitter has been acquired and planning approval obtained, and the I.T.A. has received formal permission from the Postmaster-General to construct the transmitter there. Work on the site began early in April.

As was the case at the I.T.A. transmitters in



I.T.A. Northern Region Coverage Map

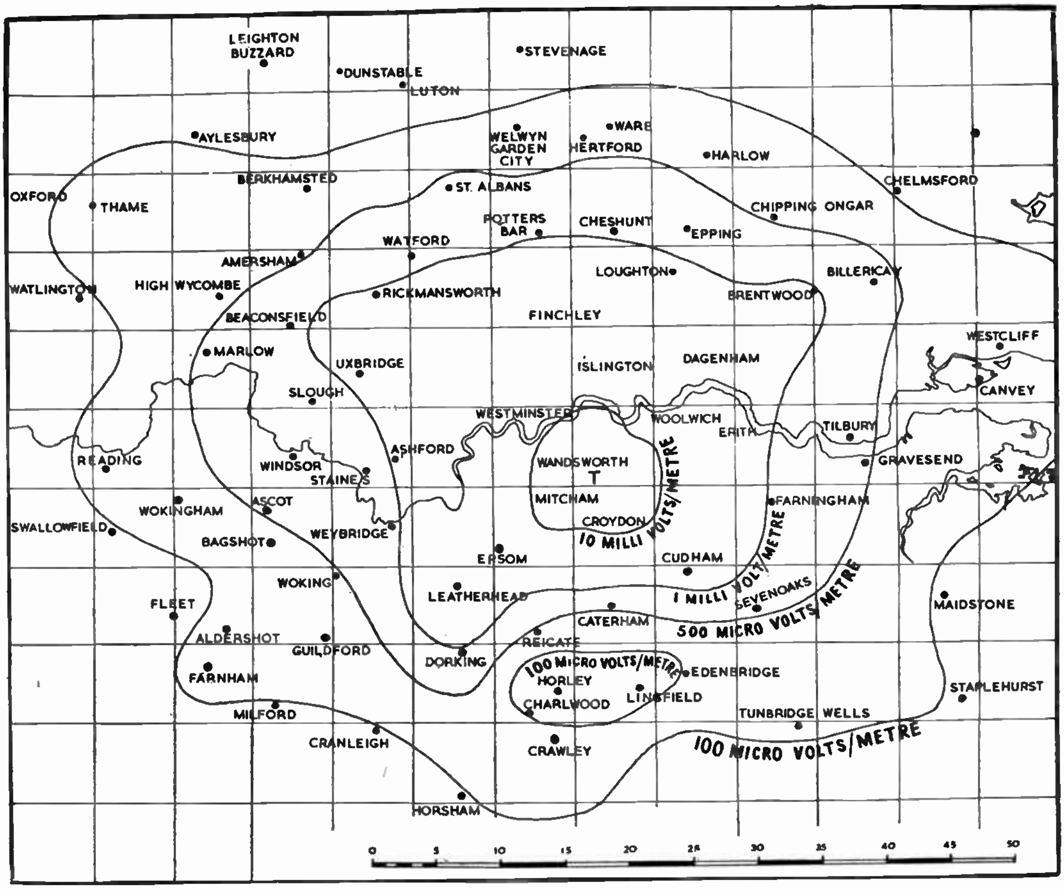
Lancashire—Channel 9

Frequencies	Vision 194·75 Mc/s
	Sound 191·25 Mc/s
E.R.P.	100 kW.
Site Height	1,450 ft. a.s.l.
Mean Aerial Height	1,850 ft. a.s.l.

Yorkshire—Channel 10

Frequencies	Vision 199·75 Mc/s
	Sound 196·25 Mc/s
E.R.P.	200 kW. (directional)
Site Height	850 ft. a.s.l.
Mean Aerial Height	1,250 ft. a.s.l.

Aerial Inputs:	Vision 7½ - 10 kW
	Sound 2·5 kW



Field strength map for the I.T.A. transmitter at Beulah Hill.

London and the Midlands, test transmissions on low power are being radiated from the Winter Hill site and it is hoped to arrange similar transmissions from Emley Moor in due course.

London Area Coverage

Following a six-month survey, the first detailed field strength map of the I.T.A. London transmitter has now been published (see above). The map differs very little in general outline from the original forecast by the Authority, referred to in the *Journal* for March 1955, page 153. The contours on the map are for the vision carrier (194·75 Mc/s in Channel 9) modulated with the test card and based on an effective radiated power from the transmitter at Beulah Hill of 60 kW. Over five thousand observations were taken with field strength measuring sets using a dipole aerial at a height of two wavelengths. Sound carrier measurements were also taken and these follow closely the pattern of the vision curves. Local variations are not shown.

It is now understood that the London station of the I.T.A. will not move to Crystal Palace next year as had been planned, but will remain at Croydon indefinitely. This is a result of the Government's instructions to cut capital expenditure. Consequently, the I.T.A. is going ahead with the installation of the second transmitter of the pair at Croydon, and hopes to achieve synchronized operation of the two units by mid-summer, thus increasing the power of the station to 120 kW e.r.p.

JOURNAL OF THE BRITISH INSTITUTION OF RADIO ENGINEERS

AUTOMATIC CONTROL OF POWER EQUIPMENT FOR TELECOMMUNICATIONS AND OTHER ESSENTIAL SERVICES*

by

A. Watkins (Associate)†

SUMMARY

Two types of no-break generating sets are described: an all-electric battery operated equipment, and a diesel electric equipment. Detailed descriptions are given of three electronic devices used with these sets: (a) a static exciter automatic voltage regulator making use of two saturated transductors; (b) an alternator synchronizer in which the generator and mains voltages are compared in a triode circuit; (c) speed regulator using a thyratron which feeds the control field of the d.c. motor and also incorporates alarm and protection devices.

1. Introduction

In general most consumers draw a reliable source of a.c. power from a public supply, but this may not be the case in all situations; furthermore, where vital services are to be provided it is necessary to have an alternative supply during public supply failure, or for occasions when the public supply frequency and voltage deviate beyond prescribed limits.

In the field of communications, the failure of supply to a transmitting or repeater station, even for a very short period, will lead to serious inconvenience to the users of the system. A repeater station carrying teleprinter lines, or links with the armed services, will be interrupted with the consequent loss of what may be vital information, while often the traffic handled by the postal and telegraph authorities, both at home and overseas, is so heavy that time is at a premium and breaks, however short, are expensive. The power engineer has therefore been called upon to provide suitable equipment for eliminating these undesirable breaks in a.c. supplies and the continuity or no-break generating set can be designed to meet these requirements, whether based in attended or unattended situations. There are a number of ways of tackling this problem, but to assist in the operation of such sets, three electronic devices have been developed, namely, a static exciter automatic voltage regulator, and electronic speed regulator, and an electronic alternator synchronizer.

This paper describes how these devices have been used in connection with two types of no-break generating sets.

2. All-Electric Battery-Operated No-Break Set

Where it is essential that a continuous a.c. supply should be made available for special telecommunication work in a telephone exchange or repeater station, it is generally found that the stations are equipped with a large battery system. This battery system can quite often be utilized to provide the stand-by power in the event of public supply failure.

The all-electric battery-operated sets consist essentially of an a.c. motor, an alternator and exciter, a d.c. motor/generator and tachometer for speed reference. Under normal circumstances, the set is driven by the a.c. motor from the public supply system; and if the public supply fails, the d.c. machine drives the alternator set from the station battery. The alternator feeds the essential load. One such scheme is shown in Fig. 1.

The supply contactor "A" connects the a.c. slip ring motor to the public supply. This remains closed while the public supply remains or does not deviate outside the limits of voltage

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U.D.C. No. 621.317.718/22/20:621.396.68—833/5.

and frequency tolerance laid down by the requirements of the system. The mains failure detection equipment comprises two contact frequency meters with high and low contacts, set, for example, at 52 and 47 c/s, also a contact voltmeter with high and low contacts, set for example at +6 per cent. and −12 per cent. on the main supply voltage. If the public supply frequency or voltage exceeds the limits given, or if the public supply fails altogether, this mains failure detection equipment opens the contactor "A" and disconnects the a.c. motor. The armature contactor "B" connects the armature of the d.c. motor to the stand-by battery immediately contactor "A" is opened, so that on public supply failure the d.c. motor takes over the drive to the alternator to provide an uninterrupted alternator output which supplies the essential load via a load contactor "C." The d.c. motor has two field windings, X1 and X2. X1 is connected permanently to the stand-by battery, X2 is supplied by the output of the electronic speed regulator. The ampere-turns on these field windings are opposed to one another, i.e. X1 provides full excitation for the lowest speed of the d.c. motor with the highest battery voltage and X2 provides the necessary opposing ampere-turns for field weakening, to give the highest speed required with the lowest battery voltage. The fly-wheel is designed to maintain the speed of the set during the period of transfer from a.c. to d.c. drive and vice versa. During the transfer period, which takes place in ⅓ sec., the voltage and frequency do not fall by more than 2 per cent. A tachometer provides the speed reference for the electronic speed regulator which is shown in Fig. 10. The field winding on the alternator is supplied from a static exciter automatic voltage regulator of the transductor type which is shown in Fig. 5. When the public supply is restored and the mains failure detection equipment cleared, the contactor "B" disconnects the d.c. machine from the battery and reconnects the a.c. motor to the public supply. At the same time, the electronic speed regulator reverts to a stand-by condition in readiness for the next changeover.

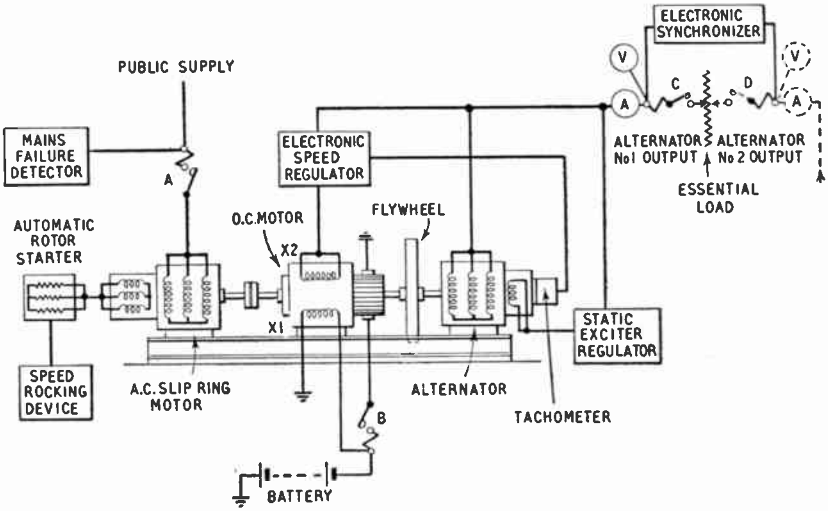

Fig. 1. All-electric battery-operated no-break set.

Where duplicate alternator sets are used, it is possible to transfer from No. 1 set to No. 2 set without interrupting the output to the essential load. This is achieved by automatic paralleling of the two alternators. For this purpose, an electronic alternator synchronizer is used. This is shown in Fig. 7. The duplicate alternator set is connected to the essential load via contactor "D." In order that the speed of the two sets being parallelled can be adjusted, the automatic rotor starter, which is normally used for initial starting of the combined set, is controlled by a speed rocking device. The set being brought into service, i.e., in this case No. 2, is started up via the automatic rotor starter on the a.c. motor and a reference of frequency and voltage is taken into the electronic alternator synchronizer from No. 1 and No. 2 alternators. Since the alternators are provided with automatic voltage regulators, the voltages will be matched. The speed of the sets, however, may differ, since the No. 1 alternator set will be on load, and due to the slip speed of the a.c. motor will be generating a frequency 2 to 3 per cent. lower than alternator set No. 2 which is at present off load. The speed rocking device on alternator set No. 1 inserts a small amount of resistance from the automatic rotor starter into the rotor circuit of the slip ring motor until the speeds and hence the frequencies of the two sets are matched. The electronic alternator synchronizer is used to detect this condition and will then automatically close contactor "D" on to the essential load. Alternator set No. 1 can then be taken out of circuit by opening contactor "C" and closing down the set. The supply, therefore, to the essential load has been transferred from one set to the other without interruption.

Figure 2 shows the control switchboard for a station with two motor alternator sets, the board comprising three panels. The two panels on the left are for the starting and control of the sets, and the third panel containing the automatic equipment is required for the transfer of the alternator drive between the a.c. supply and the station battery. The two electronic speed regulators (left) and the synchronizer (right) are shown fitted into the bottom hinged front panels of the switchboard. The speed regulators and synchronizer can be withdrawn and are fitted with plug and socket connection. They are shown in closer detail in Fig. 10 and Fig. 9 respectively.

3. Diesel Electric No-Break Stand-By Set

The Diesel electric no-break set is normally used where no mains supplies are available. These plants can be of the duplicate engine fly-wheel alternator type and are arranged so that all maintenance can be carried out without interrupting the service. In this type of automatic generating plant, the engines are automatically arranged to change over duty once a week. This is effected by a sequential timing device incorporated in the control cubicle. Changeover is achieved by clutching the stationary engine to the running set, the duty engine being maintained in operation until the incoming engine takes over to drive the alternator. The control gear is built into one floor-mounted cabinet and includes all the necessary control gear for automatic change-over, including the engine control relays, static exciter automatic voltage regulator and alarm indicator lamps. Arrangements are provided to enable the alarm indicator lamps to be extended to the base station so that constant remote checks can be made of the performance of the plant.

There are a number of alternative arrangements for the Diesel electric set, but in order to give a fairly concise explanation of the operation of one such set, details of the simple stand-by no-break Diesel electric set will be described. This type of set is brought into service under conditions of mains failure.

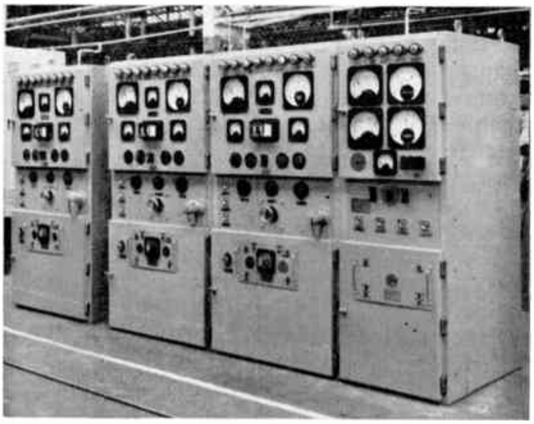

Fig. 2. Arrangement of control panels for all-electric set.

Normally the telecommunication or other vital service is fed from the mains supply and under conditions of mains failure from the Diesel driven alternator set. During normal conditions the a.c. mains supplies power direct to the essential load, the alternator operating as a synchronous motor driving a fly-wheel, with the Diesel engine stationary. Under mains failure conditions the alternator is driven by the Diesel engine to supply power to the load. On restoration of the normal supply mains, the alternator synchronizes automatically with these mains, the Diesel engine is disconnected, and the alternator operates as a synchronous motor. This type of set is shown in Fig. 3.

The essential load is fed from the public supply via the supply contactor "A" so long as the public supply remains within the tolerances laid down in the requirements of the load. The mains failure detection equipment is used to meter the public supply voltage and frequency. An alternator/synchronous induction motor normally runs at synchronous speed, maintaining a fly-wheel. This machine is initially started up via the automatic rotor starter with sequence timed contactors and brings the fly-wheel up to speed with itself. A static exciter automatic regulator provides the necessary excitation for this machine. If the public supply fails, the high speed supply contactor "A" disconnects the machine and load from the public supply. Immediately this happens, the reverse power relay, which normally carries the motoring current for the machine, reverses, since the essential load is still connected to the machine. The reverse power relay has a pair of contacts which initiate a changeover in the static exciter automatic regulator so that the machine is controlled as an alternator with automatic voltage control.

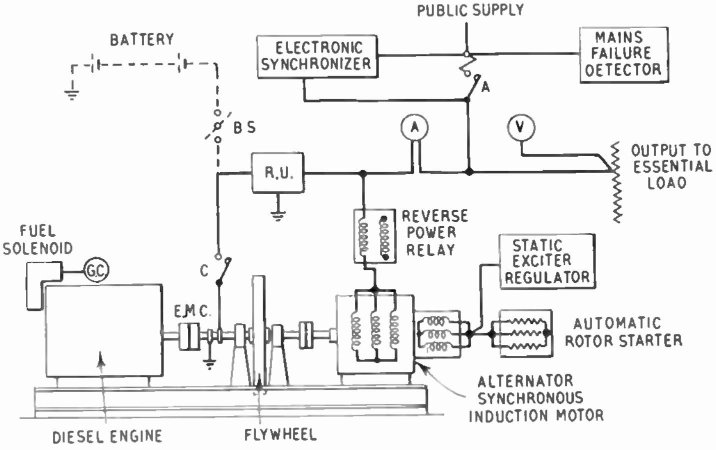

Fig. 3. Diesel electric no-break stand-by set.

The contactor "C" closes the electro-magnetic clutch EMC, opens the fuel solenoid FS and engages the Diesel engine. The flywheel has been designed so that it has enough stored energy to bring the Diesel engine up to speed and also maintain the drive to the alternator so that the speed does not fall more than 10 per cent. during the changeover. The Diesel engine governor control, GC, is set so that the variation in speed due to load changes on the alternator is not more than 2 per cent., which represents an alternator frequency of one cycle per second in 50 c/s.

The rectifier unit RU supplies the operating coils on all the contactors and the winding on the electro-magnetic clutch, which are normally 24V. The a.c. supply for the rectifier unit is connected to the same point as the supply to the essential load so that this is maintained also. When the public supply is restored and the mains failure detection equipment cleared, the electronic alternator synchronizer is connected to the alternator output on one side and the public supply on the other, taking a reference of voltage and frequency from both sides of the main contactor "A." The electronic alternator synchronizer is arranged so that it will accept voltages within the tolerances set down by the mains failure detection equipment and the static exciter automatic voltage regulator, controlling the alternator voltage. The frequency of the alternator is controlled automatically by the Diesel engine governor control GC and fuel solenoid FS. The governor control motor is brought into operation immediately the public supply is restored and proceeds to rock the speed of the Diesel engine with a cycling time of 3 minutes, giving a corresponding change in alternator frequency. The electronic alternator synchronizer has a delay switch incorporated so that it cannot synchronize the alternator on to the public supply in less than one minute. This is to ensure that the public supply has been restored with certainty. However, as soon as this time delay has elapsed and the Diesel speed has been rocked to give an alternator frequency corresponding to that of the public supply, the electronic alternator synchronizer will reclose contactor "A" and open contactor "C," de-energizing the electro-magnetic clutch and closing the fuel solenoid. The Diesel engine is then shut off and comes to rest. The static exciter automatic voltage regulator is also reconnected as a straight excitation supply for the field of the alternator which now runs as a synchronous induction motor again. In case of emergency where it is required to start the set from rest without the public supply being available to use the equipment with automatic starting, a portable battery is connected via a switch BS so that the clutch contactor "C" can be closed and the electro-magnetic clutch energized. It is then possible to hand-start the engine from rest and bring the machine up as an alternator; the alternator will then generate a supply for the rectifier unit RU and essential load, and the battery can then be disconnected.

Figure 4 shows a 6·25 kVA Diesel electric stand-by no-break set complete; the cubicle contains the complete control gear with the electronic synchronizer at the top. The flywheel and electro-magnetic clutch are enclosed by the sheet metal guards. The motorized governor control and fuel solenoid is visible above the sheet metal guard enclosing the clutch.

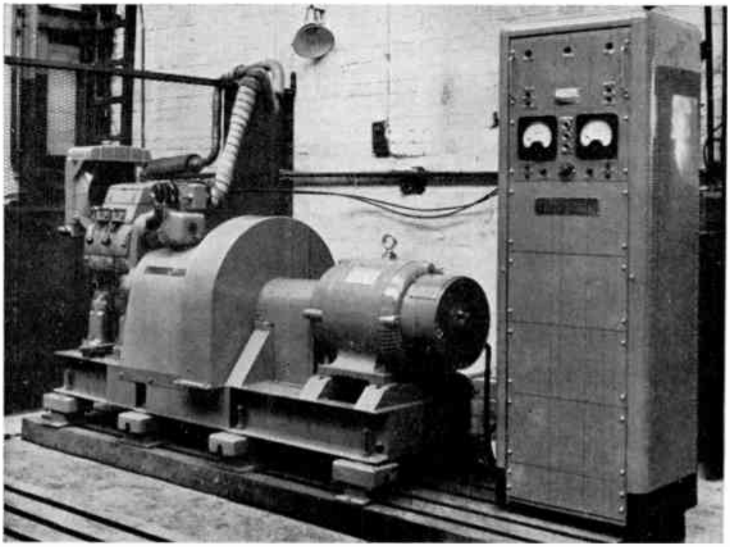

Fig. 4. Diesel electric no-break generating set.

4. Static Exciter Automatic Voltage Regulator

There is no separate exciting machine in the equipment just described, the excitation power being taken from the alternator itself and applied to its field winding via the regulating system. The circuit is shown in Fig. 6.

The voltage sensitive choke L1 is wound upon a continuous strip core of HCR alloy chosen because of its very sharp knee at the point of saturation. The winding is toroidal to give very close coupling with the core. Before the critical saturation point is reached large changes of applied voltage result in extremely small changes in current through the choke, but once the knee is reached, any further increase in voltage creates a very large change in current. The choke L1 then becomes an amplifier with a high gain and for a given applied voltage there is a value of current which is used as a reference and corresponds to the no-load voltage of the alternator. A drop of 2 per cent. in the alternator voltage results in a 30 per cent. fall in current. Fig. 5 shows the method of connecting the choke L1 via a bridge rectifier to the control winding of the transductor L2 and the performance curve obtained. A second winding has been added to the choke in order to obtain a low voltage alternating supply for the bias winding of the transductor L2, use being made in this instance of the close resemblance of L1 to a constant voltage transformer. The form of construction* adopted for the transductor is one where the a.c. coils are wound on two separate cores and the control and bias windings which carry the d.c. saturating current surround both cores. In this case the current through the a.c. windings is in such a direction that the alternating fluxes in the two individual cores cancel and no fundamental a.c. component appears across the d.c. control winding.

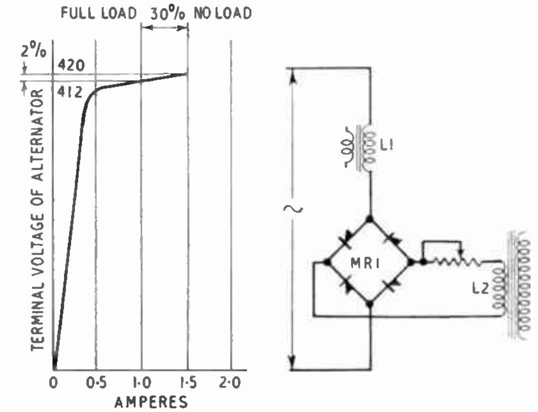

Fig. 5. Rectified current through control winding of transductor L2.

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* M. G. Say, "Magnetic Amplifiers and Saturable Reactors," pp. 77-88. (Geo. Newnes, London, 1954).

The transductor L2 is in series with the primary winding of the transformer T1, the secondary of which during normal running feeds into the alternator field via the rectifier MR3. The transductor in addition to the alternating current winding has a saturating or bias winding which is fed via the rectifier MR2 with a voltage derived from the generated voltage, the bias voltage being taken from the additional winding on the control choke L1. The second direct current winding of the transductor L2, which is the control winding, is connected across the rectifier MR1 in series with the main winding of the saturated control choke L1. The current in the bias winding is adjusted via R1 so that the core of the transductor L2 is brought to saturation point and the control winding opposes the saturating winding, tending to reduce the magnetization so that the reactance of the alternating current winding is increased. The control action can be explained by considering an increase of the alternator voltage of 2 per cent. from full load to no load, for then the reactance of the alternating current winding of the transductor L2 is increased and the current supplied to the alternator field reduced.

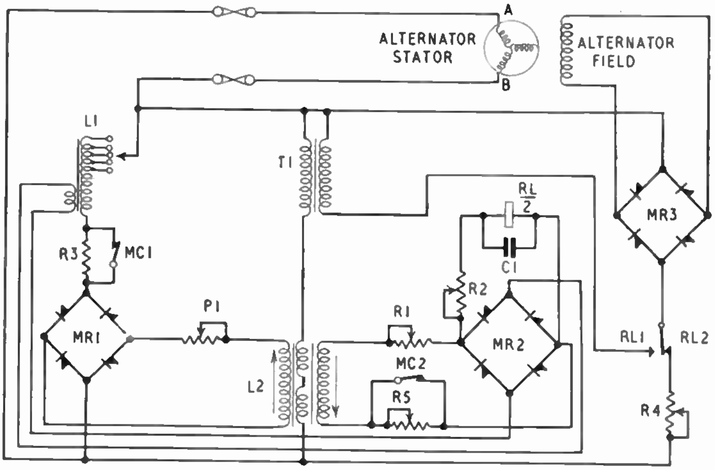

Fig. 6. Static exciter automatic voltage regulator.

To facilitate the building up of the alternator field on starting, the transformer T1 is cut out of circuit by the relay RL/2 so that the alternator field is then subjected to the whole of the residual generated voltage of the alternator, applied to it through the rectifier MR3 and the limiting resistance R4. Then although the voltage generated due to the residual field is small, the alternator excites rapidly. The relay RL/2 which operates on approaching normal alternator open circuit voltage then changes over, disconnecting the alternator voltage directly from the field rectifier MR3 and the field winding, and connecting the secondary winding of the transformer TR to the field rectifier and winding of the alternator.

The resistance R4 is included to limit the voltage applied directly to the rectifier MR3 before the contacts RL1 and RL2 switch over to the low voltage secondary of the transformer. The operating coil of the relay RL/2 is connected across the bias rectifier MR2 and is preset to its operating point by means of R2 just before the alternator voltage reaches its normal open circuit value.

Where the static exciter automatic voltage regulator is used with the alternator/synchronous induction motor, an additional control circuit resistance R3 is included so that the action of the control choke L1 can be brought below the knee of saturation and act as linear reactance. The control current is then reduced to a very small value and the additional resistance R5 in the bias circuit sets the transductor L2 to give a value of field current to excite the field of the machine as a synchronous induction motor. The action of the exciter unit is then purely a transductor-controlled rectifier system without any automatic regulating feature, since the controlling action of the control choke is swamped by R5.

The contacts MC1 and MC2 which introduce R3 and R5 into the circuit under motoring conditions are interlocking contacts on the main control switchgear. When motoring, the alternator/synchronous induction motor can be run to have a leading power factor if required, by setting the excitation to the appropriate value. Since a set of this type may spend most of its life in the stand-by condition it can be utilized to correct the power factor of other equipment running off the same supply.

5. The Electronic Alternator Synchronizer

When an alternator is to be connected in parallel with an independent alternating supply, it is important that when the connection is made, the frequency of the alternator voltage should be substantially the same as that of the independent supply and also the two voltages should be in phase so as to avoid heavy circulating currents. One simple method of obtaining an indication of these conditions is by the use of a synchronizing lamp, supplied by the voltages derived respectively from the supply and from the alternator and connected in opposition to one another. If these two voltages are equal in amplitude and in phase, they will cancel out and the lamp will not be illuminated. On the other hand, if the voltages are in anti-phase, the resultant voltage supplied to the lamp will be maximum and the illumination will therefore be a maximum. If the frequency of the alternator is different from that of the supply, the voltage supplied to the lamp will vary continuously from a maximum to a minimum at beat frequency of the two sources. The speed of the alternator has to be controlled to bring the beat frequency down to a safe value when the lamp is dark long enough to enable the alternator to be paralleled with the supply. This method also involves the manual operation of the circuit breaker closing the alternator onto the supply. The object of the electronic synchronizer is, therefore, to detect the paralleling condition and give the closing impulse to operate the circuit breaker automatically under the correct condition of voltage phase and frequency.

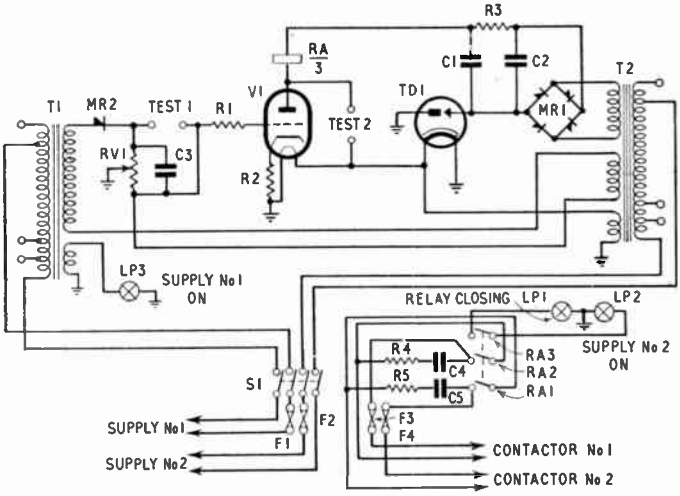

Fig. 7. Electronic alternator synchronizer.

The synchronizer employs a triode valve with an h.t. supply and voltages corresponding to that of the alternator and supply having substantially equal amplitudes. These are connected in opposition to one another and the rectified resultant is developed across a load resistor and capacitor, the output of which is applied between the grid and cathode of the triode valve.

Figure 7 shows the circuit arrangement of the electronic alternator synchronizer. A reference fraction of the alternator voltage is taken from the secondary of the transformer T1 which has its primary connected across the alternator; this is connected in opposition to a reference fraction of the supply voltage derived from a similar secondary of the transformer T2 which has its primary connected across the supply. The primary and secondary connections of these two transformers are arranged so that when both sources are equal in voltage, phase and frequency, the sum of the secondary voltages is zero. Any resultant voltages appearing when the two sources are out of synchronism are rectified by the half wave metal rectifier MR2, and the d.c. potential developed across the resistance RV1 is applied between grid and cathode of the triode valve V1 in the form of negative bias. Adjustment of the resistance RV1 determines the negative bias applied to V1.

The valve V1 has a 3,000-type Post Office relay in its anode circuit and its high tension supply is derived from another winding on the transformer T2, the metal rectifier MR1 and filter C1, C2 and R3. The purpose of the thermal delay switch TD is to prevent any attempt at parelleling until V1 has reached a stable condition, and, in the case of no-break equipments, until the public supply has been restored correctly and for a duration of not less than one minute.

Normally the valve V1 is biased beyond cut-off and the bias will fall almost to zero each time the alternator and supply are equal in voltage, phase and frequency. A small amount of self-bias for V1 is provided by the cathode bias resistance R2, for protection of the valve only. In order that the valve will not conduct each time the sum of the secondary voltages of T1 and T2 is momentarily zero, that is, when the relative frequencies of the alternator and supply are too widely apart, the resistance RV1 is shunted by the reservoir capacitor C3. The time constant of this combination is such that the voltage across C3 and hence the bias on V1 does not fall to conduction point for the valve unless the frequencies are almost identical. Fig. 8 shows basically how the network RV1, C3 discriminates the frequency difference. In Fig. 8a the period of beat frequency *F* is relatively short and the decay of voltage B is slow and intersects the rising curve at C which is below the critical value of bias for the valve, $-E_G$. In Fig. 8b the period of beat frequency F_1 is greater and the decay of voltage B1 is such that it intersects the rising curve at C1 which is above the critical value of bias $-E_G$ and sufficient anode current flows through V1 to close the relay RA/3. The rectified current pulses have been omitted from Fig. 8a and Fig. 8b for clarity, as in practice, of course, the shape of the envelope is controlled by the current pulses fed into the load resistance RV1 and the effect of the capacitor C3. The accuracy of the unit can be altered with the setting of RV1, the maximum negative bias setting being in the order of 300 V which is the maximum permissible potential for the valve V1. The setting of RV1 also depends upon the individual characteristics of the systems with which it is used. If the two voltage sources are well regulated and accurate and control of frequency is available, then the discrimination of the synchronizer can be made very precise, but where moderate voltage variations can be tolerated at the instant of synchronizing, the discrimination is less rigidly set. A further complication sometimes arises when, for various reasons, the wave-forms of the two power sources are not truly identical before synchronizing, in which case RV1 is set accordingly, the accuracy of the unit being somewhat relaxed without seriously affecting the overall performance.

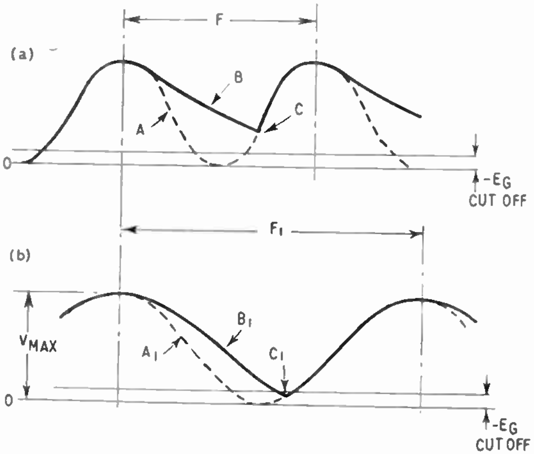

Fig. 8. Effect of network RV1.C3 in electronic synchronizer.

The relay RA/3 in the anode circuit of V1 has three make contacts, two of which (RA1 and RA2) complete the coil circuits of the external circuit breaker, while RA3 controls the pilot lamp LP1 which indicates when synchronizing has taken place. Two pilot lamp circuits LP2 and LP3 are used to indicate when the

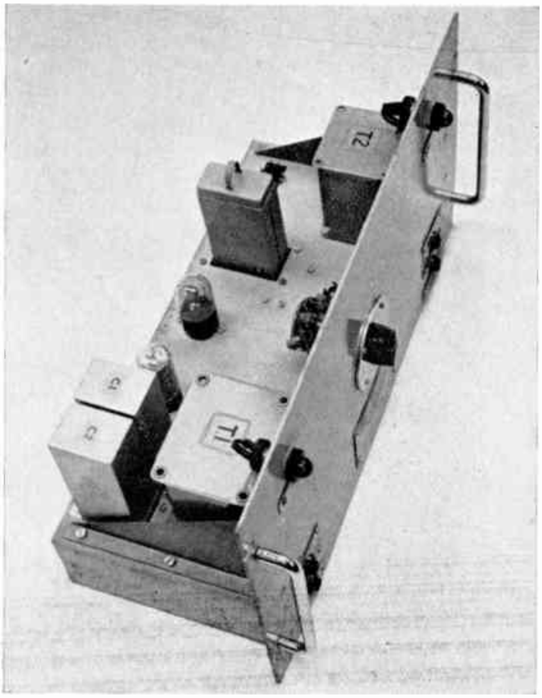

Fig. 9. Arrangement of electronic synchronizer unit.

alternator and supply have been connected to the synchronizer, prior to synchronizing. Spark quench circuits R4, C4 and R5. C5 are fitted across contacts RA1 and RA2. The circuit breaker or contactor is fitted with a self-maintaining contact and a late-break contact also which automatically disconnects the synchronizer after paralleling.

The unit is shown in Fig. 9.

6. The Electronic Speed Regulator

The speed regulator is incorporated with the all-electric battery-operated set and its main function is to maintain the speed of the alternator, and hence the frequency, substantially constant while the set is driven from the d.c. shunt-wound machine during public supply failure. It is normally called upon to correct for:—

(1) Temperature rise in the windings of the d.c. machine.

(2) Load fluctuations at the alternator.

(3) Gradual decline in the stand-by battery voltage.

Where the stand-by battery has 80 cells, the voltage applied to the d.c. machine will vary from 176 V when fully charged, to 144 V discharged. The battery ampere-hour capacity is usually large enough to power the d.c. machine for at least two hours while driving a fully-loaded alternator. The d.c. machine has two shunt field windings, the main shunt field being permanently excited from the battery and the control field which is fed from the thyratron output of the speed regulator. The control field has ampere-turns which oppose the main field. The regulator output, in other words, has a bucking action and controls the overall strength of the excitation to maintain constant speed. The ratio of ampere-turns, main to control field, is approximately 4:1. The bucking action gives good corrective response to speed changes and also has the advantage that if there is a failure in the output from the speed regulator, the d.c. machine will in emergency continue to run under hand control on the main field only.

The circuit used in one such regulator is based on conventional design with a single grid-controlled thyratron output. The whole regulator is built as a withdrawable unit on a chassis as used for standard 19½ in. rack mounting; Fig. 10 the physical arrangement, and Fig. 11 shows the circuit arrangement. The description of the regulator can be divided into two parts, the control circuits and the alarm and protection circuits which are necessary for continuous monitoring of the equipment.

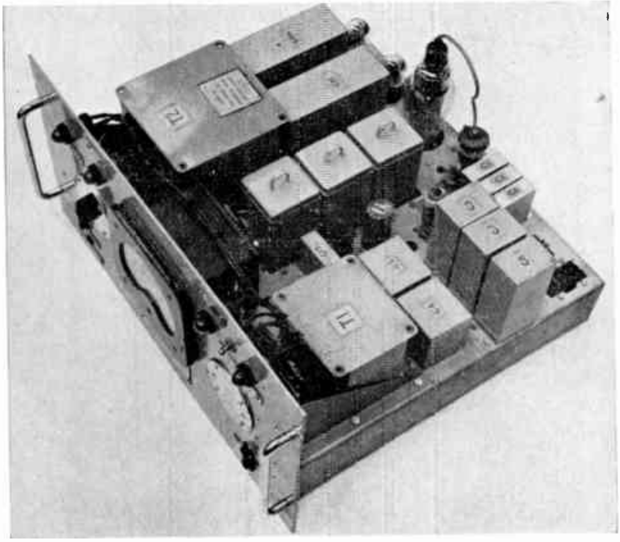

Fig. 10. Arrangement of speed regulator.

6.1. *Speed Regulator Control Circuits*

With the regulator in the operating condition, i.e., the set running on d.c. drive under mains failure conditions, relay "A" will be energized and the position of all relay "A" contacts will be opposite to those shown. A tachometer generator is fitted on the end of the machine shaft and the output from this is fed into the bridge-connected metal rectifier MR1; the resultant direct current is fed through a filter network C1, R1 and C2, the output voltage being developed across the potential divider comprising R2, R3 and R4. This voltage will be directly proportional to machine speed. It will be noted that an a.c. tachometer has been used and this has been entirely satisfactory in operation as a speed reference, since the speed regulator is not used over a wide speed range: otherwise the problem of smoothing the tachometer output might present certain difficulties.

In order to standardize the regulator to operate with sets running at 1,000 and 1,500

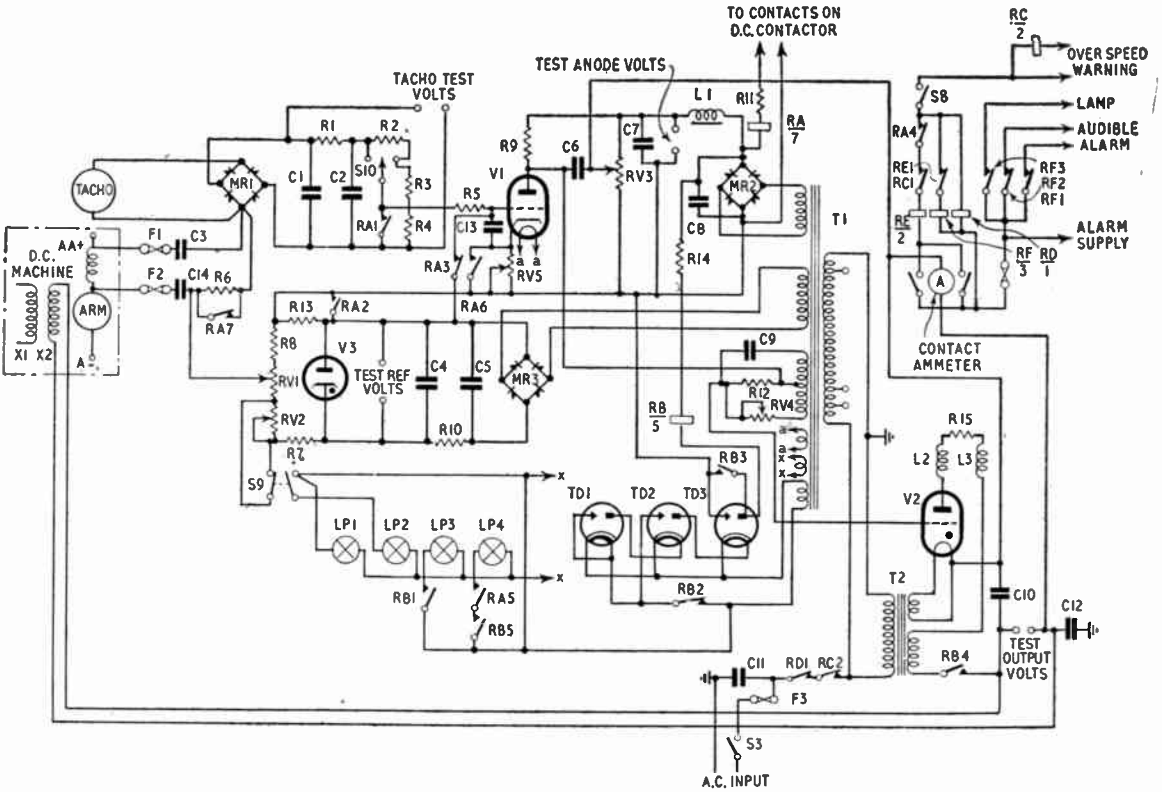

Fig. 11. Circuit of electronic speed regulator.

rev/min two preset voltages are selected from the output of the smoothing filter. A voltage of approximately 55 V is fed into the regulator for control purposes. This voltage is placed in series opposition to the reference voltage and is connected between grid and cathode of the amplifier valve V1. A third voltage source, the feedback or stabilizing voltage, is also connected in series with the grid–cathode circuit. The reference voltage is a highly stable one against which the tacho voltage is compared. The type of valve used in this circuit is the Mullard 85A2 (CV449), which has an extremely stable performance over long periods. The reference voltage exceeds the tachometer voltage by approximately 4 to 5 volts. The supply for the stabilizer valve V3 is obtained from a winding on the auxiliary transformer T1 and rectified and smoothed by the bridge rectifier MR3 and network C4, C5 and R10. In addition to forming part of the filter, R10 acts as the series regulating resistance. The potential drop across V3 also appears across the potential divider comprising R8, RV1, RV2 and R7; except under certain conditions, RV2 is shorted out by the switch S9. Manual adjustment of the regulator for setting up purposes is obtained by varying the reference voltage by means of RV1. The degree of adjustment is limited and provides a fine degree of control, which is further improved by fitting RV1 with a 10:1 reduction drive.

As stated previously, the reference voltage normally exceeds the tacho signal by a few volts, and results in a small negative bias being applied to V1. Small changes in tacho output appear as changes in V1 bias volts, giving an amplified signal across the anode load R9. The anode supply for V1 is derived from another winding on T1 and rectified and filtered by MR2, C7, C8 and L1. The amplified signal is taken from the anode of V1 and the slider of the bias potentiometer RV3. The voltage drop across the upper portion of RV3 opposes the normal drop across R9 and this permits the bias applied to the thyratron V2 to be adjusted. The thyratron V2 is controlled by means of a phase shifted sinusoidal voltage applied between grid and cathode. This voltage is superimposed upon the bias voltage derived from R9 and RV3. Any variation in the level of the d.c. bias voltage causes the envelope of the phase shifted sinusoidal voltage to cut the critical grid characteristic of the thyratron V2 at a different point. This method is commonly known as vertical control.* The phase shifted voltage is derived from a winding on the transformer T1 and phase shifted 90° lagging with respect to the alternating voltage at the thyratron anode. RV4 and C9 form the phase shift network and R12 completes the grid circuit of the thyratron and also acts as a load to the network. C6 acts as a grid decoupling capacitor and improves the stability of operation.

With the relay contact RB4 closed, the thyratron anode circuit is completed through the secondary of transformer T2, the auxiliary field winding of the machine, the high-frequency blocking choke L2, the resistance R15, the peak limiting choke L3 and the movement of the contact ammeter. Capacitor C10 is connected across the auxiliary field of the d.c. machine to reduce the time constant of the d.c. machine by tending to collapse the section of the field due to the auxiliary winding. R15 limits the charging current drawn by C10 to a figure within the peak current limits of V2. The two supply transformers T1 and T2 have their primaries in parallel and are directly connected to the output of the alternator. The overall operation of the regulator is as follows: a small increase in tacho voltage due to increase in machine speed will result in a reduced current in the control field winding, strengthening the overall field of the machine and bringing about a speed reduction; a fall in tacho volts will act in the reverse manner.

The thyratron is protected during its initial warming up period by the three thermal delay switches TD1, TD2 and TD3 and the relay RB/5. These delay switches operate sequentially, and when the contact of TD3 closes, it energizes relay RB/5 from the V1 h.t. supply. This in turn closes the maintaining contact RB3 and opens RB2, allowing the delay switches to cool off again. RB4 also completes the thyratron anode circuit via contact RB4 and completes the stand-by lamp circuit LP3 via contact RB1. In order that the speed of the machine can be reduced by a small amount without interfering with the setting of RV1, the speed setting potentiometer, a second potentiometer RV2 is included in the reference potential divider chain and is normally short circuited by S9. This potentiometer RV2 is used for trimming the speeds of two d.c. machines for the purpose of synchronizing; immediately this has been achieved S9 can be closed and shorts out RV2, leaving the regulator set to its initial speed reference. A warning lamp LP2 shows when the switch S9 is in the low speed position. Normally in any servo system there is bound to be some time delay in the system which will give an inherent tendency for hunting. In order to prevent this, negative feedback is applied so that the act of causing a correction feeds back a signal voltage which is in opposition to the original signal voltage creating the correction. The feedback voltage in this instance is derived from the drop across the interpole winding of the d.c. machine and is differentiated by C3, C14 and RC, the feedback voltage appearing across R6 which is effectively in series opposition to the tachometer signal. Under normal steady conditions, no voltage appears across R6, but when a change in armature current of the d.c. machine takes place, a signal will appear across R6 and its direction will be dictated by the nature of the armature current change, i.e. whether increasing or decreasing.

6.2. *Alarm and Protection Devices in the Speed Regulator*

Four indicator lamps are provided on the front panel of the speed regulator, these are "LP1 — Supply On," "LP2 — Low Speed Running," "LP3 — Stand-By" and "LP4 — Regulator Operating on D.C. Drive." As the regulator has to remain in the stand-by condition for long periods, i.e., the alternator set being driven from the public supply via the a.c. motor, some indication of its condition is necessary. The alarm system is designed to give warning of any failure in the regulator. In order to do this, the output from the thyratron on the regulator is fed through a contact ammeter which has both high and low level

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* R. C. Walker, "The Industrial Applications of Gas-filled Triodes," pp. 62-72. (Chapman & Hall, London, 1950).

contacts. In the stand-by condition, the regulator is set to give a constant output, and any component failure will result in either zero or maximum output, closing the respective ammeter contact and operating an alarm system.

In detail, the regulator operates as follows: under a.c. drive conditions, the relay RA/7 contacts will be as indicated on Fig. 10 the coil of this relay is energized by the V1 h.t. supply via an auxiliary set of contacts on the d.c. changeover contactor. RA1 removes the tacho input to V1 to keep the regulator output independent of speed changes on the a.c. driving motor. Contact RA6 removes the short circuit from RV5 and applies auto cathode bias to V1. RA3 connects the grid of V1 to the positive reference supply RA2 opens and introduces R13 between the h.t. negative and reference positive. The grid–cathode voltage on V1 now consists of a small positive sample of the reference supply opposed by a negative bias developed across RV5. Adjustment of RV5 will now vary the output of the thyratron. Failure of V3 will cause a rise in voltage across R13 and the failure of the reference rectifier MR3 or filter network will give zero voltage across R13. A failure of V1 has the same effect as that of a large negative bias at its grid and this will cause the thyratron to fire at its maximum, closing the high contact on the contact ammeter.

Four other relays are included on the regulator chassis. RC/2 is the over-volts and over-speed protection relay and is controlled from contacts on the alternator frequency and voltmeters on the main equipment; in the event of over-volts or over-speed, it removes the supply from the regulator. Relay D/1 disconnects the regulator on shut down. Relays RE/2 and RF/3 will be operated automatically if a fault develops within the regulator. These alarm circuits are extended to give remote indication of the condition of the regulator, the alarm relays being energized from a section of the stand-by battery. For the suppression of radio interference the chassis is fitted with a high frequency choke L2 and capacitors C11 and C12. The overall performance of this regulator between extreme conditions, i.e. maximum battery voltage with the d.c. machine hot on no-load, and minimum battery voltage with the d.c. machine cold on full load is a controlled speed within the limit of 1 per cent.

On one particular contract speed regulators of the type illustrated were used on all-electric battery-driven sets* having outputs from 4–15 kVA, the same regulator chassis being used throughout to give complete interchangeability. Speed regulators requiring a larger output than can be attained from a single thyratron output stage would normally contain an amplifier and control circuit similar to that described but feeding into a biphase or three-phase thyratron circuit. The general principle of operation would remain the same.

Up to a few years ago power engineers were reluctant to rely on electronic devices in association with power equipment, but regulators employing the type of construction described have given extremely reliable service. There is no doubt that with careful design and choice of components, reliable operation can be ensured provided that maintenance is done on a routine basis and valves replaced before reaching their ultimate limits of life. On the regulator described, test sockets have been provided for ready checks on important parts of the circuit and all connections to the regulator are taken through plugs and sockets so that in the event of a complete failure, the whole unit can be replaced quickly and the faulty unit repaired away from the equipment without seriously interrupting the whole operation of the power plant.

7. Conclusion

This paper shows how electronic equipment has been and can be utilized to advantage if it is carefully combined with the associated equipment. It has not been possible to mention all the problems and types of job on which equipment of this design can be used, but it is hoped that the information given will prove to be of interest.

8. Acknowledgment

Acknowledgment is made to the Electric Construction Company Ltd. for permission to reproduce photographs and to give details of equipment for which the company holds many patents.

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* R. C. Belton, "A New Type of Telegraph Power Plant," *Post Office Electrical Engineers Journal*, **48**, pp. 71-75, July 1955.

. . . Radio Engineering Overseas

A selection of abstracts from European and Commonwealth journals received in the Library of the Institution. All papers are in the language of the country of origin of the journal unless otherwise stated. The Institution regrets that translations cannot be supplied.

537.311.33

The concept of the hole in semiconductors.—J. L. Salpeter. *Proc. Instn. Radio Engrs., Aust.*, **16**, pp. 427-42, December 1955.

Electronic semi-conductors such as silicon and germanium merit the interest of the communications engineer because of the crystal diodes and triodes (transistors) which are being made from these materials. An important feature in which semi-conductors differ from metals is the sign of the current carriers. While metals have carriers only of negative sign (electrons), semi-conductors have carriers of both signs, i.e. electrons and "holes". This makes the phenomenon of "injection of minority carriers" possible, which in turn is mainly responsible for transistor action. The concept of the hole is based upon wave mechanics, and is explained using the transmission line and wave filter analogy. The behaviour of a semi-conductor in a magnetic field, and in respect of mechanical forces, is explained and the thermo-electric power is briefly dealt with.

621.317.763.029.6

Rod wavemeter for the range 180 to 80,000 Mc/s; its construction and results of measurements.—U. Adelsberger. *Archiv der Elektrischen Übertragung*, **10**, pp. 51-7, February 1956.

The features of the described rod wavemeter—high measuring accuracy, wavelength range of more than five octaves, high sensitivity—make it a valuable device at frequencies of 180 to 80,000 Mc/s, particularly in the form of the single node precision rod wavemeter. The rod wavemeter attains a measuring error as low as $1{\cdot}5 \times 10^{-4}$ in the u.h.f. range and is suitable for millimetric waves. The paper discusses its layout, properties, and the relationships underlying its design. Results of measurements are given for two precision type rod wavemeters and others in the range from 3·5 mm to about 1·65 m wavelength.

621.372.2.09

The excitation and propagation of TM modes in a circular waveguide with coaxial cables at the input and output.—A. Sander. *Archiv der Elektrischen Übertragung*, **10**, pp. 77-85, February 1956.

The discussion relates to a length of circular waveguide terminating at either end in coaxial lines acting as the input and output terminals of the transmission path. The concepts of "field" and "hybrid" quadripoles with the corresponding matrices are introduced, and co-ordinated with the wave modes of the cylindrical waveguide. A solution of the problem of the excitation and propagation of TM modes in a circular waveguide is found with the use of these concepts. The theory developed in the paper allows calculation of u.h.f. waveguide-below-cutoff attenuators.

621.372.413

Sectionalized spherical cavities.—G. Boudoris. *Onde Electrique*, **36**, pp. 104-21, February 1956.

The study of spherical cavities is concerned with resonant wavelength and the coefficient of surtension. Curves are established by using two different approximate methods which give results which agree. These curves show a connection between the extreme cases of cylindrical and spherical cavities which resonate respectively at modes E_{010} and E_{101}. Between these two extremes comes the sectionalized spherical cavity which is examined for its fundamental mode of operation. Examples are given for the X and S bands.

621.373.4

The stabilidyne.—H. Colas. *Onde Electrique*, **36**, pp. 83-93, February 1956.

The necessity for frequency stability is discussed, and the development of stabilizing methods. A new method of stabilizing is then described and precision, stability and practical limits are given both for reception and transmission. Several industrial equipments and their characteristics are described.

621.373.4:512.37

The isograph—an electronic root finder.—A. K. Choudhury. *Indian Journal of Physics*, **29**, pp. 468-73, October 1955.

The paper describes an electronic isograph for finding the roots of high degree polynomials. The harmonic generator used is a purely electronic device without any moving parts. The different harmonic components are generated with the help of a delay line, fed from a matched frequency-sweep generator. By controlling the amount of frequency sweep of the oscillator any desired interval of the argument can be expanded, thus enabling accurate determination of the argument of the root.

621.373.421

Frequency of the three-phase RC-coupled oscillator.—H. Rakshit and M. C. Mallik. *Indian Journal of Physics*, **29**, pp. 534-47, November 1955.

When the three stages of the conventional three-phase RC oscillator are identical, the oscillations normally produced are of radio frequency $\omega = \sqrt{3}/RC$ where R and C are the tuning resistance and capacitance. This simple formula holds when the anode load resistance is non-reactive and the cathode impedance is zero. When these conditions are not satisfied the expression for frequency becomes much more complicated. The case of finite cathode impedance of varied nature when anode load resistance is non-reactive is discussed. Results of experimental observations are also given. It has been found that a capacitative cathode impedance causes an increase while an inductive cathode circuit causes a decrease in frequency over the $\sqrt{3}/RC$ value. A purely resistive cathode impedance does not affect the frequency in any way.

621.373.431

Study of equilibrium states of a bi-stable flip-flop from the point of view of reliable and stable operation.—M. Bataille. *Onde Electrique*, **36**, 94-103, February 1956.

The influence of all the components on the equilibrium state is examined for an Eccles-Jordan circuit arrangement. From this the conditions are deduced which must be fulfilled in order that all kinds shall be interchangeable wherever possible, taking ageing into account. A simple method of calculating the circuit elements is given. Current consumption is examined to enable power supply units to be specified.

621.385.832

Some problems of after-effect phenomena in the vidicon tube.—W. Heimann, *Archiv der Elektrischen Übertragung*, **10**, pp. 73-6, February 1956.

The results of investigations into the causes underlying the disturbing inertia and after-effect phenomena in the vidicon tube are discussed. These disturbing effects are determined by properties of the semiconductor layer and the mechanism of signal generation. Systematical experiments have been conducted with tubes of different picture element capacitance (different layer thickness) and tubes of higher diameter (larger photoelectric and storage layers) operated with raster surfaces of different size. An attempt was also made to measure the layer capacitance in different ways. The discussion of the results gives evidence of the importance of the layer capacitance for the after-effect phenomena. By suitable dimensioning of the layers more favourable compromise values can thus be attained with respect to tube inertia.

621.396.11

A method of determining the relative amounts of D- and E-region absorptions of medium and short radio waves.—A. P. Mitra. *Indian Journal of Physics*, **29**, pp. 518-21, November 1955.

A new method is developed by which the relative amounts of D- and E-region absorptions in any medium and short wave observation may be determined purely on a physical basis. The method utilizes the concept of "relaxation time" in ionospheric levels and rests on the fact that the "relaxation time" at the D-region levels is appreciably different from that at the E-region levels.

621.396.677.7

Calculation of the phase centre of aperture fields.—K. Baur, *Archiv der Elektrischen Übertragung*, **9**, pp. 541-546, December 1955.

The paper begins with a description of the phase surface and the phase centre of a wave emitted from a radiator array. With use of Kirchhoff's aperture field method, the wave of a radiating aperture is calculated for the planar case. The conditions are outlined for the phase circle from which the unknown phase centre is found. By means of certain simplifications the problem can be reduced to tabulated functions. A good approximation formula for practical use is given, and the various approximations and simplifications are discussed.

621.396.677.831

Passive reflectors for radio waves (experimental investigation).—G. Andrieux. *Onde Electrique*, **36**, pp. 57-72, January 1956.

The reasons which led to the proposal to use passive reflectors for radio waves are first discussed. A brief survey is made of the properties of passive reflectors for long distance transmission which are used to get round obstacles, and a more detailed study is made of reflectors for short paths, such as those erected at the top of masts, thus permitting the s.h.f. equipment, including aerials, to be located on the ground. Practical convenience has dictated the choice of a frequency of 24,000 Mc/s for the tests. The performance of several arrangements using the same parabolic aerial but plane reflectors of different dimensions is studied. The effect of the use of these reflectors on the coupling between neighbouring aerials is also examined. From a wide range of measurements the author deduces that given a certain size of reflector, the performance of a particular radio link is not altered appreciably.

621.396.812.3.029.64

Statistical interpretation of fading on line-of-sight microwave radio links.—G. Kraus. *Archiv der Elektrischen Ubertragung*, **10**, pp. 19-25, January 1956.

Tropospherical "ducting" is apt to cause strong fading, in particular on microwave radio links, by destructive interference between rays reaching the receiving antenna over paths of different lengths. For a statistical research into this fading it is assumed that the receiving antenna is reached by a powerful main ray and a multitude of side rays with phases distributed at random. The degree of duct formation is characterized by the fraction q which the side rays contribute to the total mean receiving power. Fluctuations of the receiving power around its mean value increase with q; the mean value being assumed constant and independent of the degree of duct formation. Over long periods of time an alternation occurs between intervals of large ($q \simeq 1$), medium ($q \simeq 0.1$) and small ($q \simeq 0.01$) fluctuations of the receiving level. In the most unfavourable case, where $q = 1$, fading reaches at least 20 db for 1% of the time. A comparison with other published results of measurement shows that because of the physical relationships a certain correction is required for the fading statistics calculated for medium fluctuations ($q = 0.2$).

621.397.64

Linear phase characteristic television receivers.—A. van Weel. *Onde Electrique*, **36**, pp. 48-56, January 1956.

A television receiver with linear phase intermediate frequency amplifier is described. The selectivity is the same as that obtained in conventional receivers and uses only simple circuits. A comparison is made between the picture obtained on this receiver and that obtained on the normal receiver where phase distortion in the intermediate frequency circuit is compensated at video frequency, and it is shown that the picture obtained on the first receiver is optimum for a given bandwidth and is not appreciably affected by tuning variations.